Fuzzy and PID controller application to Load Frequency control of two area Power System”

K. Naga Deepthi[1], Dr.K.Raju[2], A. Anjaiah[3]

[1]PG Students, Department of EEE, TKR College of Engineering and Technology (Autonomous), Hyderabad, India.

[2,3]professor Department of EEE, TKR College of Engineering and Technology (Autonomous), Hyderabad, India.

ABSTRACT

Daily demand for power is rising day by day. Delivering consistent, high-quality electricity to clients in a variety of circumstances is the toughest challenge in power sector. The important challenge is to provide uninterrupted and good quality power to customer in variable conditions. There are two measurements checked such as load distribution and frequency. In order to accomplish this parameter, the load distribution and network frequency—must always be examined for each scenario. In this study, Fuzzy logic controller and the proportional integral derivative controller (PID) method are used in this work to eliminate electric energy variations in a power system connected to two areas.
Two area connected power systems were simulated in four scenarios under a variety of operating situations to highlight the efficacy of the suggested fuzzy logic control (FLC) method. In addition to all of this, the effectiveness and superiority of the suggested methodology are demonstrated by comparison of the proposed method's performance with a Proportional Integral Derivative (PID) tester using MATLAB simulation studies.

KEYWORDS:

Fuzzy Logic controller, Power system, Proportional Integral Derivative (PID)

I. INTRODUCTION

The frequency and inter-area tie power should be kept close to the scheduled levels in big power systems that consist of interconnected control areas and load frequency. The frequency deviation of the generators is monitored by the input mechanical power and the change in oscillation and tie-line power and is a measurement of the delayed in rotor angle, are measured.By maintaining the frequency and its magnitude within acceptable ranges, a well-designed system can be able to deliver the required levels of power quality.RP power is more dependent on fluctuations in voltage magnitude than it is on frequency changes, which are more sensitive to delayed in the load on the system. Real and RA power are thus controlled separately in the power system. While the AVR regulator loop controls variations in reactive power and voltage magnitude, the load frequency control primarily controls frequency and real power.

Numerous sophisticated ideas for the large-scale control of the network system are built around load frequency control. Due to rising demand and increased environmental awareness, the relevance of energy generation has recently increased. Additionally, it is a natural expectation of both producers and consumers to use electricity as efficiently as possible. Therefore, in order to meet the energy requirements of both energy suppliers and consumers, interconnected electrical power systems were created. Additionally, connected EPN have been developed for both domestic users within the nation and with its neighbouring nations to interchange electric energy under any condition [1].

The connecting of interconnected electrical power networks, both inside and between countries, calls for a number of arrangements and modifications. The frequencies that can be adjusted for the entire system and all of its subsystems must be identical to one another and be internally stable [2,3]. The balance between active power consumed and consumed determines the nominal frequency level in EPN arethat are interconnected. Differences in the overall system's frequency variation it is be used to identify the active power imbalance. However, given how much industrial loads connected to interconnect electrical power systems rely on high-quality electrical energy, the system's steady state frequency error must be kept within acceptable bounds [4].

Making the connected system's active power balance sensitive to the system frequency is presented [5-7]. The nominal frequency of the network can be often altered by the differential between the power output and instantaneous load change of the synchronous generators The working speed of the generators increases, which raises the frequency, if the quantity of power produced by the power systems exceeds power sought. The frequency is also decreased if the amount of production at my location is less than the needed power. In the event of cycle, the generators is again adjusted to restore the desired level of frequency. Due to, a model known as the (LFC) model, which regulates power and frequency generation in the system based on changing demand, must be configured for every minute. [8, 9]. By altering the micro grid sources' parameters, some research tested the IMC-based PI Controllers' robustness. For random load perturbation and random wind generator input, the two-proportional integral.

Production regions that can work together make up interconnected systems. Under typical operating circumstances, the nominal value of the system's frequency toward load changes and the power distribution between production zones, which is decided by agreement, are maintained constant. This is referred to as LFC. The three steps of the LFC operation are referred to as primary, secondary, and tertiary control [14, 15]. Two ways have been put into practise to SU control this according to PI

In order to manage the frequency, Figure 1 often develops a simplified design of the paper frame. Three important control components are present in this setup. Tertiary, Secondary, and PTR are the names of these components There are three control actions in huge systems that are coupled to one another. Secondary regulation in a restricted system. In their most basic form, frequency regulation-based DSM strategies are not represented in this diagram but can still be assessed without requiring any conceptual adjustments.

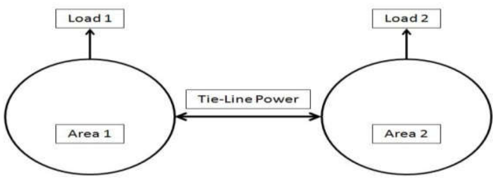

Figure 1.1 : block diagram of two area load frequency control

For frequency regulation, the following three types of reserves can be used . Primary Control Reserve: The system's automatic control back-up. With the governor, it offers a power backup against any frequency variations and maintains the declining frequency level. Secondary Control Reserve: Offers backup power to return the primary backup's frequency level to its nominal value[16].

Tertiary Control Reserve: This reserve is utilized to bring the frequency back to its nominal level in order to sustain the secondary reserve if the former is insufficient to do so. Figure 2 shows that changes in the system's operating frequency and load are always inversely proportional Any increase in current will lower the system's operating frequency. When the regulator in the primary control loop notices a change in frequency, it increases the turbine's speed of rotation and consequently the amount of production until the nominal level of frequency is reached.

II. MODELING OF TWO AREA POWER SYSTEM

Production regions that can work together make up interconnected systems. Under typical operating circumstances, the nominal value of the system's frequency toward load changes and the power distribution between production zones, which is decided by agreement, are maintained constant. This is referred to as LFC. The three steps of the LFC operation are referred to as primary, secondary, and tertiary control [14, 15]. Two ways have been put into practice to SU control this according to PI .In order to manage the frequency, Figure 1 often develops a simplified design of the paper frame. Three important control components are present in this setup. Tertiary, Secondary, and PTR are the names of these.

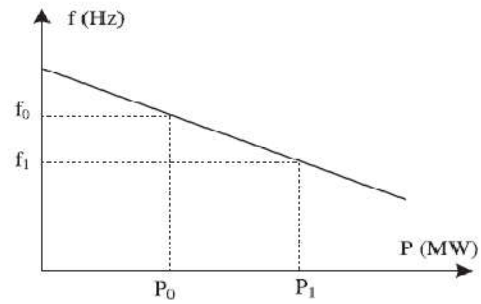

Figure 2.1: Variation of load-frequency characteristic

There are three control actions in huge systems that are coupled to one another. Secondary regulation in a restricted system. In their most basic form, frequency regulation-based DSM strategies are not represented in this diagram but can still be assessed without requiring any conceptual adjustment.

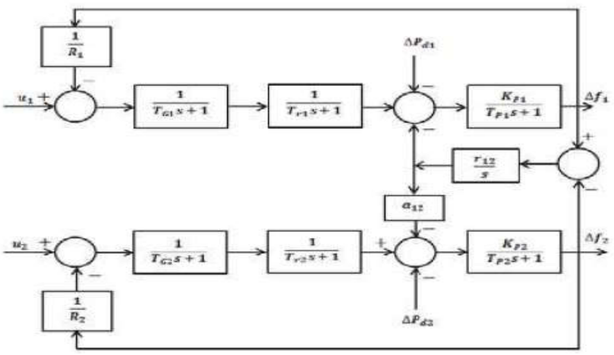

Figure 2.2 two area load frequency control

Each area have governor , turbine, and generator blocks and those are connected with the tie line power control , and the feed back loop ios connected for the each area to measure the steady state frequency deviations.

$$\Delta \omega ss = -\Delta PL1 \div (1/R1+D1) + (1/R2+D2)$$

$$(f) = f0 + \Delta f$$

$$\Delta Pm1 = -\Delta \omega \div R1$$

$$\Delta Pm2 = -\Delta \omega \div R2$$

$$\Delta \omega D2 = \Delta \times \omega D2$$

$$\Delta P12 = \Delta \omega \times (1/R2+D2)$$

Where

$\Delta \omega ss$: steady state frequency
f : The new frequency
Δ Pm1 : Change in mechanical power in area1
ΔPm2 : Change in mechanical power in area2
$\Delta\omega$D2 : Change in area 2 load
ΔP12 : Tie- line power flow

III. MODELING OF TWO AREA INTERCONNECTED POWER SYSTEM WITH FUZZY LOGIC AND PID CONTROLLER

The modeling of two area interconnected power system with out controller and modeling of two area interconnected power system with fuzzy and Pid controller is mentioned in this chapter .

1)Mathematical modeling of two area without controller

Table 3.1:parameters of two area Area 1 Area 2

Speed regulation	R1 = 0.05	R2 = 0.0625
frequency sensor load coefficient	D1 =0.6	D2=0.9
Inertia constant	H1=5	H2=4
Base power	1000 MVA	1000 MVA
Governor time constant	Tg1 =0.2 sec	Tg2 = 0.3 sec
Turbine time constant	Tt1 = 0.5 sec	Tt2 = 0.6 sec

The per unit load change in area 1 is $\Delta PL1 = 187.5 \div 1000 = 0.1875$ pu

The per unit steady state frequency deviation is $\Delta \omega ss = -\Delta PL1 \div (1/R1+D1) +(1/R2+D2)$

$\Delta \omega ss = -0.1875 \div (20 +0.6) +(16 + 0.9) = -0.005$ pu

The steady state frequency deviation in Hz is $\Delta f = (-0.005) \times 50 = -0.25$Hz

The new frequency is $(f) = f0 + \Delta f$

$F = 50 - 0.25 = 49.75$

Change in mechanical power in area1 $\Delta Pm1 = - \Delta \omega \div R1$

$\Delta Pm1 = -0.005 \div 0.05 = 0.10$ pu

Change in mechanical power in area2 $\Delta Pm2 = - \Delta \omega \div R2$

$\Delta Pm2 = -0.005 \div 0.0625 = 0.080$ pu

Change in area 1 load is $\Delta D1\omega = \Delta \times \omega \ D1$

$\Delta \omega D1 = (-0.005) \times 0.6 = -0. 003$ pu = -0.3 MW

Change in area 2 load is $\Delta \omega D2 = \Delta \times \omega D2$

$\Delta \omega D2 = (-0.005) \times 0.9 = -0.0045$ pu = -4.5 MW

Change in total area load is = -7.5 MW

Tie- line power flow $\Delta P12 = \Delta \omega \times (1/R2+D2)$

$\Delta P12 = -0.005 \times 16.9 = -0.0845$ pu

2***) Fuzzy Logic Controller***

There are numerous features for the usage of the fuzzy logic controller, which is the basis for the Mamdani method's selection in this article . The first of them does not undertake mathematical analysis for the complicated non-logical systems it is controlling; instead, it uses fuzzy logic. Second, we do not have to go back to the initial stage if there is a change in how power systems are used. However, this option allows for the addition and deletion of certain MF and rule bases. FLC can be made simpler by combining them with traditional methods.In linked systems, automatic production control tries to plan the PF and balance the frequency independently of load fluctuations.

The ACE, frequency, and link power—a linear mixture of power DS and FD—are used as the reference values for calculating the link line . There are techniques to create a more literary PS model that takes into account physical restrictions like the restriction on the production speed of thermal turbines, the dead band of the speed regulator, and the time delay .There are approaches to a more literary PS model that take into account physical limitations as the restriction on the production speed of thermal turbines, the dead band of the speed regulator, and the time delay .

A four-zone interconnected PS with control dead bands and production RR is planned for in some research. The controller in this study only has2 inputs, though. According to Figure 7, the area control error is the first input that serves as the variable ACE, and the change in the area CS error is the second input that serves as the variable ACE. As shown in

Figure 9, the output (Freq-Level) shows the degree of frequency change caused by an increase or decrease in load. Three steps are ns for the fuzzy controller's fundamental architecture, as shown.

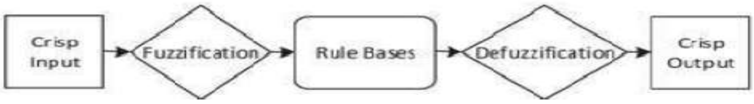

Figure3.1 Steps for fuzzy logic

By allocating a single fuzzy set, a set with MF (A), and a zero in another place, the input variables are identified. If the output variable is aFZ set, the intended control action is expressed by the maximum min and FZ relation with the composition. By blurring, the FZ sets of the output variable is solved, and the centroid method is used to produce a precise numerical value. Equation 8 illustrates the FZ rules base as a collection of forms based on the IF-THEN fuzzy base rule principle.

$$R^{(k)}: IF\ x_1\ and\ x_2\ is\ F^k,\ THEN\ y_1\ is\ G^k,\ for\ k=1,2,..n \qquad (8)$$

Where the inputs and outputs of the fuzzy sets in U1, U2, and R, which stand in for the kth antecedent pair and conclusion pair, respectively, are x1, x2,... xn U and y1 R. Ui, Ri, and n are the numbers of rules, while Fk = U1 U 2. In order to increase the stability and accuracy of the fuzzy controller, the range from -1 to 1 is split into seven-MF in Table 1, which reflects all of the rule bases of the proposed method. The results shown in Tables 3-6 demonstrate the effectiveness and application of FZ logic controllers.

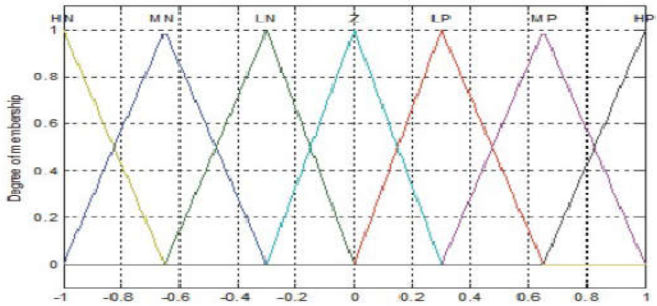

Figure 3.2: The ACE for the 1 input

This graph is input one of fuzzy logic controller and this graph shows the area control error for the first input. Here we take the seven degree of membership functions.

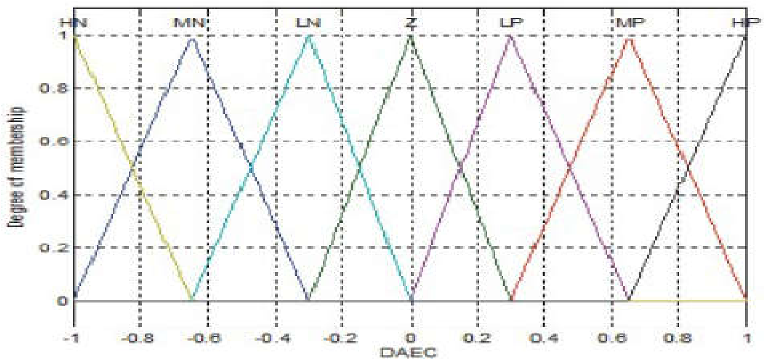

Figure 3.3 : ΔACE for the second input

This graph is input two of fuzzy logic controller and this graph shows the change in area control error for the second input. Here we take the seven degree of membership functions same as like input one

Table 3.2 : rule for the fuzzy logic controller

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

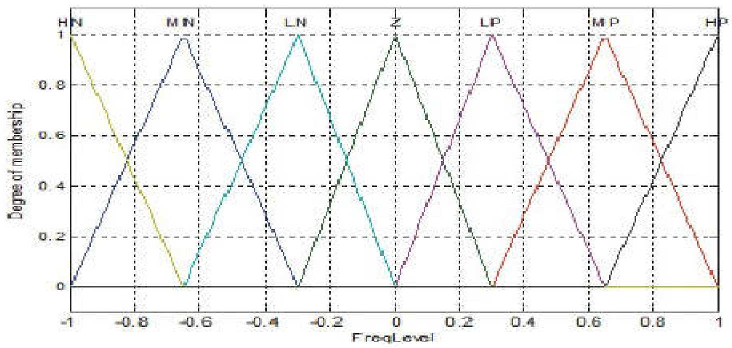

Figure .3.4: The change in frequency level for output

3) PID controller

A PID controller is a device utilized in commercial manipulates programs to alter temperature, flow, pressure, velocity and different technique variables. PID (proportional essential derivative) controllers use a manipulated loop comments mechanism to manipulate technique variables and are the maximum correct and solid controller.The sub system of the proportional derivative integral control as shown above . this consists of three main blocks those are proportional block , integral block , and derivative block. These three blocks are connected to the one common summing point.

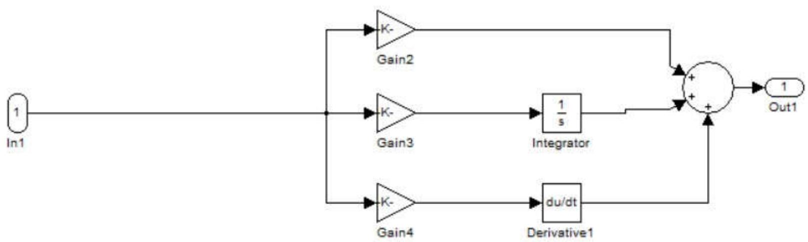

Figure 3.5 Pid controller circuit diagram

This article essentially presents a comparison of PID and fuzzy controllers in four distinct circumstances. As will be demonstrated in several simulated scenarios, the comparison of PID and fuzzy will be among the most crucial elements from which we may choose the optimum controller, including settling time (ts), maximum over shoot (O.S%) oscillation, and ss error (SSE). We will also use the FIS toolbox and Simulink in MATLAB to solve the following numerical example so that we can differentiate between the controllers.

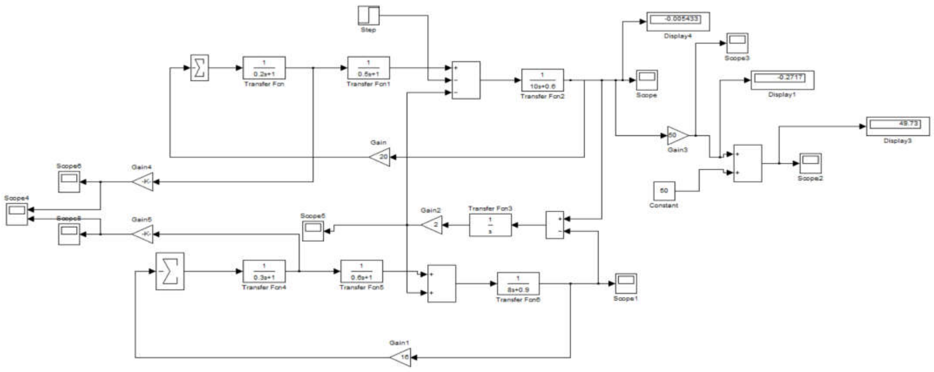

Figure .3.6:Simulation model diagram of LFC without controller

In the circuit diagram of two area load frequency manage we've 3 principal block's governor, turbine, load. We can join the 2 regions with the tile line to degree the extrude in frequency. In this diagram we join regions without any controller and degree the constant nation frequency and extrude in frequency this is new frequency and the tie line energy waft with inside the circuit and extrude in vicinity 1 load and extrude in vicinity 2 load and the whole vicinity load. Here particularly, we calculate the constant nation frequency deviation vicinity interconnected energy system.

The fallowing case studies are implemented

Case 1:

1.1) The input load is 0.2 MW at the two area modeling of LFC using PID Controller.

In this case the first and second area is connected with pid controller and increased 0.2mw for each area

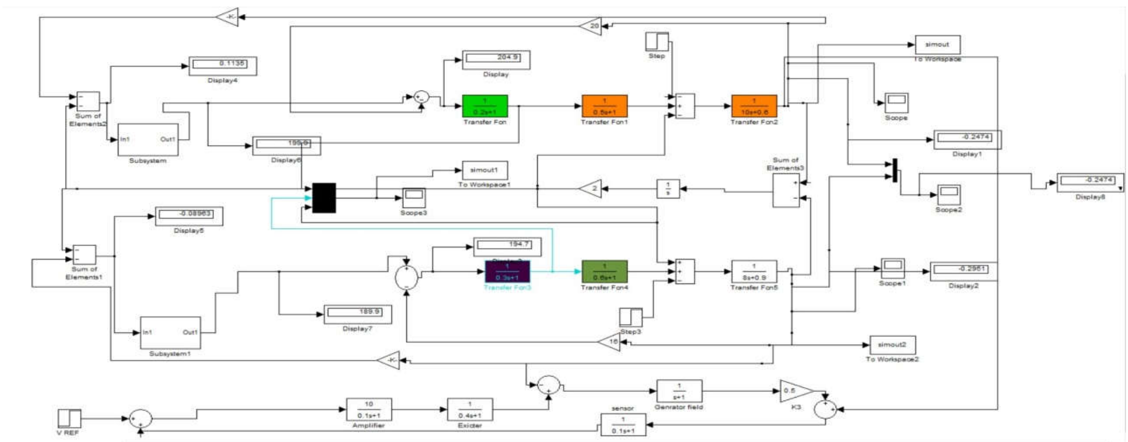

Figure 3.7. Simulation model of two area load frequency with PID controller

1.2) The input load is 0.2 mw at the two area modeling of LFC using fuzz logic controller.

In this case the first and second area is connected with fuzzy controller and increased 0.2mw for each area.

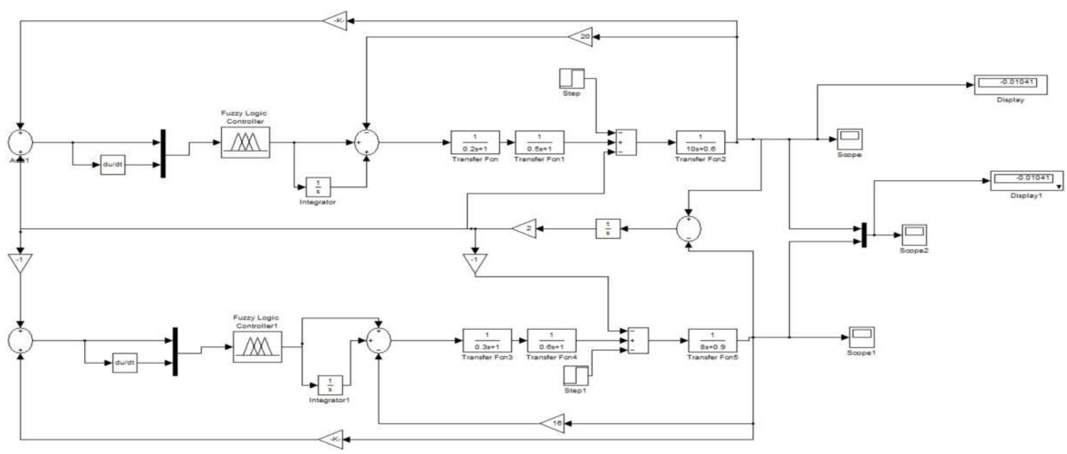

Figure 3.8 : Simulation model of two area load frequency with Fuzzy Logic Controller

Case 2 :

2.1) **<u>The input load is 0.2 mw at the first area modeling of LFC using Fuzzy Controller.</u>**

The first area is increased by 0.2mw controlled by fuzzy and the seconda area is zero controlled by fuzzy controller.

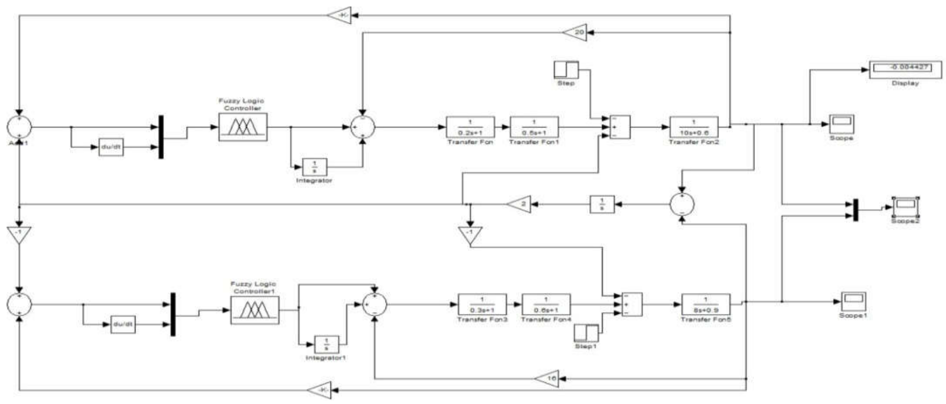

Figure.3.9: Simulation model of two area load frequency with Fuzzy Logic Controller

2.2) <u>The input load is 0.2 mw at the first area modeling of LFC using PID controller.</u>

The first area is increased by 0.2mw controlled by pid and the seconda area is zero controlled by pid controller.

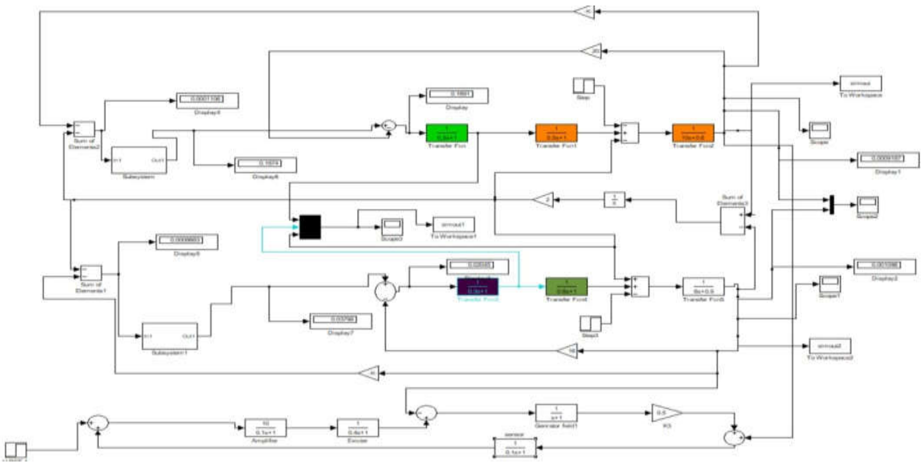

Figure 3.10: Simulation model of two area load frequency with PID Controller

Case 3 :

3.1)**<u>The input load is 0.2 mw at the first area modeling of LFC using PID and Fuzzy Controller.</u>**

the first area is increased by the 0.2mw and controlled by the pid controller and the second area is zero controlled by the fuzzy logic controller.

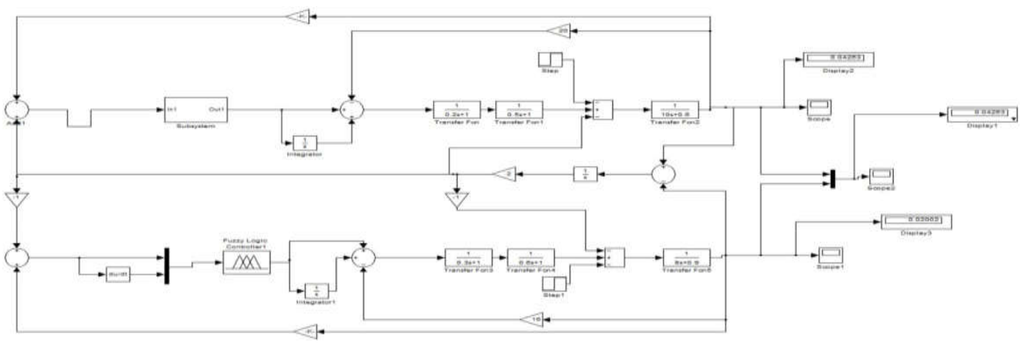

Figure 3.11: Simulation model of load frequency control with using PID and Fuzzy Controller

Case 4 :

4.1) <u>the input load is 0.2 mw at the two area modeling of lfc using pid fuzzy controller</u>

the load is increased by 0.2up at the first and second area and controlled by the both pid and fuzzy logic controller

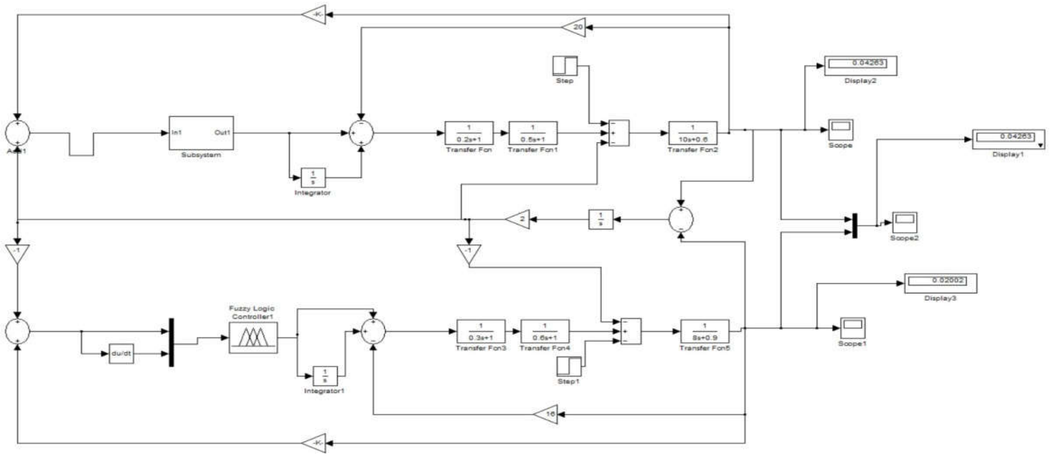

Figure 3.12:Simulation model of load frequency control with using PID and Fuzzy Controller

IV. SIMULATION RESULTS ANDDISCUSSION

Two area load frequency withoutcontroller:

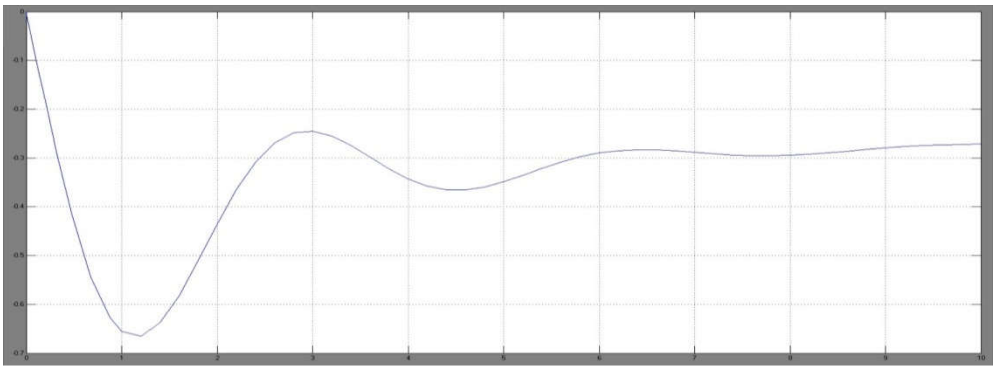

Figure 4.1: for Frequency per unit

Fig. 4.1 shows the frequency per unit of load frequency control of two area interconnected power system withoutany fuzzy and PIDcontroller and the frequency is -0.25.compared to fuzzy and PIDcontroller, without controller have the high steady state frequency and oscillations.

Case 1: 1.1) two area with PID controller

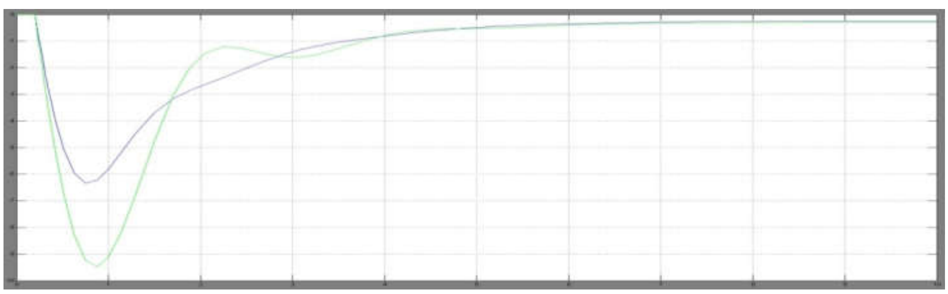

Figure 4.2: PID with two area

Fig. 4.2 shows the two area with PID controller here we take 0.2 mw for the first and second areas. Compared to two area without controller the steady state frequency response of two area with controlleris decreased.

1.3) Two area With fuzzy controller

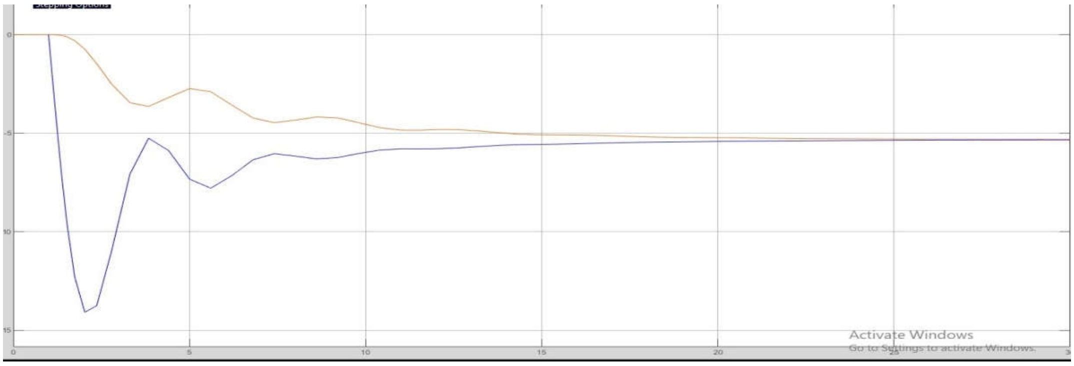

Figure4.3: for fuzzy with two area

The Fig. 4.3 shows the two area with fuzzy logic controller here we take 0.2 mw for the first and second areas. Compared to two area withoutcontroller and the two area with PID controllerthe steady state frequency response of two area with fuzzy logic controller is decreased.

Table.4.1: case 1

Name	PID	FUZZY
Change in frequency (Δf)	-0.2474	-0.01041
Settling time (ts)	30	20

Case 2: 2.1) two area with PID

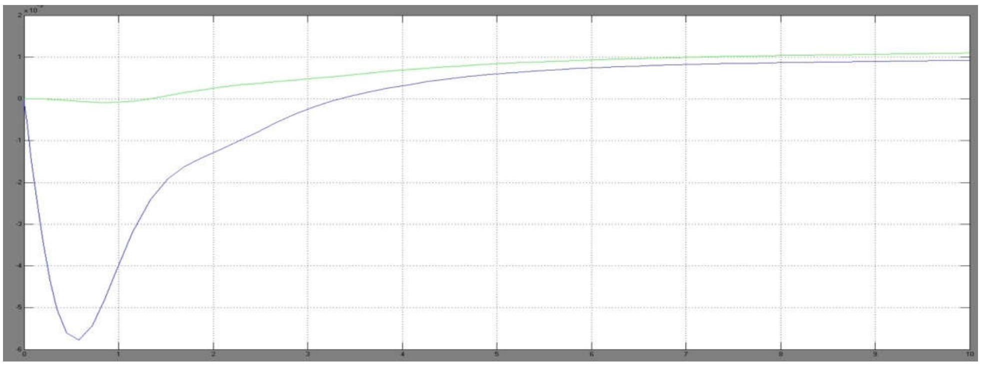

Figure 4.4: for two area pid case2

Fig. 4.4 shows the two area with pid controller here we take 0.2 mw for the first and second area is zero. Compared to two areaswithoutcontroller the steady state frequency response of two area with PID controller is decreased.

2.2) two area with Fuzzy controller

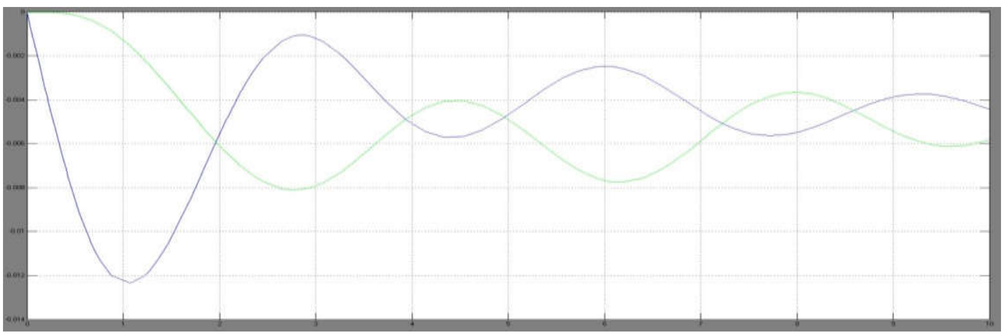

Figure4.5: for two area fuzzy case 2

Fig. 4.5 shows the two area with fuzzy logic controller here we take 0.2 mw for the first and second area is zero. Compared to two area withoutcontroller the steady state frequency response of two area with Fuzzy controlleris decreased.

Table 4.2: for case 2

Name	PID	FUZZY
Change in frequency (Δf)	0.009187	-0.004427
Settling time (ts)	22	20

Case 3:two area with PID and fuzzy

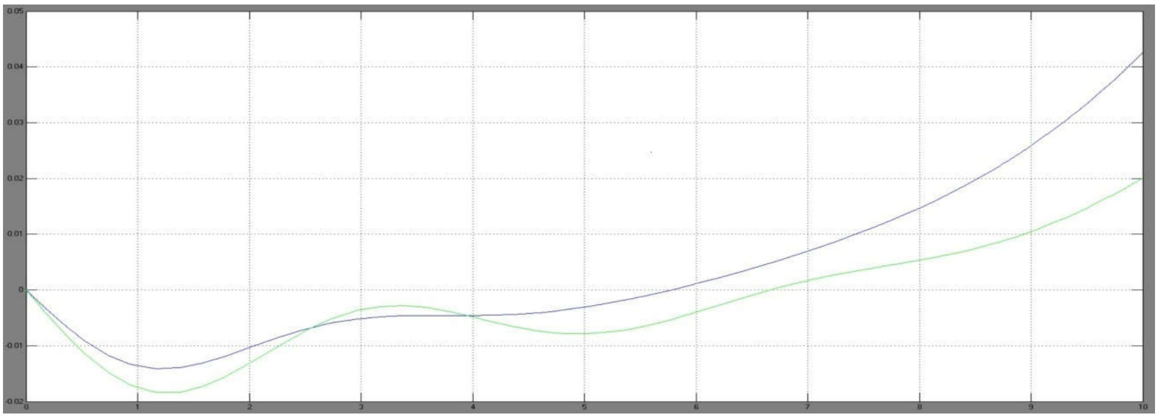

Figure 4.6: PID and Fuzzy case

Fig. 4.6 shows the two area with the PID and fuzzy logic controller here we take 0.2 mw for the first and second area is zero. Compared to two area withoutcontroller the steady state frequency response of two area with the PID and Fuzzy controller is decreased.

Table 4.3: for case 3

Name	PID	FUZZY
Change in frequency	-0.2543	-0.1341
Settling time	20	19

Case 4 :<u>two area with pid and fuzzy</u>

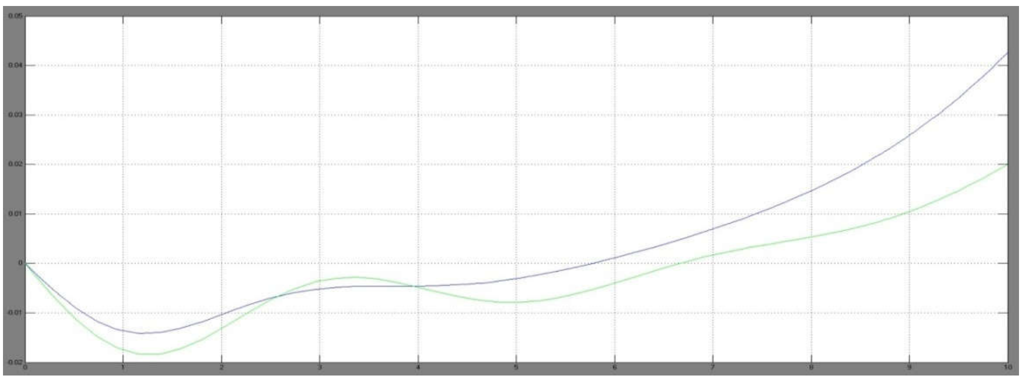

Figure 4.7: Graph for case 4

Fig. 4.7 shows the two area with the pid and fuzzy logic controller here we take 0.2 mw for the first and second area. Compared to two area withoutcontroller the steady state frequency response of two area with the PID and Fuzzy controller is decreased.

Table.4.4: for case 4

name	PID	FUZZY
Change in frequency	0.04263	0.02002
Settling time	20	10

Table 4.5:Change in frequency for every case

scenario	Controller	Ts	Δf
case 1	PID	30	-0.2474
	FUZZY	20	-0.0104
case 2	PID	22	0.00919
	FUZZY	20	-0.0044
case 3	PID	20	-0.2543
	FUZZY	19	-0.1341
case 4	PID	20	0.04263
	FUZZY	10	0.02002

V. CONCLUSION

In this project, two extremely cutting-edge techniques were employed in place of the governor control system, which controlled load frequency. PID and fuzzy logic, which are frequency used in control, are the methodologies used. In control systems, PID and fuzzy logic are often employed techniques. In actual use, the effectiveness of these controls was evaluated against various scenarios in the Two ACE-connected systems. The purpose of the study is to compare the performance aspects of PID and fuzzy controllers for the two areas' interconnected power systems, which are examined using four different scenarios. Performance of the fuzzy controller is demonstrated to be superior to PID-based applications for controlling the two area-connected power systems based on frequency and settling time (ts). The findings of four separate scenario with accompanying results show that fuzzy controllers offer numerous advantages over the latter one, including a lower settling time (ts),a steady state frequency change.

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