EFFECTS OF A STATIC SYNCHRONOUS SERIES COMPENSATOR TO STUDY THE TRANSIENT RESPONSE IN TRANSMISSION LINES

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Abstract: One of the most important requirements during the operation of the electric power system is the reliability and stability. Power system capability can be increased by the use of Flexible AC Transmission System devices (FACTS) FACTs devices are used to increase the reliability and security of the system. This paper presents a novel Power Flow model of a Static Synchronous Series Compensator (SSSC). By controlling the power system network parameters such as sending end voltage, receiving end voltage, line current, active voltage, reactive voltage the reliability of the system can be achieved. Using static synchronous series compensator power flow in fully loaded condition and any disturbance condition can be controlled by injecting the reactive power. The complete system simulated in MATLAB. Simulation of 14 bus system with and without SSSC shows the voltage, current, active and reactive power compensation and makes the system stable. This model includes multiple control modes of the SSSC. The SSSC is operated on following control modes: the active power flow on the transmission line; the reactive power flow on the transmission line; the voltage at the sending or receiving end bus. In this model, the impedance of coupling transformer is included with the transmission line impedance. Numerous case studies carried out with multiple SSSCs incorporated in the IEEE-30 bus test system validates the proposed model.

Keywords: FACTS Controllers, Reactive Power, Static Synchronous Series Compensator (SSSC), power flow

1. INTRODUCTION

In present scenario, the electrical demands has increased on the transmission network due to the increased nonutility generators and heightened competition among utilities themselves. It has been created the problem of long term planning, reduced quality of supply and mismatching of generation and demand. For power system reliability, the electrical storage, electrical generation and demand must balance at all times [1].

2. CLASSIFICATION OF POWER SYSTEM STABILITY

Dynamic Equation of Synchronous Machine Power system stability involves the study of the dynamics of the power system under disturbances. Power system stability implies that its ability to return to normal or stable operation after having been subjected to some form of disturbances. From the classical point of view power system instability can be seen as loss of synchronism (i.e., some synchronous machines going out of step) when the system is subjected to a particular disturbance. Three type of stability are of concern: Steady state, transient and dynamic stability.

A. Steady-state Stability:

Steady-state stability relates to the response of synchronous machine to a gradually increasing load. It is basically concerned with the determination of the upper limit of machine loading without losing synchronism, provided the loading is increased gradually.

B. Dynamic Stability:

Dynamic stability involves the response to small disturbances that occur on the system, producing oscillations. The system is said to be dynamically stable if theses oscillations do not acquire more than certain amplitude and die out quickly. If these oscillations continuously grow in amplitude, the system is dynamically unstable. The source of this type of instability is usually an interconnection between control systems.

C. Transient Stability:

Transient stability involves the response to large disturbances, which may cause rather large changes in rotor speeds, power angles and power transfers. Transient stability is a fast phenomenon usually evident within a few second. Power system stability mainly concerned with rotor stability analysis. For this various assumptions needed such as:

- For stability analysis balanced three phase system and balanced disturbances are considered.
- Deviations of machine frequencies from synchronous frequency are small.
- During short circuit in generator, dc offset and high frequency current are present. But for analysis of stability, these are neglected.
- Network and impedance loads are at steady state.
- Symmetric capability in both inductive and capacitive operating modes

3. FLEXIBLE AC TRANSMISSION SYSTEM

Alternating current transmission systems incorporating power electronics based and other static controllers to enhance controllability and increase power transfer capability.

i. FACTS Controller:
Power electronics based system and other static equipment that provides control of one or more AC transmission system parameters [2].

ii. Static Synchronous Series Compensator (SSSC)
The basic scheme of SSSC is shown in Fig.1. The SSSC is a series compensation device of the FACTS family which has the voltage source converter (VSC) to control power flow in transmission lines and improve transient stability in power system [8].The SSSC controls the power flow in transmission lines by controlling the magnitude and phase angle of injected voltage vse in series with the transmission line where SSSC is connected. The exchange of real and reactive power between SSSC and power system depends on the magnitude and phase displacement with respect to transmission line current [9].

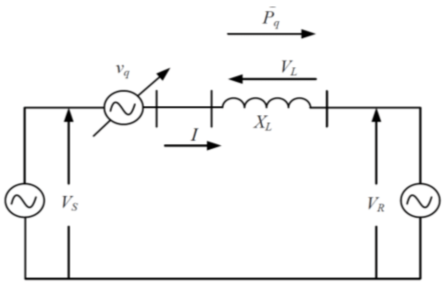

Fig1: The elementary two machine system with SSSC

4. PRINCIPLE OF SSSC OPERATION

The operation of the model is verified by connecting the model in series with a simple transmission line which can easily be replaced by the utility's existing more complex power system network.The SSSC is generally connected in series with the transmission line with the arrangement as shown in Figure 2. The SSSC comprises a coupling transformer, a magnetic interface, voltage source converters (VSC) and a DC capacitor. The coupling transformer is connected in series with the transmission line and it injects the quadrature voltage into the transmission line. The magnetic interface is used to provide multi-pulse voltage configuration to eliminate low order harmonics. The VSCs are either two-level converter or three-level converter. One side of the VSC is connected to the magnetic interface while the other side is connected to the DC bus. The DC capacitor is used to maintain the DC voltage level of the DC bus. This DC capacitor is selected to meet harmonic and economic criteria of the SSSC and the power system.

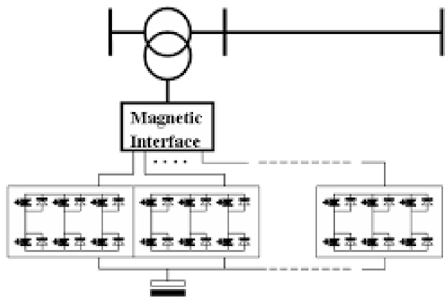

Fig 2: General arrangement of SSSC with the transmission line

The SSSC can control the power flow through the transmission line by controlling the magnitude of $vse$and injecting in quadrature with transmission line current I as mentioned in the following equations.

$vse = v2 - v1 = vd + jvq$ (1)

$vd \approx 0$ (2)

$vq>0$: SSSC is capacitive (3)

$vq<0$: SSSC is inductive (4)

The magnitude of Vse is controlled through the changes in the amplitude modulation ratio (m_{se}) according to the following equation.

$m_{se} = \sqrt{\frac{8vse}{vdc}}$ (5)

The SSSC can provide capacitive or inductive compensating voltage independent of the line current up to its specified current rating. The practical minimum line current is that at which the SSSC can still absorb enough real power from the line to replenish its losses. The VA rating of the SSSC is simply the product of the maximum line current (at which compensation is still desired) and the maximum series compensating voltage:

$VA = I_{max} Vq_{max}$ (6)

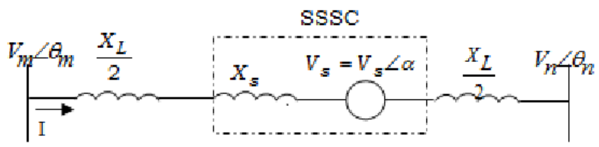

Fig:3 Equivalent Circuit of SSSC

The SSSC is connected in series via a coupling transformer. The equivalent circuit of a SSSC incorporated between any two buses 'i' and 'j' of a typical 'n' bus power system network is shown in Fig. 3. The SSSC is represented by a voltage source **Vse** which is connected via its coupling transformer impedance ZT in series with the line impedance **Zij**. Pi +jQi and Pj +jQj are the net injected active and reactive powers at the buses 'i' and 'j' respectively.

5. SIMULINK MODEL OF TRANSMISSION LINE WITH SSSC AND RESULTS

Fig

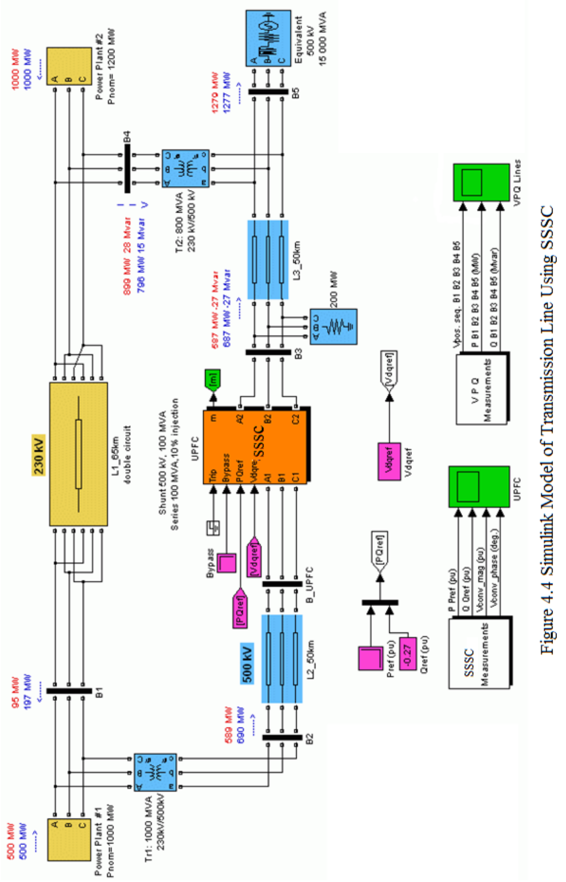

Fig: 4 Simulink model of transmission line with SSSC

The SSSC consists of a three-phase gate turn-off based voltage source converter (VSC) and a DC capacitor. The V_{SC} generates a controllable AC voltage Vo which is given by

$Vo = CVDC \angle\psi = CVDC (\cos\psi + j \sin\psi)$ (7)

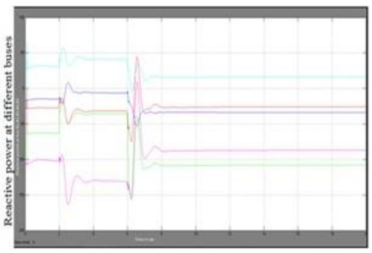

Fig: 5 Active power flows through different buses in KVA

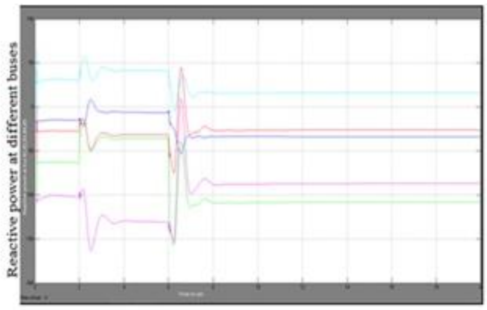

Fig: 6 Reactive power flows through different buses in KVAR

In this study, a single machine infinite bus electrical power system installed with SSSC is investigated. First the simulations were carried out when the SSSC was switched off. The three phase source voltage and current waveforms along with the real and reactive power flows were obtained as shown in Fig. 5 and Fig 6. The same parameters were observed after switching on the SSSC. The signal over the feedback loop and the control signals for the closed loop control were also studied in this work, whereas the output voltage of the multi-pulse inverter is the voltage that is injected into the line, is also analyzed. By analyzing the results and the graphical waveforms it has been observed that the synchronization and compensation are performed satisfactorily by the designed SSSC.

6. CONCLUSION

The SSSC which acts as a voltage source inverter injects a sinusoidal voltage in series with the transmission line voltage is almost in quadrature with the line current, thereby emulating an inductive reactance or a capacitive reactance in series with the transmission line. The power flow in the transmission line always decreases when the injected voltage by the SSSC reproduce an inductive reactance in series with the transmission lime and the power flow in the transmission line always increases when the injected voltage by the SSSC reproduce capacitive reactance in series with the transmission line

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