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A Review on Different FACTS Devices used in Electrical Power System

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***Abstract*—With rapidly increasing industrialization and urbanization electric power demand is increasing. Power system is subjected to supply these loads without interruption. Sometimes disturbances such as system faults, sudden addition or removal of large load, etc. cause instability in power system. There are chances of power system failure if these disturbances are not cleared. Flexible AC Transmission System (FACTS) technology is used to compensate parameters due to disturbance and helps to improve system stability. This paper is about a brief description of different FACTS devices like Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVC), Static Synchronous Series Compensator (SSSC), Thyristor controlled series capacitor (TCSC), Unified Power Flow Controller (UPFC) and Interline Power Flow Controller (IPFC).**

Keywords—FACTS; Real power; Reactive power; Voltage Source Converter (VSC).

I. INTRODUCTION

Electric power system consists of three parts; generation, transmission and distribution system. Power plants are situated nearer to fuel storages. Usually, electric loads are far away from generating units. Transmission lines transfer power from generating unit to load center. Transmission occurs at High Voltage or Extra High Voltage level [1].

With rapidly increasing industrialization and urbanization electric power demand is growing continuously. This is causing more stress on existing system. Electric power systems are interconnected through transmission lines to form power grid to overcome this issue. Power grid helps in increasing diversity of load; sharing available resources and operating generating units economically. It improves power system efficiency and reliability [2].

A stable power system remains in equilibrium under normal operating condition and regains its new acceptable state of equilibrium after disturbance. It supplies power uninterrupted. Disturbances like system faults, sudden addition or removal of load, etc. makes system unstable. There are chances of system failure if effect of these disturbances is not cleared out. System failure is unwanted and uneconomical.

Flexible AC Transmission System (FACTS) technology is used to overcome disturbance effect. FACTS devices consist of power electronic devices and controllers. Purpose of FACTS devices is to improve power system stability is by controlling System parameters such as voltage (V), power angle (δ) and series impedance (X) with help of Voltage Source Converter (VSC) which is inverter. FACTS devices are classified as i) shunt compensating devices; ii) series compensating devices and iii) combined devices. Some Facts devices like STATCOM, SVC, SSSC, TCSC, UPFC and IPFC are used to control real and reactive power through system [3-15].

II. POWER FLOW EQUATION IN TWO MACHINE SYSTEM

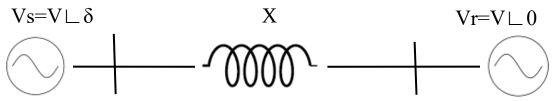

Fig. 1. Two machine system

In two machine system, voltage at sending end (Vs), voltage at receiving end (Vr), phase angle difference (δ) and impedance of transmission line (X); power equations are expressed as

$$P = \frac{Vs\,Vr}{X}\sin\delta$$

$$Q = \frac{Vs^2}{X} - \frac{Vs\,Vr}{X}\cos\delta$$

If $|Vs| = |Vs| = V$ then

$$P = \frac{V^2}{X}\sin\delta$$

$$Q = \frac{V^2}{X} - \frac{V^2}{X}\cos\delta$$

$$Q = \frac{V^2}{X}(1-\cos\delta)$$

Real power depends upon phase angle δ and reactive power depends upon voltage [1-2].

III. STATCOM

STATCOM is a shunt compensating device. It feeds static reactive power in parallel with transmission lines through connected bus.

Different components of STATCOM are: i) DC energy source such as battery or capacitor bank; ii) VSC i.e. voltage inverter to convert DC supply into AC supply; iii) Control Unit to generate pulses for inverter with the help of Pulse Width Modulation (PWM) technique; iv) Transformer to link output voltage to line voltage.

During disturbances STATCOM supplies Reactive power requirement. It improves voltage stability [3].

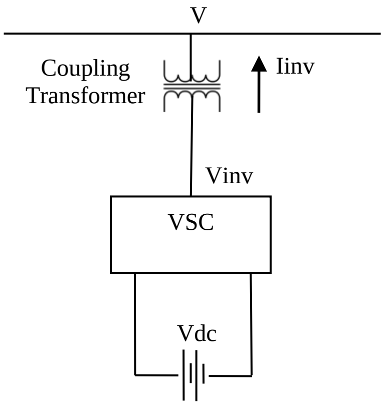

Fig. 2. Block Diagram of STATCOM

From Fig.2 power equations are

$$P = \frac{V\, Vinv}{X} \sin\delta$$

$$Q = \frac{V^2}{X} - \frac{V\, Vinv}{X} \cos\delta$$

Where Vinv and V1 are inverter output voltage and bus voltages respectively and X is reactance of line from inverter to bus.

When system bus voltage (V) reduces i.e. V<Vinv, STATCOM supplies reactive power required acting as a source. When system bus voltage (V) increases i.e. V>Vinv, STATCOM absorbs reactive power acting as a sink. When both voltages are equal i.e. V=Vinv, reactive power transfer doesn't take place. Thus, reactive power compensation is done to control voltage at bus and through transmission system [4].

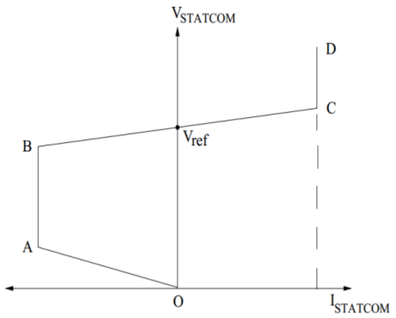

Fig. 3. V-I Characteristics of STATCOM

STATCOM shows constant current characteristics. First quadrant of graph shows inductive mode while second capacitive mode.

IV. SVC

SVC is shunt compensating device. It supplies required reactive power to bus connected in parallel.

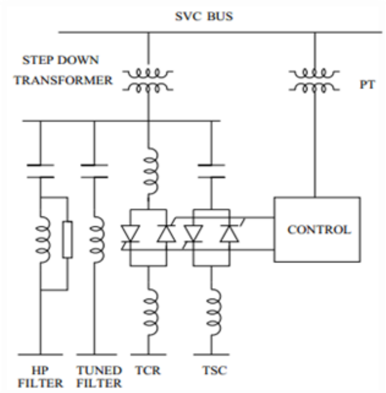

Fig. 4. Typical SVC Configuration

It consists of i) capacitor which is either fixed or switched with help of thyristor; ii) reactor which is controlled by thyristor; iii) control unit to generate signals and iv) coupling transformer [5-6].

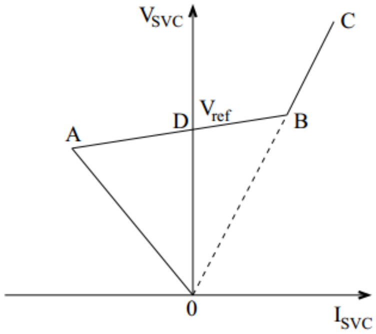

Fig. 5. V-I Characteristics of SVC

Slope of line OA gives suseptance of capacitor indicates Capacitive mode of operation and Slope of line OBC gives suseptance of reactor indicates inductiove mode of operation [1].

V. SSSC

SSSC is a series compensating device. It controls real power flow through transmission line. Different components of SSSC are- i) VSC to convert DC into AC Supply; ii) DC energy Source; iii) controlling unit and iv) series transformer to connect it with line [7].

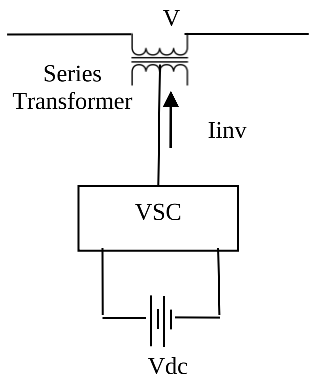

Fig. 6. Basic configuration of SSSC

Sinusoidal voltage V, 90˚ out of phase with line current, is fed to transmission line. When voltage leads by 90˚, it gives

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inductive reactance. When voltage lags by 90˚, it gives capacitive reactance. Power transfer capacity of line is controlled with injection of series voltage which changes impedance of line [8].

VI. TCSC

TCSC is series compensating device. A capacitor is in series with transmission line. Thyristor-controlled reactor (TCR) is in shunt with capacitor.

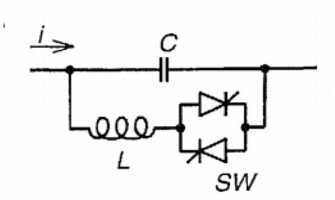

Fig. 7. Configuration of TCSC

Value of capacitance is varied by connecting inductive reactor in parallel with the help of thyristor. TCSC has capability of proving positive as well as negative reactance. It changes overall impedance of transmission line. Power flow is controlled by varying impedance [9-10].

VII. UPFC

UPFC is combined series-shunt device. Two VSCs are used; one connected in series with transmission line and other in shunt. These two VSC are connected through a common capacitor. Capacitor keeps voltage across VSC constant [11].

One inverter control reactive power through shunt transformer for voltage improvement as STATCOM. Another feeds symmetrical voltage through series transformer to control impedance and phase angle as SSSC. Thus, UPFC controls both voltage enhancement and power flow [12].

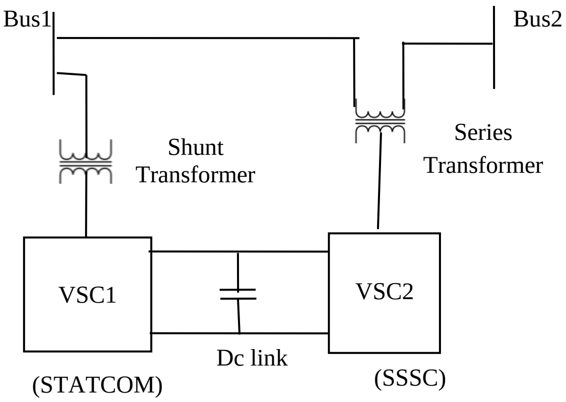

Fig. 8. Block Diagram of UPFC

VIII. IPFC

IPFC is a combined compensating device. It controls power flow through transmission system having multiple lines. SSSCs are used to transfer real and reactive power in between transmission lines [13].

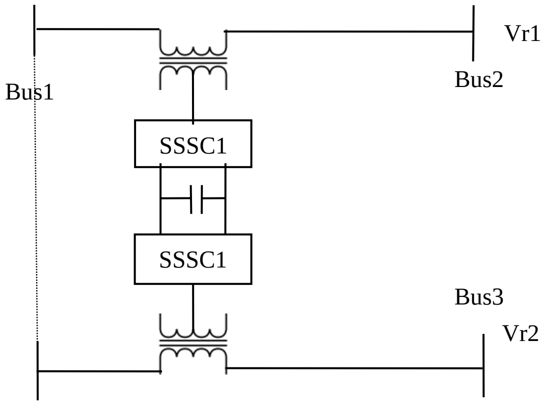

Fig. 9. Block Diagram of Two Line IPFC

Typical two-line IPFC has two SSSC connected to a common capacitor. Series transformers are used to couple outputs to transmission lines.

Injection of series voltage with line voltage controls real power flow. IPFC shifts load from overloaded line to under loaded lines. This helps to overcome resistive voltage drop across transmission line. It helps to improve voltage level. As voltage affects reactive power, reactive power gets improved [14-15].

IX. CONCLUSION

There are different facts devices used to improve power system stability under disturbances. Shunt FACTS devices such as STATCOM and SVC improve voltage stability by reactive power compensation and keep voltage at bus nearly constant. Series FACTS devices like SSSC and TCSC are used for real power compensation. While both real and reactive power compensation is achieved from combined devices like UPFC and IPFC.

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