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Enhancement of dynamic stability using PSOMBPSS

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ABSTRACT: 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. This paper is an investigation of the use of Multiband power system stabilizers to the generators of single machine infinite bus power system. In this paper, the small-signal of a single machine test system will be investigated with regard to the LFO problem. In this work an optimization technique is proposed to find the optimal parameters of Multiband Power System Stabilizer (MBPSS). A simple design method is proposed for the MBPSS to minimize the maximum overshoot. The optimization is based on a Particle Swarm optimization (PSO) aiming to find the optimal parameter set of the stabilizer. The designed PSS is applied to a single machine infinite bus system operating at different loading conditions and the results demonstrated the effectiveness of the developed technique.

I. INTRODUCTION

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 goals of maximum power transfer and power system security.

Power systems are in general nonlinear and the operating conditions can vary over a wide range. Recently, small signal stability has received much attention. The increasing size of generating units, the loading of the transmission lines and the high-speed excitation systems are the main causes of affecting the small signal stability. Conventional fixed structure Power System Stabilizers (CPSS) are widely used by power system utilities to damp out small oscillations.

Automatic voltage regulators (AVRs) helped to improve the steady-state stability of the power systems, but transient stability became a concern for the power system operators. With the creation of large, interconnected power systems, another concern was the transfer of large amounts of power across extremely long transmission lines. The addition of a supplementary controller into the control loop, such as the introduction of power system stabilizers (PSSs) to the AVRs on the generators, provides the means to reduce the inhibiting effects of low frequency oscillations [1]. The control method investigated in this thesis will focus on the use of a Multi Band power system stabilizer (MBPSS) in conjunction with the automatic voltage regulators (AVRs) of the generators in the test system to mitigate any LFOs. Damping of the LFOs contributes to the enhancement of the stability limits of the system, signifying greater power transfer through the system. The application of MBPSSs with local input signals for this particular control problem has been previously investigated. However, the use of the same controller to satisfy different end goals, namely the damping of local and inter-area modes over a broad range of operating points, has revealed itself to be difficult to achieve. Often a PSS that is expected to damp oscillations over a broad range of frequencies is not able to sufficiently damp every oscillatory mode that might be excited in the system.

II. MULTIBAND POWER SYSTEM STABILIZER (MBPSS)

The main characteristics of the MB-PSS model (IEEE PSS4B) [4] are shown in Fig. 1. As for conventional PSS [3], the MB-PSS comprises three main functions, the transducers, the lead-lag compensation and the limiters. Two speed deviation transducers are required to feed the three band structure used as lead-lag compensation. Four adjustable limiters are provided, one for each band and one for the total PSS output. The low band usually found in the range of 0.05 Hz ,is taking care of very slow oscillating phenomena such as common modes found on isolated system.

The intermediate band is used for inter-area modes usually found in the range of 0.2 to 1.0 Hz. The high band is dealing with local modes, either plant or inters machines, with a typical frequency range of 0.8 to 4.0 Hz.

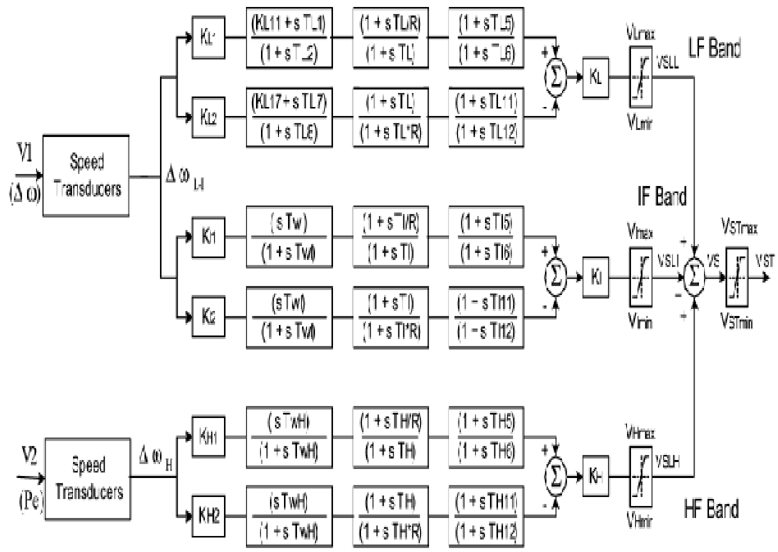

Fig. 1. IEEE PSS4B model of the MB-PSS.

III. POWER SYSTEM MODEL

A single machine-infinite bus (SMIB) system is considered for the present investigations. A schematic diagram for the models are shown in Fig. 2. The generator is equipped with excitation system and a power system stabilizer. A SMIB power system model as shown in Fig. 3 is used to obtain the modified Heffron-Phillip's model parameters.

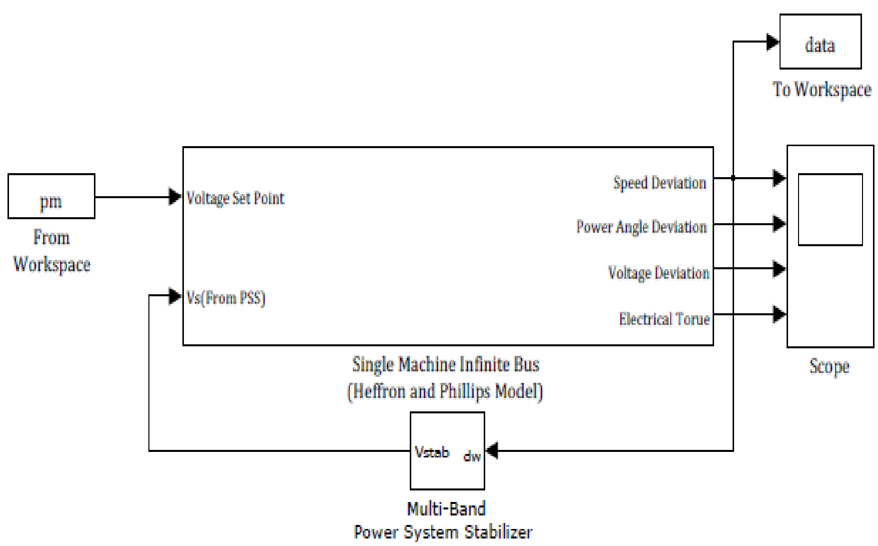

Fig. 2. MATLAB/Simulink Model of SMIB connected to MBPSS.

IV. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a stochastic optimization, evolutionary and simulating algorithm derived from human behaviour and animal behaviour as well. Special property of particle swarm optimization is that it can be operated in continuous real number space directly, does not use gradient of an objective function similar to other algorithms. Particle swarm optimization has few parameters to adjust, is easy to implement and has special characteristic of memory.

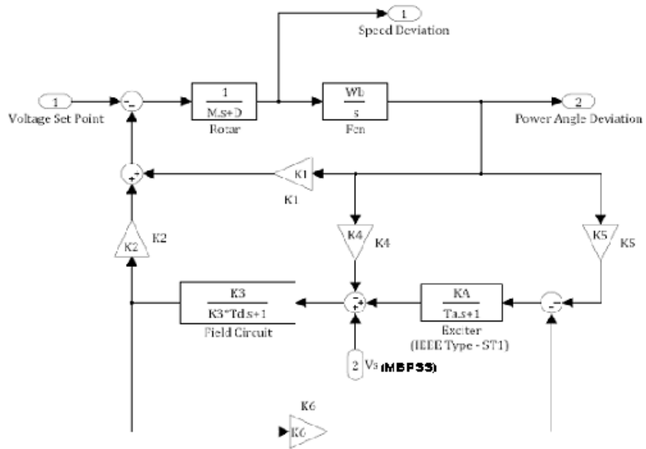

Fig. 3. Heffron-Phillip's model of SMIB.

Particle Swarm Optimization (PSO) is an evolutionary computation technique, developed for optimization of continuous non linear, constrained and unconstrained, non differentiable multimodal functions [31]. PSO is inspired firstly by general artificial life, the same as bird flocking, fish schooling and social interaction behaviour of human and secondly by random search methods of evolutionary algorithm [32]. Animals, especially birds, fishes etc. always travel in a group without colliding, each member follows its group, adjust its position and velocity using the group information, because it reduces individual's effort for search of food, shelter etc.

Particle Swarm Optimization (PSO) is an evolutionary stochastic computation technique, developed for optimization of continuous non linear, constrained and unconstrained, non differentiable multimodal functions [32]. Genetic algorithm and other similar techniques (e.g. simulated annealing), work for discrete design variables, whereas particle swarm optimization work for discrete as well as analogue systems, because it is inherently continuous. The essence for the development of particle swarm optimization was the assumption that potential solution to an optimization problem is treated as a point flying like bird in multi dimensional space, adjusting its position in search space according to its own previous experience and that of its neighbors [32]. This point has got no mass and volume and is called a particle as it has velocity vector. The particle moves towards an optimum solution through its present velocity and its individual best solution obtained by itself in each iteration and global best solution is obtained by all particles.

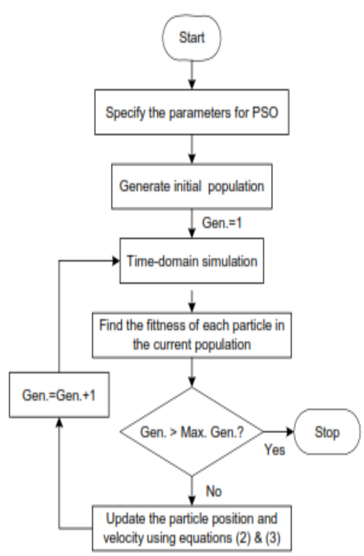

Fig. 4. Flow chart of particle swarm optimization algorithm.

V. DESIGN METHODOLOGY

In the proposed approach, the stabilizer is designed & all the parameters are optimized simultaneously using PSO optimization method. Particle Swarm Optimization (PSO) is an evolutionary computation technique, developed for optimization of continuous non linear, constrained and unconstrained, non differentiable multimodal functions. PSO is inspired firstly by general artificial life, the same as bird flocking, fish schooling and social interaction behaviour of human and secondly by random search methods of evolutionary algorithm [32]. Animals, especially birds, fishes etc. always travel in a group without colliding, each member follows its group, adjust its position and velocity using the group information, because it reduces individual's effort for search of food, shelter etc. In this study, the PSS design problem is formulated as an optimization problem and solved by PSO method to improve optimization synthesis and find the global optimum value of the fitness function. Selection of a desirable fitness function is very important to optimize PSS parameters. Because, different fitness functions promote different PSO PSS behaviors. For our optimization problem, an Integral of Absolute Error (IAE) based objective function for multiple operation conditions is considered where; t_s is the time range of simulation.

The salient feature of this objective function is that it needs the minimal dynamic plant information. It is aimed to minimize this objective function in order to improve the system response in terms of the settling time and overshoots. The design problem can be formulated as the following constrained optimization problem, where the constraints are the PSS parameters bounds the proposed approach employs PSO to solve this optimization problem and search for the optimal set of PSSs parameters. Robustness is verified by considering numerous operating conditions

VI. OBJECTIVE FUNCTION

In this study, an Integral of absolute Error (IAE) of the speed deviation as the objective functions for SMIB system, which can be expressed as follows:

$$J = \int_0^{t_s} \left| \Delta \omega \right| dt$$

$$J = \sum_{t=0}^{t_s} \left| \Delta \omega \right| \qquad \ldots (.1)$$

VII. SIMULATION RESULT

The behavior of the proposed PSO based designed MBPSS under faulty conditions is verified by applying the small perturbation for SMIB. System responses in the form of speed deviation, power angle deviation, voltage deviation & electrical torque are plotted. It can be seen that the system without MBPSS is highly oscillatory. PSO based MBPSS tuned are able to damp the oscillations reasonably well and stabilize the system at faulty conditions. System is more stable in this case, following any disturbance. PSO based MBPSS improve its dynamic stability considerably. The proposed PSO based MBPSS is effectual and achieves good system damping characteristics. These simulation have been carried out using MATLAB and SIMULINK in MATLAB 7.10.a on a core 2 duo, 2 GHz, 2.99 GB RAM. There is Small step increase in reference Voltage setting (ΔV_{ref} = 0.05p.u.) is the operating case we analyze.

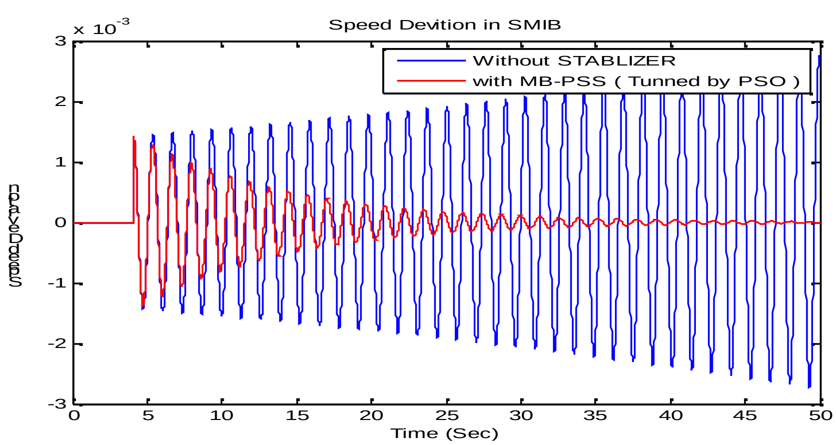

Fig. 5. Speed Deviation without PSS & with PSO based MBPSS fault at t = 5 sec.

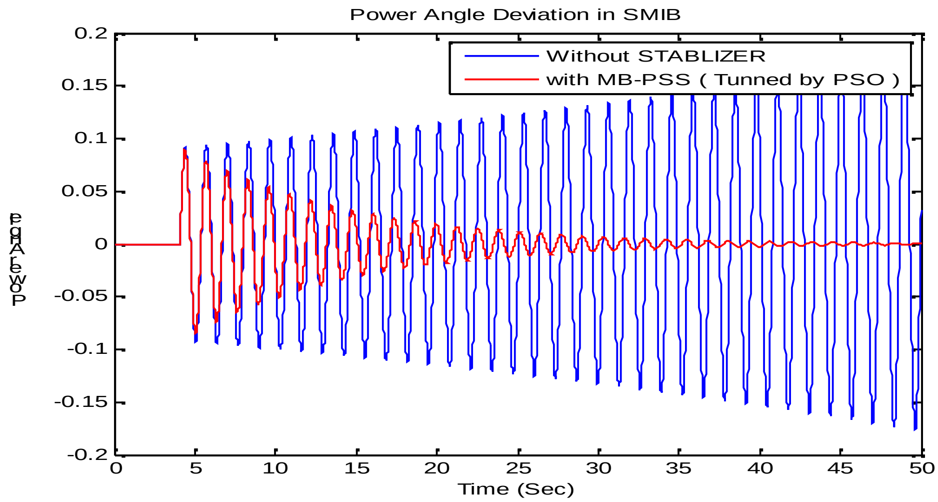

Fig. 6. Power Angle without PSS & with PSO based MBPSS fault at t = 5 sec

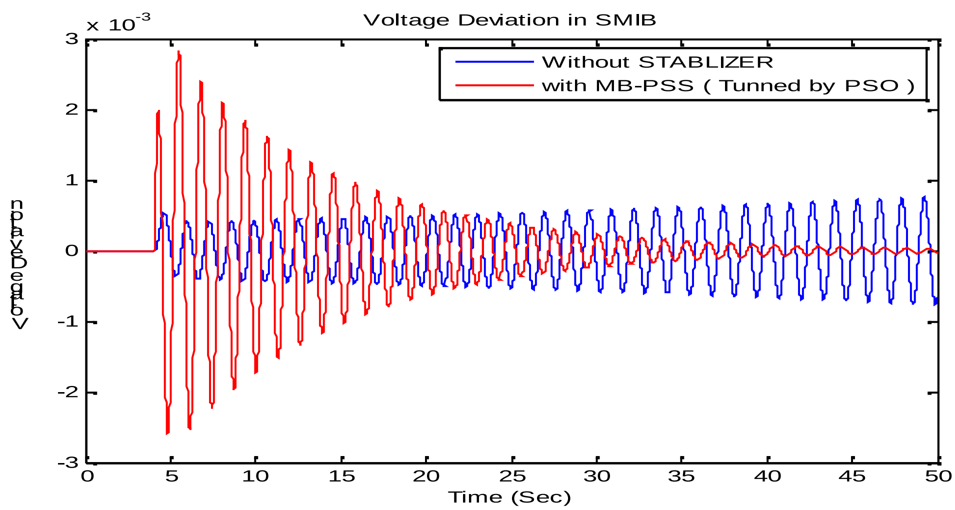

Fig. 7. Voltage Deviation without PSS & with PSO based MBPSS fault at t = 5 sec.

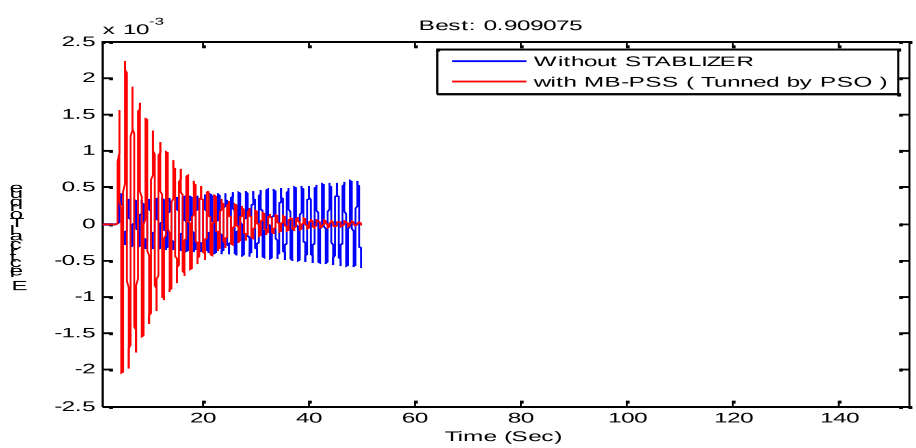

Fig. 8. Electrical torque without PSS & with PSO based MBPSS, fault at t = 5 sec.

VIII. CONCLUSION

The stability for a system of a signal machine connected to an infinite bus has been done in the work by considering different disturbances. The performance of the system with a PSO Power system stabilizer (PSOMBPSS) is analyzed using MATLAB and SIMULINK software. The investigations reveal that the PSOMBPSS has very good damping characteristics and thus its performance is satisfactory.

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