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# OPERATION OF RESTRUCTURED POWER SYSTEMS

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# Contents

# List of Acronyms

| | |
|---|---|
| ACE | Area Control Error |
| ATSOI | Association of Transmission System Operators in Ireland |
| BTM | Bilateral Transaction Matrix |
| Cal-ISO | California Independent System Operator |
| CEGB | Central Electricity Generating Board (UK) |
| CIL | Contracted Interruptible Load |
| DED | Dynamic Economic Dispatch |
| DISCO | Distribution Company |
| DSB | Demand Side Bidding (UK) |
| DVR | Dynamic Voltage Restorer |
| ELBAS | Nordpool Short-term Market |
| ELD | Economic Load Dispatch |
| ELSPOT | Nordpool Spot Market |
| EMC | Electromagnetic compatibility |
| EPACT | Energy Policy Act (US) |
| EPRI | Electric Power Research Institute (US) |
| ERPS | Enhanced Reactive Power Service (UK) |
| ETSO | European Transmission System Operators |
| EU | European Union |
| FERC | Federal Energy Regulating Authority (US) |
| GAMS | Generalized Algebraic Modeling Systems |
| GENCO | Generating Company |
| IEEE | Institute of Electrical and Electronics Engineers |
| IEC | International Electrotechnical Commission |
| IPP | Independent Power Producer |
| ISO | Independent System Operator |

| | |
|---|---|
| ITM | Interruptible Tariff Mechanism |
| LNG | Liquefied Natural Gas |
| LPG | Liquefied Petroleum Gas |
| LOLP | Loss of Load Probability |
| LRMC | Long-run Marginal Cost |
| LSE | Load Serving Entity (New York pool) |
| MC | Marginal Cost |
| NEMMCO | National Electricity Market Management Company (Australia) |
| NERC | North American Electric Reliability Council |
| NETA | New Electricity Trading Arrangements (UK) |
| NGC | National Grid Company (UK) |
| Nordel | A body for cooperation between ISOs of Nordic countries |
| Nordic | Norway, Sweden, Finland, Denmark and Iceland |
| NUG | Non-Utility Generator |
| NYISO | New York Independent System Operator (US) |
| NZEM | New Zealand Electricity Market |
| OFFER | Office of Electricity Regulation (UK) |
| OFGEM | Office of Gas and Electricity Markets (UK) |
| OPF | Optimal Power Flow |
| ORPS | Obligatory Reactive Power Service (UK) |
| PGCIL | Power Grid Corporation of India |
| PJM | Pennsylvania, Jersey, Maryland power pool (US) |
| PLF | Plant Load Factor |
| PPP | Pool Purchase Price |
| PSP | Pool Selling Price |
| PURPA | Power Utilities Regulating Policy Act (US) |
| REC | Regional Electricity Company (UK) |
| RTO | Regional Transmission Organizations (US) |
| SCED | Security Constrained Economic Dispatch |
| SMP | System Marginal Price |
| SPD | Spot Price Difference |
| SRMC | Short-run Marginal Cost |
| TRANSCO | Transmission Company |
| TSO | Transmission System Operator (Europe) |
| UC | Unit Commitment |
| UCTE | Union for Coordination of Transmission of Electricity (Europe) |
| UKTSOA | United Kingdom Transmission System Operators' Association |
| UPS | Uninterruptible Power Supply |
| WRATES | Wheeling Rate Evaluation Simulator |

# Preface

Deregulation is a fairly new paradigm in the electric power industry. And just as in the case of other industries where it has been introduced, the goal of deregulation is to enhance competition and bring consumers new choices and economic benefits. The process has, obviously, necessitated reformulation of established models of power system operation and control activities. Similarly, issues such as system reliability, control, security and power quality in this new environment have come in for scrutiny and debate.

In this book, we attempt to present a comprehensive overview of the deregulation process that has developed till now, focussing on the operation aspects. As of now, restructured electricity markets have been established in various degrees and forms in many countries. This book comes at a time when the deregulation process is poised to undergo further rapid advancements.

It is envisaged that the reader will benefit by way of an enhanced understanding of power system operations in the conventional vertically integrated environment vis-à-vis the deregulated environment. The book is aimed at a wide range of audience- electric utility personnel involved in scheduling, dispatch, grid operations and related activities, personnel involved in energy trading businesses and electricity markets, institutions involved in energy sector financing. Power engineers, energy economists, researchers in utilities and universities should find the treatment of mathematical models as well as emphasis on recent research work helpful. The book may be used for a one-semester graduate or under-graduate course, as well.

## OUTLINE OF THE BOOK

**Chapter-1** discusses the motivating factors behind deregulation of the power sector and the after-effects of the same. In this context it looks at issues specific to developed and developing nations.

**Chapter-2** focuses on the established models of operational planning activities such as economic load dispatch, unit commitment and optimal power flow. Topics such as inter-utility power transactions, power pools, power wheeling and energy brokerage systems have been discussed. This chapter lays the foundation for the discussions in the subsequent chapters.

**Chapter-3** analyzes different market models, and the operational planning issues specific to these, from the perspective of, both, the independent generator and the system operator. The requisite model development and reformulation demanded by a competitive environment is then discussed.

**Chapter-4** identifies transmission management issues and then discusses the mechanisms by which these are addressed in the various forms of deregulated structures. The issues covered here are pricing, security and congestion management.

**Chapter-5** focuses on ancillary service management, their categorization, and pricing mechanisms as practiced in different electricity markets. Reactive power management in deregulated markets has been examined in detail.

**Chapter-6** on reliability and deregulation treats the basics of reliability analysis of power systems. Both system reliability and reliability experienced by the customer is discussed. The chapter also presents ways of characterizing the observed reliability of supply. The role of the office of electricity regulation (OFFER) in the UK system has been discussed.

**Chapter-7** presents an overview of the various power quality issues. Emphasis is on issues strongly related to both the utility and the customer such as short interruptions, voltage dips and harmonics. For each of these phenomena an overview of available analysis techniques is given. The possible effect of deregulation on these aspects of power quality is discussed.

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