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# A heurstic Itelligent neuro-fuzzy system model for Load Frequency control of multi area power systems

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***Abstract***— Because electrical load demand varies unpredictably day by day in a power system, any small load change in any of the areas affects both area frequencies and tie-line power flow exchanges. The primary goal of Load Frequency Control (LFC) is to keep the frequency and target power output in the multi-area power system at the predefined values while also controlling the change in tie-line power flow between control zo nes. The purpose of this paper is to present a basic implementation of Adaptive Neuro Fuzzy Logic Controller (FLC) to control load frequency in interconnected power system. For that, control methodology is ANFIS Control for three area interconnected power system. With the help of this proposed scheme, has great advantage in terms of cost and reliability. The main objective is to design a robust controller that can ensure good performance. The main motivation of this paper is to control the change in output frequency response with minimum peak overshoot and settling time.

***Keywords***— *Load Frequency Control (LFC), Adaptive Neuro Fuzzy Logic Control (ANFIS), Three area power system, PID Controller, change in frequency error, Change in tie-line power error. Introduction (*HEADING 1*)*

# I. INTRODUCTION

As the demand for electricity is increases day by day, the complexity of power system also increases. As the complexity is increases it led to decrease of reliability and efficiency of generated and transmitted power. For improving this one of the major factors is frequency and voltage. The frequency is highly dependent on active power, while the voltage is highly dependent on reactive power. As a result, the control difficulty of the power system can be divided into two components. The first is concerned with the regulation of active power and frequency, while the second is concerned with the regulation of reactive power and voltage. Automatic Load Frequency Control is the combination of active power control with frequency control. To implement load frequency control techniques which are load frequency control using PID controller and load frequency control using ANFIS. The application of PID controller based Fuzzy Logic Control to load frequency control (LFC) of linked multi-area power systems is discussed in this study. To tune the PID controller parameters, the fuzzy logic technique is used. The interconnected multi-area power system is simulated for different disturbances in area-1, area-2, and area-3.

# II. SINGLE AREA POWER SYSTEM

A single area power system consisting of a governor, a turbine and a generator with a feedback block 1/R. This feedback is used to give change in frequency error. Below figure represents the block diagram of single area.

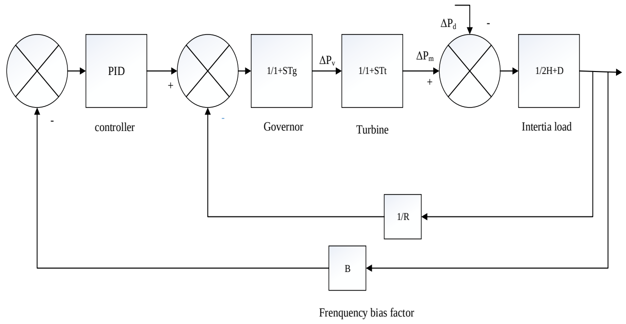


**Fig 2.1: Block diagram of single area**

**2.1 Speed Governor:** By considering various steady state conditions this speed governing model is developed. The finally obtained speed governing model is:

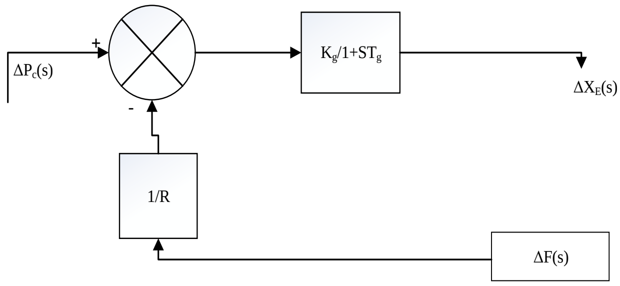


**Fig 2.2: Block diagram of speed governor**

From the above figure we get the following equation:

$$\Delta X_E(S) = \frac{K_G}{1+ST_G}\left[\Delta P_C(S) - \frac{1}{R}\Delta F(S)\right]$$

Where:
R=Speed regulation of the governor
$K_G$=Gain of speed governor
$T_G$=Time constant of speed governor.

**2.2 Turbine model:** It requires change in power output turbine to steam valve opening $\Delta X_E$

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$$\Delta G_T(S) = \frac{\Delta P_T(S)}{\Delta X_E(S)} = \frac{K_T}{1 + ST_T}$$

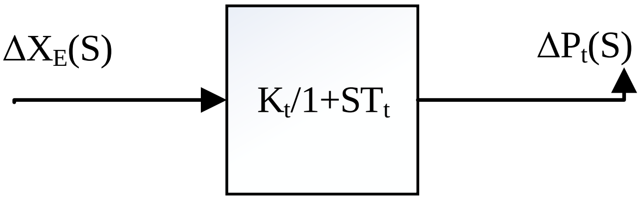

**Fig 2.3: Block diagram of turbine**

**2.3 Generator-load model:** This model gives the relation between the change in frequency as a result of change in generation when load is changing.

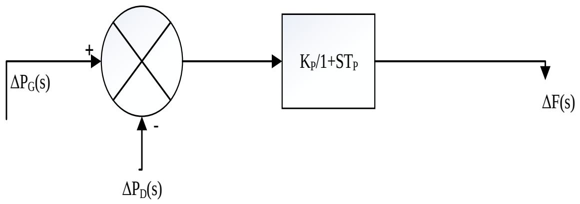

**Fig 2.4: Block diagram of Generator-load model**

From the above block diagram, we obtain an equation:

$$\Delta F(S) = [\Delta P_G(S) - \Delta P_D(S)] \frac{K_P}{1 + ST_P}$$

Where:

$T_P = \frac{2H}{DF^0}$ = power system constant

$K_P = \frac{1}{D}$ = power system gain

In single area change in frequency is obtained by:

$$\Delta f = \frac{1}{D + \frac{1}{R}} [\Delta P_C - \Delta P_D]$$

## III THREE AREA POWER SYSTEM

In this system three control areas are interconnected using transmission lines called "tie-line", which allow the flow of active power from one control area to another control area when required.

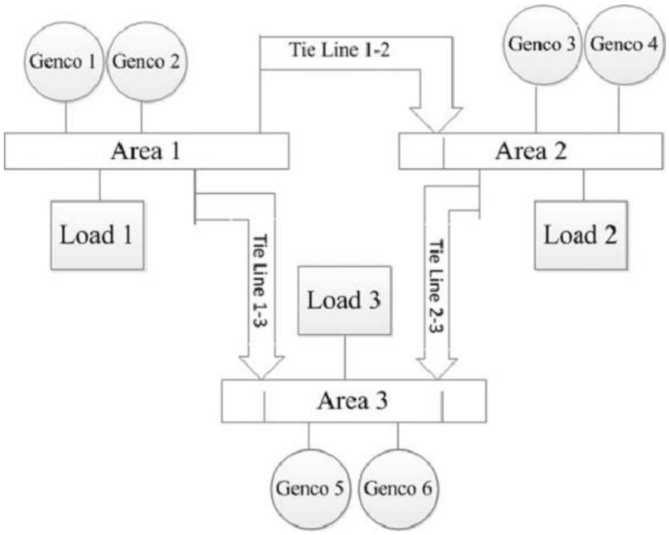

**Fig 3.1: Three area system**

As above discussed, that active power will from one area to another area when required, for that we have to maintain constant frequency. Whenever there is any disturbance in power system it may lead to frequency deviation, this may lead to no power flow between control areas, to maintain this frequency constant there are some methodologies, in this paper we discussed two methods they are load frequency control with PID controller and load frequency control with adaptive neuro fuzzy interface system (ANFIS).

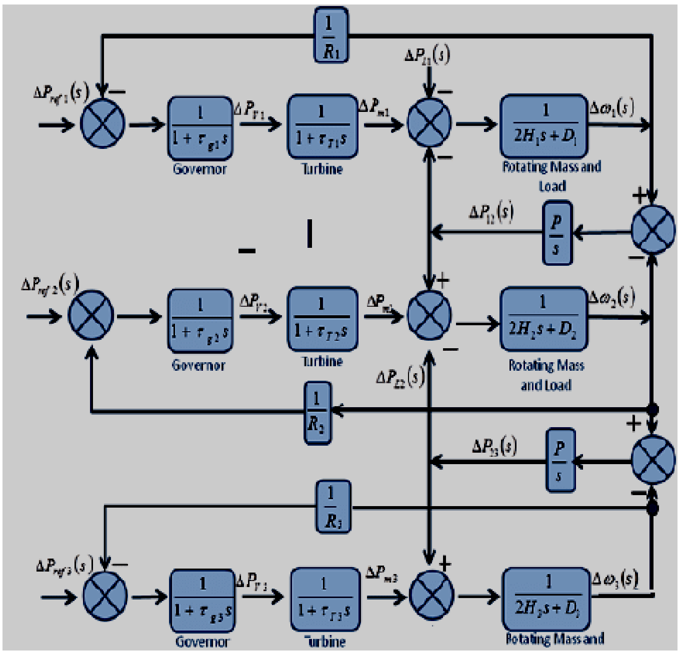

**Fig 3.2: Block diagram of Three area power system**

## IV LFC WITH PID CONTROLLER

In above figure in place of controller we have to use pid as controller. For that first we have known about pid controller.

**4.1 PID controller:** A conventional pid controller is most widely used because of easy to design and inexpensive. Pid consist of three blocks they are proportional, integral, derivative. This pid controller is the combination of the PI and

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PD controllers. The PD control, is used to improves the transient-response characteristics, improves system stability and increases the system bandwidth, which implies fast rise time. PI control and Pd control actions occur in different frequency ranges. PI control action takes place in low frequency region and PD control action takes place in high frequency region. This PID control actions may use to improve both steady-state and transient response.

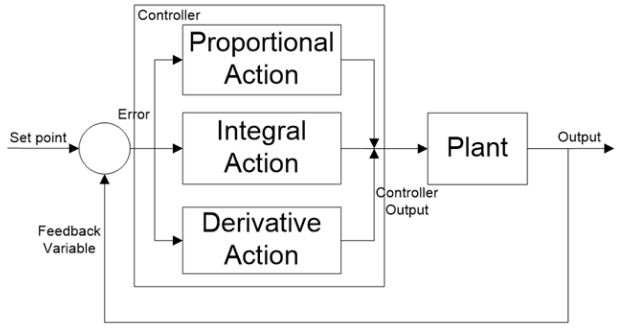


**Fig 4.1: PID controller**

**4.1.1 proportional control:** This proportional control is used to improve the rise time. The transfer function of proportional control is expressed below:

$$P_{term} = K_P e(t)$$

**4.1.2 Integral control:** This proportional control is used to reduce steady state error. The transfer function of proportional control is expressed below:

$$I_{term=}K_i \int_0^t e(t)\, d\tau$$

**4.1.3 Derivative control:** This proportional control is used to reduce peak over shoots. The transfer function of proportional control is expressed below:

$$D_{term=}K_d \frac{d\ e(t)}{dt}$$

Where:

$K_P$= proportional component

$K_i$ = integral component

$K_d$ =derivative component

$e(t)$ = error signal

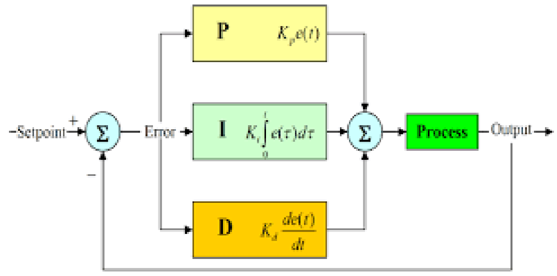


**Fig 4.2: Block diagram of pid**

**4.2 PID controller in three area power system:**

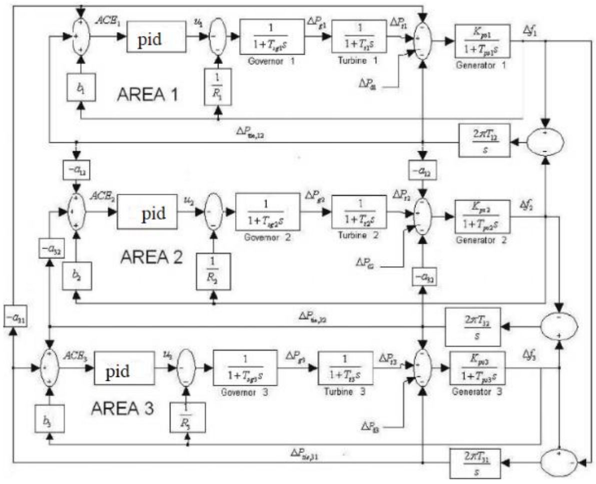


**Fig 4.3: PID controller in three area power system**

## V ANFIS

ANFIS is combination of both Artificial Neural Network and Fuzzy Logic Control. Artificial Neural Network functions when some inputs data is fed to it. This data is then processed via layers of perceptron to produce a desired output. Fuzzy logic controller is a system which is used to control the working of a physical system (ex plant) with the help of fuzzy logic.

**5.1 Architecture Artificial Neural Network:**

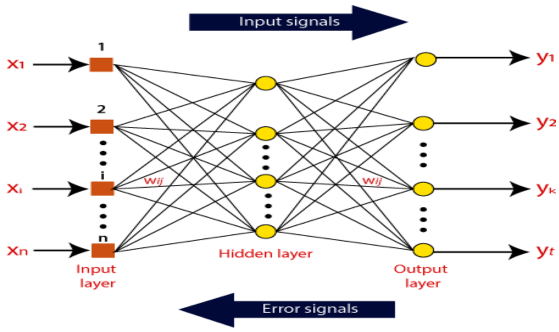


**Fig 5.1: Architecture Artificial Neural Network**

- **Input Layer:** As the name implies, it accepts inputs in a variety of formats specified by the programmer.

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- **Hidden Layer:** A hidden layer exists between the input and output layers. It does all of the math to uncover hidden features and patterns.
- **Output Layer:** The input goes through a series of changes via the hidden layer, culminating in output provided by this layer. The artificial neural network computes the weighted total of the inputs, which also includes a bias. This computation is expressed using a transfer function.

$$\sum_{i=1}^{n} W_i * X_i + b$$

The weighted total is fed into an activation function

to generate the output.

### 5.2 Fuzzy Logic Control:

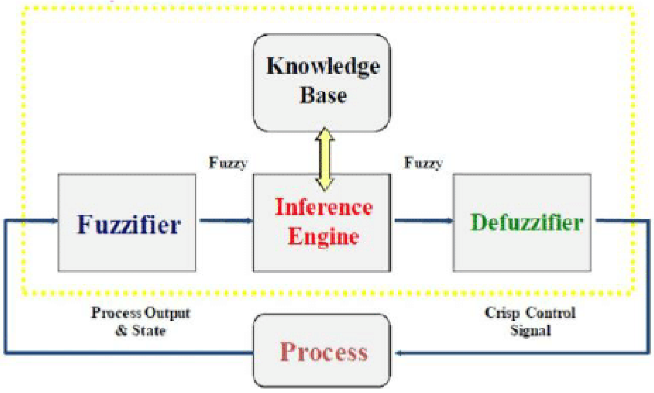


**Fig 5.2: Block diagram of Fuzzy Logic Control**

- **Fuzzification**: It converts crisp values to fuzzy values using a knowledge base. A knowledge base's input variables are defined as fuzzy variables using membership functions.
- **Fuzzy Interface System:** FIS is made up of a fuzzy rule base that takes fuzzy variables as input and produces positive fuzzy output, which is then fed into the defuzzification process.
- **Defuzzification:** It uses defuzzification variables to transform fuzzy values into crisp values.

### 5.3 Architecture ANFIS:

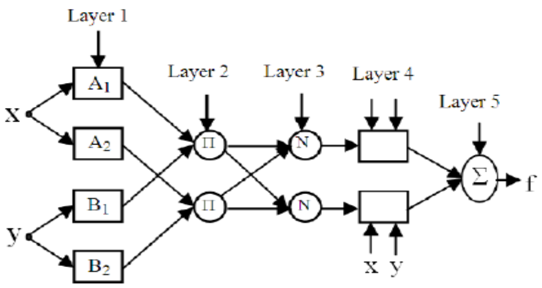


**Fig 5.3: Architecture ANFIS**

- **First layer:** It takes in input values and determines the membership functions they belong to. It's also known as the fuzzification layer. Each function's membership functions are computed using the parameters A, B, and C.
- **Second layer:** This layer has a fixed node that uses multiplication to calculate the firing strength of a rule. The output of each node represents the rule's firing strength:

$$O_i^2 = \mu\alpha_m(x).\mu_{\beta_m}(y)$$

- **Third layer:** The normalized firing strength of a rule is calculated using the preceding Layer. $O_m^3 = \overline{W_m} = \frac{W_m}{W_1+W_2}$
- **Layer-4:** This layer calculates the output contribution of the mth rule.

$$O_m^4 = \overline{W_m}(P_m x + q_m y + r_m)$$

- **Layer-5:** Each rule's contribution is added to a single node.

$$O_m^5 = \sum_m \overline{W_m} f_m \frac{\sum W_m f_m}{\sum f_m}$$

- The overall output is given as

$$\emptyset = (\overline{W_1}x)p_1 + (\overline{W_1}y)q_1(\overline{W_1})r_1 + (\overline{W_2}x)p_2 + (\overline{W_2}y)q_2 + (\overline{W_2})r_2$$

## VI SIMULATION OF THREE AREA

### 6.1 Simulation of load frequency control of three area power system:

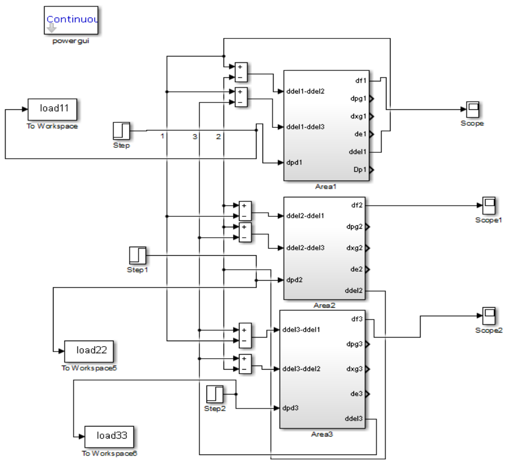


**Fig 6.1: Simulation of three area power system**

#### 6.1.1 Simulation of area1 with PID controller:

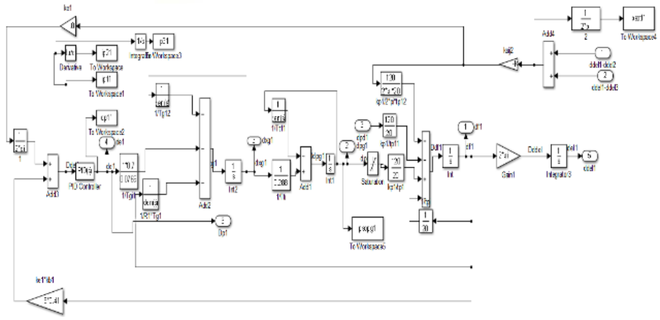

Fig 6.2: Simulation of area1 with PID controller

Similarly, simulation of area2 and area 3 also same as above.

**6.2 Simulation of area1 with ANFIS controller:**

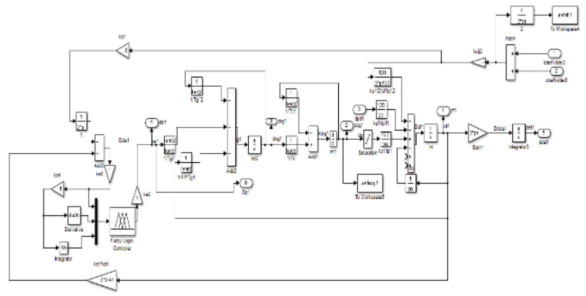

Fig 6.3: Simulation of area1 with ANFIS controller

Similarly, simulation of area2 and area 3 also same as above.

After block diagram construction is over in MATLAB, we have run the file. After this we have type anfisedit in command prompt. After this one folder will open that is shown below.

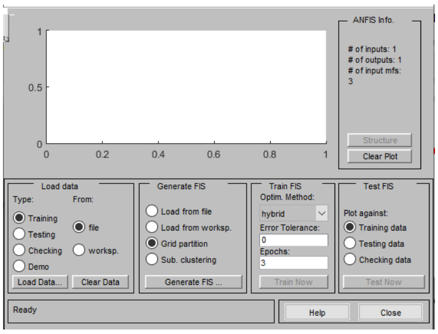


Fig 6.4: Neuro-fuzzy designer

After this we have to give the number of membership functions in anfisedit folder by clicking on generate FSI after this a FIS file is generated. After gelation of FIS file, we will get a structure based on number of membership function. Below figure represents structure of ANFIS.

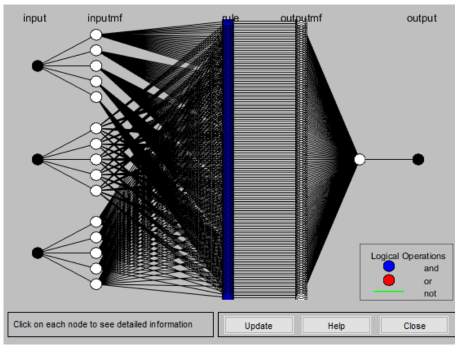


Fig 6.5: ANFIS model structure

and this is how membership function editor look like. The below figure represents the member ship function editor. Here we can observe that number of inputs and number of outputs.

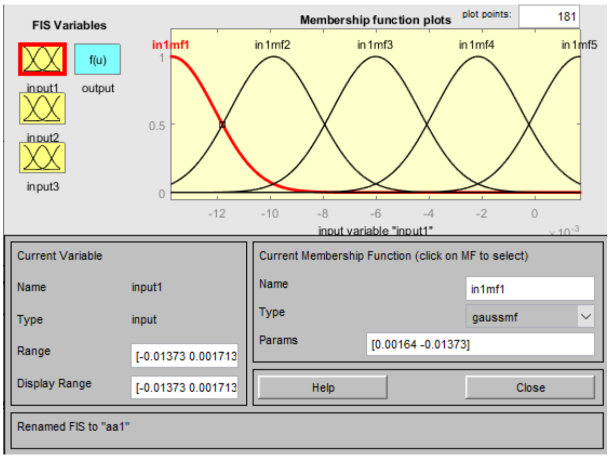


Fig 6.6: Membership Functions

In this only if we click on view button it has a button called rules. Below figure represents the rules.

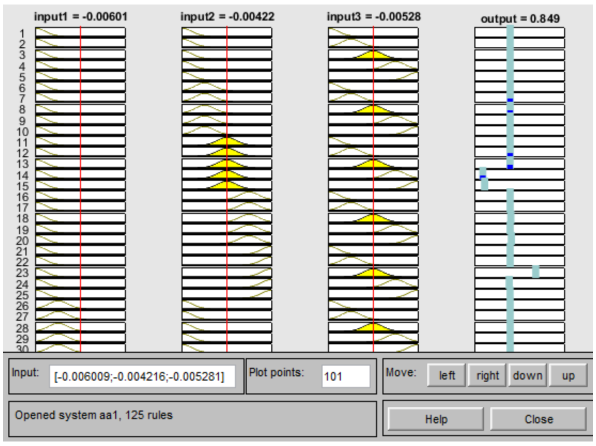


Fig 6.7: Rules of ANFIS

## VII RESULTS

### 7.1 Increase in load of AREA-1:

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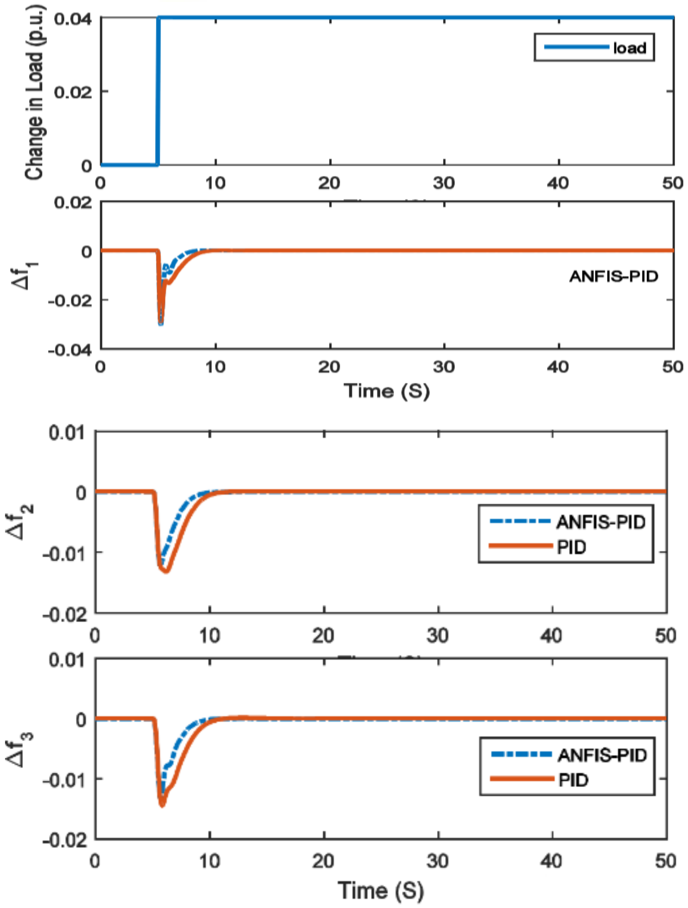
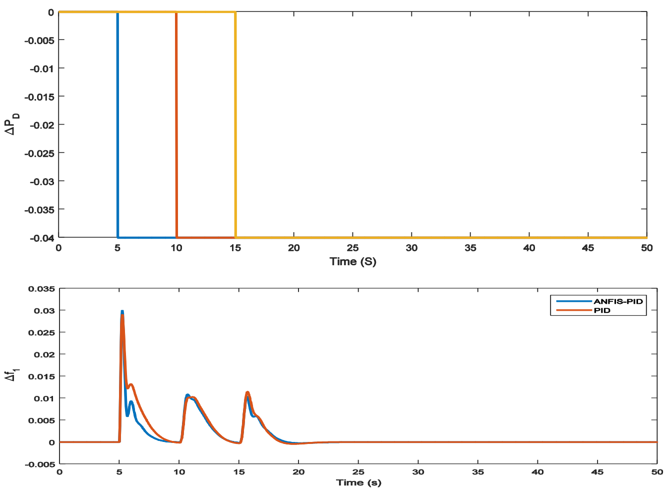



**Fig 7.1: Change in frequency of all areas when load increase in area-1**

Figure 7.1 represents the response of area-1, area-2, area-3 when there is step load increase at 5sec in area-1. The above characteristics drawn between change in frequency (p.u) with respect to time.

### 7.2 Decrease in load of all areas:



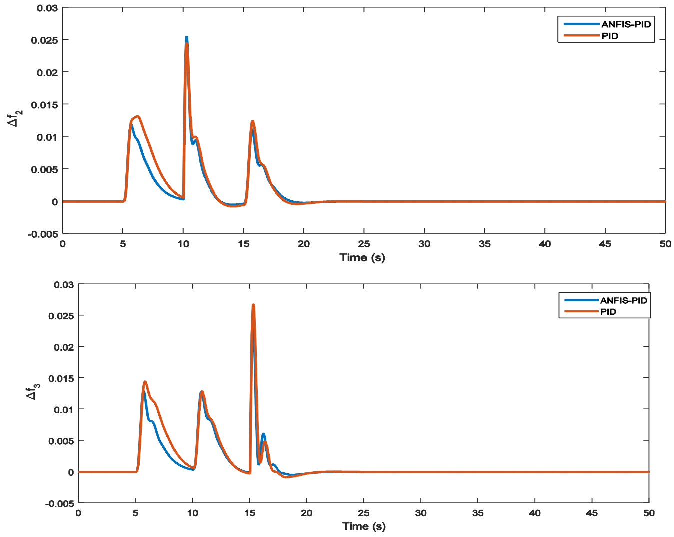
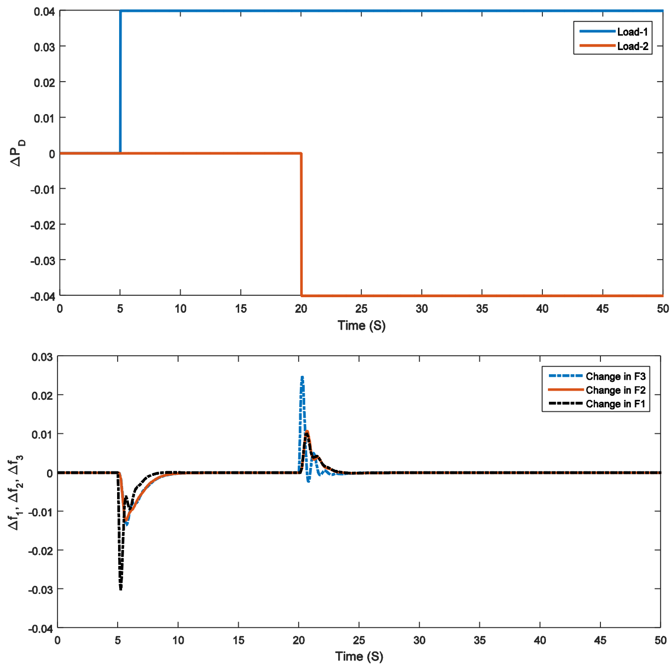




**Fig 7.2: Change in frequency of all areas when load decrease in all area**

Figure 6.9 represents the response of area-1, area-2, area-3 when there is step load decrease at 5 seconds, 10 seconds, 15 seconds in area-1, area-2, area-3 respectively. The above characteristics drawn between change in frequency (p.u) with respect to time.

### 7.3 Tie-line power variations when load change in AREA-1 and AREA-3:



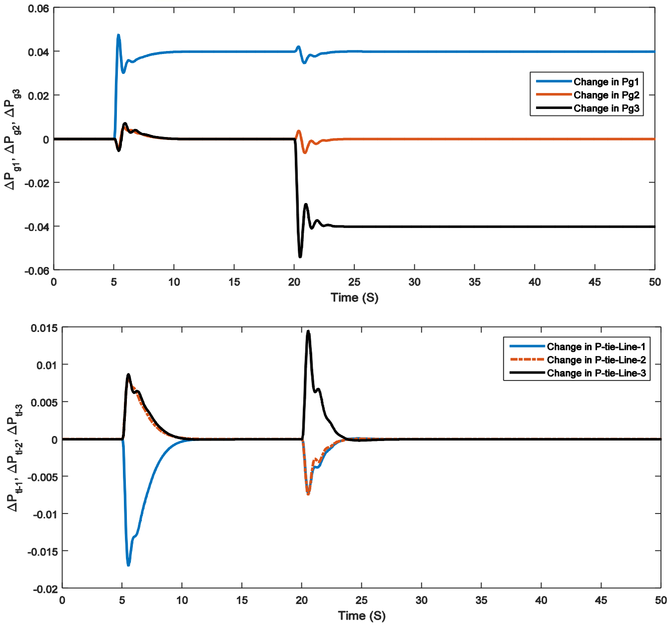


Fig 7.3: Tie-line power variations when load change in AREA-1 and AREA-3

In figure 7.3, it shows how the tie-line power varying when change in area-1 and area-3. Here in area-1 load is increased at 5sec at this time tie-line power of area-1 is in negative direction which mean there is a tie-line power flow into the area-1. Similarly, in area-3 load is decreased at 20 sec at that time tie-line power of area-1 is in positive direction which mean there is a no tie-line power flow into the area-3.

## CONCLUSION

In this paper adaptive neuro-fuzzy inference system is designed to control load frequency for three area power system in each area. In this paper we compared the results of ANFIS with conventional PID. Based on results it concludes that ANFIS based load frequency control gives better response in terms of steady state error, settling time and peak over shoot. This devolved ANFIS is easy to design and easy to implement and easy to get output when compared with PID based load frequency controller.

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