

Review on Comparison of FACTS Controllers for Power System Stability Enhancement

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Abstract- In recent years, power demand has increased substantially while the expansion of power generation and transmission has been severely limited due to limited resources and environmental restrictions. Transient stability control plays a significant role in ensuring the stable operation of power systems in the event of large disturbances and faults, and is thus a significant area of research. Flexible AC transmission systems (FACTS) controllers have been mainly used for solving various power system steady state control problems. FACTS devices are capable of controlling the active and reactive power flows in a transmission line by controlling its series and shunt parameters. This paper presents a review of comparison of different FACTS controllers in the power system for stability enhancement. Benefits of FACTS controllers to power system are also discussed.

Index Terms- FACTS, SSSC, SVC, TCSC, UPFC, Line losses and cost comparison.

I. INTRODUCTION

Flexible AC transmission system is an evolving technology to help electric utilities [4]. Its first concept was introduced by N.G Hingorani, in 1988 [7]. The solutions to improve the quality of supply in the electrical networks with go through the applications of the developments in semiconductor power devices, that is to say, the utilization of static power converters in electrical energy networks. The technological advances in power semiconductors are permitting the development of devices that react more like an ideal switch, totally controllable, admitting high frequencies of commutation to major levels of tension and power [7].

Recent development of power electronics introduces the use of FACTS controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the voltage stability, and steady state and transient stabilities of a complex power system. This allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines. The well known FACTS devices are namely SVC, STATCOM, TCSC, SSSC and UPFC.

II. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) DEVICES

It is well known fact that for reactive power compensation FACTS devices can be used. Table 1 gives an idea about the cost of various reactive power sources including all FACTS devices.

The main disadvantage of FACTS devices is expensive cost to provide smooth and fast response to secure power system during normal and steady state operations.

Table.1: Cost comparison of various facts device [8].

Sl. No	FACTS Device	Cost (Rs/kVar)
1.	Shunt Capacitor	432
2.	Series Capacitor	1080
3.	SVC	2160(controlled portions)
4.	TCSC	2160(controlled portions)
5.	STATCOM	2700
6.	UPFC Series Portions	2700 (Through power)
7.	UPFC Shunt Portions	2700(controlled portions)

FACTS controllers may be based on thyristor devices with no gate turn-off or power devices with gate turn-off capability. FACTS controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. The basic principles of the following FACTS controllers are discussed briefly.

A. Static Var Compensator (SVC)

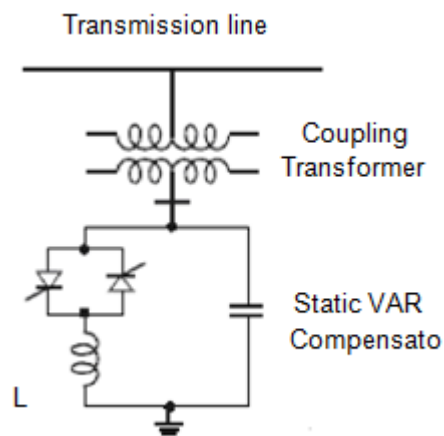


Figure 1 Basic structure of SVC

SVC is a static Var compensator which is connected in parallel to transmission line. SVC acts as a generator/load, whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific power system variables. 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. SVC is similar to a synchronous condenser but without rotating part in that it is used to supply or absorb reactive power. The basic structure of SVC is shown in Fig. 1. The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated. From Fig. 1, SVC is composed of a controllable shunt reactor and shunt capacitor(s). Total susceptance of SVC can be controlled by controlling the firing angle of thyristors. However, the SVC acts like fixed capacitor or fixed inductor at the maximum and minimum limits [1,3].

B. Thyristor Controlled Series Capacitor (TCSC)

TCSC is series type compensator, used to increase power transfer as well as to enhance system stability. TCSC controllers use TCR in parallel with segments of series capacitor bank. The combination of TCR and capacitor allow the capacitive reactance to be smoothly controlled over a wide range and switched upon command to a condition where the bi-directional thyristor pairs conduct continuously and insert appropriate reactance into the line. The basic structure of the device is shown in Fig. 3.

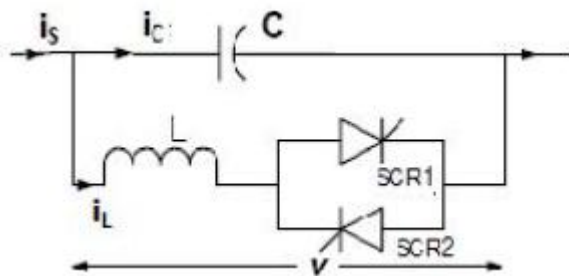


Figure 2 Configuration of a TCSC

The TCSC consists of three main components: capacitor bank C, bypass inductor L and bidirectional thyristors SCR1 and SCR2. The total susceptance of the line is controlled by controlling the firing angle of the thyristors [1,2,3].

C. Static Synchronous Series Compensator (SSSC)

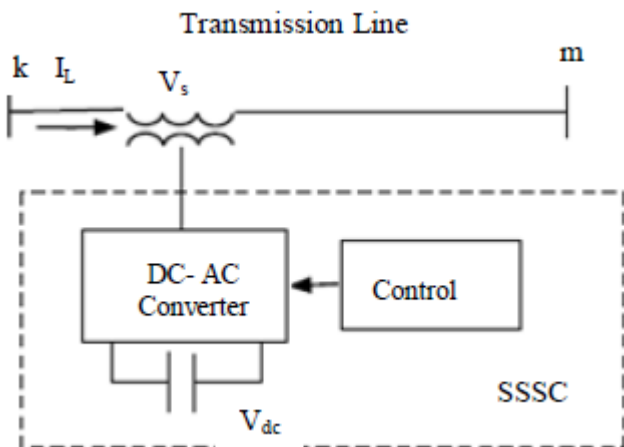


Figure 3 Simplified diagram of a SSSC

SSSC is connected in series with a power system. It has a voltage source converter serially connected to a transmission line through a transformer. It can be considered as asynchronous 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 almost in quadrature with the line current. A small part of the injected voltage that is in phase with the line current provides the losses in the inverter. Most of the injected voltage, which is in quadrature with the line current, provides the effect of inserting an 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 a SSSC is shown in Fig. 3[1,3,6].

D. Unified Power Flow Controller (UPFC)

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile device that can be used to enhance steady state stability, dynamic stability and transient stability. The basic configuration of a UPFC is shown in Fig. 4. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor, which provides dc voltage for the converter operation. The power balance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real power absorbed from or injected into the power system by the series converter plus the losses by regulating the dc bus voltage at a desired value [7,9].

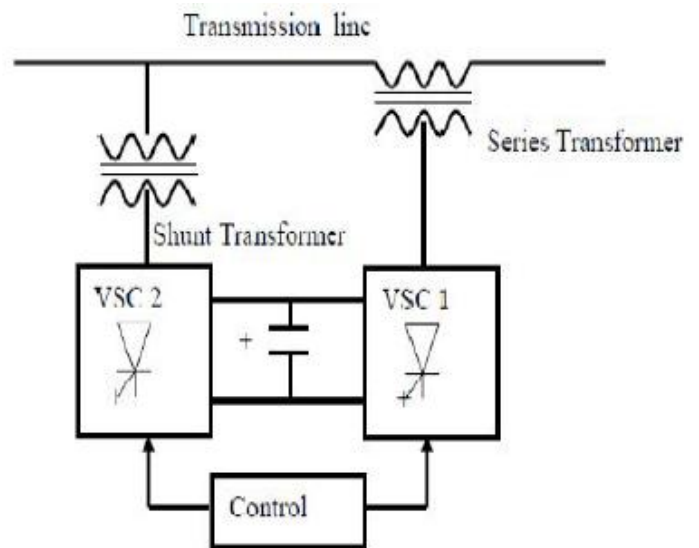


Figure 4: Unified Power Flow Controller (UPFC)

III. COMPARISON BETWEEN UPFC, SVC, TCSC, AND SSSC FOR POWER SYSTEM STABILITY ENHANCEMENT

Table 2 shows the comparison of FACTS devices of two-area power system with series and shunt FACTS devices. Series FACTS device connected between bus 2 and 3 in a single circuit long transmission line as shown in Fig. 5. The shunt FACTS device is connected parallel to bus number 2 as shown in Fig. 6. From table 2 it is investigated that the SSSC is requires more time for stability enhancement. TCSC FACTS device UPFC is the effective device for load flow, voltage control and stability enhancement of inter-area power system.

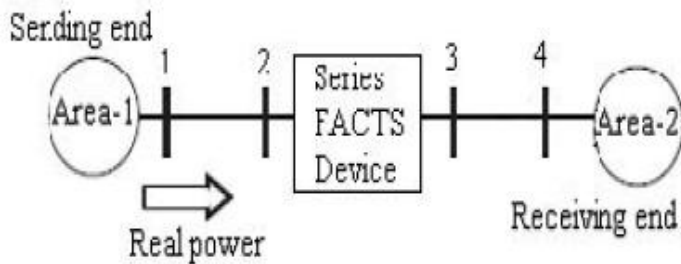


Figure 5 Two-area power systems with series FACTS device

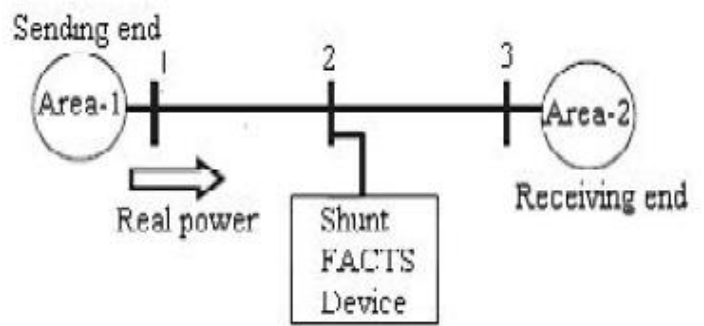


Figure 6 Two-area power systems with shunt FACTS device

Table 3 shows Simulation studies were done for different FACTS devices on IEEE 5 bus power system to find line losses [5]. TCSC, SVC and UPFC are placed in different bus and losses at each step are determined. It observed that placing TCSC in between bus 2 and bus 5 losses are reduced. It is best location for TCSC is to minimize the losses. For SVC the best location is between bus 2 and bus 3 to minimize the losses. UPFC is placed at different locations and optimal location for UPFC is between bus 5 and bus 4 to minimize the losses. UPFC regulates the voltage of the bus as well as regulates the active and reactive power of the buses and the lines losses within specified limits.

Table 2: Comparison between FACTS Devices for Power System Stability Enhancement [1,2,6]

S. No.	FACTS Device	Power System Stability Enhancement	Load flow	Voltage control	Transient stability	Dynamic stability	Time (sec)
1	UPFC	YES	High	High	Medium	Medium	0.6
2	TCSC	YES	Medium	Low	High	Medium	1.5
3	SVC	YES	Low	high	Low	Medium	7
4	SSSC	YES	Low	High	Medium	Medium	11

Table 3: Comparison between FACTS Devices for Power System Stability Enhancement

BUS		Line losses with TCSC		Line losses with SVC		Line losses with UPFC	
From	To	Real power loss	Reactive power loss	Real power loss	Reactive power loss	Real power loss	Reactive power loss
2	3	6.47328	-11.66943	6.6734	-9.5535	4.79012	-16.85673
2	4	6.53247	-12.03645	6.8625	-8.9328	4.70994	-17.10167
2	5	6.32411	-23.88476	11.3428	5.5864	5.02372	-15.57745
3	2	6.47642	-11.66949	6.7284	-9.6334	2.92428	-23.45038
3	4	6.12821	-10.85432	6.3158	-10.3962	5.04984	-16.31023
4	2	6.53872	-12.03452	6.9372	-8.9694	2.91293	-23.4464
4	3	6.12834	-10.85342	6.4121	-10.4043	2.91293	-23.4464
4	5	6.15325	-10.87238	6.1319	-11.1986	6.22885	-12.66832
5	2	6.32984	-13.85347	11.294	4.7654	1.37279	-28.66214
5	4	6.15096	-10.87543	6.1234	-11.2188	1.37279	-28.66214

IV. CONCLUSION

FACTS are powerful devices to improve the voltage profile and power system enhancement. In this paper, comparison of different FACTS devices with respect System Stability Enhancement is carried out and gives a idea about the FACT devices. It is found that the performance of the UPFC is higher for power system stability improvement is compared with the other FACTS devices such as SVC, TCSC, and SSSC respectively. The UPFC has settling time in post fault period is found to be around 0.6 second and maximum loss can be reduced compared to other FACTS device.

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