

Automatic Load Frequency Control in Three Area Power System Using Fuzzy PI Controller

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Abstract: - In this paper, the dynamic performance of automatic load frequency control of three-area power system is done by using PI Fuzzy controller. When load changes then, there is drift in system frequency and voltage which in turn leads to loss in generation owing to blackouts and line tripping. Main objectives of automatic load frequency control in each area are to supply load demand and to minimize tie-line power deviations, to minimize transient deviations, to improve steady-state error and to match the output power of generator with change in load. Thus, simulation evaluation is done to know the working of ALFC by building Simulink models in single area, two area and three area power system.

Index terms- Automatic Load frequency control, Area control error (ACE), Proportional integral derivative (PID) controller, Fuzzy PI Controller Matlab/Simulation.

NOMENCLATURE

Δp_{ref} = Incremental speed reference setting
 Δp_m = Turbine output
 Δp_G = Active power generation
 Δp_D = Active power demand
 Δp_V = Input to the turbine
 Δp_T = Output from the turbine
 P_{12} = Power due to tie-lines
 T_g = time constant of the generator

I. INTRODUCTION

Automatic load frequency control (ALFC) is very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. ALFC is basically the active power control and the frequency control. The interconnected areas of power system are divided in to three areas that are governor, turbine and generator. These all form a coherent group. In electrical power system, LFC is used for automatic generation control. One of the objectives of AGC is that there should be adjustable frequency in each area according to the control and each area should

accomplish its individual demand in load. The load demand increases or decreases in form of the kinetic energy which is stored in generator which results in variation of frequency and speed accordingly. Thus, for the safe operation of power system, the aim is to control the frequency. Since, load demand varies without prior schedule. So, frequency and voltage controller are required to maintain the generated power quality so, as to supply constant voltage and frequency to the grid.

II. LOAD-FREQUENCY CONTROL

Basically, automatic load controller determines control parameters, or determines actual value to a desired value or defines deviations in order to have deviations to be zero so that control parameters can be obtained. Main function of load frequency is to ensure stable and reliable operation of power system. The PID controller is very simple for implementation and gives better dynamic response. In a system if load occurs, the frequency also changes. If it was not important to keep frequency to a steady state or constant then, no regulation control would be required. Normally the frequency would vary by 5% approx. from light load to full load conditions. So, for the satisfactory operation of the system there should be frequency control so, that in parallel motors should run at a desired speed and time is noted by using synchronous clock.

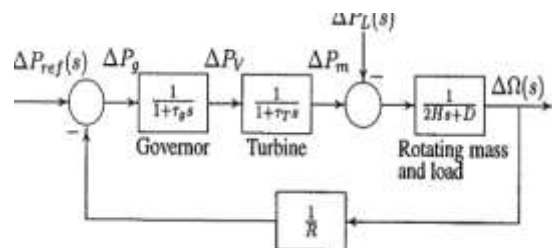


Fig.1.1 Block diagram of Automatic load frequency control

Automatic load frequency control is associated with large sized generators. Main aim of ALFC is to have frequency control so as to divide the loads among generators in order to have exchange of tie-line

power n accordance to the scheduled values. Primary control loop reacts to frequency changes through the speed governor and the hydro flow is managed. Thus speed, and frequency control is performed by primary loop. Secondary loop is slower as compared to primary loop. Excellent regulation of frequency is maintained by secondary loop. This loop is insensitive to load changes as well as frequency.

III. PID Controller

PID is known as proportional integral derivative controller. In proportional control action, the output of controller have continuous linear relationship with the actuating error signal (e). This is also known as amplifier with adjustable gain. In integral control action, the output of the controller is proportional to the actuating signal. This is also known as reset controller. In derivative control action, the output of the controller depends upon the actuating signal. PID controller is found to be superior over integral controller for automatic load frequency control (ALFC) because it has less oscillations, good dynamic response, improved steady-state error, reduce transient deviations and less settling time.

IV. ALFC by using Fuzzy PI Controller

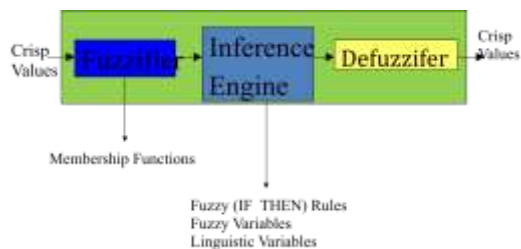


Fig. 4.1 Block Diagram of Fuzzy System

This paper presents the real-time implementation of a fuzzy coordinated classical PI control scheme for controlling the pressure in a pilot pressure tank system. The fuzzy system has been designed to track the variation parameters in a feedback loop and tune the classical controller to achieve a better control action for load disturbances and set point changes. The error and process inputs are chosen as the inputs of fuzzy system to tune the conventional PI controller according to the process condition. This online conventional controller tuning technique will reduce the human involvement in controller tuning and increase the operating range of the conventional controller. The proposed control algorithm is experimentally implemented for the real-time pressure control of a pilot air tank system and validated using a high-speed 32-bit ARM7 embedded microcontroller board. To demonstrate the

performance of the fuzzy coordinated PI control scheme, results are compared with a classical PI and PI-type fuzzy control method. It is observed that the proposed controller structure is able to quickly track the parameter variation and perform better in load disturbances and also for set point changes.

V. SIMULATION RESULTS

By using simulation models we can obtain the performance characteristics of the system very easily and quickly for analysis purpose. Below are the various simulink models with their respective response plotted against time for single area, two areas and for three areas power system.

(a) For Single area system:-

Name	K _g	T _g (s)	K _t	T _t (s)	H (s)	D (puMW/H z)	1/R
Value	1	0.2	1	0.5	5	0.80	30

TABLE 5.1: System parameters for Single Area System without using secondary control

Name	K _g	T _g (s)	K _t	T _t (s)	H (s)	D (pu M W/ Hz)	I/R	K _l
Value	1	0.2	1	0.5	5	0.80	20	7

TABLE 5.2: System parameters for Single Area System by using secondary control

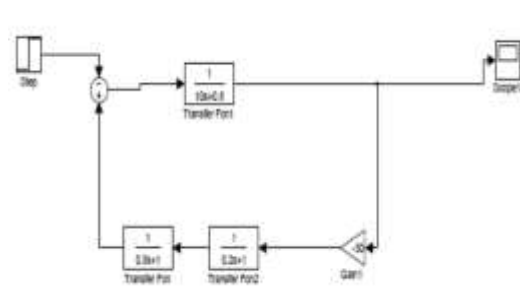


Fig.5.1: Simulink model of single area system without using secondary loop

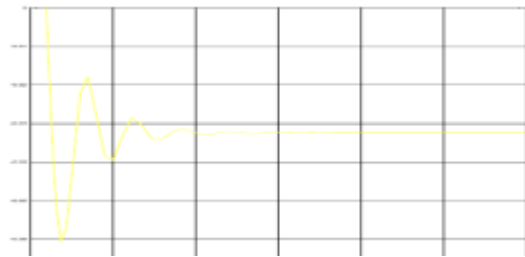


Fig.5.2 Frequency deviation with respect to time

The plot in fig. 5.2 which is obtained from simulating model from fig. 5.1 shows that change in frequency causes change in speed and frequency deviation. We have taken different values of parameters as shown in fig. 5.1.

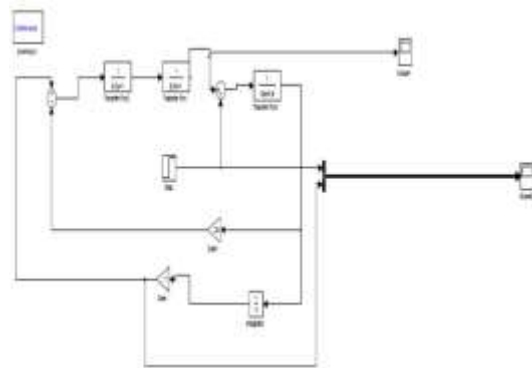


Fig. 5.3 Simulink model by using secondary loop



Fig. 5.4 Change in turbine output with respect to time

Fig.5.3 an integer controller by means of gain K_i is used to regulate the signal of speed reference Δp_{ref} so, that frequency deviation to be zero. Drift in frequency is brought to be zero because of integral

loop. Values of different parameters have been taken shown in the fig. 5.3.

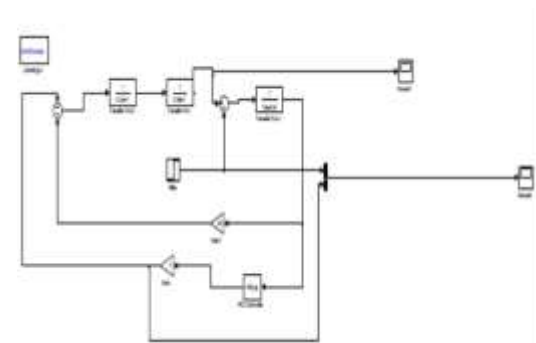


Fig. 5.5 Simulink Model using PID

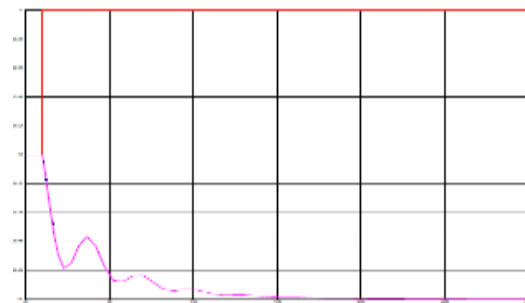


Fig. 5.6 Change in Frequency with respect to time

Fig. 5.5 shows PID controller by setting proportional gain K_p to 1.0 and adjust K_i and K_D until a step response with a min. overshoot and very small settling time is obtained.

(B) For Two Area Power System:-

Name	K_g	T_g (s)	K_t	T_t (s)	H (s)	D (pu M W/ Hz)	$1/R$	ΔP_L (p.u)
Area 1	1	0.20	1	0.50	5	0.60	20	0
Area 2	1	0.30	1	0.60	4	0.90	16	1

TABLE 5.3: System parameters for two area system without using secondary control

Name	K _g	T _g (s)	K _t	T _t (s)	H (s)	D (pu M W/ Hz)	1/R	ΔP_L (p.u)	K ₁
Area 1	1	0.20	1	0.50	5	0.60	20	0	7
Area 2	1	0.30	1	0.60	4	0.90	16	1	7

TABLE 5.4: System parameters for two area system by using secondary control

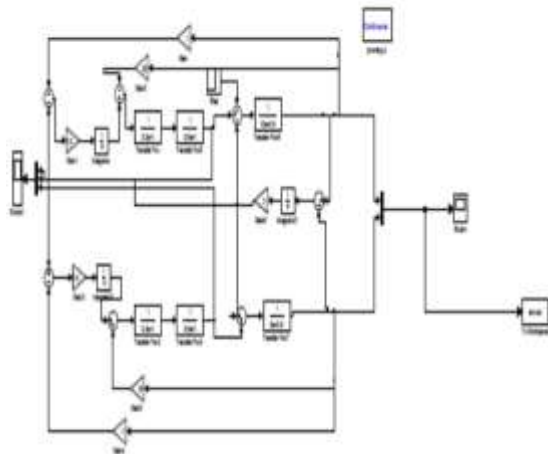


Fig. 5.8 Simulink Model of two area system without integral loop

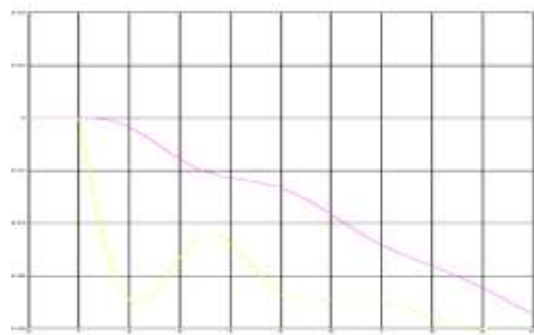


Fig. 5.9 Frequency deviation vs. time

Fig. 5.9 shows that after few oscillations the drift in the frequency will settle down for the interconnected system. Area 1 is capable to reduce the inequality power connected to the load and area 2 is capable of generating excessive power to distribute the variation in load in area 1. Different values of parameters have been taken.

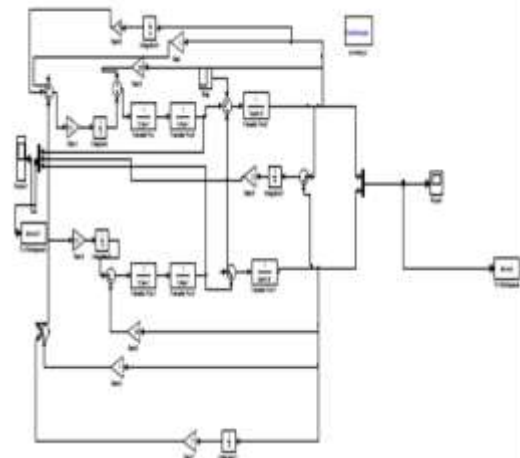


Fig. 5.10 Simulink model with integral loop

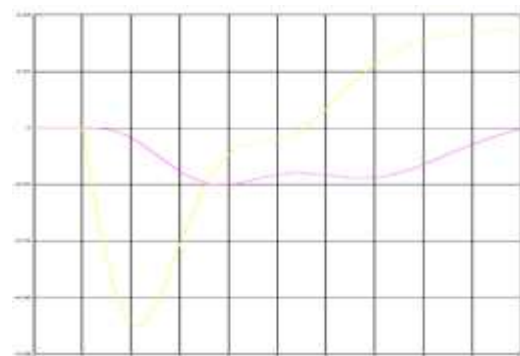


Fig. 5.11 Frequency deviation vs. time

Fig. 5.10 shows two area power system using integral loop. Drift in frequency made to be zero by using secondary loop shown in 5.11. Different values of parameters have been taken.

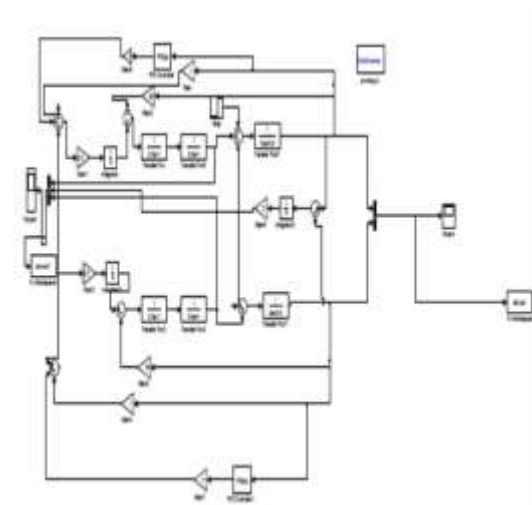


Fig. 5.12 Simulink model using PID

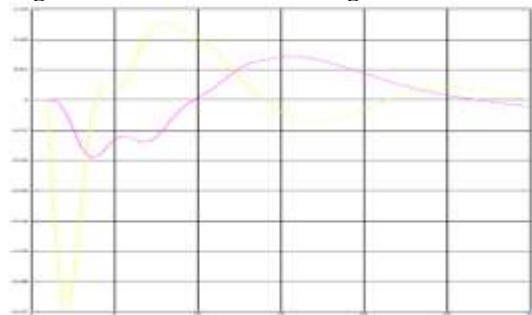


Fig. 5.13 Frequency deviation vs. time

Fig. 5.12 shows simulink model of two area power system using PID controller. PID controller is used over integral because it gives less oscillations, good dynamic response and very small settling time shown in Fig. 5.13. (C) For Three Area Power System:-

Name	K _g	T _g (s)	K _t	T _t (s)	H (s)	D (pu M W/ Hz)	1/R	ΔP L (p.u)
Area 1	1	0.80	1	0.30	10	1.00	15	1
Area 2	1	0.20	1	0.50	5	0.60	20	0
Area 3	1	0.30	1	0.60	4	0.90	16	0

TABLE 5.5: System parameters for three area system without using secondary control

Name	K _g	T _g (s)	K _t	T _t (s)	T _p (s)	H (s)	D (pu M W/ Hz)	K _i	1/R	ΔP L (p.u)
Area 1	1	0.80	1	0.30	20	10	1.00	7	17	1
Area 2	1	0.20	1	0.50	10	5	0.60	7	20	0
Area 3	1	0.30	1	0.60	8	4	0.90	7	16	0

TABLE 5.6: System parameters for three area system with using secondary control

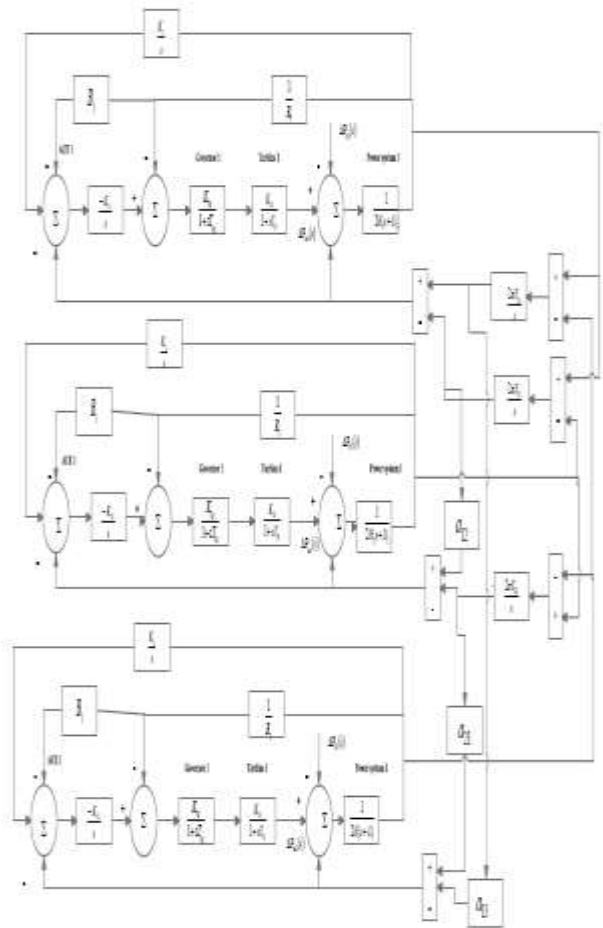


Fig. 5.14 Simulink model of three area power system without integral control

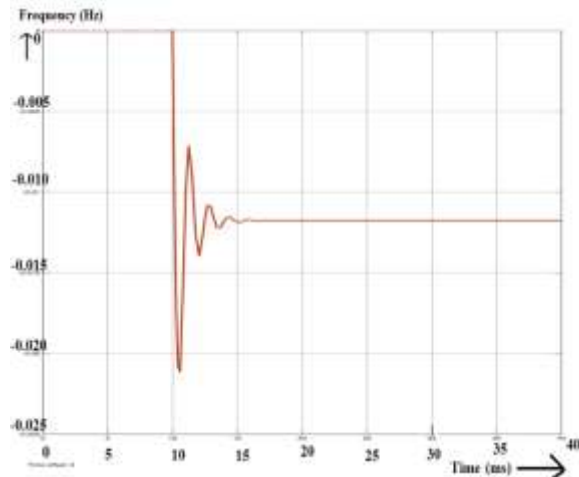


Fig. 5.15 Frequency deviation vs. time

Fig. 5.14 shows three area interconnected system without secondary loop. Fig 4.15 shows finite value of frequency which is less than the actual value. With the interconnection, stability is improved. Different values of parameters have been taken for fig. 5.15.

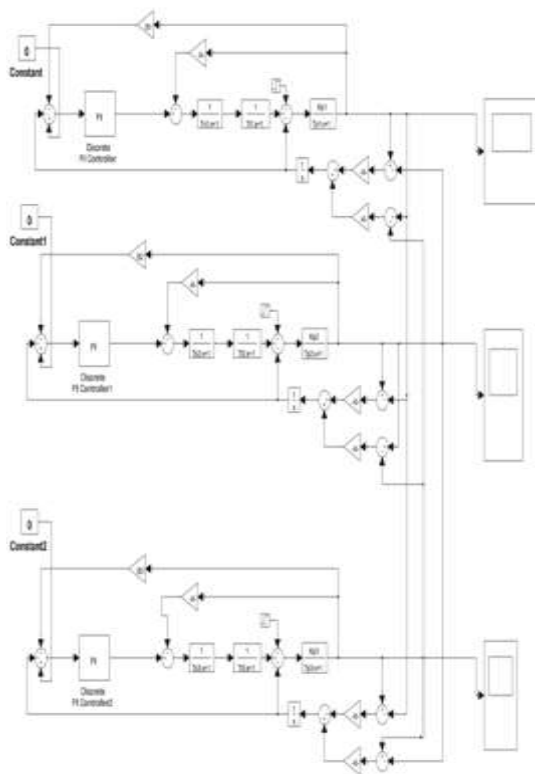


Fig. 5.16 Simulink model of three area power system with PI control

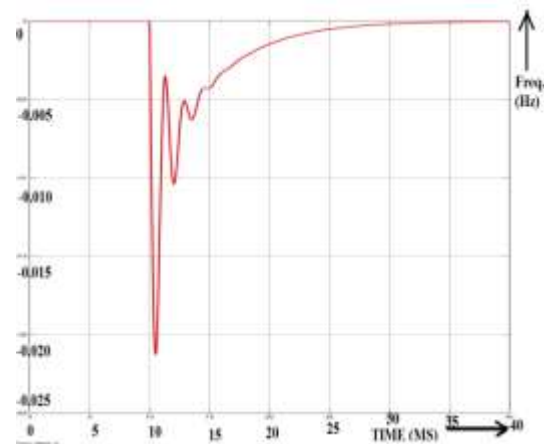


Fig. 5.17 Frequency deviation vs. time

Fig. 5.16 shows the simulink model of three area power system including PI Controller. change in frequency with respect to time are shown in fig. 5.17. Different values of parameters have been taken for fig. 5.17.

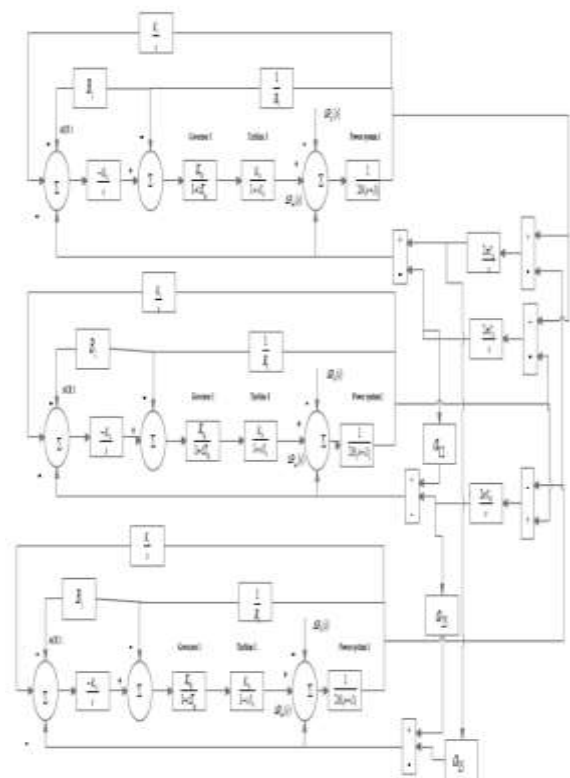


Fig. 5.18 Simulink model using PID

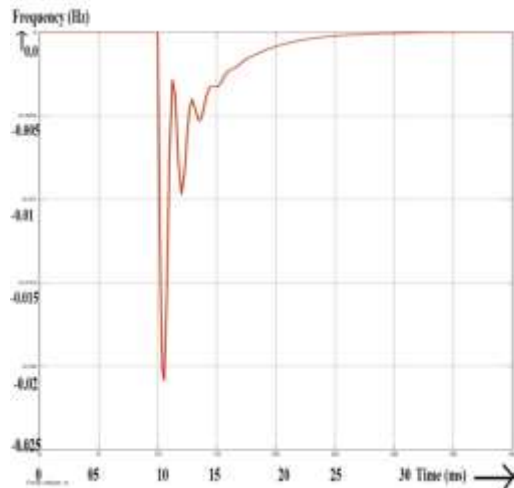


Fig. 5.19 Frequency deviation vs. time

Fig. 5.18 shows simulink model using PID controller. PID controller is used to improve the dynamic response as well as to reduce or to improve steady-state error and to eliminate transient deviations. Change in frequency with respect to time are shown in fig. 5.19. Different values of parameters have been taken for fig. 5.19.

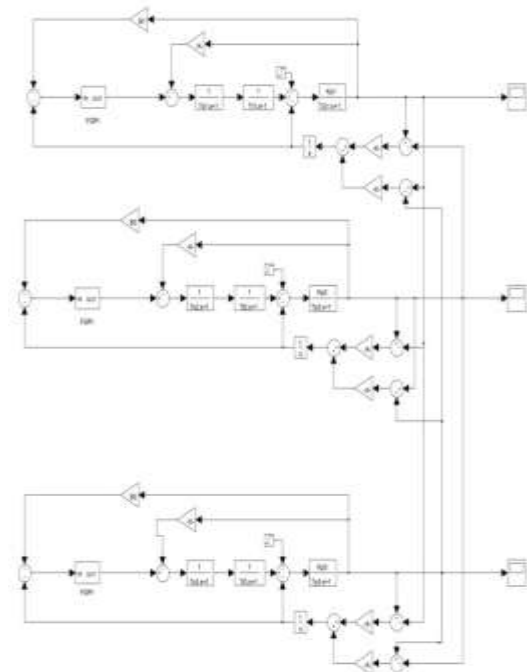


Fig. 5.19 Simulink model for Three Area Control System by using PI Fuzzy controller

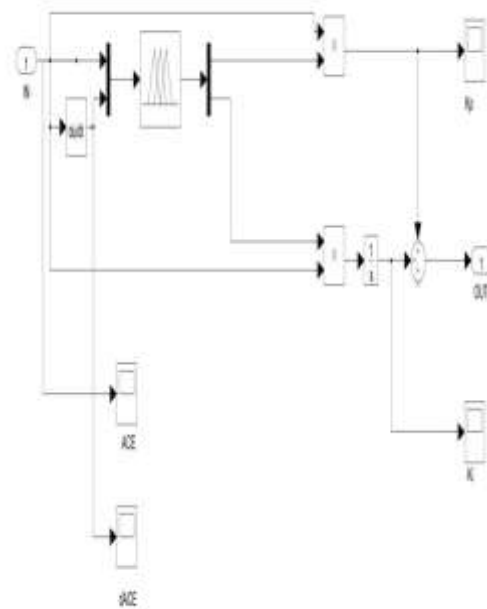


Fig. 5.20 Fuzzy Rule Model for Three Area system by using PI Fuzzy controller

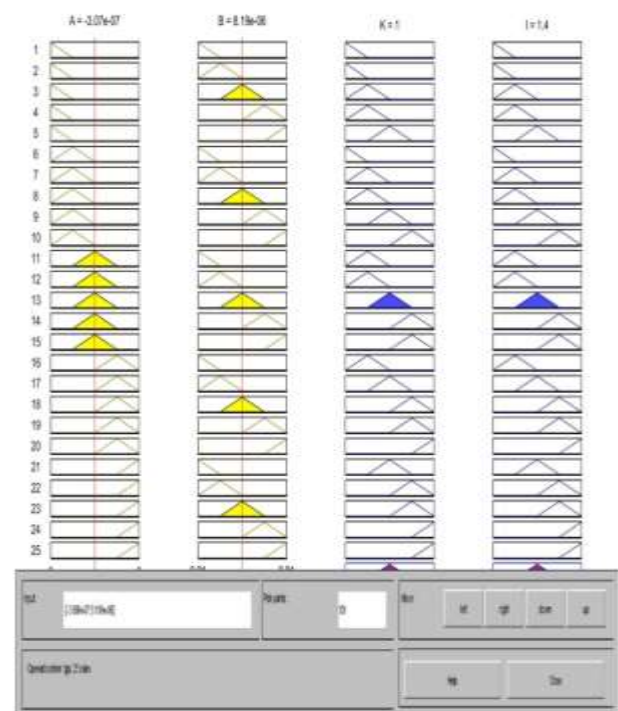


Fig. 5.21 Fuzzy Rule view for Three Area system by using PI Fuzzy controller

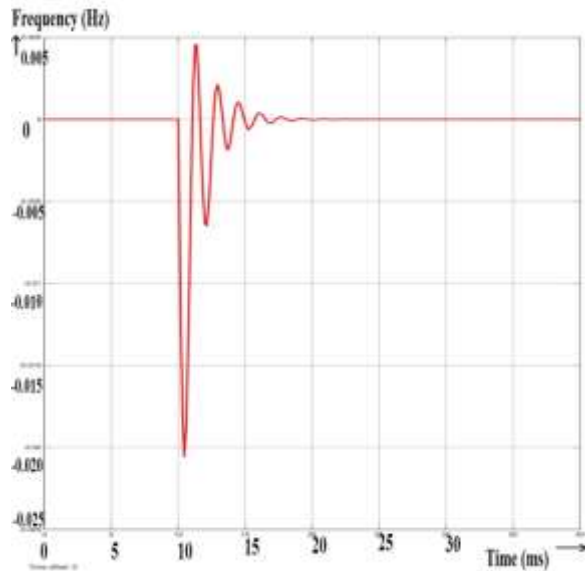


Fig. 5.22 Waveform for Three Area Control system by using PI Fuzzy controller

Fig. 5.19 shows the simulink model of three area power system including PI-Fuzzy Controller. change in frequency with respect to time are shown in fig. 5.22. Different values of parameters have been taken for fig. 5.22. PI-Fuzzy controller is used to improve the dynamic response as well as to reduce or to improve steady-state error and to eliminate transient deviations.

VI. CONCLUSION

Thus, SIMULINK models help us to understand the principle of automatic load frequency control. In single area system, the drift in frequency is settle down near to limited value. In two area power system, the drift in frequency is made to zero. In three area power system, by using interconnection the stability is improved. By using Fuzzy PI controller in three area the settling time is reduced, less oscillations occurs and good time response.

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