MODELLING OF A SMIB POWER SYSTEM-A SYSTEMATIC APPROACH OF PSO WITH THE DUAL INPUT POWER SYSTEM STABILIZER

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***Abstract:** The use of Power System Stabilizers has become increasingly important to provide improved stabilization of the system. The power system stabilizers are mainly designed to stabilize the local and inter area-mode power oscillations. A PSS detects the changing of generator output power, controls the excitation value and reduces the power swing rapidly,(i.e.),power system stabilizer (pss) is used to provide damping to the rotor oscillations of the synchronous machine by controlling its excitation. The design problem of the proposed controller is formulated as an optimization problem and PSO is employed to search for optimal controller parameters. Here this paper deals with application of Particle swarm optimization for the dual input power system stabilizer (pss) in a single machine infinite bus(SMIB)system and it is compared with conventional pss. Simulation results are presented under wide range of operating Conditions. Simulation results show that proposed pss has a significantly better performance as compared to conventional pss.*

***Keywords:** power system stabilizer (PSS), dual input power system stabilizer (DIPSS), Particle swarm optimization (PSO) , Single machine infinite bus(SMIB)* .

1. Introduction

Power systems experience frequency oscillations due to any disturbances, such as, sudden change in loads, change in transmission line parameters, fluctuation in the output of the turbine and faults etc… and use of fast acting exciters with high gain AVR can contribute to oscillatory instability in power systems. This type of instability is characterized by low frequency oscillations (0.2 to 2.0 Hz). These low frequency oscillations are classified into local mode, inter area mode and torsional mode of oscillations. This type of instability can endanger system security and limit power transfer capability. An 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 stabilizers (PSS).The objective of designing pss is to provide additional damping torque without affecting the synchronizing torque at critical oscillation frequencies. A lot of different techniques have been reported in the literature pertaining to coordinated design problem of CPSS. Different techniques of sequential design of PSSs are presented [4], [5] to damp out one of the electromechanical modes at a time. However, the stabilizers designed to damp one mode and can produce adverse effects in other modes. The sequential design of PSSs is avoided in [6]–[8], where various methods for simultaneous tuning of PSS in power systems are proposed. Unfortunately, the proposed techniques are iterative and require heavy computation burden due to system reduction procedure.

In this study, PSO technique is used for optimal tuning of PSS parameter to improve optimization synthesis and the speed of convergence. In this paper, the problem of robust PSS design is formulated and PSO is used to solve this problem .The stabilizers are automatically tuned with optimization an eigen value based objective function by PSO to simultaneously shift the lightly damped and undamped electro-mechanical modes of all machines to a prescribed zone in the s-plane such that the relative stability is guaranteed and the time domain specifications concurrently secured. The effectiveness of the proposed PSO based PSS (PSOPSS) is tested on a single machine power system under different operating conditions through Eigen value analysis and some performance indices.

2. Power system modeling with PSS:

2.1 Conventional power system stabilizer:

The block diagram of conventional power system stabilizer is shown in fig(1)

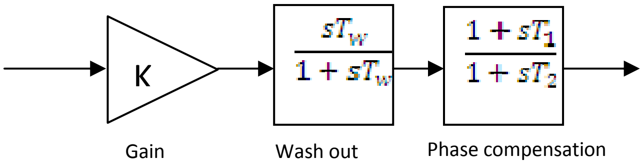


Fig-1:Block diagram of conventional power system stabilizer

The transfer function is

$$\frac{\Delta V_s}{\Delta\omega_r} = \frac{K_s(sT_W)(1+sT_1)}{(1+sT_W)(1+sT_2)}$$

Phase Lead Compensation:

To provide damping, the stabilizer must produce a component of electrical torque which is in phase with speed variations. Therefore, the PSS transfer function should have an appropriate phase-lead characteristics to compensate for the phase lag between the exciter input and the electrical torque.

Stabilizing Signal Washout:

The signal washout function is a high pass filter which removes dc signals, and without it steady changes in speed would modify the terminal voltage. The washout time constant is in the range of 1 to 20 seconds. For local mode oscillation, a wash out of 1 to 2 sec is satisfactory. From the view point of low frequency inter area oscillations a washout time constant of 10 sec or higher may be required in order to reduce phase lead at low frequencies.

Stabilizer Gain:

The stabilizer gain (KSTAB) 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. Gain is set to a value which results in satisfactory damping of the critical system mode(s) without compromising the stability of other modes, or transient stability, and which does not cause excessive amplification of stabilizer input signal noise.

Stabilizer Output Limits:

In order to restrict the level of generator terminal voltage fluctuation during transient conditions, limits are imposed on the PSS output. The effect of the two limits is to allow maximum forcing capability while maintaining the terminal voltage within the desired limits [1].

2.2 Dual Input Power System Stabilizer:

The dual input PSS, which uses power and speed as inputs, has many advantages over single input PSS, such as speed-input PSS or power input PSS, because it provides a damping torque for power system on a wide range of frequencies of concern and less sensitive to shaft torsion oscillation. In this model the stabilizing signal ΔVpss results from the vector summation of processed signals for $\Delta\boldsymbol{\omega}_r$ and Δp_e.

The block diagram for the designed dual input power system stabilizer is shown in fig2.

The time constants T1 and T3 represent the transducer time constants.T2 and T4 represents the wash out time constants. The transducer gain constant, K1 is negative and another transducer gain constant, K2 is positive.

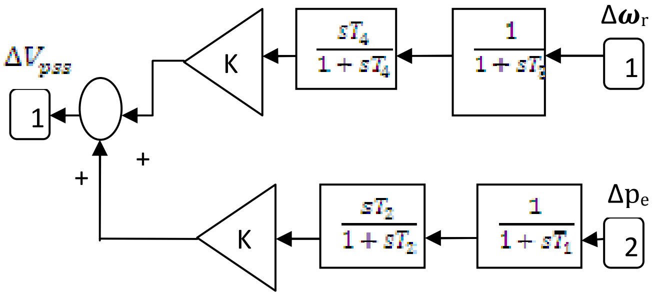


Fig.2: Block diagram for the designed dual input power system stabilizer

3. SMIB Model

A Single machine infinite bus (**SMIB**) model of a power system shown in fig-3 is used for evaluating the proposed design method is considered. A machine connected to a large system through a transmission line may be reduced to a SMIB system, by using Thevenin's equivalent of the transmission network external to the machine.

The two-axis synchronous machine representation with a field circuit in the direct axis but without damper windings is considered for the analysis.

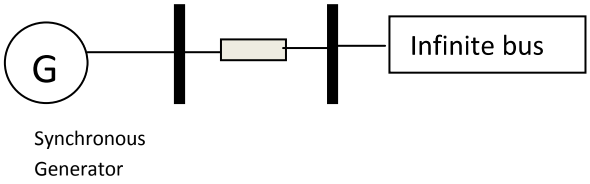


Fig -3: single line diagram of SMIB model

The equations describing the steady state operation of a synchronous generator connected to an infinite bus through an external reactance can be linearized about any particular operating point as follows:

$$\Delta T_m - \Delta P = M\frac{d^2\Delta\delta}{dt^2}$$

$$\Delta P = K_1\Delta\delta + K_2\Delta E'_q$$

$$\Delta E'_q = \frac{K_3}{1+sT'_{d0}K_3}\Delta E_{fd} - \frac{K_3K_4}{1+sT'_{d0}K_3}\Delta\delta$$

$$\Delta V_t = K_5\Delta\delta + K_6\Delta E'_q$$

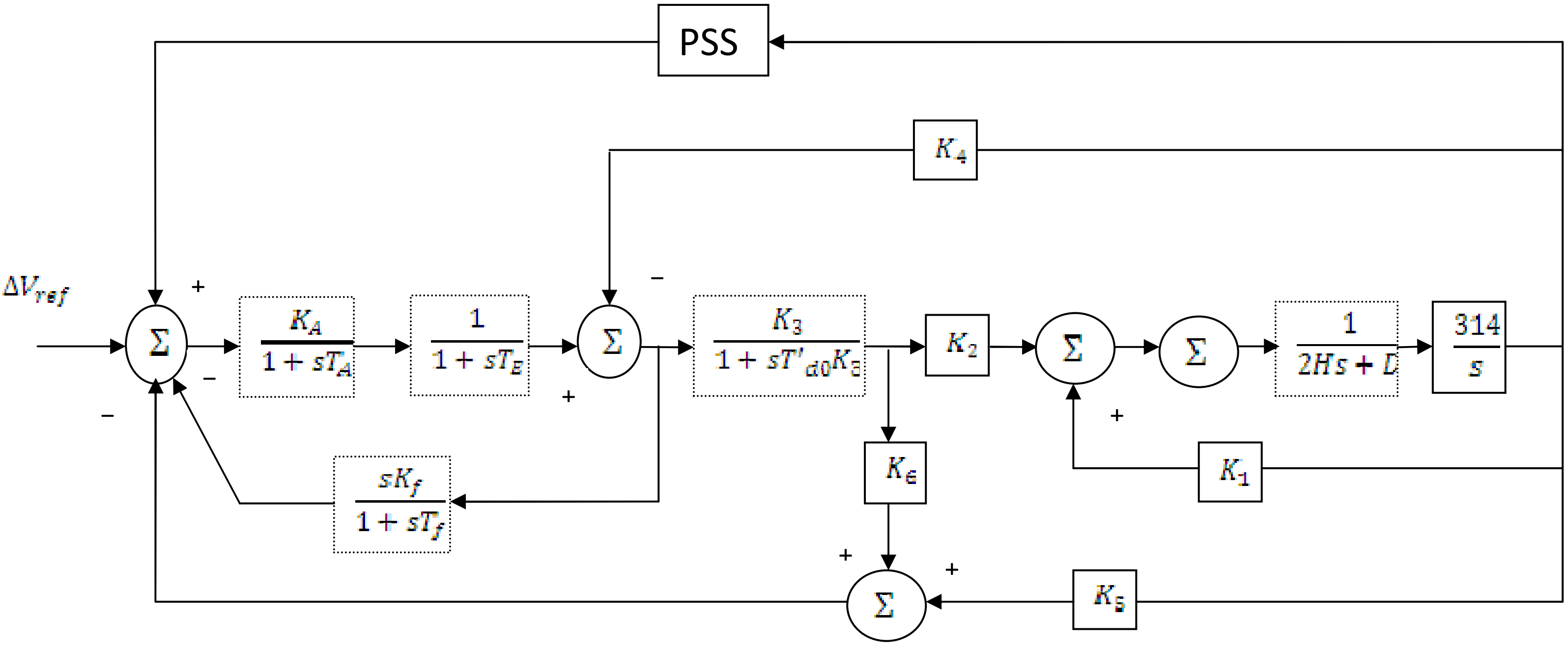


Fig4: Block diagram of AVR and PSS

The interaction between the speed and voltage control equations of the machine is expressed in terms of six constants K_1-K_6.These constants with the exception of K_3, which is only a function of the ratio of impedance, are dependent upon the actual real and reactive power loading as well as the excitation levels in the machine.

The expressions for K-constants are given by

$$K_1 = \frac{E_0 E_{q0} \cos \delta 0}{(x_e + x_q)} + \frac{(x_q - x'_d)}{(x_e + x'_d)} E_0 i_{q0} \sin \delta_0$$

$$K_2 = \frac{E_0 \sin \delta 0}{x_e + x'_d}$$

$$K_3 = \frac{x_d + x_e}{x_d + x'_d}$$

$$K_4 = \frac{x_q - x'_d}{x_d + x_e} E_0 \sin \delta_0$$

$$K_5 = \frac{x_q}{x_e + x_q} \frac{v_{d0}}{Vt0} E_0 \cos \delta_0 - \frac{x_d}{x_e + x'_d} \frac{v_{q0}}{Vt0} E_0 \sin \delta_0$$

$$K_6 = \frac{x_e}{x_e + x_q} \frac{v_{q0}}{V_{t0}}$$

4. Particle Swarm Optimization

PSO is a novel population based meta heuristic, which utilize the swarm intelligence generated by the cooperation and competition between the particle in a swarm and has emerged as a useful tool for engineering optimization. It has also been found to be robust in solving problems featuring non-linearing, non-differentiability and high dimensionality [9-11].Similar to evolutionary algorithms, the PSO technique conducts searches using a population of particles, corresponding to individuals. In a PSO system [3], particles change their positions by flying around in a multidimensional search space until a relatively changed position has been encountered, or until Computational limitations are exceeded. The following are the advantages of PSO [2] over other traditional optimization techniques. PSO is a population based search algorithm. This property ensures it to be less susceptible to getting trapped on local minima.PSO uses payoff (performance index or objective function) information to guide the search in the problem space. PSO uses probabilistic transition rules and not deterministic rules. Hence, PSO is a kind of stochastic optimization algorithm that can search a complicated and uncertain area.

4.1 Designing of objective function:

Very often, the closed-loop modes are specified to have some degree of relative stability. In this case closed-loop eigen values are constrained to lie to the left of a vertical line corresponding to a specified damping factor. The parameters of the PSS are to be selected so that some degree of relative stability and damping of electro-mechanical modes of oscillations, minimized undershoot, minimized overshoot and lesser settling time of oscillations are achieved. Therefore, to satisfy all these requirements, objective function is designed which is subject to a set of constraints based on the finite bounds for stabilizer parameters.

$$H1 = \sum_i (\delta_0 - \delta_i) \ if \ \delta_i \leq \delta_0$$

$$H_{12} = \sum_i (\alpha_0 - \alpha_i)^2$$

if (imaginary part of the ith eigen value)>0

Minimization of this objective function will minimize maximum overshoot.

$$H_{13} = \sum_i (imaginary\ part\ of\ ith\ eigen\ value)^2$$

if $\delta_i \geq -2.0$.

High Value of imaginary part of ith eigen value to the right of vertical line δ_0 =-2.0 is to be prevented. Zeroing H_3 will increase the damping further.

H_4=an arbitrarily chosen very high fixed value (say,10),which will indicate some δ_i values≥0.0. This means that unstable oscillation occurs for the particular parameters of PSS. These particular PSS parameters will be rejected during the selection step of the PSO cycles.

So, first multi- objective optimization function is

$$H_1=10H_{11}+10H_{12}+0.01H_{13}+H_{14}$$

The weighting factors 10 and 0.01 are selected to impart more weight to H1 and H2 and to reduce high value of H3, to make them mutually competitive during optimization.H3 will be high if imaginary part of ith eigen value is large. By optimizing H1, closed loop system poles are, thus increasing the damping ratios above α_0(0.2).Finally, all closed loop system poles should lie within a D- shaped sector in the negative half plane of jω –axis for which δ_0<< -2.0,α_i>> 0.2.Through computation shows that optimization of H1 is not sufficient for sharp tuning of PSS parameters. So it has become essential to design second multi optimization function.H_2 for sharp tuning of PSS parameters.

$$H_2 = (\delta_{sh} \times 0.3 \times 10^{7})^2 + t_{st}{}^2 + (\frac{d}{dt}(\Delta\omega) \times 0.3 \times 10^{2})^2$$

The weighing factors 0.3×107 are selected so that optimization of overshoot and undershoot etc may compete with that of settling time. The constrained optimization problem for the power system stabilizers is formulated here. Minimize H_1 and H_2in succession with the help of PSO based optimization of PSS parameters, which is subjected to the limits as:

For PSS

$-100.0 \leq Ks_1 \leq -10.0$
$10.0 \leq Ks_2 \leq 100.0$
$0.005 \leq Ti \leq 2.0$, i=1,2,3,4

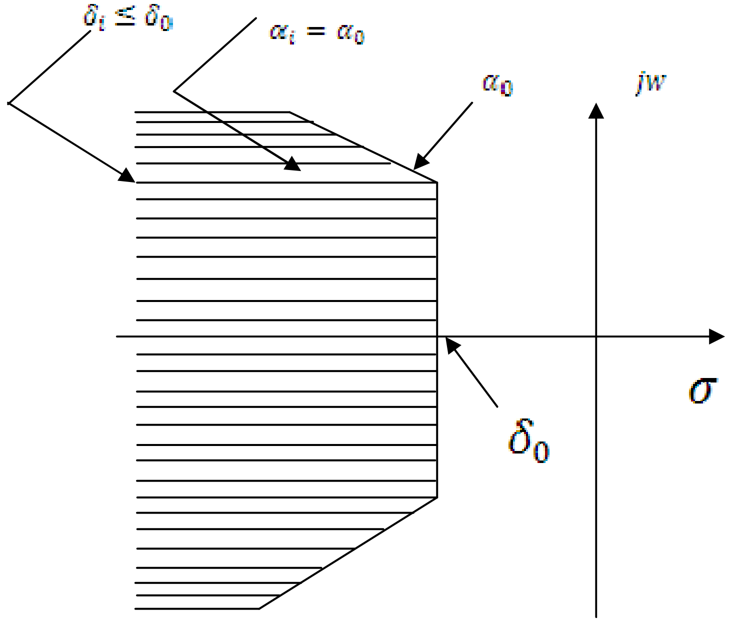


Fig. 5 – Region in the left-hand side of a vertical plane.

Mathematically, the particles are manipulated according to the following equation. The velocity of ith component of jth particle of the swarm is updated in current iteration cycle(k) as:

$$V_{j,i}(k) = w(k) * V_{j,i}(k-1) + c_1 * Rnd_1 * \left(x^*_{j,i}(k-1) - x_{j,i}\right.$$

The position of ith component of jth particle is updated /manipulated as

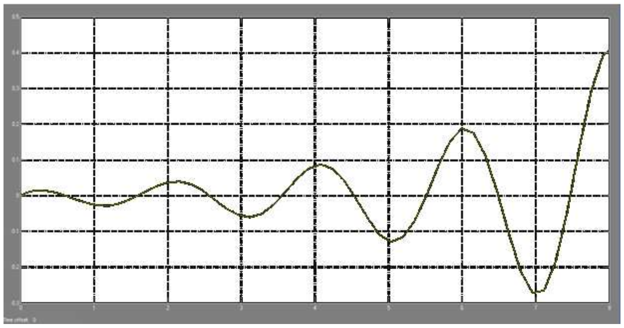
$$x_{j,i}(k) = x_{j,i}(k-1) + V_{j,i(k)}$$

C1 and C2 are positive constants and Rnd1 and Rnd2 are uniformly distributed random numbers in [0 1].

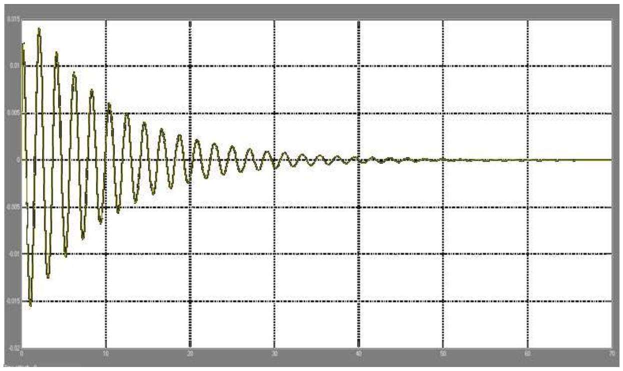
5. Simulation results:

1. Operating at P=0.9, Q=0.1, Vt=1.0 E=1.0 pu

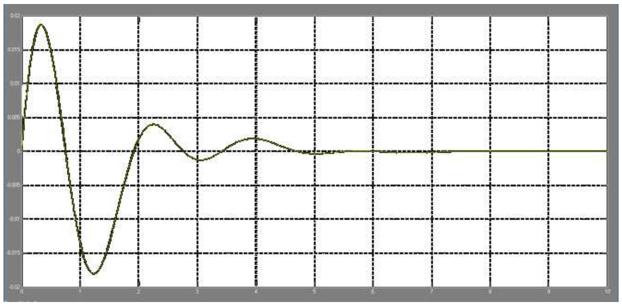
Without PSS



With conventional PSS

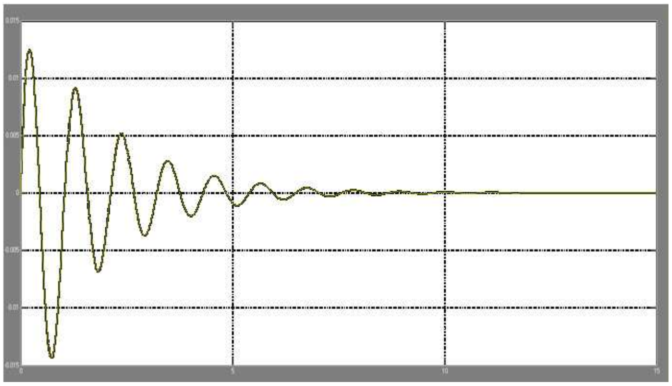


With dual input PSS



2. Operating at P=0.5,Q=0.2,X=0.4752,Vt=1.0,E=1.0

With dual input PSS



Similarly much better response can be obtained for different operating conditions [12]using dual input PSS when compared with conventional PSS.

6. Appendix:

Dual input PSS with PSO is tested under following operating conditions[12]

P(PU)	Q(PU)	Vt(PU)	E(PU)
0.9	0.1	1.0	1.0
0.5	0.2	0.4752	1.0
0.75	0.50	0.4752	0.50
0.95	0.30	0.4752	0.5
0.95	0.30	1.08	0.5
1.2	0.6	0.93	1.0

7. Conclusion:

The PSO dual input PSS does not need any fixed parameter setting and the change in electrical feedback of accelerating power is to be negative. So, K_{s1} is made negative to obtain the desired amplitude and phase of the stabilizing signal. Much lower negative real parts of the eigen values of PSS cause higher relative stability .This PSS takes the least sample based computation time because of lesser size of state matrix having only eight eigen values. So, this can handle more number of input samples for a given time.

Results evaluation show that the proposed method achieves good robust performance for damping low frequency oscillations under different operating conditions.

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