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Enhancement of Multi Machine Power System Stability Using SSSC with Power Oscillation Damping (POD) Controller

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ABSTRACT

The increasing demand in power system causes heavily loaded lines which results into voltage instability. The voltage instability takes place due to lack of reactive power, which would causes black-out. FACTS controller provides solution for such difficulties. In this project SSSC have been used in multi machine system for controlling flow of active as well as reactive power. The static synchronous series compensator is delivers a compensating voltage with an inductive or a capacitive range so as to improve voltage stability of the system. In the same system , Power oscillation damping (POD) controller is used along with SSSC to examine its performance when unsymmetrical faults were applied in the system. The performance of SSSC based POD controller in multi machine system were discussed in this paper by constructing MATLAB/SIMULINK model with unsymmetrical faults in it and obtaining voltage, active power, reactive power waveform from the same.

Keywords: SSSC based POD controller, SSSC in Multi-Machine system, Multi-Machine system Stability

I. INTRODUCTION

Now a day's demands on the power system has increased as a result of the increasing population and industrialization. Which results into excessive loading on the present transmission network [1]. However it has some limits like thermal and stability limit. FACTS controller helps to improve the transient stability, may reduce the flow of densely loaded lines and support system voltages. Power flow control within the network results into reduce the flow of densely loaded lines, reduced losses and rise in system security .A Static Synchronous Series Compensator is connected in series with a power system and have ability to control the active as well as reactive power flow. The SSSC controller principally depends on output of VSC which utilizes thyristor switches. The SSSC incorporates transformer ,VSC along with DC capacitor. The SSSC produces an AC voltage with variable magnitudes in quadrature with line current so as to increase or decrease the line impedance of the entire transmission line [2]. power system oscillations caused by numerous faults within the system which can be damped out by an application of Power oscillation damping controller. POD may typically incorporates Lead Lag compensator and PI controller. Hence during this study, SSSC based POD controller were implemented in multi machine system so as to enhance voltage stability and damp out power oscillations [3].

II. METHODS AND MATERIAL

A. Operating Principle of SSSC

The Fig.1 basic representation of SSSC [3], where the dc capacitor has been used to allow not only active but also reactive power exchange with the system. The magnitude of SSSC's output voltage and phase angle can be possibly varied so as to affect the flow of power in a transmission line.

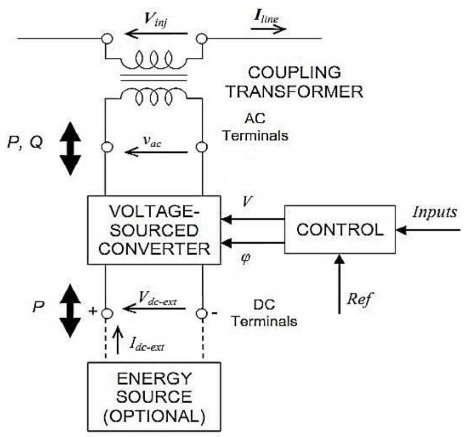

Figure 1. Basic representation of the SSSC

SSSC makes use of voltage source converter along with coupling transformer to inject a voltage (controllable voltage) in series with a line. The injected voltage is sinusoidal in nature. This AC voltage have variable magnitude, its quadrature component can be 90° leading or lagging with the line current so as to supply or absorb the reactive power. Which helps for inductive as well as capacitive compensation? The voltage injected by SSSC is independent current flowing in the line therefore it can change the X_{effi} i.e. Effective reactance. The change in X_{effi} also changes power flow in the network [4].The real and reactive power at the receiving end voltage source can be written as equation (1) and (2),

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

And

$$P = \frac{V_s V_r}{X_L}(1 - \cos\ (\delta_s - \delta_r)) = \frac{V*V}{X_L}(1 - \cos\delta)\ (2)$$

V_s and V_r are magnitudes of sending and receiving end sources, while δ_s and δ_r are phase angles The voltage magnitudes are considered as , $V_s = V_r$ = V and phase angle as δ_s - δ_r = δ. The SSSC emulates reactance X_q which is in series with reactance of the line. Hence expression for power flow can be written as $X_L(1 - X_q/X_L)$,

$$P_q = \frac{V*V}{X_{effi}}\sin(\delta) = \frac{V*V}{X_L(1 - X_q/X_L)}\sin(\delta)\ (3)$$

And

$$P_q = \frac{V*V}{X_{effi}} 1 - \cos\delta = \frac{V*V}{X_L(1 - X_q/X_L)} 1 - \cos(\delta)\ (4)$$

Here X_{effi} is an effective reactance of the line, also consist of the reactance introduced by the SSSC. X_q is the compensating reactance which is negative for inductive mode and it is positive for capacitive mode. The SSSC's output voltage were possibly reversed by making 90° lead or lag with respect to line current. V_q is injected voltage and given by [2].

$$V_q = \pm V_q\ (\xi) \frac{I}{i}\ (5)$$

Where ζ is a control parameter and V_q (ζ) is injected compensating voltage.

B. Structure Of Power Oscillation Damping Controller

Fig 2 shows the POD controller design structure . This structure contains of gain block, washout circuit and lead-lag compensator. The lead-lag compensator helps to modulate the injected voltage by the SSSC. The washout circuit acts as a high pass filter that will allows the signal related to oscillation to pass as they are. The POD controller are supplied with the voltage at Bus B-2 and current of Line L-1 as an input signal. The Power Oscillation Damping Controller makes use of V_{abc} and I_{abc} to calculate it into power. The switch remains open if there is no faults in the system. But switch becomes closed whenever there is a fault occurs in the system. Finally two error signal has been added to give V_{qref} [5,6].

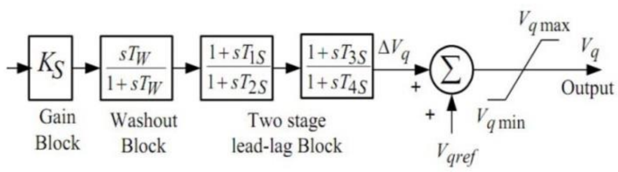

Figure 2. POD controller design structure

C. Matlab/Simulink Model Of Multi-Machine System With SSSC And Pod

The power system which is analyzed under this study contains 4 buses. It also involves 1 dynamic load centre at bus B-3, 2 generation plant which are interconnected. These 2 generating station have rating of 2100 MVA and 1400 MVA respectively. The dynamic load is of 2200 MW. Out of 2 generation plants one is connected to the load through L-1 which is is 320 km. The Line L-2 divided into into two lines each of 180 km. The another generation plant is connected to the load through L-4 of 50-km. SSSC is introduced at B-2 in series with L-1.The Multi-Machine system with SSSC and POD controller has been constructed with the help of MATLAB/SIMULINK software. The results are recorded after introducing various Unsymmetrical faults at B-4.

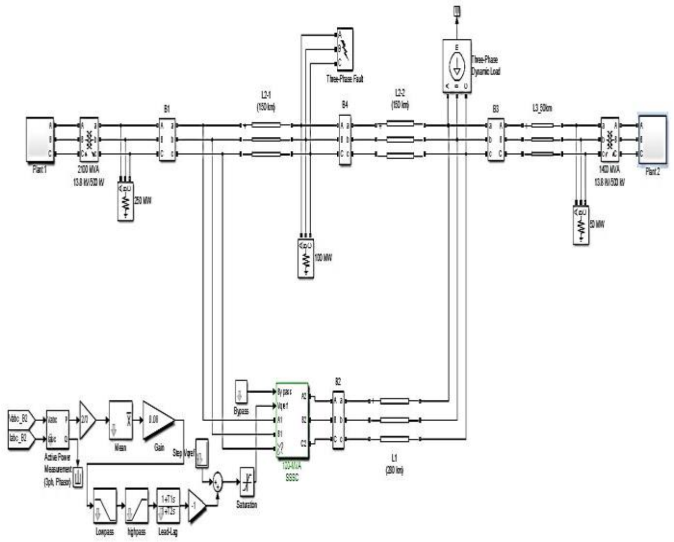

Figure 3. Multi machine system with SSSC and POD

In 1st Case powers and voltages at all buses has been recorded in absence of SSSC and with SSSC so as to study the voltage stability of the system . The results are discussed further. on the same system various unsymmetrical faults have been applied to analyze POD's performance which is simulated using MATLAB/SIMULINK software, and various results have been considered in 2nd case in absence of POD and with POD.

III. RESULTS AND DISCUSSION

A. CASE 1 -Multi Machine system with and without SSSC

✓ Multi machine system in absence of SSSC

Two machine and 4 buses Power system has been simulated in MATLAB environment in absence of SSSC, With the power and voltages in all buses have been obtained which are given in Table 1. Sudden variation in load causes voltage instability. Hence the voltages of all the buses are above 1 pu.

Table 1. Result obtained from the system without SSSC

Bus no.	Current	Voltage (pu)	Reactive power	Active power
1	13.51	1.007	-3.768	20.06
2	6.701	1.007	-1.82	9.959
3	9.881	1.002	-0.4871	14.84
4	5.566	1.015	-0.5898	8.452

✓ Multi machine system with SSSC

In this case SSSC have been included in simulation model of multi machine system . SSSC is controlling the active and reactive powers. After the installation of SSSC, besides controlling the power flow SSSC injects fast alternating voltage in the line. Thus keeping the Bus voltage value in 1 per unit, hence the results in presence of SSSC are given in Table 2. It has been proven from Obtained results of bus-2 that the stability of power system parameters has been increased.

Table 2. Result obtained from the system with SSSC

Bus no.	**Current**	**Voltage (pu)**	**Reactive power**	**Active power**
1	13.55	1	-4.743	19.99
2	7.65	0.9945	-1.843	11.25
3	9.887	1	-0.2449	14.82
4	4.65	1	-0.2401	7.094

B. CASE 2- Multi- Machine system with SSSC based POD and Without POD controller

✓ LL-G Fault in absence of POD Controller

For analyzing the performance of POD under unsymmetrical fault, a LL-G fault is applied at 1.3s. the fault is continuous for 10 cycles and gets cleat at 1.51s. The performance of SSSC and POD controller described in figures. In this condition POD is kept aside. And LL-G fault is introduced at B-4 and the waveforms of active as well as reactive power ,voltage at B-2 are recorded. Initially V_{qref} is equal to zero. V_{qref} is adjusted to -0.08 pu at 2 s. Hence SSSC operates in inductive mode. To operate in Capacitive mode V_{qref} is adjusted to 0.08 pu at 6s.Figure 4 shows the oscillations that has been observed at B-2. Fig 8 shows V_{qref} i.e. reference voltage. and Fig 5 shows the reactive power at B-2.

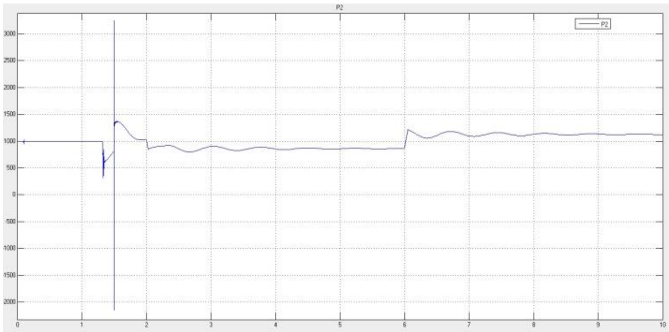

Figure 4. Active power at B-2 in absence of POD Controller

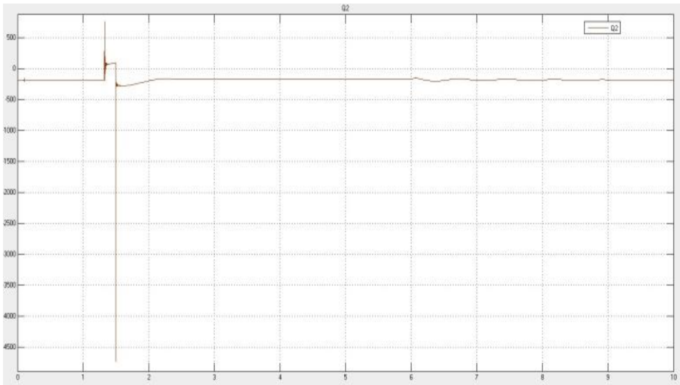

Figure 5. Reactive power at B-2 in absence of POD Controller

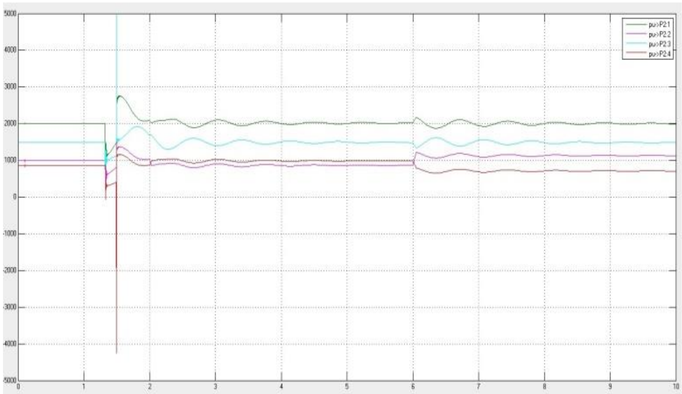

Figure 6. Active power at all buses in absence of POD controller

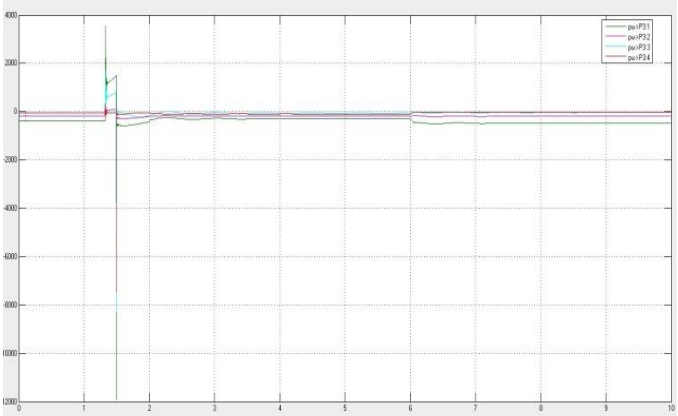

Figure 7. Reactive power at all buses in absence of POD controller

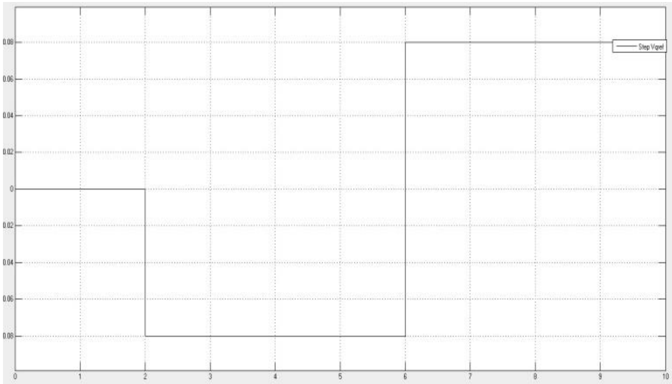

Figure 8. V_{qref} Signal

✓ LL-G Fault with POD controller

In this case POD connected in the system. Figure 9 and 10 shows the active and reactive power waveform respectively after POD has been introduced in the system. Thus POD helps to damps out these oscillations very quickly. Fig 13 shows the V_{qinj} i.e. injected voltage follow V_{qref} i.e. reference voltage.

It can be concluded from the recorded results that system oscillations are damped by introducing SSSC based POD controller in the network..

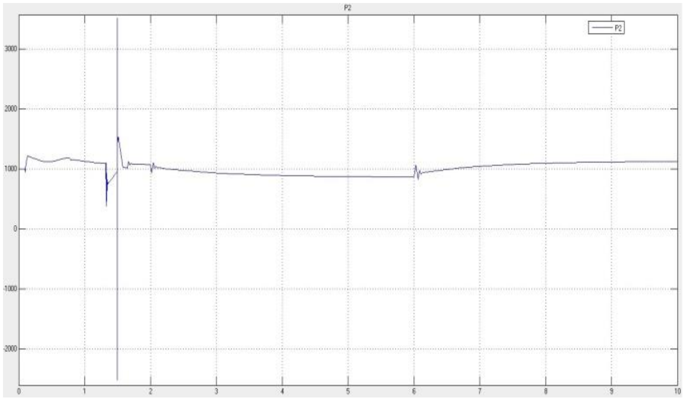

Figure 9. Active power at B-2 With POD

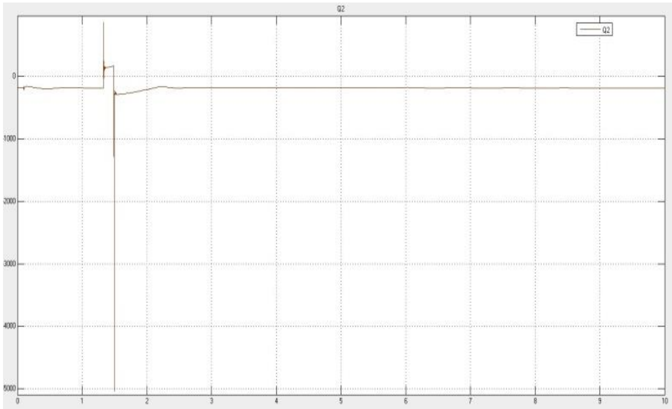

Figure 10. Reactive Power at B-2 With POD

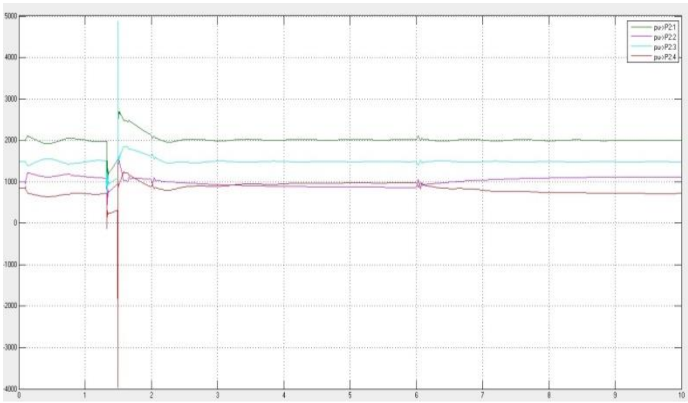

Figure 11. Active Power at All Buses with POD

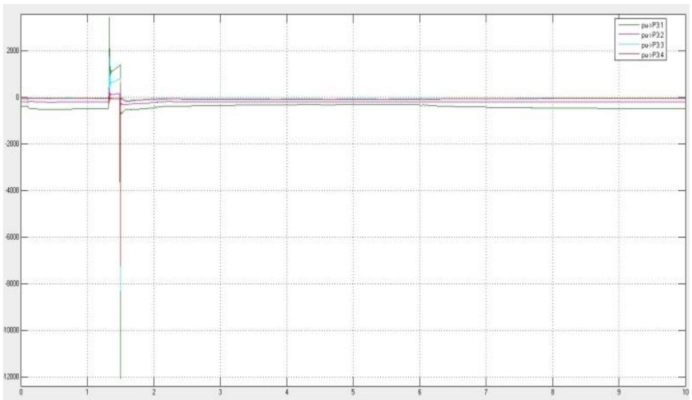

Figure 12. Reactive Power At All Buses With POD

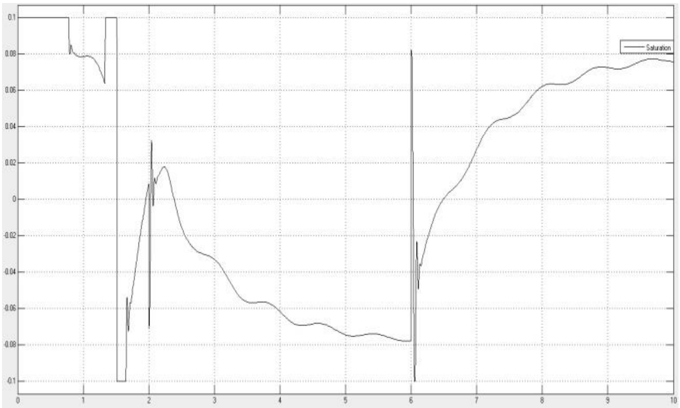

Figure 13. V_{qinj} Signal

IV. CONCLUSION

It has been concluded after simulating the multi machine power system in MATLAB environment and by connecting SSSC in series with transmission lines. The SSSC were able to control power flow at desired point in transmission line. SSSC performance against voltage stability were studied in multi machine system in both condition i.e. with and without SSSC. The value of all the bus voltages were found to be above per unit value which indicates the voltage instability in the system in absence of SSSC. After connecting the SSSC in series with transmission lines all the bus voltages value becomes per unit as SSSC injects fast changing voltage in the transmission line. Thus Improving the voltage stability of the system. In second case, to check the performance of POD against system oscillations, unsymmetrical fault were applied at B-4. MATLAB/SIMULINK model were build to study the performance of POD controller after implementing it in the system. From the results, it is concluded that the use of POD in the system causes quick damping of system oscillation when compared to system without POD.

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