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Research Article

AGC in an Interconnected Power System of Thermal Generating Unit through Evolutionary Technique

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Abstract: This study presents to obtain the dynamic response of load frequency and corresponding tie-line power of an Automatic Generation Control (AGC) in four area interconnected thermal power system by using three different technique (Controller); One is Conventional (PI) technique, second is Intelligent(Fuzzy) technique and third is Evolutionary (GA for tuning of PID Controller) Technique. In this study Evolutionary technique are proposed for improving the performance of load frequency and tie-line power and their dynamic responses are compared with the conventional and intelligent controller's responses. The results indicate that the proposed controller exhibit better performance and satisfy the automatic generation control requirements with a reasonable dynamic response. The performances of the controllers are simulated using MATLAB/SIMULINK software.

Keywords: Genetic Algorithm (GA), Proportional Plus Integral (PI), Proportional Plus Integral Plus Derivative (PID)

INTRODUCTION

Automatic Generation Control (AGC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. AGC with load following is treated as an ancillary service that is essential for maintaining the electrical system reliability at an adequate level (Roy *et al*., 2009) recent years, major changes have been introduced into the structure of electric power utilities all around the world. The successful operation in power system requires the matching of total generation with total load demand and associated system losses. As the demand deviates from its normal value with an unpredictable small amount, the operating point of power system changes and hence, system may experience deviations in nominal system frequency which may yield undesirable effects (Prakash and Sinha, 2012a; Singh Parmar *et al*., 2011). A control strategy is needed to maintain constancy of frequency and tie-line power and also achieves zero steady state error. The PI and fuzzy controllermployed to solve AGC problem and these controller gives the good response, reduces the oscillation and steady state error but the GA after tuning of PID controller gives the better result over the conventional and intelligent controller.

A literature survey shows that the Load Frequency Control (LFC) of power systems has been investigated by many researchers over the past decades (Liu *et al*., 2010). Most of the earlier works in the area of AGC pertain to thermal systems with non-reheat and reheat type turbines for single and two area with different controller but relatively lesser attention has been devoted to the comparison of PI, fuzzy and GA controllers. Four area thermal power system incorporating linearized models of governors, non-reheat turbines and reheat turbines are taken for simulation of the system. So the objective of AGC in interconnected thermal generating unit is to maintain the system frequency and tie line power at nominal value (60 Hz).

MATERIALS AND METHODS

The role of AGC in interconnected power system is to maintain the system frequency and tie-line power at nominal value after some kind of perturbation arises in the system.

To maintain the electrical power system in normal operating state, the generated power should match with power demand plus associated losses. However, in practical power system, the load is continuously changing with respect to time. Therefore, the power balance equilibrium cannot be satisfied in abnormal state. In primary control action also called without controller, when the power system is

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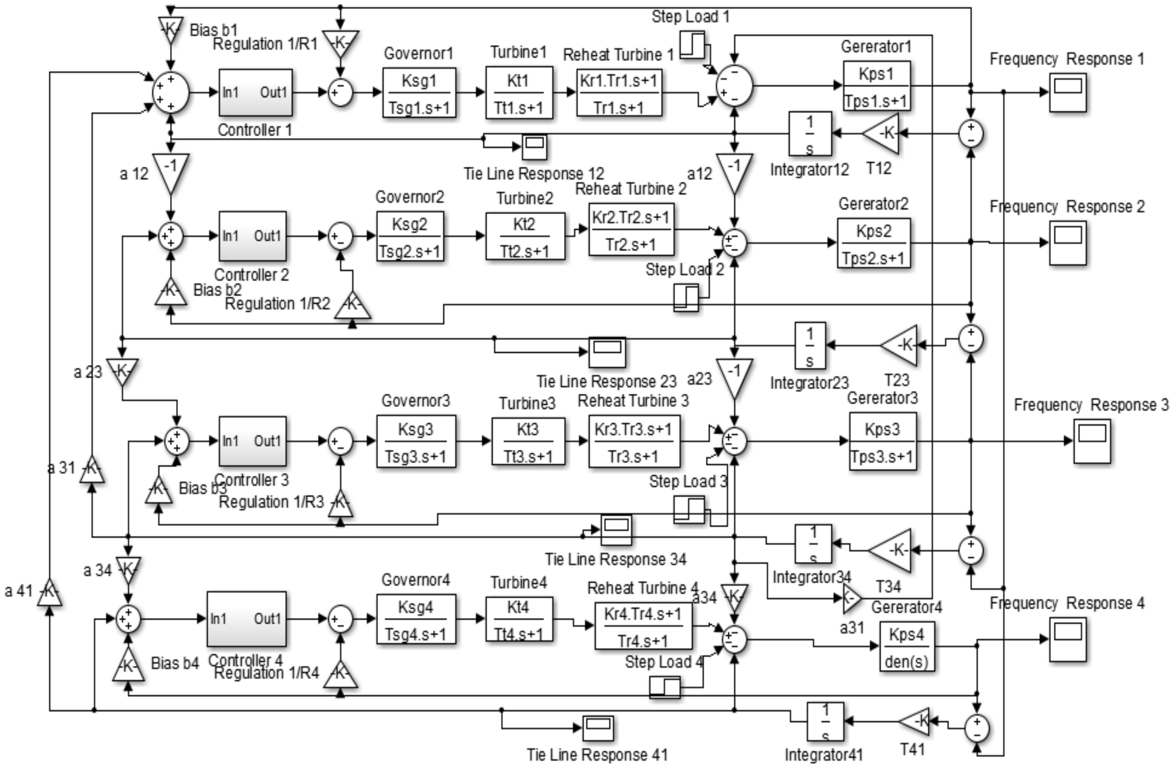

Fig. 1: Four area AGC model of thermal generating system

said to be at stable state, primary control action takes place within an area to suppress frequency oscillations. On the other hand, when the load fluctuations are more, primary control action are not adequate to control.

To overcome the problem of primary control action, the secondary control action also called with controller, need to apply, these controllers are set for a particular operating condition and they take care of small changes condition and they take care of small changes in load demand without exceeding the prescribed limits of frequency. These control action comprises of different controller like conventional, intelligent and evolutionary technique (Kothari and Nagrath, 2003; Elgerd, 1971; Challa and Rao, 2010; Sivanagaraju and Sreenivasan, 2011; Hadi, 1999; Kumari and Jha, 2014). Four area AGC model of thermal generating system is shown Fig. 1.

Let us consider the problem of controlling the power output of the generators of a closely knit electric area so as to maintain the scheduled frequency. All the generators in such an area constitute a coherent group so that all the generators speed up and slow down together maintaining their relative power angles. Such an area is defined as a control area. To understand the AGC problem of frequency control, let us consider a single turbo-generator system supplying an isolated load (Kothari and Nagrath, 2003). To simplicity the frequency-domain analyses, transfer functions are used to model each component of the area (Prakash and Sinha, 2012b):

Transfer function of governor is $\frac{\text{Ksg}}{\text{Tsg}\, s+1}$ (1)

Transfer function of turbine is $\frac{\text{Kt}}{\text{Tt}\, s+1}$ (2)

Transfer function of Reheat turbine is $\frac{\text{Kr.Tr}\, s + 1}{\text{Tr}\, s+1}$ (3)

Transfer function of generator is $\frac{\text{Kps}}{\text{Tps}\, s+1}$ (4)

Dynamic response of automatic frequency control loop is:

$$\Delta F(s) = -\frac{\frac{K_{ps}}{1+T_{ps}s}}{1+\frac{K_{PS}}{R\,(1+T_{ps}s)}}\frac{\Delta P_D}{S} \quad (5)$$

This equation can be written as:

$$\Delta F(s) = -\Delta P_D \frac{RK_{PS}}{R+K_{ps}}\left(\frac{1}{s} - \frac{1}{s+\frac{R+K_{ps}}{R\,T_{ps}}}\right) \quad (6)$$

Methodology: Controller determines the value of controlled variable, compare the actual value to the desired value (reference input), determines the deviation and produces a control signal that will reduce the deviation to zero or to a smallest possible value. In automatic generation control of thermal generating unit need to control or maintain the frequency constancy, reduced oscillation and zero steady state error, so following types of controller are used (Saeed, 2006).

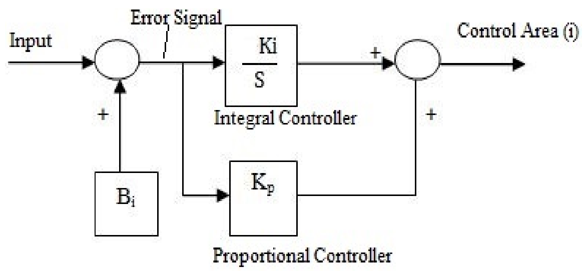

Fig. 2: Proportional plus integral control scheme model

Conventional (PI) technique: PI controller is also known as proportional plus integral controller. This controller are using from many year back for controlling such action with maintaining their performance.

This is a combination of proportional and integral control action shown in Fig. 2:

Control Area Input = K_p Error Signal + K_p K_i ∫Error Signal (7)

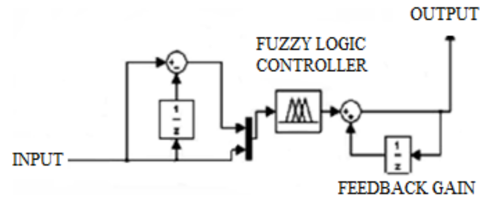

Fig. 3: Fuzzy logic control scheme model

Intelligent (Fuzzy Logic) technique: Fuzzy logic establishes the rules of a nonlinear mapping. There has been extensive use of fuzzy logic in control applications. One of its main advantages is that controller parameters can be changed very quickly depending on the system dynamics because no parameter estimation is required in designing controller for nonlinear systems. Fuzzy logic controller is shown in Fig. 3 (Prakash and Sinha, 2012a).

Figure 4 shows the inputs of the fuzzy controller are e and rate of change in ce. The appropriate membership function and fuzzy rule base is shown in

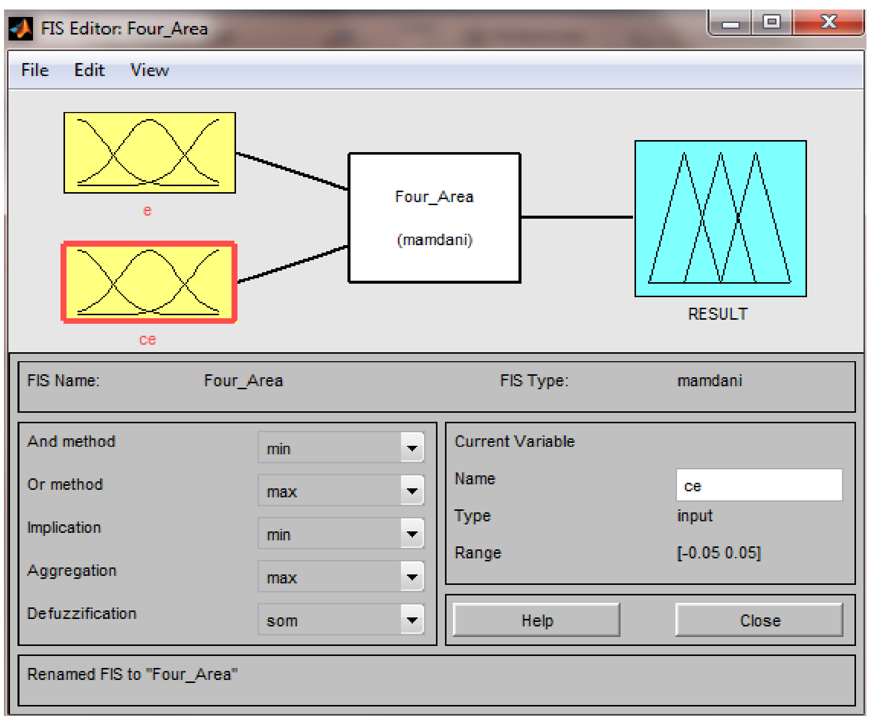

Fig. 4: Fuzzy inference system editor

Table 1: Fuzzy inference rule

		Error e						
		NB	NM	NS	ZO	PS	PM	PB
Change in error ce	NB	PB	PB	PB	PB	PM	PM	PS
	NM	PB	PM	PM	PM	PS	PS	PS
	NS	PM	PM	PS	PS	PS	PS	ZO
	ZO	NS	NS	NS	ZO	PS	PS	PS
	PS	ZO	NS	NS	NS	NS	NM	NM
	PM	NS	NS	NM	NM	NM	NB	NB
	PB	NS	NM	NB	NB	NB	NB	NB

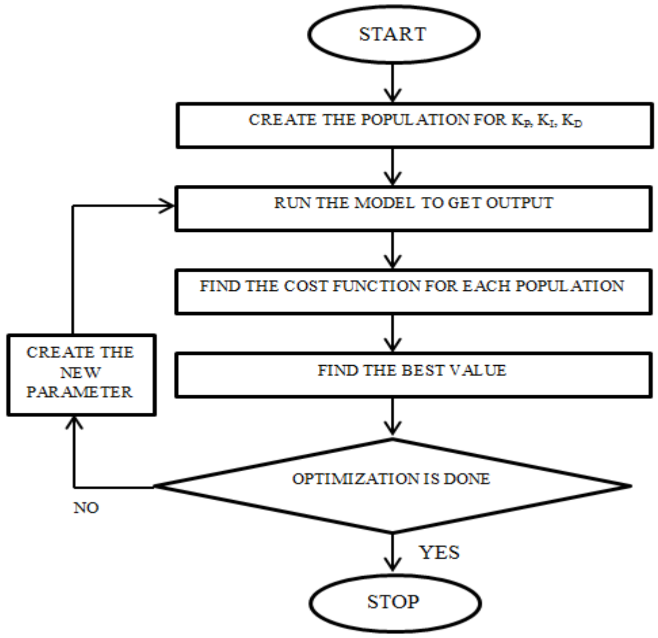

Fig. 5: Flow chart for tuning of PID using Genetic Algorithm (GA)

Table 1, where 7 membership function, NB, NM, NS, Z, PS, PM and PB represent negative big, negative medium, negative small, zero, positive small, positive medium and positive big, respectively make 49 (7×7) rule (Verma *et al*., 2013).

Evolutionary (GA controller) technique: The genetic algorithm is a robust optimization technique based on natural selection. A possible solution to a specific problem is seen as an individual. A collection of a number of individuals is called a population. The current population reproduces new individuals that are called the new generation. The new individuals of the new generation are supposed to have better performance than the individuals of the previous generation. GA has been successfully implemented in the area of industrial electronics, system identification, control robotic, pattern recognition, planning and scheduling (Bhati and Nitnawwre, 2012; Man *et al*., 1996), flow chart shown in Fig. 5.

RESULTS AND DISCUSSION

All the results are carried out by using MATLAB/Simulink to investigate the performance of four areas reheat thermal system. The power system parameters are given in appendix. The step load disturbance of 0.01 p.u was applied in four areas for all the cases and deviations in frequency and responding tie-line power were investigated. The AGC performance through PI and Fuzzy logic technique is compared with GA (Using tuning of PID Technique). The change in frequency and corresponding tie-line deviation under the load disturbances of 0.01 p.u in four areas are shown in Fig. 6 to 29. Comparative value of settling time shown in Table 2, it is observed that the evolutionary (GA for tuning of PID Controller) technique improve the dynamic performance of the system as compared to the conventional (PI) and intelligent (Fuzzy Logic) techniques.

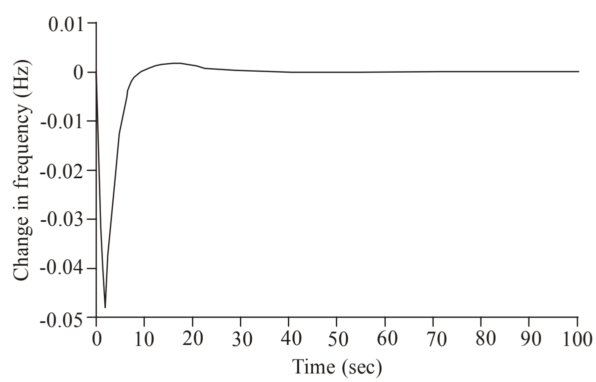

Fig. 6: Frequency response of area 1 with PI controller

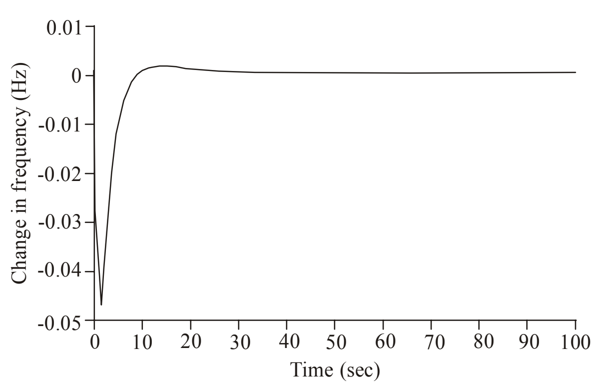

Fig. 7: Frequency response of area 2 with PI controller

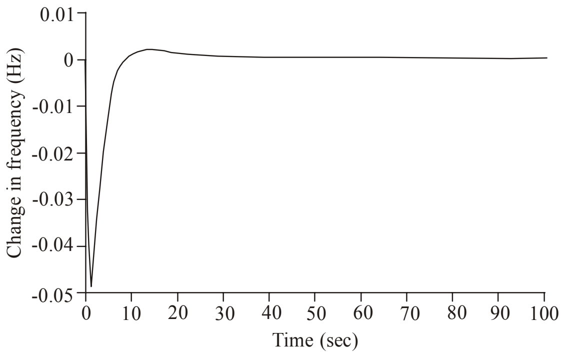

Fig. 8: Frequency response of area 3 with PI controller

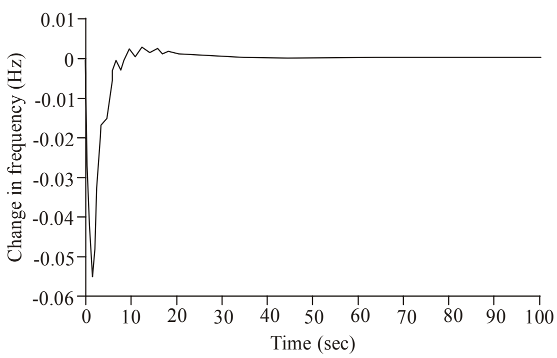

Fig. 9: Frequency response of area 4 with PI controller

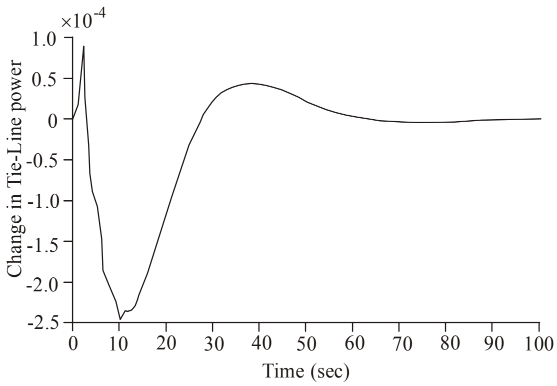

Fig. 10: Tie-line response of area 1 with PI controller

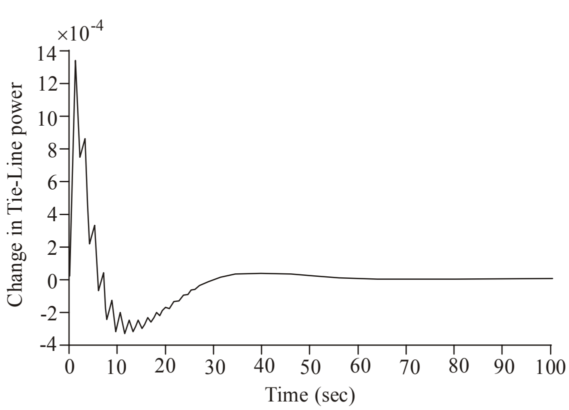

Fig. 11: Tie-line response of area 2 with PI controller

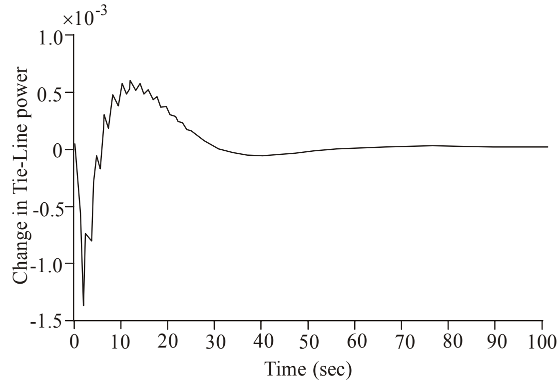

Fig. 12: Tie-line power response of area 3 with PI controller

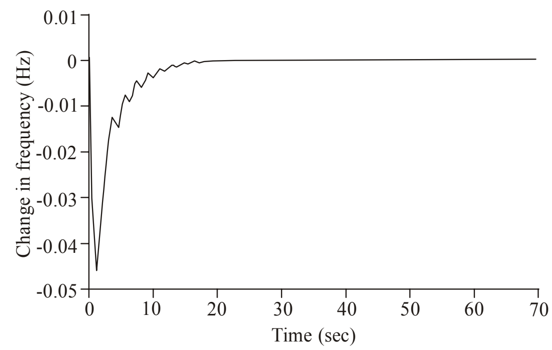

Fig. 13: Tie-line power response of area 4 with PI controller

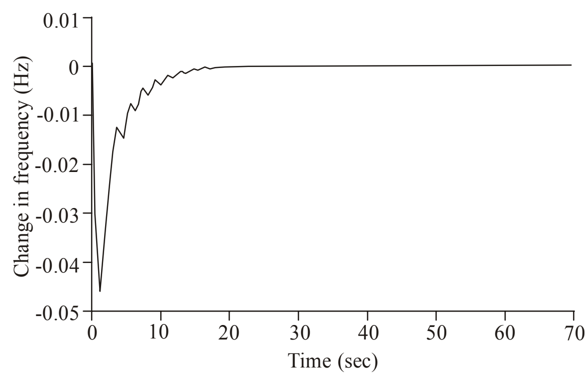

Fig. 14: Frequency response of area 1 with fuzzy controller

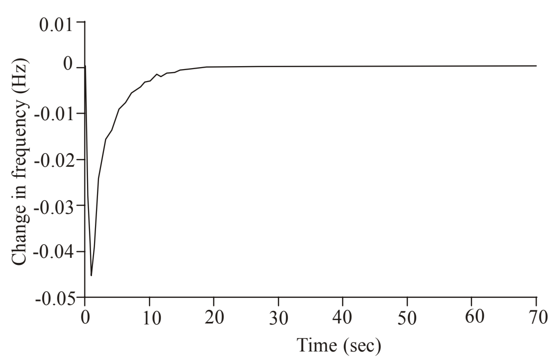

Fig. 15: Frequency response of area 2 with fuzzy controller

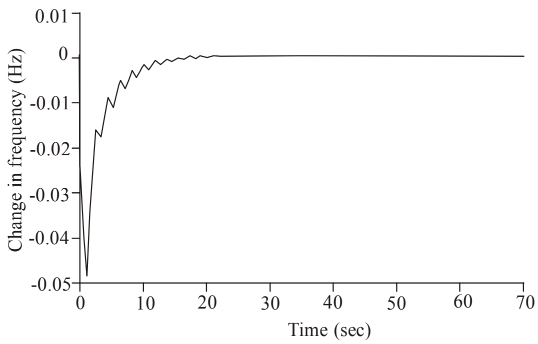

Fig. 16: Frequency response of area 3 with fuzzy controller

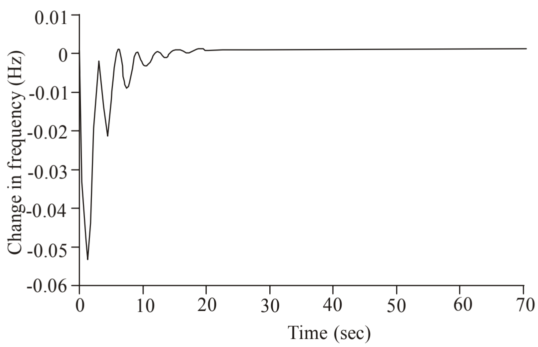

Fig. 17: Frequency response of area 4 with fuzzy controller

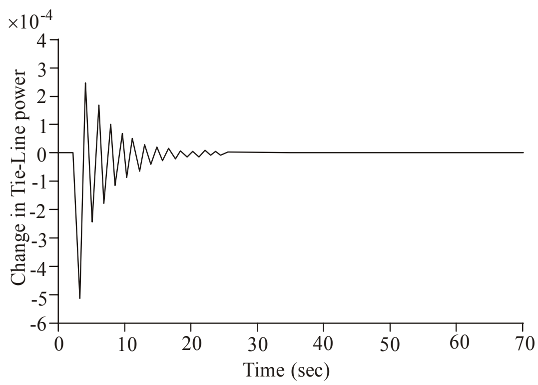

Fig. 18: Tie-line power response of area 1 with fuzzy controller

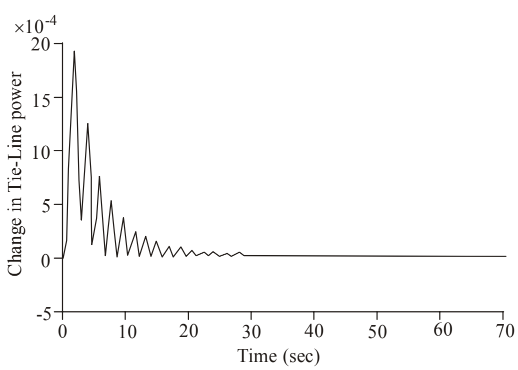

Fig. 19: Tie-line power response of area 2 with fuzzy controller

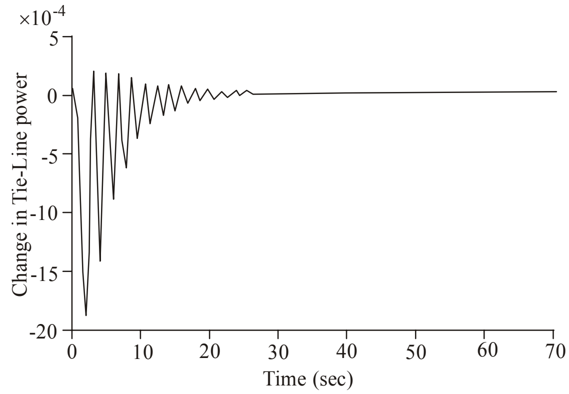

Fig. 20: Tie-line power response of area 3 with fuzzy controller

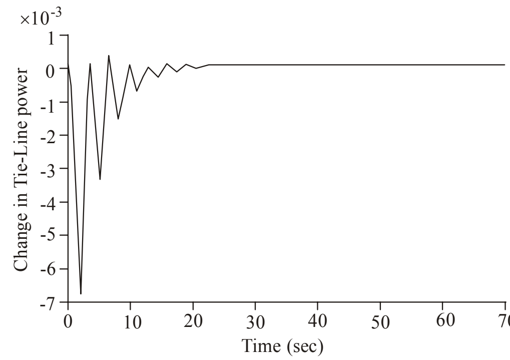

Fig. 21: Tie-line power response of area 4 with fuzzy controller

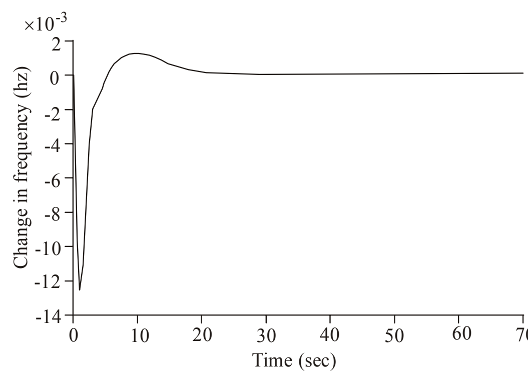

Fig. 22: Frequency response of area 1 with GA controller

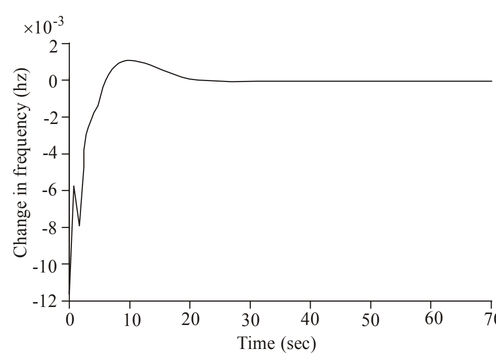

Fig. 23: Frequency response of area 2 with GA controller

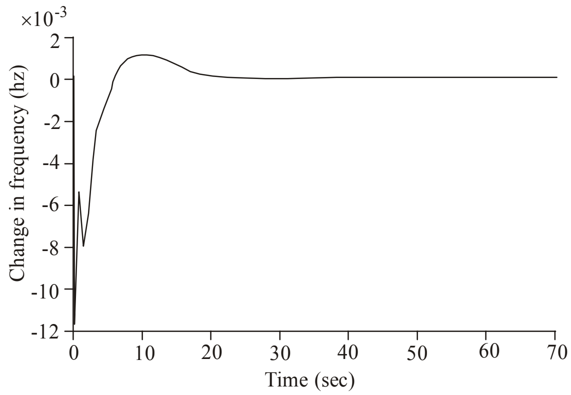

Fig. 24: Frequency response of area 3 with GA controller

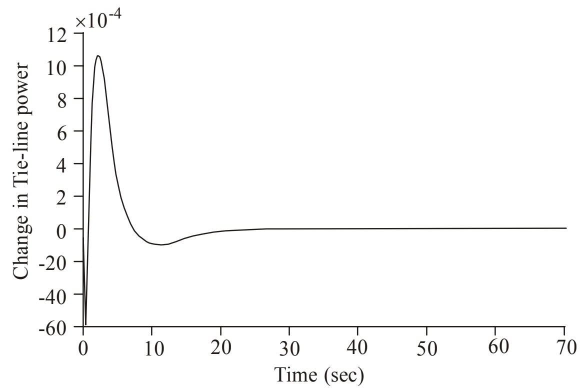

Fig. 27: Tie-line power response of area 2 with GA controller

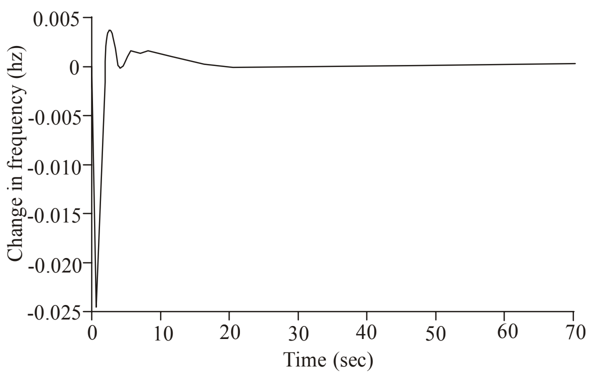

Fig. 25: Frequency response of area 4 with GA controller

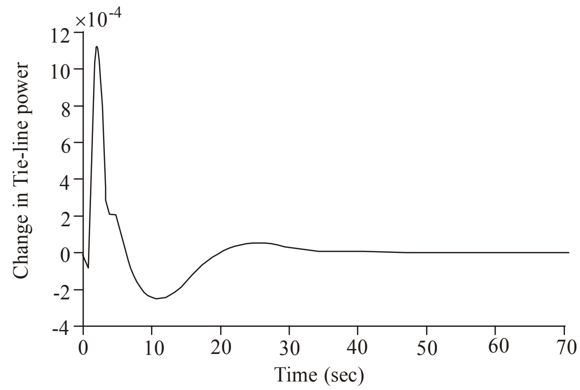

Fig. 28: Tie-line power response of area 3 with GA controller

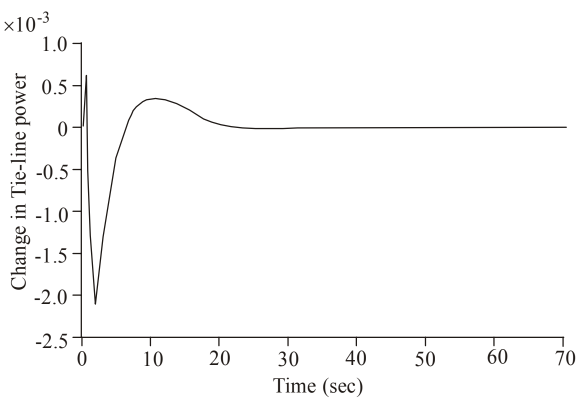

Fig. 26: Tie-line power response of area 1 with GA controller

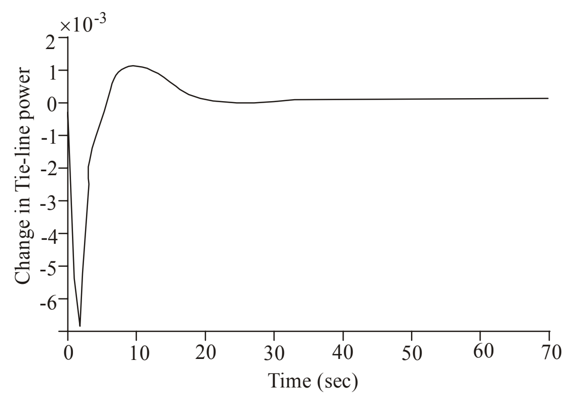

Fig. 29: Tie-line power response of area 4 with GA controller

Table 2: Comparative value of settling time

	Settling time (sec)							
	Frequency deviation				Tie line power deviation			
Controller	Area 1	Area 2	Area 3	Area 4	Area 1	Area 2	Area 3	Area 4
PI	32	33	35	35	65	58	58	50
Fuzzy	23	24	25	20	35	36	36	33
GA	20	20	21	17	32	32	33	32

CONCLUSION

The performance of automatic generation control of four area thermal power system is investigated in this study. To demonstrate the effectiveness of proposed technique, the evolutionary (Genetic Algorithm for tuning of PID controller) technique, intelligent (Fuzzy Logic) and conventional (PI) technique is applied. The performance of these techniques is evaluated through the MATLAB Simulink software. The results are tabulated in Table 2 respectively.

The results of proposed technique that is evolutionary technique have been compared with conventional and intelligent technique and it shows that the proposed technique give good dynamic performances and results. So it can be concluded that the evolutionary technique give better settling performance than the intelligent and conventional controllers.

NOMENCLATURE

AGC	:	Automatic Generation Control
P_{ri}	:	Rated power capacity of area i
f	:	Nominal system frequency
Δf	:	Change in supply frequency
D_i	:	System damping area i
T_{sg}	:	Speed governor time constant
T_t	:	Steam turbine time constant
T_{ps}	:	Power system time constant
K_{sg}	:	Speed governor gain constant
K_t	:	Steam turbine gain constant
K_{ps}	:	Power system gain constant
b_i	:	Frequency bias parameter
ΔP_{Di}	:	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
$P_{tie\ max}$	:	Tie-line power

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APPENDIX

Power system parameters are as follows:
$f = 60Hz$;
$R_1 = R_2 = R_3 = R_4 = 2.4$ Hz/p.u MW;
$T_{sg1} = T_{sg2} = T_{sg3} = T_{sg4} = 0.08$ Sec;
$T_{ps1} = T_{ps2} = T_{ps3} = T_{ps4} = 20$ Sec;
$Tt_1 = Tt_2 = Tt_3 = Tt_4 = 0.3$ Sec;
$Tr_1 = Tr_2 = Tr_3 = Tr_4 = 10$ Sec;
$Kr_1 = Kr_2 = 0.5$ TU;
$Kr_3 = 3.33$ TU;
$Kr_4 = 3$TU; $a_{12} = a_{23} = a_{34} = a_{41} = 1$;
$H_1 = H_2 = H_3 = H_4 = 5$ MW-S/MVA;
$P_{r1} = P_{r2} = P_{r3} = P_{r4} = 2000$ MW;
$K_{ps1} = K_{ps2} = K_{ps3} = K_{ps4} = 120$ Hz/pu MW;
$K_{sg1} = K_{sg2} = K_{sg3} = K_{sg4} = 1$;
$K_{t1} = K_{t2} = K_{t3} = K_{t4} = 1$;
$D_{1234} = 8.33*10^{-3}$ p.u MW/Hz.;
$b_{1234} = 0.425$ p.u. MW/hz;
$\Delta P_{D1234} = 0.01$ p.u;
$T_{12} = T_{23} = T_{34} = T_{41} = 0.0867$ MW/Radian;
$P_{tiemax} = 200$ MW.

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