International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 12, December-2015

An Overview of Facts Devices used for Reactive Power Compensation Techniques

Aishvarya Narain
M.Tech Research Scholar
Department of Electrical Engineering
Madan Mohan Malviya University of Technology
Gorakhpur, UP, India

S. K. Srivastava
Associate Professor
Department of Electrical Engineering
Madan Mohan Malviya University of Technology
Gorakhpur, UP, India

***Abstract*— In the last two decades demand of power is increasing rapidly but we have limited resources of power generation resulting transmission line getting heavily loaded and facing stability, voltage sag, reactive power issues. It is necessary to implement the FACTS devices which are better solution for power transmission problem. This paper describes about the study of various reactive power compensation techniques needed for any power system using FACTS devices such as SSSC, TCR, TCSC, STATCOM and UPFC. A classification of FACTS controller is also mentioned here. At the end comparison of various FACTS devices are done.**

Keywords— reactive power compensation, STATCOM, SVC, fact controllers

I. INTRODUCTION

Today the power system is very complex and interconnected; we need to improve power utilization to maintain security and reliability. Some transmission line are overloaded and some are loaded below the limit by which voltage profile deteriorate and system stability decreases so we need to control the power flow in the transmission line for power transfer. The development of power electronic technology has introduced Flexible AC transmission system (FACTS) devices. [12]

The fact devices can overcome limitation of mechanically controlled transmission system [1].power flow equation for lossless transmission line is given by

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin \delta ij \quad (1)$$

V_i andV_j Denotes the i^{th} and j^{th} bus voltage magnitudes, δ is bus voltage angle and Xij Denotes line reactance. From equation (1) we can say that power is a function of sending and receiving end voltage, transmission line impedance and phase angle between voltages. By controlling one of them we can control active as well as reactive power. FACTS devices, such as Static Synchronous Series Compensator (SSSC), Static Var Compensator (SVC), Unified Power Flow Controller (UPFC) and Static Synchronous Compensator (STATCOM) can regulate bus voltages, phase angles and line impedances of power transmission lines. These FACTS controllers are voltage source converters use for controlling power flow, enhancing the power transfer capability, reduce the generation cost, and improve the stability and security of the power system [2-3]

Electrical power system is always in transition between equilibrium and steady state because unwanted disturbance occur at any time. In this paper we concerned with this dynamic situation of the system which can be stabilize by Shunt and series capacitors and specially FACTS devices. Reactive power compensation technique is important factor for system stability and voltage sag during disturbance. Now a day's fact controller like STATCOM, SVC and TCR are use for reactive power compensation.

II. CONCEPT OF REACTIVE POWER

"Power" refers to the energy related quantities flowing in the transmission and distribution network. Instantaneously, power is equal to the multiplication of voltage and current. When voltage and current are not in phase.There are two components:

- Real or active power is measured in watt
- Reactive (some times refer to as imaginary) power is measured in Vars

The sum of active and reactive power is known as apparent power. It is shown in fig1.

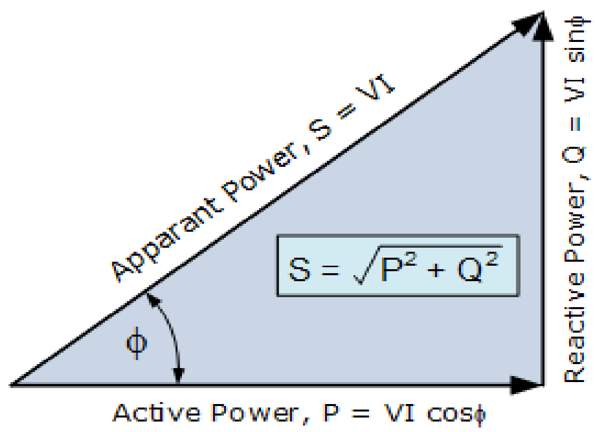

Fig.1: power triangle [7-8]

In AC circuits, energy is stored in inductor and capacitor component, which results in the periodic reversal of the direction of flow of energy between the supply and therefore the load. Further explaining the reactive power it can be said that in AC system, when the voltage and current varies up and down at the same time then only real power is transmitted and when there is time shift between voltage and current then active and reactive both power are transmitted. For average in time calculation average active power causes the net flow of energy whereas average reactive power is zero irrespective of the network or state of the system. The amount of energy flowing in one direction is equal to the amount of energy flowing in another direction in case of reactive power so we can say reactive power neither produce nor consumed. But in real we measure reactive power losses and to reduce it we have so many equipments for reactive power compensation to reduce consumption of electricity and to reduce cost. Energy store in capacitor in the form of electric field so it is use to produce reactive power given by equation (2). In AC circuit capacitive voltage is of charging nature since capacitor opposes these changes that cause the lag of voltage behind current in phase.

Instantaneous power in inductive circuit :

$$p = \frac{\text{Vmax Imax}}{2}\cos\theta(1+\cos\omega t) + \frac{\text{Vmax Imax}}{2}\sin\theta\sin 2\omega t \quad \ldots\ldots\ldots(2)$$

P =Instantaneous power
Vmax =Maximum value of the voltage waveform
Imax =Maximum value of the current waveform
ω = angular frequency
=2πf
f=Frequency of the waveform
θ=angle by which the current lags the voltage in phase
t=time period

III. NEED OF REACTIVE POWER COMPENSATION

Reactive power generated by A.C source is stored in capacitor or a reactor during a one fourth of a cycle and in the next one fourth of the cycle its send back to the power source. Therefore reactive power oscillates with twice frequency of rated value (50 or 60 Hz) between the ac source and capacitor or reactor. So we need reactive power compensation to avoid this circulation between the load and source.
The main reason in a system for reactive power compensation is:

- voltage regulation
- to increase stability of the system
- to improve system power factor
- to increase utilization of machines and equipments connected to the system
- to reduce losses of the system
- to prevent voltage sag and voltage collapse

Transmission line impedance and in generating system most machines need lagging VAR results consumption of reactive power which causes instability in the system and transmission lines.

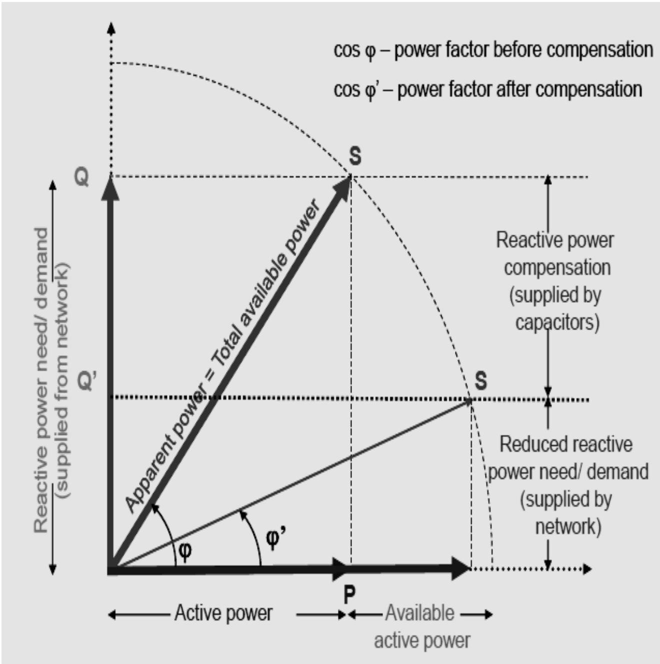

Fig.2: Reactive power compensation (supplied by capacitors)[14]

Fig.2 shows that reactive power compensation not only reduces losses, regulate voltage, and increase system stability but also helps in better transient response in case of fault and disturbances. In recent times focus on the compensation techniques increase rapidly and now including better devices in this techniques compensation is more effective. Reactive power should be supply near the load or generators for economical purpose.

IV. FACTS DEVICES

Now a day as power demand increases the power system is getting more complex to fulfill the requirements within the acceptable quality and costs [4]. Generating stations are located away from the load centres because of economic and environmental issues. As the demand of power increases uncertainty occur in the system operation resulting reduction in stability and risk of blackouts. This problem can be tackle by introducing high power electronics controller in ac transmission networks. So “flexible” operation in ac transmission network comes in to role where changes can be done easily without affecting the systems. FACTS (Flexible Alternating Current Transmission System) are a family of power electronics device which improves stability, power transfer capability and controllability of ac system [5].

FACTS devices are combination of components power system (like transformers, reactors, switches, and capacitors) with power electronics components (like various types of transistors and thyristors).we are capable to deal high power application (ten, hundreds and thousands of MW) with the help of high current rating of thyristors FACTS controller also improve the transient and dynamic performance of the power system. Electronic based switches use in FACTS device have less switching time than the conventional mechanical switches. FACTS devices using electronic based switches are more flexible and fast reacting causes many advantages like enhancement of transmission capacity, control of power flow, improvement of transient stability, voltage stability and control. With using of appropriate type and rating of FACT devices transmission capacity enhance up to 40 – 50 %.

V. FACTS CONTROLLERS USED IN REACTIVE POWER COMPENSATION TECQNICH

FACTS Controllers can be divided into four categories:[16]

• Series Controllers
• Shunt Controllers
• Combined series-series Controllers
• Combined series-shunt Controllers

Series controllers:

It may be capacitor or reactor or power electronic based variable source. These controllers inject voltages in series with the line. When voltage and current are in 90 degree phase shift controller only supply or consume variable reactive power. For any other phase real power also considered. [15]

- Static Synchronous Series Compensator (SSSC)
- Interline Power Flow Controller (IPFC)
- Thyristor Controlled Series Capacitor (TCSC)
- Thyristor Switched Series Capacitor (TSSC)
- Thyristor Controlled Series Reactor (TCSR)
- Thyristor Switched Series Reactor (TSSR)

Among these fact devices TCSC is most commonly use for reactive power compensation which is explains below.

Thyristor controlled series compensator (TCSC)

Kinney et al. proposed the concept of TCSC in 1994 in [10]. TCSC is combination of TCR in parallel with FC (fixed capacitor). SVC and TCR are shunt connected controller where as TCSC is series connected controller. That is why TCSC is always shown in single phase form rather than three phase form. it has one or more sub module. TCSC is used when increase damping is require for large interconnecting system because it provide variable capacitive reactance. To avoid sub synchronous resonance it changes apparent impedance for sub synchronous frequency. TCSC act as a fast active power flow regulator as it changes the electrical length of transmission line with approx no delay. The circuit diagram is shown in Fig.3

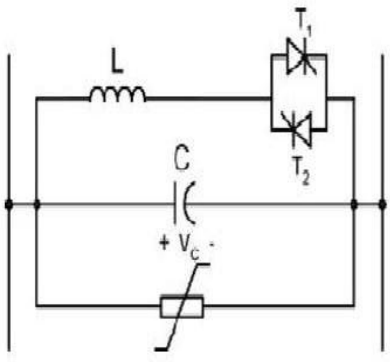

Fig.3 TCSC circuit diagram

Shunt Controllers:

Like series controller shunt controller also may be capacitor or reactor or power electronic based variable source or a combination of these. Shunt controller inject current in the system. When voltage and current are in 90 degree phase shift controller only supply or consume variable reactive power. for any other phase real power also considered.

- Static Synchronous Compensator (STATCOM)
- Static Synchronous Generator (SSG)
- Battery Energy Storage System (BESS)
- Superconducting Magnetic Energy Storage (SMES)
- Static Var Compensator (SVC):
- Thyristor Controlled Reactor (TCR)
- Thyristor Switched Reactor (TSR)
- Thyristor Switched Capacitor (TSC)
- Static Var Generator or Absorber (SVG)
- Thyristor Controlled Braking Resistor (TCBR)

STATCOM, SVC and TCR are more commonly use for commercial and industrial purpose. These devices are one by one explain below. [11]

Thyristor controlled reactor (TCR)

In 1982, Miller et al. Proposed Thyristor controlled reactor [6]. It is shown in the figure it is a combination of two antiparallel thyristor. Both thyristor conducts for the alternate half cycle. It acts as a controllable susceptance. Inductance L is important sub device of TCR. TCR is also fundamental component of TCSC and SVC. It is also a shunt compensator. For lightly loaded transmission line it is use for limiting voltage rise. Circuit diagram is shown in Fig.4

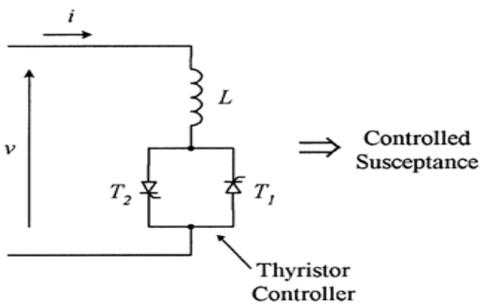

Fig.4: circuit diagram of TCR

Static VAR Compensator (SVC)

Static VAR compensator used for high voltage power system. There are many advantages using SVC like it improve system stability, reduce losses, maintain the line voltage variation within limits and better utilization of equipments.

It consists of shunt capacitors and shunt reactors. Shunt reactor and TCRs is to prevent voltage rise under low load and no load condition. Static capacitor and TSCs (Thyristor switch capacitor) are to prevent voltage sag for peak load. There are two combination uses in practise first one is TCR parallel with fixed capacitor (FC) and another one is TSC in parallel with TCR. If compare with TCR it is better than TCR as TCR only generate reactive power but SVC not only generate but also absorb reactive power. Fig 5 shows the structure of SVC.

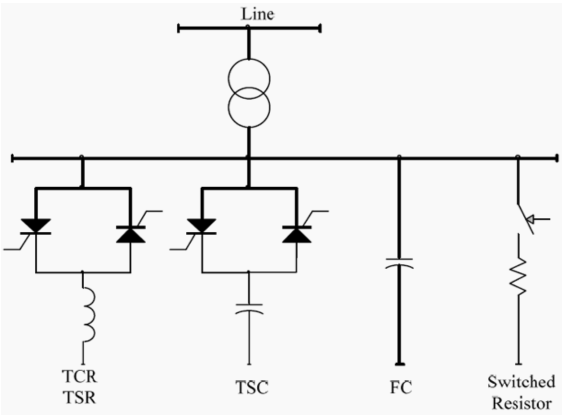

Fig.5:Static Var Compensator

Static compensator (STATCOM)

The concept of STATCOM is proposed in [9]. STATCOM consist a voltage source controller and shunt connected transformer. it is a voltage source converter that dc power into ac power of variable phase angle and magnitude. It supply desire reactive power by varying the phase angle and magnitude. For industrial application unity power factor can be obtain by using it. The basic structure of STATCOM is shown in Fig.6

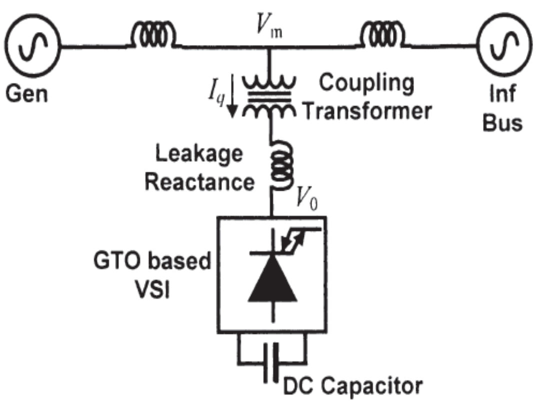

Fig.6: Basic Structure Of The STATCOM [13]

Combined series-series Controllers

It is a combination of series controller. For multiline transmission system this controller control in coordinated manner. It can be unified controller because it separately compensates the power line. It is also called “Interline Power Flow Controller” because it balances both real and reactive power. The term unified means dc terminal of controller are connected together for transfer of real power.

Combined series-shunt Controllers

It is a combination of series and shunt controller which control in a coordinated manner or it may be unified power flow controller. It injects current into system with shunt part of it and voltage with series part of the controller. When it works as unified real power exchange occurs via power link.

Example of combine series and shunt controller

- Unified Power Flow Controller (UPFC)
- Thyristor Controlled Phase Shifting Transformer (TCPST)
- Interphase Power Controller (IPC)

VI. Comparison of various FACTS Devices

Table1. Shows the comparison among SVC, STATCOM, UPFC, TCSC and SSSC on the basis of their load flow, voltage control ,transient stability and dynamic stability in the form of low, medium, and high.

TABLE I. Comparison of various FACTS Devices

S NO	FACTS Device	Load flow	Voltage control	Transient stability	Dynamic stability
1	SVC	LOW	HIGH	LOW	MEDIUM
2	STATCOM	LOW	HIGH	MEDIUM	MEDIUM
3	UPFC	HIGH	HIGH	MEDIUM	MEDIUM
4	TCSC	MEDIUM	LOW	HIGH	MEDIUM
5	SSSC	LOW	HIGH	MEDIUM	MEDIUM

On comparison it is found that UPFC used for higher load flow and voltage control where as STATCOM is used for voltage control in small distribution system and the UPFC shows better results for power system stability improvement compared to the other FACTS devices such as SVC, TCSC, and SSSC.

VI. Conclusion

In this paper we have studied about the need of reactive power compensation and the various FACTS devices used for compensation. The working principle of STATCOM, TCR, SVC, and TCSC has been described. Finally the comparison of these fact devices is done. From the comparison it is found that UPFC is better for voltage control and lad flow but for low level application STATCOM is also shows better results. From this it can be say that FACT controller will play a very vital role for reactive power compensation in electrical power system.

REFERENCES

[1] Pranesh Rao and M. L. Crow, "STATCOM Control for Power System Voltage", IEEE TRANSACTIONS ON POWER DELIVERY, Vol. 15, no 4, pp 1311-1317, Oct. 2000.
[2] N.G. Hingorani, "High Power Electronics and Flexible AC Transmission System", IEEE Power Eng. REV, 1988.
[3] B.M. Zhang and Q.F. Ding, "The Development of FACTS and its Control", Proc. APSCOM-97, Hong Kong,1997.
[4] http://www.slideshare.net/jeevan_g/37426740-facts?related=1
[5] http://www.gridtech.eu/project scope/technologies/12-technologies/21-facts-flexible-alternating-current-transmission-system
[6] T. A. Short, Electric Power Distribution Handbook. Boca Raton, FL:CRC, 2004.
[7] T. Gönen, Electric Power Distribution System. New York: McGraw- Hill, 1986.
[8] D. Murali and Dr. M. Rajaram, "Active and Reactive Power Flow Control using FACTS Devices", International Journal of Computer Applications (0975 – 8887) Volume 9– No.8, November 2010.
[9] N.G Hingroni and I Gyugyi. "Understanding FACTS: Concepts and Technology of flexible AC Transmission System", IEEE Press, New York, 2000.
[10] G.Sundar , S.RamaReddy,"Digital Simulation of D-Statcom for voltage fluctuations", International Journal of Engineering Science and Technology Vol. 2(5), 2010, 1131-1135.
[11] Zhiping Yang, Chen Shen, Mariesa L. Crow, Lingli Zhang, An Improved STATCOM Model for Power Flow Analysis , University Of Missouri, 2000.
[12] L. Dong, M.L. Crow, Z. Yang, C.Shen, L.Zhang, A Reconfigurable FACTS System For University Laboratories.
[13] C. L. Wadhwa, Electrical Power Systems, New Age International Publishers, 2009.
[14] Hadi Saadat, Power System Analysis,WCB McGraw Hill, 1999.
[15] Narain Hingorani & L. Gyugi, Understanding FACTS, Concepts and Technology of Flexible AC Transmission Systems, IEEE Press, 2000.
[16] Paserba, J.J.; "How FACTS controllers benefit AC transmission systems", Power Engineering Society General Meeting, IEEE, Vol.2, June 2004, pp: 1257 - 1262.