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Fuzzy based Tie-Line and LFC of a Two-Area Interconnected System

Pelluri Shravan[1]; T. Sreenu[2]; Talada Santhosh[3]
PG Student[1]; Assistant Professor[2,3]
Dept of Electrical and Electronics Engineering
Visakha Institute of Engineering & Technology Visakhapatnam, India

Abstract:- In order to restore the balance between load and generation in each control region, the load-frequency control (LFC) uses speed control. Reducing the steady state error and transient deviations to zero in advance is the main goal of LFC. This study investigated LFC for two area systems using fuzzy inference system (FIS) and conventional controllers. The results of the two controllers are compared using the MATLAB/Simulink application. The findings are displayed from comparisons between fuzzy inference systems and conventional controllers.

Keywords:- *Fuzzy Inference System (FIS), Conventional Controller, and Load Frequency Control.*

I. INTRODUCTION

These days, producing electricity is essential due to the increasing demand for it. The dynamic behavior of the system depends on perturbations and modifications to the operating point. The quality of the energy generated in power plants is determined by the system's output, which needs to maintain the scheduled power and have a consistent frequency. Thus, load frequency control, or LFC, is essential to the power system's capacity to produce consistent, high-grade electricity. While traditional controllers such as PD, PID, and PI can offer control actions for a single operating condition, in practice, the parameters are never static. Setting up the require adjustments to achieve zero frequency variation is so difficult. Therefore, providing automatic correction is crucial. Load frequency controllers have been designed using a range of control algorithms to enhance dynamic performance. Conventional controllers are the most common and widely used of the several types of load frequency controllers. Conventional controllers generate a large amount of frequency variation despite being simple to design. Most state feedback controllers based on linear optimal control theory have been provided in order to increase performance. Because fixed gain controllers are designed for nominal operating settings, they are unable to provide the best control performance throughout a range of operating conditions. Thus, to keep system performance near maximum, it is desirable to keep an eye on operating conditions and compute the control using the most recent parameters. Adaptive controllers offer self-adjusting gain setting. It is commonly known that the load frequency control problem led to the collapse of the Northern grid. This is the outcome of both excessive generation and excessive grid demand. It resulted in a blackout that essentially shut down the whole northern region, affecting all eight states. This resulted from the traditional controllers' poor control measures, and some states kept using more electricity than they required in spite of the warnings. An adaptive control system is required to recognize changes in load and stabilize the frequency deviation. In this study, an autonomous control action is provided by a fuzzy inference system (FIS) technology. After contrasting the recommended controller with the conventional controller, the results are shown.

II. SINGLE AREA POWER SYSTEM

A. Modelling of System Model

Modern power systems are divided into a number of categories. For example, the Eastern, Western, Northern, Southern, and North-Eastern grids are among the five regional grids in India. Every one of these regional areas has a common connection to the regions around it. Transmission lines that connect one region to its neighboring one are known as tie-lines. The purpose of these tie-lines is to divide power between two locations. As the name implies, load frequency control regulates the power flow between different sites while keeping the frequency constant.

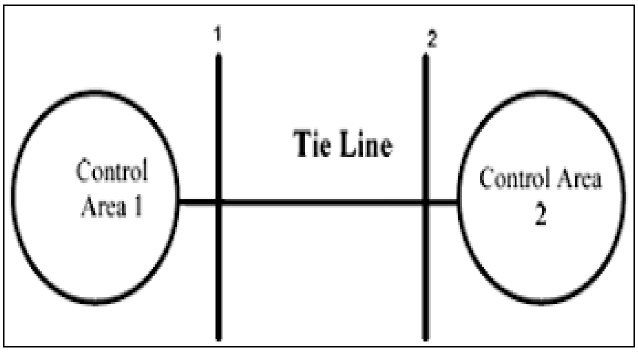

Fig 1: Inter Connected Power System

As long as "$\Delta Pref$" is set at zero, the system frequency will increase as the load reduces.

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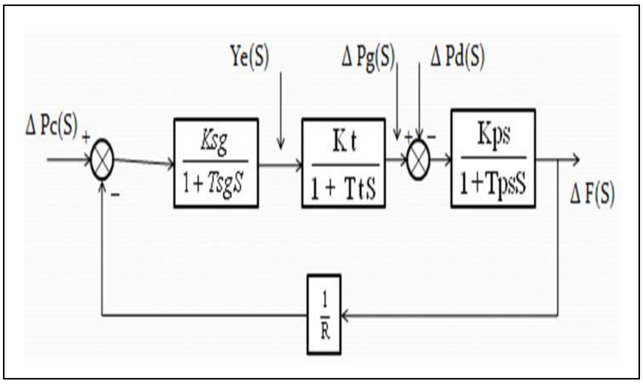

Fig 2: Single Area Power System

Likewise, frequency may decrease as load increases. Maintaining a steady frequency is crucial to guarantee that Δf=0. Power is scheduled to be transferred between the different tie lines; for example, region "I" might import a second specified quantity of power from area "k" and export a predefined amount to area "j." However, it is expected that area I will independently absorb any variations in load, including higher generation to accommodate greater load in the area or lower generation when the area's load demand has fallen. The following goals of load frequency control (LFC) are thus necessary for area "I" to continue fulfilling its duties to areas "j":

- Retain the frequency constant (Δf=0) in the face of load variations. Every area needs to be able to adapt to changes in load so that the frequency stays constant.
- Every region must keep the tie-line power flow at the predetermined level.

The first step in the Load Frequency Control is to form the area control error (ACE) that is defined as

$$ACE=(P_{tie}-P)+B_f\Delta f=\Delta P_{tie}+B_f\Delta \tag{1}$$

Where P_{tie} and P_{sch} are the tie-line power and scheduled power through tie-line respectively and the constant B_f is called the frequency bias constant. The change in the reference of the power setting ΔP_{ref_i} of the area I is then obtained by feedback of the ACE through an integral controller of the form

$$\Delta P_{ref_i}=-K_i\int ACE dt \tag{2}$$

Where K_i is the integral gain.

If there is little net power flow out of a region, a drop in frequency, or both, the ACE is negative. To fulfill the load demand in this scenario, the generation must be raised. You can do this by raising ΔPref,i. The inverse relationship between ΔPref,i and ACE is explained by this negative symbol. Each area's control center keeps an eye on the frequency and tie-line power flow. Upon computing the ACE and obtaining ΔPref,i from Equation (2), directives are issued to the several turbine-generator controllers to modify their reference power settings.

A two area electricity system is made up of tie-lines connecting two single area systems. It's crucial to create a mathematical model of the system before coming up with any control schemes. It is thought that each control zone might be conveniently represented by an equivalent turbine, speed controlling system, generator, and load. The block diagram for a single area power system is shown in Figure 2.Each area of a two-area power system has several generators that are interconnected to form a cohesive group. As a result, the generators in the power system should all respond to changes in load simultaneously. One such coherent area where it is expected that the frequency will be consistent in both static and dynamic conditions is the control region. To minimize the frequency variation, however, a separate controller (PID) is used in this system. The PI Controller might offer the best frequency deviation control action in a single operating condition. When the working range is large, the PID Controllers are unable to introduce frequency variation. This difficulty is avoided by the Fuzzy Inference System (FIS).

III. TEO AREA LOAD FREQUENCY CONTROL

The conventional AGC design has two control loops. Although frequency variation is reduced, it is not entirely removed by the primary control loop, which uses the governor's self-regulating capabilities to control the frequency. Furthermore, the feedback control loop has a controller that may be able to reduce the frequency deviation through the use of conventional proportional integral control action. The major objective of feedback control is to restore the balance between generation and load in each control region after a disturbance, thereby maintaining the tie-line power flows and system frequency at their predefined values. The load frequency control block diagram for a two-area linked power system is shown in Figure 3.

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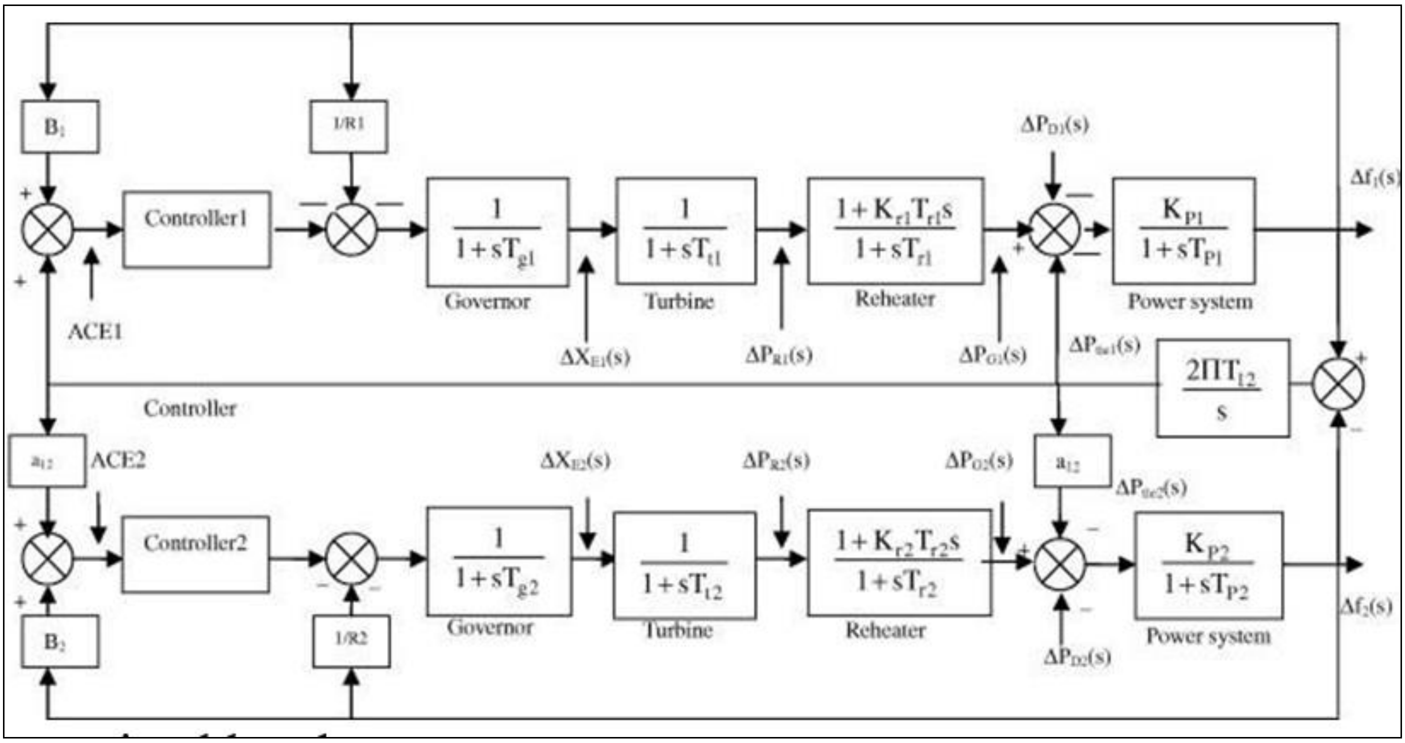

Fig 3: Two-Area Inter Connected Power System

The ACE refers to the frequency shift in a single-area scenario. In an integral-control loop with ACE, the steady state error in frequency will be zero, or V_st = 0. In a two-area example, ACE is the linear combination of the frequency change and the tie-line power change. To obtain the steady-state tie-line power zero (i.e., $\Delta Ptie = 0$), a second integrator loop for each region must be added in addition to the integral frequency loop in order to integrate the incremental tie-line power signal and send it back to the speed changer.

There requirements of the integral control action are:

ACE must be equal to zero atleast one time in all 10-minute periods. Average deviation of ACE from zero must be within specified limits based on percentage of system generation forall10-minute periods.

IV. PID CONTROLLER

- *Conventional PID Controller on i-th AreaThe control input Ui is constructed as follows:*

$$U\text{i} = -K\text{i} \int^{T} ACE\text{i}\, dt = -\int^{T} (\Delta Ptie\ \text{i} + B\text{i}\Delta F\text{i}) \qquad (3)$$

Taking the derivative of the equation yields

$$U\text{i} = -K\text{i}(ACE\text{i}) = -K\text{i}(\Delta Ptie\ \text{i} + B\text{i}\ \Delta F\text{i}) \qquad (4)$$

The constants Ki(1, 2) are the gain of the integrator. It is observed that for decrease in both frequency and tie-line power generation should decrease, i.e., if the ACE is negative, the speed-changer position decreases and hence the power generation should decrease, i.e., if the ACE is negative, then the area should increase its generation, so negative is assigned to the right-hand side term.

V. FUZZY INTERFACE

The most popular industrial controller is the PID controller because of its simple construction and effective functioning. Traditional PID controllers, however, are usually ineffectual when it comes to controlling higher order, time delay, non-linear, complex, uncertain, or systems with intricate mathematical models because of their linear architecture.

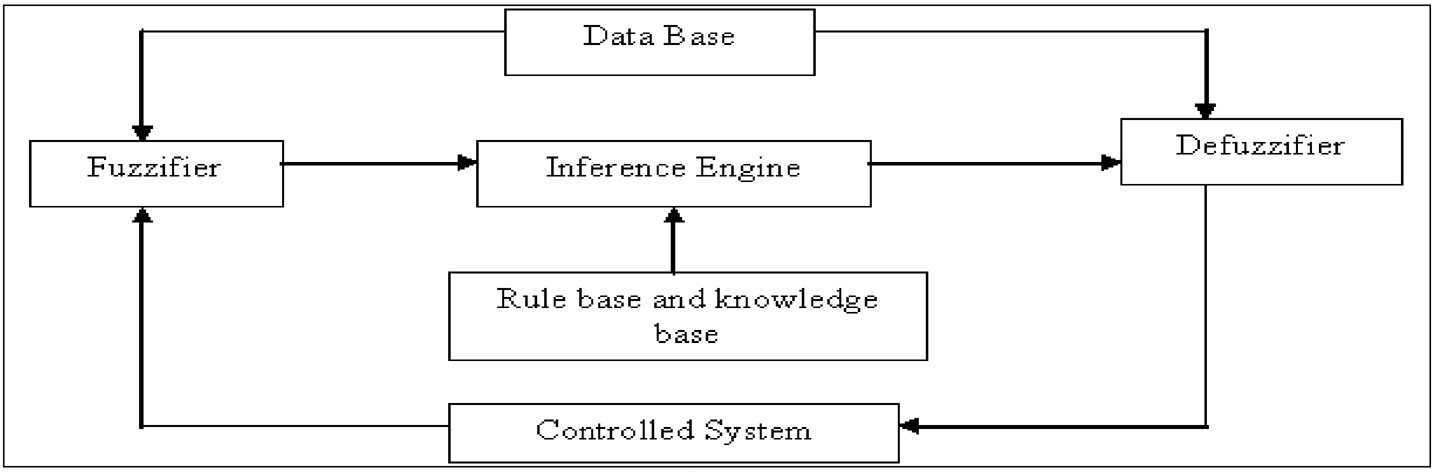

Fig.4. Structure of Fuzzy Logic controller

VI. SIMULATION AND RESULTS

A. Simulation Model for Two-Area Load Frequency Control

The two area load frequency control simulation block diagram was created in MATLAB using the parameters listed in the table and modeled using Fig. 5. and the simulation provides the findings for frequency and tie line power changes in response to load changes. Figure 6 shows the frequency regulation of a two-area load without a controller. with the 10% variation (growth) in the area's load.1 illustrates the impact on both the area's frequency and area. Moreover, it illustrates the effect on the area. tie line power and two frequencies. Both the area1,2 and tie line power Ptie1,2 frequency responses in their transient and stable states exhibit some instability. The tie-line power exhibits more oscillations in Fig. 6. as a result of the abrupt shift in load.

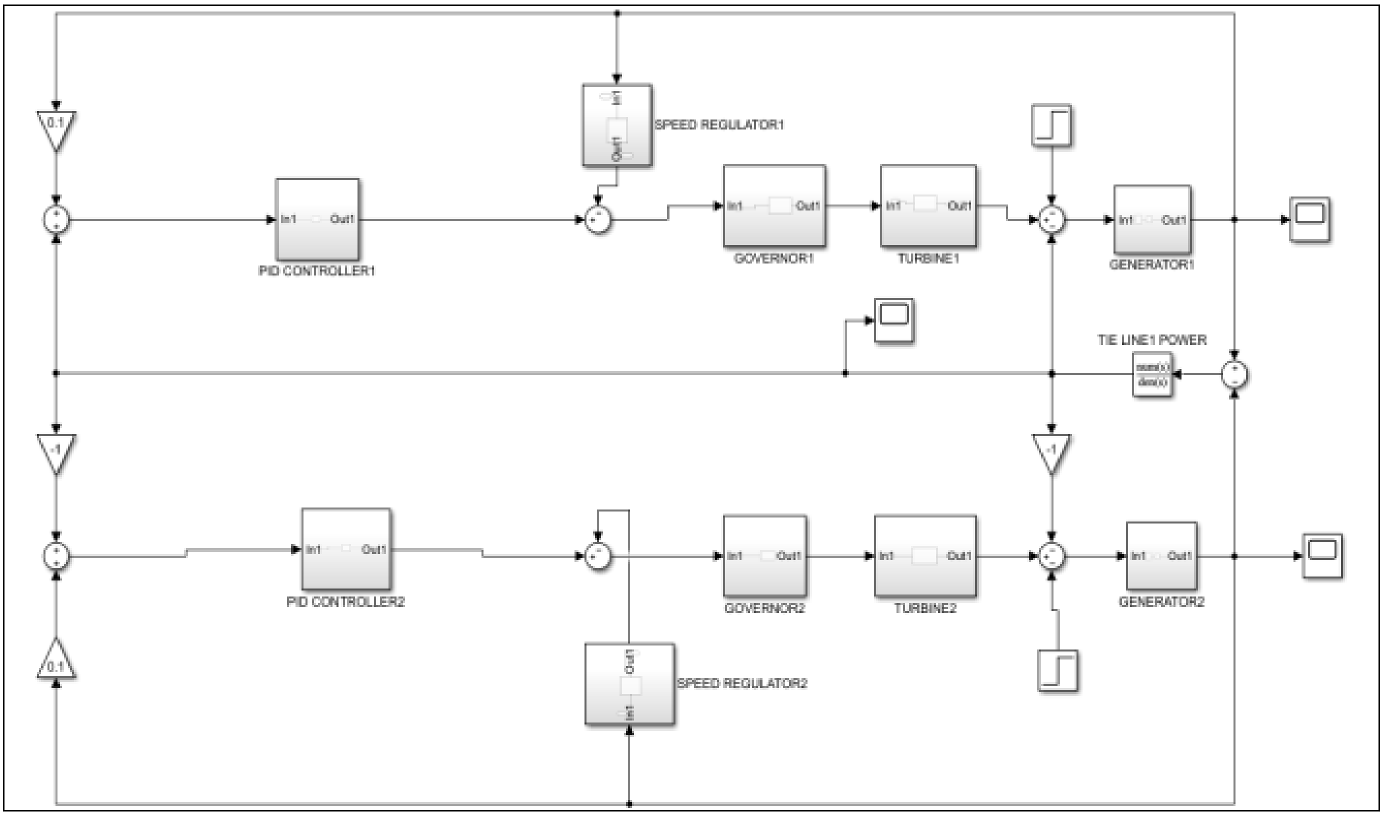

Fig 5: Simulink Model of Two Area Load Frequency Control with Conventional PID Controller

B. Simulation Results Without Controller

The power system frequency will fluctuate proportionately from its typical steady state operating circumstances as a result of an abrupt change in load in one of the control zones of 1%. With no controller, Figure 6. illustrates the significant oscillations in its transient conditions and the steady state error of -1.378.

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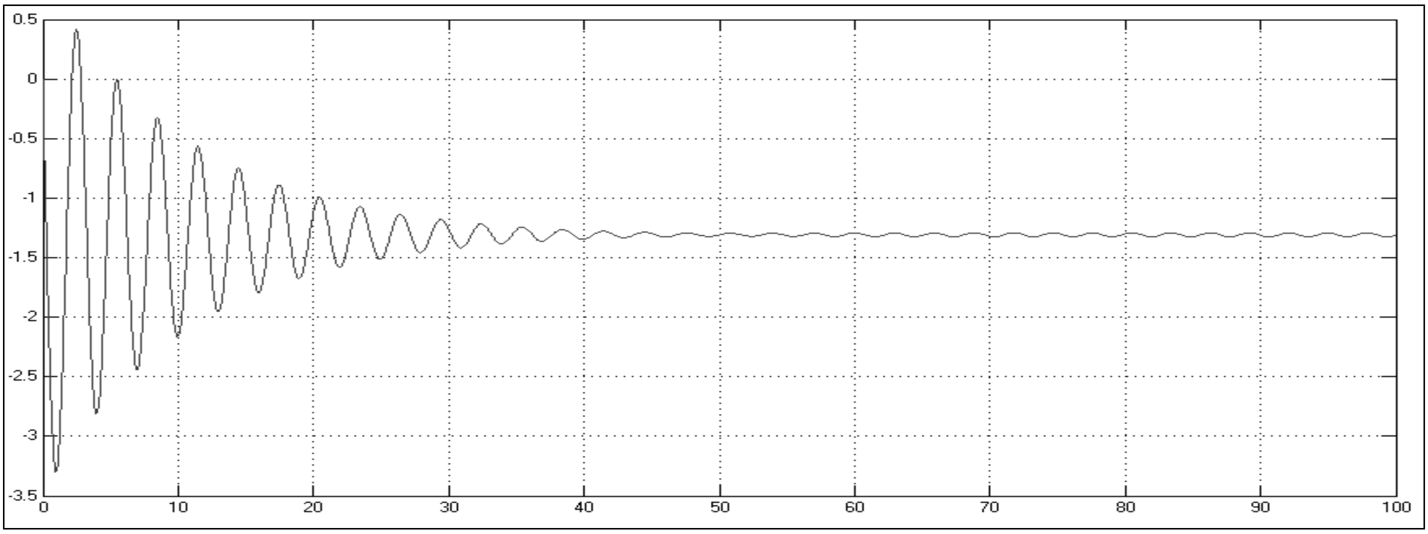


Fig 6: Two-Area Load Frequency Control Without Controller

C. Simulation Results with PID Controller

Figure .7 shows the response of two area load frequency control with PID controller which makes the steady state error is zero and also shows good control over the transient state that reduce the oscillations in transient conditions.

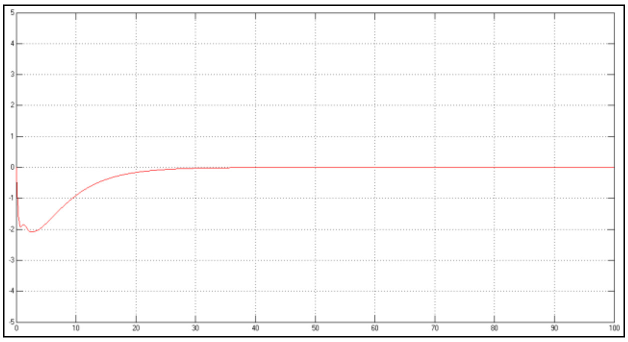
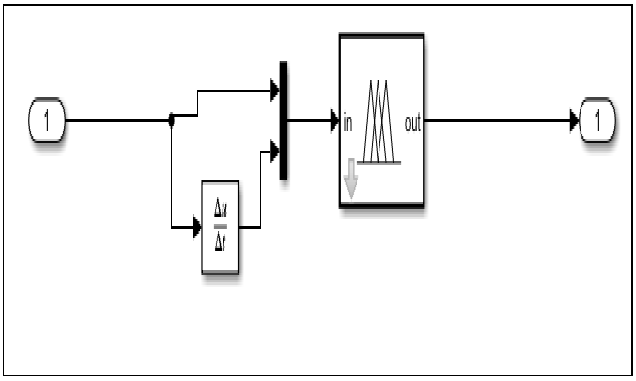


Fig 7: Response of Two Area Load Frequency Control with PID Controller

D. Simulation of Two Area Load Frequency Fuzzy Controller



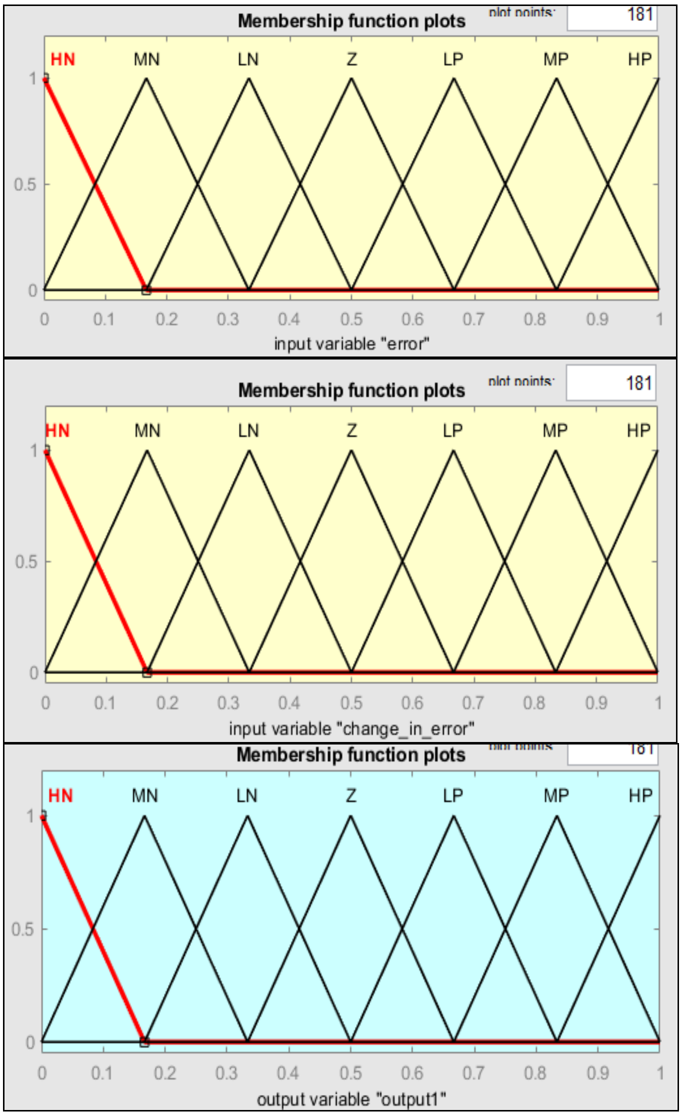


Fig 8: Fuzzy Rule Base Membership Functions

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The process design of fuzzy if-then rule knowledge bases and membership functions for inputs and outputs are crucial components of fuzzy logic control system designs. When it comes to fuzzy logic control, they are crucial. Fig. 8 shows the fundamental architecture of the fuzzy logic controller. Two inputs for the fuzzy controller and one output control input (CI) are used for two region LFC: frequency error (E) and change in frequency error (CE). A three-member and a seven-member rule base are developed for this purpose. Tables display the rule foundation for the seven membership functions.

ACE ΔACE	HN	MN	LN	Z	LP	MP	HP
HN	HP	HP	HP	MP	MP	LP	Z
MN	HP	MP	MP	MP	LP	Z	LN
LN	HP	MP	LP	LP	Z	LN	MN
Z	MP	MP	LP	Z	LN	MN	MN
LP	HP	LP	Z	LN	LN	MN	HN
MP	LP	Z	LN	MN	MN	MN	HN
HP	Z	LN	MN	MN	HN	HN	HN

HN: High Negative, MN: Medium Negative, LN: Low Negative, Z: Zero, HP: High Positive, MP: Medium Positive, LP: Low Positive

Fig 9: Fuzzy Controller Design

The fuzzy logic based control system has been studied by simulation in order to validate the design and to evaluate the performance. Simulation result gotten by a fuzzy logic controller which gives good performance in a constant load case .When one need only design the FLC to provide control command. It is seen that FLC provides faster response and less overshoot. Fig.10. Shows the output response two area LFC with FLC

E. Two Area Load Frequency Control Results with FUZZY Controller

Fuzzy controller gives better response in both transient and steady state period:

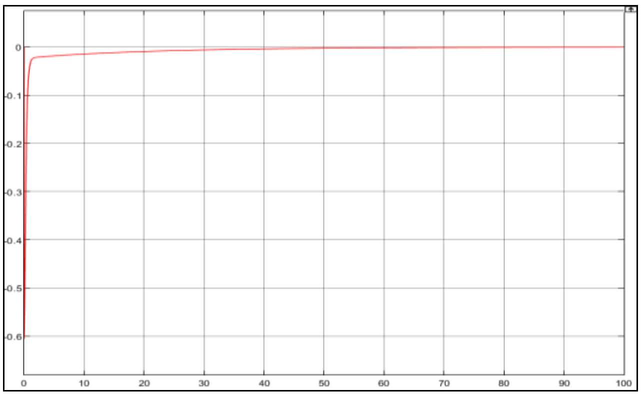

Fig 10: Output response two area LFC with FLC

VII. CONCLUSION

In this study, MATLAB simulation was used to mimic the two area load frequency control. The tie line power varies as a result of an abrupt shift (increase) in load. By boosting steady state response, integral controllers lower tie line power oscillations and guarantee that steady state error equals zero. A derivative controller reduces transient oscillations. The best controller is the classic PID controller, which is coupled in series with the tie line and reduces transient tie line power oscillation while eliminating steady state error. Fuzzy logic membership functions, which are used by a novel kind of controller called a fuzzy logic controller, are transient.

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