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Stimulation of Static Synchronous Series Compensator (SSSC) Using Power Oscillation Damping

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Abstract: This paper analyzed the problem of controlling and modulating power flow in a transmission line using a Synchronous Static Series Compensator (SSSC). The studies, which include detailed techniques of twelve- pulse and PWM controlled SSSC, are conducted and the control circuits are presented. The SSSC operating conditions and constraints are compared to the operating conditions of other FACTS devices, showing that the SSSC offers several advantages over others. However, at the present time the total cost of a SSSC installation is higher than the cost of other FACTS devices. On the other hand, if the dc side voltage is too high, the rating of both the GTO valves and dc capacitor has to be increased, which means higher installation costs. Also, Simulation results validate that Voltage and Power Oscillation can be damped properly using of Synchronous Static Series Compensator (SSSC).This paper investigates the problem of controlling and modulating power flow in a transmission line using a Synchronous Static Series Compensator (SSSC). The developed control strategies for both twelve-pulse and PWM-controlled SSSC use direct manipulations of control variables instead of typical d-q transformations. The complete digital simulation of the SSSC within the power system is performed in the MATLAB/ Simulink environment using the Power System Block set (PSB). Simulation results validate that Voltage and Power Oscillation can be damped properly using of Synchronous Static Series Compensator (SSSC).

Keywords: Series Compensator- FACTS - Power Damping Oscillators - Voltage Source Converter (VSC).

I. INTRODUCTION

Static Synchronous Series Compensator (SSSC) is a modern power quality FACTS device that employs a voltage source converter connected in series to a transmission line through a transformer. The SSSC operates like a controllable series capacitor and series inductor. The primary difference is that its injected voltage is not related to the line intensity and can be managed independently[1]. This feature allows the SSSC to work satisfactorily with high loads as well as with lower loads. The Static Synchronous Series Compensator has three basic components: 1. Voltage Source Converter (VSC) – main component, 2. Transformer – couples the SSSC to the transmission line, 3. Energy Source – provides voltage across the DC capacitor and compensate for device losses.

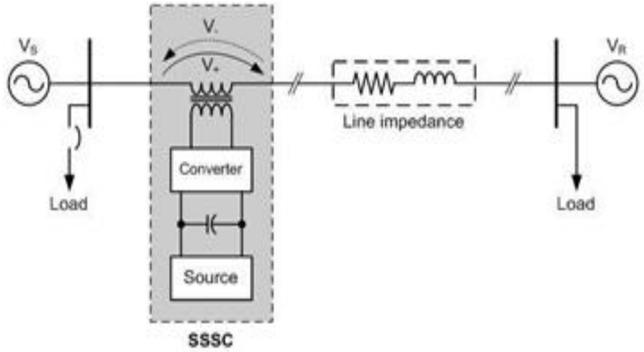


Fig1. Static Synchronous Series Compensator (SSSC) Diagram.

II. DESIGN PARAMETERS FOR STATIC SYNCHRONOUS SERIES COMPENSATOR [SSSC]

The Static Synchronous Series Compensator (SSSC), one of the key FACTS devices, consists of a voltage-sourced converter and a transformer connected in series with a transmission line. The SSSC injects a voltage of variable magnitude in quadrature with the line current, thereby emulating an inductive or capacitive reactance. This emulated variable reactance in series with the line can then influence the transmitted electric power. In our demo, the SSSC is usedto damp power oscillation on a power grid following a three-phase fault[3]. The power grid consists of two power generation substations and one major load center at bus B3. The first power generation substation (M1) has a rating of 2100 MVA, representing 6 machines of 350 MVA and the other one (M2) has a rating of 1400 MVA, representing 4 machines of 350 MVA. The load center of approximately 2200 MW is modeled using a dynamic load model where the active & reactive power absorbed by the load is a function of the system voltage.The generation substation M1 is connected to this load by two transmission lines L1 and L2. L1 is 280-km long and L2 is split in two segments of 150 km in order to simulate a three-phase fault (using a fault breaker) at the midpoint of the line[2].

The generation substation M2 is also connected to the load bya 50-km line (L3). When the SSSC is bypass, the power flow towards this major load is as follows: 664 MW flow on L1 (measured at bus B2), 563 MW flow on L2 (measured at

B4) and 990 MW flow on L3 (measured at B3).The SSSC, located at bus B1, is in series with line L1[4]. It has a rating of 100MVA and is capable of injecting up to 10% of the nominal system voltage. This SSSC is a phasor model of a typical three-level PWM SSSC. If you open the SSSC dialog box and select "Display Power data", you will see that our model represents a SSSC having a DC link nominal voltage of 40 kV with an equivalent capacitance of 375 uF. On the AC side, its total equivalent impedance is 0.16 pu on 100 MVA.

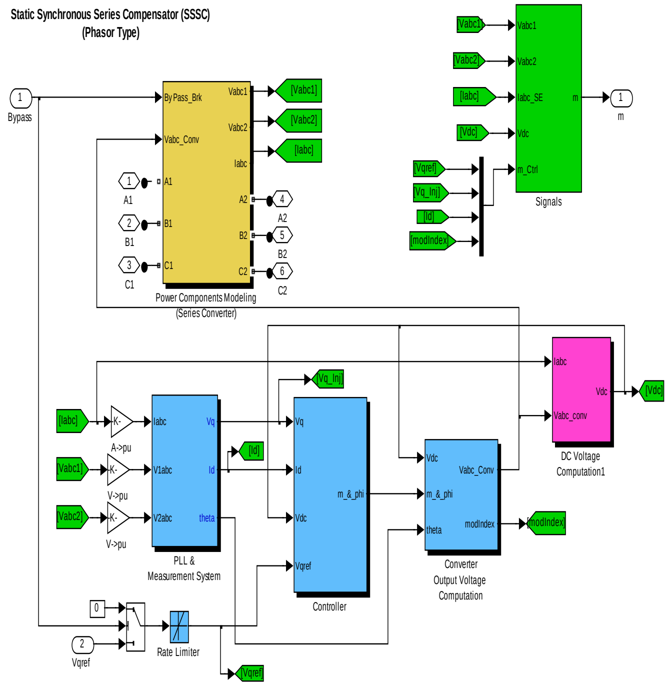


Fig2. Power Components Compensator(Phasor Model).

This impedance represents the transformer leakage reactance and the phase reactor of the IGBT bridge of an actual PWM SSSC.The SSSC injected voltage reference is normally set by a POD (Power Oscillation Damping) controller whose output is connected to the Vqref input of the SSSC. The POD controller consists of an active power measurement system, a general gain, a low-pass filter, a washout high-pass filter, a lead compensator, and an output limiter[1]. The inputs to the POD controller are the bus voltage at B2 and the current flowing in L1. Use the Edit/Look under mask" menu to see how the controller is built.

III. PHASOR MODEL OF SSSC

The Static Synchronous Series Compensator (SSSC), one of the key FACTS devices, consists of a voltage-sourced converter and a transformer connected in series with a transmission line. The SSSC injects a voltage of variable magnitude in quadrature with the line current, thereby emulating an inductive or capacitive reactance. This emulated variable reactance in series with the line can then influence the transmitted electric power. In our demo, the SSSC is usedto damp power oscillation on a power grid following a three-phase fault[5].

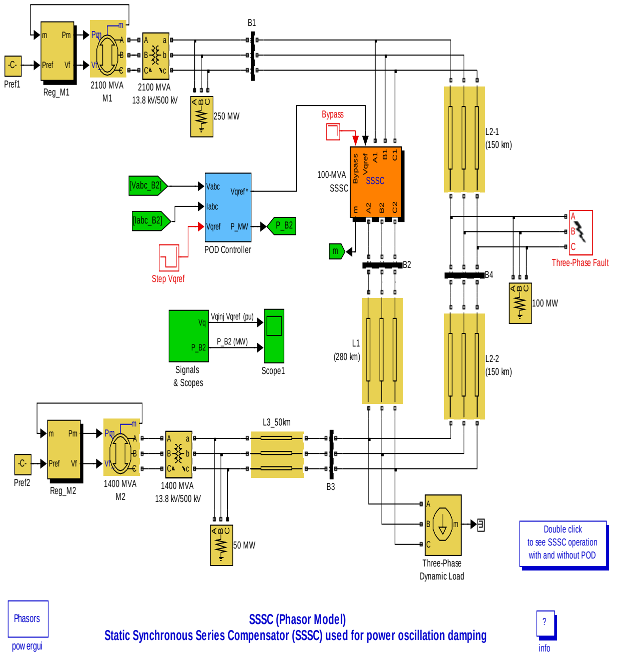


Fig3. Static Synchronous Series Compensator(Phasor Model).

IV. MATLAB/ SIMULINK FOR POWER OSCILLATION DAMPING

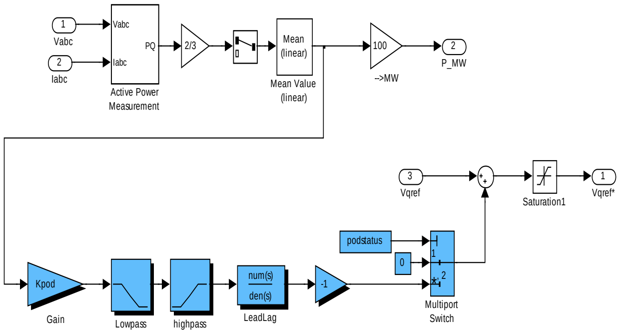


Fig4. Active Power Measurement.

Controlled series compensation can be applied effectively to damp power oscillations,For power oscillation damping it is necessary to vary the applied compensation so as to counteract the accelerating and decelerating swings of the disturbed machine.That is when the rotationally oscillating generator oscillates and angle increses the electric power transmitted must be increased to compensate for the excess the mechanical input power. Conversely when the generator decelerates and angle decreases the electric power must be decreased to balance the in-sufficent mechanical input power . SSSC based power oscillation daping(POD) controller is proposed for transient stability enhancement and to eliminate the power oscillation damping in power system.a multy machine multy bus system with SSSC is simulated in MATLAB / SIMULINK software [4]. The advantages in this list are important to achieve in the overall planning and operation of power systems.

V. PROPORSED BLOCK DIAGRAM FOR VECTOR MODEL SSSC

The basic purposeof using d-q model approach to contol the motor parameters independently that is torque and flux of the induction motor.this project modular SIMULINK implThe impact of load modelling in particular induction motor. The d-q transformations applied to three phase voltages.It proposes a methology that is based on advanced modelling capabilities, representedby dynimic modelling of induction motor. The objective is to analyze the dynamic characteristics of lodes.it decrebes the modelling approach using d-q analysis of induction motor. The d-q modelling approach for transient state analysis in the time domine of the three phase self excited induction generator with squirrel cage rotor is presented along with its operating performance evaluations.The induce voltage and the current will continue to rise untill the VAR supplied by the capacitor is balanced by the VAR demanded by the machine a condition which is essential decided by the saturation of the magnatic circuit.this process is thus cummulative and the induced voltage keeps on rising untill satuaration is reached .To start with transient analysis the dynamic modelling of induction motor asbeen used which furthur converter into induction generator.magantizing inductance is the main factor for voltage buildup and stabilization of genarator voltage for unloaded and loaded conditions[1][3].

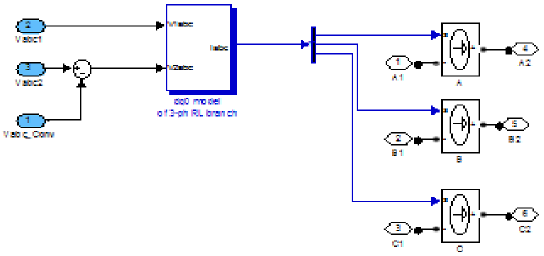


Fig5. d-q Model.

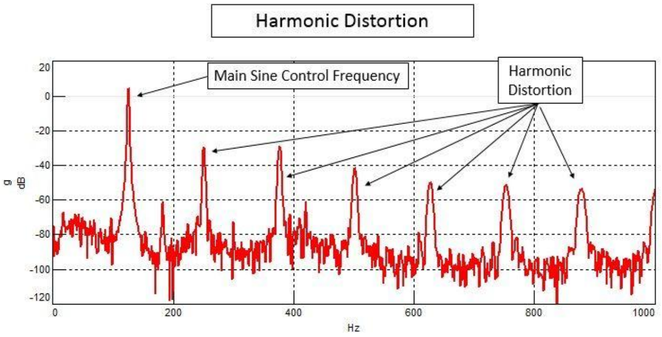
Direct Quadrature (d-q) transformation is a mathematical transformation used to simplify the analysis of three phase circuit. In the case of balanced three phase circuits, application of d-q transformation reduces the tree AC quantities to 2 quantities. Simplified calculations can then b carried out on these imaginary quantities before performing the inverse transformation to recover the actual three phase ac results [5]. The d-q transformations applied to three phase voltages. Matlab/Simulink is a systems simulator and unable to direct simulate electrical circuits. Therefore for simulation of electric circuits power system block set is used which is incorporates libraries of electrical blocks and analysis tools which are used to convert electrical circuits into Simulink diagrams. The electrical blocks or electrical models such as electrical machines ,current and voltage sources, different electric elements , power electronics switches , conductors and sensors for measurement purpose.

A. Output graphs for signal and scope

When the simulation starts Simulink use the PM block set and transfer the electrical circuit into a state space representation with the initial conditions of state variables. The actual simulation starts after this initial conversion. This allows the use of wide variety of fixed step and variable step algorithms available in Simulink. As variable time step algorithms are faster than fixed time step method because the number of steps are less so these algorithms are used for small and medium size systems, and for large systems containing a more number of stages and/or power switches, a fixed time step algorithm is used [2]. A Simulink scope can b used to display the simulation results or these results can be send to workspace during the simulation.The operation of our SSSC with and without POD control open the “Step Vqref” block and mutiple by thousand the time vector in order to disable the Vqref variations.Double click on the Fault breaker and select the peramaters “Switching of Phase A,B,C” to simulate the three phase fault.The transition times should be set as follows .This means that the fault will be applied at 1.33 sec and will last for 10 cycles.Run a simulation and observe the power oscillation on the L1 line following the three phase fault.you woll run the second simulation with the POD controller in operation. Double click on the POD controller b;lock and set the POD status parameter to “on”. Start the simulation, we can see that the SSSC with a POD controller is a very effective tool todamp power oscillation.The comparision of the SSSC operation with and without POD cntrol, double click on the blue block on the bottom right of the model [5]. In general, the SSSC can be viewed as analogous to an ideal synchronous voltage Source as it can produce a set of three-phase ac voltages at the desired fundamental frequency of variable and controllable amplitude and phase angle.

B. Harmonic Distortion

In the electrical system the harmonics are electrical voltages and currents that appear on electric power system because of uncertainty in loads. In a normal system voltage varies sinusoidal at a specific frequency. Under these conditions when a linear load is connected it draws the current at the same frequency but when the nonlinear load is connected the system draws a non-sinusoidal current which leads to the generation of harmonics [2]. High levels of harmonic distortion can cause such effects as increased transformer, capacitor, motor or generator heating, disoperation of electronic equipment (which relies on voltage zero crossing detection or is sensitive to wave shape), incorrect readings on meters, disoperation of protective relays, interference with telephone circuits, etc. The likelihood of such ill effects occurring is greatly increased if a resonant condition occurs. Resonance occurs when a harmonic frequency produced by a non-linear load closely coincides with a power system natural frequency. There are 2 forms of resonance which can occur these are Parallel resonance and series resonance. Run a simulation and observe the power oscillation on the L1 line following the three phase fault.you woll run the second simulation with the POD controller in operation. Double click on the POD controller b;lock and set the POD status parameter to “on”. Start the simulation, we can see that the SSSC with a POD controller is a very effective tool todamp power oscillation [1].The comparision of the SSSC operation with and without POD cntrol, double click on the blue block on the bottom right of the model.



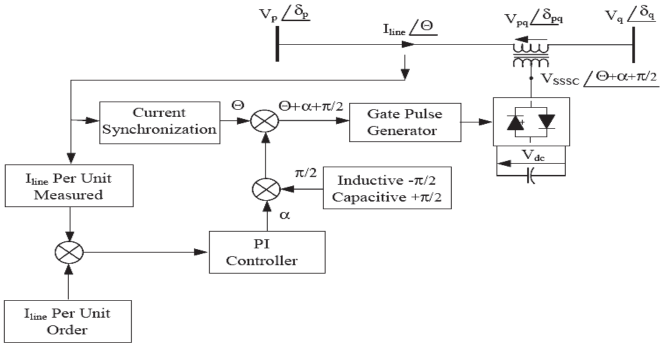


Fig 6. Functional control diagram for the phase-controlled SSSC.

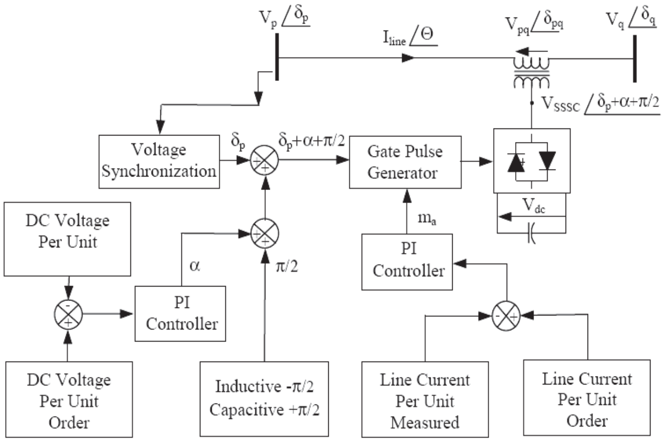


Fig7. Functional control diagram for the PWM-controlled SSSC.

The line current phasor line I is used as a reference phasor while the injected SSSC voltage phasor is allowed to rotate around the center of the circle defined by the maximum inserted voltage max Vpq. each of the four quadrants is possible, but there are some limitations to the injected SSSC voltage due to operating constraints of practical power system. In capacitive mode, the injected SSSC voltage is made to lag the transmission line current by90°; in this case, the SSSC operation is similar to the operation of a series capacitor with variable capacitance. While this equation for Vpq shows changes in the phasor magnitude and phase angle, it can be somewhat misleading; since it shows that the series injected voltage magnitude is directly proportional to the line current magnitude.

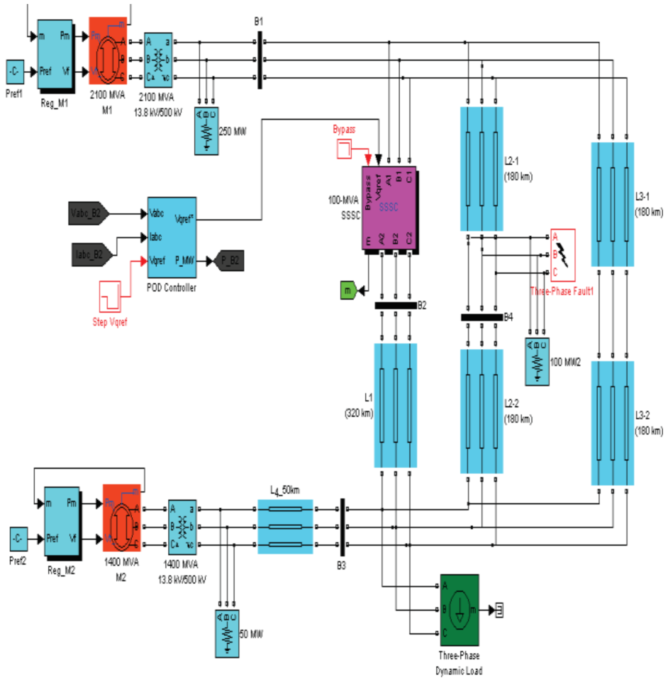


Fig8. Static Synchronous Series Compensator (SSSC) used for power oscillation damping.

C. Simulation Results

The simulation results are divided into three sections. Thus, Section (A) discusses results for SSSC Dynamic Response. The results obtained for the test system with a three-phase solid fault applied at Bus 4 without and with phase-controlled SSSC are presented in Section (B) and (C) respectively [1]. A. SSSC Dynamic Response Initially V_{qref} is set to 0pu; at t=4 s, V_{qref} is set to -0.07pu (SSSC inductive); then at t=8 s, V_{qref} is set to 0.07pu (SSSC capacitive). Also, the fault breaker will not operate during the simulation.

D. Output Graphs For Signal And Scope

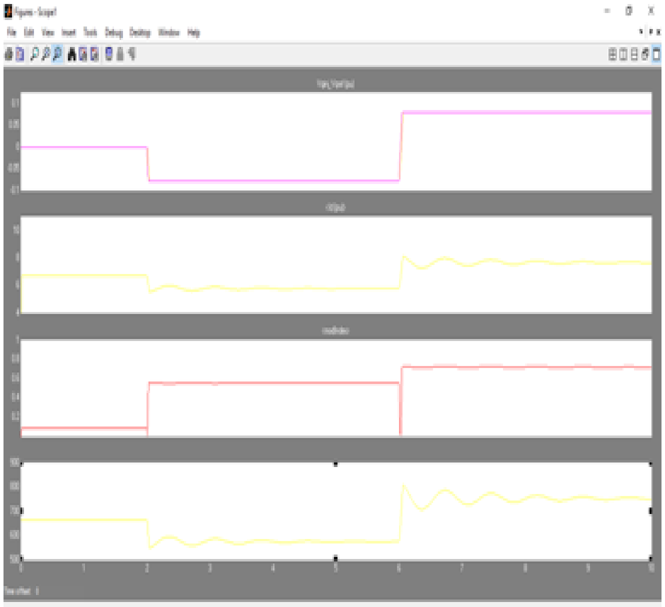


Fig9. V_{qinj}, V_{qref}(pu)&Id(pu)&mod Index.

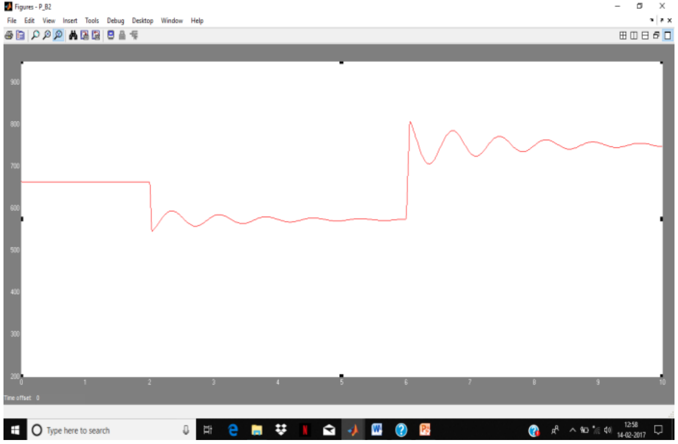


Fig10. V_{qref} and P Output.

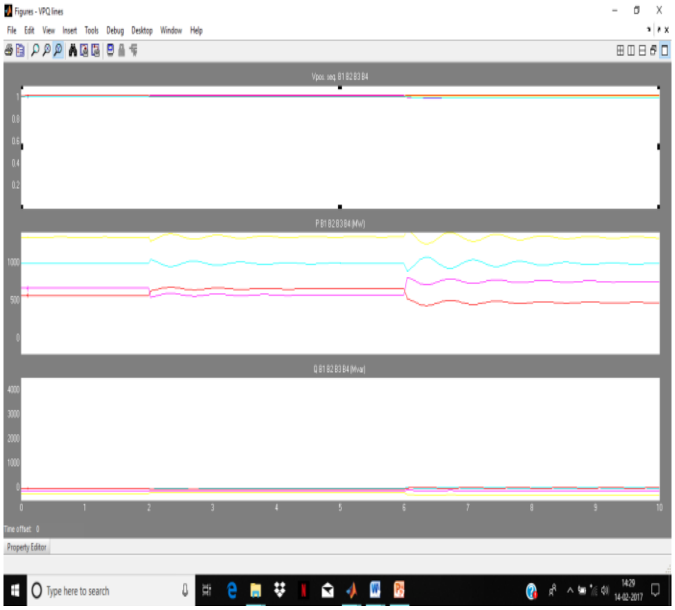


Fig11. Real And Reactive Power And Voltage Output.

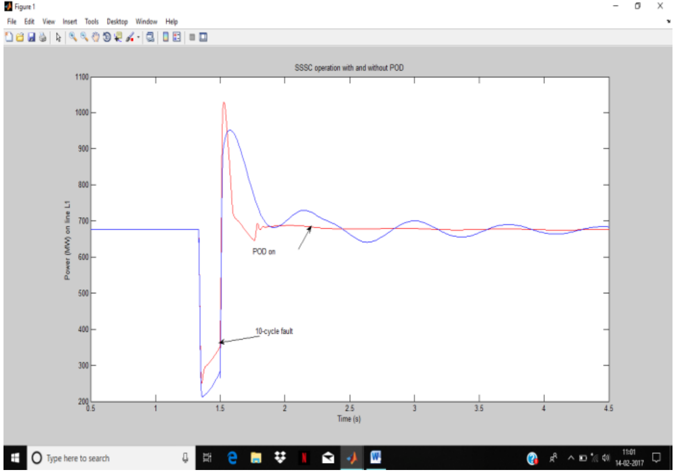


Fig12. SSSC operation with and without POD.

The simulation shows power oscillation. Test System with SSSC under a three-phase fault To further test the proposed SSSC controller, a three phase fault is applied at Bus 4.also, in this simulation the transition times is set as follows: [20/60 30/60]; In Fig. 11, the simulation result shows that the power oscillation on the L1 line following the three-phase fault. Moreover the performed simulation indicates that the SSSC compensator is a very effective tool to damp power oscillation This project analyzed the problem of controlling and modulating power flow in a transmission line using a Synchronous Static Series Compensator (SSSC) [2]. The studies, which include detailed techniques of twelve pulse and PWM controlled SSSC, are conducted and the control circuits are presented. The SSSC operating conditions and constraints are compared to the operating conditions of other FACTS devices, showing that the SSSC offers several advantages over others. However, at the present time the total cost of a SSSC installation is higher than the cost of other FACTS devices. Comparisons of two implemented control strategies clearly show that the PWM based 538 and phase controller have both disadvantages and advantages, which makes the design process somewhat complicated [3]. The dc voltage pre-set value in PWM-based controllers has to be carefully selected. As the modulation ratio lies between zero and one, the dc voltage should not be lower than the maximum of the requested SSSC output phase voltage in order to obtain proper control. On the other hand, if the dc side voltage is too high, the rating of both the GTO valves and dc capacitor has to be increased, which means higher installation costs. Not only that, a higher dc side voltage means a lower amplitude modulation ratio, and the lower modulation ratio results in higher harmonic distortion [4]. Phase control allows the dc voltage to change according to the power system conditions, which is clearly advantageous, but it requires a more complicated controller and special and costly series transformers. Also, Simulation results validate that Voltage and Power Oscillation can be damped properly using of Synchronous Static Series Compensator (SSSC).

VI. CONCLUSION

The work done in this thesis mainly focuses on the aspects related to Flexible AC Transmission Systems (FACTS) based controller design and assessment of their contribution to system stability improvement ensuring secure and stable operation of the power system.It is observed that, in terms of computational effort, the GSA approach is superior as compared with DE and PSO. It is observed that STATCOM is slightly more effective than SVC from stability point of view. It is also seen that best system response is obtained with SSSC based damping controller.It is found that coordinated ΔPa based PSS with Δω based SSSC controller provides better system response compared to coordinated ΔPa based PSS with Δω based SVC and STATCOM controllers. It is also observed that less oscillations and settling times are obtained with constant impedance load compared to constant power load and constant current load.

Research and development is a non-stopping process. For any research work carried out, there is always a possibility for better chances of improvement and lot many avenues opened for further work. As a result of the investigations carried out in the area of power system stability improvement with FACTS controllers, following aspects are identified for further scope of research work.

- The present work can be extended to power system with generalized TCSC, UPFC and Interline Power Flow Controller (IPFC).
- The system investigated has been limited up to a three-machine power system. It would be desirable to extend the proposed approach for larger and more realistic systems.
- The present work can be extended for STATCOM and SSSC with energy storage such as battery Energy Storage System (BESS) and Superconducting Magnetic Storage (SMSS) for enhancing power system stability.

VII. REFERENCES

[1]. “Static Synchronous Compensator,” CIGRE, Working group 14.19, 1998.

[2]. N. G. Hingorani and L. Gyugyi, Understanding FACTS, Concepts and Technology of Flexible AC Transmission Systems. Piscataway, NJ: IEEE Press, 2000.

[3]. R. Mohan and R. K. Varma, Thyristor-Based FACTS Controllers for Electrical Transmission Systems.Piscataway, NJ: IEEE Press, 2002.

[4]. L. Gyugyi, N. G. Hingorani, P. R. Nannery, and N. Tai “Advanced Static Var Compensator Using Gate Turn Off Thyristors for Utility Applications”, CIGRE, 23– .203, August 26 September 1, 1990, France.

[5]. J. Arrillaga, B. Barrett, N. A. Vovos “Thyristor Controlled Regulating Transformer for Variable Voltage Boosting”, IEE Proceedings, No. 10, October 1976.