International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 02 - Issue 02 || February 2017 || PP. 22-27

Analysis of FACTS Devices in Transmission System

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Abstract: In developing countries, a pressure associated with economical and environmental constraints has forced the powerutilities to meet the future demand by fully utilizing the existingresource of transmission facilities without building new lines.Flexible alternating current transmission systems (FACTS)devices are used to control the phase angle, voltage and impedance of high voltage AC lines. By using FACTS devices maximum benefits of transmission system can be managed i.e. utilization of existing transmission assets; increased transmission system availability and enabling environmental benefits. This paper presents different types of FACTS devices and their benefits for transmission in electrical power system.

Index Terms: Transmission system, FACTS Devices, Benefits these devices.

I. INTRODUCTION

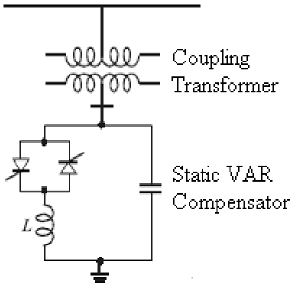
In the present day scenario, transmission systems are becoming increasingly stressed, more difficult to operate, and more insecure with unscheduled power flows and greater losses because of growing demand for electricity and restriction on the construction of new lines. However, many high-voltage transmission systems are operating below their thermal ratings due to constraints, such as voltage andstability limits. Now, more advanced technology is used for reliable and operation of transmission and distribution in power system. To achieve both reliable and benefit economically, it has become clearer that more efficient utilization and control of the existing transmission system infrastructure is required. Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics has developed the flexible AC transmission system (FACTS) devices. FACTS devices are effective and capable of increasing the power transfer capability of a line and support the power system to work with comfortable margins of stability FACTS devices are used in transmission system to control and utilize the flexibility and system performance. To achieve all, the insertion of FACTS devices required in plant in order to control the main parameters namely voltage, phase angle and impedance, which is affecting ac power transmission. The power system should be capable to for line support of power transfer with comfortable and stable for marginally.

II. CLASSIFICATION OF FACTS DEVICES

The FACTS controllers are of different types. These are classified according to their connection like shunt connectedcontrollers, series connected and combined series and shunt connected controllers. The main types of FACTS devices are

A. Static Var Compensators (SVC)

Static var systems are applied by utilities in transmission applications for several purposes. The primary purpose is usually for rapid control of voltage at weak points in a network.Installations may be at the midpoint of transmission interconnections or at the line ends. Static Var Compensators are shunt connected static generators / absorbers whose outputs are varied so as to control voltage of the electric power systems. In its simple form, SVC is connected as Fixed Capacitor-ThyristorControlled Reactor (FC-TCR) configuration as shown in Fig. The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated. The effective reactance of the FC-TCR is varied by firing angle control of the antiparallel thyristors. The firing angle can be controlled through a PI (Proportional + Integral) controller in such a way that the voltage of the bus, where the SVC is connected, is maintained at the reference value.



B. Static Synchronous Compensator (STATCOM)

STATCOM's are GTO (gate turn-off type thyristor) based SVC's. They do not require large inductive and capacitive components to provide inductive or capacitive reactive power to high voltage transmission systems as required in StaticVar Compensators (SVC). STATCOM requires less area.Another advantage is the higher reactive output at lowsystem voltages where a STATCOM can be considered as acurrent source independent from the system voltage.Schematic diagram of STATCOM is shown in figure 1.

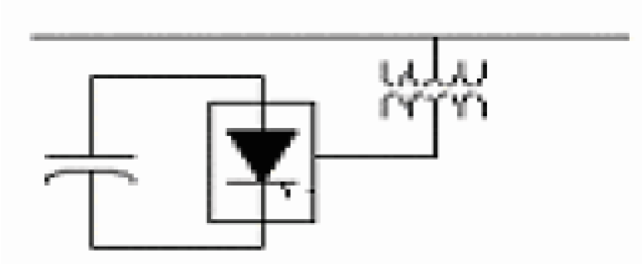
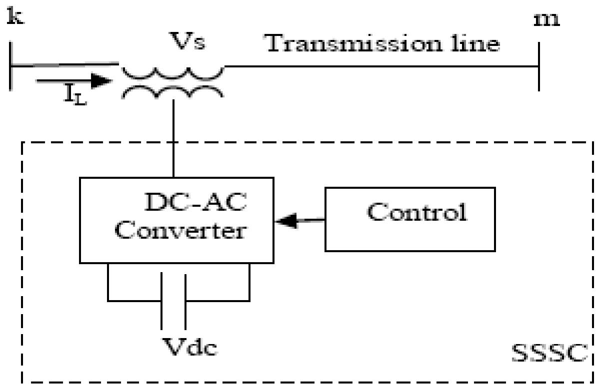


Fig. I: Schematic diagram of STATCOM

C. Static Synchronous Series Compensator (SSSC)

The SSSC is one of the most recent FACTS devices for power transmission series compensation. It can be considered as a synchronous voltage source as it can inject an almost sinusoidal voltage of variable and controllable amplitude and phase angle, in series with a transmission line. The injected voltage is almostin quadrature with the line current. A small part of the injectedvoltage that is in phase with the line current provides the losses in the inverter. Most of the injected voltage, which is inquadrature with the line current, provides the effect of insertingan inductive or capacitive reactance in series with the transmission line. The variable reactance influences the electric power flow in the transmission line. The basic configuration of aSSSC is shown in Fig.



D. Thyristor Controlled Series Compensators (TCSC)

TCSC is an extension of conventional series capacitors butonly addition of thyristor-controlled reactor with it.Connecting a reactance in parallel with a series capacitorenables a continuous and rapidly variable seriescompensation system. The main advantages of TCSC's areincreased real transfer power, power oscillations damping,sub-synchronous resonances damping, and power flow linecontrol

E. Unified Power Flow Controller (UPFC)

Among the available FACTS devices, the Unified Power Flow
Controller (UPFC) is the most versatile one that can be used toenhance steady state stability, dynamic stability and transientstability. The basic configuration of a UPFC is shown in Fig.The UPFC is capable of both supplying and absorbing real andreactive power and it consists of two ac/dc converters. One of thetwo converters is connected in series with the transmission line through a series transformer and the other in parallel with theline through a shunt transformer. The dc side of the twoconverters is connected through a common capacitor, whichprovides dc voltage for the converter operation. The powerbalance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As theseries branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with thetransmission line and thus improves the power flow capability ofthe line as well as its transient stability limit. The shuntconverter exchanges a current of controllable magnitude andpower factor angle with the power system. It

is normallycontrolled to balance the real power absorbed from or injected into the power system by the series converter plus the losses byregulating the dc bus voltage at a desired value.

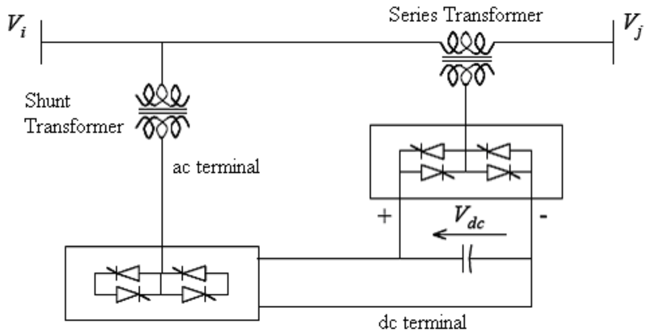


Fig. Configuration of UPFC

III. BENEFITS OF UTILIZING FACTS DEVICES

The advantages of using FACTS devices in electricaltransmission systems are described below:

- More utilization of existing transmission system
- Reliability of Transmission system increases.
- More Increased transient and dynamic stability of the system.
- Increased more quality of supply for large industries
- Beneficial for Environment.

A. More utilization of existing transmission system

In all the countries, the power demand is increasing day by day to transfer the electrical power and controlling the load flow of the transmission system is very necessary .this can be achieved by more load centers which can change frequently. Addition of new transmission line is very costly to take the increased load on the system; in that case FACTS devices are much economical to meet the increased load on the same transmission lines.

B. More Increased transient and dynamic stability ofthe system

The Long transmission lines are inter-connected with grids to absorb the changing the loading of the transmission line and it is also seen that there should be no line fault creates in the line / transmission system. By doing this the power flow is reduced and transmission line can be trip. By the use of FACTS devices high power transfer capacity is increased at the same time line tripling faults are also reduces.

C. Increased more quality of supply for large industries

New industries wants good quality of electric supply, constant voltage with less fluctuation and desired frequency as mentioned by electricity department . Reduce voltage, variation in frequency or loss of electric power can reduce the manufacturing of the industry and cause to high economical loss .FACTS devices can helps to provide the required quality of supply.

D. Beneficial for Environment

FACTS devices are becoming environmentally friendly. FACTS devices does not produce any type of waste hazard material so they are pollution free. These devices help us to deliver the electrical power more economically with better use of existing transmission lines while reducing the cost of new transmission line and generating more power.

E. Increased transmission system reliability andavailability

Transmission system reliability and availability is affected bymany different factors. Although FACTS devices had abilityto reduce such factors and improves the system reliability andavailability.

IV. APPLICATIONS AND TECHNICAL BENEFITS OF FACTS DEVICES

The basic technical benefits of the FACTS devices includes

(a) Problems of voltage limit
(b) Addressing in steady state applications
(c) Problems of thermal limits,

(d) Problems short circuit levels and
(e) Problems of sub-synchronous resonance

Which are shown in table no. 1. For each problem theconventional solution (e.g. shunt reactor or shunt capacitor)is also provided , as well as dynamic applications of FACTSin addressing problems in transient stability, damping, postcontingency voltage control and voltage stability.The conventional methods are cheaper than FACTS Devicesbut limited to their dynamic behavior. FACTS devices arerequired when dynamic network problem occurs. This is theway to find out the most economical solution for this.

Table No. I:
Benefits of FACTS devices for different applications

FACTS Devices	Load Flow control	Voltage control	Transient stability	Dynamic stability
SVC	+	+++	+	++
STATCOM	+	+++	++	++
TCSC	++	+	+++	++
UPFC	+++	+++	+++	+++

Where: - Good +, Better ++, Best +++

Table No. II:
Steady state applications of FACTS

Issues	Problems	Corrective action	Conventional solution	FACTS devices
Voltage Limits	Low voltage at heavy load	Supply reactive power	Shunt capacitor, series capacitor	SVC , , STATCOM
	High voltage at light load	Remove reactive power supply	Switch EHV and/or shunt capacitor	SVC, TCSC, STATCOM
	High voltage following outage	Absorb reactive power	Switch shunt capacitor, series capacitor	SVC, STATCOM
Thermal limits	Line or transformer over load	Reduce load	Add line or transformer	TCSC,UPSC, TCPAR
			Add series reactor	SVC,TCSC
	Tripping of parallel circuits	Limit line loading	Add series reactor , capacitor	UPSC,TCSC
Loop flow	Parallel line load sharing	Adjust series reactance/ phase reactance rearrange network or use	Add series capacitor and PAR	UPTC,TCSC, TCPAR

		thermal limit actions		
	Post fault sharing	PAR , series capacitor/ reactor	PAR, series capacitor / reactor	TCSC,UPSC, SVC,TCPAR
	Flow direction reversal	Adjust phase angle	PAR	TCPAR,UPFC
Short circuits Levels	Excessive breaker Fault current	Limit short circuit current	Add series reactor, new circuit breaker	SCCL,UPFC, TCSC,
		Change circuit breaker	Add new circuit breaker	
		Rearrange network	Split bus	
Sub-synchronous resonance	Potential turbine / generator shaft damage	Mitigate oscillations	Series compensation	NGH,TCSC

TCSC: Thyristor controlled series capacitor
PAR: Phase angle regulator
TCVL: Thyristor controlled voltagelimiter
TSBR: Thyristor switched breakingresistor
SVC: Static var compensator
TSSC: Thyristor switched seriescapacitor
STATCOM: Static compensator
UPFC: Unified power flow controller
TCPAR: Thyristor controlled phase

Table No. III:
Dynamic application of FACTS (1)

Issues	Problems	Corrective action	Conventional solution	FACTS devices
Transient stability	A,B, D	Increase synchronizing torque	High response exciter, series capacitor	TCSC, TSSC, UPFC
	A,D,	Absorb kinetic energy	Breaking resistor, Fast Valuing Turbine	TCBR, SMES ,BESS

A Review of Benefits of FACTS Devices in Power System

	B,C, D	Dynamic load flow control	HVDC	TCPAR, UPFC, TCSC
Dampening	A	Dampen 1Hz oscillations	Exciter , power system stabilizer	SVC, TCSC, STATCOM
	B.D	Dampen low frequency oscillations	Power system stabilizer	SVC, TCPAR, UPFC, NGH, TCSC, STATCOM
Post contingency voltage control	A,B, D	Dynamic voltage support	-------	SVC, STATCOM, UPFC
		Dynamic flow control	---	SVC, UPFC, TCPAR
		Dynamic voltage support and flow control	------	SVC, UPFC, TCSC
	A, B, C, D	Reduce impact of contingency	Parallel lines	SVC, TCSC, STATCOM, UPFC
Voltage stability	B, C, D	Reactive support	Shunt capacitor , Shunt reactor	SVC, STATCOM ,UPFC
		Network control action	LTC, Enclosin g , HVDC controls	TCSC, STATCOM, UPFC
		Generation control	High response exciter	--------
		Load control	Under voltage load shedding ,	------

Where:
A= Remote generation
B= Interconnected areas
C= Tightly meshed network
D = loosely meshed network.
BEES: battery energy storage system
HVDC: high voltage direct current
LTC: Transformer Load taps Changer

CONCLUSION

This paper focus on the economical and technical benefits of FACTS devices application in ac transmission system.For the present operating environment of power sector,FACTS is a viable solution. The different FACTS devicesin terms of installation and their usage in different systemconditions are analyzed.

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