International Research Journal of Education and TechnologyPeer
Reviewed Journal

ISSN 2581-7795

Transient stability Improvement using FACTS devices

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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. As a consequence, some transmission lines are heavily loaded and the system stability becomes a power transfer-limiting factor. Flexible AC transmission systems (FACTS) controllers have been mainly used for solving various power system steady state control problems. However, recent studies reveal that FACTS controllers could be employed to enhance power system stability in addition to their main function of power flow control. this paper presents a fundamental analysis of the application of first generation FACT device i.e., Static VAR compensators (SVCs) and power system stabilizers (PSSs) for stabilizing power systems. SVC is basically a shunt connected static var generator whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific power variable; typically, the control variable is the SVC bus voltage.*

Key Words: Power System, Stability, FACTS Device, Matlab Simulation,

1.INTRODUCTION

Electrical energy has attracted significant attention with the growing population and technological advancements in societies. Therefore, the use of electrical energy is a good indicator of the level of development in any given nation. Since the mid-20th century, small-signal stability problems have been reported in power systems. These problems are usually caused by inefficient damping of electromechanical oscillations over a long period. Different oscillations arise in synchronous generator rotors in power systems due to low-amplitude and low-frequency electromechanical oscillations. Insufficient damping of these oscillations can lead to failing system synchronism or separating one part of the power system from other parts. Nowadays, most synchronous generators contain Automatic Voltage Regulators (AVRs) instead of constant excitation. The fundamental purpose of AVR is to control the terminal voltage and support it to reach the reference values and keep a dependable operation during steady-state situations. The amount of power transferred, and the power angle or the synchronous generator's voltage deviates from the references in cases like electrical faults, disconnection of a large load, opening a transmission line, or sudden load activation. When the power system faces this type of disturbance, the AVR operation can increase the frequency and amplitude of the power system oscillations. There are various strategies to remove low-frequency electromechanical oscillations and the negative behavior of AVR, such as dynamic braking, high-speed fault clearing, controlling transmission lines reactance, and Power System Stabilizers [PSS]. Nevertheless, their application requires it to be attentively considered. PSSs are usually employed for damping synchronous generator disturbances by developing supplementary control signals for the excitation system of synchronous generators.

In the literature, many different PSSs, or conventional PSSs, have been suggested. Traditionally, fixed PSSs were utilized because of their simplicity of design and deployment. However, the power system is subjected to a broad range of operating situations and reveals an expansive variety of characteristics, necessitating a more complex design to achieve desirable outcomes. Classical controllers, adaptive regulators, intelligent power system stabilizers, robust controllers, and some limited studies into nonlinear controllers are all examples of PSSs that have been presented. Most of these controllers rely on linear approximations of the nonlinear system, making them linear based. The power system is a complicated nonlinear system, and power system stabilizers, designed based on the linearization of the nonlinear system, cannot ensure the system's stability.

This linearization is established on the critical assumption that the system operation area is so close to the operation points that the linear approximation error remains with a nonlinear model in an acceptable range. However, if the system is subject to a major disturbance, the performance of these stabilizers is under discussion. Consequently, it is necessary to modify nonlinear controllers that are resilient and robust to substantial deviations in light of the various operation conditions. Recently, the concept of synergetic control has been effectively used in the development of control schemes for synchronous generators and power electronics components. This is due to the synergetic control approach having the benefits of order reduction and is like the sliding mode technique but without the detriment of chattering.

The synergetic algorithm creates a new dynamical system by mapping the original set of differential equations in such a way that there exists a unique attractive point in the state space, which is located near the actual system's solution, and the rate at which the system dynamics approaches this point can be modulated. By developing optimal controllers for dynamical systems, presents a variety of approaches, all of which aim to coordinate the controllers with the expectation. Using the controllers, it has designed, the synergetic control strategy looks for a region of attraction for the new dynamical system. The synergetic theory is based on the idea of generating a region of attraction, or many attractors. In addition, the nonlinear differential equations' roots serve as the initial conditions for the creation of the attractors. In other words, this expedites the convergence of the suggested methods. To investigate the damping performance of a multi-machine system, proposes a decentralized synergetic regulator that uses reinforcement learning to adjust the parameters of the controller continuously. Using a type-2 fuzzy logic structure, create an adaptive synergetic PSS to approximatively model the system's unknown characteristics. Due to the application of PSS to damp power oscillation and improve transient stability, the PSS cannot furnish enough damping for system oscillation; so, in this condition, coordination between flexible AC transmission system (FACTS) devices and PSS is performed for optimal performance with lowest oscillations. FACTS devices can improve power systems' performance flexibility, controllability, and stability. The thyristor-controlled series capacitor (TCSC), as one type of FACTS device, can improve the unrestricted transfer capability of AC power transmission lines by adequately adjusting the impedance of the power transmission line. TCSCs are installed on long transmission lines of power systems. Utilizing TCSC comprises decreasing asymmetrical parts, managing power current, providing voltage regulation, reducing network outage, damping power oscillations, limiting current short-circuit errors, and enhancing transient stability. When two or more stability improvement strategies are employed in the power system, power system stability improvement may be restricted for each method. Therefore, in this paper, it is assumed that there is a TCSC with a practical and well-tuned controller. The proposed PSS should be capable of improving electromechanical oscillations in the presence of this FACTS device. However, the lack of a comprehensive parameter in the control procedure limits the use of all nonlinear-based control techniques in practical applications. Therefore, these types of controllers require significant offline fine-tuning and simulation.

2. POWER SYSTEM STABILITY

At present the demand for electricity is rising phenomenally especially in developing country like India. This persistent demand is leading to operation of the power system at its limit. The need for reliable, stable, high quality power comes from its sensitivity to electrical energy Industry in information technology, communications, electronics and more. In this scenario, the meeting is Electricity requirements are not the only standard, but they are also the duty of the authorities. A system engineer to ensure stable and high power for consumers. These issues are highlighted The need to understand the stability of energy systems. I'll try this course How to assess the stability of an energy system, how to improve stability, and finally How to prevent unstable systems. Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most of the system variables bounded so that practically the entire system remains intact". The disturbances mentioned in the definition could be faults, load changes, generator outages, line outages, voltage collapse or some combination of these. Power system stability can be broadly classified into rotor angle, voltage and frequency stability. Each of these three stabilities can be further classified into large disturbance or small disturbance, short term or long term.

Power system stability involves the study of the dynamics of the power system under disturbances. Power system stability implies that its ability to return to normal or stable operation after having been subjected to some form of disturbances. From the classical point of view power system instability can be seen as loss of synchronism (i.e., some synchronous machines going out of step) when the system is subjected to a particular disturbance. Three type of stability are of concern: Steady state, transient and dynamic stability

Steady-state Stability:- Steady-state stability relates to the response of synchronous machine to a gradually increasing load. It is basically concerned with the determination of the upper limit of machine loading without losing synchronism, provided the loading is increased gradually.

Dynamic Stability:- Dynamic stability involves the response to small disturbances that occur on the system, producing oscillations. The system is said to be dynamically stable if theses oscillations do not acquire more than certain amplitude and die out quickly. If these oscillations continuously grow in amplitude, the system is dynamically unstable. The source of this type of instability is usually an interconnection between control systems.

Transient Stability:- Transient stability involves the response to large disturbances, which may cause rather large changes in rotor speeds, power angles and power transfers. Transient stability is a fast phenomenon usually evident within a few second.

Power system stability mainly concerned with rotor stability analysis. For this various assumptions needed such as:

- For stability analysis balanced three phase system and balanced disturbances are considered.
- Deviations of machine frequencies from synchronous frequency are small.
- During short circuit in generator, dc offset and high frequency current are present. But for analysis of stability, theses are neglected.
- Network and impedance loads are at steady state. Hence voltages, currents • and powers can be computed from power flow equation.

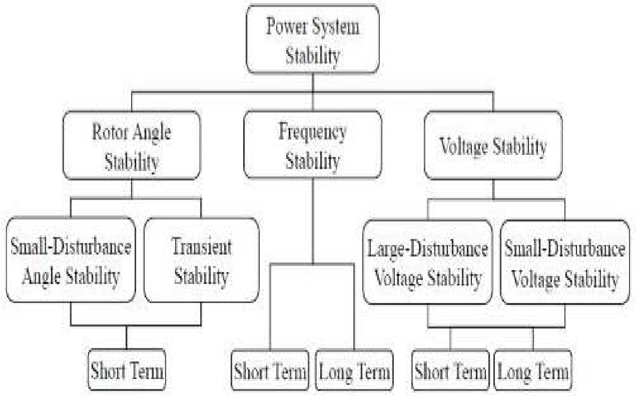

Figure:- 1: Classification of Power System Stability

Rotor angle stability

It is the ability of the system to remain in synchronism when subjected to a disturbance". The rotor angle of a generator depends on the balance between the electromagnetic torque due to the generator electrical power output and mechanical torque due to the input mechanical power through a prime mover. Remaining in synchronism means that all the generators electromagnetic torque is exactly equal to the mechanical torque in the opposite direction. If in a generator the balance between electromagnetic and mechanical torque is disturbed, due to disturbances in the system, then this will lead to oscillations in the rotor angle. Rotor angle stability is further classified into small disturbance angle stability and large disturbance angle stability.

Small-disturbance or small-signal angle stability

It is the ability of the system to remain in synchronism when subjected to small disturbances". If a disturbance is small enough so that the nonlinear power system can be approximated by a linear system, then the study of rotor angle stability of that particular system is called as small-disturbance angle stability analysis. Small disturbances can be small load changes like switching on or off of small loads, line tripping, small generators tripping etc. Due to small disturbances there can be two types of instability: non-oscillatory instability and oscillatory instability. In non-oscillatory instability the rotor angle of a generator keeps on increasing due to a small disturbance and in case of oscillatory instability the rotor angle oscillates with increasing magnitude.

Large-disturbance or transient angle stability

It is the ability of the system to remain in synchronism when subjected to large disturbances". Large disturbances can be faults, switching on or off of large loads, large generators tripping etc. When a power system is subjected to large disturbance, it will lead to large excursions of generator rotor angles. Since there are large rotor angle changes the power system cannot be approximated by a linear representation like in the case of small-disturbance stability. The time domain of interest in case of large-disturbance as well as small-disturbance angle stability is anywhere between 0.1- 10 s. Due to this reason small and large-disturbance angle stability are considered to be short term phenomenon. It has to be noted here that though in some literature "dynamic stability" is used in place of transient stability, according to IEEE task force committee report [2], only transient stability has to be used.

3. FACTS DEVICES

There are numerous classes of FACTS controllers, including shunt, series, combined series-series and combined series-shunt types. FACTS devices include a group of multiple controllers used to regulate system parameters like damping oscillation at different frequency, phase angle, voltage, current and impedance. In this paper, SVC is discussed. It is a shunt type, used to connect as a controller which enhances the transient stability and damping the power oscillation with more reliable operation.
Example of FACTS Controllers for Enhancing 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

3.1. Benefits of utilizing FACTS devices

- ➢ The benefits of utilizing FACTS devices in electrical transmission systems can be summarized as follows
- ➢ Better utilization of existing transmission system assets
- ➢ Increased transmission system reliability and availability
- ➢ Increased dynamic and transient grid stability and reduction of loop flows
- ➢ Increased quality of supply for sensitive industries
- ➢ Environmental benefits Better utilization of existing transmission system assets

A static VAR compensator (or SVC) is an electrical device for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family, regulating voltage and stabilising the system. The term "static" refers to the fact that the SVC has no moving parts (other than circuit breakers and disconnects, which do not move under normal SVC operation). Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers. The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. If the power system's reactive load is capacitive (leading), the SVC will use reactors (usually in the form of Thyristor-Controlled Reactors) to consume VARs from the system, lowering the system voltage. Under inductive (lagging) conditions, the capacitor banks are automatically switched in, thus providing a higher system voltage. They also may be placed near high and rapidly varying loads, such as arc furnaces, where they can smooth flicker voltage. It is known that the SVCs with an auxiliary injection of a suitable signal can considerably improve the dynamic stability performance of a power system . It is observed that SVC controls can significantly influence nonlinear system behavior especially under high-stress operating conditions and increased SVC gains.

Improved transient stability can be achieved by using one of the following methods:

3.2. Inertia Constant of Generator-

Machine inertia is defined as the kinetic energy stored in the machine's moving parts at synchronous speed per unit MVA machine rating. It indicates the rate of change in the rotor angle and signifies the rate of deceleration or acceleration. It's worth noting that the higher the inertia, the slower the rate of angle change will be. As a result, the kinetic energy gained during the fault is reduced, and the accelerating area is reduced.

3.3. Shunt Capacitor-

Connect capacitors are used to supply a set amount of reactive power to many buses. Because the main source of disturbances is a lack of reactive power, adding reactive power into the system will improve system stability while also increasing the load carrying capacity of the transmission line.

3. CONCLUSIONS

This article describes techniques for improving stability and describes stabilizers for SVC and PSS power systems. SVC improves system stability by controlling the amount of reactive power injected or absorbed by the power system. Meanwhile, PSS has long discovered the use of synchronous machines in strikes as an effective means to mitigate the characteristic electromechanical vibrations of generator blocks by regulating the excitation of the generator. Therefore, PSS and facts quickly become a need to increase the stability of the energy system and not take into consideration.

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