Voltage Level Improvement Of Power System By Using Static Synchronous Series Compensator With POD

Astha Dua and Surya Prakash

Abstract: Power system capability can be increased by the use of Flexible AC Transmission System devices (FACTS) in transmission systems experiencing high power flows. This thesis presents an analysis of one of these devices, namely, a Static Synchronous Series Compensator (SSSC). Voltage Source Converter (VSC) based FACTS is the most recent approach in FACTS technology. The SSSC is the series compensation devices that open up new opportunities to control the power on transmission systems in order to enhance their utilization, increase power transfer capability and to improve voltage profile. This paper describes the damping of power oscillations by static synchronous series compensator (SSSC) based damping controllers and it also improve the reactive power of the system. Simulation studies are carried out in Matlab/Simulink environment to evaluate the effectiveness of the proposed Static synchronous series compensator (SSSC).

Key word - Flexible AC Transmission System (FACTS), Static Synchronous Series Compensator (SSSC), Power Oscillation Damping (POD) controller.

I. INTRODUCTION

Some of the major issues that are involved in bulk power transmission are enhancing the level of power transfer capability of existing transmission lines and flexible control over power flow through these lines. To achieve the above goals, the current trend is to use solid state devices for faster control and reliable operation. Power electronic devices, which are used for power flow control, are categorized under the generic name of Flexible AC Transmission Systems (FACTS). There are three major facets of FACTS. They are shunt compensation, series compensation and phase angle regulation. Of these three, the series compensation is used in this project.

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Among all FACTS devices, static synchronous series compensators (SSSC) plays much more important role in reactive power compensation and voltage support because of its attractive steady state performance and operating characteristics.[6,7].

The power system is a highly nonlinear system that operates in a constantly changing environment; loads, generator outputs, topology, and key operating parameters change continually [8,9] . When subjected to a transient disturbance, the stability of the system depends on the nature of the disturbance as well as the initial operating condition. The disturbance may be small or large. Small disturbances in the form of load changes occur continually, and the system adjusts to the changing conditions. The system must be able to operate satisfactorily under these conditions and successfully meet the load demand. It is important to damp these oscillations as quickly as possible because they cause mechanical wear in power plants and many power quality problems. To improve the voltage stability and the damping of oscillations in power systems, supplementary control laws can be applied to existing devices. These supplementary actions are referred to as voltage stability and power oscillation damping (POD) control. In this work, voltage stability and POD control has been applied to Static synchronous series compensator (SSSC).The SSSC using a voltage source converter to inject a controllable voltage is quadrature with the line current of a power network is able to rapidly provide both capacitive and inductive impedance compensation independent of the power line current [12-14]. These features make the SSSC an attractive FACTS device for power flow control, power oscillation damping and improving transient stability.

In this paper, the damping performance of a two-machine power system is compared for the cases of with and without SSSC based damping controllers in the event of a 3-phase short circuit faults .Simulation results show that in damping power system oscillations, the SSSC with POD controller is more effective than the SSSC without POD controller.

II. PRINCIPLES OF OPERATIONS OF SSSC

The SSSC is generally connected in series with the transmission line with the arrangement as shown in Fig 1. The SSSC comprises a coupling transformer, a magnetic interface, voltage source converters (VSC) and a DC capacitor. The coupling transformer is connected in series with the transmission line and it injects the quadrature voltage into the transmission line. The magnetic interface is used to provide multi-pulse voltage configuration to eliminate low order harmonics. The injected voltage of the coupling transformer V_{pq} is perpendicular to the line current

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I_{line} . The SSSC's output voltage magnitude and phase angle can be varied in a controlled manner to influence power flows in a transmission line. The phase displacement of the inserted voltage V_{pq} , with respect to the transmission line current line I_{line} , determines the exchange of active and reactive power with the ac system.

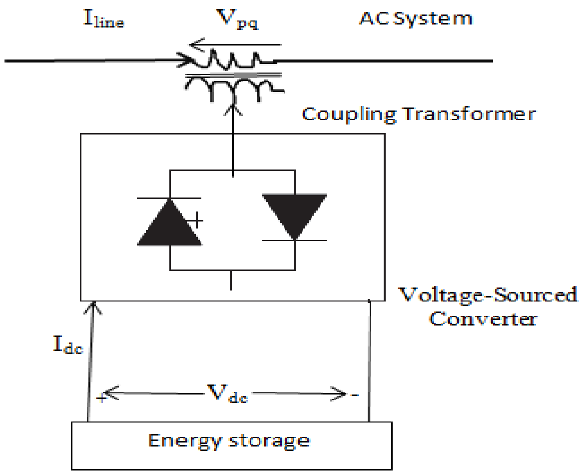
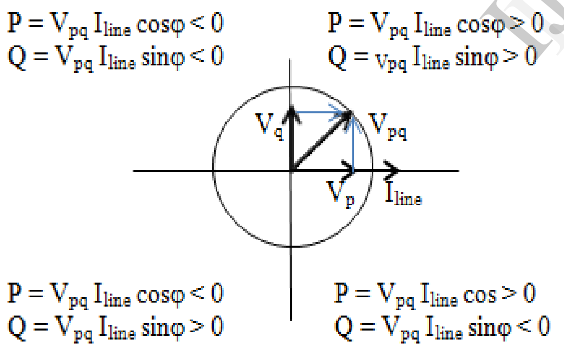
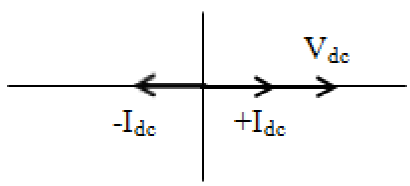


Fig.1 Functional model of SSS

Theoretically, SSSC operation in each of the four quadrants is possible, Theoretically, SSSC operation in 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.



(a)



(b)

Fig.2 SSSC Phasor diagram

In capacitive mode, the injected SSSC voltage is made to lag the transmission line current by 90°; in this case, the SSSC operation is similar to the operation of a series capacitor with variable capacitance kX_c ,i.e., V_{pq} = - j K$X_c I_{line}$, where K is variable.

III.RATING OF SSSC

The SSSC can provide capacitive or inductive compensating voltage independent of the line current. The VA rating of the SSSC (solid-state inverter and coupling transformer) is simply the product of the maximum line current (at which compensation is still desired) and the maximum series compensating voltage: VA = V_{max} .I_{max} An SSSC of 1 p.u. VA rating covers a control range corresponding to 2 p.u. compensating VARs, that is the control range is continuous from -1 p.u. (inductive) VARs to +1 p.u. (capacitive) VAR_s.

IV. POWER SYSTEM UNDER STUDY

To design and optimize the SSSC- based damping controller, a multi area power system with SSSC, shown in Fig 3 is considered. It is similar to the power systems used in references. The system consists of two generators divided in two subsystems and are connected via an intertie. Following a disturbance, the two subsystems swing against each other resulting in instability. To improve the stability the line is sectionalized and a SSSC is in between the bus-1 and 2. In the Figure, G1and G2 represent the generators; T/F1 and T/F2 represent the transformers in the bus-line1 and bus-line 2 respectively.

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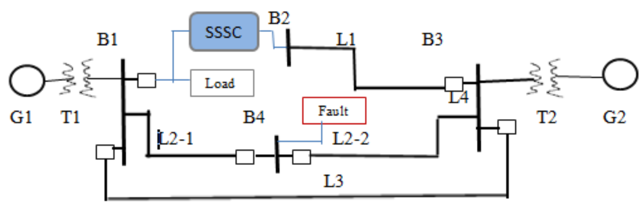
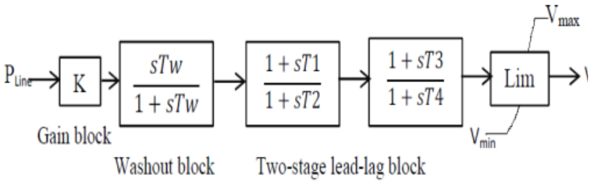


Fig.3 Single line diagram of a two-machine power system with SSSC

The SSSC injected voltage reference is normally set by a POD (Power oscillation damping) controller. In general, the structure of a FACTS POD controller is shown in Fig.4. It involves a transfer function consisting of an amplification block, a washout block and two lead-lag blocks and an output limiter. Commonly, the local signals of FACTS devices are always applied for the damping control. The inputs to the POD controller are the voltage at bus B1 and the current flowing in the line L1.



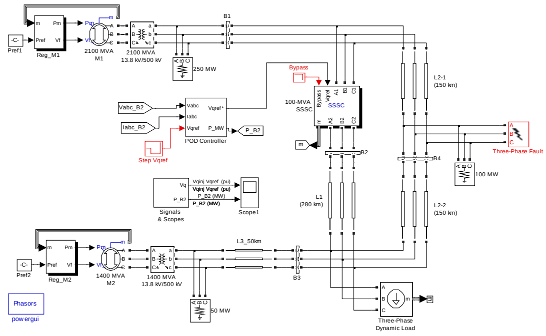


Fig. 4 The structure of a simple FACTS POD controller

V. INTERNAL CONTROLS

From the standpoint of output voltage control, converters may be categorized as "directly" and "indirectly" controlled. For directly controlled converters both the angular position and the magnitude of the output voltage are controllable by appropriate valve (on and off) gating. For indirectly controlled converters only the angular position of the output voltage is controllable by valve gating; the magnitude remains proportional to the dc terminal voltage. The control method of maintaining a quadrature relationship between the instantaneous converter voltage and line current vectors, to provide reactive series compensation and handle SSR, can be implemented with an indirectly controlled converter. The method of maintaining a single frequency synchronous (i.e. fundamental) output independent of dc terminal voltage variation requires a directly controlled converter. Although high power directly controlled converters are more difficult and costly to implement than indirectly controlled converters (because their greater control flexibility is usually associated with some penalty in terms of increased losses, greater circuit complexity, and/or increased harmonic content in the output), nevertheless they can be realized to meet practical utility requirements.

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. The SSSC is used to damp power oscillation on a power grid following a three-phase fault.

Fig. 5 Static Synchronous Series Compensator (SSSC) used for power oscillation damping

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 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. The generation substation M2 is also connected to the load by a 50-km line (L3).

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VI. SIMULATION AND RESULTS

The simulation results are mainly divided two sections. Thus, Section A discusses results for SSSC Dynamic responses for three-phase solid fault without and with POD controller. The results obtained for the test system with three-phase solid fault without and with POD controller.

A. SSSC DYNAMIC RESPONSES

We will first verify the dynamic response of our model. Open the "Step V_{qref}" block (the red timer block connected to the "V_{qref}" input of the POD Controller).This block should be programmed to modify the reference voltage Vqref as follows: Initially Vqref is set to 0 pu V_{qref}; at t=2 s, V_{qref} is set to -0.08 pu (SSSC inductive); then at t=6 s, is set to 0.08 pu (SSSC capacitive). Double-click on the POD Controller block and set the POD status parameter to "off". This will disable the POD controller. Also, make sure that the fault breaker will not operate during the simulation (the parameters "Switching of phase A, B and C" should not be selected). Run the simulation and look at Scope 1.

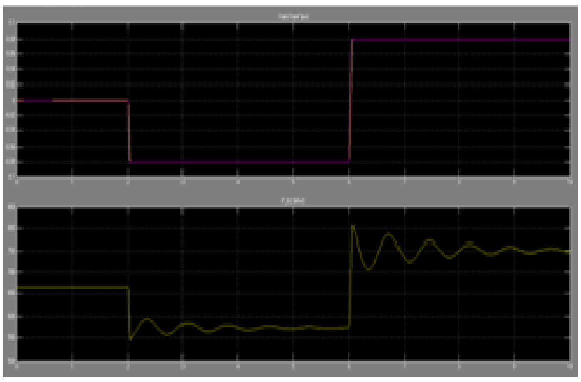

Fig. 6(a) Dynamic response of SSSC for LLL fault without POD controller.

- The first graph displays the V_{qref} signal along with the measured injected voltage by the SSSC.
- The second graph displays the active power flow (P_B2) on line L1, measured at bus B2.

Now, you will run a second simulation with the POD controller in operation. Double-click on the POD Controller block and set the POD status parameter to "on". Start the simulation. Looking again at the second graph on Scope 1(P_B2 signal), we can see that the SSSC with a POD controller is a very effective tool to damp power oscillation.

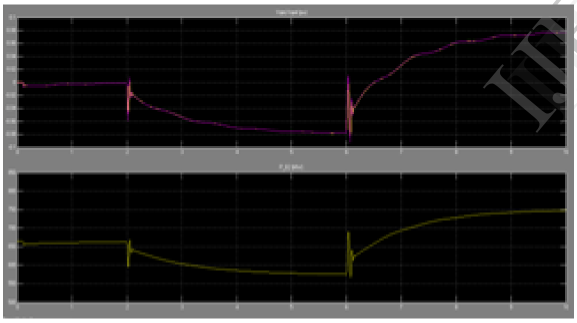

Fig. 6(b) Dynamic response of SSSC for LLL fault with POD controller.

B. Test system simulated waveform

In this test, simulation is performed without and with SSSC controller with POD.

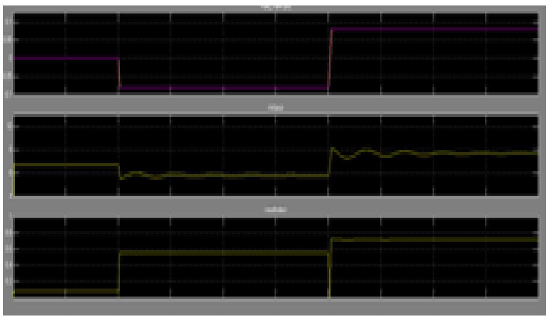

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Fig. 7(a) Simulated wave form for LLL fault without POD controller

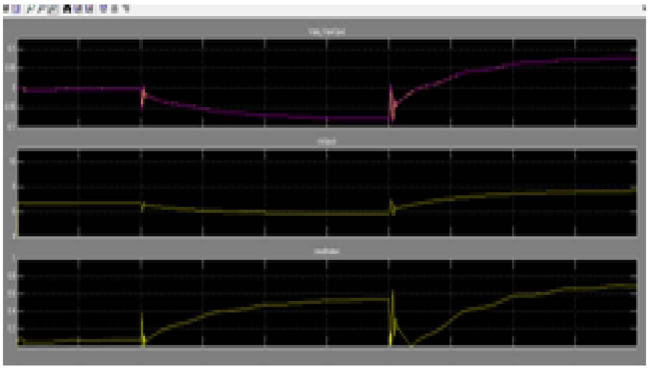

Fig. 7(b) Simulated wave form for LLL fault with POD controller

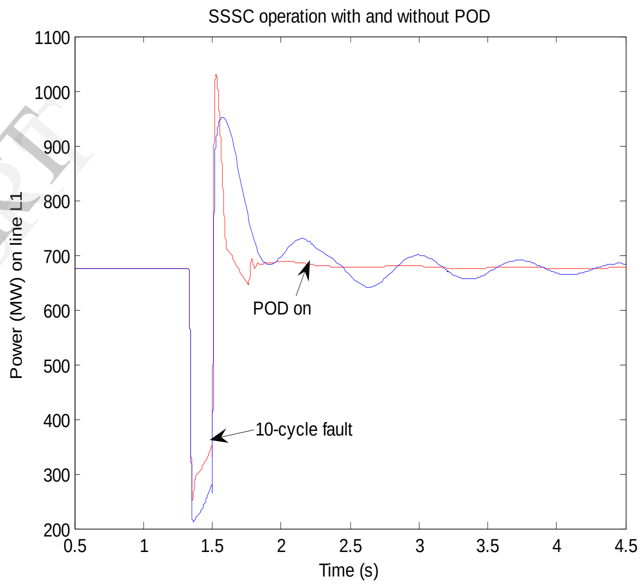

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Figure 8 showing a comparison of the SSSC operation with and without POD control.

VII. CONCLUSION

In this paper, the simulation of a two-machine power system model with Static synchronous series compensator (SSSC) based damping controllers in the presence of a three-phase short circuit fault. The results show that the power system oscillations are damped out very quickly with the help of SSSC based damping controllers in few seconds. 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. 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. 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. The results show that the use of SSSC is having improved dynamic response and at the same time faster than other conventional controllers. Moreover, this approach is also simple and easy to be realized in power system.

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