Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 4, April -2017

Damping of Local Plant Mode Power Oscillations using by Static Synchronous Series Compensator (SSSC)

Hardik Sonaiya[1],Chintan R. Patel[2]

[1]PG Student, Electrical EngineeringDepartment,G. H. Patel College of Engineering and Technology
[2]Asst. Prof., Electrical EngineeringDepartment,G. H. Patel College of Engineering and Technology

Abstract —*Static synchronous series compensator (SSSC) is an advance FACTS device that can be used to improve the power system stability. The local plant mode of oscillations produce due to the large disturbance in the system like symmetrical fault or load disturbance. In this paper, during the balance and unbalance fault the power oscillations are observed in the single machine infinite bus system. The SSSC with power oscillation damping controller (POD) is able to damp out this type of oscillations. After implementing SSSC in the single machine infinite bus system the results are observed in MATLAB/SIMULINK.*

Keywords-*SSSC, voltage stability, VSI, PI controller, MATLA/SIMULINK, POD Controller*

I. INTRODUCTION

The power system stability can be classified according to the synchronism. In voltage instability, there is no loss of synchronism. Generally the voltage instability is created due to the disturbances like increase in load demand or change in system parameters. The large disturbance voltage stability is the ability of the power system to withstand the large voltage collapse.

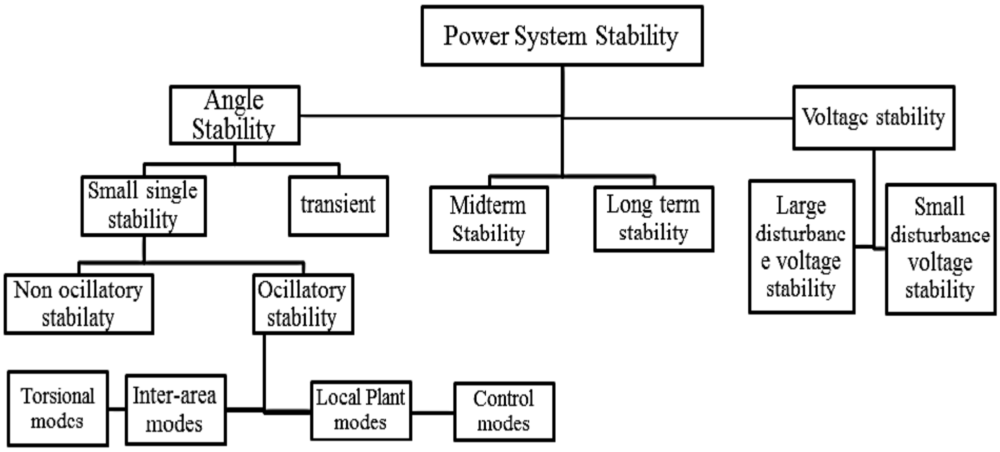


Figure 1 Classification of Power System Stability

On the other side the rotor angle stability is based on the synchronism between the rotating machines. It is the ability of the system to run in a stable mode without loss of synchronism. Power oscillations are considered in this type of angel instability.

In any synchronous machine the change in torque can be explained by using two torques.

$$\Delta T_e = T_s\Delta\delta + T_D\Delta\omega$$

$T_s\Delta\delta$ is the component of torque that changes with the change of the rotor angle $\Delta\delta$. So it is known as synchronizing torque. $T_D\Delta\omega$ is the component of torque that changes with the speed deviation $\Delta\omega$ and it is known as damping torque.

When the damping torque is negative, mostly oscillatory instability takes place. In todays practice, small signal stability is largely a problem of insufficient oscillation torque. So the oscillation instability can be classified in the following type.

- Local modes of oscillations.
- Inter-area modes
- Control mode
- Torsional mode

Local plant mode oscillations are the most commonly encountered in the system. The natural frequencies of these oscillations are in the range of 1-2 Hz. In this mode, frequency is in the range of 0.1-1 Hz.

The Inter-area modes of oscillations are observed over a large part of the network. It involves two coherent group groups of generators swinging against each other at 1 Hz or less. The variation in tie-line power can be large. The oscillation frequency is approximately 0.3 Hz.

The recent development of FACTs devices can be widely used for the VAR compensation. In addition, the FACTs devices have another function of enhancing the power system stability. By dynamically changing the series impedance of the transmission line by the controllable series capacitive compensator, the oscillations in the power system can be damped.

In the next chapter, a system considered where the power oscillations are presented and with the help of Static synchronous series compensator (FACTs device) oscillations have been damped. The SSSC is advanced FACTs device that uses a Voltage source inverter to control the VAR compensation.

The new control strategy named "Power Oscillation Damping (POD) Controller" is used to damp out the oscillations with the help of SSSC. The simulation and result analysis has been shown in the topic

II. SIMULATION OF SINGLE MACHINE INFINITE BUS SYSTEM

In the performance and analysis of power oscillation, a single machine system is considered. A 260 MW generator system is connected to bus 1 with the step up transformer. The power is supplied to the load via 400 km long transmission lines. 250 MW load is connected to bus 2 through step down transformer.

As shown in the figure, a three phase fault takes place near bus 2. When the fault is occurring, the total load is out of the circuit and only transmission system impedance remains across the generators. As we know that the all of the components of the transmission system (transformers, transmission line, etc.) have only inductive reactance, the resistance is very small.

Due to the high magnetic components, power oscillations will generate. The oscillations may cause the speed deviation in the synchronous machines.

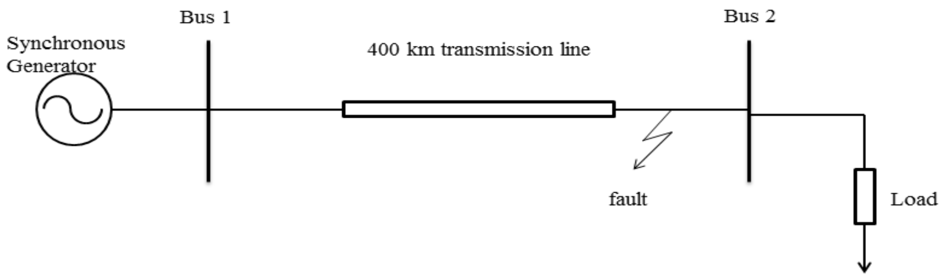


Figure 2 Single machine long transmission system

Hence, in the output frequency and voltage may violate. This contingency may lead the system to failure of the generators.

FACTs devices have the ability to improve the power system stability. With the help of high speed IGBT switches inverters by dynamically changing the series impedance of the transmission line by the controllable series capacitive compensator, the oscillations in the power system can be damped.

2.1 Case 1: Three Phase Fault:

When the three phase fault takes place in the transmission line, all the system parameters are violated. The main load of the system is bypassed and the only transmission system remains with the generator. As the lines have very low resistance compare to the inductor therefor heavy reactive power is drawn from the generator.

Hence generator swings against the whole system and the variation of the rotor speed can be noticed. The rotor speed deviation is shown in figure 3.

The simulation of fig 2 is carried out from the MATLAB/SIMULUNK model. And the result is shown in the figure 3.13. In this figure the oscillation of the rotor speed deviation is shown. From this observation, one can say that the rotor speed varies from ± 0.006 to $\pm$ 0.01 and these oscillations very harmful to generator rotor, shaft and governing system.

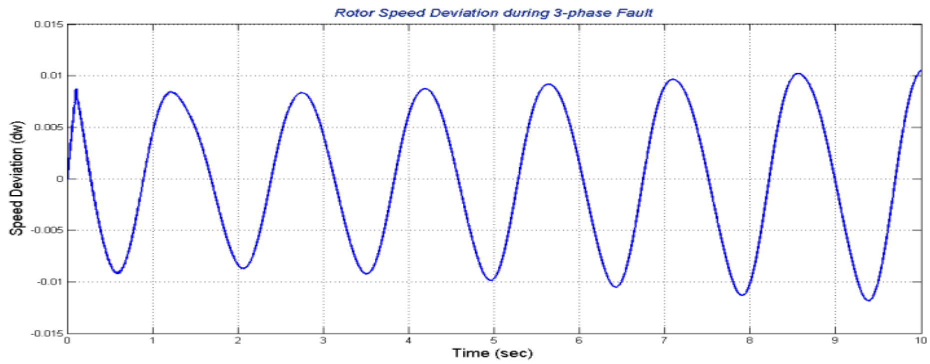


Figure 3 Rotor Speed Deviation During 3- phase fault

There are several methods can be used to eliminate this type of local plant modes of oscillations and one of the methods is by using series compensation device like TCSC or SSSC. Here SSSC with damping controller is used.

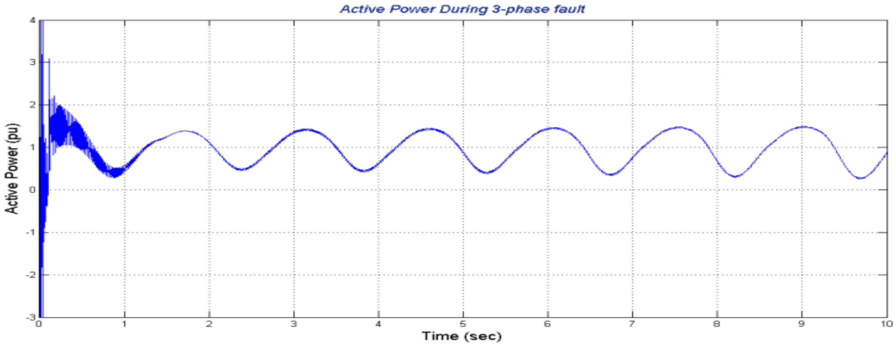


Figure 4 Active Power During 3- phase fault

When the rotor speed is varied the output of the generator is also varied and that can be noticed in active power flow. Hear power oscillate from 0.3 pu to 1.4 pu. This shows that the system is in over excitation mode and the parameters are gradually varied and the system is in unstable mode. It is very dominant to all the sensitive devices at load and the speed deviation is very harmful to rotor and turbine system.

2.2 Case 2: Unbalanced Fault:

The effectiveness of the unbalanced faults is also examined by applying self-clearing type unsymmetrical faults (namely double line-to-ground, line-to-line and single line-to-ground). Here L-L-G fault of 5-cycle duration is considered. The local modes of oscillations against time are shown in Fig. 5.

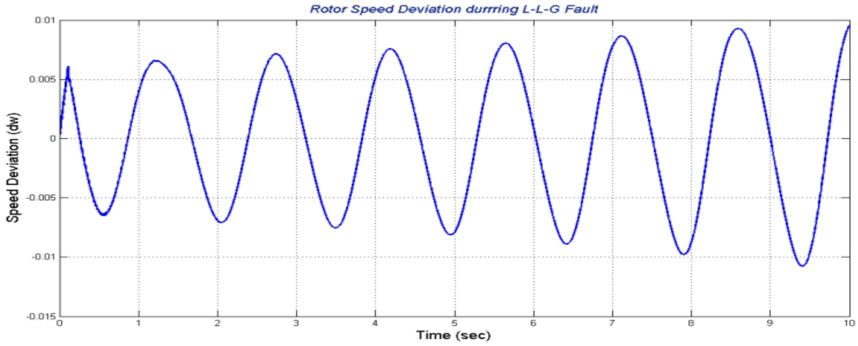


Figure 5 Rotor Speed Deviation during L-L-G fault

Same as the 3 phase fault here the rotor speed is gradually varied. The active power of the generator is also shown in the figure 6.

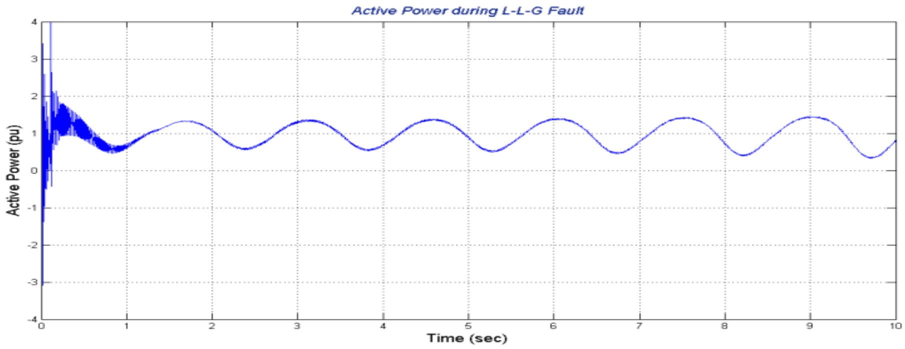


Figure 6 Active Power during L-L-G fault

III. SIMULATION OF IMPLEMENTATION OF SSSC WITH DAMPING CONTROLLER

The results of the simulation show the power oscillation instability during different cases like balanced and unbalanced fault. These types of instability can be eliminated by using SSSC with power oscillation damping (POD) controller. Now SSSC is applied to the same power system and observe the rotor speed and active power flow to observe the performance of the SSSC controller.

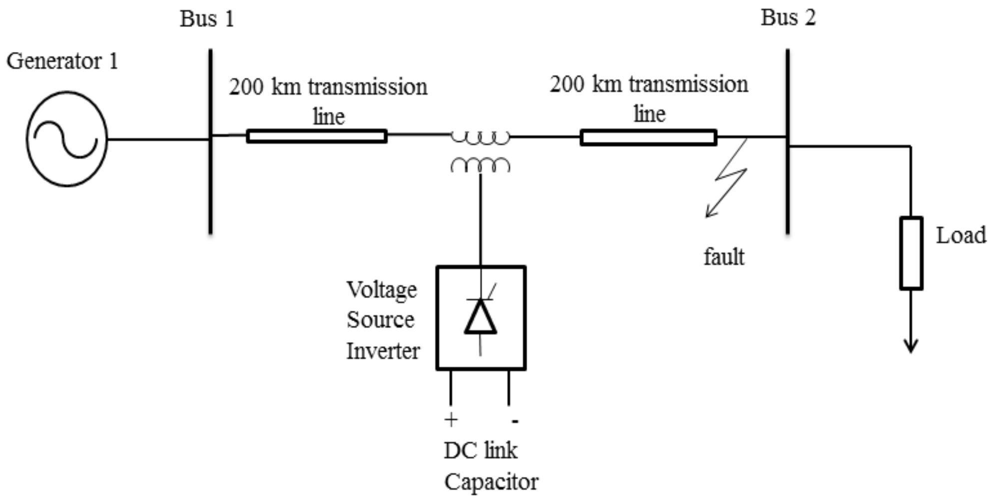


Figure 7 Implementation of SSSC at Midpoint

The DC link capacitor is connected as source across the voltage source inverter. The output of VSI is connected in series with the transmission line with the help of the coupling transformer. For the controlling of the VSI the control strategy that has been used is shown in the next topic.

The SSSC is connected to the line with the help of insertion transformer. The measurement of the line current and voltage has been taken from bus 1. These parameters are given as signals to the control system. Therefore a close loop control system can be formed.

3.1 Power Oscillation Damping Controller:

The power oscillations can be damped by controlling the quadrature voltage. Hence, in control system the Q_{ref} has been derived. The schematic diagram for the power oscillation damping controller is shown in the fig 8.

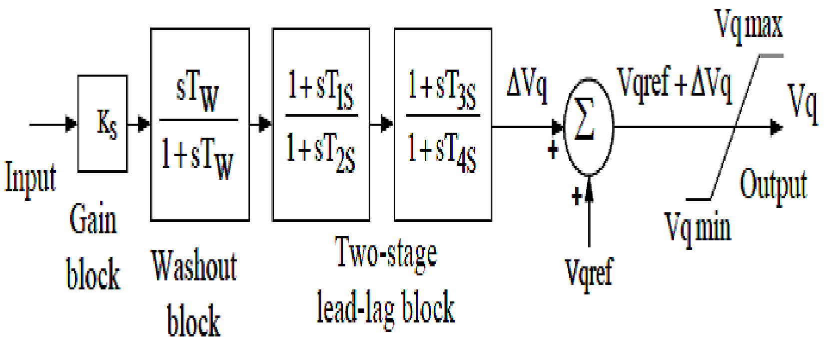


Figure 8 Block Diagram for Power Oscillation Damping Controller

The structure consists of a gain block with gain K_S, a signal washout block and two-stage phase compensation block as shown in Fig. 8. The signal washout block serves as a high-pass filter, with the time constant T_W, high enough to allow signals associated with oscillations in input signal to pass unchanged. From the viewpoint of the washout function, the value of T_W is not critical and may be in the range of 1 to 20 seconds. The phase compensation blocks (time constants T_{1S}, T_{2S} and T_{3S}, T_{4S}) provide the appropriate phase-lead characteristics to compensate for the phase lag between input and the output signals.

Here all the gains and time constants can be derived by many mathematical methods like Eigenvalue analysis. But in this case the manual trial and error method is used to derive the parameters of the power oscillation damping controller.

The line voltage and current are sensed and from that measurement, actual active power P_{act} and reactive power Q_{act} are calculated. These P_{act} and Q_{act} work as a feedback for the closed loop control system. The desired active and reactive power P_{ref} and Q_{ref} are compared with the P_{act} and Q_{act} respectively to generate error signals E_p and E_q. These error signals are processed in the controller. Here P_{ref} is a constant quantity and Q_{ref} is generated by POD controller.

This control strategy has a computational value of Q_{ref} rather simulation model has a constant signal to reactive component. The tuning method for the error signals are the same. PI controllers' gains have been derived from manual calculations.

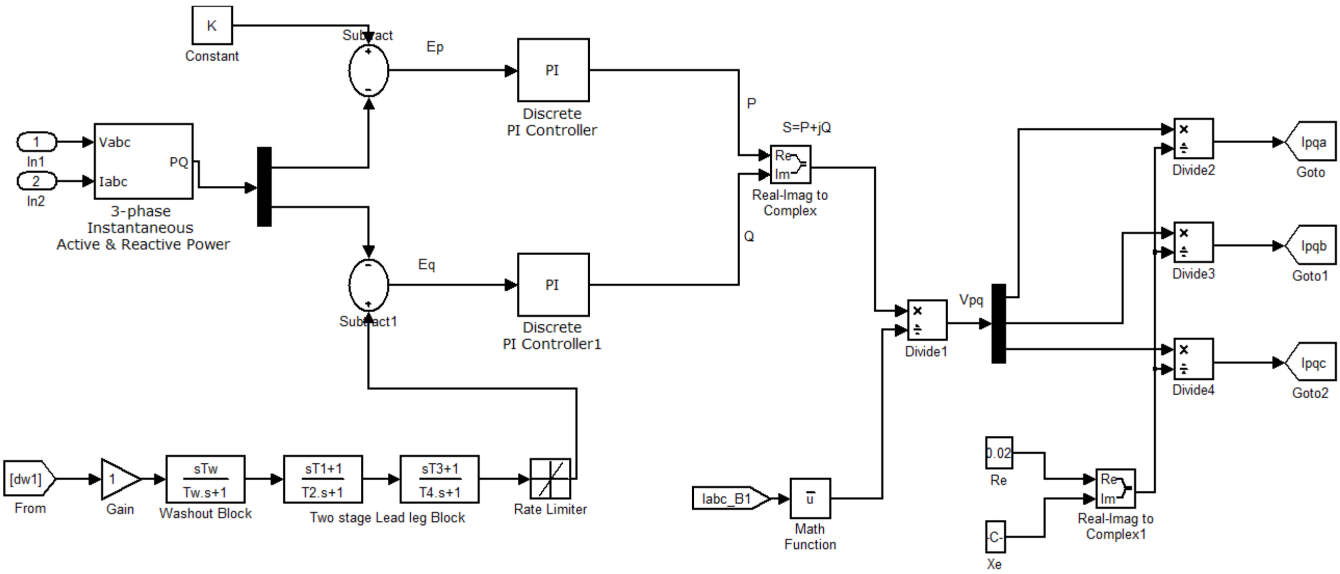


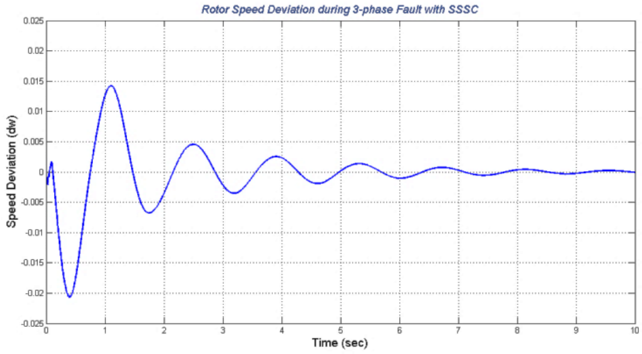
Figure 9 Control System

IV. RESULTS ANALYSIS:

The above SSSC controller is applied to all that three conditions and the results are compared with and without SSSC controller and observed the effect of the SSSC based damping controller.

4.1 Case 1: 3-phase Fault with SSSC:

Figure 10 Rotor Speed Deviations during 3-phase Fault with SSSC



As shown in figure 10 shows the oscillations of the speed deviation is damped out in 3-4 sec and the variation of the speed is within the tolerance limit. The more idea of the damping out the oscillation can be understood by active power signals that shown in figure 11.

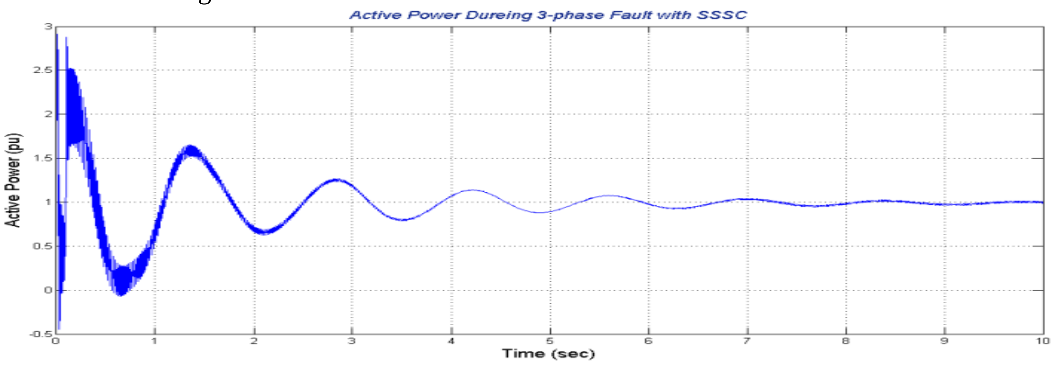


Figure 11 Active Power during 3-phase Fault with SSSC

4.2 Case 2: Unbalanced Fault:

The waveforms of rotor speed deviation and active power of the system during L-L-G fault with SSSC is shown in figure 12 and 13 respectively.

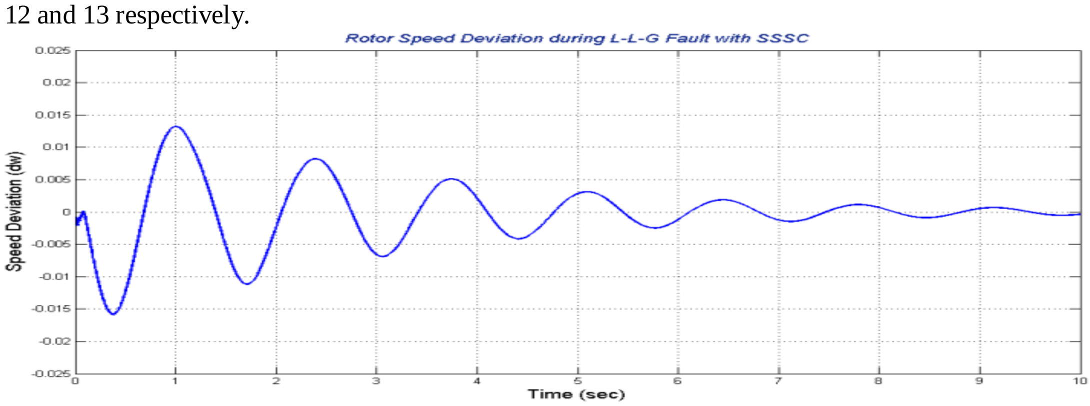


Figure 121 Rotor Speed Deviations during L-L-G Fault with SSSC

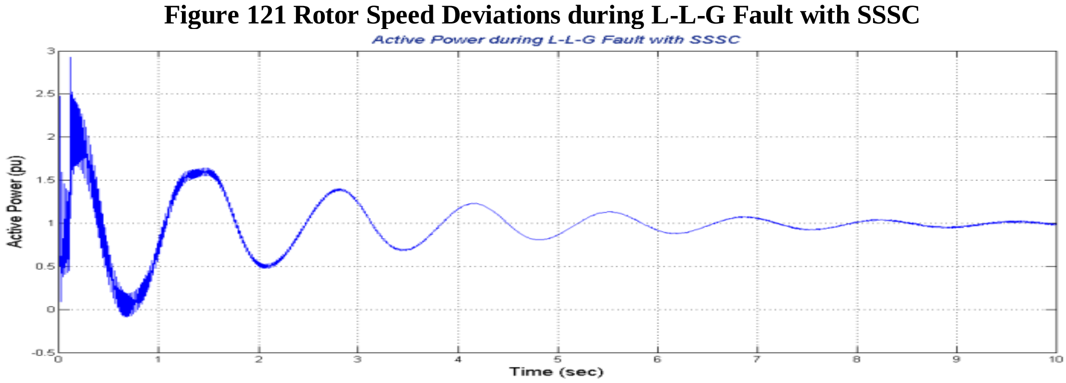


Figure 13 Active Power during L-L-G Fault with SSSC

.

V. CONCLUSION:

In advance power system FACTS devices can be used to compensate the reactive power and improve the active power transfer. As well as FACTS devices are used to improve the power system stability. The single machine infinite bus system is observed in transient state and the oscillations are observed. The SSSC is implemented to damp out this oscillation using POD controller.Also by comparing the MATLAB simulation results without and with SSSC it is clear that the power oscillation instability can be damped out by SSSC using power oscillation damping controller.

REFERENCES

[1] P. Kundar "Power System Stability and Control". Tata Mcgraw-Hill, Inc.New York, San Fancisco.
[2] Hingorani,N.G.:"High power electronics and flexible ac transmission System", IEEE Power Eng. Rv., July 1998.
[3] Sidhartha Panda; "Modelling, simulation and optimal tuning of SSSC-based controller in a multi-machine power system" World Journal of Modelling and Simulation Vol. 6 (2010).
[4] L, Sunil Kumar and Arindam Ghosh "Modeling and Control Design of a Static Synchronous Series Compensator" IEEE Tranractions on Power Delivery, Vol. 14, No. 4, October 1999.
[5] M. Farahani "Damping of subsynchronous oscillations in power system using static synchronous series compensator" IET Generation, Transmission & Distribution 2012.
[6] Chetan Kotwal UdayKiran Sangala G N Pillai "Improving Power Oscillation Damping Using Static Synchronous Series Compensator" 2013 Annual IEEE India Conference (INDICON).
[7] B.Vasantha Reddy, B.Chitti Babu "Hysteresis Controller and Delta Modulator- A Two Viable Scheme for Current Controlled Voltage Source Inverter"
[8] Fawzi A. Rahman Al Jowder "Series Compensation of Radial Power System by a Combination of SSSC and Dielectric Capacitors" IEEE Transactions on Power Delivery, Vol. 20, No. 1, JANUARY 2005.
[9] Jafar Ghaisari, Alireza Bakhshai, and Praveen K. Jain "A Nonlinear Control Approach to Increase Power Oscillations Damping by Means of the SSSC"
[10] H. Taheri , S. Shahabi), Sh. Taheri, A. Gholami "Application of Synchronous Static Series Compensator (SSSC) on Enhancement of Voltage Stability and Power Oscillation Damping"
[11] S. Panda "Differential evolution algorithm for SSSC-based damping controller design considering time delay" Journal of the Franklin Institute 348 (2011) 1903–1926
[12] B.N.Singh, A.Chandra, K.Al-Haddad and B.Singh "Performance of sliding-mode and fuzzy controllers for a static synchronous series compensator" IEE Proc.-Cenrr. Transm. Distrib.. Vol. 146. No. 2, March I999.
[13] Taha Selim Ustuny and Saad Mekhilef "Effects of a Static Synchronous Series Compensator (SSSC) Based on a Soft Switching 48-Pulse PWM Inverter on the Power Demand from the Grid" Journal of Power Electronics, Vol. 10, No. 1, January 2010.
[14] Sidhartha Panda and Narayana Prasad Padhy "MATLAB/SIMULINK Based Model of Single- Machine Infinite-Bus with TCSC for Stability Studies and Tuning Employing GA" World Academy of Science, Engineering and Technology International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:1, No:3, 2007

