Power System Stability Enhancement Using Static Synchronous Series Compensator (SSSC)

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***Abstract*:In this paper, a static synchronous series compensator (SSSC) is used to investigate the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode. The SSSC equipped with a source of energy in the DC link can supply or absorb the reactive and active power to or from the line. Simulations have been done in MATLAB/SIMULINK environment. Simulation results obtained for selected bus-2 in two machine power system shows the efficacy of this compensator as one of the FACTS devices member in controlling power flows, achieving the desired value for active and reactive powers, and damping oscillations appropriately.**

Keywords: component; active and reactive powers, FACTS, Static synchronous series compensator (SSSC), two machine power system.

I. INTRODUCTION

Nowadays, the need for flexible and fast power flow control in the transmission system is anticipated to increase in the future in view of utility deregulation and power wheeling requirement. The utilities need to operate their power transmission system much more effectively, increasing their utilization degree. Reducing the effective reactance of lines by series compensation is a direct approach to increase transmission capability. However, power transfer capability of long transmission lines is limited by stability considerations. Because of the power electronic switching capabilities in terms of control and high speed, more advantages have been done in FACTS devices areas and presence of these devices in transient stability during transient faults resulting in improvement in power system stability [1].

This paper investigates the static synchronous series Compensator (SSSC) FACTS controller performance in terms of stability improvements. A Static Synchronous Series Compensator (SSSC) is a member of FACTS family which is connected in series with a power system. It consists of a solid state voltage source converter (VSC) which generates a controllable alternating current voltage at fundamental frequency. When the injected voltage is Kept in quadrature with the line current, it can emulate as inductive or capacitive reactance so as to influence the power flow through the transmission line [2,3]. While the primary purpose of a SSSC is to control power flow in steady state, it can also improve transient stability of a power system.

II. SSSC CONFIGURATION

The basic scheme of the SSSC is shown in Figure1. The compensator is equipped with a source of energy, which helps in supplying or absorbing active power to or from the transmission line along with the control of reactive power flow.

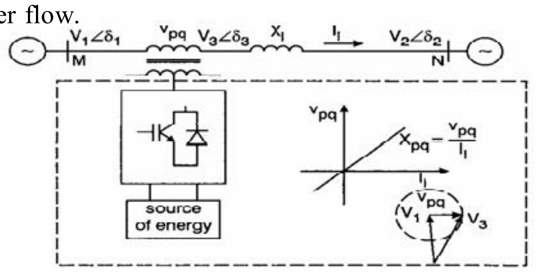


Figure1. Static synchronous series capacitor

III. CONTROL SYSTEM OF SSSC

SSSC is similar to the variable reactance because the injected voltage and current to the circuit by this device are changing depend upon to the system conditions and the loads entering/getting out. For responding to the dynamic and transient changes created in system, SSSC utilizes the series converter as shown in Figure2.

One side of the converter is connected to the AC system and the other side is connected to a capacitor and battery which in the system we assume DC source as battery. If a dynamic change in system will be occurred, SSSC circuit works such that according to the control circuit in Fig. 3 the energy of battery will be converted to the ac form by converter and then injecting this voltage to the circuit the changes will be damped appropriately.

To control the active and reactive powers of bus-2, the control circuit as shown in Figure2 is utilized. For controlling the powers, first, sampling from the voltage and current is done and transformed to the dq0 values. Active and reactive powers of bus-2 are calculated using their voltage and current in dq0 references and compared with the determined reference and the produced error signal is given to the PI controllers. Adjusting parameters of the PI controllers, we are trying to achieve the zero signal error, such that powers can follow the reference powers precisely. Then, the output of the controllers are transformed to the abc reference and given to the PWM.

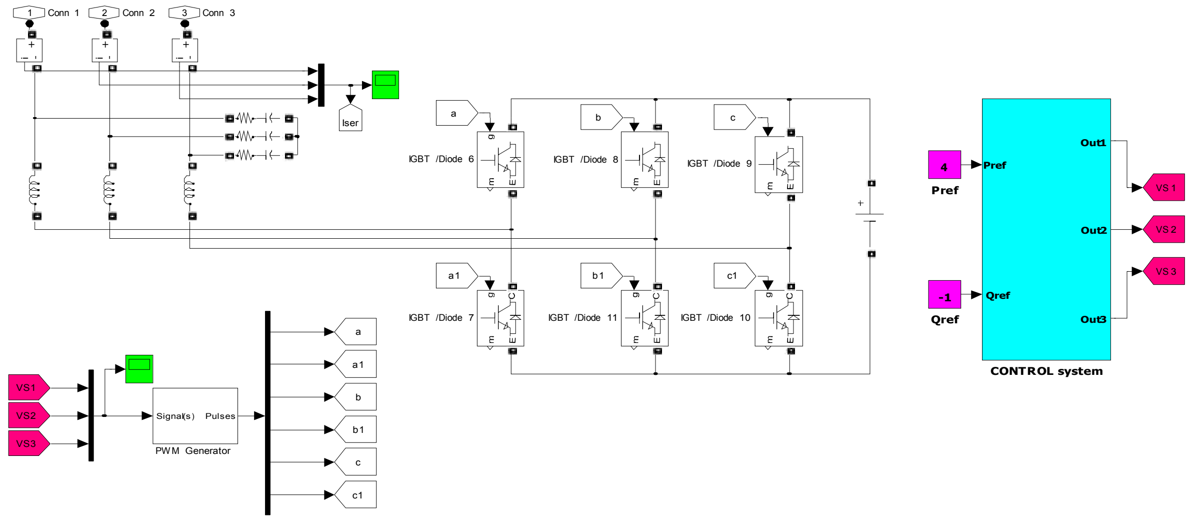
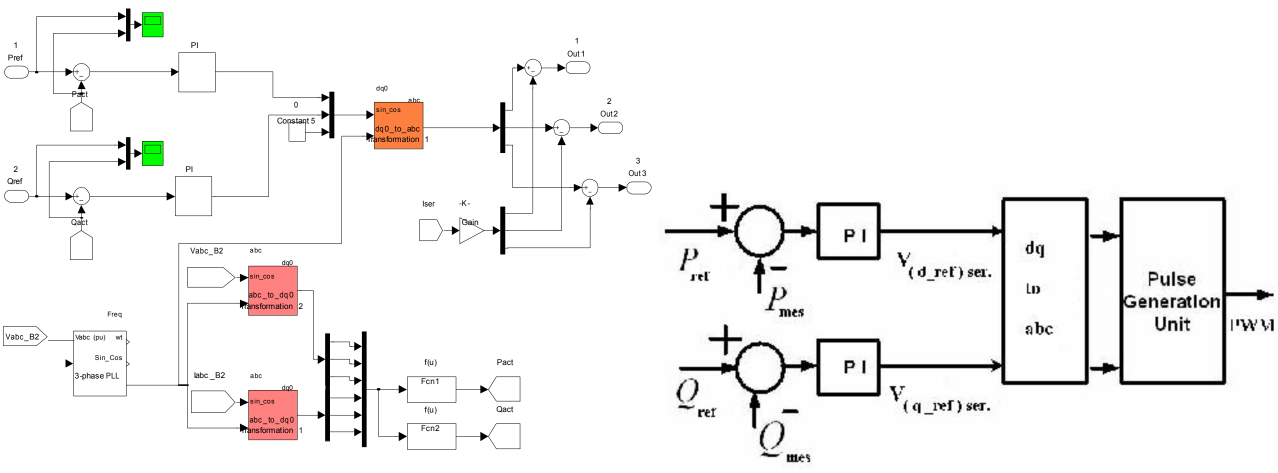


Figure 2. The convertor of SSSC



a) Simulated circuit b) Single line diagram

Figure 3. The control circuit of SSSC; a) simulated circuit b) single line diagram

IV. TWO MACHINE POWER SYSTEM MODELINGSING

The dynamic performance of SSSC is presented by real time voltage and current waveforms. Using MATLAB software the system shown in Fig. 4 has been

Obtained. In the simulation one SSSC has been utilized to control the power flow in the 500 KV transmission systems. This system which has been made in ring mode consisting of 4 buses (B1 to B4) connected to each other through three phase 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.

For controlling the powers, first, sampling from the voltage and current is done and transformed to the dq0 values. Active and reactive powers of bus-2 are calculated using their voltage and current in dq0 references and compared with the determined reference and the produced error signal is given to the PI controllers.

Active and reactive powers injected by power plants 1 and 2 to the power system are presented in per unit by using base parameters Sb=100MVA and Vb=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.

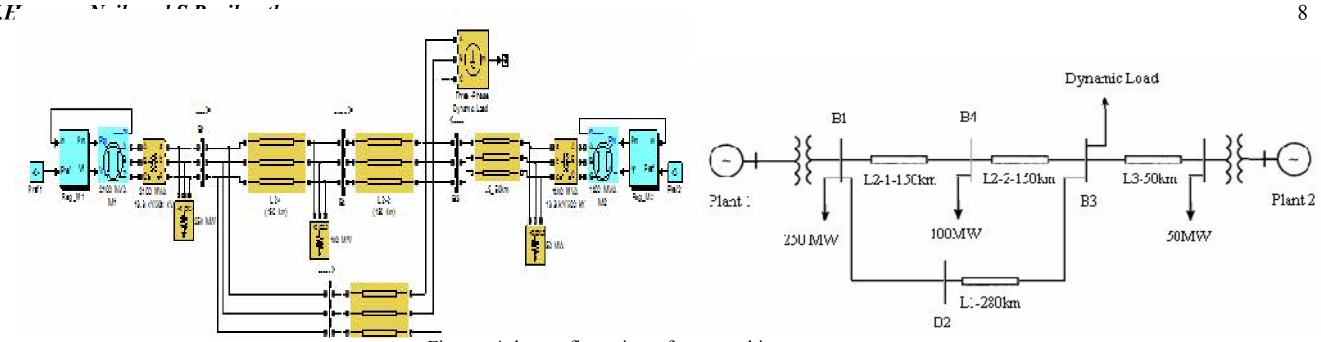


Figure .4 the configuration of two machine power system

V.SIMULATION RESULTS WITH MATLAB/SIMULINK

First, power system with two machines and four buses has been simulated in MATLAB environment, and then powers and voltages in all buses have been obtained. The results have been given in Table I. Using obtained results bus-2 has been selected as a candidate bus to which the SSSC be installed. Therefore, the simulation results have been focused on bus-2.

TABLE I. OBTAINNED RESULT FROM THE SIMULATIONS

Bus No.	*Voltage*	*Current*	*Active Power*	*Reactive Power*
1	1 pu	13.5 pu	20.06 pu	-3.77 pu
2	**1 pu**	**6.7 pu**	**9.96 pu**	**1.82 pu**
3	1 pu	10 pu	14.84 pu	-0.49 pu
4	1 pu	5.55 pu	8.45 pu	-.059 pu

VI. CASE STUDIES

A. *Bus-2 parameters without SSSC*

Changes in current, voltage, active and reactive powers of bus-2 have been obtained in real time. According to the Figure. 5, at first, due to the large loads of the system active power of bus-2 got oscillations which keep continuing for 3 seconds. However, the controlling systems in power plants 1 and 2 such as governor, PSS and other stabilizing devices are used for damping these oscillations. As shown in Figure. 6, because of the abovementioned reasons reactive power of bus-2 got oscillations at first and then will be damped properly. Oscillations amplitude for active power is more than reactive power, and this is because the ohmic parts of loads of system are much more.

According to Figure.7 and Figure.8, after transient mode created at first in system, voltage and current waveforms of bus-2 got closer to sinusoidal waveforms. Voltage amplitude is 1 per unit, but, despite the drawn currents by loads in system, current amplitude is 6.7 pu.

B. *Bus-2 parameters with SSSC*

As shown in Figure. 9, SSSC has been placed between bus-1 and bus-2 and the aim is achieving the following active and reactive powers:

$$p_{ref} = 4 \text{ PU} \qquad Q_{ref} = -1 \text{ pu}$$

The main role of SSSC is controlling the active and reactive powers; beside these SSSC could fairly improve the transient oscillations of system

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After the installation of SSSC, besides controlling thePower flow in bus-2 we want to keep constant the voltage value in 1 per unit, hence the power flow is done in the presence of SSSC and the simulation results are as follows. According to the Fig. 10, by installing the SSSC, active power damping time will be less than the mode without SSSC and it will be damped faster. Also as shown in Fig. 11, reactive power damping time will be decreased and system will follow the references value with acceptable error.

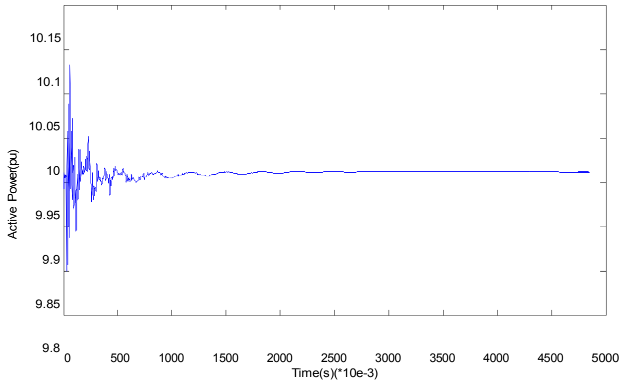

Figure 5. Active power of bus-2 without the installation of SSSC

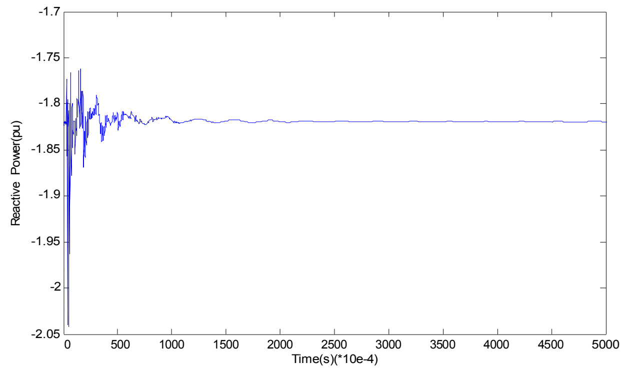

Figure 6. Reactive power of bus-2 without the installation of SSSC

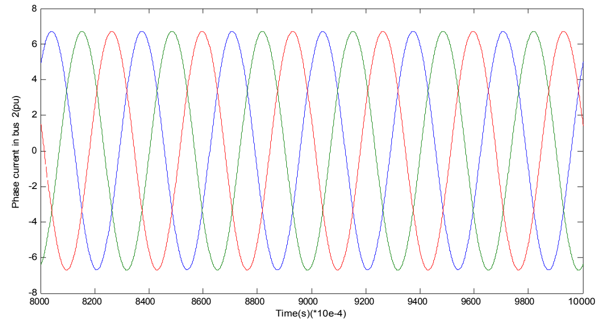

Figure 7. Current of bus-2 without the installation of SSSC

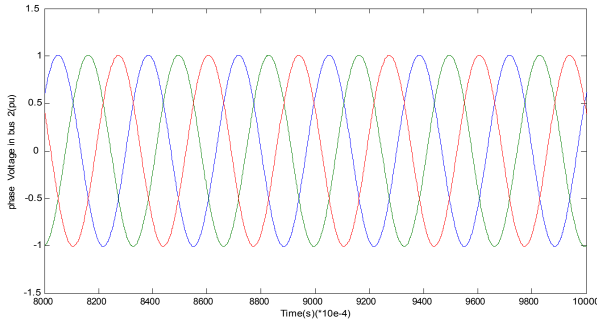

Figure 8. Voltage of bus-2 without the installation of SSSC

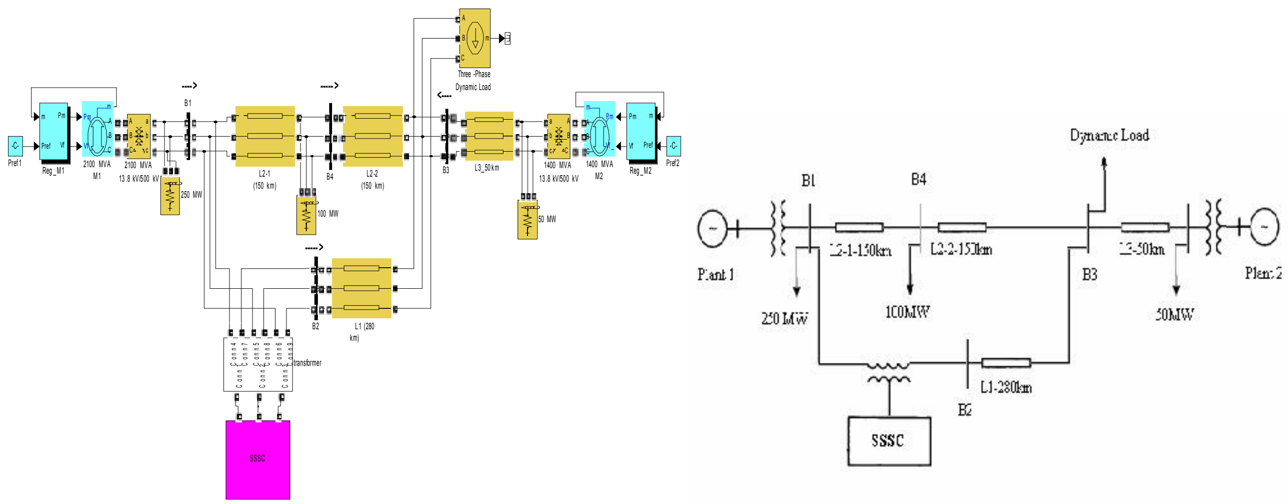

Figure 9. Two machines system with SSSC

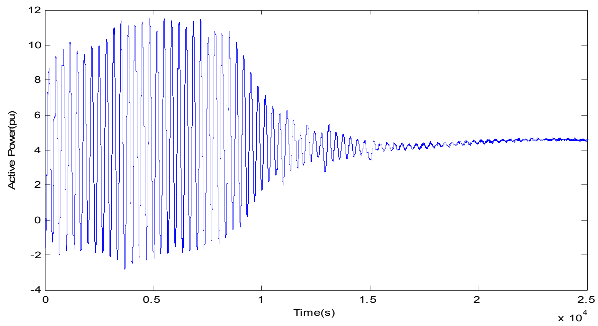

Figure 10. Active power of bus-2 in the presence of SSSC

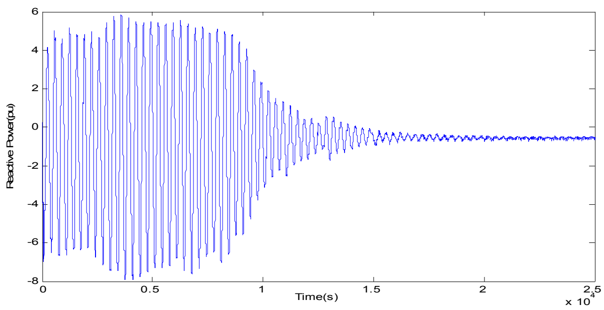

Figure 11. Reactive power of bus-2 in the presence of SSSC

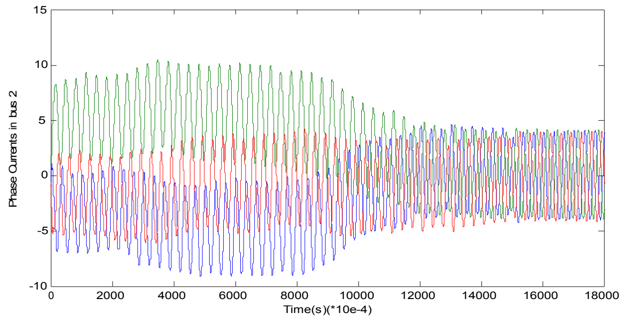

Figure 12. Current of bus-2 in the presence of SSSC

As shown in Fig. 12, Current of bus-2 in the presence of SSSC after transient mode will be in the form of sinusoidal form.

VI. CONCLUSION

It has been found that the SSSC is capable of controlling the flow of power at a desired point on the transmission line. It is also observed that the SSSC injects a fast changing Voltage in series with the line irrespective of the magnitude and phase of the line current.

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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