ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 5, Issue 5, May 2016

Comparison of Various FACTS Devices and their Role in Transmission System

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***Abstract* - Nowadays to supply power on demand to various load centres with high reliability power systems are designed to operate efficiently.The modern power system are characterized by large interconnections.Interconnections of transmission systems in addition to supplying power lead to optimal cost of generation and enhance the reliability of the system.This paper deals with various FACTS devices.For switching in or out transmission line components such as phase shifting transformer,capacitors and reactors for some desirable performance of the system FACTS devices employ high speed thyristors .**

***Keywords*- FACT DEVICEs,STATCOM,TCSC,SSSC,UPFC**

I. INTRODUCTION

AC transmission systems that employ power electronic based and other static controllers to increase power transfer capability and to enhance controllability are defined as flexible alternating current transmission systems(FACTS).The power electronics based system and other static equipment that provide control of one or more AC transmission system parameters is known as FACTS controllers.Flexible alternating current transmission systems is the technology for utilities to enhance their transmission capability by loading transmission lines to its full capacity.[1],[6]

The FACTS technology uses advanced microcomputers, high speed power electronic devices, powerful analytical tools and latest control techmology.FACTS technology increases the power transfer ability of transmission lines but this does not mean that there is no need of upgrading an existing transmission lines.The FACTs controllers primarily provide voltage support to the system when shunt connected and regulate the power in critical lines when series connected.[2]

Various Types of FACTS Controllers

FACTS controllers are power electronic based systems that with the help of other static equipments,provide control of one or more system.It can be divided into two groups that follow two distinctly different technical approaches.The first group uses thyristor devices with only gate turn on control and the turn off depends on the current attaining zero value as per the system conditions.Such controllers uses reactive elements or a tap changing transformer as controlled element.These FACT controllers are known as variable impedance type FACT controllers.They include :

1.Static VAr compensator (SVC)
2.Thyristor controlled series capacitor(TCSC)

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The second group of FACTS controller employs devices that have turn on and turn off ability such as gate turn off thyristors(GTO),MOS turn off thyristors (MTO) and integrated gate commutated thyristors (IGCT) operating as controlled voltage sources. The converter valves have to be bi-directional so that in voltage sourced converter direct current flows in both directions.These FACTS controllers are known as Voltage Source Converter(VSC) based FACTS controller.They include:

1.Static Synchronous compensator(STATCOM)
2.Static Synchronous series compensator(SSSC)
3.Interline power flow controller(IPFC)
4.Unified power flow controller(UPFC)

The FACTS controller based on VSC have several advantages over the variable impedance type.They are much more compact and is technically superior.[6],[7]

A. Static VAR Compensator (SVC)

The static VAr compensator(SVC) is a first generation FACTS controllers. in which the current through a reactor is controlled by back to back connected thyristors and hence known as variable impedance device.Through a step down transformer the SVC is connected to the transmission line and thus thyristors valves are rated for lower voltages.There are two types of SVC:

(i) Fixed Capacitor-Thyristor Controlled Reactor(FC-TCR)
(ii) Thyristor Switched Capacitor –Thyristor Cotrolled Reactor

The TSC-TCR generates less harmonics hence more flexible and requires smaller reactor .The below fig shows SVC.It is a combination of shunt connected which includes a separate thyristor controlled or for absorbing reactive power it has thyristor switched reactor and thyristors switched capacitor for supplying the reactive power.Here on the secondary side of a step down transformer the TCR and TSC are connected. when the voltage across valve is minimum and positive the TSC is switched in using two thyristors connected back to back at the instant in a cycle.This results in minimum switching transient.To improve steady state limit and transmission capacity the SVC is used. For stability improvements during small and large disturbances SVC can be used.Its use can also damp the sub synchronous oscillations.The cost of a SVC is lesser as compared to a STATCOM.[7]

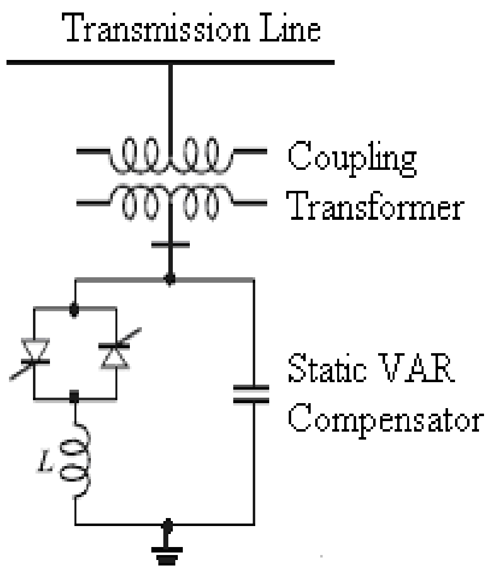

Fig. 1: Configuration of SVC

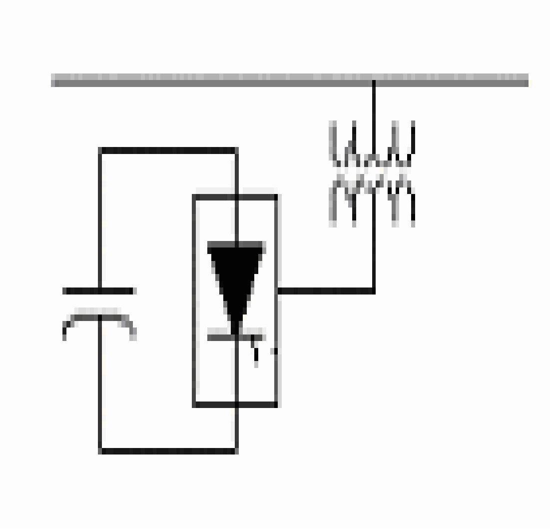

Fig.2: Schematic diagram of STATCOM

B.Static Synchronous Series Compensator:

The static synchronous series compensator or simply static compensator (STATCOM) is a shunt connected device where instead of controllable reactors and switched capacitors a voltage source converter (VSC) is used.The use of VSC require self commutating devicessuch as GTO,IGBT,IGCT,MCT etc which make them costlier.

VSC(voltage source converter) based STATCOM shown in fig.In this device a voltage source converter in each phase produces a set of 3-phase AC output voltages for a given input of DC voltage and coupled through a relatively small reactance corresponding to AC system voltage.Following technical advantages of STATCOM over a SVC they are:

1.Faster response

2.Requires less space as bulky components such as reactors are not required.

3.Modular and relocatable.

4.Can be interfaced with real energy sources such as battery,SMES etc.[7],[9]

C.Unified Power Flow Controller(UPFC):

In the unified power flow controller the shunt and series controllers are unified .It is combined by static synchronous series compensator and static synchronous compensator (STATCOM).With a common DC link the STATCOM and SSSC are coupled.Between the shunt output terminals of STATCOM and the series output terminals of the SSSC, the DC link allows bi-directional flow of real power.For series line compensation UPFC is controlled to provide concurrently reactive and active power. To control the transmission line voltage,impedance and angle and therefore the active and reactive power flow in the line it is highly capable.[4],[7]

D.Static Synchronous Series Compensator(SSSC):

For the purpose of changing the overall reactive drop in the line the output voltage(injected voltage) is kept in quadrature with the line current. It is able to control the output voltage and is normally quite small as compared to the line voltage.The SSSC may be with or without storage facility. In series with the line storage device(either a battery storage or a super conducting material) injects a voltage vector of variable angle.For current control,stability improvement and for damping oscillations during disturbances the static synchronous series compensator is used.

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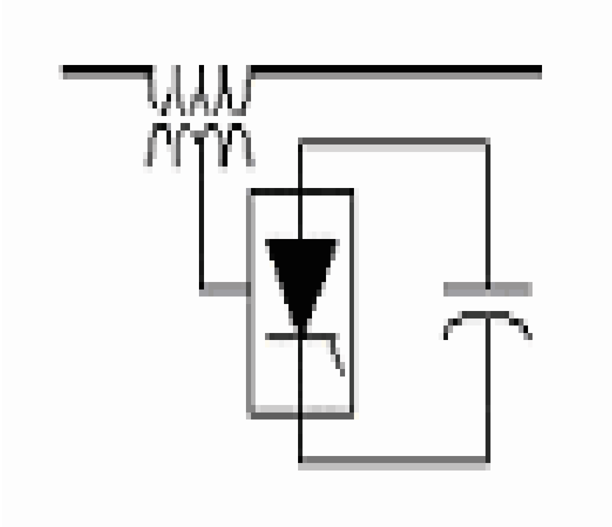

Fig. 3: Schematic diagram of SSSC

E.Thyristor Controlled Series Capacitor(TCSC):

Over their shunt counterparts the TCSC have different advantages.The reactive power increases as the square of line current with series capacitor ,where as with shunt capacitors the reactive power generated is proportional to the square of bus voltage.Controlled series compensation can be achieved in two ways:

1.By using Thyristor controlled series capacitor(TCSC)
2.GTO Thyristor controlled series capacitor

TCSC consists of a number of capacitors in series each shunted by a switch in which two thyristors connected in antiparallel.A capacitor is inserted by turning 'off' the thyristor switch.For turning 'on' the thyristor it is by passed.If all the switches are 'off' the effective capacitance becomes Ceq=C/m where'm' is the total number of capacitors.Similarly when simultaneously all the switches turned 'on' Ceq is zero.Therefore the series compensation and effective capacitance are controlled in astepped manner by changing the number of capacitors inserted in the circuit.The configuration using TCSC is not common because of its SSR characteristic.Although continuous control of the capacitor is possible with theGCSC also but is yet to be applied in practice.TCSC is a mature technology available for application in EHVAC lines.[6]

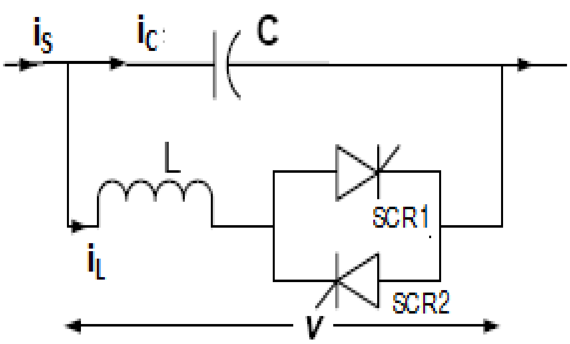

Fig. 4: Configuration of a TCSC

Benefits of Using FACTS Controllers

The FACTS controllers primarily provide voltage support to the system when shunt connected and regulate the power flow in critical lines when series connected.Both voltage and power flow control can be achieved by the use of combined series shunt connected.The main advantages of using FACTS controllers are:

1.They help in obtaining optimal system operation by reducing power losses and improving voltage profile.

2.Because of the fast controllability of FACTS controllers the power carrying capacity of lines can be increased upto thermal limits.

3. By improving the dynamic security of the system the transient stability limit is also increased.

4.Some FACTS controllers such as TCSC can damp the sub synchronous resonance experienced in thermal power stations because of the use of fixed series capacitors.

5.The problem of dynamic over voltages can be overcome by the use of FACTS controller.

FACTS technology uses high speed thyristors to vary the parameters to control the power flow.Thyristors that can be turned 'ON' and 'OFF' within a few microseconds may be operated as fast acting switches to replace electromechanical circuit breakers.The static switches have the following advantages:

1.Very high switching speeds

2.No moving parts

3.No contact bouncing

For AC switches the thyristors are line or natural commutated and the switching speed is limited by the frequency of the AC supply and the turn off time of thyristors.The DC switches are forced commutated and the switching speed depends on the "turn on" and "turn off" time of the device.Thus an alternative to HVDC transmission is the use of of FACTS controllers.A FACTS controller which injects a series voltage is also used to control power flow.Hence by using series FACTS controllers it is possible to prevent overloading on AC lines under emergency situations such as in case of loss of a parallel lines.[7]

Comparison of basic Types of Compensators

	STATCOM	TCR (With Shunt Capacitors If necessary)	TCS (with TCR If necessary)	Self-Commutated Compensator
Compensation Accuracy	**Very Good**	**Very Good**	**Good, Very good With TCR**	**Excellent**
Control Flexibility	**Good**	**Very Good**	**Good, Very good With TCR**	**Excellent**
Harmonics	**Comparatively Good**	**High (needed large filters)**	**Good, Required filters with TCR**	**Good**
Losses	**Less**	**Good, but increase in lagging Mode**	**Good**	**Very good**
Phase Balancing	**Limited**	**Good**	**Limited**	**Very good with single phase units, limited with 3 phase units**
Cost	**High**	**Moderate**	**Moderate**	**Low to moderate**

Conclusion

Use of FACTS controllers in the field of transmission line is a new topic.In this paper we have discussed about some of the FACTS controllers,their types,their circuits,working principle, advantages and disadvantages.Continuous research is going on worldwide on this topic.Using FACTS we can enhance the controllability and power transfer capability of a transmission system.More research work needed is needed in this area for the improvement of human needs.

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