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A Review on Voltage Stability and Power Quality Improvement by using UPFC Controller

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ABSTRACT

Load demand is growing rapidly these days, necessitating an increase in generating capacity to satisfy that demand. Voltage instability arises as a result of external and internal imbalance, causing the bus voltage to fluctuate. The Unified Power Flow Controller (UPFC) is a FACTS device that is used to maintain steady voltage and enhance power flow in transmission lines. This article examines the use of UPFC to manage both active and reactive power and compares it to other FACTS devices. In comparison to other FACTS devices such as STATCOM, which controls only voltage, TCSC, and SVC, which controls only impedance, UPFC is one of the most promising FACTS devices because it can control phase angle, voltage magnitude, impedance, and various line parameters selectively or simultaneously. It also goes over the UPFC topology in transmission lines in depth.

KEYWORDS: *UPFC, Active and Reactive power, Dynamic compensation, Comparison of FACTS device*

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I. INTRODUCTION

In present scenario, the electric power demand is placed on the transmission network and this demand will increase continuously. Demand for electric power is increasing rapidly and due to the financial and environmental facts of the new building center and the transmission circuit is very complex. Most of the world's electric power supply system is widely interconnected to reduce the cost of electricity and to improve the reliability of power supply. Transmission interconnection gives advantages of variety of load, source availability and to supply power to the loads at minimum cost [1].

Now a day's power systems are broad and mechanically controlled. Final power control effort is taken when operating signals are sent to power circuits, the switching instruments are mechanical and some small-scale fast response controls. The mechanical instruments cannot be controlled frequently and they are damaged very rapidly as compared to static devices, which result in uncontrolled performance of dynamic and static state.

The power systems are extremely complicated and unvarying system security. During abnormal condition, transmission losses take place commonly at high frequency and avoid these losses to requirement of latest powerful device as well as stable device for flexible power flow control in deregulated electric power industry [2].

Therefore, a new control method must be implemented. In the year 1980, a new technology program popularly known as FACTS (Flexible AC Transmission System) was launched by EPRI (Electric Power Research Institute).The FACTS technology has new ways to control the power as well as to boost the capacity of lines. FACTS controller has to control various interrelated transmission line parameters which are voltage, phase angle, series impedance and damping oscillation. The leading purpose of FACTS is to increase the potential of transmission system, enhancement of voltage stability and power system stability improvement. The FACTS controller depends upon voltage source inverter and devices such as Thyristor Controlled Compensators (TCSC), Static VAR Compensator (SVC), Static Synchronous Series Compensator (SSSC), Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC). The UPFC is one of the most rising devices in the FACTS technology. FACTS technology is capable of controlling power flow through the transmission line and also maintaining voltage stability by changing the variable such as phase angle, voltage magnitude and impedance [3-4].

II. WORKING PRINCIPLE OF UPFC

UPFC consists of two switching converters which in the implementation considered are voltage source inverters using gate turn–off thyristor. Storage capacitor along with two voltage source converters that are connected back to back and operated through a common dc link. Common dc link facilitates real power flow in both directions between ac terminals of the two converters. Each converter is capable of generating or absorbing reactive power at its ac terminal. Voltage in series is injected in line with the help of series connected converter with phase angle (0≤σ≤360), and voltage magnitude (0≤Vpq≤Vpqmax), thus exchanging real and reactive power. Series connected converter, converts demand or excess of real power of transmission line to common dc bus as supply or absorb the real power.

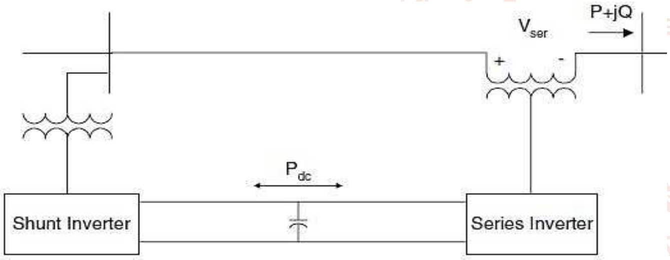

Fig. 1 Basic circuit diagram of UPFC

Shunt converter converts the demand at dc link to ac and feeds back to the line with the help of shunt connected transformer. There is closed direct path for real power exchange by series converter dc link shunt converter back to line. Reactive power is generated or absorbed by the series connected converter locally and meets the transmission line demand. Thus active power is supplied without change of reactive power flow. In AC transmission system, UPFC has to operate as real time control as well as dynamic compensation, while if there in supplying of the power in industry it also provide multifunctional solution [6].

III. ACTIVE AND REACTIVE POWER FLOW CONTROL

Consider a simple two machine system with sending end voltage Vs, receiving end voltage Vr and line impedance X as shown in fig. 2. (a). The system voltage phasor and transmission angle δ as shown in fig (b)

$$P=\frac{V^2}{x}\sin\delta \qquad (1)$$

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

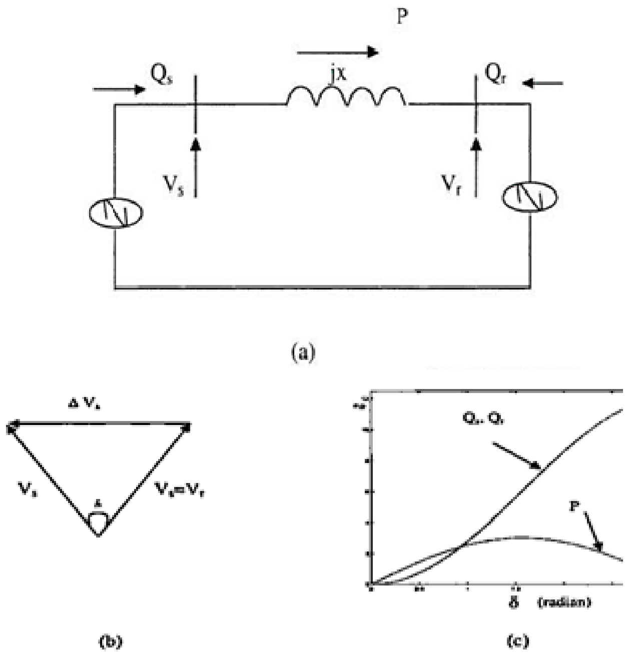

Fig 2. (a) Two machine model, (b) Voltage Phasor, (c) Active and Reactive Power at transmission line.

Fig 2. (c). shows that both the power transmitted through sending end of the line against transmission angle δ. The Active and Reactive power of the sending end as well as receiving end can be control using UPFC. Fig (3) shows UPFC can be included in two machine power system in series with the line [7].

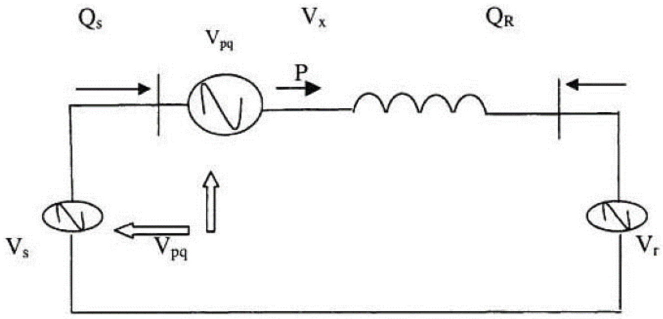

Fig.3. Two machine system with UPFC

To represent the UPFC properly, the series voltage source is designed to generate only the reactive power Qpq it exchange with the line. Generator of sending end must be fed with real power Ppq for perfect coupling. The dc link of UPFC circuit has been placed between two inverters which has bidirectional coupling for the flow of active power between sending end bus and injected voltage source. It is assume that UPFC shunt inverter is operating at unity power factor. The prime duty of UPFC circuit is to delivered active power demand of series inverter to generator of sending end. It is accessible that UPFC influence the voltage across the transmission line, it sensible except that capable of to limit varying the magnitude and angle of Vpq [8-9].

IV. Dynamic performance of UPFC

Series injected voltage of UPFC changes quickly and is constant in magnitude because of electronic controller are used. It is capable of moving from one stable operating point to another rapidly. UPFC control system can be divided into two parts that is external and internal control. The internal control works on two inverter to create the series injected voltage. Also, at same time it draws shunt reactive current. The output voltage of the inverters will respond to the output configuration when the gate signal is supplied by internal control of the inverter valve shown in fig (4). The series voltage injection is response of series inverter is directly as well as separately. Shunt inverter is operated under closed loop current control system and they have capability of controlling both the power [10-11].

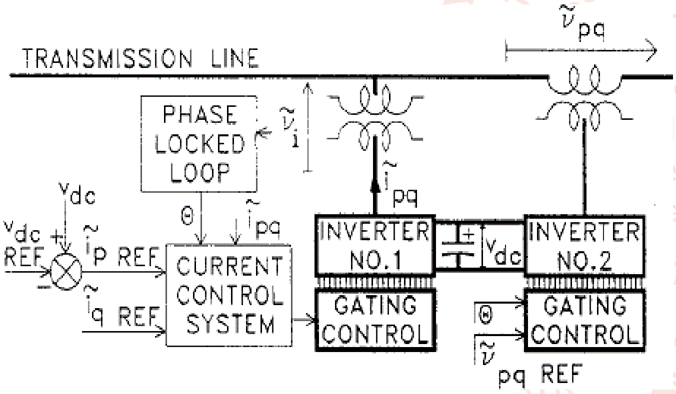

Fig.4. Internal control system of UPFC

The shunt reactive power responds directly to an input demand. The shunt real power is dictated by another control loop that acts to maintain a preset voltage level on the dc link, thereby ensuring the required real power balance between the two inverters. As mentioned previously, the inverters do not exchange reactive power through the link. The external controls are responsible to the demand for series voltage Vpq and shunt reactive current Iq. UPFC has unique function to signify the power flow control [11]. UPFC actually control the sending end voltage and is susceptible of controlling the flow of power in the line under dynamic as well as steady state condition [12]. The circuit breaker will open with occurrence of line to ground fault and three phase fault. If UPFC is not used that system voltage become unstable. UPFC implementation in such fault condition makes the system stable. If sending end and receiving end bus voltage are varied these condition are arises two buses and can be commanded force varying power level on the line will effectively damp the prevailing power oscillation [13-14].

V. Comparison of UPFC to other FACTS devices

A. TCSC

Thyristor controlled series capacitor (TCSC) has the main purpose to control the impedance and increase voltage stability in transmission line. TCSC is connected in series and thyristor controlled inductor is connected in parallel to capacitor. The impedance of TCSC is adjusted by following three modes.

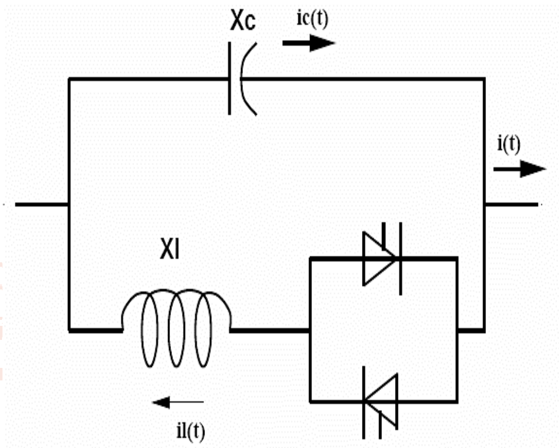

Fig.5. Basic structure of TCSC

1. Blocking Mode: During blocking mode the thyristor valve is not activated and is held on non conducting state.
2. Capacitive and Inductive Mode: During capacitive mode, the thyristor are in conducting state, line current flows through the capacitors thereby increasing the effective capacitor and inductive reactance of the circuit.
3. Bypass Mode: During bypass mode the line current flows through thyristor. When X_L= Xc, thyristor start working.

The TCSC has important advantage for to increase the level of power flow, to controlling the fault current and dynamic stability [15].

B. SVC

Static VAR Compensator is used to synchronize the transmission voltage and for improving power quality of industrial load. SVC are assembled by one or more banks of fixed capacitor or reactor and thyristor controlled system as shown in fig (6). SVC is represented in parallel with transmission line and is impedance matching at end of the line or midpoint of transmission system, in which there is absence of rotating part and is equivalent to the asynchronous condenser. Using thyristor valve to control the susceptance of SVC and to bring close to unity power factor also gives fast response to change in system.

As compared to synchronous condenser the static VAR compensator is more authentic [16].

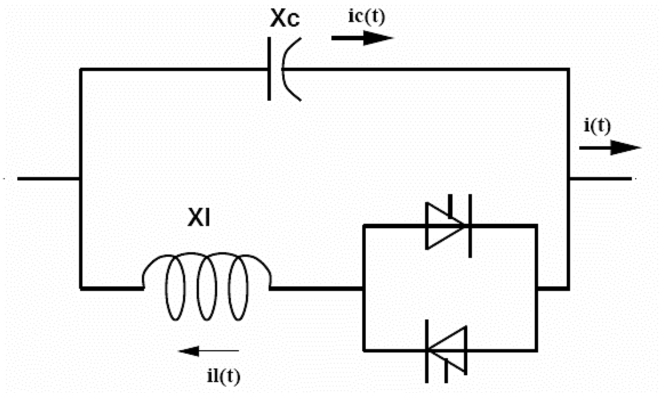

Fig.6. Basic structure of SVC

C. STATCOM

Static synchronous compensator depends upon the voltage source converter. The basic function of this device is convert DC input into AC output voltage as shown in fig (7).

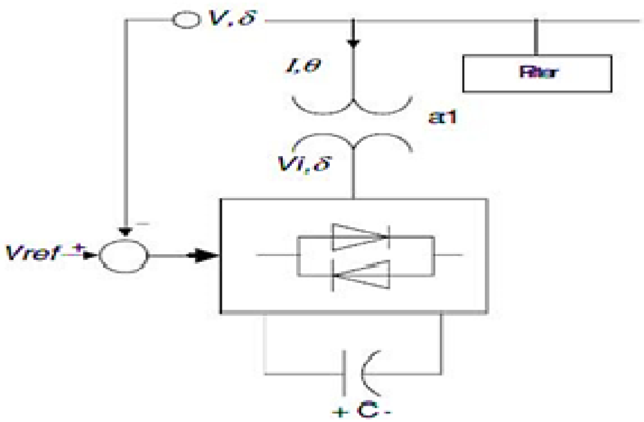

Fig.7. Basic structure of STATCOM

It has basic features to generate sinusoidal voltage, quickly control the amplitude and phase angle at fundamental frequency. STATCOM compensate both active power and reactive power. As compared to SVC the STATCOM has better characteristics.

D. SSSC

Static synchronous series compensator (SSSC) is equivalent to STATCOM and consists of solid state power electronic device which acts as synchronized voltage source. Inverter in SSSC inverts DC to AC with gate turn off thyristor (GTO). SSSC can generate three phase voltage which can be inserted in transmission line through an insertion transformer which is connected in series with transmission line. As SSSC injects current into transmission line, it indirectly controls line voltage. The main benefit of SSSC over the TCSC is that not affect the impedance in transmission line [17].

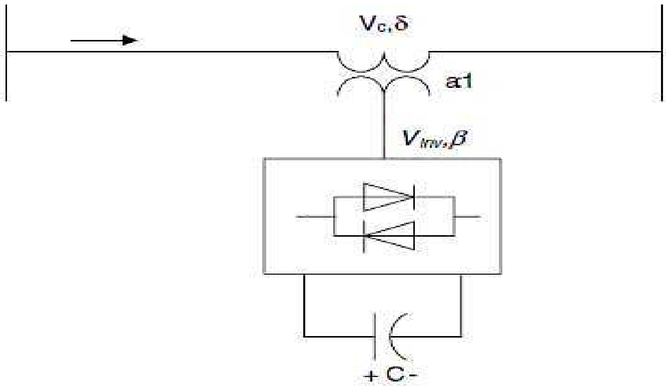

Fig.8 Basic structure of SSSC

VI. Conclusion

This paper presents description of the UPFC concept to manage the power in electrical transmission line. In power grid transmission system, the UPFC is in series with transmission line to increase power transmission capacity and system stability.

This paper also discusses some of the other FACTS controller topologies used in transmission systems and has capacity to control power transmission in multi machine infinite bus system by utilizing the UPFC device. UPFC damps out power oscillation and improves system performance. In grid transmission system, UPFC has control over various line parameters such as voltage amplitude, phase angle and power. Thus it improved overall power system stability.

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