Arab J. Nucl. Sci. Appl., Vol. 52, 3, 34-42 (2019)

Arab Journal of Nuclear Sciences and Applications

ISSN 1110-0451 **Web site: ajnsa.journals.ekb.eg** (ESNSA)

PID Controller Adjustment Using Particle Swarm Optimization for Multi-Area Load Frequency Control

Said A. Kotb, Magdy M. Z. Abdelaal and Ahmed R. Adly

ETRR-2, Nuclear Research Center, Atomic Energy Authority, Egypt

Received 01st Dec 2018
Accepted 22th Oct 2019

This study presents a control technique for the load frequency control (LFC) for a multi-area power system. This paper presents particle swarm optimization (PSO) based on the study of multi area power network. Fuzzy logic (FL) system and PSO have been used to get the PID controller gains. Frequency protection relays will mal-function when the load demand changes leading to a lower speed of generator's shaft. Matlab/Simulink is used to model a three-area power system and study the PID controllers to control the frequency deviations one of these areas is a nuclear power plant. The presented PSO technique is compared with traditional PID controller and FL system controller to show the accuracy of the presented PSO technique. Also, the results indicated the ability of the presented PSO technique over FL system and traditional system.

Keywords: *load frequency control, Nuclear power plant, fuzzy control system, particle swarm optimization*

List of Abbreviations

APB	Active power balance
CLPSO	Comprehensive learning particle swarm optimization
FL	Fuzzy logic
GA	Genetic algorithm
GWO	Gray wolf optimization
ICA	Imperialist competitive algorithm
ITAE	Integral time multiplied absolute error
LCOA	Lozi map-based chaotic algorithm
LFC	Load frequency control
PID	Proportional integral-derivative
PSO	Particle swarm optimization
SOA	Seeker optimization algorithm
TPPs	Thermal power plants

Introduction

To ensure the continuity of power supply, proficiency of power system stability has to be up to the mark. With an ever-increasing dependence on electric energy, interruption of power for a long duration can substantially weaken social and economic stability. Therefore, there is a need to reliable LFC schemes. Several blackout scenarios that have occurred throughout the world had a chain of events which led to the cascaded outages. Few of the key events responsible for such

Corresponding author: zaky_magdy@yahoo.com
DOI: 10.21608/ajnsa.2019.4923.1114

undesired tripping were load encroachment, power swing and voltage instability condition [1].
In power system, any disturbance can lead to a mismatch between generation and load demand. This can further cause acceleration or deceleration of the rotor and finally initiate swing phenomenon. To control in generations output power due to change in frequency of the power system, this control is known as LFC. In large interconnected power system, LFC is very important task to keep frequency of power system in a scheduled value [2].
Recent growth and development of power system industry and increased power demand have necessitated intelligent methodologies for practical control of the power system. To provide the stability of the electric network, constant frequency and active power balance (APB) are required. Frequency is based on APB. If power generation or power demand change, the frequency will change. Therefore, disturbance will occur in both frequency and power leading to instability problem. In this case, LFC should be used to solve this problem
A previous study [2]presented a new LFC scheme for multi-area power system. In this paper, the LFC is based on indirect adaptive FL control scheme. T.Hussein [3] proposed a PID controller scheme based on GA to solve LFC problem. In addition, PID controller scheme based on lozi map-based LCOA was proposed to solve LFC problem [4]. Guha et al. [5] presented a new LFC scheme for multi-area power system based on GWO. The GWO employing ITAE is based fitness function. Also, the presented scheme in the current study was compared by CLPSO. Parvaneh et al. [6] presented a LFC scheme for multi-area power system based on SOA. The SOA is applied for two thermal power plants.
In an earlier publication [7], the authors presented a LFC scheme for high wind energy penetration power system based on FL controller scheme. a LFC controller scheme based optimal output feedback was suggested, where state variables are put input for feedback process[8]. Yousef et al. [9 presented a LFC based on FL controller scheme adaptive FL scheme. A previous study [10 presented a LFC scheme for single-area power system based on ICA. Other researchers [11] presented a LFC scheme for multi-area power system based on combination between PSO and FL scheme. In another study [12], the authors presented a LFC scheme for multi-area power system based on ICA scheme.
Particle Swarm Optimization (PSO) is an Evolutionary computation (EC) method for solving optimization problems [13, 14]. These schemes get optima solutions faster than conventional schemes [14]. PSO is used to probe the search space of the problem under consideration [15-17].
In this study, a new PSO technique is used for LFC in multi-area power system. Soft computing techniques such as PSO and FL systems are becoming of a considerable importance in the power system. It is found that a traditional scheme is inadequate to provide correct action for all situations. In this study, depending on the PSO technique; the problem of load change will be solved. Study cases of various situations have been addressed for verifying the proposed PSO scheme characteristics and they are found to be accurate.
This paper is organized as follows: Section 1 describes the recent techniques for LFC in in multi-area power system. Section 2 presents the system under study. Section 3 demonstrates the main features of the presented PSO technique. Section 4 introduces a comparison between the presented PSO technique and other schemes reported in the literature. Section 5 is dedicated to the conclusions.

System model

Matlab Simulink software is used to model the three areas of power generation including Gas, thermal in addition to the anticipated first nuclear power plant The particle swarm optimization is used to tune the PID to optimize the control actions of the load frequency of multi area including nuclear power plant [18-19].
Figure 1 shows the model of power system. It consists of non-reheat type thermal power system, gas power system and nuclear power plant. In Figure 1, parameters of frequency bias are B1, B2 and B3. Governors speed regulations are R1, R2 and R3, Governors time constants are Tg1 Tg2 and Tg3, and turbines time constants are Tt1, Tt2 and Tt3, power systems gains are KP1, KP2 and KP3.

Particle Swarm Optimization Technique

Equations 1 and 2 mean that each bird's speed is determined by a momentum term and two attractions terms [18]. The momentum term is equal to its previous speed multiplied by the scalar a. It represents the tendency of the bird to continue on its own direction. The first attraction term represents the tendency of the bird to approach the best position found by the bird itself within its previous trajectory. The second attraction term represents the

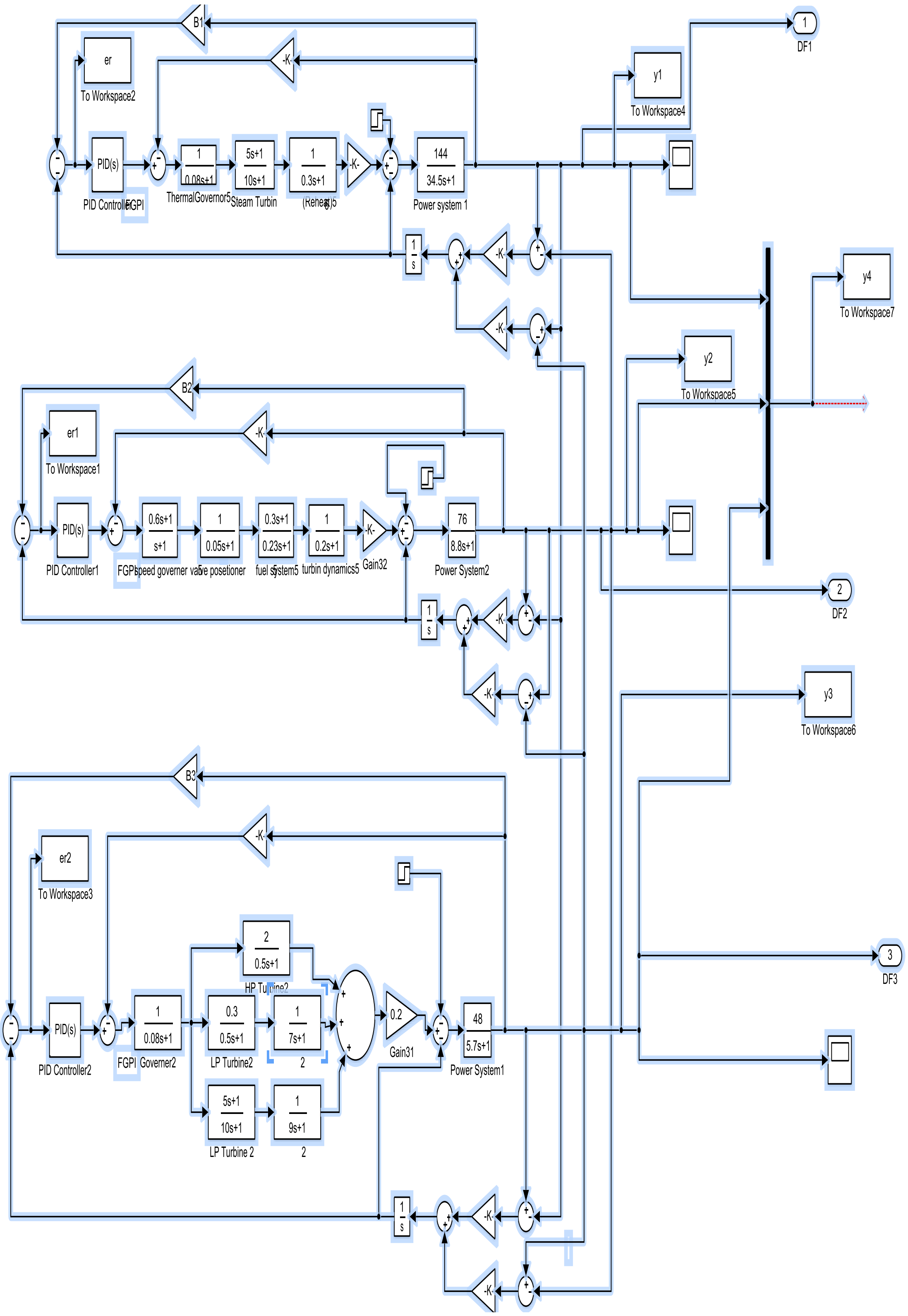

Figure (1): Simulink model of the three area

tendency of the bird to approach the best position found within the swarm. A simpler PSO model named cheap PSO where birds are attracted only to the global best, moreover, the random number r_2 is not used, and hence the bird's motion in PSO is characterized by the following vector equations:

$$v_i(k+1) = av_i(k) + r_1 b_1 (p_{lb}(k) - x_i(k)) + r_2 b_2 (p_{gb}(k) - x_i(k)) \quad (1)$$

$$x_i(k+1) = x_i(k) + v_i(k) \quad (2)$$

Where:

i=1,2…N: is the swarm size.

a, b1, b2: are constant.

r1, r2: are random numbers.

k= 1,2…: number of iteration.

$$v(k+1) = av(k) + b(p_g(k) - x(k)) \quad (3)$$

$$x(k+1) = x(k) + v(k+1) \quad (4)$$

Where *v* is a vector representing the speed of each bird, *x* is the bird position vector, *(a, b)* are learning parameters and p_g is the 'best' previous position found so far in the neighborhood [14].
The presented PSO technique is used to determine the PID parameter. Figure 2 shows the structure of the PID – PSO. Also the presented PSO technique flowchart is illustrated in figure 3.

Results and Discussion

Three-multi area included the Egyptian first nuclear power plant LFC system is designed to simulate the integration of the tie of different power generation systems and test the frequency control system. Figure 1 shows the simulation model of the three areas included the three-controller based design, fuzzy, PID and PID based tuning system with PSO and the presented optimization methodology applied to the three area interconnected power system. The PSO based tuning controller improves the system performance in comparison when no tuning. The optimized control system performance indicates that it is minimizing the over and down shoot errors and eliminating steady state frequency errors. Three cases are studies.

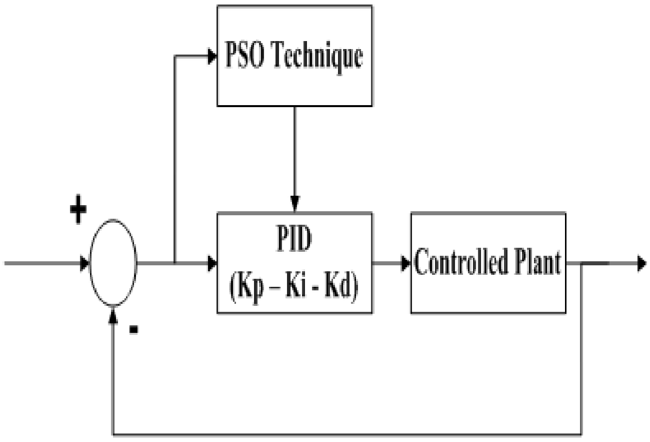

Figure (2): The proposed PID – PSO

<u>Case 1:</u> Changing load in area-1

When load is raised by 10% at area-1, the frequency will oscillate in three areas (area-1, area-2 and area-3). Figures 4 shows the frequency deviation (Δf_1) in area-1. Also Figures 5 and 6 show the frequency deviation (Δf_2, Δf_3) in area-2 and area-3, respectively.
Figures 4, 5 and 6 clearly reveal that the presented PSO technique controller proves its supremacy in terms of minimum undershoot, overshoot and settling time from fuzzy, PID schemes controller.

<u>Case 2:</u> Changing load in area-2

When load is raised by 10% at area-2, the frequency will oscillate in three areas (area-1, area-2 and area-3). Figures 7 shows the frequency deviation (Δf_1) in area-1. Also Figures 8 and 9 show the frequency deviation (Δf_2, Δf_3) in area-2 and area-3, respectively.
Figures 7, 8 and 9 clearly reveal that the presented PSO technique controller proves its supremacy in terms of minimum undershoot, overshoot and settling time from fuzzy, PID schemes controller.

<u>Case 3:</u> Changing load in area-3

When load is raised by 10% at area-3, the frequency will oscillate in three areas (area-1, area-2 and area-3). Figures 10 shows the frequency deviation (Δf_1) in area-1. Also Figures 11 and 12 show the frequency deviation (Δf_2, Δf_3) in area-2 and area-3, respectively.
Figures 10, 11 and 12 clearly reveal that the presented PSO technique controller proves its supremacy in terms of minimum undershoot, overshoot and settling time from fuzzy, PID schemes controller.

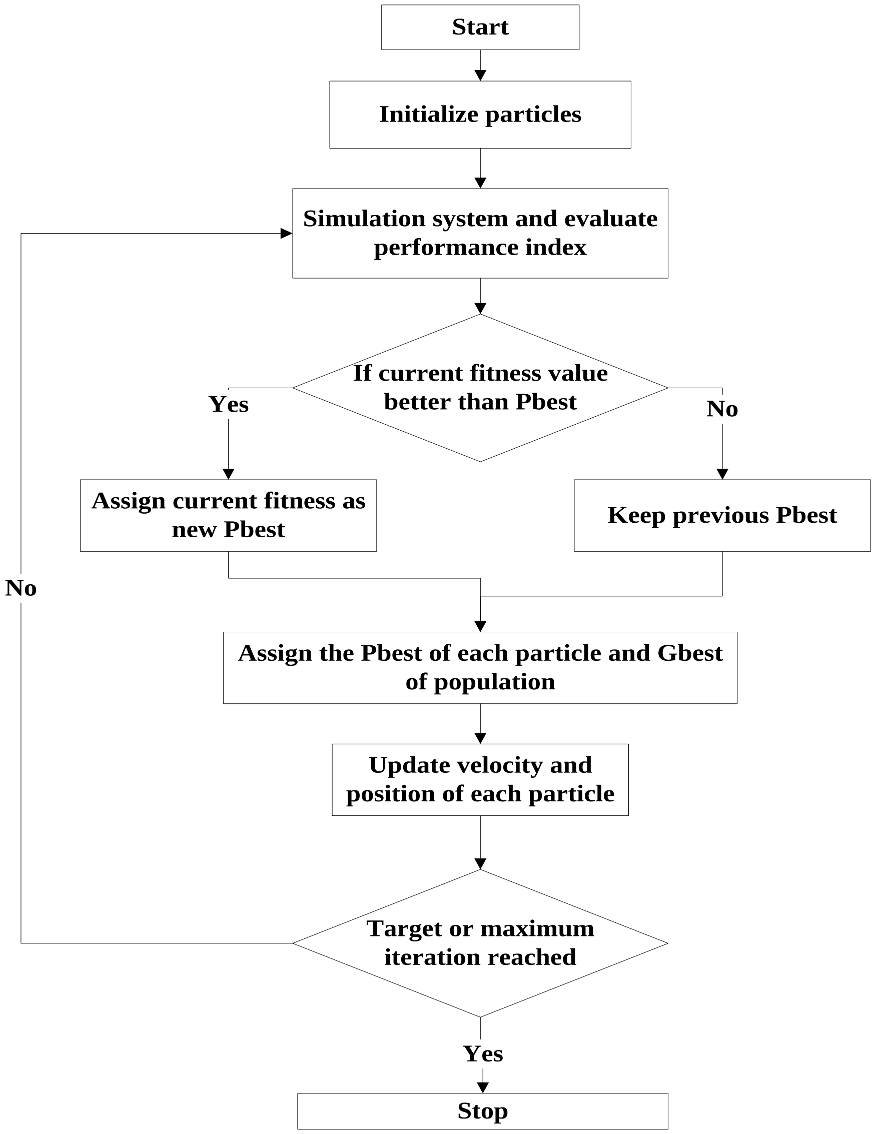

Figure (3): Flowchart of the presented PSO technique controller

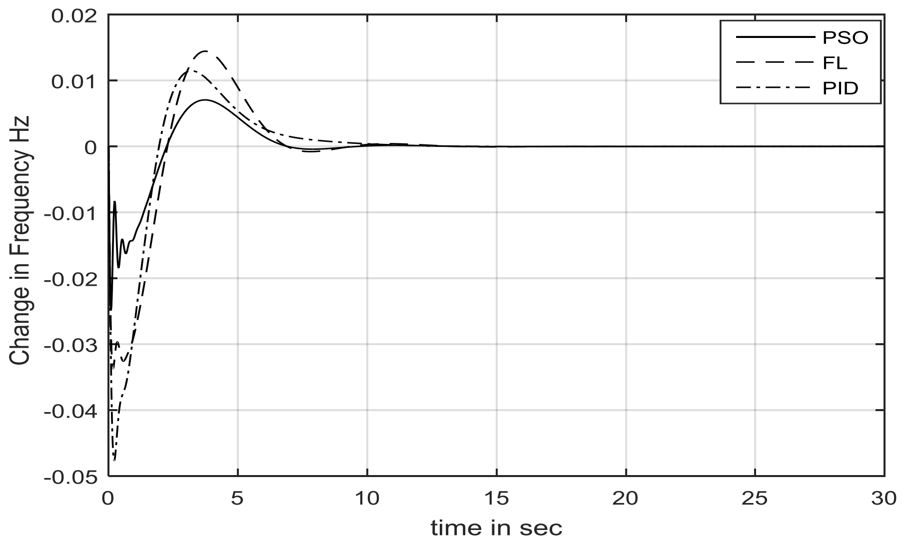

Figure (4): Area-1 frequency change for 10% change in area-1

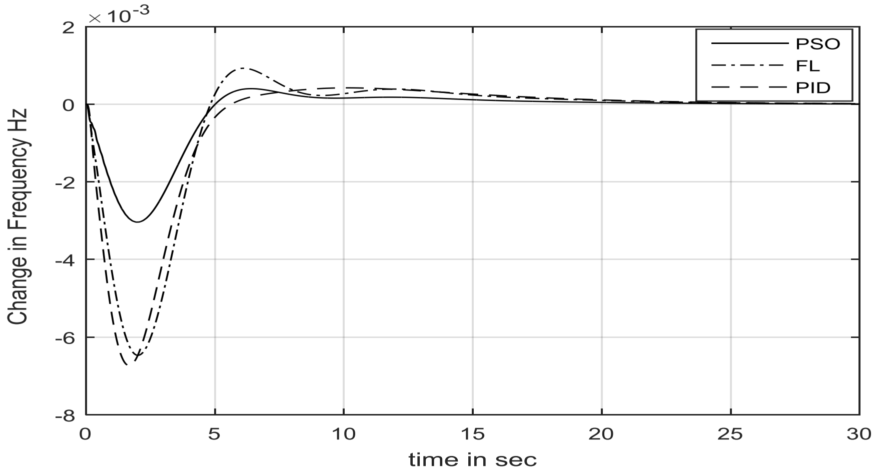

Figure (5): Area-2 frequency change for 10% change in area-1

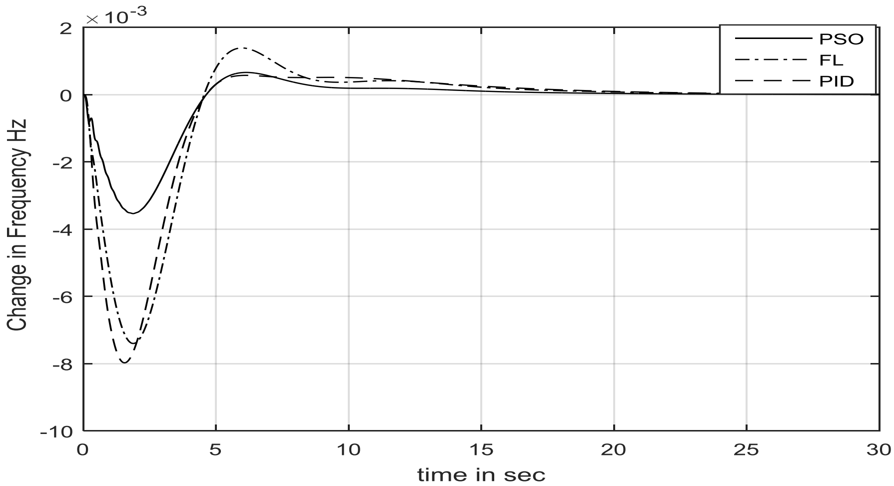

Figure (6): Area-3 frequency change for 10% change in area-1

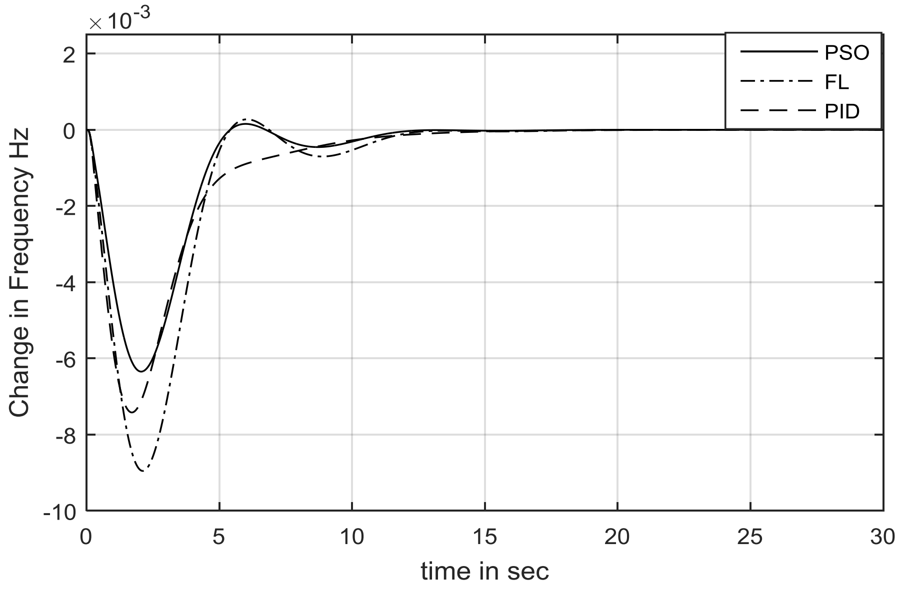

Figure (7): Area-1 frequency change for 10% change in area-2

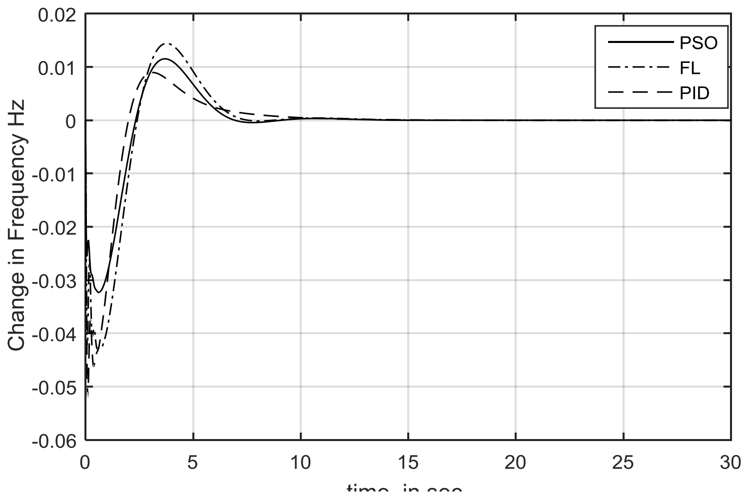

Figure (8): Area-2 frequency change for 10% change in area-2

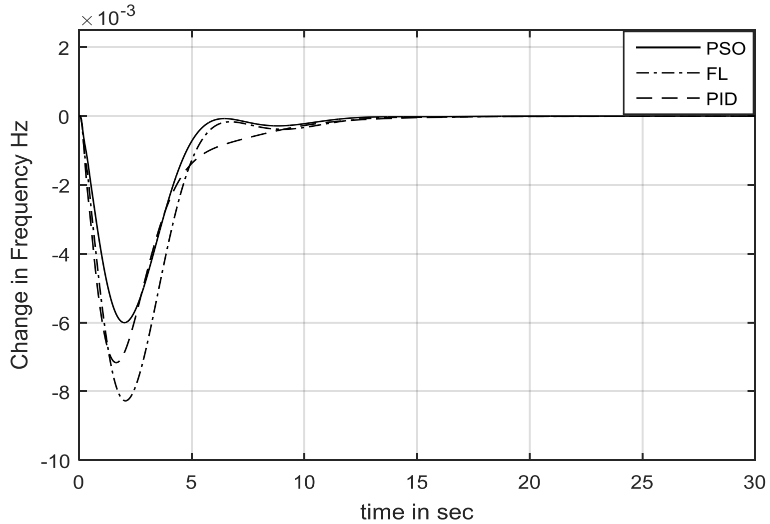

Figure (9): Area-3 frequency change for 10% change in area-2

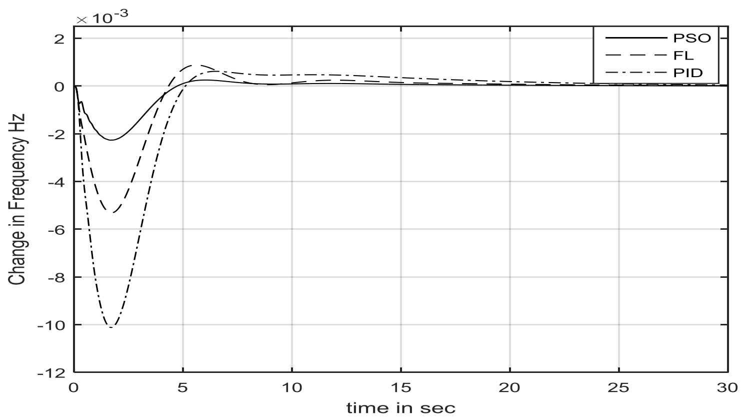

Figure (10): Area-1 frequency change for 10% change in area-3

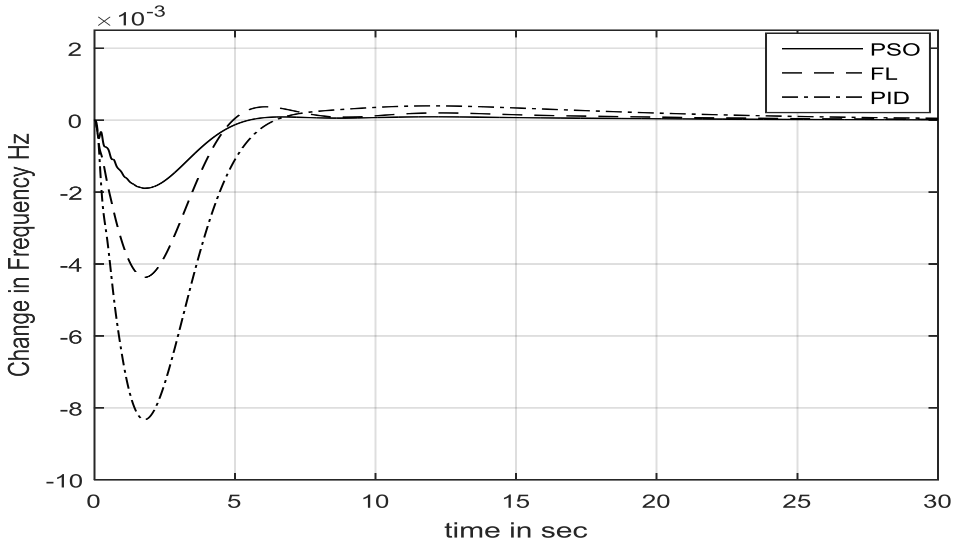

Figure (11): Area-2 frequency change for 10% change in area-3

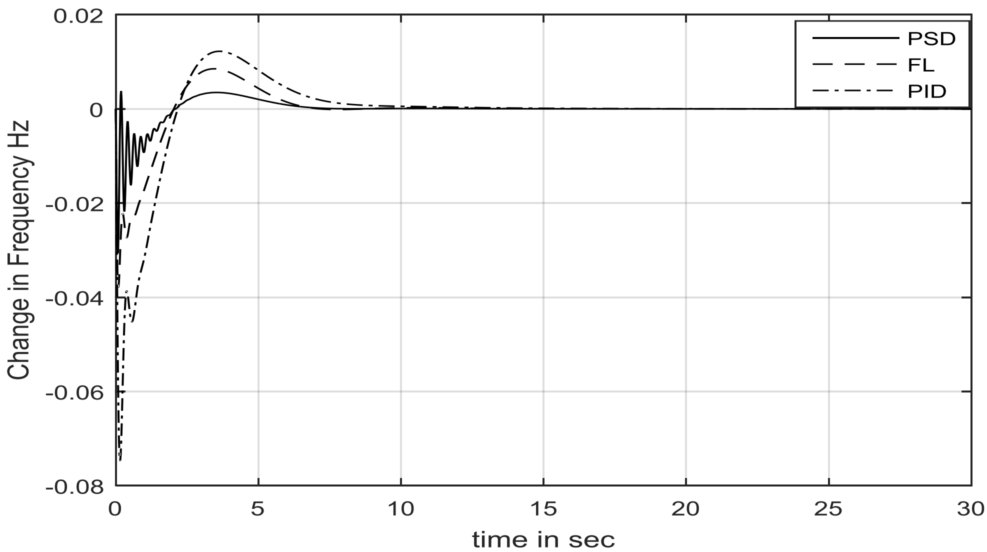

Fig (12): Area-3 frequency change for 10% change in area-3

Conclusion

In this work, a PSO technique is presented for automatic LFC of multi area power systems. The presented PSO technique provides a tuning derivative controller. This proposed technique depends on PSO algorithm. Matlab/Simulink is used to model a three-area power system and study the PID controllers to control the frequency deviations. It is concluded that the presented PSO technique controller proves its supremacy in terms of minimum undershoot, overshoot and settling time from fuzzy, PID schemes controller. The test results validated the effectiveness of the presented PSO technique for any disturbance and load changes. Also, the comparison of the results indicates that the presented PSO technique achieves a remarkable behavior for each area from traditional scheme and FL system scheme. The presented PSO technique has a high potential of implementation in practical applications in real time field.

References

1. W. Tan, Z. Xu, “Robust analysis and design of load frequency Controller for power systems”, Electrical Power System Research, 79 (5), 2009, pp.846–853.
2. H. Yousef, “Adaptive fuzzy logic load frequency control of multi-area power system”, Electrical Power and Energy Systems, 68, 2015, pp. 384–395.
3. T. Hussein, “A Genetic Algorithm for Optimum Design of PID Controller in Load Frequency Control”, International Journal of Electrical and Information Engineering, 6 (10), 2012.
4. M. Farahani, S. Ganjefar, M. Alizadeh,” PID controller adjustment using chaotic optimization algorithm for multi-area load frequency control”, IET Control Theory and Applications, 6 (13), 2012, pp. 1984-1992.
5. D. Guha, P. K. Roy, S. Banerjee, “Load frequency control of interconnected power system using grey wolf optimization”, Swarm and Evolutionary Computation, 2015, http://dx.doi.org/10.1016/j.swevo.2015.10.004i
6. H. Parvaneh, S. M. Dizgah, M. Sedighizadeh, S. T. Ardeshir, “Load Frequency Control of a Multi-Area Power System by Optimum Designing of Frequency-Based PID Controller Using Seeker Optimization Algorithm”, 6th Conference on Thermal Power Plants, 19-20 Jan., 2016, Tehran, Iran.
7. B. Hassan, and P. R. Daneshmand, “Fuzzy logic-based load-frequency control concerning high penetration of wind turbines”, IEEE Systems Journal, 2012, pp. 173-180.
8. K. P. Parmar, S. Singh, S. Majhi, and D. P. Kothari, “Multi-area load frequency control in a power system using optimal output feedback method”, Power Electronics, Drives and Energy Systems (PEDES), 2010, India.
9. H. Yousef, et al., “Load Frequency Control of a Multi-Area Power System: An Adaptive Fuzzy Logic Approach”, IEEE Transactions Power Systems, 29 (4), 2014, pp. 1822-1830.
10. G. Shankar, and V. Mukherjee, “Quasi oppositional harmony search algorithm based controller tuning for load frequency control of multisource multi-area power system”, International Journal of Electrical Power & Energy Systems, 75, 2016, pp. 289-302.
11. D. S. Singh, J. S. Lather, and S. Marwaha, “Multi Area Load Frequency Control Using Particle Swarm Optimization and Fuzzy Rules”, Procedia Computer Science, 57, 2015, pp. 460-472.
12. S. Hamed, B. Vahidi, M. Ebrahimpour, “A robust PID controller based on imperialist competitive algorithm for load frequency control of power systems”, ISA transactions, 52 (1), 2013, pp. 88- 95.
13. B. V. Prasanth and S. V. J. Kumar, “Load Frequency Control for a Two Area Interconnected Power System using Robust Genetic Algorithm Controller,” Journal of Theoretical and Applied Information Technology, 4 (12), 2008, pp. 1204-1212.
14. Y. Oysal, “A Comparative Study of Adaptive Load Frequency Controller Design in a Power System with Dynamic Neural Network Models,” Energy Conversion and Management, 46 (15), 2005, pp. 2656-2668.
15. C. F. Jaung and C. F. Lu, “Power System Load Frequency Control by Genetic Fuzzy Gain Scheduling Controller,” Journal of the Chinese Institute of Engineers, 28 (6), 2005, pp. 1013-1018.
16. A. Demiroren, A. and E. Yesil,”Automatic Generation Control with Fuzzy Logic Controllers in the Power System Including SMES Units”, Electrical Power and Energy Systems, 26, 2004, pp. 291-305.
17. M. S. Krishnarayalu et. al., “PID Controller Tuning using Simulink for Multi Area Power Systems”, International Journal of Engineering Research & Technology, 1 (7), 2012, pp. 2278-2281.
18. Y. Arya, N. Kumar, S. K. Gupta, “Load Frequency Control of a Four- Area Power System using Linear Quadratic Regulator”, IJES, 2, 2012, pp.69-76.
19. W. Ten, “Unified Tuning of PID Load Frequency Controller for Power Systems via IMC”, IEEE Transactions On Power Systems, 25 (1), 2010, pp. 341-350.