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Impacts of Facts Technology-A State of Art Review

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Abstract: FACTS (Flexible AC Transmission Systems) means a whole family of controllers and devices for increase the use and flexibility of power systems. These controllers are installed in many places and improving the capabilities of different power systems.. This paper presents a review on the research and developments in the area of FACTS controllers and their contributions. This paper will treat benefits of FACTS devices installed in power systems such as increment in power transmission capability and a reduction in transmission losses. And improved transient and dynamic stability, This paper also includes the main barriers of voltage instability and power transmission structure. Authors strongly believe that this survey article will be very much useful to the researchers for finding out the relevant references in the field of voltage stability improvement by using FACTS controllers

Index Terms: FACTS, SVC, STATCOM, UPFC.

I. INTRODUCTION

Modern power systems are prone to widespread failures. As the power demand is increasing day by day similarly the complexcity of operating large power system is also increasing. These operating conditions and vulnerable environment makes system unstable.. Voltage instability is one of the phenomena which have result in a major blackout. With this rapid growth and large demand for power has increase the possibilities of large blackout. Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating condition [1]. Voltage instability stems from the attempt of load dynamics to restore power consumption beyond the capability of the combined transmission and generation system . A possible outcome of voltage instability is loss of load in an area, or tripping of transmission lines and other elements by their protective systems leading to cascading outages. Voltage collapse is the catastrophic result of a sequence of events leading to a low voltage profile suddenly in a major part of the power system [2].

Voltage stability can be further classified to small disturbance, large disturbance, short term, and long term categories. Small disturbance voltage stability considers the power system's ability to control voltages after small disturbances, e.g. changes in load [2-4].Large-disturbance voltage stability refers to the system's ability to maintain steady voltages following large disturbances such as system faults, loss of generation, or circuit contingencies. Besides, the time frame of interest for voltage stability problems may vary from a few seconds to tens of minutes. Therefore, voltage stability may be either a short-term or a long-term phenomenon. Short term voltage stability is characterized by components such as induction motors, excitation of synchronous generators, and electronically controlled devices such as HVDC and static VAR compensator [3-4]. The study period of interest is in the order of several seconds, and analysis requires solution of appropriate system differential equations; this is similar to analysis of rotor angle stability [4]. The dynamics of the long term time scale last for several minutes. The long term voltage stability is characterized by scenarios such as load recovery by the action of on-load tap changer or through load self restoration, delayed corrective control actions such as shunt compensation switching or load shedding. The long term dynamics such as response of power plant controls, boiler dynamics and automatic generation control also affect long term voltage stability [5-6].

To maintain security of such systems, it is desirable to plan suitable measures to improve power system security and increase voltage stability margins. FACTS devices can control the active and reactive power as well as voltage- control simultaneously because of their flexibility and fast control characteristics.

II. BARRIERS OF EXISTING SYSTEMS

- The existing power-transmission structure is prone to human error, natural disasters, and intentional physical and cyber attack.
- With rapid growth in the power demand the current structure requires a very large investments for either designing new infrastructures or restructure the existing infrastructures.
- This infrastructure is not being expanded or enhanced to meet the demands of wholesale competition in the electric power industry and does not facilitate connectivity between consumers and markets.
- The infrastructure does not accommodate emerging beneficial technologies including distributed energy resources and energy storage, nor does it facilitate enormous business opportunities in retail electricity/ information services.
- The present electric power-transmission and distribution infrastructure is not designed for digital technology like microprocessors and computers.

III. SEMICONDUCTOR DEVICES

The FACTS controllers represent a relatively new technology for transmission systems [11-12]. They are made possible as a combination of conventional equipment, of rapidly developing. power electronics and of microelectronics, all of which together provide effective and fast control of such controllers.

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Telecommunication is also important for optimum and coordinated operation of FACTS equipment in the system. The driving force for new and more cost-effective FACTS equipment is the development of semiconductor devices. The idea of FACTS is explained in Fig. 1 which shows a schematic diagram of an AC interconnection between two systems. The active power transmitted between the systems is defined by the given equation where and are the voltages at both ends of the transmission, is the equivalent impedance of the transmission, and - is the phase angle difference between both systems. From the equation in Fig.1 it is evident that the transmitted power is influenced by three parameters: voltage, impedance, and voltage angle difference. FACTS devices can influence one or more of these parameters, as shown in the figure, and thereby influence power flow. Instability in power system could be relieved or at least minimized with the help of most recent developed devices called Flexible AC Transmission System (FACTS) controllers [11], [13]. The use of Flexible AC Transmission System (FACTS) controllers in power transmission system have led to many applications of these controllers not only to improve the stability of the existing power network resources but also provide operating flexibility to the power system. In addition, with relatively low investment compared to new transmission.

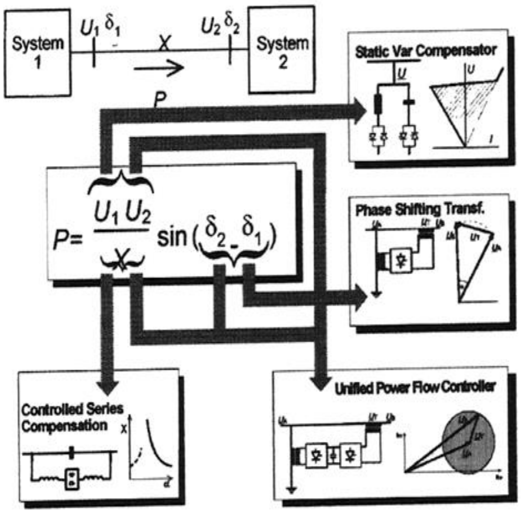

Fig.1 Power flow control in AC power system

The most powerful are still thyristors which can have a blocking ability of more than 10 kV and carry currents up to5 kA. However, the GTO devices offer additional advantages for interrupting the current. These devices permit the use of forced-commutated converters which are advantageous in building FACTS equipment with more advanced characteristics. The IGBT devices are used for converters in the lower rating ranges, mainly to be used in medium and low-voltage networks. The advantage of these devices is that they allow switching frequencies in the range up to 3–10 kHz. The main purpose of these devices is the improvement of

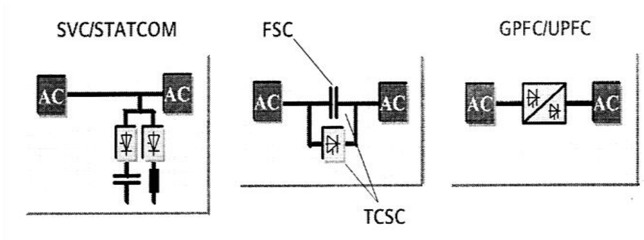

Fig.2 Diffrent FACTS controller

power quality or generation facilities, these FACTS technology allows the industries to better utilize the existing transmission and generation reserves, while enhancing the power system performance. They clearly enhance power system

Fig. 2 is a list of FACTS controllers which have been realized [13][14]. They can be used for load flow control, voltage control and stability improvement in transmission systems as well as for additional special applications. The advantage of FACTS is that different new members of the FACTS family can be created by combining a variety of different equipment.

There are two generations for realization of power electronics-based FACTS controllers: the first generation employs conventional thyristor-switched capacitors and reactors, and quadrature tap-changing transformers, the second generation employs gate turn-off (GTO) thyristor-switched converters as voltage source converters (VSCs). The first generation has resulted in the Static Var Compensator (SVC), the Thyristor- Controlled Series Capacitor (TCSC), and the Thyristor-Controlled Phase Shifter (TCPS) [13], [14]. The second generation has produced the Static Synchronous Compensator (STATCOM), the Static Synchronous Series Compensator (SSSC), the Unified Power Flow Controller (UPFC), and the Interline Power Flow Controller (IPFC) [15]. The Thyristor-Controlled Phase Angle Regulator (TCPAR), which can influence a fast change of phase angle and could be either thyristor- or GTO-based, is possible as it requires no further development, unlike the other controllers mentioned above. However, up to now there has been no need for this equipment in the systems as, in most cases; a mechanical switched phase shifter could cover the needs So far, only one book thoroughly covers component and system wise aspects of the FACTS technology [11].

This research work is solely concerned with system wise aspects of the FACTS technology. In general form, system wise aspects are related either to the improvements of security and economics or to the enhancements of transmission network capability [22]-[23].

IV. TECHNICAL ATTRIBUTES OF FACTS CONTROLLERS

It is very necessary to state here that these controllers facilitate the power systems with some of most required parameters. One or more technical benefits are listed here.

- Power flow control as ordered
- Increment in the loadability of lines to their thermal, voltage and steady state capability limits.
- Increase the transient and dynamic stability, limiting short-circuit currents and overloads and hence increasing the system security
- Reduce reactive power flows
- Provide greater flexibility for new generation.

Here a list of FACTS controllers has been designed by incorporating these possible benefits, where one or more benefits may be overlapped by most of the controllers, as some of the parameters of power system are interlinked [30].

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The measuring factors for various parameters like transient stability, voltage stability .etc may be different for different controllers and this has been ignored here.

Sr no	FACTS controllers	Technical attributes
1	Static synchronous Compensator (STATCOM)	Voltage control VAR compensation Transient and dynamic Stability Voltage stability Damping oscillations
2	Static VAR Compensator (SVC,TSC,TCR)	Voltage control VAR compensation Transient and dynamic Stability Voltage stability Damping oscillations
3	Static synchronous series Compensator (SSSC)	current control Transient and dynamic Stability Voltage stability Damping oscillations
4	Thyristor Controlled series Compensator (TCSC/TSSC)	current control Transient and dynamic Stability Voltage stability Damping oscillations
5	Unified power flow controller (UPFC)	Active and reactive power control Voltage control VAR compensation Transient and dynamic Stability Voltage stability Damping oscillations
6	Interline power flow controller (IPFC)	Voltage control Reactive power control Transient and dynamic Stability Voltage stability Damping oscillations

V. INTEREST MEASURE FOR FACTS

A detailed literature survey has been done For this extensive review, and this search includes the most important and common database, the IEEE electronic library. The survey spans over the last 24 years from 1988 to 2011. For convenience, this period has been divided to four sub-periods; 1988–1993, 1994–19992 000- 2005 and 2006–2011. The number of publications discussing FACTS applications to different power system studies has been recorded. The results of the survey are shown in Fig. 3. It is clear that the applications of FACTS to different power system studies have been drastically increased in last five years. This shows more interest for the VSC-based FACTS applications [35]. The potential of FACTS controllers to enhance power system stability has been discussed by Noorozian and Anderson [32], where a comprehensive analysis of damping of power system electromechanical oscillations using FACTS was presented. Wang and Swift [33] have discussed the damping torque contributed by FACTS devices, where several important points have been analyzed and confirmed through simulations.

VI. CONCLUSIONS

This exhaustive literature survey simply employs that the FACTS devices are capable of solving one or all problems at the power system. the essential features of FACTS controllers and their potential to improve system stability is addressed. In recent years, along with the rapid increasing electric power requirement, the reconstruction of India's urban and rural power network is more and more urgent. With the history of more than three decades and widespread application in recent years, FACTS controllers has established itself as a proven and mature technology. Authors strongly believe that this survey article will be very much useful to the researchers for finding out the relevant references as well as the previous work done in the field of voltage stability improvement by using FACTS controllers in multi-machine power systems. So that further research work can be carried out.In this review, In the changing utility environment, FACTS is one of the most important tool for the operational flexibility and controllability in system operator. In view of the various power system limits, FACTS provides the most reliable and efficient solution.

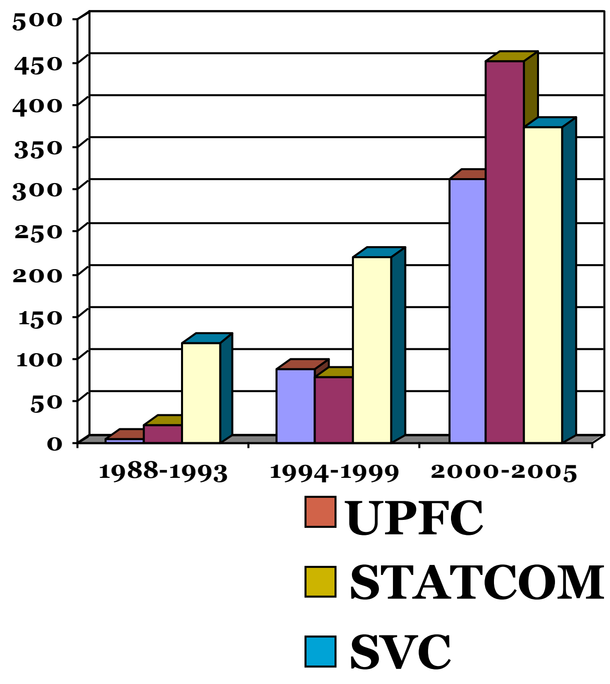

Fig 3 Publications on different FACTS controllers

The existing transmission network may use these FACTS controllers for better utilization and this is highly beneficial for those areas where transmission expansion is not possible because of the some environmental hindrances or because of some social issues. So This survey clearly indicates that there is a great potential for FACTS application in the years to come.

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