International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 02 | Feb -2017 www.irjet.net p-ISSN: 2395-0072

REACTIVE POWER COMPESATION USING STATIC SYNCRONOUS SERIES COMPENSATOR-A REVIEW

Vishal A. Manwar[1], Sumit D. Dhakulkar[2], Subhash G. Banole[3], Prof. Bhushan S. Rakhonde[4]

[1, 2, 3] UG, [4]Assistant Professor, Electrical Engineering Department, DES'sCOET, Maharashtra, India

---

Abstract - *The concept of reactive power compensation technologies. By means of reactive power compensation techniques, reactive power is controlled in such a way that the performance of electric power system gets improved. This is gives the brief idea about the principles of operation, design characteristics of various types of compensators etc. These compensation techniques are used to change the performance of AC transmission & distribution systems as per the need. The compensators enhance the stability of the AC system by increasing the maximum active power that can be transmitted. By managing the line reactive power, the working of overall electric power system can be enhanced. In the case study, after implementing series and shunt compensation techniques in the system, results are shown for comparison. This can be achieved by FACTS controllers. Static Synchronous Series Compensator (SSSC) is a series connected FACTS controller, which is capable of providing reactive power compensation to a power system. The output of an SSSC is series injected voltage, which leads or lags line current by 90°, thus emulating a controllable inductive or capacitive reactance. SSSC can be used to reduce the equivalent line impedance and enhance the active power transfer capability of the line. In this series compensation provided by an SSSC is considered.*

Keywords:

AC transmission, Compensation, FACTS, Reactive Power, SSSC

1. INTRODUCTION

Now a day, nothing is possible without electricity. Without electricity modern society would cease to function. As the volume of Power transmitted and distributed increases, so do the requirements for a high quality and reliable supply. Thus, reactive power control and voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors , to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. As the power transfer growth, the power system becomes increasingly more complex to operate and the system become less secure. It may lead to large power with inadequate control, excessive reactive power in various parts of the system and large dynamic swings between different parts of the system thus the full potential of transmission interconnections cannot be utilized. In power transmission,reactive power plays an important role. Real power accomplishes the useful work while reactive power supports the voltage that must be controlled for system reliability.

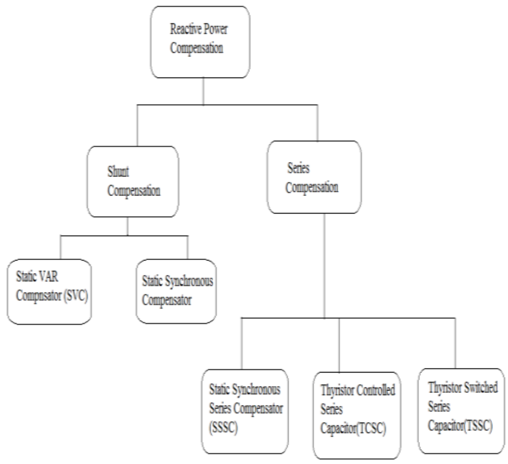

Fig. 1: Classification of Reactive Power Compensation

Reactive power has a profound effect on the security of power systems because it affects voltages throughout the system. Decreasing reactive power causing voltage to fall while increasing it causing voltage to rise. A voltage collapse may be occurs when the system try to serve much more load than the voltage can support. Voltage control and reactive power management are the two aspects of a single activity that both supports reliability and facilitates commercial transactions across transmission networks. Voltage is controlled by absorbing and generating reactive power. Thus reactive power is essential to maintain the voltage to deliver active power through transmission lines. Different reactive power compensation methods are shown in fig.1 Classification of Reactive power compensation. The rapid development of power electronics technology provides exciting opportunities to develop new power systems equipment for better utilization of existing systems. During the last decade a number of control devices under the term Flexible AC Transmission Systems (FACTS) technology have been proposed and implemented. The FACTS devices can be used for power flow control, loop flow control, load sharing among parallel corridors, voltage regulation, and enhancement of transient stability and mitigation of system oscillations. FACTS have become an essential and integral part of modern power systems. Modeling and digital simulation plays an important role in the analysis, design, testing and commissioning of such controllers. Static Synchronous Series Compensator (SSSC) is a series compensator of FACTS family. It injects an almost sinusoidal voltage with variable amplitude.

It is equivalent to an inductive or a capacitive reactance in series with the transmission line. The heart of SSSC is a VSI (voltage source inverter) that is supplied by a DC storage capacitor. With no external DC link, the injected voltage has two parts the main part is in quadrature with the line current and emulates an inductive or capacitive reactance in series with the transmission line, and a small part of the injected voltage is in phase with the line current to cover the losses of the inverter. When the injected voltage is leading the line current, it will emulate a capacitive reactance in series with the line, causing the line current as well as power flow through the line to increase. When the injected voltage is lagging the line current, it will emulate an inductive reactance in series with the line, causing the line current as well as power flow through the line to decrease.

2. NEED OF REACTIVE POWER

a) Active power is the energy supplied to run a motor, heat a home, or illuminate an electric light bulb. Reactive power provides the important function of regulating voltage.
b) If voltage on the system is not high enough, active power cannot be supplied.
c) Reactive power is used to provide the voltage levels necessary for active power to do useful work.
d) Reactive power is essential to move active power through the transmission and distribution system to the customer .Reactive power is required to maintain the voltage to deliver active power (watts) through transmission lines.
e) Motor loads and other loads require reactive power to convert the flow of electrons into useful work.
f) When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines.

3. REACTIVE POWER THEORY

Reactive Power =Vn In Sin(ωn)………………….. (1)

Where, Vn and in are respectively the voltage and current rms values of the nth harmonics of the line frequency, and ωn is the phase difference between the voltage and the current nth harmonics. A convention is also adopted stating that the reactive energy should be positive when the current is leading the voltage (inductive load).In an electrical system containing purely sinusoidal voltage and current waveforms at a fixed frequency, the measurement of reactive power is easy and can be accomplished using several methods without errors.

Alternating systems supply or consume two kind of power the real power and reactive power. Real power accomplishes useful work while reactive power supports the voltage that must be controlled for system reliability. Reactive power has a profound effect on the security of power systems because it affects voltages throughout the system.

4. REACTIVE POWER LIMITATIONS

a) Reactive power does not travel very far.
b) Usually necessary to produce it close to the location where it is needed.
c) A supplier/source close to the location of the need is in a much better position to provide reactive power versus one that is located far from the location of the need.
d) Reactive power supplies are closely tied to the ability to deliver real or active power.

5. IMPORTANCE OF REACTIVE POWER

a) Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse.
b) Decreasing reactive power causing voltage to fall while increasing it causing voltage to rise. A voltage collapse may be occurs when the system try to serve much more load than the voltage can support.
c) When reactive power supply lower voltage, as voltage drops current must increase to maintain power supplied, causing system to consume more reactive power and the voltage drops further . If the current increase too much, transmission lines go off line, overloading other lines and potentially causing cascading failures.
d) If the voltage drops too low, some generators will disconnect automatically to protect themselves. Voltage collapse occurs when an increase in load or less generation or transmission facilities causes dropping voltage, which causes a further reduction in reactive power from capacitor and line charging, and still there further voltage reductions. If voltage reduction continues, these will cause additional elements to trip, leading further reduction in voltage and loss of the load. The result in these entire progressive and uncontrollable declines in voltage is that the system unable to provide the reactive power required supplying the reactive power demands.

6. PROBLEM OF REACTIVE POWER

A) Though reactive power is needed to run many electrical devices, it can cause harmful effects on appliances and other motorized loads, as well as electrical infrastructure. Since the current flowing through electrical system is higher than that necessary to do the required work, excess power dissipates in the form of heat as the reactive current flows through resistive components like wires, switches and transformers. Keep in mind that whenever energy is expended, you pay. It makes no difference whether the energy is expended in the form of heat or useful work.

B) Determine how much reactive power electrical devices use by measuring their power factor, the ratio between real power and true power. A power factor of 1 (i.e. 100%) ideally means that all electrical power is applied towards real work. Homes typically have overall power factors in the range of 70% to 85%, depending upon which appliances may be running. Newer homes with the latest in energy efficient appliances can have an overall power factor of 90%.

C) Not as severe as in heavily industrialized areas. However, it is true that power Electric companies correct for power factor around industrial complexes, or they will request the offending customer to do so, or they will charge for reactive power. Electric companies are not worried about residential service because the impact on their distribution grid factor correction assies. The technology has been successfully applied throughout industry for yearssts the electric company by reducing demand for electricity, thereby allowing them to satisfy service needs elsewhere.

D) Reactive Power Caused Absence of Electricity -A Blackout

E) The quality of the electrical energy supply can be evaluated basing on a number of parameters. However, the most important will be always the presence of electrical energy and the number and duration of interrupts.

F) When consumption of electrical energy is high, the demand on inductive reactive power increases at the same proportion. In this moment, the transmission lines (that are well loaded) introduce an extra inductive reactive power. The local sources of capacitive reactive power become insufficient. It is necessary to deliver more of the reactive power from generators of power plants.

6. IMPROVING REACTIVE POWER AND CONTROL

Reactive power compensation is often most effective way to improve both power transfer capability and voltage stability. The control of voltage levels is accomplished by controlling the production, absorption and flow of reactive power. The generating units provide the basic means of voltage control, because the automatic voltage regulators control field excitation to maintain scheduled voltage level at the terminals of the generators.

To control voltage throughout the system we have to use addition devices to compensate reactive power. Reactive compensation can be divided into series and shunt compensation. It can be also divided into active and passive compensation. But mostly consideration will be focused on shunt capacitor banks, static var compensator (SVC) and Static Synchronous Compensators (STATCOM), which are the part of group of active compensators called Flexible AC Transmission Systems (FACTS).

The devices used for the reactive power compensation are classified as follows:

a) Shunt compensator
   i) Static VAR Compensator (SVC)
   ii) Static Synchronous Compensators (STATCOM)
b) Series compensator
   i) Static Synchronous Series Compensators (SSSC)
   ii) Thtristor controlled series capacitor (TCSC)
   iii) Thtristor switched series capacitor (TSSC)

i) Location of SSSC

The SSSC were placed on the location in such a way that the capability of SSSC to compensate a particular bus or line could be optimized. Therefore, it is best if the SSSC would be located series with the weakest bus (in the case of series connected FACTS Controllers) or series with line that have the lowest percentage of underutilize capacity (in the case of series connected FACTS Controllers). Therefore, continuous power flow analysis was applied in order to determine the weakest bus and the underutilized line in the test system. The test system was analyzed without the SSSC device andhence the original performance of the test system was required. Voltage profiles (bus voltage in per unit) for all the buses in the test network were plotted and the bus in which collapses the worst among other buses has been selected as the weak bus. On the other hand, based on the continuous power flow report, the most underutilized line was determined. The line in which has the lowest power flow out of its total rating was selected as the line that needs series compensation.

ii) Theory of SSSC

The SSSC is generally connected in series with the transmission line with the arrangement as shown in Fig 2.2.1 (a) 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 Vse perpendicular to the line current IL. The SSSC is in principle a synchronous voltage source, which is typically connected in series with a transmission circuit to provide line compensation.

This controllability is achieved by using a controllable interface between the dc voltage source (typically a capacitor) and the ac system. The series capacitive compensation basically to decrease the overall effective series transmission impedance from the sending end to the receiving end. The relationship characterizes the power transmission over a single line is

$$P = \frac{V^2}{X} \sin(\delta) \qquad (2)$$

Where,

P - Real power transmission over a single line

V - The sending end and receiving end voltage (assuming Vs = VR = V)

X - The line impedance

δ - The power angle

SSSC is a power converter connected in series with the transmission line and it injects a voltage in quadrature with the line current to emulate a series capacitive or inductive reactance into the transmission line. A SSSC equipped with energy storage system and/or absorbing is also able to exchange real power with power system. Reactive power exchange is controlled by the magnitude of the injected voltage to the transmission line, and angle control is used to regulate the active power exchange. The inductive or capacitive mode of operation is set by the injected voltage phase angle with respect to the transmission line current.

When injected voltage is leading the line current, reactive power is absorbed and SSSC operates in inductive mode. In capacitive mode injected voltage is lagging the line current and injects reactive power to the transmission line.

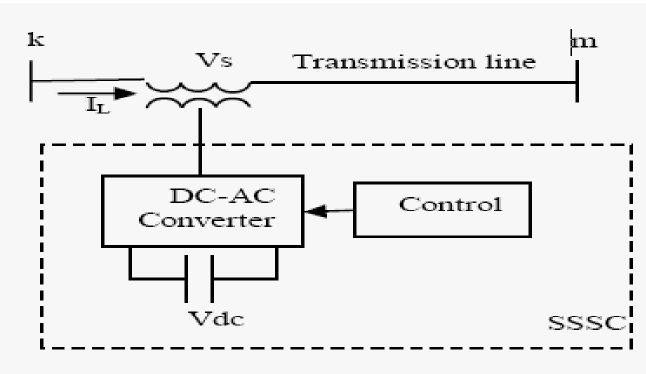

Fig. 2: Simplified diagram of SSSC

In the equivalent circuit of an SSSC compensated system, the SSSC is represented by a voltage source and impedance (Lr,Rr). The SSSC is connected between buses 1 and 2. The pair (L1, R) represents the line and L2represents a transformer.

iii) Rating of the 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 = Imax Vmax. 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) VARs.

7. CONCLUSION

It has been studied that the static synchronous series compensator (SSSC) is able to control the power flow in the transmission line. It can also inject fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. The SSSC can also damp out the oscillations of the system.

REFERENCES

[1] A.H. Norouzi and A.M. Sharaf, "*Two Control schemes to enhance the Dynami Performance of the STATCOM and SSSC",* IEEE Trans. on Power Delivery, Vol 20, Number 1, Jan 2005, pp 435.

[2] Hao, S.H., Papalexopoulos, A. "Reactive Power Pricing and Management ". *IEEE Transactions on Power Systems, Vol. 12, No.1, February 1997.*

[3] L. Gyugyi, "*Dynamic compensation of ac transmission lines by solid-state synchronous voltage sources",* IEEE Trans. On Power Delivery, Vol. 9, No. 2, April 1994.

[4] Miller, T.J. (Editor),"Reactive Power: Basics, Problems and Solutions". *IEEE Tutorial course. 1987.*

[5] N.G. Hingorani, L. Gyugyi, "*Understanding FACTS: Concepts and technology of flexible ac transmission Systems*", IEEE Press, Piscataway, New Jersey, 1999 ISBN 0-7803-3455

[6] Sharm, V. P. ,"*A Static Synchronous Series Compensator (SSSC): An approach for reactivepower compensation for the transmission system."* IJIRT, volume 1, Issu10,Augst 2014

[7] S. Lee, H. Kim, S. Sul, and F. Blaabjerg, "*A novel control algorithm for static series compensation by use of PQR instantaneous power theory*", IEEE Trans. on Power Electronics, Vol. 19, No. 3, May 2004, pp 814-827

[8] Silva, L., KundurXu, W., Zhang, Y., da, P. "Competitive Procurement of Dynamic Reactive Power Support Service for Transmission Access". *IEEE Summer Power Meeting 2000*. Whitehead, A. "A New Market in Reactive Power". Birmingham, UK. April1998.

[9] S. Lee, H. Kim, S. Sul, and F. Blaabjerg, "A novel control algorithm for static series compensation by use of PQR instantaneous power theory", *IEEE Trans. on Power Electronics,* Vol. 19, No. 3, May 2004, pp 814-827