# Power System Stabilizer In Dynamic Stability Assessment

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**Abstract – Power system disturbance have occurred since the initial development of power systems. Most disturbances are caused during stressed power system conditions followed by sequence of low-probability outages. Dynamic stability is identified as the main issue in real power system. Thus, power system stabilizer (PSS) is vital to ensure small signal stability of power systems. Low frequency oscillations are detrimental to the goals of maximum power transfer and optimal power system security. A contemporary solution to this problem is the addition of power system stabilizers to the automatic voltage regulators on the generators in the power system. The damping provided by this additional stabilizer provides the means to reduce the inhibiting effects of the oscillations. Power producers can take steps to ensure that their generator controls are equipped to support transmission system reliability by enhancing the excitation controls. This paper presents dynamic stability assessment in the presence of power system stabilizer. A simple Matlab/Simulink model has been developed to represent the transmission system in towards dynamic stability assessment. Various experiments have been conducted to realize the impact of PSS to the system stability.**

**Index terms - Power system stabilizer (PSS), Dynamic stability, Excitation system, Static Var Compensators (SVC)**

## I. INTRODUCTIONS

### *A. Overview of Studies*

Power system faults, line switching, generator disconnection and the loss and application of large blocks of load result in sudden changes of the electrical power, whereas the mechanical power input to generators remains relatively constant. Major system disturbances cause severe oscillations in machine rotor angles and severe swings in power flows. Loss of synchronism can occur between one generator and the rest of the system or between interconnected power systems. Synchronism could be maintained within each group of generators, assuming a timely separation occurs, and at such points in the power system where good balance of generation and load exists.

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[2]. The stability of electrical power system can most simply be defined as its ability to continue stable operation after disturbance occurrences.

Power system stabilizer refer to the ability of synchronous machines to move from one steady-state operating point following a disturbance to another steady state operating point without losing synchronous[1]. Faults in any power generating system that is connected top the grid can cause widespread transmission system failure. Power system oscillation (dynamic instability) can result from transmission system disturbance. PSS can be viewed as an additional block of a generator excitation control or Automatic Voltage Regulator (AVR) to improve the overall power system dynamic performance especially for the control of electromechanical oscillations.

A number of methods for designing PSS have been proposed over the years to improve dynamic stability of power system. The most common design proposed is lead-lag compensator with speed deviation ($\Delta\omega$) as an input signal and the output signal of stabilizer is added to the voltage regulator reference [11]. Frequency, terminal voltage and power are also signals considered for stabilization[12]. In recent years, proportional-integral (PI) stabilizers have also been investigated for improving the dynamic stability of power system [13,14].

In a number of PSS studies, power system load have been represented by constant impedance load model [12,14]. Power system load model play important role in power system dynamic and transient stability studies [15,16,17]. Representation of static load as a nonlinear function of load bus voltage is recommended by IEEE power system committee and by a number of utilities [18,19]. Dynamic modeling of system load is also necessary in the case of large industrial loads [20].

### *B. Problem Statement*

Some of the earliest power system stability problems included spontaneous power system oscillations at low frequencies. These low frequency oscillations (LFOs) are related to the small signal stability of a power system and are detrimental to the goal of maximum power transfer and power system security[3]. Once the solution of using damper windings on the generator rotors and turbines to control these oscillations was found to be satisfactory, the stability problem was thereby disregarded for some time. However, as power system began to be operated closer to their stability limits, the weakness of a synchronizing torque among the generators was recognized as a major cause of system instability. Automatic voltage regulators (AVR) helped to improve the steady state stability of the power system, but transient stability became a concern for the power system operators[4]. With the creation of large, interconnected power system, another concern was the transfer of large amount of power across extremely long transmission lines. The addition of a supplementary into the control loop, such as the introduction of PSS to the AVRs on the generators, provides the means to reduce the inhibiting effects of low frequency oscillations.

### *C. Objectives*

The objectives of these studies are:-

1) To be able to explain power system stabilizer consists of structure, operation and applications.
2) Able to develop power system stabilizer model using simple Matlab/Simulink.
3) To perform dynamic stability analysis with and without the presence of power system stabilizer.

### *D. Scope of studies*

The scopes of these studies are:-

1) Review the stability of the power system.
2) Do literature survey on power system stabilizer.
3) Develop power system stabilizer model using simple Matlab/ Simulink.
4) Perform an analysis on developed model to investigate the characteristic, performance and effect of power system stabilizer.

## II) POWER SYSTEM STABILITY

The electric power generation-transmission-distribution grid in developed countries constitutes a large system that exhibits a range of dynamic phenomena. Stability of this system needs to be maintained even when subjected to large low-probability disturbances so that the electricity can be supplied to consumers with high reliability. Various control methods and controllers have been developed over time that has been used for this purpose.

Power system stability is similar to the stability of any dynamic system, and has fundamental mathematical underpinnings. Precise definitions of stability can be found in the literature dealing with the rigorous mathematical theory of stability of dynamic systems. Stable operation of a power system requires a continuous match between energy input to the prime movers and the electrical load on the system. Load continuously changes as lights, appliances or electrical machinery are connected and disconnected. Most individual load changes are small in relation to the size of the system, but each load increase or decrease must be accompanied by a corresponding change in input to the prime mover5s of the generators on the system.

If mechanical input does not rapidly match the electrical load, system speed (frequency) and voltage will deviate from normal. More severe conditions exist when trouble occurs on a system, such as a fault on a transmission line or loss of generator or a large block of load. The function of the control equipment, such as governors, generator voltage regulators, and tie line load-frequency-control equipment, is to sense deviations and act to restore frequency and voltage to normal. Unfortunately, control devices are not perfect and usually permit oscillations (periodic variations) around the desired conditions. In most cases the oscillations diminish with time and in such cases the system is stable.

Actually there are three stability conditions that must be considered which are:-

1. Steady state
2. Transient
3. Dynamic

To cover any of these topics fully is far beyond the scope of this manual. An effort will be made to provide a basis for an understanding of some of the factors involved in power system stability, so that system operators will have some appreciation of the subject.

### A) Steady State Stability

Steady state stability might be defined as the ability of an electric power system to maintain synchronism between machines within the system and on external tie lines following relatively slow or normally expected load changes.[5] Steady state stability to a great extent depends upon the margins of transmission and generating capacity and the effectiveness of the automatic control devices, particularly the generator automatic voltage regulators. The above statement is also true for transient and dynamic stability. Whenever load on a synchronous generator is increased, the rotor will advance with respect to the revolving armature field or drop back for load reductions.

Normally, the rotor angle change will slightly overshoot that is retard or advance a little too much. Since it is not quite in the equilibrium position, it will continue in a stable case to oscillate in diminishing amounts until it settle down in the correct position for the new load condition. When the rotor settles to the correct position with only a few rapidly diminishing oscillations, the machine is stable, and the oscillations are said to be highly damp.

Swing of the type described are usually too fast for the machine governor to correct. However, fast-acting generator excitation systems (exciter and generator voltage regulators) can sense the voltage variations that accompany the rotor angle oscillations and strengthen or weaken the generator field in a time relationship to assist in achieving stable operation.

The conditions just described are continuously present in a power system because many loads are being added or disconnected and all the interconnected generators must continuously be readjusting energy inputs, rotor angles and excitation to match the currently existing conditions.

B) Transient Stability

A more severe situation exists when a large block of generation or load is lost or a fault occurs on a transmission line. In such cases the transient stability of the system must be adequate to withstand the shock of the relatively large change that occurs. Transient stability is the ability of the system to remain in synchronism (prior to the action of governor control) following a system disturbance.[5]

Immediately after loss of generation or load, the balance between energy input and electrical output of the system no longer exists. In the event of inadequate energy input, inertia of the rotors of the machines that remain in service will, for a short period, give up stored energy, and the machines will start to slow down. If load is lost, the energy input to the system exceeds the electrical load, and the machines will start to speed up.

Various factors affect the transient stability of the system, such as the strength of the transmission network within the system and of the tie lines to adjacent systems, the characteristics of the generating units, including the enertia of the rotating parts, and electrical properties such as transient reactances and magnetic saturation characteristics of the stator and rotor iron. Another important factor is the speed with which faulted lines or equipment can be disconnected and, with automatic reclosing of transmission lines, how rapidly lines can be restored to service. As in the case of steady state stability, the speed with which the generator excitation systems respond is important in maintaining transient stability. System disturbances are usually accompanied by rapid reductions in system voltage, and rapid restoration of voltage to normal is important in maintaining stability.

As previously stated, transient stability is the ability to remain in synchronism during the period following a disturbance and prior to the time at which governors can act. Ordinarily the first swing of machine rotors will take place within about 1s following the disturbance, but the exact time depends on the characteristics of the machines and transmission system. Following this period, governors begin to take effect, usually about 4 to 5s, and dynamic stability conditions are effective. Dynamic swings may also be affected by voltage oscillations, the gain of the excitation systems, and the timing of the network's natural frequency.

c) Dynamic Stability

Dynamic stability is the ability of a power system to remain in synchronism after the "initial swing" (transient stability period) until the system has settled down to the new steady-state equilibrium condition.[5] Dynamic stability is actually an extension of steady state stability where we also include the effects of synchronous machine and AVR by their dynamical equations[8]. When sufficient time has elapsed after a disturbance, the governors of the prime movers will react to increase or decrease energy input, as may be required, to reestablish a balance between energy input and the existing electrical load. This usually occurs in about 1 to 1 ½ s after disturbance. The period between the time when the governors begin to react and the time when steady state equilibrium is reestablished is the period during which dynamic stability characteristics of a system are effective.

The dynamic stability is concerned with small disturbances losing for a long time and therefore in dynamic stability studies we always neglect non-linearities. The source of this type of instability is usually an interaction between control systems. The system's response to the disturbance may not become apparent for some 10 to 30s. Computer simulation is the only affective means of studying dynamic stability problems and the same simulation program are of course, applicable to transient stability studies.[11]

During this period, the governors open or close valves, as required, to increase or decrease energy input to the prime movers, and tie-line controllers operate to restore tie-line flows to normal. Usually, when the governors sense a speed drop, they will act to open the throttle valves to admit more steam to a steam turbine or water to a hydro unit and provide enough energy to arrest the decline of speed (frequency) and accelerate the system back to normal speed. This is still a condition of unbalance, because energy input now exceeds the load, and speed will increase to s point beyond normal, where the governors will again act to reduce energy input. As a result, oscillations of energy input and machine rotor angles will occur. If the system is dynamically stable, the oscillations will be damped, that is reduces in magnitude, and after a few swings the system will settle down to san equilibrium (steady-state) condition with energy input equal to the electrical load on the system.

It is possible to have transiently stable but dynamically instable conditions. If the oscillations are of successively smaller amplitudes, the system is considered dynamically stable and if the oscillations grow in amplitude, the system is dynamically unstable[10]. Immediately after a disturbance, the machine rotors will go through the first swing (before governor action) successfully; then, after governor control is initiated, the oscillations will start to increase until the machine goes out of synchronism. This can occur if the time delays of the governor control are such that, following the sensing of need for increasing or decreasing energy input, action is delayed sufficiently in time to augment rather than diminish the next swing. If such a condition exists, the oscillations of the machine rotor can continue to build up until the machine drops out of synchronism.

Investigations of stability at one time included only the first (transient) swing, and it was though that if this was stable the oscillation would damp out. Until the advent of digital computers, with their capability of high speed calculations, stability studies were very time consuming. At present it is common to carry the studies through several swings to ensure that the system is stable and that the swings will diminish with time to a steady-state condition.

## III. THE SYSTEM STUDIED

A 1000MW hydraulic generation plant (machine 1) is connected to a load center through a long 500kV, 700 km transmission line. The load center is modeled by a 5000MW resistive load. The load is fed by the remote 1000 MW plant and a local generation of 5000MW (machine 2). In order to maintain system stability after faults, the transmission line is shunt compensated at its center by a 200 MVar Compensator (SVC). The two machines are equipped with hydraulic turbine and governor (HTG), Excitation system and Power System Stabilizer (PSS).

The system has been initialized so that the line carries 950 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 centre by a 200 MVar Static Var Compensator (SVC). The SVC model is a phasor model valid only for transient stability solution.

The two machines are equipped with a Hydraulic Turbine and Governor (HTG), excitation system and PSS. These three blocks are located in two turbine and regulator subsystems. The machine M1, 'Bus type' should be already initialized as 'PV generator', indicating that the load flow will be performed with the machine controlling its active power and its terminal voltage. The machine M2 will be used as a swing bus for balancing the power.

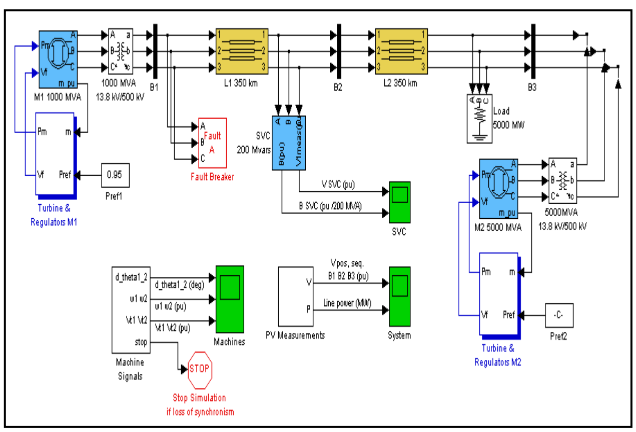


Figure 1: Circuit model

## IV) POWER SYSTEM STABILIZER

High performance excitation systems are essential for maintaining steady state and transient stability of modern synchronous generators, apart from providing fast control of the terminal voltage. It is well established that fast acting exciters with high gain AVR can contribute to dynamic stability in power systems. Small signal instability occurs when a system perturbation, even a small one, excites a natural oscillatory mode of the power system [6]. This type of instability is characterized by low frequency (0.2 to 2.0 Hz) oscillations which can persist (or even grow in magnitude) for no apparent reason. This type of instability can endanger system security and limit power transfer. The major factors that contribute to the instability are:-

a) Loading of generator or tie line
b) Power transfer capability of transmission lines.
c) Power factor of the generator (leading power factor operation is more problematic than lagging power factor operation).
d) AVR gain

A cost efficient and satisfactory solution to the problem of oscillatory instability is to provide damping for generator rotor oscillations. This is conveniently done by providing power system stabilizer (PSS) which are supplementary controllers in the excitation systems for generator control. The objective of designing PSS is to provide additional damping torque without affecting the synchronizing torque at critical oscillation frequencies [2]. Excitation systems with high gain and fast response times greatly aid transient stability (synchronous torque), but at the same time tend to reduce small signal stability (damping torque). It can generally say that need for PSS will be felt in situations when power has to be transmitted over long distances with weak AC ties. The PSS acts to modulate the generator field voltage to damp electrical power-speed oscillations. Even when PSS may not be required under normal operating conditions, they allow satisfactory operation under unusual or abnormal conditions which may be encountered at times. Thus, PSS has become a standard option with modern static exciters and it is essential for power engineers to use these effectively. Retrofitting of existing excitation systems with PSS may also be required to improve system stability.

### *A) Structure and Tuning PSS*

The block diagram of the PSS used in industry is shown in Figure 2. It consists of a washout circuit, dynamic compensator, torsional filter and limiter [3]. It is to be noted that the major objective of providing PSS is to increase the power transfer in the network, which would otherwise be limited by oscillatory instability. The PSS must also function properly when the system is subjected to large disturbances.

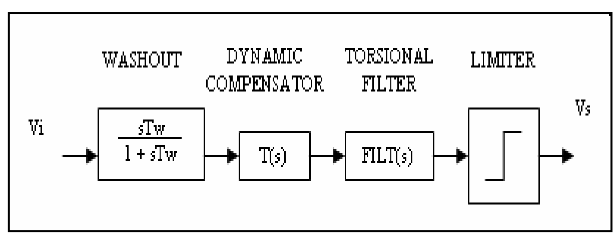


Figure 2: Block Diagram of PSS

The overall PSS transfer function is,

$$\text{PSS(s)} = \frac{sTw}{(1+sTw)}\,\frac{Ks(1+sT1)}{(1+sT2)} \tag{1}$$

### *B) Signal Control*

The obvious control signal (to be used as input to the PSS) is the deviation in the rotor velocity. However, some common input signals used in the stabilizer design are the acceleration power, frequency, active power output, terminal voltage or combination of some of them [9]. The choice of control signal for PSS can be based on the following criteria:

1) The signal must be obtained from local measurements and easily synthesized.
2) The noise content of the signal must be minimal. Otherwise, complicated filters are required which can introduce their own problems.
3) The PSS design based on a particular signal must be robust and reject noise. This implies that lead compensation must be kept to a minimum to avoid amplifying the noise.

The oldest types of PSS use a measurement of the speed deviation of the generator shaft. Obviously this signal must be processed in order to filter out all the measurement noise. The main problem with this method, when applied to turbogenerators with long shafts prone to torsional oscillations, relates to selecting a measurement position on the shaft that properly represents the speed deviation of the rotor magnetic poles. For long shafts it is necessary to measure the speed deviation number of points along the shaft and use this information to calculate the average speed deviation. Moreover the stabilizer gain is constrained by the PSS has on the torsional oscillations.

A simplified form of the PSS shown in Figure 3 can be obtained by neglecting the shaft speed measurement and only measuring the generator real power, Pe. With this arrangement only one input signal is required but it can only be used when the mechanical power can be assume to be constant. If the mechanical power does change, for example due to secondary frequency control, this solution produces transient oscillations in the voltage and reactive power that are unnecessarily forced by the PSS as it see the change in the mechanical power as a power swing.

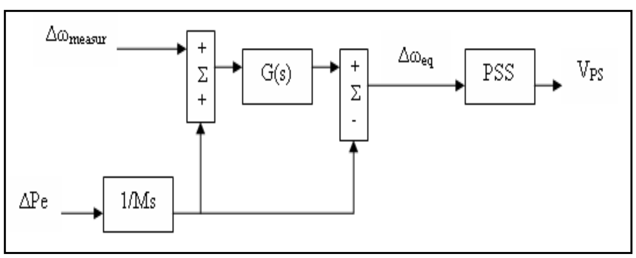


Figure 3: Simplified form of PSS

*C) Washout Circuit*

The signal washout is a high-pass filter that prevents steady changes in speed from modifying the field voltage where to reduce the over-response of the damping during severe events. The value of the washout time constant Tw should be high enough to allow signals associated with oscillations in rotor speed to pass unchanged.

The PSS is expected to respond only to transient variations in the input signal (say rotor speed) and not to the dc offsets in the signal. This is achieved by subtracting from it the low frequency components of the signal obtained by passing the signal through a low pass filter. The washout circuit shown in Figure 4.

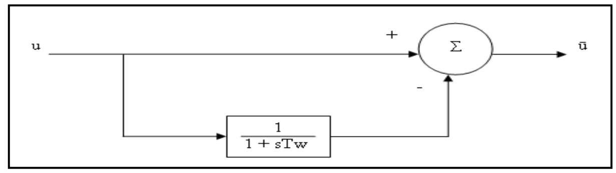


Figure 4: Washout circuit

The equation of the output, ū to the input, u as below,

$$\frac{\bar{u}}{u} = \frac{sTw}{1+sTw} \qquad (2)$$

The signal washout is a high pass filter that prevents steady changes in speed from modifying the field voltage [3]. It must pass all frequencies that are of interest. For the low-frequency inter-area oscillations, a washout time constant (Tw) of 10 seconds was selected, since lower-time constants result in significant phase lead at low frequencies which will reduce the synchronizing torque component at inter-area frequencies [1]. The higher value of Tw also improved the overall terminal voltage response during system islanding conditions. From the viewpoint of the “washout function”, the value of Tw is not critical and may be anywhere in the range of 1 to 20 seconds.

For local mode oscillations in the range of 0.8 to 2.0 Hz, a washout of 1.5 seconds is satisfactory. From the viewpoint of low-frequency interarea oscillations, a washout time constant of 10 seconds or higher is desirable, since lower-time constants result in significant phase lead at low frequencies. It will reduce the synchronizing torque component at interarea frequencies unless this is compensated for elsewhere. This desynchronizing effect is detrimental to interarea transient stability as it will cause the areas to swing farther apart following a disturbance.

The main considerations are that it should be long enough to pass stabilizing signals at the frequencies of interest relatively unchanged, but not so long that it leads to undesirable generator voltage excursions as a result of stabilizer action during system-islanding conditions. Ideally, the stabilizer should not respond to system-wide frequency variations.

*D) Dynamic Compensator*

Since, the PSS must produce a component of electrical torque in phase with the speed deviation, dynamic compensator are used to compensate for the lag between the PSS output and the control action, the electrical torque. The dynamic compensator used in industry is made up to two lead-lag stages and has the following,

$$T(s) = \frac{Ks(1+sT1)(1+sT3)}{1+sT2)(1+sT4)} \qquad (3)$$

Where Ks is the gain of PSS and the time constants, T1 to T4 are chosen to provide a phase lead for the input signal in the range of frequencies that are of interest (0.1 to 3.0 Hz).

The PSS gain, Ks is an important effect on damping of rotor oscillations provided by the PSS increases in proportion to an increase in the gain up to a certain critical gain value, after which the damping begins to decrease[7]. The value of the gain is chosen by examining the effect for a wide range of values. Ideally, the stabilizer gain should be set at a value corresponding to maximum damping. However, the gain is often limited by other considerations. In such cases, the maximum value of the stabilizer gain is likely to be limited by practical considerations such as other effect on signal noise.

The number of dynamic compensator needed depends on the particular system and the tuning of the PSS[7]. With static exciters, only one lead-lag stage may be adequate. For design purposes, the PSS transfer function is approximated to T(s), the transfer function of the dynamic compensator. The effect of the washout circuit and torsional filter may be neglected in the design but must be considered in evaluating performance of PSS under various operating conditions.

*E) Torsional Filter*

The torsional filter in the PSS is essentially a band reject to attenuate the first torsional mode frequency[9]. The transfer function of the filter can be expressed as:

$$FILT(s) = \frac{\omega_n^2}{s^2 + 2\,\zeta\,\omega_n\,s + \omega_n^2} \qquad (4)$$

For stabilizers derived from accelerating power, torsional filter can have a simple configuration of a low filter independent of the frequency of the torsional mode to be filtered out. Torsional filter is necessitated by the adverse interaction of PSS with the torsional oscillations. This can lead to shaft damage, particularly at light generator loads when the mechanical damping is small. Even if shaft damage does not occur, stabilizer output can go into saturation (due to torsional frequency components) making it ineffective.

*F) Limiter*

The output of PSS must be limited to prevent the PSS acting to counter the action of AVR[9]. The positive output limit of the stabilizer is set at a relatively large value in the range of 0.1 to 0.2 pu. This allows a high level of contribution from the PSS during large swings. With such a high value of stabilizer output limit, it is essential to have a means of limiting the generator terminal voltage to its maximum allowable value, typically in the 1.12 to 1.15 pu range. For example, when load rejection takes place, the AVR acts to reduce the terminal voltage when PSS action calls for higher value of the terminal voltage (due to the increase in speed or frequency). It may even be desirable to trip the PSS in case of load rejection.

The negative limit of PSS output is of importance during the back swing of the rotor (after initial acceleration is over). The AVR action is required to maintain the voltage (and thus prevent loss of synchronism) after the angular separation has increased. PSS action in the negative direction must be curtailed more than in the positive direction. Recent studies have shown that higher negative limit can impair first swing stability [1].

The terminal voltage signal, however, contents small components of torsional components. Hence, feedback of this signal to the excitation system through a high gain may cause torsional mode instability. On the negative side, a limit of -0.05 to -0.1 pu is appropriate. This allows sufficient control range while providing satisfactory transient response. In the unlikely event of the PSS output being held at the negative limit because of a failure of the stabilizer, this will not result in a unit trip. Figure 5 shows the generation system with power system stabilizer.

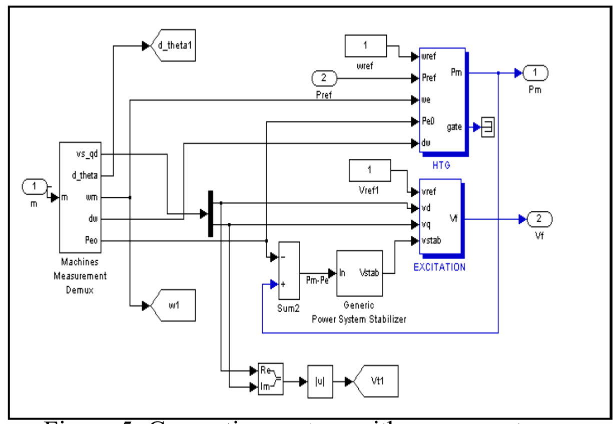


Figure 5: Generation system with power system stabilizer

V) STATIC VAR COMPENSATORS (SVC)

In recent times, Static Var Compensators (SVC) is used for fast reactive power control in power systems. Fast control of reactive power is very important for maintaining security during power system operation. The major benefits are improvement of system stability (both steady state and transient) with fast acting voltage regulation. It is necessary to model these devices in stability studies. The other functions of SVC as below:

a. Increasing power transfer in long lines
b. Damping of low frequency oscillations (corresponding to electromechanical modes).
c. Damping of subsynchronous frequency oscillations (due to torsional modes)
d. Control of dynamic overvoltages.

Traditionally, the reactive power control depended on mechanically switched shunt capacitors and reactors which only help in maintaining the desired voltage profile in the system during slowly changing load conditions. However, disturbances such as faults followed by line switching or generator tripping can result in system stability and voltage problems. If the system has to operate close to stability limits in the steady state (with minimum margins), fast control of reactive power is essential.

In recent years, thyristor controlled static var compensators are being used for fast reactive power control. Advances in high power semiconductors, microelectronics and digital controls which are already used in HVDC transmission systems have made this improvement possible.

## VI) RESULTS AND DISCUSSIONS

### *A. Single-phase fault - Impact of PSS - No SVC*

Figure 6 shows the impact of PSS in the system. After fault clearing the 0.8 Hz oscillation is quickly damped. This oscillation mode is typical of interarea oscillations in a large power system. First trace on the 'Machine' 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 a too long period of time, the machines will loose 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. Notice that that the system is unstable without PSS. From the experiment, we can conclude that the systems that have PSS are take few times and more rapidly become stable.

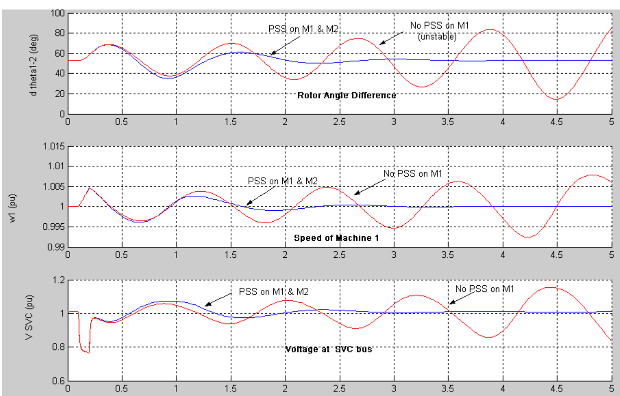


Figure 6: Impact of PSS in the system

### ***B. Three-phase fault - Impact of SVC - two PSS in service***

Figure 7 shows the impact of SVC with two PSS in the system. From this result, we can observe the impact of the SVC for stabilizing the network during a severe contingency.. By looking at the d_theta1_2 signal, we can observe 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*360degrees.

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.

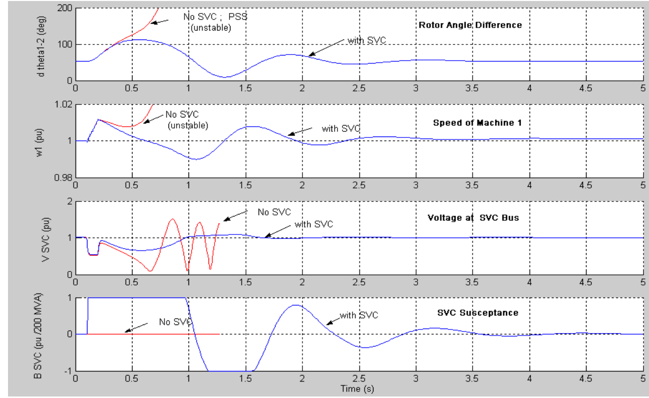


Figure 7: Impact of SVC with two PSS in the system

### ***C) The Effect of Length - Two PSS in Service***

The power system will be test with different length of transmission line to investigate the performance of PSS in the system. Efficient transmission line are very important to modern power systems because power generation is usually done at large electric generating stations located a long way from the cities and industries where the power is consumed. Most electric power consumers are used small amount of power and they are scattered over wide areas.

Figure 8 show the effect of 80 km transmission line (short) with PSS in the system. Observe that the line voltage, Va is 1.01 p.u. at the beginning of the simulation. It falls to about 0.1 p.u. then quickly damp but not sufficient to stable the line voltage. Its falls again about 0.22 p.u during the fault and returns to nominal quickly after the fault is cleared at 1.0 p.u.. This quick response in line voltage is due to the fact that the Excitation System output Vf can go as high with helping from PSS, which it does during the fault. The system takes 1.1 seconds to return nominal voltage and cleared the fault.

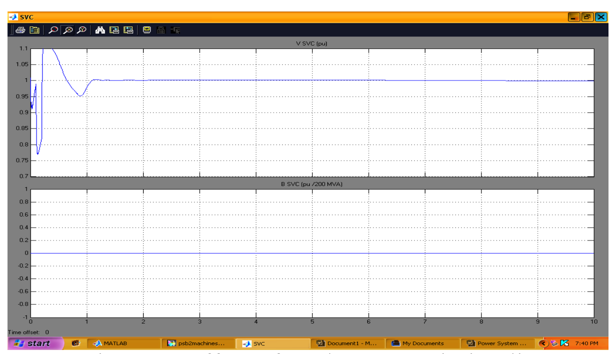

Figure 8: Effect of 80 km transmission line

Figure 9 show the effect of 200 km transmission line (medium) with PSS in the system Observe that the line voltage, Va is 1.01 p.u. at the beginning of the simulation. It falls to about 0.11 p.u. then quickly damp but not sufficient to stable the line voltage. Its falls again about 0.19 p.u then damp to 1.08 during the fault and oscillates to nominal voltage at 1.0 p.u after the fault is cleared.. The system takes 1.5 seconds to return nominal voltage and cleared the fault.

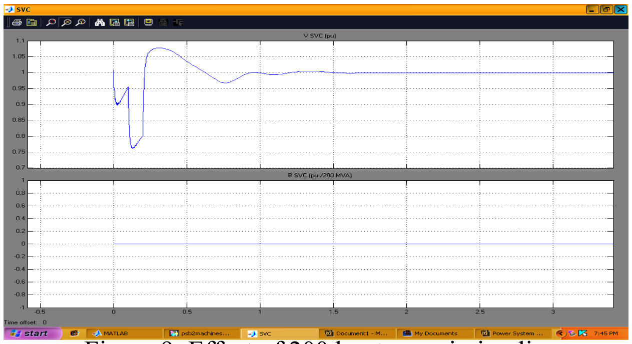

Figure 9: Effect of 200 km transmission line

Figure 10 show the effect of 700 km transmission line (long) with PSS in the system Observe that the line voltage, Va is 1.01 p.u. at the beginning of the simulation. It falls to about 0.25 p.u. then quickly damp but not sufficient to stable the line voltage and underdamp. Its falls again about 0.02 p.u then damp to 1.07 during the fault and regulate to nominal voltage at 1.01 p.u after the fault is cleared.. The system takes 4 seconds to return nominal voltage and cleared the fault.

We can make conclusion that the length of the transmission line is proportional to the time taken to clear the fault from the system. Therefore, the length is affect of the system and must be consider when design it. The PSS may be required for normal operation if the unit is connected at the end of a long transmission line.

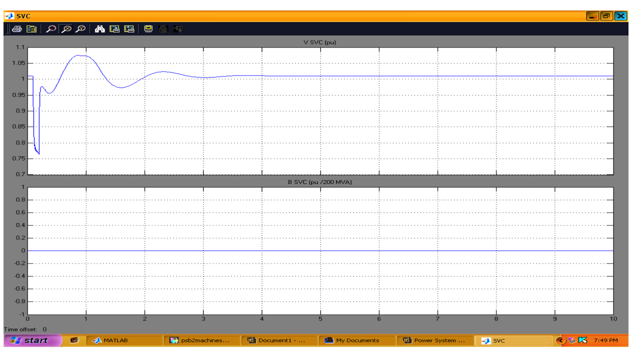

Figure 10: Effect of 700 km transmission line

## VII) CONCLUSIONS

We can make conclusion that today most large generating unit excitation using PSS as a standard option because of its efficiency and reliability. PSS can be design using root locus, frequency domain and state space method. Power system stabilizers should be considered carefully in the analysis of plant controls in stability studies. Although, the PSS controls are always beneficial for stability, its action can become critical in cases where the system becomes weak due to line out-of-service or during major system disturbances.

Concerning power system stability, there is a need for development of new automatic parameter setting technology that would make it possible to cope with the advances in system operation from future globalization and the increased diversity and complexity in the load on the generator that come with it, as well as to cope temporal consideration such as daytime, night time and the season. In addition, PSS design for systems with multiple operating conditions can be considered. PSS can be improving in more advanced techniques such as fuzzy logic, genetic algorithms, eigenvalues of the A-matrix and others method depending on the needs and applications.

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