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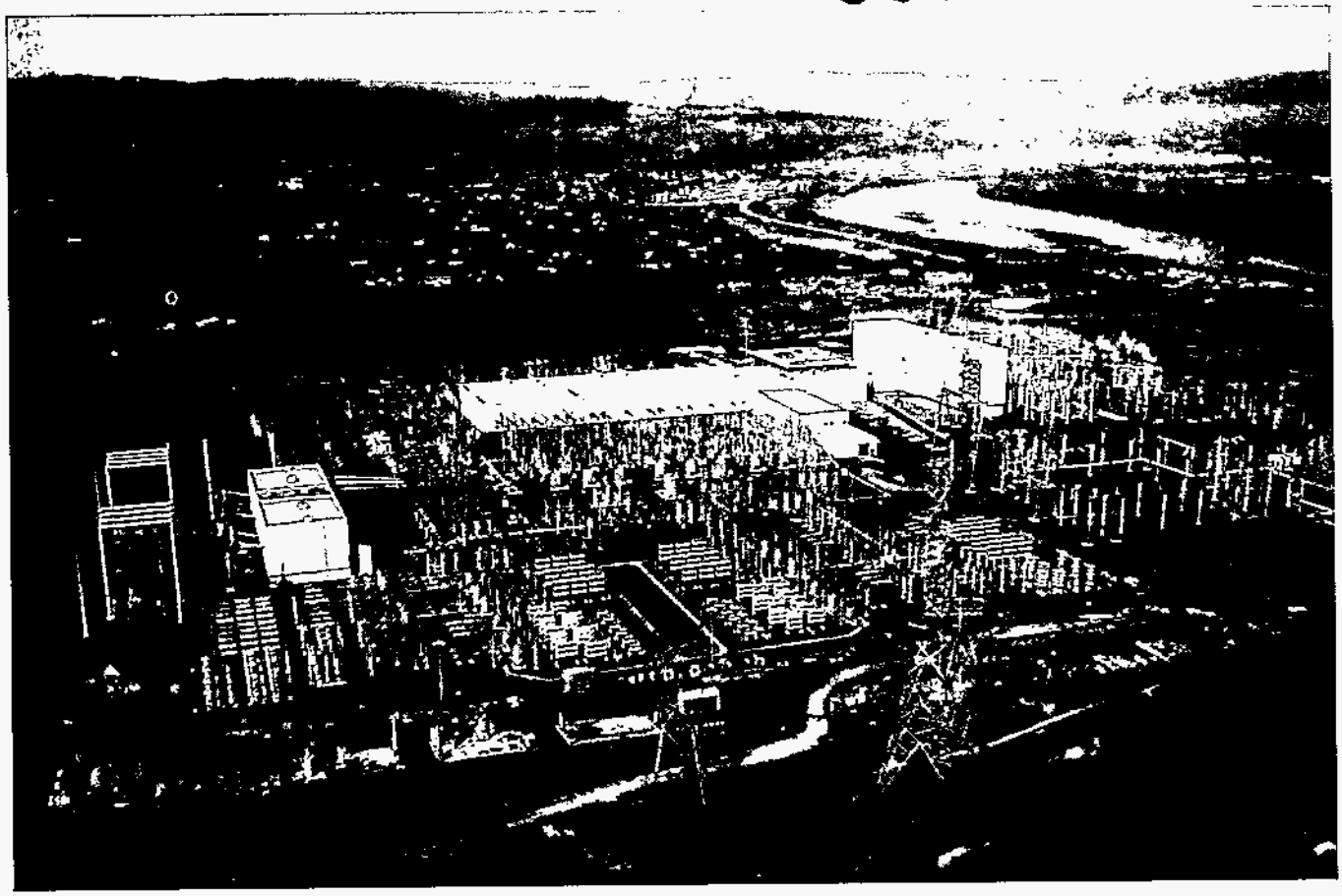
JUNE 1998

AN ANNOTATED BIBLIOGRAPHY OF HVDC TRANSMISSION AND FACTS DEVICES

1996 – 1997



Celilo HVDC Converter Station

Electric Power Research Institute

BONNEVILLE POWER ADMINISTRATION

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An Annotated Bibliography of HVDC Transmission and FACTS Devices 1996-1997

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June, 1998

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Acknowledgments and Preface

The editors gratefully acknowledge the primary support for this work provided by Dr. Aty Edris of the Electric Power Research Institute, Palo Alto, California. Co-funding was provided by Mr. Alan Courts, Manager of Technical Services, Bonneville Power Administration.

This volume is the result of the efforts and cooperation of many people. The major research and compilation of the bibliography was carried out by Dr. Rajiv K. Varma, Associate Professor of Power Systems at the Indian Institute of Technology in Kanpur, India. Mr. John Fenker, BPA Librarian, performed numerous computer searches for bibliographic information. Mr. F. James Hughes of Condor Consulting prepared software to process the bibliographic information, sort it into appropriate categories and prepare it for final editing. Mr. John D. Flanagan edited the manuscript and entered much of the raw information.

The tabulation of HVDC Projects in Section III was supplied by Mr. David J. Melvold of the Los Angeles Department of Water and Power. The listing of FACTS projects was provided by Mr. Steve Swencki of Cutler-Hammer and Mr. Duane Torgerson of Western Area Power Administration, Golden, Colorado.

The Editors gratefully acknowledge the additional support for this work provided by United States Educational Foundation in India (USEFI), New Delhi, India, and United States Information Agency and the Board of Foreign Scholarships in Washington DC, USA, in awarding the Fulbright Travel Grant to Dr. Rajiv K. Varma to visit BPA, Portland, Oregon, for preparation of the HVDC/FACTS Bibliography. Special thanks are expressed to Dr. P.J. Lavakare, Ms. Sarina Paranjape and Ms. Anita Caplan for making the grant possible.

The editors also express their sincere gratitude to Dr. R.M. Mathur, Professor and Dean, Faculty of Engineering Science, for consultations and for providing facilities for Bibliography preparation at the University of Western Ontario, London, Ontario, Canada.

Profound thanks are due to authors all over the world who sent their contributions to the bibliography through email, faxes and letters. The editors would like to particularly acknowledge the help received from Mr. Mata Prasad, Professor Yasunori Mitani, Dr. J. Senthil, Mr. Krishna V. Patil, Mr. Nikhilesh K. Sharma, and Mr. R.P. Gupta in this endeavour.

This edition of the Annotated Bibliography of HVDC Transmission and FACTS Devices continues work begun in 1962 by the late Erik Bromberg, Bonneville Power Administration Librarian. His original bibliography covered the period 1932 - 1962. Subsequent editions were compiled by Bromberg, Val S. Lava, and Wayne Litzenberger, all of Bonneville Power Administration.

Beginning with the 1991-1993 edition, the scope of the bibliography was expanded to include flexible ac transmission (FACTS) devices.

This 1996-1997 edition also contains information for 1998. Preparation of the present edition took place primarily in May-June of 1998. All pertinent references have been included that were available to the editors at the time of preparation. Papers for the 1998 IEEE Winter and Summer Power Meetings and 1998 T&D Conference have been included.

This edition contains the organizational affiliation of the first-named author as an aid to accessing the reference. Unfortunately, space limitations prevented the inclusion of the affiliations of all authors.

Some minor editorial changes have been made to abstracts to ensure consistency in style and syntax.

The editors will be pleased to receive any comments on this Bibliography and suggestions for future editions. Please send suggestions to:

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Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208
email: wlitzenberger@bpa.gov

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Previous Editions

[1] Erik Bromberg, Compiler, *An Annotated Bibliography of High Voltage Direct Current Transmission, 1932-1962*, AIEE Conference Paper, January, 1963

[2] Erik Bromberg, Compiler, *An Annotated Bibliography of High Voltage Direct Current Transmission, 1963-1965*, Published by IEEE, New York, NY, 1967

[3] Val S. Lava, Compiler, *An Annotated Bibliography of High Voltage Direct Current Transmission, 1966-1968*, Published by Bonneville Power Administration, 1968

[4] Val S. Lava, Compiler, *An Annotated Bibliography of High Voltage Direct Current Transmission, 1969-1983*, Published by Bonneville Power Administration, 1984

[5] Val S. Lava, Compiler, *An Annotated Bibliography of High Voltage Direct Current Transmission, 1984-1989*, Published by Bonneville Power Administration and Western Area Power Administration, 1990

[6] Wayne H. Litzenberger, Ed., *An Annotated Bibliography of High-Voltage Direct-Current Transmission, 1989-1991*, Published by Bonneville Power Administration and Western Area Power Administration, 1992

[7] Wayne H. Litzenberger, Ed., *An Annotated Bibliography of High-Voltage Direct-Current Transmission and Flexible AC Transmission (FACTS) Devices, 1991-1993*, Published by Bonneville Power Administration and Western Area Power Administration, 1994

[8] Wayne H. Litzenberger and Rajiv Varma, Eds., *An Annotated Bibliography of HVDC Transmission and FACTS Devices, 1994-1995*, Published by Bonneville Power Administration, Western Area Power Administration and U.S. Department of Energy, 1996

Explanation of Bibliographic Entries

Reference Number	**[1996] 07A - 24**
Title of Paper	**LOAD FLOW CONTROL IN POWER SUPPLY NETWORKS-VISION AND REAL POSSIBILITIES**
Author(s)	**Gampenrieder, R.; Hausler, M.; Povh, D.**
Affiliation of first named author	**Bayernwerk AG, Munich, Germany**
Publication in which reference is found	***Elektrizitaetswirtschaft (Germany), vol 95, no 25, December 2, 1996, pp 1671-1674, 1676-1677***
Publication language (if missing, paper is in English)	**German**
Abstract	This paper explains the content of flexible AC transmission systems (FACTS) for load flow control with power electronics, and what can be achieved in networks with them. 11 Refs.

Papers are listed by topical category. The full citation and abstract are included once in the topical category that the editors felt was most appropriate to the paper. Additional references to the same paper are included under other categories where a pointer is included to the main reference, e.g.,

[1996] 02D - REF
NEW TECHNOLOGIES IN HVDC CONVERTER DESIGN
For Abstract see entry 02A - 3

Within each category, papers are listed alphabetically by title. Users of the *Bibliography* searching for a specific author should refer to the author index at the end of the volume.

TABLE OF CONTENTS

SECTION I ABSTRACTS

HIGH VOLTAGE DC TRANSMISSION

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

SECTION 1 ABSTRACTS

HIGH VOLTAGE DC TRANSMISSION

01 HVDC SYSTEMS AND PLANNING

01A HVdc Transmission Concepts

[1996] 01A - 1

AN ANNOTATED BIBLIOGRAPHY OF HVDC TRANSMISSION AND FACTS DEVICES 1994-1995

Litzenberger, W.H.; Varma, R.K.

Bonneville Power Admin, Portland, OR, USA

US Department of Energy, Bonneville Power Admin, Western Area Power Admin, 1996, 346 pp

Over 1600 papers pertaining to HVdc transmission and FACTS from 1996 and 1997 are classified by topic. Abstracts of the papers are included with the citations. Extensive listings of HVdc and FACTS projects are included. Papers are indexed by authors. Previous editions are listed together with instructions for requesting additional copies. Electronic format copies are available from Bonneville Power Administration. This ninth volume of the Bibliography continues work begun in 1962 by the late Eric Bromberg, BPA librarian.

[1996] 01A - 2

APPLICATION OF POWER ELECTRONICS IN POWER SYSTEM

Miyazawa, Y.; Iyoda, I.

Mitsubishi Elec Corp, Tokyo, Japan

Doryoku (Energy) (Japan), vol 234, May 30, 1996, pp 22-27

Japanese

This paper describes the development trend of power devices and the application of power electronics in power system. The effective power of dc transmission is interchanged by connecting two ac systems with a converter using a thyristor through a dc transmission line. The power interchange of dc transmission is conducted by connecting Hokkaido and Honshu with a submarine cable. The BTB, which connects two ac systems back-to-back, controls the effective power flow by the thyristor firing control. The static reactive power generator does not require any capacitors or reactors differing from SVC, to reduce the installation space. The revolving speed of reversible pump-turbine can be regulated using an inverter of GTO thyristor for the secondary exciter of variable speed pumped storage power plants. The TCSC can regulate the impedance compensation of transmission line of the series capacitor, to increase the transmission power. The UPFC can control the effective and reactive power flows of the system. The reactive power compensation and effective power compensation can be conducted by connecting the superconducting coils or high performance storage batteries with SVG. 7 refs., 8 figs.

[1997] 01A - 3

CONVERTING AC POWER LINES TO DC FOR HIGHER TRANSMISSION RATINGS

Haeusler, M.; Schlayer, G.; Fitterer, G.

ABB Calor Emag Schaltanlagen AG, Mannheim, Germany

ABB Review, no 3, 1997, pp 4-11

One way of avoiding transmission bottlenecks caused by a shortage of suitable rights-of-way is to convert overhead power lines from ac to dc. This option allows the power transmission rating to be more than tripled and the specific transmission losses to be substantially reduced without having to widen the right-of-way. What is more, such conversions cost only a third to half the cost of building a new dc line. Several examples of 330-kV ac line conversions illustrate these benefits. 10 Refs.

[1997] 01A - 4

DC TECHNOLOGY FOR RURAL TRANSMISSION

Hingorani, N.G.

Hingorani Power Electronics, Los Altos Hills, CA, USA

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

This paper concerns low power transmission over long enough distance where low voltage dc transmission may be more economical. For consideration of long distance electric power transmission, it is assumed that it is more economically viable to transmit power than to provide local or additional local generation or even than to reduce local fuel consumption due to high cost of fuel. It is also assumed that only one-way power transmission is required and this may offer some possibility of reducing the cost of the dc alternative. Such a scenario for transmitting a few MW over long distance for a cost differential of say, $0.05 per kWh, is quite reasonable. This paper is about conveying ideas and various points to be considered, rather than presenting a rigorous analysis.

[1997] 01A - 5

DIRECT CURRENT DISTRIBUTION LINE INSTALLED IN SWEDEN

Hjort, T.

Vasterbergslagens Elnat AB, Hellsjon, Sweden

Transmission & Distribution World, vol 49, no 9, September 1997, pp 80, 82-83

The author describes how the idea for a new technology involving dc transmission using voltage-source converters (VSC) was conceived in 1987 by ABB Power Systems. The concept involves series connection of many transistors, isolated gate bipolar transistors (IGBTs), their physical adaptation to demanding power industry standards and innovative control software and hardware. The technology extends the economical power range for dc transmission downwards to just a few MW. In addition, new possibilities exist for improving power quality in ac networks. The voltage source converter described is compact and robust, both mechanically and electrically. The main equipment is contained in a small moveable housing and is delivered fully assembled and factory tested.

[1996] 01A - 6

HIGH-VOLTAGE TECHNOLOGY--WHAT'S NEW REPORT FROM THE CIGRE 1996

Zimmer, H.H.; Liese, M.; Knorr, W.; Gremmel, H.; Lips, P.; Kaerner, H.; Schroth, R.; Kiessling, F.; Neumann, C.; Ziegler, G.; Lotsch, H.; Hirsch, F.; Schwarz, J.; Haubrich, H.J.; Sprenger, W.

CIGRE, Paris, France

ETZ (Germany), vol 117, no 23-24, pp 14-36

German

The 36th CIGRE Conference was held in Paris on August 25-31, 1996. It was attended by more than 2350 experts from 77 countries. The results of the technical committees are presented in summary form. Most contributions were on technical problems resulting from the European deregulation processes in electric power supply and telecommunication. New information technologies were discussed in all technical committees. Some aspects were also discussed separately in panel discussions.

[1996] 01A - 7

HVDC - FACTS. STATE OF THE ART - POWER SYSTEM HARMONICS

Gjerde, J.O.; Uhlen, K.; Hernes, M.

Norwegian Electric Power Research Institute, Trondheim, Norway

Energiforsyningens Forskningsinstitutt A/S, Trondheim (Norway), Report Number EFI-TR-A-4472, December 1996, 49 pp

It is expected that challenging research and consultant projects will arise as a consequence of major investments in HVdc links, new ac power lines and several installations of power electronic equipment (FACTS) in Southern Norway. To gain more knowledge about these new technologies, the Norwegian Electric Power Research Institute (EFI) has carried out an internal project. The present report is a collection of project memos concerning: (1) HVdc - high voltage direct current, state of the art; (2) FACTS - flexible ac

transmission systems, state of the art; and (3) power system harmonics from FACTS and HVdc components. The second part of (1) discusses static power conversion and interactions between the ac and dc power systems, and includes some interesting applications where the HVdc transmission system can be used for more than power transmission. In (2), a simulation study shows that thyristor-controlled series capacitors (TCSCs) can be successfully applied for damping of power oscillations between areas, but less successfully for controlling steady state power flow on parallel transmission paths. Memo (3) discusses the problems arising from non-linear loads, such as converters with switching devices like thyristors and transistors. 28 refs., 68 figs., 3 tabs.

[1996] 01A - 8

HVDC 2000 - A NEW GENERATION OF HIGH-VOLTAGE DC CONVERTER STATIONS

Arnlov, B.

ABB Power Sys

ABB Review, no 3, 1996, pp 10-17

Improved performance and robustness, shorter lead times and faster delivery, plus reduced maintenance needs, were the development goals set by ABB Power Systems for its new generation of HVdc converter stations. Dubbed 'HVDC 2000', it is based on an existing concept and proven know-how. Newly developed components combining advanced, high-speed electronics, modern overvoltage protection and state-of-the-art computer software, make HVDC 2000 an attractive alternative to conventional HVdc station design. 1 Ref.

[1997] 01A - 9

INNOVATIONS IN HVDC FOR TRANSMISSION QUALITY ENHANCEMENT. APPLICATIONS AND STUDIES.

Povh, D.; Retzmann, D.W.; Renz, K.W.; Christl, N.; Ramaswami, V.N.

Siemens AG, Erlangen, Germany

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol VI-1, pp 1-12

Over the course of three decades of commercial use, the HVdc technique has been established as a conventional technology in the area of back-to-back and two-terminal long-distance and submarine cable systems. A three-terminal scheme has been realized. However, only limited operating experience is available. A multiterminal HVdc scheme using five and more terminals is planned for the future. HVdc schemes can be used for transmission capacities of 2000 MW and more, with multiterminal applications of over 4000 MW feasible in the future. These high transmission capabilities are only achievable at reasonable costs by using thyristor technology. Nevertheless, applications are coming up with combined schemes using thyristors and GTOs with ratings of 20 MW and more. With an increasing complexity of system conditions, e.g., in very weak power systems with enhanced stability requirements, parallel operation of HVdc and other devices of FACTS such as staticVAr compensators (SVC), thyristor-controlled series capacitors (TCSC) or thyristor-switched braking resistors (TSBR) are gaining momentum. Innovative technologies like CSCC (Siemens controlled series capacitor converter) can further optimize HVdc performance under weak and very weak system conditions.

[1996] 01A - 10

LONG DISTANCE TRANSMISSION: THE DC CHALLENGE

Clerici, A.; Longhi, A.; Tellini, B.

ABB SpA, Italy

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 86-92

The transmission of electric energy from remote large hydro, gas or coal resources is not only a means to access cheap energy supplies, but also a way to reduce global environmental problems. Transmission with direct current (dc) has already shown its value, and the recent developments and cost reductions of power converter substations have greatly extended its possible applications. The transmission at ultra high voltages (UHVdc) for distances of thousands of kilometers looks very attractive and reliable with no dramatic "quantum leaps" with respect to present EHVdc technologies up to ±600 kV. The paper reports the results of analyses performed on different dc transmission systems for power blocks in the range from 1000 to 10000 MW and for distances up to 5000 km. A parametric analysis is also included, together with a comparison between transport of gas and electric energy that is competitive up to 5000-10000 MW. 5 Refs.

[1996] 01A - 11

MITSUBISHI SOCIO-TECH ON HVDC

TECHNOLOGY (not actual title)

Mitsubishi Elec Corp, Tokyo, Japan

Mitsubishi Socio-Tech (Japan), vol 70, no 5, 1996, 100 pp

Contents: Transformer and Reactor Development for DC Power-Transmission Systems; Control and Protection Technologies for DC Power-Transmission Systems; Verification and Testing of DC Power-Transmission Equipment; Magnetic Drive Simulation and its Application to DC Circuit Breakers; World's Largest DC Flywheel Generator for the Toroidal Field Power Supply of JAERI's JFT-2M Tokamak Nuclear Fusion Reactor; Trends in the Development and Application of DC Power-Transmission Systems; System Design of an HVdc Converter Station; Development of a 500-kV High-Voltage, High-Capacity Thyristor Valve; Development of a Light-Triggered Thyristor; Development of 500-kVDC Gas-Insulated Switchgear.

[1996] 01A - 12

MORE HVDC TRANSMISSION PROJECTS BY TECHNICAL BREAKTHROUGH

Hasegawa, T.

Kansai Elec Power Co, Inc, Japan

Denki Gakkaishi (Japan), vol 116, no 10, pp 658-661

Japanese

This paper describes the reason why an eager gaze is poured on dc transmission, the barrier of dc transmission realization, and the breakthrough of a dc technology. The development result of the dc power transmission project of The Kii Channel which is scheduled an operation start in 2000 by the joint construction of The Kansai Electric Power Co., Inc., The Shikoku Electric Power Co., Inc. and The Electric Power Development Co., Ltd. is described. A last plan is consisted of four units of the thyristor ac to dc conversion equipment each ±500000V 1,400,000 kW, and about 50km 4 lines of a dc 500,000V submarine cable, and about 50km of an overhead wire which are installed in the conversion station of a both ended.

[1996] 01A - 13

DESIGNING A SUSTAINABLE ELECTRIC SYSTEM FOR THE TWENTY-FIRST CENTURY

Baker, M.H.; Rowe, B.A.; Thanawala, H.L.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

21st New Electricity Conf on Providing a Sustainable Electric System, Paris, France, May 22-24, 1995, pp 2250230

HVdc is required to exchange power between un-synchronized systems. Examples are given of the power and energy exchange, both reasons for such exchange and the technical attributes in terms of voltage and stability assistance provided by an HVdc link. Availability figures are added to demonstrate the dependability of this method of transmission.

[1996] 01A - 14

NEW TECHNOLOGY FOR IMPROVED UTILIZATION OF THE INTERCONNECTED POWER SYSTEM

Enger, A. K.

Norsk Elektroteknisk Forening, Porsgrunn, Norway

Proceedings, Norway as a Power Producer for Northern Europe: Technological and Environmental Challenges, Skien, Norway, September 4-5, 1996, NEI-NO-744, 34 pp

Norwegian

This paper deals with methods used for improving the utilization of interconnected power systems. The author discusses new technologies for improvement and safety of power transmission. The main themes are HVdc (high voltage dc) systems in Norway, possibilities of load management control and other measures in the grid system, and development trends. 21 figs.

[1997] 01A - 15

POWER TRANSMISSION AND HOW IT'S CHANGING

Baker, M.H.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

Power Engineering Journal (UK), vol 11, no 5, October 1997, pp 189-196

Originally transmission lines were built directly from energy source to load. Later they formed a mesh and voltages were raised to increase capacity. Today lines seem to be everywhere and the public is no longer saying "thank you." This paper explores how transmission capacity can be extended by boosting voltage, line sharing etc. The ability of power electronics to assist the system or to convert a segment to dc is shown. An Indian example demonstrates the benefits of dc interconnection of systems since it allows

them to maintain their independence. What are the limits of transmission, and why can blackouts occur? When and where does each conventional or power electronic solution apply?.

[1997] 01A - 16

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY OF ELECTRIC POWER DEVELOPMENT CO. LTD

Anon.

Elec Power Development Co Ltd, Tokyo, Japan

Research Bulletin of Electric Power Development Co., Ltd., vol 100, March 25, 1997, pp 159-182

Japanese

Power transmission and HVdc converter technologies of EPDC are outlined. The following technologies were developed for dc transmission: (1) the small water-cooled direct photo- ignition thyristor valve which reduced electronic parts by adopting water cooling and direct photo-ignition, (2) the tank-type dc filter which improved reliability and eliminated cleaning works by substituting a tank-type filter for previous rack-type one for dc linkage facilities, and (3) the digital control technology which improved the function of static reactive power compensators by substituting digital control for analog. The multi-terminal control and protective device for linkage are under development for use with large facilities. EPDC has constructed large-scale overhead transmission lines across channels and straits. For environmental measures and lifting of towers, the super-small base tower and T-type base were developed from analyses of tower structures. EPDC has also constructed underground (submarine) transmission facilities to link regional networks. Submarine cables, joints and laying techniques have been investigated. 3 refs., 21 figs., 9 tabs.

[1996] 01A - 17

PROCEEDINGS, NINTH NATIONAL POWER SYSTEMS CONFERENCE (NPSC '96)

Ghosh, A. (ed)

Indian Inst of Tech, Kanpur, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, 2 vols., 700 pp

Abstract not available.

[1996] 01A - 18

REBUILDING OF THREE-PHASE OVERHEAD LINES AS HVDC OVERHEAD LINES

Hausler, M.; Schlayer, G.; Fitterer, G.

ABB Calor Emag Schaltanlagen AG, Mannheim, Germany

Elektrizitaetswirtschaft (Germany), vol 95, no 19, September 9, 1996, pp 1226-1228, 1230

German

Conversion of existing three-phase lines to HVdc is one way of reducing the shortage of lines for long-distance electric power transmission. An example shows how 400--kV three-phase double lines could be rebuilt as double bipolar HVdc transmission lines for ±500 or 600 -kV, at a cost between a third and a half of that of new line construction. The rebuilding would enable more than 2 1/2 times as much power to be transmitted over the same width of right-of-way, and would reduce appreciably the specific transmission losses. 9 Refs.

[1996] 01A - 19

RING OF POWER: PREUSSENELEKTRA AND THE BALTIC RING

Anon.

Energie Spektrum (Germany), vol 11, no 6, 1996, pp 24-26

German

Since the breakup of the "Iron Curtain" in East Europe, the East European countries and countries of the former USSR are making efforts to catch up and cooperate with West European countries in the political, economic and military sectors, and a first concrete step towards integration currently in the process of preparation is synchronization with the UCPTE interconnected power system. Plans for an extension of the UCPTE network should not be regarded as an isolated initiative. Worldwide, plans are in the air to establish large-area, international, interconnected power systems. In order to assess the chances and risks of very large interconnected systems, the CIGRE Working Group 37-12 as well as other national and international bodies have been investigating the idea and the prospects of such projects, and the CIGRE Working Group recently published its report, entitled "The Extension of the Synchronous Electric Systems: Advantages and Drawbacks," CIGRE report 37-110, 1994. Members of this working group were representatives of the major international interconnected systems. The article summarizes the results published by the Working Group.

[1997] 01A - 20

STATE OF THE ART & TREND IN ANALYSIS TECHNOLOGY OF HVDC SYSTEM

Takasaki, M.

CRIEPI, Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu, (Japan) vol 1997, no 6, pp S.23.21-S.23.24

Japanese

Abstract not available.

[1997] 01A - 21

STATE-OF-ART AND DEVELOPMENT OF MULTI-TERMINAL HVDC CONTROL SYSTEMS

Sanpei, M.

Elec Power Development Co, Ltd, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan) vol 1997, no 6, pp S.23.29-S.23.32

Japanese

Abstract not available.

[1997] 01A - 22

STATE-OF-ART AND DEVELOPMENT OF HVDC TRANSMISSION TECHNOLOGIES

Horiuchi,S.; Kobayashi, T.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp S.23.1-S.23.4

Japanese

Abstract not available.

[1996] 01A - 23

THE ROLE OF DIRECT CURRENT ELECTRIC POWER TECHNOLOGY IN ELECTRIC POWER OPERATION. WORLD TRENDS

Tamanuki, S.

Japan Elec Power Inf Center, Inc

Denki Hyoron (Japan), vol 81, pp 60-66

Japanese

The improvement of thyristor valve performance has led to the expansion of dc power system technology. This paper shows global trends, with examples, regarding long distance power transmission, submarine cable interconnections, and the BTB-type asynchronous interconnection that strongly needs dc electric power technology. The 800-km, ±600-kV dc interconnection between the Itaipu power plant at the border of Brazil and Paraguay and Sao Paulo, with a capacity of 6.3 million kW is the world's largest dc interconnection at present.

[1997] 01A - 24

TRENDS IN HVDC TECHNOLOGIES DEALT WITH BY CIGRE

Inoue, Y.; Magoroku, H.; Horiuchi, T.

Elec Power Development Co, Ltd, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp S.23.37-S.23.40

Japanese

Abstract not available.

[1996] 01A - 25

UNIT CONNECTED HVDC SCHEMES

Rae, T.A.; Harley, R.G.; Jennings, G.D.; Wishart, M.T.

Dept of Elec Eng, Natal Univ, Durban, South Africa

Proceedings, 6th South African Universities Power Engineering Conf (SAUPEC '96), Witwatersrand, South Africa, January 22-23, 1996, pp 157-160

English

Conventional high voltage direct current (HVdc) has advantages in long distance transmission, and of decreased stability problems which limit high voltage alternating current (HVac) transmission, but in turn introduces other complexities. Unit connection is a refined HVdc scheme which rectifies the power of each turbogenerator individually before connecting it to the dc line. Some simulated results of the unit connected scheme, some harmonic results and effective converter transfer functions are presented. 8 Refs.

[1996] 01A - REF

TRENDS IN HVDC

For Abstract see entry 01B - 35

[1996] 01A - REF

APPLICATION AND OPERATING EXPERIENCE OF MULTI-VARIABLE FREQUENCY CONTROLLER OF HVDC SYSTEM

For Abstract see entry 01B - 5

[1997] 01A - REF

DIGITAL SIMULATION OF THE DC CONNECTION OF A WIND FARM

For Abstract see entry 05E - 7

[1998] 01A - REF

DESIGNING HVDC TRANSMISSION SCHEMES FOR DEFINED AVAILABILITY

For Abstract see entry 05L - 5

[1997] 01A - REF

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) FOR THE IMPROVEMENT OF NETWORK QUALITY

For Abstract see entry 07A - 25

[1996] 01A - REF

GLOBAL LINK OF RENEWABLE ENERGY SOURCES: TECHNICAL, ECONOMICAL, AND ENVIRONMENTAL ASPECTS OF AN INTERCONTINENTAL ELECTRICITY TRANSMISSION AND DISTRIBUTION SYSTEM

For Abstract see entry 07A - 27

[1996] 01A - REF

POWER ELECTRONIC DEVICES AND THEIR IMPACT FOR POWER TRANSMISSION

For Abstract see entry 07A - 41

[1998] 01A - REF

TRANSMISSION CAPABILITY ENHANCEMENT USING POWER ELECTRONICS TECHNOLOGIES FOR THE FUTURE POWER SYSTEM IN JAPAN

For Abstract see entry 07A - 71

[1998] 01A - REF

BIBLIOGRAPHY ON VOLTAGE STABILITY

For Abstract see entry 07A - 9

01B Planning, System Studies, Economics

[1997] 01B - 1

3000-4500 MW FROM INGA FALLS (ZAIRE) TO SOUTH AFRICA WITH HVDC: A PRE-FEASIBILITY STUDY

Clerici, A.

ABB SpA, Italy

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

In view of the continuous improvement of HVdc technology and its possible increasing application to the transmission of large amounts of power over long distances, in 1993 ABB performed a pre-feasibility study for an EHVdc line from the Inga Fall (Zaire) to the Republic of South Africa (RSA). The study was carried out on the basis of the terms of reference prepared by Prof. Francesco Iliceto (Rome University, Italy), who originated the study. This paper provides a summary of both the main hypotheses considered and the main results of the 1993 study. Although some data on line and HVdc terminal costs may have changed in the last four years with a better cost positioning of HVdc systems, the possible variations do not modify the conclusions. The same applies to the new technology developments in HVdc substations. The study was to provide initial technical and economical data for preliminary evaluations of transmitting cheap hydroelectric power from Inga in Zaire. Analyses were confined to 3000 to 4500 MW at the sending end. The two voltage levels of ±600 and ±800 kV were chosen as optimum for such a long transmission path (3000-4000 km). The study considered only one bipolar line, while further analyses involving the effects on cost and reliability of separate monopolar lines in the same or separate rights of way were left to later studies. All aspects related to HVdc terminal stations and line routing were studied with ABB Power Systems of Sweden and ABB Feralin of South Africa. The ±800-kV voltage level was considered feasible and available for the project under evaluation.

[1998] 01B - 2

A FEASIBILITY STUDY OF AN ASYNCHRONOUS INTERCONNECTION FOR INDUSTRIES WITH CAPTIVE GENERATION

Kumar, A.; Prasad, M.; Chakraborty, R.; Maheshwari, R.C.

ABB Ltd, New Delhi, India

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper presents the results of a techno-economic feasibility study for an asynchronous link (i.e., an HVdc back-to-back or a frequency stabilizer) for an aluminum industry with its own captive generation. The main objective of the study was to eliminate the problems being faced by the industry due to adverse operational characteristics of the Northern Region grid of India, especially prolonged operation at off-normal frequency. It is demonstrated that the interconnection through the asynchronous link makes the process and its associated captive power plant (CPP) immune to all the quasi steady state grid parameter variations as well as the majority of grid disturbances. The pay-back period of such an investment for the industry under study has been estimated to be just over three years.

[1997] 01B - 3

A METHOD FOR IDENTIFICATION OF BEST SITING OF CONVERTERS FOR IMPROVING VOLTAGE STABILITY BY USING ESTIMATION OF VOLTAGE SENSITIVITY.

Tada, Y.; Okamoto, H.; Sekine, Y.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 48, 50-53, 55-58, 60-62, pp 1-6

Japanese

This paper discusses a method for identifying the best sites for converters in order to improve voltage stability using estimation of voltage sensitivity. HVdc systems decrease reactive power loss at ac transmission lines. This paper describes that voltage/active power sensitivity expresses variation of reactive power loss. Using this fact, the authors propose an index for determining the best sites for HVdc converters.

[1997] 01B - 4

ANALYSIS OF THE HVDC INVERTER IN THE HARMONIC DOMAIN

Bathurst, G.; Smith, B.C.; Watson, N.R.; Arrillaga, J.

European Power Electronics Conf EPE '97, Oslo, Norway, September 1997

Abstract not available.

[1996] 01B - 5

APPLICATION AND OPERATING EXPERIENCE OF MULTI-VARIABLE FREQUENCY CONTROLLER OF HVDC SYSTEM

Honjo, N.

Elec Power Dev Co Ltd, Tokyo, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 597-600

The Hokkaido-Honshu HVdc link connects two separated Japanese power systems (the Honshu and Hokkaido systems) with an HVdc transmission line (dc 250 kV 600-MW). This HVdc link is used not only for bulk power transmission, but also for the frequency control of each power system by modulating the transmission power of the HVdc system. The authors applied traditional proportional control before the extension of the HVdc system. When they started to survey in detail the extension of the HVdc system, these studies showed that the frequency controller based on proportional control did not have sufficient capability for an extended HVdc system. They therefore applied modern control theory instead of traditional proportional control for frequency control and put this into use in 1993. Here, the authors introduce the new frequency control method as well as its effect. 1 Ref.

[1998] 01B - 6

AUTOMATIC GENERATION CONTROL IN A DEREGULATED POWER SYSTEM

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IEEE Trans on Power Delivery, Preprint order number PE-183-PWRS-0-11-1997

Load-frequency control (LFC) has been used for many years as part of the automatic generation control (AGC) in power systems around the world. In the sycnhronous Nordic power system, however, this function (termed secondary control) has so far been handled with manual control actions. Increased operation strain due to new HVdc connections in the next decade will make it increasingly difficult to maintain the current manual control system. In this paper a model of the interconnected power systems of Norway and Sweden is used to show how introduction of AGC might aid the system operator in handling the increased strain. However, the classical LFC based on the area control error is difficult to implement in a deregulated environment. An alternative concept is thus introduced

where selected units are automatically following load changes on the HVdc connections. This ramp following controller (RFC) supported by manual control seems to be a promising option.

[1997] 01B - 7

EAST EUROPEAN ELECTRICITY INFRASTRUCTURE, INTERCONNECTIONS, AND ELECTRICITY EXCHANGES

Hammons, T.J.

Univ of Glasgow, UK

Electric Machines and Power Systems, vol 25, no 7, August-September 1997, pp 693-711

This paper discusses the east and central European electricity infrastructure, interconnections and electricity exchanges following the segregation of the republics of former USSR and the independence of east European countries, and likely developments in future years. The study focuses on the present and future state of the electric power sector, future expansion of European power systems, co-operation, new capacity, separation of power systems in former USSR countries, the direction of reform in the industry, interstate relations in the fuel and energy complex, and impact of privatization on electricity supply. The role of Russian power systems in the future unified electrical power system of the Euro-Asian continent is also examined.

[1997] 01B - 8

EUROPE'S POWER BRIDGE FOR THE NEXT MILLENNIUM

Fischer, W.

Int'l Power Generation (UK), vol 20, no 1, January 1997, pp 11-12

The collapse of the Soviet Union and the political reorientation of its former satellites in eastern Europe, prompted the countries involved to seek a new "commercial realism" with the European Union and in particular with those states sharing common borders. German power utilities (Germany has the longest land frontier with the former Soviet bloc) must now consider the possibility of exchanging electrical power with east-European generators. What is missing, however, is the means of economically transmitting such potentially large amounts of energy westwards, i.e. into the power networks of western Europe yet at the same time guaranteeing the high standards of security expected by western European consumers. There are essentially three practicable means of doing this. Two combinations of 750-kV ac working with back-to-back HVdc, and the third, purely HVdc. A 500-kV direct current line has been clearly demonstrated to be the most economically feasible. The author explains the commercial and political thinking behind the trans-European power line that will link eastern Europe into the West's supply network by 2010. The route of the transmission line and its cost are outlined.

[1996] 01B - 9

EXTENSION OF CO-OPERATION IN EUROPE: TECHNOLOGY OF ELECTRICITY TRANSMISSION

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PreussenElektra AG, Hanover, Germany

Elektrizitaetswirtschaft (West Germany), vol 95, no 13, 17 June 1996, pp 865-866, 868, 870

German

Progress towards close and successful collaboration between the German power supply undertakings and those of Western Europe is reviewed, with new technology developments being pursued in Germany for optimizing electricity supply to meet the need for reliability in an economically and ecologically acceptable manner. Maps show the regions served by the author's company and others in the UCPTE network and its HVdc links to Scandinavia (Nordel) and the Baltic Ring project. Photographs of outdoor installations and valve towers at the Lubeck-Herrenwyk convertor station on the Baltic Cable link to Sweden are reproduced. 0 Refs.

[1997] 01B - 10

FEASIBILITY STUDY FOR INCREASED POWER EXCHANGE BETWEEN NORWAY AND CONTINENTAL EUROPE BY NEW HVDC LINKS

Carlsen, T.H.; Rittiger, J.; Witzmann, R.

Siemens AG, Erlangen, Germany

Elektrizitaetswirtschaft (Germany), vol 96, no 19, September 8, 1997, pp 1026-1028, 1030-1032

German

The benefits of utilizing energy exchange between the Norwegian hydroelectric power system and the thermal power systems in Europe make it interesting to establish new HVdc sea cable interconnections. As the required licenses are issued by the national authorities involved, several new HVdc links may be established from the Southern part of Norway to the continent, each having a

cable length of approximately 550 km. A total power of 3000 MW or more can then be exchanged through the HVdc links including the existing Skagerrak interconnection. It is planned to transmit a maximum power of 600 MW or even 800 MW, by each new HVdc link at a dc voltage of 500 kV, assuming that progress in submarine power cable technology allows this voltage level in the coming years. A feasibility study with detailed modeling of all HVdc interconnections, the ac system of Southern Norway and relevant parts of the UCPTE system has been carried out. Especially, the close electrical proximity between the HVdc power converter stations in Norway (the distance between these stations is 40-60 km) requires detailed studies using digital simulation. In this paper, the advantages of energy interchange, technical aspects and the main results of the power system dynamic study are discussed.

[1996] 01B - 11

HIGH-VOLTAGE DC TRANSMISSION: A POWER ELECTRONICS WORKHORSE

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IEEE Spectrum, vol 33, no 4, April 1996, pp 63-72

The economic stirrings in many parts of the world could be invigorated by access to surplus electric power generated elsewhere. One means of access now coming to the fore is high-voltage dc (HVdc) transmission. This technology is often an economical way to interconnect certain power systems as well as to transmit power over long distances by overhead transmission. Worldwide, more than 70 HVdc projects have been completed, for a total transmission capacity in operation of about 46,000 MW at voltages up to ±600 kV. In the last two decades, the average HVdc capacity brought into service has been about 2000 MW per year, indicating power electronic converter capacity of 4000 MW. This transistor-based technology thrives when it comes to highly reliable power transfer across natural or national boundaries or between ac system designed for different frequencies or incompatible frequency controls. 8 Refs.

[1997] 01B - 12

HVDC ECONOMIC ASSESSMENT IN A SOUTHERN AFRICAN CONTEXT

Baker, M.H.; Hepburn, A.; Lewis, W.P.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

Efficiently harnessing the hydroelectric energy of Africa's great river systems is a primary reason for the trend towards regional cooperation and transmission interconnection. Within the Southern African region, interconnecting the central hydroelectric potential with the southern thermal (coal-based) large generation enables the optimization of regional primary energy resources. Interconnection should bring benefits to all participants. This is the fundamental objective behind the establishment of the Southern African Power Pool (SAPP). Strategies for interconnection and electricity trade should be based on a careful review of scenarios for interconnecting regional electrical networks according to the individual needs and aspirations of participants. The purpose of this paper is to identify the important institutional and economic criteria for successful interconnection, and the transport of bulk power over large distances via HVdc transmission.

[1997] 01B - 13

IEEE GUIDE FOR PLANNING DC LINKS TERMINATING AT AC LOCATIONS HAVING LOW SHORT-CIRCUIT CAPACITIES

IEEE Transmission and Distribution Committee

T&D Committee of the IEEE PES, USA

IEEE Std 1204-1997, December 31, 1997, 205 pp

Guidance on the planning and design of dc links terminating at ac power system locations having low short-circuit capacities relative to the dc power infeed is provided in this guide. This guide is limited to the aspects of interactions between ac and dc systems that result from the fact that the ac system is "weak" compared to the power of the dc link (i.e., ac system appears as a high impedance at the ac/dc interface bus). This guide contains two parts: Part I, AC/DC Interaction Phenomena, classifies the strength of the ac/dc system, provides information about interactions between ac and dc systems, and gives guidance on design and performance; , and Part II, Planning Guidelines, considers the impact of ac/dc system interactions and their mitigation on economics and overall system performance and discusses the studies that need to be performed.

[1997] 01B - 14

IMMINENT CHALLENGES OF BULK POWER TRANSMISSION FROM THE HIMALAYAN REGION FOR INDIA

Prasad, M.; Deb, S.K.; Dass, R.; Isacsson, G.; Borsos, A.

ABB Ltd, New Delhi, India

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper discusses the available hydroelectric potential in northeastern India and Nepal and the challenges of developing optimal transmission alternatives with due cognizance of emerging transmission technologies, especially HVdc, for voltages higher than 600 kV and EHVac transmission at 800 kV or even 1100 kV. It presents a few conceptual transmission alternatives which deliver power to the beneficiaries in need of bulk power. The paper also indicates scenarios arising out of turnkey development of both the power plants and their associated transmission.

[1997] 01B - 15

INCREASING POWER TRANSMISSION CAPABILITY OF AC SYSTEMS BY MEANS OF POWER ELECTRONIC EQUIPMENT

Lei, X-Z.; Povh, D.; Renz, K.; Retzmann, D.

Siemens AG, Erlangen, Germany

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol VI-3, pp 25-34

Power electronic equipment (FACTS) has been developed and used as an economic and efficient means of solving problems concerning the full utilization of the capacity of long, heavily loaded, interconnected ac transmission systems and in scheduling power transfers between subsystems. Various FACTS devices, such as HVdc, SVC, TCSC, STATCON and UPFC are focused on improving the system stability and enhancing the transfer capability of interconnected systems with long transmission links. These are described in this paper. Based on a simple interconnected system with long transmission links, the effects of different FACTS devices, such as HVdc, SVC and TCSC, are demonstrated at transient conditions.

[1996] 01B - 16

IS THE EAST-WEST POWER BRIDGE ECONOMIC?

Anon.

Modern Power Systems (UK), vol 16, no 2, February 1996, pp 21, 23, 25

An HVdc transmission project, so large and ambitious that many authorities dismissed the idea as unfinanceable, now has to be taken seriously. The 4000-MW East-West Power Bridge, running some 1800 km from Borken near Frankfurt-am-Main in Germany across eastern Germany, Poland, Belarus and Russia to Smolensk with five interconnections to national ac networks, has now been calculated to be economically viable. The Russian participants are already planning to build vital connections at the eastern end of the system. These were the conclusions of the latest conference of the East-West Energy Bridge project in Warsaw on October 24-25, 1995. The major findings of this conference are discussed, in particular the technical and economic benefits of such a link. 0 Refs.

[1996] 01B - 17

DESIGNING A SUSTAINABLE ELECTRIC SYSTEM FOR THE TWENTY-FIRST CENTURY

Hedenstedt, A.; Hansson, B.

Vattenfall AB, Stockholm, Sweden

21st New Electricity Conf on Providing a Sustainable Electric System, Paris, France, May 22-24, 1995, pp 219-224

After the national grids were established, the comprehensive integration of the Nordic countries took place during a 20-year period beginning in early 1960s. A characteristic feature of the interconnection of the Nordic electric power systems is the need for long HVdc submarine cables for several of the interconnection links. Today the Nordel system is almost considered as one system. At present there are several ongoing, actively considered and planned projects for the integration of the Nordel system and the UCPTE system. Interconnection offers a number of benefits for both the systems. One very important benefit is the stabilization effect on the power supply security and the price of electricity. This is of special importance in view of the expected de-regulation of the electricity market.

[1996] 01B - 18

NEW TECHNOLOGY FOR IMPROVED UTILIZATION OF THE INTERCONNECTED POWER SYSTEM

Enger, A.K.

Norsk Elektroteknisk Forening, Porsgrunn, Norway

Proceedings, Norway as a Power Producer for Northern Europe, Technological and Environmental Challenges, Skien, Norway, September 4-5, 1996, 34

pp

Norwegian

The present paper deals with methods used for improving the utilization of interconnected power systems. The author discusses new technologies for improvement and safety of power transmission. The main themes covered are HVdc systems in Norway, possibilities of load management control, other possible/necessary measures in the grid system, and other developments and trends. 21 figs.

[1997] 01B - 19

NONLINEAR POWER SYSTEM BEHAVIOR USING NORMAL FORMS: EXTENSION OF LINEAR SYSTEM ANALYSIS VIA HIGHER ORDER CORRECTION

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EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-107798, February 1997, 224 pp

Today's heavily loaded and stressed power transmission networks exhibit very complex dynamic behavior when subjected to small or large disturbances. EPRI investigators analyzed power system dynamic behavior under stressed operating conditions by using normal forms of vector fields. This technique obtained nonlinear corrections to the linear behavior through normal form analysis. This second order analysis has provided insight into real power network dynamic problems associated with interaction of control modes, system separation, and effect of nonlinear elements like high-voltage direct current (HVdc) that were not obvious from linear analysis.

[1997] 01B - 20

OPTIMAL TRANSMISSION SYSTEM UPGRADE OPTIONS FOR AC-DC HYBRID REGIONAL NETWORK

Singh, S.; Bhatele, R.P.; Dhoke, M.M.; Parameswaran, S.; Sarkar, B.N.; Murty, A.S.R.; Prasad, M.; Deb, S.K.; Moni, R.S.

Madhya Pradesh Elec Board, Jabalpur, India

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper presents the results of studies made to remove the operational and evacuation constraints of India's largest state, Madhya Pradesh, as it embarks on an ambitious program to increase power generation. The studies show the benefit of carrying out realistic load flow analyses prior to detailed contingency analysis and dynamic simulations. There are several options available to increase power evacuation capability of an existing transmission system. However, growth brings in several constraints, not the least of which is the right-of-way limitations for constructing transmission lines. In a system where power stations have to necessarily be located far away from load centers, this has a profound influence on the design of the transmission system. It is possible to overcome the constraints by proper choice of technology. An open approach in selecting the appropriate technology could turn out to be economically attractive, giving a high benefit-to-investment ratio. This paper will be useful to power systems which are undergoing rapid expansion while facing increasing resources and land constraints

[1996] 01B - 21

PERFORMANCE CALCULATIONS OF HVDC SYSTEMS WITH MINIMUM COMPUTER AID

Calverley, T.E.

Mott Ewbank Preece, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 93-99

The complexity of ac/dc/ac power systems and the large number of alternative designs to be evaluated, make necessary the use of advanced computer and simulator facilities. However, there is a place for a simpler approach, both in the initial planning stages, and as an indication of the consequences of many events. Here, the author describes how, for instance, it can be instructive to: (1) appraise the sensitivity of the initial design of a proposed HVdc project to a range of major variables, such as SCR, cos phi , ac system X/R and commutating reactance X_T; and (2) understand the consequences of many transient events, without recourse to computers or possibly with their use on a very limited scale. Performance calculations of HVdc power transmission systems with a minimum of computer use are presented in this paper. 5 Refs.

[1997] 01B - 22

PLANNING INTERCONNECTIONS TO DEVELOP A SOUTHERN AFRICAN GRID

Akapelwa, K.; Sumary, C.S.; Mandalasi, O.C.; Hepburn, A.; Leask, K.P.

ZESCO, Zambia

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper presents an overview of the methods applied in regional inter-utility planning studies. The need for these studies arose from the desire of the participating utilities to have a better understanding of the operation of their networks if coupled with a transmission interconnector. Where mutual advantages were identified, this has led to development of financial justification and implementation of some of the projects. The conclusions from planning studies of two such possible ac interconnections together with their reactive compensation requirements are reviewed.

[1996] 01B - 23

POWER ELECTRONICS IN INDIA - RETROSPECT AND PROSPECTS

Sarkar, T.K.

Govt of India, New Delhi, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 2, pp 1059-1064

Electric power is the key to the economic growth of any country. Developing countries are faced with gaps between demand and supply of electricity, on one hand, and rising cost of power generation on the other. Power electronics helps in conservation of electricity and the improvement of power quality. India has witnessed a moderate growth in power electronics activities in the past two-and-a-half decades and has built-up reasonable infrastructure concerning its manufacture, application and skilled manpower requirements. Economic reforms in the country are opening up new opportunities for larger application. Greater efforts by industry to build-up an internal strength on technology using available resources is now essential to meet these challenges.

[1996] 01B - 24

RECONSTRUCTION OF OVERHEAD LINES FOR THREE-PHASE CURRENT INTO HVDC LINES

Haeusler, M.; Schlayer, G.; Fitterer, G.

ABB Calor Emag Schaltanlagen AG, Mannheim, Germany

Elektrizitaetswirtschaft (Germany), vol 95, no 19, September 9, 1996, pp 1226-1230

German

One way of overcoming the shortage of long-distance transmission lines for electric power is by converting existing HVac lines into HVdc lines. An example is presented. The reconstruction cost amounts to about one-third to one-half of the cost of a newly constructed transmission system, while power transmission would be increased to more than 2.5 times the original capacity. The specific transmission cost is reduced significantly.

[1997] 01B - 25

REDUCING VULNERABILITY OF AN ELECTRICITY-INTENSIVE PROCESS THROUGH AN ASYNCHRONOUS INTERCONNECTION

Kumar, A.; Prasad, M.; Maheshwari, R.C.

ABB Ltd, New Delhi, India

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper presents the results of a study conducted for M/s Hindalco Industries Ltd., to find ways and means to reduce the vulnerability of its electricity-intensive smelting process. The industry's power system is interconnected with the Northern Regional Grid of India, which experiences rather frequent disturbances and operates within a wide frequency range. It has been found that an asynchronous connection of the industry power system, which includes its captive power plant, to the grid in association with an intelligent load management scheme, is one of the most suitable means of tackling its stability, frequency excursion and power flow-related problems. With the proposed frequency stabilizer being placed between the grid and Hindalco Plant 1 busbar, the industry will be in a position to operate its generating units at near rated frequency of 50 Hz, irrespective of the operating grid frequency and at the same time avail continuous support from the grid under normal or emergency operating conditions. The pay-back period for such an investment has been estimated to be just over three years.

[1996] 01B - 26

SCOPE AND VOLTAGE GRADE OF THE DIRECT CURRENT TRANSMISSION PROJECT FROM XIAOWAN POWER STATION TO GUANGDONG PROVINCE

Liu, S-L.; Zhang, C-H.

Kunming Hydroelec Survey, Min of Elec Power, Kunming, China

Power System Technology (China), vol 20, no 9,

September 1996, pp 17-19

Chinese

The authors discuss the scope and voltage grade of the direct current transmission project from Xiaowan hydroelectric power station in Yunnan Province to Guangdong Province. They carry out a techno-economical comparison among various combinations of transmission capacities and cross-sectional areas of transmission lines when a voltage grade of ±500 kV is adopted, and suggest proposals for the scale of the project. An empirical formula for selecting the voltage grade for direct current transmission is put forward in this paper. 0 Refs.

[1997] 01B - 27

SOME ASPECTS OF THE FEASIBILITY OF AN INTERCONNECTION BETWEEN THE DEMOCRATIC REPUBLIC OF CONGO AND EGYPT

Swidan, M.; Sakrini, M.; Julliard, G.; Adam, P.; Bohner, R.

Egyptian Electricity Authority, Egypt

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper presents the main technical questions related to the transmission of large amount of electricity over a very long distance, and more specifically to the project of an interconnection between the hydroelectric site of Inga in the Democratic Republic of Congo, and the Egyptian 500-kV unified power system near Cairo. After a description of the main parameters of the project, it shows how different criteria have been considered to define an adequate level of losses. Once applied to the project, these principles have led to the definition of the main equipment of the project: the main converter stations, the parallel and series tap stations, and the switching substations along the 5300-km line route. Some results of the dynamic performances of the interconnection are also given, based on digital simulation using stability and electromagnetic transient programs. As a conclusion, the authors indicate that except for the 800-kV dc voltage and the proposed conductor bundle arrangements (8 x 806 mm^2), the project is based on proven HVdc techniques and technologies that make this very long interconnection feasible from a technico-economic point of view.

[1997] 01B - 28

STATE OF THE ART; DEVELOPMENT OF HVDC TRANSMISSION TECHNOLOGY IN JAPAN

Hayashi, T.

CRIEPI, Tokyo, Japan

Ohm (Japan), vol 84, no 12, pp 65-70

Japanese

Abstract not available.

[1997] 01B - 29

SUBJECTS FOR EXPANSION OF HVDC

Nakamura, F.

Sci Univ of Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, p S.23.41

Japanese

Abstract not available.

[1996] 01B - 30

SYSTEM ANALYSIS OF HYBRID HVDC TRANSMISSION

Iwata, Y.; Tanaka, S.; Kawazoe, H.; Konishi, H.

Tokyo Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 421-422

Japanese

Abstract not available.

[1996] 01B - 31

SYSTEM CHARACTERISTICS OF HAENAM-CHEJU HVDC LINK IN KOREA

Kim, J-Y.; Kwon, G-O.; Lim, S-J.

T&S Dept, Korea Elec Power Corp, South Korea

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 558-562

The Korea mainland to Cheju island HVdc link has many characteristics. This system is the 300-MW, ±180-kV bi-directional dc link and a 100-km long submarine bipolar cable scheme, scheduled for operation no later than June, 1997. This paper describes the main system features, generation planning and

control characteristics and examines the transient response from faults at both rectifier and inverter terminal busbars. 5 Refs.

[1997] 01B - 32

TECHNICAL AND ECONOMIC ASPECTS OF USING A LONG SUBMARINE HVDC CONNECTION FOR FREQUENCY CONTROL

Bakken, B.H.; Faanes, H.H.

Norwegian Univ of Sci and Tech, Trondheim, Norway

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1252-1257

Several new submarine HVdc connections between the hydro dominated Norwegian power system and the thermal dominated UCPTE system of western Europe are being planned, giving a total transfer capacity of approximately 3000 MW. Both existing and new HVdc exchange agreements are based mainly on the pumped storage principle, where Norwegian hydro power is exported during peak load, while surplus energy can be imported during off-peak periods. This paper focuses on an additional benefit of these HVdc connections: the possibility to supply frequency control in the thermal system of northern UCPTE. Typical costs related to frequency control in thermal units are estimated, giving a strong economic motivation for this possibility. Furthermore, it is shown that the substitution of thermal frequency control reserves with a long submarine HVdc connection is possible without additional equipment or extensive control strategies, and without causing large disturbances in either the thermal or the hydro system. 9 Refs.

[1996] 01B - 33

THE NEXT GENERATION OF HVDC - NEEDED R&D, EQUIPMENT COSTS, AND COST COMPARISONS

VanCoevering, J.; Stoval, J.P.; Hauth, R.L.; Tatro, P.J.; Railing, B.D.; Johnson, B.K.

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Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, pp 3/183-3/195

High voltage dc transmission (HVdc) offers important advantages over ac because of its ability to move more power over a given right of way than ac lines of comparable voltage, as well as allowing exchanges of power between otherwise nonsynchronous ac systems. HVdc may also be appealing in a competitive utility environment because of its ability to precisely control power flow, avoiding parallel path problems. Finally, HVdc may be more acceptable than ac transmission to a public concerned over potential health impacts of ac power lines. These advantages can only be realized if the cost of HVdc as a planning option is competitive with the cost of ac construction. HVdc transmission lines are cheaper than comparably rated ac lines, but terminal costs are much higher. The challenge, therefore, is to reduce the cost of the HVdc converter terminal to about half its current value. A research and development program to reduce dc converter terminal costs is presented and consists of five research areas: converter configurations, valves and devices, advanced converter transformer designs, technology assessment, and monopolar operation. As part of the technology assessment, turnkey costs of today's converter terminal have been identified to be about $100/kW/terminal. The costs of other ac equipment have also been identified as the basis for economic comparisons. A comparison of dc and ac transmission shows the break-even distance near their thermal ratings.

[1996] 01B - 34

THE OUTLINE OF KII CHANNEL HVDC LINK

Yamaji, K.

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Pawa Erekutoronikusu Kenkyukai Ronbunshi (Japan), vol 22, no 1, pp 14-19

Japanese

An HVdc project of ±500-kV and 2800-MW bipolar system is planned to interconnect the ac 500-kV networks of Shikoku Electric Power Company and The Kansai Electric Power Company. At the first stage, the HVdc system will be commissioned at ±250 kV and 1400 MW in the year 2000. The HVdc system will link the two 500-kV systems in parallel with existing ac 500-kV interconnection lines, transmit power from a coal power station to the Kansai area, and reinforce the existing interconnection. This paper describes the planning of the HVdc project and the technical innovation involved with this project.

[1996] 01B - 35

TRENDS IN HVDC

Povh, D.

Siemens AG, Erlangen, Germany

Proceedings, Int'l Conf on Electrical Engineering

(ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1316-1327

The HVdc technique has become a conventional technology in the area of back-to-back and two-terminal long-distance and submarine cable schemes. Three-terminal schemes have been realized and multiterminal schemes are being planned. The introduction of thyristor technology and engineering improvements have resulted in strong cost reductions for HVdc stations. However, increased system requirements have flattened down this trend. The report discusses experiences with HVdc technique and expected trends, with the goal of making making HVdc even more economical in the future. 2 Refs.

[1996] 01B - REF

LONG DISTANCE TRANSMISSION: THE DC CHALLENGE

For Abstract see entry 01A – 10

[1996] 01B - REF

DESIGNING A SUSTAINABLE ELECTRIC SYSTEM FOR THE TWENTY-FIRST CENTURY

For Abstract see entry 01A - 13

[1996] 01B - REF

NEW TECHNOLOGY FOR IMPROVED UTILIZATION OF THE INTERCONNECTED POWER SYSTEM

For Abstract see entry 01A - 14

[1997] 01B - REF

CONVERTING AC POWER LINES TO DC FOR HIGHER TRANSMISSION RATINGS

For Abstract see entry 01A - 3

[1996] 01B - REF

INTRODUCTION OF KII CHANNEL HVDC LINK

For Abstract see entry 01C - 19

[1997] 01B - REF

SYSTEM DESIGN OF HVDC SYSTEM

For Abstract see entry 01C - 33

[1996] 01B - REF

REACTIVE POWER CONTROL IN HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

For Abstract see entry 02D - 23

[1997] 01B - REF

A TWO-STAGE DC THYRISTOR CIRCUIT BREAKER

For Abstract see entry 02F - 1

[1996] 01B - REF

ANALYSIS OF AN HVDC SYSTEM CONSIDERING VARIOUS CONTROLS

For Abstract see entry 05B - 10

[1996] 01B - REF

DESIGN AND TESTING OF THE BIPOLAR 12-PULSE HVDC PROTECTION SYSTEM

For Abstract see entry 05B - 26

[1997] 01B - REF

HYBRID SIMULATION STUDY OF FACTORS CONTRIBUTING TO HARMONIC INSTABILITY OF HVDC SYSTEMS

For Abstract see entry 05D - 15

[1998] 01B - REF

PROPOSED 4 GW RUSSIA-GERMANY LINK - IMPACT OF 1 GW INVERTER STATION ON TORSIONAL STRESSING OF GENERATORS IN POLAND

For Abstract see entry 05D - 24

[1996] 01B - REF

REGULATION CONCEPT FOR A MULTITERMINAL HIGH-VOLTAGE DC TRANSMISSION

For Abstract see entry 05E - 12

[1996] 01B - REF

SIMULATION OF A 5-TERMINAL HVDC CONFIGURATION BETWEEN EASTERN AND WESTERN EUROPE

For Abstract see entry 05E - 13

[1996] 01B - REF

THE CONTROL PROBLEMS OF CONVERTER IN A MULTITERMINAL HVDC SYSTEM ON THE EXAMPLE OF EAST-WEST TRANSMISSION LINE

For Abstract see entry 05E - 17

[1996] 01B - REF

HVDC MULTI-INFEED PERFORMANCE

For Abstract see entry 05F - 1

[1996] 01B - REF

PROSPECTIVE USE OF HVDC AND FACTS FOR ENHANCEMENT OF POWER SYSTEM STABILITY IN THE MAIN GRID OF THE SOUTHERN NORWAY

For Abstract see entry 05G – 6

[1997] 01B - REF

DIAGNOSING THE HEALTH OF BULK GENERATION AND HVDC TRANSMISSION SYSTEMS

For Abstract see entry 05L - 6

[1997] 01B - REF

ANALYSIS OF POWER OSCILLATIONS IN THE SOUTH AFRICAN HIGH-VOLTAGE GRID USING COMBINED TIME DOMAIN AND EIGENVALUE TECHNIQUES

For Abstract see entry 06C - 2

[1997] 01B - REF

PROBLEMS OF NORTHERN ELECTRICITY REGION OF INDIA

For Abstract see entry 07B - 43

[1998] 01B - REF

THE STATE-OF-THE-ART OF POWER ELECTRONICS IN JAPAN

For Abstract see entry 07B - 60

[1996] 01B - REF

USE OF HVDC AND FACTS-COMPONENTS FOR ENHANCEMENT OF POWER SYSTEM STABILITY

For Abstract see entry 07B - 65

01C HVDC Projects: Description, Commissioning, Testing, Performance

[1997] 01C - 1

350-KV HVDC OIL-FILLED SUBMARINE CABLE PROJECT IN THE PHILIPPINES

Harada, K.; Yoshida, F.; Midorikawa, M.; Koibuchi, S.

Hitachi Cable Ltd, Japan

Hitachi Cable Review (Japan), no 16, pp 3-8

In July 1994, Hitachi Cable, Ltd was awarded a dc 350-kV submarine power cable project to lay cable between Samar Island and Luzon Island as part of the HVDC Interconnection Project to deliver electric power from Leyte Island to Luzon Island. The project required two dc 350-kV submarine power cables to be manufactured in continuous lengths of 22 km each, without factory joints, and installed across the strait, whose maximum depth exceeds 160 m. After careful investigation and thorough planning based on the route survey results, the cables were installed along the optimum cable route and protected and stabilized by covering with rock at some free-span portions of the route where they were susceptible to harm.

[1996] 01C - 2

A SUMMARY OF THE OPERATION PERFORMANCE OF GE-NAN HVDC LINK IN 1994

Wang, M-X.; Zeng, N-C.; Tao, Y.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 20, no 5, May 1996, pp 53-57

Chinese

This paper is a summary of the operation performance of Ge-Nan HVdc link in 1994. The causes of faults and the actions of dc protection are given, the utilization of dc equipment is evaluated, and the problems which

remain to be solved are pointed out. 2 Refs.

[1996] 01C - 3

ASPECTS AND EXPERIENCES FOR GESHA HVDC LINK

Zhou, D-B.; Yuan, Q-Y.

CCEPG, Wuhan, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 563-568

The 1989 Gesha (Gezhouba to Shanghai) HVdc project was the first imported HVdc transmission system with advanced technologies to be built. This paper collected data on electricity exchange, energy use, forced outages, and availability of Gesha HVdc link from 1989 to 1995. Some forced outages have been analyzed. Existing problems of the Gesha HVdc link are pointed out and its main configuration and parameters discussed. 0 Refs.

[1997] 01C - 4

BIG PROJECTS OF HVDC(HIGH VOLTAGE DIRECT CURRENT) SYSTEM. KII-CHANNEL HVDC INTERCONNECTION PROJECT

Oue, Y.; Nakagoshi, Y.; Hatano, M.

Kansai Elec Power Co, Inc, Japan

Ohm (Japan), vol 84, no 2, pp 22-30

Japanese

The project in the title is the largest class dc interconnection facility in the world, connecting the Kansai Electric Power system and Shikoku Electric Power system. The two utilities and the Electric Power Development Co. are cooperating on construction the link. This paper outlines the Kii Channel dc interconnection project, construction progress, features of Anan substation, Kohoku substation and the Ura switching station. 1400 MW out of 2100 kW from the Tachibana bay thermal power plant will go to the Kansai Power system.

[1997] 01C - 5

BIG PROJECTS OF HVDC (HIGH VOLTAGE DIRECT CURRENT) SYSTEM. MINAMI-FUKUMITSU HVDC BTB (BACK-TO-BACK) SYSTEM

Sasaki, K.; Mori, Y.

Chubu Elec Power Co, Ltd, Japan

Ohm (Japan), vol 84, no 2, pp 38-42

Japanese

This paper introduces the Minami-Fukumitsu back-to-back interconnection facility (BTB) which is under construction to strengthen the interconnection between the Chubu Electric Power Co. and the Hokuriku Electric Power Co. systems. This paper describes purpose of the Minami-Fukumitsu dc interconnection, outlines the facility, special design and construction features, and the future schedule. The BTB interconnection facility installed at Minami-Fukumitsu connects the dc outputs of the transformers directly, without using dc transmission lines.

[1997] 01C - 6

BIG PROJECTS OF HVDC (HIGH VOLTAGE DIRECT CURRENT) SYSTEM. HVDC PROJECTS IN FOREIGN COUNTRIES

Hayashi, T.

CRIEPI, Tokyo, Japan

Ohm (Japan), vol 84, no 2, pp 43-48

Japanese

This paper describes recent developments in multi-terminal HVdc transmission.

[1997] 01C - 7

BIG PROJECTS OF HVDC (HIGH VOLTAGE DIRECT CURRENT) SYSTEM. HIGASHI-SHIMIZU FREQUENCY CONVERTER STATION

Sasaki, K.

Chubu Elec Power Co, Ltd, Japan

Ohm (Japan), vol 84, no 2, pp 31-37

Japanese

The East Shimizu Substation now being constructed in Shimizu City is not only an electric power supply base but also functions as a frequency exchange substation to strengthen the power exchange between 50-Hz and 60-Hz systems. This paper describes background and significance of the installation of the East Shimizu frequency exchange facility, special features of the equipment, construction progress, and future plans. Plane diagrams of the substation, equipment layout drawings, specifications of the main equipment, single wire circuit diagrams, etc., are shown.

[1997] 01C - 8

CAHORA BASSA GMPC TESTING USING AN REAL TIME DIGITAL SIMULATOR

Claus, M.; Neufeldt, T.; Retzmann, D.; Troger, D.; Coetzee, M.; Venter, F.; Forsyth, P.; Maguire, T.

Siemens AG, Germany

Proceedings, 1997 Int'l Conf on Digital Power Systems Simulators, Montreal, Canada, May 28-30, 1997, pp 251-256

This paper presents the use of an RTDS™ simulator for the testing of a grid master power controller (GMPC) implemented in a commercial project for the Cahora Bassa HVdc upgrade. Three ac systems are connected by the 1500-km bipolar HVdc and a relatively weak 330/400-kV ac link. The GMPC uses coordinated HVdc and braking resistor control technologies for the stabilization of the system during and after transients. A GPS satellite signal provides long distance angle measurement facilities. The real-time simulation requires detailed models of the complex HVac and HVdc systems. The verification of the simulator setup is done by comparison with site recordings, EMTDC™ and PSS/E™ and NETOMAC(R) study results. The GMPC performance is verified by different types of ac and dc faults. Results of the tests are presented.

[1997] 01C - 9

CAHORA BASSA HVDC LINE BEGINS A SECOND LIFE

Breuer, W.; Habur, K.

Electric Power Int'l, June 1997, pp 32, 34

Africa's most powerful high-voltage direct current link, the Cahora Bassa HVdc link between South Africa and Mozambique, and the first worldwide to use thyristors, has been dormant for over 15 years due to the civil war in Mozambique. Following a modernization project, it will begin operation in autumn 1997. The authors discuss the user friendly controls, grid control, and the Songo converter station upgrades that have enabled this link to be reactivated.

[1996] 01C - 10

CHANDRAPUR-PADGHE HVDC LINK IN MAHARASHTRA

Isacsson, G.; Nadkarny, R.V.

ABB Power Sys AG, Ludvika, Sweden

Indian Journal of Power and River Valley Development (India), vol 46, no 12, December 1996, pp 230-234, 238

The authors describe the Chandrapur-Padghe HVdc bipole (India) which is rated for 1500-MW continuous power flow and has also a two hour overload at 1650 MW and a five seconds overload at 2000 MW. The two hour overload capability can also be utilized continuously at low ambient, i.e. temperatures below 33°C. The minimum power flow is set to 75 MW at monopolar operation. The link is operated at a direct voltage of +500 kV and on the ac sides it is connected to 400 kV in both Chandrapur and Padghe. The ac voltage is allowed to vary between 380 kV to 430 kV in Chandrapur and between 360 kV to 420 kV in Padghe. The frequency can vary between 47.5 Hz and 51.5 Hz. There are four ac filter banks at both stations. Each bank is rated 200 MVAr. There are two dc filter branches per pole and station. 0 Refs.

[1997] 01C - 11

CHANDRAPUR-PADGHE HVDC LINK COMBATS BLACKOUTS

Lescale, V.

ABB Power Sys, Ludvika, Sweden

Modern Power Systems (UK), vol 17, no 3, March 1997, pp 45, 47, 49

The blackout experienced across large parts of northern India has highlighted the benefits that high capacity HVdc links can bring to such countries. India has already made considerable progress in implementing and strengthening regional interconnections as part of its programme to create a national grid. The latest connection, a 1500-MW link in the western region, is under construction and should be operating by early 1998. The Maharashtra State Electricity Board with BHEL and ABB is building the 750-km Chandrapur to Padghe link to reinforce the network and extend the 1000-MW HVdc link constructed to interconnect the western and southern electricity regions.

[1997] 01C - 12

COMMISSIONING AND OPERATING EXPERIENCE WITH THE APOLLO CAHORA BASSA HVDC SCHEME

Venter, F.P.; Marshall, D.A.; Guedes, C.; Diseko, N.L.

ESKOM, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

The civil war in Mozambique brought the power transmission on the Apollo Cahora-Bassa HVdc scheme to an abrupt halt. Extensive modernizing and recommissioning efforts have recently been made in preparation for the planned recommissioning in 1997. This paper will discuss the salient recommissioning activities and the new electrical environment in which the HVdc will be operating. The impact of the developing Southern African grid will also be considered.

[1998] 01C - 13

COMMISSIONING THE 1000 MW BACK-TO-BACK HVDC LINK AT CHANDRAPUR, INDIA

Andersen, B.R.; Monkhouse, D.R.; Whitehouse, R.S.; Williams, J.D.G.; Prasher, V.K.; Kumar, D.

GEC ALSTHOM, UK

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper describes the commissioning of the Chandrapur 2x500-MW back-to-back HVdc link in India and explains the characteristics of the station which have been optimized to suit this location. One particular feature is the control of reactive power exchange with both ac networks by the HVdc converters. Commissioning and subsequent operating experience have shown that the HVdc link performs as designed, meets the specification and effectively integrates with the ac networks to which it is connected. The HVdc link is thus able to transfer at least 1000-MW of power to either ac system under a wide range of ac system operating conditions.

[1996] 01C - 14

DEEP DC SOUNDINGS IN SOUTHWESTERN FINLAND USING THE FENNO-SKAN HVDC LINK AS A SOURCE

Kaikkonen, P.; Pernu, T.; Tiikkainen, J.; Nozdrina, A.A.; Palshin, N.A. ; Vanyan, L.L.; Yegorov, I.V.

Dept of Geophys, Oulu Univ, Finland

Physics of the Earth and Planetary Interiors (Netherlands), vol 94, no 3-4, April 1996, pp 275-290

The Fenno-Skan high voltage direct current (HVdc) power line links Finland and Sweden across the Bothnian Sea. A 180-km long cable has been installed at the sea bottom. A return current up to 1280 A flows through water and sea-bottom rocks. This source gives a unique possibility for large-scale dc sounding. First test measurements were done by the Department of Geophysics, University of Oulu in May 1991. In June 1992, a bilateral experiment was carried out by Finnish and Russian geophysicists. On the base of 42 sites measured during two field seasons, apparent resistivity values were calculated. For the interpretation of the measured data, a thin-sheet approximation was used. The model consisted of two thin sheets. The uppermost sheet had a conductance S due to the sea water and sediments according to a priori information, while the second one had a depth-integrated resistivity R due to the Earth's upper crust. A good conductor was located beneath. Comparisons of the experimental and theoretical apparent resistivities show that the R value for the Earth's upper crust in southwestern Finland is about 3×10^8 Ω/m^2, which is in good agreement with the value calculated from the magnetotelluric (MT) data in the Proterozoic Central Finland Granitoid Complex. However, it is more than a factor of 10 lower than the value calculated similarly from the MT data in the Kuhmo region in the Archaean part of the Fennoscandian Shield in eastern Finland and the reported value based on the magnetohydrodynamic (MHD) data in the Kola Peninsula. The results do not reveal any distinct crustal conductors within the research area. This experiment indicates that deep geoelectrical resistivity studies can be carried out successfully at rather large distances, at least 50 km, in the surroundings of a high voltage, dc power link. 23 Refs.

[1998] 01C - 15

GE-NAN ±500-KV HVDC TRANSMISSION SYSTEM OPERATION ANALYSIS

Li, W-Y.; Li, Z-Y.

China Power Grid Development Co., Ltd

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Ge-Nan ±500-kV HVdc transmission system has been in operation for over seven years. It connects the East and Central China networks, which are two of China's five regional electric power networks. One interconnected electric power network has been formed after its construction. This paper gives some information about Ge-Nan HVdc transmission system operation. After analysis of the present situation of Ge-Nan HVdc transmission system, some existing problems discussed, along with some suggestions for improving operation and equipment.

[1996] 01C - 16

HVDC TRANSMISSION LINK BETWEEN DENMARK AND GERMANY

Hausler, M.; Jonsson, B.; Krause, J.

ABB Calor Emag Schaltanlagen AG, Mannheim, Germany

ETZ (Germany), vol 117, no 23-24, December 1996, pp 38-43

German

The new Kontek link enables Scandinavian hydroelectric power to be utilized in Germany, and conversely, shortages of energy in Scandinavia to be alleviated from lignite power stations in eastern Germany. The HVdc rectifiers regulate the flow of power between the networks in accordance with demand. Experience so far shows high reliability of the installation. 1 Ref.

[1997] 01C - 17

IEEE GUIDE FOR COMMISSIONING HIGH-VOLTAGE DIRECT-CURRENT (HVDC) CONVERTER STATIONS AND ASSOCIATED TRANSMISSION SYSTEMS

Substations Committee, IEEE PES, USA

IEEE Std 1378-1997, October 13, 1997, 25 pp

General guidelines for commissioning high-voltage direct-current (HVdc) converter stations and associated transmission systems are provided in this IEEE Standard. These guidelines apply to HVdc systems utilizing 6-pulse or 12-pulse thyristor-valve converter units operated as a two-terminal HVdc transmission system or an HVdc back-to-back system.

[1997] 01C - 18

INTERCONNECTED HVDC STATIONS LINK EUROPE

Liegl, K.; Richter, W.

Bayernwerk AG, Munchen, Germany

Transmission & Distribution World, vol 49, no 5, May 1997, pp 54-56, 58-60

The 420-kV transmission systems in Austria were first interconnected to the Czech Grid in 1983 via the Durnrohr HVdc back-to-back station (BBS). In 1993, two additional HVdc stations were commissioned at Etzenricht and Vienna Southeast bridging the transmission systems of Germany and the Czech Republic, as well as Austria and Hungary. These three HVdc links between the UCPTE and CENTREL networks have a nominal capacity of 1750 MW. Because these links are important for energy exchange agreements between countries in Western and Eastern Europe, circuit availability and component reliability were the main objectives considered at the design stage. The BBS at Etzenricht links the transmission systems of the German utility, Bayernwerk AG (UCPTE network), and the Czech utility CEZ (CENTREL network). Vienna Southeast BBS links the networks of Osterreichische Elektrizitatswirtschafts-AG in Austria (UCPTE network) and the Hungarian utility Magyar Villamos Muvek Rt (MVM) (CENTREL network). After two years in operation their performance is compared with the design specification. The two stations are of similar design. The availability specification, reliability measures, spare components, and reliability and operating performances are discussed.

[1996] 01C - 19

INTRODUCTION OF KII CHANNEL HVDC LINK

Hasegawa, T.; Yamaji, K.; Oi, H.

Kansai Elec Power Co, Inc, Japan

Doryoku (Japan), vol 46, no 237, pp 15-21

Japanese

Shikoku Electric Power Company and Electric Power Development Company are now constructing Tachibanawan thermal power station (2800 MW) in Tokushima Prefecture in Shikoku Island. Part of the power (1400 MW) will be transmitted to Kansai Electric Power Company. Kii Channel HVdc is constructed between Anan Converter Station in Shikoku Island and Kihoku Converter Station in Kii Peninsula to transmit the power generated at Tachibana PS. Kii Channel HVdc link will be 100 km long (cable: 50.7 km; overhead line: 50.9 km) and will be commissioned in July 2000 with a capacity of 1400 MW (and ultimately espanded to 2800 MW). Kii Channel HVdc will be the sixth and the largest HVdc system in Japan. It will apply some new technologies to achieve reliable and economical operation.

[1996] 01C - 20

MORE HVDC TRANSMISSION PROJECTS BY TECHNICAL BREAKTHROUGH

Hasegawa, T.

Kansai Elec Power Co, Inc, Osaka, Japan

Denki Gakkaishi (Journal of the Institute of Electrical

Engineers in Japan), vol 116, no 10, September 20, 1996, pp 658-661

Japanese

This paper surveys the state of 500-kV dc transmission by taking the Kii Channel project as an example. The Kii Channel project consists of four thyristor ac-dc converters of ±500,000 V, 140 kW installed in converter stations at both ends of the channel, four strings of 500-kV dc submarine cables of about 50 km and a 500-kV dc overhead cable of about 50 km. If the conventional technology had been used, 8,000 thyristors would have been needed, but development of an 8-kV 3.5-kA class thyristor with a six-inch diameter reduced the number by half. In order to reduce cost of the dc submarine cable, a semi synthetic insulation composed of paper and polypropylene which has been used in ac application was used to reduce insulation thickness. For controlling the ac-dc converter when ac voltage has dropped, a continuous dc operation control system which analyzes operation patterns by simulation was developed. Tank coating technology, trapping device technology and a Y-suspension insulator string device were developed to prevent salt damage. The newly developed technologies are expected to have good results with ac transmission as well. 9 figs.

[1997] 01C - 21

NEW DC CONTROL AND OPERATOR INTERFACE FOR THE CAHORA BASSA HVDC SYSTEM

Venter, F.; Greuer, W.; Guedes, G.; Kuhn, M.; Sebening, C.

ESKOM, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

After a 15-year interruption of power transfer, due to the civil war in Mozambique, the Cahora Bassa HVdc system will be in operation once again in 1997. Extensive modernizing and recommissioning efforts have been made to bring the Cahora HVdc system back into operation. One part of this project has been the complete replacement and upgrade of the open loop dc control and the operators desk in both converter stations with modern, high performance programmable logical controllers (PLCs) and computer-based man machine interface (MMI). This task included the removal of the old relay-based systems, and the design, manufacturing, installation and commissioning of the new computerized system based on standard PLCs and workstation-based MMI. This paper deals with the general design philosophy of the dc control system, including operator interface and its components in comparison to the old relay technology. The focus of this paper is to describe the advantages of the upgrade and replacement and the new features of the operator interface.

[1996] 01C - 22

DESIGNING A SUSTAINABLE ELECTRIC SYSTEM FOR THE TWENTY-FIRST CENTURY

Carcano, C.; Oliva, P.

ENEL, Rome, Italy

21st New Electricity Conf on Providing a Sustainable Electric System, Paris, France, May 22-24, 1995, pp 205-209

Interconnection between the power networks of Italy and Greece has long been declared of European interest. The link, which will directly connect Greece with the power network of UCPTE, is perfectly in line with the targets of the European Union in terms of trans-European power networks. The interconnection, which benefits from a financial contribution of the EU, will rely on a 400-kV dc transmission system with one submarine cable between the Italian and Greek coasts, overhead lines on land, dc/ac conversion stations, return of current to sea via marine electrodes. The main technical features of the project are described, highlighting its most significant design concepts.

[1996] 01C - 23

OPERATING EXPERIENCE OF RIHAND-DADRI ±500-KV HVDC TRANSMISSION SYSTEM

Dube, S.K.; Sasmal, R.P.; Bronsdon, J.A.N.; Crocker, T.; Howsam, J.M.

Power Grid Corp of India Ltd, India

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 134-138

The first high voltage direct current transmission system in India was planned between Rihand Super Thermal Power Station and Dadri to transmit bulk power of 1500 MW at ±500 kV over a distance of 810 km. National Thermal Power Corporation (NTPC) specified the overall design and supervised the construction and commissioning. Operating in parallel with this HVdc line, are 400-kV ac lines. These are required to supply Delhi and part of the Northern Grid. Under a Government re-organization of the power industry, ownership was transferred to the National Power Transmission Corporation Limited, subsequently

renamed as Powergrid Corporation of India Ltd (POWERGRID) in 1993. The first pole was commissioned in December 1990 and the second pole in September 1991. Since then the HVdc link has regularly transmitted between 1000 MW and 1100 MW continuously; at times reaching 1200 MW. The scheme has operated successfully and has established a high availability and reliability. Because this project was the first of its kind in India and since there was no previous experience of design, construction and operation available within the Indian utilities, the scheme is not entirely without problems. A few of the salient points which affect the performance of the link are discussed and modifications which have been carried out in order to improve availability and reliability are described. 1 Ref.

[1996] 01C - 24

OPERATING EXPERIENCES OF THE NELSON RIVER HVDC SYSTEM

Dhaliwal, N.S.; Recksiedler, L.D.; Tang, D.T.Y.

Manitoba Hydro, Winnipeg, Canada

Proceedings, 14th IEEE T&D Conf Conf, Los Angeles, CA, September 15-20, 1996, pp 174-180

This paper discusses unique operation problems on the Nelson River HVdc system. They are: - HVdc line faults; repeated commutation failures; filter reactor replacement; ferroresonance and dc neutral circuit resonances. 3 Refs.

[1997] 01C - 25

OPERATING EXPERIENCE OF HOKKAIDO-HONSHU HIGH VOLTAGE DIRECT CURRENT LINK

Sampei, M.; Magoroku, H.; Hatano, M.

Elec Power Development Co, Ltd, Tokyo, Japan

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1362-1367

The Hokkaido-Honshu HVdc link was increased to 600 MW in 1993. In the dc link, new devices and equipment, such as light-triggered thyristors, dead-tank-type dc filters and so on, are employed. This dc link features a unique control system, Automatic Frequency Control (AFC), applying modern control theory. This paper describes these new techniques and operating experiences. The Tohoku Region, where the one terminal is located, was hit by a large earthquake in 1994, the effects and damages to the equipment was described in this paper. 2 Refs.

[1998] 01C - 26

OPERATION EXPERIENCE OF VYBORG BACK-TO-BACK HVDC LINK

Kovalev, V.D.; Khoudiakov, V.V.; Mazurenko, A.K.; Taratuta, I.P.; Balyberdin, L.L; Kazarov, S.S.

All Russian Electrotechnical Inst, Russia

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Vyborg back-to-back link has been operating for 16 years. It contains equipment manufactured in 1980. Computation of availability of the link at the project design stage helped establish reliability specifications for the equipment and create the methods and program for equipment reliability tests. The extensive quality assurance program was developed to achieve the specified reliability of the equipment. Operating experience was of great importance for the future expansion of the link and the design of new HVdc links. Since Vyborg HVdc link was one of the first back-to-back HVdc links in 1981, the operational experience data of HVdc systems collected and published by SC 14 of CIGRE was of great value in evaluating reliability specifications for Vyborg at the design stage. Collection of operational experience of Vyborg converter station after commissioning and the presentation of annual operational reports for the SC 14 helped to evaluate its availability and reliability data, to compare them with the customers specifications, with world standards, and to define measures for future improvements. After five years of operation, reconstruction of the link was begun. Most changes concerned HV thyristor valves, C-P equipment and ac filters. Operation experience of the link is summarized in this paper.

[1997] 01C - 27

OPERATIONAL TESTS ON HVDC THYRISTOR MODULES IN A SYNTHETIC TEST CIRCUIT FOR THE SYLMAR EAST RESTORATION PROJECT. DISCUSSION

Bauer, T.; Lips, H.P.; Thiele, G.; Tylutki, T.; Uder, M.

Siemens AG, Erlangen, Germany

IEEE Trans on Power Delivery, vol 12, no 3, 1997, pp 1151-1158

According to IEC 700 and IEEE 857, operational tests on HVdc thyristor modules can be performed either in a six-pulse back-to-back test circuit or in a synthetic test circuit. Because of the high rating of modern thyristors, the use of a six-pulse bridge configuration would require facilities with a high installed capacity. In a synthetic

test circuit even high current and voltage stresses can be represented using less than 1/100 of that installed capacity. Thus, synthetic test circuits are an economical alternative to test a representative part of a modern thyristor valve. The paper describes the operational tests on thyristor modules for the Sylmar East Restoration Project, which were completely carried out in a synthetic test circuit. 8 refs.

[1997] 01C - 28

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY

Irokawa, H.; Otsubo, Y.; Terashima, K.

Elec Power Development Co Ltd, Japan

Dengen Kaihatsu K.K. Chosa Shiryo (Japan), no 100, pp 159, 161-181

Japanese

It was in October 1965 that the Sakuma Frequency HVdc Converter Station, which we constructed using imported dc power transmission technology, commenced commercial operation with a transmission capacity of 300 MW. About 30 years have passed since then. Today, dc transmission facilities are in operation at three locations with a total transmission capacity of 1,500 MW, and similar facilities are under construction at three more locations for a total transmission capacity of 3,500 MW. The Shin-Shinano Frequency HVDC Converter Station (Tokyo Electric Power Co.) and the Hokkaido-Honshu HVDC Link, the two units constructed after Sakuma, reflect the research results of the Sakuma Thyristor Laboratory, which was established in 1970 to develop indigenous dc transmission technology. The results of research and development projects implemented thereafter have provided the prime motive force for the construction of additional facilities (Shin-Shinano No. 2, which commenced commercial operation in May 1993, and the third addition to the Hokkaido-Honshu HVDC Link, which went into commercial operation in May 1994) and replacement facility (Sakuma Frequency HVDC Converter Station, which commenced commercial operation in June 1994). We are now developing dc 500-kV equipment and dc multi-terminal power transmission technology in anticipation of increases in the scale of dc transmission facilities and application of such facilities to trunk transmission systems. Since the early days of our history, we have been constructing major overhead transmission lines across channels and straits, bulk-power submarine cables, and bridge installed cables to link regional electric power networks separated due to geographical conditions.

[1997] 01C - 29

QUALITY ASSESSMENT OF HVDC COMPONENTS BY PD ANALYSIS

Morshuis, P.; Beyer, J.

Tech Univ of Delft, Netherlands

Proceedings, IEEE Annual Conf on Electrical Insulation and Dielectric Phenomena, Minneapolis, MN, October 19-22, 1997, vol 2, pp 542-545

HVdc components for both energy (HVdc submarine cables) and non-energy (X-ray equipment, television screens, traveling wave tubes) applications can successfully be tested for partial discharges (PD). Contrary to the situation for ac equipment that is used for the electrical energy supply (IEC270), no detailed PD testing procedures are available for dc. ASTM 1868 only mentions "repetitive pulses of more than one per minute." In this paper, the merits of PD testing will be shown for several HVdc components. By carefully representing the PD data, a surprising amount of information can be obtained on the PD generating defect. The conclusion is that PD analysis, specially designed for dc, can be of great help when designing and testing HVdc equipment. 6 Refs.

[1998] 01C - 30

RECOMMISSIONING EXPERIENCE WITH THE APOLLO-CAHORA BASSA HVDC SCHEME

Venter, F.P.; Marshall, D.A.; Guedes, C.; Oberholzer, G.

ESKOM, South Africa

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

The Apollo-Cahora Bassa HVdc scheme has been dormant for more than a decade due to the political situation in Mozambique. Recent developments in Southern Africa, however, have paved the way for extensive modernizing and refurbishment efforts in preparation for the planned recommissioning in 1997 and 1998. This paper will discuss the salient recommissioning activities, focusing on the required equipment changes, refurbishment of plant, commissionning results and operational requirements.

[1996] 01C - 31

SURVEY OF HVDC OPERATING AND MAINTENANCE PRACTICES AND THEIR IMPACT ON RELIABILITY AND PERFORMANCE

Cochrane, J.J.; Emerson, M.P.; Donahue, J.A.; Wolf, G.

New England Power Co, Ayer, MA, USA

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 514-518

A questionnaire about operating, maintenance, and spare parts practices and station performance was sent to all HVdc converter stations worldwide. This survey is sponsored by IEEE Working Groups 15.05.08, Economics and Operating Strategies, and 17, Reliability of HVdc Converter Stations. Responses from thirty-eight stations are analyzed, and information about the most popular practices is reported. One important conclusion is that energy contracts, ac system constraints, and dedicated generation frequently have strong influences on the operation and maintenance practices of HVdc stations. A search is made for correlations between the operating, maintenance, and spare parts practices, including spending, and the stations' performance and availability. No conclusions about the most cost-effective practices can be made. The results are compared with those of a study published in 1992 which covered a few of the same topics. 2 Refs.

[1997] 01C - 32

SWEDISH AND POLISH GRIDS TO BE CONNECTED BY SWEPOL LINK

Sodeerberg, L.; Johnson, T.

Modern Power Systems (UK), vol 17, no 12, December 1997, pp 33, 35-36

This paper describes the SwePol 600-MW high voltage direct current link connecting the Swedish and Polish 400-kV power grids, which is scheduled to be in commercial operation by November 1. 1999. Two turnkey contracts were signed between the operating company SwePol Link AB and ABB Power Systems for the power converter substations, and ABB High Voltage Cables for the cable, on 23 July 1997. The 230-km power cable is to be installed beneath the Baltic Sea from Karlshamn in the South of Sweden to Slupsk in the North of Poland.

[1997] 01C - 33

SYSTEM DESIGN OF HVDC SYSTEM

Tanaka, M.; Murakami, H.; Honjo, N.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 7-12

Japanese

We explain about the design of HVdc systems, use system design of HVdc system, according to the case study for Kii Channel HVDC Link system design. This paper convers the basic conditions of system design, system configuration and analysis.

[1996] 01C - 34

TIAN-GUANG HVDC TRANSMISSION PROJECT FUNDAMENTAL FREQUENCY OVERVOLTAGE AND OVERVOLTAGE LIMITING MEASURES FOR TIANSHENGQIAO CONVERTER STATION

Bailu, Q.; Xiqiao, Z.; Burton, R.S.

Central Southern China Elec Power Design Inst, Wuhan, China

Proceedings, IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 112-117

For the Tian-Guang HVDC Transmission Project, the fundamental frequency overvoltages which can occur as a result of partial or complete interruption to transmitted power play an important role in the design and operation of the converter at Tianshengqiao. The paper describes some of the operating conditions which may result in high values of overvoltages along with solutions and trade-offs which were adopted to limit the overvoltages to acceptable levels.

[1997] 01C - 35

TIAN-GUANG WILL TRANSMIT 500 KV OVER 1000 KM

Albrecht, H.J.

Siemens AG, Erlangen, Germany

Modern Power Systems (UK), vol 17, no 6, June 1997, pp 59, 61, 63

When a country has disparate generating capacity spread over an area of what amounts to a subcontinent, a means of distribution other than three-phase ac needs to be considered. A good example of this is the new 1000-km HVdc transmission link that will transport power generated at Tianshengqiao in southwest China (in Guangxi province) to Guangzhou Beijiao (in Guangdong province).

[1996] 01C - 36

UHV AC AND HVDC TRANSMISSION LINES IN THE WORLD

Matsui, S.

NGK Insul Ltd, Japan

NGK Rebyu (Japan), no 56, pp 51-57

Japanese

The total length of 500-kV transmission line becomes 5000 km in Japan, and commercial use of 1000-kV line is planned for the beginning of the 21st century. Hokkaido-Honshu ±250-kV dc transmission system is in commercial use, and Anan-Kihoku ±500-kV line is also planned. This paper outlines the present states and future plans of dc power transmission systems in Japan and the world. The latest data on UHV and dc transmission are reported.

[1996] 01C - 37

UTILITY PROJECTS SHOW THE RANGE OF T&D TECHNOLOGY

Lewis, S.

Transmission & Distribution World, vol 48, no 1, January 1996, pp 70-71

Utilities around the world are upgrading and adding to their facilities in order to remain competitive and provide reliable service. New or advanced technologies, such as static VAr systems, distribution automation software and controls, power thyristors for HVdc systems and static condensers, are enabling utilities to improve power flow through power grids while lowering costs and achieving greater reliability and control. The application of these technologies is occurring around the world in both developed and developing countries. Some of these projects are briefly outlined. 0 Refs.

[1996] 01C - 38

VALVE HALL FIRE REPORT AND ANALYSIS FOR GEZHOUBA CONVERTER STATION

Lou, D-Q.; Yuan, Q-Y.

Gezhouba Converter Station, Natl Grid Constr Co, China

Proceedings, 1996 T&D Conf Conf and Exposition, Los Angeles, CA, September 15-20, 1996, pp 152-157

A valve fire occurred in the Gezhouba HVdc Converter Station in China on June 25, 1994. This paper reports on the investigation and analysis of the incident involving a 12-pulse thyristor valve. Valve hall fire detection and fire control is also discussed. 0 Refs.

[1996] 01C - REF

MORE HVDC TRANSMISSION PROJECTS BY TECHNICAL BREAKTHROUGH

For Abstract see entry 01A - 12

[1996] 01C - REF

THE ROLE OF DIRECT CURRENT ELECTRIC POWER TECHNOLOGY IN ELECTRIC POWER OPERATION. WORLD TRENDS

For Abstract see entry 01A - 23

[1997] 01C - REF

CONVERTING AC POWER LINES TO DC FOR HIGHER TRANSMISSION RATINGS

For Abstract see entry 01A - 3

[1997] 01C - REF

DIRECT CURRENT DISTRIBUTION LINE INSTALLED IN SWEDEN

For Abstract see entry 01A - 5

[1996] 01C - REF

DESIGNING A SUSTAINABLE ELECTRIC SYSTEM FOR THE TWENTY-FIRST CENTURY

For Abstract see entry 01B - 17

[1996] 01C - REF

SYSTEM CHARACTERISTICS OF HAENAM-CHEJU HVDC LINK IN KOREA

For Abstract see entry 01B – 31

[1996] 01C - REF

THE OUTLINE OF KII CHANNEL HVDC LINK

For Abstract see entry 01B - 34

[1997] 01C - REF

HVDC SUBSTATIONS AUDIBLE NOISE

For Abstract see entry 02A - 1

[1996] 01C - REF

THYRISTOR VALVE REPLACEMENT OF THE PACIFIC INTERTIE EXPANSION SYLMAR EAST

500-KV HVDC CONVERTER STATION

For Abstract see entry 02C - 38

[1996] 01C - REF

DEVELOPMENT AND FIELD TEST RESULTS OF THE AC 275-KV COMPACT FILTER

For Abstract see entry 02D - 11

[1997] 01C - REF

HARMONIC EVALUATION OF BENMORE CONVERTER STATION WHEN OPERATED AS A GROUP CONNECTED UNIT

For Abstract see entry 02D - 13

[1996] 01C - REF

SAFETY AND SIGNALING UNIT FOR THE FILTRATION AND COMPENSATION CIRCUITS OF THE VYBORGSK SUBSTATION

For Abstract see entry 02D - 24

[1997] 01C - REF

APPLICATION OF REAL TIME DIGITAL SIMULATION FOR COMMISSIONING AUTOMATIC VOLTAGE REGULATORS FOR SYNCHRONOUS CONDENSERS

For Abstract see entry 02D - 5

[1996] 01C - REF

FIELD TESTS OF HVDC 500-KV-600-KV SF_6 GAS TANK TYPE SURGE ARRESTERS

For Abstract see entry 02G - 6

[1996] 01C - REF

DC 500-KV OIL-FILLED CABLES AND ACCESSORIES

For Abstract see entry 04B - 7

[1997] 01C - REF

DEVELOPMENT AND TESTING OF PROTOTYPE TRANSFORMER CORE MODELS FOR A HIGH-POWER SELF-COMMUTATED AC/DC CONVERTER

For Abstract see entry 05A - 7

[1996] 01C - REF

DESIGN ASPECTS OF UPGRADATION FROM 6 PULSE TO 12 PULSE OPERATION OF NHVDC PROJECT

For Abstract see entry 05B – 27

[1996] 01C - REF

MODERN CONTROL AND PROTECTION SYSTEM FOR HVDC

For Abstract see entry 05B - 50

[1996] 01C - REF

PERFECTION OF THE COMPUTER AUTOMATIC CONTROL FUNCTION IN GESHANG HVDC CONVERTER STATIONS

For Abstract see entry 05B - 56

[1997] 01C - REF

INTERACTIONS AND COUNTERMEASURES OF AC-DC INTERCONNECTED SYSTEM WITH LARGE CAPACITY THERMAL POWER PLANTS IN THE VICINITY

For Abstract see entry 05C - 14

[1997] 01C - REF

PROPOSED SWEDEN/POLAND HVDC SUBMARINE CABLE LINK: IMPACT ON POLISH GENERATORS AND GRID NETWORK

For Abstract see entry 05D - 25

[1996] 01C - REF

JOINT OPERATION HVDC/SVC

For Abstract see entry 05G - 5

[1997] 01C - REF

NELSON RIVER HVDC LINE FAILURES

For Abstract see entry 05H - 8

[1996] 01C - REF

ENVIRONMENTAL AND GEOGRAPHICAL ASPECTS IN HVDC ELECTRODE DESIGN

For Abstract see entry 05I - 2

[1996] 01C - REF

AVAILABILITY AND RELIABILITY OF THE 600 MW HVDC BACK-TO-BACK STATIONS ETZENRICHT/GERMANY AND VIENNA SOUTHEAST/AUSTRIA

For Abstract see entry 05L – 4

[1996] 01C - REF

FURNAS HVDC SYSTEM PERFORMANCE AND EXPERIENCE

For Abstract see entry 05L - 7

[1997] 01C - REF

A GROWING NEED FOR QUALITY POWER SUPPLIES

For Abstract see entry 07B - 1

02 CONVERTER STATIONS AND COMPONENTS

02A Station Layout

[1997] 02A - 1

HVDC SUBSTATIONS AUDIBLE NOISE

Nyman, A.

CIGRE WG 14.26

Proceedings, Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 1997

The purpose of the Working Group 14.26 is to develop recommendations to guide the development of IEC and other standards related to equipment audible noise performance and station acoustic modeling. The proposed guide will develop in a logical flow, starting with general aspects followed by existing acoustic environments, regulations, equipment producing audible noise and sound reduction measures, HVdc station operation conditions to be used for audible noise calculations, sound level prediction and measurements, and finally verification of component sound power and station sound levels.

[1996] 02A - 2

NEW TECHNOLOGIES IN HVDC CONVERTER STATION DESIGN

Persson, A.; Carlsson, L.; Asplund, G.

ABB Power Sys AB, Ludvika, Sweden

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 601-605

HVdc technology took a big step forward around 20 years ago when thyristor valves succeeded the mercury arc valves previously used. The converter station concept introduced at that time, however, has remained practically unchanged since then. The time has now come for a further major advance in technology. The introduction of new concepts will change whole approach to building an HVdc station. Even though this innovation may not be quite as significant as when thyristor valves were introduced, the new features will greatly improve the operating characteristics of HVdc transmissions and reduce the size and complexity of converter stations. The new generation of converter stations is now likely to include some of the following features: a new type of converter circuit, the capacitor commutated converter; actively timed ac filters; air insulated outdoor thyristor valves; and active dc filters. This paper briefly describes the above concepts and their combination forming the next generation of HVdc power converter substations. 4 Refs.

[1996] 02A - 3

NEW TECHNOLOGIES IN HVDC CONVERTER DESIGN

Persson, A.; Carlsson, L.

ABB Power Sys, Ludvika, Sweden

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 387-392

The new generation of HVdc power converter substations is now likely to include some of the following features: a new type of power converter circuit--the capacitor commutated converter; actively tuned ac filters; air-insulated outdoor thyristor valves; and active dc filters. This paper briefly describes the above concepts and their combination, forming the next generation of HVdc power converter substations. 4 Refs.

[1996] 02A - 4

SYSTEM DESIGN OF AN HVDC CONVERTER

STATION

Hasegawa, T.; Yamaji, K.; Sanpei, M.; Tada, K.; Yasuda, S.; Ishiguro, F.

Kansai Elec Power Co, Inc, Osaka, Japan

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 5-12

Japanese

The article reports on system design procedures for dc converter stations, design specifications and network conditions essential for appropriate system-level behavior, and optimization of various parameters. System analysis examples are also presented. The design of a high-capacity ac/dc converter system requires far-ranging studies and extensive simulation analysis. Experience gained through the dc converter system design will contribute to the design of future dc power-transmission systems. 4 Refs.

[1997] 02A - REF

VERIFICATION OF THE CCC CONCEPT IN A HIGH POWER TEST PLANT

For Abstract see entry 02B - 8

02B Converter Assemblies

[1997] 02B - 1

CAPACITOR COMMUTATED CONVERTERS FOR HVDC SYSTEMS

Bjorklund, P.-E.; Jonsson, T.

ABB Power Sys AB, Ludvika, Sweden

ABB Review, no 2, 1997, pp 25-33

HVDC 2000 is the name given by ABB to a new generation of high-voltage dc power transmission systems based on the capacitor commutated converter, or CCC. The concept, which has been mainly of academic interest for many years, has now become reality on account of numerous special features offered by the CCC. Capacitor commutated converters perform better than conventional converters and are less sensitive to ac system disturbances. 1 Refs.

[1996] 02B - 2

COMPACT AND EFFICIENT TRANSFORMERLESS POWER CONVERSION SYSTEM

Limpaecher, R.

DC Transformation, Inc, Beverly, MA, USA

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 2, pp 649-655

The power conversion system (PCS) is a new technology that efficiently transforms power between ac and dc. The conversion process permits the input voltage level to be stepped up or down without the use of magnetic core transformers. The transformation is accomplished using solid-state switching devices, capacitors, air-core inductors and an intelligent control system. The technology is based on the property of resonance charging, thereby permitting the use of self commutating switches. The current through the switches, being sinusoidal in nature, has a low dI/dt. This permits the use of slower, less expensive thyristors, similar to those used in high voltage phase control applications. Using these components, a highly efficient inverter can be constructed for a variety of large utility applications. 4 Refs.

[1997] 02B - 3

COMPARISON OF ALTERNATE CONVERTER TOPOLOGIES

Sadek, K.; Pereira, M.; Brandt, D.P.; Gole, A.M.; Daneshpooy, A.

Seimens AG, Erlangen, Germany

European Power Electronics Conf EPE '97, Oslo, Norway, September 1997

Abstract not available.

[1996] 02B - 4

CONVERTER FOR HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

Yoshino, T.; Tanabe, S.

Toshiba Corp, Japan

National Convention Record, IEE Japan, Industry Applications Society (Denki Gakkai Sangyo Oyo Bumon Zenkoku Taikai Koen Ronbunshu), vol 1996, pt 3, pp S.27-S.30

Japanese

Abstract not available.

[1997] 02B - 5

DEVELOPMENT OF HIGH-PERFORMANCE

SELF-COMMUTATED AC/DC CONVERTER

Nakajima, T.; Suzuki, H.; Izumi, K.; Sugimoto, S.; Hakugin, T.; Abe, H. ; Kitahara, T.; Aizawa, H.; Asaeda, T.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 1006-1015

Japanese

A technical project is under way to develop a high-performance, self-commutated ac/dc power converter for future HVdc bulk power transmission and dc interconnection. In the first stage of the project, prototype power converter models for a 300-MW self-commutated converter were developed. The models were subjected to factory testing to verify the technologies for series connection of multiple gate turn-off thyristors (GTOs), a gate power supply from the high voltage main circuit, and regeneration of energy in snubber circuits. The power converter mounting technologies for the application of the most advanced GTO, rated at 6 kV/6 kA/500 Hz, were also developed and tested. Satisfactory results were obtained.

[1997] 02B - 6

Deleted

[1996] 02B - 7

STATE-OF-THE-ART VERIFICATION OF THE HARD DRIVEN GTO INVERTER DEVELOPMENT FOR A 100 MVA INTERTIE

Steimer, P.K.; Gruning, H.; Werninger, I.; Schroder, D.

ABB Ind AG, Turgi, Switzerland

Conf Record, 27th IEEE Power Electronics Specialists Conf (PESC), Baveno, Italy, June 23-27, 1996, vol 2, pp 1401-1407

The 100-MVA intertie described is mainly characterized by the following innovations: a hard driven GTO (HD-GTO) with a new housing; series connection of hard driven GTOs; low-inductive high power HD-GTO inverter valves; and fuseless high power HD-GTO inverters. The presented HD-GTO technology allows the robust, reliable and cost-efficient series connection of GTOs. The concept of the 100-MVA intertie, which is based on the HD-GTO technology, is reviewed. The development of the high power HD-GTO inverter module through a state-of-the-art development process is presented. The use of a circuit simulator with accurate physical models of the power semiconductors, especially during the concept phase, supported the development and verification phases. 6 Refs.

[1997] 02B - 8

VERIFICATION OF THE CCC CONCEPT IN A HIGH POWER TEST PLANT

Hagman, L.; Jonsson, T.

ABB Power Sys AB, Ludvika, Sweden

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper presents the first high power verification of ABB's capacitor commutated converter (CCC) concept. The high power tests were performed in a 6-pulse back-to-back test plant. The purpose of the CCC tests was to gather experience of the concept with the plant run at high power and with components manufactured in the same manner as for commercial plants. The test results presented include steady state operation, valve short circuit and ac ground faults. The CCC tests in the high power test circuit have also verified the results obtained from calculations and computer simulations. The high power tests have confirmed that the CCC is a safe and robust converter alternative.

[1996] 02B - REF

NEW TECHNOLOGIES IN HVDC CONVERTER STATION DESIGN

For Abstract see entry 02A - 2

[1996] 02B - REF

NEW TECHNOLOGIES IN HVDC CONVERTER DESIGN

For Abstract see entry 02A - 3

[1997] 02B - REF

SPACE VECTOR PATTERN GENERATORS FOR MULTI-MODULE LOW SWITCHING FREQUENCY HIGH POWER VAR COMPENSATORS

For Abstract see entry 05A - 20

[1997] 02B - REF

DEVELOPMENT AND TESTING OF PROTOTYPE MODELS FOR A HIGH-PERFORMANCE 300 MW SELF-COMMUTATED AC/DC CONVERTER

For Abstract see entry 05A - 6

[1996] 02B - REF

DIGITAL FIRING CONTROL FOR LINE-COMMUTATED HIGH POWER CONVERTERS

For Abstract see entry 05A – 9

[1996] 02B - REF

REACTIVE POWER COMPENSATION OF HVDC CONVERTER BY FORCED COMMUTATION SVC. BEHAVIOR IN UNBALANCED FAULT CONDITION

For Abstract see entry 05B - 59

[1996] 02B - REF

A NOVEL MULTI-LEVEL INVERTER CONFIGURATION FOR HIGH VOLTAGE CONVERSION SYSTEM

For Abstract see entry 17B - 3

[1996] 02B - REF

CONVERTERS FOR GRID-CONNECTED DC ENERGY SOURCES: A SIMULATION TOOL TO MEET EXPECTED UTILITY SPECIFICATIONS

For Abstract see entry 17B - 8

02C Switching Elements, Valves

[1997] 02C - 1

6-KV, 5.5-KA LIGHT-TRIGGERED THYRISTOR

Katoh, S.; Choi, J.H.; Yokota, T.; Watanabe, A.; Yamaguchi, T.; Saito, K.

Research Lab, Hitachi Ltd, Ibaraki, Japan

Proceedings, 9th Int'l Symp on Power Semiconductor Devices and IC's, Weimar, Germany, May 26-29, 1997, pp 73-76

A 6-kV, 5.5-kA light-triggered thyristor has been developed for BTB (back-to-back) converter systems. A double-diffused p emitter structure was used to improve the trade-off relationship between on-state voltage and blocking capability, and a high-injection low-lifetime structure was used to improve the trade-off relationship between on-state voltage and reverse recovery charge. The double-diffused p emitter consists of a thin p^+ emitter in the main area and a thick p^- emitter there and elsewhere. High injection was achieved by increasing the p^+ emitter concentration and decreasing the p^- emitter thickness. A locally-controlled lifetime profile was used to compensate for the high injection efficiency. These structures decreased the on-state voltage by about 0.15 V.

[1996] 02C - 2

A 500-KV HVDC VALVE USING 8-KV LTT

Hasegawa, T.; Yamaji, K.; Irokawa, H.; Tanabe, S.

Kansai Elec Power Co, Inc, Osaka, Japan

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 393-398

Japan's demands for electric power have been increasing year after year. Increased difficulty in obtaining rights-of-way for new power generating plants and their growing distances to consumer areas are giving rise to many problems, such as longer transmission lines, more submarine cables, power interchanges among utilities, and an increase in the short-circuit capacity of the existing ac power systems. Under these circumstances HVdc transmission is drawing attention as a useful means for solving these problems. In Japan, the ±250-kV, 600-MW Hokkaido-Honshu HVdc link is in service in good condition, but we have no experience with a 500-kV HVdc system. Hence, we decided to develop a valve, a core of the HVdc system, to be applied to a ±500-kV/2800-A, 2800-MW system. The valve consists of an 8-kV light-triggered thyristor (LTT) using a 150-mm diameter silicon wafer, which has its characteristic optimized to reduce the external size and loss of the valve. Main development items are described. 3 Refs.

[1996] 02C - 3

ADVANCED GTO DEVELOPMENT

Eriksson, L.O.; Barrow, J.

GE Power Sys Eng, Schenectady, NY, USA

EPRI Technical Report TR-107012, Final Report, October 1996, 193 pp (M. Wilhelm, EPRI prog mgr)

This report was initiated to leapfrog existing technology by developing the buried grid version of the gate-turn-off (GTO) thyristor. Considerable challenges were encountered and overcome. Experiments conducted at the GE Static Power Components Operation led to consideration of a GTO thyristor with a mesa-like

structure. This GTO was produced using conventional thyristor processing steps and a lower temperature, high lifetime oxidation system. A computer program was written to optimize diffusion profiles, resulting in the lowest P sheet resistance with an 18- to 25-V cathode avalanche. These new diffusion profiles and a new island design resulted in a new GTO device operating at 15 V gate with higher spike voltage capability and a lower snubber capacitor and at inherently lower cost. Samples were delivered to the US Army, Fort Monmouth, New Jersey in 1989, and to GE Corporate Research Development in 1990. The initial step towards commercialization was marked by an order from Westinghouse Science and Technology Center, Pittsburgh, Pennsylvania.

[1996] 02C - 4

AN 8-KV/3.6-KA LIGHT-TRIGGERED THYRISTOR

Satoh, K.; Ohta, K.; Yamamoto, M.; Ide, K.; Taguchi, K.

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 3, 1996, pp 67-69

Japanese

Mitsubishi Electric has developed the world's largest capacity light-triggered thyristor using a 6 in wafer. Using a new circuit design, the device achieves an 8-kV blocking voltage and 3.6-kA average current capacity. The article reports on the construction, features, ratings and other characteristics. The device has applications in ac-dc converters and static VAr compensators for electric power systems. 0 Refs.

[1998] 02C - 5

ANODE REACTOR CORE FOR THYRISTOR VALVES

Horie, H.; Tanabe, S.

Toshiba Corp, Japan

Journal of the Magnetics Society of Japan (Nippon Oyo Jiki Gakkaishi), vol 22, no 2, pp 45-51

Japanese

For high reliability and effective operation of electric power systems, power electronic technologies are being increasingly applied in power converters, such as the thyristor valves used in high-voltage dc (HVdc) transmission, 50-60-Hz link, and back-to-back. The thyristor valves consist of many thyristor modules, in which anode reactors are key components. The reactors protect the thyristors from turn-on stress and surges. This paper describes some required properties of the anode reactor core material, and outlines a newly developed magnetic powder core material for the anode reactors.

[1997] 02C - 6

CORROSION IN HVDC VALVE COOLING SYSTEMS

Jackson, P.O.; Abrahamsson, B.; Gustavsson, D.; Igetoft, L.

ABB Power Sys, Ludvika, Sweden

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 1049-1052

Stainless steel couplings in the main cooling water pipes of HVdc thyristor valves have been in use since 1983, with an overall satisfactory behavior. However, some water leakage due to corrosion below the sealing O-rings of the couplings was observed during 1992. An extensive investigation and follow-up worldwide showed a direct correlation between water quality and the corrosion rate of the stainless steel couplings. Recommendations are given about actions to be taken in order to maintain a long lifetime for the fine water systems.

[1998] 02C - 7

DC TRANSMISSION BASED ON VOLTAGE SOURCE CONVERTERS

Asplund, G.; Eriksson, K.; Jiang, H-B.; Lindberg, J.; Palsson, R.; Svensson, K.

ABB Power Sys AB, Ludvika, Sweden

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Voltage source converters (VSC) have for the first time been used for HVdc transmission in a real network. Experience from the design and commissioning of the transmission shows that the technology has now reached the stage where it is possible to build high-voltage converters utilizing insulated gate bipolar transistors (IGBTs). Operation and system tests have proved that the properties that have been discussed for many years regarding VSCs for HVdc are a reality now. They include independent control of active and reactive power, operation against isolated ac networks with no generation of their own, very limited need of filters, and no need of transformers for the conversion process. This is only the first installation of VSC for HVdc. The development of semiconductors and control equipment

is presently very rapid and it is evident that this technology will play an important role in the future expansion of electric transmission and distribution systems.

[1997] 02C - 8

DC V-T CHARACTERISTICS OF FRP INSULATORS FOR THYRISTOR VALVES

Yamada, S.; Kuroda, H.; Taniguchi, Y.; Tanabe, S.

Toshiba Corp, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 2, p 2.56

Japanese

Abstract not available.

[1996] 02C - 9

DEVELOPMENT OF 500-KV HIGH VOLTAGE LARGE CAPACITY THYRISTOR VALVES

Yoshida, Y.; Oue, Y.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Kaihei Hogo Kenkyukai Shiryo (Japan), vol SP-96, no 62-80, pp 1-10

Japanese

Reinforcing power system interconnection is a major trend among electric utilities. More HVdc transmission or BTB projects will be adopted for solid interconnection. Cost reduction of the converter station is a big concern of the utilities. Compact large capacity thyristor valves of 500 kV are developed for cost reduction and good seismic performance. This paper describes recent works about development of 6-inch light-triggered thyristors of the rating of 8 kV and 3500 A, and development of 500-kV thyristor valves with 6-inch thyristors.

[1996] 02C - 10

DEVELOPMENT OF 500-KV AC-DC CONVERTING SUBSTATION EQUIPMENTS. (PART 1). DEVELOPMENT OF HIGH VOLTAGE AND LARGE CAPACITY THYRISTOR VALVES

Yamada, M.

Kansai Elec Power Co, Inc, Japan

R&D News Kansai (Japan), no 347, pp 21-22

Japanese

A high voltage large capacity thyristor valve using 6-inch optical thyristor elements was developed as a device for a 500-kV large capacity ac/dc conversion substation. A report is made regarding the development of the element, the module and the proto-valve. This research and development will lead to the realization of a compact, high-voltage, low-loss, large capacity thyristor.

[1996] 02C - 11

DEVELOPMENT OF A 500-KV HIGH-VOLTAGE, HIGH-CAPACITY THYRISTOR VALVE

Yoshida, Y.; Hirose, M.; Irokawa, H.; Yamamoto, Y.; Takeda, M.

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 13-20

Japanese

Mitsubishi Electric has cooperated in the joint development of a thyristor valve rated at 500 kV and 2800 A for enhancing the capacity of dc power-transmission systems. The four-arm laminated valve is insulated by air, water-cooled and utilizes 6-inch. light-triggered thyristors. Basically designed to achieve low loss and high reliability, the valve is planned for application in the submarine-cable dc power-transmission project between Kansai and Shikoku. 4 Refs.

[1996] 02C - 12

DEVELOPMENT OF A LIGHT-TRIGGERED THYRISTOR

Hayashida, H.; Nishio, T.; Isaji, H.; Nakagawa, T.; Yamamoto, M.; Sato, K.

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 21-24

Japanese

Mitsubishi Electric has cooperated in the joint development of the world's largest capacity light-triggered thyristor, rated at 8 kV and 3.6 kA, for use in thyristor valves for dc transmission systems. Based on a six-inch wafer, the device features new structures for the light-sensitive area and gate-emitters that improve dv/dt and di/dt capability and light sensitivity. Low loss is achieved through a high-purity wafer process and optimized carrier lifetime control. 0 Refs.

[1996] 02C - 13

DEVELOPMENT OF A THYRISTOR VALVE FOR NEXT GENERATION 500-KV HVDC

TRANSMISSION SYSTEMS

Hasegawa, T.; Yamaji, K.; Irokawa, H.; Shirahama, H.; Tanaka, C.; Akabane, K.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1783-1788

A high voltage thyristor valve is the basic component of an HVdc transmission systems is described. First, the power loss of the valve is analyzed to decide a reasonable wafer size for the light-triggered thyristor. From these results, a six-inch diameter wafer size is selected. A light-triggered thyristor, with ratings of 8 kV and 3.5 kA, is developed using the six-inch wafer. The design of the valve employing the thyristor and test results with a prototype valve prove that a 500-kV valve can be realized by this design method. 17 Refs.

[1996] 02C - 14

DEVELOPMENT OF A THYRISTOR VALVE FOR 500-KV HVDC TRANSMISSION SYSTEMS

Yoshida, Y.; Irokawa, H.; Hashimoto, T.; Ishida, T.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-J, pp 281-286

Japanese

A half-size prototype was produced in order to develop thyristor valve of, 700 MW, 500 kV and 2800 A per converter and/or inverter. The light-triggered thyristor element, with a rating for 6-inch wafer, 8 kV, 3.5 kA, was developed and manufactured to minimize the converter loss. The valve was constituted by thyristor module which mounted 6 to 7 thyristors on one arm, and seismic analysis was carried out by finite element method. As a result of the test, an outlook for the realization of the 500-kV valve was obtained.

[1997] 02C - 15

DEVELOPMENT OF HIGH-PERFORMANCE THYRISTOR VALVE USING LARGE LIGHT-TRIGGERED THYRISTORS WITH 6-INCH WAFERS

Hasegawa, T.; Yamaji, K.; Irokawa, H.; Takeda, M.; Chishaki, H.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 945-952

Japanese

A thyristor valve for a large HVdc power system is required to have such characteristics as compact size, small power consumption and high reliability. The authors have developed a dc 500-kV thyristor valve using 8-kV light-triggered thyristors with 6-inch wafers which can meet the above requirements. Studies into the rating of the thyristors show that an 8-kV thyristor with 6-inch wafer can be the most optimum for the proposed valve. Newly developed 8-kV light-triggered thyristors provide good characteristics. The most optimum parameters of valve components to keep the valve within its allowable level against the critical stresses are made clear from the quantitative analysis. An effective test method for valve turn-on test during the arrester discharging is proposed. The test results show that the proposed method can impose proper turn-on stresses on the thyristors. A dc 500-kV prototype valve developed with the aid of the above studies shows that it can satisfy the requirements.

[1996] 02C - 16

DEVELOPMENT OF THE EQUIPMENT FOR 500-KV AC/DC CONVERSION STATIONS. PARTS 1-4. HIGH-VOLTAGE LARGE-CAPACITY THYRISTOR VALVE, TRANSFORMER AND DC REACTOR FOR CONVERSION, DC, GIS, AND GROUND TYPE AC AND DC FILTERS

Yamada, M.; Tanaka, M.; Yomo, M.; Tatsuoka, K.

Kansai Elec Power Co, Inc, Osaka, Japan

R and D News Kansai (Japan), vol 347, September 10, 1996, pp 21-28

Japanese

This paper outlines the future development of the equipment for 500-kV ac/dc conversion stations. Thyristor valves for ac/dc and dc/ac conversion are indispensable for conversion stations. Kansai Electric Power Co. developed, first in the world, the high-voltage large-capacity thyristor valve with the 6-inch optical thyristor device largest in the world. The compact efficient transformer and dc reactor for conversion was developed for 500-kV large-capacity dc transmission. In the newly developed 500-kV dc GIS, the effect of conductive foreign materials under dc electric field, and the effect of charging phenomenon on solid insulator surfaces on withstand voltage characteristics at polar inversion were considered as proper phenomena for dc. In order to prevent the adverse effect of electromagnetic interference and voltage distortion on common communication lines due to harmonic currents generated by ac/dc conversion equipment, the compact safety ac and dc filters were

developed whose condenser tanks are directly installed on the ground. 17 figs., 3 tabs.

[1997] 02C - 17

EARTHQUAKE AND FIRE RESISTANT. MEASURES TAKEN AT SYLMAR SUBSTATION, US WEST COAST

Fischer, W.

Int'l Power Generation (UK), vol 6, no 1, October 1997, pp 47-49

A high-voltage current transmission line runs north for 1361 km along the west coast of the USA from the Sylmar substation to the south of Los Angeles. Two groups of 500-kV, 12-pulse thyristor valves connected in parallel were installed at the Sylmar-East converter station in 1988 in order to upgrade the transmission capacity of the line. In October 1993, one of the new groups of thyristor valves was destroyed by a fire in the converter building. The program to replace the components with the latest generation of thyristor valves, and all the associated assemblies and subsystems, within tight time and cost constraints, is described. The opportunity was taken to reduce fire risk for the future and also, since the sub-station is near the San Andreas fault line, to improve the station's resilience to seismic effects such as severe vibrator ground motions.

[1997] 02C - 18

HUMIDITY DEPENDENCE OF DC INSULATION CHARACTERISTICS OF FRP INSULATORS FOR THYRISTOR VALVES

Yamada, M.; Hashimoto, T.; Irokawa, H.; Kobayashi, K.; Ishida, T.; Tanaka, C.; Endo, F.

Kansai Elec Power Co, Inc, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 690-691

Japanese

Abstract not available.

[1997] 02C - 19

IEEE RECOMMENDED PRACTICE FOR TEST PROCEDURES FOR HIGH-VOLTAGE DIRECT-CURRENT THYRISTOR VALVES

IEEE Substations Committee

Substations Committee, IEEE PES, USA

IEEE Std 857-1996, July 29, 1997, 27 pp

Information and recommendations for the type testing of thyristor valves for high-voltage direct-current (HVdc) power transmission systems are provided. These tests cover only the principal tests on the valves and do not include tests of auxiliary equipment associated with the valves.

[1996] 02C - 20

INSULATION CHARACTERISTIC OF 500-KV WATER-COOLED THYRISTOR VALVE FOR HVDC TRANSMISSION

Hasegawa, T.; Yamaji, K.; Irokawa, H.; Tanabe, S.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-E, pp 303-308

Thyristor valve of 500-kV rating for 2800-MW, 500-kV dc system was developed. One of the development objectives is a decrease in the outside dimension of the valve by a rational insulation design. Therefore, the following were attempted: (1) Optimization of the gap insulation distance between top and bottom thyristor modules. (2) Optimization of the creepage insulation distance of insulation poles. The optimization was carried out by in long-term field analysis, preparation of an insulation model between modules, and study of dc V-t characteristics of insulation poles. As the result, the valve was reduced to 75% of its height and 70% of its volume in the 8-kV optical-trigger thyristor in comparison with the thyristor valve of Hokkaido-Honshu dc interconnection system. Insulation characteristics in the cooling water leakage were examined, and it was confirmed that flashover was not caused.

[1997] 02C - 21

INVESTIGATION OF ELECTRO-STATIC ATOMIZATION PHENOMENON IN AN HVDC THYRISTOR VALVE

Yamada, M.; Miyazaki, N.; Kawakami, S.; Chishaki, H.; Tadokoro, M.; Nojima T.; Sato, A.

Kansai Elec Power Co, Inc, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 1032-1033

Japanese

Abstract not available.

[1996] 02C - 22

INVESTIGATION OF THE TEMPERATURE RISE OF THE 500-KV THYRISTOR VALVE

Takahashi, N.; Shoji, Y.; Hibino, A.; Miyashita, T.; Takeda, M.; Hasegawa, T.; Hirose, M.; Irokawa, H.

Mitsubishi Electric Corp, Hyogo, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-E, pp 309-314

The diffusion of heat of air was only 5% of the total loss in the water-cooling thyristor valve, but it affected the temperature rise of a photodiode and a capacitor in the snubber circuit. Consequently, the temperature distribution was estimated, and thermal equilibrium experiments and simulations of the model's valve were carried out. This paper describes test equipment, and fundamental equation of the simulation and the result. In the simulation, the fundamental equation was solved by the finite-volume method, and hydrodynamic calculation program STAR-CD was utilized. Calculation results agreed well with experimental results. Intake air-volume necessary for a 500-kV, 2800-A valve was estimated to be 340 m^2/minute per single phase.

[1996] 02C - 23

MAGNETIC CORES MADE OF VITROVAC AND VITROPERM IN SEPARATING TRANSFORMERS USED IN THYRISTOR TRIPPING CIRCUITS

Markowski, G.; Szczyglowski, J.

Tech Univ of Czestochowa, Poland

Journal of Magnetism and Magnetic Materials, vol 160, July 1, 1996, pp 215-216.

The paper discusses the possibility of using VITROVAC and VITROPERM magnetic cores in circuits generating the current impulse tripping thyristors in current transforming units. The magnetic cores used in present-day technology are usually made with a ferrite of high impulse permeability and low-loss generating tripping current impulses of 0.5-1.0 A/μsec which ensure constant thyristor switching times, independent of the parameter values. This study has shown that steeper steering impulses of about 5-6 A/μsec can be obtained using VITROVAC 6030F cores with higher impulse permeabilities μ//p equals 60 000-100 000. The use of such magnetic cores in dc transformers also reduces the energy losses in thyristor steering circuits to be used in HVdc transformer stations. It may be possible to simplify the steering system, especially compared with systems exploiting opto-isolation. 3 Refs.

[1996] 02C - 24

MODERN HVDC THYRISTOR VALVES

Stomberg, H.; Abrahamsson, B.; Saksvik, O.

ABB Power Sys, Ludvika, Sweden

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 606-610

The modern HVdc power converter valve has been designed for high reliability and availability. Essentially based on the earlier well-proven generation, the authors describe how the modern valve adds features such as: implemented fire safety measures in valve design and choice of materials; improved plant utilization through the HAS concept; simplified voltage sharing circuits; single circuit cooling system; improved water leakage detection; and higher thyristor voltage and current rating. 0 Refs.

[1997] 02C - 25

NEXT-GENERATION POWER SEMICONDUCTOR DEVICES. HIGH-VOLTAGE, LARGE-CAPACITY GTO AND LTT

Iwasaki, M.; Harada, T.; Nimura, T.

Toshiba Corp, Tamagawa Work, Japan

Toshiba Rebyu (Japan), vol 52, no 2, pp 51-54

Japanese

The ratings of gate turn-off thyristors (GTOs) and light-triggered thyristors (LTTs) have been growing year by year over the past 15 years. GTOs and LTTs are power semiconductors that are widely used for power converter applications in the several-hundred-kVA and MVA range for rolling stock, static VAr compensators, high-voltage dc transmission systems, and large industrial motor drives. This paper describes our 6-kV-6-kA GTO (anode-short type), 4.5-kV-4.5-kA GTO (reverse-blocking type) and 8-kV-3.5-kA LTT using 6-inch silicon wafers. These power semiconductors have the highest voltage/current ratings in the world for devices of this type, and can contribute to lower power losses in converter equipment.

[1996] 02C - 26

NUMERICAL INVESTIGATION OF THE

EFFECT OF VALVE REACTOR DESIGN ON THYRISTOR STRESS IN AN HVDC THYRISTOR VALVE

Tadokoro, M.; Yamamoto, T.; Shoji, Y.; Yamaji, K.; Hasegawa, T.; Irokawa, H.

Mitsubishi Elec Corp, Hyogo, Japan

Proceedings, 14th IEEE T&D Conf Conf, Los Angeles, CA, September 15-20, 1996, pp 320-325

Overvoltage on thyristor elements is of particular interest in equipment design. The dependence of the behavior of the overvoltage on the characteristics of the anode reactor was investigated by numerical simulation with a transient voltage program. The point in the valve, to which the core of the anode reactor is connected, critically changes the voltage that appears on the thyristor elements. The stray capacitance of the winding to the core is another important characteristic value. A structure supported thyristor valve for dc transmission of ±500 kV, 2800 MW was developed. 2 Refs.

[1996] 02C - 27

OPERATIONAL TEST METHODS ON VALVE SECTIONS FOR HVDC THYRISTOR VALVE

Tanabe, S.; Kobayashi, S.

Toshiba Corp, Tokyo, Japan

Toshiba's Selected Papers on Science and Technology (Japan), vol 10, no 4, January 1996, pp 119-124

The recent progress of power semiconductor technology is now making possible the practical use of large single-crystalline silicon wafers of 150-mm diameter. Thyristors are thus increasing in capacity. Thyristors now becoming available have a voltage rating in excess of 8-kV for HVdc applications and a current rating in excess of 5 kA for BTB applications. From the background where thyristor capacity is increasing more and more, the synthetic test which requires only a small facility capacity will become increasingly advantageous. This paper proposes an oscillatory circuit composed of inductance and capacitance as synthetic test circuit for periodic firing and extinction tests on a valve section. The proposed test circuit has such features as equivalency of voltage and current stresses, simple test facilities, and the ease with which individual thyristors can be observed. 3 refs., 13 figs.

[1997] 02C - 28

OPERATIONAL TESTS ON HVDC THYRISTOR MODULES IN A SYNTHETIC TEST CIRCUIT FOR THE SYLMAR EAST RESTORATION PROJECT

Bauer, T.; Lips, H.P.; Thiele, G.; Tylutki, T.; Uder, M.

Siemens AG, Erlangen, Germany

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1151-1158

According to IEC 700 and IEEE 857, operational tests on HVdc thyristor modules can be performed either in a six-pulse back-to-back test circuit or in a synthetic test circuit. Because of the high rating of modern thyristors the use of a six-pulse bridge configuration would require facilities with a high installed capacity. In a synthetic test circuit even high current and voltage stresses can be represented using less than 1/100 of that installed capacity. Thus synthetic test circuits are an economical alternative to test a representative part of a modern thyristor valve. The paper describes the operational tests on thyristor modules for the Sylmar East Restoration Project which were completely carried out in a synthetic test circuit. 8 Refs.

[1997] 02C - 29

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. DEVELOPMENT OF HIGH-PERFORMANCE THYRISTOR VALVE USING LARGE LIGHT-TRIGGERED THYRISTORS WITH 6-INCH WAFERS

Hasegawa, T.; Yamaji, K.; Irokawa, H.; Takeda, M.; Chishaki, H.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 945-952

Japanese

A thyristor valve for a large HVdc system is required to have such characteristics as compactness in size, smaller power consumption and higher reliability. The authors developed a dc 500-kV thyristor valve using 8-kV light-triggered thyristors with 6-inch wafers which can meet above requirements. Followings are the results of development and investigation in this paper; (1) Studies about the rating of thyristors show that a 8-kV thyristor with 6-inch wafer can be the most optimum for the objective valve. Newly developed 8-kV light-triggered thyristors provide good characteristics. (2) The most optimum parameters of valve components to keep the valve within its allowable level against the critical stresses are made clear from the quantitative analysis. (3) An effective test method for valve turn-on test

during the arrester discharging is proposed. The test results show that the proposed method can impose proper turn-on stresses on the thyristors. (4) A dc 500-kV proto-valve developed with the aide of above studies shows that it can satisfy the requirements.

[1997] 02C - 30

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. SOME DISCUSSIONS ON THYRISTOR CHARACTERISTIC OPTIMIZATION FOR HVDC VALVES

Tanabe, S.; Kobayoshi, S.

Toshiba Corp, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 1024-1031

Japanese

We have been developing thyristor valves for high-voltage dc transmission systems for more than 20 years. During this period, the size, power loss and reliability are dramatically improved and one of the technical advancements which support the improvements is to increase the voltage and current rating of thyristors. However when thyristor voltage rating becomes higher than 6 kV, increasing the voltage rating does not lead size and power loss reduction of the valve because of turn-off characteristic deteriorations. This paper describes the method which can optimize the thyristor characteristics in such a way that the size and power loss of valves are minimized. Two different approaches for HVdc and back-to-back systems are presented.

[1996] 02C - 31

POWER ELECTRONICS. APPLICATION OF SELF-COMMUTATED INVERTERS TO ELECTRIC POWER SYSTEMS

Kanai, T.; Kawakami, N.; Ishizuki, T.; Irokawa, S.

Toshiba Corp, Fuchu Work, Japan

Toshiba Rebyu (Japan), vol 51, no 4, pp 10-15

Japanese

The remarkable development of power electronics technologies has enabled the wide application of various types of equipment in electric power systems. Typical examples are high-voltage dc (HVdc) transmission systems for prompt power exchange, and static VAr compensators (SVCs) for improving voltage stability. In particular, further demand will be created for self-commutated converters using self-turn-off devices such as gate turn-off thyristors (GTOs), due to their advantages such as reduced dependence on system conditions, increased controllability, compactness, and so on. This paper outlines two self-commutated converters which were recently applied to power systems: a GTO converter for an adjustable-speed generator-motor, and one for a large-capacity self-commutated SVC.

[1997] 02C - 32

RECENT TRENDS IN DEVELOPMENT OF THYRISTOR VALVES AND POWER DEVICES

Muraoka, Y.

Hitachi, Ltd, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp S.23.5-S.23.8

Japanese

Abstract not available.

[1997] 02C - 33

SECULAR CHANGE IN CHARACTERISTICS OF THYRISTORS USED IN HVDC VALVE

Sampei, M.; Yamada, T.; Tanabe, S.; Takeda, H.; Kobayashi, S.

Elec Power Development Co, Inc, Tokyo, Japan

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1159-1167

The Hokkaido-Honshu HVdc link entered service in 1979 for the first phase (150 MW, 125 kV-1200 A) and in 1980 for the second phase (300 MW, 250 kV-1200 A) and has since been operating in good condition. In the Kamikita converter station situated on the Honshu side, the thyristor valves for the first and second phases use 1,344 thyristors rated 4 kV-1.5 kA. To examine secular changes in the characteristics of thyristors and estimate their life expectancy, we picked up eight thyristors from the thyristor valves, measured main characteristics and compared measurements with the corresponding values measured before they entered service. Further, two thyristors were subjected to temperature and voltage acceleration tests to check for a change over time of leakage current. From the results of these investigations it was verified that the thyristors that have been in service for 16 years have the characteristics and service life equivalent to those of the new ones. But further investigation is required as to the change of turn-off characteristics. 5 Refs.

[1997] 02C - 34

SEMICONDUCTOR POWER DEVICES FOR USE IN HVDC AND IN FACTS CONTROLLERS

Lips, H.P.

Siemens AG, Erlangen, Germany

Proceedings, Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 1997

This paper is based on a CIGRE Report which was developed by Working Group 14.17 "Semiconductor Power Devices." Although the report was finalized in June 1996, and printed in April 1997, because of the rapid progress in power semiconductor technology, some of its results already seem to have been overtaken by reality. Thus it is inevitable that some of the views expressed in this paper are different to those given in the base report.

[1997] 02C - 35

Deleted

[1997] 02C - 36

THE STATUS OF CVD DIAMOND FOR POWER ELECTRONIC APPLICATIONS

Katz, A. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-107122, January 1997, 82 pp

The physical and electrical properties of diamond--wide band gap, high breakdown voltage, high saturated-drift velocity, radiation hardness, and high thermal conductivity--make it a promising material for fabrication of high-power, high-frequency, and high-temperature electric devices. This report provides a comprehensive description of the state-of-the-art in chemical vapor deposition (CVD) diamond technology including its prospects for widespread commercial use.

[1996] 02C - 37

THE WORLD'S LARGEST-CAPACITY 8-KV/3.6 KA LIGHT-TRIGGERED THYRISTOR

Sato, K.

Mitsubishi Electric Advance (Japan), vol 75, June 1996, pp 31-32

Mitsubishi Electric has developed an 8-kV/3.6-kA light-triggered thyristor (LTT) based on a six-inch wafer for power converter applications in HVdc transmission and back-to-back power systems. New design features give the device double the power control capacity of previous LTTs based on four-inch wafers while mitigating the problems that occur with large-capacity devices. 0 Refs.

[1996] 02C - 38

THYRISTOR VALVE REPLACEMENT OF THE PACIFIC INTERTIE EXPANSION SYLMAR EAST 500-KV HVDC CONVERTER STATION

Christl, N.; Faehnrich, W.; Lips, P.; Rasmussen, F.; Sadek, K.

Siemens AG, Erlangen, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 128-133

The Pacific Intertie Expansion Project was successfully commissioned in 1988 in order to expand the overall transmission capacity of the 500-kV dc transmission line connecting Sylmar substation with the northern terminal at Celilo converter station from 2000 MW to 3100 MW. This upgrading had been realized by current upgrading from 2000 A dc to 3100 A dc by means of paralleling two new 500-kV dc 12-pulse groups at the Sylmar East Converter Station operated by the City of Los Angeles Department of Water and Power (DWP). One of these expansion converters was completely destroyed in October 1993 by a hazardous fire inside the converter building. To improve the energy availability and to reduce the risk for a similar event in the remaining group in the future, an emergency plan was launched to design, manufacture and commission a new thyristor valve 12-pulse group with improved fire withstand capabilities and to replace the hazardous components in the other healthy converter group. The main objectives during this project execution were to study and design new thyristor valves, which are able to operate under the same system conditions as the original valves. 3 Refs.

[1997] 02C - 39

UNIFIED PROPOSAL IN THE CHARACTERISTICS TESTING METHODS OF 8-KV 3.5 KA CLASS LIGHT TRIGGERED THYRISTORS

Asano, Ka.; Sugawara, Y.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denshi Debaisu Kenkyukai Shiryo (Japan), vol 97, no 42-55, pp 25-29

Japanese

Unified testing standards are proposed for 8-kV, 3.5-kA class light-triggered thyristors, based on the operating requirements of the Kii Channel HVdc project.

[1997] 02C - 40

V-T CHARACTERISTICS OF ARTIFICIALLY POLLUTED SOLID INSULATORS UNDER DC VOLTAGE APPLICATION

Yamada, M.; Hashimoto, T.; Hatano, M.; Kimura, T.; Chishaki, H.; Hasegawa, T.; Fujii, H.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Koden'atsu Kenkyukai Shiryo (Japan), vol HV-97, no 29-43, pp 33-38

Japanese

Understanding of the V-t characteristics of artificially polluted solid insulating materials under dc voltage application is very important to achieve reliable insulation design of thyristor valves for HVdc transmission system. FRP pipes, Teflon pipes and optical fiber cables were tested. As a result, it was found that the slope of the V-t curves of these insulating materials with contamination of 0.03 mg/cm^2 (equivalent salt deposition) under 50.DEG.C. and 80% RH was very small.

[1996] 02C - 41

VIBRATION TESTS OF 500-KV THYRISTOR VALVE

Oue, Y.; Hirose, M.; Irokawa, H.; Teramoto, H.; Kiso, M.; Asada, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.194-6.195

Japanese

Abstract not available.

[1996] 02C - 42

VOLTAGE DISTRIBUTION CHARACTERISTICS OF THE 500-KV THYRISTOR VALVE AGAINST STEEP FRONT IMPULSE STRIKES

Yoshida, Y.; Hirose, M.; Irokawa, H.; Yamamoto, T.; Chishaki, H.; Yamamoto, Y.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 7, p 7.175

Japanese

Abstract not available.

[1996] 02C - 43

VOLTAGE DISTRIBUTION OF HVDC THYRISTOR VALVE IN CASE OF STEEP FRONT IMPULSE OCCURS

Yamada, M.; Hirose, M.; Irokawa, H.; Yamato, I.; Ishida, T.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 858-859

Japanese

Abstract not available.

[1997] 02C - REF

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY OF ELECTRIC POWER DEVELOPMENT CO. LTD

For Abstract see entry 01A - 16

[1996] 02C - REF

MORE HVDC TRANSMISSION PROJECTS BY TECHNICAL BREAKTHROUGH

For Abstract see entry 01C - 20

[1997] 02C - REF

OPERATING EXPERIENCE OF HOKKAIDO-HONSHU HIGH VOLTAGE DIRECT CURRENT LINK

For Abstract see entry 01C - 25

[1997] 02C - REF

OPERATIONAL TESTS ON HVDC THYRISTOR MODULES IN A SYNTHETIC TEST CIRCUIT FOR THE SYLMAR EAST RESTORATION PROJECT. DISCUSSION

For Abstract see entry 01C - 27

[1996] 02C - REF

NEW TECHNOLOGIES IN HVDC CONVERTER DESIGN

For Abstract see entry 02A - 3

[1997] 02C - REF

DEVELOPMENT OF HIGH-PERFORMANCE SELF-COMMUTATED AC/DC CONVERTER

For Abstract see entry 02B - 5

[1996] 02C - REF

V-T CHARACTERISTICS OF SOLID INSULATORS FOR THYRISTOR VALVES

For Abstract see entry 02G - 18

[1996] 02C - REF

DC INSULATION CHARACTERISTICS OF FRP INSULATORS AND LIGHT GUIDES FOR THYRISTOR VALVES

For Abstract see entry 02G - 2

[1996] 02C - REF

DEVELOPMENT OF SURGE ARRESTER FOR THYRISTOR VALVE

For Abstract see entry 02G - 3

[1996] 02C - REF

INSULATION CHARACTERISTICS OF FRP INSULATORS FOR THYRISTOR VALVE

For Abstract see entry 02G - 8

[1998] 02C - REF

CHARACTERISTICS OF A CURRENT SOURCE AC/DC CONVERTER WITH ENERGY RECOVERY SNUBBER CIRCUITS UNDER THE PWM CONTROL

For Abstract see entry 05A - 4

[1997] 02C - REF

DEVELOPMENT AND TESTING OF PROTOTYPE MODELS FOR A HIGH-PERFORMANCE 300 MW SELF-COMMUTATED AC/DC CONVERTER

For Abstract see entry 05A - 6

[1997] 02C - REF

FUZZY LOGIC CONTROL OF HIGH VOLTAGE DC TRANSMISSION SYSTEM

For Abstract see entry 05B - 35

[1997] 02C - REF

INSULATION CHARACTERISTICS OF 500-KV WATER-COOLED THYRISTOR VALVE FOR HVDC TRANSMISSION

For Abstract see entry 05J – 3

[1996] 02C - REF

A METHOD FOR INVESTIGATION OF THYRISTOR REVERSE VOLTAGES DUE TO THE EFFECT OF CHARGE ACCUMULATION

For Abstract see entry 17B - 1

[1996] 02C - REF

FEASIBILITY STUDY FOR MOS-CONTROLLED THYRISTOR. FINAL REPORT

For Abstract see entry 17B - 13

[1996] 02C - REF

CHARACTERIZATION OF A NEW HIGH VOLTAGE INTEGRATED SWITCH: MOS-GATED OPTICALLY TRIGGERED THYRISTOR

For Abstract see entry 17B - 5

[1996] 02C - REF

MODELLING OF HIGH-VOLTAGE THYRISTORS UNDER DYNAMIC CONDITIONS

For Abstract see entry 19D - 12

02D Reactive Compensation, Harmonics, Filters

[1996] 02D - 1

AC SYSTEM MODELLING FOR AC FILTER DESIGN-AN OVERVIEW OF IMPEDANCE MODELLING

Arrillaga, J.; Juhlin, L.; Lahtinen, M.; Ribeiro, P.; Saavedra, A.R.

Electra (France), no 164, February 1996, pp 132-151

French; English

As there is a general feeling that ac filters for HVdc

stations have been unnecessarily conservatively designed, CIGRE WG 14.03 is making an overall review of the factors influencing ac filter specification and design. The aim is to get an optimal filter solution which takes into account the costs of specification, engineering and equipment as well as those related to the final distortion level in the network, i.e. all the costs which in the end have to be paid by the power consumers. In this respect, it must be emphasized that the cost involved in design calculations are not insignificant. This, coupled to the fact that filter design is normally on the critical path for the completion of HVdc schemes, often forces the use of relatively simple representations of the ac system. Clearly a balance must be found to provide realistic models which are not unnecessarily complex. While in some cases general rules based on simple empirical values may be acceptable for the ac system model, in general detailed calculations of harmonic interference and harmonic penetration in the ac network have to be performed. An overview of ac modelling algorithms has been carried out with special interest in transmission lines and linear power system components, as well as the derivation of the harmonic impedance loci needed for ac filter design. Although the main interest of the report is concerned with ac filters for HVdc convertors, the principles and conclusions are equally applicable to other harmonic producing sources such as SVC, arc furnaces and thyristor-controlled power equipment. 33 Refs.

[1997] 02D - 2

ACTIVE DC FILTERS IN HVDC APPLICATIONS

Andersen, N.; Gunnarsson, S.; Pereira, M.; Fitz, P.; Damstra, G.C.; Enslin, J.H.R.; O'Lunelli, D.

CIGRE WG 14.28

Proceedings, Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 1997

The conversion process in an HVdc transmission system injects harmonic currents into the transmission lines connected to the converters. These currents may cause interference in the adjacent systems, like telecommunication equipment. The conventional solution to reduce the harmonic currents has been to install passive filters in converter stations. The development of power electronics devices and digital computers has made it possible to manufacture a new powerful way for mitigation of harmonics, namely, active filters. The active filters can be divided into two groups, active ac and dc filters. Active dc filter applications are in operation in several HVdc links and have been economically competitive due to increased demand on telephone interference levels on the dc lines. An active ac filter prototype installation is still to be expected. Since no active ac filters are available, this paper will only focus on the already installed active dc filters in HVdc schemes today.

[1997] 02D - 3

ACTIVE POWER FILTERS--RECENT ADVANCES

Mohan, N.; Kamath, G.R.

Univ of Minnesota, Minneapolis, MN, USA

Sadhana (India), vol 22, pt 6, December 1997, pp 723-732

Power electronic loads inject harmonic currents into the utility causing overheating of power transformers and neutral wires in the power system, unpredictable performance of protection systems, etc. In addition, electric resonances in such loads can also cause other undesirable phenomena like voltage fluctuations, radio frequency interference (RFI), etc. To mitigate these undesirable effects, a new class of power electronics equipment (active filters) is being considered. A review of present-day solutions in the area of active filters is conducted in this paper. Finally, this paper discusses the trends in the design of active filters and the factors influencing them.

[1997] 02D - 4

AN EVALUATION OF DIFFERENT ACTIVE FILTER TOPOLOGIES FOR THE CAHORA BASSA HVDC PROJECT

Holtzhausen, H.N.; Enslin, J.H.R.; Venter, F.

Univ of Stellenbosch, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

At present passive filters are installed at the converter substations of the Cahora Bassa HVdc line. Pending the evaluation of these filters on the recommissioned line, active filtering may be necessary at Apollo inverter station to reduce the induced telephone interference. This paper investigates the different active filter topologies that could be useful in this regard. The active filters are analyzed and suitable control algorithms are developed for a simplified circuit. Simulations are conducted on TMTDC with the objective of comparing these filters with one another. Useful results are obtained that will form the foundation of more detailed simulations and practical verification.

[1997] 02D - 5

APPLICATION OF REAL TIME DIGITAL SIMULATION FOR COMMISSIONING AUTOMATIC VOLTAGE REGULATORS FOR SYNCHRONOUS CONDENSERS

Valiquette, R.; Mazur, G.; Dhaliwal, N.; Jiang, X.; Wierckx, R.

Manitoba Hydro, Winnipeg, Canada

Proceedings, 1997 Int'l Conf on Digital Power Systems Simulators, Montreal, Canada, May 28-30, 1997, pp 211-216

This paper describes the use of a real time digital simulator (RTDS) for commissioning and optimization of the excitation system of a synchronous machine. Manitoba Hydro is replacing the excitation system on three synchronous condensers at Dorsey HVDC Converter Station. A discussion is included on RTDS models for the synchronous machine, 6-pulse exciter bridge, three winding converter transformer, 278-MW valve group and 230-kV system equivalent developed on RTDS. RTDS features available for model development are also addressed. The tests performed on the AVR are described and the results are presented.

[1996] 02D - 6

ASPECTS OF FILTER DESIGN FOR THE CHANDRAPUR 2*500 MW HVDC BACK-TO-BACK CONVERTOR STATION

Luckett, M.J.; Macleod, N.M.; Young, D.J.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 191-196

In back-to-back HVdc power convertor substations, such as that at Chandrapur in India, considerable benefits can be realized by dispensing with a dc smoothing reactor. This paper considers the effects of this design of convertor substation on the generation of harmonic currents and on the design of the ac harmonic filters. Other factors which influenced the filter design for the Chandrapur project were the wide variation of system frequency, possible resonance conditions with the ac power system, operation of the convertors at high firing angle for reactive power control and the presence of an adjacent HVdc scheme. A successful filter design was achieved using a common design for both ac systems with only two filter types. 4 Refs.

[1996] 02D - 7

CALCULATION OF HVDC CONVERTER NONCHARACTERISTIC HARMONICS USING DIGITAL TIME-DOMAIN SIMULATION METHOD

Sarshar, A.; Iravani, M.R.; Li, J.

Trench Electric, Scarborough, Ontario, Canada

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 335-343

In this paper, noncharacteristic harmonics of an HVdc converter station are calculated based on the use of digital time-domain simulation methods. An enhanced version of the Electromagnetic Transients Program (EMTP) is used for the studies. The noncharacteristic harmonics of interest are (1) the dc side triplen harmonics, and (2) the ac side second harmonic. Impacts of loading conditions, neutral filter, and converter firing angle on the dc side triplen harmonics are discussed. Effects of ac side network parameters, static VAr compensator (SVC), transformer half-cycle saturation, and geomagnetically induced current (GIC) on the ac side second harmonic instability are also presented. This paper concludes that the digital time-domain simulation method provides significant flexibility for accurate prediction of (1) generation mechanism, and (2) adverse impacts of HVdc noncharacteristic harmonics. 20 Refs.

[1997] 02D - 8

DC HARMONIC DISTORTION MINIMIZATION OF THYRISTOR CONVERTERS UNDER UNBALANCED VOLTAGE SUPPLY USING ASYMMETRICAL FIRING ANGLE

Ngandui, E.; Olivier, G.; April, G.-E.; Guimaraes, C.

Dept of Elec & Computer Eng, Ecole Polytech de Montreal, Quebec, Canada

IEEE Trans on Power Electronics, vol 12, no 2, March 1997, pp 332-342

Noncharacteristic harmonics of significant magnitude are produced at the output and input terminals of phase-controlled power converters under unbalanced voltage supply conditions. The concept of switching functions has been proposed before to evaluate the harmonics produced by a phase-controlled six-pulse power converter under both balanced and unbalanced power supply conditions. This paper extends the switching-functions approach to establish analytical equations for the dc output voltage harmonics produced by 12-, 18-,

and 24-pulse power converters. The problem is approached from the standpoint of symmetrical voltage components. The increase in distortion under unbalance is caused by the appearance of a second harmonic component. A method, based on an asymmetrical firing angle, to cancel the second harmonic at the power converter output under unbalanced voltage supply is also presented. Cancellation of the second harmonic improves power converter dc output voltage quality.

[1996] 02D - 9

DC SIDE FILTERS FOR MULTITERMINAL HVDC SYSTEMS

Working Groups on Multiterminal HVDC Systems and Harmonic Aspects of HVDC Transmission

IEEE Trans on Power Delivery, vol 11, no 4, 1996, pp 1970-1984

Multiterminal HVdc systems present challenges in the specification and design of suitable dc side filtering. This document examines the existing experience and addresses the particular technical problems posed by multiterminal systems. The filtering requirements of small taps are discussed, as is the potential use of active filters. Aspects of calculation and design are considered and recommendations made to guide the planners and designers of future multiterminal schemes. 29 refs.

[1996] 02D - 10

DC SIDE HARMONIC REDUCTION IN HVDC CONVERTERS BY DIRECT RIPPLE REINJECTION

Arrillaga, J.; Enright, W.; Wood, A.R.; Perez Hidalgo, F.

Canterbury Univ, Christchurch, New Zealand

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 197-201

The conventional means for the reduction of dc side harmonics from HVdc power converters is the passive filter, an expensive solution, and therefore normally restricted to the elimination of the twelfth harmonic. However, higher order harmonics can still be a source of electromagnetic interference and often need to be filtered. A novel scheme to remove the higher order harmonics has been recently implemented in the form of a combined passive-active filter configuration which uses the capacitor of the twelfth harmonic filter to inject the smaller current harmonic content in opposition. This paper describes an alternative solution to passive and active filter arrangements on the dc side of the power converter. It shares with the active filter the principles of an active cancellation of harmonic content, but differs from it in the absence of processing and amplification and in the use of voltage rather than current harmonic cancellation. Another concept to reduce the harmonic content is pulse multiplication. A dc ripple reinjection scheme has been proposed to increase the number of pulses on both sides of the conventional ac/dc power converter. In that scheme, the dc ripple was used as the commutating voltage of a single-bridge thyristor-controlled rectifier, which is placed in series with dc line or load. The concept proposed here is not pulse-related and unlike the earlier dc ripple reinjection scheme, only attenuates the dc side harmonics. It is, however, considerably simpler than the above alternatives since does not involve any switching devices. 7 Refs.

[1996] 02D - 11

DEVELOPMENT AND FIELD TEST RESULTS OF THE AC 275-KV COMPACT FILTER

Yamazaki, T.; Karaki, S.; Muraoka, T.; Matsumoto, Y.; Oonishi, K.; Inno, S.

Tokyo Elec Power Co, Inc, Japan

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1707-1712

The ac filters of an HVdc converter station usually require a large installation space and are sensitive to seismic activity due to using an air-insulation platform. As a solution to these problems, we have developed compact filters in which all energized parts are enclosed. As a result, the installation space is one-third of the platform type and seismic performance considerably improves. After the field tests were conducted, these filters were put in service in May, 1992. 5 Refs.

[1996] 02D - 12

EXPERIMENTAL MEASUREMENT OF NON-CHARACTERISTIC HARMONIC POWER GENERATED BY THYRISTOR PULSE-CONTROLLED AC/DC THREE PHASE CONVERTERS

Segura, A.N.; Sanchez, P.B.

Univ de las Americas, Puebla, Mexico

Proceedings, IEEE Int'l Symp on Industrial Electronics (ISIE'96), Warsaw, Poland, June 17-20, 1996, vol 1, pp 549-554

This paper presents an experimental investigation to measure the non-characteristic harmonic power caused by network asymmetries in the ac source feeding thyristor-controlled ac/dc three-phase power converters. The experimental measurements were made in an ac/dc/ac transmission link physical model. Two three-phase converters linked by a lumped parameters transmission line are operating in its rectifying and inverting modes, respectively. The converter acting in the rectifier mode of operation allows the simulation of weak ac-line non-characteristic power generation as is usual in the electrochemical and electrometallurgical industries, when they are fed by ac/dc power rectifiers. The converter acting in the inverter mode of operation serves to simulate the effects of network asymmetries in the reception end of HVdc transmission links. To the authors' best knowledge no desegregation has been produced neither theoretically nor experimentally between the characteristic harmonic power generated during steady-state operating conditions and the non-characteristic harmonic power generated that follows a transient-state operating condition. It is the authors' opinion that this research may prove to be helpful within the framework of investigations that are being carried out to achieve full or partial suppression of non-characteristics harmonics. This is argued in the following pages, where the above mentioned research efforts are also further commented. 17 Refs.

[1997] 02D - 13

HARMONIC EVALUATION OF BENMORE CONVERTER STATION WHEN OPERATED AS A GROUP CONNECTED UNIT

Dinh, Q.N.; Arrillaga, J.; Wood, A.R.; Chen, S.; Enright, W.; Smith, B.C.; Du, Z.

Univ of Canterbury, Christchurch, New Zealand

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1730-1735

Three-phase harmonic measurements of a group connected generator-HVdc converter unit were recently carried out at the Benmore end of the New Zealand HVdc link. This paper describes the test measurement procedures, the set up and configuration of the CHART instrumentation, and presents the results which include measured waveforms and their harmonic contents in sequence components for a range of dc line current. Dynamic simulation accurately predicts the harmonic current contents. The generator harmonic impedances are estimated from the measured and simulated terminal voltages and currents. The generator harmonic ratings for direct connections are also investigated. 5 Refs.

[1996] 02D - 14

HARMONIC FLOW AND INSTABILITIES IN POWER GRIDS WITH HVDC

Hernes, M.

Energiforsyningens Forskningsinstitutt A/S, Trondheim, Norway

Energiforsyningens Forskningsinstitutt A/S, Trondheim (Norway), Report Number EFI-TR-A-4498, December 1996, 70 pp

Norwegian

This report is based on a literature search for publications which describe possible problems, methods of analysis and possible remedies related to harmonic flow and harmonic interaction between the ac and dc sides in high voltage direct current (HVdc) terminals. The main objective is to (1) give a survey of the extent of the problem by sorting out publications reporting problems actually experienced; (2) systematize the problem of harmonic interaction by type of phenomenon; (3) describe analysis methods and simulation tools, pointing out their limitations and sources of errors; and (4) describe ways of damping or eliminating harmonic flow. 15 refs., 28 figs.

[1996] 02D - 15

HARMONIC GENERATION BY HVDC SCHEMES INVOLVING CONVERTERS AND STATIC VAR COMPENSATORS

Yacamini, R.; Resende, J.W.

Univ of Aberdeen, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 143, no 1, January 1996, pp 66-72

The paper makes use of interactive harmonic analysis (IHA) to examine the harmonic behavior of an HVdc scheme. The scheme is treated as a complete system including HVdc converters, static VAr compensators, system impedance and harmonic filters. It is shown that the type and performance of the controller can have a significant effect on harmonic behavior. The paper illustrates by analytical and computational analysis the effect of equally pulse spaced EPS controllers and voltage zero crossing (VZC) type for both the above power electronic circuits. The EPS has clear advantages for 6- and 12-pulse HVdc converters, but has little influence on the behavior of thyristor-controlled reactors. The need to represent the complete systems is highlighted by example. 10 Refs.

[1998] 02D - 16

INFLUENCE OF THE FIRING ANGLE CONTROL IN THE HARMONIC GENERATION OF THYRISTOR PULSE-CONTROLLED AC/DC/AC SYSTEMS

Nava-Segura, A.; Banuelos-Sanchez, P.

Univ de las Americas Puebla, Puebla, Mexico

Proceedings, Intl Power Electronics Congress, Cuernavaca, Mexico, October 14-17, 1996, pp 207-211

This paper presents selected results of experimentally-based research into the firing angle control influence on the harmonic level generated by two 6-pulse-controlled, three-phase converters connected in an ac/dc/ac configuration. The sending end of this scheme is constituted by a rectifier, while the reception end is made up of a three-phase converter acting in its inverter mode of operation. Thus, such harmonic phenomena as the one presented in a weak ac line feeding electrochemical and electro-metallurgical industries is readily simulated. Also, the harmonic effects of network asymmetries in the reception end of HVdc transmission links can be easily implemented in this physical model. The paper includes selected graphs showing the dependence of both individual harmonic voltages and currents on the firing angles of rectifier and inverter operations. The firing angle control impact is observed for both filtered and non-filtered harmonic phenomena. 11 Refs.

[1997] 02D - 17

INVESTIGATION OF AC/DC CONVERTER HARMONICS BY AN ANALYTICAL BASED TIME-DISCRETE APPROACH

Grotzbach, M.; Ried, C.

Dept of Elec Eng, Univ of Fed Defense, Neubiberg, Germany

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 874-880

By investigating ac/dc converter harmonics in more detail, the interaction of ac and dc side as well as nonideal conditions have to be considered. This paper proposes a time discrete approach, which allows one to calculate analytically the steady-state dc currents at the firing points of each thyristor, if voltage harmonics or asymmetries disturb the ideal operation conditions. This forms the basis for an effective and accurate evaluation of ac/dc converter harmonics, especially for the investigation of parameter dependencies and for the application in harmonic distortion studies. Selected examples demonstrate particularly the analytical description of the discrete dc currents.

[1996] 02D - 18

NEW EXPERIMENTAL METHOD TO DESEGREGATE THE HARMONIC POWER PRODUCED BY THYRISTOR AC/DC THREE PHASE CONVERTERS

Nava-Segura, A.; Banuelos-Sanchez, P.

Univ de las Americas Puebla, Puebla, Mexico

Proceedings, Intl Power Electronics Congress, Cuernavaca, Mexico, October 14-17, 1996, pp 188-193

A new experimental method that desegregates the harmonic power in the ac coupling point of thyristor pulse-controlled ac/dc three-phase power converters is presented. This method resolves the total harmonic power into two orthogonal harmonic components, whose existence is demonstrated for sinusoidal voltage and non-sinusoidal current conditions. A scaled down ac/dc/ac transmission link physical model that includes characteristic harmonics passive filtering, and ac primary side weakening facilities is used for measurement purposes. Balanced and unbalanced voltage conditions are also simulated in physical model. 22 Refs.

[1996] 02D - 19

NONCHARACTERISTIC HARMONICS IN AC/DC CONVERTER GENERATED BY SUPPLY VOLTAGE UNBALANCE. I. FUNDAMENTALS AND UNCONTROLLED DIODE CONVERTER

Grotzbach, M.; Bauta, M.

Dept of Elec Eng, Univ of Federal Defense, Neubiberg, Germany

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 775-780

The behavior of a three-phase ac/dc power converter is not affected by the zero sequences of an unbalanced supply voltage system. Thus, a simplified presentation of voltage unbalance by the distortion of only one phase voltage is proposed to reduce significantly the analytical description by discrete small-signal models. The results of the investigation of a diode converter show a strong influence of the dc current smoothing on the generation of noncharacteristic harmonics. Using a normalized presentation of the complex third line current harmonics as phasor diagrams, an estimation of the maximum value can be carried out by geometrical addition of weighted phasors. 9 Refs.

[1996] 02D - 20

NONCHARACTERISTIC HARMONICS IN AC/DC CONVERTER GENERATED BY SUPPLY VOLTAGE UNBALANCE. II. CURRENT CONTROLLED THYRISTOR CONVERTER

Grotzbach, M.; Tseggai, F.

Dept of Elec Eng, Univ of Federal Defense, Neubiberg, Germany

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 781-787

For Part I, see 02D-19, above. Based on the preparatory work in Part I, a simplified small signal model of controlled ac/dc converters is presented to describe the effect of voltage unbalance on the discrete dc current behavior. This analytical approach shows that the effective voltage unbalance is determined by a control angle dependent rotation of the disturbance vector of the phase voltage. A normalized presentation of the behavior of noncharacteristic line current harmonics allow both more physical insight into basic mechanisms, and the estimation of 3rd harmonics using the superposition of corresponding weighted phasors. Comparing simulations proves the validity of the proposed method within the limits of voltage asymmetries laid down in the standards. 9 Refs.

[1997] 02D - 21

NOVEL CALCULATION OF HVDC CONVERTER HARMONICS BY LINEARIZATION IN THE TIME-DOMAIN

Perkins, B.K.; Iravani, M.R.

Univ of Toronto, Ontario, Canada

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 867-873

There is an increasing interest in the steady-state analysis of high power converter circuits for the computation of both characteristic and uncharacteristic harmonics. Uncharacteristic harmonics arise due to asymmetries in excitation/operation and are of particular interest given their overall adverse effect on the power system. Frequency domain methods for harmonic analysis are efficient though not necessarily comprehensive; that is not all the necessary details of the system are simultaneously modeled. This paper presents a novel technique that is both efficient and comprehensive as the time domain nature of the differential/algebraic equations describing the converter operation is retained. Efficient convergence of the time domain boundary value problem is assured by an appropriate linearization. Subsequent Fourier analysis of the time domain solution yields the harmonic spectra. Comparison is made with time domain steady-state solutions obtained by brute-force computation. 8 Refs.

[1996] 02D - 22

NOVEL METHOD FOR HARMONIC ANALYSIS OF AC/DC POWER SYSTEMS COUPLED BY THYRISTOR CONVERTERS

Jiang, J-G.; Xie, W-M.; Zhang, T-Z.

China Univ of Mining and Tech, Jiangsu, China

Proceedings, Intl Conf on Industrial Technology, Shanghai, China, December 5-9, 1994, pp 740-744

For harmonic analysis of ac/dc power systems coupled by thyristor converters, a novel method is proposed in this paper, i.e., the switching-points sampling (SPS) method. Only recording the sampling data at switching points, merely computing the harmonics of two current equations, the harmonics of the integrated system containing ac and dc sides can be obtained. The suggested method has the advantages of less memory capacity needed, fast computation and high accuracy. It is very useful and effective in estimating harmonic sources, predicting the harmonic flow and propagation and researching harmonics suppression. According to the number of sampling-points and the sampling length, the SPS method can be divided into the twelve-points or twenty-four-points sampling method and the periodic sampling method. The computing results agree closely with the measured results. 2 Refs.

[1996] 02D - 23

REACTIVE POWER CONTROL IN HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

Pandit, N.N.

Gujarat Electrical Board, Baroda, India

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 574-578

Reactive power control is the center of focus among the controlling parameters of HVdc transmission. The necessity of reactive power control, sources of reactive power control and a case study of HVdc transmission on the Rihand-Delhi line is discussed. 3 Refs.

[1996] 02D - 24

SAFETY AND SIGNALING UNIT FOR THE FILTRATION AND COMPENSATION CIRCUITS

OF THE VYBORGSK SUBSTATION

Zhdanov, E.V.; Ivanova, G.S.; Kirilina, V.A.; Lutsenko, G.A.; Sharlot, V.A.; Zarkov, N.W.; Vladimirov, I.V.

All-Russian Elect Eng Inst, Russia

Russian Electrical Engineering (Elektrotekhnika), vol 67, no 9, 1996, pp 76-80

The Vyborgsk rectifier-inverter substation (Russia) was designed as three identical rectifier and power converter modules (RCM). To compensate the reactive power in the ternary windings of the power converter transformers, rectifiers and inverters of each RCM, 38.5-kV capacitor batteries are employed which compensate around half of the reactive power of the modules. This paper describes a device which is intended to signal the presence of faults in the tunable and broad-band filters (including capacitor batteries, filter reactors and damping resistors) used in HVdc converter substations, as well as static thyristor compensators.

[1996] 02D - 25

SIMULATION STUDY ON THE SWITCHING TRANSIENTS DURING DE-ENERGISATION OF FILTER AND CAPACITOR BANKS

Fu, Y.H.

KEMA Nederland BV, Netherlands

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 375-380

A simulation study on the switching transients during de-energization of filter and shunt capacitor banks for HVdc applications is presented by using the EMTDC program. The circuit breaker restrike phenomenon can be simulated by applying the restrike and current interruption conditions in the circuit breaker model. Case studies of de-energizing filter or capacitor bank after clearing of a three-phase ac fault have been carried out. Factors which influence the severity of the circuit breaker recovery voltage have been studied, as well as factors which govern the severity of the switching overvoltage with or without restrikes. This treatment can also be used to evaluate the methods of controlling the switching transient overvoltage. 6 Refs.

[1996] 02D - 26

SMOOTHING TRANSFORMER, A NEW CONCEPT IN DC SIDE HARMONIC REDUCTION OF HVDC SCHEMES

Enright, W.; Arrillaga, J.; Wood, A.R.; Perez Hidalgo, F.

Elec Corp of New Zealand Ltd, Wellington, New Zealand

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1941-1947

Direct connection schemes have been a subject of recent investigation, offering operational flexibility and substantial reductions in ac components. In these schemes the use of active dc filters has been suggested to replace the conventional tuned passive filter design. This paper presents the smoothing transformer as a new means for reducing dc harmonics at characteristic and non-characteristic frequencies using only passive components. A realistic smoothing transformer design is examined using the New Zealand HVdc system operating in the direct connection mode. The steady-state and transient performance of the smoothing transformer design is compared with that of the existing dc smoothing reactor and filter bank. 9 Refs.

[1997] 02D - 27

STUDY ON CONNECTING ADF TO DC-SIDE OF HVDC STATION

Tang, Z.; Ren, Z.; Lu, Z.; Wang, G.; Dai, Y.

Chongqing Univ, China

Automation of Electric Power Systems (China), vol 21, no 11, November 1997, pp 31-34, 38

Chinese

Applying a hybrid passive-active filter (HPA) to suppressing harmonic current on the dc-side of an HVdc station is feasible from both the technical and economical point of view. This paper analyzes the GZB-NQ filtering characteristic of passive filters on the dc-side of a GZB HVdc station using a frequency analysis method and points out its drawbacks in construction. In order to reasonably design ways to connect an active dc filter (ADF), the paper proposes a new construction model for HPA filters and proves its reasonableness. The new model not only overcomes these defects existing in original filters, but also puts forward a reasonable location for connecting ADF to the HVdc system.

[1996] 02D - 28

THE NEW CONCEPTS OF CHARACTERISTIC AND NON-CHARACTERISTIC HARMONIC REACTIVE POWER IN AC/DC POWER SYSTEMS

Nava-Segura, A.; Banuelos-Sanchez, P.

Univ de las Americas Puebla, Mexico

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 96-102

This paper presents a theoretical and experimental investigation to desegregate the reactive harmonic power, generated by thyristor-controlled ac/dc three-phase power converters, into two orthogonal reactive harmonic power components. These two components have been given, by the authors, the names of characteristic harmonic reactive power and noncharacteristic harmonic reactive power, respectively. The characteristic harmonic reactive power is produced by the so-called characteristic harmonic currents, i.e., those of order 5, 7, 11, 13, etc., while the noncharacteristic harmonic reactive power is produced by the so-called noncharacteristic harmonic currents, i.e., those of order other than 5, 7, 11, 13, etc. The theoretical analysis departs from the instantaneous power's general formulation of a set of nonsinusoidal voltages and nonsinusoidal currents. This situation can appear practically when ac/dc three-phase thyristor-controlled converters are fed by weak and unbalanced ac systems. Experimentally, research was undertaken by measuring both characteristic and noncharacteristic harmonic reactive power, in an ac/dc scaled-down physical model operating under unbalanced voltage conditions. The paper includes, for illustration, some experimentally obtained oscillograms of measured instantaneous voltage, current and power, as well as the voltage/current harmonic spectra and power relationships for strong and weak ac voltage conditions. Filtered and nonfiltered situations were investigated in order to desegregate the harmonic reactive power into its two components. 13 Refs.

[1997] 02D - 29

THE USE OF MODULATION THEORY TO CALCULATE THE HARMONIC DISTORTION IN HVDC SYSTEMS OPERATING ON AN UNBALANCED SUPPLY

Hu, L.; Morrison, R.E.

Staffordshire Polytech, Stafford, UK

IEEE Trans on Power Systems, vol 12, no 2, May 1997, pp 973-980

This paper describes a means of calculating harmonic distortion due to an HVdc power converter operating on a nonideal supply. The switching functions of a power converter system are derived including the effects of an unbalanced supply and unbalanced ac side impedance. The paper describes how the functions can be used in the calculation of harmonic and interharmonic currents in HVdc and similar power systems.

[1997] 02D - REF

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY OF ELECTRIC POWER DEVELOPMENT CO. LTD

For Abstract see entry 01A - 16

[1996] 02D - REF

UNIT CONNECTED HVDC SCHEMES

For Abstract see entry 01A - 25

[1996] 02D - REF

HVDC - FACTS. STATE OF THE ART - POWER SYSTEM HARMONICS

For Abstract see entry 01A - 7

[1997] 02D - REF

PLANNING INTERCONNECTIONS TO DEVELOP A SOUTHERN AFRICAN GRID

For Abstract see entry 01B - 22

[1996] 02D - REF

OPERATING EXPERIENCES OF THE NELSON RIVER HVDC SYSTEM

For Abstract see entry 01C - 24

[1997] 02D - REF

OPERATING EXPERIENCE OF HOKKAIDO-HONSHU HIGH VOLTAGE DIRECT CURRENT LINK

For Abstract see entry 01C - 25

[1996] 02D - REF

NEW TECHNOLOGIES IN HVDC CONVERTER STATION DESIGN

For Abstract see entry 02A - 2

[1996] 02D - REF

NEW TECHNOLOGIES IN HVDC CONVERTER

DESIGN

For Abstract see entry 02A - 3

[1996] 02D - REF

DEVELOPMENT OF THE EQUIPMENT FOR 500-KV AC/DC CONVERSION STATIONS. PARTS 1-4. HIGH-VOLTAGE LARGE-CAPACITY THYRISTOR VALVE, TRANSFORMER AND DC REACTOR FOR CONVERSION, DC, GIS, AND GROUND TYPE AC AND DC FILTERS

For Abstract see entry 02C - 16

[1998] 02D - REF

HARMONIC CANCELLATION OF A HYBRID CONVERTER

For Abstract see entry 05A - 11

[1997] 02D - REF

PERFORMANCE CHARACTERISTICS OF ARTIFICIALLY COMMUTATED HVDC CONVERTER

For Abstract see entry 05A - 16

[1996] 02D - REF

PWM AND CONTROL OF THREE LEVEL VOLTAGE SOURCE BACK-TO-BACK STATION

For Abstract see entry 05A - 17

[1997] 02D - REF

SPACE VECTOR PATTERN GENERATORS FOR MULTI-MODULE LOW SWITCHING FREQUENCY HIGH POWER VAR COMPENSATORS

For Abstract see entry 05A - 20

[1997] 02D - REF

VOLTAGE CONTROL OF MODIFIED SERIES-CONNECTED HVDC BRIDGES

For Abstract see entry 05A - 22

[1998] 02D - REF

A REVIEW OF ITERATIVE HARMONIC ANALYSIS FOR AC-DC POWER SYSTEMS

For Abstract see entry 05C - 1

[1996] 02D - REF

HARMONIC INTERACTION ON AC/DC SYSTEMS: EFFECTS OF CONTROL ACTIONS

For Abstract see entry 05C - 12

[1996] 02D - REF

NEWTON SOLUTION FOR THE STEADY-STATE INTERACTION OF AC/DC SYSTEMS

For Abstract see entry 05C - 16

[1998] 02D - REF

HARMONIC TENSOR LINEARIZATION OF HVDC CONVERTERS

For Abstract see entry 05D - 12

[1997] 02D - REF

HARMONIC TRANSFER IN HVDC SYSTEMS UNDER UNBALANCED CONDITIONS

For Abstract see entry 05D - 13

[1996] 02D - REF

METHOD FOR THE INDICATION OF POWER TRANSFORMER SATURATION

For Abstract see entry 05D - 18

[1996] 02D - REF

APPLICATION OF SVC IN HVDC SYSTEM

For Abstract see entry 05G - 1

[1997] 02D - REF

DYNAMIC COMPENSATION TO THE FLUCTUATION OF REACTIVE POWER CONSUMPTION AT HVDC CONVERTER WITH THE INSTALLATION OF SSC-SVC

For Abstract see entry 05G - 3

[1996] 02D - REF

DYNAMIC PERFORMANCE OF A STATCON AT AN HVDC INVERTER FEEDING A VERY WEAK AC SYSTEM

For Abstract see entry 05G - 4

[1997] 02D - REF

HARMONICS IN POWER SYSTEMS. AN OVERVIEW

For Abstract see entry 17C - 15

[1998] 02D - REF

ANALYSIS OF RESONANCE PROBLEMS AND HARMONIC FILTER DESIGN IN POWER FACTOR CORRECTION CAPACITOR APPLICATIONS

For Abstract see entry 17C - 4

[1997] 02D - REF

APPLICATION AND DESIGN TRENDS OF FILTERS

For Abstract see entry 17C - 5

02E Transformers, Reactors

[1996] 02E - 1

CONSIDERATION OF IMPEDANCE AND TOLERANCES FOR HVDC CONVERTER TRANSFORMER

Lindroth, A.; Jorendal, G.; Kennedy, W.N.; Harrison, T.H.; Yasuda, E.J. ; Astrom, B.; Sharma, C.M.; Hall, A.C.; Lair, P.; Persson, J.-O.; Lintz, N.P.; Desilets, G.L.; Peixoto, C.A.O.; Okuyama, K.; Lokhanin, A.K.; Stein, W.W.; Preininger, G.; Bickley, T.A.; Tada, K.; Bhardwaj, A.

CIGRE, Paris, France

Electra (France), no 167, August 1996, pp 48-57

French; English

The HVdc power converter transformer plays an important part in the design, construction, size and cost of an HVdc power converter substation. In particular, the transformer impedance strongly influences the design of the valves and associated equipment. The level of impedance is controlled by the need to resist short circuits, and to optimize the valve assembly design. In general terms, low impedance transformers are larger, heavier and more costly so that there is an economic trade-off between the transformer cost and the cost of the valve equipment. Having fixed a basic level of impedance, however, a further complication arises from the need to have tolerance limits on impedance relating to the base level, across the tapping range and between windings on different phases or bridges. This paper presents the results from a CIGRE JWG 12/14.10 study into the consideration of the possibilities. 0 Refs.

[1997] 02E - 2

DIELECTRIC STRENGTH OF TRANSFORMER INSULATION AT DC POLARITY REVERSAL

Hasegawa, T.; Hatano, M.; Yamaji, K.; Kouan, T.; Hosokawa, N.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1526-1531

Among special insulation tests for dc power converter transformers, polarity reversal tests can be substituted by applied ac voltage tests from a stress similarity in oil ducts. In order to investigate equivalent levels of other insulation tests to polarity reversal tests, the dielectric strength of a transformer at polarity reversals was examined by use of a model of typical oil/paper composite insulation. From the comparison of polarity reversal and other insulation tests, it was found that dielectric strength of transformer insulation at polarity reversals is phenomenally similar to that under switching impulse stresses. Equivalent ac test voltage to polarity reversal test was also estimated from the experimental results. The breakdown characteristics of polarity reversal tests showed that partial discharges at polarity reversals impose less harmful stress on insulation barriers than those at usual ac or impulse tests.

[1996] 02E - 3

HVDC CONVERTER TRANSFORMER NOISE CONSIDERATIONS

Lindroth, A.; Jorendal, G.; Kennedy, W.N.; Harrison, T.H.; Yasuda, E.J. ; Astrom, B.; Sharma, C.M.; Hall, A.C.; Lair, P.; Persson, J.-O.; Lintz, N.P.; Desilets, G.L.; Peixoto, C.A.O.; Okuyama, K.; Lokhanin, A.K.; Stein, W.W.; Preininger, G.; Bickley, T.A.; Tada, K.; Bhardwaj, A.

CIGRE, Paris, France

Electra (France), no 167, August 1996, pp 38-46

French; English

The environmental impact from HVdc converter transformers due to acoustic noise is of growing interest. Compared to normal ac operation, the problem is aggravated with HVdc operation due to the harmonic

content of the winding currents and distorted voltages. In this paper, the importance of transformer noise in HVdc substations is illustrated, the differences between actual noise levels in service and values recorded during standard factory sound level tests under no-load conditions are exemplified. Finally, the use and effect of noise reduction methods is discussed briefly. 0 Refs.

[1996] 02E - 4

HVDC CONVERTER TRANSFORMERS

Darwin, A.W.; Harrison, T.H.; White, A.

GEC ALSTHOM Trans & Dist Projects Ltd, Stafford, UK

GEC ALSTHOM Technical Review (France), no 19, March 1996, pp 29-40

In addition to long distance transmission, HVdc substations are used to connect large HVac electrical transmission systems in "back-to-back" schemes where the converter and inverter operation are contained in one substation. GEC ALSTHOM has completed such a scheme at Chandrapur in India. The article describes the HVdc transformers which in addition to the normal ac high voltage, high power considerations also had to satisfy the special HVdc scheme requirements. These include dielectric, electromagnetic, noise, impedance and short circuit current performance together with issues related to the major sub-components, the on-load tapchanger and bushings. Reference is made to the modern design tools. These permit the design engineer to examine, modify and confirm performance "on line" and thus produce an optimized, secure design meeting the specification constraints. 0 Refs.

[1997] 02E - 5

IMPROVED SIMULATION OF HVDC CONVERTER TRANSFORMERS IN ELECTROMAGNETIC TRANSIENT PROGRAMS

Arrillaga, J.; Enright, W.; Watson, N.R.; Wood, A.R.

Univ of Canterbury, Christchurch, New Zealand

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 2, March 1997, pp 100-106

In electromagnetic transient simulation, HVdc converter transformers are normally represented as magnetically independent single-phase units. However, three-limb converter transformers are often used in HVdc schemes. Single-phase and three-limb three-phase transformer models are derived using a unified magnetic equivalent circuit concept. The new models are verified with laboratory and field data. Also, a comparison is made between the transient performance of HVdc converters with conventional and proposed transformer models. 6 Refs.

[1997] 02E - 6

LOAD LOSSES IN HVDC CONVERTER TRANSFORMERS

Lindroth, A.; Jorendal, G.; Kennedy, W.N.; Harrison, T.H.; Yasuda, E.J. ; Astrom, B.; Sharma, C.M.; Hall, A.C.; Lair, P.; Persson, J.-O.; Lintz, N.P.; Desilets, G.L.; Peixoto, C.A.O.; Okuyama, K.; Lokhanin, A.K.; Stein, W.W.; Preininger, G.; Bickley, T.A.; Tada, K.; Bhardwaj, A.

CIGRE, Paris, France

Electra (France), no 174, October 1997, pp 52-57

French; English

HVdc power converter transformers are exposed to nonsinusoidal currents during normal service conditions. This circumstance increases the eddy losses of the transformer in a dramatic way. The traditional way to solve this problem has been to establish an equivalent 50/60-Hz current giving the same load loss as in service and to run load loss and heat run tests with the same current. The main task is to estimate the load losses with consideration of the harmonics in the service load current. Here, a new calculation procedure based on the IEC proposal for industrial transformers is proposed. The difference is that the division of the eddy losses between winding and other structural parts is calculated based on the actual loss measurements.

[1996] 02E - 7

SPECIFIC REQUIREMENTS ON HVDC CONVERTER TRANSFORMERS

Carlson, A.

ABB Transformers AB, Ludvika, Sweden

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 611-614

The converter transformer is an integral part of an HVdc system. High ac and dc voltages put specific requirements on the dielectric insulation. Nonsinusoidal currents give rise to additional losses which are considered. The transformer connections, dielectric stress, losses, short circuit impedance, tap-changer and tapping range, dc magnetization, and general design are

discussed. 4 Refs.

[1996] 02E - 8

TRANSFORMER AND REACTOR DEVELOPMENT FOR DC POWER-TRANSMISSION SYSTEMS

Yoshida, Y.; Sugihara, H.; Hatano, M.; Koan, T.; Oue, T.; Hosokawa, N.

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 33-40

Japanese

Mitsubishi Electric has cooperated in the joint development of insulation technologies for transformers and reactors that will be used in 500-kV dc power transmission systems. The authors examined the dc insulation performance of the main component (oil and paper), investigated the optimum construction ratio of these materials, and then constructed full-scale models. DC voltage capability and other insulation performance parameters were successfully tested. The improved insulation reduces equipment size and contributes to low power loss. 3 Refs.

[1996] 02E - REF

DEVELOPMENT OF THE EQUIPMENT FOR 500-KV AC/DC CONVERSION STATIONS. PARTS 1-4. HIGH-VOLTAGE LARGE-CAPACITY THYRISTOR VALVE, TRANSFORMER AND DC REACTOR FOR CONVERSION, DC, GIS, AND GROUND TYPE AC AND DC FILTERS

For Abstract see entry 02C - 16

[1996] 02E - REF

VERIFICATION AND TESTING OF DC POWER-TRANSMISSION EQUIPMENT

For Abstract see entry 02F - 18

[1996] 02E - REF

INSULATION MODEL TESTS OF PRINCIPAL PARTS FOR HVDC CONVERTER TRANSFORMER AND SMOOTHING REACTOR

For Abstract see entry 02G - 9

[1996] 02E - REF

METHOD FOR THE INDICATION OF POWER TRANSFORMER SATURATION

For Abstract see entry 05D - 18

[1996] 02E - REF

MITIGATING POTENTIAL TRANSFORMER FERRORESONANCE IN A 230-KV CONVERTER STATION

For Abstract see entry 05D - 19

[1996] 02E - REF

SOLVING THE FERRORESONANCE PROBLEM WHEN COMPENSATING A DC CONVERTER STATION WITH A SERIES CAPACITOR

For Abstract see entry 05D - 32

[1996] 02E - REF

COORDINATION OF THE INSULATION OF SUPERHIGH-VOLTAGE CONVERTER TRANSFORMERS

For Abstract see entry 05J - 2

02F Switchgear, Gas-Insulated Systems (GIS), DC Circuit Breakers

[1997] 02F - 1

A TWO-STAGE DC THYRISTOR CIRCUIT BREAKER

McEwan, P.M.; Tennakoon, S.B.

Sheffield Hallam Univ, UK

IEEE Trans on Power Electronics, vol 12, no 4, July 1997, pp 597-607

High-current dc thyristor circuit breaker (TCB) devices, based on the parallel capacitor-current commutation-forced turn-off principle, require very large capacitors to effect correct operation as fault-current interrupters in electrical circuits. The commutation capacitors of TCB devices that interrupt current in a single switching operation absorb virtually all the electromagnetic energy stored in circuits, where they operate during the single switching process. These device types interrupt current extremely fast, but because of the scale of the energy transfer to the commutation capacitor, they are especially prone to producing short-duration switching overvoltages of excessive magnitude. A novel TCB

device involving two switching operations or stages is presented and analyzed. With this device type, the circuit-stored energy is transferred to the commutation capacitor in two stages, which, in so doing, produces significantly lower switching overvoltages than the conventional "single-stage" TCB device. Results of a range of tests on a low-voltage two-stage TCB device and a high-power-prototype version are given together with the basis for determining their optimum design criteria. Comparative simulation studies are also provided. Finally, the limitations of TCB devices are examined and discussed in conjunction with cost comparisons and their merits and limitations for typical applications.

[1996] 02F - 2

CIGRE WG 13.06 STUDIES ON THE RELIABILITY OF SINGLE PRESSURE SF_6-GAS HIGH-VOLTAGE CIRCUIT-BREAKERS

Janssen, A.L.J.; Brunke, J.H.; Heising, C.R.; Lanz, W.

KEMA, Netherlands

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 274-282

The final results of the CIGRE second international inquiry on the reliability of high voltage circuit-breakers in service are presented. In the seventies the first international inquiry, that covered all technology circuit-breakers, was conducted. The second international inquiry (from 1.1.88 to 31.12.91) was limited to single-pressure SF_6 gas circuit-breakers, thus showing the improvements due to this technology. The main conclusion is that the reliability concerning major failures has increased considerably and that the maintainability of modern SF_6 circuit-breakers is much better than the older technology circuit-breakers. Also the conclusions from several other studies, based on the results of the inquiries, are presented. The publication of this paper, as a result of an international effort by CIGRE SC 13, is sponsored here by the IEEE Switchgear Committee in order to support this valuable contribution to the industry and to continue the cooperation between the two organizations. 15 Refs.

[1996] 02F - 3

CIRCUIT BREAKERS FOR MESHED MULTITERMINAL HVDC SYSTEMS. II. SWITCHING OF TRANSMISSION LINES IN MESHED MTDC SYSTEMS

Greenwood, A.; Kanngiessner, K.W.; Lesclae, V.; Margaard, T.; Schultz, W.

Electra (France), no 164, February 1996, pp 62-82

French; English

The meaning of multiterminal HVdc (MTDC) schemes and the specific advantages of meshed MTDC systems have been described in Part I. The importance of line redundancy has been emphasized and it was shown that it can be fully utilised only with the application of HVdc circuit breakers (DCCBs) which allow switching operations and clearing of line-to-ground faults without reducing the converter current to zero. In Part II we concentrate on line breakers, i.e. DCCBs which connect each line section at both ends to the remaining MTDC system. The single pole representation of a meshed MTDC system in its simplest form, i.e. a ring-shaped configuration, is considered. We assume that in reality a meshed MTDC system will always be of bipolar design. This is the reason why a bipolar simulator set-up has been used for the investigations described in this report. The basic elements of a DCCB as assumed in this investigation are shown. Control plays a decisive role in the performance of an MTDC system and must not interfere with the DCCB operation. 3 Refs.

[1996] 02F - 4

DC DIELECTRIC CHARACTERISTICS AND CONCEPTION OF INSULATION DESIGN FOR DC GIS

Hasegawa, T.; Yamaji, K.; Hatano, M.; Aoyagi, H.; Taniguchi, Y.; Kobayashi, A.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1776-1782

In order to discuss the dielectric performance of dc GIS, the flashover characteristics of gas-insulated bus were studied under conical- and disk-type spacers. The test involves the investigation on effect of electrification for charge to be accumulated in spacers and the effect of metallic particles. As the result, it was found that the dielectric characteristics of conical-type spacer are better than disk type. Moreover, the dielectric performance of dc GIS is more affected by the characteristics of coaxial electrode system than spacer surface with regard to metallic particle. On the basis of the results of these tests, this report presents the conception of insulation design for dc GIS. 10 Refs.

[1997] 02F - 5

DEVELOPMENT AND DESIGN OF DC-GIS

Shikata, M.; Yamaji, K.; Hatano, M.; Tsuchie, E.; Takeuchi, H.; Inami, K.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 5, pp 737-742

Japanese

In order realize a reliable, compact and economical converter station for HVdc transmission, applications of gas-insulated switchgears (GIS) for dc transmission lines are considered. The characteristics of dc gas insulation are different from those of ac. The behavior of metallic particles left in the enclosure is one of the largest differences. The accumulation of electrical charges on solid insulators is another essential factor in designing a dc-GIS. Also degradation of metal oxide arrester blocks under dc stress must be considered. Based on the fundamental studies, we developed the components of the ±500-kV dc-GIS. Electrical and mechanical performances of these components have been tested and proven to be satisfactory. Finally these components had been assembled into a full dc-GIS and subjected to a long-term voltage endurance test. In this paper, design philosophy of ±500-kV dc-GIS, details of the components and the test results are described.

[1996] 02F - 6

DEVELOPMENT OF 500-KV DC GAS INSULATED SWITCHGEAR

Yoshida, Y.; Takahata, K.; Hatano, M.; Takatsuka, K.; Tsuchie, E.

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 25-32

Japanese

Mitsubishi Electric has been cooperating in the joint development of 500-kV dc gas-insulated switchgear for dc switching in ac/dc power conversion substations. The development team investigated basic specifications for the switchgear, solved dc problems such as charge accumulation on insulator surfaces and the "fire-fly" phenomenon caused by conducting particles, and then assembled and tested a prototype device. Plans call for the first production units to be completed early in the next decade. 4 Refs.

[1996] 02F - 7

DEVELOPMENT OF 500-KV DC GAS-INSULATED SWITCHGEAR

Yamaji, K.; Nakagoshi, Y.

Shikoku Elec Power Co, Inc, Japan

Denki Gakkai Kaihei Hogo Kenkyukai Shiryo (Japan), vol SP-96, no 62-80, pp 11-20

Japanese

500-kV dc gas-insulated switchgear (dc GIS) which is composed of dc buses, lightening arresters, disconnecting switches and dc circuit breakers has been recently developed to improve the reliability and economy of HVdc transmission systems. Though there were many technical difficulties such as metallic particles in GIS and charge accumulation on spacers which reduce dielectric strength greatly, those problems were conquered through enthusiastic studies and discussions by the participants of the utilities and manufacturers. Prototype models of 500-kV dc GIS were manufactured and tested to meet the specifications by several kinds of tests. This paper describes the design and specifications of dc GIS equipment and the results of the prototype model's test.

[1996] 02F - 8

DEVELOPMENT OF GAS INSULATED SWITCHGEAR FOR HVDC. (PART 2)

Shikata, M.; Shinohara, R.; Asai, Y.; Kashimura, K.; Yamaji, K.; Hatano, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.321-6.322

Japanese

Abstract not available.

[1997] 02F - 9

DEVELOPMENT OF GAS INSULATED SWITCHGEAR FOR HVDC. (PART 3)

Shikata, M.; Shinohara, R. Yamada, H.; Yamagiwa, T.; Yamaji, K.; Hatano, M.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 800-801

Japanese

Abstract not available.

[1996] 02F - 10

DEVELOPMENT OF GAS INSULATED

SWITCHGEAR FOR HVDC. (PART 4)

Shikata, M.; Shinohara, R.; Kashimura, K.; Kida, J.; Ozawa, J.; Yamaji, K.; Hatano, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.401-6.402

Japanese

Abstract not available.

[1997] 02F - 11

DEVELOPMENT OF INSULATION STRUCTURE AND ENHANCEMENT OF INSULATION RELIABILITY OF 500-KV DC GIS

Hasegawa, T.; Yamaji, K.; Hatano, M.; Endo, F.; Rokunohe, T.; Yamagiwa, T.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Delivery, vol 12, no 1, January 1997, pp 194-202

The paper describes the development of insulation structure and enhancement of insulation reliability of 500-kV dc GIS (gas-insulated switchgear). Considering problems of metallic particles and charge accumulation on spacers, the developed insulation structure of GIS consisted of three regions, i.e. the spacer, particle scavenging and nonlevitating regions. Particles could be efficiently scavenged, and the developed GIS withstood all insulation specifications with sufficient margins under both clean and particle-contaminated conditions. Long-term testing of the 500-kV dc GIS began in October 1995.

[1996] 02F - 12

HVDC DC CLOSED LOOP CURRENT COMMUTATION TEST OF GIS DISCONNECTOR

Shikata, M.; Takahata, K.; Hatano, M.; Kokumai, T.; Koshizuka, T.; Takahashi, N.; Nishiwaki S.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, p 6.327

Japanese

Abstract not available.

[1996] 02F - 13

INFLUENCE OF THE HVDC SYSTEM TO THE MRTB DC CURRENT INTERRUPTION

Shikata, M.; Takahata, K.; Hatano, M.; Koshizuka, T.; Nishiwaki, S.; Kobayashi, A.; Murao T.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.319-6.320

Japanese

Abstract not available.

[1998] 02F - 14

INSTABILITY CHARACTERISTIC OF DC ARC IN GAS CIRCUIT BREAKER

Ito, H.; Sawada, T.; Kamei, K.; Nitta, E.; Hidaka, M.; Ibuki, K.

Mitsubishi Elec Corp, Japan

Denki Gakkai Kaihei Hogo Kenkyukai Shiryo (Japan), vol 98, no 1-13, pp 53-58

Japanese

Arc-circuit instability in an HVdc circuit breaker was analytically investigated. Frequency and an amplification coefficient of an amplitude of an oscillation that leads to the current zero can be obtained as a function of an arc time constant, an arc loss, a capacitance and a reactance by this analysis. The critical frequency for a negative arc characteristic decreases with an increasing amplitude of a current oscillation. A linear differential equation for a perturbation component in the interrupting current gives analytical solutions of frequency and the amplification coefficient on various circuit parameters. The amplification coefficient has a maximum at an optimum reactance. The effect of a stray capacitance and a cable inductance on the breaker performance was also explained by this analysis method.

[1997] 02F - 15

INSTABILITY OF DC ARC IN SF_6 CIRCUIT BREAKER

Ito, H.; Hamano, S.; Ibuki, K.; Yoshinaga, K.; Yamaji, K.; Hasegawa, T.; Irokawa, H.

Mitsubishi Elec Corp, Hyogo, Japan

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1508-1513

Instability of the arc in an HVdc circuit breaker was investigated both analytically and experimentally. The analytical work showed that the amplification coefficient and the frequency of the oscillation that leads to the current zero can be given as functions of parallel impedance and arc characteristics. The process of

estimating the arc characteristics from the amplification coefficient and the experimentally observed frequency was proposed and the result compared with the estimation of the same characteristics by the analysis of the current zero behavior. It was shown that a description of the dc arc by a simple Mayr-type model could reproduce the initiation and the growth of the oscillation and the interruption of the current. 4 Refs.

[1998] 02F - 16

INTERRUPTING DUTIES ON HVDC SYSTEM

Shin, M.; Hatano, M.; Akutsu, K.; Hidaka, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Kaihei Hogo Kenkyukai Shiryo (Japan), vol 98, no 1-13, pp 11-12

Japanese

Abstract not available.

[1997] 02F - 17

REQUIREMENTS FOR HVAC CIRCUIT BREAKER USED IN HVDC CONVERTER STATIONS - STUDY OF THE CAHORA BASSA DC AND AC BUSBAR CONDITIONS

Kuntze, T.; Schmitt, H.; Schmidt, H.-P.; Voelcker, O.; de Grijp, M.; Diseko, D.

Siemens AG, Erlangen, Germany

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

In HVdc converter stations, very specific requirements for the switchgear may be encountered. This necessitates a detailed study of the switching processes for the proper specification of the switchgear. A case study covering a wide variety of system conditions shows the implications for the circuit breaker ratings. The Cahora Bassa HVdc system in Mozambique is the subject of this investigation. Here, a new ac line will be linked in parallel to the existing HVdc transmission scheme. A dedicated bus-coupler circuit breaker will connect the dc busbar and the ac busbar linking the new line. The voltage and current stresses on the bus coupler and the line breaker are assessed by detailed numerical simulations. The results of the calculations are discussed in the light of circuit breaker ratings and the implications for the specification are given.

[1996] 02F - 18

VERIFICATION AND TESTING OF DC POWER-TRANSMISSION EQUIPMENT

Yoshida, Y.; Satoh, M.; Hashimoto, T.; Irokawa, H.; Takeuchi, H.; Oue, M.; Naito, H.

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 49-58

Japanese

Mitsubishi Electric is cooperating in the joint development of 500-kV dc power transmission equipment and practical applications are planned for early in the next decade. The article reports on the accelerated voltage testing of dc gas-insulated switchgear and tests on a power transformer and dc reactor for ac/dc power conversion. The authors conducted verification testing using a real-time power grid simulator designed to test the suitability of various dc transmission control algorithms. 0 Refs.

[1996] 02F - REF

DEVELOPMENT OF THE EQUIPMENT FOR 500-KV AC/DC CONVERSION STATIONS. PARTS 1-4. HIGH-VOLTAGE LARGE-CAPACITY THYRISTOR VALVE, TRANSFORMER AND DC REACTOR FOR CONVERSION, DC, GIS, AND GROUND TYPE AC AND DC FILTERS

For Abstract see entry 02C - 16

02G Insulation, Bushings, Surge Arresters

[1996] 02G - 1

BEHAVIOR OF HVDC WALL BUSHINGS UNDER NONUNIFORM RAIN : VOLUME 1

Lambeth, P.J.; Beausejour, Y.; Kamel, S.I.

Hydro-Quebec, Varennes, Quebec, Canada

Canada Electricity Association, Report Number CEA-203 T 787, July 1996, 300 pp

A study was conducted in which attempts were made to improve the performance of HVdc wall bushings in critical weather conditions. The objective of the work was to develop better booster sheds by using a new principle, and show their performance on wall bushings with porcelain and aged RTV silicone-rubber surfaces. Performance tests were also conducted on SF_6-filled wall bushing with a glass-fiber/silicone rubber housing in high-conductivity, critical non-uniform rain, and in clean fog conditions. The degradation of each surface

was measured. The study showed that wall bushing flashovers occur in a wide variety of wetting conditions from mist to icing, but mostly in light rain. Flashovers were not confined to heavily polluted sites or dirty bushings. A new multi-layer method for coating polymer surfaces with a pollution layer, without damaging it, was developed. Complementary long-term monitoring of wall bushings fitted with booster sheds of a simple disk pattern was carried out in a service environment. Measurements showed that the maximum voltage measured on the voltmeter collar on the negative polarity bushing was 2.8 times the value of that of uniform voltage distribution. This value is close to the breakdown strength of the dry collar/flange gap. 29 refs., 40 tabs., 56 figs.

[1996] 02G - 2

DC INSULATION CHARACTERISTICS OF FRP INSULATORS AND LIGHT GUIDES FOR THYRISTOR VALVES

Yamada, M.; Hashimoto, T.; Irokawa, H.; Kobayashi, K.; Ishida, T.; Tanaka, C.; Endo, F.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 860-861

Japanese

Abstract not available.

[1996] 02G - 3

DEVELOPMENT OF SURGE ARRESTER FOR THYRISTOR VALVE

Tanaka, M.; Hashimoto, T.; Irokawa, H.; Takeshina, T.; Nozuki, M.; Shimizu, N.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.340-6.341

Japanese

Abstract not available.

[1996] 02G - 4

DEVELOPMENTS OF HVDC 500-KV-600-KV SF_6 GAS TANK TYPE SURGE ARRESTERS

Hasegawa, T.; Yamaji, K.; Hatano, M.; Watahiki, S.; Shirakawa, S.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-E, pp 315-320

Reducing the insulation level of the equipment in an ac/dc converter station is important for the miniaturization of the facility, and therefore, an arrester of high-performance with low discharge voltage using a zinc oxide element, was developed. Protection levels were reduced by about 25% by this system in the dc 500-kV system in comparison with a conventional system. The discharge voltage was 945 kV/10 kA in LL characteristics, and the insulation level of the main dc circuit was possible to reduce to LIWV 1300 kV by installing this arrester at the entrance of the dc facility. In addition, the arrester of the gas tank type is more resistant to stain and earthquake than the insulator type, and it is advantageous for connection with cable heads and gas-insulation circuit breakers.

[1997] 02G - 5

EVALUATION OF CONTAMINATION CHARACTERISTICS OF DC TWO STAGED PORCELAIN TYPE SURGE ARRESTERS

Shirakawa, S.; Watahiki, S.; Shikata, M.; Yamaji, K.; Hatano, M.

Hitachi, Ltd, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 2, pp 252-257

Japanese

There is a little data on the contamination characteristics of HVdc porcelain-type surge arresters. Therefore, this paper describes contamination withstand characteristics of dc 250-kV porcelain-type surge arresters with special sheds and nominal sheds. Uniform pollution and non uniform pollution (partial wetting) slurry methods have been applied to contamination evaluations. This dc 250-kV porcelain-type surge arrester with special sheds can withstand on slurry pollution tests at equivalent salt deposit density 0.01-0.03 mg/cm^2.

[1996] 02G - 6

FIELD TESTS OF HVDC 500-KV-600-KV SF_6 GAS TANK TYPE SURGE ARRESTERS

Shikata, M.; Shirakawa, S.; Watahiki, S.; Kanazawa, T.; Takahata, K.; Hatano, M.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi

Bumon Taikai Ronbunshu), vol 7, no 2, pp 401-402

Japanese

Abstract not available.

[1996] 02G - 7

HYDROPHOBICITY LOSS AND LEAKAGE CURRENTS OF LONG-TERM AC- AND DC-ENERGIZED POLYMERIC INSULATORS

Sorqvist, T.; Vlastos, A.E.

Dept of Elec Machines & Power Eng, Chalmers Univ of Tech, Goteborg, Sweden

Proceedings, Nordic Insulation Symp, Bergen, Norway, June 10-12, 1996, pp 249-256

At Anneberg outdoor field station, on the west coast of Sweden, a long-term study of polymeric insulators started in 1987. This paper presents a relative comparison of the performance, with respect to leakage current peaks exceeding 25 mA, of several commercially available EPDM, silicone rubber and porcelain line insulators. The paper also presents the hydrophobicity of the insulators. The results refer to both HVac (130 kV RMS phase-to-ground) and HVdc (+300 kV) energized insulators. The results show that the EPDM rubber-based insulators lose their initial hydrophobicity in a relatively short period of environmental exposure and that this hydrophobic loss results in substantial leakage currents and heavy arcing under wet and salt polluted conditions, while the silicone rubber-based insulators maintain their high surface resistance and low leakage currents. During a salt-storm, the magnitude of the leakage current activity of the EPDM rubber-based insulators is generally higher than that of the porcelain insulators. Moreover, a highly stressed silicone rubber insulator can under severe contamination conditions lose its high surface resistivity, which results in considerable surface arcing. 14 Refs.

[1996] 02G - 8

INSULATION CHARACTERISTICS OF FRP INSULATORS FOR THYRISTOR VALVE

Yamada, M.; Hashimoto,T.; Irokawa, H.; Kobayashi, K.; Ishida, T.; Endo, F.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 2, p 2.84

Japanese

Abstract not available.

[1996] 02G - 9

INSULATION MODEL TESTS OF PRINCIPAL PARTS FOR HVDC CONVERTER TRANSFORMER AND SMOOTHING REACTOR

Hasegawa, T.; Yamaji, K.; Hatano, M.; Hosokawa, N.; Koan, T.; Oue, T.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 5, pp 5.243-5.244

Japanese

Abstract not available.

[1996] 02G - 10

INVESTIGATION OF SINGLE UNIT FLASHOVERS IN HVDC INSULATOR STRINGS

Ishikawa, K.; Kageyama, H.; Yamada, Y.; Matsuoka, R.; Ito, S.; Sakanishi, K.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1888-1894

In HVdc transmission lines, a special phenomenon, so called single unit flashover, is observed under some special conditions. Only one or two insulator units repeat flashovers, not resulting in an overall flashover along the string. However, higher magnitudes of audible noise, radio and television interference, may cause serious problems. Based on the investigation on ±500-kV full scale insulator strings, higher occurrence probability of single unit flashovers under cold-wet-switch-on conditions was clarified and compared with normal continuous operating voltage conditions. Effectiveness of our newly proposed countermeasures to prevent single unit flashovers was demonstrated by experiments in the laboratory and in the field. 7 Refs.

[1997] 02G - 11

NUMERICAL EVALUATION OF THE EFFICACY OF BOOSTER SHEDS AND RTV COATING IN IMPROVING THE PERFORMANCE OF HVDC WALL BUSHINGS

Tang, L.; Raghuveer, M.R.

Univ of Manitoba, Winnipeg, Canada

Proceedings, IEEE Conf on Electrical Insulation and Dielectric Phenomena, Minneapolis, MN, October 19-22, 1997, vol 2, pp 410-413

In this paper, the critical flashover voltages of a 600-kV HVdc wall bushing with booster sheds and RTV coating

are estimated by using a model recently developed by the authors. Their efficacy in improving the performance of HVdc wall bushings is numerically verified, which agrees well with the results of large scale experiments and operational experience. The numerical evaluation and results obtained are very helpful in assessing the performance of HVdc wall bushings under different severe conditions and promoting the use of remedial measures. 9 Refs.

[1996] 02G - 12

NUMERICAL PREDICTION OF HVDC WALL BUSHING FLASHOVER CAUSED BY UNEVEN WETTING

Tang, L.; Raghuveer, M.R.

Univ of Manitoba, Winnipeg, Canada

Proceedings, Conf on Electrical Insulation and Dielectric Phenomena (CEIDP), Millbrae, California, October 20-23, 1996, vol 2, pp 455-458

In this paper, a numerical model is developed to determine the critical flashover voltage of an unevenly wetted HVdc wall bushing. The electric field of a 600-kV HVdc wall bushing is calculated by using the finite element method, and the E-field distribution, particularly that along the critical line, is used to determine the critical flashover voltage (CFO). The simulation results show that predicted critical flashover voltages agree well with experimental data in literature. Furthermore, various aspects of uneven wetting flashover phenomena are verified. The influence of the dry zone length, rain conductivity, air pressure as well as altitude on the critical flashover voltage are also investigated using the developed model. The results presented in this paper suggest that the proposed E-field-based model is an effective tool to evaluate the performance of an HVdc wall bushing. 8 Refs.

[1996] 02G - 13

ON THE ION MIGRATION OF FRP ROD UNDER HVDC

Chen, Y.; Liang, X-D.; Lu, G-Q.; Guan, Z-C.; Zhang, R-Y.

Tsinghua Univ, Beijing, China

Proceedings, 1996 Asian Intl Conf on Dielectrics & Electrical Insulation Diagnosis (96'AICDEI & 4th-JCCEID), Xi'an, China, October 8-11, 1996, pp 283-286

Ion migration is one of the main factors causing conventional insulators' faults under HVdc, but it is unknown whether the ion migration under HVdc can cause composite insulators' electric strength to deteriorate. In this paper, a set of ion migration test equipment used for composite insulators is designed, a test lasting two months has been done and some conclusions have been drawn. 3 Refs.

[1997] 02G - 14

OUTDOOR POLYMERIC INSULATORS LONG-TERM EXPOSED TO HVDC

Sorqvist, T.; Vlastos, A.E.

Chalmers Univ of Tech, Gothenburg, Sweden

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 1041-1048

Field experience from outdoor polymeric insulators exposed to HVdc under natural contamination conditions is presented. This paper summarizes the peak leakage current statistics, the hydrophobicity and the surface material conditions studied by electron spectroscopy for chemical analysis (ESCA) and attenuated total reflection Fourier transform infrared (ATR-FTIR) spectroscopy. The results show a strong interrelation between the surface conditions and the performance with respect to leakage currents. Moreover, the results show that the surface conditions and the performance of the insulators exposed to HVdc are rather similar to those of the insulators exposed to HVac.

[1996] 02G - 15

SEISMIC PERFORMANCE OF HVDC 500-KV-600-KV SF_6 GAS TANK TYPE SURGE ARRESTERS

Tanaka, M.; Watahiki, S.; Shiga, M.; Shirakawa, S.; Hashimoto, T.; Hatano, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.336-6.337

Japanese

Abstract not available.

[1997] 02G - 16

SIMULATION OF HVDC WALL BUSHING PERFORMANCE UNDER UNEVENLY WETTED CONDITIONS

Tang, L.; Raghuveer, M.R.

Univ of Manitoba, Winnipeg, Canada

Proceedings, IEEE WESCANEX Conf on Communications, Power and Computing, Winnipeg, Manitoba, Canada, May 22-23, 1997, pp 109-113

The electric field distributions for HVdc wall bushings with different dry zone lengths are discussed and their critical flashover voltages predicted using an E-field-based model. The simulation yields results in good agreement with experimental results. It is shown that some important aspects of wall bushing flashover, such as the U-shaped characteristics of critical flashover voltage versus dry zone length, critical dry zone length, are well reproduced by the simulation. 9 Refs.

[1996] 02G - 17

THE DESIGN OF DIELECTRIC BARRIERS FOR HVDC BUSHINGS

Sellars, A.G.; MacGregor, S.J.

Dept of Electrn & Elec Eng, Strathclyde Univ, Glasgow, UK

IEE Colloquium on Field Modelling: Applications to High Voltage Power Apparatus (Digest No.1996/008) (UK), January 17, 1996, pp 3/1-6

High voltage bushings employ capacitive grading foils to control the electric field distribution under ac conditions. However, under dc conditions, the foils are unable to prevent a concentration of electric field within the bushing due to its high resistivity relative to that of the surrounding oil. A method of controlling the electric field is therefore required for dc conditions, and this is usually achieved through the use of dielectric barriers which surround the oil-immersed end of the bushing. This paper describes analytical techniques used to assess the performance of a particular barrier configuration in order to optimize its design. 4 Refs.

[1996] 02G - 18

V-T CHARACTERISTICS OF SOLID INSULATORS FOR THYRISTOR VALVES

Yamada, M.; Yamaji, K.; Irokawa, H.; Kimura, T.; Chishaki, H.; Fujii, H.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 2, p 2.85

Japanese

Abstract not available.

[1996] 02G - 19

WHAT DO YOUNG MEMBERS AIM AT AT PRESENT ? LIQUID INSULATION : UHV, HVDC TRANSFORMER INSULATION TECHNOLOGY

Yamada, S.; Taniguchi, Y.

Toshiba Corp, Japan

Hoden Kenkyu (Japan), no 151, pp 32-41

Japanese

Abstract not available.

[1997] 02G - REF

HUMIDITY DEPENDENCE OF DC INSULATION CHARACTERISTICS OF FRP INSULATORS FOR THYRISTOR VALVES

For Abstract see entry 02C - 18

[1997] 02G - REF

DC V-T CHARACTERISTICS OF FRP INSULATORS FOR THYRISTOR VALVES

For Abstract see entry 02C - 8

[1997] 02G - REF

DIELECTRIC STRENGTH OF TRANSFORMER INSULATION AT DC POLARITY REVERSAL

For Abstract see entry 02E - 2

[1996] 02G - REF

HVDC CONVERTER TRANSFORMERS

For Abstract see entry 02E - 4

03 OVERHEAD TRANSMISSION LINES

03A Tower Designs, Conductors, Insulation

[1996] 03A - 1

PRINCIPAL PECULIARITIES OF CERAMIC AND COMPOSITE INSULATORS FOR OVERHEAD

EHV/UHV POWER TRANSMISSION LINES: ELECTRICAL CHARACTERISTICS, PERFORMANCE, RELIABILITY AND APPLICATION AREAS

Tikhodeev, N.N.

Dept of High Voltage Tech, HVDC Power Trans Research Inst, St. Petersburg, Russia

European Trans on Electrical Power (Germany), vol 6, no 6, November-December 1996, pp 419--425

Areas of rational application of cap-and-pin and rod line insulators manufactured from various materials (porcelain, glass and polymers) are discussed in terms of ensuring high reliability and adequate performance of strings on EHV and UHV ac and dc overhead power transmission lines. It is shown that the most critical characteristics of both cap-and-pin and rod units are their quality in terms of annual in-service failure rates and their polluted dielectric strength at long-duration exposure to operating voltages. Additional features of importance for HVdc power lines are high resistivity of the dielectric and good dielectric strength of each individual unit. 14 Refs.

03B Corona Effects and Losses

[1996] 03B - 1

CALCULATION OF SINGLE PHASE AC AND MONOPOLAR DC HYBRID CORONA EFFECTS

Zhao, T.; Sebo, S.A.; Kasten, D.G.

Ohio State Univ, Columbus, OH, USA

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1454-1463

Operating a hybrid HVac and HVdc line is an option for increasing the efficiency of power transmission and overcoming the difficulties in obtaining a new right-of-way. This paper proposes a new calculation method for the study of hybrid line corona. The proposed method can be used to calculate dc corona losses and corona currents in dc or ac conductors for single-phase ac and monopolar dc hybrid lines. Profiles of electric field strength and ion current density at ground level can be estimated. The effects of the presence of an energized ac conductor on dc conductor corona and dc voltage on ac conductor corona area are included in the method. Full-scale and reduced-scale experiments were utilized to investigate the hybrid line corona effects. Verification of the proposed calculation method is given. 16 Refs.

[1996] 03B - 2

CALCULATION OF SINGLE PHASE AC AND MONOPOLAR DC HYBRID CORONA EFFECTS. DISCUSSION

Zhao, T.; Sebo, S.A.; Kasten, D.G.

Ohio State Univ, Columbus, OH, USA

IEEE Trans on Power Delivery, vol 11, no 3, 1996, pp 1454-1463

Operating a hybrid HVac and Hvdc line is an option for increasing the efficiency of power transmission and overcoming the difficulties in obtaining a new right-of-way. This paper proposes a new calculation method for the study of hybrid line corona. The proposed method can be used to calculate dc corona losses and corona currents in dc or ac conductors for single-phase ac and monopolar dc hybrid lines. Profiles of electric field strength and ion current density at ground level can be estimated. The effects of the presence of an energized ac conductor on dc conductor corona and dc voltage on ac conductor corona are included in the method. Full-scale and reduced-scale experiments were utilized to investigate the hybrid line corona effects. Verification of the proposed calculation method is given. 16 refs.

[1996] 03B - 3

CORONA DISCHARGE IN A TWIN-WIRE SYSTEM

Taplamacioglu, M.C.

Gazi Univ, Turkey

Denki Gakkai Hoden Kenkyukai Shiryo (Japan), vol ED-96, no 156-163, pp 11-19

In HVdc lines bundle geometry is mainly used for the purpose of reducing the electric field at the surface of the subconductors with a subsequent decrease of corona losses, radio and television interference and audible noise. Bundle geometry decreases the surge impedance and increases the power carrying capacity in power systems. In the present paper, twin conductor system experiments, within a cylindrical boundary, are conducted in ambient air at positive polarity. The effects of wire separation are analyzed on the current density and field profiles. The electric field modification by corona is analyzed in the twin system and results are compared both Laplacian and measured corona values of the single wire (paraxial) data. For physical modelling, the interaction of two drift regions from independent corona sources has been little studied.

[1996] 03B - 4

CORONA LOSSES IN HVDC BIPOLAR LINES

Corbellini, U.; Pelacchi, P.

Univ of Pisa, Italy

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1475-1481

The problem related to the prediction of corona losses in HVdc bipolar lines has been solved, in the past, by means of semi-empirical monomial formulae. However, the proposed formulae that are simpler to use do not always give adequate calculation precision, while the formulae that provide the closest results require implicit functions of different complexity, which are difficult to apply; moreover, it is not possible to understand clearly what influence the variations of the different line parameters have on the losses themselves. The new monomial semi-empirical relationship, proposed to predict the corona losses in HVdc bipolar lines, is very simple to use; it highlights the dependence of power losses due to the corona effect by the different line parameters. The formula has been developed by elaborating a considerable amount of available experimental data. 33 Refs.

[1997] 03B - 5

DEVELOPMENT OF CORONA-RELIEF SHIELDS FOR 500-KV HVDC THYRISTOR VALVES

Satyanarayana, S.; Bhoomaiah, A.; Rajaraman, R.; Mukherji, S.; Sheriff, K.R.S.; Arunachalam, M.; Singh, S.; Holla, K.G.; Lal, G.

Osmania Univ, Hyderabad, India

BHEL Journal (India), vol 18, no 1, February 1997, pp 9-16

BHEL, playing a key role in the country in establishing HVdc systems, has developed corona-relief shields for thyristor valves of ±500-kV HVdc systems. Shields of different profiles and sizes have been designed, based on extensive analytical studies using electrostatic field plots. They have performed successfully under all evaluation tests for voltage withstand and corona levels.

[1996] 03B - 6

FINITE ELEMENT SOLUTION OF MONOPOLAR CORONA AS INFLUENCED BY ION LIFE TIME

Al-Hamouz, Z.

King Fahd Univ of Petrol & Min, Dhahran, Saudi Arabia

Conf Record, 31st IAS, San Diego, CA, October 6-10, 1996, vol 4, pp 1919-1924

This paper presents an iterative finite element technique for the analysis of monopolar ionized fields in transmission line conductor to plane configurations. One of the main underlying assumptions adopted in the literature namely, the constant ion mobility, is waived in a simple way. The impact of waiving this assumption on the computed corona current and ground plane current density profile is investigated. A laboratory model was built to check the accuracy of the calculated corona current and the ground plane current density characteristics. It has been found that the present calculated corona current and the ground plane current density, which assumed variable ion mobility, agreed well with those measured experimentally for laboratory and full scale models and are less than those obtained when assuming constant ion mobility. 27 Refs.

[1997] 03B - 7

FINITE ELEMENT SOLUTION OF MONOPOLAR CORONA ON BUNDLE CONDUCTORS

Al-Hamouz, Z.; Abdel-Salam, M.

King Fahd Univ of Petrol & Min, Dhahran, Saudi Arabia

Proceedings, 32nd Industry Applications Conf (IAS '97), New Orleans, LA, October 5-9, 1997, vol 3, pp 1777-1783

A modified finite element iterative-based method (FEM) is developed to analyze the monopolar ionized field and hence compute the associated corona power loss on bundle conductors (bundles two, three and four are considered). The effect of the number of bundles, and the bundle spacing on the corona current and ground plane current density profiles is investigated. It has been found that with the increase in the number of bundles, the corona current decreases. On the other hand, the corona current increases with the increase in the bundle spacing. A laboratory model was built to check the accuracy of the calculated corona current and the ground plane current density profiles. It has been found that the present results agreed well with the present and previous experimental values.

[1996] 03B - 8

IMPROVED CALCULATION OF FINITE ELEMENT ANALYSIS OF BIPOLAR CORONA INCLUDING ION DIFFUSION

Al-Hamouz, Z.; Abdel-Salam, M.; Mufti, A.

King Fahd Univ of Petrol & Min, Dhahran, Saudi Arabia

IEEE Trans on Industry Applications, vol 34, no 2, March/April 1998, pp 301-309

This paper presents an iterative method for the analysis of bipolar corona associated with the ionized field around high-voltage bipolar direct-current (HVdc) transmission line conductors. A new finite element technique (FET) is proposed to solve Poisson's equation where the constancy of the conductors' surface field at the corona onset value is directly implemented in the finite element formulation. Satisfying the current continuity condition and updating the space charge density are based on the application of Kirchoff's current balance law at each node of the finite element grid and take the ion diffusion into account. In order to investigate the effectiveness of the proposed method, a laboratory model was built. It has been found that the calculated V-I characteristics and the ground plane current density profiles agreed well with those measured experimentally. The simplicity in writing the computer program in addition to the low number of iterations required to achieve convergence characterize the new method of analysis. 17 Refs.

[1998] 03B - 9

INCEPTION VOLTAGE OF CORONA IN BIPOLAR IONIZED FIELDS - EFFECT ON CORONA POWER LOSS

Al-Hamouz, Z.M.; Abdel-Salam, M.; Al-Shehri, A.M.

King Fahd Univ of Petrol and Min, Dhahran, Saudi Arabia

IEEE Trans on Industry Applications, vol 34, no 1, January-February 1998, pp 57-65

In this paper, an iterative finite-element-based algorithm is presented as a numerical tool for the solution of the bipolar ionized field around high-voltage dc (HVdc) transmission lines. The effect of including unequal values of the positive and negative corona inception voltages and ion mobilities on the corona power loss is investigated. In addition, the effect of negative ion field enhancement on reducing the positive conductor corona inception voltage is also studied. The present algorithm is applied to different laboratory and full-scale transmission line configurations. Comparison with previously computed V-I characteristics showed that the present computed values were in better agreement with the experiment. Also, it has been found that the effect of unequal corona inception voltages on the corona power loss (or corona current) is noticeable at applied voltages very near to the inception values. 17 Refs.

[1996] 03B - 10

ON THE CORONA VOLTAGE-CURRENT CHARACTERISTIC OF UNIPOLAR HVDC TRANSMISSION LINES

Li, X.; Raghuveer, M.R.; Ciric, I.R.

Univ of Manitoba, Winnipeg, Canada

Proceedings, Conf on Electrical Insulation and Dielectric Phenomena (CEIDP), Millbrae, California, October 20-23, 1996, vol 2, pp 654-657

Simplified analytical analysis of ionized fields associated with HVdc transmission lines is possible if it is based on Deutsch's assumption. The resulting voltage-current (V-I) characteristic may be conveniently used to calculate the power losses of an HVdc transmission line. However, such an approach has been criticized because Deutsch's assumption is considered invalid for the line-plane geometry. This paper verifies the validity of the V-I characteristic thus obtained by comparing it with numerical results which are generated using a new method developed by the authors, in which Deutsch's assumption is not employed. 9 Refs.

[1996] 03B - 11

THE UNIPOLAR ION CORONA CURRENTS IN OVERHEAD SHVDC AND UHVDC POWER TRANSMISSION LINES

Tikhodeyev, N.N.

Applied Energy: Russian Journal of Fuel, Power and Heat Systems (Energetika), vol 34, no 4, 1996, pp 55-72

The specific influence of overhead SHVdc and UHVdc power lines on the environment is largely ascribed to unipolar corona currents flowing from the conductors (poles) of a bipolar line to ground. These currents considerably increase ion-current density, ion concentration (n_i), and electric-field intensity near the ground surface near overhead power lines, change the charging mechanism of big rubber-tired vehicles, etc. To limit E, j, and n_i to admissible quantities, one must have an experimental or a fairly accurate forecast of the situation under a designed overhead dc line. In this paper, methods of estimation and physical modeling of the main quantities of unipolar currents I, j, and E are proposed and discussed. 25 Refs.

[1996] 03B - REF

ADAPTIVE FINITE-ELEMENT BALLOONING ANALYSIS OF BIPOLAR IONIZED FIELDS

For Abstract see entry 03D - 1

[1997] 03B - REF

OPEN-BOUNDARY FINITE-ELEMENT ANALYSIS OF IONIZED FIELD AROUND MONOPOLAR TRANSMISSION LINES [HVDC]

For Abstract see entry 03D - 12

[1997] 03B - REF

PARTIAL DISCHARGE PART XXIV: THE ANALYSIS OF PD IN HVDC EQUIPMENT

For Abstract see entry 03D - 13

[1996] 03B - REF

CLASSIFICATION OF PARTIAL DISCHARGES FOR DC EQUIPMENT

For Abstract see entry 03D - 3

[1997] 03B - REF

HIGHLY STABLE FINITE VOLUME BASED RELAXATION ITERATIVE ALGORITHM FOR SOLUTION OF DC LINE IONIZED FIELDS IN THE PRESENCE OF WIND

For Abstract see entry 03D - 6

03C Radio and Television Interference (RI and TVI)

[1996] 03C - 1

INVESTIGATIONS ON RADIO INTERFERENCE AND POWER LINE CARRIER INTERFERENCE OF A BACK-TO-BACK CONVERTER

Jaekel, B.W.

Siemens AG, Erlangen, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 58-63

The first German link between the power distribution networks of western and eastern Europe was installed in Etzenricht/Bavaria in 1993. It is realized as a back-to-back station and connects the asynchronous operation of the Bavarian and the Czech power networks. The main components of such stations are the converter valves consisting of many hundreds of connected thyristors. Due to the processes at the firing of the valves, high frequency currents occur leading to high frequency emissions-radiation as well as noise on the power lines-from the converter station. In order to ensure the electromagnetic compatibility (EMC) of the station, calculations of these emissions were carried out. These calculations were performed by means of network analysis and an integral equation method which is based on the method of moments in order to cover radiation effects self consistently. The influence of power line carrier filters as well as of the shielding effectiveness of the station building was also considered. A comparison between the theoretical results and experimental data recorded at the operational station shows a good correspondence. 4 Refs.

[1997] 03C - REF

AN EVALUATION OF DIFFERENT ACTIVE FILTER TOPOLOGIES FOR THE CAHORA BASSA HVDC PROJECT

For Abstract see entry 02D - 4

[1996] 03C - REF

INVESTIGATION OF SINGLE UNIT FLASHOVERS IN HVDC INSULATOR STRINGS

For Abstract see entry 02G - 10

03D Electric Fields, Magnetic Fields, Biological Effects, Environmental Issues

[1996] 03D - 1

ADAPTIVE FINITE-ELEMENT BALLOONING ANALYSIS OF BIPOLAR IONIZED FIELDS

Al-Hamouz, Z.M.

King Fahd Univ of Petrol & Min, Dhahran, Saudi Arabia

IEEE Trans on Industry Applications, vol 32, no 6, November-December 1996, pp 1266-1277

This paper presents an adaptive finite-element iterative method for the analysis of the ionized field around bipolar high-voltage direct-current (HVdc) transmission

line conductors without resort to Deutsch's assumption. A new iterative finite-element ballooning technique is used to solve Poisson's equation wherein the commonly used artificial boundary around the transmission line conductors is simulated at infinity. Unlike all attempts reported in the literature for the solution of ionized field, the constancy of the conductors' surface field at the corona onset value is directly implemented in the finite-element formulation. In order to investigate the effectiveness of the proposed method, a laboratory model was built. It has been found that the calculated V-I characteristics and the ground-plane current density agreed well with those measured experimentally. The simplicity in computer programming in addition to the low number of iterations required to achieve convergence characterize this method of analysis. 30 Refs.

[1997] 03D - 2

ANALYSIS OF THE IONIZED FIELD ASSOCIATED WITH A BUNDLED DC LINE INCLUDING EFFECT OF WIND

Li, X.; Raghuveer, M.R.; Ciric, I.R.

Univ of Manitoba, Winnipeg, Canada

Proceedings, IEEE Conf on Electrical Insulation and Dielectric Phenomena, Minneapolis, MN, October 19-22, 1997, vol 2, pp 406-409

In this paper, the ground level ionized field quantities of a bundled line are investigated by using an upwind node-centered finite volume method (FVM)-based algorithm recently introduced by the authors. The geometries considered are typical of practical HVdc transmission lines and the effect of wind is included. The validity of the equivalent single conductor approach is verified. 5 Refs.

[1996] 03D - 3

CLASSIFICATION OF PARTIAL DISCHARGES FOR DC EQUIPMENT

Hoogenraad, G.; Morshuis, P.H.F.; Petrarca, C.

Tech Univ of Delft, Netherlands

Proceedings, Conf on Electrical Insulation and Dielectric Phenomena (CEIDP '96), Millbrae, CA, October 20-23, 1996, vol 1, pp 110-112

Computer aided partial discharge detection, recognition and classification at ac voltage has become common practice in recent years. Characteristic discharge phase distributions have been found, thus providing the possibility to recognize and assess possible defects in HV apparatus. For diagnostic purposes, fingerprints from these distributions can be derived and compared to those previously ascertained and stored in a data-bank. For dc voltage a similar technique can be used when the phase angle is replaced by the time between discharges. Successful results have been obtained by employing this method on several artificial defects.

[1997] 03D - 4

COMPARISON OF CALCULATED AND MEASURED MAGNITUDES OF ELECTRIC FIELD ADJACENT TO A SWITCH LINE IN A DC SWITCHYARD

Raghuveer, M.R.; Tarko, N.J.; Lu, C.; Norris-Elye, O.C.

Univ of Manitoba, Winnipeg, Canada

Electric Power Systems Research, vol 42, no 1, July 1997, pp 41-46

Although the electric field due to high voltage power transmission lines has received considerable attention, relatively few papers have been published concerning fields prevalent in an HVdc switchyard. This paper reports measurements of electric field intensity conducted adjacent to and along a switch line in the Dorsey Converter Station of Manitoba Hydro at and above ground level. In addition, system data and weather information were also compiled. Because of the large volume of data collected, a database approach was used to analyze the results based upon chosen criteria. The magnitude of the electric field at the measurement locations has been computed using the charge simulation method. Three models are considered, each incorporating different levels of refinement. The calculated values are then compared with the recorded maximum and overall average values. 11 Refs.

[1996] 03D - 5

ENVIRONMENTAL CONCERNS FOR HIGH-VOLTAGE TRANSMISSION LINES IN UNIPEDE COUNTRIES

Kalkani, E.C.; Boussiakou, L.G.

Natl Tech Univ, Athens, Greece

Journal of Environmental Engineering, vol 122, no 11, November 1996, pp 1042-1045

High-voltage transmission lines can pose an environmental problem, especially in countries where the electricity production is at a distance from the demand location. Planning, construction, and operation of high voltage transmission lines should be conducted

within a comprehensive environmental policy, which may include assessment of visual impact, landscape and wildlife protection, and reduction of health risks. This paper reviews the environmental policies and action in planning, construction, and operation as developed by the utility members of the Union Internationale des Producteurs et Distributeurs d'Energie Electrique (UNIPEDE). The paper also presents a brief outline of the health issues associated with the effects of electromagnetic fields to humans. 7 Refs.

[1997] 03D - 6

HIGHLY STABLE FINITE VOLUME BASED RELAXATION ITERATIVE ALGORITHM FOR SOLUTION OF DC LINE IONIZED FIELDS IN THE PRESENCE OF WIND

Li, X.; Ciric, I.R.; Raghuveer, M.R.

Univ of Manitoba, Winnipeg, Canada

Int'l Journal of Numerical Modelling: Electronic Networks, Devices and Fields, vol 10, no 6, November-December 1997, pp 355-370

This paper presents a highly stable relaxation iterative algorithm for solving the ionized fields of unipolar HVdc transmission lines in the absence or in the presence of wind. The finite element method is employed to solve Poisson's equation, and the upwind finite volume method is applied to solve the current continuity equation. The algorithm has been tested up to a wind velocity of 45 m/s. Results obtained for a unipolar HVdc transmission line model show that the application of the upwind method increases the stability and convergence of the iterative algorithm when wind is stronger, while the implementation of a relaxation technique makes it possible for the iterative algorithm to cover a wide range of wind velocities, geometric parameters and ratios of the applied voltage to the corona onset value. 25 Refs.

[1996] 03D - 7

HUMAN PERCEPTION OF ELECTRIC FIELDS AND ION CURRENTS ASSOCIATED WITH HIGH-VOLTAGE DC TRANSMISSION LINES

Blondin, J.-P.; Nguyen, D.-H.; Sbeghen, J.; Goulet, D.; Cardinal, C.; Sarma Maruvada, P.; Plante, M.; Bailey, W.H.

Dept de Psych, Montreal Univ, Quebec, Canada

Bioelectromagnetics, vol 17, no 3, 1996, pp 230-241

The objective of this study was to assess the ability of humans to detect the presence of dc electric fields and ion currents. An exposure chamber simulating conditions present in the vicinity of high-voltage dc (HVdc) lines was designed and built for this purpose. In these experiments, the facility was used to expose observers to dc electric fields up to 50-kV/m and ion current densities up to 120 nA/m^2. Forty-eight volunteers (25 women and 23 men) between the ages of 18 and 57 years served as observers. Perception of dc fields was examined by using two psychophysical methods: an adaptive staircase procedure and a rating method derived from signal-detection theory. Subjects completed three different series of observations by using each of these methods; one was conducted without ion currents, and the other two involved various combinations of electric fields and ion currents. Overall, subjects were significantly more likely to detect dc fields as the intensity increased. Observers were able to detect the presence of dc fields alone, but only at high intensities; the average threshold was 45-kV/m. Except in the most sensitive individuals, ion current densities up to 60 nA/m^2 did not significantly facilitate the detection of dc fields. However, higher ion current densities were associated with a substantial lowering of sensory thresholds in a large majority of observers. Data analysis also revealed large variations in perceptual thresholds among observers. Normative data indicating dc field and ion current intensities that can be detected by 50% of all observers are provided. In addition, for the most sensitive observers, several other detection proportions were derived from the distribution of individual detection capabilities. These data can form the basis for environmental guidelines relating to the design of HVdc lines. 23 Refs.

[1996] 03D - 8

HVDC TRANSMISSION AND THE ENVIRONMENT

Schmidt, G.; Fiegl, B.; Kolbeck, S.

Power Engineering Journal, vol 10, no 5, October 1996, pp 204-210

The increased use of electrical systems has led to significant changes in the electromagnetic environment. The extent to which large electrical systems, such as HVdc transmission networks, impinge on the environment has become a topical and even controversial issue in recent years. This article takes a look at some of the more important technical considerations as well as the consequences HVdc transmission systems have on human beings and the environment in general. The article also considers briefly what measures can minimize the detrimental effects of HVdc transmission. It should be noted,

however, that the article considers only the direct-current case; the effects of high-voltage alternating-current transmission is a separate issue and beyond the scope of this article. 19 Refs.

[1996] 03D - 9

MORTALITY IN PEOPLE RESIDING NEAR ELECTRIC POWER SUPPLY STATION WITH VOLTAGE OF 500 KV

Gurvich, E.B.; Novokhatskaya, E.A.; Rubtsova, N.B.

Inst Meditsiny Truda RAMN, Moscow, Russia

Gigiena Truda i Professional'nye Zabolevaniya (Russia), no 9, September 1996, pp 23-27

Russian

The epidemiological study covered causes and levels of mortality in the settlement situated near electric power supply line (voltage is 500 kV). The work used retrospective cohort method adjusted for evaluation of mortality in general population. The study revealed no higher mortality risk with all the causes totally and with leading causal groups under influence of high frequency electromagnetic fields. However, higher relative mortality risk with leukemia and suicide appeared statistically insignificant. 8 Refs.

[1997] 03D - 10

NEW METHOD FOR SOLVING IONIZED FIELDS OF UNIPOLAR HVDC LINES INCLUDING EFFECT OF WIND. PART I: FEM FORMULATION

Li, X.; Ciric, I.R.; Raghuveer, M.R.

Univ of Manitoba, Winnipeg, Canada

Int'l Journal of Numerical Modelling: Electronic Networks, Devices and Fields, vol 10, no 1, January-February 1997, pp 47-56

In this paper, a finite element method for solving ionized fields is developed based on a novel solution philosophy. Employing the Galerkin finite element method, the solution problem of an ionized field has been formulated as an optimization problem, i.e. as a problem of minimizing an objective function whose minimum gives the solution. The effect of wind is taken into account by introducing a scalar potential of its velocity. 24 Refs.

[1997] 03D - 11

NEW METHOD FOR SOLVING IONIZED FIELDS OF UNIPOLAR HVDC LINES INCLUDING EFFECT OF WIND. PART II: ITERATIVE TECHNIQUES AND NUMERICAL TESTS

Xin, L.; Raghuveer, M.R.; Ciric, I.R.

Univ of Manitoba, Winnipeg, Canada

Int'l Journal of Numerical Modelling: Electronic Networks, Devices and Fields, vol 10, no 1, January-February 1997, pp 57-69

The modified Gaussian algorithm is introduced for solving the ionized fields of unipolar HVdc lines including the effect of wind. Specific techniques of incorporating in the algorithm the special structure of the optimization problem of the ionized field have been developed to economize the requirements for the computer memory and CPU time. Numerical tests are carried out on a coaxial cylindrical geometry and on a line-plane geometry both in the absence and in the presence of wind. Comparison with available experimental data shows good agreement. 9 Refs.

[1997] 03D - 12

OPEN-BOUNDARY FINITE-ELEMENT ANALYSIS OF IONIZED FIELD AROUND MONOPOLAR TRANSMISSION LINES [HVDC]

Abdel-Salam, M.; Al-Hamouz, Z.M.; Mufti, A.

Dept of Elec Eng, Assiut Univ, Egypt

Journal of Electrostatics (Netherlands), vol 39, no 2, February 1997, pp 129-144

This paper presents a new iterative finite-element ballooning technique to solve Poisson's equation for different numbers of ballooning layers to set different boundaries of the ionized field around an HVdc transmission-line coronating conductor. This is aimed at explaining how the accuracy of calculation increases with the increase of the number of ballooning layers. A laboratory model was built to check the accuracy of the calculated corona current and the ground plane current density.

[1997] 03D - 13

PARTIAL DISCHARGE PART XXIV: THE ANALYSIS OF PD IN HVDC EQUIPMENT

Morshuis, P.; Jeroense, M.; Beyer, J.

Tech Univ of Delft, Netherlands

IEEE Electrical Insulation Magazine, vol 13, no 2, March-April 1997, pp 6-16

An overview of detection and analysis techniques for

partial discharges (PD) in direct current (dc) equipment is presented. Statistical analysis of PD data from dc systems provide detailed information about defects which can be identified by comparison with the typical defects stored in a database. An evaluation technique was developed based on characteristic PD patterns to detect various defect types. The ADAMS method is also applied in testing the high voltage direct current equipment for defects detection and recognition. 21 Refs.

[1996] 03D - 14

PREVENTION, CONTAINMENT, CLEAN-UP OF SPILLS

Manitoba Hydro

Manitoba Hydro, Winnipeg, Canada

Manitoba Hydro Sustainable Development Report, 1994 and 1995, Manitoba Hydro, Winnipeg, Canada, 1996, pp 40-41

Manitoba Hydro intends to invest $60 million by the year 2003 to prevent future oil spills and remediate previous oil spill-damaged areas. The major facilities whose oil spill prevention and containment systems will be upgraded include hydroelectric and thermal generating stations, HVdc converter stations, ac stations, terminals, and mobile substations, and operational diesel generator sites, buildings, and service centers. A list of oil spill containment measures for all these facilities is provided. Environmental risk assessments will prioritize the order in which projects will be undertaken. 1 tab., 1 fig.

[1996] 03D - 15

TEST AND STUDY ON THE ELECTRIC-FIELD EFFECTS OF HVDC AND HVAC SUPERPOSED FIELD

Lu, G-Q.; He, H-M.; Xu, L-F.; Chen, S-J.; Zhang, J.; Lin, Y-F.

Guangdong Prov Elec Power Test & Research Inst, Guangzhou, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 682-688

By means of testing in the HV test hall, the authors studied the electric-field effects, including ground-level total electric field strength (GTEFS), the ion current density (ICD), and sensations of a person in various HVdc and HVac superposed fields. Some significant regular patterns have been found. The authors have also performed some measurements on the operating line site, and the results verified the conclusions obtained in the HV test hall. 5 Refs.

[1996] 03D - 16

WAVE ELECTRODYNAMIC OF THE STATIONARY FIELD OF THE DC TRANSMISSION LINES

Damyanov, S.

Dept of Power Electrn, Tech Univ, Sofia, Bulgaria

Proceedings, 7th Conf on Electromagnetic Field Computation (CEFEC'96), Okayama, Japan, March 18-20, 1996, p 116

Contrary to modern electrodynamics theory, the author initiates a wave approach to the theory of the stationary EM field of dc transmission lines. The method brings together fundamental theoretical generalization and a high extent of optimization. 6 Refs.

03E Maintenance

[1997] 03D - REF

FINITE ELEMENT SOLUTION OF MONOPOLAR CORONA ON BUNDLE CONDUCTORS

For Abstract see entry 03B - 7

[1996] 03E - REF

SEISMIC PERFORMANCE OF HVDC 500-KV-600-KV SF_6 GAS TANK TYPE SURGE ARRESTERS

For Abstract see entry 02G - 15

04 HVDC CABLES

04A Installation, Performance

[1997] 04A - 1

DEVELOPMENT OF 500-KV DC PPLP-INSULATED OIL-FILLED SUBMARINE CABLE

Fujimori, A.; Fujii, K.; Takashima, H.; Suzuki, H.; Mitani, M.; Fujii, O.; Shigetoshi, I.; Shimada, M.

Kansai Elec Power Co, Inc, Japan

Electrical Engineering in Japan, vol 120, no 3, August 1997, pp 29-41

This paper outlines the development of a 500-kV dc oil-filled submarine cable capable of transmitting 2800 MW with a ±500-kV 2800 A bipole system. Although polypropylene laminated paper (PPLP) has been employed as ac cable insulation material, this is the world's largest first application to dc cables. The conductor size is 3000 mm^2, which would be the largest size for submarine cables. Various fundamental and prototype tests have proved that the cable has excellent characteristics electrically as well as mechanically. The cable and accessories are currently undergoing a long-term accelerated aging test as a final confirmation of their reliability and stability.

[1996] 04A - 2

GETTING POWER UP TO SPEED

Anon

Journal of Offshore Technology, vol 4, no 4, November 1996, pp 35-37

Many offshore oil and gas discoveries are often too remote to be exploited economically using subsea technology. One of the factors limiting the stepout distance is the ability to transmit electrical power to remote devices. This may be solved soon following a project to develop a new high voltage transmission system. Work to demonstrate the viability of this concept has resulted in the SPEED (Subsea Power Electrical Equipment Demonstrator), which will address problems such as siting equipment at various depths, distances, and capacities.

[1997] 04A - 3

INSTALLATION OF DC ±350-KV OIL-FILLED SUBMARINE CABLE FOR LEYTE-LUZON HVDC POWER TRANSMISSION PROJECT IN THE PHILIPPINES

Seki, Y.; Yamaguchi, H.; Yamada, N.; Ishiyama, H.; Maeda, H.; Matsushita, S.; Kiuchi, S.

Fujikura Ltd, Japan

Fujikura Giho (Japan), no 92, pp 28-32

Japanese

This paper describes the design, manufacture, tests, and laying of dc ±350-kV single core oil-filled submarine cable to supply power from Leyte to Luzon in the Philippines. Oil-filled-type submarine cable was employed for this project and installed in the San Bernardino Strait, which measured about 22.5 km in length and had a maximum depth of 166 m.

[1997] 04A - REF

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY OF ELECTRIC POWER DEVELOPMENT CO. LTD

For Abstract see entry 01A - 16

[1997] 04A - REF

350-KV HVDC OIL-FILLED SUBMARINE CABLE PROJECT IN THE PHILIPPINES

For Abstract see entry 01C - 1

04B Cable Design, Insulation

[1997] 04B - 1

±250-KV DC XLPE CABLE-LONG-TERM PERFORMANCE VERIFICATION TEST

Fujii, K.; Terashima, K.; Watanabe, C.; Suzuki, H.; Hozumi, N.; Yoshida, M.; Kataoka, K.; Watanabe, K.; Watanabe, A.; Takahashi, T.; Miyata, H.; Yamanouchi, H.; Yokoyama, S.; Shiseki, N.; Ikeda, H.; Sakaguchi, H.

Fujikura Giho (Japan), no 92, April 1997, pp 43-49

Japanese

±250-kV XLPE-insulated dc power cables have been developed, which have used a kind of XLPE compound containing an inorganic filler to suppress the accumulation of space charge within XLPE insulation. After a series of research and development work, such as material investigation, evaluation of model cables and electrical initial performance test of full sized ±250-kV dc cables and factory joints, a long-term performance verification test was carried out as the final stage of development. This paper reports the contents and results of this long-term test.

[1996] 04B - 2

BASIC STUDY ON POLYMER-INSULATED DC CABLE

Uchida, K.; Yamamoto, M.; Kawashima, T.; Uozumi,

T.; Inoue, Y.; Hata, R.

Chubu Elec Power Co, Inc, Nagoya, Japan

Proceedings, 1996 Asian Intl Conf on Dielectrics & Electrical Insulation Diagnosis (96'AICDEI & 4th-JCCEID), Xi'an, China, October 8-11, 1996, pp 89-92

The development of polymer-insulated dc cables is affected by the morphology on the interface between two insulation layers and between a semiconductor layer and an insulation layer. The number of space charges accumulated on the interfaces increases with the temperature during voltage application. The dc breakdown strength is almost similar regardless of the difference of the morphology on the interface. 1 Refs.

[1997] 04B - 3

CHARGE BUILDUP IN LOSSY DIELECTRICS WITH INDUCED INHOMOGENEITIES

Coelho, R.; Aladenize, B.; Guillaumond, F.

Alcatel Alsthom Recherche, France

IEEE Trans on Dielectrics and Electrical Insulation, vol 4, no 5, October 1997, pp 477-486

In addition to their normal inhomogeneities, insulation may also become inhomogeneous under stress, for instance if its temperature is not uniform. Then, a charge density builds up wherever material properties such as conductivity and permittivity are not uniform. This is the case of HVdc cables, in which the core is heated by the Joule effect, while the sheath remains at near ambient temperature, so that an average temperature gradient of less than equivalent to 50 K/cm may occur in the insulation, under a field which can reach 100 kV/cm. If the conductivity of the insulation is assumed to depend only on temperature, with an activation energy of 1 eV, the steady charge density predicted by electrostatics may reach levels easily measurable by the techniques now available. This charge density is somehow lowered in non-ohmic insulation. An early analysis of the transient charge build-up is discussed here, and extended to the case of a non-ohmic insulation. This allows calculation of the transient current generated in the external circuit by the accumulating charge, in the cases of ohmic and non-ohmic insulation. Finally, other manifestations of the space charges in question are mentioned. Among these, unexpected results on electroconvection in slightly ionic liquids in the presence of a temperature gradient are analyzed in terms of these charges, and suggest practical applications. 25 Refs.

[1997] 04B - 4

CHARGES AND DISCHARGES IN HVDC CABLES--IN PARTICULAR IN MASS-IMPREGNATED HVDC CABLES

Jeroense, M.J.P.

Tech Univ of Delft, Netherlands

PhD dissertation, Technische University Delf, Netherlands, ISBN-90-407-1419-3, March 24, 1997, 209 pp

Mass-impregnated HVdc (high voltage direct current) cables are just as reliable as high voltage, ac cables. However, there is still a lack of knowledge concerning HVdc cables. In addition , the tests for HVdc cables are less well developed than those for high voltage ac cables. The purpose of this study is to gain a better understanding of the HVdc cables and to propose a better-developed set of tests. This is of particular interest in respect to new generations of HVdc cables which have higher operating voltages and higher power transmission capacities.

[1997] 04B - 5

CHARGES IN NON HOMOGENEOUS DIELECTRICS

Coelho, R.

Alcatel Alsthom Recherche, Marcoussis, France

Proceedings, IEEE Conf on Electrical Insulation and Dielectric Phenomena, Minneapolis, MN, October 19-22, 1997, vol 1, pp 1-10

If a weakly conducting non-homogeneous medium is stressed by an applied field, a charge density builds up in areas where the conductivity and/or the permittivity are not uniform. The non-uniformity may be constitutional, but may also appear in uniform media, for instance if the temperature is not uniform. This is the case, in particular, of HVdc cables in which the core is heated by Joule effect while the sheath remains roughly at ambient. For non polar materials with an activation energy of 1 eV in a mean field of 100 kV/cm and a temperature gradient of 50 K/cm, usual in HVdc cables, this generates a charge density which should be measurable by the advanced techniques now available. The build-up of this space-charge obeys an integro-differential equation involving the mean radius at which the field equals the Laplace field. The analytic solution given by Lau for a conductivity depending on temperature alone is extended to the case where it also increases with the field, and is used to derive the current transient generated in the external circuit by the accumulating charge. Finally, other manifestations of

the space-charges in question and their potential applications, are mentioned. 25 Refs.

[1996] 04B - 6

CONFERENCE RECORD OF THE 1996 IEEE INTERNATIONAL SYMPOSIUM ON ELECTRICAL INSULATION. VOLUME 2

Wang, S.; Fujita, M.; Tanimoto, G.; Aida, F.; Fujiwara, Y.

Showa Electric Wire and Cable Co, Ltd, Kawasaki, Kanagawa, Japan

Conf Record, 1996 IEEE Int'l Symp on Electrical Insulation, Montreal, Canada, June 16-19, 1996, pp 657-660

Applicability of polyethylene polymerized using a metallocene catalyst to an insulation material for dc power cables has been investigated. The accumulation properties of space charge in a range from room temperature to 90 C was examined using the pulse electroacoustic method. The result indicated that hetero-charge was observed in the vicinity of the surface of the sample at increased temperature, and that hetero-space charge produced by activation of an antioxidant added to the sample was increased or decreased with the increase of the temperature of the sample. A hetero-charge absorber was added for controlling the hetero-space charge. As a result, hetero-charge was not observed on the sample in a high electric field extending from room temperature to high temperature. It was confirmed that the volume resistivity of sample was increased at high temperature.

[1996] 04B - 7

DC 500-KV OIL-FILLED CABLES AND ACCESSORIES

Hara, T.; Miyafuji, R.; Nakiri, T.; Terashima, K.; Morikawa, T.; Takashima, H.; Okamoto, T.; Suzuki, H.; Hozumi, N.; Nakao, Y.; Matsuura, T.; Hirasawa, T.; Iwata, T.; Shigetoshi, I.; Nakamura, Y.; Maruyama, T.; Kobayashi, T.; Kurai, Y.; Sano, A.

Fujikura Giho (Japan), no 91, October 1996, pp 19-28

Japanese

At present, a 500-kV dc submarine cable project is under way to establish a 2800-MW dc link between the Honshu and Shikoku islands in Japan. As a result of a feasibility study, an oil-filled-type power cable employing a 3,000-mm^2 conductor and polypropylene laminated paper (PPLP) insulation was developed for its higher permissible conductor temperature and reliability. At the final stage of development, long-term accelerated aging tests have been carried out since November 1994, and will be finished by February 1996. This paper outlines the design/test results of the cable and its accessories. 27 Refs.

[1997] 04B - 8

DC AND IMPULSE TREEING CHARACTERISTICS IN INSULATING MATERIAL FOR HVDC CABLE

Katsuta, G.; Itaya, T.; Nakatsuka, T.; Miyata, H.; Takahashi, T.; Niwa, T.

Tokyo Elec Power Co, Inc, Yokohama, Japan

Proceedings, 5th IEEE Int'l Conf on Properties and Applications of Dielectric Materials, Seoul, South Korea, May 25-30, 1997, vol 1, pp 422-425

We have developed new insulating material, modified high density polyethylene (modified HDPE), for high voltage dc cable, and tested several electrical properties of the material (in the forms of sheet and cable), such as dc dielectric breakdown, conductivity, and space charge property. In practical use, defects in material, especially metallic impurities are serious matter for cables. In this paper, the breakdown characteristics of modified HDPE have been tested, using treeing sample with needle electrode, for four kinds of voltage (dc, dc polarity reversal, impulse (Imp), and impulse superposed on to dc voltage). As a result, it was clarified that the treeing breakdown voltage largely depended on kind of voltage. Namely, the order of breakdown strength were dc greater than Imp greater than Imp superposed on to dc greater than equivalent to dc polarity reversal, and the scattering of breakdown voltage become smaller in the above order. With respect to radius dependence of needle tip, breakdown voltage was almost same value from 1.5 μm to several tens mu m, showing polarity effect for dc and Imp. These experimental results are thought to correspond to the space charge formation near the needle tip, dependent on the kind of voltage. 6 Refs.

[1997] 04B - 9

DEPENDENCE OF DC INSULATION RESISTIVITY OF POLYETHYLENE ON TEMPERATURE AND ELECTRIC FIELD

Khalil, M.S.; Gastli, A.

Sultan Qaboos Univ, Alkhod, Oman

Proceedings, IEEE Conf on Electrical Insulation and Dielectric Phenomena, Minneapolis, MN, October 19-

22, 1997, vol 1, pp 296-299

Recently, the development of HVdc cables with polymeric insulation has received renewed attention. The present work aims at determining the dependence of the dc insulation resistivity on temperature and electric field for low-density polyethylene (LDPE), which is used for manufacturing modern high voltage ac cables. Using a highly precise technique, resistivity measurements were made using thick (approximately 2 mm) disc samples at different dc electric fields ranging from 17 kV/mm to 33 kV/mm for a temperature range from 50°C to 80°C. Results indicate that the dc insulation resistivity of the investigated LDPE (ρ) is a rapidly decreasing function of both temperature (T) and electric field (E). Comparison between the present results and similar previously reported measurements made on less clean grades of LDPE indicates that the inherent dependence of the dc insulation resistivity of LDPE on temperature and electric field has not been appreciably improved by using a ultra-clean polymer. It is concluded that the successful utilization of LDPE for HVdc cables will require the modification of such dependence. 13 Refs.

[1997] 04B - 10

DESIGN FOR HVDC PLASTIC INSULATED CABLES. STUDY OF PERMISSIBLE DEFECT LEVEL

Katsuta, G.; Tanaka, T.; Itaya, T.; Nakatsuka, T.; Miyata, H.; Takahashi, T.

Tokyo Elec Power Co, Inc, Japan

Fujikura Giho (Japan), no 92, pp 58-62

Japanese

We have found that modified HDPE has an excellent dc characteristic for the development of high voltage dc cable, and have investigated this characteristic in the hope of applying the material to the production of cables. In this paper, we studied about harmful defects for dc cable and permissible defect level to design a practical HVdc cable. Firstly, dielectric breakdown tests were done for a sample containing contaminant, and it was found that metallic contaminant is the most harmful. Secondly, using a block sample with treeing needle, a breakdown test applying four types of voltage were done, and dependence of breakdown voltage on tip radius of the needle was obtained. Finally, we have considered the mechanism of breakdown at tip of needle.

[1996] 04B - 11

DEVELOPMENT OF NEW INSULATING POLYMER FOR HVDC CABLES

Katsuta, G.; Tanaka, T.; Itaya, T.; Miyata, H.; Nakatsuka, T. Takahashi, T.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Densen, Keburu Kenkyukai Shiryo (Japan), vol EC-96, no 26-32, pp 11-20

Japanese

In this paper, we describe the process for the selection of modified HDPE as new insulating material for HVdc cable. The effect of insulation thickness and the long-term V-t characteristics for dc breakdown of the modified HDPE cable were investigated and promising results for an application to HVdc cable were obtained. In order to clarify the mechanism of the excellent dc characteristics of modified HDPE cable, we examined the space charge characteristics of modified HDPE by using a pulsed electro-acoustic method. The advantageous space charge distribution in modified HDPE is found to be the complex effect of a modified group and additives which are included in modified HDPE.

[1998] 04B - 12

ELECTRIC FIELDS IN HVDC PAPER-INSULATED CABLES

Jeroense, M.J.P.; Morshuis, P.H.F.

Tech Univ of Delft, Netherlands

IEEE Trans on Dielectrics and Electrical Insulation, Vol 5, no 2, April 1998, pp 225f

HVdc cables are beginning to play a more and more important role in interconnecting national grids. This paper deals with the calculation of electric fields in HVdc cables. The calculation of fields in an HVdc cable is far more complex than the equivalent case in HVac cables. This is due to the fact that the conductivity of the cable insulation is temperature- and field-dependent and that the electric fields under dc voltage may be time-dependent. The field distribution in an HVdc cable may be of a capacitive, intermediate (and time-dependent) or resistive nature. The kind of field depends on the stage the cable finds itself in: for instance, whether the voltage has just been applied, whether a polarity reversal has occurred, or whether the field distribution has become stable. For each stage, the method of calculating, together with the computed results on a real HVdc cable are discussed. Usually, the effect of heating of the insulation by the leakage current

may be disregarded. However, in certain cases, i.e., the cable temperature and applied voltage are high enough, the field distribution is influenced by these insulation losses. They even may lead to an instability that causes breakdown of the cable. A cable in service may be subjected to impulses superimposed on the dc voltage. The most severe case is that of an impulse superimposed on a dc voltage of opposite polarity. The calculation of the field distribution in this situation also is carried out.

[1997] 04B - 13

Deleted

[1997] 04B - 14

INTERNATIONAL RESEARCH AND DEVELOPMENT TRENDS AND PROBLEMS OF HVDC CABLES WITH POLYMERIC INSULATION

Khalil, M.S.

Sultan Qaboos Univ, Alkhod, Oman

IEEE Electrical Insulation Magazine, vol 13, no 6, November-December 1997, pp 35-47

The effects of space charges on the performance of HVdc cables with polymeric insulation are difficult to assess using indirect methods and destructive techniques of space charge measurements. With the development of the modern non-destructive methods for investigating space charge in solid polymeric materials, space charge effects can be determined with accuracy, not only on material samples or miniature cables but also on actual cables. The problems of developing HVdc cables with polymeric insulation are diversified, and the evaluation of the new material/cable should be made using different methods and by measuring different relevant parameters. 76 Refs.

[1996] 04B - 15

MECHANISM OF DC DETERIORATION IN MATERIAL FOR DC CABLE

Katsuta, G.; Itaya, T.; Nakatsuka, T.; Miyata, H.; Yamamoto, S.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Hoden Kenkyukai Shiryo (Japan), vol 97, no 79-92 94-95, pp 95-103

Japanese

We found new insulating material, modified HDPE, for HV dc cable and reported its dc characteristics in previous reports. In this paper, we report that, using treeing needle, dc and dc polarity reversal breakdown depend on radius of the tip for clarification of the mechanism of dc deterioration. In addition, in dc polarity reversal repeat test, electrical tree grows when the polarity is changed from minus to plus.

[1996] 04B - 16

MPS [MORE POWER SUBMARINE] CABLES COULD BE MIND [MASS IMPREGNATED NON-DRAINING CABLE] BLOWING FOR 1200 MW LINKS

Anon.

Modern Power Systems (UK), vol 16, no 7, July 1996, pp 43, 45-46

ABB High Voltage Cables AB started the MPS (More Power Submarine cables) project in 1993 with a view to exploring new technology opportunities. The goal is to design and type test a submarine HVdc cable for a capacity of 1200 MW at 600 kV. On the day before ABB announced its success in winning the contract for the world's largest ever submarine HVdc link project for the gigantic Bakun project in Malaysia, ABB Power Systems described progress to date at a symposium in Karlskrona. The proceedings included a test demonstration on an extruded cable which eventually broke down at a stress of over 935 kV--not in the insulation itself but in the end terminations. The electric field was in excess of 200 kV/mm which is higher than ever before reported. (UK)

[1996] 04B - 17

NO DANGER WITH LEAKS IN DC SUBMARINE CABLES

Worzyk, T.B.

ABB High Voltage Cables, Karlskrona, Sweden

Elektrizitaetswirtschaft (Germany), vol 95, no 26, December 16, 1996, pp 1731-1732, 1734-1735

German

The proportion of HVdc transmission sections in long-distance power transmission is increasing. High-power submarine cables pertaining to many HVdc systems run through habitats close to shores. The author shows that bulk-impregnated HVdc submarine cables as used in the Baltic Cable System pose no threat to the environment. Their extremely compact structure effectively dams any leakage of oil even from a broken cable. 2 Refs.

[1997] 04B - 18

ON THE INTRINSIC SPACE CHARGE IN A DC POWER CABLE

Aladenize, B.; Coelho, R.; Guillaumond, F.; Mirebeau, P.

Alcatel Alsthom Recherche, Marcoussis, France

Journal of Electrostatics, vol 39, no 4, August 1997, pp 235-251

In an HVdc power cable connected to its standard load, radial thermal, and therefore conductivity gradients exist which, combined with the local field, build up an intrinsic space charge. This steady-state space charge is calculated with a simplified account of a field-dependent conductivity as well as with field independent conductivity. The shape of the accumulating charge distribution is shown to depend strongly on the thermal gradient. An approximate solution for temperature- and local field-dependent conductivity provides a sound basis for numerical solution. Comparison with measured charged and field distributions suggests extrinsic space charges to be crucial to the cable life, and therefore should be identified. 8 Refs.

[1996] 04B - 19

ON THE USE OF DOPED POLYETHYLENE AS AN INSULATING MATERIAL FOR HVDC CABLES

Khalil, M.S.

College of Eng, Sultan Qaboos Univ, Muscat, Oman

Conf Record, IEEE Int'l Symp on Electrical Insulation, Montreal, Canada, June 16-19, 1996, vol 2, pp 650-656

The merits of HVdc power cables with polymeric insulation are well recognized. However, the development of such cables is still hampered due to problems resulting from the complicated dependence of the electrical conductivity of the polymer on the temperature and the dc electric field and the effects of space charge accumulation in this material. Different methods have been suggested to solve these problems yet none of these methods seem to give a conclusive solution. The present report provides a critical review of the previous works reported in the literature concerning the development of HVdc power cables with polymeric insulation. Different aspects of those works are examined and discussed. An account is given on an investigation using low-density polyethylene (LDPE) doped with an inorganic additive as a candidate insulating material for HVdc power cables. Preliminary results from measurements of dc breakdown strength and insulation resistivity of both the undoped and the doped materials are presented. It is shown that the incorporation of an inorganic additive into LDPE has improved the performance of the doped material under polarity reversal dc conditions at room temperature. Moreover, the dependency of the insulation resistivity on temperature for the doped material appears to be beneficially modified. 9 Refs.

[1996] 04B - 20

PARTIAL DISCHARGE MEASUREMENTS ON A HIGH VOLTAGE DIRECT CURRENT MASS IMPREGNATED PAPER CABLE

Jeroense, M.J.P.; Kreuger, F.H.

NKF KABEL B.V., Delft, Netherlands

Proceedings, IEEE Int'l Symp on Electrical Insulation, Montreal, Canada, June 16-19, 1996, vol 1, pp 134-137

Partial discharge measurement has been a good tool for the quality assurance of cables under alternating voltage. With the growing interest in high voltage direct current cables it seems therefore logical to extend this technique for use at direct voltage. The paper describes this technique as used on an HVdc cable with mass impregnated paper. The different phases of operation (no load, full load, cooling phase, etc.) are characterized by a different discharge behavior. Special attention is given to the dangerous cooling phase. Models have been developed which can explain the discharge patterns that were measured. This paper gives an insight in the electrical behavior of an HVdc cable with mass impregnated paper insulation. 5 Refs.

[1997] 04B - 21

RECENT PROGRESS AND TECHNICAL TRENDS OF HVDC CABLE

Hata, R.; Hirose, M.

Sumitomo Elec Ind, Ltd, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp S.23.17-S.23.20

Japanese

Abstract not available.

[1997] 04B - 22

RECOMMENDATIONS IN HV DC TESTING OF MV CABLE INSULATION

Finke, B.H.

Okonite Co of Atlanta, GA, USA

IEEE Industry Applications Magazine, vol 3, no 5, September-October 1997, pp 85-87

Concern over the effect of dc testing on extruded cross-linked polyethylene (XLPE) insulated cable has driven the utility industry to recommend and implement changes in cable standards to reduce the levels and frequency of dc testing. Statistical analysis of factory testing shows dc testing after ac withstand and corona tests has no additional benefit. The first organization to make changes and recommendations was the Association of Edison Illuminating Companies (AEIC) followed by the IEEE and Insulated Cable Engineers Association (ICEA). Other industry organizations have revised and are preparing standards which reflect the dc voltage test requirements similar to AEIC standards.

[1998] 04B - 23

RESEARCH AND DEVELOPMENT OF ±250-KV DC XLPE CABLES

Terashima, K.; Sukuki, H.; Hara, M.; Watanabe, K.

Elec Power Development Co Ltd, Tokyo, Japan

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 7-16

This paper describes the development of ±250-kV dc XLPE cables. Through a series of material investigations and the evaluation of model cables using two kinds of XLPE compound containing inorganic filler to suppress the accumulation of space charge within XLPE insulation, ±250-kV dc XLPE cables and factory joints were designed and manufactured. To check the dc electrical performance and reliability of ±250-kV dc submarine cable, electrical tests, mechanical test and long-term aging tests were performed. The test results showed that they had sufficient properties and reliability for practical use.

[1998] 04B - 24

SPACE CHARGE BEHAVIOR IN FULL-SIZE 250-KV DC XLPE CABLES

Takeda, T.; Hozumi, N.; Suzuki, H.; Fujii, K.; Terashima, K.; Hara, M.; Mutrata, Y.; Wantanabe, K.; Yoshida, M.

CREIPI, Japan

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 28-39

The space charge in full size 250-kV HVdc power cables was measured using the pulse-electroacoustic method. Measurements of two types of newly developed dc XLPE cables with 20-mm insulation were taken under a dc voltage of 500 kV with the conductor temperature at room temperature and at 85°C. A qualitative analysis of the space-charge distribution and a quantitative analysis of the electric fields in the vicinity of semiconductor interfaces were conducted. It was shown that the field in the vicinity of the inner semiconductor tends to increase by 10-40% when the polarity of the applied voltage was reversed, in the case when the conductor was kept at 85°C. However, the distortion of the electric field was significantly less than that expected in conventional XLPE cables. As the result, the subjected dc cables are considered to have stable dc characteristics from the viewpoint of space-charge behavior.

[1997] 04B - 25

SPACE CHARGE IN HVDC CABLE INSULATION

Morshuis, P.; Jeroense, M.

Tech Univ of Delft, Netherlands

Proceedings, IEEE Conf on Electrical Insulation and Dielectric Phenomena, Minneapolis, MN, October 19-22, 1997, vol 1, pp 28-31

High voltage cables that are used for dc transmission are subjected to a range of operating conditions. The resulting distribution of the electric field inside the cable is highly dependent on, for instance loading of the cable and polarity reversals. This is because the conductivity of the insulation is dependent both on the temperature and on the electric field. An essential parameter in the process to determine the internal electric field is space charge. For a thorough understanding of the behavior of the cable, knowledge of the location and amount of space charge under different operating conditions is paramount. 3 Refs.

[1997] 04B - 26

Deleted

[1996] 04B - 27

THE 800-MW HVDC SUBSEA CABLE ALMOST READY FOR USE

Bjoerlow-Larsen, K.

Elektro (Norway), vol 2, 1996, pp 24-27

Norwegian

The article relates to the development of an new high voltage direct current (HVdc) subsea cable. The

Norwegian developed cable, having a transmission capacity of 800 MW, is soon to be on the market. The cable design and procedure of deep water installation is discussed. 3 figs.

[1996] 04B - REF

MORE HVDC TRANSMISSION PROJECTS BY TECHNICAL BREAKTHROUGH

For Abstract see entry 01C - 20

[1997] 04B - REF

DEVELOPMENT OF 500-KV DC PPLP-INSULATED OIL-FILLED SUBMARINE CABLE

For Abstract see entry 04A - 1

[1997] 04B - REF

INSTALLATION OF DC ±350-KV OIL-FILLED SUBMARINE CABLE FOR LEYTE-LUZON HVDC POWER TRANSMISSION PROJECT IN THE PHILIPPINES

For Abstract see entry 04A - 3

04C Superconducting Cables

[1996] 04C - 1

DC TRANSMISSION CABLE PROTOTYPE USING HIGH-TEMPERATURE SUPERCONDUCTORS

Beales, T.P.; Friend, C.M.; Segir, W.; Ferrero, E.; Vivaldi, F.; Ottonello, L.

BICC Cables Ltd, Tyne and Wear, UK

Superconductor Science & Technology vol 9, no 1, January 1996, pp 43-47

This paper gives the results from a recent collaboration between BICC Cables Ltd, its Italian subsidiary Ceat Cavi srl, and Ansaldo Ricerche srl on the design and testing of a high-temperature superconducting dc transmission cable prototype. The cable was designed to carry 10 000 A to 40 kV, operating at 40 K. Qualification testing was carried out from 4.2 K up to 40 K. At an operating temperature of 31 K the prototype cable had a current capacity of 11 067 A (the largest dc current reported in a high-temperature prototype to date), which represents a tenfold increase in current over a conventional 1000-mm^2 copper cable. 21 Refs.

[1997] 04C - 2

INVESTIGATION ON THE RAMP-RATE LIMITATION OF SUPERCONDUCTING CICC (CABLE-IN CONDUIT CONDUCTOR)

Jeong, S.-K.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 4, April 1997, pp 490-495

Korean

Cable-in-conduit conductor (CICC) is widely accepted as an advanced superconductor configuration for large scale applications such as superconducting tokamak fusion reactors, MAGLEV (magnetic levitation), and SMES (superconducting magnetic energy storage). The stability of CICC which is cooled with supercritical helium can be very high if it is operated below a certain limiting current. This limiting current can be determined by Stekly-type energy balance equation. The stability characteristic of CICC for ac operation is more complicated than that of dc because there are additional instability sources which are associated with local flux change. Ramp-rate limitation is a phenomenon discovered during US-DPC (United States-Demonstration Poloidal Coil) program, which showed apparent quench current degradation associated with high dB/dt. This paper describes experimental investigation results on the ramp-rate limitation and discusses current imbalance, induced current, current redistribution due to local quench of the strand in the cable.

[1996] 04C - REF

SUPERCONDUCTORS IN ELECTRICAL ENGINEERING: IT IS FOR SOON

For Abstract see entry 14A - 131

05 SYSTEM DESIGN AND OPERATION

05A Converter Design and Specification

[1998] 05A - 1

ANALYSIS OF DIVIDE CAPACITOR VOLTAGE OF DUAL CONNECTED MULTI-LEVEL CONVERTER

Matsumoto, A.; Kimura, N.; Morizane, T.; Taniguchi, K.

Osaka Inst of Tech, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol 98, no 10-21, pp 1-6

Japanese

Voltage source-forced commutation converter is investigated for high power applications, such as STATCOM or HVdc. To reduce higher harmonics while keeping switching frequency at fundamental frequency, a multilevel converter is an attractive configuration. In this paper, we have performed loss analysis of proposed dual-connected 5-level converter. From the results, we show the relation between the phase angle and the pulse-width of the converter. We also show the restriction for the stable operation and verify it with the simulation results of P'Spice.

[1997] 05A - 2

BASIC CHARACTERISTICS OF A CAPACITOR COMMUTATED CONVERTER FOR HVDC LINKS

Yamada, T.; Sano, T.; Yamato, I.; Ohashi, T.; Kashiwazaki, H.

Elec Power Development Co, Ltd, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.320-6.321

Japanese

Abstract not available.

[1998] 05A - 3

CAPACITOR COMMUTATED CONVERTER CIRCUIT CONFIGURATIONS FOR DC TRANSMISSION

Sadek, K.; Pereira, M.; Brandt, D.P.; Gole, A.M.; Daneshpooy, A.

Siemens AG, Erlangen, Germany

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

Two non-conventional HVdc converter arrangements are compared. These include the capacitor-commutated converter (CCC), in which series capacitors are included between the converter transformer and the valves, and the controlled series capacitor converter (CSCC), based on more conventional topology, in which series capacitors are inserted between the ac filter bus and the ac network. Results show that both options have comparable steady-state and transient performance. Danger of ferroresonance with the CSCC option is eliminated by controlling the amount of series compensation.

[1998] 05A - 4

CHARACTERISTICS OF A CURRENT SOURCE AC/DC CONVERTER WITH ENERGY RECOVERY SNUBBER CIRCUITS UNDER THE PWM CONTROL

Oka, T.; Ise, T.; Komagai, S.

Osaka Univ, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol 98, no 10-21, pp 7-12

Japanese

In this paper, a computer simulation is used to study an ac/dc current source converter using pulse-width modulation control.

[1997] 05A - 5

DC TRANSMISSION BASED ON VOLTAGE SOURCE CONVERTERS

Asplund, G.; Eriksson, K.; Svensson, K.

ABB Power Sys AB, Ludvika, Sweden

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper surveys the development and limitations of HVdc transmission technology, in particular the need for rotating machines in the receiving network and the risk of commutation failure (i.e., no transmission of power for some cycles), which have been alleviated by the application of voltage source converter (VSC) technology.

[1997] 05A - 6

DEVELOPMENT AND TESTING OF PROTOTYPE MODELS FOR A HIGH-PERFORMANCE 300 MW SELF-COMMUTATED AC/DC CONVERTER

Suzuki, H.; Nakajima, T.; Izumi, K.; Sugimoto, S.; Mino, Y.; Abe, H.

Tokyo Elec Power Co, Inc, Yokohama, Japan

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1589-1598

A technical project is under way in Japan to develop a high-performance self-commutated converter for future

HVdc transmission and dc interconnection. In the first stage of the project, prototype converter models for a 300-MW self-commutated converter were developed. The models were subjected to factory testing to verify the technology for series connection of a large number of gate turn-off thyristors (GTOs), a gate power supply from the high voltage main circuit, and regeneration of energy in snubber circuits. Satisfactory results were obtained. 7 Refs.

[1997] 05A - 7

DEVELOPMENT AND TESTING OF PROTOTYPE TRANSFORMER CORE MODELS FOR A HIGH-POWER SELF-COMMUTATED AC/DC CONVERTER

Suzuki, H.; Nakajima, T.; Izumi, K.; Sugimoto, S.; Yonezawa, H.; Abe, H.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 91-99

Japanese

A project is under way to develop a high-power self-commutated ac/dc converter system for future HVdc transmission and dc interconnection. Prototype core models of the transformer for a 300-MW self-commutated ac/dc converter were developed. The models were subjected to factory testing to verify the technologies for improvement of voltage sharing between series connected ac windings, prevention of dc magnetization, and reduction of core losses and audible noises. Satisfactory results were obtained.

[1998] 05A - 8

DEVELOPMENT OF A CONTROL SYSTEM FOR A HIGH-PERFORMANCE SELF-COMMUTATED AC/DC CONVERTER

Sakamoto, K.; Yajima, M.; Ishikawa, T.; Sato, T.; Sugimoto, S.; Abe, H.

Tokyo Elec Power Co, Inc, Yokohama, Japan

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 225-232

A self-commutated ac/dc converter composed of controlled turn-off devices to be applied to future system interconnections is described. The advantages of a control system for this type of converter are: (1) Commutation does not fail when the system voltage is decreased or distorted by a power system fault. (2) It needs no equipment for reactive power supply, such as static capacitors or synchronous rotating condensers, when used in a low short-circuit capacity power system. (3) It can independently control active power through dc lines and reactive power from each terminal. The proposed back-to-back (BTB) control system using the voltage margin method was verified with a power system simulator, and the results demonstrated the excellent features of the high-performance self-commutated converter. 5 Refs.

[1996] 05A - 9

DIGITAL FIRING CONTROL FOR LINE-COMMUTATED HIGH POWER CONVERTERS

Hugelschafer, L.; Vaupel, G.

Fachhochschule Hamburg, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 157-162

Typical line-commutated high power converters for HVac systems are thyristor-controlled reactors (TCR), thyristor-switched capacitors (TSC), high voltage direct current transmission (HVdc) and rectifiers for dc arc furnaces. These high power converters require higher dynamics and higher quality of their control hardware than applications of smaller size because they are directly affected by disturbances in the HV-network. In order to reach a high system availability, the converter has to remain in operation and to recover within a few cycles. To meet the requirements of control accuracy and speed in new installations, only digital controls are used. Even old analog equipment is being replaced because of the technical and economic advantages of digital systems over analog ones. The interface between power electronics and control system, called firing control, provides line synchronous firing pulses to the thyristor valves according to the firing angle ordered by the control. Implementation of the digital firing control requires high computing performance. The computer hardware used performs the necessary filtering and achieves better accuracy and more equidistant firing than the former analog hardware. 4 Refs.

[1998] 05A - 10

FUNDAMENTALS OF A SERIES CAPACITOR COMMUTATED HVDC TERMINAL

Kazachkov, Y.

Power Technologies, Inc, Schenectady, NY, USA

IEEE Trans on Power Delivery, Preprint order number PE-682-PWRD-0-11-1997

The increased interest in this HVdc technology, which has been put forward as one of the possible advanced HVdc technologies to be implemented in the next century, is based on studies accomplished as early as in the 1950s and 1960s. This paper contains basic equations, derived long ago by Russian experts, and their analysis. The considerations on the controllability of a series capacitor-commutated converter and on the transformerless arrangement of a series capacitor-commutated HVdc terminal, will hopefully be useful in further development of this technology.

[1998] 05A - 11

HARMONIC CANCELLATION OF A HYBRID CONVERTER

Jiang, H.; Ekstrom, A.

Royal Inst of Tech, Stockholm, Sweden

IEEE Trans on Power Delivery, Preprint order number PE-096-PWRD-1-12-1997

All HVdc converter stations have until now been built up of line-commutated current source converters (CSCs). The CSC has the advantages of being robust and able to control the dc current, especially at ground faults on the dc lines. However, one disadvantage has been the sensitivity to ac voltage disturbance and the need to supply reactive power from the ac system. Forced commutated voltage source converter (VSC) which would be less sensitive to disturbances in the ac network and which can supply reactive power has, on the other hand, the disadvantage of being more expensive and very sensitive to disturbance on the dc side. Some studies have shown that a possible alternative solution could be to use a hybrid converter consisting of a CSC connected in series on the dc side with a VSC. It is shown in this study that the VSC can be used as an active filter to compensate the harmonics generated to the ac side from the current source converter.

[1997] 05A - 12

HARMONIC REDUCTION IN HVDC LINK BY MODIFIED DC CURRENT CONTROLLER

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

Proceedings, IPEC '97, Singapore, May 1997, pp 304-309

This paper presents a design procedure for a new current controller for an HVdc link, which can be used to attenuate low order no-characteristic harmonics on dc link. The controller design is performed using discrete control systems theory based on discrete HVdc system model. The designed controller consists of two compensators placed in series with the existing PI controller. When compared with the original system, for the same harmonic disturbance on the dc line, the system with the new controller shows much reduced oscillations on system output signals. Practical implementation issues were also taken into consideration in designing the compensators.

[1996] 05A - 13

MICROPROCESSOR CONTROL AND SAFETY SYSTEM FOR A 24-PHASE RECTIFIER-INVERTER MODULE

Mazurenko, A.K.; Mestergazi, V.A.; Kubareva, I.S.; Lobastov, K.Z.

Russian Electrical Engineering (Elektrotekhnika), vol 67, no 9, 1996, pp 69-75

The All-Russian Institute of Electrical Engineering (AEI) has developed the KURB control and safety (CS) complex for a 24-phase rectifier-inverter module under a program of modernization of the CS equipment at the Vyborgsk segment of the Russia-Finland HVdc transmission line. It is undergoing acceptance testing. The distinguishing feature of the new generation of CS equipment is the complex solution of high-speed control, automation and safety problems within a single device in which the control and safety systems share a common channel for the input of current and voltage signals from power equipment. This considerably reduces the volume of the input unit and the equipment for connecting the control and safety equipment and consequently improves the power consumption, metal content and other important parameters.

[1998] 05A - 14

MODELING OF AN HVDC SYSTEM AS A LINEAR CONTINUOUS MIMO SYSTEM

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

Proceedings, IASTED MIC '98, Grindelwald, Switzerland, February 1998

This paper presents important principles in analytical modeling of HVdc systems. The paper emphasizes that the dynamics of ac systems connected to an HVdc system must be properly represented in the overall system model. The dynamics of phase-locked loops and HVdc-HVac interactions in general, are also crucial for

the system behavior. The discrete representation of conversion process on the other hand, is not necessary for the study of system stability in the frequency range below 100 Hz. The inverter firing angle and the conventionally used rectifier firing angle are considered in this paper as control inputs. This has prompted the investigation of multi-input multi-output properties of the system. The analysis of the system principal gains and relative gain array gives initial recommendations for the selection of feedback signals at the inverter side. The studies show that direct current feedback is the least desirable inverter feedback strategy, despite the fact that this control logic is sometimes used in industry.

[1996] 05A - 15

NEW PRINCIPLES FOR BIG-SIZED CONVERTER STATIONS

Anon.

Elektro (Norway), vol 108, no 8, 1996, pp 12, 18

Norwegian

The article relates to new principles of big-sized converter stations for the high voltage dc systems of submarine lines. These lines are designed for the supply of electric power between Norway and the European continent. Two types of converters are discussed. 4 figs.

[1997] 05A - 16

PERFORMANCE CHARACTERISTICS OF ARTIFICIALLY COMMUTATED HVDC CONVERTER

Kanetkar, V.R.; Dawande, N.S.; Kalra, P.K.

ABB Ltd, Vadodara, India

Proceedings, 2nd Int'l IEEE Conf on Power Electronics and Drive Systems (PEDS), Singapore, May 26-29, 1997, vol 2, pp 889-895

The reactive power drawn by artificially commutated converters (ACCs) can be reduced in comparison with natural commutated converters (NCCs) over maximum possible operating range of the firing angle by properly selecting the Xc/X1 ratio. However, the dv/dt stress on the thyristors increases considerably as this ratio increases. This can have constraints on ACC design and implementation. The non-characteristic harmonics in ac line are observed to be less than 3% of the operating output direct current. Thus, they do not pose any serious threat to the input filter design. A single high pass filter can be effectively used to attenuate the higher order harmonics beyond 6 to an acceptable limit. 7 Refs.

[1996] 05A - 17

PWM AND CONTROL OF THREE LEVEL VOLTAGE SOURCE BACK-TO-BACK STATION

Lindberg, A.; Larsson, T.

Royal Inst of Tech, Stockholm, Sweden

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 297-302

The forced commutated voltage source converter (VSC) is an interesting alternative for HVdc back-to-back stations. The use of pulse width modulation (PWM) for the VSC result in less low frequency harmonics in the bridge ac voltage and increased speed of response at disturbances and load changes. By using the three-level converter instead of the two-level converter, further improvements of the harmonic levels and the control responses are achieved. Carrier-based PWM in combination with inner current loop control is used for the control of the three-level converters in the back-to-back station. System performance, when the switching frequency per valve is 400 Hz or 1 kHz, has been studied at load changes and single-phase ac faults. Results are presented from dynamical studies in an analog real time simulator with a digital control system. 7 Refs.

[1996] 05A - 18

SIMULATION STUDY OF A HYBRID HVDC SYSTEM COMPOSED OF A SELF-COMMUTATED CONVERTER AND A LINE-COMMUTATED CONVERTER

Iwata, Y.; Tanaka, S.; Sakamoto, K.; Konishi, H.; Kawazoe, H.

Tokyo Elec Power Co, Inc, Japan

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 381-386

Development of large-capacity, gate turn-off thyristors (GTOs) has led to a self-commutated power converter (SCC) system applicable to electric power transmission systems. During introduction of the SCC systems, a hybrid HVdc system composed of a conventional line-commutated converter (LCC) and the SCC was studied. The LCC controls dc current as a rectifier and the SCC controls dc voltage as an inverter. In this paper, new control schemes, start-stop operations and behaviors of ac system faults of the hybrid HVdc system were studied by digital simulations. Comparisons were made to the HVdc systems, both terminals of which were composed of LCCs or SCCs, and to the hybrid HVdc systems. 3 Refs.

[1996] 05A - 19

SIMULATION STUDY OF AN HVDC SYSTEM COMPOSED OF SELF-COMMUTATED CONVERTERS

Iwata, Y.; Tanaka, S.; Sakamoto, K.; Konishi, H.; Kawazoe, H.

Tokyo Elec Power Co, Inc, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 579-583

Development of large-capacity, gate turn-off thyristors (GTOs) has led to a self-commutated converter (SCC) system applicable to electric power transmission systems. During introduction of the SCC system, a hybrid HVdc system composed of a conventional line-commutated converter (LCC) and the SCC was studied. In the hybrid HVdc system, the LCC controls dc current as a rectifier and the SCC controls dc voltage as an inverter. In this paper, a new control system for the SCC is proposed and start-stop operations and behavior of ac system faults of the hybrid HVdc system using the proposed control system are studied by digital simulations. 3 Refs.

[1997] 05A - 20

SPACE VECTOR PATTERN GENERATORS FOR MULTI-MODULE LOW SWITCHING FREQUENCY HIGH POWER VAR COMPENSATORS

Bakhshai, A.R.; Joos, G.; Jin, H.

Concordia Univ, Montreal, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 1, pp 344-350

Force-commutated series-connected multi-converter modules have found applications in SVC and dc transmission stations, high power drive systems, and reactive power compensation units. This paper shows how relatively slow gate turn off (GTO) thyristors may be utilized In multi-converter modules in conjunction with a delayed sampling principle applicable to the space vector modulation (SVM) technique. The paper demonstrates the advantages of the SVM over the other existing modulation techniques in terms of switching frequency, voltage utilization, harmonic distortion, implementation, and control. 6 Refs.

[1996] 05A - 21

TIAN-GUANG HVDC TRANSMISSION PROJECT FUNDAMENTAL FREQUENCY OVERVOLTAGE AND OVERVOLTAGE LIMITING MEASURES FOR TIANSHENGQIAO CONVERTER STATION

Jansson, B.; Friis, T.; Stovring-Hallsson, S.; Quan, B-L.; Zhu, X-Q.; Burton, R.S.

ABB Power Sys, Ludvika, Sweden

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 118-123

For the Tian-Guang HVdc Transmission Project, the fundamental frequency overvoltages which can occur as a result of partial or complete interruption to transmitted power play an important role in the design and operation of the converter at Tianshengqiao. The paper describes some of the operating conditions which may result in high values of overvoltages along with solutions and trade-offs which were adopted to limit the overvoltages to acceptable levels. 0 Refs.

[1997] 05A - 22

VOLTAGE CONTROL OF MODIFIED SERIES-CONNECTED HVDC BRIDGES

Al-Majali, H.D.

Mu'tah Univ, Al-Karak, Jordan

Electric Power Systems Research, vol 43, no 1, October 1997, pp 37-44

High voltage direct current (HVdc) power transmission systems constitute an important application of power electronics technology. This article presents a new method to control the HVdc converters by modified series-connected bridges to give a reduction in both harmonic generation and reactive volt-ampere absorption for the rectifier and inverter modes of operation. Moreover, a voltage control scheme is proposed which uses by-pass thyristor valves connected to tapping points on the secondary windings of the transformer for one bridge with the other one operating as a conventional bridge. Fast and continuous control of the dc voltage are possible using the proposed scheme without the conventional on load-tap changer on the converter transformer. 15 Refs.

[1996] 05A - REF

UNIT CONNECTED HVDC SCHEMES

For Abstract see entry 01A - 25

[1997] 05A - REF

INNOVATIONS IN HVDC FOR TRANSMISSION QUALITY ENHANCEMENT. APPLICATIONS AND STUDIES.

For Abstract see entry 01A – 9

[1996] 05A - REF

VALVE HALL FIRE REPORT AND ANALYSIS FOR GEZHOUBA CONVERTER STATION

For Abstract see entry 01C - 38

[1996] 05A - REF

NEW TECHNOLOGIES IN HVDC CONVERTER STATION DESIGN

For Abstract see entry 02A - 2

[1996] 05A - REF

NEW TECHNOLOGIES IN HVDC CONVERTER DESIGN

For Abstract see entry 02A - 3

[1998] 05A - REF

DC TRANSMISSION BASED ON VOLTAGE SOURCE CONVERTERS

For Abstract see entry 02C - 7

[1996] 05A - REF

SOLVING THE FERRORESONANCE PROBLEM WHEN COMPENSATING A DC CONVERTER STATION WITH A SERIES CAPACITOR

For Abstract see entry 05D - 32

[1996] 05A - REF

POWER ELECTRONICS TECHNOLOGIES (EXPANDING CAPACITY OF EQUIPMENT AND APPLICATION TO POWER SYSTEMS)

For Abstract see entry 12A - 11

[1996] 05A - REF

PRINCIPLES OF SWITCHING POWER CONVERTERS

For Abstract see entry 17B - 27

05B Control and Protection

[1996] 05B - 1

A CONSTANT MARGIN ANGLE CONTROL IN HVDC TRANSMISSION TAKING ACCOUNT OF FREQUENCY DEVIATION

Nobayashi, M.; Yamaji, K.; Honjo, N.; Fujii, T.; Hamano, A.; Morishima, N.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 403-404

Japanese

Abstract not available.

[1997] 05B - 2

A DESIGN OF SELF-TUNING FUZZY CONTROLLERS USING GENETIC ALGORITHM FOR HVDC CURRENT CONTROL

Yoon, J.Y.; Hwang, G.H.; Park, J.H.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 10, October 1997, pp 1461-1467

Korean

This paper presents an optimal design method for fuzzy controllers using genetic algorithms (GA) in HVdc system. Inherently, an HVdc system has the advantage of allowing fast power controls and modulation. Also, HVdc systems are highly nonlinear, depending on ignition angles of converters. Generally speaking, fuzzy logic systems show good control performances when systems are complex and nonlinear. In this paper, fuzzy controllers using GA are applied to the IEEE Benchmark system in order to damp the dynamic disturbances, such as sudden changes of ac system loads. The dynamic performances of fuzzy controllers are compared with those of PI controllers. In both controllers, GA is used for tuning fuzzy membership functions and PI gains. All of the simulation results including tuning and any other conditions show that the disturbances are well damped by both controllers and the dynamic performances of fuzzy controllers have better responses than those of PI controllers when ac system load changes suddenly.

[1996] 05B - 3

A DISTRIBUTED SEQUENTIAL CONTROL

SYSTEM FOR THE APOLLO HVDC SUBSTATION

Venter, F.; Grant, J.; Joannides, C.

ESKOM, Johannesburg, South Africa

Proceedings, IEEE 4th Conf in Africa (AFRICON'96), Stellenbosch, South Africa, September 24-27, 1996, vol 2, pp 869-873

The refurbishment of the Apollo-Cahora Bassa HVdc system between South Africa and Mozambique required the application of state of the art technology in order to get the availability and reliability of the HVdc scheme to levels that are in accordance with present day power electronic and power equipment standards. This paper deals with the refurbishment of the open-loop control system for the Apollo Converter Station and how the goals of high reliability and availability were achieved. 0 refs.

[1996] 05B - 4

A NEURAL NETWORK BASED FEEDBACK LINEARISING CONTROLLER FOR HVDC LINKS

Routray, A.; Dash, P.K.; Mishra, B.R.

Regional Eng College, Rourkela, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 218-224

Feedback linearization has been used successfully to address some practical control problems. This paper introduces a practical control philosophy for a point-to-point HVdc link, based on the above principle. The basic dc link equation has been used to evaluate the firing angle for the rectifier. An Adaline has been trained to identify the parameters of the simplified system model prior to the application of this control. The simulation results presented in this paper proves the advantage of the proposed control scheme.

[1997] 05B - 5

A STUDY OF MARGIN ANGLE CONTROL TO THE CCC-HVDC SYSTEM

Watanabe, K.; Tanaka, K.; Funaki, T.; Matsuura, K

Osaka Univ, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, p 6.322

Japanese

Abstract not available.

[1996] 05B - 6

A STUDY ON COMPARATIVE ANALYSIS OF DIRECT CURRENT CONTROL IN A.C-D.C INTERCONNECTED POWER SYSTEM

Chong, H-H.; Wang, Y-P.; An, B-C.; Lee, K-W.

Dong-A Univ, Pusan, South Korea

Chongi Hakhoe Nonmunchi (Trans of the Korean Institute of Electrical Engineers) (Korea), vol 45, no 4, April 1996, pp 474-483

Korean

In this paper, as a part of the method improving stability, the load-flow calculation in dc power system and the models for stability analysis are studied with ac-dc interconnected power system transmission. Moreover, the theory is established in relation to each control method of dc power systems. Then the stability of ac-dc interconnected power systems is compared using various control modes. The dynamic characteristic of terminal voltage, frequency, active-reactive power and rotor angle of the generator with disturbances and load fluctuations are considered. A comparative analysis is made of the direct current control method and stability analysis of ac-dc interconnected power system. 24 refs., 10 figs., 2 tabs.

[1997] 05B - 7

A VARIABLE PULSE NUMBER PWM SCHEME FOR SELF-COMMUTATED HVDC SYSTEM

Nakajima, T.; Suzuki, H.; Shigeta, M.; Yamamoto, H.; Karube, T.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 79-84

Japanese

Large pulse number PWM (Pulse Width Modulation) is effective to improve transient performance of HVdc (High Voltage dc) transmission converter terminals. The large number of switching operations, however, cause large power losses and lowers efficiency of the converter. Variable pulse number PWM is a solution to the issue. This paper investigates the multiple space vector control which is one of the variable pulse number PWM techniques and discusses basic characteristics of the control to apply self-commutated HVdc transmission systems.

[1996] 05B - 8

ADMITTANCE RELAY HELPS WASH OUT

SYSTEM INSTABILITY

Sweezy, G.; Swift, G.; Zhang, Z.

Minnesota Power, Duluth, MN, USA

IEEE Computer Applications in Power, vol 9, no 1, January 1996, pp 48-52

The delta-current admittance relay (DCAR) has been successfully applied at the Forbes 500-kV switching substation for detecting severe power system disturbances and initiating fast power order reduction signal to Manitoba Hydro's Nelson River high voltage dc transmission system. Real-time testing and actual power system operation have verified the effectiveness of the DCAR algorithm as well as its hardware implementation.

[1996] 05B - 9

ADVANCED HVDC LINK CONTROL FOR DAMPING POWER SYSTEM OSCILLATIONS

Dash, P.K.; Mohapatra, A.; Liew, A.C.

Dept of Elec Eng, Regional Eng College, Rourketa, India

Electric Machines and Power Systems, vol 24, no 3, April-May 1996, pp 249-262

This paper presents a new approach to the design of an integrated ac/dc power system control scheme using variable structure systems theory based on the concepts of sliding mode control. The sliding mode control constrains the system motion to a state trajectory and provides greater robustness and insensitivity to plant parameter variations and is practically realizable. The paper highlights the designs of the dc link current regulator and gamma modulation controllers for fast transient stability control of an interconnected ac/dc power system. 11 Refs.

[1996] 05B - 10

ANALYSIS OF AN HVDC SYSTEM CONSIDERING VARIOUS CONTROLS

Tsukamoto, M.; Kawarai, H.; Honjo, N.; Mori, T.; Noro, Y.; Arai, J.

Shikoku Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 419-420

Japanese

Abstract not available.

[1998] 05B - 11

APPLICATION OF A RADIAL BASIS FUNCTION (RBF) NEURAL NETWORK FOR FAULT DIAGNOSIS IN AN HVDC SYSTEM

Narendra, K.G.; Sood, V.K.; Khorasani, K.; Patel, R.

Concordia Univ, Montreal, Quebec, Canada

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 177-183

The application of a radial basis function (RBF) neural network (NN) for fault diagnosis in an HVdc system is presented in this paper. To provide a reliable pre-processed input to the RBF NN, a new pre-classifier is proposed. This pre-classifier consists of an adaptive filter (to track the proportional values of the fundamental and average components of the sensed system variables), and a signal conditioner which uses an expert knowledge base (KB) to aid the pre-classification of the signal. The proposed method of fault diagnosis is evaluated using simulations performed with the EMTP package. 12 refs.

[1997] 05B - 12

AUTOMATIC FEEDBACK STRATEGY FOR REGULATION OF REAL AND REACTIVE POWER IN AN ASYNCHRONOUS LINK BASED ON A VOLTAGE-SOURCE MATRIX CONVERTER

Lu, B.; Kazerani, M.; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 2, pp 842-846

One application of the voltage-source, matrix converter is as an asynchronous link, joining two ac power systems with different frequencies (50 Hz/60 Hz), or at the same frequency (60 Hz/60 Hz) but at different phase angles. This paper shows that for this kind of link, there exists an automatic closed-loop feedback strategy to control the real and reactive powers quickly and independently. Digital simulations are presented. 9 Refs.

[1997] 05B - 13

BALANCE CONTROL OF DC VOLTAGES FOR SERIES CONNECTED SELF-COMMUTATED POWER CONVERTERS FOR HVDC TRANSMISSION

Nakajima, T.; Suzuki, K. Suzuki, H.; Shigeta, M.; Yamamoto, H.; Karibe, T.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 4, pp 4.265-4.266

Japanese

Abstract not available.

[1997] 05B - 14

CHARACTERISTICS ANALYSIS OF COOPERATIVE CONTROL FOR PARALLEL BTB SYSTEMS COMPOSED OF SELF-COMMUTATED CONVERTERS AND LINE-COMMUTATED CONVERTERS

Sugimoto, S.; Koda, I.; Konishi, H.; Kawazoe, H.

Chubu Elec Power Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 73-78

Japanese

Development of HVdc or back-to-back (BTB) systems composed of self-commutated converters (SCCs) are expected to be used in future power transmission systems and interconnections, since the SCC is capable of controlling active and reactive power independently. Parallel BTB systems, one of which consists of conventional line-commutated converters (LCCs) and the other of SCCs, are studied using EMTP simulations. In this paper, SCC control methods in cooperation with the LCC control were proposed and it was confirmed that the proposed cooperative control could make the LCC operation stable.

[1996] 05B - 15

CONTROL AND PROTECTION TECHNOLOGIES FOR DC POWER-TRANSMISSION SYSTEMS

Sato, M.; Murakami, H.; Honjo, N.; Hayashi, S.; Tamai, S.; Toki, N.

Kansai Elec Power Co, Inc, Japan

Mitsubishi Electric Review (Mitsubishi Denki Giho) (Japan), vol 70, no 5, 1996, pp 41-48

Japanese

Mitsubishi Electric has cooperated in the joint development of a power converter control system that can cope with harmonics or unbalanced ac voltages present during and immediately after ac power system faults. The system improves the performance of network control equipment and works in concert with generator control to increase power transmission reliability. Digital simulations were used to develop and test the system, and an analog simulator was constructed for testing a prototype control unit. The control equipment proved ready for practical service. 4 Refs.

[1997] 05B - 16

CONTROL SCHEME OF OVERCURRENT AND OVERVOLTAGE OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER

Takasaki, M.; Gibo, N.; Takenaka, K.; Konishi, H.; Tanaka, S.; Ito, H.

CRIEPI, Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.331-6.332

Japanese

Abstract not available.

[1997] 05B - 17

CONTROL STRATEGIES OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTERS. COMPOUND METHOD OF VOLTAGE DROP AND AVR

Suzuki, H.; Suzuki, K.; Sakamoto, K.; Ishii, J.; Tsumenaga, M.; Otsuki, M.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.327-6.328

Japanese

Abstract not available.

[1997] 05B - 18

CONTROL STRATEGIES OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTERS. ADJUSTMENT OF CONTROL GAIN FOR VOLTAGE DROP METHOD

Suzuki, H.; Suzuki, K.; Sakamoto, K.; Ishii, J.; Kawakami, N.; Karube, T.

Tokyo Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.325-6.326

Japanese

Abstract not available.

[1997] 05B - 19

CONTROL STRATEGIES OF SELF-COMMUTATED HVDC CONVERTER FOR ISOLATED SYSTEM OPERATION

Sugimoto S.; Koda I.; Otsuki M.; Tamura Y.

Chubu Elec Power Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 61-66

Japanese

A voltage-type self-commutated converter operates as an ac voltage source. Therefore, it is possible for it to behave stably by means of a suitable control when it is forced into sudden isolated operation. We have developed the control strategies of self-commutated converter for isolated operation and investigated it by digital simulations.

[1996] 05B - 20

CONTROLLER STRUCTURE AND DESIGN OF FIRING ANGLE CONTROLLERS FOR (UNIT CONNECTED) HVDC SYSTEMS

Rae, T.A.; Boje, E.; Jennings, G.D.; Harley, R.G.; Wishart, M.T.

Dept of Elec Eng, Natal Univ, Dalbridge, South Africa

Proceedings, IEEE 4th Conf in Africa (AFRICON'96), Stellenbosch, South Africa, September 24-27, 1996, vol 2, pp 856-863

This paper investigates the control of an HVdc link, fed from an ac source through a controlled rectifier and feeding an ac line through a controlled inverter. The overall objective is to maintain maximum possible link voltage at the inverter while regulating the link current. In this paper the practical feedback design issues are investigated with a view of obtaining simple, robust designs that are easy to evaluate for safety and operability. The investigations are applicable to back-to-back links used for frequency decoupling and to long dc lines. The design issues discussed include: (1) a review of overall system dynamics to establish the time scale of different feedback loops and to highlight feedback design issues; (2) the concept of using the inverter firing angle control to regulate link current when the rectifier firing angle controller saturates; and (3) the design issues for the individual controllers including robust design for varying line conditions and the trade-off between controller complexity and the reduction of nonlinearity and disturbance effects. 10 Refs.

[1996] 05B - 21

COUNTERMEASURES ON OVERVOLTAGE GENERATED NEARBY HVDC SYSTEMS DUE TO AC SYSTEM FAULT. (PART 1)

Matsushita, J.; Kawaji, A.; Kato, K.; Matori, I.; Komiya, Y.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 409-410

Japanese

Abstract not available.

[1996] 05B - 22

COUNTERMEASURES OF OVERVOLTAGE GENERATED NEARBY HVDC SYSTEMS DUE TO AC SYSTEM FAULT. (PART 2)

Matsushita, J.; Kawaji, A.; Kato, K.; Komiya, Y.; Matori, I.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 411-412

Japanese

Abstract not available.

[1996] 05B - 23

CURRENT-LOOP GAIN WITH A NONLINEAR COMPENSATING RAMP

Dong Tan, F.

TRW Inc, Redondo Beach, CA, USA

Conf Record, 27th IEEE Power Electronics Specialists Conf (PESC), Baveno, Italy, June 23-27, 1996, vol 1, pp 796-802

It is revealed for the first time that the crossover frequency of current-loop gain can be designed to be independent of duty ratio if a nonlinear compensating ramp, instead of a linear ramp, is used. This unique property allows current programming to be extended to (active) ac-to-dc and dc-to-ac power converters, where duty ratio is constantly changing. The basic principle behind this technique is first presented. Current-loop gain and the invariance of crossover frequency are then established. Measurement of current-loop gain for different values of duty ratio supports analytical predictions. 9 Refs.

[1996] 05B - 24

DAMPING CONTROL METHOD FOR DC POWER OSCILLATION IN HVDC SYSTEM FOLLOWING AC FAULT CLEARANCE

Nobayashi, M.; Tsukamoto, M.; Honjo, N.; Nishimura, M.; Kawamura, N.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 415-416

Japanese

Abstract not available.

[1997] 05B - 25

DECENTRALIZED ROBUST LOAD-FREQUENCY CONTROL IN COORDINATION WITH FREQUENCY-CONTROLLABLE HVDC LINKS

Lim, K.Y.; Wang, Y.; Zhou, R.

Nanyang Tech Univ, Singapore

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 7, October 1997, pp 423-431

A decentralized robust load-frequency controller (DRLFC), in coordination with auxiliary frequency controllers (AFCs), is introduced. It is designed for a power system comprising areas interconnected by normal tie-lines and frequency-controllable high-voltage direct current (HVdc) transmission links where AFCs are present. The bounds of system parameter uncertainties are also considered for robustness. The DRLFC comprises local load-frequency controllers, one for each area, which operates on its local measurements. Overall system stability, for all admissible uncertainties, is ensured when the DRLFC and the AFCs are in operation. The coordination among the DRLFC and AFCs is demonstrated by a three-area example system. 17 Refs.

[1996] 05B - 26

DESIGN AND TESTING OF THE BIPOLAR 12-PULSE HVDC PROTECTION SYSTEM

Fang, M.; Liang, D.; Jiang, S-F.; Ni, Y-X.

Academia Sinica, Beijing, China

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 2, pp 531-534

This paper presents a multiprocessor-based protection system for the bipolar 12-pulse high voltage direct current (HVdc) transmission, which is developed according to the operating requirements of Gezhouba to Shanghai (GS) HVdc project in China. For improved reliability, a two-level hierarchical multiprocessor architecture is used. The developed protection system covers all the protection functions of that imported from ABB Corporation and with a superior performance-to-price ratio. Besides, a new traveling wave protection is proposed to detect line faults. The simulation test showed that the protection system has improved performance and reliability. 5 Refs.

[1996] 05B - 27

DESIGN ASPECTS OF UPGRADATION FROM 6 PULSE TO 12 PULSE OPERATION OF NHVDC PROJECT

Singhal, A.; Gera, R.; Tripathy, A.K.; Adhikari, T.; Hanif, M.; Prakash, K.S.; Das, R.L.

Bharat Heavy Electricals Ltd, New Delhi, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 2, pp 1065-1070

In India, the first high voltage dc (HVdc) project was a back-to-back link between the Northern grid and the Western grid at Vindhyachal. The stage I of this National HVDC (NHVDC) project was successfully commissioned in October 1990, and has since operating satisfactorily. In continuation of this effort, India has approved a stage II project. A unique feature of this project over stage I will be the possibility of operating a 12-pulse system in either of the two six-pulse modes. Also, the control and protection systems for the two six-pulse will use different technologies. An effort has been made to include the new six-pulse into the existing six-pulse system with minimum changes in the latter. The final setup will greatly improve the reliability and availability of the HVdc system. 1 Refs.

[1996] 05B - 28

DEVELOPMENT OF A HYBRID MARGIN ANGLE CONTROLLER FOR HVDC CONTINUOUS OPERATION

Sato, M.; Yamaji, K.; Sekita, M.; Amano, M.; Nishimura, M.; Konishi, H. ; Oomori, T.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 1792-1798

The objective of this paper is to present a new hybrid margin angle control method for HVdc continuous operation under ac system fault conditions. For stable continuous operation of HVdc systems, the margin angle controller must be designed to maintain the necessary margin angle to avoid commutation failures. The proposed method uses the open loop margin angle controller (MAC) as the basic controller, and adds output from the closed loop MAC to correct the control angle. A fast voltage detection algorithm is used for open loop control, and margin angle reference correction using harmonics detection for closed loop control are also developed. The combination of open and closed loop control provides quick responses when faults occur with stable and speedy recovery after fault clearance. The effectiveness of the developed controller is confirmed through EMTP digital simulations and also with the experiments using an analog simulator. 7 Refs.

[1996] 05B - 29

DEVELOPMENT OF CONTROL FOR SELF-COMMUTATED CONVERTER. (PART I). DEVELOPMENT OF SIMULATOR MODEL AND STUDY ON CONVERTER OVERCURRENT IN AC SYSTEM FAULT CONDITION

Takasaki, M.; Gibo, N.; Takenaka, K.

CRIEPI, Tokyo, Japan

Denryoku Chuo Kenkyujo Komae Kenkyujo Hokoku (Japan), no T95073, 41 pp

Japanese

Application of self-commutated converter to the future trunk power system is expected as an effective measure for enhancing transmission capability and overall control performance. It is important to develop a stable control scheme for various system faults as well as to consider converter losses and cost reductions. This report first describes component configuration and functional feature of newly developed self-commutated converter model for ac-dc power system simulator, then discusses the cause of converter overcurrent of self-commutated HVdc system in ac system fault condition and its control scheme through simulator test. (1) Development of self-commutated converter model. Subjects to be developed using the simulator had been clarified prior to designing and manufacturing the self-commutated converter model. Functions such as the availability to implement user-defined control and the capability to change between 21- & 9-pulse operation are equipped to investigate the principal research items which contain the control of converter overcurrent and overvoltage. (2) Cause of converter overcurrent and its control scheme. Converter overcurrent in ac system fault condition is mainly caused by the saturation of the converter current control input signal detected at ac system unbalanced fault. Overcurrent control can be realized through the adequate processing of input signal into converter control.

[1996] 05B - 30

DEVELOPMENT OF DC CONTROL FUNCTION. DEVELOPMENT OF UNINTERRUPTED CONTROL IN CASE OF AS SYSTEM ACCIDENT

Nobayashi, M.

Kansai Elec Power Co, Inc, Osaka, Japan

R and D News Kansai (Japan), vol 345, July 10, 1966, pp 29-31

Japanese

Control method for dc systems enabling uninterrupted operation in case of ac system accident was developed for application to the Kii channel dc linkage. In case of an accident in the ac system, there emerge a voltage drop, voltage phase deviation, and waveform deformation due to harmonics in the ac/dc converter plant bus-bar voltage. For the purpose of coping with such troubles, three methods were developed and verified. In a closed loop AγR method, the thyristor valve reverse voltage period is directly detected, and the obtained value is treated as an object of feedback. In an adaptive AγR method, the conventional open loop-type control is combined with a closed loop-type control using the reverse voltage time. A high-speed open loop AγR method is a higher-speed version of the conventional AγR in which not only the ac voltage magnitude but also the phase and harmonics are detected, and the control angle is so adjusted that a proper allowance angle will be assured. For each of the three methods, performance was confirmed by simulation analysis. Serviceability was also confirmed, by use of experimentally built devices, by manufacturers' simulators and by the advanced power system analyzer of Technical Research Center of The Kansai Electric Power Co., Ltd. 8 figs.

[1997] 05B - 31

ENHANCING TRANSIENT STABILITY BY SUPPLEMENTARY DC DAMPING CONTROL OF AN HVDC CONVERTER

Hammons, T.J.; Sim, K.Y.; Kacejko, P.A.

Univ of Glasgow, UK

Proceedings, 32nd Univertsities Power Engineering

Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 621-625

This paper describes a new method of control of power flow of an HVdc transmission link which connects two arid networks asynchronously to enhance transient stability of a power system. The study is undertaken first on an elementary single machine infinite busbar system, then on a mirror image system to check whether the computer programs are functioning correctly and finally on a multi-machine benchmark system (modified CIGRE system). Comparisons are made using HVdc control and power system stabilizer and other controls to compare quality of control and transient system performance. Comparisons are made by studying critical fault clearing times and system damping. Algorithms are based on readily available system variables using linear theory. 4 Refs.

[1997] 05B - 32

FAST AND PREDICTIVE HVDC EXTINCTION ANGLE CONTROL

Tamai, S.; Naitoh, H.; Ishiguro, F.; Sato, M.; Yamaji, K.; Honjo, N.

Mitsubishi Elec Corp, Hyogo, Japan

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1268-1274

This paper proposes unique dc control strategies to prevent dynamic commutation failures during and following faults, and to obtain better recovery from the faults. The strategy is based on an idea of sine-cosine components detector in which ac voltages are detected fast in terms of two components on the rotational reference frame synchronized with an ac system frequency. The controller quickly predicts a necessary control angle according to the magnitude, the phase angle, and involved harmonics that are calculated from these two components. The validity and effectiveness of the controller are confirmed through the EMTP simulations. The dc simulator results using the fabricated controller confirm the EMTP simulations. 6 Refs.

[1996] 05B - 33

FAULT DETECTION AND DIAGNOSIS OF POWER CONVERTERS USING ARTIFICIAL NEURAL NETWORKS

Swarup, K.S.; Chandrasekharaiah, H.S.

Indian Inst of Sci, Bangalore, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 2, pp 1054-1058

Fault detection and diagnosis in real-time are areas of research interest in knowledge-based expert systems. Rule-based and model-based approaches have been successfully applied to some domain, but are too slow to be effectively applied in a real-time environment. This paper explores the suitability of using artificial neural networks for fault detection and diagnosis of power converter systems. The paper describes a neural network design and simulation environment for real-time fault diagnosis of thyristor converters used in HVdc power transmission systems. 13 Refs.

[1997] 05B - 34

FUZZY LOGIC CONTROL FOR HVDC TRANSMISSION

Daneshpooy, A.; Gole, A.M.; Chapman, D.G.; Davies, J.B.

Univ of Manitoba, Winnipeg, Canada

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1690-1697

The conventional proportional-integral-type control system loops for the current and extinction angle controllers in high voltage dc converters are replaced with fuzzy logic-based controls. The two approaches are compared using simulations on an electromagnetic transients simulation program. A method to further refine the fuzzy logic formulation to improve the transient response is presented. The results show that the fuzzy logic-based approach can provide, at the minimum, a marginal improvement over the P-I-based controller. 11 Refs.

[1997] 05B - 35

FUZZY LOGIC CONTROL OF HIGH VOLTAGE DC TRANSMISSION SYSTEM

Olcer, E.; Karagoz, B.; Dincer, H.; Ozdemir, E.; Karakas, E.; Reusch, B.

Dept of Computer Sci Eng, Kocaeli Univ, Izmir, Turkey

Proceedings, Computational Intelligence Theory and Applications. Int'l Conf, 5th Fuzzy Days, Dortmund, Germany, April 28-30, 1997, pp 492-500

The paper introduces a fuzzy controller for the rectifier side in a high voltage direct current (HVdc) system. The rectifier side of the typical point-to-point system has been given special consideration. In the rectifier,

thyristors are used as control devices that can handle high voltage and power. Turn on, turn off triggering and protection of these devices have lots of problem and are very sensitive. These problems appear upon changing voltage and frequency. Therefore, the dc current of the rectifier output becomes unstable. Device dissipation, transmission losses and environment effects exacerbate these problems. A fuzzy controller is designed to solve these problems. Finally, a comparative study has been performed with and without fuzzy control.

[1996] 05B - 36

FUZZY SELF-TUNING PI CONTROLLER FOR HVDC LINKS

Routray, A.; Dash, P.K.; Panda, S.K.

Regional Eng College, Rourkela, India

IEEE Trans on Power Electronics, vol 11, no 5, September 1996, pp 669-679

This paper introduces a fuzzy logic-based tuning of the controller parameters for the rectifier side current regulator and inverter side gamma controller in a high voltage direct current (HVdc) system. A typical point-point system has been taken with the detailed representation of converters, transmission links, transformers, and filters. The current error and its derivative and the gamma error and its derivative are used as the principal signals to adjust the proportional and integral gains of the rectifier pole controller and the inverter gamma controller, respectively, for the optimum system performance under various normal and abnormal conditions. Finally, a comparative study has been performed with and without tuning, to prove the superiority of the proposed scheme. 10 Refs.

[1996] 05B - 37

GAIN SCHEDULING ADAPTIVE CONTROL STRATEGIES FOR HVDC SYSTEMS USING FUZZY LOGIC

Dash, P.K.; Routray, A.; Panda, S.K.

Regional Eng College, Rourkela, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 134-139

The paper introduces different types of fuzzy tuning methods for the controller parameters of the firing and extinction angle controller of an HVdc link. The test system, a point-to-point dc link has been subjected to various small and large disturbances to examine the effectiveness of the proposed schemes. The current error and its derivative in case of rectifier and the gamma error and its derivative in case of the inverter are taken as the two principal signals to generate the change in the proportional and the integral gains according to a definite rule base. The results obtained have been compared graphically to prove the superiority of the proposed controllers. 10 Refs.

[1996] 05B - 38

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

Lindberg, A.; Lindberg, L.

Royal Inst of Tech, Stockholm, Sweden

Int'l Journal of Electronics, vol 80, no 2, February 1996, pp 377-390

In high-power applications, i.e., HVdc and SVC, the coupling between rating, performance and utilization is of high interest. Therefore, the performance of inner current loop control for large voltage source converters is studied with respect to the ability to limit the converter current during disturbances in the supplying ac network. The disturbance studied here is the impact of a phase shift in the ac bus voltage that can occur at line disconnections. A comparison is made between whether the inner current loop is implemented in either the alpha beta-plane or the rotating dq-plane. The influences of an extra time delay introduced using digital control and the sample period (pulse number) are also evaluated. Results are presented from dynamical studies, using both digital simulations and real-time analog simulations with a digital control system. The simulations verify that the ability of the implemented inner current loop to limit the converter current during a phase shift in the line voltage is highly dependent on the chosen sample period (i.e., switching frequency). 13 refs.

[1997] 05B - 39

HVDC CONVERTER CONTROL FOR FAST POWER RECOVERY AFTER AC SYSTEM FAULT

Sato, M.; Honjo, N.; Yamaji, K.; Yoshino, T.; Arai, J.

Kansai Elec Power Co, Inc, Osaka, Japan

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1319-1326

This paper describes an elementary control system that enhances ac system stabilization by HVdc. This control system focuses on HVdc power recovery after the ac system fault. The control function has been developed through digital simulation. Finally, a prototype controller with this control function has been evaluated by simulator tests. The digital simulation results and the simulator test results were consistent and the control function was verified to be applicable to an actual HVdc project. 7 Refs.

[1996] 05B - 40

HVDC PROTECTION SYSTEM BASED MULTIPROCESSOR

Fang, M.; Jiang, S-F.; Jiao, L-W.; Chen, S-S.; Zhang, W.; Guo, H-G.; Chen, J.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 619-623

In this paper, a multiprocessor-based protection system for the bipolar 12-pulse high voltage direct current (HVdc) transmission is described, which is developed according to the operating requirements of Gezhouba to Shanghai (GS) HVdc project in China. The developed protection system is based on a two-level hierarchical multiprocessor architecture, and covers all the protection functions of the imported HVdc protection system from ABB Corporation with a superior performance to price ratio. The extensive test on an advanced HVdc has been made, and the results prove that the system scheme is feasible and the developed prototype can meet the needs of the real HVdc project. This paper describes the basic hardware and software constructions. The typical test results for line faults are also reported and analyzed in detail. 6 Refs.

[1998] 05B - 41

INFLUENCE OF LOAD CHARACTERISTICS ON THE POWER/VOLTAGE STABILITY OF HVDC SYSTEMS, PART 1: BASIC EQUATIONS AND RELATIONSHIPS

Aik, D.L.H.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

Recently, the influence of load characteristics on the power stability of a specific HVdc system configuration had been shown. This points to a more fundamental influence of load characteristics on the power/voltage stability of HVdc systems in general. Thus, a fundamental analysis of the influence of load characteristics on the power/voltage stability of three typical HVdc system configurations is carried out in this two-part work. Three aspects are treated: (1) the basic power/voltage stability equations incorporating load characteristics, the effect of load characteristics and system parameters; (2) the relationships between the maximum power and voltage sensitivity-based methods for all the configurations incorporating load characteristics; (3) the most unfavorable load characteristics with respect to degrading power/voltage stability margins and the sensitivity of these margins to load characteristics. This paper, which constitutes part 1 of the work, presents (1) and (2), while a companion paper dealt with (3).

[1998] 05B - 42

INFLUENCE OF LOAD CHARACTERISTICS ON THE POWER/VOLTAGE STABILITY OF HVDC SYSTEMS, PART 2: STABILITY MARGIN SENSITIVITY

Aik, D.L.H.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998, Preprint order number PE-270-PWRD-0-12-1997

Recently, the influence of load characteristics on the power stability of a specific HVdc system configuration had been shown. This points to a more fundamental influence of load characteristics on the power/voltage stability of HVdc systems in general. Thus, a fundamental analysis of the influence of load characteristics on the power/voltage stability of three typical HVdc system configurations is carried out in this two-part work. Three aspects are treated: (1) the basic power/voltage stability equations incorporating load characteristics, the effect of load characteristics and system parameters; (2) the relationships between the maximum power and voltage sensitivity-based methods for all the configurations incorporating load characteristics; (3) the most unfavorable load characteristics with respect to degrading power/voltage stability margins and the sensitivity of these margins to load characteristics. This paper, which constitutes part 2 of the work, presents (3), while the first paper dealt with (1) and (2).

[1997] 05B - 43

INSPECTION OF SELF-COMMUTATED HVDC SYSTEM CONNECTED WITH LINE-COMMUTATED HVDC SYSTEM IN PARALLEL

Sugimoto, S.; Koda, I.; Otsuki, M.; Tamura, Y.

Chubu Elec Power Co, Ltd, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 443-444

Japanese

Abstract not available.

[1997] 05B - 44

INTELLIGENT CURRENT CONTROLLER FOR AN HVDC TRANSMISSION LINK

Narendra, K.G.; Khorasani, K.; Sood, V.K.; Patel, R.V.

Concordia Univ, Montreal, Quebec, Canada

Proceedings, 20th IEEE Int'l Conf on Power Industry Computer Applications, Columbus, OH, May 11-16, 1997, pp 67-74 (Preprint order number PE-188-PWRS-16-09-1997)

This paper describes an intelligent current controller for the fast and flexible control of an HVdc transmission link using artificial neural network (ANN) and fuzzy logic (FL) paradigms. A simple yet effective ANN architecture is presented with on-line adaptation of the activation function and learning parameters. Two methods of adapting the learning parameters are presented. In the first method, a heuristic approach to evaluate the learning rate as a polynomial of an energy function is considered. In the second method, a FL-based on-line adaptation of the learning parameters is discussed. Performance of ANN, ANN-FL-based and PI controllers are compared. A feasibility analysis is carried out to implement the proposed neural controller algorithm in real-time. 12 Refs.

[1998] 05B - 45

INVERTER CONTROLLER FOR VERY WEAK RECEIVING AC SYSTEMS

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

Provisional patent document no 329981, March 1998, New Zealand Ministry of Commerce Patent Office

This document describes a novel HVdc inverter control strategy aimed primarily for HVdc operation with very weak receiving ac systems. The new control method consists of an additional inverter feedback loop with a second order feedback filter. The controller can significantly improve the system dynamic performance, by eliminating the critical oscillatory mode (2-7 Hz), when the inverter ac system has very low SCR. The controller is tested on CIGRE HVdc Benchmark Model. The simulation results show that the system has satisfactory dynamic responses with SCR as low as SCR=1.0. The controller also significantly improves the system robustness to the changes in ac system parameters.

[1997] 05B - 46

INVESTIGATION INTO AN ARTIFICIAL NEURAL NETWORK BASED ON-LINE CURRENT CONTROLLER FOR AN HVDC TRANSMISSION LINK

Narendra, K.G.; Sood, V.K.; Khorasani, K.; Patel, R.V.

Concordia Univ, Montreal, Quebec, Canada

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1425-1431

An artificial neural network (ANN)-based current controller for an HVdc transmission link is described in this paper. Different ANN architectures and activation functions (AFs) are investigated for this ANN controller. Small (set current change) and large (dc-line fault) signal perturbations are applied to optimize the learning parameters for the controller. Performance evaluation of the ANN controller under noise conditions is studied. A comparison between a traditional PI and the proposed ANN controller is made for various system contingencies and it is shown that the latter has many attractive features. 11 Refs.

[1997] 05B - 47

MARGIN ANGLE CONTROL ON CCC-HVDC AND ITS PARTICIPATION WITH OPERATING PARAMETERS

Watanabe, K.; Funaki, T.; Matsuura, K.

Osaka Univ, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 389-390

Japanese

Abstract not available.

[1996] 05B - 48

MICROPROCESSOR BASED HVDC CONVERTER PROTECTION

Madan, S.; Bollinger, K.E.; Banerjee, S.K.

Univ of Alberta, Edmonton, Canada

Proceedings, Canadian Conf on Electrical and Computer Engineering (CCECE'96), Calgary, Canada, May 29-29, 1996, vol 2, pp 750-753

High voltage direct current (HVdc) transmission system complements the characteristics of existing ac networks. One big advantage is the ability to control power between the sending and the receiving end. This paper describes the development of a microprocessor-based dedicated protection unit for converter protection and dc line to ground fault. 7 Refs.

[1997] 05B - 49

MODERN MAN-MACHINE INTERFACE FOR HVDC SYSTEMS

Laursen, O.; Bjorklund, H.; Stein, G.

ABB Power Sys AB, Ludvika, Sweden

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

The relevance of a well designed and flexible man machine interface (MMI) is obvious when it comes to more demanding application areas such as HVdc power transmission. Conveying the information to the operator in a comprehensive yet systematic way is of great importance. The new generation of integrated MMI adopted by ABB Power Systems, the station control and monitoring (SC) system, employs the most advanced software concepts with regard to system openness and flexibility as well as ergonomic aspects. Distributed over an Ethernet LAN, the Windows NT-based OWSs are characterized by high performance and an open software architecture based on the latest trends in data engineering supporting TCP/IP, SQL and DDE. The SCM system integrates a large number of features, such as: Control of the HVdc from process images; sequence of event recorder; archiving of events; powerful alarm handling via list windows; effective user defined data filtering; flexible handling of both on-line and historical trends; on-line help functions and direct access to plant documentation; TFR analysis; remote control; instant access to standard applications such as e-mail, word processing, spreadsheet, internet; automatic performance report generation; developed with most versatile graphical on the market, InTouch.

[1996] 05B - 50

MODERN CONTROL AND PROTECTION SYSTEM FOR HVDC

Karlsson, T.; Hyttinen, M.; Carlsson, L.; Bjorklund, H.

ABB Power Sys AB, Ludvika, Sweden

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1163-1167

For high voltage direct current (HVdc) applications, the control and protection system plays an essential role in the overall performance of the transmission system. The control and production system adopted by ABB Power Systems uses the latest technology from the fields of electronics and microprocessors. The main objective of this paper is to describe the experience from using the MACH (modular advanced control for HVdc) system with Base Design, from development, design, implementation and testing to commercial use. MACH is a fully computerized control and protection system. Base Design is the internal name of a complete well-proven platform for the implementation of the control and protection system for an HVdc project, including the method of working of such a project. 0 Refs.

[1998] 05B - 51

MULTIPLE SPACE VECTOR CONTROL FOR SELF-COMMUTATED POWER CONVERTERS

Nakajima, T.; Suzuki, H.; Sakamoto, K.; Shigeta, M.; Yamamoto, H.; Miyazaki, Y.; Tanaka, S.; Saito, S.

Tokyo Elec Power Co, Inc, Yokohama, Japan

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

This paper proposes the multiple space vector control strategy for self-commutated converters. The strategy makes it possible to realize a significant reduction in power losses with lowest possible switching frequency in steady state, continuous operation with high-speed tracking of commands in the transient state and flexible controls with the utilization of degrees of freedom in the assignment of voltage vectors to the converters. High efficiency of the strategy is confirmed by experiments in which two-pulse switching mode and the speed of response in 5 ms, with one side model of the converter terminals of self-commutated HVdc. The continuous operation is verified by simulations in a one-line ground fault. Another simulation based on the unbalanced dc voltages shows the balance control of dc voltages to be effective in HVdc transmission with self-commutated

converters connected in series on the ac and dc sides.

[1996] 05B - 52

NEW CLOSED LOOP CONTROL METHOD FOR HVDC TRANSMISSION

Karlecik-Maier, F.

Siemens AG, Erlangen, Germany

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1955-1960

The paper presents a new closed loop control method which uses information locally available at each converter station and combines and coordinates control possibilities with the objective of improving the dynamic behavior during fault recoveries and disturbances around the operating points. 2 Refs.

[1998] 05B - 53

NOVEL CURRENT CONTROLLER FOR ELIMINATION OF DOMINANT OSCILLATORY MODE ON AN HVDC LINE

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

A procedure for designing a novel HVdc current controller is presented. The proposed controller makes HVdc system performance less prone to fundamental frequency oscillations on a dc line, and thus less susceptible to the second harmonic instability. The design is based on a linearized ac/dc system model and on the pole-placement technique. Controller performance is tested against the CIGRE HVdc Benchmark Model using the EMTDC/PSCAD simulation package. It is demonstrated that this controller eliminates the dominant oscillatory mode on the dc side, and that it gives a significant improvement in system response, even for low SCR ac systems.

[1997] 05B - 54

OVERCURRENT CONTROL COMPENSATING NEGATIVE CURRENT COMPONENT FOR HVDC WITH SELF-COMMUTATED CONVERTER

Kibo, N.; Takasaki, M.; Hayashi, T.; Konishi, H.; Tanaka, S.

CRIEPI, Tokyo, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 67-71

Japanese

Self-commutated devices have been studied extensively . Control and protection development requires numerical simulation using highly detailed models.

[1997] 05B - 55

OVERCURRENT PHENOMENA FOR HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER

Gibo, N.; Takasaki, M.; Takenaka, K.; Konishi, H.; Tanaka, S.; Ito, H.

CRIEPI, Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.329-6.330

Japanese

Abstract not available.

[1996] 05B - 56

PERFECTION OF THE COMPUTER AUTOMATIC CONTROL FUNCTION IN GESHANG HVDC CONVERTER STATIONS

Liu, G-Y.; Lou, D-Q.; Dai, Y-J.

Gezhouba Hydraulic Power Plant Converter Station, Yichang, China

Automation of Electric Power Systems (China), vol 20, no 9, September 1996, pp 64-65, 73

Chinese

This paper describes the function of the power setting generators (PSG) installed in the power converter substations of the Geshang HVdc transmission project, China. The PSG have played an important part in the perfection of computer control methods and the realization of load dispatch automation. 0 Refs.

[1997] 05B - 57

PHASE ROOT LOCUS APPROACH TO DESIGN ROBUST CONTROLLERS FOR POWER SYSTEMS

Jones, L.E.; Herbig, A.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

Proceedings, 32nd Univertsities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 519-522

This paper demonstrates the use of phase-root locus

(PRL) as a graphical tool for designing robust auxiliary controllers to improve the stability and performance of power systems. PRL provides a means to study how the phase margin, hence robustness of stability and performance, is affected by changes in the phase of the closed-loop system. The main points about plotting PRL are explained as well as the relationships to the well-known Nyquist and Bode plots. In addition, related robustness issues are discussed. To illustrate the use of PRL, a supplementary controller for HVdc power modulation is designed for a test power system. 5 Refs.

[1997] 05B - 58

PROTECTION SYSTEM OF KII CHANNEL HVDC LINK

Sato, M.; Murakami, H.; Honjo, N.; Yoshizumi, T.; Kawamura, N.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Hogo Rire Shisutemu Kenkyukai Shiryo (Japan), vol 97, no 10-17, pp 19-24

Japanese

This paper presents a summary of the protection scheme for the Kii Channel HVdc Link commissioned in the year 2000. The summary describes technical features and new developments on the protection for dc transmission line, return neutral line and pole/group convertors, including cooperative dc blocking and ac tripping sequence.

[1996] 05B - 59

REACTIVE POWER COMPENSATION OF HVDC CONVERTER BY FORCED COMMUTATION SVC. BEHAVIOR IN UNBALANCED FAULT CONDITION

Funaki, T.; Matsuura, K.; Xu, X.; Kimura, N.

Osaka Univ, Japan

National Convention Record, IEE Japan, Industry Applications Society (Denki Gakkai Sangyo Oyo Bumon Zenkoku Taikai Koen Ronbunshu), vol 1996, pt 2, p T.27

Japanese

Abstract not available.

[1996] 05B - 60

SELECTING ROBUST INPUT SIGNALS FOR HVDC DAMPING CONTROLLERS

Jones, L.E.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 152-156

A systematic procedure for selecting robust input signals for HVdc damping controllers is presented in this paper. A set of robust signal candidates are identified by applying quantitative measures of modal controllability and observability. The criteria for selecting the robust signals from the set are formulated on the basis of generic power system stability properties, linear control theory, requisites imposed by physical constraints, and rules of thumb. The procedure follows the conventional approach to determine robustness which involves repeated small-signal analysis of a power system over a range of operating conditions. The steps in the procedure are discussed briefly. A simplified ac/dc test system is used to illustrate the procedure. 11 Refs.

[1997] 05B - 61

SELF-TUNING FUZZY LOGIC CONTROLLERS USING GENETIC ALGORITHM: HVDC SYSTEM APPLICATION

Yoon, J.Y.; Park, D.W.; Hwang, G.H.; Park, J.H.

Korea Electrotech Research Inst, Changwon, South Korea

Proceedings, 1997 Conf on Intelligent System Applications to Power Systems (ISAP '97), Seoul, South Korea, July 6-10, 1997, pp 291-295

This paper presents an optimal design method for fuzzy logic controllers using genetic algorithms in an HVdc power system. Fuzzy logic controllers are applied for the fast damping of dynamic disturbances such as sudden changes of ac system loads. The dynamic performance of fuzzy logic controllers is compared with that of PI controllers. In both controllers, the genetic algorithm is used for tuning membership functions and PI gains. Simulation results show that the dynamic performances of fuzzy controllers have better responses than those of PI controllers when the ac system load changes.

[1997] 05B - 62

STUDY ON CALCULATION TIME OF SELF-COMMUTATED CONVERTER CONTROLLER FOR HVDC SYSTEM

Hayashi, T.; Takasaki, M.; Konishi, H.; Kawazoe, H.

CRIEPI, Tokyo, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku,

Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 447-448

Japanese

Abstract not available.

[1997] 05B - 63

STUDY ON ROBUST MULTIVARIABLE EMERGENCY FREQUENCY CONTROL BY HVDC

Kawarai, H.; Tsukamoto, M.; Sekita, M.; Amano, M.; Sekoguchi, M.; Shimamura, H.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.333-6.334

Japanese

Abstract not available.

[1996] 05B - 64

THE APPLICATION OF VDCOL FOR OVERVOLTAGE LIMITING CONTROL UNDER ABNORMAL INVERTER GATE BLOCK IN HVDC TRANSMISSION

Tanaka, M.; Yamaji, K.; Hatano, M.; Kuroda, K.; Morishima, N.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 407-408

Japanese

Abstract not available.

[1996] 05B - 65

THEORETICAL ANALYSIS OF STEADY-STATE PERFORMANCE OF UNSYMMETRICALLY OPERATED AC/DC INTERCONNECTOR

Emarah, A.S.; El-Sharkawy, M.A.; Migalla, G.R.; Yassin, I.; Swidan, M.A.

Ain-Shams Univ, Cairo, Egypt

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 1, pp 187-190

This paper presents a theoretical analysis of three-phase steady state performance of ac/dc power systems under unbalanced loading. New equations relating converter dc voltage, currents and extinction angles are obtained assuming unbalanced ac voltages. In the analysis performed, two types of dc controls are used: namely individual phase control (IPC) and equidistant pulse control (EPC). A three-phase simulation program based on phase-coordinates is used to check the steady-state performance obtained for the converter using the developed model. Both approaches have been applied for a study system consisting of two ac systems interconnected by a dc link. The results obtained using both approaches show good agreement. 8 Refs.

[1996] 05B - 66

TIAN-GUANG HVDC TRANSMISSION PROJECT FUNDAMENTAL FREQUENCY OVERVOLTAGE AND OVERVOLTAGE LIMITING MEASURES FOR TIANSHENGQIAO CONVERTER STATION

Quan, B-L.; Zhu, X-Q,; Burton, R.S.

Central Southern China Elec Power Design Inst, Wuhan, China.

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 112-117

For the Tian-Guang HVdc transmission project, the fundamental frequency overvoltages, which can occur as a result of partial or complete interruption to transmitted power, play an important role in the design and operation of the converter at Tianshengqiao. The paper describes some of the operating conditions which may result in high values of overvoltages along with solutions and trade-offs which were adopted to limit the overvoltages to acceptable levels. 0 Refs.

[1997] 05B - 67

TRENDS AND DEVELOPMENTS OF HVDC CONVERTER CONTROL AND PROTECTION

Yoshino, T.; Noro, Y.; Irokawa, S.

Toshiba Corp, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp S.23.9-S.23.12

Japanese

Abstract not available.

[1997] 05B - 68

WIDE-AREA PROTECTION AGAINST VOLTAGE COLLAPSE

Ingelsson, B.; Lindstrom, P.-O.; Karlsson, D.; Runvik, G.; Sjodin, J.-O.

Svenska Kraftnat, Sweden

IEEE Computer Applications in Power, vol 10, no 4, October 1997, pp 30-35

A wide-area protection system against long-term voltage collapse was designed, implemented, tested, modified, and commissioned. The system is based on the SCADA system in southern Sweden, which has been complemented with input signals and equipment to execute action orders from the protection system. Bus voltages from the transmission system, reactive power output from generators, and current limiter information from main generators were used as input signals to the wide-area protection system. Actions from the protection system are shunt reactor disconnection/capacitor connection, start of gas turbines, emergency power request from the HVdc connection to Germany, low priority load disconnection, and shedding of high priority load.

[1996] 05B - REF

APPLICATION AND OPERATING EXPERIENCE OF MULTI-VARIABLE FREQUENCY CONTROLLER OF HVDC SYSTEM

For Abstract see entry 01B - 5

[1996] 05B - REF

MORE HVDC TRANSMISSION PROJECTS BY TECHNICAL BREAKTHROUGH

For Abstract see entry 01C - 20

[1997] 05B - REF

NEW DC CONTROL AND OPERATOR INTERFACE FOR THE CAHORA BASSA HVDC SYSTEM

For Abstract see entry 01C - 21

[1997] 05B - REF

OPERATING EXPERIENCE OF HOKKAIDO-HONSHU HIGH VOLTAGE DIRECT CURRENT LINK

For Abstract see entry 01C - 25

[1997] 05B - REF

CAHORA BASSA GMPC TESTING USING AN REAL TIME DIGITAL SIMULATOR

For Abstract see entry 01C - 8

[1997] 05B - REF

CAPACITOR COMMUTATED CONVERTERS FOR HVDC SYSTEMS

For Abstract see entry 02B - 1

[1996] 05B - REF

SAFETY AND SIGNALING UNIT FOR THE FILTRATION AND COMPENSATION CIRCUITS OF THE VYBORGSK SUBSTATION

For Abstract see entry 02D - 24

[1996] 05B - REF

MICROPROCESSOR CONTROL AND SAFETY SYSTEM FOR A 24-PHASE RECTIFIER-INVERTER MODULE

For Abstract see entry 05A - 13

[1996] 05B - REF

SIMULATION STUDY OF AN HVDC SYSTEM COMPOSED OF SELF-COMMUTATED CONVERTERS

For Abstract see entry 05A - 19

[1997] 05B - REF

SPACE VECTOR PATTERN GENERATORS FOR MULTI-MODULE LOW SWITCHING FREQUENCY HIGH POWER VAR COMPENSATORS

For Abstract see entry 05A - 20

[1998] 05B - REF

DEVELOPMENT OF A CONTROL SYSTEM FOR A HIGH-PERFORMANCE SELF-COMMUTATED AC/DC CONVERTER

For Abstract see entry 05A - 8

[1996] 05B - REF

EFFECT OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER FOR ENHANCING TRANSMISSION CAPABILITY

For Abstract see entry 05C - 11

[1996] 05B - REF

IMPACT OF OPTIMAL CONTROL OF HVDC

CONVERTERS ON TRANSIENT STABILITY OF MULTI-MACHINE POWER SYSTEMS

For Abstract see entry 05C - 13

[1997] 05B - REF

INVESTIGATION OF NONLINEAR MODAL BEHAVIOR OF HVDC/AC POWER SYSTEMS THROUGH A SCANNING TOOL VIA NORMAL FORM TECHNIQUE

For Abstract see entry 05C - 15

[1996] 05B - REF

ON LINE IDENTIFICATION AND CONTROL OF AN AC/DC POWER SYSTEM

For Abstract see entry 05C - 18

[1997] 05B - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. POWER SWING DAMPING CONTROL BY HVDC POWER MODULATION IN AC/DC HYBRID TRANSMISSION SYSTEM

For Abstract see entry 05C - 21

[1996] 05B - REF

A STUDY ON LOAD FREQUENCY CONTROL OF AC-DC POWER TRANSMISSION USING FUZZY CONTROL

For Abstract see entry 05C - 3

[1996] 05B - REF

MODELLING OF CURRENT CONTROL IN THE ANALYSIS OF HARMONIC INTERACTIONS IN HVDC SYSTEMS

For Abstract see entry 05D - 20

[1997] 05B - REF

CONTROL OF 100-Hz GAMMA OSCILLATIONS ON NEW ZEALAND HVDC LINK

For Abstract see entry 05D - 6

[1996] 05B - REF

DAMPING OF TORSIONAL OSCILLATIONS IN A PARALLEL AC/DC SYSTEM USING AN ARTIFICIAL NEURAL NETWORK TUNED SUPPLEMENTAL SUBSYNCHRONOUS DAMPING CONTROLLER

For Abstract see entry 05D - 8

[1997] 05B - REF

DEVELOPMENT OF CONTROL FOR SELF-COMMUTATED CONVERTER. (PART II). CONTROL SCHEME OF OVERCURRENT AND OVERVOLTAGE AT SYSTEM FAULT CONDITION

For Abstract see entry 05H - 3

[1996] 05B - REF

SEISMIC EXPERIMENT OF FRP COLUMNS IN A THYRISTOR VALVE BY A REAL-TIME HYBRID VIBRATION TESTING METHOD

For Abstract see entry 05N - 2

[1996] 05B - REF

STABILITY ANALYSIS OF HVDC SYSTEM CONNECTED TO WEAK AC SYSTEMS

For Abstract see entry 06A - 2

[1997] 05B - REF

VALIDATING THE REAL TIME DIGITAL SIMULATOR FOR HVDC DYNAMIC PERFORMANCE STUDIES

For Abstract see entry 06E - 12

[1997] 05B - REF

ADVANCED AC/DC REAL-TIME AND COMPUTER SIMULATIONS FOR THE GMPC CAHORA BASSA DESIGN VERIFICATION

For Abstract see entry 06E - 2

[1997] 05B - REF

AN INTEGRATED SIMULATION AND CONTROL IMPLEMENTATION ENVIRONMENT

For Abstract see entry 06E - 3

[1998] 05B - REF

DISSIPATIVITY AS A UNIFYING CONTROL DESIGN FRAMEWORK FOR SUPPRESSION OF

LOW FREQUENCY OSCILLATIONS IN POWER SYSTEMS

For Abstract see entry 18A - 9

05C AC-DC Interaction

[1998] 05C - 1

A REVIEW OF ITERATIVE HARMONIC ANALYSIS FOR AC-DC POWER SYSTEMS

Smith, B.C.; Arrillaga, J.; Wood, A.R.; Watson, N.R.

Univ of Canterbury, New Zealand

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 180f

Detailed models of a static converter capable of representing the effect of ac and dc system distortion, as well as harmonic modulation of the firing and commutation angles, are becoming available. Using iterative techniques, such models are combined with linear harmonic penetration into ac network equivalents to provide accurate information about the system harmonic content. This paper provides a critical review of the state of the art in interactive harmonic analysis.

[1996] 05C - 2

A SOLUTION FOR THE STEADY-STATE INTERACTION OF THE AC/DC SYSTEMS WITH WEAK AC AND DC SYSTEMS

Smith, B.C.; Watson, N.R.; Wood, A.R.; Arrillaga, J.

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQ96), Las Vegas, NV, October 16-18, 1996

Abstract not available.

[1996] 05C - 3

A STUDY ON LOAD FREQUENCY CONTROL OF AC-DC POWER TRANSMISSION USING FUZZY CONTROL

Yukita, K.; Kunishi, R.; Goto, Y.; Mizutani, Y.

Tokai Univ, Kanagawa, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 3, March 1996, pp 367-368

With an increasing demand for electric power, electric power systems are becoming more and more complicated. Therefore, the supply of electric power with stability and high reliability is required. Then, high-voltage direct current (HVdc) power transmission that can permit the connection of two power systems having different power frequencies and capable of fast and precise power flow control is regarded as important. This paper presents a control method to improve the characteristics of load frequency control of ac-dc transmission in power systems. 2 Refs.

[1996] 05C - 4

AC-DC INTERACTION STUDY OF CAPACITOR COMMUTATED CONVERTER HVDC SYSTEM

Onishi, K.; Matsukawa, N.; Nagasaki, N.; Kuroda, K.; Ihara ,S.

Nissin Elec Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 111-120

Japanese

This paper presents the results of ac-dc interaction study of capacitor commutated converter HVdc system, CCC. The parameters of the commutation capacitors, CC for CIGRE Benchmark Model are studied and a 3LG-fault simulation by EMTP is presented. The results indicate that CCC can reduce the possibility of the core saturation instability.

[1996] 05C - 5

AC/DC SYSTEM TRANSIENT STABILITY ANALYSIS

Hu, L-X.; Chen, X-Y.

Journal of the Harbin Institute of Technology (China), vol 28, no 3, June 1996, pp 77-81

Chinese

Based on the detailed simulation of an HVdc power line regulator, this paper presents a fast algorithm to calculate the transient stability of ac/dc power systems using factor technology and the regular solution between differentials of Taylor series expansion. The calculations of two power systems prove that the algorithm is both fast and accurate. 3 Refs.

[1998] 05C - 6

ANALYTICAL MODELLING OF HVDC-HVAC SYSTEMS

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

A new HVdc-HVac analytical model is presented in this paper. The model is comprised of three subsystems: ac system, PLL and dc system. The model is structured in such a manner to enable small signal analysis of HVdc-HVac interactions and possible problems arising from these interactions. CIGRE HVdc Benchmark Model is used as a test system. Model verification, performed using PSCAD/EMTDC simulations, showed good response matching for all dc and ac system variables. As an example of an application of this model, the influence of PLL dynamics on the system stability is studied, offering important rules for tuning of PLL gains.

[1997] 05C - 7

CHARACTERISTICS OF HVDC CONNECTED TO WEAK AC SYSTEMS. I

Xu, Z.

Zhejiang Univ, Hangzhou, China

Power System Technology (China), vol 21, no 1, January 1997, pp 12-16

Chinese

Through the analysis of the simplified ac/dc interconnected system model, the transmission capabilities of HVdc systems connected to weak ac systems have been studied in detail. The concepts and their computation algorithm of the maximum power curve, the maximum available power, the critical short circuit ratio, and the boundary short circuit ratio are discussed. The strength classification of the connected ac systems according to the critical short circuit ratio and the boundary short circuit ratio is proposed in this paper.

[1996] 05C - 8

CONTROL MEASURES TO ENSURE DYNAMIC STABILITY OF THE CAHORA BASSA SCHEME AND THE PARALLEL HVAC SYSTEM

Bayer, W.; Habur, K.; Povh, D.; Jacobson, D.A.; Guedes, J.M.G.; Marshall, D.

Siemens AG, Erlangen, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 146-151

The paper discusses parallel operation of a 1500-km bipolar HVdc link and a relatively weak parallel 400/330-kV ac link. Stable operation can be ensured by use of a thyristor-switched braking resistor and control of the voltage angle difference between sending and receiving end. During critical contingencies, dynamic splitting of the HVdc and ac link at the sending end is necessary with respect to stability. 0 Refs.

[1996] 05C - 9

COORDINATION OF POWER RAMP AND MODULATION FOR AC/DC PARALLEL SYSTEM WITH WEAK AC LINKS

Liu, Z-H.; Shi, Y.; Xi, H-H.

Elec Power Research Inst, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 591-596

This paper describes the coordination method of dc power quick ramp, large signal active power modulation and small signal power modulation using the HVac/dc parallel system from TSQ to Guangdong as an application example. It is proposed to utilize both the quick dc power ramp with quick washout based on logical signal and large signal active power modulation with proper strength to enhance the first-swing stability and to improve the adaptability of the additional control of the HVdc system to system configuration and operation conditions. In order to eliminate the effect of large signal modulation in steady state operation mode and system performance after minor disturbances, a dead zone was applied. Small signal active power modulation was used to improve the damping of the ac/dc parallel power system. According to eigenvalue analyses based on linearized systems under various operating conditions and dynamic simulation based on nonlinear system models, the effectiveness of the method proposed in this paper was clearly demonstrated. 6 Refs.

[1998] 05C - 10

DAMPING IMPROVEMENT OF AN AC-DC INTERCONNECTED SYSTEM USING A FUZZY LOGIC COORDINATED MODULATION CONTROLLER

Peiris, H.J.C.; Annakkage, U.D.; Pahalawaththu, N.C.

Univ of Auckland, New Zealand

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper S13-3

Abstract not available

[1996] 05C - 11

EFFECT OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER FOR ENHANCING TRANSMISSION CAPABILITY

Takasaki, M.; Hayashi, T.

CRIEPI, Tokyo, Japan

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 411-416

HVdc systems with self-commutated converters can greatly improve overall ac-dc system performance in comparison with a conventional line-commutated HVdc system. It is acheived by the capability of controlling active and reactive power independently. This paper presents a comprehensive P-Q control scheme for self-commutated HVdc system for overall stability improvement. Its effect on transmission capability enhancement has been evaluated through stability simulation study using a model system which typically represents large interconnected power system. Transient converter controls required to ensure HVdc system stable operation are also discussed. 7 Refs.

[1996] 05C - 12

HARMONIC INTERACTION ON AC/DC SYSTEMS: EFFECTS OF CONTROL ACTIONS

Mattavelli, P.; Perna, M.

Dept of Elec Eng, Univ of Padova, Italy

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 501-508

In ac/dc thyristor power converters, noncharacteristic harmonics can arise due to the interaction between the ac and dc sides. The control action, if it is not properly designed, may greatly amplify the converter current harmonics and cause instability in the whole power system. In order to analyze the effects of control action, a small-signal model of an ac/dc thyristor-controlled system which includes the ac and dc impedance effects is derived. This allows the analysis of low-order ac/dc harmonic interaction and the evaluation of the transfer function between firing angle and dc current taking into account line impedances, resonances introduced by harmonic filters and load behavior effects. Based on this analysis, suitable design criteria for the current regulator of ac/dc power systems and for the damping resistors of the harmonic filters can be derived. As an application example, a dc arc furnace installation is considered. The frequency domain model has been verified by extensive comparison with a detailed time domain simulation based on EMTP. 16 Refs.

[1996] 05C - 13

IMPACT OF OPTIMAL CONTROL OF HVDC CONVERTERS ON TRANSIENT STABILITY OF MULTI-MACHINE POWER SYSTEMS

Kacejko, P.A.; Hammons, T.J.; Gwee, C.L.; Wancerz, M.

Tech Univ of Lublin, Poland

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 2, pp 539-542

The transient stability of an ac power system can be enhanced by optimally controlling the HVdc transmission link to damp ac electromechanical oscillations. Algorithms are also presented for HVdc power control which may be used during abnormal ac system conditions. These algorithms are based on minimizing the time of dissipation of turbine-generator rotor oscillation energy due to transients. 3 Refs.

[1997] 05C - 14

INTERACTIONS AND COUNTERMEASURES OF AC-DC INTERCONNECTED SYSTEM WITH LARGE CAPACITY THERMAL POWER PLANTS IN THE VICINITY

Yamaji, K.; Tanaka, M.; Sekita, M.; Matori, I.

Shikoku Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 975-984

Japanese

The large capacity (1400-MW) HVdc link connecting Shikoku and Kansai is under construction to be commissioned in the year of 2000. Its significant features include: (1) largest converter capacity ever made in Japan; (2) hybrid mode system configuration in parallel with 500-kV ac trunk lines; and (3) possibility for an islanded transmission mode with direct connection to the large thermal power plant. Since this HVdc link is large in its capacity and plays significant roles in the 60-Hz power systems, studies and countermeasures on various subjects arising from ac/dc interaction phenomena are very important. This paper describes mechanisms, analysis results and countermeasures for ac overvoltages, harmonic instability, dc power oscillation and SSTI (turbine-

generator subsynchronous torsional interactions) which take place based on ac and dc interactions.

[1997] 05C - 15

INVESTIGATION OF NONLINEAR MODAL BEHAVIOR OF HVDC/AC POWER SYSTEMS THROUGH A SCANNING TOOL VIA NORMAL FORM TECHNIQUE

Ni, Y.; Vittal, V.; Kliemann, W.

Iowa State Univ, Ames, IA, USA

Proceedings, 1997 IEEE Int'l Symp on Circuits and Systems (ISCAS), Hong Kong, June 9-12, 1997. Circuit Theory and Power Systems Communication and Multimedia, vol 2, pp 945-948

In this paper, a scanning tool based on the normal form technique is developed for the investigation of nonlinear modal behavior of ac/dc power systems with dc power modulation. The ac-dc interface variables are solved by symbolic calculation software MAPLE. A state space model is then formed for normal form method with second order approximation. A four-generator ac/dc power system is studied with different fault locations and various input signals for dc power modulation. 8 Refs.

[1996] 05C - 16

NEWTON SOLUTION FOR THE STEADY-STATE INTERACTION OF AC/DC SYSTEMS

Smith, B.C.; Watson, N.R.; Wood, A.R.; Arrillaga, J.

Univ of Canterbury, Christchurch, New Zealand

IEE Proceedings Generation, Transmission and Distribution (UK), vol 143, no 2, March 1996, pp 200-210

The steady-state interaction of a six-pulse converter with a Thevenin equivalent of the three-phase ac and dc systems is solved. The converter is represented by harmonic phasor mismatch equations, and the interaction between the converter and ac and dc systems is embodied in the solution of harmonic mismatch equations for the converter terminal conditions. Since there are a large number of simultaneous nonlinear equations to be solved, a sparse Newton-type solution is developed that exploits the harmonic three-port nature of the converter, and the relatively weak interaction between switching angles and terminal harmonics. The resulting solution is fast, and closely matches a time domain simulation of the test system. 21 Refs.

[1996] 05C - 17

NONLINEAR MODAL INTERACTION IN HVDC/AC POWER SYSTEMS WITH DC POWER MODULATION

Ni, Y-X.; Vittal, V.; Kliemann, W.; Fouad, A.A.

Tsinghua Univ, Beijing, China

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 2011-2017

In this paper investigation of nonlinear modal interaction using the normal form of vector fields technique is extended to HVdc/ac power systems with dc power modulation. The ac-dc interface equations are solved to form a state space model with second order approximation. Using the normal form technique, the system's nonlinear dynamic characteristics are obtained. The proposed approach is applied to a four-generator HVdc/ac test power system, and compared with the time domain solution. 9 Refs.

[1996] 05C - 18

ON LINE IDENTIFICATION AND CONTROL OF AN AC/DC POWER SYSTEM

To, K.W.V.; David, A.K.

Dept of Elec Eng, Hong Kong Polytech, China

Int'l Journal of Electrical Power & Energy Systems (UK), vol 18, no 4, May 1996, pp 223-227

This paper is concerned with the control of a parallel ac/dc power systems using low-order models derived directly from test data. Experimental data are obtained by applying a pseudo random binary sequences (PRBS) signal to the excitation system and one dc power converter terminal of a laboratory system and recursive least-squares-based system identification, premised on the exciter and dc current order as reference inputs, is implemented. The models so obtained have been successfully used for ac/dc power system controller design. 5 Refs.

[1997] 05C - 19

OPERATING CONDITIONS OF CONTROLLED POWER TRANSMISSION LINES

Kochkin, V.I.; Shakaryan, Y.G.

AO VNIIE, Moscow, Russia

Elektrichestvo (Russia), no 8, August 1997, pp 2-8

Russian

The paper considers a controlled ac transmission line, with a low power dc/ac back-to-back link used as a

controller. Analytical dependences are obtained to show a relationship between the operational parameters of the controlled power transmission line and the operational parameters of its converter part. It is shown that the line considered is an effective means of active power flow control. It is underscored that it is possible, in this case, to obtain optimal reactive power flows at the ends of the line. 8 Refs.

[1997] 05C - 20

Deleted

[1997] 05C - 21

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. POWER SWING DAMPING CONTROL BY HVDC POWER MODULATION IN AC/DC HYBRID TRANSMISSION SYSTEM

Tomiyama, K.; Sato, M.; Yamaji, K.; Sekita, M.; Goto, M.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 938-944

Japanese

This paper describes a power swing damping control by HVdc power modulation. In a hybrid system (ac transmission system and HVdc system compose a loop transmission system), a damping control of power swings by control of HVdc power is called power modulation control. The new inter-connection by HVdc link between Shikoku and Kansai power systems composes a loop transmission system, a power modulation control can be applied to stabilize the ac system. In this paper, a newly developed power modulation control system to damp two power swing modes occurring in a 60-Hz inter-connected system using the HVdc converter. Characteristics of power swings in ac systems, the principle of power swing damping control by power modulation, design of the control system, and results of verification tests by digital and analog simulator are described. It is shown that the developed power modulation system applied to the HVdc link is effective for damping two power swing modes.

[1997] 05C - 22

POWER LIMITATIONS OF THE HVDC TRANSMISSION SYSTEM

Kremens, Z.; Seleem, Z.

Inst of Elec Power Eng, Tech Univ of Wroclaw, Poland

Archives of Electrical Engineering (Poland), vol 46, no 1, 1997, pp 89-100

The scope of the presented paper concentrates on a two-terminal HVdc transmission system. The intention of the paper is to present a precise insight into the limitations of the power transmitted through an HVdc system incorporated into a real ac power system. The paper demonstrates the impacts of the combined ac/dc system model parameters on the power transmitted through the dc link. An efficient method of ac/dc load flow study is also developed. This method accommodates perfectly the various types of HVdc power system control modes. In addition, the switching between these control modes can be performed easily in the developed method. Moreover, the method is considered a reliable computational tool used to evaluate the power limitations of the HVdc transmission system. Then, the effectiveness of the developed method of calculation and the influence of the system parameters on the capability of the HVdc transmission system are investigated on a test system composed of two parallel HVdc/ac lines incorporated into an ac power system.

[1997] 05C – 23

Deleted

[1996] 05C - 24

RESEARCH ON THE OVERLOAD PARAMETER OF TIAN-GUANG HVDC AND THE IMPROVEMENT OF THE PARALLEL AC SYSTEM POWER TRANSMISSION CAPABILITY

Chen, X.

Power Test & Research Inst, Guangdong Provincial Power Bureau, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 584-590

The authors put forward an advanced small disturbance and power shifting power system stability program calculation method based on the definition of static state stability (SSS), and a new kind of method based on increasing dc transient overload capability whilst properly decreasing overload time. These propositions have been adopted by Tian-Guang HVDC Engineering, China. The calculation results show that the SSS limit and power transmission capability are increased

significantly without further engineering investment. 7 Refs.

[1998] 05C - 25

SMALL SIGNAL ANALYSIS OF HVDC-HVAC INTERACTIONS

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

This paper presents a small signal analysis of interactions between HVac and HVdc systems. The eigenvalue analysis, along with analysis of participation factors, is first described. The eigenvalue sensitivity analysis shows how the changes of ac system parameters influence the stability of the considered HVdc-HVac system. The influence of SCR changes on both the rectifier and the inverter ac system, is studied by examining the relative movement of the system eigenvalues. The most important conclusions about ac-dc interactions are obtained by investigating the nature of inherent feedback loops between the systems. By examining the changes of all interaction variables, it is determined which of the interaction variables should be controlled and which are better left uncontrolled.

[1998] 05C - 26

STABILITY AND CONTROL OF HVDC AND AC TRANSMISSIONS IN PARALLEL

Hammad, A.E.

Consultant, NE Swiss Power Co., Baden, Switzerland

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998.

A generic concept combining transient angle and voltage stabilities of parallel ac/dc transmission is introduced. It proves that HVdc schemes in parallel operation with ac transmission are prone to both transient swing angle and voltage instabilities. This tendency is intensified as the parallel ac interconnection becomes stronger. The concept also explains why an HVdc scheme fitted with classical dc power controls does not contribute to system synchronizing torque and may increase the risks for instability. The concept offers a solid means to develop robust strategies to control the dynamic operation of dc and ac transmissions in parallel. With such strategies, the HVdc scheme can positively participate in the instantaneous rescheduling of power according to changing network conditions, particularly during disturbance conditions.

[1996] 05C - 27

STUDY OF MODULATION CONTROLLER: TO DAMP POWER OSCILLATIONS OF PARALLEL AC LINE IN THE TIANSHENGQIAO TO GUANGDONG HVDC TRANSMISSION

Hao, C.

Central Southern China Elec Power Design Inst, Wuhan, China

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 169-172

The 1800-MW Tianshengqiao to Guangdong HVdc transmission link in China, will be provided with an HVdc power modulation feature intended to stabilize the ac power system. In a transmission system which has both ac and dc lines running in parallel, a reduction in the power swings in the ac line thus increases the stability limit of the integrated ac/dc power system. Comprehensive digital computer studies show the importance of the power modulation for the Tianshengqiao to Guangdong HVdc transmission link. This paper describes the results of a study carried out to design the power modulator for the HVdc link. It shows how the transient stability limit can be increased by power modulation on HVdc systems. 0 Refs.

[1997] 05C - 28

STUDY OF POWER TRANSFER CAPABILITY OF DC SYSTEMS INCORPORATING AC LOADS AND A PARALLEL AC LINE

Reeve, J.; Uzunovic, E.

Univ of Waterloo, Ontario, Canada

IEEE Trans on Power Delivery, vol 12, no 1, January 1997, pp 426-434

Concepts of maximum power transfer of dc systems and associated ac voltage variations, particularly at inverter stations having low short-circuit ratios, have been extended to include various ac load models and an ac line in parallel with the dc line. The operating capabilities are shown to vary from those predicted from either a Thevenin ac source model or the corresponding short-circuit ratio. The study used an ac/dc load flow program. 7 Refs.

[1996] 05C - 29

VARIABLE STRUCTURE CONTROL OF AC-DC SYSTEM

Dash, P.K.; Panda, S.K.

Dept of Elec Eng, Regional Eng College, Rourkela, India

Electric Machines and Power Systems, vol 24, no 4, June 1996, pp 345-362

The paper presents a new approach to the design of variable structure current and VAr regulators for improving the dynamic stability of parallel ac-dc systems. The variable structure regulators are based on the concept of sliding mode control which constrains the system motion to a state trajectory. The sliding mode control provides greater robustness and insensitivity to plant parameter variations and is feasible for practical implementation. The transient simulations for a typical parallel ac-dc system connected to a weak ac system are performed to demonstrate the effectiveness of the variable structure control. 8 Refs.

[1997] 05C - REF

IEEE GUIDE FOR PLANNING DC LINKS TERMINATING AT AC LOCATIONS HAVING LOW SHORT-CIRCUIT CAPACITIES

For Abstract see entry 01B - 13

[1998] 05C - REF

AUTOMATIC GENERATION CONTROL IN A DEREGULATED POWER SYSTEM

For Abstract see entry 01B - 6

[1996] 05C - REF

ASPECTS OF FILTER DESIGN FOR THE CHANDRAPUR 2*500 MW HVDC BACK-TO-BACK CONVERTOR STATION

For Abstract see entry 02D - 6

[1998] 05C - REF

MODELING OF AN HVDC SYSTEM AS A LINEAR CONTINUOUS MIMO SYSTEM

For Abstract see entry 05A - 14

[1996] 05C - REF

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

For Abstract see entry 05B - 38

[1996] 05C - REF

ADVANCED HVDC LINK CONTROL FOR DAMPING POWER SYSTEM OSCILLATIONS

For Abstract see entry 05B - 9

[1996] 05C - REF

DYNAMIC PERFORMANCE OF A STATCON AT AN HVDC INVERTER FEEDING A VERY WEAK AC SYSTEM

For Abstract see entry 05G - 4

[1996] 05C - REF

DYNAMIC ANALYSIS OF VOLTAGE INSTABILITY IN AC-DC SYSTEMS

For Abstract see entry 05H - 4

[1997] 05C - REF

ENERGIZATION TRANSIENTS OF SHUNT REACTORS

For Abstract see entry 05H - 5

[1997] 05C - REF

VOLTAGE STABILITY ANALYSIS OF AC/DC SYSTEMS

For Abstract see entry 06B - 5

[1996] 05C - REF

AC SYSTEM ANALYSIS OF MULTI-TERMINAL HVDC SYSTEM COMPOSED OF SELF-COMMUTATED CONVERTERS

For Abstract see entry 06C - 1

05D Harmonic and Torsional Interactions, GIC Effects

[1997] 05D - 1

A CONTROLLER FOR HIGH VOLTAGE DIRECT CURRENT CONVERTER

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.; Brown, R.

Univ of Auckland, New Zealand

Provisional patent document no 328801, September

1997, Patent Office, New Zealand Ministry of Commerce

This document presents a design of an HVdc controller intended for elimination of 100-Hz oscillations on the dc side (dc current and gamma angle). The primary cause for second harmonic on the dc side is the ac system unbalance. The new controller can be implemented as a modification of the existing current controller, in the frequency domain of interest. The controller performance affects primarily the following three variables: ac voltage unbalance, dc current, and extinction angle gamma, leading to a careful trade off and balancing the importance between the three variables. The tests with the New Zealand HVdc system show that it is possible to reduce gamma oscillations to less than 40 percent of its original value, without introducing negative influence on the ac system voltage unbalance.

[1996] 05D - 2

A DIRECT FREQUENCY DOMAIN INVESTIGATION OF THE PROPERTIES OF CONVERTOR TRANSFORMER CORE SATURATION INSTABILITY

Chen, S.; Wood, A.R.; Arrillaga, J.

Canterbury Univ, Christchurch, New Zealand

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 173-178

A direct frequency domain approach has been used in this paper to describe the properties of HVdc transmission systems susceptible to convertor transformer core saturation instability. The properties considered are the impedance profiles of ac and dc power systems, the influence of the convertor controller and the effect of different convertor steady-state operating conditions.

[1996] 05D - 3

A NEW APPROACH TO SSR PROBLEM IN POWER SYSTEM WITH HVDC

Wu, J-Y.; Cheng, S-J.

Huazhong Univ of Sci & Tech, Wuhan, China

Automation of Electric Power Systems (China), vol 20, no 11, November 1996, pp 9-12

Chinese

In this paper, a complex frequency domain model of HVdc power systems and a complex frequency domain network equation of multiple machine ac/dc power systems under arbitrary topologies are derived. The effects of HVdc power systems on the subsynchronous resonance (SSR) of interconnected power systems are investigated. The calculation results of a three-machine ac/dc power system verify the correctness and effectiveness of the proposed approach. 4 Refs.

[1996] 05D - 4

A SCREENING METHOD FOR CORE SATURATION INSTABILITY IN HVDC SYSTEM AND ITS APPLICATION

Matsushita, J.; Tomiyama, K.; Oue, Y.; Hasegawa, T.; Tatsuoka, K.; Ihara, S.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 60.62-71, pp 81-90

Japanese

Low-order harmonic interaction can interfere with HVdc system performance. An unstable oscillation may start during an ac fault and recovery, or may grow out of steady-state condition without initiating events. This paper describes the harmonic instability involving the core saturation of the converter transformers. Also presented is a screening method to measure the potential for core saturation instability. This method uses the core interaction factor determined simple analysis of the ac and dc system impedance. The validity of the method is demonstrated with EMTP simulation. The paper characterizes system design concepts to prevent core saturation instability.

[1996] 05D - 5

ANALYSIS OF EFFECT OF HVDC WITH SELF-COMMUTATED CONVERTER ON SHAFT TORSIONAL OSCILLATION BY FREQUENCY RESPONSE METHOD

Nishi, K.; Yokoyama, A.

Univ of Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.103-6.104

Japanese

Abstract not available.

[1997] 05D - 6

CONTROL OF 100-Hz GAMMA OSCILLATIONS ON NEW ZEALAND HVDC LINK

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.; Brown, R.

Univ of Auckland, New Zealand

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper presents a novel control strategy for reduction of second harmonic oscillations on the dc side of an HVdc link. The paper presents an analytical model for harmonic transfer through ac-dc converters and gives causes of the 100-Hz gamma oscillations. Based on this analytical model and a discrete HVdc system model, a new control strategy is developed and new controller designed. The controller was tested on the New Zealand HVdc system PSCAD/EMTDC model. The results from simulations show that the controller can noticeably reduce 100-Hz gamma oscillations with very little negative effect on the connected ac system. The controller shows good robustness when tested against various disturbances of the inverter ac system. The paper also discusses the possibility of controlling the ac voltage unbalance using the presented controller. The controller implementation requirements are analyzed in the last section.

[1996] 05D - 7

DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO THE INTERACTION WITH HVDC

Sato, M.; Yamaji, K.; Kato, K.; Sekoguchi, M.; Matori, I.; Goto, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-E, pp 75-80

Abstract not available.

[1996] 05D - 8

DAMPING OF TORSIONAL OSCILLATIONS IN A PARALLEL AC/DC SYSTEM USING AN ARTIFICIAL NEURAL NETWORK TUNED SUPPLEMENTAL SUBSYNCHRONOUS DAMPING CONTROLLER

Jeng, L-H.; Hsu, Y-Y.

Natl Taiwan Univ, Taipei, Taiwan

Proceedings of the National Science Council, Republic of China, Part A: Physical Science and Engineering, vol 20, no 2, March 1996, pp 174-184

Torsional oscillations in an ac/dc transmission system are damped by the supplemental subsynchronous damping control (SSDC), which is, in principle, a rectifier current regulator (RCR). To provide good damping characteristics of torsional oscillations under disturbance conditions, it is desirable to adapt the parameters of SSDC according to generator load changes. To do this, a multilayer feedforward neural network is used to achieve the desired control action based on generator loading conditions. After having been trained by a supervised training process with the patterns in the training set, the artificial neural network (ANN) can be used to tune the control parameters. When a pair of generator outputs P and Q, which are used to describe the operating point of a generator, are fed to the input terminal of the ANN, a suitable set of parameters for SSDC will be generated by the ANN as its outputs. To demonstrate the effectiveness of the proposed adaptation scheme, both single-machine and multi-machine systems were used as test systems. Time domain simulations were performed on these systems for comparison purposes. It is concluded from the results that the proposed adaptive SSDC can provide better damping effects of torsional oscillations than other control schemes can over a wide operating range of generators. Refs.

[1997] 05D - 9

DRAMATIC CALCULATION OF TURBO-GENERATOR SHAFT TORSIONAL VIBRATION IN COMPLEX AC/DC POWER SYSTEM

Wu, J.; Chen, X.; Wang, F.; He, Y.Z.; Cheng, S.

Huazhong Univ of Sci & Tech, Wuhan, China

Automation of Electric Power Systems (China), vol 21, no 4, April 1997, pp 6-8, 20

Chinese

In this paper, a new approach to calculate the turbo-generator shaft torsional vibration characteristics based on the complex frequency domain port-equivalent conductance matrix concept and the distributing elimination method has been proposed. The shaft torsional vibration problems in the Huazhong network and Gezhouba-Shanghai HVdc system are investigated.

[1996] 05D - 10

FREQUENCY DOMAIN ANALYTICAL METHOD FOR STUDYING HARMONIC INTERACTION BETWEEN AC AND DC SIDES OF CONVERTERS IN HVDC

Jiang, Y.; Ekstrom, A.

Dept of Elec Eng, Royal Inst of Tech, Stockholm,

Sweden

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 2, pp 339-343

This paper presents a frequency domain analysis method for studying harmonic interactions between the ac and dc sides of power converters in HVdc applications. With the help of the space-vector and the switching function of HVdc power converters, the open-loop transfer function for a two-terminal HVdc power system is developed. Possible resonance frequencies for the complete system are identified by evaluating the frequency characteristic of the obtained transfer function denominator. This frequency domain analysis method is also verified with EMTDC-based time domain simulations. 15 Refs.

[1997] 05D - 11

HARMONIC CROSS-MODULATION IN HVDC TRANSMISSION

Arrillaga, J.; Wood, A.R.; Ainsworth, J.D.; Arrillaga, J.; Bergdahl, B.; Eggleston, J.F.; Rittiger, J.; Yacamini, R.

CIGRE WG 14.25

Proceedings, Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 1997

The objective of the Working Group is to provide a rigorous explanation of the mechanism of frequency cross-modulation and to quantify its effect. This paper considers the harmonic interactions for the case where the ac and dc systems are very strong. This means that the ac system impedance is very low, and the dc system admittance is very low. This eliminates some second order interactions, and facilitates explanation of the mechanisms involved. Strictly speaking, a harmonic is an integer multiple of the fundamental frequency. However, in this report we are using the term "harmonic" in a broader sense, to represent also inter-harmonics (frequencies of non-integer multiple orders) and subharmonics (frequencies below the fundamental). The factor "k" is used throughout to indicate frequencies as a multiple of the fundamental; k may or may not be an integer. The discussion is related exclusively to 12-pulse converters, although the principles are the same for other pulse numbers.

[1998] 05D - 12

HARMONIC TENSOR LINEARISATION OF HVDC CONVERTERS

Smith, B.C.; Watson, N.R.; Wood, A.R.; Arrillaga, J.

Univ of Canterbury, Christchurch, New Zealand

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

The equivalent harmonic impedances associated with time-variant devices such as FACTS and HVdc converters are in many cases phase dependent. The second rank tensor is proposed as a means of performing the nodal analysis of networks incorporating phase-dependent admittances. A useful geometric interpretation of phase dependency is developed, and applied to the calculation of the harmonic phase-dependent impedance of an HVdc converter on the ac side.

[1997] 05D - 13

HARMONIC TRANSFER IN HVDC SYSTEMS UNDER UNBALANCED CONDITIONS

Sadek, K.; Pereira, M.

Siemens AG, Erlangen, Germany

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

The harmonic interaction between ac and dc systems has been discussed in various publications with respect to both characteristic and non-characteristic harmonics injected into ac power transmission systems by HVdc converters. This paper presents a method to determine the transfer of harmonics from the supplying ac network to the dc system and vice versa. The imbalance in both fundamental and harmonic voltages is introduced in the mathematical model by the corresponding symmetrical components, e.g., by their positive and negative components. The method presented is valid for both power flow directions.

[1996] 05D - 14

HVDC CONVERTER TRANSFORMER CORE SATURATION INSTABILITY: A FREQUENCY DOMAIN ANALYSIS

Chen, S.; Wood, A.R.; Arrillaga, J.

Univ of Canterbury, Christchurch, New Zealand

IEE Proceedings Generation, Transmission and Distribution (UK), vol 143, no 1, January 1996, pp 75-81

The interaction between an HVdc converter and the saturation characteristic of a converter transformer can lead to a type of harmonic instability widely known as converter transformer core saturation instability. The

paper presents a linearized direct frequency domain analysis of the mechanism behind this instability. Using linearized converter transfer functions and transformer saturation characteristics on ac and dc system equivalents, the system equations are solved to describe the phenomenon. A measure of the level of stability, saturation stability factor, is derived and utilized to predict the system dynamics. The analysis is verified by dynamic simulation of several systems. 10 Refs.

[1997] 05D - 15

HYBRID SIMULATION STUDY OF FACTORS CONTRIBUTING TO HARMONIC INSTABILITY OF HVDC SYSTEMS

Nojiri, K.; Ikeda, T.; Kita, T.

Kansai Elec Power Co, Inc, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 131-132

Japanese

Abstract not available.

[1996] 05D – 16

Deleted

[1996] 05D - 17

INVESTIGATIONS OF THE IMPACTS OF HVDC SELF-COMMUTATED CONVERTER SYSTEM ON TORSIONAL OSCILLATIONS

Issarachai, N.; Mitani, Y.; Funaki, T.; Matsuura, K.

Osaka Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 60.62-71, pp 91-100

The recent development of large capacity self-turnoff switching devices, such as, GTO etc., has made it possible to apply the self-commutated converter to HVdc converter systems instead of line-commutated converter which is used in conventional HVdc systems. Because of the superior characteristics of self-commutated converter, such as feasibility of simultaneous and independent control of active and reactive power, independent control of magnitude and phase angle of converter output voltage. On the other hand, the torsional oscillations interactions between turbine-generator set and HVdc self-commutated converter system have not been sufficiently discussed yet. This paper investigates the impacts of an HVdc self-commutated converter system on the torsional oscillations of turbine generator set. The eigenvalue analysis and frequency response method are used to investigate the effects of the self-commutated converter which influence the occurrence of the torsional oscillations and to explain the mechanism of occurrence of this phenomena. The results from two methods show that the control system of the HVdc self-commutated converter system may excite the torsional oscillations mode. In this paper, the supplementary subsynchronous damping control based on lead-lag control is used to damp the unstable torsional mode of turbine-generator set. From the results, it can effectively stabilize the torsional oscillations.

[1996] 05D - 18

METHOD FOR THE INDICATION OF POWER TRANSFORMER SATURATION

Tousignant, D.; Bolduc, L.; Dutil, A.

Inst de Recherche d'Hydro-Quebec, Varennes, Quebec, Canada

Electric Power Systems Research, vol 37, no 2, May 1996, pp 115-120

DC currents flowing from the earth cause many Hydro-Quebec transformers to saturate due to geomagnetically induced currents (GICs) or monopolar operation of HVdc systems with ground return. The resulting voltage distortion may affect the operation of control systems. This paper offers an explanation of the internal behavior of currents generated in the presence of dc currents. It also contains a harmonic analysis of these currents together with a detailed study of the magnetizing current. In saturation, a transformer core acts as a source of current generating harmonics, some of which will flow directly toward the primary and secondary windings. On the basis of these observations, the paper proposes a measurement method for obtaining the parameters needed to calculate a reliable indicator of the state of saturation of transformers. The method is based on the difference between the primary and secondary currents and on amplitude readings of the second and fourth harmonics. 5 Refs.

[1996] 05D - 19

MITIGATING POTENTIAL TRANSFORMER FERRORESONANCE IN A 230-KV CONVERTER STATION

Jacobson, D.A.N.; Swatek, D.R.; Mazur, R.W.

Manitoba Hydro, Winnipeg, Canada

Proceedings, 1996 T&D Conf Conf and Exposition, Los Angeles, CA, September 15-20, 1996, pp 269-275

A wound potential transformer failed catastrophically on the Manitoba Hydro system. The failure was attributed to excessive current flow in the primary winding due to a sustained ferroresonance between the circuit breaker grading capacitance and nonlinear magnetizing inductance of the potential transformer. In order to prevent future occurrences, switching guidelines have been revised and permanently connected damping resistors were installed. Modern nonlinear techniques of analysis are evaluated for their suitability of defining safe and unsafe zones of operation. A new two-dimensional bifurcation diagram is proposed as a new visualization tool. 11 Refs.

[1996] 05D - 20

MODELLING OF CURRENT CONTROL IN THE ANALYSIS OF HARMONIC INTERACTIONS IN HVDC SYSTEMS

Padiyar, K.R.; Bhowmick, A.

Indian Inst of Sci, Bangalore, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 207-211

This paper presents the modelling of current control in the analysis of harmonic interactions in HVdc systems. The analysis results are validated by time domain digital simulation. The effects of the variation in the gains and time constants are studied.

[1997] 05D - 21

POWER ELECTRONICS APPLICATION TECHNOLOGY TO ELECTRIC POWER FIELD

Hayashi, T.; Sakurai, T.

CRIEPI, Tokyo, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 901-904

Japanese

Abstract not available.

[1997] 05D - 22

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. STEADY-STATE STABILITY ANALYSIS OF SHAFT TORSIONAL OSCILLATION IN AC-DC INTERCONNECTED SYSTEM WITH SELF-COMMUTATED CONVERTERS

Nishi, K.; Yokoyama, A.; Nakajima, T.

Univ of Tokyo, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 905-914

Japanese

Recent progress of power electronics technology makes it possible that self-commutated converter using GTOs (gate turn-off thyristors) is considered to be applied to HVdc transmission systems. Since the self-commutated converter can be operated stably without depending on ac-side voltage, the magnitude and the phase angle of the converter output voltage can be controlled independently. Therefore, this type of converter will improve the voltage stability at its ac side. On the other hand, shaft-torsional oscillation of a thermal power plant caused by the interaction between shaft-generator system and control system of the self-commutated converter is still an open problem. In this paper, a linearized model for eigenvalue analysis of a power system including HVdc interconnection with self-commutated converters is described to analyze the effect of the self-commutated converter on the shaft-torsional oscillation of a thermal power plant. Then, numerical results from the eigenvalue analysis of the shaft-torsional oscillation are presented. Results obtained by frequency response method are also reported. The numerical results make it clear that there exist the parameter regions of DC-AVR and ACR control systems of the self-commutated converter where the shaft-torsional oscillation may be caused.

[1996] 05D - 23

PREDICTION OF CORE SATURATION INSTABILITY AT AN HVDC CONVERTER

Burton, R.S.; Fuchshuber, C.F.; Woodford, D.A.; Gole, A.M.

Teshmont Consultants Inc, Winnipeg, Manitoba, Canada

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1961-1969

Core saturation instability has occurred on several HVdc schemes resulting from interactions between second harmonic and dc quantities (voltages and currents) on the ac side of the converter and fundamental frequency quantities on the dc side of the converter. The instability can be reinforced by unbalanced saturation of the converter transformers. The paper presents an analytical method which can be used to quickly screen ac and dc

system operating conditions to predict where core saturation instability is likely to occur. Analytical results have been confirmed using the digital transients simulation program PSCAD/EMTDC. 11 Refs.

[1998] 05D - 24

PROPOSED 4 GW RUSSIA-GERMANY LINK - IMPACT OF 1 GW INVERTER STATION ON TORSIONAL STRESSING OF GENERATORS IN POLAND

Hammons, T.J.; Lim, C.K.; Lim, Y.P.; Kacejko, P.

Univ of Glasgow, UK

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 190-196

The European power systems are in the process of a new orientation which will facilitate and promote exchange of electric power between Eastern and Western European nations. One such example is the 4 GW HVdc link from Russia to Germany where a 1 GW converter station has been proposed for central Poland. This paper considers the impact of the proposed 4 GW Russia-Germany HVdc link on the Polish Grid Network and possible excitation of torsional vibrations in shafts of steam turbine-generator-exciter units connected to the system by non-characteristic currents due to the link. Excitation of torsional vibrations in machine shafts due to modulating currents and the level of risk of damage to machine shafts due to subsynchronous currents injected into the network by the inverter is assessed. Dynamic parameters of system loads and the power factor of loads which influence system scaling factors are also discussed. The paper also examines the most probable location of the proposed 1000-MW converter on the Polish Grid Network. System scaling factors are evaluated for different system configurations for each generator at risk and generators most at risk are identified. The paper then investigates transient behavior of the Polish power system following loss of the proposed link at full import. Transient stability performance is also evaluated for a range of system faults of different fault durations, distances, and locations from power plants. 3 Refs.

[1997] 05D - 25

PROPOSED SWEDEN/POLAND HVDC SUBMARINE CABLE LINK: IMPACT ON POLISH GENERATORS AND GRID NETWORK

Hammons, T.J.; Lee, E.C.L.; Kacejko, P.A.

Univ of Glasgow, UK

Proceedings, 32nd Univertsities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 626-629

This paper analyzes rectifier ripple current superimposed on the dc current of a proposed 600-MW, 450-kV HVdc monopolar asynchronous link in evaluating possible torsional vibrations in steam turbine-generator-exciter shafts. The studies are performed for machines in close proximity to an inverter station in northern Poland. It extends earlier work to analyze attenuation or amplification of dc ripple current at the inverter due to the submarine cable with its overhead line and smoothing inductors. It examines HVdc link harmonic scaling factors and ac system scaling factors for modulation product harmonic currents impressed on generators of the Polish grid network by the inverter not examined in the literature heretofore. Amplitude of shaft torsional torque due to resonant excitation imposed by the link is also discussed. 4 Refs.

[1998] 05D - 26

SCREENING AC/DC HARMONIC INSTABILITIES

Hasegawa, T.; Matsushita, J.; Oue, Y.; Tomiyama, K.; Ihara, S.; Pratico, E.R.; Walling, R.A.; Zhu, W.

Kansai Elec Power Co, Inc, Japan

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

A small signal analysis method has been successfully applied to efficiently screen a variety of conditions for core saturation instability and second harmonic amplification. The screening measures have been defined in terms of the dc system driving point impedances.

[1997] 05D - 27

SECOND HARMONIC INSTABILITY ON HVDC SYSTEMS

Jovcic, D.; Pahalawaththa, N.; Zavahir, M.

Univ of Auckland, New Zealand

Proceedings, 4th New Zealand Postgraduate Conf, Hamilton, NZ, July 1997, pp 71-77

This paper addresses the second harmonic instability on HVac/HVdc systems. Two reported cases of harmonic instability are first reviewed. The mechanism of instability is studied and the conditions which lead to the instability are explained. The paper also elaborates the possible conventional solutions to the problem. A

control solution which was successfully implemented on Chateauguay HVdc scheme is briefly presented. A novel control method for elimination of the instability, based on the pole assignment technique and state space feedback, is presented in the last section of the paper.

[1997] 05D - 28

SIMULATION STUDY OF METHOD OF DAMPING SSO IN AC/DC SYSTEM

Yu, J.; He, F.; Zhou, B.

North China Inst of Elec Power, Baoding, China

Proceedings of the CSEE (China), vol 17, no 6, November 1997, pp 386-390, 402

Chinese

A simulation study of the method of damping SSO is made in an ac/dc power system composed of two turbogenerator units connected to an infinite bus via an HVdc line. A BORLAND C++ based digital simulation program for both steady state and SSO in time domain is compiled. The measurement for damping SSO in this present paper is proved to be effective.

[1997] 05D - 29

SIMULATOR STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC. PART 1. STABILITY LIMITS BY AC SYSTEM STRENGTH

Murakami, H.; Azuma, M.; Sekita, M.; Omori, T.; Nishimura, M.

Shikoku Elec Power Co, Inc, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 379-380

Japanese

Abstract not available.

[1997] 05D - 30

SIMULATOR STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC. PART 2. EFFECT OF DAMPING CONTROL

Murakami, H.; Azuma, M.; Sekita, M.; Shimamura, H.; Sekoguchi, M.

Shikoku Elec Power Co, Inc, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 381-382

Japanese

Abstract not available.

[1997] 05D - 31

SIMULATOR STUDY RESULTS OF SUB-SYNCHRONOUS RESONANCE DAMPING BY HVDC CONVERTER CONTROL

Murakami, H.; Azuma, M.; Kida, Y.; Yoshino, T.; Tanomura, K.; Ota, S.

Shikoku Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.335-6.336

Japanese

Abstract not available.

[1996] 05D - 32

SOLVING THE FERRORESONANCE PROBLEM WHEN COMPENSATING A DC CONVERTER STATION WITH A SERIES CAPACITOR

Woodford, D.A.

Manitoba HVdc Res Center, Winnipeg, Canada

IEEE Trans on Power Systems, vol 11, no 3, August 1996, pp 1325-1331

When a dc link feeds into an ac system where the short circuit ratio is low or very low, the ac voltage requires some form of supplementary control. The concept of a series capacitor located between the ac system and the dc link has been an attractive consideration but is susceptible to ferroresonance between the series capacitor and the converter transformers. Using dc link controls judiciously, it is shown that any onset of ferroresonance can be eliminated. Benefits to series compensating a dc converter are presented. 6 Refs.

[1996] 05D - 33

STEADY-STATE STABILITY ANALYSIS OF EFFECT OF HVDC WITH SELF-COMMUTATED CONVERTER ON SHAFT TORSIONAL OSCILLATION

Nishi, K.; Yokoyama, A.

Univ of Tokyo, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1, pp 97-102

Japanese

Torsion vibration of shaft, which is caused by the interaction of a generator shaft system and a self-excited converter control system, is an unsolved problem. This paper proposes a linearization model of dc electric power system interconnection using the eigenvalue method and analyzes the effect on the torsion vibration of shafts of a thermal power plant of a self-excited converter. Solutions of the eigenvalue are shown and as results of further analysis by the frequency response method, it is proven that the control loop which passes through direct current AVR and ACR gives large effect for occurrence of the torsion vibration of the shafts.

[1997] 05D - 34

STUDY OF HARMONIC INSTABILITIES IN HVDC SYSTEM

Yamaji, K.; Azuma, M.; Honjo, N.; Noro, Y.; Hibana, M.; Ota, S.

Shikoku Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.337-6.338

Japanese

Abstract not available.

[1997] 05D - 35

STUDY OF NON-INTEGER HARMONIC INSTABILITIES IN HVDC SYSTEM

Yamaji, K.; Azuma, M.; Honjo, N.; Noro, Y.; Yoshino, T.

Shikoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 8, no 1, pp 235-240

Japanese

Harmonic instability is a phenomenon in which illogical harmonic currents occur from some cause and are expanded by interactions with ac and dc systems, making stable operation of the dc system impossible. Phenomenon which occur in integer order, such as those caused by a phase detection system and control system, or magnetic saturation of transformers for conversion, and phenomena which occur in non-integer order are reported. Especially, analysis has not been sufficiently carried out on harmonic instability phenomenon which occurs in non-integer order. This paper proposes a method to quantitatively judge the harmonic stability limit of non-integer order and examine the result of this method, comparing with a test result of an analog simulator, to provide a guideline for harmonic instability countermeasures.

[1997] 05D - 36

STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC

Uehara, N.; Omori, T.; Nishimura, M.; Azuma, M.; Sekita, M.; Sekoguchi, M.

Shikoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 19-24

Japanese

An interaction between the turbine-generator shaft torsional oscillation and the high voltage direct current (HVdc) transmission system has a possibility of occurring and the shaft torsional oscillation of increasing, when turbine-generators are connected to an HVdc converter station without any ac network. We have developed a damping control scheme for generator torsional oscillation. The damping control using a bus voltage at the converter station is verified as effective according to a real-time digital simulator (RTDS) and a time-domain digital simulation.

[1996] 05D - 37

SUBSYNCHRONOUS OSCILLATIONS COMPARISON STUDY BETWEEN HVDC LINE AND SELF-COMMUTATED CONVERTER SYSTEM

Issarachai, N.; Funaki, T.; Matsuura, K.

Osaka Univ, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, p 6.107

Abstract not available.

[1996] 05D - 38

THE APPEARANCE OF SUBSYNCHRONOUS RESONANCE BETWEEN AN HVDC SYSTEM AND A TURBINE GENERATOR

Aten, M.; Kling, W.L.; Mijnlieff, J.D.

GEC ALSTHOM, Stafford, UK

Elektrotechniek (Netherlands), vol 74, no 2, February 1996, pp 104-108

Dutch

Subsynchronous resonance (SSR) can be described as a condition where the electric network exchanges energy with the mechanical part of a turbine generator at one of the natural (eigen) frequencies of the combined system. The oscillations have a frequency which is below the synchronous system frequency, in the range of 5-50 Hz. Subsynchronous resonance, in case of an HVdc system, can occur because of the interaction between the HVdc thyristor control scheme and the rotational masses of a production unit. After a random disturbance, these subsynchronous oscillations might be poorly damped or even become unstable, resulting in a possible shortening of the lifetime of the rotor shaft of the turbine generator or in the most severe case direct damage to the shaft. Besides the features of the turbine generator, the following is of influence: the parameters of the current control, the transmitted dc power, the firing angle [alpha] and the strength of the connected ac network. The adverse interaction is at most in case of an HVdc rectifier together with a production unit isolated from the grid. 9 figs., 9 refs.

[1997] 05D - 39

TORQUES IN TURBINE-GENERATOR-EXCITER SHAFTS DUE TO DC CURRENTS IN ASYNCHRONOUS HVDC LINKS

Hammons, T.J.; Bremner, J.J.; Kacejko, P.A.

Glasgow Univ, UK

Electric Machines and Power Systems, vol 25, no 1, January 1997, pp 87-105

This paper makes an in-depth analysis of excitation of shaft torsional vibrations in steam turbine-generator-exciter shafts by variable-frequency ripple currents superimposed on dc currents in asynchronous links. Shaft torques in multimachine power networks are estimated by proportioning HVdc link disturbance current to each machine at risk using system network data, generator data, fault analysis data, and load flow data, considering the frequency dependence of the system parameters. 660-MW and 1000-MW machines are considered in the analyses that are made.

[1996] 05D - REF

OPERATING EXPERIENCES OF THE NELSON RIVER HVDC SYSTEM

For Abstract see entry 01C – 24

[1996] 05D - REF

HARMONIC FLOW AND INSTABILITIES IN POWER GRIDS WITH HVDC

For Abstract see entry 02D - 14

[1997] 05D - REF

INVESTIGATION OF AC/DC CONVERTER HARMONICS BY AN ANALYTICAL BASED TIME-DISCRETE APPROACH

For Abstract see entry 02D - 17

[1996] 05D - REF

ASPECTS OF FILTER DESIGN FOR THE CHANDRAPUR 2*500 MW HVDC BACK-TO-BACK CONVERTOR STATION

For Abstract see entry 02D - 6

[1996] 05D - REF

CALCULATION OF HVDC CONVERTER NONCHARACTERISTIC HARMONICS USING DIGITAL TIME-DOMAIN SIMULATION METHOD

For Abstract see entry 02D - 7

[1998] 05D - REF

NOVEL CURRENT CONTROLLER FOR ELIMINATION OF DOMINANT OSCILLATORY MODE ON AN HVDC LINE

For Abstract see entry 05B - 53

[1997] 05D - REF

INTERACTIONS AND COUNTERMEASURES OF AC-DC INTERCONNECTED SYSTEM WITH LARGE CAPACITY THERMAL POWER PLANTS IN THE VICINITY

For Abstract see entry 05C - 14

[1996] 05D - REF

NEWTON SOLUTION FOR THE STEADY-STATE INTERACTION OF AC/DC SYSTEMS

For Abstract see entry 05C - 16

[1996] 05D - REF

MODELING AND SIMULATION OF THE

PROPAGATION OF HARMONICS IN ELECTRIC POWER NETWORKS PART II: SAMPLE SYSTEMS AND EXAMPLES

For Abstract see entry 17C - 17

[1997] 05D - REF

FOURTH SUPPLEMENT TO A BIBLIOGRAPHY FOR THE STUDY OF SUBSYNCHRONOUS RESONANCE BETWEEN ROTATING MACHINES AND POWER SYSTEMS

For Abstract see entry 18A - 16

05E Multi-Terminal Transmission Systems and Taps

[1998] 05E - 1

A CUSTOMIZED AIR-CORE TRANSFORMER FOR A SMALL POWER TAPPING STATION

Aghaebrahimi, M.R.; Menzies, R.W.

Univ of Manitoba, Winnipeg, Canada

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998, Preprint order number PE-063-PWRD-0-11-1997

In this paper, a specially designed air-core transformer, to be employed in a small power tapping scheme from HVdc transmission systems, is studied. First, the transformer is analyzed by classical electromagnetic theory. Next, a small prototype transformer is built and studied in the laboratory. Experimental results, confirm the validity and accuracy of the proposed method for calculating the self- and mutual-inductances of the transformer. The results of the digital simulation of the transformer by the PSCAD/EMTDC software package, too, are in good agreement with the lab observations. Next, the transformer is incorporated into the proposed tapping scheme and the system performance is digitally analyzed. It is concluded that with this transformer, a load of 600 kW can be successfully tapped from the HVdc system. Finally, the field effects of the transformer are studied.

[1996] 05E - 2

AN OBJECT ORIENTED PERSPECTIVE FOR AC/MTDC SYSTEM SIMULATION

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Dept of High Voltage Eng, Indian Inst of Sci, Bangalore, India

Electric Power Systems Research (Switzerland), vol 39, no 1, October 1996, pp 9-15

The object oriented methodology (OOM) has added a new dimension for the representation, modeling and simulation of various day-to-day applications. The basic paradigm of OOM reflects the closeness to which the methodology relates to the real world entities. Over a period of time, the requirement of detailed and exact representation with no approximation of real world objects that reflects its behavioral pattern is on the rise. This has resulted in the terminology of complex objects in system simulation. An AC-MTDC system has several interrelated/interconnected components and poses a complex picture. Objectifying such a system will improve system design, analysis, identification, performance evaluation and control and provide a better understanding of the system in its entirety. In this paper a full representation of the various dc system sub-components is used for developing classes of components. A detailed representation along with the various attributes and methodologies associated with each of these components is given. The case study undertaken in this paper is a four-terminal MTAC/DC system with all its terminal components. The paper highlights the various advantages the OOM technique offers for power system modeling. This notation is of immense help, especially during the system design stage wherein the tuning of various system components can be achieved without undergoing the rigor of conventional methods. 15 Refs.

[1996] 05E - 3

ANALYSIS OF HYBRID MULTI-TERMINAL HVDC TRANSMISSION COMPOSED OF SELF-COMMUTATED CONVERTER AND LINE-COMMUTATED CONVERTER

Abe, H.; Konishi, H.; Kawazoe, H.

Elec Power Development Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 101-110

Japanese

Performance of multi-terminal HVdc system composed of self-commutated converters (SCCs) and line-commutated converters (LCCs) are analyzed using EMTP. In the system, one of the SCCs controls dc system voltage, while LCCs control dc current. And power margin is added to the power reference of the dc voltage-controlled converter. Simulation studies confirm

that stable operation of the system can be obtained using the proposed control system without coordination of power references even when one of the converter of the system lost by accidents.

[1996] 05E - 4

CONTROL STRATEGIES OF HYBRID MULTI-TERMINAL HVDC SYSTEM

Suzuki, M.; Abe, H.; Otsuki, M. Tsumenaga, M.

Elec Power Development Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 91-100

Japanese

Hybrid multi-terminal HVdc (MTDC) system with self-commutated converters and line-commutated converters is an efficient method for reliable power transmission with comparatively low cost. This paper proposes a control strategy of a hybrid multi-terminal HVdc system based on the 2-AVR control, which is the method for MTDC with self-commutated converters, and the 2-level ACR control, which is the method for MTDC with line-commutated converters, and describes the simulation study using EMTP.

[1996] 05E - 5

CONTROL SYSTEM FOR MULTI-TERMINAL HVDC SYSTEM COMPOSED OF SELF-COMMUTATED CONVERTERS

Konishi, H.; Kawazoe, H.

Hitachi Research Lab, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.198-6.199

Japanese

Abstract not available.

[1997] 05E - 6

DEVELOPMENT OF ADVANCED MULTI-TERMINAL HVDC CONTROL AND PROTECTION SYSTEMS AND SIMULATOR TESTS

Ooi, H.; Watanabe, T.; Kawada, K.; Hayashi, T.; Konishi, H.; Hirose, S.

Elec Power Dev Co, Ltd, Tokyo, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 967-974

Japanese

A technical project is undertaken for a development of multi-terminal HVdc (MTDC) control and protection systems applicable to future long distance HVdc bulk power transmissions and power network interconnections. Through study and digital analyses of the previously proposed MTDC control and protection systems, the advanced voltage margin control system and the 2-automatic current regulator (2-ACR) control system are developed with new control functions. Then simulator tests are performed for the two systems with power network models expected to be realized in the future. The results of simulator tests are believed that the two MTDC control and protection systems are capable of application to the future long distance HVdc bulk power transmissions and power network interconnections in Japan.

[1997] 05E - 7

DIGITAL SIMULATION OF THE DC CONNECTION OF A WIND FARM

Karlecik-Maier, F.; Rittiger, J.; Wuensche, H.

Siemens AG, Erlangen, Germany

Elektrizitaetswirtschaft (Germany), vol 96, no 24, November 17, 1997, pp 1464-1467

German

In areas other than coastal areas, wind energy can be harnessed in certain sites only. But often, then, an ac transmission line or a consumer center nearby is not available. The novel concept of a multiterminal HVdc transmission is described, which permits connection of a wind farm to a remote ac grid at low cost and with little line disturbance. (orig./)

[1998] 05E - 8

MULTITERMINAL HVDC SYSTEMS IN URBAN AREAS OF LARGE CITIES

Jiang, H.; Ekstrom, A.

Royal Inst of Tech, Stockholm, Sweden

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

Subtransmission and distribution systems for large cities are usually built up of underground cable systems of considerable length. With regard to both cost and performance, a multiterminal HVdc system might be an interesting alternative to the conventional HVac system. The performance of such a multiterminal system has been studied. The simulation results have shown that a great improvement might be offered by the introduction

of such a multiterminal HVdc system, especially with regard to power quality and disturbances from earth faults.

[1996] 05E - 9

Deleted

[1997] 05E - 10

ON THE CONTROL OF A MULTITERMINAL HVDC SYSTEM HAVING ALSO WEAK INVERTER STATIONS

Joetten, R.; Wess, T.; Woodford, D.

Electra (France), no 171, April 1997, pp 7-32

French; English

In a multiterminal system an inverter station which is weak in rated power, in the short-circuit ratio, or both, poses some difficult problems. In the paper, such a substation is called a "weak" inverter. There are some obvious reasons to run the weakest substation preferably in the current-control-mode, with a sufficient reserve of available direct voltage, hence an increased extinction angle in the case of an inverter. It is not advisable to assign the determination of the system voltage to this inverter. In the gamma-control-mode the system voltage would considerably decrease with the load of this weak station. The weak station would have to absorb transient current imbalances due to disturbances. Thus it would be vulnerable to commutation failures consequential to such disturbances. Conventional converter theory is used to calculate the reserve margins of the substations, including the weak one, assuming rated voltage at the ac bus. In this paper, these problems are investigated using the FGH simulator and the EMTDC program at Manitoba HVdc Research. The system chosen for the investigations, mode change of the weak inverter into gamma control, the mode change of the weak inverter into the direct voltage control, recovery from faults in the ac system, and the substation breaker at the weak inverter are discussed.

[1997] 05E - 11

Deleted

[1996] 05E - 12

REGULATION CONCEPT FOR A MULTITERMINAL HIGH-VOLTAGE DC TRANSMISSION

Clodius, D.; Kulicke, B.; Povh, D.; Rittiger, J.

Div of Network Planning, PreussenElektra AG, Hanover, Germany

ETZ (West Germany), vol 117, no 7, 1996, pp 36-38, 40, 42

German

Considerations are presented as to how the three-phase networks of eastern Europe can be combined with the UCPTE network in order to permit an exchange of power between eastern and western Europe. In principle the two power systems can be coupled by a three-phase or a dc link. The former is not feasible on account of the different strategies of frequency regulation. The alternative is suggested as the most technically and economically favorable solution. A bipolar dc link is planned with a maximum transmission capacity of 4 GW at a dc voltage of ±500 kV. The control strategy for multiterminal transmission is treated in particular. 6 Refs.

[1996] 05E - 13

SIMULATION OF A 5-TERMINAL HVDC CONFIGURATION BETWEEN EASTERN AND WESTERN EUROPE

Rittiger, J.; Kulicke, B.; Clodius, D.

Siemens AG, Erlangen, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 106-111

Investigations have been made into how the ac networks in eastern Europe can be coupled together with the UCPTE system so that energy exchange between the existing interconnected systems will become possible. In order to study the performance of a dc interconnection, a simulation model of a bipolar 5-terminal HVdc system was developed. The calculation model was used for studies of the system stability of the connected ac networks which is substantially influenced by the reaction of the dc link. One major demand was that it should be possible to study also dc faults in detail which normally is not possible with conventional stability programs, where the dc transfer functions are represented only in a simplified manner. For this reason an improvement in the simulation program was made that allows stability calculation of large ac networks using complex admittances and parallel solution of the differential equations in the dc circuit. With this new method for stability studies, accurate transient behavior of the dc quantities can be obtained. In the following, the calculation model is referred to as the advanced stability model (ASM). After an overview at the system

configuration some economic aspects are discussed and a description of the HVdc multiterminal configuration is given. Then the ASM is discussed and comparisons with a detailed commutation model of the multiterminal HVdc are shown in order to demonstrate the performance and the accuracy of the ASM. In the last section, some relevant simulation results of the multiterminal configuration are presented. 5 Refs.

[1997] 05E - 14

SMALL POWER TAPPING FROM HVDC TRANSMISSION SYSTEMS: A NOVEL APPROACH

Aghaebrahimi, M.R.; Menzies, R.W.

Univ of Manitoba, Winnipeg, Canada

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1698-1703

This paper deals with the issue of small power tapping from HVdc transmission systems. Based on the availability of powerful solid state devices in the market, a novel solution is proposed and studied. The proposed scheme is digitally simulated by the aid of the EMTDC/PSCAD software package. Simulation results indicate the feasibility of the proposed scheme. The operation of the tapping station meets necessary standards in terms of power quality as well as the non-dependency of the tapped power on the normal range of power being transmitted through the HVdc line. 8 Refs.

[1996] 05E - 15

STUDY OF CONTROL AND PROTECTION SYSTEM OF MULTI-TERMINAL HVDC CONTROL SYSTEM COMPOSED OF SELF COMMUTATED CONVERTERS

Abe, H.; Konishi, H.; Kawazoe, H.

Elec Power Development Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 81-90

Japanese

Basic control and protection systems have been studied using EMTP simulation for a multi-terminal HVdc system composed of self-commutated converters. A new control system is proposed. In the control system, each converter has active power control circuits and a dc voltage control circuit. One of the converters controls a dc voltage and the rest control active power. A power margin is added to the voltage-controlled converter. EMTP simulations such as ac and dc system faults, loss of converters were done with the control system and confirmed verification of the control system.

[1997] 05E - 16

STUDY OF POWER FLOW SOLUTIONS WITH MULTI TERMINAL HVDC SYSTEMS. PART II

Sasaki, H.; Kubokawa, J.; Iwata, J.

Hiroshima Univ, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.181-6.182

Japanese

Abstract not available.

[1996] 05E - 17

THE CONTROL PROBLEMS OF CONVERTER IN A MULTITERMINAL HVdc SYSTEM ON THE EXAMPLE OF EAST-WEST TRANSMISSION LINE

Plenzler, G.; Fedak, V.; Fedor, J.

Inst of Elec Power Eng, Poznan Tech Univ, Poland

Proceedings, Int'l Conf on Electrical Drives and Power Electronics (EDPE'96), The High Tatras, Slovakia, October 1-3, 1996, vol 2, pp 484-489

The paper deals with the basic problems in cooperation of devices and the rules of selection of external characteristics in multiterminal dc power networks. Possible loads of particular stations of the East-West transmission system were given and shapes of external characteristics of converters to be installed in these stations were proposed. These characteristics will ensure the operation of the line at the planned loads and during maintenance or emergency shut-downs of particular stations as well. 5 refs.

[1997] 05E - REF

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY OF ELECTRIC POWER DEVELOPMENT CO. LTD

For Abstract see entry 01A - 16

[1997] 05E - REF

STATE-OF-ART AND DEVELOPMENT OF MULTI-TERMINAL HVDC CONTROL SYSTEMS

For Abstract see entry 01A - 21

[1997] 05E - REF

BIG PROJECTS OF HVDC(HIGH VOLTAGE DIRECT CURRENT) SYSTEM. HVDC PROJECTS IN FOREIGN COUNTRIES

For Abstract see entry 01C - 6

[1996] 05E - REF

DC SIDE FILTERS FOR MULTITERMINAL HVDC SYSTEMS

For Abstract see entry 02D - 9

[1996] 05E - REF

CIRCUIT BREAKERS FOR MESHED MULTITERMINAL HVDC SYSTEMS. II. SWITCHING OF TRANSMISSION LINES IN MESHED MTDC SYSTEMS

For Abstract see entry 02F - 3

[1996] 05E - REF

STUDY OF POWER FLOW SOLUTIONS WITH MULTI TERMINAL HVDC SYSTEM

For Abstract see entry 06B - 4

05F Multi-Infeed HVdc Systems

[1996] 05F - 1

HVDC MULTI-INFEED PERFORMANCE

Andersson, G.; De Toledo, P.F.; Liss, G.

ABB Power Sys, Ludvika, Sweden

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 569-573

The number of power system configurations with two or more HVdc links feeding power to different points in the same ac network area is increasing as the total number of HVdc links in the world increases. This gives rise to a greater interest in studying the performance of such applications. A very special and extreme case of multi-infeed is the asynchronous interconnection of the Scandinavian (the NORDEL) network to continental Europe, today by 6 cable poles, but probably using more poles in the future. A number of technical aspects specifically related to multi-infeed configurations must be considered: is coordination of recovery control needed? How can dc power modulation for stabilization be established? Infeed by two or more dc transmissions to one and the same ac network area often means that a large amount of power is fed into a network that is relatively weak, thus risking voltage instability. The consequence of feeding a large amount of power into a weak network must be considered. And how effective is the electrical separation between inverters in reducing the risk of mutual commutation failures? A method is described which is a generalization of the method of analysis used for single-infeed HVdc systems. The method has been proposed and work is going on concerning the implications and use of the method. It is the intention that it should be a powerful and useful method for future system planners when analyzing and designing multi-infeed HVdc systems. 2 Refs.

[1998] 05F - 2

USE OF PARTICIPATION FACTORS IN MODAL VOLTAGE STABILITY ANALYSIS OF MULTI-INFEED HVDC SYSTEMS

Aik, D.L.H.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

IEEE Trans on Power Delivery, vol 13 no 1, January 1998, pp 203-211

In recent works, a method based on the eigenvalue decomposition technique, known as modal analysis, had been applied to the voltage stability analysis of multi-infeed HVdc systems. In this method, not only the critical eigenvalues are useful in evaluating the voltage stability of the system, but their associated eigenvectors also contain information on the most severe disturbances to the system. In this paper, the use of these modal information for such analysis is further exploited. In particular, bus participation factors are used to identify the critical ac commutation bus for effective remedial measures to be implemented. The significant influence of system parameters on the bus participation factors are also investigated. 13 Refs.

[1997] 05F - 3

VOLTAGE STABILITY ANALYSIS OF MULTI-INFEED HVDC SYSTEMS

Aik, D.L.H.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1309-1318

With the increased use of HVdc transmission systems in power systems, situations have arisen and will be even

more frequent in the future, where several HVdc systems are located in the vicinity of each other. It is evident that interactions between the different HVdc systems will occur in such configurations, and it is of importance to analyze such systems in a systematic way to ensure that there are no risks of adverse interactions. A method of analysis to cope with this task is presented and motivated in this paper. This method is demonstrated by application to a system with dual HVdc converters, and using the identified factors influencing the interactions, its practical realization is also illustrated. 1 Refs.

05G Coordinated Control with FACTS and Other Systems

[1996] 05G - 1

APPLICATION OF SVC IN HVDC SYSTEM

Wang, Y-L.; Ren, Z.; Wang, G-J.

Beijing Grad School, North China Inst of Elec Power, Beijing, China

Power System Technology (China), vol 20, no 12, December 1996, pp 34-37

Chinese

In the inverter station of an HVdc system, SVC can be successfully used for reactive power compensation. A method of using SVC in an HVdc system is proposed in this paper, and its feasibility is also proved. Investigating the steady-state performance of SVC by the node analysis method, the compensation capacity of SVC and the steady-state values of voltage at each node are calculated. Then, by means of dynamic simulation, the dynamic performance of SVC used in an HVdc system is researched. The compensation capacity and the corresponding parameters of SVC for the voltage fluctuation on the ac bus of the inverter station and for three typical faults are emphatically analyzed. To verify this method, the comparison of SVC with shunt capacitor sets in the fields of restraining voltage fluctuation and improving the transient voltage stability of an ac system is carried out. The result of comparison reveals that this SVC compensation is of benefit. 4 Refs.

[1997] 05G - 2

COORDINATION OF CONTROLS WITH MULTIPLE FACTS/HVDC CONTROLLERS IN THE SAME AREA: SURVEY OF PRACTICAL EXPERIENCE

Bilodeau, H.; Liss, G.; Szechtman, M.; Thio, C.V.; Woodford, D.A.

CIGRE WG 14-29

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

Working group 14-29 was established in 1995, aiming at producing a report that could summarize the various forms of interactions when multiple power electric controllers (HVdc, SVC, TCSC, STATCOM, etc.) are located in the same electrical area; and to define mechanisms of interaction that would require coordination studies in order to optimize the overall system performance and avoid possible detrimental effects resulting from the action of one controller upon the others. This paper summarizes the proposed report.

[1997] 05G - 3

DYNAMIC COMPENSATION TO THE FLUCTUATION OF REACTIVE POWER CONSUMPTION AT HVDC CONVERTER WITH THE INSTALLATION OF SSC-SVC

Funaki, T.; Matsuura, K.

Osaka Univ, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 439-440

Japanese

Abstract not available.

[1996] 05G - 4

DYNAMIC PERFORMANCE OF A STATCON AT AN HVDC INVERTER FEEDING A VERY WEAK AC SYSTEM

Zhuang, Y.; Menzies, R.W.; Nayak, O.B.; Turanli, H.M.

Univ of Manitoba, Winnipeg, Canada

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 958-964

This paper investigates the dynamic performance of the advanced static VAr compensator or STATCON at a high voltage direct current (HVdc) converter terminal where the ac systems has a very low short circuit ratio (SCR). The STATCON is based on a nine-level GTO thyristor inverter. The studies include operating

characteristics of the STATCON under various ac and dc disturbances. The simulation results are compared with other types of reactive power compensation options available for such applications. It is shown that the STATCON has clear advantages over the other compensators, in areas such as; fault response time, voltage support ability, and dc recovery, while operating with very weak ac systems. 15 Refs.

[1996] 05G - 5

JOINT OPERATION HVDC/SVC

Thorvaldsson, B.; Arnlov, B.; Saethre, E.; Ohnstad, T.

ABB Power Sys, Sweden

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 281-284

This paper highlights some of the benefits of using SVC together with HVdc. It is based on the experience from studying, designing and installing an SVC in Norway. In June 1995 the SVC rated ±200 MVAr was commissioned in Kristiansand, Norway. It is located within the Kristiansand HVdc converter station. The HVdc converter station is part of the 1000-MW Skagerrak HVdc link connecting the Norwegian power grid to Jutland on the Danish mainland via three submarine cables. The decision to install the SVC was primarily taken in order to eliminate the operational restrictions and to efficiently substitute a synchronous condenser. A desire to enhance the system dynamic performance in respect of voltage was also a major factor behind the decision. 3 Refs.

[1996] 05G - 6

PROSPECTIVE USE OF HVDC AND FACTS FOR ENHANCEMENT OF POWER SYSTEM STABILITY IN THE MAIN GRID OF THE SOUTHERN NORWAY

Flolo, R.; Gjerde, J.O.; Gjengedal, T.

Eng Dept for Trans Sys, Oslo Energi Konsult AS, Oslo, Norway

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 1105-1111

This paper discusses the application of HVdc and thyristor-controlled series compensation (TCSC) for enhancing system stability in a multi-machine power system. A decentralized control scheme has been applied for control of a TCSC device and power frequency controllers have been applied for the control of HVdc transmissions. Case studies from the main grid in the southern Norway are presented to illustrate the dynamic behavior of the power system at various load conditions. 16 Refs.

[1996] 05G - 7

STATCOM APPLICATION TO THE REACTIVE POWER COMPENSATION FOR THE CONVENTIONAL HVDC CONVERTER

Funaki, T.; Fukui, S.; Matsuura, K.; Kimura, N.; Morita, M.

Osaka Univ, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-E, pp 81-86

Abstract not available.

[1997] 05G - REF

POWER TRANSMISSION AND HVDC CONVERTER TECHNOLOGY OF ELECTRIC POWER DEVELOPMENT CO. LTD

For Abstract see entry 01A - 16

[1997] 05G - REF

INNOVATIONS IN HVDC FOR TRANSMISSION QUALITY ENHANCEMENT. APPLICATIONS AND STUDIES.

For Abstract see entry 01A - 9

[1996] 05G - REF

HARMONIC GENERATION BY HVDC SCHEMES INVOLVING CONVERTERS AND STATIC VAR COMPENSATORS

For Abstract see entry 02D - 15

[1996] 05G - REF

CONTROL MEASURES TO ENSURE DYNAMIC STABILITY OF THE CAHORA BASSA SCHEME AND THE PARALLEL HVAC SYSTEM

For Abstract see entry 05C - 8

[1998] 05G - REF

CONTROLLING SVCs FOR BETTER MANAGEMENT OF NORTHERN GRID OF INDIA

For Abstract see entry 08A - 45

05H Faults, Failures in HVdc Transmission Systems

[1996] 05H - 1

COMMUTATION FAILURES IN HVDC TRANSMISSION SYSTEMS

Thio, C.V.; Davies, J.B.; Kent, K.L.

Manitoba Hydro, Winnipeg, Canada

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 946-957

This paper provides a formulation for the initiation or onset mechanism of commutation failures in line-commutated thyristor converters, assuming infinite (zero impedance) ac systems. A theoretical development and a parametric analysis is given. Theory validation by simulation and comparison to actual field experience data is also given. 8 Refs.

[1996] 05H - 2

COMMUTATION FAILURES IN HVDC TRANSMISSION SYSTEMS DUE TO AC SYSTEM FAULTS

Anon.

CIGRE, Paris, France

Elektra (France), no 169, December 1996, pp 58-85

French; English

A theoretical development and formulation for the initiation or onset mechanism of commutation failures in line-commutated thyristor converters has been produced. Theory validation by simulation, a parametric analysis, simulation on various HVdc schemes and a comparison to actual field experience is given. 6 Refs.

[1997] 05H - 3

DEVELOPMENT OF CONTROL FOR SELF-COMMUTATED CONVERTER. (PART II). CONTROL SCHEME OF OVERCURRENT AND OVERVOLTAGE AT SYSTEM FAULT CONDITION

Takasaki, M.; Gibo, N.; Takenaka, K.; Hayashi, T.

CRIEPI, Tokyo, Japan

Denryoku Chuo Kenkyujo Komae Kenkyujo Hokoku (Japan), no T96035, 31 pp

Japanese

To extensively apply self-commutated converters to future trunk power systems, it is important to develop a stable operation scheme at system fault conditions as well as to pursue cost reduction through rationalized converter and system design. This report first discusses the cause of converter overcurrent and HVdc system overvoltage at various ac and dc system fault conditions. Converter control and protection schemes with coordinated control of overcurrent and overvoltage are newly developed through AC DC Power System Simulator test and EMTP analysis. (1) Development of control and protection at ac system fault condition Converter overcurrents at ac system fault are caused by (a) control impossibility in PWM switching interval just after a balanced ac line fault, and (b) converter current control delay in compensating negative-sequence current at an unbalanced fault condition. To achieve continuous operation with suppressing converter overcurrent below about 1.5 pu, an effective control has been developed by adding a converter current order limiter and a negative sequence compensation to the converter control, which has sufficient sampling control speed and PWM pulse number. (2) Development of control and protection at dc system fault condition Coordinated control of converter overcurrent and dc line overvoltage can be achieved by the combination of (a) selection of adequate resistance and capacitance in neutral line grounding, and (b) adoption of converter gate block by detecting dc line voltage drop. A control and protection sequence employing converter gate block followed by dc circuit breaker opening (to restore dc line insulation by extinguish fault current) and reclosing ensures high speed stop-restart operation as fast as line-commutated HVdc system.

[1996] 05H - 4

DYNAMIC ANALYSIS OF VOLTAGE INSTABILITY IN AC-DC SYSTEMS

Padiyar, K.R.; Rao, S.S.

Indian Inst of Sci, Bangalore, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 18, no 1, January 1996, pp 11-18

This paper presents the analysis and study of voltage collapse at any converter bus in ac-dc systems considering the dynamics of dc system. The problem of voltage instability is acute when HVdc links are connected to weak ac systems, the strength determined by short circuit ratio (SCR) at the converter bus. The converter control strategies are important in

determining voltage instability. Small signal analysis is used to identify critical modes and evaluate the effect of ac system strength and control parameters. A sample two-terminal dc system is studied and the results compared with those obtained from static analysis. Also, the results obtained from small signal analysis are validated with nonlinear simulation. 14 Refs.

[1997] 05H - 5

ENERGIZATION TRANSIENTS OF SHUNT REACTORS

Wang, X.; Iravani, M.R.

Xi'an Jiaotong Univ, Xi'an, China

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1626-1631

This paper investigates impacts of energization transients of large shunt reactors on the operation of HVac and HVdc/ac power systems. The Electromagnetic Transients Program for dc systems (EMTDC) is used for the simulation studies. The studies conclude that shunt reactor energization can result in undesirable response of power system apparatus and even interruption of power flow, e.g. commutation failure of HVdc converters. The studies also indicate that the energization transients can be adequately alleviated based on the use of pre-insertion resistor and/or controlled energization strategies. 9 Refs.

[1996] 05H - 6

IMPROVEMENT OF AN HVDC OPERATION CONTROL SYSTEM IN A SYSTEM ACCIDENT

Higashi, M.; Shimamura, H.; Nishimura, M.; Omori, T.; Tsukamoto, M.; Honjo, N.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Tokyo Shibu Ibaraki Shisho Kenkyu Happyokai Koen Yokoshu (Japan), vol 4, pp 101-102

Japanese

Abstract not available.

[1996] 05H - 7

LINE-COMMUTATED THYRISTOR INVERTER OPERATION DURING SHORT-CIRCUITS IN POWER SYSTEM

Plenzler, G.

Inst of Elec Power Eng, Poznan Univ of Tech, Poland

Archives of Electrical Engineering (Poland), vol 45, no 3, 1996, pp 307-326

Conditions of operation of a three-phase line commutated thyristor inverter bridge with interference caused by ac system short-circuits have been presented in the paper. The conditions have been formulated for the safe commutation when the asymmetry of the system parameters occurs. The influence of the short-circuits upon the limits of the safe inverter's work has also been given. The system of checking the thyristor control process enabling decrease of the decays in the inverter during short-circuits, has also been presented. The analysis has been illustrated by the diagrams of current and voltages obtained by the digital simulation method. 8 Refs.

[1997] 05H - 8

NELSON RIVER HVDC LINE FAILURES

Rashwan, M.M.

Manitoba Hydro, Winnipeg, Canada

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

On September 5, 1996, a severe windstorm destroyed 19 HVdc transmission towers on the two bipolar Nelson River system. The storm also destroyed several wooden poles on both electrode lines. The event was the first of its kind on the Nelson River HVdc system in its 25 years of commercial operation. This paper describes the event and discusses the design criteria of the dc lines as well as the repairs and the impact on Manitoba Hydro's system following an event of this magnitude.

[1997] 05H - 9

OPERATIONAL CHARACTERISTICS OF HVDC SYSTEM COMPOSED OF SELF-COMMUTATED CONVERTERS UNDER AC SYSTEM FAULT

Hayashi, T.; Takasaki, M.; Konishi, H.; Kawazoe, H.

CRIEPI, Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.323-6.324

Japanese

Abstract not available.

[1996] 05H - 10

SIMULATION STUDY USING EMTDC ON THREE GORGES HVDC TRANSMISSION SYSTEM

Shi, Y.; Zeng, N-C.

Elec Power Research Inst, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 624-629

In this paper, based on a simulation analysis using EMTDC for three HVdc links from Three Gorges hydro power station multiply-terminated at the ac network of East China Power Network (ECPN), the possibility of simultaneous commutation failure of the three dc inverters is investigated and the preliminary conclusions obtained. It is also shown that commutation failure will occur in a certain critical condition due to a sudden drop in commutation voltage caused by a disturbance, and the critical value of commutation voltage is presented. 9 Refs.

[1996] 05H - REF

OPERATING EXPERIENCES OF THE NELSON RIVER HVDC SYSTEM

For Abstract see entry 01C - 24

[1996] 05H - REF

TIAN-GUANG HVDC TRANSMISSION PROJECT FUNDAMENTAL FREQUENCY OVERVOLTAGE AND OVERVOLTAGE LIMITING MEASURES FOR TIANSHENGQIAO CONVERTER STATION

For Abstract see entry 01C - 34

[1996] 05H - REF

SIMULATION STUDY OF A HYBRID HVDC SYSTEM COMPOSED OF A SELF-COMMUTATED CONVERTER AND A LINE-COMMUTATED CONVERTER

For Abstract see entry 05A - 18

[1996] 05H - REF

TIAN-GUANG HVDC TRANSMISSION PROJECT FUNDAMENTAL FREQUENCY OVERVOLTAGE AND OVERVOLTAGE LIMITING MEASURES FOR TIANSHENGQIAO CONVERTER STATION

For Abstract see entry 05A - 21

[1998] 05H - REF

APPLICATION OF A RADIAL BASIS FUNCTION (RBF) NEURAL NETWORK FOR FAULT DIAGNOSIS IN AN HVDC SYSTEM

For Abstract see entry 05B - 11

[1997] 05H - REF

CONTROL SCHEME OF OVERCURRENT AND OVERVOLTAGE OF HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER

For Abstract see entry 05B - 16

[1996] 05H - REF

DEVELOPMENT OF CONTROL FOR SELF-COMMUTATED CONVERTER. (PART I). DEVELOPMENT OF SIMULATOR MODEL AND STUDY ON CONVERTER OVERCURRENT IN AC SYSTEM FAULT CONDITION

For Abstract see entry 05B - 29

[1996] 05H - REF

DEVELOPMENT OF DC CONTROL FUNCTION. DEVELOPMENT OF UNINTERRUPTED CONTROL IN CASE OF AS SYSTEM ACCIDENT

For Abstract see entry 05B - 30

[1997] 05H - REF

FAST AND PREDICTIVE HVDC EXTINCTION ANGLE CONTROL

For Abstract see entry 05B - 32

[1996] 05H - REF

FAULT DETECTION AND DIAGNOSIS OF POWER CONVERTERS USING ARTIFICIAL NEURAL NETWORKS

For Abstract see entry 05B - 33

[1996] 05H - REF

MICROPROCESSOR BASED HVDC CONVERTER PROTECTION

For Abstract see entry 05B - 48

[1997] 05H - REF

OVERCURRENT PHENOMENA FOR HVDC SYSTEM WITH SELF-COMMUTATED CONVERTER

For Abstract see entry 05B - 55

[1997] 05H - REF

WIDE-AREA PROTECTION AGAINST VOLTAGE COLLAPSE

For Abstract see entry 05B - 68

[1998] 05H - REF

MULTITERMINAL HVDC SYSTEMS IN URBAN AREAS OF LARGE CITIES

For Abstract see entry 05E - 8

[1997] 05H - REF

ADVANCED AC/DC REAL-TIME AND COMPUTER SIMULATIONS FOR THE GMPC CAHORA BASSA DESIGN VERIFICATION

For Abstract see entry 06E - 2

05I Ground Return, Electrode Design

[1996] 05I - 1

CAHORA BASSA-APOLLO HVDC LINK

Moore, R.J.

ESKOM, Johannesburg, South Africa

Proceedings, IEEE 4tH Conf in Africa (AFRICON'96), Stellenbosch, South Africa, September 24-27, 1996, vol 2, pp 699-704

The Cahora-Bassa HVdc link consists of two 533-kV lines spaced approximately 1 km apart. If one line is out power can be supplied with one line and earth return. The current being dc will flow through the whole earth, however where it enters or leaves the earth the cross sectional area must reduce before it can pass up the electrode connecting the conductor to earth. The author discusses the design of the earth electrodes and an electronically conducting backfill material which excluded ionic conduction. Laboratory tests on backfill media are discussed as is the testing and installation of the new electrode. 0 Refs.

[1996] 05I - 2

ENVIRONMENTAL AND GEOGRAPHICAL ASPECTS IN HVDC ELECTRODE DESIGN

Tykeson, K.; Nyman, A.; Carlsson, H.

Sydkraft Konsult AB, Malmo, Sweden

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1948-1954

An essential element in HVdc electrode design is to minimize all environmental stresses in order to meet and verify conformance to the laws and regulations associated with the concessions granted by the authorities. The environmental disturbance caused in anode or cathode operation is more or less entirely dependent on the materials used, the geographical location and the electrode size. The electrode materials and the related electrochemical process in the surrounding medium are discussed in the paper in order to shed further light on the chemical properties of different materials in an electrolyte process. The geographical location of an electrode is described, taking into account new aspects such as the impact of the earth's magnetic field and the interaction with existing HVdc electrodes. The experiences described in this paper are based on the design, tests and operation of the electrodes in the Baltic Cable HVdc link and other Scandinavian HVdc links. 8 Refs.

05J Insulation Coordination

[1996] 05J - 1

APPLICATIONS OF EMTP ON CALCULATING OVERVOLTAGE IN HIGH VOLTAGE INSULATION SYSTEM

Chu, R-H.

Northwest Elec Power Test & Research Inst, Xi'an, China

Proceedings, 1996 Asian Intl Conf on Dielectrics & Electrical Insulation Diagnosis (96'AICDEI & 4th-JCCEID), Xi'an, China, October 8-11, 1996, pp 295-298

Electro Magnetic Transient Program (EMTP) has been a valid tool of solving overvoltages in power systems. Two calculations, which are ferro-resonance overvoltage calculation and reignition overvoltage calculation of shunt capacitors, are finished by using EMTP. The paper offers how to describe power system by EMTP, such as equivalent circuit of system, parameter selection and setting, simultaneously, provides the calculating results and charts which represent the varied theories of the overvoltage as their parameters changed. The calculation results are compared with measured data and standards separately, and coincide with them too. They have great value in insulation design and safety operation of electrical apparatus, and can be references

to practical operation of power system. 2 Refs.

[1996] 05J - 2

COORDINATION OF THE INSULATION OF SUPERHIGH-VOLTAGE CONVERTER TRANSFORMERS

Lokhanin, A.K.

Russian Electrical Engineering (Elektrotekhnika), vol 67, no 8, pp 34-36

The electric strength of insulation for dc power-transmission equipment depends on the conductivity fields and, hence, on factors such as the temperature, humidity, level and type of pollution, electric field strength, and duration of voltage application. In addition, for dc transmission equipment, fundamentally new electrical factors associated with the position of the electrostatic and conduction fields, must be considered. For superhigh-voltage dc power transformers in Russia, oil-barrier insulation is mainly used. The electrical strength of oil-barrier insulation is largely determined by the voltage distribution between the oil and the solid insulation. For direct current, depending on the ratio of resistivities of the cardboard and oil, the strength of the insulation may be determined by the load of the oil or that of the cardboard. The voltage distribution between the oil and the solid insulation under the action of a dc voltage may be found by calculation or by direct measurement, for example, using probes. 2 Refs.

[1997] 05J - 3

INSULATION CHARACTERISTICS OF 500-KV WATER-COOLED THYRISTOR VALVE FOR HVDC TRANSMISSION

Tanabe, S.; Hasegawa, T.; Yamaji, K.; Irokawa, H.

Toshiba Corp, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 6, June 1997, pp 791-797

A thyristor valve rated at 500-kV is being developed for use in a 2800-MW, 500-kV HVdc power system. One aim of this development effort is to reduce valve size by adopting a rational insulation design. The authors studied the optimization of the air-gap insulation between the upper and lower thyristor modules and of creepage insulation distance of insulation poles, both being considered to make the greatest contribution to size reduction. An electric field analysis was performed to determine the air-gap insulation. Next, a module-to-module insulation model was manufactured to verify the adequacy of the analysis. A long-term dc V-t characteristic (voltage-time characteristic) for insulation poles under postulated environmental conditions was obtained to optimize creepage insulation distance of the insulation poles. Such a rationalized insulation design combined with the adoption of an 8-kV light-triggered thyristor offered the prospect of reducing the height of the thyristor valves by about 25% and the volume by about 30% compared with those designed by the Hokkaido-Honshu dc link design method. They also investigated the change in insulation characteristic caused by cooling water leakage.

[1996] 05J - REF

INVESTIGATION OF SINGLE UNIT FLASHOVERS IN HVDC INSULATOR STRINGS

For Abstract see entry 02G - 10

05K Measurements, Instrumentation

[1996] 05K - 1

PHASE ANGLE MEASUREMENT TECHNIQUES

Madge, R.; Fischer, D.

Ontario Hydro Technologies, Toronto, Canada

Canada Electricity Association, Report Number CEA-466 T 957, January 1996, 90 pp

Real-time measure of the power transfer across a transmission line is discussed. Phase angle measurement techniques, algorithms and applications relevant to power utilities are assessed. Phase-based applications compute the voltage angle difference between two stations, thereby allowing for power transfer calculations and power system control applications. A list of phase angle measurement applications is provided. It includes frequency measurement, state estimation, adaptive relaying, power system control, system restoration, real power flow monitoring and stability assessment, reactive power requirements monitoring, HVdc modulation, subsynchro-nous resonance, sequence of event recording, and loss reduction and fault location. The optimum timing requirement is determined for each application. Among the timing systems available today, the Global Positioning System (GPS), supported by powerful computers and other custom hardware, is the only tool that can provide the accuracy and coverage needed by today's power system applications.

Commercially available equipment for phase angle measurements are also reviewed. 30 refs., 32 tabs., 5 figs.

[1996] 05K - REF

THE INFLUENCE OF THREE-PHASE QUANTITY SYMMETRY ON MEASURING ERROR OF REACTIVE POWER TRANSDUCER

For Abstract see entry 18E - 22

[1996] 05K - REF

CURRENT TRANSDUCER BEHAVIOR IN A NOISY ENVIRONMENT

For Abstract see entry 18E - 6

05L Reliability

[1998] 05L - 1

A SURVEY OF THE RELIABILITY OF HVDC SYSTEMS THROUGHOUT THE WORLD DURING 1995-1996

Christofersen, D.J.; Ellahi, H.; Bennett, M.G.

CIGRE Study Committee 14

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

CIGRE Working Group 14.04 collects data annually on the reliability performance of HVdc systems in operation throughout the world. This report is a summary of the reliability performance of HVdc systems in operation throughout the world during 1995 and 1996. The summary was developed through data prepared by utilities that operate the HVdc systems and submitted to Working Group 04 of CIGRE Study Committee 14 (DC Links). The report contains data on energy availability, energy utilization, forced and scheduled outages and other data in accordance with a reporting protocol developed by the Working Group, which was revised in January 1997 and distributed in time to be used for the 1996 survey. The report contains statistics on the frequency and duration of forced outages for the years 1995 and 1996 and combined with previous data to present a cumulative average of forced outages by frequency and duration covering the years 1988 to 1996. The cumulative averages are categorized by back-to-back stations and stations with one and two converters per pole. The data in this report, together with that published in previous reports, provide a continuous record of reliability performance for the majority of HVdc systems in the world since they first went into operation. This now constitutes about 350 system-years of data on thyristor valve systems.

[1997] 05L - 2

AN EXAMPLE OF REPORTING HVDC THYRISTOR VALVE PERFORMANCE USING 1983-1994 AVERAGE UNAVAILABILITY DATA

Christofersen, D.J.; Kahle, V.; Thio, C.V.

CIGRE WG 14.04 and TF 14.04.03

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

CIGRE Study Committee 14 (SC14), Working Group (WG) 14.04 annually collects performance data from HVdc systems in operation throughout the world. A performance report is prepared from the data and presented at the SC 14 Technical Session during the Paris CIGRE biennial symposium. The protocol for reporting all systems developed within WG 14.04 was updated in 1997. Use of this protocol will be demonstrated by utilizing HVdc system component average unavailabilities obtained from performance data reported between 1983 and 1994. The average unavailability data may be used for benchmarking performance of HVdc systems. WG 14.04 is also considering revising the format of the biennial report and this paper may be a prelude of the reporting style being considered.

[1996] 05L - 3

AVAILABILITY AND RELIABILITY OF HVDC MULTI-TERMINAL PLANTS

Alm, S. ; Haeusler, M.

ABB Power Sys AB, Ludvika, Sweden

Elektrizitaetswirtschaft (Germany), vol 95, no 23, November 4, 1996, pp 1567-1571

German

A large HVdc multi-terminal system allows access to remote power stations, but requires an energy availability comparable to that of power stations in close proximity. Transmission of remotely-supplied energy by means of HVdc two-terminal system is a tried and tested method. The authors explain that the reliability and availability of multi-terminal HVdc systems is almost as good as that of two-terminal systems. This statement is corroborated by experiences with the HVdc

multi-terminal system in Quebec, Canada.

[1996] 05L - 4

AVAILABILITY AND RELIABILITY OF THE 600 MW HVDC BACK-TO-BACK STATIONS ETZENRICHT/GERMANY AND VIENNA SOUTHEAST/AUSTRIA

Flassbeck, W.; Liegl, K.; Hofbauer, F.; Ritcher, W.

Siemens AG, Erlangen, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 139-145

The 600-MW HVdc back-to-back station at Etzenricht connects the 420-kV transmission systems of Bayernwerk AG in Bavaria, Germany (UCPTE network) and the Czech power utility CEZ (CENTREL network). The station went into commercial operation in June 1993. To link the 420-kV transmission systems of Osterreichische Elektrizitatswirtschafts-AG in Austria (UCPTE network) with the Hungarian power utility MVM Rt. (CENTREL network) the 600-MW HVdc back-to-back station Vienna Southeast was commissioned in June 1993. The HVdc back-to-back stations at Etzenricht/Germany and Vienna Southeast/Austria have now been in operation since completion in 1993. This report describes the measures taken in considering the levels of availability and reliability of the two installations. The in service experiences gained during network operation is evaluated here in detail, and confirm the effectiveness of the measures taken. The report also discusses other constructive proposals made on the basis of operating results. 8 Refs.

[1998] 05L - 5

DESIGNING HVDC TRANSMISSION SCHEMES FOR DEFINED AVAILABILITY

Barker, C.D.; Sykes, A.M.

GEC ALSTHOM T&D Power Electrn Sys Ltd, UK

IEE Colloquium on Power Electronics Reliability - Promise and Practice (Does it Deliver?) (Digest No.1998/202) (UK), 11 February 1998, pp 4/1-11

Over long distances bulk power transfer can be carried out by a high voltage direct current (HVdc) connection cheaper than by a long distance ac transmission line. HVdc transmission can also be used where an ac transmission scheme could not (e.g. through very long cables or across borders where the two ac systems are not synchronized or operating at the same frequency). However, in order to achieve these long distance transmission links, power convertor equipment is required, which is a possible point of failure and any interruption in delivered power can be costly. It is therefore of critical importance to design an HVdc scheme for a given availability.

[1997] 05L - 6

DIAGNOSING THE HEALTH OF BULK GENERATION AND HVDC TRANSMISSION SYSTEMS

Billinton, R.; Aboreshaid, S.; Fotuhi-Firuzabad, M.

Univ of Saskatchewan, Saskatoon, Canada

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1740-1745

This paper presents a technique to evaluate the degree of reliability well-being of bulk generation and HVdc transmission systems. The system well-being is categorized in terms of system health and margin in addition to the conventional risk index. Such a technique enable power system designers, planners and engineers to analyze the generating system and the HVdc transmission system independently by obtaining the well-being area diagrams for each system. The bulk generation and HVdc transmission well-being area diagram can be found by combining both diagrams. Two performance indices designated as the expected healthy performance index and the not at risk performance index which account for the system load characteristics are introduced to describe the degree of system well-being. The technique is illustrated by application to a simple hypothetical configuration and a practical HVdc system. 11 Refs.

[1996] 05L - 7

FURNAS HVDC SYSTEM PERFORMANCE AND EXPERIENCE

Santos, R.P.P.; de Aquino, C.A.S.; Neto, E.C.; Alves, S.R.M.

Furnas Centrais Eletricas S.A, Foz do Iguacu, Brazil

Proceedings, 14th IEEE T&D Conf Conf, Los Angeles, CA, September 15-20, 1996, pp 164-169

The main performance indexes, mean time between failure, mean time to repair, availability and reliability of Itaipu HVdc transmission system in the last years are presented and commented. General maintenance aspects emphasis on flash-overs in bypass breakers and valve hall fire detection system are seen. Operational aspects about high-MVAr and reduced voltage operation,

parallel operation and double monopolar operation are also discussed. 5 Refs.

[1997] 05L - 8

HYBRID DETERMINISTIC/PROBABILISTIC TECHNIQUE FOR HVDC SYSTEM RELIABILITY EVALUATION

Billinton, R.; Aboreshaid, S.; Fotuhi-Firuzabad, M.

Univ of Saskatchewan, Saskatoon, Canada

Proceedings, IEEE WESCANEX Conf on Communications, Power and Computing, Winnipeg, Manitoba, Canada, May 22-23, 1997, pp 35-40

This paper extends the conventional probabilistic approaches for reliability evaluation of high voltage direct current (HVdc) transmission systems by including acceptable deterministic criteria in the stochastic evaluation of the reliability indices. The operation of the HVdc transmission system is categorized into three operating states designated as healthy, marginal and at risk. The well-being of the system is quantified using the healthy and marginal states in addition to the existing conventional risk index. A brief discussion on the modeling techniques used to translate the single line diagram of an HVdc system into a reliability diagram is also presented. The impact on the system well-being of factors such as component failure rates and repair times is also illustrated. The propose technique is illustrated by application to a hypothetical system. 13 Refs.

[1996] 05L - 9

RELIABILITY ASSESSMENT OF AUTONOMOUS POWER SYSTEMS INCORPORATING HVDC INTERCONNECTION LINKS

Dialynas, E.N.; Koskolos, N.C.; Agoris, D.

Natl Tech Univ, Athens, Greece

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 519-525

The objective of this paper is to present an improved computational method for the overall reliability assessment of autonomous power systems that may or may not contain HVdc interconnection links. This is a hybrid method based on a Monte - Carlo simulation sequential approach which incorporates an analytical approach for the reliability modeling of the HVdc transmission links. The developed models and techniques have been implemented into a computer program that can be used to simulate the operational practices and characteristics of the overall system under study efficiently and realistically. A set of reliability indices are calculated for each load-point of interest and the entire system while a set of additional indices is calculated for quantifying the reliability performance of the interconnection links under the specified operating requirements. The analysis of a practical system is also included for a number of studies representing its various operating and design characteristics. 19 Refs.

[1996] 05L - REF

HVDC TRANSMISSION LINK BETWEEN DENMARK AND GERMANY

For Abstract see entry 01C - 16

[1997] 05L - REF

INTERCONNECTED HVDC STATIONS LINK EUROPE

For Abstract see entry 01C - 18

[1996] 05L - REF

ASPECTS AND EXPERIENCES FOR GESHA HVDC LINK

For Abstract see entry 01C - 3

[1996] 05L - REF

SURVEY OF HVDC OPERATING AND MAINTENANCE PRACTICES AND THEIR IMPACT ON RELIABILITY AND PERFORMANCE

For Abstract see entry 01C - 31

[1997] 05L - REF

BIG PROJECTS OF HVDC(HIGH VOLTAGE DIRECT CURRENT) SYSTEM. HVDC PROJECTS IN FOREIGN COUNTRIES

For Abstract see entry 01C - 6

[1997] 05L - REF

DEVELOPMENT OF INSULATION STRUCTURE AND ENHANCEMENT OF INSULATION RELIABILITY OF 500-KV DC GIS

For Abstract see entry 02F - 11

[1997] 05L - REF

DEVELOPMENT OF 500-KV DC PPLP-

INSULATED OIL-FILLED SUBMARINE CABLE

For Abstract see entry 04A - 1

[1996] 05L - REF

DESIGN AND TESTING OF THE BIPOLAR 12-PULSE HVDC PROTECTION SYSTEM

For Abstract see entry 05B – 26

[1996] 05L - REF

DESIGN ASPECTS OF UPGRADATION FROM 6 PULSE TO 12 PULSE OPERATION OF NHVDC PROJECT

For Abstract see entry 05B - 27

[1996] 05L - REF

A DISTRIBUTED SEQUENTIAL CONTROL SYSTEM FOR THE APOLLO HVDC SUBSTATION

For Abstract see entry 05B - 3

[1996] 05L - REF

SEISMIC EXPERIMENT OF FRP COLUMNS IN A THYRISTOR VALVE BY A REAL-TIME HYBRID VIBRATION TESTING METHOD

For Abstract see entry 05N - 2

05M Telecommunications

[1997] 05M - 1

TELECOMMUNICATION TECHNOLOGY

Yamaoka, K.; Tamada, S.; Yoshioka, K.; Nakamizo, H.

Elec Power Development Co Ltd, Japan

Dengen Kaihatsu K.K. Chosa Shiryo (Japan), no 100, pp 203, 205-213

Japanese

This chapter describes our telecommunication facilities, and in particular, historical developments in our data transmission technologies and facilities. It briefly reviews transmission technologies, developments and features of transmission devices, contemplated concepts, and so on. With regard to information transmission technology, we have been actively performing remote control of power stations since our establishment. Besides reviewing early remote control and information transmission technologies, this chapter describes cyclic digital data transmission(CDT) systems used for concentrated control and the high-speed information transmission system for the Hokkaido-Honshu HVdc Link. Since our establishment, a large number of unmanned radio relay stations have been constructed.

05N Safety and Seismic Considerations

[1998] 05N - 1

PROCEEDINGS, IEEE POWER ENGINEERING SOCIETY'S 8TH INTERNATIONAL CONFERENCE ON TRANSMISSION AND DISTRIBUTION CONSTRUCTION, OPERATION, AND LIVE-LINE MAINTENANCE (EMSO '98)

IEEE Power Engineering Society, IEEE Piscataway, NJ,

IEEE EMSO '98 focused on the practical, hands-on methods and procedures for the construction, operation, maintenance and safety of overhead and underground transmission and distribution lines, including substations. The conference included two days of outdoor field demonstrations and exhibits.

[1996] 05N - 2

SEISMIC EXPERIMENT OF FRP COLUMNS IN A THYRISTOR VALVE BY A REAL-TIME HYBRID VIBRATION TESTING METHOD

Inoue, M.; Horiuchi, T.

Hitachi, Ltd., Mech Eng Research Lab, Japan

Trans of the Japan Society of Mechanical Engineers (Nippon Kikai Gakkai Ronbunshu), pt C, vol 62, no 596, April 1996, pp 1295-1300

Japanese

A thyristor valve is a power electrical system in which thyristor modules are supported by metal frames and electrical isolation columns made of fiber-reinforced plastic (FRP). Since the stiffness of the FRP columns is not very large, seismic reliability is a important design factor of thyristor valves. However, it is difficult to conduct experiments on seismic response of the structure using a shaking table because of its large scale and heavy weight. Therefore, we conducted a seismic experiment on a part of the FRP columns by means of a real time hybrid vibration experimental method, in

which an actuator-excited vibration experiment and a response analysis with a computer are on line combined and simultaneously conducted in real time. From the results of the experiments, it was found that the FRP columns were damaged only at their end-flanges and the failure of the entire structural system was not observed even with strong excitation. 8 Refs.

[1996] 05N - REF

DEVELOPMENT OF A THYRISTOR VALVE FOR 500-KV HVDC TRANSMISSION SYSTEMS

For Abstract see entry 02C - 14

[1997] 05N - REF

EARTHQUAKE AND FIRE RESISTANT. MEASURES TAKEN AT SYLMAR SUBSTATION, US WEST COAST

For Abstract see entry 02C – 17

[1996] 05N - REF

THYRISTOR VALVE REPLACEMENT OF THE PACIFIC INTERTIE EXPANSION SYLMAR EAST 500-KV HVDC CONVERTER STATION

For Abstract see entry 02C - 38

[1996] 05N - REF

DEVELOPMENT AND FIELD TEST RESULTS OF THE AC 275-KV COMPACT FILTER

For Abstract see entry 02D - 11

[1996] 05N - REF

SEISMIC PERFORMANCE OF HVDC 500-KV-600-KV SF_6 GAS TANK TYPE SURGE ARRESTERS

For Abstract see entry 02G - 15

[1996] 05N - REF

MICROPROCESSOR CONTROL AND SAFETY SYSTEM FOR A 24-PHASE RECTIFIER-INVERTER MODULE

For Abstract see entry 05A - 13

06 MODELING AND SIMULATION OF HVDC SYSTEMS

06A Small Signal Stability

[1997] 06A - 1

S-DOMAIN MODEL OF AN HVDC CONVERTER

Todd, S.; Wood, A.R.; Bodger, P.S.

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1723-1729

This paper describes a technique to model an HVdc converter installation in the s-domain. A system equivalent is developed, utilizing a frequency domain model, allowing the closed loop frequency response to be expressed. A rational function approximation of the closed loop frequency response is found by writing an overdetermined equation set, solved directly using singular value decomposition. System poles and zeros in the s-domain are extracted through the solution of the rational function roots. Validation of the model at two converter operating points is obtained via time domain simulation and step response techniques for an inverter voltage perturbation. 11 Refs.

[1996] 06A - 2

STABILITY ANALYSIS OF HVDC SYSTEM CONNECTED TO WEAK AC SYSTEMS

Pandey, R.K.; Sachchiudanand; Ghosh, A.

MMM Eng College, Gorakhpur, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 2, pp 669-677

This paper describes the development of a discrete-time ac/dc system model for small signal stability analysis. The operation of HVdc converters is discrete in nature. It is, therefore, proper to take into account the discrete behavior of converter operation while developing the complete system model. The converter model is developed utilizing the concept of multirate sampling. The ac/dc system model developed has a modular structure and is quite general. The model does not assume that the converter ac bus voltages at different terminals are coincident. The model developed is utilized to critically examine the effect of the ac system strength on the stability characteristics in an integrated ac/dc system.

[1996] 06A - REF

NONCHARACTERISTIC HARMONICS IN AC/DC CONVERTER GENERATED BY SUPPLY VOLTAGE UNBALANCE. I. FUNDAMENTALS AND UNCONTROLLED DIODE CONVERTER

For Abstract see entry 02D - 19

[1996] 06A - REF

NONCHARACTERISTIC HARMONICS IN AC/DC CONVERTER GENERATED BY SUPPLY VOLTAGE UNBALANCE. II. CURRENT CONTROLLED THYRISTOR CONVERTER

For Abstract see entry 02D - 20

[1997] 06A - REF

NOVEL CALCULATION OF HVDC CONVERTER HARMONICS BY LINEARIZATION IN THE TIME-DOMAIN

For Abstract see entry 02D - 21

[1996] 06A - REF

SMOOTHING TRANSFORMER, A NEW CONCEPT IN DC SIDE HARMONIC REDUCTION OF HVDC SCHEMES

For Abstract see entry 02D - 26

[1998] 06A - REF

CAPACITOR COMMUTATED CONVERTER CIRCUIT CONFIGURATIONS FOR DC TRANSMISSION

For Abstract see entry 05A - 3

[1998] 06A - REF

INFLUENCE OF LOAD CHARACTERISTICS ON THE POWER/VOLTAGE STABILITY OF HVDC SYSTEMS, PART 1: BASIC EQUATIONS AND RELATIONSHIPS

For Abstract see entry 05B - 41

[1998] 06A - REF

INFLUENCE OF LOAD CHARACTERISTICS ON THE POWER/VOLTAGE STABILITY OF HVDC SYSTEMS, PART 2: STABILITY MARGIN SENSITIVITY

For Abstract see entry 05B - 42

[1996] 06A - REF

A STUDY ON COMPARATIVE ANALYSIS OF DIRECT CURRENT CONTROL IN A.C-D.C INTERCONNECTED POWER SYSTEM

For Abstract see entry 05B - 6

[1996] 06A - REF

SELECTING ROBUST INPUT SIGNALS FOR HVDC DAMPING CONTROLLERS

For Abstract see entry 05B - 60

[1996] 06A - REF

HARMONIC INTERACTION ON AC/DC SYSTEMS: EFFECTS OF CONTROL ACTIONS

For Abstract see entry 05C - 12

[1996] 06A - REF

RESEARCH ON THE OVERLOAD PARAMETER OF TIAN-GUANG HVDC AND THE IMPROVEMENT OF THE PARALLEL AC SYSTEM POWER TRANSMISSION CAPABILITY

For Abstract see entry 05C - 24

[1998] 06A - REF

SMALL SIGNAL ANALYSIS OF HVDC-HVAC INTERACTIONS

For Abstract see entry 05C - 25

[1998] 06A - REF

ANALYTICAL MODELLING OF HVDC-HVAC SYSTEMS

For Abstract see entry 05C - 6

[1996] 06A - REF

COORDINATION OF POWER RAMP AND MODULATION FOR AC/DC PARALLEL SYSTEM WITH WEAK AC LINKS

For Abstract see entry 05C - 9

[1996] 06A - REF

HVDC CONVERTER TRANSFORMER CORE SATURATION INSTABILITY: A FREQUENCY DOMAIN ANALYSIS

For Abstract see entry 05D - 14

[1996] 06A - REF

INVESTIGATIONS OF THE IMPACTS OF HVDC SELF-COMMUTATED CONVERTER SYSTEM ON TORSIONAL OSCILLATIONS

For Abstract see entry 05D - 17

[1997] 06A - REF

POWER ELECTRONICS APPLICATION TECHNOLOGY TO ELECTRIC POWER FIELD

For Abstract see entry 05D - 21

[1997] 06A - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. STEADY-STATE STABILITY ANALYSIS OF SHAFT TORSIONAL OSCILLATION IN AC-DC INTERCONNECTED SYSTEM WITH SELF-COMMUTATED CONVERTERS

For Abstract see entry 05D - 22

[1996] 06A - REF

STEADY-STATE STABILITY ANALYSIS OF EFFECT OF HVDC WITH SELF-COMMUTATED CONVERTER ON SHAFT TORSIONAL OSCILLATION

For Abstract see entry 05D - 33

[1996] 06A - REF

DYNAMIC ANALYSIS OF VOLTAGE INSTABILITY IN AC-DC SYSTEMS

For Abstract see entry 05H - 4

[1997] 06A - REF

ANALYSIS OF POWER OSCILLATIONS IN THE SOUTH AFRICAN HIGH-VOLTAGE GRID USING COMBINED TIME DOMAIN AND EIGENVALUE TECHNIQUES

For Abstract see entry 06C - 2

[1998] 06A - REF

APPROPRIATE HVDC TRANSMISSION SIMULATION MODELS FOR VARIOUS POWER SYSTEM STABILITY STUDIES

For Abstract see entry 06C - 3

[1996] 06A - REF

CONVERTERS FOR GRID-CONNECTED DC ENERGY SOURCES: A SIMULATION TOOL TO MEET EXPECTED UTILITY SPECIFICATIONS

For Abstract see entry 17B – 8

06B Power Flow, Contingency Analysis

[1996] 06B - 1

A NEWTON SOLUTION FOR THE HARMONIC PHASOR ANALYSIS OF AC/DC CONVERTERS

Smith, B.C.; Watson, N.R.; Wood, A.R.; Arrillaga, J.

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 965-971

Abstract not available.

[1996] 06B - 2

DEVELOPMENT OF OPTIMAL POWER FLOW ALGORITHM FOR COMBINED AC-DC SYSTEM

Sasaki, H.; Nakamura, S.; Kubokawa, J.

Hiroshima Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-D, no 2, February 1996, pp 181-186

Japanese

Optimal power flow (OPF) is to minimize a certain power system objective function such as generation cost or transmission loss while satisfying various constraints posed from system operations and hence can be a powerful tool for making up reasonable operation plans. Since the advent of dc transmissions in mid 1950s, it has been used as a useful substitute of ac transmission in cases of long distance transmission, transmission through marine cables, frequency changers, ac-dc parallel transmission, etc. Therefore, it is highly needed to develop an efficient OPF algorithm into which dc transmission systems can be integrated without significant modifications of an OPF program for ac systems. This paper presents an extension of the current Newton OPF program, which directly solves the Kuhn-Tucker conditions and is regarded as most efficient and

robust at present, so that the OPF can incorporate dc transmission systems. The control schemes of dc systems have been satisfactorily integrated into the developed OPF algorithm. Numerical experiments on a test system have verified the effectiveness of the proposed algorithm. 12 Refs.

[1997] 06B - 3

MATHEMATICAL STUDY OF VERY HIGH VOLTAGE POWER NETWORKS. I. THE OPTIMAL DC POWER FLOW PROBLEM

Bonnans, J.F.

Inst Natl de Recherche en Inf et Autom, Rocquencourt, France

SIAM Journal on Optimization, vol 7, no 4, November 1997, pp 979-990

The optimal power flow problem involves setting the voltage and power delivered at the nodes of an electrical network in order to minimize the loss of power over the lines. The paper is the first of a series dedicated to the mathematical study of this problem. We use an asymptotic analysis in which the small parameter is the inverse of the reference voltage of the network. We call this scheme the very high voltage approximation. We deal with the case of direct current. We obtain an analytic expansion for the optimal value and the solution.

[1996] 06B - 4

STUDY OF POWER FLOW SOLUTIONS WITH MULTI TERMINAL HVDC SYSTEM

Sasaki, H.; Iwata, J.; Kubokawa, J.

Hiroshima Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 37-48, pp 43-50

Japanese

This paper presents a method of power flow solutions with multi terminal HVdc system. Formulation for both parallel-connected and series-connected ac-dc converter are described. Jacobian matrix has particular structure in order to use its sparsity for fast solution. Simulation result of model system based on IEEE 57 system is shown.

[1997] 06B - 5

VOLTAGE STABILITY ANALYSIS OF AC/DC SYSTEMS

Kim, Y.-H.; Nam, H.-K.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 2, February 1997, pp 171-178

Korean

This paper describes an extension of a pair of multiple load flow solutions and nose curve method developed for the voltage stability analysis of ac systems to ac/dc power systems. ac/dc power flow equations are solved by an improved eliminated variable method; the accurate power converter equations are incorporated and dc variables are numerically eliminated in the power flow equations. Assuming that the converters consume the same power at the both stable and unstable solutions comprising the upper and lower PV nose curves, the unstable solutions are determined by a pair of multiple load flow solutions. These nose curves are fitted to third-order Lagrange polynomials and the critical point for voltage collapse is determined as the extreme point of the polynomial. This method is very efficient, since the voltage collapse point and the voltage stability margin are determined by a few iterations of multiple load flow solutions. The Jacobian matrix obtained in the process of the improved eliminated variable method is readily applicable to modal analysis. Such modal analysis results are also presented.

[1996] 06B - REF

SIMULATION STUDY ON THE SWITCHING TRANSIENTS DURING DE-ENERGISATION OF FILTER AND CAPACITOR BANKS

For Abstract see entry 02D - 25

[1998] 06B - REF

INFLUENCE OF LOAD CHARACTERISTICS ON THE POWER/VOLTAGE STABILITY OF HVDC SYSTEMS, PART 1: BASIC EQUATIONS AND RELATIONSHIPS

For Abstract see entry 05B - 41

[1998] 06B - REF

INFLUENCE OF LOAD CHARACTERISTICS ON THE POWER/VOLTAGE STABILITY OF HVDC SYSTEMS, PART 2: STABILITY MARGIN SENSITIVITY

For Abstract see entry 05B - 42

[1996] 06B - REF

A STUDY ON COMPARATIVE ANALYSIS OF DIRECT CURRENT CONTROL IN A.C-D.C INTERCONNECTED POWER SYSTEM

For Abstract see entry 05B - 6

[1998] 06B - REF

A REVIEW OF ITERATIVE HARMONIC ANALYSIS FOR AC-DC POWER SYSTEMS

For Abstract see entry 05C - 1

[1997] 06B - REF

OPERATING CONDITIONS OF CONTROLLED POWER TRANSMISSION LINES

For Abstract see entry 05C - 19

[1997] 06B - REF

POWER LIMITATIONS OF THE HVDC TRANSMISSION SYSTEM

For Abstract see entry 05C – 22

[1997] 06B - REF

STUDY OF POWER TRANSFER CAPABILITY OF DC SYSTEMS INCORPORATING AC LOADS AND A PARALLEL AC LINE

For Abstract see entry 05C - 28

[1997] 06B - REF

STUDY OF POWER FLOW SOLUTIONS WITH MULTI TERMINAL HVDC SYSTEMS. PART II

For Abstract see entry 05E - 16

06C Transient Stability, Long-Term Stability

[1996] 06C - 1

AC SYSTEM ANALYSIS OF MULTI-TERMINAL HVDC SYSTEM COMPOSED OF SELF-COMMUTATED CONVERTERS

Abe, H.; Konishi, H.; Kawazoe, H.

Elec Power Development Co, Ltd, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 423-424

Japanese

Abstract not available.

[1997] 06C - 2

ANALYSIS OF POWER OSCILLATIONS IN THE SOUTH AFRICAN HIGH-VOLTAGE GRID USING COMBINED TIME DOMAIN AND EIGENVALUE TECHNIQUES

Rittiger, J.; Witzmann, R.; Wang, X.; Muller, D.; Boshoff, S.; Davel, P.

Siemens AG, Erlangen, Germany

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

In this paper, the results of a study of the dynamic behavior of the ESKOM power grid are presented. An analysis of inter-area oscillations in the South African power system and between the ESKOM system and South Africa's neighboring countries was performed. The simulation model comprises ESKOM's complete high-voltage system, including the HVdc from Cahora Bassa. The high-voltage ac grids of the neighboring countries are represented by equivalent networks. The dynamic behavior of the power system was analyzed for different load flow and fault scenarios. In order to check the correctness of the digital simulation model, comparison calculations with on-site recordings were performed. The study was carried out using a combined time domain and eigenvalue analysis approach, which gives optimum insight into the behavior of a large power system. An explanation of the mechanism of power oscillations is given. Mitigation strategies for inter-area power oscillations and the application of FACTS devices in the ESKOM system are discussed.

[1998] 06C - 3

APPROPRIATE HVDC TRANSMISSION SIMULATION MODELS FOR VARIOUS POWER SYSTEM STABILITY STUDIES

Arabi, S.; Kundur, P.; Sawada, J.H.

Powertech Labs Inc

IEEE Trans on Power Delivery, Preprint order number PE-085-PWRS-1-12-1997

HVdc stability modeling requirements differ for various studies, as well as for various systems. In particular, representation of fast dynamics may significantly slow down the time simulations due to smaller step size

requirements. While such details are required in some cases, their proper simplification may be quite desirable in many routine planning and operating studies, especially for longer term or on-line simulations. In this paper, detailed and response models are developed using both time domain and eigenvalue analyses, as well as comparison with field information. A novel two-time scale reduction of the detailed model is presented, which offers a flexible compromise between detail and efficiency. Appropriate model selection is discussed.

[1998] 06C - 4

COMBINED TRANSIENT AND DYNAMIC ANALYSIS OF HVDC AND FACTS SYSTEMS

Sultan, M.; Reeve, J.; Adapa, R.

Hatch Associates

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

A new approach to HVdc and FACTS transient/dynamic simulation based on an interactive execution of an ac transient stability program (TSP) and the Electromagnetic Transients Program (EMTP) is described. Through the integration of the detailed transient model of FACTS with the transient stability program, authentic simulation is achieved without simplifications. Both HVdc and thyristor-controlled series capacitor (TCSC) systems are used to validate the approach, under different coupling situations between both TSP and EMTP.

[1997] 06C - 5

DYNAMIC SIMULATION OF HVDC TRANSMISSION SYSTEMS ON PC-AT. PART-I: MATHEMATICAL MODEL

Sarkar, T.K.N.; Singh, A.

Punjab Eng College, Chandigarh, India

Advances in Modelling and Analysis A, vol 32, no 1, 1997, pp 35-45

Dynamic simulation of HVdc link using central process technique have been presented in this paper. Each bridge convertor of HVdc system is represented by central process, repetitive use of central process simulate the continuous operation of bridge. The mathematical representation of central process by set of differential equations is given in this paper. The solution procedure. for dynamic simulation of HVdc system is discussed in Part II of the paper. 9 Refs.

[1997] 06C - 6

DYNAMIC SIMULATION OF HVDC TRANSMISSION SYSTEMS ON PC-AT. PART II - COMPUTATIONAL ALGORITHM AND TEST RESULTS

Sarkar, T.K.N.; Singh, A.

Punjab Eng College, Chandigarh, India

Advances in Modelling and Analysis A, vol 32, no 1, 1997, pp 46-56

Based on the mathematical model developed in Part I of the paper, an algorithm for solving dynamic simulations of HVdc systems is presented in this paper. Test results obtained for an HVdc link are also given. 4 Refs.

[1997] 06C - 7

RATIONAL FUNCTIONS AS FREQUENCY DEPENDENT EQUIVALENTS FOR TRANSIENT STUDIES

Todd, S.; Wood, A.R.; Bodger, P.S.; Smith, B.C.

Int'l Conf on Power System Transients (IPST 97), Seattle, June 22-26, 1997, pp 137-142

Abstract not available.

[1997] 06C - REF

SOME ASPECTS OF THE FEASIBILITY OF AN INTERCONNECTION BETWEEN THE DEMOCRATIC REPUBLIC OF CONGO AND EGYPT

For Abstract see entry 01B - 27

[1997] 06C - REF

ENHANCING TRANSIENT STABILITY BY SUPPLEMENTARY DC DAMPING CONTROL OF AN HVDC CONVERTER

For Abstract see entry 05B - 31

[1996] 06C - REF

A STUDY ON COMPARATIVE ANALYSIS OF DIRECT CURRENT CONTROL IN A.C-D.C INTERCONNECTED POWER SYSTEM

For Abstract see entry 05B - 6

[1996] 06C - REF

ADVANCED HVDC LINK CONTROL FOR DAMPING POWER SYSTEM OSCILLATIONS

For Abstract see entry 05B - 9

[1996] 06C - REF

STUDY OF MODULATION CONTROLLER: TO DAMP POWER OSCILLATIONS OF PARALLEL AC LINE IN THE TIANSHENGQIAO TO GUANGDONG HVDC TRANSMISSION

For Abstract see entry 05C - 27

[1996] 06C - REF

AC/DC SYSTEM TRANSIENT STABILITY ANALYSIS

For Abstract see entry 05C – 5

[1998] 06C - REF

PROPOSED 4 GW RUSSIA-GERMANY LINK - IMPACT OF 1 GW INVERTER STATION ON TORSIONAL STRESSING OF GENERATORS IN POLAND

For Abstract see entry 05D - 24

[1996] 06C - REF

SIMULATION OF A 5-TERMINAL HVDC CONFIGURATION BETWEEN EASTERN AND WESTERN EUROPE

For Abstract see entry 05E - 13

[1997] 06C - REF

ADVANCED AC/DC REAL-TIME AND COMPUTER SIMULATIONS FOR THE GMPC CAHORA BASSA DESIGN VERIFICATION

For Abstract see entry 06E - 2

06D Electromagnetic Transients

[1997] 06D - 1

EMTP MODEL FOR HVDC WITH SELF-COMMUTATED CONVERTER

Gibo, N.; Takasaki, M.; Takenaka, K.

CRIEPI, Tokyo, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 441-442

Japanese

Abstract not available.

[1996] 06D - 2

EMTP MODELLING OF CIGRE BENCHMARK BASED HVDC TRANSMISSION SYSTEM OPERATING WITH WEAK AC SYSTEMS

Sood, V.K.; Khatri, V.; Jin, H.

Hydro-Quebec, Varennes, Canada

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 426-432

An EMTP-based study of a CIGRE Benchmark-based HVdc system operating with weak ac systems is carried out. The modeled system provides a starting point for educators teaching HVdc transmission courses and for utility planners to develop their own low-cost dedicated digital simulators for training purposes. In this paper, modelling details of the ac-dc system, dc converters and controls are presented. To validate the control schemes presented, the HVdc system is tested under ac-dc fault conditions. Results obtained from an EMTP-based study under these fault conditions are also presented in this paper. 8 Refs.

[1997] 06D - 3

IMPLEMENTATION AND EFFECTIVENESS OF LINEAR INTERPOLATION WITHIN DIGITAL SIMULATION

Kuffel, P.; Kent, K.; Irwin, G.

Manitoba Hydro, Winnipeg, Canada

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 4, May 1997, pp 221-227

The greater use of detailed models and the increasing size and complexity of system studies in power system digital simulation has resulted in the need to re-examine the ability of digital computations performed at finite time intervals to accurately represent the actual system. These concerns are manifested in two distinct areas. The first is the ability to switch elements at a specific point in time. Traditional digital simulation techniques allow switching elements to change state only at discrete computation times, whereas in reality switching can occur at any instant in time. The second area of concern is in the ability to accurately represent detailed control systems. These concerns are of particular importance in

simulations containing a large number of controlled switching devices, such as HVdc systems or ac systems containing FACTs devices. This paper presents a discussion of the implementation and effectiveness of linear interpolation techniques in a digital simulation program. The paper addresses interpolation in both the network solution and the control system. The CIGRE HVdc Benchmark Model (Szechtman, M. et al., Electra, 1991, 135 and Wess, T. and Ring, H., CIGRE Report, WG 14-02, 1988) with detailed control models is used to demonstrate how linear interpolation is implemented and its effectiveness. All simulation results presented were generated using EMTDC, but the techniques discussed can be applied to any electromagnetic transients program. 9 Refs.

[1996] 06D - 4

SOME EXPERIENCES IN POWER SYSTEM SIMULATION USING ELECTROMAGNETIC TRANSIENT PROGRAMS

Bui, L.X.; Morin, G.

Hydro-Quebec, Montreal, Canada

Proceedings, Canadian Conf on Electrical and Computer Engineering, Calgary, Canada, May 26-29, 1996, vol 2, pp 647-650

In recent years, considerable progress in computer techniques has allowed power system engineers to perform complex transient analysis through the use of various available large scale power network simulation tools. New trends in control system design fully exploit the better capability of microprocessors to achieve advances in controlling power system networks. For example, the Hydro-Quebec-New England multiterminal dc transmission (HQ-NE) system is one excellent example of the success of such techniques. This paper presents some experiences of the simulation of the HQ-NE power system using EMTP. Some cases of numerical simulations, validated against simulator and field tests, are also included. Finally, a brief discussion on available commercial and noncommercial software is also given. 7 Refs.

[1996] 06D - 5

STUDY OF SYNTHETIC COMPANION MODEL METHOD IN HVDC SYSTEM'S DIGITAL SIMULATION

Chen, C-Y.; Wang, G.; Li, Y-L.; He, J-L.

Tianjin Univ, China

Proceedings of the Chinese Society of Electrical Engineering (Zhongguo Dianji Gongcheng Xuebao), vol 16, no 4, July 1996, pp 279-284

Chinese

Based on the analysis of companion model method in HVdc system's digital simulations, this paper presents a synthetic companion model method in which the complex elements, such as valves and filters, are considered as a whole element and their synthetic companion models are deduced respectively. For the commutating power transformers a new simulation model based on the theory of dependent sources is proposed, which enables to computer both the ac and dc side synchronously. The method can greatly simplify the computation and increase its speed and accuracy. The calculation examples show that the method is effective. 7 Refs.

[1997] 06D - 6

THE IMPLEMENTATION AND EFFECTIVENESS OF LINEAR INTERPOLATION WITHIN DIGITAL SIMULATION

Kuffel, P.; Kent, K.; Irwin, G.

Manitoba Hydro, Winnipeg, Canada

International Journal of Electrical Power and Energy Systems (UK), vol 19, no 4, 1997, pp 221-227

The greater use of detailed models and the increasing size and complexity of system studies in power system digital simulation has resulted in the need to re-examine the ability of digital computations performed at finite time intervals to accurately represent the actual system. These concerns are manifested in two distinct areas. The first is the ability to switch elements at a specific point in time. Traditional digital simulation techniques allow switching elements to change state only at discrete computation times, whereas in reality switching can occur at any instant in time. The second area of concern is in the ability to accurately represent detailed control systems. These concerns are of particular importance in simulations containing a large number of controlled switching devices, such as HVdc systems or ac systems containing FACTS devices. This paper presents a discussion of the implementation and effectiveness of linear interpolation techniques in a digital simulation program. The paper addresses interpolation in both the network solution and the control system. The CIGRE HVdc Benchmark Model with detailed control models is used to demonstrate how linear interpolation is implemented and its effectiveness. All simulation results presented were generated using EMTDC, but techniques discussed can be applied to any electromagnetic transients program.

[1997] 06D - 7

VALIDATION OF EMTDC FOR HVDC DYNAMIC PERFORMANCE STUDIES

Lagerkvist, M.; Tulkiewicz, T.

ABB Power Sys, Ludvika, Sweden

Proceedings, 1997 Int'l Conf on Digital Power Systems Simulators, Montreal, Canada, May 28-30, 1997, pp 239-243

The development of the electromagnetic transients analysis program EMTDC offers an alternative to traditional simulation tools such as the analog simulator for optimizing the control software in respect of the dynamic properties of HVdc power transmission control systems. This paper presents the results of a validation study of the EMTDC program developed by the Manitoba HVdc Research Centre, Canada. As a reference, an analog simulator model for a dynamic performance study performed by ABB Power Systems AB of Ludvika, Sweden as part of the Leyte-Luzon HVdc project on the Philippines, has been used. All relevant main circuits and HVdc control functions have been considered. The results show very good agreement between the results in EMTDC and the analog simulator. The general conclusion of this validation study is that EMTDC could well be used as a simulation tool in studies of dynamic performance, provided that the control system is identical to the delivery version. To ensure this, a procedure for downloading the delivery control system code to EMTDC has been developed.

[1997] 06D - REF

SOME ASPECTS OF THE FEASIBILITY OF AN INTERCONNECTION BETWEEN THE DEMOCRATIC REPUBLIC OF CONGO AND EGYPT

For Abstract see entry 01B - 27

[1997] 06D - REF

CAHORA BASSA GMPC TESTING USING AN REAL TIME DIGITAL SIMULATOR

For Abstract see entry 01C - 8

[1996] 06D - REF

SMOOTHING TRANSFORMER, A NEW CONCEPT IN DC SIDE HARMONIC REDUCTION OF HVDC SCHEMES

For Abstract see entry 02D - 26

[1996] 06D - REF

CALCULATION OF HVDC CONVERTER NONCHARACTERISTIC HARMONICS USING DIGITAL TIME-DOMAIN SIMULATION METHOD

For Abstract see entry 02D - 7

[1997] 06D - REF

IMPROVED SIMULATION OF HVDC CONVERTER TRANSFORMERS IN ELECTROMAGNETIC TRANSIENT PROGRAMS

For Abstract see entry 02E - 5

[1997] 06D - REF

NUMERICAL EVALUATION OF THE EFFICACY OF BOOSTER SHEDS AND RTV COATING IN IMPROVING THE PERFORMANCE OF HVDC WALL BUSHINGS

For Abstract see entry 02G - 11

[1997] 06D - REF

SIMULATION OF HVDC WALL BUSHING PERFORMANCE UNDER UNEVENLY WETTED CONDITIONS

For Abstract see entry 02G - 16

[1998] 06D - REF

CAPACITOR COMMUTATED CONVERTER CIRCUIT CONFIGURATIONS FOR DC TRANSMISSION

For Abstract see entry 05A - 3

[1998] 06D - REF

APPLICATION OF A RADIAL BASIS FUNCTION (RBF) NEURAL NETWORK FOR FAULT DIAGNOSIS IN AN HVDC SYSTEM

For Abstract see entry 05B - 11

[1997] 06D - REF

CHARACTERISTICS ANALYSIS OF COOPERATIVE CONTROL FOR PARALLEL BTB SYSTEMS COMPOSED OF SELF-COMMUTATED CONVERTERS AND LINE-COMMUTATED CONVERTERS

For Abstract see entry 05B - 14

[1996] 06D - REF

DEVELOPMENT OF A HYBRID MARGIN ANGLE CONTROLLER FOR HVDC CONTINUOUS OPERATION

For Abstract see entry 05B - 28

[1996] 06D - REF

DEVELOPMENT OF DC CONTROL FUNCTION. DEVELOPMENT OF UNINTERRUPTED CONTROL IN CASE OF AS SYSTEM ACCIDENT

For Abstract see entry 05B – 30

[1997] 06D - REF

FAST AND PREDICTIVE HVDC EXTINCTION ANGLE CONTROL

For Abstract see entry 05B - 32

[1997] 06D - REF

FUZZY LOGIC CONTROL FOR HVDC TRANSMISSION

For Abstract see entry 05B - 34

[1996] 06D - REF

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

For Abstract see entry 05B - 38

[1997] 06D - REF

HVDC CONVERTER CONTROL FOR FAST POWER RECOVERY AFTER AC SYSTEM FAULT

For Abstract see entry 05B - 39

[1998] 06D - REF

INVERTER CONTROLLER FOR VERY WEAK RECEIVING AC SYSTEMS

For Abstract see entry 05B - 45

[1998] 06D - REF

NOVEL CURRENT CONTROLLER FOR ELIMINATION OF DOMINANT OSCILLATORY MODE ON AN HVDC LINE

For Abstract see entry 05B - 53

[1997] 06D - REF

OVERCURRENT CONTROL COMPENSATING NEGATIVE CURRENT COMPONENT FOR HVDC WITH SELF-COMMUTATED CONVERTER

For Abstract see entry 05B - 54

[1996] 06D - REF

HARMONIC INTERACTION ON AC/DC SYSTEMS: EFFECTS OF CONTROL ACTIONS

For Abstract see entry 05C - 12

[1996] 06D - REF

NONLINEAR MODAL INTERACTION IN HVDC/AC POWER SYSTEMS WITH DC POWER MODULATION

For Abstract see entry 05C - 17

[1996] 06D - REF

VARIABLE STRUCTURE CONTROL OF AC-DC SYSTEM

For Abstract see entry 05C - 29

[1998] 06D - REF

ANALYTICAL MODELLING OF HVDC-HVAC SYSTEMS

For Abstract see entry 05C - 6

[1996] 06D - REF

COORDINATION OF POWER RAMP AND MODULATION FOR AC/DC PARALLEL SYSTEM WITH WEAK AC LINKS

For Abstract see entry 05C - 9

[1996] 06D - REF

FREQUENCY DOMAIN ANALYTICAL METHOD FOR STUDYING HARMONIC INTERACTION BETWEEN AC AND DC SIDES OF CONVERTERS IN HVDC

For Abstract see entry 05D - 10

[1996] 06D - REF

PREDICTION OF CORE SATURATION INSTABILITY AT AN HVDC CONVERTER

For Abstract see entry 05D - 23

[1997] 06D - REF

SIMULATION STUDY OF METHOD OF DAMPING SSO IN AC/DC SYSTEM

For Abstract see entry 05D - 28

[1997] 06D - REF

STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC

For Abstract see entry 05D - 36

[1996] 06D - REF

A SCREENING METHOD FOR CORE SATURATION INSTABILITY IN HVDC SYSTEM AND ITS APPLICATION

For Abstract see entry 05D - 4

[1997] 06D - REF

CONTROL OF 100-Hz GAMMA OSCILLATIONS ON NEW ZEALAND HVDC LINK

For Abstract see entry 05D - 6

[1998] 06D - REF

A CUSTOMIZED AIR-CORE TRANSFORMER FOR A SMALL POWER TAPPING STATION

For Abstract see entry 05E - 1

[1997] 06D - REF

ON THE CONTROL OF A MULTITERMINAL HVDC SYSTEM HAVING ALSO WEAK INVERTER STATIONS

For Abstract see entry 05E - 10

[1997] 06D - REF

SMALL POWER TAPPING FROM HVDC TRANSMISSION SYSTEMS: A NOVEL APPROACH

For Abstract see entry 05E - 14

[1996] 06D - REF

ANALYSIS OF HYBRID MULTI-TERMINAL HVDC TRANSMISSION COMPOSED OF SELF-COMMUTATED CONVERTER AND LINE-COMMUTATED CONVERTER

For Abstract see entry 05E - 3

[1996] 06D - REF

SIMULATION STUDY USING EMTDC ON THREE GORGES HVDC TRANSMISSION SYSTEM

For Abstract see entry 05H - 10

[1996] 06D - REF

APPLICATIONS OF EMTP ON CALCULATING OVERVOLTAGE IN HIGH VOLTAGE INSULATION SYSTEM

For Abstract see entry 05J - 1

[1997] 06D - REF

S-DOMAIN MODEL OF AN HVDC CONVERTER

For Abstract see entry 06A - 1

[1998] 06D - REF

APPROPRIATE HVDC TRANSMISSION SIMULATION MODELS FOR VARIOUS POWER SYSTEM STABILITY STUDIES

For Abstract see entry 06C - 3

[1998] 06D - REF

COMBINED TRANSIENT AND DYNAMIC ANALYSIS OF HVDC AND FACTS SYSTEMS

For Abstract see entry 06C - 4

[1997] 06D - REF

DYNAMIC SIMULATION OF HVDC TRANSMISSION SYSTEMS ON PC-AT. PART II - COMPUTATIONAL ALGORITHM AND TEST RESULTS

For Abstract see entry 06C – 5

[1997] 06D - REF

DYNAMIC SIMULATION OF HVDC TRANSMISSION SYSTEMS ON PC-AT. PART-I:

MATHEMATICAL MODEL

For Abstract see entry 06C - 6

[1997] 06D - REF

ADVANCED AC/DC REAL-TIME AND COMPUTER SIMULATIONS FOR THE GMPC CAHORA BASSA DESIGN VERIFICATION

For Abstract see entry 06E - 2

[1996] 06D - REF

CONVERTERS FOR GRID-CONNECTED DC ENERGY SOURCES: A SIMULATION TOOL TO MEET EXPECTED UTILITY SPECIFICATIONS

For Abstract see entry 17B - 8

[1996] 06D - REF

MODELLING OF HIGH-VOLTAGE THYRISTORS UNDER DYNAMIC CONDITIONS

For Abstract see entry 19D - 12

[1997] 06D - REF

GUIDELINES FOR MODELING POWER ELECTRONICS IN ELECTRIC POWER ENGINEERING APPLICATIONS

For Abstract see entry 19D - 7

06E Simulators, Experimental Models

[1997] 06E - 1

ACCURATE SOLUTION OF HVDC CONVERTERS IN REAL TIME TRANSIENTS SIMULATION

Marti, J.R.; Acevedo, S.; Linares, L.R.; Dommel, H.W.; Fujimoto, Y.

Int'l Conf on Power System Transients (IPST 97), Seattle, June 22-26, 1997, (pages not noted)

A very efficient model has been developed to represent HVdc converters in real-time transient simulators. Real-time performance of 46 ms per solution step has been achieved for a 12-pulse monopolar converter and 81 ms for the bipolar converter using an inexpensive off-the-shelf Pentium Pro 200 MHz desktop computer. The converter model is solved simultaneously with the power network, making it valid for continuously running real-time power system simulators. The critical damping adjustment (CDA) technique is used to provide numerically clean and accurate waveforms.

[1997] 06E - 2

ADVANCED AC/DC REAL-TIME AND COMPUTER SIMULATIONS FOR THE GMPC CAHORA BASSA DESIGN VERIFICATION

Coetzee, M.; Venter, F.; Guedes, J.M.G.; Da Silva, F.M.; Forsyth, P.; Maguire, T.; Claus, M.; Esters, P.H.;

Neufeldt, T.; Retzmann, D.

ESKOM, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

This paper discusses the use of an RTDS real time simulator for testing the grid master power controller (GMPC) of the Cahora Bassa HVdc upgrade. The GMPC uses coordinated HVdc and optional braking resistor control technologies to ensure stable operation. The physical design of the dynamic braking resistor is described as well as the GMPC setup with SIMADYN D and RTDS. For the real-time simulation, detailed models of the complex HVac and HVdc systems are represented in RTDS. The verification of the simulator setup is done by comparison with site recordings, EMTDC, PSS/E and NETOMAC study results. The GMPC performance is verified by different types of ac and dc faults. Results of the tests are presented.

[1997] 06E - 3

AN INTEGRATED SIMULATION AND CONTROL IMPLEMENTATION ENVIRONMENT

Wild, G.; Messner, G.; Moosburger, A.; Xie, M.H.; Gole, A.M.; Brandt, D.P.

Int'l Conf on Power Systems Transients (IPST97), Seattle, WA, June 22-26, 1997, pp 150-155

Abstract not available.

[1997] 06E - 4

CONTROL SYSTEM MODELLING USING THE REAL-TIME DIGITAL SIMULATOR

Wierckx, R.P.; Yu, M.; Forsyth, P.A.

Proceedings, 2nd Int'l Conf on Power System Simulators (ICDS '97), Montreal, Quebec, Canada,

May 28-30, 1997, pp 197-202

Abstract not available.

[1997] 06E - 5

FAST DECOUPLED SIMULATION OF LARGE POWER ELECTRONIC SYSTEMS USING NEW TWO-PORT COMPANION LINK MODELS

Hui, S.Y.R.; Fung, K.K.

City Univ of Hong Kong, Kowloon, China

IEEE Trans on Power Electronics, vol 12, no 3, May 1997, pp 462-473

Algorithms of novel two-port companion link models for fast decoupled simulation are presented. The link models enable a large circuit to be broken down into many small subcircuits for easy circuit formulation and fast simulation. The proposed link algorithms are demonstrated in a converter-fed dc transmission system with a transmission-line length equivalent to 1000 km. Simulation and experimental results from a laboratory setup have confirmed the validity of the link models. Proposed simulations are also found to be faster and more accurate than PSpice simulations in the example. 10 Refs.

[1997] 06E - 6

HVDC OPERATOR TRAINING SIMULATOR FOR THE NEW ZEALAND HYBRID HVDC LINK - A TOOL FOR OPERATOR DIVERSIFICATION

Brown, R.W.

Transpower NZ Ltd, Wellington, New Zealand

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg,South Africa, September 28-30, 1997

Due to the highly automated and reliable nature of the New Zealand HVdc link, the operators gain insufficient experience from day-to-day operation of the link to maintain their essential skill base. In 1996 the New Zealand HVdc operator training simulator, the first comprehensive HVdc operator training simulator, was completed and training programs utilizing it commenced. This paper explains the need for the simulator, its development, its use as a training tool, and the confidence it has given its owner to move HVdc operational centers.

[1996] 06E - 7

HVDC SIMULATION TRAINING SYSTEM

Zhang, J-H.; Shi, Y.; Zhao, G.; Jiao, B-L.

Elec Power Research Inst, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 630-633

This paper introduces the HVdc simulation training system developed by EPRI, China. The software platform of this system is X windows and INGRES database. The hardware platform is a SUN Sparc workstation and the HVdc simulator developed by BBC. The architecture and the outstanding features are presented in this paper. 4 Refs.

[1996] 06E - 8

INTRODUCING DIGITAL SIMULATION INTO AN ANALOG REAL-TIME POWER SYSTEM SIMULATOR

Gick, B.; Gallenkamp, T.; Wess, T.

FGH, Mannheim, Germany

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 369-374

A new digital real-time simulator (DRTS) with a high resolution, high-speed interface to an analog simulator (ARTS) is presented for power system modelling. The ability of the DRTS is shown in an experimental setup, using the ARTS for modelling a point-to-point HVdc transmission system. The multiprocessor DRTS simulates a synchronous generator with a 50 mu s calculation time step. 11 Refs.

[1997] 06E - 9

NOVEL SIMULATION SCHEME OF POWER ELECTRONICS SYSTEM WITH THE PARALLEL INFERENCE MACHINE (PIM)

Masada, E.; Baba, J.; Wakamiya, H.; Tamura, M.

Univ of Tokyo, Japan

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3-6, 1997, vol 1, pp 379-384

This paper proposes a parallel inference machine (PIM) is proposed for dynamic simulation of power converters and their control systems. The PIM emulates a parallel computing machine with several hundreds of processors. Utilizing its para-cell soft-ware, the simulation can be realized with a multi-layered structure, which is convenient to separately describe controllers, converters and plants. The authors examine PIM simulator for two cases: the one is HVdc system and the other is SMES system. Simulation results were

compared with analog simulator and other simulating methods. It was concluded that power electronics control system simulation can be made on PIM without much knowledge on the numerical technique. The multilayered cell structure provides easy access to the model for modification and parameter adjustment. Improvement of PIM itself will make this approach more powerful and possible for the real-time control purpose. 6 Refs.

[1996] 06E - 10

SIMULATOR OF HVDC TRANSMISSION SYSTEM

Onishi, T.; Miki, M.; Kawasaki, K.

Univ of Tokushima, Japan

Denki Kankei Gakkai Shikoku Shibu Rengo Taikai Koen Ronbunshu (Japan), vol 1996, p 65

Japanese

Abstract not available.

[1998] 06E - 11

STUDY OF CONTROL STRATEGIES FOR NEW CIGRE HVDC BENCHMARK MODEL

Narayanan, M.M.B.; Parameswaran, S.

Central Power Research Inst, Bangalore, India

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper presents the results of a Simulator study on the new CIGRE HVdc Benchmark Model using plant-size digital control system. Comparison is made with the results obtained through EMTDC simulation. The Simulator control system is the same generation of controls as the Rihand-Delhi project in India. The object of the study was to investigate the steady state and dynamic performance of this control system using the new CIGRE Benchmark Model, which represents an operationally difficult dc system. Tuning of current controller and voltage dependent current order limits under steady state and dynamic conditions are discussed. Fault recovery plots are also presented. The dc system response to rectifier-side ac faults have been found to be satisfactory. For inverter-end ac faults, there is a reduction in dc power level following fault recovery. Reasons for this have been explained. It was found that there is a good correlation between physical simulator and EMTDC simulation results.

[1997] 06E - 12

VALIDATING THE REAL TIME DIGITAL SIMULATOR FOR HVDC DYNAMIC PERFORMANCE STUDIES

Duchen, H.; Lagerkvist, M.; Lovgren, N.; Kuffel, R.

ABB Power Sys, Ludvika, Sweden

Proceedings, 1997 Int'l Conf on Digital Power Systems Simulators, Montreal, Canada, May 28-30, 1997, pp 245-250

This paper. describes and presents results from a validation study in which the Real Time Digital Simulator (RTDS™) was compared with a conventional analog simulator. The particular phase of the validation work presented relates to dynamic performance studies (DPS) of HVdc systems and their associated controls.

[1997] 06E - REF

OPERATIONAL TESTS ON HVDC THYRISTOR MODULES IN A SYNTHETIC TEST CIRCUIT FOR THE SYLMAR EAST RESTORATION PROJECT. DISCUSSION

For Abstract see entry 01C - 27

[1997] 06E - REF

CAHORA BASSA GMPC TESTING USING AN REAL TIME DIGITAL SIMULATOR

For Abstract see entry 01C - 8

[1997] 06E - REF

OPERATIONAL TESTS ON HVDC THYRISTOR MODULES IN A SYNTHETIC TEST CIRCUIT FOR THE SYLMAR EAST RESTORATION PROJECT

For Abstract see entry 02C - 28

[1996] 06E - REF

EXPERIMENTAL MEASUREMENT OF NON-CHARACTERISTIC HARMONIC POWER GENERATED BY THYRISTOR PULSE-CONTROLLED AC/DC THREE PHASE CONVERTERS

For Abstract see entry 02D - 12

[1996] 06E - REF

NEW EXPERIMENTAL METHOD TO

DESEGREGATE THE HARMONIC POWER PRODUCED BY THYRISTOR AC/DC THREE PHASE CONVERTERS

For Abstract see entry 02D - 18

[1996] 06E - REF

NOVEL METHOD FOR HARMONIC ANALYSIS OF AC/DC POWER SYSTEMS COUPLED BY THYRISTOR CONVERTERS

For Abstract see entry 02D - 22

[1996] 06E - REF

THE NEW CONCEPTS OF CHARACTERISTIC AND NON-CHARACTERISTIC HARMONIC REACTIVE POWER IN AC/DC POWER SYSTEMS

For Abstract see entry 02D – 28

[1997] 06E - REF

APPLICATION OF REAL TIME DIGITAL SIMULATION FOR COMMISSIONING AUTOMATIC VOLTAGE REGULATORS FOR SYNCHRONOUS CONDENSERS

For Abstract see entry 02D - 5

[1996] 06E - REF

VERIFICATION AND TESTING OF DC POWER-TRANSMISSION EQUIPMENT

For Abstract see entry 02F - 18

[1997] 06E - REF

NUMERICAL EVALUATION OF THE EFFICACY OF BOOSTER SHEDS AND RTV COATING IN IMPROVING THE PERFORMANCE OF HVDC WALL BUSHINGS

For Abstract see entry 02G - 11

[1997] 06E - REF

SIMULATION OF HVDC WALL BUSHING PERFORMANCE UNDER UNEVENLY WETTED CONDITIONS

For Abstract see entry 02G - 16

[1996] 06E - REF

CALCULATION OF SINGLE PHASE AC AND MONOPOLAR DC HYBRID CORONA EFFECTS. DISCUSSION

For Abstract see entry 03B - 2

[1996] 06E - REF

FINITE ELEMENT SOLUTION OF MONOPOLAR CORONA AS INFLUENCED BY ION LIFE TIME

For Abstract see entry 03B - 6

[1996] 06E - REF

IMPROVED CALCULATION OF FINITE ELEMENT ANALYSIS OF BIPOLAR CORONA INCLUDING ION DIFFUSION

For Abstract see entry 03B - 8

[1996] 06E - REF

ADAPTIVE FINITE-ELEMENT BALLOONING ANALYSIS OF BIPOLAR IONIZED FIELDS

For Abstract see entry 03D - 1

[1997] 06E - REF

OPEN-BOUNDARY FINITE-ELEMENT ANALYSIS OF IONIZED FIELD AROUND MONOPOLAR TRANSMISSION LINES [HVDC]

For Abstract see entry 03D - 12

[1997] 06E - REF

DC AND IMPULSE TREEING CHARACTERISTICS IN INSULATING MATERIAL FOR HVDC CABLE

For Abstract see entry 04B - 8

[1996] 06E - REF

PWM AND CONTROL OF THREE LEVEL VOLTAGE SOURCE BACK-TO-BACK STATION

For Abstract see entry 05A - 17

[1997] 06E - REF

DEVELOPMENT AND TESTING OF PROTOTYPE MODELS FOR A HIGH-PERFORMANCE 300 MW SELF-COMMUTATED

AC/DC CONVERTER

For Abstract see entry 05A - 6

[1998] 06E - REF

DEVELOPMENT OF A CONTROL SYSTEM FOR A HIGH-PERFORMANCE SELF-COMMUTATED AC/DC CONVERTER

For Abstract see entry 05A - 8

[1996] 06E - REF

CONTROL AND PROTECTION TECHNOLOGIES FOR DC POWER-TRANSMISSION SYSTEMS

For Abstract see entry 05B - 15

[1996] 06E - REF

DESIGN AND TESTING OF THE BIPOLAR 12-PULSE HVDC PROTECTION SYSTEM

For Abstract see entry 05B - 26

[1996] 06E - REF

DEVELOPMENT OF A HYBRID MARGIN ANGLE CONTROLLER FOR HVDC CONTINUOUS OPERATION

For Abstract see entry 05B - 28

[1996] 06E - REF

DEVELOPMENT OF CONTROL FOR SELF-COMMUTATED CONVERTER. (PART I). DEVELOPMENT OF SIMULATOR MODEL AND STUDY ON CONVERTER OVERCURRENT IN AC SYSTEM FAULT CONDITION

For Abstract see entry 05B - 29

[1996] 06E - REF

DEVELOPMENT OF DC CONTROL FUNCTION. DEVELOPMENT OF UNINTERRUPTED CONTROL IN CASE OF AS SYSTEM ACCIDENT

For Abstract see entry 05B - 30

[1996] 06E - REF

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

For Abstract see entry 05B - 38

[1997] 06E - REF

HVDC CONVERTER CONTROL FOR FAST POWER RECOVERY AFTER AC SYSTEM FAULT

For Abstract see entry 05B - 39

[1996] 06E - REF

HVDC PROTECTION SYSTEM BASED MULTIPROCESSOR

For Abstract see entry 05B - 40

[1997] 06E - REF

INTELLIGENT CURRENT CONTROLLER FOR AN HVDC TRANSMISSION LINK

For Abstract see entry 05B - 44

[1997] 06E - REF

OVERCURRENT CONTROL COMPENSATING NEGATIVE CURRENT COMPONENT FOR HVDC WITH SELF-COMMUTATED CONVERTER

For Abstract see entry 05B - 54

[1996] 06E - REF

ON LINE IDENTIFICATION AND CONTROL OF AN AC/DC POWER SYSTEM

For Abstract see entry 05C - 18

[1997] 06E - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. POWER SWING DAMPING CONTROL BY HVDC POWER MODULATION IN AC/DC HYBRID TRANSMISSION SYSTEM

For Abstract see entry 05C - 21

[1997] 06E - REF

HYBRID SIMULATION STUDY OF FACTORS CONTRIBUTING TO HARMONIC INSTABILITY OF HVDC SYSTEMS

For Abstract see entry 05D - 15

[1997] 06E - REF

SIMULATOR STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC. PART 1. STABILITY LIMITS BY AC SYSTEM STRENGTH

For Abstract see entry 05D - 29

[1997] 06E - REF

SIMULATOR STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC. PART 2. EFFECT OF DAMPING CONTROL

For Abstract see entry 05D - 30

[1997] 06E - REF

SIMULATOR STUDY RESULTS OF SUB-SYNCHRONOUS RESONANCE DAMPING BY HVDC CONVERTER CONTROL

For Abstract see entry 05D - 31

[1997] 06E - REF

STUDY RESULT OF DAMPING CONTROL FOR GENERATOR TORSIONAL OSCILLATION DUE TO INTERACTION WITH HVDC

For Abstract see entry 05D - 36

[1998] 06E - REF

A CUSTOMIZED AIR-CORE TRANSFORMER FOR A SMALL POWER TAPPING STATION

For Abstract see entry 05E - 1

[1997] 06E - REF

ON THE CONTROL OF A MULTITERMINAL HVDC SYSTEM HAVING ALSO WEAK INVERTER STATIONS

For Abstract see entry 05E - 10

[1997] 06E - REF

DEVELOPMENT OF ADVANCED MULTI-TERMINAL HVDC CONTROL AND PROTECTION SYSTEMS AND SIMULATOR TESTS

For Abstract see entry 05E - 6

[1996] 06E - REF

COMMUTATION FAILURES IN HVDC TRANSMISSION SYSTEMS

For Abstract see entry 05H - 1

[1996] 06E - REF

SOME EXPERIENCES IN POWER SYSTEM SIMULATION USING ELECTROMAGNETIC TRANSIENT PROGRAMS

For Abstract see entry 06D - 4

[1997] 06E - REF

VALIDATION OF EMTDC FOR HVDC DYNAMIC PERFORMANCE STUDIES

For Abstract see entry 06D - 7

[1996] 06E - REF

A FULLY DIGITAL POWER SYSTEM SIMULATOR OPERATING IN REAL TIME

For Abstract see entry 19E - 1

[1996] 06E - REF

GRAPHICAL ELECTROMAGNETIC SIMULATION LABORATORY FOR POWER SYSTEMS ENGINEERING PROGRAMS

For Abstract see entry 19E - 20

[1997] 06E - REF

STABILITY SIMULATION USING REAL TIME POWER SYSTEM SIMULATOR

For Abstract see entry 19E - 23

[1998] 06E - REF

AN ADVANCED AND POWERFUL REAL-TIME DIGITAL TRANSIENT NETWORK ANALYZER

For Abstract see entry 19E - 9

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

07 FACTS SYSTEMS AND PLANNING

07A General Concepts of FACTS

[1996] 07A - 1

A COMPARISON OF ALTERNATIVES TO ENHANCE THE POWER AND ENERGY TRANSFER CAPABILITY OF TRANSMISSION LINES

Tam, K.S.

Virginia Polytech Inst and State Univ, Blacksburg, VA, USA

Proceedings, 58th American Power Conf, Chicago, IL, April 9-11, 1996, pp 1562-1567

In response to the Energy Policy Acts of 1992 and the subsequent actions by the Federal Energy Regulatory Commission (FERC), electric utilities are motivated to increase the power and energy transfer capability of transmission facilities and rights-of-way, not only to cope with present and future challenges but also as a new alternative to generate revenues. Towards addressing this need, this paper provides a technical comparison of several approaches that can be used to increase the power and energy transfer capability of transmission lines. The first approach modifies the characteristics of transmission networks by using FACTS (flexible ac transmission system) devices. The second approach uses load management techniques and pricing incentives to modify transmission load patterns. The third approach uses advanced energy storage systems (such as battery energy storage systems, superconductive magnetic energy storage systems, etc.) to perform one or more of the following functions: (1) to modify the transmission load pattern; (2) to provide real and/or reactive power control; and (3) to improve transient stability. In addition to a comparison of individual approaches, the impact of combining these approaches, the concept of energy storage link and its impact on reducing loop flows are also discussed.

[1997] 07A – 2

Deleted

[1997] 07A - 3

A COMPARISON OF ALTERNATIVES TO ENHANCE THE UTILIZATION OF TRANSMISSION LINES

Tam, K.S.

Bradley Dept of Elec Eng, Virginia Polytech Inst and State Univ, Blacksburg, VA, USA

Electric Power Systems Research (Switzerland), vol 41, no 2, 1997, pp 131-138

While the growing environmental concerns and other economic and regulatory factors make it very difficult for utilities to build new transmission lines, the need for new transmission facilities is compounded by the trend to deregulate the electric power industry. The need to build new lines may be lessened if existing transmission lines can be more effectively utilized. The objective of this paper is to provide a comparison of various alternatives that can enhance the utilization of transmission lines. The major constraints that limit real power transfer are identified and various ways to overcome one or more of these constraints constitute the

various alternatives to improve the power and energy transfer capabilities of transmission lines. An evaluation framework has been developed to provide a quantitative comparison of various alternatives. The results demonstrate that utilization of transmission lines can be significantly enhanced by several alternatives. The best alternative in each performance category and the best alternative from the viewpoint of overall performance are presented. (c) 1997 Elsevier Science S.A.

[1996] 07A - 4

A PRELIMINARY STUDY ON PARALLEL PATHS FLOW CONTROL [POWER SYSTEM LOAD FLOW]

Liu, Y-H.

Monthly Journal of Taipower's Engineering (Taiwan), vol 571, March 1996, pp 61-69

Chinese

This paper presents a preliminary study of the control methods of parallel paths load flow problems occurring in the Taiwan power system. The control alternatives include transmission system reconfiguration and conventional and modern equipment installation. The merits and disadvantages of these alternatives are briefly discussed. Cost estimates are also included in this paper. 15 Refs.

[1996] 07A - 5

A REVIEW ON TRANSIENT STABILITY CONTROL IN POWER SYSTEMS

Liu, Y-T.; Du, Z-C.; Xia, D-Z.

Shandong Univ of Tech, Jinan, China

Automation of Electric Power Systems (China), vol 20, no 8, August 1996, pp 53-57

Chinese

This paper presents a review on the recent advances in the transient stability control of electric power systems. Nonlinear stability control, artificial intelligence and FACTS technology all show promise. 18 Refs.

[1996] 07A - 6

AN IMPROVED DEFINITION FOR FACTS TECHNOLOGY AND EXPANDED SCOPE OF ITS CONTROLLERS

He, D-Y.

Elec Power Research Inst, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 889-892

In this paper an improved statement on FACTS definition and a new term for FACTS controllers were suggested aiming at helping unification of different views, and an expanded scope of FACTS controllers was also introduced based on the new definition and the research achievements on FACTS technology. 23 Refs.

[1996] 07A - 7

AN INVESTIGATION INTO THE REALITIES OF FACTS DEVICES

McGillis, D.T.; Toussaint, M.; Galiana, F.D.; Joos, G.; Marceau, R.; Atanackovic, D.; Cheng, J.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 252-257

Increasing the transmission capability of an electric power network while respecting its design criteria may require enhancements such as the implementation of FACTS devices. The impact of these devices is studied in the context of the steady-state and transient behavior of the network as well as from the perspective of power system interconnections and the emerging deregulated environment. Possible electronic implementation of these devices is also examined. The underlying consideration is whether the improvement in power system performance justifies the cost of the enhancements required. 11 Refs.

[1998] 07A - 8

AN OUTLINE OF POWER SYSTEM TECHNOLOGIES IN JAPAN

Torizuka, T.; Tanaka, H.

Tokyo Elec Power Co, Inc, Japan

Electric Power Systems Research, vol 44, 1998, pp 1-5

Metropolitan areas such as Tokyo, Osaka and Nagoya are major consumers of electricity in Japan. As the construction of power plants near these areas has become more difficult in recent years, there is a tendency for large-scale power plants to be constructed in remote locations. The construction of transmission lines and substations is also becoming more difficult, so that power is being transmitted by fewer lines over long distances. Consequently, the stability of the power system is a very important problem, and numerous stabilizing technologies are therefore being used. With

this as a background, the author focuses on the main stabilizing technologies applied in the Japanese power system and outlines them in this paper.

[1998] 07A - 9

BIBLIOGRAPHY ON VOLTAGE STABILITY

Ajjarapu, V.; Lee, B.

Iowa State Univ, Ames, IA, USA

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 115f

This paper provides a comprehensive list of books, reports, workshops and technical papers related to voltage stability and security.

[1996] 07A - 10

CUSTOM POWER: OPTIMIZING DISTRIBUTION SERVICES

Douglas, J.

EPRI Journal, vol 21, no 3, May-June 1996, pp 6-11, 13, 15

Power disturbances that once would barely have been noticed may now produce costly malfunctions in critical customer equipment. Fortunately, a new generation of power electronic controllers is becoming available for use on distribution systems, which will enable utilities to provide premium-quality electricity to customers with sensitive loads. The first of these controllers, called Custom Power devices, are now entering utility service, providing a cost-effective alternative to the power-conditioning equipment previously installed on customers' premises. Eventually the integration of Custom Power controllers with distribution automation equipment will help create distribution systems that are optimized from both the utility's and the customer's point of view. The Custom Power devices discussed include switches, dynamic voltage restorer, static compensator, and the IntelliVAr reactive power compensator. 0 Refs.

[1997] 07A - 11

DEFINING INTERCONNECTED OPERATIONS SERVICES UNDER OPEN ACCESS

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-108097, May 1997, 156 pp

Interconnected Operations Services (IOS), also referred to as ancillary services, are the unbundled electric services necessary to facilitate electric market operations. These services provide for system reliability, enable transmission system access, and address equity concerns in electric market operations. This report provides definitions, technical requirements, and commercial rights and obligations associated with these services.

[1997] 07A - 12

DYNAMIC IDLE CURRENT COMPENSATION

Kirschner, H.

GHK Energie- und Datentechnik, Ostfildern, Germany

ETZ (Germany), vol 118, no 20, October 1997, pp 24-27

German

Thyristor-controlled idle current compensation systems have been used in power distribution networks for several decades now to improve the network quality. Dynamic compensation systems are even more favorable and have a wider range of applications.

[1998] 07A - 13

ELIMINATION OF DYNAMIC BIFURCATION AND CHAOS IN POWER SYSTEMS USING FACTS DEVICES

Srivastava, K.N.; Srivastava, S.C.

ABB Corp Research, Vasteras, Sweden

IEEE Trans on Circuits and Systems I: Fundamental Theory and Applications, vol 45, no 1, January 1998, pp 72-78

Existence of dynamic bifurcations and chaos has been shown by some of the researchers in simple power system networks. This brief first demonstrates, through numerical simulation, the existence of various types of dynamic bifurcations in two sample power systems. Presence of torus and limit point of periodic orbits has been observed for the first time in a power system model. Further study has been performed to damp out the Hopf bifurcation using flexible ac transmission system (FACTS) devices such as controllable series capacitors (CSCs), controllable phase angle regulators (PARs), and static VAr compensators (SVCs). The participation of states for the critical mode to undergo Hopf bifurcation has been used to select appropriate input to these control elements. 14 Refs.

[1997] 07A - 14

END-USE LOAD CONTROL FOR POWER SYSTEM DYNAMIC STABILITY ENHANCEMENT

Dagle, J.E.; Winiarski, D.W.; Donnelly, M.K.

Pacific Northwest Lab (PNL), Richland, WA, USA

Pacific Northwest Laboratory, Richland, WA, February 1997, PNNL-11488 (DE97052455), 51 pp

Faced with the prospect of increasing utilization of the transmission and distribution infrastructure without significant upgrade, the domestic electric power utility industry is investing heavily in technologies to improve network dynamic performance through a program loosely referred to as flexible ac transmission system (FACTS). Devices exploiting recent advances in power electronics are being installed in the power system to offset the need to construct new transmission lines. These devices collectively represent investment potential of several billion dollars over the next decade. A similar development, designed to curtail the peak loads and thus defer new transmission, distribution, and generation investment, falls under a category of technologies referred to as demand side management (DSM). A subset of broader conservation measures, DSM acts directly on the load to reduce peak consumption. DSM techniques include direct load control, in which a utility has the ability to curtail specific loads as conditions warrant. A novel approach has been conceived by Pacific Northwest National Laboratory (PNNL) to combine the objectives of FACTS and the technologies inherent in DSM to provide a distributed power system dynamic controller. This technology has the potential to dramatically offset major investments in FACTS devices by using direct load control to achieve dynamic stability objectives. The potential value of distributed versus centralized grid modulation has been examined by simulating the western power grid under extreme loading conditions. In these simulations, a scenario is analyzed in which active grid stabilization enables power imports into the southern California region to be increased several hundred megawatts beyond present limitations. Modeling results show distributed load control is up to 30 percent more effective than traditional centralized control schemes in achieving grid stability.

[1998] 07A - 15

FACTS CONTROLLERS AND THE DEREGULATED ELECTRIC UTILITY ENVIRONMENT

Ooi, B-T.; Joos, G.; Galiana, F.D.; McGillis, D.; Marceau, R.

McGill Univ, Montreal, Quebec, Canada

Proceedings, IEEE Canadian Conf on Electrical and Computer Engineering, Waterloo, Ontario, May 1998, vol 1, pp 597f

The push towards deregulation in the electric utility industry is forcing a revaluation of the way transmission systems are operated. Reliance on the natural flow of current cannot meet the new requirements imposed by deregulation. One method to dictate the power flows is the increased reliance on flexible ac transmission systems (FACTS). This paper presents some of the new directions being investigated to adapt and exploit the potential of power electronic converters to increase the flexibility and reliability of modern power systems.

[1996] 07A - 16

FACTS DEVICES IN UPLIFT CONTROL

Strbac, G.; Jenkins, N.

Centre for Elec Energy, Univ of Manchester Inst of Sci & Tech, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 214-219

Traditionally, security constrained economic dispatch is implemented by adding constraints to the plain economic dispatch-typically limits on line flows and nodal voltages for all credible post-disturbance configurations. However, advances in power electronics, and in particular the concept of FACTS are now challenging conventional approaches to system security operation, planning and overall economy of power systems. Based on FACTS devices, some part: of the security of the system can be achieved in post contingency mode, after an outage occurs. Such an economic dispatch, that incorporates the abilities of FACTS devices to assist in post-fault rearranging of transmission system power flows, allows the system to be operated with relaxed security most of the time. This results in reduction of the system operating costs without actually jeopardizing the level of system security. In the context of the England and Wales electricity market, this paper demonstrates how FACTS devices can be used in uplift control. The paper proposes a method to the solution of the economic dispatch

problem with an optimal balance between the level of security achieved in preventive and in corrective mode. The method is based on mathematical programming decomposition techniques that allow the iterative solution of a base-case economic dispatch for the intact system and separate contingency analysis with post-contingency corrective control by FACTS devices used to eliminate line/transformer overloads. A case study on a test system is presented and discussed. 3 Refs.

[1996] 07A - 17

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

Lacoste, J.; Cholley, P.; Trotignon, M.; Daniel, D.; Nativel, G.

Electricite de France

Collection de notes internes de la Direction des etudes et recherches. Materiel electrique, transport et distribution d'energie (France), no 9, 1996, 8 pp

FACTS offer a way of controlling certain parameters of the system : voltage, impedance, phase shift etc. They can also improve operation of an electrical power system subject to power flow limitations, electromechanical stability and voltage stability. One of the major challenges of current research into this area consists in determining the most suitable FACTS for each power system problem likely to arise. The methodology adopted for comparing the effectiveness of different types of FACTS refers to modeling work, theoretical studies and simulations. The authors also give the results obtained using this approach. The paper is structured in three sections. The first section sets out the general method drawn up, which is a two-stage one. The first stage is the result of a broad approach, which consists in studying the different FACTS for a range of representative power system configurations, given in the form of diagrams equivalent to those used for real power systems. Next, studies of selected real power system configurations, by incorporating the latest developments in powerful regulator technology for the most promising FACTS. The second section sets out the results of research carried out on an equivalent power systems. The authors first cover modeling-related aspects, setting out equivalent power system diagrams, and designing the FACTS models studied: static VAr compensator (SVC), advanced static VAr compensator (ASVC), superconducting magnetic energy storage (SMES), dynamic brake, thyristor-controlled series iImpedance, advanced series impedance, unified power flow controller (UPFC). The authors go on to analyze the effect of FACTS on the dynamic performance of the power system, incorporating theoretical considerations and simulations into their analysis. The simulations are produced with the EUROSTAG program and make use of power systems and FACTS models produced earlier. 6 refs.

[1996] 07A - 18

FACTS FOR DISTRIBUTION APPLICATIONS

Barnard, J.; Loser, T.

Elektron (South Africa), vol 13, no 4, April 1996, pp 15-17

Flexible ac transmission systems (FACTS) was initiated by the Electric Power Research Institute (EPRI) in America as part of their research program. FACTS devices use advanced power electronics to control the network parameters. he power electronics used are mainly gate controllable i.e. gate turn-off thyristors (GTOs) and insulated gate bipolar transistors (IGBTs). This controllability and the switching frequency introduces a new generation of devices superior to any devices previously available. Some of these devices are briefly described and a case study comparing the alternatives for an 88-kV distribution network is discussed. 1 Ref.

[1997] 07A - 19

FACTS TECHNOLOGY AND NEW PROGRESS IN THE DEVELOPMENT OF ITS CONTROLLERS-TCPST, IPC (TCIPC) AND SSSC

He, D.

China Elec Power Inf Centre, Beijing, China

Automation of Electric Power Systems (China), vol 21, no 6, July 1997, pp 1-6

Chinese

The technology of flexible ac transmission systems (FACTS) as well as its controllers have been developed ahead at an increasing pace, and are recognized worldwide as a new effective power transmission technology. Moreover the new progress achieved in the FACTS concept and specification. The technology of its controllers is also developing rapidly. This paper presents the research results of three new controllers (TCPST, IPC (interphase power controller) and SSSC (static synchronous series compensator)) classified as "controllers which are expected to be available in the foreseeable future" by the IEEE's FACTS Working Group. Meanwhile, their working layout and operating features have received insufficient understanding and attention. Besides, some analysis or proposals of FACTS

controller's comparison and application raised in the paper may serve altogether for further discussion and reference.

[1996] 07A - 20

FLEXIBLE AC TRANSMISSION SYSTEMS

Hingorani, N.G.

Hingorani Power Electronics, Los Altos Hills, CA

Electricity Transmission Pricing and Technology, Klumer Academic Publishers, Dordrecht, Netherlands, pp 259-275

Narain Hingorani and Karl Stahlkopf conclude this volume with two related papers concerning a major wave of the future: the Flexible Alternative Current Transmission System (or FACTS). FACTS involves the use of high-power microelectronics to enhance the controllability and capacity of utility transmission systems, secure loading of conductors to thermal limits, reduce necessary generation margins through increased usable capacity, and prevent cascading outages by limiting the effects of faults and equipment failures. These opportunities arise from the ability of FACTS to control the inter-related parameters that constrain today's transmission systems including series and shunt impedance, phase angle, and the occurrence of frequency oscillations below the rated frequency. The papers discuss the nature of the constraints, the power electronic controllers that can overcome these constraints, and the scope of applications. A separate abstract has been prepared for the paper of Stahlkopf. 10 figs.., 6 refs.

[1997] 07A - 21

FLEXIBLE AC TRANSMISSION SYSTEMS PART 3 CONVENTIONAL FACTS CONTROLLERS

Moore, P.; Ashmole, P.

Power Engineering Journal (UK), vol 11, no 4, August 1997, pp 177-183

In this tutorial FACTS controllers are examined which are currently commercially available, or could be developed in the short term using currently available hardware - conventional FACTS controllers. The distinguishing feature of conventional FACTS controllers, compared to advanced FACTS controllers, is that the former are based on the use of conventional thyristors, i.e. thyristors relying on natural commutation.

[1996] 07A - 22

FLEXIBLE AC TRANSMISSION LINES

Ivakin, V.N.; Kovalev, V.D.; Khudyakov, V.V.

Russian Electrical Engineering (Elektrotekhnika), vol 67, no 8, pp 16-22

Voltage-inverter circuits based on switchable thyristors offer great promise for the application of modern power converter technology in the power industry. On the basis of such circuits, flexible ac power transmission lines may be created; such power lines may radically transform power systems in the future and permit considerable increase in carrying capacity and controllability of power systems. This topic has been much discussed in CIGRE publications and in non Russian journals. It is a fundamental trend in power system development. This paper argues, therefore, that research, design and development work on static power converter (statcon) prototypes and other equipment for flexible ac transmission lines must be given high priority. 8 Refs.

[1997] 07A - 23

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

Hammons, T.J.; Lim, S.K.

Glasgow Univ, UK

Electric Machines and Power Systems, vol 25, no 1, January 1997, pp 73-85

The paper reviews literature which addresses the application of flexible ac transmission system (FACTS) concepts to the improvement of power system utilization and performance. It summarizes literature on using high speed thyristor based control of HVAC power system elements to enhance the power carrying capacity of existing transmission circuits without compromising reliability. It describes a study system representative of existing power systems that has been developed to evaluate the economic and technical issues of loading transmission lines to their thermal limits. Considered are two scenarios, a multi-line corridor and a long radial interconnection, where the issues addressed are transient and dynamic stability, power flow control, reactive support and voltage stability. A benchmark system is developed to validate performance of the more simple devices. It is concluded that FACTS devices have the potential to significantly increase system stability margins thereby increasing loading capability of existing transmission corridors such as between Scotland and England. Economic evaluations of the applications reviewed in the literature show that FACTS

devices are attractive when compared with the other methods of achieving similar performance objectives.

[1997] 07A - 24

FLEXIBLE AC TRANSMISSION SYSTEMS: A STATUS REVIEW

Padiyar, K.R.; Kulkarni, A.M.

Sadhana (India), vol 22, pt 6, December 1997, pp 781-796

With the availability of high power semiconductor switches with turn-off capability, voltage source converter based controllers for power transmission system applications have become a reality. Prototypes of some second generation flexible ac transmission system (FACTS) controllers like TCSC and STATCON have been installed. This paper presents a review of the progress in FACTS. A generalized description of FACTS controllers is also presented.

[1997] 07A - 25

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) FOR THE IMPROVEMENT OF NETWORK QUALITY

Braun, K.; Posh, D.; Pregizer, K.; Retzmann, D.; Weinhold, M.

Seimens AG, Erlangen, Germany

ETZ (Germany), vol 118, no 6, March 1997, pp 28-31

German

The article deals with problems concerning reliability and quality of the supply of electricity arising especially in developing countries where the demand is apt to overtake the means for meeting it and excessive fluctuations of frequency (±3 HZ) and voltage (20%) not to mention complete breakdown, are apt to occur. It describes a number of means for improving the quality of supply, notably better network planning, aided by computer simulation and digital network models, flexible ac transmission systems (FACTS), HVDC transmission, the Siemens Power Conditioner (SIPCON), static compensation systems, and small economic transmission systems (SETS).

[1996] 07A - 26

FLEXIBLE ALTERNATING CURRENT ELECTRIC TRANSMISSIONS

Ivakin, V.N.; Kovalev, V.D.; Khudyakov, V.V.

Russian Electrical Engineering (Elektrotekhnika) (Russia), no 8, August 1996, pp 16-20

Russian

Lately are investigated very intensively the special devices for alternating current electric power transmission on the base of new power semiconductor devices. The electric transmissions with these devices are called the double prime flexible double prime electric power transmissions on the base of autonomous voltage inverters with locked thyristors shunted with semiconductor diodes. It is shown that the circuits of voltage inverters with locked thyristors may be used for development of flexible electric transmissions of alternating current with substantially improved performances. 8 Refs.

[1996] 07A - 27

GLOBAL LINK OF RENEWABLE ENERGY SOURCES: TECHNICAL, ECONOMICAL, AND ENVIRONMENTAL ASPECTS OF AN INTERCONTINENTAL ELECTRICITY TRANSMISSION AND DISTRIBUTION SYSTEM

Wiese, A.; Kaltschmitt, M.

Lahmeyer Int GmbH, Frankfurt, Germany

Energy Sources, vol 18, no 8, December 1996, pp 841-854

The present energy system mainly depends on worldwide transport of fossil primary energy carriers. One way to reduce fossil fuel consumption would be to substitute the worldwide transport of fossil primary energy carriers by transportable secondary energy carriers converted from renewable energy sources. This could also reduce global and local environmental effects resulting from the use of fossil fuels as energy. By means of a global link the regions with large supplies of renewable energy could be connected to regions where the energy demand is relatively high. In this context, it is the objective of this article to, first, give a general overview of the different possibilities. Then possible compensation and equalization effects of an intercontinental electricity transmission and distribution system are analyzed; environmental and economic aspects are also discussed. Some conclusions are drawn in the final section. 8 Refs.

[1996] 07A - 28

GUIDE TO CHOICES IN ELECTRIC POWER SUPPLY FOR STEEL MAKING ARC FURNACES

Kratz, M.

Electricite de France

Collection de notes internes de la Direction des etudes et recherches. Materiel electrique, transport et distribution d'energie (France), no 53, 1996, 36 pp

French

The main function of an arc furnace, whether supplied with alternating or direct current, is to melt down solid scrap iron (or possibly of pre-reduced ore), transforming it into raw liquid steel. This raw steel may be refined, i.e. brought to its final composition through a number of further metallurgical operations, either within the furnace itself, or without, in another, more appropriate installation (ladle furnace). For faster arc furnace steel processing, electric power must be transmitted as efficiently as possible to the charge. This can only be achieved if the arc is perfectly controlled, in particular its position and stability. However, phenomena of arc instability and power electronics based power supply are the underlying cause of a number of disturbances transmitted into the electric power network (flicker and harmonics). After presenting the characteristics of the various arc furnaces used in steel making, the present document describes the disturbances caused by arc furnaces, and possible technical solutions to such problem, as applied to the electrical power supply for such furnaces. Flicker compensation techniques are : - increase in network short-circuit power; serial capacity compensation; linear or saturable reactor; static VAr compensator; serial dimmer; new power supply architectures for dc furnaces. Harmonic compensation techniques are: increase in network short-circuit power; antiharmonic filtering; converter optimization. A reduction of these disturbances by appropriate systems is beneficial first to the steel makers, as it improves arc stability, and consequently optimizes the efficiency of furnaces, while also increasing equipment service life. Secondly, any reduction in electric network disturbances is also desirable from the energy distributor's point of view, in order to keep constant quality in electrical power supplies to other customers connected to the same electric networks. 10 refs.

[1997] 07A - 29

IMPROVEMENT OF SUPPLY QUALITY IN DISTRIBUTION SYSTEMS

Povh, D.; Pregizer, K.; Weinhold, M.; Zurowski, R.

Siemens AG, Erlangen, Germany

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

The growing number of low-pulse power electronic loads in distribution networks causes an increasing line voltage distortion. At the same time, a large portion of consumers are sensitive to deviations of the line voltage from its ideal sinusoidal waveform, which can also result from network faults or unbalanced loading. This paper describes the main power quality problems in distribution systems and ways of solving them by utilizing state-of-the-art power electronic equipment, the so-called power conditioner.

[1998] 07A - 30

INTERCONNECTED POWER SYSTEM DYNAMICS TUTORIAL: DYNAMICS OF INTERCONNECTED POWER SYSTEMS TUTORIAL: SECOND EDITION

Sobajic, D. (prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-107726-R1, January 1998, 745 pp

Thousands of readers in the power system community have benefited from the first edition of this tutorial as a training tool and reference document on power system operation and engineering. This edition substantially revises the earlier tutorial and incorporates many suggestions and requests offered by users.

[1997] 07A - 31

INVESTIGATING THE DIFFERENT COMBINATIONS OF FACTS DEVICES IN LOW COST RURAL ELECTRIFICATION

Mostert, C.; Thiel, S.; Enslin, J.H.R.; Herman, R.; Stephen, R.

Univ of Stellenbosch, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

More economically viable rural electrification schemes have to be found in order to make the enormous task of Southern African rural electrification possible. The proposal rests on the implementation of FACTS devices. This idea incorporated an active rectifier front-end together with an inverter. This would enable the system, commonly referred to as USE (universal semiconductor electrification), to supply an ac voltage within the ±10 percent regulation, while the supply to the USE system could vary up to ±40 percent at a rating of 45 kW-100 kW. This paper gives practical results and focuses on the viability of different combinations of high and lower power units. Advantages and disadvantages will be discussed, including dc reticulation. Cogeneration plants can also be integrated with this system. These include photovoltaic and hydro

generators with minimal energy storage.

[1996] 07A - 32

LOAD FLOW CONTROL IN POWER SUPPLY NETWORKS-VISION AND REAL POSSIBILITIES

Gampenrieder, R.; Hausler, M.; Povh, D.

Bayernwerk AG, Munich, Germany

Elektrizitaetswirtschaft (Germany), vol 95, no 25, December 2, 1996, pp 1671-1674, 1676-1677

German

This paper explains the content of flexible ac transmission systems (FACTS) for load flow control with power electronics, and what can be achieved in networks with them. 11 Refs.

[1996] 07A - 33

MARKET OPTIONS FOR REACTIVE POWER

Wilson, D.

Ian Pope Associates Ltd

IEE Colloquium (Digest) (UK), no 190, 1996, pp 4/1-4/3.

Some of the issues involved in the development of a market in reactive energy are discussed. The primary factor to be considered is the control over the production and absorption of reactive energy which is essential for the operation of any integrated power system. The component on a power system that can either generate or absorb reactive energy include: generating plant, synchronous compensators; reactors an capacitors; static VAr systems; overhead lines and transformers. The cost of provision of reactive energy as well as its market characteristics and requirements require discussion since these are one of the most influential factors on the market development of reactive power.

[1997] 07A - 34

MODELING SYNCHRONOUS VOLTAGE SOURCE CONVERTERS IN TRANSMISSION SYSTEM PLANNING STUDIES

Kosterev, D.N.

Oregon State Univ, Corvallis, OR, USA

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 947-952

A Voltage Source Converter (VSC) can be beneficial to power utilities in many ways. To evaluate the VSC performance in potential applications, the device has to be represented appropriately in planning studies. This paper addresses VSC modeling for EMTP, powerflow, and transient stability studies. First, the VSC operating principles are overviewed, and the device model for EMTP studies is presented. The ratings of VSC components are discussed, and the device operating characteristics are derived based on these ratings. A powerflow model is presented and various control modes are proposed. A detailed stability model is developed, and its step-by-step initialization procedure is described. A simplified stability model is also derived under stated assumptions. Finally, validation studies are performed to demonstrate performance of developed stability models and to compare it with EMTP simulations. 11 Refs.

[1998] 07A - 35

MODELING, CONTROL AND STABILITY ANALYSIS OF A PEBB-BASED DPS

Thandi, G.S.; Zhang, R.; Xing, K.; Lee, F.C.; Boroyevich, D.

Analog Devices, Santa Clara, CA, USA

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

Power electronic building block (PEBB) concept is to provide generic building blocks for power conversion, regulation and distribution with control intelligence and autonomy. A comprehensive modeling and analysis of a PEBB-based dc distributed power system (DPS), comprising of a front end power factor correction (PFC) boost rectifier, a dc-dc converter and a three-phase, four-leg inverter is performed. All the subsystems of the dc DPS are modeled and analyzed for stability and good transient performance. The effect of impedance overlap on the system and individual subsystems is examined. Ability of a PEBB-based converter to stabilize the integrated system by actively changing the system bandwidth is presented.

[1996] 07A - 36

NETWORK UPGRADING: UNIFIED POWER FLOW CONTROLLER: THE ULTIMATE FACTS DEVICE

Stahlkopf, K.E.

EPRI, Palo Alto, CA, USA

Modern Power Systems (UK), vol 16, no 4, April 1996, pp 57, 59, 61

The flow of power in ac transmission systems is difficult to control resulting in loop flows and bottlenecks.

Mechanical voltage controllers react too slowly to keep voltage disturbances from spreading. The Electric Power Research Institute (EPRI) has sponsored the development of a new generation of electronic power controllers which can form the basis of a flexible ac transmission system (FACTS), described here. FACTS will be especially valuable in the USA where increasing electric power sales are placing a strain on the interconnected power grids. Devices such as the unified power flow controller (UPFC) will allow power systems to function well beyond their design capacity at a time when there is increased demand but little construction of new transmission facilities. (UK)

[1996] 07A - 37

NEW TECHNOLOGY IN POWER SYSTEM-DEVELOPMENT AND STUDY OF FLEXIBLE AC TRANSMISSION SYSTEMS

Wu, S-Y.; Zhou, X-X.; Zhao, H.; Zhang, W-T.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 20, no 5, May 1996, pp 1-3, 7

Chinese

The flexible ac transmission system (FACTS) is a new technology in the field of power systems. This paper gives a general overview of its development and briefly describes its component elements. Simulation and test results are used to demonstrate the effectiveness of these FACTS elements. 18 Refs.

[1996] 07A - 38

NEW TRANSMISSION CONTROL SYSTEMS OPTIMIZE POWER FLOW

Beaty, W.

Electric Light and Power, vol 74, no 3, March 1996, pp 19-21

This article is a review of developments in the control of power distribution systems. Historical aspects of the problem are first noted, and then current techniques are discussed. These include: (1) STATCON---a static condenser device developed by Westinghouse for voltage support within the TVA system, (2) unified power flow controller---a device developed by EPRI and Westinghouse for American Electric Power Company, (3) Static Synchronous Series Converter---a solid-state voltage source inverter connected in series with the transmission line, and (4) Electro-Optic Voltage Transducer System---a state-of-the-art voltage sensing device developed by a team consisting of ABB, NYPA, TVA, and the Empire State Electric Energy Research Corp.

[1997] 07A - 39

ON THE NEW PROGRESS EXTENDED IN THE FACTS CONCEPT

He, D.

China Elec Power Inf Centre, Beijing, China

Power System Technology (China), vol 21, no 2, February 1997, pp 9-14

Chinese

In this paper, R&D progress in the FACTS (flexible ac transmission lines) field, as a result of several years' discussion and mutual consultation by the IEEE and CIGRE are described. The author presents both the rapid develop-ment of FACTS technology and the further explicitness of technical specifications of the FACTS concept as well as its controllers. A brief enumeration of cooperative development projects of FACTS controllers in China is also given.

[1997] 07A - 40

POWER ELECTRONIC BASED SYSTEM FOR AC TRANSMISSION SYSTEM

Tamai, S.

Systems, Control and Information (Japan), vol 41, no 7, July 1997, pp 252-257

Japanese

The following topics are discussed: power system stability; power electronics; ac power transmission; FACTS, and var compensation.

[1996] 07A - 41

POWER ELECTRONIC DEVICES AND THEIR IMPACT FOR POWER TRANSMISSION

Ballad, J.P.; Bassett, R.J.; Davidson, C.C.

GEC ALSTHOM Eng Res Centre, Stafford, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 245-251

The use of power semiconductor devices in the transmission of electrical power is at once well established and growing rapidly. HVDC transmission is an established technology for which the thyristor has become the workhorse since the installation of the first solid-state power converter at Eel River in 1972. For

improving the utilization of ac networks and the quality of the supply of ac power, flexible ac transmission systems (FACTS) technology can be utilized. FACTS equipment based on thyristors, e.g. the static VAr compensator (SVC), are now well established, whilst others, requiring fully controllable (bimodal) power electronic devices, are under development. Examples include the advanced static compensator (STATCOM), the unified power flow controller (UPFC) and the active filter. Additionally, power integrity may be reinforced by drawing from a reservoir of energy, for example a superconducting magnetic energy store (SMES), requiring access via power electronic converters. 13 Refs.

[1997] 07A - 42

POWER ELECTRONICS AND APPLIED SUPERCONDUCTIVITY

Murakami, Y.; Ise, T.

Systems, Control and Information (Japan), vol 41, no 7, July 1997, pp 258-266

Japanese

The following topics are discussed: superconducting magnet energy storage (SMES); four quadrant SMES current control; H^{∞} fusion magnet current control; magnetic levitation; and high temperature superconductor motors.

[1997] 07A - 43

POWER ELECTRONICS AND DRIVES-TECHNOLOGY STATUS AND ADVANCEMENT

Bose, B.K.

Tennessee Univ, Knoxville, TN, USA

Proceedings, IEEE Int'l Symp on Industrial Electronics (ISIE '97), Guimaraes, Portugal, July 7-11, 1997, vol 1, pp TU1

Summary form only given. The technology of power electronics and ac motor drives has advanced tremendously in recent years. The reduction of cost and improvement of performance of power electronic apparatus have promoted their widespread applications in dc and ac drives, dc and ac power supplies, high frequency lighting, static VAr and harmonic compensation, electrochemical processes, induction heating, etc. Increasing emphasis on industrial automation and energy saving are making power electronics and drives more important day by day. This comprehensive tutorial reviews the recent power semiconductor devices, important converter topologies, industrial drives using induction and synchronous motors and advanced control of ac drives including the modern intelligent control techniques. The presentation starts with a discussion on the importance of the technology, various applications and R&D trends. Among the devices, IGBTs and MCTs are particularly emphasized. Both hard-switched and soft-switched power converters are discussed. Variable frequency ac drives and their control principles are adequately illustrated with practical applications. Finally, sensorless control and intelligent control with fuzzy logic and neural networks are discussed.

[1996] 07A - 44

POWER ELECTRONICS ENTERS ELECTRIC POWER NET

Daniel, D.; Therond, P.G.; Lafon, L.

Electricite de France, Paris, France

Recherche (France), Special Edition, 1996, pp 38-40

French

FACTSs (flexible alternating current transmission systems) developed with high voltage GTOs (gate turn-off thyristors) allow the control of long and interconnected power lines thanks to ac to dc, and then controlled dc to ac conversions. Enhanced circuit breakers optimize the net efficiency by unloading power lines of excess load only. Electricite de France works on one of these computerized power conditioning circuits, and in particular on a switching circuit made of six series connected GTOs. (D.L.). 3 figs., 1 photo.

[1996] 07A - 45

POWER ELECTRONICS: A REVIEW

Virani, H.

Electrotechnology (UK), vol 7, no 4, August-September 1996, pp 26-27

Power electronics has been defined as a multidisciplinary technology that encompasses power semiconductor devices, converter circuits, electrical machines, signal electronics, control theory and microcomputers. The author reviews some significant developments as follows: power semiconductor devices; modern power devices; ac-dc power converters; ac-ac power converters; dc-dc power converters; dc-ac power converters; and power integrated circuits. 0 Refs.

[1997] 07A - 46

POWER SYSTEM DYNAMICS AND STABILITY

Machowski, J.; Bialek, J.W.; Bumby, J.R.

J. Wiley & Sons Ltd., 1997, ISBN 0-471-95643-0

Chapter 9 of this textbook deals with deriving optimal control strategy of damping power swings in the system using series and shunt FACTS devices. Lyapunov direct method is employed and implemented using local measurements available at the point of the device installation.

[1998] 07A - 47

PROCEEDINGS, ENERGY MANAGEMENT POWER DELIVERY CONFERENCE (EMPD'98)

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO2.2

Abstract not available

[1997] 07A - 48

PROCEEDINGS, INTERNATIONAL CONFERENCE ON INTELLIGENT SYSTEM APPLICATION TO POWER SYSTEMS

Park, Y.-M.; Park, J.-K.; Lee, K.Y. (eds)

Korean Inst of Elec Engineers

Int'l Conf on Intelligent System Application to Power Systems (ISAP '97), Seoul, Korea, July 6-10, 1997

Abstract not available.

[1997] 07A - 49

PROCEEDINGS: FACTS CONFERENCE 3

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

Proceedings, EPRI FACTS Conf 3, October 5-7, 1994, Baltimore Maryland, May 1997

This volume contains the papers and discussions of the Third International Conference on flexible ac transmission systems (FACTS). Organized by the Grid Operations & Planning Business Area of EPRI's Power Delivery Group (PDG), the conference was held in Baltimore, Maryland, on October 5-7, 1994. An international team of power electronics applications experts gathered for this conference, including engineers and executives from EPRI member utilities, university researchers, consultants and equipment manufacturers. Conference topics centered on EPRI's FACTS initiative to achieve the maximum possible loading, control, flexibility and utilization of the ac power grid using semiconductors and advanced control concepts. Four sessions covered the following topics: Session I: Operating Experience of FACTS Controllers; Session II: FACTS Demonstration Projects; Session III: FACTS Implementation Studies and Planning; Session IV: Panel Session on Research Directions.

[1997] 07A - 50

PROPOSED TERMS AND DEFINITIONS FOR FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

Edris, A.-A.; Adapa, R.; Baker, M.H.; Bohmann, L.; Clark, K.; Habashi, k.; Gyugyi, L.; Lemay, J.; Mehraban, A.S.; Myers, A.K.; Reeve, J.; Sener, F.; Torgerson, D.R.; Wood, R.R.

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1848-1853

FACTS is an acronym which stands for flexible ac transmission system. FACTS is an evolving technology-based solution envisioned to help the utility industry to deal with changes in the power delivery business. This paper presents results of Task Force 3 of the IEEE's FACTS Working Group of the dc and FACTS Subcommittee which had the assignment to establish appropriate definitions of FACTS-related terminology. These definitions will be included in the IEEE Dictionary. 14 Refs.

[1996] 07A - 51

PROSPECTS FOR A NEW GENERATION OF HIGHLY RELIABLE 1150 KV ELECTRICAL EQUIPMENT

Varivodov, V.N.; Volkova, O.V.; Kovalev, V.D.; Kozlov, V.B.; Koryavin, A.R.; Ostapenko, E.I.

Russian Electrical Engineering (Elektrotekhnika), vol 67, no 8, pp 8-15

As it develops, electrical-engineering equipment is increasing in unit power and rated voltage. Equipment for the 1150-kV Ekibastuz-Ural ac power line has been developed and introduced. Equipment for the 1500-kV Ekibastuz-Tsentr ac power line has been developed. Development work is underway on 1800-kV ac electrical-engineering equipment and 3000-kV dc equipment. However, in the short term, the Russian electric-power industry calls for equipment of voltage no higher than 1150 kV. Around the world, research has begun on controllable devices based on converter technology for the creation of flexible ac energy

systems. The corresponding devices permit increase in the capacity of transmission lines and in the controllability of energy systems. The prospects for the development of a new generation of 1150-kV electrical-energy equipment are considered. Converter equipment for the creation of flexible ac transmission lines are reviewed, and their operating principles are described. Engineering methods for calculating the electrical strength of the external insulation on superhigh- and ultrahigh-voltage terminals are proposed; these methods permit significant reduction in the volume of experiments required. 9 Refs.

[1997] 07A - 52

REACTIVE POWER CONTROL: VOLTAGE OR POWER FACTOR?

Cowan, P.; Saunders, R.

Elektron (South Africa), vol 14, no 3, March 1997, pp 59-60

Electricity supply utilities use reactive power devices (capacitors, reactors, SVCs, synchronous machines) to control busbar voltage for improved power transfer and stability. This article discusses the question of how to control reactive power equipment, namely by power factor or voltage sensing.

[1996] 07A - 53

REAL-TIME-MONITORING AND DYNAMIC THERMAL RATING OF POWER TRANSMISSION CIRCUITS

Douglass, D.A.; Edris, A.-A.

Power Technologies, Inc, Schenectady, NY, USA

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1407-1418

ANSI standards for power equipment, describe various method by which thermal ratings may be adjusted if actual weather conditions are known or if the 'overload' is to be applied for a limited period of time. These methods have been given various names including dynamic thermal rating, on-line rating, and dynamic ratings to describe the process of adjusting thermal ratings of power equipment for actual weather conditions and actual electrical load patterns. This paper discusses in detail a recent project undertaken by the Electric Power Research Institute as part of its research on flexible AC transmission. This project avoids dependence on temperature measurement, instead, calculating critical equipment component temperatures based solely on real-time weather and electrical current. 9 Refs.

[1996] 07A - 54

RELOCATABLE STATIC VAR COMPENSATORS HELP CONTROL UNBUNDLED POWER FLOWS

Knight, R.C.; Young, D.J.; Horwill, C.

The National Grid Co, UK

Modern Power Systems (UK), vol 16, no 12, December 1996, pp 49, 51-54

In competitive electricity markets, the operators of electricity transmission networks may no longer have direct control over the siting of power plant nor of the timing of plant retirement. Combined with variability in load patterns, these changes lead to new requirements for reactive power control and power system planning. This paper describes how, in England and Wales, the National Grid Company plc (NGC) has identified the need for reactive power plant that can be relocated at short notice, and GEC Alsthom's T&D division has been commissioned to design and install three relocatable static VAr compensators at NGC's Iron Acton substation near Bristol. 0 Refs.

[1997] 07A - 55

SECURITY SUPERVISORY CONTROL IN ELECTRIC POWER SYSTEMS

Sobajic, D. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-108327, June 1997, 64 pp

Control systems for power systems are typically hierarchical in structure with higher level controllers coordinating lower level controllers. This report investigates the synthesis of supervisory controllers for power system security applications in which both the system and its controlling agent are viewed as discrete-event systems.

[1996] 07A - 56

STATE OF THE ART AND FUTURE PROSPECTS OF SUPERCONDUCTOR APPLICATIONS-DREAM IS COMING TRUE

Tsukamoto, O.; Umeda, M.; Akita, S.

Yokohama Natl Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 7, July 1996, pp 762-769

Japanese

Abstract not available. 25 Refs.

[1996] 07A - 57

STATE OF THE ART AND LEADING EDGE TECHNOLOGIES OF POWER ELECTRONICS APPLICATIONS TO POWER TRANSMISSION

Naitoh, H.; Yamamoto, H.; Irokawa, S.

Ind Equipment Dept, Toshiba Corp, Japan

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 2, pp 102-109

The worldwide demand for electrical energy will increase steadily in the coming decades. Power transmission systems must expand to keep pace with this. It is likely that some limits arise on ac power transmission alone. Power electronics has provided power transmission with promising alternatives. This paper first surveys existing power electronics applications mainly based on thyristors and line-commutated power converters. The advent of self-turnoff power semiconductor devices with high voltage and large capacity ratings have made the self-commutated power converters more attractive for the use in power transmission systems, while there are many problems to be solved for their practical use. This paper proposes two innovative techniques which contribute to better use of these self-commutated power converters. 8 Refs.

[1997] 07A - 58

STATE OF THE ART AND FUTURE IN POWER ELECTRONICS FOR ELECTRIC POWER FIELDS

Imai, K.

Toyota Tech Inst, Nagoya, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 898-900

Japanese

Abstract not available.

[1997] 07A - 59

SUBJECTS FOR ELECTRIC ENERGY SUPPLY IN THE 21ST CENTURY. FACTS(FLEXIBLE AC TRANSMISSION SYSTEM) IDEA

Hayashi, T.

CRIEPI, Tokyo, Japan

Ohm (Japan), vol 84, no 1, pp 57-61

Japanese

Abstract not available.

[1996] 07A - 60

SUPERCONDUCTING STORAGE SYSTEMS: AN OVERVIEW

Luongo, C.A.

Bechtel Corp, San Francisco, CA, USA

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2214-2223

The last couple of years have seen an expansion on both applications and market development strategies for SMES (superconducting magnetic energy storage). Although originally envisioned as a large-scale load-leveling device, today's utility industry realities point to other applications of SMES. These applications: transmission line stabilization, spinning reserve, and voltage control, are likely to open the door to SMES commercialization in the utility sector. In the industrial sector, power quality concerns are already driving the development of a market for micro-SMES devices, and load-leveling at an industrial scale is fast becoming a potential application. Work recently completed as part of the U.S. SMES program, as well as ongoing design activities, point to self- (or cold-) supported SMES as the design option in the near-future. This is a major departure from the earth-supported SMES systems first envisioned 25 years ago for utility load-leveling. The path to commercialize SMES is not likely to include a large `demonstration' unit, or model, but rather follow an evolutionary process in which bigger and better units will be fielded in response to specific applications. This paper reviews the developments in the U.S. SMES program that have taken us to where we are today, briefly reviews SMES-related activities around the world, and points out trends in applications and development of SMES. 80 Refs.

[1997] 07A - 61

SYSTEM SYMMETRIZATION BY FACTS FOR INCREASED TRANSMISSION CAPACITY

Glavitsch, H.

Swiss Fed Inst of Tech, Zurich, Switzerland

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

Realizing that the majority of faults on transmission circuits are unsymmetrical faults gives rise to the idea

that the sound conductors not affected by the fault should be utilized for the transmission of power. FACTS devices offer the possibility to absorb and inject currents at the terminals of a disturbed circuit such that from the outside the circuit appears as symmetrical. The analysis for the necessary currents performing the symmetrization and for determining the gain in transmission capacity is given. The FACTS device is a compensator which acts as a single-phase to three-phase converter connected phase to ground and is a var compensator at the same time. Gains for the transmission capacity are worked out. An equivalent circuit for the symmetrized circuit can be used for a general security analysis in a multi-node network without resorting to the details of symmetrization. An extension to a distributed use of compensators in large networks is suggested allowing reduced ratings of the FACTS devices.

[1998] 07A - 62

TECHNOLOGY ASSESSMENT AND BUSINESS PLANNING FOR POWER CONDITIONING TECHNOLOGIES

Edris, A.-A. (prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-109896, January 1998, 111 pp

This report includes a review of technologies for power quality improvement and an assessment of the future potential for these technologies. With a focus on providing ride-through support for voltage sags and momentary interruptions, the report also addresses other power quality concerns, including the economics of evaluating power conditioning alternatives

[1996] 07A - 63

TECHNOLOGY DEVELOPMENT OF FLEXIBLE AC TRANSMISSION SYSTEM

Edris, A.-A.

EPRI, Palo Alto, CA, USA

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 882-888

Flexible ac transmission system (FACTS) is a technology-based solution envisioned by the Electric Power Research Institute (EPRI) in the USA to help the utility industry to deal with changes in the power delivery business. A major thrust of FACTS is the development of controllers that control the power flow by changing the impedance of a transmission line, phase angle and voltages at critical buses. Power electronic-based controllers are the vehicles that provide the speed and flexibility needed for these controls to achieve better utilization of the electric transmission system while maintaining sufficient steady-state and transient margins. The paper presents an overview of the development and demonstrations of the FACTS technology program. The following FACTS controllers are described: thyristor-controlled series compensator; static synchronous compensator; and unified power flow controller. 11 Refs

[1996] 07A - 64

THE DEFINITION, OPPORTUNITIES AND LIMITATIONS OF FACTS TECHNOLOGY

He, D-Y.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 20, no 6, June 1996, pp 18-24

Chinese

FACTS (flexible ac transmission systems) technology is a new concept which originated in 1986. Its definitions and opportunities, background of its appearance, limitations and existing problems are stated and analyzed in this paper. An improved new definition is also proposed by the author. 50 Refs.

[1996] 07A - 65

THE FACTS CONTROLLERS AND PROPOSALS FOR THEIR DEVELOPMENT AND APPLICATION IN CHINA

He, D-Y.

Elec Power Inf Research Inst, Beijing, China

Power System Technology (China), vol 20, no 7, July 1996, pp 1-8, 13

Chinese

In this paper, FACTS controllers as well as their terms and classification are described and analyzed. Based on a new definition, a new classification by which FACTS controllers are classified as three subgroups is offered, and recent applications and the future development of FACTS controllers are also presented. Several proposals for foreseeing research and practical use of FACTS controllers in China are put forward to conclude this paper. 56 Refs.

[1996] 07A - 66

THE FUTURE OF POWER DELIVERY: 1996 CONFERENCE

Edris, A.-A. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, 838 pp

EPRI's 1996 conference on the Future of Power Delivery provided opportunities to learn about state-of-the-art power delivery technologies for accommodating changes in electric transmission systems or operating conditions while maintaining sufficiently secured steady-state and transient margins. The conference--organized by EPRI's Power Delivery Group--explored the future of power delivery, in specific, the four Rs: research, reliability, regulation and regional transmission groups. This report contains papers presented at the conference, which was held April 9-11, 1996, in Washington, D.C. The papers were presented by special reporters in three sessions, covering the subjects of FACTS technologies, system reliability aspects, and transmission system utilization. In each session, the special reporter presented an overview of the focus subject and summarized the primary findings and conclusions of the session's papers. In addition, the reporters drafted a number of clarifying questions for each paper, and authors were given the opportunity to respond to these questions. The conference also included a plenary session on the changing utility environment and a panel session summarizing the other four sessions and identifying future R&D needs. In all, this conference provided a valuable opportunity to explore how the future of power delivery must change to accommodate new regulations and meet reliability requirements.

[1998] 07A - 67

THE FUTURE OF POWER DELIVERY IN THE 21ST CENTURY: 1998 CONFERENCE

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-109806, May 1998, Proceedings

The fifth conference on future power delivery systems and flexible ac transmission system (FACTS) stressed the importance of maximizing the use of existing power systems while maintaining system security and reliability with minimum capital investment and reduced O&M costs. This report presents the proceedings of that conference.

[1996] 07A - 68

THE INTRODUCTION OF FLEXIBLE AC TRANSMISSION SYSTEM

Huang, C-Y.

Monthly Journal of Taipower's Engineering (Taiwan), vol 578, October 1996, pp 18-40

Chinese

FACTS (flexible ac transmission system) devices use power electronics to enhance the controllability of ac transmission systems, to improve economic power transfers and to increase system security and reliability. Currently, based on high-power, high-speed semiconductor switches, a lot of FACTS devices such as static VAr compensator (SVC), thyristor-controlled series capacitor (TCSC), static synchronous compensator (statcom) and unified power flow controller (UPFC), have been developed. This paper describes the operational principles, performance characteristics and technology features of FACTS. 27 Refs.

[1996] 07A - 69

THE SECOND SILICON REVOLUTION

Stahlkopf, K.E.

EPRI, Palo Alto, CA, USA

Electricity Transmission Pricing and Technology, Kluwer Academic Publishers, Dordrecht, Netherlands, pp 259-275

Narain Hingorani and Karl Stahlkopf conclude this volume with two related papers concerning a major wave of the future: the Flexible Alternative Current Transmission System (or FACTS). FACTS involves the use of high-power microelectronics to enhance the controllability and capacity of utility transmission systems, secure loading of conductors to thermal limits, reduce necessary generation margins through increased usable capacity, and prevent cascading outages by limiting the effects of faults and equipment failures. These opportunities arise from the ability of FACTS to control the inter-related parameters that constrain today's transmission systems including series and shunt impedance, phase angle, and the occurrence of frequency oscillations below the rated frequency. The papers discuss the nature of the constraints, the power electronic controllers that can overcome these constraints, and the scope of applications. A separate abstract has been prepared for the paper of Hingorani. 7 figs.

[1997] 07A - 70

TIGHTER CONTROLS FOR BUSIER SYSTEMS

Stahlkopf, K.E.; Wilhelm, M.R.

EPRI, Palo Alto, CA, USA

IEEE Spectrum, vol 34, no 4, April 1997, pp 48-52

Power flow control difficulties on contract paths lead to flow controller development that furnished the foundation for the flexible alternating current transmission system (FACTS), making it possible to redirect power in real-time and instantaneous response to system disturbance. Several FACTS devices using thyristor technology were developed to adapt to the system needs, some of which are in the design stage, while others are already in operation. To use these devices along with on-line analysis of the system requires analytical tools that use real time information as well as dependable and wide area control center communication.

[1998] 07A - 71

TRANSMISSION CAPABILITY ENHANCEMENT USING POWER ELECTRONICS TECHNOLOGIES FOR THE FUTURE POWER SYSTEM IN JAPAN

Hayashi, T.; Takasaki, M.

CRIEPI, Tokyo, Japan

Electric Power Systems Research vol 44, no 1, January 1998, pp 7-14

Many power system stabilization measures realized by the upgrading transmission lines, generator controls, and power system controls and protections have been developed and utilized toward increasing transmission capability of power systems in Japan. With restriction of transmission routes and power system deregulation, it is now inevitable that transmission capability will be increased to sustain such power system reliability. Various remarkable power electronic technologies such as self-commutated SVC are being introduced toward improving power system stability. It is expected that these will also be employed in power flow control to avoid faults from cascading throughout the entire power system. This paper describes the present researches related to the application of power electronics to power systems in CRIEPI, including the recent results of the research carried out in cooperation with ten Electric Power Companies subsidized by MITI. Specifically: (1) analytical studies in power system enhancement by self-commutated SVC, thyristor-controlled series capacitance (TCSC), and unified power flow controller (UPFC); (2) analytical studies on transmission capability increase of the interconnected power system applying the HVDC system with self-commutated converters; and (3) experimental studies of the self-commutated converter for continuous operation of converters at ac system faults. 5 Refs.

[1996] 07A - 72

TRANSMISSION CAPACITY IN POWER NETWORKS

Ilic, M.; Galiana, F.; Fink, L.; Bose, A.; Mallet, P.; Othman, H.

MIT, Cambridge, MA, USA

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 1, pp 5-21

This survey paper deals with the complex topic of transmission capacity, starting from its definition through modeling and analysis. Methods for evaluating transmission capacity are also briefly described. The second part of the paper is concerned with possible means of increasing the transmission capacity at the locations of most interest. The third part is concerned with possible economic incentives for enhancing transmission capacity in a changing electric power industry. 53 Refs.

[1996] 07A - 73

TRANSPORTABLE WATTLESS POWER COMPENSATORS

Haesler, M.; Gruenbaum, R.

ABB Calor Emag Schaltanlagen AG, Mannheim, Germany

ETZ (Germany), vol 117, no 7, September 1996, pp 18-23

German

Deregulation of electric power supply is now a worldwide issue out of competitivity considerations. This makes higher demands on the flexibility of network control. The load-dependent wattless power must be compensated. In case of network modifications, it may be necessary to change the point of compensation. Transportable wattless power compensators developed by ABB for their UK grid solve this problem. They are compact, modular and easily transportable.

[1996] 07A - 74

UNBUNDLED PRODUCTS AND THE POTENTIAL ROLE OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE IN A COMPETITIVE ELECTRIC MARKETPLACE

Faber, S.R.

Strategic Energy Ltd, Pittsburgh, PA, USA

Proceedings, 38th IEEE/PCA Cement Industry Technical Conf, Los Angeles, CA, April 14-18, 1996, pp 79-83

Like the natural gas industry before it, the electric industry is undergoing a fundamental change from a regulated monopoly to a competitive industry where market forces prevail. Today, a retail electric customer still purchases a bundled product (delivered electric energy) from its native electric utility. However, in a truly competitive retail environment, an end-user will be able to competitively source its purchase of various unbundled products from different suppliers. Types of unbundled products that should be available include demand and energy, load following, operating reserves, reactive power, and others. Electric energy storage, which is being developed using superconductor technology, could play a vital role in the developing competitive electric market. Superconducting magnetic energy storage devices can presently store electric energy up to several megawattseconds, but new advances are creating the possibility of storing thousands of megawatthours. This increased energy storage would enable end-users to peak shave and displace traditional sources of power when economically appropriate as is currently done with gas storage. 6 Refs.

[1996] 07A - 75

UNIFIED POWER FLOW CONTROLLER: THE ULTIMATE FACTS DEVICE

Stahlkopf, K.E.

EPRI, Palo Alto, CA, USA

Modern Power Systems (UK), vol 16, no 4, April 1996, pp 57, 59, 61

Increasing acceleration of electricity sales will place a strain on the highly interconnected North American power grid, which will be expected to perform functions well beyond its original design capacity, at a time when there is little or no incentive for construction of new transmission facilities. Similar challenges are also arising in many other areas of the world. Here, the author describes how such changes can best be accommodated by timely use of advanced power flow control technologies, and explains how the most versatile of these is the unified power flow controller (UPFC). 0 Refs.

[1998] 07A - 76

USE OF POWER ELECTRONICS FOR RURAL ELECTRIFICATION

Hingorani, N.G.; Stephen, R.G.; Sudja, N.; Nietsch, C.; Weinhold, M.

Hingorani Power Electronics, Los Altos Hills, CA, USA

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

The increasing demand for electricity in evolving and developing countries requires new concepts for energy transmission and distribution. In many cases loads are far away from the centers of energy generation and not big enough to justify the building of common transmission lines and distribution systems. Therefore, a strong demand for small economic transmission systems (SETS) and for usage of locally available energy sources, including regenerative sources such as solar and wind power, exists. Power electronics can be used to improve the rural electrification by more economic transmission of energy, management of decentralized distribution systems, and interfacing of energy sources to the system. The paper addresses the issues of rural electrification by describing the situation in South Africa and Indonesia and summarizes the benefits of power electronics in these typical scenarios.

[1997] 07A - 77

USER-DEFINED MODELING FOR NEW CONTROL EQUIPMENT IN POWER SYSTEM

Wu, S.; Zhou, X.; Zhao, H.; Zhang, W.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 21, no 6, June 1997, pp 1-4

Chinese

A user-defined modeling method for new control equipment and those devices with special parameters in power systems are presented in this paper. This method can be applied to the analysis of the network with power electronics and FACTS devices.

[1997] 07A - 78

VOLTAGE STABILITY STUDIES FOR SOUTHERN COMPANY SERVICES

Maratukulam, D. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-109490, December 1997, 159 pp

This report describes a study conducted under an EPRI Tailored Collaboration project to develop and demonstrate procedures for the assessment of voltage security of the Southern Electric System (SES). The contractor used EPRI steady-state analysis tools including VSTAB (Voltage STABility assessment program) to assess stability margins and verified them using EPRI dynamic tools including ETMSP (Extended Transient / Mid-term Stability Program).

[1998] 07A - 79

VOLTAGE-SOURCE MATRIX CONVERTER AS A CONTROLLER IN FLEXIBLE AC TRANSMISSION SYSTEMS

Ooi, B.-T.; Kazerani, M.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 247-253

This paper shows that the voltage-source matrix converter has all the features of an asynchronous intertie, namely: (1) frequency changing capability, (2) 360 degree phase shift range, and (3) bi-directional real power transfer. In addition, it has the capabilities for: (4) series line reactance compen-sation using a complex conjugate property, and (5) static VAr compensation. Series reactance compensation gives rise to high synchronization power which improves transient stability. The matrix converter also has the flexibility to control both the transmitted real power and, independently, the reactive power flows at the sending-end and receiving-end of the transmission line. 8 Refs.

[1997] 07A - 80

WHO SAYS YOU CAN'T STORE ELECTRICITY?

Zink, J.C.

Power Engineering, vol 101, no 3, March 1997, pp 21-25

The changing face of the electric utility industry may, at last, lead to commercial application of several energy storage technologies. Electricity storage, when coupled with the current regulatory and business trends, has the potential to contribute to a revolutionary change in the electric business. The impact of competitive pricing on providing the impetus for electricity storage is discussed, as are the reliability issues and the application of storage technology. Cost competitive storage and the dynamic benefits of storage are outlined. The following storage techniques are then discussed: compressed air energy storage, batteries, and superconducting magnet energy storage.

[1996] 07A - REF

AN ANNOTATED BIBLIOGRAPHY OF HVDC TRANSMISSION AND FACTS DEVICES 1994-1995

For Abstract see entry 01A - 1

[1996] 07A - REF

MITSUBISHI SOCIO-TECH ON HVDC TECHNOLOGY (NOT ACTUAL TITLE)

For Abstract see entry 01A - 11

[1996] 07A - REF

APPLICATION OF POWER ELECTRONICS IN POWER SYSTEM

For Abstract see entry 01A - 2

[1996] 07A - REF

HIGH-VOLTAGE TECHNOLOGY--WHAT'S NEW REPORT FROM THE CIGRE 1996

For Abstract see entry 01A - 6

[1996] 07A - REF

HVDC - FACTS. STATE OF THE ART - POWER SYSTEM HARMONICS

For Abstract see entry 01A - 7

[1997] 07A - REF

INCREASING POWER TRANSMISSION CAPABILITY OF AC SYSTEMS BY MEANS OF POWER ELECTRONIC EQUIPMENT

For Abstract see entry 01B - 15

[1996] 07A - REF

USE OF HVDC AND FACTS-COMPONENTS FOR

ENHANCEMENT OF POWER SYSTEM STABILITY

For Abstract see entry 07B - 65

[1996] 07A - REF

USING DISTRIBUTION STATIC COMPENSATORS (D-STATCOMS) TO EXTEND THE CAPABILITY OF VOLTAGE-LIMITED DISTRIBUTION FEEDERS

For Abstract see entry 07B - 66

[1997] 07A - REF

ADVANCED SHUNT VAR GENERATOR (ASVG) PRESENT SITUATION

For Abstract see entry 09A - 12

[1996] 07A - REF

DC-AC INVERTERS FOR STATIC CONDENSER AND DYNAMIC VOLTAGE RESTORER APPLICATIONS

For Abstract see entry 09A - 39

[1998] 07A - REF

SERIES COMPENSATION ON POWER SYSTEM WITH VERY LOW HARMONIC DISTORTION

For Abstract see entry 10A - 99

[1997] 07A - REF

HTS TRANSFORMER FOR UTILITY POWERING

For Abstract see entry 14A - 61

[1998] 07A - REF

THE INTERLINE POWER FLOW CONTROLLER CONCEPT: A NEW APPROACH TO POWER FLOW MANAGEMENT IN TRANSMISSION SYSTEMS

For Abstract see entry 16E - 1

[1997] 07A - REF

THREE-PHASE REACTIVE POWER COMPENSATION USING A SINGLE-PHASE AC/AC CONVERTER

For Abstract see entry 17B - 34

[1996] 07A - REF

FACTS CONTROLLER FOR STABILITY IMPROVEMENT OF ELECTRICAL POWER SYSTEMS: A FUZZY APPROACH

For Abstract see entry 18A - 15

[1996] 07A - REF

GPFC MODEL BASED LINE POWER FLOW CONTROL OF POWER SYSTEM

For Abstract see entry 18A - 19

[1997] 07A - REF

IMPROVEMENT OF NETWORK DAMPING AND TRANSIENT STABILITY BY ACTIVE AND REACTIVE POWER CONTROL

For Abstract see entry 18A - 21

[1997] 07A - REF

MODELING WITH INDEPENDENT INTELLIGENT AGENTS FOR DISTRIBUTED CONTROL OF THE ELECTRIC POWER GRID

For Abstract see entry 18A – 25

07B Planning, System Studies, Device Placement, Economics

[1997] 07B - 1

A GROWING NEED FOR QUALITY POWER SUPPLIES

Evett, B.

Int'l Power Generation (UK), vol 20, no 4, July 1997, pp 60-62

The technology associated with power transmission and distribution is well known but is constantly being refined to meet the requirements of new applications. Some examples from a number of companies are described. These include: the construction of high-voltage direct-current (HVDC) links in the Philippines and China; the development of three 60-MVAr relocatable static VAr compensators and a 225 VAr

static synchronous compensator for the United Kingdom's National Grid Company; a 4-MVA dynamic voltage regulator for a Scottish paper mill; the development of disc insulators of 160-kN rating for use in HVDC transmission lines.

[1997] 07B - 2

A STUDY OF FACTS APPLICATION METHODS TO POWER SYSTEM SECURITY ENHANCEMENT

Lee, G.-J.; Oh, T.-K.; Chang, B.-H.; Chu, J.-B.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 10, October 1997, pp 1435-1440

Korean

This paper presents a procedure of FACTS application study to a practical power system and the case study results to increase power transfer capability by enhancing system security of KEPCO's power system. The system behaviors were analyzed for the contingency of route (parallel two circuit) outage due to 3 phase faults based on the current practices of system planning and operation of KEPCO's system. FACTS compensation methods were applied to enhance the transient stability for the unstable cases. The site of FACTS controllers were selected based on load flow study, Q-V curve analysis, and participation factors calculation. As a result of this study a FACTS application approach to stabilize KEPCO's system were proposed.

[1996] 07B - 3

A STUDY OF THE IMPACT OF FACTS ON THE SECURE-ECONOMIC OPERATION OF POWER SYSTEMS

Griffin, J.; Atanackovic, D.; Galiana, F.D.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 1077-1082

This paper addresses the question of how to evaluate the impact of flexible ac transmission systems (FACTS) on the secure-economic operation of power systems. Three measures of power system performance are discussed here: the security constrained economic dispatch cost; the power system loadability; and the maximum power exchange between two arbitrary buses. These measures are evaluated in a number of simulated cases with and without FACTS devices. In all cases, a device called the ideal FACTS is used to compare performances in an objective manner. The most effective and economically justifiable use of FACTS technology appears to be to increase the power system loadability and the power exchange capability between two buses. The latter has important implications in a deregulated environment. 8 refs.

[1997] 07B - 4

AN EFFICIENT METHOD FOR CAPACITOR PLACEMENT WITH PARALLEL TABU SEARCH

Mori, H.; Hayashi, T.

Meiji Univ, Japan

Int'l Conf on Intelligent System Application to Power Systems (ISAP '97), Seoul, Korea, July 6-10, 1997

This paper presents a new method for capacitor placement in power systems. The proposed method is based on parallel Tabu Search that allows combinatorial problems to be efficiently solved. Tabu Search is one of several deterministic meta-heuristic approaches to combinatorial problems. In order to speed up the Tabu Search algorithm, this paper develops a parallel scheme for Tabu Search, so that the neighborhoods of solutions are efficiently searched. The effectiveness of the proposed method is demonstrated in a sample system. A comparison is made between the proposed method and simulated annealing (SA) in capacitor placement.

[1997] 07B - 5

AN EXPERT SYSTEM FOR POWER SYSTEM VOLTAGE STABILITY IMPROVEMENT

Bansilal; Thukaram, D.; Parthasarathy, K.

Dept of Elec Eng, Indian Inst of Sci, Bangalore, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 6, 1997, pp 385-392

This paper presents a prototype of an expert system for monitoring and improving steady-state voltage stability in power systems. The monitoring methodology is based on the L-index of load buses (Kessel and Glavitsch, IEEE Transactions, 1986, PWRD-1(3), 346-354). This index uses information on a normal load flow and is in the range from 0 (no load on the system) to 1 (voltage collapse). The control against voltage collapse is based on reducing the magnitude of the L-indices of the critical nodes for a given system operating condition based on heuristic criteria. The control variables considered are switchable VAr compensators, OLTC transformers and generators excitation. The proposed expert system technique has been tested under simulated

conditions on a few practical Indian power systems. The performance of the expert system is compared with conventional optimization technique and concurrent results have been obtained. The proposed expert system technique is found to be suitable for on-line application in an Energy Control Center for voltage stability improvement as the solution is obtained fast, with a minimum of numerical computations. Results obtained for a 24 node EHV Indian power network and a modified IEEE 30 bus system are included for illustration purposes. 12 refs.

[1998] 07B - 6

ANALYSIS OF CONTROL INTERACTIONS ON FACTS-ASSISTED POWER SYSTEMS

Pilotto, L.A.S.; Ping, W.W.; Carvalho, A.R.C.; Wey, A.; Bianco, A.; Long, W.F., Alvarado, F.L.; DeMarco, D.L.

CEPEL, Centro de Pesquisas de Energia Eletrica, Rio de Janeiro, Brazil

EPRI TR-109969, Final Report, January 1998 (A.-A. Edris, EPRI prog mgr)

This report presents results of comprehensive analyses of the dynamic behavior for power systems controlled by multiple FACTS controllers. Using a representative "benchmark" power system throughout the analyses and studies, an approach identifying the most effective FACTS controllers, location, type and ratings was developed. The control and coordination among the implemented FACTS controllers in the studied power system were extensively investigated.

[1996] 07B - 7

ANALYTICAL STUDIES TO DEMONSTRATE ADDITIONAL FACTS TECHNOLOGIES ON THE NEW YORK STATE TRANSMISSION SYSTEM. FINAL REPORT

Fardanesh, B.; Henderson, M.I.; Zellingher, S.; Shperling, B.R.; Rufrano, R.; Koessler, R.J.; Mountford, J.D.; Kazachkov, Y.

Power Authority of the State of New York, NY, USA

EPRI Technical Report TR-106464, May 1996, 140 pp

Power transfers across the state of New York, resulting from a concentration of generation in the north and west and a concentration of load in the southeast New York metropolitan area, are subject to thermal, voltage, and stability constraints. Consequently, optimum power dispatch is sometimes hindered, and economic penalties are incurred. Difficulties in obtaining new rights-of-way prevent resolution of the problems by constructing new transmission. Previous work performed by the New York power Authority (NYPA) under EPRI projects WO3022-12 and WO3022-15 (see EPRI Report TR-103641) investigated the extent to which system operating limitations could be removed by using thyristor-controlled series compensation (TCSC). Evaluation of the impact, performance, and costs of other FACTS technologies was needed. This report evaluates the potential for application of FACTS technologies on New York State Transmission System. The study found that FACTS technologies and conventional alternatives are effective means of increasing the transfer capability across the central-east interface by at least 200 MW.

[1997] 07B - 8

APPLICATION OF FACTS DEVICES TO INCREASE THE NY STATE CENTRAL-EAST/TOTAL-EAST INTERFACE TRANSFER LIMITS

Mountford, J.D.; Lam, B.P.; Zelingher, S.; Fardanesh, B.B.; Henderson, M.I.

Power Technologies, Inc, New York, USA

EPRI TR-108505 Final Report, August 1997 (R. Adapa, EPRI prog mgr)

In New York, bulk power is transferred from generation sources in the west to meet loads in the east. Thermal, voltage, and stability constraints impose limits on these power transfers, resulting in suboptimal power dispatch and economic penalties. This report addresses implementation of a specific FACTS device, the static compensator (STATCOM), to provide both near-term and long-term benefits to the New York state transmission system. In the near-term, the STATCOM would provide voltage support, while in the longer-term the device could be modified to form part of a more global power flow control system. NYPA engineers could achieve the latter objective through conversion of the STATCOM to a static synchronous series compensator (SSSC).

[1997] 07B - 9

APPLICATION OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR THIRD RAIL VOLTAGE SUPPORT

Reading, M. M.; Stolte, W.; Heinzmann, J. D.

Bay Area Rapid Transit Dist, Oakland, CA, USA

FTA-CA-26-0018-97-1, Federal Transit

Administration, Washington, DC, August 21, 1997, 208 pp

This Report examines the technical and economic feasibility of utilizing superconducting magnetic energy storage (SMES) Technology on the San Francisco Bay Area Rapid Transit system. The problem addressed was the voltage sag on the traction power third rail during times of high current demands by trains on the BART system. The study establishes a functional specification for a storage system to support the transient voltage sag problem in BART's transbay tube.

[1996] 07B - 10

APPLICATION STUDY FOR SIZING AND RATING CONTROLLED AND CONVENTIONAL SERIES COMPENSATION

Kosterev, D.N.; Mittelstadt, W.A.; Mohler, R.R.; Kolodziej, W.J.

Oregon State Univ, Corvallis, OR, USA

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 1105-1111

A step by step method for determining controlled and conventional series compensation requirements is developed. The Montana 500-kV transmission system is taken as an example in this study. A base transfer rating of 2200 MW for the system already exists, and it is assumed that as its power loading increases, controlled series compensation is needed to reinforce the system. Combination of conventional and thyristor-controlled series compensators (TCSCs) is considered as a means of increasing the system transfer capability. Powerflow and transient stability studies are performed to rate and size the series compensators. The TCSC reactance control capabilities are established for steady-state and transient conditions. An installation sequence is developed relating facility requirements to system loading. 10 Refs.

[1998] 07B - 11

BRAZILIAN NORTH-SOUTH INTERCONNECTION. APPLICATION OF THYRISTOR CONTROLLED SERIES COMPENSATION (TCSC) TO DAMP INTER-AREA OSCILLATION MODE

Gama, C.; Leoni, R.L.; Gribel, J.; Fraga, R.; Eiras, M.J.; Ping, W.; Ricardo, A.; Cavalcanti, J.; Tenorio, R.

Eletronorte, Brazil

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper presents the relevant aspects and results of a detailed electromechanical stability study carried out to support the task of locating and designing a TCSC to damp the low frequency inter-area oscillation mode in the Brazilian North-South Interconnection. It deals with a pioneer commercial TCSC application in a very important step of the Brazilian power system expansion. The North/South Interconnection, a single 500-kV compact transmission line (rx954 MCM bundle), 1020-km long, will connect Imperatrix substation (n the State of Maranhao) to Serra da Mesa (in the State of Golas) and is dimensioned to transmit up to 1300 MW with suitable operation being required from no load up to maximum flow, in both directions. It is to be in operation by December 1998 in order to reduce the risk of energy deficit in the systems. A TCSC control system suitable for transient and dynamic stability analysis was designed and, together with extensive study results, formed the basis for the equipment specification and its location along the interconnection. The utilization of two small TCSCs (6% compensation each) proved to be very effective in damping the inter-area mode and eliminated the technical restriction on the ac transmission alternative, making possible the application of such alternative to establish the first stage of the North-South Interconnection.

[1998] 07B - 12

CAPACITOR BANK SERIES GROUP SHORTING (CAPS) DESIGN STUDY

Bruns, D.P.; Miske, S.A. Jr.; Newcomb, G.; Taylor, C.W.; Lee, G.

GE Power Sys Consulting

EPRI Technical Report TR-110273, March 1998, 128 pages (A.-A. Edris, EPRI prog mgr)

The report presents results of a design study for a low-cost, emergency volt-ampere-reactive (var) compensator. The compensator is termed CAPS (CAPacitor bank series group Shorting). The report encompasses all aspects of capacitor bank design, capacitor units, capacitor bank arrangement, switch-gear, fusing (external, internal, and fuseless), control and protection, risk assessments, and economics.

[1997] 07B - 13

COST ANALYSIS OF ENERGY STORAGE SYSTEMS FOR ELECTRIC UTILITY APPLICATIONS

Akhil, A.; Swaminathan, S.; Sen, R.K.

Sandia Natl Labs, Albuquerque, NM, USA

SAND-97-0443 (DE97004047), Sandia National Laboratories., Albuquerque, NM, February 1997, 62 pp

Under the sponsorship of the Department of Energy, Office of Utility Technologies, the Energy Storage System Analysis and Development Department at Sandia National Laboratories (SNL) conducted a cost analysis of energy storage systems for electric utility applications. The scope of the study included the analysis of costs for existing and planned battery, SMES, and flywheel energy storage systems. The analysis also identified the potential for cost reduction of key components.

[1997] 07B - 14

COST OF PROVIDING ANCILLARY SERVICES FROM POWER PLANTS: REACTIVE SUPPLY AND VOLTAGE CONTROL

Stein, J. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-107270-V3 ,TR-107270-V3SI June 1997, vol 3. 115 pp, Vol 3S, 98 pp

This report provides a methodology for determining the variable costs of generating and supplying reactive power to a transmission system, via the generator step-up transformer, for system voltage control. The report examines the costs of additional energy losses, maintenance, repair, and plant aging associated with the generation of reactive power. TR-107270-V3SI contains System of International units.

[1997] 07B - 15

COST OF PROVIDING ANCILLARY SERVICES FROM POWER PLANTS: VOLUME 1. A PRIMER

Stein, J. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-107270-V1, March 1997, vol 1, 253 pp

As the electric power industry undergoes deregulation, managers of power plants will need to decide whether it makes business sense to provide ancillary services such as Reactive Supply and Voltage Control and Operating Reserves-Spinning. This report outlines two methodologies for calculating the variable cost of providing ancillary services from power plants.

[1997] 07B - 16

DAMPING OF POWER SWINGS BY OPTIMAL CONTROL OF SERIES COMPENSATORS

Machowski, J.; Robak, S.; Bialek, J.W.

Proceedings, 10th Int'l Conf on Power System Automation and Control, Bled, Slovenia, October 1997, pp

39-44

Direct Lyapunov method is used to derive the optimal control strategy of damping power swings in the system using a series compensator. This optimal strategy is then implemented using local measurements available at the point of the compensator installation.

[1997] 07B - 17

DRAFT ENVIRONMENTAL IMPACT STATEMENT - BPA/LOWER VALLEY TRANSMISSION PROJECT

Bonneville Power Administration

Bonneville Power Administration, Portland, OR, USA

DOE/BP-2984, US Department of Energy, Bonneville Power Administration, Portland, OR, June 1997, 269 pp

Bonneville Power Administration and Lower Valley Power and Light, Inc., propose to solve a voltage stability problem in the Jackson and Afton, Wyoming areas. For the Agency Proposed Action, BPA and Lower Valley would construct a new 115-kV line from BPA's Swan Valley substation near Swan Valley in Bonneville County, Idaho about 58 km (36 miles) east to BPA's Teton substation near Jackson in Teton County, Wyoming. The new line would be next to an existing 115-kV line. Most of the line would be supported by a mix of single-circuit wood pole H-frame structures would be used. The Single-Circuit Line Alternative has all the components of the Agency Proposed Action except that the entire line would be supported by single-circuit structures. The Short Line Alternative has all the components of the Single-Circuit Line Alternative except it would then be removed. For the Static Var Compensation Alternative, BPA would install a static VAr compensator (SVC) at Teton or Jackson substation. An SVC is a group of electrical equipment placed at a substation to help control voltage on a transmission system. The No Action Alternative assumes that no new transmission line is built, and no other equipment is added to the transmission system. The USFS (Targhee and Bridger-Teton National Forests) must select al alternative based on their needs and objectives, decide if

the project complies with currently approved forest plans, decide if special use permits or easements are needed for construction, operation, and maintenance of project facilities, and decide if they would issue special use permits and letters of consent to grant easements for the project.

[1997] 07B - 18

ECONOMIC ALTERNATIVE FOR VOLTAGE SUPPORT WHEN URBAN GENERATION IS RETIRED

Nelson, R.J.; McGaha, P.L.; Kohistani, G.R.

Westinghouse Elec Corp, Orlando, FL, USA

Proceedings, 59th American Power Conf, Chicago, IL, vol 59-2, 1997, pp 1070-1075

The application of a static shunt compensator (STATCOM) to increase apparent short circuit strength and allow continuous voltage regulation without increasing three-phase short circuit interrupting duties is discussed. STATCOM proves to be the most economical choice for supporting system voltage when factors such as flexibility, life cycle costs, long range asset management, and installation cost and lead time are considered. It is an excellent choice for large integrated systems as well as for interim solutions to the concerns associated with operating uneconomic generation urban areas. 4 Refs.

[1996] 07B - 19

ENGINEERS STRETCH POWER DELIVERY SYSTEMS WITH TECHNOLOGY

Beaty, W.

Electric Light and Power, vol 74, no 9, September 1996, p 29

Efforts to increase electric power transmission capacity by four major distributors are described in the article. The Pennsylvania-Jersey-Maryland Power Pool restructuring for operation as an independent system operator is discussed, and equipment upgrades are briefly outlined. The Inex project of American Electric Power, which uses a unified power flow controller to operator a flexible alternating current transmission system (FACTS), is highlighted. Options being considered by Electricite de France are directed at making full use of existing resources; these include optimizing conductor alloy materials and shapes, operating at maximum conductor temperatures, and using FACTS technology to maintain voltages, adjust power flows, and improve network stability. Increasing capacity in the National Grid Company (NGC) system in the United Kingdom involves a combination of load sharing according to thermal capabilities. Technical considerations of NGCs measures to more evenly match load flows to line ratings are also discussed.

[1996] 07B - 20

EVALUATION OF FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) TECHNOLOGIES ON THE TENNESSEE VALLEY AUTHORITY'S TRANSMISSION SYSTEM

Clark, K.; Larsen, E.V.; Leonard, D.J.; Smead, M.

GE Power Sys Eng, Schenectady, NY, USA

EPRI Technical Report TR-106462, May 1996, 110 pp (R. Adapa, EPRI prog mgr)

This report evaluated the potential for applying flexible ac transmission system (FACTS) controllers on the Tennessee Valley Authority (TVA) system. Part A of this report describes the potential voltage collapse resulting from a loss of the West Point transformer, as well as potential solutions. an economic evaluation was performed to provide a comparison between the various conventional, FACTS and hybrid solutions. Part B of the report describes the potential application of FACTS controllers, specifically static synchronous condensers, to loss-of-infeed problems. This section also includes an economic evaluation that compares the various solutions. Part C of this final report describes methods to increase the interchange capability of the TVA system.

[1997] 07B - 21

FACTS ASSESSMENT STUDY TO INCREASE THE ARIZONA-CALIFORNIA TRANSFER CAPACITY

Torre, W.V.; Carranza, J.C.

San Diego Gas & Elec, CA, USA

EPRI TR-107934 3789-04, Final Report, April 1997 (R. Adapa, EPRI prog mgr)

This report is an extension of a research effort conducted by SDG&E over the past three years evaluating various options to increase the Arizona/California transfer capability. SDG&E has reviewed concepts with other utilities to evaluate regional solutions that benefit all involved parties. The goal is to examine transmission improvements that can be implemented in a staged manner so that the added benefits to all parties can be maximized and no one be

negatively impacted. It is also desirable to increase transmission transfer capability while maintaining inter-regional reliability. This "screening study" examined many alternatives evaluating FACTS performance and costs. The western power system for 1996 was simulated in this study using WSCC peak summer data. Performance evaluation includes evaluation of FACTS for improving transient stability, steady-state powerflow, post-transient voltage stability, as well as subsynchronous resonance damping. Economic analysis has been performed using the latest cost estimates provided by manufacturers and recent production cost analysis of increased power transfer capability benefits. Although the study did examine costs and post-transient stability benefits, the focus of this report is to discuss the technical merits of FACTS for increasing the Arizona-California transfer capability based on power flow, stability analysis and subsynchronous resonance mitigation. As this research study was being completed, many changes were occurring regarding the Arizona-California transmission system and the electric utility industry within California. The results documented in this report may no longer be applicable. However, it does give an expression of the relative merit of FACTS for increasing transfer capability.

[1997] 07B - 22

FACTS FOR IMPROVED POWER QUALITY

Smale, M.J.; Jenkins, N.; Collinson, A.

EA Technology Ltd

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 855-858

This paper considers the power quality problems of concern at 11 kV and below and develops a logical sequence to their efficient mitigation, incorporating developments made in FACTS. This analysis is part of a study into power conditioning technology with the aim of developing design tools and cost/benefit models to aid decision making for such technology. 5 Refs.

[1996] 07B - 23

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) SYSTEM STUDIES: SOUTHERN COMPANY SERVICES

D'Aquila, R.; Hill, A.T.; Miller, N.W.; Price, W.W.

GE Power Sys Eng Consulting, Schenectady, NY, USA

EPRI Technical Report TR-106461, May 1996, 272 pp

(R. Adapa, EPRI prog mgr)

The objective of the study is to evaluate the dynamic performance of the transmission interface between Southern Company (SC) and Florida Power Light Company (FPL) as it is affected by the addition of reactive compensation to the existing 500-kV tie lines. The focus of this study is on the voltage stability of the interface, and the dynamic performance of the two interconnected systems under conditions of voltage stress. The potential to increase transfer on the interface through the addition of series compensation is examined. The intent is to provide quantitative insight into performance, and to explore how flexible ac transmission system (FACTS) controllers might be employed to improve that performance. Consideration of the economics of the reinforcement is made. The use of series compensation is demonstrated to allow a substantial improvement in the power transfer capability and loss of performance of the system. The possibility of including thyristor controller series compensation (TCSC) in a voltage regulating mode is introduced. One significant benefit of this is to permit using larger series compensation banks than could otherwise be allowed using only conventional series compensation in a single site. This result has significance since this introduces the potential for utilities to develop fewer sites than might otherwise be required. It is shown that, even though a conventional compensation plan may be the preferred option for this specific application, a TCSC-augmented approach could be the preferred option in other situations. In addition, a TCSC-augmented approach may be preferable for systems where improved voltage controllability, reduced SSR risk, and better system damping, are significant. The results indicate that TCSC is a viable option for utilities whose operating constraints tend to be voltage and postcontingency power flow, as well as systems with faster dynamic concerns.

[1996] 07B - 24

FLEXIBLE AC TRANSMISSION SYSTEMS PART 2 METHODS OF TRANSMISSION LINE COMPENSATION

Moore, P.; Ashmole, P.

Univ of Bath, UK

Power Engineering Journal, vol 10, no 6, December 1996, pp 273-278

A report published last December 1995 presented an overview of FACTS and explained the importance of FACTS controllers. The present report gives a detailed appreciation of the effects of applying FACTS

controllers from a systems point of view without specific reference to how they work and describes the effect of applying compensation methods to a simple two-ended transmission line model.

[1996] 07B - 25

FLEXIBLE AC TRANSMISSION SYSTEM DEVICES ON LARGE INTERCONNECTED POWER SYSTEMS

Besanger, Y.; Feuillet, R.

Natl Polytech Inst, Grenoble, France

PhD dissertation at the French National Polytechnic Institute, Grenoble, France. 1996-97, 205 pp

French

FACTS devices are designed to improve the performance of transmission systems and interconnected networks. Several studies that have been done recently on FACTS devices are concerned with increasing of the speed of controlling line parameters (voltage, impedance, and phasing). Shunt and series compensation utilize power electronics systems related to the FACTS concept and permit greater network flexibility. The shunt compensation application is primarily for voltage support, while the series compensation is used to reduce line impedance. Therefore, the series compensation allows an increase in the capacity of power transfers and improves the power transmission distribution on the network. The stability margins can be equally increased. Several systems have been developed in past years. This report describes a study comparing the static and dynamic behavior of three FACTS devices for network transmission: the SVC, the STATCON and the TCSC. This work is based on the voltage stability and the power transfer capability, and includes the effect of transformer regulators (LTC). The effects of PSS are also analyzed for comparison with other FACTS devices. The results have been obtained from different network tests (14 nodes of IEEE network, simplified French UHV network, 39 nodes of the New England network) and have demonstrated the impact of each FACTS device upon the power network.

[1996] 07B - 26

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) TECHNOLOGIES ON THE TVA TRANSMISSION

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-106462, June 1996, 126 pp

This report evaluated the potential for applying FACTS controllers on the TVA Transmission System. Study results indicate that FACTS solutions are technically feasible and economically viable for voltage collapse mitigation from a loss of the West Point transformer, meeting minimum reliability requirements during loss of in-feed problems, and increasing the interchange capability of the TVA system.

[1996] 07B - 27

FOR NOW, ADAPTIVE VAR COMPENSATOR IS BIGGER NEWS IN OTHER COUNTRIES THAN IN CANADA

Anon.

Electricity Today, vol 8, no 2, February 1996, p 13

Development by a Canadian firm, Trench Electric Inc., of an adaptive VAr (volt, amp, reactive) compensator (AVC), was announced. AVC is a solid-state switched capacitor device compensating for reactive power fluctuations. As a result, electrical energy can be used more efficiently, saving money and allowing utilities to run their systems without sudden losses of energy. Interest in Canada was said to be slow in developing, however, it is very high in the United States and in Europe , where expanding electrical generating systems are becoming increasingly difficult. Costs vary from $50,000 to $500,000 for an AVC unit but savings on electrical costs mean the AVC is paid for in about two years.

[1996] 07B - 28

FREQUENCY RESPONSE ANALYSIS FOR. INVESTIGATING THE IMPACT OF FACTS ON POWER TRANSMISSION SYSTEMS

Caldon, R.; Mari, A.; Paolucci, A.; Turri, R.

Univ of Padova, Italy

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 1, pp 176-179

In this work a simplified procedure which could be used at the planning stage for assessing the dynamic performance of FACTS devices on interconnected systems is described. The method is based on a linearized model of the power system which account for, besides the action of FACTS, the other regulations usually present in a transmission system. This procedure enables to easily assess the impact on the power system of different FACTS control strategies and to analyze the

interactions with the other system regulations. 11 Refs.

[1997] 07B - 29

GUIDE FOR ECONOMIC EVALUATION OF FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) IN OPEN ACCESS ENVIRONMENTS

Clark, K.; Clayton, R.E.; Larsen, E.V.; Miller, N.W.; Mukerji, R.; Oplinger, J.L.; Pourbeik, P.; Schorr, M.M.; Zhu, W.

GE Power Sys Eng Consulting, Schenectady, NY, USA

EPRI TR-108500, Final Report, August 1997 (R. Adapa, EPRI prog mgr)

The pending deregulation of many countries' power industry has created a situation in which utilities may be reluctant to make reinforcements to their power delivery infrastructure. This reluctance is due primarily to three perceived risks: (1) that improved infrastructure will allow other power providers easier access to their customer base; (2) that transmission and distribution investments may be unrecoverable (i.e., stranded); and (3) that development of such devices will be delayed or blocked by opposition from other interconnected system users. The emergence of new power electronics devices and improvements in other complementary technologies, such as capacitors, have introduced new options for utilities. New systems, including various FACTS devices, provide electric utilities with the capability to control power flows, increase selected transfer capability and provide increased options for siting of new generation. By careful placement and control of these systems, utilities can serve future load growth while eliminating or deferring risky major power delivery infrastructure investments. These environmentally friendly systems also have the potential to provide substantial benefits in terms of improved voltage profiles and protection from power interruptions when compared to conventional reinforcements. The development of regional, competitive and unbundled corporate structures with an emphasis on regional planning and open access will create a favorable environment for the application of power electronic devices. This report describes this new environment, and shows the possible advantages from the application of power electronics and reviews the range of new technology options.

[1998] 07B - 30

IMPROVEMENT OF THE DYNAMIC PERFORMANCE OF THE SPANISH POWER SYSTEM WITH FACTS DEVICES

Crindo, R.; Rouco, L.; Rodriguez, J.M.; Noroozian, M.

Iberdrola, Spain

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper explores the application of FACTS devices for the improvement of the dynamic performance of the Spanish power system. The application of controllable series capacitors to improve the damping of its inter-area oscillations is examined. The results of this study are compared with the suggestions of previous steady-state studies. Small -signal stability tools (i.e., eigenvalue sensitivities) are used to find the best locations of controllable series capacitors to damp the inter-area oscillations and to design the device damping controller. A non-linear time domain simulation tool is also used to verify the dynamic performance of the system. A realistic model of the Spanish power system is considered by both tools.

[1997] 07B - 31

INDICES FOR SELECTING THE BEST LOCATION OF PSSS OR FACTS-BASED STABILIZERS IN MULTIMACHINE POWER SYSTEMS: A COMPARATIVE STUDY

Wang, H.F.; Swift, F.J.; Li, M.

Manchester Metropolitan Univ, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 2, March 1997, pp 155-159

One of the first stages in the design of a PSS or a FACTS-based stabilizer in a multimachine power system is the selection of the best installing location. Among the most popular techniques used to perform this selection, two groups of indices from the residue and the damping torque analysis (DTA) methods were considered to be different both in their calculation and principle of derivation. However, the authors have found that these two groups of indices are in fact closely related to each other, and indeed are equivalent under certain conditions. In the paper, this finding is presented by considering the relationship between these two groups of indices and shows how equivalence may be concluded. Thus a deeper insight into the residue and DTA methods emerges which facilitates a comparison between the accuracy of these indices. 14 Refs.

[1996] 07B - 32

INDUSTRY UPHEAVAL DRIVES CHANGES AT EPRI

Zink, J.C.

Power Engineering (Barrington), vol 100, no 12, November 1996, pp 70-74

This article describes how the Electric Power Research Institute (EPRI) is rethinking and modifying its program and business relationships with its members to reflect the significant changes occurring in the utility business. They are in the midst of changes as profound as any the (electric utility) industry has ever seen, according to Kurt Yeager, EPRI's new president and CEO. The renewed availability of natural gas for power generation, along with the development of more efficient gas turbines, have been important factors. The ability to better manage the delivery system has contributed to the arguments in favor of increased competition, although the application of the management tools, such as flexible ac transmission systems (FACTS), is not coming as quickly as many had expected. And new digitally-controlled electrotechnologies have made electricity a growth business again, creating a third wave of growth driven by technologies that allow more precise and efficient control of industrial processes.

[1998] 07B - 33

LOAD-FLOW CONTROL IN EHV NETWORKS. FEASIBILITY STUDY ON THE POSSIBILITIES OF APPLICATION OF FACTS ELEMENTS IN THE GERMAN POWER SYSTEM

Gampenrieder, R.; Gick, B.; Wess, T.; Haeusler, M.; Rittiger, J.; Glaunsinger, W.; Zimmermann, U.

Bayernwerk, Muenchen, Germany

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

In the framework of a feasibility analysis, the possibilities of using flexible ac transmission systems (FACTS) in the closely meshed German grid were investigated under technical and economic aspects. The calculations were carried out on the basis of a realistic model network. The results of the model calculations show that the use of FACTS elements in the closely meshed German power system with a view to increasing the transmission capacity can be profitable only in the case of a high load increase with generation partly remote from consumption centers and with considerable superimposed power transport. in such cases, FACTS elements are temporarily used until remedy of the overload situation. From the technical point of view, the use of FACTS elements could be particularly advisable if they carry out additional functions such as damping of low-frequency oscillations. under competitive aspects, FACTS elements basically permit to influence power flows for strategic purposes which require a permanent action of FACTS elements. In the concrete case, the desired load-controlling effects necessitate a high technical expenditure which has to be compared tot he economic benefit of power transmission by means of FACTS. The model analysis permitted to derive basic technical findings as well as the requirements that have to be met by a load-flow control concept. However, a verification on quantitative terms can only be obtained through a concrete case of planning. A concrete solution concept is described below as an example of superordinate FACTS control (master controller).

[1996] 07B - 34

MEOP: A SOFTWARE FOR OPTIMIZATION OF POWER PLANT UTILIZATION FOR THE LOAD DISPATCH CENTER OF BEWAG, BERLIN

Kreye, H.; Lorenz, U.; Voigt, B.

Berliner Kraft- und Licht, Berlin, Germany

Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, pp 2/61-2/74

For the company "Berliner Kraft- und Licht (Bewag) - AG" which supplies the city of Berlin with electricity and district heat, a computer program for creating optimum generation schedules is currently developed. Bewag is operating the largest district heating network in West Europe and generates most of the district heat through Combined Heat and Power Plants (CHP). The heat is distributed in several partly interconnected district heating networks on four energy levels. The optimum generation schedules are created for different periods, like day, month and year, and consider various options such as feeding of energy from the superposed European network, annual revision schedules, primary control reserve and secondary control mechanisms. A focal point is the calculation of costs for power and heat generation in each power plant. A cost allocation method is applied which ensures, on the one hand, that the district heating branch gets all the advantages of the CHP process and, on the other hand, the electricity branch shall not subsidize the district heat branch.

[1997] 07B - 35

MID-POINT SITING OF FACTS DEVICES IN TRANSMISSION LINES

Ooi, B.-T.; Kazerani, M.; Marceau, R.; Wolanski, Z.; Galiana, F.D.; McGillis, D.; Joos, G.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1717-1722

Many controllers of flexible ac transmission systems (FACTS), such as the STATCOM, the unified power flow controller (UPFC), the PWM asynchronous dc link, the thyristor-controlled series capacitor (TCSC) and the PWM series static VAr compensator have stabilized ac voltage support. Thus, they can be sited at the mid-point of the transmission line, which has been proven by the late E.W. Kimbark, as the optimum location for shunt capacitor compensation. This paper points out that the ability to double the power transfer of the uncompensated line applies also to the aforementioned FACTS devices. The mid-point siting also facilitates the independent control of reactive power at both ends of the transmission line. 14 Refs.

[1996] 07B - 36

ON-LINE VOLTAGE SECURITY ASSESSMENT: FRAMEWORK AND IMPLEMENTATION

Ejebe, G.C.; Tong, J.; Waight, J.G.

Siemens Empros Power Sys Control, MN, USA

Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, pp 2/75-2/85

A framework for the implementation of an on-line voltage security assessment (VSA) package as part of an existing energy management system is presented. The key components of VSA as well as requirements for their implementation are described. The VSA framework allows the study of multiple contingencies and the determination of operating and voltage security limits for any desired type of operating contingency. These limits may be determined for any base case operating point as well as for near-future operating points minutes into the contingency condition. A fast quasi-static simulation technique called QSIM is a key feature of the implementation.

[1997] 07B - 37

OPTIMAL FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) DEVICES ALLOCATION

Lie, T.T.; Deng, W.

School of Elec & Electrn Eng, Nanyang Tech Univ, Singapore

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 2, February 1997, pp 125-134

This paper presents the development of mathematical model representations of variable series capacitors and static phase shifters which are also known as flexible ac transmission systems (FACTS) in power system economic dispatch. The objective of this research is to find the optimal locations of FACTS devices for improved economic dispatch. The proposed approach is based on the decomposition-coordination method and the network compensation technique. Taking advantage of accumulated experience in power system optimization and the existence of the optimal power flow (OPF) software, the software development cost for implementing the proposed algorithm is reduced. In this paper, digital simulation studies on small power systems under different network parameters, with and without FACTS devices, were conducted. The purpose of the simulation studies was to assess the effectiveness of the proposed algorithm in minimizing the operating cost and enhancing the systems performance. The results of the simulation studies and the proposed algorithm are presented and discussed in detail in this paper.

[1997] 07B - 38

OPTIMAL SVC PLACEMENT FOR VOLTAGE STABILITY REINFORCEMENT

Chang, C.S.; Huang, J.S.

Natl Univ of Singapore, Singapore

Electric Power Systems Research, vol 42, no 3, September 1997, pp 165-172

This paper presents a scheme of hybrid optimization using the simulated annealing and Lagrange multiplier techniques for optimal SVC planning and voltage stability enhancement. It also proposes a 4-step procedure for synthesizing the optimal reactive reinforcement. The hybrid optimization is formulated into a constrained problem with non-differentiable objective function in both continuous and discrete variables. By decomposing the optimization into two subproblems, an optimal SVC placement is obtained and the reactive margin is maximized. 8 Refs.

[1996] 07B - 39

OPTIMUM SERIES COMPENSATED HIGH VOLTAGE TRANSMISSION LINES

Bellarmine, T.

Univ of West Florida, Pensacola, FL, USA

Proceedings, IEEE SOUTHEASTCON '97: Engineering the New Century, Blacksburg, VA, April 12-14, 1996, pp 307-309

Reduction in the line reactance of power transmission lines can be best obtained by the use of capacitors in series with the line conductors. The important application of the series power capacitor is to decrease voltage flicker problems. In this article, the steady-state stability limits, with series power capacitors at various locations of power transmission lines, are analyzed. The series power capacitor can be located at the sending end, the receiving end or at the center of the power line, or one-third of the distance from either end. The performance of the series power capacitor arrangement has been compared for various locations. The center of the transmission line is shown to be the most suitable choice for the optimum compensation effect of a series power capacitor. 7 Refs.

[1996] 07B - 40

PLANNING AND OPERATING RATINGS FOR INVERTER-BASED FACTS POWER FLOW CONTROLLERS

Waples, S.A.; Law, A.S.; Nelson, R.J.; Gernhardt, M.G.

Washington Water Power, Spokane, WA, USA

Proceedings, 58th American Power Conf, Chicago, IL, April 9-11, 1996, pp 1555-1561

The power industry may soon join the electronic age. It seems fair to predict that the EPRI tailored collaboration projects, including the recent demonstration of the Tennessee valley Authority Static Compensator (STATCOM), the imminent introduction of the Dynamic voltage Restorer (DVR) and the Distribution STATCOM (D-STATCOM), as well as the initiation of development for a unified power flow controller (UPFC) with AEP will usher the bulk power industry into a new era of inverter-based power electronic controllers. Just as pocket digital calculators made analog calculators (slide rules) obsolete, it seems likely that the day is not too far off when bulky switched capacitors and reactors will be supplemented by (and, in some cases, displaced by) sleek, modern, nearly infinitely adjustable and flexible electronic components. It seems likely that the use of these controllers will proliferate in a deregulated, competitive power market, since they offer a means of increasing transmission capacity without increasing the number of transmission lines. They also offer a means of forcing actual flows to correspond faithfully to contractual flows. The purpose of this paper is to outline some of the major performance considerations associated with specifying the planning and operating parameters of inverter-based FACTS devices, especially the unified power flow controller, and to outline some of the principal differences between the inverter-based controllers and those which are conventionally applied to power systems. While the capabilities afforded by these devices are quite unique and revolutionary, the means of analyzing and designing them are often available from a standard planning load flow.

[1997] 07B - 41

POWER QUALITY--ASSESSMENT OF IMPACT (PROCEEDINGS)

Varma, C.V.J. (ed)

CIGRE, India

CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997

Abstract not available.

[1996] 07B - 42

POWER SYSTEM CONTROL IN THE NEXT CENTURY

Lachs, W.R.; Sutanto, D.; Logothetis, D.N.

Univ of New South Wales, Sydney, Australia

IEEE Trans on Power Systems, vol 11, no 1, February 1996, pp 11-18

The present evolution of power systems is making operational control increasingly difficult and this paper identifies reactive power and voltage control as one of the prime culprits. Energy storage devices incorporating microprocessors and power electronics, coupled through a communications network provide an opportunity to enhance existing control measures. The continuing fast access to the energy storage will permit direct control measures for reducing the variations of consumer demand throughout the total grid. This approach has the potential of overcoming the growing technical and financial difficulties now facing large interconnected power systems. The projected introduction of electric vehicles in cities will be able to provide the battery energy storage capacity for overcoming the difficulties of power system control. 9 Refs.

[1997] 07B - 43

PROBLEMS OF NORTHERN ELECTRICITY REGION OF INDIA

Prasher, V.K.; Jha, I.S.; Prasad, M.; Chakravorty, S.; Moni, R.S.; Dass, R.

Power Grid Corp of India Ltd, New Delhi, India

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

This paper presents the results of a study which has been made to remove the operational and evacuation constraints and deficiencies in India's northern electricity region. It shows that there is a need to carry out a realistic load flow analysis followed by dynamic simulations. It is possible to remove the constraints by limited investment and proper deployment of techno-economically attractive conventional and state-of-the-art technologies. The payback period could be quite attractively small and there is a high benefit-to-investment ratio. This paper will be useful in the context of those developing countries where electrical systems are passing through a similar transition phase. In such cases, the problems can be avoided if the planners take up preemptive measures by means of planning studies followed by regular operational studies which serve as early warning indicators and throw light on the impending operational deficiencies or technical shortfalls.

[1997] 07B - 44

PROSPECTS FOR FUTURE FACTS DEVICE APPLICATION DURING TRANSMISSION SYSTEM DEVELOPMENT IN SOUTH AFRICA

Hough, F.T.G.; Vajeth, R.A.; Smith, R.D.; Estment, R.D.

ESKOM, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

This paper deals with the prospects for future FACTS device application during transmission system development in South Africa. Current indications are that the future application of these devices will be limited to the transmission network supplying customers in the Southern and Western Cape and the Kwa Zulu Natal region. The main focus of this paper is therefore on the static var compensators envisaged for the transmission areas mentioned. The future application of thyristor-controlled series compensation, albeit in a limited fashion, is also explored.

[1997] 07B - 45

REDUCED ORDER MODAL ANALYSIS TO SELECT THE INSTALLING LOCATIONS AND FEEDBACK SIGNALS OF FACTS-BASED STABILIZERS

Wang, H.F.; Swift, F.J.

Univ of Bath, UK

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 13-16

A reduced-order method of modal analysis, based on the extended Phillips-Heffron model, is proposed in this paper for the selection of installing locations and feedback signals of FACTS-based stabilizers in multi-machine power systems. The method proposed is not only as accurate as the conventional method of modal analysis, but also guarantees that the order of all matrices involved in the reduced-order modal analysis is low, being not higher than the number of machines in the power system. 5 Refs.

[1998] 07B - 46

RESPONDING TO THE CHANGING DEMANDS OF LOWER VOLTAGE NETWORKS. THE UTILIZATION OF CUSTOM POWER SYSTEMS

Taylor, G.A.; Hill, J.E.; Burden, A.B.; Mattern, K.

Rolls-Royce, UK;

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper addresses the improved standards of supply quality at the distribution level that are now possible through the utilization of power electronics devices generically known as custom power systems. The paper specifically focuses on the recent installation of one of these systems, a dynamic voltage restorer, rated at ±4 MVA, at the site of a paper mill in Scotland. The impact of such developments upon the operation of electrical networks is also discussed, with the proposition that electricity networks will become increasingly local in nature relying on embedded generation and future versions of devices, such as the one described, to facilitate active management of energy at the distribution point.

[1996] 07B - 47

RETAINING RING FAILURE AT COMANCHE UNIT 2: ROOT CAUSE ANALYSIS

Dorfman, L.S.; Riccardella, P.C.; Rosario, D.A.;

Sherlock, T.P.

Structural Integrity Assoc, Inc, San Jose, CA, USA

EPRI Technical Report TR-106640, July 1996, 190 pp (F. Ammirato, EPRI prog mgr)

A root cause analysis was conducted of a 1994 failure of a retaining ring in the Unit 2 generator of Public Service of Colorado's Comanche station. Metallurgical examination showed that the cause was not intergranular stress corrosion cracking. Fretting fatigue had resulted in multiple cracks in the ring at the shrink-fit area near the hydrogen vent scoops at both pole faces. Crack propagation occurred at a 45° angle indicating torsional fatigue. A stress and fracture model was developed to relate torsional stresses in the ring to the levels of rotational acceleration/deceleration of the retaining ring with respect to the rotor. Levels of torsional excitation were associated with various operating modes at a nearby steel mill. Under certain low-power operating conditions, the mill's static VAr flicker controller (SVFC) system created a frequency spike that coincided with the 114.5 Hz rotor resonance of the generator and resulted in high level vibrations. Several steps were taken to prevent a repeat of the ring failure, including an improved ring design and changes in the mills SVFC system.

[1997] 07B - 48

SELECTION OF INSTALLING LOCATIONS AND FEEDBACK SIGNALS OF FACTS-BASED STABILIZERS IN MULTIMACHINE POWER SYSTEMS BY REDUCED-ORDER MODAL ANALYSIS

Wang, H.F.; Swift, F.J.; Li, M.

Manchester Metropolitan Univ, England

IEE Proceedings Generation, Transmission and Distribution, vol 144 (UK), no 3, May 1997, pp 263-269

A reduced-order method of modal analysis, based on the extended Phillips-Heffron model, is proposed for the selection of installing locations and feedback signals of FACTS-based stabilizers in multimachine power systems. The method proposed is not only as accurate as the conventional method of modal analysis, but also guarantees that the order of all matrices involved in the reduced-order modal analysis is low, being not higher than the number of machines in the power system. Hence, the numerical difficulty of the eigensolution of high-dimensional matrices is successfully avoided and the computational effort is greatly reduced. The method is demonstrated on a sample three-machine power system for the selection of stabilizing signal and installing location of a static VAr compensator (SVC). 17 Refs.

[1996] 07B - 49

SELECTION OF THE BEST SITING OF STATIC VAR COMPENSATORS FOR EFFECTIVE DAMPING

Okamoto, Hi.; Kurita, A.; Kobayashi, N.; Sekine, Y.

Tokyo Elec Power Co, Inc, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 117, no 1, July 1996, pp 71-84

A static Var compensator (SVC) can improve the steady-state stability (or the small signal stability), if it is located appropriately. The present paper proposes a method for selecting the best siting of SVC in large-scale power systems for damping effectively. Conventionally, it is thought that SVC improves steady-state stability by its voltage regulating ability. From this point of view, the stability can be improved significantly if SVC is located at the bus which has a large voltage fluctuation due to the lightly damped power swing mode. In contrast to the conventional viewpoint, the present paper makes it clear that the steady-state stability deteriorates by the conventional voltage regulating control of SVC in some cases. Therefore, the voltage fluctuation is not an appropriate index for effective damping. This paper explains the mechanism of improvement of steady-state stability by SVC in terms of modal analysis. On the basis of modal analysis, an index for determining the location of SVC is derived. The index is called LIED (Location Index for Effective Damping) by the authors. Digital simulations are conducted for an 8-machine longitudinal system and a 29-machine looped system to demonstrate the validity of the proposed index. 11 Refs.

[1998] 07B - 50

SIMPLE RULES FOR THE APPLICATION OF SERIES VOLTAGE SOURCES IN POWER TRANSMISSION SYSTEMS

Wong, K.T.

GEC ALSTHOM, UK

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998, Preprint order number PE-316-PWRD-0-11-1997

This paper addresses the influence of the network characteristics of transmission systems on the use of a number of series voltage sources for the regulation of

power flows on transmission lines. The relationship between the number of independent voltage sources and the number of nodes and branches are employed to explore the interactions among series voltage sources taking place through the network, and to demonstrate the viability of a simple rule, called the Smallest Tree-Impedance Rule, for selecting locations of the series voltage sources in a network of any size, from the point of view of minimizing interactions.

[1997] 07B - 51

STUDY OF FACTS REQUIREMENTS FOR CLEVELAND ELECTRIC ILLUMINATING COMPANY

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-108127, May 1997, 100 pp

This report assesses system compensation schemes, including the use of flexible ac transmission system (FACTS) devices, for the Cleveland Electric Illuminating Company. The study recommended four plans to accommodate different generating unit retirement scenarios.

[1997] 07B - 52

SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) UTILITY APPLICATION STUDIES

Feak, S.D.

Wisconsin Elec Power Co, Milwaukee, WI, USA

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1094-1102

The results of a study performed with Oak Ridge National Laboratory to assess the benefits of superconducting magnetic energy storage (SMES) for electric utility applications are presented. The study was conducted for the Defense Nuclear Agency and the Department of Energy as part of their efforts to develop SMES for military and civilian applications. The technical benefits of the SMES and alternative technology options and the economic value of those benefits were determined for two stability-related cases. 3 Refs.

[1998] 07B - 53

SURVEY OF UNBUNDLED ELECTRIC POWER SERVICES

Clark, C (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-109461, February 1998, 153 pp

In the separating, or unbundling, of electric power services, electric energy generation is the sub-service that is of the greatest direct concern to both customers and suppliers. Generation, however, is just one component of several for providing service to customers. Examples include operating reserves, frequency control, reactive power, transportation, and system operations. How a small, representative sampling of utilities from across the United States are presently unbundling their electric power services provides the content for this survey.

[1997] 07B - 54

SYSTEM DISTURBANCE STABILITY STUDIES FOR WESTERN SYSTEM COORDINATING COUNCIL (WSCC)

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-108256, September 1997, 82 pp

Two 1996 system disturbances in the Western Systems Coordinating Council (WSCC) resulted in widespread outages across western North America. EPRI initiated disturbance studies to gain a better understanding of the causes of these events and to suggest ways to enhance system reliability. This report summarizes the results of these system disturbance stability studies and recommends preventive and remedial strategies to minimize interconnected system disturbances.

[1996] 07B - 55

T&D RESEARCH FOCUSES ON REAL-TIME CONTROL, HIGH CAPACITY

Rodgers, B.

Public Power, vol 54, no 2, March-April 1996, pp 21-23

This article is a review of ongoing research programs on the transmission and distribution of electric power. Programs briefly noted include: (1) real-time system control, (2) high capacity transmission, and (3) advanced systems analysis.

[1997] 07B - 56

TAIWAN POWER TCSC EVALUATION STUDY

Arabi, S.

Powertech Labs, Inc, Surrey, British Columbia, Canada

EPRI TR-107896, 3191-04, Final Report, May 1997 (R. Adapa, EPRI prog mgr)

This report evaluates the use of thyristor-controlled series compensation (TCSC) and conventional series compensation to more evenly distribute power flows on the Taiwan Power Company's 345-kV Center-North interface and improve system dampings. This study concludes that the proposed compensation scheme would significantly improve the interface's performance capability.

[1996] 07B - 57

THE APPLICATION OF FACTS IN TAIPOWER'S SYSTEM

Lee, T-H; Tasi, L-L.

Ting Consultants Ltd, Canada

Monthly Journal of Taipower's Engineering (Taiwan), vol 574, June 1996, pp 69-76

Chinese

This paper deals with the FACTS which could be a candidate to eliminate the bottleneck of Taipower's power supply capability due to the delay of completion of the 3rd EHV transmission line and the different capability between the 1st and 2nd transmission lines. FACTS is also effective in enhancing power equipment utilization. 0 Refs.

[1997] 07B - 58

THE DEVELOPMENT OUTLOOK FOR FOUR MAJOR POWER SYSTEM TECHNOLOGIES (FACTS, AEMS, DOA, AND AIC) AND THEIR CORRELATIONS IN THE 21ST CENTURY

He, D.

China Elec Power Inf Centre, Beijing, China

Power System Technology (China), vol 21, no 11, November 1997, pp 16-22

Chinese

The progressive formation of the "China Unified Interconnected Power System" based on the construction of the Three Gorges Hydropower Station will indicate the new high-level stage of development of China's power industry. Meanwhile, it will also be the era that the development of science and technology in China will move ahead and reach a forward position in the world. So, in the light of two related prospects of the engineering construction and technology development, it is useful and necessary to analyze and predict the trend of future development of four major power system technologies (FACTS, AEMS, DOA and AIC) as well as the possible progress of their correlations for further discussions.

[1997] 07B - 59

THE PROSPECTS IN DEVELOPMENT OF INTERCONNECTED POWER SYSTEMS IN WEST AFRICA

Anku, N.; Modey, B.T.

Volta River Authority, Ghana

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

The synchronous connection of the power systems of neighboring countries in the West Africa subregion is relatively new. Most of the earlier transmission system extensions were limited to the supply of power to the recipient countries without the possibility of sending power in the other direction. An example is the 1972 extension of the Ghana power system to neighboring Togo/Benin and it was not until 1984 after the commissioning of the Nangbeto hydroelectric project that the two systems were tied together. The first major interconnection between two utilities/countries in West Africa was between Ghana and Ivory Coast, which was commissioned in 1983. Subsequently, a number of power system extensions including system ties have been constructed. Others are either under construction or plans are far advanced to have them implemented. There is considerable potential for interconnecting a lot more power systems in the subregion. And it is well known that Nigeria has considerable amount of natural gas resources which are currently being flared. This can be tapped to generate cheaper electricity to be supplied to West African countries. It is therefore unfortunate that the proposed 330-kV interconnection from Nigeria through Togo/Benin to Ghana has as yet not materialized. Meanwhile, over the past few years, there has been a considerable shortage of electricity in parts of the subregion. Apart from Nigeria's potential, there are other cheaper energy sources such as the hydroelectric potential of Cameroon and Ghana, which can easily be implemented on a subregional basis. This paper presents the existing, proposed and potential power system developments in the West African subregion. It

also discusses the problems associated with the implementation of such schemes and recommends strategies to be adopted for the advancement of potential projects.

[1998] 07B - 60

THE STATE-OF-THE-ART OF POWER ELECTRONICS IN JAPAN

Akagi, H.

Okayama Univ, Japan

IEEE Trans on Power Electronics, vol 13, no 2, March 1998, pp 345f

Since the late 1950s, power electronics has been developing by leaps and bounds without saturation to become the key technology essential to modern society and human life as well as to electrical engineering. This paper mainly focuses on the state-of-the-art of power electronics technology and its medium to high-power applications because the author cannot survey the whole spectrum of power electronics ranging from a 5-W switching regulator to a 2.8-GW high-voltage dc transmission system now under construction in Japan. This paper also presents prospects and directions of power electronics in the 21st century, including the personal views and expectations of the author.

[1997] 07B - 61

THE STUDY OF FACTS APPLICATION EFFECTS FOR POWER TRANSMISSION CAPABILITY ENHANCEMENT IN POWER SYSTEM

Chang, B.-H.; Lee, G.-J.; Kim, Y.-H.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 2, February 1997, pp 192-197

Korean

This paper presents the study results of flexible ac transmission systems (FACTS) application for KEPCO's medium- (Year 2000) and long- (Year 2006) term power system strategies. In the study, for the compensation method, line impedance changes and SVC models in the PSS/E simulation software are adopted for series and shunt compensation, respectively. For KEPCO's medium-term power system plan, the series compensation method shows better performance of power flow control, voltage regulation and damping of oscillations than shunt compensation with several contingency cases. For KEPCO's long-term power system plan, the output of Uljin nuclear generators, which is restricted in the dynamic stability at the contingency condition, can be improved to the full range of generation output with series or series-shunt compensation to the Yeongdong-Kyungin transfer corridor. It is verified that FACTS application is one of the methods suitable to solve the problems which may occur in KEPCO's medium- and long-term power system strategies.

[1997] 07B - 62

THREE NEW FRONT SUBJECTS IN POWER SYSTEMS-FACTS, INTELLIGENT CONTROL AND DYNAMIC SECURITY ANALYSIS AND MONITOR SYSTEM BASED ON GPS

Han, Y.; Wang, Z.; Lin, K.; Yang, Y.; Huang, Q.; Jiang, J.

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Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 1-6

Chinese

With the development of electrification and automation, power systems are increasing in quality and quantity. Modern technologies are being applied in power systems more and more. The importance, research status and development tendency of three major new subjects-flexible ac transmission technology, intelligent control and a new generation of dynamic security analysis and monitoring system based on GPS-which will cause great changes in power systems in the beginning of 21st Century, are systematically reviewed in this paper. The industrial application of these new technologies will greatly boost the development of the Chinese electric power industry and create some new industries. The paper argues that China should trace the new development of these technologies and enforce the fundamental research work which will avoid complete dependence on imports in these new fields in the future.

[1997] 07B - 63

TO DEVELOP POWER SYSTEM TECHNOLOGY SUITABLE TO THE NEED IN 21ST CENTURY

Zhou, X.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 21, no 11, November 1997, pp 11-15

Chinese

At the change of the 20th century into the 21st century the development of the power system is facing a series

of challenges, such as the restraint from environment protection, the demand on high power long distance transmission, the interconnection of regional networks, the trend of international interconnections, the influence of the commercial operation of electric power etc. It is predicted that the traditional power system will obtain a new chance of development, thus the technical progress and innovation suitable to the need in the 21st century will be promoted. In the light of the demand for developing power systems in China and according to the trend of power system technology the development in the following respects should be performed: high power ac/dc transmission, FACTS, the operation and control of interconnected large power networks, analysis and simulation of power systems.

[1997] 07B - 64

UPFC APPLICATION ON THE AEP SYSTEM: PLANNING CONSIDERATIONS

Rahman, M.; Ahmed, M.; Gutman, R.; O'keefe, R.J.; Nelson, R.J.; Bian, J.

American Elec Power, Columbus, OH, USA

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1695-1701

In 1995, American Electric Power (AEP), an investor owned electric utility company, completed detailed planning studies to resolve voltage and thermal loading concerns in parts of its Kentucky/West Virginia service areas. These studies led to the initiation of a project including a unified power flow controller (UPFC), which is currently being developed through a tailored collaboration by AEP, Electric Power Research Institute (EPRI), and Westinghouse Electric Corporation (Westinghouse). This paper describes the planning concerns, the study objectives, and the UPFC function in resolving these concerns. It also provides information on the UPFC modeling for system studies and its technical parameters that would be of interest to transmission system planners and other prospective users of this new technology. 16 Refs.

[1996] 07B - 65

USE OF HVDC AND FACTS-COMPONENTS FOR ENHANCEMENT OF POWER SYSTEM STABILITY

Gjerde, J.O.; Flolo, R.; Gjengedal, T.

Norwegian Elec Power Res Inst, Trondheim, Norway

Proceedings, 8th IEEE Mediterranean Electrotechnical Conf, MELECON'96, Bari, Italy, May 13-16, 1996, vol 2, pp 802-808

This paper has discussed the application of high voltage power electronics (FACTS) for enhancing system stability in the main grid of Southern Norway. General aspects of application of FACTS in the Norwegian power system has been discussed. A decentralized control scheme has been applied for control of a FACTS device. Case studies with a simplified model of the South Norwegian grid are presented to illustrate the dynamic behavior of the power system including HVDC transmissions and FACTS for various load conditions. The results indicate that TCSC could be used to redispatch the power flow on tie lines and prevent synchronization problems after major disturbances in the South Norwegian main grid. 14 Refs.

[1996] 07B - 66

USING DISTRIBUTION STATIC COMPENSATORS (D-STATCOMS) TO EXTEND THE CAPABILITY OF VOLTAGE-LIMITED DISTRIBUTION FEEDERS

Ramsay, S.M.; Cronin, P.E.; Nelson, R.J.; Bian, J-H.; Menendez, F.E.

UMS Group, Inc, Parsippany, NJ, USA

Proceedings, 40th IEEE Conf on Rural Electric Power, Fort Worth, TX, April 28-30, 1996, pp A4-1-A4-7

The application of distribution system static synchronous compensators (D-STATCOMs) are examined for distribution voltage regulation. In particular, the concern of voltage regulation on long, voltage-limited feeders is considered and the D-STATCOM is shown to be a cost-effective means of resolving it. 5 Refs.

[1996] 07B - 67

VARIABLE STRUCTURE TCSC CONTROL IN MULTIMACHINE POWER SYSTEMS

Wang, Y.; Mittelstadt, W.A.; Mohler, R.

Pacificorp, Portland, OR, USA

Proceedings, 58th American Power Conf, Chicago, IL, April 9-11, 1996, pp 1542-1547

Due to the long distances which separate electric power generation resources from electric load centers, utility planning engineers have been searching for ways to increase transfer capability while maintaining system stability and good damping performance. The traditional solution to this problem has been to reduce transfer impedance by constructing additional

transmission lines. However, high cost, very long lead time and environmental concerns become more and more severe restrictions to this option. In recent years, new power-electronic technology has been the basis for a program sponsored by the Electric Power Research Institute known as flexible ac transmission system (FACTS). Related devices such as the thyristor-controlled series-capacitor (TCSC), thyristor-controlled braking-resistor (TCBR) and thyristor-controlled static-Var-compensator are appropriately linked to powerful network control measures because they are able to respond very quickly to meet system demands under transient conditions. To utilize this capability, appropriate control for the thyristors must be developed. This task becomes a big challenge for control experts because the power system is very large scale geographically, highly nonlinear and of variable structure. In this paper, the multimachine power system model with TCSC is derived; then the control law is designed. Using the Bonneville Power Administration transient stability program, the variable-structure TCSC control is tested in a 54-bus system.

[1996] 07B - 68

WEST COAST UTILITY TRANSMISSION BENEFITS OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE. FINAL REPORT

DeSteese, J.G.; Dagle, J.E.; Trudnowski, D.J.

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-104803, January 1996, 75 pp

A scoping study is described that assessed the ability of superconducting magnetic energy storage (SMES) to improve the stability and power transfer capacity of selected pathways in the utility transmission system serving Southern California. Work was guided by transmission planners from five major west coast utilities known, for the purpose of the study, as the West Coast Utility Group (WCUG). The scope of analyses focused on a working case set of 11 system contingency scenarios consisting of the 5 base cases and 6 sensitivity cases identified by the WCUG as being of special interest under the increased loading conditions expected beyond the end of this century. The transmission enhancement potential of SMEs was analyzed using the Extended Transient/Midterm Stability Package, developed by the Electric Power Research Institute. The simulations and analyses utilized a 5,000-bus 1999 heavy summer model of the western North American power system developed by utility members of the Western Systems Coordinating Council. The study evaluated the control effectiveness of SMES in each scenario and compared SMES with other options.

[1997] 07B - REF

INCREASING POWER TRANSMISSION CAPABILITY OF AC SYSTEMS BY MEANS OF POWER ELECTRONIC EQUIPMENT

For Abstract see entry 01B - 15

[1996] 07B - REF

POWER ELECTRONICS IN INDIA - RETROSPECT AND PROSPECTS

For Abstract see entry 01B - 23

[1997] 07B - REF

EAST EUROPEAN ELECTRICITY INFRASTRUCTURE, INTERCONNECTIONS, AND ELECTRICITY EXCHANGES

For Abstract see entry 01B - 7

[1996] 07B - REF

UTILITY PROJECTS SHOW THE RANGE OF T&D TECHNOLOGY

For Abstract see entry 01C - 37

[1996] 07B - REF

PROSPECTIVE USE OF HVDC AND FACTS FOR ENHANCEMENT OF POWER SYSTEM STABILITY IN THE MAIN GRID OF THE SOUTHERN NORWAY

For Abstract see entry 05G - 6

[1997] 07B - REF

ANALYSIS OF POWER OSCILLATIONS IN THE SOUTH AFRICAN HIGH-VOLTAGE GRID USING COMBINED TIME DOMAIN AND EIGENVALUE

TECHNIQUES

For Abstract see entry 06C - 2

[1997] 07B - REF

END-USE LOAD CONTROL FOR POWER SYSTEM DYNAMIC STABILITY

ENHANCEMENT

For Abstract see entry 07A - 14

[1996] 07B - REF

FACTS DEVICES IN UPLIFT CONTROL

For Abstract see entry 07A - 16

[1996] 07B - REF

FACTS FOR DISTRIBUTION APPLICATIONS

For Abstract see entry 07A - 18

[1996] 07B - REF

FLEXIBLE AC TRANSMISSION LINES

For Abstract see entry 07A - 22

[1997] 07B - REF

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

For Abstract see entry 07A - 23

[1996] 07B - REF

MARKET OPTIONS FOR REACTIVE POWER

For Abstract see entry 07A - 33

[1997] 07B - REF

ON THE NEW PROGRESS EXTENDED IN THE FACTS CONCEPT

For Abstract see entry 07A - 39

[1996] 07B - REF

A PRELIMINARY STUDY ON PARALLEL PATHS FLOW CONTROL [POWER SYSTEM LOAD FLOW]

For Abstract see entry 07A - 4

[1996] 07B - REF

POWER ELECTRONICS ENTERS ELECTRIC POWER NET

For Abstract see entry 07A - 44

[1996] 07B - REF

RELOCATABLE STATIC VAR COMPENSATORS HELP CONTROL UNBUNDLED POWER FLOWS

For Abstract see entry 07A - 54

[1996] 07B - REF

SUPERCONDUCTING STORAGE SYSTEMS: AN OVERVIEW

For Abstract see entry 07A - 60

[1998] 07B - REF

THE FUTURE OF POWER DELIVERY IN THE 21ST CENTURY: 1998 CONFERENCE

For Abstract see entry 07A - 67

[1996] 07B - REF

AN INVESTIGATION INTO THE REALITIES OF FACTS DEVICES

For Abstract see entry 07A -

[1996] 07B - REF

TRANSMISSION CAPACITY IN POWER NETWORKS

For Abstract see entry 07A - 72

[1998] 07B - REF

USE OF POWER ELECTRONICS FOR RURAL ELECTRIFICATION

For Abstract see entry 07A - 76

[1996] 07B - REF

STATIC VAR COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATION. PART I: THEORETICAL ANALYSIS

For Abstract see entry 08A - 109

[1997] 07B - REF

STUDY OF POWER ELECTRONICS EQUIPMENT FOR DAMPING CONTROL OF PUMPED STORAGE GENERATOR/MOTOR AND STABILIZING LOAD

VOLTAGE

For Abstract see entry 08A – 114

[1996] 07B - REF

SVC FOR THE DEREGULATED ELECTRIC POWER INDUSTRY

For Abstract see entry 08A - 116

[1996] 07B - REF

TRANSPORTABLE REACTIVE POWER COMPENSATORS

For Abstract see entry 08A - 132

[1998] 07B - REF

ANALYSIS OF SVC AND TCSC CONTROLLERS IN VOLTAGE COLLAPSE

For Abstract see entry 08A - 25

[1996] 07B - REF

APPLICATION OF THE PHILLIPS-HEFFRON MODEL IN THE ANALYSIS OF THE DAMPING TORQUE CONTRIBUTION TO POWER SYSTEMS BY SVC DAMPING CONTROL

For Abstract see entry 08A - 29

[1996] 07B - REF

A DESIGN FOR A RELOCATABLE TERTIARY CONNECTED SVC

For Abstract see entry 08A - 3

[1998] 07B - REF

CONTROLLING SVCs FOR BETTER MANAGEMENT OF NORTHERN GRID OF INDIA

For Abstract see entry 08A - 45

[1996] 07B - REF

IMPROVING THE ECONOMIC COMPETITIVENESS OF SMALL-LOAD LONG-DISTANCE AC TRANSMISSION SYSTEMS BY THE USE OF STATIC

COMPENSATORS AT THE RECEIVING END

For Abstract see entry 08A - 72

[1997] 07B - REF

MODELING OF ELECTRIC ARC FURNACE FOR HARMONIC AND FLICKER ASSESSMENT. A CASE STUDY

For Abstract see entry 08A - 79

[1998] 07B - REF

POWER SYSTEMS TRANSIENT STABILITY ENHANCEMENT USING STATIC VAR COMPENSATORS

For Abstract see entry 08A - 93

[1997] 07B - REF

RELOCATABLE STATIC VAR COMPENSATORS

For Abstract see entry 08B - 11

[1997] 07B - REF

A THYRISTOR-CONTROLLED STATIC CONDENSER WITH THE DOUBLE-FIRING PHASE CONTROL

For Abstract see entry 09A - 11

[1997] 07B - REF

ADVANCED SHUNT VAR GENERATOR (ASVG) PRESENT SITUATION

For Abstract see entry 09A - 12

[1997] 07B - REF

PERFORMANCE EVALUATION OF PAM BY MINIATURE MODEL EXPERIMENT

For Abstract see entry 09A - 77

[1997] 07B - REF

TCSC EFFECT ANALYSIS IN MULTI-MACHINE POWER SYSTEM

For Abstract see entry 10A - 112

[1998] 07B - REF

APPLICATION OF THYRISTOR CONTROLLED SERIES COMPENSATORS TO ENHANCE OSCILLATORY STABILITY AND TRANSMISSION CAPABILITY OF LONGITUDINAL POWER SYSTEM

For Abstract see entry 10A - 18

[1996] 07B - REF

DAMPING OF POWER OSCILLATIONS USING THYRISTOR CONTROLLED SERIES CAPACITORS

For Abstract see entry 10A - 31

[1997] 07B - REF

EIGENVALUE SENSITIVITY APPROACH TO LOCATION AND CONTROLLER DESIGN OF CONTROLLABLE SERIES CAPACITORS FOR DAMPING POWER SYSTEM OSCILLATIONS

For Abstract see entry 10A - 42

[1996] 07B - REF

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[1996] 07B - REF

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[1997] 07B - REF

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[1996] 07B - REF

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[1997] 07B - REF

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[1996] 07B - REF

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[1997] 07B - REF

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[1996] 07B - REF

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[1996] 07B - REF

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For Abstract see entry 14B - 17

[1997] 07B - REF

A NEW CONCEPT FOR A SOLID-STATE ON-LOAD TAP CHANGERS

For Abstract see entry 15B - 1

[1998] 07B - REF

CONVERTIBLE STATIC COMPENSATOR APPLICATION TO THE NEW YORK TRANSMISSION SYSTEM

For Abstract see entry 16A - 6

[1996] 07B - REF

ENERGY APPROACH TO ANALYSIS OF INTERAREA OSCILLATIONS IN POWER SYSTEMS

For Abstract see entry 18A - 13

[1996] 07B - REF

COMPARISON OF MODAL CONTROLLABILITY BETWEEN FACTS-BASED STABILIZERS AND PSS IN INCREASING THE OSCILLATION STABILITY OF MULTIMACHINE POWER SYSTEMS

For Abstract see entry 18B - 4

[1997] 07B - REF

DETERMINATION OF NEEDED FACTS CONTROLLERS THAT INCREASE ASSET UTILIZATION OF POWER SYSTEMS

For Abstract see entry 18B - 5

[1997] 07B - REF

COORDINATED DESIGN OF FACTS CONTROLLERS TO ENHANCE POWER SYSTEM DYNAMIC PERFORMANCE

For Abstract see entry 18C - 4

[1996] 07B - REF

COORDINATION OF THE THYRISTOR CONTROLLED SERIES COMPENSATION WITH OTHER FACTS DEVICES IN INTERCONNECTED POWER SYSTEMS

For Abstract see entry 18C - 6

[1996] 07B - REF

LONG WAVE TELESWITCHING. A NEW WAY IN LOAD MANAGEMENT TECHNOLOGY

For Abstract see entry 19B - 10

[1996] 07B - REF

POWER FLOWS AND VOLTAGE CONTROL IN ELECTRIC SYSTEMS BY TRADITIONAL AND INNOVATIVE DEVICES

For Abstract see entry 19B - 16

[1996] 07B - REF

AN ADAPTIVE RECURRENT NEURAL NETWORK SYSTEM FOR SHORT-TERM HOURLY LOAD FORECASTING

For Abstract see entry 19B - 2

08 STATIC VAR COMPENSATOR (SVC)

08A Modeling, Control, Applications

[1997] 08A - 1

A CLOSED-LOOP REACTIVE POWER CONTROLLER FOR POWER SYSTEM VOLTAGE STABILITY

Raju, V.V.; Kuppurajulu, A.

CMC Ltd, Hyderabad, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 3, March 1997, pp 153-164

Generator overload due to excessive reactive power generation is one of the most common and serious causes of voltage instability. Low voltage at load buses is another. By closely monitoring the reactive power generation and load voltages, it is possible to avoid such major disturbances. A closed-loop controller can steer the system to a safer state by rescheduling the reactive power generation from generators and SVCs through voltage set point controls in real time. A closed-loop controller which dynamically steers the system to a safer state on violation of specified operating conditions of reactive power generation and load bus voltages is designed. During normal operation, the controller minimizes active power transmission losses due to reactive power transfers. The principle of the controller is based on a multi-variable control concept. A closed-loop controller is synthesized to steer the system dynamically to an acceptable state while satisfying Kuhn-Tucker conditions of optimality in steady state. The proposed closed-loop reactive power controller which gives set point control signals to AVRs and SVCs in the secondary mode of control, can be viewed as a parallel to the AGC for active power/frequency control. The controller performs this task on a real-time basis using SCADA measurements. The controller also issues load shedding commands in case it is necessary. The controller is tested under normal as well as contingency operation. Broad details of the closed-loop controller and its efficacy in avoiding system breakdown due to reactive power disturbance is demonstrated with examples.

[1997] 08A - 2

A CLOSED-LOOP REACTIVE POWER CONTROLLER FOR POWER SYSTEM VOLTAGE STABILITY

Veera, R.V.; Kuppurajulu, A.

CMC Limited, Hyderabad, India

Int'l Journal of Electrical Power & Energy Systems (UK), vol 19, no 3, 1997, pp 153-164

Any imbalance between reactive power supply and demand disturbs the normal operation of a power system. Power system contingencies sometimes cause excessive reactive power imbalance, even leading to total system breakdown. The problem is usually aggravated when the system is heavily loaded. Generator overload due to excessive reactive power generation is one of the most common and serious causes of voltage instability. Low voltage at load buses is another cause which is likely to result in voltage stability problems. By closely monitoring the reactive power generation and load voltages, it is possible to avoid such major disturbances. A closed-loop controller can steer the system to a safer state by rescheduling the reactive power generation from generators and SVCs through voltage set point controls in real time. A closed-loop controller which dynamically steers the system to a safer state on violation of specified operating conditions of reactive power generation and load bus voltages is designed. During normal operation, the controller minimizes active power transmission losses due to reactive power transfers. The principle of the controller is based on a multi-variable control concept. A closed-loop controller is synthesized to steer the system dynamically to an acceptable state while satisfying Kuhn- Tucker conditions of optimality in steady state. The proposed closed-loop reactive power controller which gives set point control signals to AVRs and SVCs in the secondary mode of control, can be viewed as a parallel to the AGC for active power/frequency control. The controller performs this task on a real-time basis using SCADA measurements. The controller also issues load shedding commands in case it is necessary. The controller is tested under normal as well as contingency operation. Broad details of the closed-loop controller and its efficacy in avoiding system breakdown due to reactive power disturbance is demonstrated with examples. 23 refs.

[1996] 08A - 3

A DESIGN FOR A RELOCATABLE TERTIARY CONNECTED SVC

Horwill, C.; Young, D.J.; Wong, K.T.G.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 399-404

In 1994, the National Grid Company (NGC) began procuring a new kind of static VAr compensator (SVC) which can be connected to the tertiary of any of its supergrid transformers (SGTs) and, if necessary, moved from one site to another to match the changes in VAr demand at various parts of the network. These SVCs, which are rated 0/+60 MVAr, are called relocatable SVCs (RSVCs). The authors discuss the specification requirements and design of the RSVCs. 2 Refs.

[1996] 08A - 4

A FLEXIBLE AC TRANSMISSION SYSTEM "STEADY STATE AND DYNAMIC PERFORMANCE ANALYSIS"

Dave, M.P.; Kumar, N.

Dept of Elec Eng, Roorkee Univ, India

Electric Machines and Power Systems, vol 24, no 5, July-August 1996, pp 541-553

The steady-state and dynamic performance of a flexible ac transmission system (FACTS) with a midpoint located static VAr system (SVS) are presented with and without series compensation. The maximum capacitor of the SVS branch in the case of lines without series compensation, is split into two locations; two-thirds at the sending end (for the purpose of series compensation) and one third at the SVS branch. This has the advantage of reduced ' delta ' without upsetting greatly the cost of equipment. The degree of series compensation thus obtained is used to evaluate the steady-state and dynamic performance of series compensated transmission lines. The results are then compared over a wide operating range. A line reactive power auxiliary controller and bus frequency auxiliary controller are employed in the SVS control system to stabilize unstable system modes and the performance of the two auxiliary controllers is also compared over wide operating conditions. It has been established that such a series capacitor compensated power line can give improved static and dynamic performance at a reduced value of delta . 10 Refs.

[1997] 08A - 5

A METHOD FOR SVC DAMPING CONTROLLER DESIGN USING ROBUST POLE ASSIGNMENT METHOD

Okamoto, H.; Kurita, A.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 4, April 1997, pp 578-584

Japanese

A method for SVC damping controller design based on a robust pole assignment method is proposed. In the design procedure, the proposed method uses a nominal model which represents weakly damped interarea modes. The ignored higher order modes and perturbation of the low frequency modes are considered as multiplicative perturbations. A controller with high performance and high robustness can be derived easily utilizing H_∞ optimal control theory. The present paper makes it clear, through eigenvalue analyses and digital simulations, that the designed controller is effective for damping interarea modes and achieves higher robustness against change of load flow condition than the well tuned conventional controller.

[1996] 08A - 6

A METHOD OF REACTIVE POWER COMPENSATION ARRANGEMENT TO MAINTAIN VOLTAGE STABILITY

Tada, Y.; Okamoto, H.; Kurita, A.; Sekine, Y.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 8, August 1996, pp 956-962

Japanese

In this paper, a method of reactive power compensation to prevent power system voltage instability is proposed. The proposed method of reactive power compensation maximizes the static power transfer capability under given short circuit current constraints. The concept of a voltage-ideal power system (ideal voltage regulated system) is first introduced in which all node voltages are kept constant by powerful voltage regulators such as SVCs and synchronous condensers. This system is absolutely free from voltage instability, but its short circuit capacity becomes very large and a large amount of reactive power has to be supplied in order to keep all node voltages constant. To meet the practical levels of reactive power requirement and short circuit current capacity, a quasi voltage-ideal regulated system is discussed. This system is obtained by carefully choosing a limited number of nodes to be kept voltage constant in order to maximize the active power transmission capacity with a reasonable reactive power requirement without exceeding a specified short circuit capacity level. 10 Refs.

[1997] 08A - 7

A POWER DISTRIBUTION SYSTEM. STUDY OF VOLTAGE AND REACTIVE POWER CONTROL METHODS FOR HIGH-EFFICIENCY OPERATION OF DISTRIBUTION NETWORK

Fudo, H.; Genji, T.; Abe, S.; Hashimoto, T.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 10, pp 1336-1344

Japanese

Transformers with on-load tap changer and step voltage regulators are now mainly used for regulating the distribution network voltage. Therefore, several problems exist in the present system, i.e. the voltage control is in discrete steps and the response time is not enough satisfactory. In the meantime, power factor (p.f.) compensation relies on capacitors installed by electricity customers, which give another problems of unexpected over voltage during light load and increase of power losses. To solve those problems, the authors have proposed a new voltage and p.f. control system for distribution networks which adopts sophisticated power electronics technology. This paper describes the study for the operating theory of a inverter-controlled regulator and a thyristor-controlled reactor, which bear important roles in this system, and the result of simulation through which the usefulness of these equipment has been ascertained.

[1996] 08A - 8

A PWM STATIC VAR COMPENSATOR BASED ON PHASE-SHIFT-CONTROLLED MULTIPLE-BRIDGE SUPERPOSITION HARMONIC ELIMINATION TECHNIQUE

Ji, Y-C.; Hu, Y-X.; Liu, Z.; Wu, C-G.; Feng, Y-G.

Dept of Elec Eng, Harbin Inst of Tech, China

Proceedings, 31st IEEE Industry Applications Conf (IAS '96), San Diego, CA, October 6-10, 1996, vol 2, pp 1271-1277

In this paper, a four-bridge PWM static VAr compensator (FB-PSVC) based on an improved version of the PWM controller is presented in this paper, and a novel phase-shift-controlled multiple-bridge superposition harmonic elimination technique is also proposed. Theoretical analysis shows that the harmonic pairs of $[(2k+1)\ f_s \pm f]$ and $[(4k+2)\ f_s \pm f]$ generated in each bridge are effectively eliminated through appropriate phase shift control. To satisfy the same total harmonic distortion (THD) requirement (usually under 5%), this new compensator can work at 200 Hz, which is much lower than the previously reported 1.9 kHz of a single-bridge PWM static VAr compensator (SB-PSVC). The efficiency is increased and reliability enhanced. The fairly low switching frequency and multiple bridge structure facilitate its use in high-power VAr compensators since GTOs can be employed as power switch. Theoretical analysis was verified through simulations and experimental results. 7 Refs.

[1998] 08A - 9

A ROBUST CONTROL STRATEGY FOR SHUNT AND SERIES REACTIVE COMPENSATORS TO DAMP ELECTROMECHANICAL OSCILLATIONS

Noroozian, M.

ABB Power Sys, Vasteras, Sweden

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

This paper examines improvement of power system dynamics by use of thyristor-controlled series capacitors (TCSCs) and static var systems (SVCs). Models suitable for incorporation in dynamic simulation programs for studying angle stability are analyzed. A control strategy for damping of electromechanical power oscillations using an energy function method is derived. Using this control strategy, each device (TCSC and SVC) will contribute to the damping of power swings without deteriorating the effect of the other power oscillation damping (POD) devices. The damping effect is robust with respect to loading condition, fault location and network structure. Furthermore, the control inputs are based on local signals. The effectiveness of the controls are demonstrated for model power systems.

[1996] 08A - 10

A STATIC VAR COMPENSATOR CONTROL STRATEGY TO MAXIMIZE POWER SYSTEM DAMPING

Machowski, J.; Nelles, D.

Tech Univ of Wroclaw, Poland

Electric Machines and Power Systems, vol 24, no 5, July-August 1996, pp 477-495

A study of power system transient stability enhancement through effective use of static VAr compensators is presented. An optimal theoretical control strategy is derived from the direct Lyapunov method for a multimachine power system model as a control method which forces the fastest dissipation of energy released in the power system by a given fault. The strategy of this theoretical optimal control scheme uses a signal based on the state variables unavailable at the compensator bus. It is shown that the optimal control signal can be replaced by the time derivative of locally measurable electric quantities. The dynamic properties of two such quantities are compared using eigenvalue analysis. On the basis of this study, a current-orientated control strategy is proposed. Its validity and robustness is confirmed by simulation results for a nonlinear multimachine power system model. 15 Refs.

[1996] 08A - 11

A STUDY ON ADAPTIVE SVC CONTROLLER USING NEURAL NETWORKS FOR ENHANCEMENT OF POWER SYSTEM STABILITY

Nagahara, J.; Yokoyama, A.

Univ of Tokyo, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 13-24, pp 31-40

Japanese

Because of nonlinearity of a power system, performance of a control system of static VAr compensator (SVC) may deteriorate when the operating condition of the power system changes. The authors have proposed an adaptive control system using neural networks, which is called Adaptive Neuro-Control System(ANCS) by the authors, and have studied its application to generator control. In this paper, ANCS applied to the SVC control is compared with the conventional damping controller of the SVC from the viewpoint of stability enhancement. Simulation results show that the ANCS can stabilize the power system even when the operating condition changes widely.

[1996] 08A - 12

A STUDY ON THE EFFECT OF CONTROLLERS IN SMALL SIGNAL STABILITY OF POWER SYSTEMS

Kwon, S-H.; Kim, D-Y.

Korea Univ, Seoul, South Korea

Energy Engineering (Korea), vol 5, no 1, March 1996, pp 72-79

Korean

The effect of controllers-exciter, power system stabilizer, and static VAr compensator-in one machine infinite bus system is investigated in this paper. The structure of generator state matrix with controllers is represented, while the static VAr compensator is installed in generator terminal bus. Eigenvalue analysis is performed and the effects of controllers to the dominant eigenvalue in one machine infinite bus system are represented by first order eigenvalue sensitivity coefficients while the operating conditions of the system are varied. Optimization of controller parameters using first order eigenvalue sensitivity coefficients is performed by the Simplex Method. It is proved that exciter control is the most efficient method to improve stability of the system and the effect of static VAr compensator is small, in the case of one machine infinite bus system. . 9 refs., 7 figs., 5 tabs.

[1996] 08A - 13

A THYRISTORIZED SATURABLE REACTOR WITH SELF-EXCITATION

Lashine, A.E.

Dept of Elec Eng, Menoufia Univ, Egypt

Electric Machines and Power Systems, vol 24, no 4, June 1996, pp 437-439

In this paper, a variable reactor suitable for voltage control of resistive loads is presented. The proposal gives the desired impedance variation using two naturally commutated thyristor switches in conjunction with a three-limb magnetic circuit. Load voltage can be controlled by varying the thyristor firing angles and accordingly the dc flux level in the magnetic circuit. The effective impedance is smoothly varied with no need for external dc excitation. It is shown that the proposed voltage control method is accompanied by high power factor and lower harmonic content in the supply current. An equivalent circuit for the device is deduced from which analytical results are obtained. Theoretical and experimental results of a prototype are compared and shown to be of satisfactory agreement. 6 Refs.

[1996] 08A - 14

ADAPTIVE FUZZY LOGIC CONTROL OF A STATIC VAR SYSTEM

Dash, P.K.; Routray, A.; Panda, P.C.; Panda, S.K.

Regional Eng College, Rourkela, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth

(PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 128-132

A fuzzy gain scheduling scheme for PID controller for transient and dynamic voltage stabilization of power transmission systems has been presented in this paper. Fuzzy rules and reasoning are utilized on-line to determine the controller parameters based on the error signal and its derivative. The static VAr controller is designed with the bus angle deviation and its rate as the input signal to a fuzzy PI or PID control loop. This control is tested for a power transmission system supplying dynamic loads and provides superior performance. 10 Refs.

[1996] 08A - 15

ADAPTIVE STATIC VAR COMPENSATOR FOR ENHANCING POWER SYSTEM STABILITY

El-Sadek, M.Z.; El-Saady, G.; El-Soud, M.A.

Assiut Univ, Egypt

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 969-972

The paper develops an adaptive static VAr compensator (SVC) for enhancing power system stability. The Self Tuning adaptive scheme is used to design the adaptive SVC controller. The main feature of the proposed controller is that the controller parameters are tuned and updated on line for an optimum performance of power system. The simulated power system consists of a synchronous machine connected to an infinite Bus through double circuit transmission line. The Excitation system of synchronous machine is included and the SVC is connected at the machine terminal. The digital simulation results of the above power system behavior due to three-phase short circuit or small speed deviation of machine with the proposed adaptive SVC controller are presented. Moreover, a comparison between the power system response using the SVC controlled by the conventional PI controller and the SVC controlled by the proposed adaptive controller is obtained. The results prove the robustness and reliability of the adaptive SVC controller in terms of high performance of power system. 9 Refs.

[1996] 08A - 16

ADAPTIVE VAR COMPENSATOR PROMISES AN END TO CAPACITOR-SWITCHING WOES

Koch, W.A.

Special Reports, Seattle, WA, USA

Electrical World, vol 210, no 6, June 1996, pp 30, 33-34

Mechanically switched capacitors, the standard cure for low power factor, do a good job of compensating for average power factor, but they cannot be switched fast enough to keep up with quick and frequent variations in reactive demand. An even greater drawback is the high transient current caused by mechanical capacitor switching and the havoc it plays with sensitive computer-based loads. Here, the author describes how the adaptive VAr compensator (AVC) offers a refined way of switching capacitors that provides quick response to reactive demands and the capability of addressing power quality issues such as voltage regulation and flicker. The device uses solid-state devices to switch a binary stepped capacitor bank and is capable of compensating for rapidly changing reactive demand within one-half cycle, without generating harmful transients or harmonics. 0 Refs.

[1998] 08A - 17

AN ACCURATE AND CONCISE METHOD OF EVALUATING AND FLICKER REDUCTION STRATEGIES IN POWER SYSTEMS

Jatskevich, J.; Conrad, L.; Wasynczuk, O.

Purdue Univ, West Lafayette, IN, USA

IEEE Trans on Power Delivery, Preprint order number PE-310-PWRD-0-1-1998

The UIE/IEC flicker characteristics of a three-phase power system which includes resistance welders are evaluated in this paper. Welder operation produces cyclic flicker which leads to customer complaints. An adaptive var compensator (AVC) has been installed to reduce flicker. In order to investigate the effectiveness of the AVC and to set the stage for the analysis of alternative control strategies, a detailed computer model of the given system, including the AVC, has been developed. The model also includes a simulation of the UIE/IEC flicker meter to determine the effectiveness of the AVC in an objective manner. The simulated system response is compared with actual system measurements revealing excellent agreement. The modeling methodology set forth provides an efficient and convenient means of evaluating complex flicker resulting in a simple measure of human irritability.

[1996] 08A - 18

AN EVALUATION OF STATIC VAR COMPENSATION STRATEGIES FOR VOLTAGE FLICKER MITIGATION IN ELECTRIC DISTRIBUTION SYSTEMS

King, B.; Olejniczak, K.J.

Dept of Elec Eng, Arkansas Univ, Fayetteville, AR, USA

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 6-11

This paper describes the application and evaluation of various strategies for voltage flicker compensation in electric distribution systems. Simulations were performed using the Electromagnetic Transients Program (EMTP). A model of the distribution system is first developed. Then, models for different compensatory schemes are adapted for use in the EMTP

model of the distribution system. The compensatory schemes evaluated include the series capacitor, the thyristor-controlled reactor with a fixed capacitor, the thyristor-switched capacitor, and the thyristor-switched capacitor and thyristor-controlled reactor hybrid. 12 Refs.

[1996] 08A - 19

AN HYBRID ACTIVE POWER FACTOR COMPENSATOR USING AN INTELLIGENT HIERARCHICAL STRUCTURE

da Silva, L.E.B.; Lambert-Torres, G.; da Silva, V.F.; Caloba, L.P.; Diniz, P.S.R.; de Querioz, A.C.M.; Watanabe, E.H.

Escola Federal de Engenharia de Itajuba, Brazil

Proceedings, 38th Midwest Symp on Circuits and Systems, Rio de Janeiro, Brazil, August 13-16, 1996, vol 2, pp 212-215

This article describes the application of a hybrid converter as a line conditioner. The hybrid converter basically is a converter bridge with two GTOs, that transform it in a fully controllable inverter. Therefore, this converter allows independent control of voltage and displacement factor. When appropriately controlled, this converter can produce part of the reactive power consumed by the load. Fabricated with a well known technology, this converter is suitable for large power compensation. Theoretical analysis and experimental results are presented. A control strategy based on learning is proposed. This hierarchical approach, uses hints, coded in fuzzy conditional rules, to train a neural network responsible for converter variables manipulation. 8 Refs.

[1996] 08A - 20

Deleted

[1996] 08A - 21

ANALOG SIMULATION OF SELF-COMMUTATED STATIC VAR COMPENSATOR WITH COMPENSATION OF HARMONIC AND UNBALANCED CURRENT

Kishibe, H.; Yoshioka, Y.; Konishi, S.

Tohoku Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 258-259

Japanese

Abstract not available.

[1997] 08A - 22

ANALYSIS OF INTER-AREA DAMPING ENHANCEMENT BY STATIC VAR COMPENSATORS IN LONGITUDINAL POWER SYSTEMS

Messina, A.R.; Rosales, M.A.A.

ESIME Seccion de Estudos de Posgrado e Investigacion, Mexico

Control Engineering Practice, vol 5, no 1, January 1997, pp 117-122

The work reported in this paper synthesizes the main findings of an eigen-analysis-based research program, aimed at assessing the potential for dynamic stability improvement by means of static VAr compensators. The results of the first phase of this research include the determination of modes that are more controllable by existent SVCs, and the use of modulation controls to damp low-frequency inter-area modes of oscillation in longitudinal power systems. 11 Refs.

[1997] 08A - 23

ANALYSIS OF REGIME CHARACTERISTICS OF CONTROLLED INTERCONNECTION WITH STATIC VOLT-AMPERE COMPENSATORS

Zelenokhat, N.I.

Moskovskij Energeticheskij Inst, Moscow, Russia

Elektrichestvo (Russia), no 3 March 1997, pp 13-18

Russian

An algorithm of control of the static volt-ampere compensator (SVC) is developed to maintain a given re-flow of active power via controlled interconnection. The calculations performed confirm its effectiveness. Different properties of controlled interconnection with the SVC have been studied under the simple and complex electric power system. For control of the active power re-flow via the intersystem connection link, the SVC operation is necessary in the reactor regime. Using the capacitance regime allows to extend the admissible angle variations. 5 Refs.

[1996] 08A - 24

ANALYSIS OF SUPPLEMENTARY CONTROLS IN DAMPING SUBSYNCHRONOUS OSCILLATIONS

Balasubramanyam, P.V.; Murty, A.S.R.; Sarkar,

B.N.; Murthy, P.R.

Central Research and Testing Lab, Bangalore, India

Journal of the Institution of Engineers (India), Electrical Engineering Division, vol 77, November 1996, pp 144-150

Analysis and damping of torsional oscillations through thyristor control reactor (TCR) is presented in this paper. The reactive power control is achieved through TCR at the machine terminals. Generator speed deviation signal is used as auxiliary signal and terminal voltage feed back signal as main control signal for TCR. The different control strategies for auxiliary control to TCR have been analyzed. The main objective of this paper is to discuss the modeling aspects and analyze the performance of different control strategies for damping torsional oscillations when a generator is connected to an infinite bus via double circuit 400-kV transmission line, in which one circuit is series compensated. This configuration is similar to IEEE benchmark two model. 11 Refs.

[1998] 08A - 25

ANALYSIS OF SVC AND TCSC CONTROLLERS IN VOLTAGE COLLAPSE

Canizares, C.A.; Faur, Z.T.

IEEE Trans on Power Delivery, Preprint order number PE-200-PWRS-0-2-1998

This paper presents detailed steady-state models with controls of two flexible ac transmission system (FACTS) controllers, namely, static VAr compensators (SVCs) and thyristor-controlled series capacitors (TCSCs), to study their effect on voltage collapse phenomena in power systems. Based on results at the point of collapse, design strategies are proposed for these two controllers, so that their locations, dimensions and controls can be optimally defined to increase system loadability. A European system is used to illustrate the application of all proposed models and techniques.

[1996] 08A - 26

APPLICATION OF AN AUXILIARY CONTROLLED STATIC VAR SYSTEM FOR DAMPING SUBSYNCHRONOUS RESONANCE IN POWER SYSTEMS

Kumar, N.; Dave, M.P.

Univ of Roorkee, India

Electric Power Systems Research, vol 37, no 3, June 1996, pp 189-201

In this paper a novel concept of a static var system (SVS) auxiliary controller application for damping subsynchronous resonance in power systems has been proposed and demonstrated. An SVS controller, known as the combined reactive power and frequency (CRPF) auxiliary controller has been developed and incorporated in the SVS control system located at the middle of a series compensated long transmission line. The studies are conducted on a system having a similar spread of the torsional modes as the first IEEE Benchmark Model. The proposed SVS auxiliary controller stabilizes all the torsional modes over a wide operating range. A digital computer simulation study has been performed, using a nonlinear system model, to illustrate the effectiveness of the proposed SVS auxiliary controller. 17 Refs.

[1997] 08A - 27

APPLICATION OF STATIC VAR COMPENSATION FOR LOAD FREQUENCY CONTROL

El-Emary, A.A.; El-Shibina, M.A.

Cairo Univ, Egypt

Electric Machines and Power Systems, vol 25, no 9, November 1997, pp 1009-1022

In this paper, the problem of designing a load frequency control (LFC) system which reduces frequency oscillation based on static VAr compensation has been investigated. A linear model of a power system area has been used, and a new feedback control signal sent from SVCs to power houses is suggested. The new feedback controller includes the frequency deviation and the change of reactive power due to SVCs. The dynamic response of the system is determined in the presence of the suggested control system and compared with the case of no control action to evaluate the capabilities of the proposed control systems.

[1997] 08A - 28

APPLICATION OF SVS AUXILIARY CONTROLLERS FOR POWER SYSTEM CONTROL

Kumar, N.; Dave, M.P.

Dept of Elec Eng, Roorkee Univ, India

Int'l Journal of Power and Energy Systems, vol 17, no 2, 1997, pp 69-77

This paper presents a comparative performance evaluation of static VAr systems (SVS) auxiliary controllers for transient stability enhancement of long

transmission lines. A new controller, namely, the combined reactive power and frequency (CRPF) auxiliary controller, has been developed for the SVS located at the middle of the transmission line. The application of auxiliary controllers considerably enhances the system damping, and unstable system modes are stabilized. A digital computer simulation study has been performed to illustrate the comparative effectiveness of the auxiliary controllers under disturbance conditions, and the superiority of the CRPF auxiliary controller has been established.

[1996] 08A - 29

APPLICATION OF THE PHILLIPS-HEFFRON MODEL IN THE ANALYSIS OF THE DAMPING TORQUE CONTRIBUTION TO POWER SYSTEMS BY SVC DAMPING CONTROL

Wang, H.F.; Swift, F.J.

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Int'l Journal of Electrical Power and Energy Systems (UK), vol 18, no 5, June 1996, pp 307-313

In this paper, an extended Phillips-Heffron model of a power system installed with a static VAr compensator (SVC) is established and applied to analyze the damping torque contribution of SVC damping control to the power system. Some basic issues, such as the capability of the SVC damping control to supply positive damping to the power system, the best location of the SVC damping control, its control strategy and its robustness to the changes of the operating conditions of the power system, are investigated. Previous findings from numerical calculations and simulations of the effects of SVC damping control are confirmed by the analytical results in the paper. To supplement the analysis, the results of the calculations and simulations of an example power system are also presented. 10 Refs.

[1996] 08A - 30

APPLICATIONS AND MAINTENANCE OF THE POWER ELECTRONICS. (7) . STATIC VAR SYSTEM (SVC)

Miyata, N.

Nissin Elec Co, Ltd, Japan

Tetsudo to Denki Gijutsu (Japan), vol 7, no 9, pp 55-59

Japanese

Abstract not available.

[1997] 08A - 31

APPROACH TO DESIGNING THE FUZZY IF-THEN RULES FOR FUZZY-CONTROLLED STATIC VAR COMPENSATOR (FCSVC)

Yamakawa, T.; Uchino, E.; Takayama, M.

Kyushu Inst of Tech, Fukuoka, Japan

Information Sciences, vol 101, no 3-4, October 1997, pp 249-260

This paper describes an approach to designing fuzzy if-then rules for the fuzzy-controlled static var compensator (FCSVC) in a three-phase electric power system. In general, it is very difficult to control the rms line voltage in the three-phase ac circuit. We propose the FCSVC system to control the voltage. FCSVC is an rms line voltage stabilizer using three static var compensators (SVC) which are controlled by a fuzzy logic controller (FLC). Moreover, we propose an easier and more efficient approach to designing the fuzzy if-then rules of FCSVC. The effectiveness of the FCSVC described in this paper is verified by the experimental results. 5 Refs.

[1997] 08A - 32

AUTOMATIC CONTROL SYSTEM FOR A THYRISTOR-CONTROLLED SHUNT COMPENSATOR

Malafeyev, S.I.

Tech & Econ Sys Dept, Vladimir State Tech Univ, Russia

Electrical Technology (UK), no 4-6, 1997, pp 111-121

A control system for a thyristor shunt compensator is considered. The system ensures high-speed control of the quadrature components of the fundamental current harmonic of the power supply network. An analysis of the system dynamic characteristics is carried out with the help of an approximate discrete model.

[1997] 08A - 33

AUTOMATIC SYSTEM FOR CONTROLLING THYRISTOR-REACTOR COMPENSATOR

Malafeyev, S.I.

Elektrichestvo (Russia), no 6, June 1997, pp 13-18

Russian

The paper considers a control system for a thyristor shunt compensator. The system considered ensures a high-speed regulation of the feeding network alternating current fundamental harmonic quadrature-lagging

component. An analysis of the system dynamic characteristics is carried out with the help of an approximate discrete model.

[1997] 08A - 34

AUXILIARY-CONTROLLED STATIC VAR SYSTEM FOR DAMPING SUBSYNCHRONOUS RESONANCE IN POWER SYSTEMS

Kumar, N.; Dave, M.P.

Dept of Elec Eng, CR State College of Eng, Murthal, India

Int'l Journal of Power and Energy Systems, vol 17, no 3, 1997, pp 198-205

In this paper, a novel static VAr system (SVS) controller known as the combined reactive power and frequency (CRPF) auxiliary controller has been developed and incorporated in the SVS control system located at the middle of a series-compensated long transmission line. The proposed SVS auxiliary controller stabilizes all the torsional modes over a wide operating range. A digital computer simulation study has been performed, using a nonlinear system model, to illustrate the effectiveness of the proposed SVS auxiliary controller.

[1996] 08A - 35

CAPABILITY OF THE STATIC VAR COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATIONS

Wang, H.F.; Swift, F.J.

Manchester Metropolitan Univ, UK

IEE Proceedings, Generation, Transmission and Distribution (UK), vol 143, no 4, July 1996, pp 353-358

The capability of the static VAr compensator (SVC) in damping power system oscillations is investigated on the basis of a Phillips-Heffron model of single-machine infinite-bus power systems. Analysis shows that the ability of the SVC to provide positive damping torque to power systems is influenced not only by the load conditions, as has been found previously, but also by the type (or parameters) of the generator and the strength of the SVC voltage control. It is found that the 'dead point' of the SVC damping control function, which has been reported in two-area power systems, may also exist in a single-machine infinite-bus power system. All the conclusions in the paper have been obtained by theoretical analysis, which ensures their generality and validity in all power systems with the same basic structure, and are confirmed by numerical calculations and nonlinear simulations of an example power system. 13 Refs.

[1997] 08A - 36

COMPARATIVE ANALYSIS OF HARMONIC GENERATION FOR SVC AND STATCOM SYSTEMS

Wilkosz, K.; Sobierajaski, M.; Kwasnicki, W.T.

4th Int'l Conf on Electrical Power Quality and Utilization (JUEE'97), Krakow, Poland, September 1997

Abstract not available.

[1997] 08A - 37

COMPARATIVE STUDY OF DISTURBANCES CAUSED BY AC AND DC ARC FURNACES

Mauras, P.; Kratz, M.; Martinon, J.

Electricite de France

Collection de notes internes de la Direction des etudes et recherches. Materiel electrique, transport et distribution d'energie (France), no 34, 1997, 29 pp

French; English

Substantial work and measurements performed by EDF over the last few years regarding ac and dc arc furnaces have shed light on these very special loads, their associated disturbances, and have allowed the efficiency of the many technical solutions to forestall these disturbances to be ascertained. Among the main teachings, certain values have been confirmed, such as the order of magnitude of the difference in flicker between ac and dc furnaces of similar size and technology (two-fold), the flicker damping coefficients, or the flicker reduction ratio by series reactance or SVC. It has also been possible to identify the Kst coefficients used in the pre-determination of flicker of a new furnace (50 to 60 for ac furnaces without instrumented reactance). It should be remarked that the constant changes in metallurgical techniques (use of reduced iron, shredding and crushing of scrap, pre-heating or charging liquid pig-iron, post-combustion and increased energy from fossil fuel, conductor electrode-holder brackets, etc.) make it necessary to update these data on a regular basis. Other findings show that phenomena are sometimes more complex than theory may allow for. Substantial variation is observed in the coincidence factor of flicker produced by two furnaces, as well as a difference in damping of flicker depending on the direction of propagation of the disturbance. The

simultaneity of harmonics when several converters are operating simultaneously is also difficult to comprehend. Measurements have shown that, in some configurations, harmonic currents can be considerably amplified. The different technical solutions for the reduction of these disturbances, both for flicker and harmonics, are well under control today. One of the most promising avenues appears to be, in the field of the dc furnace, use of free-wheeling diode an shifted control rectifiers at constant reactive power. 12 refs.

[1996] 08A - 38

COMPARING THE VOLTAGE CONTROL CAPABILITIES OF PRESENT AND FUTURE VAR COMPENSATING TECHNIQUES IN TRANSMISSION SYSTEMS

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IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 475-481

The phenomenon of transient voltage stability in power transmission systems is explained. A generic method is used to examine the dynamics of stabilization as influenced by mechanically switched shunt capacitors and by static compensators. A comparison is made for the voltage stabilizing performance of different configurations of static VAr compensators. Technical merits of newly developed devices, such as voltage-source GTO converter-based VAr compensators and thyristor-controlled series capacitors, in terms of counteracting voltage instability are also examined. A newly developed special controller for SVC schemes with TCR in transmission systems is presented. The controller ensures a stable operation of the load interconnecting network at the usually unstable region where conventional SVC controls are void. 14 Refs.

[1997] 08A - 39

COMPENSATION OF VOLTAGE DROP USING STATIC VAR COMPENSATOR AT SECTIONING POST IN AC ELECTRIC RAILWAY SYSTEM

Kawahara, K.; Hase, S.; Mochinaga, Y.; Hisamizu, Y.; Inoue, T.

Railway Tech Research Inst, Tokyo, Japan

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3, 1997, vol 2, pp 955-960

In this paper, the authors describe the application of SVC (static VAr compensator) to ac electric railway system, outlines SVC installed at Shin-syo sectioning post on San-yo Shinkansen and report on the result of verifiable site investigations. Single-phase SVC can reduce the voltage drop in the feeding circuit and improve the power factor at substation by compensating the reactive power. In the case of compensating the voltage drop, it is more effective to locate SVC at sectioning post than at substation. The site investigation has revealed that SVC can reliably suppress the voltage drop. 3 Refs.

[1996] 08A - 40

CONTROL DESIGN FOR SVC'S ON THE MEAD-ADELANTO AND MEAD-PHOENIX TRANSMISSION PROJECT

Larsen, E.V.; Clark, K.; Hill, A.T.; Piwko, R.J.; Beshir, M.J.; Bhuiyan, M.; Hormozi, F.J.; Braun, K.

GE Power Sys Eng, Schenectady, NY, USA

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1498-1506

A major project is under construction to increase the capability of the 500-kV transmission system between Arizona and Southern California. This project includes two 388-MVAr SVC's, which are needed primarily to stabilize power oscillations across the interface. The control system for these SVC's includes some new concepts to accomplish this stabilizing influence. This paper describes the important features of this control system, including the main design considerations. 3 Refs.

[1996] 08A - 41

CONTROL METHOD FOR 50 MVA SELF-COMMUTATED STATIC VAR COMPENSATOR

Suzuki, K.; Yajima, M.; Nohara, M.; Ueda, S.; Toita, H.; Sato, H.

Tokyo Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 864-865

Japanese

Abstract not available.

[1996] 08A - 42

CONTROL METHOD OF DC YARD VOLTAGE FLUCTUATION IN 5 LEVEL OUTPUT SELF-EXCITED VAR COMPENSATOR

Migaki, T.; Sato, K.; Kondo, H.; Fukao, T.

Tokyo Inst of Tech, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol SPC-96, no 1-14, pp 88-98

Japanese

Regarding a method to suppress voltage fluctuation at a dc voltage divider in a VAr compensating system with a five level converter of diode clamp type, a study is made with an ac equivalent circuit. If the potential of the voltage divider is symmetrical with respect to the neutral point, by controlling the charging angle of the converter with respect to the system voltage by feeding back the potential of the dc voltage divider, the potential of the dc voltage divider can be kept constant.

[1996] 08A - 43

CONTROL SCHEME FOR REACTIVE POWER COMPENSATION USING FIXED CAPACITOR AND A SWITCHED INDUCTOR

Venkatesh, C.; Vijaykumar, S.; Sastry, V.V.

Dept of Elec Eng, Indian Inst of Tech, Madras, India

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 3, pp 556-559

This paper presents a new control scheme for a reactive power compensator which uses a fixed capacitor and a thyristor switched inductor. The power factor improvement is achieved by firing the thyristors in such a way that the instantaneous power supplied by the source is always positive. The technique also results in low distortion levels at the source end. The validity of the proposed technique has been studied through SABER and KREAN simulators. A prototype employing the proposed technique was also built and tested for the validity of the concept. 6 Refs.

[1996] 08A - 44

CONTROL STRATEGIES FOR A HYBRID STATIC REACTIVE COMPENSATOR

Manjrekar, M.; Venkataramanan, G.

Montana State Univ, Bozeman, MT, USA

Proceedings, Canadian Conf on Electrical and Computer Engineering (CCECE'96), Calgary, Canada, May 29-29, 1996, vol 2, pp 834-837

This paper presents a hybrid approach for the reactive power compensation. The proposed approach combines a current regulated power electronic converter in series with the conventional static VAr compensator (SVC) connected in shunt to the power line. The current through this power electronic converter is controlled to inject sinusoidal currents of desired compensation level into the power system. The firing angle of the thyristors in SVC is be controlled such that the fundamental voltage developed across it is equal to the line voltage. Consequently, the voltage stress on the power converter is decreased. A controller for this compensation system along with the start up strategy is proposed in the paper. Performance of the proposed approach is evaluated using computer simulations. 6 Refs.

[1998] 08A - 45

CONTROLLING SVCs FOR BETTER MANAGEMENT OF NORTHERN GRID OF INDIA

Gupta, R.P.; Varma, R.K.; Prabhu, S.S.; Sachchidanand; Das, A.K.; Nath, R.; Nayar, S.; Tripathy, A.K.

Indian Inst of Tech, Kanpur, India

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

The objective of the paper is to design controllers of static var compensators (SVC) to ensure system stability and to provide sufficient system damping during the outage of major ac or dc trunk lines in the Northern Region Electricity Board (NREB) system of India. The design methodology ensures that the proposed three SVCs do not adversely interact not only amongst themselves but also with the existing SVC and the dc link. The weakest network state has been determined after conducting various outage studies. Voltage controllers of SVCs have been designed using eigenvalue analysis employing root locus technique and subsequently their performance validated through time domain simulation. It is shown that the three proposed SVCs (70 MVAr capacitive and 35 MVAr inductive) at Panki, Lucknow and Muradabad not only ensure voltage support at critical buses in the network but also are sufficient to retain the system stability with adequate system damping after the outage of Lucknow-Moradabad 400-kV line which is one of the major ac trunk lines. The performance of the three proposed SVCs in improving system damping is compared with two other alternatives of making a critical 400-kV line (Kampur-Ballabhgarh) double circuit or series compensated. The paper also considers the problem of recent incidents of NREB system collapse and shown through static voltage stability studies that just one SVC of enhanced capacity placed at Moradabad will help in avoiding grid collapse.

[1996] 08A - 46

CONVERSION SYSTEMS USING WIND-DRIVEN INDUCTION GENERATORS WITH ELECTRONICALLY CONTROLLED REACTIVE AND ACTIVE POWERS. II. DYNAMICAL ANALYSIS

Dezza, F.C.; Di Gerlando, A.; Perini, R.

Dipt di Elettrotecnica, Politecnico di Milano, Italy

Proceedings, Symp on Power Electronics, Industrial Drives Power Quality, Traction Systems, Capri, Italy, June 5-7, 1996, pp B6-31-38

Some operation aspects of a wind energy conversion system (WECS) based on the use of an autonomous self-excited induction generator are analyzed. The reactive power is regulated by a static VAr compensator and the active power, transferred towards a storage battery by means of a diode bridge, is regulated by a chopper. The design criteria of the capacitors and of the inductors for the harmonic filtering are defined and the control loops of the active and reactive powers are described. The results of some simulations in the time domain are shown, comparing them with the design predictions and analyzing the dynamical behavior of the system.

[1996] 08A - 47

COORDINATED FUZZY LOGIC CONTROL BETWEEN SVC AND PSS TO ENHANCE STABILITY OF POWER SYSTEMS

Kihara, H.; Hiyama, T.; Miyauchi, H.; Ortmeyer, T.H.

Kumamoto Univ, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 116, no 1, January 1996, pp 43-54

This paper presents a new switching control scheme for static var compensator (SVC) using fuzzy logic control rules to enhance the overall stability of electric power systems. In addition, the coordination with power system stabilizers (PSS) is also considered to achieve a wider stable region. An SVC is set on one of the busbars in the transmission system, where the real power flow signal is utilized at the location of the SVC to determine the firing angle of the thyristor switch. The switching control scheme is simple so as not to require heavy computation on the microcomputer-based switching controller. The PSSs are also set on the generators in the study system. Simulation results show the effectiveness of the proposed fuzzy logic switching control scheme for the SVC. The coordination between SVC and PSS is also effective to enlarge the stable region. 13 Refs.

[1996] 08A - 48

COUNTERMEASURE FOR THE VOLTAGE DROP IN AKITA SHINKANSEN

Kawamae, S.; Suzuki, Y.

East Japan Railway Co

Tetsudo Denki Gijutsu Kenkyu Happyokai Ronbunshu (Japan), vol 6, pp 21-25

Japanese

The voltage drop compensation due to the feeding distance extension in the Akita Shinkansen was examined, and outline of a capacitor switching system (TSC) static var compensator (SVC) using the thyristor, and the results of its performance verification test are described. As measures for the voltage drop, the train load current values and calculated value of the lowest overhead line voltage are shown, and the closing method of the TSC system SVC and results of the performance verification test (transient phenomenon and voltage drop compensation effect when closing the capacitor and higher harmonic absorption with the SVC) are explained.

[1996] 08A - 49

DAMPING EFFICIENCY OF SVC AND CSC [POWER SYSTEM CONTROL]

Pastos, D.A.; Vovos, N.A.; Giannakopoulos, G.B.; Lygdis, A.D.

Patras Univ, Greece

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 275-280

The damping capability of controllable shunt capacitors (SVC) and controllable series capacitors (CSC) on the small signal system oscillations is studied and compared and its dependence on characteristic parameters is investigated. Based on small perturbation analysis a method is proposed and a computer program using as input the results of a load flow program has been developed for the calculation of damping capability of controllable compensators and their impact on voltage sensitivity. Also the voltage instability related to load characteristics is briefly studied. 10 Refs.

[1998] 08A - 50

DAMPING ENHANCEMENT BY ROBUST TUNING OF SVC CONTROLLERS IN THE PRESENCE OF LOAD PARAMETERS UNCERTAINTY

Milanovic, J.V.

Univ of Tasmania, Australia

IEEE Trans on Power Delivery, Preprint order number PE-096-PWRS-0-12-1997

The paper explores the influence of power system loads on static var compensator (SVC) damping effectiveness. Equipped with properly tuned additional stabilizers, SVCs have been successfully used for improving the damping of electromechanical oscillations in power systems. The damping improvement is usually achieved through indirect voltage influence through voltage dependent loads. Tuning of an additional compensator stabilizer (ACS) traditionally assumes that loads are statically voltage dependent. However, load parameters are generally uncertain and loads often exhibit some dynamic response. This uncertain dynamic behavior of loads can introduce an additional phase shift between voltage and load response and such can detune the ACS. Examples of detuning effects of dynamic loads as well as robust tuning of ACS are presented and discussed.

[1996] 08A - 51

DESIGN FOR A RELOCATABLE TERTIARY CONNECTED SVC

Horwill, C.; Young, D.J.; Wong, K.T.G.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

Elektron (South Africa), vol 13, no 10, October 1996, pp 19-21

In 1994, the National Grid Company (NGC), UK, began procuring a new kind of static VAr compensator (SVC) which can be connected to the tertiary of any of its supergrid transformers (SGTs) and, if necessary, moved from one site to another to match the changes in VAr demand at various parts of the network. These SVCs which are rated 0/+60 MVAr, are called relocatable SVCs (RSVCs). The authors discuss the specification requirements, design procedures, cooling, and control system for the RSVCs.

[1996] 08A - 52

DESIGN OF A STATIC REACTIVE POWER COMPENSATOR USING FUZZY SLIDING MODE CONTROL

Wang, S-Y.; Hong, C-M.; Liu, C-C.; Yang, W-T.

Dept of Elec Eng, Natl Taiwan Univ, Taipei, Taiwan

Int'l Journal of Control (UK), vol 63, no 2, January 20, 1996, pp 393-413

This paper demonstrates a fuzzy sliding mode control (FSMC) scheme for a static reactive power compensator (static VAr compensator or SVC) to improve the damping of a synchronous generator. A robust sliding regime is derived to guarantee the stability of the proposed FSMC under parameter uncertainties. Two types of FSMC, the fuzzy switching gain compensation and the fuzzy control signal compensation, are recommended to regulate the reactive power of the SVC. A synchronous generator system with the proposed FSMC-SVC has been studied and its dynamic responses are simulated. The results show that the suggested FSMC scheme possesses the advantages of fuzzy control and sliding mode control, e.g. insensitivity to parameter variations and load disturbances. Note that the dynamic performance of the synchronous machine system can be improved dramatically over a wide range of operating conditions. Furthermore, for simplification of practical implementation, the reducing switches (or local feedback) control is adopted. 17 Refs.

[1996] 08A - 53

DEVELOPMENT OF AN INDUSTRIAL LOAD BUS POWER FACTOR REGULATOR BY USING SVC AND PARALLEL PROCESSING OF MICROPROCESSOR

Das, A.; Mukhopadhyay, A.K.

Dept of Appl Phys, Calcutta Univ, India

Journal of the Institution of Engineers, Electrical Engineering Division (India), vol 77, August 1996, pp 94-98

An on-line microprocessor-based digitally-controlled power factor regulator has been developed to regulate the power factor in industrial load bus during running of industry by compensating the reactive power demand by means of a static VAr compensator (SVC). The power factor is regulated by adjusting variable reactance, through controlling the trigger angle of the thyristor connected with SVC. For accurate, sequential and symmetrical triggering control and quick response, parallel processing of two 8085A CPU-based microprocessors, one used as a master processor and the other as a slave, has been taken into consideration. The software developed is such that, at every instant the master processor senses the status of power factor of the load bus and checks the deviation from a pre-set value in the range of 0.9 lagging to unity and informs the slave processor for control action. After receiving the message from its master the slave processor adjusts the triggering angle and helps in maintaining power factor within the recommended value. 3 Refs.

[1996] 08A - 54

DEVELOPMENT OF THREE-PHASE UNBALANCE VOLTAGE FLUCTUATION COMPENSATING SYSTEM USING SELF-COMMUTATED STATIC VAR COMPENSATOR

Takeda, M.; Murakami, S.; Iizuka, A.; Mochinaga, Y.

Mitsubishi Elec Corp, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-D, no 8, August 1996, pp 826-834

Japanese

This paper describes a self-commutated static VAr compensator for suppressing voltage fluctuations caused by an ac electric railway (Shinkansen, or new trunk line). The ac electric railway is a single-phase load with large changes of reactive power and it causes large voltage fluctuations and power unbalances among three phases in the power system. The authors have developed a new voltage fluctuation compensating system using a self-commutated static VAr compensator. This system has the functions of reactive power compensation and negative-phase-sequence current absorption and can suppress rapidly-changing voltage fluctuations and reduce the three-phase power unbalance caused by the ac electric railway, effectively. This compensating system with a capacity of 40 MVA has been put to practical use, for the first time in the world, in 1993. The test results at site show that the system has excellent performance characteristics. Theoretical analysis on the characteristics of voltage fluctuations with or without the compensating system and the evaluation of the test results including the comparison between the theoretical values and measured ones are also reported. 5 Refs.

[1996] 08A - 55

DEVELOPMENT OF VOLTAGE FLUCTUATION COMPENSATING SYSTEM USING A SELF-COMMUTATED TYPE STATIC VAR COMPENSATOR

Takeda, M.; Murakami, S.; Iizuka, A.; Mochinaga, Y.

Mitsubishi Elec Corp, Japan

Pawa Erekutoronikusu Kenkyukai Ronbunshi (Japan), vol 21, no 2, pp 114-123

Japanese

This paper describes a self-commutated type static VAr compensator for suppressing voltage fluctuations caused by an ac electric railway. (Shinkansen, or New trunk line). The ac electric railway is a single-phase load with large changes of reactive power, and causes large voltage fluctuations and power unbalances among three phases. The authors have developed a new voltage fluctuation compensating system using a self-commutated static VAr compensator. This system has functions of both reactive power compensation and negative-sequence current absorption and can suppress the rapidly changing voltage fluctuations caused by an ac electric railway, effectively. The system of 40 MVA has been put into practical use, first in the world, in 1993. The test results at site showed that it has excellent performance characteristics. In this paper, the theoretical analysis on the characteristics of voltage fluctuations with or without the compensating system and the evaluation of the test results are described.

[1996] 08A - 56

DEVELOPMENT TRENDS FOR SVC'S

Stromberg, G.; Thorvaldsson, B.; Rudin, S.

ABB Power Sys, Vasteras, Sweden

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1300-1304

This paper highlights some aspects of modern-day SVC designs. It covers the functional rating concept as well as modern control system design. Asymmetrical voltage control is discussed. A system for station control and monitoring (SCM) is described. Finally two SVC installations, one in the USA and one in Norway are presented. The two SVCs serve as good representatives modern-day technology. 2 Refs.

[1996] 08A - 57

DIGITAL AND REAL TIME STUDIES OF THE ESKOM SVCS

Boshoff, S.; Magg, T.; Bergmann, K.; Schettler, F.

ESKOM, South Africa

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 363-368

Three SVCs were installed in 1994/95 at the Natal Transmission System of the South African utility ESKOM. Their main task is to regulate rapidly the voltage in order to increase the stability of the transmission network. In addition, they are required to exercise VAr control and to reduce existing voltage asymmetry in the network. For this, a special SVC layout was created and a control loop developed.

Verification was done using the ATP (alternative transients program) computer simulation as well as the actual control system in conjunction with an ac/dc analog real-time simulator (TNA). This article describes the task, design concept and verification. 6 Refs.

[1997] 08A - 58

ECONOMIC OPERATION OF A WIND PARK BY VAR COMPENSATORS

Bergmann, K.; Renz, K.; Schettler, F.; Tyll, H.; Weinhold, M.; Soebrink, K.

Siemens AG, Erlangen, Germany

ETZ (Germany), vol 118, no 20, October 1997, pp 28-31

German

Asynchronous generators in wind power systems necessitate dynamic idle current compensation. Static compensators (SVC) provide the required dynamic idle current, keep the voltage at a constant level, prevent transmission losses and, with its fast response, limits excessive voltage increase. This is proved by a European project in the Danish wind farm at Rejsby Hede.

[1997] 08A - 59

EFFECT OF STATIC VAR COMPENSATOR UPON SYNCHRONIZING TORQUE COEFFICIENT

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Cairo Univ, Egypt

Electric Machines and Power Systems, vol 25, no 4, May 1997, pp 371-386

As power systems have increased in size and complexity, and as the number of power ties between different systems has increased, the nature of the system stability has changed. A static var compensator (SVC), constructed by fixed capacitor (FC) and thyristor-controlled reactor (TCR), is designed and implemented to improve the damping of a synchronous generator, as well as controlling the system voltage. The SVC is placed at the generator bus terminal, with the speed and voltage deviation as the feedback signals. In this paper, a formula has been developed showing the effect of SVC upon synchronizing torque coefficient, such that damping is improved and the system voltage is controlled. A simplified analysis of the effect of SVC on the stability of a machine connected to an infinite bus, as well as 21-bus real system is presented. It is observed that the SVC is capable of increasing damping and controlling the system voltage. 19 Refs.

[1996] 08A - 60

ENHANCEMENT OF POWER SYSTEM STABILITY BY CONTROLLABLE SERIES COMPENSATION

Chen, H-J.

Hohai Univ, Nanjing, China

Automation of Electric Power Systems (China), vol 20, no 10, October 1996, pp 14-17, 36

Chinese

This paper presents an output feedback control approach for the control of thyristor-controlled series compensation (TCSC). Both eigenvalue analysis and time domain simulation methods are used to investigate the effectiveness of the approach to improve power system dynamic, steady-state as well as transient stability. Numerical results of a single-machine infinite bus system has shown that the TCSC, if properly controlled, could be very effective in enhancing power system stability.

[1997] 08A - 61

ENHANCEMENT OF STEADY-STATE VOLTAGE STABILITY BY STATIC VAR COMPENSATORS

El-Sadek, M.Z.; Dessouky, M.M.; Mahmoud, G.A.; Rashed, W.I.

Assiut Univ, Egypt

Electric Power Systems Research, vol 43, no 3, December 1997, pp 179-185

Steady-state voltage instability can certainly be enhanced by static VAr compensators which can hold certain node voltages constant and create infinite buses within the system nodes. Static VAr compensator parameters needed for this purpose are found. Controller gains, droop slopes, reference voltages and compensator ratings are determined for maintaining the load node voltages constant irrespective of system loadabilities to values which lead to voltage instabilities. Influence of system equivalent impedances on these parameters is finally discussed. 14 Refs.

[1998] 08A - 62

EXPERIMENTAL INVESTIGATION OF VOLTAGE SAG MITIGATION BY AN ADVANCED STATIC VAR COMPENSATOR

Wang, P.; Jenkins, N.; Bollen, M.H.J.

IEEE PES Winter Meeting, Tampa, FL, 1998, Preprint order number PE-289-PWRD-0-12-1997

A laboratory model of an advanced static VAr compensator (ASVC) was constructed to examine its capability for voltage sag mitigation. In this paper, the main structure of the laboratory ASVC is described briefly. Its mitigation effect on voltage sags of different magnitude is then demonstrated. The influences of its initial operating point, system impedance, and dc capacitance are considered. The behavior of this laboratory ASVC during a phase-angle jump associated with a voltage sag is examined.

[1997] 08A - 63

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) FOR BALANCING ARC FURNACE LOADS

El-Sadek, M.Z.; Dessouky, M.; Mahmoud, G.A.

Assiut Univ, Egypt

Electric Power Systems Research, vol 41, no 3, June 1997, pp 211-218

A flexible ac transmission system (FACTS) is a proposed new technique for balancing unbalanced three-phase arc furnace loads. Although reactances of conductors can be balanced by traditional methods, the method proposed here is a unique method for balancing inevitably unbalanced arc resistances. Compensator controller elements and relations between their variables and the actual firing angles are derived. The influence of furnace load balancing on its characteristics is discussed. The inherent improvement of input power factor to unity is highlighted. 7 Refs.

[1996] 08A - 64

FLICKER COMPENSATION BY ANALYSING THE LOAD POWER

Larsson, T.; Ekstrom, A.

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Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 1, pp 105-109

Power quality is a topic receiving more and more attention. One of the power quality issues is flicker, voltage variations that cause annoying changes in illumination intensity. A major source of flicker is the electric arc furnace. Mitigation by the state-of-the-art technology, in the term of static VAr compensators (SVC), is in many cases not enough. A better understanding of the phenomena and the countermeasures is thus needed. In this paper, the flicker impact from small voltage variations is first theoretically analyzed. A typical system is then simulated with a model of the IEC flicker meter connected to the voltage in the point of common connection. By using an ideal compensator, the reading from the IEC flicker meter (i.e. the Pst value) is reduced from 4.0 to 1.2 when the instantaneous imaginary power of the arc furnace is fully compensated. Further improvement can be obtained compensating parts of the real power ripple. 9 Refs.

[1996] 08A - 65

FORMULA FOR THE EFFECT OF A STATIC VAR COMPENSATOR ON SYNCHRONISING TORQUE COEFFICIENT

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Cairo Univ, Egypt

IEE Proceedings, Generation, Transmission and Distribution (UK), vol 143, no 6, November 1996, pp 582-586

A static VAr compensator (SVC), constructed by a fixed capacitor (FC) and a thyristor-controlled reactor (TCR), is designed and implemented to improve the damping of a synchronous generator, as well as controlling the system voltage. The SVC is placed at the generator bus terminal, with the speed and voltage deviation as the feedback signals. In the paper a formula has been developed showing the effect of SVC on synchronizing torque coefficient, such that damping is improved and the system voltage is controlled. A simplified analysis of the effect of SVC on the stability of a machine connected to an infinite bus, as well as a simplified 21-bus real system, is presented. Results from digital simulation show that the SVC can greatly enhance the damping of the system oscillation caused by disturbance. Also, the voltage profile of the generator is controlled by the SVC. 20 Refs.

[1998] 08A - 66

FUZZY LOGIC CONTROL SCHEME WITH VARIABLE GAIN FOR STATIC VAR COMPENSATOR TO ENHANCE POWER SYSTEM STABILITY

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IEEE Trans on Power Delivery, Preprint order

number PE-375-PWRS-0-2-1998

This paper presents a fuzzy logic (FL) control scheme with variable gain for static VAr compensators (SVC) to enhance power system stability. The proposed control scheme is simple and has low computational requirements, therefore, it is suitable for online implementation using a microcomputer. To control the SVC, only the real power flow signal is utilized at the location of the SVC. Variable gain is proposed to terminate the switching control of the SVC soon after reaching quasi steady state to avoid excessive and unnecessary control action from the SVC. Coordination with power system stabilizer (PSS) is also considered for further enhancement of stability. The performed simulation studies demonstrate the effectiveness of the proposed control scheme.

[1996] 08A - 67

HIGH-SPEED FLICKER AND POWER-FACTOR COMPENSATION

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Dept of Elec Eng, Queen's Univ, Belfast, UK

Proceedings, 6th South African Universities Power Engineering Conf (SAUPEC '96), Witwatersrand, South Africa, January 22-23, 1996, pp 31-34

High-speed reactive compensation has a significant role to play in the correction of flicker and voltage drop in ac systems. The majority of the drop will be due to the reactive component of the current and thus compensation can often solve the problem simply be removing the quadrature component of current. However, if the lines are largely resistive it is possible to restore the voltage to normal by overcompensating during the load periods. To achieve high-speed compensation only thyristors can offer the reliability and power levels which provide an acceptable level of performance and with the direct switching of capacitor banks without transients an economic solution to the problem is possible. Practical results have been shown which illustrate thyristor switched capacitors in two different modes of operation giving virtually transient free operation and providing the compensation required for the pulsating loads. 2 Refs.

[1997] 08A - 68

HOPF BIFURCATION CONTROL IN POWER SYSTEMS WITH STATIC VAR COMPENSATORS

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Dept of Elec. & Computer Eng, Illinois Univ, Urbana, IL, USA

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 5, June 1997, pp 339-347

In this paper we propose a flexible modular approach for incorporating FACTS devices into the small-signal analysis framework of a power system. In particular, static VAr compensators (SVCs) with auxiliary controllers are illustrated. The effect of adding SVCs on the Hopf bifurcation is to increase the dynamic stability range. This is illustrated via the PV curve.

[1996] 08A - 69

HYBRID COMPENSATION STRATEGIES IN NONSINUSOIDAL CONDITIONS

Mattavelli, P.; Tenti, P.; Blundell, R.

Dept of Elec Eng, Univ of Padova, Italy

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 166-174

The paper describes compensation strategies for hybrid compensation systems, including passive filters and thyristor-switched capacitors and inductors. The approach, which is valid even for nonlinear and unbalanced loads fed by unsymmetrical and distorted supply voltages, relays on a load identification by means of parallel passive impedances. With this identification the load currents can be orthogonally decomposed into active balanced, reactive balanced, unbalanced and residual terms. Based on this decomposition, this paper presents strategies for the compensation of reactive and unbalanced terms and for an integrated design of the whole compensating system including thyristor-switched capacitors and inductors, and resonant passive filters. The approach is valid irrespective of the nature of the load and characteristics of the supply. As an application example, the case of an ac arc furnace compensator is considered. 13 Refs.

[1997] 08A - 70

IDENTIFICATION AND MODELING OF A THREE PHASE ARC FURNACE FOR VOLTAGE DISTURBANCE SIMULATION

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Inst de Investigacion Tecnologica, Univ Pontificia Comillas, Madrid, Spain

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1812-1817

This paper presents a new arc furnace model which

copes with the two main voltage disturbances normally associated with arc furnaces: voltage fluctuations; and harmonics. The model is based on the stochastic nature of the electric arc current-voltage characteristic. The model has been estimated from measurements made in two actual electric plants. Although a single-phase model has been normally proposed, this paper develops a three-phase model in order to fully represent the unbalances that are present in real industrial plants and which play a central role in the behavior of compensation devices such as SVCs. The model has been implemented using the SIMULINK environment in order to facilitate later simulation of advanced disturbance control systems. Finally, the simulation results are compared with actual data in order to validate the accuracy of the model.

[1997] 08A - 71

IMPROVE DAMPING CHARACTERISTIC BY USE OF SVC

Ai, X.; Cai, G.; Mu, G.; Chen, Y.; Zhang, X.; Zou, M.

Northeast China Inst of Elec Power Eng, Jilin, China

Power System Technology (China), vol 21, no 1, January 1997, pp 6-8, 11

Chinese

The poor damping characteristic during transient processes is the main character of a long distance high power transmission system. In this paper, it is theoretically proved that the damping characteristic of a power system can be improved by use of SVC and that using frequency as the control signal the damping effect could be the best. The effect of improving system damping characteristic by use of SVC is tested and verified in the simulation of a real long distance 500-kV transmission system.

[1996] 08A - 72

IMPROVING THE ECONOMIC COMPETITIVENESS OF SMALL-LOAD LONG-DISTANCE AC TRANSMISSION SYSTEMS BY THE USE OF STATIC COMPENSATORS AT THE RECEIVING END

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European Trans on Electrical Power (Germany), vol 6, no 4, July-August 1996, pp 245-252

To supply small loads located very far from low-cost generation areas local diesel generation or transmission from the generation areas to loads are the alternatives to be considered. The competitiveness of the latter solution can be improved by the use of static devices, able to compensate active and/or reactive powers, installed in suitable locations of the transmission system. In this paper the possibility of installing at the receiving end either a static VAr compensator (SVC) or a static watt-VAr compensator (SWVC) is discussed. A possible operating strategy is proposed for both devices, the loading limits of various options are determined, and an economical comparison of the schemes without compensators and with SVC or SWVC is also carried out in a practical case of application. 9 Refs.

[1996] 08A - 73

INTEGRATED MEDIUM VOLTAGE (2300V-6900V) AC DRIVE/VAR COMPENSATOR

Zargari, N.R.; Rizzo, S.

Allen Bradley Inc, Cambridge, Ontario, Canada

Proceedings, Canadian Conf on Electrical and Computer Engineering (CCECE'96), Calgary, Canada, May 29-29, 1996, vol 2, pp 627-630

This paper proposes an integrated ac drive/VAr compensator system which uses information available from the ac drive control boards to generate the reference waveforms for the SVC, hence achieving faster response times to transients. The paper also investigates the device ratings required for the proposed medium voltage ac drive/SVC system and means of connection to ac mains. Various front end rectifiers (different levels of VAr/harmonic compensation) are studied and their effects on the switch ratings are compared. Simulation results are obtained to confirm theoretical derivations. 4 Refs.

[1998] 08A - 74

INTERACTION ANALYSIS MODEL FOR TRANSMISSION STATIC COMPENSATOR WITH EMTP

Han, B.M.; Karady, G.G.; Park, J.K.; Moon, S.I.

Myongji Univ, South Korea

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

This paper describes controller design for the static compensator with mathematical analyses, and simulation model development with the EMTP to analyze the dynamic interaction with the ac transmission system. The main circuit was modeled by

a 12-pulse voltage source inverter with ideal gate turn-off switches, and the signal generation and control circuit was modeled using the TACS in the EMTP. The effects of increasing transmission capacity, damping low-frequency oscillation, and improving transient stability were verified with the model developed, assuming that the static condenser is connected to the 154-kV line for a typical one-machine-infinite-bus transmission system.

[1997] 08A - 75

MITIGATION OF VOLTAGE FLUCTUATIONS WITH AN ADAPTIVE VAR COMPENSATOR (AVC)

Chan, F.; Castanheira, A.

Transalta Utilities Corp, Calgary, Canada

Proceedings, Electricity '97 Conf: New Opportunities Ahead, Vancouver, Canada, April 20-24, 1997, vol 3, pp 1-3

The installation of an Adaptive Var Compensator (AVC) to remedy a voltage flicker problem at the TIMEU sawmill in Fort Assiniboine, Alberta, was described. The TIMEU sawmill is a 980-kVA load at the end of a 25-kV feeder. Two older style J bar type saws, each driven by a 200 Hp motor, are used to operate the wood processing services. The sawing and chipping process resulted in the generation of significant voltage flicker on the 25-kV distribution system. The AVC provided cycle per cycle reactive compensation and voltage support; no further complaints of flicker were received.

[1996] 08A - 76

MODEL OF STATIC VAR COMPENSATOR USING SELF-COMMUTATED INVERTERS

Uchida, K.; Kato, M.; Morioka, Y.; Hirose, M.; Miyamoto, J.; Nakachi, Y.; Asada, M.; Futatsuki, K.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 250-251

Japanese

Abstract not available.

[1996] 08A - 77

MODELING OF A STATIC VAR COMPENSATOR FOR REACTIVE COMPENSATION

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Dept of Elec Eng & Computer Sci, Evansville Univ, Evansville, IN, USA

Proceedings, Int'l Conf on Modeling and Simulation (IASTED/ISMM) Pittsburgh, PA, April 25-27, 1996, pp 392-393

Semiconductor technology has made it possible to apply high power converters to electric drives for hundreds of applications in ac and dc systems. There has also been an increased use of static VAr compensators to produce volt ampere reactive for industrial systems due to their efficiency and low cost. Both set the stage for problems and uncontrolled harmonic resonances on power systems. This paper describes an example case for reactive compensation at converters. 4 Refs

[1996] 08A - 78

MODELING OF CONVENTIONAL AND ADVANCED STATIC VAR COMPENSATORS IN AN ELECTROMAGNETIC TRANSIENT SIMULATION PROGRAM

Fernando, I.T.; Kwasnicki, W.T.; Gole, A.M.

Proceedings, Int'l Symp on Modern Electric Power Systems, Wroclaw, Poland, vol 1, no 1, September 26-27, 1996, pp 60-70

Abstract not available.

[1997] 08A - 79

MODELING OF ELECTRIC ARC FURNACE FOR HARMONIC AND FLICKER ASSESSMENT. A CASE STUDY

Rathna, G.N.; Shenoy, U.J.; Parthasarathy, K.; Nagaraja, R.; Hota, S.C.; Jaya, H.

CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol III-7, pp 56f

Electric arc furnaces are widely used in steel the steel industry. Two basic problems existing with electric arc furnaces are they cause voltage flicker and introduce harmonics into the system. This paper proposes a methodology to incorporate the arc furnace model in transient stability and electromagnetic transient programs. The model incorporation in transient stability studies helps to find the performance of the system for varying load, steady-state and transient voltage dips when electrodes are short circuited from open circuit conditions. The generator automatic voltage regulator (AVR) and SVC response to arc furnace load are presented and based on the results,

SVC sizing can be determined. Arc furnace flicker severity and harmonic problems are best assessed by modeling it in an electromagnetic transient program (EMTP). The paper proposes the modeling technique of arc furnace in an EMTP. Based on the proposed technique, case studies are presented to ascertain the effect of flicker severity at point of common coupling (PCC). From the case studies conducted, it is observed that if the generation exists at arc furnace bus in a plant with captive generation, the SVC size can be reduced. The paper also proposes a DSP (discrete signal processor)-based meter to measure the flicker severity. Flicker meter performance is simulated using the results obtained from the EMTP study.

[1996] 08A - 80

MULTI-MODULE PWM SWITCHED-REACTOR-BASED STATIC VAR COMPENSATOR

Lopes, L.A.C.; Joos, G.; Ooi, B-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 515-520

This paper presents a variable reactance type static VAr compensator (SVC) which employs force-commutated switches as well as thyristors. The proposed compensator employs thyristor-switched capacitors (TSC) and a fixed capacitor bank to control in steps the amount of reactive power generated. Fine adjustment of the reactive power generated and also the reactive power absorbed by the SVC are obtained with N modules of a new 4-switch (force-commutated) PWM controllable reactor. These are controlled with phase shifted carriers in order to achieve harmonic cancellation. The features of this multi-module PWM SVC are analyzed using switching functions and confirmed with simulation results. 10 Refs.

[1997] 08A - 81

NEURAL NETWORK BASED SELF-TUNING INTERNAL MODEL CONTROL FOR SVC

Peng, J.; Wang, Y.; Huang, C.

Huan Univ, Changsha, China

Power System Technology (China), vol 21, no 11, November 1997, pp 32-36

Chinese

A neural network-based self-tuning internal model controller for SVC is presented in this paper. Three-layer BP neural network models are used for the internal model and the reverse model of the controlled system in the controller. The controller needs no models of SVC and power network and is of good robustness as well as control accuracy.

[1996] 08A - 82

NEW CONTROL METHOD PREVENTING TRANSFORMER DC MAGNETIZATION FOR VOLTAGE SOURCE SELF-COMMUTATED CONVERTERS

Nakajima, T.; Suzuki, K.-I.; Yajima, M.; Kawakami, N.; Tanomura, K.-I.; Irokawa, S.

Tokyo Elec Power Co, Inc, Yokohama, Japan

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1522-1528

A dc component contained in an output of a voltage source self-commutated converter makes a converter transformer to be dc-magnetized, in the worst case causing an overcurrent due to saturation. We experienced the dc-magnetization of the converter transformer of a 50-MVA self-commutated SVC installed in the Shinshinano substation of Tokyo Electric Power Company when system disturbances occurred by energizing of an adjacent large capacity transformer. After analyzing the problem, a novel dc magnetization preventing control was developed that makes a fast flux correction according to the voltage dc component detected in the converter output. This method was applied to the 50-MVA self-commutated SVC and produced satisfactory operation results. 7 Refs.

[1996] 08A - 83

NONLINEAR DYNAMICS AND SWITCHING TIME BIFURCATIONS OF A THYRISTOR CONTROLLED REACTOR CIRCUIT

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Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Circuits and Systems I: Fundamental Theory and Applications, vol 43, no 12, December 1996, pp 1001-1006

We study a thyristor-controlled reactor circuit used for static VAr control of utility electric power systems. The circuit exhibits switching times which jump or bifurcate as fold or transcritical bifurcations. We study the nonlinear dynamics of the circuit using a Poincare map and demonstrate that the Poincare map has discontinuities and is not invertible. The circuit has multiple attractors. Moreover, the basin boundary separating the basins of attraction intersects with the

Poincare map discontinuities. These novel properties illustrate some of the basic features of dynamical systems theory for thyristor switching circuits. 15 Refs.

[1997] 08A - 84

NOVEL HIGH POWER SELF-COMMUTATED STATIC VAR COMPENSATOR FOR LOAD COMPENSATION

Chatterjee, K.; Fernandes, B.G.; Dubey, G.K.

Indian Inst of Tech, Kanpur, India

Proceedings, 2nd Int'l IEEE Conf on Power Electronics and Drive Systems (PEDS), Singapore, May 26-29, 1997, vol 1, pp 65-71

A novel high power self-commutated static VAr compensator for load compensation is proposed. The harmonics are eliminated by combining low frequency high power devices and high frequency low power devices. A modified control strategy is also proposed for applications involving high and faster rate of change in VAr demand. Detailed simulation studies for single-phase and three-phase topologies are presented. 18 Refs.

[1996] 08A - 85

OPTIMAL REACTIVE POWER DISPATCH ALGORITHM FOR VOLTAGE STABILITY IMPROVEMENT

Thukaram, B.D.; Parthasarathy, K.

Dept of Elec Eng, Indian Inst of Sci, Bangalore, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 18, no 7, October 1996, pp 461-468

This paper presents an algorithm for monitoring and improving voltage stability in power systems for a base case and credible contingency conditions. The monitoring methodology proposed here is based on the L-index of load buses. This index uses information on a normal load flow and is in the range of 0 (no load of system) to 1 (voltage collapse). The control against voltage collapse is based on minimizing the stem of the squares of L-indices for a given system operating condition. The proposed algorithm gives an optimal setting of various control devices like generator excitation, switchable VAr compensators and OLTC transformers. The algorithm also identifies critical OLTCs that should be made manual to avoid possible voltage instability due to their operation based on voltage improvement criteria under peak load conditions. The proposed algorithm has been tested under simulated conditions on a number of real Indian power systems and the results obtained for a 24-node EHV Indian power network and for a modified IEEE 30-bus system are included for illustration purposes. 15 Refs.

[1996] 08A - 86

OPTIMIZING THE INDUSTRIAL SYSTEM UTILITY INTERFACE BY MEANS OF AC/DC BOOST CONVERTERS

Carpinelli, G.; Marino, P.; Testa, A.; Vasca, F.

Dipt di Ingegneria Ind, Cassino Univ, Italy

Proceedings, IEEE4th Conf in Africa (AFRICON'96), Stellenbosch, South Africa, September 24-27, 1996, vol 1, pp 473-478

The problem of voltage disturbance compensation in an industrial power system is considered. Reference is made to a case-study where a transformer feeds an ac/dc boost power converter, a capacitor VAr compensator and a balanced ac load. The transformer supplying voltages are supposed to be affected by flicker, slow variations and unbalance. The proposed perturbation compensation consists in suitably controlling the boost power converter which so acts as both a rectifier and static VAr compensator. The power converter sizing is discussed and the controller design presented. The effectiveness of the proposed compensation is shown via simulations obtained by means of the SIMULINK implementation of the power system dynamic model. 6 Refs.

[1997] 08A - 87

POWER FACTOR CORRECTION USING ADAPTIVE VAR COMPENSATOR

Wilson, E.P.; Jefferson, T.

Baltimore Gas & Elec Co, MD, USA

Proceedings, 10th Int'l Power Quality '97 Power Value '97 Conf, Baltimore, MD, September 9-12, 1997, pp 178-187

A power factor correction system employing adaptive VAr compensation (AVC) technology was successfully installed to handle the dynamic reactive load at the Seagirt Marine Terminal in Baltimore, USA. Using solid-state commutation to achieve cycle by cycle response, the poor power factor caused by variable speed direct current (dc)motor drives powering the terminal's crane motors was improved from less than 40% to greater than 98.5% during periods of peak demand.

[1997] 08A - 88

POWER FACTOR CORRECTION SYSTEM BY MEANS OF CONTINUOUS MODULATION. FINAL REPORT

Zabar, Z.; Kaish, N.

International Electronic Technology Corp, Farmingdale, NY, USA

DOE/CE/15523-T4, US Department of Energy, Washington, DC, 1997, 25 pp

The novel power factor correction system described here is an improvement over existing ones because it reduces the VAr's with no switching transients, continuously; i.e., without the customary VAr-jumps that result from the usual capacitor-switchings. Work on this concept was begun in the early 1980's by Mr. Frederick Rohatyn. The invention was granted a U.S. Patent (No. 4,672,298) in June 1987. Mr. Rohatyn continued his experiments for four year's following issuance of the patent. During that time, he built several prototypes in order to develop a practical realization of his idea. The invention was evaluated technically by the U.S. Department of Commerce, National Institute of Standards and Technology (NIST), resulting in very favorable recommendations. In the invention, the compensating reactive power is generated by a linear capacitor. A transformer is connected in series with the capacitor. The voltage applied to the capacitor terminals can be varied from zero to a maximum level. This is done by supplying the primary winding of the series transformer from a variable auto-transformer. This feature permits continuous variation of the reactive power generated by the capacitor. Based on the results of this study, the industrial partner intends to develop a line of production models and market them to power management companies worldwide.

[1996] 08A - 89

POWER SYSTEM DISTURBANCE MONITORING

O'Shea, P.; Palmer, E.

Royal Melbourne Inst of Tech, Melbourne, Australia

Proceedings, 4th Intl Symp on Signal Processing and its Applications, Gold Coast, Australia, August 25-30, 1996, vol 1, pp 282-285

The stability enhancement of power systems and the early detection of unstable electromechanical oscillations between generators is something which has been of increasing concern to power system engineers in recent years. Much research has focused on the development and control of thyristor-based stability enhancement devices such as Controlled Series Capacitors (CSC)s and static VAr compensators. This paper considers the use of generator angles after a fault or disturbance as the input signals for these control devices. Typically, the angles (or the angle derivatives - the instantaneous frequencies) are not measured directly, but are inferred from the instantaneous power at the substation. Since there is a complicated non-linear relationship between the power and the frequency, some bias is incurred in the measurement. This paper proposes instead that the angle and or instantaneous frequency be obtained directly via an analytic signal readily constructed from the three-phase output of the power system. The paper also proposes enhancements for some of the currently employed signal analysis techniques, and a new technique based on an extension of Thompson's harmonic line test. 11 Refs.

[1996] 08A - 90

POWER SYSTEM OPERATION STABILIZATION BY CONTROLLED ELECTRICAL BRAKING

Zelenokhat, N.I.; Barghuti, K.S.; Bha, T.S.; Negash, G.A.

Applied Energy: Russian Journal of Fuel, Power and Heat Systems (Energetika), vol 34, no 6, 1996, pp 113-123

It is suggested to control the intensity of electromechanical transient process damping using a static VAr compensator and generator automatic excitation control. The approach to the synthesis of control algorithms is given. The efficiency of power system operation stabilization is investigated by computer simulation. 9 Refs.

[1996] 08A - 91

POWER SYSTEM STABILITY IMPROVEMENT BY USE OF STATIC POWER CONVERTERS

Kouadri, B.; Draou, A.

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 3, pp 526-530

This paper deals with a performance comparison using digital simulation between a classical compensator and that of self commutated and continuous control and describes different functions applicable to static VAr compensators. Some simulation results are included to show the effectiveness of the thyristor-controlled compensator as compared with the classical one. A section is dedicated to the emphasis of the improvement of dynamic performance of a power system by the use of current control feedback loop. 5 Refs.

[1997] 08A - 92

POWER SYSTEM VOLTAGE IMPROVEMENT FOR GRID-CONNECTION OPERATION OF WIND POWER GENERATION SYSTEM BY APPLYING SVC

Nakashima, H.; Komatsu, M.; Nishiura, S.

Toyamamatsushitadenki

Denki Gakkai Seishiki Kenkyukai Shiryo (Japan), vol 97, no 22-25, pp 11-16

Japanese

The thyristor-controlled SVC(Static Voltage Compensator or static VAr compensator) can improve a power system voltage by controlling line reactive power. Recently SVC is apply for grid-connection operation of a wind power generation system. In this paper, we report response of 6.6-kV power system voltage improvement by SVC, and describe other characteristics of a wind power generation system with applying SVC.

[1998] 08A - 93

POWER SYSTEMS TRANSIENT STABILITY ENHANCEMENT USING STATIC VAR COMPENSATORS

Graham, J.L., Jr.; Feliachi, A.

Fairchild Controls Corp, Frederick, MD, USA

Proceedings, 30th Southeastern Symp on System Theory, Morgantown, WV, March 8-10, 1998, pp 233-237

Electrical power demand continues to grow, but because of cost, and growing environmental concerns construction of new transmission lines is not keeping up with this trend. Therefore, power utilities are forced to load existing power lines to their thermal limits by improving on the transient stability limit. Several devices are used for this purpose; amongst them are static Var compensators (SVC), which are the topic of this paper. Specifically, this paper describes a method to (1) select the best location where to place SVCs, (2) identify the best supplementary signals to use for stability enhancement, and (3) tune the controller parameters to dampen inter-area oscillations. The algorithm is tested on a system developed by Ontario Hydro and used extensively in the literature to prove the effectiveness of proposed methodology. The software used in this study is based on an EPRI package (PSAPAC) and MATLAB.

[1996] 08A - 94

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. NISSIN'S POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT

Kondo, O.; Ogihara, Y.

Nissin Elec Co, Ltd, Japan

Nisshin Denki Giho (Japan), vol 41, no 3, pp 3-7

Japanese

Since the first installation of the thyristor phase-controlled reactor (TCR)-type static VAr compensator (SVC) in 1973, we NISSIN Electric has been keeping the leading manufacture of the SVC in Japan. Following that success. our development efforts have been concentrated on the realization of the power-electronics-based products for power quality enhancement in power supply network. We will describe here the progress of NISSIN's power-electronics application such as thyristor-based SVC (TQC), inverter-based SVC (VSVC), active harmonic filter (AF), and series voltage compensator for voltage dips (UNISAFE), which all features high performance and high efficiency.

[1996] 08A - 95

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. APPLICATION OF SVC (STATIC VAR COMPENSATOR) TO AC ELECTRIC RAILWAY SYSTEM

Mogi, K.; Miyata, T.; Masuda, T.; Nakamura, T.

Nissin Elec Co, Ltd, Japan

Nisshin Denki Giho (Japan), vol 41, no 3, pp 8-22

Japanese

AC Electric Railway System in Japan receives it's power from three-phase transmission system, and electric cars arc moving, fluctuating single-phase loads and moreover the generator of higher-harmonic currents. This means the difficulty in maintaining power quality in the systems. Conventionally, series capacitors, parallel capacitors, and so on arc adopted to improve power quality. But this conventional equipment proved its technical limit of improving quality to the growing traction load capacity. Recently, installation of SVCs are increasing to replace conventional equipment. This paper describes the application of SVCs to the ac electric railway systems, characteristics of each SVC systems and some experience and operational results of SVC.

[1997] 08A - 96

PRESENT AND FUTURE FLICKER MITIGATION TECHNIQUES

Poumarede, C.; Lombard, X.; Therond, P.G.; Saadate, S.; Zouiti, M.; Ekstrom, A.; Larsson, T.

Electricite de France

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol V-2, pp 13f

In a context where power quality has become a major point of interest for utilities, the installation of loads generating voltage distortions, such as arc furnaces, is a technical challenge worth picking up. Electricite de France (EDF) established a long time ago partnerships with steel manufacturers. In recent years, as the world competition is more acute, EDF has reinforced its action, offering its electrical knowledge to propose arrangements which improve the steel plant competitiveness without spoiling the electrical power quality for the other customers in the neighborhood. To provide improved services, EDF is leading a research program on flicker mitigation techniques, in collaboration with universities and manufacturers. The first point of this program concerns both the optimized use of classical techniques (static VAr compensator, series reactance, etc.) and some investigations on the coming ones (STATCOM). The second point deals with the innovative approach to the problem, consisting in the operation of devices mitigating flicker through active power compensation. Series compensators appear to be very promising from technical and economical point of view. This paper describes, for ac furnaces, how the flicker mitigation is improved by these techniques, including validation through digital models.

[1996] 08A - 97

PREVENTION OF VOLTAGE INSTABILITY OR COLLAPSE BY STATIC VAR COMPENSATORS

Shikoana, V.; Darie, S.I.

Dept of Elec Eng, Cape Town Univ, Rondebosch, South Africa

Proceedings, 6th South African Universities Power Engineering Conf (SAUPEC '96), Witwatersrand, South Africa, January 22-23, 1996, pp 169-172

Static VAr compensators (SVC) are an established device for meeting reactive power requirements in transmission, distribution and industrial power systems. This paper analyses the application of SVC to prevent transient voltage instability that may lead to voltage collapse. Analysis is supported by time simulations illustrating the effect of disturbances on the power system with and without SVC. The results show that without SVC, voltage instability occurs and with SVC, transient voltage instabilities are eliminated and the load voltage is maintained near the rated value. The possibility of replacing the SVC with a breaker switched capacitor is also investigated. 8 Refs.

[1997] 08A - 98

PROPER SELECTION OF STATIC VAR COMPENSATOR CONFIGURATION FOR INDUSTRIAL APPLICATION

Biswas, P.L.

ABB Ltd, Bangalore, India

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol VI-5, pp 43f

Thyristor-controlled reactor (TCR) and thyristor-switched capacitor (TSC) are used in static VAr compensation (SVC) since several years. In SVC applications, harmonics are encountered in the network basically from two sources, one being the load and the other the TCR. Harmonics generated by load can be reduced by use of filters, but harmonics generated by TCR can also be reduced by adopting different configurations. This paper mainly describes the different schemes of TCR and TSC combination by which the total network harmonics and losses can be reduced. Apart from the different types of TCR configuration, this paper also describes various types of dynamic loads which are under fixed compensation and suggested suitable TCR configuration to convert the fixed compensation into a dynamic compensation.

[1996] 08A - 99

Deleted

[1996] 08A - 100

RAPIDLY VARIABLE PHASE CONTROL METHOD OF CAPACITOR CURRENTS

Ogawa, M.

Toyama Natl College of Tech, Toyama, Japan

Denki Gakkai Ronbunshi, D (Trans of the Institute of Electrical Engineers of Japan. Industry Applications), vol 116, no 4, March 20, 1996, pp 390-396

Japanese

At present, thyristor-controlled reactor (TCR) method that carries out equivalent controls by the phase control

of the reactor attached in parallel to the capacitor, and the thyristor-switched capacitor (TCS) method in which capacitor charged at normal wave high potential controls the turn-off by appropriate combinations of various back structures, and each of these methods are used independently or are used in combination as phase control methods of capacitor currents. These methods are improved from both simplicity and economic point of view. However, the power loss of the parallel reactor with same capacity as that of capacitor or direct reactor for preventing high pulses can not be neglected. Further, reactive power compensator effect against load current was low. Therefore, operation characteristics of basic circuits, that can achieve the phase control of capacitor currents using self-turn-off devices in order to develop phase control method easily by using circuit system that is able to carry out continuous control of capacitor current using self-turn-off devices whose development towards large capacity is significant, were studied. 10 refs., 15 figs.

[1997] 08A - 101

REACTIVE POWER COMPENSATION FOR ROLLING MILLS

Vidhya, M.K.; Sinha, V.P.

ABB Ltd, Bangalore, India

CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol II-7, pp 67ff

In the modern industrial era the need for metals in various shapes and sizes, like sheets, rods, bars, etc., are well known. Rolling is one of the principal methods of deformation of metals, accomplished by applying mechanical forces to metal surface. The modern rolling mill employs variable speed ac and or dc drives using thyristor converters for the process of thickness reduction and conveying. The converter loads the supply system with reactive power and harmonic currents. A careful network analysis is required before installing reactive power compensation equipment. This paper briefly analyses the load characteristic of rolling mills and various reactive power compensation solutions. Case studies indicating the performance obtained with different reactive power compensation solutions are also covered.

[1998] 08A - 102

RELOCATION OF FACTS DEVICES. THE ZIMBANE EXPERIENCE

Billingham, C.; McLaren, R.; Boshoff, J.; Boshoff, S.

ESKOM, South Africa

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

This paper reflects the power network problems being experienced in the Eastern Cape region with specific reference to the system in and around Umtata, and the novel decision taken to relocate a static VAr compensator from Buffalo substation to Zimbane substation to alleviate these problems. Reference to the possible utilization of various other remedial measures is discussed, as well as the specific technological and financial risks associated with the relocation of the FACTS device. The challenges of physically decommissioning and recommissioning the SVC is also described.

[1997] 08A - 103

RETAINING RING FAILURE AT COMANCHE UNIT 2: INFLUENCES AND INTERACTIONS OF THE ELECTRIC SYSTEM

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EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-106640-V2, April 1997, vol 2, 37 pp

Computer simulations of Public Service Company of Colorado's Comanche Station replicated electrical and electro-mechanical signals on two fossil-fired synchronous generators to determine the cause of a retaining ring failure. The simulations verified that a unique combination of mechanical resonance and the frequency of unstable static VAr flicker compensator (SVFC) oscillation was the cause of the failure.

[1997] 08A - 104

SELF-COMMUTATED SVC WITH COMPENSATION OF HARMONIC AND NEGATIVE-PHASE-SEQUENCE CURRENTS USING DIGITAL CONTROL SYSTEM

Kishibe, H.; Yoshioka, Y.; Konishi, S.

Tohoku Elec Power Co, Inc, Sendai, Japan

Proceedings, 32nd IEEE Industry Applications Conf, New Orleans, LA, October 5-9, 1997, vol 2, pp 1479-1486

To improve the operating ability of future transmission systems and to prevent the inflow of harmonic currents and negative-phase-sequence current, the authors have developed a self-commutated static VAr compensator (SVC) with a digital control. For the control system to

realize superior accuracy, high performance functions and easy maintenance, a Direct Digital Control system (DDC system) is used. The DDC system is composed of multiple CPUs and DSPs. In a preliminary verification before installing the proposed SVC in the power system, the authors verified the compensating function of the proposed SVC with a mini-model and an analog-simulator. The results of the tests and simulations with the mini-model and the analog-simulator confirmed that the proposed SVC could sufficiently compensate for voltage fluctuation and the inflow of harmonic currents and negative-phase-sequence current. Therefore, the effectiveness of compensation with the DDC system was confirmed. 3 Refs.

[1996] 08A - 105

SHUNT CONTROLLED REACTOR APPLIED IN SUPPRESSING THE CLOSING OVERVOLTAGE

Liu, H.; Yin, Z-D.; Chen, W-X.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 670-673

This paper introduces a new type of shunt-controlled reactor and studies its ability of suppressing the closing overvoltage which is the most serious in the high-voltage transmission system. We first describe the working principle of it, and then the effect and mechanism of closing overvoltage suppression by the reactor are analyzed based on a single-phase-controlled reactor. 1 Ref.

[1997] 08A - 106

SIMULATION OF UNIFIED STATIC VAR COMPENSATOR AND POWER SYSTEM STABILIZER FOR ARRESTING SUBSYNCHRONOUS RESONANCE

Khaparde, S.A.; Krishna, V.

Indian Inst of Tech, Bombay, India

Proceedings, 20th IEEE Int'l Conf on Power Industry Computer Applications, Columbus, OH, May 11-16, 1997, pp 302-308 (Preprint order number PE-183-PWRS-16-09-1997)

In the literature, co-ordination of static VAr compensator (SVC) and Power System Stabilizer (PSS) using generator speed deviation or modal speeds as stabilizing signals is shown to damp the system oscillations. Though such schemes are able to damp the SSR modes for small disturbances, they are unable to damp transient SSR due to large disturbances. Here in this report improvement in the control aspect of the SVC at the midpoint of the transmission line is suggested. This scheme attempts different auxiliary signals that include line current, computed internal frequency, bus angle deviations. A system of configuration similar to IEEE First Benchmark Model is considered, eigen value analysis has been carried out, and results indicate that bus angle deviation signal as auxiliary control signal for SVC was able to damp most of the modes leaving some of them still oscillatory. The main feature of the proposed work is to use combination of deviation in speed and electrical power output of the generator as input signals to PSS which operates simultaneously along with SVC. Such simultaneous PSS and SVC scheme is found to improve the damping under large disturbances i.e. the growth of system oscillations is arrested. The simulations are carried out on PSCAD. The efficacy of controllers to damp SSR under steady-state and faulted conditions where one of the torsional modes gets excited is presented and discussed. 14 Refs.

[1996] 08A - 107

SLIDING MODE CONTROL OF A STATIC VAR CONTROLLER FOR SYNCHRONOUS GENERATOR STABILIZATION

Dash, P.K.; Sahoo, N.C.; Elangovan, S.; Liew, A.C.

Regional Eng College, Rourkela, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 18, no 1, January 1996, pp 55-64

The paper deals with the design and evaluation of a variable-structure stabilizer for static VAr compensators using a sliding mode control technique. The static VAr system plays an important role as a stability aid for small and large signal transient disturbances in an interconnected power system. A systematic procedure for selection of switching hyperplanes in the design of variable-structure controllers is developed by using a geometric approach known as projector theory. The sliding mode control of static VAr controllers improves the transient response of the power system and provides significant damping to the electromechanical oscillations of the synchronous generator. Computer simulation results for a typical power system shows the effectiveness of a VSS static VAr stabilizer. 9 Refs.

[1997] 08A - 108

STATIC VAR COMPENSATORS FOR DAMPING POWER SYSTEM OSCILLATIONS AND

ENHANCING TRANSMISSION CAPABILITY OVER LONG INTERCONNECTIONS

Hammons, T.J.; Wong, Y.P.; Kacejko, P.A.

Univ of Glasgow, UK

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 25-28

This paper makes an in-depth study of the literature on damping power system electro-mechanical oscillations using controllable shunt capacitors together with controllable series compensators (series capacitors and phase shifters) in enhancing transmission capability of long distance transmission schemes. It then briefly examines damping of power system electro-mechanical oscillations using controllable shunt capacitors for a modified multi-machine CIGRE benchmark system where alternative devices are employed to enhance transient power system response. In these studies, controllable shunt capacitors are located either at a busbar close to a predominant system load or close to a long transmission circuit where transmission capability is to be enhanced. The paper provides an insight into understanding the basic characteristics of damping effects of the studied devices in a typical multi-machine power system to which the device is applied. 27 Refs.

[1996] 08A - 109

STATIC VAR COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATION. PART I: THEORETICAL ANALYSIS

Wang, H-F.; Li, N-H.; Chen, H.; Tang, G-Q.

Southeast Univ, Nanjing, China

Proceedings of the Chinese Society of Electrical Engineering (Zhongguo Dianji Gongcheng Xuebao), vol 16, no 3, May 1996, pp 190-195

Chinese

In this paper, an extended Phillips-Heffron model of a power system with static VAr compensator (SVC) was established. On the basis of this model, some basic issues, such as the condition for the SVC to provide positive damping to the power system, the influence of control strength of the SVC voltage and damping control, operating conditions and parameters of the power system on SVC capability of supplying damping to the power system, the best location of SVC damping control, were investigated by detailed theoretical analysis. The concept of ineffective-point of SVC damping control was proposed in the paper and the cause of its existence was discussed. All the analytical conclusions have been confirmed by the results of eigenvalue calculation and non-linear simulation of example power systems, which are presented in the second part of the paper. 12 Refs.

[1996] 08A - 110

STATIC VAR COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATION. PART II: CASE STUDY

Wang, H-F.; Li, N-H.; Chen, H.; Tang, G-Q.

Southeast Univ, Nanjing, China

Proceedings of the Chinese Society of Electrical Engineering (Zhongguo Dianji Gongcheng Xuebao), vol 16, no 3, May 1996, pp 196-200

Chinese

In this paper, the detailed numerical calculation and simulation for the power systems installed with SVC damping control was carried out. The results obtained confirm the analytical conclusions presented in the first part of the paper. 7 Refs.

[1996] 08A - 111

STATIC VAR SYSTEM AUXILIARY CONTROLLERS FOR TRANSIENT STABILITY IMPROVEMENT OF POWER SYSTEMS

Kumar, N.; Dave, M.P.

Dept of Elec Eng, Univ of Roorkee, India

Electric Machines and Power Systems, vol 24, no 2, 1996, pp 171-187

The paper presents a comparative performance evaluation of SVS auxiliary controllers for transient stability enhancement of long transmission lines over a wide operating range. The SVS has been considered located at the middle of the transmission line. The application of the auxiliary controllers considerably enhances the system damping and unstable system modes are stabilized. A new controller, namely Combined Reactive Power and Frequency (C.R.P.F.) auxiliary controller, has been developed for the SVS located at the middle of the transmission line. To illustrate the comparative effectiveness of the auxiliary controllers under disturbance condition, a digital computer simulation study has been performed. 7 Refs.

[1998] 08A - 112

STUDIES ON VIPI BASED CONTROL METHODS FOR IMPROVING VOLTAGE STABILITY

Nanba, M.; Huang, Y.; Kai, T.; Iwamoto, S.

Waseda Univ, Tokyo, Japan

Int'l Journal of Electrical Power & Energy Systems (UK), vol 20, no 2, February 1998, pp 141-146

Based on the concept of voltage instability proximity index (VIPI) proposed by Y. Tamura et al. (1988), this paper develops two control methods for improving voltage stability. The first method maximizes the value of VIPI by using a successive quadratic programming (SQP) method to find the optimal controls under various system conditions. The second determines the controls needed to maintain the specified threshold value, based on the sensitivities of VIPI with respect to control variables. The controllers used in these methods are transformer tap changers, static capacitors, SVCs and generator terminal voltages. The proposed methods have been tested for a 6-bus power system and successful results have been obtained.

[1996] 08A - 113

STUDY OF EFFECT TO POWER SYSTEM STABILITY BY INTRODUCING SVG (STATIC VAR GENERATOR)

Kagiya, S.; Sakabayashi, M.

Hokuriku Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 242-243

Japanese

Abstract not available.

[1997] 08A - 114

STUDY OF POWER ELECTRONICS EQUIPMENT FOR DAMPING CONTROL OF PUMPED STORAGE GENERATOR/MOTOR AND STABILIZING LOAD VOLTAGE

Terada, O.; Yonaga, S.; Nagano, T.; Watanabe, M.; Konishi, H.

Hokkaido Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 25-30

Japanese

This paper shows evaluations of power electronics equipment applied for stabilizing a pumped storage generator/motor and load voltage. An adjustable speed motor/generator(FWG), a static VAr compensator(SVC) and a thyristor-controlled series compensator(TCSC) was considered as stabilizing equipment. A damping control ability using a bus frequency deviation was evaluated. An optimal location method for TCSCs improving system damping ability and voltage stability was also proposed.

[1997] 08A - 115

STUDY ON CONTROL OF STATIC VOLTAGE COMPENSATOR (SVC)

Furukawa, K.

Hokuriku Elec Power Co, Inc, Toyama, Japan

Hokuriku Denryoku Kabushiki Kaisha Kenkyu Kaihatsu Hokoku (Japan), vol 2, February 25, 1997, pp 46-51

Japanese

The voltage compensation effect of the newly developed SVC was studied. The SVC controls voltage by rapidly continuously changing reactive power to control distribution line voltage, and is composed of reactors, high-voltage capacitors and thyristors. The SVC controls voltage by injecting capacitive or reactive current obtained by phase control of thyristors into distribution lines. Reactive power and harmonics were measured by installing one or two SVCs in a line with large-capacity equipment at the terminal. In the case of one SVC operation, voltage drop was dependent on SVC operation condition, and voltage drop was again observed after starting. In the case of two SVCs operation without any loss of generated reactive power, the response delay was scarcely found among thyristor themselves, and voltage drop was dependent on SVC operation condition. It was effective to change reactive power at starting for reduction of voltage drop. The total current distortion factor was estimated to be nearly 3% of the rated fundamental wave current. 8 figs., 2 tabs.

[1996] 08A - 116

SVC FOR THE DEREGULATED ELECTRIC POWER INDUSTRY

Wong, W.K.; Bahrman, M.P.; Lindberg, P.

ABB Trans Tech Inst, Raleigh, NC, USA

Proceedings, 58th American Power Conf, Chicago, IL, April 9-11, 1996, pp 1548-1554

The electric power industry in the US is undergoing dramatic changes brought on by the expected deregulation and subsequent competition. In the new market environment, it is expected that (1) there will be more power transactions between and across regions, (2) dispatch of expensive local generation will be greatly reduced, (3) the power system will be operated closer to the limits, and (4) few new transmission lines will be

built. Reactive power service entails steady-state and dynamic voltage support and regulation. The importance of dynamic reactive power control and reserve must be recognized and properly incorporated in the pricing structure of reactive power to ensure investments in such equipment will be made. The relocatable SVC is a recent development in SVC design that is particularly suited to meet the needs of a changing deregulated power system. The relocatable SVC enables its owner to maximize transmission asset utilization and minimize the risk of stranded investment. Finally, this paper addresses the issue of the SVC operating at its limits, and presents SVC controls that can avoid or minimize prolonged operation at the limit of control range and maintain voltage regulating capability. In addition, innovative and cost-effective methods of specifying and designing the SVC to extend its dynamic control range are presented.

[1996] 08A - 117

SVS AUXILIARY CONTROLLERS TO IMPROVE THE DYNAMIC PERFORMANCE OF LONG TRANSMISSION LINES WITH AND WITHOUT SERIES COMPENSATION

Dave, M.P.; Kumar, N.

Univ of Roorkee, India

Journal of the Institution of Engineers (India), Electrical Engineering Division, vol 77, May 1996, pp 25-32

In the present paper a comparative performance of the SVS auxiliary controllers for the dynamic performance enhancement of long transmission lines with and without series compensation has been evaluated. A new controller, namely, combined reactive power and frequency (CRPF) auxiliary controller has been developed and incorporated in the SVS control system located at the middle of the transmission line. The proposed SVS auxiliary controllers, considerably, enhances the system damping and the unstable system modes are stabilized. A digital computer simulation study, using a nonlinear system model, has been performed to illustrate the performance of the proposed controller. 9 Refs.

[1996] 08A - 118

SWITCHING TIME BIFURCATIONS IN A THYRISTOR CONTROLLED REACTOR

Jalali, S. Dobson, I.; Lasseter, R.H.; Venkataramanan, G.

Siemens Energy and Automation, Atlanta, GA, USA

IEEE Trans on Circuits and Systems I: Fundamental Theory and Applications, vol 43, no 3, March 1996, pp 209-218

Thyristor-controlled reactors are high power switching circuits used for static VAr control and the emerging technology of flexible ac transmission. The static VAr control circuit considered in the paper is a nonlinear periodically operated RLC circuit with a sinusoidal source and ideal thyristors with equidistant firing pulses. This paper describes new instabilities in the circuit in which thyristor turn off times jump or bifurcate as a system parameter varies slowly. The new instabilities are called switching time bifurcations and are fold bifurcations of zeros of thyristor current. The bifurcation instabilities are explained and verified by simulation and an experiment. Switching time bifurcations are special to switching systems and, surprisingly, are not conventional bifurcations. In particular, switching time bifurcations cannot be predicted by observing the eigenvalues of the system Jacobian. We justify these claims by deriving a simple formula for the Jacobian of the Poincare map of the circuit and presenting theoretical and numerical evidence that conventional bifurcations do not occur. 27 Refs.

[1996] 08A - 119

SYNCHRONOUS GENERATOR DAMPING ENHANCEMENT THROUGH COORDINATED CONTROL OF EXCITER AND SVC

Rahim, A.H.M.A.; Nassimi, S.G.A.

King Fahd Univ of Petrol and Min, Dhahran, Saudi Arabia

IEE Proceedings Generation, Transmission and Distribution (UK), vol 143, no 2, March 1996, pp 211-218

Damping improvement of a weakly connected generating system through control of excitation and static VAr compensators has been investigated. Stabilizing signals derived through a minimum time quasioptimum feedback strategy have been tested on a synchronous generator infinite bus system connected through a long transmission line. The response was compared with standard linear state and output regulator formulations. It was observed that although excitation control enhances the stability of the system, the SVC provides most of the damping. The proposed feedback strategy with coordinated control of excitation and SVC were found to provide a much superior response compared to the standard techniques. 15 Refs.

[1997] 08A - 120

THE ANALYSIS OF CONDITIONAL PROPERTIES OF CONTROLLED INTERCONNECTION WITH STATIC VOLTAMPERES COMPENSATOR

Zelenokhat, N.I.

Elektrichestvo (Russia), no 3, March 1997, pp 13-18

Russian

A method of controlling a static voltamperes compensator (SVC) is worked out to maintain the given recurrence of active power by controlled interconnection with SVC. Its efficiency is confirmed by the carried out calculations. Different properties of controlled connections with SVC were investigated under simple and complex conditions of electrical power systems.

[1998] 08A - 121

THE APPLICATION OF RELOCATABLE POWER ELECTRONIC AND OTHER DEVICES TO IMPROVE TRANSMISSION CAPABILITY AND FLEXIBILITY

Knight, R.C.; Power, A.J.

The National Grid Co, UK

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

The National Grid Company plc (NGC) is responsible for operating the 400-kV and 275-kV electricity transmission system in England and Wales. Since the privatization of the electricity supply industry in 1990, NGC has no control over the siting of new generating stations and no control over the closure of existing stations. As a consequence of this, NGC has to be able to respond quickly to changing generating patterns in order to maintain the system within security and quality standards. For this purpose, NGC has pioneered the development of relocatable static VAr compensators (RSVCs), seven of which are now in service on the NGC system, with a further five on order. NGC is also keen to encourage the development of new power electronic-based power flow controllers in order to improve transmission system capability and flexibility, and as a consequence a relocatable static VAr compensator employing gate turn-off thyristor (GTO) technology has been ordered for commissioning in 1999. This paper provides details of the ongoing work within NGC in this respect and describes the relocatable SVC and GTO-SVC projects as they stand to date. The paper also discusses the development of a novel tap-changer design and its possible application in a compensator for use in voltage control applications. The application of energy storage to the NGC system is considered and the benefits and problems associated with this are discussed. The paper also provides a summary of other longer-term technological developments under consideration by NGC for possible future system application.

[1997] 08A - 122

THE CONTROLLER OF THE CURRENT BASIC HARMONIC IN THE FC/TCR-STATIC VAR COMPENSATOR

Hanzelka, Z.

Akad Gorniczo-Hutnicza, Krakow, Poland

Przeglad Elektrotechniczny (Poland), vol 73, no 6, 1997, pp 146-153

Polish

This paper presents two configurations of thyristor-controlled reactor in FC/TCR. They are alternative systems for the conventional plant. The analysis of their various working states are presented and advantages and disadvantages are emphasized.

[1998] 08A - 123

THE EFFECTS OF LOAD MODELS ON POWER SYSTEM STABILIZERS AND STATIC VAR COMPENSATORS FOR THE TAIWAN POWER SYSTEM

Kao, W.S.; Chen, S.C.

Taipei Univ of Tech, Taipei

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper S10.5

Abstract not available

[1996] 08A - 124

THE OPTIMIZATION METHOD FOR COORDINATED TUNING OF POWER SYSTEM REGULATORS

Maslennikov, V.A.; Ustinov, S.M.

Dept of Elec Eng, Sydney Univ, Australia

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 1, pp 70-75

A numerical method of robust coordinated tuning of power system regulators (AVR, PSS, SVC, etc.) to

improve the damping of small disturbed oscillations is given. It is based on multi-parameter numerical optimization to shift eigenvalues of interest to the left on a complex plane. The method provides the unified adjustments of regulators for a variety of power system operating conditions. The design of a PSS for the New England test system is illustrated. 17 Refs.

[1997] 08A - 125

THE ROLE OF STATIC VAR COMPENSATORS IN STAVING OFF VOLTAGE COLLAPSE

Wong, K.T.G.

GEC ALSTHOM T&D Power Electrn Sys Ltd, UK

IEE Colloquium on Voltage Collapse (Digest No.1997/101), London, UK, April 24, 1997, 66 pp

Continuous operating voltages in a power system are kept typically within +5% of the nominal voltage levels for power transmission and sometimes a slightly wider range for distribution. Standards generally provide for equipment to be able to operate correctly within the range of +10%. It is vital that voltages do not fall too far below these lower limits for any significant period of time because, in general, reactive current demand increases as the voltage falls. The increase in reactive demand causes the voltage to fall further and the system tends towards complete collapse. Poor power-factor loads, induction motors running at a high slip after a disturbance, and transformers changing taps to raise the secondary voltages but inadvertently increasing VAr absorption, have been known to have precipitated such unstable operating conditions. This contribution illustrates how static VAr compensators (SVCs) help to stave off voltage collapse by improving the stiffness of the voltage at a given power level or by permitting more power to be transmitted without increasing the risk of voltage collapse.

[1997] 08A - 126

THE STUDY ON IMPROVEMENT OF YIMIN-DAQING 500 KV SYSTEM STABILITY BY SVC

Ai, X.; Cai, G.; Xu, X.; Mu, G.

Northeast Inst of Elec Power Eng, Jilin, China

Automation of Electric Power Systems (China), vol 21, no 3, March 1997, pp 54-57, 66

Chinese

This paper analyzes the effects of SVC on power system steady-state and transient stability. The principles of enhancing transmission line active power transfer capability and damping power oscillation are expounded. On this basis the SVC control system is designed and a SVC model is built.

[1998] 08A - 127

THE USE OF SWITCHING FUNCTIONS AND WALSH SERIES TO CALCULATE WAVEFORM DISTORTION IN THYRISTOR-CONTROLLED COMPENSATED POWER CIRCUITS

Rico, J.J.; Acha, E.

Univ of Glasgow, UK

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998, Preprint order number PE-188-PWRD-0-12-1997

A new model based on Walsh series for assessing the steady-state operation of three-phase thyristor-controlled reactors (TCRs) is presented in this paper. The model represents the TCR as an admittance matrix which interfaces easily with other power plant components in the network. Clearly, the admittance matrix representation is not confined to Walsh domain but rather it is valid for any orthogonal approximation of functions having the operational properties used in this paper. However, the switching functions which characterize the operation of TCRs are better represented by Walsh series and they have been used in this paper. This is a new development in power systems analysis. Other orthogonal series expansions such as Fourier series and Hartley series have been used elsewhere. Walsh transform possesses the important operational properties of the Product, Coefficient and Integration matricies. The relevant aspects of the interaction between the TCR and the electric network are analyzed. A three-phase TCR and a transmission network represented by a Thevenin equivalent are used for this purpose.

[1996] 08A - 128

THYRISTOR SWITCHED CAPACITORS FOR VOLTAGE AND VAR CONTROL [OF DISTRIBUTION NETWORKS]

Anon.

Elektron (South Africa), vol 13, no 7, July 1996, pp 71-72

The inability of the distribution system to maintain the voltage within an acceptable range can limit the use of certain loads on the system. This article describes the use of the Minicomp thyristor switched shunt filter capacitor system, with six steps of 1 MVAr, each tuned

at 225 Hz, in order to overcome such problems. 0 Refs.

[1996] 08A - 129

TRANSFER CAPACITY OF LONGITUDINAL POWER SYSTEM AND VOLTAGE CONTROL OF SVC

Kakimoto, N.; Mizuguchi, T.; Nojiri, K.

Kyoto Univ, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 116, no 8, pp 909-917

Japanese

Power transfer between systems is getting an important mean due to uneven distribution of generating plants. This paper investigates relation between transfer capacity of a longitudinal power system and voltage control of static VAr compensators. The transfer capacity is basically limited by thermal capacity of transmission lines. However, in practical systems, it is much restricted by stabilities, and power transfer level is considerably lower than the thermal capacity. In this paper, we consider a basic case where SVCs are set to all buses except generator terminals. In this case, it is possible to transfer power up to a reciprocal of transmission reactance value. Two modifications are applied next to the basic case. One is removal of SVCs at high-voltage sides of generator transformers. In this case, generator damping torques deteriorate, and a local oscillation mode gets unstable. The other is removal of SVCs at intermediate buses on the trunk system. In this case, shapes of oscillation modes change much, and a global mode gets unstable. The voltage control of SVCs maintains generator damping torques, and prevents deformation of mode shapes. By investigating with different system sizes and transmission circuits, we show that the system transfer capacity is determined by those of individual transmission lines.

[1996] 08A - 130

TRANSIENT RESPONSE OF A STATIC VAR SHUNT COMPENSATOR

Best, R.A.; Parra, Z.-De La

Univ of Birmingham, UK

IEEE Trans on Power Electronics, vol 11, no 3, May 1996, pp 489-494

A typical static VAr shunt compensator has been analyzed so that the step response and steady-state errors can be identified. The results show that the steady-state error is dependent upon the error in the measurement of the currents' phase alone. They also show that an unstable condition can occur, though it should rarely arise in practice. All the theory was verified on a low power (240 V, 3 A) system. 9 Refs.

[1997] 08A - 131

TRANSMISSION CAPACITY OF LONGITUDINAL POWER SYSTEMS AND SVC VOLTAGE CONTROL

Kakimoto, N.; Mizuguchi, T.; Nojiri, K.

Kyoto Univ, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 119, no 3, May 1997, pp 49-60

Power transfer between systems is important due to uneven distribution of generating plants. This paper investigates the relation between the transfer capacity of a longitudinal power system and voltage control of static VAr compensators. The transfer capacity is basically limited by the thermal capacity of transmission lines. However, the practical systems, it is much restricted by stability and the power transfer level is considerably lower than the thermal capacity. In this paper, we consider a basic case in which SVCs are applied to all buses except generator terminals. In this case, it is possible to transfer power up to the reciprocal of the transmission reactance. Two modifications are then applied to the basic case. One is removal of SVCs on the high-voltage sides of the generator transformers. In this case, generator damping torques deteriorate, and the local oscillation mode becomes unstable. The other is removal of SVCs at intermediate buses on the trunk system. In this case, the shapes of the oscillation modes change greatly, and the global mode becomes unstable. The voltage control of SVCs maintains the generator damping torques and prevents deformation of mode shapes. By investigating different system sizes and transmission circuits, we show that the system transfer capacity is determined by the capacities of the individual transmission lines. 18 Refs.

[1996] 08A - 132

TRANSPORTABLE REACTIVE POWER COMPENSATORS

Hausler, M.; Grunbaum, R.

ABB Calor Emag Schaltanlagen AG, Mannheim, Germany

ETZ (Germany), vol 117, no 17, September 1996, pp 18, 21-23

German

There is worldwide pressure to deregulate the supply of electric power on grounds of competition. This places higher demands on the flexibility of network management. To ensure the quality of transmission one must compensate for load-flow-dependent reactive power. With changes to the network it may be necessary to vary the site of the compensation. The problem is solved by a transportable design developed by ABB for the National Grid Company of Great Britain. Its compact and modular structure makes for easy removal to other sites. 2 Refs.

[1996] 08A - 133

TUNING A STATIC VAR COMPENSATOR CONTROLLER OVER A WIDE RANGE OF LOAD MODELS USING AN ARTIFICIAL NEURAL NETWORK

Ellithy, K.A.; Al-Alawi, S.M.

Cairo Univ, Egypt

Electric Power Systems Research, vol 38, no 2, August 1996, pp 97-104

A novel approach using an artificial neural network (ANN) for tuning a static VAr compensator (SVC) controller over a wide range of load models is presented in this paper. To enhance power system damping over a wide range of load models, it is desirable to adapt the SVC controller gain in real time based on load models. To do this, online measurements of load parameters which are representative of load models are chosen as the input signals to the neural network. The output of the neural network is the desired gain of the SVC controller. The neural network, once trained by a set of input-output patterns in the training set, can yield a proper SVC controller gain under any load model. Simulation results show that the tuning gain of a SVC controller using the ANN approach can provide better damping of the power system over a wide range of load models than the fixed-gain controller. 28 Refs.

[1997] 08A - 134

TUNING OF SVC STABILISER TO COMPENSATE THE INFLUENCE OF VOLTAGE DEPENDENT LOADS

Milanovic, J.V.

Dept of Elec Eng & Computer Sci, Tasmania Univ, Hobart, Tasmania, Australia

Proceedings, 36th IEEE Conf on Decision and Control, San Diego, CA, December 10-12, 1997, vol 3, pp 2553-2558

The paper explores the influence of power system loads on static VAr compensator (SVC) damping effectiveness. Equipped with properly tuned additional stabilizer SVCs have been successfully used for improving the damping of electromechanical oscillations in power system. The damping improvement is usually achieved through indirect voltage influence through voltage dependent loads. Tuning of additional compensator stabilizer (ACS) traditionally assumes that loads are statically voltage dependent. However load parameters are generally uncertain and loads often exhibit some dynamic response. This uncertain dynamic behavior of loads can introduce an additional phase shift between voltage and load response and such can detune the ACS. Example of robust tuning of ACS to compensate influence of load dynamics and uncertainty is presented and discussed.

[1997] 08A - 135

UNIFIED MODEL FOR THE ANALYSIS OF FACTS DEVICES IN DAMPING POWER SYSTEM OSCILLATIONS PART I: SINGLE-MACHINE INFINITE-BUS POWER SYSTEMS

Wang, H.F.; Swift, F.J.

Manchester Metropolitan Univ, UK

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 941-946

The static VAr compensator (SVC), Controllable Series Compensator (CSC) and Phase Shifter (PS) are three of the options of power electronic devices, referred to as FACTS (flexible ac transmission systems) devices. They are becoming of increasing importance in suppressing power system oscillations and improving system damping. In this paper, a unified model of a power system installed with these three FACTS devices is established. Their effectiveness in suppressing power system oscillations is investigated by analyzing their damping torque contributions to the power system. The work in this paper relies on the theoretical analysis of a general single-machine infinite-bus power system where the objective is to present an insight into the operation of the damping control of the FACTS devices. 17 Refs.

[1996] 08A - 136

USE OF A STATIC VAR COMPENSATOR FOR GENERATOR NEGATIVE-SEQUENCE CURRENT REDUCTION

Chen, J-H.; Lee, W-J.; Chen, M-S.

Energy Sys Research Center, Texas Univ, Arlington,

TX, USA

Electric Power Systems Research (Switzerland), vol 38, no 3, September 1996, pp 183-190

The presence of negative-sequence current in a generator, due to system imbalance, induces double-frequency currents in the rotor iron. These currents may cause rotor overheating and serious damage if permitted to persist. Negative-sequence current relaying practices that alarm or trip the generator before damage can occur are well established in the power industry. However, tripping major generation facilities may create social, security, and economic problems. In addition, for an isolated system with relatively poor frequency regulation, the combination of negative-sequence current and frequency perturbation may cause supersynchronous resonance in turbine blades if one of the mechanical resonance frequencies of the turbine blade is close to double the system frequency (60 Hz). This paper presents a method for correcting the problem at source by reducing the negative-sequence current through a specially designed delta-connected static VAr compensator (SVC). The derivation of the mathematical model and computer simulations verify and explain the capability of this approach. In addition, a scaled-down model is implemented in a physical simulation laboratory. Some laboratory test results are also presented. 8 Refs.

[1996] 08A - 137

USE OF THYRISTOR CONTROLLED REACTOR FOR SYMMETRIZATION OF ACTIVE LOAD IN NETWORK

Pavelka, J.

CKD Elektrotechnika a.s., Praha, Czech Republic

Proceedings, Int'l Conf on Electrical Drives and Power Electronics (EDPE'96), The High Tatras, Slovakia, October 1-3, 1996, vol 2, pp 473-478

The paper deals with the cause of unbalanced load in the electric network and with methods for a load symmetrisation. In the first part an active filter method is described. In the main part the method using the thyristor-controlled reactor is explained and detailed mathematical analysis is presented. It is proved that the active load symmetrisation can be made by the reactive load controller. 3 Refs.

[1996] 08A - 138

USING A STATIC VAR COMPENSATOR TO BALANCE A DISTRIBUTION SYSTEM

Chen, J-H.; Lee, W-J.; Chen, M-S.

Energy Sys Research Center, Texas Univ, Arlington, TX, USA

Proceedings, 31st IEEE Industry Applications Conf (IAS '96), San Diego, CA, October 6-10, 1996, vol 1, pp 2321-2326

An algorithm for applying a fixed capacitor-thyristor-controlled reactor (FC-TCR) type of static VAr compensator (SVC) in the distribution system to dynamically balance a system is introduced. With a newly developed individual phase control scheme, an SVC can reduce negative sequence current caused by the load to improve system balance. Since the control circuit is governed by a microcomputer, which replaces the traditional discrete load switching and makes the capability of rapid and dynamic balancing of the system become possible. In addition, the power factor can be improved simultaneously by selecting an appropriate amount of capacitive/inductive compensation. This paper presents a mathematical model for computer simulation and control of a delta connected SVC to achieve the purpose of negative sequence reduction. Some computer simulation and scaled laboratory test results are discussed. 9 Refs.

[1996] 08A - 139

VARIABLE STRUCTURE CONTROL OF A STATIC VAR COMPENSATOR FOR SYSTEM DYNAMIC STABILITY

Collins, G.F.; Patton, R.J.; Irving, M.R.; Canales-Ruiz, R.

Dept of Electrn Eng, Hull Univ, UK

Proceedings, Int'l Symp on Control of Power Plants and Power Systems (SIPOWER'95), Cancun, Mexico, December 6-8, 1995, pp 37-42

Power transmission networks are driven harder than ever before. Developments in high speed power electronics devices have created new opportunities for robust control strategies for power systems. Variable structure control (VSC) theory is a viable method of achieving a very high degree of closed-loop robustness for such systems. This paper presents the results of a study of the application of VSC to two power system examples, one a scalar SISO system, whilst the second is a MIMO control problem. Included is the novel use of the unit vector type of nonlinear controller for VSS, which is based upon Lyapunov theory. 13 Refs.

[1996] 08A - REF

POWER ELECTRONICS. APPLICATION OF SELF-COMMUTATED INVERTERS TO ELECTRIC POWER SYSTEMS

For Abstract see entry 02C - 31

[1996] 08A - REF

AC SYSTEM MODELING FOR AC FILTER DESIGN-AN OVERVIEW OF IMPEDANCE MODELING

For Abstract see entry 02D - 1

[1996] 08A - REF

APPLICATION OF SVC IN HVDC SYSTEM

For Abstract see entry 05G - 1

[1997] 08A - REF

COORDINATION OF CONTROLS WITH MULTIPLE FACTS/HVDC CONTROLLERS IN THE SAME AREA: SURVEY OF PRACTICAL EXPERIENCE

For Abstract see entry 05G - 2

[1998] 08A - REF

ELIMINATION OF DYNAMIC BIFURCATION AND CHAOS IN POWER SYSTEMS USING FACTS DEVICES

For Abstract see entry 07A - 13

[1996] 08A - REF

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

For Abstract see entry 07A - 17

[1996] 08A - REF

RELOCATABLE STATIC VAR COMPENSATORS HELP CONTROL UNBUNDLED POWER FLOWS

For Abstract see entry 07A - 54

[1997] 08A - REF

SYSTEM SYMMETRIZATION BY FACTS FOR INCREASED TRANSMISSION CAPACITY

For Abstract see entry 07A - 61

[1998] 08A - REF

VOLTAGE-SOURCE MATRIX CONVERTER AS A CONTROLLER IN FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 07A - 79

[1998] 08A - REF

CAPACITOR BANK SERIES GROUP SHORTING (CAPS) DESIGN STUDY

For Abstract see entry 07B - 12

[1997] 08A - REF

SELECTION OF INSTALLING LOCATIONS AND FEEDBACK SIGNALS OF FACTS-BASED STABILISERS IN MULTIMACHINE POWER SYSTEMS BY REDUCED-ORDER MODAL ANALYSIS

For Abstract see entry 07B - 48

[1996] 08A - REF

SELF-COMMUTATED STATIC FLICKER COMPENSATOR FOR ARC FURNACES

For Abstract see entry 08B - 13

[1997] 08A - REF

SYSTEM STABILITY IMPROVEMENT IN THE RSA-ZIMBABWE AC INTERCONNECTION BY INSTALLATION OF AN SVC

For Abstract see entry 08B - 16

[1996] 08A - REF

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. THE 154 KV 60 MVA SVC (STATIC VAR COMPENSATOR) INSTALLED IN HIGASHI-OSAKA SUBSTATION OF THE KANSAI ELECTRIC POWER CO., INC

For Abstract see entry 08B - 8

[1997] 08A - REF

REACTIVE POWER ON THE MOVE: VAR MOBILITY FOR THE 21ST CENTURY

For Abstract see entry 08B - 9

[1996] 08A - REF

APPLICATION OF CONTROLLED SERIES COMPENSATION AND STATIC VAR SYSTEM FOR FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 10A - 15

[1996] 08A - REF

VOLTAGE QUALITY CONTROL IN ELECTRICAL INDUSTRIAL SYSTEMS BY MEANS OF THREE-PHASE BOOST CONVERTERS

For Abstract see entry 17B - 36

[1996] 08A - REF

HARMONIC DOMAIN MODELING OF THREE PHASE THYRISTOR-CONTROLLED REACTORS BY MEANS OF SWITCHING VECTORS AND DISCRETE CONVOLUTIONS

For Abstract see entry 17C - 12

[1997] 08A - REF

HARMONIC MODELING IN HARTLEY'S DOMAIN WITH PARTICULAR REFERENCE TO THREE PHASE THYRISTOR-CONTROLLED REACTORS

For Abstract see entry 17C - 14

[1997] 08A - REF

HARMONICS IN POWER SYSTEMS. AN OVERVIEW

For Abstract see entry 17C - 15

[1996] 08A - REF

PREDICTION OF HARMONIC MAGNIFICATION IN POWER SYSTEM DUE TO STATIC VAR COMPENSATORS

For Abstract see entry 17C - 19

[1996] 08A - REF

FUZZY LOGIC SWITCHING OF FACTS DEVICES FOR STABILITY ENHANCEMENT

For Abstract see entry 18A - 17

[1997] 08A - REF

ROBUST DECENTRALISED DESIGN FOR MULTIPLE FACTS DAMPING CONTROLLERS

For Abstract see entry 18A - 28

[1998] 08A - REF

ROBUST DECENTRALISED CONTROL DESIGN USING GENETIC ALGORITHMS IN POWER SYSTEM DAMPING CONTROL

For Abstract see entry 18A - 29

[1997] 08A - REF

TUNING OF POWER SYSTEM DAMPING CONTROLLERS USING GENETIC ALGORITHMS

For Abstract see entry 18A - 32

[1996] 08A - REF

VOLTAGE STABILITY ASSESSMENT AND ENHANCEMENT USING ARTIFICIAL NEURAL NETWORKS AND REACTIVE COMPENSATION

For Abstract see entry 18A - 33

[1996] 08A - REF

DAMPING AND SYNCHRONIZING TORQUES INDUCED ON GENERATORS BY FACTS STABILIZERS IN MULTIMACHINE POWER SYSTEMS

For Abstract see entry 18A - 5

[1997] 08A - REF

DEVELOPMENT OF FUZZY CONTROLLER UNDER HYBRID SIMULATION ENVIRONMENT FOR POWER SYSTEM STABILITY ENHANCEMENT: A SHOWCASE

For Abstract see entry 18A - 7

[1998] 08A - REF

DISSIPATIVITY AS A UNIFYING CONTROL DESIGN FRAMEWORK FOR SUPPRESSION OF LOW FREQUENCY OSCILLATIONS IN POWER SYSTEMS

For Abstract see entry 18A - 9

[1996] 08A - REF

INFLUENCE OF THE REAL POWER MODULATION PROVIDED BY A SHUNT COMPENSATOR ON DAMPING POWER SWINGS

For Abstract see entry 18B - 10

[1996] 08A - REF

AUXILIARY CONTROLLED SVS AND CONTROLLED SERIES COMPENSATION FOR FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 18B - 2

[1996] 08A - REF

EFFECTS OF FACTS DEVICES ON STATIC VOLTAGE STABILITY

For Abstract see entry 18B - 7

[1996] 08A - REF

IMPROVEMENT OF POWER SYSTEM PERFORMANCE BY INSERTING FACTS DEVICES

For Abstract see entry 18B - 9

[1998] 08A - REF

SERIES CAPACITORS COMBINED WITH STATIC VAR COMPENSATORS FOR ENHANCEMENT OF STEADY-STATE VOLTAGE STABILITIES

For Abstract see entry 18C - 13

[1996] 08A - REF

ANALYSIS AND CONTROL OF DYNAMIC INTERACTION AMONG MULTIPLE STATIC VAR COMPENSATORS IN THE NREB POWER SYSTEM

For Abstract see entry 18C - 2

[1997] 08A - REF

DAMPING CONTROLLER DESIGNS FOR AN SVC AND OTHER FACTS DEVICES

For Abstract see entry 18C - 7

[1997] 08A - REF

DESIGN OF SERIES AND SHUNT FACTS CONTROLLER USING ADAPTIVE NONLINEAR COORDINATED DESIGN TECHNIQUES

For Abstract see entry 18C - 8

[1997] 08A - REF

IMPROVED POWER SWING DAMPING BY COORDINATED FACTS CONTROLS

For Abstract see entry 18C - 9

[1997] 08A - REF

VERIFICATION OF LOCATOR ORIENTATION ERROR AND THE COUNTERMEASURES

For Abstract see entry 18D - 28

[1996] 08A - REF

REACTIVE POWER COMPENSATION AND VOLTAGE FLICKER CONTROL OF AN ARC FURNACE LOAD

For Abstract see entry 18E - 20

[1997] 08A - REF

AN EXPERT SYSTEM FOR POWER SYSTEM VOLTAGE STABILITY IMPROVEMENT

For Abstract see entry 19B - 4

[1996] 08A - REF

EXPANSION OF THE VOLTAGE STABILITY LIMIT VIA SHUNT VAR COMPENSATION

For Abstract see entry 19B - 8

[1996] 08A - REF

TRANSIENT STABILITY ENHANCEMENT WITH FACTS CONTROL

For Abstract see entry 19C - 4

[1996] 08A - REF

MODELING A STATIC VAR COMPENSATOR USING EMTP

For Abstract see entry 19D - 9

[1998] 08A - REF

AN ELECTRONIC SIMULATOR REPRESENTING A SVC INCORPORATED POWER SYSTEM

For Abstract see entry 19E - 10

08B Commissioning, Testing, Performance

[1997] 08B - 1

DEVELOPMENT OF 60 MVA SVC (STATIC VAR COMPENSATOR) USING LARGE CAPACITY 8 KV AND 3.5 KA THYRISTORS

Hasegawa, T.; Aoshima, Y.; Sato, T.; Kondo, O.; Matsukawa, T.

Kansai Elec Power Co, Inc, Osaka, Japan

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3, 1997, vol 2, pp 725-730

A static VAr compensator (SVC) of 154-kV and 60-MVA ratings was developed with the largest capacity thyristors of 8 kV and 3.5 kA in the world. The SVC was commissioned in The Kansai Electric Power Company in 1996 and has shown good performance. This paper presents the following items, i.e. system design of the SVC (hardware and software), field test results and effects of SVC application. 1 Refs.

[1996] 08B - 2

EFFECT OF SVC (STATIC VAR COMPENSATOR) FOR AKITA SHIN-KANSEN

Inoue, H.; Kawamae, S.; Suzuki, H.; Suzuki, Y.

East Japan Railway Co

National Convention Record, IEE Japan, Industry Applications Society (Denki Gakkai Sangyo Oyo Bumon Zenkoku Taikai Koen Ronbunshu), vol 1996, pt 1, pp 65-66

Japanese

Abstract not available.

[1996] 08B - 3

ELF MAGNETIC FIELDS BY CLOSE PROXIMITY TO A LARGE STATIC VAR COMPENSATOR: A CASE STUDY

Pretorius, P.H.; Britten, A.C.

Tech Research & Investigations, Eskom, Cleveland, South Africa

Proceedings, IEEE 4th Conf in Africa (AFRICON'96), Stellenbosch, South Africa, September 24-27, 1996, vol 2, pp 1056-1061

An investigation was conducted to determine the magnetic field levels in the vicinity of the static VAr compensator (SVC) at Eskom's Impala 275-kV substation. Of specific interest were the variation in magnetic field levels and harmonic content resulting from changes in the firing angle of the thyristor-controlled reactor (TCR). Magnetic field levels were measured during three different settings of firing angle and with the SVC off. The results of this investigation are reported in this paper. (8 Refs)

[1997] 08B - 4

GET THE FACTS

Renz, K.; Tyll, H.

Siemens AG, Erlangen, Germany

Int'l Power Generation (UK), vol 20, no 2, March 1997, pp 40-41

Based on high-speed, high-power thyristors and control algorithms, flexible ac transmission systems (Facts) can be used for the dynamic control of voltage, impedance and the phase-angle of a transmission line. The most important Facts devices are Static VAr Compensators (SVCs). They have been used for a number of years to improve the economics of transmission line operation by resolving dynamic voltage problems. Because of their accuracy, availability and fast response, SVCs provide higher performance steady-state and transient voltage control than classical shunt compensators. Examples of their successful use in a number of power transmission systems across the world are given. (UK)

[1996] 08B - 5

HIGH POWER SYSTEM QUALITY FOR ESKOM USING SVCS

Bergmann, K.; Friedrich, B.; Retzman, D.; Tyll, H.

Elektron (South Africa), vol 13, no 11, November-December 1996, pp 31-34

In 1995 Siemens supplied three static VAr compensators (SVCs) to Eskom for the Richards Bay area. This article gives details of SVCs in general and about this Eskom installation in particular. The overload capacity, closed loop control, voltage control, network

symmetry, VAr control, dc component control of the TCR, digital simulation, and commissioning tests are discussed. 0 Refs.

[1996] 08B - 6

IMPROVING SYSTEM STABILITY

Alexiades, A.N.; Humble, D.A.; Young, D.J.

GEC ALSTHOM Inc, USA

Technical Review, GEC Alsthom, no 2, 1996, pp 21-31

To reduce voltage swings and increase system stability throughout the upper midwest portion of the United States, a static VAr system (SVS) has been installed by GEC ALSTHOM T&D for the Western Area Power Administration at Watertown, South Dakota. At the heart of the Watertown SVS is a ±100-MVAr static VAr compensator comprised of 100-MVAr fixed capacitors and a 200-MVAr thyristor-controlled reactor. The system was commissioned for commercial operation on July 28, 1995.

[1997] 08B - 7

INSTALLATION OF AN ARC FURNACE IN SOUTH FRANCE : FLICKER MITIGATION WITH A SATURABLE REACTANCE COMBINED TO A STATIC VAR COMPENSATOR

Poumarede, C.; Lafon, L.; Therond, P.G.; Lefranc, B.; Lachaume, J.; Fauquembergue, P.

Electricite de France

Collection de notes internes de la Direction des etudes et recherches. Materiel electrique, transport et distribution d'energie (France), no 50, 1997, 13 pp

Industrial loads cause more and more voltage distortions on the feeding electrical network, as new means of production are available. The installation of a large arc furnace (100 MW) in south of France is a good example of this situation since the technical challenge to smooth its impact on the grid was worth picking it up. The principle of arc furnace is to melt scrap with the heat produced by an extremely high current (several tens of kA) induced by an electric arc ignited between an electrode and the scrap. This accurate process gives rise to perturbations on the feeding grid : due to the unstable nature of the electric arc, the load current is highly time-varying, leading to voltage fluctuations. The problem is that the human eye is very sensitive to the resulting 1 to 30 Hz illumination variations. This phenomenon is called 'flicker'. In the case studied, two compensation devices are necessary to lower the flicker rate down to an acceptable value. The first one is a saturable reactor, manufactured by DANIELI, which is in charge of the current smoothing, the second one is a static VAr compensator, produced by ABB, maintaining the voltage level through the reactive power regulation. 7 refs.

[1996] 08B - 8

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. THE 154 KV 60 MVA SVC (STATIC VAR COMPENSATOR) INSTALLED IN HIGASHI-OSAKA SUBSTATION OF THE KANSAI ELECTRIC POWER CO., INC

Aoshima, Y.; Hakugin, T.; Sato, T.; Koura, H.; Kondo, O.; Matsukawa, T.; Nishiyama, S.; Nakamura, T.

Kansai Elec Power Co, Inc, Japan

Nisshin Denki Giho (Japan), vol 41, no 3, pp 23-27

Japanese

A 154 KV 60-MVA SVC was installed in Higashi-Osaka substation of The Kansai Electric Power Co., Inc. in March, 1996. And it has been operated successfully. The SVC was equipped with an Automatic Voltage Regulator function control panel. This paper presents the system design of the SVC and field testing data.

[1997] 08B - 9

REACTIVE POWER ON THE MOVE: VAR MOBILITY FOR THE 21ST CENTURY

Young, D.J.; Horwill, C.; Trainer, D.R.; Loughran, J.; Baker, M.H.

GEC ALSTHOM Power Electrn Sys Ltd, Stafford, UK

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

Historically, power system development was undertaken on the basis of coordinated strategic planning of generation and transmission. In numerous countries, unbundling of power systems has introduced the scenario of the elimination of system support from withdrawn generation, or conversely, redundancy of reactive power installations by injudicious location of new generation. A solution adopted with great success in the UK, but with application also to rapidly developing power systems, is the concept of relocatable static VAr compensators (RSVC). In order to comply with UK regulations on notification periods for introduction or withdrawal of generation or provision of

new supply connections, a requirement has been identified to provide relocatability of such RSVCs within a three month period. The practical implementation of this requirement is illustrated with respect to three contrasting examples with a wide range of applicability. The first application is for a standardized design of 60-MVAr rating embodying binary switched TSCs connected at 13 kV, which, in the UK scenario, are connectable to the tertiary winding of appropriate grid transformers, but can be deployed for direct connection to a 13-kV or similar distribution system. The remaining applications relate to alternative designs for a 400-kV, 225-MVAr RSVC, the first incorporating conventional TCR and TSC technology, the second employing an innovative GTO-based STATCOM for which a pioneering order has recently been placed by the National Grid Company plc in the UK. The building blocks described in the paper present the possibility of a range of modular, standardized elements from which a highly adaptive solution can be constructed to meet rapidly changing requirements.

[1998] 08B - 10

RELOCATABLE GTO-BASED STATIC VAR COMPENSATOR FOR NGO SUBSTATIONS

Knight, R.C.; Young, D.J.; Trainer, D.R.

The National Grid Co, UK

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Since privatization in 1990, NGC has invested heavily in reactive compensation equipment in order to maintain the 400-kV and 275-kV grid system in England and Wales within security and quality standards. As part of this continuing investment program, NGC has ordered a relocatable 0-225-MVAr static VAr compensator (SVC) incorporating a STATCOM, which utilizes a gate turn-off thyristor-based converter, for commissioning in September 1999. This is the first device of its type to be purchased by NGC and it represents a commitment to the application of new technologies for system control and power flow improvement.

[1997] 08B - 11

RELOCATABLE STATIC VAR COMPENSATORS

Stromberg, G.; Grunbaum, R.; Larsson, L.-O.; Hausler, M.

ABB Power Sys, Sweden

ABB Review, no 5, 1997, pp 16-23

Four relocatable static VAr compensators have been installed by ABB in the 400/275-kV power transmission network of the National Grid Company (UK). The installations, which have a dynamic rating of 0-60 MVAr and are connected to the 13-kV tertiary windings of existing substation autotransformers, are designed to maintain the stability and power transmission capability of the grid under varying network conditions. Transportation on standard road vehicles as well as easy site assembly is ensured by the compact, modular design of the RSVCs.

[1997] 08B - 12

REVIEW OF PERFORMANCE AND OPERATIONAL EXPERIENCE OF THE NATAL SVCS, ESKOM SOUTH AFRICA

Magg, T.; Boshoff, S.; Hitchin, C.; Mohabir, H.; Hammad, A.

ESKOM, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

The dynamic performance and operational experience of the three static VAr compensators in Natal are reviewed. Recordings of several system disturbances are used to analyze the performance of the SVCs under conditions of loss of major transmission lines, large load rejections and severe faults. The performance of automatically switching external shunt capacitors by the SVD controls is also assessed. Actual SVC operation in terms of reliability, availability and maintainability (RAM) requirements is compared with the guaranteed values.

[1996] 08B - 13

SELF-COMMUTATED STATIC FLICKER COMPENSATOR FOR ARC FURNACES

Yoshioka, Y.; Konishi, S.; Eguchi, N.; Yamamoto, M.; Endo, K.; Maruyama, K.; Hino, K.

Fuji Elec Corp R&D Ltd, Tokyo, Japan

Proceedings of Applied Power Electronics Conf (APEC `96), San Jose, CA, March 3-7, 1996, vol 2, pp 891-897

To suppress a flicker that occurs in a power system with arc furnaces, the authors have developed a self-commutated static flicker compensator (SFC). To verify the SFC's compensation performance, the authors performed experiments with a mini-model and an analog simulator. As a result of these experiments, it was confirmed that the current deviation of the SFC

output current was less than the desired value of 5%, and the response time of current control was about 1 ms. They also tested the flicker compensating effect with an actual SFC which was installed in a power system. The SFC achieved a flicker suppression factor of 36%, and has been operating trouble-free since April 1995. 3 Refs.

[1996] 08B - 14

SIMULATOR AND FIELD TESTING OF FORBES SVS

Sybille, G.; Giroux, P.; Dellwo, S.; Mazur, R.; Sweezy, G.

Inst de Recherche d'Hydro-Quebec, Varennes, Canada

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1507-1514

The paper reports on the power system simulator tests that were performed on the actual control system of the Forbes Static Var System (SVS). This SVS, commissioned in May 1994, is one of the major components of the Manitoba-Minnesota Transmission Upgrade (MMTU) project. The MMTU project and the need for a SVS at Forbes are first discussed. The main characteristics of the SVS and the testing methodology used on the simulator are also presented. The main results of tests performed to evaluate the steady-state and dynamic performance of the SVS controller, as well as the control-based protections are presented. Field tests are also discussed and typical test results are compared with those obtained on the simulator. Finally, the paper concludes by emphasizing the importance of simulator testing to optimize control systems, and to identify and resolve potential problems which would be extremely difficult to resolve in the field. 6 Refs.

[1996] 08B - 15

STATIC VAR COMPENSATORS STABILIZE POWER VOLTAGES

Burch, R.

Electric Light and Power, vol 74, no 6, June 1996, p 26

This article discusses the operation of a static VAr compensator as installed by Alabama Power near a steel mill with a large arc furnace load. This is expected to result in a number of benefits, including flicker reduction, dynamic power factor correction, harmonics filtering and a reduction in system losses.

[1997] 08B - 16

SYSTEM STABILITY IMPROVEMENT IN THE RSA-ZIMBABWE AC INTERCONNECTION BY INSTALLATION OF AN SVC

Heggli, P.M.; Dihwa, S.; Stromberg, G.; Thorvaldsson, B.; Larsson, L.-O.

ZESA, Zimbabwe

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

The paper discusses background, design, installation and testing of an SVC in the Insukamini substation close to Bulawayo in Zimbabwe. The SVC is required to provide high-speed dynamic reactive power absorption and generation for system voltage control purposes under certain system outages and load conditions. The paper also describes the design of the SVC, its configuration, control system, protection and auxiliary equipment. A review of the system test including performance verification, harmonic verification and test of the power oscillation function is also made.

[1996] 08B - 17

TNA STUDIES OF DIGITAL SVC CONTROLLER FOR BALANCED VOLTAGE AND REACTIVE POWER CONTROL APPLICATION

Dhal, B.; Meera, K.S.; Sarkar, B.N.; Subhash, S.; Murugesan, N.; Padmakumar, M.; Ramakrishna, N.

Central Power Research Inst, Bangalore, India

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 289-293

A digital static VAr compensator (SVC) controller for balanced voltage and reactive power control has been tested comprehensively on a Transient Network Analyzer (TNA). The entire power transmission system, different loads and the SVC are modeled on TNA. The controller was tested for various steady-state and dynamic conditions and performance figures, viz., voltage with or without a controller at: (a) steady state; and (b) with different faults (L-L, SLG) at far and near the SVC, unbalanced voltage, power factor and reactive power at steady state with and without controller, transient response with and without controller have been evaluated. Results have been checked with digital simulation. This paper gives some of the TNA test results. 2 Refs.

[1996] 08B - REF

JOINT OPERATION HVDC/SVC

For Abstract see entry 05G - 5

[1996] 08B - REF

RETAINING RING FAILURE AT COMANCHE UNIT 2: ROOT CAUSE ANALYSIS

For Abstract see entry 07B - 47

[1998] 08B - REF

RELOCATION OF FACTS DEVICES. THE ZIMBANE EXPERIENCE

For Abstract see entry 08A - 102

[1996] 08B - REF

A DESIGN FOR A RELOCATABLE TERTIARY CONNECTED SVC

For Abstract see entry 08A - 3

[1996] 08B - REF

COUNTERMEASURE FOR THE VOLTAGE DROP IN AKITA SHINKANSEN

For Abstract see entry 08A - 48

[1996] 08B - REF

DEVELOPMENT TRENDS FOR SVC'S

For Abstract see entry 08A - 56

[1996] 08B - REF

DIGITAL AND REAL TIME STUDIES OF THE ESKOM SVCS

For Abstract see entry 08A - 57

[1996] 08B - REF

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. APPLICATION OF SVC (STATIC VAR COMPENSATOR) TO AC ELECTRIC RAILWAY SYSTEM

For Abstract see entry 08A - 95

[1997] 08B - REF

ADVANCED REAL-TIME SIMULATOR TESTS FOR THE PERFORMANCE VERIFICATION OF STATIC VAR COMPENSATORS IN EXTENDED GRIDS

For Abstract see entry 19E - 7

09 STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

09A Modeling, Control, Applications

[1996] 09A - 1

±300 KVAR PROTOTYPE ADVANCED STATIC VAR GENERATOR BASED ON GTO

Liu W.; Liang, X.; Chen, J.; Wang, Z.; Yang, Y.; Li, C.; Li, X.; Liu, Y.

Tsinghua Univ, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 924-929

The availability of high power gate-turn-off (GTO) thyristors has led to the development of advanced static VAr generator (ASVG). This paper describes some essential techniques for the development of a ±300-kVAr prototype ASVG planned to be installed at the MengZhai substation in Henan Province. The ±300-kVAr prototype ASVG consists of an 18-pulse stepped-wave voltage source GTO inverter. Reduction of harmonics of VSI output voltage, choice of dc capacitor, GTO protection scheme, a new controller scheme and field test results are described in this paper. 4 Refs.

[1997] 09A - 2

12-PULSE STATIC SYNCHRONOUS COMPENSATOR FOR THE DISTRIBUTION SYSTEM EMPLOYING THE 3-LEVEL GTO-INVERTER

Hatziadoniu, C.J.; Chalkiadakis, F.E.

Southern Illinois Univ, Carbondale, IL, USA

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1830-1835

The paper presents an advanced scheme for the shunt compensation of the distribution system that can significantly improve the harmonic profile of the line without increasing the system complexity and size. The scheme employs a transformer-less arrangement of 3-level GTO inverters that can generate a 5-level output. A gate control is developed that fully utilizes the capabilities of this arrangement to provide a 12-pulse operation for the compensator. The proposed compensator can connect directly to the distribution grid without a transformer. The effectiveness and performance of the proposed compensator are tested through simulated studies on a 13.8-kV distribution system. 12 Refs.

[1998] 09A - 3

A DC VOLTAGE CONTROL METHOD OF 5 LEVEL INVERTER FOR SELF-COMMUTATED SVC WITH AN ASYMMETRICAL SWITCHING PATTERN

Harada, H.; Michioka, C.; Ichikawa, O.; Fukao, T.

Tokyo Inst of Tech, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol 98, no 10-21, pp 41-46

Japanese

A multilevel voltage source inverter (VSI), especially 5 level one, is suitable for a static VAr compensator as a large scale power source in a view of the dc high-voltage and harmonic elimination under low switching frequency. However equalization of dc capacitor voltages is necessary to ensure the even sharing of voltage stresses in the switching devices and to prevent the degradation of total harmonic distortion factors. In this paper, dc voltage deviation caused by not only fundamental component but harmonic ones under the asymmetrical switching pattern is analyzed, and we propose the dc voltage control method by handling the switching pattern asymmetrically. Finally, through the experimental results from 3.5-kVA experimental test system, it is shown that the dc voltages can be controlled by this method.

[1996] 09A - 4

A MULTILEVEL VOLTAGE-SOURCE INVERTER WITH SEPARATE DC SOURCES FOR STATIC VAR GENERATION

Fang, Z-P.; Lai, J-S.; McKeever, J.W.; Vancoevering, J.

Tennessee Univ, Knoxville, TN, USA

IEEE Trans on Industry Applications, vol 32, no 5, September-October 1996, pp 1130-1138

A new multilevel voltage-source inverter with separate dc sources is proposed for high-voltage, high-power applications, such as flexible ac transmission systems (FACTS) including static VAr generation (SVG), power-line conditioning, series compensation, phase shifting, voltage balancing, fuel cell, and photovoltaic utility systems interfacing, etc. The new M-level inverter consists of (M-1)/2 single-phase full bridges in which each bridge has its own separate dc source. This inverter can generate almost sinusoidal waveform voltage with only one time switching per cycle as the number of levels increases. It can solve the size-and-weight problems of conventional transformer-based multipulse inverters and the component-counts problems of multilevel diode-clamp and flying-capacitor inverters. To demonstrate the superiority of the new inverter, an SVG system using the new inverter topology is discussed through analysis, simulation, and experiment. 16 Refs.

[1998] 09A - 5

A NEURAL NETWORK-CONTROLLED OPTIMAL PULSE-WIDTH MODULATED STATCOM

Mohaddes, M.; Gole, A.M.; McLaren, P.G.

Univ of Manitoba, Winnipeg, Canada

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

The paper describes a technique to control the harmonic output of a static synchronous compensator (STATCOM) using a pulse width modulation (PWM) scheme with a minimal number of additional switchings. A neural network algorithm is developed to define the switching instants. This technique offers an alternative to the multi-pulse techniques that require complex magnetic circuit arrangements as well as to the conventional PWM technology that requires a large number of switchings.

[1997] 09A - 6

A NEW CONTROL STRATEGY FOR MULTILEVEL INVERTER-BASED STATCOM FOR REACTIVE POWER COMPENSATION AND

POWER FACTOR CORRECTION

Mahapatra, K.K.; Ghosh, A.; Doradla, S.R.

Indian Inst of Tech, Kanpur, India

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol VI-9

A simplified closed-loop model is proposed for a static compensator (STATCOM). This model makes it possible to extract instantaneous active fundamental component of the load current. The STATCOM is configured using a multilevel voltage source inverter. For high power applications the multilevel inverter is preferred over the commonly used two level voltage source inverter from the standpoint of harmonic components, dc link voltage and inverter switching frequency. The STATCOM is capable of providing reactive power compensation for fundamental and harmonics, power factor correction under balanced and unbalanced loading conditions. The performance of the STATCOM together with the proposed model is validated by extensive simulation results.

[1997] 09A - 7

A NEW LOW DISTORTION SELF-COMMUTATED STATIC VAR COMPENSATOR AS A VAR SOURCE

Chatterjee, K.; Fernandes, B.G.; Dubey, G.K.

Indian Inst of Tech, Kanpur, India

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol IV-2, pp 13f

A novel, self-commutated static VAr compensator having low harmonic distortion is proposed. The harmonics are eliminated by combining low frequency high power devices and high frequency low power devices. Detailed simulation studies of the proposed scheme are presented. Feasibility of the scheme in applications of voltage support of transmission line are also ascertained. Steady-state experimental results validating the operation of the proposed scheme are obtained from a scaled down laboratory prototype.

[1997] 09A - 8

A NEW TRANSFORMER-LESS MULTI-LEVEL CONVERTER FOR HIGH VOLTAGE HIGH POWER APPLICATIONS

Hosseini, S.H.; Mathur, R.M.

Univ of Tabriz, Iran

CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol II-2, pp 12ff

A new static VAr generator (SVG) using cascaded full-bridge inverters (FBI) with binary output levels and the parallel connections of two cascaded inverters by means of current sharing reactor in each phase is introduced. The new M-level inverter, where M is (2n+2) - 3, consists of only 2n single-phase full bridges for each phase. The proposed technique not only increases the current capacity of proposed SVG but also decreases the output harmonic contents. Also, it can be connected directly to the distribution system without a transformer. Simulation results, based on the PSCAD/EMTDC, a high performance electromagnetic transient simulation program, are used to illustrate the flexibility of control action and also the performance of the proposed SVG in a power system environment.

[1997] 09A - 9

A NOVEL ACTIVE THREE PHASE VAR COMPENSATOR

Wekhande, S.; Prasad, D.

Indian Inst of Tech, Bombay, India

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol IV-4, pp 29f

This paper presents a closed-loop computer simulation of a novel three-phase active VAr compensator which compensates reactive power and harmonics in the supply current. The compensator also balances supply current in case of load imbalance. The proposed three-phase VAr compensator requires only two current sensors and the compensating currents are derived without sensing the reactive power. This simplifies the controller hardware. The converter is simulated with PI controller to study its transient and steady-state behavior. The converter is simulated for leading power factor, lagging power factor and non-linear loads. The results of parametric analysis are also presented to study the performance of the converter for various values of system parameters. The computer simulation was carried out with PSPICE software using macro modeling techniques.

[1996] 09A - 10

A NOVEL DOUBLE-BRIDGE PWM STATIC VAR COMPENSATOR

Ji, Y-C.; Hu, Y-X.; Liu, Z; Tang, Z-G.; Wang, X-Y.

Dept of Elec Eng, Harbin Inst of Tech, China

Proceedings, 22nd Int'l Conf on Industrial Electronics, Control, and Instrumentation (1996 IEEE IECON), Taipei, Taiwan, August 5-10, 1996, vol 2, pp 700-705

A novel double-bridge PWM static VAr compensator (DB-PSVC) is presented in this paper. Theoretical analysis shows that the harmonic pairs of $[(2k+1) f_g \pm f]$ generated in each bridge are effectively eliminated through phase shift control. To satisfy the same 5% total harmonic distortion (THD) requirement, this new structure can work at 650 Hz, which is much lower than the previously reported 1.9 kHz of a single-bridge PSVC. The efficiency is increased and reliability enhanced. The fairly low switching frequency facilitates its use in high power applications since gate turn-off thyristors (GTOs) can be employed as power switches. The proposed concept is verified through simulations and experimental results on a 10-kVA prototype. 6 Refs.

[1997] 09A - 11

A THYRISTOR-CONTROLLED STATIC CONDENSER WITH THE DOUBLE-FIRING PHASE CONTROL

Park, I.G.; Yoon, J.T.; Kim, S.I.

Dept of Control & Instrum Eng, Wonkwang Univ, Chonbuk, South Korea

IEEE Trans on Industry Applications, vol 33, no 6, November-December 1997, pp 1594-1600

A current-source-type static condenser (Statcon) employing ordinary thyristors for controlling the reactive power of the power system is studied, and the double-firing phase-control method is characterized. The double-firing phase-control method can control the active and the reactive power of the Statcon directly and independently, so that the maximum speed of response can be achieved. However, the level of harmonics is still too high to be used practically, therefore, the 12-pulse configuration is considered for further reducing the harmonics. The thyristor-controlled Statcon can be useful in very-high-power applications in which the gate-turn-off (GTO) Statcon may not be evaluated as being economical.

[1997] 09A - 12

ADVANCED SHUNT VAR GENERATOR (ASVG) PRESENT SITUATION

Chen, J.; Wang, Z.; Han, Y.; Wu, T.; Yang, Y.; Fang, Z.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 7-12

Chinese

Based on a literature search and their experience in the development of a 300-kVAr prototype advanced shunt VAr compensator (ASVG), the authors give an overview of the current practices and the trend of technological advances in ASVG over the last two decades. Different ASVG modeling methods, control strategies and the main circuit configuration are described and their respective merits and shortcomings are explained. The behavior of ASVGs under unbalanced input voltage conditions is studied in particular and the effectiveness of suppression approaches are investigated. The authors suggest that an LC shunt resonant filter be a simple and effective approach for suppressing the second harmonic ripple of dc intermediate voltage and improving the performance of ASVG under unbalanced power network state. The paper provides a quick reference for the practicing researcher to decide which methods should be considered for developing a GTO-based static VAr compensator (SVC).

[1996] 09A - 13

ADVANCED STATIC VAR COMPENSATOR USING MULTIMODULES OF MULTILEVEL CONVERTERS WITH EQUALIZATION CONTROL OF DC VOLTAGE LEVELS

Chen, Y-Q.; Ooi, B-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 747-752

This paper describes a high MVA static Var compensator based on 4 modules of the diode-clamped, 5-level converter operating under the fundamental frequency method of control. By designing the switching instants of GTOs in the 4 modules, it is possible to achieve a high quality voltage waveform (THD approximately equals 4%) and at the same time assure even current loadings in the parallel connected modules. Equalization feedback control balances the GTO voltage stresses. 10 Refs.

[1997] 09A - 14

AN EMTDC MODEL OF A THREE LEVEL FOUR

MVAR COMPENSATOR

Rasmussen, T.W.

ELSAM, Frederica, Denmark

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 659-662

The paper discusses the dynamic characteristics of a three level ±4-MVAr solid-state VAr compensator which is built and will be used for dynamic reactive power compensation in a wind farm. An investigation has been carried out of the influence of the compensator reactor, the dc intermediate voltage capacitor and the losses of the compensator for its speed of control, specifically its response to fast phase shift in the grid. Furthermore the need for dc midpoint control is compared with the inherent stabilization. The harmonics made by the midpoint control are compared with the harmonics without midpoint control. The simulations were made by an EMTDC model, the compensator is being made by SIEMENS and the control in the model was built together with UMIST.

[1996] 09A - 15

AN INVESTIGATION OF THE VOLTAGE SAG MITIGATION EFFECT OF AN ADVANCED STATIC VAR COMPENSATOR

Wang, P.; Bollen, M.H.J.; Jenkins, N.

Centre for Elec Energy, Univ of Manchester Inst of Sci & Tech, UK

Proceedings, 1996 Universities Power Engineering Conf (UPEC'96), Iraklio, Greece, September 18-20, 1996, vol 3, pp 1012-1015

This paper describes the simulation of an advanced static VAr compensator (ASVC) using EMTDC, and presents the results of its voltage sag mitigation effect. Besides the ordinary shunt connection, two other connecting methods, as well as their control schemes, are proposed. It has been found that the voltage sag mitigation effect of an ASVC depends not only on the different configurations, but also on the nature of the voltage sags. 4 Refs.

[1996] 09A - 16

ANALYSIS AND CONSEQUENCES OF THE PHASE JUMP ASSOCIATED WITH A VOLTAGE SAG

Bollen, M.H.J.; Wang, P.; Jenkins, N.

Centre for Elec Energy, Univ of Manchester Inst of Sci & Tech, UK

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 1, pp 316-322

A fault somewhere in the supply not only leads to a reduction in voltage (a voltage sag) but often also to a jump in the phase angle of the voltage. Simple circuit theory models are used to estimate the expected phase-angle jumps. Jumps exceeding 10 degrees will not be uncommon. Detailed models of an advanced static VAr compensator and a dc motor drive are used to assess equipment reaction to phase-angle jumps. Phase-angle jumps of only a few degrees can be as disturbing as voltage drops. This calls for including them in equipment design and testing. 11 Refs.

[1996] 09A - 17

ANALYSIS AND CONTROLLER DESIGN OF STATIC VAR COMPENSATOR USING THREE-LEVEL GTO INVERTER

Cho, G.C.; Jung, G.H.; Choi, N.S.; Cho, G.H.

Korea Advanced Inst of Sci and Tech (KAIST), Taejon, South Korea

IEEE Trans on Power Electronics, vol 11, no 1, January 1996, pp 57-65

A static VAr compensator (SVC) using three-level GTO voltage source inverter (VSI) is presented for high-voltage, high-power applications. The three-level VSI has lower harmonic components and higher dc-link voltage than the two-level VSI and thus can be operated at lower switching frequency without excessive harmonic contents. From the DQ-transformed equivalent circuit of the presented SVC system, dc and ac analyses are carried out to know the steady-state and the dynamic characteristics of the system. Based on the open-loop transfer function of the system, a controller is designed to achieve fast dynamic response. The experimental results confirm the theoretical analyses and controller design. 10 Refs.

[1996] 09A - 18

ANALYSIS AND CONTROL OF ASVC FOR INTERPHASE LOAD FLOW COMPENSATION

Smith, K.S.; Ran, L.; Penman, J.

Aberdeen Univ, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 285-290

This paper presents a novel control method for the advanced static VAr compensator (ASVC) to achieve interphase load flow compensation. The estimation of the desired line load flow and the control of the dc link voltage are inherently related in a closed loop control algorithm which is not affected by the load bus voltage distortion. The power balance between the ac and dc sides of the compensator is analyzed. When the system load power unbalance is increased, a partial compensation can be obtained by varying the dc side voltage within its operating limits. Time domain simulation is used to verify the method proposed. 9 Refs.

[1996] 09A - 19

ANALYSIS AND DESIGN OF VOLTAGE CONTROL OF STATIC CONDENSER

Padiyar, K.R.; Kulkarni, A.M.

Indian Inst of Sci, Bangalore, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 393-398

The STATic CONdenser (STATCON) is a shunt connected voltage source converter using self commutating device like GTO s. The principle of working is similar to that of a synchronous condenser. This paper is concerned with the application of the STATCON for the reactive power compensation of a long transmission line by regulating the voltage at its midpoint. The design of the voltage controller and the analysis of its dynamic behavior using eigenvalue analysis and digital simulation is presented. An important observation is that the plant transfer function is generally of the nonminimum phase type. This precludes the use of large gains in a PI controller as there is a risk of instability of an oscillatory mode of frequency between 200 - 300 rad/s. Eigenvalue analysis using linearized model was carried out to design a compensator in cascade with an integral controller to overcome this problem. 8 Refs.

[1996] 09A - 20

ANALYSIS AND DESIGN OF A DC VOLTAGE-CONTROLLED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE INVERTERS

Fujita, H.; Tominaga, S.; Akagi, H.

Okayama Univ, Japan

IEEE Trans on Industry Applications, vol 32, no 4, July-August 1996, pp 970-978

This paper presents a dc voltage-controlled static VAr compensator (SVC) using quad-series voltage-source non-PWM inverters. The SVC consists of four three-phase voltage-source inverters having a common dc capacitor and four three-phase transformers, the primary windings of which are connected in series with each other. Although each inverter outputs a square wave voltage, the synthesized ac voltage of the SVC has a 24-step waveshape. This results not only in a great reduction of harmonic currents and dc voltage ripples but also in less switching and snubbing losses. This paper develops the analysis of the transient response and the resonance between the ac reactors and the dc capacitor, with the focus on practical use. Experimental results obtained from a 10-kVA laboratory system are shown to agree well with the analytical results, thus verifying the analysis and leading to the design of dc capacitance value. 9 Refs.

[1996] 09A - 21

ANALYSIS OF A 3 LEVEL-VSI NEUTRAL-POINT-CONTROL FOR FUNDAMENTAL FREQUENCY MODULATED SVC-APPLICATIONS

Scheuer, G.; Stemmler, H.

Swiss Federal Inst of Tech, Lausanne, Switzerland

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 303-310

This paper presents a new method to control the neutral-point (NP) of a 3-level-VSI in SVC-applications with fundamental frequency modulation (FFM) or optimized pulse patterns. In a first step the systems equations for a 3-level-VSI connected to a symmetrical, ideal sinusoidal load are derived. This includes a general equation for the NP-current. Based on this, investigations on the self-balancing abilities are performed. It is shown that, in the presence of a resistance in the system, the 3-level VSI is self-balancing for all pulse patterns symmetrical to a quarter of a period and for all power factors on the AC-side. However, in high power applications the self-balancing is very slow due to very small resistances in the system. This is verified by SABER simulations for an SVC-application. In a further step, a NP-control principle for fundamental frequency modulated SVC-applications is deduced on a simplified model. The validity of this scheme for a wide operation range is verified by mathematical analysis and simulation results with Matlab. In a further step, this analysis is extended

by including all harmonics of the 3 level-VSI output currents, which shows their influence on the control scheme. Simulation results with Matlab and SABER proof the validity of the theoretical investigations. Finally the control method is adapted to PWM-SVC-applications. 3 Refs.

[1998] 09A - 22

APPLICATION OF A NONLINEAR PID CONTROLLER ON STATCOM WITH A DIFFERENTIAL TRACKER

Ni, Y.; Jiao, L.; Chen, S.; Zhang, B.

Univ of Hong Kong, China

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO2.2

Abstract not available

[1998] 09A - 23

APPLICATION OF A STATCOM FOR WINDFARM OPERATION

Renz, K.; Tyll, H.; Sobrink, K.

Siemens AG, Germany

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

Wind energy is one of the leading renewable energy technologies for the generation of electricity. Electrical energy may be generated over a wide range of operating conditions, particularly if far more than one wind turbine is connected to the network. Low electrical energy production in one part of the windfarm may occur with high production in another part, together with highly variable reactive power consumption from the system. The operation of wind turbines with asynchronous generators requires reactive power which, if supplied from the network, leads to low voltages and increased losses. The voltage quality can be improved considerably if the wind turbine's varying reactive power consumption is provided from a dynamic compensator, which supplies reactive power corresponding to the varying consumption of the wind turbines, whereas only the constant no-load consumption of reactive power is provided by fixed capacitors. In this way the risk of overvoltages at islanding can also be reduced. Gate turn-off (GTO) thyristor-based static VAr compensators can be used to provide dynamic reactive power to eliminate any possibility of self-excitation. Furthermore, STATCOM can be efficiently used for dynamic control of network voltage, and thus to increase the size of windfarms which are to be connected to existing weak electrical networks without any need for network upgrading. STATCOMs are an emerging technology and have not so far been applied for such an application. The use of dynamic compensation in windfarm application requires detailed harmonic and control studies prior to installation to guarantee smooth implementation to the system. A GTO-based static VAr compensator, or STATCOM, is used in the Rejsby Hede Windfarm in Denmark for dynamic reactive power compensation and voltage limitation when islanding occurs. This is the first application of a STATCOM for windfarm operation. The installation went into operation in 1997.

[1997] 09A - 24

APPLICATION OF ADVANCED STATIC VAR COMPENSATORS TO WIND FARMS

Saad-Saoud, Z.; Jenkins, N.

Univ of Manchester Inst of Sci and Tech, UK

Proceedings, IEE Colloquium on Power Electronics for Renewable Energy, London, UK, June 16, 1997, no 170, pp 6/1-6/5

The modeling of the application of advanced static VAr compensator (ASVC) to an operating wind farm is described. The ASVC was able to supply the reactive power requirements of the wind turbines under various operating conditions. A three-level converter was operated in a selective harmonic elimination modulation mode with a 12 pulse configuration. The ASVC was used to prevent over voltages observed under islanding conditions which was possible only if the total reactive power in the network is less than the ASVC capacity.

[1996] 09A - 25

APPLICATION OF SELF-COMMUTATED INVERTERS TO ELECTRIC POWER SYSTEMS

Kanai, T.; Ishizuki, T.; Kawakami, N.; Irokawa, S.

Toshiba Corp, Tokyo, Japan

Toshiba Rebyu (Toshiba Review) (Japan), vol 51, no 4, April 1, 1996, pp 10-12

Japanese

This paper describes application of self-commutated inverters to electric power systems. Keeping the pace with advancement of power electronics technologies, application of power electronics devices to electric power systems is expanded. The devices include a static reactive power compensator for direct current transmission to broaden wide area connections and for

system voltage stabilization. Separately excited converters using thyristors have been used as a mainstream, while the self-excited converters are expected of expansion in their applications in the future as a result of increasing capacities in such devices having self-turn off function as gate turn-off thyristors. Although there are some technical problems, the self-commutated converters have a number of advantages, such as less dependence on system conditions, high control freedom, and capability of making the device more compact. In order to control system frequency by using speed variable operation in generator motors in a pumped-storage power plant, a GTO self-commutated converter was applied for excitation of the generator motors. The converter has higher continuous operation performance than the cyclo-converter system as a result of suppressing approaching overvoltage during a system failure. It can reduce capacities of excitation transformers and generator motors. 3 figs., 1 tab.

[1997] 09A - 26

APPLICATION OF SOFT-SWITCHING TECHNIQUE TO A DC VOLTAGE-CONTROLLED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE INVERTERS

Tominaga, S.; Fujita, H.; Akagi, H.

Okayama Univ, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-D, no 4, pp 449-455

Japanese

This paper discusses the potential of applying the soft-switching technique to a dc voltage-controlled static VAr compensator. The main circuit of the static VAr compensator (SVC) consists of quad-series voltage-source six-step inverters and four three-phase transformers. The SVC is characterized by a "commutation capacitor" connected in parallel with each switching device, without any additional active or passive element. The commutation capacitor plays an essential role in achieving soft-switching. Experimental results obtained from a small-rated laboratory model of 10 kVA verify the operating principle and effectiveness of the soft-switched SVC proposed in this paper. The zero-voltage-switching enables to reduce dv/dt across each switching device, thus resulting in reduced EMI and switching losses.

[1996] 09A - 27

APPLICATION OF ZERO-VOLTAGE-SWITCHING TO A DC VOLTAGE-CONTROLLED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE INVERTERS

Tominaga, S.; Fujita, H.; Akagi, H.

Okayama Univ, Japan

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 482-488

This paper discusses the potential of applying the zero-voltage-switching technique to a dc voltage-controlled static VAr compensator. The main circuit of the static VAr compensator (SVC) consists of quad-series voltage-source six-step inverters and four three-phase transformers. The SVC is characterized by a 'commutation capacitor' connected in parallel with each switching device, without any additional active or passive element. The commutation capacitor plays an essential role in achieving zero-voltage-switching. Experimental results obtained from a small-rated laboratory model of 10 kVA verify the operating principle and effectiveness of the zero-voltage-switched SVC proposed in this paper. The zero-voltage-switching enables to reduce dv/dt across each switching device, thus resulting in reduced EMI and switching losses. 18 Refs.

[1996] 09A - 28

APPLICATION TO VOLTAGE FLUCTUATION SUPPRESSION SYSTEM (POWER ELECTRONICS)

Kaga, S.; Ito, K.; Ito, H.; Horie, M.; Watanabe, Y.; Masuyama, T.

Toshiba Corp, Tokyo, Japan

Toshiba Rebyu (Toshiba Review) (Japan), vol 51, no 4, April 1996, pp 24-27

Japanese

Outlined herein is a voltage fluctuation suppression system (SVG) aided by a large-capacity self-commutated converter, in service at Shintakatsuka Sub-station for Tokaido Shinkansen, which supplies power to the railway after reducing a feeder voltage of 154 KV by a feeder transformer. The SVG is connected to a voltage reduced to 33 kV by an SVG transformer. It has 3 GTO inverters (including a spare) of 16 MVA, to suppress, after detecting the primary current at the feeder transformer, voltage unbalance and fluctuations in the

154 KV system by compensating reactive power and antiphase current. It uses 4500V-3000A grade GTO's, multiplexed in 6 stages, to secure a large capacity. A snubber energy regenerative circuit is adopted, to reduce switching loss and increase converter efficiency to 97% or higher. The major devices are water-cooled, to make the system compactor. Its effect of suppressing voltage fluctuations is confirmed, as the fluctuations are suppressed from 3% to 0.6% or lower. Almost balanced three-phase current flows in the power-receiving systems, which also confirms its effect of voltage unbalance compensation. 2 refs., 6 figs., 1 tab.

[1998] 09A - 29

ASVG MODEL FOR TRANSIENT STABILITY STUDIES IN UNBALANCED SYSTEMS

Li, X.L.; Duan, X.Z.; He, Y.Z.; Yin, X.G.; Zhou, H.; Li, J.S.; Wang, F.; Ling, X.

Huazhong Univ of Sci and Tech, China

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO7.4

Abstract not available

[1996] 09A - 30

AVERAGED MODELING AND NONLINEAR CONTROL OF AN ASVC (ADVANCED STATIC VAR COMPENSATOR)

Petitclair, P.; Bacha, S.; Rognon, J.P.

Lab d'Electrotechnique de Grenoble, Saint Martin d'Heres, France

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 753-758

This paper deals with the modeling and control of an advanced static VAr compensator (ASVC) or STATCON. A time invariant model is obtained. This model is used to design an efficient nonlinear control law. Simulations are carried out to validate both the time invariant model and the nonlinear control law. 6 Refs.

[1997] 09A - 31

CIGRE TECHNICAL BROCHURE: STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

Erinmez, I.A.

CIGRE WG 14.19

Proceedings, Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 1997

The CIGRE brochure prepared by Working Group 14.19 is focused on providing practicing electric power utility engineers with appropriate material which enables not only a working knowledge to be obtained, but most importantly, the practical information which enables application of STATCOM to particular performance improvement challenges faced by the utilities.

[1996] 09A - 32

CONTROL STRATEGIES OF A THREE LEVEL PWM INVERTER FOR STATIC VAR GENERATOR

Chen, X-M.; Xu, H-P.; Dan, J.; Wang, H.

Nanjing Automation Research Inst, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 930-935

The paper described basic operation principle of a static VAr generator (SVC) with a three level inverter (TLI). A programmed PWM method of harmonic elimination as an important part of control strategies was studied in detail, especially for using gate turn-off thyristors (GTOs). The essence causing neutral point potential (NPP) deviation in dc link of TLI was explored carefully and the simulation results were presented. 2 Refs.

[1997] 09A - 33

CONTROL SYSTEM DESIGN FOR TRANSMISSION STATCON BY APPLYING NONLINEAR FEEDBACK

Han, B.-M.

Korean Inst of Elec Eng, Seoul, South Korea

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 1, January 1997, pp 31-37

Korean

This paper describes a control system design for the transmission STATCON by applying nonlinear feedback and the performance analysis results for the transmission STATCON with a newly designed control system. A mathematical model for the STATCON was derived by using a three-phase equivalent circuit and a perturbation state equation with respect to a typical operating point. A transfer function to describe the dynamics of STATCON was derived by a numerical computation and nonlinear feedback. A controller design was completed by analyzing the feedback system

stability with bode plot and root locus methods. The performance analysis of the conceived control system was verified by a simulation with the EMTP, assuming that the STATCON is connected to an 154-kV transmission system. Simulation results show that the conceived control system has excellent performance to control the reactive power of the transmission system.

[1997] 09A - 34

CONTROLLER DESIGN FOR ADVANCED REACTIVE POWER COMPENSATORS BASED ON INPUT-OUTPUT LINEARIZATION

Yao, Z.; Dawande, M.S.; Rajagopalan, V.

Univ du Quebec a Trois-Rivieres, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 2, pp 936-941

This paper presents a reactive power compensator for electric power systems, which consists essentially of a self commutated inverter and a nonlinear controller. This compensator permits us to regulate voltage of the power systems by compensating reactive power with desired transient performance. The design of control system is based upon the 'Input-Output Linearization Technique'. Such a control system enables us to stabilize globally the compensation system and thus helps to improve largely the transient performance of the global system. The system is simulated using simplified models as well as more sophisticated models for inverters in order to validate the controller performance. 14 Refs.

[1996] 09A - 35

CONVERTER-BASED SOLUTION TO POWER QUALITY PROBLEMS ON RADIAL DISTRIBUTION LINES

van Zyl, A.; Enslin, J.H.R.; Spee, R.

Univ of Stellenbosch, South Africa

IEEE Trans on Industry Applications, vol 32, no 6, November-December 1996, pp 1323-1330

In this paper it is shown that the converter-based Power Quality Manager is a viable solution to power quality problems on radial lines. It is capable of harmonic isolation, improving voltage regulation and flicker compensation simultaneously. These functions can also be implemented independently. The Power Quality Manager is a hybrid device comprising passive components and a converter. The converter power rating is lower than that required by an equivalent active filter or converter-based static VAr compensator. 16 Refs.

[1997] 09A - 36

CUSTOM POWER. THE UTILITY SOLUTION TO DISTRIBUTION POWER QUALITY

Woodley, N.H.

Westinghouse Elec Corp., Pittsburgh, PA, USA

Proceedings, Electricity '97 Conf: New Opportunities Ahead, Vancouver, Canada, April 20-24, 1997, vol 3, pp 1-10

The design of custom power products for electric power distribution system was discussed. Problems with power quality that result in loss of production to critical processes are costly and create a problem for the customer as well as the electric utility. Westinghouse has developed power quality improvement equipment for customers and utilities, using new technologies based on power electronics concepts. The Distribution Static Compensator (DSTATCOM) is a fast response, solid-state power controller that provides flexible voltage control for improving power quality at the point of connection to the utility's 4.16 to 69-kV distribution feeder. STATCOM is a larger version of the DSTATCOM that can be used to solve voltage flicker problems caused by electric arc furnaces. Westinghouse has also developed a Dynamic Voltage Restorer (DVR) which protects a critical customer plant load from power system voltage disturbances. Solid-State Breakers (SSB) have also been developed which offer a solution to many of the distribution system problems that result in voltage sags, swells, and power outages. 6 refs., 8 figs.

[1996] 09A - 37

DAMPING OF TORSIONAL OSCILLATIONS IN AC SYSTEM USING STATCOM

Patil, K.V.; Senthil, J.; Jiang, J.; Mathur, R.M.

Univ of Western Ontario, London, Canada

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 243-247

This paper presents the results of a study on the application of the recently developed FACTS device, static compensator (STATCOM), for the damping of torsional oscillations that occur in a series compensated ac system. The IEEE first benchmark system is considered for this study. In order to suppress unstable torsional mode oscillations, STATCOM with PI controller to regulate the bus voltage, and with an auxiliary signal derived from the generator speed deviations is employed at the generator terminal. Eigenvalue analysis technique is used for small signal analysis, and optimization of the control system parameters is done through step response studies. In

addition, dynamic performance of the nonlinear system with optimized STATCOM controller is evaluated under a three-phase fault. Results from the analytical and digital simulation studies reveal the technical feasibility of using STATCOM for damping of turbine-generator torsional oscillations in series compensated ac systems.

[1998] 09A - 38

DC MAGNETIZATION IN THE TRANSFORMER OF A SELF-COMMUTATED CONVERTER, AND A METHOD FOR ITS PREVENTION

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Tokyo Elec Power Co, Inc, Japan

Journal of the Magnetics Society of Japan (Nippon Oyo Jiki Gakkaishi), vol 22, no 2, pp 52-57

Japanese

A dc component in the output of a self-commutated converter causes the converter transformer to become dc-magnetized, in the worst case causing an overcurrent due to saturation. We experienced dc-magnetization of the converter transformer in a 50-MVA self-commutated SVC (static VAr compensator) at the Shin-Shinano substation of Tokyo Electric Power Company when system disturbances occurred as a result of energizing an adjacent large-capacity main transformer. To deal with this problem, a novel method of preventing dc magnetization was developed that makes a fast flux correction according to the voltage dc component detected in the converter output. This method was applied to the 50-MVA self-commutated SVC and produced satisfactory operation results.

[1996] 09A - 39

DC-AC INVERTERS FOR STATIC CONDENSER AND DYNAMIC VOLTAGE RESTORER APPLICATIONS

Ashcraft, S.R.; Halpin, S.M.

Mississippi State Univ, MS, USA

Proceedings, 28th IEEE Southeastern Symp on System Theory (SSST), Baton Rouge, LA, March 31-April 2, 1996, pp 215-219

There has been significant recent interest in general classes of power electronic-based active power conditioners such as static condensers and dynamic voltage restorers. These systems are discussed in this paper with a focus on the inverter output stage. The inverters considered include conventional six- and twelve-pulse square wave, pulse-width modulated, and multi-level inverters. Current- and voltage-controlled inverters are considered where appropriate. Each of these inverter topologies has been successfully applied to a number of applications such as adjustable-speed motor drives and static VAr compensators but only limited information is available concerning the use of various topologies with active power conditioning equipment. This paper is intended to assimilate the information that is available in a convenient manner so as to provide the basis for continued research in this area. 7 Refs.

[1996] 09A - 40

DESIGN AND IMPLEMENTATION OF A PWM SOLID-STATE SYNCHRONOUS CONDENSER

Jiang, M-C.; Pan, C-T.

Natl I-Lan Inst of Agriculture and Tech, I-Lan, Taiwan

Int'l Journal of Electronics (UK), vol 80, no 1, January 1996, pp 107-126

A new PWM solid-state synchronous condenser (SSSC) is designed and implemented in this paper. The power circuit of this SSSC is simple as only four power semiconductor switches are used. The SSSC allows leading or lagging reactive power compensation, and continuous control of reactive power. It has a rapid response, which allows an almost instantaneous reactive current control, with low harmonic distortion in the line current. Because it uses a current control, instantaneous overcurrent protection is provided naturally, thereby increasing the reliability. The capability of the proposed synchronous condenser is estimated. To ensure a clean line current waveform is obtained, the current-tracking mechanism is analyzed with a graphical aid and a critical condition is presented. The performance of the SSSC is demonstrated with some simulation and experimental results. 7 Refs.

[1997] 09A - 41

DESIGN OF REACTIVE CURRENT AND VOLTAGE CONTROLLER OF STATIC CONDENSER

Padiyar, K.R.; Kulkarni, A.M.

Indian Inst of Sci, Bangalore, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 6, August 1997, pp 397-410

The static condenser (STATCON) is a shunt connected voltage source converter using self-commutating devices like GTOs which can be used for reactive power control.

Their principle of operation is similar to that of a synchronous condenser. A typical application of a STATCON is for voltage regulation at the midpoint of a long transmission line. In this paper, a two stage structure for the control of voltage is investigated. This uses a closed loop reactive current controller whose reference is set by an outer voltage controller. For reactive current control, the use of a PI controller and a fuzzy logic PI controller is investigated. It is found that the fuzzy logic controller overcomes the problem of oscillatory instability encountered when a conventional PI controller is used. An important observation is that the plant transfer function for voltage control (by reactive current injection) is generally of the nonminimum phase type. This precludes the use of large gains in a PI controller as there is a risk of instability of an oscillatory mode. Eigenvalue analysis using a linearized model is carried out to design a compensator in cascade with an integral controller to overcome this problem.

[1997] 09A - 42

DEVELOPMENT OF A THREE-PHASE UNBALANCED VOLTAGE FLUCTUATION COMPENSATING SYSTEM USING A SELF-COMMUTATED STATIC VAR COMPENSATOR

Takeda, M.; Murakami, S.; Iizuka, A.; Mochinaga, Y.

Mitsubishi Elec Corp, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 121, no 3, November 30, 1997, pp 67-78

This paper describes a self-commutated static VAr compensator for suppressing voltage fluctuations caused by an ac electric railway (Shinkansen, or new trunk line). The ac electric railway is a single-phase load with large changes of reactive power and it causes large voltage fluctuations and power imbalances among the three phases in the power system. The authors have developed a new voltage fluctuation compensating system using a self-commutated static VAr compensator. This system has the functions of reactive power compensation and negative-phase-sequence current absorption. It can suppress rapidly changing voltage fluctuations and reduce the three-phase power imbalance caused by the ac electric railway effectively. This compensating system, with a capacity of 40 MVA, was put to practical use for the first time in the world in 1993. The test results at the site show that the system has excellent performance characteristics. A theoretical analysis of the characteristics of voltage fluctuations with or without the compensating system and an evaluation of test results, including a comparison between the theoretical and measured values, are also reported. 5 Refs.

[1996] 09A - 43

DEVELOPMENT OF A VOLTAGE SOURCE INVERTER BASED STATIC VAR GENERATOR

Xu, L-A.; .Liu, W-H.; Jiang, Q-R.; Wang, Z-H.; Li, X-R.; Liu,, Z-Y.; Li, J-S.

Dept of Elec Power, Tsinghua Univ, Beijing, China

Proceedings, 31st Intersociety Energy Conversion Engineering Conf (IECEC 96), Washington DC, August 11-16, 1996, vol 1, pp 611-616

A 300-kVAr advanced static VAr generator (ASVG) utilizing gate turn-off thyristors (GTO) was developed successfully by Tsinghua University, China. In this paper, by using a phasor diagram to reveal the relationship between Us (voltage of system), Uc (voltage of dc capacitor), delta (phase angle difference between voltage of ASVG and system) and theta (pulse width of squarewave of inverters), a detailed description of its operating principles is given. This 300-kVAr ASVG is composed of 18-pulse multiple inverters and typical tests show that the experimental results of an ASVG with this kind of structure (such as harmonic level, steady-state and dynamic performance) are as expected. 3 Refs.

[1997] 09A - 44

DIGITAL MODELING OF TWO DIFFERENT STATCOM CONFIGURATIONS

Ma, T.; Thanawala, H.L.; Abbott, K.M.

GEC ALSTHOM T&D Power Electrn Sys Ltd, Stafford, England

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 646-650

The Static Synchronous Compensator (STATCOM), based on gate turn-off (GTO) thyristor, is becoming commercially available for shunt reactive compensation in EHV transmission systems. A conventional three-phase Graetz bridge converter with a single dc capacitor and an alternative multiple single-phase bridge (chain link) converters in series and requiring multiple dc capacitors are two configurations digitally modeled in this paper. The EMTDC program using full three-phase R, L, C circuit models, bridges and controls, and producing time-domain transient waveforms is

employed in one analysis and the simpler balanced fundamental frequency phasor (i.e. rms quantities) representation similar to that normally employed in transient stability programs in another. The responses for disturbed system conditions are studied for the two types of converter, and the transient variations in the generated full three-phase waveforms and in the alternative rms phasors are compared. 5 Refs.

[1996] 09A - 45

DIGITAL SIMULATION OF ADVANCED STATIC VAR COMPENSATOR WITH EMTP AND VERIFICATION

Ying, J.; de Oliveira, M.M.; Ekstrom, A.; Long, W.F.

Royal Inst of Tech, Stockholm, Sweden

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 884-887

This paper presents an advanced static VAr compensator (ASVC) model implemented in the Electromagnetic Transients Program (EMTP). The implemented ASVC control system as well as the basic control functions are described. The transient behavior of the ASVC under different disturbances is studied with the model. Simulation results are presented and compared with the results obtained in an analog real-time simulator. 6 Refs.

[1996] 09A - 46

DSP BASED CONTROL OF HIGH POWER STATIC VAR COMPENSATOR USING NOVEL VECTOR PRODUCT PHASE LOCKED LOOP

Jung, G.H.; Cho, G.C.; Hong, S.W.; Cho, G.H.

Korea Advanced Inst of Sci and Tech, Taejon, South Korea

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 238-243

This paper presents a new dual loop control using novel vector product phase locked loop (VP-PLL) for a high power static VAr compensator (SVC) with three-level GTO voltage source inverter (VSI). Through circuit DQ-transformation method, a simple dq-axis equivalent circuit is obtained. From this, dc analysis is carried out to obtain maximum controllable phase angle per unit current between the three-phase source and the switching function of inverter, and ac open-loop transfer function is given. Because the phase angle becomes small in high power SVC, this paper proposes VP-PLL for more accurate alpha control. As a result, the overall control loop has dual loop structure, which consists of inner VP-PLL for synchronizing the phase angle with source and outer Q-loop for compensating reactive power of load. Finally, the validity of the proposed control method is verified through the experimental results. 7 Refs.

[1997] 09A - 47

DYNAMIC COMPENSATION OF A DISTRIBUTION SYSTEM USING A NEW BINARY MULTILEVEL VOLTAGE SOURCE INVERTER

Patil, K.V.; Mathur, R.M.; Jiang, J.; Hosseini, S.H.

Univ of Western Ontario, London, Canada

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol VI-8, pp 71f

A new binary multilevel voltage source inverter with separate dc sources is proposed. The new n level voltage source inverter produces ([2n+1] - 1) steps ac voltage output with n full bridge inverters connected in series. The use of selective harmonic elimination modulation technique to either completely eliminate or minimize the harmonics is studied. A closed-loop controller to control the capacitor voltages and adjust the inverter reactive power output is developed. Application of such a compensator for dynamic compensation of 13.8-kV distribution system is examined through transient studies using PSCAD/EMTDC program. The proposed inverter configuration not only reduces the system complexity and size, but also improves the harmonic profile significantly.

[1996] 09A - 48

DYNAMIC MODELING AND TRANSIENT SIMULATION FOR ADVANCED STATIC VAR GENERATOR

Sun, Y-Z.; Liu, J-H.; Yang, Z-P.; Zhao, Z-Y.; Lu, Q-A.; Ji, Y.

Tsinghua Univ, Beijing, China

Automation of Electric Power Systems (China), vol 20, no 1, January 1996, pp 5-10

Chinese

The three-order nonlinear differential equation set which is used to describe dynamic behavior of the advanced static VAr generator (ASVG) is proposed in

this paper. The influence of the dc capacitor value, transformer reactance and controller parameters on power system stability is analyzed. The transient characteristics of ASVG during disturbance have been simulated overall. 2 Refs.

[1997] 09A - 49

DYNAMIC PERFORMANCE AND CONTROL OF A STATIC VAR GENERATOR USING CASCADE MULTILEVEL INVERTERS

Peng, F.Z.; Lai, J.-S.

Oak Ridge Natl Lab, Oak Ridge, TN, USA

IEEE Trans on Industry Applications, vol 33, no 3, May-June 1997, pp 748-755

A cascade multilevel inverter is proposed for static VAr compensation/generation applications. The new cascade M-level inverter consists of (M-1)/2 single-phase full bridges in which each bridge has its own separate dc source. This inverter can generate almost sinusoidal waveform voltage with only one time switching per cycle. It can eliminate the need for transformers in multipulse inverters. A prototype static VAr generator (SVG) system using 11-level cascade inverter (21-level line-to-line voltage waveform) has been built. The output voltage waveform is equivalent to that of a 60-pulse inverter. This paper focuses on dynamic performance of the cascade-inverter-based SVG system. Control schemes are proposed to achieve a fast response which is impossible for a conventional static var compensator (SVC). Analytical, simulated, and experimental results show the superiority of the proposed SVG system. 14 Refs.

[1997] 09A - 50

Deleted

[1996] 09A - 51

ENHANCEMENT OF POWER SYSTEM STABILITY USING NONLINEAR CONTROL STRATEGY OF ASVG

Sun, Y-Z.; Yang, Z-P.; Zhao, Z-Y.; Lu, Q-A.

Tsinghua Univ, Beijing, China

Automation of Electric Power Systems (China), vol 20, no 11, November 1996, pp 17-22

Chinese

A nonlinear control design approach based on differential geometric control theory and nonlinear control strategies of advanced static VAr generators (ASVG) are presented in this paper. The effects for enhancing the stability and dynamic performance of power systems by using an ASVG nonlinear control scheme are illustrated by the simulation on a one-machine infinite-bus and three-machine power systems. The results confirm the validity and significant advantages of the control design approach proposed in this paper. 6 Refs.

[1997] 09A - 52

EXACT ANALYSIS OF A MULTIPULSE SHUNT CONVERTER COMPENSATOR OR STATCON. PART 1: PERFORMANCE

Hill, J.E.; Norris, W.T.

Aston Univ, Birmingham, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 2, March 1997, pp 213-218

As the converter we take a voltage sourced inverter bridge with perfect switches. There is a single capacitor on the dc side and the output is connected to an ac system through an inductive link. By changing the phase, theta //o, of the operation of the inverter switches relative to phase of the ac system, the voltage across the capacitor can be controlled thus controlling the magnitude of the fundamental of the inverter ac output voltage. The difference between the inverter output voltage and the ac system voltage determines the flow of reactive power through the linking inductor to or from the system. There is a size of the passive elements below which the performance of the compensator is poor and above which it is not greatly enhanced. The required passive components are smaller than are needed for a compensator formed from switched capacitors and thyristor-controlled inductors. Increasing the number pulses in the inverter by using phase-shifting transformers, reduces the size of the passive components that are required as well as reducing the magnitude of the harmonic currents in the output. 16 Refs.

[1997] 09A - 53

EXACT ANALYSIS OF A MULTIPULSE SHUNT CONVERTER COMPENSATOR OR STATCON. PART 2: ANALYSIS

Hill, J.E.; Norris, W.T.

Aston Univ, Birmingham, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 2, March 1997, pp 219-

224

The derivation of the equations whose characteristics were discussed in the companion paper links together linear circuit behavior between switching epochs of the inverter. Fourier components of the composite current wave forms are found giving the reactive and active power transferred together with harmonics. The analysis is essentially algebraic. 6 Refs.

[1996] 09A - 54

EXACT LINEARIZATION FOR ADVANCED REACTIVE POWER COMPENSATORS

Yao, Z.; Neacsu, D.O.; Rajagopalan, V.

Univ du Quebec a Trois-Rivieres, Quebec, Canada

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 521-526

This paper presents a reactive power compensator for electric power systems, which consists essentially of a self commutated inverter and a nonlinear controller. This compensator permits us to regulate voltage of the power systems by compensating reactive power with high transient performance. The design of control system is based upon the 'Differential Geometry Technique'. Such a control system enables us to linearize globally the compensation system including the power system and the self commutated inverter and thus helps to improve largely the transient performance of the global system. The system is simulated using simplified models as well as more sophisticated models for inverters in order to validate the robustness of the controllers. 10 Refs.

[1996] 09A - 55

EXPERIMENT AND ANALYSIS OF ASVG [ADVANCED STATIC VAR GENERATOR]

Sun, Y-Z.; Liu, J-Z.; Zhao, Z-Y.; Yang, Z-P.; Lu, Q-A.

Tsinghua Univ, Beijing, China

Automation of Electric Power Systems (China), vol 20, no 5, May 1996, pp 10-13, 18

Chinese

Open-loop and closed-loop experimental results of an advanced static VAr generator (ASVG) with a 15-kVAr capacity are described in this paper. Its operating principles and control characteristics are also described. It is shown that these experiment results agree well with theoretical analyses, thus providing a scientific basis for developing large capacity ASVG equipment. 5 Refs.

[1996] 09A - 56

FACTS (FLEXIBLE AC TRANSMISSION SYSTEM) FACES INTO THE WIND

Soebrink, K.H.; Renz, K.W.; Tyll, H.K.

ELSAM, Denmark

Int'l Power Generation (UK), vol 19, no 6, November 1996, pp 51-52

When wind generators are connected to the network, electrical energy is fed in over a wide range of operating conditions. The authors discuss the GTO-based static VAr compensator (GTO-SVC), used on the Rejsby Hede wind farm in Denmark for dynamic reactive power compensation and voltage limitation.

[1996] 09A - 57

FACTS FACES INTO THE WIND

Sobrink, K.H.; Renz, K.W.; Tyll, H.K.

Int'l Power Generation (UK), vol 19, no 6, November 1996, pp 51-52

When wind generators are connected to a power network, electrical energy is fed in over a wide range of operating conditions. Here, the authors discuss the GTO-based static VAr compensator (GTO-SVC), used on the Rejsby Hede wind farm in Denmark for dynamic reactive power compensation and voltage limitation of the power transferred. 0 Refs.

[1997] 09A - 58

FACTS MODELING AND CONTROL: APPLICATIONS TO THE INSERTION OF A STATCOM ON POWER SYSTEM

Petitclair, P.; Besanger, Y.; Bacha, S.; Hadjsaid, N.

CNRS UMR, Saint Martin d'Heres, France

Proceedings, 32nd IEEE Industry Applications Conf, New Orleans, LA, October 5-9, 1997, vol 3, pp 2213-2217

Much attention has been focused recently on FACTS (flexible ac transmission system) devices. Among these devices, the STATCOM (STATic Compensator) contributes to the voltage support especially in terms of static and dynamic stability. This paper proposes three developed models with control structure for the STATCOM. At first, a comparative study for dynamic operations is presented. Afterwards, the performances of these models, when the STATCOM is inserted in a

power system, are studied. For the models, the CPU time requirements have been compared. 11 Refs.

[1996] 09A - 59

GTO BASED MULTI-LEVEL STATIC VAR COMPENSATOR

Scheidecker, D.; Tennakoon, S.B.

Dept of Elec Eng, Staffordshire Univ, Stafford, UK

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 159-165

This paper presents the general analysis of an n-level advanced static VAr compensator (ASVC). A method of achieving capacitor voltage balance is also demonstrated and implemented on an experimental model. The theoretical studies in both the time domain and frequency domains are supported by experimental studies based on a low power model of a three-phase five-level ASVC. 7 Refs.

[1996] 09A - 60

HIGH-PERFORMANCE SELF-EXCITED SVC

Eguchi, N.; Kato, M.

Fuji Elec Corp R&D Ltd, Japan

Denki Hyoron (Japan), vol 81, no 6, pp 57-60

Japanese

A high performance self-exciting SVC (static VAr compensator) compared with the conventional separately excited SVC was developed. This paper describes principles and features and application examples of the recent high-performance SVC System constitution, main circuit constitution, and control methods are shown for the self-exciting SVC with three-phase unbalance compensation function in power feed circuit for ac electric rail way loads, the self-exciting SVC for power flicker compensation for steel making arc furnaces are shown. Excellent results are obtained in performance verification tests.

[1997] 09A - 61

INFLUENCE OF VOLTAGE UNBALANCE ON THE ADVANCED STATIC VAR GENERATOR

Zhang, L.; Chen, J.; Wang, Z.; Han, Y.; Zhu, Q.; Lin, F.; Wang, Xi.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 55-58

Chinese

The influence of the system voltage unbalance on the advanced static VAr generator (ASVG) has been discussed through the ways of theoretical analysis and simulation. It is recognized that the dc capacitor voltage pulsation and negative sequence current, which is caused by the power flow due to the system negative sequence voltage, is the key point that influences the operation of ASVG. A larger system voltage unbalance degree causes larger capacitor voltage pulsation and negative sequence current. Using the following control method such as choosing the positive sequence voltage as the synchronizing signal of ASVG output voltage, using larger capacitor C and reactance L, and using a 100 Hz LC resonant filter, restrains the influence of the system voltage unbalance effectively.

[1996] 09A - 62

INVESTIGATION OF THE VOLTAGE SAG MITIGATION EFFECT OF AN ADVANCED STATIC VAR COMPENSATOR

Wang, P.; Bollen, M.H.J.; Jenkins, N.

UMIST, Manchester, UK

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 1012-1015

This paper describes the simulation of an advanced static VAr compensator (ASVC) using EMTDC, and presents the results of its voltage sag mitigation effects. Besides the ordinary shunt connection, two other connecting methods, as well as their control schemes, are proposed. It has been found that the voltage sag mitigation effect of an ASVC depends not only on the different configurations, but also on the nature of the voltage sags. 4 Refs.

[1997] 09A - 63

MATHEMATICAL MODELS OF A THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

Ekanayake, J.B.; Jenkins, N.

UMIST, Manchester, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 2, March 1997, pp 201-206

Two mathematical models of an advanced static VAr compensator (ASVC) are described. One model was

obtained using time-domain analysis of the ASVC circuit and then developed into an s-domain model which was used to study the compensator's control system. Both models were validated using a three-phase, 4-kVAr hardware model of a three-level ASVC. The time-domain model was also validated using computer simulations carried out with the EMTDC program. Two switching strategies were considered in the study: fundamental frequency modulation (FFM) and selective harmonic elimination modulation (SHEM). The time domain model was used to predict the waveforms at various parts of the ASVC circuit, for both switching strategies. 6 Refs.

[1997] 09A - 64

MODELING AND CONTROL OF ADVANCED STATIC VAR GENERATOR

Jiang, Q.; Wang, Q.; Han, Y.; Liu, Y.; Liu, Z.; Ji, Y.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 21-25

Chinese

An advanced static VAr generator (ASVG) is a new type of reactive power generator based on GTOs. This paper presents a transient model of ASVGs using a "switching function". A great difference between ASVGs with capacitors and ASVGs with voltage sources on the dc side is pointed out. A new inverse nonlinear PI control law based on this model is proposed. Simulation and real testing results show that the model is correct and the control law has shorter response time than the classical PI control law.

[1996] 09A - 65

MODELING AND SIMULATION OF AN ADVANCED STATIC VAR COMPENSATOR USING SABER

Papantoniou, A.; Coonick, A.; Freris, L.

Imperial College of Sci, Tech & Med, London, UK

Proceedings, 6th Int'l Conf on Power Electronics and Variable Speed Drives, Nottingham, UK, September 23-25, 1996, pp 490-495

The need for fast and reliable VAr compensators has never been more urgent. VAr compensators have advanced from switched capacitors to advanced static VAr compensators (ASVCs). However, the dynamics of the devices themselves as well as their dynamic interaction with the system are little understood. SABER provides a complete solution to the problem of modeling and simulation of such devices. Behavioral modeling through the SABER language, MAST, enables the accurate representation of the ASVC and the system it is designed to improve. Furthermore, the use of special SABER small signal ac routines has also made possible the design of an ASVC controller based on a linearized model. Finally, time domain analysis was used to provide the responses of the integral ASVC solution to a number load conditions. The overall work can be used as a reference for the design and operation of ASVCs serving in similar or other environments. Hence a generic MAST ASVC model can be developed. 10 Refs.

[1997] 09A - 66

MULTILEVEL CONVERTERS AS SERIES VAR COMPENSATORS

Mwinyiwiwa, B.; Wolanski, Z.; Ooi, B.-T.; Chen, Y.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 1, pp 338-342

This paper presents experimental results of a multilevel converter applied as a series static VAr compensator (SVS or STATCOM). An outer feedback loop maintains the VAr operating condition and inner feedback loops equalize the dc capacitor voltages. The delta connection or the transformer secondaries provide paths for zero sequence currents to flow. The tests show its capability for operation under normal balanced condition and under faulted conditions of single line and double line outages. 10 Refs.

[1997] 09A - 67

MULTILEVEL STATCOM WITH THIRD HARMONIC ELIMINATION ON THE DC LINK CAPACITOR VOLTAGES

Mwinyiwiwa, B.; Wolanski, Z.; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 1, pp 317-322

Simulation studies, confirmed by laboratory experiments, show that the undesirable third harmonic inherently present on the dc link capacitor voltages of multilevel converters can be eliminated by a 6-phase configuration in a shunt multilevel STATCOM. The principle can be extended to eliminate the residual sixth harmonic by configuring a 12-please STATCOM. 7

Refs.

[1996] 09A - 68

MULTILEVEL VOLTAGE-SOURCE INVERTER WITH SEPARATE DC SOURCES FOR STATIC VAR GENERATION

Peng, F.Z.; Lai, J.-S.; McKeever, J.W.; Vancoevering, J.

Univ of Tennessee, Knoxville, TN, USA

IEEE Trans on Industry Applications, vol 32, no 5, September-October 1996, pp 1130-1138

A new multilevel voltage-source inverter with separate dc sources is proposed for high-voltage, high-power applications, such as flexible ac transmission systems (FACTS) including static VAr generation (SVG), power-line conditioning, series .compensation, phase shifting, voltage balancing, fuel cell, and photovoltaic utility systems interfacing, etc. The new M-level inverter consists of (M minus 1)/2 single-phase full bridges in which each bridge has its own separate dc source. This inverter can generate almost sinusoidal waveform voltage with only one time switching per cycle as the number of levels increases. It can solve the size-and-weight problems of conventional transformer-based multipulse inverters and the component-counts problems of multilevel diode-clamp and flying-capacitor inverters. To demonstrate the superiority of the new inverter, an SVG system using the new inverter topology is discussed through analysis, simulation, and experiment. 16 Refs.

[1997] 09A - 69

MULTIPULSE CONTROL OF VOLTAGE SOURCE CONVERTERS FOR STATIC VAR COMPENSATION

Kanetkar, V.R.; Dubey, G.K.; Vaidyanathan, K.

CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol II-3, pp 21ff

Multipulse waveforms generated using multilevel economical boost type voltage source converters (VSCs) are presented in this paper. Voltage control is achieved using zero voltage "notch" angles. Five cases are investigated using two different 12-pulse waveforms to obtain a 24-pulse waveform with minimum harmonics. Based on this waveform, economical schemes are suggested for static VAr compensation. Comparison is provided for a 100-MVA static VAr compensation application in support of viability of the economical schemes.

[1997] 09A - 70

NEW OPEN-WINDING CONFIGURATIONS FOR HIGH-POWER INVERTERS

Kawabata, T.; Ejiogu, E.C.; Kawabata, Y.; Nishiyama, K.

Ritsumeikan Univ, Shiga, Japan

Proceedings, IEEE Int'l Symp on Industrial Electronics (ISIE), Guimaes, Portugal, July 7-11, 1997, vol 2, pp 457-462

New configurations of high-power inverters suitable for ac motor drives and static VAr controllers will be presented. A usual method of supplying large ac drives rated at more than several thousands of kilowatts is to combine the outputs of two inverters using inter-phase reactors. However, the inter-phase reactors have several disadvantages such as losses and acoustic noise. To solve these problems, several new configurations which combine two different type of inverters or converters to both terminals of the open windings will be presented. 7 Refs.

[1996] 09A - 71

Deleted

[1997] 09A - 72

NOVEL FOUR-BRIDGE PWM STATIC VAR COMPENSATOR

Ji, Y.; Hu, Y.; Liu, Z.

Harbin Inst of Tech, China

IEE Proceedings: Electric Power Applications (UK), vol 144, no 4, July 1997, pp 249-256

A novel four-bridge PWM static VAr compensator is presented. Theoretical analysis shows that the harmonic pairs of $[(2k+1)\ f_s \pm f]$ and $[(4k+2)\ f_s \pm f]$ generated in each bridge are effectively eliminated through appropriate phase shift control. To satisfy the same 5% total harmonic distortion requirement, this new compensator can work at 200 Hz, which is much lower than the previously reported 1.9 kHz of a single-bridge PWM static VAr compensator. The efficiency is increased and reliability is enhanced. The fairly low switching frequency and multiple-bridge structure facilitate its use in a high-power VAr compensator since GTO can be employed as the power switch. Theoretical analysis was verified through simulations and experimental results. 6 Refs.

[1997] 09A - 73

OPEN-LOOP VAR COMPENSATOR FOR INDUSTRIAL APPLICATIONS, USING A SINGLE PWM PATTERN

Dixon, D.W.; Veas, D.R.

Univ Catolica de Chile, Santiago, Chile

IEE Proceedings: Electric Power Applications (UK), vol 144, no 4, July 1997, pp 257-262

The authors present the analysis of an open-loop, three-phase static VAr compensator (SVC) based on a voltage source inverter, using only one fixed pulse width modulation (PWM) pattern. The VAr generation is controlled by shifting this PWM pattern according to the AC-mains voltage. Because the system is naturally stable, there is no need to control the capacitor dc voltage, which takes a particular stable voltage for each power factor operation condition. To prove this particular behavior, a stability analysis, based on the d-q frame is developed. From this analysis, the circle diagram of the VAr compensator is obtained, which gives all the operating characteristics related to the dc voltage, power angle operation, and reactive power generated. The main characteristics of this compensator are its simplicity and its strong stability, which are particularly suitable for use in industrial loads, such as induction motors, thyristor rectifiers and other low power factor loads. This open-loop system is suitable in the range 1-20 kVAr. The experimental results confirm the operating characteristics given by computer simulations and analysis. 11 Refs.

[1998] 09A - 74

OPERATING PRINCIPLES OF SHUNT STATCOM BASED ON 3-LEVEL DIODE-CLAMPED CONVERTERS AND TWELVE-PHASE MAGNETICS

Ooi, B.-T.; Joos, G.; Huang, X.

McGill Univ, Montreal, Quebec, Canada

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

This paper offers a novel topology for the implementation of a shunt STATCOM based on a grouping of four 3-level, diode-clamped converters, switching at line frequency and coupled to the ac system through wye/wye and wye/delta phase-shifting transformers. Advantages include direct voltage control through the gating pattern and reduced size of dc capacitor. The dominant harmonic on the ac side is the 11th and on the dc side the 12th. The proposed STATCOM can meet typical harmonic distortion requirements.

[1997] 09A - 75

OPERATION AND CONTROL OF ASVG UNDER SYSTEM ASYMMETRIC CONDITIONS

Jiang, Q.; Shen, D.; Han, Y.; Li, X.; Liu, Z.; Ji, Y.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 26-29

Chinese

In this paper, an approach controlling the triggering pulse of GTOs of an advanced static VAr generator (ASVG) to generate a negative sequence voltage component while generating a positive sequence voltage to counteract the system negative sequence component in order to suppress the negative sequence current through ASVG caused by system negative sequence voltage is presented. An algorithm to control the triggering pulse of ASVG is proposed based on modeling ASVG with "function of switchings" method. ASVG can operate normally and not under a 15% negative sequence voltage component in system voltage with this control algorithm. Simulation results show that the analysis and algorithm are correct.

[1997] 09A - 76

OPTIMIZED LINEARIZATION VIA FEEDBACK CONTROL LAW FOR A STATCOM

Petitclair, P.; Bacha, S.; Ferrieux, J.-P.

ENSIEG - LEG, Saint Martin d'Heres, France

Proceedings, 32nd IEEE Industry Applications Conf, New Orleans, LA, October 5-9, 1997, vol 2, pp 880-885

Recently, much attention has been paid to FACTS devices. The STATCOM is a FACTS used to maintain voltage stability and is usually represented as a time-invariant model. This model can then be used to design an efficient nonlinear control law, based on exact linearization via feedback. In this paper, the control law is optimize in order to stabilize the internal dynamics of the STATCOM. Furthermore, the model is implemented into the EUROSTAG software in order to analyze the influence of the control law on the transient response of the power system. 9 Refs.

[1997] 09A - 77

PERFORMANCE EVALUATION OF PAM BY MINIATURE MODEL EXPERIMENT

Chida, T.; Sato, Y.; Shirasaki, T.; Tsukada, M.; Yamaoka, K.; Ito, D.; Murakami, S.; Akamatsu, M.

Tohoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 73-78

Japanese

PAM SVG (pulse amplitude modulation static Var generator) has better cost performance than of PWM SVG (pulse width modulation static VAr generator) due to its low power loss during operation and smaller installation-area requirement, but it is generally said that PAM SVG has difficulty in continuous operation under unbalanced-voltage conditions and that its response is slow. The authors carried out miniature model experiments of PAM SVG, and obtained high performance under unbalanced-voltage conditions and fast response. Power system stabilization effect of the SVG was also confirmed through the experiments. We also established a digital simulation model which gives calculation results in good accordance with the experiments.

[1997] 09A - 78

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. CONTROL METHOD FOR 50 MVA SELF-COMMUTATED STATIC VAR COMPENSATOR

Suzuki, K.; Yajima, M.; Nohara, M.; Ueda, S.; Sato, H.; Eguchi, Y.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 953-959

Japanese

With the development of high power gate turn-off (GTO) thyristors, large capacity self-commutated power converters have been applied to electric power systems. The self-commutated static VAr compensator (SVC) contributes to power system stabilization since it dose not fail in commutation due to any power system fault. Pulse width modulation (PWM) control keeps harmonics low. Active and reactive power can be controlled separately and continuously. On the other hand, there are two problems, a large loss at the high switching frequency of the GTOs, and excessive current due to dc excitation of the multiple transformer needed for large capacity. A 50-MVA self-commutated SVC has been installed in the Shin-Shinano substation of Tokyo Electric Power Company where it has been undergoing a field test since March 1992. Recently, we developed a high performance control method, which uses low harmonics PWM control and high response inhibition of dc excitation of the multiple transformer, under the condition of 2-pulse PWM control (GTO switching frequency is 100 Hz). The control method has been applied to the 50-MVA self-commutated SVC since June 1995. In this paper, the control method and the field test results are described.

[1996] 09A - 79

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. DEVELOPMENT OF NOVEL STATIC VAR COMPENSATOR (VSVC)

Kawasaki, Y.; Tada, S.; Kawakami, R.; Yoshida, T.; Kurio, N.; Morita, H.; Hasebe, T.

Nissin Elec Co, Ltd, Japan

Nisshin Denki Giho (Japan), vol 41, no 3, pp 28-34

Japanese

We developed a new voltage source type SVC (VSVC), which consists of 100 % rating of mono-pulse PAM inverters and 15 % rating of multi-pulse PWM inverters in series. The new concept makes it possible to realize both of the fast response of three-phase unbalanced VAr compensation and the remarkable operating efficiency. This paper describes the system design of the VSVC.

[1997] 09A - 80

PRACTICAL EXAMPLE OF THE USE OF DISTRIBUTION STATIC COMPENSATOR (D-STATCOM) TO REDUCE VOLTAGE FLUCTUATIONS

Hill, J.E.

Rolls-Royce Trans and Distr

Proceedings, IEE Colloquium on Power Electronics for Renewable Energy, London, UK, June 16, 1997, no 170, pp 7/1-7/5

Voltage fluctuations at the point of common coupling of the generator to the electricity supply network are an inevitable consequent of the variable nature of some renewable energy sources. These can be mitigated by a number of techniques but the fast response of the Distribution STATic COMpensator (D-STATCOM) makes it the ideal solution. 7 Refs.

[1997] 09A - 81

PREDICTIVE FUZZY CONTROL AND ITS MATERIALIZATION ON ASVG

Shen Chen; Sun, Y.; Lu, Q.

Tsinghua Univ, Beijing, China

Automation of Electric Power Systems (China), vol 21, no 10, October 1997, pp 4-8, 42

Chinese

This paper presents a new idea of applying the predictive fuzzy control method to power network adjustment. The authors use the advanced static VAr generator (ASVG) as an example to introduce the new control approach. Simulation results show that it is possible to use the predictive fuzzy control method to realize intelligent control of power networks. The simulation results also indicate that the design steps presented by the authors are simple and effective.

[1996] 09A - 82

PRINCIPLE AND APPLICATION OF FLEXIBLY ADJUSTABLE DYNAMIC RESOURCE FOR VAR COMPENSATION

Bi, S-C.; Xu, Y-S.; Feng. G-Q.

Dept of Elec Eng, Shanghai Inst of Elec Power, China

Proceedings, IEEE Int'l Conf on Industrial Technology (ICIT'96), Shanghai, China, December 2-6, 1996, pp 745-747

In this paper, a sort of power system VAr generator mainly based on GTO (gate turn-off thyristor) is described. The principle and the characteristics are analyzed. The prototype of the device is realized in the laboratory. The adjustment is flexible and fast as expected. 3 Refs.

[1998] 09A - 83

REACTIVE POWER COMPENSATION OF A 24 MW WIND FARM USING A 12-PULSE VOLTAGE-SOURCE INVERTER

Sobrink, K.H.; Jinkins, N.; Schettler, F.; Pedersen, J.K.; Pedersen, K.O.H.; Bergmann, K.

CIGRE, Paris, France

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Integration of large wind farms in distribution and transmission systems may have a severe influence on the power quality at the connection points and may also influence the voltage controlling capability of the electrical system. The purpose of the described project has been to develop and investigate the use of a STATCOM by field testing an 8-MVAr unit in a 24-MW wind farm. A further purpose of the project has been to investigate how STATCOMs may be used for dynamic control of network voltages, thus making it possible to increase the size of wind farms which may be connected to existing weak electrical distribution networks without any need for network upgrading. Such use of a STATCOM is evaluated over a one-year trial period during which a comprehensive measurement program is carried out.

[1997] 09A - 84

RECENT ADVANCES IN VAR COMPENSATORS

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Concordia Univ, Montreal, Quebec, Canada

Sadhana (India), vol 22, pt 6, December 1997, pp 705-721

Static VAr compensators have been, for many years, an essential component in the operation of power transmission systems. They are part of a family of devices known as flexible ac transmission system (FACTS) devices. The advent of large capacity force-commutated semiconductor switches allows many developments in power electronic converters to be applied to the implementation of high power compensators. This paper describes the principles of controlled reactive power compensation, particularly in the context of power systems. It focuses on active static power converter-based compensators and discusses issues related to the power circuit topology and the control techniques, including the impact of pulse width modulation (PWM) techniques. Compensators based on current and voltage source converters and on ac controllers, both in the shunt and series configurations, are covered. Methods to enhance power capacity using multilevel and multipulse arrangements are discussed.

[1997] 09A - 85

REGULATING AND EQUALIZING DC CAPACITANCE VOLTAGES IN MULTILEVEL STATCOM

Chen, Y.; Mwinyiwiwa, B.; Wolanski, Z.; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 901-907

Because of the high MVA ratings, it would be expensive

to provide independent, equal, regulated dc voltage sources to power the multilevel converters which are presently proposed for STATCOMs. Dc voltage sources can be derived from the dc link capacitances which are charged by the rectified ac power. This paper addresses two control issues: (1) regulation of the dc capacitance voltages and (2) their equalization. Equalization is necessary (i) to ensure the even sharing of voltage stresses in the gate-turn-off thyristors (GTOs), and (ii) to prevent the degradation of total harmonic distortion (THD) factors, as all harmonic elimination strategies depend on equal voltages in their assumptions. The strategies considered are: (a) the Fundamental Frequency Method, (b) the Sinusoidal pulse width modulation Method. Digital Simulations are used to confirm the feasibility of the control methods. 17 Refs.

[1997] 09A - 86

RESEARCH ON THE START-UP OF THE ±300 KVAR ASVG

Zhang, L.; Chen, J.; Wang, Z.; Han, Y.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 44-47

Chinese

This paper deals systematically with the start-up of the advanced static VAr generator (ASVG) through the ways of theoretical analysis and simulation research. The analytical formula which can describe the transient characteristic of ASVG start-up is deduced through the way of theoretical analysis under the condition of simplification of the ASVG model. The simplification is considered to be right by the comparison of the analytical calculation results and simulation results. The results of the analysis and simulation have a good agreement. The influence of the angle B on the transient time constant and the capacitor voltage of the ASVG start-up is analyzed. The three kinds of start-up of ±300-kVAr ASVG are compared by simulation using EMTDC software. The auxiliary-excited start-up is considered to be the best one.

[1998] 09A - 87

SELECTION OF PASSIVE ELEMENTS FOR A THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

Ekanayake, J.B.; Jenkins, N.

Univ of Peradeniya, Sri Lanka

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

Mathematical models for a three-phase, three-level advanced static VAr compensator (ASVC) working with both fundamental frequency modulation and selective harmonic elimination modulation are described. The mathematical models were simplified to obtain the ASVC ac side current, the dc capacitor voltage and the ripple for both switching strategies. These simplified design tools were validated using the exact model. The resonance between the dc side capacitance and the ac side inductance was studied using the mathematical model, and the resonance frequency for the three-level ASVC was obtained. The resonance frequency was validated against results of electromagnetic computer simulations. using the design tools developed and considering the resonance studies, the process for selection of the size of dc side capacitors for a small ASVC was demonstrated.

[1997] 09A - 88

SIMULATION OF THE STATIC CONDENSER FOR THE PREVENTION OF TRANSIENT VOLTAGE INSTABILITY DUE TO INDUCTION MOTOR LOAD

Yu, D.C.; Liu, H.

Univ of Wisconsin, Milwaukee, WI, USA

Proceedings, 59th American Power Conf, Chicago, IL, vol 59-2, 1997, pp 1076-1081

A mathematical model of the static condenser (Statcon) and its controller is developed in this paper. A simulation method for the study of transient voltage stability in electric power systems is presented. The goal of this paper is to facilitate the study of Statcon for the prevention of transient voltage instability due to large induction motor loads. The simulation results are compared with the results from the thyristor-controlled reactor/fixed capacitor (TCR/FC) static VAr compensator (SVC) and a static capacitor bank. The results demonstrate that Statcon performs better in preventing transient voltage instability. 11 Refs.

[1997] 09A - 89

STABILITY ENHANCEMENT USING ASVG NONLINEAR CONTROL

Sun, Y.Z.; Proske, D.

Tsinghua Univ, Beijing, China

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 983-986

In this paper, the mathematical model of an advanced static VAr generator (ASVG) is developed. A nonlinear ASVG control strategy based on the nonlinear control theory is proposed and also applied for enhancing power system stability. The research results show it is significant that the power system stability can be improved and the power oscillation can be attenuated with the help of the nonlinear controller of ASVG. 5 Refs.

[1998] 09A - 90

STATCOM CONTROLS FOR OPERATION WITH UNBALANCED VOLTAGES

Hochgraf, C.; Lasseter, R.H.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 538-544

Voltage sourced static VAr compensators such as the Statcom need to be able to handle unbalanced voltages. Mild imbalance can be caused by unbalanced loads while severe short-term imbalance can be caused by power system faults. A synchronous frame voltage regulator is presented that works even when three-phase symmetry is lost. This regulator addresses voltage imbalance by using separate regulation loops for the positive and negative sequence components of the voltage. The proposed regulator allows the Statcom to ride through severe transient imbalance without disconnecting from the power system and, further, to assist in rebalancing voltages. The regulator maintains sufficient bandwidth to perform flicker compensation. The controller's performance is simulated for a Statcom in a model distribution system where it is subjected to a severe single line to ground fault and a rapidly varying three-phase load.

[1996] 09A - 91

STATCOM(SVG) AND ACTIVE FILTER

Uchida, R.

Mitsubishi Elec Corp, Japan

National Convention Record, IEE Japan, Industry Applications Society (Denki Gakkai Sangyo Oyo Bumon Zenkoku Taikai Koen Ronbunshu), vol 1996, pt 3, pp S.31-S.34

Japanese

Abstract not available.

[1996] 09A - 92

STUDY OF THE 300 KVA STATIC VAR GENERATOR

Li, Z.; Chen, J-Y.; Han, Y-D.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 941-944

In this paper, a simulation system of 10-kVA static VAr generator (ASVG) based on the EMTDC/PSCAD simulation software is introduced. For the reason that the 300-kVA ASVG prototype is under experiment in Tsinghua University laboratory power plant, the parameters in the simulation system are the same as those in the real power system. The simulation system can represent the real system correctly. Because some experiments such as three-phase short circuit fault are difficult to be accomplished in practice, we focus our efforts on the cases, in which experiments cannot be done but are very important to the operation of ASVG, by the way of simulation in the study of ASVG. Some valuable simulation results are given in this paper. 7 Refs.

[1998] 09A - 93

SYSTEM STABILITY IMPROVEMENT WITH PAM SVG

Chida, T.; Sato, Y.; Shirasaki, T.; Tsukada, M.; Yamaoka, K.; Ito, D.; Murakami, S.; Akamatsu, M.

Tohoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Keito Gijutsu Kenkyukai Shiryo (Japan), vol 98, no 1-6, pp 31-36

Japanese

PAM SVG (pulse amplitude modulation static VAr Generator) has better cost performance than PWM SVG (pulse width modulation Static Var Generator) due to its low loss in operation and smaller installation-area requirement, but it is generally said that PAM SVG has difficulty in continuous operation under unbalanced-voltage conditions and that its response is slow. This paper presents power system stabilization effect of PAM SVG which is confirmed through effective value analysis on a model power system. High performance under unbalanced-voltage conditions and fast response are also demonstrated with experimental results of a miniature model. Improvement of power system stability is confirmed through the experiments, too. The authors established a digital simulation model which gives calculation results in good accordance with the

experiments.

[1998] 09A - 94

THREE LEVEL BINARY VOLTAGE SOURCE INVERTER AS STATIC SYNCHRONOUS COMPENSATOR

Patil, K.V.; Jiang, J.; Mathur, R.M.

Univ of Western Ontario, London, Canada

Proceedings, IEEE Canadian Conf on Electrical and Computer Engineering, Waterloo, Ontario, May 1998, vol 1, pp 842f

The use of fast-acting power electronics converter with its equally fast and efficient controller gives a precise and flexible control of an electrical power system. These devices are suitable for applications in both transmission and distribution. The voltage source inverters (VSI) which convert dc voltage into a single or polyphase ac voltage at a desired amplitude and frequency are increasingly used in power systems for dynamic compensation, improving system stability, directing power flows, etc. The inverters usually synthesize a staircase voltage wave from several levels of dc voltage sources. The various multilevel VSI configurations studied and tested so far include diode-clamp, flying-capacitor and cascaded separate dc source inverters. There have been various topologies of separate dc source inverters suggested in (the references). This paper presents a new binary multilevel voltage source inverter (BMVSI) configuration which can be used as a dynamic compensator.

[1996] 09A - 95

THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

Ekanayake, J.B.; Jenkins, N.

Univ of Manchester, UK

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 540-545

An advanced static VAr compensator (ASVC) employing a three level inverter has been investigated for three-phase applications. The paper describes the operating principles of the ASVC using an elementary single-phase ASVC circuit. The construction of a hardware model of the three-phase, three level ASVC is then presented. The performance of the ASVC is obtained from an experimental study carried out on this laboratory model. The use of the selective harmonic elimination modulation (SHEM) technique to minimize harmonics is explored. Experimental studies have been carried out to determine the speed of response of the scheme by controlling it in a closed loop. 4 Refs.

[1998] 09A - 96

THREE-PHASE COMPENSATOR FOR LOAD BALANCING AND REACTIVE POWER COMPENSATION IN THREE-PHASE, FOUR-WIRE ELECTRIC POWER DISTRIBUTION SYSTEMS

Singh, B.; Anuradha; Kothari, D.P.; Al-Haddad, K.; Chandra, A.

Dept of Elec Eng, Indian Inst of Tech, New Delhi, India

Electric Machines and Power Systems, vol 26, no 1, January 1998, pp 27-37

This paper deals with a three-phase active power compensator (APC) to compensate reactive power and to balance unbalanced loads in the three-phase four-wire electric power distribution system. An APC is realized employing three single-phase IGBT-based VSI bridges with a common dc bus capacitor. Reference supply currents are estimated using P-I control over the average dc bus voltage and three-phase supply voltages. APC reference currents are derived from reference supply currents and load currents. A hysteresis rule-based carrierless . PWM current control is used over compensating currents of the APC and its derived reference currents. Simulated performance of the APC for the single-phase, two-phase and three-phase lagging power-factor loads is illustrated to demonstrate the reactive power compensation and load balancing features of the APC.

[1996] 09A - 97

THYRISTOR CONTROLLED STATIC CONDENSER WITH NEW DOUBLE FIRING PHASE CONTROL

Park, I.G.; Yoon, J.T.; Kim, S.I.

Wonkwang Univ, Choubuk, South Korea

Proceedings, 31st IAS, San Diego, CA, October 6-10, 1996, vol 2, pp 999-1006

A current source type static condenser (Statcon) employing ordinary thyristors for controlling the reactive power of the power system is studied, and a new double firing phase control method is proposed, which makes it possible to control the active and the reactive power directly and independently without any sacrifice of the harmonic characteristics, so that the maximum speed of response is achieved. The 12-pulse

configuration is considered for reducing the harmonics further. The main advantage of the thyristor-controlled Statcon is that the high power technology of the power circuit configuration has been established through the experiences of the high voltage dc (HVDC) transmission systems, so that the thyristor-controlled Statcon with the proposed double firing phase control method is expected suitable for very high power applications in which gate turn-off (GTO) Statcons may not be evaluated economical. 12 Refs.

[1997] 09A - 98

THYRISTOR-CONTROLLED STATIC CONDENSER WITH THE DOUBLE-FIRING PHASE CONTROL

Park, I.G.; Yoon, J.T.; Kim, S.I.

Wonkwang Univ, Chonbuk, South Korea

IEEE Trans on Industry Applications, vol 33, no 6, November-December 1997, pp 1594-1600

A current-source-type static condenser (Statcon) employing ordinary thyristors for controlling the reactive power of the power system is studied, and the double-firing phase-control method is characterized. The double-firing phase-control method can control the active and the reactive power of the Statcon directly and independently, so that the maximum speed of response can be achieved. However, the level of harmonics is still too high to be used practically, therefore, the 12-pulse configuration is considered for further reducing the harmonics. The thyristor-controlled Statcon can be useful in very-high-power applications in which the gate-turn-off (GTO) Statcon may not be evaluated as being economical. 13 Refs.

[1997] 09A - 99

TRANSFORMER-LESS STATIC SYNCHRONOUS COMPENSATOR EMPLOYING A MULTI-LEVEL INVERTER

Hochgraf, C.; Lasseter, R.H.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 881-887

This paper examines the application of a high-voltage multi-level inverter in a 13.8-kV distribution system Static Synchronous Compensator SSC. Equations are developed for the component MVA of the multi-level inverter. Trends in component MVA as a function of the number of inverter voltage levels and the modulation strategy are identified. Control of the dc bus capacitor voltages during phase voltage imbalance is identified as a problem. A method is described whereby the multi-level inverter's dc bus capacitor voltages are actively controlled without using additional power components. The operation of the capacitor voltage control loop is demonstrated through EMTP simulations of an SSC responding to single-phase and three-phase load variations in a model distribution system. 10 Refs.

[1996] 09A - 100

TRANSIENT ANALYSIS OF AN ADVANCED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE PAM INVERTERS

Tominaga, S.; Fujita, H.; Akagi, H.

Okayama Univ, Japan

Electrical Engineering in Japan (translation of Denki Gakkai Ronbunshi), vol 117, no 2, August 1996, pp 93-106

This paper deals with an advanced static Var compensator (ASVC) using quad-series voltage-source PAM inverters. The ASVC consists of four three-phase voltage-source inverters with a common dc capacitor and four three-phase transformers, each primary winding of which is connected in series with each other. Each inverter outputs a square-wave voltage, while the synthesized output voltage of the ASVC has a 24-step wave shape. This results not only in a great reduction of harmonic currents and dc voltage ripples but also in fewer switching and snubbing losses. In this paper, transient analysis is performed with the focus on the response of reactive power and the resonance between the dc capacitor and ac reactors. Experimental results obtained from a small-rated laboratory model of 10 kVA are also shown to verify analytical results based on the p-q transformation. The analytical results help in the design of system parameters such as the capacity of the dc capacitor and feedback gains. 11 Refs.

[1996] 09A - 101

TRANSIENT PERFORMANCE OF THREE-PHASE STATIC VAR COMPENSATOR USING VOLTAGE-SOURCE INVERTER

Mansour, A.A.; Mahgoub, O.A.; Zaki, A.M.; Abu-Elzahab, E.E.

Electrn Research Inst, Cairo, Egypt

Proceedings, Intl Conf on Industrial Technology, Shanghai, China, December 5-9, 1994, pp 411-415

The transient performance of the solid-state VAr compensator using VSI (self-controlled dc bus) is

studied in this paper when the system is transferred from full leading compensation to full lagging compensation and vice-versa according to the load requirements to achieve both leading and lagging compensation. The analysis is based on space vector theory (d-q synchronous frame). 6 Refs.

[1997] 09A - 102

VOLTAGE CONTROL AT A LOAD BUS USING A STATIC COMPENSATOR

Sensarma, P.S.; Padiyar, K.R.; Ramanarayanan, V.

Indian Inst of Sci, Bangalore, India

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol VI-4, pp 35f

Voltage sags in a weak distribution system can arise due to normal load switchings like the direct-on-line start of an induction motor for which custom power approaches provide suitable solutions. A GTO- or IGBT-based voltage source inverter can be used as a reactive power compensator to solve this problem. This controller has a feedforward term in addition to the inner current and outer voltage loops. Simulation results show that load bus voltage has a reduced sag and the starting time of the motor is also substantially reduced, thus reducing the duration of the sag.

[1996] 09A - 103

VOLTAGE STABILITY IMPROVEMENT USING ASVG NONLINEAR CONTROL

Sun, Y-Z.; Yang, Z-P.; Wang, Z-F.; Lu, Q-A.

Tsinghua Univ, Beijing, China

Automation of Electric Power Systems (China), vol 20, no 6, June 1996, pp 21-26, 60

Chinese

The control system model of an advanced static VAr generator (ASVG) is developed in this paper. The nonlinear control scheme of ASVG is proposed on the basis of the nonlinear control theory, and the law is also applied in the study of enhancing power system voltage stability. The research results show that the voltage stability can be effectively improved and voltage collapse can be suppressed efficiently with the nonlinear ASVG controller. 8 Refs.

[1997] 09A - REF

SPACE VECTOR PATTERN GENERATORS FOR MULTI-MODULE LOW SWITCHING FREQUENCY HIGH POWER VAR COMPENSATORS

For Abstract see entry 05A - 20

[1997] 09A - REF

COORDINATION OF CONTROLS WITH MULTIPLE FACTS/HVDC CONTROLLERS IN THE SAME AREA: SURVEY OF PRACTICAL EXPERIENCE

For Abstract see entry 05G - 2

[1996] 09A - REF

STATCOM APPLICATION TO THE REACTIVE POWER COMPENSATION FOR THE CONVENTIONAL HVDC CONVERTER

For Abstract see entry 05G - 7

[1996] 09A - REF

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

For Abstract see entry 07A - 17

[1997] 09A - REF

DAMPING OF POWER SWINGS BY OPTIMAL CONTROL OF SERIES COMPENSATORS

For Abstract see entry 07B - 16

[1997] 09A - REF

ECONOMIC ALTERNATIVE FOR VOLTAGE SUPPORT WHEN URBAN GENERATION IS RETIRED

For Abstract see entry 07B - 18

[1996] 09A - REF

FLEXIBLE AC TRANSMISSION SYSTEM DEVICES ON LARGE INTERCONNECTED POWER SYSTEMS

For Abstract see entry 07B - 25

[1997] 09A - REF

APPLICATION OF FACTS DEVICES TO INCREASE THE NY STATE CENTRAL-EAST/TOTAL-EAST INTERFACE TRANSFER

LIMITS

For Abstract see entry 07B - 8

[1998] 09A - REF

AN ACCURATE AND CONCISE METHOD OF EVALUATING AND FLICKER REDUCTION STRATEGIES IN POWER SYSTEMS

For Abstract see entry 08A - 17

[1997] 09A - REF

COMPARATIVE ANALYSIS OF HARMONIC GENERATION FOR SVC AND STATCOM SYSTEMS

For Abstract see entry 08A - 36

[1996] 09A - REF

COMPARING THE VOLTAGE CONTROL CAPABILITIES OF PRESENT AND FUTURE VAR COMPENSATING TECHNIQUES IN TRANSMISSION SYSTEMS

For Abstract see entry 08A - 38

[1997] 09A - REF

A POWER DISTRIBUTION SYSTEM. STUDY OF VOLTAGE AND REACTIVE POWER CONTROL METHODS FOR HIGH-EFFICIENCY OPERATION OF DISTRIBUTION NETWORK

For Abstract see entry 08A - 7

[1997] 09A - REF

POWER SYSTEM VOLTAGE IMPROVEMENT FOR GRID-CONNECTION OPERATION OF WIND POWER GENERATION SYSTEM BY APPLYING SVC

For Abstract see entry 08A - 92

[1996] 09A - REF

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. NISSIN'S POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT

For Abstract see entry 08A - 94

[1997] 09A - REF

PRESENT AND FUTURE FLICKER MITIGATION TECHNIQUES

For Abstract see entry 08A - 96

[1998] 09A - REF

UPFC - UNIFIED POWER FLOW CONTROLLER: THEORY, MODELING, AND APPLICATIONS

For Abstract see entry 11A - 48

[1997] 09A - REF

POWER SYSTEM STABILITY BY SMES AND SELF-COMMUTATED STATIC VAR COMPENSATOR

For Abstract see entry 14A - 90

[1998] 09A - REF

CONVERTIBLE STATIC COMPENSATOR APPLICATION TO THE NEW YORK TRANSMISSION SYSTEM

For Abstract see entry 16A - 6

[1997] 09A - REF

MULTI-LEVEL CONVERTERS FOR STATIC VAR COMPENSATION

For Abstract see entry 17B - 20

[1997] 09A - REF

STUDY ON HIGH ACCURATE ASVG DIGITAL PULSE GENERATOR

For Abstract see entry 17B - 33

[1997] 09A - REF

BINARY MULTI-LEVEL VOLTAGE-SOURCE INVERTER FOR STATIC VAR GENERATION

For Abstract see entry 17B - 4

[1996] 09A - REF

CONTROL OF NEUTRAL POINT VOLTAGE OF NEUTRAL POINT CLAMPED INVERTERS CONNECTED TO ELECTRIC POWER SYSTEMS

For Abstract see entry 17B - 6

[1997] 09A - REF

CONVERTER CONFIGURATIONS AND SWITCHING FREQUENCY FOR A GTO REACTIVE POWER COMPENSATOR

For Abstract see entry 17B - 7

[1997] 09A - REF

HARMONIC ANALYSIS AND COMPARISON OF SEVERAL TYPICAL CONFIGURATION FOR ASVG

For Abstract see entry 17C - 10

[1997] 09A - REF

HARMONIC ISSUES OF THE APPLICATION OF AN ADVANCED STATIC VAR COMPENSATOR TO A WIND FARM

For Abstract see entry 17C - 13

[1996] 09A - REF

A NEW HARMONIC ELIMINATION PWM TECHNIQUE FOR THREE-LEVEL GTO-SVG

For Abstract see entry 17C - 2

[1996] 09A - REF

APPLICATION OF DOUBLE-LAYER CAPACITOR TECHNOLOGY TO STATIC CONDENSERS FOR DISTRIBUTION SYSTEM VOLTAGE CONTROL

For Abstract see entry 17E - 1

[1998] 09A - REF

EXPERIMENTAL EVALUATION OF STATCOM CLOSED LOOP DYNAMICS

For Abstract see entry 18A - 14

[1996] 09A - REF

INFLUENCE OF THE REAL POWER MODULATION PROVIDED BY A SHUNT COMPENSATOR ON DAMPING POWER SWINGS

For Abstract see entry 18B - 10

[1996] 09A - REF

EFFECTS OF FACTS DEVICES ON STATIC VOLTAGE STABILITY

For Abstract see entry 18B - 7

[1996] 09A - REF

IMPROVEMENT OF POWER SYSTEM PERFORMANCE BY INSERTING FACTS DEVICES

For Abstract see entry 18B - 9

[1997] 09A - REF

LOW FREQUENCY OSCILLATIONS DAMPING BY FACTS AND POWER SYSTEM STABILIZERS

For Abstract see entry 18C - 10

[1997] 09A - REF

APPLYING PWM TO CONTROL OVERCURRENTS AT UNBALANCED FAULTS OF FORCED-COMMUTATED VSCS USED AS STATIC VAR COMPENSATORS

For Abstract see entry 18D - 6

[1997] 09A - REF

NEWTON-TYPE ALGORITHM FOR THE CONTROL OF POWER FLOW IN ELECTRICAL POWER NETWORKS

For Abstract see entry 19B - 12

[1996] 09A - REF

TRANSIENT STABILITY ENHANCEMENT WITH FACTS CONTROL

For Abstract see entry 19C - 4

[1997] 09A - REF

DYNAMIC INTERACTION ANALYSIS BETWEEN STATCON AND TRANSMISSION SYSTEM WITH EMTP

For Abstract see entry 19D - 4

[1998] 09A - REF

ANALOGUE SIMULATION STUDIES WITH ACTUAL CONTROLLERS FOR FACTS EQUIPMENT

For Abstract see entry 19E - 11

[1997] 09A - REF

DEVELOPMENT OF STATCOM FOR POWER SYSTEM SIMULATOR AND HARMONIC ELIMINATION METHOD USING COUPLING TRANSFORMER

For Abstract see entry 19E - 15

[1996] 09A - REF

DEVELOPMENT OF THE MINIATURE MODEL OF STATIC VAR COMPENSATOR USING SELF-COMMUTATED INVERTERS AND THE TEST OF THEM ON SIMULATORS

For Abstract see entry 19E - 18

[1996] 09A - REF

VERIFICATION TEST OF THE SELF-EXCITING SVC SCALE MODEL BY APSA, AS A PART OF THE STUDY ON DEVELOPMENT OF ADVANCED SYSTEM INTERCONNECTION TECHNOLOGY. PART 1

For Abstract see entry 19E - 24

09B Commissioning, Testing, Performance

[1997] 09B - 1

ADVANCED STATIC VAR GENERATOR OF ±300 KVAR EMPLOYING GTO THYRISTORS

Liang, X.; Liu, W.; Chen, J.; Wang, Z.; Yang, Y.; Li, C.; Li, X.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 13-16

Chinese

A prototype advanced static VAr generator (ASVG) based on an 18-pulse GTO voltage source power converter is developed as the first phase of a 20-MVAr ASVG development project. The ASVG, which is rated ±300 kVAr, has been put into experimental operation at Tsinghua University and the Mengzhai substation, Henan Province, China, since July 1995. Design considerations, such as parameters selection and harmonic suppression, are presented. The hardware configuration of the ASVG is also described. Experimental results show it can operate in two quadrants (leading and lagging VArs) at the full 300-kVAr rating, and is capable of rapid control of reactive power with a transient response less than 30 ms to changes in command values. Furthermore it operates correctly under 10% voltage unbalance conditions in the Mengzhai substation.

[1998] 09B - 2

AEP UPFC PROJECT: INSTALLATION, COMMISSIONING AND OPERATION OF THE ±160 MVA STATCOM (PHASE I)

Schauder, C.; Stacey, E.; Lund, M.; Gyugyi, L.; Kovalsky, L.; Keri, A.; Mehraban, A.; Edris, A.-A.

Westinghouse Elec Corp, USA

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

American Electric Power (AEP) has selected its Inez substation in eastern Kentucky for the location of the world's first unified power flow controller (UPFC) installation. Comprising two ±160-MVA voltage-sourced GTO-thyristor-based inverters, this installation is not only the first practical demonstration of the UPFC concept, but also by far the highest power GTO-based flexible ac transmission systems (FACTS) equipment ever installed. The installation will be the first demonstration of this type of equipment connected in series with a transmission line. The project is a collaborative effort between AEP, the Westinghouse Electric Corporation, and the Electric Power Research Institute (EPRI), and has been divided into two phases corresponding to the installation of the shunt- and series-connected inverters, respectively. Phase I (installation and commissioning of the shunt inverter (STATCOM)) was completed successfully in July 1997, and the STATCOM is now operational. Phase II is scheduled for completion in early 1998. This paper gives a brief background to the project, describes the installation and special features of the equipment, and reports on the Phase I commissioning and STATCOM operation.

[1997] 09B - 3

FIELD DEMONSTRATION PROJECT EXPERIENCE ON THE DISTRIBUTION SYSTEMS' DSTATCOM (DISTRIBUTION STATIC COMPENSATOR) USED TO MITIGATE VOLTAGE FLICKER

Clouston, J.R.; Armanini, G.; Abi-Samra, N.C.;

Edwards, C.W.; Sundaram, A.

British Columbia Hydro, Vancouver, Canada

Proceedings, 10th Int'l Power Quality '97 Power Value '97 Conf, Baltimore, MD, September 9-12, 1997, pp 244-264

The DSTATCOM is a fast response, inverter-based power controller that provides flexible voltage control at the point of connection for improving the power quality in distribution systems. It can also provide instantaneous power factor correction to improve line utilization and minimize energy losses. The DSTATCOM is an alternating, synchronous voltage source connected in shunt (parallel) to the distribution three-phase feeder circuit via a coupling transformer. It can exchange reactive power with the distribution system by varying the amplitude and phase angle of an internal voltage source with respect to the line terminal voltage resulting in controlled current flow through the coupling transformer. The DSTATCOM is a solid-state, dc to ac voltage-sourced inverter, utilizing advanced power semiconductor switching devices. They can effectively replace conventional voltage and VAr control elements, load tap changing transformers, voltage regulators, and switched capacitors used in distribution systems. This paper presents the field test results conducted on the prototype model which was connected at a lumber mill for the purpose of mitigating running voltage flicker.

[1997] 09B - 4

OPERATION OF PLUS OR MINUS 100 MVAR TVA STATCON

Schauder, C.; Gernhardt, M.; Stacey, E.; Lemak, T.; Gyugyi, L.; Cease, T.W.; Edris, A.-A.

Westinghouse Elec Corp

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1805-1811

In 1995 a plus or minus 100-MVA static synchronous compensator (STATCON) was commissioned for the Tennessee Valley Authority (TVA) at the Sullivan substation in North-Eastern Tennessee. This was an historic milestone in the initiative for flexible ac transmission systems (FACTS) promoted by the Electric Power Research Institute (EPRI). The TVA STATCON is the first of its kind, using GTO thyristor valves, to be commissioned in the United States, and is currently the largest installation of this type in the world. Commissioning tests have now been completed and the STATCON is operating continuously on line. The demonstrated performance of the equipment has either met or exceeded expectations in all areas and has proven beyond doubt the viability of this type of equipment in high power transmission systems. This paper briefly reviews the STATCON installation and reports on the static and dynamic performance observed during commissioning. 12 Refs.

[1996] 09B - 5

STUDY ON SMALL-SIZE MULTIFUNCTIONAL SELF-EXCITING SVC USING HIGH PERFORMANCE POWER DEVICE

Anon.

Tohoku Elec Power Co, Ltd, Sendai, Japan

Tohoku Denryoku R&D (Japan), vol 1, March 1996, pp 7-8

Japanese

A prototype small-size model of multi-functional self-exciting static VAr control (SVC) system was fabricated to contribute to stabilization and quality improvement in the future power systems, assuming installation at substations. The system has a reactive power compensating function, and a compensating function for harmonics due to multiple number of unspecified loads and an unbalance compensating function. The converter section uses IGBT gate bipolar transistors, and six multi-structure of three-phase voltage type inverters of 9-pulse width modulation (PWM). The control section employs a direct digital control (DDC) by means of multi-CPUs and multi digital signal processors (DSP). The control consists of a system voltage detection control circuit to compensate reactive power and a harmonics, and inverse-phase current detection circuit to perform harmonics compensation and unbalance compensation. A simulated system has been configured, with which verification of voltage stabilization, and of function and effect to suppress influence on high-order systems due to harmonics and unbalance on the load side is being performed.

[1996] 09B - REF

±300 KVAR PROTOTYPE ADVANCED STATIC VAR GENERATOR BASED ON GTO

For Abstract see entry 09A - 1

[1996] 09B - REF

ANALYSIS AND CONSEQUENCES OF THE PHASE JUMP ASSOCIATED WITH A VOLTAGE SAG

For Abstract see entry 09A - 16

[1997] 09B - REF

DEVELOPMENT OF A THREE-PHASE UNBALANCED VOLTAGE FLUCTUATION COMPENSATING SYSTEM USING A SELF-COMMUTATED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 42

[1996] 09B - REF

DEVELOPMENT OF A VOLTAGE SOURCE INVERTER BASED STATIC VAR GENERATOR

For Abstract see entry 09A - 43

[1996] 09B - REF

HIGH-PERFORMANCE SELF-EXCITED SVC

For Abstract see entry 09A - 60

[1997] 09B - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. CONTROL METHOD FOR 50 MVA SELF-COMMUTATED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 78

[1996] 09B - REF

DEVELOPMENT OF A 275 V MODEL AND THE SIMULATION STUDIES OF THYRISTOR CONTROLLED SERIES COMPENSATOR

For Abstract see entry 19E - 13

[1997] 09C - REF

DESIGN OF SERIES AND SHUNT FACTS CONTROLLER USING ADAPTIVE NONLINEAR COORDINATED DESIGN TECHNIQUES

For Abstract see entry 18C - 8

[1996] 09E - REF

A NOVEL DOUBLE-BRIDGE PWM STATIC VAR COMPENSATOR

For Abstract see entry 09A - 10

[1997] 09E - REF

PERFORMANCE EVALUATION OF PAM BY MINIATURE MODEL EXPERIMENT

For Abstract see entry 09A - 77

10 STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

10A Modeling, Control, Applications

[1998] 10A - 1

A GTO CONTROLLED SERIES CAPACITOR FOR DISTRIBUTION LINES

de Souza, L.F.W.; Watanabe, E.H.; Aredes, M.

CEPEL, Brazil

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

This paper presents a novel series compensation method for power distribution lines. It consists of a capacitor and a pair of GTO switches connected in anti-parallel. A continuous control of the capacitor voltage is achieved by varying the blocking angle of the GTOs. Possible applications to improve power systems performance are discussed. This system is studied, including its basic operating principles and harmonic analysis. An application example is presented showing the performance of this compensator both for steady-state and transient conditions. The duality of the proposed scheme with the conventional thyristor-controlled reactor (TCR) is also presented. The concept of dual thyristor switch is introduced and results of digital simulations are presented.

[1996] 10A - 2

A NOVEL POWER FLOW CONTROLLER FOR CONTROLLED SERIES COMPENSATION

Padiyar, K.R.; Geetha, M.K.; Rao, K.U.

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 329-334

Indian Inst of Sci, Bangalore, India

The controlled series compensator (CSC) is a second generation FACTS device capable of providing fast, variable on-line VAr compensation. The compensation can be varied to meet various objectives such as control of power, damping of oscillations and improvement of stability. This paper presents a novel constant angle (CA) controller for transmission network power control and the results are presented with a case study. 6 Refs.

[1998] 10A - 3

A SOLID-STATE CONTROLLABLE SERIES CAPACITIVE REACTANCE FOR IMPROVED UTILISATION OF HIGH-POWER TRANSMISSION LINES

Rigby, B.S.; Harley, R.G.

Univ of Natal, South Africa

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

This paper describes the results of preliminary investigations into the use of an inverter-based, dynamically variable series reactance compensator to provide closed-loop control of the power oscillation phenomenon in a transmission system. The results show that a previously developed inverter-based series compensator can successfully be used to dynamically damp out power oscillations in a transmission system. Furthermore, the results indicate that a promising degree of improvement in power oscillation damping can theoretically be achieved with a relatively small rating of dynamically variable compensating reactance.

[1997] 10A - 4

A STUDY OF THYRISTOR CONTROLLED SERIES CAPACITOR MODELS FOR POWER SYSTEM STABILITY ANALYSIS

Kai, T.; Takeuchi, N.; Sato, T.; Akagi, H.

Meidensha Corp, Tokyo, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 915-920

Japanese

A thyristor-controlled series capacitor (TCSC) is expected as a powerful device to make power transfer capability and transient stability increase. The basic configuration of the TCSC consists of a series of capacitors connected in anti-parallel with thyristor-controlled reactors, so that the firing angle control of the thyristors makes the TCSC capable of achieving impedance control in a wide range with quick response. It is important to clarify the relationship between the fundamental reactance of the TCSC and the firing angle of the thyristors, thus leading to practical applications of the TCSC for the enhancement of the power transfer capability and transient stability in transmission lines. Two relationship equations for TCSC fundamental reactance have already proposed. One is the relationship equation derived from TCSC circuit, source of which is voltage. The other is the relationship equation derived from TCSC circuit, source of which is current. For the case of installing TCSC in the transmission line, it is not clarified that which equation is adequate to analyze power system stability. In this paper, the authors developed whether either of the equation is valid to analyze power system stability: (1) in the steady state, TCSC fundamental reactance is analyzed, and compared with two equations and EMTP. It is clear that TCSC reactance based on current source is adequate; and (2) swinging angle of a generator when the firing angle is stepped up is analyzed with EMTP and analytical model using TCSC model based on current source. It is shown that the proposed model is effective for power system stability analysis.

[1996] 10A - 5

ADVANCED SERIES COMPENSATION (ASC) MODEL FOR STABILITY PROGRAMS

Pereira, M.; Sadek, K.; Jalali, S.; Hedin, R.

Siemens AG, Erlangen, Germany

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 294-298

This paper presents a newly developed model for the representation of advanced series compensators (ASC) in a power system dynamic stability program. This model reproduces the ASC dynamic behavior with high accuracy, over the full frequency range considered in stability studies. Its performance is verified using the EMTP/ATP as well as the PSS/E stability programs. Furthermore, it exhibits great generality and requires no parameters besides the nominal values of the series capacitor and of the TCR reactor. 7 refs.

[1996] 10A - 6

AN ANALYTICAL MODEL CONSIDERING LOSSES FOR A THYRISTOR CONTROLLED SERIES CAPACITOR

Matsuki, J.; Hasegawa, S.; Abe, M.

Kyoto Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 10, October 1996, pp 1304-1310

Japanese

This paper presents an accurate mathematical model for a thyristor-controlled series capacitor. Conventional models assume that the TCSC has no loss and neglect the presence of the resistance component of its equivalent impedance. Mathematical equations considering the effect of the resistance component of TCSC were developed using Laplace transformation by separating the thyristor on and off equivalent circuits. They represent the inherent slow response of the TCSC by solving the differential equations of the TCSC circuit every on/off period. Anti-parallel thyristors and the firing circuits were also simulated correctly. It is more accurate in determining the transient response of TCSC voltages and currents than previous models. The conventional models have a limitation on operating regions, while the developed model is valid for both the capacitive and inductive regions of the TCSC operation as well as the resonant region. The proposed model is also capable of incorporating unstable operating conditions of TCSC. Simulations by the proposed model were conducted and compared with experimental results to check the validity of the model. Effects of resistance on the TCSC performances have been also investigated. 6 Refs.

[1997] 10A - 7

AN ANN-TYPE OUTPUT FEEDBACK EXCITATION CONTROL TO DAMP THE SUB-SYNCHRONOUS RESONANCE

Lee, H.-J.; Kim, M.-G.; Lee, C.K.; Yim, W.-Y.

Kwangwoon Univ, Seoul, Korea

Int'l Conf on Intelligent System Application to Power Systems (ISAP '97), Seoul, Korea, July 6-10, 1997

This paper presents a robust excitation controller to damp out subsynchronous resonance phenomenon using ANN (artificial neural network). In the nonlinear control area, ANN controller has many advantages, such as good fitness to nonlinear system, massive parallel structure, robustness, noise characteristics, etc. The controller has three layers of back-propagation network and it uses two easily measurable inputs of angular velocity, and field voltage. The proposed controller is applied to IEEE first bench mark model. Several case studies prove better performance of the ANN controller than that of full state feedback linear optimal controller in spite of the simple output feedback structure of ANN controller.

[1997] 10A - 8

AN INTRODUCTION TO THYRISTOR CONTROLLED SERIES CAPACITOR

Huang, C.-Y.

Monthly Journal of Taipower's Engineering (Taiwan), vol 583, March 1997, pp 60-74

Chinese

A thyristor-controlled series capacitor (TCSC) was used to adjust capacitance rapidly in series with a power transmission line to allow the variation of the total line impedance. This paper presents the possible operation modes and applications of TCSC. A TCSC sizing and rating method based on a planning case on the Montana 500-kV transmission system (USA) is then illustrated.

[1996] 10A - 9

AN LQG BASED DISCRETE-TIME PSS AND TCSC SUPPLEMENTARY CONTROLLER DESIGN FOR CONTROLLING THE SSR IN THE FLEXIBLE AC TRANSMISSION SYSTEMS

Seo, J-C.; Kim, T-H.; Park, J-K.; Moon, S.I.; Han, B-M.

Korean Inst of Elec Eng, Seoul, South Korea

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 45, no 12, December 1996, pp 1695-1699

Korean

This paper presents an LQG (linear quadratic Gaussian)-based discrete-time PSS (power system stabilizer) and TCSC (thyristor-controlled series compensator) supplementary controller design to suppress the SSR (subsynchronous resonance) in the modified IEEE second benchmark, System-1 model. Time domain simulation using a nonlinear system model shows that the proposed PSS and TCSC supplementary controller can control the SSR efficiently. 9 Refs.

[1996] 10A - 10

ANALYSIS AND CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATOR FOR POWER SYSTEM OSCILLATION DAMPING

Son, K-M.; Han, H-G.; Lee, S-K.; Park, J-K.; Lee, B-H

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 45, no 4, April 1996, pp 484-489

Korean

FACTS equipment can control the power flow and increase the loading on the existing lines to the thermal limits. This paper focuses on the ability of the thyristor-controlled series compensator (TCSC) to increase the damping of the disturbed power system. For precise analysis of the effect of the TCSC on the power system stability, a linearized dynamic equation reflecting TCSC dynamics should be considered. In this paper, based on this model, a model-based compensator is designed. The effect of the time constant of TCSC on the power system oscillation damping is analyzed. It is shown that simultaneous control of the auxiliary input of the exciter can increase the effect of the TCSC on the power system oscillation damping. Nonlinear system verification of the regulator shows the effectiveness of the TCSC with a model-based compensator for stability enhancement. 8 Refs.

[1996] 10A - 11

ANALYSIS OF CONTROL MODES OF THYRISTOR CONTROLLED SERIES COMPENSATORS USING A PERIODIC LINEAR SYSTEM MODEL

Han, H-G.; Son, K-W.; Park, J-K.; Lee, B-H.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 45, no 5, May 1996, pp 625-633

Korean

The TCSC consists of a series capacitor connected in parallel with a thyristor-controlled reactor. The TCSC has variable reactance according to the firing angle of thyristors. This paper provides a new analysis method for TCSC. The TCSC can be linearized as a periodic linear system by the switching function. The switching function of thyristors and input sources are the periodic coefficients in the linearized TCSC model. The TCSC has three operating modes. Those are thyristor-blocked operating mode, thyristor-bypassed operating mode and vernier control mode. This paper analyzes the dynamic characteristics of TCSC control modes using the proposed model. The power system for a case study is an infinite bus power system of 200 km, 345 kV and 3 phi 300 MVA. The MATLAB program is used for the simulation. The simulation results are verified using the EMTP program. This paper proves that the accurate dynamic characteristics of TCSC can be obtained using the proposed model and analysis. 11 Refs.

[1996] 10A - 12

ANALYSIS OF CONTROLLABLE SERIES COMPENSATOR TO SUPPRESS POWER SYSTEM OSCILLATIONS

Swift, F.J.; Wang, H.F.; Li, M.

Manchester Metropolitan Univ, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 202-207

The controllable series compensator (CSC) is one of the potential options of recently proposed FACTS (flexible ac transmission systems) devices. In this paper, the application of the CSC in damping power system oscillations is investigated by analyzing its damping torque contribution to power systems. Basic properties of the CSC damping control are discussed and useful analytical conclusions are presented, which are confirmed by the results of numerical calculation and nonlinear simulation of a sample single-machine infinite-bus power system. 10 Refs.

[1997] 10A - 13

ANALYSIS OF THYRISTOR CONTROLLED SERIES COMPENSATOR DYNAMICS USING THE STATE VARIABLE APPROACH OF A PERIODIC SYSTEM MODEL

Han, H.-G.; Park, J.-K.; Lee, B.-H.

Seoul Natl Univ, South Korea

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1744-1750

This paper deals with analysis of the detailed dynamics of the TCSC. The system considered is a system of one machine connected to an infinite bus through a thyristor-controlled series compensated transmission line. This system can be described as periodic state equations. This paper provides analysis of the periodic state equations using the state variable approach. Transient characteristics as well as steady-state characteristics of the TCSC are presented using the analytical equations for three operating modes of the TCSC. The simulations are performed using the MATLAB program. 11 Refs.

[1996] 10A - 14

ANALYTICAL MODELING OF THYRISTOR-CONTROLLED SERIES CAPACITORS FOR SSR STUDIES

Othman, H.A.; Angquist, L.

ABB Power T&D Co, Inc, Raleigh, NC, USA

IEEE Trans on Power Systems, vol 11, no 1, February

1996, pp 119-127

Thyristor-controlled series capacitors (TCSC) have dynamic characteristics that differ drastically from conventional series capacitors especially at frequencies outside the operating frequency range. Therefore suitable models are needed to properly study the applications of TCSC on a utility system. An accurate analytical model of the TCSC which is valid in the frequency range from 0 Hz to twice the operating frequency is presented. The model incorporates the thyristor triggering logic, the synchronization system, and higher level control loops such as power oscillation damping loop. This model is suited for linearized analyses of a power system using frequency domain methods such as eigenvalues. It is particularly valuable in studying subsynchronous resonance (SSR) and enables the utility industry to better evaluate the interactions between TCSC and other devices. 6 Refs.

[1996] 10A - 15

APPLICATION OF CONTROLLED SERIES COMPENSATION AND STATIC VAR SYSTEM FOR FLEXIBLE AC TRANSMISSION SYSTEMS

Kumar, N.; Dave, M.P.

CR State College of Eng, Murthal, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 264-271

In this paper the effectiveness of the controlled series compensation (CSC) in coordination with an SVS auxiliary controller has been demonstrated for their use in flexible ac transmission systems (FACTS). An effective SVS controller known as combined reactive power and frequency (CRPF) auxiliary controller has been developed and demonstrated.

[1996] 10A - 16

APPLICATION OF SELF-TUNING FUZZY CONTROL IN TRANSIENT STABILITY OF POWER SYSTEM

Chi-Kwong, L.; Ki-Leung, N.; Cheuk-Ming, L.

Hong Kong Polytech Univ, China

Proceedings, 3rd Int'l Conf on Advances in Power System Control, Operation & Management, Hong Kong, November 9-11, 1995, IEE Pub. no 417, pt 1, pp 335-339

In this paper, an adaptive fuzzy controller is introduced for the control of transmission system in an interconnected power system. The objective is to improve the transient stability by tuning a variable series capacitor compensator. A well-known model (6) is used for the related simulation studies. It follows that combination of self-tuning and fuzzy control there can be a substantial improvement in the enhancement of power system steady-state performance and transient stability. 8 refs.

[1996] 10A - 17

APPLICATION OF THE CONTROLLABLE SERIES COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATIONS

Swift, F.J.; Wang, H.F.

Manchester Metropolitan Univ, UK

IEE Proceedings, Generation, Transmission and Distribution (UK), vol 143, no 4, July 1996, pp 359-364

In the paper, the application of the controllable series compensator (CSC) in damping power system oscillations is investigated on the basis of the Phillips-Heffron model, which is established for a general n-machine power system. The capability of the CSC damping control to provide damping to the power system is analyzed in terms of its damping torque contribution both for single-machine infinite-bus and multimachine power systems. Brief guidelines for the design of the CSC damping controller are given and demonstrated on sample power systems. 9 Refs.

[1998] 10A - 18

APPLICATION OF THYRISTOR CONTROLLED SERIES COMPENSATORS TO ENHANCE OSCILLATORY STABILITY AND TRANSMISSION CAPABILITY OF LONGITUDINAL POWER SYSTEM

Luor, T.S.; Hsu, Y.Y.; Guo, T.Y.; Lin, J.T.; Chen, Y.Y.; Huang, C.Y.; Wang, S.K.; Jeng, L.H.

Natl Taiwan Univ, Taiwan

IEEE Trans on Power Delivery, Preprint order number PE-298-PWRS-0-2-1998

Power transfer capability between the northern area and the central area of the Taiwan power system is severely limited by the fact that the power flows over the two parallel corridors connecting the two areas are rather disproportionate to their thermal limits due to different conductor sizes. Placing series capacitors on the corridor which is lightly loaded seems to be a reasonable means to enhance the overall transfer capability of the parallel corridors without overloading the other corridor which is already close to its thermal limit. A joint

research project is conducted by the researchers at National Taiwan University and the engineers at Taiwan Power Company (TPC) in order to examine the feasibility of installing a combination of conventional series capacitors and thyristor-controlled series compensators (TCSCs) at TPC's 345-kV transmission system. Extensive power flow studies are conducted to investigate how the power flows over the two corridors are affected by different locations and capacities of the series capacitors. In addition to steady-state power transfer levels over the two corridors, the eigenvalues for the inter-area oscillation modes are also computed for the system with various compensation plans. A proper compensation plan is determined based on requirements on both steady-state power transfer level and inter-area mode damping. To improve system dynamic performance, a supplementary TCSC damping controller is designed.

[1997] 10A - 19

APPLICATIONS OF CSCS FOR DAMPING OF POWER SWINGS

Noroozian, M.; Halvarsson, P.

ABB Power Sys, Sweden

Vector (Electrical Engineering), November 1997, pp 2, 4, 6, 8

The use of controllable series capacitors for damping of electrochemical oscillations is examined. The fundamental input signal for damping of power swing is discussed based on the study of eigenvalues of a linearized power system. The impact of a controllable series capacitor (CSC) on damping of a power system is shown through an analytical approach. The performance of CSC for damping of power swing is compared with that of a power system stabilizer. It is shown that CSC can be a very effective device for damping of power swing using locally measurable signals. 7 Refs.

[1996] 10A - 20

ASSESSMENT OF FACTS REQUIREMENTS ON THE PSE&G SYSTEM: SUBSYNCHRONOUS RESONANCE MITIGATION OPTIONS FOR THE PENNSYLVANIA-NEW JERSEY-MARYLAND INTERCONNECTION

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-106463, March 1996, 46 pp

Subsynchronous resonance (SSR) due to nearby generating units and capacitors has limited the application of series capacitors to increase bulk power transfer capability. This report investigated use of thyristor control on a portion of the series capacitor system to mitigate SSR.

[1997] 10A - 21

AUTO-DISTURBANCES REJECTION CONTROLLER FOR THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC)

Zhang, C.; Zhou, X.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 21, no 5, May 1997, pp 57-61

Chinese

In this paper, a new kind of controller for a thyristor-controlled series capacitor (TCSC) based on the theory of the auto-disturbances rejection control and the platform of the Power System Analysis Software Package/User Program Interface (PSASP/UPI) is presented. The controller can detect automatically the real time effect of the disturbances from inside and outside of the system and compensate it. Using the local signal to realize its control, the structure of the controller is very simple. The convenient and flexible PSASP/UPI platform is an effective tool for the design of this controller. The results from computer simulation demonstrate that the controller is independent of the mathematical expression of the controlled system, it not only can regulate immediately the impedance of the transmission line, increase the damping of the power system, improve the stability, but also has good adaptability and robustness.

[1997] 10A - 22

CAPABILITIES AND STRESSES, ON MAIN COMPONENTS OF YI-FENG TCSC

Lin, J.; Zheng, J.; Liu, C.; Chen, G.; Wu, C.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 21, no 9, September 1997, pp 1-6, 10

Chinese

The voltage and current stresses on the main components, such as capacitor bank, thyristor, bypass inductor and MOV for Yi-Feng thyristor-controlled series compensation (TCSC) during steady-state or pseudosteady-state, including normal operation, N-1 operation and transient stability control, are investigated

in this paper. The capabilities of the TCSC for various operation conditions are presented.

[1997] 10A - 23

CHARACTERIZATION OF A THYRISTOR CONTROLLED REACTOR

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Arizona State Univ, Tempe, AZ, USA

Electric Power Systems Research, vol 41, no 2, May 1997, pp 141-149

This paper characterizes the operation of a thyristor-controlled reactor (TCR) which consists of an inductance and a bi-directional thyristor switch connected in parallel. Firing angle control of the thyristor switches regulates the time for which the inductance is included in the circuit. This controls the average value of the inductance. The continuously regulated inductance can be used for line flow regulation and short circuit current reduction. It can also be used for series compensation when the TCR is connected in series with a fixed capacitor and when the combination is inserted in series with transmission lines. This paper analysis the operation of the TCR using equations and EMTP simulations. The analysis shows that a series compensator using TCR regulates the level of compensation from inductive to capacitive and the system response is faster than the recently commercialized 'Advanced Series Compensation' (ASC) scheme. Also, the problems of resonance and harmonic instability associated with the ASC are eliminated. The TCR can control short circuit current within half cycle. 6 Refs.

[1997] 10A - 24

CLARIFICATION OF THE SSR MITIGATION MECHANISM OF A TCSC

Kakimoto, N.; Iida, A.; Seki, M.; Minoyama, K.; Takuma, T.

Kyoto Univ, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 120, no 4, September 1997, pp 31-39

A thyristor-controlled series capacitor (TCSC) is considered to be effective not only for flow control and stabilization of power systems, but also for mitigation of subsynchronous resonance (SSR). This paper clarifies the SSR mitigation mechanism of a TCSC. First, using time simulations, we show that SSR appears and disappears depending on the firing angle of the TCSC. Next, we show that the frequency characteristics vary considerably with the firing angle. Further, we show that SSR occurs in TCSC-compensated systems as well as in conventional series-capacitor-compensated systems when 60 Hz minus the electrical resonance frequency of a transmission system coincides with the torsional oscillation frequency of a generator-turbine shaft. TCSC can avert SSR by changing the firing angle and by shifting the electrical resonance frequency. Next, we propose an equivalent circuit to TCSC which consists of a series capacitor in parallel with a resistor and a reactor. We adjust the parameters so that it shows the same frequency characteristics as TCSC. We apply it to time simulations to see if it is equivalent to TCSC. Finally, we perform an eigenvalue analysis on the equivalent circuit. We obtain results that correspond to the time simulations. 11 Refs.

[1998] 10A - 25

COMPARATIVE STUDIES ON SYNCHRONIZATION SCHEMES FOR A THYRISTOR CONTROLLED SERIES CAPACITOR

Matsuki, J.; Hasegawa, S.; Abe, M.

Kyoto Univ, Japan

Pawa Erekutoronikusu Kenkyukai Ronbunshi (Japan), vol 32, no 2, pp 9-16

Japanese

This paper presents the results of experimental study on the effects of synchronization systems for a thyristor-controlled series capacitor(TCSC). A comparison has been made between two different synchronization schemes: synchronization with respect to zeros of TCSC capacitor voltage and synchronization with respect to zeros of line current. No such comprehensive investigation has been reported in the literature yet. A laboratory-scale TCSC has been designed, produced and installed in a laboratory power system at Kyoto University. Effects of the two synchronization systems on the performances of TCSC have been investigated on the experimental system. Steady-state impedance characteristics, dynamic response, and instability of TCSC in a variety of operating conditions have been compared. Both advantages and disadvantages of the two synchronization systems have been clarified.

[1996] 10A - 26

COMPUTING THE DAMPING OF SUBSYNCHRONOUS OSCILLATIONS DUE TO A THYRISTOR CONTROLLED SERIES CAPACITOR

Rajaraman, R.; Dobson, I.; Lasseter, R.H.; Shern, Y-C.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 1120-1127

We extend eigenvalue analysis of subsynchronous resonance (SSR) to include thyristor switchings. The eigenvalue computation takes account of the time variations and nonlinearities of both the thyristor switchings and the generator. An example is presented using the IEEE first benchmark SSR model. The paper contributes an accurate method to compute the damping of the SSR modes with a TCSC. 19 Refs.

[1996] 10A - 27

CONSIDERATION IN THE SYNCHRONIZATION SHEMES FOR A THYRISTOR CONTROLLED SERIES CAPACITOR

Matsuki, J.; Hasegawa, S.; Tanaka, T.; Abe, M.; Katagi, T.

Kyoto Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 31-40

Japanese

This paper is a comparative study on two different synchronization systems for a thyristor-controlled series capacitor (TCSC): capacitor voltage synchronization and line current synchronization. Steady-state impedance character-istics and dynamic responses of a developed TCSC have been compared experimentally under the two systems. Both advantages and disadvantages of the two systems have been clarified in this paper. These experimental results have been confirmed by simulation models we have developed. No such comprehensive investigation has been reported in the literature yet.

[1997] 10A - 28

CONTROLLED SERIES COMPENSATION: DYNAMIC PERFORMANCE UNDER FAULT CONDITIONS

Neto, O.M.; Leao, P.C.A.; Araujo, A.E.A.

Federal Inst of High Education of Sao Joao del Rei, Sao Joao del Rei, Brazil

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 5-8

FACTS devices have had a wide spread use in power system around the world. Among the various types of these devices the Thyristor-Controlled-Series-Capacitor (TCSC) has shown to be one of the most promising. TCSC has received very much attention in respect to its basic modeling and steady-state behavior. This paper discusses a modeling for dynamic studies of a TCSC. A single-phase fault is applied in the system. Capacitor voltages and thyristor currents are shown for different thyristor firing angles. Simulations have been implemented using EMTP (Electromagnetic Transient Program). 4 Refs.

[1996] 10A - 29

DAMPING CONTROLLER DESIGN FOR POWER SYSTEM OSCILLATIONS USING GLOBAL SIGNALS

Aboul-Ela, Magdy E.; Sallam, A.A.; McCalley, James D.; Fouad, A.A.

Suez Canal Univ, Egypt

IEEE Trans on Power Systems, vol 11, no 2, May 1996, pp 767-773

This paper describes a new power system stabilizer (PSS) design for damping power system oscillations focusing on interarea modes. The input to the PSS consists of two signals. The first signal is mainly to damp the local mode in the area where PSS is located using the generator rotor speed as an input signal. The second is an additional global signal for damping interarea modes. Two global signals are suggested; the tie-line active power and speed difference signals. The choice of PSS location, input signals and tuning is based on modal analysis and frequency response information. These two signals can also be used to enhance damping of interarea modes using SVC located in the middle of the transmission circuit connecting the two oscillating groups. The effectiveness and robustness of the new design are tested on a 19-generator system having characteristics and structure similar to the Western North American grid. 12 Refs.

[1996] 10A - 30

DAMPING ESTIMATES OF SUBSYNCHRONOUS AND POWER SWING OSCILLATIONS IN POWER SYSTEMS WITH THYRISTOR SWITCHING DEVICES

Rajaraman, R.; Dobson, I.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 1926-1930

We extend the torque per unit velocity method for estimating the modal damping of subsynchronous oscillations to general power systems with thyristor switching devices. This allows damping of SSR by thyristor-controlled series capacitors to be obtained from time domain simulations of only the electrical part of the system. Our method generalizes to the case of multiple torsional modes with the same natural frequency. A new method is used to estimate the damping and frequency of the swing mode. Torque per unit velocity methods are easier than exact eigenvalue analysis and testing on the IEEE first benchmark SSR model shows excellent agreement with exact eigenvalue analysis. 18 Refs.

[1996] 10A - 31

DAMPING OF POWER OSCILLATIONS USING THYRISTOR CONTROLLED SERIES CAPACITORS

Othman, H.; Halvarsson, P.

ABB Power T&D Co, Inc, Raleigh, NC, USA

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1311-1315

Controlled series capacitor (CSC) technology is well established, as evidenced by several commercial installations. CSC is a very powerful system for power flow control and is immune to SSR. In addition, CSC is very effective for damping electromechanical power oscillations which makes it ideal for interconnection projects between existing and planned power systems. Systematic procedures are introduced in this paper for the selection of CSC sites, measurement signals and damping controller parameters. 5 Refs.

[1996] 10A - 32

DAMPING OF POWER OSCILLATIONS USING ADVANCED SERIES COMPENSATION

Attia, A.A.

Mansoura Univ, Egypt

IEEMA Journal (India), vol 16, no 1, January 1996, pp 21-22, 25-26, 28

This article describes how advanced series compensation (ASC) can be used to damp power oscillations. This has a particular interest in the case of weakly coupled networks. The ASC is constructed by means of a fixed capacitor (FC) and thyristor-controlled reactor (TCR). Transient stability limit and power system damping enhancement by application of ASC are analyzed based on the well-known equal area criterion. Effectiveness of ASC to control the power flow on the transmission line is discussed. The continuous control of ASC, using the power deviation on the line to damp intermachine and intersystem oscillations is developed. The time domain simulations of the proposed ASC control are demonstrated in a one-machine system and a 3-machine system. 7 Refs.

[1996] 10A - 33

DEVELOPMENT OF 500 KVAR CLASS THYRISTOR CONTROLLED SERIES CAPACITOR MODEL

Kida, J.; Arita, H.; Yamagiwa, T.; Makino, J.

Hitachi, Ltd, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 868-869

Japanese

Abstract not available.

[1997] 10A - 34

DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

Kato, M.; Morioka, Y.; Mishima, Y.; Nakachi, Y.; Asada, M.; Watanabe, M.; Konishi, H.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 1016-1023

Japanese

The thyristor-controlled series compensator (TCSC) can stabilize a power system by controlling line impedance and, in the future, it is expected to provide a scheme for dealing with stability problems. However, detailed reports about control and protection methods of the TCSC are lacking regarding such points as firing angle control of thyristors. This paper proposes some new methods to control and to protect the TCSC. First, methods for firing angle control to synchronize line current, pulse width control and total impedance control of two TCSC modules are described. Continuous impedance control ranging from capacitive to inductive conditions is possible by these methods. Furthermore, achievement of zero impedance can reduce the influence when the TCSC was installed on transmission lines. Next, the impedance feedback control method is explained which makes the impedance response of the

TCSC faster. Finally, protection schemes by cooperative operation of arresters, thyristors and bypass switches are proposed. The effectiveness of these control methods is confirmed by EMTP simulations and experiments using the TCSC miniature model for a simulator.

[1997] 10A - 35

DIGITAL SIMULATION OF IMPEDANCE-CONTROL TRANSIENTS CHARACTERISTICS FOR YI-FENG TCSC SYSTEM

Lin, J.; Zheng, J.; Liu, C.; Chen, G.; Wu, C.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 21, no 7, July 1997, pp 1-5, 9

Chinese

This paper presents the digital simulation of the impedance-control transient characteristics for the Chinese Yi-Feng power system thyristor-controlled series compensation (TCSC) scheme. It covers smooth impedance control response, step impedance control response and transitions between inductive and capacitive reactance modes. The effectiveness of different control methodologies, for example the open-loop and closed-loop impedance control, is compared.

[1997] 10A - 36

DISCRETE CONTROL OF SERIES COMPENSATION FOR STABILITY IMPROVEMENT IN POWER SYSTEMS

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Indian Inst of Sci, Bangalore, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 5, June 1997, pp 311-319

Changes in the network such as connecting a shunt resistor, inserting a series capacitor and reducing of generation/load, when accomplished under a suitable control scheme can improve transient stability. Switching of series capacitors in a transmission line can also help to damp oscillatory power transients. In this paper a detailed analysis and study of a discrete control strategy for the thyristor-controlled series capacitor to improve stability is presented. A single machine infinite bus system is considered to illustrate the development of the control strategy. The energy function is used to determine the switching instants. The control philosophy is later extended to the multimachine system where the energy of the transmission line is used to determine the control strategy.

[1997] 10A - 37

DYNAMIC MODELING OF A TCSC WITH APPLICATION TO SSR ANALYSIS

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IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1619-1625

Conventional subsynchronous resonance (SSR) study methods such as eigenanalysis require a linear dynamic model of each device. FACTS devices, such as thyristor-controlled series capacitors (TCSC) are difficult to model due to their nonlinear switching behavior. Linearizing the TCSC steady-state average model is inadequate, as this does not model the passive damping associated with the open loop operation of a TCSC. The proposed approach exploits the fact that the thyristor-controlled reactor associated with the TCSC is switched in a regular pattern. A linear model is obtained by linearizing the half-period map associated with sampling the TCSC capacitor voltage twice every cycle. Such an approach models the passive damping which varies with the steady-state conduction angle of the TCSC. It is shown that passive damping has a significant effect on the modal damping of the torsional modes associated with subsynchronous resonance phenomena. 11 refs.

[1996] 10A - 38

DYNAMIC PERFORMANCE OF A THYRISTOR-CONTROLLED SERIES CAPACITOR SYSTEM

Matsuki, J.; Ikeda, K.; Tanaka, T.; Abe, M.

Kyoto Univ, Japan

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 961-964

This paper describes the results of basic study on dynamic performance of an electric power system when a thyristor-controlled series capacitor (TCSC) is applied to the system. A laboratory-scale TCSC was produced and installed on a one-machine infinite-bus laboratory power system. Insertion response and step response tests under a variety of operating conditions were conducted on the experimental system. Effects of excitation system and damper windings as well as TCSC circuit component size upon the dynamic performances of TCSC were discussed. A comparative study between the conventional series capacitor (SC) and TCSC was also conducted. EMTP simulations were used to confirm the experimental results. 6 Refs.

[1998] 10A - 39

DYNAMIC PHASOR MODEL OF THYRISTOR-CONTROLLED SERIES CAPACITOR

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Dept of Elec Eng, Univ of Padova, Italy

IEEE Trans on Power Systems

In previous work we have studied the phasor dynamics of thyristor-controlled series capacitors (TCSCs), and derived associated models for studying power swing oscillations in a power system. This paper presents the use of a dynamic phasor model of the TCSC in studies of subsynchronous resonance (SSR). Our earlier dynamic phasor models of the TCSC are further simplified here, and tested at typical subsunchronous frequencies. The phasor model of the TCSC is directly compatible with the conventional models used for the other system components relevant to SSR. The proposed approach to SSR analysis is an attractive alternative to approaches based on sampled-data models, and to torque-per-unit-velocity methods. The dynamic phasor approach has been tested on the IEEE first benchmark SSR model, showing outstanding agreement with more computationally demanding alternative methods for eigenvalue analysis.

[1997] 10A - 40

DYNAMIC STATE ESTIMATION USING A NONLINEAR OBSERVER FOR OPTIMAL SERIES-CAPACITOR SWITCHING CONTROL

Chang, J.; Taranto, G.N.; Chow, J.H.

Dept of Power Planning, Korea Elec Power Corp, Seoul, South Korea

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 7, October 1997, pp 441-447

Time-optimal control of network impedances by a series capacitor has been considered to be a powerful method to enhance transient stability in power systems. A time-optimal control scheme relies on the availability of the synchronous machine angle and speed variables. However, a TCSC (thyristor-controlled series compensator) will, in general not be located near any synchronous machines, so that angle and speed variables cannot be measured locally. In this paper we propose a gain-scheduled nonlinear observer to provide estimates of the system states to the TCSC control design. Kalman filter design and gain scheduling techniques are used in this procedure. The method is used to design a TCSC time-optimal control in a single-machine infinite-bus power system and is shown to give satisfactory results.

[1996] 10A - 41

EFFECTS OF LOSS RESISTANCE ON THE CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR(TCSC)

Matsuki, J.; Hasegawa, S.; Tanaka, T.; Abe, M.; Katagi, T.

Kyoto Univ, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 33-34

Japanese

Abstract not available.

[1997] 10A - 42

EIGENVALUE SENSITIVITY APPROACH TO LOCATION AND CONTROLLER DESIGN OF CONTROLLABLE SERIES CAPACITORS FOR DAMPING POWER SYSTEM OSCILLATIONS

Rouco, L.; Pagola, F.L.

Univ Pontificia Comillas, Madrid, Spain

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1660-1666

This paper presents tools and methods to study the application of controllable series capacitors for damping power system electromechanical oscillations. Two problems are discussed: location and controller design. The location of a controllable series capacitor consists of determining the series capacitor of the power system where the modulation of its series reactance will be more effective to damp out the modes of interest. It also involves the selection of the input variable to the controller. The basic design of the controller requires the design of the phase compensation network and the calculation of the controller gain. Small signal models of the power system and the corresponding eigenvalue sensitivities will be used to address both problems. 10 Refs.

[1996] 10A - 43

ENHANCEMENT OF POWER SYSTEM STABILITY BY USING CONTROLLED SERIES COMPENSATION

Chen, X.R.; Pahalawaththa, N.C.; Annakkage, U.D.; Kumble, C.S.

Univ of Auckland, New Zealand

Int'l Journal of Electrical Power and Energy Systems (UK), vol 18, no 7, October 1996, pp 475-481

This paper studies the application of controlled series compensator (CSC) to damp power swings in multi-machine power systems. For the design of CSC damping controllers, a necessary step is the derivation of the linear state equation for the system. In order to consider the dynamics of the CSC, it is important to present the change in the CSC reactance as one of the state variables. In this case, unlike the traditional network representation, the network admittance matrix is no longer a constant matrix. Under this situation, the conventional linearization method for obtaining the linear state equation for the system must be modified. In this paper, a linear dynamic model for a multi-machine power system equipped with controlled series compensators (CSCs) is derived. Based on this linear dynamic model, a state feedback controller is designed for CSC control. The feedback control gains are obtained by using the pole placement technique. Given that CSCs are to be installed in a meshed system, the optimum location for installing CSCs is determined by analyzing the mode controllability. The effectiveness of this controller for damping the oscillations caused by power system disturbances is verified by simulation studies. 11 Refs.

[1997] 10A - 44

ENHANCING POWER SYSTEMS DYNAMICS WITHOUT RISKING SSR PHENOMENA BY MEANS OF TCSCS

Tenorio, A.R.M.; Jenkins, N.

Companhia Hidro Eletrica do Sao Francisco, Sao Francisco, Brazil

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 879-882

This paper describes the advantages of thyristor-controlled series capacitors (TCSC) over conventional series capacitors (SC). It is shown that the TCSC is able to improve damping torque in addition to synchronizing torque, enhancing consequently the power system's stability as a whole. This power system stability improvement is carried out without a risk of subsynchronous resonance (SSR). The mechanism by which the TCSC is able to avoid SSR is described and the capability of the TCSC in decreasing transient torques on turbine-generator shafts is demonstrated. 4 Refs.

[1997] 10A - 45

FACTS STABILIZATION CONTROL FOR MULTI-MACHINE POWER SYSTEM

Fujita, G.; Yokoyama, R.; Koyanagi, K.; Shiratori, S.; Takeuchi, S.; Shirai, G.

Tokyo Metropolitan Univ, Japan

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 17-20

This paper presents stabilization control method for multi-machine scale power systems using variable series capacitor (VSrC). A new methodology has been proposed to determine the optimal location of installing VSrCs to provide a most effective damping based on the system sensitivity. Here, as a large scale disturbance, three-phase short-circuit is considered. In addition to VSrC, the combined effects of AVRs and governors are considered for stabilization. Simulation results are obtained on 4-generator 11-bus model. Encouraging results have been obtained for the application of VSrCs through the simulations tests. 3 Refs.

[1996] 10A - 46

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) SYSTEM STUDIES: SOUTHERN COMPANY SERVICES

Adapa, R. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-106461, May 1996, 282 pp

This report evaluates use of thyristor controller series compensation (TCSC) and conventional series compensation to increase power transfer on the transmission interface between Southern Company and Florida Power & Light by 500 MW. The increase in power transfer will result in increased revenue at a reasonable cost.

[1997] 10A - 47

GTO BASED ADVANCED STATIC VAR GENERATOR

Liu, W.; Chen, J.; Wang, Z.; Wang, X.; Li, C.; Liu, Y.; Li, X.

Tsinghua Univ, Beijing, China

Automation of Electric Power Systems (China), vol 21, no 3, March 1997, pp 24-28, 32

Chinese

The availability of large gate-turn-off thyristors has led

to the application of advanced static VAr generators (ASVG) to actual power systems for voltage stabilization. For this reason, Henan Electric Power Bureau and Tsinghua University decided to jointly develop a 20-MVAr ASVG. For the basic principle research, a 300-kVAr prototype has been developed and put into practical operation. This prototype is based on an 18-pulse voltage-sourced GTO inverter. An overview of the principle, electrical configuration and test results are given in this paper.

[1998] 10A - 48

GTO THYRISTOR CONTROLLED SERIES CAPACITOR SWITCH PERFORMANCE

Nejad, M.M.; Ortmeyer, T.H.

Clarkson Univ, Potsdam, NY, USA

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 615-621

Many efforts have been devoted to system studies involving switched series compensation. While the majority of the interest has focused on thyristor switches, there has also been interest in advanced compensators involving other switching methods. In particular, a GTO-controlled series capacitor (GTO-CSC) scheme was proposed by T.H. Ortmeyer et al. Snubber design and fault performance for the GTO-CSC is developed in this paper, and a feasible circuit design is proposed.

[1996] 10A - 49

IMPROVED CONTROL SCHEME FOR A SERIES CAPACITIVE REACTANCE COMPENSATOR BASED ON A VOLTAGE SOURCE INVERTER

Rigby, B.S.; Harley, R.G.

Univ of Natal, Dalbridge, South Africa

Proceedings, 31st IAS, San Diego, CA, October 6-10, 1996, vol 2, pp 870-877

Power utilities have traditionally used series capacitors to increase the power transfer capability of transmission lines, but their widespread use has been limited by concerns for the harmful effects of series resonances. An advanced, controllable series compensator has the potential to avoid such problems and therefore allow more efficient use of existing transmission plant. This paper describes a modified control scheme for an advanced series compensator based on a single voltage source inverter. Practical results from a working prototype demonstrate the ability of the compensator to provide a rapidly controllable magnitude of compensation. 9 Refs.

[1996] 10A - 50

IMPROVEMENT OF DAMPING ON MULTI-MACHINE POWER SYSTEMS BY THYRISTOR CONTROLLED SERIES CAPACITOR WITH LOCAL SIGNAL

Kobayashi, N.; Hara, T.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 116, no 12, pp 1500-1507

Japanese

Thyristor-controlled series capacitor (TCSC) can improve power system damping. This paper proposes a systematic design procedure based on modal analysis for tuning damping controllers of TCSC. The procedure makes it possible to improve damping in multi-machine power systems by using single input and single output TCSC. In this procedure, the influence to the control input signal caused by output of TCSC can be taken into account. This procedure is used to design TCSC controllers to improve power system damping in a 3 machine system and its validity is demonstrated through digital simulations.

[1998] 10A - 51

IMPROVEMENT OF DAMPING LOW FREQUENCY OSCILLATIONS BY TCSC

Fan, L.; Li, N.; Wang, H.

Dept of Elec Eng, Southeast Univ, Nanjing, China

Power System Technology (China), vol 22, no 1, January 1998, pp 35-39

Chinese

In this paper, an extended linear model of a power system with thyristor-controlled series capacitors (TCSC) installed was developed. By use of the complex torque coefficient method, the principle of suppressing oscillations by TCSC's damping control was also explained. The oscillation modes were analyzed and, as a result, an index to select the placement of TCSC and its input signal was explored. Using optimal linear control theory, the damping control of TCSC was designed. The relation between the control parameters of TCSC's damping control and the oscillation modes in power system was discussed later. Eigenvalue analysis and nonlinear simulation demonstrated that the developed method is very effective.

[1996] 10A - 52

IMPROVEMENT OF PERFORMANCE OF POWER SYSTEM WITH THYRISTOR CONTROLLED SERIES COMPENSATION

Liang, J.; Zhou, X-X.

Elec Power Research Inst, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 154-159

A nonlinear control scheme of TCSC (thyristor-controlled series compensation) is presented in this paper. The nonlinear control mode can reflect the nonlinearity of the power system. It has more adaptability than some conventional control schemes such as PI (proportional-integral) control which is effective only in a limited operating range. In this paper, a nonlinear control scheme is deduced from a set of nonlinear differential equations that described the operating characteristics of a power system. The deduced scheme has some remote input variables that are hard to measure and transfer. So a local control approach is presented in the paper as an alternative. The input variables can all be acquired locally. Thus, this scheme can be easy to implement in a real power system. Simulation of the proposed control scheme of TCSC is made with Power System Analysis Software Package (PSASP) and its User-Define function to test effectiveness of the nonlinear control. 8 refs.

[1996] 10A - 53

IMPROVEMENT OF POWER SYSTEM STABILITY BY A THYRISTOR CONTROLLED SERIES CAPACITOR

Kai, T.; Takeuchi, N.; Sato, T.; Akagi, H.

Meidensha Corp, Tokyo, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 358-361

The thyristor-controlled series capacitor (TCSC) is expected as an improvement method of power system stability and power transfer capability. The basic circuit consists of a thyristor-controlled reactor paralleled by a capacitor. To study the improvement method, accurate relationship between the fundamental impedance of TCSC and the firing angle of the thyristors is certainly required. In this paper, a mathematical equation of TCSC fundamental impedance is analyzed, thus the mathematical relationship with higher accuracy between the firing angle and the fundamental impedance is derived. 4 Refs.

[1996] 10A - 54

IMPROVEMENT OF POWER SYSTEM STABILITY BY ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS

Hara, T.; Kobayashi, N.; Takei, A.; Tanomura, K.; Koyanagi, K.; Komukai, T.

Tokyo Elec Power Co, Inc, Japan

Electrical Engineering in Japan (translation of Denki Gakkai Ronbunshi), vol 117, no 4, October 1996, pp 19-33

Application of controlled series capacitors with anti-parallel thyristor combination across the capacitor segment is one of the new and promising countermeasures for enhancement of power system stability. The line reactance can be directly controlled by the controlled series capacitors, hence, it is very effective to apply the capacitors for damping power system disturbances. In this paper, we describe the following. (1) The design method of control system for the segmented series capacitors with thyristor switches is proposed. (2) The effectiveness of the controlled capacitors proposed for power system stabilization is shown with the results of EMTP analysis. (3) The possibility of zero passing missing phenomena of capacitor voltage is indicated by EMTP simulation, and a countermeasure is proposed in order to avoid the phenomena. The effects of the countermeasure are indicated by the results of EMTP simulation. 10 Refs.

[1998] 10A - 55

IMPROVEMENT OF POWER SYSTEM TRANSIENT STABILITY BY USING CONTROLLABLE SERIES COMPENSATOR

Poshtan, M.; Rastgoufard, P.

Dept of Elec Eng & Computer Sci, Tulane Univ, New Orleans, LA, USA

Proceedings, 30th Southeastern Symp on System Theory, Morgantown, WV, March 8-10, 1998, pp 225-228

The purpose of this investigation is three fold: (1) development of a nonlinear controller suitable for short-time frame dynamics; (2) application of the developed nonlinear controller to improvement of transient stability of large scale power systems; and (3) implementation of the designed controller and its application on power systems for simulation and analysis purposes. In this paper, we outline the mathematical development and the application of the developed controller to study transient stability of a small scale power system. Because power system

transient stability, flexible ac transmission systems (FACTS), and nonlinear control are the key building blocks in this paper, we briefly outline these building blocks and how they relate to each other for improved transient stability analysis and power system control.

[1996] 10A - 56

IMPROVEMENT OF POWER SYSTEM STABILITY BY ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS

Hara, T.; Kobayashi, N.; Takei, A.; Tanomura, K.; Koyanagi, K.; Komukai, T.

Tokyo Elec Power Co, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 117, no 4, 1996, pp 19-33

Abstract not available

[1996] 10A - 57

IMPROVEMENT OF TRANSIENT STABILITY OF MULTI-MACHINE POWER SYSTEMS USING FACTS EQUIPMENT APPLYING FUZZY CONTROL

Senjyu, T.; Shiroma, T.; Uezato, K.

Faculty of Eng, Ryukyus Univ, Okinawa, Japan

Bulletin of the Faculty of Engineering, University of the Ryukyus (Japan), no 51, March 1996, pp 15-24

Japanese

The improvement of transient stability of power systems has been a very important issue. For this issue, the concept of FACTS (flexible ac transmission system) has been advocated and has attracted the attention of many power system engineers. FACTS equipment has the ability to control power flow and has fast control response. The development of high performance control schemes is required. Many control schemes for FACTS equipment have been reported, e.g. state feedback control using pole placement technique and fuzzy control, etc. However, there are few reports that consider the stability and nonlinearity of power systems. This paper presents a novel fuzzy controller for a variable series capacitor. In this fuzzy controller, fuzzy rules are constructed to satisfy the system stability based on sliding mode control law. Moreover the proposed control law has the robustness for the state variable and machine parameter variations. Therefore, the transient stability of power systems can be improved by the proposed fuzzy controller. The validity of the proposed control scheme is confirmed by numerical simulations. 14 Refs.

[1996] 10A - 58

Deleted

[1997] 10A - 59

IMPROVEMENT OF TRANSIENT STABILITY OF POWER SYSTEMS USING VARIABLE SERIES CAPACITOR APPLYING NEURO-FUZZY CONTROLLER

Uezato, K.; Shiroma, S.; Senjyu, T.

Bulletin of the Faculty of Engineering, University of the Ryukyus (Japan), no 53, March 1997, pp 43-52

Japanese

The improvement of transient stability of power systems has become a very important issue. The concept of FACTS (flexible ac transmission system) has been advocated and has attracted the attention of many power systems' engineers, because FACTS equipment has the abilities of direct power flow control and rapid control response applying power electronics technologies. Now, the development of high performance control scheme has been required, so many control schemes using FACTS equipment have been reported, e.g. state feedback control using pole placement technique and fuzzy control, etc. However, there are few reports that consider the stability and nonlinearity of power systems. In this paper, a neuro-fuzzy controller for a variable series capacitor to enhance the damping of power systems is proposed. The proposed neuro-fuzzy controller is constructed using fuzzy theory. The initialization of weights is not necessary since this is supplied by the fuzzy reasoning and no prelearning is done. Additionally, all parameters of fuzzy reasoning are adjusted using the well known BP learning algorithm. The proposed controller can consider the power systems stability because the fuzzy theory is constructed to satisfy the stability of power systems based on the sliding mode control. Therefore, the proposed controller has the robustness in terms of parameter variations and nonlinearity of a power system. The validity of the proposed control method by computer simulations is modeled on a single-machine infinite bus system.

[1996] 10A - 60

IMPROVING SYSTEM STABILITY USING AN ADVANCED SERIES COMPENSATION SCHEME TO DAMP POWER SWINGS

Hedin, R.; Jalali, S.; Weiss, S.; Cope, L.; Johnson, B.; Mah, D.; Torgerson, D.; Vossler, B.

Siemens, Atlanta, GA, USA

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 311-314

In 1992, the world's first thyristor-controlled series compensation (TCSC) scheme was installed at Kayenta, Arizona, USA. Since then many studies including field tests have shown the ability of this FACTS element to improve power system performance. The results indicate that the TCSC can increase power flow and also enhance power system damping. This paper presents a novel method of controlling the TCSC impedance in order to increase power system damping. The control uses locally available signals. Simulation results performed in the ac-dc analog real-time simulator (transient network analyzer, TNA), and the power system simulator PSS/E show the significant damping improvement obtained using this controller. The transient stability studies use the newly developed advanced series compensator (ASC) model to allow for the accurate modeling of the ASC dynamics and also the control. 5 Refs.

[1998] 10A - 61

INVESTIGATION OF POWER SYSTEM HARMONICS AND SSR PHENOMENA RELATED TO THYRISTOR CONTROLLED SERIES CAPACITORS

Leonidaki, E.A.; Hatziargyriou, N.D.; Papadias, B.C.; Georgantzis, G.J.

Proceedings, 8th Int'l Conf on Harmonics and Quality of Power (ICHQP '98), October 14-16, 1998

Thyristor-controlled equipment is one of the major sources of harmonics in power systems impacting power quality. In this paper, thyristor-controlled series capacitor (TCSC) installed by power utilities to increase power transfer capability of transmission lines is investigated in terms of harmonic distortion in the power system. In addition, series compensation may cause subsynchronous oscillations leading to subsynchronous resonance (SSR) phenomena. The investigation of a TCSC control strategy that ensures sufficient SSR damping is presented.

[1997] 10A - 62

INVESTIGATION OF THE THYRISTOR-CONTROLLED SERIES COMPENSATION. I. STEADY-STATE AND TRANSIENT-STATE SIMULATION OF A POWER SYSTEM WITH DETAILED TCSC MODEL

Tian, J.; Yin, J.

Nanjing Automation Research Inst, China

Automation of Electric Power Systems (China), vol 21, no 10, October 1997, pp 43-47

Chinese

An accurate mathematical model of thyristor-controlled series compensation (TCSC) is established. By solving the established differential equations, the formula of fundamental frequency wave impedance and the expressions of voltage and current in inductors and capacitors under steady and transient conditions are obtained, and then the principle and method for simulating the power system containing TCSC devices are proposed. Interfacing the TCSC model with a power system analysis program, a simulation taking the TCSC effect into account in steady and transient states simulation calculations is realized. The ability for improving system damping to raise power system stability is demonstrated by a simulated sample.

[1997] 10A - 63

INVESTIGATION OF THE THYRISTOR-CONTROLLED SERIES COMPENSATION. II. THE EFFECT OF TCSC FIRING CONTROL SCHEMES ON THE SYSTEM PERFORMANCE

Tian, J.; Yin, J.

Nanjing Automation Research Inst, China

Automation of Electric Power Systems (China), vol 21, no 12, December 1997, pp 34-36

Chinese

A new equidistant firing control scheme is developed. The analysis reveals the different effects of the individual phase control and the equidistant firing control on the TCSC dynamic performance. The newly proposed firing control scheme can greatly improve the dynamics, and shorten the TCSC response time. The analysis also reveals that the system damping characteristic with firing synchronized to zeros of the voltage across the TCSC is better than that to zeros of line current. This characteristic has not been revealed in the previous papers which analyze the TCSC dynamics based on the current source model.

[1996] 10A - 64

INVESTIGATIONS INTO CONTROL STRATEGIES FOR VARIABLE SERIES

COMPENSATION OF TRANSMISSION LINES

Bhat, S.V.; Prabhu, S.S.

Siemens, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 258-263

The paper considers application of one of the most important FACTS devices, namely, the variable series compensator (VSC) for transmission lines. Various control strategies are studied for a double circuit line connecting a generator to an infinite bus. Power flow regulation is described for the lines. Improvement in transient stability is shown. Auxiliary stabilizers for improvement of small signal stability are studied. Interaction between the two lines due to control is examined.

[1996] 10A - 65

INVESTIGATIONS OF A THYRISTOR-CONTROLLED SERIES CAPACITOR

Matsuki, J.; Ikeda, Kei.i; Abe, M.

Kyoto Univ, Japan

Proceedings, 22nd IEEE Int'l Conf on Industrial Electronics, Control, and Instrumentation, (IECON), Taipei, Taiwan, August 5-10, 1996. vol 2, 1996, pp 683-688

Thyristor-controlled series capacitors (TCSC) are expected to provide many benefits for an electric power system including the increase of power transfer capability and transient stability as well as the mitigation of subsynchronous resonance (SSR). However, there has been little operating experience and thus further understanding of the characteristics of TCSC is still to be sought. A laboratory-scale TCSC has been designed, produced and installed on a laboratory power system at Kyoto University to investigate the performances of TCSC experimentally. The paper provides the fundamental impedance characteristics and the dynamic responses of the laboratory-scale TCSC, the effects of inductor and resistor size on these performances, and a detailed analysis of loop current dynamics based on a developed mathematical model. 4 Refs.

[1996] 10A - 66

INVESTIGATIONS OF THE FIRING CONTROL SCHEME AND DYNAMIC RESPONSE OF A THYRISTOR-CONTROLLED SERIES CAPACITOR

Tian, J.; Yin, J-H.; Han, Z-X.

Zhejiang Univ, Hangzhou, China

Automation of Electric Power Systems (China), vol 20, no 6, June 1996, pp 34-36, 60

Chinese

The digital simulation results of a thyristor-controlled series capacitor (TCSC) under steady-state and dynamic-state are presented in this paper. A method for the dynamic simulation of TCSC is developed which consists of the firing control system representation. The analysis reveals the different effect of the individual phase control and the equidistant firing control on the TCSC dynamic performance. It also reveals that the dynamics can be greatly improved with the new proposed firing control scheme. 6 Refs.

[1997] 10A - 67

LOOP CURRENT CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR

Matsuki, J.; Ikeda, K.

Kyoto Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 991-998

Japanese

This paper presents the results of an investigation on the loop current of a thyristor-controlled series capacitor (TCSC). The knowledge of loop current characteristics is important for understanding analytically the equivalent impedance of TCSC, estimating harmonics produced by TCSC and determining ratings of the TCSC circuit components. However, little has been written on the loop current of TCSC circuit. Therefore, using a laboratory-scale TCSC installed on a laboratory power system, the TCSC currents and voltages were measured and analyzed to investigate the behavior of loop current. A mathematical model of TCSC was also developed to compare with the experimental results and further clarify a relationship between loop current and steady-state impedance characteristics, including effects of TCSC circuit component size on the characteristics. Capacitor voltage harmonics and their impacts on the power system were also investigated.

[1996] 10A - 68

MATHEMATICAL RELATIONSHIP BETWEEN FIRING ANGLE AND FUNDAMENTAL IMPEDANCE OF A THYRISTOR CONTROLLED SERIES CAPACITOR

Kai, T.; Takeuchi, N.; Sato, T.; Akagi, H.

Meidensha Corp, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-J, pp 19-24

Japanese

This paper examines the stability of electric power systems and improvement in ability of the electric power transmission performance by a thyristor-controlled series capacitor (TCSC) of a modulation control system. This paper presents a relational expression of TCSC firing angle controlling and impedances. On the basis of analytical results of firing angle of a TCSC circuit driven by a current source, and impedances for a fundamental wave of the source current, this paper presents that the accuracy of this expression is higher than that of the conventional expression.

[1996] 10A - 69

MODULATION AND SSR TESTS PERFORMED ON THE BPA 500 KV THYRISTOR CONTROLLED SERIES CAPACITOR UNIT AT SLATT SUBSTATION

Hauer, J.F.; Mittelstadt, W.A.; Piwko, R.J.; Damsky, B.L.; Eden, J.D.

Pacific Northwest Natl Lab (PNL), Richland, WA, USA

IEEE Trans on Power Systems, vol 11, no 2, May 1996, pp 801-806

Field experience is reported for a thyristor-controlled series capacitor (TCSC) recently commissioned at BPA's Slatt substation. Subsynchronous resonance tests show that TCSC interactions with shaft dynamics of PGE's Boardman steam generator are well understood and are effectively avoided by normal TCSC valve firing logic. Modulation tests, performed with the Boardman plant off line, show that the TCSC can be a powerful and responsive actuator for swing damping. Security considerations did not permit lightly damped operation of the controlled plant. Close analysis indicates that the TCSC damping contribution, though small, was measurable. The best estimate is that damping for the McNary mode is 7.33% and 8.55%, for the TCSC damper loop open and closed respectively. TCSC testing and monitoring is facilitated by an advanced interactive measurement network representing BPA's approach to the information requirements of major control systems. 10 Refs.

[1997] 10A - 70

MULTI-MACHINE POWER SYSTEM STABILIZING CONTROL BASED ON H8 CONTROL THEORY

Makita, D.; Takeuchi, S.; Shirai, G.

Hosei Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 1-10,12-15, pp 73-78

Japanese

Power system controls using flexible ac transmission systems (FACTS) are frequently studied. In order to make effective power system controller the strategies based on optimal control theory have been developed using VSrC (variable series capacitor) which is one of FACTS equipments. Now, H8 control theory which is more robust for uncertain parameter changes and various disturbances is applied to power system control. In this paper the power system stabilizing control scheme is established using H8 control theory. As the control units, VSrC equipment is used. A power system with sixteen buses and five synchronous machines is used to demonstrate the effectiveness of the proposed control scheme. In the previous paper, it was assumed that all the state variables are known. However it is very difficult to get all of the state variables. Therefore, in this paper some state variables are estimated by observer. It is shown that the proposed method is encouraging.

[1996] 10A - 71

NEW CAPACITOR SWITCHING SCHEMES TO CONTROL SUB-SYNCHRONOUS RESONANCE

Lee, H-G.; Lee, S-H.; Kang, S-W.; Han, K-H.; Chung, Y-T.

Chungnam Jr College, Taejon, South Korea

Chongi Hakhoe Nonmunchi (Trans of the Korean Institute of Electrical Engineers), vol 45, no 1, January 1996, pp 67-73

Subsynchronous resonance (SSR) causes a torsional shaft torque on the generator. Damages resulting from uncontrolled SSR have resulted in the breakdown in the shaft and costs for replacement power. This paper is to determine the feasibility of controlling SSR by the fast modulation of series compensation capacitors. The presence of sub-synchronous currents in the system was detected by a sub-synchronous relay which was modeled by the transient analysis of control systems (TACS) in Electromagnetic Transients Program (EMTP). The capacitor segments were switched by bi-directional thyristor switches. These were modeled into EMTP. The strategy to switch the capacitors was modeled as a closed loop system. The paper proves that effective

control of SSR can be obtained only by the detuning of the system and the removal or blocking of sub-synchronous energy from the system. . 8 refs., 10 figs., 6 tabs.

[1998] 10A - 72

NON-LINEAR CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATOR FOR IMPROVING POWER SYSTEM TRANSIENT STABILITY

Guo, Q.; Lu, S.; Liu, X.; Xia, D.

Xi'an Jiaotong Univ, Xi'an, China

Power System Technology (China), vol 22, no 1, January 1998, pp 40-42

Chinese

For designing the nonlinear controller of a thyristor-controlled series compensator (TCSC) in order to improve the transient stability of power systems, a direct feedback linearization method is presented in this paper. The effectiveness and adaptability of the proposed controller is demonstrated using the results of digital simulation.

[1996] 10A - 73

NONLINEAR CONTROL ALGORITHMS AND POWER SYSTEM APPLICATION

Mohler, R.R.; Zakrzewski, R.R.; Vedam, R.

Dept of Elec & Computer Eng, Oregon State Univ, Corvallis, OR, USA

Applied Mathematics and Computation, vol 78, no 2-3, September 1996, pp 197-207

Two distinct approaches to the design of nonlinear control systems are discussed in the context of stabilization of interconnected power transmission systems. The control problem considered involves manipulation of line impedance through a thyristor-controlled series capacitor to increase stability of the transmission system in case of a large fault. Since the control signal affects system dynamics multiplicatively, traditional linear control strategies are found to be inappropriate and nonlinear techniques must be used instead. The first method considered is a self-tuning predictive controller based on a bilinear model structure. The algorithm is shown to quickly identify the system dynamics and effectively damp oscillations following a simulated fault. The second method is a neural network-based hierarchical controller using simplified models of the system and offline training to classify and interpolate between different operating conditions of the system. Both nonlinear controllers are based on a concept of optimization of a performance criterion and naturally incorporate limits on control signals. 11 Refs.

[1997] 10A - 74

ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS FOR POWER SYSTEM STABILITY WITH TORSIONAL OSCILLATION COUNTERMEASURE

Kobayashi, N.; Tanomura, K.; Takei, A.; Hara, T.; Koyanagi, K.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 7, July 1997, pp 921-929

Japanese

Application of controlled series capacitors with antiparallel thyristor combination across the capacitor segment is one of new and promising countermeasures for enhancement of power system stability. The line reactance can be directly controlled by the controlled series capacitors, hence, it is very effective to apply the capacitors for damping power system disturbances. However, the segmented series capacitors may cause subsynchronous resonance (SSR) that can lead to turbine-generator shaft failure and electrical instability at oscillation frequencies lower than normal system frequency as well as the conventional capacitor may cause. In this paper, the authors describe the following: (1) the response of turbine-generator shaft torque are analytically discussed when the number of inserted series capacitor in power system is changed; (2) it is proposed for SSR countermeasure that the control system will be designed to avoid the number of series capacitor segment which may cause SSR in addition to selecting the better on-off timing of series capacitors; and (3) the effects of the proposed countermeasures are confirmed by the results of EMTP simulation using both simplified two-mass shaft model and detailed five-mass shaft model of turbine-generator.

[1996] 10A - 75

OPTIMAL CONTROL OF SERIES COMPENSATORS AND PHASE SHIFTING TRANSFORMERS IN POWER SYSTEMS

Kacejko, P.A.; Hammons, T.J.; Wancerz, M.

Tech Univ of Lublin, Poland

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 2,

pp 376-379

This paper focuses on the application of two series elements in large interconnected power systems to enhance power flow and improve transient response, namely the series compensator and the phase-shifting transformer. The aim of these devices is to increase transmission capability and to give a more stable response following a severe system disturbance. Additional aspects of control of the devices are developed and presented; fast control for enhancing transient stability of the power system, optimal modulation of added capacitive reactance in series compensators, and fast optimal control of shifting angle in phase-shifting transformers. These controls force faster dissipation of energy of rotor swing which results from a severe power system disturbance. Optimal modulation strategy is derived using the direct Lyapunov method. Validity of the proposed control algorithms is verified by simulating disturbances in a simple power system. 3 Refs.

[1997] 10A - 76

OPTIMIZATION OF FUZZY CONTROLLER FOR IMPROVING POWER SYSTEM STABILITY WITH VARIABLE SERIES CAPACITOR (VSRC)

Senjyu, T.; Tamaki, T.; Uezato, K.

Bulletin of the Faculty of Engineering, University of the Ryukyus (Japan), no 54, September 1997, pp 33-43

Japanese

The development of a high performance control scheme of FACTS equipment is required in power system operation and planning. In this context, a fuzzy controller is being extensively researched, giving some promising results. However the parameters of fuzzy controllers are usually decided by trial and error, therefore, considerable investment of time and effort is involved in tuning these parameters. In this paper, to overcome this problem, we propose a method of fuzzy parameter autotuning applying a genetic algorithm (GA). By tuning fuzzy parameters applying a GA, we can get a better performance without considerable time and effort investment. We verify that the control method using a genetic algorithm has appropriate control performances by the simulation results on a multi-machine power system model.

[1996] 10A - 77

OSCILLATION STABILIZATION OF MULTIMACHINE POWER SYSTEMS BY CONTROLLABLE SERIES COMPENSATOR

Wang, H.F.; Swift, F.J.; Li, M.

Manchester Metropolitan Univ, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 315-320

In this paper, the application of the controllable series compensator (CSC) in damping power system oscillations is studied for a general multimachine power system on the basis of the Phillips-Heffron model. The capability of the CSC damping control to provide damping to the power system is analyzed in terms of its damping torque contribution and brief guidelines for the design of the CSC damping controller, such as the selection of the optimum location are discussed and demonstrated on sample power system. 9 Refs.

[1997] 10A - 78

OUTPUT FEEDBACK TCSC CONTROLLERS TO IMPROVE DAMPING OF MESHED MULTI-MACHINE POWER SYSTEMS

Chen, X.R.; Pahalawaththa, N.C.; Annakkage, U.D.; Kumble, C.S.

Design Power New Zealand Ltd, Auckland, New Zealand

IEE Proceedings Generation, Transmission and Distribution, vol 144 (UK), no 3, May 1997, pp 243-248

Methods for coordinated design of output feedback damping controllers, for thyristor-controlled series compensators (TCSCs) in a meshed power system, are developed in the paper. The locations for installing TCSCs and the co-ordination of TCSC controls are determined by analyzing the mode controllability. The analysis of mode observability is used to select the effective output feedback signals local to the TCSC locations. The design of controller gains is divided into two steps. First, initial gains for each controller are calculated according to the coordination determined by the analysis of the mode controllability. These initial gains are then optimized by using linear programming to satisfy the given design criteria. It is shown that, by using this procedure, the desired damping of the critical modes can be achieved without significantly deteriorating the damping of the other modes and the stability of the power system. It is also shown that the prolonged saturation in the TCSC actuators and the adverse interaction among TCSC controllers can be avoided. The proposed controller design methods are validated by a case study. 9 Refs.

[1997] 10A - 79

PHASOR DYNAMICS OF THYRISTOR-CONTROLLED SERIES CAPACITOR SYSTEMS

Mattavelli, P.; Verghese, G.C.; Stankovic, A.M.

Univ of Padova, Italy

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1259-1266

This paper develops simple but accurate continuous-time, large-signal dynamic models for a thyristor-controlled series capacitor (TCSC). The models are based on the representation of voltages and currents as time-varying Fourier series, and focus on the dynamics of the short-term Fourier coefficients. Truncating the series to keep only the fundamental components provides a natural dynamic generalization of the familiar quasi-static phasor representation. Systematic simplifications or refinements of our fundamental phasor dynamics model yield a variety of other models. We establish that even the simplest of these models predicts the dynamic behavior of the TCSC very accurately. Our phasor models provide a powerful basis for simulation, more than an order of magnitude faster than detailed time-domain circuit simulation. The phasor models present an attractive alternative to sampled-data models, having the advantages of simpler representation, modularity, and direct compatibility with the phasor models that are routinely used to represent the dynamics of generators and other power system components. 19 Refs.

[1997] 10A - 80

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS FOR POWER SYSTEM STABILITY WITH TORSIONAL OSCILLATION COUNTERMEASURE

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Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 921-929

Japanese

Application of controlled series capacitors with antiparallel thyristor combination across the capacitor segment is one of new and promising countermeasures for enhancement of power system stability. The line reactance can be directly controlled by the controlled series capacitors, hence, it is very effective to apply the capacitors for damping power system disturbances. However, the segmented series capacitors may cause subsynchronous resonance (SSR) that can lead to turbine generator shaft failure and electrical instability at oscillation frequencies lower than normal system frequency as well as the conventional capacitor may cause. In this paper, we describe the following. (1) The response of turbine-generator shaft torque are analytically discussed when the number of inserted series capacitor in power system is changed. (2) It is proposed for SSR countermeasure that the control system will be designed to avoid the number of series capacitor segment which may cause SSR in addition to selecting the better on-off timing of series capacitors. (3) The effects of the proposed countermeasures are confirmed by the results of EMTP simulation using both simplified two-mass shaft model and detailed five mass shaft model of turbine-generator.

[1997] 10A - 81

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. LOOP CURRENT CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR

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Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 991-998

Japanese

This paper presents the results of an investigation on the loop current of a thyristor-controlled series capacitor (TCSC). The knowledge of loop current characteristics is important for understanding analytically the equivalent impedance of TCSC, estimating harmonics produced by TCSC, and determining ratings of the TCSC circuit components. However, little has been written on the loop current of TCSC circuit. Therefore, using a laboratory scale TCSC installed on a laboratory power system, the TCSC currents and voltages were measured and analyzed to investigate the behavior of loop current. A mathematical model of TCSC was also developed to compare with the experimental results and further clarify a relationship between loop current and steady-state impedance characteristics, including effects of TCSC circuit component size on the characteristics. Capacitor voltage harmonics and their impacts on the power system were also investigated.

[1997] 10A - 82

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. A STUDY OF THYRISTOR CONTROLLED SERIES CAPACITOR MODELS FOR POWER SYSTEM STABILITY ANALYSIS

Kai, T.; Takeuchi, N.; Sato, T.; Akagi, H.

Meidensha Corp, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 915-920

Japanese

A thyristor-controlled series capacitor (TCSC) is expected to be a powerful device in increasing power transfer capability and transient stability. The basic configuration of the TCSC consists of a series of capacitors connected in anti-parallel with thyristor-controlled reactors, so that the firing angle control of the thyristors makes the TCSC capable of achieving impedance control in a wide range with quick response. It is important to clarify the relationship between the fundamental reactance of the TCSC and the firing angle of the thyristors, thus leading to practical applications of the TCSC for the enhancement of the power transfer capability and transient stability in transmission lines. Two relationship equations for TCSC fundamental reactance have already been proposed. One is the relationship equation derived from TCSC circuit, source of which is voltage. The other is the relationship equation derived from TCSC circuit, source of which is current. For the case of installing TCSC in the transmission line, it is not clarified that which equation is adequate to analyze power system stability. In this paper, the authors developed whether either equation is valid to analyze power system stability. (1) In the steady state, TCSC fundamental reactance is analyzed, and compared with two equations and EMTP. It is clear that TCSC reactance based on current source is adequate. (2) Swinging angle of a generator when the firing angle is stepped up is analyzed with EMTP and analytical model using TCSC model based on current source. It is shown that the proposed model is effective for power system stability analysis.

[1997] 10A - 83

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

Kato, M.; Morioka, Y.; Asada, M.; Watanabe, M.; Konishi, H.; Mishima, Y.; Nakachi, Y.

Kansai Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 1016-1023

Japanese

The thyristor-controlled series compensator (TCSC) can stabilize a power system by controlling line impedance and in the future, it is expected to provide a scheme for dealing with stability problems. However, detailed reports about control and protection methods of the TCSC are lacking regarding such points as firing angle control of thyristors. This paper proposes some new methods to control and to protect the TCSC. First, methods for firing angle control to synchronize a line current, pulse width control, and total impedance control of two TCSC modules are described. Continuous impedance control ranging from capacitive to inductive conditions is possible by these methods. Furthermore, achievement of zero impedance can reduce the influence when the TCSC was installed on transmission lines. Next, the impedance feedback control method is explained which makes the impedance response of the TCSC faster. Finally, protection schemes by cooperative operation of arresters, thyristors and bypass switches are proposed. The effectiveness of these control methods is confirmed by EMTP simulations and experiments using the TCSC miniature model for a simulator.

[1996] 10A - 84

POWER SWING DAMPING CONTROLLER DESIGN USING LINEAR MATRIX INEQUALITY ALGORITHM

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Proceedings, IEEE Int'l Conf on Control Applications and Symposia on Intelligent Control and Computer-Aided Control System Design, Dearborn, MI, September 15-18, 1996, pp 727-732

This paper discusses a promising new method for designing power swing damping controllers. The method solves directly for a low-order robust controller satisfying a frequency-response bound. It is based on the optimization of dynamic systems with linear matrix inequalities as the design constraints. Constraints on the controllers such as positive redness can also be imposed in the design. The proposed method is used to design a power system stabilizer and a damping controller for a thyristor-switched series capacitor. 13 Refs.

[1996] 10A - 85

POWER SYSTEM STABILITY ENHANCEMENT BY ADAPTIVE FUZZY CONTROL

Senjyu, T.; Shiroma, S.; Molinas, M.; Uezato, K.

Faculty of Eng, Ryukyus Univ, Okinawa, Japan

Proceedings, IEEE Int'l Symp on Industrial Electronics, Warsaw, Poland, June 17-20, 1996, vol 1, pp 409-414

This paper presents a systematic approach to the enhancement of power system stability using adaptive fuzzy controllers. The adaptive fuzzy controller design, which is based on the main concepts of sliding mode control, is applied to variable series capacitors on a single-machine infinite-bus model power system. The fuzzy control rules that guarantee power system stability are systematically obtained, through an adaptation mechanism introduced in the operation part. This technique, with a qualitative experimental model, enables the adaptive fuzzy controller to be profitable for consistent performance in the face of changing operating conditions. The effectiveness of the proposed control is demonstrated by computer simulations. 6 Refs.

[1996] 10A - 86

POWER SYSTEM STABILITY ENHANCEMENT BY USING CONTROLLED SERIES COMPENSATION

Chen, X.R.; Pahalawaththa, N.C.; Annakkage, U.D.; Kumble, C.S.

Univ of Auckland, New Zealand

Int'l Journal of Power and Energy Systems (UK), vol 16 no 2, 1996, pp 67-72

Automatic voltage regulators (AVR) and power system stabilizers (PSS) are used for damping transient and dynamic oscillations in power systems. The concept of flexible ac transmission systems (FACTS) provides several novel techniques for this purpose. Controlled series compensation (CSC) of transmission lines is one of these techniques. In this paper, the use of CSC for improving power system stability is investigated. A linearized model of a simple power system (a synchronous machine connected to an infinite bus through a transmission line) is derived for analyzing the effects of CSC control. The pole placement technique is used to design a state feedback CSC controller. Performance of the designed CSC controller is compared with that of a traditional PSS controller. It is found that the CSC controller performs better than the PSS controller in damping the power oscillations, thus increasing the power transmission ability. 4 Ref.

[1997] 10A - 87

POWER SYSTEM STABILIZING CONTROL USING VARIABLE SERIES CAPACITOR BASED ON H8 CONTROL THEORY CONSIDERING AVR AND GOVERNOR

Fujita, G.; Yokoyama, R.; Niimura, T.; Makita, D.; Takeuchi, S.; Shirai, G.

Tokyo Metropolitan Univ, Japan

Proceedings, IEEE 1997 Canadian Conf on Electrical and Computer Engineering (CCECE'97), St. John, Canada, May 25-28, 1997, vol 1, pp 43-46

With the progress of power electronics, power system control systems using flexible ac transmission systems (FACTS) have been eagerly studied. variable series capacitor (VSrC) for power system stabilization control is a typical application. For effective control of VSrC, the optimal control theory has been applied. However H8 control theory is expected to be more robust than the optimal control, because there are uncertain parameter changes and various disturbances in power systems. In this paper, the authors apply H8 control theory to the power system stabilization control including the characteristics of conventional equipment such as AVR and governor. VSrC equipment is integrated into the power system stabilization control and its effect of enhancing stabilization was investigated. Numerical analyses have been done on a power system model to demonstrate the effectiveness of the proposed control scheme. Encouraging results have been obtained for H8 control of VSrC through the simulation. 5 Refs.

[1996] 10A - 88

POWER SYSTEM STABILIZING CONTROL FOR FACTS DEVICES USING FUZZY NEURAL NETWORKS

Senyu, T.; Shiroma, S.; Molinas, M.; Uezato, K.

Faculty of Eng, Ryukyus Univ, Okinawa, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 338-342

A novel approach using fuzzy neural networks is proposed as stabilizing control method for power systems. The control scheme consists of a fuzzy neural controller for variable series capacitors and a neural estimator of the system dynamics. Both, the fuzzy neural controller and the neural estimator are trained in a supervised manner by means of the standard back

propagation learning algorithm. The premises to construct the fuzzy rules are developed using the concept of variable structure systems and Lyapunov stability criteria. It is concluded from the simulations results that accurate performance can be achieved with the proposed control, and it can serve as a valuable tool to power systems stability control. 6 Refs.

[1996] 10A - 89

POWER SYSTEM STABILIZING CONTROL USING THYRISTOR CONTROLLED SERIES CAPACITORS(TCSC) BASED ON H8. CONTROL THEORY

Makita, D.; Fujita, G.; Takeuchi, S.; Shirai,G.

Hosei Univ, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 37-38

Japanese

Abstract not available.

[1996] 10A - 90

POWER SYSTEM STABILIZING CONTROL USING VARIABLE SERIES CAPACITOR BASED ON H8. CONTROL THEORY CONSIDERING AVR AND GOV

Makita, D.; Shiratori, S.; Fujita, G.; Takeuchi, S.; Shirai, G.

Hosei Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 72-83, pp 23-32

Japanese

At present, with the progress of electronic technologies, power system control using flexible ac transmission systems (FACTS) is much studied. In order to make effective power system controller the strategies based on optimal control theory have been developed using a VSrC (variable series capacitor). H8. control theory (which is more robust for uncertain parameter changes and various disturbances) is applied to power system control. In this paper the power system stabilizing control scheme including the characteristics of AVR and GOV is established using H8. control theory. In the proposed method both AVR and GOV are included The reason is that AVR and GOV both contribute to damping the power swing after faults. As the rotating units, VSrC equipment are used for damping. A simple power system model with nine buses and three synchronous machines is used to demonstrate the effective-ness of the proposed control scheme. It is shown that the proposed method is encouraging.

[1996] 10A - 91

POWER SYSTEM STABILIZING CONTROL USING THYRISTOR CONTROLLED SERIES CAPACITORS(TCSC) CONSIDERING COMPUTATION TIME DELAY

Takayama, S.; Fujita, G.; Takeuchi, S.; Shirai, G.

Hosei Univ, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 39-40

Japanese

Abstract not available.

[1997] 10A - 92

PWM-CONTROLLED SERIES COMPENSATION WITH LOW HARMONIC DISTORTION

Chu, K.-H.; Pollock, C.

Warwick Univ, Coventry, England

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 6, November 1997, pp 555-563

The paper describes a pulse width modulation (PWM) controlled series compensator with continuously variable reactance, employing simple PWM duty ratio control. Each phase of the compensator comprises a switched reactor and parallel capacitor. The duty ratio control gives a wide range of capacitive and inductive compensation. The harmonics created by the switched reactor have been analyzed. The switched reactor and parallel capacitor have been simulated with a range of switching frequencies and duty ratios. With appropriate choice of capacitor and reactor, a scaled-down experimental model of the compensator has been simulated and constructed. The harmonics have been found to be small even with the switching frequency of the controlled turn-off switches as low as 400 Hz. A large step change in duty ratio from maximum capacitive compensation to inductive compensation shows the rapid dynamic response of the compensator with a fast settling time. This demonstrates that the proposed compensator should be considered as another useful FACTS controller for series compensation. 10 Refs.

[1997] 10A - 93

ROBUST NONLINEAR DESIGN FOR TRANSIENT STABILIZATION USING SERIES POWER FLOW COMPENSATOR

Tan, Y.L.; Wang, Y.

School of Elec & Electrn Eng, Nanyang Tech Univ, Singapore

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 6, August 1997, pp 367-374

A robust nonlinear thyristor-controlled field excitation and series power flow controller is proposed to enhance the transient stability of a single-machine, infinite-bus power system. The design of the resulting controller is independent of the operating point. Simulation results are presented to demonstrate the effectiveness of the proposed controller for transient stability enhancement of the power system.

[1996] 10A - 94

ROBUST, NEAR TIME-OPTIMAL CONTROL OF POWER SYSTEM OSCILLATIONS WITH FUZZY LOGIC. DISCUSSION

Noroozian, M.; Andersson, G.; Tomsovic, K.

Royal Inst of Tech, Stockholm, Sweden

IEEE Trans on Power Delivery, vol 11, no 1, 1996, pp 393-400

This paper presents a fuzzy logic controller for series reactance switching to damp power system electromechanical oscillations. A set of control rules are constructed and inference is provided by fuzzy logic reasoning. The knowledge base for the controller is established from observation of the dynamical behavior of a simple power system and the general engineering knowledge about the system dynamics. The performance of the controller is shown to be robust and comparable to that of a minimum-time optimal controller. 17 refs.

[1996] 10A - 95

SELECTION OF OPTIMAL TCSC DAMPING CONTROL PARAMETERS AND PLACEMENT BY USE OF EIGENVALUE AND SENSITIVITY ANALYSIS METHODS

Gjerde, J.O.; Flolo, R.; Gjengedal, T.

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Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1328-1333

This paper has discusses the selection of optimal control parameters and location of thyristor-controlled series compensation (TCSC) devices for enhancing power system stability. A procedure for selecting optimal TCSC location based on sensitivity analysis is developed. A procedure for determining the optimal TCSC control parameters based on a pole placement technique is compared to an optimization approach involving time domain analysis. Computer simulations of a meshed multimachine example system are used to verify the proposed procedures for selection of optimal TCSC location and controller parameters. 11 Refs.

[1997] 10A - 96

SERIES ACTIVE CAPACITANCE FOR COMPENSATING VOLTAGE DROPS CAUSED BY SOURCE IMPEDANCES IN POWER SYSTEMS

Nabae, A.; Nakajima, Y.; Cao, L.; Tanaka, T.; Ariga, S.

Tokyo Inst of Polytech, Atsugi, Japan

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 1, pp 351-355

This paper proposes a series active capacitance for power systems which can compensate both harmonic and fundamental voltage drops caused by source impedances. In addition, for the fundamental component, not only the amplitude but also the phase angle can be controlled, so that a receiving-end voltage which is identical to the source voltage is obtained. The basic principles and compensation characteristics of the active capacitance are discussed, and its validity and practicability are demonstrated. The authors conclude that the series active capacitance system proposed in this paper can be applied to flexible ac transmission systems (FACTS). 6 Refs.

[1996] 10A - 97

SERIES COMPENSATION AND SUBSYNCHRONOUS RESONANCE DETAILS ANALYSIS OF THE PHENOMENON AND OF ITS DAMPING BY A TCSC

Lombard, X.; Therond, P.G.

Electricte de France, Paris, France

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 321-328

The concern of electric utility company engineers versus

phenomena like the risk of subsynchronous resonance (SSR) limits seriously the installation of series VAr compensation on transmission systems. Traditionally if the problem is to be considered seriously, numerous case by case studies are necessary. In fact, it is shown that many parameters have to be taken into account to evaluate precisely the risk of SSR. They are generally complex and it is difficult to limit the number of network's configurations to be considered, especially in a highly meshed power network. This paper shows that a 60% series compensation ratio can be securely added to typical lines from the French network provided that only 20% of variable series compensation is included in fixed series capacitor equipment. Such reduced variable series compensation should lead to limited extra costs, which are probably acceptable compared for instance to engineering studies required for a precise understanding of SSR risk in a given practical situation. 5 Refs.

[1996] 10A - 98

SERIES COMPENSATION USING POWER ELECTRONIC SWITCHES: THE SERCOM

James, D.A.; Norris, W.T.

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Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 405-410

Electricity transmission line losses are largely inductive which can cause difficulties in maintaining the voltage at the load, in balancing power flows between two different parallel links between supply and load and in maintaining steady power flow through a transmission link. This paper considers various methods of addressing the difficulties by applying series compensation to electricity transmission lines including the use of power electronic switches. Different schemes are considered: the quad booster, the thyristor-controlled series capacitor (TCSC) and voltage and current sourced inverters. The TCSC inserts a capacitor in series with the transmission line and using an inductor connected in parallel and controlled by thyristors can boost the voltage across the capacitor. A current- or voltage-sourced inverter introduces a series voltage onto the transmission line as a TCSC does by allowing the system current to flow though a component with reactive impedance and adjusting the voltage drop by injecting current from a low-voltage source through the reactive component. 3 Refs.

[1998] 10A - 99

SERIES COMPENSATION ON POWER SYSTEM WITH VERY LOW HARMONIC DISTORTION

Chu, K.H.; Pollock, C.

Univ of Warwick, UK

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

This paper describes a series compensation scheme employing two PWM-switched reactor modules in parallel with a capacitor. The two module PWM switched reactors provide continuously variable reactance by employing simple duty ration control. The switching instants of the two reactor modules are controlled to have 180 degree phase shift, but equal duty ratio, to achieve harmonic cancellation. The complete series compensator provides a wide range of capacitive and inductive compensation. The harmonic distortion produced by this series compensation scheme with a single switched reactor and two switched reactors is analyzed and compared. An experimental model of the proposed compensator has been simulated, constructed and tested. In the case of the two module system, the voltage harmonics have been found to be well below the IEEE 519-1992 recommended limit, with a switching frequency of only 300 Hz. The simplicity of the scheme and the quality of the results indicates potential as another useful FACTS controller.

[1997] 10A - 100

SIMULATION OF THYRISTOR CONTROLLED SERIES CAPACITORS AND SUBSYNCHRONOUS STUDIES

Leonidaki, E.A.; Hatziargyriou, N.D.; Georgantzis, G.J.

Natl Tech Univ of Athens, Greece

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 883-886

The advantage of thyristor-controlled series capacitors (TCSC) over fixed capacitors in power systems is their controlled operation during and after transient phenomena resulting in enhancing dynamic stability or mitigation of subsynchronous resonance problems. In this paper the basic model of TCSC is analyzed and its operation in steady-state is verified by developing a simplified model using the MODELS language of EMTP/ATP program. Also, the effect of TCSC in positive damping of torsional interactions is investigated by applying the developed model equipped with the NGH-SSR damping scheme logic in the IEEE First

Benchmark Model for SSR. 9 Refs.

[1998] 10A - 101

SSR ANALYSIS WITH DYNAMIC PHASOR MODEL OF THYRISTOR-CONTROLLED SERIES CAPACITOR.

Mattavelli, P.; Stankovic, A.M.; Verghese, G.C.

Univ of Padova, Italy

IEEE Trans on Power Delivery, Preprint order number PE-383-PWRS-0-2-1998

In previous work we have studied the phasor dynamics of thyristor-controlled series capacitors (TCSCs), and derived associated models for studying power swing oscillations in a power system. This paper presents the use of a dynamic phasor model of the TCSC in studies of subsynchronous resonance (SSR). Our earlier dynamic phasor models of the TCSC are further simplified here, and tested at typical subsynchronous frequencies. The phasor model of the TCSC is directly compatible with the conventional models used for the other system components relevant to SSR. The proposed approach to SSR analysis is an attractive alternative to approaches based on sampled-data models, and to torque-per-unit-velocity methods. The dynamic phasor approach has been tested on the IEEE first benchmark SSR model, showing outstanding agreement with more computationally demanding alternative methods for eigenvalue analysis.

[1996] 10A - 102

STABILITY MODEL FOR THE ADVANCED SERIES COMPENSATOR (ASC)

Jalali, S.G.; Hedin, R.A.; Pereira, M.; Sadek, K.

Siemens Energy & Automation, Atlanta, GA, USA

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 1128-1137

This paper develops an accurate and general stability model for the ASC. The model is valid for both the capacitive and inductive regions of the ASC operation. It is accurate in that the instantaneous voltage and current waveforms and also the fundamental component of the capacitor voltage (needed for stability) are determined every half-cycle by solving the differential equations of the ASC circuit. The model is capable of incorporating any control algorithms. The validity of the model is demonstrated by comparing the model with the Electro-Magnetic Transient Program (EMTP) digital simulations using step time of 10 microseconds. 7 Refs.

[1997] 10A - 103

STABILIZATION OF MULTI-MACHINE POWER SYSTEM USING VARIABLE SERIES CAPACITOR WITH H_∞ CONTROL THEORY

Fujita, G.; Yokoyama, R.; Makita, D.; Takeuchi, S.; Shirai, G.

Tokyo Metropolitan Univ, Japan

Proceedings, 1997 Conf on Intelligent System Applications to Power Systems (ISAP '97), Seoul, South Korea, July 6-10, 1997, pp 84-88

At present, with the progress of electronic technology, power system controls using flexible ac transmission systems (FACTS) are much studied. In order to make an effective power system controller the strategies based on optimal control theory have been developed using VSrC (variable series capacitor) which is one of FACTS devices. Now, H_∞ control theory which has more robustness for uncertain parameter changes and various disturbances is applied to power system controller design. In this paper the power system stabilizing control scheme including the characteristics of AVR and GOV is demonstrated using H_∞ control theory. In the proposed method both AVR and GOV are included. The reason is that AVR and GOV contribute much to damp the power swing after faults. As additional control units, VSrC equipment are used. A simple power system with nine busses and three synchronous machines is used to demonstrate the effectiveness of the proposed control scheme. The proposed method is proved to be encouraging.

[1996] 10A - 104

STABILIZATION OF POWER SYSTEMS WITH VARIABLE SERIES CAPACITOR APPLYING FUZZY CONTROL

Senjyu, T.; Shiroma, T.; Uezato, K.

Faculty of Eng, Ryukyus Univ, Okinawa, Japan

Japanese Journal of Fuzzy Theory and Systems, vol 8, no 3, 1996, pp 379-391

To improve the stability of the ac transmission system, the concept of flexible ac transmission system (FACTS) has been proposed. In this paper, the fuzzy controller which is based on the sliding-mode control is applied to the variable series capacitor, which is one of the FACTS equipment, so as to improve the stability of the power systems. The proposed fuzzy controller has the characteristic such that the fuzzy rules are constructed systematically and simply on the basis of sliding-mode control. The proposed method is applied to a single-

machine against infinite bus system with variable series capacitor, as well as to a multi-machine system. Simulation results indicate the validity of the proposed fuzzy controller. 11 Refs.

[1996] 10A - 105

STEADY-STATE CHARACTERISTICS AND INSTABILITY OF A THYRISTOR CONTROLLED SERIES CAPACITOR

Matsuki, J.; Hasegawa, S.; Abe, M.; Katagi, T.

Kyoto Univ, Japan

Pawa Erekutoronikusu Kenkyukai Ronbunshi (Japan), vol 22, no 1, pp 28-35

Japanese

This paper describes the results of an experimental study on the steady-state impedance characteristics and instability of a thyristor-controlled series capacitor (TCSC). A laboratory-scale TCSC was produced and installed in a laboratory power system. The impedance characteristics for various combinations of circuit components were measured and analyzed. Instability caused by harmonics was also investigated.

[1997] 10A - 106

STUDIES OF SSR CONTROL METHOD USING TCSC MINIATURE MODEL

Kato, M.; Morioka, Y.; Mishima, Y.; Nakachi, Y.; Asada, M.; Watanabe, M.; Konishi, H.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 67-72

Japanese

Subsynchronous resonance (SSR) can be reduced by controlling the impedance of a thyristor-controlled series compensator (TCSC). This paper shows that a simple control method that fixes the firing angle of thyristors can reduce SSR by EMTP simulations and experiments using a TCSC miniature model. It is also confirmed that an active control method which modulates the firing angle is effective by EMTP simulations.

[1997] 10A - 107

STUDY ON MULTI-OBJECTIVE CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATION

Tan, X.; Tong, L.; Zhang, N.; Wang, Z.

Dept of Autom, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 63-66

Chinese

Transient stability control of thyristor-controlled series compensator (TCSC) is a multi-objective control problem since we need to keep back the first swing of power angle, and to rapidly damp the power swings after the faults. This paper presents a Takagi-Sugeno (T-S) model based TCSC fuzzy control strategy. In the fuzzy control scheme, the nonlinearity of TCSC is well considered, and linear optimal control theory is flexibly combined with expert knowledge. The fuzzy controller acts as an adaptive gain-variable linear optimal controller, and it can satisfy the multi-objective control requirements of the TCSC system. Digital simulation has demonstrated that the fuzzy control scheme is superior to other conventional control methods (PI control, bang-bang control and linear optimal control) in the transient stability control.

[1997] 10A - 108

SUPPRESSION OF TORSIONAL OSCILLATIONS USING THYRISTOR-CONTROLLED CONDUCTANCE IN PARALLEL TO SERIES-CAPACITOR SEGMENT

Wang, L.

European Trans on Electrical Power (Germany), vol 7, no 5, September-October 1997, pp 311-318

This paper presents the analyzed results of a study on the application of thyristor-controlled conductance in parallel to one series-capacitor segment for suppressing subsynchronous resonance (SSR) that occurs in a series-compensated power system. The IEEE Second Benchmark Model, system-I, which has one turbine-generator set, is taken as a standard model for this study. In order to stabilize all SSR modes in the studied system, a unified approach based on modal control theory is proposed to design a damping controller which is a dynamic output feedback compensator using shaft speed deviation of the studied generator as a feedback signal. To demonstrate the effectiveness of the proposed control scheme, a frequency-domain approach based on eigenvalue analyses and time-domain approach based on nonlinear model simulations are performed. The simulated results show that the proposed SSR damping scheme can effectively suppress torsional oscillations of the studied system.

[1996] 10A - 109

SUPPRESSION OF TRANSMISSION SYSTEM OSCILLATIONS BY THYRISTOR-CONTROLLED SERIES COMPENSATION

Choi, S.S.; Jiang, F.; Shrestha, G.

Nanyang Tech Univ, Singapore

IEE Proceedings Generation, Transmission and Distribution (UK), vol 143, no 1, January 1996, pp 7-12

The role of a variable series compensator in a multimachine infinite-bus system is investigated. The proposed compensator comprises a combination of thyristor-switched capacitors (TSCs) and a thyristor-controlled reactor (TCR). The role of the TSCs is to suppress large power oscillations while that of the TCR is to damp out small power perturbations. A performance index to quantify the overall power imbalance in the system is proposed and is used to formulate the control strategies for the TSCs and TCR. The coordination between the control actions of the TSCs and TCR is established on the basis of the magnitudes of the power oscillations. Computer simulations show that the proposed scheme is effective in suppressing power flow oscillations in transmission networks. 13 Refs.

[1998] 10A - 110

TCSC CONTROLLER DESIGN FOR DAMPING INTERAREA OSCILLATIONS

Yang, N.; Liu, Q.; McCalley, D.

Iowa State Univ, Ames, IA, USA

IEEE PES Winter Meeting, Tampa, FL, 1998, Preprint order number PE-122-PWRS-0-12-1997

Thyristor-controlled series compensator (TCSC), a prominent FACTS device, can rapidly modulate the impedance of a transmission line, resulting in improvement of system performance. The purpose of the work reported in this paper is to design a controller to damp interarea oscillations. We have applied the residue method to the linearized power system equations and obtained a generalized form which is suitable for different controller input/output channels and therefore suitable for different control devices. This method, together with modal sensitivities, is applied to TCSC to determine the location, feedback signal, and controller design. The damping result is illustrated by comparing changes in damping ratio and identifying the increase of transfer capacity.

[1998] 10A - 111

TCSC DAMPING CONTROLLER DESIGN USING ROBUST CONTROL THEORY

Zhao, Q.; Jiang, J.

Univ of Western Ontario, London, Canada

Int'l Journal of Electrical Power and Energy System, vol 20, no 1, January 1998, pp 25-33

This paper deals with a robust controller design using the H8 optimization technique for thyristor-controlled series compensation (TCSC) to improve the damping of inter-area oscillations in power systems. Several issues, such as the selection of feedback signals, treatment of the model uncertainties, the synthesis of weighting functions for damping control, are addressed. The performance of the designed controller has been evaluated on a two-area four-machine power system using a PSCAD/EMTDC simulation package. 13 Refs.

[1997] 10A - 112

TCSC EFFECT ANALYSIS IN MULTI-MACHINE POWER SYSTEM

Sul, Y.-T.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 3, March 1997, pp 305-311

Korean

This paper describes the effects of thyristor-controlled series capacitors (TCSC) in multimachine power systems. An EMTP model of TCSC is proposed to analyze the basic characteristics of TCSC and the control signal of the thyristor-controlled reactor (TCR) is determined by RMS value which was measured from the power system. An oscillation model of generators is proposed to analyze the damping effect and the most effective location of TCSC in multimachine power systems is identified by the residues associated with the natural oscillation modes. A 3-generator-9-bus model system is used to demonstrate the applicability of the proposed model.

[1997] 10A - 113

TCSC OPERATION IN INDUCTIVE REGION AND ITS CURRENT LIMITING EFFECTS

Yamaoka, K.; Toki, N.

Mitsubishi Elec Corp, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 61-66

Japanese

TCSC (thyristor-controlled series capacitor) is one of the major FACTS devices and many studies have been reported ranging from fundamental principles to practical experiments. Among the reports, various kinds of control methods of firing signal are proposed. In this paper, voltage comparison method is spotlighted and its fundamental operation is confirmed through EMTP analysis. Effects of TCSC as a current limiting device is also examined on a simple model power system by EMTP analysis.

[1996] 10A - 114

THE COORDINATED CONTROL OF TCSC AND PSS TO IMPROVE POWER SYSTEM DAMPING

Kim, T-H.; Kim, T.H.; Seo, J.C.; Son, K.M.; Park, J.K.; Moon, S.I.

Seoul Natl Univ, Seoul, South Korea

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 904-908

A study of the coordinated control of a thyristor-controlled series compensator (TCSC) and an existing PSS is presented when both are used to damp power system low frequency oscillations. The TCSC is modeled by a first order delay model. A linear quadratic Gaussian controller is used for designing PSS and TCSC supplementary controllers. The performance of the proposed controllers is simulated in a one machine infinite-bus model. As a result, it is shown that to damp the low frequency oscillations efficiently, it is necessary to control TCSC and PSS simultaneously. 6 Refs.

[1998] 10A - 115

THE KAYENTA ASC. THE TCSC PIONEER

Renz, K.

Siemens AG, Germany

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

Power electronic thyristor valves used in static var compensators (SVC) have enabled the realization of rapid thyristor-controlled series compensators (TCSC) in power transmission systems. Energized in 1992, the 230-kV, 330-MVAr (60-Hz) Kayenta advanced series compensator (ASC) incorporates several innovative features and offers system operational advantages not available with conventional fixed or switched series compensation systems by providing direct control of transmission line impedance. The system belongs to what are commonly known as FACTS or flexible ac transmission systems. The Kayenta ASC has been in service for nearly six years and has shown its capability to perform as predicted. All expectations regarding the ASC's electrical characteristics have been confirmed. It is anticipated that in future installations the ASC will play an important role. The ASC is robust and relatively simple and appears to have significant cost advantage over other FACTS controllers, especially where fixed series compensation is to be installed to increase transfer capability.

[1998] 10A - 116

THE STODE THYRISTOR CONTROLLED SERIES CAPACITOR

Holmberg, D.; Danielsson, M.; Halvarsson, P.; Angquist, L.

Svenska Kraftnat, Sweden

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

In Sweden some long series-compensated 400-kV transmission lines are connected to nuclear power stations. An SSR problem has been noticed and caused repeated triggering of the protections. A study indicated that SSR conditions might appear for some network configurations. Rebuilding one of SC, splitting its total reactance into a fixed part and a thyristor-controlled series capacitor (TCSC) part, was found to eliminate the problem. The paper discusses the problem and the studies performed, and also outlines the TCSC that has be installed in the Stode SC station. The TCSC permits that the degree of compensation remains at its earlier level, while the SSR conditions are similar to the case when 30% of the series capacitor reactance is bypassed.

[1998] 10A - 117

THYRISTOR CONTROLLED SERIES COMPENSATION (TCSC) IMPEDANCE AND LINEARIZED MODELS FOR POWER SWING AND TORSIONAL ANALYSIS

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EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-110553, May 1998,

Optimal use of flexible ac transmission system (FACTS) devices requires enhanced control capabilities and understanding of complex behaviors. This report describes the development of analytical models to more accurately study and operate the thyristor-controlled series compensation (TCSC) device.

[1997] 10A - 118

THYRISTOR CONTROLLED SERIES COMPENSATION

Allaire, J.; Chakravorty, S.; Clark, K.; Edris, A.-A.; Gamma, C.; George, T.; Kinney, S.; Othman, H.; Ping, W.; Renz, K.; Thanawala, H.; Torgerson, D.; Wegner, C.; Weiss, S.

CIGRE WG 14.18

Proceedings, Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 1997

The application of power electronic thyristor valves in high-voltage direct-current (HVDC) and static var compensator (SVC) technologies has enabled the development of controllable series compensation devices with rapid response for use in electric power transmission systems. Increased use of transmission networks for bulk power transfers, growing demands for transmission access by non-utility generators, and economic factors can be expected to push the limits of existing power delivery systems. The need to maximize use of existing or new transmission corridors, by increasing the amount of power that can be transmitted through these corridors, will also become more important because of difficulties in obtaining new rights-of-way. Improving transmission system flexibility to reliably respond to fluctuating operating conditions as a result of changing network conditions, disturbances, and contingencies can enhance system performance and improve power system operations. These conditions will require closer control of power dispatch and reactive power flow, which in turn will require real-time control capability and create opportunities for thyristor-controlled compensation applications.

[1997] 10A - 119

THYRISTOR-CONTROLLED SERIES CAPACITOR USED AS A MEANS TO REDUCE TORSIONAL INTERACTION SUBSYNCHRONOUS RESONANCE

Ahlgren, K.; Holmberg, D.; Halvarsson, P.; Angquist, L.

Svenska Kraftnat, Sweden

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

In Sweden some long series-compensated 400-kV transmission lines are connected to nuclear power stations. An SSR problem has been noticed and caused repeated triggering of the protections. A study indicated that SSR conditions might appear for some network configurations. Rebuilding of one SC, splitting its total reactance into a fixed part and a thyristor-controlled series capacitor (TCSC) part, was found to eliminate the problem. This paper discusses the problem and the studies performed and also outlines the TCSC that has been realized in the Stode SC station. The TCSC permits the degree of compensation to remain at its earlier level, while the SSR conditions are similar to the case when 30 percent of the series capacitor reactance is bypassed.

[1997] 10A - 120

TIME-OPTIMAL SERIES CAPACITOR CONTROL FOR DAMPING INTERAREA MODES IN INTERCONNECTED POWER SYSTEMS. DISCUSSION

Chang, J.; Chow, J.H.

Rensselaer Polytech Inst, Troy, NY, USA

IEEE Trans on Power Systems, vol 12, no 1, 1997, pp 215-221

Controllable series capacitors have been proposed to damp power swings resulting from large transient disturbances in systems with two machines. In this paper we describe a time-optimal series capacitor control to damp interarea modes in multi-machine systems. To find the switching line, we apply the slow coherency transformation to the system and project a slow subsystem trajectory found from the trajectory reversing method onto the predominant interarea mode. The method is illustrated by the time simulation of a six-machine power system with two interarea modes and is shown to give the desired result. 20 refs.

[1996] 10A - 121

TORSIONAL INTERACTION IN FLEXIBLE AC TRANSMISSION SYSTEMS WITH A THYRISTOR CONTROLLED SERIES CAPACITOR

Ndayizamba, J.; Lefebvre, S.; Xuan, D.D.

Ecole Polytechnique de Montreal, Quebec, Canada

Proceedings, 5th Electrimacs, Modeling and Simulation of Electric Machines, Converters & Systems, Saint Nazaire, France, September 17-19, 1996, pp 1187-1192

This paper presents results obtained in torsional interaction analysis of a flexible ac transmission systems (FACTS) using thyristor-controlled series capacitor.

The Component Connection Method (CCM) is used to point out the interaction between the current regulator of the thyristor-controlled series capacitor (TCSC) and the electromechanical part of the synchronous machine. The results are validated by an electromagnetic transients program (EMTP) study. 7 refs.

[1996] 10A - 122

TRANSMISSION SYSTEM STABILITY ENHANCEMENT VIA VARIABLE SERIES COMPENSATION

Choi, S.S.; Shrestha, G.; Jiang, F.

School of Elec & Electrn Eng, Nanyang Tech Inst, Singapore

Electric Machines and Power Systems, vol 24, no 5, July-August 1996, pp 569-582

A new approach to the design of variable series compensators for transmission systems is proposed. The compensators incorporate an optimal minimum time control strategy which suppresses power oscillations following large disturbances and a linear control part suitable for the regulation of power flows during small perturbations. The coordination between these two control functions is based on the magnitudes of the power oscillations. Computer simulation of the proposed scheme shows that it is effective in improving the stability performance of transmission networks. 11 Refs.

[1996] 10A - REF

HVDC - FACTS. STATE OF THE ART - POWER SYSTEM HARMONICS

For Abstract see entry 01A - 7

[1997] 10A - REF

COORDINATION OF CONTROLS WITH MULTIPLE FACTS/HVDC CONTROLLERS IN THE SAME AREA: SURVEY OF PRACTICAL EXPERIENCE

For Abstract see entry 05G – 2

[1998] 10A - REF

ELIMINATION OF DYNAMIC BIFURCATION AND CHAOS IN POWER SYSTEMS USING FACTS DEVICES

For Abstract see entry 07A - 13

[1996] 10A - REF

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

For Abstract see entry 07A - 17

[1996] 10A - REF

TECHNOLOGY DEVELOPMENT OF FLEXIBLE AC TRANSMISSION SYSTEM

For Abstract see entry 07A - 63

[1998] 10A - REF

VOLTAGE-SOURCE MATRIX CONVERTER AS A CONTROLLER IN FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 07A - 79

[1998] 10A - REF

BRAZILIAN NORTH-SOUTH INTERCONNECTION. APPLICATION OF THYRISTOR CONTROLLED SERIES COMPENSATION (TCSC) TO DAMP INTER-AREA OSCILLATION MODE

For Abstract see entry 07B - 11

[1997] 10A - REF

DAMPING OF POWER SWINGS BY OPTIMAL CONTROL OF SERIES COMPENSATORS

For Abstract see entry 07B - 16

[1996] 10A - REF

FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) SYSTEM STUDIES: SOUTHERN COMPANY SERVICES

For Abstract see entry 07B - 23

[1996] 10A - REF

FLEXIBLE AC TRANSMISSION SYSTEM DEVICES ON LARGE INTERCONNECTED POWER SYSTEMS

For Abstract see entry 07B - 25

[1998] 10A - REF

IMPROVEMENT OF THE DYNAMIC PERFORMANCE OF THE SPANISH POWER

SYSTEM WITH FACTS DEVICES

For Abstract see entry 07B - 30

[1997] 10A - REF

TAIWAN POWER TCSC EVALUATION STUDY

For Abstract see entry 07B - 56

[1996] 10A - REF

VARIABLE STRUCTURE TCSC CONTROL IN MULTIMACHINE POWER SYSTEMS

For Abstract see entry 07B - 67

[1997] 10A - REF

STATIC VAR COMPENSATORS FOR DAMPING POWER SYSTEM OSCILLATIONS AND ENHANCING TRANSMISSION CAPABILITY OVER LONG INTERCONNECTIONS

For Abstract see entry 08A - 108

[1997] 10A - REF

UNIFIED MODEL FOR THE ANALYSIS OF FACTS DEVICES IN DAMPING POWER SYSTEM OSCILLATIONS PART I: SINGLE-MACHINE INFINITE-BUS POWER SYSTEMS

For Abstract see entry 08A - 135

[1998] 10A - REF

ANALYSIS OF SVC AND TCSC CONTROLLERS IN VOLTAGE COLLAPSE

For Abstract see entry 08A - 25

[1996] 10A - REF

COMPARING THE VOLTAGE CONTROL CAPABILITIES OF PRESENT AND FUTURE VAR COMPENSATING TECHNIQUES IN TRANSMISSION SYSTEMS

For Abstract see entry 08A – 38

[1996] 10A - REF

DAMPING EFFICIENCY OF SVC AND CSC [POWER SYSTEM CONTROL]

For Abstract see entry 08A - 49

[1996] 10A - REF

POWER SYSTEM DISTURBANCE MONITORING

For Abstract see entry 08A - 89

[1998] 10A - REF

A ROBUST CONTROL STRATEGY FOR SHUNT AND SERIES REACTIVE COMPENSATORS TO DAMP ELECTROMECHANICAL OSCILLATIONS

For Abstract see entry 08A - 9

[1996] 10A - REF

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. NISSIN'S POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT

For Abstract see entry 08A - 94

[1997] 10A - REF

PRESENT AND FUTURE FLICKER MITIGATION TECHNIQUES

For Abstract see entry 08A - 96

[1997] 10A - REF

REACTIVE POWER ON THE MOVE: VAR MOBILITY FOR THE 21ST CENTURY

For Abstract see entry 08B - 9

[1998] 10A - REF

A GTO CONTROLLED SERIES CAPACITOR FOR DISTRIBUTION LINES

For Abstract see entry 10A - 1

[1996] 10A - REF

ESTIMATING DAMPING EFFECTIVENESS OF BPA'S THYRISTOR CONTROLLED SERIES CAPACITOR BY APPLYING TIME AND FREQUENCY DOMAIN METHODS TO MEASURED RESPONSE

For Abstract see entry 10B - 1

[1996] 10A - REF

SYSTEM ASPECTS OF GTO-CONTROLLED

SERIES COMPENSATION

For Abstract see entry 16C - 3

[1997] 10A - REF

INFLUENCE OF HARMONICS GENERATED BY THYRISTOR CONTROLLED SERIES CAPACITOR ON POWER SYSTEM AND GENERATOR

For Abstract see entry 17C - 16

[1996] 10A - REF

EXPERIMENTAL STUDY ON PROTOTYPE THYRISTOR CONTROLLED SERIES CAPACITOR MODEL CONNECTED TO 275V TEST SYSTEM. (III)

For Abstract see entry 17C - 8

[1997] 10A - REF

EFFECTS OF FACTS ON POWER SYSTEM DYNAMICS

For Abstract see entry 18A - 11

[1996] 10A - REF

FUZZY LOGIC SWITCHING OF FACTS DEVICES FOR STABILITY ENHANCEMENT

For Abstract see entry 18A - 17

[1997] 10A - REF

ROBUST DECENTRALISED DESIGN FOR MULTIPLE FACTS DAMPING CONTROLLERS

For Abstract see entry 18A – 28

[1998] 10A - REF

ROBUST DECENTRALISED CONTROL DESIGN USING GENETIC ALGORITHMS IN POWER SYSTEM DAMPING CONTROL

For Abstract see entry 18A - 29

[1997] 10A - REF

TUNING OF POWER SYSTEM DAMPING CONTROLLERS USING GENETIC ALGORITHMS

For Abstract see entry 18A - 32

[1996] 10A - REF

DAMPING ANALYSIS AND CONTROL FOR LONGITUDINAL POWER SYSTEMS

For Abstract see entry 18A - 4

[1998] 10A - REF

DISSIPATIVITY AS A UNIFYING CONTROL DESIGN FRAMEWORK FOR SUPPRESSION OF LOW FREQUENCY OSCILLATIONS IN POWER SYSTEMS

For Abstract see entry 18A - 9

[1997] 10A - REF

POWER FLOW CONTROL USING STATIC SYNCHRONOUS SERIES COMPENSATOR

For Abstract see entry 18B - 11

[1996] 10A - REF

AUXILIARY CONTROLLED SVS AND CONTROLLED SERIES COMPENSATION FOR FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 18B - 2

[1998] 10A - REF

DYNAMIC POWER FLOW CONTROL WITH CONTROLLABLE REACTIVE SERIES ELEMENTS

For Abstract see entry 18B - 6

[1996] 10A - REF

EFFECTS OF FACTS DEVICES ON STATIC VOLTAGE STABILITY

For Abstract see entry 18B - 7

[1996] 10A - REF

FACTS-APPLICATION IN MESHED SYSTEMS-A COMPARATIVE ANALYSIS

For Abstract see entry 18B - 8

[1996] 10A - REF

IMPROVEMENT OF POWER SYSTEM PERFORMANCE BY INSERTING FACTS DEVICES

For Abstract see entry 18B - 9

[1996] 10A - REF

A STUDY OF IMPROVEMENT FOR POWER SYSTEM STABILITY BY A TCSC WITH ?P TYPE PSS

For Abstract see entry 18C - 1

[1997] 10A - REF

COORDINATED SMES AND VARIABLE SERIES IMPEDANCE FOR LOAD FREQUENCY CONTROL

For Abstract see entry 18C - 5

[1997] 10A - REF

DAMPING CONTROLLER DESIGNS FOR AN SVC AND OTHER FACTS DEVICES

For Abstract see entry 18C - 7

[1997] 10A - REF

IMPROVED POWER SWING DAMPING BY COORDINATED FACTS CONTROLS

For Abstract see entry 18C - 9

[1996] 10A - REF

INTEGRATED ADAPTIVE PROTECTION AND CONTROL FOR CONTROLLABLE SERIES COMPENSATED TRANSMISSION SYSTEMS USING NEURAL NETWORKS

For Abstract see entry 18D - 15

[1997] 10A - REF

PROTECTION SCHEME FOR EHV TRANSMISSION SYSTEMS WITH THYRISTOR CONTROLLED SERIES COMPENSATION USING RADIAL BASIS FUNCTION NEURAL NETWORKS

For Abstract see entry 18D – 21

[1998] 10A - REF

AN ADAPTIVE PROTECTION SCHEME FOR ADVANCED SERIES COMPENSATED (ASC) TRANSMISSION LINES

For Abstract see entry 18D - 4

[1997] 10A - REF

NEWTON-TYPE ALGORITHM FOR THE CONTROL OF POWER FLOW IN ELECTRICAL POWER NETWORKS

For Abstract see entry 19B - 12

[1997] 10A - REF

IMPROVING POWER SYSTEM DYNAMICS BY SERIES-CONNECTED FACTS DEVICES

For Abstract see entry 19C - 2

[1996] 10A - REF

SERIES-CONNECTED FACTS DEVICES CONTROL STRATEGY FOR DAMPING OF ELECTROMECHANICAL OSCILLATIONS

For Abstract see entry 19C - 3

[1996] 10A - REF

TRANSIENT STABILITY ENHANCEMENT WITH FACTS CONTROL

For Abstract see entry 19C - 4

[1997] 10A - REF

MODELLING OF A THYRISTOR CONTROLLED SERIES CAPACITOR IN MATLAB™ ENVIRONMENT

For Abstract see entry 19D - 10

[1997] 10A - REF

TRANSIENT BEHAVIOR OF SYSTEMS CONTAINING FACTS DEVICES: MODELING OF THE THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 19D - 16

[1996] 10A - REF

EFFICIENT AND FLEXIBLE THYRISTOR CONTROLLED SERIES CAPACITOR SIMULATION IN EMTP-TACS

For Abstract see entry 19D - 5

[1998] 10A - REF

ANALOGUE SIMULATION STUDIES WITH ACTUAL CONTROLLERS FOR FACTS

EQUIPMENT

For Abstract see entry 19E - 11

[1997] 10A - REF

DEVELOPMENT OF THE MINIATURE MODEL OF THYRISTOR CONTROLLED SERIES COMPENSATOR AND THE TEST OF THEM ON SIMULATORS

For Abstract see entry 19E - 16

[1996] 10A - REF

EXPERIMENTAL STUDY ON STEP RESPONSE OF THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC)

For Abstract see entry 19E - 19

[1996] 10A - REF

A LABORATORY-SCALE THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 19E - 3

10B Commissioning, Testing, Performance

[1996] 10B - 1

ESTIMATING DAMPING EFFECTIVENESS OF BPA'S THYRISTOR CONTROLLED SERIES CAPACITOR BY APPLYING TIME AND FREQUENCY DOMAIN METHODS TO MEASURED RESPONSE

Trudnowski, D.J.; Donnelly, M.K.; Hauer, J.F.

Pacific Northwest Natl Lab (PNL), Richland, WA, USA

IEEE Trans on Power Systems, vol 11, no 2, May 1996, pp 761-766

Recently, a 500-kV thyristor-controlled series capacitor (TCSC) was installed in the Bonneville Power Administration system in the northwestern United States. Extensive field testing has included modulation experiments to determine the effect of the TCSC on low-frequency oscillations. This paper discusses modulation procedures, analysis methods, and results for estimating the damping effectiveness of the TCSC. Modulation methods include driving the TCSC with step and random noise, and analysis techniques include time (Prony analysis) and frequency-domain identification. Results indicate that: (1) the TCSC can have significant impact on system dynamics; and (2) under a very small feedback gain, the TCSC provides measurable added damping. 18 Refs.

[1996] 10B - 2

FOUR YEARS OF OPERATIONAL EXPERIENCE OF THE KAYENTA ADVANCED SERIES COMPENSATOR

Krause, P.; Torgerson, D.; Renz, K.; Weiss, S.; Lei, X.

Western Area Power Admin, Golden, CO, USA

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 160-164

The innovative combination of conventional fixed series capacitors and thyristor-controlled reactors as a flexible ac transmission (FACTS) device was introduced into transmission system for the first time in 1992. By providing direct control of transmission line impedance, this advanced series compensation (ASC) system offers several advantages not available with conventional fixed series capacitor installations. The Kayenta ASC has been in service for nearly four years and has shown its capability to perform as predicted. All expectations regarding the ASC's electrical characteristics have been confirmed. It is predicted that in future installations the ASC will be able to play an important role in SSR mitigation and in providing damping at power swing frequencies. The ASC is robust and relatively simple in concept and appears to have significant cost advantage over other FACTS controllers especially where fixed series compensation is to be installed to increase transfer capability. 6 Refs.

[1997] 10B - 3

OPERATIONAL EXPERIENCE WITH AEP'S 345 KV KANAWHA RIVER SERIES CAPACITOR INSTALLATION

Fecho, T.R.; Chan, K.; Sachdeva, M.K.

Strategic Studies and Projects, AEP Energy Services, Inc, USA

Proceedings, 59th American Power Conf, Chicago, IL, vol 59-1, 1997, pp 1058-1063

Series capacitor installations are usually associated with long distance extra-high voltage alternating current

transmission lines. In most situations, the application of series capacitors is included as a necessary and integral part of the long distance transmission scheme. When applied as part of a long distance transmission scheme, most series capacitor installations are planned for continuous operation. In such applications, the capacitors serve the intended purpose of improving operational stability of the network by counteracting the natural inductive reactance of the transmission line. This paper describes the experience gained from an application of series capacitors that were retrofitted on a 28 year old, 345-kV transmission line. The paper describes the operational experience of the 787-MVAr, 345-kV variable series capacitor bank installed in 1991 at American Electric Power's Kanawha River station. This installation, one of the world's largest at one location, improved the performance characteristics of a 345-kV transmission line which operates as part of a highly integrated transmission system. The Kanawha River series capacitors depart from the traditional model of operation in that the capacitors are kept in reserve, i.e., they are often in a bypass mode. The capacitors can be quickly switched into operation whenever loading of the network warrant their energization. Although the Kanawha River series capacitors can operate continuously, it was decided in the original planning of this installation to minimize their operation so as to avoid the unnecessary increase in associated operating costs. This increase in operating costs is a direct result of the increase in system active power losses incurred whenever the series capacitors are in operation. The paper develops an estimate of the reduction in operating costs that have been accrued by adopting this philosophy of system operation. Loss minimization and attendant cost savings are made possible through the use of real-time system operating data obtained from AEP's supervisory control and data acquisition system and from the application of operating guidelines developed through extensive off-line power flow simulation studies. This knowledge is used to balance the concerns for operational reliability and security of the integrated transmission system with the goal of minimizing operating costs. 4 refs.

[1997] 10B - 4

RESEARCH ON CHARACTERISTICS OF TCSC DYNAMIC SIMULATION EXPERIMENT APPARATUS ON YIMIN-FENGTUN TRANSMISSION LINE

Zheng, W.; Hu, G.; Wang, Z.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 59-62

Chinese

This paper presents the characteristics of the thyristor-controlled series compensator (TCSC) dynamic experimental apparatus based on the Northeast China Yimin-Fengtun transmission line. The testing waveforms under all situations are provided. Several basic results are gained to prepare for further discussion of control modes and strategies: the equivalent impedance of the TCSC will increase when the firing angle is getting close to the resonant point; when firing angle varies sharply, it needs at most 40-60 ms to arrive at the next steady state in the normal operation region; the interchange between capacitive and inductive regions can be realized steadily; it can also change between by-pass state and the previous operating point; and the voltage across the capacitance, not the line current, will be a better choice as the synchronous signal.

[1996] 10B - 5

SUBSYNCHRONOUS RESONANCE PERFORMANCE TESTS OF THE SLATT THYRISTOR-CONTROLLED SERIES CAPACITOR

Piwko, R.J.; Wegner, C.A.; Kinney, S.J.; Eden, J.D.

GE Power Sys Eng, Schenectady, NY, USA

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 1112-1119

A thyristor-controlled series capacitor (TCSC) has been designed, installed, and field tested on the BPA 500-kV transmission system. The Slatt TCSC is a variable series capacitor with high control bandwidth. Field test results demonstrate that this TCSC does not participate in or contribute to subsynchronous resonance (SSR). It is SSR neutral in itself, and it can reduce SSR effects due to other nearby conventional series capacitors. 3 Refs.

[1996] 10B - 6

DELETED

[1997] 10B - 7

THE DEVELOPMENTS OF THYRISTOR CONTROLLED SERIES CAPACITOR IN THE UNITED STATES

Huang, C.-Y.

Monthly Journal of Taipower's Engineering (Taiwan),

vol 581, January 1997, pp 39-49

Chinese

The development and operation experiences of the thyristor-controlled series capacitor (TCSC) in the United States are mentioned. Installation examples of American Electric Power Company Kanawha River substation, Western Area Power Administration Kayenta site, and Bonneville Power Administration Slatt substation are described.

[1997] 10B - REF

STUDY OF POWER ELECTRONICS EQUIPMENT FOR DAMPING CONTROL OF PUMPED STORAGE GENERATOR/MOTOR AND STABILIZING LOAD VOLTAGE

For Abstract see entry 08A - 114

[1997] 10B - REF

REACTIVE POWER ON THE MOVE: VAR MOBILITY FOR THE 21ST CENTURY

For Abstract see entry 08B - 9

[1997] 10B - REF

THYRISTOR-CONTROLLED SERIES CAPACITOR USED AS A MEANS TO REDUCE TORSIONAL INTERACTION SUBSYNCHRONOUS RESONANCE

For Abstract see entry 10A - 119

[1997] 10B - REF

GTO BASED ADVANCED STATIC VAR GENERATOR

For Abstract see entry 10A - 47

[1996] 10B - REF

MODULATION AND SSR TESTS PERFORMED ON THE BPA 500 KV THYRISTOR CONTROLLED SERIES CAPACITOR UNIT AT SLATT SUBSTATION

For Abstract see entry 10A - 69

11 UNIFIED POWER FLOW CONTROLLER (UPFC)

11A Modeling, Control, Applications

[1996] 11A - 1

A CONTROL SCHEME FOR UNIFIED POWER FLOW CONTROLLER TO IMPROVE STABILITY OF POWER SYSTEMS

Padiyar, K.R.; Rao, K.U.

Indian Inst of Sci, Bangalore, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 248-252

FACTS controllers are emerging as viable and economic solutions to the problems of large interconnected ac networks, which can endanger the system security. These devices are characterized by their fast response, absence of inertia, and minimal maintenance requirements. Thyristor-controlled equipment, like the TCSC, SVC, TCPR, etc., require passive elements (reactors and capacitors) of large ratings. In contrast, an all solid-state device using GTOs leads to a reduction in equipment size and improved performance. The unified power flow controller (UPFC) is an all solid-state power flow controller which can be used to control the active and reactive power in the line independently, in addition to controlling local bus voltage. In this paper, we present a control scheme for the UPFC to improve stability and damping.

[1996] 11A - 2

A NEW CALCULATION METHOD FOR POWER FLOW CONTROL IN POWER SYSTEM WITH UPFC

Cui, Y-X.; Huang, Z-Y.; Chen, Z.; Chen, S-S.; Zhang, B-L.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 945-948

This paper describes a new method for load flow calculation of UPFC (unified power flow controller) in power system. This method can solve not only the load

flow under the condition that the control parameters of UPFC are given (forward calculation), but also the problem that the UPFC parameter setting is the aim of concern (backward calculation). By leading the branch power equation of a transmission line with UPFC into the conventional node power equations, a set of nonlinear equations can be obtained and the Newton-Raphson method can be used to solve these equations. A program using this method was developed and the calculation results proved the correctness of this method. 11 Refs.

[1996] 11A - 3

Delete

[1996] 11A - 4

AN ADVANCED UNIFIED POWER FLOW CONTROLLER

Aredes, M.; Heumann, K.

Inst fur Allgemeine Elektrotech, Tech Univ Berlin, Germany

Electrical Engineering (Germany), vol 79, no 4, August 1996, pp 303-310

This paper describes the implementation of a new control approach for the unified power flow controller (UPFC), which provides active filtering capabilities to this equipment, besides the functions of power flow control and voltage control, as originally proposed by L. Gyugyi (1992, 1995). The power circuit is made up from two PWM converters which share a common dc link without the need of dc power supplies. An integrated controller attends to both series and shunt converters of the UPFC. It is based on the theory of instantaneous active and reactive power defined in the alpha - beta -0 reference frame. A complete model of the new UPFC has been implemented in a digital simulator. Simulation results have confirmed that the new approach has higher performance than those UPFCs which use traditional definitions of powers in the controller. 8 Refs.

[1998] 11A - 5

AN UNIVERSAL ACTIVE POWER LINE CONDITIONER

Aredes, M.; Heumann, K.; Watanabe, E.H.

CEPEL, Brazil

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 545-551

The power circuit of a general active power line conditioner (APLC) is based on series and shunt power converters that share a single dc link. In the present paper, a generic control concept for these series and shunt converters is proposed. It is based on the instantaneous real and imaginary power theory. In fact, the resulting equipment deals with the custom power and FACTS concepts. This equipment incorporates not only the compensation functions at the fundamental frequency like a unified power flow controller (UPFC), but also provides active harmonic mitigation capabilities. For these reasons, the compensator proposed here is called the universal active power line conditioner (UPLC). Simulation and experimental results are presented to confirm that the new approach has better performance than those obtained by controllers based on traditional concepts of active and reactive power.

[1996] 11A - 6

ANALYSIS OF THE EFFECT OF POWER TRANSMISSION FAILURE IN UNIFIED POWER FLOW CONTROLLERS

Chida, T.; Sato, Y.; Sugawara, J.; Morikawa, R.; Tamura, Y.; Irokawa, S.

Tohoku Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 866-867

Japanese

Abstract not available.

[1996] 11A - 7

ANALYSIS, SIMULATION AND IMPLEMENTATION OF A PWM BASED UPFC

Al-Mawsawi, S.A.; Coonick, A.

Bahrain Univ, Isa Town, Bahrain

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 239-244

The unified power flow controller (UPFC) has the potential to become one of the most important flexible ac transmission system (FACTS) devices since it can provide four types of compensation, i.e., voltage regulator, phase shifting regulator, impedance compensation and reactive compensation. The practical implementation of the UPFC consists of two similar

solid-state three-phase voltage-source inverters (shunt compensation block and series compensation block) operated from a common dc link capacitor. The series compensation block of the UPFC can provide three types of compensation (voltage regulation, impedance compensation, and phase shift regulation). Although the shunt block can be used as the reactive compensation, it also provides the real power demand of the series block at the common dc link from the ac power terminal. Therefore, it was decided to use a fixed dc voltage source to supply the real power demand of the series block. This paper deals with the analysis, simulation and implementation of a PWM based UPFC with a series compensation block. In this paper, the analysis results of the UPFC with a series compensation block is presented. The modeling, simulation of the open-loop UPFC with a series compensation block are also presented using the Electromagnetic Transients Program (EMTP, ATP version). In addition, the implementation of this system is presented and the experimental steady-state performance results are given and compared with that obtained from the simulation. 9 Refs.

[1997] 11A - 8

BASIC CONTROL OF UNIFIED POWER FLOW CONTROLLER

Papic, I.; Zunko, P.; Povh, D.; Weinhold, M.

Faculty of Elec Eng and Computer Sci, Univ of Ljubljana, Slovenia

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1734-1739

A unified power flow controller (UPFC) is a typical FACTS device capable of instantaneous control of three system parameters. This paper presents a basic control system which enables the UPFC to follow the changes in reference values of the active and reactive power supplied from the outer system controller. The analysis is based on the transformation of the three-phase system to the rotating reference frame. As a step closer to a practical application of the UPFC a modified control structure with a predictive control loop and precontrol signal for a dc-voltage control was designed. The new control system offers better stability and transient performance in comparison with the classical decoupled strategy, especially considering the harmonic distortion of the current being controlled. The derived basic control of the UPFC was tested with the NETOMAC program system. 5 Refs.

[1997] 11A - 9

BASIS STUDY OF POWER SYSTEM STABILIZING CONTROL USING UNIFIED POWER FLOW CONTROLLER (UPFC)

Kono, H.; Yokoyama, A.

Univ of Tokyo, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 159-166, 168-172, pp 49-54

Japanese

The unified power flow controller (UPFC) can inject voltage with controllable magnitude and phase angle in series with a transmission line. And it can also generate or absorb controllable reactive power. It is expected to be able to damp power system oscillations more effectively than conventional power electronics equipment such as SVC, VSrC and HSPS. UPFC controllers are designed using global information and local information. The effects of input signals to UPFC controller on small-signal stability and transient stability enhancement are compared.

[1998] 11A - 10

CONTROL DESIGN AND SIMULATION OF UNIFIED POWER FLOW CONTROLLER

Padiyar, K.R.; Kulkarni, A.M.

Indian Inst of Sci, Bangalore, India

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

The UPFC is a solid-state controller which can be used to control active and reactive power flows in a transmission line. In this paper we propose a control strategy for UPFC in which we control real power flow through the line, while regulating magnitudes of the voltages at its two ports. We design a controller for this purpose which uses only local measurements. The control strategy is evaluated using digital simulation for a case study.

[1997] 11A - 11

CONTROL OF UNIFIED POWER FLOW CONTROLLER: COMPARISON OF METHODS ON THE BASIS OF A DETAILED NUMERICAL MODEL

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Electricite de France, Clamart, France

IEEE Trans on Power Systems, vol 12, no 2, May 1997, pp 824-830

This article is based on results from numerical simulation, including GTOs, of a complete unified power flow controller (UPFC) structure using EMTP (Electromagnetic Transients Program) code. A new type of control is presented. This Linear Quadratic control allows to take into account the coupling of the equations in the shunt part of a UPFC. Three types of 'converter control' are simulated. They are compared in relation to capacitance rating, transformation ratios, switching losses and harmonics. Choice of the most suitable command-control method will result in a reduction of losses and of the harmonics injected into the system, and will optimize the rating of the component elements of the UPFC. 4 Refs.

[1998] 11A - 12

CONTROLLING THE FLOW OF REAL AND REACTIVE POWER

Edris, A.-A.; Mehraban, A.S.; Rahman, M.; Gyugyi, L.; Arabi, S.; Reitman, T.

EPRI, Palo Alto, CA, USA

IEEE Computer Applications in Power, vol 11, no 1, January 1998, pp 20-25

The unified power flow controller (UPFC) is the cornerstone of the Electric Power Research Institute's flexible ac transmission system program. It was proposed for the real-time control and dynamic compensation of ac transmission systems and offers multiple compensation functions. UPFC makes the control of the voltage, line impedance and phase angle of ac transmission systems possible. This functional flexibility offers a great potential in solving many of the problems facing the utility industry. For the American Electric Power Inez substation, the benefits of having a UPFC includes increased power transfer capability by about 125 MW and regulated area voltage within one percent. 6 Refs.

[1997] 11A - 13

DEPENDABILITY ANALYSIS OF A UNIFIED POWER FLOW CONTROLLER (UPFC)

Malarange, G.; Daniel, D.; Boucon; Eyraud

Electricite de France

Collection de notes internes de la Direction des etudes et recherches. Materiel electrique, transport et distribution d'energie (France), 1997, no 20, 15 pp

French; English

The objective of this paper is to illustrate by an application on power electronic device called "UPFC" (unified power flow controller), the contribution of the main methods of functional analysis and failure modes, by comparison of different designs of a same system. Inserted in a power network, the UPFC improves the power system stability, at the same time by a voltage control and a power flow control between parallel lines. The approach breaks down into two main stages, classic in a dependability and adapted to the context: functional analysis with external and internal level, then qualitative analysis of the malfunctions as inductive by the FMECA, as deductive by the fault tree. This method is apply to the UPFC with two prototypes with differences on the redundancy location. 3 refs.

[1996] 11A - 14

DEVELOPMENT AND EVALUATION OF CONTROLS FOR UNIFIED POWER FLOW CONTROLLER

Padiyar, K.R.; Kulkarni, A.M.

Indian Inst of Sci, Bangalore, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 1, pp 253-257

The UPFC is a solid-state controller which can be used to control active and reactive power flows in a transmission line. In this paper we propose a control strategy for UPFC in which we control real power flow through the line, while regulating magnitudes of the voltages at its two ports. We develop a controller for this purpose which uses only local measurements.

[1996] 11A - 15

DYNAMIC CONTROL OF A UNIFIED POWER FLOW CONTROLLER

Yu, Q.; Round, S.D.; Norum, L.E.; Undeland, T.M.

Norwegian Univ of Sci and Tech, Trondheim, Norway

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 508-514

The performance of a unified power flow controller (UPFC) with four different controllers is evaluated through simulation and implementation in an experimental laboratory model. The controllers which were investigated are the PI controller, PI controller with decoupling, cross-coupling controller and robust H8 controller. It is found that the cross-coupling and robust H8 controllers have the best performance when the exact value of the power transmission parameters are unknown. 9 Refs.

[1997] 11A - 16

DYNAMIC MODELING AND OPTIMAL CONTROL FOR UNIFIED POWER FLOW CONTROLLER

Luo, C.; Sun, H.; Xu, G.

Chongqing Univ, China

Automation of Electric Power Systems (China), vol 21, no 11, November 1997, pp 4-6

Chinese

This paper studies the power equation of a single machine infinite-bus system including UPFC. A two-order differential equation is presented to describe the dynamic behavior of UPFC. Then an optimal control system is designed. Dynamic simulation results demonstrate the effectiveness of this method.

[1997] 11A - 17

DYNAMIC MODELLING OF A UNIFIED POWER FLOW CONTROLLER

Smith, K.S.; Ran, L.; Penman, J.

Heriot-Watt Univ, Edinburgh, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 1, January 1997, pp 7-12

A method to regulate the unified power flow controller (UPFC) to improve the dynamic performance of the power system is proposed in the paper. The series voltage responds to the power variations of the transmission line, while the shunt compensation is controlled to maintain the system bus voltage and to stabilize the dc link of the UPFC. Decoupled control algorithms for active and reactive power are developed. A nonlinear dynamic model of the network is established for transient studies. The small-signal model is derived using linearization and network reduction. An integrated formulation can be achieved which represents the dynamics of the generators, loads and the UPFC. The effectiveness of the UPFC and the accuracy of the analytical models are examined using numerical examples. 13 Refs.

[1996] 11A - 18

EMTP SIMULATION OF MULTI-PULSE UNIFIED POWER FLOW CONTROLLERS

Bakhshai, A.R.; Joos, G.; Jin, H.

Concordia Univ, Montreal, Quebec, Canada

Proceedings, Canadian Conf on Electrical and Computer Engineering (CCECE'96), Calgary, Canada, May 29-29, 1996, vol 2, pp 847-850

A simulation study of a unified power flow controller (UPFC) aimed at examining its capability to operate as a general purpose device for power system is presented. The simulation is made using the Electromagnetic Transient Program (EMTP). To utilize the UPFC's possibilities, the three controllable UPFC's parameters have been adjusted during the digital simulation process performed by EMTP. Among the different UPFC power circuit structures the most practical from the view point of efficiency and power device availability based on the concept of multi-pulse inverters is simulated and studied. 8 Refs.

[1997] 11A - 19

FUZZY LOGIC CONTROL OF A UNIFIED POWER FLOW CONTROLLER FOR WIND FARM APPLICATIONS

Papantoniou, A.; Coonick, A.

Imperial College, London, UK

Proceedings, IEE Colloquium on Power Electronics for Renewable Energy, London, UK, June 16, 1997, no 170, pp 9/1-9/6

A fuzzy controller was used to control the series branch of a unified power flow controller (UPFC) in order to improve the terminal voltage of a grid connected wind farm. Fuzzy control offers an alternative method to classical control design and needs minimum system knowledge. A fuzzy controller with two different defuzzification techniques was tested, namely, the Maximum (MAX) and the center of axis criteria. Although the former offers fast initial response, the latter provides a smaller steady-state error and generally superior overall performance. Both fuzzy approaches gave tighter terminal voltage control and improved voltage stability than the P plus I controller. 9 Refs.

[1996] 11A - 20

GENETIC ALGORITHMS AND UPFC FOR POWER FLOW CONTROL

Lai, L.L.; Ma, J.T.

City Univ, London, UK

Int'l Journal of Engineering Intelligent Systems for Electrical Engineering and Communications vol 4, no 4, December 1996, pp 237-242

This paper presents a genetic algorithm (GA) to solve optimal power flow (OPF) problems in flexible ac transmission systems (FACTS). The unified power flow

controller (UPFC) is used as a phase shifter and/or a series compensator to regulate both angle and magnitude of branch voltage. The GA, coupled with P-Q power flow, selects the best regulation to minimize the real power loss and keep the power flows in their secure limits. The optimization process with GA will be illustrated in detail. 11 Refs.

[1997] 11A - 21

IMPLEMENTATION OF UNIFIED POWER FLOW CONTROLLER AND VERIFICATION FOR TRANSMISSION CAPABILITY IMPROVEMENT

Kato, M.; Morioka, Y.; Nakahigashi, Y.; Asada, M.; Tokuhara, K.; Akamatsu, M.; Furuta, M.; Mishima, Y.; Nakachi, Y.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 8, no 1, pp 157-162

Japanese

This paper describes an outline and a control system of an UPFC model manufactured in trial, confirms a system stability improvement function and power flow control function, connecting to an electric power system simulator. This paper examines an orthogonal voltage control, an impedance control and a voltage phase control as a control mode of a series compensator and obtains a prospect that the orthogonal voltage control mode is the most practical from a point of stabilization control sensibility independent of power flow quantity and minimize the capacity of the parallel compensator side though there is little difference for stability improvement effect of the applied system. It is confirmed by a simulator test that capacity of the serial compensator necessary for the middle region stability improvement might be small. A system composition and a start/stop system are developed, which are necessary for series connection and isolation of the UPFC that is a series equipment in a transmission line without transient variation, and an operation confirmation test is carried out by a reduced small model. As the result, suitability of the proposed plan to the system is verified and prospect of a practical application of the UPFC is obtained.

[1997] 11A - 22

IMPROVEMENT OF POWER SYSTEM TRANSIENT STABILITY USING UNIFIED POWER FLOW CONTROLLER

Xi, J.; Tu, G.

Huazhong Univ of Sci & Tech, Wuhan, China

Automation of Electric Power Systems (China), vol 21, no 3, March 1997, pp 51-53

Chinese

The unified power flow controller (UPFC) is one of the important contents of the flexible ac transmission systems (FACTS). The parameters of power systems such as voltage, phase and the reactance of the transmission lines can be controlled respectively or simultaneously by using UPFC. In this paper, the UPFC with tap-changer is studied to improve power system transient stability and the simulation results on a simple power system are shown.

[1996] 11A - 23

IMPROVEMENT OF TRANSIENT STABILITY USING UNIFIED POWER FLOW CONTROLLER

Mihalic, R.; Zunko, P.; Povh, D.

Faculty of Elec Eng and Computer Sci, University of Ljubljana, Slovenia

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 485-491

The aim of the paper is to analyze the effect of an unified power flow controller (UPFC) on transient stability margin enhancement of a longitudinal system. To utilize the UPFC possibilities fully, the three controllable UPFC parameters were determined during the digital simulation process performed by the NETOMAC simulation program. The basis for determination of the suitable damping strategy and for determination of the optimal UPFC parameters is a mathematical model, which describes the interdependence between longitudinal transmission system parameters, operating conditions and UPFC parameters in the form of analytical equations. On the basis of the mathematical model, the theoretical UPFC limits were also detected, and their appearance explained. 4 Refs.

[1997] 11A - 24

INTELLIGENT AUTONOMOUS CONTROL OF A UNIFIED POWER FLOW CONTROLLER

Sreenivasachar, K.; Jayaram, S.; Salama, M.M.A.

Univ of Waterloo, Ontario, Canada

Proceedings, 2nd Int'l IEEE Conf on Power Electronics and Drive Systems (PEDS), Singapore, May 26-29, 1997, vol 2, pp 862-868

Intelligent autonomous controllers (IAC) are advanced level controllers with an ability to self govern the control functions. The self governing capacity includes adaptation to environment changes and internal failures in control functions without external intervention. Control functions therefore require proper coordination between several controllers in a system and the built-in intelligence to accommodate for various contingencies. In this paper, a hierarchical autonomous controller has been designed for a special power flow control equipment called the unified power flow controller (UPFC). The performance of the UPFC with autonomous controller has been studied on a single-machine infinite-bus system. A single contingency has been evaluated and proper intelligent action is incorporated into the controller to maintain system stability. 20 Refs.

[1996] 11A - 25

INTERNAL CONTROL OF PWM-BASED UPFC

Liu, J.Y.; Song, Y.H.

Univ of Bath, UK

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 914-918

This paper is concerned with the digital studies of the internal control of the SPWM UPFC. At first the SPWM scheme generation and the main factors affecting the functions and the control of the UPFC are discussed. Secondly, how the series part and shunt part of the SPWM UPFC are controlled and coordinated is analyzed. The paper then places the emphasis on the detailed internal control of SPWM UPFC. The closed-loop controller of UPFC is designed on the basis of operating envelop of open-loop simulation. The information presented gives a deep insight into UPFC performance. 8 Refs.

[1996] 11A - 26

INVESTIGATION OF DYNAMIC CONTROLLERS FOR A UNIFIED POWER FLOW CONTROLLER

Yu, Q.; Norum, L.; Undeland, T.; Round, S.N.

Norwegian Univ of Sci and Tech, Trondheim, Norway

Proceedings, 22nd IEEE Intl Conf on Industrial Electronics, Control, and Instrumentation, (IECON), Taipei, Taiwan, August 5-10, 1996, vol 3, 1996, pp 1764-1769

In this paper, a unified power flow controller (UPFC) model based on a d-q rotating frame is introduced. The performance of the UPFC system with three different controllers, PI controller, PI controller with decoupling and cross-coupling controller, are investigated through simulation and implementation in an experimental laboratory model. It is found that the cross-coupling controller produces the best performance when the transmission line parameters are unknown. Furthermore, the measures implemented to reduce the interaction between the series and shunt inverters are also introduced. 7 Refs.

[1996] 11A - 27

MODELLING AND CONTROL TECHNIQUE OF UNIFIED POWER FLOW CONTROLLER (UPFC)

Universite de Lille, France

Proceedings, 5th Electrimacs, Modelling and Simulation of Electric Machines, Converters & Systems, Saint Nazaire, France, September 17-19, 1996, pp 853-858

This paper is dealing with modeling and control of flexible alternative current transmission systems (FACTS) and more particularly the unified power flow controller (UPFC). An original control technique is proposed and validated by simulation. 9 refs.

[1997] 11A - 28

MULTIMODULAR UPFC OPERATED BY PHASE-SHIFTED TRIANGLE CARRIER SPWM STRATEGY

Mwinyiwiwa, B.; Ooi, B.-T.; Wolanski, Z.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 32nd IEEE Industry Applications Conf, New Orleans, LA, October 5-9, 1997, vol 2, pp 1641-1646

The acronym UPFC covers L. Gyugyi's unified power flow controller and Akagi and Fujita's unified power flow conditioner. The paper describes one method of meeting high MVA specifications by using multiple modules of 2-level, three-phase converter modules controlled by the phase-shifted triangle carrier technique of the sinusoidal pulse width modulation (SPWM) strategy. Two conceptual designs are presented: (1) the GTO-SPWM-UPFC at the lowest switching rate, f_c/f_m equals 3, to minimize GTO switching loss. The design is based on applying the fundamentals of SPWM theory to overcome unbalances arising from sideband harmonic interferences. (2) the

IGBT-SPWM-UPFC, at f_c/f_m equals 12 or higher, which SPWM theory assures that direct paralleling of the modules is free of current unbalance. A laboratory UPFC based on 6 modules of three-phase, 5-kVA size, IGBT converters operating at the base-line condition of dual unity displacement factor at the sending-end and the receiving end, has been implemented. 10 Refs.

[1996] 11A - 29

OPERATION OF THE UNIFIED POWER FLOW CONTROLLER AS HARMONIC ISOLATOR

Enslin, J.H.R.; Zhao, J.; Spee, R.

Univ of Stellenbosch, South Africa

IEEE Trans on Power Electronics, vol 11, no 6, November 1996, pp 776-784

The unified power flow controller (UPFC) is a tool in the implementation of flexible ac transmission systems (FACTS). It provides for the equivalent of static VAr compensation and series injection using back-to-back force commutated converters. This paper proposes a control strategy to extend UPFC operation to allow for the isolation of harmonics due to nonlinear loads. Simulation results based on the Electromagnetic Transients Program (EMTP) are used to illustrate device performance in a power system environment. Experimental results based on a single-phase laboratory implementation verify the proposed control algorithm. 14 Refs.

[1998] 11A - 30

OPERATION OF THE UNIFIED POWER FLOW CONTROLLER (UPFC) UNDER PRACTICAL CONSTRAINTS

Schauder, C.D.; Gyugyi, L.; Lund, M.R.; Hamai, D.M.; Rietman, T.R.; Torgerson, D.R.; Edris, A.-A.

Westinghouse Elec Corp, USA

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 630-639

The UPFC is the most versatile and complex power electronic equipment that has emerged for the control and optimization of power flow in electrical power transmission systems. It offers major potential advantages for the static and dynamic operation of transmission lines, but it brings with it major design challenges, both in the power electronics and from the perspective of the power system. As the UPFC transitions from concept to full-scale power system implementation, the control and protection of this sophisticated equipment are of primary concern. This paper describes the basic control, sequencing and protection philosophies that govern the operation of the UPFC, subject to the practical constraints encountered in an actual high power installation. The operation of the UPFC is illustrated with representative results from a TNA study, undertaken jointly by the Electric Power Research Institute (EPRI), Western Area Power Administration (WAPA) and Westinghouse Science and Technology Center (STC).

[1997] 11A - 31

PERFORMANCE EVALUATION OF UNIFIED POWER FLOW CONTROLLER USING TRANSIENT SIMULATION

Kulkarni, A.M.; Padiyar, K.R.

Indian Inst of Sci, Bangalore, India

Proceedings, 2nd Int'l IEEE Conf on Power Electronics and Drive Systems (PEDS), Singapore, May 26-29, 1997, vol 2, pp 734-739

The unified power flow controller (UPFC) is a power electronic controller which can be used to control active and reactive power flows in a transmission line by injection of (variable) voltage in series and reactive current in shunt. In this paper we evaluate the performance of a control strategy for UPFC in which we control real power flow through the line, while regulating magnitudes of the voltages at its two ports using transient simulation. The real power reference is modulated in order to improve the damping of power swings in the line. The effectiveness of the UPFC with this control strategy is clearly brought out by the simulation study. 7 Refs.

[1996] 11A - 32

PERFORMANCE OF A UNIFIED POWER FLOW CONTROLLER USING A D-Q CONTROL SYSTEM

Round, S.D.; Yu, Q.; Norum, L.E.; Undeland, T.M.

Canterbury Univ, Christchurch, New Zealand

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 357-362

The real and reactive power flow in a transmission line can be controlled by a pair of back-to-back power electronic inverters. This configuration is called a unified power flow controller (UPFC). Operation of a UPFC using a control strategy which is based on d-q axis theory is presented by simulation and experimental laboratory results. A new cross-coupling control strategy

is also presented which has an improved performance. 6 Refs.

[1997] 11A - 33

POSSIBLE ALLEVIATION OF VOLTAGE STABILITY PROBLEM BY USE OF UNIFIED POWER FLOW CONTROLLER

Dizdarevic, N.; Arnborg, S.; Andersson, G.

Royal Inst of Tech, Stockholm, Sweden

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 975-978

This paper investigates the impact of the unified power flow controller (UPFC) on alleviation of voltage stability problem from a viewpoint of time domain simulations achieved by using in-house developed computer program. The control system of the UPFC's injection model is developed to fulfill functions of reactive shunt compensation, voltage regulation, line power flow regulation, series compensation and phase shifting meeting multiple control objectives by applying boosting transformer injected voltage and exciting transformer reactive current. In addition to these types of regulation, the block for damping of electromechanical oscillations based on transient energy function (TEF) is also implemented in the model. The benefits of the UPFC's contribution to avoiding of voltage collapse are explored by analyzing a simple two machine test system retaining versatile regulating and damping capabilities of the controller. 4 Refs.

[1997] 11A - 34

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. SIMULATION STUDY OF UNIFIED POWER FLOW CONTROLLER.

Chida, T.; Sato, Y.; Sugawara, J.; Morikawa, R.; Tamura, Y.; Irokawa, S.

Tohoku Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 7, pp 960-966

Japanese

The increasing complexity of ac power networks requires a high performance power flow control system in order to obtain a desired power flow and enhance static and dynamic stability. One of the most effective power electronic systems to satisfy these requirements is a UPFC (unified power flow controller) employing self-commutated converters. This paper presents basic control strategies and simulation results for the UPFC using EMTP (Electromagnetic Transients Program). The simulations were carried out for start and stop operations, power flow change operations in normal system conditions, as well as operations during system fault conditions. Thyristor-based bypass switches are used for the protection of the series compensator of the UPFC from system fault currents, and satisfactory protection capability was confirmed.

[1997] 11A - 35

POWER FLOW CONTROL AND VOLTAGE SUPPORT IN A MESHED POWER SYSTEM USING UNIFIED POWER FLOW CONTROLLERS

Liu, J.Y.; Song, Y.H.; Foss, A.M.

Brunel Univ, UK

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 531-534

The UPFC, with its unique combination of fast shunt and series compensation, offers a versatile device for the relief of transmission constraints, which is able to accommodate a wide range of generation patterns. However, in order to realize this potential benefit, appropriate local and global power system control strategies must first be identified. This paper presents preliminary result on the steady-state aspects of this control, with results demonstrated on a 28-node test system. 13 Refs.

[1996] 11A - 36

POWER FLOW CONTROL WITH UPFC USING GENETIC ALGORITHMS

Lai, L.L.; Ma, J.T.

Dept of Elec, Electrn & Inf Eng, City Univ, London, UK

Proceedings, Int'l Conf on Intelligent System Application to Power Systems (ISAP'96), Orlando, FL, January 28-February 2, 1996, pp 373-377

This paper presents a genetic algorithm (GA) to solve optimal power flow problems in flexible ac transmission systems (FACTS). The unified power flow controller (UPFC) is used as a phase shifter and/or a series compensator to regulate both angle and magnitude of branch voltage. The GA, coupled with P-Q power flow, selects the best regulation to minimize the real power loss and keep the power flows in their secure limits. 10

Refs.

[1997] 11A - 37

POWER SYSTEM STABILISING CONTROL USING UNIFIED POWER FLOW CONTROLLER

Kato, M.; Morioka, Y.; Nakahigashi, Y.; Asada, M.; Mishima, Y.; Nakachi, Y.; Tokuhara, K.; Furuta, M.; Akamatsu, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.256-6.257

Japanese

Abstract not available.

[1996] 11A - 38

POWER TRANSMISSION CONTROL USING UNIFIED POWER FLOW CONTROLLER

Mihalic, R.; Papic, I.

Faculty of Elec Eng and Computer Sci, Univ of Ljubljana, Slovenia

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 1, pp 285-288

The load flow control in electric power systems is one of the crucial factors affecting the development of modern power systems. The unified power flow controller (UPFC) is considered as a means for power flow control. First, the basic UPFC operating principles and mathematical model are explained. On the example of two parallel lines it is shown how transmission capability can be enhanced. Using UPFC in the loop formed network the power flows through the "foreign" system can be avoided without line disconnection. Further, applying digital simulation in the test meshed system UPFC was used to control three system parameters under dynamic conditions. 5 Refs.

[1996] 11A - 39

SIMULATION STUDY OF A TRANSMISSION SYSTEM CONTAINING TWO UNEQUALLY RATED PARALLEL LINES AND A UPFC

Hu, L-H.; Morrison, R.E.

Staffordshire Univ, Stafford, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 346-350

When transmission lines are connected in parallel, the distribution of power between them depends on the ratio of the line impedances rather than the line thermal ratings. This paper considers the use of a unified power flow controller (UPFC) to modify the natural load distribution of two parallel connected transmission lines to enable both lines to operate close to their thermal limits. A 400-kV, 160-km transmission system is considered with a twin bundle line in parallel with a quad bundle line. A simulation study shows that a series voltage injector may force the system to share the load to enable the full thermal capacity to be used. The harmonic aspects of the UPFC are also considered and it is suggested that harmonic filtering may not be required providing a 36-pulse series power converter is used. 5 Refs.

[1996] 11A - 40

STEADY-STATE AND DYNAMIC MODELS OF UNIFIED POWER FLOW CONTROLLER (UPFC) FOR POWER SYSTEM STUDIES

Nabavi-Niaki, A.; Iravani, M.R.

Univ of Toronto, Ontario, Canada

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp p 1937-1943

This paper provides comprehensive development procedures and final forms of mathematical models of unified power flow controller (UPFC) for steady-state, transient stability and eigenvalue studies. Based on the developed models, the impacts of control strategy, parameters and location of UPFC on power system operating conditions are discussed. The accuracy of the developed models is verified through comparing the study results with those obtained from detailed time-domain simulation using the Electromagnetic Transients Program (EMTP). 7 Refs.

[1997] 11A - 41

STUDY OF EQUIPMENT SIZES AND CONSTRAINTS FOR A UNIFIED POWER FLOW CONTROLLER

Bian, J.; Ramey, D.G.; Nelson, R.J.; Edris, A.-A.

Westinghouse Power Gen Business Unit, Orlando, FL, USA

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1385-1391

This paper provides a quantitative measurement of the benefit that a unified power flow controller (UPFC) can provide to increase firm power transfer between two

large power systems. Included is a complete model for a UPFC control system that contains bus voltage control by the shunt inverter, real power transfer between the shunt and series inverters, and real and reactive power control for the transmission line into which the series inverter is inserted. A significant part of the model is representation of dynamic limits that coordinate injected current limits for the shunt inverter, power transfer limits between inverters, voltage injection limits for the series inverter, current limits for the series inverter, and line voltage limits for the transmission line. This paper contains a simple system simulation to demonstrate the coordinated dynamic control and illustrate issues that system planning engineers must consider in defining applications for a UPFC. 7 Refs.

[1997] 11A - 42

SYNCHRONOUS REFERENCE FRAME BASED CONTROL OF AN UNIFIED POWER FLOW CONTROLLER

Vilathgamuwa, M.; Shing, C.S.; Jet, T.K. Xin, Z.

Nanyang Tech Univ, Singapore

Proceedings, 2nd Int'l IEEE Conf on Power Electronics and Drive Systems (PEDS), Singapore, May 26-29, 1997, vol 2, pp 844-849

The device unified power flow controller (UPFC), which has the capability of controlling real power flow and reactive power flows at sending end and receiving end of a transmission line, is originally proposed by Gyugyi. According to this scheme, an ac voltage vector generated by a GTO-based inverter is injected in series with the phase voltage in the transmission line. In this paper a robust H8 controller is used to control line currents in both the shunt aid series inverters of the UPFC. The line current controller is designed to ensure robust performance and internal stability of the UPFC against disturbances and unstructured parameter variations. Conventional PI control system performance is compared with the H8 control to highlight their contrasting features. 6 Refs.

[1997] 11A - 43

TRANSMISSION PLANNING APPLICATION GUIDELINES FOR THE UNIFIED POWER FLOW CONTROLLER (UPFC)

Nelson, R.J.

Westinghouse Elec Corp, Orlando, FL, USA

Proceedings, 59th American Power Conf, Chicago, IL, vol 59-2, 1997, pp 1257-1262

The unified power flow controller is a transmission power flow controller for providing dynamic bus voltage control, series real power flow control, and series reactive power flow control. The operation and modeling of this controller are described along with the three applications where its unique attributes can be used to advantage. These advantages are: to increase power transfers on a low-voltage lines during contingencies while keeping terminal voltage within operating limits; to increase the maximum effective length and capability of long ac subterranean and submarine cables limited by charging current; and power flow control in low-impedance metropolitan systems. 18 Refs.

[1997] 11A - 44

UNIFIED POWER FLOW CONTROLLER (UPFC) BASED ON CHOPPER STABILIZED MULTILEVEL CONVERTER

Chen, Y.; Mwinyiwiwa, B.; Wolanski, Z.; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 1, pp 331-337

A system of class B choppers equalizes the dc voltages of the back-to-back multilevel converters of the UPFC thus removing the constraint that the voltages of the series and the shunt converter must operate at a fix ratio. This allows the UPFC to operate with independent controls over the real power and the reactive powers on both sides. The claims are substantiated by digital simulations and laboratory experiments. 9 Refs.

[1996] 11A - 45

UNIFIED POWER FLOW CONTROLLER BASED ON MATRIX CONVERTER

Ooi, B-T.; Kazerani, M.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 27th IEEE Power Electronics Specialists Conf (PESC), Maggiore, Italy, January 1996, vol 1, pp 502-507

Recently, L. Gyugyi introduced the concept of the unified power flow controller (UPFC) in flexible ac transmission systems (FACTS). This paper shows that the voltage-source type matrix converter can not only fulfill the specifications of the UPFC but also surpass it on the following points: (1) the ability to link power systems at different frequency standards (60 Hz and 50 Hz), (2) 360 degree phase-shift range, and (3) high

synchronizing power associated with series reactance compensation. This paper shows the modifications required to adapt the matrix converter for UPFC application and presents experimental results which substantiate its capabilities.

[1998] 11A - 46

UNIFIED POWER FLOW CONTROLLER (UPFC): MODELING AND ANALYSIS

Keri, A.J.F.; Mehraban, A.S.; Lombard, X.; Elriachy, A.; Edris, A.-A.

American Electric Power, USA

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

The unified power flow controller (UPFC) is a novel power transmission controller. The UPFC provides a full dynamic control of transmission parameters, voltage, line impedance and phase angle. This paper presents a useful tool for power utility engineers to evaluate the application of the UPFC, its impact on their power system and what would be the shunt and series ratings. This paper gives sets of equations for a system, including the UPFC and an equivalent two-bus power network. A new numerical method tested with Matlab has been successfully validated with analog model and EMTP.

[1997] 11A - 47

Deleted

[1998] 11A - 48

UPFC - UNIFIED POWER FLOW CONTROLLER: THEORY, MODELING, AND APPLICATIONS

Sen, K.K.; Stacey, E.J.

Westinghouse Elec Corp, USA

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

This paper describes the theory and the modeling technique of a flexible alternating current transmission systems (FACTS) device, namely, unified power flow controller (UPFC) using an Electromagnetic Transients Program (EMTP) simulation package. The UPFC, in this paper, consists of two solid-state voltage source inverters which are connected through a common dc link capacitor. Each inverter is coupled with a transformer at its output. The first voltage source inverter, known as static synchronous compensator (STATCOM), injects an almost sinusoidal current, of variable magnitude, at the point of connection. The second voltage source inverter, known as static synchronous series compensator (SSSC) injects an almost sinusoidal voltage, of variable magnitude, in series with the transmission line. This injected voltage can be at any angle with respect to the line current. The exchanged real power at the terminals of one inverter with the line flows to the terminals of the other inverter through the common dc link capacitor. In addition, each inverter can exchange reactive power at its terminals independently. The functionalities of the models have been verified.

[1996] 11A - REF

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

For Abstract see entry 07A - 17

[1996] 11A - REF

TECHNOLOGY DEVELOPMENT OF FLEXIBLE AC TRANSMISSION SYSTEM

For Abstract see entry 07A - 63

[1996] 11A - REF

UNIFIED POWER FLOW CONTROLLER: THE ULTIMATE FACTS DEVICE

For Abstract see entry 07A - 75

[1997] 11A - REF

DAMPING OF POWER SWINGS BY OPTIMAL CONTROL OF SERIES COMPENSATORS

For Abstract see entry 07B - 16

[1996] 11A - REF

PLANNING AND OPERATING RATINGS FOR INVERTER-BASED FACTS POWER FLOW CONTROLLERS

For Abstract see entry 07B - 40

[1997] 11A - REF

UPFC APPLICATION ON THE AEP SYSTEM: PLANNING CONSIDERATIONS

For Abstract see entry 07B - 64

[1997] 11A - REF

POWER SYSTEM STABILIZING CONTROL USING HIGH SPEED PHASE SHIFTER (HSPS)

For Abstract see entry 12A - 12

[1996] 11A - REF

HARMONIC ANALYSIS OF THE UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 17C - 11

[1998] 11A - REF

EXPERIMENTAL EVALUATION OF STATCOM CLOSED LOOP DYNAMICS

For Abstract see entry 18A - 14

[1996] 11A - REF

SIMULATION STUDY OF UNIFIED POWER FLOW CONTROLLERS

For Abstract see entry 18D - 24

[1997] 11A - REF

NEWTON-TYPE ALGORITHM FOR THE CONTROL OF POWER FLOW IN ELECTRICAL POWER NETWORKS

For Abstract see entry 19B - 12

[1997] 11A - REF

THE APPLICATION OF POWER FLOW CALCULATION WITH PQV NODE FOR UPFC

For Abstract see entry 19B - 20

[1997] 11A - REF

USE OF UPFC FOR OPTIMAL POWER FLOW CONTROL

For Abstract see entry 19B - 23

[1996] 11A - REF

LOAD FLOW STUDIES FOR POWER SYSTEMS EQUIPPED WITH UPFC

For Abstract see entry 19B - 9

[1997] 11A - REF

IMPROVING POWER SYSTEM DYNAMICS BY SERIES-CONNECTED FACTS DEVICES

For Abstract see entry 19C - 2

[1996] 11A - REF

SERIES-CONNECTED FACTS DEVICES CONTROL STRATEGY FOR DAMPING OF ELECTROMECHANICAL OSCILLATIONS

For Abstract see entry 19C - 3

[1996] 11A - REF

TRANSIENT STABILITY ENHANCEMENT WITH FACTS CONTROL

For Abstract see entry 19C - 4

[1997] 11A - REF

SIMULATION OF FACTS FOR WIND FARM APPLICATIONS

For Abstract see entry 19D - 15

[1996] 11A - REF

DIGITAL SIMULATIONS OF THE PWM UPFC USING EMTP

For Abstract see entry 19D - 3

[1998] 11A - REF

ANALOGUE SIMULATION STUDIES WITH ACTUAL CONTROLLERS FOR FACTS EQUIPMENT

For Abstract see entry 19E - 11

[1997] 11A - REF

DEVELOPMENT OF THE MINIATURE MODEL OF UNIFIED POWER FLOW CONTROLLER AND THE TEST OF THEM ON SIMULATORS

For Abstract see entry 19E - 17

11B Commissioning, Testing, Performance

[1997] 11B - 1

A FIRST: A UNIVERSAL POWER-FLOW

CONTROLLER TO INCREASE POWER TRANSMISSION CAPACITY

Anon.

Hydro-Tech (Montreal, Canada, ed. francaise), vol 11, no 2, Spring-Summer 1997, p 2

A new universal power-flow controller, (UPFC) a device which American Electric Power (AEP) plans to install on its power line facilities, will be tested at Hydro-Quebec's Institut de recherche (IREQ). Installing this 160-MVA universal power-flow controller at its Inez substation in Kentucky, AEP is expanding its power line capacity in response to the imminent deregulation of the electric power industry. The UPFC to be installed at Inez is the first of its kind, and will be used to demonstrate the advantages of this technology in the field. Results will be made available to a large number of interested parties, including equipment manufacturers, electrical engineers and utilities involved in the transmission and distribution of electricity. Last year, IREQ used its state-of-the-art real-time power system simulator to test another type of controller (the phase-shifting transformer). The request to test the UPFC provides IREQ scientists with the opportunity to acquire further expertise in this area.

[1997] 11B - 2

VERIFICATION TEST OF A UPFC (THYRISTOR CONTROLLED PHASE ADJUSTER) SCALE MODEL BY APSA. AS PART OF "INTERCONNECTION STRENGTHENING TECHNOLOGY DEVELOPMENT" RESEARCH. PART 3. LAST

Morioka, Y.

Kansai Elec Power Co, Inc, Japan

R&D News Kansai (Japan), no 357, pp 9-11

Japanese

Abstract not available.

[1998] 11B - 3

WORLD'S FIRST UNIFIED POWER FLOW CONTROLLER ON THE AEP SYSTEM

Renz, B.A.; Kerl, A.J.F.; Mehraban, A.S.; Kessinger, J.P.; Schauder, C.D.; Gyugyi, L.; Kovalsky, L.J.; Edris, A.-A.

American Electric Power

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Utility companies are faced with growing demand, challenges of open transmission access, and the delivery of electric power with minimal environmental impact. Since the Electric Power Research Institute (EPRI) initiated the flexible ac transmission system (FACTS) concept, a family of products, including thyristor-controlled series capacitors (TCSC), static synchronous compensators (STATCOM), static synchronous series compensators (SSSC), and unified power flow controllers (UPFC) has emerged. The UPFC is a novel concept which offers multiple compensation functions providing a very flexible and independent control for bus voltage and the active and reactive power flow on a transmission line. American Electric Power (AEP), in a joint effort with EPRI and Westinghouse, undertook the development and application of the world's first high power UPFC. This UPFC employs two GTO-based inverters, each rated ±160 MVA, connected by a common dc link. One inverter is connected in shunt configuration with the transmission line and the other is in series. The two inverters can be decoupled and operated separately, one as a STATCOM, the other as an SSSC, each with inverter ratings of ±160 MVA. Normally they will be operated as a UPFC, with a total inverter rating of ±320 MVA, to regulate terminal bus voltage and simultaneously control power flow. In 1997, the shunt inverter was installed and commissioned as a STATCOM. The series inverter was also installed in 1997 and will be commissioned as part of the UPFC in 1998. This paper presents the operating principles of the UPFC, describes the application studies, control features, technical development, and UPFC equipment installation. TNA studies, commissioning tests and initial operating experiences for the STATCOM portion of the worlds first UPFC project are also included.

[1996] 11B - REF

ENGINEERS STRETCH POWER DELIVERY SYSTEMS WITH TECHNOLOGY

For Abstract see entry 07B - 19

[1998] 11B - REF

OPERATION OF THE UNIFIED POWER FLOW CONTROLLER (UPFC) UNDER PRACTICAL CONSTRAINTS

For Abstract see entry 11A - 30

12 THYRISTOR-CONTROLLED PHASE SHIFTING TRANSFORMER (TCPST)

12A Modeling, Control, Applications

[1998] 12A - 1

A HIGH-POWER PWM QUADRATURE BOOSTER PHASE SHIFTER BASED ON A MULTIMODULE AC CONTROLLER

Lopes, L.A.C.; Joos, G.; Ooi, B.-T.

Univ Federal do Para, Brazil

IEEE Trans on Power Electronics, vol 13, no 2, March 1998, pp 357-365

Pulse-width-modulated (PWM) phase shifters allow the smooth control of power flow in a transmission line. This paper analyzes a PWM quadrature booster phase shifter based on a multimodule ac controller structure to attain high voltage levels and improve the harmonic spectrum. The modules are based on a three-phase PWM ac controller topology that employs only four force-commutated switches and is controlled by duty-cycle variation. The PWM technique is carrier based and the individual modules are gated through phase-shifted triangular carriers. As a result, harmonic cancellation takes place in the input current and output voltage. Low-order harmonics are therefore eliminated and the amplitude of remaining components reduced. An additional operating mode with negligible harmonic generation and step-like control is identified. The feasibility and advantages of the proposed phase shifter are demonstrated by means of a power system simulator.

[1998] 12A - 2

A HYBRID SOLID STATE PHASE SHIFTER USING PWM AC CONVERTERS

Johnson, B.K.; Venkataramanan, G.

Univ of Idaho, Moscow, ID, USA

IEEE Trans on Power Delivery, Preprint order number PE-134-PWRD-0-12-1997

Active power flow in transmission lines can be varied using a conventional or thyristor-controlled phase shifter in series with the line, which introduces a phase shift between sending and receiving end voltages. However, the control of the phase shift can be executed only in steps depending on the taps available in the phase-shifting transformer. An approach to obtain continuous control of the phase shift using a conventional tap changing transformer and a pulse width modulated buck an ac-ac converter is presented in this paper. Operating principles, design considerations and other practical issues are discussed. Detailed computer simulation results are presented in the paper. The advantages and disadvantages of the proposed approach in relation to the conventional approaches are discussed.

[1997] 12A - 3

ANALYSIS OF THYRISTOR-CONTROLLED PHASE SHIFTER APPLIED IN DAMPING POWER SYSTEM OSCILLATIONS

Wang, H.F.; Swift, F.J.; Li, M.

Dept of Elec & Electrn Eng, Manchester Metropolitan Univ, UK

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 1, January 1997, pp 1-9

The thyristor-controlled phase shifter (TCPS) is one of the potential options of recently proposed FACTS (flexible ac transmission systems) devices. In this paper, its application in damping power system oscillations is investigated on the basis of a Philips-Heffron model established in the paper. The capability of the TCPS damping control is analyzed in terms of its damping torque contribution to the power system. The basic issues relating to the application of the TCPS damping control in both single machine and multimachine power systems are discussed. The results of numerical calculations and simulations from sample power systems are presented.

[1997] 12A - 4

APPLICATION OF STATIC PHASE SHIFTERS ON THE DAMPING OF COMMON-MODE TORSIONAL OSCILLATIONS

Wang, L.

European Trans on Electrical Power (Germany), vol 7, no 6, November-December 1997, pp 389-396

A study on the application of thyristor-controlled static phase shifters (SPS) to stabilize the common-mode torsional oscillations occurring in a series-capacitor compensated power system is presented in this paper. The IEEE Second Benchmark Model, system-2, which has two nonidentical turbine-generator sets connected to an infinite bus through a series-capacitor compensated

transmission line, is employed to investigate whether the possible unstable subsynchronous resonance (SSR) modal interactions can be suppressed by the proposed damping scheme. The torsional interactions due to one of the torsional oscillating frequencies in one machine is nearly the same as the one in another machine. In order to effectively suppress the unstable torsional modes in the studied system, a systematic approach based on modal control theory is proposed and a set of static phase-shifter controllers (SPSC) is designed. The effectiveness of the proposed damping scheme is demonstrated by means of frequency-domain approach based on eigenvalue analyses and time-domain approach based on nonlinear model simulations. The simulations results show that the static phase shifters and the designed controllers can be applied to suppress common-mode torsional interactions.

[1997] 12A - 5

CONTROL SCHEMES AND TRANSIENT CHARACTERISTICS OF A HIGH SPEED PHASE SHIFTER FOR POWER FLOW CONTROL IN POWER TRANSMISSION SYSTEMS.

Watanabe, Y.; Fujita, H.; Akagi, H.

Okayama Univ, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-D, no 11, pp 1327-1333

Japanese

In recent years, attention has been paid to the concept of FACTS (flexible ac transmission systems), along with significant progress in power electronic technology. A high speed phase shifter, which is one of the most promising devices in the FACTS concept, has the potential of power flow control and/or voltage stability in power transmission systems. In this paper, theory and experiment reveal that conventional high speed phase shifters may cause power swing in a transient state as a result of coupling between instantaneous active and reactive power control loops. Then, a couple of new control schemes for a high speed phase shifter are proposed to achieve both power flow control and power swing damping. The second proposed control scheme is based on the control scheme of an already proposed series active filter. Simulated and experimental results agree well with analytical results, not only in steady states but also in transient states.

[1998] 12A - 6

DYNAMIC QUADRATURE BOOSTER AS AN AID TO SYSTEM STABILITY

Fang, Y.J.; Macdonald, D.C.

Nanjing Automation Research Inst, China

IEE Proceedings: Generation, Transmission and Distribution (UK), vol 145, no 1, January 1998, pp 41-47

Quadrature boosters (QB) have been widely used to control the power flow distribution between parallel transmission lines. The advent of very fast thyristor/vacuum switch tap changers makes the dynamic quadrature booster a powerful FACTS device for the improvement of the transient and dynamic stability of power systems. The basic concepts of the dynamic QB operation, the modeling aspects of a multimachine power system in which dynamic QB are situated, the ideal control strategy and practical considerations are presented. Simulations show that in a small, simple, power system the QB can substantially suppress disturbances before swings in load angle have become large. In a large interconnected system the action is less successful. 12 Refs.

[1996] 12A - 7

ENHANCEMENT OF TRANSIENT STABILITY AND DAMPING OF POWER SYSTEM USING STATIC PHASE SHIFTER

Basu, K.P.; Prakash, H.

Aligarh Muslim Univ, Aligarh, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 2, pp 512-518

The main object of the paper is to outline the various ways a static phase shifter (SPS) may be used to improve transient stability and damping in a power system. Relationship of fixed, step change and rate of change of phase shift with transient stability enhancement and optimum damping (dead-beat mode) has been established. Control of time and angle of swing with rate of change of phase shift by SPS is possible and its applicability with slow- and fast-acting SPS has been explored.

[1998] 12A - 8

EXPERIMENTAL STUDY ON DYNAMIC STABILITY IMPROVEMENT OF A SINGLE-MACHINE INFINITE bus POWER SYSTEM BASED ON A SLIDING MODE CONTROL OF PHASE SHIFTER

Kaizu, H.; Yokoyama, K.; Sato, T.; Kikuchi, H.

Niigata Inst of Tech, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 118B, no 1, January 1998, pp 44-51

Japanese

This paper describes an experimental study on the dynamic stability improvement of a single-machine (laboratory size 3-kVA generator) connected to an infinite-bus power system using a phase shifter. Phase-shift injection is implemented by thyristor-associated fast tap-changers based on sliding mode control during transient conditions of the generator. Digital simulation studies are also carried out to test the control scheme and the dynamic performances of system. As a result, numerical studies show good agreement with experimental results. The proposed controller is verified to damp the transient swings caused by power system faults.

[1996] 12A - 9

HYBRID SOLID STATE PHASE SHIFTER FOR CONTINUOUS PHASE SHIFT CONTROL IN TRANSMISSION LINES

Johnson, B.K.; Venkataramanan, G.; Manjrekar, M.

Univ of Idaho, Moscow, ID, USA

Proceedings, Canadian Conf on Electrical and Computer Engineering (CCECE'96), Calgary, Canada, May 29-29, 1996, vol 2, pp 851-854

Active power flow in transmission lines can be varied using a conventional or thyristor-controlled phase shifter in series with the line which introduces a phase shift between sending and receiving end voltages. However, the control of the phase shift can be executed only in steps depending on the taps available in the phase shift transformer. An approach to obtain continuous control of the phase shift using a conventional tap changing transformer and a pulse width modulated buck ac-ac converter is presented in this paper. Operating principles, design considerations and other practical issues are discussed. Detailed computer simulation results are presented in the paper. The advantages and disadvantages of the proposed approach in relation to the conventional approaches are discussed. 9 Refs.

[1996] 12A - 10

NONLINEAR EXCITATION AND PHASE SHIFTER CONTROLLER FOR TRANSIENT STABILITY ENHANCEMENT OF POWER SYSTEMS USING ADAPTIVE CONTROL LAW

Tan, Y.L.; Wang, Y.

Nanyang Tech Univ, Singapore

Int'l Journal of Electrical Power and Energy Systems (UK), vol 18, no 6, 1996, pp 397-403

The highly nonlinear nature of the generator and system behavior following a severe disturbance precludes the use of classical linear control techniques. In this paper, a nonlinear adaptive excitation and static phase shifter controller is proposed to enhance the transient stability of a power system. The phase shifter is located near the generator terminal in a power system. A third-order generator model is used, which is in the standard form of the nonlinear system representation. The phase shifter is represented by a first-order model. Nonlinear feedback control laws are found which linearize and decouple the power system. An adaptive control law is used to design the controller for the excitation and phase shifter. The design of the resulting controller is independent of the operating point. Our simulation results demonstrate that the proposed controller can ensure transient stability of the power system under a large sudden fault which may occur at the generator bus terminal. 24 refs.

[1996] 12A - 11

POWER ELECTRONICS TECHNOLOGIES (EXPANDING CAPACITY OF EQUIPMENT AND APPLICATION TO POWER SYSTEMS)

Saito, S.; Irokawa, S.; Ikeda, H.

Toshiba Corp, Tokyo, Japan

Toshiba Rebyu (Toshiba Review) (Japan), vol 51, no 7, July 1, 1996, pp 19-22

Japanese

Introduction of power electronics devices into power systems is in progress. It is attempted to reduce dimensions and improve efficiency of a separately excited converter by using a large-capacity light-triggered thyristor. Research and development is moved forward on a self-excited converter as a key technology for flexible ac transmission systems (FACTS). Specifically, aims are directed to realization of size reduction in devices by developing high-voltage, large-current elements, increase in speed of control which allows continuous operation even during a system failure by means of a new type of instantaneous vector control, and large loss reduction in devices by using a new type of multiplied vector control. This paper presents summary of these developments and examples of stabilization effects in power by using self-excited dc transmission and a self-excited phase adjuster as

application examples of the FACTS device. Since the self-excited dc transmission performs power exchange between systems at a high level of performance, active and reactive powers can be controlled independently. The self-excited phase adjuster is a multi-functional system stabilizing device which uses amplitude and phase of voltage, and adjustment of impedance. 4 refs., 10 figs.

[1997] 12A - 12

POWER SYSTEM STABILIZING CONTROL USING HIGH SPEED PHASE SHIFTER (HSPS)

Ise, T.; Hayashi, T.; Ishii, J.; Kumagai, S.

Osaka Univ, Japan

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3, 1997, vol 2, pp 735-740

A high speed phase shifter (HSPS) presented here is composed of three sets of a single-phase PWM inverter which are connected in series to a power system, and another PWM inverter to control the dc link voltage of inverters at a specified value which is connected in parallel to a power system. The configuration is same as a UPFC (unified power flow controller). The experimental mini model for 10-kVA transmission line was developed and its performance for power system stabilizing control was examined. It was shown that not only transient stability but also dynamic stability can be improved by the HSPS. 8 Refs.

[1997] 12A - 13

POWER SYSTEM STABILIZING CONTROL BY HSPS(HIGH SPEED PHASE SHIFTER)

Hayashi, T.; Ishii, J.; Ise, T.; Kumagai, S

Osaka Univ, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol SPC-97, no 26-38, pp 21-26

Japanese

A high speed phase shifter (HSPS) using PWM (pulse width modulation) inverters is paid much attention in FACTS (flexible ac transmission system). The HSPS presented here is composed of three sets of a single-phase PWM inverter, transformers which connect the inverters with ac power system in series and ac filters for suppressing switching ripples of inverters. Adding a dc voltage controller which is composed of three-phase PWM inverter and transformer, the system can control magnitude and phase of the output voltage freely. Therefore, the proposed system can be used for power system stabilizing control. The structure of the controller and experimental results of power system stabilizing control on a 10-kVA model power transmission are presented.

[1997] 12A - 14

POWER SYSTEM STABILITY ENHANCEMENT USING STATIC PHASE SHIFTER

Jiang, F.; Choi, S.S.; Shrestha, G.

School of Elec & Electrn Eng, Nanyang Tech Univ, Singapore

IEEE Trans on Power Systems, vol 12, no 1, February 1997, pp 207-214

The role of static phase shifters in improving power system stability is investigated. A new technique, based on the nonlinear variable structure control principle, is used to formulate a control algorithm for the static phase shifter. Parameter uncertainty has been considered in the proposed scheme. Computer simulations show that a static phase shifter with the new control scheme has produced significant improvement in power system performance.

[1996] 12A - 15

PWM AC CONTROLLER-BASED PHASE-SHIFTERS

Lopes, L.A.; Joos, G.; Ooi, B-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, Canadian Conf on Electrical and Computer Engineering (CCECE'96), Calgary, Canada, May 29-29, 1996, vol 2, pp 988-991

This paper discusses the use of a practical force-commutated ac controller in PWM phase-shifters. The operating principles are presented for a basic structure, which is then modified to allow implementation with the currently available GTOs. This high power version of the PWM phase-shifter employs a multi-module ac controller to attain the high voltage levels required for operation at transmission system levels. Moreover, the individual modules are controlled with phase shifted carriers in order to achieve harmonic cancellation. Low distortion waveforms are thus obtained with GTOs switching at low frequencies, resulting in reduced switching losses. A design procedure to calculate the required number (N) of PWM ac controller modules so as to meet given harmonic constraints without filters is presented. The proposed concept is verified with EMTDC-based simulation results. 7 Refs.

[1996] 12A - 16

PWM QUADRATURE BOOSTER PHASE-SHIFTER FOR FACTS

Lopes, L.A.C.; Joos, G.; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1999-2004

This paper presents a static phase-shifter based on a parallel connection of modules of a non-conventional PWM ac-ac converter. Conduction losses are kept low by using only one active power conversion stage where the average number of switches through which the current flows is small. Filtering losses are also expected to be low because of the high order and small magnitude of the harmonics generated by switching. This is obtained by operating the modules with symmetrically phase shifted carriers to provide harmonic cancellation. Thus, even with the switches operating at low frequencies to keep the switching losses low, a high equivalent switching frequency is achieved. The performance of the phase-shifter for damping power oscillations in open loop is also evaluated. 14 Refs.

[1997] 12A - 17

PWM QUADRATURE-BOOSTER PHASE SHIFTER FOR AC POWER TRANSMISSION

Lopes, L.A.C.; Joos, G.; Ooi, B.-T.

Fed Univ of Para, Belem, Brazil

IEEE Trans on Power Electronics, vol 12, no 1, January 1997, pp 138-144

The conventional structures used for phase shifters employ quadrature voltage injection controlled by means of on-load tap changers that require considerable maintenance. Line-commutated thyristor structures have been proposed to replace tap changers, but problems related to filter requirements or the number of switches have limited their utilization. This paper proposes a pulse width modulation (PWM) quadrature-booster phase shifter based on a force-commutated ac controller. It offers features such as fast dynamic response, continuous variation of the phase angle with low harmonic injection, and it requires a simple power structure and can be controlled by adjusting the duty cycle of the switches. The operating principles of the proposed phase shifter are analyzed and their feasibility is demonstrated through digital simulation and experimental implementation. 15 Refs.

[1996] 12A - 18

VARIABLE REACTOR USING SOLID STATE PHASE SHIFTER (COMPENSATION FOR VOLTAGE FLUCTUATION)

Eguchi, N.; Tokuda, H.; Uemura, S.; Hirayama, I.; Shimada, R.

Fuji Elec Corp R&D Ltd, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 8, August 1996, pp 1007-1014

Japanese

Recently, FACTS have been actively researched and developed. A solid-state phase shifter is one of the FACTS equipment, and has become of major interest to control power flow with its phase-shift function. This paper describes voltage compensations by a variable reactor (VR) using a solid-state phase shifter. The VR is connected in series with a power system, and controls the line voltage by compensation of the line impedance. In this paper, characteristics of voltage compensation with the series compensators are compared with those of parallel compensators such as static VAr compensators in a power system. A power circuit configuration and control system of the VR are also presented. The authors have examined the performances of the VR through digital simulation and experiments using mini-models and obtained satisfactory characteristics. Voltage fluctuations caused by reactive loads were completely compensated, and voltage unbalance ratio was improved from 7.4% to 1.7%. 17 Refs.

[1998] 12A - 19

VOLTAGE AND POWER SWING STABILIZATION BY DECOUPLED CONTROL WITH AVR AND PHASE SHIFTER

Hojo, M.; Mitani, Y.; Tsuji, K.

Osaka Univ., Japan

Proceedings, Int'l Conf on Energy Management and Power Delivery (EMPD), Singapore, March 3-5, 1998, pp 183-188

With the development of power system controllers, it becomes feasible to control the output power of a synchronous generator directly and quickly by some FACTS controller like a solid-state phase shifter. The authors have proposed a scheme for power system stabilization by the direct generator power control which virtually linearizes swing equations. As the proposed control is capable of controlling the rotor swing to follow the prespecified linear response, it reveals some attractive characteristics: the controller is designed

based on the linear system theory, the controller is robust even if some parameters are changed, and so on. The robustness guarantees the AVR to be designed independently of the stabilizing control scheme for power swing as well as for voltage fluctuation by applying a decoupled control with a phase shifter and an AVR. The effectiveness of the proposed control has been supported with a series of simulation results from a view point of generator power and voltage stabilization.

[1998] 12A - REF

ELIMINATION OF DYNAMIC BIFURCATION AND CHAOS IN POWER SYSTEMS USING FACTS DEVICES

For Abstract see entry 07A – 13

[1997] 12A - REF

UNIFIED MODEL FOR THE ANALYSIS OF FACTS DEVICES IN DAMPING POWER SYSTEM OSCILLATIONS PART I: SINGLE-MACHINE INFINITE-BUS POWER SYSTEMS

For Abstract see entry 08A - 135

[1996] 12A - REF

OPTIMAL CONTROL OF SERIES COMPENSATORS AND PHASE SHIFTING TRANSFORMERS IN POWER SYSTEMS

For Abstract see entry 10A - 75

[1998] 12A - REF

LFC AND STABILIZATION OF MULTI-AREA INTERCONNECTED POWER SYSTEM BY DECENTRALIZED CONTROL OF A SMES AND SOLID-STATE PHASE SHIFTERS

For Abstract see entry 14A - 67

[1996] 12A - REF

FUZZY LOGIC SWITCHING OF FACTS DEVICES FOR STABILITY ENHANCEMENT

For Abstract see entry 18A - 17

[1996] 12A - REF

FACTS-APPLICATION IN MESHED SYSTEMS-A COMPARATIVE ANALYSIS

For Abstract see entry 18B - 8

[1997] 12A - REF

DAMPING CONTROLLER DESIGNS FOR AN SVC AND OTHER FACTS DEVICES

For Abstract see entry 18C - 7

[1997] 12A - REF

DESIGN OF SERIES AND SHUNT FACTS CONTROLLER USING ADAPTIVE NONLINEAR COORDINATED DESIGN TECHNIQUES

For Abstract see entry 18C - 8

[1997] 12A - REF

IMPROVING POWER SYSTEM DYNAMICS BY SERIES-CONNECTED FACTS DEVICES

For Abstract see entry 19C - 2

[1996] 12A - REF

SERIES-CONNECTED FACTS DEVICES CONTROL STRATEGY FOR DAMPING OF ELECTROMECHANICAL OSCILLATIONS

For Abstract see entry 19C - 3

12B Project Studies

[1996] 12B - 1

APPLICATION OF THE WORLD'S FIRST UPFC ON THE AEP SYSTEM

Mehraban, A.S.; Keri, A.J.F.; Gernhardt, M.G.; Schauder, C.D.; Stacey, E.J.; Edris, A.-A.

American Electric Power, USA

EPRI Seminar, Spring 1996

Flexible ac transmission system (FACTS) is a technology-based solution envisioned to help the utility industry deal with changes in the power delivery business. The idea behind the FACTS concept is to enable the transmission system to be an active element, playing an active role in increasing the flexibility of power transfer requirements and in securing the stability of the dynamics of integrated power systems. A major thrust of FACTS is the development of controllers that control power flow by changing the impedance of a transmission line or phase angle between the ends of

specific lines and also controlling the voltages at critical busses. The unified power flow controller (UPFC) is a novel concept which offers multiple compensation functions for power transmission systems. The UPFC is capable of controlling the three basic transmission parameters (voltage, line impedance, and phase angle). Thus, the UPFC allows a very flexible control of both active and reactive power flows on transmission corridors. The paper presents the principles, hardware features, functional characteristics, operational functions, and application of the world's first UPFC installation, cosponsored by AEP, EPRI and Westinghouse Electric Corp. The installation is a part of the AEP's transmission upgrading program, which includes the addition of a new high capacity 138-kV transmission line. The UPFC will provide dynamic reactive power support and active power flow control on the high capacity 138-kV transmission line. The UPFC will consist of a shunt voltage sourced inverter or static synchronous compensator (STATCOM), rated at ±160 MVA to provide ±50-MVAr reactive power support and 50 MW active power required in full UPFC mode of operation. The series voltage sourced inverter is rated ±160 MVA to provide phase shifting and/or series compensation.

[1997] 12B - REF

DAMPING CONTROLLER DESIGNS FOR AN SVC AND OTHER FACTS DEVICES

For Abstract see entry 18C - 7

13 INTERPHASE POWER CONTROLLER (IPC)

13A Modeling, Control, Applications

[1997] 13A - 1

APPLICATION OF THE INTERPHASE POWER CONTROLLER TECHNOLOGY FOR TRANSMISSION LINE POWER FLOW CONTROL

Brochu, J.; Beauregard, F.; Lemay, J.; Morin, G.; Pelletier, P.; Thallam, R.S.

CITEQ Hydro-Quebec, Varennes, Canada

IEEE Trans on Power Delivery, vol 12, no 2, April 1997, pp 888-894

This paper presents an application of the IPC technology for controlling power flows while maintaining the natural synchronizing capacity of transmission lines. The benefits for transmission systems are a substantial increase in steady-state transmission capability, lower losses and voltage support. An example based on the 500-kV Mead-Phoenix Project demonstrates the effectiveness of the IPC solution: the addition of a 370-MVAr capacitor in parallel with the two 500-kV phase-shifting transformers increases their maximum capability from 1300 to 1910 MW. The concepts presented are the results of the first phase of work leading to the development of an IPC using power electronics. 7 Refs.

[1998] 13A - 2

IPC TECHNOLOGY - A NEW APPROACH FOR SUBSTATION UPRATING WITH PASSIVE SHORT-CIRCUIT LIMITATION

Brochu, J.; Beauregard, F.; Morin, G.; Lemay, J.; Pelletier, P.; Kheir, S.

CITEQ Hydro-Quebec, Varennes, Canada

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 233-240

The paper presents a new approach to fault current limitation based on the phase-shifting transformer (IPC) technology. From a power system point of view, this IPC has the same function as a transformer: it handles its share of the load current but, during a fault, it does not contribute to the fault current. It thus allows a substation to be uprated without increasing the fault level. A four-transformer 315-120-kV substation is used to illustrate the concept. 9 Refs.

[1997] 13A - 3

REGULATING TRANSFORMERS IN POWER SYSTEMS - NEW CONCEPTS AND APPLICATIONS

Wirth, E.T; Ravot, J.-F.

ABB High Voltage Technology Ltd

ABB Review, no 4, 1997, pp 12-20

Originally, regulating transformers were installed in power systems to compensate for voltage fluctuations.

However, studies have shown that they also have several other important advantages for transmission systems. By carefully choosing the transformation ratios, it is possible to control the active and reactive power flow in the power system to allow for a more economic utilization of the transmission capacity. In addition, the power losses associated with energy distribution can be considerably reduced and circulating currents largely avoided. When these transformers are installed at strategic locations in the network, return on investment is achieved within a short time. New applications for phase-shifting transformers have evolved in connection with interphase power control technology. 5 Refs.

[1996] 13A - 4

THE INTERPHASE POWER CONTROLLER-A ROBUST SOLUTION FOR SYNCHRONOUS INTERCONNECTIONS AND MANAGEMENT OF POWER FLOWS

Pelletier, P.; Lemay, J.; Brochu, J.; Beauregard, F.; Morin, G.

CITEQ Hydro-Quebec, Varennes, Quebec, Canada

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 291-296

In the context of deregulation, the operation of modern electric power transmission systems needs to be more and more flexible. In particular, three aspects of steady-state operating conditions should be addressed more carefully: loop flows, excessive short-circuit levels and post-contingency conditions. Indeed, unwanted loop flows can cause overloads and additional losses in neighboring networks thus hampering commercial aspects of energy contracts. Simple additions of lines or transformers in tightly meshed networks can lead to excessive short-circuit levels. This situation is becoming more and more frequent in North American as well as in European networks. Rather than replacing a large number of circuit breakers, electric power utilities have resorted to other actions such as rearranging network configurations and opening ties, often at the cost of reducing reliability and operating flexibility. Finally, the maximum amount of power that can be transmitted by a given line at any moment is governed by the impact on neighboring networks of the loss of that line. Generally, the negative impact is an overload or a voltage drop. This suggests one of the qualities to be expected of FACTS controllers, to be able to reduce the impact of contingencies. From the technical point of view, the interphase power controller (IPC) brings solutions to all three problems above. It should also facilitate the management of energy contracts. 6 Refs.

[1997] 13A - REF

DAMPING OF POWER SWINGS BY OPTIMAL CONTROL OF SERIES COMPENSATORS

For Abstract see entry 07B - 16

[1997] 13A - REF

NEWTON-TYPE ALGORITHM FOR THE CONTROL OF POWER FLOW IN ELECTRICAL POWER NETWORKS

For Abstract see entry 19B - 12

13B Project Studies

[1996] 13B - 1

SIMULATOR DEMONSTRATION OF THE INTERPHASE POWER CONTROLLER TECHNOLOGY

Sybille, G.; Haj-Maharsi, Y.; Morin, G.; Beauregard, F.; Brochu, J.; Lemay, J.; Pelletier, P.

CITEQ Hydro-Quebec, Varennes, Canada

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1985-1992

The paper reports on a simulator demonstration of the phase-shifting transformer (IPC) technology. The simulator models developed and the testing methodology are described. The main results confirm the basic attributes of the IPC (robust power flow control characteristic, fault current limitation and decoupling of the interconnected networks) and that the IPC can be built from conventional equipment. Random testing performed on the simulator proved to be useful in assessing the maximum stresses on the equipment. 5 Refs.

[1997] 13B - 2

TWO INNOVATIVE DEVICES DESIGNED BY CITEQ AND MANUFACTURED BY ABB

Anon.

Hydro-Tech (Montreal, Canada, ed. francaise), vol 11, no 2, Spring-Summer 1997, p 10

A technology transfer agreement concerning an

environmentally friendly transformer and an ac interconnection technology, both developed by the Centre d'innovation sur le transport d'energie du Quebec (CITEQ), has been recently concluded between CITEQ and Asea Brown Boveri (ABB). The submersible dry-type distribution transformer is designed for underground distribution systems. It is corrosion resistant, non-hazardous and environmentally friendly. It contains no oil, consequently there is no risk of spillage. It reduces the need for maintenance and eliminates the risk of contamination in underground ducts, soil, drain systems and ground water. The other new technology covered by this agreement is the phase-shifting transformer (IPC), which allows the optimal flow of power between electric utilities. It also has the added advantage of facilitating the interconnection without transferring disturbances from one power system to the other. The IPC is a very timely piece of new technology in view of the impending deregulation of the electric industry and the need for equipment that facilitates the exchange of energy between systems.

[1997] 13B - REF

APPLICATION OF THE INTERPHASE POWER CONTROLLER TECHNOLOGY FOR TRANSMISSION LINE POWER FLOW CONTROL

For Abstract see entry 13A - 1

14 ENERGY STORAGE SYSTEMS

14A Modeling, Control, Applications

[1997] 14A - 1

A DESIGN CONCEPT OF DC FILTERS FOR MAGNET POWER SUPPLIES

Kim, H.; Choi, J.

Cheonan Natl Tech College, South Korea

Proceedings, Power Conversion Conf (PCC '97), Nagaoka, Japan, August 3-6, 1997, vol 2, pp 919-924

Passive filters are essentially used for attenuating current/voltage harmonics generated from pulse-modulation type converters which are prevalent in high-power magnet power supplies (MPS). But the passive filter limits the operation range of the output dc current, causes harmful filter resonance, and makes the system equation more complicated. This paper presents, a systematic and simple filter design method which considers not only filtering but also controlling the magnet current. The design algorithm is extended to the applications on superconducting magnetic energy storage (SMES) systems.

[1997] 14A - 2

A METHOD FOR HARMONIC REDUCTION ON THE SOURCE SIDE OF A PARALLEL-CONNECTED THYRISTOR CONVERTER HAVING AN INTERPHASE REACTOR

Tanaka, T.; Koshio, N.

Shokugyonoryokukaihatsudai

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117, no 1, pp 19-25

Japanese

A parallel-connected twelve-pulse thyristor converter consisting of two six-pulse groups with an interphase reactor has been used for low-voltage high-current dc power supplies because of its high efficiency compared with a series one. It seems to be the most suitable converter for superconducting magnetic energy storage systems (SMES), which are expected to be used in actual power systems in the near future as a power system stabilizer. Harmonic reduction on the source side is required for such large-capacity thyristor converters. A number of methods have been proposed. These methods, however, require additional devices. Thus, a simple parallel-connected converter without any additional devices remains to be constructed to reduce harmonic currents on the source side. This paper attempts to construct a simple 12-pulse thyristor converter by proposing a novel design concept of the interphase reactor. This method proposed here requires no additional devices and only reducing the inductance of the interphase reactor. The source current of the 12-pulse thyristor converter with the reduced inductance interphase reactor approaches sinusoidal waveforms, which are approximately equivalent to those of the 36-pulse thyristor converter. Simulation results show that decreasing the inductance of the interphase reactor contributes to reducing harmonic currents on the source side. In addition to the simulation results, experimental results verify the validity and practicability of the

proposed novel design concept of the interphase reactor.

[1997] 14A - 3

A METHOD FOR OBSERVING NONLINEAR DYNAMICS IN POWER SYSTEMS BY USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Kawasaki, K.; Imamura, T.; Mitani, Y.; Tsuji, K.

Osaka Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 31-36

Japanese

Power system is a dynamic system which includes several kinds of nonlinear structure. According to nonlinear analyses using the Hopf bifurcation theory, it is detected that a limit cycle exists around an operating point, which may affect the stability of power system significantly. This paper proposes a method to observe Hopf bifurcation characteristics in power systems where a superconducting magnetic energy storage is available. The effectiveness of this proposed method is confirmed through some numerical analyses.

[1996] 14A - 4

A WORLDWIDE OVERVIEW OF SUPERCONDUCTIVITY DEVELOPMENT EFFORTS FOR UTILITY APPLICATIONS

Giese, R.F.

Argonne Natl Lab, Argonne, IL, USA

Proceedings, 58th American Power Conf, Chicago, IL, April 9-11, 1996, 7 pp

The progress and prospects for the application of high temperature superconductivity to the electric power sector has been the topic of an IEA Implementing Agreement begun in 1990. The present task members are: Canada, Denmark, Finland, Germany, Israel, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. As a result of the Implementing Agreement, work has been performed by the Operating Agent with the full participation of all of the member countries. This work has facilitated the exchange of information among experts in all member countries and is the basis for much of the information contained in this paper. This paper summarizes progress toward application of high temperature superconductivity to devices for use in the electric power sector such as: fault-current limiters, cables, superconducting magnetic energy Storage, rotating machinery, transformers, and flywheels incorporating magnetic bearings. Such devices are being designed, built and tested throughout the world.

[1996] 14A - 5

AC LOSSES OF A 10 KA NBTI CABLE-IN-CONDUIT SUPERCONDUCTOR FOR SMES APPLICATIONS

Kwasnitza, K.; Sultan, A.; Al-Wakeel, S.

Paul Scherrer Inst, Villigen, Switzerland

Cryogenics, vol 36, no 1, January 1996, pp 27-34

In this paper we present ac loss investigations performed on a 10 kA prototype cable-in-conduit superconductor with a NbTi basis. The twisted and braided conductor was under development for a superconducting 180-MJ energy storage model coil with B_{max} equals 5.4 T at I_{max} equals 10 kA. Special aspects of our measurements are the coupling loss dependence on the Cr coating and on the plastic deformation of the basic multifilament wires in the cable. Further, we separately determined the individual contributions from the different conductor components to the coupling losses. Also, the influence of the void fraction in the conductor on the coupling losses was investigated. In addition, dc transverse resistance measurements were performed on the cable. The measured hysteresis and coupling losses are small for such a large current conductor and were sufficiently low for our purposes. Further ac loss reduction could be achieved by a proper choice of the basic multifilament wire in the cable. Our ac loss results should also be useful for other pulsed magnetic field applications of this conductor type. 13 Refs.

[1996] 14A - 6

ACTIVELY SHIELDED TRANSPORTABLE SMES-SYSTEMS

Fresacher, G.; Schonwetter, G.; Gerhold, J.

Tech Univ Graz, Austria

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2349-2352

Previous investigations on active shielding of SMES systems have proved to be successful in reducing the stray field. It was shown that the stray field of a single solenoidal SMES can be diminished by adding shielding solenoids under the condition that the sum of the magnetic dipole moments of all coils equals zero. Computations revealed diameters of those SMES arrangements in the range of several meters for a given SMES capacity of 50 kWh, which may be appropriate

for grid stabilization. This restricts coil transportation severely. The present paper mainly concentrates on this problem and deals with SMES systems with outer diameters not more than 2.3 m. This provides easy transportation either on rail or on road with the crucial benefit that only final assembly of pre-fabricated modules has to be done on the prospective site. An arrangement of such an actively shielded transportable SMES will be optimized for a minimum of length and for a minimum of superconductor. Furthermore its performance in reducing the stray field will be compared to previous SMES systems. 7 Refs.

[1996] 14A - 7

AN EVALUATION OF ENERGY STORAGE TECHNIQUES FOR IMPROVING RIDE-THROUGH CAPABILITY FOR SENSITIVE CUSTOMERS ON UNDERGROUND NETWORKS

Braz, A.; Hofmann, P.; Mauro, R.; Melhorn, C.J.

Con Edison, New York, NY, USA

Proceedings, 1996 IAS Industrial and Commercial Power Systems Technical Conf, New Orleans, LA, May 6-9, 1996, pp 55-64

Most Con Edison customers are supplied through extensive secondary network systems. These customers do not experience interruptions or outages except under very rare circumstances. This is a significant advantage for these customers since they do not normally need to apply conventional UPS systems for protection of critical loads against outages. However, voltage sags, which occur whenever there is a fault on the power system, can cause dropout or mis-operation of sensitive equipment. Some type of protection may be needed for these loads to provide ride through support during voltage sags. This paper describes the methodology used in a research project sponsored by EPRI and Con Edison to evaluate the need for voltage sag ride through improvement for selected customers. Technologies that can supply the required ride through and application considerations were evaluated (SMES, motor-generator sets). Two case studies are presented to illustrate the methodology used to perform the evaluations. 9 Refs.

[1996] 14A - 8

ANALYTICAL DESIGN OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR PULSED POWER PEAK

Netter, D.; Leveque, J.; Rezzoug, A.; Caron, J.P.; Sargos, F.M.

GREEN-Univ H Poincare, Vandoeuvre-les-Nancy, France

IEEE Trans on Magnetics, vol 32, no 5, pt 2, September 1996, pp 5139-5141

A superconducting magnetic energy storage can be used to produce very high pulsed power peak. A superconducting coil is magnetically coupled with another coil linked to the load. During the storage phase, the current is constant. In order to transfer the energy to the load, we cause the quench of the superconducting coil. It is very important to know the efficiency of the transfer and how much energy is discharged in the helium vessel. In this paper, we propose an analytical method which enables to calculate very quickly the electrical parameters of such a device.

[1996] 14A - 9

APPLICATION OF SUPERCONDUCTING TECHNOLOGY TO POWER ENGINEERING. ITS APPLICATION TO SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Neo, S.

International Superconductivity Tech Center, Japan

Ohm (Japan), vol 83, no 8, pp 44-50

Japanese

This paper describes the principle and basic configuration of SMES (superconductive energy storage), and introduces the outline of the project for the establishment of elemental technologies necessary for construction of a small-scale SMES pilot plant. On superconducting coil, quench detection and protection, ac/dc converter, dc circuit breaker, persistent current switch and optimum system, this paper describes technological problems and development state.

[1996] 14A - 10

CHARACTERIZATION OF HIGH-CURRENT, HIGH-TEMPERATURE SUPERCONDUCTOR CURRENT LEAD ELEMENTS

Niemann, R.C.; Evans, D.J.; Fisher, B.L.; Brockenborough, W.E.; Roberts, P.R.; Rodenbush, A.J.

Argonne Natl Lab, Argonne, IL, USA

Proceedings, Applied Superconductivity Conf, Pittsburgh, PA, August 25-30, 1996, 7 pp

The refrigeration loads of current leads for superconducting magnets can be significantly reduced by using high-temperature superconductor (HTS) leads.

An HTS conductor type that is well suited for this application is a laminated sintered stack of HTS powder-in-tube (PIT) tapes. The superconducting elements are normally characterized by their manufacturer by measuring critical currents at 77 K in self field. Additional characterization, which correlates electrical performance at 77 K and at lower temperatures with applied magnetic fields, provides the current lead designer and conductor element manufacturer with critical information. For HTS conductor elements comprising a laminated and sintered stack of Bi-2223 PIT tapes having an alloyed Ag sheath, this characterization uses variable applied fields and operating temperatures.

[1997] 14A - 11

CHARACTERIZATION OF HIGH PURITY ALUMINUM MATERIAL FOR USE AS A STABILIZER OF THE 60 KA SMES CONDUCTOR

Abdelsalam, M.K.; Zhang, W.; Lowry, J.F.

Univ of Wisconsin, Madison, WI, USA

Advances in Cryogenic Engineering, vol 42B, 1997, pp 1049-1056

High purity aluminum is used to stabilize the 60-kA SMES monolithic conductor. The stability margin of this conductor depends on the low temperature resistivity of the HPAl. Residual resistivity ratio (RRR) tests of annealed aluminum samples are used as an acceptance test from the material vendor. Starting with a HPAl of a given RRR, the conductor manufacturing and assembly process further degrades the aluminum RRR. In this paper the authors outline the test program that has been used to characterize the HPAl material for the SMES conductor along with the test results. Two standard RRR measurement techniques are used: the four point potentiometric dc method and the eddy current decay (ECD) method. The conventional four point probe method is used on wires while the ECD is used for the 25.4-mm rods. RRR measurements of samples machined at different radii of the twisted grooved 25.4-mm rods show that the twisting effect on RRR is higher at the outer surface of the rod.

[1996] 14A - 12

CIRCUIT ANALYSIS OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM WITH PSPICE

Xu, D.; Inagawa, T.; Osaki, H.; Masada, E.

Univ of Tokyo, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 5, pp 5.315-5.316

Japanese

Abstract not available.

[1997] 14A - 13

COMPARISON OF AVAILABILITY BETWEEN 4.2 K AND 77 K SMES CONCEPTS

Saari, P.; Mikkonen, R.

Tampere Univ of Tech, Finland

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 869-872

The influence of nitrogen-cooled superconductors to the availability of a 100-kWh SMES concept has been analyzed. A conceptual design of a reference unit at 4.2 K has been used as a basis of the study. This kind of unit with independent control of real and reactive power is suitable for load management for example in foundries. The comparison of availability has been done between 77-K and 4.2-K concepts. In order to do this analysis one has to assume that the mechanical and electrical performance of a HTS cable is equivalent to that of a conventional one. The method used is based on the failure modes, effects and criticality analysis (FMECA). Fault trees describe the outage logic based on the functional analysis. Event trees clarify the consequences of the primary events and criticality of these consequences is expressed as a system down time. The existing data base is extremely limited, so extrapolation of data from other technologies can not be avoided. 17 Refs.

[1997] 14A - 14

CONNECTING TESTS OF SUPERCONDUCTING PERSISTENT-CURRENT-SWITCH IN A TYPE OF TRANSFORMER TO SMES SYSTEM

Sato, S.; Matsuo, M.; Funaki, K.; Hashimoto, K.; Takeo, M.; Kisu, T.; Hayashi, H.; Imayoshi, T.; Tsutsumi, K.

Kyudai Ko Chodendokakense

Chodendo Kagaku Kenkyu Senta Hokoku (Japan), vol 4, pp 128-149

Japanese

Superconducting magnetic energy storage (SMES) system is developed for a stabilization and supplement to momentary voltage drop of power transmission line, because of a high storage efficiency of SMES and a high

response on transferring the storage energy between the power transmission line and the SMES system. It is considered that the SMES system is operated in only case of the fluctuation or momentary voltage drop on the power transmission line, and also stands by in persistent current mode for a chance to be operated. A persistent current switch (PCS) for the SMES system is necessary to be developed with quick response and large current capacity. We have studied on PCS in a type of transformer which works according to the principle of a current transformer. This paper describes experimental results with connecting tests of a PCS with current capacity of 100 A and maximum switch-off resistance of 160 ? to a SMES system which consists of a pulse width modulation converter with maximum power of 32-kVA and a superconducting pulse coil with stored energy of 60 kJ at 100 A and 12 H.

[1996] 14A - 15

CONTROL OF RESONANT MODES IN A SERIES COMPENSATED SYSTEM THROUGH SUPERCONDUCTING MAGNETIC ENERGY STORAGE UNITS

Rahim, A.H.M.A.; Mohammad, A.M.; Khan, M.R.

Univ of Bahrain, Isa Town, Bahrain

IEEE Trans on Energy Conversion, vol 11, no 1, March 1996, pp 175-180

A simple and novel strategy for damping subsynchronous resonant oscillations through control of converter firing angles of a superconducting magnetic energy storage system (SMES) is proposed. The strategy is derived such that the current injected or drawn by the SMES compensates for any deviation in real and reactive power in the system. The proposed control has been tested on the IEEE Second Benchmark Model for subsynchronous resonance studies. It has been found to eliminate the slowly growing transients resulting from the unstable modes very effectively. The control algorithm is simple and its realization will require very little hardware. 12 Refs.

[1997] 14A - 16

CONTROL STRATEGY FOR LEVELING LOAD POWER FLUCTUATIONS WITH A SUCCESSIVE LEARNING FUZZY-NEURAL NETWORK BASED ON PREDICTION OF AVERAGE LOAD POWER

Fujii, T.; Funabiki, S.

Okayama Univ, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 120, no 2, July 30 1997, pp 72-80

The effective usage of power facilities can be realized by leveling the fluctuating active power and compensating the reactive power. A fuzzy control strategy of superconducting magnetic energy storage (SMES) has been proposed for this purpose. The control results depend on the values of the scaling factors in fuzzy reasoning. Therefore, to obtain better control results, the scaling factor should be successively adjusted according to the load power fluctuations. In this paper, a control strategy based on autotuning of scaling factors and a fuzzy singleton reasoning method using back propagation in a neural network is proposed for leveling load fluctuations. The prediction and revision of the teaching signal in terms of the energy of the SMES is proposed. The learning rate and the revision of the teaching signal are discussed. Better leveling of load power fluctuation are shown to be achievable by using fuzzy logic and neural networks. 14 Refs.

[1996] 14A - 17

COUPLING LOSSES IN RUTHERFORD CABLE DESIGNED FOR 1 KWH/1 MW-SMES

Sumiyoshi, F.; Kawabata, S.; Imayoshi, T.; Tsutsumi, K.; Irie, F.; Sato, Y. ; Asano, K.; Nose, S.

Kagoshima Univ, Japan

Teion Kogaku (Cryogenic Engineering) (Japan), vol 31, no 3, March 25, 1996, pp 24-30

Japanese

In recent years, many studies have been conducted on small and medium scale superconducting magnetic energy storage (SMES) used for control of an electric system. In this small and medium scale SMES, speed for input and output of energy was relatively fast, a changing horizontal magnetic field equivalent to a maximum of about 0.05 Hz would be added for superconductors as coil wires. As a result, hysteresis losses and coupling losses occurred, and general efficiency reduced during SMES operation. In this study, development of conductors used to 1-kWh/1-MW module-type SMES took place. As a conductor, a kA-class Rutherford cable in which the strand with the pulse having a lot of CuNi in its matrix was used. For clarifying properties of coupling losses in the Rutherford cable, concerning to making three kinds of Rutherford cables without insulation on their surfaces, inter-strand coupling losses and intra-strand coupling losses were tested, theoretically calculated and comparatively investigated, respectively. 11 refs., 8 figs., 3 tabs.

[1996] 14A - 18

CRYOGENICS CHARACTERISTICS OF THE INPUT CIRCUIT OF SUPERCONDUCTING MAGNETICS ENERGY STORAGE FOR DC LINES

Takeno, K.; Otsu, S.; Yamashita, T.

Nippon Telegraph and Telephone Corp, Japan

NTT R D (Japan), vol 45, no 1, pp 73-78

Japanese

A superconducting magnetic energy storage (SMES) system stores energy in a superconducting coil by flowing a high current at very low temperature. SMES is considered to be the next generation technology for storing electrical energy because it has higher energy storage efficiency, shorter charging time, and faster discharging response than any conventional energy storage systems, such as storage batteries. SMES has been researched only for application to ac power lines. This paper presents an input circuit using a dc/dc switching converter to apply SMES to dc lines, which are used in telecomunications power lines. The control method of the input circuit is discussed and the stable condition of the input circuit is presented. Test results showing the basic capability of the input circuit to transfer energy to a superconducting coil are presented.

[1996] 14A - 19

DAMPING OF ELECTROMECHANICAL OSCILLATIONS IN POWER SYSTEMS WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEMS: LOCATION AND CONTROLLER DESIGN

Rouco, L.; Pagola, F.L.; Garcia-Cerrada, A.; Rodriguez, J.M.; Sanz, R.M.

Univ Pontifica Comillas, Madrid, Spain

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 1097-1104

This paper explores the application of superconducting magnetic energy storage (SMES) systems for damping power system electromechanical oscillations. Two issues are discussed: location and controller design. The location of a SMES unit consists of determining the buses of the power system where the connection of a SMES unit will be more effective to damp out the modes of interest. Location also involves the selection of the input variable (bus voltage, bus frequency) and the modulation to be performed (either active or reactive power or both). The basic design of the controller requires the calculation of the controller gain and phase compensation network. Small signal models and corresponding eigenvalue sensitivities are used to address both location and controller design of SMES systems. 14 Refs.

[1997] 14A - 20

DESIGN AND CONSTRUCTION OF THE 4 TESLA BACKGROUND COIL FOR THE NAVY SMES CABLES TEST APPARATUS

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Westinghouse Sci & Tech Center, Pittsburgh, PA, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 840-843

The design and construction of a background coil being built by Westinghouse STC for the Navy SMES cable test apparatus are presented. One objective of the Navy SMES development program is to develop and test improved superconductors for SMES use. The background coil generates a 4-Tesla field on a 1.85-meter diameter SMES conductor sample. The coil stores 49.4 MJ, and has an inner diameter of 2.13 meters. The background coil and SMES conductor sample are housed in separate, concentric cryostats so that the SMES conductor samples can be changed without warming the background coal. The background coil is a pancake style winding, utilizing Rutherford cable conductor cowound with a stainless steel strap and mylar insulation. 1 Refs.

[1997] 14A - 21

DESIGN STUDY OF HIGH-T/SUB C/ SMES

Akita, S.; Wachi, Y.; Meguro, S.; Saito, T.; Ueshiro, K.; Nishida, K.; Shintomi, T.

CRIEPI, Tokyo, Japan

Proceedings, 9th Int'l Symp on Superconductivity (ISS'96). Sapporo, Japan, October 21-24, 1996, vol 2, pp 1345-1348

Superconducting magnetic energy storage (SMES) with high-Tc superconductor should have various advantages to low-Tc SMES because of a high cooling system efficiency, a possibility of compact SMES with high magnetic field, and a wide design freedom of electromagnetic force support. The research association of superconducting magnetic energy storage (RASMES) started a conceptual design work in 1995 on a 5.6-MWh high-Tc SMES for a MAGLEV power supply system to

level the power demand in each substation. According to the research results of high-Tc superconductor characteristics on strain effects, we concluded that design criteria for Nb_3Sn superconductor can be directly applied to high-Tc SMES except yield strength. This means that tensional stress can be applied on high-Tc superconducting wires, and the conventional magnet design can be used. On the other hand, ac loss of high-Tc superconducting wires is still high compared to the loss of low-Tc wires. It means that a further development to reduce ac loss of high-Tc superconducting wires is needed in the field of SMES to realize the high tolerance for heat generation with liquid nitrogen cooling. As for the quenching of high-Tc SMES, we found that a slow propagation speed of normal zone will not lead to any burn-out of high-Tc superconductor.

[1996] 14A - 22

DEVELOPMENT AND TEST RESULTS OF MAGNETICALLY CONTROLLED PERSISTENT CURRENT SWITCHES

Noto, K.; Kimura, H.; Matsukawa, M.; Fujinuma, S.; Segawa, T.; Takahashi, T.; Sadakata, N.; Saito, T.; Goto, K.; Kohno, O.; Honma, H.; Takahashi, C.

Faculty of Eng, Iwate Univ, Morioka, Japan

Materials Trans (JIM) (Japan), vol 37, no 4, April 1996, pp 907-911

The authors have developed 50-A, 50-A-high resistance, 200-A, and 1-kA class fast response magnetically-controlled persistent current switches (magnetic PCS), which are thought to be necessary for small-to medium scale superconductive magnetic energy storage (SMES) systems. In this paper, they report test results on the 200 A class magnetic PCS. A 6.6-m long cable made from 6 strands of 55 core, in-situ processed CuNb composite wire with high resistivity CuNi alloy matrix was noninductively wound on a FRP bobbin and set into a control magnet which can be swept up to the maximum 1.2 T within 2 sec. The magnetic PCS was combined with a small superconducting magnet (~50 mH, 200 A, 2.72 T) and realized a persistent current mode at 200 A. The fast response was checked with a combination of an outer resistance load and by switching-off of the magnetic PCS in a persistent current mode. The switching time of the magnetic PCS was shorter than 0.16 s. The recent results of an energy retaining test for 10 hours by a 1 kA class magnetic PCS at 1 kA are also reported briefly. 7 Refs.

[1996] 14A - 23

DEVELOPMENT AND TEST RESULTS OF A DOUBLE 0.5 MJ COIL SMES SYSTEM

Keilin, V.E.; Agalakov, V.P.; Anashkin, O.P.; Britousov, N.N.; Dudarev, A.V.; Krivykh, A.V.; Kulikov, A.S.; Lysenko, V.V.; Miklyaev, S.M.; Shevchenko, S.A.; Surin, M.I.

RRC Kurchatov Institute, Moscow, Russia

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2312-2315

The design and test results of a SMES system built for Korea Electrical Power Company are described. The system consists mainly of two superconducting (sc) coils, two cryostats, primary power supply and dc-ac-dc converter to transfer the stored energy from one coil to another and vice versa. Each of two almost identical coils can store more than 0.5 MJ at about 1.55 kA. Minimum energy transfer time is about 2 s. The conductor is made by cabling of several sc, copper and stainless steel strands around a copper core. At 2 s transfer time mode, the ac losses in each coil are about 500 J. The cryostats are manufactured mainly of thin-walled stainless steel. Their eddy current losses at liquid helium temperatures are lower than ac losses in the coils. After preliminary testing in Moscow the system was delivered to Republic of Korea and successfully tested at Korea Electrotechnology Research Institute.

[1997] 14A - 24

DEVELOPMENT OF A 1 KWH-CLASS MODULE-TYPE SMES - DESIGN STUDY

Imayoshi, T.; Kanetaka, H.; Hayashi, H.; Honda, K.; Tsutsumi, K.; Irie, F.; Takeo, M.; Funaki, K.; Okada, H.; Ezaki, T.; Sumiyoshi, F.

Kyushu Elec Power Co, Inc, Fukuoka, Japan

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 844-848

We are planning to build a 1-kWh/1-MW (Maximum stored energy/Maximum power capability) module-type SMES (named ESK; experimental SMES of Kyushu Electric Power) as a first step to aiming at the realization of practical SMESs for power line control. Main points of the design are those of module-type coils (each 3 coils and a converter as one unit of 2 modules) for the development to scale up a capacity of SMES, the choice of low-loss stranded cables for reducing of pulse operating loss, the choices of modified D shape coils reduced of stresses in the conductor which become more serious in the scaling up, and high Tc superconductor (HTS) current leads for covering a weak point on

thermal loss in a module-type SMES which needs many current leads. Some other points are also studied such as; design of cooling system in which a quench of coil does not induce that of other, and harmonics suppression in the converter system. 9 Refs.

[1997] 14A - 25

DEVELOPMENT OF A 400 KJ NB_3SN SUPERCONDUCTING MAGNET FOR AN SMES SYSTEM

Harada, N.; Toyoda, K.; Minato, T.; Ichihara, T.; Kishida, T.; Koike, T.; Izumi, T.; Murakami, Y.

Mitsubishi Elec Corp, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 121, no 3, November 30, 1997, pp 44-52

An Nb//3Sn superconducting magnet to store 400 kJ was developed as a unit magnet for a 2.4-MJ SMES system used for stabilization studies of electrical power systems. The superconducting magnet consists of a cryostat and an Nb_3Sn coil. The dimensions of the coil are: 340-mm inner diameter, 700-mm outer diameter and 177-mm axial length. The pool-cooled coil is a stack of 20 Nb_3Sn double pancakes, and the cooling channels are aligned between pancake coils. To reduce Joule loss in electrical power converters, the maximum operating current of the coil is designed to be 350 A, which is one order of magnitude less than the operating currents of similar scale coils for pulse use. The conductor is an Nb_3Sn monolithic conductor with cross section 1.50 multiplied by 2.38 mm. For good superconducting stability and high dielectric strength of the coil, the Nb_3Sn double pancakes were wound by the react-and-wind technique. Operation of dc current to 105% (367.5 A) of the design operating current was achieved without quench. After the whole of the coil was exposed out of liquid helium, the coil did not quench under 120-A current operation for more than 2 hours. It was verified that the coil was stable for the SMES system. 9 Refs.

[1996] 14A - 26

DEVELOPMENT OF AN ALUMINUM STABILIZED REINFORCED SUPERCONDUCTING CONDUCTOR

Fritz, D.; Horvath, I.L.; Harzenmoser, M.; Neuenschwander, J.; Wittgenstein, F.

PTR Praezisionstechnik GmbH Maintal, Germany

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2200-2202

For high performance superconducting magnets as used in large detectors for high energy Physics or for magnets of magnetic storage devices (SMES) the mechanical stresses on the conductor go beyond the yield stress level of the high purity matrix stabilizer, especially if aluminum is used. Therefore, a novel method is proposed to join high strength aluminum strips to high purity aluminum stabilizer by using the electron beam (EB) welding. The proposed EB - welding, combined with roll-pressing under vacuum, provides the minimum heat input on the conductor in comparison with other welding techniques. This method provides the advantage to allow the production of very long conductor lengths and includes the potentiality of repairing without losing expensive material. As this process has to be adapted to the high purity aluminum on the one side and to the high strength material on the other, we started in a first step with investigation and development of the process, using standard laboratory machines together with laboratory-size tooling. In this report the development program is described and first results of the quality control measurements are presented. 4 Refs.

[1997] 14A - 27

DEVELOPMENT OF HTS (HIGH-TEMPERATURE-SUPERCONDUCTOR) CURRENT LEADS FOR 1-MW/1-KWH MODULAR SMES SYSTEM

Bohno, T.; Tomioka, A.; Nose, S.; Konno, M.; Uede, T.; Imayoshi, T.; Hayashi, H.; Tsutsumi, K.; Irie, F.

Fuji Elec Corp R&D, Ltd, Ichihara, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 120, no 1, July 15, 1997, pp 23-30

We are developing high-temperature-superconductor (HTS) current loads for a 1-MW/1-kWh modular SMES system. In the modular SMES system, a pair of current leads would be installed in each module so that the heat load to the low-temperature end through the leads is minimized. Design study of the lead configuration including the safety lead and its thermal characteristics is presented herein. The safety lead composed of stainless steel is placed in parallel to the bulk HTS. A test unit for verification of safe operation has been developed and the simulated bulk HTS quench test has been demonstrated. The maximum temperature of the safety lead reached 200 K and the terminal voltage of the safety lead was only 1.2 V in the case of a 1000-A quench test. This temperature rise was well below the designed value. 8 Refs.

[1997] 14A - 28

DEVELOPMENT OF HTS CURRENT LEADS FOR 1 KWH/1 MW MODULE TYPE SMES SYSTEM (1) - DESIGN STUDY

Konno, M.; Sakaki, K.; Uede, T.; Tomioka, A.; Bohno, T.; Nose, S.; Imayoshi, T.; Hayashi, H.; Tsutsumi, K.; Irie, F.

Fuji Elec Co, Ltd, Kawasaki, Japan

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 684-687

We have been developing high-temperature superconducting (HTS) current leads for a 1-kWh/1-MW module-type SMES. Each module of a module-type SMES requires a pair of current leads. Therefore, we employed bulk HTS in order to reduce the heat load of the current leads. It is important that HTS current leads for SMES be reliable. The HTS current leads described in this paper have been designed to minimize the heat load and to maintain a high level of reliability. The HTS current leads are designed to hold the heat load at the cold-end terminal to less than 0.1 W. They are also designed with safety leads to bypass current in the event the HTS is quenched and with metal superconductors to assure the continuation of SMES operation even if the HTS should fail or deteriorate in performance. This paper describes an optimal design and the results of a heat load evaluation of HTS current leads for SMES. 2 Refs.

[1997] 14A - 29

DEVELOPMENT OF HTS CURRENT LEADS FOR 1 KWH/1 MW MODULE TYPE SMES SYSTEM (2) - MANUFACTURING AND TESTING OF PROTOTYPE LEADS

Bohno, T.; Tomioka, A.; Nose, S.; Konno, M.; Sakaki, K.; Uede, T.; Imayoshi, T.; Hayashi, H.; Tsutsumi, K.; Irie, F.

Fuji Elec Corp R&D, Ltd, Ichihara, Japan

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 688-691

We have been developing HTS current leads for a 1-kWh/1-MW module type SMES system (which we call "ESK" for Experimental SMES of Kyushu Electric Power Co., Inc.). Each module of a module type SMES system has a pair of current leads. For the purpose of reducing the heat load from the current leads, we have employed a bulk HTS. As a step in the preparation of HTS current leads for ESK, we trial produced HTS current leads and tested them to evaluate their characteristics. Our test results indicated that the heat load in a steady state at a rated current of 1 kA and with a rated flow rate of 0.05 g/s was 0.035 W, well below the specified value of 0.1 W. Also, our results indicated that the HTS current leads can be satisfactorily energized for pulsing operation at a rated current for ESK of 500 A-1 kA. The heat load under such conditions was 0.025 W, approximately 80% of that under normal 1-kA operating conditions. It was also verified that operation could be continued for 15 minutes even when the coolant flow was stopped. 4 Refs.

[1996] 14A - 30

DEVELOPMENT OF LARGE-CURRENT-CARRYING SUPERCONDUCTING CABLE FOR AC USE

Takahashi, R.; Taniguchi, T.; Yamaguchi, K.; Maki, N.

Hitachi Ltd, Ibaraki-ken, Japan

Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2894-2897

Large-current-carrying superconducting cable with sub-micrometer NbTi filaments has been developed for the application of ac power devices such as superconducting rotating machines, SMES and fault current limiters. The quench current and the loss under ac operation have been measured. The results show that the superconducting cable has ac transport current of at least 2000 A_{rms} at 50 Hz in a 5-T dc background magnetic field. The ac losses are measured to be 1.5 x 10^3 W/m^3 with 1000 A_{rms} transport current at 50 Hz, which are remarkably low. 6 Refs.

[1996] 14A - 31

DEVELOPMENT OF SMES FOR SYSTEM STABILIZATION. 3. SUCCESS IN TORODIAL TYPE RATED OPERATION

Koike, T.

Kansai Elec Power Co, Inc, Osaka, Japan

R and D News Kansai (Japan), vol 345, July 10, 1966, pp 36-38

Japanese

Technical Research Center of The Kansai Electric Power Co., Ltd., has been engaged in the study of small superconductive energy storage device (SMES) aiming primarily at system stabilization, and has so far

completed in the center a toroidal type SMES constituted of three 400-kJ-class superconductive coils, and a system stabilization test using the toroid type was performed with success for the first time in the world. Now, superconductive coils are connected to the system for the reinforcement of the ac/dc converter for exchanging energy. This enabled toroidal type rated operation, and a verification test was conducted over 3-coil characteristics. In this paper, the results of the electromagnetic force measurement test and energy transfer test are reported. The former test measured electromagnetic force produced by energization near the rated value, and the measured value was equal to or lower than the value calculated by analysis. The latter test examined the energy transfer characteristics between the coils, and the current increased in the energy receiving coil while the current decreased in the energy transmitting coil, which meant that energy was smoothly transferred. 3 figs., 2 tabs.

[1996] 14A - 32

DEVELOPMENT OF SYSTEM STABILIZING SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) SYSTEM. SYSTEM STABILIZATION TESTS BEING CARRIED OUT FREQUENTLY IN THE GENERAL RESEARCH INSTITUTE

Koike, T.

Kansai Elec Power Co, Inc, Osaka, Japan

R and D News Kansai (Japan), vol 339, January 10, 1996, pp 17-19

Japanese

System stabilization tests are in progress on a toroidal coil type superconducting magnetic energy storage (SMES) system, and the system stabilizing effect of the SMES is being verified. The toroidal coil-type SMES consists of three superconducting coils of 400-kJ class, each coil being connected to the system via a converter comprising an inverter and a chopper. The transmission system simulates a power of 500-kV, two lines, and a distance from 200 km to 900 km. In an active stability test, one line of the two simulated transmission lines was opened to give fluctuation to the generator, and compare the convergence conditions with or without the SMES control. While the case without the SMES control required several cycles, the SMES control required only one cycle for the convergence. In a transition stability test, one simulated transmission line was short-circuited in three phases at a terminal closest to the generator to compare the convergence of fluctuation with or without the SMES control. Quicker convergence due to the SMES control was recognized. 7 figs.

[1996] 14A - 33

DEVELOPMENT OF Y-BASED HIGH-TC SUPERCONDUCTING CURRENT LEAD

Masegi, T.; Kimura, S.; Yamada, Y.

Toshiba Corp, Japan

Toshiba Rebyu (Japan), vol 51, no 2, pp 59-62

Japanese

A high-Tc oxide superconducting current lead has been developed for application to large-scale superconducting devices such as superconducting magnetic energy storage. A current lead test model was fabricated by the unidirectional solidification method, with a Y-based oxide superconductor having a high critical current density. The stable dc current of this test model reached 5560 A, which is more than twice the value previously obtained for a high-Tc oxide superconducting current lead. Heat leakage through the current lead was also reduced to about half the value of a conventional metal current lead. These results show that high-Tc oxide superconducting current leads can be used for 5-kA-class superconducting devices to reduce liquid helium consumption.

[1997] 14A - 34

DYNAMIC SIMULATION OF HYBRID WIND-DIESEL POWER GENERATION SYSTEM WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE

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Energy Conversion and Management (UK), vol 38, no 9, June 1997, pp 919-930

In this paper, a systematic method of choosing the gain parameter of the wind turbine generator pitch control is presented, using the Lyapunov technique, that guarantees stability. A comprehensive digital computer model of a hybrid wind-diesel power generation system, including the diesel and wind power dynamics with a superconducting magnetic energy storage (SMES) unit, for stability evaluation is developed. The effect of introducing the SMES unit for improvement of stability and system dynamic response is studied. Analysis of the stability has been further explored using an eigenvalue sensitivity technique. The eigenvalues of the system

with and without the SMES unit have been studied, and the effects of variation of the SMES unit parameters or eigenvalue locations are plotted. The dynamic response of the power system to random load changes with optimal gain setting is also presented.

[1998] 14A - 35

EFFECT OF SMES UNIT ON AGC DYNAMICS

Devotta, J.B.X.; Rabbani, M.G.; Elangovan, S.

Natl Univ of Singapore

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO3.1

Abstract not available

[1997] 14A - 36

EFFECTS OF ENERGY STORAGE EFFICIENCY ON OPTIMAL OPERATION OF PHOTOVOLTAIC/DIESEL HYBRID GENERATION SYSTEM

Ochihata, M.; Osawa, Y.

Kobe Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 110-124, pp 1-5

Japanese

A photovoltaic/diesel hybrid power generation system consists of solar cells, diesel generator, storage batteries and electric power conversion systems. In the present paper, we assume a SMES (superconducting magnetic energy storage) as the energy storage system, and analyze the effects of its high storage efficiency on the optimal operation of the energy storage system via dynamic programming (DP) method compared with the case of lead-acid batteries.

[1997] 14A - 37

ELECTRIC UTILITY SYSTEM APPLICATIONS OF FAST-ACTING ENERGY STORAGE AS ILLUSTRATED BY SMES

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Int'l Journal of Global Energy Issues, vol 9, no 3, 1997, pp 113-127

Utility energy storage media can be classified as fast- or slow-acting in reference to command and control response times ranging from milliseconds to less than a minute. World-wide, the generation and delivery of electric power typically relies on less fast-acting energy storage per unit of capacity than may be optimal. The present situation is expected to change as utility planners respond to new demands and begin to recognize that the near-instant availability of stored energy offers many high-value, cost-effective system benefits. This paper summarizes two application studies of superconducting magnetic energy storage (SMES) to illustrate some generation and transmission benefits of fast-acting storage. Emphasis is placed on the performance and economic criteria that can justify utility adoption and use of SMES options. 15 Refs.

[1996] 14A - 38

ELECTROMAGNETIC ENERGY STORAGE BALANCES THE ENERGY ECONOMY

Kinnunen, L.

Teknotietaemys Tmi, Vantaa, Finland

Energia (Finland), vol 11, no 8, 1996, pp 27-28

Finnish

Unbalance in power production and power consumption causes troubles for power transmission networks and energy economy. These are the daily power consumption peaks in the industry, e.g. the starting of large electric motors, momentary power distribution failures in insular networks, and the stability of power transmission networks, during instantaneous power fluctuations. The problem of the use of renewable energy sources is the seasonality of this form of energy. Energy storage, based on superconductors seems to offer a solution for these kinds of problems. The target of the Department of Electrical Engineering of the Tampere University of Technology is to demonstrate an energy storage based on high-temperature superconductors by the end of 1997. The construction of electromagnetic energy storage is rather simple. The main principle is to store energy into magnetic field created by a superconducting coil. Direct current is fed into the coil, so the it is necessary to put a control bridge between the network and the magnet. Other main components of the storage are a thermally insulated container, a so-called cryostat, a cooling system, and electric conductors. The energy stored into the magnetic is field $W=1/2\ LI^2$ in which L is the inductance of the coil and I is the strength of the current. The energy density of the magnetic field is low, but the field does not require any special intermediate medium, but it is spread into the air surrounding the coil. The advantages of the magnetic storage are its high efficiency, even as high as 90-95 %,

and the short activation time. On the basis of different cost analyses, the total costs of traditional helium-cooled storage system are about $100 million for a 100-MWh unit, and about $300 million for a 1000-MWh unit. The costs of an energy storage based on high-temperature superconductors are hard to estimate because the technology is still under development.

[1997] 14A - 39

ENERGY AND GREENHOUSE EFFECT ANALYSIS OF A POWER SYSTEM CONSIDERING SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM (SMES)

Kamiya, S.; Tanaka, E.; Kita, H.; Hasegawa, J.; Shirasaki, T.

Hokkaido Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 1-6

Japanese

This paper presents energy and Greenhouse effect analysis of a power system with superconducting magnetic energy storage System (SMES). This analysis shows that, introduction of SMES can considerably cut down CO_2 emissions because it can substitute the operation of the thermal power plant during peak load periods. On the other hand, nuclear plants are also needed for charging purposes. The introduction of SMES was simulated on a power system subject to CO_2 emission constraints.

[1996] 14A - 40

ENERGY STORAGE: WATTS IN STORE

Sacks, T.

Electrical Review (UK), vol 229, no 14, July 9-22, 1996, pp 20-22

Changes in the electricity supply sector are making large-scale energy storage a subject of considerable interest. Whereas in the past schemes such as pumped storage were used mainly in emergencies, to smooth the demand curve and to compensate for drops in frequency, minimizing the use of fossil-fired stations is now an environmental incentive. Utilities are seeing the advantages of using large-scale energy storage in many different ways and are looking at new storage options alongside established ones like pumped storage and batteries. For example, studies suggest that spinning reserve at power stations could be achieved cost effectively using superconducting magnetic energy storage (SMES). Each storage technology has its own characteristics. Some can provide hours of back-up or top-up power but take a relatively long time to come on stream. Others may be available virtually immediately but cannot sustain an output for extended periods. A comparative study has shown that batteries, SMES, supercapacitors and flywheels could be particularly useful for voltage sag compensation. Batteries and flywheels are best suited for emergency supplies during outages of about an hour. Compressed air storage looks most promising for long-term diurnal storage, while supercapacitors and flywheels could be used to compensate for fluctuations in wind power supplies. The attractions, drawbacks and state of development of the various technologies are summarized in a table. (UK)

[1996] 14A - 41

EVALUATION OF STEADY STATE STABILITY OF ELECTRIC POWER SYSTEM BY USE OF SUPERCONDUCTING MAGNET ENERGY STORAGE

Nitta, T.; Shirai, Y.; Ito, Y.

Kyoto Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 6, June 1996, pp 678-684

Japanese

A new application of superconducting magnetic energy storage (SMES) for diagnosis of power systems is proposed. Basic experiments for diagnosis of power systems by use of SMES were carried out by use of small generators, artificial transmission lines and a small SMES. The SMES gives small power disturbances to the power system without affecting operating conditions of the power system. The small power oscillations in the power system due to continuous power disturbances generated by SMES are observed. The relations between the power disturbances and the power change of SMES are discussed. Natural frequencies of the power system are obtained by investigating the oscillations due to the sinusoidal power change of SMES. The relations between the natural frequencies and the steady-state stability of the power system are also discussed. The possibility of estimation of the steady-state power system stability by monitoring the natural frequencies of the operated power system by use of SMES can be shown experimentally. 6 Refs.

[1997] 14A - 42

EVALUATION OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR SAN

DIEGO GAS AND ELECTRIC COMPANY

Eckroad, S. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-106286, August 1997, 70 pp

By providing rapid-response, real-power (P) or reactive-power (Q) modulation, superconducting magnetic energy storage (SMES) devices can increase power transfer capabilities. This report documents two phases of a technical study to determine potential benefits of locating a SMES unit at San Diego Gas and Electric's Blythe site.

[1998] 14A - 43

EVALUATION OF SYSTEM STABILIZING UNITS USING ENERGY FUNCTION METHOD

Shinya, K.

Dept of Electrn Comm, Tohoku Univ, Sendai, Japan

Record of Electrical and Communication Engineering Conversazione Tohoku University (Japan), vol 66, no 1, January 1998, pp 7-8

Japanese

In this paper, the energy function is used to evaluate the performance of SMES for the enhancement of power system stability. We investigate the formulation of energy function including the stabilizing action of SMES. Some numerical examples are illustrated in a one-unit-infinite-bus system including SMES. The result shows the effectiveness of the proposed approach.

[1996] 14A - 44

EVALUATION OF VOLTAGE AND REACTIVE POWER CONTROL USING DISPERSED ENERGY STORAGE SYSTEMS

Sano, R.; Kita, H.; Tanaka, E.; Hasegawa, J.; Sato, T.

Hokkaido Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 96-106, pp 79-88

Japanese

The introduction of energy storage systems into power systems is considered one of the most effective measures for economical operation, preserving quality and power supply reliability. The authors consider an electric power system with dispersed energy storage systems as one promising form for the future. It is considered that dispersed energy storage systems have functions as voltage stabilizing device for controlling voltage instability phenomenon or voltage fluctuation resulting from increase of load demand of power systems. We have investigated their characteristics on voltage and reactive power control through a comparison with usual static VAr compensator (SVC) and individual VQC method. In this paper, we investigate the control performance of superconducting magnetic energy storage system (SMES), considering its converter capacity constraint and energy storage capacity constraint.

[1997] 14A - 45

EXPERIMENTAL AND SIMULATED RESULTS OF A SMES FED BY A CURRENT SOURCE INVERTER

Iglesias, I.J.; Bautista, A.; Visiers, M.

CEDEX (Centro de Estudios y Experimentacion del Ministerio de Fomento), Madrid, Spain

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 861-864

This paper presents the first experimental results obtained with a 6-pulse, 50-kW GTO current source inverter (CSI) feeding a 25-kJ superconducting coil. This SMES system is the first step into the project AMAS500 which consists of developing a 1-MJ SMES fed by a 500-kW CSI. The complete system will be in operation at the end of this year, but this paper shows the first results of the 25-kJ SMES when compensating a voltage oscillation in a scaled network. The paper is mainly focused on showing the experimental results of the 50-kW power converter and its comparison with simulation results obtained by means of EMTP and SABER™ simulators. The very good agreement obtained between both results has validated the simulation models. Based on these models the design of the 500-kW power converter has been carried out. The results of simulating the 12-pulse 500-kW CSI feeding a 1-MJ superconducting coil are also presented in this paper. 8 Refs.

[1997] 14A - 46

EXPERIMENTAL STUDY ON SUPPRESSION OF FREQUENCY DEVIATION OF WIND/DIESEL HYBRID GENERATION SIMULATOR EQUIPPED WITH SMES

Yasui, H.; Nakamura, A.; Osawa, Y.; Ito, T.

Kobe Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo

(Japan), vol 97, no 110-124, pp 7-11

Japanese

The present study is concerned with the simulated experiments of suppression of frequency deviation for wind/diesel hybrid generation system by means of SMES (superconducting magnetic energy storage). An induction generator and a synchronous generator were used for the wind turbine generator and the diesel generator, respectively. The effects of the output power variation from the wind turbine generator and the SMES on the system frequency deviation are examined.

[1996] 14A - 47

EXPERIMENTAL STUDY ON DIAGNOSIS OF LONGITUDINAL SYSTEM ON POWER SYSTEM SIMULATOR BY USE OF SMES

Shirai, Y.; Akita, K.; Nitta, T.; Nishigaito, H.

Kyoto Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 96-106, pp 29-38

Japanese

We have proposed a new application of superconducting magnetic energy storage (SMES) for diagnosis of power systems. In one-machine infinite-bus system, we have shown the possibility of estimation of the steady-state power system stability by monitoring the natural frequency of the operated power system by use of SMES experimentally. For the next step, the availability of the proposed method for measuring natural frequencies in multi-machine power system is investigated. In this paper, basic experiments for measuring natural frequencies of the 5-machine longitudinal power system by use of SMES are described. The availability of the proposed method is discussed using experimental results.

[1997] 14A - 48

EXPERIMENTAL STUDY ON THE CONTROL METHOD FOR POWER SYSTEM STABILIZATION USING SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SUPERSMES)

Ise, T.; Ishii, J.; Kumagai, S.; Mitani, Y.

Osaka Univ, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 222-223

Japanese

Abstract not available.

[1996] 14A - 49

EXPERIMENTAL STUDY ON MEASURING NATURAL FREQUENCIES OF LONGITUDINAL SYSTEM ON POWER SYSTEM SIMULATOR BY USE OF SMES

Shirai, Y.; Akita, K.; Nitta, T.; Nishigaito, H.

Kyoto Univ, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-J, pp 37-42

Japanese

This paper describes the grasping of an electric power system conditions by a superconducting magnetic energy storage system (SMES). This technique is to measure the synchronizing power and a damping coefficient of a system by giving the steady electric power fluctuation to an electric power system from SMES, and analyzing the response. This paper examined the validity of this method by a system of which the principal electric power oscillation mode is a multiple. This paper presents the result which measured the natural frequency by installing an SMES simulator in a 5-units tandem system.

[1996] 14A - 50

FAST SMES FOR GENERATION OF HIGH POWER PULSES

Juengst, K.P.; Salbert, H.

Inst fuer Tech Physik, Karlsruhe, Germany

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2272-2275

A technique for generation of high power pulses based on a fast SMES has been developed and a model of a power modulator for linear accelerators was built. The basic function of the modulator that generates 2 ms long, approximately 1-MW power pulses at a repetition rate of 10 Hz is described in this paper. A modular construction of the SMES that consists of up to six coils has been chosen to meet the demands of several applications in high energy physics and energy distribution. The rate of change of magnetic field achieved during ramping of the magnet was more than 60 T/s without a quench. The magnet was designed with respect to the high ac losses during repetitive ramping of the SMES. The suitability of mixed matrix superconductors instead of more expensive net

frequency wires for this kind of ac stress was investigated. The applied mixed matrix Cu/CuNi/NbTi wire and the construction of a single coil is described. 5 Refs.

[1996] 14A - 51

FBIS REPORT: SCIENCE AND TECHNOLOGY. CENTRAL EURASIA

Foreign Broadcast Information Service

Foreign Broadcast Information Service, Washington, DC. FBIS-UST-96-020, May 1996, 59 pp

Translated articles cover the following topics: phase transformations and thermal processing of titanium alloys; molecular beam epitaxy of cubic GaN on GaAs (001) substrates using hydrazine; analysis of laser imaging system with pulse brightening; detection characteristics of laser imaging systems examined; optoelectronic vector-matrix processor for radar signals examined; superconducting magnetic energy storage for electric power systems; parameters and design of power thyristor converters for superconducting magnetic energy storage; and high-efficiency narrow-band free-electron laser with Bragg cavity and reversed conducting field.

[1996] 14A - 52

FEASIBILITY STUDY ON SUPERCONDUCTING ENERGY STORAGE FOR INSTANTANEOUS PROVISION OF RESERVE CAPACITIES. FINAL REPORT

Hockl, V.; Koetschau, S.; Nick, W.; Peschel, H.; Prescher, K.; Rzezonka, B.; Thiel, C.; Voelzke, R.; Zaviska, O.

Siemens AG, Erlangen, Germany

Siemens AG, Erlangen, Germany, BMBF 0329574, November 1996, 107 pp

German

The present integrated research project conducted by Siemens AG in cooperation with the power supply companies PreussenElektra AG and RWE Energie AG was started in March 1994 and finally concluded in March 1996 after a run time of 25 months. On the strength of their know-how as manufacturers of electrotechnical installations and power plants, the cooperating partners were fully equipped to examine the technical and economic conditions relevant to the practical application of superconducting energy storage. The aim of the study was to examine the feasibility and economic efficiency of superconducting magnetic energy storage (SMES) for instantaneous provision of reserve capacities. The SMES is also to provide the power for primary regulation, a function effected by slight throttling of live steam valves in conventional thermal power plants. A basic cost estimation was made for economic assessment purposes., The estimated cost of the first plant (including development costs and component testing) and subsequent (series produced) plants is to serve as a basis for the ensuing decision on prototype construction.

[1996] 14A - 53

FREQUENCY STABILIZATION BY SMES FOR WIND/DIESEL HYBRID POWER SYSTEM VIA FUZZY CONTROL

Yasui, H.; Ohsawa, Y.; Nakamura, A.

Grad School of Sci & Tech, Kobe University, Kobe, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1274-1278

The present study is concerned with the suppression of frequency variation on a wind/diesel hybrid power generation system by an SMES (superconducting magnetic energy storage) scheme. PI control and fuzzy control are adopted for the stabilizing control by SMES, and they are compared with each other in terms of capacity of energy storage of SMES. The control effect of the fuzzy control system is confirmed via transient calculation under the assumed wind speed variation. Also examined was the strategy for keeping the SMES stored energy as near the center of the permissible range as possible, in order that the SMES can be either charged or discharged according to wind power variations. 6 Refs.

[1996] 14A - 54

FUZZY APPROACH FOR MULTIOBJECTIVE OPTIMIZATION IN MAGNETICS

Chiampi, M.; Ragusa, C.; Repetto, M.

Dipt di Ingegneria Elettrica Ind, Politecnico di Torino, Italy

IEEE Trans on Magnetics, vol 32, no 3, pt 1, pp 1234-1237

The multiobjective optimization problem is of interest in almost all EM design problems. Fuzzy logic can be used in the definition of a decision making scheme for a compromise between conflicting objective functions. In the proposed approach a fuzzy "global performance"

index of the design is defined. This parameter can be optimized by any scalar optimization algorithm. The fuzzyfication process, based on a set of linguistic rules defined by the user, is explained. Results obtained on multiobjective optimization problems, which show the good performance of the proposed approach, are presented and discussed. The problems discussed are the design of dc electromagnets and superconducting magnetic energy storage devices. 8 Refs.

[1998] 14A - 55

FUZZY CONTROLLED SMES UNIT FOR POWER SYSTEM APPLICATION

Rabbani, M.G.; Devotta, J.B.X.; Elangovan, S.

Natl Univ of Singapore

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO2.4

Abstract not available

[1997] 14A - 56

FUZZY SET THEORY BASED CONTROL OF SUPERCONDUCTIVE MAGNETIC ENERGY STORAGE UNIT TO IMPROVE POWER SYSTEM DYNAMIC PERFORMANCE

Rabbani, M.G.; Devotta, J.B.X.; Elangovan, S.

Natl Univ of Singapore

Electric Power Systems Research, vol 40, no 2, February 1997, pp 107-114

At present fuzzy logic control is receiving increasing emphasis in process control applications. The paper describes the application of fuzzy logic control in a power system that uses a 12-pulse bridge converter associated with superconductive magnetic energy storage (SMES) unit. The fuzzy control is used in both the frequency and voltage control loops, replacing the conventional control method. The control algorithms have been developed in detail and simulation results are presented. These results clearly indicate the superior performance of fuzzy control during the dynamic period of energy transfer between the power system and SMES unit. 14 Refs.

[1996] 14A - 57

GTO PWM CURRENT CONVERTER ARRAY FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Xu, D.; Baba, J.; Masada, E.; Ohsaki, H.

Univ of Tokyo, Japan

National Convention Record, IEE Japan, Industry Applications Society (Denki Gakkai Sangyo Oyo Bumon Zenkoku Taikai Koen Ronbunshu), vol 1996, pt 1, pp E.38-E.43

Abstract not available.

[1996] 14A - 58

HIGH POWER GTO CURRENT CONVERTER FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Xu, D.; Masada, E.; Ohsaki, H.

Dept of Elec Eng, Tokyo Univ, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 824-828

A multi-modular GTO current converter structure is presented for application to superconducting magnetic energy storage systems. N*N power converters are arranged in a array form. The GTO current converter array with appropriate arrangement of modulation and carrier signals can output large power with high quality line current waveforms. Only low switching of the GTO is required since PWM is primarily used as a method to control flow of power instead of reducing harmonics. Using of only N transformers, $6N^2$ pulse number power converter performance is obtained. For the case of a 4 converter connection, the proposed method is compared with conventional direct paralleled multi-modular converter structures. Simulations show that the proposed multi-converter structure has advantageous harmonic performance. 3 Refs.

[1997] 14A - 59

HIGH-T/SUB C/ CURRENT LEADS FOR MAGLEV SYSTEM

Kato, T.; Hayashi, K.; Sato, K.; Kurihara, M.; Suzuki, E.

Sumitomo Elec Ind Ltd, Osaka, Japan

Proceedings, 9th Int'l Symp on Superconductivity (ISS'96). Sapporo, Japan, October 21-24, 1996, vol 2, pp 1425-1428

High-Tc current leads using the metal-sheathed wires show the properties of low heat leakage and high stability because of their high critical current density and a metallic stabilizer, therefore they have been

successfully applied to SMES (superconducting magnetic energy storage), SR (synchrotron radiation) apparatus and so on. In the maglev system, the high-Tc current leads also have the possibility to simplify the cooling system for the current leads as well as the low heat leakage in contrast to conventionally used copper leads which need a considerable cooling gas when operating. In this experiment, we investigated the low heat leakage current leads with a 600 A transmission capacity even in no cooling gas condition. Ag-Au alloy sheathed Bi2223 wires were used to reduce the thermal conduction through the metal, and 11 pieces of wire were stacked so that the critical current would be more than 600 A. They were fixed on an FRP by an epoxy resin, and copper terminals were prepared at the both ends. The hot and cold ends were fixed at 77 K and 4 K respectively. The current lead were located within FRP pipes so as not to be cooled by helium gas vapor. They showed no voltage generation up to 600 A except for the copper terminals, and the heat leakages were 0.25 W/leads at 0 A and 0.33 W/leads at 600 A, which were lower than that of the copper leads. It was proven that the high-Tc current leads would be effective for the Maglev system.

[1996] 14A - 60

HIGH-TEMPERATURE SUPERCONDUCTING COIL EXPERIMENTALLY MANUFACTURED. EFFORTS FOR DEVELOPING SUPERCONDUCTING APPARATUSES EASY TO HANDLE

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Kansai Elec Power Co, Inc, Osaka, Japan

R and D News Kansai (Japan), vol 344, June 10, 1996, pp 25-27

Japanese

A high-temperature superconducting coil, capable of operation at the liquid nitrogen temperature, was experimentally manufactured for a superconducting energy storing device. A silver-coated multiconductor cable was used, whose critical current density at -196°C was 25000A/cm^2. Impact of electromagnetic force upon the Ic (current immediately before conversion from superconductivity to normal conductivity) in liquid nitrogen was investigated, and it was found that the electromagnetic force as imposed upon the coil did not affect the Ic. More energy was stored when the temperature was lowered below the liquid nitrogen temperature. Possibilities are that this efforts may realize a storage device with its energy density high enough to approximate an NbTi- or Nb_3Sn-aided superconducting energy storage device. The spacer cooling channels were so modified to extend inward beyond the coil inmost diameter so as to provide a gap between the cooling channels and the coil for liquid He penetration. No decrease was noted in the critical current even when the heater capacity was increased, showing uniform cooling. An energization test was conducted by applying a 1-Hz sinusoidal wave, when it was found that the current was stable up to the peak of 35 A. 7 figs., 1 tab.

[1997] 14A - 61

HTS TRANSFORMER FOR UTILITY POWERING

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American Superconducting Corp, MA, USA

Modern Power Systems (UK), vol 17, no 6, June 1997, pp 19, 21-22

High temperature superconductor (HTS) technology, although still undergoing development, offers numerous potential advantages for the power industry in a wide range of applications. One application a HTS transformer was installed at a utility headquarters in Geneva, Switzerland. This demonstration project, a collaboration between ABB, American Superconductor Corporation and Electricite de France, is showing very positive results for HTS technology development. This project is described and other HTS equipment outlined including transmission cables, motors, and SMES. The advantages of HTS are discussed.

[1997] 14A - 62

INCORPORATION OF A SMES COIL INTO A SUPERCONDUCTING LVDC TRANSMISSION SYSTEM

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Univ of Idaho, Moscow, ID, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 419-422

The performance of a superconducting low-voltage direct current (LVdc) transmission system can be significantly enhanced through the addition of a superconducting magnetic energy storage (SMES) coil. The power conversion equipment necessary for connecting a SMES coil to a dc system is much simpler and easier to control than the interface needed to connect a SMES coil to an ac system. There is also added flexibility if the LVdc system is mesh connected. The LVdc system already has the power conditioning necessary for connection to the ac load and supply

systems. The SMES coil can be connected to the LVdc mesh either through a dedicated dc-dc converter or it can be added directly into the mesh and controlled using the converters already present on the mesh. The rectifier voltage regulation schemes control the charging and discharging of the coil. If one of the rectifiers is supplied by a unit-connected generator, a simpler rectifier scheme can be used, and the generator field excitation control can be used to control the SMES coil. The SMES coil could then be used both to level generator loading and provide added reliability in case of disturbances on the ac supply system. 16 Refs.

[1996] 14A - 63

INFLUENCE OF MAGNETIC LINKAGE BETWEEN COILS OF A MODULE TYPE SMES

Okada, H.; Tutinaga, Y.; Itoh, R.; Irie, F.

Oita Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 6, June 1996, pp 724-730

Japanese

To scale up the capacity of SMES for practical applications, it should be necessary to adopt a high voltage system, a large current system or a module type system. The first system is difficult because of the very low withstand voltage of superconducting coils and the second also leads to difficulties such as multiple connections of many power converter units at the dc side and large current conductors of superconducting coils. The third system, which is composed of numbers of modules with small-scale power converter units and element coils, might be a solution to the above difficulties, In this module type system, module coils have magnetic linkage with one another. In this paper, the influence of magnetic linkage between the coils of a module type SMES are investigated by computer simulation. The magnetic linkage differs with numbers of modules and the coils connection method. Through the effect of this magnetic linkage, each module coil current is different at the same power of each converter module. The transfer characteristics of current and energy are shown for discharges from one or more of the 6 modules consisting of 18 coils. Discussions are made on the situation of the existence of an unused module at the quench. Power transfer with same current of each module is shown to be possible by the current feedback control of converter power. 7 Refs.

[1997] 14A - 64

INSULATION DESIGN OF POOL-BOILING HE-COOLED SUPERCONDUCTING COILS. COIL PARAMETERS AFFECTING INSULATION SPACING

Hara, M.; Miyama, M.; Satow, T.; Gerhold, J.

Kyushu Univ, Fukuoka, Japan

IEEE Trans on Dielectrics and Electrical Insulation, vol 4, no 6, December 1997, pp 792-799

An insulation design procedure for SC (superconducting) coils for electric power apparatus is proposed and applied to a small scale SMES (superconducting magnetic energy storage system) consisting of two modules of pool-boiling helium-cooled SC coils. Coil operation parameters affecting insulation spaces are discussed on the basis of an estimated time-dependent ratio of insulation withstand voltage to induced voltage for different quenching states according to the proposed procedure. 16 Refs.

[1996] 14A - 65

INTEGRATION OF AN HTc-MICRO SMES IN AN ACTIVE COMPENSATOR FOR IMPROVING VOLTAGE QUALITY

Tromm, A.

EUS Gesellschaft fuer Innovative Energieumwandlung und -Speicherung Gmbh, Gelsenkirchen, Germany

Proceedings, Symp '96, Economic Efficiency of Electric Energy Storage Systems, Hannover, Germany, April 24-26, 1996, pp 140-148

German

The present article reports on a study conducted in a laboratory of EUS. GmbH, in which a small-scale superconducting magnetic energy storage (micro-SMES) was integrated in an active compensator for the purpose of improving voltage quality. The new idea was that the line-side self-commutated converter would not have to be especially adapted to the superconducting coil as it would be supplied on the dc side by a practically ideal constant voltage source. To this end, a two-quadrant regulator equipped with an intelligent switching function control unit was used and the protective functions integrated in the system were made detectable.

[1998] 14A - 66

INVESTIGATION OF THE TRANSIENT BEHAVIOUR OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) GENERATING HIGH POWER PULSES

Miri, A.M.; Sihler, C.; Salbert, H.; Vollmer, K.-U.

Inst of Elec Energy Sys & High Voltage Tech, Karlsruhe Univ, Germany

European Trans on Electrical Power (Germany), vol 8, no 1, January-February 1998, pp 13-19

A method for calculating transient voltages in superconducting magnets has been developed. The prediction of overvoltages is an essential requirement in avoiding insulation damages in expensive high-power magnets. A single coil of a modular built superconducting magnet energy storage (SMES) was modeled as a strongly coupled R-L-C network with 8556 mutual inductances. The calculated transient behavior of the model corresponds well to the measured unit function response of the investigated coil. The coil was designed with respect to the fast repetitive ramping of the SMES. Resonant oscillations are well damped by the mixed matrix Cu/CuNi/NbTi wire used. Due to the high safety margin of the insulation, the maximum overvoltages could not endanger the winding. A comparison of the results with those of large superconducting fusion coils leads to the recommendation that during the design stage of larger sized SMES, a numerical investigation of the resonance behavior of the system should be performed.

[1998] 14A - 67

LFC AND STABILIZATION OF MULTI-AREA INTERCONNECTED POWER SYSTEM BY DECENTRALIZED CONTROL OF A SMES AND SOLID-STATE PHASE SHIFTERS

Ngamroo, I.; Mitani, Y.; Tsuji, K.

Osaka Univ, Japan

Proceedings, Int'l Conf on Energy Management and Power Delivery (EMPD), Singapore, March 3-5, 1998, paper SO4.2, pp 85-90

This paper proposes a decentralized direct tie-line power flow control strategy of a superconducting magnetic energy storage (SMES) and solid-state phase shifter (SSPS) for load frequency control (LFC) and power system stabilization in multi-area interconnected power systems. Simulation results distinctly exhibit that, under the occurrence of sudden load fluctuations or some disturbances in any areas, the proposed control strategy is capable of suppressing the frequency deviations as well as stabilizing inter-area oscillation modes, simultaneously and effectively.

[1997] 14A - 68

MEASUREMENT OF THE DAMPING COEFFICIENT OF AN ELECTRIC POWER SYSTEM BY USE OF A SUPERCONDUCTING MAGNET ENERGY STORAGE SYSTEM

Shirai, Y.; Nitta, T.; Shimoda, K.

Kyoto Univ, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 119, no 3, May 1997, pp 40-48

In this paper, a new application of superconducting magnetic energy storage (SMES) for diagnosis of power systems is proposed. Basic experiments for measurement of damping coefficient of power systems by use of SMES are carried out in an experimental system with a small generator, artificial transmission lines, and a small SMES. The SMES produces small power disturbances in the power system without affecting its operating conditions. The small power oscillations in the power system due to continuous power disturbances generated by SMES are observed. The relations among the damping coefficient, the power disturbances, and the power change of SMES are discussed for a one-machine infinite-bus system. The damping coefficients of the power system are obtained by investigating the oscillations due to the sinusoidal power changes of the SMES. The possibility of estimation of the steady-state power system stability by monitoring the damping coefficients of an operating power system by the use of SMES can be shown experimentally. 5 Refs.

[1996] 14A - 69

MICRO SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) SYSTEM FOR PROTECTION OF CRITICAL INDUSTRIAL AND MILITARY LOADS

Kalafala, A.K.; Bascunan, J.; Bell, D.D.; Blecher, L.; Murray, F.S.; Parizh, M.B.; Sampson, M.W.; Wilcox, R.E.

Intermagnetics General Corp, Latham, NY, USA

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2276-2279

A 6-MJ, 750-kVA micro SMES system has been designed to protect critical loads against voltage sags and interruptions, as well as to provide continuous power conditioning. Life-cycle costs have been minimized through the use of energy efficient refrigeration units. Maintenance is simplified through the use of line replaceable units (LRU). Availability is maximized through a design approach which allows the

magnet to continue protecting the load even in the case of refrigeration degradation or total failure. Reliability is maximized by the use of proven commercial-off-the-shelf items. The system provides ride-through capability for approximately 9 seconds at a power level of 454 kW. The system comprises a niobium titanium superconducting magnet, permanent conduction cooled hybrid current leads, a low loss cryostat, a closed-loop refrigeration subsystem, an off-the-shelf uninterruptible power supply (UPS), a magnet interface unit to connect the magnet to the UPS, and an off-the-shelf monitoring unit providing both local and remote monitoring capability of system parameters. 3 Refs.

[1997] 14A - 70

MICRO-SMES FOR POWER QUALITY APPLICATIONS

Finger, K.

Intermagnetics General Corp, Latham, NY, USA

Proceedings, Electricity '97 Conf: New Opportunities Ahead, Vancouver, Canada, April 20-24, 1997, vol 3, pp 1-12

An overview of work by Intermagnetics of Latham, NY, in the development of superconducting magnetic energy storage (SMES) based products, used to mitigate power quality problems, was presented. A 6-MJ, 750-kVA relocatable, in-line SMES system which protects 600 kW critical loads against up to 5 second-long voltage sags and interruptions was built. The system also provides continuous power conditioning via an in-line uninterruptible power supply. The features of the system include a niobium-titanium superconducting magnet, high temperature superconducting current leads, closed-loop refrigeration, a 24-month maintenance interval, a 20+ year service life, and remote monitoring capability. A second generation design concept has been developed for protection of critical loads connected to a utility substation. 17 refs., 4 tabs., 10 figs.

[1996] 14A - 71

MINIMAL PERFORMANCES OF HIGH TC WIRES FOR COST EFFECTIVE SMES COMPARED WITH LOW TC'S

Levillain, C.; Therond, P.G.

Electricite de France, Clamart, France

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2308-2311

On the basis of a 22-MJ/10-MVA unit without stray field, we determine minimal performances for high Tc superconducting (HTS) wires, in order to obtain HTS superconducting magnetic energy storage (SMES) competitive compared with low Tc superconducting (LTS) ones. The cost equation mainly considers the wire volume, the fabrication process and losses. We then recommend HTS critical current densities and operating magnetic fields close to the present state of the art for short samples. A 30% gain for HTS SMES compared with LTS one could be expected. 10 Refs.

[1996] 14A - 72

MODELING AND STABILIZING CONTROLLER OF POWER SYSTEMS WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE UNIT

Tsuruda, H.; Matsuo, T.; Suemitsu, H.; Ezaki, T.; Okada, H.

Oita Univ, Japan

Keisoku Jido Seigyo Gakkai Kyushu Shibu Gakujutsu Koenkai Yokoshu (Japan), vol 15, pp 93-94

Japanese

Abstract not available.

[1996] 14A - 73

MULTI-LEVEL 2-QUADRANT BOOST CHOPPERS FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Mao, H-C.; Boroyevich, D.; Lee, F.C.

Virginia Polytech Inst and State Univ, Blacksburg, VA, USA

Proceedings, IEEE 11th Power Electronics Conf and Exposition (APEC'96), San Jose, CA, March 3-7, 1996, vol 2, pp 876-882

Multi-level two-quadrant boost choppers are proposed for superconducting magnetic energy storage (SMES) and other applications with inductive energy storage such as magnetic resonance imaging (MRI) and switching reluctance motor drives. The advantages of multi-level power conversion includes lower current ripple, lower switching loss and better voltage sharing, as illustrated with a 3-level converter as an example. Its operation principle and PWM strategies are investigated, and a small signal model is developed for control design. Simulation results are used to verify the analysis. 11 Refs.

[1997] 14A - 74

MULTI-MACHINE POWER SYSTEM TRANSIENT STABILITY IMPROVEMENT USING FUZZY SLIDING MODE CONTROL OF SMES

Sadeghzadeh, S.M.; Ehsan, M.; Said, N.H.; Feuillet, R.

Sharif Univ of Tech

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 2, pp 671-674

A fuzzy sliding mode control is proposed to improve the transient stability and damping requirements of the large power systems. This control strategy is applied to a super-conducting magnetic energy storage (SMES) unit. The SMES unit is installed at a mid-point along a transmission line and is controlled locally. The modeling aspects of the power system, the SMES unit and the simplified system for controller design are presented. The generalization of the sliding mode control and fuzzy control to the proposed problem are discussed. The simulation results of the New-England test system are clearly demonstrated. Finally the conclusions are provided. 8 Refs.

[1996] 14A - 75

MULTIOBJECTIVE OPTIMIZATION IN MAGNETOSTATICS: A PROPOSAL FOR BENCHMARK PROBLEMS

Alotto, P.; Kuntsevitch, A.V.; Magele, C.; Molinari, G.; Paul, C.; Preis, K.; Repetto, M.; Richter, K.R.

Dipt di Ingegneria Elettrica, Genova Univ, Italy

IEEE Trans on Magnetics, vol 32, no 3, pt 1, pp 1238-1241

A proposal for benchmark problems to test electromagnetic optimization methods, relevant to multiobjective optimization of a solenoidal superconducting magnetic energy storage with active and passive shielding is presented. The system has been optimized by means of different optimization procedures based on the global search algorithm, evolution strategies, simulated annealing and the conjugate gradient method, all coupled to integral or finite element codes. A comparison of results is performed and the features of the problem as a test of optimization procedures are discussed. 4 Refs.

[1996] 14A - 76

MULTIPLE PWM STRATEGY OF PARALLEL-CONNECTED CURRENT-SOURCE CONVERTER FOR SMES

Itoh, R.; Ishizaka, K.; Okada, H.

Fukuoka Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-D, no 2, February 1996, pp 216-217

Japanese

Abstract not available. 2 Refs.

[1996] 14A - 77

NEW COMBINED POWER-CONDITIONING SYSTEM FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Han, B.M.; Karady, G.G.

Myongji Univ, Kyonggi-Do, South Korea

Electric Power Systems Research, vol 37, no 2, May 1996, pp 79-85

This paper proposes a new combined power-conditioning system for large-scale superconducting magnetic energy storage; it consists of a dc chopper and a PWM (pulse-width modulation) voltage-source converter. The proposed system can independently control the active and reactive power of the utility network by regulating the chopper duty cycle and the converter firing angle. The operational concept was verified through mathematical analyses using an equivalent circuit. The dynamic interaction was analyzed using a simulation model with EMTP (Electromagnetic Transients Program). The analysis results show that the new system is feasible for development with commercially available components and technologies. 7 Refs.

[1996] 14A - 78

DESIGNING A SUSTAINABLE ELECTRIC SYSTEM FOR THE TWENTY-FIRST CENTURY

Yndurain, F.

Electrica de Espana, Alcobendas, Spain

21st New Electricity Conf on Providing a Sustainable Electric System, Paris, France, May 22-24, 1995, pp 289-293

The different activities in the field of applied superconductivity carried out in Spain under the auspices of the MIDAS program are reported. Applications using both low- and high-temperature superconductors are considered. In the low temperature superconductors case, the design and construction of a

1-MJ SMES (superconducting magnetic energy storage) unit, as well as the fabrication of voltage and resistance standards, are reviewed. Developments involving the design and fabrication of an inductive current fault limited and mono- and multi-filamentary wires and tapes using high-temperature superconductors are discussed. Finally, the prospects for the application of superconductivity technology to electric power systems for the electric utilities is considered.

[1997] 14A - 79

NUMERICAL ANALYSES OF MAGNETIC FIELD AND FORCE IN TOROIDAL SUPERCONDUCTING MAGNETIC ENERGY STORAGE USING UNIT COILS

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Dept of Elec Eng, Kanazawa Inst of Tech, Ishikawa, Japan

Journal of Applied Physics, vol 81, no 8, April 15, 1997, pp 4094

Superconducting magnetic energy storage (SMES) is more useful than other systems of electric energy storage because of its larger amounts of stored energy and its higher efficiency. There are two types of SMES. One is the solenoid type and the other is the toroidal type. Some models of solenoid type SMES are designed in the US and in Japan. But the large scale SMES causes a high magnetic field in the living environment, and causes the erroneous operation of electronic equipment. The authors previously studied some suitable designs of magnetic shielding for the solenoidal type SMES to reduce the magnetic field in the living environment. The toroidal type SMES is studied in this article. The magnetic leakage flux of the toroidal type SMES is generally lower than that of the solenoid type SMES. The toroidal type SMES is constructed of unit coils, which are convenient for construction. The magnetic leakage flux occurs between unit coils. The electromagnetic force of the coils is very strong. Therefore analyses of the leakage flux and electromagnetic force are important to the design of SMES. The authors studied the number, radius, and length of unit coils. The storage energy is 5 G Wh. The numerical analyses of magnetic fields in the toroidal type SMES are obtained by analytical solutions.

[1996] 14A - 80

ON-LINE MEASUREMENT OF EIGEN-FREQUENCIES OF POWER SYSTEMS BY USE OF SMES

Miyauchi, H.; Hiyama, T.; Shirai, Y.; Nitta, T.

Dept of Elec Eng & Computer Sci, Kumamoto Univ, Japan

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 895-900

It is important for power system operators to grasp the conditions of the power system being operated. In this paper, a new application of superconducting magnetic energy storage (SMES) for the online diagnosis of power systems is proposed and studied. Since SMES is a power source with quick response, it can give continuous power disturbances of arbitrary patterns to a power system without changing the operating conditions. The responses of the power system for the disturbance are analyzed to obtain the eigenfrequencies systematically. In this paper, the authors apply this method to multi-machine systems to check the possibility of online measurement. 5 Refs.

[1996] 14A - 81

OPPORTUNITIES FOR AN APPLICATION OF UNCONVENTIONAL NETWORK COMPONENTS

Schildge, P.; Klemimaier, M.

RWE Energie AG, Essen, Germany

Elektrizitaetswirtschaft (Germany), vol 95, no 25, December 2, 1996, pp 1701-1706

German

This paper considers the prospects for superconducting network components (cables, motors, generators, transformers, current limiters), novel energy storage systems (capacitors, SMES, pumped storage, batteries, flywheels) and fuel cells which offer manifold possibilities of network optimization and reduction of network losses. The question of integrability into existing systems is of special importance along with economic criteria. 0 Refs.

[1997] 14A - 82

OPPORTUNITIES FOR SUPERCONDUCTIVITY IN THE ELECTRIC POWER INDUSTRY

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Houston Advanced Research Center, Woodlands, TX, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 239-244

The Federal Energy Policy Act of 1992 has fostered the rapid evolution of a competitive electric power industry.

Its implementation by the Federal Energy Regulatory Commission (FERC) and the various state public utility commissions has created an opportunity for vastly expanded application of superconducting devices in transmission and distribution systems. Historically, the entrance of new technologies into the electric power system has been a long laborious process. Conservative utility technologists focused on reliability and long track records on someone else's system. The long range planning process (5-10 years) required in the regulatory environment further delayed implementation of newer technologies. Finally, regulations that limited return on investment fostered high cost generation over transmission. This has changed. The functional unbundling of the utilities into generation, transmission, and service components has put in place new management teams. Regulations are focusing on increased performance and reduced costs as well as reliability. A favorable environment is developing for a wide range of new devices that include transmission enhancement SMES, MicroSMES for power quality applications, and superconducting fault current limiters, motors, generators, transformers and transmission lines. It is important for technologists to fully understand how the changes in the $270 billion electric power industry are opening unprecedented opportunities for superconductivity as an enabling technology. 8 Refs.

[1997] 14A - 83

OPTIMIZATION OF A SMES DEVICE UNDER NONLINEAR CONSTRAINTS

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Inst for Fundamentals and Theory of Elec Eng, Graz, Austria

Applied Computational Electromagnetics Society Journal, vol 12, no 2, March 1997, pp 50-53

In this paper a method to calculate the gradients for the TEAM 22 problem is presented. Furthermore an objective function different from the one proposed in the benchmark is used where the energy requirement was handled as an equality constraint. The so derived gradients of the objective function and the constraints together with a standard optimization routine are used to solve the problem. In the last section some new results concerning the presence of local minima for the problem are given. 4 Refs.

[1996] 14A - 84

OPTIMIZATION OF FERROMAGNETIC SHIELDS FOR SOLENOIDAL SMES

Brammer, U.; Rasch, P.

Lehrstuhl fur Elektrische Maschinen, Tech Univ Munchen, Munich, Germany

IEEE Trans on Magnetics, vol 32, no 3, pt 1, pp 1274-1277

Ferromagnetic shields for solenoidal superconducting magnetic energy storage (SMES) are optimized with respect to the stray field or the mass of the shield. Two optimization strategies of zero order are compared: the deterministic downhill simplex method and the evolution strategy, a stochastic method. Due to the comparison a combination of both methods is tested. To guarantee short computation times the underlying nonlinear field analysis is based on an integral equation method. 10 Refs.

[1997] 14A - 85

OPTIMIZATION OF THE MAGNETOSTATIC FIELD IN SMES DEVICES

Formisano, A.; Martone, R.; Villone, F.

Univ degli Studi di Napoli Federico II, Italy

IEEE Trans on Magnetics, vol 33, no 2, pt 2, March 1997, pp 1832-1835

The aim of this paper is to show how SMES devices, if arranged with more than two magnetic dipoles, can perform better. The analysis is carried out either considering or not the presence of a ferromagnetic shield. In the latter case a shape optimization of the iron shield is performed using a combined stochastic/deterministic method. The paper shows how advantages can be taken by evaluating the sensitivity matrix of the iron shape optimization by means of a Lagrangian formulation of the Maxwell's equations. 12 Refs.

[1996] 14A - 86

PERFORMANCE EVALUATION OF HIGH-TEMPERATURE SUPERCONDUCTING CURRENT LEADS FOR ELECTRIC UTILITY SMES SYSTEMS

Niemann, R.C.; Cha, Y.S.; Hull, J.R.; Rey, C.M.; Dixon, K.D.

Argonne Natl Lab, Argonne, IL, USA

Proceedings, Int'l Cryogenic Materials Conf/Cryogenic Engineering Conf (ICMC/CEC 1995), Columbus, OH, July 17-21, 1995, vol 1, pp 619-626

As part of the US DOE's Superconductivity Technology Program, the authors are developing high-temperature

superconductor (HTS) current leads for application to electric utility superconducting magnetic energy storage systems. A 16000-A HTS lead has been designed and is being constructed. An evaluation program for component performance was conducted to confirm performance predictions and/or to qualify the design features for construction. Performance of the current lead assemblies will be evaluated in a test program that includes assembly procedures, tooling, and quality assurance; thermal and electrical performance; and flow and mechanical characteristics. Results of the evaluations to date are presented. 7 Refs.

[1996] 14A - 87

PERFORMANCE OF A POWER CONVERSION SYSTEM FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES)

Skiles, J.J.; Kustom, R.L.; Ko, K-P. Wong, V.; Ko, K-S.; Vong, F.; Klontz, K.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 1718-1723

This paper presents results of laboratory tests of a power conversion system (PCS) for superconducting magnetic energy storage (SMES). The PCS uses a two-quadrant chopper and a voltage source converter. Operating modes of the chopper are discussed. Operation of the SMES to provide independent control of real and reactive power, operation as a static var compensator, low frequency modulation of the real power, and speed of response are demonstrated. A circuit is presented for testing a SMES PCS that does not require a superconducting coil. 11 Refs.

[1996] 14A - 88

POWER APPLICATIONS OF HIGH-TEMPERATURE SUPERCONDUCTIVITY: VARIABLE SPEED MOTORS, CURRENT SWITCHES, AND ENERGY STORAGE FOR END USE

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Oak Ridge Natl Lab, Oak Ridge, TN, USA

Oak Ridge National Laboratory, ORNL/M-5223, August 1996, 16 pp

The objective of this project is to conduct joint research and development activities related to certain electric power applications of high-temperature superconductivity (HTS). The new superconductors may allow development of an energy-efficient switch to control current to variable speed motors, superconducting magnetic energy storage (SMES) systems, and other power conversion equipment. Motor types that were considered include induction, permanent magnet, and superconducting ac motors. Because it is impractical to experimentally alter certain key design elements in radial-gap motors, experiments were conducted on an axial field superconducting motor prototype using 4 NbTi magnets. Superconducting magnetic energy storage technology with 0.25-5-kWh stored energy was studied as a viable solution to short duration voltage sag problems on the customer side of the electric meter. The technical performance characteristics of the device were assembled, along with competing technologies such as active power line conditioners with storage, battery-based uninterruptible power supplies, and supercapacitors, and the market potential for SMES was defined. Four reports were prepared summarizing the results of the project.

[1996] 14A - 89

POWER REGULATION OF A PWM TYPE SUPERCONDUCTING MAGNETIC ENERGY STORAGE UNIT

Jiang, Q.; Conlon, M.F.

Victoria Univ of Tech, Melbourne, Australia

IEEE Trans on Energy Conversion, vol 11, no 1, March 1996, pp 168-174

This paper presents an analysis of the power regulation of a SMES unit under PWM switching control. The criteria for executing a power limit scheme to maintain power flows of the SMES unit within a controllable range are described. A general technique for design of power controllers based on the power limit scheme is developed. Two illustrative examples, being separate active and reactive power compensations of a model power system, are presented. The study indicates that active power priority control plays a dominant role in the power regulation of a SMES unit. Experimental results for two examples are also presented. 10 Refs.

[1997] 14A - 90

POWER SYSTEM STABILITY BY SMES AND SELF-COMMUTATED STATIC VAR COMPENSATOR

Sato, T.; Takahashi, C.; Akatsuka, S.

Tohoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 13-18

Japanese

Improvement of power system stability is studied by a power system simulator with a superconducting magnetic energy storage (SMES) system and a self-commutated static var compensator(SVC). From experimental results, increasing of power system stability limit by SMES and SVC is clarified. Moreover effective locations of SMES and SVC are also appreciated.

[1996] 14A - 91

PRELIMINARY INVESTIGATION OF SMALL SCALE SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) SYSTEMS. FINAL REPORT

Schwartz, J.; Burkhardt, E.E.; Taylor, W.R.

Army Construction Eng Research Lab., Champaign, IL, USA

Army Construction Engineering Research Lab., Champaign, IL, CERL-TR-96/4111, January 1996, 64 pp

Most Army installations purchase electricity from local utilities and pay an additional charge for peak demand. If the peak demand can be reduced, installations can realize significant cost savings. This research investigated the technical and economic issues associated with constructing a small scale superconducting magnetic energy storage (SMES) system for reducing peak demand at Army installations. Analyses included magnetic design parameters, and costs of materials currently available and those being developed. Although advanced materials could reduce costs by as much as 45 percent, current SMES technology is still too costly for use at Army installations. Technological advances and future wide spread use of SMES systems may reduce costs to the point where this alternative would be practical.

[1996] 14A - 92

PRESENT STATUS FOR LARGE SCALE APPLICATION OF SUPERCONDUCTING TECHNOLOGY

Kamata, K.

Hitachi Cable, Ltd, Japan

Shindo Gijutsu Kenkyu Kaishi (Japan), vol 35, pp 20-27

Japanese

It is now possible to build superconductivity related giant systems with very high reliability, resulting from the great progress in designing and manufacturing technology for multifilamentary NbTi and Nb_3Sn superconductors with high stability, and high-field large scale magnets utilizing them, combined with that in cryogenic technology refrigerating the magnets around LHe temperature of 4.2 K. In the field of elemental particle physics, two superconducting accelerator rings are under operation: Tevatron at Fermilab, USA and HERA at DESY, Germany, both with diameters of about 2 km. Though the SSC program was canceled in the USA, CERN council approved the construction of the 14 TeV Large Hadron Collider (LHC), in CERN's existing 27-km circular tunnel for the LEP electron-positron collider, in 1994. In fusion, high-field large scale superconducting magnets are indispensable in order to confine extremely high temperature plasma. Engineering design activities (EDA) of ITER (International Thermonuclear Experimental Reactor) shall be practiced until 1998, under international cooperation betweem Japan, EU, Russia and USA. It is to be determined if ITER might be constructed actually, through studying whole the EDA results in detail. The Yamanashi Maglev test line will start its first trial run in the spring of 1997, in 18.4-km preceding work section among the total planned length of 42.8 km. In power application, two national development programs are practiced in Japan, that is, of superconducting generator and SMES (superconducting magnetic energy storage). A slow response type 70-MW SC generator will make its first test operation in 1996. It is under studying to develop superconducting ac power apparatuses such as current limiters, etc., utilizing extremely low ac loss NbTi wires and cables.

[1997] 14A - 93

PRESENT STATUS OF R AND D IN HIGH-TC SUPERCONDUCTORS

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Superconductivity Research Lab, Inst Superconductivity Tech Center, Tokyo, Japan

Enerugi, Shigen (Japan), vol 18, no 3, May 5, 1997, pp 14-19

Japanese

Recent state of high-temperature superconductor technologies are introduced covering the development of single crystals, bulk materials, and line materials for superconductors and their application to power and energy equipment. In this report, International Superconductivity Technology Center, using a Y123 large single crystal growing method that it developed in

1992, which is an improved pull method involving the Y211 precipitate and BaCuO solvent, yields a large single crystal approximately 20 mm x 20 mm in size. Molten bulk materials are produced from Y-base materials by the MPMG (melt-powder-melt-growth) method, and from Nd-base materials by the OCMG (oxygen-control- melt-growth) method. As applications of bulk superconductive materials, non-contact magnetic bearings, power storing flywheels, and magnetically levitated transportation systems for use in semiconductor manufacturing clean rooms are discussed. Superconductive bulk magnets capable of functioning as permanent magnets have been realized. Bi- and Y-base line materials are in production for application to transmission cables and magnets. In the effort to apply line materials, power cables, transformers, motors, superconducting coils, etc., have been experimentally fabricated. The development of next-generation line materials using Y- and Hg-base materials will be the important tasks for the future. 31 refs., 3 figs., 1 tab.

[1997] 14A - 94

PROCEEDINGS OF PACIFIC RIM INTERNATIONAL WORKSHOP ON APPLIED SUPERCONDUCTIVITY

Shirabe, A.

CRIEPI Komae Lab, Japan

Korea electrotechnology Research Institute, July 15, 1997, pp 143-147

The future technological development of superconducting generators, superconducting energy storage, superconducting cables, superconducting current limiters, and superconducting transformers are discussed. Effects of high-Tc materials on each application are shown. . 1 ref.

[1997] 14A - 95

PROCEEDINGS, ENERGY STORAGE IN A RESTRUCTURED ELECTRIC UTILITY INDUSTRY: REPORT ON EPRI THINK TANKS I AND II

Eckroad, S. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-108894, September 1997, 104 pp

Energy storage will play an increasingly crucial role in the deregulated electric power industry, with future generation probably decreasing in size and becoming more distributed. EPRI sponsored two think tanks to explore the need for energy storage in a deregulated environment and to assess the state of development of energy storage technologies. The think tanks described the U.S. Federal Energy Regulatory Commission (FERC) view of deregulation and how electric utility deregulation compares to the deregulation of natural gas. A panel of technology experts discussed the present status and research needs for the energy storage systems which would likely find increased utilization and value under deregulation.

[1997] 14A - 96

PROGRESS IN BSCCO-2223 TAPE TECHNOLOGY

Malozemoff, A.P.; Li, Q.; Fleshler, S.

American Supercond Corp, Westborough, MA, USA

Physica C (Netherlands), vol 282-287, pt 1, August 1997, pp 424-427

A filamentary composite tape based on BSCCO-2223 high temperature superconductor HTS and a scalable rolling process has reached a record superconductor critical current density J_c (77 K, 0 T) of up to 58 000 A/cm^2, and engineering full cross-section including metal sheath J_e (77 K, 0 T) up to 15 000 A/cm^2. Pilot manufacturing of long lengths 100-400 m has permitted a variety of increasingly significant prototypes, including a 200-hp ac synchronous motor, a 3300 A (77 K) 50-m machine-stranded cable conductor, a 5-kJ SMES system, and an operational ion-beam switching magnet installed in a tandem accelerator for carbon mass spectrometry dating. Recent ASC progress in manufacturing with J_e over 8000 A/cm^2 creates new opportunities for yet more advanced prototypes and commercial development.

[1996] 14A - 97

PROSPECTS FOR HTS APPLICATIONS

Gamble, B.B.; Snitchler, G.L.; Schwall, R.E.

American Superconductor Corp, Westborough, MA, USA

IEEE Trans on Magnetics, vol 32, no 4, pt 1, July 1996, pp 2714-2719

High temperature superconductor (HTS) wire is rapidly maturing into a working material being produced in ever larger quantities and being used in more significant demonstrations and prototypes. Conductor is now produced routinely in several hundred-meter lengths with reproducible results. Current density has

progressed to a level suitable for demonstration of many applications. Wire strength has improved and large prototypes fabricated or under consideration using HTS include superconducting magnetic energy storage (SMES), rotating electrical machines including synchronous ac and dc homopolar motors and drives, generators and condensers, underground transmission cables, utility distribution equipment such as transformers and current limiters, commercial processing applications such as magnetic separation, and specialty magnets such as high field inserts. In this paper the requirements, progress toward these requirements, and the prospects for the future are reviewed. 12 Refs.

[1996] 14A - 98

PROTECTING SENSITIVE CONTROLS FROM MOMENTARY DISTURBANCES

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Transmission & Distribution World, vol 48, no 3, March 1996, pp 62-63, 67

Because critical industrial processes depend on computers and other electronic equipment, momentary voltage sags and outages pose serious problems with respect to continuity of the manufacturing process. Electronic equipment is particularly sensitive to degradation in power quality, requiring close attention to the maintenance of voltage levels. A unique solution has been developed to store energy and to provide carryover support during temporary power disturbances by using a superconducting magnetic energy storage (SMES) system, known as the SSD (R), manufactured by Superconductivity, Inc. of Middleton, Wisconsin, US. Five years of field experience with the SSD at nine installations provided the incentive for Carolina Power and Light Co. (CP&L) to install the device at the ITW Angleboard plant in Hartsville, South Carolina. The author describes the system, its operation and performance. 0 Refs.

[1997] 14A - 99

PROVIDING VOLTAGE DIP PROTECTION TO CRITICAL INDUSTRIAL LOADS USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES)

Gravely, M.L.

Superconductivity Inc, Madison, WI, USA

Proceedings, 10th Int'l Power Quality '97 Power Value '97 Conf, Baltimore, MD, September 9-12, 1997, pp 429-435

Superconductivity, Inc. (SI), a subsidiary of American Superconductor Corporation, commissioned the world's first deep voltage dip protection devices using superconducting magnetic energy storage in April 1997 at the South African Pulp and Paper Industry (SAPPI) mill located in Stanger, Republic of South Africa. The PQ VR™ provides protection from voltage dips up to 75% (nominal voltage down to 25% of nominal voltage) by injecting "real power" from the SMES system into the utility supply. The extensive use of computer-controlled and integrated production processes result in industrial customers finding their facilities very susceptible to losses of production and potential plant shutdowns as a result of voltage dips (also referred to as voltage sags) lasting from only a few cycles to up to several seconds. This paper reviews the progress of the SI over the last few years with specific emphasis on the PQ VR™ installed at the Stanger paper mill.

[1997] 14A - 100

QUALITY OF POWER SUPPLY IMPROVES WITH TECHNOLOGY

Coney, R.G.

ESKOM, Johannesburg, South Africa

Transmission & Distribution World, vol 49, no 3, March 1997, pp 44-47

The introduction many years ago of the fast breaker that tripped and reclosed in three cycles solved the problem of momentary power interruptions that were common in electric utility operations. The reclosure was so fast that electric lights scarcely blinked. The solution, however, did not anticipate the ensuing development of customer equipment that used precision controls with sophisticated electronics requiring uninterrupted voltage supply. Fortunately, superconducting magnetic storage technology was developed to overcome the momentary interruptions and voltage sags. This technology enabled the Eskom system to solve the voltage problem that was affecting many industrial customers. The author describes the SSD SMES system manufactured by Superconductivity, Inc., Middleton, Wisconsin, US, chosen by Eskom, which solved short-term power disturbances. The SSD was selected as a solution to the power quality problem because of its shunt-connected, industrial-grade, power electronics and for the inherent advantages of SMES technology, which include small footprint, high efficiency, high discharge rates and environmental friendliness. The energy from the superconducting magnet supplies the load until the

disturbance has passed. Once the incoming power has stabilized and all three phases are synchronized, the load is switched back to normal utility supply.

[1997] 14A - 101

QUENCH PROTECTION AND STAGNANT NORMAL ZONES IN A LARGE CRYOSTABLE SMES

Lvovsky, Y.; Rey, C.M.

Babcock & Wilcox, Lynchburg, VA, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 857-860

The quench protection system for a 30-MW SMES built by Babcock & Wilcox is discussed. The magnet uses a cryostable conductor with an aluminum stabilizer cooled by pool boiling helium. A general approach to protection of a cryostable magnet is presented. The phenomenon of stagnant zones is identified as a catastrophic process which can raise the conductor temperature in a localized area to hundreds of K in several minutes and has been selected as the target for quench protection system. A stagnant zone can appear in an area covered by vapor and is characterized by uncontrollably growing temperature in the center, while its fronts slowly advance in cryostable regions. Stagnant zones are difficult to detect because of the cryostable nature of the conductor and the existence of other types of normal zones analyzed in the paper, such as steady zones or traveling normal zones, each with its unique behavior. The complexity of quench detection for cryostable magnet and our approach to the problem are discussed. 6 Refs.

[1996] 14A - 102

REACTIVE POWER COMPENSATION OF PARALLEL-CONNECTED CURRENT-SOURCE CONVERTER FOR SMES

Itoh, R.; Ishizaka, K.; Okada, H.

Fukuoka Univ, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-D, no 8, August 1996, pp 887-888

Japanese

Abstract not available. 2 Refs.

[1997] 14A - 103

RESEARCH OF APPLIED SUPERCONDUCTIVITY IN KOREA

Oh, S-S.; Ryu, K-S.

Korea Electrotech Research Inst, Changwon City, South Korea

Teion Kogaku (Cryogenic Engineering) (Japan), vol 32, no 1, January 25, 1997, pp 2-9

Japanese

The beginning of research on superconductivity in Korea is the discovery of oxide high-Te superconductor. The discoveries of a series of oxide high-Te superconductors since 1986 created big sensations in the academic circles and the industrial circles in Korea. At present, meetings for research on superconductivity are held, centering around the High-Te Superconductivity Research Association in which institutes of big companies, governmental institutes, research groups of universities, etc. participate. In this paper, regarding the results of research on applied superconductivity done by each research group in Korea and their future plans, etc., these are briefly introduced. Since superconducting magnets are the basis for various superconducting devices, the importance of their development is high and the research is being made centering around the Korea Electrotechnology Research Institute. A superconducting energy storage device was developed by the Institute of Seoul University during the period from 1990 to 1994. A superconducting current limiter was developed by Yonse University during the period from 1993 to 1995. The SQUID which can measure faint magnetism and micro wave filters are the center of interest. 12 refs., 7 figs., 4 tabs.

[1996] 14A - 104

ROBUST TRANSIENT STABILIZER FOR POWER SYSTEMS WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE UNIT

Matsuo, T.; Shirakawa, Y.; Tsuruda, H.; Okada, H.; Ezaki, T.

Oita Univ, Japan

Proceedings, 22nd IEEE Intl Conf on Industrial Electronics, Control, and Instrumentation, (IECON), Taipei, Taiwan, August 5-10, 1996. vol 3, 1996, pp 1687-1692

In this paper, we establish the nonlinear model of a single machine-infinite-bus power systems with SMES based on the Park's electric and mechanical equations and derive its linearized model with the structural uncertainties caused by the sinusoidal nonlinearities. Moreover, we design the quadratic transient stabilizer for the power systems by using the descriptor-type H8 control theory and show a simulation result by

MATLAB/SIMULINK. 15 Refs.

[1997] 14A - 105

SAMPLED DATA AUTOMATIC GENERATION CONTROL WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE IN POWER SYSTEMS

Tripathy, S.C.; Juengst, K.P.

Indian Inst of Tech, New Delhi, India

IEEE Trans on Energy Conversion, vol 12, no 2, June 1997, pp 187-192

A discrete state-space model of a two-area interconnected power system with reheat steam turbine, governor dead band nonlinearity and superconducting magnetic energy storage is developed in this paper. The effect of a small-capacity superconducting magnetic energy storage (SMES) system is studied in relation to supplying sudden power requirements of real power load. The feasibility, of using an IGBT converter instead of a thyristor converter as a power conditioning system with the SMES is studied. Time domain simulation results are also presented which show improvement of transient response with SMES. 13 Refs.

[1996] 14A - 106

SELECTED TOPICS IN APPLIED SUPERCONDUCTIVITY FOR POWER QUALITY APPLICATIONS

Cave, J.; Roberge, R.

Hydro-Quebec, Varennes, Quebec, Canada

Proceedings, Electricity '96, Montreal, Canada, April 28-May 3, 1996, pp 1-6

A wide variety of topics involving superconductivity were briefly reviewed. Among the topics were: a historical overview, superconducting fault current limiters, power distribution over superconducting cables, and superconducting magnetic energy storage (SMES). The advantages of superconducting cables for electric power transmission (more compact lines, reduction in electricity losses), areas of research and development for SMES, and a visionary description of superconductivity and power engineering, extolling the unique properties and new opportunities presented by superconductivity, were also on the agenda.

[1997] 14A - 107

SIMULATION OF PARALLEL-CONNECTED CURRENT-SOURCE CONVERTERS FOR SMES SYSTEM

Itoh, R.; Ishizaka, K.; Okada, H.

Central Research Inst, Fukuoka Univ, Japan

Fukuoka University Review of Technological Sciences (Japan), no 58, March 1997, pp 19-25

Japanese

Operations of current-source power converters (CSCs), connected in parallel via interphase reactors for superconducting magnetic energy storage (SMES) systems, are simulated in the paper. To suppress the line current harmonics so they are as small as possible by means of the lower switching frequency, a sinusoidal pulsewidth modulation (PWM) with multiple switching strategy is introduced and its switching function is optimized. State equations for nine operating modes per $\pi/3$ period are derived from the voltage and current equations of the system, and they are provided for numerical calculation using a state-space method. The simulations are executed for various modulation indexes, which enable the SMES system to operate with controlled active and reactive powers. The simulated results confirm that the coil current is equally divided into each power converter and low-order harmonics of line current are effectively suppressed by the PWM method presented.

[1996] 14A - 108

SIMULATION OF POWER SYSTEM STABILITY BY USING SUPERCONDUCTING MAGNET ENERGY STORAGE

Moudjahed, M.; Kauffmann, J.M.

Inst de Genie Energetique, Univ de Franche-Comte, Besancon, France

Int'l Journal of Power and Energy Systems, vol 16, no 3, 1996, pp 145-150

The superconducting magnetic energy storage (SMES) unit is one of the effective measures to suppress instabilities which will occur in a power system if there are system disturbances. A 12-pulse cascaded bridge-type ac/dc converter is an interface between the three-phase power system and the superconducting coil. This paper presents a general mathematical model of a SMES unit and its integration into a multimachine power system which is studied for load change and short-circuit faults. The SMES unit can be located at any bus of the system. Computer studies show the benefit of the SMES unit on power system stability. The impact of the system parameters on the size of the SMES is also examined. 6 Refs.

[1998] 14A - 109

SMALL SMES FOR REDUCTION OF SYSTEM PERTURBATION AND SYSTEM LOSSES

Haubrich, H.-J.; Heider, A.; Dany, G.; Tischbein, T.

IAEW, RWTH, Aachen, Germany

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

This paper describes the potentialities and limits of a super-conductive magnetic energy storage (SMES) with regard to the reduction of system perturbation and system losses. After briefly introducing the technical structure, it is focused on the simulation of the SMES application in low-voltage grids. With the help of new simulation methods, different control concepts are compared and the SMES system's performance is illustrated.

[1996] 14A - 110

SMES IN ALASKA

Aslam, M.T.; Kral, S.F.; Hayakawa, H.; Enomoto, Y.

Municipal Light & Power, Anchorage, AK, USA

Proceedings, 8th Int'l Symp on Superconductivity (ISS'95), Hamamatsu, Japan, October 30-November 2, 1995, vol 2, pp 1255-1267

The application of a 1800-MJ and under 50-MVA superconducting magnetic energy storage (SMES) system is presently under consideration and development for Anchorage Municipal Light and Power (ML&P), interconnected in the Alaska Railbelt electrical power system. Commercial operation is planned for 1998, after the SMES is installed in ML&P's 115-kV transmission system. The project is expected to provide primarily spinning reserve, voltage support and other reliability benefits. Initial estimates show that economic benefits could be up to two million dollars a year for ML&P and there is also a potential for economic benefits to all interconnected electric utilities in the Alaskan power system. Additional studies are being undertaken for further technical and economic benefit analysis and size optimization. 17 Refs.

[1997] 14A - 111

SMES SYSTEMS APPLICATIONS TO IMPROVE QUALITY SERVICE

Esteban, P.; Bautista, A.; Gutierrez-Iglesias, J.L.; Rodriguez, J.M.; Urretavizcaya, E.

ASINEL, Spain

Proceedings, 14th Int'l Conf and Exhibition on Electricity Distribution (CIRED), Birmingham, UK, June 2-5, 1997, IEE Pub. no 438, pt 1/2, pp 2.12.1-2.12.4. IEE, Stevenage, England

This article presents the contribution of SMES (superconducting magnetic energy storage) systems to improvement quality of service, either as a mitigating element or as a power support for critical loads. It also describes these systems and its operation. Finally, a description is shown of the state of the art of this technology in Spain, as developed until now in the AMAS500 project. 7 Refs.

[1998] 14A - 112

STABILITY ENHANCEMENT USING SMES AND ROBUST NONLINEAR CONTROL

Tan, Y.L.; Wang, Y.Y.

Nanyang Tech Univ, Singapore

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO7.1

Abstract not available

[1997] 14A - 113

STABILITY IN THE VENTILATED, CABLED SUPERCONDUCTOR PROPOSED FOR THE NAVY SMES CABLE TEST APPARATUS

Christianson, O.R.; Hassenzahl, W.V.; Scherbarth, D.W.

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 946-949

Improved superconductors for SMES devices will be developed and tested in the Navy SMES cable development program. To test these improved SMES cables, Westinghouse Science & Technology Center is constructing a background field coil for the SMES cable test apparatus that will provide a magnetic field of up to 4 T on a 1.8-meter diameter test specimen. The background coil superconductor design operating point is determined by stability considerations and the superconductor critical surface. Stability of the ventilated, cabled superconductor proposed for the background field magnet is reviewed in terms of cryostability, current redistribution, and enthalpy stabilization of surrounding liquid helium. 7 Refs.

[1996] 14A - 114

STATE OF THE ART OF SUPERCONDUCTIVE

MAGNETIC ENERGY STORAGE

Irce, F.

Kyushu Elec Power Co, Inc, Fukuoka, Japan

Denki Gakkai Ronbunshi, (Trans of the Institute of Electrical Engineers of Japan. Power and Energy), vol 116, no 9, August 20, 1996, pp 1029-1032

Japanese

In recent years, the development of and research into the superconductive magnetic energy storage (SMES) have progressed and taken an increasing public interest. Although the SMES has excellent characteristics as an electric power technique, it involves a problem in the cost, so that it has not yet generally been accepted. This paper describes the present status of development and problems of the SMES. As concrete examples, the paper describes the SMES which is being developed by the Anchorage Electric Power Corporation, the ETM (Engineering Test Model) Plan of EPRI's, the multi-purpose SMES which is being developed by the international Superconductive Industrial Techniques Research Center (ISTEC) in Japan, the BPA system stabilization SMES of the Los Alamos National Laboratory, and studies made by electric power companies in Japan. As the future problems, the paper describes the problems in the coil techniques, such as the electromagnetic force support, increase of coil current, quenching protection, circuit breaking and permanent current switch, and the problems of leakage magnetic field. 17 refs., 1 fig., 3 tabs.

[1996] 14A - 115

STATUS AND FUTURE PROSPECTS OF HIGH CURRENT SUPERCONDUCTIVITY

Komarek, P.

Inst of Tech Physics, Research Centre, Karlsruhe, Germany

Proceedings, 8th Int'l Symp on Superconductivity (ISS'95), Hamamatsu, Japan, October 30-November 2, 1995, vol 1, pp 9-14

The key to high current superconductivity application was always sufficient progress in conductor properties. NbTi and Nb_3Sn wires are the foundation for the present market products in MRI and NMR and for large research projects in elementary particle physics and nuclear fusion. HTSC would be able to immerse the mentioned applications, depending on improved properties. As a start, HTSC current leads are already becoming an important component to improve equipment built with LTSC windings, e.g. to construct cryogenfree magnets. Electric power engineering has not been conquered much by superconductivity yet. However, small SMES units for power quality improvement, and for spinning reserve are now making progress. In areas such as e.g. power transmission cables, HTSC cooled at ~77 K are essential for a breakthrough. It is good to see that relevant development projects for cables, transformers, fault current limiters (FCL) and even motors, have been started. The FCL in particular became a strongly desired device by the utilities, increasing the development effort everywhere. For all these applications the properties of HTSC wires must further improve, to meet certain application needs. Meeting these constraints will take time and patience will be needed. For the meantime the capabilities of LTSC should be used as aggressively as possible to strengthen the superconductivity market. 30 Refs.

[1996] 14A - 116

STATUS ON THE JAPANESE SMES R&D PROGRAM

Takakazu, S.

Natl Lab for High Energy Physics, Japan

Korea-Japan Research Forum on Applied Superconductivity '96, Changwon, Korea, April 23, 1996, pp 1-8

One of the promising applications of superconductivity in future is superconducting magnetic energy storage (SMES). The Japanese activities on this subject were started at the end of 1970's and has been continued with large effort. The program for the 100-kWh SMES R&D was started in 1989 by the Ministry of International Trade and Industries. Some other activities by Research Association of SMES and electric power companies will be reported in this paper. 11 refs., 3 figs., 5 tabs.

[1996] 14A - 117

STATUS-QUO AND FUTURE PERSPECTIVE OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Tanaka, T.

CRIEPI, Tokyo, Japan

Nippon Kikai Gakkai Tsujo Sokai Koenkai Koen Ronbunshu (Japan), vol 73, pt 5, pp 62-64

Japanese

Superconducting magnetic energy storage or SMES in brief is a future potential energy storage device in an electric power network, which will give a great benefit for load levelling, load following and system stability.

Study was started in 1970s large SMES almost equivalent to large pumped hydro storage in capacity. Conceptual design was made for 5 GWh class in USA and Japan. In 1980s, engineering test facility of 20 MWh was designed and its superconducting conductors were constructed, which were equivalent for 5 GWH in current capacity. In 1990s small scale SMES of 100 kWh and 500 kWh in energy capacity becomes a target for research and development. Even smaller SMES called a micro SMES of 1-MJ class is now for rent and sale, which assures demand side power quality. Accumulated experience of small SMES R&D is considered to evolve a step toward large SMES that is really needed in future power networks. Battery energy storage is briefly reviewed on its R&D status as additional information.

[1997] 14A - 118

STRUCTURAL ADVANTAGES OF DISK MAGNETS FOR SMES

Titus, P.H.

Stone & Webster Engineering Corp, New York, NY, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 865-868

A simple reorientation of the strip solenoid allows improvements in the support of a SMES magnet. A large diameter storage magnet is the focus of the study, but smaller applications are discussed. For large diameters, the peak field and energy storage are nearly the same for a strip solenoid and a disk magnet. The characteristics and benefits of the disk magnet arrangement are discussed. The disk geometry allows improved access for maintenance, reduces excavation, and facilitates repair of conductors. Shimmed radial support at the outer edge allows controlled thermal contraction, and control of conductor strains and is a simplification over rippled solutions proposed independently. Winding pack radial loads produce compressive stresses, no out-of-plane loads develop and there are no bending or shear loads in the winding pack. 4 Refs.

[1997] 14A - 119

STUDIES ON EVALUATION OF A POWER SYSTEM STABILIZING CONTROL BY USE OF SMES

Shirai, Y.; Akita, K.; Sekiya, K. Nitta, T.; Nishigaito, H.

Kyoto Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 19-24

Japanese

We have studied on a new application of superconducting magnetic energy storage (SMES) for diagnosis of power systems. In this paper, an application of SMES for evaluation of a certain power system stabilizing control is proposed. The SMES gives a small power disturbances to a power system with and without a power system stabilizing control. By comparing amplitudes of the power oscillations due to the small power disturbances in the two cases, an ability of the power system stabilizing control is evaluated. In this way, an ability of the power system stabilizing control of the SMES itself is evaluated experimentally.

[1996] 14A - 120

STUDY OF QUENCH PHENOMENA WITH SUPERCONDUCTING MODEL COILS

Morimoto, H.; Nakade, M.; Hara, T.; Okada, S.; Tachimura, K.; Komura, A.

Hitachi Ltd, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 116-B, no 7, July 1996, pp 785-791

Japanese

The quench phenomenon is very important for superconducting power devices, such as SMES, superconducting generators, superconducting current limiters, etc. because the reliability of such devices depends on the stability against quench, in which the superconducting state varies into the normal state rapidly. The authors have produced two kinds of coils and investigated, experimentally the relation between stability and several parameters (e.g. external magnetic field, electrical current, duration time of heating by a heater). The quench phenomenon has been simulated numerically with the same conditions as experiments, and the stability has been estimated quantitatively. As the result, it is found that the larger an external field or a coil current, the less stabilized it is for quench. Experimental results have been reproduced on their simulation. They improved their two-dimensional quench simulation code by considering the delay time of heat transfer due to the insulator and the thermal capacity of the insulator and spacer. An expansion of the quenched region was recorded with a high speed video camera, and the two-dimensional expansion of quenched region such as quench propagation between superconducting wires was reviewed on their

simulation. 4 Refs.

[1996] 14A - 121

STUDY OF SMES FOR POWER SYSTEM STABILIZATION

Koike, T.; Izumi, T.; Kishida, T.

Kansai Elec Power Co, Inc, Japan

Nippon Kikai Gakkai Doryoku, Enerugi Gijutsu Shinpojiumu Koen Ronbunshu (Japan), vol 5, pp 183-186

Japanese

In order to study power system stabilization effects and appropriate control methods for a superconducting magnetic energy storage (SMES), a small toroidal coil SMES was fabricated and testing commenced in 1994. This SMES system has a discharge resistor for protection and dc circuit breaker at each coil, and is composed of two 400-kJ coils made of NbTi, one made of Nb_3Sn, one 20-kVA voltage type inverter, and three chopper units. Specifications of the superconducting coil were 400 V 350 A, with an excitation rate of 0.5T/sec, a central magnetic field of approximately 4T. The power system testing was conducted by connecting a 50-kVA conventional generator and SMES to a simulated 500-kV 2-circuit power transmission line. The results verified that the SMES led to improved power system stability with one circuit open, and with a three-phase short.

[1996] 14A - 122

STUDY ON APPLICABILITY OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM

Anon.

Tohoku Elec Power Co, Ltd, Sendai, Japan

Tohoku Denryoku R&D (Japan), vol 1, March 1996, pp 9-10

Japanese

In association with unevenly distributed power source locations, maintaining the safety in power systems is becoming an important problem. Therefore, discussions are being given on applicability of a superconducting magnetic energy storage (SMES) system for the purpose of system stabilization. The SMES is a system consisting of superconducting coils, an ac-dc converter, and controls, to flow dc current into the superconducting coils from the ac system via the ac-dc converter to store electric power in the form of magnetic energy. The system has high response speed, can stabilize any failure instantaneously, and has less degradation and longer life. The currently used static var control (SVC) system controls reactive power only, but the SMES system can control both of active and reactive power simultaneously, hence effective in stabilization, especially for generators. The system is also effective in voltage stabilization, and suppression of load and frequency variations. A prototype SMES system with a storage energy of 1 MJ was fabricated to verify the basic system characteristics and its effectiveness in the test on the system connected with a simulated power system. The system is under a process of verifying its effects in combination with SVC and application to the full-scale systems.

[1996] 14A - 123

STUDYING OF A TRANSFORMER-TYPE PERSISTENT CURRENT SWITCH USED IN SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM

Wang, Q-L.; An, C-W.; Wang, Y-Q.; Li, Z-G.

Natl Lab of Laser Tech, Huazhong Univ of Sci & Tech, Wuhan, China

Chinese Journal of Low Temperature Physics (China), vol 18, no 5, October 1996, pp 388-394

Chinese

On the basis of the properties of transformer, the paper proposes a transformer-type persistent current switch (PCS) for use in a superconducting magnetic energy storage system. The structure of transformer-type PCS is a transformer with three coils, the turn number of the primary coil (T1) is more than that of the secondary coils (T2, T3). The normal state resistance of PCS is increased by connecting bifilar coils (B1, B2). Two large current diodes are connected in the secondary circuit. Based on the principle, a transformer-type PCS with current capacity 100 A and normal state resistance 100 was designed. 3 Refs.

[1997] 14A - 124

SUPER-GM AND OTHER SUPERCONDUCTIVITY PROJECTS IN JAPANESE ELECTRIC POWER SECTOR

Ueda, K.; Ageta, T.; Nakayama, S.

CRIEPI, Tokyo, Japan

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 245-251

This paper summarizes R&D trends of superconductivity applications in electric power sector in Japanese government and power companies. The background of SCG (superconducting generator) and SMES (magnetic energy storage) are mentioned. The recent results of LTS/HTS superconductor for power apparatus in Super-GM project are reported. The progress, field testing, and analytical method of SCG are also described. 4 Refs.

[1996] 14A - 125

SUPERCONDUCTING MAGNETIC ENERGY STORAGE AND DISPATCHING ELECTRIC NETWORKS

Zhang, X.; Zhang, Y.

Journal of Shanghai Jiaotong University (China), vol 30, no 12, December 1996, pp 97-102

Chinese

The development of the latest energy storage technique-superconducting magnetic energy storage (SMES)-and its research status throughout the world are analyzed and presented. From this, it is shown that is will be important for SMES techniques to be developed in China. Meanwhile, a method of the design for SMES is provided in the paper. 10 Refs.

[1997] 14A - 126

SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR SUBSTATION APPLICATIONS

Parizh, M.; Kalafala, A.K.; Wilcox, R.

Intermagnetics General Corp, Latham, NY, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 849-852

Requirements and possible configurations for a SMES operating in 15-kV substations are discussed. The system will experience approximately 25 full discharges a year. Such a SMES system should provide 1- to 2-second ride-through capability, a response time of less than 8 milliseconds, and demonstrate a high efficiency. 13 Refs.

[1998] 14A - 127

SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) APPLICATION AND PERFORMANCE IN AN INDUSTRIAL DIP MITIGATION APPLICATION

Coney, R.G.; Smit, L; Rawlins, W.T.

ESKOM, South Africa

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

This paper describes the superconducting magnetic energy storage (SMES or sometimes referred to as SSD) device application and performance, used in a dip protector mode, as applied in the paper industry. An operational background and some measurement results are given.

[1997] 14A - 128

SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) UTILITY APPLICATION STUDIES

Peak, S.D.

Wisconsin Elec Power Co, Milwaukee, WI , USA

IEEE Trans on Power Systems, vol 12, no 3, 1997, pp 1094-1102

The results of a study performed with Oak Ridge National Laboratory to assess the benefits of superconducting magnetic energy storage (SMES) for electric utility applications are presented. The study was conducted for the Defense Nuclear Agency and the Department of Energy as part of their efforts to develop SMES for military and civilian applications. The technical benefits of the SMES and alternative technology options and the economic value of those benefits were determined for two stability-related cases. 3 refs.

[1996] 14A - 129

SUPERCONDUCTING TECHNOLOGIES FOR NEXT GENERATION ELECTRIC POWER EQUIPMENT

Hamajima, T.; Takano, H.; Kitajima, T.

Toshiba Corp, Tokyo, Japan

Toshiba Rebyu (Toshiba Review) (Japan), vol 51, no 7, July 1, 1996, pp 7-10

Japanese

This paper introduces mainly superconducting technologies used in a superconducting magnet energy storage (SMES) system, a fusion machine, and a superconducting generator as next-generation power equipment using superconduction. A superconducting coil uses suitably a force-cooled conductor constructed by a large number of stranded superconducting cables put in stainless steel tubes, with super-critical helium pressure-fed into clearances between cables and tubes. A

super high-speed response magnetization type generator operates in direct current normally, but when a disturbance has occurred in a power system, it functions to suppress power oscillation by executing the so-called super high-speed response magnetization. In that event, the variable magnetic field is added onto the superconductor in association with variation in the magnetic field current. This variable magnetic field generates ac loss, and temperature rise due to the loss quenches the superconducting coil. Prevention of this event requires reduction in the loss. It is necessary to arrange properly a high-resistant layer of CuNi midway a loop made of superconducting filaments in a superconducting cable and copper. A proper arrangement was made possible by applying electromagnetic field analysis to the finite element method. 8 figs., 1 tab.

[1996] 14A - 130

SUPERCONDUCTIVITY APPLICATIONS TO ELECTRICAL POWER ENGINEERING

Chao, C.; Bonwick, W.J.; Conlon, M.F.

Monash Univ, Clayton, Australia

Journal of Electrical and Electronics Engineering (Australia), vol 16, no 2, June 1996, pp 123-132

The research and development of superconductivity for electrical power engineering applications started in the 1960s when useable low-temperature superconductors (cooled in liquid helium at 4.2 K) such as niobium-titanium were developed. The discovery of high-temperature superconductors (cooled in liquid nitrogen at 77 K) in the mid 1980s triggered a renewal of interest in this area. However, the performance of these new materials (YBCO, BSCCO and TBCCO) is not yet at a level to allow their use in electrical power applications. To date, superconductivity applications cover not only conventional areas of electrical power engineering but have also led to new devices based on the special characteristics of a superconductor, such as superconducting magnetic energy storage (SMES) and superconducting fault current limiters. This paper reviews the principles, benefits, history and future issues of the development of superconductivity applications to electrical power engineering. 48 Refs.

[1996] 14A - 131

SUPERCONDUCTORS IN ELECTRICAL ENGINEERING: IT IS FOR SOON

Therond, P.G.

Electricite de France, Paris, France

Recherche (France), Special Edition, 1996, pp 35-37

French

A progress report is given on Electricite de France's industrial development program in the fields of superconducting devices and superconducting cables. Data are given on a research program for a superconducting current limiter for 220-kV ac power net. Trends are given for superconducting magnetic energy storage devices and for superconducting composite cables. 1 fig., 3 photos.

[1996] 14A - 132

SUPERCONDUCTORS: HELP OR HYPE

Schuler, J.F. Jr.

Fortnightly, vol 134, no 2, January 15, 1996, pp 30-34

This article is a review and summary of several applications of superconducting equipment in the electric utility industry. These applications include the SSD, a low-temperature SMES device used to balance out power fluctuations. This device can be installed at the user or on the grid. Currently available at 3 MJ, capacities of 12 MJ are anticipated by 1997 and 30 MJ by 2000. Other applications include current limiters and power transformers. Superconducting transmission cables are in the near future.

[1997] 14A - 133

SUPERSMES AS A UNIVERSAL POWER QUALITY CONTROLLER USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE

Ise, T.; Hayashi, T.; Ishii, J.; Kumagai, S.; Mitani, Y.; Tsuji, K.

Dept of Elec Eng, Osaka Univ, Japan

Proceedings, 10th Int'l Power Quality '97 Power Value '97 Conf, Baltimore, MD, September 9-12, 1997, pp 394-403

The SuperSMES is composed of inverters connected in series and parallel to a power system and a superconducting magnet for absorbing and discharging transient energy during operation. It is expected that the SuperSMES cannot only enhance power system stability, but also compensate voltage and load power fluctuations, current and voltage harmonics and act as dynamic voltage restorer which can compensate voltage sags, swells and so on. An experimental mini model with 10-kJ superconducting magnet has been developed.

As a first step, its performance for power system stabilizing control was examined. It was shown that not only transient stability but also dynamic stability can be improved.

[1997] 14A - 134

SWITCHING CHARACTERISTICS OF A MAGNETIC PCS AT 1 KA PERSISTENT CURRENT MODE

Sadakata, N.; Goto, K.; Saitoh, T.; Kohno, O.; Matsukawa, M.; Noto, K.; Honma, H.

Fujikura Ltd, Tokyo, Japan

Proceedings, 9th Int'l Symp on Superconductivity (ISS'96). Sapporo, Japan, October 21-24, 1996, vol 2, pp 1422-1436

Magnetic persistent current switch is expected to perform fast switching operation for a superconducting magnetic energy storage (SMES) system because its switching speed theoretically depends on the external magnetic field sweep to the critical field of the conductor. A small non-inductively wound 1 Omega model PCS windings using 1-kAclass magnetic PCS multi-stranded conductor was fabricated to examine its switching performance. A persistent current circuit with 7-kJ superconducting storage magnet was constructed, and its switching performance at persistent current mode at 1-kA current flow were tested and investigated.

[1997] 14A - 135

TEST RESULTS OF A 1.5 KA HTS CURRENT LEAD FOR MICRO SMES

Pfotenhauer, J.M.; Lokken, O.D.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 363-366

A pair of 1.5-kA current leads incorporating a conventional (copper) upper stage, a lower BSCCO stage, and intermediate cooling from a twin-cold-finger GM cryocooler have been designed, fabricated and tested. A lower stage has been fabricated and tested using a stacked-tape sample of BSCCO-2223 material donated by American Superconductor Corporation. Test results characterize the helium boil-off rate, cryocooler power consumed, and joint resistances measured during the base line operation of the current leads at various currents. Additionally, the transient performance of the leads in response to a loss of cooling is reported. Here the temperatures and voltage drops at significant locations on the leads are reported as a function of time for the various operation conditions. Test results show that the most significant factor in determining the allowable operation time subsequent to a loss of cooling is the thermal inertia of the cold bus connecting the current leads to the cryocooler. The current leads are designed for use in a micro SMES system and incorporate the necessary lead-to-lead voltage isolation within the body of the cryocooler. 3 Refs.

[1996] 14A - 136

THE SITUATION AND PROSPECTS OF SMES AS WORKED OUT WITHIN THE IEA IMPLEMENTING AGREEMENT ON SUPERCONDUCTIVITY

Komarek, P.

Kernforschungszentrum, Karlsruhe, Germany

Energy Storage Technologies for Utility Network Optimisation Conf, Capenhurst, UK, April 18-19, 1996, p 13

By the summer of 1990 an IEA Implementing Agreement for a Co-Operative Program for Assessing the Impacts of High-Temperature Superconductivity on the Electric Power Sector was signed. In 1995, by unanimous vote of all participants and subsequent approval of the IEA Governing Board, the Implementing Agreement (IA) has been prolonged for another 5 years. The IA calls for Argonne National Laboratory (ANL) to act for the USDOE as the Agreement's Operating Agent. ANL performs three subtasks with the participation of the member countries. SubTask I was to create and subsequently keep current a directory of all the relevant activity in each member's country. SubTask II was to summarize and synthesize assessments already performed within members countries. SubTask III calls for reports, each describing a topic of common interest. These topics have included: High Amperage Conductors, HTS Use in Generators and Motors, Refrigeration for HTS, Progress toward superconducting magnetic energy storage (SMES), Modeling Behavior of Power System Using Superconducting Devices, Cables and Fault Current Limiters.

[1997] 14A - 137

THE UNITED STATES AIR FORCE'S MICRO-SUPERCONDUCTING MAGNETIC ENERGY STORAGE TECHNOLOGY INSERTION PROGRAM PROJECT RESULTS

Abel, T.R.

Div of Integrated Tech, Sci Applications Intl Corp, USA

Proceedings, 10th Int'l Power Quality '97 Power Value '97 Conf, Baltimore, MD, September 9-12, 1997, pp 404-417

Science Applications International Corp., under contract to the US Air Force's Power Conditioning Equipment (PCE) Materiel Group, initiated the Micro SMES program on September 28, 1993, to field and evaluate superconducting magnetic energy storage devices in the power quality application area. The PCE Materiel Group Manager received funding from the Defense Nuclear Agency (DNA) to accomplish this effort. This four-year program field-tested micro-SMES systems on government facilities and evaluated their effectiveness as an alternative to other power quality commercial products. This program has benefited from the strong interest and support of government and industry representatives and provided a boost to the academic community and aids in the transfer of the micro-SMES technology. The final SMES product has potential for sales in the entire world market and thereby boosting the US economy. This effort is an ideal example of using government funding to provide a means of transferring military technology to the US commercial industry.

[1996] 14A - 138

THERMAL AND ELECTRICAL STABILIZATION OF HIGH-TEMPERATURE SUPERCONDUCTOR POWDER-IN-TUBE CONDUCTOR

Niemann, R.C.; Evans, D.J.; Rey, C.M.

Argonne Natl Lab, Argonne, IL, USA

Applied Superconductivity, vol 4, no 3, March 1996, pp 157-165

High-temperature superconductor (HTS) powder-in-tube conductors often require thermal and/or electrical stabilization to ensure their long-term integrity. An example of such a stabilization need is the safety bypass lead of an HTS current lead intended for application to superconducting magnetic energy storage (SMES) devices. The bypass lead functions include current sharing during upset conditions and conductor element temperature control. This paper presents a bypass lead design for an HTS current lead in an 0.5-MWh SMES system. Included are predictions of thermal and electrical stabilization and current lead heat leaks. The results of a supporting development program are presented, as are details of a method to connect conductor element/bypass leads, an assembly procedure, a cleaning method, and thermal-stress tolerance measurements. 9 Refs.

[1996] 14A - 139

USE OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR ACTIVE POWER CONTROL

Zaviska, O.; Reichel, H.

Siemens AG, Erlangen, Germany

Automatisierungstechnische Praxis (Germany), vol 38, no 9, pp 33-34, 36-38, 40-41

German

Requirements for rapid power increase capability in power plants are met by a number of measures which are all based on use of stored energy. To date, the stored heat in the steam generator and in the water/steam circuit have been exploited for primary control purposes. Advances in the field of superconductors have yielded a new type of energy storage suitable for use to cover the needs of such rapid power increases-superconducting magnetic energy storage (SMES). The present article describes the use of an SMES for active power control on the basis of a dynamic model of a power plant unit. 9 Refs.

[1996] 14A - 140

UTILITY BENEFITS OF SMES IN THE PACIFIC NORTHWEST

Eckroad, S. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-104802, September 1996, 110 pp

Superconducting magnetic energy storage (SMES) is an emerging technology expected to have wide-spread asset value in the electric utility industry. This project updates an earlier assessment of SMES benefits in the Pacific Northwest by estimating net present values of several system-specific application scenarios with the SMES cost model developed by EPRI.

[1996] 14A - 141

UTILITY ENERGY STORAGE APPLICATIONS STUDIES

Schoenung, S.M.; Burns, C.

Longitude 122 West Inc, Menlo Park, CA, USA

IEEE Trans on Energy Conversion, vol 11, no 3, September 1996, pp 658-665

The values of benefits and costs have been estimated for applying energy storage to three situations on the Niagara Mohawk Power Corporation system, One situation is a valuable industrial customer requiring high quality, reliable power. The second situation is the need for reliable power at the end of a radial distribution feeder. The third situation is a case of thermal overload on a transmission line to a growing load in an environmentally sensitive location. The first case requires a small storage system (30 MJ); the second and third require relatively large systems (250 and 550 MWh, respectively). A variety of energy storage technologies was considered for each case: superconducting magnet energy storage (SMES), batteries, flywheels, capacitors, compressed air energy storage (CAES), compressed air in vessels, and pumped hydro. This paper presents the benefit/cost results for the technologies considered for each case. 9 Refs.

[1996] 14A - 142

UTILITY TESTS SUPERCONDUCTING TECHNOLOGY AS PART OF POWER-QUALITY PROGRAM

Coney, R.G.; Koeppe, P.F.

Electric Power Int'l, February 1996, pp 52-53

Long transmission lines serving large industrial loads, very high lightning activity, and flashovers present significant challenges to the Eskom electric utility, South Africa. Here, the authors describe how Eskom is testing the application of SMES technology to the improvement of power system supply quality. 0 Refs.

[1997] 14A - 143

VARIABLE COMPOSITION NBTI SUPERCONDUCTORS PRODUCED BY ARTIFICIAL PINNING CENTER PROCESS

Wong, T.; Rudziak, M.K.; Seuntjens, J.M.; Wong, J.

Supercon, Inc, Shrewsbury, MA, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 2, June 1997, pp 1126-1129

An artificial pinning center (APC) process, that utilizes pure niobium and titanium as the starting material, has been used to manufacture NbTi superconductors. The Ti content has been varied from 45.4 wt% to 59.3 wt% by adjusting the relative thicknesses of the Nb and Ti sheets in the starting monofilaments. Any composition can be produced in this manner, as compared to the conventional alloy which is commercially available in only one composition. The higher Ti content is designed to improve critical current density (J_c) in the low field range (less than 5 T) and lower raw material costs, thus reducing the overall cost to the end user. The APC process does not suffer from the poorer ductility of the conventional NbTi approach when utilizing higher Ti content alloys. The new conductors would be suitable for applications such as magnetic resonance imaging (MRI), superconducting magnetic energy storage (SMES) and detector magnets. 7 Refs.

[1997] 14A - 144

WELDED SPLICE DESIGN IN A MID-SIZE SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM

Tong, W.

Naval Nuclear Fuel Div, Lynchburg, VA, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 977-980

The splice design is one of the most important issues in the design of a superconducting magnetic energy storage (SMES) system. A welded splice is made by overlapping two sheath-free stabilized conductors and welding at the sides of the contact interface. To achieve the ultimate goal in the SMES reliability, one of the primary concerns is the electrical resistance across welded joints though high-purity aluminum (HPA) stabilizers. Highly resistive welds could lead to conductor instability. This paper addresses the splice design for a 30-MW, 1800-MJ mid-size SMES system. The splices are required to transmit current at the level of 16,000 A under the normal operating conditions. Gas-tungsten arc welding has been chosen as the joining method for its high reliability, high quality, low distortion, and low cost. The welding setup and welding parameters were determined for the present splice design. Other design issues such as the splice protection, support, and cooling, have been also addressed. 7 Refs.

[1997] 14A - REF

INVESTIGATION ON THE RAMP-RATE LIMITATION OF SUPERCONDUCTING CICC (CABLE-IN CONDUIT CONDUCTOR)

For Abstract see entry 04C - 2

[1997] 14A - REF

NOVEL SIMULATION SCHEME OF POWER ELECTRONICS SYSTEM WITH THE PARALLEL INFERENCE MACHINE (PIM)

For Abstract see entry 06E - 9

[1996] 14A - REF

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

For Abstract see entry 07A - 17

[1996] 14A - REF

SUPERCONDUCTING STORAGE SYSTEMS: AN OVERVIEW

For Abstract see entry 07A - 60

[1996] 14A - REF

UNBUNDLED PRODUCTS AND THE POTENTIAL ROLE OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE IN A COMPETITIVE ELECTRIC MARKETPLACE

For Abstract see entry 07A - 74

[1997] 14A - REF

WHO SAYS YOU CAN'T STORE ELECTRICITY?

For Abstract see entry 07A - 80

[1996] 14A - REF

WEST COAST UTILITY TRANSMISSION BENEFITS OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE. FINAL REPORT

For Abstract see entry 07B - 68

[1997] 14A - REF

APPLICATION OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR THIRD RAIL VOLTAGE SUPPORT

For Abstract see entry 07B - 9

[1996] 14A - REF

STUDY OF SMES FOR POWER SYSTEM STABILIZATION

For Abstract see entry 14A - 121

[1997] 14A - REF

POWER SYSTEM STABILITY BY SMES AND SELF-COMMUTATED STATIC VAR COMPENSATOR

For Abstract see entry 14A - 90

[1996] 14A - REF

MOTOR MODELS AND TRANSIENT ANALYSIS FOR HIGH-TEMPERATURE SUPERCONDUCTOR SWITCH-BASED ADJUSTABLE SPEED DRIVE APPLICATIONS

For Abstract see entry 17B - 19

[1996] 14A - REF

MULTILEVEL CURRENT SOURCE INVERTER - THE SWITCHING CONTROL STRATEGY FOR HIGH POWER APPLICATION

For Abstract see entry 17B - 22

[1996] 14A - REF

A GEOMETRIC APPROACH TO DESIGNING OF FILTER FOR SMES

For Abstract see entry 17C - 1

[1997] 14A - REF

IMPROVEMENT OF TRANSIENT STABILITY LIMIT IN POWER SYSTEM TRANSMISSION LINES USING FUZZY CONTROL OF FACTS DEVICES

For Abstract see entry 18A - 22

[1998] 14A - REF

POWER FLOW DURING POWER SYSTEM STABILIZING CONTROL BY A SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SUPERSMES)

For Abstract see entry 18C - 12

[1997] 14A - REF

COORDINATED SMES AND VARIABLE SERIES IMPEDANCE FOR LOAD FREQUENCY CONTROL

For Abstract see entry 18C - 5

[1997] 14A - REF

DEVELOPMENT OF A MINI-MODEL OF A

SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SUPERSMES) AND EXPERIMENT OF POWER SYSTEM STABILIZING CONTROL

For Abstract see entry 19E - 14

[1998] 14A - REF

A SIMULATOR OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE AND AN EXPERIMENT OF LEVELING LOAD POWER FLUCTUATION

For Abstract see entry 19E - 5

[1997] 14A - REF

A SIMULATOR OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE AND AN EXAMINATION OF A CONTROL STRATEGY FOR LEVELING LOAD POWER FLUCTUATION

For Abstract see entry 19E - 6

14B Battery Energy Storage Systems (BESS)

[1997] 14B - 1

A LOAD MANAGEMENT SYSTEM USING PHOTOVOLTAIC AND BATTERY ENERGY STORAGE

Huang, Cl-L.; Tsai, M.-T.; Lin, C.-E.; Yuan, C.-M.

Dept of Elec Eng, Natl Cheng Kung Univ, Tainan, Taiwan

Proceedings, National Science Council, Republic of China, Part A (Physical Science and Engineering) (Taiwan), vol 21, no 1, January 1997, pp 85-95

This paper describes a hybrid photovoltaic and battery energy storage system (PVBESS) which consists of a step-up chopper used to boost the solar panel voltage to a variable level and a current-mode controlled bilateral converter used to transfer the energy between the PVBESS and utility. The proposed PVBESS operates in two modes: one is the parallel processing mode, which can play a role as an active filter, a power conditioner, or a voltage stabilizer; the other is the stand-alone mode, which acts as a conventional uninterruptible power supply. The basic principle from the conventional control method is used and modified to develop the desired operation function. The proposed theoretical formulations are verified by system analysis and simulation to demonstrate its performance. A laboratory prototype has been fabricated and tested to support the proposed idea of a multifunction PVBESS.

[1998] 14B - 2

A NEW TOPOLOGY OF A BATTERY ENERGY STORAGE SYSTEM

Leung, K.K.; Sutanto, D.

Hong Kong Polytech Univ, China

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO9.3

Abstract not available

[1997] 14B - 3

A STRATEGY FOR LOW-COST UTILITY CONNECTION OF BATTERY ENERGY STORAGE SYSTEMS

Wall, S.; McShane, D.

Wavedriver Ltd, Litlington, UK

Journal of Power Sources (Switzerland), vol 67, no 1-2, pp 193-200

Battery energy storage is a well-known concept that has applications within the electricity supply industry. In a battery energy storage system (BESS), the dc energy in the batteries is exchanged with the dc utility using a power conversion system (PCS). The development of a generic low-cost PCS is identified as being critical to commercial viability of battery energy storage. The paper presents commercial and functional advantages of using a modular approach to power conversion in a BESS. Dynamic models are developed for both single and networked power converters. These are used to demonstrate the technical feasibility of the modular approach. The Wavedriver PCS is presented. This uses a modular network of generic power converters to provide higher functionality. Each power converter incorporates a higher level of systems integration than is usually present in a traditional PCS. This approach changes the balance on the commercial viability of energy storage systems.

[1996] 14B - 4

A STUDY ON ECONOMIC EVALUATION FOR APPLICATION OF THE BATTERY ENERGY STORAGE SYSTEM (BESS)

Kim, E-S.; Kim, H-Y.; Kim, J-C.; Rim, S-S.; Ryoo, Y-D.; Ko, Y.

Korea Electrotech Research Inst, Changwon, South Korea

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 1288-1292

The battery energy storage system (BESS) can help the load factor improve by discharging the battery energy when the load is peak in the daytime. BESS has the advantages such as spinning reserve, control of voltage and frequency, deferment of investment for generation and transmission capacity construction, and reliability improvement of utility power service. To develop BESS and to apply it to Korea's power system, economic evaluation must be performed. In this paper, we analyzed the investment costs, by modifying and complementing the SysplanModel, through the economic assessment. 5 Refs.

[1996] 14B - 5

ANNUAL PROGRESS REPORT ON THE DEVELOPMENT OF A 2 MW/10 SECOND BATTERY ENERGY STORAGE SYSTEM FOR POWER DISTURBANCE PROTECTION

Omnion Power Engineering Corp.

Omnion Power Eng Corp, East Troy, WI, USA

U.S. Department of Energy, DOE/AL/99852-TI (DE 96005072), January 29, 1996, 23 pp

Sandia National Laboratories (SNL), acting for the US Department of Energy (DOE), contracts for and administers programs for the purpose of promoting the development and commercialization of large scale, transportable battery energy storage systems. Under DOE Co-Op Agreement No. DE-FC04-94AL99852, SNL has contracted for the development and delivery of an initial prototype 250-kW bridge that becomes an integral subsystem of a 2-MW/10-second system that can be used by utility customers to protect power sensitive equipment from power disturbances. Development work includes field installation and testing of the prototype unit at a participating utility site for extended product testing with subsequent relocation to an industrial or commercial participating utility customer site for additional evaluation. The program described by the referenced document calls for cost sharing with the successful bidder and eventual title transfer to the participating utility. Prototype delivery is scheduled for January of 1996, with a period of two years allowed for field testing. A final report summarizing the test data with conclusions and recommendations is part of the contract.

[1998] 14B - 6

APPLICATION OF AN ENERGY SOURCE POWER SYSTEM STABILIZER ON THE 10 MW BATTERY ENERGY STORAGE SYSTEM AT CHINO SUBSTATION

Bhargava, B.; Dishaw, G.

Southern California Edison Co, CA, USA

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 145-151

Southern California Edison (SCE) installed a 10-MW battery energy storage system (BESS) at its Chino substation facility in 1988. The BESS facility has been in operation for the last six years and has been used for load leveling and peaking functions. The BESS power conversion system was built with the then state of the art technology and has a very fast response rate when changing power output of the batteries. SCE recently installed an energy source power system stabilizer (ESPSS) to test the concept of providing damping of power system swings using the ESPSS. The ESPSS basically modulates the power output / input of the energy storage batteries to respond to system frequency deviations caused by power system oscillations. The ESPSS differs from a conventional power system stabilizer. It is designed to change the power output of the power source rather than the voltage or the reactive power output. While installing the ESPSS several upgrades to the BESS were made to improve reliability. Installation of the ESPSS on the battery enables SCE to test the concept of system stabilization using power source output modulation instead of reactive power modulation. The energy storage batteries provide an easy test bed for conducting field tests and response of the ESPSS to system disturbances. This paper discusses the BESS, the ESPSS and presents recently recorded results from system disturbance monitoring and field tests conducted on the ESPSS and the batteries. 3 Refs.

[1997] 14B - 7

ASSESSMENT OF UTILITY SIDE COST SAVINGS FROM BATTERY ENERGY STORAGE

Alt, J.T.; Anderson, M.D.; Jungst, R.G.

Univ of Missouri, Rolla, MO, USA

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1112-1120

A method of determining dynamic operating cost benefits of energy storage systems for utility applications is presented. The production costing program DYNASTORE is used to analyze economic benefits for "utility B," an isolated island utility, using heuristic unit commitment algorithms. The unit commitment is done using chronologic load data and a detailed model of the utility characteristics. Several unit commitment scenarios are run for utility B, and the results are presented. Comparisons between various battery energy storage system (BESS) applications, as well as cases with and without battery storage, are shown. Results show that for utility B, a BESS of 300-MW size used for spinning reserve provides the greatest economic benefit. 18 Refs.

[1997] 14B - 8

BASIC DESIGN OF LOAD CONDITIONER

Ishikawa, R.; Iwahori, T.; Yokota, T.

CRIEPI, Tokyo, Japan

Denryoku Chuo Kenkyujo Komae Kenkyujo Kenkyu Hokoku (Japan), no T86087, 44 pp

Japanese

This report describes the basic design of a load conditioner system. The load conditioner is a small-size battery energy storage system which can be installed at a customer's site. It is expected to contribute to efficient and fast load-leveling of electric power demand and to provide benefits for both the customer and electric utility. Specifications for the load conditioner for residential customers are as follows. Output: 2-3 kW; Capacity: 2-8 kWh; I/O: one phase, 100V, 50(60) Hz; Operation: 8-hour charge/8-hour discharge; Efficiency (target): over 70 percent. The estimated cost of load conditioner is comparatively expensive. The cost reduction of both battery and power conditioning system is necessary for commercialization.

[1996] 14B - 9

BATTERY ENERGY STORAGE SYSTEMS FOR ELECTRIC UTILITY, INDUSTRIAL AND COMMERCIAL APPLICATIONS

Miller, N.W.; Zrebiec, R.S.; Delmerico, R.W.; Hunt, G.

GE Power Sys Eng Consulting, Schenectady, NY, USA

Proceedings, 11th Battery Conf on Applications and Advances, Long Beach, CA, January 9-12, 1996, pp 235-240

Voltage depressions and power interruptions are rapidly becoming two of the hottest topics in the field of power quality. Of particular interest is the need to supply a dependable, efficient and controllable source of real and reactive power, which is available instantly to support a large (>0.5-MVA) load, even if the utility connection is lost. This paper describes a versatile solution to this problem for utility, industrial and commercial applications using battery energy storage systems (BESS). BESS have the potential to provide other substantial benefits in terms of improved voltage and energy management in conjunction with this protection from interruptions. 3 Refs.

[1996] 14B - 10

BATTERY ENERGY STORAGE SYSTEMS AS A SOLUTION FOR PREMIUM POWER QUALITY

Nerbun, W.J.

AC Battery Corp, East Troy, WI, USA

National Engineer, vol 100, no 12, December 1996, pp 13-21

Voltage sags and power outages pose serious problems for many commercial and industrial power consumers with sensitive microprocessor-controlled equipment. Recent studies have indicated that 95% of all power problems occur when power is "disrupted" for 5 seconds or less. For those customers who normally have a 1- or 2-MVA service, a conventional uninterruptable power supply (UPS) can be an inappropriate solution. As an alternative, AC Battery Corporation has developed a 2-MVA/10 second power quality system designed to eliminate power disturbances. The PQ2000 provides immediate response capacity appropriate for short duration, high-energy discharges. The PQ2000 power quality system dynamically disconnects critical loads from the utility and seamlessly transfers the load to battery power within approximately one quarter cycle. The PQ2000 draws from existing technologies and products that are commercially available today. The system combines mature battery energy storage technology with advanced power switching and sophisticated power conversion techniques to produce a new category of power quality protection devices for large industrial and commercial power consumers. Markets targeted for distribution include semiconductor manufacturers, hospitals, chemical processing plants, automated manufacturing facilities, biotechnology

firms, data centers and other communications facilities with critical or sensitive transactions.

[1998] 14B - 11

BATTERY ENERGY STORAGE SYSTEMS FOR SUSTAINABLE ENERGY DEVELOPMENT IN ASIA

Sutanto, D.; Lachs, W.R.

Hong Kong Polytech Univ, China

Electric Power Systems Research, vol 44, no 1, January 1998, pp 61-67

The process of power system generation expansion planning to meet forecasted load demand and shows that such a planning process is very expensive is reviewed. The increase in generation capacity is mainly determined by the annual peak demand which only occurs for a very short period of time in a year. The use of battery energy storage system (BESS) significantly improve the utilization and efficiency of the generating units by improving the load factor, allowing deferral of generation expansion and hence reduction in pollution level. The introduction of electric vehicles will accelerate the availability of BESS and provide support continuing economic growth, provide energy security and reliability and meet environmental considerations. 7 Refs.

[1997] 14B - 12

BIDIRECTIONAL VOLTAGE-FED THREE PHASE PWM CONVERTER WITH RESONANT DC LINK FOR BATTERY ENERGY STORAGE SYSTEM

Hiraki, E.; Kurokawa, M.; Nakaoka, M.; Sugimoto, S.

Dept of Elec & Electrn Eng, Yamaguchi Univ, Japan

Proceedings, 2nd Int'l Telecommunications Energy Special Conf (Telescon 97), Budapest, Hungary, April 22-24, 1997, pp 191-197

In this paper, a prototype of a resonant dc link (RDCL) bidirectional voltage-fed converter operating at zero voltage switching PWM mode for a battery energy storage system (BESS) is presented. The operating principle of this RDCL circuit and multi-function controlled-base converter, including soft-switched PWM inverter operation mode in which energy flows through from a battery bank to the three-phase utility-grid ac source and an active soft switched PWM converter operation mode in which energy flows through from utility-grid to source battery bank are described. The multi-functional operation characteristics of this three-phase soft-switching ZVS-PWM converter with RDCL for BESS is demonstrated including peak-cut mode, battery charging mode, reactive current compensation mode and active power filtering mode in comparison with three-phase hard-switching PWM bidirectional converter for BESS, and its effectiveness is proved by simulation analysis.

[1998] 14B - 13

CONTROL STRATEGIES TO DAMP INTER-AREA OSCILLATIONS USING A BATTERY ENERGY STORAGE SYSTEM

Tsang, M.W.; Sutano, D.

Hong Kong Polytech Univ, China

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO8.7

Abstract not available

[1996] 14B - 14

DESIGN AND COMMISSIONING OF A 5 MVA, 2.5 MWH BATTERY ENERGY STORAGE SYSTEM

Miller, N.W.; Zrebiec, R.S.; Delmerico, R.W.; Hunt, G.

GE Power Sys Eng Consulting, Schenectady, NY, USA

Proceedings, 14th IEEE T&D Conf Conf, Los Angeles, CA, September 15-20, 1996, pp 339-345

Momentary and sustained power interruptions are some of the most difficult and important power quality problems facing many industrial and commercial users. Battery energy storage systems (BESS) have the potential to provide versatile solutions to this problem for utility, industrial and commercial applications. This paper describes the design and commissioning of a 5-MVA, 2.5-MWh BESS which is now in operation at the GNB Battery Recycling Plant in Vernon, California. The BESS at Vernon provides the required power combined with both voltage and frequency control to allow the plant to tolerate disconnection from the utility grid without suffering unacceptable impacts on critical loads. 3 Refs.

[1997] 14B - 15

DESIGN AND COMMISSIONING OF A 2.5 MWH BATTERY ENERGY STORAGE SYSTEM

Miller, N.W.; Zrebiec, R.S.; Delmerico, R.W.; Hunt, G.

GE Power Sys Eng Consulting, Schenectady, NY, USA

Proceedings, 14th Int'l Conf and Exhibition on Electricity Distribution (CIRED), Birmingham, UK, June 2-5, 1997, IEE Pub. no 438, pt 1/2, pp 2.10.1-2.10.5. IEE, Stevenage, England

Momentary and sustained power interruptions are one of the most difficult and important power quality problems facing many industrial and commercial users. A particularly challenging problem is the need to supply an economical, dependable, efficient and controllable source of real and reactive power, which is available instantly to support a large (greater than 1.0 MW) load, if the utility connection is lost. Battery energy storage systems (BESS) have the potential to provide versatile solutions to this problem for utility, industrial and commercial applications. This paper describes the design and installation 5-MW peak, 2.5-MWh BESS which is now in commercial operation at the BNG Battery Recycling Facility in Vernon, California. Results of commissioning test are discussed. The BESS at Vernon provides the required power combined with both voltage and frequency control necessary to allow the Vernon facility to tolerate disconnection from the utility grid without suffering unacceptable impacts on critical loads. 3 Refs.

[1997] 14B - 16

DESIGN AND COMMISSIONING OF A VALVE-REGULATED LEAD/ACID BATTERY ENERGY-STORAGE SYSTEM FOR BACKING UP CRITICAL ENVIRONMENTAL LOADS

Hunt, G.W.

GNB Technologies, Lombard, IL, USA

Journal of Power Sources (Switzerland), vol 67, no 1-2, pp 179-186

Momentary and sustained electrical power interruptions and voltage depressions represent two of the most difficult and important power quality and delivery problems that face many industrial and commercial users. There is a definite need at many industrial processing plants and commercial users of electrical power to have a dependable, efficient and controllable source of real and reactive power that is available instantly to support large electrical loads (greater than 5 MVA), even if the incoming utility ac connection is lost. When power is interrupted or lost, the results can be extremely disruptive for critical processes and cause lost production, costly downtime and loss of customer good will, and in certain industries, can lead to environmental damage through the release of toxic emissions into the air. Recently, this challenge was faced by GNB Technologies at its lead reclaiming and smelting facility in Vernon, CA, USA. This study describes a versatile, cost-effective, workable solution to the problem that has resulted in the design and installation of a 5-MVA, 3.5-MWh battery energy storage system (BESS) which provides uninterruptible power to the critical environmental control equipment throughout the plant. The BESS at Vernon provides the required power, combined with both voltage and frequency control, to allow the plant to tolerate disconnection from the utility grid without suffering unacceptable impacts on critical loads. The system also provides the company with a demand-side energy management system for conducting daily peak shaving of energy demand and, thereby, reduces its electrical bills.

[1996] 14B - 17

DETERMINATION OF THE INSTALLATION SITE AND OPTIMAL CAPACITY OF THE BATTERY ENERGY STORAGE SYSTEM FOR LOAD LEVELING

Jung, K-H.; Kim, H-Y.; Rho, D-S.

POSCO Research Inst, Seoul, South Korea

IEEE Trans on Energy Conversion, vol 11, no 1, March 1996, pp 162-167

This study aims to show methods of determining the installation site and the optimal capacity of a battery energy storage system (BESS) to attain load leveling. The methods are based on the hardware characteristics of 20-kW/100-kWh and 1-MW/4-MWh prototype BESSs, which are already developed and are being developed, respectively. The candidate site of BESS installation is the secondary side of a distribution substation's main transformer (MTR). These tasks are performed by first classifying the load pattern of an MTR and comparing it to the load pattern of a total power system. If the load factor improves, then the location is determined to be a BESS installation site. Subsequently, the optimal BESS capacity for an MTR is determined using the given operation pattern, the charging/discharging characteristics and efficiency. Computational experimentation was performed on an actual distribution system in Korea. After determining the optimal capacity, the authors verified that installing the BESS on the selected MTR improved both daily and nightly load factors. 12 Refs.

[1997] 14B - 18

DEVELOPMENT OF UNINTERRUPTIBLE SECONDARY BATTERY SYSTEM

Ohshima, M.; Miyazaki, S.; Inagaki, K.; Kikuchi, H.; Nirasawa, H.

Tokyo Elec Power Co, Inc, Yokohama-shi, Japan

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3, 1997, vol 2, pp 707-710

This paper presents the system configuration and control schemes of USBS (Uninterruptible Secondary Battery System), which acts as BESS when no fault occurs in commercial power network and functions as UPS in case of fault of the network. If some fault such as a voltage interruption occurs on the network, USBS disconnects critical loads from it at instant, and supply power to them as a UPS. It takes less than 2 ms to restart supplying power to the loads in case of emergency, so there happens no damage on them. Simulations and experimental tests are carried out to confirm feasibility of the proposed system. 3 Refs.

[1996] 14B - 19

DYNASTORE OPERATING COST ANALYSIS OF ENERGY STORAGE FOR A MIDWEST UTILITY

Anderson, M.D.; Jungst, R.G.

Univ of Missouri, Rolla, MO, USA

Proceedings, 29th Frontiers of Power Conf, Oklahoma State University, Stillwater, OK, October 28-29, 1996, 6 pp

The objective of this project was to determine the savings in utility operating costs that could be obtained by installing a battery energy storage system (BESS). The target utility was Kansas City Power and Light (KCPL), a typical midwestern utility with a mix of generating plants and many interconnections. The following applications of battery energy storage were modeled using an Electric Power Research Institute (EPRI) developed and supported program called DYNASTORE: (1) spinning reserve only, (2) load leveling with spinning reserve, (3) load leveling only, and (4) frequency control. DYNASTORE commits energy storage units along with generating units and calculates operating costs with and without energy storage, so that savings can be estimated. Typical weeks of hourly load data are used to make up a yearly load profile. For this study, the BESS power ranged from "small" to 300 MW (greater than the spinning reserve requirement). BESS storage time ranged from 1 to 8 hours duration (to cover the time-width of most peaks). Savings in operating costs were calculated for each of many sizes of MW capacity and duration. Graphs were plotted to enable the reader to readily see what size of BESS affords the greatest savings in operating costs. 13 Refs.

[1998] 14B - 20

ECONOMIC DISPATCH AND OPTIMAL SIZING OF BATTERY ENERGY STORAGE SYSTEMS IN UTILITY LOAD-LEVELING OPERATIONS

Lo, C.H.; Anderson, M.D.

Univ of Missouri, Rolla, MO, USA

IEEE Trans on Power Delivery, Preprint order number PE-385-EC-0-2-1998

Battery energy storage (BES) systems show promise of savings for both the utility and the customer. An algorithm combining multi-pass dynamic programming (MPDP) with a time-shift technique has been developed for two purposes: economic dispatch of BES and finding optimal BES power and energy capacity in power system. Due to the daily cyclic nature of the load curve, a 168-hour load curve is decomposed into seven 24-hour subsections for easy management. Each subsection is treated independently. Decomposition can save computation time and computer memory. A time-shift technique provides better starting state values and improves the finding process of the MPDP approach. The Kansas City Power and Light system is used as an example to test this algorithm. The results obtained in this research have been compared with those from EPRI's DYNASTORE with reasonable discrepancy.

[1996] 14B - 21

FINAL REPORT ON THE DEVELOPMENT OF A 2 MW/10 SECOND BATTERY ENERGY STORAGE SYSTEM FOR POWER DISTURBANCE PROTECTION

Omnion Power Engineering Corp, East Troy, WI, USA

U.S. Department of Energy, DOE/AL/99852-T2, December 11, 1996, 37 pp

Voltage sags, swells and momentary power interruptions lasting a few cycles to several seconds are common disturbances on utility power distribution systems. These disturbances are a result of normal utility recloser switching activity due in part to distribution system short circuits from natural causes such as lightning, rodents, traffic accidents, and current overloads. Power disturbances pose serious problems for many customers with critical, voltage sensitive

equipment. Faults can interrupt a manufacturing process, cause PLC's to initialize their programmed logic and restart equipment out of sequence, create computer data errors, interrupt communications, lockup PC keyboards and cause equipment to malfunction. These momentary disturbances result in billions of dollars of lost productivity annually due to downtime, cleanup, lost production and the loss of customer confidence in the business. This report describes prototype development work for a factory assembled 2-MW/10-second battery energy storage system. The system design includes (1) a modular battery energy storage system comprised of several strings of batteries-each string provided with an integral power conversion system (PCS), (2) an electronic selector device (ESD) comprised of a solid-state static switch with sensing and power switching controls, and utility interconnection termination bus bars, and (3) a separate isolation transformer to step-up PCS output voltage to interface directly with the distribution transformer serving the industrial or commercial customer. The system monitors the utility distribution system voltage for voltage sags, swells, and interruptions, switches the customer's critical loads from utility power to the energy stored in the systems batteries and provides up to 2 MVA until the disturbance clears or up to 10 seconds. Once the ESD sensing circuits have confirmed that the utility is again stable, it seamlessly returns the critical load to the utility. 22 figs., 1 tab.

[1997] 14B - 22

FUNDAMENTAL STUDY ON MULTIPURPOSE SODIUM-SULFUR BATTERY ENERGY STORAGE SYSTEM

Amano, M.; Yoshikawa, T.

Hitachi, Ltd, Japan

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 270-271

Japanese

Abstract not available.

[1997] 14B - 23

MODELING OF BATTERY ENERGY STORAGE IN THE NATIONAL ENERGY MODELING SYSTEM

Swaminathan, S.; Flynn, W.T.; Sen, R.K.

Sentech, Inc, Bethesda, MD, USA

SAND-97-2926 (DE98001719), Sandia National Laboratories., Albuquerque, NM, December 1997, 36 pp

The national energy modeling system (NEMS) developed by the U.S. Department of Energy's Energy Information Administration is a well-recognized model that is used to project the potential impact of new electric generation technologies. The NEMS model does not presently have the capability to model energy storage on the national grid. The scope of this study was to assess the feasibility of, and make recommendations for, the modeling of battery energy storage systems in the electricity market of the NEMS. Incorporating storage within the NEMS will allow the national benefits of storage technologies to be evaluated.

[1996] 14B - 24

MULTI-MODULE PARALLEL SMALL BATTERY ENERGY STORAGE SYSTEM

Chiang, S.J.; Liaw, C.M.; Chang, W.C.; Chang, W.Y.

Natl Tsing Hua Univ, Hsinchu, Taiwan

IEEE Trans on Energy Conversion, vol 11, no 1, March 1996, pp 146-154

This paper presents a multi-module parallel single-phase battery energy storage system (BESS). The single module BESS to be paralleled consists of only a full-bridge converter. When the utility is in normal condition, the BESS serves as a power conditioner as well as an active power filter. It can be arranged to charge the battery bank or to share daily peak load. In any case, the current supplied by the utility can be maintained sinusoidal and almost in phase with voltage. When the utility power failure happens, the BESS functions as an inverter to supply uninterruptible power to the load. With the good current sharing feature possessed by this BESS, a central power distribution control scheme with smooth current transfer characteristic is proposed to control the parallel operation of the multi-module BESS. The current sharing of each BESS module can be programmed according to its rating and the load condition. Designs of the power circuit and the central power distribution control scheme are described in detail in this paper. The effectiveness and performance of the proposed parallel BESS are demonstrated by some experimental results. 14 Refs.

[1997] 14B - 25

NOVEL RESONANT DC LINK BIDIRECTIONAL

THREE PHASE PWM CONVERTER FOR BATTERY ENERGY STORAGE SYSTEM

Hiraki, E.; Kurokawa, M.; Sugimoto, S.; Nakaoka, M.

Yamaguchi Univ, Japan

Proceedings, 2nd Int'l IEEE Conf on Power Electronics and Drive Systems (PEDS), Singapore, May 26-29, 1997, vol 1, pp 163-168

In this paper, a simple prototype of quasi-resonant dc link (QRDCL) voltage-fed bidirectional converter operating at zero voltage soft-switching PWM mode is presented for battery energy storage system (BESS). The operating principle of this QRDCL circuit and multi-functional control-based converter system, including PWM inverter mode in which energy flows through from the battery bank to the three-phase utility-grid and an active PWM converter mode in which energy flows through from the utility-grid to the battery bank are described. The multi-functional operation characteristics of this three-phase soft-switching ZVS-PWM bidirectional converter with QRDCL for BESS is demonstrated under the conditions of peak-cut mode and battery charging mode in comparison with three-phase hard-switching PWM bidirectional converter for BESS, and its effectiveness is proved by simulation analysis. 4 Refs.

[1996] 14B - 26

OPERATION CONTROL OF PARALLELED THREE-PHASE BATTERY ENERGY STORAGE SYSTEM

Liaw, C.M.; Jan, L.C.; Wu, W.C.; Chiang, S.J.

Natl Tsing Hua Univ, Hsinchu, Taiwan

IEE Proceedings, Electric Power Applications (UK), vol 143, no 4, July 1996, pp 317-322

Parallel operation for capacity enlargement of three-phase battery energy storage system (three-phase BESS) is presented. The proposed paralleled system consists of some inner-loop parallel-connected current-regulated pulse width modulated (CRPWM) converters, a current command distributor and an outer-loop common controller. Every single-module CRPWM three-phase converter possesses good current tracking control characteristics, so is easy to parallel connect. The proposed current command distributor receives current commands from the common controller and generates suitable current commands for each paralleled converter module according to the proposed current sharing control strategy. The sophisticated system arrangement of the common controller gives the BESS many power processing functions. When it is connected to the utility grid, it can be arranged to give peak load shaving, active power filtering, power factor correction and battery charging. In the event of utility failure the BESS can supply uninterrupted power with low distortion sinusoidal voltage waveform to critical loads. Performance of the proposed paralleled BESS at various operating conditions is demonstrated experimentally. 13 Refs.

[1996] 14B - 27

POWER FLOW MODELLING OF BATTERY ENERGY STORAGE SYSTEMS CONNECTED TO THE ELECTRICAL NETWORK

Burrowes, G.; Hiskens, I.A.; Kalam, A.

Victoria Univ of Tech, Footscray, Austria

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 1, pp 82-85

Battery energy storage systems (BESS) are gaining increasing interest by utilities and industry alike as a management tool to improve system stability and manage load variations. These BESS have the possibility of performing operational functions including: peak shaving; load leveling; voltage control; frequency control; and acting as spinning reserve. Economic factors such as deferral of costs for upgrade of transmission lines and construction of new generating facilities are also added benefits. However it is clear that many of the suggested applications have not yet been fully explored. This paper presents and analyses a BESS model of steady-state operation and discusses its performance in conjunction with its limitations and control. The model is structured to allow incorporation into power flow techniques. The aim is to allow steady-state analysis of electricity supply networks which contain BESSs. The power flow equations describing the BESS provide the interface between the internal state variables of the BESS and the network constraints. BESSs can operate in a number of different control modes. In general, different sets of constraints are required to describe the different control modes. The paper will establish the various modes and provide the appropriate sets of equations. 15 Refs.

[1997] 14B - 28

RESEARCH ON THE OPERATION OF NA-S BATTERY ENERGY STORAGE SYSTEM. PROGRESS IN THE OPERATION TEST OF 100 KW-CLASS NA-S BATTERY

Sakabe, T.

Chubu Elec Power Co, Ltd, Japan

Chubu Denryoku K.K. Gijutsu Kaihatsu Nyusu (Japan), no 73, pp 13-14

Japanese

100 kW-class Na-S battery energy storage system, which was started operation in January 1996 was carried out a charge and discharge test of approximately 300 cycles by the end of May 1997. It was operated with a battery energy efficiency (dc) of 90% or higher and no failure or other trouble occurred. Concerning the flexibility of operation, it was confirmed through the examination of the peak-cutting high-output operational conditions that continuous double-output operation was possible. We will continue a cycle life test and will study a practical a plant.

[1998] 14B - 29

SHORT TERM GENERATION SCHEDULING IN PHOTOVOLTAIC-UTILITY GRID WITH BATTERY STORAGE

Marwali, M.K.C.; Ma, H.; Shahidehpour, S.M.; Abdul-Rahman, K.H.

Illinois Inst of Tech, Chicago, IL, USA

IEEE Trans on Power Delivery (reprints from IEEE Customer Service, 1 (800) 678-4333)

This paper presents an efficient approach to short term resource scheduling for an integrated thermal and photovoltaic-battery generation. The proposed model incorporates battery storage for peak load shaving. Several constraints, including battery capacity, minimum up/down time and ramp rates for thermal units, as well as natural photovoltaic (PV) capacity are considered in the proposed model. A case study composed of 26 thermal units and a PV-battery plant is presented to test the efficiency of the method.

[1997] 14B - 30

SRP DISCOVERS TBESS WAY TO STORE ELECTRICITY

Alteneder, K.P.; Nerbun, W.J.; Eckroad, S.W.

Power Engineering (Barrington, Illinois), vol 101, no 3 March, 1997, 3pp

The partnership between Salt River Project (SRP) and EPRI to build a transportable battery energy storage system (TBES) is reported. The goal of the project is to produce a TBESS capable of multimode operation and of physical relocation for demonstration at multiple sites. SRP and EPRI expect their TBESS project to be a major step forward in the advancement of improved utility asset utilization, electric system reliability and enhanced energy security. A unique and powerful characteristic of the TBESS unit is that it can switch directly from the PM mode to the PQ mode to service a distribution system disturbance.

[1997] 14B - 31

TRANSIENT PROPERTY ANALYSIS OF DISTRIBUTION SYSTEMS INTERCONNECTED WITH BATTERY ENERGY STORAGE SYSTEMS

Kim, E.; Rho, D.; Kim, J.; Kim, J.

Korea Electrotechnology Research Inst

Proceedings of the Annual Conf of Power & Energy Society. IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 8, no 2, pp 3-4

Japanese

Abstract not available.

[1997] 14B - REF

WHO SAYS YOU CAN'T STORE ELECTRICITY?

For Abstract see entry 07A - 80

15 EMERGING SHUNT FACTS DEVICES

15A Thyristor-Controlled Braking Resistor (TCBR)

[1996] 15A - 1

A NEW CONTROL SCHEME FOR DYNAMIC BRAKE

Das, B.; Ghosh, A.; Sachchidanand

Indian Inst of Tech, Kanpur, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 2, 501-507

In this paper, it is shown that the application of a

dynamic brake at the generator terminal significantly enhances the power transfer limit over a transmission line. Two types of dynamic brake configuration have been considered here: a three-phase, bi-directional, full wave, Y-connected phase-controlled ac/ac converter and a three-phase, full wave, thyristor-controlled rectifier bridge. A simple rule-based "on-off" control law for dynamic brake based on the local measurements of generator output power and its derivative is proposed in this paper. Effectiveness of the proposed control law has been validated through detailed digital simulation studies using the PSCAD/EMTDC software.

[1996] 15A - 2

A STUDY ON THE POWER OSCILLATION DAMPING CONTROL OF THYRISTOR CONTROLLED DYNAMIC BRAKING RESISTOR

Kato, M.; Hirose, M.; Uchida, K.; Tanomura, K.; Fujisawa, Y.

Kansai Elec Power Co, Inc, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 254-255

Japanese

Abstract not available.

[1996] 15A - 3

ADMITTANCE CHARACTERISTICS OF THYRISTOR CONTROLLED DYNAMIC BRAKE: PRACTICAL VALIDATION

Chatterji, S.; Nagsarkar, T.K.; Rao, C.S.

Tech Teachers' Training Inst, Chandigarh, India

Proceedings, 9th National Power Systems Conf (NPSC '96), Kanpur, India, 1996, vol 2, pp 507-511

G and B characteristics of a three-phase thyristor bridge with resistive load obtained as the first stage of the laboratory simulation of a thyristor-controlled dynamic brake have been compared with those obtained earlier through mathematical modeling. The details of laboratory simulation consisting of the control of the three-phase thyristor bridge with resistive load through a microprocessor-based triggering mechanism are also given.

[1997] 15A - 4

ISLANDING PROBLEMS OF GRID-CONNECTED WIND TURBINES AND THE USE OF RESISTIVE BRAKES FOR THEIR IMPROVEMENT

Papantoniou, A.; Coonick, A.; Freris, L.; Anderson, M.

Imperial College of Sci, Tech & Med, London, UK

Proceedings, BWEA Conf, Exeter, UK, September 25-27, 1997, pp 257-261

Grid connected wind turbines usually employ induction generators. When autoreclosure relays are used to disconnect the turbine from the grid, the generator might self-excite if sufficient capacitance is present (shunt capacitor banks for power factor correction or SVCs-static VAr compensators). In the absence of a load, the induction generator rotor speed will steadily increase and its stator voltage will rise rapidly. Upon reconnection grave damage may be caused to consumers connected to the same supply node. Such a system is simulated and it is shown that the stator voltage of the self-excited wind turbine generator exceeds the statutory limits to levels that pose serious threat for consumers connected on the same node. It is also shown how a GTO-controlled resistive brake can divert the wind turbine generator power and keep the stator voltage within acceptable limits. This enables fast autoreclosure relays to provide fast reconnection in the presence of nonpersistent faults while maintaining the operation of the wind turbine generator without any additional danger for consumers in the same grid vicinity. The topology and control of such resistive brakes is also discussed as well as their ability to deal with changing wind turbine input power inputs (as a result of the changing wind speed). The integral wind turbine-grid system is modeled and simulated using SABER.

[1996] 15A - 5

STUDY ON POWER SYSTEM STABILITY USING THYRISTOR CONTROLLED SYSTEM DAMPING RESISTOR

Nanbu, M.; Shimomura, M.

Mitsubishi Elec Corp, Japan

Proceedings, Annual Conf of Power & Energy Society, IEE of Japan (Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu), vol 7, no 2, pp 252-253

Japanese

Abstract not available.

[1996] 15A - 6

THYRISTOR CONTROLLED BRAKING RESISTORS TO IMPROVE POWER ELECTRIC SYSTEMS

Ceraolo, M.; Barsali, S.

Pisa Univ, Italy

Energia Elettrica (Italy), vol 73, no 4, July-August 1996, pp 288-294

Italian

The developments in power electronics technology make possible the use in power systems of devices called thyristor-controlled braking resistors. These have the advantage over the traditional (electromechanical) braking resistors or a higher speed of intervention and the possibility to modulate the current, and consequently the power, drawn from the network to which they are connected. In the study, a technique to control these devices is proposed, having the purpose of improving the electromechanical behavior of a transmission system, in terms of both first-swing stability and oscillation damping. 5 Refs.

[1997] 15A - 7

TRANSIENT STABILIZATION USING ADAPTIVE EXCITATION AND DYNAMIC BRAKE CONTROL

Tan, Y.L.; Wang, Y.

School of Elec & Electrn Eng, Nanyang Tech Inst, Singapore

Control Engineering Practice (UK), vol 5, no 3, March 1997, pp 337-346

In the event of severe disturbances, a power system can undergo structural changes, following the clearing of faults by protection gear. The response of the power system is then highly nonlinear. In this paper, a nonlinear adaptive excitation and dynamic brake controller is proposed, to enhance the transient stability of a power system. The thyristor-controlled braking resistor is located near the generator terminal. Nonlinear feedback control laws are found which linearize and decouple the power system. An adaptive control law is used to design the controller. The controller design is based on local measurements, and it is independent of operating points and fault locations. Simulation results demonstrate that the proposed controller can ensure transient stability of the power system under a large sudden fault which may occur at the generator bus terminal.

[1996] 15A - REF

CONTROL MEASURES TO ENSURE DYNAMIC STABILITY OF THE CAHORA BASSA SCHEME AND THE PARALLEL HVAC SYSTEM

For Abstract see entry 05C - 8

[1996] 15A - REF

FACTS EQUIPMENT AND POWER SYSTEM DYNAMICS

For Abstract see entry 07A - 17

[1996] 15A - REF

FUZZY LOGIC SWITCHING OF FACTS DEVICES FOR STABILITY ENHANCEMENT

For Abstract see entry 18A - 17

15B On-Load Tap Changer, Dynamic Voltage Restorer (DVR)

[1997] 15B - 1

A NEW CONCEPT FOR A SOLID-STATE ON-LOAD TAP CHANGERS

Degeneff, R.C.

Rensselaer Polytech Inst, Troy, NY, USA

Proceedings, 14th Biennial Int'l Conf and Exhibition on Electricity Distribution (Distributing Power for the Millennium), Birmingham, UK, June 2-5, 1997, vol 1, pp 7/1-4

This paper presents a new approach for constructing a solid-state on-load tap changer. Through a judicious choice of the tap changer topology and a novel use of the control, the proposed solid-state on-load tap changer uses fewer thyristors of lower rating than conventional thyristor based tap changer configurations. Further, it is able to accomplish the conventional 16 5/8% taps with fewer physical transformer tap winding leads. The tap changer concept has been experimentally verified at Rensselaer Polytechnic Institute. This paper contains a cost comparison for a 13.8-kV 10-MVA transformer and is presented to illustrate the economic potential of this concept. Depending upon the system voltage, power, and % taps, the approach presented can be 20-60% less expensive than previous efforts to realize solid-state on-load tap changers.

[1997] 15B - 2

A NOVEL THYRISTOR-ASSISTED TAP CHANGER SCHEME

Shuttleworth, R.; Power, A.J.; Tian, X.; Jiang, H.; Al Zahaei, B.A.T.

Manchester Univ, UK

Proceedings, 14th Biennial Int'l Conf and Exhibition on Electricity Distribution (Distributing Power for the Millennium), Birmingham, UK, June 2-5, 1997, vol 1, pp 28/1-5

On-load tap-changing power transformers are an essential part of any modern power system, since they allow voltages to be maintained at desired levels despite load changes. This paper describes a new thyristor-assisted tap changing scheme which has selector and divertor units, as in a traditional tap changer, but these need not be in separate compartments. The scheme is shown and its operation is explained in detail. The constituent parts of the tap changer are also described.

[1997] 15B - 3

DEVELOPMENT OF A 300 KVA NOVEL THYRISTOR ASSISTED TAPCHANGER

Jiang, H.; Shuttleworth, R.; Al Zahawi, B.A.T.; Tian, X.; Power, A.

Univ of Manchester, UK

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 117-120

A 300-kVA prototype tapchanger has been successfully developed to prove a novel tap changing scheme. The scheme employs solid-state ac switches to assist tap current transfer and electro-magnetically actuated vacuum switches to take steady-state load current. Switching arcs and tap winding circulating current are almost eliminated from the tap changing process. The novel tap changer has a fast response and the potential for a long service life with low maintenance costs. 4 Refs.

[1996] 15B - 4

DYNAMIC AND TRANSIENT STABILITY ENHANCEMENT BY USE OF FAST CONTROLLED QUADRATURE BOOSTERS IN POWER SYSTEMS

Fang, Y.J.; Macdonald, D.C.

Nanjing Automation Research Inst, China

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 1083-1089

Quadrature boosters (QB) have been widely used to control the power flow distribution between parallel power trans-mission lines. The advent of very fast thyristor/vacuum switch tap changers makes the dynamic quadrature boosters a natural choice of FACTS devices to improve the transient and dynamic stability of power systems. It is shown in this paper that a novel nonlinear control strategy can lead to greatly simplified QB design giving excellent control effects. 11 Refs.

[1996] 15B - 5

RECOVERY VOLTAGE ACROSS TRANSFORMER TAP CHANGER THYRISTOR SWITCH

Smol'nikov, V.L.

Elektrichestvo (Russia), no 12, December 1996, pp 32-36

Russian

The paper considers transient processes that take place during transformer tap changing. To select a class of thyristors in terms of voltage and critical rate of voltage increase, the process of voltage recovery after commutation breaking down by thyristor switches was observed. It is meant that power diodes were imposed on this current commutation process. To decrease the effect of disturbances in a circuit, control electrode-cathode, on the critical rate of voltage increase, it is recommended to choose thyristors by two parameters. 8 Refs.

[1997] 15B - 6

THE DYNAMIC VOLTAGE REGULATOR (DVR) FOR IMPROVING POWER QUALITY

Johansson, T.; Matele, M.L.

ABB Power Sys, Vasteras, Sweden

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol IV-8, pp 61f

Power quality has many aspects. Stability of voltage supply being a primary requirement. It is necessary that at important loads where a stable voltage is critical, a dynamic voltage regulator is employed. The dynamic voltage regulator (DVR) is a new solution from ABB within the power quality field. It is a simple and robust system, protecting critical loads from voltage sags in the feeding system. The DVR makes use of well proven standard components to provide a reliable system. The

DVR is a solution to the increasing demands for high quality power supplies. It is useful at important loads, where a stable voltage is critical. A DVR can also stabilize the voltage during longer voltage dips or sags in the feeding voltage. It improves the power quality at the customer site and can handle most voltage variations, except outage and very deep voltage dips (<0.5 p.u.). A DVR generates no harmonics, thus no additional filtering is required. The basic working principle is very simple, and is best described as a very fast tap changer. Each phase is individually controlled and voltage sags can be compensated within one cycle at mains frequency. The DVR is customized, with the design depending on occurring voltage dips and the required voltage control. The key component is the thyristor-based static electronic tap changer. It is naturally an on-load tap changer and besides the increased speed, the use of thyristors gives advantages such as low losses and elimination of moving parts in the current path. This results in an equipment with high reliability and long service life, minimizing required maintenance. The compact design with a limited number of components makes it very suitable for mobile solutions. ABB can provide DVRs for the protection of critical loads up to 50 MVA at all industrial voltages.

[1996] 15B - REF

FLEXIBLE AC TRANSMISSION SYSTEM DEVICES ON LARGE INTERCONNECTED POWER SYSTEMS

For Abstract see entry 07B - 25

16 EMERGING SERIES FACTS DEVICES

16A Static Synchronous Series Compensator (SSSC)

[1996] 16A - 1

A NEW PWM-CONTROLLED SERIES COMPENSATOR WITH FAST STEP RESPONSE AND LOW HARMONIC DISTORTION

Chu, K.-H.; Pollock, C.

Warwick Univ, Coventry, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 208-213

A new PWM-controlled series compensator (PWM-CSC) is described which provides adjustable capacitive compensation for power system load flow and receiving end voltage improvement. An experimental single-phase radial feed transmission line model has been constructed, using MOS-controlled thyristors. The compensator exhibits a very low level of low order, receiving end voltage harmonic components and minimal transmission line current harmonics are generated into the power system. The PWM-CSC can also provide vernier inductive compensation. The transient response to a step change is fast which facilitates the damping of a power system oscillation after a disturbance. 4 Refs.

[1996] 16A - 2

ADVANCED SERIES COMPENSATOR USING POWER ELECTRONIC SWITCHES

James, D.

Aston Univ, Birmingham, UK

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 776-779

This paper investigates the possibility of using a voltage source inverter (VSI) as a series compensation (Sercom) scheme for use on electricity transmission lines. The studies indicate that the scheme is more flexible than traditional methods of series compensation and has the ability to respond quickly to fluctuations in demand. This is because the gate turn-off (GTO) thyristors in the inverter allow a continuously variable voltage across the capacitive energy store. 3 Refs.

[1996] 16A - 3

AN IMPROVED CONTROL SCHEME FOR SOLID STATE SERIES REACTANCE COMPENSATION

Rigby, B.S.; Harley, R.G.

Dept of Elec Eng, Natal Univ, Durban, South Africa

Proceedings, 6th South African Universities Power Engineering Conf (SAUPEC '96), Witwatersrand, South Africa, January 22-23, 1996, pp 117-120

This paper presents a theoretical analysis and simulation results to highlight the shortcomings of a

FACTS control scheme initially proposed for a solid-state series reactance compensator. A modified control scheme is then proposed to address these shortcomings. Simulation results of this modified scheme indicate that it is in fact sufficiently robust for further investigation as a laboratory prototype. 6 Refs.

[1998] 16A - 4

AN IMPROVED CONTROL SCHEME FOR A SERIES-CAPACITIVE REACTANCE COMPENSATOR BASED ON A VOLTAGE-SOURCE INVERTER

Rigby, B.S.; Harley, R.G.

Univ of Natal, South Africa

IEEE Trans on Industry Applications, vol 34, no 2, March/April 1998, pp 355f

Power utilities have traditionally used series capacitors to increase the power transfer capability of transmission lines, but their widespread use has been limited by concerns for the harmful effects of series resonances. An advanced, controllable series compensator has the potential to avoid such problems and, therefore, allow more efficient use of existing transmission plant. This paper describes a modified control scheme for an advanced series compensator based on a single voltage-source inverter. Practical results from a working prototype demonstrate the ability of the compensator to provide a rapidly controllable magnitude of compensation.

[1996] 16A - 5

AN INVESTIGATION INTO THE USE OF ACTIVE SERIES VOLTAGE INJECTION IN DISTRIBUTION SYSTEMS

Kuypers, K.-H.; Tennakoon, S.B.; Hu, L.; Morrison, R.E.

Staffordshire Univ, Stafford, UK

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 147-152

A possible use of a series compensator as a power quality controller is considered. A system is described based on a pulse width modulation (PWM) power converter to provide voltage injection. It is shown that a series compensator may control voltage fluctuations introduced by a load having fluctuating demand. Although harmonic voltage distortion is also injected by the series compensator, it is shown that this may be controlled by an appropriate choice of impedance for the series injection transformer. 5 Refs.

[1998] 16A - 6

CONVERTIBLE STATIC COMPENSATOR APPLICATION TO THE NEW YORK TRANSMISSION SYSTEM

Fardanesh, B.; Henderson, M.; Shperling, B.; Zelingher, S.; Gyugyi, L.; Schauder, C.; Lam, B.; Mountford, J.; Adapa, R.; Edris, A.-A.

New York Power Authority, NY, USA

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

A new approach to utilization of FACTS controllers providing a multifunctional power flow management device is presented in this paper. The proposed device, named the convertible static compensator (CSC) offers a high degree of operational flexibility and adaptability. The CSC, being a third generation voltage-source-inverter based FACTS controller, includes a control mode never used before. This control mode, called the interline power flow control (IPFC), makes possible control of both real and reactive power on two or more lines with a single controller. It is shown that the CSC applied to New York transmission system maximizes transmission asset utilization as power transfer increases over critical system interfaces.

[1998] 16A - 7

DAMPING CONTROL DESIGN BASED ON TIME-DOMAIN IDENTIFIED MODELS

Leirbukt, A.B.; Chow, J.H.; Larsen, E.C.; Sanchez-Gasca, J.J.

Norwegian Univ of Sci and Tech, Trondheim, Norway

IEEE Trans on Power Delivery, Preprint order number PE-281-PWRS-0-1-1998

This paper presents an integrated approach for designing damping controllers for large power systems. First, a low-order model is identified from a time simulation of the nonlinear power system model. Then an exact multimodal decomposition is used to develop design indices for selecting a appropriate input signal to the controller. The method is illustrated with the design of thyristor-controlled series compensator damping controllers in two test systems.

[1996] 16A - 8

DEVELOPMENT OF A CONTROL SCHEME FOR

A SERIES-CONNECTED SOLID-STATE SYNCHRONOUS VOLTAGE SOURCE

Hatziadoniu, C.J.; Funk, A.T.

Southern Illinois Univ, Carbondale, IL, USA

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 1138-1144

This paper addresses the problem of controlling and modulating the power flow of long transmission lines using a series-connected solid-state synchronous voltage source (SVS). The design of the various control functions of the SVS is presented along with EMTP simulation studies. The results from these studies demonstrate the effectiveness of the proposed approach in regulating the line power and, also, in providing power modulation that can enhance the dynamic and transient performance of the line. 9 Refs.

[1998] 16A - 9

FUZZY LOGIC BASED SUPPLEMENTARY CONTROLLER FOR STATIC SYNCHRONOUS SERIES COMPENSATOR

Kannan, S.; Jayaram, S.; Salama, M.M.A.

Dept of Elec and Computer Eng, Waterloo, Canada

Proceedings, IEEE Canadian Conf on Electrical and Computer Engineering, Waterloo, Ontario, May 1998, vol 1, pp 489f

In recent years, static synchronous series compensators (SSSC) have been gaining a lot of consideration in power systems with respect to increase and control of power flow in transmission lines. In this paper, a fuzzy logic based supplementary controller has been designed for SSSC to improve power system dynamic performance. A signal based on transmission line current has been used as a supplementary signal to the controller. The performance of the fuzzy logic based supplementary controller has been studied on a multi-machine system and the results have been presented.

[1998] 16A - 10

SSSC-STATIC SYNCHRONOUS SERIES COMPENSATOR: THEORY, MODELING, AND APPLICATIONS

Sen, K.K.

Westinghouse Elec Corp, Pittsburgh, PA, USA

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 241-246

This paper describes the theory and the modeling technique of a flexible ac transmission systems (FACTS) device, namely, static synchronous series compensator (SSSC) using an Electromagnetic Transient Program (EMTP) simulation package. The SSSC, a solid-state voltage source inverter coupled with a transformer, is connected in series with a transmission line. An SSSC injects an almost sinusoidal voltage, of variable magnitude, in series with a transmission line. This injected voltage is almost in quadrature with the line current, thereby emulating an inductive or a capacitive reactance in series with the transmission line. This emulated variable reactance, inserted by the injected voltage source, influences the electric power flow in the transmission line. 2 Refs.

[1997] 16A - 11

STATIC SYNCHRONOUS SERIES COMPENSATOR: A SOLID-STATE APPROACH TO THE SERIES COMPENSATION OF TRANSMISSION LINES

Gyugyi, L.; Schauder, C.D.; Sen, K.K.

Westinghouse Elec Corp, USA

IEEE Trans on Power Delivery, vol 12, no 1, January 1997, pp 406-417

This paper describes an active approach to series line compensation, in which a synchronous voltage source, implemented by a gate turn-off thyristor (GTO) based voltage-sourced inverter, is used to provide controllable series compensation. This compensator, called static synchronous series compensator (SSSC), can provide controllable compensating voltage over an identical capacitive and inductive range, independently of the magnitude of the line current. It is immune to classical network resonances. In addition to series reactive compensation, with an external dc power supply it can also compensate the voltage drop across the resistive component of the line impedance. The compensation of the real part of the impedance can maintain high X/R ratio even if the line has very high degree of series compensation. Concurrent and coordinated modulation of reactive and real compensation can greatly increase power oscillation damping. The paper discusses the basic operating and performance characteristics of the SSSC, and compares them to those characterizing the more conventional compensators based on thyristor-switched or controlled series capacitors. It also presents some of the results of TNA simulations carried out with an SSSC hardware model. 12 Refs.

[1996] 16A - 12

THE DEVELOPMENT OF AN ADVANCED

SERIES COMPENSATOR BASED ON A SINGLE VOLTAGE SOURCE INVERTER

Rigby, B.S.; Harley, R.G.

Dept of Elec Eng, Natal Univ, Durban, South Africa

Proceedings, IEEE4th Conf in Africa (AFRICON'96), Stellenbosch, South Africa, September 24-27, 1996, vol 1, pp 215-220

This paper describes the progress of a project to develop a working laboratory prototype of an advanced transmission line series compensator, based on a single voltage source inverter. The paper describes the development of a control scheme suitable for practical implementation of the inverter based compensator idea and presents practical results to confirm the predicted capabilities of this unified power flow controller. Practical results from a working laboratory prototype demonstrate the ability of the compensator to provide a rapidly controllable magnitude of compensating reactance in the transmission line. 8 refs.

[1997] 16A - 13

TRANSFORMERLESS REACTIVE SERIES COMPENSATORS WITH VOLTAGE SOURCE INVERTERS

Stemmler, H.; Beer, A.

Swiss Federal Inst of Tech (ETH), Zurich, Switzerland

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3-6, 1997, vol 1, pp 197-202

This paper proposes a configuration for transformerless connected compensators consisting of voltage source inverters with parallel and series connected capacitors. The behavior of transmission lines and power flow control with reactive series compensators are described. After presentation of the circuits and configurations their mode of operation is shown in more details using an example which is representative for practical applications. 3 Refs.

[1996] 16A - REF

TECHNOLOGY DEVELOPMENT OF FLEXIBLE AC TRANSMISSION SYSTEM

For Abstract see entry 07A - 63

[1997] 16A - REF

APPLICATION OF FACTS DEVICES TO INCREASE THE NY STATE CENTRAL-EAST/TOTAL-EAST INTERFACE TRANSFER LIMITS

For Abstract see entry 07B - 8

[1996] 16A - REF

SERIES COMPENSATION USING POWER ELECTRONIC SWITCHES: THE SERCOM

For Abstract see entry 10A - 98

[1998] 16A - REF

UPFC - UNIFIED POWER FLOW CONTROLLER: THEORY, MODELING, AND APPLICATIONS

For Abstract see entry 11A - 48

[1997] 16A - REF

EXPERIMENTAL STUDY ON THE CONTROL METHOD FOR POWER SYSTEM STABILIZATION USING SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE(SUPERSMES)

For Abstract see entry 14A - 48

[1997] 16A - REF

SERIES POWER LINE COMPENSATOR USING SELF-COMMUTATED INVERTER

For Abstract see entry 16D - 5

[1997] 16A - REF

IMPROVEMENT OF TRANSIENT STABILITY LIMIT IN POWER SYSTEM TRANSMISSION LINES USING FUZZY CONTROL OF FACTS DEVICES

For Abstract see entry 18A - 22

[1997] 16A - REF

POWER FLOW CONTROL USING STATIC SYNCHRONOUS SERIES COMPENSATOR

For Abstract see entry 18B - 11

[1998] 16A - REF

DYNAMIC POWER FLOW CONTROL WITH CONTROLLABLE REACTIVE SERIES ELEMENTS

For Abstract see entry 18B - 6

[1998] 16A - REF

POWER FLOW DURING POWER SYSTEM STABILIZING CONTROL BY A SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE(SUPERSMES)

For Abstract see entry 18C - 12

[1997] 16A - REF

DEVELOPMENT OF A MINI-MODEL OF A SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE(SUPERSMES) AND EXPERIMENT OF POWER SYSTEM STABILIZING CONTROL

For Abstract see entry 19E - 14

16B Current Limiters and Circuit Breakers

[1996] 16B - 1

COMMUTATION PROCESSES IN THYRISTOR SWITCHING DEVICES WITH A CURRENT-LIMITING REACTOR

Altunin, B.Y.

Nizhegorodskij Gosudarstvennyj Tekhnicheskij Univ, Nizhnij Novgorod, Russia

Russian Electrical Engineering (Elektrotekhnika) (Russia), no 3, March 1996, pp 34-36

Russian

To increase electrical wear-resistance of regulating voltage converters, experimental thyristor switching devices were developed. These devices have thyristors with a current-limiting reactor, instead of a electromechanical contactor with vacuum arc extinguishing chambers. Several equations are derived to describe commutation processes in thyristor switching devices. In particular, maximum values of currents through thyristor switches and the growth rate of current can be obtained from these equations. It is pointed out that the advantage of thyristor switches is that the commutation process directed at reducing voltage depends very poorly on the load component of the current in the transformer. 4 Refs.

[1997] 16B - 2

DEVELOPMENT OF HIGH-SPEED CURRENT LIMITER FOR 6 KV DISTRIBUTION SYSTEM AND THEIR APPLICATION EFFECT

Kurioka, H.; Genji, T.; Isozaki, M.; Iwai, H.; Yamada, M.

Kansai Elec Power Co, Inc, Osaka, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 10, October 1997, pp 1360-1368

Japanese

The authors have developed high-speed fault current limiting equipment for 6-kV distribution systems. The main components of this equipment are a high-speed vacuum switch (VCB) and gate turn-off thyristors (GTO) connected in parallel and a current limiting impedance of low linear resistance in parallel with the switch. The usual load current is carried by the VCB. In the case of a power system fault, the fault current is commutated to and interrupted by the GTO by opening the VCB. Through test results, it has been confirmed that this equipment can interrupt an estimated short-circuit current of 13 kA (RMS) by limiting the current to less than 3.5 kA (peak). The interrupting time was less than 2 ms. This response time is about 100 times faster than that of conventional mechanical circuit breakers. The current limiter, which has fast interruption, can protect distribution systems within a few ms from severe short circuit fault occurrences. The primary operational benefit of this equipment is the reduction of the instantaneous voltage drop at the bus or at sound lines and of the current stress on power system equipment during a power failure.

[1998] 16B - 3

FAULT CURRENT LIMITER AS A DEVICE TO INCREASE POWER QUALITY

Javadi, H.; Mohammadi, A.; Rasouli, M.

Power & Water Inst of Tech, Tehran, Iran

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol IV-7, pp 54f

In this paper the design and application requirements for a fault current limiter (FCL) which can be made by a LC parallel resonant circuit is described. The electrical performance of this kind of fault current limiter and sensitivity analysis of its components is simulated by EMTP software. The obtained results for application of this kind of FCL in a distribution system shows several interesting characteristics which can be regarded as an

effective means for utility power quality improvement.

[1997] 16B - 4

FAULT CURRENT LIMITING SYSTEM FOR 500KV POWER SYSTEMS

Sugimoto, S.; Kida, J.; Arita, H.; Fukui, C.; Yamagiwa, T.; Murai, Y.

Chubu Elec Power Co, Ltd, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 117-B, no 10, pp 1403-1410

Japanese

Recently, expansion in the scale of power systems and development of the localized power sources are leading to an increase in fault current of 500-kV systems. In future, it is quite likely that the fault current at the interconnection of such power systems may exceed the rated short-time current of existing electric power facilities. As one of the solutions to this problem, a thyristor-controlled series resonant type fault current limiter (FCL) is proposed to restrain the fault current. This paper deals with the FCL system configuration, the placement method of the FCL in power system, the outline of the FCL's specification and the operation method of the protective relay in the multi-machine system. Finally, the effectiveness of the FCL is evaluated from the viewpoints of limiting the fault current by simulation analysis. The FCL is shown to be a useful protection device for large, high capacity power systems.

[1996] 16B - 5

FEASIBILITY STUDY OF PASSIVE FAULT CURRENT LIMITER

Nishiguchi, A.; Shimomura, K.; Sudo, Y.; Hill, A.; Ihara, S.; Larsen, E.

Chubu Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 37-48, pp 1-8

The fault current limiter studied for the 500-kV intertie between the Chubu system and a neighboring system includes a series capacitor. As with all series capacitor installations, it is prudent to ensure that inherent oscillations between the series capacitor and the inductance of the FCL and transmission network are damped. Eignevalue and time-domain simulations have been used to demonstrate that the FCL can benefit the dynamic performance of the system as well as avoid any practical risk of subsynchronous resonance of nearby turbine-generators.

[1997] 16B - 6

HIGH TEMPERATURE SUPERCONDUCTING FAULT CURRENT LIMITER DEVELOPMENT

Leung, E.M.; Rodriguez, A.; Albert, G.W.; Burley, B.; Dew, M.; Gurrola, P.; Madura, D.; Miyata, G.; Muehleman, K.; Nguyen, L.; Pidcoe, S.; Ahmed, S.; Dishaw, G.; Nieto, C.; Kersenbaum, I.

Lockheed Martin Corp, Rancho Bernardo, CA, USA

IEEE Trans on Applied Superconductivity, vol 7, no 2, pt 1, June 1997, pp 985-986

A near term high temperature superconductor (HTS) application is the fault current limiter (FCL). This paper describes the development and testing of a 2.4-kV, 2.2-kA rms fault current, 150 Arms continuous current, HTS FCL that uses a Bi-2223 Ag-based conductor. The Lockheed Martin team, which included Southern California Edison (SCE), American Superconductor Corporation (ASC), and Los Alamos National Laboratory (LANL), completed in October 1995 a two-year Phase I program. This unit has undergone a six-week extensive testing at SCE's Center substation in Norwalk, California. The unit's capability and test results are presented. Plans for the construction of higher rating units including a Phase II program are outlined. Descriptions of the underlying principle of a FCL and how it can benefit the power utility industry are also presented. 5 Refs.

[1997] 16B - 7

HIGH TEMPERATURE SUPERCONDUCTING FAULT CURRENT LIMITER FOR UTILITY APPLICATIONS

Leung, E.M.W.; Albert, G.W.; Dew, M.; Gurrola, P.; Muehleman, K.; Gamble, B.; Russo, C.; Dishaw, G.; Boenig, H.; Peterson, D.; Rodriguez, A.; Summers, L.T.

Lockheed Martin Corp, San Diego, CA, USA

Advances in Cryogenic Engineering. Materials, vol 42, pt 2, 1997, pp 961-968

One of the most near-term high-temperature superconductor (HTS) applications is the fault current limiter (FCL). It is a device that can provide significant energy benefits and cost savings for the power utility industry. This is especially important when the industry is facing deregulation. The Lockheed Martin team, which also includes ASC, SCE, and LANL, has been developing a 2.4-kV, 2.2-kA HTS FCL since October

1993. This two-year Department of Energy cost sharing program is for developing HTS power utility applications. In this paper, a general review of FCLs is first given, followed by a brief description of its requirement definition and underlying working principle. A survey of the recent worldwide progress made in the development of this new utility device is then given. A description of the salient features of the LMC FCL is described and compared to other competing FCL concepts. Finally, a status report of this two year program is given and future development plans outlined.

[1998] 16B - 8

ON USING THE SOLID-STATE BREAKER IN DISTRIBUTION SYSTEMS

Palav, L.; Gole, A.M.

Univ of Manitoba, Winnipeg, Canada

Proceedings, IEEE Canadian Conf on Electrical and Computer Engineering, Waterloo, Ontario, May 1998, vol 1, pp 693f

The paper demonstrates, through the use of electromagnetic transient simulations, the key issues in the application of solid-state devices for fault control and protection in the distribution systems. Three types of topologies have been considered, viz. a bus tie breaker, a transfer switch, a fault current limiter, but only two have been discussed in detail; the bus tie breaker is taken to be a special case of the fault current limiter. The control scheme for each topology has been designed and studied, with emphasis on the detection schemes and the responses to various system and load parameters. All simulations have been carried out using the PSCAD/EMTDC program.

[1996] 16B - 9

PRINCIPLE AND CHARACTERISTICS OF A FAULT CURRENT LIMITER WITH SERIES COMPENSATION

Sugimoto, S.; Kida, J.; Arita, H.; Fukui, C.; Yamagiwa, T.

Chubu Elec Power Co, Inc, Nagoya, Japan

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 842-847

A fault current limiter with series compensation, which is composed of a compensation capacitor and a limiting reactor in series, is proposed. A solid-state switch connected in parallel with the capacitor controls either the ordinal series compensation or fault current limitation. A feasibility study of the current limiter by simulation analysis is presented and the effectiveness of the current limiter is evaluated from the viewpoints of transient stability improvement and device capacity. The current limiter is a useful protection device for large, high power transmission systems. 8 Refs.

[1996] 16B - 10

SPECIFICATION STUDY OF A THYRISTOR CONTROLLED SERIES RESONANT TYPE FAULT CURRENT LIMITER

Arita, Hi.; Kida, J.; Yamagiwa, T.; Sugimoto, S.; Koda, I.

Hitachi, Ltd, Japan

Denki Gakkai Seishiki Kenkyukai Shiryo (Japan), vol SA-96, no 30-46, pp 1-10

Japanese

For a 500-kV systems, along with the predicted expansion of their scale and the additional construction of new power sources, it has been forecast that fault current will exceed the rating range of electric power facilities in the near future. As a solution to this problem, a thyristor-controlled series resonant type fault current limiter (FCL) is proposed. This paper deals with the necessary hard components for the FCL, and in particular, the component specification. One example of hard component specification is shown in detail. Furthermore, the effectiveness of the thyristor control is evaluated by simulation analysis from the viewpoint of transient stability improvement. The FCL is shown to be a useful protection device for large, high power transmission systems.

[1996] 16B - 11

STATIC FAULT CURRENT LIMITER AND CIRCUIT BREAKER

Putrus, G.A.; Jenkins, N.; Cooper, C.B.

Univ of Northumbria, Newcastle, UK

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 925-928

Fault current limiters are employed to prevent the short-circuit duty of a substation and associated plant from being exceeded. Developments in GTO thyristor technology and high-Tc superconducting materials show promise of meeting the fault-current limiting requirements of modern power systems. This paper describes a new technique to develop a fault current limiter employing GTO thyristors. The proposed device

not only can limit the fault current but also is capable of fully interrupting it at any desired delay-time after fault inception. Therefore, two functions are achieved using the same device. Experimental results of a laboratory model device are also presented to verify the validity of the new concept. 10 Refs.

[1997] 16B - 12

STUDY OF A NEW FAULT CURRENT LIMITER

Zhang, L.; Liu, W.; Cen, W.; Liu, R.; Ren, N.; Zhu, Q.; Jiang, J.; Wu, C.; Deng, G.

Shanghai Jiaotong Univ, China

Automation of Electric Power Systems (China), vol 21, no 7, July 1997, pp 15-18

Chinese

After reviewing the development of fault current limiters, the paper presents a new type of GTO-based fast fault current limiter. The device can limit both peak and steady-state values of fault current in an extremely short time after occurrence of a short circuit, so it can be widely used in a power system. The good performance of this device is proved by digital simulation.

[1996] 16B - 13

THYRISTOR CONTROLLED GROUND FAULT CURRENT LIMITING SYSTEM FOR UNGROUNDED POWER DISTRIBUTION SYSTEMS

Sugimoto, S.; Neo, S.; Arita, H.; Kida, J.; Matsui, Y.; Yamagiwa, T.

Chubu Elec Power Co, Inc, Nagoya, Japan

IEEE Trans on Power Delivery, vol 11, no 2, April 1996, pp 940-945

A thyristor-controlled ground fault current limiting system (TGCL) was proposed to prevent one-line ground fault current rises due to increased capacitance to ground. Basic components of the TGCL are a main ground fault current limiter, which rapidly adjusts a compensating reactor level for the capacitance to ground, and the TGCL's controller. Control is ensured by an in-phase control method for zero-phase sequence voltage and current. The method determines the direction of ground faults and the compensating reactor level. The fast control which can be realized shows the TGCL is a valuable protecting system for high ground fault current distribution systems. 6 Refs.

[1997] 16B - REF

EXACT ANALYSIS OF A MULTIPULSE SHUNT CONVERTER COMPENSATOR OR STATCON. PART 1: PERFORMANCE

For Abstract see entry 09A - 52

[1997] 16B - REF

TCSC OPERATION IN INDUCTIVE REGION AND ITS CURRENT LIMITING EFFECTS

For Abstract see entry 10A - 113

[1996] 16B - REF

SUPERCONDUCTORS IN ELECTRICAL ENGINEERING: IT IS FOR SOON

For Abstract see entry 14A - 131

16C Subsynchronous Resonance Damper

[1998] 16C - 1

DAMPING OF COMMON-MODE TORSIONAL OSCILLATIONS USING A MODIFIED NGH SSR DAMPING SCHEME

Wang, L.

Dept of Elec Eng, Natl Cheng Kung Univ, Tainan, Taiwan

European Trans on Electrical Power (Germany), vol 8, no 1, January-February 1998, pp 21-29

This paper presents the analyzed results on the application of a modified NGH SSR damping scheme for damping common-mode torsional oscillations that occur in a power systems containing series-capacitor compensation. The IEEE Second Benchmark Model, System-2, which has two nonidentical turbine-generator sets connected to an infinite bus through a series-capacitor compensated transmission line, is employed to investigate the possible unstable subsynchronous resonance (SSR) which can be suppressed by the proposed damping scheme. A unified approach based on modal control theory is employed to design damping controllers for the modified NGH SSR damping module. Frequency-domain approach based on eigenvalue analyses such as different operating conditions and stable regions on R_E-X_C plane is performed. A time-

domain approach based on nonlinear model simulations under a severe three-phase short-circuit fault at an infinite bus is also carried out. It can be concluded from the simulation results that the proposed modified NGH SSR damping scheme incorporated with the designed damping controllers can effectively suppress the common-mode torsional oscillations.

[1997] 16C - 2

SIMULATIONS OF PREFIRING NGH DAMPING SCHEME ON SUPPRESSING TORSIONAL OSCILLATIONS USING EMTP

Li Wang

Dept of Elec Eng, Natl Cheng Kung Univ, Tainan, Taiwan

IEEE Trans on Power Systems, vol 12, no 2, May 1997, pp 882-888

This paper presents the simulation results of the employment of both conventional firing and prefiring NGH damping schemes on damping unstable torsional oscillations occurring in the IEEE Second Benchmark Model, system-1 which contains a turbine-generator set connected to an infinite bus through two parallel transmission lines, one of which is series-capacitor compensated. The electromagnetic transient program (EMTP) is employed to simulate the damping effects respectively contributed by the two damping NGH schemes. The simulation results show that the NGH device is capable to damp out low level subsynchronous oscillations of the studied system much faster by prefiring at an advanced angle than by conventional firing scheme.

[1996] 16C - 3

SYSTEM ASPECTS OF GTO-CONTROLLED SERIES COMPENSATION

Mihalic, R.

Faculty of Elec Eng and Computer Sci, Univ of Ljubljana, Slovenia

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 2, pp 433-436

This paper presents an explanation of the basic GTO-CSC features regarding power-flow control in the system. Comparisons have been made between GTO-CSC and CSC power-flow-control effectiveness. First this comparison has been made on the example of a simple longitudinal system by applying analytical derivation. Theoretical considerations have been tested on the poorly damped test system. In order to improve damping, GTO-CSC and CSC respectively should be applied. Comparison of effectiveness has been made on the basis of simulations. The results have shown that the ratings that assure the same damping effect of various series compensation devices differ by factor 13. 4 Refs.

[1997] 16C - REF

EXACT ANALYSIS OF A MULTIPULSE SHUNT CONVERTER COMPENSATOR OR STATCON. PART 1: PERFORMANCE

For Abstract see entry 09A - 52

16D Static Series Voltage Compensators

[1997] 16D - 1

DIRECT-COUPLED MULTILEVEL CASCADED SERIES VAR COMPENSATORS

Joos, G.; Huang, X.; Ooi, B.-T.

Concordia Univ, Montreal, Quebec, Canada

Proceedings, 32nd IEEE Industry Applications Conf, New Orleans, LA, October 5-9, 1997, vol 2, pp 1608-1615

Series var compensators based on force commutated static power converters are proving to be a viable alternative to shunt compensators as a means of enhancing power transmission and distribution capability. This paper proposes a converter structure, based on a multilevel cascade of single-phase converters, which can be coupled to the transmission system without transformers. The individual converters are switching at very low frequencies, resulting in high efficiency, and are fed from independent self-controlled dc capacitor buses. Advantages of the proposed series compensator include low injected voltage harmonic distortion and fast response to changes in the compensation level. Pattern generation options are presented. Gating and control schemes are discussed. Simulation results are verified experimentally. 8 Refs.

[1998] 16D - 2

DYNAMIC VOLTAGE RESTORER THE CUSTOMER'S PERSPECTIVE

McHattie, R.

IEE Half Day Colloquium on Dynamic Voltage Restorers - Replacing those Missing Cycles (Digest No.1998/189) (UK), 11 February 1998, pp 1/1-5

Paper mill variable speed drives are vulnerable to power dips because of control of thyristor firing. Firing angle control has difficulty following the voltage change, with possible consequent damage to the thyristors. To prevent damage, it is common for drives to be equipped with protection that trips the drive, with settings dependent on sensitivity to voltage dips. This paper describes how Caledonian Paper, UK, installed a dynamic voltage restorer (DVR) in order to overcome such problems in its Irvine plant in Scotland.

[1998] 16D - 3

FAST ALGORITHM FOR VOLTAGE UNBALANCE COMPENSATION AND REGULATION IN FAULTED DISTRIBUTION SYSTEMS

Haddad, K.; Joos, G.

Concordia Univ, Montreal, Quebec, Canada

Proceedings, 13th Applied Power Electronics and Exposition (APEC'98), Anaheim, CA, February 15-19, 1998, vol 2, pp 962-969. IEEE, Piscataway, NJ, USA, 98CH36154

Among the factors affecting power quality in distribution systems are occurrence of faults. This paper discusses an approach to ensure a high quality power supply to critical loads under the most common faults, short circuits on adjacent feeders, resulting in temporary partial or total collapse of one or more phases. The approach is based on static series voltage compensators, rated at only a fraction of the load. A voltage regulation algorithm is proposed to ensure fast response of the compensator in suppressing voltage sags and swells. It is demonstrated that good voltage regulation is achieved under the more severe faults. Compensation capability and voltage boost requirements are derived. Control and power circuit design procedures are presented. Static and dynamic performance characteristics are demonstrated on a 2-kVA experimental unit. 7 Refs.

[1997] 16D - 4

POWER QUALITY IMPROVEMENT THROUGH STATIC SERIES VOLTAGE REGULATOR

Kaul, N.; Miller, N.

GE Power Sys Eng Consulting, Schenectady, NY, USA

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol IV-10, pp 77f

Sensitive electronic equipment in the modern industrial facilities can shut down due to a power system disturbance like a single line-to-ground fault in the utility system. These faults, which cause momentary voltage sags at the load bus, could be of long enough duration to cause the electronic equipment to trip. The loss of production and clean-up cost could be large. Industry was eagerly seeking a practical and cost effective solution to remedy the problem. The answer is provided by GE's static series voltage regulator (SSVR), which prevents such voltage disruptions by automatically and rapidly regulating the three-phase supply voltage, thereby buffering critical loads from disturbances and avoiding downtime and cleanup costs. The device senses the voltage sag and rapidly applies a voltage boost in the effected phases by adding to the depressed voltage a voltage component of right magnitude and phase angle to restore the voltage. Voltage boost is generated by a voltage-source inverter and the boost is applied through transformer winding connected in series with the load. Amount of boost is precisely determined by a micro-processor-based control system. SSVR has been in service since September 1994 and has shown remarkable results to the total satisfaction of the customers. The paper aims at presenting the SSVR device in some detail for the benefit of industry in India, which is losing productivity due to frequent shutdowns caused by voltage sags.

[1997] 16D - 5

SERIES POWER LINE COMPENSATOR USING SELF-COMMUTATED INVERTER

Tokuda, H.; Eguchi, N.; Uemura, S.; Shimada, R.

Fuji Elec Corp R&D, Ltd, Tokyo, Japan

Proceedings, IEEE 1997 Power Conversion Conf, Nagaoka, Japan, August 3-6, 1997, vol 1, pp 203-208

A novel power line compensator is proposed, which has an inverter connected to a power transmission line in series. One of the advantages of this compensator is to compensate even the voltage drop which occurs in the power supply side of the transmission line, which needs a larger capacity for the SVC. The operating principle and control systems of this compensator are described in this paper. The protective method of the compensator is also treated. The validity of this compensator and its control system are examined by experimental tests, including static and transient characteristics, harmonic effects and the protective functions. 9 Refs.

[1998] 16D - 6

SIMULATION AND ANALYSIS OF SERIES VOLTAGE BOOST TECHNOLOGY FOR POWER QUALITY ENHANCEMENT

Heydt, G.T.; Tan, W.; LaRose, T.; Negley, M.

Arizona State Univ, Tempe, AZ, USA

IEEE Trans on Power Delivery, Preprint order number PE-153-PWRD-0-12-1997

Bus voltage sags may be one of the most visible power quality problems facing power engineers today. The use of a series transformer to boost bus voltage during sags is described. The emphasis in the paper is on the series voltage boost technology using pulse width modulation. The term "series voltage booster" (SVB) is used in the paper to refer to this hardware. The electronic technology of the SVB is described and analyzed in its basic capabilities. Simulation of a boost device, and the transient response are discussed. Simulation is used to identify the required component ratings under a range of steady-state and transient operating conditions. Key advantages and limitations of this technology are also discussed.

[1998] 16D - 7

TECHNICAL AND PERFORMANCE ASPECTS OF A DYNAMIC VOLTAGE RESTORER

Chan, K.

Sys Eng Div, ABB High Voltage Technology Ltd, Switzerland

IEE Half Day Colloquium on Dynamic Voltage Restorers - Replacing those Missing Cycles (Digest No.1998/189) (UK), 11 February 1998, pp 5/1-25

One of the major issues in improving power quality in distribution networks is the mitigation of voltage sags. Voltage sags in distribution networks caused by system faults can adversely affect sensitive electrical equipment in industrial production processes, such as in semiconductor fabrication, resulting in substantial financial losses. A safe, reliable and clean power supply to these industries is therefore a prerequisite to their profitable operation. A dynamic voltage restorer (DVR), with its excellent dynamic capabilities, when installed between the supply and a critical load feeder, can compensate for voltage sags, restoring line voltage to its nominal value within a few milliseconds and hence avoiding any power disruption to that load. This paper presents the technical aspects of designing an integrated gate commutated thyristor (IGCT)-based DVR shown, a new device capable of meeting the stringent requirements of voltage sags mitigation. Furthermore, performance assessments of the DVR using a real-time hardware simulator model and computer simulations are discussed.

[1996] 16D - REF

DC-AC INVERTERS FOR STATIC CONDENSER AND DYNAMIC VOLTAGE RESTORER APPLICATIONS

For Abstract see entry 09A - 39

[1997] 16D - REF

SERIES ACTIVE CAPACITANCE FOR COMPENSATING VOLTAGE DROPS CAUSED BY SOURCE IMPEDANCES IN POWER SYSTEMS

For Abstract see entry 10A - 96

16E Interline Power Flow Controller

[1998] 16E - 1

THE INTERLINE POWER FLOW CONTROLLER CONCEPT: A NEW APPROACH TO POWER FLOW MANAGEMENT IN TRANSMISSION SYSTEMS

Gyugi, L.; Sen, K.K.; Schauder, C.D.

Westinghouse Elec Corp, USA

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

The interline power flow controller (IPFC) proposed is a new concept for the compensation and effective power flow management of multi-line transmission systems. In its general form, the IPFC employs a number of inverters with a common dc link, each to provide series compensation for a selected line of the transmission system. Because of the common dc link, any inverter within the IPFC is able to transfer real power to any other and thereby facilitate real power transfer among the lines of the transmission system. Since each inverter is also able to provide reactive compensation, the IPFC is able to carry out an overall real and reactive power compensation of the total transmission system. This capability makes it possible to equalize both real and reactive power flow between the lines, transfer power from overloaded to underloaded lines, compensate

against reactive voltage drops and the corresponding reactive line power, and to increase the effectiveness of the compensating system against dynamic disturbances. The paper explains the basic theory and operating characteristics of the IPFC with phasor diagrams, P-Q plots and simulated wave-forms.

17 FACTS STATIONS AND COMPONENTS

17A Station Layout, Transmission Lines/Cables

[1998] 17A - REF

AEP UPFC PROJECT: INSTALLATION, COMMISSIONING AND OPERATION OF THE ±160 MVA STATCOM (PHASE I)

For Abstract see entry 09B - 2

[1997] 17A - REF

DEVELOPMENT OF 60 MVA SVC (STATIC VAR COMPENSATOR) USING LARGE CAPACITY 8 KV AND 3.5 KA THYRISTORS

For Abstract see entry 08B - 2

[1996] 17A - REF

FOUR YEARS OF OPERATIONAL EXPERIENCE OF THE KAYENTA ADVANCED SERIES COMPENSATOR

For Abstract see entry 10B - 2

[1996] 17A - REF

HIGH POWER SYSTEM QUALITY FOR ESKOM USING SVCS

For Abstract see entry 08B - 5

[1997] 17A - REF

OPERATION OF PLUS OR MINUS 100 MVAR TVA STATCON

For Abstract see entry 09B - 4

[1996] 17A - REF

POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT. NISSIN'S POWER-ELECTRONICS-BASED PRODUCTS FOR POWER QUALITY ENHANCEMENT

For Abstract see entry 08A - 94

[1997] 08B - 11

RELOCATABLE STATIC VAR COMPENSATORS

For Abstract see entry 08B - 11

1997] 17A - REF

SYSTEM STABILITY IMPROVEMENT IN THE RSA-ZIMBABWE AC INTERCONNECTION BY INSTALLATION OF AN SVC

For Abstract see entry 08B - 16

1998] 17A - REF

WORLD'S FIRST UNIFIED POWER FLOW CONTROLLER ON THE AEP SYSTEM

For Abstract see entry 11B - 3

17B Switching Elements, Valves, Converters

[1996] 17B - 1

A METHOD FOR INVESTIGATION OF THYRISTOR REVERSE VOLTAGES DUE TO THE EFFECT OF CHARGE ACCUMULATION

Popov, E.I.

Tech Univ Sofia, Bulgaria

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 1, pp 176-179

In this paper a method is proposed for investigation and determination of dynamic reverse voltages of a single thyristor or a multitude of serially connected thyristors, appearing across them during their turn off process due to the great rate of their reverse current decrease. The computer simulation program, developed upon this method, makes possible the optimal dimensioning of the

RC snubber groups, which can be seen from the presented example. The solving of this problem is of great significance for the thyristor power converters of electrical energy. 4 Refs.

[1997] 17B - 2

A NEW REGENERATIVE SNUBBER CIRCUIT FOR LARGE-CAPACITY THREE-LEVEL GTO INVERTER SYSTEMS

Okayama, H.; Tsuchiya, T.; Shimomura, Y.

Mitsubishi Elec Corp, Japan

Electrical Engineering in Japan, vol 120, no 2, 30 July 1997, pp 41-48

Increase in the capacity of GTOs has made progress. At present, 4.5-kV, 4.0-kA GTOs are commercially available, and 6.0-kV, 6.0-kA GTOs made from 6-inch silicon wafers are appearing. The 6-inch GTOs will be applied to our three-level GTO inverter system. In order to apply GTOs to voltage-source inverters, snubber circuits are necessary for limiting on the turn-on di/dt and turn-off dv/dt. To realize high efficiency of the system, regenerative snubber circuits are often applied. A conventional circuit applied to three-level GTO inverters had the problem of long paths created for snubber circuits of the inner GTOs. Another circuit using a current transformer for recovering the energy trapped in the snubber circuits of the inner GTOs has been presented. In this paper, a new regenerative snubber circuit is proposed, which is more suitable for three-level GTO inverter systems with many phase-legs. By applying the snubber circuit, all .snubber energy generated by each GTO switching can be regenerated to the dc link. In addition, high current turn-off performance of both the inner and the outer GTOs is verified by several successful experimental results using 6-inch 6.0-kV, 6.0-kA GTOs.

[1996] 17B - 3

A NOVEL MULTI-LEVEL INVERTER CONFIGURATION FOR HIGH VOLTAGE CONVERSION SYSTEM

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Journal of Electrical Engineering and Information Science (Taiwan), vol 1, no 2, June 1996, pp 109-118

This paper deals with a new multi-level high voltage source inverter with GTO thyristors. Recently, a multi-level approach seemed to be the best suited for implementing high voltage conversion systems because it lead to harmonic reduction and dealt with safe high power conversion systems independent of the dynamic switching characteristics of each power semiconductor device. A conventional multi-level inverter has some problems-voltage unbalance between dc-link capacitors and larger blocking voltage across the inner switching devices. To solve these problems, a novel multi-level inverter structure is proposed by the authors. 8 Refs.

[1997] 17B - 4

BINARY MULTI-LEVEL VOLTAGE-SOURCE INVERTER FOR STATIC VAR GENERATION

Hosseini, S.H.; Mathur, R.M.

Univ of Tabriz, Iran

Proceedings, IEEE 1997 Canadian Conf on Electrical and Computer Engineering (CCECE'97), St. John, Canada, May 25-28, 1997, vol 2, pp 427-430

In this paper a new binary multi-level voltage-source inverter (BMVSI) with separate dc sources for high-voltage, high power applications is introduced, which can be used for the dynamic compensation and real time control of power flow in transmission and distribution systems. The new M-level inverter, where M is 2^{n+1}-1, consists of only n single-phase full bridges for each phase, in which each bridge has its own separate dc source. This inverter can generate almost sinusoidal voltage waveform. It employs the least number of components and also is modular in design. 6 Refs.

[1996] 17B - 5

CHARACTERIZATION OF A NEW HIGH VOLTAGE INTEGRATED SWITCH: MOS-GATED OPTICALLY TRIGGERED THYRISTOR

Patel, Y.; Jalade, J.; Sanchez, J.-L.; Berriane, R.; Laur, J.P.; Austin, P.

EPE Journal (Belgium), vol 6, no 2, September 1996, pp 20-24

For power applications derived from an industrial power supply network, galvanic isolation is usually required between the power stage and control circuits. In practice, for high galvanic isolation, it may be difficult to achieve a power device materially separated from the signal processing part. A good tradeoff consists of associating control detection and amplification circuits and control defect detection circuits with each power switch. In this paper, the performance of a MOS-gated optically triggered thyristor is presented to illustrate the capabilities of new power structures based on this functional integration concept. An application of this

device to a resonant power converter is also given. 7 Refs.

[1996] 17B - 6

CONTROL OF NEUTRAL POINT VOLTAGE OF NEUTRAL POINT CLAMPED INVERTERS CONNECTED TO ELECTRIC POWER SYSTEMS

Ichihara, M.; Akiyama, T.; Shimomura, J.; Tamura, K.; Terashima, M.

Meidensha Corp, Tokyo, Japan

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 1, pp 239-243

A neutral point clamped inverter (NPC inverter) permits construction of high-voltage inverter systems without a transformer. They are suitable for large-scale inverter systems connected to electric power systems. However, to use an NPC inverter, the neutral point voltage must be controlled. This paper describes the 6th harmonic wave injection method for quick control of the neutral point voltage even at low power factors. The performance of the control method is demonstrated by simulation and experiment. Finally, the effect of the control method in a SVG system is verified experimentally. 1 Ref.

[1997] 17B - 7

CONVERTER CONFIGURATIONS AND SWITCHING FREQUENCY FOR A GTO REACTIVE POWER COMPENSATOR

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IEEE Trans on Industry Applications, vol 33, no 4, July-Aug 1997, pp 1011-1018

This paper compares two converter configurations for a multi-10-MVA gate-turn-off (GTO) reactive power compensator (STATCOM) from the viewpoints of converter connection and switching frequency. One is a single-bridge system consisting of a three-phase bridge converter unit and a transformer. Its pulse width modulation (PWM) frequency varies from 450 to 1800 Hz, and its line frequency is 50 Hz. The other is a multiconnected converter system consisting of plural, single-, or three-phase converter units and transformers. Its switching frequencies are chosen to be the lowest possible. The evaluated items are harmonic distortion, power loss, GTO utilization factor, and control response. Our simulation study shows that the multiconnected converter system with the lowest switching frequency is superior to the single-bridge system with the higher switching frequency in every case, even when there are severe line faults requiring very quick response. A new control strategy is adopted for obtaining quick response. 8 Refs.

[1996] 17B - 8

CONVERTERS FOR GRID-CONNECTED DC ENERGY SOURCES: A SIMULATION TOOL TO MEET EXPECTED UTILITY SPECIFICATIONS

Dezza, F. Castelli; Chiesa, E.; Monti, A.

Politecnico di Milano, Italy

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 578-583

The spreading use of power converter makes the study of their control more interesting also for the problems related to the interactions between the converter and the other parts of the system. In particular the problem of the control and of the interaction can not be studied separately. This paper takes in consideration the variety of problems posed by connecting a dc converter-source (DCCS) to a public grid, and intends to propose and demonstrate a general method suitable to analyze and simulate this type of system both in steady-state and transient conditions. 7 Refs.

[1997] 17B - 9

CURRENT EQUALIZATION IN SPWM FACTS CONTROLLERS AT LOWEST SWITCHING RATES

Mwinyiwiwa, B.; Wolanski, .; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

Proceedings, 28th IEEE Power Electronics Specialists Conf, St. Louis, MO, USA, June 23-26, 1997, vol 1, pp 325-330

This papers shows that SPWM FACTS controllers can be synthesized by employing "phase shifted triangle carrier technique" to multiconverters at a switching rate of only 3 pulses. The options of parallel, series and series/parallel module connections are examined for current equalization. The paper presents simulation and experimental results. 10 Refs.

[1996] 17B - 10

DESIGN AND OPERATIONAL BEHAVIOUR OF AIR COOLED HIGH POWER 3-LEVEL-

INVERTER WITH REVERSE CONDUCTING GTOS

Fischer, G.; Neeser, M.; Lang, J.; Kirklewski, M.; Salzmann, T.

Siemens AG, Erlangen, Germany

Proceedings, 18th European Conf on Power Electronics, Drives and Motion (PCIM'96), Nurnberg, Germany, May 21-23, 1996, pp 623-628

GTO power converters have already proven themselves in practice up to the megawatt range. Further increase of the power limits based on conventional voltage-source inverter circuits requires GTOs to be connected either in series or parallel. This leads to additional technical problems regarding the snubber circuits for balancing the voltages and currents and significantly increases cost and losses at a much lower GTO utilization level. Advanced circuit technology, such as the three-level inverter enables extension of the power range without connecting GTOs directly in series or parallel. It also greatly improves the voltage and current waveforms. For most industry applications, the customer requires power converters with high overload capability for a more or less short time period. An air-cooled system with its high thermal capacity of the heat sink can fulfill this requirement economically. A constraint, though, constitutes the need for low-loss snubber circuits with low stray inductances. With reverse conducting GTOs, the number of power semiconductor devices is reduced making it easier to meet the challenge of developing an economic solution with high performance. The following paper presents a specific solution of the design of an air-cooled three-level inverter phase leg. These components are utilized in the SIMOVERT ML three-level inverter for high power drive applications. 6 Refs.

[1996] 17B - 11

DEVELOPMENT OF A VOLTAGE BREAK-OVER FUNCTION IN A LIGHT-TRIGGERED THYRISTOR. FINAL REPORT

Eriksson, L.O.; Temple, V.A.K.

GE Power Sys Eng, Schenectady, NY, USA

EPRI Technical Report TR-107013, Final Report, October 1996, 126 pp (M. Wilhelm, EPRI prog mgr)

This report covers the last phase of the EPRI/GE advanced light-triggered thyristor project. The goal of this project was to develop a direct light-triggered thyristor (LTT) with a built-in voltage break-over (V_{BO}) protective function. This function is necessary because when a thyristor is exposed to an overvoltage, avalanches are formed through which the current begins to conduct. Usually, the avalanche sites are small and the follow-on energy dissipation is large so the device overheats and loses its ability to block voltage (that is, internal short circuits have developed). It is therefore necessary to increase the size of the avalanche area and limit the amount of follow-on current. There are several possible approaches for this. The approach emphasized in this work was introduction of a gate junction curvature that would lower the turn-on voltage of the thyristor in a region from which safe turn-on would initiate. Efforts targeted a separate light-triggered thyristor (SLTT), used as a pilot device for controlling large, conventional, electrically triggered thyristors. It was proposed that successful development of a self-protected SLTT could be followed by transfer of the technology to an LTT. This research resulted in a greater understanding of the design parameters governing safe overvoltage turn-on of thyristors, which eventually may lead to improved power-electronics-based equipment for utilities. 51 figs., 14 tabs.

[1996] 17B - 12

EVALUATION OF LOSSES IN THYRISTOR VALVE FOR SVC APPLICATION

Arunachalam, M.; Babu, R.R.; Bose, B.; Dutta, D.

Bharat Heavy Electricals Ltd, Bangalore, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth

(PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 399-402

This paper describes methods to determine the operating losses of thyristor valves for SVC applications. Thyristor valves for thyristor-controlled reactor (TCR), thyristor-switched capacitor (TSC) and thyristor-switched reactor (TSR) are considered. The procedure for loss evaluation requires some data which are to be estimated through factory measurements or type tests. 1 Refs.

[1996] 17B - 13

FEASIBILITY STUDY FOR MOS-CONTROLLED THYRISTOR. FINAL REPORT

Temple, V.A.K.

GE Corp R&D Center, Schenectady, NY, USA

EPRI Technical Report TR-106991, November 1996, 105 pp (M. Wilhelm, EPRI prog mgr)

MOS-controlled thyristors (MCTs) are thyristor-based switching devices that are simple to control because of a highly interdigitated MOS gate that allows both turn-on

and turn-off. The many advantages of MCTs make them a strong candidate to replace almost all other switching power devices with the exception of the power field effect transistor (FET), which should remain dominant in low-voltage and very high frequency applications. At the start of this project, devices had reached the 4A, 200 C turn-off level in a 0.04 cm^2 active area MCT. What was needed was some exploratory work on improvements that could lead to twice the turn-off current density in devices of several times the size. This project also investigated faster turn-off and higher temperatures. All of these improvements were to be accomplished, wherever possible, within the bounds of standard semiconductor processing. The results met and exceeded these goals, offering strong evidence that the proposed MCT theory is correct an that the MCT is going to be a dominant power switching device. The exploratory MCT work also led to a better understanding of processing techniques and improvements in both current and current density capabilities in the MCT. This project confirmed that the MCT forward drop vs. breakdown voltage vs. turn-off time trade-off is diode-like. In addition, the FET aspects of the device give good control to about 500 A/cm^2 at 25 C and 200 A/cm^2 at 200 C. The FET element in the MCT has much the same process yield as in any power FET. However, its operating requirements make operation feasible up to and beyond 300 C, depending on blocking voltage. Operation to very low temperatures has been shown elsewhere. Future work should investigate processes capable of smaller cell size. Further work also needs to be performed to determine safe operating area (SOA), but this cannot be done without a very large stock of a more mature device in a production package. 63 figs., 2 tabs.

[1996] 17B - 14

FUNDAMENTAL TECHNOLOGIES FOR THE ELECTRIC POWER FIELD. POWER ELECTRONICS TECHNOLOGIES-EXPANDING CAPACITY OF EQUIPMENT AND APPLICATION TO POWER SYSTEMS

Saito, S.; Irokawa, S.; Ikeda, H.

Toshiba Corp, Heavy Apparatus Eng Lab, Japan

Toshiba Rebyu (Japan), vol 51, no 7, pp 19-22

Japanese

In the field of line-commutated converters, remarkable progress has recently been made toward converters of smaller size and higher efficiency by using large-capacity light-triggered thyristors. Furthermore, research and development is progressing of a self-commutated converter which can contribute to the stabilization and effective operation of ac power systems such as equipment for flexible ac transmission systems (FACTS). This paper describes the development of high-voltage/large-current power devices, in order to construct converters of small size; the investigation of a new space vector control based on the instantaneous value of the line voltage, in order to realize faster response in current regulation resulting in improved capability for continuous operation; and the investigation of a new space vector control in multiple converter systems, in order to significantly reduce converter loss.

[1996] 17B - 15

HIGH POWER CONVERTERS AND THEIR APPLICATIONS IN FUTURE

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Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 1, pp K1-4

With an increase of the diameter of the wafer for Si devices and the introduction of irradiation technology with neutron beams and gamma rays, the capacity of thryristors and GTOs have progressed significantly. High-voltage IGBTs have also been introduced. Such devices have made the realization of high power converters possible. Utilization of self-commutated power converters based on them is remarkable. Their capability to control power flow has enlarged their application fields into industrial drives, railway traction, electrical power systems and research installations for high energy physics. Further developments are being carried out for their application in superconducting systems and flexible ac transmission systems. 8 Refs.

[1996] 17B - 16

HIGH-POWER HARD-DRIVEN GTO MODULE FOR 4.5 KV/3 KA SNUBBERLESS OPERATION

Gruning, H.; Odegard, B.; Rees, J.; Weber, A.; Carroll, E.; Eicher, S.

ABB Ind AG, Turgi, Switzerland

Proceedings, 18th European Conf on Power Electronics, Drives and Motion (PCIM'96), Nurnberg, Germany, May 21-23, 1996, pp 169-183

The conventionally driven GTO suffers from a limited safe-operating area which necessitates large protective snubber capacitors. A novel low inductance drive

technique is presented which endows the GTO with a square safe-operating area, obviating the use of snubbers and reducing storage time to that of IGBTs. Full area, homogeneous switching enhances operational reliability by eliminating current filamentation which in turn allows turn-off current to scale linearly with silicon area. The appropriate circuit techniques for this optimal use of the GTO are presented with reference to a low-cost, compact and reliable phase-leg module with minimal parts-count, thus heralding a new era of power converter design. New semiconductor technologies which further enhance the hard-drive concept by reducing losses and gate-drive requirements are discussed and device characteristics presented. 9 Refs.

[1997] 17B - 17

IMPLEMENTATION OF AN AUXILIARY-RESONANT COMMUTATED-POLE INVERTER

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EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-107731, April 1997, 80 pp

Because of their nonlinear characteristics, semiconductor devices can contribute to the degradation of the quality of electric power by injecting harmonic currents into the power system. Inverter-based compensating equipment can cancel the injected harmonic currents. The auxiliary resonant commutated pole inverter (ARCPI) is a relatively new soft-switched inverter topology that may be a potential candidate for use in such compensating equipment.

[1996] 17B - 18

LARGE-CAPACITY SELF-COMMUTATED SVC

Kanai, T.; Ishizuki, T.; Kawakami, N.; Irokawa, S.

Toshiba Corp, Tokyo, Japan

Toshiba Rebyu (Toshiba Review) (Japan), vol 51, no 4, April 1, 1996, pp 12-15

Japanese

A self-commutated device is developed to replace a thyristor for an SCV which controls a system voltage by reactive power. It controls reactive power from advanced to retarded phase, is highly controllable and capable of switching irrespective of system voltage, produces more reactive power available for controlling when system voltage drops, and needs no filter because of small quantities of harmonics generated at a low voltage. A large-capacity, high-voltage 50-MVA unit, now in service at Tokyo Electric Power's Shinano substation, is described. A multi-series GTOs are adopted to increase converter capacity. This is aimed at even distribution of voltage during a switching operation. This voltage type self-commutated converter may have a biased magnetic field in the iron core of its transformer, when the dc component is present in the output, possibly leading to overcurrent, when things come to the worst. It is controlled by correcting output voltage command with the dc component in the exciting current at the transformer (in which strain caused by exciting inrush current resulting from large capacity load is considered). It has been successfully in service in the commercial unit. 1 ref., 8 figs., 3 tabs.

[1996] 17B - 19

MOTOR MODELS AND TRANSIENT ANALYSIS FOR HIGH-TEMPERATURE SUPERCONDUCTOR SWITCH-BASED ADJUSTABLE SPEED DRIVE APPLICATIONS

Banerjee, B. (EPRI prog mgr)

EPRI, Palo Alto, CA, USA

EPRI Technical Report TR-102338, June 1996, 72 pp

New high-temperature superconductor (HTSC) technology may allow development of an energy-efficient power electronics switch for adjustable speed drive (ASD) applications involving variable-speed motors, superconducting magnetic energy storage systems, and other power conversion equipment. This project developed a motor simulation module for determining optimal applications of HTSC-based power switches in ASD systems.

[1997] 17B - 20

MULTI-LEVEL CONVERTERS FOR STATIC VAR COMPENSATION

Tennakoon, S.B.; Scheidecker, D.

Staffordshire Univ, Stafford, UK

Proceedings, IEE Colloquium on Update on New Power Electronic Techniques, London, UK, May 23, 1997, no 091, pp 4/1-4/6

Multi-level topology is adopted to overcome the problems associated with the use of voltage source converters as advanced static var compensators (ASVC). A number of gate turn-off thyristors (GTO) are connected in series to form the high voltage switches in the ASVC converter to achieve the required power rating. All the GTO thyristors in the series are switched together. The multi-level approach also leads to excellent harmonic performance. 5 Refs.

[1996] 17B - 21

MULTI-LEVEL CONVERTERS AND LARGE POWER INVERTERS

Soto, D.; Green, T.C.; Coonick, A.

Imperial College of Sci, Tech & Med, London, UK

Proceedings, 6th Int'l Conf on Power Electronics and Variable Speed Drives, Nottingham, UK, September 23-25, 1996, pp 354-359

The voltage and current ratings of FACTS equipment place it at the limit of semiconductor technology. The multi-level converter is examined here to compare its performance with the 2-level multi-pulse converter in terms of the number and rating of the devices, harmonic distortion of the ac side waveforms, harmonic current flow in the dc side capacitor, capacitor ratings and overall control requirements. From this study it is concluded that a multi-pulse arrangement of multi-level converters, each with a small number of levels, can provide very large power ratings and achieve low distortion with the restriction of line frequency switching. 9 Refs.

[1996] 17B - 22

MULTILEVEL CURRENT SOURCE INVERTER - THE SWITCHING CONTROL STRATEGY FOR HIGH POWER APPLICATION

Daher, S.; Silva The, R.; Antunes, F.

Univ Federal do Ceara, Fortaleza, Brazil

Proceedings, 22nd IEEE Intl Conf on Industrial Electronics, Control, and Instrumentation, (IECON), Taipei, Taiwan,

August 5-10, 1996. vol 3, 1996, pp 1752-1757

The generalized structure and control problem of a multilevel current source inverter using a generalized current multilevel cell are presented in this paper. The necessary control laws are established and the control problem of the seven-level and nine-level structures is studied. Optimizing the step width of the inverter output current ensures current harmonic reduction and even current distribution among the switches of the cell. The output harmonic contents can be reduced without frequency modulation, which is imperative in high power applications such as interconnecting a Superconductive Magnetic Energy Storage (SMES) to a power system. 8 Refs.

[1997] 17B - 23

MULTIMODULAR MULTILEVEL CONVERTERS WITH INPUT/OUTPUT LINEARITY

Mwinyiwiwa, B.; Wolanski, Z.; Chen, Y.; Ooi, B.-T.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Industry Applications, vol 33, no 5, September-October 1997, pp 1214-1219

Multilevel converters constitute the key technology of power electronics to reach the high power ratings required by controllers of flexible ac transmission systems (FACTS). This paper shows that the sinusoidal pulsewidth modulation (SPWM) technique, as applied to multilevel converters, inherently requires a high switching rate. The paper then presents a strategy based on multiple modules of multilevel converters which operate with the lowest possible switching loss (each gate-turn-off thyristor switches ON and OFF only once during the modulation period), while maintaining the high gain-bandwidth product of linear amplifiers to handle fast feedbacks, which FACTS controllers must be capable of, in order to carry out dynamic performance enhancement. 16 Refs.

[1996] 17B - 24

NEW HIGH-VOLTAGE VARIABLE-FREQUENCY RESONANT-COMMUTATED CONVERTER

Chickamenahalli, S.A.; Cathey, J.J.

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Proceedings, IEEE Int'l Symp on Circuits and Systems (ISCAS), Atlanta, GA, USA, May 12-15, 1996, vol 1, pp 22-25

A new scheme of a power converter in a high-voltage application is described. By accomplishing resonant-commutation of the dc link, switching losses are minimized and use of naturally commutated SCRs as the converter devices is made possible, in turn resulting in lower costs than forced commutated converters. Modulation techniques employed in the converter control facilitate harmonic elimination. Passive filters at the input and output enable lower harmonic distortion than power factor correction capacitors of present day topologies. The converter operates with greater stored energy in the dc link, thus offering current holdup capabilities during a contingency. The potential applications of the converter are in variable frequency custom power delivery, adjustable speed motor drives, static VAr compensation and active filtering. Results of simulation are discussed along with reference to

experimental results of a low power model. Scope of further work is presented along with conclusions for the high-voltage converter. 4 Refs.

[1996] 17B - 25

NEW SNUBBER CIRCUIT WITH PASSIVE ENERGY RECOVERY FOR POWER INVERTERS

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IEE Proceedings-Electric Power Applications (UK), vol 143, no 5, September 1996, pp 403-408

The paper proposes a new passive circuit for partial snubber-energy recovery in GTO thyristor high-power voltage-source inverters. The analysis and simulations show that the proposed bridge-leg snubber circuit can recover greater than sixty five per cent of the total snubber energy, as well as the freewheel diode reverse recovery energy. This energy is recovered back to the dc supply through a closely coupled transformer, without any active or associated control circuitry. This circuit, being simple, is particularly for use in GTO thyristor high-power. Design equations, simulations and experimental results are given. 8 Refs.

[1996] 17B - 26

OPTIMISED DIODES FOR HIGH VOLTAGE GTO SNUBBERS

Profumo, F.; Tenconi, A.; Facelli, S.; Passerini, B.; Fimiani, S.

Dipt di Ingegneria Elettrica, Bologna Univ, Italy

Proceedings, 31st IEEE Industry Applications Conf (IAS '96), San Diego, CA, October 6-10, 1996, vol 3, pp 1292-1297

In this paper, discussion is focused on the optimum characteristics of the diode for an active GTO snubber circuit. A description of the high voltage GTO turn-off operation which put in evidence the critical voltage and power loss spikes is reported. In this description, attention is drawn on the importance assumed by the electrical parameters of the snubber diode for the GTO safe turn-off operation. A new snubber diode with improved characteristics is proposed and the advantages of this new design with respect to the traditional solutions are explained. In the last section, the performance of the new generation snubber diode and the standard high voltage soft switching fast recovery diode are experimentally compared. 6 Refs.

[1996] 17B - 27

PRINCIPLES OF SWITCHING POWER CONVERTERS

Putrus, G.A.

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Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 2, pp 653-656

Developments in high-power solid-state devices and control technologies have opened up new domains in power electronic applications such as motor drives, HVDC transmission systems, FACTS technology. A new range of solid-state high-power converters which was not considered before is presently being developed. This paper describes the basics of switching power converters with particular emphasis on their operating principles, external characteristics and the new concepts arising from modern developments in power electronics technology. The analysis presented is summarized in a table which can be used as a general reference for converter circuits. 6 Refs.

[1997] 17B - 28

PROPOSAL OF NEWLY REGENERATED SNUBBER CIRCUIT FOR LARGE CAPACITY 3-LEVEL GTO INVERTER SYSTEM

Okayama, H.; Tsuchiya, T.; Shimomura, Y.

Mitsubishi Elec Corp, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117D, no 2, February 1997, pp 189-195

Japanese

Increase in the capacity of GTOs has made remarkable progress in recent years. At present, 4.5-kV-4.0 kA GTOs are commercially available. Now, 6-kV-6 kA GTOs, which are made from 6-inch silicon wafers, are being developed. These 6-inch GTOs will be applied to the authors' three-level GTO inverter system. In order to apply GTOs to voltage-source-inverters, snubber circuits are necessary for limiting turn-on di/dt and turn-off dv/dt. To realize a power conversion system of high efficiency, a regenerative snubber circuit is applied. The conventional circuit, which was applied to three-level GTO inverters, had a problem in that long paths are created for the snubber circuits of the inner GTOs. In order to solve this problem, a circuit using a transformer which provided for recovering the trapped energy of snubber circuits for inner GTOs was presented. In this paper, a newly regenerative snubber circuit is proposed, which is more suitable for three-level GTO inverter

systems with many phase-legs. By applying this snubber circuit, the snubber energy generated by the switching of all GTOs in the main circuit can be regenerated to DC-link capacitors. Higher turn-off capability of both inner and outer GTOs are verified by several successful experiments results using 6-inch (6-kV, 6 kA) GTO technology.

[1996] 17B - 29

RECENT TURN-OFF DEVICES AND THEIR APPLICATIONS

Seki, N.; Murayama, Y.; Saito, S.; Hideshima, M.; Matsuda, H.

Toshiba Corp, Tokyo, Japan

Toshiba Rebyu (Toshiba Review) (Japan), vol 51, no 4, April 1996, pp 4-7

Japanese

Turn-off devices are having their capacity increased, performance improvement advanced, and application areas expanded. Increase in use of self-commutated converters is expected as expansion of their applications, particularly in the area of electric power use. This paper describes the technology developed thereon and their future prospects. An inverter using diodes inversely paralleled with a self-turn off device is the base for a self-commutated converter. As compared with separately excited converters, the self-commutated converter can be operated regardless of system voltage conditions, and can continue operation even under a severe system failure. A gate turn-off thyristor (GTO) suits high voltage and large current use, and ones with such large capacity of 6000 V-6000 A have been developed as a mainstream device in the electric power area. In order to ensure insulation at high voltages, a system that supplies gate driven power from a main circuit was developed. A snubber energy regenerative system was also developed. Because of their high control performance and convenience in handling, insulated-gate bipolar transistors (IGBT) are used in consumer, industrial and general purpose applications, and their application scope in the electric power area is intended of expansion not only in small-to-medium capacity range, but also capacity range exceeding 1 MVA and voltage range exceeding 1000 V. 6 figs.

[1996] 17B - 30

SERIES CONNECTION OF GTO THYRISTORS FOR HIGH-POWER STATIC FREQUENCY CONVERTERS

Steimer, P.; Gruning, H.; Werninger, J.; Dahler, P.; Linhofer, G.; Boeck, R.

ABB Industries AG

ABB Review, no 5, 1996, pp 14-20

The introduction of gate turn-off (GTO) thyristors was an important milestone in the development of high-power static frequency converters. Used in conventional circuits, they allow converters with ratings of up to 30 MVA to be built. For higher powers, ABB has developed a technology for the series connection of GTO thyristors that offers considerably better availability and economy. The first high-power frequency converter with series-connected GTO thyristors is due to enter commercial operation with the German utility Stadtwerke Bremen. 2 Refs.

[1996] 17B - 31

SIMULATION ANALYSES OF POWER SYSTEM INTERCONNECTING INVERTERS

Nakamori, A.; Eguchi, N.

Fuji Elec Corp R&D, Ltd, Kanagawa, Japan

Fuji Jiho (Fuji Electric Journal) (Japan), vol 69, no 3, March 10, 1996, pp 12-16

Japanese

Large-capacity inverters interconnected to power systems are advancing and becoming increasingly complex. Therefore, detailed computer-aided simulation techniques capable of grasping behavior of whole systems are essential, in order to design the control systems or to solve various problems that may occur in the interconnected systems. This paper describes 3 simulation analysis examples; analysis of controlling self-commutated flicker compensators, characteristics analysis of inverters suited for large-capacity power systems to which they are interconnected, and analysis of the effects of resumption of power systems after instantaneous power failure. Flicker compensation, or instantaneous current compensation, is a measure against flicker caused by an arc furnace. The compensator, which is required to have a high responsibility, is analyzed by the tests and simulation to improve its steady-state and transient characteristics, where 72 GTOs of a commercial unit are strictly simulated by numerical models and series circuits with a control delay target set at 1 ms or less. 2 refs., 11 figs.

[1997] 17B - 32

STATE SPACE CALCULATION OF 6-PULSE CURRENT CONVERTER BRIDGES IN STEADY-

STATE

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Erlangen-Nurnberg Univ, Germany

Electrical Engineering (Germany), vol 80, no 1, February 1997, pp 51-64

German

The method of approach presented here for the calculation of 6-pulse current converter bridges is applicable for higher order current converters as well as for modern FACTS (flexible ac transmission systems) equipment. It utilizes the periodicity of the complex space phasor state variables of the three-phase ac system and the dc state variables in steady-state operation. The entire system is transferred into two linear independent space phasor component networks for each switching status and is represented in state space with regard to its eigenvalues and the periodic 'strokes' of the current converter. The analytic solution of the resulting linear inhomogeneous boundary value problem leads to the time functions of the state variables after the retransformation into original (R, S, T) coordinates. The result represents a complete system description.

[1997] 17B - 33

STUDY ON HIGH ACCURATE ASVG DIGITAL PULSE GENERATOR

Xiu, L.; Wang, Q.; Shen, D.; Han, Y.; Li, J.; Wu, D. ; Lin, F.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 35-38

Chinese

This paper presents a hardware implementation method for 18 pulses similar sine wave advanced static VAr generator (ASVG) pulse generator using stored logic. The real operation shows that the pulse generator has high accuracy, nonphase noise and is reliable, and solves the problems of nonsymmetry and VAr control nonsmoothness. The pulse generator has been applied in industrial ASVG. The main technology of the pulse generator is the highly stable, high accuracy, nonphase noise multiple frequency pulse source. An implementation method for such a pulse source is also presented. The pulse generator is applicable to other GTO inverters as well.

[1997] 17B - 34

THREE-PHASE REACTIVE POWER COMPENSATION USING A SINGLE-PHASE AC/AC CONVERTER

Ye, Z.

Univ of Toledo, OH, USA

Proceedings, IEEE 12th Applied Power Electronics Conf (APEC'97), Atlanta, GA, February 23-27, 1997, vol 1, pp 213-219

A new control strategy and topology for VAr compensation is presented and analyzed. It treats a three-phase power system as two energy ports and uses one single-phase bidirectional ac/ac converter to transfer reactive energy between the two ports to produce three-phase reactive power. The compensated reactive power can be leading or lagging. Hysteresis control is investigated as a means of current modulation. The system has fast transient response capability, and one unit of ac/ac converter power generates 2.412 units of reactive power. The characteristics of the topology and predicted results are verified experimentally. 5 Refs.

[1996] 17B - 35

THYRISTORS REVISITED. THE ROLE OF IMPROVED PERFORMANCE AND DESIGN IN MODERN APPLICATIONS

Smith, C.J.

GEC Plessey Semicond, UK

Proceedings, 6th Int'l Conf on Power Electronics and Variable Speed Drives, Nottingham, UK, September 23-25, 1996, pp 75-80

More than 35 years ago the SCR/thyristor became the first semiconductor capable of controlling substantial levels of voltage and current and has since taken over many applications previously done by electro-mechanical and ignitron type devices. In the same period other power semiconductors have come along, e.g. high power bipolar transistors, darlingtons, MOSFETs, IGBTs and GTOs which in their turn have taken over some of the applications formally done by thyristors. Yet the thyristor has remained the first choice where proven reliability, high current, high voltage and not least, cost effectiveness are the main considerations. This paper shows how modern market applications have driven the way which device development has gone and the way in which device performance is measured. Emphasis is placed on low frequency, converter or phase control thyristors. 3 Refs.

[1996] 17B - 36

VOLTAGE QUALITY CONTROL IN

ELECTRICAL INDUSTRIAL SYSTEMS BY MEANS OF THREE-PHASE BOOST CONVERTERS

Carpinelli, G.; Marino, P.; Testa, A.; Vasca, F.

Dipt di Ingegneria Ind, Univ, Cassino, Italy

Proceedings, Symp on Power Electronics, Industrial Drives Power Quality, Traction Systems, Capri, Italy, June 5-7, 1996, pp B3-27-34 suppl

The three-phase boost power converter can act as multifunctional converter. In the paper, with reference to a case-study system constituted by a supply transformer, a boost converter feeding a dc load, a capacitor VAr compensator and a group of unbalancing or fluctuating loads, the boost converter is utilized as a rectifier and static VAr compensator. Firstly, converter sizing is discussed, then the mathematical model of the system is presented with its implementation by SIMULINK; taking into account the dc voltage, the reactive power and the negative sequence current controls. Finally, the simulation results are presence of unbalancing and fluctuating loads are presented and discussed.

[1996] 17B - REF

COMPACT AND EFFICIENT TRANSFORMERLESS POWER CONVERSION SYSTEM

For Abstract see entry 02B – 2

[1997] 17B - REF

NEXT-GENERATION POWER SEMICONDUCTOR DEVICES. HIGH-VOLTAGE, LARGE-CAPACITY GTO AND LTT

For Abstract see entry 02C - 25

[1996] 17B - REF

ADVANCED GTO DEVELOPMENT

For Abstract see entry 02C - 3

[1997] 17B - REF

SEMICONDUCTOR POWER DEVICES FOR USE IN HVDC AND IN FACTS CONTROLLERS

For Abstract see entry 02C - 34

[1997] 17B - REF

UNIFIED PROPOSAL IN THE CHARACTERISTICS TESTING METHODS OF 8 KV 3.5 KA CLASS LIGHT TRIGGERED THYRISTORS

For Abstract see entry 02C - 39

[1996] 17B - REF

AN 8 KV/3.6 KA LIGHT-TRIGGERED THYRISTOR

For Abstract see entry 02C - 4

[1998] 17B - REF

ANALYSIS OF DIVIDE CAPACITOR VOLTAGE OF DUAL CONNECTED MULTI-LEVEL CONVERTER

For Abstract see entry 05A - 1

[1996] 17B - REF

DIGITAL FIRING CONTROL FOR LINE-COMMUTATED HIGH POWER CONVERTERS

For Abstract see entry 05A - 9

[1996] 17B - REF

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

For Abstract see entry 05B - 38

[1997] 17B - REF

MODELING SYNCHRONOUS VOLTAGE SOURCE CONVERTERS IN TRANSMISSION SYSTEM PLANNING STUDIES

For Abstract see entry 07A - 34

[1997] 17B - REF

POWER ELECTRONICS AND DRIVES-TECHNOLOGY STATUS AND ADVANCEMENT

For Abstract see entry 07A - 43

[1996] 17B - REF

POWER ELECTRONICS ENTERS ELECTRIC POWER NET

For Abstract see entry 07A - 44

[1996] 17B - REF

PROSPECTS FOR A NEW GENERATION OF HIGHLY RELIABLE 1150 KV ELECTRICAL EQUIPMENT

For Abstract see entry 07A - 51

[1996] 17B - REF

STATE OF THE ART AND LEADING EDGE TECHNOLOGIES OF POWER ELECTRONICS APPLICATIONS TO POWER TRANSMISSION

For Abstract see entry 07A - 57

[1998] 17B - REF

VOLTAGE-SOURCE MATRIX CONVERTER AS A CONTROLLER IN FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 07A - 79

[1996] 17B - REF

AN HYBRID ACTIVE POWER FACTOR COMPENSATOR USING AN INTELLIGENT HIERARCHICAL STRUCTURE

For Abstract see entry 08A - 19

[1996] 17B - REF

APPLICATION OF SELF-COMMUTATED INVERTERS TO ELECTRIC POWER SYSTEMS

For Abstract see entry 09A - 25

[1997] 17B - REF

DYNAMIC PERFORMANCE AND CONTROL OF A STATIC VAR GENERATOR USING CASCADE MULTILEVEL INVERTERS

For Abstract see entry 09A - 49

[1997] 17B - REF

EXACT ANALYSIS OF A MULTIPULSE SHUNT CONVERTOR COMPENSATOR OR STATCON. PART 2: ANALYSIS

For Abstract see entry 09A - 53

[1997] 17B - REF

MULTIPULSE CONTROL OF VOLTAGE SOURCE CONVERTERS FOR STATIC VAR COMPENSATION

For Abstract see entry 09A - 69

[1997] 17B - REF

MULTIPULSE CONTROL OF VOLTAGE SOURCE CONVERTERS FOR STATIC VAR COMPENSATION

For Abstract see entry 09A - 69

[1998] 17B - REF

OPERATING PRINCIPLES OF SHUNT STATCOM BASED ON 3-LEVEL DIODE-CLAMPED CONVERTERS AND TWELVE-PHASE MAGNETICS

For Abstract see entry 09A - 74

[1997] 17B - REF

A NEW TRANSFORMER-LESS MULTI-LEVEL CONVERTER FOR HIGH VOLTAGE HIGH POWER APPLICATIONS

For Abstract see entry 09A - 8

[1997] 17B - REF

REGULATING AND EQUALIZING DC CAPACITANCE VOLTAGES IN MULTILEVEL STATCOM

For Abstract see entry 09A - 85

[1997] 17B - REF

TRANSFORMER-LESS STATIC SYNCHRONOUS COMPENSATOR EMPLOYING A MULTI-LEVEL INVERTER

For Abstract see entry 09A - 99

[1998] 17B - REF

GTO THYRISTOR CONTROLLED SERIES CAPACITOR SWITCH PERFORMANCE

For Abstract see entry 10A - 48

[1996] 17B - REF

POWER ELECTRONICS TECHNOLOGIES (EXPANDING CAPACITY OF EQUIPMENT AND APPLICATION TO POWER SYSTEMS)

For Abstract see entry 12A - 11

[1997] 17B - REF

A METHOD FOR HARMONIC REDUCTION ON THE SOURCE SIDE OF A PARALLEL-CONNECTED THYRISTOR CONVERTER HAVING AN INTERPHASE REACTOR

For Abstract see entry 14A - 2

[1996] 17B - REF

HIGH POWER GTO CURRENT CONVERTER FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 58

[1996] 17B - REF

A NOVEL METHOD OF REDUCING THE SUPPLY CURRENT HARMONICS OF A 12-PULSE THYRISTOR RECTIFIER WITH AN INTERPHASE REACTOR

For Abstract see entry 17C - 3

[1996] 17B - REF

HIGH POWER SWITCH MODE LINEAR AMPLIFIERS FOR FLEXIBLE AC TRANSMISSION SYSTEM

For Abstract see entry 18A - 20

[1997] 17B - REF

APPLYING PWM TO CONTROL OVERCURRENTS AT UNBALANCED FAULTS OF FORCED-COMMUTATED VSCS USED AS STATIC VAR COMPENSATORS

For Abstract see entry 18D - 6

[1996] 17B - REF

MODELLING OF HIGH-VOLTAGE THYRISTORS UNDER DYNAMIC CONDITIONS

For Abstract see entry 19D - 12

17C Harmonics, Filters

[1996] 17C - 1

A GEOMETRIC APPROACH TO DESIGNING OF FILTER FOR SMES

Xu, D.; Masada, E.; Ohsaki, H.

Tokyo Univ, Japan

Proceedings, 7th Int'l Power Electronics and Motion Control Conf (PEMC'96), Budapest, Hungary, September 2-4, 1996, vol 2, pp 344-348

A geometric method to design a filter for SMES applications is presented. The effects of the filter on the fundamental power transferring both from the utility supply to the load and from the power converter to the load are investigated. A filter is found which ensures load voltage harmonic distortion satisfying a given harmonic criteria whilst at the same time having the least effect on the power transfer fundamental frequency. 5 Refs.

[1996] 17C - 2

A NEW HARMONIC ELIMINATION PWM TECHNIQUE FOR THREE-LEVEL GTO-SVG

Wang, X-H.; Wang, L-K.; Chen, X-M.; Dai, J.

Nanjing Automation Research Inst, China

Automation of Electric Power Systems (China), vol 20, no 9, September 1996, pp 26-29, 32

Chinese

A new programmed PWM technique to selectively eliminate several lower order harmonics at the output of a static VAr generator (SVG) with three level GTO inverter is investigated. Theoretical description and harmonic analysis are presented. Switching angles for selective elimination PWM with various output voltages of SVG are given. Analysis has been verified with the PSIM simulator. 3 Refs.

[1996] 17C - 3

A NOVEL METHOD OF REDUCING THE SUPPLY CURRENT HARMONICS OF A 12-PULSE THYRISTOR RECTIFIER WITH AN INTERPHASE REACTOR

Tanaka, T.; Koshio, N.; Akagi, H.; Nabae, A.

Polytech Univ, Sagamihara, Japan

Proceedings, 31st IEEE Industry Applications Conf (IAS '96), San Diego, CA, October 6-10, 1996, vol 2, pp 1256-1262

A novel design concept of an interphase reactor in a three-phase twelve-pulse thyristor rectifier is proposed for reducing supply current harmonics. This concept requires only an interphase reactor with a small inductance value, and requires no additional switching devices. As the inductance value is decreased, the supply current approaches a sinusoidal waveform, which is more sinusoidal than that of a 36-pulse thyristor rectifier. The basic principle of the proposed concept is discussed in detail, and confirmed by using digital computer simulation. Experimental results verify the effectiveness and practicability of the proposed design concept of the interphase reactor. 8 Refs.

[1998] 17C - 4

ANALYSIS OF RESONANCE PROBLEMS AND HARMONIC FILTER DESIGN IN POWER FACTOR CORRECTION CAPACITOR APPLICATIONS

Rao, N.D.; Sporea, S.I; Sawma, A.

Univ of Calgary, Canada

Proceedings, IEEE Canadian Conf on Electrical and Computer Engineering, Waterloo, Ontario, May 1998, vol 1, pp 293f

Increased use of power electronic control equipment has made it necessary to pay greater attention to harmonic voltages and currents in power systems. Moreover, power electronic control equipment tends to operate at relatively low power factor. Since low power factor leads to poor voltage regulation, increased line losses and larger plant VA rating, it is normal practice to install shunt capacitors either on the customer service or on the utility system.

[1997] 17C - 5

APPLICATION AND DESIGN TRENDS OF FILTERS

Srivastava, S.; Koul, R.; Tripathy, A.K.

Bharat Heavy Electricals Ltd, New Delhi, India

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol V-6, pp 39f

Harmonic filters in power systems are used primarily to mitigate the harmonics generated by various kinds of nonlinear loads and thyristor-switched devices existing in ac systems. Additionally, capacitors in these filters supply reactive power at fundamental frequency, which improves power factor of the ac system. The advantages of using filter bank instead of shunt capacitor banks are highlighted in the paper. Depending on the configuration, filters are either of passive or active type. The paper discusses various design aspects of active filters as well as passive for various ac system applications and present trends in filter installations. Various types of filters and their advantages as well as disadvantages and guidelines for choosing correct type of filter for the desired applications are presented in the paper. Since active filters are very effective for wide frequency variations, they are used these days in power systems for very effective filtering. Advantages and disadvantages in using an active instead of passive filter are also presented. The paper gives an overview of the continuously tuned filters and multiple tuned filters which can be used to meet very stringent harmonic performance requirements set by the utilities. These filters have been proven to be very economical compared to installation of large number of filter banks to meet the same performance.

[1996] 17C - 6

COMPARING THE CONVERGENCE PROPERTIES OF A HARMONIC POWER FLOW STUDY UNDER THREE DIFFERENT TECHNIQUES OF TCR CONDUCTION ANGLE CALCULATION

Garcia M.J.M.; Naredo V.J.L.

Univ de Guadalajara, Jalisco, Mexico

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 509-515

Three techniques for calculating thyristor-controlled reactor conduction angles in harmonic power flow studies are analyzed in this paper. For each one of these techniques, an analytical expression to determine the conduction angle is first obtained. Then, the sensitivity of these expressions to various thyristor-controlled reactor and power system parameters is established. A harmonic power flow study is then performed by applying each one of the techniques being considered. The convergence properties for each technique are compared, both analytically and through computer runs. Finally, recommendations are made as to an efficient application of each technique as well as to the one that was found the best in this study. 7 Refs.

[1996] 17C - 7

EFFECTS OF HARMONICS ON POWER SYSTEMS - PART 2

Sankaran, C.

Electro-Test, Inc, Renton, WA, USA

EC&M: Electrical Construction and Maintenance, vol 95, no 2, February 1996, 5 pp

As the number of VFDs, electronic ballasts, battery chargers, and static var compensators installed in facilities increases, so are the problems related to harmonics. By determining harmonic levels and analyzing system data, the corrective measures can be implemented hence, avoiding serious problems.

[1996] 17C - 8

EXPERIMENTAL STUDY ON PROTOTYPE THYRISTOR CONTROLLED SERIES CAPACITOR MODEL CONNECTED TO 275V TEST SYSTEM. (III)

Nakachi, Y.; Fujita, H.; Koda, I.; Watanabe, M.; Konishi, H.; Kizawa, T.

Chubu Elec Power Co, Ltd, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 1-10

Japanese

This paper reports the results of harmonic and protection tests carried out on a prototype thyristor-controlled series capacitor (TCSC) connected to artificial power system (nominal voltage 275V). The tests results show that harmonics content of voltage generated by the TCSC is found to be less than 1%. And the ability of protection function of TCSC was confirmed by varying the parameters such as the thyristor reactor inductance and bypass reactor and the firing angle of thyristors etc.

[1996] 17C - 9

FREQUENCY RESPONSE OF SERIES AND SHUNT COMPENSATED TRANSMISSION LINES

Black, J.; Baghzouz, Y.

Dept of Elec & Computer Eng, Nevada Univ, Las Vegas, NV, USA

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 487-493

This paper presents the effect of series and shunt transmission line compensators on the overall harmonic impedance of the compensated line. Eight of the most common compensating schemes are considered in the analysis. The influence of source impedance, line length and degree of compensation on the line impedance of to the 25th harmonic order are investigated. Computer simulation results for on an actual 345-kV line are shown for illustration purposes. 9 Refs.

[1997] 17C - 10

HARMONIC ANALYSIS AND COMPARISON OF SEVERAL TYPICAL CONFIGURATION FOR ASVG

Bai, K.; Li, L.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 30-34

Chinese

To obtain the required power rating and to keep the harmonic distortion of the output low, the advanced static VAr generator (ASVG) must be combined with the multiple inverters and transformers. Because many possible configurations may be adopted to realize the same rating, it is necessary to compare various aspects of different configurations according to demands and conditions. In this paper, after the principles to eliminate harmonics of several typical configurations are analyzed, the mathematical function relations between the harmonic distortions and pulse trigger patterns are introduced, and the curves of output voltage THD (total harmonic distortion) varying with trigger parameters are proposed. To compare harmonic distortions of these configurations, a star-triple series connection circuit with three-phase three-iron-pillar transformers is chosen as the first scheme suitable for the domestic ASVG development because of its lower harmonic distortion, simpler configuration, better manageability and lower transformer cost.

[1996] 17C - 11

HARMONIC ANALYSIS OF THE UNIFIED POWER FLOW CONTROLLER

Liu, J.Y.; Song, Y.H.

Univ of Bath, UK

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 2, pp 676-677

This paper first reviews the regulation theory of the shunt part and series part of the unified power flow controller (UPFC) using pulse width modulation

(PWM). EMTP/TACS based UPFC model is then set up. The focus is placed on the detailed analysis of the harmonics of various variables of the PWM UPFC. Finally, preliminary design of filters to effectively reduce the harmonics is reported. The simulation results show that the PWM UPFC under filters have high quality of waveforms. 5 Refs.

[1996] 17C - 12

HARMONIC DOMAIN MODELLING OF THREE PHASE THYRISTOR-CONTROLLED REACTORS BY MEANS OF SWITCHING VECTORS AND DISCRETE CONVOLUTIONS

Rico, J.J.; Acha, E.; Miller, T.J.E.

Univ of Glasgow, UK

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1678-1684

The main objective of this paper is to report on a newly developed three-phase TCR model which is based on the use of harmonic switching vectors and discrete convolutions. This model is amenable to direct frequency domain operations and provides a fast and reliable means for assessing 6- and 12-pulse TCR plant performance at harmonic frequencies. The use of alternate time domain and frequency domain representations is avoided as well as the use of FFTs. In this approach, each single-phase unit of the TCR is modeled as a voltage-dependent harmonic Norton equivalent where all the harmonics and cross-couplings between harmonics are explicitly shown. This model is suitable for direct incorporation into the harmonic domain frame of reference where all the bus-bars, phases, harmonics and cross-couplings between harmonics are combined together for a unified iterative solution through a Newton-Raphson technique exhibiting quadratic convergence. 17 Refs.

[1997] 17C - 13

HARMONIC ISSUES OF THE APPLICATION OF AN ADVANCED STATIC VAR COMPENSATOR TO A WIND FARM

Ekanayake, J.B.; Jenkins, N.

Univ of Peradeniya, Sri Lanka

Wind Engineering, vol 21, no 4, 1997, pp 215-226

The paper surveys a range of problems associated with the connection of an advanced static VAr compensator (ASVC) to a wind farm network. Harmonic resonances in the network and their influence on ASVC design are considered, as are the possible dc side resonances that can occur in the ASVC in certain conditions; various means of reducing these effects are studied. The design criteria for the design of high pass filters are described, and it is shown that a high pass filter can effect a significant harmonic reduction for all harmonic frequencies above the designed tuned frequency. 8 Refs.

[1997] 17C - 14

HARMONIC MODELLING IN HARTLEY'S DOMAIN WITH PARTICULAR REFERENCE TO THREE PHASE THYRISTOR-CONTROLLED REACTORS

Acha, E.; Rico, J.J.; Acha, S.; Madrigal, M.

Univ of Glasgow, UK

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1622-1628

The main objectives of this paper are to present a new frame-of-reference based on the use of Hartley's transform and to present a three-phase thyristor-controlled reactor (TCR) harmonic model which uses Hartley's domain. Solutions using the new frame-of-reference are between two to four times faster than solutions using an established frame-of-reference based on Fourier's transform because Hartley's transform makes use of the real plane as opposed to the complex plane. Harmonic switching vectors in Hartley's domain have been developed for maximum computer efficiency. Their use, combined with discrete convolution operations, provide cleaner and faster operations than those afforded by the Fast Hartley transform. The TCR model is completely general and caters for any kind of plant imbalances, e.g. uneven firing angles and inductances. Network imbalances are accounted for via the excitation voltage. The new frame-of-reference accommodates any number of buses, phases, harmonics and cross-couplings between harmonics. It provides a reliable and efficient means for the iterative solution of power systems harmonic problems through a Newton-Raphson method which exhibits quadratic convergence. 22 Refs.

[1997] 17C - 15

HARMONICS IN POWER SYSTEMS. AN OVERVIEW

Kapur, A.K.; Agrawal, S.K.; Saxena, N.S.; Chaitanya, K.V.R.

CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol III-4, pp 26ff

The term 'power quality' has been used to describe the variation of the voltage, current, frequency of the power supply and the continuity of power supply. In Indian power systems, the variation in voltage and frequency often exceeds the permissible variations given in the Indian Electricity Rules 1956 due to imbalance between demand and supply of both MW and MVAr power and poor regulatory mechanisms. Most power system equipment has been able to operate successfully with relatively wide variations of these parameters till recently. However, with the recent addition of large amount of equipment controlled by electronics to the power system, these variations are becoming less and less tolerable. These electronic equipment include thyristor controls used for rectification, power control and inversion, etc. These also include computers, programmable logic controllers, and ac/dc drives. The sophisticated controls and the thrust of induction of energy efficient equipment has led to further contamination of power supply manifesting itself by way of harmonics, voltage dips and flickers, etc. The term harmonics is used to define the components of a repetitive wave form and these consist exclusively of frequencies which are exact multiples of the fundamental frequency. Thus the harmonic distortion describes the continuous or steady-state variation in the fundamental frequency wave form. The other common sources of harmonics are power converters/inverters, thyristor drives employed in rolling mills, traction loads, steel mills and cement plants, etc., static var compensators (SVCs), arc furnaces, welding plants, saturated transformers, etc.

[1997] 17C - 16

INFLUENCE OF HARMONICS GENERATED BY THYRISTOR CONTROLLED SERIES CAPACITOR ON POWER SYSTEM AND GENERATOR

Katagi, T.; Tanaka, T.; Fujiyama, T.; Matsuki, J.; Abe, M.

Kobe Univ of Merchant Marine, Japan.

Denjiryoku Kanren no Dainamikkusu Shinpojiumu Koen Ronbunshu (Japan), vol 9, pp 147-152

Japanese

This paper describes the results of experimental study on the influence of harmonics generated by a thyristor-controlled series capacitor (TCSC) on the power system and a generator. A laboratory-scale TCSC has been produced and installed in a laboratory power system to investigate the performance of harmonics. Harmonics instability of TCSC has been observed in the laboratory system. Line currents and terminal voltage in the system, air-gap induced electromotive forces, field currents, induced electromotive forces in damper windings and damper bar currents in the generator, and TCSC voltages for various thyristor firing angles were measured and Fourier analyses were conducted.

[1996] 17C - 17

MODELING AND SIMULATION OF THE PROPAGATION OF HARMONICS IN ELECTRIC POWER NETWORKS PART II: SAMPLE SYSTEMS AND EXAMPLES

Bonner, A.; Grebe, T.; Gunther, E.; Hopkins, L.; Marz, M.B.; Mahseredjian, J.; Miller, N.W.; Ortmeyer, T.H.; Rajagopalan, V.; Ranade, S.J.; Ribeiro, P.F.; Spherling, B.R.; Sims, T.R.; Xu, W.

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 466-474

This report is the second part of a review on the nature and modeling of harmonic sources in electrical power systems and the analysis of harmonics propagation. Existing IEEE standard test systems are used to develop sample systems for harmonic studies. Examples of model development and study results are provided. Research needs in the area are identified. 7 Refs.

[1996] 17C - 18

MODELLING AND ANALYSIS GUIDELINES FOR SLOW TRANSIENT. PART II CONTROLLER INTERACTIONS ; HARMONIC INTERACTIONS

Slow Transients Task Force

IEEE Trans on Power Delivery, vol 11, no 3, 1996, pp 1672-1677

The first part of this three-part report explains the objectives of the task force and the scope of its report. The first part also provides modeling guidelines for the investigation of small-signal torsional oscillations, large-signal shaft transient stresses, turbine-blade vibrations, and fast bus transfer based on the use of digital computer time-domain simulation methods. This paper provides modeling guideline for the analysis of controller interactions, harmonic interactions, and resonance phenomena. Sample test systems and typical time-domain simulation results for each phenomenon are also provided. 27 refs.

[1996] 17C - 19

PREDICTION OF HARMONIC MAGNIFICATION IN POWER SYSTEM DUE TO STATIC VAR COMPENSATORS

Abdulla, M.; Salameh, Z.

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 643-649

The static VAr compensator, SVC is one of the important electronic devices in use in the power system. From the power quality point of view, SVCs should maintain constant voltage on loads' buses. The operation of SVCs may affect these voltages due to harmonic magnification at certain conduction angles of SVCs, even though the voltage provided by the utility company is a strong 60 Hz sinusoidal waveform. In this paper, harmonic magnification due to the operation of SVCs is studied. The reasons for the harmonic magnification are represented. An explanation of why one harmonic component is magnified at a certain conduction angle is given. A method is suggested to predict the harmonic magnification neither by solving the nonlinear system's state equations nor by calculating the Jacobian matrix at different conduction angles. The method provides a graphical way to test the system's parameters and the effect of the SVC inductor and capacitor on the harmonic magnification. 9 Refs.

[1996] 17C - 20

REACTIVE POWER COMPENSATORS WITH NATURAL COMMUTATION THYRISTORS

Labuntsov, V.A.; Chaplygin, E.E.

Moskovskij Energeticheskij Inst, Moscow, Russia

Electric Technology (Elektrichestvo) (Russia), no 9, September 1996, pp 55-59

Russian

The paper considers asymmetrical power compensators and subharmonic component distortion power compensators on the basis of natural commutation thyristor circuits. A three-phase circuit and three single-phase bridges are compared and fields of their application are outlined. Ways of controlling a compensator which ensure suppressing subharmonic components in specified frequency range are presented. Values of inductance of compensator accumulative elements are estimated. 4 Refs.

[1996] 17C - 21

REDUCING HARMONICS OF THE MULTI-PULSE RECTIFIER CIRCUIT WITHOUT 3-PHASE INPUT TRANSFORMER

Yu, C-R.; Kim, H-G.; Park, H-C.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 45, no 6, June 1996, pp 803-807

Korean

In this paper, a new method for reducing harmonics in the input ac line currents of power converters is presented which is based on a multi-pulse rectifier circuit without an input transformer. This system can reduce the harmonics found in conventional 12-pulse power converters. Both the bridge circuits are controlled with a shifted firing angle and a connected 2-tap interphase reactor. Using 2-tap changing on the interphase reactor, the input current is controlled with two different values in order to make an input current waveform of 12 pulses. Theoretical analysis of the operation characteristics was confirmed through computer simulation and experiments. The system is easily adaptable to varying loads and thought to be very economical. 7 Refs.

[1996] 17C - REF

HVDC - FACTS. STATE OF THE ART - POWER SYSTEM HARMONICS

For Abstract see entry 01A - 7

[1996] 17C - REF

HARMONIC GENERATION BY HVDC SCHEMES INVOLVING CONVERTERS AND STATIC VAR COMPENSATORS

For Abstract see entry 02D - 15

[1997] 17C - REF

ACTIVE POWER FILTERS--RECENT ADVANCES

For Abstract see entry 02D - 3

[1998] 17C - REF

HARMONIC TENSOR LINEARISATION OF HVDC CONVERTERS

For Abstract see entry 05D - 12

[1997] 17C - REF

SELF-COMMUTATED SVC WITH COMPENSATION OF HARMONIC AND

NEGATIVE-PHASE-SEQUENCE CURRENTS USING DIGITAL CONTROL SYSTEM

For Abstract see entry 08A - 104

[1997] 17C - REF

STUDY ON CONTROL OF STATIC VOLTAGE COMPENSATOR (SVC)

For Abstract see entry 08A - 115

[1996] 17C - REF

HYBRID COMPENSATION STRATEGIES IN NONSINUSOIDAL CONDITIONS

For Abstract see entry 08A - 69

[1996] 17C - REF

INTEGRATED MEDIUM VOLTAGE (2300V-6900V) AC DRIVE/VAR COMPENSATOR

For Abstract see entry 08A - 73

[1996] 17C - REF

A PWM STATIC VAR COMPENSATOR BASED ON PHASE-SHIFT-CONTROLLED MULTIPLE-BRIDGE SUPERPOSITION HARMONIC ELIMINATION TECHNIQUE

For Abstract see entry 08A - 8

[1997] 17C - REF

PROPER SELECTION OF STATIC VAR COMPENSATOR CONFIGURATION FOR INDUSTRIAL APPLICATION

For Abstract see entry 08A - 98

[1997] 17C - REF

SYSTEM STABILITY IMPROVEMENT IN THE RSA-ZIMBABWE AC INTERCONNECTION BY INSTALLATION OF AN SVC

For Abstract see entry 08B - 16

[1996] 17C - REF

ELF MAGNETIC FIELDS BY CLOSE PROXIMITY TO A LARGE STATIC VAR COMPENSATOR: A CASE STUDY

For Abstract see entry 08B - 3

[1997] 17C - REF

AN EMTDC MODEL OF A THREE LEVEL FOUR MVAR COMPENSATOR

For Abstract see entry 09A - 14

[1998] 17C - REF

A DC VOLTAGE CONTROL METHOD OF 5 LEVEL INVERTER FOR SELF-COMMUTATED SVC WITH AN ASYMMETRICAL SWITCHING PATTERN

For Abstract see entry 09A - 3

[1998] 17C - REF

A NEURAL NETWORK-CONTROLLED OPTIMAL PULSE-WIDTH MODULATED STATCOM

For Abstract see entry 09A - 5

[1997] 17C - REF

EXACT ANALYSIS OF A MULTIPULSE SHUNT CONVERTOR COMPENSATOR OR STATCON. PART 2: ANALYSIS

For Abstract see entry 09A - 53

[1997] 17C - REF

MATHEMATICAL MODELS OF A THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 63

[1997] 17C - REF

MULTILEVEL STATCOM WITH THIRD HARMONIC ELIMINATION ON THE DC LINK CAPACITOR VOLTAGES

For Abstract see entry 09A - 67

[1997] 17C - REF

MULTIPULSE CONTROL OF VOLTAGE SOURCE CONVERTERS FOR STATIC VAR COMPENSATION

For Abstract see entry 09A - 69

[1997] 17C - REF

A NEW LOW DISTORTION SELF-

COMMUTATED STATIC VAR COMPENSATOR AS A VAR SOURCE

For Abstract see entry 09A - 7

[1998] 17C - REF

OPERATING PRINCIPLES OF SHUNT STATCOM BASED ON 3-LEVEL DIODE-CLAMPED CONVERTERS AND TWELVE-PHASE MAGNETICS

For Abstract see entry 09A - 74

[1997] 17C - REF

A NEW TRANSFORMER-LESS MULTI-LEVEL CONVERTER FOR HIGH VOLTAGE HIGH POWER APPLICATIONS

For Abstract see entry 09A - 8

[1997] 17C - REF

A NOVEL ACTIVE THREE PHASE VAR COMPENSATOR

For Abstract see entry 09A - 9

[1996] 17C - REF

THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 95

[1996] 17C - REF

STEADY-STATE CHARACTERISTICS AND INSTABILITY OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A -- 105

[1997] 17C - REF

CHARACTERIZATION OF A THYRISTOR CONTROLLED REACTOR

For Abstract see entry 10A - 23

[1998] 17C - REF

INVESTIGATION OF POWER SYSTEM HARMONICS AND SSR PHENOMENA RELATED TO THYRISTOR CONTROLLED SERIES CAPACITORS

For Abstract see entry 10A - 61

[1997] 17C - REF

LOOP CURRENT CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 67

[1997] 17C - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. LOOP CURRENT CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 81

[1998] 17C - REF

SERIES COMPENSATION ON POWER SYSTEM WITH VERY LOW HARMONIC DISTORTION

For Abstract see entry 10A - 99

[1996] 17C - REF

OPERATION OF THE UNIFIED POWER FLOW CONTROLLER AS HARMONIC ISOLATOR

For Abstract see entry 11A - 29

[1996] 17C - REF

SIMULATION STUDY OF A TRANSMISSION SYSTEM CONTAINING TWO UNEQUALLY RATED PARALLEL LINES AND A UPFC

For Abstract see entry 11A - 39

[1997] 17C - REF

A DESIGN CONCEPT OF DC FILTERS FOR MAGNET POWER SUPPLIES

For Abstract see entry 14A - 1

[1997] 17C - REF

SIMULATION OF PARALLEL-CONNECTED CURRENT-SOURCE CONVERTERS FOR SMES SYSTEM

For Abstract see entry 14A - 107

[1997] 17C - REF

SERIES POWER LINE COMPENSATOR USING SELF-COMMUTATED INVERTER

For Abstract see entry 16D - 5

[1997] 17C - REF

MULTI-LEVEL CONVERTERS FOR STATIC VAR COMPENSATION

For Abstract see entry 17B - 20

[1996] 17C - REF

NEW HIGH-VOLTAGE VARIABLE-FREQUENCY RESONANT-COMMUTATED CONVERTER

For Abstract see entry 17B - 24

[1997] 17C - REF

REAL-TIME DETECTION METHODS OF GENERALIZED INSTANTANEOUS REACTIVE CURRENTS USED FOR ACTIVE COMPENSATORS

For Abstract see entry 18E - 21

[1996] 17C - REF

VALIDATION OF PHASOR CALCULATIONS IN THE MACRODYNE PMU FOR CALIFORNIA-OREGON TRANSMISSION PROJECT TEST OF MARCH 1993

For Abstract see entry 18E - 23

[1997] 17C - REF

DEVELOPMENT OF STATCOM FOR POWER SYSTEM SIMULATOR AND HARMONIC ELIMINATION METHOD USING COUPLING TRANSFORMER

For Abstract see entry 19E - 15

17D Transformers, Reactors

[1997] 17D - REF

CAPABILITIES AND STRESSES, ON MAIN COMPONENTS OF YI-FENG TCSC

For Abstract see entry 10A - 22

17E Capacitors

[1996] 17E - 1

APPLICATION OF DOUBLE-LAYER CAPACITOR TECHNOLOGY TO STATIC CONDENSERS FOR DISTRIBUTION SYSTEM VOLTAGE CONTROL

Halpin, S.M.; Spyker, R.L.; Nelms, R.M.; Burch, R.F.

Mississippi State Univ, MS, USA

IEEE Trans on Power Systems, vol 11, no 4, 1996, pp 1899-1904

Static condensers may be utilized to mitigate many power quality problems in distribution systems. The condenser requires some type of energy storage such as a battery, a superconducting magnetic system, or a capacitor. The use of double-layer capacitors in static condensers is examined in this paper. These capacitors are characterized by high values of capacitance and equivalent parallel resistance and low values of equivalent series resistance. Double-layer capacitor technology is discussed and equivalent circuit models are presented. Test results for a 2.3-V, 470-F double-layer capacitor are presented to demonstrate how operation in a static condenser may affect capacitor performance. Design considerations for the use of this technology in a static condenser are discussed. Operation of a static condenser employing double-layer capacitors is illustrated using EMTP. 10 refs.

[1996] 17E – 2

BPA'S PACIFIC AC INTERTIE SERIES CAPACITORS: EXPERIENCE, EQUIPMENT & PROTECTION

Lee, G.E.; Goldsworthy, D.L.

Bonneville Power Admin, Portland, OR, USA

IEEE Trans on Power Delivery, vol 11, no 1, January 1996, pp 253-259 .

Over BPA's 40 years of series capacitor experience, equipment evolution has dramatically reduced the complexity of capacitor protection systems. BPA and other utilities in the Pacific Northwest recently installed 13 new metal oxide varistor (MOV) protected series capacitors. Nearly all the banks use a simplified design which eliminates the typical triggered gap bypass protection for the MOV. The decision to use a gapless design, the MOV energy sizing, and the protective bypass thresholds require extensive EMTP fault simulations. A large number of staged system fault tests were performed to evaluate the integrity of the banks. 3 Refs.

[1996] 17E – 3

PRE-CHARGE CIRCUIT UTILIZING NON-LINEAR FIRING ANGLE CONTROL

Gilmore, T.; Skibinski, G.

Allen Bradley Standard Drives Div, Mequon, WI, USA

Proceedings, 31st IEEE Industry Applications Conf (IAS '96), San Diego, CA, October 6-10, 1996, vol 2, pp 1099-1105

A new capacitor pre-charge circuit is described that limits both peak dc link and peak ac input line current to any desired magnitude, thereby providing for optimum pre charge control and robust operation. Pre-charge control is optimum since the link capacitor is charged without voltage overshoot in the shortest possible time with maximum allowable power converter current. The new control is robust in applications containing partially precharged bus capacitors, ground and bus faults, input ac line transients or momentary ac line loss. The precharge circuit employs a microprocessor which implements a novel nonlinear discontinuous current control scheme without the need for current sensors. The pre-charge circuit is well suited for use with an ac to dc power converter having a link inductor and a dc bus capacitor which requires pre-charging before full power is applied to the power converter. The paper describes the problem with existing pre-charge circuits while emphasizing the advantages of the new control. Governing equations and a control block diagram of the new nonlinear control algorithm is given along with implementation suggestions. 3 Refs.

[1998] 17E – REF

CAPACITOR BANK SERIES GROUP SHORTING (CAPS) DESIGN STUDY

For Abstract see entry 07B – 12

[1997] 17E – REF

CAPABILITIES AND STRESSES, ON MAIN COMPONENTS OF YI-FENG TCSC

For Abstract see entry 10A – 22

18 PERFORMANCE OF FACTS DEVICES

18A Analytical Techniques for Design of FACTS Controllers

[1997] 18A – 1

APPLICATION OF MANIFOLD TO TRANSIENT STABILITY ANALYSIS OF POWER SYSTEMS WITH FACTS CONTROLLERS

Kitagawa, A.; Mitani, Y.; Tsuji, K.

Osaka Univ, Japan

Shisutemu Seigyo Joho Gakkai Kenkyu Happyo Koenkai Koen Ronbunshu (Japan), vol 41, pp 93-94

Japanese

The power system stabilizing control by FACTS (flexible ac transmission system), to which much advanced technology of power electronics is applied, are very much attracting attention of power system engineers. This paper proposes a general method to evaluate the effect of power system stabilization quantitatively by the means of the manifold of a second order oscillatory system, especially the method to evaluate necessary capacities of FACTS controllers by approximating the function of manifolds without iterative calculation.

[1996] 18A – 2

APPLICATION OF SLIDING MODE CONTROL IN A POWER SYSTEM WITH TORSIONAL OSCILLATIONS

Takahashi, K.; Mitani, Y.; Tsuji, K.

Osaka Univ, Japan

Denki Gakkai Denryoku, Enerugi Bumon Taikai Ronbunshu (Japan), vol 7, no 1-E, pp 189-194

The effect of slip mode control on the electric power system having the torsional mode was investigated. It was clarified that the torsional vibration generated in the electric power system depend on the dead time of switching operation, because the slip mode control was carried out by a series of on/off switching. The addition of the feedback control loop was proposed as measures for relaxation of the torsional vibration in the electric power system by the subsynchronous resonance during operation of the slip mode control.

[1998] 18A – 3

COORDINATED DECENTRALIZED OPTIMAL CONTROL OF INTER-AREA OSCILLATIONS IN POWER SYSTEMS

Lie, T.T.; Li, G.J.; Shrestha, G.B.; Lo, K.L.

Nanyang Tech Univ, Singapore

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO4.4

Abstract not available

[1996] 18A - 4

DAMPING ANALYSIS AND CONTROL FOR LONGITUDINAL POWER SYSTEMS

Chen, H-J.; Chen, X-Y.

Hehai Univ, Nanjing, China

Proceedings of the Chinese Society of Electrical Engineering (Zhongguo Dianji Gongcheng Xuebao), vol 16, no 4, July 1996, pp 257-261

Chinese

One of the typical features of the longitudinal power systems is the poor system damping if they are not properly controlled. Some factors that have strong influence on the damping of the longitudinal systems are analyzed. To increase system damping, decentralized control method is used in the study of the supplementary damping control of excitation systems as well as thyristor-controlled series compensation. Some significant results have been obtained. 3 Refs.

[1996] 18A - 5

DAMPING AND SYNCHRONIZING TORQUES INDUCED ON GENERATORS BY FACTS STABILIZERS IN MULTIMACHINE POWER SYSTEMS

Pourbeik, P.; Gibbard, M.J.

Univ of Adelaide, Australia

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 1920-1925

Using modal analysis, a new technique is described for calculating the electrical damping and synchronizing torque coefficients induced on generators through the action of FACTS stabilizers in multimachine systems. At a given modal frequency and for an increment in gain of each stabilizer, it is possible to assess from an array of induced damping and synchronizing torque coefficients the effect of each stabilizer on the damping of individual generators. Furthermore, using this array, the technique is extended to calculate the contribution of each generator to the eigenvalue shift resulting from the gain increment. To illustrate the application and interpretation of the technique, stabilizers for two SVCs are designed to improve the damping of the inter-area mode in a 11 machine, 2 area power system. 9 Refs.

[1998] 18A - 6

DETERMINATION OF LOCAL TRANSIENT STABILITY CONTROL BASED ON NEURAL NETWORKS

Liu, Y.T.; Zhang, P.; Gao, T.; Xia, D.Z.

Shandong Univ of Tech, Jinan, China

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper S14.2

Abstract not available

[1997] 18A - 7

DEVELOPMENT OF FUZZY CONTROLLER UNDER HYBRID SIMULATION ENVIRONMENT FOR POWER SYSTEM STABILITY ENHANCEMENT: A SHOWCASE

Chang, C.S.; Liang, Y.C.; Lim, B.H.

Dept of Elec Eng, Natl Univ of Singapore

Journal of the Institution of Engineers Singapore (Singapore), vol 37, no 1, 1997, pp 56-64

This paper presents the process in the development of a non-adaptive and adaptive fuzzy logic controller (FLC) under the methodology of hybrid simulation. The FLC is developed with a 12-bit digital fuzzy processor (Omron FP-3000) and interfaced to a digital host computer. During the simulations, the fuzzy control process is handled by the FLC hardware developed and verified online, and the plant controlled is emulated by the host computer to interact with the controller designed. The simulation results were recorded and used for modification on fuzzy controller design. This helps to design the hardware controller under a more realistic environment and in a more accurate manner. A showcase on development of FLC of static var source (SVS) for a longitudinal power system is described in the text to demonstrate the effectiveness of this methodology.

[1996] 18A - 8

DISCUSSIONS ON SAMPLING TIME FOR POWER SYSTEM CONTROL METHOD USING FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

Takayama, S.; Shiratori, S.; Fujita, G.; Takeuchi, S.; Shirai, G.

Hosei Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 119-129, pp 37-45

Japanese

This paper shows the influence by the change of sampling time in a study of FACTS control, which has been watched and studied because it will be very effective for stabilizing the complicated power systems after faults. So far, the control system methods for FACTS have been designed by continuous time control. However, it must be designed with digital control theory for actual applications. Digital control has some advantages such as the conveniences of sampling time decision, designing control, and consideration for computation time delay. In this paper, in order to determine the effective sampling time, including the computation time delay, the relations between continuous and discrete time system are examined.

[1998] 18A - 9

DISSIPATIVITY AS A UNIFYING CONTROL DESIGN FRAMEWORK FOR SUPPRESSION OF LOW FREQUENCY OSCILLATIONS IN POWER SYSTEMS

Stankovic, A.M.; Stefanov, P.C.; Tadmor, G.; Sobajic, D.J.

Northeastern Univ, Boston, MA

IEEE Trans on Power Delivery, Preprint order number PE-380-PWRS-0-1-1998

In this paper we present a unifying framework for design of controllers that suppress low-frequency oscillations in power systems. The proposed methodology is based on the physical notion of dissipativity, and on its system-theoretic counterparts. We illustrate the capabilities of this framework in four application areas: power system stabilizers (PSSs), supplementary control for a high-voltage dc (HVDC) line, auxiliary control for static var systems (SVCs) and regulation of thyristor-controlled series capacitors (TCSCs). All case studies involve a standard benchmark case of a multimachine power system, and all controllers use only locally available information.

[1996] 18A - 10

DYNAMIC COMPENSATOR DESIGN FOR HV AC POWER SYSTEM USING ARTIFICIAL NEURAL NETWORKS

Salim, G.A.; Choudhry, M.A.; Ellithy, K.A.; Naraghi-Pour, M.

Dept of Elec & Computer Eng, West Virginia Univ, Morgantown, WV, USA

Proceedings, 28th Southeastern Symp on System Theory, Baton Rouge, LA, March 31-April 2, 1996, pp 202-205

This paper presents a method for designing a dynamic compensator based on artificial neural networks (ANN). The ANN is trained to give the proper compensator parameters (X, Tz) so as to always assign certain eigenvalues to desired locations in the output feedback system. The eigenvalues of concern are those associated with the angle delta and speed omega . These eigenvalues are to be assigned to the specified locations under variations in several system parameters (static nonlinear load parameters A_p and A_q, transmission line reactance x_e, and generated real power P_G). The exact and ANN's results of compensator parameters are plotted. In addition speed response is provided for the compensated and uncompensated systems. Results show that the ANN can be used on line once the off line training is performed to determine the compensator data so as to maintain the desired response of the system under variations in system parameters. 4 Refs.

[1997] 18A - 11

EFFECTS OF FACTS ON POWER SYSTEM DYNAMICS

Varaiya, P.; Wu, F.

Univ of California, Berkeley, CA, USA

EPRI TR-108328 8050-09, Final Report, June 1997 (D. Sobajic, EPRI prog mgr)

A two-part study examined the effect of transmission line compensators. Part 1 analyzed phenomena of subsynchronous resonance (SSR) in a macro-model of a series-compensated control system for a turbine generator. Part 2 looked at switch time jumps in a micro-model of thyristor circuits. Because of the difference in time scale, the bifurcations studied in the two parts are quatilatively different. Analysis of SSR in a macro-model of a turbine generator system with series-capacitor compensation showed that after the first Hopf bifurcation, the stable limit cycle bifurcates into a stable torus and an unstable limit cycle that connects to a stable limit cycle by supercritical torus bifurcation. The stable limit cycle joins with an unstable limit cycle as a cyclic fold bifurcation. This unstable limit cycle is connected to the second Hopf. It was numerically demonstrated that such a strange sequence of periodic orbits is created by a q-axis damper winding. The study of bifurcations of periodic orbits in power electronic circuits focused on circuits operating under closed-loop control and/or containing nonlinear components including period doubling bifurcations and bifurcations due to Poincare map discontinuities. An interesting feature of power electronic circuits is that they may have Poincare maps that are continuous but not everywhere differentiable or discontinuous.

[1996] 18A - 12

ELECTROMAGNETIC DESIGN CONSIDERATIONS FOR FAST ACTING CONTROLLERS

Woodford, D.A.

Manitoba HVDC Research Centre, Winnipeg, Manitoba, Canada

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1515-1521

Electromagnetic design considerations for fast acting controllers in a power system is introduced and defined. A distinction is made in relation to the more commonly understood system control design necessary for damping electromechanical oscillations using stability programs and eigenanalysis. Electromagnetic eigenanalysis tools have limited availability and are consequently rarely used. Electromagnetic transients programs (EMPT) on the other hand are widely used and a procedure for undertaking electromagnetic control design of fast acting controllers in a power system using emtp is presented.

[1996] 18A - 13

ENERGY APPROACH TO ANALYSIS OF INTERAREA OSCILLATIONS IN POWER SYSTEMS

Jing, C.; McCalley, J.D.; Kommareddy, M.

Siemens Empros Power Sys Control, Plymouth, MN, USA

IEEE Trans on Power Systems, vol 11, no 2, May 1996, pp 734-740

In this paper, an energy approach to analysis of interarea oscillations (IAO) in power systems has been developed. IAO is characterized as oscillatory behavior, following a disturbance, of the rotor motion for two or more generator groups such that there is a periodic interchange of energy between them. By comparing the phase of the coefficient of the dominant energy mode in the kinetic energy for each generator, we identify the groups for which there are periodic interchanges of energy. The location of these groups in the system provides insight regarding transmission lines over which the energy interchange is taking place. Numerical results are obtained using a test system similar in structure and characteristics to that of the WSCC system in North America. Time domain simulation indicates installation of thyristor-controlled series capacitors in key transmission lines identified using the results of the energy analysis provides an effective control for damping IAO. 13 Refs.

[1998] 18A - 14

EXPERIMENTAL EVALUATION OF STATCOM CLOSED LOOP DYNAMICS

Lehn, P.W.; Iravani, M.R.

Univ of Toronto, Canada

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

This paper presents a new approach for the dynamic control of FACTS apparatus, such as the STATCOM and UPFC, which utilize voltage source inverters (VSI) as the main building block. The control concept is based on linearization of the dq inverter model. Feed-forward techniques, which are traditionally used for the approximate decoupling of d and q axis control are

discarded in favor of a high gain full state feedback approach, which assigns both closed loop system poles and, more importantly, their associated eigenvectors. Experimental validation of the approach is carried out on a laboratory STATCOM setup. Due to the nonlinear nature of the VSI equations and the uncertainty of ac system parameters, actual closed loop system dynamics can stray quite dramatically from the desired. Root locus analysis is therefore performed to investigate the small signal system dynamic behavior. The loci demonstrate that the effect of system nonlinearity on the closed loop poles is virtually eliminated by the proposed control. The effect of ac system parameter variations is also shown to be minimal.

[1996] 18A - 15

FACTS CONTROLLER FOR STABILITY IMPROVEMENT OF ELECTRICAL POWER SYSTEMS: A FUZZY APPROACH

Gagliardi, F.; De Martinis, U.; Lauria, D.; Luciano, A.M.; Napoli, E.; Romano, P.

Naples Univ, Italy

Proceedings, Symp on Power Electronics, Industrial Drives Power Quality, Traction Systems, Capri, Italy, June 5-7, 1996, pp B6-1-7

Some considerations are performed with reference to the electrical power systems stability improvements. In the first part of the paper the flexible ac transmission system (FACTS) devices employment is highlighted. These apparatuses are used for dynamically adjusting the network configuration in order to enhancing both the steady-state behavior and the transient stability. In the second part, a new general method for the generation of fuzzy rules to a fuzzy logic variable structure FACTS controller is applied. The correctness of our approach is verified by some numerical applications, while no evaluation of the economical effectiveness is performed.

[1997] 18A - 16

FOURTH SUPPLEMENT TO A BIBLIOGRAPHY FOR THE STUDY OF SUBSYNCHRONOUS RESONANCE BETWEEN ROTATING MACHINES AND POWER SYSTEMS

Iravani, M.R.; Agrawal, B.L.; Baker, D.H.; Bowler, C.E.J.; Farmer, R.G. ; Hedin, R.A.; Larsen, E.H.V.; Tang, J.F.

IEEE Torsional Issues Working Group

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1276-1282

This is the fourth supplement to `A Bibliography for the Study of Subsynchronous Resonance Between Rotating Machines and Power Systems'. This paper includes the published papers in the area of subsynchronous resonance during the time span of February 1990 to end of January 1996. 32 Refs.

[1996] 18A - 17

FUZZY LOGIC SWITCHING OF FACTS DEVICES FOR STABILITY ENHANCEMENT

Hiyama, T.; Kihara, H.; Miyauchi, H.; Ortmeyer, T.H.

Kumamoto Univ, Japan

Proceedings, IEEE Int'l Symp on Circuits and Systems (ISCAS), Atlanta, GA, USA, May 12-15, 1996, vol 1, pp 605-608

This paper presents a new switching control scheme for FACTS devices such as high speed phase shifter, thyristor-controlled series capacitor modules, braking resistor, and static var compensator, using a fuzzy logic to enhance overall stability of electric power systems. All the FACTS devices are set on one of the buses including generator terminals in transmission systems. The real power flow at the location of the FACTS devices is utilized to determine the thyristor switching. Because the switching control scheme is simple, it does not require heavy computation on the micro-computer based switching controller. The same fuzzy logic switching control scheme is applied to all the FACTS devices. Simulation results show the effectiveness of the proposed fuzzy logic switching control scheme. 7 Refs.

[1996] 18A - 18

GLOBAL CONTROLLABILITY OF THE POWER TRANSMISSION NETWORK

Khapalov, A.Y.; Mohler, R.R.

Dept of Elec & Computer Eng, Oregon State Univ, Corvallis, OR, USA

Proceedings, 35th IEEE Conf on Decision and Control, Kobe Japan, December 11-13, 1996, vol 3, pp 3400-3405

Global controllability of 2D and 4D nonlinear models of power transmission networks governed via flexible ac transmission systems (FACTS) is studied. This suggests that control functions enter the system via coefficients. The approach employed is based on a qualitative method. 9 Refs.

[1996] 18A - 19

GPFC MODEL BASED LINE POWER FLOW CONTROL OF POWER SYSTEM

Yu, J-L.; Liu, Z.

Harbin Inst of Tech, China

Power System Technology (China), vol 20, no 4, April 1996, pp 19-22, 26

Chinese

Based on the analysis of series compensation, shunt compensation, phase shifters and unified power flow controllers, this paper presents a novel unified analysis method for line power flow control of power systems using the model of a generalized power flow controller (GPFC). Examples of test systems show that the method can use a unified mathematical model and a unified data format to deal with the problem of line power flow control with various control means, such as series compensation, shunt compensation, phase shifters and unified power flow controllers. Therefore the method can be widely applied and provides an effective tool for the analysis of various power flow control schemes. 11 Refs.

[1996] 18A - 20

HIGH POWER SWITCH MODE LINEAR AMPLIFIERS FOR FLEXIBLE AC TRANSMISSION SYSTEM

Mwinyiwiwa, B.; Wolanski, Z.; Ooi, B-T.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Power Delivery, vol 11, no 4, October 1996, pp 1993-1998

The pulse width modulation (PWM) technique has been proposed for the force-commutated shunt and series VAr controllers and unified power flow controllers in flexible ac transmission systems. The PWM converters can be operated as linear amplifiers of constant gain so that treasure trove of linear control system theory can be brought to bear more easily when applying feedback controls. For example, pole-placement and active filtering have been successfully applied in laboratory models. This paper is written as a tutorial describing the stages of signal processing: modulation, amplification and demodulation, without reference to power electronics since the solid-state switches are modeled as ON-OFF switches. 22 Refs.

[1997] 18A - 21

IMPROVEMENT OF NETWORK DAMPING AND TRANSIENT STABILITY BY ACTIVE AND REACTIVE POWER CONTROL

Dilger, R.; Nelles, D.

Univ of Kaiserslautern, Germany

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 2, March 1997, pp 125-128

It is shown how FACTS can be used to improve the dynamic behavior of electrical power systems. The aspects presented for the applications of compensators are damping of power oscillations and amelioration of transient stability. Control strategies based on local measurable quantities are derived using the direct Lyapunov method, and the relation between observability, controllability and effectiveness of active and reactive power control is discussed. 10 Refs.

[1997] 18A - 22

IMPROVEMENT OF TRANSIENT STABILITY LIMIT IN POWER SYSTEM TRANSMISSION LINES USING FUZZY CONTROL OF FACTS DEVICES

Sadeghzadeh, S.M.; Ehsan, M.; Said, N. Hadj; Feuillet, R.

Sharif Univ of Tech, Tehran, Iran

Proceedings, 20th IEEE Int'l Conf on Power Industry Computer Applications, Columbus, OH, May 11-16, 1997, pp 331-336 (Preprint order number PE-100-PWRS-16-09-1997)

The objective of this paper is to investigate the application of FACTS devices to increase the maximum loadability of the transmission lines which may be constrained by a transient stability limit. Hence, the on-line fuzzy control of the superconducting magnetic energy storage (SMES) and the static synchronous series compensator (SSSC) are suggested. The fuzzy rule-bases are defined and explained. The validity of the suggested control strategies are confirmed by simulation tests. The simulation results show that by the use of the proposed method, the line power transfer can be increased via the improvement of the transient stability limit. Finally, the effect of the control loop time delay on the performance of the controller is presented. 8 Refs.

[1996] 18A - 23

LOW-ORDER BLACK-BOX MODELS FOR CONTROL SYSTEM DESIGN IN LARGE POWER SYSTEMS

Kamwa, I.; Trudel, G.; Gerin-Lajoie, L.

Inst de Recherche d'Hydro-Quebec, Varennes, Canada

IEEE Trans on Power Systems, vol 11, no 1, February 1996, pp 303-311

The paper studies two multi-input multi-output (MIMO) procedures for the identification of low-order state-space models of power systems, by probing the network in open loop with low-energy pulses or random signals. Although such data may result from actual measurements, the development assumes simulated responses from a transient stability program, hence benefiting from the existing large base of stability models. While pulse data is processed using the eigensystem realization algorithm, the analysis of random responses is done by means of subspace identification methods. On a prototype Hydro-Quebec power system, including SVCs, dc lines, series compensation, and more than 1100 buses, it is verified that the two approaches are equivalent only when strict requirements are imposed on the pulse length and magnitude. The 10th-order equivalent models derived by random-signal probing allow for effective tuning of decentralized power system stabilizers (PSSs) able to damp both local and very slow inter-area modes. 25 Refs.

[1998] 18A - 24

MEASURING POWER FLOWS CONTROLLERS BENEFITS FOR POWER TRANSFER CONSTRAINTS ON EHV NETWORKS

Pramayon, P.; Zaoui, L.; Mallet, P.

Electricite de France

Proceedings, CIGRE 3rd South African Regional Conf, May 20-21, 1998

Within FACTS technology, power flow controllers such as UPFC or more conventional PST are considered by many as efficient means to enhance the power systems capability, offering flexibility and easiness to a more competitive power industry. This paper presents the methodologies adopted to measure such device abilities to solve constraints due to power transfer limitations with an application to quite a typical example of power transfer between two regions or countries, or between a producer and a high consumption zone. Some results are sketched out, both to illustrate the method functionaliities and the power flow controller's abilities to bring additional transfer capacity with regard to the security of the system and economic profitability.

[1997] 18A - 25

MODELING WITH INDEPENDENT INTELLIGENT AGENTS FOR DISTRIBUTED CONTROL OF THE ELECTRIC POWER GRID

Wildberger, A.M.

EPRI, Palo Alto, CA, USA

Proceedings, 59th American Power Conf, Chicago, IL, vol 59-1, 1997, pp 361-364

The North American power network may realistically be considered to be the largest machine in the world since its transmission lines connect all the electric generation and distribution on the continent. With the advent of deregulation, unbundling and competition in the electric power industry, new ways are being sought to improve efficiency without seriously diminishing reliability. This paper describes a model for real-time, distributed control of an electric power system by independent, intelligent agents operating locally with minimal supervisory control. It is intended to provide the mathematical and computational basis for maximizing the benefit obtainable from enhanced FACTS and other active control devices when used in conjunction with the artificial intelligence-based, self-calibrating, self-diagnostic sensors that are also being developed. This modeling approach is intended to place computation and automated decision making at the same locations as sensors and controllers in order to significantly accelerate computation for global optimization and facilitate recovery after failure. 13 Refs.

[1996] 18A - 26

ON THE APPLICATION OF FACTS CONTROLLERS DERIVED FROM LOSSLESS MODELS TO LOSSY SYSTEMS

Gronquist, J.F.; Hiskens, I.A.

Dept of Elec & Computer Eng, Univ of Wisconsin, Madison, WI, USA

Proceedings, 35th IEEE Conf on Decision and Control, Kobe Japan, December 11-13, 1996, vol 3, pp 3459-3463

This paper studies the effects of applying controls for FACTS (flexible ac transmission system) devices derived from energy functions for lossless systems to systems with losses. The intent is to examine whether such controls can be effective, and under what

circumstances they could produce a destabilizing effect.

[1996] 18A - 27

PLANNING AND OPERATING RATINGS FOR INVERTER-BASED FACTS POWER FLOW CONTROLLERS

Waples, S.A.; Law, A.S.; Nelson, R.J.; Gernhardt, M.G.

Washington Water Power, Spokane, WA, USA

Proceedings, 58th American Power Conf (Technology for Competition and Globalization), Chicago, IL, 1996, vol 1, pp 1555-1561

Abstract not available

[1997] 18A - 28

ROBUST DECENTRALISED DESIGN FOR MULTIPLE FACTS DAMPING CONTROLLERS

Taranto, G.N.; Shiau, J.-K.; Chow, J.H.; Othman, H.A.

COPPE/Fed Univ of Rio de Janeiro, Brazil

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 1, January 1997, pp 61-66

A systematic robust decentralized design procedure based on the H8-optimization technique for tuning multiple FACTS devices is presented. The design procedure uses a model-matching robustness formulation and requires the design of a parameter to achieve decentralized control. The approach is used to design damping controllers for an SVC and a TCSC to enhance the damping of the interarea modes in a 3-area 6-machine system. The feedback signals for the controllers are synthesized from the local voltage and current measurements. 19 Refs.

[1998] 18A - 29

ROBUST DECENTRALISED CONTROL DESIGN USING GENETIC ALGORITHMS IN POWER SYSTEM DAMPING CONTROL

Taranto, G.N.; Falcao, D.M.

COPPE/Fed Univ of Rio de Janeiro, Brazil

IEE Proceedings: Generation, Transmission and Distribution (UK), vol 145, no 1, January 1998, pp 1-6

The paper presents the design of linear robust decentralized fixed-structure power system damping controllers using genetic algorithms (GA). The designed controllers follow a classical structure consisting of a gain, a wash-out stage and two lead-lag stages. To each controller is associated a set of three parameters representing the controller gain and the controller phase characteristics. The GA searches for an optimum solution over the parameter space. Controller robustness is taken into account as the design procedure considers a prespecified set of operating conditions to be either stabilized or improved in the sense of damping ratio enhancement. A truly decentralized control design is achieved as the loop control channels are closed simultaneously. The approach is used to design SVC and TCSC damping controllers to enhance the damping of the interarea modes in a three-area six-machine system. Local voltage and current measurements are used to synthesize remote feedback signals. 17 Refs.

[1997] 18A - 30

STRUCTURE-BASED MODELING AND CONTROL OF ELECTRIC POWER SYSTEMS

Ilic, M.; Liu, X.; Eidson, B.; Vialas, C.; Athans, M.

MIT, Cambridge, MA, USA

Automatica, vol 33, no 4, April 1997. pp 515-531

This paper addresses the modeling and closed-loop control of large-scale electric power systems operating under normal conditions. A new structure-based modeling approach is introduced - an approach which reveals fundamental properties of power system dynamics, and offers physical insight into the interaction between its constituent subsystems. These properties and insights lead to the formulation of simple, higher level models which represent slow interactions among subsystems driven by slow load variations. The models which evolve from this structure-based approach enable hierarchical control design, without any a priori assumptions regarding the strength of the interactions among the subsystems. New control designs are thus proposed at both the subsystem and the interconnected system levels, a key element in their formulation being that both react to variables reflecting interactions between subsystems. Reactive power/voltage (Q/V) control problems are used to illustrate the proposed modeling and control approach. 19 Refs.

[1997] 18A - 31

THE CONNECTION BETWEEN MODAL ANALYSIS AND ELECTRIC TORQUE ANALYSIS IN STUDYING THE OSCILLATION STABILITY OF MULTI-MACHINE POWER SYSTEMS

Swift, F.J.; Wang, H.F.

Manchester Metropolitan Univ, UK

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 5, June 1997, pp 321-330

Modal analysis and electric torque analysis are two of the most widely used techniques for studying the oscillation stability of multi-machine power systems, such as for the design of power system stabilizers or FACTS-based stabilizers. Modal analysis is based on the modal control theory and electric torque analysis is established and developed from a physical understanding of the characteristics of the electromechanical oscillation loop of generators in power systems. These two techniques have been considered to be different both in their principles of derivation and methods of calculation. However, in this paper, a connection between these two methods is revealed. It is found that they are basically equivalent. Through the revelation of the connection between these two methods, a deeper insight and understanding into the mechanisms of the methods is presented.

[1997] 18A - 32

TUNING OF POWER SYSTEM DAMPING CONTROLLERS USING GENETIC ALGORITHMS

do Bomfim, A.L.B.; Taranto, G.N.; Falcao, D.M.

COPPE/Fed Univ of Rio de Janeiro, Brazil

Proceedings, 1997 Conf on Intelligent System Applications to Power Systems (ISAP '97), Seoul, South Korea, July 6-10, 1997, pp 79-83

This paper presents a robust method for tuning power system damping controllers using genetic algorithms (GAs). The method is centered on a tuning criterion function based on the sum of the spectrum damping ratios for a set of operating conditions and constraints on the minimum damping ratio. Evaluations of the design criterion are based on computations of the eigenvalues of a linearized model of the power system electromechanical dynamics. As an example, the method is applied to the design of a static VAr compensator (SVC) and a thyristor-controlled series compensator (TSCS) damping controllers to enhance the damping of the inter-area modes in a 3 areas, 6 machines, test system. Several different GAs strategies were tested and compared.

[1996] 18A - 33

VOLTAGE STABILITY ASSESSMENT AND ENHANCEMENT USING ARTIFICIAL NEURAL NETWORKS AND REACTIVE COMPENSATION

Momoh, J.A.; Dias, L.G.; Adapa, R.

Dept of Elec Eng, Howard Univ, Washington, DC, USA

Proceedings, Int'l Conf on Intelligent System Application to Power Systems (ISAP'96), Orlando, FL, January 28-February 2, 1996, pp 410-415

This paper demonstrates the use of artificial neural networks for voltage stability assessment and enhancement of a power system. The neural network is trained with data containing a variety of load patterns. The reactive compensation is applied via switchable shunt VAr support. studies are conducted on the New England 39-bus power system. It is concluded that artificial neural networks can be used for assessment of the support needed for extending the margin, and to assess the extended stability margin with reasonable accuracy. 27 Refs.

[1997] 18A - REF

POWER ELECTRONICS AND DRIVES-TECHNOLOGY STATUS AND ADVANCEMENT

For Abstract see entry 07A - 43

[1997] 18A - REF

SELECTION OF INSTALLING LOCATIONS AND FEEDBACK SIGNALS OF FACTS-BASED STABILISERS IN MULTIMACHINE POWER SYSTEMS BY REDUCED-ORDER MODAL ANALYSIS

For Abstract see entry 07B - 48

[1998] 18A - REF

ANALYSIS OF CONTROL INTERACTIONS ON FACTS-ASSISTED POWER SYSTEMS

For Abstract see entry 07B - 6

[1996] 18A - REF

A STATIC VAR COMPENSATOR CONTROL STRATEGY TO MAXIMIZE POWER SYSTEM DAMPING

For Abstract see entry 08A - 10

[1996] 18A - REF

SLIDING MODE CONTROL OF A STATIC VAR CONTROLLER FOR SYNCHRONOUS GENERATOR STABILIZATION

For Abstract see entry 08A - 107

[1996] 18A - REF

A STUDY ON ADAPTIVE SVC CONTROLLER USING NEURAL NETWORKS FOR ENHANCEMENT OF POWER SYSTEM STABILITY

For Abstract see entry 08A - 11

[1998] 18A - REF

STUDIES ON VIPI BASED CONTROL METHODS FOR IMPROVING VOLTAGE STABILITY

For Abstract see entry 08A - 112

[1996] 18A - REF

A STUDY ON THE EFFECT OF CONTROLLERS IN SMALL SIGNAL STABILITY OF POWER SYSTEMS

For Abstract see entry 08A - 12

[1998] 18A - REF

THE USE OF SWITCHING FUNCTIONS AND WALSH SERIES TO CALCULATE WAVEFORM DISTORTION IN THYRISTOR-CONTROLLED COMPENSATED POWER CIRCUITS

For Abstract see entry 08A - 127

[1997] 18A - REF

TUNING OF SVC STABILISER TO COMPENSATE THE INFLUENCE OF VOLTAGE DEPENDENT LOADS

For Abstract see entry 08A - 134

[1996] 18A - REF

VARIABLE STRUCTURE CONTROL OF A STATIC VAR COMPENSATOR FOR SYSTEM DYNAMIC STABILITY

For Abstract see entry 08A - 139

[1996] 18A - REF

ADAPTIVE STATIC VAR COMPENSATOR FOR ENHANCING POWER SYSTEM STABILITY

For Abstract see entry 08A - 15

[1997] 18A - REF

APPROACH TO DESIGNING THE FUZZY IF-THEN RULES FOR FUZZY-CONTROLLED STATIC VAR COMPENSATOR (FCSVC)

For Abstract see entry 08A - 31

[1997] 18A - REF

A METHOD FOR SVC DAMPING CONTROLLER DESIGN USING ROBUST POLE ASSIGNMENT METHOD

For Abstract see entry 08A - 5

[1998] 18A - REF

DAMPING ENHANCEMENT BY ROBUST TUNING OF SVC CONTROLLERS IN THE PRESENCE OF LOAD PARAMETERS UNCERTAINTY

For Abstract see entry 08A - 50

[1996] 18A - REF

DESIGN OF A STATIC REACTIVE POWER COMPENSATOR USING FUZZY SLIDING MODE CONTROL

For Abstract see entry 08A - 52

[1997] 18A - REF

HOPF BIFURCATION CONTROL IN POWER SYSTEMS WITH STATIC VAR COMPENSATORS

For Abstract see entry 08A - 68

[1996] 18A - REF

VOLTAGE STABILITY IMPROVEMENT USING ASVG NONLINEAR CONTROL

For Abstract see entry 09A - 103

[1997] 18A - REF

CONTROL SYSTEM DESIGN FOR TRANSMISSION STATCON BY APPLYING NONLINEAR FEEDBACK

For Abstract see entry 09A - 33

[1998] 18A - REF

A NEURAL NETWORK-CONTROLLED OPTIMAL PULSE-WIDTH MODULATED

STATCOM

For Abstract see entry 09A -- 5

[1996] 18A - REF

ENHANCEMENT OF POWER SYSTEM STABILITY USING NONLINEAR CONTROL STRATEGY OF ASVG

For Abstract see entry 09A - 51

[1996] 18A - REF

EXACT LINEARIZATION FOR ADVANCED REACTIVE POWER COMPENSATORS

For Abstract see entry 09A - 54

[1997] 18A - REF

STUDY ON MULTI-OBJECTIVE CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATION

For Abstract see entry 10A - 107

[1996] 18A - REF

ANALYSIS OF CONTROLLABLE SERIES COMPENSATOR TO SUPPRESS POWER SYSTEM OSCILLATIONS

For Abstract see entry 10A - 12

[1997] 18A - REF

TIME-OPTIMAL SERIES CAPACITOR CONTROL FOR DAMPING INTERAREA MODES IN INTERCONNECTED POWER SYSTEMS. DISCUSSION

For Abstract see entry 10A - 120

[1996] 18A - REF

APPLICATION OF SELF-TUNING FUZZY CONTROL IN TRANSIENT STABILITY OF POWER SYSTEM

For Abstract see entry 10A - 16

[1996] 18A - REF

APPLICATION OF THE CONTROLLABLE SERIES COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATIONS

For Abstract see entry 10A - 17

[1997] 18A - REF

AUTO-DISTURBANCES REJECTION CONTROLLER FOR THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC)

For Abstract see entry 10A - 21

[1996] 18A - REF

DAMPING CONTROLLER DESIGN FOR POWER SYSTEM OSCILLATIONS USING GLOBAL SIGNALS

For Abstract see entry 10A - 29

[1998] 18A - REF

A SOLID-STATE CONTROLLABLE SERIES CAPACITIVE REACTANCE FOR IMPROVED UTILISATION OF HIGH-POWER TRANSMISSION LINES

For Abstract see entry 10A - 3

[1997] 18A - REF

DISCRETE CONTROL OF SERIES COMPENSATION FOR STABILITY IMPROVEMENT IN POWER SYSTEMS

For Abstract see entry 10A - 36

[1996] 18A - REF

IMPROVEMENT OF TRANSIENT STABILITY OF MULTI-MACHINE POWER SYSTEMS USING FACTS EQUIPMENT APPLYING FUZZY CONTROL

For Abstract see entry 10A - 57

[1997] 18A - REF

IMPROVEMENT OF TRANSIENT STABILITY OF POWER SYSTEMS USING VARIABLE SERIES CAPACITOR APPLYING NEURO-FUZZY CONTROLLER

For Abstract see entry 10A - 59

[1997] 18A - REF

MULTI-MACHINE POWER SYSTEM STABILIZING CONTROL BASED ON H8. CONTROL THEORY

For Abstract see entry 10A - 70

[1996] 18A - REF

OPTIMAL CONTROL OF SERIES COMPENSATORS AND PHASE SHIFTING TRANSFORMERS IN POWER SYSTEMS

For Abstract see entry 10A - 75

[1997] 18A - REF

OUTPUT FEEDBACK TCSC CONTROLLERS TO IMPROVE DAMPING OF MESHED MULTI-MACHINE POWER SYSTEMS

For Abstract see entry 10A - 78

[1996] 18A - REF

POWER SYSTEM STABILITY ENHANCEMENT BY ADAPTIVE FUZZY CONTROL

For Abstract see entry 10A - 85

[1997] 18A - REF

POWER SYSTEM STABILIZING CONTROL USING VARIABLE SERIES CAPACITOR BASED ON H8 CONTROL THEORY CONSIDERING AVR AND GOVERNOR

For Abstract see entry 10A - 87

[1996] 18A - REF

POWER SYSTEM STABILIZING CONTROL FOR FACTS DEVICES USING FUZZY NEURAL NETWORKS

For Abstract see entry 10A - 88

[1996] 18A - REF

ROBUST, NEAR TIME-OPTIMAL CONTROL OF POWER SYSTEM OSCILLATIONS WITH FUZZY LOGIC. DISCUSSION

For Abstract see entry 10A - 94

[1996] 18A - REF

ESTIMATING DAMPING EFFECTIVENESS OF BPA'S THYRISTOR CONTROLLED SERIES CAPACITOR BY APPLYING TIME AND FREQUENCY DOMAIN METHODS TO MEASURED RESPONSE

For Abstract see entry 10B - 1

[1996] 18A - REF

IMPROVEMENT OF TRANSIENT STABILITY USING UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 23

[1996] 18A - REF

PERFORMANCE OF A UNIFIED POWER FLOW CONTROLLER USING A D-Q CONTROL SYSTEM

For Abstract see entry 11A - 32

[1997] 18A - REF

POWER SYSTEM STABILITY ENHANCEMENT USING STATIC PHASE SHIFTER

For Abstract see entry 12A - 14

[1998] 18A - REF

EXPERIMENTAL STUDY ON DYNAMIC STABILITY IMPROVEMENT OF A SINGLE-MACHINE INFINITE bus POWER SYSTEM BASED ON A SLIDING MODE CONTROL OF PHASE SHIFTER

For Abstract see entry 12A - 8

[1996] 18A - REF

FUZZY APPROACH FOR MULTIOBJECTIVE OPTIMIZATION IN MAGNETICS

For Abstract see entry 14A - 54

[1997] 18A - REF

FUZZY SET THEORY BASED CONTROL OF SUPERCONDUCTIVE MAGNETIC ENERGY STORAGE UNIT TO IMPROVE POWER SYSTEM DYNAMIC PERFORMANCE

For Abstract see entry 14A - 56

[1998] 18A - REF

DAMPING CONTROL DESIGN BASED ON TIME-DOMAIN IDENTIFIED MODELS

For Abstract see entry 16A - 7

[1996] 18A - REF

FUNDAMENTAL TECHNOLOGIES FOR THE ELECTRIC POWER FIELD. POWER

ELECTRONICS TECHNOLOGIES-EXPANDING CAPACITY OF EQUIPMENT AND APPLICATION TO POWER SYSTEMS

For Abstract see entry 17B - 14

[1996] 18A - REF

SIMULATION ANALYSES OF POWER SYSTEM INTERCONNECTING INVERTERS

For Abstract see entry 17B - 31

[1997] 18A - REF

DAMPING CONTROLLER DESIGNS FOR AN SVC AND OTHER FACTS DEVICES

For Abstract see entry 18C - 7

[1998] 18A - REF

STEADY-STATE ANALYSIS OF POWER FLOW CONTROLLERS USING THE POWER CONTROLLER PLANE

For Abstract see entry 19B - 19

[1997] 18A - REF

COMPUTER AIDED ENGINEERING PLATFORM FOR FACTS

For Abstract see entry 19E - 12

18B Performance Comparison of FACTS Devices

[1996] 18B - 1

ASSESSMENT AND CONTROL OF THE IMPACT OF FACTS DEVICES ON POWER SYSTEM PERFORMANCE

Galiana, F.D.; Almeida, K.; Toussaint, M.; Griffin, J.; Atanackovic, D. ; Ooi, B.T.; McGillis, D.T.

McGill Univ, Montreal, Quebec, Canada

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 1931-1936

The concept of security regions is used to systematically and objectively compare the impact of various FACTS devices on the behavior of power systems. Scalar measures of the steady-state performance of a power system with FACTS devices are used to quantify this impact. Such measures are obtained by solving an optimal power flow within the constraints of the security region. The concept of the ideal FACTS device is introduced as a means to establish a theoretical upper bound on the performance of any realizable FACTS. Such a device is tested and compared against non-ideal FACTS including the variable series reactance and the variable phase-shifter. Simulations on the IEEE 118 and 30-bus networks illustrate the above concepts. 11 Refs.

[1996] 18B - 2

AUXILIARY CONTROLLED SVS AND CONTROLLED SERIES COMPENSATION FOR FLEXIBLE AC TRANSMISSION SYSTEMS

Dave, M.P.; Kumar, N.

Univ of Roorkee, India

Proceedings, IEEE Int'l Conf on Power Electronics, Drives & Energy Systems for Industrial Growth (PEDES'96), New Delhi, India, January 8-11, 1996, vol 1, pp 121-127

In this paper the coordinated application of the controlled series compensation (CSC) and the SVS auxiliary controllers has been demonstrated for the dynamic and transient performance enhancement of a series compensated long transmission line. An SVS controller, known as the combined reactive power and frequency (CRPF) auxiliary controller, has been developed and incorporated in the SVS control system located at the middle of the transmission line. A digital computer simulation study, using a nonlinear system model, has been performed to illustrate the comparative effectiveness of the CSC and the SVS auxiliary controllers developed. 7 Refs.

[1996] 18B - 3

COMPARATIVE STUDY ON TRANSIENT STABILITY IMPROVING CAPABILITY OF SERIES AND SHUNT COMPENSATION

Choi, K.-H.; Jeong, C.-Y.; Oh, T.K.

Korea Electrotech Research Inst, Changwon, South Korea

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 1, pp 378-381

This paper presents a method of comparing series and shunt-controlled reactive power compensation approaches to improve power system transient stability.

The performance of controlled reactive compensation schemes has a major impact on both the efficiency and economy of the application of compensation devices. The proposed method is based upon the performance measure of damping power oscillation. For the purpose of comparative analysis, simple but idealized dynamic models of thyristor-controlled series/shunt compensation are used. The results obtained by EMTP simulation for a one-machine infinite-bus test system are presented. 4 Refs.

[1996] 18B - 4

COMPARISON OF MODAL CONTROLLABILITY BETWEEN FACTS-BASED STABILISERS AND PSS IN INCREASING THE OSCILLATION STABILITY OF MULTIMACHINE POWER SYSTEMS

Wang, H.F.; Swift, F.J.; Li, M.

Manchester Metropolitan Univ, UK

IEE Proceedings, Generation, Transmission and Distribution (UK), vol 143, no 6, November 1996, pp 575-581

The effectiveness of three types of FACTS-based stabilizers are compared with the PSS in terms of their modal controllability to the oscillation modes in multimachine power systems. The comparison is focused on two aspects of the damping effect of the stabilizers; first the robustness of the stabilizers to the variations of system parameters and operating conditions and secondly, the influence of the installing location. A sample three-machine power system is presented to demonstrate the analytical conclusions which emerge from the comparison. 18 Refs.

[1997] 18B - 5

DETERMINATION OF NEEDED FACTS CONTROLLERS THAT INCREASE ASSET UTILIZATION OF POWER SYSTEMS

Pilotto, L.A.S.; Ping, W.W.; Carvalho, A.R.; Wey, A.; Long, W.F.; Alvarado, F.L.; Edris, A.-A.; Demarco, C.L.

CEPEL, Centro de Pesquisas de Energia Eletrica, Rio de Janeiro, Brazil

IEEE Trans on Power Delivery, vol 12, no 1, January 1997, pp 364-371

The paper presents an approach for identifying the most effective flexible ac transmission system (FACTS) Controllers, locations, types and ratings that increase asset utilization of power systems. The approach is a combined static/dynamic procedure based on the use of a continuation power flow, an optimal power flow and an eigenvalue analysis. The application of this approach on a representative studied transmission system has resulted in an increase of the maximum stable loadability limit by 6.7%. The paper finally shows that the proposed approach is helpful in coordinating the functionality of FACTS controllers to enhance power system dynamics. 6 Refs.

[1998] 18B - 6

DYNAMIC POWER FLOW CONTROL WITH CONTROLLABLE REACTIVE SERIES ELEMENTS

Mihalic, R.

Faculty of Elec Eng and Computer Sci, Univ of Ljubljana, Slovenia

IEEE PES Winter Meeting, Tampa, Florida, February 1-5, 1998

The contribution presents the basic features of a controllable reactive series elements (CRSE), i.e., controllable series compensation (CSC) and a static synchronous series compensator (SSSC) regarding power flow control in a power system. First the CRSE impact on a simplified transmission system model was studied, applying a mathematical model. The physical background of the basic differences between CSC and SSC regarding power flow control has been presented. According to theoretical considerations, from the point of view of power-flow-control capability, SSSC is superior to CSC, especially in the area of low transmission angles. Therefore, SSSC seems to be suitable in cases where power flow should be controlled in short lines or in low-load conditions. On the basis of detailed CSC and SSSC models, simplified models for stability mode have been built and applied in two power oscillation stability studies. In one of the studies, CRSE was positioned in a heavy loaded line, while in the other study, the CRSE-compensated line was low-loaded. Digital simulation studies confirmed the theoretical considerations and simulation studies confirmed the theoretical considerations and showed SSSC advantages over CSC in low load flow conditions.

[1996] 18B - 7

EFFECTS OF FACTS DEVICES ON STATIC VOLTAGE STABILITY

Passelergue, J.-C.; Besanger, Y.; Hadjsaid, N.; Feuillet, R.

Inst Natl Polytech de Grenoble, Saint Martin d'Heres, France

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 945-948

Flexible ac transmission systems are expected to improve power systems performance. This paper describes a comparison study between three FACTS systems for static behavior in UHV transmission lines: a static VAr compensator (SVC), a STATic CONdenser (STATCON) and a thyristor-controlled series compensator (TCSC). This work focuses on voltage stability and power transmission capability. Results that have been obtained on two different test systems (IEEE 14 buses system, French-simplified UHV network) have shown the impact of each device on power systems. 10 Refs.

[1996] 18B - 8

FACTS-APPLICATION IN MESHED SYSTEMS-A COMPARATIVE ANALYSIS

Papazoglou, T.M.

Tech Education Inst, Greece

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 258-262

Comparison is made of the effectiveness on the steady-state load flow control of phase-shifting transformers (PST) and series compensation (SC). Attention is focused on the ability to reduce unscheduled loop flows and redirect power flows in the system. The Balkan section of the UCPTE system resulting after the parallel synchronous interconnection of Bulgaria is used as test system with loading conditions corresponding to the 1995 peak load. The properties of PST on power flow control are shown to be superior. The positive effects of PST in maintaining a high level of steady-state security while realizing relatively large multilateral power exchange programs are demonstrated. A comparison of the power flow control efficiencies and all economic estimation are made for PST and SC. 10 Refs.

[1996] 18B - 9

IMPROVEMENT OF POWER SYSTEM PERFORMANCE BY INSERTING FACTS DEVICES

Besanger, Y.; Passelergue, J.C.; Hadjsaid, N.; Feuillet, R.

Lab de Electrotechnique de Grenoble, Inst Natl Polytech de Grenoble, France

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 263-268

Flexible ac transmission system (FACTS) devices are expected to improve power system performance. This paper describes a comparative study between three FACTS systems for static behavior in UHV transmission lines: a static VAr compensator (SVC), a static condenser (STATCON) and a thyristor-controlled series compensator (TCSC). This work focuses on voltage stability and power transmission capability. It also contains a comparative study of dynamic performance for TCSC and SVC systems including load tap changers. Results that have been obtained on different test systems (IEEE 14-bus system, French-simplified UHV network, 30-bus New England network) have shown the impact of each device on power systems. 11 Refs.

[1996] 18B - 10

INFLUENCE OF THE REAL POWER MODULATION PROVIDED BY A SHUNT COMPENSATOR ON DAMPING POWER SWINGS

Pastos, D.A.; Giannakopoulos, G.B.; Vovos, N.A.

Univ of Patras, Rion, Greece

Proceedings, 3rd Intl Conf on Electronics, Circuits, and Systems, Rhodes, Greece, October 13-16, 1996, vol 2, pp 884-887

In this paper a comparison is made between the conventional shunt compensator (static VAr compensator, SVC) providing only reactive power modulation and the GTO-based advanced compensator (static condenser, STATCON) providing both active and reactive power modulation, regarding their effectiveness in damping power oscillations. Based on small perturbation analysis, the damping efficiency in terms of the real power flow change caused by a change of the compensating reactive or real power is calculated and compared. Also, the dependence of the damping on the compensator and load location is investigated. 7 Refs.

[1997] 18B - 11

POWER FLOW CONTROL USING STATIC SYNCHRONOUS SERIES COMPENSATOR

Mihalic, R.; Papic, I.

Faculty of Elec Eng and Computer Sci, Univ of Ljubljana, Slovenia

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 174-177

In this paper an attempt has been made to point out the basic differences between an impedance based controllable series compensation (CSC) and a static synchronous series compensator (SSSC) which is based on power electronic converters with GTO thyristors. First basic theoretical considerations regarding power flow control in the transmission line using SSSC have been studied applying the mathematical model. Results clarify basic differences between CSC and SSSC regarding this question. The time-domain simulation using detailed SSSC simulation model confirmed theoretical considerations. On the test system, which may be found in various countries, the differences between CSC and SSSC regarding power oscillation damping have been demonstrated. Results showed that in specific conditions SSSC can be much more effective than CSC. 5 Refs.

[1996] 18B - REF

COMPARING THE VOLTAGE CONTROL CAPABILITIES OF PRESENT AND FUTURE VAR COMPENSATING TECHNIQUES IN TRANSMISSION SYSTEMS

For Abstract see entry 08A - 38

[1997] 18B - REF

SIMULATION OF THE STATIC CONDENSER FOR THE PREVENTION OF TRANSIENT VOLTAGE INSTABILITY DUE TO INDUCTION MOTOR LOAD

For Abstract see entry 09A - 88

[1996] 18B - REF

EVALUATION OF VOLTAGE AND REACTIVE POWER CONTROL USING DISPERSED ENERGY STORAGE SYSTEMS

For Abstract see entry 14A - 44

[1997] 18B - REF

STATIC SYNCHRONOUS SERIES COMPENSATOR: A SOLID-STATE APPROACH TO THE SERIES COMPENSATION OF TRANSMISSION LINES

For Abstract see entry 16A – 11

[1996] 18B - REF

SYSTEM ASPECTS OF GTO-CONTROLLED SERIES COMPENSATION

For Abstract see entry 16C – 3

[1996] 18B - REF

TRANSIENT STABILITY ENHANCEMENT WITH FACTS CONTROL

For Abstract see entry 19C - 4

18C Coordinated Control of FACTS Devices

[1996] 18C - 1

A STUDY OF IMPROVEMENT FOR POWER SYSTEM STABILITY BY A TCSC WITH ?P TYPE PSS

Kai, T.; Takeuchi, N.; Sato, T.; Akagi, H.

Meidensha Corp, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 11-20

Japanese

Thyristor-controlled series capacitor (TCSC) is expected as an improvement method of power system stability and power transfer capability. The basic circuit consists of a thyristor-controlled reactor paralleled by a capacitor. This paper presents an improvement of power system stability by installing the TCSC with ?P type PSS between one machine and infinite-bus system. Additionally, a model, which is based on the transient model of a generator and TCSC model is developed, and compared with the result of EMTP.

[1996] 18C - 2

ANALYSIS AND CONTROL OF DYNAMIC INTERACTION AMONG MULTIPLE STATIC VAR COMPENSATORS IN THE NREB POWER SYSTEM

Gupta, R.P.; Reddy, P.V.K.; Varma, R.K.; Sachchidanand; Prabhu, S.S.; Das, A.K.,Tripathi, A.K.; Chaukiyal, G.P.; Adhikari, T.

Indian Inst of Tech, Kanpur, India

Proceedings, 9th National Power Systems Conf (NPSC

'96), Kanpur, India, 1996, vol 1, pp 272-277

The objectives of the paper are (1) to analyze the dynamic interaction among the proposed multiple static var compensator in electrical proximity within the Northern Regional Electricity Board (NREB) power system, and (2) to design appropriate controllers for these static var compensators so that they not only do not adversely interact among themselves, but also with the existing SVC and the dc link in the NREB power system. To meet these objectives, a software tool dynamic interaction study program (DISP) has been developed. Utilizing this software the NREB power system has been studied. Investigations performed both under nominal and outage conditions include (i) load flow analysis, (ii) eigenvalue studies, and (iii) time domain simulation. Appropriate controllers have been designed for the various SVCs to meet the desired objectives. The results of studies performed show close correlation between the small signal eigenvalue analysis and time domain simulation.

[1997] 18C - 3

CO-ORDINATED TUNING OF PSS AND FACTS-BASED STABILIZERS IN MULTI-MACHINE POWER SYSTEMS

Swift, F.J.; Wang, H.F.

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Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 1-4

In this paper, a new scheme for the coordinated synthesis of FACTS-based stabilizers and PSS in multi-machine power systems to improve system oscillation stability is proposed. An example three-machine power system is demonstrated in the paper, where a TCSC-based stabilizer and a PSS is installed and tuned by the new scheme to damp the multi-mode oscillations occurring in the power system. 4 Refs.

[1997] 18C - 4

COORDINATED DESIGN OF FACTS CONTROLLERS TO ENHANCE POWER SYSTEM DYNAMIC PERFORMANCE

Pilotto, L.A.S.; Ping, W.W.; Carvalho, A.R.; Long, W.F.; Alvarado, F.L.; DeMarco, C.L.; Edris, A.-A.

CEPEL, Centro de Pesquisas de Energia Eletrica, Rio de Janeiro, Brazil

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

The paper presents an approach for identifying the most effective FACTS controllers, locations, types and ratings that increase asset utilization of power systems. The approach is a combined static/dynamic procedure based on the use of a continuation power flow, an optimal power flow and an eigenvalue analysis. Mechanisms of control interactions among FACTS devices operating in the same electrical area are investigated using both an eigenvalue and the EMTP programs.

[1997] 18C - 5

COORDINATED SMES AND VARIABLE SERIES IMPEDANCE FOR LOAD FREQUENCY CONTROL

Ngamroo, I.; Mitani, Y.; Tsuji, K.

Osaka Univ, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 94-109, pp 7-12

This paper proposes a decentralized direct tie-line power flow control strategy of a superconducting magnetic energy storage (SMES) and variable series impedance (VSrZ) for load frequency control (LFC) in multi-area interconnected power system. Based on the concept of decentralized control, the multi-area interconnected power system is decomposed into several areas. Then, a SMES is located in the area which has the largest capacity, while decentralized VSrZs are located on the tie-lines between the areas. Each area is controlled separately by the SMES or a decentralized VSrZ which is utilized as the local-frequency controller. Only the local frequency deviation of each area is used as the feedback signal of a SMES or a VSrZ. Under the occurrence of sudden load change in any area, the active power output of SMES is controlled to minimize the frequency deviation of its located area, while decentralized VSrZs modulate tie-line power flows directly in order to suppress frequency deviations of other areas. The effectiveness of proposed control strategy is verified by simulation study. Simulation results show that, when the sudden load fluctuations occur in any area, the proposed decentralized control strategy of a SMES and VSrZ is capable of suppressing frequency deviations of all interconnected areas simultaneously and effectively, independent of the configuration of multi-area interconnected power system.

[1996] 18C - 6

COORDINATION OF THE THYRISTOR CONTROLLED SERIES COMPENSATION WITH

OTHER FACTS DEVICES IN INTERCONNECTED POWER SYSTEMS

Lei, X.; Lerch, E.; Povh, D.; Renz, K.; Weiss, S.

Siemens AG, Erlangen, Germany

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 893-898

The integration of a new TCSC device into a power system in which other FACTS devices as, for example, SVCs are already in operation, could cause the problem of possible interactions among the controls of different FACTS devices. This problem can even increase if a larger number of different FACTS devices are installed. This paper presents a method for determining parameter settings of the new TCSC controller taking into account the whole nonlinear power system. By minimizing power oscillations using an optimization mode in the simulation program system NETOMAC, the controller of the TCSC will be coordinated and optimized with other FACTS controllers to achieve desired performance of the whole system at transient condition. Based on power oscillation modes studied by an eigenvalue analysis, a possible location of TCSC is evaluated, and effects of the controllers optimized with the optimization are also demonstrated. As an example FACTS device existing in the system is a SVC. Results obtained from a real power system validated the necessity of global settings of the power system tested. 6 Refs.

[1997] 18C - 7

DAMPING CONTROLLER DESIGNS FOR AN SVC AND OTHER FACTS DEVICES

Miller, N.W.; Sanchez-Gasca, J.J.; Clark, K.

GE Power Sys Eng Consulting, Schenectady, NY, USA

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

The first part of this paper presents the design of a damping controller for a static var compensator (SVC) based on a low order system representation derived from time domain simulations using a standard stability program. This new approach circumvents the need for specialized software for computing system matrices and their associated modal characteristics. The validity of this technique is demonstrated with the design of a damping controller for an SVC located between interconnected grids to allow for increased power transfers. The second part of the paper illustrates the design of a coordinated damping controller to allow for increased power transfers with improved system damping. The controller coordinates the action of a thyristor-controlled series capacitor (TCSC) and a thyristor-controlled phase angle regulator (TCPAR), using readily available measurements.

[1997] 18C - 8

DESIGN OF SERIES AND SHUNT FACTS CONTROLLER USING ADAPTIVE NONLINEAR COORDINATED DESIGN TECHNIQUES

Tan, Y.L.; Wang, Y.

Nanyang Tech Univ, Singapore

IEEE Trans on Power Systems, vol 12, no 3, August 1997, pp 1374-1379

A nonlinear coordinated generator excitation, static phase shifter (SPS) and static Var compensator (SVC) controller is proposed to enhance the transient stability of a power system. The proposed controller is novel since it is able to control the three main parameters affecting a.c. power transmission; namely voltage, phase angle, and reactance in a coordinated manner. The SPS is located near the generator terminal and the SVCs are located at the midpoint of each transmission line in a power system. Nonlinear feedback control law is found which linearize and decouple the power system. The coordinated controller consists of three separate controllers: an adaptive excitation and SPS controller and two SVC controllers. These controllers are designed based on local measurements only. The results show that the proposed nonlinear coordinated series and shunt FACTS controller is able to enhance the transient stability of a single-machine-infinite-bus (SMIB) power system. 19 Refs.

[1997] 18C - 9

IMPROVED POWER SWING DAMPING BY COORDINATED FACTS CONTROLS

Lei, X.Z.; Povh, D.; Renz, K.

Siemens AG, Erlangen, Germany

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

A number of different FACTS controls among a power system could cause interactions between FACTS devices. In order to successfully cope with global load flow and stability problems, coordination of all devices involved has become a challenging task. This paper presents a method for global coordination of FACTS controls. Using an optimization mode in the simulation program system, parameters of controllers associated

with FACTS devices and PSSs in the system can be globally determined at transient conditions. For the minimization of the power swings, also other operation constraints such as voltage profiles can be considered taking into account the whole non-linear system. Results obtained from a three area power system by events of both large and small disturbances validated the improvement of damping of power swings in the system studied, where a SVC and a TCSC and three PSSs are involved.

[1997] 18C - 10

LOW FREQUENCY OSCILLATIONS DAMPING BY FACTS AND POWER SYSTEM STABILIZERS

Passelergue, J.-C.; Hadjsaid, N.; Besanger, Y.; Feuillet, R.

Lab d'Electrotechnique de Grenoble, France

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 9-12

This paper presents a study of the application of a flexible ac transmission system device (STATic COMpensator) and a power system stabilizer to enhance the damping of an interarea oscillation exhibited by a two-area four-machine power system. The study has been carried out using small signal stability theory and eigenvalues analysis. The results are illustrated by simulations obtained with the EUROSTAG software program. The interarea oscillation damping is improved more by the STATCOM. However, the PSS permits to improve the damping coefficient of the local mode concerning the area where this one is connected, when the STATCOM is not efficient. The study of the system has also shown that an appropriate coordination has to be realized in order to avoid a worse damping of the interarea mode when both a PSS and a STATCOM are connected. 10 Refs.

[1997] 18C - 11

METHOD AND SOFTWARE FOR COORDINATED TUNING OF POWER SYSTEM REGULATORS

Maslennikov, V.A.; Ustinov, S.M.

Sydney Univ, Australia

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1419-1424

A method for coordinated tuning of power system regulators (AVR, PSS, SVC, etc.) to improve damping of small disturbed oscillations for a variety of power systems operating conditions is given. The method is based on multi parameter numerical optimization to shift eigenvalues of interest to the left on the complex plane. The advanced POISK software which utilizes the proposed method is described. 19 Refs.

[1998] 18C - 12

POWER FLOW DURING POWER SYSTEM STABILIZING CONTROL BY A SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SUPERSMES)

Ise, T.; Okamoto, I.; Ishii, J.; Kumagai, S.

Osaka Univ, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol 98, no 10-21, pp 35-40

Japanese

The combination of a superconducting magnetic energy storage (SMES) and a static synchronous series compensator (SSSC), which was named as SuperSMES, is considered to be a promising unified power quality controller which can perform power system stabilizing control, compensation of load fluctuation, harmonic voltage and current compensation and etc. This paper shows the results of power flow analysis during power system stabilizing control by the SuperSMES based on experimental results with a 10-kJ superconducting magnet and a 10-kVA model transmission line.

[1998] 18C - 13

SERIES CAPACITORS COMBINED WITH STATIC VAR COMPENSATORS FOR ENHANCEMENT OF STEADY-STATE VOLTAGE STABILITIES

El-Sadek, M.Z.; Dessouky, M.; Mahmoud, G.A.; Rashed, W.I.

Assiut Univ, Egypt

Electric Power Systems Research, vol 44, no 2, February 1998, pp 137-143

Use of series capacitors (SC) alone or in combination with static VAr compensators (SVC) for enhancement of steady-state voltage stability are illustrated. The appropriate compensation percentage is obtained from the steady-state voltage stability point of view. The influence of a combination of SC and SVC on ratings and performance are studied. Limitations of the use of series capacitors alone are examined. 14 Refs.

[1998] 18C - REF

ANALYSIS OF CONTROL INTERACTIONS ON FACTS-ASSISTED POWER SYSTEMS

For Abstract see entry 07B - 6

[1997] 18C - REF

SIMULATION OF UNIFIED STATIC VAR COMPENSATOR AND POWER SYSTEM STABILIZER FOR ARRESTING SUBSYNCHRONOUS RESONANCE

For Abstract see entry 08A – 106

[1997] 18C - REF

STUDY ON CONTROL OF STATIC VOLTAGE COMPENSATOR (SVC)

For Abstract see entry 08A - 115

[1996] 18C - REF

SYNCHRONOUS GENERATOR DAMPING ENHANCEMENT THROUGH COORDINATED CONTROL OF EXCITER AND SVC

For Abstract see entry 08A - 119

[1996] 18C - REF

THE OPTIMIZATION METHOD FOR COORDINATED TUNING OF POWER SYSTEM REGULATORS

For Abstract see entry 08A - 124

[1998] 18C - REF

CONTROLLING SVCs FOR BETTER MANAGEMENT OF NORTHERN GRID OF INDIA

For Abstract see entry 08A - 45

[1996] 18C - REF

COORDINATED FUZZY LOGIC CONTROL BETWEEN SVC AND PSS TO ENHANCE STABILITY OF POWER SYSTEMS

For Abstract see entry 08A - 47

[1998] 18C - REF

FUZZY LOGIC CONTROL SCHEME WITH VARIABLE GAIN FOR STATIC VAR COMPENSATOR TO ENHANCE POWER SYSTEM STABILITY

For Abstract see entry 08A - 66

[1998] 18C - REF

A ROBUST CONTROL STRATEGY FOR SHUNT AND SERIES REACTIVE COMPENSATORS TO DAMP ELECTROMECHANICAL OSCILLATIONS

For Abstract see entry 08A - 9

[1996] 18C - REF

THE COORDINATED CONTROL OF TCSC AND PSS TO IMPROVE POWER SYSTEM DAMPING

For Abstract see entry 10A - 114

[1996] 18C - REF

APPLICATION OF CONTROLLED SERIES COMPENSATION AND STATIC VAR SYSTEM FOR FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 10A - 15

[1998] 18C - REF

APPLICATION OF THYRISTOR CONTROLLED SERIES COMPENSATORS TO ENHANCE OSCILLATORY STABILITY AND TRANSMISSION CAPABILITY OF LONGITUDINAL POWER SYSTEM

For Abstract see entry 10A - 18

[1997] 18C - REF

OUTPUT FEEDBACK TCSC CONTROLLERS TO IMPROVE DAMPING OF MESHED MULTI-MACHINE POWER SYSTEMS

For Abstract see entry 10A - 78

[1996] 18C - REF

STUDY ON APPLICABILITY OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM

For Abstract see entry 14A - 122

[1997] 18C - REF

EXPERIMENTAL STUDY ON THE CONTROL

METHOD FOR POWER SYSTEM STABILIZATION USING SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE(SUPERSMES)

For Abstract see entry 14A - 48

18D Faults, Protection of FACTS Devices

[1998] 18D - 1

A NOVEL NON-UNIT PROTECTION FOR SERIES COMPENSATED EHV TRANSMISSION LINES BASED ON FAULT GENERATED HIGH FREQUENCY VOLTAGE SIGNALS

Jayasinghe, J.A.S.B.; Aggarwal, R.K.; Johns, A.T.; Bo, Z.Q.

Univ of Bath, UK

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 405f

A new high-speed protection technique based on fault generated high frequency (HF) voltage signals is developed and applied to the protection of series-compensated lines. It is a non-unit protection technique as it relies totally on locally derived information, but it has the discriminative properties normally associated with unit protection schemes. The protection scheme has been designed using computer-aided-design (CAD) techniques, including emulation of analog interface and hardware. It is shown that the new relay scheme is able to overcome many difficult protection problems encountered on such lines using conventional methods, and discriminates clearly between internal and external faults, producing a fast trip output.

[1996] 18D - 2

ALGORITHMS FOR LOCATING FAULTS ON SERIES COMPENSATED LINES USING NEURAL NETWORK AND DETERMINISTIC METHODS. DISCUSSION

Novosel, D.; Bachmann, B.; Hart, D.; Hu, Y.; Saha, M.M.

ABB-TTI, USA

IEEE Trans on Power Delivery, vol 11, no 4, 1996, pp 1728-1736

This paper investigates a scheme to improve the reach measurement of distance relays and fault locators for series compensated lines. A deterministic method and a feedforward neural network method have been implemented for on-line calculation of the voltage across a non-linear capacitor installation. These techniques are compared and incorporated into a new relaying scheme which is independent of the series capacitor installation, operation of the capacitor protection, and the surrounding power system elements. The proposed scheme is simple and accurate and requires only local voltage and current at the bus. Detailed testing using EMTP has been done to show the benefits of the new adaptive scheme. The results demonstrate the suitability of the techniques for real world applications. 11 refs.

[1997] 18D - 3

ALGORITHMS FOR PROTECTION OF SERIES COMPENSATED LINES - THE COMPARATIVE ANALYSIS

Kasztenny, B.; Izykowski, J.; Rosolowski, E.; Saha, M.M.

Tech Univ of Wroclaw, Poland

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 299-302

Distance protection for series compensated lines faces certain problems caused by the fact that the impedance seen by a relay is not a strict geometrical measure of the distance to a fault. The apparent impedance is affected by the series capacitors and their non-linear overvoltage protecting arresters. Also subsynchronous oscillations may occur under high resistance faults as well as the voltage and/or current inversion what causes all traditional protection methods to fail. The phenomena specific to a series compensated line affect also the auxiliary functions of its distance relay including fault detection, phase selection and direction detection. All these blocks are essentially important for the overall performance of the complete distance relay. This presents a number of algorithms for fault detection, phase selection and direction detection as well as discusses conditions for their application to protection of a series compensated line. Selected results of EMTP/ATP-based testing of the algorithms are provided too. 10 Refs.

[1998] 18D - 4

AN ADAPTIVE PROTECTION SCHEME FOR ADVANCED SERIES COMPENSATED (ASC)

TRANSMISSION LINES

Girgis, A.A.; Sallam, A.A.; El-Din, A.K.

Clemson Univ, SC, USA

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 414-420

This paper presents an adaptive protection scheme for advanced series compensated (ASC) transmission lines. The scheme is based on Kalman and adaptive Kalman filters. The adaptive scheme utilizes the differences in the transient current signals for faults encountering and not encountering the ASC to determine the fault location with respect to the ASC and the faulted phases. Equations to determine the line impedance to the fault on these lines are developed. The adaptive scheme is tested for faults along and outside the protected line using EMTP simulated data.

[1996] 18D - 5

APPLICATION OF ARTIFICIAL NEURAL NETWORKS FOR SERIES COMPENSATED LINE PROTECTION

Bachmann, B.; Novosel, D.; Hart, D.; Yi Hu; Saha, M.M.

Proceedings, Int'l Conf on Intelligent System Application to Power Systems (ISAP'96), Orlando, FL, January 28-February 2, 1996, pp 68-73

This paper investigates the feedforward neural network (with a quasi-Newton method for minimization of the error function) for on-line calculation of the voltage across a nonlinear capacitor installation. This technique is incorporated into a new scheme which is independent of the series capacitor installation, operation of the capacitor protection, and the surrounding power system elements. The proposed scheme is simple and accurate and requires only local voltage and current at the bus to improve the reach measurement of distance relays and fault locators. Detailed testing using EMTP has been done to show the benefits, robustness and generalization capabilities of the ANN technique. 9 Refs.

[1997] 18D - 6

APPLYING PWM TO CONTROL OVERCURRENTS AT UNBALANCED FAULTS OF FORCED-COMMUTATED VSCS USED AS STATIC VAR COMPENSATORS

Jiang, Y.; Ekstrom, A.

Royal Inst of Tech, Stockholm, Sweden

IEEE Trans on Power Delivery, vol 12, no 1, January 1997, pp 273-278

This study is devoted to investigating the possibility of controlling the overcurrent of a forced-commutated voltage source converter (VSC) by PWM when the ac system is undergoing large unbalanced disturbance. The converter is supposed to be used as a static var compensator at a high power level. A novel control strategy is proposed for controlling the reactive current and the dc side voltage independently. Digital simulation results are presented and compared with the results by using just the reactive current control with fundamental switching frequency. 9 Refs.

[1996] 18D - 7

ARTIFICIAL NEURAL-NETWORK-BASED PROTECTION SCHEME FOR CONTROLLABLE SERIES-COMPENSATED EHV TRANSMISSION LINES

Song, Y.H.; Johns, A.T.; Xuan, Q.Y.

Univ of Bath, UK

IEE Proceedings, Generation, Transmission and Distribution (UK), vol 143, no 6, November 1996, pp 535-540

Controllable series compensation (CSC) is one of the main flexible ac transmission systems (FACTS) devices, which have the ability to improve the utilization of existing transmission systems. However, the implementation of this technology changes the apparent line impedance, which is controlled by the firing angle of thyristors, and is accentuated by other factors. This poses problems for conventional protection schemes. The paper proposes an adaptive protection scheme, based on neural networks, with special emphasis on the analysis of the zone-1 performance. The paper describes, in detail, the feature extraction, sampling rate, data window length and training of the designed artificial neural networks (ANNs). The main idea of the protection scheme is to employ an artificial neural network (ANN) to make a decision based on extracting useful features in the desired spectra within a certain frequency range under fault conditions. System simulation and test results are presented and analyzed in this paper to indicate the feasibility of using an ANN-based protection scheme in CSC transmission systems. 18 Refs.

[1997] 18D - 8

CONTROL AND CHARACTERISTICS OF A STATIC VAR GENERATOR UNDER SINGLE-LINE-TO-GROUND FAULTS

Kawahira, K.; Fujita, H.; Akagi, H.

Okayama Univ, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 4, pp 6.243-6.244

Japanese

Abstract not available.

[1997] 18D - 9

EVALUATION AND TESTING OF LINE PROTECTIONS FOR SERIES-COMPENSATED TRANSMISSION LINES

Marttila, R.J.

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Proceedings, 6th Int'l Conf on Developments in Power System Protection, Nottingham, UK, March 25-27, 1997, IEE Pub. no 434, 1997, pp 155-158

Fundamental-frequency models of protective relays can play an important role in the testing and evaluation of the relays' suitability in complex applications. This paper describes a process for evaluation of distance protections for application in series-compensated and adjacent lines. The process consists of the use of fundamental-frequency phasor models of relays to reduce the scope of necessary testing for a particular application. The application is a major North-South power corridor in the Ontario Hydro system, where it was proposed to install series capacitors in two parallel 500-kV lines at approximately midpoint of the 176-km lines. (Subsequent to these studies, the plan has been canceled). The proposed compensation was to be either 40% or 60%. Investigation of the effect of 60% compensation on the line protection on the compensated and adjacent lines is reported in this paper. Included in this investigation were studies to evaluate the suitability of existing protections and the selection of new protection equipment where deemed necessary. 5 Refs.

[1997] 18D - 10

FAST PROTECTION UNDER DIFFICULT CONDITIONS NECESSARY FOR POWER QUALITY

Povh, D.; Claus, M.; Holbach, J.; Krebs, R.; Marksteiner, J.

Siemens AG, Erlangen, Germany

Proceedings, CIGRE Regional Meeting "Power Quality – Assessment of Impact," New Delhi, India, September 10-11, 1997, vol V-1, pp If

While the globalization of electrical power supplies has resulted in the use of higher transmission voltages, there has been no equivalent increase in the number of installed transmission lines. Series capacitors can effectively increase the transmission capability in long distance ac power transmission systems, but the physical phenomena associated with such transmission methods have high demands on the protection systems. The necessary numerical methods can be implemented today in modern protection relays. When developing and type-testing EHV numerical line protection relays, great importance must be attached to exact simulation of physical processes that are also verified by primary tests. The experience of South African and American power suppliers with series-compensated lines also featured in the TNA simulation.

[1996] 18D - 11

FAULT LOOP IMPEDANCE MEASUREMENT FOR DIGITAL DISTANCE PROTECTION OF SERIES-COMPENSATED TRANSMISSION LINE

Izykowski, J.; Kasztenny, B.; Rosotowski, E.; Saha, M.M.

Inst Energoelektryki, Politech, Wroclawska, Poland

Przeglad Elektrotechniczny (Poland), vol 72, no 8, 1996, pp 199-204

Polish

Difficulties with protection of series-compensated lines result from the specific nature of transients for such lines. Slowly decaying sub-synchronous components appear in both voltage and current input relay signals. Due to that, direct application of protection systems designed for traditional lines to series-compensated lines fail. Therefore a new algorithm for fault loop impedance measurement dedicated to series-compensated lines has been developed. The paper describes the algorithm for the line treated as a linear system and presents EMTP/ATP simulation results showing its efficiency. 9 Refs

[1997] 18D - 12

GENETIC ALGORITHM BASED NEURAL NETWORKS APPLIED TO FAULT CLASSIFICATION FOR EHV TRANSMISSION LINES WITH A UPFC

Song, Y.H.; Johns, A.T.; Xuan, Q.Y.; Liu, J.Y.

Brunel Univ, UK

Proceedings, 6th Int'l Conf on Developments in Power System Protection, Nottingham, UK, March 25-27, 1997, IEE Pub. no 434, 1997, pp 278-281

This paper proposes a novel fault detection and classification scheme based on genetic algorithm based neural networks. The application concerned is fault classification for EHV transmission lines with a UPFC as fault classification is a key part of protective relaying schemes. After genetic algorithm based neural network is briefly discussed in general, EMTP based digital simulation results of a UPFC transmission system are presented. Then the generation of training/test data and preprocessing of these data for neural networks are described. 7 Refs.

[1997] 18D - 13

GTO PROTECTION IN ADVANCED STATIC VAR GENERATOR

Liu, W.; Liang, X.; Shen, D.; Wang, Z.; Li, C.; Zhu, Q.; Li, J.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 17-20

Chinese

Static VAr generators based voltage-source GTO inverters have entered the practical application stage due to the availability of high power gate-turn-off (GTO) thyristors. The reliability of advanced static VAr generator (ASVG) installations depends on the safe operation of these GTOs. A GTO protection scheme for ASVG installations under abnormal operations is analyzed in this paper, including the design of GTO gate drive circuits, GTO overvoltage protection and GTO overcurrent protection. A new GTO overcurrent protection scheme, called current-loop overcurrent protection, which can greatly improve the reliability of ASVG installations is given in this paper. A multi-level activating overvoltage and overcurrent protection scheme is proposed for ASVG installation which has been implemented in a ±300-kVAr ASVG installation.

[1998] 18D - 14

INCREASED TRANSMISSION CAPACITY BY FORCED SYMMETRIZATION

Glavitsch, H.; Rahmani, M.

Swiss Fed Inst of Tech, Zurich, Switzerland

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 79-85

Present planning procedures are based on single outages of three-phase circuits which do not take the actual fault pattern into account. The majority of faults are single-phase faults which is motivating the present approach to exploit the remaining conductors for power transmission. A shunt device (FACTS) is conceived which is able to generate a loading pattern at breaker locations with one or two phases open such that the network side always sees a symmetrical loading. The theoretical background is given and numerical examples illustrate the efficiency of the concept. The circuit affected by a fault may be modeled by a positive sequence impedance which can be inserted in ordinary power flow programs for security calculations. 6 Refs.

[1996] 18D - 15

INTEGRATED ADAPTIVE PROTECTION AND CONTROL FOR CONTROLLABLE SERIES COMPENSATED TRANSMISSION SYSTEMS USING NEURAL NETWORKS

Song, Y.H.; Xuan, Q.Y.; Johns, A.T.; Aggarwal, R.K.

Univ of Bath, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 335-339

This paper proposes a novel integrated adaptive protection and control scheme by using neural networks for controllable series compensated (CSC) EHV transmission systems. The emphasis is placed on the feature extraction, the selection of appropriate neural network architectures and their training. The adaptive protection scheme is tested under the influences of various factors, such as different fault type, fault position, fault resistance, fault inception angle, source capacity and load angle. All the test results demonstrate the proposed protection scheme has higher speed, reliability and sensitivity compared with conventional approaches when used for series compensated EHV transmission systems. By identifying the characteristic features of the faulted voltage waveforms, a neural network based adaptive autoreclosure scheme is then developed. The outcome of the study indicates that the neural network can be used as effective strategy for the development of adaptive protection and control schemes for controllable series compensated transmission systems. 8 Refs.

[1997] 18D - 16

METHOD FOR ELIMINATING THE EFFECT OF MOV OPERATION ON DIGITAL DISTANCE RELAYS WHEN USED IN SERIES COMPENSATED LINES

Ghassemi, F.; Goodarzi, J.; Johns, A.T.

Isfahan Univ of Tech, Iran

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 113-116

This paper describes a novel method that enhances the accuracy of digital distance relays applied on series compensated lines where the series capacitors are protected against over voltages by the metal oxide varistor (MOV). The technique is applicable to systems where the relaying voltage is taken from the busbar side of the series capacitor. The basis of the technique is a method known as voltage compensation. In this method the voltage across the series capacitor and over voltage protective device is calculated in the relay and hence the relaying signal is modified by the relay. The new compensation technique makes the impedance measurement immune to the MOV operations thus enhancing the relay integrity and the accuracy of impedance measurement. The new technique is simulated in a typical differential equation distance relay algorithm and is examined for ground and phase faults using the EMTP (ATP) simulation package. 4 Refs.

[1996] 18D - 17

NEW APPROACH TO MEASURING FAULT GENERATED HIGH FREQUENCY NOISE ON SERIES COMPENSATED EHV TRANSMISSION LINES

Jayasinghe, J.A.S.B.; Aggarwal, R.K.; Bo, Z.Q.; Johns, A.T.

Univ of Bath, UK

Proceedings, 31st Universities Power Engineering Conf, Iraklio, Greece, September 18-20, 1996, vol 3, pp 704-706

EHV transmission lines employing series capacitors pose many protection problems for conventional protection techniques, not ordinarily encountered with plain feeders. However, there is evidence to suggest that the relatively new concept based on non-power frequency components can provide an attractive alternative. This paper describe a new technique for modeling and the measurement of fault-generated high frequency signals associated with series-compensated EHV line application. 7 Refs.

[1996] 18D - 18

ON-LINE FAULT DIAGNOSIS TECHNIQUE FOR ADVANCED STATIC VAR GENERATOR USING NEURAL NETWORKS

Wang, Z-Q.; Su, P-S.; Jiang, J-G.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 936-940

This paper develops a new approach for on-line fault diagnostic technique in an ASVG device using artificial neural networks. The paper first discusses the main circuit fault feature through the circuit simulation approach technology. The pattern recognition of voltage wave through the use of artificial neural networks follows. Both the simulation and 300-kVAr ASVG prototype test results clearly show that the fault diagnosis scheme yields satisfactory performance for ASVG devices. 3 Refs.

[1996] 18D - 19

OVERVOLTAGES FOLLOWING LOAD REJECTION ON A SYSTEM WITH A SERIES-COMPENSATED TRANSMISSION LINE AND SATURATED TRANSFORMS

Pierrat, L.; Tran-Quoc, T.; Lam-Du, S.

Electricite de France, Grenoble, France

Proceedings, 8th IEEE Mediterranean Electrotechnical Conf, MELECON'96, Bari, Italy, May 13-16, 1996, vol 3, pp 1551-1554

This paper presents a digital simulation concerning load rejection on a system with a series capacitor compensated transmission line and saturated transformers. The simulation takes into account the nonlinearities of magnetization characteristic of transformer. Influences of the compensation level, the amount of load to be rejected, the line loading and the asymmetrical operation on overvoltages are investigated. 11 Refs.

[1996] 18D - 20

PERFORMANCE OF AN ADAPTIVE PROTECTION SCHEME FOR SERIES COMPENSATED EHV TRANSMISSION SYSTEMS USING NEURAL NETWORKS

Xuan, Q.Y.; Song, Y.H.; Johns, A.T.; Morgan, R.; Williams, D.

Univ of Bath, UK

Electric Power Systems Research, vol 36, no 1, January 1996, pp 57-66

Since the complex variation of line impedance is accentuated as the capacitor's own protection equipment operates randomly under fault conditions in series compensated transmission systems, conventional distance protection schemes are limited to certain applications. This paper proposes an adaptive protection scheme based on neural networks with special emphasis on analysis of the first-zone performance. The paper describes in detail the feature extraction, sampling rate, data window and structures of the neural networks. The basic idea of the method is to design a protection scheme using a neural network approach by catching the feature signals in a certain frequency range under fault conditions. This is different from conventional schemes that are based on deriving implicit mathematical equations based on the information obtained by complex filtering techniques. System simulation and test results presented and analyzed in the paper demonstrate the feasibility of the proposed scheme. 14 Refs.

[1997] 18D - 21

PROTECTION SCHEME FOR EHV TRANSMISSION SYSTEMS WITH THYRISTOR CONTROLLED SERIES COMPENSATION USING RADIAL BASIS FUNCTION NEURAL NETWORKS

Song, Y.H.; Xuan, Q.Y.; Johns, A.T.

Univ of Bath, UK

Electric Machines and Power Systems, vol 25, no 5, June 1997, pp 553-565

Since the complex variation of line impedance measured is controlled by thyristors and is accentuated as the capacitor's own protection equipment operates randomly under fault conditions in controllable series compensated transmission systems (CSC), conventional distance protection schemes are limited to certain applications. The authors have extensively addressed the development of new protection techniques for such systems using multilayer perceptrons. The basic idea of the method is to design a protection scheme using a neural network approach by catching the feature signals in a certain frequency range under fault conditions. This is different from conventional schemes that are based on deriving implicit mathematical equations based on the information obtained by complex filtering techniques. This paper presents some recent results of employing radial basis function neural networks (RBFN) for this particular application. The use of RBFN is because it has a number of advantages over multilayer perceptrons. The study shows that the RBFN based protection works well in CSC systems under a number of system and fault conditions. 14 Refs.

[1996] 18D - 22

RADIAL BASIS FUNCTION NEURAL NETWORKS FOR FAULT DIAGNOSIS IN SERIES COMPENSATED TRANSMISSION LINES: A COMPARISON STUDY

Song, Y.H.; Xuan, Q.Y.; Johns, A.T.; Aggarwal, R.K.

Univ of Bath, UK

Proceedings, Intelligent Industrial Automation (IIA'96/SOCO'96) (Canada), Reading, UK, March 26-28, 1996, pp B121-125

Since the complex variation of line impedance is accentuated as the capacitor's own protection equipment operates randomly under fault conditions in series compensated transmission systems, conventional distance protection schemes are limited to certain applications. The authors have extensively addressed the development of new adaptive protection techniques for such systems using multilayer perceptrons. The basic idea of the method is to design a protection scheme using a neural network approach by catching the feature signals in a certain frequency range under fault conditions. This is different from conventional schemes that are based on deriving implicit mathematical equations based on the information obtained by complex filtering techniques. This paper presents some recent results of employing different types of neural networks for this particular application. The performances of three neural networks have been analyzed and compared, including: (1) back propagation network (BP); (2) radial basis function network (RBFN) and (3) counter-propagation network (CP). The study shows that CP and RBFN have better performance than the commonly used BP network. As fault identification is only part of the protection scheme, further work is towards the development of a completed neural network based protection technique. 7 Refs.

[1996] 18D - 23

RADIAL BASIS FUNCTION NEURAL NETWORKS FOR FAULT DIAGNOSIS IN CONTROLLABLE SERIES COMPENSATED TRANSMISSION LINES

Song, Y.H.; Johns, A.T.; Xuan, Q.Y.

Univ of Bath, UK

Proceedings, 8th IEEE Mediterranean

Electrotechnical Conf, MELECON'96, Bari, Italy, May 13-16, 1996, vol 3, pp 1449-1452

This report presents some recent results of employing different types of neural networks for fault diagnosis. The performance of two neural networks have been analyzed and compared including: (1) back propagation network (BP); and (2) radial basis function network (RBFN). The study shows that the RBFN has better performance than the commonly used BP network. As fault identification is only part of the protection scheme, further work is towards the development of a completed neural network based protection technique. 8 Refs.

[1996] 18D - 24

SIMULATION STUDY OF UNIFIED POWER FLOW CONTROLLERS

Chida, T.; Sato, Y.; Sugawara, J.; Morikawa, R.; Tamura, Y.; Irokawa, S.

Tohoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 71-79

Japanese

This paper presents simulation results for UPFC (unified power flow controllers) using EMTP. The simulations were carried out for start and stop operations, power flow change operations in normal system conditions, and operations during system fault conditions. Thyristor-based bypass switches are used for the protection of the series compensator from system fault currents, and satisfactory protection capability was confirmed.

[1996] 18D - 25

THE ADAPTIVE PROTECTION AND THE FUTURE DEVELOPMENT OF THE PROTECTION AND CONTROL

Chen, D.; Liu, P.; Xianggang, Y.; Zhang, Z.; Ma, T.

Huazhong Univ of Sci and Tech, China

Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, pp 2/183-2/187

The basic principle and the concept of the adaptive protective relaying (APR) are reviewed in this paper, along with classification methods of APR and benefits from introducing the adaptive principle. The application experience and development of adaptive protective relaying in PR China, especially in Huazhong University of Science and Technology, are introduced. The adaptive protection for the grounding fault of the generator stator, adaptive protection for the grounding fault of the generator rotor and the adaptive double busbar protection are described in more detail. The developing directions of protective relaying are discussed.

[1996] 18D - 26

THE SIMULATION STUDY OF THE SHORT-CIRCUIT CURRENT OF THE VOLTAGE SOURCE INVERTER

Liu, H.; Chen, J.Y.; Shen, D.; Han, Y.D.; Li, C.Y.; Liu, Y.X.; Zhu, Q..X.

Tsinghua Univ, Beijing, China

Proceedings, 31st Intersociety Energy Conversion Engineering Conf (IECEC 96), Washington DC, August 11-16, 1996, vol 1, pp 507-512

In the voltage source inverter, a suitable circuit designed to protect the inverter against a short-circuit fault is a critical problem, because such a fault will cause permanent damage of the system. Recently a new bias loop overcurrent limiting circuit was proposed. In this paper, both computer simulation and circuit experiments are used to investigate its effectiveness and the influence of the reverse recovery characteristic of the diode on the protecting process. Both results show, with a carefully chosen GTO turn-off time, the new approach is preferred. 5 Refs.

[1996] 18D - 27

TRANSIENT SIMULATION OF SERIES COMPENSATED EHV TRANSMISSION LINES FOR SHORT-CIRCUIT STUDIES

Georgantzis, G.J.; Hatziargyriou, N.D.; Leonidaki, E.A.

Public Power Corp, Athens, Greece

Proceedings, 8th IEEE Mediterranean Electrotechnical Conf, MELECON'96, Bari, Italy, May 13-16, 1996, vol 3, pp 1584-1587

In this paper the behavior of fixed series compensated EHV transmission lines during faults is simulated. Emphasis is given on the impact of modern capacitor protection techniques (MOV protection). The simulation study is performed using EMTP and results are given for a three-phase and a two-phase-to ground fault. 7 Refs.

[1997] 18D - 28

VERIFICATION OF LOCATOR ORIENTATION ERROR AND THE COUNTERMEASURES

Ichikawa, K.; Miyoshi, H.; Yamada, Y.; Maruoka, S.

Central Japan Railway Co

Tetsudo to Denki Gijutsu (Japan), vol 8, no 6, pp 47-51

Japanese

Out of the grounding troubles that took place a few times after installation of the static var compensator (SVC) at Higashiyama feeder substation of Central Japan Railway Company, large error occurred twice with the fault locator of the central command. As the result of verification, it is confirmed that the cause of the locator orientation error was in the SVC current. A circuit which corrects orientation error is provided as the permanent countermeasure, and the error is eliminated. This paper reports locator orientation principle, cause of error, and countermeasures.

[1997] 18D - REF

SYSTEM STABILITY IMPROVEMENT IN THE RSA-ZIMBABWE AC INTERCONNECTION BY INSTALLATION OF AN SVC

For Abstract see entry 08B - 16

[1996] 18D - REF

±300 KVAR PROTOTYPE ADVANCED STATIC VAR GENERATOR BASED ON GTO

For Abstract see entry 09A - 1

[1996] 18D - REF

DESIGN AND IMPLEMENTATION OF A PWM SOLID-STATE SYNCHRONOUS CONDENSER

For Abstract see entry 09A - 40

[1998] 18D - REF

STATCOM CONTROLS FOR OPERATION WITH UNBALANCED VOLTAGES

For Abstract see entry 09A - 90

[1997] 18D - REF

CHARACTERIZATION OF A THYRISTOR CONTROLLED REACTOR

For Abstract see entry 10A – 23

[1997] 18D - REF

DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

For Abstract see entry 10A - 34

[1998] 18D - REF

GTO THYRISTOR CONTROLLED SERIES CAPACITOR SWITCH PERFORMANCE

For Abstract see entry 10A - 48

[1997] 18D - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

For Abstract see entry 10A - 83

[1997] 18D - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. SIMULATION STUDY OF UNIFIED POWER FLOW CONTROLLER.

For Abstract see entry 11A - 34

[1998] 18D - REF

EXPERIMENTAL STUDY ON DYNAMIC STABILITY IMPROVEMENT OF A SINGLE-MACHINE INFINITE bus POWER SYSTEM BASED ON A SLIDING MODE CONTROL OF PHASE SHIFTER

For Abstract see entry 12A - 8

[1998] 18D - REF

IPC TECHNOLOGY - A NEW APPROACH FOR SUBSTATION UPRATING WITH PASSIVE SHORT-CIRCUIT LIMITATION

For Abstract see entry 13A - 2

[1996] 18D - REF

STUDY OF SMES FOR POWER SYSTEM STABILIZATION

For Abstract see entry 14A – 121

[1997] 18D - REF

SERIES POWER LINE COMPENSATOR USING SELF-COMMUTATED INVERTER

For Abstract see entry 16D - 5

[1996] 18D - REF

EXPERIMENTAL STUDY ON PROTOTYPE THYRISTOR CONTROLLED SERIES CAPACITOR MODEL CONNECTED TO 275V TEST SYSTEM. (III)

For Abstract see entry 17C - 8

[1996] 18D - REF

DEVELOPMENT OF THE MINIATURE MODEL OF STATIC VAR COMPENSATOR USING SELF-COMMUTATED INVERTERS AND THE TEST OF THEM ON SIMULATORS

For Abstract see entry 19E - 18

18E Measurements, Instrumentation, Active/Reactive Power Concepts

[1996] 18E - 1

A NEW DEFINITION OF INSTANTANEOUS ACTIVE-REACTIVE CURRENT AND POWER BASED ON INSTANTANEOUS SPACE VECTORS ON POLAR COORDINATES IN THREE-PHASE CIRCUITS

Nabae, A.; Tanaka, T.

Tokyo Inst of Polytech, Japan

IEEE Trans on Power Delivery, vol 11, no 3, 1996, pp 1238-1243

This paper proposes a new definition of the instantaneous active-reactive current and power based directly on instantaneous space vectors on polar coordinates, and presents its application. The definition is applicable in three-phase three-wire systems. The instantaneous active-reactive power and current on alpha-beta orthogonal coordinates have been defined by the so-called p-q theory. In comparison with the p-q theory, our new definition offers a lucid physical concept for the active-reactive current and power in three-phase circuits. The new method, thus, can decompose current into the instantaneous active and reactive currents without calculating the instantaneous active and reactive powers. An application example is presented to confirm the validity and practicability of the new definition using digital simulation. 12 refs.

[1996] 18E - 2

A UNIVERSAL THEORY OF INSTANTANEOUS ACTIVE-REACTIVE CURRENT AND POWER INCLUDING ZERO-SEQUENCE COMPONENT

Nabae, A.; Cao, L.; Tanaka, T.

Tokyo Inst of Polytech, Atsugi, Japan

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 90-95

The new definition of instantaneous active-reactive current and power based on instantaneous space vectors on polar coordinates in three-phase circuits, which the authors have previously proposed, is extended to unbalanced three-phase four-wire power systems. The extended definition is called a universal theory of instantaneous active-reactive current and power for three-phase four-wire power systems. It is shown that the compensation currents of the instantaneous reactive power calculated from the universal theory contain third-harmonics. When both the instantaneous reactive currents and unbalanced currents are compensated, ideal balanced currents flow on the source side. The authors, thus, propose an alternative way for compensating these components. Digital simulation is carried out for both compensation methods to verify the validity of the universal theory. 2 Refs.

[1996] 18E - 3

ABOUT INSTANTANEOUS REACTIVE POWER THEORY IN NON-SINUSOIDAL ASYMMETRICAL CIRCUITS

Zhang, D-R.

Southwest Jiaotong Univ, Sichuan, China

Automation of Electric Power Systems (China), vol 20, no 4, April 1996, pp 26-28

Chinese

Two definitions of instantaneous reactive power in nonsinusoidal asymmetrical power system circuits and their advantages and disadvantages are analyzed in this paper. 4 Refs.

[1996] 18E - 4

AN IMPROVED FOURIER ALGORITHM SUITED FOR MICRO-COMPUTER FIXED TIME ALTERNATING CURRENT SAMPLING

Xiong, G.; Ti, Z-X.

Shanghai Jiaotong Univ, China

Power System Technology (China), vol 20, no 8, August 1996, pp 33-35

Chinese

Based on the Fourier transform, the computation method of ac sampling adopted in a micro-computer system is used widely in power systems. By using the Fourier transform it is easy to calculate the effective value of fundamental voltage and current. From this, the value of active and reactive power can be obtained. If the sampling period is not accurate, there will be errors in the results of calculation. In this paper the authors analyze the reasons causing the calculation errors, and put forward a new algorithm for periodic ac sampling. The result of calculation example indicates that the algorithm is of higher precision and is suitable for automatic control systems and intelligent measuring apparatus in power systems. 3 Refs.

[1998] 18E - 5

AN ITERATIVE TECHNIQUE FOR FAST AND ACCURATE MEASUREMENT OF POWER SYSTEM FREQUENCY

Sidhu, T.S.; Sachdev, M.S.

Univ of Saskatchewan, Saskatoon, Canada

IEEE Trans on Power Delivery, vol 13, no 1, January 1998, pp 109f

This paper describes the design, computational aspects and implementation of an iterative technique for measuring power system frequency. The technique provides accurate estimates to a resolution of 0.01-0.02 Hz for near-nominal, nominal and off-nominal frequencies in about 20 ms. Computation requirements are modest and the technique has been implemented on a modern digital signal processor. The proposed technique was extensively tested using voltage signals obtained from a dynamic frequency source and from a power system. Some test results are presented in the paper.

[1996] 18E - 6

CURRENT TRANSDUCER BEHAVIOUR IN A NOISY ENVIRONMENT

Avallone, F.; Daponte, P.; Grimaldi, D.

Dipt di Ingegneria Elettrica, Univ di Napoli Federico II, Italy

Measurement (Netherlands), vol 17, no 3, March 1996, pp 189-200

This paper deals with the behavioral analysis in a noisy environment of high precision current transformers, in which the performance is considerably improved by electronic compensation of the flux in the magnetic core. To this end, an electronically compensated current transformer (ECCT) model has been developed and its behavior evaluated both in normal operation and under the effects of several noise sources. The model's validity and its application range are investigated through several simulation and experimental tests. The analysis highlights the noise sources most affecting ECCT performance, the design solutions for improving ECCT immunity, and some suggestions regarding standard tests to perform on this kind of device for estimating their disturbance rejection. 27 Refs.

[1996] 18E - 7

DECOMPOSITION OF NONSINUSOIDAL INSTANTANEOUS CURRENTS AND POWER IN THREE-PHASE SYSTEMS

Zhao, Y-Q.; Tong, M.; Sun, S-Q.

Journal of Zhejiang University (China), vol 30, no 3, May 1996, pp 327-332

Chinese

Decomposition of instantaneous currents in three-phase circuits is discussed. Simulated by the classical decomposition of current complexes, an instantaneous current is decomposed into active and reactive components, from which the instantaneous active and reactive power are defined. Finally, the meanings of all quantities are illustrated by three examples, and compared with traditional concepts of currents and power. 7 Refs.

[1996] 18E - 8

DEFINITION OF GENERALIZED INSTANTANEOUS REACTIVE POWER IN DQO COORDINATES AND ITS COMPENSATION

Li, G-Y.; Chen, Z-Y.; Ding, Q-L.; Wang, X-W.

North China Inst of Elec Power, Baodding, China

Proceedings of the Chinese Society of Electrical Engineering (Zhongguo Dianji Gongcheng Xuebao), vol 16, no 3, May 1996, pp 176-179

Chinese

A new definition of generalized instantaneous reactive power of three-phase circuits in dqO coordinates was presented. The measurement and compensation schemes for different current components were proposed, and then the implementation scheme of the generalized instantaneous reactive power compensation was proposed and simulation experiment was carried out. 6 Refs.

[1996] 18E - 9

ELIMINATION OF ASYMMETRY ERROR IN THREE PHASE REACTIVE POWER MEASUREMENT BY MICROCOMPUTER SAMPLING FROM ALTERNATIVE SIGNALS

Shen, J-W.; Ma, N-Z.

Nanjing Automation Research Inst, China

Automation of Electric Power Systems (China), vol 20, no 5, May 1996, pp 33-36

Chinese

After analyzing and calculating the "asymmetry error" (caused by the asymmetrical voltages and/or currents) in the traditional method of three-phase reactive power measurement, the necessity and importance of elimination of asymmetry error in reactive power are pointed out. A method of three-phase reactive power measurement, which is accurate regardless of asymmetry, is also proposed. 1 Ref.

[1997] 18E - 10

EVALUATION OF UNWANTED NETWORK INFLUENCE BY COMPENSATION ACCORDING TO THE "INSTANTANEOUS POWER THEORY"

le Roux, W.; van Wyk, J.D.

Energy Lab, Rand Afrikaans Univ, Johannesburg, South Africa

4th Int'l Workshop on Power Definitions and Measurements Under Nonsinusoidal Conditions, Milano, Italy, September 2-4, 1997, pp 49-55

A theoretical evaluation is done on a three-phase three-wire power system to show the unwanted network influence when a dynamic filter is controlled according to the "instantaneous power theory". The evaluation is also simulated on Math-Cad for various network configurations. It is shown that the line currents contain frequencies that it did not have before compensation of the "instantaneous reactive current". The frequencies introduced increase with the complexity of the power systems. It is concluded that the use of this power theory for control of dynamic filters is less desirable.

[1996] 18E - 11

EXPLANATION OF GENERALIZED REACTIVE POWER AND POWER FACTOR IN NONSINUSOIDAL SYSTEMS

Yang, R-G.; Yang, M-H.; Tang, T-G.; Sun, S-Q.

Inst of Elec Eng, Beijing Agricultural Eng Univ, Beijing, China

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 78-82

The relationships between generalized reactive power and waveforms of voltage and current are analyzed with a correlation technique. The concepts of similarity and complete similarity of voltage and current waveforms are proposed. With these concepts, it is derived and proved that the generalized power factor is essentially a measure of the difference between voltage and current waveforms, while the reactive power is just the result of this difference. Two characteristic parameters are given to evaluate the quality of electric energy: the similarity coefficient; and the complete similarity coefficient of voltage and current waveforms. The similarity coefficient characterizes the degree of distortion and the symmetry of load current related to voltage source. The complete similarity coefficient is equivalent to the generalized power factor and characterizes the efficiency of power delivery of power systems. 4 Refs.

[1996] 18E - 12

GENERALIZED INSTANTANEOUS REACTIVE POWER THEORY FOR THREE-PHASE POWER SYSTEMS

Peng, F-Z.; Lai, J-S.

Dept of Elec & Computer Eng, Tennessee Univ, Knoxville, TN, USA

IEEE Trans on Instrumentation and Measurement, vol 45, no 1, February 1996, pp 293-297

A generalized theory of instantaneous reactive power for three-phase power systems is proposed in this paper. This theory gives a generalized definition of instantaneous reactive power, which is valid for sinusoidal or nonsinusoidal, balanced or unbalanced, three-phase power systems with or without zero-sequence currents and/or voltages. The properties and physical meanings of the newly defined instantaneous reactive power are discussed in detail. A three-phase

harmonic distorted power system with zero-sequence components is then used as an example to show reactive power measurement and compensation using the proposed theory. 5 Refs.

[1996] 18E - 13

INSTANTANEOUS POWER COMPONENTS IN POLYPHASE SYSTEMS UNDER NONSINUSOIDAL CONDITIONS

Salmeron, P.; Montano, J.C.

IRNAS (Consejo Superior de Investigaciones Cientificas), Sevilla, Spain

IEE Proceedings: Science, Measurement and Technology (UK), vol 143, no 2, March 1996, pp 151-155

A generalized theory of electric power for polyphase systems has been developed which is based on the concepts of instantaneous real power and instantaneous imaginary power. The line current vector is decomposed into two orthogonal components, without need of appealing to a mathematical transformation of the phase components. Each current component is physically associated with a term of different instantaneous power. The proposed theory permits both identifying defined current/power components in three-phase circuits, and setting the bases of the use of instantaneous reactive power compensation via an active power filter without energy storage circuits. Simulation of a practical case shows results that confirm the proposed theory. 12 Refs.

[1996] 18E - 14

MATHEMATICAL FOUNDATIONS OF THE INSTANTANEOUS POWER CONCEPTS: A GEOMETRICAL APPROACH

Willems, J.L.

Ghent Univ, Belgium

European Trans on Electrical Power (Germany), vol 6, no 5, September-October 1996, pp 299-304

In this paper a mathematical formalism, based on a geometrical approach, is proposed for defining the concepts of instantaneous active and instantaneous reactive power. Use is made of the dot product and the cross product for three-dimensional vectors. The relationship with the analysis proposed by Akagi et al. and by Ferrero and co-authors is discussed in detail. In particular it is shown that the proposed formalism is well suited to deal with three-phase currents and voltages with zero-sequence components. 12 Refs.

[1996] 18E - 15

MATHEMATICAL FOUNDATIONS OF THE INSTANTANEOUS POWER CONCEPTS : AN ALGEBRAIC APPROACH

Cristaldi, L.; Ferrero, A.

Dipt di Elettrotecnica, Politecnico di Milano, Italy

European Trans on Electrical Power (Germany), vol 6, no 5, 1996, pp 305-309

In this paper a mathematical framework is proposed for defining the concepts of instantaneous real and instantaneous imaginary power in three-phase systems. Up to now, the approach to the definition of these quantities has mainly been a geometrical approach, which is not generally convenient for the quantitative analysis of the electric system behavior. The proposed framework is an algebraic approach, based on the innovative use of the hypercomplex number algebra, which is shown to be well suited to deal with three-wire and four-wire three-phase systems. The relationship with the geometrical analysis proposed by Willems is discussed. 8 refs.

[1998] 18E - 16

NEW ADAPTIVE ALGORITHM FOR PRECISE VOLTAGE PHASOR MEASUREMENT IN A SERIES COMPENSATED NETWORK

Leclerc, M.; Lambert, J.; Lord, R.; Hebert, Y.

Cybectec, Quebec, Canada

Proceedings, IEEE Canadian Conf on Electrical and Computer Engineering, Waterloo, Ontario, May 1998, vol 1, pp 293f

This paper describes a new adaptive algorithm which estimates the positive sequence voltage phasor in a series compensated network with a high precision. This measurement is used in a shunt reactor switching scheme which will control voltage profiles along the Hydro-Quebec transmission grid. The particular nature of the noise observed in the voltage wave forms is discussed. The noise particularities have been considered in the development of the algorithm. The real time implementation of the algorithm is briefly discussed.

[1997] 18E - 17

NEW DEFINITION OF INSTANTANEOUS ACTIVE-REACTIVE CURRENT AND POWER IN THREE-PHASE CIRCUITS, AND ITS

APPLICATION

Nabae, A.; Yoshikawa, A.; Cao, L.; Tanaka, T.

Tokyo Polytech Inst, Tokyo, Japan

Electrical Engineering in Japan (Denki Gakkai Ronbunshi), vol 121, no 2, November 15, 1997, pp 83-91

A new definition of the instantaneous active-reactive current and power based on instantaneous space vectors in polar coordinates for three-phase circuits is proposed. The instantaneous active-reactive power and current are defined in the voltage-current vector plane without any special fictitious power. The new definition offers a lucid concept of electric power in three-phase circuits. An example is shown to confirm the validity and practicability of the new definition using digital simulation. 12 Refs.

[1996] 18E - 18

NEW DEFINITION OF INSTANTANEOUS ACTIVE-REACTIVE CURRENT AND POWER BASED ON INSTANTANEOUS SPACE VECTORS ON POLAR COORDINATES IN THREE-PHASE CIRCUITS

Nabae, A.; Tanaka, T.

Tokyo Inst of Polytech, Kanagawa, Japan

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1238-1243

This paper proposes a new definition of the instantaneous active-reactive current and power based directly on instantaneous space vectors on polar coordinates, and presents its application. The definition is applicable in three-phase three-wire systems. The instantaneous active-reactive power and current on alpha - beta orthogonal coordinates have been defined by the so-called p-q theory. In comparison with the p-q theory, our new definition offers a lucid physical concept for the active-reactive current and power in three-phase circuits. The new method, thus, can decompose current into the instantaneous active and reactive currents without calculating the instantaneous active and reactive powers. An application example is presented to confirm the validity and practicability of the new definition using digital simulation. 12 Refs.

[1996] 18E - 19

REACTIVE POWER AND HARMONIC COMPENSATION BASED ON THE GENERALIZED INSTANTANEOUS REACTIVE POWER THEORY FOR THREE-PHASE POWER SYSTEMS

Peng, F.Z.; Lai, J-S.

Oak Ridge Natl Lab, Oak Ridge, TN, USA

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 83-89

A generalized theory of instantaneous reactive power for three-phase power systems is proposed in this paper. This theory gives a generalized definition of instantaneous reactive power, which is valid for sinusoidal or nonsinusoidal, balanced or unbalanced, three-phase power systems with or without zero-sequence currents and/or voltages. The properties and physical meanings of the newly defined instantaneous reactive power are discussed in detail. With this new reactive power theory, it is very easy to calculate and decompose all components, such as fundamental active/reactive power and current, harmonic current, etc. Reactive power and/or harmonic compensation systems for a three-phase distorted power system with and without zero-sequence components in the source voltage and/or load current are then used as examples to demonstrate the measurement, decomposition, and compensation of reactive power and harmonics. 9 Refs.

[1996] 18E - 20

REACTIVE POWER COMPENSATION AND VOLTAGE FLICKER CONTROL OF AN ARC FURNACE LOAD

Girgis, A.A.; Moss, B.D.; Makram, E.B.

Elec Power Research Assoc, Clemson University, Clemson, SC, USA

Proceedings, 7th Int'l Conf on Harmonics and Quality of Power (ICHQP), Las Vegas, NV, October 16-18, 1996, pp 242-247

Arc furnace voltage flicker is characterized by a 0.5 to 30 Hz periodic fluctuation in the magnitude of the supply voltage envelope. In order to effectively reduce periodic flicker disturbances, the flicker is first identified and evaluated using a voltage flicker measurement scheme based on voltage samples at the point of measurement. The measurement scheme uses Kalman filter theory to determine the magnitude and frequency of the flicker disturbance. Based on these two factors, a violation of the flicker limitation requirements for the system can be identified, The voltage magnitude at the point of measurement is then used to calculate the required amount of reactive compensation to reduce the magnitude of the flicker disturbance to an acceptable level. An algorithm based on this premise is developed

and tested on a simulated arc furnace system. 15 Refs.

[1997] 18E - 21

REAL-TIME DETECTION METHODS OF GENERALIZED INSTANTANEOUS REACTIVE CURRENTS USED FOR ACTIVE COMPENSATORS

Li, G.; Chen, Z.; Ding, Q..

North China Inst of Elec Power, Baoding, China

Automation of Electric Power Systems (China), vol 21, no 10, October 1997, pp 28-31

Chinese

The existing detection methods of reactive and harmonic currents for active compensators are analyzed. A real-time detection method of generalized instantaneous reactive currents and its principle are presented. The theoretical analysis and simulation results show that three-phase generalized instantaneous active currents can be detected by using this method, and three-phase instantaneous active currents, fundamental positive-sequence instantaneous reactive currents and fundamental unsymmetrical and harmonic instantaneous reactive currents can also be extracted.

[1996] 18E - 22

THE INFLUENCE OF THREE-PHASE QUANTITY SYMMETRY ON MEASURING ERROR OF REACTIVE POWER TRANSDUCER

Lei, H-B.

Northwest China Elec Power Test & Research Inst, Xian, China

Automation of Electric Power Systems (China), vol 20, no 8, August 1996, pp 26-29

Chinese

Three-phase reactive power transducers are divided into various types according to their measuring principle. For most of them, errors exist in the method of their application to unbalanced three-phase circuits. This paper analyzes these errors and offers a suggestion on selecting the type of transducer for a particular application. 0 Refs.

[1996] 18E - 23

VALIDATION OF PHASOR CALCULATIONS IN THE MACRODYNE PMU FOR CALIFORNIA-OREGON TRANSMISSION PROJECT TEST OF MARCH 1993

Hauer, J.F.

Bonneville Power Admin, Portland, OR, USA

IEEE Trans on Power Delivery, vol 11, no 3, July 1996, pp 1224-1231

Faults applied during March 1993 commissioning tests for the California-Oregon Transmission Project produced 14 Hz transient oscillations that were conspicuous in BPA's enhanced transducers at Malin, and in PG&E's dynamic system monitor at Table Mountain. Prony analysis of high speed fault data provided a detailed model for the underlying network resonance signal, and a basis for validating transient performance of a Macrodyne phasor measurement unit (PMU) at the test site. This instrument, which is closely associated with EPRI's FACTS project, provides useful insight into emerging technology for high speed digital transducers. The phasor calculations are found to be of very high quality, but filtering enhancements are recommended for broadband applications. 7 Refs.

[1996] 18E - REF

AN ADVANCED UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A – 4

18F Reliability

[1996] 18F - REF

FOUR YEARS OF OPERATIONAL EXPERIENCE OF THE KAYENTA ADVANCED SERIES COMPENSATOR

For Abstract see entry 10B - 2

[1997] 18F - REF

OPERATIONAL EXPERIENCE WITH AEP'S 345 KV KANAWHA RIVER SERIES CAPACITOR INSTALLATION

For Abstract see entry 10B - 3

19 SIMULATION OF FACTS

19A Small Signal Stability

[1997] 19A - 1

DAMPING TORQUE ANALYSIS IN MULTI-MACHINE POWER SYSTEMS AND ITS APPLICATION

Wang, H.F.; Swift, F.J.

Univ of Bath, UK

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 527-530

In this paper, damping torque analysis is applied in a multi-machine power system installed with FACTS-based stabilizers and PSSs, which leads to the establishment of a multi-channel model describing the pattern by which the stabilizers provide damping to the oscillation modes in the power system. One of the applications of the multi-channel model is given in a companion paper presented in this conference. 13 Refs.

[1997] 19A - 2

POWER SYSTEM SMALL SIGNAL STABILITY ANALYSIS WITH FACTS ELEMENTS

Tang, Y.; Meliopoulos, A.P.S.

Global Engineering Co, Roswell, GA, USA

IEEE Trans on Power Delivery, vol 12, no 3, July 1997, pp 1352-1361

FACTS (flexible ac transmission systems) elements include low frequency electronic switching devices which result in periodic but nonsinusoidal voltage and current waveforms. Methods based on the assumption of sinusoidal waveforms may not be accurate enough for systems with FACTS elements, while averaging methods work well for high frequency switching systems but they are less accurate for systems with low switching frequencies. This paper presents a rigorous methodology for small signal stability analysis of systems with FACTS elements and nonlinear elements. The method consists of: (1) FACTS and nonlinear device modeling, (2) system periodic steady-state analysis and (3) system eigenvalue analysis. The methodology is compared to the averaging method and its capabilities are demonstrated with example systems. 12 Refs.

[1996] 19A - REF

FREQUENCY RESPONSE ANALYSIS FOR INVESTIGATING THE IMPACT OF FACTS ON POWER TRANSMISSION SYSTEMS

For Abstract see entry 07B - 28

[1998] 19A - REF

IMPROVEMENT OF THE DYNAMIC PERFORMANCE OF THE SPANISH POWER SYSTEM WITH FACTS DEVICES

For Abstract see entry 07B - 30

[1996] 19A - REF

A STATIC VAR COMPENSATOR CONTROL STRATEGY TO MAXIMIZE POWER SYSTEM DAMPING

For Abstract see entry 08A - 10

[1996] 19A - REF

STATIC VAR COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATION. PART II: CASE STUDY

For Abstract see entry 08A - 110

[1997] 19A - REF

THE STUDY ON IMPROVEMENT OF YIMIN-DAQING 500 KV SYSTEM STABILITY BY SVC

For Abstract see entry 08A - 126

[1997] 19A - REF

ANALYSIS OF INTER-AREA DAMPING ENHANCEMENT BY STATIC VAR COMPENSATORS IN LONGITUDINAL POWER SYSTEMS

For Abstract see entry 08A - 22

[1998] 19A - REF

ANALYSIS OF SVC AND TCSC CONTROLLERS IN VOLTAGE COLLAPSE

For Abstract see entry 08A - 25

[1996] 19A - REF

DAMPING EFFICIENCY OF SVC AND CSC [POWER SYSTEM CONTROL]

For Abstract see entry 08A - 49

[1997] 19A - REF

A METHOD FOR SVC DAMPING CONTROLLER DESIGN USING ROBUST POLE ASSIGNMENT METHOD

For Abstract see entry 08A - 5

[1996] 19A - REF

ENHANCEMENT OF POWER SYSTEM STABILITY BY CONTROLLABLE SERIES COMPENSATION

For Abstract see entry 08A - 60

[1996] 19A - REF

ANALYSIS AND DESIGN OF VOLTAGE CONTROL OF STATIC CONDENSER

For Abstract see entry 09A - 19

[1997] 19A - REF

DESIGN OF REACTIVE CURRENT AND VOLTAGE CONTROLLER OF STATIC CONDENSER

For Abstract see entry 09A - 41

[1996] 19A - REF

ANALYSIS AND CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATOR FOR POWER SYSTEM OSCILLATION DAMPING

For Abstract see entry 10A - 10

[1997] 19A - REF

SUPPRESSION OF TORSIONAL OSCILLATIONS USING THYRISTOR-CONTROLLED CONDUCTANCE IN PARALLEL TO SERIES-CAPACITOR SEGMENT

For Abstract see entry 10A - 108

[1997] 19A - REF

APPLICATIONS OF CSCS FOR DAMPING OF POWER SWINGS

For Abstract see entry 10A - 19

[1997] 19A - REF

CLARIFICATION OF THE SSR MITIGATION MECHANISM OF A TCSC

For Abstract see entry 10A - 24

[1996] 19A - REF

DAMPING ESTIMATES OF SUBSYNCHRONOUS AND POWER SWING OSCILLATIONS IN POWER SYSTEMS WITH THYRISTOR SWITCHING DEVICES

For Abstract see entry 10A - 30

[1997] 19A - REF

EIGENVALUE SENSITIVITY APPROACH TO LOCATION AND CONTROLLER DESIGN OF CONTROLLABLE SERIES CAPACITORS FOR DAMPING POWER SYSTEM OSCILLATIONS

For Abstract see entry 10A - 42

[1998] 19A - REF

IMPROVEMENT OF DAMPING LOW FREQUENCY OSCILLATIONS BY TCSC

For Abstract see entry 10A - 51

[1997] 19A - REF

INVESTIGATION OF THE THYRISTOR-CONTROLLED SERIES COMPENSATION. I. STEADY-STATE AND TRANSIENT-STATE SIMULATION OF A POWER SYSTEM WITH DETAILED TCSC MODEL

For Abstract see entry 10A - 62

[1996] 19A - REF

POWER SYSTEM STABILITY ENHANCEMENT BY USING CONTROLLED SERIES COMPENSATION

For Abstract see entry 10A - 86

[1997] 19A - REF

DYNAMIC MODELLING OF A UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 17

[1996] 19A - REF

STEADY-STATE AND DYNAMIC MODELS OF UNIFIED POWER FLOW CONTROLLER (UPFC) FOR POWER SYSTEM STUDIES

For Abstract see entry 11A - 40

[1997] 19A - REF

BASIS STUDY OF POWER SYSTEM STABILIZING CONTROL USING UNIFIED POWER FLOW CONTROLLER(UPFC)

For Abstract see entry 11A - 9

[1997] 19A - REF

POWER SYSTEM STABILIZING CONTROL USING HIGH SPEED PHASE SHIFTER (HSPS)

For Abstract see entry 12A - 12

[1997] 19A - REF

APPLICATION OF STATIC PHASE SHIFTERS ON THE DAMPING OF COMMON-MODE TORSIONAL OSCILLATIONS

For Abstract see entry 12A - 4

[1997] 19A - REF

CONTROL SCHEMES AND TRANSIENT CHARACTERISTICS OF A HIGH SPEED PHASE SHIFTER FOR POWER FLOW CONTROL IN POWER TRANSMISSION SYSTEMS.

For Abstract see entry 12A - 5

[1998] 19A - REF

DYNAMIC QUADRATURE BOOSTER AS AN AID TO SYSTEM STABILITY

For Abstract see entry 12A - 6

[1997] 19A - REF

SUPERSMES AS A UNIVERSAL POWER QUALITY CONTROLLER USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 133

[1997] 19A - REF

DYNAMIC SIMULATION OF HYBRID WIND-DIESEL POWER GENERATION SYSTEM WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 34

[1997] 19A - REF

MEASUREMENT OF THE DAMPING COEFFICIENT OF AN ELECTRIC POWER SYSTEM BY USE OF A SUPERCONDUCTING MAGNET ENERGY STORAGE SYSTEM

For Abstract see entry 14A - 68

[1996] 19A - REF

CONVERTERS FOR GRID-CONNECTED DC ENERGY SOURCES: A SIMULATION TOOL TO MEET EXPECTED UTILITY SPECIFICATIONS

For Abstract see entry 17B - 8

[1996] 19A - REF

MODELLING AND ANALYSIS GUIDELINES FOR SLOW TRANSIENT. PART II CONTROLLER INTERACTIONS ; HARMONIC INTERACTIONS

For Abstract see entry 17C - 18

[1998] 19A - REF

EXPERIMENTAL EVALUATION OF STATCOM CLOSED LOOP DYNAMICS

For Abstract see entry 18A - 14

[1996] 19A - REF

INFLUENCE OF THE REAL POWER MODULATION PROVIDED BY A SHUNT COMPENSATOR ON DAMPING POWER SWINGS

For Abstract see entry 18B - 10

[1997] 19A - REF

DETERMINATION OF NEEDED FACTS CONTROLLERS THAT INCREASE ASSET UTILIZATION OF POWER SYSTEMS

For Abstract see entry 18B - 5

[1997] 19A - REF

LOW FREQUENCY OSCILLATIONS DAMPING BY FACTS AND POWER SYSTEM STABILIZERS

For Abstract see entry 18C - 10

[1997] 19A - REF

METHOD AND SOFTWARE FOR COORDINATED TUNING OF POWER SYSTEM REGULATORS

For Abstract see entry 18C - 11

[1997] 19A - REF

COORDINATED DESIGN OF FACTS CONTROLLERS TO ENHANCE POWER SYSTEM DYNAMIC PERFORMANCE

For Abstract see entry 18C - 4

[1997] 19A - REF

IMPROVED POWER SWING DAMPING BY COORDINATED FACTS CONTROLS

For Abstract see entry 18C - 9

[1996] 19A - REF

VERSATILE FACTS DEVICE MODEL FOR POWERFLOW AND STABILITY SIMULATIONS

For Abstract see entry 19B - 24

19B Power Flow

[1998] 19B - 1

A NEW METHOD TO INCORPORATE FACTS DEVICES IN OPTIMAL POWER FLOW

Ge, S.Y.; Chung, T.S.; Wong, Y.K.

Hong Kong Polytech Univ, China

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper SO5.3

Abstract not available

[1996] 19B - 2

AN ADAPTIVE RECURRENT NEURAL NETWORK SYSTEM FOR SHORT-TERM HOURLY LOAD FORECASTING

Khotanzad, A.; Abaye, A.; Maratukulam, D.

Southern Methodist Univ, Dallas, TX, USA

Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, pp 2/87-2/97

A recurrent neural network (RNN) based hourly load forecaster is developed. The system is modular, consisting of 24 RNNs, one for each hour of the day. The RNNs investigated are three-layer sigmoid neural networks. Two topologies are considered: one has connections between hidden layer nodes and the other has feedback from output to hidden layer nodes. The hours of the day are divided into four categories and a different set of load and temperature inputs is defined for RNNs of each category. The RNNs are trained with Pineda's recurrent back-propagation algorithm. To handle non-stationarity, an adaptive scheme is used to adjust the RNN weights during the on-line forecasting phase. The performance of the forecaster is evaluated on real data from two utilities and compared to a feed-forward neural network based load forecaster that is presently in use at several utilities.

[1997] 19B - 3

AN ALTERNATIVE APPROACH TO THE LOAD FLOW PROBLEM

da Costa, V.M.; Martins, N.; Pereira, J.L.R.

COPPE, Univ Federal do Rio de Janeiro, Brazil

Controle & Automacao (Brazil), vol 8, no 1, January-April 1997, pp 21-30

Portuguese

This paper presents a new formulation for the solution of load flow problem, using the current injection equations written in rectangular coordinates. For each voltage-controlled bus, an additional equation is introduced and the reactive power mismatch becomes a dependent variable on the linearized system of equations. From this methodology, an augmented formulation is obtained with the same convergence characteristics of the conventional formulation written in polar coordinates. This formulation is more adequate for incorporation of FACTS (flexible ac transmission system) devices. These model are tested in real power systems with 730 and 1653 buses, related to the interconnected South-Southeastern Brazilian power systems. The results are compared with those obtained by means of conventional formulation.

[1997] 19B - 4

AN EXPERT SYSTEM FOR POWER SYSTEM VOLTAGE STABILITY IMPROVEMENT

Thukaram, B.D.; Parthasarathy, K.

Dept of Elec Eng, Indian Inst of Sci, Bangalore, India

Int'l Journal of Electrical Power and Energy Systems (UK), vol 19, no 6, August 1997, pp 385-392

This paper presents a prototype of an expert system for monitoring and improving steady-state voltage stability in power systems. The monitoring methodology is based on the L-index of load buses. This index uses information on a normal load flow and is in the range from 0 (no load on the system) to 1 (voltage collapse). The control against voltage collapse is based on reducing the magnitude of the L-indices of the critical nodes for a given system operating condition based on heuristic criteria. The control variables considered are switchable VAr compensators, OLTC transformers and generators excitation. The proposed expert system technique has been tested under simulated conditions on a few practical Indian power systems. The performance of the expert system is compared with conventional optimization technique and concurrent results have been obtained. The proposed expert system technique is found to be suitable for on-line application in an energy control center for voltage stability improvement as the solution is obtained fast, with a minimum of numerical computations. Results obtained for a 24-node EHV Indian power network and a modified IEEE 30-bus system are included for illustration purposes.

[1996] 19B - 5

ANIMATED VECTORS FOR VISUALIZATION OF POWER SYSTEM PHENOMENA

Gronquist, J.; Sethares, W.; Alvarado, F.; Lasseter, R.

Univ of Wisconsin, Madison, WI, USA

IEEE Trans on Power Systems, vol 11, no 1, February 1996, pp 267-273

This paper presents an exact mechanical analog for an electric power system that proves to be a powerful visualization tool for studying power systems issues such as load flow, transient stability, and the effects of FACTS devices. Techniques based on color and highlighting that make the method applicable to the visualization of large systems are introduced. The analog provides a means for demonstrating complex issues to audiences with little or no background in power systems. For the power engineer, the analog provides unique insights into the hows and whys of power system behavior. To the control center operator, an accurate model of the dynamic modes may bring about improved understanding of system behavior after contingencies and illustrate the relative merits of various dispatch options. 9 Refs.

[1997] 19B - 6

COMPARISON OF STEADY STATE POWER FLOW ANALYSIS METHODS WITH FACTS DEVICES

Chen, J.; Duan, X.; He, Y.; Ling, X.; Jiang, W.; Li, W.

Huazhong Univ of Sci & Tech, Wuhan, China

Automation of Electric Power Systems (China), vol 21, no 7, July 1997, pp 53-56

Chinese

Controlling the operating conditions and regulating the power flow in power systems is one of the important functions of FACTS devices. Steady-state power flow calculation is one of the basic ways to analyze the power system's operating conditions. This paper reviews the methods that have been presented in recent years on power flow calculation with FACTS devices and divides them into two types according to their different premises. In this paper, three criteria (extensive adaptation, less computation time and high convergence reliability) are used to compare them. Some instances are given to test and verify these conclusions.

[1996] 19B - 7

COUPLED ACTIVE AND REACTIVE POWER OPTIMIZATION USING FACTS EQUIPMENT

Handschin, E.; Westermann, D.; Handke, J.; Wiesmann, B.

Dortmund Univ, Germany

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 981-987

In this paper, an optimal power flow algorithm based on quadratic programming is presented that can take into account the operational capabilities of innovative operational devices for a coupled consideration of active and reactive power flow control. Using innovative operational devices (IOD), high speed response times and high reliable operation of the power system can be achieved. In order to realize a coupled active/reactive power optimization, an iterative algorithm is presented. The proposed algorithm represents one component in the control center of a flexible ac transmission system

(FACTS). 8 Refs.

[1996] 19B - 8

EXPANSION OF THE VOLTAGE STABILITY LIMIT VIA SHUNT VAR COMPENSATION

Momoh, J.A.; Dias, L.G.; Adapa, R.

Dept of Elec Eng, Howard Univ, Washington, DC, USA

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 631-636

This paper describes a contingency-constrained optimal power flow (OPF) formulation for the power system voltage stability enhancement problem in the presence of static VAr compensators. Results of tests carried out on the IEEE 30-bus and 118-bus test systems are reported in the paper. The results are verified using EPRI VSTAB 2.1. It is concluded that SVCs, in conjunction with optimization, can boost the power system stability limit by over 10 percent, even in the presence of contingencies. 15 Refs.

[1996] 19B - 9

LOAD FLOW STUDIES FOR POWER SYSTEMS EQUIPPED WITH UPFC

Chen, H-J.; Bai, Z.

Hohai Univ, Nanjing, China

Automation of Electric Power Systems (China), vol 20, no 3, March 1996, pp 23-27

Chinese

This paper presents a circuit load flow solution for a power system equipped with unified power flow controllers (UPFC). The Jacobian matrix of the proposed method is the same as that of a conventional PQ decoupling approach. A rapid estimation method for the feasible line flow region of arbitrary lines is also proposed. 4 Refs.

[1996] 19B - 10

LONG WAVE TELESWITCHING. A NEW WAY IN LOAD MANAGEMENT TECHNOLOGY

Saupe, R.; Shick, B.

EFR Europaeische Funk-Rundsteuerung GmbH, Berlin, Germany

Proceedings, EPRI The Future of Power Delivery 1996 Conf, April 9-11, 1996, Washington, DC, December 1996, pp 2/205-2/210

Ripple-control is a well adapted technology in the utility industry world-wide. It is used for tariff-switching applications and load management as well as for the control of street lighting, for example. Basically, ripple control systems are used to spread information to lots of receivers installed in the supply region of a utility. The conception and characteristics of this technology were applied in a quite early state of technical development and have been modernized continually. Today, ripple-control is not considered to be a very economical method but, for that, a relatively safe method. Ripple control systems use the existing mains system as signal carrier. Since the mains network is designed for 50/60 Hz, a ripple-control frequency of some 100 Hz is being affected under certain circumstances. Consequently the conventional ripple-control will face changes due to new transmission methods and additional intelligence in modern receivers. The newly offered long wave teleswitching system is using a radio channel to transmit the information via air, apart from that, it follows the same basic principles known from conventional ripple-control.

[1996] 19B - 11

NEWTON-RAPHSON ALGORITHM FOR THE RELIABLE SOLUTION OF LARGE POWER NETWORKS WITH EMBEDDED FACTS DEVICES

Fuerte-Esquivel, C.R.; Acha, E.

Glasgow Univ, UK

IEE Proceedings, Generation, Transmission and Distribution (UK), vol 143, no 5, September 1996, pp 447-454

A new and efficient algorithm for the reliable load flow solution of power network branches controlled by flexible ac transmission systems (FACTS) is presented. General admittance-based models are given for series compensators, phase-shifters and tap-changers. Their inclusion in a Newton-Raphson load flow exhibiting quadratic convergence is described and the prowess of the algorithm is demonstrated by comparison with production-grade load flow programs where the state variables of the controllable devices are updated at the end of each Newton-Raphson iteration. Control coordination and initialization strategies for the controlled branches and nodes have been thoroughly investigated. 9 Refs.

[1997] 19B - 12

NEWTON-TYPE ALGORITHM FOR THE

CONTROL OF POWER FLOW IN ELECTRICAL POWER NETWORKS

Fuerte-Esquivel, C.R.; Acha, E.

Univ of Glasgow, UK

IEEE Trans on Power Systems, vol 12, no 4, November 1997, pp 1474-1480

This paper addresses the issue of controllable branch models suitable for assessing the steady-state response of FACTS devices on a network wide basis. Generalized nodal admittance models are presented for series compensators, phase shifters, interphase power controllers and unified power flow controllers. A Newton-Raphson load flow program has been developed which includes comprehensive control facilities and yet exhibits very strong convergence characteristics. Test results are presented which demonstrate the effectiveness of the proposed models. 19 Refs.

[1996] 19B - 13

OPTIMAL ACTIVE POWER FLOW DISPATCH INCORPORATING FACTS DEVICES

Ge, S-Y.; Chung, T.S.

Dept of Elec Power & Autom, Tianjin Univ, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 909-913

This paper presents a new approach to optimal real power flow dispatch taking into account the representation of FACTS devices and the specified line flow constraints. The proposed approach separates the real power OPF problem into two subproblems. The first subproblem solves a power flow control problem to obtain the control variables of controllable FACTS devices and the second subproblem solves a linear programming problem to obtain the optimum active power flow dispatch schedule. The two subproblems are iterated until a stop criterion is reached. The proposed approach has been tested on several IEEE test systems and results show that the approach is effective and accurate. 9 Refs.

[1996] 19B - 14

OPTIMAL POWER DELIVERY PROBLEM IN DEREGULATED OPEN ACCESS ENVIRONMENTS

Huang, G.M.; Hsieh, S-C.

Texas A&M Univ, College Station, TX, USA

Proceedings, IEEE Int'l Conf on Control Applications, Dearborn, MI, September 15-18, 1996, pp 450-455

In this paper, we formulate an optimal power delivery (OPD) problem, in terms of transmitted line flows, for the future deregulated/restructured open access environments. It includes some FACTS (flexible ac transmission systems) devices, such as phase shifters and series compensators. The transmission losses are considered and are represented by the transmitted line flows across those lines. The problem can be solved by our fast textured decomposition algorithm. Moreover, the formulation takes care of the loop flow problem by minimizing the total transmission loss. Examples are used to demonstrate this point. We also show that the FACTS devices can be used to reduce the total transmission loss. 12 Refs.

[1998] 19B - 15

POWER FLOW CONTROL AND POWER FLOW STUDIES FOR SYSTEMS WITH FACTS DEVICES

Gotham, D.J.; Heydt, G.T.

Purdue Univ, West Lafayette, IN, USA

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 60-65

In this paper, the modeling of flexible ac transmission system (FACTS) devices for power flow studies and the role of that modeling in the study of FACTS devices for power flow control are discussed. FACTS devices are solid-state converters that have the capability of control of various electrical parameters in transmission circuits. A number of power flow study programs were developed in order to model various types of FACTS devices. Three main generic types of FACTS devices are suggested and the integration of those devices into power flow studies, studies relating to wheeling, and interchange power flow control are illustrated. 16 Refs.

[1996] 19B - 16

POWER FLOWS AND VOLTAGE CONTROL IN ELECTRIC SYSTEMS BY TRADITIONAL AND INNOVATIVE DEVICES

Berizzi, A.; Silvestri, A.; Tironi, E.; Zaninelli, D.

Politecnico di Milano, Italy

Proceedings, 8th IEEE Mediterranean Electrotechnical Conf, MELECON'96, Bari, Italy, May 13-16, 1996, vol 3, pp 1620-1626

The paper deals with the control of power flows and voltages in electric power systems, in presence of branch overloads and poor voltage profile. The possible compensation tools - series devices such as phase

shifters or FACTS, or shunt devices, as the traditional capacitors or SVCs - are examined in order to obtain feasible operation points also following severe contingencies. Using optimization techniques, the optimal location and size of compensation are calculated considering also the possibility of making use of redispatch to reduce the total operation costs. The behavior of the proposed procedures is shown on some test networks. 17 Refs.

[1996] 19B - 17

PREVENTIVE ACTIONS FOR POWER SYSTEM STABILITY PRESERVATION

Vaiman, M.Y.; Vaiman, M.M.

V&R Co, Los Angeles, CA, USA

Proceedings, Wescon Conf, Anaheim, CA, October 22-24, 1996, pp 153-158

As deregulation occurs, power quality will be more important to electric utilities' customers. Power quality problems are mainly devoted to maintaining the supply voltage within certain limits. We have developed a new approach to maintain a given voltage value in the load nodes and increase the region of existence of solution to power flow equations by optimal selection of contingency arming schemes actions. The actions include estimation of the minimum value of generator tripping and load shedding, determination of the necessary level of static VAr compensation, and choice of minimum values of admittance increase in controlled lines using FACTS. 18 Refs.

[1997] 19B - 18

SOME FUNDAMENTAL OBSERVATIONS ON THE OPTIMALITY OF LOAD FLOW CONTROL

Kobayashi, N.; Yamada, T.; Okamoto, H.; Kurita, A.; Tada, Y.; Sekine, Y.

Tokyo Elec Power Co, Inc, Japan

Trans of the Institute of Electrical Engineers of Japan, vol 117B, no 8, August 1997, pp 1091-1100

Japanese

This paper deals with the optimality of load flow control of power system with many loops. In this paper, three kinds of linear or nonlinear programming problems are formulated. The first one is the maximum flow problem under the condition that growth rate of each generation and load node is given. The second one aims at minimizing the VAr-loss of the whole power system using FACTS apparatus under the condition that the power system transmits the maximum power obtained in the first problem. The third problem is to minimize the capacity of installed FACTS apparatus under the condition that VAr-loss of power system is kept equal to the minimum value obtained in the second problem. In this problem, installation points and capacities of FACTS apparatus are assumed as the only controllable parameters. At first, the effects of FACTS apparatus from the viewpoints of the first and second problems are discussed and some important results are obtained. Secondly, using these obtained results, three problems shown above are formulated into linear or nonlinear programming problems in three steps using dc flow calculation method. Each problem is solved sequentially using the results obtained in each previous step. Thirdly an example of calculation is shown using model power system. The solutions obtained above are compared with those, obtained by using the conventional ac flow calculation to study the calculation accuracy of the proposed method. Finally, the first and the third problems are formulated into two steps linear or nonlinear problems.

[1998] 19B - 19

STEADY-STATE ANALYSIS OF POWER FLOW CONTROLLERS USING THE POWER CONTROLLER PLANE

Brochu, J.; Beauregard, F.; Lemay, J.; Pelletier, P.; Marceau, R.J.

CITEQ Hydro-Quebec, Varennes, Canada

IEEE PES Summer Meeting, San Diego, July 12-16, 1998

This paper presents a new approach which simplifies the steady-state analysis and design of power flow controllers (PFC). The method is independent of the size and complexity of networks. It introduces the power controller plane where two families of nearly decoupled active power characteristics are defined as a function of the phase angle across the PFC: one for the network and the other for the PFC. Limiting cases of each family are used to define a working area which contains all the operating points of a given PFC and where its most stressing operating conditions can be readily identified. With this approach, only a few network cases are needed to perform steady-state PFC studies for both pre- and post-contingency conditions. Because the method looks at networks from the PFC's point of view, it simplifies contingency analysis, the design of PFCs and the definition of simple network equivalents suitable for active power flow studies.

[1997] 19B - 20

THE APPLICATION OF POWER FLOW CALCULATION WITH PQV NODE FOR UPFC

Luo, C.; Sun, H.; Xu, G.

Chongqing Univ, China

Automation of Electric Power Systems (China), vol 21, no 4, April 1997, pp 34-36

Chinese

This paper analyzes the principle of unity power factor control (UPFC) in power systems, and a method for calculating the power flow with a PQV node for UPFC is presented. Using this method, it is easy to find the controlling parameters of UPFC schemes. Simulation results show the method's effectiveness.

[1997] 19B - 21

AN ALTERNATIVE PROCEDURE FOR POWER FLOW COMPUTATION

da Costa, V.M.; Martins, N.; Pereira, J.L.R.

COPPE-EE/UFRJ, Rio de Janeiro, Brazil

Controle & Automacao (Brazil), vol 8, no 1, January-April 1997, pp 21-30

Portuguese

This paper presents a new formulation for the solution of load flow problem, using the current injection equations written in rectangular coordinates. For each voltage-controlled bus an additional equation is introduced and the reactive power mismatch becomes a dependent variable on the linearized system of equations. From this methodology an augmented formulation is obtained with the same convergence characteristics of the conventional formulation written in polar coordinates. This formulation is more adequate for incorporation of FACTS (flexible ac transmission system) devices. These models are tested in real systems with 730 and 1653 buses, related to the interconnected south-southeastern Brazilian systems. The results are compared with those obtained by means of conventional formulation. 18 Refs.

[1997] 19B - 22

UNIFIED POWER FLOW CONTROLLER: A CRITICAL COMPARISON OF NEWTON-RAPHSON UPFC ALGORITHMS IN POWER FLOW STUDIES

Fuerte-Esquivel, C.R.; Acha, E.

Univ of Glasgow, UK

IEE Proceedings Generation, Transmission and Distribution (UK), vol 144, no 5, September 1997, pp 437-444

A new and comprehensive load flow model for the unified power flow controller (UPFC) is presented. The UPFC model is incorporated into an existing FACTS Newton-Raphson load flow algorithm. Critical comparisons are made against existing UPFC models, which show the newly developed model to be far more flexible and efficient. It can be set to control active and reactive powers and voltage magnitude simultaneously. Unlike existing UPFC models, it can be set to control one or more of these parameters in any combination or to control none of them. Limits checking and an effective control coordination between controlling devices are incorporated in the enhanced load flow program. The algorithm exhibits quadratic or near-quadratic convergence characteristics, regardless of the size of the network and the number of FACTS devices. 10 Refs.

[1997] 19B - 23

USE OF UPFC FOR OPTIMAL POWER FLOW CONTROL

Noroozian, M.; Angquist, L.; Ghandhari, M.; Andersson, G.

ABB Power Sys, Vasteras, Sweden

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1629-1634

This paper deals with optimal power flow control in electric power systems by use of unified power flow controller (UPFC). Models suitable for incorporation in power flow programs are developed and analyzed. The application of UPFC for optimal power flow control is demonstrated through numerical examples. It is shown that a UPFC has the capability of regulating the power flow and minimizing the power losses simultaneously. An algorithm is proposed for determining the optimum size of UPFC for power flow applications. The performance of UPFC is compared with that of a phase-shifting transformer (PST). 7 Refs.

[1996] 19B - 24

VERSATILE FACTS DEVICE MODEL FOR POWERFLOW AND STABILITY SIMULATIONS

Arabi, S.; Kundur, P.

Powertech Labs Inc, Surrey, BC, Canada

IEEE Trans on Power Systems, vol 11, no 4, November 1996, pp 1944-1950

While early FACTS devices consisted mainly of thyristor-controlled/switched RLC/transformer components, the newer generation is based on the self-commutated voltage-sourced converter. The variety of devices and applications, and the changing nature of the technology, call for versatile modeling capabilities at different levels of detail. This paper describes a model conceived as a coordinated and interconnected set of controllable shunt and series elements. For each device, functional characteristics, typical settings and controls, and simulation examples are presented. The model is capable of representing virtually any FACTS device for powerflow and all types of stability simulations. 20 Refs.

[1996] 19B - REF

FACTS DEVICES IN UPLIFT CONTROL

For Abstract see entry 07A - 16

[1997] 19B - REF

MODELING SYNCHRONOUS VOLTAGE SOURCE CONVERTERS IN TRANSMISSION SYSTEM PLANNING STUDIES

For Abstract see entry 07A - 34

[1996] 19B - REF

APPLICATION STUDY FOR SIZING AND RATING CONTROLLED AND CONVENTIONAL SERIES COMPENSATION

For Abstract see entry 07B - 10

[1997] 19B - REF

FACTS ASSESSMENT STUDY TO INCREASE THE ARIZONA-CALIFORNIA TRANSFER CAPACITY

For Abstract see entry 07B - 21

[1996] 19B - REF

ON-LINE VOLTAGE SECURITY ASSESSMENT: FRAMEWORK AND IMPLEMENTATION

For Abstract see entry 07B - 36

[1996] 19B - REF

DIGITAL AND REAL TIME STUDIES OF THE ESKOM SVCS

For Abstract see entry 08A - 57

[1996] 19B - REF

A NEW CALCULATION METHOD FOR POWER FLOW CONTROL IN POWER SYSTEM WITH UPFC

For Abstract see entry 11A - 2

[1996] 19B - REF

GENETIC ALGORITHMS AND UPFC FOR POWER FLOW CONTROL

For Abstract see entry 11A - 20

[1996] 19B - REF

PERFORMANCE OF A UNIFIED POWER FLOW CONTROLLER USING A D-Q CONTROL SYSTEM

For Abstract see entry 11A - 32

[1996] 19B - REF

POWER FLOW CONTROL WITH UPFC USING GENETIC ALGORITHMS

For Abstract see entry 11A - 36

[1996] 19B - REF

ASSESSMENT AND CONTROL OF THE IMPACT OF FACTS DEVICES ON POWER SYSTEM PERFORMANCE

For Abstract see entry 18B - 1

[1997] 19B - REF

DETERMINATION OF NEEDED FACTS CONTROLLERS THAT INCREASE ASSET UTILIZATION OF POWER SYSTEMS

For Abstract see entry 18B - 5

[1997] 19B - REF

COORDINATED DESIGN OF FACTS CONTROLLERS TO ENHANCE POWER SYSTEM DYNAMIC PERFORMANCE

For Abstract see entry 18C - 4

[1998] 19B - REF

INCREASED TRANSMISSION CAPACITY BY FORCED SYMMETRIZATION

For Abstract see entry 18D - 14

19C Transient Stability, Long-Term Stability

[1996] 19C - 1

POWER NETWORK STABILITY ENHANCEMENT

Alexiades, A.N.; Young, D.J.; Humble, D.A.

GEC ALSTHOM Sales Network Inc, USA

Revue T&D (France), vol 2, 1996, pp 21-31

French

Abstract not available

[1997] 19C - 2

IMPROVING POWER SYSTEM DYNAMICS BY SERIES-CONNECTED FACTS DEVICES

Noroozian, M.; Angquist, L.; Ghandhari, M.; Andersson, G.

ABB Power Sys, Vasteras, Sweden

IEEE Trans on Power Delivery, vol 12, no 4, October 1997, pp 1635-1640

This paper examines improvement of power system dynamics by use of unified power flow controller (UPFC), thyristor-controlled phase-shifting transformer (TCPST) and thyristor-controlled series capacitor (TCSC). Models suitable for incorporation in dynamic simulation programs for studying angle stability are analyzed. A control strategy for damping of electromechanical power oscillations using an energy function method is derived. The achieved control laws are shown to be effective both for damping of large signal and small signal disturbances and are robust with respect to loading condition, fault location and network structure. Furthermore, the control inputs are easily attainable from the locally measurable variables. The effectiveness of the controls are demonstrated for model power systems. 9 Refs.

[1996] 19C - 3

SERIES-CONNECTED FACTS DEVICES CONTROL STRATEGY FOR DAMPING OF ELECTROMECHANICAL OSCILLATIONS

Noroozian, M.; Anguist, L.; Petterson, A.; Chamia, M.; Ghandhari, M.; Andersson, G.

ABB Power Sys, Vasteras, Sweden

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 1090-1096

This paper examines the improvement of power system dynamics by the use of unified power flow controllers (UPFC), phase angle regulators (PAR) and controllable series capacitors (CSC). Models suitable for incorporation in dynamic simulation programs for studying angle stability are analyzed. A control strategy for damping of electromechanical power oscillations using an energy function method is derived. The achieved control laws are shown to be effective both for damping of large signal and small signal disturbances and are robust with respect to loading condition and power network structure. Furthermore, the control inputs are easily attainable from the locally measurable variables. The effectiveness of the controls are demonstrated for model power systems. 10 Refs.

[1996] 19C - 4

TRANSIENT STABILITY ENHANCEMENT WITH FACTS CONTROL

Nelson, R.J.; Bian, J.; Ramey, D.G.; Lemak, T.A.; Rietman, T.R.; Hill, J.E.

Westinghouse Elec Corp, USA

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 269-274

This paper presents the results of transient stability simulations on a small (2-generator, 5-bus) study power system. The study compares the effects of different FACTS controllers using critical fault clearing time (CFCT) as a figure of merit. Specifically, the study compared the application of five controllers: the high initial response (HIR) generator excitation system, the static VAr compensator (SVC), the static synchronous compensator (STATCOM), the thyristor-controlled series capacitor (TCSC), and the unified power flow controller (UPFC). The study demonstrates that FACTS devices, in general, are considerably more powerful than high response excitation systems in enhancing transient stability. Among FACTS devices, the study shows that

the STATCOM with its superior low-voltage performance, has superior transient stability performance characteristics compared to an SVC of the same rating. The UPFC, with its ability to independently control real and reactive power flow, as well as bus terminal voltage, has the greatest potential to enhance transient stability, compared with any of the other controllers studied. 11 Refs.

[1998] 19C - REF

COMBINED TRANSIENT AND DYNAMIC ANALYSIS OF HVDC AND FACTS SYSTEMS

For Abstract see entry 06C - 4

[1997] 19C - REF

MODELING SYNCHRONOUS VOLTAGE SOURCE CONVERTERS IN TRANSMISSION SYSTEM PLANNING STUDIES

For Abstract see entry 07A - 34

[1997] 19C - REF

USER-DEFINED MODELING FOR NEW CONTROL EQUIPMENT IN POWER SYSTEM

For Abstract see entry 07A - 77

[1996] 19C - REF

APPLICATION STUDY FOR SIZING AND RATING CONTROLLED AND CONVENTIONAL SERIES COMPENSATION

For Abstract see entry 07B - 10

[1997] 19C - REF

FACTS ASSESSMENT STUDY TO INCREASE THE ARIZONA-CALIFORNIA TRANSFER CAPACITY

For Abstract see entry 07B - 21

[1996] 19C - REF

A STATIC VAR COMPENSATOR CONTROL STRATEGY TO MAXIMIZE POWER SYSTEM DAMPING

For Abstract see entry 08A - 10

[1996] 19C - REF

STATIC VAR COMPENSATOR IN DAMPING POWER SYSTEM OSCILLATION. PART II: CASE STUDY

For Abstract see entry 08A - 110

[1997] 19C - REF

THE STUDY ON IMPROVEMENT OF YIMIN-DAQING 500 KV SYSTEM STABILITY BY SVC

For Abstract see entry 08A - 126

[1996] 19C - REF

ENHANCEMENT OF POWER SYSTEM STABILITY BY CONTROLLABLE SERIES COMPENSATION

For Abstract see entry 08A - 60

[1997] 19C - REF

MODELLING OF ELECTRIC ARC FURNACE FOR HARMONIC AND FLICKER ASSESSMENT. A CASE STUDY

For Abstract see entry 08A - 79

[1998] 19C - REF

A ROBUST CONTROL STRATEGY FOR SHUNT AND SERIES REACTIVE COMPENSATORS TO DAMP ELECTROMECHANICAL OSCILLATIONS

For Abstract see entry 08A - 9

[1998] 19C - REF

POWER SYSTEMS TRANSIENT STABILITY ENHANCEMENT USING STATIC VAR COMPENSATORS

For Abstract see entry 08A - 93

[1998] 19C - REF

ASVG MODEL FOR TRANSIENT STABILITY STUDIES IN UNBALANCED SYSTEMS

For Abstract see entry 09A - 29

[1997] 19C - REF

SIMULATION OF THE STATIC CONDENSER FOR THE PREVENTION OF TRANSIENT

VOLTAGE INSTABILITY DUE TO INDUCTION MOTOR LOAD

For Abstract see entry 09A - 88

[1997] 19C - REF

STABILITY ENHANCEMENT USING ASVG NONLINEAR CONTROL

For Abstract see entry 09A - 89

[1996] 19C - REF

ANALYSIS AND CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATOR FOR POWER SYSTEM OSCILLATION DAMPING

For Abstract see entry 10A - 10

[1997] 19C - REF

STUDY ON MULTI-OBJECTIVE CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATION

For Abstract see entry 10A - 107

[1998] 19C - REF

THYRISTOR CONTROLLED SERIES COMPENSATION (TCSC) IMPEDANCE AND LINEARIZED MODELS FOR POWER SWING AND TORSIONAL ANALYSIS

For Abstract see entry 10A - 117

[1996] 19C - REF

APPLICATION OF SELF-TUNING FUZZY CONTROL IN TRANSIENT STABILITY OF POWER SYSTEM

For Abstract see entry 10A - 16

[1997] 19C - REF

FACTS STABILIZATION CONTROL FOR MULTI-MACHINE POWER SYSTEM

For Abstract see entry 10A - 45

[1996] 19C - REF

ADVANCED SERIES COMPENSATION (ASC) MODEL FOR STABILITY PROGRAMS

For Abstract see entry 10A - 5

[1998] 19C - REF

IMPROVEMENT OF DAMPING LOW FREQUENCY OSCILLATIONS BY TCSC

For Abstract see entry 10A - 51

[1998] 19C - REF

IMPROVEMENT OF POWER SYSTEM TRANSIENT STABILITY BY USING CONTROLLABLE SERIES COMPENSATOR

For Abstract see entry 10A - 55

[1996] 19C - REF

IMPROVEMENT OF TRANSIENT STABILITY OF MULTI-MACHINE POWER SYSTEMS USING FACTS EQUIPMENT APPLYING FUZZY CONTROL

For Abstract see entry 10A - 57

[1996] 19C - REF

IMPROVING SYSTEM STABILITY USING AN ADVANCED SERIES COMPENSATION SCHEME TO DAMP POWER SWINGS

For Abstract see entry 10A - 60

[1998] 19C - REF

NON-LINEAR CONTROL OF THYRISTOR CONTROLLED SERIES COMPENSATOR FOR IMPROVING POWER SYSTEM TRANSIENT STABILITY

For Abstract see entry 10A - 72

[1997] 19C - REF

ROBUST NONLINEAR DESIGN FOR TRANSIENT STABILIZATION USING SERIES POWER FLOW COMPENSATOR

For Abstract see entry 10A - 93

[1998] 19C - REF

CONTROL DESIGN AND SIMULATION OF UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 10

[1997] 19C - REF

IMPROVEMENT OF POWER SYSTEM

TRANSIENT STABILITY USING UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 22

[1996] 19C - REF

IMPROVEMENT OF TRANSIENT STABILITY USING UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 23

[1996] 19C - REF

STEADY-STATE AND DYNAMIC MODELS OF UNIFIED POWER FLOW CONTROLLER (UPFC) FOR POWER SYSTEM STUDIES

For Abstract see entry 11A - 40

[1997] 19C - REF

BASIS STUDY OF POWER SYSTEM STABILIZING CONTROL USING UNIFIED POWER FLOW CONTROLLER(UPFC)

For Abstract see entry 11A - 9

[1996] 19C - REF

NONLINEAR EXCITATION AND PHASE SHIFTER CONTROLLER FOR TRANSIENT STABILITY ENHANCEMENT OF POWER SYSTEMS USING ADAPTIVE CONTROL LAW

For Abstract see entry 12A - 10

[1997] 19C - REF

POWER SYSTEM STABILIZING CONTROL USING HIGH SPEED PHASE SHIFTER (HSPS)

For Abstract see entry 12A - 12

[1998] 19C - REF

DYNAMIC QUADRATURE BOOSTER AS AN AID TO SYSTEM STABILITY

For Abstract see entry 12A - 6

[1997] 19C - REF

SUPERSMES AS A UNIVERSAL POWER QUALITY CONTROLLER USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 133

[1996] 19C - REF

DEVELOPMENT OF SYSTEM STABILIZING SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES) SYSTEM. SYSTEM STABILIZATION TESTS BEING CARRIED OUT FREQUENTLY IN THE GENERAL RESEARCH INSTITUTE

For Abstract see entry 14A - 32

[1997] 19C - REF

MULTI-MACHINE POWER SYSTEM TRANSIENT STABILITY IMPROVEMENT USING FUZZY SLIDING MODE CONTROL OF SMES

For Abstract see entry 14A - 74

[1997] 19C - REF

TRANSIENT STABILIZATION USING ADAPTIVE EXCITATION AND DYNAMIC BRAKE CONTROL

For Abstract see entry 15A - 7

[1996] 19C - REF

SPECIFICATION STUDY OF A THYRISTOR CONTROLLED SERIES RESONANT TYPE FAULT CURRENT LIMITER

For Abstract see entry 16B - 10

[1996] 19C - REF

PRINCIPLE AND CHARACTERISTICS OF A FAULT CURRENT LIMITER WITH SERIES COMPENSATION

For Abstract see entry 16B - 9

[1997] 19C - REF

APPLICATION OF MANIFOLD TO TRANSIENT STABILITY ANALYSIS OF POWER SYSTEMS WITH FACTS CONTROLLERS

For Abstract see entry 18A - 1

[1997] 19C - REF

IMPROVEMENT OF TRANSIENT STABILITY LIMIT IN POWER SYSTEM TRANSMISSION LINES USING FUZZY CONTROL OF FACTS DEVICES

For Abstract see entry 18A - 22

[1998] 19C - REF

DYNAMIC POWER FLOW CONTROL WITH CONTROLLABLE REACTIVE SERIES ELEMENTS

For Abstract see entry 18B - 6

[1997] 19C - REF

IMPROVED POWER SWING DAMPING BY COORDINATED FACTS CONTROLS

For Abstract see entry 18C - 9

[1996] 19C - REF

VERSATILE FACTS DEVICE MODEL FOR POWERFLOW AND STABILITY SIMULATIONS

For Abstract see entry 19B - 24

[1996] 19C - REF

ANIMATED VECTORS FOR VISUALIZATION OF POWER SYSTEM PHENOMENA

For Abstract see entry 19B - 5

[1996] 19C - REF

MULTIRATE SIMULATION OF FACTS DEVICES IN POWER SYSTEM DYNAMICS

For Abstract see entry 19D - 13

19D Electromagnetic Transients

[1998] 19D - 1

A LINK BETWEEN EMTP AND MATLAB FOR USER-DEFINED MODELING

Mahseredjian, J.; Benmouyal, G.; Lombard, X.; Zouiti, M.; Bressac, B.; Gerin-Lajoie, L.

Hydro-Quebec, Varennes, Canada

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 667-674

This paper presents a programmed link between MATLAB and EMTP (Electromagnetic Transients Program). It is an interconnection where MATLAB functions can be called in from the EMTP Fortran code. The interconnection provides a user-defined modeling tool where the high-level computation facilities of MATLAB and its powerful Toolboxes can be advantageously used in the general network simulator context of the EMTP.

[1997] 19D - 2

ATP SIMULATION OF POWER ELECTRONICS SYSTEMS USING A DATA-MODULE APPROACH

Martinez-Velasco, J.A.; Mohan, N.

Univ Politecnica de Catalunya, Barcelona, Spain

Proceedings, 32nd Universities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 495-498

The EMTP/ATP is a general-purpose program intended for time-domain simulation of power systems. ATP capabilities allow users to represent the most important components of a power system. Several options are available to prepare an ATP input file. One of these options is based modularization technique. A full library for simulation of power electronics and FACTS devices has been developed using this technique. Time-domain simulations, as well as harmonic and frequency response analyses, can be performed using a very simple data file structure with almost-free format modules. This paper summarizes the main features of the library and illustrates its application with a complete test case.

[1996] 19D - 3

DIGITAL SIMULATIONS OF THE PWM UPFC USING EMTP

Liu, J.Y.; Song, Y.H.; Foss, A.M.

Univ of Bath, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 351-356

This paper presents preliminary digital simulation studies based on the Electromagnetic Transient Program (EMTP) to investigate device performance of the unified power flow controller (UPFC) in an ac transmission system environment. First, the series part and the shunt part of the UPFC under PWM regulation are analyzed. Secondly, simulation of the UPFC to verify the analysis has been carried out. Finally, some preliminary studies on power system voltage and power control by the UPFC are presented. The EMTP-based simulation of PWM UPFC provides a useful tool for the derivation of

the UPFC phasor model, and development of control strategies for power system control. 12 Refs.

[1997] 19D - 4

DYNAMIC INTERACTION ANALYSIS BETWEEN STATCON AND TRANSMISSION SYSTEM WITH EMTP

Han, B.-M.; Park, J.-K.

Korean Inst of Elec Eng, Seoul, South Korea

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 7, July 1997, pp 991-997

Korean

This paper describes a simulation model of static condensers using EMTP software to analyze its dynamic interaction with ac transmission systems. The main circuit was modeled by a 12-pulse voltage source inverter with ideal gate turn-off switches, and the signal generation and control circuit was modeled using the TACS subroutine in the EMTP package. The effects on increasing power transmission capability, damping low-frequency oscillations and improving transient stability were verified with the model developed, assuming that the static condenser is connected to a 154-kV line of a typical one-machine-infinite-bus transmission system.

[1996] 19D - 5

EFFICIENT AND FLEXIBLE THYRISTOR CONTROLLED SERIES CAPACITOR SIMULATION IN EMTP-TACS

Ndayizamba, J.; Lefebvre, S.; Xuan D-D.

Ecole Polytech de Montreal, Quebec, Canada

Proceedings, 12th Power Systems Computation Conf, Dresden, Germany, August 20-23, 1996, vol 2, pp 1122-1127

This paper describes an innovative implementation of thyristor-controlled series capacitors (TCSC) models in the EMTP. The TCSC model has been built solely from published information in the technical literature and results have been duplicated. The model can thus be used with confidence as benchmark for validation of less detailed models suitable for planning applications. 9 Refs.

[1996] 19D - 6

FEATURES AND PROBLEMS OF FAST ELECTROMAGNETIC TRANSIENT DIGITAL SIMULATION IN POWER SYSTEMS

Lin, J-M.

Elec Power Research Inst, Beijing, China

Power System Technology (China), vol 20, no 10, October 1996, pp 1-4

Chinese

The purpose, applications and the main features of fast electromagnetic digital simulation in power systems are presented in this paper. Some emerging problems, such as the initial conditions, models for frequency dependent components, electrical machines, nonlinear elements, control systems, FACTS and power electronics devices and their algorithms, etc., are discussed. 7 Refs.

[1997] 19D - 7

GUIDELINES FOR MODELING POWER ELECTRONICS IN ELECTRIC POWER ENGINEERING APPLICATIONS

Gole, A.M.; Keri, A.; Kwankpa, C.; Gunther, E.W.; Dommel, H.W.; Hassan, I.; Marti, J.R.; Martinez, J.A.; Fehrle, K.G.; Tang, L.; McGranaghan, M.F.; Nayak, O.B.; Ribeiro, P.F.; Iravani, R.; Lasseter, R.

IEEE Trans on Power Delivery, vol 12, no 1, January 1997, pp 505-514

This paper presents a summary of guidelines for modeling power electronics in various power engineering applications. This document is designed for use by power engineers who need to simulate power electronic devices and subsystems with digital computer programs. The guideline emphasizes the basic issues that are critical for successfully modeling power electronics devices and the interface between power electronics and the utility or industrial system. The modeling considerations addressed in this guideline are generic for all power electronics modeling independent of the computational tool. However, for the purposes of illustration, the simulation examples presented are based on the EMTP or EMTP type of programs. The procedures used to implement power electronics models in these examples are valuable for using other digital simulation tools.

[1997] 19D - 8

MODELING OF POWER ELECTRONIC APPARATUS: ADDITIONAL INTERPOLATION ISSUES

Gole, A.M.; Fernando, I.T.; Irwin, G.D.; Nayak, O.B.

Int'l Conf on Power Systems Transients (IPST97), Seattle, WA, June 22-26, 1997, pp 23-28

Abstract not available.

[1996] 19D - 9

MODELLING A STATIC VAR COMPENSATOR USING EMTP

de Lima, A.C.S.; Wanderley, S.S.; Stephan, R.M.

COPPE, Univ Federal do Rio de Janeiro, Brazil

Proceedings, 38th Midwest Symp on Circuits and Systems, Rio de Janeiro, Brazil, August 13-16, 1996, vol 2, pp 219-222

A digital simulation of a static VAr compensator (SVC) using a thyristor-controlled reactor (TCR) and fixed capacitor (FC) is presented. This configuration is widely used in power system applications. The model is tested under EMTP (ATP version). 5 Refs.

[1997] 19D - 10

MODELLING OF A THYRISTOR CONTROLLED SERIES CAPACITOR IN MATLAB™ ENVIRONMENT

Neto, O.M.; Meneguim, R.A.; Oliveira, F.D.; Oliveira, J.M.

Federal Inst of High Education of Sao Joao del Rei, Sao Joao del Rei, Brazil

Proceedings, 32nd Univertsities Power Engineering Conf (UPEC'97), Manchester, UK, September 10-12, 1997, vol 1, pp 21-14

This paper presents the modeling of a TCSC (thyristor-controlled series capacitor) using the MATLAB™ The model consists of a series capacitor connected in parallel with a thyristor-controlled reactor (TCR). The equations which describes the TCSC are presented and modeled in MATLAB™. Comparisons are made between the results obtained with the MATLAB™ and with the EMTP (Electromagnetic Transient Program). The main characteristics of using MATLAB™ in this kind of modeling are discussed. 7 Refs.

[1996] 19D - 11

MODELLING OF FACTS DEVICES

Tenorio, A.R.M.; Ekanayake, J.B.; Jenkins, N.

Univ of Manchester Inst of Sci & Tech, UK

Proceedings, 6th IEE Int'l Conf on AC and DC Power Transmission, London, UK, April 29-May 3, 1996, pp 340-345

A variety of FACTS devices are now being proposed as a means of increasing the capability and flexibility of power systems. The planning and design stage of the implementation of this new technology will require reliable and easy-to-use models to represent the FACTS devices and associated networks. The type of modeling needed will depend on the studies being undertaken but will include detailed electromagnetic transient simulations as well as simpler representations. In this paper, digital and physical models for the advanced static VAr compensator (ASVC) and a digital model for the thyristor-controlled series capacitor (TCSC) are presented. The detailed models included representations of the power electronic switching circuits, the control systems and the power system network. 7 Refs.

[1996] 19D - 12

MODELLING OF HIGH-VOLTAGE THYRISTORS UNDER DYNAMIC CONDITIONS

Tarasov, A.N.

Electrical Technology (UK), no 4, 1996, pp 129-144

The paper describes the development of dedicated mathematical models of high-voltage thyristors, intended for investigating the electromagnetic processes in high-power, high-voltage converters. The models proposed allow for features of the electrophysical processes in thyristor circuits containing a large number of series-connected thyristors. The models make it possible to determine the electrical actions in thyristors under dynamic conditions during converter current commutation. The model proposed can also be used as a subprogram package in systems for computer design of converters. 16 Refs.

[1996] 19D - 13

MULTIRATE SIMULATION OF FACTS DEVICES IN POWER SYSTEM DYNAMICS

Crow, M.L.; Chen, J.G.

Univ of Missouri, Rolla, MO, USA

IEEE Trans on Power Systems, vol 11, no 1, February 1996, pp 376-382

In this paper, the multirate method is applied to the problem of simulating the dynamics of a power system which contains fast components such as induction machine loads and FACTS devices. Results concerning the numerical stability and accuracy of the multirate method are presented. Implementation concerns are also addressed by studying an example power system which contains a wide range of time response behavior. 10 Refs.

[1996] 19D - 14

POWER ELECTRONICS MODEL LIBRARY FOR POWER SYSTEM ANALYSIS

Zhao, H.; Zhou, X-X.; Wu, S-Y.

Elec Power Research Inst, Beijing, China

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 802-807

Power electronic devices will be widely adopted in power systems. This technique is called flexible ac transmission systems (FACTS). For system analysis and transient performance evaluation, the library of power electronics models has been used. This paper discusses the establishment of the library and the associated simulation methods. 9 Refs.

[1997] 19D - 15

SIMULATION OF FACTS FOR WIND FARM APPLICATIONS

Papantoniou, A.; Coonick, A.

Imperial College, London, UK

Proceedings, IEE Colloquium on Power Electronics for Renewable Energy, London, UK, June 16, 1997, no 170, pp 8/1-8/5

The interaction of wind farms and flexible alternating current transmission systems (FACTS) provide a difficult problem for the analysis of power systems that incorporate renewables. SABER, a special simulation package built around MAST programming language, was used to simulate the system containing a resistive brake and a UPFC. The simulation results were used to indicate that the resistive brake can be used as a dump load for isolated wind farms and that unified power flow controller can provide both voltage control and the reactive power of a grid connected wind farm. 5 Refs.

[1997] 19D - 16

TRANSIENT BEHAVIOR OF SYSTEMS CONTAINING FACTS DEVICES: MODELING OF THE THYRISTOR CONTROLLED SERIES CAPACITOR

Sultan, M.R.; Reeve, J.

Univ of Waterloo, Ontario, Canada

EPRI TR-108191 2149-15, Final Report, July 1997 (R. Adapa, EPRI prog mgr)

Developing a FACTS implementation for large, extended ac systems represents a challenge for power system planners. Improved FACTS modeling tools and techniques could increase accuracy in predicting FACTS performance in these systems. This report describes proposed modeling techniques for the ac/dc and FACTS systems using interfaced digital simulations to analyze FACTS performance in transient studies. The researchers used EPRI's EMTP as the basis for one digital simulation and in-house transient stability software for the other. By interfacing these two simulations while both were in progress, the most comprehensive picture of FACTS performance was achieved. After reviewing these techniques, the authors demonstrated the method by modeling a specific FACTS device, a thyristor-controlled series capacitor (TCSC)

[1996] 19D - REF

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

For Abstract see entry 05B - 38

[1998] 19D - REF

COMBINED TRANSIENT AND DYNAMIC ANALYSIS OF HVDC AND FACTS SYSTEMS

For Abstract see entry 06C - 4

[1997] 19D - REF

IMPLEMENTATION AND EFFECTIVENESS OF LINEAR INTERPOLATION WITHIN DIGITAL SIMULATION

For Abstract see entry 06D - 3

[1997] 19D - REF

MODELING SYNCHRONOUS VOLTAGE SOURCE CONVERTERS IN TRANSMISSION SYSTEM PLANNING STUDIES

For Abstract see entry 07A - 34

[1998] 19D - REF

MODELING, CONTROL AND STABILITY ANALYSIS OF A PEBB-BASED DPS

For Abstract see entry 07A - 35

[1997] 19D - REF

USER-DEFINED MODELING FOR NEW CONTROL EQUIPMENT IN POWER SYSTEM

For Abstract see entry 07A - 77

[1997] 19D - REF

FACTS ASSESSMENT STUDY TO INCREASE THE ARIZONA-CALIFORNIA TRANSFER CAPACITY

For Abstract see entry 07B - 21

[1997] 19D - REF

SIMULATION OF UNIFIED STATIC VAR COMPENSATOR AND POWER SYSTEM STABILIZER FOR ARRESTING SUBSYNCHRONOUS RESONANCE

For Abstract see entry 08A - 106

[1996] 19D - REF

AN EVALUATION OF STATIC VAR COMPENSATION STRATEGIES FOR VOLTAGE FLICKER MITIGATION IN ELECTRIC DISTRIBUTION SYSTEMS

For Abstract see entry 08A - 18

[1998] 19D - REF

INTERACTION ANALYSIS MODEL FOR TRANSMISSION STATIC COMPENSATOR WITH EMTP

For Abstract see entry 08A - 74

[1996] 19D - REF

MODELLING OF CONVENTIONAL AND ADVANCED STATIC VAR COMPENSATORS IN AN ELECTROMAGNETIC TRANSIENT SIMULATION PROGRAM

For Abstract see entry 08A - 78

[1997] 19D - REF

MODELLING OF ELECTRIC ARC FURNACE FOR HARMONIC AND FLICKER ASSESSMENT. A CASE STUDY

For Abstract see entry 08A - 79

[1996] 19D - REF

TRANSIENT ANALYSIS OF AN ADVANCED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE PAM INVERTERS

For Abstract see entry 09A - 100

[1997] 19D - REF

AN EMTDC MODEL OF A THREE LEVEL FOUR MVAR COMPENSATOR

For Abstract see entry 09A - 14

[1996] 19D - REF

ANALYSIS AND CONTROL OF ASVC FOR INTERPHASE LOAD FLOW COMPENSATION

For Abstract see entry 09A - 18

[1996] 19D - REF

ANALYSIS OF A 3 LEVEL-VSI NEUTRAL-POINT-CONTROL FOR FUNDAMENTAL FREQUENCY MODULATED SVC-APPLICATIONS

For Abstract see entry 09A - 21

[1997] 19D - REF

CONTROL SYSTEM DESIGN FOR TRANSMISSION STATCON BY APPLYING NONLINEAR FEEDBACK

For Abstract see entry 09A - 33

[1997] 19D - REF

DIGITAL MODELLING OF TWO DIFFERENT STATCOM CONFIGURATIONS

For Abstract see entry 09A - 44

[1996] 19D - REF

DIGITAL SIMULATION OF ADVANCED STATIC VAR COMPENSATOR WITH EMTP AND VERIFICATION

For Abstract see entry 09A - 45

[1997] 19D - REF

DYNAMIC PERFORMANCE AND CONTROL OF A STATIC VAR GENERATOR USING CASCADE MULTILEVEL INVERTERS

For Abstract see entry 09A - 49

[1996] 19D - REF

INVESTIGATION OF THE VOLTAGE SAG MITIGATION EFFECT OF AN ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 62

[1997] 19D - REF

MATHEMATICAL MODELS OF A THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 63

[1996] 19D - REF

MODELLING AND SIMULATION OF AN ADVANCED STATIC VAR COMPENSATOR USING SABER

For Abstract see entry 09A - 65

[1997] 19D - REF

OPTIMIZED LINEARIZATION VIA FEEDBACK CONTROL LAW FOR A STATCOM

For Abstract see entry 09A - 76

[1997] 19D - REF

A NEW TRANSFORMER-LESS MULTI-LEVEL CONVERTER FOR HIGH VOLTAGE HIGH POWER APPLICATIONS

For Abstract see entry 09A - 8

[1997] 19D - REF

RESEARCH ON THE START-UP OF THE ±300 KVAR ASVG

For Abstract see entry 09A - 86

[1998] 19D - REF

SELECTION OF PASSIVE ELEMENTS FOR A THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 87

[1997] 19D - REF

TRANSFORMER-LESS STATIC SYNCHRONOUS COMPENSATOR EMPLOYING A MULTI-LEVEL INVERTER

For Abstract see entry 09A - 99

[1997] 19D - REF

SIMULATION OF THYRISTOR CONTROLLED SERIES CAPACITORS AND SUBSYNCHRONOUS STUDIES

For Abstract see entry 10A - 100

[1996] 19D - REF

STABILITY MODEL FOR THE ADVANCED SERIES COMPENSATOR (ASC)

For Abstract see entry 10A - 102

[1997] 19D - REF

STUDIES OF SSR CONTROL METHOD USING TCSC MINIATURE MODEL

For Abstract see entry 10A - 106

[1997] 19D - REF

SUPPRESSION OF TORSIONAL OSCILLATIONS USING THYRISTOR-CONTROLLED CONDUCTANCE IN PARALLEL TO SERIES-CAPACITOR SEGMENT

For Abstract see entry 10A - 108

[1996] 19D - REF

ANALYSIS OF CONTROL MODES OF THYRISTOR CONTROLLED SERIES COMPENSATORS USING A PERIODIC LINEAR SYSTEM MODEL

For Abstract see entry 10A - 11

[1998] 19D - REF

TCSC DAMPING CONTROLLER DESIGN USING ROBUST CONTROL THEORY

For Abstract see entry 10A - 111

[1997] 19D - REF

TCSC EFFECT ANALYSIS IN MULTI-MACHINE POWER SYSTEM

For Abstract see entry 10A - 112

[1997] 19D - REF

TCSC OPERATION IN INDUCTIVE REGION AND ITS CURRENT LIMITING EFFECTS

For Abstract see entry 10A - 113

[1996] 19D - REF

TORSIONAL INTERACTION IN FLEXIBLE AC TRANSMISSION SYSTEMS WITH A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 121

[1997] 19D - REF

ANALYSIS OF THYRISTOR CONTROLLED SERIES COMPENSATOR DYNAMICS USING THE STATE VARIABLE APPROACH OF A PERIODIC SYSTEM MODEL

For Abstract see entry 10A - 13

[1997] 19D - REF

CHARACTERIZATION OF A THYRISTOR CONTROLLED REACTOR

For Abstract see entry 10A - 23

[1997] 19D - REF

CLARIFICATION OF THE SSR MITIGATION MECHANISM OF A TCSC

For Abstract see entry 10A - 24

[1997] 19D - REF

CONTROLLED SERIES COMPENSATION: DYNAMIC PERFORMANCE UNDER FAULT CONDITIONS

For Abstract see entry 10A - 28

[1997] 19D - REF

DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

For Abstract see entry 10A - 34

[1996] 19D - REF

DYNAMIC PERFORMANCE OF A THYRISTOR-CONTROLLED SERIES CAPACITOR SYSTEM

For Abstract see entry 10A - 38

[1997] 19D - REF

A STUDY OF THYRISTOR CONTROLLED SERIES CAPACITOR MODELS FOR POWER SYSTEM STABILITY ANALYSIS

For Abstract see entry 10A - 4

[1996] 19D - REF

ADVANCED SERIES COMPENSATION (ASC) MODEL FOR STABILITY PROGRAMS

For Abstract see entry 10A - 5

[1996] 19D - REF

IMPROVEMENT OF POWER SYSTEM STABILITY BY ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS

For Abstract see entry 10A - 54

[1997] 19D - REF

INVESTIGATION OF THE THYRISTOR-CONTROLLED SERIES COMPENSATION. I. STEADY-STATE AND TRANSIENT-STATE SIMULATION OF A POWER SYSTEM WITH DETAILED TCSC MODEL

For Abstract see entry 10A - 62

[1996] 19D - REF

NEW CAPACITOR SWITCHING SCHEMES TO CONTROL SUB-SYNCHRONOUS RESONANCE

For Abstract see entry 10A - 71

[1997] 19D - REF

ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS FOR POWER SYSTEM STABILITY WITH TORSIONAL OSCILLATION COUNTERMEASURE

For Abstract see entry 10A - 74

[1997] 19D - REF

PHASOR DYNAMICS OF THYRISTOR-CONTROLLED SERIES CAPACITOR SYSTEMS

For Abstract see entry 10A - 79

[1997] 19D - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. ON-OFF DISCRETE CONTROL OF SERIES CAPACITORS FOR POWER SYSTEM STABILITY WITH TORSIONAL OSCILLATION COUNTERMEASURE

For Abstract see entry 10A - 80

[1997] 19D - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. A STUDY OF THYRISTOR CONTROLLED SERIES CAPACITOR MODELS FOR POWER SYSTEM STABILITY ANALYSIS

For Abstract see entry 10A - 82

[1997] 19D - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

For Abstract see entry 10A - 83

[1996] 19D - REF

AN LQG BASED DISCRETE-TIME PSS AND TCSC SUPPLEMENTARY CONTROLLER DESIGN FOR CONTROLLING THE SSR IN THE FLEXIBLE AC TRANSMISSION SYSTEMS

For Abstract see entry 10A - 9

[1997] 19D - REF

CONTROL OF UNIFIED POWER FLOW CONTROLLER: COMPARISON OF METHODS ON THE BASIS OF A DETAILED NUMERICAL MODEL

For Abstract see entry 11A - 11

[1997] 19D - REF

DYNAMIC MODELLING OF A UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 17

[1996] 19D - REF

EMTP SIMULATION OF MULTI-PULSE UNIFIED POWER FLOW CONTROLLERS

For Abstract see entry 11A - 18

[1997] 19D - REF

PERFORMANCE EVALUATION OF UNIFIED POWER FLOW CONTROLLER USING TRANSIENT SIMULATION

For Abstract see entry 11A - 31

[1997] 19D - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. SIMULATION STUDY OF UNIFIED POWER FLOW CONTROLLER.

For Abstract see entry 11A - 34

[1996] 19D - REF

STEADY-STATE AND DYNAMIC MODELS OF UNIFIED POWER FLOW CONTROLLER (UPFC) FOR POWER SYSTEM STUDIES

For Abstract see entry 11A - 40

[1997] 19D - REF

UNIFIED POWER FLOW CONTROLLER (UPFC) BASED ON CHOPPER STABILIZED MULTILEVEL CONVERTER

For Abstract see entry 11A - 44

[1998] 19D - REF

UNIFIED POWER FLOW CONTROLLER (UPFC): MODELING AND ANALYSIS

For Abstract see entry 11A - 46

[1998] 19D - REF

UPFC - UNIFIED POWER FLOW CONTROLLER: THEORY, MODELING, AND APPLICATIONS

For Abstract see entry 11A - 48

[1998] 19D - REF

AN UNIVERSAL ACTIVE POWER LINE CONDITIONER

For Abstract see entry 11A - 5

[1996] 19D - REF

ANALYSIS, SIMULATION AND IMPLEMENTATION OF A PWM BASED UPFC

For Abstract see entry 11A - 7

[1996] 19D - REF

PWM AC CONTROLLER-BASED PHASE-SHIFTERS

For Abstract see entry 12A - 15

[1997] 19D - REF

PWM QUADRATURE-BOOSTER PHASE SHIFTER FOR AC POWER TRANSMISSION

For Abstract see entry 12A - 17

[1997] 19D - REF

APPLICATION OF STATIC PHASE SHIFTERS ON THE DAMPING OF COMMON-MODE TORSIONAL OSCILLATIONS

For Abstract see entry 12A - 4

[1997] 19D - REF

CONTROL SCHEMES AND TRANSIENT CHARACTERISTICS OF A HIGH SPEED PHASE SHIFTER FOR POWER FLOW CONTROL IN POWER TRANSMISSION SYSTEMS.

For Abstract see entry 12A - 5

[1997] 19D - REF

SAMPLED DATA AUTOMATIC GENERATION CONTROL WITH SUPERCONDUCTING MAGNETIC ENERGY STORAGE IN POWER SYSTEMS

For Abstract see entry 14A - 105

[1996] 19D - REF

NEW COMBINED POWER-CONDITIONING SYSTEM FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 77

[1997] 19D - REF

DEVELOPMENT OF UNINTERRUPTIBLE SECONDARY BATTERY SYSTEM

For Abstract see entry 14B - 18

[1996] 19D - REF

DEVELOPMENT OF A CONTROL SCHEME FOR A SERIES-CONNECTED SOLID-STATE SYNCHRONOUS VOLTAGE SOURCE

For Abstract see entry 16A - 8

[1998] 19D - REF

ON USING THE SOLID-STATE BREAKER IN DISTRIBUTION SYSTEMS

For Abstract see entry 16B - 8

[1998] 19D - REF

DAMPING OF COMMON-MODE TORSIONAL OSCILLATIONS USING A MODIFIED NGH SSR DAMPING SCHEME

For Abstract see entry 16C - 1

[1997] 19D - REF

SERIES POWER LINE COMPENSATOR USING SELF-COMMUTATED INVERTER

For Abstract see entry 16D - 5

[1998] 19D - REF

SIMULATION AND ANALYSIS OF SERIES VOLTAGE BOOST TECHNOLOGY FOR POWER QUALITY ENHANCEMENT

For Abstract see entry 16D - 6

[1997] 19D - REF

CURRENT EQUALIZATION IN SPWM FACTS CONTROLLERS AT LOWEST SWITCHING RATES

For Abstract see entry 17B - 9

[1996] 19D - REF

HARMONIC ANALYSIS OF THE UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 17C - 11

[1996] 19D - REF

MODELLING AND ANALYSIS GUIDELINES FOR SLOW TRANSIENT. PART II CONTROLLER INTERACTIONS ; HARMONIC INTERACTIONS

For Abstract see entry 17C - 18

[1996] 19D - REF

APPLICATION OF DOUBLE-LAYER CAPACITOR TECHNOLOGY TO STATIC CONDENSERS FOR DISTRIBUTION SYSTEM VOLTAGE CONTROL

For Abstract see entry 17E - 1

[1996] 19D - REF

ELECTROMAGNETIC DESIGN CONSIDERATIONS FOR FAST ACTING CONTROLLERS

For Abstract see entry 18A - 12

[1996] 19D - REF

COMPARATIVE STUDY ON TRANSIENT STABILITY IMPROVING CAPABILITY OF SERIES AND SHUNT COMPENSATION

For Abstract see entry 18B - 3

[1996] 19D - REF

A STUDY OF IMPROVEMENT FOR POWER SYSTEM STABILITY BY A TCSC WITH ?P TYPE PSS

For Abstract see entry 18C - 1

[1997] 19D - REF

COORDINATED DESIGN OF FACTS CONTROLLERS TO ENHANCE POWER SYSTEM DYNAMIC PERFORMANCE

For Abstract see entry 18C - 4

[1997] 19D - REF

GENETIC ALGORITHM BASED NEURAL NETWORKS APPLIED TO FAULT CLASSIFICATION FOR EHV TRANSMISSION LINES WITH A UPFC

For Abstract see entry 18D - 12

[1996] 19D - REF

ALGORITHMS FOR LOCATING FAULTS ON SERIES COMPENSATED LINES USING NEURAL NETWORK AND DETERMINISTIC METHODS. DISCUSSION

For Abstract see entry 18D - 2

[1996] 19D - REF

SIMULATION STUDY OF UNIFIED POWER FLOW CONTROLLERS

For Abstract see entry 18D - 24

[1998] 19D - REF

AN ADAPTIVE PROTECTION SCHEME FOR ADVANCED SERIES COMPENSATED (ASC) TRANSMISSION LINES

For Abstract see entry 18D - 4

[1996] 19D - REF

APPLICATION OF ARTIFICIAL NEURAL NETWORKS FOR SERIES COMPENSATED LINE PROTECTION

For Abstract see entry 18D - 5

[1996] 19D - REF

A LABORATORY-SCALE THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 19E - 3

[1997] 19D - REF

A PHYSICAL LABORATORY MODEL OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 19E - 4

19E Simulators, Experimental Models

[1996] 19E - 1

A FULLY DIGITAL POWER SYSTEM SIMULATOR OPERATING IN REAL TIME

Kuffel, R.; Giebrecht, J.; Maguire, T.; Wierckx, R. P.; McLaren, P. G.

Canadian Elec Assoc, Montreal, Quebec, Canada

Proceedings, Electricity '96, Montreal, Canada, April 28-May 3, 1996, pp 1-11

Opportunities created by recent developments in computing hardware and power system component modeling techniques for digital simulation of power systems development, design, and testing, and more particularly to study electromagnetic transients, were discussed. Details of a real time digital simulator (RTDS) developed at the Manitoba HVDC Research Centre, specifically for the solution of power system electromagnetic transients, were provided. Hardware and software components, and various applications, including protective relay testing, control system testing, analog simulator expansion, and operation as a power system training tool, were described. 10 refs., 7 figs.

[1998] 19E - 2

A LABORATORY FOR POWER SYSTEMS CONTROL WITH STATIC CONVERTERS

Bonert, R.

Univ of Toronto, Ontario, Canada

IEEE Trans on Power Systems, vol 13, no 1, February 1998, pp 15f

The 4th year course "Power Systems Control" at the University of Toronto includes a laboratory familiarizing the student with the function and use of static converters for the control of power systems. This paper describes the concept of the laboratory and the required equipment. The experiments are discussed in detail to demonstrate the possibility to teach the different aspects of power systems control with static converters.

[1996] 19E - 3

A LABORATORY-SCALE THYRISTOR CONTROLLED SERIES CAPACITOR

Matsuki, J.; Ikeda, K.; Abe, M.

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 116-B, no 11, pp 1397-1402

Kyoto Univ, Japan

This paper describes the results of an experimental study on the characteristics of a thyristor-controlled series capacitor (TCSC). At present, there are two major thyristor-controlled series compensation projects in the US.: the Kayenta ASC and the Slatt TCSC. However, there has been little operating experience and thus further understanding of the characteristics of TCSC is still to be sought. Therefore, a laboratory-scale TCSC was produced and installed in a laboratory power system. The impedance characteristics, wave shapes of voltages and currents in the TCSC circuit, and harmonics, for various thyristor firing angles, and insertion responses were measured and analyzed. In particular, effects of the size of the circuit components, i.e., parasitic resistance, additional damping resistance and series reactor, on the overall TCSC performances were investigated. The results were compared with EMTP simulations.

[1997] 19E - 4

A PHYSICAL LABORATORY MODEL OF A THYRISTOR CONTROLLED SERIES CAPACITOR

Leonidaki, E.A.; Papadias, B.C.; Hatziargyriou, N.D.; Giorgas, S.

Proceedings, 33rd Universities Power Engineering Conf, Edinburgh, UK, September 8-10, 1997,

Series compensation is used in power systems in order to increase the transfer capability of transmission lines. For this reason, thyristor-controlled series capacitors (TCSC) in combination with fixed capacitors are employed providing controlled apparent reactance. To provide a better understanding of various physical phenomena in TCSCs, a three-phase low-voltage physical laboratory model has been constructed for laboratory exercises. This paper describes the results of preliminary tests performed on the TCSC laboratory model and their verification with simulation results obtained from the Electromagnetic Transient Program (EMTP/ATP).

[1998] 19E - 5

A SIMULATOR OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE AND AN EXPERIMENT OF LEVELLING LOAD POWER FLUCTUATION

Funabiki, S.; Yorioka, T.; Fujii, T.

Shimane Univ, Japan

Trans of the Institute of Electrical Engineers of Japan (Denki Gakkai Ronbunshi), vol 118-D, no 1, pp 82-88

Japanese

A superconducting magnetic energy storage (SMES) using superconductive coil is effective power storage system. An electric power system using SMES can perform leveling load power fluctuation and improve the stability of power system. It is impossible to examine a control strategy for leveling load power fluctuation using a SMES, because we can not realize a large capacity of SMES. So we build a SMES simulator as a trial that operates coordinately as a superconductive coil. In this paper, a superconductive coil composed of a coil and a inverter circuit is realized by numerical expression and experiment. The control strategy based on an auto-tuning of scaling factors with neural network can realize leveling the fluctuating active power and compensating the reactive power using the SMES simulator.

[1997] 19E - 6

A SIMULATOR OF SUPERCONDUCTING MAGNETIC ENERGY STORAGE AND AN EXAMINATION OF A CONTROL STRATEGY FOR LEVELLING LOAD POWER FLUCTUATION

Yorioka, T.; Funabiki, S.

Okayama Univ, Japan

Denki Gakkai Handotai Denryoku Henkan Kenkyukai Shiryo (Japan), vol SPC-97, no 26-38, pp 27-32

Japanese

It is impossible to examine a control strategy for leveling load power fluctuation using a superconducting magnetic energy storage (SMES), because we can not realize a large capacity of SMES. So we build a SMES simulator as a trial that operates coordinately as a superconductive coil. This paper describes the principle of the SMES simulator and the results of the load power leveling experiment using the SMES simulator.

[1997] 19E - 7

ADVANCED REAL-TIME SIMULATOR TESTS FOR THE PERFORMANCE VERIFICATION OF STATIC VAR COMPENSATORS IN EXTENDED GRIDS

Boshoff, S.; Davel, P.; Magg, T.; Badelt, T.; Friedrich, B.; Habur, K.; Retzmann, D.; Forsyth, P.; Maguire, T.

ESKOM, South Africa

CIGRE Int'l Colloquium on HVDC and FACTS, Johannesburg, South Africa, September 28-30, 1997

This paper presents the use of an RTDS™ simulator for testing of static var compensators (SVC) in extended grids. SVCs are the fastest devices within the family of FACTS, which contribute substantially to improved voltage quality in power systems. Capabilities and limitations of computer, analog and digital SVC real-time simulations are discussed. On the basis of these results, a new approach for an advanced hybrid SVC real-time simulator using classical physical models for the converter section in combination with a fully digital complex ac power system simulator implemented on RTDS is developed. Results of large project studies and applications are presented.

[1997] 19E - 8

ADVANCED SVC TESTING USING A REAL TIME DIGITAL SIMULATOR

Badelt, T.; Claus, M.; Friedrich, B.; Retzmann, D.; Boshoff, S.; Davel, P.; Magg, T.; Forsyth, P.; Maguire, T.

Siemens AG, Germany

Proceedings, 1997 Int'l Conf on Digital Power Systems Simulators, Montreal, Canada, May 28-30, 1997, pp 265-270

This paper presents the use of an RTDS™ simulator for real-time testing of static VAr compensators (SVC). SVCs are the fastest devices within the family of FACTS (flexible ac transmission systems), which contribute substantially to improved voltage quality in power systems. In principle, they are shunt compensation devices which employ powerful thyristor valves for controllability. However, the SVC's high speed control can only be applied effectively if the type and size of the power components as well as the control and protection schemes are well matched to the specific network parameters and requirements. Hence, design verification by computer and real-time simulation is imperative to successful commissioning.

[1998] 19E - 9

AN ADVANCED AND POWERFUL REAL-TIME DIGITAL TRANSIENT NETWORK ANALYSER

Devaux, O.; Levacher, L.; Huet, O.

Electricite de France

IEEE Trans on Power Delivery, vol 13, no 2, April 1998, pp 421f

A few years ago, the study and simulation of fast phenomena in real-time was the private ground of analog simulators. But the limitation in modeling, the complexity and the costly maintenance of these simulators was a brake upon their development and made their profitability uncertain. The test of power system equipment such as controls, relays or power electronic devices needed a new type of simulator, much more versatile and cost-efficient than their predecessors: the real-time digital transient network analyzers (DTNA). Until a few months ago, the design of DTNAs was based on dedicated technologies. Today, the ever increasing calculation power has now reached a level that allows real-time simulations of fast phenomena to be carried on standard computers. We present in this paper a new and fully digital TNA that relies on a standard computer.

[1998] 19E - 10

AN ELECTRONIC SIMULATOR REPRESENTING A SVC INCORPORATED POWER SYSTEM

Forughian, T.

Ngee Ann Polytech, Singapore

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper S24.3

Abstract not available

[1998] 19E - 11

ANALOGUE SIMULATION STUDIES WITH ACTUAL CONTROLLERS FOR FACTS EQUIPMENT

Matsuno, K.; Taniguchi, H.; Egawa, M.; Fujita, H.; Konishi, H.; Irokawa, S.; Akamatsu, M.

CIGRE Study Committee 14

Proceedings, 37th CIGRE Conf, Paris, France, August 30-September 5, 1998

Experimental small scale models of a static var compensator composed of a self-commutated converter (STATCOM), a thyristor-controlled series compensator (TCSC) and a unified power flow controller (UPFC) were made for FACTS equipment which is expected to be put into practical use in the near future in Japan. The control and protection systems of the equipment were real and could be used practically and immediately. Effectiveness and the possibility of realization of the equipment for power system stabilization were confirmed through digital simulations and tests with an analog simulator, which combines the small scale models. Finally, the actual equipment was fabricated and the control and protection systems were developed.

[1997] 19E - 12

COMPUTER AIDED ENGINEERING PLATFORM FOR FACTS

Shen, D.; Wang, Z.; Jiang, Q.; Tan, S.

Dept of Elec Eng, Tsinghua Univ, Beijing, China

Journal of Tsinghua University (Science and Technology) (China), vol 37, no 7, July 1997, pp 52-54

Chinese

This paper introduces a computer aided engineering (CAE) platform that provides a unified environment to design and realize the control system of flexible ac transmission system (FACTS) equipment. The system configuration, data flow process, and functions of the CAE platform are described. The design method of the software and hardware parts of the CAE platform is given. The software provides a friendly interface to the users. The hardware based on industrial PC and DSP is used to control the FACTS equipment in a real system, and it has high reliability. The CAE platform can support the whole cycle of the design of FACTS equipment, including theoretical design, digital simulation, regulation on-line, physical experiment, and real time operation.

[1996] 19E - 13

DEVELOPMENT OF A 275 V MODEL AND THE SIMULATION STUDIES OF THYRISTOR CONTROLLED SERIES COMPENSATOR

Nakachi, Y.; Fujita, H.; Watanabe, M.; Konishi, H.; Kizawa, T.

Chubu Elec Power Co, Inc, Nagoya, Japan

Proceedings, Int'l Conf on Electrical Engineering (ICEE'96), Beijing, China, August 12-15, 1996, vol 2, pp 919-923

This paper presents a 275 V miniature model of a thyristor-controlled series compensator (TCSC) and its experimental test results. Measurements of TCSC impedance agree well with calculation results and the power flow control and damping ability of the TCSC are effective. The experimental results also agree well with the simulation results. 3 Refs.

[1997] 19E - 14

DEVELOPMENT OF A MINI-MODEL OF A SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE(SUPERSMES) AND EXPERIMENT OF POWER SYSTEM STABILIZING CONTROL

Ise, T.; Ishii, J.; Kumagai, S.

Osaka Univ, Japan

Denki Gakkai Chodendo Oyo Denryoku Kiki Kenkyukai Shiryo (Japan), vol 97, no 30-46, pp 99-104

Japanese

Abstract not available.

[1997] 19E - 15

DEVELOPMENT OF STATCOM FOR POWER SYSTEM SIMULATOR AND HARMONIC ELIMINATION METHOD USING COUPLING TRANSFORMER

Oh, T.K.; Jeong, C.-Y.; Hwang, C.; Moon, Y.H.; Lee, Y.W.

Trans of the Korean Institute of Electrical Engineers (South Korea), vol 46, no 8, August 1997, pp 1147-1153

Korean

This paper describes a power system simulator that was developed to simulate and test FACTS controllers such as TCSC and STATCOM in a laboratory environment. The components of the simulator are physically scaled down models of generator, transmission line, and transformer. Also, development of STATCOM for the simulator is described. Elimination of harmonics generated from the inverters is very important for both reliable operation of STATCOM and loss reduction. A harmonic elimination method using a coupling transformer is presented. The impedance of the coupling transformer was calculated in the course of STATCOM design. The effect of harmonic elimination was verified by analysis of harmonic components obtained by simulation as well as actual testing. The proposed method shows good results without filters, which is desirable to make the system configuration simple with less investment, especially for the simulator.

[1997] 19E - 16

DEVELOPMENT OF THE MINIATURE MODEL OF THYRISTOR CONTROLLED SERIES COMPENSATOR AND THE TEST OF THEM ON SIMULATORS

Kato, M.; Morioka, Y.; Nakahigashi, Y.; Mishima, Y.; Nakachi, Y.; Watanabe, M.; Konishi, H.; Asada, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.254-6.255

Japanese

Abstract not available.

[1997] 19E - 17

DEVELOPMENT OF THE MINIATURE MODEL OF UNIFIED POWER FLOW CONTROLLER AND THE TEST OF THEM ON SIMULATORS

Kato, M.; Morioka, Y.; Nakahigashi, Y.; Mishima, Y.; Nakachi, Y.; Akamatsu, M.; Furuta, M.; Asada, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1997, no 6, pp 6.266-6.267

Japanese

Abstract not available.

[1996] 19E - 18

DEVELOPMENT OF THE MINIATURE MODEL OF STATIC VAR COMPENSATOR USING SELF-COMMUTATED INVERTERS AND THE TEST OF THEM ON SIMULATORS

Uchida, K.; Kato, M.; Morioka, Y.; Hirose, M.; Miyamoto, J.; Nakachi, Y.; Asada, M.; Futatsuki, K.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol PE-96, no 107-118, pp 61-70

Japanese

static VAr compensator using self-commutated Inverters improve power system stability and voltage stability. The miniature model of them were developed and tested on simulators. Prospect of the development of advanced control/protection system were obtained through the test. Prospect of the application of static VAr compensators using self-commutated inverters to the interconnected power system were also obtained.

[1996] 19E - 19

EXPERIMENTAL STUDY ON STEP RESPONSE OF THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC)

Matsuki, J.; Hasegawa, S.; Tanaka, T.; Abe, M.; Bradt, M.; Katagi, T.

Kyoto Univ, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.123-6.124

Japanese

Abstract not available.

[1996] 19E - 20

GRAPHICAL ELECTROMAGNETIC SIMULATION LABORATORY FOR POWER SYSTEMS ENGINEERING PROGRAMS

Gole, A.M.; Nayak, O.B.; Sidhu, T.S.; Sachdev, M.S.

Univ of Manitoba, Winnipeg, Canada

IEEE Trans on Power Systems, vol 11, no 2, May 1996, pp 599-606

The recent availability of Electromagnetic Transient Programs with graphical front ends now makes it possible to put together models for circuits and systems in a manner similar to the connection of components in a laboratory. In the past, the non-graphical EMT programs required considerable expertise in their use and thus distracted the students into the details of simulation. The introduction of a graphical simulation based laboratory into undergraduate and graduate Engineering programs is presented, based on the PSCAD/EMTDC program. The philosophy behind the design of suitable example cases is presented within the framework of an undergraduate Power Electronics course, an HVdc Transmission course and a course on Power System Protection. 6 Refs.

[1996] 19E - 21

MECHANICAL MODEL OF ELECTRIC POWER SYSTEMS WITH AVR GENERATOR AND VAR COMPENSATOR

Nojiri, K.; Noda, K.; Hakoda, M.

Kansai Elec Power Co, Inc, Japan

Denki Gakkai Zenkoku Taikai Koen Ronbunshu (Japan), vol 1996, no 6, pp 6.178-6.179

Japanese

Abstract not available.

[1998] 19E - 22

MODEL DEVELOPMENT OF AN ACTUAL HVDC CONTROL FOR THE RTDS SIMULATOR

Giesbrecht, W.J.; Jiang, X.; Mazur, G.

RTDS Technologies, Inc, Canada

Proceedings, Energy Management Power Delivery Conf (EMPD'98), Singapore, March 3-5, 1998, paper S16.2

Abstract not available

[1997] 19E - 23

STABILITY SIMULATION USING REAL TIME POWER SYSTEM SIMULATOR

Sugihara, H.

Chugoku Elec Power Co, Inc, Japan

Denki Gakkai Denryoku Gijutsu Kenkyukai Shiryo (Japan), vol 97, no 125-129, 131-141, pp 79-83

Japanese

Recently, progress of power-electronics technology, dc link and FACTS (flexible ac transmission system) have been studied to improve capability of load flow control or stability of power systems. To simulate power system behavior involving such devices, we installed Real-Time Digital Simulator (RTDS) made by RTDS technology (CANADA) into our research center. We have added controls compiler to RTDS to simulate the control systems of our own design, and checked some power system components models. And made up a model system of Middle-Western Interconnection system. This model has been verified concerning dynamic stability by comparing with Y-method which is a reliable simulation method.

[1996] 19E - 24

VERIFICATION TEST OF THE SELF-EXCITING SVC SCALE MODEL BY APSA, AS A PART OF THE STUDY ON 'DEVELOPMENT OF ADVANCED SYSTEM INTERCONNECTION TECHNOLOGY. PART 1

Morioka, Y.

Kansai Elec Power Co, Inc, Osaka, Japan

R and D News Kansai (Japan), vol 347, September 10, 1996, pp 29-30

Japanese

As a part of development of advanced system interconnection technology promoted by collaboration of 10 electric power companies and CRIEPI (Japan), this paper presents the verification test of the self-exciting SVC scale model by advanced power system analyzer (APSA). The development was promoted to improve a

continuous operation performance in power system accidents and realize a power fluctuation suppression control, considering simulation accuracy problem proper to scale models for power loss characteristics. As the verification result of the above performance in accident at the terminal nearest the SVC, it was confirmed that continuous operation is possible if voltages more than 0.1 pu survive even in three-phase ground accident. Under the power flow condition followed by one-phase step-out in three-phase ground accident because of no self-exciting SVC, the improvement of a transient stability and damping by adding the power fluctuation suppression control, and early stabilization due to fast recovery of damping of power fluctuation were confirmed by installing the self-exciting SVC. 4 figs.

[1996] 19E - REF

HIGH-POWER VOLTAGE SOURCE CONVERTER CONTROL RESPONSE AT LARGE AC VOLTAGE PHASE SHIFTS

For Abstract see entry 05B - 38

[1997] 19E - REF

NOVEL SIMULATION SCHEME OF POWER ELECTRONICS SYSTEM WITH THE PARALLEL INFERENCE MACHINE (PIM)

For Abstract see entry 06E - 9

[1997] 19E - REF

SELF-COMMUTATED SVC WITH COMPENSATION OF HARMONIC AND NEGATIVE-PHASE-SEQUENCE CURRENTS USING DIGITAL CONTROL SYSTEM

For Abstract see entry 08A - 104

[1997] 19E - REF

THE STUDY ON IMPROVEMENT OF YIMIN-DAQING 500 KV SYSTEM STABILITY BY SVC

For Abstract see entry 08A - 126

[1996] 19E - REF

TRANSIENT RESPONSE OF A STATIC VAR SHUNT COMPENSATOR

For Abstract see entry 08A - 130

[1996] 19E - REF

USING A STATIC VAR COMPENSATOR TO BALANCE A DISTRIBUTION SYSTEM

For Abstract see entry 08A - 138

[1996] 19E - REF

ANALOG SIMULATION OF SELF-COMMUTATED STATIC VAR COMPENSATOR WITH COMPENSATION OF HARMONIC AND UNBALANCED CURRENT

For Abstract see entry 08A - 21

[1997] 19E - REF

APPROACH TO DESIGNING THE FUZZY IF-THEN RULES FOR FUZZY-CONTROLLED STATIC VAR COMPENSATOR (FCSVC)

For Abstract see entry 08A - 31

[1996] 19E - REF

CONTROL SCHEME FOR REACTIVE POWER COMPENSATION USING FIXED CAPACITOR AND A SWITCHED INDUCTOR

For Abstract see entry 08A - 43

[1996] 19E - REF

DIGITAL AND REAL TIME STUDIES OF THE ESKOM SVCS

For Abstract see entry 08A - 57

[1996] 19E - REF

FLICKER COMPENSATION BY ANALYSING THE LOAD POWER

For Abstract see entry 08A - 64

[1996] 19E - REF

SELF-COMMUTATED STATIC FLICKER COMPENSATOR FOR ARC FURNACES

For Abstract see entry 08B - 13

[1996] 19E - REF

SIMULATOR AND FIELD TESTING OF FORBES SVS

For Abstract see entry 08B - 14

[1996] 19E - REF

TNA STUDIES OF DIGITAL SVC CONTROLLER FOR BALANCED VOLTAGE AND REACTIVE POWER CONTROL APPLICATION

For Abstract see entry 08B - 17

[1996] 19E - REF

TRANSIENT ANALYSIS OF AN ADVANCED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE PAM INVERTERS

For Abstract see entry 09A - 100

[1996] 19E - REF

ANALYSIS AND CONTROLLER DESIGN OF STATIC VAR COMPENSATOR USING THREE-LEVEL GTO INVERTER

For Abstract see entry 09A - 17

[1996] 19E - REF

ANALYSIS AND DESIGN OF A DC VOLTAGE-CONTROLLED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE INVERTERS

For Abstract see entry 09A - 20

[1997] 19E - REF

APPLICATION OF SOFT-SWITCHING TECHNIQUE TO A DC VOLTAGE-CONTROLLED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE INVERTERS

For Abstract see entry 09A - 26

[1996] 19E - REF

APPLICATION OF ZERO-VOLTAGE-SWITCHING TO A DC VOLTAGE-CONTROLLED STATIC VAR COMPENSATOR USING QUAD-SERIES VOLTAGE-SOURCE INVERTERS

For Abstract see entry 09A - 27

[1998] 19E - REF

A DC VOLTAGE CONTROL METHOD OF 5 LEVEL INVERTER FOR SELF-COMMUTATED SVC WITH AN ASYMMETRICAL SWITCHING PATTERN

For Abstract see entry 09A - 3

[1996] 19E - REF

A MULTILEVEL VOLTAGE-SOURCE INVERTER WITH SEPARATE DC SOURCES FOR STATIC VAR GENERATION

For Abstract see entry 09A - 4

[1996] 19E - REF

DESIGN AND IMPLEMENTATION OF A PWM SOLID-STATE SYNCHRONOUS CONDENSER

For Abstract see entry 09A - 40

[1996] 19E - REF

DEVELOPMENT OF A VOLTAGE SOURCE INVERTER BASED STATIC VAR GENERATOR

For Abstract see entry 09A - 43

[1996] 19E - REF

DIGITAL SIMULATION OF ADVANCED STATIC VAR COMPENSATOR WITH EMTP AND VERIFICATION

For Abstract see entry 09A - 45

[1997] 19E - REF

DYNAMIC PERFORMANCE AND CONTROL OF A STATIC VAR GENERATOR USING CASCADE MULTILEVEL INVERTERS

For Abstract see entry 09A - 49

[1996] 19E - REF

EXPERIMENT AND ANALYSIS OF ASVG (ADVANCED STATIC VAR GENERATOR)

For Abstract see entry 09A - 55

[1996] 19E - REF

GTO BASED MULTI-LEVEL STATIC VAR COMPENSATOR

For Abstract see entry 09A - 59

[1997] 19E - REF

A NEW CONTROL STRATEGY FOR

MULTILEVEL INVERTER-BASED STATCOM FOR REACTIVE POWER COMPENSATION AND POWER FACTOR CORRECTION

For Abstract see entry 09A - 6

[1997] 19E - REF

MATHEMATICAL MODELS OF A THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 63

[1997] 19E - REF

MULTILEVEL STATCOM WITH THIRD HARMONIC ELIMINATION ON THE DC LINK CAPACITOR VOLTAGES

For Abstract see entry 09A - 67

[1996] 19E - REF

MULTILEVEL VOLTAGE-SOURCE INVERTER WITH SEPARATE DC SOURCES FOR STATIC VAR GENERATION

For Abstract see entry 09A - 68

[1997] 19E - REF

A NEW LOW DISTORTION SELF-COMMUTATED STATIC VAR COMPENSATOR AS A VAR SOURCE

For Abstract see entry 09A - 7

[1996] 19E - REF

PRINCIPLE AND APPLICATION OF FLEXIBLY ADJUSTABLE DYNAMIC RESOURCE FOR VAR COMPENSATION

For Abstract see entry 09A - 82

[1996] 19E - REF

STUDY OF THE 300 KVA STATIC VAR GENERATOR

For Abstract see entry 09A - 92

[1998] 19E - REF

SYSTEM STABILITY IMPROVEMENT WITH PAM SVG

For Abstract see entry 09A - 93

[1996] 19E - REF

THREE-LEVEL ADVANCED STATIC VAR COMPENSATOR

For Abstract see entry 09A - 95

[1997] 19E - REF

ADVANCED STATIC VAR GENERATOR OF ±300 KVAR EMPLOYING GTO THYRISTORS

For Abstract see entry 09B - 1

[1997] 19E - REF

FIELD DEMONSTRATION PROJECT EXPERIENCE ON THE DISTRIBUTION SYSTEMS' DSTATCOM (DISTRIBUTION STATIC COMPENSATOR) USED TO MITIGATE VOLTAGE FLICKER

For Abstract see entry 09B - 3

[1996] 19E - REF

STEADY-STATE CHARACTERISTICS AND INSTABILITY OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 105

[1997] 19E - REF

STUDIES OF SSR CONTROL METHOD USING TCSC MINIATURE MODEL

For Abstract see entry 10A - 106

[1998] 19E - REF

COMPARATIVE STUDIES ON SYNCHRONIZATION SCHEMES FOR A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 25

[1996] 19E - REF

CONSIDERATION IN THE SYNCHRONIZATION SCHEMES FOR A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 27

[1997] 19E - REF

DEVELOPMENT OF A THYRISTOR-

CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

For Abstract see entry 10A - 34

[1996] 19E - REF

DYNAMIC PERFORMANCE OF A THYRISTOR-CONTROLLED SERIES CAPACITOR SYSTEM

For Abstract see entry 10A - 38

[1997] 19E - REF

GTO BASED ADVANCED STATIC VAR GENERATOR

For Abstract see entry 10A - 47

[1996] 19E - REF

IMPROVED CONTROL SCHEME FOR A SERIES CAPACITIVE REACTANCE COMPENSATOR BASED ON A VOLTAGE SOURCE INVERTER

For Abstract see entry 10A - 49

[1996] 19E - REF

AN ANALYTICAL MODEL CONSIDERING LOSSES FOR A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 6

[1996] 19E - REF

IMPROVING SYSTEM STABILITY USING AN ADVANCED SERIES COMPENSATION SCHEME TO DAMP POWER SWINGS

For Abstract see entry 10A - 60

[1996] 19E - REF

INVESTIGATIONS OF A THYRISTOR-CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 65

[1997] 19E - REF

LOOP CURRENT CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 67

[1997] 19E - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. LOOP CURRENT CHARACTERISTICS OF A THYRISTOR CONTROLLED SERIES CAPACITOR

For Abstract see entry 10A - 81

[1997] 19E - REF

POWER ELECTRONICS TECHNOLOGIES IN THE FIELD OF ELECTRIC POWER ENGINEERING. DEVELOPMENT OF A THYRISTOR-CONTROLLED SERIES COMPENSATOR FOR A SIMULATOR

For Abstract see entry 10A - 83

[1997] 19E - REF

PWM-CONTROLLED SERIES COMPENSATION WITH LOW HARMONIC DISTORTION

For Abstract see entry 10A - 92

[1998] 19E - REF

SERIES COMPENSATION ON POWER SYSTEM WITH VERY LOW HARMONIC DISTORTION

For Abstract see entry 10A - 99

[1996] 19E - REF

DYNAMIC CONTROL OF A UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 15

[1997] 19E - REF

IMPLEMENTATION OF UNIFIED POWER FLOW CONTROLLER AND VERIFICATION FOR TRANSMISSION CAPABILITY IMPROVEMENT

For Abstract see entry 11A - 21

[1996] 19E - REF

INVESTIGATION OF DYNAMIC CONTROLLERS FOR A UNIFIED POWER FLOW CONTROLLER

For Abstract see entry 11A - 26

[1997] 19E - REF

MULTIMODULAR UPFC OPERATED BY PHASE-SHIFTED TRIANGLE CARRIER SPWM STRATEGY

For Abstract see entry 11A - 28

[1996] 19E - REF

OPERATION OF THE UNIFIED POWER FLOW CONTROLLER AS HARMONIC ISOLATOR

For Abstract see entry 11A - 29

[1998] 19E - REF

OPERATION OF THE UNIFIED POWER FLOW CONTROLLER (UPFC) UNDER PRACTICAL CONSTRAINTS

For Abstract see entry 11A - 30

[1996] 19E - REF

PERFORMANCE OF A UNIFIED POWER FLOW CONTROLLER USING A D-Q CONTROL SYSTEM

For Abstract see entry 11A - 32

[1997] 19E - REF

UNIFIED POWER FLOW CONTROLLER (UPFC) BASED ON CHOPPER STABILIZED MULTILEVEL CONVERTER

For Abstract see entry 11A - 44

[1996] 19E - REF

UNIFIED POWER FLOW CONTROLLER BASED ON MATRIX CONVERTER

For Abstract see entry 11A - 45

[1998] 19E - REF

AN UNIVERSAL ACTIVE POWER LINE CONDITIONER

For Abstract see entry 11A - 5

[1996] 19E - REF

ANALYSIS, SIMULATION AND IMPLEMENTATION OF A PWM BASED UPFC

For Abstract see entry 11A - 7

[1997] 19E - REF

VERIFICATION TEST OF A UPFC (THYRISTOR CONTROLLED PHASE ADJUSTER) SCALE MODEL BY APSA. AS PART OF "INTERCONNECTION STRENGTHENING TECHNOLOGY DEVELOPMENT" RESEARCH. PART 3. LAST

For Abstract see entry 11B - 2

[1998] 19E - REF

A HIGH-POWER PWM QUADRATURE BOOSTER PHASE SHIFTER BASED ON A MULTIMODULE AC CONTROLLER

For Abstract see entry 12A - 1

[1997] 19E - REF

POWER SYSTEM STABILIZING CONTROL USING HIGH SPEED PHASE SHIFTER (HSPS)

For Abstract see entry 12A - 12

[1997] 19E - REF

POWER SYSTEM STABILIZING CONTROL BY HSPS (HIGH SPEED PHASE SHIFTER)

For Abstract see entry 12A - 13

[1997] 19E - REF

PWM QUADRATURE-BOOSTER PHASE SHIFTER FOR AC POWER TRANSMISSION

For Abstract see entry 12A - 17

[1997] 19E - REF

CONTROL SCHEMES AND TRANSIENT CHARACTERISTICS OF A HIGH SPEED PHASE SHIFTER FOR POWER FLOW CONTROL IN POWER TRANSMISSION SYSTEMS.

For Abstract see entry 12A - 5

[1998] 19E - REF

EXPERIMENTAL STUDY ON DYNAMIC STABILITY IMPROVEMENT OF A SINGLE-MACHINE INFINITE-BUS POWER SYSTEM BASED ON A SLIDING MODE CONTROL OF PHASE SHIFTER

For Abstract see entry 12A - 8

[1996] 19E - REF

SIMULATOR DEMONSTRATION OF THE INTERPHASE POWER CONTROLLER TECHNOLOGY

For Abstract see entry 13B - 1

[1997] 19E - REF

STUDIES ON EVALUATION OF A POWER SYSTEM STABILIZING CONTROL BY USE OF SMES

For Abstract see entry 14A - 119

[1996] 19E - REF

STUDY OF QUENCH PHENOMENA WITH SUPERCONDUCTING MODEL COILS

For Abstract see entry 14A - 120

[1996] 19E - REF

STUDY ON APPLICABILITY OF A SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM

For Abstract see entry 14A - 122

[1997] 19E - REF

SUPERSMES AS A UNIVERSAL POWER QUALITY CONTROLLER USING SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 133

[1997] 19E - REF

CONNECTING TESTS OF SUPERCONDUCTING PERSISTENT-CURRENT-SWITCH IN A TYPE OF TRANSFORMER TO SMES SYSTEM

For Abstract see entry 14A - 14

[1997] 19E - REF

A METHOD FOR HARMONIC REDUCTION ON THE SOURCE SIDE OF A PARALLEL-CONNECTED THYRISTOR CONVERTER HAVING AN INTERPHASE REACTOR

For Abstract see entry 14A - 2

[1996] 19E - REF

DEVELOPMENT AND TEST RESULTS OF A DOUBLE 0.5 MJ COIL SMES SYSTEM

For Abstract see entry 14A - 23

[1996] 19E - REF

EVALUATION OF STEADY STATE STABILITY OF ELECTRIC POWER SYSTEM BY USE OF SUPERCONDUCTING MAGNET ENERGY STORAGE

For Abstract see entry 14A - 41

[1997] 19E - REF

EXPERIMENTAL AND SIMULATED RESULTS OF A SMES FED BY A CURRENT SOURCE INVERTER

For Abstract see entry 14A - 45

[1996] 19E - REF

EXPERIMENTAL STUDY ON DIAGNOSIS OF LONGITUDINAL SYSTEM ON POWER SYSTEM SIMULATOR BY USE OF SMES

For Abstract see entry 14A - 47

[1996] 19E - REF

EXPERIMENTAL STUDY ON MEASURING NATURAL FREQUENCIES OF LONGITUDINAL SYSTEM ON POWER SYSTEM SIMULATOR BY USE OF SMES

For Abstract see entry 14A - 49

[1997] 19E - REF

MEASUREMENT OF THE DAMPING COEFFICIENT OF AN ELECTRIC POWER SYSTEM BY USE OF A SUPERCONDUCTING MAGNET ENERGY STORAGE SYSTEM

For Abstract see entry 14A - 68

[1996] 19E - REF

MULTI-LEVEL 2-QUADRANT BOOST CHOPPERS FOR SUPERCONDUCTING MAGNETIC ENERGY STORAGE

For Abstract see entry 14A - 73

[1996] 19E - REF

POWER REGULATION OF A PWM TYPE SUPERCONDUCTING MAGNETIC ENERGY STORAGE UNIT

For Abstract see entry 14A - 89

[1997] 19E - REF

DEVELOPMENT OF UNINTERRUPTIBLE SECONDARY BATTERY SYSTEM

For Abstract see entry 14B - 18

[1996] 19E - REF

MULTI-MODULE PARALLEL SMALL BATTERY ENERGY STORAGE SYSTEM

For Abstract see entry 14B - 24

[1997] 19E - REF

A NEW CONCEPT FOR A SOLID-STATE ON-LOAD TAP CHANGERS

For Abstract see entry 15B - 1

[1996] 19E - REF

A NEW PWM-CONTROLLED SERIES COMPENSATOR WITH FAST STEP RESPONSE AND LOW HARMONIC DISTORTION

For Abstract see entry 16A - 1

[1997] 19E - REF

STATIC SYNCHRONOUS SERIES COMPENSATOR: A SOLID-STATE APPROACH TO THE SERIES COMPENSATION OF TRANSMISSION LINES

For Abstract see entry 16A - 11

[1996] 19E - REF

THE DEVELOPMENT OF AN ADVANCED SERIES COMPENSATOR BASED ON A SINGLE VOLTAGE SOURCE INVERTER

For Abstract see entry 16A - 12

[1998] 19E - REF

AN IMPROVED CONTROL SCHEME FOR A SERIES-CAPACITIVE REACTANCE COMPENSATOR BASED ON A VOLTAGE-SOURCE INVERTER

For Abstract see entry 16A - 4

[1997] 19E - REF

DIRECT-COUPLED MULTILEVEL CASCADED SERIES VAR COMPENSATORS

For Abstract see entry 16D - 1

[1998] 19E - REF

FAST ALGORITHM FOR VOLTAGE UNBALANCE COMPENSATION AND REGULATION IN FAULTED DISTRIBUTION SYSTEMS

For Abstract see entry 16D - 3

[1997] 19E - REF

SERIES POWER LINE COMPENSATOR USING SELF-COMMUTATED INVERTER

For Abstract see entry 16D - 5

[1996] 19E - REF

NEW HIGH-VOLTAGE VARIABLE-FREQUENCY RESONANT-COMMUTATED CONVERTER

For Abstract see entry 17B - 24

[1996] 19E - REF

NEW SNUBBER CIRCUIT WITH PASSIVE ENERGY RECOVERY FOR POWER INVERTERS

For Abstract see entry 17B - 25

[1997] 19E - REF

PROPOSAL OF NEWLY REGENERATED SNUBBER CIRCUIT FOR LARGE CAPACITY 3-LEVEL GTO INVERTER SYSTEM

For Abstract see entry 17B - 28

[1997] 19E - REF

THREE-PHASE REACTIVE POWER COMPENSATION USING A SINGLE-PHASE AC/AC CONVERTER

For Abstract see entry 17B - 34

[1996] 19E - REF

CONTROL OF NEUTRAL POINT VOLTAGE OF NEUTRAL POINT CLAMPED INVERTERS CONNECTED TO ELECTRIC POWER SYSTEMS

For Abstract see entry 17B - 6

[1996] 19E - REF

CONVERTERS FOR GRID-CONNECTED DC ENERGY SOURCES: A SIMULATION TOOL TO MEET EXPECTED UTILITY SPECIFICATIONS

For Abstract see entry 17B - 8

[1997] 19E - REF

CURRENT EQUALIZATION IN SPWM FACTS CONTROLLERS AT LOWEST SWITCHING RATES

For Abstract see entry 17B - 9

[1997] 19E - REF

INFLUENCE OF HARMONICS GENERATED BY THYRISTOR CONTROLLED SERIES CAPACITOR ON POWER SYSTEM AND GENERATOR

For Abstract see entry 17C - 16

[1996] 19E - REF

EXPERIMENTAL STUDY ON PROTOTYPE THYRISTOR CONTROLLED SERIES CAPACITOR MODEL CONNECTED TO 275V TEST SYSTEM. (III)

For Abstract see entry 17C - 8

[1998] 19E - REF

EXPERIMENTAL EVALUATION OF STATCOM CLOSED LOOP DYNAMICS

For Abstract see entry 18A - 14

[1998] 19E - REF

POWER FLOW DURING POWER SYSTEM STABILIZING CONTROL BY A SUPER-SUPERCONDUCTING MAGNETIC ENERGY STORAGE(SUPERSMES)

For Abstract see entry 18C - 12

[1996] 19E - REF

ON-LINE FAULT DIAGNOSIS TECHNIQUE FOR ADVANCED STATIC VAR GENERATOR USING NEURAL NETWORKS

For Abstract see entry 18D - 18

[1996] 19E - REF

MODELLING OF FACTS DEVICES

For Abstract see entry 19D - 11

[1998] 397f - REF

NEW ADAPTIVE ALGORITHM FOR PRECISE VOLTAGE PHASOR MEASUREMENT IN A SERIES COMPENSATED NETWORK

For Abstract see entry 18E - 16

[1997] - REF

PROCEEDINGS, INTERNATIONAL CONFERENCE ON INTELLIGENT SYSTEM APPLICATION TO POWER SYSTEMS

For Abstract see entry 07A - 48

[1996] - REF

CRYOGENICS CHARACTERISTICS OF THE INPUT CIRCUIT OF SUPERCONDUCTING MAGNETICS ENERGY STORAGE FOR DC LINES

For Abstract see entry 14A - 18

SECTION II

HVDC AND FACTS PROJECTS LISTINGS

HIGH VOLTAGE DC TRANSMISSION (HVDC) FACILITIES AND PROJECTS

This list of HVDC installations and projects was provided by David Melvold of the Los Angeles Department of Water and Power.

HVDC Projects Listing

Project	Supplier	Year	Rating (MW)	DC Voltage (kV)	Line or Cable (km)	LOCATION
Moscow-Kashira#	F	1951	30	±100	100	Russia
Gotland 1#	A	1954	20	±100	96	Sweden
English Channel#	A	1961	160	±100	64	England-France
Volgograd-Donbass*		1965	720	±400	470	Russia
Inter-Island	A	1965	600	±250	609	New Zealand
Konti-Skan I	A	1965	250	250	180	Denmark-Sweden
Sakuma #	A	1965	300	2x125	B-B***	Japan
Sardinia	I	1967	200	200	413	Italy
Vancouver I	A	1968	312	260	69	Canada
Pacific Intertie§§	JV	1970	1440	±400	1362	U.S.A.
		1982	1600			
Nelson River I**	I	1972	1620	±450	892	Canada
Kingsnorth#	I	1975	640	±266	82	England
Gotland Extension#	A	1970	30	±150	96	Sweden
Eel River	C	1972	320	2x80	B-B	Canada
Skagerrak I	A	1976	250	250	240	Norway
II	A	1977	500	±250		Denmark
Vancouver II	C	1977	370	-280	77	Canada
Shin-Shinao	D	1977	300	2x125	B-B	Japan
		1993	600	3x125		
Square Butte	C	1977	500	±250	749	U.S.A.
David A. Hamil	C	1977	100	50	B-B	U.S.A.
Cahora Bassa	J	1978	1920	±533	1414	Mocambique-So. Africa§§§
Nelson River II	J	1978	900	±250	930	Canada
		1985	1800§	±500		
CU	A	1979	1000	±400	710	U.S.A.
Hokkaido-Honshu	E	1979	150	125	168	Japan
	E	1980	300	250		
		1993	600	±250		
Acaray	G	1981	55	25.6	B-B	Paraguay
Vyborg	F	1981	355	1x170(±85)	B-B	Russia (tie w/Finland)
	F	1982	710	2x170		
	F	1984	1065	3x170		
		Future	1420	4x170		
Zhou Shan Project		1982	50	100	42	China
Duernrohr	J	1983	550	145	B-B	Austria
Gotland II	A	1983	130	150	100	Sweden
Gotland III	A	1987	260	±150	103	Sweden
Eddy County	C	1983	200	82	B-B	U.S.A.
Chateauguay	J	1984	1000	2x140	B-B	Canada
Oklaunion	C	1984	200	82	B-B	U.S.A.
Itaipu I	A	1984	1575	±300	785	Brazil
	A	1985	2383			
	A	1986	3150	±600		
Inga-Shaba	A	1982	560	±500	1700	Zaire
Pac Intertie Upgrade	A	1984	2000	±500	1362	U.S.A.
Blackwater	B	1985	200	57	B-B	U.S.A.
Highgate	A	1985	200	±56	B-B	U.S.A.
Madawaska	C	1985	350	140	B-B	Canada

Project	Supplier	Year	Rating (MW)	DC Voltage (kV)	Line or Cable (km)	LOCATION
Miles City	C	1985	200	±82	B-B	U.S.A.
Broken Hill	A	1986	40	2x17(±8.33)	B-B	Australia
Intermountain	A	1986	1920	±500	784	U.S.A.
Cross-Channel		1986	2000	2x±270	72	
(Les Mandarins)	H					France
(Sellindge)	I					England
Des Cantons-Comerford	C	1986	690	±450	172	Canada-U.S.A.
Sacoi##	H	1986	200	200	415	Corsica Island
###		1992	300			Italy
Itaipu II	A	1987	3150	±600	805	Brazil
Sidney (Virginia Smith)	G	1988	200	55.5	B-B	U.S.A.
Gezhouba-Shanghai	B+G	1989	600	500	1000	China
		1990	1200	±500		
Konti-Skan II	A	1988	300	285	150	Sweden-Denmark
Vindhyachal	A	1989	500	2x69.7	B-B	India
Pac Intertie Expansion	B	1989	1100	±500	1362	U.S.A§§§§
McNeill	I	1989	150	42	B-B	Canada
Fenno-Skan	A	1989	500	400	200	Finland-Sweden
Sileru-Barsoor	K	1989	100	±200	196	India
		Future	400			
Rihand-Delhi	AB	1991	750	±500	910	India
		1991	1500	±500		
Hydro Quebec-New England	A	1990	2000*** *	±450	1500	Canada-U.S.A.
Nicloet Tap	A	1992	2000			Canada
Welch-Monticello	G	1995 est	600	160	B-B	U.S.A.
Etzenright	G	1993	600	160	B-B	Germany (tie w/Czech)
Vienna South-East	G	1993	600	160	B-B	Austria (tie w/Hungary)
DC Hybrid Link	G	1993	992	+270/-350	617	New Zealand
Uruguaiana	D	1994	50	15	B-B	Brazil-Argentina
Baltic Cable Project	AB	1994	600	450	250	Sweden-Germany
Kontek HVDC Intercon.	AB	1995	600	400	170	Denmark-Germany
Chandrapur-Phadghe	AB	1997 est	1500	±500	900	India
Chandrapur-Ramagundum	I	1996 est	1000	2x205	B-B	India
Visakhapatnam	I	1998 est	500	205	B-B	India
Leyte-Luzon	AB	1997 est	440	350	440	Philippines
Hainam-Cheju	I	1997 est	300	±180	100	South Korea
Victoria-Tasmania			300	300		Australia
Scotland-N. Ireland		1998 est	250	150	60	United Kingdom
Greece-Italy		1998 est	500			Italy
Tiang-Guang		1998 est	1800	500	903	China
Thailand-Malaysia		1998 est	300	300	110	Malaysia-Thailand
Rivera		1998 est	70		B-B	Uruguay
North-Southeast		1999 est	1000			Brazil
Iceland-Scotland Link		2000 est	550	400	950	
			1100	±400		
Layte-Mindano		2000 est	400			Philippines
Norned		2001 est	600	500	600	Norway-Netherlands

Project	Supplier	Year	Rating (MW)	DC Voltage (kV)	Line or Cable (km)	LOCATION
Bakun		2003 est	2800	±500	1335	Sarawak-Malaysia
Three Gorges		2002 est	3000			China
Viking Cable		2003 est	600	450	600	Norway-Germany
Storebaelt		2003 est	600	450	<50	Denmark
Eurocable		2003 est	600	500	600	Norway-Germany
East-West Energy Bridge		2005 est	500	600	1800	Germany-Poland-Russia
		2010 est	1000			
CEPA (Raspier-Rajasthan)			2000	500		India
Iceland-Scotalnd Link		2005 est	550	400	950	
			1100	±400		

Suppliers

A - ASEA
B - Brown Boveri
C - General Electric
D - Toshiba
E - Hitachi
F - Russian
G - Siemens
H - CGEE Alsthom
I - GEC Alsthom (Formerly Eng. Electric.)
J - HVDC W.G. [AEG, BBC, Siemens]
K - [Independent]
AB - ABB
JV - Joint Venture (GE and ASEA)

Notes

* 2V.G.'sreplaced with thyristors in 1977.
** 3 V.G.'s in Pole 1 replaced with thyristors by GEC Alsthom in 1991-93
*** Back-to-back HVDC system
**** Multi-terminal system. Largest terminal is rated 2250 MW @ 500 Kv.
\# Retired from service
50 MW thyristor tap
Uprate with Thyristor valves
§ 2000 Mw in Winter
§§ Out of service 1994
§§§ Out of service since 1985
§§§§ Out of service Oct. 1993 to Nov. 1995

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) DEVICES AND PROJECTS

This list of FACTS devices and projects was provided by Steve Swencki of Cutler-Hammer and Duane Torgerson of the Western Area Power Administration.

The list is a condensation of a much larger tabulation that includes many industrial static Var converters. Believing that the smaller SVCs are of less interest to the users of the Bibliography, the editors have limited the list to installations of 100 MVAr and above.

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
1	Sweden	1972	Domnarvets Jernverk	Borlange	TCR	Arc Furn	20kV@50Hz	600V		100	ASEA
2	Norway	1973	Norsk Jernverk	Bergen	TCR	Rolling Mill	10kV@50Hz	600V		53	ASEA
3	South Africa	1974	ISCOR	Vanderbijlpark	TCR	Rolling Mill	30kV@50Hz	600V		48	ASEA
4	Sweden	1974	Smedjebackens Valsverk	Smedjebacken	TCR	Arc Furn	20kV@50Hz	63.0kV		41	ASEA
5	USA	1974	Auburn Steel Company	Auburn New York	TCR+FC	FRL	13.8kV@60Hz	13.8kV	6	0/+35	Westinghouse
6	Sweden	1975	Halmstads Jörnverk	Halmstad	TCR	Arc Furn	20kV@50Hz	30.0kV		50	ASEA
7	DDR	1979	VEB Stahl und Walzwerk	Brandenburg	TCR	Arc Furn	30kV@50Hz	600V		125	ASEA
8	Nigeria	1980	FMI	Delta Steel I	TCR	Arc Furn	33kV@50Hz	600V		121	ASEA
9	Nigeria	1980	FMI	Delta Steel II	TCR	Arc Furn	33kV@50Hz	600V		121	ASEA
10	Nigeria	1980	FMI	Delta Steel III	TCR	Arc Furn	33kV@50Hz	600V		121	ASEA
11	USA	1980	Lukens Steel	Coatesville Penns	TCR+FC	FRL	14.4kV@60Hz	14.4kV	6	0/+100	Westinghouse
12	USA	1981	Bethlehem Steel	Franklin EF #10, Johnstown Penns	TCR+FC	FRL	34.5kV@60Hz	34.5kV	12	-20/+105	Westinghouse
13	USA	1981	Bethlehem Steel	Franklin EF #20, Johnstown Penns	TCR+FC	FRL	34.5kV@60Hz	34.5kV	6	-20/+105	Westinghouse
14	USSR	1984	OMEK	Kursk I	TCR	Arc Furn	110kV@50Hz	600V		125	ASEA
15	USSR	1984	OEMK	Kursk II	TCR	Arc Furn	110kV@50Hz	600V		125	ASEA
16	USSR	1984	BMZ	Shlobin	TCR	Arc Furn	33kV@50Hz	600V		130	ASEA
17	Norway	1987	Norsk Jerneverk	Mo I Rana	TCR	Arc Furc & Rolling Mill	23kV@50Hz	600V		155	ASEA
18	Yugoslavia	1987	Zelezarna Jesenice	Jesenice	TCR	Arc Furc	35kV@50Hz	600V		125	ASEA
19	Italy	1988	Beltrame	Vizenza	TCR	Arc Furn	35kV@50Hz	11.0kV		110	ASEA
20	Mexico	1988	TAMSA	Veracruz	TCR	Arc Furn & Rolling Mill	33kV@60Hz	6.6kV		100	ASEA
21	USA	1988	Nucor Steel	Indiana	TCR	Arc Furn	35kV@60Hz	6.6kV		140	ASEA
22	Canada	1989	Sydney Steel	Sydney, Nova Scotia	TCR	Arc Furn	35kV@60Hz			140	ASEA
23	Iran	1989	NISIC	Ahwaz I	TCR	Arc Furn	30kV@50Hz	600V		170	ASEA
24	Iran	1989	NISIC	Ahwaz II	TCR	Arc Furn	30kV@50Hz	600V		170	ASEA
25	Iran	1989	NISIC	Ahwaz III	TCR	Arc Furn	30kV@50Hz	600		170	ASEA
26	South Korea	1988	Posco Iron & Steel	Pohang	TCR	Arc Furn	22kV@50Hz	30.0kV		105	ASEA
27	Bulgaria	1990	Kremikovtzy	Sofia	TCR	Arc Furn	35kV@50Hz			110	
28	USA	1990	Keystone Steel and Wire	Peoria	TCR	Arc Furn	34kV@60Hz			165	
29	China	1991	Tianjim Seamless Tube	Tianjin	TCR	Arc Furn	34kV@50Hz			120	
30	China	1991	Wuyang Steelworks	Wuyang	TCR	Arc Furn	35kV@50Hz			100	
31	Germany	1991	Stadtwerke	Bremen	TCR	Rolling Mill	33kV@50Hz			110	
32	S. Korea	1991	Kang Won Industries	Pohang	TCR	Arc Furn	22kV@60Hz			115	
33	Turkey	1991	Cucurova IIA	Izmir	TCR	Arc Furn	35kV@50Hz			110	
34	Turkey	1991	Cucurova IIB	Izmir	TCR	Arc Furn	35kV@50Hz			110	
35	Italy	1992	Ferdofin	Brescia	TCR	Arc Furn	16kV@50Hz			110	
36	Malaysia	1992	Antara Steel	Pasir Gudang	TCR	Arc Furn	33kV@50Hz			110	
37	Thailand	1992	NTS Steel Groups	Chonburi	TCR	Arc Furn	22kV@60Hz			110	
38	USA	1992	Nucor	Blytheville AR IV	TCR	DC-ArcFurn	34kV@60Hz			195	
39	Iran	1994	NISCO	YAZD	TCR	Arc Furn	33kV@50Hz			115	
40	South Africa	1994	Columbus Joint Venture	Middelburg	TCR	Arc Furn	33kV@50Hz			165	
41	Turkey	1994	ICDAS	Istanbul II	TCR	Arc Furn	35kV@50Hz			105	
42	S. Korea	1996	Posco Stainless Steel Plant	Posco	TCR	Arc Furn	22kV@60Hz			120	
43	Canada	1979	Hydro-Quebec	Laurentides	TCT+FC	VC+DS	735kV@60Hz	39.0kV	6	-100/350	Brown Boveri, Inc.
44	USA	1980	Public Service of New Mexico	San Juan Power Plant Unit 1	TCR	DSSR	22kV@60Hz	11.0kV	6	-120/0	Westinghouse
45	USA	1980	Public Service of New Mexico	San Juan Power Plant Unit 2	TCR	DSSR	22kV@60Hz	11.0kV	12	-120/0	Westinghouse
46	USA	1980	AEP	Beaver Creek, Kentucky	TSC+TCR +MSC	SS	138kV@60Hz			-125/125	ASEA
47	Norway	1981	Norwegian State Bd. NVE	Hasle	TCR	SS	420kV		12	360	ASEA

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
48	Mexico	1982	CFE	Acatlan	TCR		400kV			200	ASEA
49	Mexico	1982	CFE	Puebla	TSC		230kV			300	ASEA
50	Mexico	1982	CFE Comision Federal Electricidad	Temascal	TSC+TCR +MSR	SS	400kV		12	-300/300	ASEA
51	Norway	1982	Norwegian State Bd. NVE	Kvandal	TCR		420kV			160	ASEA
52	Sweden	1982	Swedish State Power Board	Hagby I (TSC Portion)	TSC	SS+DS+UL	400kV	220kV		200	ASEA
53	Argentina	1983	SEGBA	Rodriquez I	TSC+TCR +MSR	SS	500kV	132kV	12	426	ASEA
54	Argentina	1983	SEGBA	Rodriquez II	TSC+TCR +MSR	SS	500kV	132kV	12	426	ASEA
55	Australia	1983	SECV	Rowville I	TSC+TCR	SS+DS	220kV			-60/100	ASEA
56	Australia	1983	SECV	Rowville II	TSC+TCR	SS+DS	220kV			-60/100	ASEA
57	Canada	1984	Hydro-Quebec	Chateauguay	TCR+TSC	FRL	120kV@60Hz	12.5kV	12	-120/150	Brown Boveri, Inc.
58	Canada	1984	Hydro-Quebec	Chateauguay	TCR+TSC	FRL	120kV@60Hz	12.5kV	12	-120/150	Brown Boveri, Inc.
59	Canada	1984	Hydro-Quebec	La Verendrye I	TSC+TCR	SS+DS	735kV			-115/300	ASEA
60	Canada	1984	Hydro-Quebec	La Verendrye II	TSC+TCR	SS+DS	735kV			-115/300	ASEA
61	Norway	1984	NVE	Rod	TCR+TSC	VC	420kV@50Hz	16.3kV	12	500	Brown Boveri, Inc.
62	USA	1985	Tucson Elec. Power	Springerville Unit #1	TCR	DSSR	19kV@60Hz	11.0kV	12	-120/0	Westinghouse
63	Canada	1985	Hydro-Quebec	Chibougamau I	TSC+TCR	SS+DS	735kV			-115/330	ASEA
64	Canada	1985	Hydro-Quebec	Chibougamau II	TSC+TCR	SS+DS	735kV			-115/330	ASEA
65	Canada	1985	TransAlta Utilities Corp.	Langdon	TCR+TSC +FC	VC	240kV@60Hz	20.0kV	12	-250/+250	Westinghouse
66	Venezuela	1985	EDELCA	San Geronimo	TSC+TCR	SS	765kV@60Hz			-280/300	ASEA
67	Venezuela	1985	EDELCA	La Horqueta	TSC+TCR	SS	765kV@60Hz			580	ASEA
68	Bulgaria	1986	Energoimpex	Dobrudja I	TCR+MS C		400kV			300	ASEA
69	Saudi Arabia	1986	SCECO-EAST	Shedgum	TCR	VC+DS	380kV@50Hz	12.0kV	12	200	Brown Boveri, Inc.
70	USA	1986	Kansas Gas & Electric Company	Gordon Evans, Wichita	TSC+TCR	SS+DS	138kV			300	ASEA
71	USA	1986	Kansas Gas & Electric Company	Murray Gill, Wichita	TSC+TCR	SS+DS	138kV	225kV		225	ASEA
72	Australia	1987	QEC	Nebo	TSC+TCR		275kV			340	ASEA
73	Bulgaria	1987	Energoimpex	Dobrudja II	TCR+MS C		400kV			300	ASEA
74	China	1987	Guangdong General Power Company	Guangdong	TCR+FC+ BSC	VC+DS	500kV@50Hz		6	290	Brown Boveri, Inc.
75	China	1987	China National Technical Import Corp.	Shenyang	TCR+TSC		500kV@50Hz			270	ABB
76	Iran	1987	TAVANIR	Omedieh	TSC		420kV			300	ASEA
77	Saudi Arabia	1987	SCECO-EAST	Faras	TCR	VC+DS	380kV@60Hz		12	200	Brown Boveri, Inc.
78	Singapore	1987	Public Utility Board	Labrador	TCR		230kV			100	ASEA
79	Sweden	1987	SSPB	Hamra	TSC+TCR		400kV			400	ASEA
80	China	1988	CNMIEC	Zhengzhou	TCR+MS C		500kV			240	ASEA
81	Norway	1988	Norwegian State Bd, NVE	Nedre Rossaga			300kV			320	ASEA
82	Norway	1988	Norwegian State Bd, NVE	Verdal			300kV			320	ASEA
83	Sweden	1988	Swedish State Power Board	Stenkullen			400kV@50Hz			400	ASEA

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
84	USA	1988	New York State Electric & Gas Corp.	Fraser	TCR+TSC +FC	VC+DS+SS	345kV@60Hz	18.2kV	6	-300/+325	Westinghouse
85	USA	1988	Niagara Mohawk Power Company	Leeds	TSC+TCR +FC		345kV@60Hz			600	ASEA
86	USA	1988	Tucson Elec. Power	Springerville Unit #2	TCR	DSSR	19kV@60Hz	11.0kV	12	-120/0	Westinghouse
87	Thailand	1989	EGAT	Tha Tako I	TCR+TSC		500kV@60Hz			190	ABB
88	Thailand	1989	EGAT	Tha Tako II	TCR+TSC		500kV@60Hz			190	ABB
89	USA	1989	Jersey Central Power & Light	Atlantic	TCR+TSC		230kV@60Hz			130	ABB
90	Brazil	1990	Electronorte	Coxipo	TCR+TSC		230kV@60Hz			130	ABB
91	Canada	1990	Hydro-Quebec	Chamouchouane I	TCR+TSC	VC+DS+SS	735kV@60Hz	16kV	6	-145/+300	ABB
92	Canada	1990	Hydro-Quebec	Chamouchouane II	TCR+TSC	VC+DS+SS	735kV@60Hz	16kV	6	-145/+300	ABB
93	USA	1990	Maine Electric Power Co.	Chester	TCR+TSC		345kV@60Hz			565	ABB
94	Malaysia	1991	NEB	KI North 1			275kV@50Hz			200	
95	Malaysia	1991	NEB	KI North 2			275kV@50Hz			200	
96	Malaysia	1991	NEB	Yong Peng			275kV@50Hz			200	
97	India	1992	NTPC	Kanpur 1			400kV@50Hz			280	
98	India	1992	NTPC	Kanpur 2			400kV@50Hz			280	
99	USA	1992	AEA	Soldatna			115kV@60Hz			110	
100	Canada	1993	B.C. Hydro	Dunsmuir			132kV@60Hz			300	
101	Norway	1993	Statnett	Sylling			400kV@50Hz			320	
102	USA	1993	BPA	Keeler			230kV@60Hz			650	
103	USA	1993	BPA	Maple Valley			230kV@60Hz			650	
104	USA	1994	North. States Power	Forbes S/S			500kV@60Hz			800	
105	Canada	1995	HQ	Chamouchouane I ext.			735kV@60Hz			220	
106	Canada	1995	HQ	Chamouchouane II ext.			735kV@60Hz			220	
107	Norway	1995	Statnett	Kristiansand			300kV@50Hz			400	
108	Thailand	1995	EGAT	Bang Saphan			230kV@60Hz			350	
109	Zimbabwe	1995	ZESA	Insukamini			330kV@50Hz			300	
110	Canada	1996	HQ	La Verendrye I ext.			735kV@60Hz			220	
111	Canada	1996	HQ	La Verendrye II ext.			735kV@60Hz			220	
112	USA	1996	LANL	Los Alamos			115kV@60Hz			150	
113	Canada	1997	HQ	Chibougamau I ext.			735kV@60Hz			220	
114	Canada	1997	HQ	Chibougamau II ext.			735kV@60Hz			220	
115	DDR	1981	VER Stahl-U. Walzwerk	Ilsenburg	Forced Comm. Rectif. + FC	FRL	15kV@50Hz	936V	12	-17/+17	AEG
116	DDR	1981	VER Edenstahl - Werke	Freital	Forced Comm. Rectif. + FC	FRL	15kV@50Hz	936V	12	-3.4/+3.4	AEG
117	DDR	1984	VEB BKE EKO	Eisenhuttenstadt	Forced Comm. Rectif. + FC	FRL	15kV@50Hz	936V	12	-6.5/+6.5	AEG
118	FRG	1986	DBE	Gorleben	Forced Comm. Rectif. + FC	FRL	20kV@50Hz	936V	12	-3.25/+3.25	AEG
119	Germany	1995	PSAG	Salzgitter	TCR+FC	FRL	30kV@50Hz	30kV	6	0 to +110	AEG
120	South Africa	1984	ESCOM	Perseus I	TCR+FC	VC+VL+SS	400kV@50Hz	30kV	6	300	AEG
121	South Africa	1984	ESCOM	Perseus II	TCR+FC	VC+VL+SS	400kV@50Hz	30kV	6	300	AEG
122	South Africa	1984	ESCOM	Hydra I	TCR+FC	VC+VL+SS	400kV@50Hz	30kV	6	300	AEG
123	South Africa	1984	ESCOM	Hydra II	TCR+FC	VC+VL+SS	400kV@50Hz	30kV	6	300	AEG

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
124	South Africa	1985	ESCOM	Poseidon	TCR+FC+MSC	VC+VL+SS	400kV@50Hz	30kV	6	300	AEG
125	USA	1989	Georgia Power	Atlantic Steel	TCR+FC	FRL (Arc Furn)	34.5kV	34.5kV	6	-23 to +144	Cegelec/CANA
126	USA	1992	Appalachian Power	Roanoke Steel	TCR+FC	FRL (Arc Furn)	34.5kV	34.5kV	6	-42 to +169	Cegelec/CANA
127	UK	1992	Transmanche-Link	Folkstone	TCR+FC	UL (Traction Load)	132kV@50Hz	26.3kV	6	-126 to +174	Cegelec/CANA
128	USA	1995	AEP	Steel Dynamics	TCR+FC	FRL (Arc Furn)	34.5kV	34.5kV	6	0 to +250	Cegelec/CANA
129	USA	1995	AEP	Steel Dynamics	TCR+FC	FRL (Rolling Mill)	34.5kV	34.5kV	6	+5 to +175	Cegelec/CANA
130	USA	1996	Centerior Energy	North Star/BHP	TCR+FC	FRL (Arc Furn)	34.5kV	34.5kV	6	0 to +150	Cegelec/CANA
131	Mexico	1998*	CFE	Hylsa, Monterrey	TCR+FC	FLR (Arc Furn)	34.5	34.5	6	-50 to +100	Cegelec/CANA
132	Uruguay	1983	COMPIAL	Palmar	TCR+FC+MSC	VC	150kV@60Hz	31.5kV	6	140	Cogelex Alsthom
133	Brazil	1989	Furnas	Bandeirantes	TCR+TSC+FC	VC	345kV@60Hz	10.5kV	6	100	Cogelex Alsthom
134	Brazil	1989	Acominas	Acominas	TCR+FC	FRL (Roll Mill)	69kV@60Hz	6.3kV	6	110	Cogelex Alsthom
135	Zaire	1990	SNEL	Kirvenza	TCR+TSC+FC	VC	220kV@60Hz	10.5kV	6	130	Cogelex Alsthom
136	USA	1973	CFI Steel		TCR+FC	FRL (Arc Furn)	230kV@60Hz	34.5kV		100	Cegelec/CANA
137	Argentina	1979	Acindar		TCR+FC	FRL (Arc Furn)	220kV@50Hz	33.0kV		120	Cegelec/CANA
138	USA	1981	Nucor #3		TCR+FC	FRL (Arc Furn)	138kV@60Hz	34.5kV		100	Cegelec/CANA
139	Canada	1980	Hydro-Quebec	Nemishau (2 Syst.)	TCR+FC	VC	765kV@60Hz	22.0kV	12	445 Each	Cegelec/CANA
140	Canada	1982	Hydro-Quebec	Albanel (2 Syst.)	TCR+FC	VC	765kV@60Hz	22.0kV	12	445 Each	Cegelec/CANA
141	USA	1984	Utah P&L	90 South	TCR+MSC	DS	138kV@60Hz	13.8kV	6	100	Cegelec/CANA
142	USA	1984	El Paso Elec.	Amrad	TCR+FC	SS	138kV@60Hz	13.8kV	6	75	Cegelec/CANA
143	USA	1984	Texas Elec. Service	Odessa	TCR+MSC	DS	138kV@60Hz	13.8kV	6	80	Cegelec/CANA
144	USA	1985	Alaska Power	Gold Hill	Transductor	SS	69kV@60Hz	13.8kV	6	38	Cegelec/CANA
145	U.K.	1990	CEGB	Exeter	TCR+TSC+FC	VC+SS	400kV@50Hz	400kV	6	-75/+150	GEC
146	MALAYSIA	1982	Perwaja Steel	Trengganu	TCR+FC	FRL	275 kV	33 kV	6	-12/108	Fuji Electric Co.
147	JAPAN	1991	Kansai Bilet Center		TCR+FC	FRL	77kV	33kV	6	0.173553719	Fuji Electric Co.
148	TAILAND	1994	Siam Yamato Steel		TCR+FC	FRL	115kV	22kV	6	+8/108	Fuji Electric Co.
149	JAPAN	1995	Tokyo Steel	Utsunomia	TCR+FC	FRL+SS	154kV	33kV	6	+24/119	Fuji Electric Co.
150	JAPAN	1995	Tokyo Steel	Utsunomia	TCR+FC	FRL+SS	154kV	33kV	6	+24/119	Fuji Electric Co.
151	U.K.	1953	GEC	Witton Works	SR+FC	UL	11 to 25kV	Same		-460	GEC
152	Ethiopia	1964	Elec. Light & Power Auth. (EELPA)	Akaki	Transductor+MSC	SS+VC	45kV@50Hz	15.0kV		0/+7	GEC
153	U.K.	1973	British Steel	Scunthorpe	SR+FC	UL	132kV@50Hz	33.0kV		-15/+100	GEC
154	Paraguay	1985	ANDE	Asuncion	TCR+FC+MSC+MSR	DS	220kV@50Hz	66.0kV	12	-80/+100	GEC
155	U.K.	1985	CEGB	Sellindge	SR+FC+MSC	VC+SS	400kV@50Hz	56.6kV	18	-150/+150	GEC
156	U.K.	1985	CEGB	Sellindge	SR+FC+MSC	VC+SS	400kV@50Hz	56.6kV	18	-150/+150	GEC
157	U.K.	1996	CEGB	Ninfield	SR+FC+MSC	VC+SS	400kV@50Hz	56.6kV	18	-150/+150	GEC
158	U.K.	1991	National Grid Co.	St. John's Wood I	TCR+TSC+FC	VC+SS	275kV@50Hz	275kV	6	-106/+150	GEC ALSTHOM

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
159	U.K.	1992	National Grid Co.	St. John's Wood II	TCR+TSC +FC	VC+SS	275kV@50Hz	275kV	6	-106/+150	GEC ALSTHOM
160	U.K.	1990	National Grid Company	Exeter 3	TCR+TSC +FC	SS+VC	400kV@50Hz	400kV	6	-0.5	GEC ALSTHOM
161	U.K.	1991	National Grid Company	Lovedean	TCR+TSC +FC	SS+VC	400kV@50Hz	400kV	6	-0.5	GEC ALSTHOM
162	U.K.	1992	National Grid Company	Exeter 5	TCR+TSC +FC	SS+VC	400kV@50Hz	400kV	6	-0.5	GEC ALSTHOM
163	U.K.	1992	National Grid Company	Mannington	TCR+TSC +FC	SS+VC	400kV@50Hz	400kV	6	-0.5	GEC ALSTHOM
164	U.K.	1993	National Grid Company	Mannington	TCR+TSC +FC	SS+VC	400kV@50Hz	400kV	6	-0.5	GEC ALSTHOM
165	UK	1994	National Grid Company	Cellarhead	TCR/TSC/ FC	SS+VC	400kV@50Hz	7.9kV	6	-0.5	GEC ALSTHOM
166	USA	1994	Western Area Power Administration	Watertown	TCR/FC/ MSR/MS C	SS+VC	230kV@60Hz	20	6	-0.75	GEC ALSTHOM
167	UK	1995	National Grid Company	Cellarhead	TCR/TSC/ FC	SS+VC	400kV@50Hz	7.9kV	6	-0.5	GEC ALSTHOM
168	UK	1995	National Grid Company	Willington	TCR/TSC/ FC	SS+VC	400kV@50Hz	7.9kV	6	-0.5	GEC ALSTHOM
169	Japan	1989	Tokyo Electric Power Co., Inc.	Shin-Fuji	TCT+FC	VC+DS+SS	500kV@50Hz	63kV	6	+20/+120	Hitachi
170	Japan	1978	Tokyo Steel Mfg. Co.	Okayama Steel Works	TCR	FRL	33kV			120	Mitsubishi
171	Japan	1979	Kansai Electric Power Co.	Kita-Osaka S/S	INVERTE R	VC	77kV		48	-1	Mitsubishi
172	Japan	1990	Chubu Steel Co.	Nagoya Seel Works	INVERTE R	FRL	22kV@60Hz	1.0kV	36	-1	Mitsubishi
173	Japan	1991	Kansai Electric Power Co.	Inuyama SW/S	INVERTE R	DS+VU+SS+P C	154kV@60Hz	2.0kV	48	-1	Mitsubishi
174	Japan	1993	Central Japan Railway Co.	Shin-Biwajima S/S	INVERTE R	VC+UL+VU	77kV@60Hz	2.0kV	18	-1	Mitsubishi
175	Japan	1993	Central Japan Railway Co.	Shin-Biwajima S/S	INVERTE R	VC+UL+VU	77kV@60Hz	2.0kV	18	-1	Mitsubishi
176	Japan	1994	Mitsubishi Steel Co.	Muroran Steel Works	INVERTE R	FRL	22kV@50Hz	2.0kV	18	-1	Mitsubishi
177	Japan	1994	Central Japan Railway Co.	Shimizu S/S	INVERTE R	VC+UL+VU	154kV@50Hz	2.0kV	18	-1	Mitsubishi
178	Japan	1994	Central Japan Railway Co.	Shimizu S/S	INVERTE R	VC+UL+VU	154kV@50Hz	2.0kV	18	-1	Mitsubishi
179	Japan	1994	Central Japan Railway Co.	Shimizu S/S	INVERTE R	VC+UL+VU	154kV@50Hz	2.0kV	18	-1	Mitsubishi
180	Japan	1995	Central Japan Railway Co.	Shin-Biwajima S/S	INVERTE R	VC+UL+VU	77kV@60Hz	2.0kV	18	-1	Mitsubishi
181	Japan	1995	Chubu Steel Co.	Nagoya Seel Works	INVERTE R	FRL	22kV@60Hz	2.0kV	24	-1	Mitsubishi
182	Japan	1995	Sumitomo Steel Co.	Osaka Steel Works	INVERTE R	FRL	22kV@60Hz	1.2kV	24	-1	Mitsubishi
183	Soviet Union		Italimpianti	Voljskyd Seamless Pipe Works	TCR+FC	FRL+UL (Arc Furn)		33.0kV	6	160	Nokia Capacitors
184	Soviet Union		Voest Alpine	Pluscord	TCR+FC	FRL+UL (Arc Furn)		33.0kV	6	109	Nokia Capacitors
185	Canada		Hydro-Quebec	Laurentides	TCR+FC	VC+DS	735kV@60Hz	39.0kV	6	450	Nokia & BBC Consortium
186	Zambia		Zesco	Luano	TCR+MS C	VC	330kV@50Hz	11.0kV	6	103.4	Nokia Capacitors
187	Zimbabwe		Zesa	Sherwood	TCR+FC+ MSC+MS R	VC	330kV@50Hz	11.0kV	6	192	Nokia Capacitors
188	Indonesia	1976	P.T. Krakatau Steel	Kota Beja	TCT	UL+VC+SS	30kV@50Hz	1.0kV	6	259	Siemens
189	Trinidad	1979	Iron & Steel Company of Trinidad and Tobago	ISCOTT	TCR	UL+VC+SS	33kV@50Hz	33.0kV	6	266	Siemens
190	Trinidad	1979	Iron & Steel Company of Trinidad and Tobago		Static Watt Control	FC	33kV@50Hz	1.0kV	6	-30/0	Siemens
191	Brazil	1986	CHESF	Fortaleza	TCR+FC	VC+FRL	230kV@60Hz	26.0kV	12	-140/200	Siemens

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
192	Indonesia	1983	P.T. Krakatau Steel	KotaBeja Mainstation SMS	TCR	VC	30kV@ 50Hz	30.0kV	6	-110/150	Siemens
193	Libya	1983	ELPCO	Zemzem	TCR+FC	VC+FRL	230kV@50Hz	13.5kV	12	-100/50	Siemens
194	Saudi Arabia	1982	Voest Alpine for Saudi Iron & Steel Co.	HADEED Al Jubail	TCR	VC+SS+FRL+PC	34.5kV@60Hz	34.5kV	6	-20/120	Siemens
195	Brazil	1988	CHESF	Milagres	TCR+FC	VC+FRL	230kV@60Hz	12.5kV	12	+30/100	Siemens
196	Brazil	1989	CHESF	Banabuin	TCR+FC	VC+FRL	230kV@60Hz	12.5kV	12	+30/100	Siemens
197	Lybia	1986	EBISCO	Misurata TS-6	TCR	VC+SS+FRL	30kV@50Hz	30.0kV	6	-30/210	Siemens
198	Brazil	1989	CHESF	Rio Largo	TCR+FC	VC+FRL	230kV@ Hz	26.0kV	12	-200/200	Siemens
199	Canada	1988	NSPC-Novia Scotia Power Corporation	Brushby Mill SCV	TCR+TSC	VC+FRL+PC	138kV@50Hz	7.75kV	6	-20/120	Siemens
200	U.S.A.	1988	NUCOR-YAMATO STEEL	Nucor-Yamato, Blytheville	TCR	VC+FRL	34.5kV@50Hz	34.5kV	6	+7/147	Siemens
201	Belgium	1988	ALZ	Compensation Iron Works	TCR	VC+SS	30kV@50Hz	30.0kV	6	-44/96	Siemens
202	Australia	1989	ECNSW - Australia	KEMPS CREEK I	TSR+2xTSC	VC+PC	330kV@50Hz	16.0kV	6	-100/150	Siemens
203	Australia	1989	ECNSW - Australia	KEMPS CREEK II	TSR+2xTSC	VC+PC	330kV@50Hz	16.0kV	6	-100/150	Siemens
204	Brazil	1993	Eletronote, Brasilia Brazil	Sao Luis	TCR+TSR	VC	500kV@50Hz	20kV	6	-140/200	Siemens
205	Brazil	1993	Eletronote, Brasilia Brazil	Sao Luis	TCR+TSR	VC	500kV@50Hz	20kV	6	-140/200	Siemens
206	U.K.	1991	CEGB, U.K.	Pelham	TCR+TSC	VC	400kV@50Hz	14kV	6	-80/150	Siemens
207	U.K.	1991	CEGB, U.K.	Pelham	TCR+TSC	VC	400kV@50Hz	14kV	6	-80/150	Siemens
208	U.S.A.	1992	SPS, Amarillo Texas, USA	Eddy County	TCR+TSC	VC+SS	230kV	8.5kV	6	-54/144	Siemens
209	Saudi Arabia	1992	Voest Alpine for Saudi Iron & Steel Co.	HADEED Al Jubail	TCR	VC+FRL	34.5kV	34.5kV	6	-50/110	Siemens
210	Indonesia	1992	P.T. Krakatau Steel	Kota Baja	TCR	VC+FRL	30kV@50 Hz	30kV	6	-65/115	Siemens
211	U.K.	1993	NGC The National Grid Company PLC	Harker	TCR+TSC	VC+PC	275kV@50Hz	14kV	6	-80/150	Siemens
212	U.K.	1993	NGC The National Grid Company PLC	Harker	TCR+TSC	VC+PC	275kV@50Hz	14kV	6	-80/150	Siemens
213	U.K.	1993	NGC The National Grid Company PLC	Drakelow	TCR+TSC	VC	275kV@50Hz	14kV	6	-80/150	Siemens
214	U.K.	1994	NGC The National Grid Company PLC	Feckenham	TCR+TSC	VC	275kV@50Hz	14kV	6	-80/150	Siemens
215	Luxembourg	1994	Arbed Schifflingen	Arbed Schifflingen	TCR	VC+FRL	33kV@50Hz	33kV	6	-40/150	Siemens
216	India	1994	ESSAR	ESSAR	TCR	VC+FRL	33kV	33kV	6	0/150	Siemens
217	India	1994	ESSAR	ESSAR	TCR	VC+FRL	33kV	33kV	6	0/150	Siemens
218	Turkey	1994	EGE-METAL	EGE-METAL	TCR	VC+FRL	34.5kV	34.5kV	6	0/125	Siemens
219	South Africa	1994	ESKOM	Impala	TCR	VC	275kV@50Hz	15kV	6	-50/100	Siemens
220	South Africa	1994	ESKOM	Illovo	TCR	VC	275kV@50Hz	15kV	6	-50/100	Siemens
221	South Africa	1995*	ESKOM	Athene	TCR	VC	400kV@50Hz	15kV	6	-50/100	Siemens
222	Belgium	1994	Thy Marcinelle	Arc Furnace	TCR	VC+FRL	30kV	30kV	6	-10/120	Siemens
223	U.S.A.	1994	Gallatin Steel	Ft. Mitchell, Ky	TCR	VC+FRL	34.5kV	34.5kV	6	0/150	Siemens
224	U.S.A.	1995*	LADWP(Los Angeles Dept. of Water & Power)	Adelanto	TSC	VC+PC+DS	500kV	16kV	6	388	Siemens
225	U.S.A.	1995*	LADWP(Los Angeles Dept. of Water & Power)	Marketplace	TSC	VC+PC+DS	500kV	16kV	6	388	Siemens
226	India	1995*	ESSAR	DC-Arc Furnace	TCR	VC+FRL	33kV	33kV	6	0/150	Siemens
227	Japan	1987	Ishihara Seikousyo Co.,Ltd	Ichikawa Works	STATCOM	FRL	22 kV			-5 to 5	Toshiba
228	Japan	1989	Japan Railway Tokai	Otaka	TCR	VC	15 kV@60Hz			0 to 165	Toshiba
229	Japan	1989	Japan Railway Tokai	Otaka	TCR	VC	15 kV@60Hz				Toshiba
230	Mexico	1989	Sicartsa	Lazaro Cardenas	TCT	FRL	69 kV@60Hz			0 to 320	Toshiba
231	Australia	1989	The Electricity Trust of South Australia	South East	TCR+TSC	VC+PC	275 kV@50Hz			-100 to 160	Toshiba

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
232	Australia	1989	The Electricity Trust of South Australia	Para	TCR+TSC	VC+PC	275 kV@50Hz			-140 to 160	Toshiba
233	Japan	1990	Japan Railway Tokai	Iwabuchi	TCR	VC	154 kV@60Hz			0 to 120	Toshiba
234	Japan	1990	Nisshin Seikou Co.,Ltd	Shinnannyou Works	STATCOM	FRL	22 kV			-20 to 20	Toshiba
235	Japan	1991	Chiyoda Koutetsu Kougyou Co.,Ltd	Tokyo Works	STATCOM	FRL	22 kV			-15 to 15	Toshiba
236	Brazil	1991	Companhia Energetica de Minas Gerais	Ouro Preto 2	TCR	VC	138 kV@60Hz			0 to 100	Toshiba
237	Japan	1991	The Tokyo Electric Power Co.,Ltd	Shin Shinano	STATCOM	PC	66 kV@50Hz	525kV		-50 to 50	Toshiba
238	Japan	1991	Tokyo Seitetsu Co.,Ltd	Okayana Works	STATCOM	FRL	33 kV			-49.5 to 49.5	Toshiba
239	Japan	1992	Hokkaido Electric Power Corp.	Teine	STATCOM	FRL	66 kV@50Hz			-20 to 20	Toshiba
240	Australia	1992	Osterreichische Elekftizitatswirtschaft s, AG	Dumrohr	TCR	VC	400 kV@50Hz			150 to 0	Toshiba
241	Japan	1992	Tokyo Steel Company Ltd.	Okayama	TCR	FRL	110 kV@60Hz			0 to 191	Toshiba
242	U.A.E.	1992	Water & Electricity Dept.	Al Ain	TCR	VC	220 kV@50Hz			-80 to 180	Toshiba
243	Japan	1993	Japan Railway Tokai	Shintakatsuka	STATCOM	VC	154 kV			-48 to 48	Toshiba
244	Japan	1994	Daidou Tokushukou Co.,Ltd	Shibukawa Works	STATCOM	FRL	22 kV			-16.5 to 16.5	Toshiba
245	Japan	1994	Mukoyama Koujyou Co.,Ltd	Mukoyama Works	STATCOM	FRL	22 kV			-22 to 22	Toshiba
246	Japan	1995	Daidou Tokushukou Co.,Ltd	Chita Works	STATCOM	VC	22 kV			-27 to 27	Toshiba
247	Japan	1995	Nihon Kinzoku Kougyou	Kinuura Works	STATCOM	FRL	22 kV			-18 to 18	Toshiba
248	USA	1980	Lukens Steel		TCR+FC	FRL	14.4kV@60Hz	14.4kV	6	0/+100	Westinghouse
249	USA		Public Service of New Mexico	San Juan Power Plant Unit 1	TCR	DSSR	22kV@60Hz	11.0kV	6	-120/0	Westinghouse
250	USA		Public Service of New Mexico	San Juan Power Plant Unit 2	TCR	DSSR	22kV@60Hz	11.0kV	12	-120/0	Westinghouse
251	USA	1981	Bethlehem Steel	Franklin EF #10	TCR+FC	FRL	34.5kV@60Hz	34.5kV	12	-20/+105	Westinghouse
252	USA	1981	Bethlehem Steel	Franklin EF #20	TCR+FC	FRL	34.5kV@60Hz	34.5kV	6	-20/+105	Westinghouse
253	USA	1985	Tucson Elec. Power	Springerville Unit #1	TCR	DSSR	19kV@60Hz	11.0kV	12	-120/0	Westinghouse
254	USA	1989*	Tucson Elec. Power	Springerville Unit #2	TCR	DSSR	19kV@60Hz	11.0kV	12	-120/0	Westinghouse
255	Canada	1985	TransAlta Utilities Corp.	Langdon	TCR+TSC +FC	VC	240kV@60Hz	20.0kV	12	-250/+250	Westinghouse
256	USA	1988	New York State Electric & Gas Corp.	Fraser	TCR+TSC +FC	VC+DS+SS	345kV@60Hz	18.2kV	6	-300/+325	Westinghouse
257	USA	1996	Tennessee Valley Authority	Sullivan Substation	Inverter - STATCOM	VC, DT	161 kV@60Hz	6.6 kV DC	48	-100 to +100	Westinghouse
258	USA	1997*	Structural Metals Inc.	Seguin, Texas Plant	Inverter - STATCOM	FRL	15 kV@60Hz	10.4 kV DC	48	-80 to +80	Westinghouse
259	USA	1997*	American Electric Power	Inez Substation	Inverter - UPFC (Shunt)	Shunt part of UPFC	138 kV@60Hz	20.9 kV DC	48	-160 to +160	Westinghouse
260	USA	1998*	American Electric Power	Inez Substation	Inverter - UPFC (Series)	Series part of UPFC, and PFC + PC + HDS	138 kV@60Hz	20.9 kV DC	48	-160 to +160	Westinghouse
261	USA	1998*	Pacific Gas & Electric Co.	Paul Sweet Substation	Inverter - STATCOM	VC	115 kV@60Hz	10.2 kV DC	24	-20 to +60	Westinghouse
262	USA	1980	Southern California Edison		NGH SSR Damper	DSSR					Siemens
263	USA	1985	Orange & Rockland Utilities		STATCOM	DT				1	Westinghouse/ ESEERCO

REF NO.	COUNTRY	YEAR	OWNER	STATION	TYPE	USE	SYSTEM VOLTAGE	CONNECT VOLTAGE	PULSE	TOTAL MVAR	EQUIPMENT MANUF
264	USA	1991	American Electric Power	Kanawha River substation	TSSC	Valve Test	345kV				ABB
265	USA	1992	Western Area Power Administration	WAPA Kayenta substation, Arizona	TCSC - Single Module	PFC + DT				15 ohm, 1kA 16.2kV	Siemens
266	USA	1993	Bonneville Power Administration	BPA's Slatt substation, Oregon	TCSC - Six Module	PFC + PC + DSSR + DT	500kV			8 ohm, 2.9 kA 26.7 kV	General Electric (GE)
267	USA	1993	Western Area Power Administration		TCPST	Develop Concept + PC					General Electric (GE)
268	USA	1994	Minnesota Power and Light	North Dakota Coal Fields	TCBR	Stability Studies	230 kV			100 - 500 MW	
269	France	1997*	Electricite' de France		UPFC	PFC + HDS	225 kV			-7 to +7	GE/GEC - Alsthom
270	Canada	1996*	Hydro Quebec		IPC	PFC + SCL	161kV			200	CITEQ/ABB

NOTE: * SCHEDULED

TYPE OF SYSTEM:

TCR - Thyristor Controlled Reactor
TCT - Thyristor Controlled Transformer
SR - Saturable Reactor
FC - Fixed Capacitor
TSC - Thyristor Switched Capacitor
MSC - Mechanical Switched Capacitor
BSC - Breaker Switched Capacitor
MSR - Mechanical Switched Reactor
STATCOM - Static Synchronous Condensor
TSSC - Thyristor Switched Series Compensator
TCSC - Thyristor Controlled Series Compensator
UPFC - Unified Power Flow Controller
TCBR - Thyristor Controlled Braking Resistor
IPC - Interphase Power Controller
TCPST - Thyristor Controlled Phase Shifting Transformer

USE:

VC - Voltage Control
FC - Frequency Control
DS - Dynamic Stability
UL - Compensation of Unsymmetrical Loading
FRL - Compensation of Fast Reactive Load Variations
VL - Voltage Unbalanced
SS - System Voltage Stability
PC - Power Oscillation Control
DSSR - Damping of Generator Subsynchronous Resonance
PFC - Power Flow Control
DT - Demonstrate Technology
HDS - Hardware Design Studies
SCL - Short Circuit Limiter

KINDLY NOTE:
THE INFORMATION CONTAINED IN THIS TABLE HAS BEEN COLLECTED FROM VARIOUS SOURCES WHILE EVERY ATTEMPT HAS BEEN MADE TO ENSURE AUTHENTICITY, THE READERS ARE ADVISED TO RECONFIRM THE ACCURACY OF INFORMATION FROM THE CONCERNED UTILITIES.

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