FACTS (A Revolution for Improvement of Power System Stability)

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Abstract- In this paper we discuss about the facts role for improvement of power system stability. A power system is a combination of generation, transmission and distribution and covers a wide area with number of connections. In such large area no of interruptions occurs which effect the efficiency as well as stability of electrical energy.

Key words- Steady state stability, transient stability, Facts (series and shunt controlled), IPC, SSSC, TCSC, SVC, SATCOM

Introduction-

The main criterion for stability is that the synchronous machines maintain synchronism at the end of the transient period. So we can say that if the oscillatory response of a power system during the transient period following a disturbance is damped and the system settles in a finite time to a new steady operating condition, we say the system is stable. If the system is not stable, it is considered unstable. This primitive definition of stability requires that the system oscillations be damped. This condition is sometimes called asymptotic stability and means that the system contains inherent forces that tend to reduce oscillations.

This is a desirable feature in many systems and is considered necessary for power systems. The definition also excludes continuous oscillation from the family of stable systems, although oscillators are stable in a mathematical sense. The reason is practical since a continually oscillating system would be undesirable for both the supplier and the user of electric power. Hence the definition describes a practical specification for an acceptable operating condition. The stability problem is concerned with the behavior of the synchronous machines after a disturbance. For convenience of analysis, stability problems are generally divided into two major categories-steady state stability and transient state stability.

Steady State Stability-

Small signal stability is the ability of power system to maintain synchronous operation under small disturbances. In large power system, small signal stability problems may be either local or global in nature. Local modes are associated with the oscillations of generating units at a particular station with respect to the rest of system; these oscillations are localized in a small part of power system. Global modes are associated with the oscillations of many machines in one part of the system against machines in the other parts; these oscillations are also called inter-area mode oscillation. In an interconnected power system, the rotors of each synchronous machine in the system rotate at the same average electrical speed.

The power delivered by the generator to the power system is equal to the mechanical power applied by the prime mover, neglecting losses. During steady state operation, the electrical power out balances the mechanical power in. The mechanical power input to the shaft from the prime mover is the product of torque and speed, $PM= TM\omega$. The mechanical torque is in the direction of rotation. An electrical torque is applied to the shaft by the generator and is in a direction opposite of rotation.

When the system is disturbed due to a fault or the load is changed quickly, the electrical power out of the machine changes. The electrical power out of the machine can change rapidly, but the mechanical power into the machine is relatively slow to change. Because of this difference in speed of response, there

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exists a temporary difference in the balance of power. This power unbalance causes a difference in torque applied to the shaft, which causes it to accelerate or decelerate, depending on the direction of the unbalance. As the rotor changes speed, the relative rotor angle changes.

Transient State Stability-

Transient stability is the ability of the power system to maintain synchronism when subjected to a severe transient disturbance; the resulting system response involves large excursions of generator rotor angles and is influenced by the non linear power angle relationship. Stability depends on both the initial operating state of the system and severity of the disturbance. Usually the system is altered so that the post disturbance steady state operation differs from that prior to the disturbance.

FACTS-

The rapid development of power electronics technology provides exciting opportunities to develop new power system equipment for better utilization of existing systems [5]. A number of control devices under the term FACTS technology have been proposed and implemented. Applications of this technology started with the Static Var Compensator (SVC) since 1970 and were followed by the Thyristor Controlled Series Compensator (TCSC). Then advances in power electronics devices allowed the use of the second generation of FACTS devices based on the self-commutated Voltage-Sourced Converter (VSC) using Gate-Turn-Off thyristor technology.

It includes the Static synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), VSC-based Static Phase Shifter (SPS), Unified Power Flow Controller (UPFC) and Interline Power Flow Controller (IPFC). It was shown by researchers around the world that FACTS devices are good choices to improve the voltage profile in power systems that operate near their steady-state stability limits and may result in voltage instability. Furthermore, many studies have been also carried out on the use of FACTS devices in improving angle stability.

Taking advantages of the FACTS devices depends greatly on how these devices are placed in the power system, namely on their location and size. In view of this, different works are reported around the world to find a way to place FACTS devices optimally in power systems. In addition to their primary function of FACTS devices, the supplementary damping control action can be also added and how to utilize their control capabilities effectively as stabilizing aids is becoming very important. FACTS are utilized for accomplishing the following objectives.

- Increase / control of power transmission capacity in a line, and for preventing loop flows.
- Improvement of system transient stability limit.
- Enhancement of system damping.
- Mitigation of sub synchronous resonance.
- Alleviation of voltage instability.
- Limiting short circuit currents.

Classification Scheme-

FACTS controllers are classified by considering five independent characteristics:

1) Connection; 2) commutation; 3) switching frequency; 4) energy storage; and 5) dc port

Connection-

FACTS controllers modify the series and parallel impedances of transmission lines. The way a FACTS controller is connected to the ac power system has a direct effect on the transfer of active and reactive power within the system. Series connected controllers are usually employed in active power control and to improve the transient stability of power systems. Shunt connected controllers govern reactive power and improve the dynamic stability. The IEEE groups FACTS controllers into three main categories based on how they are connected to the ac power system: series, shunt, and combined series-and-shunt . We follow this, but we first Divide them into one-port and two-port connections, then subdivide the one-ports into series and parallel (Shunt) connections

Series controlled fact controller-

Series FACTS devices are classified into three categories, namely inter phase power controller (IPC), static synchronous series compensator (SSSC) Thyristor Controlled Series Capacitor (TCSC)

A.Interphase Power Controller (IPC)

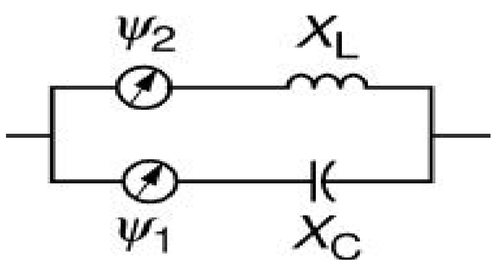

Fig.1

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The IPC is a series controller of active and reactive power. It consists of inductive and capacitive branches subjected to separately phase-shifted voltages. The active and reactive power can be set independently by adjusting the phase shifters and/or branch impedances, using mechanical or electronic switches. The IPC can regulate both the direction and the amount of active power transmitted through a Transmission line. The IPC is a two-port circuit (in series with a transmission line and in parallel with a busbar); it uses natural commutation; its switching frequency is low; it has insignificant energy storage; and it has no dc port.

B.StaticSynchronousSeriesCompensator (SSSC)

The SSSC is a static, synchronous generator operated as a series compensator. Its output voltage is in quadrature with the line current, and is controllable independently of it. Its purpose is to increase or decrease the overall reactive voltage drop across the line and thereby control the transmitted power. Fig. 2 shows the SSSC model. It employs a step-down transformer, whose leakage inductance forms the reactance in series with an ac/dc converter.
The SSSC is a one-port circuit in series with a transmission line; it uses forced commutation; its switching frequency is high; its energy storage element is a capacitor; and it has a dc port.

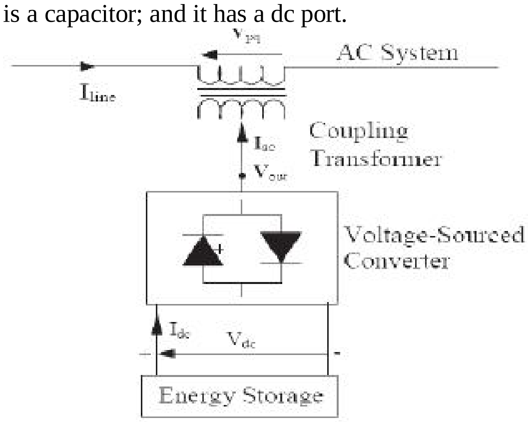

Fig.2

C.Thyristor Controlled Series Capacitor (TCSC)

The TCSC consists of a series capacitor bank, shunted by a Thyristor Controlled Reactor to provide a smoothly variable series capacitive reactance. Fig. 3 shows a TCSC in series with a transmission line. It injects a series voltage proportional to the line current but in quadrature with it. Inserting a TCSC modifies the equivalent reactance of the line, and the active power flow can be varied. The TCSC is a one-port circuit in series with a transmission line; it uses natural commutation; its switching frequency is low; it contains insignificant energy storage elements; and it has no dc port

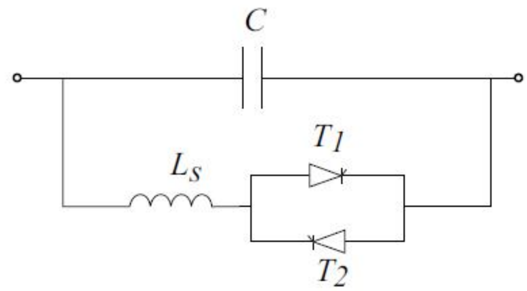

Fig.3

Shunt controlled fact controller-

Shunt FACTS devices are classified into two categories, namely variable impedance type (SVC) and switching converter type (STATCOM).

A. SVC

The SVC uses conventional thyristors to achieve fast control of shunt-connected capacitors and reactors. The configuration of the SVC is shown in Fig. 4 (a), which basically consists of a fixed capacitor (C) and a thyristor controlled reactor (L). The firing angle control of the thyristor banks determines the equivalent shunt admittance presented to the power system.

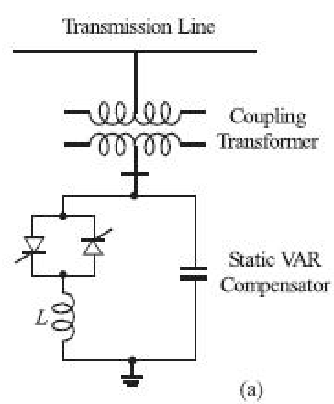

Fig.4

B. STATCOM

The STATCOM is based on a solid state synchronous voltage source which generates a balanced set of three sinusoidal voltages at the fundamental frequency with rapidly controllable amplitude and phase angle. The con- figuration of a STATCOM is shown in Fig. 4 (b). Basically it consists of a voltage source converter (VSC), a coupling transformer and a dc capacitor. Control of re- active current and hence the susceptance presented to power system is possible by variation of the magnitude of output voltage (V_{VSC}) with respect to bus voltage (V_B) and thus operating the STATCOM in inductive region or capacitive region

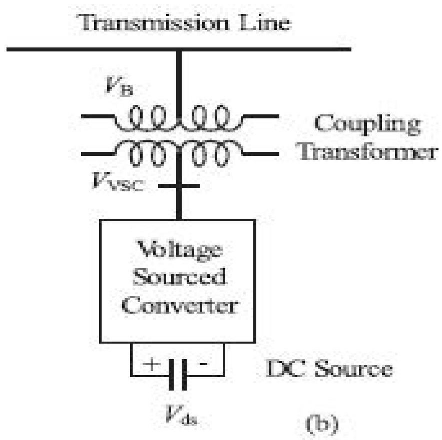

Fig .4

Conclusion-

In this paper various series and shunt controlled fact controller are present for improvement of power system stability.

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