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Research Paper

POWER SYSTEM STABILITY ENHANCEMENT USING STATIC SYNCHRONOUS SERIES COMPENSATOR

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In this study, a Static Synchronous Seriescompensator (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-3 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: Static Synchronous Seriescompensator (SSSC), FACTS, Tow machine power system, Active and reactive powers

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 (Gyugyi, 1989).

This paper investigates the Static Synchronous Seriescompensator (SSSC)

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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 (Gyugyi, 1994; and Sen, 1998). 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.

SSSC CONFIGURATION

The basic scheme of the SSSC is shown in Figure 1. 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.

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 load centering/getting out. For responding to the dynamic and transient changes created in system, SSSC utilizes the series converter as shown in Figure 2.

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 Figure 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-3, the control circuit as shown in Figure 2 is utilized. For controlling the powers, first, sampling from the voltage and current is done and transformed to the dq0 values. Active and

Figure 1: Static Synchronous Series Compensator

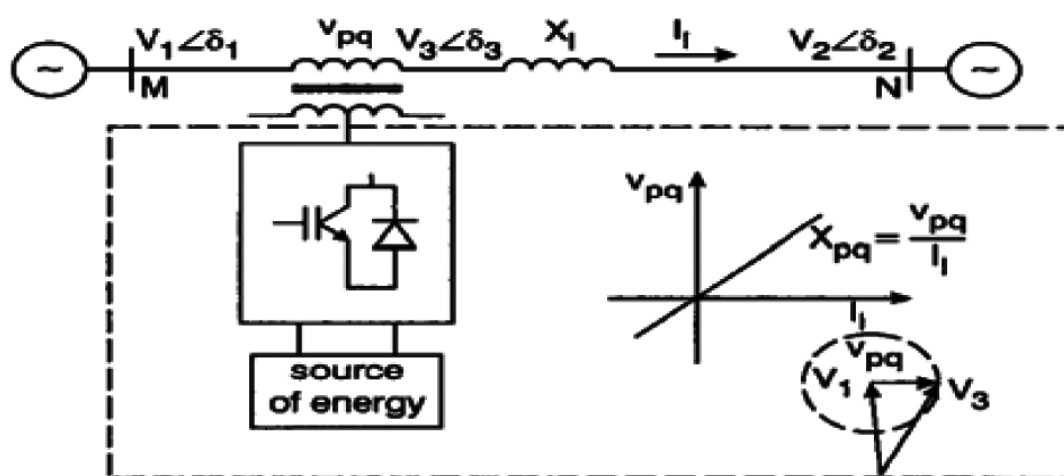
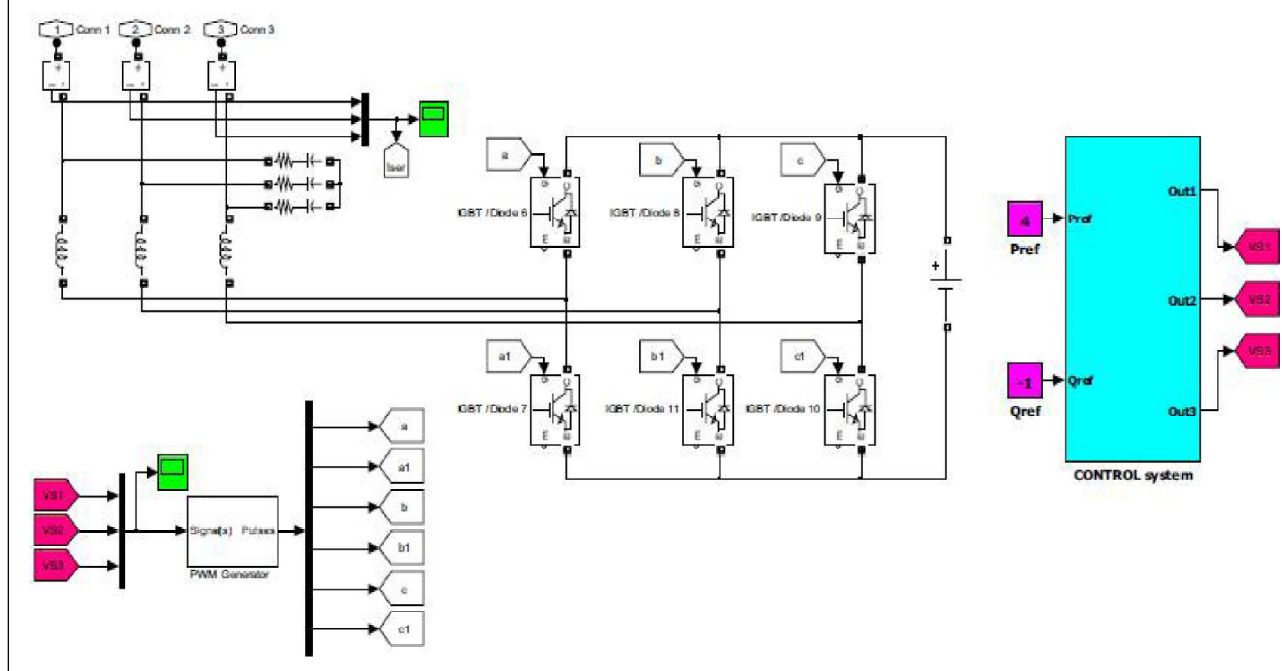
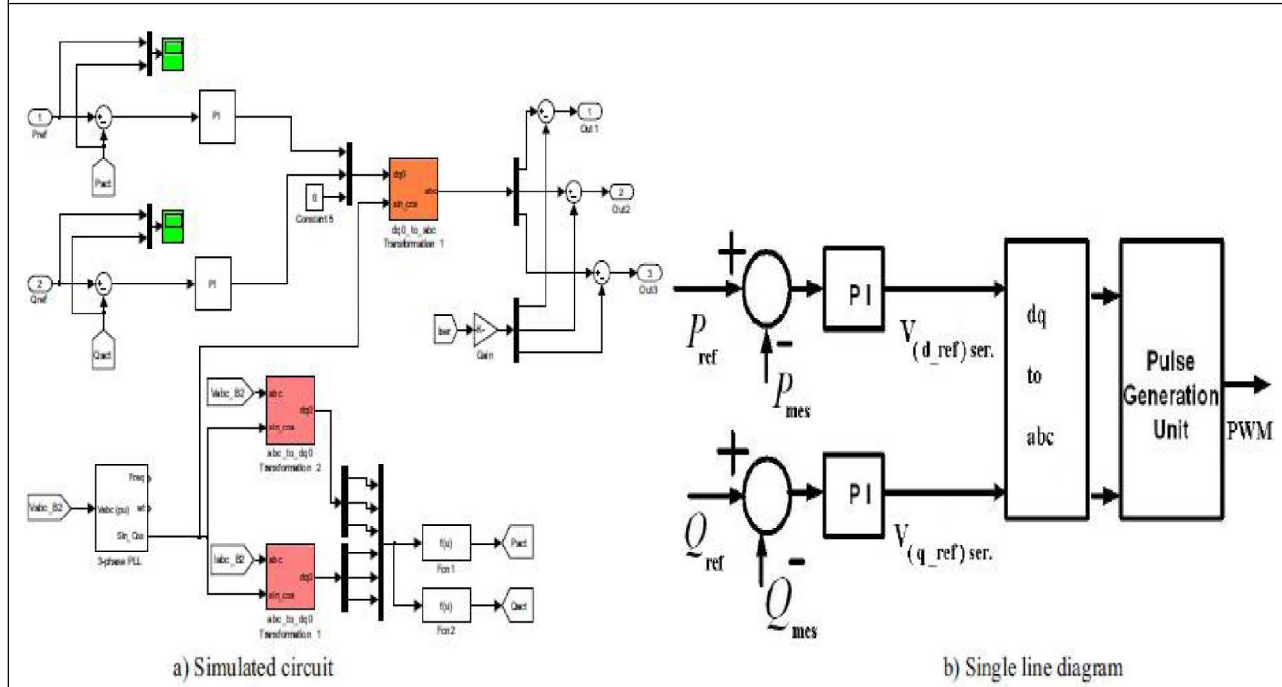


Figure 2: The Converter of SSSC**Figure 3: The Control Circuit of SSSC**

reactive powers of bus-3 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.

TWO MACHINE POWER SYSTEM MODEL

The dynamic performance of SSSC is presented by real time voltage and current waveforms. Using MATLAB software the system shown in Figure 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. Active and reactive powers injected by power plants 1 and 2 to the power system are presented in per unit by using base parameters $S_b = 100$ MVA and $V_b = 500$ KV, which active and reactive powers of power plants 1 and 2 are $(24-j3.8)$ and $(15.6-j0.5)$ in per unit, respectively.

SIMULATION RESULTS WITH MATLAB/SIMULINK

First, power system with two machines and four buses has been simulated in MATLAB

Figure 4: The Configuration of Two Machine Power System

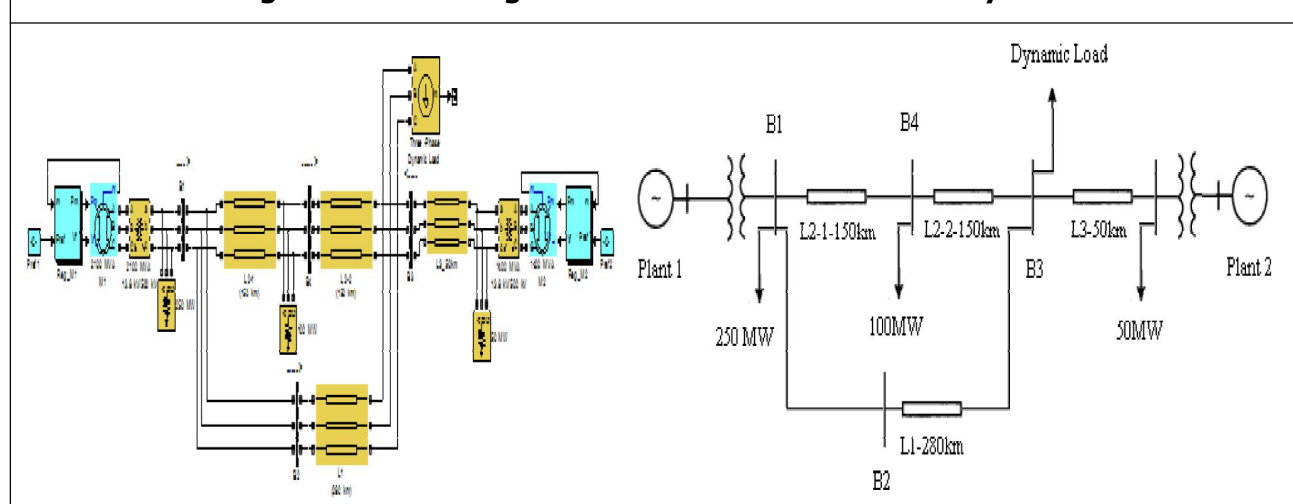


Table 1: Obtained Result from the Simulations

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	-0.059 pu

environment, and then powers and voltages in all buses have been obtained. The results have been given in Table 1. Using obtained results bus-3 has been selected as a candidate bus to which the SSSC be installed. Therefore, the simulation results have been focused on bus-3.

CASE STUDIES

Bus-3 Parameters Without SSSC

Changes in current, voltage, active and reactive powers of bus-3 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-3 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 above mentioned reasons reactive power of bus-3 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-3 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.

Figure 5: Active Power of Bus-3 Without the Installation of SSSC

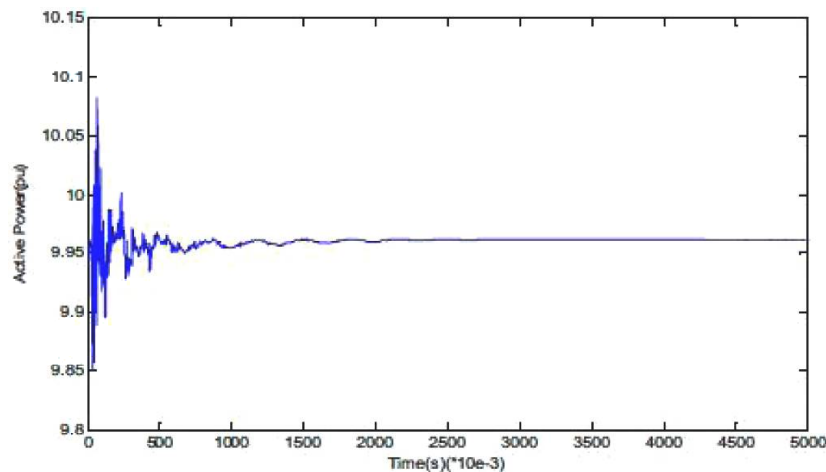


Figure 6: Reactive Power of Bus-3 Without the Installation of SSSC

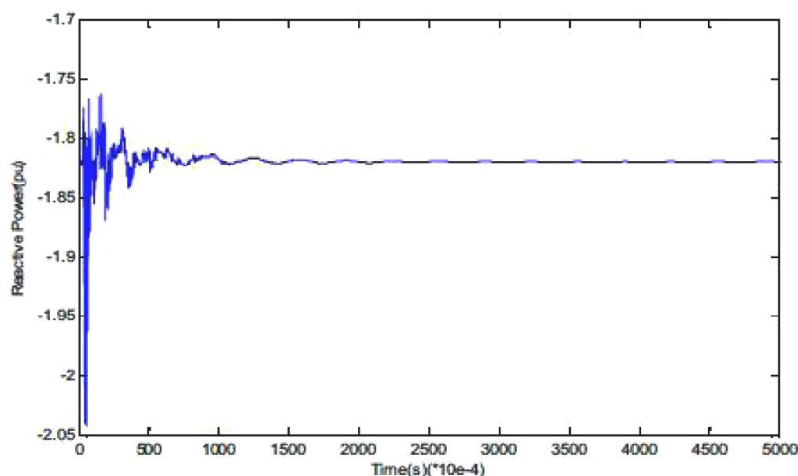
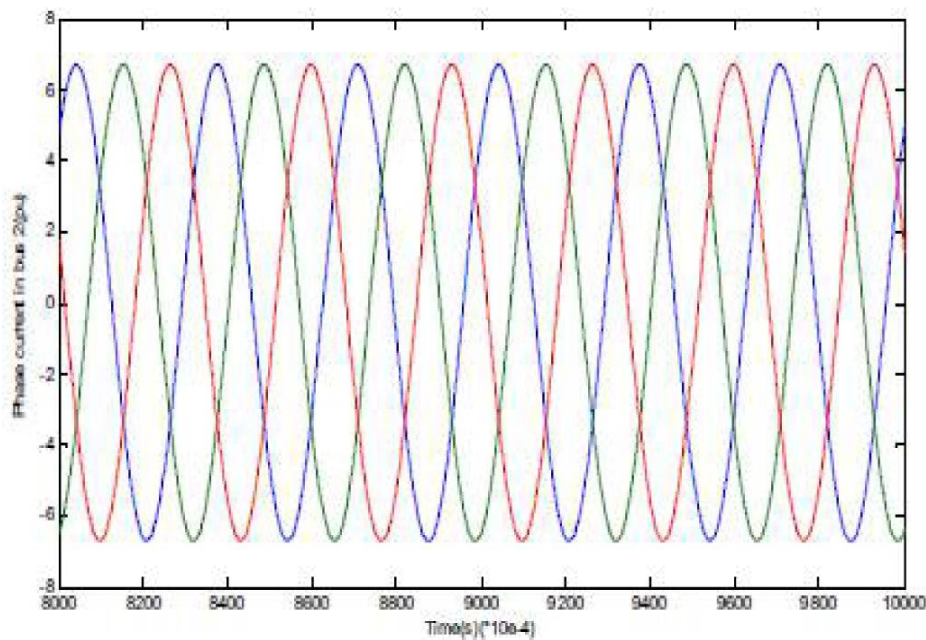
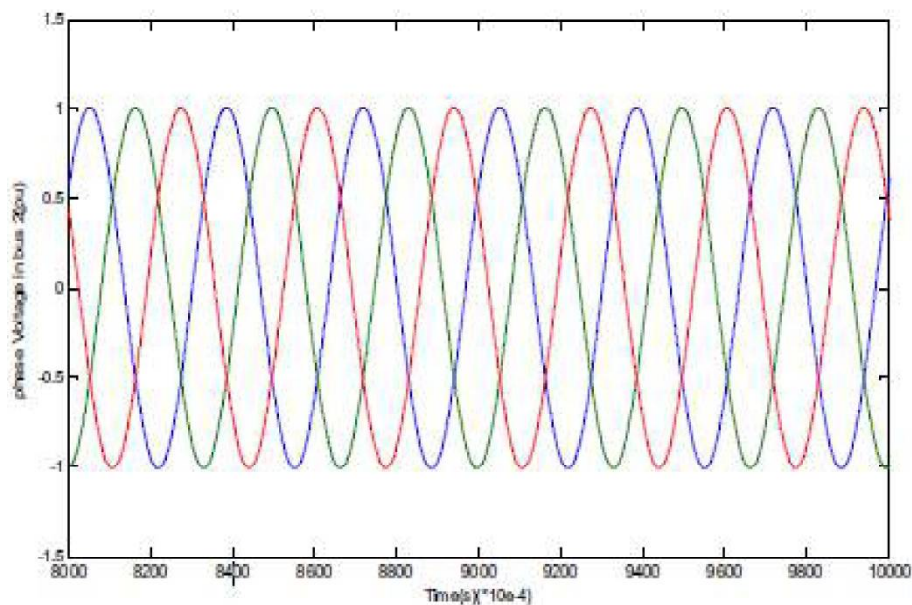
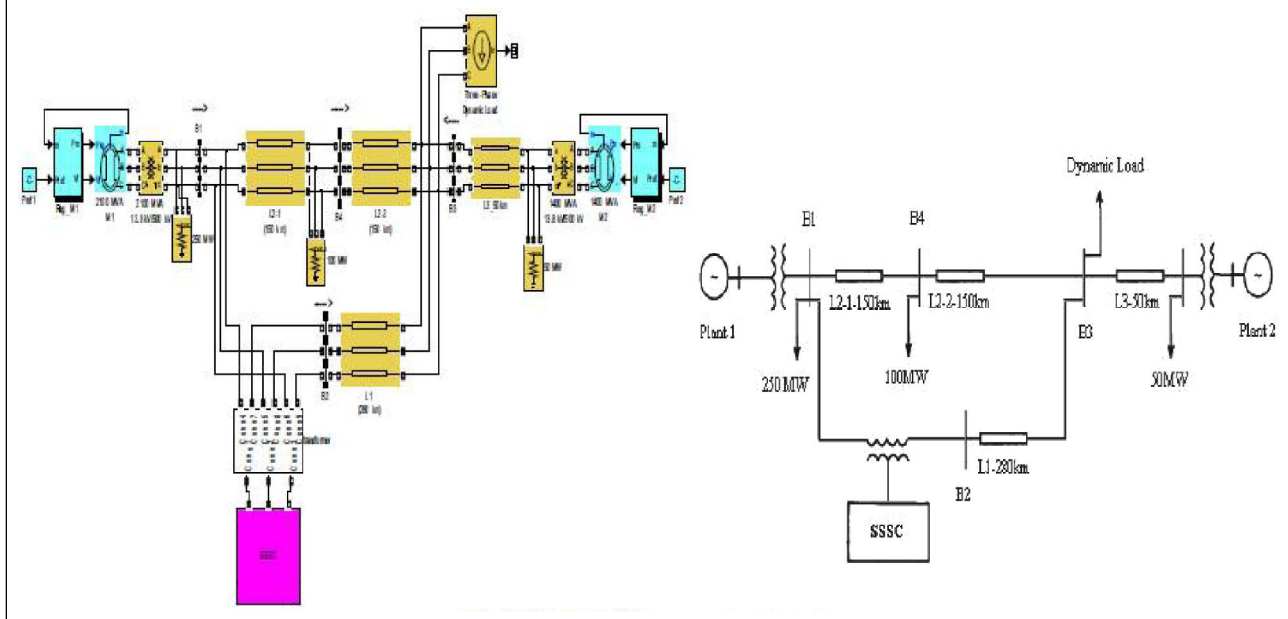


Figure 7: Current of Bus-3 Without the Installation of SSSC**Figure 8: Voltage of Bus-3 Without the Installation of SSSC**

Bus-3 Parameters with SSSC

As shown in Figure 9, SSSC has been placed between bus-1 and bus-3 and the aim is achieving the following active and reactive powers:

The main role of SSSC is controlling the active and reactive powers; beside these SSSC could fairly improve the transient oscillations of system. After the installation of SSSC, besides controlling the power flow in

Figure 9: Two Machines System with SSSC

bus-3 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 Figure 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 Figure 11, reactive power damping time will be decreased and system will follow the references value with acceptable error.

As shown in Figure 12, current of bus-3 in the presence of SSSC after transient mode will be in the form of sinusoidal form.

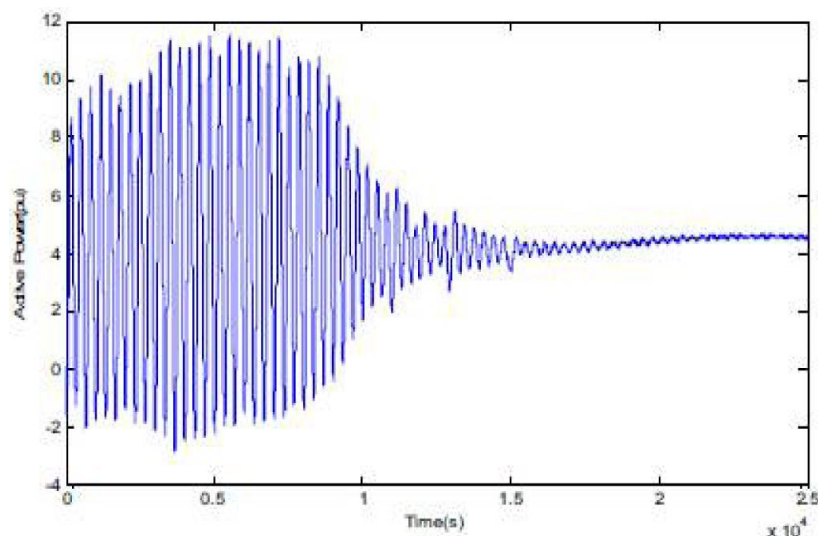
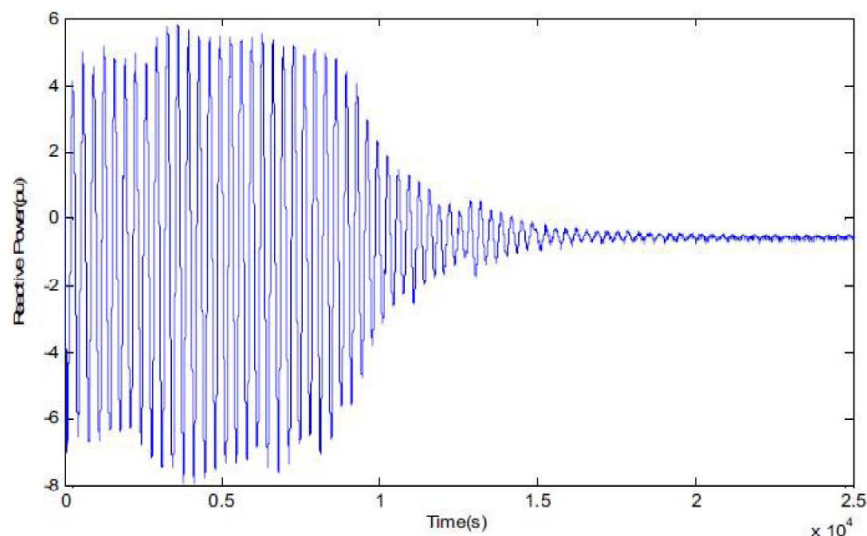
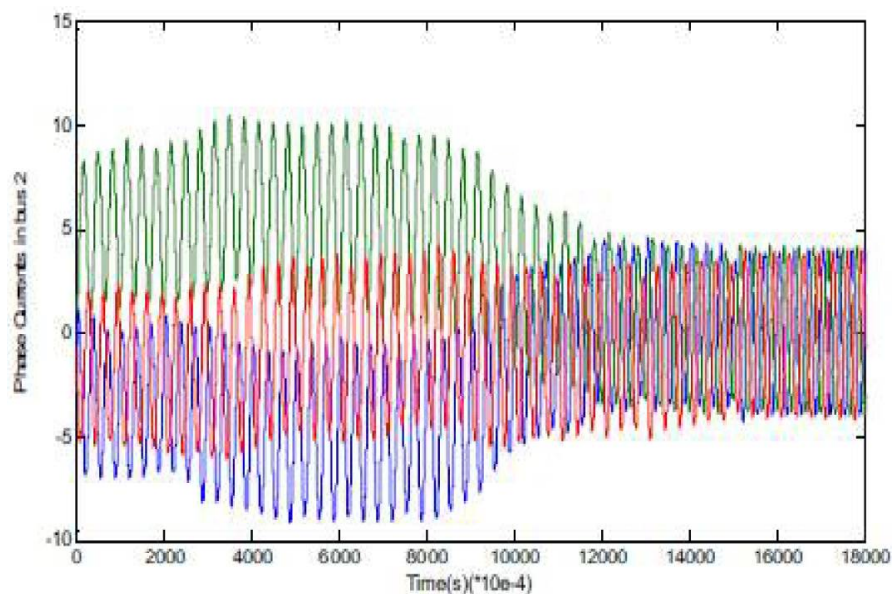
Figure 10: Active Power of Bus-3 in the Presence of SSSC

Figure 11: Reactive Power of Bus-3 in the Presence of SSSC**Figure 12: Current of Bus-3 in the Presence of SSSC**

SIMULATION RESULTS WITH MATLAB/SIMULINK

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-3, 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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