Performance Comparison of FOA Optimized 2DOF PID Controller for Interconnected Power System

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Abstract— This study extensively represents a practical two area power system. Each area includes reheat thermal power system. A new population based algorithm i.e fruit fly optimisation algorithm (FOA) is applied for tuning purpose. Initially, the parameters of proportional- integral (PI) controller, proportional-integral-derivative (PID) and two degree of freedom PID (2DOFPID) parameters are optimised with FOA algorithm employing integral time absolute error (ITAE) as an objective function. Further, performances of proportional - integral (PI), proportional-integral-derivative (PID) and two degree of freedom PID (2DOFPID) are compared with FOA algorithm for the concerned system. The investigation reveals that 2DOFPID controller tuned with FOA algorithm outer performs than other PI & PID controllers.

Key words: Automatic Generation Control (AGC); Fruit Fly Optimisation Algorithm (FOA); 2DOFPID

I. INTRODUCTION

Previously power system network is not so complex or complicated. Due to this stability of the system was not much in concern. But, due to increase in intricacy of the present power system network serious distress about the voltage and frequency steadiness of the system. Automatic generation control (AGC) acting as a vibrant role in operation and control of complex interconnected power system [1].

Different controllers are implemented as supplementary controller in the system not only to maintain the frequency at scheduled value but also to settle the frequency deviation as quickly as possible. Classical controllers [2], state feedback controllers [3], fuzzy logic controllers, ANFIS controllers [4], sliding mode controller (SMC) [5], fractional order controller [6] are implemented for AGC system in last few years. Different controller has some shortcomings, like for fuzzy logic, ANN and ANFIS controller a proper-trained person is required to operate the controllers. SMC has the chattering problem. Whereas proportional-integral-derivative (PID) controller is simple in construction, easy to understand, operate and tuning. For this reason, PID controller is established to be best controller for operating engineers. In [2], a number of classical controller's structures such as Integral (I), Proportional Integral (PI), Integral Derivative (ID), PID and Integral Double Derivative (IDD) have implemented and their enactment has been evaluated for an AGC system. In [7], a multiplicity of generations conventional as well as renewable energy have been well thought-out in different control areas. In [8], BFOA optimised fuzzy IDD controller has been compared with several classical controllers for a hydro-thermal AGC system. But, PID controller is fixed point controller. The environmental effects change the system parameters, which affect the controller performance. Due to this, the optimal controller parameter must be a robust one to sustain the system parameter variation. To achieve this different meta-heuristic algorithms are applied to AGC system like BFOA [9], PSO [10], ABC [11], DE [12], BBO [13], TLBO [13], KHA [13], QOHS [14].

All the above-mentioned techniques are successfully implemented and improve system performance are also furnished. However, some algorithm requires to initialize number of parameters over which performance of the algorithm depends. For some algorithm computational time is more, execution process is complex, convergence rate is poor etc. Fruit fly optimisation algorithm (FOA) is recently developed algorithm successfully applied in many engineering problems and it is developed by Pan [15]. This algorithm is a parameter free optimization algorithm, computational time is less and easy to implement and understand.

In sight of the above, an effort is made in present work to put on FOA to optimised PI, PID and 2DOF PID for a practical two area thermal power system.

II. SYSTEM MODELLING

A convincing power system taken for analysis is consisting of thermal power plant. The model of two area thermal system is shown in Fig.1.

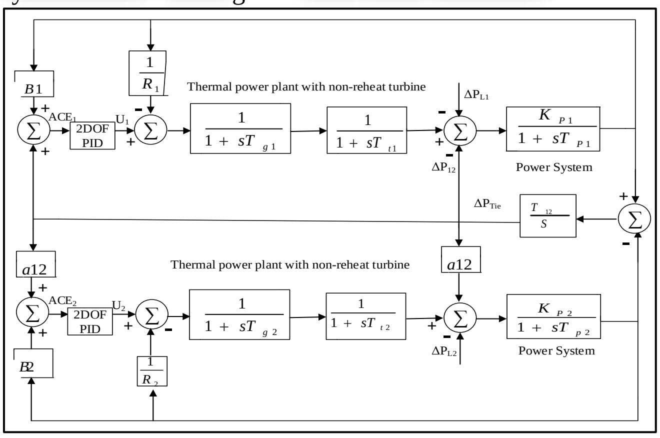

Fig. 1: Block diagram of interconnected thermal power system

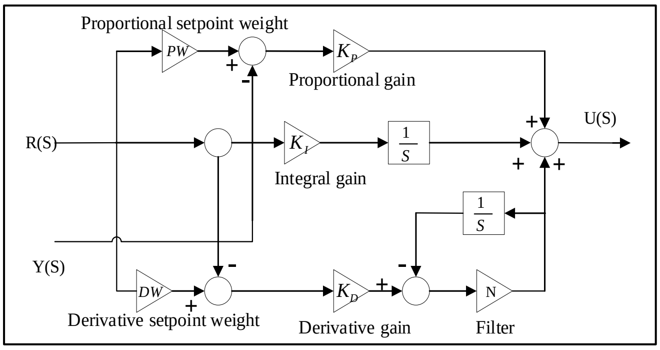

Fig. 2: Control structure of 2DOFPID

The control structure of 2DOFPID is also shown in Fig. 2. The parameters of the proposed system are specified in Appendix-A.

For tuning with different algorithms, the objective function considered is given below in

$$J = \int_{0}^{t_{sim}} \left(\left|\Delta f_1\right| + \left|\Delta f_2\right| + \left|\Delta P_{tie}\right| \right) \cdot tdt \quad (2)$$

Where, Δf_1 and Δf_2 are the area frequency deviations; ΔP_{Tie} is incremental change in tie-line power; t_{sim} is the time range of simulation.

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

$$\text{Minimize } J \quad (3)$$

Subject to

$$K_{P\min} \le K_P \le K_{P\max} \quad K_{I\min} \le K_I \le K_{I\max}$$

$$\text{and } K_{D\min} \le K_D \le K_{D\max} \quad (4)$$

Where J is the objective function and $K_{P\min}$ & $K_{P\max}$ $K_{I\min}$ & $K_{I\max}$ and $K_{D\min}$ & $K_{D\max}$ are the minimum and maximum value of the control parameters. Controller parameters are chosen in the range of -2 and 2.

FOA is a process for locating global optimization considering the fruit fly food searching behaviour. Considering the behaviour of sensing and perception fruit fly is exceptional to other type of species, especially inosphresis and vision. Even from a distance of 40Km, it can smell food through osphresis organs. Then, after getting near to food location, exercise its sensitive vision to search food, and fly in that direction [15]. FOA has been effectively employed in various fields such as load forecasting [16], phasor measure unit(PMU) placement [17], standalone hybrid PV-wind-diesel system sizing [18], PID controller tuned with modified FOA [19],scheduling and testing of semiconductor [20] etc. In this work, FOA technique is proposed for optimising gains of different classical controller for AGC system.

Controllers	K_P	K_I	K_D	N	b	c
PI	-0.3597	0.4756	-	-	-	-
PID	0.4935	0.7619	0.3007	177.4023	-	-
2DOFPID	0.3135	0.7452	0.2147	177.4023	0.5997	2.5641

Table 1: FOA optimized values of PI, PID and 2DOF PID controller for two area thermal system

Steps of FOA explained in [15] and mentioned in flow chart Fig. 3

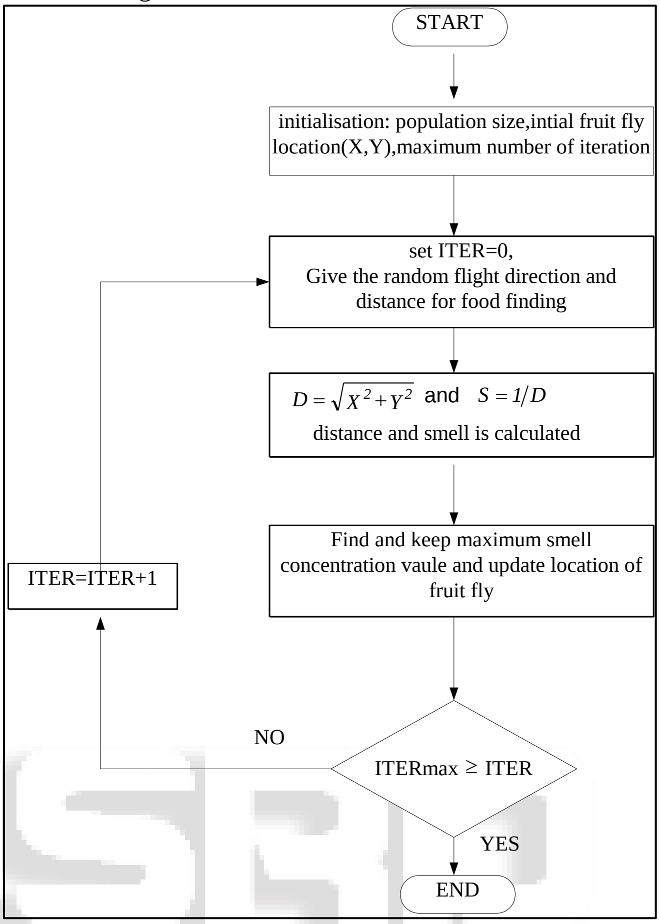

Fig. 3: Flow Chart of FOA

III. Analysis of Results

From the Fig. 4 (a-c) we observed that 2DOF is better and reduces the overshoot and undershoot comparison with PI and PID controllers The settling time of 2DOF PID controller is 4.800 which is 4% better improvement comparing to PID controller and 15.79% better than PI controller, over shoot of 2DOF PID controller reduces to 99% compared to PID controller and 99.99% compared to PI controller , under shoot of 2DOF PID controller reduces to 59.35% compare with PID The settling time of 2DOF PID controller is 4.800 which is 4% better improvement comparing to PID controller and 15.79% better than PI controller, over shoot of 2DOF PID controller reduces to 99% compared to PID controller and 99.99% compared to PI controller , under shoot of 2DOF PID controller reduces to 59.35% compare with PIDcontroller and 97.91% compare with PI controller at area-1. The settling time of 2DOF PID controller is 3.2 which is 49.20% better comparing to PID controller and 51.51% better than PI controller, over shoot of 2DOF PID controller reduces to 82.71% compare with PID controller and 99.97% compared to PI controller, under shoot of 2DOF PID controller reduces to 70.88% compare with PID controller and 98.83% compare with PI controller for frequency deviation of area-2.

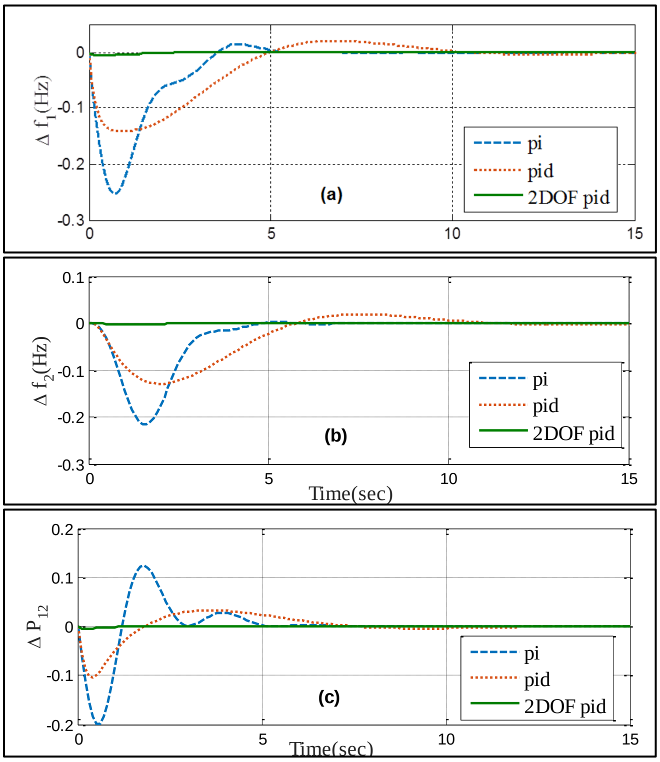

Fig. 4: (a-c) Comparison of dynamic responses of two area system (a) Δf_1 Vs Time (b) Δf_2 Vs Time (c) ΔP_{12} Vs Time

The settling time of 2DOF PID controller is 5.6 which is 9.6% better comparing to PID controller and 26.31% better than PI controller, over shoot of 2DOF PID controller reduces to 66.66% compare with PID controller and 99.25% compared to PI controller, undershoot of 2DOF PID controller reduces to 55.23% compare with PID controller and 97.56% compare with PI controllers for power deviation in area-1&2.

Deviations	Time domain factors	PI	PID	2DOF PID
ΔF_1	ST	5.7	5	4.8
	$OS\times10^{-4}$	292	8.6294	0.014
	US	-0.2399	-0.0123	-0.005
ΔF_2	ST	6.6	6.3	3.2
	$OS\times10^{-4}$	202	0.28342	0.049
	US	-0.1982	-0.0079	-0.0023
ΔP_{12}	ST	7.6	6.2	5.6
	$OS\times10^{-4}$	1480	33	11
	US	-0.1929	-0.0105	-0.0047
OBJ	ITAE	1.4088	0.0664	0.0384

Table 2: Settling time, Overshoot, under shoot values of two area thermal system with 2DOF PID controller

IV. Conclusion

In the present analysis, FOA algorithm as new population based optimisation technique used to optimize interconnected AGC system and its tuning performance is analysed. To compare the tuning performance of FOA algorithm, the dynamic performance of the system with PI, PID, and 2DOFPID is studied. Controlling of power systems in order to meet the demands of consumers is a challenging task that motivates to design optimum controllers. They should have the capability of monitoring the power system like maintenance of frequency and voltage in 1ess time. In this paper, FOA is used to tune parameters of Two degree of freedom controller. A two-area system is taken into consideration to show the better performance of the proposed controller. Different plots of frequency deviation were obtained by varying the load demand of areas. Its superiority over other methods used to tune the controller is justified by comparing the error values.

A. Appendix-A

$B_1 = B_2 = 0.4312$ p.u. MW/Hz; $R_1 = R_2 = R_3 = 2.4$ Hz/p.u.; $T_{SG} = 0.08$ s; $T_T = 0.3$s; $K_{PS1} = K_{PS2} = 120$ Hz/p.u. MW; $T_{PS1} = T_{PS2} = 12$ s; $T_{12} = 0.545$; $a_{12} = -1$

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