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DAMPING OF POWER SYSTEM LOW FREQUENCY OCSILATTION'S USING INTERACTIVE ARTIFICIAL BEE COLONY BASED MULTIBAND POWER SYSTEM STABILIZER

[1]Amit Shrivastava and [2]Manisha Dubey

[1] Research Scholar, Department of Electrical Engineering, India

[2]Professor Department of Electrical Engineering, India

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A B S T R A C T

An Enhanced Artificial Bee Colony (ABC) optimization algorithm, which is called the Interactive Artificial Bee Colony (IABC) optimization, for numerical optimization problems, is proposed in this paper. This paper presents a multiband Power System Stabilizer (MBPSS) for single machines using an Interactive Artificial Bee Colony (IABC), which is called IABCMB Power System Stabilizer (IABCMBPSS) and is used to damp the oscillations of the single-machines power system. The proposed IABCMBPSS is simulated for single machines generator, the results demonstrate that the efficiency of the proposed (IABCMBPSS) and reduces its compassion to system instability. The operating range demonstrated is found to be better than the customary MBPSS.

INTRODUCTION

The electrical energy has become the main form of energy for end use consumption in today's era. There is always a need of making electric energy generation and transmission, both more cost-effective and reliable. The voltages throughout the system are also controlled to be within ±5% of their specified values by automatic voltage regulators acting on the generator field exciters, and by the sources of reactive power in the network.

For suitable working, this large integrated system requires a stable operating condition. The power system is a lively system. It is frequently subjected to small disorders, due to which the generators relative angles changes. For the interconnected system to be able to provide the load power demand when the transients caused by disturbance die out, a new acceptable steady state operating condition is attained. That is, the power system has to be stable. It is important that these disturbances do not drive the system to an unstable situation. Stability in power systems is generally referred to as the ability of generating units to maintain synchronous operation [1]. Electro-mechanical oscillations between interconnected synchronous generators are phenomena inherent to power systems. In an N-machine power system there are (N-1) natural electromechanical modes of oscillations. The stability of these oscillations is of fundamental concern, and is a requirement for secure system operation. The oscillations linked with a single generator or a single plant that is called "local modes" or "plant modes". Local modes in general have frequencies in the range of 0.7 to 2 Hz. The characteristics of these oscillations are well understood. They may be studied adequately, and satisfactory solutions to stability problems are developed for a system, which has detail representation only in the vicinity of the plant.

The oscillations associated with groups of generators, or groups of plants are called "inter-area modes". Inter-area modes have frequencies in the range of 0.1 to 0.8 Hz. The characteristics of these modes of oscillation, and the factors affecting them, are not fully understood. They are more complex to study, and to control. A detailed representation of the entire interconnected system requires studying inter-area modes [1]. The basic function of a power system stabilizer is to modulate generator excitation to provide damping to the system oscillations of concern. These oscillations are typically in the frequency range of 0.2 to 2.0Hz, and insufficient damping of these oscillations may limit the ability to transmit power [4].

To provide damping, a new concept of PSS has been presented here in which delta omega stabilizer, so called the multi-band PSS has a innovative compensation circuit which is composed of three distinct working bands respectively dedicated to the low, intermediate and high frequencies of oscillations found on power systems. It was shown that such a structure offers a high degree of flexibility and, at the same time, is quite simple to use in terms of setting when symmetrical filters are being used. The Multi-Band PSS concept was derived [4] to provide an original and efficient solution to multi-modes damping problem. Many random heuristic methods, such as like Tabu search, genetic algorithms, chaotic optimization algorithm, rule based bacteria forging and particle swarm

*Corresponding author: **Amit Shrivastava**
Research Scholar, Department of Electrical Engineering, India

optimization (PSO) have recently received much interest for achieving high efficiency and search global optimal solution in the problem space and they have been applied to the problem of PSS design [5-8]. These evolutionary methods are heuristic population based search procedures that incorporate random variables and selection operators. Although, these methods seem to be good approaches for the solution of the PSS parameter optimization problem, however, when the system has a highly epistemic objective function (i.e. where parameters being optimized are highly correlated), and number of parameters to be optimized is large, then they have degraded effectiveness to obtain the global optimum solution.

In recent years, swarm intelligence becomes more and more attractive for the researchers, who work in the related research field. It can be classified as one of the branches in evolutionary computing. Swarm intelligence can be defined as the measure introducing the collective behavior of social insect colonies or other animal societies to design algorithms or distributed problem-solving devices.[15] Generally, the algorithms in swarm intelligence are applied to solve optimization problems. The classical algorithmin evolutionary computing and is used to solve problems of optimization is the Genetic Algorithm (GA) [26-27, 32, 34, 36]. Later then, many swarm intelligence algorithms for solving problems of optimization are proposed such as the Cat Swarm Optimization(CSO) [19-20], the Parallel Cat Swarm Optimization (PCSO) [37], the Artificial Bee Colony(ABC) [30-31], the Particle Swarm Optimization (PSO) [16, 18, 29, 37], the Fast Particle Swarm Optimization (FPSO) [32], and the Ant Colony Optimization (ACO) [33]. Moreover, several applications of optimization algorithms based on computational intelligence or swarm intelligence are also presented one after another [25, 33, 35].Karaboga proposed the Artificial Bee Colony (ABC) algorithm based on a particular intelligent behavior of the honeybee swarms [31] in 2005. In addition, the accuracy and the efficiency of the ABC are compared with the Differential Evolution (DE), the PSO and the Evolutionary Algorithm (EA) for numeric problems with multi-dimensions [15].By observing the operation and the structure of the ABC algorithm, we notice that the operation of the agent, e.g. the artificial bee, can only move straight to one of the nectar sources of those are discovered by the employed bees. Nevertheless, this characteristic may narrow down the zones of which the bees can explore and may become a drawback of the ABC. Hence, we propose an interactive strategy in this paper by considering the universal gravitation between the artificial bees for the ABC to retrieve the disadvantages. To test and verify the advantages, which we gain in the proposed method, series of experiments are executed and are compared with the original ABC and the PSO. The experimental results exhibit that the IABC performs the best on solving the problems of numerical optimization. [25]

In order to overcome these drawbacks, an interactive Artificial Bee Colony (IABC) algorithm is proposed for optimal tune of MBPSS parameters to improve power system low frequency oscillations damping in this paper. Based on the framework of the ABC, the IABC introduces the concept of universal gravitation into the consideration of the affection between employed bees and the onlooker bees. By assigning different values of the control parameter, the universal gravitation should be involved for the IABC when there are various quantities of employed bees and the single onlooker bee. Therefore, the exploration ability is redeemed about on average in the IABC. The proposed method has been applied and tested on a weekly connected power system under wide range of operating conditions to show the effectiveness and robustness of the proposed IABC based tuned MBPSS and their ability to provide efficient damping of low frequency oscillations .To show the superiority of the proposed design approach, the simulations results are compared with the conventional MBPSS under faulty conditions. The results evaluation shows that the proposed method achieves good robust performance for wide range of load changes in the presence of very high disturbances and is superior to the other stabilizers. A Comprehensive literature review is carried out in the subject area. Some of the most relevant research papers are described here.

Multiband power system stabilizer (MBPSS)

The main characteristics of the MB-PSS model (IEEE PSS4B) [4] are shown in figures 1 and 2. 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.

The speed deviation transducers, shown in figure 2, are both derived from machine terminal voltages and currents. The first one, so called $\Delta\omega_L$ is associated with the first two bands. Its measurement is accurate in the 0 to 2.0 Hz range. $\Delta\omega_H$, the Second transducer, is designed for the high band with a frequency range of 0.8 to 5.0 Hz. The MBPSS also provide two tunable notch filters to reject the high frequency torsional modes originate on turbo-generators. These are tuned for the first two torsional modes of a given machine. Each branch of a differential filter was designed to provide flexibility similar to a conventional PSS**.**

On the other hand, the differential capabilities of such a filter bring additional possibilities. The most frequent one is the symmetrical band-pass filter that provides inherent dc washout, zero gain at high frequency and phase leading up to the resonant frequency. The band-pass filter can be synthesized with one pair of lead lag blocks. The two other pairs may then be used to introduce additional compensating effects. As an example, the wash-out block might be added to increase dc rejection while the third block may he used to boost or attenuate the signal in a certain range of frequency.

Nevertheless, the simplest and most natural way to use these differential band filters is the symmetrical approach. With a simple and efficient setting method such as the one presented here, it is possible to set the PSS with only two high level parameters per band .Doing so, the whole lead-lag compensation circuit is specified with six parameters. They are the three filter central frequencies F_L, F_I, F_H and gains K_L, K_{IT} K_H, Being plain band-pass filters, only the first block in each branch is involved. Time constants and gains are derived from simple equations as shown here for the high band case.

K_{Hl1}, = K_{H17}= 1/(2ΠF_H√R) (lead-lag blocks) (1)

T_{H2} = T $_{H7}$ (2)

T $_{H\,1}$=T $_{H2}$/ R (3)

T $_{H\,8}$=T $_{H7}$x R (4)

K_{H1} = K_{H2} = (R^2 + R+) / (R^2 -2R + 1) (5)

Central time constants T_{H2} and T_{H7} are directly derived from the filter central frequency FH while the symmetrical time constants, T_{H1} and $T_{H8}$are computed using constant ratio R. Equation (5) is used to derive branch gains K_{H1} and K_{H2} to obtain a unit gain for the differential filter. The band gain is therefore equal to KH. This technique allows us to represent the MBPSS in a simplified model as shown in figure 3.

Power System Model

A power system model consisting of a Single Machine connected to an Infinite Bus (SMIB) through a circuit transmission line is used in the simulation studies. A schematic diagram for the model is shown in Figure 4 .The generator is equipped with excitation system and a power system stabilizer. A SMIB power system model as shown in Fig. 5 is used to obtain the modified Heffron-Phillip's model parameters All the relevant parameters are given in Appendix.

Objective Function

It is worth mentioning that the MB PSS is designed to minimize the power system oscillations after a small & large disturbance so as to improve the power system stability. These oscillations are reflected in the deviations in power angle, rotor speed and line power. Minimization of any one or all of the above deviations could be chosen as the objective. In this study, an Integral of Absolute Error (IAE) of the speed deviations is taken as the objective function expressed as follows:

$$j = \int_0^{t1} | \ \mu | dt \qquad (6)$$

In the above equations, Δω denotes the rotor speed deviation for a set of controller parameters X. Here X represents the parameters to be optimized. A total of 7 parameters of MB PSS controller are being tuned to get the optimal response.t_1 is the time range of the simulation.

It is aimed to minimize this objective function in order to improve the system response in terms of the settling time and overshoots under different operating condition. The design problem can be formulated as the constrained optimization problem, where objective function j has to be minimized optimally and the constraints GG, FL, KL, FI, KI, FH & KH should lie within certain given range of minimum and maximum values, which put upper & lower bounds for controller parameters.

Interactive Artificial Bee Colony (IABC)

In general, the ABC algorithm works well on finding the better solution of the object function. However, the original design of the onlooker bee's movement only considers the relation between the employed bee, which is selected by the roulette wheel selection, and the one selected randomly. Therefore, it is not strong enough to maximize the exploitation capacity. The Interactive Artificial Bee Colony algorithm is proposed based on the structure of ABC algorithm. By employing the Newtonian law of universal gravitation [10] described in the equation (4), the universal gravitations between the onlooker bee and the selected employed bees are exploited. It leads in the concept of universal gravitation to the movement of onlooker bees in ABC, and it successfully increases the exploitation ability of ABC The process of the IABC can be described in 5 steps:

Step 1. Initialization: Spray *ne* percentage of the populations into the solution space randomly, and then calculate their fitness values, which are called the nectar amounts, where *ne* represents the ratio of employed bees to the total population. Once these populations are positioned into the solution space, they are called the employed bees.

Step 2. Move the Onlookers: Calculate the probability of selecting a food source by equation (7),

$$P_i = \frac{F(\theta_i)}{\sum_{k=1}^{S} F(\theta_k)}$$

P_i : The probability of selecting the i^{th} employed bee
S : The number of employed bees
θ_i : The position of the i^{th} employed bee
: The fitness value
select a food source to move to by roulette wheel selection for every onlooker bees and then determine the nectar amounts of them. The movement of the onlookers follows the equation (8).

Calculation of the new position

$$x_{ij}(t+1) = \theta_{ij}(t) + ¤(\theta_{ij}(t) - \theta_{kj}(t)) \qquad (8)$$

t : The iteration number
j : The dimension of the solution

Step 3. Move the Scouts: If the fitness values of the employed bees do not be improved by a continuous predetermined number of iterations, which is called "*Limit*",those food sources are abandoned, and these employed bees become the scouts. The scouts are moved by the equation (9).
The movement of the scout bees follows equation (9).

$$\theta_{ij} = \theta_{j\min} + r \cdot (\theta_{j\max} - \theta_{j\min}) \qquad (9)$$

$$r \in [0,1]$$

r : A random number and

Step 4. Update the Best Food Source Found So Far: Memorize the best fitness value and the position, which are found by the bees.

Step 5. Termination Checking: Check if the amount of the iterations satisfies the termination condition. If the termination condition is satisfied, terminate the program and output the results; otherwise go back to the Step 2.

IABCMBPSSs improve its dynamic stability considerably and it shows its superiority over MB PSS. The proposed ABC based MBPSS is effectual and achieves good system damping characteristics. It can be seen that the proposed IABC based MB PSS has good performance in damping low frequency oscillations and stabilizes the system quickly. Moreover, it is superior to the classical based methods stabilizer.

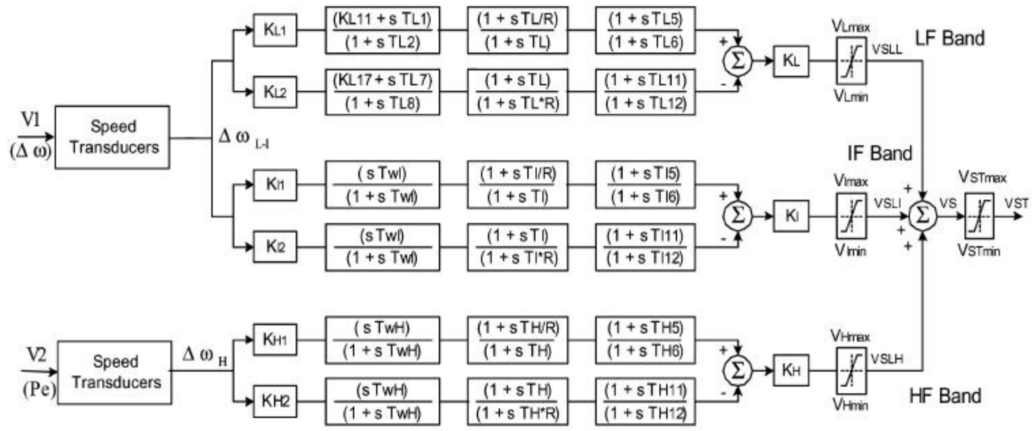


Fig. 1 IEEE PSS4B model of the MB-PSS

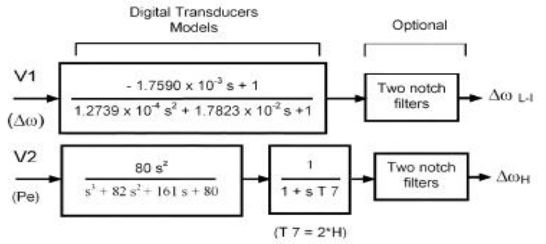


Fig. 2 IEEE PSS4B model of the MB-PSS

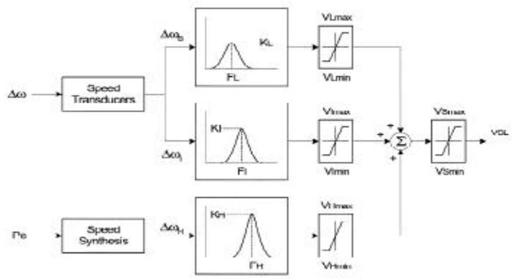


Fig. 3 Conceptual block diagram of the multiband PSS (IEEE PSS4B)

SIMULATION & RESULT

The behavior of the proposed IABC based designed MBPSS (IABCMBPSS) under faulty conditions is verified by applying disturbance classical MBPSS. The Impulsive disturbance is given at t = 5 sec. 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. IABC 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.

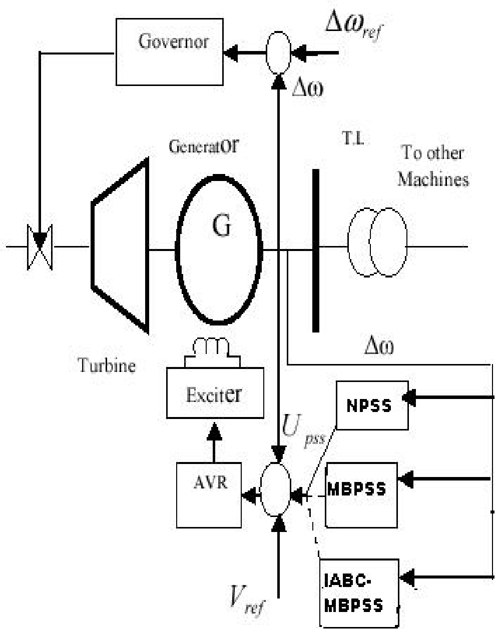


Fig 4 SMIB connected to MBPSS

CONCLUSIONS

The IABC leads in the concept of universal gravitation to the movement of onlooker bees in the ABC, and it successfully increases the exploration ability of the ABC. In this paper, IABC optimization technique has been successfully applied for power system stabilizer design in a SMIB power system. To design MBPSS problem, a nonlinear simulation-based objective function is taken to increase the system damping and then IABC technique is implemented to search for the optimal stabilizer parameters. The proposed IABC algorithm is easy to implement without additional computational complexity.

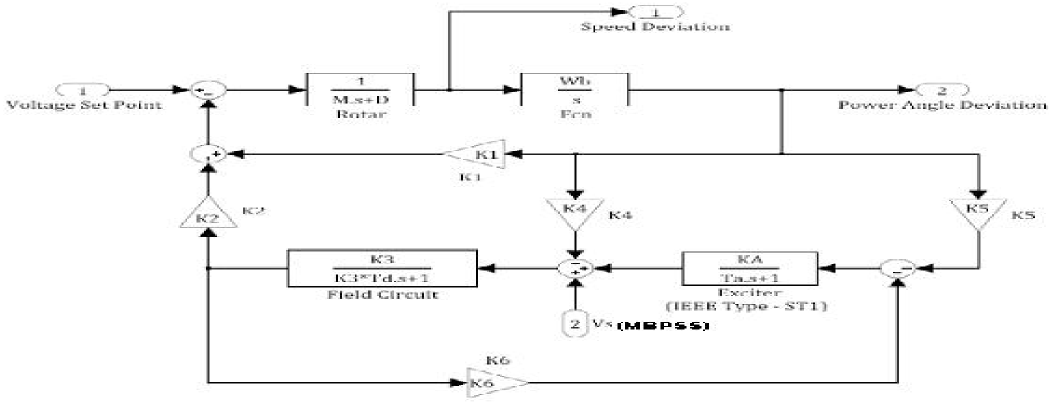
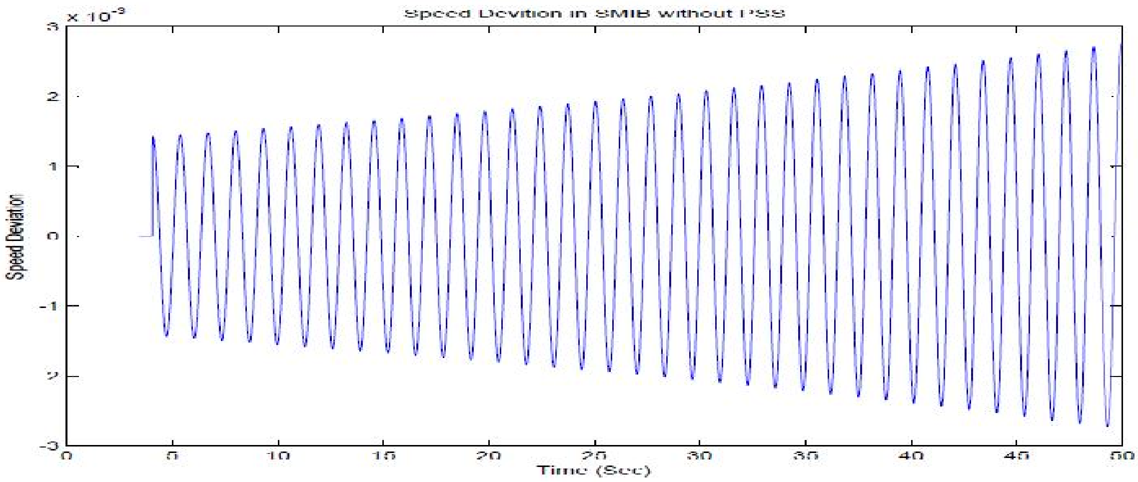


Fig 5 Heffron-Phillip's model of SMIB



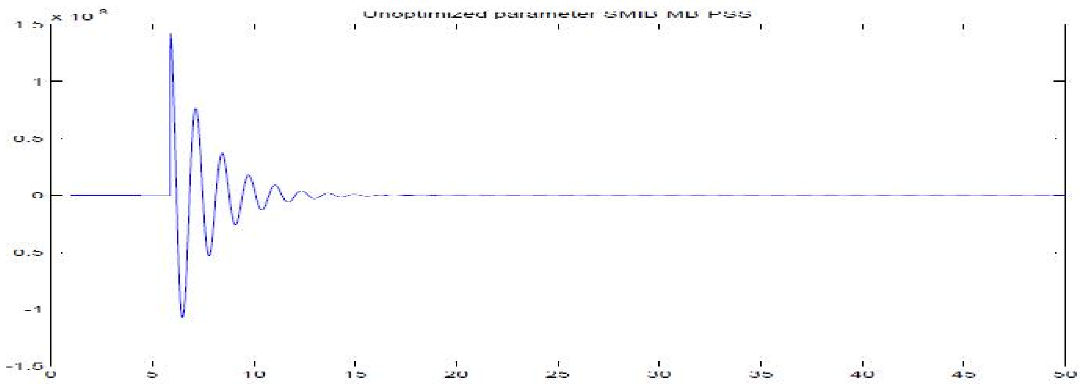


Fig.7 Speed deviation with MB PSS @ t=5 sec (Impulsive disturbance)

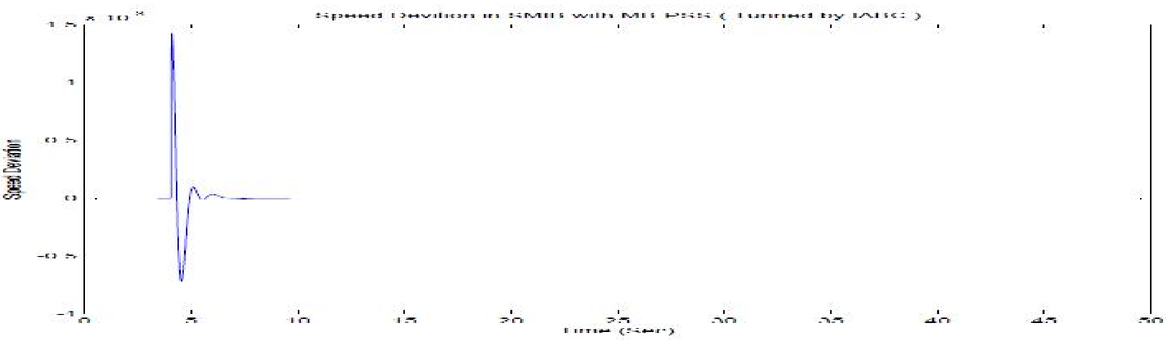


Fig.8 Speed deviation with IABCMB PSS@ t=5 sec (Impulsive disturbance)

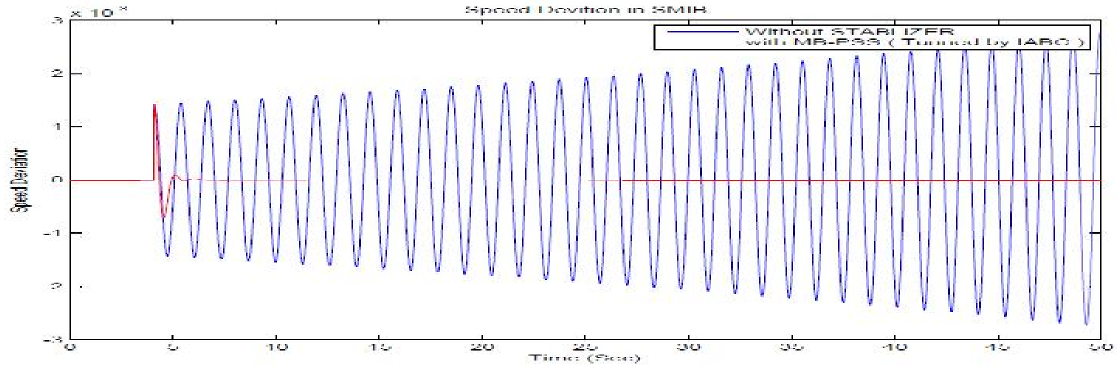


Fig.9 Speed deviation with IABCMB PSS@ t=5 sec (Impulsive disturbance)

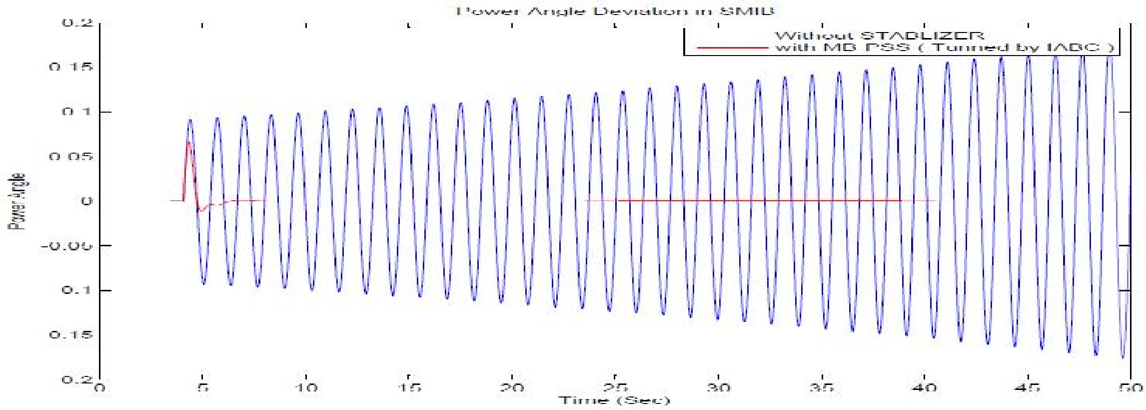


Fig10 Power Angle deviation with IABCMB PSS@ t=5 sec (Impulsive disturbance)

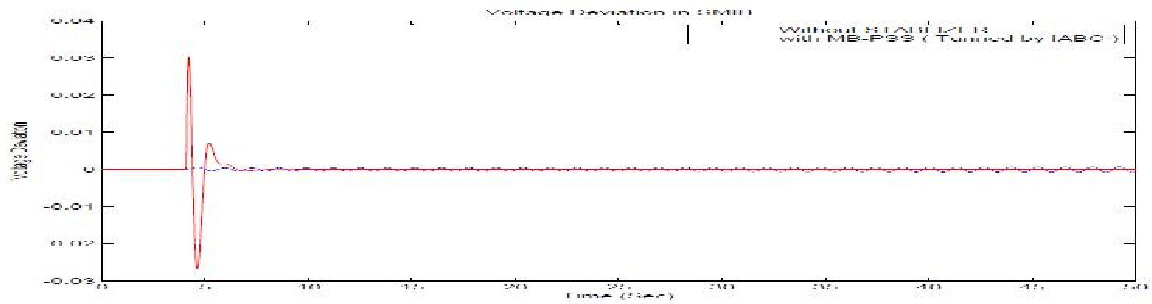


Fig.11 Voltage deviation with IABCMB PSS @ t=5 sec (Impulsive disturbance)

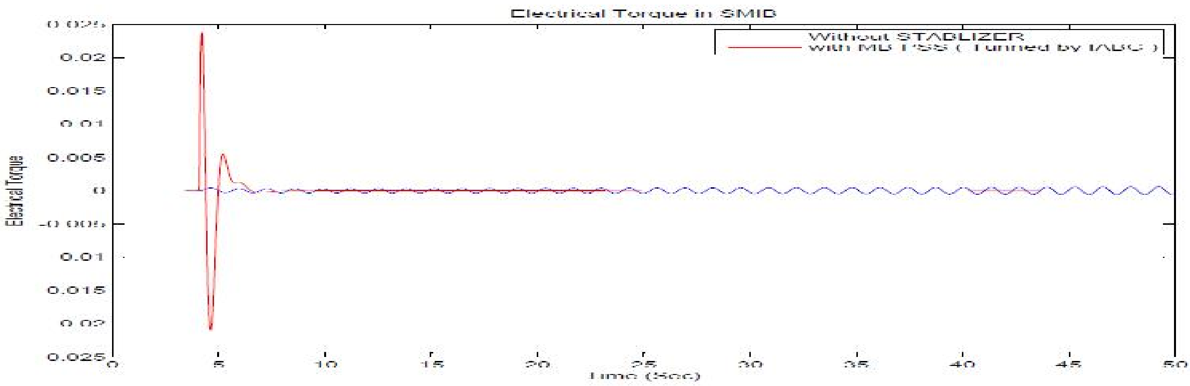


Fig .12 Electrical Torque with IABCMB PSS @ t=5 sec (Impulsive Disturbance)

Thereby experiments with this algorithm give quite promising results.The ability to jump out the local optima, the convergence precision and speed are remarkably enhanced and thus the high precision and efficiency are achieved. The effectiveness of the proposed stabilizer, for power system stability improvement, is demonstrated for a weakly connected example power system subjected to severe disturbance .The dynamic performance of IABC based tuned MBPSS has also been compared with classical methods based designed MBPSS to show its superiority. The nonlinear simulation results under wide range of operating conditions show the robustness of ABC based MBPSS ability to provide efficient damping of low frequency oscillations. The system performance characteristics in terms of the overshoot undershoot, settling time and speed deviations of the machine are greatly reduced under severe disturbance conditions.

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Amit Shrivastava was born in Bhopal, India. on 1st Jan 1977. He received B.E (Hons). & M.Tech. (Silver Medalist) from Maulana Azad National Institute of Technology, Bhopal India in 1998 & 2002 respectively. Presently, he is Pursuing his Ph. D. degree at Maulana Azad National institute of Technology, Bhopal India. He is at present an Associate Professor at Oriental College of Technology, Bhopal India. His research interests include power system stability, adaptive Control, fuzzy control & Optimization Techniques like ABC, IABC, PSO etc. he is life member of IEEE,ISTE , SESI& IAENG etc.

Manisha Dubey was born in Jabalpur, India. on 15 December 1968. She received B.E (Gold Medalist) M.Tech (Power System) & PhD (Electrical Engg.) in 1990,1997, & 2006 respectively. She is working as Professor at the Department of Electrical Engg., Maulana Azad National Institute of Technology, Bhopal India. Her research interests include power system, Genetic Algorithms, fuzzy Logic control & Application of soft computing Technique in Power system dynamics & control .she is life member of IEEE, IE & ISTE, etc.

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