International Journal of Advancements in Technology

Research Article Open Access

Multi Area AGC Problem of T.G.U Solved Through GA (Using Tuning of PID) Controller

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Abstract

Major issue of modern power system having complex power structure, it is necessary for Thermal Generating Unit (TGU) to continuous supplying an electric power with the increasing demand. Owing to this Automatic Generation Control (AGC) play a key role for maintaining the frequency oscillation and tie-line power due to unpredictable load changes. This paper help to solve the settling time issue of load frequency and tie-line power for multi area (Five area) AGC interconnected TGU Reheat and Non-Reheat system using different controllers like GA (Using Tuning of PID) controller, Fuzzy controller and PID controller. For better results the combined response of frequency and tie-line deviation has been obtained separately for multi areas reheat and non-reheat T.G.U system and the comparative Tables of the entire controller's response is taking place separately. The results obtain from the combined response and comparative table, shows that GA controller gives the better dynamic performance due to settle down frequency and tie-line power deviation in less time and satisfy the automatic generation control requirements.

Keywords: Multi area (Five area); Thermal generating unit (TGU); Automatic generation control (AGC); Genetic algorithm (GA); Fuzzy controller

Abbreviations: AGC: Automatic Generation Control; Pri: Rated Power Capacity of Area i; f: Nominal System Frequency; Δf: Change in Supply Frequency; Di: System Damping Area i; Tsg: Speed Governor Time Constant; Tt: Steam Turbine Time Constant; Tps: Power System Time Constant; Ksg: Speed Governor Gain Constant; Kt: Steam Turbine Gain Constant; Kps: Power System Gain Constant; Bi: Frequency Bias Parameter; ΔPDi: Incremental Load Change in Area i; i: Subscript Referring to Area 1 2 3 etc.; H: Inertia Constant; R: Speed Regulation of Governor; a: Ratio of Rated Power of A Pair of Areas Four Area System; T: Synchronous Coefficient of Tie-Line System; Ptiemax: Tie-line Power

Introduction

Random load changes result in power generation-consumption mismatch, which in turn, affects the quality and reliability of electric power. These mismatches have to be corrected because generation and distribution of sufficient and reliable electric power with good quality is very important in power system operation and control. This can be achieved by AGC which is the major component of generation management system.

Experimental

The goal of AGC is to maintain the nominal frequency in an interconnected power system and to maintain the net interchange of power between control areas at predetermined values. AGC has been used for several years to meet these objectives. If we assume that each control area in an interconnected power system had a single generating unit, then the control system have been able to directly stabilize the system frequency with a change in load and maintain a tie-line interchange. But in real world there exist numerous control areas with more generating units with outputs that must be set according to economic dispatch. There are frequent changes in load it is un-realistic to specify the amount of unit output for each unit. This has led to the need of an AGC control scheme that will enable scheduled MW production and distribution among generation units. AGC schemes are managed at a central location where information is telemetered to the controlled areas.

The frequency sensor are sensed the change in frequency and tie line real power that can be measured of change in rotor δ angle. The load frequency controller are amplify and transform error signal, i.e., (Δfi and ΔPtie) in to real power command signal ΔPci which is sent to the prime mover via governor (that control the valve mechanism) to call for an increment or decrement in torque the prime mover balance the output of governor which will compensate the value of error signal that is Δfi and ΔPtie the process continue till deviation in form of Δfi and ΔPtie as well the specify tolerance. Modern power system network consists of a number of utilities interconnected together and power is exchanged between utilities over tie-lines by which they are connected.

Literature survey shows that most of the earlier works in the area of AGC pertain to interconnected thermal systems with non-reheat and reheat type turbine separately but relatively lesser attention has been devoted to the AGC of interconnected thermal system with non-reheat and reheat type turbines combined. In these turbines increasing the number of areas, the system network becomes more complex and difficult to control it [1-36].

The control action comprises of different controller like GA (Using Tuning of PID), Fuzzy, and PID controller. The model of multi areas, non-reheat and reheat thermal generating unit are shown in below Figure 1 and Figure 2.

For a sudden step change of load demand,

$$\Delta P_g(s) = \frac{\Delta P_d}{s}$$

For the simplicity of frequency-domain analyses, transfer functions

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Received: May 05, 2017; **Accepted:** June 19, 2018; **Published:** June 26, 2018

Citation: Dhamanda A, Bhardwaj AK (2018) Multi Area AGC Problem of T.G.U Solved Through GA (Using Tuning of PID) Controller. Int J Adv Technol 9: 207. doi:10.4172/0976-4860.1000207

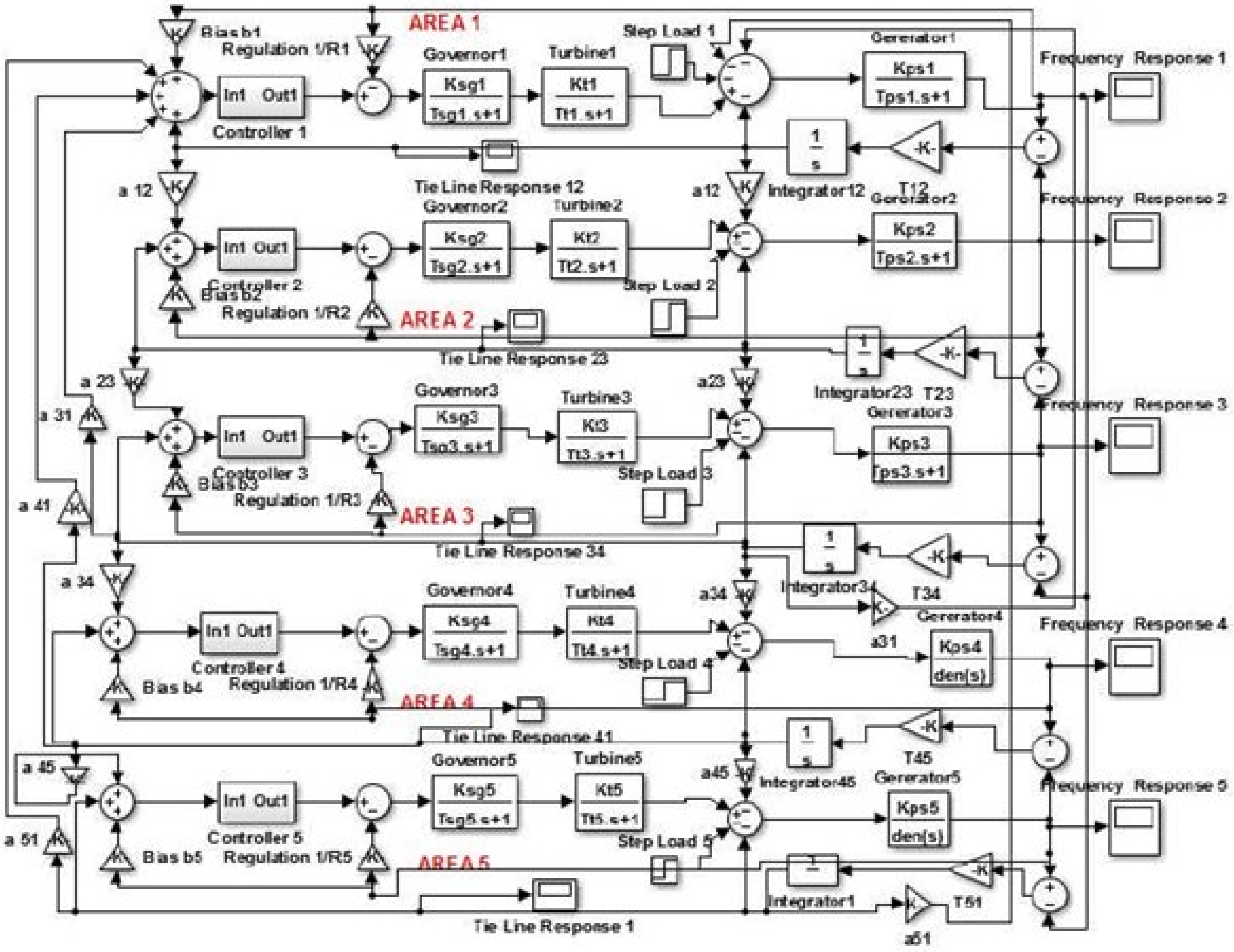

Figure 1: Multi area AGC model of thermal generating system with non-reheat turbine.

are used to model each component of the area. [4,8,11,17,18]

Governor's Transfer function is $\frac{\mathrm{Ksg}}{\mathrm{Tsg\ s+1}}$ (1)

Turbine's Transfer function is $\frac{\mathrm{Kt}}{\mathrm{Tt\ s+1}}$ (2)

Reheat turbine's Transfer function is $\frac{\mathrm{Kr.Tr\ s+1}}{\mathrm{Tr\ s+1}}$ (3)

Generator's Transfer function is $\frac{\mathrm{Kps}}{\mathrm{Tps\ s+1}}$ (4)

Dynamic response of automatic frequency control loop is

$$\Delta F(s)=-\Delta P_d\frac{RK_{PS}}{R+K_{PS}}\left(\frac{1}{s}-\frac{1}{s+\frac{R+K_{ps}}{R\,T_{ps}}}\right) \quad (5)$$

This is equation for dynamic state, and help to determine the dynamic response of the system.

Power flow out of control area-1 can be expressed as

$$P_{TL1}=\frac{|E_1||E_2|}{X_{TL}}sin(\delta_1-\delta_2) \quad (6)$$

Where|E1| and | E2| are voltage magnitude of area 1 and area 2, respectively, δ1 and δ2 are the power angles of equivalent machines of their respective area, and XTL is the tie line reactance. If there is change in load demands of two areas, there will be incremental changes in power angles (Δδ1 and Δδ2). Then, the change in the tie line power is [36],

$$\ddot{A}P_{TL1}(s)=2\eth T_{12}\left[\frac{\ddot{A}F_1(s)}{s}-\frac{\ddot{A}F_2(s)}{s}\right]$$

Where, $T_{12}=\frac{|E_1||E_2|}{X_{TL}P_1}cos(\delta_1-\delta_2)$ MW/rad (7)

T12 is known as the synchronizing coefficient or the stiffness coefficient of the tie-line.

Controller

For multi area non-reheat and reheat thermal generating unit, following types of controller are used:

PID controller

This controller provides a generic and efficient solution to real world

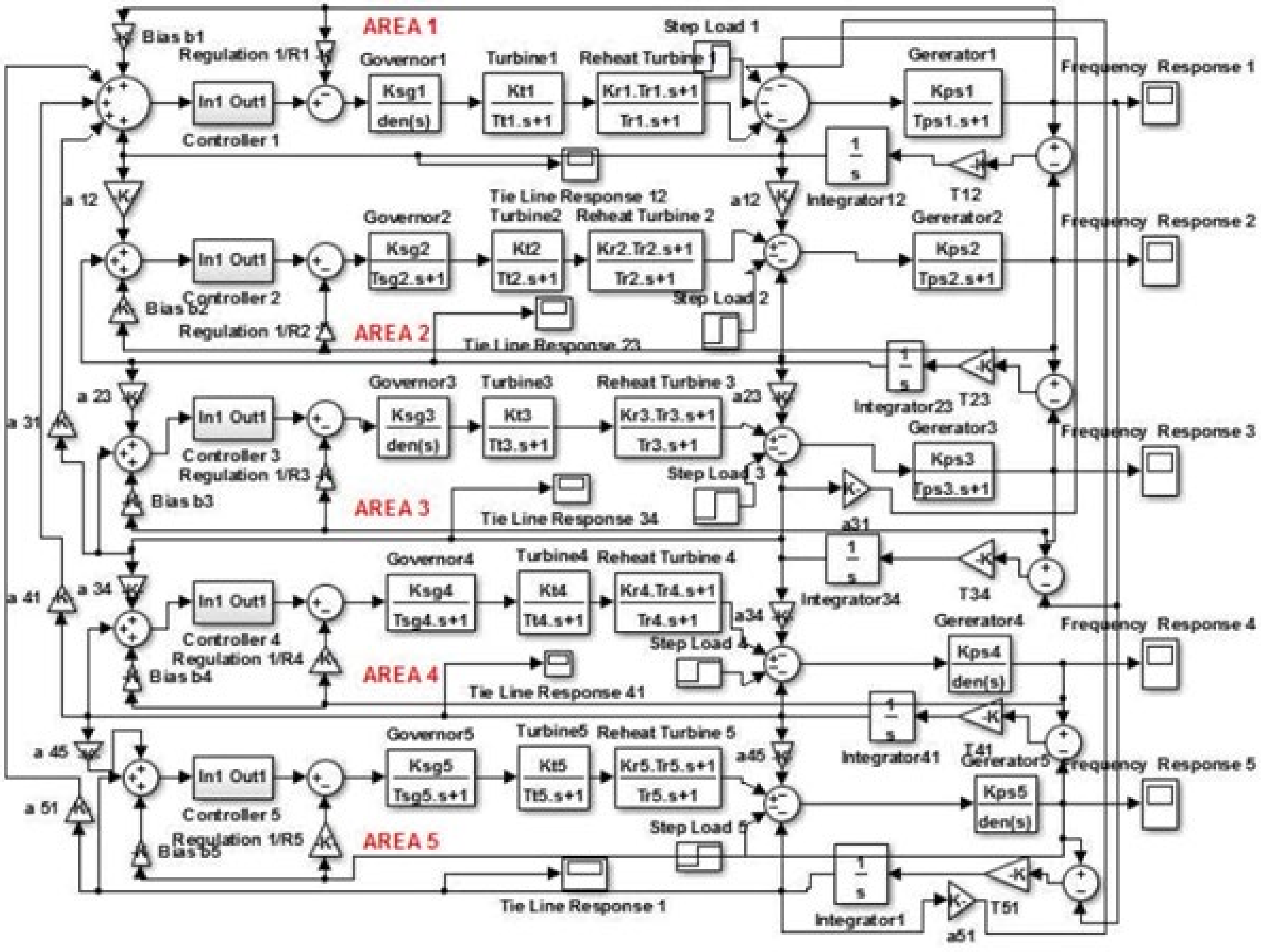

Figure 2: Multi area AGC model of thermal generating system with reheat turbine.

control problems. This controller reduced the number of oscillation and corresponding settling time automatically reduced.

Fuzzy logic controller

Fuzzy logic is a type of multi valued logic. It deals with approximate reasoning rather than precise. The ability of fuzzy logic to handle imprecise and inconsistent real-world data made it suitable for a wide variety of applications. In particular, the methodology of the fuzzy logic controller (FLC) appears very useful when the processes are too complex for analysis by conventional quantitative techniques or when the available sources of information are interpreted qualitatively, inexactly or with uncertainty. Fuzzy logic controller is shown below (Figure 3) [6,7].

The inputs of the proposed fuzzy controller are error (e) and rate of change in error (ce). The fuzzy inference rule with 9 membership functions like; NBB, NB, NM, NS, Z, PS, PM, PB and PBB represent negative big big, negative big, negative medium, negative small, zero, positive small, positive medium, positive big and positive big big respectively make 81 (9 × 9) rule shown in Table 1.

GA controller

Genetic algorithm is a robust optimization technique based on natural selection, and collection of functions that extend the capabilities of the numeric computing environment. The basic goal of GA is to optimize functions called fitness functions. A possible solution to a specific problem is seen as an individual. A collection of a number of individuals is called a population [36]. The flow chart of genetic algorithm for tuning of PID using GA controller is given below (Figure 4).

Results and Discussion

The simulation result of the developed model of multi areas automatic generation control in interconnected power system of non-reheat and reheat thermal generating unit has been discussed. The result of developed model has been finding out by using three different types of controllers; (i) PID Controller (ii) Fuzzy Controller (iii) GA Controller (For tuning of PID controller). GA controller (For tuning of PID controller) has been proposed to find out the performance of non-reheat and reheat system, which is evaluated using MATLAB Simulink software. The performance of AGC through GA controller is compared with PID and fuzzy logic controller. Comparative response of frequency and tie-line power deviation has been obtained and the value of settling time tabulated in Table 2 and Table 3, it is observed that the GA controller improve the dynamic performance of the system

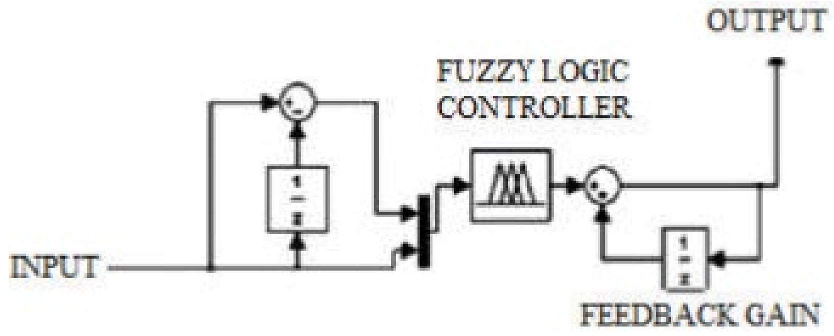

Figure 3: Fuzzy logic control scheme model.

		Error (e)								
		NBB	**NB**	**NM**	**NS**	**ZO**	**PS**	**PM**	**PB**	**PBB**
Change in Error (ce)	**NBB**	PBB	PB	PB	PM	PBB	PB	PM	PB	PBB
	NB	PBB	PB	PM	PS	PB	PM	PM	PM	PB
	NM	PB	PM	PS	PS	PM	PS	PS	PM	PB
	NS	PM	PS	PS	ZO	PS	PS	PS	PM	PM
	ZO	PS	PS	ZO	PS	ZO	PS	PS	PS	PM
	PS	ZO	ZO	NS	PS	NS	NS	NS	NS	NM
	PM	NS	NS	NS	PS	NM	NM	NM	NM	NB
	PB	NS	NM	NM	PM	NB	NB	NM	NM	NB
	PBB	NM	NM	NB	PM	NBB	NBB	NB	NB	NBB

Table 1: Fuzzy inference rule.

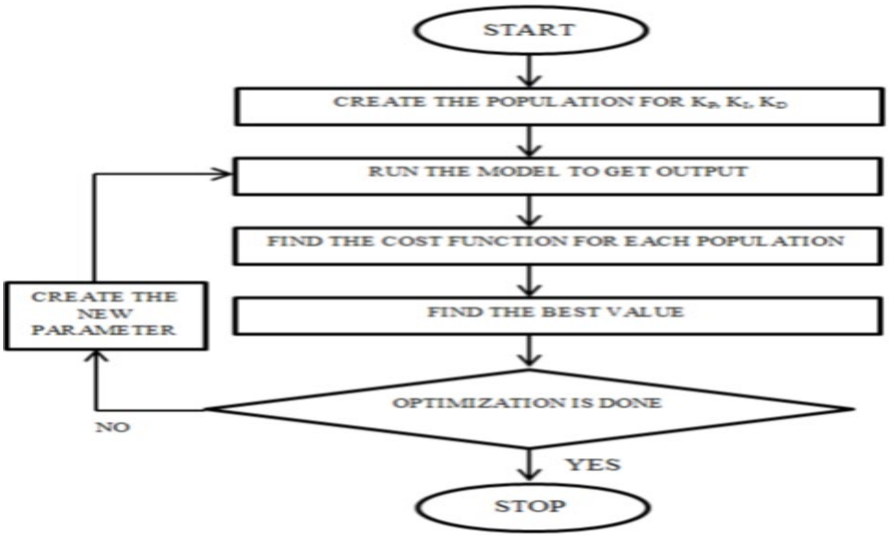

Figure 4: Flow chart for tuning of PID using genetic algorithm (GA).

as compared to PID and fuzzy logic controller. The power system parameters are given in appendix.

The combined response of change in frequency and corresponding tie-line power deviation under the load disturbances of 0.01 p.u. with different controller of multi areas non-reheat thermal generating unit are shown in Figures 5-14 and result are tabulated in the Table 2.

Figures 5-14 shows that comparative response of frequency deviation and tie-line power deviation, obtained by PID, Fuzzy and GA controller reduces the steady state error and improve the performances of settling response but GA controller gives better settling response of non-reheat thermal generating system out of the other controllers. The combined response of change in frequency and corresponding tie-line deviation under the load disturbances of 0.01 p.u. with different controller of multi areas reheat thermal generating unit are shown in Figures 15-24 and result are tabulated in the Table 3.

Figures 15- 24 shows that comparative response of frequency

	Frequency deviation's separate thermal area settling time (Sec)					Tie-line deviation's thermal-thermal settling time (Sec)				
Controllers	**Area 1 (Sec)**	**Area 2 (Sec)**	**Area 3 (Sec)**	**Area 4 (Sec)**	**Area 5 (Sec)**	**Area 1-Area 2 (Sec)**	**Area 2-Area 3 (Sec)**	**Area3-Area4 (Sec)**	**Area 4-Area 5 (Sec)**	**Area 5-Area 1 (Sec)**
PID	20	19	19	21	20	30	28	28	30	29
Fuzzy	19	17	17	20	19	30	22	27	22	27
GA	16	15	14	16	17	18	22	17	17	23

Table 2: Comparative value of settling time for multi area non-reheat system.

	Frequency deviation's separate thermal area settling time (Sec)					Tie-line deviation's thermal-thermal settling time (Sec)				
Controllers	**Area 1 (Sec)**	**Area 2 (Sec)**	**Area 3 (Sec)**	**Area 4 (Sec)**	**Area 5 (Sec)**	**Area 1-Area 2 (Sec)**	**Area 2-Area 3 (Sec)**	**Area 3-Area 4 (Sec)**	**Area 4-Area 5 (Sec)**	**Area 5-Area 1 (Sec)**
PID	38	38	39	20	30	59	47	59	58	68
Fuzzy	23	21	21	20	20	38	32	33	42	38
GA	15	15	15	15	16	29	21	29	21	29

Table 3: Comparative values of settling time for multi area reheat system.

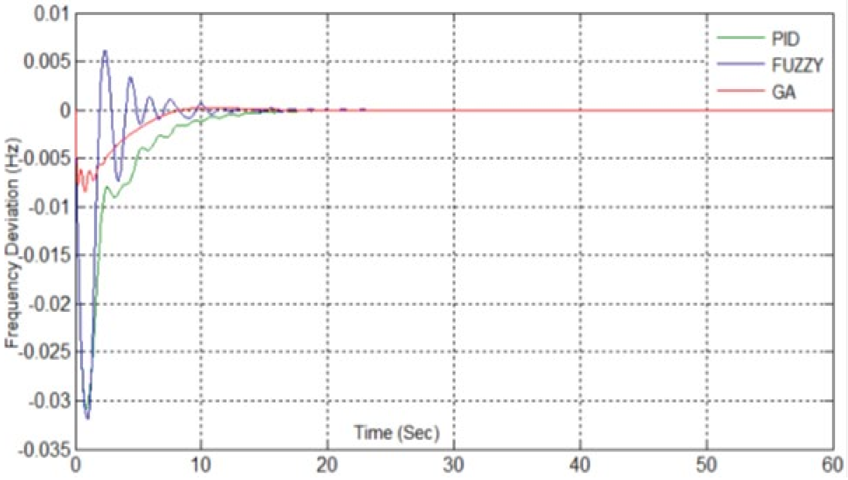

Figure 5: Frequency deviation of area 1 of non-reheat system.

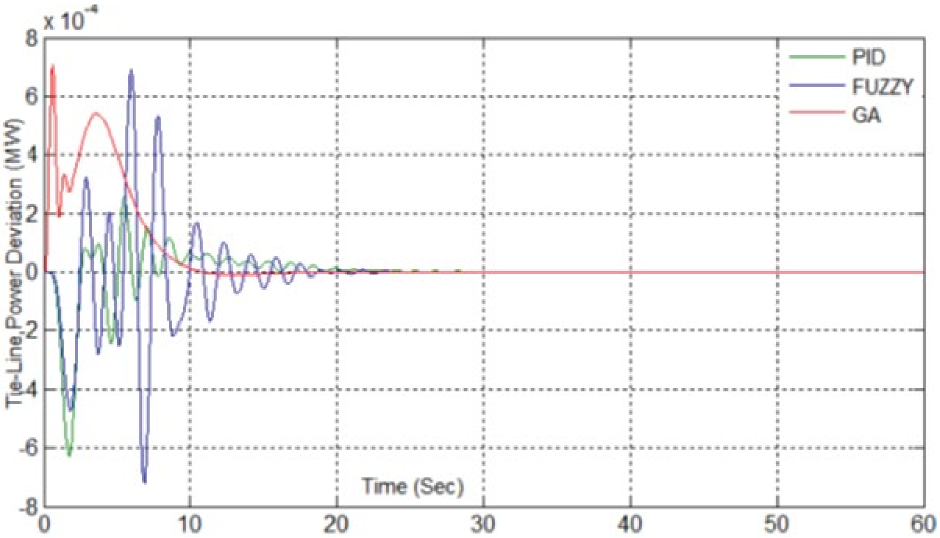

Figure 6: Tie-line power deviation of area 1 of non-reheat system.

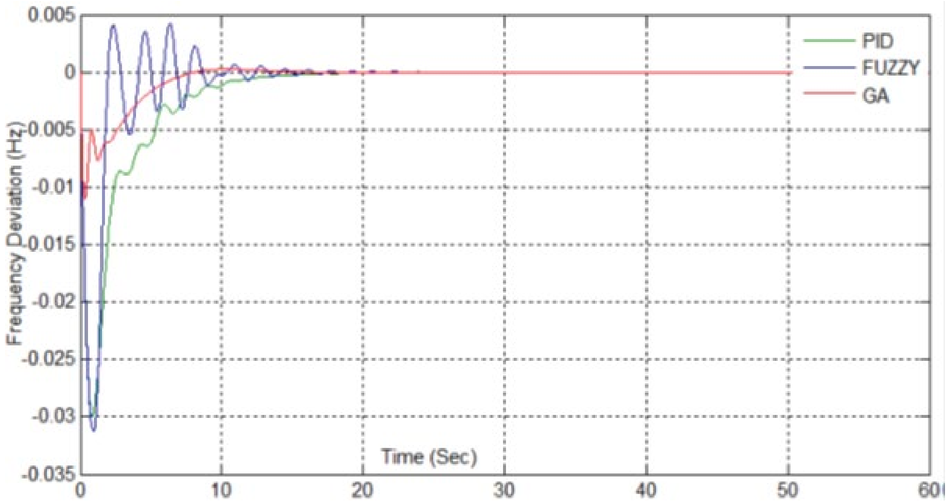

Figure 7: Frequency deviation of area 2 of non-reheat system.

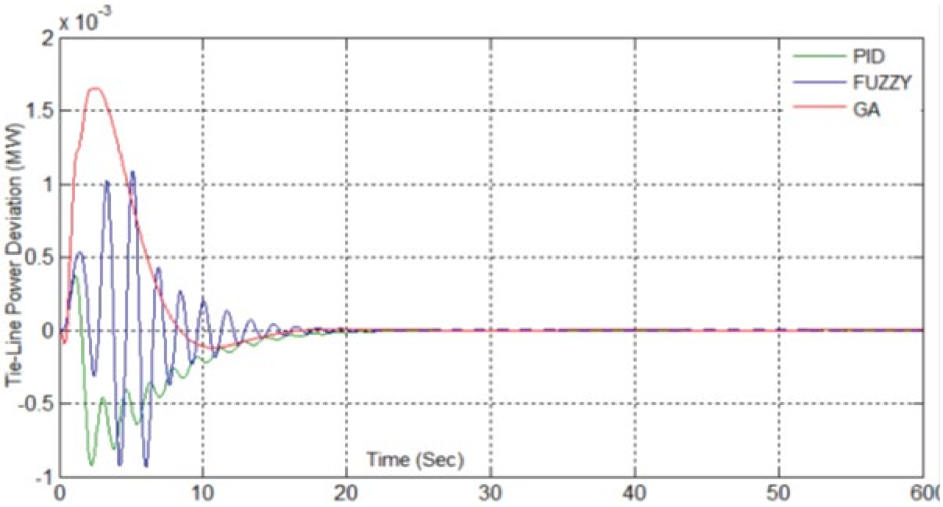

Figure 8: Tie-line power deviation of area 1 of non-reheat system.

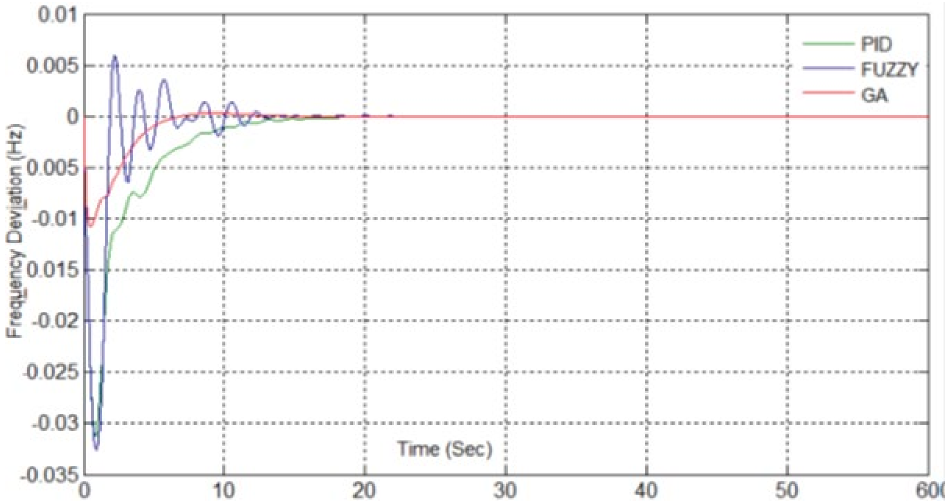

Figure 9: Frequency deviation of area 3 of non-reheat system.

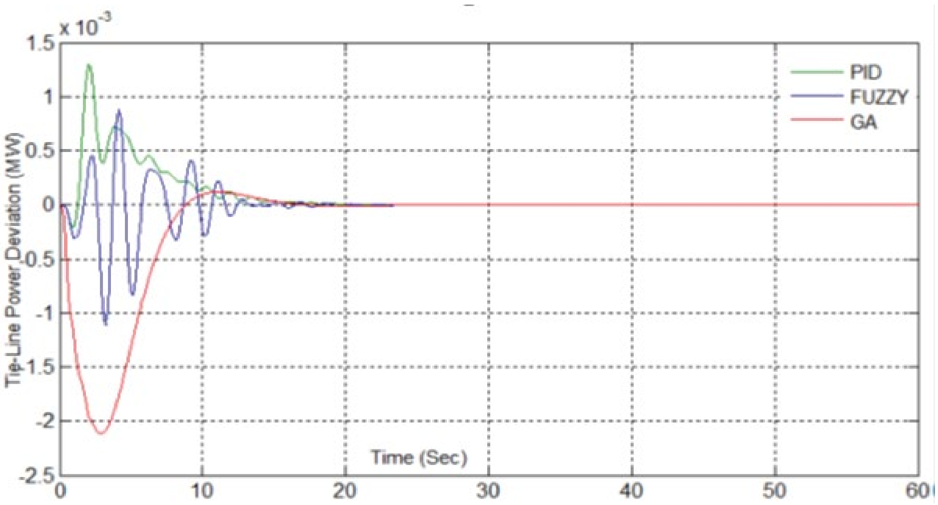

Figure 10: Tie-line power deviation of area 4 of non-reheat system.

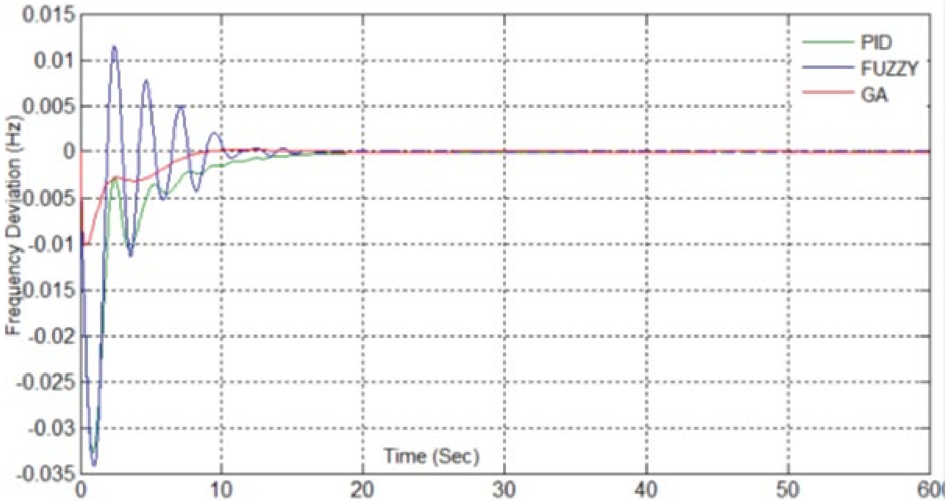

Figure 11: Frequency deviation of area 4 of non-reheat system.

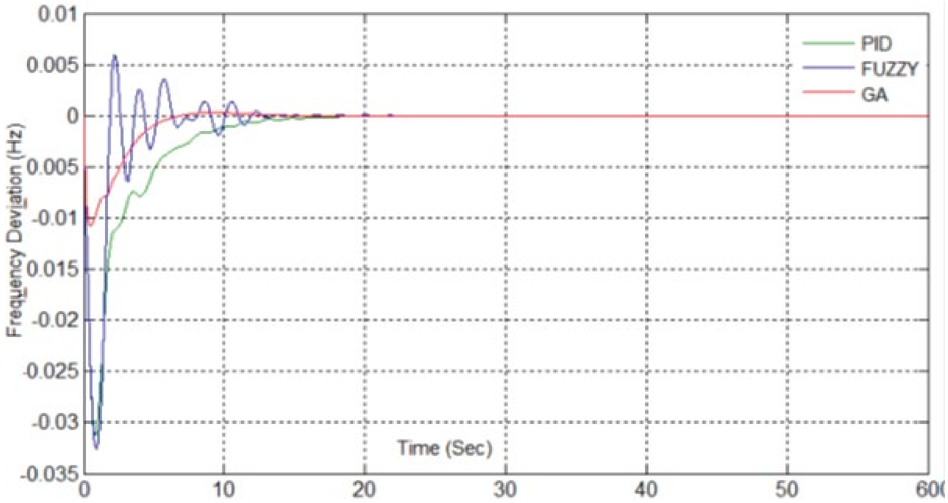

Figure 12: Tie-line power deviation of area 4 of non-reheat system.

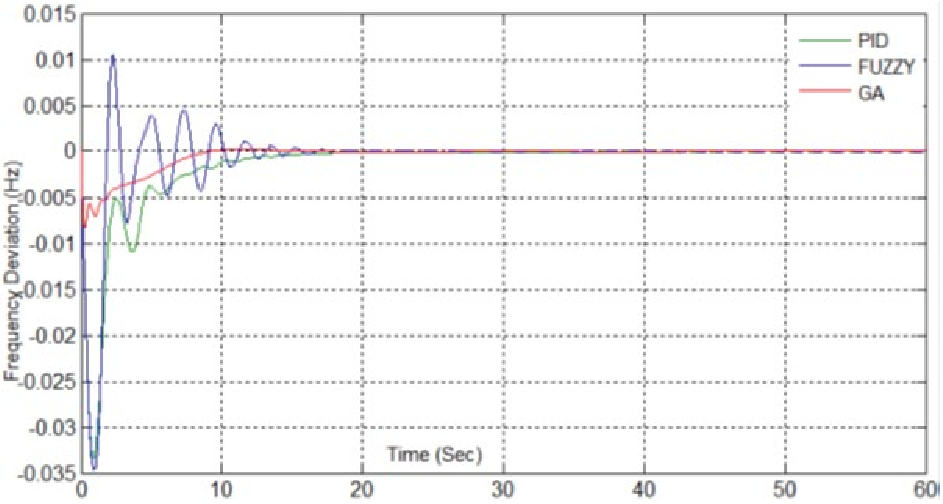

Figure 13: Frequency deviation of area 5 of non-reheat system.

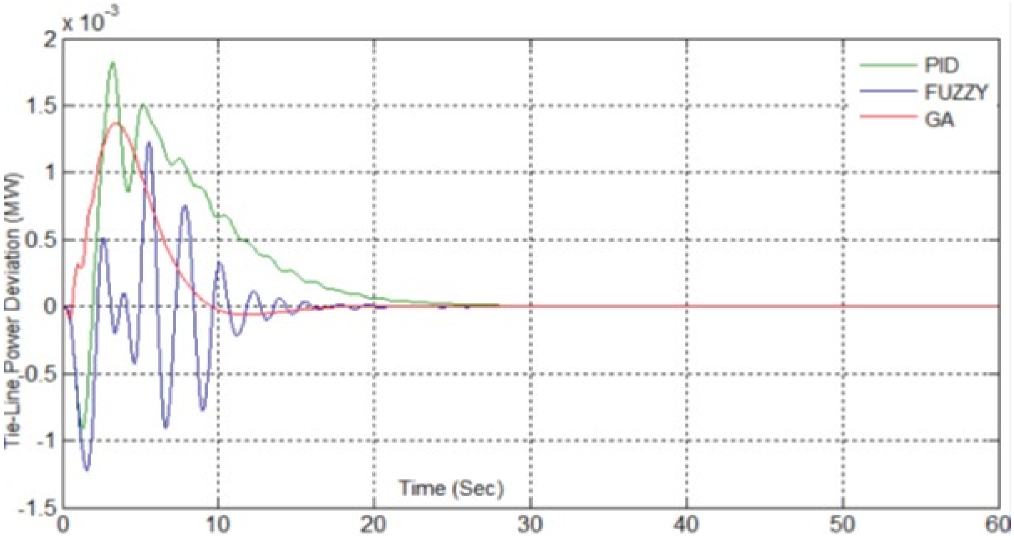

Figure 14: Combined response of tie-line power deviation of area 5 of non-reheat system.

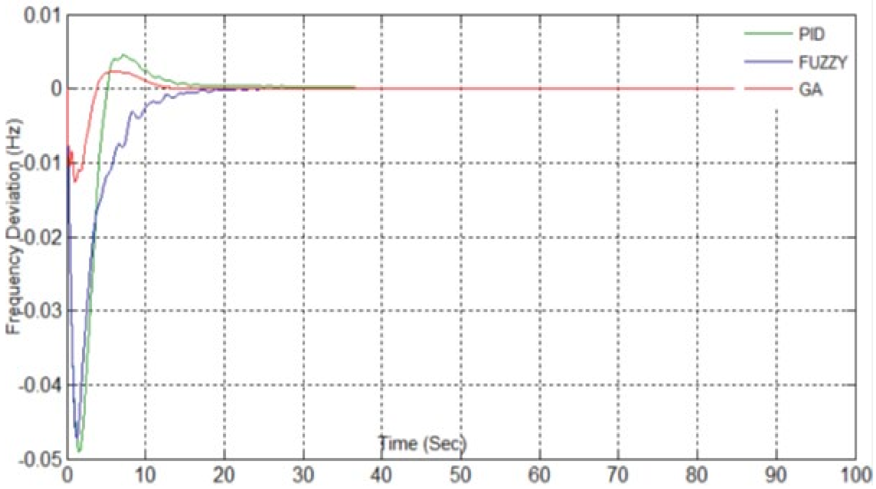

Figure 15: Frequency deviation of area 1 of reheat system.

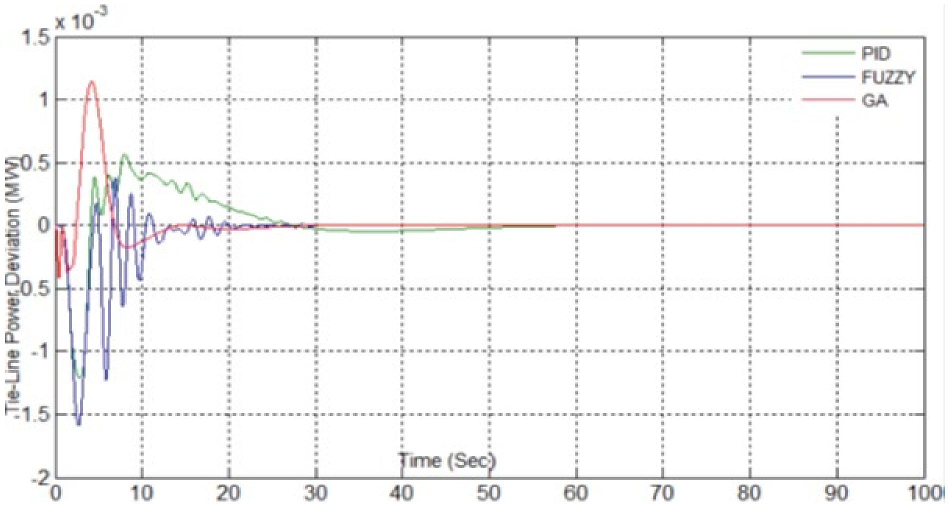

Figure 16: Tie-line power deviation of area 1 of reheat system.

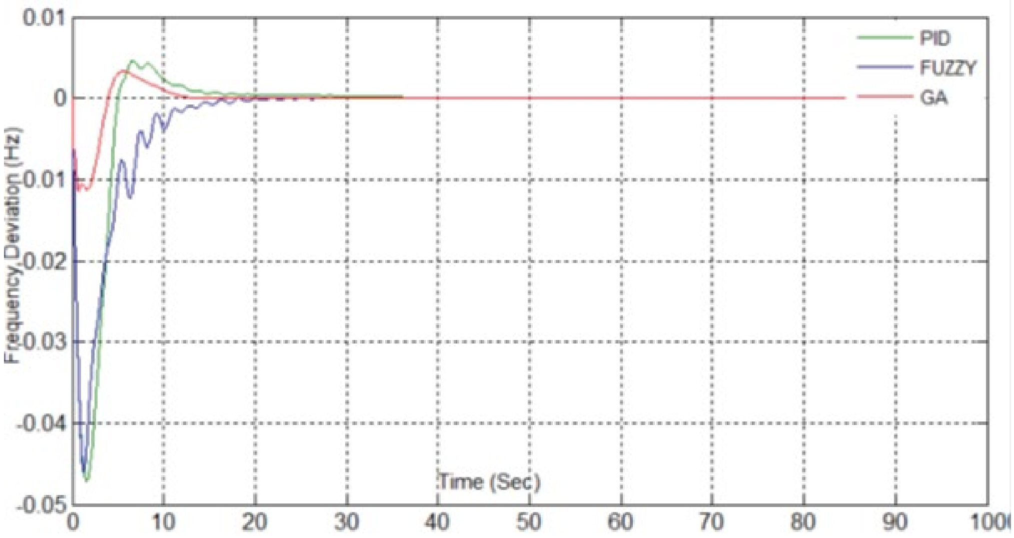

Figure 17: Frequency deviation of area 2 of reheat system.

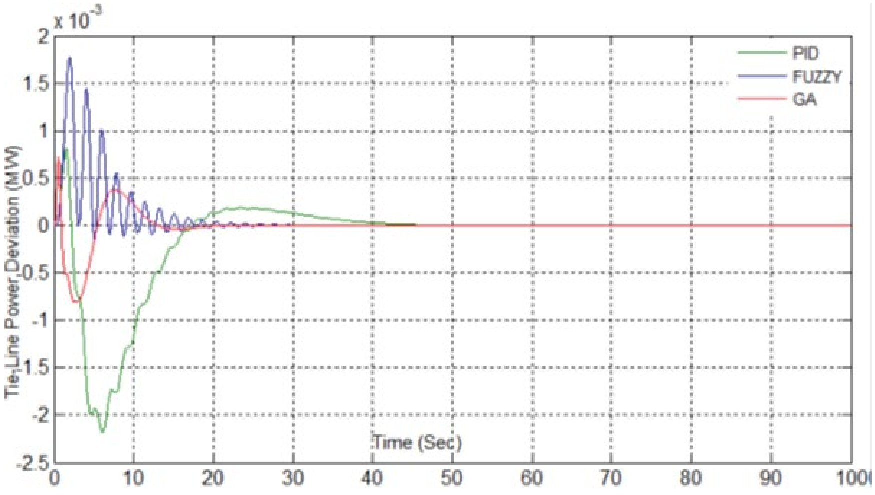

Figure 18: Tie-line power deviation of area 2 of reheat system.

deviation and tie-line power deviation, obtained by PID, Fuzzy and GA (Using Tuning of PID) controller reduces the steady state error and improve the performances of settling response but GA controller gives better settling response of reheat thermal generating system out of the other controllers. All combined responses obtained by MATLAB/Simulink software. The step load disturbance of 0.01 p.u was applied in multi areas thermal generating system and deviation in frequency and corresponding tie-line power response was obtained by using PID, Fuzzy and GA (Using Tuning of PID) controller. The comparative table of settling time of multi area systems after frequency and tie-line deviation under the load disturbance of 0.01 p.u is shown in Table 2 and Table 3.

It is clear from the comparative Table 2 and Table 3 that the results obtained from GA (Using Tuning of PID) controller gives better settling time due settle down the frequency and tie-line deviation in the less time in comparison to Fuzzy and PID controller.

Hence for both non-reheat and reheat system, the GA (Using Tuning of PID) controller gives the better settling time performance for three areas, four areas, five areas and six areas thermal generating units.

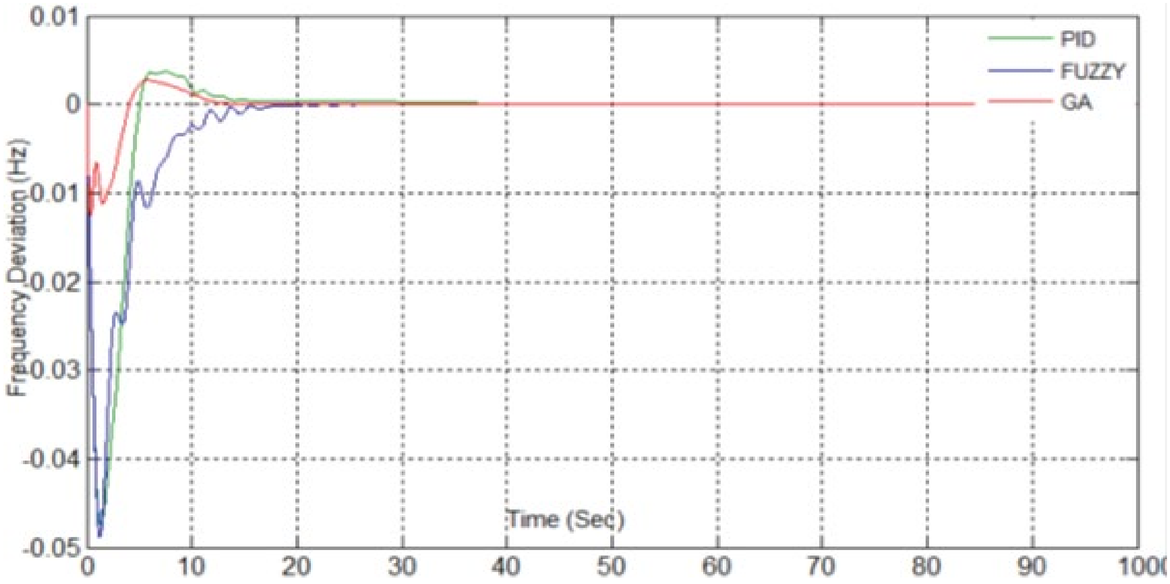

Figure 19: Frequency deviation of area 3 of reheat system.

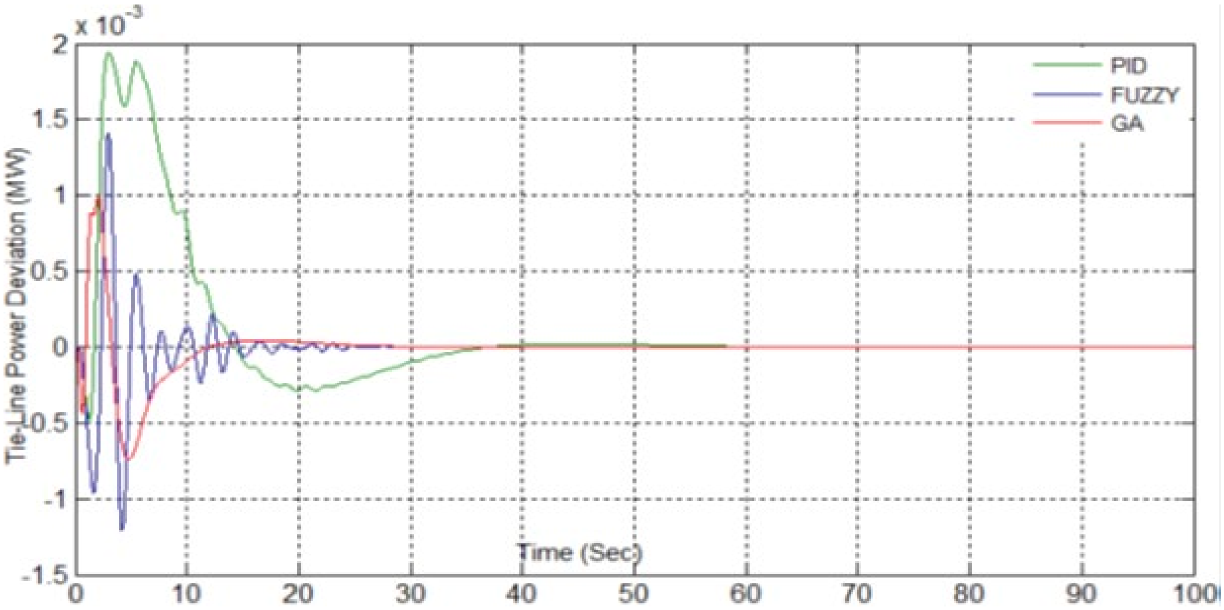

Figure 20: Tie-line power deviation of area 3 of reheat system.

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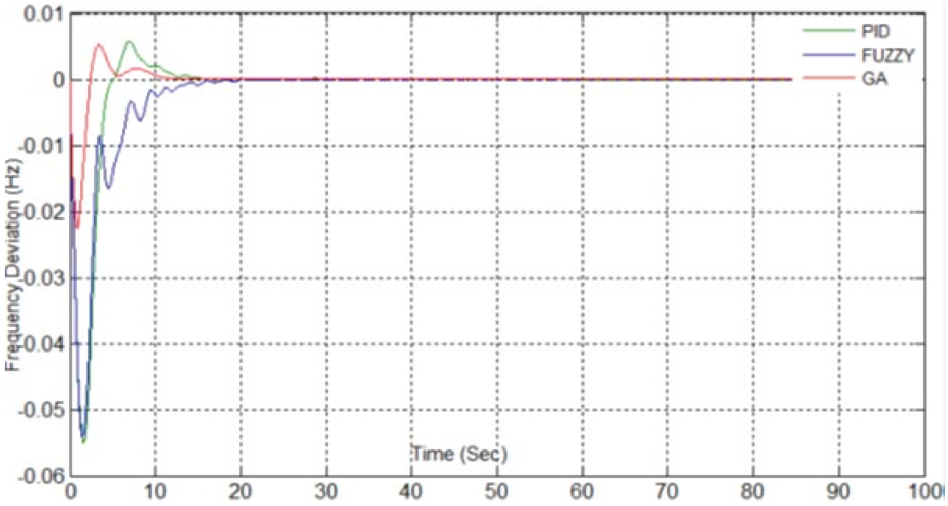

Figure 21: Frequency deviation of area 4 of reheat system.

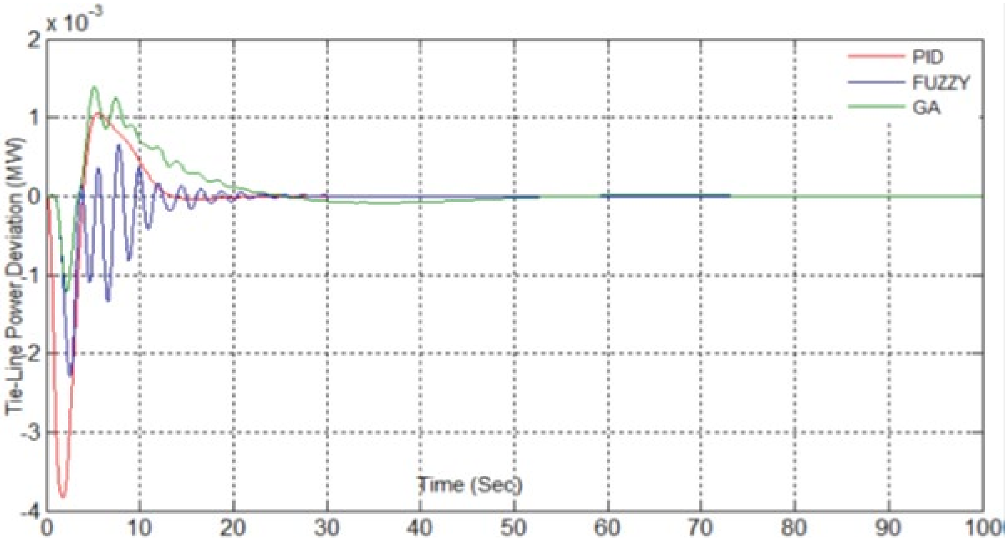

Figure 22: Tie-line power deviation of area 4 of reheat system.

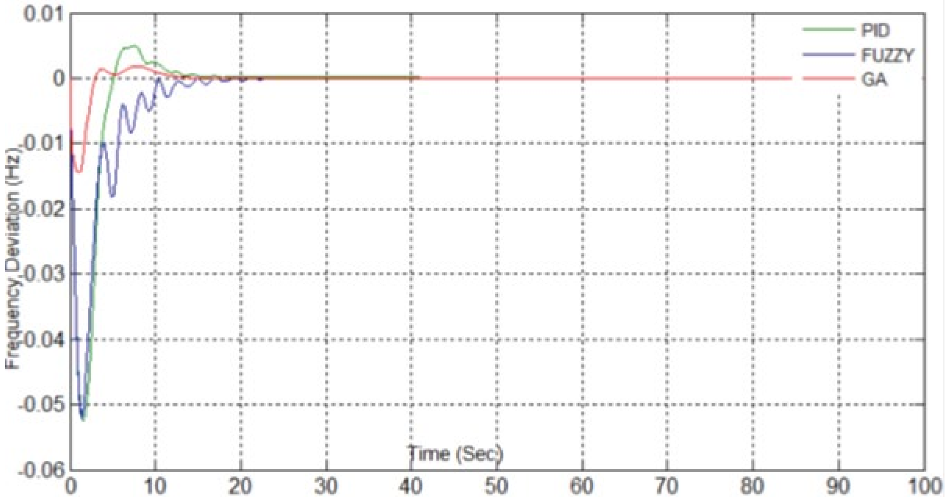

Figure 23: Frequency deviation of area 5 of reheat system.

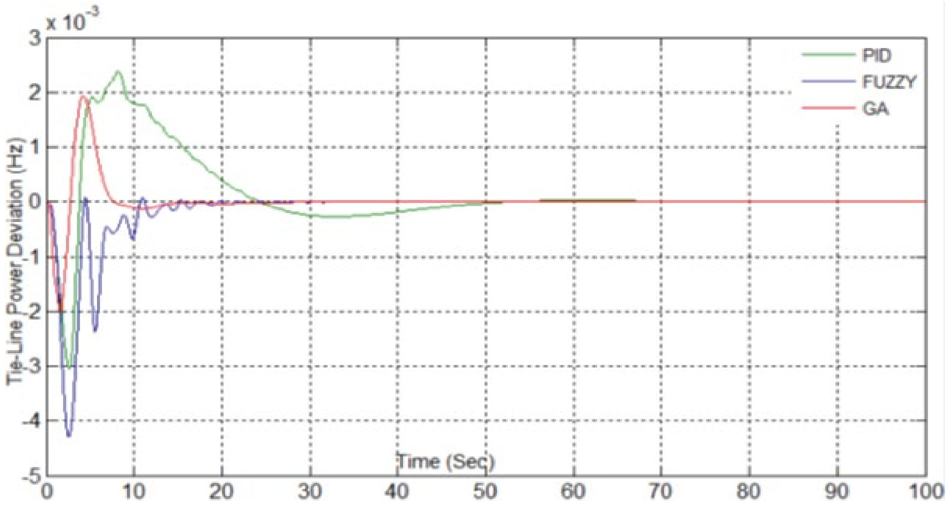

Figure 24: Tie-line power deviation of area 5 of reheat system.

Conclusion

From this paper the settling time of load frequency and tie line power of automatic generation control for multi areas non-reheat and reheat thermal power system has been investigated by GA (For tuning of PID), Fuzzy and PID controller. The model developed for multi area system (non-reheat and reheat) has been simulated through MATLAB SIMULATION Software. Settling time of frequency deviation and tie line power has been obtained from the response from figures 5-14 of non-reheat system and figures 15-24 of reheat system and tabulated these values in Table 2 and Table 3. The result (settling time) of different controller has been compared it shows that the GA (For tuning of PID) controller give better dynamic performances due to reduce frequency and tie line deviation in less settling time.

It can be concluded that the GA (Using for Tuning of PID) controller gives the better settling performance than the Fuzzy and PID controller.

Appendix

Parameters of power system are as follows:

F=60 Hz;R1=R2=R3=R4=2.4 Hz/p.uMW;Tsg1=Tsg2=Tsg3=Tsg4=0.08 Sec; Tps1=Tps2=Tps3=Tps4=20 Sec; Tt1=Tt2=Tt3=Tt4=0.3 Sec; Tr1=Tr2=Tr3=Tr4=10 Sec; Kr1=Kr2=0.5 TU; Kr3=3.33 TU; Kr4=3 TU; a12=a23=a34=a41=1; H1=H2=H3=H4=5 MW-S/MVA;Pr1=Pr2=Pr3=Pr4=2000 MW; Kps1=Kps2=Kps3=Kps4=120 Hz/pu MW; Ksg1=Ksg2=Ksg3=Ksg4=1; Kt1=Kt2=Kt3=Kt4=1; D1234=8.33*10-3 p.uMW/Hz.; B1234=0.425 p.u. MW/hz; ΔPD1234=0.01 p.u; T12=T23=T34=T41=0.0867 MW/Radian; Ptiemax=200 MW.

Acknowledgement

This work is supported by Electrical Engineering Department, Faculty of Engineering and Technology, Gurukula Kangri Vishwavidyalaya, Haridwar, Uttarakhand, India and Electrical Engineering Department, Sam Higginbottom Institute of Agriculture Technology and Sciences, Allahabad, Uttar Pradesh, India.

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