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# Multi Machine Power System Stabilizer Design Using Particle Swarm Optimization Technique

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***ABSTRACT:*** *In this paper, multi objective design of multi-machine Power System Stabilizers (PSSs) using Particle Swarm Optimization (PSO) is presented. The stabilizers are tuned to simultaneously shift the lightly damped and undammed electro-mechanical modes of all machines to a prescribed zone in the s-plane. A multi objective problem is formulated to optimize a composite set of objective functions comprising the damping factor, and the damping ratio of the lightly damped electromechanical modes. The PSSs parameters tuning problem is converted to an optimization problem which is solved by PSO with the eigen value-based multi objective function. The proposed PSO based PSSs is tested on a multi machine power system under different operating conditions and disturbances through eigen value analysis and some performance indices to illustrate its robust performance. The eigen value sensitivity analysis has been used for PSS design in many literatures under deterministic system operating conditions. To consider the effect of more system operating factors, the technique of probabilistic eigen value analysis was proposed and has been applied for the parameter design of power system damping controllers. In the probabilistic eigen value analysis the system stability is enhanced by shifting the distribution ranges of the critical eigen values to the left side of the complex plane. A new approach for the optimal decentralized design of PSSs with output feedback is investigated in.*

***Key words****: Eigen value analysis, Genetic Algorithm, Particle Swarm Optimization, Power System Stabilizers.*

## I. Introduction

STABILITY of power systems is one of the most important aspects in electric system operation. This arises from the fact that the power system must maintain frequency and voltage in the desired level, under any disturbance, the development of interconnection of large electric power systems; there have been spontaneous system oscillations at very low frequencies in the order of 0.2 to 3.0Hz. Moreover, low-frequency oscillations present limitations on the power-transfer capability.

To enhance the system damping, the generators are equipped with power system stabilizers (PSSs) that provide supplementary feedback stabilizing signals in the excitation systems. The robustness nature of the CPSS is due to the fact that the torque-reference voltage and transfer function remains approximately invariant over a wide range of operating conditions. A gradient procedure for optimization process which requires of PSS parameters at different operating conditions is presented in this optimization process requires computations of sensitivity factors and eigenvectors at each iteration. This gives rise to heavy computational burden and slow convergence. Though the conventional methods content with a good solution it could not able to locate or identify the global optimum. Consequently, heuristic methods are widely used for global optimization problems. Recently, global optimization techniques like genetic algorithms (GA), evolutionary **programming, Tabu** search, simulated annealing and rule based bacteria foraging have been applied for PSS parameter optimization. These evolutionary algorithms are heuristic population-based search procedures that incorporate random variation and selection operators. Although,these methods seem to be good methods for the solution of PSS parameter optimization problem. However, when the system has a highly epistatic objective function (i.e. where parameters being optimized are highly correlated), and number of parameters to be optimized is large, then they have degraded efficiency to obtain global optimum solution and also simulation process use a lot of computing time. Moreover, in the robust PSS design was formulated as a single objective function problem, and not all PSS parameter were considered adjustable. In order to overcome these drawbacks, a Particle Swarm Optimization (PSO) based PSS (PSOPSS) is proposed in this paper. In this study, PSO technique is used for optimal tuning of PSS parameter to improve optimization synthesis and the speed of algorithms convergence PSO is a novel population based metaheuristic, which utilize the swarm intelligence generated by the cooperation and competition between the particles 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.

## II. Problem Statement

### 2.1. Power system model

The complex nonlinear model related to an n–machine interconnected power system, can be described by a set of differential- algebraic equations by assembling the models for each generator, load, and other devices such as controls in the system and connecting them appropriately via the network algebraic equations. The generator in the power system is represented by Heffron-Philips model and the problem is to design the parameters of the power system stabilizers.

### 2.2. PSS Structure

The operating function of a PSS is to produce a proper torque on the rotor of the machine involved in such a way that the phase lag between the exciter input and the machine electrical torque is compensated A widely speed based used conventional PSS is considered and the transfer function. The transfer function of the $i_{th}$ PSS is given by

$$\sigma_0 \square \sigma_i$$

Where, σi is the real part of the ith eigen value, and σ0 is a chosen threshold. The value of σ0 represents the desirable level of system damping. This level can be achieved by shifting the dominant eigen values to the left of s=σ0 line in the s-plane. This also ensures some degree of relative stability. The condition σi≥σ0 is imposed on the evaluation of J1 to consider only the unstable or poorly damped modes that mainly belong to the electromechanical ones. The relative stability is determined by the value of σ0.

$$U_i = K_i \frac{sT_W}{1+sT_W} \frac{(1+sT_{1i})(1+sT_{3i})}{(1+sT_{2i})(1+sT_{4i})} \Delta\, \omega_i(s)$$

Where, Δωi is the deviation in speed from the synchronous speed.

This type of stabilizer consists of a washout filter, a dynamic compensator. The output signal is fed as a supplementary input signal, Ui, to the regulator of the excitation system. The washout filter, which essentially is a high pass filter, is used to reset the steady-state offset in the output of the PSS. The value of the time constant Tw is usually not critical and it can range from 0.5 to 20 s. In this paper, it is fixed to 10 s. The dynamic compensator is made up to two lead-lag stages and an additional gain. The adjustable PSS parameters are the gain of the PSS, Ki, and the time constants, T1i-T4i. The lead-lag block present in the system provides phase lead compensation for the phase lag that is introduced in the circuit between the exciter input and the electrical torque. The required phase lead can be derived from the lead-lag block even if the denominator portion consisting of T2i and T4i gives a fixed lag angle. Thus, to reduce the computational burden here, the values of T2i and T4i are kept constant at a reasonable value of 0.05 s and tuning of T1i and T3i are undertaken to achieve the net phase lead required by the system.

### 2.3. Objective function

1) In this case, the 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 may be selected to minimize the following objective function
2) To limit the maximum overshoot, the parameters of the PSS may be selected to minimize the following objective function

$$J_1 = \sum (\sigma_0 - \sigma_i)^2$$

$$J_2 = \sum (\zeta_0 - \zeta_i)$$

$$\zeta_i \leq \zeta_0$$

Where ζi is the damping ratio of the $i^{th}$ eigen value. This will place the closed-loop eigen values in a wedge-shape sector in whichζi≥ζ0.

In the case of J2, ζ0 is the desired minimum damping ratio, which is to be achieved. This is usually the case in dynamic stability where it is desired to relocate the electromechanical modes of oscillations.

3) The parameters of the PSS may be selected to minimize the following objective function:

$$J_3 = J_1 + aJ_2$$

This will place the system closed-loop eigen values in the D-contour sector characterized by σi ≤ σ0 and ζi ≥ ζ0.

The optimization problem can be stated as:
Minimize Ji subject to:

$K_i^{min} \leq Ki \leq Ki$

$T_{1i}^{min} \leq T_{1i} \leq T_{1i}^{max}$

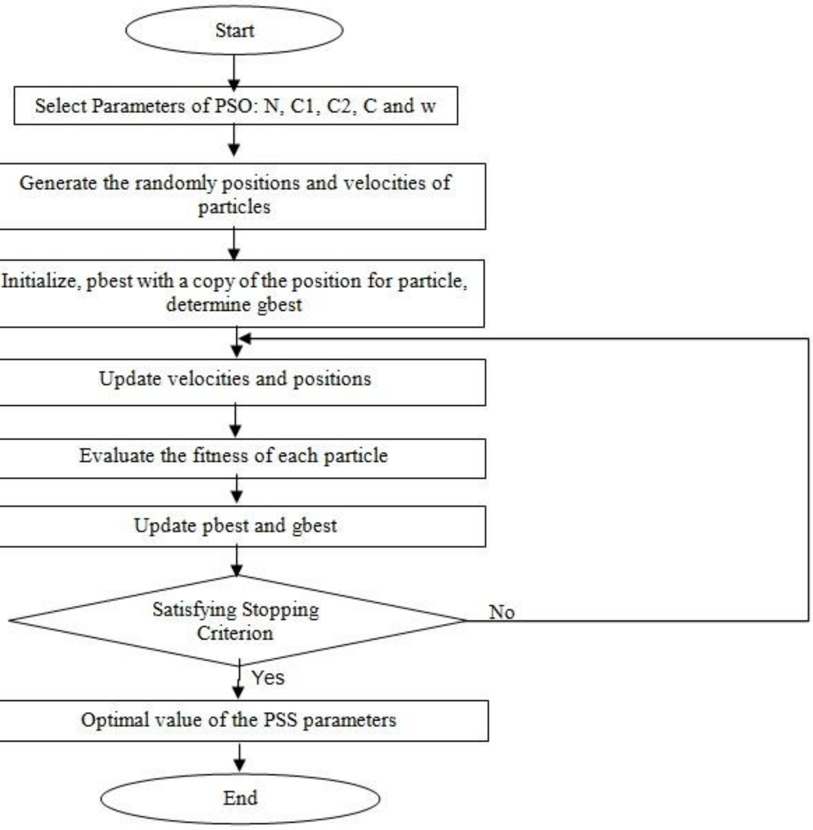
$T_3{}^{min}{}_i \leq T_{3i} \leq T_3{}^{max}{}_i$

The proposed approach employs PSO to solve this optimization problem and search for an optimal set of PSS parameters, Ki , T1i and T3i ; i=1, 2,3.

## III. PSO Technique

Particle swarm optimization algorithm, which is tailored for optimizing difficult numerical functions and based on metaphor of human social interaction, It is capable of mimicking the ability of human societies to process knowledge. It has roots in two main component methodologies. Artificial life(such as bird flocking, fish schooling and swarming) and, Evolutionary computation. Its key concept is that potential solutions are flown through hyperspace and are accelerated towards better or more optimum solutions. Its paradigm can be implemented in simple form of computer codes and is computationally inexpensive in terms of both memory requirements and speed. It lies somewhere in between evolutionary programming and the genetic algorithms. Vectors are taken as presentation of particles since most optimization problems are convenient for such variable presentations. In fact, the fundamental principles of swarm intelligence are adaptability, diverse response, proximity, quality, and stability. It is adaptive corresponding to the change of the best group value. The higher dimensional space calculations of the PSO concept are performed over a series of time steps. The population is responding to the quality factors of the previous best individual values and the previous best group values. As it is reported in , this optimization technique can be used to solve many of the same kinds of problems as GA, and does not suffer from some of GAs difficulties. It has also been found to be robust in solving problem featuring non-linearing, non-differentiability and high-dimensionality. PSO is the search method to improve the speed of convergence and find the global optimum value of fitness function.

3.1. A Flow Chart of the Proposed PSO technique



### 3.2. Case study

**Table 1 : Generator Operating Conditions (in PU)**

| Gen | Nominal | | Heavy | | Light | |
|---|---|---|---|---|---|---|
| | P | Q | P | Q | P | Q |
| $G_1$ | 0.72 | 0.27 | 2.21 | 1.09 | 0.36 | 0.16 |
| $G_2$ | 1.63 | 0.07 | 1.92 | 0.56 | 0.80 | -0.11 |
| $G_3$ | 0.85 | -0.11 | 1.28 | 0.36 | 0.45 | -0.20 |

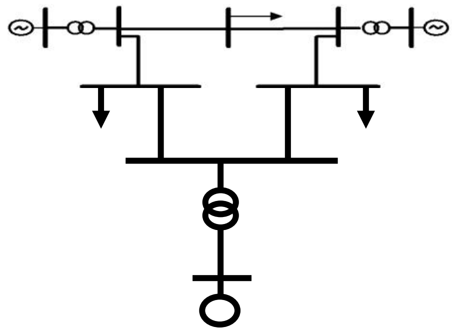


**Table 2 : Loading Conditions (in PU)**

| Load | Nominal | | Heavy | | Light | |
|---|---|---|---|---|---|---|
| | P | Q | P | Q | P | Q |
| A | 1.25 | 0.50 | 2.00 | 0.80 | 0.65 | 0.55 |
| B | 0.90 | 0.30 | 1.80 | 0.60 | 0.45 | 0.35 |
| C | 1.00 | 0.35 | 1.50 | 0.60 | 0.50 | 0.25 |

In this study, the three-machine nine-bus power system is considered. Detail of system data are given in Ref.
To assess the effectiveness and robustness of the proposed method over a wide range of loading conditions, three different cases designated as nominal, light and heavy loading conditions are considered. The generator and system loading levels at these cases are given in Tables 1 and 2.

## IV. Conclusion

An optimal multi objective design for multi machine power system stabilizers using PSO technique has been proposed. The stabilizers are tuned to simultaneously shift the lightly damped electromechanical modes of all plants to a prescribed zone in the s-plane.

A multi objective problem is formulated to optimize a composite set of objective functions comprising the damping factor, and the damping ratio of the lightly damped electromechanical modes. The design problem of the robustly PSSs parameters selection is converted into an optimization problem which is solved by a PSO technique with the eigen value-based multi objective function.

Eigen value analysis give the satisfactory damping on system modes, especially in low-frequency modes, for the systems with the proposed multi-objective function based tuned PSSs. Time-domain simulations show that the oscillations of synchronous machines can be quickly and effectively damped for power systems with the proposed PSSs over a wide range of loading conditions. The system performance characteristics in terms of 'ITAE' and 'FD' indices reveal that the proposed multi-objective function based tuned PSSs demonstrates its superiority in computational complexity, success rate and solution quality.

## V. Appendix: Machine Models

$\delta_i = \omega_b(\omega_i - 1)$ (A.1)

$$\omega_i = \frac{1}{M_i}(P_{mi} - P_{ei} - D_i(\omega_i - 1)) \quad \text{(A.2)}$$

$$\dot{E}_{qi} = \frac{1}{T'_{doi}}(E_{fdi} - (x_{di} - x'_{di})i_{di} - E'_{qi}) \quad \text{(A.3)}$$

$$\dot{E}_{fdi} = \frac{1}{T_{Ai}}(K_{Ai}(v_{refi} - v_i + u_i) - E_{fd}) \quad \text{(A.4)}$$

$T_{ei} = E'_{qi}i_{qi} - (x_{qi} - x'_{di})i_{di}\, i_{qi}$ (A.5)

## VI. Future Of Work

It's proposed to implement damping of low frequency oscillations with Multi machine Infinite bus system using GENITIC ALGORITHM (GA) to the system and the simulated results are compared with and without power system stabilizer in the future Of work.

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