Comparative study of PSO/PI and PSO/PID Approaches for AGC of Two Area Interconnected Thermal Power System

Niharika Soni, Rajesh Bhatt, Girish Parmar

Abstract*— The solution of one or more control optimization problems regarding automatic generation control (AGC) through the efficient techniques are required in interconnected areas of power system. Heuristic optimization methods have replaced the analytical methods to tune the parameters of controllers used in power system since the analytical methods suffer from slow convergence and the curse of dimensionality. In the same direction, the Particle Swarm Optimization (PSO) technique among the swarm intelligence family has been applied in order to improve the performance of the two area interconnected thermal power plants. Proportional Integral Derivative (PID) controllers and Proportional Integral (PI) controllers have been employed in the system under study and the PSO optimization technique has been used to optimize the parameters of PI and PID controllers by considering the Integral Time Multiplied by Absolute Error (ITAE) as the objective function. Both the approaches PSO/PI and PSO/PID have been compared for the same system under investigation to show the superiority of the PSO/PID approach. The results have been simulated with the MATLAB /SIMULINK environment and it has been shown that PSO optimized PID controllers for the LFC provides the better dynamic responses than PSO optimized PI controllers for same system.

***Keywords:* automatic generation control, two areas interconnected power systems, PID-controllers, particle swarm optimization.**

I. INTRODUCTION

The production of generation of electric power is dependent on the generation plants. The generators are interconnected by transmission network in order to meet up the load demand in geographical areas which in turn make the complicated large power systems. The large power systems fall in to two categories according to the control areas based on the principle of coherency. The tie-lines are used for subsequent purpose:

a. To interconnect the coherent areas.
b. To exchange contractual energy between areas.
c. To provide inter area support during special operation.

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If a mismatch is occurred in actual power balance, it will affect the system frequency. So, in order to preserve the system frequency at a preferred level, the automatic generation control (AGC) also known as load frequency control (LFC) comes in the picture which in turns manage the generation in an area by eliminating the mismatch as well as the unintended exchange of power with other areas via tie-lines [1-2].

The number of control strategies used for LFC problems have been discussed and implemented in [3] and the comparative comparison among the AGC controllers for the LFC problems has previously been suggested in literatures [4] which comprise Integral, Proportional Integral, Integral Derivative, Proportional Integral Derivative and Integral Double Derivative have been implemented for controlling load frequency in an AGC system.

Because optimization/tuning of the parameters of the controllers used in multi area inter connected thermal power plants is require for AGC, number of the research articles in this path have been published in the literature and this topic has also become a eager interest of the researchers. In this path, Soft computing based optimization methods have come in the image to improve the performance of the AGC of interconnected power system. The soft computing based optimization techniques comprises of BFOA and ICA for PID controllers in multi area power system, DE for PI controller, DE for classical controllers in a multi-area multi source power system (MAMS-PS), TLBO technique for I/PID controllers for a multi-units multi-sources power system (MUMS-PS), an intelligent controller based on emotional learning for LFC system, FA for AGC of an interconnected unequal three area power system, ABC for AGC system and GSA for PI/PIDF controller for AGC system [5-14].

Additional, Artificial Intelligence (AI) techniques like Fuzzy Logic, Artificial Neural Networks, Genetic Algorithms and Particle Swarm Optimization can be applied for automatic generation control, which can beat the restrictions of conventional control methods [15]-[17].

In this paper, PI and PID controllers with alike characteristics have been separately used in each area of two area inter connected thermal power plant and a challenge towards evolving the application of Particle Swarm Optimization (PSO) is elaborated in order to optimize the parameters of PID and PI controllers for enhancing the performance of AGC. A comparative learning between PI and PID optimized by PSO is given.

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The system with PID controllers optimized by PSO gives far better performance in terms of settling times, overshoots, ITAE values and system oscillations than PSO optimized PI controllers for the same system beneath investigation.

The organization of remaining part of this paper is as follows: In Section II, the two area interconnected power system of thermal plants, PI and PID controllers have been discussed. The ITAE as objective function is presented in Section III. Section IV provides the brief knowledge of Particle Swarm Optimization technique. The simulation results are elaborated in Section V. The paper is concluded in Section VI along with the references at the end.

II. TWO AREA INTERCONNECTED THERMAL POWER SYSTEM WITH PI AND PID CONTROLLER

The two area interconnected power system of thermal power plants [6] is considered in the projected work and it is shown in Fig. 1. The ratings of each area and nominal load are 2000 MW and 1000 *MW*

From Fig. 1, the area control error for area-1 and area-2 are defined as:

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{Tie} \quad (1)$$

$$ACE_2 = B_2 \Delta f_2 - \Delta P_{Tie} \quad (2)$$

A. PID Controller

The transfer function of PI and PID controller is given as follows:

PI-Controller: $$T(s) = K_P + \frac{K_I}{s} \quad (3)$$

PID-Controller: $$T(s) = K_P + \frac{K_I}{s} + K_D s \quad (4)$$

The block diagram of closed loop control system with PI or PID controller is shown in Fig. 2. The variables for the closed loop system are distinct in TABLE I as follows:

TABLE I VARIABLES IN CLOSED LOOP CONTROL WITH PI AND PID CONTROLLERS

Abbreviations	Nomenclature	Definition/Description
R	Reference input or set-point	What is expected from the system is defined as the set point.
Y	Controlled variable or Actual output	The variable which is to be controlled and measured is defined as the controlled variable or actual output.
E	Error signal	This is the difference between the desired input value (*R*) and the actual output (*Y*). This error signal (*e*) will be sent to the PI or PID controller, and the controller computes both the derivative and the integral of this error signal.

The output of PI and PID controller is defined as:

PI-Controller: $$u = K_P e(t) + K_I \int e(t)dt \quad (5)$$

PID-Controller: $$u = K_P e(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt} \quad (6)$$

The signal (*u*) will be sent to the plant, and the new output (*Y*) will be obtained. This new output (*Y*) will be sent back to the sensor again to find the new error signal (*e*). The controller takes this new error signal and calculates its derivative and it's integral again. This process goes on and on till the error is minimized to optimum value.

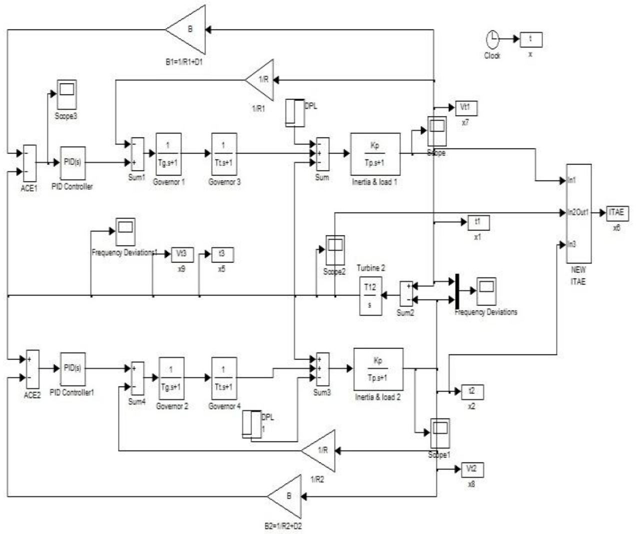

Fig. 1 Two area interconnected thermal Power Plants

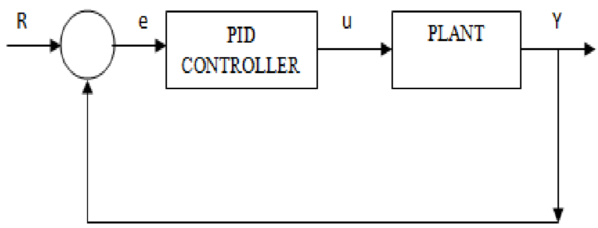

Fig. 2 close loop system with PID controller

II. OBJECTIVE FUNCTION

An Integral of time multiplied absolute error (ITAE) is used as an objective function in the present work and it is defined by (7) instead of other integral based objective functions.

$$J = ITAE = \int_0^{t_{ssimulation}} w_1 \cdot \left(|\Delta f_1| + |\Delta f_2| + |\Delta P_{tie}| \right) \cdot t \cdot dt \quad (7)$$

Where, Δf_1 , Δf_2 represent system frequency deviations; ΔP_{tie} is incremental change in tie-line power and; $t_{simulation}$ denotes time range of simulation;

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III. PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM

Particle Swarm Optimization is a population based stochastic optimization technique, inspired by social behavior of bird flocking or fish schooling. The system is initialized with a population of arbitrary resolutions and searches for optima by updating generations. In PSO, the possible solutions, called particles, fly through the problem space by following the current optimum particles. In PSO technique, each individual adjusts its flying according to its own flying experience and its companion's flying experience. Each particle keeps path of its coordinates in the problem space which are connected with the best solution (fitness) it has achieved so far. This value is called 'pbest'. One more "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called 'gbest'. The flowchart given in Fig. 3 explains the process in brief.

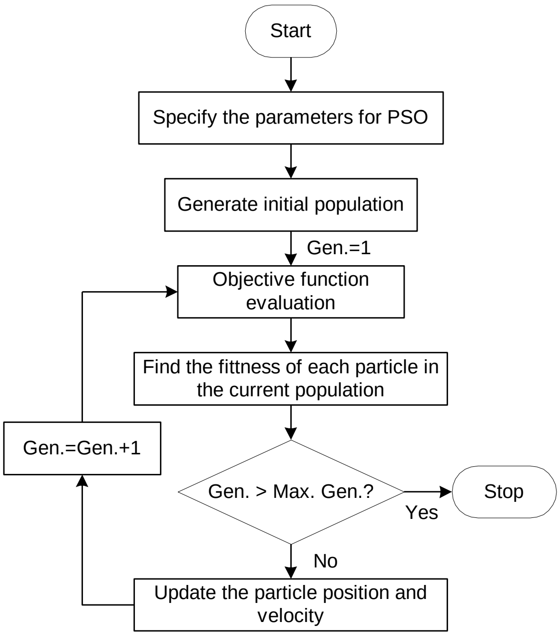

Fig.3. Flow Chart of PSO algorithm.

IV. SIMULATION RESULTS

A. ITAE Value

The PID and PI controllers are employed individually into the two area interconnected non reheat thermal power plant for which the SIMULINK environment of MATLAB is employed. The simulation results show that the PSO optimized PID controllers gives smooth and better system dynamic response in terms of peak overshoots, settling times and ITAE value for same system under study as compared to PSO optimized PI controllers for the identical system under study.

At t=0 second, a 10% step load boost in area-1 is introduced and the parameters, oscillations and ITAE values obtained for PSO optimized PID controller and PSO optimized PI controllers are tabulated in TABLE II. TABLE II shows the dominance of the PSO/PID approach over PSO/PI approach for the identical thermal system in terms of less ITAE value and better smoothness.

TABLE II TIME DOMAIN PARAMETERS OBTAINED BY PSO/PID FOR CONSIDERED SYSTEM

ITAE	K_P	K_I	K_D	*Oscillations*
3.8669	0.4076;	0.4054	-	More oscillations
1.5149	0.4029	0.4929	0.4730	Very less oscillations

B. Dynamic behavior of System with and without PI/PID controllers

A step increase in demand of 10% is applied in the area-1 at time t=0 second:

The dynamic responses of the two area interconnected thermal system with and without PI and PID controllers are shown in fig. 4-7. The simulation results show that the dynamic response of the system without PI and PID controllers are worse and not return to zero frequency deviations and tie-line power deviation while evaluating with PI and PID controllers optimized by PSO for identical system under consideration.

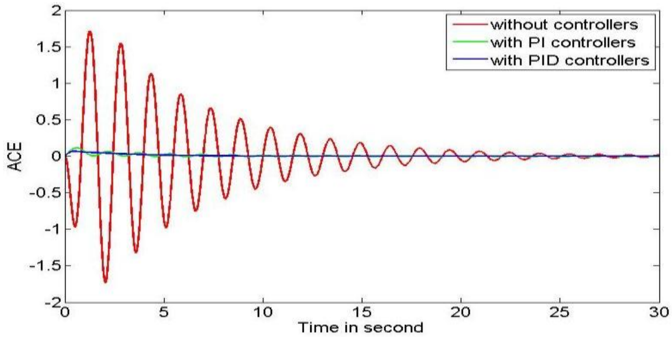

Fig. 4 ACE with and without PI and PID controllers

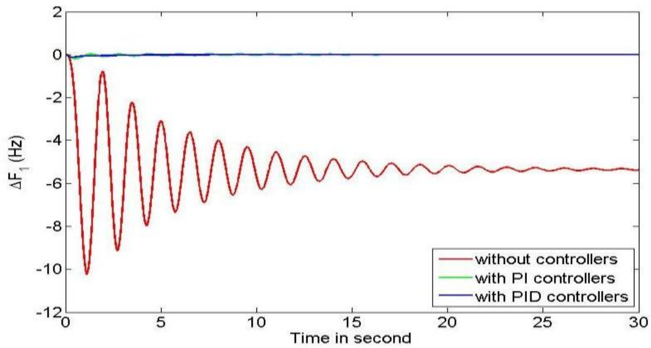

Fig. 5 ΔF_1 with and without PI and PID controllers

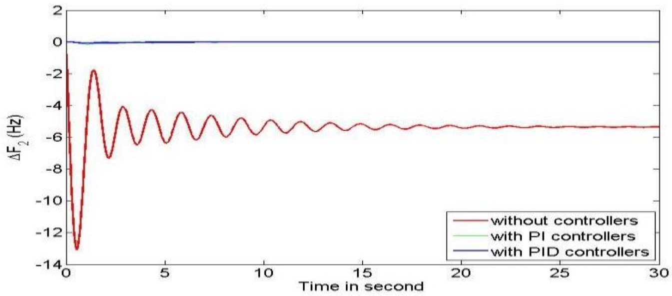

Fig. 6 ΔF_2 with and without PI and PID controllers

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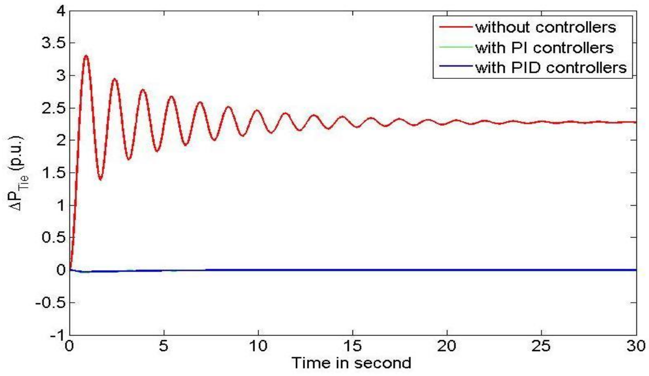

Fig. 7 ΔP_{Tie} with and without PI and PID controllers

C. Comparison of System Dynamic Responseswith PI and PID Controllers

A step increase in demand of 10% is applied in the area-1 at time t=0 second:

From Figs 4-7, it is not understandable that which responses are superior, so in order to show the superiority of the introduced approaches (PSO//PI and PSO/PID), the comparative comparisons are shown in Figs. 7-10. The simulation results demonstrate that the PSO/PID for AGC of considered system gives the superior dynamic responses as compared to PSO/PI approach in terms of settling times, peak overshoots and oscillations or smoothness.

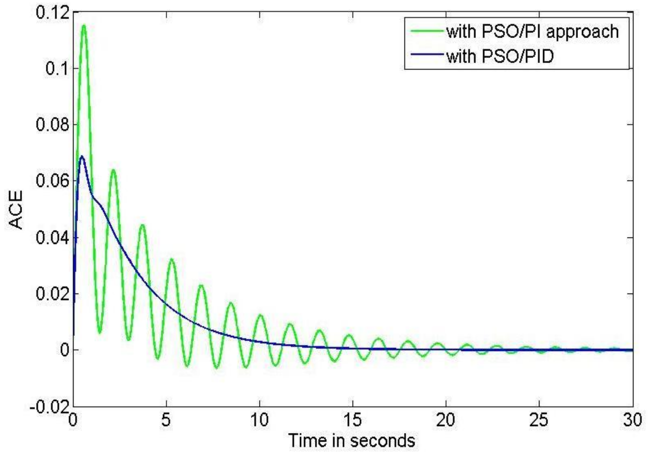

Fig. 8 ACE with PI and PID controllers

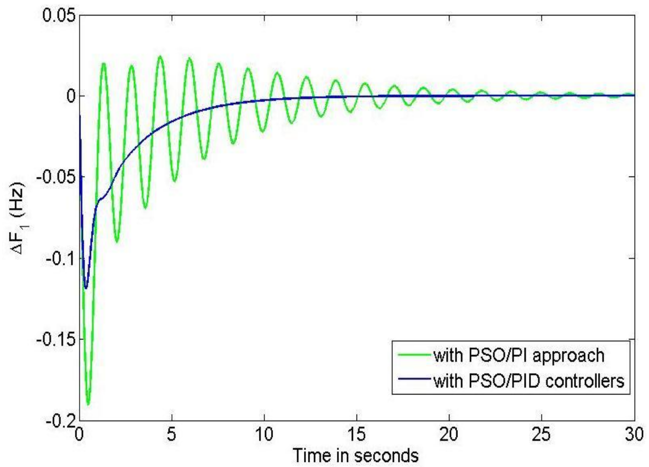

Fig. 9 ΔF_1 with PI and PID controllers

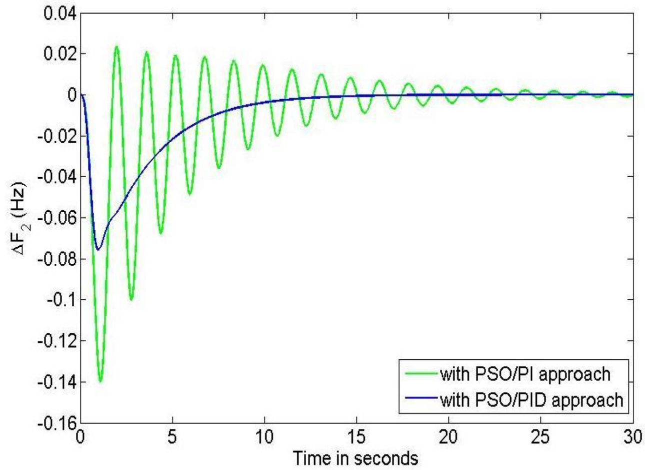

Fig. 10 ΔF_2 with and without PI and PID controllers

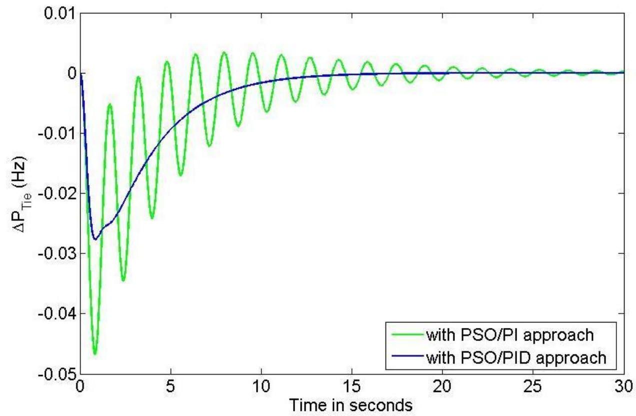

Fig. 11 ΔP_{Tie} with PI and PID controllers

The performance index in terms of ITAE values and settling times/overshoots in frequency and tie-line power deviations for the above disturbance are also summarized in TABLE III for better illustration of the approaches. Table III shows that the PSO/PID approach gives improved time domain specifications as compared to PSO/PI approach for the identical system

TABLE III TIME DOMAIN PARAMETERS OBTAINED BY PSO/PID FOR CONSIDERED SYSTEM

ITAE	Settling Times (2% band) PSO/PID		
	ΔF_1	ΔF_2	ΔP_{tie}
	8.38	9.51	9.98
1.5149		Peak Overshoots	
	0.1203	0.078	0.0259
ITAE	Settling Times (2% band) PSO/PI		
	ΔF_1	ΔF_2	ΔP_{tie}
	25.68	24.16	22.21
3.8669		Peak Overshoots	
	0.1894	0.396	0.04678

V. CONCLUSIONS

The Particle Swarm Optimization approach has been applied to optimize the parameters of PID controllers as well as PI controllers in two area interconnected thermal power plants for Load Frequency Control.

The outcomes have been simulated using MATLAB/SIMULINK software. The Integral Time Multiplied Absolute Error (ITAE) performance index has been considered as an objective function of the optimization problem. The dynamic responses of the system beneath investigation has been studied for 10% step load change at area1 and the relative comparison between PSO/PID and PSO/PI approaches for the identical system has been given. The simulation results show that PSO/PID approach for AGC provides enhanced dynamic performances and smooth response in terms of lower ITAE, less settling times and less overshoot over PSO/PI approach for the same system.

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