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Power system stability enhancement using Static Synchronous Series Compensator (SSSC)

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ABSTRACT: Day by day the demand of electric power system is increased and due to this continuous demand in electric power system network is becoming more complex and heavily loaded and leading tovoltage instability. This paper presents the enhancement of voltage stability as well as damping power system oscillation in transient mode. In this study FACTS device (SSSC) static synchronous series compensator is used to investigate the effect of this device in controlling active and reactive power as well as damping power system oscillations. The SSSC is equipped with a source of energy in DC link, which can supply or absorb the active and reactive power to or from the line. PI controller is used to tune the circuit. For the simulation purpose, the model of multi-machine power system without and with SSSC controller is developed in MATLAB/SIMULINK using Sim Power System (SPS) block set.

KEYWORDS:static synchronous series compensator(SSSC), active and reactive power, proportional integral controller, two machine power system.

I. INTRODUCTION

In recent year, the increase in electrical energy demand has presented higher requirement. Due to increasing demand of electrical energy more substations, power plant, transmission line needs to be constructed. Increasing demands and the need to provide open access electricity market for generating companies have created tendencies towards less security and reduce quality of supply. The power system of today, are mechanically controlled. However there are so many draw backs of using mechanical devices in power grid. In case of mechanical controlled circuit breaker long switching period make them difficult to handle the frequently changed loads and damp out transient oscillation quickly. In order to compensate these draw back large operational margin are maintained to protect the system from variations and also recover from fault. The problem with mechanical device is that the control cannot be initiated frequently, because such types of mechanical device tends to wear out very quickly as compared to static device. Sever black outs were happens in power grid and these have revealed that the conventional transmission system are not able to manage the control requirement of complicated interconnections. Hence the investment is necessary for the studies into the stability and security of power grid also for the transmission system. Based on the success of research in power electronics switching devices FACTS has become the technology of choice in active & reactive power flow control, voltage control and damping power system oscillation that improves the operation and functionality of existing power transmission system.

In this paper the (SSSC) static synchronous series compensator FACTS controller is used for the purpose of stability improvement. A static synchronous series compensator (SSSC) device is the member of FACTS family, which is connected in series with transmission line i.e. with power system. It consist of a solid state voltage source converter (VSC) which is the main part of the static synchronous series compensator. A solid state voltage converter (VSC) generates a controllable AC voltage at fundamental frequency. when the injected voltage is kept in quadrature with line current, it can imitate as inductive reactance or capacitive reactance to control the power flow through transmission line. Here PI controller is used to control parameter of the system.

II.WORKING PRINCIPLE OF SSSC

A transmission line needed controllable compensation for power system stability and voltage regulation. This can be achieved by using FACTS device. Static Synchronous Series Compensator (SSSC) is the important series FACTS controller which is capable of providing

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reactive power compensation to a power system. SSSC consist of a solid-state
Voltage source converter which injects an almost sinusoidal voltage, of variable magnitude in series with the transmission line.

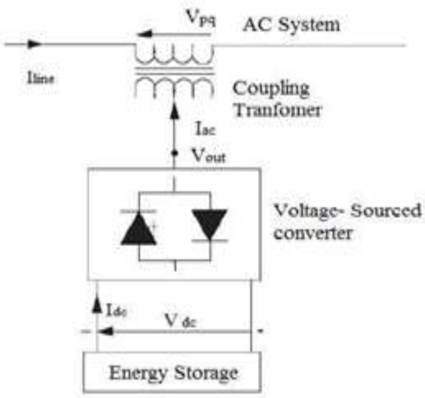

Fig1(a) : Static synchronous Series Compensator

The fig.1 shows the functional model of SSSC, it consists of coupling transformer, voltage source converter and source of energy. In SSSC the dc capacitor is replaced by the energy storage device like a high energy battery installation to allow active and reactive power exchange with the AC system. The phase displacement of the inserted voltage Vpq, with transmission line current I, determines the exchange of real and reactive power

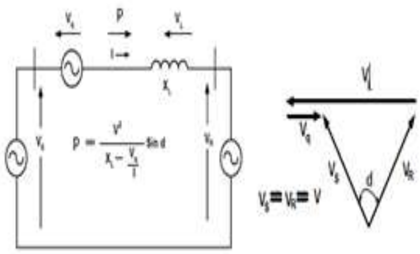

Fig 1(b) Elementary two machine system with an SSSC and phasor diagram.

The SSSC injects compensating voltage in series with transmission line irrespective of the line current. Hence
the transmitted power become the parametric function of the injected voltage and can be expressed by using following equations.

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

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

XL = inductive reactance
Vs= sending end voltage source
Vr = receiving end voltage source
For simplicity, the voltage magnitude are chosen such as
Vs = Vr =V
Thus, SSSC can increased the transmittable power and also it can be decreased, simply by reversing the polarity of the injected AC voltage.

III. CONTROL SYSTEM OF SSSC

In case of SSSC the injected voltage and current to the circuit are changing depend upon the system condition and load entering/getting out. SSSC utilize the series converter for responding to the dynamic and transient changes created in system. One side of the converter is connected to the AC system and other side of converter is connected to a capacitor and battery which is assume as DC source as a battery in the system. The energy of battery will be converted into the AC form by converter and then injecting this voltage to the circuit, the change will be damped appropriately.

Fig. 3 shows the control circuit of SSSC, which is used to control active and reactive power of Bus-2. For controlling active and reactive power, first, sampling from the voltage and current is done then abc to the dq0 transformation is done. Active and reactive power of Bus-2 are calculated using voltage and current values in dq0 references and compared
this active and reactive power with the determined references and produces error signal, which is given to the PI controllers. By adjusting parameter of the PI controllers, we are trying to achieve the zero-signal error, such that power can follow the reference powers precisely. Then, the output of controllers are transferred to the abc values and given to the PWM generator, which generates desired pulses. These pulses are given to the VSC for triggering IGBTs which generates a controllable alternating current voltage at fundamental frequency. This voltage is given to the AC system through coupling transformer in quadrature with line current, it can emulate as inductive or capacitive reactance so as to influence the power flow through transmission line.

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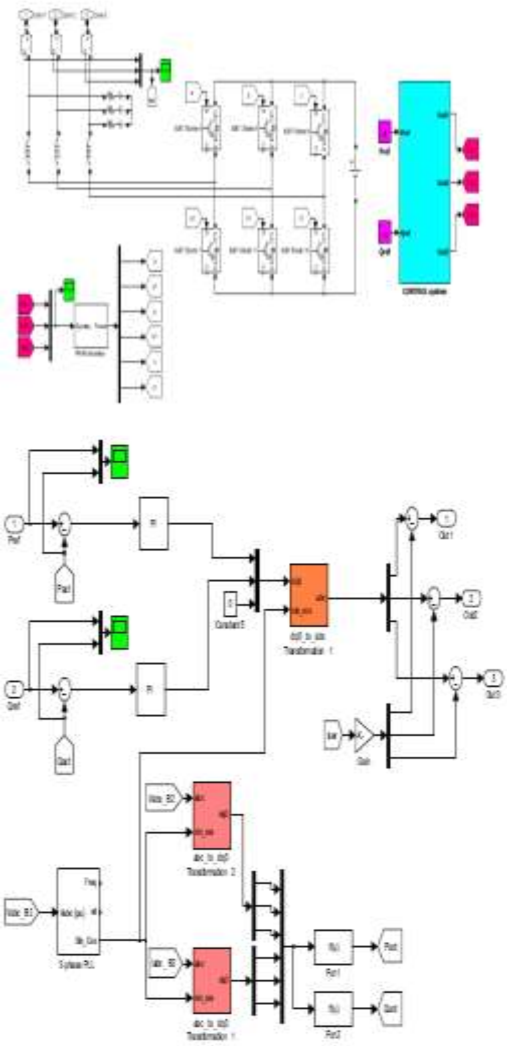

Fig:2.Control circuit of SSSC in Matlab/Simulink

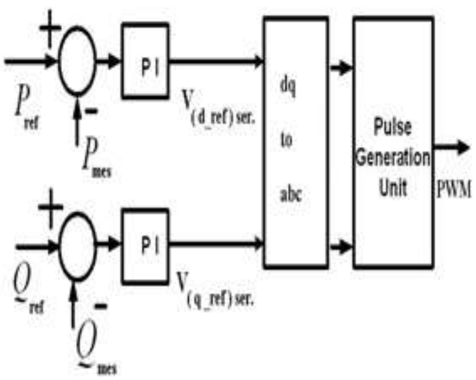

Fig .3 Single line diagram of control system

IV . TWO MACHINE POWER SYSTEM MODELING

In this paper we take two machine power system with and without SSSC. The dynamic performance of SSSC is presented by real time current and voltage waveforms, using MATLAB software. The two-machine power system with and without SSSC are shown in fig.4 and fig.9 respectively.

A. Two machine power system without SSSC

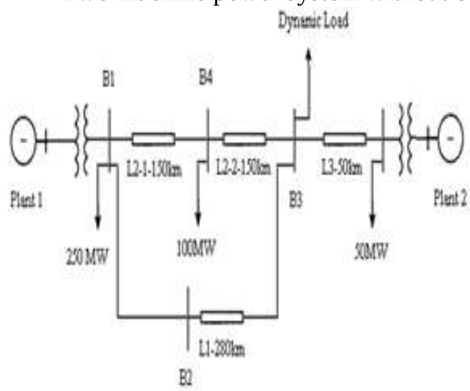

Fig 4. Two machine power system without SSSC

Fig .4 shows the two-machine system which has been made in ring mode consisting of 4 buses- B1 to B4 connected to each other by three phase 500kv transmission lines L1, L2-1, L2-2 and L3s.system has been supplied by two power plants with phase-to-phase voltage equal to 13.8KV.

Active and reactive power of plant 1 and plant 2 of the power system are presented in per unit by using base parameters Sb=100MVA and Vb= 500KV. Active and reactive power of power plants 1 and 2 are (24-j3.8) and (15.6-j0.5) in per unit respectively.

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Table I: Values of System Parameter

S.N.	SYSTEM QUQNTITES	STANDARD
1.	Synchronous machine 1	2100MVA, 13.8KV, 60HZ
2.	Transformer 1	2100MVA, 13.8KV/500KV
3.	Synchronous machine 2	1400 MVA, 13.8KV,60HZ
4.	Transformer 2	1400 MVA, 13.8/500KV
5.	Loads On –B1 B2 B3 B4	250MW 2.2e+009W 1e+008VAR 50MW 100MW
6.	Line length	L1- 280km, L2_1 - 150km, L2_2- 150km, L3-50km

V.SIMULATIONRESULTS IN MATLAB/SIMULINK

Firstly two machine power system without SSSC has been simulated in MATLAB/SIMULINK environment. Then we got the power, voltage and current of all buses, as shows in following table II. Due to large load on power system bus-2 got oscillate and continuing this oscillations for few second. Our aim is to damped out that oscillations to make system stable and healthy, thus bus-2 has been selected as a candidate bus to which the SSSC be installed. Therefore simulations results have been focused on bus-2.

Table II: Obtained values without SSSC

Bus no.	Voltage	Current	Active power	Reactive power
1	1 PU	13.5 PU	20.05 PU	-3.76 PU
2	**1.007 PU**	**6.7 PU**	**9.97 PU**	**-1.82 PU**
3	1 PU	10 PU	14.83 PU	-0.49 PU
4	1 PU	5.55 PU	8.44 PU	-0.58 PU

The results of active power, reactive power, current and voltage of bus two are shown in below fig.

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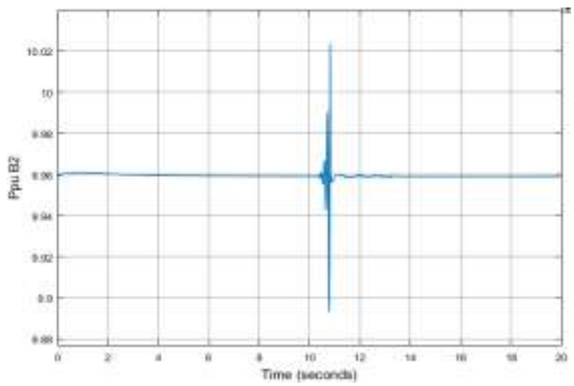

Fig 5. Active power of bus-2 without SSSC

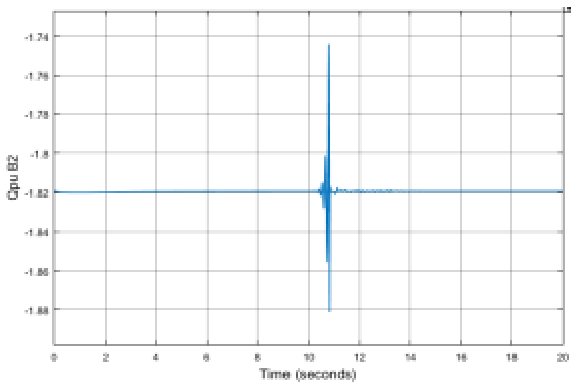

Fig 6. Reactive power of bus-2 without SSSC

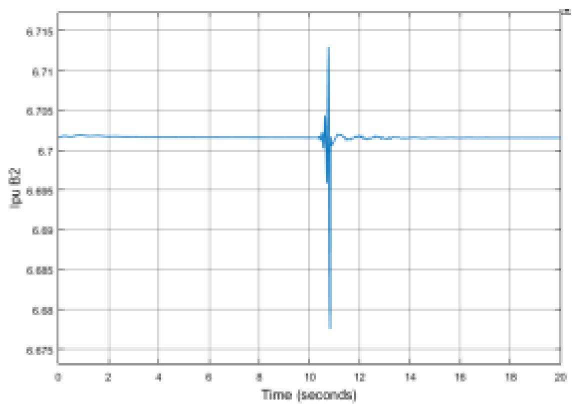

Fig 7. Current of bus-2 without SSSC

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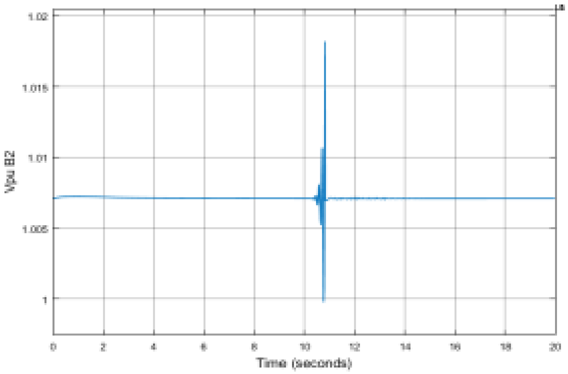

Fig 8. Voltage of bus-2 without SSSC

VI. CASE STUDY

1. Bus-2 parameters without SSSC

Above results shows that the change in current, voltage, active and reactive power of bus-2 have been obtained in MATLAB/SIMULINK . from fig 5 and fig.6 at first due to large load on system active power and reactive power of bus-2 got oscillation which keep continuing for 3 second. And these oscillations are damped out by using SSSC.

Two machine power system with SSSC is shown in fig.9. in which SSSC has been placed in between bus-1 and bus-2. The aim is achieving following active and reactive powers and damping Oscillations in min

Pref= 11pu and Qref=-1pu

The main role of SSSC is controlling active and reactive power and damping power system oscillations. And increase power flow through transmission line

2. Bus-2 parameters with SSSC

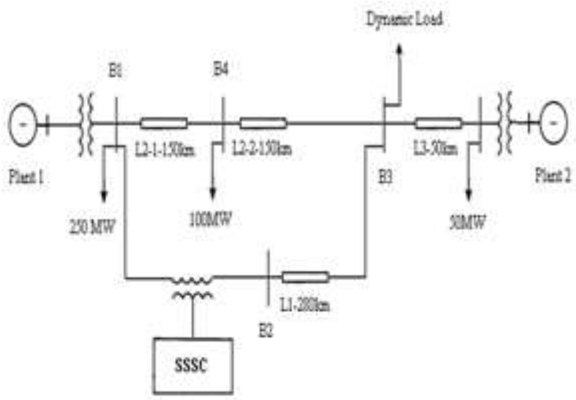

Fig.9 Two machine power system withSSSC

After the installation of SSSC, besides controlling active and reactive power of bus-2, we want to keep constant voltage value i.e. 1 per unit. Hence the results of SSSC after the installation of SSSC are shown in following figs. According to fig.10 by installing SSSC, active power damping time will be less than the mode without SSSC and it will be damped faster. Also from fig.11 reactive power damping time of bus-2 will be decreased and system follow the references value with acceptable error.

Table III: Obtained values with SSSC

Bus no.	Voltage	Current	Active power	Reactive power
1	1 PU	13.5 PU	19.99 PU	-4.74 PU

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2	**0.9945 PU**	**7.6 PU**	**11.26 PU**	**-1.84 PU**
3	1 PU	9.8	14.82	-0.24 PU
4	1 PU	4.6 PU	7.09 PU	-0.24 PU

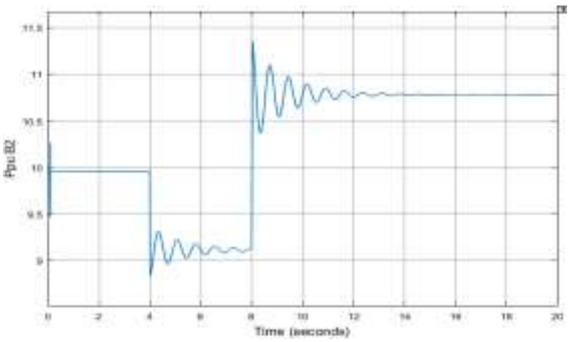

Fig 10. Active power of bus-2 in presence of SSSC

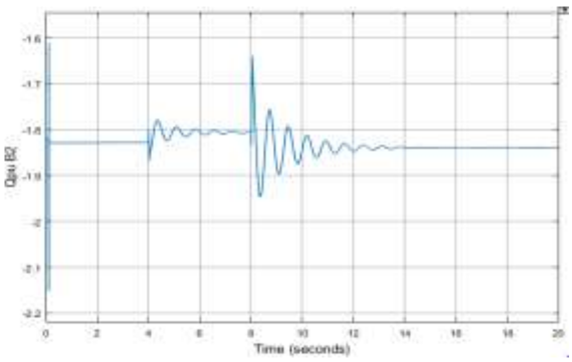

Fig 11. Reactive power of bus-2 in presence of SSSC

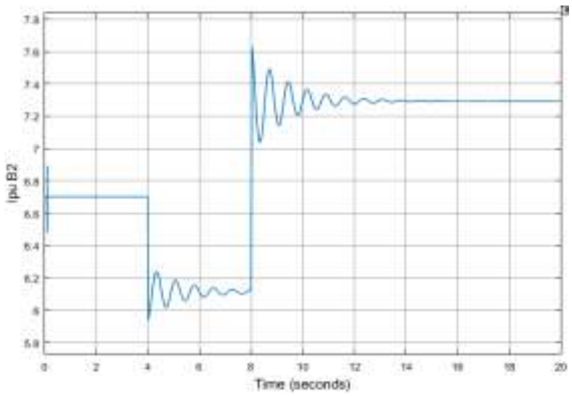

Fig 12. Current of bus-2 in the presence of SSSC

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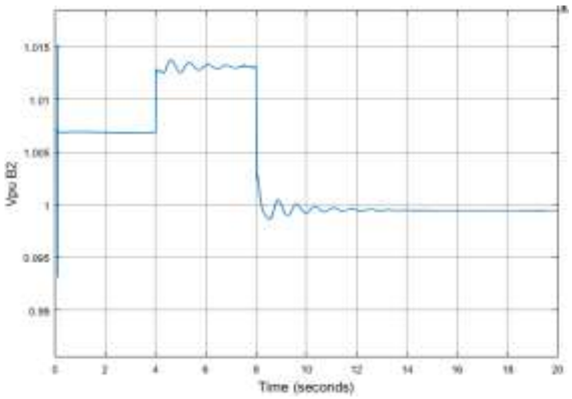

Fig 13. Voltage of bus-2 in the presence of SSSC

VI. CONCLUSION

It has been found that the SSSC has ability to control theflow of active and reactive power at a desired point on the transmission line. Also it is observed that the SSSC injects a fast changing voltage inseries with the line irrespective of the magnitude and phase ofthe line current. From simulation results theperformance of the SSSC has been examined in two machine system, and applications of the SSSC will be extended in future to a complicated systemto investigate theproblems related to the different modes of power system oscillation inthe power systems.

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