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Enhancement of Unsymmetrical Power system stability faults in multi bus system using Static Synchronous Series Compensator (SSSC)

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Abstract: -- *This paper investigates the problem of controlling and modulating power flow in a transmission line using a Synchronous Static Series Compensator (SSSC). The power system network is becoming more complex now a days and it is very difficult to maintain the stability of the power system. The continuous demand in electrical power system network may cause the system to be heavily loaded which leads to voltage instability. This work is presented to improve the stability and to damp the oscillations by using SSSC with and without controller at different faults and compare their performances. Simulation results show that SSSC with controllers enhance the stability of Multi-machine power system effectively. The power system under consideration is simulated by using MATLAB/SIMULINK software.*

Keywords *--- Power System Stability, static synchronous series compensator (SSSC), FACTS, Types of faults, Two machine power system, Active and reactive powers.*

I. INTRODUCTION

The performance of transmission lines, those of short medium and long can be improved by the series compensation. Series compensation consists of a capacitor bank placed in series with each phase conductor of the line. Series compensation decreases the impedance of the line which is the main cause in drop of voltage and principal factor for determining the maximum power that the line can transmit. The reactance of the capacitor bank can be known by compensating a specific amount of inductive reactance of the line. This defines the term compensation factor which is given by the ratio of the capacitive reactance of the capacitor bank to the inductive reactance of line per phase.

Usage of the switching power converters for the generation of reactive power to provide compensation for transmission and as well as distribution lines has been realized and a prototype static synchronous series compensator has been installed using a thyristor based voltage course inverter. (Commissioned at the Sullivan substation of Tennessee valley Authority (TVA) power system). (A book on power system analysis by John J. Grainger and William D. Stevenson). This further lead to the concept of unified power flow Controller (UPFC) for the dynamic power flow control. Usually static synchronous series compensators are used as regulating devices in the transmission networks. There are several advantages and applications for these static synchronous compensators. These are introduced in 1990s to deal with the power quality problems. These have also been used in the renewable energy distribution and transmission. In the power distribution system regulation of the load voltage is very important to compensate the time varying loads. For this purpose reactive power sources are commonly used for regulation in case of disturbances. The control bandwidth is very large. So in order to handle that the static compensators based on voltage source converters are being proposed. For the effective regulation of the load voltage the static compensators are modeled by the axis theory for three phase systems. The effect of the change in the parameters of distribution system is studied with regard to dynamics of the static synchronous compensator. Firstly the model is used to address the problem of regulation of load voltage with the static synchronous compensator to control the current source. Subsequently nonlinear and linear controllers are designed and the performance is compared with the simulations obtained. Then the static synchronous compensator that is controlled is combined with the distribution system model and load voltage controller. In this way the static synchronous series compensator helps in the regulation of the voltage in distribution and transmission systems.

II. BASIC OPERATION PRINCIPLE OF SSSC

Static Synchronous Series Compensator (SSSC) is a modern power quality FACTS device that employs a voltage source converter connected in series to a transmission line through a transformer. The SSSC operates like a controllable series capacitor and series inductor. The primary difference is that its injected voltage is not related to the line intensity and can be managed independently. This feature allows the SSSC to work satisfactorily with high loads as well as with lower loads.

The Static Synchronous Series Compensator has three basic components:

a. Voltage Source Converter (VSC) – main component
b. Transformer – couples the SSSC to the transmission line

c. Energy Source – provides voltage across the DC capacitor and compensates for device losses as shown fig: 1.

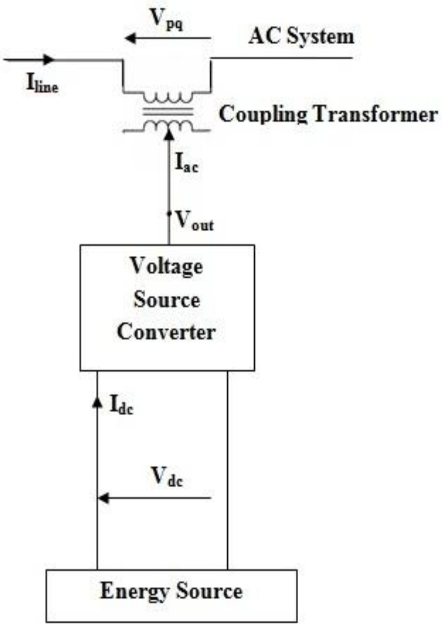

Fig: 1. Functional Model of SSSC

III. CONTROL SYSTEM OF SSSC

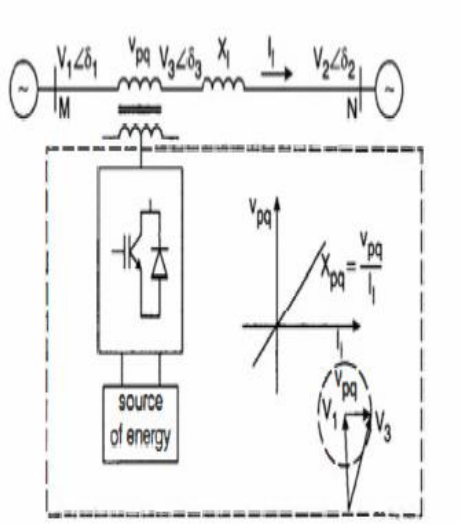

Fig: 2. Single Line Diagram of Simple Transmission Line

Nowadays the power width modulation control is becoming the more important and practical technology for the applications related to power systems. The effect of the losses due to fast switching of the electronic devices is more on the calculation of power flow in the power width modulation control and has a very large impact on the charging and discharging of the capacitor.

Fig. 2 shows a single line diagram of a simple transmission

Line with an inductive reactance, X_L, connecting a sending end Voltage source, V_S, and a receiving-end voltage source, Vr respectively [7].

The real and reactive power (P and Q) flow at the receiving end voltage source are given by the expressions

$$P=\frac{V_s V_r}{X_L}\sin(\delta_s-\delta_r)=\frac{V^2}{X_L}\sin\delta \quad (1)$$

$$Q=\frac{V_s V_r}{X_L}(1-\cos(\delta_s-\delta_r))=\frac{V^2}{X_L}(1-\cos\delta) \quad (2)$$

Where Vs and Vr are the magnitudes and δs and δr are the phase angles of the voltage sources Vs and Vr respectively.
For simplicity, the voltage magnitudes are chosen such those Vs = Vr = V and the difference between the phase angles is:

$$\delta = \delta_s = \delta_r \qquad (3)$$

An SSSC, limited by its voltage and current ratings, is capable of emulating a compensating reactance Xq (both inductive and capacitive) in series with the transmission line inductive reactance X_L, Therefore, the expressions for power flow given in equation (1 & 2) becomes

$$P_q = \frac{V^2}{X_{eff}} \sin\delta = \frac{V^2}{X_L(1 - X_q/X_L)} \sin\delta \qquad (4)$$

$$Q_q = \frac{V^2}{X_{eff}} (1 - \cos\delta) = \frac{V^2}{X_L(1 - X_q/X_L)} (1 - \cos\delta) \qquad (5)$$

Where X_{eff} is the effective reactance of the transmission line between its two ends, including the emulated variable reactance inserted by the injected voltage source of the Static Synchronous Series Compensator (SSSC). The compensating reactance Xq is defined to be negative when the SSSC is operated in an inductive mode and positive when the SSSC is operated in a capacitive mode.

IV. TWO MACHINE POWER SYSTEM MODELLING

The dynamic performance of SSSC is presented by real time voltage and current waveforms. Using MATLAB software the system shown in Fig. 3, has been obtained [1]. In the simulation one SSSC has been utilized to control the power flow in the 500 KV transmission systems.

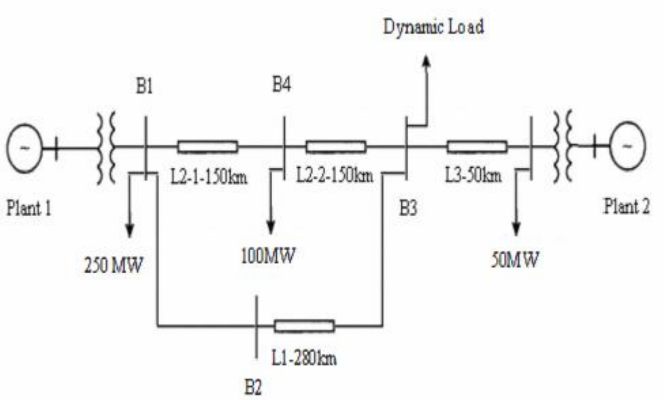

Fig: 3. Two Machine System without SSSC

This system which has been made in ring mode consisting of 4 buses (B1 to B4) connected to each other through 3-Φ transmission lines L1, L2-1, L2-2 and L3 with the length of 280, 150, 150 and 5 km respectively. System has been supplied by two power plants with the phase-to-phase voltage equal to 13.8 KV.

Active and reactive powers injected by power plants 1 and 2 to the power system are presented in per unit by using base parameters S_b=100MVA and V_b=500KV, which active and reactive powers of power plants 1 and 2 are (24-j3.8) and
(15.6-j0.5) in per unit, respectively.

V. UNSYMMETRICAL FAULTS

The sequence circuits and the sequence networks developed in the previous chapter will now be used for finding out fault current during unsymmetrical faults. Specifically we are going to discuss the following three types of faults:

- Single-line-to-ground (LG) fault
- Line-to-line (LL) fault
- Double-line-to-ground (LLG) fault

VI. MATLAB/SIMULINK RESULTS WITHOUT SSSC

Power system with two machines and four buses has been simulated in MATLAB and then active and reactive powers in bus-2 have been obtained for different types of unsymmetrical faults (i.e. L-G, L-L and L-L-G), which are shown in following without SSSC.

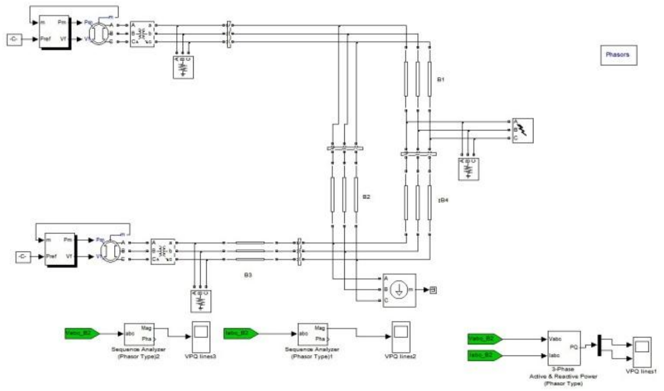

Fig: 4. Matlab/Simulink Model for Multi-bus System without SSSC

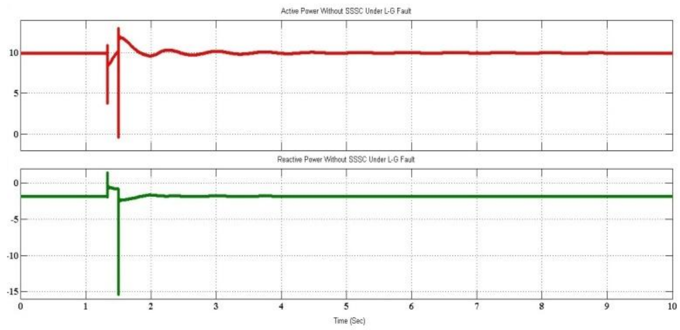

Fig: 5. Active and Reactive Power without SSSC under L-G Fault

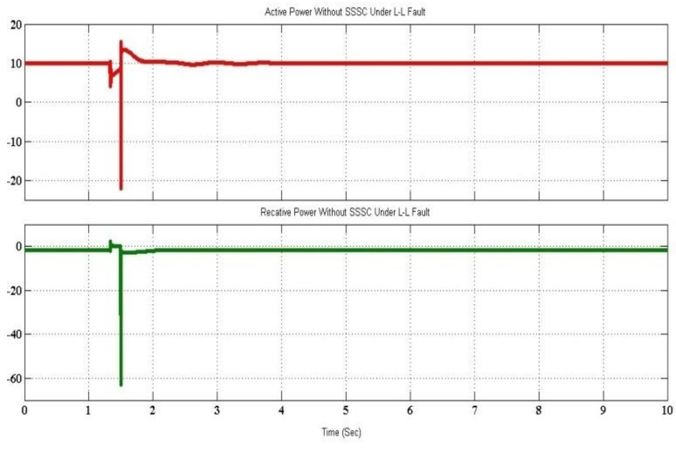

Fig: 6. Active and Reactive Power without SSSC under L-L Fault

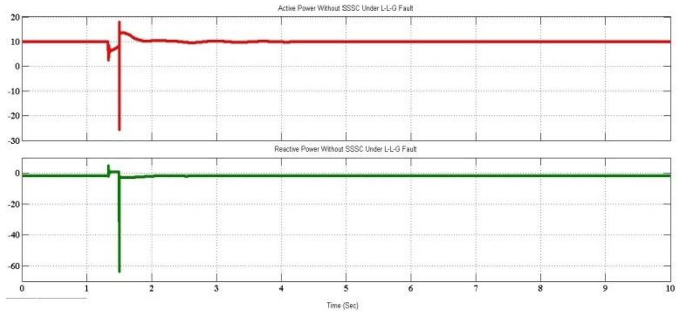

Fig: 7. Active and Reactive Power without SSSC under L-L-G Fault

VII. MATLAB/SIMULINK RESULTS WITH SSSC

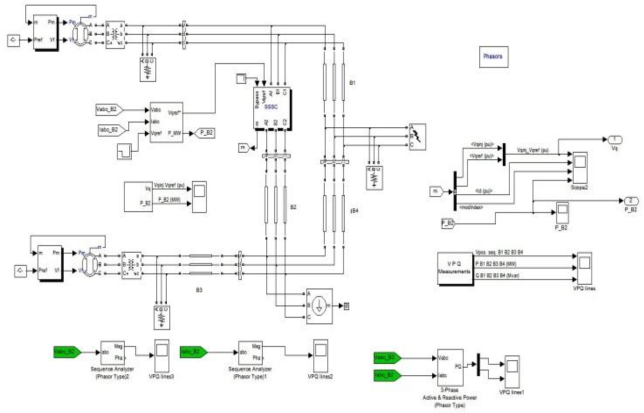

Fig: 8. Matlab/Simulink Model for Multi bus System with SSSC

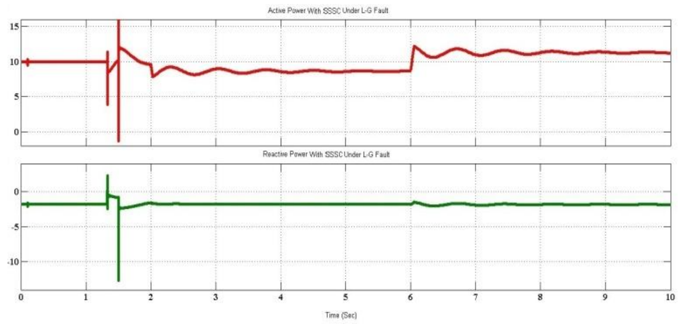

Fig: 9. Active and Reactive Power with SSSC under L-G Fault

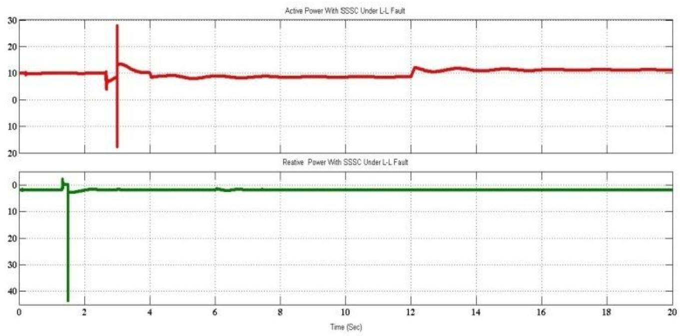

Fig: 10. Active and Reactive Power with SSSC under L-L Fault

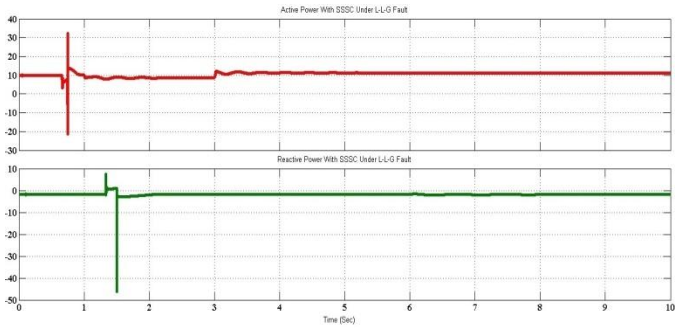

Fig: 11. Active and Reactive Power with SSSC under L-L-G Fault

VIII. CONCLUSION

Therefore we can conclude that the static synchronous series compensator offers flexibility to many applications there these compensators are widely used. The solid state devices present in the system makes it more efficient and accurate in the results. Many power quality issues and voltage stability issues can be solved using these static synchronous series compensator which is very essential for the accurate performance of the power system which helps in delivering the uninterrupted power supply to the consumers depending on the demand.

Based on obtained simulation results the performance of the SSSC has been examined in a simple two-machine system simply on the selected bus-2, and applications of the SSSC will be extended in future to a complex and multi machine system to investigate the problems related to the various modes of power oscillation in the power systems.

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BIOGRAPHIES

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