Standard Stability improvement using Particle Swarm Optimization Power System Stabilizer

SYED SAHAB, E.RAVI TEJA,
Assistant professor., Assistant professor.
Department of EEE
St.Johns College of Engineering and Technology, Yemmiganur, Kurnool (Dist).

Abstract-- ***In this paper the dynamics of a single device related to limitless bus electricity machine is analyzed. Such evaluation calls for a sure degree of gadget modeling. the main gadget components fashions are the synchronous gadget, excitation machine and the strength gadget Stabilizer. The Matlab/Simulink is used as a programming tool to research the gadget performance. in keeping with the device performance a right design for the energy gadget Stabilizer (PSS) using Particle Swarm Optimization (PSO) is achieved. Then the designed PSS is carried out in the model and the dynamic machine reaction is analyzed. for the reason that simulation effects without the PSS showed unacceptable machine response, the gadget response with the PSS has advanced and the PSS succeeded to stabilize an volatile device.***
Index Terms—Power System Stabilizer, Particle Swarm Optimization, Dynamic Stability.

I. INTRODUCTION

Power System Stability is concerned as one of the main factors that affect the power system in its three main sectors: generation, transmission and distribution. There are several factors that can affect the stability of the system such as sudden load change, fault and generator shaft speed change. The instability problem is resulting in scillatory behavior that, if undamped may eventually build up. Even undamped oscillations at low frequencies are undesirable because they limit power transfers in transmission lines and induce stress in the mechanical shaft. With proper design and compensation, the excitation system can be an effective means of enhancing stability in the dynamic range as well as in the first few cycles after a disturbance. The compensation by adding damping to the generator rotor oscillations is related to an auxiliary stabilizing signal and the device used to generate this signal is called Power System Stabilizer (PSS). Stability can be controlled by controlling the excitation of the generator or its speed. In addition, the excitation can be controlled using Automatic Voltage regulator AVR. Nowadays, PSS becomes one of the main solutions to the instability behind the AVR. PSS is a device which provides additional supplementary control loops to the automatic voltage regulators system and/or the turbine governing system of a generating unit. It is considered as one of the most common ways of enhancing both small signal (steady-state) stability and large-signal (transient) stability. PSS are often used as an effective and economic means of damping such oscillations. The automatic voltage regulator (AVR) regulates the generator terminal voltage by controlling the amount of current supplied to the generator field winding by the exciter. It is mainly used to damp any oscillations accrued to the power system when load is changing. It keeps the terminal voltage of the generator constant so that the voltage on the load side will remains almost constant even the load is vary with time. Next section will present the motivation on this paper. Section three will discuss the system modeling. Then PSS design will be discussed in section four. Finally implementation and simulation will be discussed in section five.

II. MOTIVATION

The stability problem is concerned with the behavior of the synchronous machines after they have been perturbed. If the perturbation does not involve any net change in power, the machines should return to their original state. If an unbalance between the supply and demand is created by a change in load, in generation, or in network conditions, a new operating state is necessary. In any case the synchronous machine should remain in synchronism with other machines and they should operate in parallel as well as at the same speed. The transient following a system perturbation is oscillatory in nature and such oscillations could affect power generation significantly. Those oscillations differ in magnitude according to the disturbance. Small random changes in the load or generation are an example of small disturbance. However any disturbance small or large can affect the synchronous operation and may lead the machine to run out of stability. Nevertheless those oscillations due to such disturbances have to be damped to improve power system stability. This paper will investigate; how to solve the dynamic stability of the single machine connected to infinite bus during small disturbances using PSS. The main objective of this work is to design and implement a power system stabilizer for single machine connected to infinite bus power system to stabilize the system and improve the system response during small disturbances or changes in the system.

III. System Modeling

Modeling of the system is an important part of the design. This chapter presents the modeling of the system parts which are; synchronous machine, Automatic Voltage Regulator and the Power System Stabilizer.

A. Full order model

The state-space form of the synchronous generator model has two main sets of variables which are the flux linkages and currents. But these two sets are mutually dependent so, one of them can be eliminated and express in terms of the other.

B. Single machine connected to infinite bus linear model:

The synchronous generator experience an oscillatory period which can be classified into a transient period and a steady state or dynamic period .The transient period is the first cycles after the disturbance. The consideration on dynamic area reduces the system model to the third order model. Since the interest of this paper is to look after small change in the system, the linearized third order model is sufficient for the analysis. The simplified third order model of synchronous generator connected to infinite bus through a transmission line having resistance Re and reactance Xe has the following assumption over the full order model:

1. Stator winding resistance is neglected.
2. Balancing conditions are assumed and saturation effects are neglected.
3. Damper winding effect is neglected .From this assumption the linear equation of stator voltage that proportional to the main winding flux linkage can be found as follow:[1][2].

$$\Delta E'_q = \frac{K_3}{1+K_3\tau'_{d0}s}\Delta E_{FD} - \frac{K_3K_4}{1+K_3\tau'_{d0}s}\Delta\delta \qquad [3.1]$$

Where $_{FD}E$ is the rms value of E'_q, τ'_{d0} direct-axis transient time constant. On the other hand, the incremental electrical torque is computed according to the following:

$$\Delta T_e = K_1\Delta\delta + K_2\Delta E'_q \qquad [3.2]$$

$$E'_q = E + (x_d - x'_d)I_d \qquad [3.3]$$

Where E is the stator air gap rms voltage. The synchronous generator linearized terminal voltage *delta* is given by:

$$\Delta V_t = K_5\Delta\delta + K_6\Delta E' \qquad [3.4]$$

Note that the constants *K1* , *K2* , $_3K$, *K4* , *K5* and *K6* are depended on system parameter and operation conditions. In general *K1* , *K2* , $_3K$ and $_6K$ are positive, whereas *K4* is positive unless $_eR$ is high. However, $_5K$ is positive for low and medium loading and external impedance. But if the loading and the external impedance is high $_5K$ will be negative. The summary of the simplified linear differential equations. of the synchronous machine are as follows:

$$\Delta E'_q = \frac{K_3}{1+K_3\tau'_{d}s}\Delta E_{FD} - \frac{K_3K_4}{1+K_3\tau_{do}s}\Delta\delta \quad [3.5]$$

$$\Delta\omega_m = \frac{1}{2Hs}[\Delta T_m - \Delta T_e - D\Delta\omega_m] \qquad [3.6]$$

$$\Delta\delta = \frac{\omega B}{s}\Delta\omega_m = \frac{\omega B}{s}\Delta\bar{\omega} \qquad [3.7]$$

Where is the Laplace operator.

C. Excitation system model

Excitation system is one of prime importance for the proper operation of synchronous generators. The excitation system can be as simple as a fixed dc power supply connected to the Rotor winding of the synchronous generator ,primary function of a synchronous generator excitation system is to regulate the voltage at the generator output. On other words, using the excitation system in any synchronous machine is to control the field current injected to the rotor. The point of controlling the field current is to regulate the terminal voltage of the machine and maintaining the terminal voltage constant and hence keeping the synchronization of the generator.

D. Representation of excitation system:

The excitation system representation is shown in Fig.3.1

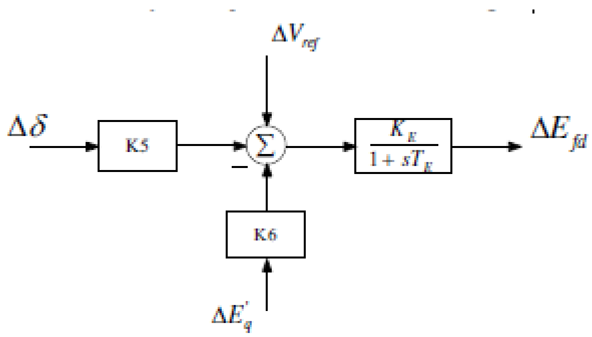

Fig. 3.1 Simple excitation system model

The linearized equation of the excitation system is given by the following equation: [1]

$$\Delta E_{fd} = \frac{K_e}{1+sT_E}(\Delta V_{ref} - \Delta V_t) \qquad [3.8]$$

E. PSS Model:

Power System Stabilizer (PSS) is a device which provides additional supplementary control loops to the automatic voltage regulator system and/or the turbine governing system of a generating unit. PSS are often used as an effective and economic means of damping such oscillations. Adding supplementary control loops to the generator AVR is one of the most common ways of enhancing both small-signal (steady state) stability and large-signal (transient) stability [3]. PSS is working in parallel with the excitation system in order to modify the power angle to increase the damping of the oscillation. Since the PSS and the excitation system are working in parallel, the performance of the excitation system is very important to PSS [4].

The main idea of power system stabilization is to recognize that in the steady-state, that is when the speed deviation is zero or nearly zero, the voltage controller should be driven by the voltage error ΔV only (Fig.3.2). However in the transient state the generator speed is not constant, the rotor swings, and undergoes oscillations caused by the change in rotor angle. The task of PSS is to add an additional signal which compensates for the ΔV oscillation and provides a damping component that is in phase with $delta\omega$[3]. From the below Fig. 3.2, it is clear that there is a reference voltage to compare with the terminal voltage taken from the generator and the result is added with the PSS output (VPSS) that be an enhancing signal to AVR to return the generator terminal voltage to its value.

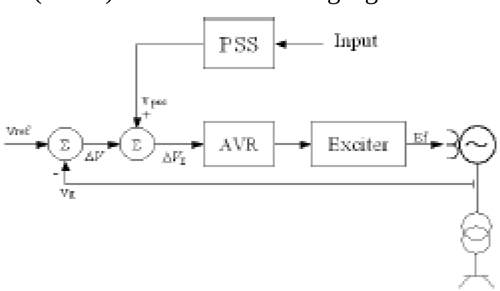

Fig.3.2: block diagram of supplementary control loop for the AVR system.

Fig. 3.3 represents the general (2 stages lead-lag power system stabilizer) structure of the PSS where VPSS is the generated based on the measured signal of the generator terminals.

Fig.3.3: lead-lag power system stabilizer.

The general equation and the used equation of the PSS is:

$$V_{PSS}(s) = \frac{sK_S T_W}{(1+sT_W)} \frac{(1+sT_1)(1+sT_3)}{(1+sT_2)(1+sT_4)} \text{Input}(s) \qquad [3.9]$$

This particular controller structure contains a washout block, sTW/ (1+sTW), which is used to reduce the over response of the damping during severe events. The constants T1, T2, T3, and T4 should be set to provide damping over the range of frequencies at which oscillations are likely to occur.

IV. PSS DESIGN

ISSN: 1475-7192

A. Design PSS parameters using PSO:

Particle Swarm Optimization is an optimization technique which provides an evolutionary based search. This search algorithm was introduced by Dr Russ Eberhart and Dr. James Kennedy in 1995[5]. Particle Swarm Optimization (PSO) technique is inspired from birds flocking & fish schooling. Fig.4.1 shows the flow chart of PSO [6]

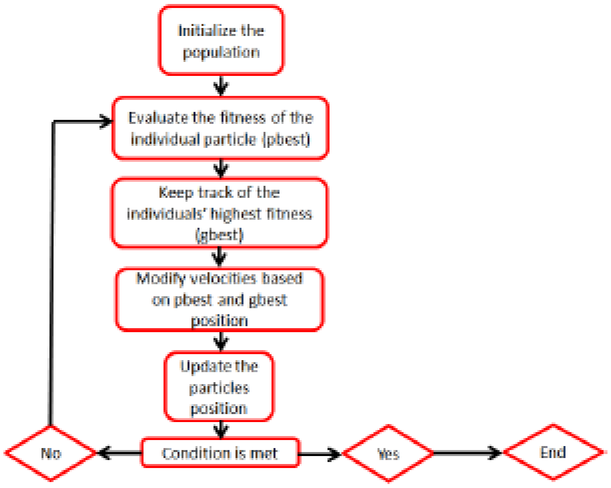

Fig 4.1: PSO Algorithm Chart

The fitness function used in PSO is the area under the curve of the deviation in speed. PSO will try to minimize the fitness function when designing the PSS parameters [4]. Fitness function is obtained as follows; first the system model is simulated in Simulink with a disturbance. Then the signal of the speed is squared, to get rid of negative portion of the signal. After that the squared signal is passed through integrator to get the area under the curve which is the fitness function (J). Next, the PSO starts the iterations to design the PSS parameters which will be used in the next simulation of the system with PSS to get a new area under the curve. PSO will iterate the same process searching for minimum area as shown in Fig. 4.2. The searching will stop if one of the following conditions satisfied:

1.The fitness function value doesn't change for M iterations. Where M is the maximum number iterations of unchanged solution.

2. The maximum number of iterations is exhausted.

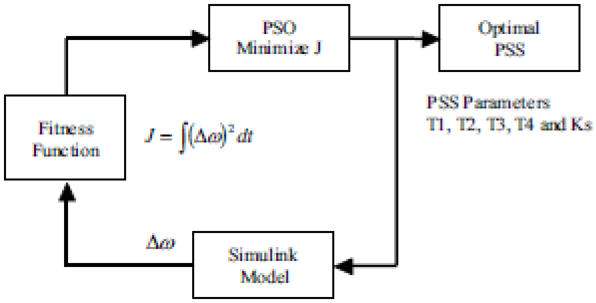

Fig.4.2: Design procedure with PSO

V. Implementation and Model Simulation

A. Model Implementation

The system is simulated using MATLAB/Simulink toolbox. The models of the synchronous machine, PSS and the excitation system are linked together to form the overall system representation showing Fig 5.1.

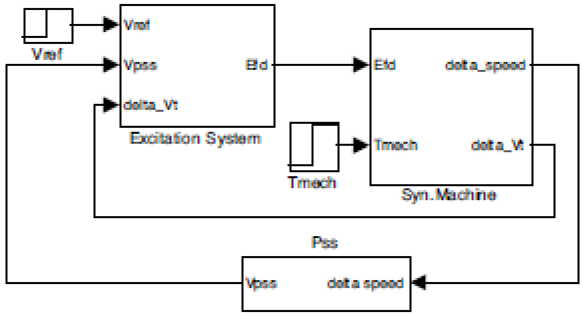

Fig.5.1: Overall system representation in Simulink

B. Synchronous machine model implementation:

Synchronous machine model consist of flux decay loop, and torque-angle loop. The model is implemented in Matlab/ Simulink as shown in Fig.5.2.

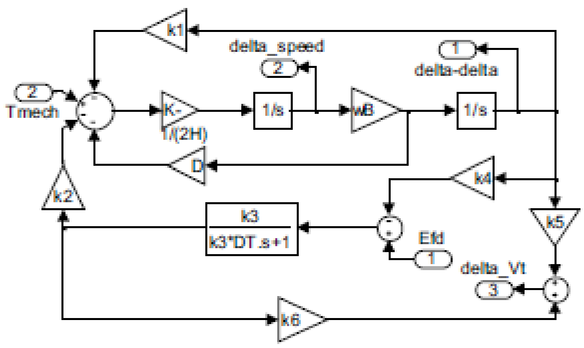

Fig.5.2: overall representation of synchronous machine

C. Excitation system implementation

Excitation system is described by equation (3.4) and equation (3.8). These equations are implemented in Matlab / Simulink as shown in Fig.5.3.

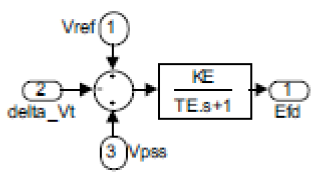

Fig.5.3: Simulink layout of excitation system

D. Power system stabilizer implementation

The PSS model presented in equation (3.9) is implemented in Matlab / Simulink as shown in Fig.5.4. The input signal to PSS is speed deviation and the output signal is VPSS which is an auxiliary signal to the excitation system.

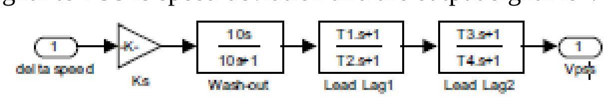

Fig.5.4: PSS implementation in Simulink

E. Case study

The performance of single machine connected to infinite bus power system is tested under a selected operating condition; the dynamic system response is analyzed considering the following variables:

1. Rotor angle deviation
2. Velocity/Speed deviation

The operating condition is listed below, where K5 < 0 [6]:

ISSN: 1475-7192

Operating condition:
K_1= 0.9831 K_2= 1.0923
K_3= 0.3864 K_4= 1.4746
K_5= - 0.1103 K_6= 0.4477

T_{do}' =5 sec, T_A =0.2 sec, H=6 sec

Considering the operating condition listed above; the system response without PSS during a step load disturbance oscillates and goes out of stability.

F. Simulation Results

Table 5.1 presents a PSS parameters designed by Genetic Algorithm (GA) [4]. PSO is used in this paper to tune PSS parameters as described in the previous section. Table 5.2 presents the PSS parameters as designed by PSO.

TABLE 5.1
PSS PARAMETERS [4]

T1	T2	T3	T4	Kpss
1.4557	0.6143	1.0083	0.1005	2.1783

TABLE 5.2
PSS PARAMETERS DESIGNED BY PSO

T1	T2	T3	T4	Kpss
0.3730	0.1096	0.7910	0.0819	7.1144

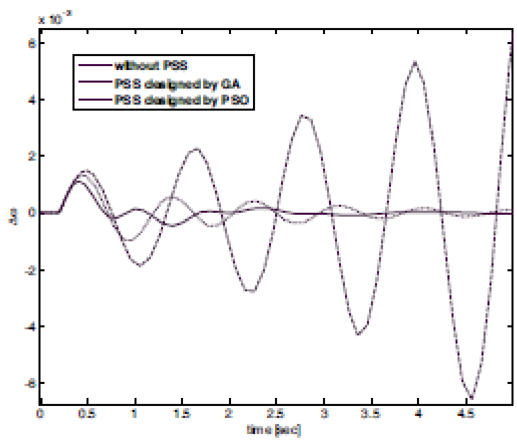

Fig 5.5: Speed deviation during 15% step load change

Figure 5.5 compare the generator speed deviation without PSS, with GA designed PSS, and with the proposed PSO designed PSS during 15% load change. It is clear that the proposed PSS enhance the speed deviation compared to the designed PSS as published in [4].

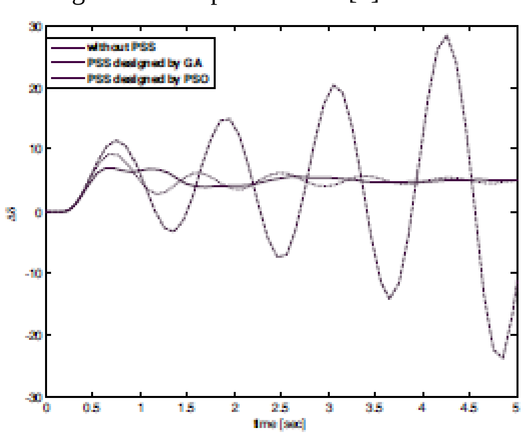

Fig 5.6: Rotor angle deviation during 15% step load change

Figure 5.6 compare the generator rotor angle deviation without PSS, with GA designed PSS, and with the proposed PSO designed PSS during 15% load change. It is clear that the proposed PSS improve the system transient stability.

VI. CONCLUSION

The power system is subjected to different types of disturbances such as small changes in the load that affects its efficiency and sometimes leads to unstable system. These disturbances cause oscillations at low frequencies that are undesirable since it affects the amount of transferred power through the transmission lines and leads to external stress to the mechanical shaft. To avoid such situation a power system stabilizer is added to the Automatic Voltage Regulator (AVR) to enhance stability in the dynamic range as well as in the first few cycles after a disturbance. The input control signal to the Power system Stabilizer (PSS) is selected to be the deviation in the generator speed $(\Delta\omega)$. The single machine-infinite bus system is used in this paper as a case study. The effect of the PSS on the system response was studied. Analyzing the results showed that adding PSS gave more damping to the oscillatory system and brings it back to normal operation, stable. The main contribution of this paper is to design an optimal PSS.Particle Swarm optimization (PSO) is used to design the PSS parameters. The proposed PSS design enhance the system response and provide good damping to the oscillation compared with a similar design by Genetic Algorithm [4].

VII. REFERENCES

[1] Paul M. Anderson & A. A. Fouad, Power system control and Stability, IEEE PRESS, 1991.

[2] K.R Padiyar, Power system Dynamics stability & Control, John Wiley & sons (Asia), 1996.

[3] Jan Machowski, Janusz W. Bialek & James R. Bumby, Power System Dynamics and Stability,, John Wiley & sons, 1997

[4] B. Al-Hadabi, A. Al-Oissi, A. Al-Hinai, M. Al-Lawati, and A.Al-Design and implementation of a power system stabilizer for power system dynamic stability enhancement ofIndustrial Application of Energy Systems Conference (IAES'2007), Sohar, Oman, April 3-4, 2007

[5]http://pages.cpsc.ucalgary.ca/~khemka/pso/model.h tml

[6] B. S. Al-Omari, and A. S. Al- “design of PID –Swarm load frequency controller of interconnected power system “ternational Conference on Communication, Computer and Power (ICCCP'07), Muscat, Oman, February 19-21, 2007