International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No. 6, Special Issue 2. PP : 130-133 22-23 Dec. 2017

# Reactive Power Compensation using Static Synchronous Series Compensator (SSSC)[A Review Paper]

**Ruchirkumar Mehta, N. G. Mishra**
Department of Electrical Engineering, Birla VishvakarmaMahavidyalaya
Corresponding Authoor: ruchirsmehta@gmail.com

***Abstract : The power system has now a daybecome very complex and the load on the system is increasing rapidly resulting in a major increase in reactive power absorption. Flexible Alternating Current Transmission System (FACTS) devices are very useful in providing reactive power compensation to the system. One such device is Static Synchronous Series Compensator (SSSC). The SSSC provides series compensation to the power system through series voltage injection. This paper represents the reactive power compensation and voltage regulation obtained by SSSC in the power system. Simulation of the SSSC is carried out in MATLAB software. The control circuit comprises of d-q transformation and PI controllers. The simulated converter circuit of SSSC has a six-pulse Voltage Source Inverter (VSI) whose output AC voltage is fed into the system. The injected voltage is independent from the line current. The injected voltage (compensating voltage) can lead or lag the line current by 90° i.e. it can operate in both the inductive and capacitive region. The SSSC not only provides reactive power compensation but also voltage regulation.***

**Keywords- SSSC, Active power, Reactive power compensation, FACTS device, Voltage Source Inverter.**

## I. INTRODUCTION

Today, there is need for fast and flexible power flow control in transmission system because increase in utility deregulation and power wheeling requirement is expected in the future. The power transmission system needs to be effectively operated and their utilization degree needs to be increased by the utilities. The FACTS devices like SSSC are used to prove their performance in terms of stability and reactive power compensation [1].

The SSSC can control both the active and reactive power flow in the line. The compensating voltage is independent of the line current. TheSSSC can produce three-phase AC voltage at the desired fundamental frequency with controllable variable amplitude and phase angle. Therefore, SSSC is having analogy with synchronous voltage source.The SSSC does not have sub synchronous resonance oscillations because it does not resonate with inductive line impedance [6].

The SSSC is also analogous to synchronous compensator as it can both generate or absorb reactive power from the system. It can also provide real power compensation if DC battery is used instead of the DC capacitor and thus resistive compensation in the transmission line is also obtained. The SSSC controls power flow in steady state as well as improves transient stability of the power system.The parameters of the power system are controlled by PI controllers.The reactive power compensation of the power system will reduce voltage drop and provide voltage regulation in the power system. The injecting voltage can emulate as inductive or capacitive reactance as the injecting voltage is in quadrature with line current. This paper presents mainly reactive power compensation using SSSC [4].

## II. PRINCIPLE OF OPERATION OF SSSC

Transmission line inductance is compensated by a series capacitor by presenting a lagging quadrature voltage with respect to the transmission line current. The lagging quadrature voltage works in opposition to the leading quadrature voltage across the transmission line inductance. The inductive reactance of the line is reduced due to the net effect. The schematic diagram of SSSC is shown in fig.1. The operation of SSSC is similar as it also injects quadrature voltage $V_C$which is independent of the line current but lagging in phase [5].

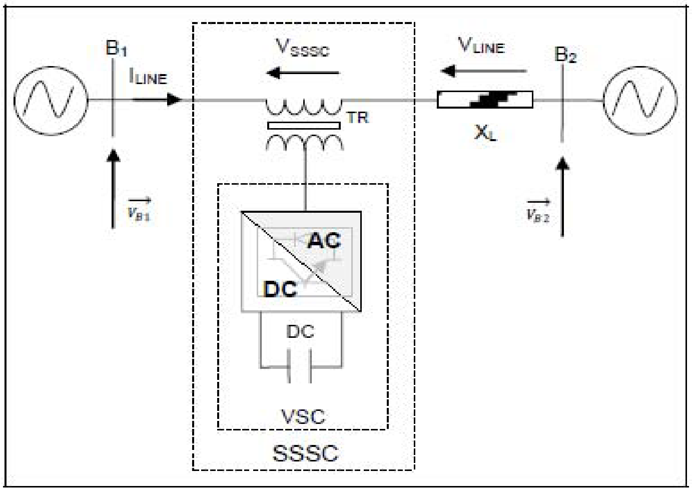


Fig.1: Static Synchronous Series Compensator

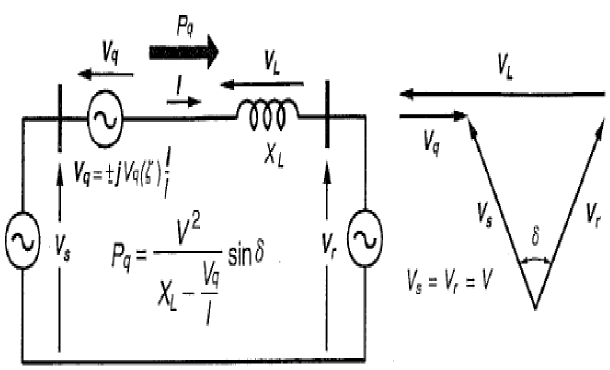


Fig.2: Two machine system with SSSC and the phasor diagram of SSSC

Fig.2 shows Static Synchronous Series Compensator (SSSC) for a two-machine system and the associated phasor diagram. The insertion of AC output voltage of the inverter in the transmission line is performed by a voltage source inverter (VSI) and a coupling transformer. The SSSC controls the magnitude and phase angle of this inserted ac compensating voltage effectively. The transmitted power $P_q$is a parametric function of injected voltage. The real and reactive power (P and Q) without SSSC at the receiving end voltage are given respectively by expressions (1) and (2).$\delta$ is the transmission angle between the two machines.

$$\mathbf{P} = \frac{V_s V_r}{X_L}\sin(\delta s - \delta r) = \frac{V^2}{X_L}\sin\delta \qquad (1)$$

$$\mathbf{Q} = \frac{V_s V_r}{X_L}(1-\cos(\delta s - \delta r)) = \frac{V^2}{X_L}(1-\cos\delta) \qquad (2)$$

Where $V_s$ and $V_r$are magnitudes of voltage sources and $\delta_s$ and $\delta_r$ are the phase angles of voltage sources $V_s$ and $V_r$respectively. Assume $V_s = V_r$.

$$\boldsymbol{\delta} = \boldsymbol{\delta_s - \delta_r} \qquad (3)$$

Thus, the real and reactive power equations are represented this way:

$$\mathbf{P} = \frac{V^2}{X_{eff}}\sin\delta = \frac{V^2}{\left(1-\frac{X_q}{X_L}\right)X_L}\sin\delta \qquad (4)$$

$$\mathbf{Q} = \frac{V^2}{X_{eff}}(1-\cos\delta) = \frac{V^2}{\left(1-\frac{X_q}{X_L}\right)X_L}(1-\cos\delta) \qquad (5)$$

When the SSSC is operated in the inductive mode the compensating reactance $X_q$is defined to be negative and in the capacitive mode compensating reactance $X_q$is defined to be positive.$X_{eff}$is the effective reactance of the transmission line including the variable compensating reactance inserted by the injected voltage source of the SSSC [3].

## III. CONTROL STRATEGY

The specifications and model parameters are givenbelow in table 1.There are four buses in the given power system B1, B2, B3 and B4 connected in the ring mode. Two power plants suppliesphase-to-phase voltage 13.8 kV to the power system. The transmission line voltage is of 500 kV.The lengths of the transmission lines Line1, line2, line3 and line4 are 150 km, 280 km, 150 km and 50 km respectively.

**Table 1: Specification and parameters of model**

| Specifications | System parameters |
|---|---|
| Generator G1 or Machine M1 | 2100 MVA, 13.8 kV |
| Generator G2 or Machine M2 | 1400 MVA, 13.8 kV |
| Transformer TR1 | 2100 MVA, 13.8 kV/ 500 kV |
| Transformer TR2 | 1400 MVA, 13.8 kV /500 kV |
| System phase to phase voltage | 13.8 kV |
| Transmission line voltage | 500 kV |
| Load | 2000 MVA |
| Base parameters | Base voltage= 500 kV<br>Base power= 500 MVA |
| Line length | Line1= 150 km, Line2=280 km, Line3= 150km,Line4= 50 km |

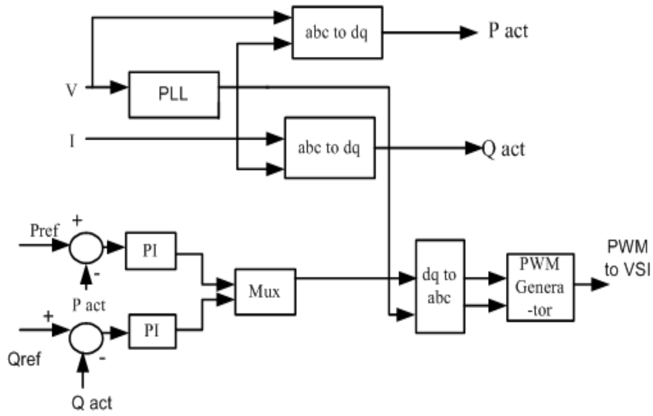


Fig.3: Control system of SSSC

The above fig. 3 shows the control system of the SSSC. First,line voltage V and line current I both from the bus are measured for controlling the power flow in transmission line. Active power $P_{act}$along with reactive power $Q_{act}$is calculated using values of line voltage $V_1$ and line current $I_1$. Feedback signals of the control loop utilizes these calculated active and reactive power. $P_{ref}$ and $Q_{ref}$ are the ideal reference values provided for the system. $P_{act}$ and $Q_{act}$are compared with the reference values $P_{ref}$ and$Q_{ref}$. The error signals obtained from this comparison are then forwarded to PI controller. The PI controller reduces the steady state error and eliminates inaccuracy of the signals. The error is reduced to its least possible values of signals and it is made sure that actual calculated values $P_{act}$ and $Q_{act}$ match with the reference values $P_{ref}$ and $Q_{ref}$.Thus power flow control is attained. These controller results are then converted to abc reference and forwarded to the pulse width modulator (PWM).

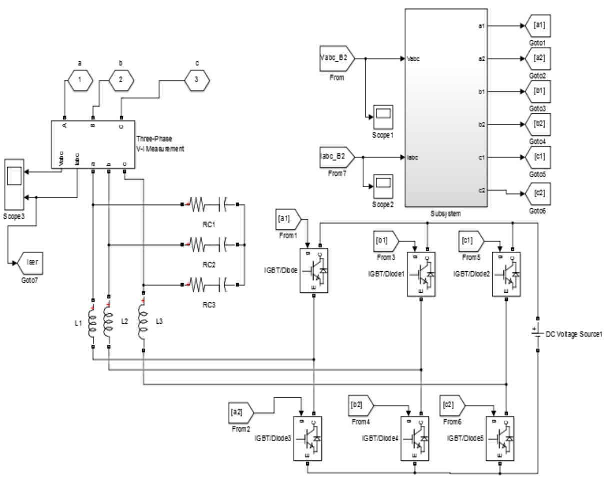

Fig.4: Simulated converter circuit of SSSC

International Journal of Scientific Engineering and Technology
Volume No. 6, Special Issue 2. PP : 130-133
ISSN : 2277-1581
22-23 Dec. 2017

The expressions of the calculated actual values of real and reactive powers $P_{act}$ and $Q_{act}$ are given below:

$$\mathbf{P_{act} = V_d{*}I_d + V_q{*}I_q} \quad \textbf{(6)}$$

$$\mathbf{Q_{act} = V_q{*}I_d + V_d{*}I_q} \quad \textbf{(7)}$$

Six high frequency signals are produced by PWM. Control to the switches of Voltage Source Inverter is provided by these signals. The voltage source inverter (VSI) produce three phase voltages using these signals. These three phase voltages are injected into the transmission line through series transformer. Transmission line current is in quadrature to this injected voltage. As shown in above fig.5, active and reactive power can be fed or absorbed using the compensator provided with a DC voltage source in the converter circuit. The SSSC converter circuit works along with the control circuit [2,3].

## IV. SIMULATION OF SSSC

The two machine power system without SSSC and with SSSC both are represented in fig.5 and fig.6 respectively.

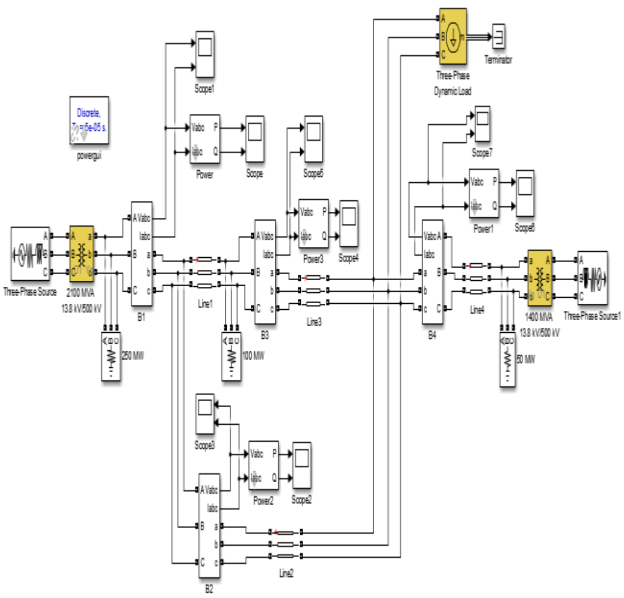

Fig.5: Two machine power system without SSSC

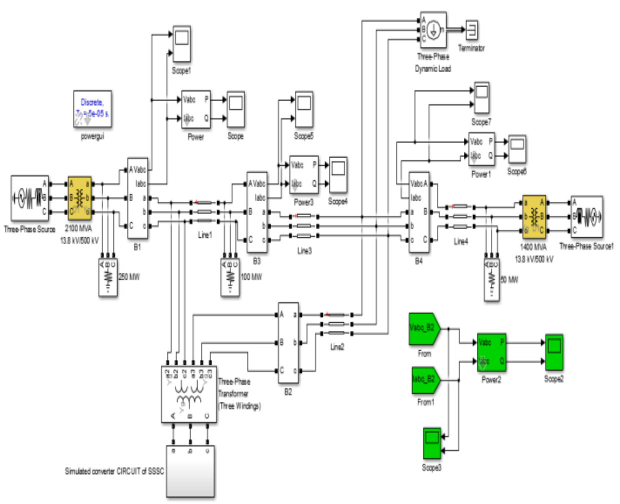

Fig.6: Two machine power system with SSSC

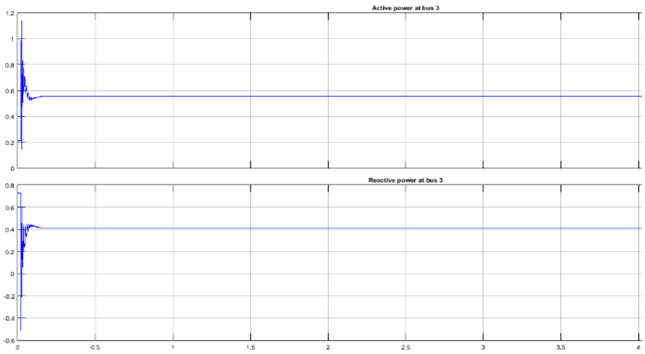

Fig.7: Active and reactive power at bus 3 for system without SSSC (in p.u. value)

The results of the without SSSC power system and with SSSC power sytem are shown in fig.7 and fig.8.

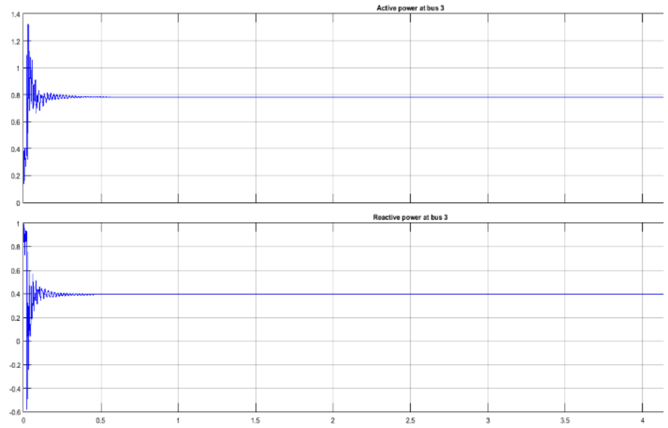

Fig.8: Active and reactive power at bus 3 for system with SSSC (in p.u. value)

From fig.8 and fig.9, it is observed that SSSC increases the active power and does reactive power compensation. The active power is increased to 0.78 p.u. and reactive power is compensated from 0.42 p.u. to 0.40 p.u. at bus 3 of the power system.

## V. CONCLUSION

The SSSC can effectively compensate the reactive power of the power system. The reactive power absorption at The active power flow is also increased from 0.55p.u. to 0.78 p.u. The

SSSC can also be used for multi-machine power systems. Active power and reactive power both can be controlled by SSSC. The SSSC can also provide improvement in the voltage profile of the power system. The SSSC also provides stability to the power system.

## REFERENCES

i. *Mohammed abdulkhaderazizbiabani, Mohdakram, Ikram ahmed shareef, "Power System Stability Enhancement using Static Synchronous Series Compensator", International conference on Signal Processing, Communication, Power and Embedded System (SCOPES)-2016, IEEE.*

ii. *Pooja Nagar, S.C.Mittal, "Reactive power compensation by Static Synchronous Series Compensator", 2016 International Conference on Micro-Electronics and Telecommunication Engineering.*

ISSN : 2277-1581
22-23 Dec. 2017

*iii. H. Taheri , S. Shahabi , Sh. Taheri , A. Gholami , "Application of Synchronous Static Series Compensator (SSSC) on Enhancement of Voltage Stability and Power Oscillation Damping", IEEE 2009.*

*iv. M. Faridi, H. Maeiiat, M. Karimi ,P. Farhadi, H. Mosleh,"Power System Stability Enhancement Using Static Synchronous Series Compensator (SSSC)", Islamic Azad University-Ahar Branch, Ahar, Iran, IEEE 2011.*

*v. Narain G. Hingorani, Laszlo Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", IEEE Press, A John Wiley & Sons, Inc., Publication.*

*vi. Abdul Haleem, RavireddyMalgireddy, "Power Flow Control with Static Synchronous Series Compensator (SSSC)", Proc. of the International Conference on Science and Engineering (ICSE 2011).*