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Load Frequency Controls of Three Are Interconnected Power System with Adaptive Neuro Fuzzy Inference System Approach

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ABSTRACT:

Now days in industry or any area increasing load is a vast problem for power generation plants due to increase in demand for power. So making balance between generation and demand is the operating principle of load frequency control (LFC). So there is a need of robust control of both systems frequency and tie-line power flows. This thesis presents the design and analysis of Neuro Fuzzy controller based on Adaptive Neuro-Fuzzy inference system (ANFIS) architecture for Load frequency control (LFC) of interconnected areas, to regulate the frequency deviation and tile line power deviations. Any mismatch between generation and demand causes the system frequency to deviate from its nominal value. Thus high frequency deviation may lead to system collapse. This necessitates a very fast and accurate controller to maintain the nominal system frequency. This newly developed control strategy combines the advantage of neural networks and fuzzy inference system and has simple structure that is easy to implement. So, In order to keep system performance near its optimum, This ANFIS replaces the original conventional proportional Integral (PI) controller and a fuzzy logic (FL) controller were also utilizes the same area criteria error input. Simulation results are tested in MATLAB/SIMULINK.The performance of the proposed ANFIS based Neuro-Fuzzy controller damps out the frequency deviation and attains the steady state value with less settling time and reduces the overshoot of the different frequency deviations and also reduces the interchanged tie line power compare to the Conventional PI, Fuzzy Controllers.

Keywords:

Load Frequency Control (LFC), Adaptive Neuro-Fuzzy Inference System, Conventional PI Controller, Fuzzy Logic Controller, Neuro-Fuzzy Controller, Tie Line, Interconnected Power System.

I. Introduction:

In order to keep the system in the steady state, both the active and the reactive powers are to be controlled. The objective of the control strategy is to generate and deliver power in an interconnected system as economically and reliably as possible while maintaining the voltage and frequency with in permissible limits. Changes in real power mainly affect the system frequency, while the reactive power is less sensitive to the changes in frequency and is mainly dependent on the changes in voltage magnitude. Thus real and reactive powers are controlled separately.

The load frequency control loop (LFC) controls the real power and frequency and the automatic voltage regulator regulates the reactive power and voltage magnitude. Load frequency control has gained importance with the growth of interconnected systems and has made the operation of the interconnected systems possible. In an interconnected power system, the controllers are for a particular operating condition and take care of small changes in load demand to maintain the frequency and voltage magnitude within the specified limits.

II. Reasons for keeping frequencyconstant:

The following are the reasons for keeping strict limits on the system frequency variations. The speed of AC motors is directly related to the frequency. Even though most of the AC drives are not much affected for a frequency variation of even 50±0.5Hz but there are certain applications where speeds consistency must be of higher order. The electric clocks are driven by synchronous motors and the accuracy of these clocks is not only a function of frequency error but is actually of the integral of this error. If the normal frequency is 50Hz, and the turbines are run at speeds corresponding to frequency less than 47.5Hz or more than 52.5Hz the blades of the turbine are likely to get damaged. Hence a strict limit on frequency should be maintained [1]. The system operation at sub normal frequency andvoltage leads to the loss of revenue to the suppliers due to accompanying reduction in load demand .It is necessary to maintain the network frequency constant so that powerstations run satisfactorily in parallel. The overall operation of power system can be better controlled if a strict limit on frequency deviation is maintained. The frequency is closely related to the real power balance in the overall network. Change in frequency [2-6], causes change in speed of the consumers' plant affecting production processes.

III. Mathematical Modeling:
1 Complete Block Diagram Representation of Load Frequency Control of an Isolated Power System:

The complete block diagram representation of an isolated power system comprising turbine, generator, governor and load is obtained by combining the block diagrams of individual components.

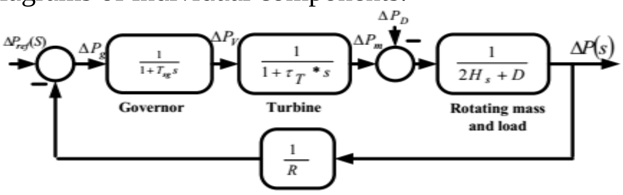

Fig .1 Block Diagram Representation of Load Frequency Control of an Isolated Power System

IV.Two AreaLoad Frequency Controls:

An extended power system can be divided into a number of load frequency control areas interconnected by means of tie-lines. Let us consider a two-area case connected by a single tie-line

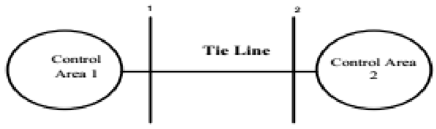

Fig 2 Two Area with Tie-Line Connection

The control objective is now to regulate the frequency of each area and to simultaneously regulate the tie-line power as per inter-area power contracts. As in the frequency, proportional plus integral controller will be installed so as to give steady state error in tie-line power flowas compared to the contracted power. Each control area can be represented by an equivalent turbine, generator and governor system. Symbols with suffix 1 refer to area 1 and those with suffix 2 refer to area 2. In an isolated control area case the incremental power (ΔPG-ΔPD) was accounted for by the rate of increase of stored kinetic energy and increase in area load caused by increase in frequency. Since a tie-line transports power in or outof an area, this must be accounted for in the incremental power balance equation of each area. Power transported out of area 1 is given by

$$P_{tie1} = \frac{|V_1||V_2|}{X_{12}} \sin(\delta_1 - \delta_2) \quad (1)$$

Where, δ1, δ2 are power angles of equivalent machines of two areas. For incremental changes in δ1 and δ2 , the incremental tie line power can be expressed as

$$\Delta P_{tie1}(pu) = T_{12}(\Delta\delta_1 - \Delta\delta_2) \quad (2)$$

$$\text{Where } T_{12} = \frac{V_1 V_2}{P_{r1} X_{12}} \cos(\delta_1^0 - \delta_2^0) \quad (3)$$

is a synchronizing coefficient. Since incremental power angles are integrals of incremental frequencies, we can write above equation as follows

$$\Delta P_{tie1} = 2\pi T_{12} \left(\int \Delta f_1\, dt - \int \Delta f_2\, dt\right) \quad (4)$$

Where Δf1 and Δf2 are incremental frequency changes of areas 1 and 2 respectively. Similarly, the incremental tie-line power out of area 2 is given by

$$\Delta P_{tie2} = 2\pi T_{21} \left(\int \Delta f_2\, dt - \int \Delta f_1\, dt\right) \quad (5)$$

$$\text{Where } T_{21} = \left(\frac{P_{r1}}{P_{r2}}\right) T_{12} = a_{12} T_{12} \quad (6)$$

The power balance equation for area 1 is given by

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$$\Delta P_{G1} - \Delta P_{G2} = \frac{2H_1}{f_0}\frac{d}{dt}(\Delta f_1) + B\Delta f + \Delta P_{tie,1}. \quad (7)$$

In two-area power system, in order that the steady state tie line power error be made zero, another integral control loop must be introduced to integrate the incremental tie-line power signal and feed it back to the speed changer. This is accomplished by defining ACE as a linear combination of incremental frequency and tie-line power. Thus, for control area 1,

$ACE_1 = \Delta P_{tie1} + b_1 \Delta f_1$ ....
Taking the Laplace transform we get
$ACE_1(s) = \Delta P_{tie1} + b_1 \Delta F_1(s)$.......
Similarly, for control area 2,
$ACE_2(s) = \Delta P_{tie2} + b_2 \Delta F_2(s)$....... (8)

The complete block diagram of two-area load frequency control is shown below. For the steady state error to be zero, the change in tie-line power and the frequency of each area should be zero. This can be achieved by integration of ACEs in the feedback loops of each area.

V. Different types of controllers

1 PI controller:

A controller in the forward path, which changes the controller output corresponding to the proportional plus integral of the error signal is called PI controller. The PI controller increases the order of the system, increases the type of the system and reduces steady state error tremendously for same type of inputs.

Fuzzy controller:

In control systems, the inputs to the systems are the error and the change in the error of the feedback loop, while the output is the control action. The general architecture of a fuzzy controller is depicted in Fig 5.3[1].The core of a fuzzy controller is a fuzzy inference engine (FIS), in which the data flow involves fuzzification, knowledge base evaluation and defuzzification.

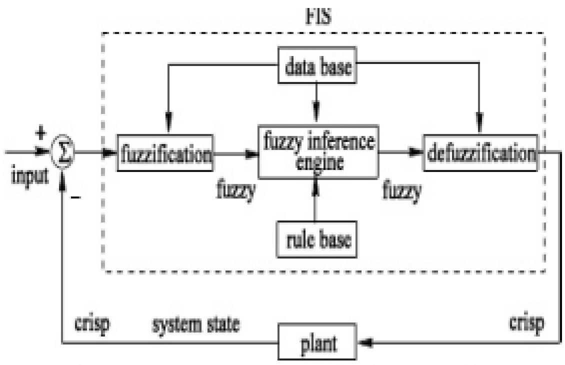

Fig 3 Structure of fuzzy logic controller

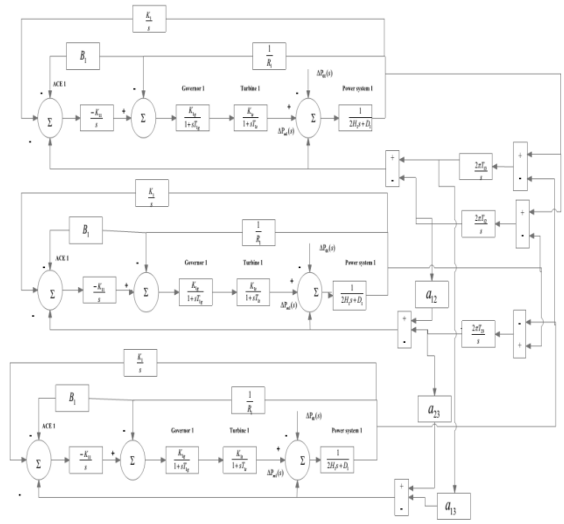

Fig 4 Complete block diagram of Three- area LFC

VI FUZZY LOGIC CONTROLLER:

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique.

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Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

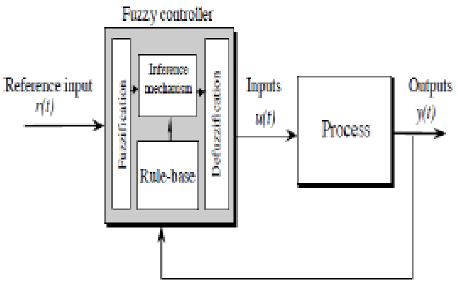

Fig.5. General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

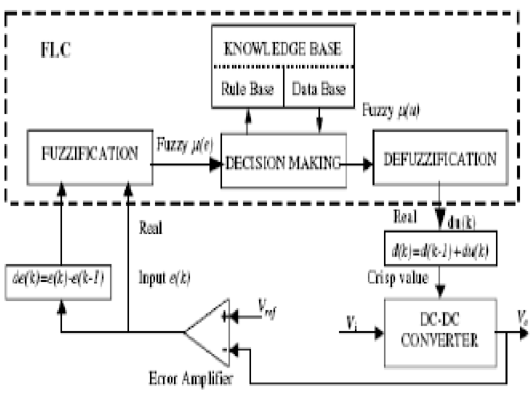

Fig.6. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

Fuzzy Logic Membership Functions:

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

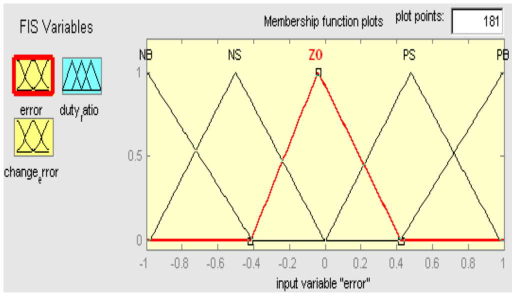

Fig. 7.The Membership Function plots of error

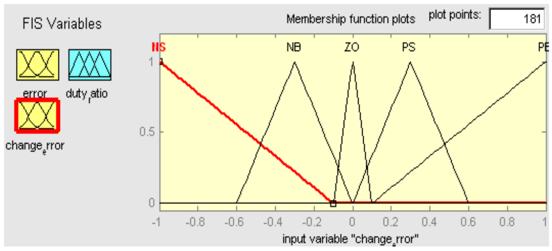

Fig.8. The Membership Function plots of change error

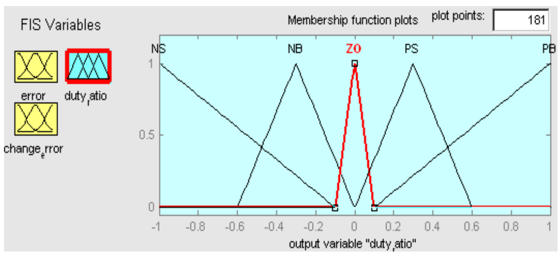

Fig.9. the Membership Function plots of duty ratio

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Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table II as per below:

Table I:Table rules for error and change of error

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

Artificial Neural Networks:

The proposed model membership functions are controlled by the ANN. It can reduce the steady state errors in frequency disturbances from the turbines. It can also compensate the over shoot errors in the three areas. The settling time and peak overshoot losses are minimized very effectively than the P, PI, PID controllers.

The neuro-fuzzy method grabs the advantages of neural networks and fuzzy theory to design a model that uses fuzzy theory to represent knowledge in an interpretable manner and the learning ability of a neural network to optimize its parameters. ANFIS is a separate approach in neuro-fuzzy development which was first introduced by Jang [14 the model considered here is based on Takagi-Sugeno Fuzzy inference model.

The block diagram of the proposed ANFIS based Neuro-Fuzzy controller for two area power system consists of parts, i.e. fuzzification, knowledge base, neural network and de-fuzzification blocks, shown in Fig.8

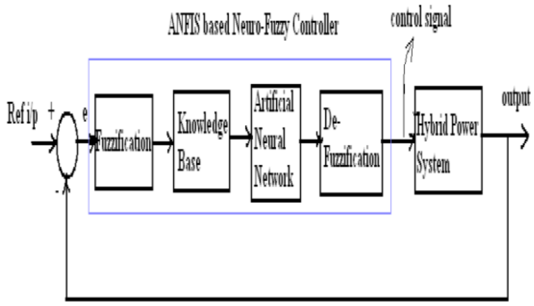

Fig.8 Block diagram of ANFIS based Neuro-fuzzy Controller.

The figure 8 gives the structure of the ANN network. It consisted five membership functions of two inputs. These can maintain the rules to identify the error effectively by logic layer 1 and logic layer2 and output layer. Logic layers are provided to calculate the errors and back propagation techniques from the input variables. Finally the output layer which generates the error less signal to Anfis controller.

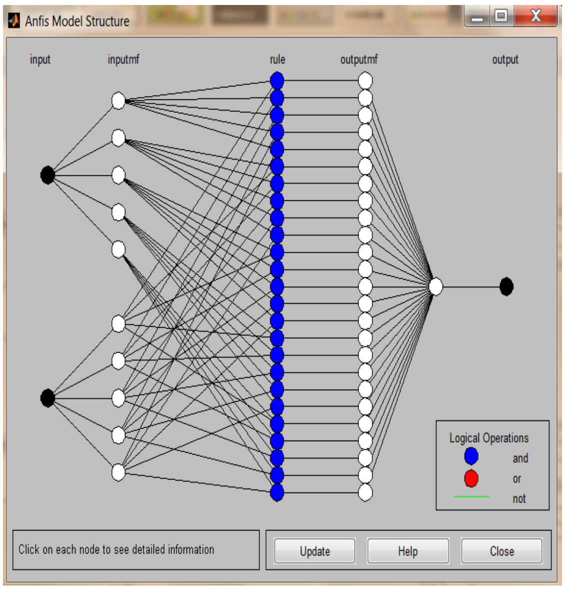

Fig 9: ANN structure for the proposed Model

Anfis Controller:

The developed input and output variables can detect the variable limits and membership functions and then simulate or adopt by Anfis structure. The automatic generation control (AGC) and rate of change of its error signal and with a generated output signal C.

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Procedure for the ANFIS controller:

- Design and develop the required Simulink model under specified conditions with fuzzy logic controller and modulate the rules within the limited range of variables.
- Gather the required training data from the operating devices while designing the FLC. The two input functions such as automatic generation control (AGC) and change in error signal AGC/dt with an output signal of the controller from the trained data. The training data will gives us the much information about possible power system behaviour for different operating dynamic disturbances.
- Use anfisedit command in the MATLAB command window for to create the .fis file.
- Load the training data operate step 2and produce the FIS file with flexible supported membership functions.
- Generate the FIS file from the loaded signal and trained the generated fis file at different epochs in the controller.

The Anfis controller operated under back propagation approachment with 100epchos.

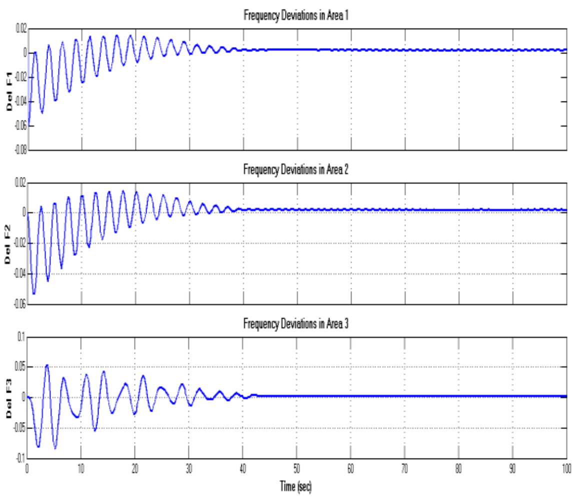

Fig.12 Frequency deviations verses time in three areas as delf1, delf2 & delf3 in interconnected power system without any controller

Load Frequency Control in Three Area Power System with PI Controller:

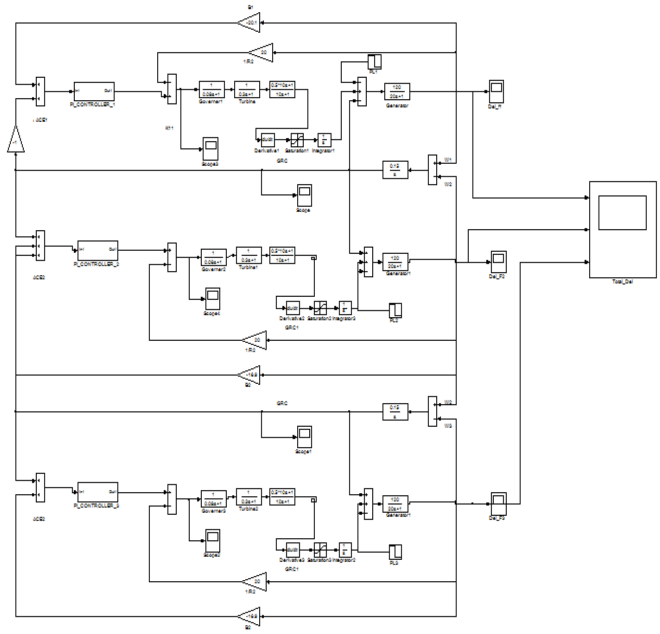

Fig.13 Load Frequency Control in three Area Interconnected Power Systems with PI Controller.

The output response of Frequency deviation response verses time in area Delf1, Delf2 & Delf3 with PI controller in three area interconnected power system is

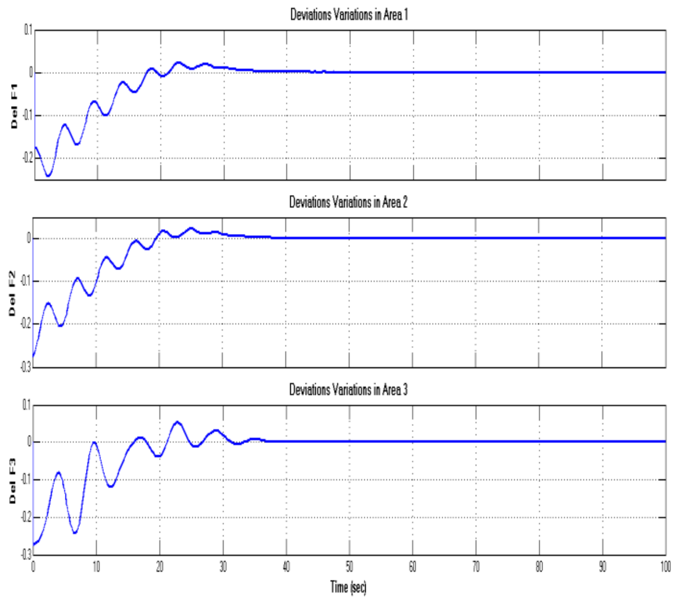

Fig.14 Frequency deviation response verses time in area Delf1, Delf2 &Delf3 with PI controller in three area interconnected power system.

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Simulink block diagram of three Areas interconnected power system with Fuzzy controller:

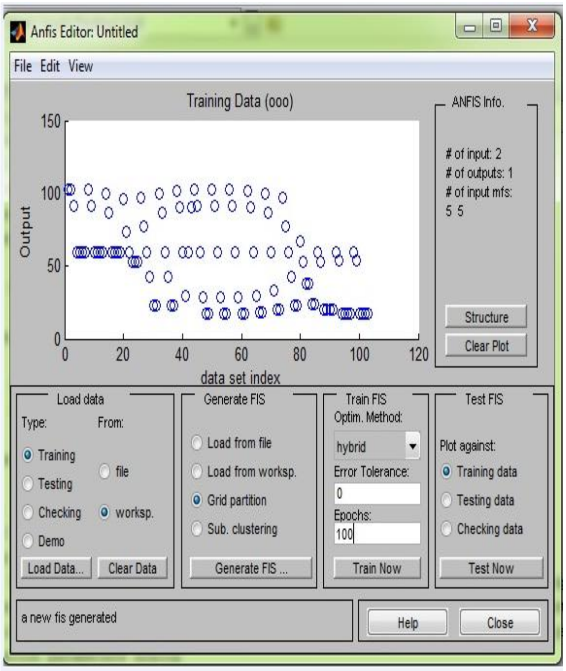

Fig 10: Training data for Anfis controller

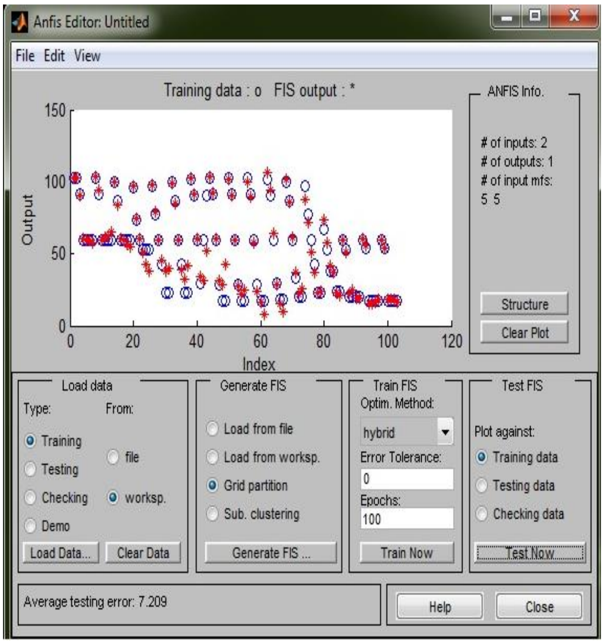

Fig 11: Generated Output after testing process from ANFIS

VII Simulink block diagramwithout controller:

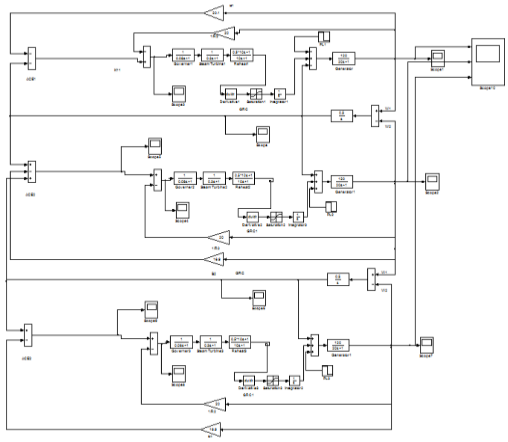

Fig: 11 Load Frequency Control in Three Area Interconnected Power System without Controller

The output response of Load Frequency Control in Three Area Interconnected Power System without Controller

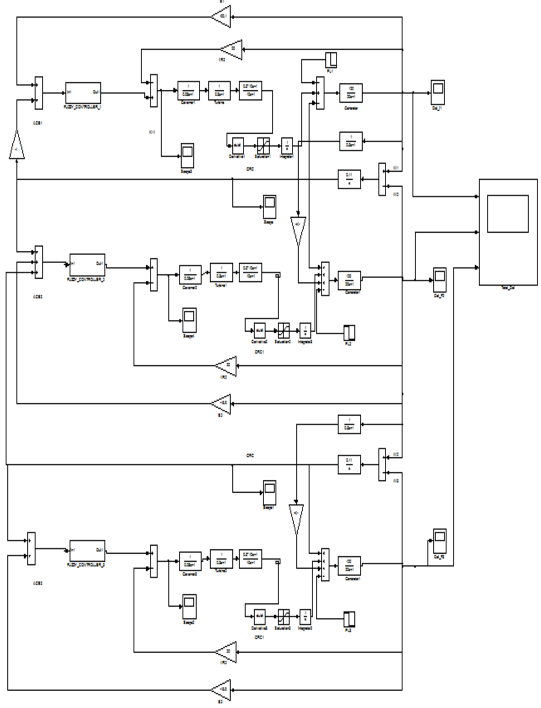

Fig: 15 Load Frequency Control in Three Area inter connected Power System with Fuzzy Controller

The output response of Load Frequency Control in Three Area inter connected Power System with Fuzzy Controller

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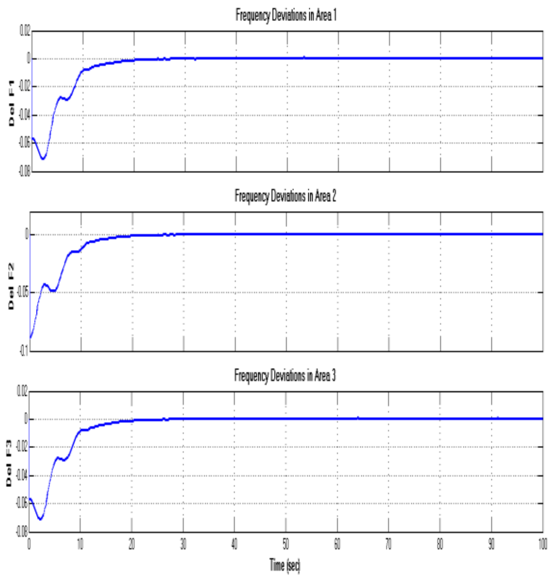

Fig.16 Frequency deviations response verses time in three areas Del f1, Del f2 & Del f3 with Fuzzy controller of interconnected power systems.

Three Areas with ANFIS controller:

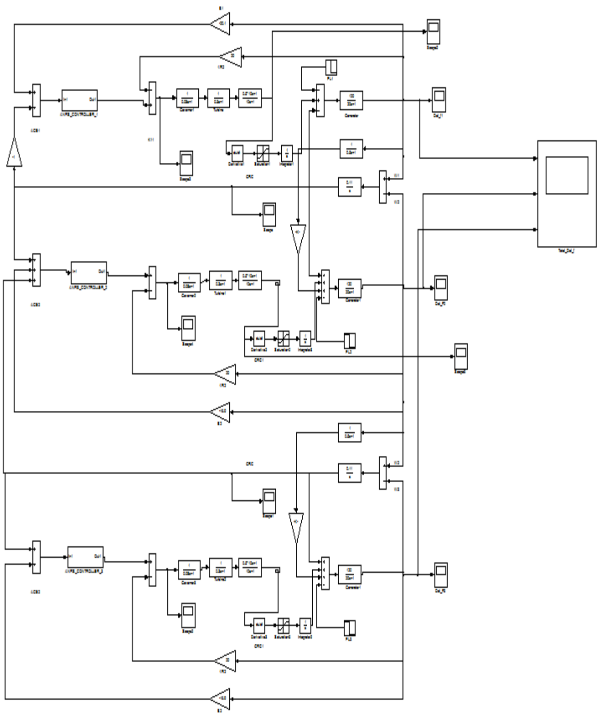

Fig: 17 Load Frequency Control in Three Area inter connected Power Systemwith ANFIS Controller

The output response for the three Area inter connected Power System with ANFIS Controller

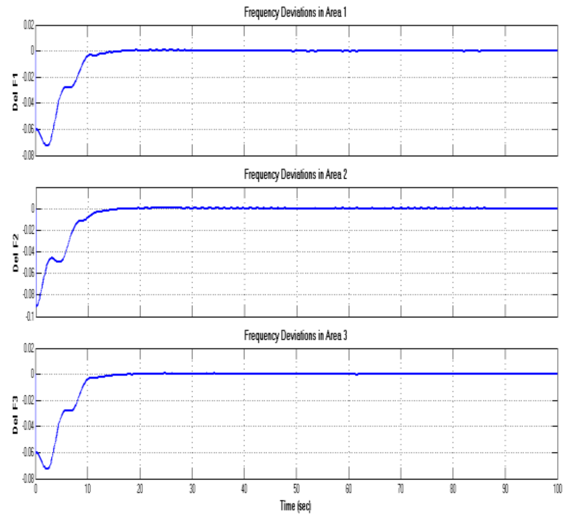

Fig. 6.7 Frequency deviation response verses time in three areas Del f1, Del f2 & Del f3 with ANFIS controller of interconnected power systems

Performance comparison Table:

Sl. No.		Without Controller	With Controller		
			PI	Fuzzy	ANFIS
Settling time (Sec.)	Area 1	45sec	35 sec	20 sec	15 sec
	Area 2	45 sec	35 sec	20 sec	15 sec
	Area 3	45sec	35 sec	20 sec	15 sec
Maximum peak over shoot (p.u)	Area 1	-0.059	-0.24	-0.07	-0.07
	Area 2	-0.056	-0.27	-0.09	-0.09
	Area 3	-0.055	-0.29	-0.07	-0.07

From the above comparison, it is clearly notice that the "Adaptive Neuro Fuzzy Interface System (ANFIS) based Load Frequency Controller gives best controller action compared to the conventional PI controller and Fuzzy controller.

VIII Conclusion:

In this project, the Adaptive Neuro Fuzzy Inference System based Load Frequency Control is proposed for a three area power system in each control area. The results have been compared with without controllers, conventional PI controller & Fuzzy controller. The results proved that the Adaptive Neuro Fuzzy Inference System based LFC gives better response as compared to conventional controller & Fuzzy controller in terms of peak overshoot, settling time and steady sate error. The results show that the proposed ANFIS controller is having improved dynamic response and at the same time faster than Fuzzy integral controller.

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