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A multi objective vector evaluated improved honey bee mating optimization for optimal and robust design of power system stabilizers

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ABSTRACT

This paper presents the Parallel Vector Evaluated Improved Honey Bee Mating Optimization (VEIHBMO) as a novel multi objective technique to obtain a set of optimal Power System Stabilizers (PSSs) parameters. It includes a feedback signal of a remote machine and local and remote input signal ratios for each machine in a multi-machine power system under various operating conditions. This goal is formulated as a multi objective optimization process with two competing and non-commensurable fitness functions. The objectives considered in this paper are the time domain based integral square time of square error (ISTSE) and eigenvalues based comprising the damping factor. The effectiveness of the proposed method is demonstrated on 4-machine two-area and 16-machine five-area power system under different loading conditions. The system performance is assessed through the time multiplied absolute value of the error (ITAE), eigenvalues and figure of demerit (FD) analysis performance indices. The simulation results show that the performance of the proposed stabilizer is comparable to that which could be obtained by the conventional design, but without the need for the estimation and computation of the external system parameters.

Introduction

In their early years electric power systems did not reach far from the generating station. Power systems are inherently nonlinear and undergo a wide range of transient conditions, that results in under damped low frequency speed as well as power oscillations that are difficult to control. Sufficient damping of oscillations is important in an interconnected power system. Small signal disturbances observed on the power system are caused by many factors such as heavy power transmitted over weak tie – line, the effect of fast acting and high gain Automatic Voltage Regulator (AVRs) [1,2]. The most cost-effective way of countering this instability is to use auxiliary controllers called Power System Stabilizer (PSS) to produce additional damping in the system. In the other hand, the use of PSS is although the most widespread strategy today. Power system stability may be broadly defined as that property of a power system that enables it to regain an acceptable state of equilibrium after being subjected to a disturbance [2]. Recently, many methods of PSS tuning have been developed such as Particle Swarm Optimization (PSO) [3], Genetic Algorithms (GAs) [4] and honey bee mating optimization HBMO [5] to find the optimum set of parameters to effectively design the PSS.

In [6], PSS tuning by hybrid PSO and bacterial foraging algorithm (BFA) was performed on three machine nine bus power system. Its objective function was set to maximize the sum of eigenvalues dampings for all operating conditions. The results showed that it could be a powerful tool for robust PSS damping controller design. Also, the operating at absolute minimum objective can no longer be the only criterion for designs PSS. In [7], a new-fangled adaptive mutation breeder GA based tuning PSS parameters was reported and performed for large-scale realistic systems. It is emphasized here the importance of an accurate fitness function and the fact that a power system expert's input in the designing stage of the optimization process is very important. Sometimes it required to select the best solution out of a pool of solutions resulted from the algorithm. However, this technique has some limitations such as difficulties in selecting optimal genetic operators, premature convergence and high computational capacity required to solve tuning problem of PSS.

A robust PID-based PSS was suggested in Ref. [8]. In this study, a constrained structure of Lyapunov function and generalized static output feedback gain matrix were used. Iterative Linear Matrix Inequality (ILMI) was employed for optimal tuning of controller

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parameters. The importance and the difficulties in the selection of weighting functions were reported for this method.

In [9] artificial neural network (ANN) has been suggested for PSS design. Two reasons are put forward for using ANN. First, since an ANN is based on parallel processing, it can supply extremely fast processing facility. The other reason for the high level of interest is the ability of ANN to realize complicated nonlinear mapping from the input space to the output space. Also, one disadvantage of ANNs can be found in the individual relations between the input and output variables that are not developed by engineering judgment. So the ANN tends to be a 'black box' system or input/output table without analytical basis. On the other hand, such ANNs are not good at providing understandable knowledge on how a problem is solved. Also, the computation time to develop and train a neural network can be demanding, particularly on large problems.

However, all these methodologies mentioned above have their disadvantages which make algorithms suffer from premature convergence. In addition, searching ability of these algorithms is sensitive to parameter settings [10,11]. Also, these algorithms lost several non-dominated solutions during the search process. In order to overcome these drawbacks, a Parallel Vector Evaluated Improved Honey Bee Mating Optimization (VEIHBMO) based multi objective method is proposed for the solution of the PSS design problem in this paper. The consideration of many objectives in the planning process accomplishes two major improvements in the problem solving:

(1) Multi objective programming and planning promotes more appropriate roles for the participants in the planning and decision making process.
(2) A wider range of alternatives is usually identified.

The proposed algorithm contains multi-drone, which this structure is inspired by the Vector Evaluated Particle Swarm Optimization (VEPSO) [12] and Vector Evaluated Genetic Algorithm (VEGA) [13]. The proposed design of PSSs strategy is robust and computationally efficient as compared with other meta-heuristic techniques. Simulations are carried out on two typical multi-machine electric power systems; 4-machine 2-area and 16-machine 5-area, respectively. The simulation results clearly confirm that the proposed method enhances the small signal stability, particularly when the operating point changes. Also, the result shows that the proposed approach provides more rapid and robust convergence on function optimization problems considered in this study. In other words, the proposed multi objective VEIHBMO method achieves good robust performance for wide range of load changes in the presence of very highly disturbance and is superior to the other stabilizers.

The rest of the paper is organized as follows; Section 'Power system model' describes the formulation of the non-linear multi machine and PSS structure. Section 'Vector evaluated improved honey bee mating optimization algorithm' introduces the standard HBMO and the proposed algorithms. To demonstrate the advantages of the proposed algorithm in the design robust PSS problem, it is applied to four-machine two-area and sixteen-machine five-area standard power system; results and comparison with the reported results in the literature are brought in Section 'Results and Simulations'. Finally, the paper is concluded in Section 'Conclusion'.

Power system model

Fig. 1 shows the schematic of a multimachine system consists of *n* machine. This schema describes the dynamic equations represented by each block shown in the *i*th machine and external network [14].

Non-linear machine model

In this work, the *i*-th machine model is given as follows.

$$\dot{\delta}_i = \omega_b(\omega_i - 1) \tag{1}$$

$$\dot{\omega}_i = (T_{mi} - T_{ei} - D_i(\omega_i - 1))/M_i \tag{2}$$

$$\begin{cases} \dot{E}'_{qi} = (E_{fdi} - (x_{di} - x'_{di})i_{di} - E'_{qi})/T'_{doi} \\ \dot{E}'_{di} = (-(x_{qi} - x'_{qi})i_{qi} - E'_{di})/T'_{qoi} \end{cases} \tag{3}$$

$$\dot{E}_{fd,i} = (K_{ai}(V_{refi} - V_i - U_i) - E_{fdi})/T_{ai} \tag{4}$$

$$T_{ei} = E'_{di}i_{di} + E'_{qi}i_{qi} - (x'_{qi} - x'_{di})i_{di}i_{qi} \tag{5}$$

where *d* and *q* refer to the direct and quadrature axes, respectively. δ is the rotor angle; ω is rotor speed; E'_q and E'_d are the internal voltages behind x'_d and x'_q, respectively; E_{fd} is the equivalent excitation voltage; T_e is the electric torque; T'_{do} and T'_{qo} are time constants of excitation circuit; K_a is the regulator gain; T_a is the regulator time constant.

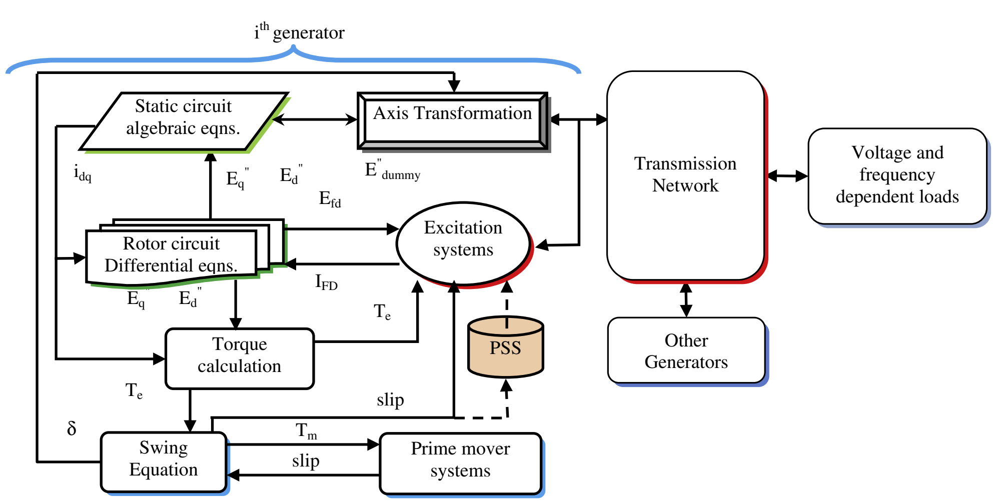

Fig. 1. Structure of a multi-machine system.