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ROBUST FUZZY-PID CONTROLLER TO ENHANCE LOW FREQUENCY OSCILLATION USING IMPROVED PARTICLE SWARM OPTIMIZATION

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Abstract- This paper presents a new improved from particle swarm optimization to tune optimal rule-base of a Fuzzy Proportional Integral Differential (FPID) which leads to damp low frequency oscillation following disturbances in power systems, while called Particle Swarm Optimization with Time Variant Acceleration Coefficient (PSO-TVAC). Thus, extraction of an appropriate set of rules or selection of an optimal set of rules from the set of possible rules is an important and essential step toward the design of any successful fuzzy logic controllers. Consequently, in this paper, a PSO-TVAC based rule generation method is proposed for automated fuzzy PID design to improve power system stability and reduce the design effort. The effectiveness of the proposed method is demonstrated on a four-machine 2-area standard power system in comparison with the other heuristic algorithms and classical Power System Stabilizer (CPSS) under different loading condition through some performance indices.

Keywords: Fuzzy-PID, Multi-Machine, Enhances Low Oscillation.

I. INTRODUCTION

Electro-mechanical oscillations on the transmission grid are becoming a critical problem for the power systems; there are two distinct types of dynamic oscillations which have been known to present problems on power systems. One type occurs when a generating unit (group of units) at a station is (are) swinging against the rest of the system. Such oscillations are called local mode oscillations. The characteristic frequency of a typical local mode is generally in the 1-2 Hz range, depending mainly on the impedance of the transmission system.

The second type of oscillations, known as inter-area modes, are more complex because they usually involve a combination of many machines on one part of a system swinging against machines on another part of the system. The characteristic frequency of inter-area modes of oscillations is generally in the range of 0.1-0.6 Hz. A Power System Stabilizer (PSS) is an electronic feedback control that is a part of the excitation system control for generating units. PSS acts to modulate the generator field voltage to damp power system oscillations [1].

Over the years, a number of techniques have been developed for designing PSSs. Conventionally lead-lag control has been widely used in power system control to damp the low frequency oscillations. The main problem encountered in the Conventional PSS (CPSS) design is that the power system constantly experiences changes in operating conditions due to variation in generation and load patterns, as well as changes in transmission networks. Thus, research using these approaches reveals that it exhibits poor dynamic performance [2]. Genetic Algorithm (GA) is a powerful optimization technique, independent on the complexity of problems where no prior knowledge is available [3].

Literature reveals many contributions using GAs for simultaneously stabilization of multi-machine power system over a wide range of scenarios via PSS with fixed parameters. Although GA is very efficient in finding global or near global optimal solution of the problem, it requires a very long computation time depending on the size of the system under study [4]. Fuzzy systems work with a set of linguistic rules, which are carefully designed by experienced operators. It is a model-free approach, which is generally considered suitable for controlling imprecisely defined systems. In fuzzy control, the controller is synthesized from a collection of fuzzy If-Then rules which describe the behavior of the unknown plant. Fuzzy PSSs (FPSSs) has been applied in a number of publications [5]. In [6] the parameters of the FPSS are kept fixed after the design is completed. The performance of the FPSS depends on the operating conditions of the power system, although it is less sensitive than CPSSs.

The PSO with time-varying acceleration coefficients represented by Ratnaweera et al. [7] (2004) is one the best technique for effectively improvements of the classical PSO performance in terms of robustness to control parameters and computational effort. All algorithm parameters including inertia weight and acceleration coefficients are varied with time (iterations) to efficiently control the local search and convergence to the global optimum solution. This strategy is caused to improve the global search in the early stage of the optimization process and cheering the particles to converge toward the global optima at the end of it.

Moreover, it was shown that the PSO-TVAC has very few parameters to adjust than other heuristic optimization methods and a higher success convergence rate since it does exploration and exploitation processes together efficiently. The effectiveness of the proposed method is tested on a multi-machine power system under different operating conditions in comparison with the CPSS, bacterial foraging algorithm [8] and PSO based one through nonlinear time domain simulation and some performance indices. The simulation results demonstrate the robust performance of the proposed method for damping low frequency oscillations than the CPSO, BFA and classical method one such that the relative stability is guaranteed and the time domain specifications concurrently secured.

II. POWER SYSTEM MODELING

A four-machine, two-area study system, shown in Figure 1, is considered for the damping control design. Each area consists of two generator units. The rating of each generator is 900 MVA and 20 kV. Each of the units is connected through transformers to the 230 kV transmission line. There is a power transfer of 400 MW from Area 1 to Area 2. The detailed bus data, line data, and the dynamic characteristics for the machines, exciters, and loads are given in [1]. The loads are modeled as constant impedances. For the power system stability analysis a sufficient mathematical models considering a set of nonlinear differential-algebraic equations by assembling the models for each generator, load and other devices such as controls in the system is required. The two-axis model (fourth order) [2] given in Appendix is used for the time domain simulations study for each machine. The loads are modeled as constant impedances. A first order model of a static type automatic voltage regulator was used.

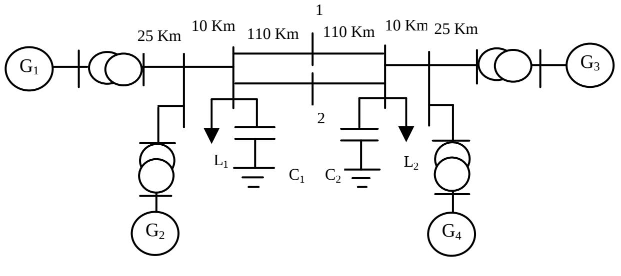

Figure 1. Single line diagram of a two area system

Nonlinear dynamic equations of the multi-machine system considered can be summarized as

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

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

$$\dot{E}'_{qi} = \frac{1}{T'_{doi}}(E_{fdi} - (x_{di} - x'_{di})i_{di} - E'_{qi}) \tag{3}$$

$$\dot{E}_{fdi} = \frac{1}{T_{Ai}}(K_{Ai}(v_{refi} - v_i + u_i) - E_{fdi}) \tag{4}$$

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

where d, rotor angle; x, rotor speed; P_m, mechanical input power; P_e, electrical output power; E_q, internal voltage behind x_d; E_{fd}, equivalent excitation voltage; T_e, electric torque; T_{do}, time constant of excitation circuit; K_A, regulator gain; T_A, regulator time constant; v_{ref}, reference voltage; and v, terminal voltage.

III. FUZZY PID CONTROLLER DESIGN

Recently the research for control methods based on Fuzzy Logic Controllers (FLC) as PSS has greatly improved the dynamic characteristics of power system. Membership functions' shape and fuzzy rules should be adjusted to obtain the best control performance in FLC. Conventionally the adjustment is done by experts or by trial and error methods. Therefore it is difficult to determine the suitable membership functions and rule base without the knowledge of the system. These problems make the design process more difficult [9]. On the other hand, FLC robustness and reliability make fuzzy controllers useful for solving a wide range of control problems in power systems. In general, the application of fuzzy logic to PID control design for the PSS design can be classified in two major categories according to the way of their construction [9]:

1. A typical PSS is constructed as a set of heuristic control rules, and the control signal is directly deduced from the knowledge base.
2. The gains of the conventional PID controller are tuned on-line in terms of the knowledge base and fuzzy inference, and then, the conventional PID controller generates the control signal.

At design of fuzzy logic controller, there are five parts for fuzzy inference process:

1. Fuzzification of the input variables.
2. Application of the fuzzy operator (AND or OR) in the antecedents.
3. Implication from the antecedent to the consequent.
4. Aggregation of the consequents across the rules.
5. Defuzzification.

Figure 2 shows the block diagram of the classical fuzzy type controller to PSS design for each generator.

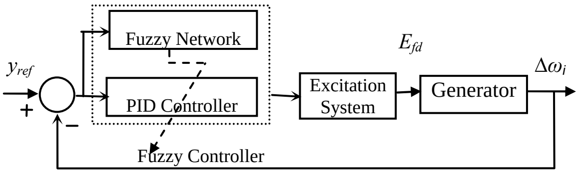

Figure 2. The classical FPID controller design problem

The structure of the classical FPID controller has two stages. The first level is fuzzy network and the second level is the PID controller. The controller block is formed by fuzzification of ($\Delta\omega_i$), the interface mechanism and defuzzification. Therefore, u_i is a control signal that applies to the excitation system in each generator. By taking $\Delta\omega_i$ as the system output, the control vector for the conventional PID controller is given by:

$$u_i = K_{Pii}\Delta\omega_i(t) + K_{Ii}\int_0^t \Delta\omega_i(t)dt + K_{di}\Delta\dot{\omega}_i(t) \tag{6}$$

The parameters, K_{Ii}, K_{di} and K_{pi} are determined by a set of fuzzy rules of the form:

If $\Delta\omega_i$ is A_i and $\Delta(\Delta\omega_i)$ is B_i then K_{di} is C_i and K_{pi} is D_i and K_{Ii} is E_i, $i=1,2,\cdots,n$.

where, A_i, B_i, C_i, D_i and E_i are fuzzy sets on the corresponding supporting sets.

According to the FLC design, and depending on the performance of FPID controller on a designed knowledge base and rules criteria it should be considered that; the intelligent design method for FPID control, which can generate an optimal rule tables without human experts, is desirable.

IV. PSO-TVAC PROCEDURE

A. Review PSO

The PSO is a population-based method and is described by its developers as an optimization paradigm, which models the social behavior of the birds flocking or fish schooling for food. Therefore, PSO works with a population of potential solutions rather than with a single individual [10].

In the PSO technique a number of simple entities, the particles, are placed in the search space of some problem or function, and each evaluates the objective function at its current location. Each particle then determines its movement through the search space by combining some aspect of the history of its own current and best locations by those of one or more members of the swarm with some random perturbations. The next iteration takes place after all particles have been moved. Eventually the swarm as a whole, like a flock of birds collectively foraging for food, is likely to move close to an optimum of the fitness function [10].

In the PSO technique, the trajectory of each individual in the search space is adjusted by dynamically altering the velocity of each particle, according to its own flying experience and the flying experience of the other particles in the search space. The position and velocity vectors of the ith particle in the D-dimensional search space can be represented as $X_i=(x_{i1}, x_{i2}, ..., x_{id})$ and $V_i=(v_{i1}, v_{i2}, ..., v_{id})$, respectively. According to a user defined fitness function, let us assume that the best position of each particle, which corresponds to the best fitness value (*pbest*) obtained by that particle at time, be $P_i=(p_{i1}, p_{i2}, ..., p_{id})$, and the global version of the PSO keeps track of the overall best value (*gbest*), and its location, obtained thus far by any particle in the population. The new velocities and the positions of the particles for the next fitness evaluation are calculated using the following two equations [11]:

$$\begin{aligned} &v_{id}(t+1) = \omega v_{id}(t) + c_1\,\text{rand}_1(p_{id}(t) - \\ &-x_{id}(t)) + c_2\,\text{rand}_2(g_{gd}(t) - x_{id}(t)) \\ &\vec{x}(t+1) = \vec{x}(t) + \vec{v}(t+1) \end{aligned} \tag{7}$$

where P_{id} and P_{gd} are *pbest* and *gbest*. The positive constants c_1 and c_2 are the cognitive and social components that are the acceleration constants responsible for varying the particle velocity towards *pbest* and *gbest*, respectively. Variables r_1 and r_2 are two random functions based on uniform probability distribution functions in the range [0, 1]. The inertia weight w is responsible for dynamically adjusting the velocity of the particles, so it is responsible for balancing between local and global searches and hence requiring less iteration for the algorithm to converge [11]. The following inertia weight is used in Equation (8):

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{iter_{\max}}.iter \tag{8}$$

where $iter_{\max}$ is the maximum number of iterations and iteration is the current number of iteration. The Equation (8) presents how the inertia weight is updated, considering $w_{\max}$ and $w_{\min}$ are the initial and final weights, respectively.

B. PSO-TVAC

All coefficients including inertia weight and acceleration coefficients are varied with iterations. The equation of PSO-TVAC for velocity updating can be expressed as [8]:

$$\begin{aligned} &v_i(t+1) = C\{wv_i(t) + \\ &+((c_{1f} - c_{1i})\frac{k}{k_{\max}} + c_{1i}).r_1(t)[pbest_i(t) - x_i(t)] + \\ &+((c_{2f} - c_{2i})\frac{k}{k_{\max}} + c_{2i}).r_2(t)[leader_i(t) - x_i(t)]\} \end{aligned} \tag{9}$$

$$w = (w_{\max} - w_{\min}).\frac{(k_{\max} - k)}{k_{\max}} + w_{\min} \tag{10}$$

$$C = \frac{2}{\left|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}\right|} \quad , \quad 4.1 \le \varphi \le 4.2 \tag{11}$$

The procedure of PSO-TVAC for tuning fuzzy-PID parameters is described in Figure 3.

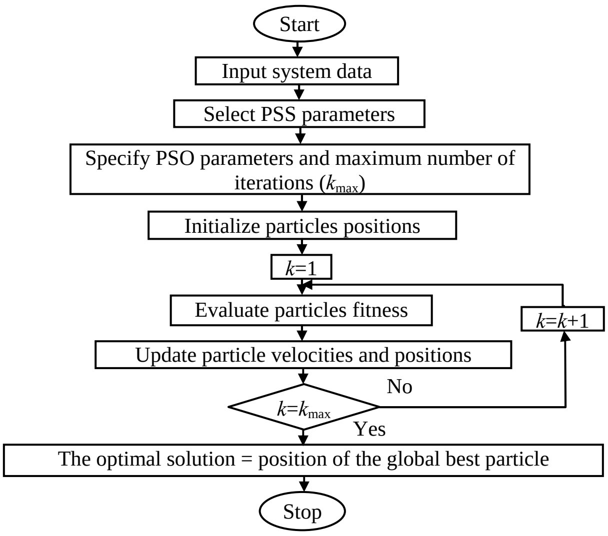

Figure 3. The block diagram of fuzzy-PID

V. APPLYING PSO-TVAC ALGORITHM TO POWER SYSTEM

The simulation operated with multi objective with PSO-TVAC algorithm and the objective functions for optimization as follow:

$$f_1 = 100 \sum_{j=1}^{N_l} \sum_{i=1}^{N_g} \int_0^{t_{sim}} t \,|\, \Delta\omega_{ij} \,|\, dt \tag{12}$$

In this study the ITAE are presented by f_1, respectively. The parameters for PSO-TVAC algorithm are presented in Table 1.

Table 1. Parameters for PSO-TVAC algorithm

C_{1f}	0.2	φ	4.1
C_{1i}	2.5	$w_{\min}$	0.4
C_{2f}	2.5	$w_{\max}$	0.9
C_{2i}	0.2	Population	40
		Iteration	100

The optimization of the Fuzzy-PID parameters is carried out by evaluating the objective cost function as given in Equation (12), which considers a multiple of operating conditions are 1- Base Case, 2- Heavy (20% increase for load), 3- Light (20% decrease for load), 4- Trip line.

The operating conditions are given in Table 2. The results of fuzzy rule base sets are listed in Tables 3-5.

Table 2. Four operating condition (p.u.)

Case	G_1		G_2	
	P	*Q*	*P*	*Q*
1	0.7778	0.1021	0.7777	0.1308
2	1.084	0.3310	0.7778	0.4492
3	0.7778	0.0502	0.2333	0.0371
4	0.7778	0.1021	0.7777	0.1308
Case	G_3		G_4	
	P	*Q*	*P*	*Q*
1	0.7879	0.0913	0.7778	0.0918
2	0.7879	0.1561	0.7778	0.2501
3	0.7989	0.0794	0.7778	0.0704
4	0.7989	0.0903	0.7778	0.0981

Table 3. Optimal rule base for K_{Pi}

	NB	**NS**	**PS**	**PB**
NS	NS	NS	PM	NM
NS	PM	NB	ZO	NM
ZO	ZO	PB	PM	PB
PS	NS	PM	NS	NM
PB	PM	NB	NS	NS

Table 4. Optimal rule base for K_{Ii}

	NB	**NS**	**PS**	**PB**
NB	NS	NS	NM	PB
NS	NM	ZO	NB	NM
ZO	PM	NM	PM	PM
PS	NS	PM	PM	NB
PB	NM	PB	NB	NS

Table 5. Optimal rule base for K_{Ii}

	NB	**NS**	**PS**	**PB**
NB	PM	NS	NM	PB
NS	PM	ZO	NB	ZO
ZO	PM	NM	PM	ZO
PS	NS	ZO	PM	NB
PB	NS	PB	NB	NS

VI. SIMULATION RESULTS

The effectiveness and robustness of the performance of the proposed controller under transient conditions is verified by applying a three-phase fault of 100 ms duration at the middle of one of the transmission lines between bus-7 and bus-8. To evaluate the performance of the proposed simultaneous design approach the response with the proposed controllers are compared with the response of the PSO and PSO-TVAC damping controller individual design. The inter-area and local mode of oscillations with coordinated and uncoordinated design of the controllers is shown in Figures 4-6, respectively. It is clear from these figures that, the simultaneous design of the PID damping controller by the proposed approach significantly improves the stability performance of the example power system and low frequency oscillations are well damped out. To demonstrate the performance and robustness of the proposed method, two performance indices: the *ITAE*, *FD*, *IAE*, and *ISE* based on the system performance characteristics are defined as [11, 12, 13]:

$$ITAE = 10000. \int_0^{t_{sim}} t[(\omega_1 - \omega_2) + (\omega_1 - \omega_3) + \\ +(\omega_1 - \omega_4) + (\omega_3 - \omega_4)]dt \tag{13}$$

$$FD = \frac{1}{4} \sum_{i=1, j=1}^{4} \alpha_1.OS_{i,j}^2 + \alpha_2.US_{i,j}^2 + T_{i,j}^2 \;, \; \begin{cases} \alpha_1 = 4000 \\ \alpha_2 = 1000 \end{cases} \tag{14}$$

$$IAE = 10000. \int_0^{t_{sim}} [(\omega_1 - \omega_2) + (\omega_1 - \omega_3) + \\ +(\omega_1 - \omega_4) + (\omega_3 - \omega_4)]dt \tag{15}$$

$$ISE = 10000. \int_0^{t_{sim}} [(\omega_1 - \omega_2)^2 + (\omega_1 - \omega_3)^2 + \\ +(\omega_1 - \omega_4)^2 + (\omega_3 - \omega_4)^2]dt \tag{16}$$

Numerical results of the performance robustness for all cases are listed in Figure 7.

VII. CONCLUSIONS

The PSO with time-varying acceleration coefficients algorithm has been successfully applied to determine the optimal parameters of Fuzzy-PID, simultaneously to enhance the relative stability and secure operation of the multi machine power systems. To optimal setting of the stabilizers parameters a time domain-based cost function under multiple operation conditions is introduced and solved by PSO-TVAC. It performs both global and local search at each iteration process for significant increasing the probability of finding the optimal solution. Hence, the convergence precision and speed are remarkably improved and then the high precision and efficiency are achieved. The non-linear time domain simulation results show the improved PSO-TVAC algorithm provides good ability for effectively damping low frequency oscillations over a wide range of operation conditions. Moreover, the system characteristics analysis using different introduced performance indices reveal that the proposed PSO-TVAC algorithm is superior that of the BFA and CPSS in terms of accuracy and computational effort.

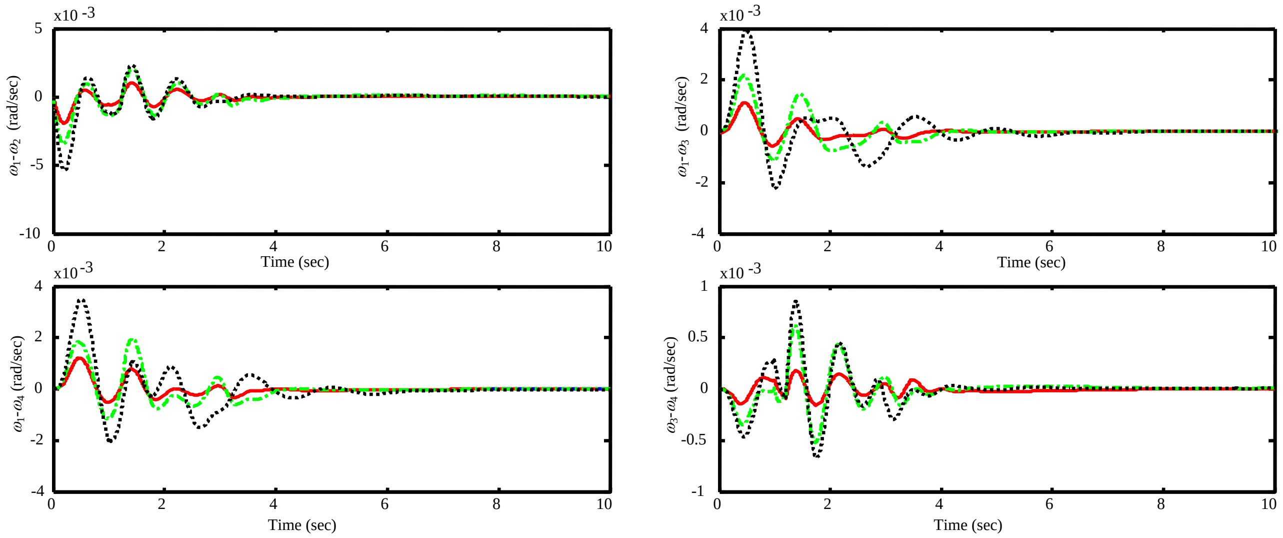

Figure 4. Inter-area and local mode of oscillations for case 1: Solid (PSO-TVAC-Fuzzy-PID), Dashed-Doted (BFAPSS [12]), Dotted (CPSS [12])

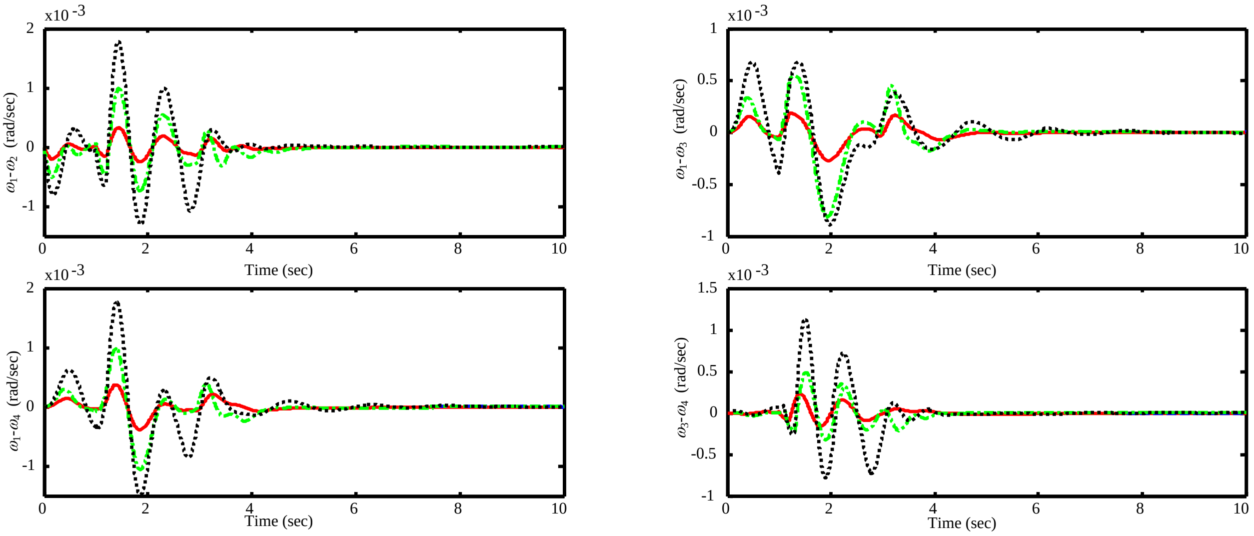

Figure 5. Inter-area and local mode of oscillations for case 2: Solid (PSO-TVAC-Fuzzy-PID), Dashed-Doted (BFAPSS [12]), Dotted (CPSS [12])

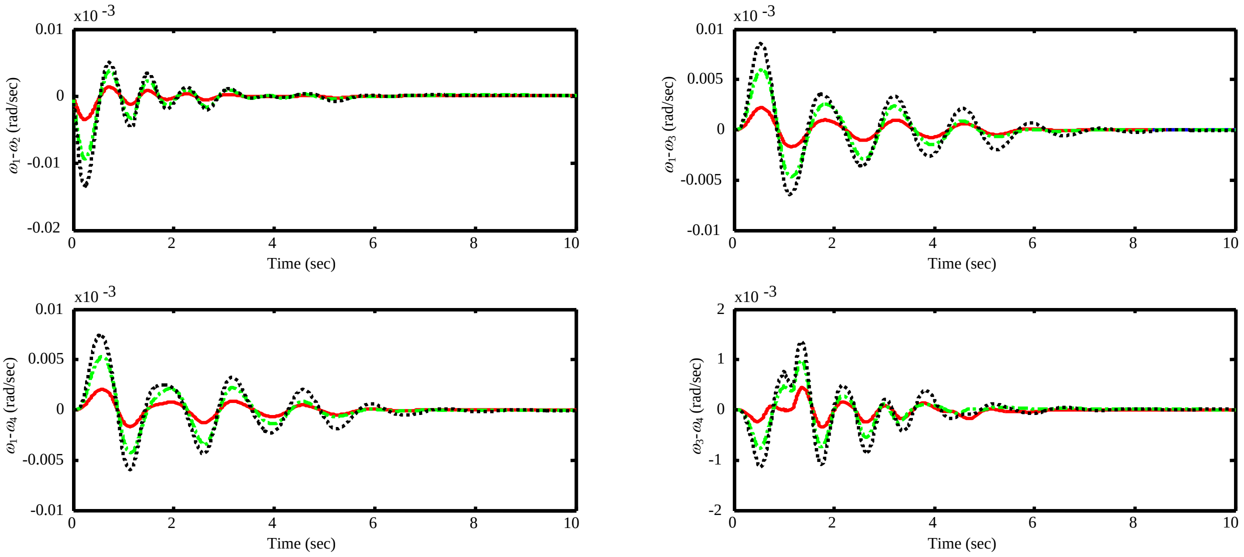

Figure 6. Inter-area and local mode of oscillations for case 4: Solid (PSO-TVAC-Fuzzy-PID), Dashed-Doted (BFAPSS [12]), Dotted (CPSS [12])

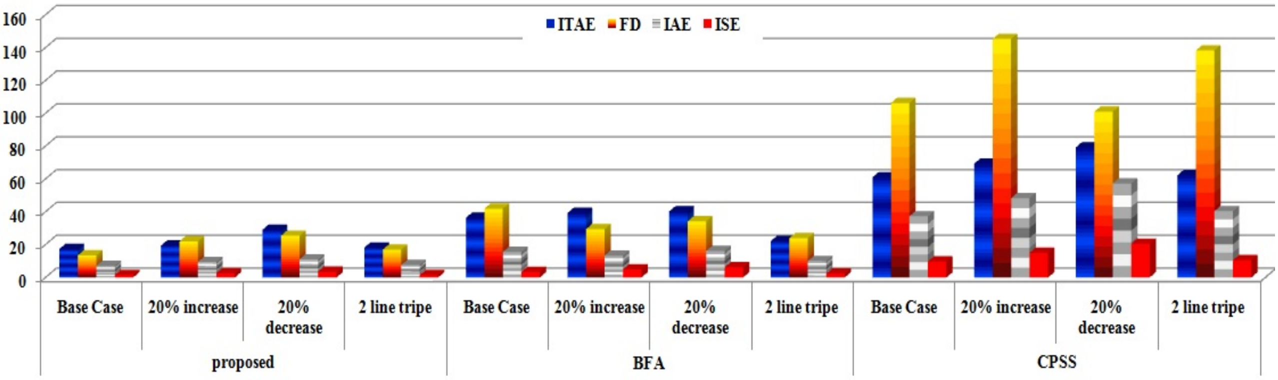

Figure 7. Values of the performance indices under different conditions

REFERENCES

[1] M.J. Basler, R.C. Schaefer, "Understanding Power System stabIlity", IEEE Trans. on Industry Applications, Vol. 44, pp. 463-474, 2008.

[2] P. Kundur, "Power System Stability and Control", McGraw-Hill, New York, 1994.

[3] O. Abedinia, M. Salay Naderi, A. Jalili, B. Khamenehpour, "Optimal Tuning of Multi-Machine Power System Stabilizer Parameters Using Genetic Algorithm", International Conference on Power System Technology, Hangzhou, China, pp. 24-28, October, 2010.

[4] J.M. Call, "Genetic Algorithms for Modeling and Optimization", Journal of Computational and Applied on Mathematics, Vol. 184, pp. 205-222, 2005.

[5] H.A. Shayanfar, H. Shayeghi, O. Abedinia, A. Jalili, "Design Rule-Base of Fuzzy Controller in Multi-Machine Power System Stabilizer Using Genetic Algorithm", International Conference on Artificial Intelligence, Las Vegas, Nevada, USA, pp. 43-49, July 2010.

[6] E.L. Zonkoly, A.A. Khalil, N.M. Ahmied, "Optimal Tuning of Lead-Lag and Fuzzy Logic Power System Stabilizers Using Particle Swarm Optimization", Expert System with Applications, Vol. 10, pp. 1-10, 2008.

[7] A. Ratnaweera, S.K. Halgamuge, H.C. Watson, "Self-Organizing Hierarchical Particle Swarm Optimizer with Time-Varying Acceleration Coefficients", IEEE Transaction on Evolutionary Computations, Vol. 8, pp. 240-55, 2004.

[8] T.K. Das, G.K. Venayagamoorthy, U.O. Aliyu, "Bio-Inspired Algorithms for the Design of Multiple Optimal Power System Stabilizers: SPPSO and BFA", IEEE Transaction on Industrial Applications, Vol. 44, No. 5, pp. 1445-1457, 2008.

[9] J.H. Hwang, D.W. Kim, J.H. Lee, Y.J. An, "Design of Fuzzy Power System Using Adaptive Evolutionary Algorithm", Engineering Applications of Artificial Intelligence, Vol. 21, pp. 86-96, 2008.

[10] H. Shayeghi, A. Safari , H.A. Shayanfar, "PSS and TCSC Damping Controller Coordinated Design Using PSO in Multi-Machine Power System", Energy Conversion and Management, Vol. 51, pp. 2930-2937, 2010.

[11] A. Ghasemi, M.A. Abido, "Optimal Design of Power System Stabilizers: A PSOIIW Procedure", 27th International Power System Conference, pp. 1-11, 2012.

[12] H. Shayeghi, H.A. Shayanfar, A. Ghasemi, "A Robust ABC Based PSS Design for a SMIB Power System", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 8, Vol. 3, No. 3, pp. 86-92, September 2011.

[13] H. Shayeghi, A. Ghasemi, "Optimal Design of Power System Stabilizer Using Improved ABC Algorithm", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 12, Vol. 4, No. 3, pp. 24-31, September 2012.

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