Transient Stability Enhancement of a Four-machine Power System using SVC & PSS

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Abstract- **The objective of this paper is to compare the performance of a conventional power system stabilizer and Static VAR compensator to improve the transient stability of multi machine power system Power system stabilizers (PSS) and flexible ac transmission system (FACTS) devices are applied to increase the system stability. The problem of transient stability for a two machine power system with SVC and PSS is addressed in this paper. The main focus is on simultaneous enhancement of transient stability.. Simulations results are performed for three cases: reference change, load change and three phase fault. The performance of this system is now compared with one of FACTS devices used Static VAR compensator Transient stability is one of the most important stability of the power system. The loss of Transient stability is due to overloading of some of the lines (or due to sever line fault) as a consequence of tripping off of the other lines after fault or heavy loss of loads. The proposed work includes (WSCC) 4-machine 3-bus system incorporated with Power system stabilizer and Static VAR compensator respectively controller using Matlab. The simulated SVC shows how the oscillations are damped out with PSS and SVC controller. Performance of both PSS and SVC are compared. Power system stabilizers (PSS) and flexible ac transmission system (FACTS) devices are applied to increase the system stability. The main focus is on simultaneous enhancement of transient stability. Digital simulation is carried out by the Matlab Simulink software. Simulations results are performed for three cases: reference change, load change and three phase fault**

Index Terms- transient stability, power system stabilizer, static var compensator, multi-machine power system.

I. INTRODUCTION

Recent advances in power electronics have led to the development of the Flexible AC Transmission Systems (FACTS) devices in power systems. Modern utilities are beginning to install FACTS devices in their transmission networks to increase the transmission capacities and enhance controllability. In view of their advantages, there is a growing interest in use of FACTS devices in the operation and control of power systems. There are two main aspects that should be considered in using FACTS controllers. The first aspect is the flexible power system operation according to the power flow control capability of FACTS controllers. The other aspect is the improvement of stability of power systems. This thesis reports the development of novel control techniques for Flexible AC Transmission System (FACTS) devices for the purpose of power system stability improvement.

1.1 POWER SYSTEM STABILITY

Electric power systems are constituted by the interconnection of a huge number of different components. They can therefore be considered among the most complex systems to be planned and safely operated. This complexity arises as a consequence of the large amount of devices simultaneously in operation, each one with its own internal dynamics, which may interact with each other, giving rise to a complex collective behavior 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 system variables bounded so that practically the entire system remains intact". Power system stability problem has been and continues to receive a great deal of attention over the years. For convenience in analysis, gaining a better understanding of the nature of stability problems, and developing solutions to problems, power system stability problems are classified into following three categories [1]. • Rotor angle stability – ability of the system to maintain synchronism. • Voltage stability – ability of the system to maintain steady acceptable voltage. • Frequency stability – ability of the system to maintain frequency within an acceptable variation range.

Rotor angle stability refers to the ability of synchronous machines of an interconnected power system to remain at a steady state operating condition after being subjected a disturbance. The stability depends on the ability of each synchronous machine of power system to maintain the equilibrium between mechanical torque (generator input) and electromagnetic torque (generator output). The change in electromagnetic torque of a synchronous machine following a perturbation can be split into two components: the synchronizing torque and the damping torque. Rotor angle stability depends on the both components of torque for all synchronous machines in the power system. Lack of synchronizing torque results in a periodic or non-oscillatory instability and lack of damping torque results in oscillatory instability .Commonly the rotor angle stability is characterized in terms of two sub categories: • Small-disturbance rotor angle stability (Small-signal stability) • Large-disturbance rotor angle stability (Transient stability) Small-disturbance rotor angle stability is usually associated with insufficient damping and is concerned with the ability of the power system to maintain a steady state operating point when subjected to a small disturbance, e.g. small changes in load. The changes are hereby considered sufficiently small to allow system linearization for purpose of stability analysis. Small disturbance rotor angle stability. Power System Stabilizers (PSSs) are now routinely employed in the industry in conjunction with generator excitation systems to enhance the system damping and extend power transfer limits, thus ensuring secure and stable operation of the power system. However, during some operating conditions, this device may not produce adequate damping, and other effective alternatives are needed in addition to PSS. FACTS controllers are capable of controlling the network condition in a very fast. A typical PSS block diagram is shown in Fig. 1. It consists of an amplifier block of gain constant KQ, a block having a washout time constant TQ and lead-lag compensators. The output of the PSS is applied as a supplementary control signal to the machine voltage regulator terminal

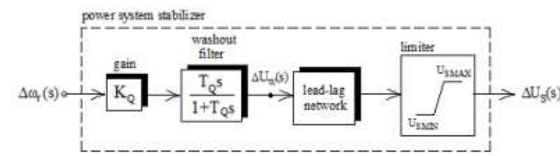

Figure. 1. Block diagram of power system stabilizer

1.2 FACTS CONTROLLERS

The process to permit, site, and construct new transmission lines has become extremely difficult, expensive, time-consuming, and controversial. FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines. FACTS controllers control the interrelated parameters that govern the operation of transmission system like series impedance, shunt impendence, current, voltage and phase angle. So FACTS controllers can be utilized to control power flow and enhance system stability. A better utilization of the existing transmission systems by increasing their capacities close to the thermal ratings and enhancing controllability by installing FACTS controllers becomes imperative in today's competitive power market. The development of FACTS controllers has followed two distinctly different technical approaches, both resulting in a comprehensive group of controllers able to address targeted transmission problems. The first group employs reactive impedances with thyristor switches as controlled elements

II. SYSTEM UNDER STUDY

Description of System

The single line diagram shown below represents a simple 500 kV transmission system [2].

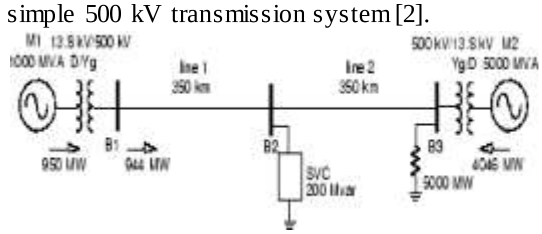

Figure 2: 500 KV transmission system

A 1000 MW hydraulic generation plant (M1)and (M3) is connected to a load center through a long 500 kV, 700 km transmission line. The load center is modeled by a 5000 MW resistive load. The load is fed by the remote 1000 MVA plant and a local generation of 5000 MVA (plant M2 & M4) .

A load flow has been performed on this system with plant M1 generating 950 MW so that plant M2 produces 4046 MW. The line carries 944 MW which is close to its surge impedance loading (SIL = 977 MW). To maintain system stability after faults, the transmission line is shunt compensated at its center by a 200 Mvar static var compensator (SVC). The SVC does not have a power oscillation damping (POD) unit. The two machines are equipped with a hydraulic turbine and governor (HTG), excitation system, and power system stabilizer (PSS).

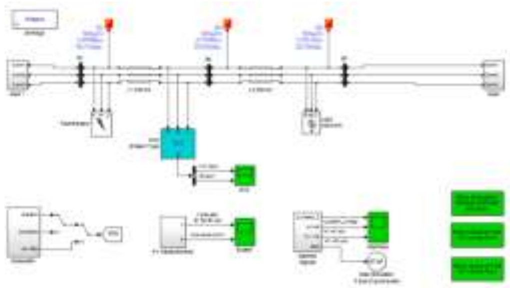

Figure 3: Transient stability of a two machine transmission system with Power System Stabilizers(PSS) and Static Var Compensator(SVC

Here four Turbine and Regulators subsystems to see how the HTG and the excitation system are implemented. Two types of stabilizers can be connected on the excitation system: a generic model using the acceleration power (Pa= difference between mechanical power Pm and output electrical power Po) and a Multiband stabilizer using the speed deviation (dw). These two stabilizers are standard models of the Fundamental Blocks/Machines library. Manual Switch blocks surrounded by a blue zone allow a person to select the type of stabilizer used for both machines or put the PSS out of service.

The SVC is the phasor model from the FACTS library. Open its dialog box and check in the Power data parameters that the SVC rating is +/- 200 Mvar. In the Control parameters, one can select either Voltage regulation or Var control (Fixed susceptance Bref) mode. Initially the SVC is set in Var control mode with a susceptance Bref=0, which is equivalent to having the SVC out of service.

A Fault Breaker block is connected at bus B1. One will use it to program different types of faults on the 500 kV system and observe the impact of the PSS and SVC on system stability.

To start the simulation in steady-state, the machines and the regulators have been previously initialized by means of the Machine Initialization utility of the Powergui block. Load flow has been performed with machine M1 defined as a PV generation bus (V=13800 V, P=950 MW) and machine M2 M4 defined as a swing bus (V=13800 V, 0 degrees). After the load flow has been solved, the reference mechanical powers and reference voltages for the four machines have been automatically updated in the two constant blocks connected at the HTG and excitation system inputs: Pref1=0.95 pu (950 MW), Vref1=1.0 pu; Pref2=0.8091 pu (4046 MW), Vref2=1.0 pu.

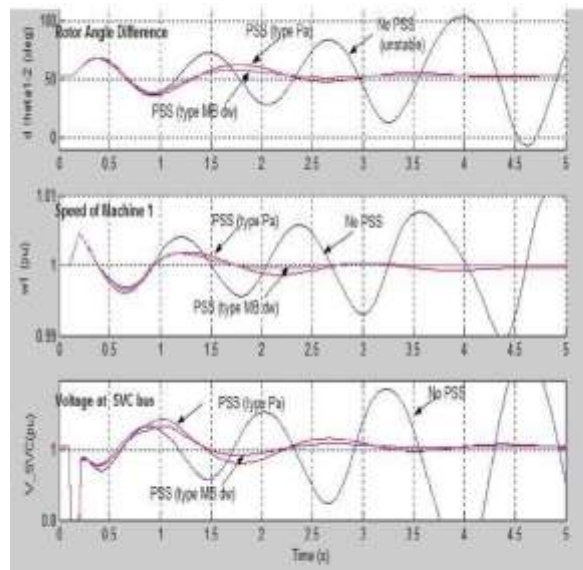

Figure 4.Single Phase Fault Impact of PSS No SVC

The PSSs (Generic Pa type) are in service and that a single-phase fault is programmed in the Fault Breaker block (Phase A checked, fault applied at t=0.1 s and cleared at t=0.2 s).

Start the simulation and observe signals on the Machines scope. For this type of fault the system is stable without SVC. After fault clearing, the 0.6 Hz oscillation is quickly damped. This oscillation mode is typical of inter area oscillations in a large power system. First trace on the Machines scope shows the rotor angle difference d_theta1_2 between the two machines. Power transfer is maximum when this angle reaches 90 degrees. This signal is a good indication of system stability. If d_theta1_2 exceeds 90 degrees for too long a period of time, the machines will lose synchronism and the system goes unstable. Second trace shows the machine speeds. Notice that machine 1 speed increases during the fault because during that period its electrical power is lower than its mechanical power. By simulating over a long period of time (50 seconds) you will also notice that the machine speeds oscillate together at a low frequency (0.025 Hz) after fault clearing. The two PSSs (Pa type) succeed to damp the 0.6 Hz mode but they are not efficient for damping the 0.025 Hz mode. If instead the Multi-Band PSS is selected , it will be noticed that this stabilizer type succeeds to damp both the 0.6 Hz mode and the 0.025 Hz mode.

The test is repeated with two PSS. Restart simulation. It is noticed that the system is unstable without PSS. Results are compared with and without PSS by double-clicking on the blue block on the right side labeled "Show impact of PSS for 1-phase fault." The displayed waveforms are reproduced below.

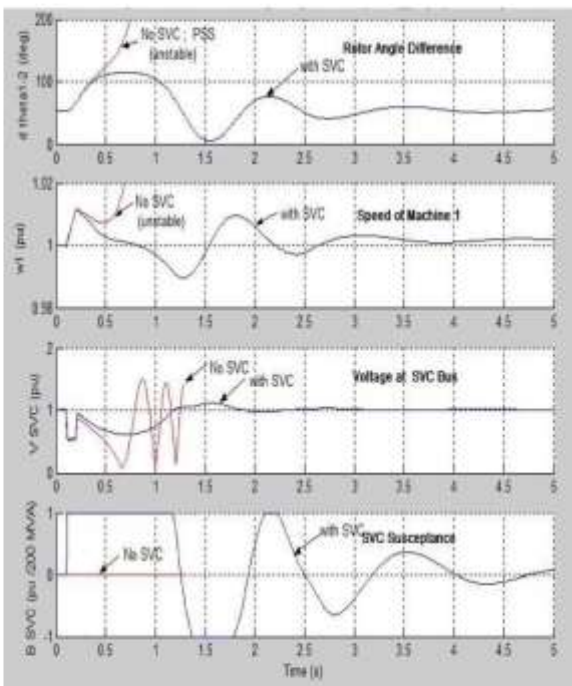

Figure.5 Three Phase Fault PSS In Service With SVC

First put the two PSS (Generic Pa type) in service. Reprogram the Fault Breaker block to apply a 3-phase-to-ground fault. Verify that the SVC is in fixed susceptance mode with Bref = 0. Start the simulation. By looking at the d_theta1_2 signal, it should be observed that the two machines quickly fall out of synchronism after fault clearing. In order not to pursue unnecessary simulation, the Simulink Stop block is used to stop the simulation when the angle difference reaches 3*360 degree

Now the SVC block menu is opened and changed the SVC mode of operation to Voltage regulation. The SVC will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.009 pu). The chosen SVC reference voltage corresponds to the bus voltage with the SVC out of service. In steady state the SVC will therefore be floating and waiting for voltage compensation when voltage departs from its reference set point.

Restart simulation and observe that the system is now stable with. The displayed waveforms are reproduced below

IV. CONCLUSION

PSS and FACTS devices can help the damping of powers ystem oscillations. This study deals with demonstration of transient stability enhancement using PSS and SVC through Matlab Simulink. For the simulation, different loading conditions with different fault locations in the four -machine power system using the PSS and SVC are considered

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