The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 9 || Pages || PP 67-72 || 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

# Optimal control of load frequency control power system based on particle swarm optimization technique

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**ABSTRACT**
*In this work, PSO is proposed to set the gains of PID controller for LFC in single power systems area. This work has very significant issue because of persistent and random change load through working of power system. The proposed algorithm offer fluent performance, stable, and fast convergence to target value. Simulation results using MATLAB R2015a demonstrate that the proposed controller has more efficient of dynamic performance, better convergence, fast response from the other methods depend on rise and settling time of frequency deviation.*

***Keywords:*** *LFC, single area power system, PSO, PID controller*

Date of Submission: 17 May 2016 Date of Accepted: 03 October 2016

## I. INTRODUCTION

The substantial development of universally led to increasing demand of electric power. For normal operation of power system, the frequency should be constant with specific limits. Hence, the LFC has essential role to control real power output of generating unit. The objective of the LFC is preserving zero error steady state of frequency deviation [1]. Classical LFC used an integral control that had limits dynamic response. Therefore, to improve the power system stability must be enhance the control loop of system. Traditional PID controller is widely used to control almost process loops of industrial systems due to their simple structure and reliable [2]. The PID parameters (Kp, Kd, and Ki) should be accurately tuned. In literatures, many methods have been sophisticated to tune these parameters like Fuzzy logic system, evolutionary algorithms, and Neural Network … etc. In [3] the authors present a PID controller tuning by two artificial algorithms, GA and PSO to improve LFC response. In [4] the authors proposed a PSO and BFO for LFC to boost the power systems stability.

This paper presents a PSO algorithm to tune optimal PID parameters of single area load frequency controller. This includes Integral absolute error (IAE), integral square error (ISE), and integral of time multiplied by square error (ITSE) which ITSE was experimentally better than the other based on maximum overshoot, rise, and settling time.

## II. MATHEMATICAL MODEL OF LFC

The schematic diagram of LFC is illustrated in figure (1). It consists of three sections; governor, turbine, and rotor inertia & load with feedback of speed regulation [5]:

- The Governor $G_g(s)$ is:

$$G_g(s) = \frac{1}{T_G S+1} \tag{1}$$

- The Turbine $G_T(s)$ is:

$$G_T(s) = \frac{1}{T_T S+1} \tag{2}$$

The Rotor inertia and Load $G_p(s)$ is:

$$G_p(s) = \frac{K_p}{T_p S+D} \tag{3}$$

$1/R$ is the droop characteristics.

Where:

$\Delta P_L$ Load disturbance (p.u. MW)

| | |
|---|---|
| $T_G$ | Time constant of governor (sec) |
| $T_T$ | Time constant of turbine (sec) |
| $T_p$ | = 2H: Time constant of rotor inertia (sec) and H: Inertia constant |
| $K_p$ | Gain of electric power system |
| $R$ | Governor speed regulation (Hz/p.u. MW) |
| $D$ | Is a percent change in load divided by percent change in frequency (pu MW/Hz) |

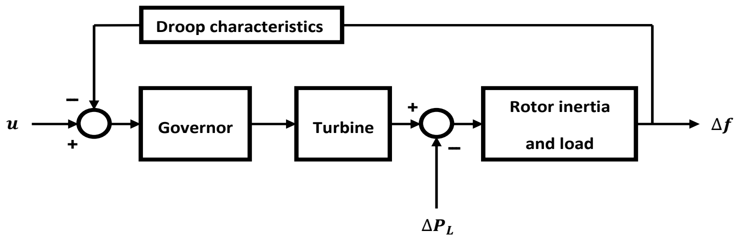


**Figure (1)** Block diagram of single area power system

The first American electrical engineer Eberhart and psychologist Kennedy developed a PSO algorithm depend on similarity of swarm of bird and fish pool [6]. In PSO the system is initialized the swarm assigning random position and searches for optimal location by update of generations. Each particle is flying out of the problem search space by following the current optimum particles. The velocity of each particle can be modified as follows:

$$V_i^{k+1} = WV_i^k + C_1R_1 * \left(Pbest - S_i^k\right) + C_2R_2 * \left(gbest - S_i^k\right) \tag{4}$$

$$S_i^{k+1} = S_i^k + V_i^{k+1} \tag{5}$$

In order to increase convergence of algorithm, linearly decreasing inertia weight W function is used to enhance the efficiency and performance of PSO as following [7]:

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \text{ x } iter \tag{6}$$

Where:

| | |
|---|---|
| $V_i^k$ | Velocity of particle I of iteration k. |
| $W_{max}$ | Initial weight |
| $W_{min}$ | Final weight |
| $iter$ | Maximum iteration |
| $iter_{max}$ | Current iteration |
| $R_1, R_2$ | Random number between 0 and 1. |
| $C_1, C_2$ | Acceleration constant. |
| $S_i^k$ | Current searching point. |
| $S_i^{k+1}$ | Modified searching point. |
| $Pbest$ | Best position of the ith particle. |
| $gbest$ | The index of best particle among the entire particle in the population. |

## IV. Design of the Proposed Controller

The proposed algorithm is used to set the PID parameter and enclose the better dynamic performance in LFC. The structure of the PID – PSO is shown in figure (2).

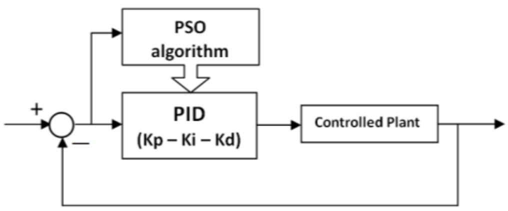


**Figure (2)** The proposed PID – PSO

The accurate setting of PID parameters can get better response. Therefore, the performance criteria has important role to realize it. The most common performance indices are shown in Table (1) [8], a minimization fitness function is selected as follows:

$$Fitness\ Function = \frac{1}{J} \tag{7}$$

**Table (1)** Mathematical description of different performance criteria

| Performance Criteria | Symbol | Mathematical description of the error |
|---|---|---|
| Integral of Absolute Magnitude of the Error | IAE | $J_{IAE} = \int_0^T \lvert e(t)\rvert dt$ |
| Integral of the Square of the Error | ISE | $J_{ISE} = \int_0^T e^2(t) dt$ |
| Integral of Time multiplied by Square Error | ITSE | $J_{ITSE} = \int_0^T t.e^2 dt$ |

These performance indices have an advantage and disadvantage. The disadvantage of the IAE and ISE indices is short overshoot but long settling time. ITSE index can cope of this disadvantage but it is complex and requires time to its analytical formula [9]. The proposed algorithm flowchart is illustrated in figure (3) and the combining of LFC with PID controller are demonstrated in figure (4).

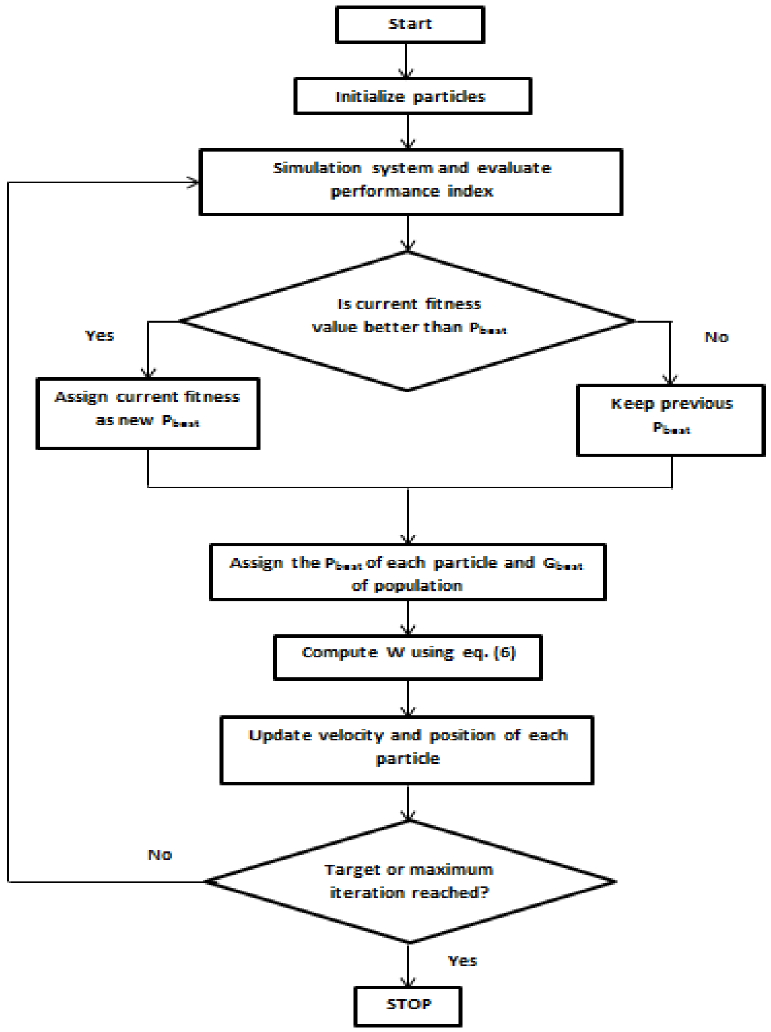


**Figure (3)** Flowchart of the proposed controller

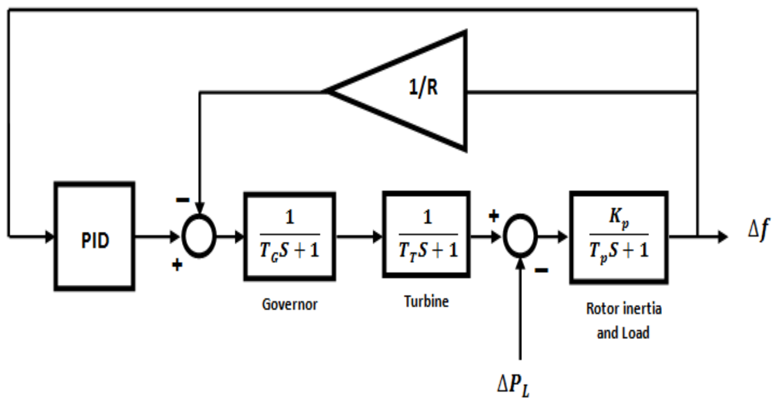


**Figure (4)** The structure of LFC including PID controller

The traditional LFC is designed with PI controllers that have a limit transient response comparison with other controller methods. The proposed controller is used to control the frequency deviation in LFC. The single area parameters are given in appendix A and the PSO algorithm parameters are set as follows:

- Population size: 80
- Maximum iteration: 100
- Acceleration factors C1 & C2: 1.2 and 1.4 respectively
- Wmax and Wmin: 0.9 and 0.4 respectively that be found experimentally to get excellent Convergence of algorithm.
- Search space of each particle: 0 to +100

Each particle set of the PID parameters and will search for their optimal value in three dimensional search space P, I, and D. So as to confirm the efficient of the proposed controller to control the steady state frequency deviation is tested. The simulation result shown in figure (5) is achieved using multi performance indices in PSO algorithm. It can be obviously seem that the performance index ITSE has lowest rise and settling time as listed in table (2).

TABLE (2) Step performance of LFC

| # | Rise time (sec) | Settling time (sec) |
|---|---|---|
| PID-IAE | 0.004 | 5.3668 |
| PID-ISE | 0.009 | 7.4138 |
| PID-ITSE | 0.0012 | 1.02 |

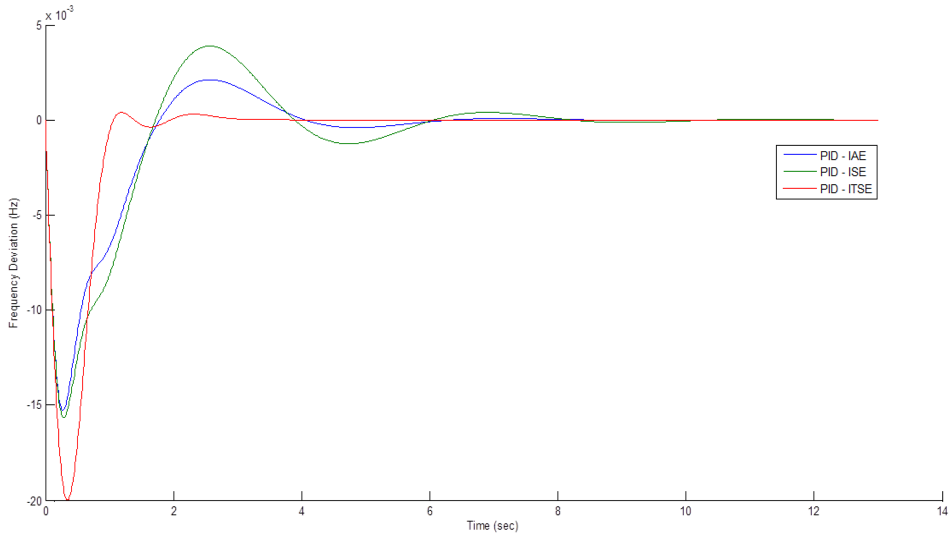


**Figure (5)** Step response of LFC with different performance indices

To emphasize the robustness of the proposed controller, a comparison is made with the traditional PI controller as shown in figure (6) and different control scheme methods used by researchers as listed in table (3).

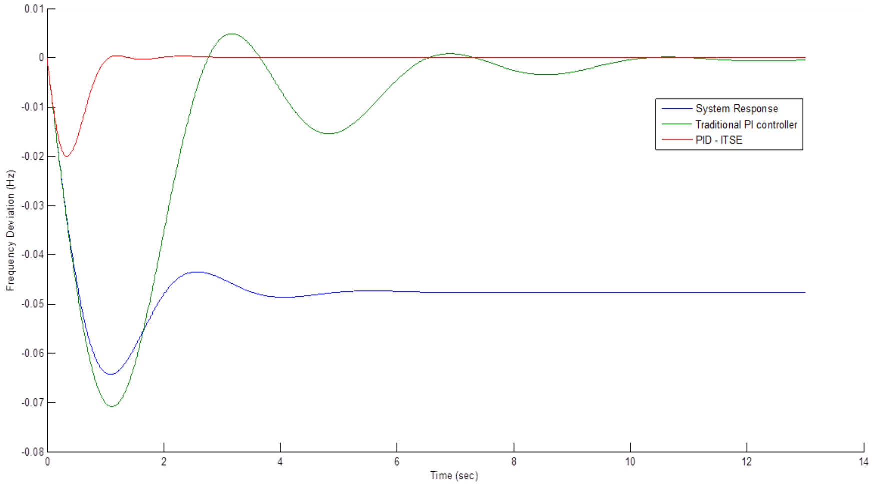


**Figure (6)** Step response of LFC

TABLE (3) Comparison of different control scheme

| # | Rise time (sec) | Settling time (sec) |
|---|---|---|
| Traditional PI controller | 0.3152 | 10 |
| GA-PID [2] | ---- | 2.18 |
| PSO-PID [2] | ---- | 2.39 |
| PSO-PID [3] | ---- | 5.91 |
| BFO-PID [3] | ---- | 5.08 |
| PSO-PID | 0.0012 | 1.02 |

Figure (7) demonstrate the ability of the proposed controller to damp the frequency oscillation when 10% step change increase in power demand depends on rise and settling time.

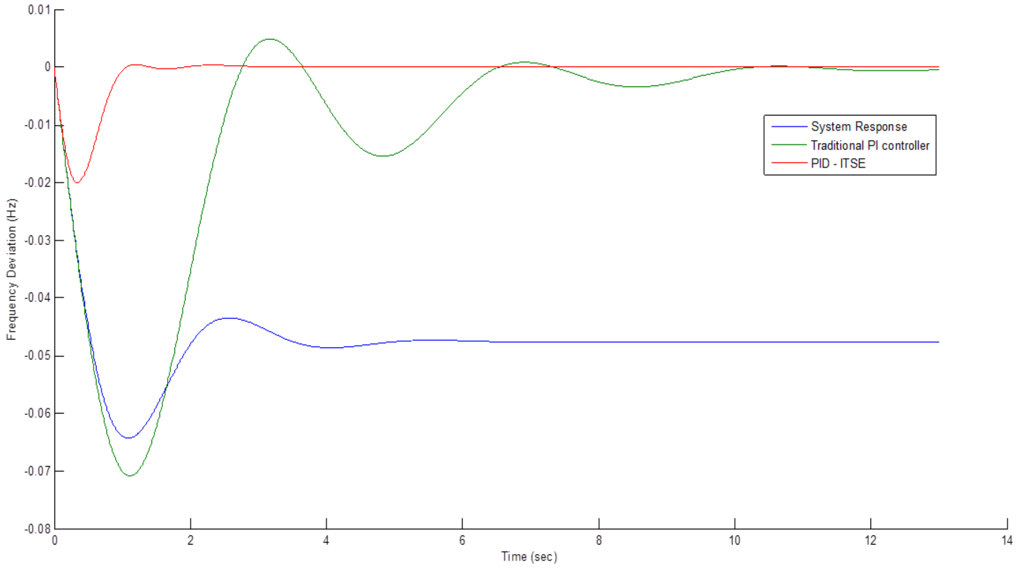


**Figure (7)** 10% step change response of LFC

## VI. CONCLUSION

In this work, the design of PSO algorithm is present to set optimal value of PID controller. The frequency deviation of LFC is controlled by PSO-PID controller. Through simulation results, the proposed controller can perform an accurate PID parameters set than the other methods and can improve the dynamic performance through damping oscillation of frequency deviation in LFC.

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### APPENDIX

The nominal parameter values of the single area power system are:

| | |
|---|---|
| $T_G$ | 0.2 sec |
| $T_T$ | 0.5 sec |
| $T_p$ | 10 sec |
| $K_p$ | 1 |
| $R$ | 0.05 Hz/pu MW |
| $D$ | 0.8 pu MW/Hz |