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Power System Stabilizer Design based on Honey-Bee Mating Optimization Algorithm

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Abstract

Power system stability is one of the main factors in performance of electrical system. A control system must retain frequency and voltage size under any distortion such as sudden increase in load, to leave a generator from circuit or cut off a transmission line in a constant level. In this paper, Honey-bee mating optimization (HBMO) algorithm has been used to design power system stabilizer. It is based on the mating between queen and bees. Meta-heuristics honey-bee mating optimization algorithm is considered to be an intelligent algorithm. Simulation results show that HBMO algorithm is simple to solve optimization issues.

Keywords: *Dynamic stability, honey-bee mating, power system stabilizer, intelligent algorithm*

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INTRODUCTION

One of initial principles in dynamic studies is stability. In order to avoid unwanted dynamic phenomenon, control system is used in this research. There are several control systems in power stations such as automatic voltage control, multi-control system in power network such as static reactive power compensation and power system stability [1]. Dynamic stability is one of the safety performance indicators in a power system which depends on the reaction and performance of system against disturbances. Among dynamic subjects, excitation system stability and power system stabilizer (PSS) is the most important subject in recent years.

Power system stabilizer with control of synchronous generator excitation makes suitable stability and performance improvement of whole system against entrance disturbances [2]. Linear controllers have been used as power system stabilizers in previous decades but their performance is limited due to nonlinearity of power system. Over the time having fuzzy systems, neural networks, etc., power system control appeared with a new phase. With development of power system to multi-machine systems, request to stability of power system is considered more than ever. So, dynamic stability is one of the safety performance indicators in power system which depends on the reaction and performance of system against disturbances [3]. Thereafter, the controllers based on intelligent algorithms have been used in power system. Actually, suitable efficiency of power system stabilizer depends on the appropriate selections of its parameters [4, 5].

Power System Stabilizer (PSS)

Power system stability is an important aspect in performance of electrical system, where size- frequency control systems should retain voltage under any disturbances such as unexpected increase in load, disconnecting generators from circuit and cut off transmission lines in stable levels. Power system stabilizer can be considered as a feature in a system that enables the system to balance in natural mode [6]. PSS is one of the cheapest tools for dynamic stability optimization methods of power system, which provides control loops for automatic voltage regulator and dynamic performance of power system caused by electromechanical oscillation damping of system, considering the fact that this method is suitable to boost the performance of large and small-signal stability. Power system stability with control of synchronous generator excitation makes suitable stability and performance improvement of the whole system against entrance disturbances [7]. However, design of PSS is not simple because of structural changes and operational condition of power system and confrontation of it with various disturbances and constant changes in load [8]. According to the significance of PSS in stability and safe operation of power system, many studies have been done in this regard and after more than three decades, much attention has been attracted toward it. Also many control theories have been employed to design PSS which can be classified into theories based on classic, comparative, intelligent and variable structure methods [9].

Main defects in classic controller are inattention to model uncertainty, sensitivity toward operation point and lack of robust performance. In addition, the use of comparative and variable structure controllers is limited due to complexity of control algorithm and switching matters as well as use of state variables. Although, in resistance control methods, uncertainty is caused by changes in performance situations during designing of controllers, obtained controller has higher dynamic rank that implementation comes difficult [10].

Intelligent Algorithms in PSS Application

In recent years, genetic algorithm has been used as a popular intelligent method to solve the complex nonlinear optimization issues like designing of power system stabilizer. Optimization based on genetic algorithm is used to regulate PSS parameters based on rules in which the advantages are seen with less computation, resistance and simple research. In addition, use of genetic algorithm to justify simultaneous parameters of stabilizers causes the interaction among such parameters during designing process [11].

The advantage of this design lies on system robustness, low volume of calculations and suitable distinction of system. Simultaneous adjustment of parameter stabilizers based on genetic algorithm is done as which specific values of system transfer to certain region of stability. In simultaneous adjustment of parameter, stabilizer is defined as a multi-purpose optimization issue and formulization as a combination of objective functions based on the damping coefficient and damping ratios of unstable electromechanical modes and with low damping [12].

In PSS parameter, efficiency of proposed method is confirmed by analysis of specific values and nonlinear simulation [13]. So far, various methods such as optimization based on genetic algorithm, particle swarm and other intelligent methods have been used but they do not have sufficient ability for optimization and in many complex issues, they are unable to find an optimum solution. Designing and optimum selection of power system stabilizer parameters in order to damping electromechanical oscillations are the most important issues in applying these controllers [14]. In this study, honey-bee mating optimization algorithm (HBMO) is used in order to overcome the problems of classic methods and to obtain optimum parameters of PSS. The present problems in designing controllers can be limited by use of positive points in various approaches [15].

HMBO DESIGN METHODOLOGY

In this study, honey-bee mating optimization algorithm has been used to improve design in various operating conditions. In this study, meta-heuristics honey-bee mating optimization algorithm (HBMO) is considered as intelligent algorithm. Bees mating take place in close relationship in comparison with natural bee colony. The important features of HBMO algorithm consist of mating process, breeding, and selectivity method of queen in mating with male bees and baby feed by worker bees and the manner of queen’s feed by workers bees to find optimum response.

$$prob(Q,D)=e^{\frac{-\Delta(f)}{S(t)}}\geq q_0 \qquad (1)$$

in which, Prob(Q,D) is increasing possibility of male sperm, D is the volume of queen sperm and Q is possibility of success mating. $\Delta(f)$ is the difference between functions; $S(t)$ is queen speed in t and q time which is accident value between 0 and 1. Speed and energy of queen after each mating process decreases as follows:

$$S(t+1)=\alpha\times S(t) \quad (2)$$

$$E(t+1)=E(t)-\gamma \quad (3)$$

where α is a coefficient between 0 and 1 to decrease queen's speed and γ is a coefficient between 0 and 1 to decrease queen's energy after each mating. At the end of flight, the energy and speed values reduce as which it can be considered equal to zero. The new bee babies are born with moving male bees gene to queen genes and it is calculated by following function:

$$child = parent1+\beta(parent2-parent1) \quad (4)$$

that β is accident number between 0 and 1.

In this stage, worker bees are engaged to care brood bees:

$$Brood_i^k = Brood_i^k \pm(\delta+\varepsilon)Brood_i^k$$
$$\delta\in[0,1], 0<\varepsilon<1 \quad (5)$$

where δ is created randomly between 0 and 1 and $\dot{E}$ is constant number.

SIMULATION RESULTS

First Scenario

In this scenario three fuzzy errors of 6 cycle at the time of 1/0 second is done near 7 bus between 7 and 5 lines. Figures 1 and 2 show the speed changes in nominal charge.

Second Scenario

In this scenario six-cycle three-phase fault is imposed as 0.01 at the time of 1.0 second around the bus. The obtained results are displayed in Figures 3 and 4; and the results of comparative criteria are shown in Table 2.

Third Scenario

In this scenario, like the first scenario, the three-phase fault is imposed at the time of 0/5 second and the torque error is imposed on the system as 0/1 per unit at the time of 5/0 second. The obtained results are displayed in the following figures and table.

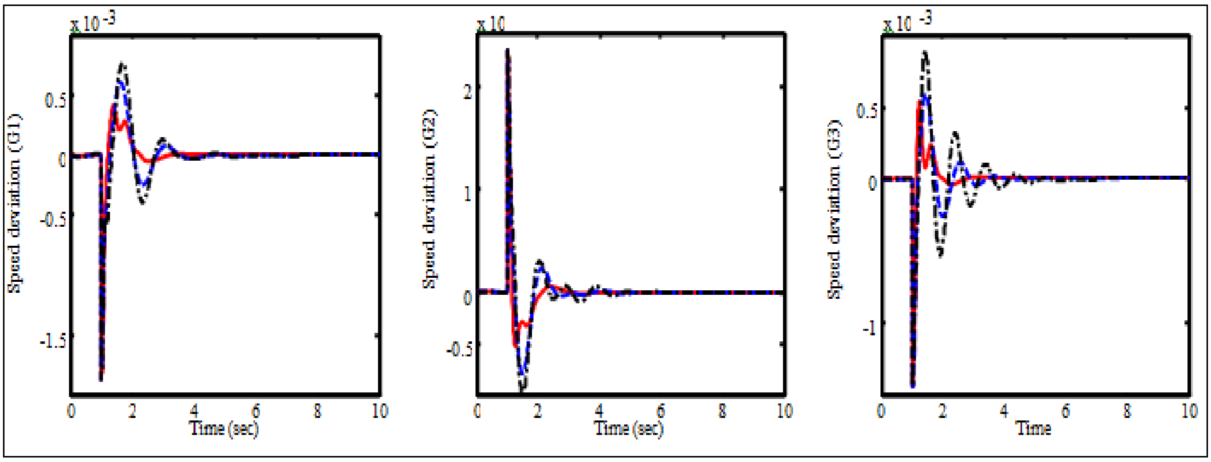

Fig. 1: *Changes in Output Speed of the Generators for Nominal Load: IHBMO (bold line). HBMO (dash line), PSO (dot line).*

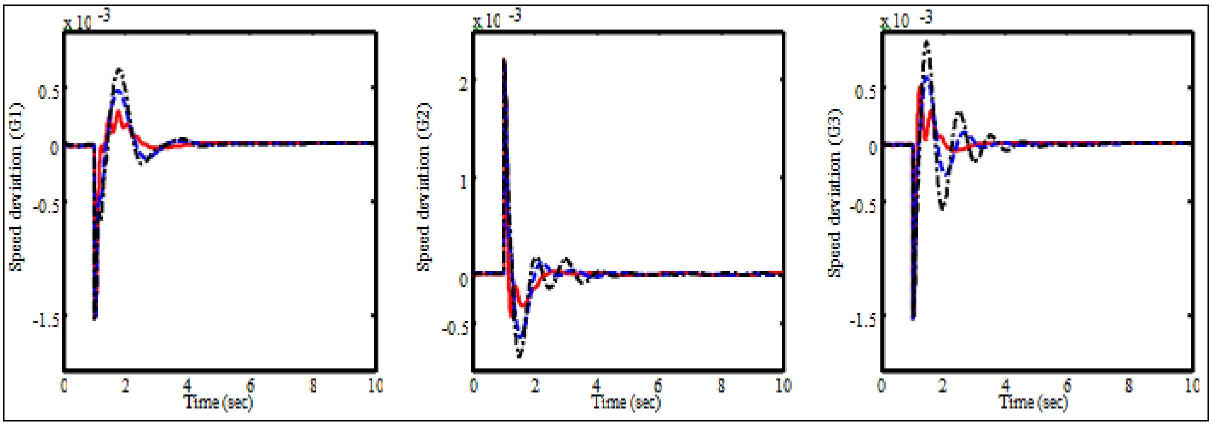

Fig. 2: *Changes in Output Speed of the Generators for Heavy Load: IHBMO (bold line). HBMO (dash line), PSO (dot line).*

Table 1: *The Results of the Comparison of the Algorithms.*

Change load	**IHBMO**		**HBMO**		**PSO**	
	ITAE	**FD**	**ITAE**	**FD**	**ITAE**	**FD**
25%	0.1553	0.4237	0.2750	0.5029	0.4255	0.6031
20%	0.1583	0.4362	0.2803	0.5164	0.4312	0.6428
15%	0.1617	0.4496	0.2856	0.5449	0.4374	0.6610
10%	0.2936	0.5645	0.4435	0.6779	0.4465	0.6745
5%	0.1703	0.4953	0.3026	0.5810	0.4507	0.6944
Nominal	0.1750	0.5318	0.3135	0.5981	0.4604	0.7116
−5%	0.1812	0.5521	0.3265	0.6155	0.4728	0.7289
−10%	0.1897	0.5902	0.3425	0.6498	0.4877	0.7451
−15%	0.2012	0.6149	0.3627	0.6897	0.5132	0.7852
−20%	0.2162	0.6417	0.3888	0.7122	0.5508	0.8220
−25%	0.2354	0.6719	0.4241	0.7395	0.6028	0.8657

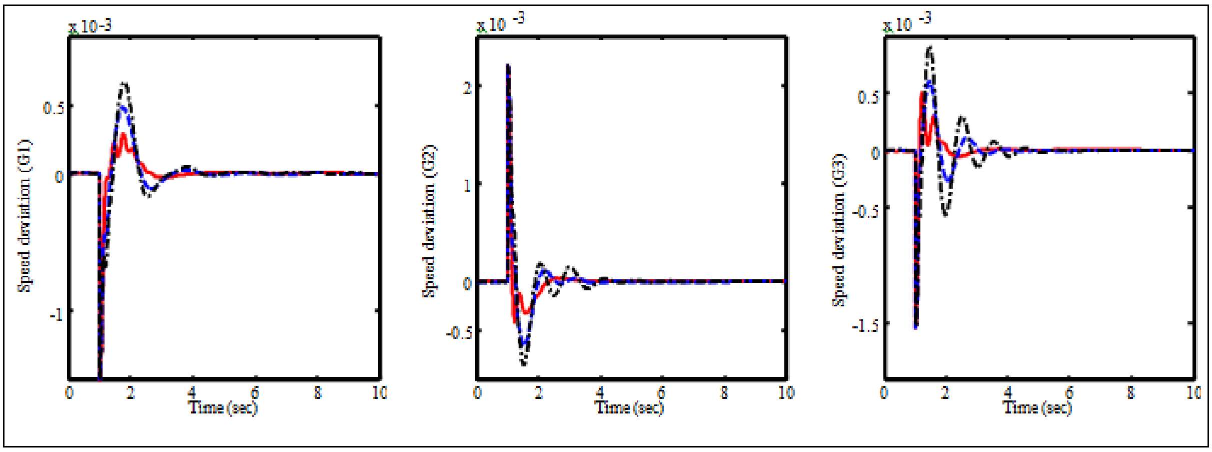

Fig. 3: *Changes in Output Speed of the Generators for Nominal Load: IHBMO (bold line). HBMO (dashline), PSO (dotline).*

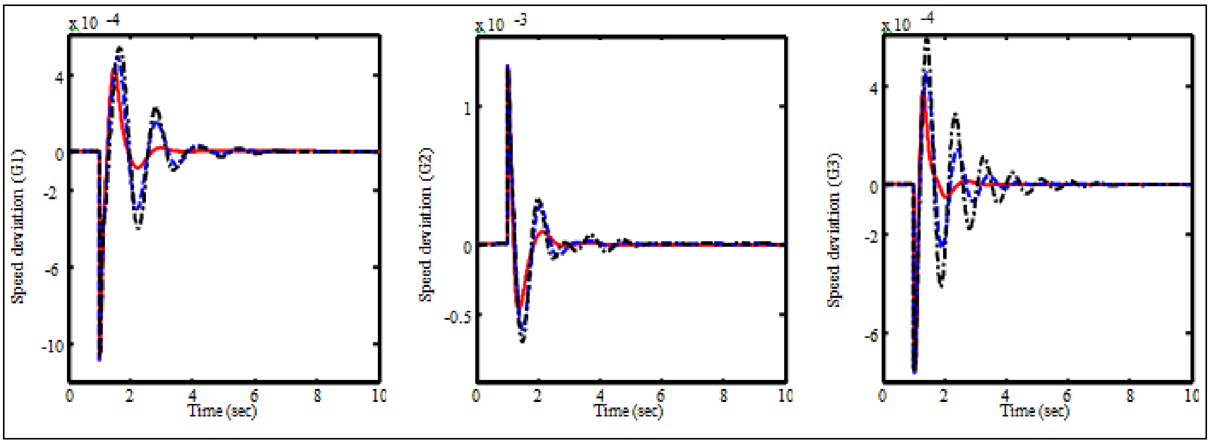

Fig. 4: *Changes in Output Speed of the Generators for Light Load: IHBMO (bold line). HBMO (dash line), PSO (dot line).*

The first stage studied the number of the selected population for the HBMO algorithm. In this stage, the volume of queen’s sperm is 15; the number of children equals 10; the queen’s deceleration coefficient is considered as 0/98; and β and ε + δ coefficients are respectively 1/97 and 0/95.

ISTSE criterion, which is defined as follows, was used for comparison. The number of repetition for each value was 100 for changes in each parameter. The obtained results are proposed in Figure 8 and display the level of convergence. Table 4 shows the obtained comparative criterion.

Table 2: *The Results of the Comparison of the Algorithms.*

Change load	**IHBMO**		**HBMO**		**PSO**	
	ITAE	**FD**	**ITAE**	**FD**	**ITAE**	**FD**
25%	0.1550	0.4209	0.2761	0.5008	0.4265	0.6117
20%	0.1580	0.4331	0.2812	0.5142	0.4320	0.6398
15%	0.1619	0.4467	0.2864	0.5425	0.4384	0.6577
10%	0.1652	0.4739	0.2944	0.5614	0.4449	0.6746
5%	0.1702	0.4915	0.3035	0.5768	0.4539	0.6929
Nominal	0.1752	0.5281	0.3153	0.5952	0.4639	0.7101
−5%	0.1817	0.5489	0.3289	0.6129	0.4765	0.7273
−10%	0.1904	0.5868	0.3454	0.6475	0.4920	0.7579
−15%	0.2025	0.6113	0.3667	0.6880	0.5190	0.7826
−20%	0.2181	0.6379	0.3944	0.7098	0.5583	0.8193
−25%	0.2379	0.6673	0.4318	0.7366	0.6146	0.8640

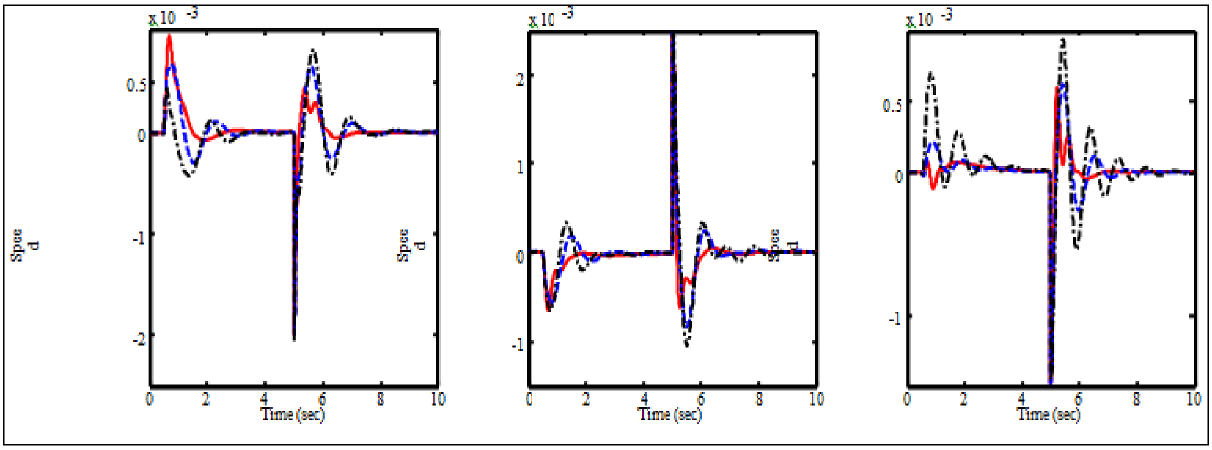

Fig. 5: *Changes in Output Speed of the Generators for Nominal Load: IHBMO (bold line). HBMO (dashline), PSO (dotline).*

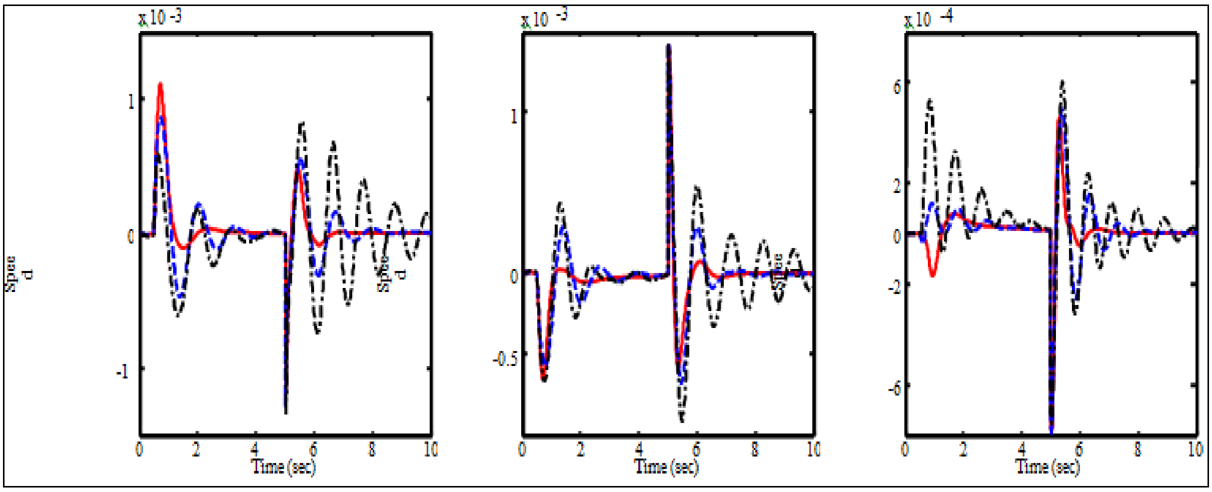

Fig. 6: *Changes in Output Speed of the Generators for Nominal Load: IHBMO (bold line). HBMO (dashline), PSO (dotline).*

The next criterion for studying the efficacy of improved HBMO algorithm is the amount of total volume of sperm chamber [16–18]. The obtained results are shown in the below figures and the below table.

Table 5 shows selected parameters for improved HBMO algorithm. Then, selecting the above parameters as the best response, the simulation was followed by three discrete scenarios [19].

Table 3: *The Results of the Comparison of the Algorithms.*

Change load	**IHBMO**		**HBMO**		**PSO**	
	ITAE	**FD**	**ITAE**	**FD**	**ITAE**	**FD**
25%	0.7097	0.8504	1.0941	0.9240	1.6316	1.0291
20%	0.7135	0.8658	1.1037	0.9387	1.6402	1.0710
15%	0.7217	0.8805	1.1211	0.9712	1.6464	1.0887
10%	0.7420	0.8970	1.1465	0.9894	1.6535	1.1062
5%	0.7719	0.9317	1.1847	1.0082	1.6654	1.1232
Nominal	0.8071	0.9771	1.2320	1.0274	1.6933	1.1442
−5%	0.8487	1.0091	1.2876	1.0510	1.7279	1.1626
−10%	0.9029	1.0662	1.3602	1.0975	1.7808	1.1980
−15%	0.9733	1.1198	1.4484	1.1505	1.8605	1.2197
−20%	1.0580	1.1875	1.5572	1.1910	1.9708	1.2576
−25%	1.1573	1.2736	1.7031	1.2453	2.1262	1.3170

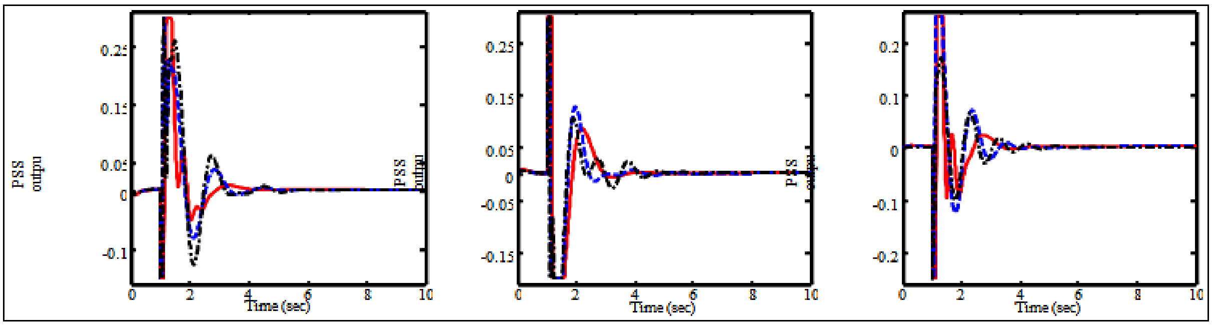

Fig. 7: *Changes in Power System Stabilizer's Output Signal of the Generators for Nominal Load: IHBMO (bold line). HBMO (dash line), PSO (dot line).*

Table 4: *Changes in the Population of Males*

Number of the population	20	40	60	80	100
Number of algorithm implementation	ISTSE	ISTSE	ISTSE	ISTSE	ISTSE
1	0.3129	0.1270	0.1239	0.1236	0.1396
2	0.2193	0.3508	0.1286	0.1298	0.1296
3	0.1320	0.2360	0.1298	0.1287	0.2297
4	0.1645	0.1283	0.1325	0.1282	0.1504
5	0.3421	0.4098	0.1236	0.1293	0.1236
6	0.1329	0.1236	0.1453	0.1295	0.1365
7	0.1382	0.1505	0.1605	0.1286	0.1257
8	0.1236	0.1467	0.1486	0.1910	0.1383
9	0.5291	0.1275	0.1582	0.1236	0.1236
10	0.2891	0.2105	0.2872	0.1288	0.1240
SD	0.1244	0.0975	0.0463	0.0191	0.0304

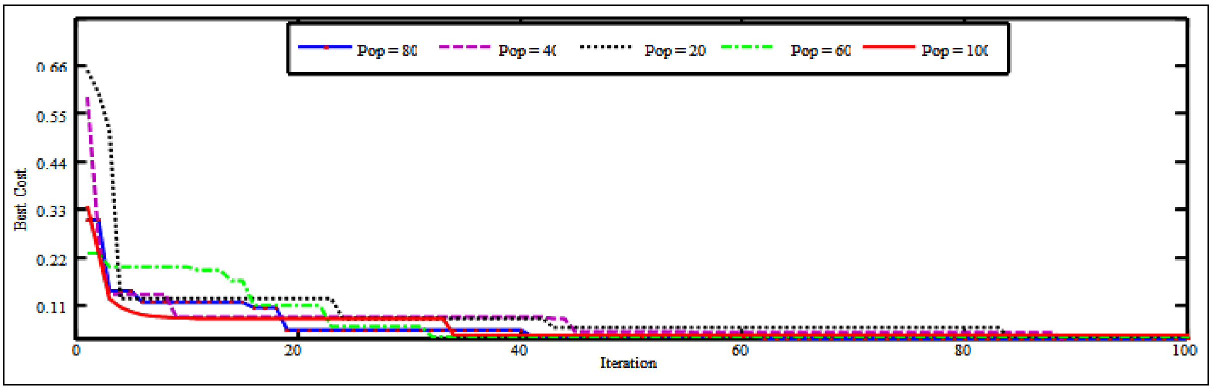

Fig. 8: *Changes in the Convergence for Different Populations.*

Table 5: *Obtained Results for the Parameters of the Proposed Algorithm.*

Number of drones	60
Number of workers	40
Number of children	10
Spectra	50
$\alpha = \varepsilon + \delta$	1.97
B	0.98

CONCLUSIONS

This paper has presented the problem of offline tuning of power-system stabilizers (FPSSs) present in a multi-machine power system in order to damp the power system oscillations. A new technique based on honey bee mating optimization (HBMO) was proposed to optimize the parameters settings of PSS. In fact, the presented algorithm is a combination of three algorithms of genetic, local search and annealing.

The performance and robustness of optimized PSS was tested on 11-bus multi-machine system under normal operating conditions, heavy loadings and response to three phase short circuit. Final results and simulation showed the effectiveness and robustness of the proposed PSS over CPSS under different proposed cases.

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