Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

Automatic Generation Control of Two Area Power System with Hybrid Control Technique

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***Abstract*: In this paper dynamic performance of Automatic Generation Control (AGC) for two area power system with conventional PID and Fuzzy PID controller with different load disturbance and for different systems is presented. AGC plays an important role in multi area power system to maintain system frequency and tie-line powers at their normal values. The performance analysis of AGC for two area power system done in MATLAB/SIMULINK environment. The simulation results show that the Fuzzy-PID controller gives improved dynamic performance of system compared to conventional PID controller.**

Keywords: Automatic Generation Control, Load Frequency Control, Proportional Integral Derivative Controlling Techniques, Fuzzy Logic Controller, Tie Line Power, Settling Time, Peak Over Shoot, Fuzzy - PID.

I. INTRODUCTION

Power systems consist of control areas representing a coherent group of generators. These control areas are interconnected through tie-lines for providing exchange of power and to eliminate mismatch between generation and demand in addition to their own generations under normal operating conditions. Due to sudden disturbances or some other reasons if the generated active power less than the actual power demand the frequency of generating units tends to decreases. This causes system frequency deviates from its nominal value which is undesirable. To damp out frequency deviation and to keep tie line power at its scheduled value Automatic Generation Control is used. Automatic generation control (AGC), is a major control function within a utility's energy control centre, for tracking load variations while maintaining system frequency, net tie-line interchanges, and optimal generation levels close to scheduled values. The reason to keep system frequency constant is speed of ac motors are directly related to frequency, steam and hydro turbine blades are gets damaged if frequency variations are large and also operation of transformer below rated frequency is not desirable. The AGC loop continuously regulates the active power output of the generator to match with the randomly varying load.

In order to improve stability and performance of AGC, a very fast accurate and robust controller is required to maintain system nominal frequency. The well-known proportional-integral-derivative (PID) controllers are still widely employed in industrial process control though many control theories have been developed. The popularity of a PID controller is due to its good performance and functional simplicity [1]-[4]. The disadvantage of the conventional controllers are they exhibit poor dynamic performance especially in the presence of parameter variations, Loading conditions and nonlinearities. So it is required a flexible controller to improve the performance of the system under these conditions. Artificial intelligence techniques such using algorithms like fuzzy logic [7], [8], [9] [10], Artificial Neural Networks (ANN) [5], Hybrid Fuzzy ANN [6] to improve dynamic performance of system under such conditions.

This study uses Fuzzy – PID controller for AGC problem. For comparative analysis proportional-integral-derivative (PID) controller has also been implemented. The results obtained show that the Fuzzy PID control scheme give good dynamic response with respect to conventional controllers.

The two-area interconnected thermal power system taken in this study. The model of the power system is as shown in Fig. 1. The control task is to minimize the system frequency deviation Δf_1 in area 1, Δf_2in area 2 and the deviation in the tie-line power flowΔP_{12} between the two areas under the load disturbances ΔP_{L1} andΔP_{L2} in the two areas. This is achieved conventionally with the help of controller which acts on ACE which is an input signal to the controller. Error input to the controller are respective area control errors (ACE) given by

$$\boldsymbol{e_1} = ACE_1 = B_1\Delta f_1 + \Delta P_{12} \text{ --- (1)}$$
$$\boldsymbol{e_2} = ACE_2 = B_2\Delta f_2 + \Delta P_{12} \text{ --- (2)}$$

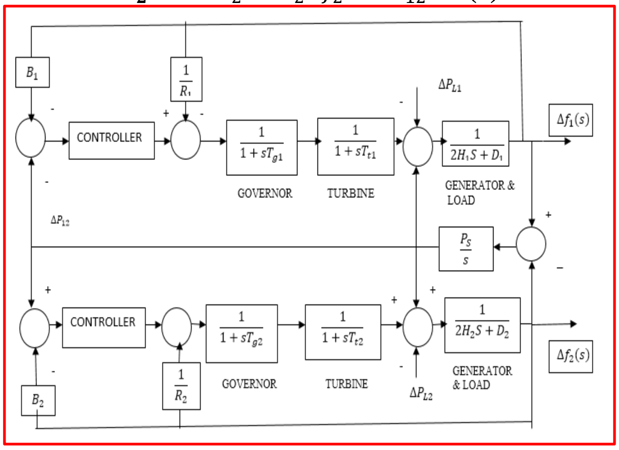

Fig:1.Transfer function model of two area inter connected power system

II. PID CONTROLLER

Proportional-Integral-Derivative (PID) control is the most common control tool in many industrial controlling applications because they can improve both transient response and steady state error of the system. The parameters of PID controller are proportional, integral and derivative which are varied to get optimal response shown in fig:2.

In general, increasing the proportional gain will increase the speed of the control system response. However, if the proportional gain is too large, the process variable will begin to oscillate. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero. Increasing the derivative time (T_d) parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response.

The transfer function of a PID controller has the following form

$$G_C(s) = k_p + \frac{k_i}{s} + k_d(s) \text{ --- (3)}$$

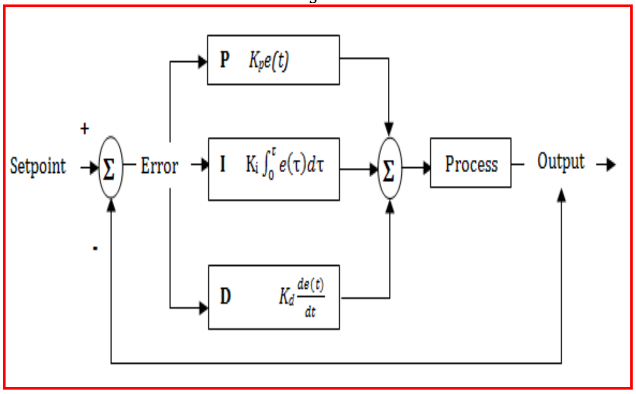

Fig:2. Block diagram of PID controller

Where, k_p, k_i, and k_d are the proportional, integral, and derivative gains, respectively. In this work PID controller is designed and tuned using the method proposed in paper [4].

III. FUZZY-PID CONTROLLER

The parameters of a classical PID controller are fixed during operation. Consequently, such a controller is inefficient for control a system while the system is disturbed by surrounding environment and presence of nonlinearities in the system.

Fuzzy logic technology has the ability to give approximate recommended solution for unclear and complicated systems. It uses simple rules to explain behaviour of the system instead of using analytical equations, which makes it easy to implement. Fuzzy logic contains three primary elements fuzzification stage, rule base and defuzzification stage. In fuzzification stage crisp values of input variables are transformed into fuzzy membership values. Here are no general rules to select those variables, although typically the variables chosen are the states of the controlled system, their errors, error variation. Then, these membership values are processed within rule–base using conditional if-then statements. The output are summed and transformed input crisp values by using defuzzification procedure for appropriate control action.

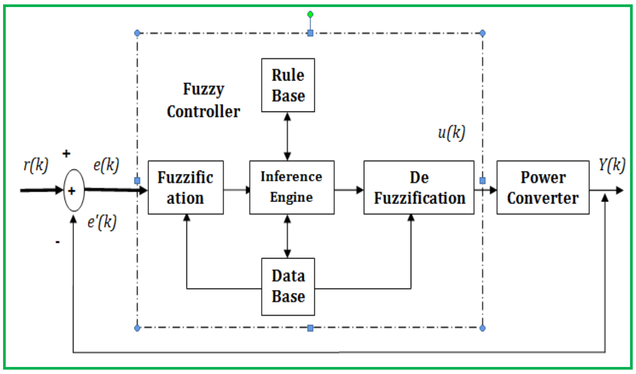

Fig:3. Block diagram of fuzzy logic controller

Conventional PID controllers are sensitive to variations in the system parameters, fuzzy controllers do not need precise information about the system variables in order to be effective. However, PID controllers are better able to control and minimize the steady state error of the system. To enhance the controller performance, hybridization of these two controller structures is done to utilize the advantages of both PID controller and fuzzy controller.

Like conventional PI or PD controllers, FLCs also have PI-type or PD-type and PID controllers. Essentially, a FLC design includes the type of FLC, the number and shape of membership functions (MFs), and the fuzzy rules. The block diagram of Fuzzy-PID controller in shown in Fig.4.

Fuzzy controller uses error (e) and derivative of error (de) as input signals. The input scaling factors are the tuneable parameters K_1 and K_2. The proportional, integral and derivative gains of fuzzy PID controller are represented by K_P, K_D and K_I respectively. Block diagram of fuzzy PID controller shown in fig:4.

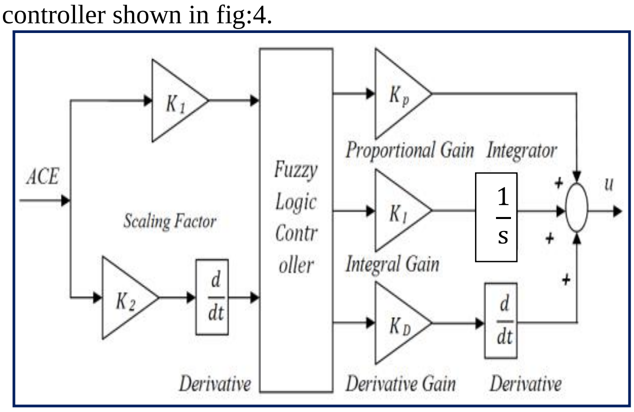

Fig:4. Block diagram of fuzzy PID controller

In this triangular membership functions are used with seven fuzzy linguistic variables such as NB (negative big), NM (negative medium), NS (negative small), Z (zero), PS (positive small), PM (positive medium) and PB (positive big) for both the inputs and the output. Membership functions for error, error derivative and FLC output are shown in Fig 5-7 respectively. Mamdani fuzzy interface engine is selected for this work. The FLC output is determined by using centre of gravity method of defuzzification. The two dimensional rule base for error, error derivative and FLC output is shown in the table1.

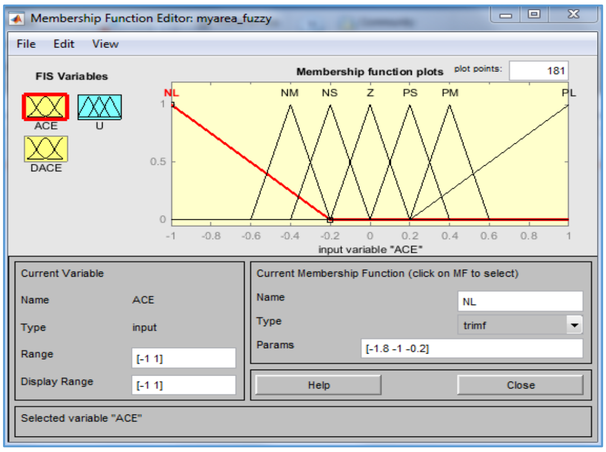

Fig:5. Membership function for Error

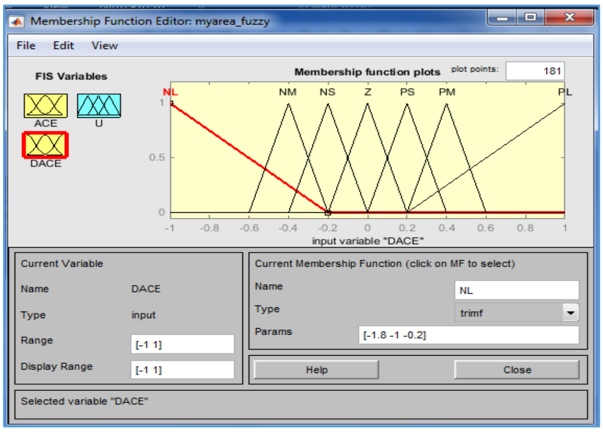

Fig:6. Membership function for Change in Error

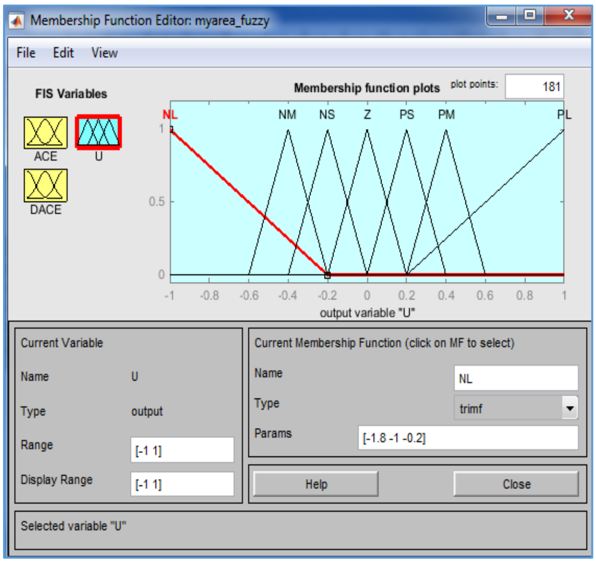

Fig:7. Membership function for FLC output

Table:1. Rule base for error, change in error, FLC output

		Error (e)						
		NB	NM	NS	Z	PS	PM	PB
Change in Error (de)	NB	NB	NB	NB	NB	NM	NS	Z
	NM	NB	NB	NB	NM	NS	Z	PS
	NS	NB	NB	NM	NS	Z	PS	PM
	Z	NB	NM	NS	Z	PS	PM	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PB	Z	PS	PM	PB	PB	PB	PB

IV. SIMULATION RESULTS AND COMPARATIVE ANALYSIS

(A). Simulation are performed on two area power system using PID and Fuzzy-PID controller under consideration. System parameters for two area power system for three cases is shown is shown in Appendix. The control parameters of PID controller proportional gain, integral gain and derivative gain are shown in Table 9. The frequency deviations of two area power system with PID Controller are shown from Fig.8 to Fig.13 for the case1, case2 and case3 respectively.

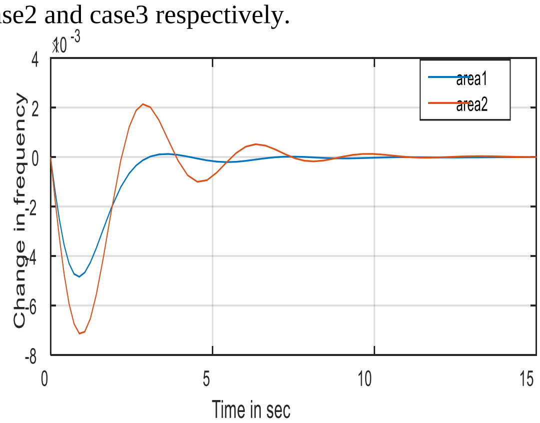

Fig:8. Frequency deviation of system in case1 for 0.1pu load change

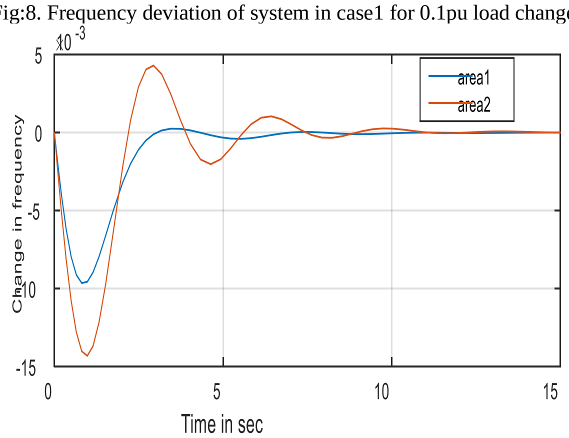

Fig:9. Frequency deviation of system in case1 for 0.2pu load change

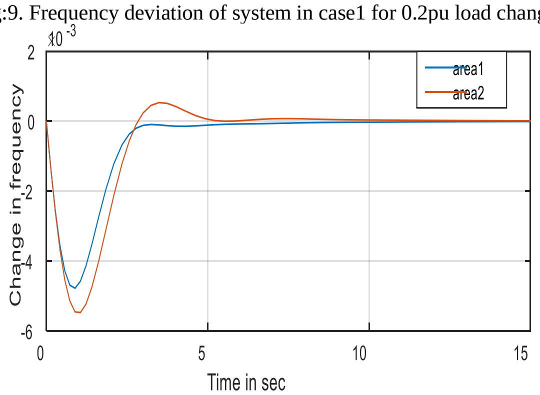

Fig:10. Frequency deviation of system in case2 for 0.1pu load change

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

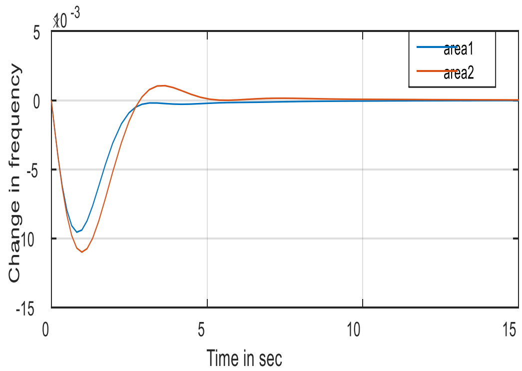

Fig:11. Frequency deviation of system in case2 for 0.2pu load change

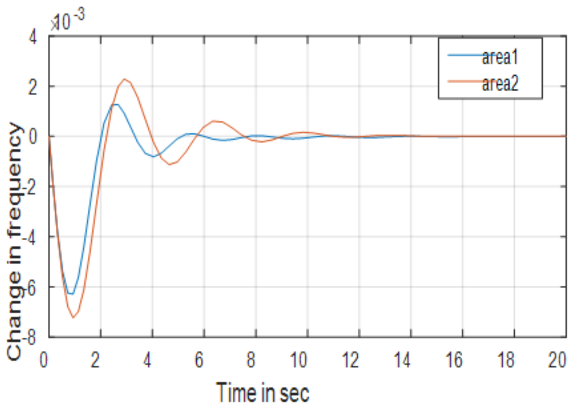

Fig:12. Frequency deviation of system in case3 for 0.1pu load change

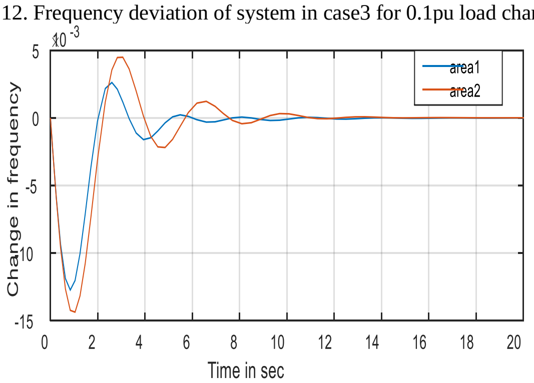

Fig:13 Frequency deviation of system in case3 for 0.2pu load change

(B). System parameters for two area power system for three cases is shown is shown in Appendix. The control parameters of Fuzzy- PID controller K_1, K_2, K_P, K_I, and K_d are shown in table 10. The frequency deviations of two area power system with Fuzzy-PID controller are shown from Fig.14. to Fig.19.

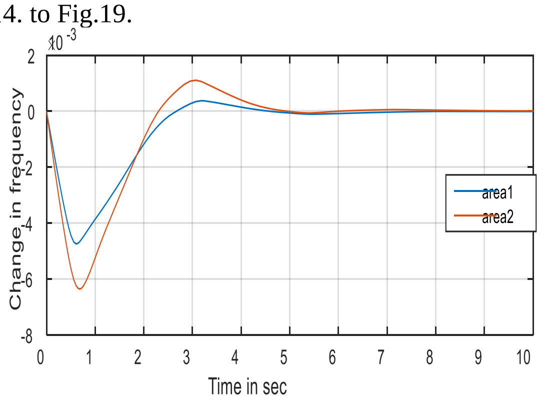

Fig:14. Frequency deviation of system in case1 for 0.1pu load change

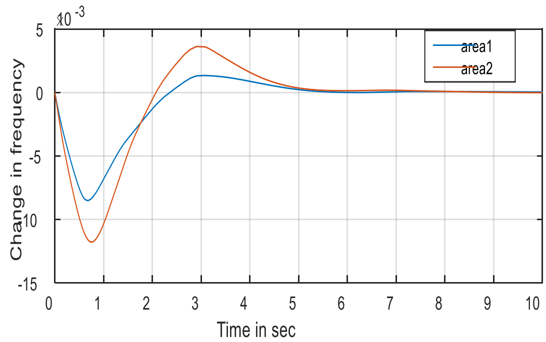

Fig:15. Frequency deviation of system in case1 for 0.2pu load change

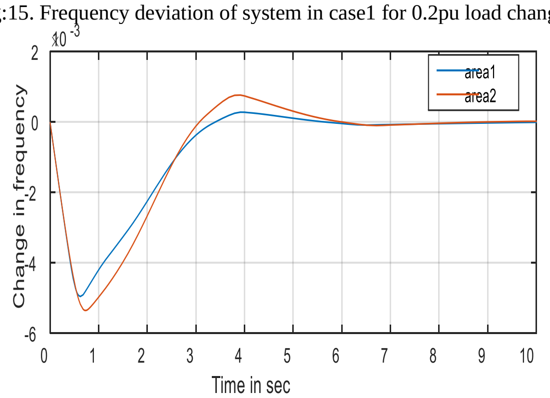

Fig:16. Frequency deviation of system in case2 for 0.1pu load change

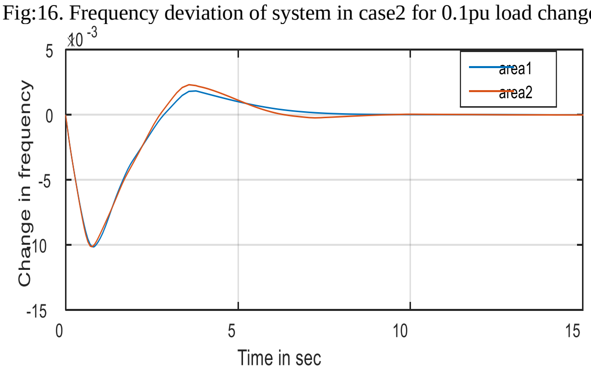

Fig:17. Frequency deviation of system in case2 for 0.2pu load change

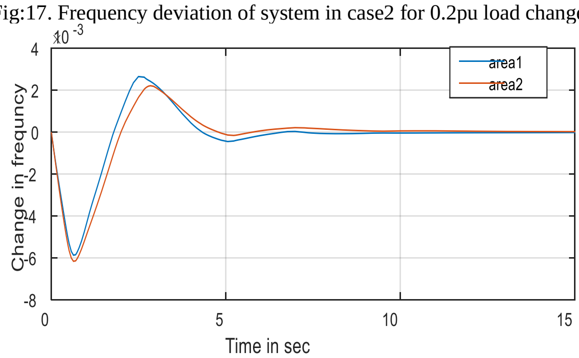

Fig:18. Frequency deviation of system in case3 for 0.1pu load change

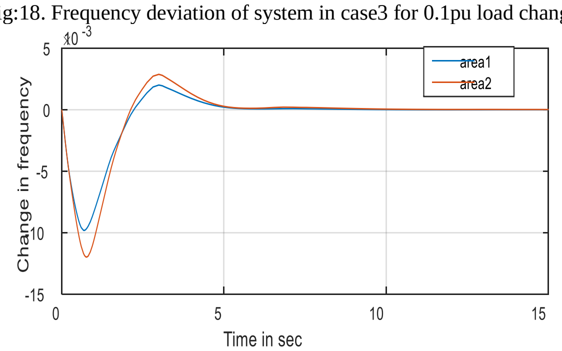

Fig:19. Frequency deviation of system in case3 for 0.2pu load change

Table2: Different parameter response for AGC with PID

AGC with PID Load variation (10%)		Case1	Case2	Case3
Area1	Settling time (sec)	10	14	14
	Maximum overshoot	$-4.5x10^{-3}$	$-4.7x10^{-3}$	$-6x10^{-3}$
Area2	Settling time (sec)	12	11	12
	Maximum overshoot	$-7.2x10^{-3}$	$-5.5x10^{-3}$	$-7.5x10^{-3}$

Table3: Different parameter response for AGC with PID

AGC with PID Load variation (20%)		Case1	Case2	Case3
Area1	Settling time (sec)	11	14	13
	Maximum overshoot	$-10x10^{-3}$	$-9.5x10^{-3}$	$-13x10^{-3}$
Area2	Settling time (sec)	12	12	14
	Maximum overshoot	$-12\ x10^{-3}$	$-11\ x10^{-3}$	$-14x10^{-3}$

Table4: Different parameter response for AGC with Fuzzy- PID

AGC with Fuzzy-PID Load variation (10%)		Case1	Case2	Case3
Area1	Settling time (sec)	8	8	7
	Maximum overshoot	$-4.5x10^{-3}$	$-4.7x10^{-3}$	$-6x10^{-3}$
Area2	Settling time (sec)	7	5	5
	Maximum overshoot	$-6.2x10^{-3}$	$-5.5x10^{-3}$	$-6.5x10^{-3}$

Table5: Different parameter response for AGC with Fuzzy- PID

AGC with Fuzzy-PID Load variation (20%)		Case1	Case2	Case3
Area1	Settling time (sec)	5.5	5	5
	Maximum overshoot	$-8.5\ x10^{-3}$	$-7\ x10^{-3}$	$-10\ x10^{-3}$
Area2	Settling time (sec)	7	6	6
	Maximum overshoot	$-11\ x10^{-3}$	$-9\ x10^{-3}$	$-12\ x10^{-3}$

V CONCLUSION

The frequency response analysis of two area AGC is analysed with PID and Fuzzy-PID controllers for different disturbances for different systems. It can be concluding that by using conventional PID controller number of oscillations, peak overshoot and settling time are high. To reduce oscillations, peak over shoot and settling time Fuzzy- PID controller is employed. The simulation results show that Fuzzy- PID controller gives better results in system response. The load frequency control is used to maintain zero steady state error. The reliable power supply has the characteristic of minimum frequency deviation and quality of power supply is determined by having constant frequency.

Appendix:

Table 6: Numerical values of two area power system model for case1

Parameters	Case 1 Area1(pu)	Case 1 Area2(pu)
Regulation	$R_1 = 0.05$	$R_2 = 0.0625$
Load frequency sensitivity coefficient	$D_1 = 0.6$	$D_2 = 0.09$
Inertia	$M_1 = 10$	$M_2 = 8$
Base power	1000MVA	1000MVA
Governor time constant	0.2	0.3
Prime mover time constant	0.5	0.6
Synchronizing power coefficient	2	

Table7: Numerical values of two area power system model for case2

Parameters	Case 2 Area1(pu)	Case 2 Area2(pu)
Regulation	$R_1 = 0.05$	$R_2 = 0.05$
Load frequency sensitivity coefficient	$D_1 = 0.6$	$D_2 = 0.6$
Inertia	$M_1 = 10$	$M_2 = 10$
Base power	1000MVA	1000MVA
Governor time constant	0.2	0.2
Prime mover time constant	0.5	0.5
Synchronizing power coefficient	2	

Table8: Numerical values of two area power system model for case3

Parameters	Case 3 Area1(pu)	Case 3 Area2(pu)
Regulation	$R_1 = 0.05$	$R_2 = 0.05$
Load frequency sensitivity coefficient	$D_1 = 0.6$	$D_2 = 0.6$
Inertia	$M_1 = 10$	$M_2 = 10$
Base power	1000MVA	1000MVA
Governor time constant	0.2	0.2
Prime mover time constant	0.5	0.5
Synchronizing power coefficient	2	

Table9: Different parameters of two area with PID controller

Inter connected area	Optimum parameters	PID controller
Area 1	k_I	0.7
	k_p	0.25
	k_D	0.33
Area 2	k_I	0.7
	k_p	0.25
	k_D	0.33

Table10: Different parameters of two area with Fuzzy- PID controller

Inter connected area	Optimum Parameters	PID controller
Area 1	k_I	0.7
	k_p	0.25
	k_D	0.33
	k_1	2.5
	k_2	1
Area 2	k_I	0.7
	k_p	0.25
	k_D	0.33
	k_1	2.5
	k_2	1

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