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AUTOMATIC GENERATION CONTROL IN MULTI AREA INTERCONNECTED POWER SYSTEM USING PID CONTROLLER BASED ON GA AND PSO

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ABSTRACT: - The goal of paper is to maintain the frequency and tie line power changes are maintained at their scheduled values, so in this paper presents two methods for determination of the optimal (Proportional-Integral-Derivate) PID parameters for Automatic Generation Control (AGC) of the three areas (non reheat thermal-reheat thermal-hydraulic) interconnected power system, the first is the Genetic Algorithm (GA) and the second is the Particle Swarm Optimization (PSO). The GA and PSO are applied to search for the optimal PID controller parameters to minimize various performance indexes as objective functions. These objective functions namely Integral Absolute Error (IAE) and Integral Square Error (ISE) are considered for optimization.

The performance of the intelligent controllers based on GA and PSO has been compared with tie line bias control strategy, the settling time, maximum deviation and peak time with the proposed controllers are better than the outputs of the tie line bias control strategy. From combination sets (GA-IAE, PSO-IAE, GA-ISE and PSO-ISE), GA-IAE and PSO-IAE have better settling time and lesser peak time when compared with GA-ISE and POS-ISE while, GA-ISE has lower maximum deviation when compared with other sets.

KEYWORDS: - Load Frequency Control (LFC), Automatic Generation Control (AGC), Area Control Error (ACE), PID Controller, Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Integral Absolute Error (IAE), Integral Square Error (ISE).

1- INTRODUCTION

The main goal of a power system control is to maintain supplying of power with an acceptable quality and reliable to all the consumers in the system. The system will be in equilibrium, when there is a balance between the power generated and the power demand. There are two basic control mechanisms used to achieve power balance; real power balance is called the automatic Load Frequency Control (LFC) or Automatic Generation Control (AGC) and reactive power balance is called the Automatic Voltage Regulator (AVR). For multi area power systems, which normally consist of interconnected control area, AGC is an important aspect to keep the system frequency and the interconnected area tie line power as close as possible to the desired values [1,2,3]. The mechanical input power to the generators is used to control the system as it is affected by the output electrical power demand and to maintain the power exchange between the areas as planned. The AGC monitors the system frequency and tie line flows, calculates the net change in the generation required according to the change in demand and changes the set position of the generators within the area so as to keep the time average of the Area Control Error (ACE) at a low value. The ACE is generally treated as controlled output of AGC. As the ACE is adjusted to zero by the AGC, both frequency and tie line power errors will become zero [4,5].

The PID type controller is still widely used for the solution of LFC problem. On the other hand, the optimal tuning of PID gains is required to get the desired level of robust performance under different operation conditions. Optimal gains tuning of a PID controller for solution of the LFC problem in power system is proposed using Genetic Algorithms (GA) in [6,7], while Particle Swarm Optimization (PSO) have been applied for optimal tuning of PID based LFC schemes in [8,9,10].

In this paper, three area automatic generation controls have been studied Area 1 (non reheat thermal plant), Area 2 (reheat thermal plant) and Area 3 (hydraulic plant) and it is implementation GA and PSO for tuning the parameter of PID based to minimize two different objective functions. First is Integral Absolute Error (IAE) and second is Integral Square Error (ISE).

2- THREE AREA INTERCONNECTED POWER SYSTEM MODEL.

The system under investigation consists of three area interconnected power system Area 1 (non reheat thermal plant), Area 2 (reheat thermal plant) and Area 3 (hydraulic plant). In multi area power system, the first objective of the LFC is to keep the system frequency at nominal value and the second objective to maintain the tie line power exchange at schedule value. When the power in any area is change, generation in all the areas is increased to meet a change in the tie line power and a reduction in frequency. But the normal operating state of the power system in each area will be satisfied at a normal frequency. There ACE for each area and this area will try to reduce its own ACE to zero [11]. The transfer function model of three area (non reheat thermal-reheat thermal-hydraulic) power system is depicted in Figure 1 and the pertinent parameters are given in Table 1. The ACE for each area is defined as:

$$ACE_1 = -\Delta P_{12} + \Delta P_{31} - B_1 \Delta\omega_1 \quad \dots (1)$$
$$ACE_2 = +\Delta P_{12} - \Delta P_{23} - B_2 \Delta\omega_2 \quad \dots (2)$$
$$ACE_3 = +\Delta P_{23} - \Delta P_{31} - B_3 \Delta\omega_3 \quad \dots (3)$$

Where ΔP_{12}, ΔP_{23} and ΔP_{31} are change in tie line power area, B_1, B_2 and B_3 are frequency bias for each area, $\Delta\omega_1$, $\Delta\omega_2$ and $\Delta\omega_3$ are frequency deviation for each area.

3- PID CONTROLLER MODEL.

The PID controller is one of the majority successful and influential control instrument in industry since of uncomplicated and simple implementation. According to [12,13] a typical structure of the conventional PID controlled system is shown in Figure 2 and the transfer function model of PID controller in terms of Laplace domain is described as follow:

$$G_{PID}(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s} + k_d s \quad \dots (4)$$

Where, $U(s)$ and $E(s)$ are the control signal and the error signal which is the difference between input and feedback in terms of Laplace domain correspondingly; k_p is the proportional gain, k_i is the integration gain and k_d is the derivative gain.

The output of PID controller in term of time domain is represented as follow:

$$u(t) = k_p e(t) + k_i \int_0^t e(t)dt + k_d \frac{de(t)}{dt} \quad \dots (5)$$

Where, u(t) and e(t) are the control and tracking error signal which is in the form of time domain.

For area 1

$$u_1(t) = k_{p1}ACE_1(t) + k_{i1}\int_0^t ACE_1(t)dt + k_{d1}\frac{dACE_1(t)}{dt} \quad \dots (6)$$

For area 2

$$u_2(t) = k_{p2}ACE_2(t) + k_{i2}\int_0^t ACE_2(t)dt + k_{d2}\frac{dACE_2(t)}{dt} \quad \dots (7)$$

For area 3

$$u_3(t) = k_{p3}ACE_3(t) + k_{i3}\int_0^t ACE_3(t)dt + k_{d3}\frac{dACE_3(t)}{dt} \quad \dots (8)$$

In this paper the effect of two different objective functions is studied for optimization of parameters. First is IAE and second is ISE. Has been defined as follows:

$$OB_1 = IAE = \int_0^t [|ACE_1(t)| + |ACE_2(t)| + |ACE_3(t)|]dt \quad \dots (9)$$
$$OB_2 = ISE = \int_0^t [(ACE_1)^2(t) + (ACE_2)^2(t) + (ACE_3)^2(t)]dt \quad \dots (10)$$

Minimize OB_1 and OB_2 subjected to:

$$k_p^{min} \le k_p \le k_p^{max}\ ,\ k_i^{min} \le k_i \le k_i^{max} \text{ and } k_d^{min} \le k_d \le k_d^{max} \quad \dots (11)$$

4- INTELLIGENCE TECHNIQUES.

The main objective of this paper is to control the set of goals, which are: ACE, frequency deviation and tie line power for a power imbalance between the load disturbance and power generation by keeping controllable sources power output within the limits. Generally tuning of controller parameters is achieved by trial and error method and Ziegler's Nichols method. But unfortunately, these methods are not feasible in practical systems. Consequently, many powerful mathematical optimization techniques are using to tune the parameters of PID and most reliable are population based optimization methods especially GA and PSO.

The GA is an optimization and search technique based on the principles of genetics and natural selection. The GA allows a population composed of many individuals to evolve under specified selection rules to a state that minimizes the objective function; many versions of evolutionary programming have been tried with varying degrees of success [6,7].

The basic operating principles of GAs are based on the principles of natural evolution. This algorithm works with a set of population of candidate solution represented as strings. The initial population consists of randomly generated individuals. The objective function of each individual in current population is computed. The population is then transformed in stages to yield a new current population for next iteration. The transformation is usually done in three stages by simply applying the following genetic operators:

1. Selection: - selection operator is applied as many times as there are individuals in the population. In this stage every individual is replicated with a probability proportional to its relative objective function in the population.
2. Crossover: - crossover operator is applied. Two individuals (parents) are chosen and combined to produce two new individuals. The combination is done by choosing at random a

cutting point at which each of parents is divided into two parts; these are exchanged to form the two offspring which replace their parents in the population.
3. Mutation: - mutation operator changes the values in a randomly chosen location on an individual. The algorithm terminates after a fixed number of iterations and the best individual generated during the run is taken as the solution.
The PSO is one of the modern heuristic algorithms, which can be effectively used to solve nonlinear and non-continuous optimization problems. In the PSO method, a swarm consists of a set of individuals named as particles are specified by their position and velocity [8,9,10].

Each particle in the swarm has knowledge of the location with best objective value of the entire swarm which is called the global best (g_{best}). At each point along their path, each particle also compares the objective value of their personal best (p_{best}) to that of (g_{best}). If any particle has a (p_{best}) with better objective value than that of current (g_{best}) , then the current (g_{best}) is replaced by that particle's (p_{best}). The movement of particles is stopped once all particles reach sufficiently close to the position with best objective value of the swarm. The algorithm can search an optimum solution in a specified search space by updating the positions and velocities of particles, each particle initializes positions and velocities using following equations:

$$V_i^{k+1} = wV_i^k + c_1 r_1 \left(p_{best\,i}^k - X_i^k\right) + c_2 r_2 \left(g_{best\,i}^k - X_1^k\right) \quad \ldots (12)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad \ldots (13)$$

$$w = \frac{maxiter - iter}{maxiter} \quad \ldots (14)$$

Where V_i^{k+1} is velocity of particle at k+1 iteration, V_i^k is velocity of particle at k iteration, w is inertia weight parameter, X_i^{k+1} is position of particle at k+1 iteration, X_i^k is position of particle at k iteration, c_1 and c_2 are learning factors, r_1 and r_2 are random number in the interval [0 1].

The GA and PSO are used for tuning PID parameters based on minimization OB_1 and OB_2, the simulation results carried out using MATLAB/Simulink software.

5- RESULTS AND DISCUSSION

The three area interconnected power system model was implemented with PID controller in MATLAB/Simulink as shown in Figure 1 and the plant parameters for three area power system is presented in Table 1. At first the simulation result carried out with and without tie line bias control, the ACE with and without tie line bias control are shown in Figure 3, Δω with and without tie line bias control are shown in Figure 4 and ΔP_{ij} with and without tie line bias control are shown in Figure 5. Although simulation was performed for 80 seconds, for clarity graphs are shown for first 60 seconds for ACE and Δω while is shown for first 70 seconds for ΔP_{ij}. The settling time, maximum deviation and peak time for ACE, Δω and ΔP_{ij} with tie line bias control are given in Table 2.

Then, different algorithms were implemented for tuning the k_p, k_i and k_d gains of PID controller to improve the dynamic performance of three area interconnected power system. The lower bound value for PID controller parameters is chosen as -1 and upper bound is chosen as 2. First of all, in Figure 6 the performance index IAE is used to determine optimal values of the PID controller as objective function, which is explained as the sum of absolute of cumulative errors in area control error. Secondly, in Figure 7 the performance index ISE is used to determine optimal values of the PID controller as objective function, which is explained as the sum of square of cumulative errors in area control error. The optimization process of combination namely, GA-IAE, GA-ISE, PSO-IAE and PSO-ISE are used for minimization OB_1 and OB_2. From these 4 sets, the optimal tuning gains of PID controller are given in Table 3.

Figures (8-10) give the response of ACE obtained by GA and PSO, Figures (11-13) give the response of $\Delta\omega$ obtained by GA and PSO and Figures (14-16) give the response of ΔP_{ij} obtained by GA and PSO. Although simulation was performed for 80 seconds, for clarity graphs are shown for first 30 seconds for ACE and $\Delta\omega$ while is shown for first 50 seconds for ΔP_{ij}. The settling time, maximum deviation and peak time for ACE are given in Table 4, for $\Delta\omega$ are given in Table 5 and for ΔP_{ij} are given in Table 6.

In all the results above, the settling time, maximum deviation and peak time are reduced by GA and PSO for tuning of PID controller. When compared with tie line bias control, the damping characteristics of power system are improved more effectively by GA and PSO for tuning of PID controller. Also, stability of the system is preserved and power system oscillations are reduced.

6- CONCLUSIONS.

Artificial intelligence techniques have been used for the tuning of PID controllers to improve the performance of the AGC systems. In this paper, GA and PSO which are proposed to tune the gains of PID controller for AGC. A three area (non reheat thermal-reheat thermal-hydraulic) power systems is considered to indicate effectiveness and robustness of the proposed approach under different objective functions (OB_1 and OB_2). From the results, the proposed algorithms have simple architecture, better settling time, lesser peak time as well as lower maximum deviation when compared with the tie line bias control. A comparison between performance indices shows that performance index (IAE) has better performance of the convergence to the best solution than performance index (ISE) for settling time and peak time and vice versa for maximum deviation. In general, GA gives better results than that obtained with PSO but, the elapsed time for tuning the gains of PID controller obtained with GA is greater than from the elapsed time obtained with PSO.

REFERENCES:-

1) P.Kundur, (1994), "Power System Stability and Control", McGraw Hill, New York, pp. 1-1196.
2) D.Das, (2006), "Electrical Power Systems", New Age International (P) Ltd., New Delhi, pp. 1-483.
3) Hadi Saddat, (1999), "Power System Analysis", McGraw Hill, New York, pp. 1-697.
4) S. K. Sinha, R. N. Patel and R. Prasad, (2010), "Application of GA and PSO Tuned Fuzzy Controller for AGC of Three Area Thermal- Thermal-Hydro Power System", International Journal of Computer Theory and Engineering, Vol. 2, No. 2, pp. 238-244.
5) Surya Prakash and S.K. Sinha, (2011), " Load frequency control of three area interconnected hydro-thermal reheat power system using artificial intelligence and PI controllers", International Journal of Engineering, Science and Technology, Vol. 4, No. 1, pp. 23-37.
6) Vikas Jain, Naveen sen and Kapil Parikh, (2014), "Modeling and simulation of Load Frequency Control in Automatic Generation Control using Genetic Algorithms Technique", International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 8, pp. 356-362.
7) G. Konar, K. K. Mandal, and N. Chakraborty, (2014), "Two Area Load Frequency Control Using GA Tuned PID Controller in Deregulated Environment", Proceedings of the International Multi Conference of Engineers and Computer Scientists 2014 Vol. 2, pp. 1-6.
8) Ashok Mohan Jadhav and Dr.K.Vadirajacharya, (2012), "Performance Verification of PID Controller in an Interconnected Power System Using Particle Swarm Optimization ", Energy Procedia 14, pp. 2075-2080.

9) A.Jerin Sharmili and M.Antony Livingston, (2015), "Particle Swarm Optimization based PID controller for two area Load Frequency Control System ", International Journal of Engineering Research and General Science Volume 3, Issue 2, pp. 772-778.
10) Santigopal Pain and Parimal Acharjee, (2014),"Multiobjective Optimization of Load Frequency Control using PSO "International Journal of Emerging Technology and Advanced Engineering, Vol. 4, Special Issue 7, pp. 16-22.
11) S.P. Ghoshal and N.K. Roy, (2004), "A Novel Approach for Optimization of Proportional Integral Derivative Gains in Automatic Generation Control", Australasian Universities Power Engineering Conference, pp. 1-5.
12) V. Ganesh, K.Vasu and P.Bhavana, (2012), "LQR Based Load Frequency Controller for Two Area Power System", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 1, Issue 4, pp. 262-269.
13) Mohamed. M .Ismail and M. A. Mustafa Hassan, (2012), "Load Frequency Control Adaptation Using Artificial Intelligent Techniques for One and Two Different Areas Power System", International Journal of Control, Automation And Systems Vol. 1, No. 1, pp. 12- 23.

Table 1: Typical parameters of the system investigated are (1,2,3).

Area 1 (non reheat thermal plant)	Area 2 (reheat thermal plant)	Area 3 (hydraulic plant)
$R_1 = 0.05$ p.u. $T_{G1} = 0.2$ sec. $T_{T1} = 0.3$ sec. $M_1 = 10$ sec. $D_1 = 1$ p.u. $B_1 = (\frac{1}{R_1} + D_1) = 21$ p.u. $P_{S1} = 1.2$ p.u. $\Delta P_{L1} = 0.1$ p.u.	$R_2 = 0.05$ p.u. $T_{G2} = 0.2$ sec. $T_{T2} = 0.3$ sec. $T_{R2} = 7$ sec. $K_{R2} = 0.3$ p.u. $M_2 = 10$ sec. $D_2 = 1$ p.u. $B_2 = (\frac{1}{R_2} + D_2) = 21$ p.u. $P_{S2} = 0.8$ p.u. $\Delta P_{L2} = 0.2$ p.u.	$R_3 = 0.05$ p.u. $T_{G3} = 0.2$ sec. $T_{T3} = 0.3$ sec. $T_{R3} = 5$ sec. $K_{R3} = 7.6$ p.u. $M_3 = 6$ sec. $D_3 = 1$ p.u. $B_3 = (\frac{1}{R_3} + D_3) = 21$ p.u. $P_{S3} = 0.4$ p.u. $\Delta P_{L3} = 0.0$ p.u.

Table 2: Settling time, maximum deviation and peak time with tie line bias control.

	Settling time (sec.)	Max. deviation (p.u)	Peak time (sec.)
ACE_1	22.17	0.1308	0.994
ACE_2	23.24	0.4582	2.095
ACE_3	29.35	0.1926	4.351
$\Delta\omega_1$	18.71	-0.0064	0.979
$\Delta\omega_2$	27.25	-0.0201	1.615
$\Delta\omega_3$	26.81	-0.0105	4.354
ΔP_{12}	58.17	0.0420	4.352
ΔP_{23}	60.05	-0.0316	3.719
ΔP_{31}	62.12	0.0084	24.70

Table 3: Optimal values gain of PID controller using GA and PSO.

PID Parameters	GA-IAE	GA-ISE	PSO-IAE	PSO-ISE
K_{p1}	0.786	0.362	0.659	0.415
K_{i1}	1.002	0.921	1.195	1.534
K_{d1}	0.906	1.031	0.453	0.924
K_{p2}	1.299	1.842	1.440	1.189
K_{i2}	1.354	1.245	1.177	0.626
K_{d2}	1.004	1.600	0.901	0.914
K_{p3}	0.649	0.490	0.604	0.062
K_{i3}	0.391	0.391	0.796	0.421
K_{d3}	0.913	0.663	0.941	1.011
Min. OB	0.837	0.049	0.892	0.092
Elapsed time (sec.)	18.14	18.54	9.989	11.37

Table 4: Settling time, maximum deviation and peak time for ACE.

		Settling time (sec.)	Max. deviation (p.u)	Peak time (sec.)
GA-IAE	ACE_1	4.206	0.0484	0.467
	ACE_2	12.59	0.1980	0.947
	ACE_3	**12.36**	0.0519	**2.550**
GA-ISE	ACE_1	7.734	**0.0483**	1.179
	ACE_2	**10.48**	**0.1550**	**0.804**
	ACE_3	12.58	**0.0457**	2.785
PSO-IAE	ACE_1	**2.935**	0.0663	0.584
	ACE_2	13.51	0.2019	0.936
	ACE_3	14.68	- 0.0614	5.174
PSO-ISE	ACE_1	5.525	0.0494	**0.463**
	ACE_2	16.41	0.2146	1.082
	ACE_3	18.59	0.0521	2.827

Table 5: Settling time, maximum deviation and peak time for $\Delta\omega$.

		Settling time (sec.)	Max. deviation (p.u)	Peak time (sec.)
GA-IAE	$\Delta\omega_1$	**4.439**	**-0.0023**	**0.467**
	$\Delta\omega_2$	**6.967**	-0.0090	0.914
	$\Delta\omega_3$	8.118	-0.0029	2.550
GA-ISE	$\Delta\omega_1$	7.833	-0.0025	1.301
	$\Delta\omega_2$	9.683	**-0.0071**	**0.761**
	$\Delta\omega_3$	**7.923**	**-0.0026**	2.783
PSO-IAE	$\Delta\omega_1$	4.592	-0.0032	0.583
	$\Delta\omega_2$	8.773	-0.0092	0.917
	$\Delta\omega_3$	11.46	-0.0031	**2.534**
PSO-ISE	$\Delta\omega_1$	8.463	-0.0024	0.473
	$\Delta\omega_2$	16.14	-0.0097	1.001
	$\Delta\omega_3$	15.38	-0.0031	2.695

Table 6: Settling time, maximum deviation and peak time for ΔP_{ij}.

		Settling time (sec.)	Max. deviation (p.u)	Peak time (sec.)
GA-IAE	ΔP_{12}	33.77	0.0114	**2.406**
	ΔP_{23}	34.76	-0.0094	**2.094**
	ΔP_{31}	32.97	**0.0015**	8.118
GA-ISE	ΔP_{12}	34.59	**0.0081**	2.442
	ΔP_{23}	35.05	**-0.0079**	2.261
	ΔP_{31}	33.52	0.0016	8.053
PSO-IAE	ΔP_{12}	**31.61**	0.0119	2.531
	ΔP_{23}	**29.57**	-0.0095	2.220
	ΔP_{31}	**28.89**	0.0020	**6.966**
PSO-ISE	ΔP_{12}	36.97	0.0166	3.288
	ΔP_{23}	32.18	-0.0117	2.695
	ΔP_{31}	32.21	0.0020	10.72

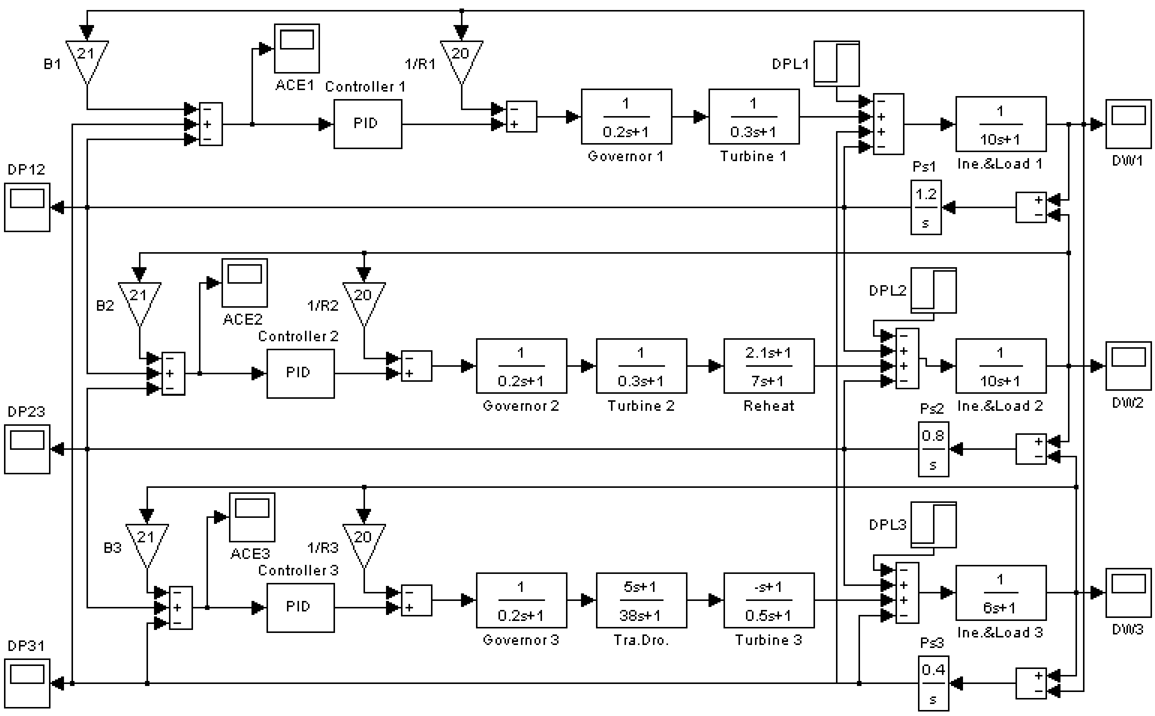

Figure 1:

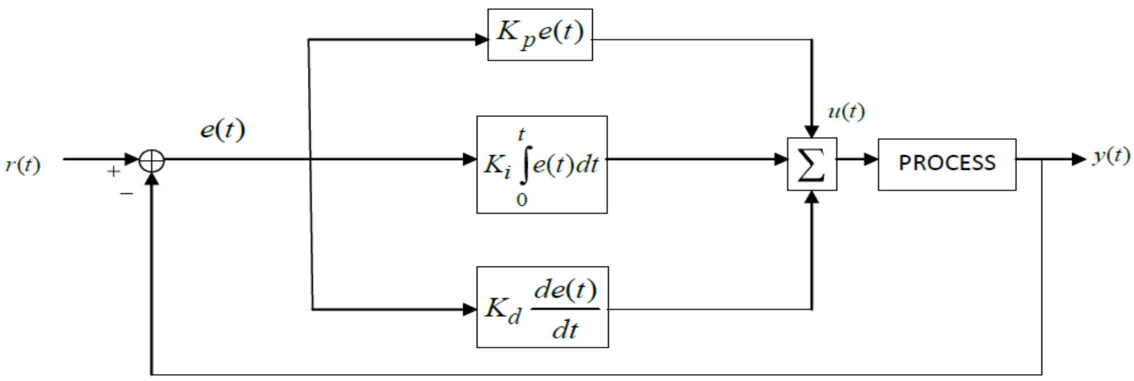

Figure 2: Block diagram of PID controller.

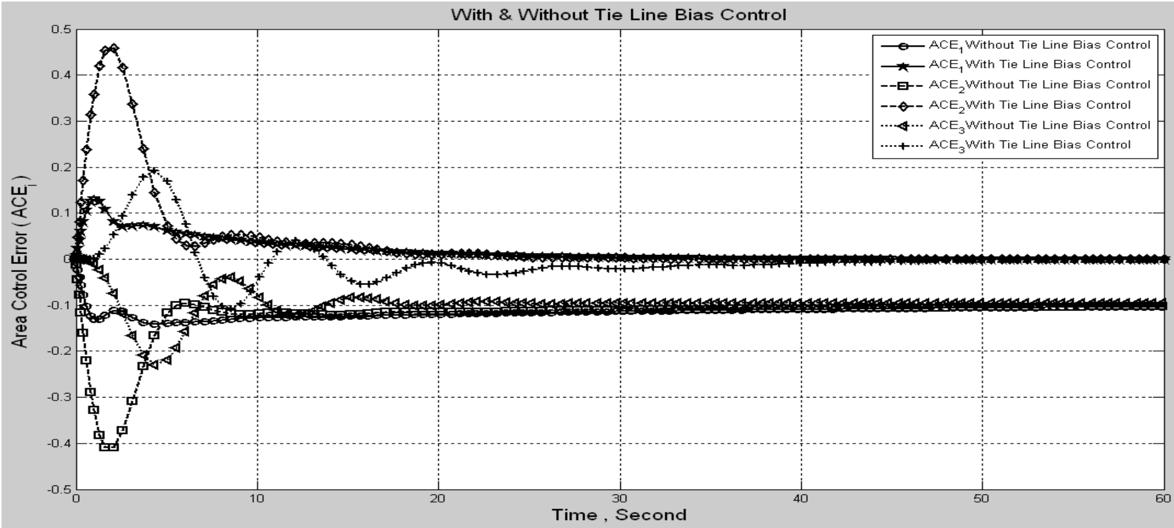

Figure 3: ACE with and without tie line bias control.

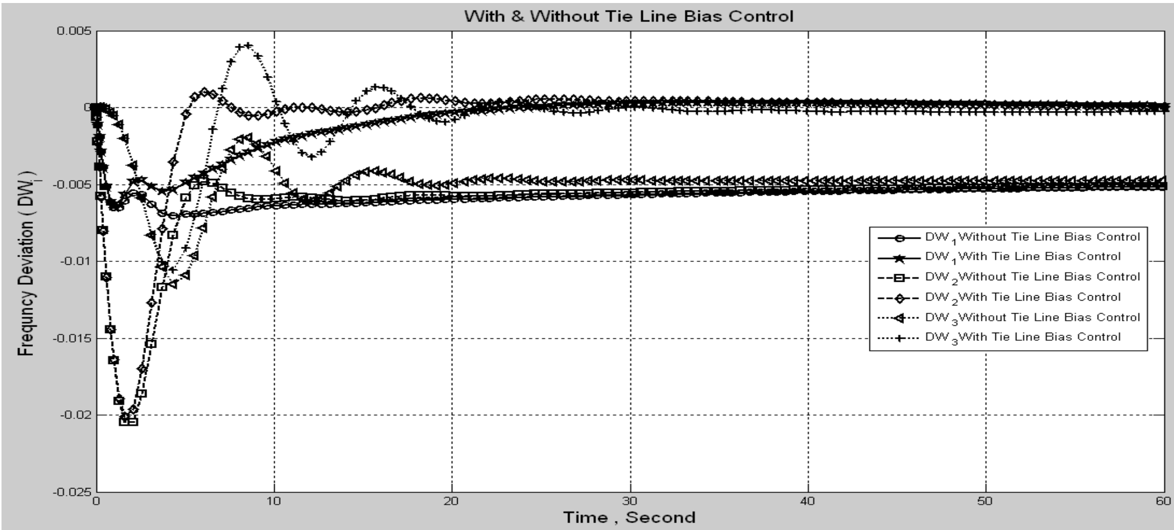

Figure 4: Δω with and without tie line bias control.

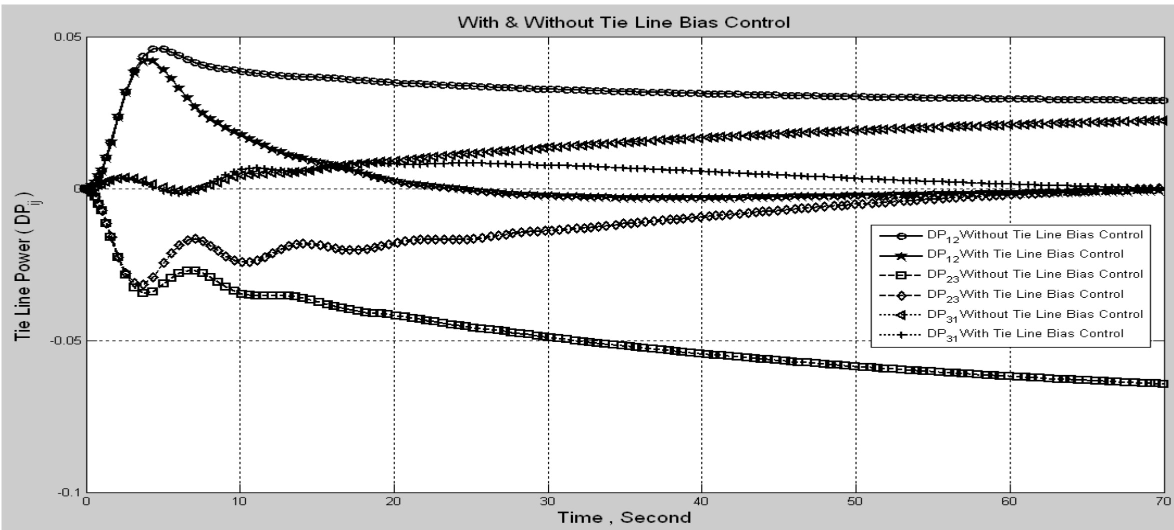

Figure 5: ΔP_{ij} with and without tie line bias control.

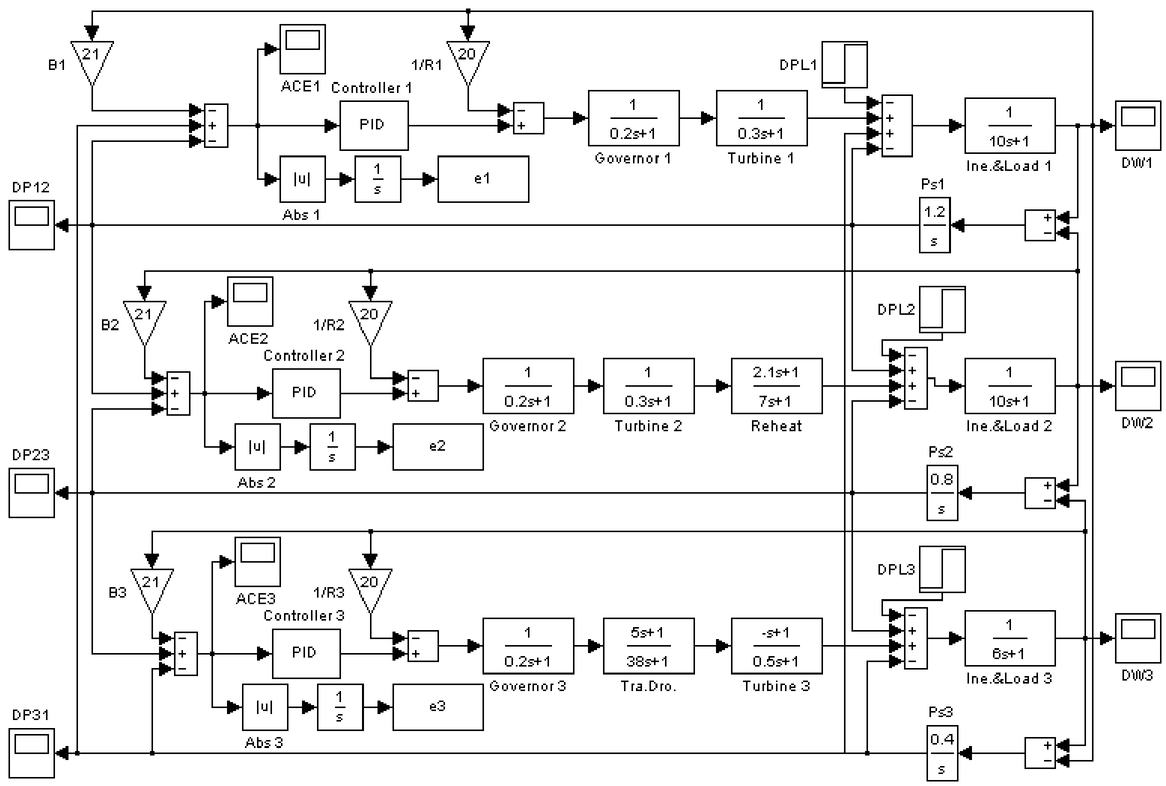

Figure 6: MATLAB/Simulink model of the LFC system based on IAE.

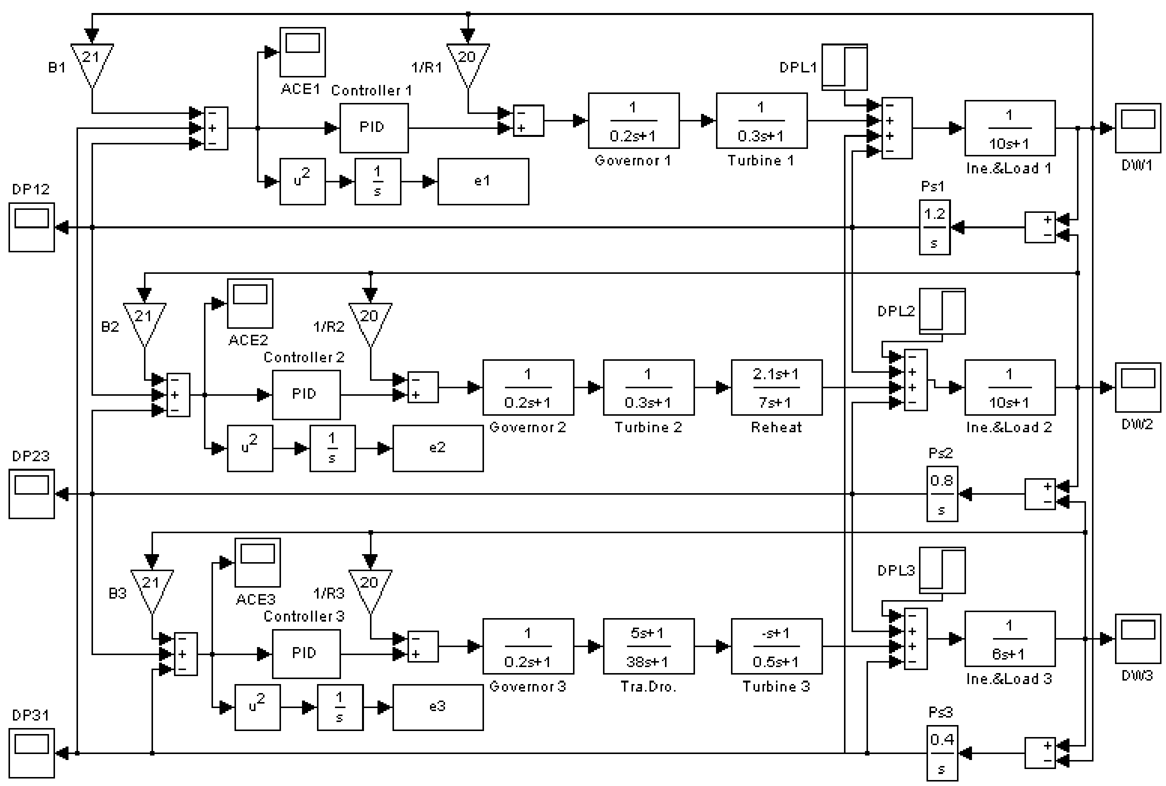

Figure 7: MATLAB/Simulink model of the LFC system based on ISE.

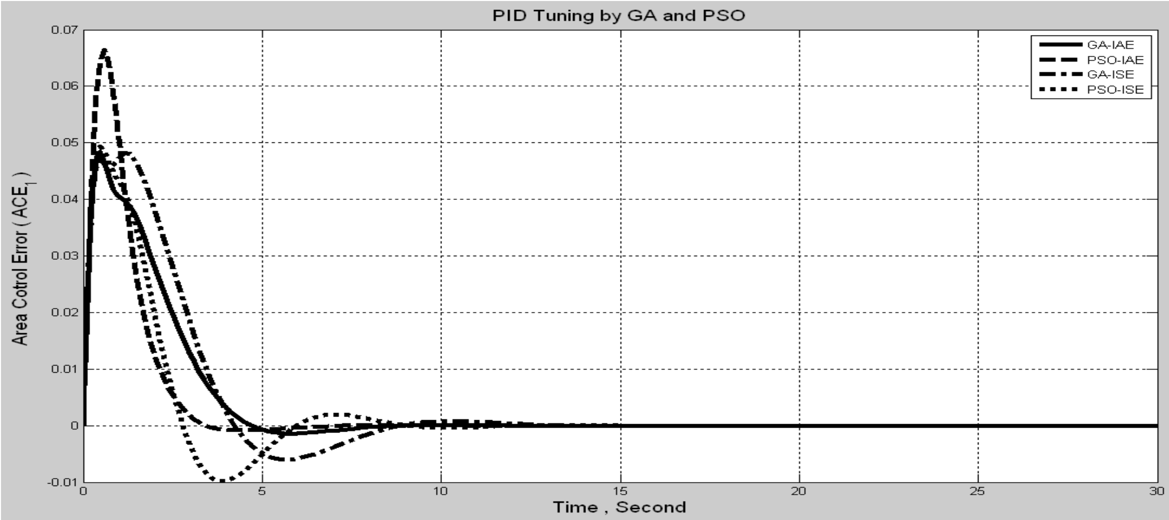

Figure 8: ACE $_1$ with PID tuning by GA and PSO.

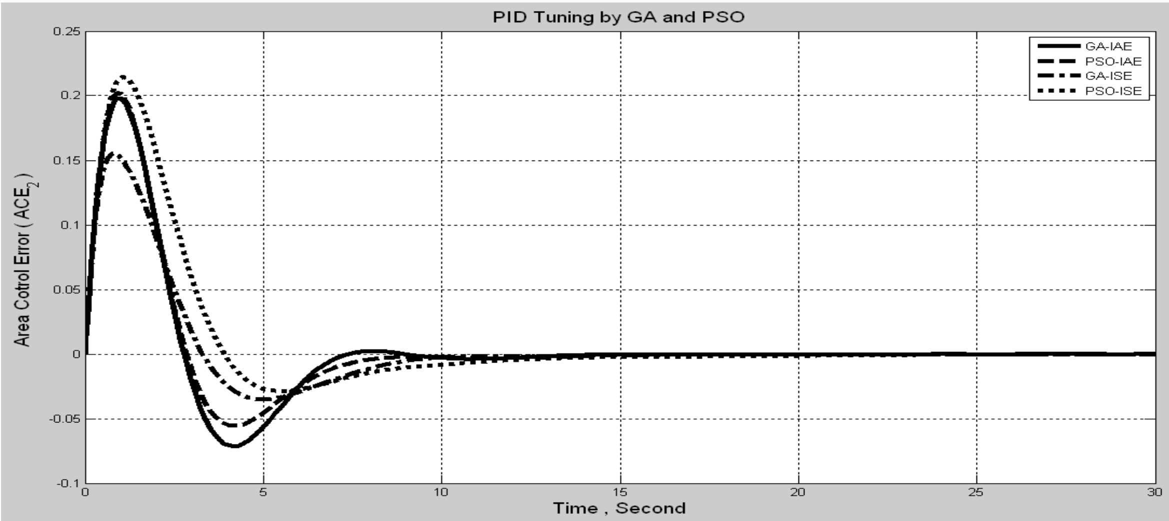

Figure 9: ACE $_2$ with PID tuning by GA and PSO.

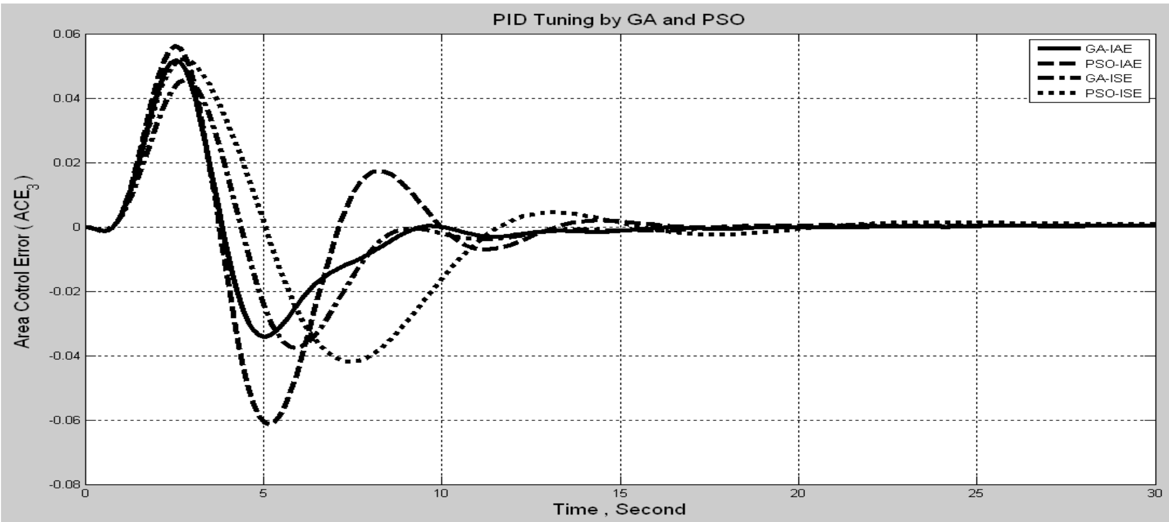

Figure 10: ACE $_3$ with PID tuning by GA and PSO.

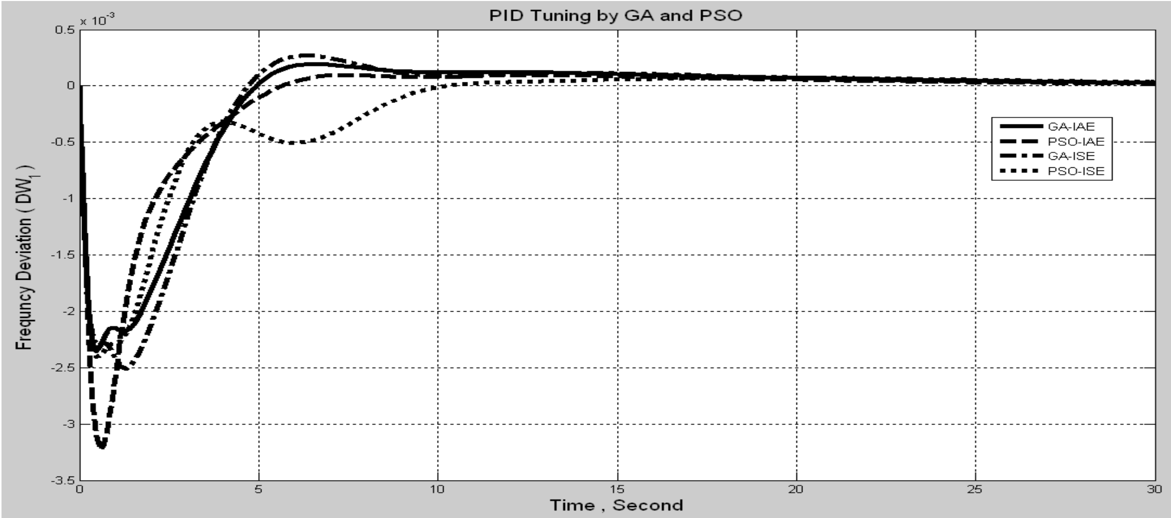

Figure 11: $\Delta\omega_1$ with PID tuning by GA and PSO.

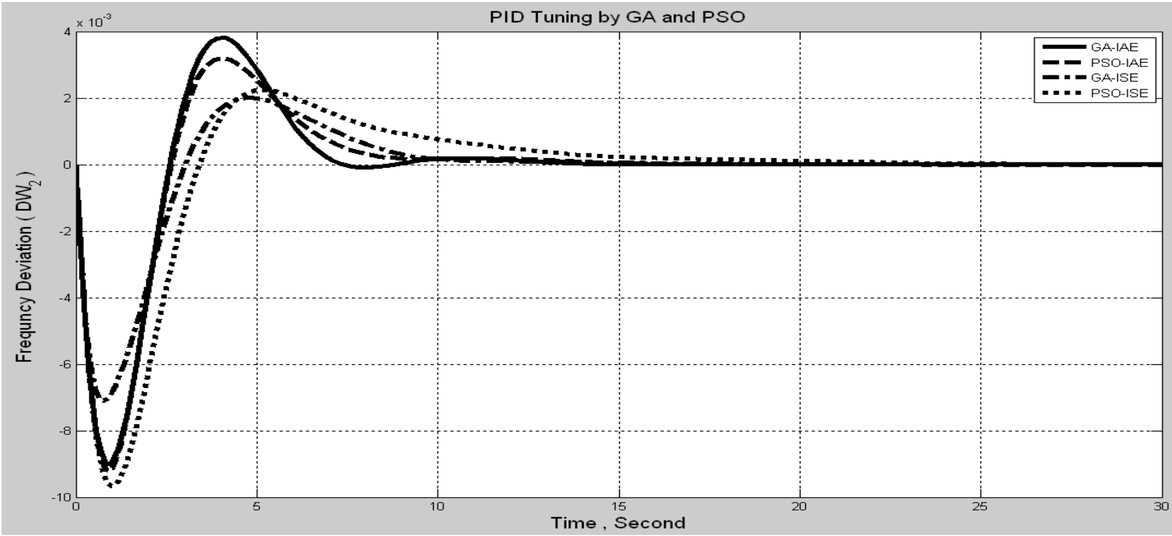

Figure 12: $\Delta\omega_2$ with PID tuning by GA and PSO.

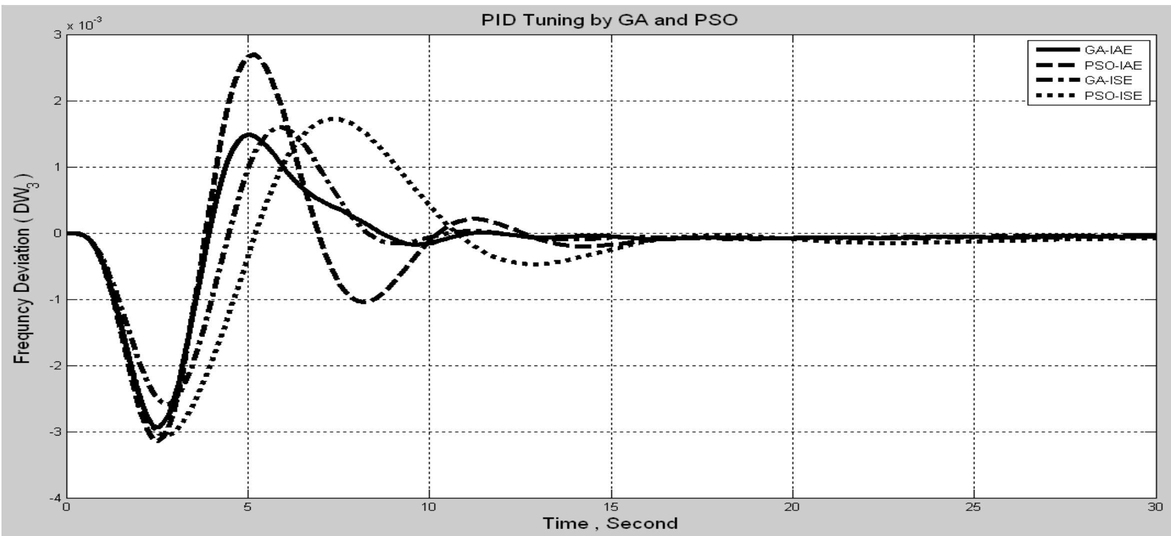

Figure 13: $\Delta\omega_3$ with PID tuning by GA and PSO.

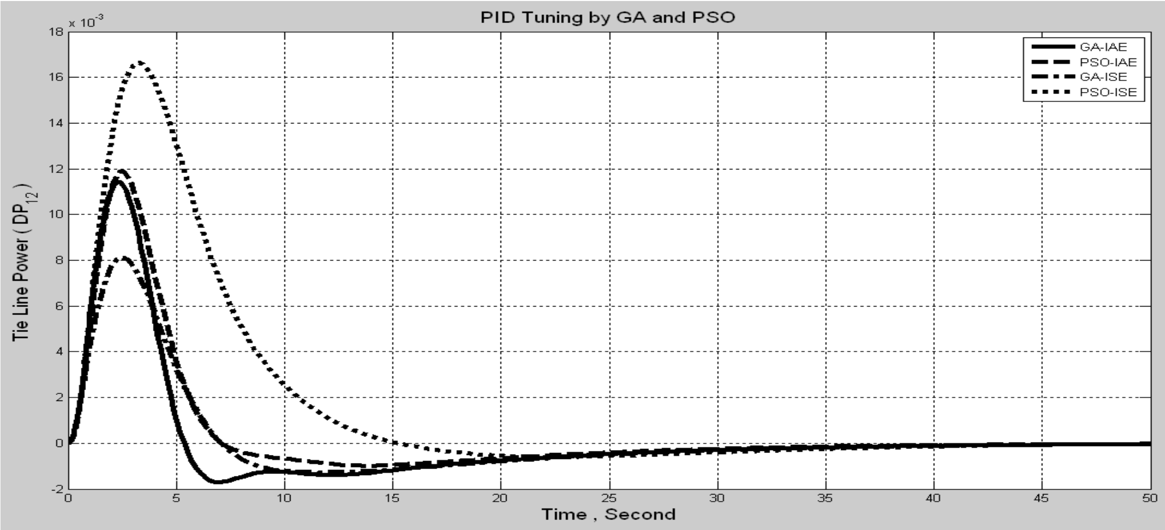

Figure 14: ΔP_{12} with PID tuning by GA and PSO.

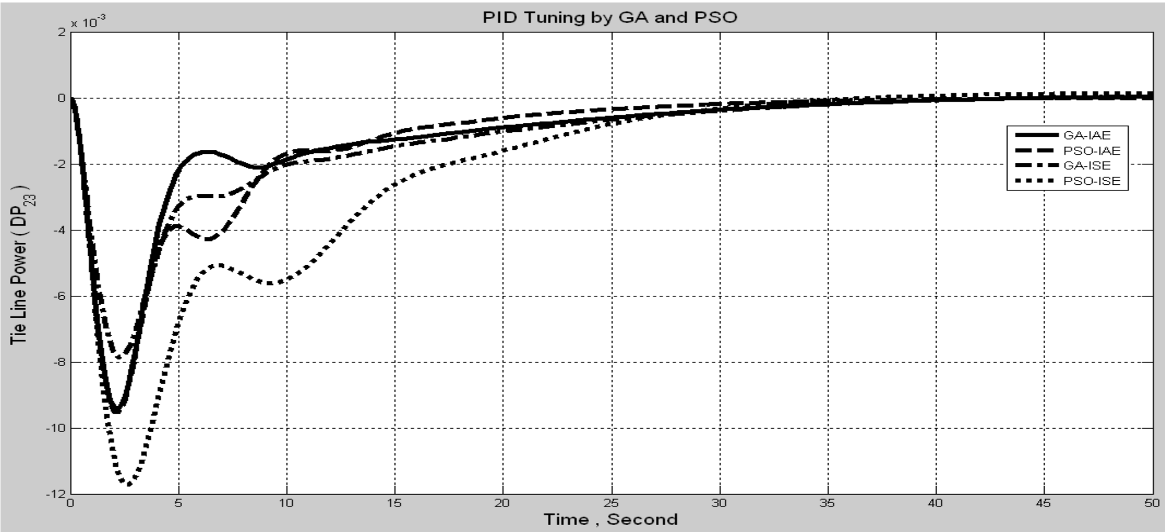

Figure 15: ΔP_{23} with PID tuning by GA and PSO.

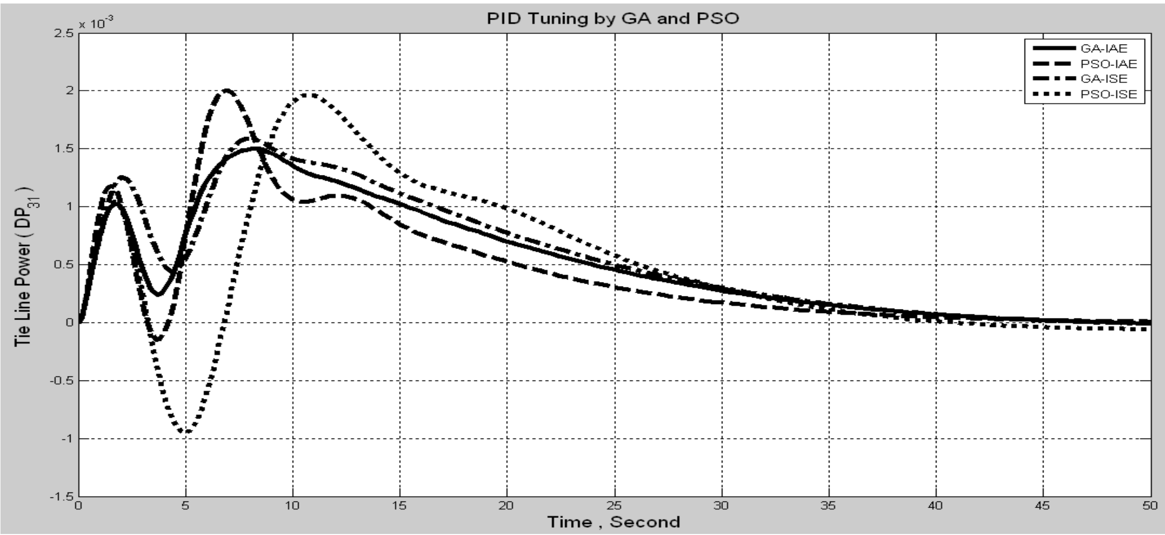

Figure 16: ΔP_{31} with PID tuning by GA and PSO.

التحكم بنظام التوليد الذاتي (AGC) لمنظومة قدرة متعددة المناطق باستخدام المسيطر (تناسبي- تكاملي- تفاضلي) (PID) بالاستناد إلى الخوارزمية الجينية(GA) وأمثليه أسراب الجسيمات(PSO)

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الخلاصة:

الهدف من النشرية هو الحفاظ على التردد والتغيرات ما بين خطوط نقل القدرة عند القيم المقررة, تم عرض طريقتين لتحديد المتغيرات الأمثل للمسيطر(تناسبي- تفاضلي- تكاملي) (PID) للتحكم بنظام التوليد الذاتي (AGC) لمنظومة قدرة ذات ثلاث مناطق (non reheat thermal-reheat thermal-hydraulic), الأول هو الخوارزمية الجينية (GA) والثاني هو أمثلية أسراب الجسيمات (PSO). تطبق الخوارزمية الجينية (GA) و أمثلية أسراب الجسيمات (PSO) في هذا البحث للسيطرة على متغيرات (PID) لتقليل مؤشرات أداء متعددة والتي أعتمدت كأهداف موضوعية. تم إعتماد تكامل مطلق الخطأ (IAE) وتكامل مربع الخطأ (ISE) كمقايس لدقة العمل والمفاضلة. المسيطرات الذكية كالخوارزمية الجينية (GA) وأمثلية أسراب الجسيمات (PSO) تم مقارنة أدائها مع المسيطر الانحياز الاستراتيجي (bias control strategy), ولاحظنا أن المسيطرات المقترحة ذات أداء أفضل من حيث زمن الاستقرار و الحد الأقصى للانحراف و زمن القمة مقارنة مع المسيطر الانحياز الاستراتيجي (bias control strategy). ومع مزيج المجاميع (GA-IAE, PSO-IAE, GA-ISE and PSO-ISE), GA-IAE و PSO-IAE توصلنا إلى أفضل زمن استقرار و زمن قمة مقارنة مع GA-ISE و PSO-ISE بينما لاحظنا أن GA-ISE يمتلك أقل حد للانحراف مقارنة مع بقية المجاميع.