Analysis of Load Frequency Control in an Multi Area Power System Using Conventional and Fuzzy Logic Controller

Kuldeep Singh, Shimpy Maheshwari

Abstract— **The variations of load in a power system result in frequency drift from its nominal value. It is necessary to reduce the frequency fluctuations for providing reliable and good quality electrical power. This is achieved by maintaining a balance between the load demand and power supply in real time, called Automatic generation control (AGC). In this paper, different control areas models are building in MATLAB Simulink and then simulation evaluation is done to analyze the dynamic response of the load frequency control. The performance of the conventional controller and Fuzzy Logic controller is compared on single area, two areas and three areas systems. Area control error (ACE) is measured and the result of the conventional method and fuzzy logic is compared. The result obtained show that the Fuzzy logic controller gives higher performance than the traditional PI technique.**

Index Terms—**Load Frequency Control (LFC), Automatic Generation Control (AGC), Area Control Error (ACE), Fuzzy Logic Controller**

I. Introduction

When load in the system will increase, rotary engine speed drops before the governor will modify the input. If, we are failing to achieve this variation in load, the speed of the generator is varied and also the frequency is changing, which may be highly undesirable. As the change within the speed decreases, the error signal becomes smaller and therefore the positions of governor valve get near the specified position to maintain constant speed. However, the constant speed cannot be the set point and there will be an offset, to overcome this problem an integrator is added, which can automatically modify the generation to revive the frequency to its value. This scheme is referred to as automatic generation control (AGC). Modern power system network consists of variety of utilities interconnected along and power is changed between utilities over tie- lines by that they're connected. Automatic generation control (AGC) plays a terribly necessary role in facility as its main role is to take care of the system frequency and tie line flow at their scheduled values during normal period. Automatic generation management with primary speed control action, a change in system load can result in a steady state frequency deviation, depending upon droop characteristics of governor and frequency sensitivity of the load. The system frequency restoration to nominal value needs supplementary control action that adjusts the load reference point. Therefore the primary objectives of the automated generation control are to regulate frequency to the nominal value and to take care of the interchange power between control areas at the nominal values by adjusting the output of selected generators. This function is normally spoken as load frequency control.

The control of frequency in a multi area system is accomplished through the combination of primary control and secondary control. The main objective of primary control is to maintain the frequency of the system at a reference value following a load disturbance and to maintain the tie-line power interchange between control areas at the scheduled values by varying the generator outputs Secondary control is primarily used for automatic restoration of the frequency and therefore the power changed between the various areas of the interconnected systems, at their scheduled values (i.e. $\Delta f = 0$, $\Delta P_i = 0$), taking into account the control program. Hence, the growth of interconnected systems leads to the importance of automatic generation control (AGC). A number of control methods exist to realize higher performance. Due to non-linearity of facility, system parameters are linearised around an operative point. PI controller is the most widely used. The disadvantage of PI controller is that it takes more time and offers massive frequency deviation. Also, their performance deteriorates with complex power system. Hence, Fuzzy logic controller has received increasing attention in facility stabilization problem in recent years. The advantage of fuzzy logic has complex modeling, nonlinear issues lingually rather than mathematically and using natural language process. The main building units of an FLC are a fuzzification, a fuzzy logic reasoning, a knowledge base, and a defuzzification. Defuzzification is the process of converting inferred fuzzy control actions into a crisp control action.

II. Design Model For Various System

A. Single Area System

The frequency which changes with load is contrasted with reference speed setting. The frequency can be adjusted to the desired value by making generation and load demand equal with the help of controller of the steam valve to regulate it and increases power output from generators. It serves the primary/basic purpose of balancing the real power by

Manuscript received May 20, 2016

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regulating turbine output (ΛP_{in}) according to the variation in load demand (ΔP_0). Here, the transfer function of the power system is given as $\frac{1}{2Hs+D}$ i.e. $\left[\frac{1}{2Hs+D} = \frac{K_p}{1+sT_p}\right]$ where $K_p - \frac{1}{D}$ and $T_p = \frac{M}{D}$.

The integral controller which gives zero steady state error is put in the secondary loop.

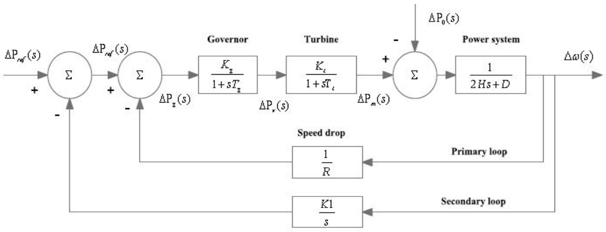

Fig.1: Model of single area ALFC by using secondary control

Automatic Load Frequency Control transfer function with integral group is shown below by representing in the form of equations.

$$\omega - \frac{1}{D+\frac{1}{R}}\left[\Delta P_{ref} - \Delta P_0\right] \quad (1)$$

B. Two Area System

The two areas are interconnected by single transmission line. The flow of power over the transmission line will appear as a positive load to one control area and an equal but negative load to other or vice versa depending upon the direction of flow.

For change in area 1 load by ΔP_{01}, we have,

$$\Delta\omega = \frac{-\Delta P_{01}}{\left(\frac{1}{R_1}+D_1\right)\left(\frac{1}{R_2}-D_2\right)} = \frac{-\Delta P_{01}}{\beta_1+\beta_2} \quad (2)$$

$$\Delta P_{12} = \frac{-\Delta P_{01}\left(\frac{1}{R_2}+D_2\right)}{\left(\frac{1}{R_1}+D_1\right)\left(\frac{1}{R_2}+D_2\right)} = \frac{-\Delta P_{01}\beta_2}{\beta_1+\beta_2} \quad (3)$$

Where β_1 and β_2 are the composite characteristics of area 1 and 2 respectively.

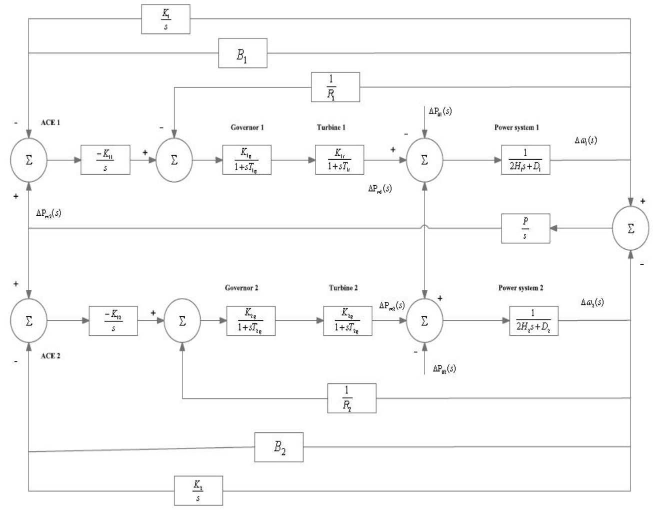

Fig.2: Model of Two areas ALFC by using secondary Control

C. Three Area System

Three area interconnected system consists of three interconnected control areas. The tie line power is flowing as per the variation in the load demand due to the interconnection between the control areas. Thus the overall stability of the system is maintained at a balanced in spite of the constant variations in the load.

The tie-line power flow among three areas is as below:

$$\Delta P_{12}(s) = \frac{2\pi T}{s}\left[\Delta f_1(s) - \Delta f_2(s)\right] \quad (4)$$

$$\Delta P_{13}(s) = \frac{2\pi T}{s}\left[\Delta f_1(s) - \Delta f_3(s)\right] \quad (5)$$

$$\Delta P_{23}(s) = \frac{2\pi T}{s}\left[\Delta f_2(s) - \Delta f_3(s)\right] \quad (6)$$

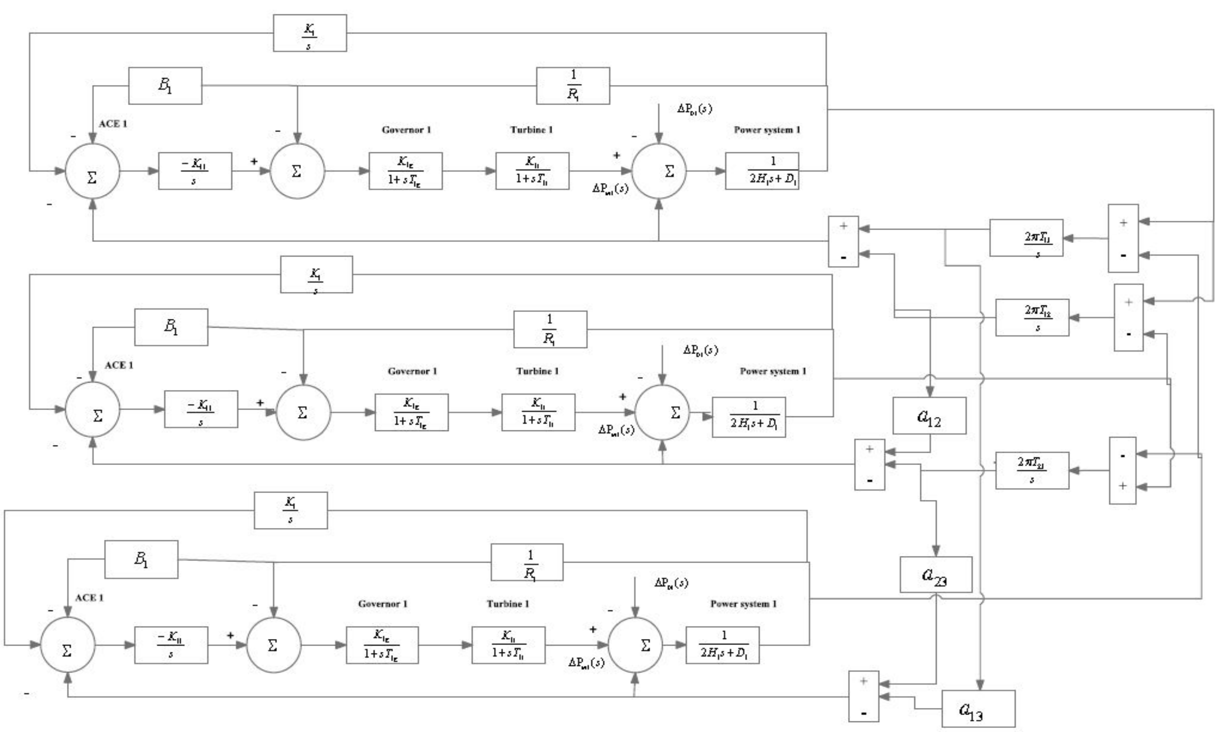

Fig.3: Model of Three areas ALFC by using secondary Control

III. Fuzzy Controller

Artificial intelligence based gain planning may be a technique used normally in coming up with controllers for non-linear systems. Fuzzy logic system is basically converting a human knowledge into mathematical formula. Fuzzy Logic Controller (FLC) is more helpful than typical controller and helps in achieving quick and sensible dynamic response in load frequency issues. The fuzzy logic controller designed for the system analysis is shown in Figure 4.

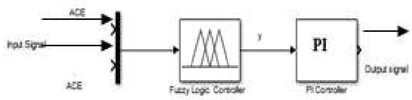

Fig.4: Fuzzy Logic Controller

A fuzzy logic controller consists of three sections namely: fuzzifier, rule base and defuzzifier. Fuzzy logic is used to find out the value of Area Control Error. A control signal in generated in the form of area control error that will be provide to all the control areas of interconnected power system to maintain a balance between load demand and generation for reducing frequency deviations. In this paper, input to the fuzzy controller is taken as area control error (ACE) and change in error (ΔACE).

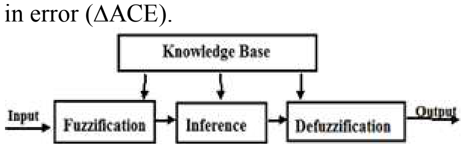

Fig.5: Block Diagram of Fuzzy Logic Controller

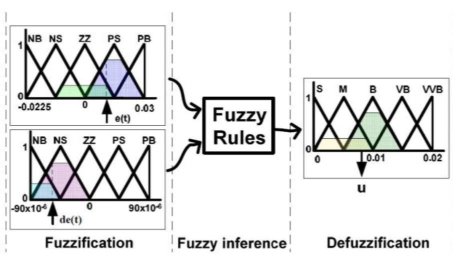

Fig.6: Fuzzy Interference System for LFC

The degree to which a given input belongs to set is specified by Membership Function. Membership functions of Triangular type are used for both the inputs and output of the Fuzzy Controller. Firstly, calculating a area control error and change of frequency and then convert it into fuzzy variables i.e. linguistic variables such as PB-Positive Big , PS-Positive Small, ZZ-Zero, NS-Negative Small, NB-Negative Big, S-Small, M-Medium, B-Big, VB-Very Big, VBB-Very Very Big.

		ė				
		NB	NS	ZZ	PS	PB
e	NB	S	S	M	M	B
	NS	S	M	M	B	VB
	ZZ	M	M	B	VB	VB
	PS	M	B	VB	VB	VVB
	PB	B	VB	VB	VVB	VVB

Fig.7: Fuzzy Rule

The decision rules are evaluated by using the integrative rule of logical thinking. Finally, Defuzzification process yields a non-fuzzy, control action from an inferred fuzzy control action. The technique utilized here is that the centre of area method.

IV. Simulation Results

The models of Single Area, Two Areas and Three Areas are simulated in SIMULINK.

A. Single Area System with PI controller

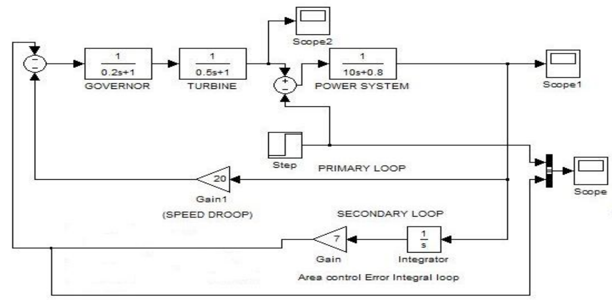

Fig.8: Single Area System with PI controller

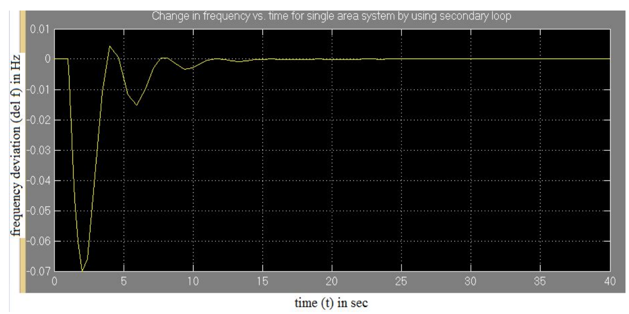

Fig.9: Frequency Deviation vs. time for Single Area System with PI Controller

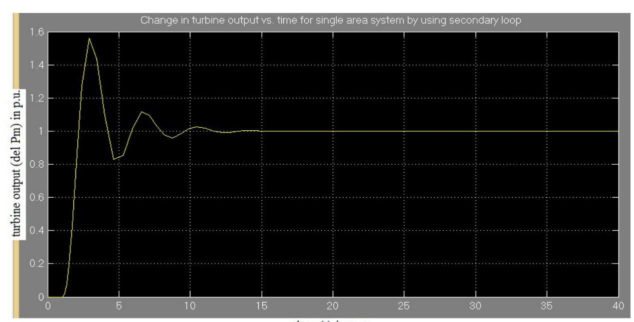

Fig.10: Change in Turbine output vs. time for Single Area System with PI Controller

Figure 8 shows the single area system with a secondary loop where an integral controller with a gain is adopted to adjust the speed reference signal so that ($\Delta\omega$) returns to zero.
Figure 9 shows the simulation results of single area with the secondary loop and it can be seen that the frequency drift has been made zero due to the integral loop.

B. Single Area System with Fuzzy controller

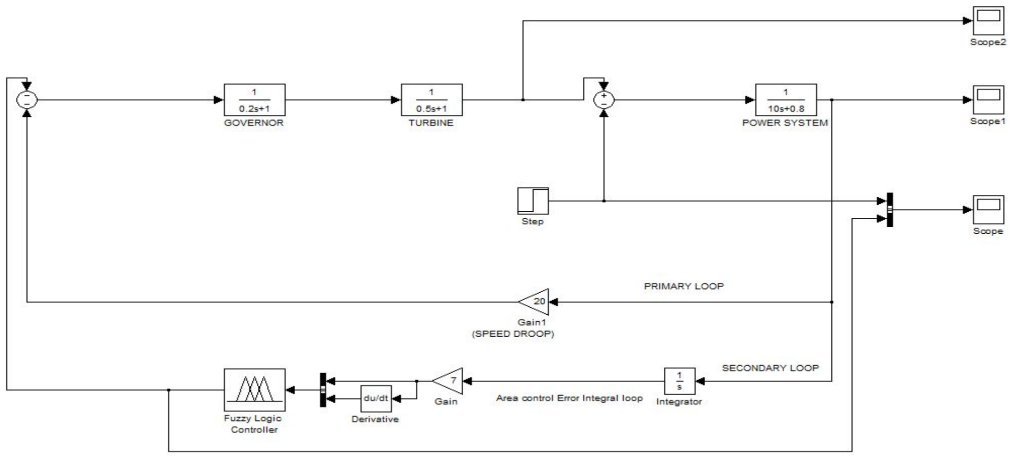

Fig.11: Single Area System with Fuzzy controller

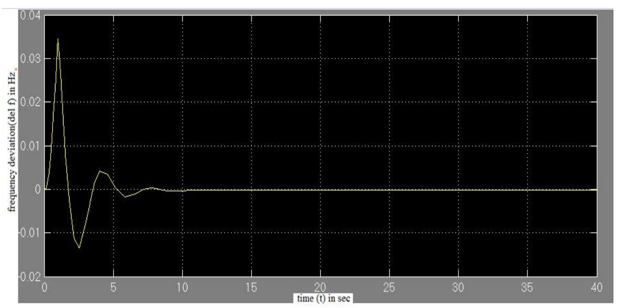

Fig.12: Frequency Deviation vs. time for single area system with Fuzzy Controller

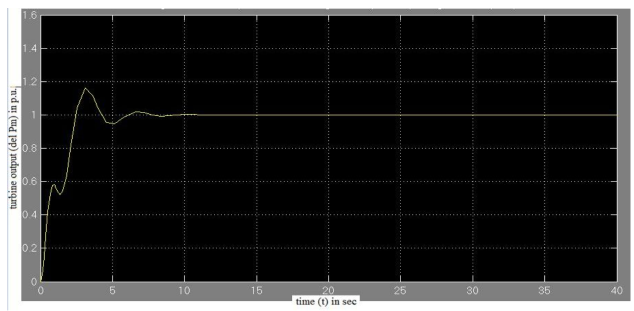

Fig.13: Change in Turbine output vs. time for Single Area System with Fuzzy Controller

C. Two Area System with Fuzzy controller

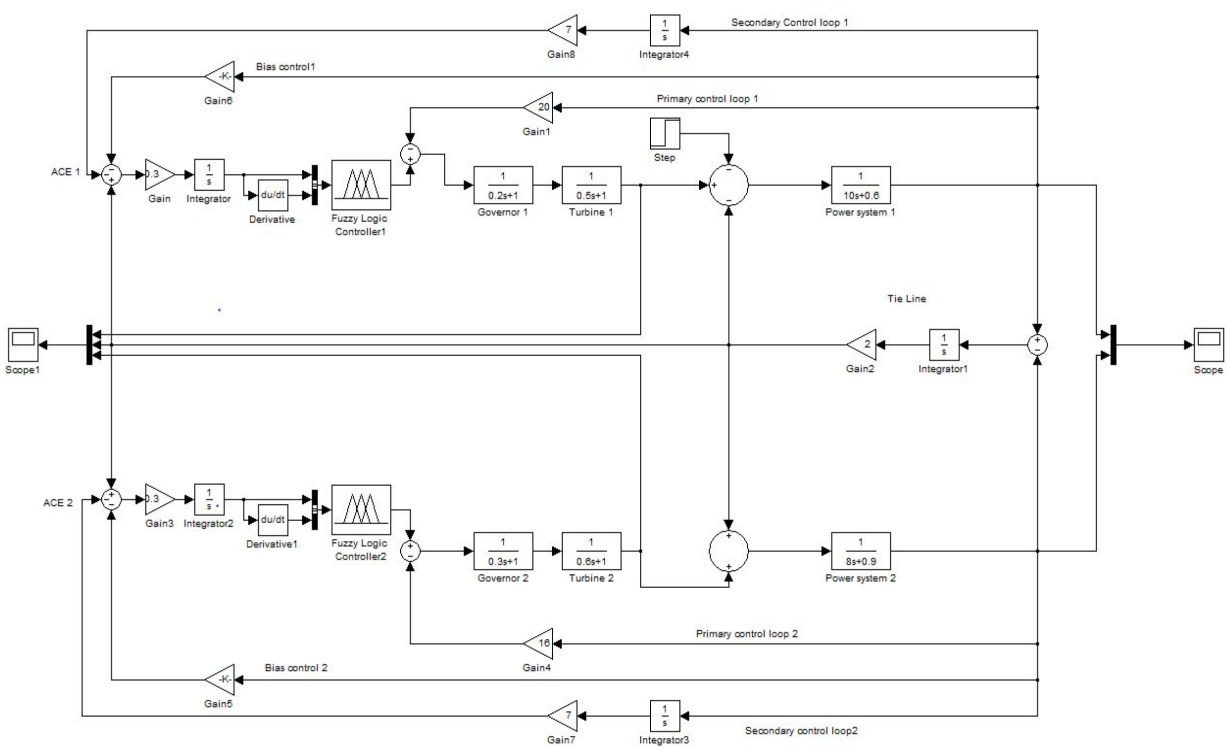

Fig.14: Two Area System with Fuzzy controller

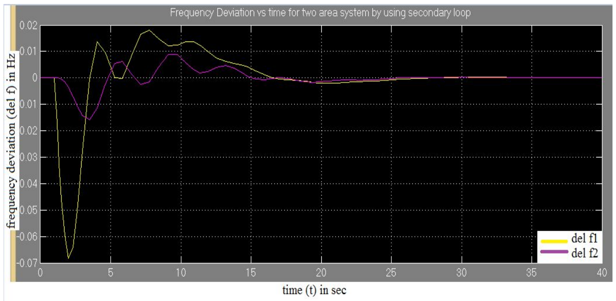

Fig.15: Frequency Deviation vs. time for Two Area System with PI Controller

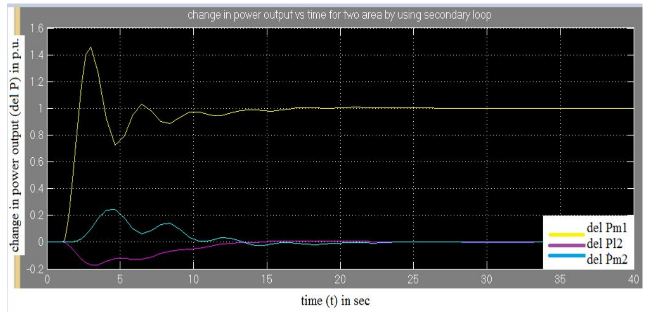

Fig.16: Change in Turbine output vs. time for Two Area System with PI Controller

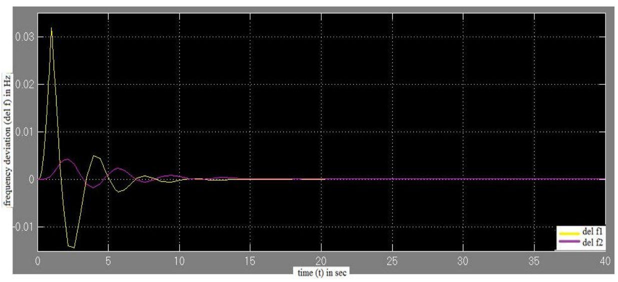

Fig.17: Frequency deviation vs. time for Two Areas with Fuzzy Controller

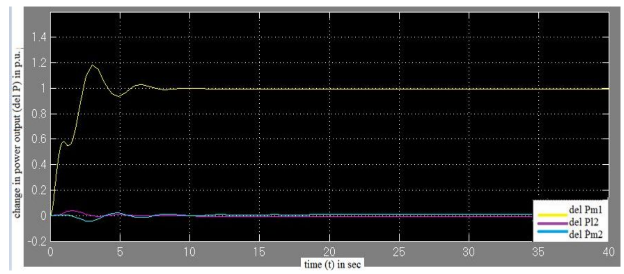

Fig.18: Change in Power Output vs. time for Two Areas with Fuzzy Controller

D.Two Area System with Fuzzy controller

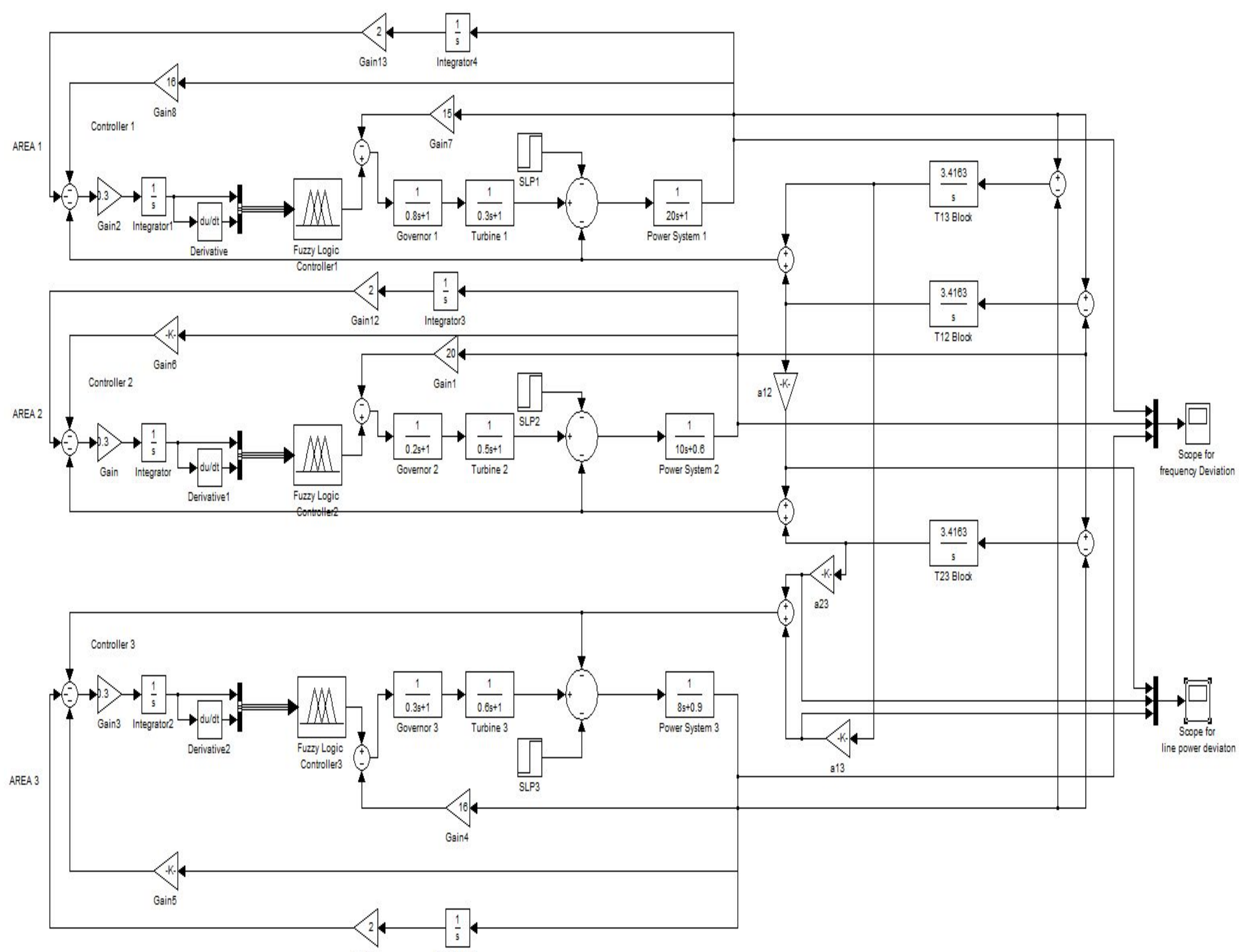

Fig.19: Three Area System with Fuzzy controller

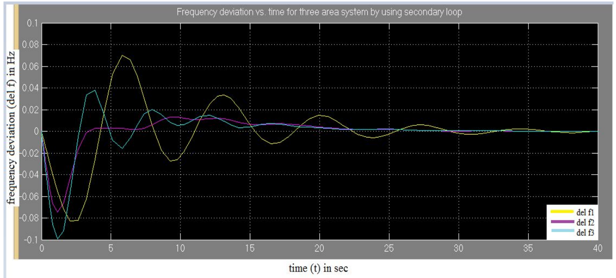

Fig.20: Frequency Deviation vs. time for Three Area System with PI Controller

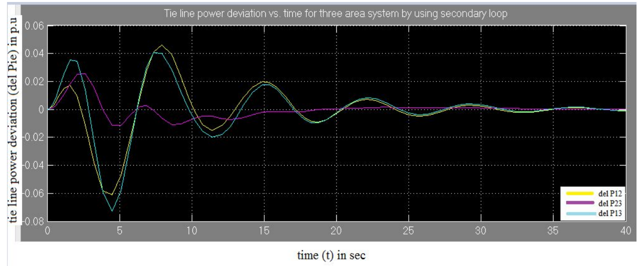

Fig.21: The line power deviation vs. time for Three Area System with PI Controller

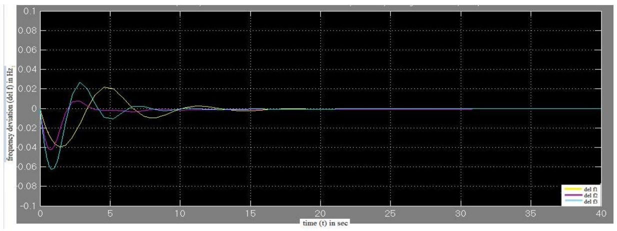

Fig.22: Frequency Deviation vs. time for Three Area System with Fuzzy Controller

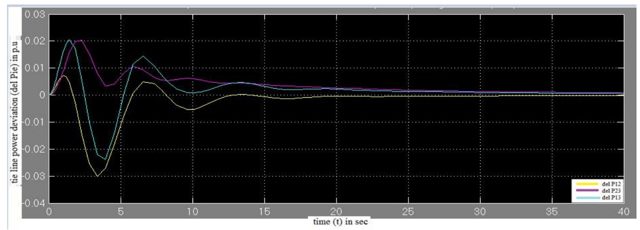

Fig.23: The line power deviation vs. time for Three Area System with Fuzzy Controller

V. CONCLUSION

A simulation study of single, two and three area system with automatic generation and control is carried out with models developed in SIMULINK and results are analyzed. In this paper, we study the frequency change as well as change in the tie line power due to the change in the load and also the fuzzy controller techniques that may be used for obtaining the optimized values of various parameters for minimizing the changes. The operation of single area, two area and three area systems with secondary loops are depicted through simulation models. The advantage of interconnection is can be understood by comparing the results of single and two area systems. It can be seen that the oscillations due to change in load in any area is damped down quickly because of tie line power flow. It can additionally be determined that the dynamic response is principally ruled by the secondary loop and hence its design criteria are very important for economical implementation. Also, the dynamic performance of conventional PI controller and Fuzzy logic controller is compared on single area, two area and three area system. The output of FLC is compared with Conventional controller and is found superior in terms of peak overshoot, number of oscillations and settling time.

APPENDIX

Data for interconnected system:
R1 =0.05 R2=0.0625 R3=0.0588
B1 =20.6 B2= 16.9 B3=16
H1=5 H2 = 4 H3=10
D1 =0.6 D2 = 0.9 D3=1.0
Tg1 = 0.2 Tg2=0.3 Tg3=0.8
Tt1= 0.5 Tt2=0.6 Tt3=0.30

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