Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 03, March-2018

Firefly Algorithm based PID Controller for Load Frequency Control of Two Area Interconnected Power System-A Review

D.Khamari[1*], Ishan K. Sa[2], R.K. Tripathy[3], H. K. Sa[4], M. Banji[5], L. Sai Sandeep[6]
Department of Electrical & Electronics Engineering
Vikash Institute of Technology, Bargarh, Odisha, India

Abstract: **This paper deals with load frequency control (LFC) of two area interconnected power system. A two area non-reheat thermal system is taken in to consideration with proportional plus integral (PI)/ proportional plus integral plus derivative (PID) controller. Further firefly algorithm based PID controller approach provides better result than conventional and genetic algorithm based PI controller is demonstrated in this paper. Lastly robustness analysis is carried out by varying the time constant of turbine, speed governor and tie-line power within the range of +50% to -50% with respect to their nominal values as well as size and position of step load perturbation to show the robustness of the Firefly Algorithm based PID Controller.**

Keywords: Load frequency control (LFC), Two-area power system, Firefly algorithm (FA), proportional plus integral (PI), proportional plus integral plus derivative (PID) controller.

1. INTRODUCTION

An electric energy system must be maintained at a desired operating level characterized by nominal frequency and voltage profile and this is achieved by close control of real and reactive powers generated through the controllable source of the system. . Therefore, the control issue in power systems can be decoupled into two independent problems. One is about the active power and reactive power and voltage control [1]. The active power and frequency control is referred to as LFC. A large frequency deviation can damage equipment, degrade load performance, cause the transmission lines to be over loaded and can impede with system protection schemes, ultimately leading to an unstable condition for power system [2]. Thus, the primary job of LFC is to maintain the frequency constant against the arbitrarily varying active power loads, which also referred to unknown external disturbance. Another job of the LFC is to regulate the tie-line power exchange error. A typical large-scale power system is composed of several areas of generating units. To reduce the cost of electricity and to improve reliability of power supply, these generating units are connected via tie lines [1]. The usage of tie-line power imports a new error into the control problem, i.e., tie-line power exchange error. When a sudden active power load exchange occurs to an area, the area will obtain energy via tie-lines from other areas. But eventually, the area that is subject to the load change should balance it without external supports; otherwise there would be economic conflicts between the areas. Hence, each area requires a separate load frequency controller to regulate the tie-line power exchange error so that all the areas in an interconnected power system can set their set-point differently [3,4]. In [5] author were employed modified classical controller structure such as structure 1 and 2 of PID controller (PID1) and structure 2(PID2) were applied and their performances was compared for an automatic generation control (AGC) system. In [6], Ali and abd-Elazim employed a BFOA to optimize the PI controller parameters and shown its superiority over GA in a two-area non-reheat thermal system. In [7] Saroj et al. (2014) demonstrated the superiority of Firefly Algorithm tuned PI/PID controller of two area interconnected power system for AGC. In [9] , a modified objective function using integral of time multiplied by absolute value of error(ITAE), damping ratio of dominant eigen values, and settling time was proposed, where the PI controller parameters are optimizes employed differential evolution(DE) algorithm and the results were compared with the BFOA-and GA-optimized ITAE-based PI controller to show its superiority. A hybrid BFOA-PSO technique was employed in [10] to tune the PI controller parameters of two-and three area power system. The superiority of BFOA-PSO technique over PSO, BFOA, GA, craziness-based PSO (CRAZYPSO), and adaptive neuro-fuzzy interence system (ANFIS) has been demonstrated by the authors.

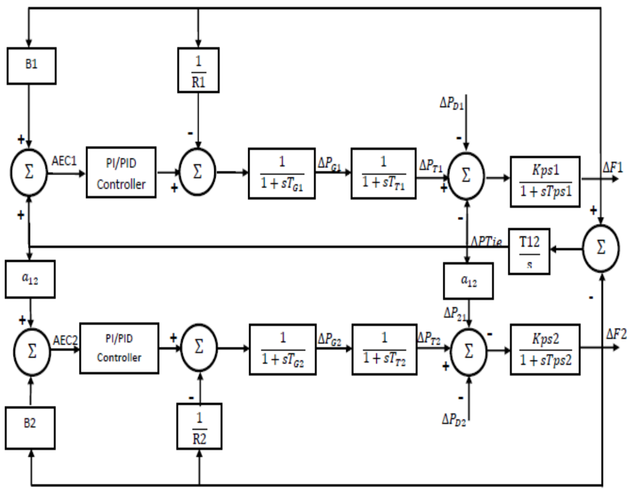

Fig. 1 Transfer function model of two-area non-reheat thermal system.

2. POWER SYSTEM MODEL

2.1. LFC model

The Load Frequency Control (LFC) for two-area interconnected non-reheat thermal power system is shown in Figure 1. Each area has two outputs and three inputs. The inputs are the controller input ΔP_{ref}, tie-line power error ΔP_{Tie} and load disturbance ΔP_D .The outputs are the generator frequency Δf and area control error (ACE) given by Eq. (1).

$$AEC = B\,\Delta f + \Delta P_{Tie} \qquad (1)$$

Where B represents the frequency bias parameter.

To simplicity the frequency-domain analysis, transfer functions are used to model each component of the area. Turbine is represented by the transfer function [2]:

$$G_s(s) = \frac{\Delta P_T(s)}{\Delta P_V(s)} = \frac{1}{1+sT_T} \qquad (2)$$

From [2], the transfer function of a governor is:

$$G_G(s) = \frac{\Delta P_V(s)}{\Delta P_G(s)} = \frac{1}{1+sT_G} \qquad (3)$$

The speed governing system has two inputs ΔP_{ref} and Δf with one output $\Delta P_G(s)$ given by [4]

$$\Delta P_G(s) = \Delta P_{ref}(s) - \frac{1}{R}\Delta f(s) \qquad (4)$$

The generator and load is represented by the transfer function [5]

$$G_p(S) = \frac{kps}{1+sTps} \qquad (5)$$

Where Kps=$\frac{1}{D}$ and Tps = $\frac{2H}{fD}$

The generation load system has two inputs $\Delta P_T(s)$ *and* $\Delta P_D(s)$ with one output $\Delta f(s)$ given by

$$\Delta F(s) = Gp(s)[\Delta P_T(s) - \Delta P_D(s)] \qquad (6)$$

2.2. Controller Structure and Objective Function

To control the frequency PI/PID controller are provided in each area. The structure of the PID controller is show in figure2 where K_P, K_I, K_D are the proportional, integral &derivative gains respectively, when used as a PI controller, the derivative path along is removal from figure2. The error input to the controllers is the respective ACE given by,

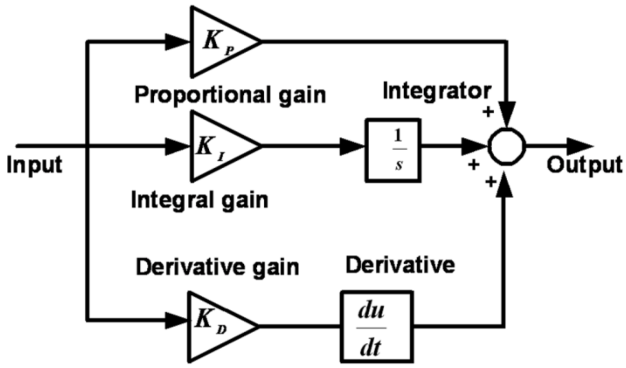

Fig. 2 Block diagram of PID controller structure

$$e_1(t) = AEC_1 = B_1\Delta f_1 + \Delta P_{Tie} \qquad (7)$$

$$e_2(t) = AEC_2 = B_2\Delta f_2 - \Delta P_{Tie} \qquad (8)$$

In this paper ITAE is used as objective function to properly design the proposed PI/PD controller. The expression for Integral Time Absolute Error (ITAE) objective function is given in equation (9):

$$J = ITAE = \int_0^{t_{sim}} (|\Delta F_m| + |\Delta P_{Tie-m-n}|).t.dt \quad (9)$$

In the above equations, ΔF_m is the incremental change in frequency of area m, $\Delta P_{Tie-m-n}$ is the incremental change in the tie line power connecting between area m and n, and t_{sim} is the time range simulation.

Therefore, the design problem can be formulated as the following optimization problem.

$$\text{Minimize J} \qquad (10)$$

Subject to

$$K_{pmin} \le K_p \le K_{pmax},\ K_{Imin} \le K_I \le K_{Imax},\ K_{Dmin} \le K_D \le K_{Dmax} \qquad (11)$$

The minimum and maximum values of PID controller parameters are chosen as -2.0 and 2.0 respectively.

3. RESULT AND DISCUSSION

The controller parameter values are shown in Table1.

Table 1 PI/PID controller parameter.

Parameters	Conv :PI[6]	GA:PI [6]	FA:PID [7]
K_P	0.7005	0.2346	1.056
K_I	0.3802	0.2662	1.0373
K_D	-	-	0.9626

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 03, March-2018

A 10% step increase in load demand is applied in area-1 at t = 0 sec and the system performance with the PI/PID controller are shown in table 2. It is clear from table 2 that better system performance in terms of ITAE objective function, minimum settling times in frequency and tie- line power deviation is achieved with FA PID controller compare to conventional PI and genetic algorithm PI [6] approaches as mentioned in table 2.

Table 2. Comparative performance values for 10% step load change in area-1

Techniques/parameters	Settling times(2% band) T_S			ITAE
	ΔF_1	ΔF_2	ΔP_{Tie}	
Conventional :PI[6]	45	45	28	3.7568
GA:PI [6]	10.59	11.39	9.37	2.7475
FA:PID [7]	4.25	5.49	4.78	0.4714

Case I: Step load variation in area-1

Initially, a step increase in load of 10% in area-1 is considered and the system dynamic response i.e. the deviation in frequency of the area-1, the deviation in frequency of area-2 and deviation in tie-line power are shown in figures 3-5. It is clear from figures 3-5 that stability is improved and frequency error, tie-line power deviation and settling time get reduced.

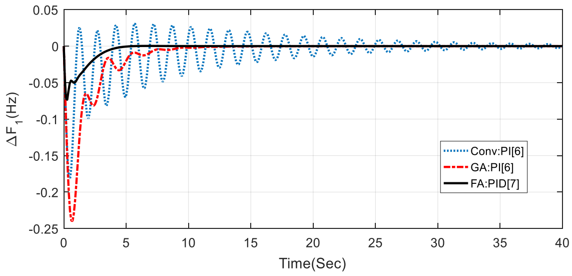

Fig.3. Change in frequency of area-1 for 10% SLP in area-1

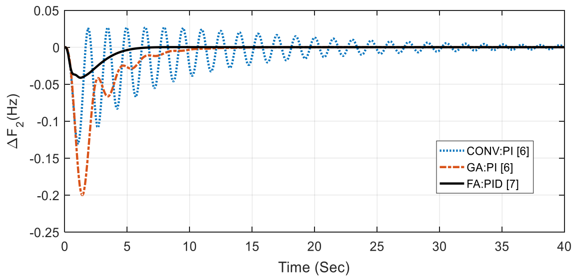

Fig.4. Change in frequency of area-2 for 10% SLP in area-1

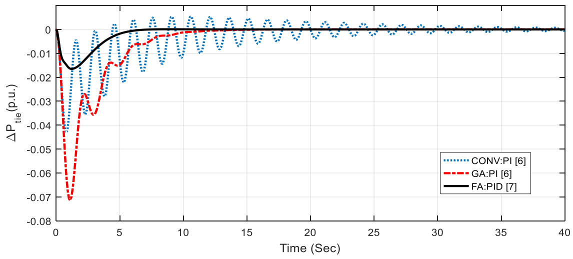

Fig.5. Change in tie-line power for 10% SLP in area-1

Case II: Step load variation in area-2

In this case, a step increase in load of 10% in area 2 is considered and the system dynamic response i.e. The deviation in frequency of the area-1, the deviation in frequency of area-2 and deviation in tie-line power are shown in figures 6-8. From these figures it can be seen that the under shoot, over shoot are also reduced which improves the stability of the power system.

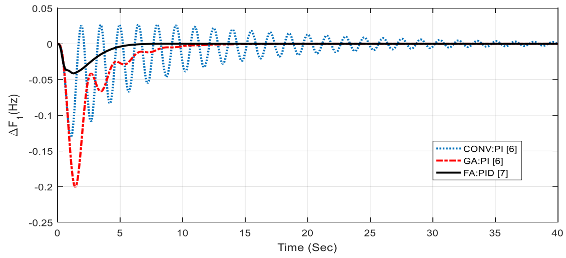

Fig.6. Change in frequency of area-1 for 10% SLP in area-2

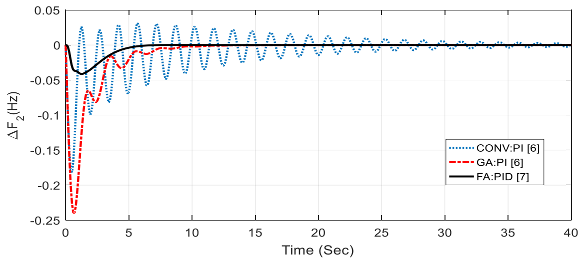

Fig.7. Change in frequency of area-2 for 10% SLP in area-2

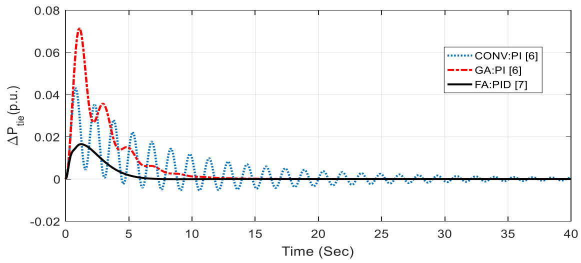

Fig.8. Change in tie-line power for 10% SLP in area-2

Case III: Step load variation of 10% in area-1and 20% in area-2 simultaneously.

In this case step increase in load of 10% in area-1 and 20% in area-2 simultaneously are considered and system dynamic response is shown in figure 9-11. It is clear from figure 9-11

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 03, March-2018

that the best dynamic performance is achieved by firefly algorithm PID controller compare to the conventional PI controller and Genetic algorithm PI controller for the two area power system.

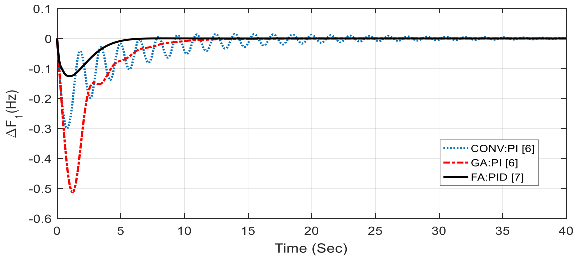

Fig.9. Change in frequency of area-1 for 10% SLP in area-1 and 20% SLP in area-2

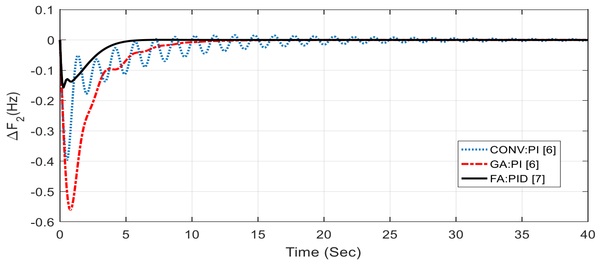

Fig.10. Change in frequency of area-2 for 10% SLP in area-1 and 20% SLP in area-2

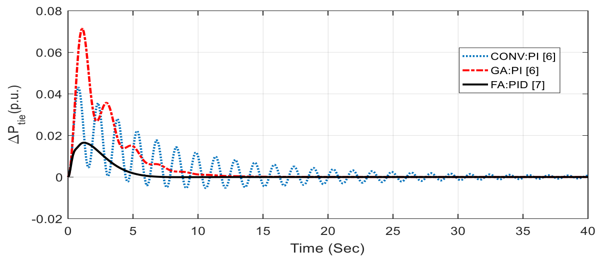

Fig.11. Change in tie-line power for 10% SLP in area-1 and 20% SLP in area-2

4. SENSITIVITY ANALYSIS

Sensitivity analysis is performed to study the robustness of the system to wide changes in the system parameters [4,6,7,8,9].The speed governor time constant, turbine time constant and T_{12} are changed from their nominal values within the range of +50% to -50%. Deviation in frequency of area-1 for 10% change in area-1 with these varied condition are depicted in figure 12-14. It is clear from figure 12-14 that there is negligible effect of the change of system parameter variation.

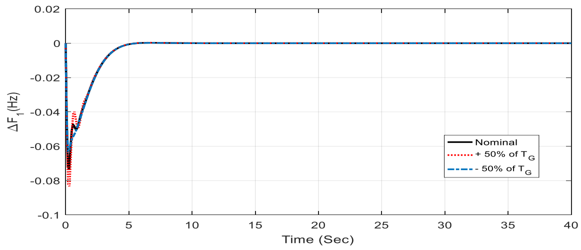

Fig.12. Deviation in frequency of area-1 for 10% change in area-1 with variation of TG

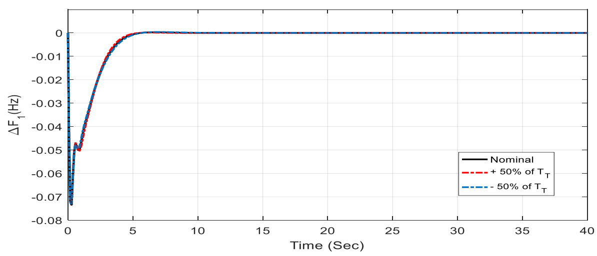

Fig.13. Deviation in frequency of area-1 for 10% change in area-1 with variation of TT

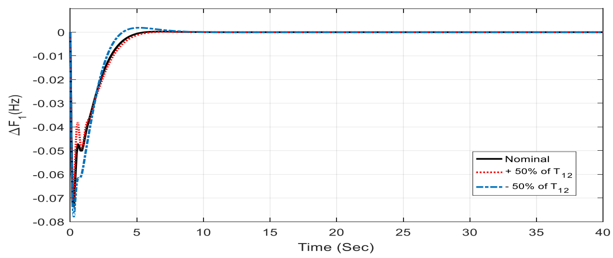

Fig.14. Deviation in frequency of area-1 for 10% change in area-1 with variation of T12

5. CONCLUSION

In this paper an attempt has been made to apply firefly algorithm based PID controller for LFC of two area interconnected power system. Simulation results show that better system performance in terms of ITAE objective function, minimum settling times in frequency and tie- line power deviation is achieved with FA PID controller compare to conventional PI and genetic algorithm PI controller. Lastly sensitivity analysis is carried out by varying the system parameters from their nominal values to elaborate the robustness of the approach. It has the potentiality of implementation in real time environment.

REFERENCES

[1] Elgerd, O.I.: Electric Energy Systems Theory – An Introduction,New Delhi: Tata McGraw Hill, (2000)

[2] Hassan Bevrani.: Robust Power System Frequency Control, Springer, (2009)

[3] Kundur P.: Power System Stability and Control, New Delhi: Tata McGraw Hill ,(2009)

[4] L.C. Saikia, J.Nanda, and S. Mishra.: Performance comparison of several classical controllers in AGC for multi-area interconnected thermal system. International Journal of Electrical Power & Energy SystemsVol. 33,(2011) 394–401

[5] D.Khamari, L.Mishra,S.Sahu,P.Gartia,B.P.Gouda,M.Dash,: Automatic generation control of an interconnect power system using modified classical control. Int.journal of Eng.Research and Technology Vol.6 (2017) 303-312.

[6] E.S. Ali, and S.M. Abd-Elazim.:Bacteria foraging optimization algorithm based load frequency controller for interconnected power system. International Journal of Electrical Power & Energy SystemsVol. 33, (2011) 633–638.

[7] S.Padhan, R.K.Sahu, and S.Panda.:Application of firefly algorithm for load frequency control of multi-area interconnected power system. Elect. Power Comp. and Syst.,Vol. 42(13), (2014) 1419-1430.

[8] U.K.Rout, R.K.Sahu, andS.Panda: Design and analysis of differential evolution algorithm based automatic generation control for interconnected power system. Ain Shams Engineering Journal, Vol. 4(3), (2013) 409–421.

[9] S.Panda, B.Mohanty,P.K.Hota,: Hybrid BFOA-PSO algorithm for automatic generation control of linear and non-linear interconnected power system. Appl.Soft Comput.,Vol.13,No. 12, pp.4718-4730,2013.

APPENDIX A.

Nominal parameters of the two area system investigated are [7]

P_{R1}=2000MW;P_{R2}=2000 MW;P_{L1}=1000 MW;P_{L2}=1000 MW;(nominal loading)

f=60 Hz; B_1==0.425 pu MW/Hz; B_2=0.425 pu MW/Hz;
R_1=2.4Hz/pu;R_2=2.4Hz/pu;T_{G1}=0.08s;T_{G2}=0.08 s;T_{T1}=0.3s;T_{T2}=0.3s;
K_{PS1}=120Hz/puMW;K_{PS2}=120Hz/puMW;T_{PS1}=20s; T_{PS2}=20s;T_{12}=0.545s;
a_{12}=-1;