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Improvement of LFO Problem using PSO Optimization Technique in Multi Band Power System Stabilizer

Ankit Awasthi*, Abhijeet Singh** and P. Yadav***
**P.G. Scholar, Department of Electrical Engineering,*
Oriental College of Technology, Bhopal, (MP), INDIA
***Assistant Professor, Department of Electrical Engineering,*
Oriental College of Technology, Bhopal, (MP), INDIA
****Professor, Department of Electrical Engineering,*
Oriental College of Technology, Bhopal, (MP), INDIA

(Corresponding author: Ankit Awasthi)
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ABSTRACT: 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 PSO optimization technique is proposed to find the optimal parameters of Multiband Power System Stabilizer (MBPSS).

I. INTRODUCTION

Low frequency oscillations (LFOs) are generator rotor angle oscillations having a frequency between 0.1-3.0 Hz, and are defined by how they are created or where they are located in the power system. The use of high-gain generator exciters, poorly tuned generation excitation, HVDC converters or static var compensators may create LFOs with negative damping; this is a small-signal stability problem [1]. The mitigation of these oscillations is commonly performed with power system stabilizers (PSSs) [3]. LFOs include local plant modes, control modes, tensional modes induced by the interaction between the mechanical and electrical modes of a turbine-generator system, and inter-area modes, which may be caused by either high-gain exciters or heavy power transfers across weak tie-lines [3].Of special interest here, inter-area oscillations are on the order of 0.1-0.7 Hz, and are characterized by groups of coherent generators swinging against each other. When present in a power system, this type of oscillation limits the amount of power transfer on the tie-lines between the regions containing the groups of coherent generators.

LFOs can be created by small disturbances in the system, such as changes in the load, and are normally analyzed through the small-signal stability (linear response) of the power system. These small disturbances lead to a steady increase or decrease in generator rotor angle caused by the lack of synchronizing torque, or to rotor oscillations of increasing amplitude due to a lack of sufficient damping torque. The most typical instability is the lack of a sufficient damping torque on the rotor's low frequency oscillations. Small-signal stability analytical tools aid in the identification and analysis of LFOs. As defined in the following chapter, the eigenvectors of the system state matrix yield indices that provide identification and classification information. Specifically, the concepts of participation factors, mode shape, observability and controllability will be defined when discussing the control of LFOs in a power system. The control method investigated in this paper 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.

(i) Intraplant mode oscillations

II. POWER SYSTEM OSCILLATIONS

Oscillations in power systems are classified by the system components that they effect. Some of the major system collapses attributed to oscillations are described.
Nature of electromechanical oscillations
Electromechanical oscillations are of the following types:

(ii) Local plant mode oscillations
(iii) Interarea mode oscillations
(iv) Control mode oscillations
(v) Torsional modes between rotating plant

Intraplant mode oscillations Machines on the same power generation site oscillate against each other at 2.0 to 3.0 Hz depending on the unit ratings and the reactance connecting them. This oscillation is termed as intraplant because the oscillations manifest themselves within the generation plant complex. The rest of the system is unaffected.

III. MULTI –BAND POWER SYSTEM STABILIZER:

The need for effective damping of a wide range of electromechanical oscillations motivated the concept of the (MB-PSS). As its name reveals, the MB-PSS structure is based on multiple working bands.

The main idea of the MB-PSS is that three separate bands are used, respectively dedicated to the low, intermediate, and high frequency modes of oscillations. The low band is typically associated with the power system global mode, the intermediate band with the inter-area modes, and the high band with the local modes. Each of the three bands is made of a differential band-pass filter, gain, and limiter . The outputs of the three bands are summed and passed through a final limiter producing the stabilizer output V_{stab} . This signal then modulates the set point of the generator voltage regulator so as to improve the damping of the electromechanical oscillations. Usually, a few of the lead-lag blocks should be used in MB-PSS circuits. Figure 1shows MATLAB/Simulink Model of IEEE PSS4B model of the MB-PSS.

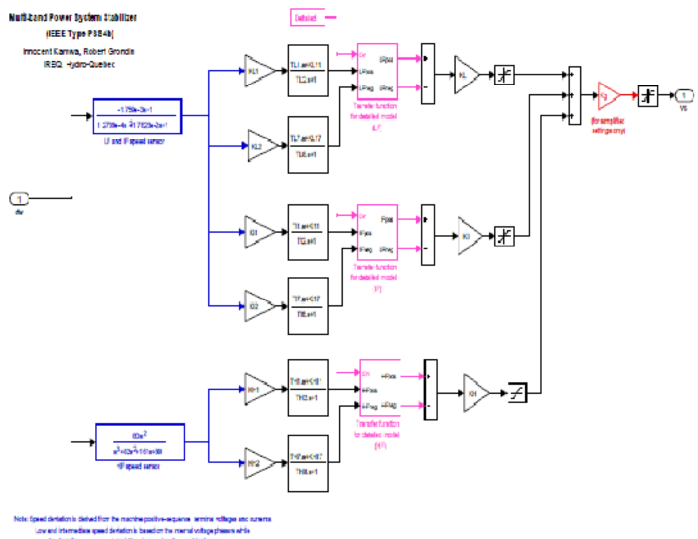

Fig. 1. MATLAB/Simulink Model of IEEE PSS4B model of the MB-PSS.

IV. LITERATURE SURVEY

A Comprehensive Literature review is carried out in the subject area. In this section, a serious attempt is made to present a comprehensive analysis of various methods of PSS & Optimization techniques for designing PSSs, which were recently proposed by various researchers. This also includes important mathematical optimization techniques used in power system optimization problems. Supplementary excitation control of the low frequency oscillations is well known as a power system stabilizer (PSS). It was developed to aid in damping the electromechanical oscillations via modulation of the generator excitation. Although modern control methods have been used by several researchers to minimize the prescribed objective function, but power system utilities still prefer the conventional lead-lag power system stabilizer structure. In this section, a serious attempt is made to present a comprehensive analysis of various methods of PSS & Optimization techniques for designing PSSs, which were recently proposed by various researchers. To understand the effects of CPSSs with different parameters on the overall dynamic performance of the power system, an extensive investigation was done in [1]. The general concepts associated with applying power system stabilizers utilizing shaft speed, ac bus frequency and electrical power inputs were developed. This lays the foundation for discussion of the tuning concepts and practical aspects of stabilizer application in Parts II and III. Two main techniques used for the parameter tuning of the PSS in the power system are sequential tuning and simultaneous tuning.

To achieve a set of optimal PSS parameters under different operating conditions, the tuning and testing of PSS parameters must be repeated under different operating conditions of the system. This type of optimization problem is very difficult to solve by applying traditional differentiable optimization algorithms. Sequential quadratic programming (SQP) techniques are fast deterministic optimization techniques [3], but they are very sensitive to the choice of initial point. To overcome the above- mentioned problems, many random search methods such as Tabu Search (TS) , Simulated Annealing (SA) , Ant Colony Optimization (ACO) and Harmony Search (HS) ,Evolutionary Programming (EP) , Bacteria Foraging Optimization (BFO) , Genetic Algorithm (GA) , and Particle Swarm Optimization (PSO) have been used.

Several linear methods were proposed to design the power system stabilizers which are:

(i) Pole-Placement ,Pole-Shifting

(ii) Linear Quadratic Regulator Formulation ,Linear Matrix Inequalities,

(iii) Linear Optimal Control,

(iv) Quantitive Feedback Theory,

(v) Eigenvalue Sensitivity Analysis,

(vi) Sliding Mode Control,

(vii) Conventional P-Vr Method,

(viii) Reduced Order Model,

(x) H_2 Controls,

Genetic Algorithm (GA) is a search heuristic that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization and search problems. GAs belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.The GA has been applied by many authors for tuning PSS parameters. Simulation results show activity of GA in tuning PSS parameters with a fixed location .

However, these PSSs cannot guarantee good damping performance when the location of the stabilizer is changed. Therefore, in a simple method is applied to find the optimal locations and the best PSSs parameters simultaneously in multi-machine power systems using GA. Nonlinear simulation and Eigen values analysis demonstrate the effectiveness of the technique in damping of oscillations under different scenarios. Also, a method to simultaneously tune PSSs in a multi-machine power system was presented using hierarchical GA and parallel micro GA based on a multi-objective function . Abdel-Magid and Dawoud investigated the tuning of PSS using GA. A digital simulation of a linearized model of a single-machine infinite bus power system at some operating point was used in conjunction with the GA optimization process . Optimal multi-objective design of robust multi-machine PSSs using GA was presented by Abido and Abdel-Magid [27-28].

V. 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.

Particle Swarm Optimization (PSO) is an evolutionary computation technique, developed for optimization of continuous non linear, constrained and unconstrained, non differentiable multimodal functions [32].

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.

VI. ADVANTAGES OF EVOLUTIONARY METHODS

•Simple constraint handling

•Capable of producing solutions for problems where classical mathematical methods fail

•Do not depend on initial guess •Parallel search through a population rather than from a single point

Evolutionary techniques have some very attractive features due to which they are gaining over traditional methods of optimization, particularly for real world problems. These techniques can be integrated to create hybrid evo. Techniques which are likely to perform better.

VII. OBJECTIVE OF PROPOSED WORK FOR SMALL POWER SYSTEM

-To propose an approach for design intelligent MB PSS

-To analyze the dynamic performance of single machine with the MB PSS, this is optimized by PSO.

VIII. 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:

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

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

IX. SINGLE MACHINE INFINITE BUS SYSTEM

For this study we have obtained Heffron Phillips model by linearizing the system equations around an operating condition and implementation is done by Simulink. We have taken IEEE type ST1 model of static excitation system & also that of conventional PSS.

The time-domain simulation of the nonlinear system model was performed for the simulation period. It is aimed to minimize this objective function in order to improve the system response in terms of the settling time and overshoots. There is Small step increase in reference Mechanical Power (ΔT_{ref} = 0.05p.u.) is the operating case we analyzed.

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.

CASE-Small step increase in reference Mechanical Power (ΔT_{ref} = 0.05p.u.)

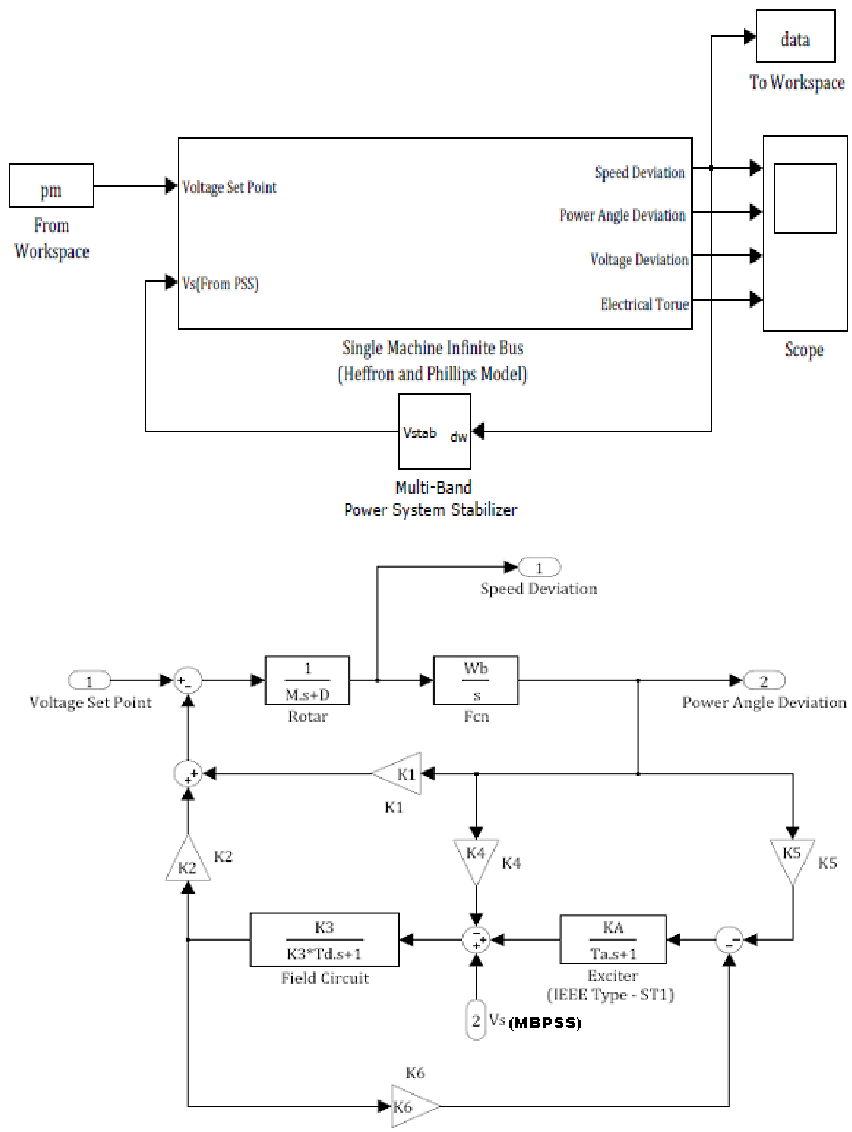

Fig. 2. SMIB system connected to MB PSS.

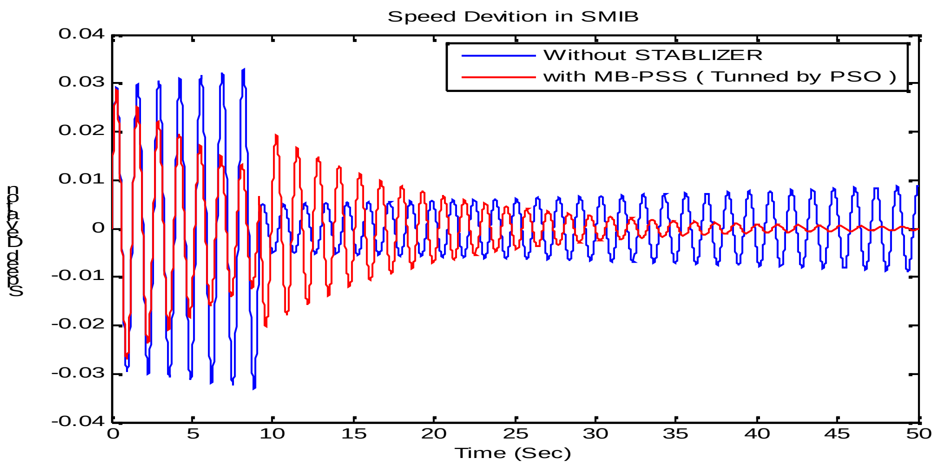

Fig. 3. Speed Deviation without PSS & with PSO based MBPSS fault at t = 5 sec.

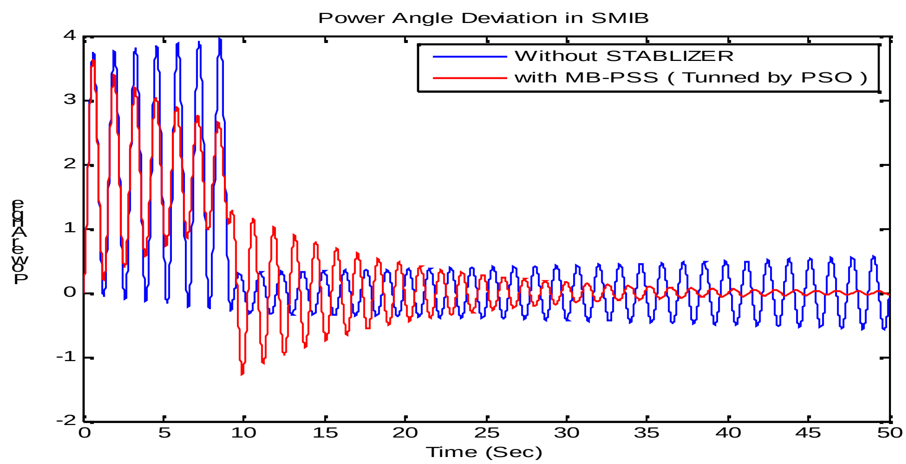

Fig. 4. Power Angle without PSS & with PSO based MBPSS fault at t = 5 sec.

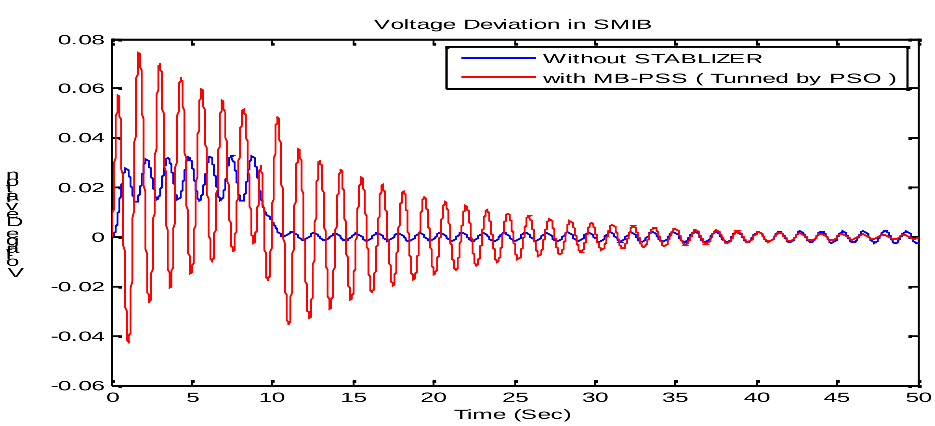

Fig. 5. Voltage Deviation without PSS & with PSO based PSS fault at t = 5 sec.

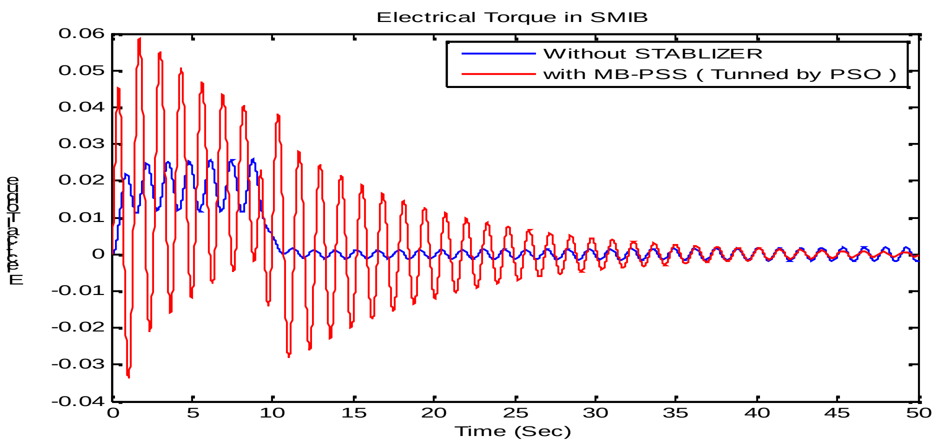

Fig. 6. Electrical torque without PSS & with PSO based MBPSS, fault at t = 5 sec.

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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