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A Study on Transient Stability Improvement of 5-machine 14-bus system using SVC

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Abstract— Power System is subjected to sudden changes in load levels. Stability is an important concept which determines the stable operation of power system. In general rotor angle stability is taken as index, but the concept of transient stability, which is the function of operating condition and disturbances, deals with the ability of the system to remain intact after being subjected to abnormal deviations. A system is said to be synchronously stable (i.e., retain synchronism) for a given fault if the system variables settle down to some steady-state values with time, after the fault is removed.

For the improvement of transient stability, the general methods adopted are fast acting exciters, circuit breakers and reduction in system transfer reactance. The modern trend is to employ FACTS devices in the existing system for effective utilization of existing transmission resources. Flexible AC Transmission System technology by virtue of its flexible and rapid technique of control over the AC transmission parameters and network topology is capable of: (i) facilitating the power control, (ii) raising the power transfer capacity, (iii) decreasing the line losses and generation costs, (iv) enhancing the stability and security of the power system. These FACTS devices contribute to power flow improvement besides they extend their services in transient stability improvement as well. The FACTS controllers are broadly classified as: (i) variable impedance type controllers and (ii) voltage source converter based controllers. The variable impedance type controllers include SVC, TCSC etc. and voltage source converter based controllers include STATCOM, SSSC etc.

In the present work, the studies had been carried out in order to improve the Transient Stability of 14 Bus 5 machine System with SVC for better results. In this thesis, in order to improve the transient stability margin further FACTS device has been implemented.

***Keywords**-component; Power System Stability, FACTS, SVC, SSSC, STATCOM..*

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I. INTRODUCTION

Power system stability has been recognized as an important problem for secure system operation since the 1920s. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, voltage stability, frequency stability and inter area oscillations have become greater concerns than in the past. The power system is a highly nonlinear system that operates in a constantly changing environment; loads, generator outputs and key operating parameters change continually. When subjected to a disturbance, the stability of the system depends on the initial operating condition as well as the nature of the disturbance. Stability of an electric power system is thus a property of the system motion around an equilibrium set, i.e., the initial operating condition.

II. CLASSIFIACATION OF POWER SYSTEM STABILITY

A typical modern power system is a high-order multivariable process whose dynamic response is influenced by a wide array of devices with different characteristics and response rates. Stability is a condition of equilibrium between opposing forces. Depending on the network topology, system operating condition and the form of disturbance, different sets of opposing forces may experience sustained imbalance leading to different forms of instability.

III. CATEGORIES OF STABILITY

The classification of power system stability proposed here is based on the following considerations:

- The physical nature of the resulting mode of instability as indicated by the main system variable in which instability can be observed.
- The size of the disturbance considered which influences the method of calculation and prediction of stability.
- The devices, processes, and the time span that must be taken into consideration in order to assess stability.

IV. CLASSIFICATION BASED ON DISTURBENCE

The power system is a highly nonlinear system that operates in a constantly changing environment; loads, generator outputs and key operating parameters change continually. When subjected to a disturbance, the stability of the system depends on the initial operating condition as well as the nature of the disturbance. Stability of an electric power system is thus a property of the system motion around an equilibrium set, i.e., the initial operating condition.

- **Steady state**
- **Dynamic state**
- **Transient state**

- **STEADY STATE**

In an interconnected power system, the rotors of each synchronous machine in the system rotate at the same average electrical speed. The power delivered by the generator to the power system is equal to the mechanical power applied by the prime mover, neglecting losses. During steady state operation, the electrical power out balances the mechanical power in. The mechanical power input to the shaft from the prime mover is the product of torque and speed, $P_M = \omega T_M$. The mechanical torque is in the direction of rotation.

- **DYNAMIC STATE**

Generators are connected to each other by a network that behaves much like weights interconnected by rubber bands as shown in Figure. The weights represent the rotating inertia of the turbine generators and the rubber bands are analogous to the inductance of the transmission lines. By pulling on a weight and letting go, an oscillation is setup with several of the weights that are interconnected by the rubber bands. The result of disturbing just one weight will result in all the weights oscillating. Eventually the system will come to rest, based on its damping characteristics. The frequency of oscillation depends on the mass of the weights and the springiness of the rubber bands. Likewise, a transient disturbance to the generator/network can be expected to cause some oscillations due to the inability of the mechanical torque to instantaneously balance out the transient variation in electrical torque.

Dynamic instability is more probable than steady state stability. Small disturbances are continually occurring in a power system (variations in loadings, changes in turbine speeds, etc.) which are small enough not to cause the system to lose synchronism but do excite the system into the state of natural oscillations. In a dynamically unstable system, the oscillation amplitude is large and these persist for a long time (i.e., the system is under damped). This kind of instability behavior constitutes a serious threat to system security and creates very difficult operating conditions.

- **TRANSIENT STATE**

For a large disturbance, changes in angular differences may be so large as to cause the machines to fall out of step. This type of instability is known as transient stability and is a fast phenomenon usually occurring within 1sec for a generator close to the cause of disturbance.

Power systems are subjected to a wide range of disturbances, small and large. Small disturbances in the form of load changes occur continually; the system must be able to adjust to the changing conditions and operate satisfactorily. It must also be able to survive numerous disturbances of a severe nature, such as a short circuit on a transmission line or loss of a large generator. A large disturbance may lead to structural changes due to the isolation of the faulted elements. At an equilibrium set, a power system may be stable for a given (large) physical disturbance, and unstable for another. It is impractical and uneconomical to design power systems to be stable for every possible disturbance. The design contingencies are selected on the basis that they have a reasonably high probability of occurrence. Hence, large-disturbance stability always refers to a specified disturbance scenario.

The response of the power system to a disturbance may involve much of the equipment. For instance, a fault on a critical element followed by its isolation by protective relays will cause variations in power flows, network bus voltages, and machine rotor speeds; the voltage variations will actuate both generator and transmission network voltage regulators; the generator speed variations will actuate prime mover governors; and the voltage and frequency variations will affect the system loads to varying degrees depending on their individual characteristics.

V. BASIC TYPES OF FACTS CONTROLLER

Generally FACTS controllers are classified as:

- Series Controllers
- Shunt Controllers
- Combined Series-Series Controllers
- Combined Series -Shunt Controllers

VI. MATLAB/SIKULINK BASED MODEL OF MULTI-MACHINE SYSTEM EQUIPPED WITH SVC

SIMULINK, a simulation tool associated with MATLAB, is very widely used software package for modeling simulating, analyzing dynamic systems .It supports linear as well as non-linear systems. Simulations are interactive in nature which provides an opportunity to the user to change the parameters and verify results. SIMULINK provides an instant access to all the analysis tools in MATLAB, so results can be taken for analysis and visualization.

Sim Power System software is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. The software package uses the SIMULINK environment, allowing building a model by making use of simple click and drag procedures. The circuit topology can be drawn rapidly and the circuit analysis can include interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive SIMULINK modeling library. Since, SIMULINK uses the MATLAB computational engine, designers can also use MATLAB toolboxes and SIMULINK block sets. Sim Power System software belongs to the Physical Modeling product family and it uses similar block and connection line interface. Sim Power Systems libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. The FACTS library is accessible in the SIMULINK Library Browser under the Sim Power System / Application Libraries folder at any point of time.

The Sim Power System Block set in SIMULINK is a tool for modeling and simulating generation, transmission, distribution and consumption of electrical power. It provides models of many components used in these systems including three-phase machines, electric drives and libraries of application specific models such as FACTS and wind power generation. FACTS Block set consists of STATCOM, SSSC and SVC blocks.

FACTS controllers are basically high power thyristor switches and are capable of taking extremely fast control actions. Because of their fast operating capability they can enlarge the safe operating limits of a transmission system without risking its stability. In the present thesis work the investigator has analyzed the effect of FACTS controllers such as SVC, STATCOM and SSSC on IEEE 5 machine 14 bus systems. A three-phase fault has been considered to occur at bus 10 with SVC connected at bus 3 as shown in fig1. The fault is considered to occur at the instant just after 0.5 seconds and the fault clearing time has been assumed to be 0.1 second. The variation of relative angular

positions del 1-2, del 2-3, del 3-4, del 4-5, and del 5-1 .
The effect of SVC in damping out oscillations has been critically studied and analyzed by incorporating an SVC of 100 MVAR at bus 3. The plot of the relative rotor angular positions del 1-2, del 2-3, del 3-4, del 4-5, and del 5-1 with time for the MM system with fault and SVC connected is shown in figure 3.8. The variation of relative angular positions del 1-2, del 2-3, del 3-4, del 4-5, and del 5-1.
It is observed that the time taken to attain stability has reduced to 1.0 second for the relative angular positions del 5-1, when fault occurred at different location with the SVC connected in bus 4 in the system. The highest time taken to attain stability is 37 seconds for del 5-1 without any FACTS device. It is thus inferred from the observations that the system attains stability at a faster rate when reactive power compensation is provided by the SVC.
The investigator has analyzed the performance of the system for the fault occurring at different busses and SVC at different locations. The minimum value has been seen when the SVC is connected at bus 3 for fault at different locations for all relative angular positions. It is analyzed that without incorporating SVC the maximum overshoot values for del 1-2, del 2-3, del 3-4 and del 5-1, when fault occurred at bus 3, are 5.76, 16.24, 38.58, 20.33 and 26.06 degrees respectively as in Table 3.5. When SVC is connected at bus 3 these values are very much reduced as can be seen in Table 3.9. The value of del 5-1 is reduced to 8.26 degrees from 26.06 degrees when SVC is connected at bus 3.

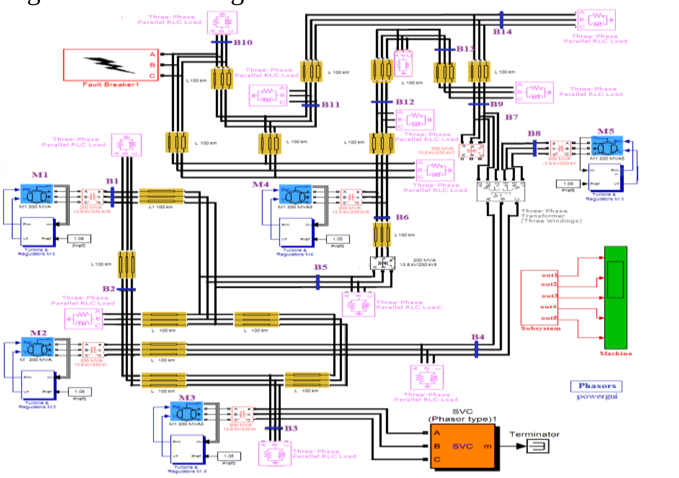

Fig1 SIMULINK Model of Multi-Machine System with Fault and SVC

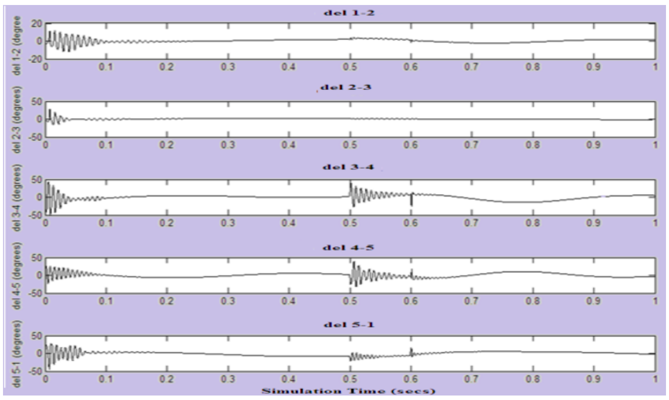

Fig.2 Plot of Relative Rotor Angle with Time of MM System with SVC

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We both support each other very much.I blessed him from my heart. Stability is an important factor affecting the secure operation of power systems. FACTS devices are effective measures to flexibly adjust power flow in transmission systems, improve dynamic and transient performance of power systems, provide voltage support etc. The family of FACTS devices based on voltage source converters consists of a SVC, A test case of power system i.e. 5 machines 14 bus system, equipped with these VSC based FACTS controllers have been simulated. The transient stability and damping of power oscillations have been evaluated with SVC. From the results it has been concluded that: With these controllers the rotor angle characteristic curves exhibit less overshoots.The oscillations are damped out in a lesser time.The response characteristics take less time to reach the final steady value.

SCOPE FOR FUTURE WORK

In spite of the rising applications of FACTS devices, there are some factors that have been limiting the application of this technology, prominent being the cost factor. The investment cost of FACTS and their impact on the power generation costs are not wholly considered yet for study. Since these FACTS controllers are very costly devices, researches in some hybrid technology may be taken up in future and the economics of different FACTS options may be assessed.

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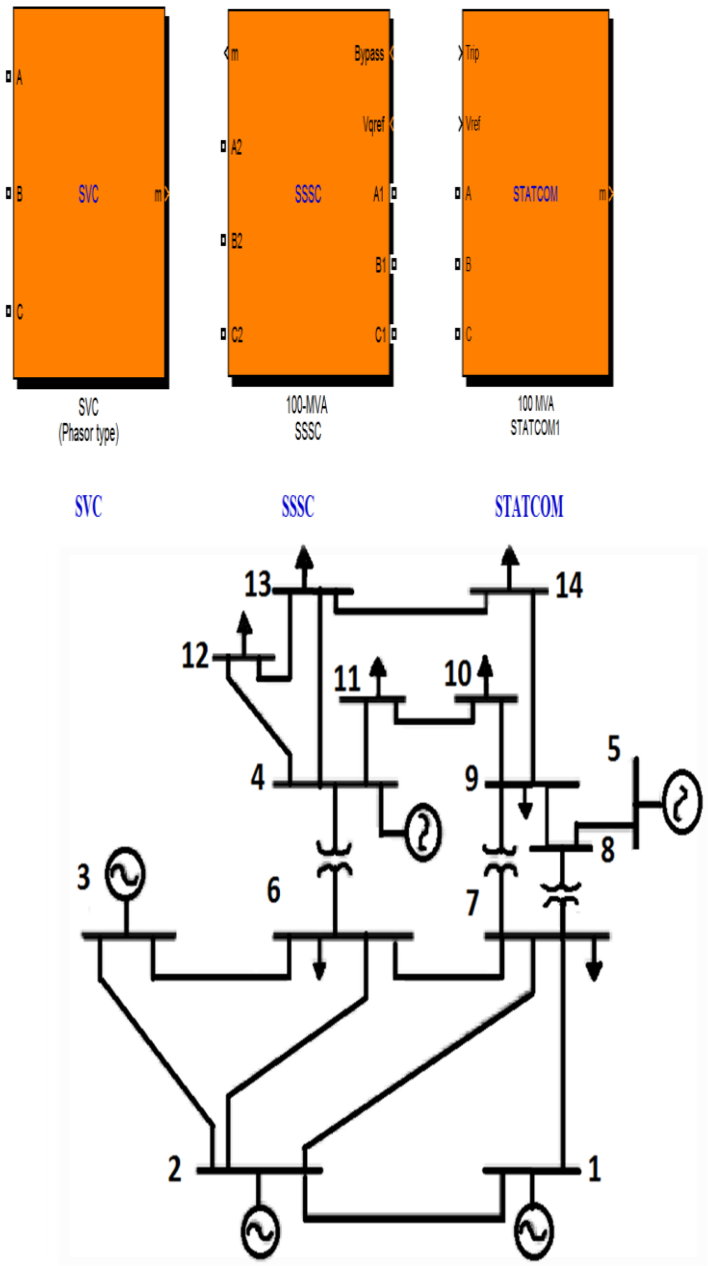

Figure 1. View of the Model of SVC, SSSC & STATCOM in the SIMULINK Library