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Stability Enhancement for Transmission Lines using Static Synchronous Series Compensator

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Abstract-- **In this study, a static synchronous series compensator (SSSC) is used to controlling active and reactive powers as well as damping power system oscillations in transient mode. For fast power flow control in the transmission line system this Reducing the effective reactance of lines by series compensation is a direct approach to increase transmission power capability. However power transfer capability of long transmission lines is limited by stability consideration. Because of the capability of power electronic switching devices control and high speed, more advantages have in FACTS devices areas and presence of these devices in transient stability during transient faults resulting in improvement in power system stability.**

In this paper, review of technique a Static Synchronous Series compensator (SSSC) is used to study the effect of this device in controlling active and reactive powers as well as damping of power oscillations in transient mode. The SSSC with a source of energy in the DC link can supply or absorb the reactive and active power from the line. Complete Simulations have been done in MATLAB/SIMULINK environment. simulation result shows the accuracy of proposed compensator and achieving the desired value for active and reactive powers, and damping of oscillations.

Keywords - Transmission line, Power oscillation damping, Static Synchronous Series compensator (SSSC), Active and Reactive power

I. INTRODUCTION

An inherent characteristic of electric energy transmission and distribution by alternating current (AC) is that real power is generally associated with reactive power. Distribution lines and AC transmission are reactive power networks that are characterized by their per-Kilometre series inductance and shunt capacitance. As load power factor changes the transmission lines voltage profile change that can cause large change amplitude variations in the receiving end voltage. voltage degradation is affect in the performance of loads. The Over voltage is causes harmonic generation and magnetic saturation in system equipment is cause insulation breakdown. After any disturbance of the system Power system has ability to regain its original operating condition. Power system transient stability analysis is, generation or transmission system due to fault or switching [1] . Reactive power compensation has identified as a very key measure to improve the transient stability of the system. For increasing system stability margin gain Flexible AC Transmission Systems (FACTS) devices provides suitable control strategy. Static Synchronous Series compensator (SSSC) is a member of FACTS family which is connected in series with a power system. It is consist solid state Voltage Source Converter (VSC) which generates a controllable alternating current voltage at fundamental frequency. While the primary purpose of a SSSC is to control power flow in steady state also improve transient stability of a power system.

II. STATIC SYNCHRONOUS SERISE COMPENSATOR

The Static Synchronous Series Compensator (SSSC) is a series type FACTS controller based on Voltage Sourse Compensate. A SSSC has several advantages over a TCSC such as elimination of passive components , improve technical system characteristics , symmetric capability in both inductive and capacitive operating modes, possibility of connecting an energy source on the DC side to exchange real power with the AC network.

A. OPERATION OF SSSC AND THE CONTROL OF POWER FLOW

The Static Synchronous Series Compensator (SSSC) is one of series FACTS devices. SSSC is a solid-state voltage source inverter, injects an nearly sinusoidal voltage, with variable magnitude in series with the transmission line. The injected voltage is in quadrature with the line current, that provides the losses in the inverter. The injected voltage, which is in quadrature with the line current, follows an inductive or a capacitive reactance in series with the transmission line. This variable reactance, inserted by the injected voltage source and the electric power flow through the transmission line. schematic of a SSSC is shown in Fig. 2(a). The equivalent circuit of the SSSC is shown in Fig. 2(b). Regulation of power flow can control with control The magnitude of Vc. The winding resistance and leakage reactance of the connecting transformer appear is series with the voltage source V_C. If there is no energy source on The DC side, neglecting losses in DC capacitor and the converter, the power balance in steady state .

Equation (2.1) V_c is in quadrature with current I . If V_c lags I by 90, the operating mode is capacitive and the current (magnitude) in the line is increased with resultant increase in power flow. On the other hand, if V_c leads I by 90, the operating mode is inductive, and the line current is decreased.

Note that we are assuming the injected voltage is sinusoidal (neglecting harmonics).

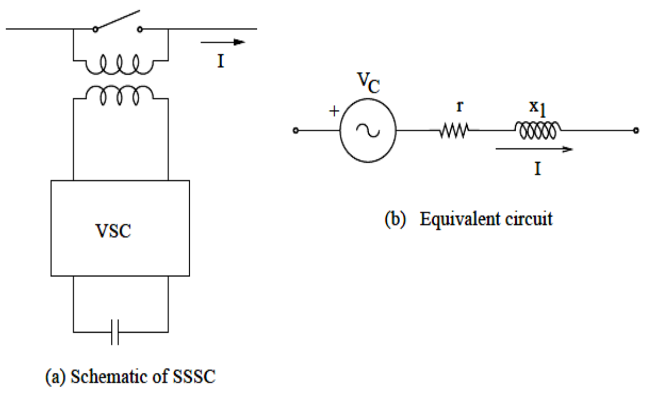

Figure 2. Schematic of SSSC.

Since the losses are always present, the phase shift between current and V_C is less than 90 (in steady state). In general, It can be written as

$$\mathrm{Re}[V_C I^*] = 0 \qquad (2.1)$$

$$\begin{aligned} \hat{V_C} &= V_C(\cos\gamma - j\sin\gamma)e^{j\phi} \\ &= (V_{Cp} - jV_{Cr})e^{j\phi} \end{aligned} \qquad (2.2)$$

Equation (2.2) where Φ is the phase angle of the line current, γ is the angle by which lags the current. V_{Cp} and V_{Cr} are the in-phase and quadrature components of the injected voltage (with reference to the line current). We can also term them as active (or real) and reactive components. The real component is required to meet the losses in the converter and the DC capacitor.

III. Single-Line Diagram of a SSSC and Its Control System Block Diagram

The Static Synchronous Series Compensator (SSSC) is a series device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve power oscillation damping on power grids [1]. The SSSC is injects a voltage V_s in series with the transmission line where it is connected. Figure (3.1) shows single line diagram of SSSC transmission system and its control structure. As the SSSC does not use any active power source, the injected voltage must stay in quadrature with line current. By varying the magnitude of the injected voltage Vq in quadrature with current, the SSSC performs the function like a variable reactance compensator either capacitive or inductive. The variation in injected voltage is performed by means of a Voltage-Sourced Converter (VSC) that is connected on the secondary side of a coupling transformer. The Voltage-Sourced Converter (VSC) uses forced-commutated power electronic devices (GTOs or IGBTs) to synthesize a voltage V_{conv} from a DC voltage.

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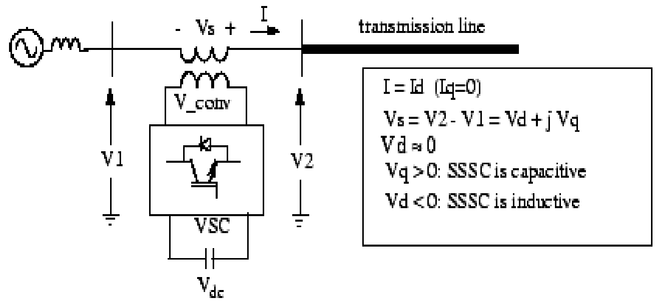

Figure 3.1 Single-line Diagram of a SSSC.

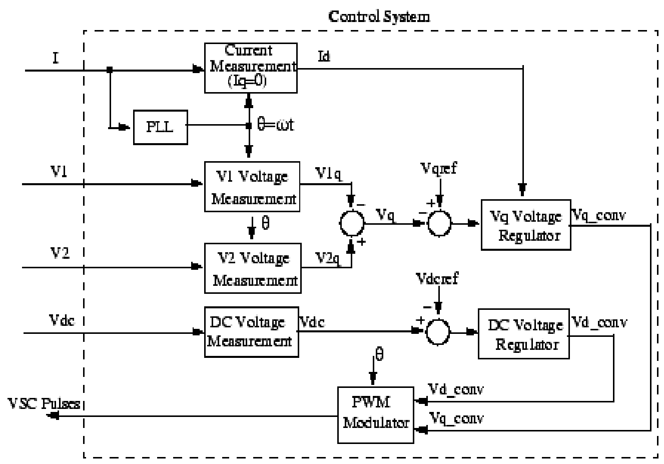

Figure 3.2 Control System Block Diagram Diagram of a SSSC.

A capacitor connected on the DC side of the VSC acts as a DC voltage source. In this a small active power drawn from the line to keep the capacitor charged and provide to transformer, so that the injected voltage V_s is practically 90 degrees out of phase with current I. the control system block diagram V_{d_conv} and V_{q_conv} designated the components of converter voltage V_{conv} which are respectively in phase and in quadrature with current.

VSC using GTO-based square-wave inverters and special interconnection transformers. In this system typically four three-level inverters are used to build a 48-step voltage waveform. Special interconnection transformers technique are used to neutralize harmonics contained in the square waves generated by individual inverters. In this Voltage-Sourced Converter (VSC), the fundamental component of voltage V_{conv} is proportional to the voltage V_{dc} . This type of inverter uses Pulse-Width Modulation (PWM) technique to synthesize a sinusoidal waveform from a DC voltage with a typical chopping frequency of a few kilohertz. Harmonics are eliminating by connecting filters at the AC side of the VSC. This type of VSC uses a fixed type of DC voltage V_{dc} . Voltage V_{conv} is varied by changing the modulation index of the PWM modulator.

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A. The control system of SSSC consists of:

A phase-locked loop (PLL) which synchronizes on the positive-sequence component of the current I. The output of the PLL (angle Θ=ωt) is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltages and currents (labeled as V_d, V_q or I_d, I_q on the diagram).Measurement systems measuring the q components of AC positive-sequence of voltages V_1 and V_2 (V_{1q} and V_{2q}) as well as the DC voltage V_{dc}.

AC and DC voltage regulators which compute the two components of the converter voltage (V_{d_conv} and V_{q_conv}) required obtaining the desired DC voltage (V_{dcref}) and the injected voltage (V_{qref}). The V_q voltage regulator is assisted by a feed forward type regulator which predicts the V_{conv} voltage from the I_d current measurement.

IV. METHODOLOGY

A Static Synchronous Series compensator (SSSC) is a member of FACTS family which is connected in series with a power system. Its consist of a solid state Voltage Source Converter (VSC) which generates a controllable alternating current and voltage at fundamental frequency. When the voltage injected is kept in quadrature with the line current, it can follow as inductive or capacitive reactance so as to influence the power flow through the transmission line (Gyugyi, 1994; and Sen, 1998). While the primary purpose of a SSSC is to control power flow in steady state and also improve transient stability of a power system. A Static Synchronous Series compensator (SSSC) is used to investigate the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode. The SSSC set with a source of energy in the DC link can supply or absorb the reactive and active power from or to the line. Simulations have been done in MATLAB/SIMULINK environment. Simulation results shows for selected bus-2 in three phase 500 KV transmission line system shows the accuracy of this compensator.

FACTS devices member in controlling power flows, achieving the desired value for reactive and active powers, and damping oscillations appropriately. The methodology of this paper is shown in the figure (4.1) with the help of simulink diagram representation. The description of each block in the above figure is as follows:

1. Three Phase Source – The three phases block supplies 500KV three phase voltage to the transmission line.
2. Three phase fault generator- this block generator fault on the transmission line according to user specification.
3. B1 Bus- this bus indicates interfacing connection between 500 KV 2100 MVA source and SSSC block and also provides Voltage(V) & Current (I) measurement.
4. Static Synchronous Series Compensator (SSSC) block- this block represents the SSSC simulation model for the project work.
5. B2 Bus- this bus indicates interfacing connection between SSSC block and 280 KM line and also provides Voltage(V), Current(I) measurement.280 Km Line – this block represents 280 KM transmission line.
6. Three Phase Dynamic Load – represents load at the end of transmission side.
7. 150 Km Line – this block represents 150 KM transmission line.
8. B4 Bus- this bus indicates interfacing connection between 150 KM line to next 150 KM line.
9. B3 Bus- this bus indicates interfacing connection between 50 KM line and dynamic load.

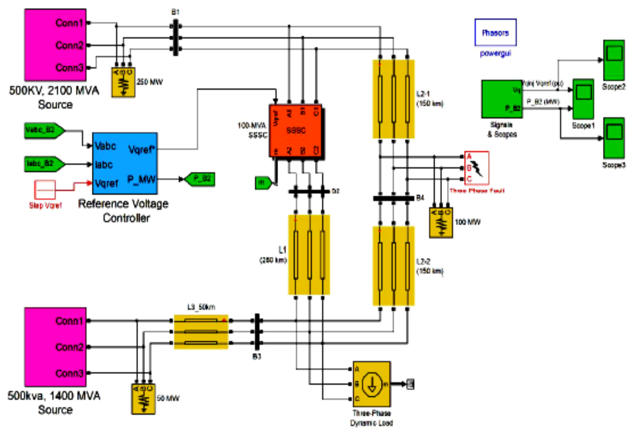

Figure 4.1 Simulink diagram representation of proposed work.

V. RESULTS AND DISCUSSIONS

The Power regulation using a Static Synchronous Series compensator (SSSC) has been successfully implemented in the Simulink. This section deploys the results obtained and steady state and dynamic performance analysis of results obtained. For the comparative analysis a three phase fault is generated on times 1.33 and 1.5 sec using three phase fault generator. Let us first take the three phase transmission line system without SSSC. Figure (5.1) illustrates, the power obtained at bus B2 without SSSC. Figure (5.2) shows the power obtained at all the buses B1, B2, B3 and B4 without SSSC.

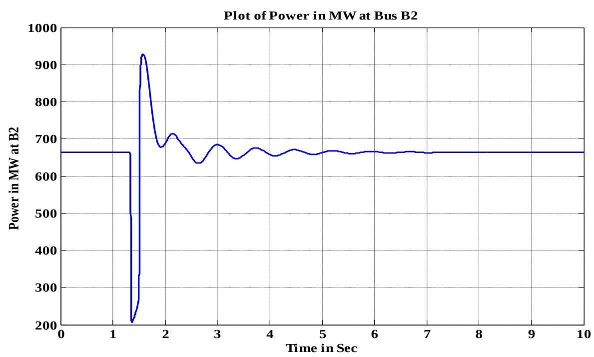

Figure 5.1 Power obtained at bus B2 without SSSC.

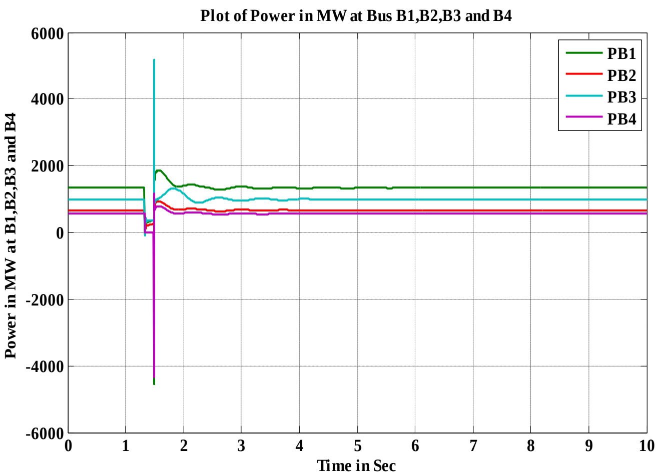

Figure 5.2 Power obtained at all the buses B1, B2, B3 and B4 without SSSC

Now let us consider the SSSC in the same transmission line system with same amount of three phase fault. The power obtained at bus B2 with SSSC is shown in figure (5.3). Figure (5.4) shows the power obtained at all the buses B1, B2, B3, and B4 with SSSC structure. Figure (5.5) shows the reference voltage and modified reference voltage by reference voltage controller. Finally figure (5.6) shows the plot of reference voltage and injected voltage by SSSC.

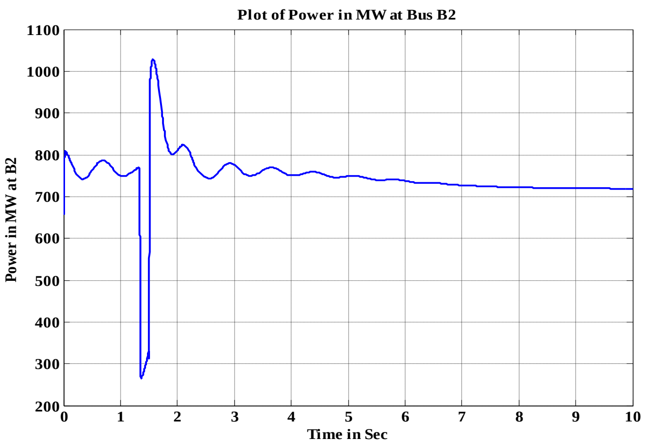

Figure 5.3 power obtained at bus B2 with SSSC

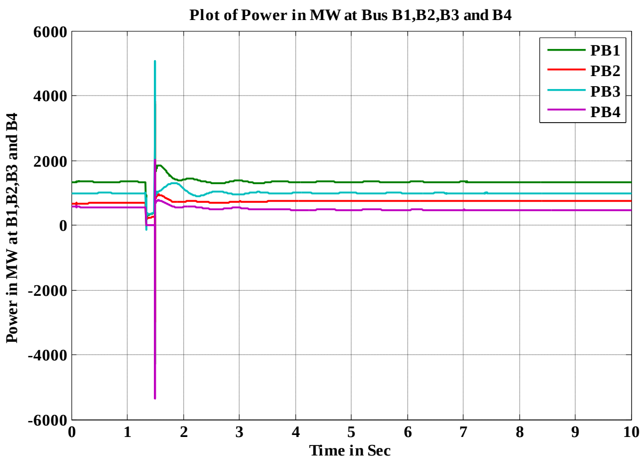

Figure 5.4 Power obtained at all the buses B1, B2,B3and B4 with SSSC structure.

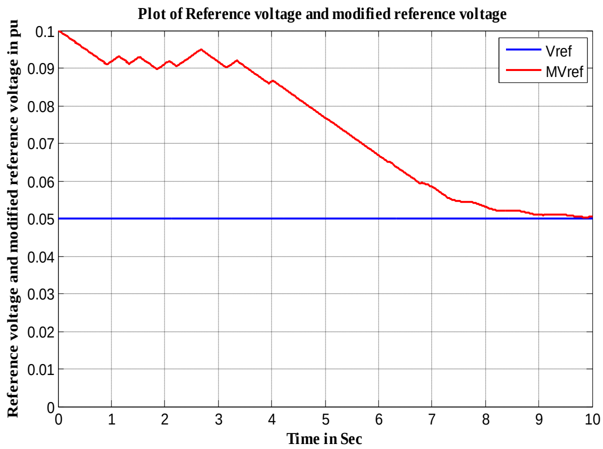

Figure 5.5 Reference voltage and modified reference voltage by reference voltage controller.

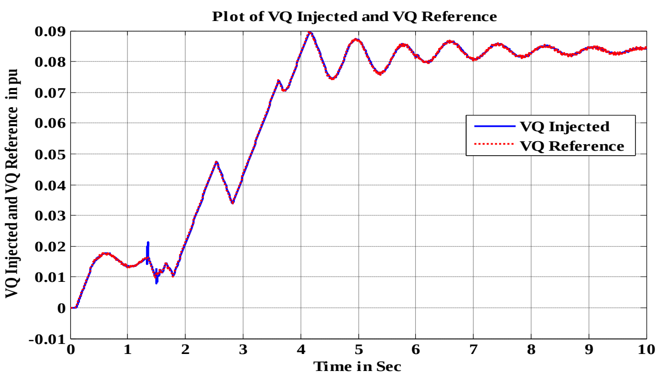

Figure 5.6 The plot of reference voltage and injected voltage by SSSC

From the resultant figures it is clear that the SSSC with reference voltage controller provides good damping for power oscillation.

VI. CONCLUSION

The advancement in the technology like home equipments and plant equipments, demands for precession and highly regulation in the received power from energy generator through the lines, because in current scenario the equipments are very much sensitive to supply power regulation. Any kind of fluctuation either damage the costly equipment or may harm full for further used equipments. In this paper used algorithm shows an efficient solution of this problem. In this paper, a Static Synchronous Series compensator (SSSC) is has been investigated to analyze the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode. The SSSC setup with a source of energy in the DC link can supply or absorb the reactive and active power to or from the line. Complete Simulations have been done in MATLAB/SIMULINK environment. Simulation results shows of selected bus-2 in three phase 500 KV transmission line system shows the accuracy of this compensator as one of the FACTS devices member controlling power flows, achieving the desired value for active and reactive powers, and also damping oscillations appropriately.

The result section provides complete idea about the power oscillation damping capability of the SSSC. Moreover the system developed is able to provide damping for power oscillations, but still this system demands further improvement for higher damping during power oscillation.

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