Importance of FACTS Devices in Power System

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Abstract: ***Modern power system networks are not able to cope with the increasing demand of power because the generation and transmission capacities are not increasing proportionally with the demand which leads to many problems such as instability, degrading power quality, threat to security and unreliable operation. Earlier mostly the control of power system is done with mechanical switches but now due to the advancement of technology, these conventional control methods are replaced with the new devices called as flexible AC transmission system which increase power system capability and enhance controllability of power system. In this paper a review is presented about FACTS devices that described how these devices prove a boon for power system, while dealing with problems of reactive power control, improving voltage profile, harmonic reduction and congestion management by allowing the static and dynamic control of power system.***

Keywords: SSSC, SVC, UPFC, ATC

1. Introduction

The flexible AC transmission Technology has created new opportunities for power system planning engineers to control power and increase the present power system capacity and helpful in expansion of future transmission line by controlling one or more parameters of transmission system. The concept of FACTS devices came into picture in late 1980. The fundamental concept of FACTS devices emphasis the use of high-voltage power electronics devices to control complex power flow and voltage in the transmission system [1-2]. Over the last few years, the transmission network is stressed due to continuous rise in demands. The reason behind the continuous rise in demands is due to the increasing number of nonutility generators and higher competition between utilities. Apart from this, less secure power system is the results of the problems like continuous rise in demand, lack of planning, and the necessity to deliver open access to generating companies and customers which further leads to reduction in power quality also. The FACTS technology is necessary to mitigate some of these problems by allowing utilities to obtain the maximum service from transmission facilities and thus there is enhancement in reliability of Grid.

2. Literature Review

Extensive literature is available since the FACTS device introduced. FACTS controllers such as Thyristor Controlled Series Compensators (TCSC), Unified Power Flow Controllers (UPFC) and Static VAR Compensator (SVC) was first introduced by Hingorani [1, 2,] to increase transmission capacity by managing the reactive power. Ramey D, Nelson R, illustrate how to reduce the operating cost of a plant by using Genetic Algorithm and Differential Evolution technique with FACTS devices, such as Thyristor Controlled Series Compensator Static VAR Compensator (SVC) and Unified Power Flow Controller (UPFC). [5] Song YH, Johns AT discuss the power flow control and improvement of static voltage instability using numerous FACTS device. Moreover how load shedding can be done using FACTS is also discussed. [6] F. D. Galina, elaborate the impacts on static security regions using FACTS devices [9]. Definitions of FACTS and presented terms are given by IEEE Transactions on Power Delivery. [10]C. Gama, discussed about damping of oscillations the final commissioning tests involved verification of using TCSC which is placed at each end of the interconnection. Along with this, some algorithms has also illustrated to improve the dynamic behavior of power system. [12]. S. N Singh illustrated a sensitivity-based approach for enhancing the security of system \which can be used to find the optimal location of FACTS devices. [13]The modelling and simulation of numerous FACTS devices has been described in detail. [15] Bindeshwar Singh, discuss a review on techniques used in multi machine power system for coordinated control and optimal allocation of FACTS devices [20]. Lashkar Ara A, find solution for optimal Steady-state performance of power systems with the help of optimal unified power flow controller model. [21] Lee, S. Hu, and Y. Chan, elaborate in detail the mitigation of positive and negative sequence voltage using the control techniques with D-STATCOM. [28] Karthikeyan, presented the market power impact in steady state conditions using TCSC and TCPAR using IEEE-14 bus system with conventional method and FACTS devices and their comparison is also presented**. [28]** Puja Dash, elaborate the automatic generation control of multi-area system using Facts devices [29] C. Rehtanz and J. Zhang has presents the latest development in FACTS devices with introduction of some new FACTS controller. [31]Zhang XP, Rathan C, Bikash also discuss the modelling and simulation of numerous FACTS devices. Jai Govind, discuss the role of congestion management in power system and how it is achieved with various FACTS devices. [32]Castillo, A, Laird, describe how unit commitment becomes easy with the FACTS devices. [35] A bilevel model is solved using the customized reformulation and decomposition algorithm. Added to this, for facilating wind power integration, the role of series FACTS using the numerical computation on 118 bus system is demonstrated. [39]

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3. Types of Facts Controller

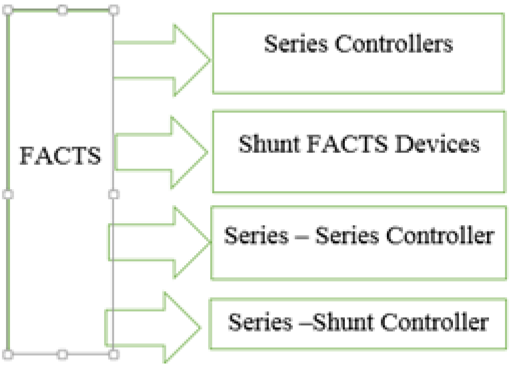

Figure 1: Types of Controller

3.1. Series Controllers: Series FACTS controller may be consisting of a variable impedance which can be a reactor or capacitor or a variable source of frequency. The voltage is injected in series with the line in these types of controllers. As long as voltage and line current have phase difference of 90 degrees, these Controllers only supplies or consumes variable reactive power.

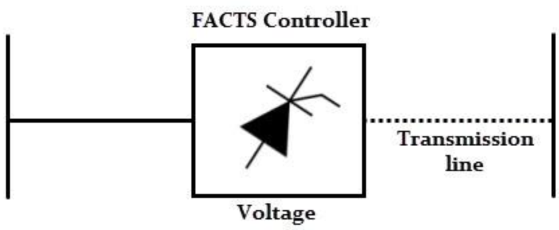

Figure 2: Series Controller

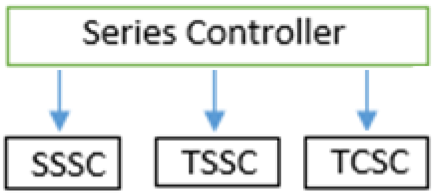

Figure 3: Types of Series Controller

3.2 Shunt Controllers

These controllers represent injection of current in the line as the variable impedance which is connected in shunt with the line voltage cause variable current to flow through it.

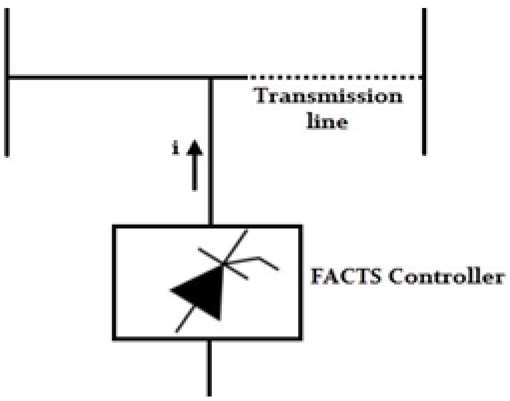

Figure 4: Shunt Controller

The Shunt controllers can be classified as Static Voltage Compensator, Static Compensator

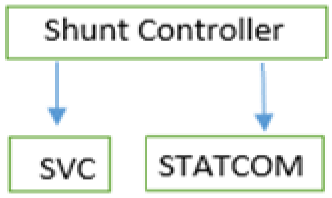

Figure 5: Types of Shunt Controller

3.2.1. SVC: A static VAR compensator is used to obtain fast-acting reactive power on high-voltage electricity transmission networks by regulating and controlling the voltage. It is constructed by the combination of shunt capacitors and shunt reactors. Shunt reactor and TCRs are used to prevent voltage rise under low load and no-load condition. Static capacitor and Thyristor switch capacitor are used to prevent voltage sag for maximum load. There are two combination uses in practice first one is TCR parallel with fixed capacitor (FC) and another one is TSC in parallel with TCR. In comparison with TCR, it is as TCR only generate reactive power but SVC not only generates but also absorb reactive power.

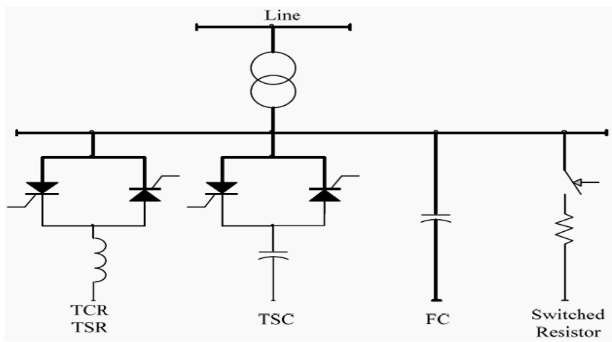

Figure 6: Structure of SVC.

3.2.2 STATCOM

STATCOM is a static synchronous generator operated as a shunt active FACT controller connected to the mid-point of a transmission line and is used to improve the stability of power system, voltage regulation. Moreover output current is also controlled over the rated maximum capacitive or inductive range. Added to this STATCOM is effective in power flow control also as compared to other FACTS devices.

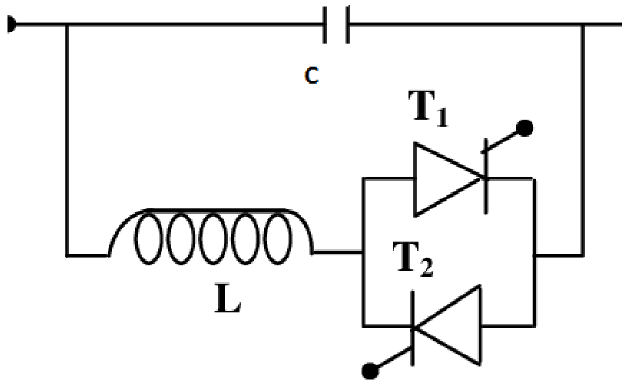

Figure 7: Structure of STATCOM

3.3. Combined series-series Controllers

In a multiline transmission system, a combination of separate series controllers controlled in a coordinated manner is an example of this type of FACTS devices. IPFC (Interline Power Flow Controller) is a typical example of this.

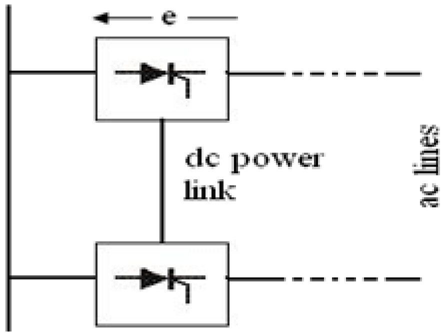

Figure 8: Structure of series – series Controller

3.4 Combined series-shunt Controllers

A combination of separate series and shunt Controllers, in a coordinated manner is called combined series and shunt controllers. The shunt controller injects current into the system and voltage is injected in series in the line with the series Controller. Unified Power flow controller (UPFC), Thyristor Controlled Phase Shifting Transformer (TCPST) are the typical examples of these types of FACTS controllers. The basic structure is shown below in fig

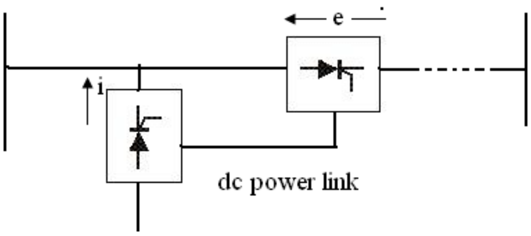

Figure 9: Series shunt Controllers

4. UPFC

The simultaneous control of transmission voltage, line impedance and phase angle is possible with unified power flow FACTS controller as it is most versatile FACTS device. It consists of two voltage source converters which are connected together using a dc link storage capacitor. It is third generation FACT device which can control power flow by controlling the active and reactive power and provide fast reactive compensation. It is combination of series and shunt FACTS. The main purpose of the shunt converter is to regulate voltage at DC link and provide the active power flow balance that is exchanged between series converter and the transmission line.

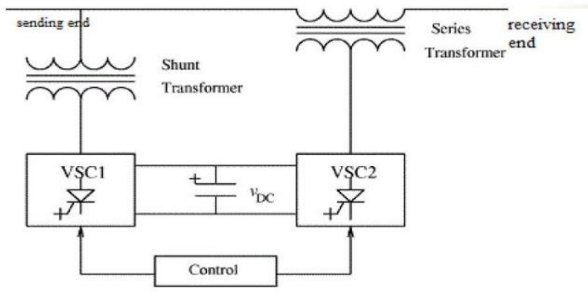

Figure 10: UPFC

5. Advantages of FACTS technology

FACTS technologies are helpful in making cost effective solutions while planning a new transmission line construction. The major advantages of FACTS devices are now widely recognized by the power systems planning engineers.

1) Dynamic control of power flow in transmission lines
2) Suppression of sub synchronous oscillations
3) Decreases DC offset voltages
4) Reduce the frequent variation in output
5) Reduction in short Circuit current
6) Smoothly adjustable output
7) Power swings Damping of Local and inter-area oscillations

Table 1: Various FACTS devices with their feature

	FACTS devices	Features	Applications
Series controller	SSSC	1) Injected voltage can be managed independently 2) high effective X/R is maintained 3) Inherently neutral to sub-synchronous resonance. 4) Compensation over a wider range is provided	1) Reduce harmonic distortion 2) Load balancing in interconnected distribution networks. 3) Power flow control 4) Power Factor correction 5) Improves the available transfer capability in deregulated market
	TSSC	1) High degree of series capacitive compensation. 2) Reduce the overall transmission impedance in electrically shorter line	1) Reactive power compensation 2) Improvement of stability
	TCSC	1) Increased real transfer power, power oscillations damping, sub-synchronous 2) resonances damping, and power flow line controls able to continuously control and maintain the compensating voltage can provide compensation over a wider range,	1) Reduction in effect of contingency 2) Damping of low frequency oscillation 3) Dynamic load flow control 4) ATC improvement 5) Reduce in congestion 6) Improvement of power system stability involving both transient and steady state stability.

Shunt Controllers	SVC	1) Reactive power is either supplied or absorbed to support a specified voltage magnitude 2) improve the thermal limit	1) Damping of low frequency oscillation 2) Improvement of system stability 3) Maintain the line voltage variation within limits 4) Improve power factor 5) To prevent voltage collapse
	STATCOM	1) The higher reactive output at low system voltages. 2) It behaves like current source independent from the system voltage. 3) It behaves like a fast synchronous condenser	1) Damping of low frequency oscillation 2) Reactive power and voltage control 3) Sub synchronous Resonance Elimination 4) Dynamic Voltage Control
Series – series Controller	IPFC	1) Effectively manages the power flow of multi-transmission line	1) Damping of low frequency oscillations 2) Congestion Management 3) Reduction in operating cost of plants
Series – shunt Controller	UPFC	1) Improves voltage profile 2) Control Voltage, impedance and phase angle 3) Generates and absorbs real and reactive power	1) Resolve power quality issues such as harmonics, voltage flickering, voltage sag 2) Real and reactive power flow control in transmission line 3) ATC improvement 4) Reduction in Congestion 5) Power factor correction
	Thyristor Controlled Phase Shifting Transformer (TCPST)	1) It influence the power flow in the transient states. 2) Control power flow by regulating the phase angle	1) Active power control 2) Damping Oscillations 3) ATC improvement 4) Congestion reduction 5) Improvement of transient stability

6. Conclusion

This paper discussed about the numerous FACTS devices and their features and applications. A review on the benefits and applications of Numerous FACTS devices in transmission and distribution network is discussed and it is observed that the most crucial problems of power system can be resolved with the application of different types of FACTS controller.

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