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European Journal of Advances in Engineering and Technology, 2015, 2(11): 43-48

Research Article **ISSN: 2394 - 658X**

PSO Optimized PID Controller for Load Frequency Control

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ABSTRACT

Proportional-Integral-Derivative (PID) controller based Load Frequency Control (LFC) proposed here for controlling the frequency deviation which is a one of major technical issue of a two area interconnected power system. In order to improvise the performance of supplying power of a power system, error function is minimized. The objective function taken into consideration over here is Integral of Square of Error (ISE). To optimize the gain values of controller, the Particle Swarm Optimization (PSO) algorithm is used. Tuning of controllers is done in order to get the gain values or controller parameters such that the desired frequency and power interchange with adjoining systems are maintained within specific value. Controllers must possess the property of being sensitive against changes in frequency and load. Tuning of controllers based on PSO algorithm is justified by making a comparison with Conventional Ziegler–Nichols tuning method.

Key words: Load frequency control, PID controller, Particle swarm optimization, Ziegler–Nichols method, Integral of square of error

INTRODUCTION

Electricity generation is the process of generating electric power from natural sources of primary energy. In an electric power system, Load Frequency Control (LFC) is a system for adjusting the multiple generators power output in response to changes in the load. The prime objective of the LFC to regulates the power flow between interconnecting areas while holding the frequency constant. It distributes the load between generators and controls the tie-line power to pre-specified scheduled values.

In order to keep electric power system operation reliable, economical and safe, LFC in power system is very important. In general, constant frequency is identified as a normal operation. The balance can be judged by measuring the frequency. If frequency is increasing, more power is being generated than demand, and if the frequency is decreasing, more demand than the instantaneous generation.

By proper tuning of PID controller parameters based on operating point this drawback can be overcome. Artificial intelligence (AI) based algorithm can be utilized for this purpose. There are different AI algorithms for tuning of controller parameters for load frequency control of an interconnected power system like genetic algorithm, particle swarm optimization, ant colony optimization etc. But many AI algorithms are difficult to implement because of its complexity in coding. From past decade PSO become popular due to its simple structure and implementation. It is also having ability to solve non-linear and complex problems. Here PSO based PID controller proposed for LFC in which PID controller parameters are optimized using PSO and results also compared *w.r.t.* classical technique Ziegler–Nichols tuned PID controller. Comparison is done by selecting two performance indices, first one is peak undershoot and other one is settling time.

LOAD FREQUENCY CONTROL

A power system is a highly non-linear and complex system with different dynamic responses and characteristics. Several interconnected generating units supply a variety of loads across the huge geographical area through tie-lines. So, it is highly desirable to improve the performance of power system during normal and abnormal operations. But it is not that much easy task, due to constantly changing load, frequency as well as voltage instability and so many environmental disturbances. In real power systems, frequency instability may lead to systems fail. The frequency is closely related to the real power balance whereas voltage is related to reactive power. The real power and frequency control is referred as LFC [1–6].

LFC is very important in power systems to supply reliable electric power at consumer end. However, on the consumers' side, loads fluctuate randomly. Change in load demand leads to adjustment of generation so that there is power imbalance. To bring the power system in balance condition power generation need to control in same manner. So, this control is very important to nullify the unbalancing effects due to load fluctuation[7–9].

If there are changes in load then this will affect both frequency as well as bus voltages. LFC adjusts the power flow between different areas while keeping the frequency constant. LFC is actually a loop that regulates output in the range of megawatts and frequency of the generator [5], [10]. LFC basically consists of two control loops; these are primary loop and secondary loop.

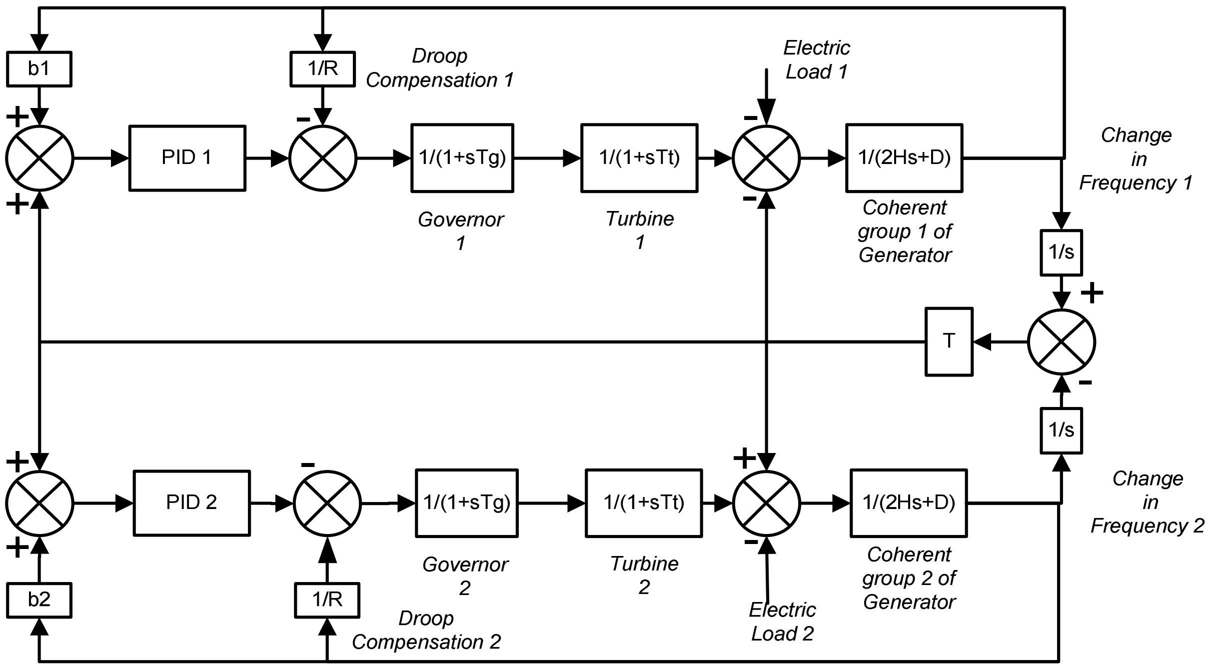

Fig. 1 LFC for two area interconnected power system

PSO OPTIMIZED PID CONTROLLER FOR LFC

Basically controller is a device, which works on sense -understand-act in another means monitor the variable and process them to alter the operating conditions. The fundamental of control loop can be simplified as in Fig. 1. External disturbances in the system ignored.

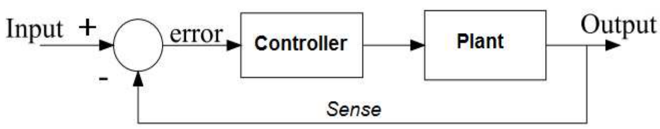

Fig. 2 Controller in closed loop with plant

PID Controller

There are different types of controllers based on their type of structure but from last few decades most popular controller utilized in most of industrial process is PID type controller [11–16]. The transfer function of the PID controller is given by,

$$U(s) = K_p + \frac{K_i}{s} + K_d s \quad (1)$$

Where, K_p: Proportional gain, K_i: Integral gain and K_d: Derivative gain

PID controller combines the effect of proportional, derivative and integral components on the closed loop response of system.

- In case of proportional controller the time response improves but there will offset between the output response and desired response. This offset can be reduced by increasing the proportional gain, but this may also cause increase oscillations for higher order systems.
- When integral controller is considered then it reduces steady state error to zero. Structure-wise, order of the closed loop system increases by one. But by increasing more integral gain the system response may be oscillatory and become slow as well as even sometimes tend to unstable.
- Derivative action predicts system behavior and improves settling time and stability of system.

Suitable combination of proportional, integral and derivative actions gives all the desired performances e.g. fast response, elimination of steady state error; low undershoot, less peak overshoot. PID controllers wide accepted for so many different industrial processes due to its robustness and simplicity.

Ziegler–Nichols tuning Method for PID controller

The gains of PID controller can be tuned by conventional ZN method; this is one of popular classical tuning method for PI or PID controllers. ZN tuning method is preferable for very complex and bulky system those mathematical modeling is tedious task. The ZN method is a heuristic approach to tune PID Controller. This method is based on selection of proper value of proportional gain at which sustained oscillation occurs, from which ultimate gain K_u and oscillation period T_u are obtained [17-18]. Once for any system value of ultimate gain and oscillation period obtained then gains value of PID controller calculated, as per given below in Table -1.

Table -1 PID Controller Gains from Ultimate Gain and Oscillation Period

Controller Parameter	Value
Kp	0.6Ku
Ki	2Kp/Tu
Kd	KpTu/8

Objective Function

For finding optimum values of parameters by using optimization, the objective function is the medium. Objective function based on error which is a function of error known as integral of the square of the error criterion (ISE) but this performance index is not taken into consideration. ISE penalize large error over small errors. ISE has the benefits of fast response. The objective function is,

$$J = \int_0^{\infty} |e|^2 \, dt \tag{2}$$

Here for LFC problem, the objective function is modified in such a way,

$$J = \int_0^{T} |\Delta f_1|^2 + a|\Delta f_2|^2 + b|\Delta P_{tie}|^2 \, dt \tag{3}$$

Where a and b are weighting factors and T is simulation time.

PARTICLE SWARM OPTIMIZATION

PSO is a stochastic heuristic population based optimization method, which is based on swarm intelligence. It is originated by idea comes from the research on the bird and fish flock movement behavior. PSO algorithm is first given by Kennedy and Eberhart in 1995 [20-21]. This algorithm is widely used for so many applications because of its easy implementation and only few parameters need to be tuned.

Basic idea of PSO is while the birds in search of food from one place to another, there will always a bird that is moving close to food very well or having information of good food. Then birds will eventually flock to the place where food can be found, their movement is inspired by their best known position as well as flock best known position. As far as PSO algorithm is concerned, each bird position is compared to the best known position of swam as well as their best known position, and the birds' next move from one place to another root for development of the solution, good position is equal to most optimist solution [21].

$$v_i^m(iter+1) = w * v_i^m(iter) + c_1 * R_1(0,1) * \left(pbest_i^m(iter) - x_i^m(iter)\right) + c_2 * R_2(0,1) * \left(gbest^m(iter) - x_i^m(iter)\right) \tag{4}$$

$$x_i^m(iter+1) = x_i^m(iter) + v_i^m(iter+1) \tag{5}$$

Where, $iter$	Iteration number
i	Particle index
m	Dimension
v_i^m	Velocity of i^{th} particle in m^{th} dimension
x_i^m	i^{th} Particle position in m^{th} dimension
$gbest^d$	Swarm global best position in m^{th} dimension
$pbest_i^d$	Particle best position of i^{th} particle in m^{th} dimension
w	Momentum
c_1, c_2	Acceleration constants
R_1, R_2	Random numbers with uniform distribution [0, 1]

Pseudo Code for PSO

```
Setting lower and higher limits of position;
Setting lower and higher limits of velocity;
Setting size of swarm;
Setting maximum numbers of steps;
Setting problem dimensions;
Setting acceleration constants;
```

```
Setting Inertia;
Initialize Population;
while iter < max_iteration do
    for each particle do
        Update the velocity using eq. (1);
        Update position using eq. (2);
        Evaluate the fitness of particle;
        if f(x_i) < f(p_best) then
            p_best = x_i ;
            if f(p_best) < f(g_best) then
                g_best = p_best ;
            end if
        end if
    end for
    iter = iter + 1;
end while
```

SIMULATION RESULTS

Tuning of PID controller

In this work, tuning or optimization of PID controller is done through two method, these are Z-N method and PSO optimization respectively. After 20 runs the best values of found by PSO optimization for PID tuning and these fitness values at every iteration is shown in Fig.3. The acceleration constants C1, C2 and w values selected for present algorithm is 1.2, 0.12 and 0.9 respectively. PID controller gains for different tuning or optimization algorithm have been shown in Table-2.

Table 2- PID Controller Gains for Different Controllers

	PID controller for area-1			PID controller for area-2		
	K_{p1}	K_{i1}	K_{d1}	K_{p2}	K_{i2}	K_{d2}
Z-N tuned PID	1.0286	1.2939	0.2044	1.0286	1.2939	0.2044
PSO optimized PID	1.22	1.94	0.31	1.53	1.61	0.31

System Response at Step Load

At initial stage the system at balance condition, when step load is applied then system will be unbalanced. In consequence the frequency at both areas will change and tie-line power will deviate. For this present system taken in consideration, the loads applied in both areas are 0.01p.u. and 0.02p.u. respectively. These changes from nominal values are shown in Fig. 4-6, for change in frequency of area-1, area-2 and change in tie-line power error respectively.

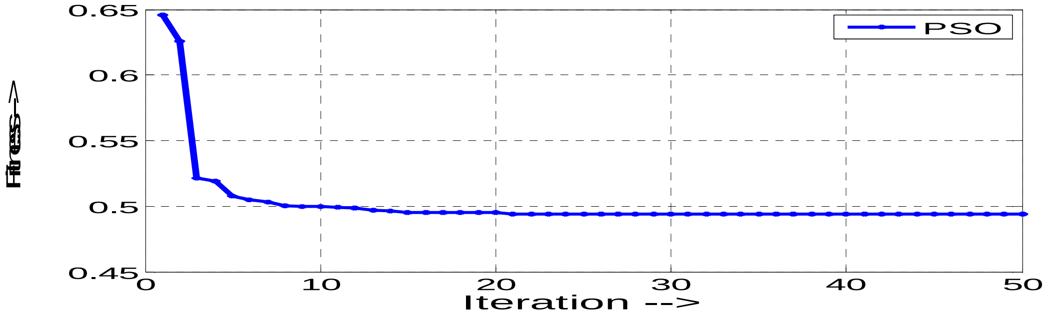

Fig. 3 Comparison of Fitness vs Iteration for PSO

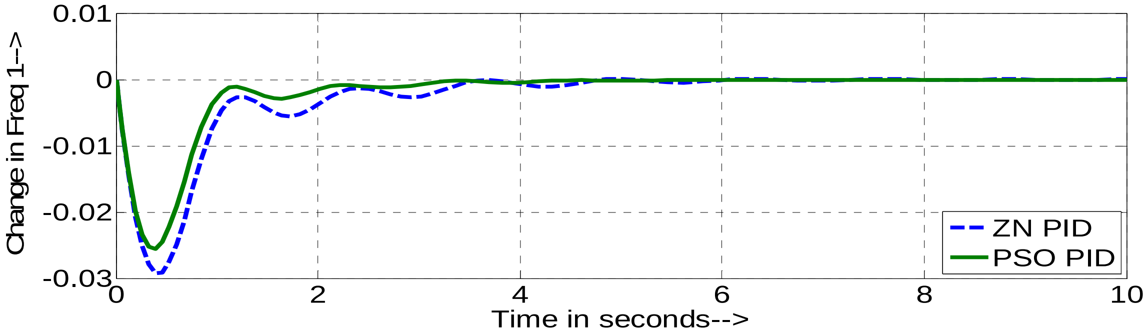

Fig. 4 Change in frequency of area-1 for different controller that ZN tuned PID controller and PSO optimized PID controller

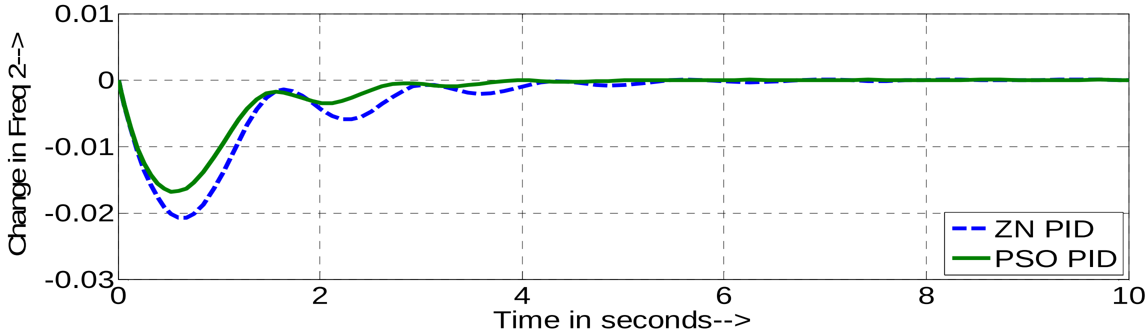

Fig. 5 Change in frequency of area-2 for different controller that ZN tuned PID controller and PSO optimized PID controller

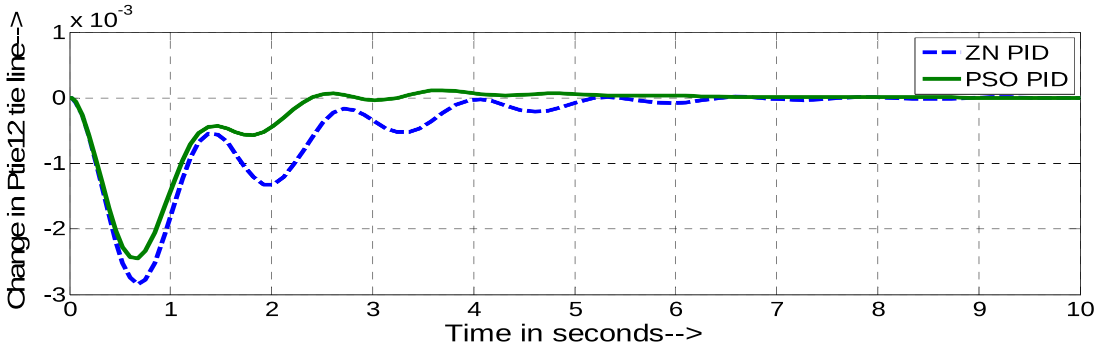

Fig. 6 Change in tie-line power connecting between area-1 and area-2 error for different controller that ZN tuned PID controller and PSO optimized PID controller

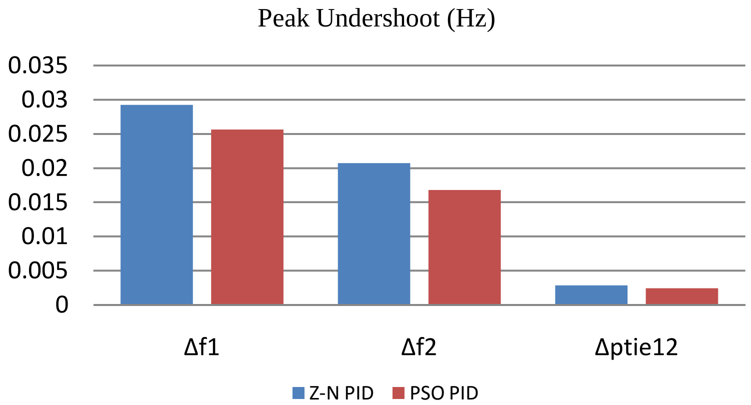

Fig. 7 Peak undershoot for different controller

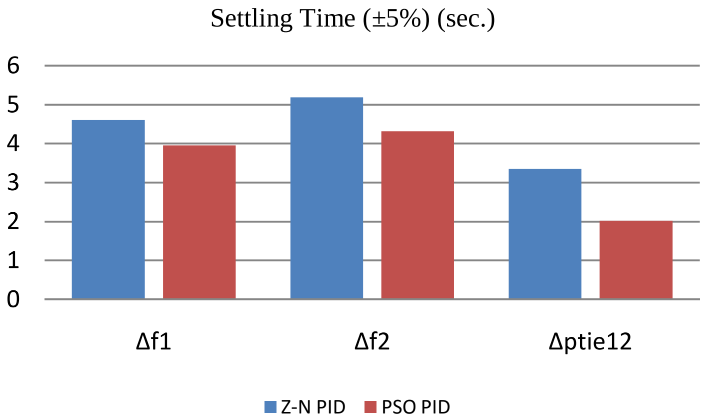

Fig. 8 Peak undershoot for different controller

Result shown in fig. 7 & 8 represents that performance of two different controllers for LFC. In comparison, it is found that PSO optimized controller gives better results than Z-N tuned PID controller.

CONCLUSION

Balancing the power generation and demand is most prime requirement tin power system and in day to day increasing complexity of power system made it as challenging task to design device a superior controller for it. PID controller is shown it suitable for this purpose, but challenging is finding gain values for optimum performance of PID controller. In this work, PSO is used to tune parameters of PID controllers. A two-area interconnected power system is taken into consideration for application of this proposed controller.

The ISE is used as objective function to get fast response. Different plots of frequency as well as tie-line power error deviation were obtained by applying different step load demand of both areas. This graphs shows superiority of proposed scheme of optimization for PID controller over other method taken for consideration.

REFERENCES

[1] C Concordia and LK Kirchmayer, Tie-Line Power and Frequency Control of Electric Power Systems, *Power Appar Syst Part III Trans Am Inst Electr Eng*, **1953**,72 (2), 562–572,
[2] P Kundur, *Power System Stability and Control*, New York: McGraw-Hill, **2006**.
[3] N Cohn, Some Aspects or Tie-Line Bias Control on Interconnected Power Systems, *IEEE Trans Power Appar Syst*, **1956**, 1415–1436.
[4] E Fosha and O IElgerd, Optimum Megawatt-Frequency Control of Multiarea Electric Energy Systems, *IEEE Trans Power Appar Syst*, **1970**, 89(4), 556–563.
[5] RK Cavin, MC Budge, and P Rasmussen, An Optimal Linear Systems Approach to Load-Frequency Control, *IEEE Trans Power Appar Syst*, **1971**, 90(6).
[6] ML Kothari, PS Satsangi and J Nanda, Sampled-Data Automatic Generation Control of Interconnected Reheat Thermal Systems Considering Generation Rate Constraints, *IEEE Trans on Power Appar Syst*, **1981**, 5, 2334–2342.
[7] N Cohn, Methods of Controlling Generation on Interconnected Power Systems, *Trans Am Inst Electr Eng Part III Power Appar Syst*, **1961**, 80 (3), 202–209.
[8] AG Hoffmann, *IEEE Standard Definitions of Terms for Automatic Generation Control on Electric Power Systems*, **1991.**
[9] N Jaleeli, LS VanSiyck, DN Ewart, LH Fink and AG Hoffmann, Understanding Automatic Generation Control, *IEEE Trans power Syst*, **1992**, 7(3), 1106–1122,
[10] G Ray, N Prasad and GD Prasad, A New Approach to the Design of Robust Load-Frequency Controller for Large Scale Power Systems, *Electr Power Syst Res*, **1999**, 51 (1), 13–22.
[11] R Wai, S Member, J Lee and K Chuang, Real-Time PID Control Strategy for Maglev Transportation System via Particle Swarm Optimization, *IEEE Trans Ind Electron*, 2011, 58 (2), 629–646.
[12] M Ünal, A Ak, V Topuz and H Erdal, Optimization of PID Controllers Using Ant Colony and Genetic Algorithms, *Springer*, **2012**, 449.
[13] BP Padhy and B Tyagi, Tuning of Pid Controller Used in AGC Scheme, **2008.**
[14] A Khodabakhshian and M Edrisi, A New Robust PID Load Frequency Controller, *Control Eng Pract*, **2008**, 16 (9),1069–1080.
[15] H Varol and Z Bingul, A New PID Tuning Technique using ANT Algorithm, *Am Control Conference,* **2004,** 54 (1), 54–59.
[16] I Chiha, N Liouane and P Borne, Tuning PID Controller using Multiobjective ANT Colony Optimization, *Appl Comput Intell Soft Comput*, **2012**, 1, 1–7.
[17] JG Ziegler and NB Nichols, Optimum Settings for Automatic Controllers, *Trans ASME*, 1942, 65 (5), 433–444.
[18] YK Bhateshvar and HD Mathur, Comparative Dynamic Analysis on Frequency Stabilization for Multi-Area power system in Deregulated Environment, *IEEE International Conference on Signal Processing, Computing and Control*, **2012**, 1–6.
[19] J Kennedy and R Eberhart, Particle swarm optimization, *Proceedings of International Conference on Neural Networks*, **1995**, 1942–1948.
[20] Y Shi and RC Eberhart, Parameter Selection in Particle Swarm Optimization, in *Eutionary Programming VII SE - 57*, **1998**, 591–600.
[21] YK Bhateshvar and HD Mathur, Frequency Stabilization for Thermal-Hydro Power System with Fuzzy Logic Controlled SMES unit in Deregulated Environment, *Fourth International Conference on Advanced Computing & Communication Technologies Frequency*, **2014**, 536–540.