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

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ABSTRACT:The continuous demand in electric power system leads to voltage instability. There may be insufficient reactive power causing voltage drop. The enhancement of voltage stability using static synchronous series compensator (SSSC) improves the system performance such as increase in transmittable power, transmission angle, power factor improvement and decrease line series reactance. Static synchronous series compensator (SSSC) is used to investigate the effect of this device and will be controlling active and reactive power as well as power oscillation damping. The steady state performance of SSSC will be presented using MATLAB software.

KEYWORDS: Active power, reactive power, power factor, Voltage stability, FACTS, Multi-bus system, Static synchronous series compensator (SSSC).

I.INTRODUCTION

In the deregulated power environment, the loads and generations change rapidly, causing certain corridors to be loaded to thermal limits. A small disturbance in the system, may lead to catastrophic failure resulting in complete blackout. In case, a line is overloaded or a contingency has occurred such as loss of line, or loss of large generator, the balance of load and generation in the system is distributed causing some of the lines to be overloaded. Therefore, a secure, stable and reliable operation of power system has become a serious challenge in the emerging electricity market scenario. The continuous growth in power demand and supply along with the limited expansion of transmission network changes the power flow pattern in the power system in such a way that some of the lines are overloaded. The flexible AC Transmission systems (FACTS) controllers find their enhanced application areas to resolve some of the challenges to ensure the proper power flow control, voltage control and stability enhancement.

The FACTS devices (Flexible AC Transmission Systems) could be a means to carry out this function without the drawbacks of the electromechanical devices such as slowness and wear. FACTS can improve the stability of network, such as the transient and the small signal stability, and can reduce the flow of heavily loaded lines and support voltages by controlling their parameters including series impedance, shunt impedance, current, voltage and phase angle. Controlling the power flows in the network leads to reduce the flow of heavily loaded lines, increased system loadability, less system loss and improved security of the system.

The static synchronous series compensator (SSSC) FACTS controller is used to prove its performance in terms of stability improvement. 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. 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.

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II.SSSC CONFIGURATION

SSSC is basically a solid state VSC(Voltage Source Converter) attached in series to the transmission line and it generates the controllable AC voltages in quadrature to the line current. It provides virtual compensation of the line impedance by inserting the controllable voltage in the line which in turn controls the amount of real power transmitted by the network [2]. By controlling the magnitude and polarity of injected voltage (V) we can control the compensation level. It can be operated in both inductive as well as capacitive mode as per power system requirement. With DC energy source like battery, SSSC is capable for injecting real power in three systems. As a energy storage device we used DC link capacitor connected to DC side of the VSC. The VA rating of insertion transformer and converter of SSSC is depend on maximum line current (Imax) and maximum injected voltage (Vqmax).

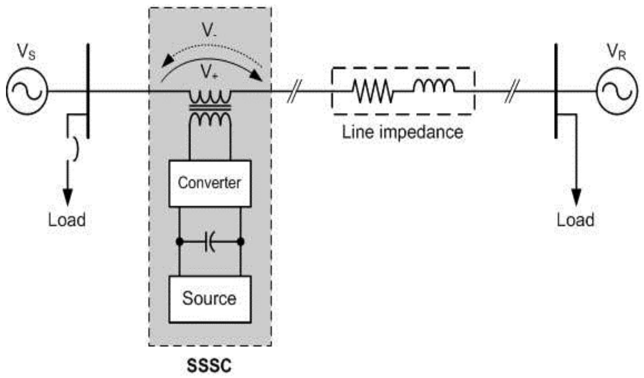

Figure 1. Basic configuration of SSSC

III.MODELLING OF THE PROPOSED FOUR BUS SYSTEM

The dynamic performance of the SSSC is presented by real time voltage and current waveforms obtained after simulation. The simulation diagram for a two machine four bus system is given below. In this system SSSC is used for controlling the power flow through a 220KV transmission system. The system which has been made in ring mode consisting of four buses(B1-B4),connecting each other by transmission lines L1,L4, L2 and L3 having length 150KM,150KM, 75KM and 50KM respectively. The system has been supplied by two power plants with phase to phase voltage 11 KV. The simulation results obtained for bus 2 is given below. The SSSC has been connected to a bus that shows more variations in real and reactive power values.

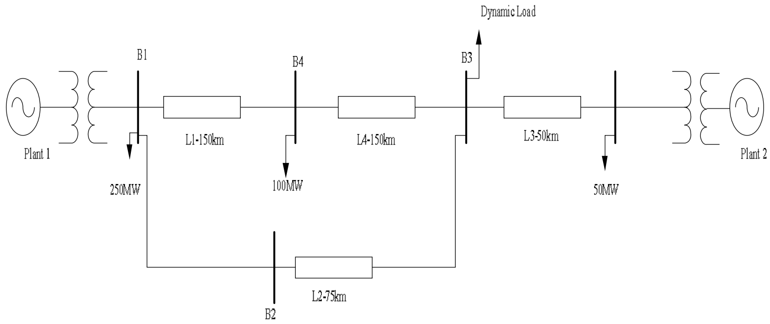

Figure 1:Two Machines Four Bus System Without SSSC

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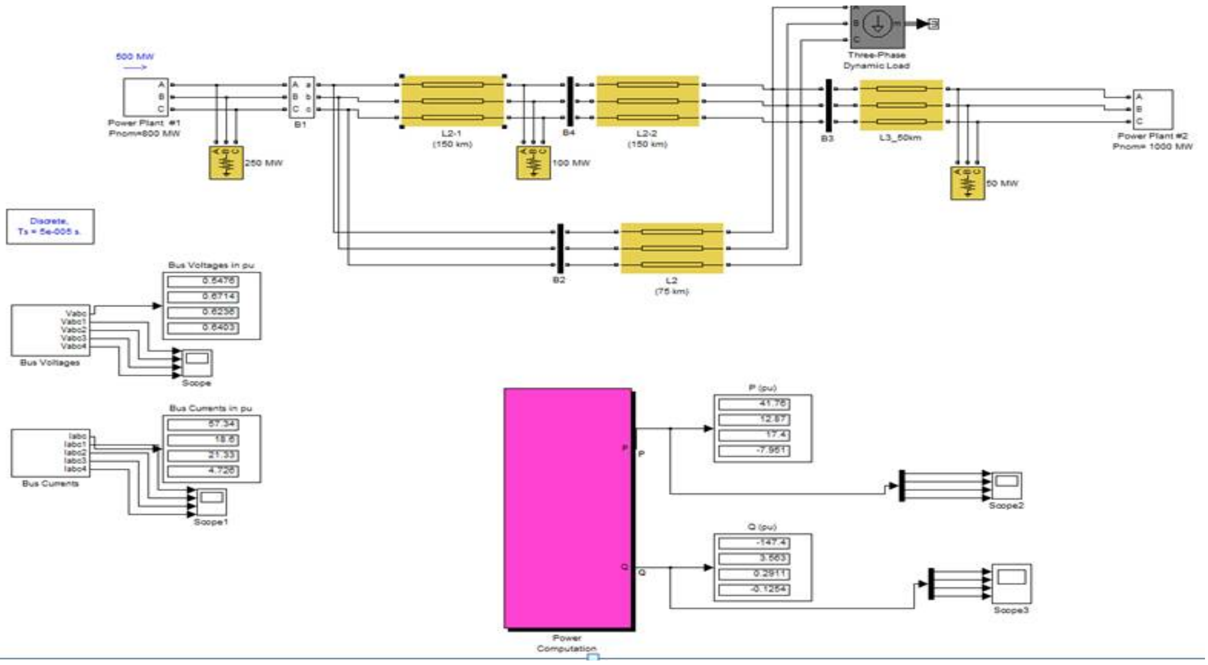

Figure 2 . Two machine four bus system without SSSC

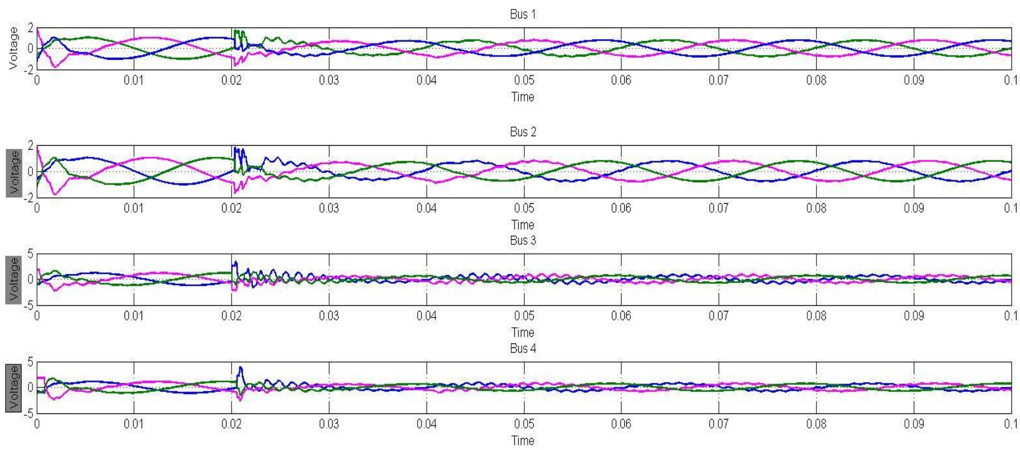

Figure 3 : Voltage Waveform of Four buses without SSSC

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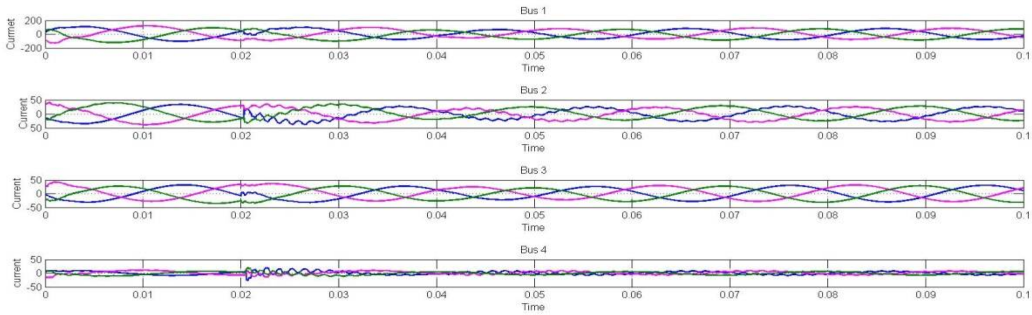

Figure 4 : Current Waveform of Four buses without SSSC

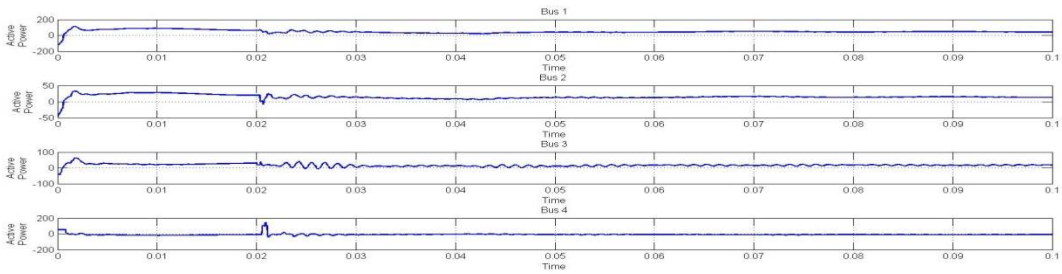

Figure 5 : Active Power Waveform of Four buses without SSSC

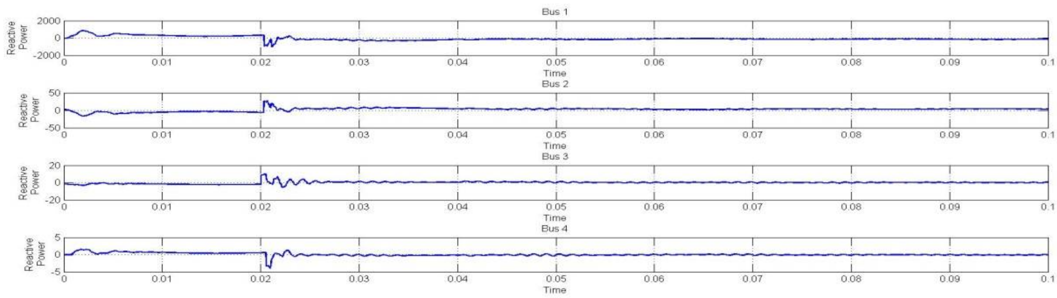

Figure 6 : Reactive Power Waveform of Four buses without SSSC

IV.TWO MACHINES FOUR BUS SYSTEM WITH SSSC

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 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. According to the Fig., 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, reactive power damping time will be decreased and system will follow the references value with acceptable error.

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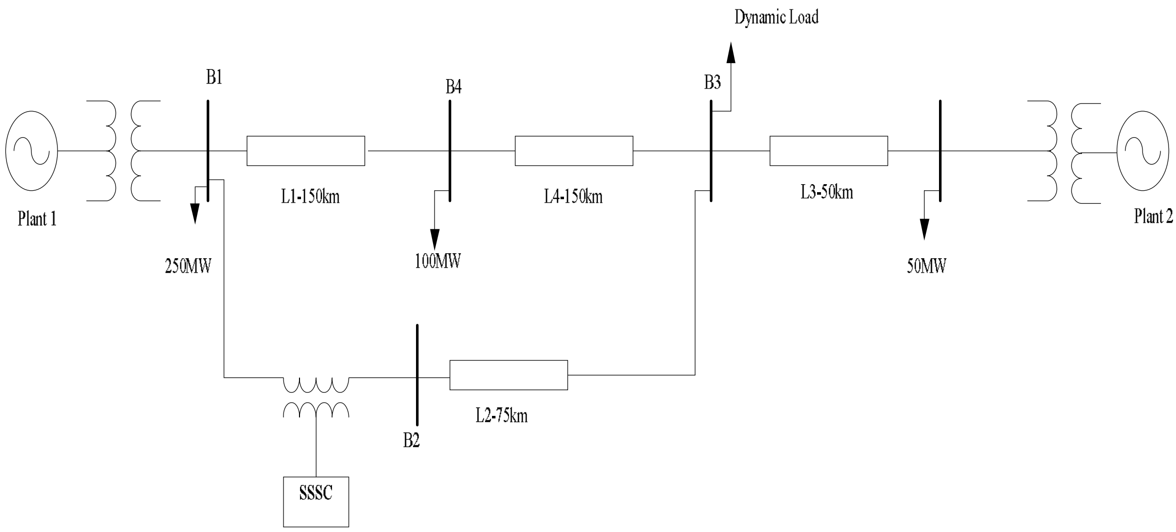

Figure 7:Two Machines Four Bus System With SSSC

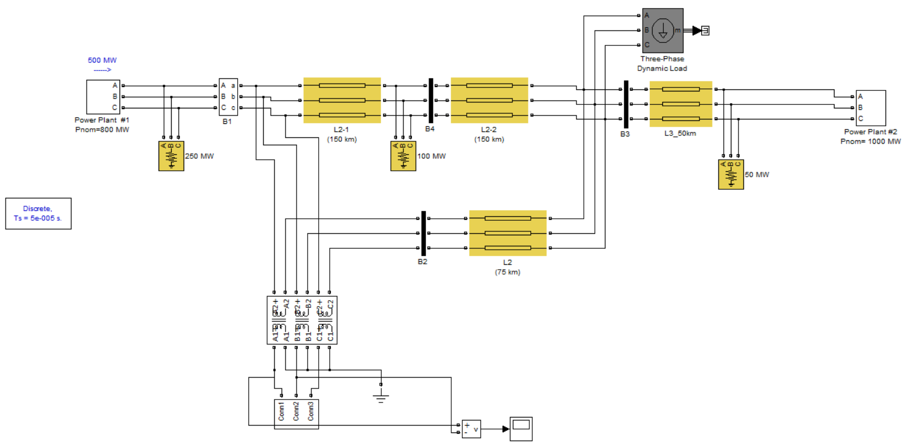

Figure 8 : Two machine Four bus with SSSC Connected in Series with Bus 2 (B2)

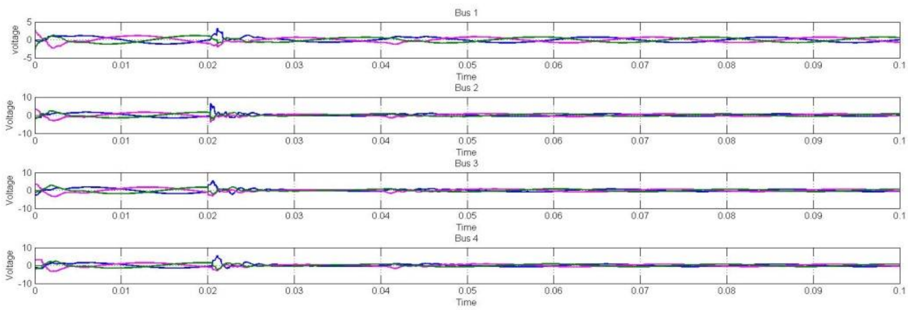

Figure 9 : Voltage Waveform of Four buses with SSSC Connected in Series with Bus 2 (B2)

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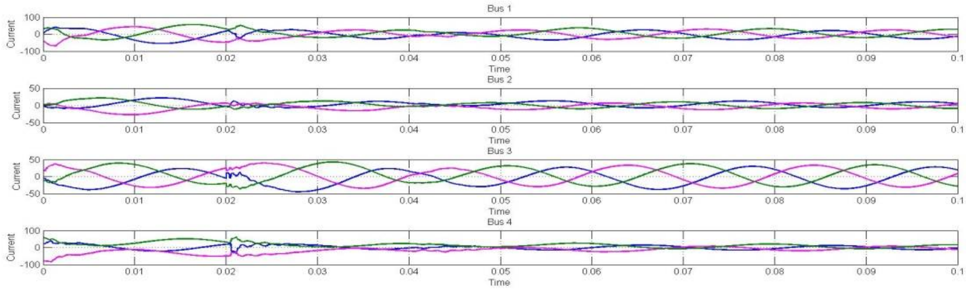

Figure 10 : Current Waveform of Four buses with SSSC Connected in Series with Bus 2 (B2)

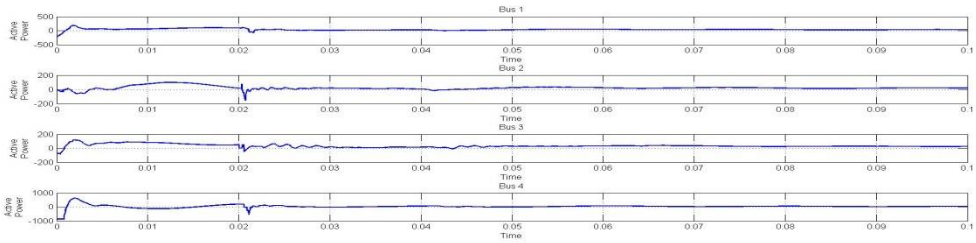

Figure 11 : Active Power Waveform of Four buses with SSSC Connected in Series with Bus 2 (B2)

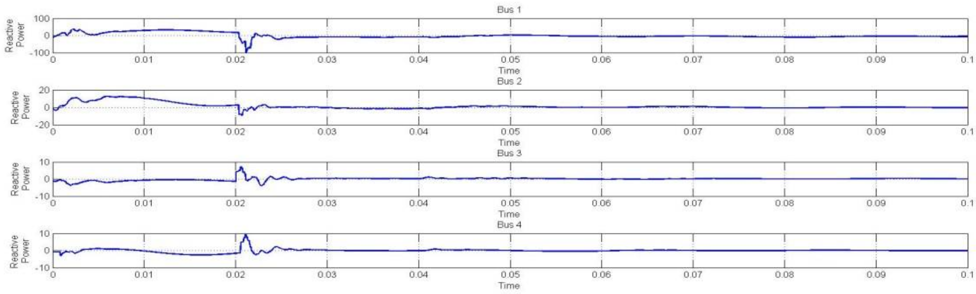

Figure 12 : Reactive power Waveform of Four buses with SSSC Connected in Series with Bus 2 (B2)

V. RESULTS

The performance of the SSSC is presented by real time voltage and current waveforms obtained after simulation. The simulation diagram for a two machine four bus system is given below. In this system SSSC is used for controlling the power flow through a 220 KV transmission system. The system which has been made in ring mode consisting of four buses(B1-B4),connecting each other by transmission lines L1, L4, L2 and L3 having length 150KM,150KM, 75KM and 50KM respectively. The system has been supplied by two power plants with phase to phase voltage 11 KV. The simulation results obtained for bus 2 is given below. The SSSC has been connected to a bus that shows more variations in real and reactive power values.

Power system with two machines and four buses after incorporating SSSC has been simulated in MATLAB environment, and then powers and voltages in all buses have been obtained. The results have been given in Table 8.2 Obtained results of bus-2 had proven that the improvement in active power, reactive power and power factor. After changing the voltage source inverter of SSSC input, the power should be changes and also improve the power factor shown in table 1 and table 2.

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A. Simulation result of Two Machine System without SSSC

Bus	V (pu)	I (pu)	P (pu)	Q (pu)	S (pu)	Power Factor
1	0.54	57.34	41.76	-14.7	44.27	0.9433
2	0.67	18.6	12.87	3.563	13.35	0.9640
3	0.62	21.33	17.4	0.2911	17.402	0.9999
4	0.64	4.73	7.951	-0.1254	7.95	1.0000

Table 1 : Simulation Result without SSSC

B. Simulation Result of Two Machine System with SSSC

Bus	V (pu)	I (pu)	P (pu)	Q (pu)	S (pu)	Power Factor
1	0.63	25.57	35.68	-7.32	36.423	0.9796
2	0.63	8.94	18.88	-0.514	18.886	0.9997
3	0.60	32.53	25.27	0.1136	25.2702	1.0000
4	0.57	12.44	41.33	-0.009	41.33	1.0000

Table 2 : Simulation Result with SSSC

VI. CONCLUSION

Static synchronous series compensator is capable of enhancing the power flow through the transmission system by injecting a fast changing voltage in series with the line. It is also observe that the SSSC injected voltage is in quadrature with line current. Based on obtained simulation result the performance of SSSC has been examined in multi-machine system. Here the performance of SSSC is presented by the real time voltage and current waveforms obtained after the simulation of a four bus system. The application of this can be extended to a multi machine multi-bus system to investigate the problems related to stability.

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