Paper from Proceeding of the National Conference on Innovative Developments in Science, Technology & Management (NCIDSTM-2015) Organized by Ganga Technical Campus, Soldha, Bahadurgarh, Haryana (India) March 1st 2015 Published by International Journal of Engineering Sciences Paradigms and Researches (IJESPR) with ISSN (Online): 2319-6564, Impact Factor: 2.20 and Website: www.ijesonline.com

Implementation of FACTS Devices for Power System Stability Improvement

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Abstract

This paper presents the introduction of various FACTS controllers such as Static Var Compensator (SVC), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), and Unified Power Flow Controller (UPFC) for solving various power system steady state control problem. Flexible AC transmission system devices allow the flexible and dynamic control of power system. The aim of this paper is to examine the ability of FACTS devices for power flow control in a power system. A power flow control strategy is based on linearization of active and reactive power flows around an operating point. The comparison of performance of various FACTS controllers has been discussed. Application of FACTS devices to power system studies have also been discussed.

***Keywords**: AC, FACTS, IPFC, SVC, STATCOM, SSSC, TCSC, UPFC.*

1. Introduction

FACTS technology opens up new opportunities for controlling power and improvement in the usable capacity of present as well as new and upgraded lines. FACTS controllers have ability to control the interrelated parameters that governs the operation of transmission system including series impedance, shunt impedance, current, voltage, phase angle and the damping of oscillations at various frequencies below the rated frequency. The FACTS technology is a collection of controllers which is used individually or in a combination with other to control one or more of the interrelated system parameters. For the development of the FACTS controllers there are basically two generation of FACTS controllers. The following controllers such as StaticVar Compensator (SVC) ,Thyristor Controlled Series Capacitor(TCSC), and Thyristor Controlled Phase Shift Transformer (TCPST) are developed in the first generation of FACTS controllers. The FACTS controllers such as Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC),Unified Power Flow Controller(UPFC) and Interline Power Flow Controller(IPFC) are developed in the second generation of FACTS controllers. In general FACTS controllers can be divided in following four categories such as series controller, parallel controller, combined series-series controller and combined series-shunt controller.

2. **Control of power systems**

2.1 Power flow in an AC system

In an ac power system, the electrical power generation and load must be balance at all the time. If it is unbalance or if generation is less than load, the voltage and frequency decrease and the load becomes equal to the generation minus the transmission losses. In any power transmission system power can be flow by the following loop paths as

- Power flow in parallel path
- Power flow in a meshed system.

2.2 Loading capability limits

Basically there are three types of loading capability limitations in power system are

- Thermal
- Dielectric
- Stability

Thermal capability of any overhead system is a function of the wind conditions, conditions of the conductor, ambient temperature and ground clearance. For the designing of lines care is needed to ensure that dynamic and transient over voltage are within limits. Following are the stability issues which limits the transmission capacity such as transient stability, dynamic stability, steady state stability, voltage collapse etc.

2.3. Controllability of Power Systems

There are mainly three variables which can be directly controlled in the power system to impact its performance. These are:

- Voltage
- Angle
- Impedance

We can also infer the point that direct control of power is a fourth variable of controllability in power systems. With the establishment of "what" variables can be controlled in a power system, the next question is "how" these variables can be controlled. The answer is presented in two parts: namely conventional equipment and FACTS controllers.

Conventional Equipment for Improving Power System Control

- Series Capacitor -Controls impedance
- Switched Shunt-Capacitor and Reactor -Controls voltage
- Transformer LTC -Controls voltage
- Phase Shifting Transformer -Controls angle
- Synchronous Condenser -Controls voltage
- Special Stability Controls-Focuses on voltage Control but often include direct control of Power

FACTS Controllers for Improving Power System Control

- Static Synchronous Compensator (STATCOM) -Controls voltage
- Static VAR Compensator (SVC) –Controls voltage
- Unified Power Flow Controller (UPFC)
- Convertible Series Compensator (CSC)
- Inter-phase Power Flow Controller (IPFC)
- Static Synchronous Series Controller (SSSC)

Each of the above mentioned controllers have impact on voltage, impedance, and/or angle (and power)

- Thyristor Controlled Series Compensator (TCSC)-Controls impedance
- Thyristor Controlled Phase Shifting Transformer (TCPST)-Controls angle
- Super Conducting Magnetic Energy Storage (SMES)-Controls voltage and power

2.4. Benefits of Control of Power Systems

Once power system constraints are identified, the benefits of the added power system control must be determined. The following are the benefits:

- Added Power Flow Control
- Improved Power System Stability
- Increased System Security
- Increased System Reliability
- Added Flexibility in Starting New Generation
- Elimination or Deferral of the Need for New Transmission Lines

2.5. Benefits of utilizing FACTS devices

The following are the benefits of utilizing FACTS devices in electrical transmission system:

- Increase the system security
- Increase the loading capability
- Provide secure tie line connection
- Improve the system flexibility
- Upgrade of lines

• Reduced reactive power flow
• Reduced loop flows

3. Classifications of FACTS Devices

3.1. Static VAR Compensator (SVC)

It is a set of electrical devices used on high voltage electricity transmission network for producing fast acting reactive power. These are part of the flexible AC transmission system device family. It does not contain any moving parts. It is an automated impedance matching device, designed to bringing the system near to the unity power factor. It is connected near to the large industrial loads, for improving the power quality and it is also used to regulate the grid voltage in transmission application. It consist of one or more banks of fixed or switched shunt capacitors or reactors. SVC are cheaper, high capacity ,faster and more reliable. Its output is adjusted to exchange capacitive or inductive current for maintaining or controlling specific parameter of the electrical power system. It is based on thyristors with gate turn-off capability

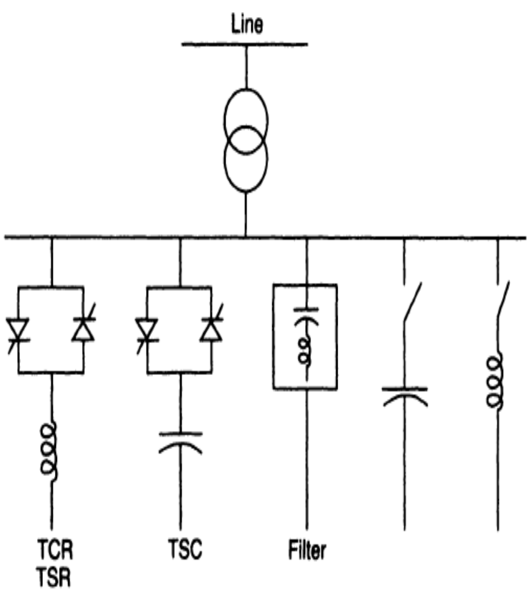

Fig-1.Static Var Compensator

3.2Thyristor-Controlled Series Capacitor (TCSC)

It consist of a series capacitor bank in parallel with a thyristors controlled reactor for providing a smoothy variable series capacitive reactance. Like SVC it is bases on thyristors without the gate turn-off. It is a very important FACTS controller and an alternative to SSSC. In this a thyristors control reactor is connected across a series capacitor. For achieving a superior it may be single, large unit, or it may consist of many equal or different sized smaller capacitors. It is used for providing sufficient load compensation in power system to dynamically control the reactance of transmission line.

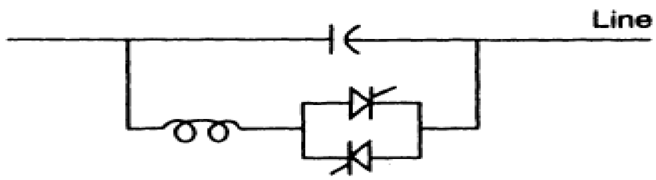

Fig-2.Thyristor-Controlled Series Capacitor

3.3 Static Compensator (STATCOM)

It is also known as a static synchronous condenser. It is based on a voltage source or current source convertor. It is used to support electricity network which have poor power factor and poor voltage regulation. In this the voltage source is produced by a DC capacitor, so these have a very small active power capability. If we connect suitable energy storage device across the DC capacitor, its active power capability can be increased. As compare to SVC it provides better reactive power support at low AC voltages.

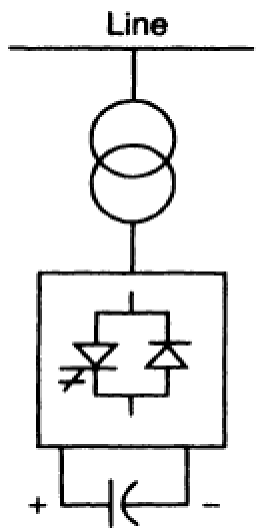

Fig-3.Static Compensator

3.4 Static Synchronous Series Compensator (SSSC)

It consists of a solid state voltage source inverter connected in series with the transmission line through an insertion transformer. It was proposed by Gyugyi in 1989. It provides capacitive or inductive compensating voltage. Which is independent of line current up to its specific current rating. By controlling the angular position of the injected voltage with respect to the line current, it can negotiate both of the active and reactive power with the AC system. For providing compensation for the line resistance by the injection of real power, it has the inherent ability to interface with an external DC power supply.

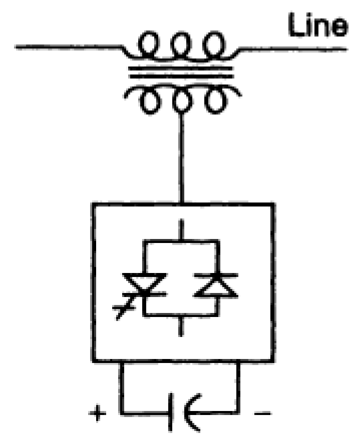

Fig-4.Static Synchronous Series Compensator

3.5 Unified Power Flow Controller (UPFC)

It was proposed by Gyugyi in1991. For providing fast acting reactive power compensation on high voltage electricity transmission network, it uses a pair of 3 phase controllable bridge. It can control active and reactive power flows in a transmission line. It is the combination of STATCOM and SSSC which is coupled through common DC voltage link. Controlling active and reactive power flow in the transmission line is its main advantage. Phase angle, voltage and reactance in the line are the controllable parameters of the UFC. These are placed at the buses for improving the bus voltage of the system and also improving the power capacity of the line.

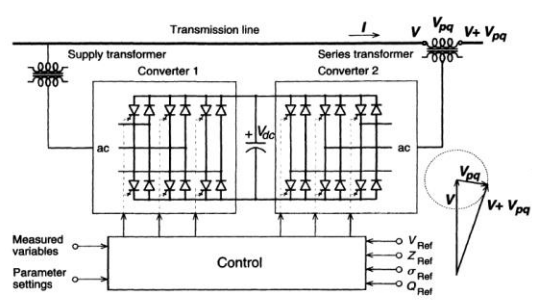

Fig-5.Unified Power Flow Controller

4. FACTS applications to steady state Power system problems

In this section we presented a brief overview of the FACTS devices applications to different steady state power system problems. Specifically, applications of FACTS in optimal power flow and deregulated electricity market will be reviewed.

4.1 FACTS Applications to Optimal Power Flow

For solving the optimal power flow problem by using various FACTS devices researchers developed new algorithms. Generally in power flow studies, the Thyristor controlled FACTS devices, such as SVC and TCSC, are usually modeled as controllable impedance. However, VSC-based FACTS devices, including IPFC and SSSC, shunt devices like STATCOM, and combined devices like UPFC, are more complex and usually modeled as controllable sources. The Interline Power Flow Controller (IPFC) is one of the voltage source converters (VSC) based FACTS Controllers which can effectively manage the power flow via multi-line Transmission System.

4.2 FACTS Applications to Deregulated Electricity Market

Nowadays, electricity demand is increasing rapidly without major reinforcement projects to improve power transmission networks. Also, the electricity market is going toward open market and deregulation creating an environment for forces of competition and bargaining. FACTS devices are used to reduce the flows in heavily loaded lines, resulting in increased load ability, low system loss, improved stability of the network, reduced cost of production, and fulfilled contractual requirements by controlling the power flows in the network. Generally, the changing nature of the electricity supply industry is introducing many new subjects into power system operation related to trading in a deregulated competitive market. Using FACTS devices commercial pressures on obtaining greater returns from existing assets suggests an increasingly important role for dynamic network management and energy storage as an important resource in generation, transmission, distribution, and customer service. There has been an increased in the use of FACTS devices applications in an electricity market having pool and contractual dispatches.

5. Conclusion

The important features of FACTS controllers and their ability to improve stability of the system is the prime concern for effective & economic operation of the power system. In this the coordination problem in different control schemes was also considered. Comparison of performance of different FACTS controllers has been reviewed. The future scopes of FACTS technology, was also discussed. In addition, utility experience and major real-world installations and semiconductor technology development have been summarized. A brief review of FACTS applications to optimal power flow and deregulated electricity market has been presented.

References

[1] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York: IEEE Press, 2000.

[2] N. G. Hingorani, "FACTS-Flexible AC Transmission System", Proceedings of 5th International Conference on AC and DC Power Transmission-IEE Conference Publication 345, 1991, pp. 1–7.

[3] N. G. Hingorani, "Flexible AC Transmission", IEEE Spectrum, April 1993, pp. 40–45.

[4] N. G. Hingorani, "High Power Electronics and Flexible AC Transmission System", IEEE Power Engineering Review, July 1988

[5] R. M. Mathur and R. S. Basati, Thyristor-Based FACTS Controllers for Electrical Transmission Systems. IEEE Press Series in Power Engineering, 2002.

[6] Yong Hua Song and Allan T. Johns, Flexible AC Transmission Systems (FACTS).

London, UK: IEE Press, 1999.

[7] E. Acha, C. R. Fuerte-Esquivel, and H. Ambriz-Perez et al., FACTS: Modeling and Simulation in Power Networks, London, U.K.: Wiley, 2004

[8] Y. N. Yu, Electric Power System Dynamics. Academic Press, 1983.

[9] P. W. Sauer and M. A. Pai, Power System Dynamics and Stability. Prentice Hall, 1998.

[10] J. R. Smith, G. Andersson, and C. W. Taylor, "Annotated Bibliography on Power System Stability Controls: 1986- 1994", IEEE Trans. on PWRS, 11(2)(1996), pp. 794–800.