Power Flow Improvement In Transmission Network Using SSSC

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Abstract: This paper discusses a Static Synchronous Series Compensator (SSSC) which is designed with a control scheme in which PI controller with *abc-dqo* transformation and space vector pulse width modulation (SV-PWM) technique discussed in this paper. In MATLAB/SIMULINK environment, the designed device is connected to a power system transmission network model and effect on system parameters such as line voltage, line current, reactive power (Q) and real power (P) are observed. The motivation of modeling a SSSC from a multi-pulse inverter is to enhance the voltage waveform of the system and to maintain the total harmonic distortion (THD) up to a permissible level. The results show that the voltage injection is successfully achieved by the device and the power flow and phase angle can be controlled.

Keywords - Flexible Alternating Current Transmission System (FACTS), Pulse Width Modulation, Power factor measurement, Static Synchronous Series Compensator (SSSC).

I. Introduction

Today's modern interconnected power system is highly complex in nature. One of the most important requirements during the operation of the electric power system is the reliability and stability. Maintaining stability of such an interconnected multi area power system has become a cumbersome task. As a counter measure against these problems, Flexible AC Transmission System (FACTS) devices were proposed [1].

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The outage of transmission lines, congestion, cascading line tripping, and power system stability loss are the major ideas where capability and utilization of FACTS are considered. It is known that one of the last and new generations of FACTS devices is **Static Synchronous Series Compensators (SSSC).** The SSSC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle).This device is Voltage Source Inverter (VSI) with DC link capacitor which is connected in series with the transmission line through a series transformer. This inverter can be used to control both real and reactive line power flow and voltage with controllable magnitude and in phase with the transmission line. Therefore, SSSC can do responsibility of, active and reactive series compensation and phase shifting. In addition to this, SSSC is also damped the power system oscillations. Therefore improving the transient stability of power system [4-5].

To improve the voltage stability and the damping of oscillations in power systems, supplementary control techniques 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) [4].

In this paper, the reactive power, voltage, power factor and power factor angle of a two-machine power system is compared for the cases of two parallel lines in which one of the line is connected with SSSC.

There are four sections this paper 1st section prescribed the introducing part. 2nd section is describing the basic principle and model of SSSC .3rd section includes the simulink model and control strategy of SSSC. 4th section includes the results and waveform of voltage, reactive, power and power factor and the last section includes the conclusion.

II. PRICIPLE OF OPERATION 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 VSCs are either two-level converter or three level converters. One side of the VSC is connected to the magnetic interface while the other side is connected to the DC bus.

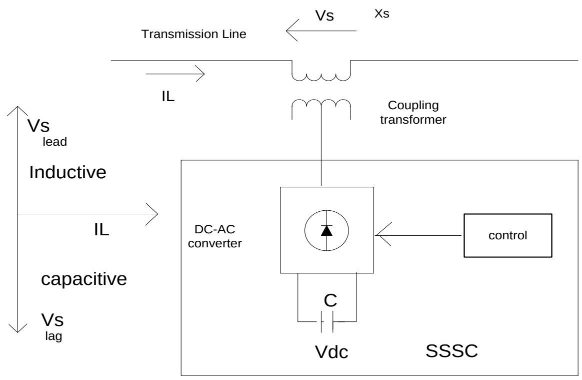

Fig.1 static synchronous series compensator

The VSC generates six-pulse voltage waveform and it is combined into multi-pulse (12 pulses) voltage waveform by Wye-Delta connection of the magnetic interface. More pulses (24 or 36 pulses) can be achieved if zigzag transformers are used as the magnetic interface. The DC capacitor is used to maintain DC voltage level on the DC bus. This DC capacitor is selected to meet harmonic and economic criteria of the SSSC and the power system. Figure.2 shows a single line diagram of a simple Transmission line with an inductive transmission reactance, X_L, connecting a sending end voltage source, and a receiving end voltage source,respectively.

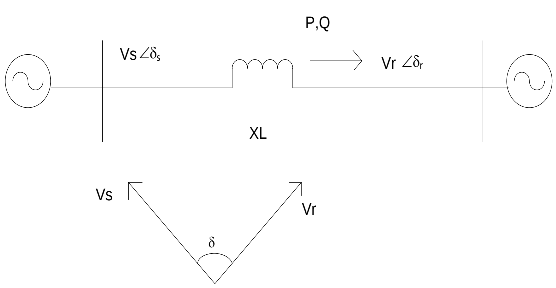

Fig.2 an Elementary Power Transmission System

The real and reactive power (P and Q) flow at the receiving-end voltage source are given by eq. (1) and (2)

$$P = V_r V_s / X_L \sin(\delta_s - \delta_r) = V^2/X_L \sin\delta$$

$$Q = V_r V_s / X_L (1 - \cos(\delta_s - \delta_r)) = V^2/X_L (1 \cos\delta)$$

Where V_s and V_r are voltage magnitudes and δ_s and δ_r are the phase angles of the respective voltage sources. The voltage magnitudes are chosen such that $Vs = Vr = V$ and the difference between the phase angles is $\delta = \delta_s - \delta_r$

An SSSC, limited by its voltage and current ratings, is capable of emulating a compensating reactance, Xq, (both inductive and capacitive) the expression of power flow given

in equation (1) and equation (2) becomes

$$P_q = V^2/X_{eff} \sin\delta = V^2/X_L (1 - X_q/X_L) \sin\delta$$

$$Q_q = V^2$$

$$X_{eff}(1 - cos\delta) = V^2/X_L\left(1 - \frac{X_q}{X_L}\right)(1 - cos\delta)$$

Where X_{eff} is the effective total transmission line reactance between its sending and receiving power system ends, including the equivalent "variable reactance" inserted by the equivalent injected voltage (V_q) (Buck or Boost) by the SSSC. The compensating reactance is defined to be negative when the SSSC is operated in inductive mode and positive when SSSC operated in capacitive mode. Fig.3 shows an example of a simple power transmission system with an SSSC and the related phasor diagrams.

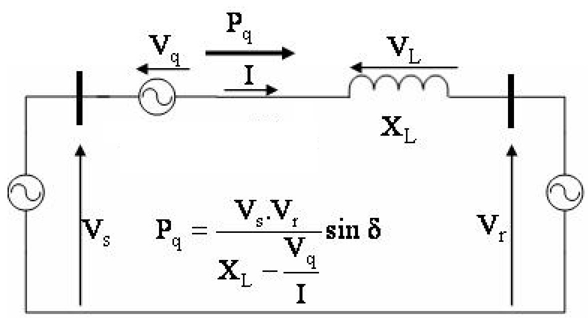

Fig.3 Two machine system with SSSC

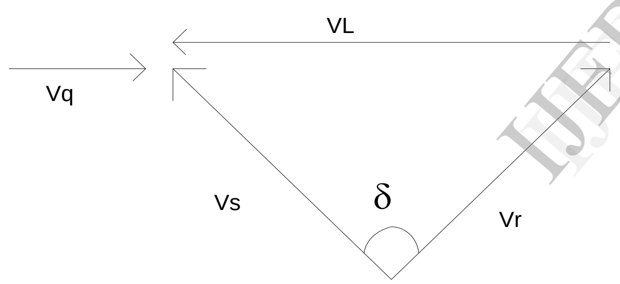

Fig.4 Phasor diagram

The SSSC injects the compensating voltage in series with the line irrespective of the line current. The transmitted power Pq therefore becomes a parametric function of the injected voltage and it can be expressed as follows.

$$P = \left(\frac{V^2}{X_L}\right) sin\delta + \left(\frac{V}{X_L}\right) V_q cos\delta/2$$

III. SIMULINK Model

The SSSC consists of a voltage source inverter which is connected to a transmission line through a transformer. On dc side of converter a 2000μF dc capacitor is connected. Fig.5 shown below shows the transmission model with SSSC installed on one transmission line and other parallel line is uncompensated.

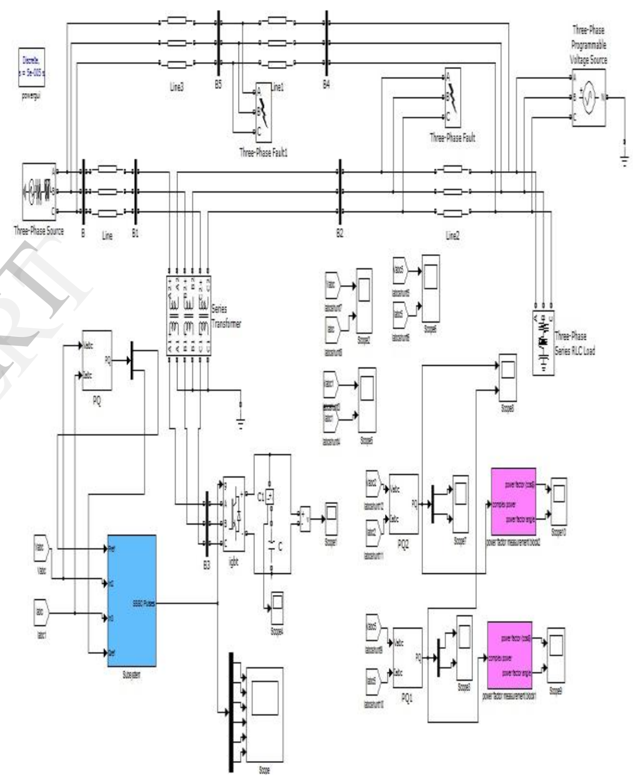

Fig.5. SIMULINK Transmission System Model

A. Control Strategy

Control technique of SSSC is shown in Fig. 6. For this part, of which the series converter controller controls the transmission line power (real and reactive power), impedance compensation, damp oscillations, voltage compensation.

The error output generated by comparing reference real power (P_{ref}) with measured power (P_m) and reference reactive power (Q_{ref}) with measured reactive power (Q_m) is applied to PI controller. The angle is calculated from both V_{abc} and V_{dqo} by using PLL. Atlast both Vmag. and angle are send to SV-PWM pulse generator. These pulses are then applied to converter.

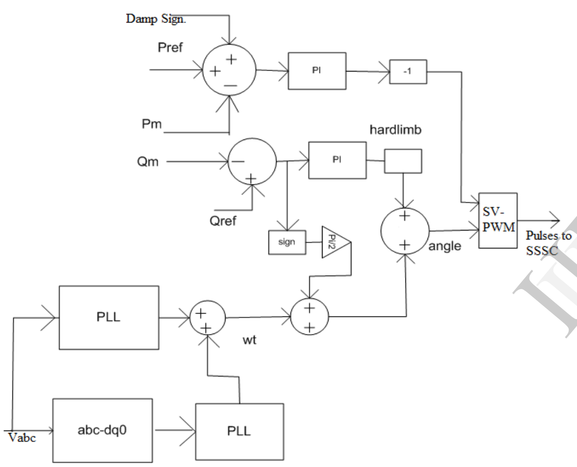

Fig.6.control technique of SSSC

IV. Simulation Results

The transmission network which is designed in MATLAB/SIMULINK. As discussed earlier SSSC control the power flow and line voltage under fault condition. To achieve this, a novel design is implemented in SSSC control technique which measures the power factor angle of power factor. In the following model single phase fault has been introduced in the somewhere between bus 2 and load in compensated line and in uncompensated line the fault is between bus 4 and 5 during transition time from 0.2 to 0.3sec.

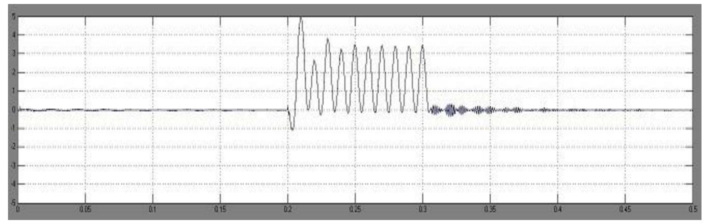

Fig.7.1 Reactive power without SSSC

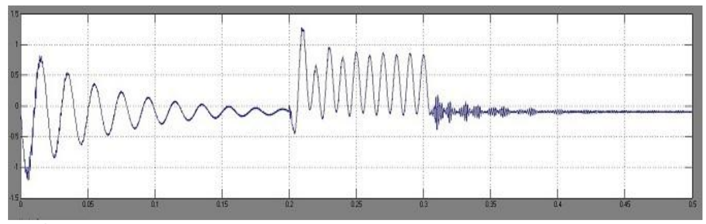

Fig.7.2 Reactive power with SSSC

Result 1: Reactive power control: Fig 7.1 shows that reactive power component in the transmission line is very high without using any technique when a fault is introduced in the line (0.2 to 0.3 sec). With the use of SSSC technique, this reactive power components magnitude reduced to a permissible level during the fault time in fig 7.2

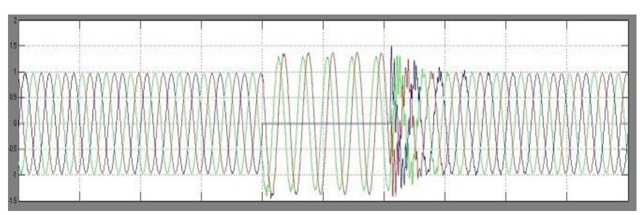

Fig.8.1Line voltage without SSSC

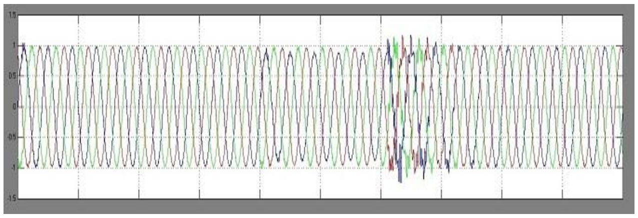

Fig.8.2Line voltage with SSSC

Result 2 Bus voltage: From the fig 8.1 and fig 8.2, it has been cleared that SSSC device improve the performance of the transmission line by injecting the voltage component during the fault condition and hence improves the efficiency of the transmission line.

Result3 Real Power: From the above fig.9.1 and 9.2 it has been clear that power oscillating damping is reduced to a great extent under fault condition with the use of SSSC.

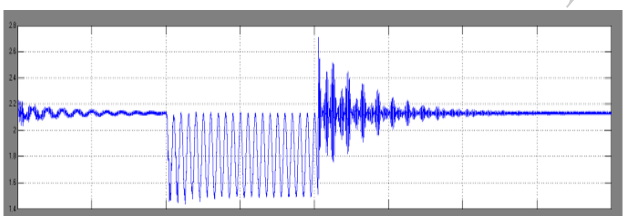

Fig9.1 Real power without SSSC

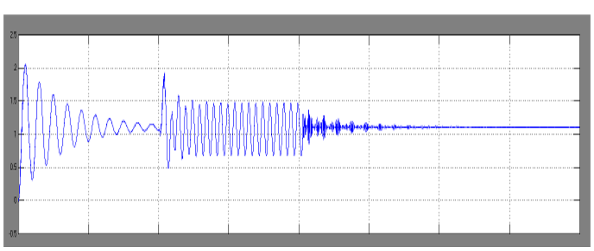

Fig.9.2 Real power with SSSC

Conclusion: In this paper, the simulation of a transmission power system model with Static synchronous series compensator (SSSC) based damping controllers in the presence of a single phase short circuit fault is considered. The results shows that the power system oscillations are damped out very quickly with the help of SSSC based technique in few seconds. The voltage waveform along with the instantaneous active and reactive power calculations reveals that the designed topology works satisfactorily. The compensation of the reactive power flow over the power line due to the power line inductance is compensated with the help of series injected voltage. The balance or the stability of the system is not affected and the harmonic distortion is kept to reasonable levels.

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