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A SUITABLE SECONDARY CONTROLLER FOR THERMAL-THERMAL POWER SYSTEM WITH PSO OPTIMIZATION TECHNIQUE

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***Abstract*— In this article the different secondary controller is analyzed for the load frequency control problem. A conventional Proportional-Integral-Derivative (PID) controller is utilized as secondary controller and compared with the PI controller. Secondary controller gains are optimized using genetic algorithm optimization (GA) technique. To check the robustness of the controller the system is also tested with the random loading instead of step load perturbation. Analysis concluded that dynamic behavior of PID controller is better than PI in terms of settling time, peak overshoot and undershoots. Cost value of the PID controller is also found better and the cost curve shows its superiority.**

***Keywords*— Cost value, Deregulated Environment, Particle Swarm Optimization, Reheat Turbine, and Secondary Controllers etc.**

I. INTRODUCTION

In the large interconnected power system it is very important to choose the suitable secondary controller for the load frequency control (LFC) issue. Since frequency is the one of the main concerns of the power system. The main target of power system is to match the consumer load demand at minimal cost and with sufficient reliability. 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 behavior 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 behavior. In [3], Bethala Prasad et al. investigates the AGC with PSO optimized secondary controllers. Mahapatra et al. in [11]control the reactive power planning using. Authors in [12] worked with PSO for MPPT for PV system and can be applied in AGC to design PID parameters.

Authors is this work inspired from [13] to use PSO for AGC in deregulated environment.

So, the main purpose of this article is to design a two area thermal-thermal system initially without reheat turbine (RT) and then with reheat turbine (RT).The tuning of PID-N controller with GA and compare the results in terms of frequency and tie-line power variations**.**

II. SYSTEM INVESTIGATED

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

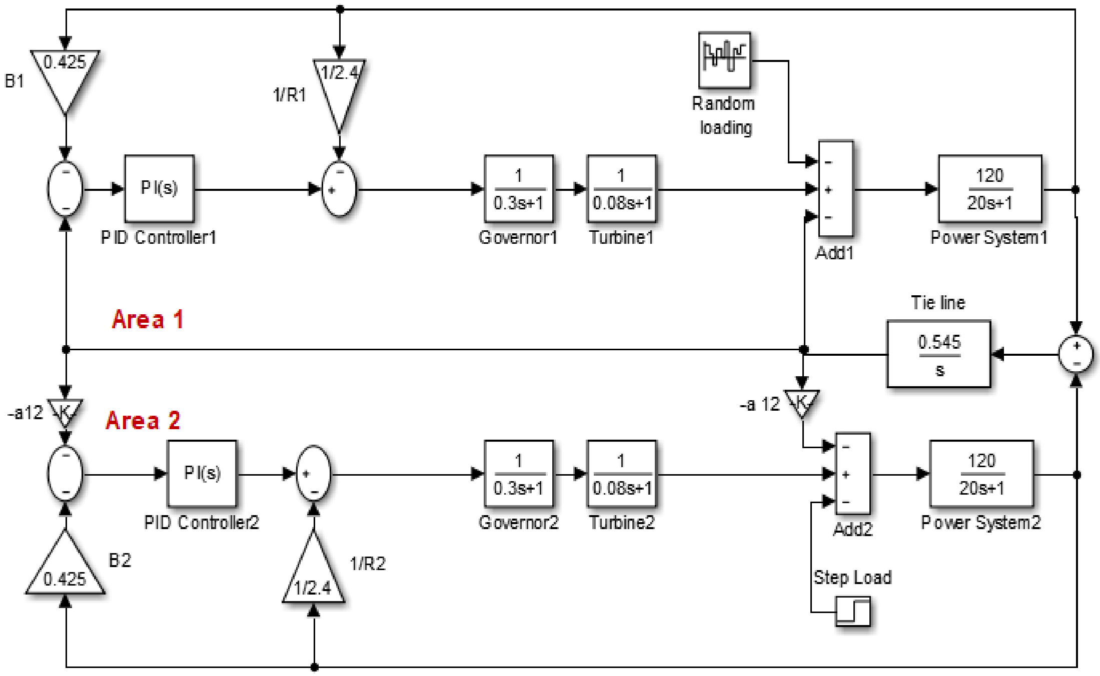

Fig 2: Transfer function model of two area thermal-thermal AGC

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

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

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 (PSO) technique is employed. Cost function (J) is generated by integral of square error (ISE) method given by (3).

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

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. PARTICLE SWARM OPTIMIZATION (PSO) 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.

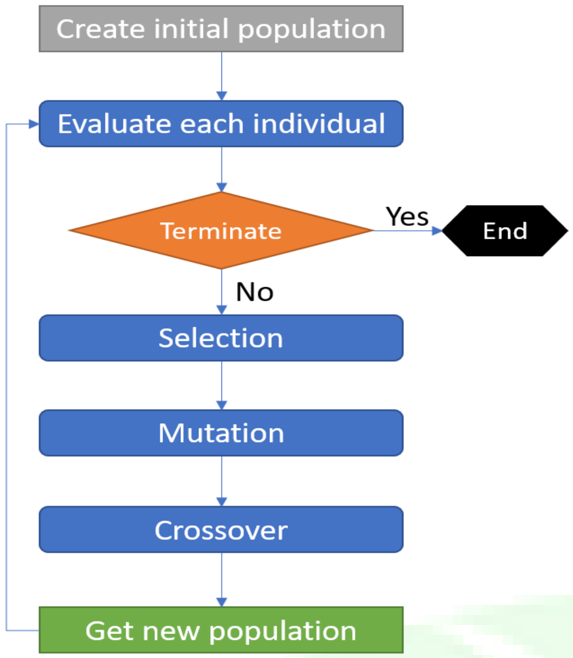

Fig. 2. Flowchart of GA Algorithm

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 TABLE1 contain the gains of the PI and PID controllers and cost function value while, TABLE 2 shows the comparison of the dynamics in terns 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 comment 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	

TABLE2. Comparison of the dynamics

Parameters		Peak Overshoot (Hz) x10^-3	Peak Undershoot (-Hz) x10^-3	Settling time (s)
Δf1	PI	5.8	19.2	35.3
	PID	2.1	15.7	8.7
Δf2	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

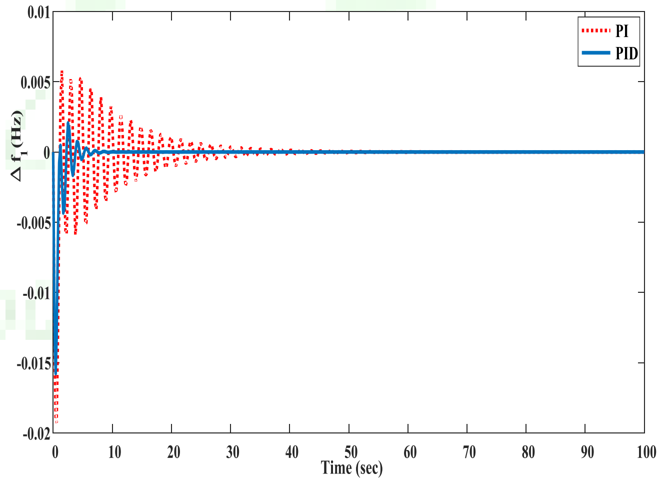

Fig. 3(a)

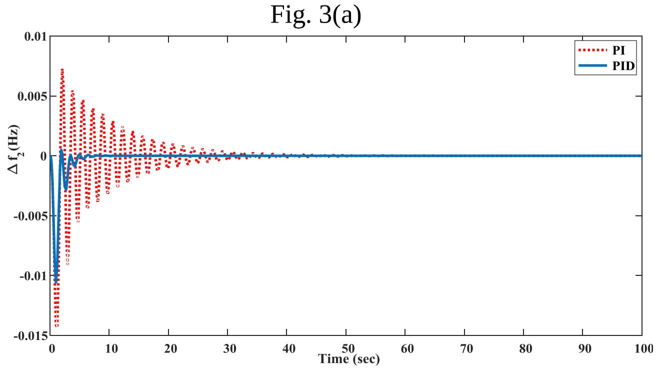

Fig. 3(b)

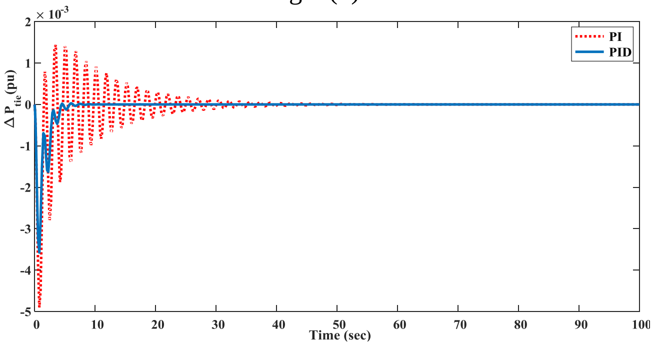

Fig. 3(C)

Fig. 3. Comparison of dynamic responses with PI and PID controller.

(a), (b) , (c) Deviations in area-1&2 frequency and tie-line power.

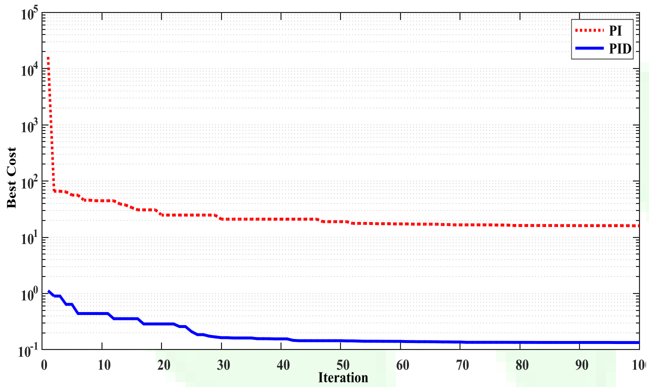

Fig. 4 Comparison of convergence curves of PI and PID

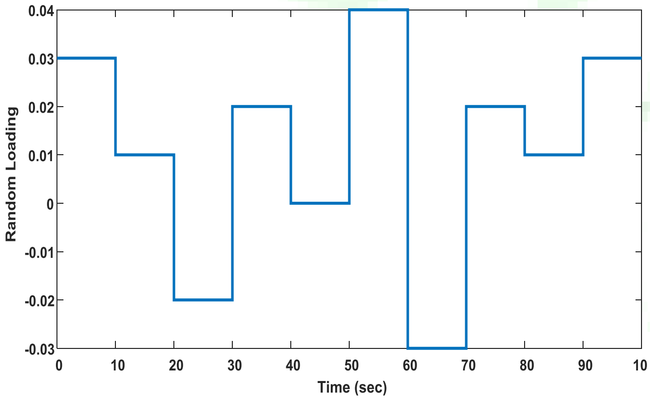

Fig. 5 Random load pattern

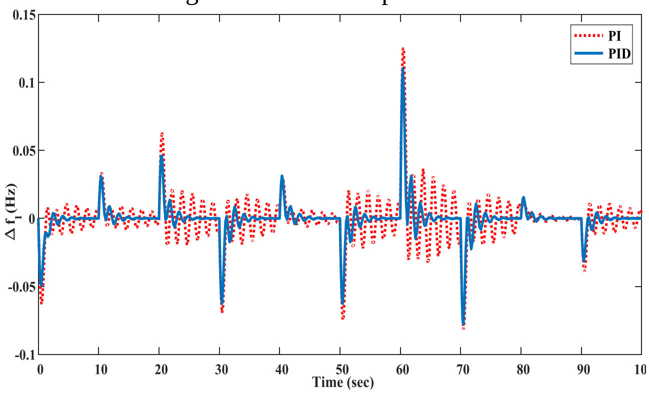

Fig. 6(a)

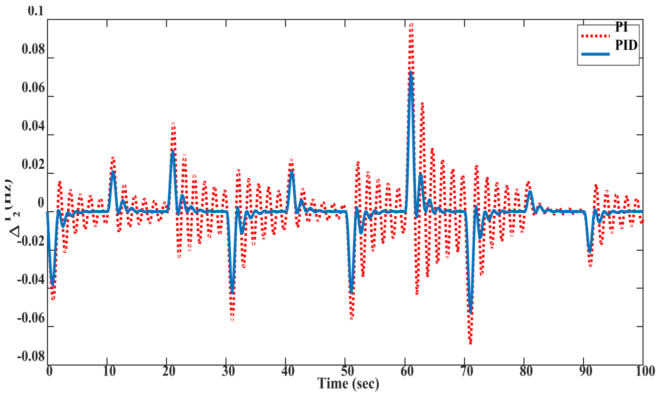

Fig. 6(b)

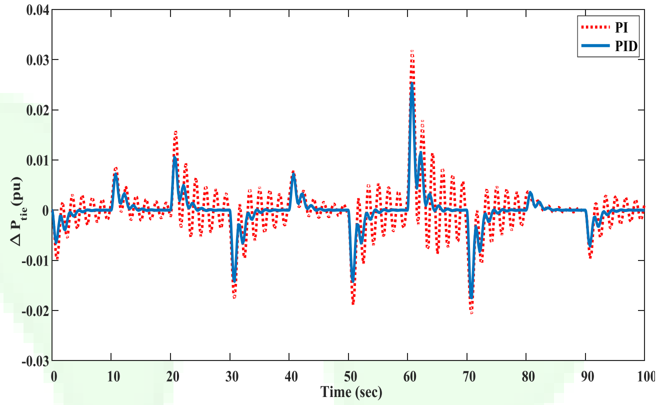

Fig. 6(c)

Fig. 6. Comparison of dynamic responses with PI and PID Controllers for random load.

(a), (b), (c) Deviation in area-1&2 frequency and tie-line power.

V. CONCLUSION

The GA optimized PI and PID controllers are successfully utilized for the load frequency control of the two-area power system problem. Investigation shows that system dynamic behaviors in all the two cases i.e. SLP and RLP, the dynamics due to PID controllers shows the better response compared with PI in terms of peak overshoot, peak undershoot and settling times. And it is also observed that cost value (J) is found to be minimum for the PID controllers which means lesser the cost value better the controller and better the dynamics. In the future this system can be study with the fractional order controllers.

APPENDIX

- **System Parameters**
- **$T_g$is equal to 0.08s,**
- **R_1 andR_2 are equal to 2.4 PU MW/Hz,**
- **$T_t$is equal to 0.3s,**
- **K_{ps1} and K_{ps2} are equal to 120 Hz/pu Mw,**
- **B_1 and B_2 are equal to 0.425 pu Mw/Hz,**
- **a_{12} is taken as 1 and ,**
- **T_{12} is 0.086 pu Mw/rad.**

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