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An Efficient Secondary Controller for Two Area Power System with GA Optimization Technique

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***Abstract*—For the load frequency control issue, many secondary controllers are studied in this article. As a secondary controller, a traditional proportional-integral-derivative (PID) controller is used and put up against the PI controller. Genetic algorithm optimization (GA) is used to optimize secondary controller gains. The system is further evaluated with random loading rather than step load perturbation to assess the controller's robustness. According to analysis, PID controllers have better dynamic behavior than PI in terms of settling time, peak overshoots, and undershoots. The PID controller's cost value is likewise judged to be better, and the cost curve supports this conclusion.**

Keywords—Thermal plant, Cost value, Deregulated Environment, Genetic Algorithm, Reheat Turbine, Secondary Controllers.

I. INTRODUCTION

It is crucial to select the right secondary controller for the load frequency control (LFC) problem in a big, interconnected power system. Since one of the primary issues with the electrical system is frequency. The primary goal of the power system is to reliably and affordably match consumer load demand. In the condition of mismatch between the load demand and power generation for any specific control area, system's point of stability moves away from its equilibrium position. The LFC plays an important role with redistribution of power through the tie-lines, satisfying the load demand with maintaining frequency constant. The contracts between GENCO units and DISCO units can be visualized with the help of DISCO Participation Matrix (DPM) which was introduced by Donde et al. [1]. The contents of DPM are treated as factors termed as participation factors (cpfs), based on which other factors named area participation factors (apfs) can be calculated [2].

The AGC is utilized to meet the continuously changing load demand to diminish the frequency and tie-line power oscillations. Various literatures are available on AGC under deregulated environment [3-7]. Authors in [3] investigated a single area thermal AGC. Sanki et al. in [4] studied a two area thermal-thermal AGC with reheat turbine in only area-1. In [5] and [6] Researchers also analyzed AGC system with reheat turbines. Vimal Kumar et al. in [7] worked on a two area thermal-thermal AGC system without reheat turbine. In all the above discussed literature, some authors used reheat turbine which is a realistic parameter that incorporates the non-linearities into the AGC studies. Hence, it is worth to compare the system performance with and without the reheat turbines that needs further study.

The duties of minimizing the area control error (ACEs) which represent the combined deviations in frequency and tie-line power, are assigned to the governors and they act as the primary controller in AGC. But this action is not enough to tackle the oscillations, for which a secondary controller is incorporated in addition to the primary controller. Donde et al. in [1] and Nanda and Parida in [2] studied deregulated AGC with Integral (I) controller. Nandi et al. in [8], Hota and Mohanty in [9] and Jagatheesan et al. in [10] studied deregulated AGC with proportional-integral-derivative (PID) controller and in their comparative studies PID controller is found superior over integral (I) and proportional-integral (PI) controllers in terms of system dynamic behaviour and cost value. This motivated the authors to consider PID controllers in this manuscript. Proper designing of controllers is also important for the proper functioning of AGC. Parameters of the secondary controllers are properly tuned to improve the system dynamic behaviour. In [3], Bethala Prasad et al. investigates the AGC with GA optimized secondary controllers. Mahapatra et al. in [11] control the reactive power planning using. Authors in [12] worked with GA for MPPT for PV system and can be applied in AGC to design PID parameters. Authors is this work inspired from [13] to use GA for AGC in deregulated environment. The primary goal of this paper is to build a two-area thermal system, first without a reheat turbine (RT), and then with a reheat turbine (RT). The PID-N controller'stuning with GA and comparison of the results' variations in frequency and tie-line power.

II. SYSTEM CONFIGURATION

The system is investigated for load frequency control problem in which two area power system with thermal unitsin each control area is considered. The area capacity ratio is 1:1 is taken for the study which means each area having thesame capacity of 500MW says. Transfer function equations of governor and turbine is given in Equations (1) and (2) respectively.

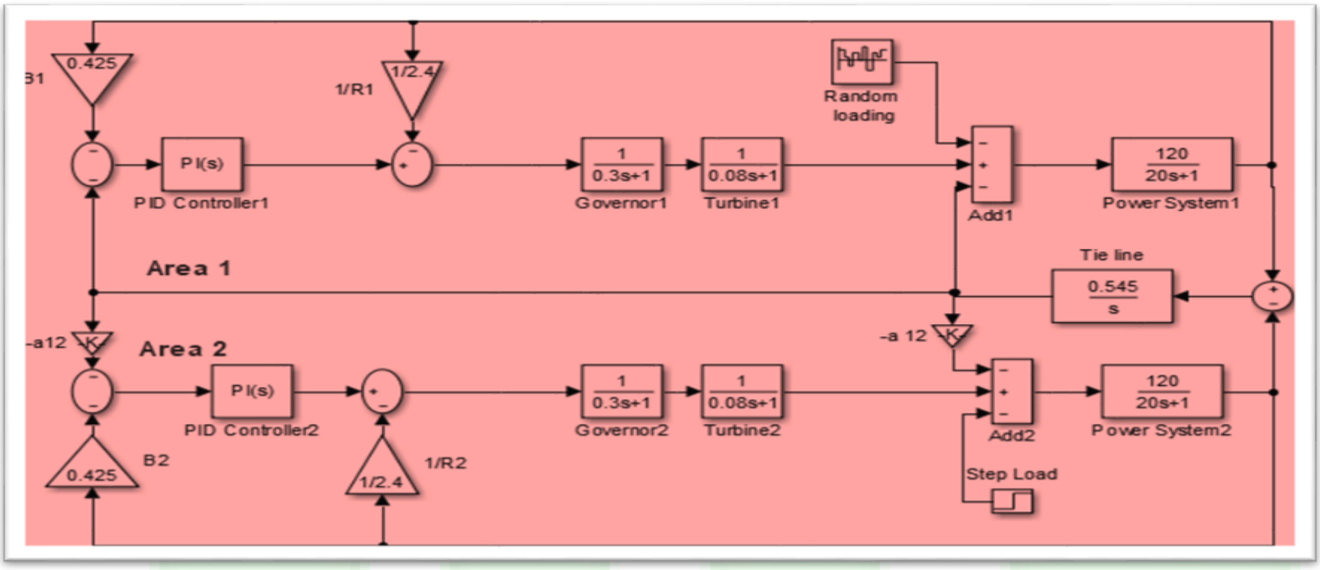

Fig. 1. Transfer function model of two area AGC.

$$TF_{Gov} = \frac{1}{T_g.s+1} \qquad (1)$$

$$TF_{Tur} = \frac{1}{T_t.s+1} \qquad (2)$$

The considered system having comparative study of two secondary controllers i.e., proportional and integral (PI) and proportional integral and derivative (PID).

For the tuning of the secondary controller parameters and minimization of Cost function (J) particle swarm optimization (GA) technique is employed. Cost function (J) is generated by integral of square error (ISE) method given by (3).

$$J_{ISE} = \int_0^T \{\Delta f_1^2 + \Delta f_2^2 + \Delta P_{tie}^2\} dt \qquad (3)$$

With the ISE method of cost value calculation, it is easier to penalize the larger errors. Transfer function parameters for the TF model are collected from [6] and [7] and given in Appendix.

III. GENETIC ALGORITHM (GA) TECHNIQUE

GA is a flexible, robust population-based optimization algorithm, which can easily handle with non-differential objective functions, unlike traditional optimization methods.

The genetic algorithm (GA), developed by John Holland and his collaborators in the 1960s and 1970s, is a model or abstraction of biological evolution based on Charles Darwin's theory of natural selection.

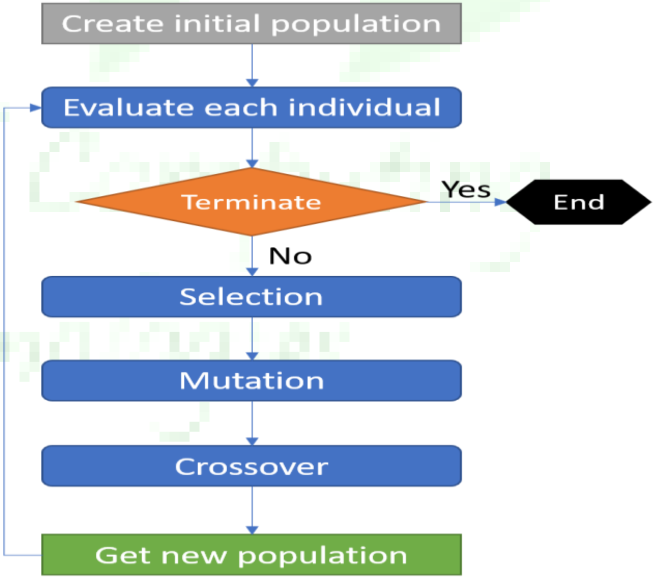

Fig. 2. Flowchart of GA Algorithm

IV. RESULT AND ANALYSIS

The system studied is investigated for two area power system in which each area has the thermal power plant. The main purpose of this study is to understand the importance of the secondary controller for load frequency control. For this purpose, two classical controllers PI and PID have been used. To get the gains of these controller the popular known genetic algorithm (GA) has been implemented. The analysis of the results are as follows:

Case-1: Step load perturbation (SLP)

In this case, it is considered that 1% SLP is applied in area-1 only i.e., first area demands a power of 0.01 PU and no power demand by the area-2. Figure 3 (a-c) represents the system dynamics for this case and TABLE 1 contain the gains of the PI and PID controllers and cost function value while, TABLE 2 shows the comparison of the dynamics in terms of peak overshoot, peak undershoot and settling time. It is observed from TABLE 2 and figure 3 that, PID is outperforms in all the comparing parameters. From the cost function curves (Fig. 4) it can be commenting that PID is converging fast which shows its superiority.

Case-2: Random load perturbation (RLP)

In this case, instead of 1 % SLP random load pattern is applied in area-1 only. This study also shows the robustness of the controller. Figure 5 shows the pattern of the random load and figure 6 represents the system dynamics with this load patter. In such loading conditions also PID reveals its superiority compared to PI controller. The obtained gains during this case are showed in TABLE 3.

TABLE 1. Optimized controller gain and Cost value

Parameter	**PI**		**PID**	
	Area-1	**Area-2**	**Area-1**	**Area-2**
K_P	0.2874	0.2853	0.5179	0.182
K_I	0.8814	0.8553	1	0.9999
K_D			0.2074	0.0921
Cost value	16.01		0.1341	

TABLE 2. Comparison of the dynamics

Parameters		Peak Overshoot (Hz) x10^-3	Peak Undershoot (-Hz) x10^-3	Settling time (s)
$\Delta f1$	PI	5.8	19.2	35.3
	PID	2.1	15.7	8.7
$\Delta f2$	PI	1.4	4.8	47.1
	PID	-	3.6	10.3
ΔP_{tie}	PI	7.2	14.2	49.6
	PID	0.5	10.1	7.2

TABLE 3. Optimized controller gain.

Parameter	**PI**		**PID**	
	Area-1	**Area-2**	**Area-1**	**Area-2**
K_P	0.3012	0.2991	0.6089	0.2109
K_I	0.911	0.8219	0.8945	1
K_D			0.1939	0.1881

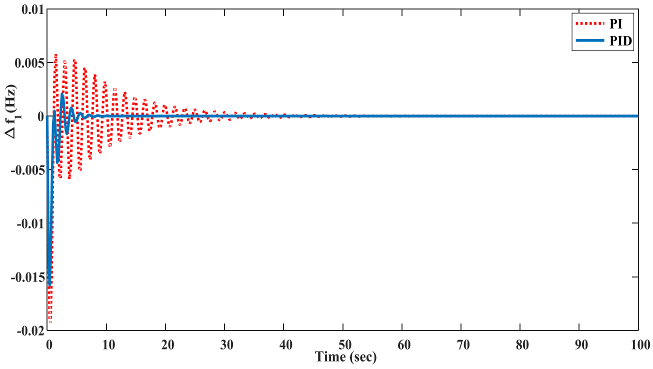

Fig. 3(a)

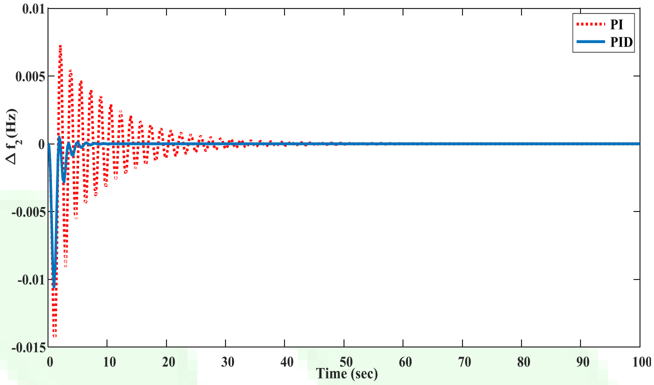

Fig. 3(b)

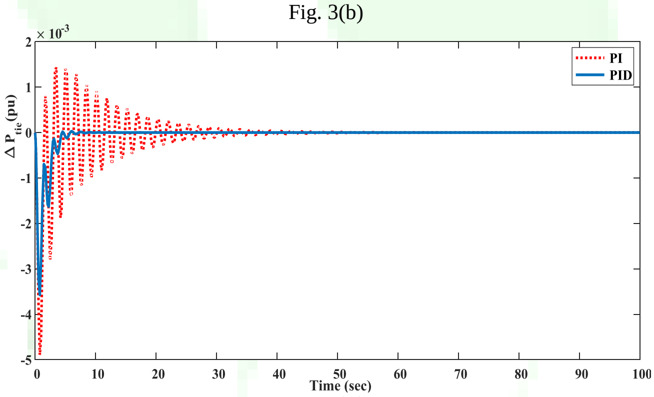

Fig. 3(C)

Fig. 3. Comparison of dynamic responses with PI and PID controller.
(a), (b), (c) Deviations in area-1&2 frequency and tie-line power.

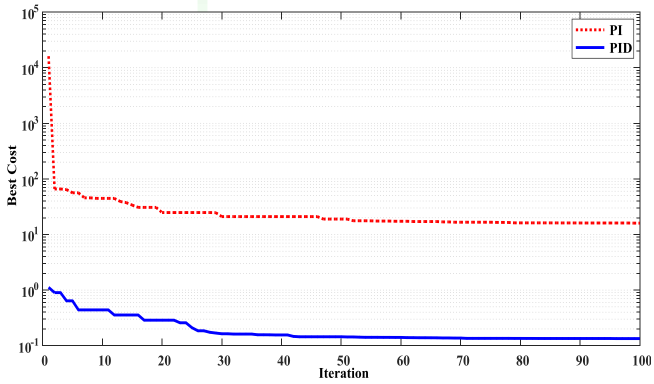

Fig. 4 Comparison of convergence curves of PI and PID

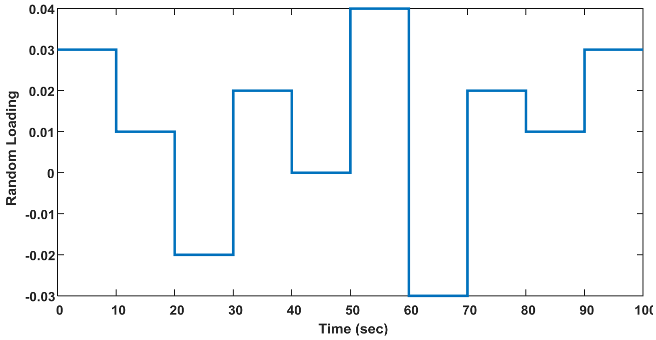

Fig. 5 Random load pattern

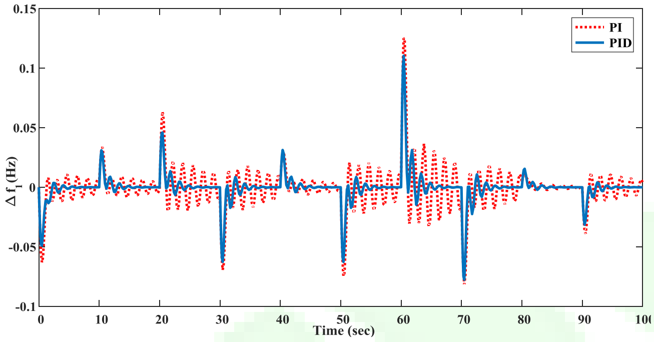

Fig. 6(a)

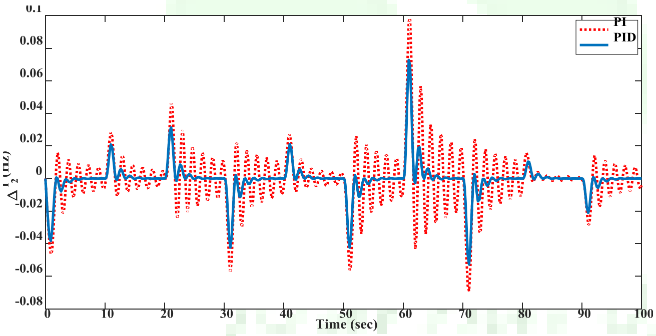

Fig. 6(b)

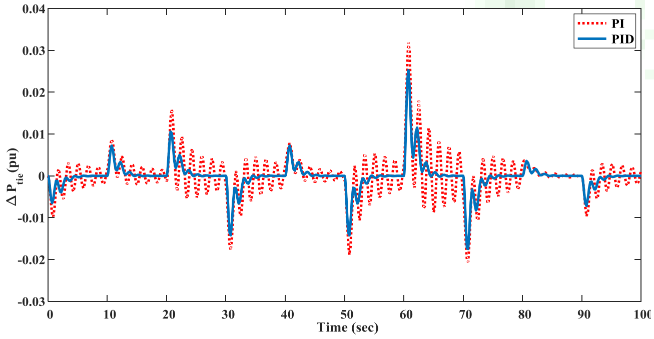

Fig. 6(c)

Fig. 6. Comparison of dynamic responses with PI and PID Controllers for random load. fig (a), (b), (c) Deviation in area-1&2 frequency and tie-line power.

V. Conclusion

The load frequency control of the two-area power system problem is successfully carried out using the GA optimized PI and PID controllers. The results of the investigation demonstrate that, in both SLP and RLP, the system dynamics caused by PID controllers respond more quickly than those caused by PI in terms of peak overshoot, peak undershoot, and settling times. Additionally, it has been noted that the cost value (J) for PID controllers is found to be the lowest, indicating that a controller with a lower cost will have superior dynamics. Future research on this system using fractional order controllers is possible.

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