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PSO-PID Tuning Technique for Load Frequency Control Problem

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Abstract:

Now a day because of the increment in the interconnection of the power system, load and also power flow in tie-line are contrasting intensely. Any difference between generation and demand causes the system frequency to digress from its nominal value. Thus, high frequency deviation may provoke system breakdown. So there is a need of robust control of both system's frequency and tie-line power flows. This robust control can be achieved utilizing particle swarm optimization (PSO) controller instead of conventional Controllers like P, PI, PD and PID. To optimize the gains of PID controller in an interconnected power structure, algorithm strategies are utilized. In this work, Particle Swarm Optimization (PSO) strategy is implemented for optimization of conventional gains and to enhance the transient behavior of the structure.

Keywords

Load Frequency Control (LFC), Automatic Generation Control (AGC), Particle Swarm optimization (PSO), Area Control Error (ACE), Proportional Integral Derivative (PID).

1. INTRODUCTION

Power systems are utilized to change natural energy into electric power. They transport Electric Power to production lines and houses to fulfill a wide range of power requirements. To improve the Performance of electrical equipment, it is critical to guarantee the quality of the electric Power. It is understood that three-phase alternating current (AC) is for the most part used to Transport the power. Throughout the transportation, both the active power equalization and the reactive power equalization must be kept between generating and using the AC power [2]. Those two equalization's match to two equilibrium points: frequency and voltage. At the point when both of the equalization's is broken and reset at another level, the equilibrium points will drift.

Despite the fact that the active power and reactive power mutually affect the Frequency and voltage, the control issue of the frequency and voltage can be decoupled. The frequency is exceptionally subject to the active power while the voltage is profoundly reliant on the reactive power. The most crucial objective of power system controller is to keep up the consistent equilibrium between electrical generation and fluctuating load demand while system frequency and voltage level are looked after steady. Load variation in the power system impacts the quality of power. In this way a control system is vital to cross out the impacts of arbitrary load changes and to keep the frequency and voltage at the steady level.

The control problem in power systems can be decoupled into two self-governing issues. One is concern with the active power and frequency control while the other is regard with the reactive power and voltage control. The active power and frequency control is suggested as load frequency control (LFC). The goals of the LFC in interconnected power system is to keep up the frequency of every area against the indiscriminately changing active power loads, which are moreover implied as unknown external disturbance and to keep tie-line power flows within the prespecified tolerance by altering the output of the

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high capacity generators when fluctuations happen in load demands [3], [4].

An ordinary huge – scale power system is made out of a few areas of producing units interconnected together and power is interchanged between the utilities. The issue of an interconnected power system is the control of electric energy with supposed system frequency, voltage profile and tie-line power exchanges within their affirmed limit.

Automatic generation control is a standout among the most critical issues in power system design. The principle motivation behind AGC is utilized for quick minimization of area frequency deviation and common tie-line power flow deviation of areas for stable operation of the system. The general performance of AGC in any power system is depends on upon the best possible design of speed regulation parameters and gains of the controller. AGC action is guided by the Area Control Error (ACE) which is a function of system frequency and tie line flows. Here the ACE identifies a mismatch between area load and generation by taking record into any exchange agreement with the neighbouring areas. Every control area may have substantial number of different sources of power generation, for example, hydro, thermal, gas, nuclear and so forth. The different generations are joined by an inflexible network that is the reason the frequency deviations are thought to be equivalent in an area [5], [12].

There are various techniques accessible for Load Frequency Control in an interconnected power system. The initially proposed control methodology is integral control action to minimize the Area Control Error (ACE). The fundamental disadvantage of this controller is that the dynamic performance of the system is restricted by its integral gain. To crush this issue, intense computational intelligent evolutionary strategy, for example, Particle Swarm Optimization (PSO) is proposed to enhance the gains of controller for the Load Frequency Control (LFC) issue in power systems.

The goal of this study is to observe the load frequency control and inter area tie-power control issue for a two-area power system considering about the uncertainties in the parameters of system. An optimal control scheme based Particle swarm optimization (PSO) Algorithm technique is utilized to improve the gains of the controller. The proposed controller is simulated for a single area and two-area power system with multi-sources power generation.

2. CONVENTIONAL CONTROLLER

The conventional controllers are very rigid in system implementation. In general, this selection of gains K_p, K_i and K_d are the control parameters have been acquired by different approaches and one of the approach is trial and error method. It consumes more amount of time in optimization. The controller parameters of the Conventional Controller have the different characteristics is represented in Table 1.

Parameter	Rise time	Peak Overshoot	Settling time	Steady State error
K_p(Proportional Gain)	Reduces	Raises	Unchanged	Reduces
K_i(Integral Gain)	Reduces	Raises	Raises	Removes
K_d(Derivative Gain)	Unchanged	Reduces	Reduces	Unchanged

Table 1: Impacts of controller Parameters

3. Particle Swarm Optimization (PSO)

The Particle Swarm Optimization algorithm (abbreviated as PSO) is a novel population-based stochastic search algorithm. To the complex non-linear optimization issue, PSO is another resolution. The PSO algorithm was initially presented by Dr. Kennedy and Dr. Eberhart in 1995 and its basic thought was initially stimulated by imitation of the social conduct of creatures, for example, bird flocking, fish schooling etc [13].

It depends on the normal procedure of group communication to share individual information when a collection of birds or insects look for food or to move and so forth in a searching space, even though all birds or insects don't know where the best position is. If any member can discover a required path to go, the left of the individuals will take after rapidly as indicated by the nature of the social conduct.

The PSO algorithm fundamentally learned from animal's activity or conduct to take care of optimization issues. In PSO, every individual from the population is known as particle and the population is known as a swarm. Beginning with an arbitrarily initialized population and moving in haphazardly selected directions, every particle experiences the searching space and recollects the best past positions of itself and its neighbors.

Rather than utilizing evolutionary operators to control the individual particle, every particle is dealt with as a volume less particle (point) in g-dimensional search space. Every particle keeps track of its coordinates in g-dimensional search space which are connected with the best solution (fitness) it has accomplished as such. (The estimation of that fitness is additionally stored).

This quality is known as p_{best}. Another “best” esteem is additionally followed. The “global” variant of the particle swarm optimizer keeps track of the overall the best esteem, and its area, acquired so far by any particle in the population; this is known as g_{best}[14]. The fundamental idea of PSO lies in accelerating every particle toward it’s p_{best} and the g_{best} locations, with an arbitrary weighted acceleration at every time step as appeared in Fig.1.

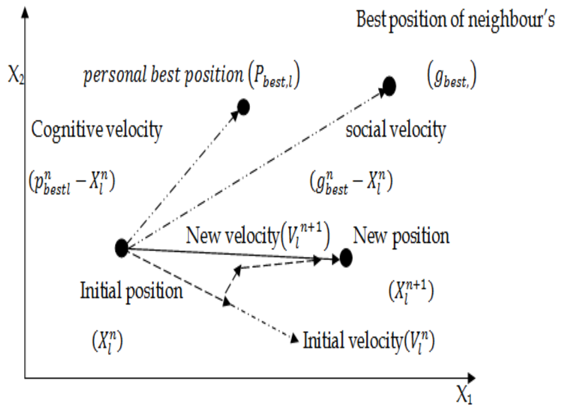


Fig.1 Concept of searching mechanism of PSO

After discovering p_{best} and g_{best}, the particle upgrades its speed and positions with taking after following mathematical equations.

$$V_{lm}^{n+1} = wV_{lm}^{n} + c_1 r_{1m}^{n}(p_{bestlm}^{n} - X_{lm}^{n}) + c_2 r_{2m}^{n}(g_{bestm}^{n} - X_{lm}^{n}) \quad (3.1)$$

$$X_{lm}^{n+1} = X_{lm}^{n} + V_{lm}^{n+1} \quad (3.2)$$

There are three terms in Eq. (3.1).

1. wV_{lm}^n is called inertia component that gives a memory of the past flight direction that implies movement in the immediate past.

2. $C_1 r_{1m}^n (p_{bestlm}^n - X_{lm}^n)$ is called cognitive component(part). This segment resembles an individual memory of the position that was best for the particle.

3.$C_2 r_{2m}^n (g_{bestm}^n - X_{lm}^n)$ is known as social component(part). The impact of this segment is every particle fly towards the best position found by the neighborhood particles.

Where

l = 1, 2,. . , N, and N is the swarm size.

m =1, 2,. . . , D, and D is the quantity of dimensions of the issue.

n =1, 2,. . . , Iter, and Iter is the most extreme iteration number.

X_{lm}^n is the position of particle l, dimension m, at iteration n. The position is likewise parameter of the issue.

V_{lm}^n is the speed (position change in a unit time step) of particle l, dimension m, at iteration n.

c_1 *and* c_2 are two acceleration constants.
r_1, r_2 are free arbitrary numbers, consistently dispersed in (0, 1).
p_{bestlm}^{n} is the individual best position of particle *l*, dimension *m*, at iteration *n.*
g_{bestm}^{n} is the neighborhoods' best position, dimension *m*, at iteration *n.*
w is the inertia weight; c1, c2 are two positive constants.

The velocity in Eq. (3.1) is restricted by the greatest velocity; V_{max}.This cut-off diminishes the excessive step size in Eq. (3.2). The greatest velocity is processed as

$$V_{max} = C_V(X_{max} - X_{min}) \qquad (3.3)$$

C_V is a most extreme velocity coefficient, X_{max} *and*X_{min} are the greatest and least positions of a particle.

The prescribed decision for constants C_1 *and* C_2 is 2 since overall it makes the weights for cognitive and social parts to be 1.

Coefficient *w* is utilized to contain the blast as particles velocities and positions move toward a limit. While a vast inertia weight *w* supports a global search, a little esteem supports a local search. A suitable choice of the inertia weight can give equilibrium between global and local investigation capacities.

Assuming such a part, normally its quality ought to be huge in ahead of schedule period of search with a specific end goal to diminish discarding potential targets. Once a search zone is discovered, little estimation of *w* may be suitable for refining the search. As initially created, *w* diminishes directly from 0.9 to 0.4 joined with the cut-off of the velocity V_{max}. Usually, inertia weight *w* is set by taking after mathematical equation.

$$w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter \qquad (3.4)$$

Where
$iter_{max}$ is the greatest number of iterations (generations), and *iter* is the present number of cycles.

The flowchart for particle swarm optimization is shown in Fig.2.

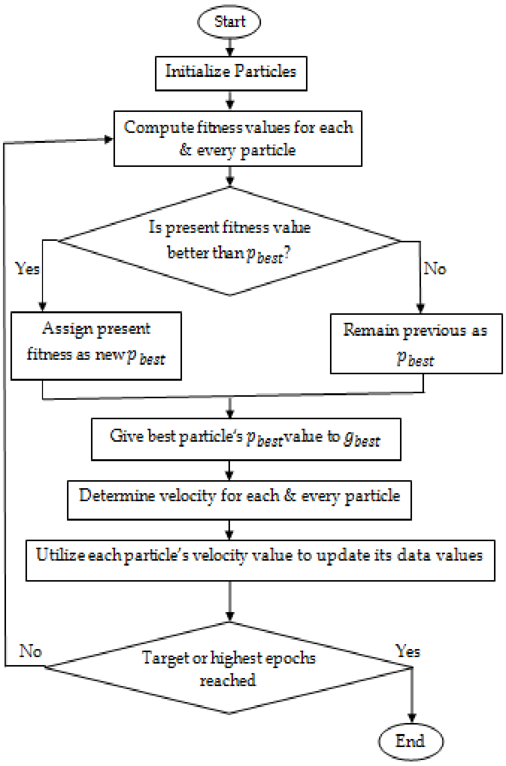


Fig.2 Flowchart of Particle Swarm Optimization (PSO)

4. MODELING OF INTERCONNECTED POWER SYSTEMS

The two area interconnected power system is shown in Fig.3, where Δf_1 and Δf_2 are the frequency deviations in area 1(Thermal with Reheater) and area 2(Nuclear with Reheater) respectively [6-11]. ΔP_{d1} and ΔP_{d2} are the load demand increments.

In most of the studies earlier the researchers have used the dynamic model of the power system given by O. I. Elgerd [1]. A dynamic model with Δf_1,$\Delta \dot{f}_1$,$\Delta \ddot{f}_1$ and Δf_2, $\Delta \dot{f}_2$ and $\Delta \ddot{f}_2$, as state variables is derived. The dynamic equations are represented in eqn. (4.1 & 4.2).

Thermal Power Plant

$$\dot{X}_1 = X_2$$
$$\dot{X}_2 = X_3$$
$$\dot{X}_3 = X_4$$
$$\dot{X}_4 = -f_1X_4 - f_2X_3 - f_3X_2 - f_4X_1 - f_5\Delta P_{dT} \qquad (4.1)$$

Where

$X_1 = \Delta f_T, X_2 = \Delta \dot{f}_T, X_3 = \Delta \ddot{f}_T$ and $X_4 = \Delta \dddot{f}_T$

$f_1 = \frac{T_6}{T_7}; f_2 = \frac{T_5}{T_7}; f_3 = \frac{T_8}{T_7}; f_4 = \frac{T_9}{T_7}; f_5 = \frac{K_{psT}}{T_7}$

$T_1 = T_{sgT} + T_{tT} + T_{rT1}$

$T_2 = T_{sgT}T_{tT} + T_{tT}T_{rT1} + T_{rT1}T_{sgT}$

$T_3 = T_{sgT}T_{tT}T_{rT1}$

$T_4 = T_1 + T_{psT}$

$T_5 = T_2 + T_1T_{psT}$

$T_6 = T_3 + T_2T_{psT}$

$T_7 = T_3T_{psT}$

$$T_8 = T_4 + \frac{K_{rT}K_{psT}}{R_T}$$

$$T_9 = 1 + \frac{K_{psT}}{R_T}$$

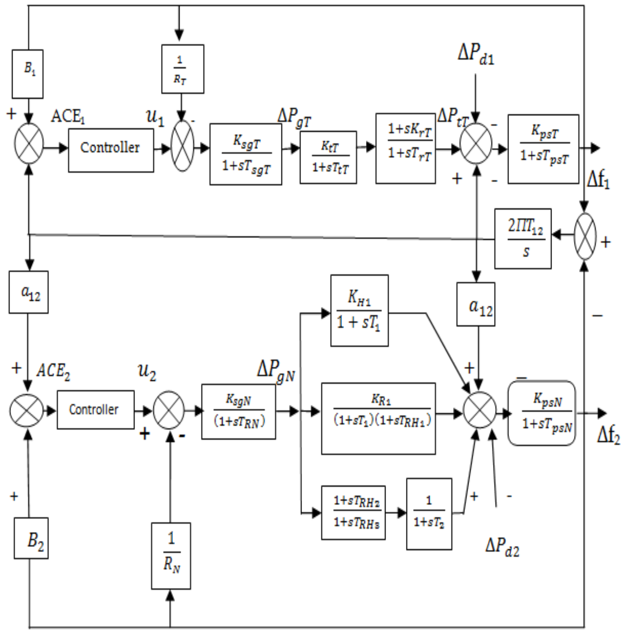


Fig.3 Two area interconnected power system

Nuclear power plant

$\dot{X}_1 = X_2$

$\dot{X}_2 = X_3$

$\dot{X}_3 = X_4$

$\dot{X}_4 = X_5$

$\dot{X}_5 = X_6$

$$\dot{X}_6 = -f_1X_6 - f_2X_5 - f_3X_4 - f_4X_3 - f_5X_2 - f_6X_1 - K_{psN}\Delta P_{dN} \qquad (4.2)$$

Where

$X_1 = \Delta f_N, X_2 = \Delta \dot{f}_N, X_3 = \Delta \ddot{f}_N, X_4 = \Delta \dddot{f}_N$

$X_5 = \Delta \overset{....}{f}_N, X_6 = \Delta \overset{.....}{f}_N$

$f_1 = \frac{T_z}{T_3}; f_2 = \frac{T_Y}{T_3}; f_3 = \frac{T_X + T_7}{T_3}, f_4 = \frac{T_W + T_6}{T_3}$

$f_5 = \frac{T_V + T_5}{T_3}; f_6 = \frac{1 + T_4}{T_3}$

$T_a = K_{H1}(T_2 + T_{RH1} + T_{RH3})$

$T_b = K_{H1}(T_2T_{RH1} + T_{RH1}T_{RH3} + T_{RH3}T_2)$

$T_c = K_{H1}T_2T_{RH1}T_{RH3}$

$T_d = K_{R1}(T_2 + T_{RH3})$

$T_e = K_{R1}(T_2T_{RH3})$

$T_f = T_1 + T_{RH1} + T_{RH2}$

$T_g = T_1T_{RH1} + T_{RH1}T_{RH2} + T_{RH2}T_1$

$T_h = T_1T_{RH1}T_{RH2}$

$T_i = T_a + T_d + T_f$

$T_j = T_b + T_e + T_g$

$T_k = T_c + T_h$

$T_l = T_1 + T_2 + T_{RN}$

$T_m = T_1T_2 + T_2T_{RN} + T_{RN}T_1$

$T_n = T_1T_2T_{RN}$

$T_o = T_{RH1} + T_{RH3}$

$T_p = T_{RH1}T_{RH3}$

$T_q = T_o + T_l$

$T_r = T_p + T_lT_o + T_m$

$T_s = T_lT_p + T_mT_o + T_n$

$T_t = T_mT_p + T_nT_o$

$T_u = T_nT_p$

$T_v = T_q + T_{psN}$

$T_w = T_r + T_{psN}T_q$

$T_x = T_s + T_rT_{psN}$

$T_y = T_t + T_rT_{psN}$

$T_z = T_u + T_tT_{psN}$

$T_3 = T_uT_{psN}$

$$T_4 = \frac{(K_{H1} + K_{R1} + 1)}{R_N}K_{psN}$$

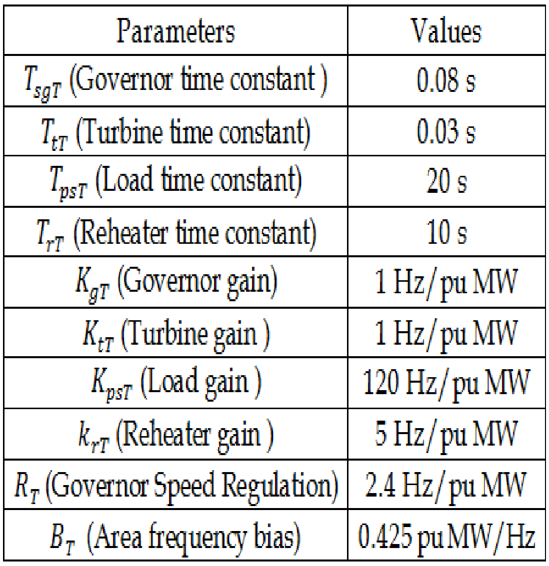
$$T_5 = \frac{T_i}{R_N}K_{psN}$$

$$T_6 = \frac{T_j}{R_N}K_{psN}$$

$$T_7 = \frac{T_k}{R_N}K_{psN}$$

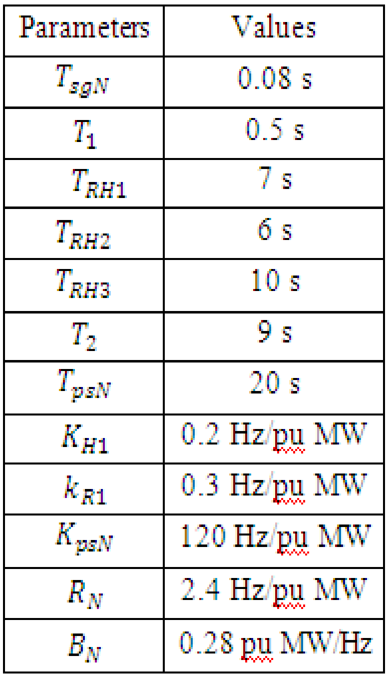
5. RESULTS & CONCLUSIONS

In this paper, PID & PSO-PID controller has been applied to a two area interconnected power system having the following data shown in tables 2 & 3. A step load change of 0.01 is assumed in both areas and with and without control responses are shown in Fig.4 & 5.



Parameters	Values
T_{sgT} (Governor time constant)	0.08 s
T_{tT} (Turbine time constant)	0.03 s
T_{psT} (Load time constant)	20 s
T_{rT} (Reheater time constant)	10 s
K_{gT} (Governor gain)	1 Hz/pu MW
K_{tT} (Turbine gain)	1 Hz/pu MW
K_{psT} (Load gain)	120 Hz/pu MW
k_{rT} (Reheater gain)	5 Hz/pu MW
R_T (Governor Speed Regulation)	2.4 Hz/pu MW
B_T (Area frequency bias)	0.425 pu MW/Hz

Table 2: Thermal Power system



Parameters	Values
T_{sgN}	0.08 s
T_1	0.5 s
T_{RH1}	7 s
T_{RH2}	6 s
T_{RH3}	10 s
T_2	9 s
T_{psN}	20 s
K_{H1}	0.2 Hz/pu MW
k_{R1}	0.3 Hz/pu MW
K_{psN}	120 Hz/pu MW
R_N	2.4 Hz/pu MW
B_N	0.28 pu MW/Hz

Table 3: Nuclear Power system

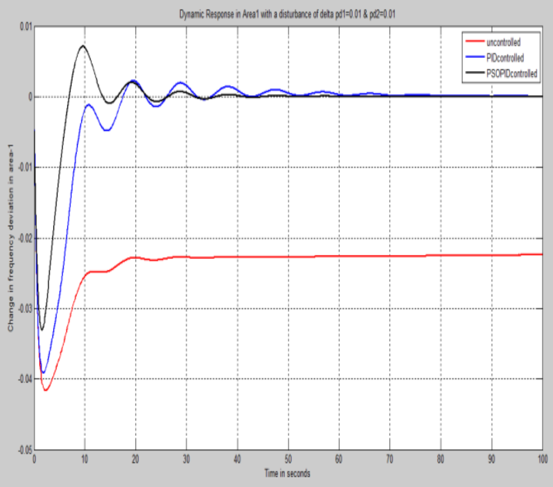


Fig.4 Dynamic Response in area-1 with a disturbance of ΔP_{d1}=0.01 & ΔP_{d2}=0.01.

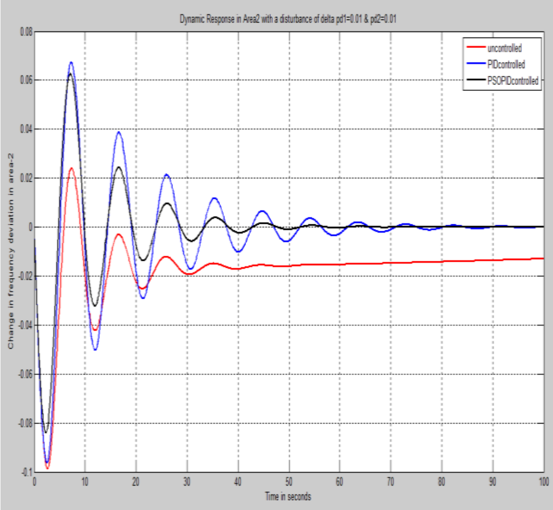
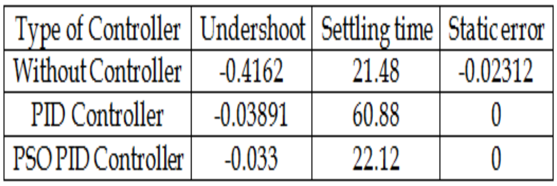


Fig.5 Dynamic Response in area-2 with a disturbance of ΔP_{d1}=0.01 & ΔP_{d2}=0.01.

An interconnected power system is represented deviation and its derivative as state using new state variables namely frequency variables in both the areas without integral control of frequency in each case.

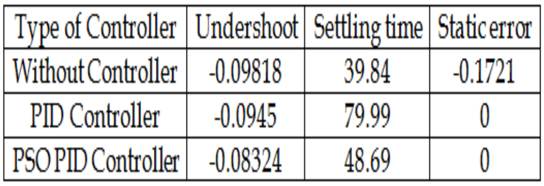
The static errors of the frequency deviations are increasing with increase in load changes without PID & PSO-PID controller.

The case study with PID & PSO-PID controllers in both the areas for a load change in area 1 indicates that the responses are oscillatory. However, PSO-PID controller magnitudes of the overshoots are less compared to that of the PID case. It is also observed that the values of the maximum overshoots are increasing with increase in load changes. The settling times for frequency deviations are less in PSO-PID as compared with the PID controller as shown in tables 4 & 5. Also, unequal disturbance in both areas and controlling in both areas are shown in table 6 & 7.



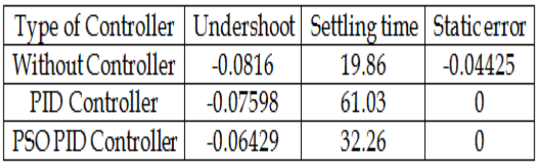
Type of Controller	Undershoot	Settling time	Static error
Without Controller	-0.4162	21.48	-0.02312
PID Controller	-0.03891	60.88	0
PSO PID Controller	-0.033	22.12	0

Table 4: Comparative study of Undershoot, Settling Time & static error in area-1



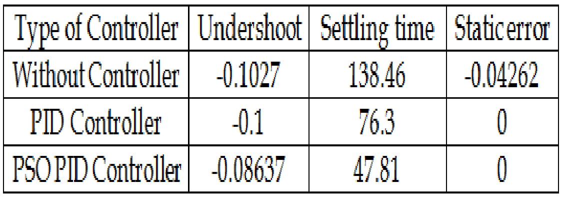
Type of Controller	Undershoot	Settling time	Static error
Without Controller	-0.09818	39.84	-0.1721
PID Controller	-0.0945	79.99	0
PSO PID Controller	-0.08324	48.69	0

Table 5: Comparative study of Undershoot, Settling Time & static error in area-2



Type of Controller	Undershoot	Settling time	Static error
Without Controller	-0.0816	19.86	-0.04425
PID Controller	-0.07598	61.03	0
PSO PID Controller	-0.06429	32.26	0

Table 6: Comparative study of Undershoot, Settling Time & static error in area-1when ΔP_{d1}=0.02 & ΔP_{d2}=0.01.



Type of Controller	Undershoot	Settling time	Static error
Without Controller	-0.1027	138.46	-0.04262
PID Controller	-0.1	76.3	0
PSO PID Controller	-0.08637	47.81	0

Table 7: Comparative study of Undershoot, Settling Time & static error in area-2 when ΔP_{d1}=0.02 & ΔP_{d2}=0.01.

REFERENCES:

[1] Elgerd O.I., “Electrical energy system theory – An introduction”, (Mc Graw –Hill, New Delhi, 1983).

[2] Ivan Zelinka, Pandian Vasant, Nader Barsoum “Power, Control and Optimization (Lecture Notes in Electrical Engineering)”, Hardcover – Import, 23 May 2013.

[3] Muthana T. Alrifai and Mohamed Zribi “Decentralized Controllers for Power System Load Frequency Control” ASCE Journal, Volume (5), Issue (II), June, 2005.

[4] B. Venkata Prasanth, S.V. Jayaram Kumar, “Load frequency control for a two area Interconnected power system using robust Genetic algorithm controller”, Journal of Theoretical and Applied Information Technology.

[5] Hadi Saadat: “Power system analysis” Tata McGraw Hill 2002 Edition, New Delhi.

[6] Prabha Kundur, “Power System Stability and Control”, Tata Mc Graw-Hill Edition, New Delhi.

[7] Naimul Hasan, Ibraheem, Shuaib Farooq, “Real Time Simulation of Automatic Generation Control for Interconnected Power System”, International Journal on Electrical Engineering and Informatics - Volume 4, Number 1, March 2012.

[8] Malik, O.P., Kumar, A., and Hope, G.S., “A load frequency control algorithm based on generalized approach”, IEEE Trans. On Power Systems, Vol 3, No.2, pp. 375-382, 1998.

[9] E.Tacker, C.Lee, T.Reddoch, T.Tan, P.Julich, Optimal Control of Interconnected Electric Energy System- A new formulation, Proc. IEEE, 109 (1972) 1239.

[10] P.P. Khargonekar, I.R. Petersen, K. Zhou, Robust stabilization of uncertain linear systems: quadratic

stabilizability and H control theory, IEEE Trans. AC 35 (1990) 356.

[11] Shah, N.N., Kotwal, C.D., The state space modeling of single, two and three area ALFC of Power System using Integral Control and Optimal LQR Control method, IOSR Journal of Engineering, Mar 2012, Vol 2(3), pp:501-510.

[12] B. Venkata Prasanth, S. V. Jayaram Kumar, "New control strategy for load frequency Problem of a single area power system using Fuzzy logic control", Journal of Theoretical and Applied Information Technology.

[13] Yamille Del Valle, Ganesh Kumar Venayagamoorthy, Salman Mohagheghi, Jean-Carlos Hernandez and Ronald G., "Harley Particle Swarm Optimization: Basic Concepts, Variants and Applications in Power Systems", IEEE transactions on evolutionary computation, vol. 12, no. 2, April 2008.

[14] J. Kennedy, R. Eberhart "Particle swarm optimization", Proceedings of IEEE Int. Conf. on Neural Networks, vol. 4, pp. 1942-1948, 1995.