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ENHANCEMENT OF POWER SYSTEM AND CONTROL BY IMPLEMENTATION OF FACTS DEVICES

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ABSTRACT

Modern power systems complicate power system research and pose new issues for stability of power system, notably in the areas of unstable transients and stability of small-signals.Transient stability regulation is basic in guaranteeing the relentless operation of control frameworks within the nearness of noteworthy unsettling influences and glitches. This study looks at how a 2-area power system that uses a TCSC, STATCOM, SVC and UPFC can improve its transient stability. The TCSC, SVC and STATCOM has been used to contrast the capability of the UPFC with other FACTS devices. The results of the simulations illustrate the productivity and constancy of the FACTS devices in improving the system's transient stability.
Keywords- Transient stability, UPFC , UPSC, TCSC, 2-area power system, SVC, STATCOM, FACTS.

I. INTRODUCTION

Growing demand and limits on adding new lines are straining modern power system transmission networks. A disturbed stressed system may lose stability. Flexible AC Transmission System (FACTS) gadgets are competent of transmission to extend its capacity without risking its stability. Flexible AC Transmission System (FACTS) controllers like SVC, TCSC utilize the foremost up-to-date control electronic exchanging gadgets in electric control transmission frameworks to control voltage and control stream inside endorsed limits and balance out interconnected control frameworks[1]. The FACTS controllers provide a wonderful chance to manage the flow of alternative current (AC), increasing or decreasing the control flow on certain lines and reacting to unexpected changes in solidity problems. The prospective use of this kind of innovation is based on the capacity to coordinate the stream of power and interface systems that are insulant interconnected, permitting for the trade of vitality between far-off gadgets.

Power systems are complex networks of generators, transmission lines, loads, and transformers. Due to rising energy usage, certain transmission lines are transporting more than expected. As lengthy transmission lines are loaded, transient stability after a severe failure may limit transmission. [2]. FACTS controllers allow real-time management of AC gearbox, power flow on individual lines, and stability issues. This system can manage power flow, connect unintegrated networks, and trade energy between distant agents. FACTS, a static device, transmits AC electricity. FACTS power electronics increase power transfer and controllability. Transient stability is the capability of the framework to keep working inspite of circuit failures or line switching[3]. The nonlinear power angle link has an effect on how the system responds, which includes big changes in the angle of the generator's rotor. The quantity of noise and how the system was set up when it initially started running both have an impact on stability.

The stationary equipment transmits AC is Flexible Alternating Current Transmission System (FACTS). It enhances controllability and power transfer. FACTS devices like phase shifting transformers which is mechanically switched , quickly switched , or thyristor switched (IGBTs). FACTS like the SVC are as of now utilized in control frameworks, but control gadgets and control propels have extended their business. Power systems use FACTS controllers, a recent power electronics finding. Quickly restoring voltage, steady-state, and transient stability to a complex power system is possible using FACTS controllers [4-8].A FACTS device belonging to the first-generation, the Static VAR Compensator (SVC) may make voltage adjustments at the required bus to enhance the system's voltage profile. SVCs have outperformed traditional shunt compensation for voltage control. By optimization of reactive power control, the SVCs can also dampen power swings, reduce system losses and increase transient stability[11,13-20].

II Literature Review

FACTS devices can be set up in many different ways. These tools offer solid solutions to problems in the power system. For a successful deployment, these studies looked at several control and operation situations. Experts in FACTS control found that FACTS devices can give accurate dynamic reactive power compensation that is well controlled. This makes the receiving and outgoing ends better in terms of voltage quality, power angle, and stability margin. Senjyu et al.,[6] suggests that the rebuilt power system use series FACTS devices to ease congestion and make it safer. Harmony search algorithm, a new heuristic algorithm, is used to place and size series FACTS devices in the best way possible.

Chung [12] coordinates several FACTS supplemental damping controllers for system small-signal stability. Robust damping control is solved using a BMI-based system model determines controller variables in two steps. Control objectives are regional pole placement and effort optimisation. Sequentially designing damping controller utilizing SVC and TCSC, reduces decoupling effort.

S.Panda et.al., [21] designed a Power System Stabiliser (PSS) and a TCSC-based controller to improve stability of the power system by using Particle Swarm Optimisation (PSO). PSS and TCSC-based controller plan may be a time-domain enhancement issue. PSO calculation finds ideal controller parameters. Limiting the time-domain-based objective work, which incorporates the generator's oscillatory rotor speed variety, progresses framework steadiness.

Mithulananthan et al.,[23] proposed HPSO, an amalgam of PSO, EP, TS, and SA. Merging optimizes the allocation of FACTS of several types to maximize power transfer between generators without exceeding system limits.Regarding the implementation of an effective and affordable way to improve voltage stability, Zhou [24] addressed the issue. A combination of SVC and TCSC's performance to achieve UPFC's, the most expensive and versatile FACTS device was suggested. They ensure stable power system operation in this way while avoiding expensive investments.

FACTS device design, production, configuration, and implementation research covers several issues and FACTS control designing viewpoints. Design and control context for the research issue is always obvious from the literature. Many researchers design and use FACTS controls worldwide[22]. This is usually acceptable as FACTS devices control and operations have multiple distinct works classified into several categories of FACTS devices design, production, and implementation. They are source converters of voltage, shunt compensators which are static (SVC, STATCOM), regulation of phase angle for static voltage (TCVR, TCPR),line and self commuted converters for current source, compensators for static series (GCSC, TSSC, TCSC), and combined compensators (UPFC, IPFC).

III. FACTS CONTROLLER- An Overview

FACTS controllers are used to dynamically adjust phase angle, voltage and resistance of high voltage alternating current across the lines of transmission. The FACTS devices are divided into several categories based on the network connection type such as serial ,derivative , serial-to-serial and serial-to-derivative controllers .

FACTS devices are classified into two generations based on technological features. The devices belonging to the first generation utilizes thyristors with gate-controlled ignition .Second generation makes use of gate-controlled (GTOs, MCTS, IGBTS, IGCTS, etc.).

The production and exchange of reactive and active power is where first- and second-generation electronics diverge the most. The thyristor-controlled transformers used in the first FACTS devices were used to simulate the impedance or tap of a passive element. Synchronous voltage that can be swiftly measured and controlled using converters, electronic, or automatically switched voltage sources.

A.1G FACTS

i.Static Var Compensator (Svc)

In power transmission networks with high-voltage, static VAR compensator(SVC), provides instantaneous reactive power. SVCs are a form of devices within the flexible AC control system family of devices.They are responsible for regulating voltage and maintaining the stability of the system. The SVC is employed in transmission applications to control grid voltage. The word "static" refers to an SVC that does not have any moving parts, with the exception of the circuit breakers, which are inactive while the SVC is operating normally.

Massive spinning devices such as synchronous capacitors were the only devices that could remedy power factor issues until the invention of the synchronous variable capacitor (SVC). If the reactive load on the electrical system is capacitive, signaling that it is leading, the SVC will employ reactors, which are normally thyristor-controlled reactors, to consume VARs from the electrical system. This will result in a reduction in the voltage across the system.

When conditions are inductive, also referred to as lagging, the capacitor banks gets activated, resulting in a system voltage that increases spontaneously . They can also be placed close to rapidly varying high loads, like arc furnaces, to smooth out the voltage flickering induced by the high loads. It has been noted that the SVC factors can have a big effect on a system's nonlinear behavior, especially when the system is under a lot of load and the SVC gains go up. Figure 1 shows how the SVC is set up. It is made up of a capacitor (C) and a choke (L), which controls the angle of discharge of the thyristor and, in turn, sets the power system's shunt admittance.

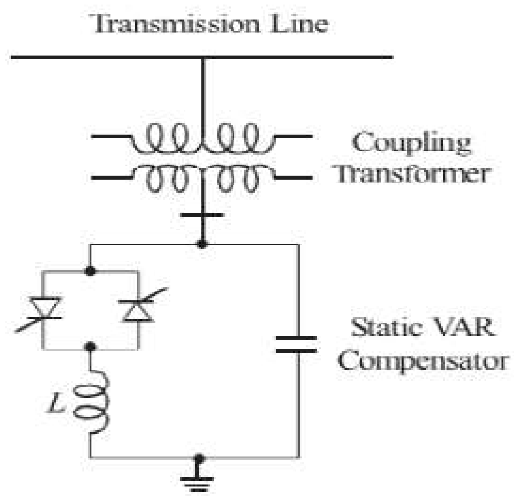


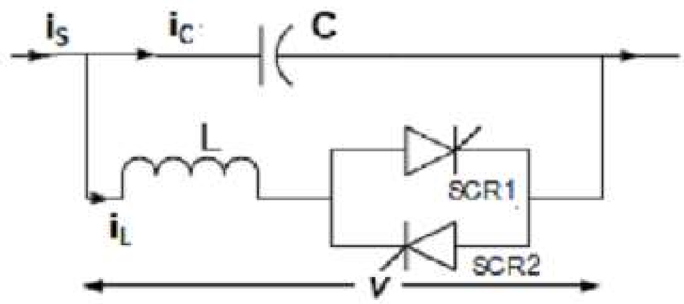
Fig.1 Connection Setup of SVC

ii. Thyristor-Controlled Phase Shifter (TCPS)

A TCPS methodology works by calculating the angle of phase shift using a non-linear function that depends on both rotor angle and speed. In contrast, a single generator's rotor angle is evaluated against the system reference may not have much significance in a network representation with a significant number of the real world generators.

iii.Thyristor -Controlled Series Capacitor (TCSC)

Parallel connections between segments of TCR and capacitors are used in TCSC controllers. The TCR and capacitor setup allows for continuous reactance adjustment over a wide range, with the ability to instantly transition to a state where the SCR pairs present continually and inject an inductive reactance into the line. By adding a TCC in series, the TCSC, which is the initial version of FACTS, may alter the transmission line's impedance. This allows the line impedance to be modified. A TCSC is made up of a series-regulated capacitive reactance. This reactance offers the capacity to continuously regulate ac line power throughout a wide range. One of the most crucial FACTS components is the TCSC, which has long been used to improve power transmission and system stability. Figure 3 depicts the primary circuit of a TCSC. The TCSC is made up of a bank of capacitors C, an inductive element L, and two dual-direction thyristors (SCR1 and SCR2). Changing the discharge angles of thyristors in line with a system monitoring algorithm to vary the TCSC reactance, often in response to changes in system parameters. Based on a change in the angle of firing of the thyristor or the degree of conduction, this process is shown as a fast transition between equivalent reactances delivered



to the power supply.

Fig.3 Connection Setup of TCSC

B.2G FACTS

i.Static -Synchronous Compensator (STATCOM)

It is now conceivable to suggest such a technology as a workable substitute for conventional SVC due to the development of FACTS devices, particularly STATCOMs based on GTO thyristors [21]. A STATCOM is a gadget that controls how AC power flows across transmission lines. It can provide active AC power.In most circumstances, a STATCOM is built to help power distribution networks having poor power factor as well as voltage regulation. Nevertheless, there are other purposes, the provision of voltage stability being the primary one. Because it can temporarily swap current power with the system, the STATCOM has greater dampening capabilities than the system does. In Figure 2, the STATCOM setup is shown.

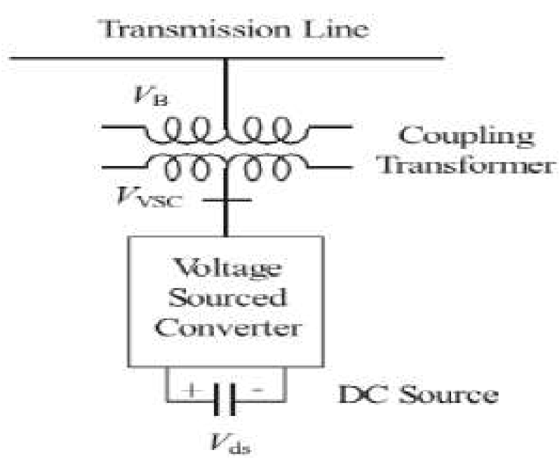


Fig.2 Connection setup of STATCOM

ii.Static- Synchronous Series Compensator (SSSC)

This piece of equipment has the same weight as the STATCOM in terms of its significance. It links a voltage converter that is connected in series to the transmission line by using a transformer as the connecting component. To compensate for the voltage source converter (VSC) losses, a continuous supply of voltage must be provided from a power source through a capacitor. An SSSC may be distinguished by a number of features, one of which is its capacity to interchange active power and reactive power with the transmission system. If, on the other hand, our only objective is to strike a balance between active and reactive electrical power, therefore the origin of energy may be kept quite simple. If we have an energy source that is powerful enough to fulfil our needs, we will be able to manage the injected voltage's phase and amplitudeBecause the grid intensity and the voltage vector both form a right angle, the power factor adjustment can only be used to alter the voltage. This is because intensity and voltage both form a right angle.In this situation, the behavior of the voltage that is being injected serially will determine whether the line current will be advanced or delayed.

iii.Unified-Power Flow Controller (UPFC)

The Unified-Power Flow Controller (UPFC), that may be utilized to increase long-term stability, and power flow, is the FACTS device with the greatest degree of versatility that is currently available. The FACTS concept centers on a piece of hardware known as the Unified Power Flow Controller (UPFC), which has the greatest potential for success. It has the ability to modify the bus voltage, line's reactance, and phase angle between buses. It can specifically modify the bus voltage. Controlling and optimizing power flow within power distribution systems, the UPFC is probably the most complex and versatile device ever designed. It provides substantial potential advantages for lines of transmission operations. UPFC was designed to establish supervision and dynamic compensation for AC transmission systems.

It provides the multifunctional adaptability required to address a number of present difficulties in the field of energy. In accordance with conventional notions of power transfer, the UPFC can either simultaneously or specifically control all parameters influencing the distribution of electricity within an electrical line. Alternately, it can independently govern both the reactive and active electrical power in the line, that no other device can do with short-term stability. It can specifically modify the bus voltage. Controlling and optimizing power flow within power distribution systems, the UPFC is probably the most complex and versatile device ever designed. It provides substantial potential advantages for lines of transmission operations. UPFC was designed to establish supervision and dynamic compensation for AC transmission systems. It provides the multifunctional adaptability required to address a number of present difficulties in the field of energy. In accordance with conventional notions of power transfer, the UPFC can either simultaneously or specifically control all parameters influencing the distribution of electricity within an electrical line. Alternately, it can independently govern both the reactive and active electrical power in the line, that no other device can do with short-term stability.

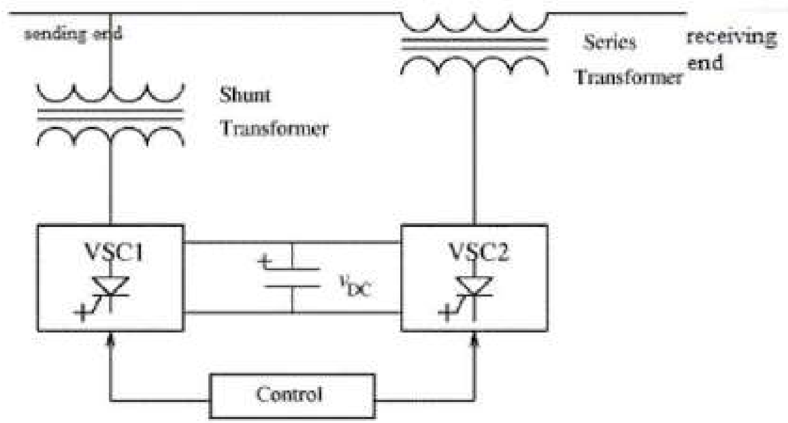


Fig.3 Connection setup of UPFC to a transmission line

C.APPLICATIONS AND TECHNICAL BENEFITS OF FACTS

When it comes to responding to dynamic, rapidly changing grid conditions, FACTS devices are required. The conventional solutions often have lower costs than the FACTS devices, but the dynamic capabilities of these solutions are restricted. The planners' job is to figure out which solution will be the most cost-effective overall. When network conditions need to be dynamic (constantly changing), FACTS devices are required. Generally speaking, conventional solutions are a bit cheaper than FACTS gadgets but their dynamic behavior is limited. Supervisors are responsible for determining the most cost-effective option.

IV.SYSTEM MODEL OF THE POWER SYSTEM

Similar to Figs. 4 and 5, a single transmission line connects FACTS devices in shunt and series to the power supply in both the first and second domains. Bus-2 has a FACTS device like an SVC shunt placed on it, while buses 2-3 have a UPFC, SSSC, and TCSC set up in sequence. In this case, energy is being transferred from Area-1 to Area-2. In this energy system's structure, areas 1 and 2 house generators 1 and 2, whereas areas 3 and 4 house generators 3 and 4. Details on the system may be found in [21].

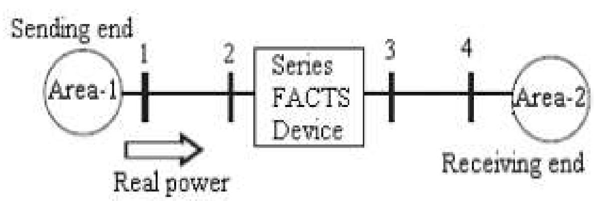


Fig. 4 Power system employing series FACTS device

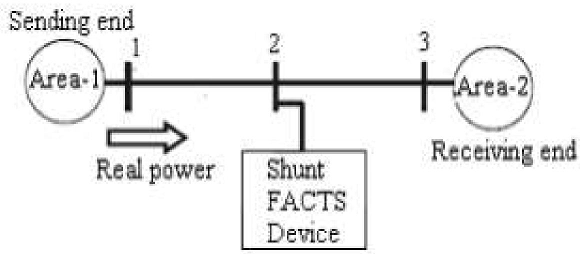


Fig. 5 Power system employing shunt FACTS device

A.POWER SYSTEM EMPLOYING UPFC

In this study, the two-surface method shown in Fig. 4 is considered. There is a UPFC between the buses in the system. It is assumed that a 300 millisecond 3-phase symmetrical short circuit fault occurs on Bus-3. Matlab/Simulink is used to model the system and Figs. 6 and 7 show the associated graphics. We can observe from Fig. 6 that in the absence of UPFC, there is a rise in the frequency of oscillations in the angle of the rotor for Area1 (Generator 1 and 2) and Area-2 (Generator 3 and 4), and it takes a considerable amount of time for the oscillations to end.

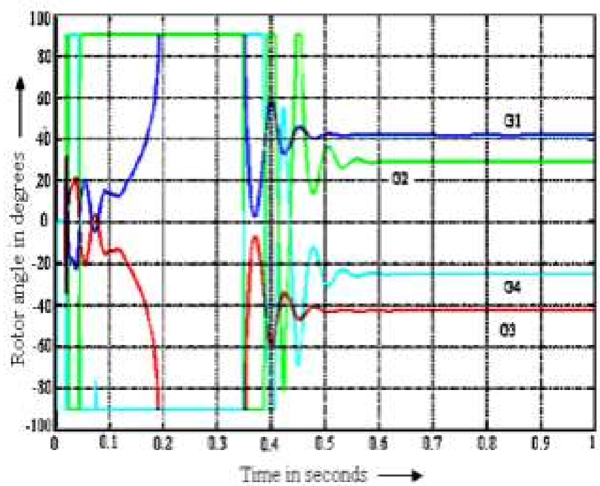


Fig. 6 UPFC based Variation in rotor angle of generator

On the other hand, Fig. 8 demonstrates that when a UPFC is used, the tremors in the angle of the rotor of both areas diminish, and the vibrations become more stable in a significantly shorter amount of time. As a result, the dual-zone electrical system is more stable as a result of UPFC's involvement in the process.

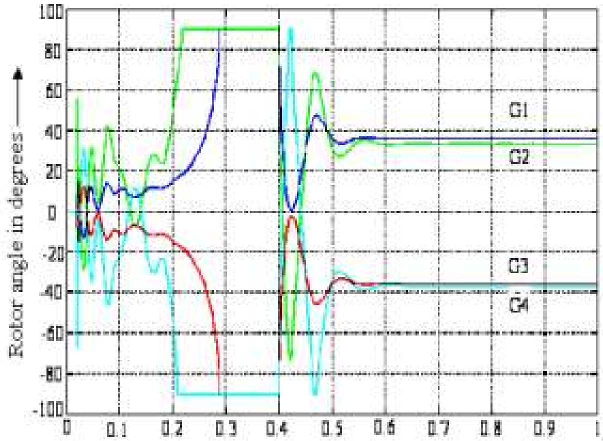


Fig. 7 UPFC based Variation in rotor angle of generator

B.POWER SYSTEM EMPLOYING SVC

This investigation takes into account the 2-area system that is depicted in Fig. 6A SVC is now integrated into the system and is now located at the bus-2 node. Located closer to bus-2 is a three-phase symmetrical short-circuit flaw that has an average duration of three hundred milliseconds. The simulations are carried out in Matlab setup. Figure 8 displays, the results of the simulation about the modification of the bus-2 voltage. It is evident from Fig.8 that the implementation of SVC results in an improvement in the stability of voltage in the system.

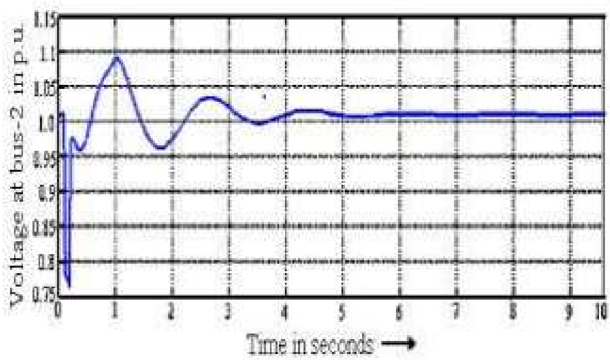


Fig. 8 SVC based Variation in line power

C.TCSC Employed Power System

This investigation takes into account the 2-area system that is depicted in Fig. 5. There is a TCSC installed between buses has been put in this system. At the bus-3 location, there is a defect that lasts for 300 milliseconds and is 3-phase symmetrical short-circuit fault. Simulations are carried out in the Matlab/Simulink environment. Fig. 10 displays, the fluctuation in line power that is conveyed. Figure 9 makes it abundantly evident that the use of TCSC results in an improvement to the power system's stability.

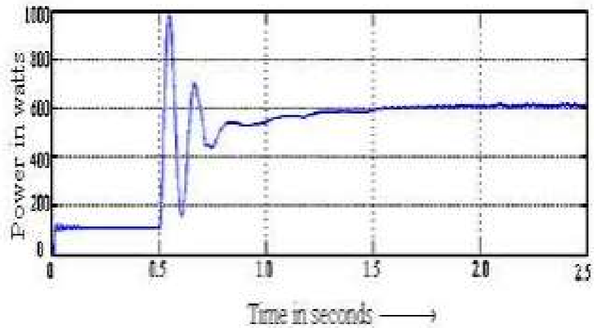


Fig. 9 TCSC based Variation in line power

D.SSSC employed Power System

This investigation takes into account the 2-area system that is depicted in Fig. 5. There is a SSSC installed between buses has been put in this system. At the bus-3 location, there is a defect that lasts for 300 milliseconds and is 3-phase symmetrical short-circuit fault. Simulations are carried out in the Matlab/Simulink environment, and Fig. 10 displays the fluctuation in line power that is conveyed. It can be deduced from Figure 10 that the use of SSSC results in an increase in the overall system stability. The beginning of the time scale is set to six seconds so that the settling time for the line power can be displayed.

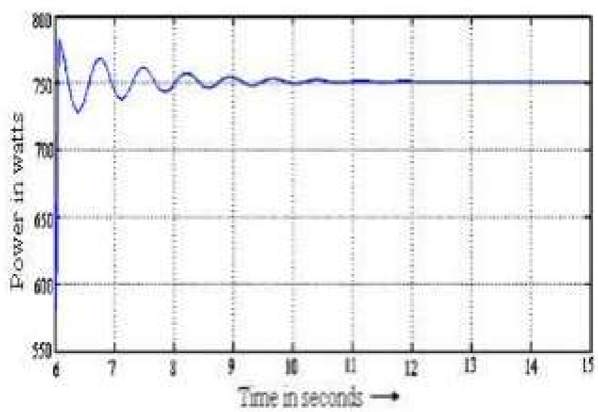


Fig. 10 SSSC based Variation in line power

In order to improve the reliability of the energy systems that are the focus of this inquiry, a comparative analysis of the different FACTS devices that were described earlier is carried out on the basis of the simulation findings that are shown in Figures 6 through 10, as stated in Table 1. This analysis is undertaken with the intention of enhancing the efficiency of the power systems. It has been established that the UPFC is probably the most efficient among all of the FACTS devices for increasing the long-term reliability of inter-area power networks in light of the results.

Comparative Analysis of Various FACTS Devices for Enhancement of PSS

FACTS Devices Employed	Enhancement of PSS	Settling time (in seconds)
UPFC	Possible	0.7
SVC	Possible	8

TCSC	Possible	1.6
SSSC	Possible	12

CONCLUSION

The essential qualities possessed by FACTS controllers, notably their ability to increase the system's level of stability, are of the utmost importance for the economical and efficient operation of the power system. The discussion focused on the position of the damping controllers as well as the feedback signals that were employed in their design. Additionally, the difficulty of synchronising the various control techniques was taken into account.

The effectiveness of the different FACTS controllers have all been compared. The most likely path that technology will go in the future in terms of FACTS was examined. A overview of utility experiences, significant installations in real-world, and the advancement of technology employing semiconductor has also been provided. Applications of FACTS to the deregulated electricity market and optimal power flow have also been offered, along with a brief review of such applications.

REFERENCES

1. 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.
2. N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York: IEEE Press, 2000.
3. 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.
4. N. G. Hingorani, “Flexible AC Transmission”, IEEE Spectrum, April 1993, pp. 40–45.
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. M. A. Abdel-Moamen and N. P. Padhy, “Optimal Power Flow Incorporating FACTS Devices Bibliography and Survey”, IEEE PES Transmission and Distribution Conference and Exposition, 7–12 September 2003, vol. 2,pp. 669 – 676.
8. E. Acha, C. R. Fuerte-Esquivel, and H. Ambriz-Perez, “Advanced SVC model for Newton-Raphson Load Flow and Newton Optimal Power Flow Studies”, IEEE Trans. PWRS, 15(1)(2000), pp. 129–136.
9. E. Acha, C. R. Fuerte-Esquivel, and H. Ambriz-Perez et al., FACTS: Modeling and Simulation in Power Networks, London, U.K.: Wiley, 2004.
10. D. J. Gotham and G. T. Heydt, “Power Flow Control and Power Flow Studies for Systems with FACTS Devices”, IEEE Trans. PWRS, 13(1)(1998), pp. 60–65.

11. L. Gyugyi, K. K. Sen, and C. D. Schauder, “The Interline Power Flow Controller Concept: a New Approach to Power Flow Management in Transmission Systems”, IEEE Trans. PWRD, 14(3)(1999), pp. 1115–1123.
12. T. S. Chung, D. Qifeng, Z. Bomina, “Optimal Active OPF with FACTS Devices by Innovative Load-Equivalent Approach”, IEEE Power Engineering Review, 20(5)(2000), pp. 63–66.
13. Ying Xiao, Y. H. Song, and Y. Z. Sun, “Power Flow Control Approach to Power Systems With Embedded FACTS Devices”, IEEE Trans. on PWRS, 17(4)(2002), pp. 943–950
14. X. Dai, J. Liu, Y. Tang, N. Li, and H. Chen, “Neural Network αth-Order Inverse Control of Thyristor Controlled Series Compensator”, Electric Power Systems Research, 45(1998), pp. 19–27.
15. T. Senjyu, S. Yamane, Y. Morishima, K. Uezato, and H. Fujita, “Improvement of Multimachine Power System Stability with Variable Series Capacitor Using On-Line Learning Neural Network”, Int. J. Electrical Power & Energy Systems, 25(3)(2003), pp. 403–409.
16. R. Mihalic, P. Zunko and D. Povh, 1996, “Improvement of Transient Stability using Unified Power Flow Controller,” IEEE Transactions on Power Delivery, 11(1), pp. 485-491.
17. Igor Papic, Peter Zunko, 2002, “Mathematical Model and Steady State Operational Characteristics of a Unified Power Flow Controller,”Electro-technical Review, Slovenija, 69(5), pp. 285-290.
18. Prechanon Kumkratug, 2009, “Application of UPFC to Increase Transient Stability of Inter-Area Power System,” Journal of Computers, 4(4), pp. 283-287.
19. Prechanon Kumkratug, Panthep Laohachai, 2007, “Direct Method of Transient Stability Assessment of a Power System with a SSSC,”Journal of Computers, 2(8), pp. 7782.
20. S.V. Ravi Kumar, S. Siva Nagaraju, 2007, “Transient Stability Improvement using UPFC and SVC,” ARPN Journal of Engineering and Applied Sciences, 2(3), pp. 3845.
21. S. Panda, Ramnarayan N. Patel, 2006, “Improving Power System Transient Stability with an off-centre Location of Shunt FACTS Devices,” Journal of Electrical Engineering, 57(6), pp. 365-368.
22. N.G. Hingorani, L. Gyugyi, 1999, “Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems,”IEEE Press, New York.
23. N. Mithulananthan, C.A. Canizares, J. Reeve, Graham J. Rogers, 2003, “Comparison of PSS, SVC and STATCOM Controllers for Damping Power System Oscillations,” IEEE Transactions on Power Systems, 18(2), pp. 786-792.
24. E.Z. Zhou, 1993, “Application of Static Var Compensators to Increase Power System damping,” IEEE Transactions on Power Systems, 8(2), pp. 655-661.
25. P. Mattavelli, G.C. Verghese, A.M. Stankovic, 1997, “Phasor Dynamics of Thyristor-Controlled Series Capacitor Systems,” IEEE Transactions on Power Systems, 12(3), pp. 1259-1267.