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A Relative Analyse of Schematic and Advanced Controllers with respect to Two Area and Three Area Power Systems

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ABSTRACT: Uninterrupted and dependable electricity is a compulsion for the functioning of today's new and advanced society. Since the early to mid 1980s, majority of the attempt in power systems analysis has turned off from the methodology of formal mathematical modelling which arrived from the areas of operations research, control theory and numerical analysis to the less thorough and less tedious mechanisms of Artificial Intelligence (AI). Power systems keep on incrementing on the ground of geographical regions, assets additions, and debut of new technologies in generation, transmission and distribution of electricity.AI techniques have become popular for solving different troubles in power systems like control, planning, scheduling, forecast, etc. These mechanisms can deal with tough tasks faced by applications in modern large power systems with even more interconnections set up to meet incrementing load demand. The usage of these techniques has been successful in lots of areas of power system engineering. In this paper, descriptive and thorough analysis has been done on the Two and Three area systems with respect to settling time and peak overshoot.

KEYWORDS: Artificial Intelligence, Automatic Load Frequency control.

I.INTRODUCTION

An electric power system is a network of electrical components applied to supply, transmit and utilize electric power. Power systems engineering is a branch of electrical engineering that contends with the generation, transmission, distribution and utilization of electric power and the electrical devices affiliated to such systems like generators, motors and transformers. Electrical energy is conserved at all paces in the process of Generation, Transmission, Distribution and utilization of electrical energy. The electrical utility industry is plausibly the largest and most sturdy industry in the world and hence very complex and challenging jobs to be handled by power engineering particularly, in designing future power system to deport increasing amounts of electrical energy. This calls for staring understanding, inspection and decision making of the system. This power system process and its control play a very vital task in the world of Electrical Power Engineering. Generating stations and distribution systems are linked through transmission lines which links one power system (grid, area) to another. A distribution system links all the loads in a specific area to the transmission lines. For economical and technical reasons, individual power systems are unionized in the form of electrically connected areas or regional grids.

Ordinarily, Artificial Intelligence is cognized to be the intelligence presented by machines and software which could be like robots and computer programs. The term is normally used in the project of developing systems embedded with the intellectual processes lineaments and characteristics of humans, like the capability to think, reason, find the meaning, generalize, compare, grasp from past experience or refine their mistakes. Artificial General Intelligence (AGI) is the intelligence of a hypothetical device or computer which can complete and finish any intellectual assignment properly and successfully exactly in the manner in which a human being can complete.

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II.NEED FOR ARTIFICIAL INTELLIGENCE IN POWER SYSTEMS

Power system analysis by older techniques becomes more complex due to:

[1] Difficult, versatile and huge amount of information and data which is used in calculation, inspection and learning.
[2] Increase in the calculation time period and accuracy because of extensive and wide system data handling.

The modern power system functions closer to the limits because of the ever incrementing energy usage and the increase of present that is existing electrical transmission networks and lines. This stage requires a less conservative power system operation and control operation which is permissible only by regularly checking the system states in a much more depth manner than it was compulsory. Sophisticated computer tools are now a day the basic tools in solving the complex problems that grow in the trade of power system planning, operation, diagnosis and design. Among these computer methodologies, Artificial Intelligence has grown preponderantly in recent years and has been practiced to various fields of power systems.

III.ARTIFICIAL INTELLIGENCE TECHNIQUES

A. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are biologically inspired systems which change a set of inputs into a set of outputs by a network of neurons, where each neuron develops one output as a function of inputs. A profound neuron can be treated as a processor which creates a simple non linear functioning of its inputs producing a single output. The understanding of the bringing of neurons and the pattern of their interconnection can be utilized to make computers for solving real world complex problems of recognition of patterns and pattern recognition.

They are sorted by their architecture: number of layers and topology: connectivity pattern, feedforward or recurrent. In input layer, the nodes are input units which do not act on the data and information but broadcast this data and information to other units. In hidden layers, the nodes are hidden units which are not directly evident and seeable. They furnish the networks with the capability to map or classify the nonlinear problems. In output layer, the nodes are output units which encode potential values to be allocated to the case which is under consideration.

Advantages:

[1] Speed of working.
[2] They do not require any particular knowledge of the system model.
[3] They have the capability to handle situations of insufficient data and information.
[4] They are fault resistant.
[5] While being fast and robust, they own learning capability and adjust to the data.
[6] They are able to generalize.

Disadvantages:

[1] Large dimensionality.
[2] Results are constantly rendered even if the input data are unauthentic.
[3] They are not climbable as after being trained to do a particular task; it is problematic to extend for other problems without making changes or retraining the neural network.

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B. FUZZY LOGIC

Fuzzy logic or Fuzzy systems are coherent systems for standardization and formalization of estimated reasoning for the problems whose answer is not exactly known to us. It is alike to human decision making with a capability to produce precise and accurate solutions from particular or even approximate information and data. The reasoning in fuzzy logic is exactly to human reasoning. Fuzzy logic is the way in which human brain functions and we can make of use this technology in machines so that they can execute somewhat like humans. Fuzzification provides better expressive power, more prominent generalization and an improved ability to model tough problems at low or medium solution cost. Fuzzy logic allows a concerned level of many interpretations throughout a particular inspection and analysis. Because this ambiguity can determine available information and reduce problem complexity, fuzzy logic is helpful in many practical applications. For power systems, fuzzy logic is opted for applications in many areas where the currently available information and data involves uncertainty. For example, a problem may have logical reasoning but could be applied to numerical problems other than symbolic inputs and outputs. Fuzzy logic provides us with the conversions from numerical to symbolic inputs and back again for the outputs.

Advantages:

Fuzzy Logic Controller is a fuzzy code planned to control something, generally mechanical input. They could be in software or hardware mode and can be applied in anything from small circuits to large mainframes. Adaptive fuzzy controllers learn to control rigorous processes much similar to as we human beings do.

Applications:

[1] Stability analysis and improvement
[2] Power system operation and control
[3] Fault diagnosis in three phase systems
[4] Security assessment
[5] Load forecasting during generation period
[6] Reactive power planning as per the requirement and its control
[7] State estimation in power systems

III.AUTOMATIC LOAD FREQUENCY CONTROL

The ALFC is to govern the frequency deviation by asserting the real power balance in the power system. The main tasks of the ALFC are to hold the steady frequency, ascertain the tie-line flows and allot the load among the generating units which are taking part. The control (input) signals are the tie-line deviation ΔPtie (evaluated from the tie-line flows), and the frequency deviation Δf (obtained by valuating the angle deviation). These error signals Δf and ΔPtie are amplified, mixed and translated to a real power signal, which then checks the valve position. As per the valve position, the turbine (prime mover) manages its output power to constitute the real power balance.

A. AGC IN A SINGLE AREA SYSTEM

In a single area system, there is no tie-line schedule to be preserved. Thus the application of the AGC is only to bring the frequency to the nominal value in case of any sort of deviation. This will be achieved using the supplementary loop which makes use of the integral controller to vary the reference power setting so as to change the speed set point. The integral controller gain Ki needs to be adjusted for satisfactory response (in terms of overshoot, settling time) of the system. While each generator will be having a different speed governor, all the generators in the control area are exchanged by a single equivalent generator, and the ALFC for the area responds to this equivalent generator.

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B. AGC IN A MULTI AREA SYSTEM

In an interconnected or multi area system, there will be one ALFC loop for every control area. They are merged as shown in for the interconnected system operation.

C. EXPRESSION FOR TIE-LINE FLOW IN A TWO AREA INTERCONNECTED SYSTEM

Consider a variation in load ΔPD1 in area l. The steady state frequency deviation Δf is the alike for both the areas. That is $\Delta f = \Delta f_1 = \Delta f_2$.

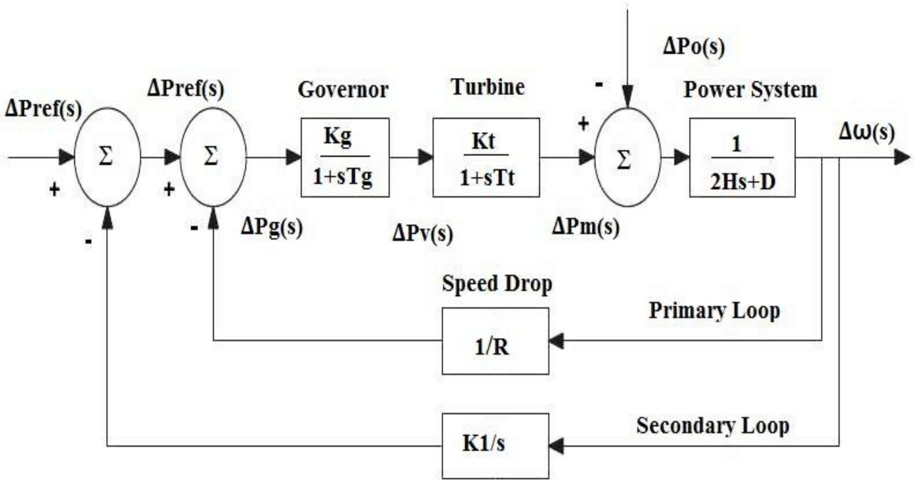

Fig. 1 - Model of single area ALFC by using secondary control

An increment of load in area l by ΔP_{D1} results in a frequency reduction in both areas and a tie-line flow of ΔP_{12}. A positive ΔP_{12} is indication of flow from Areal to Area 2 while a negative ΔP_{12} corresponds to flow from Area 2 to Area l. Similarly, for a change in Area Frequency bias tie line control, the tie line deviation depicts the contribution of regulation features of one area to another. The root purpose of supplementary control is to restore balance between each area corresponding to the load generation.

This target is met when the control action sustains

[1] Frequency at the scheduled value
[2] Net interchange power (tie line flow) with neighboring areas at the scheduled values

The supplementary control should ideally make changes only for changes in that area. In other words, if there is a variation in Area l load, there should be supplementary control only in Area l and not in Area 2. For this purpose the Area Control Error (ACE) is used. The ACE of the two areas are given by

For area 1: $ACE_1 = \Delta P_{12} + \beta_1 \Delta f$

For area 2: $ACE_2 = \Delta P_{12} + \beta_2 \Delta f$

Where; β_1 and β_2 are the composite frequency response characteristic of Area l and Area 2 respectively.

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IV.DESIGN MODEL FOR VARIOUS SYSTEMS

Two area interconnected system which is conjoined by way of tie-lines for the flow of tie-line power is given in Fig. 2. Let the additional input be ΔP_{12}, ΔP_{01}be the load change in area 1 and the corresponding frequencies of the two areas be $\Delta\omega = \Delta\omega 1 = \Delta\omega 2$.

The control in Three Area System is just like the Two Area system and is shown in Fig. 3. The integral control loop which is employed in the Single Area system and Two Area system can also be linked to the Three Area systems. Due to variation in load there is variation in the steady state frequency ($\Delta\omega$) so we require another loop asunder from primary loop to attain the frequency to the initial value, before the load disturbance happens.

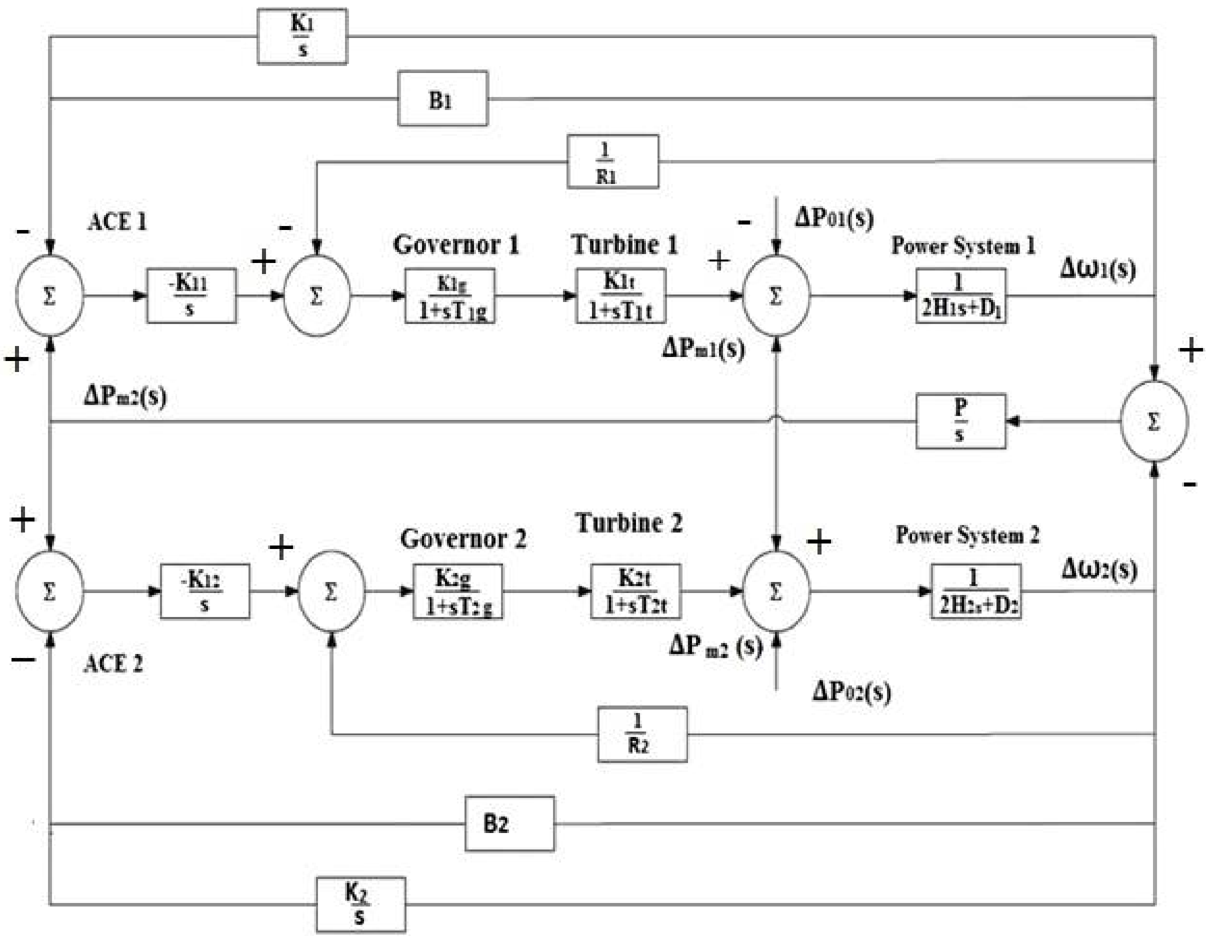

Fig. 2 - Model of Two Area System by using secondary loop

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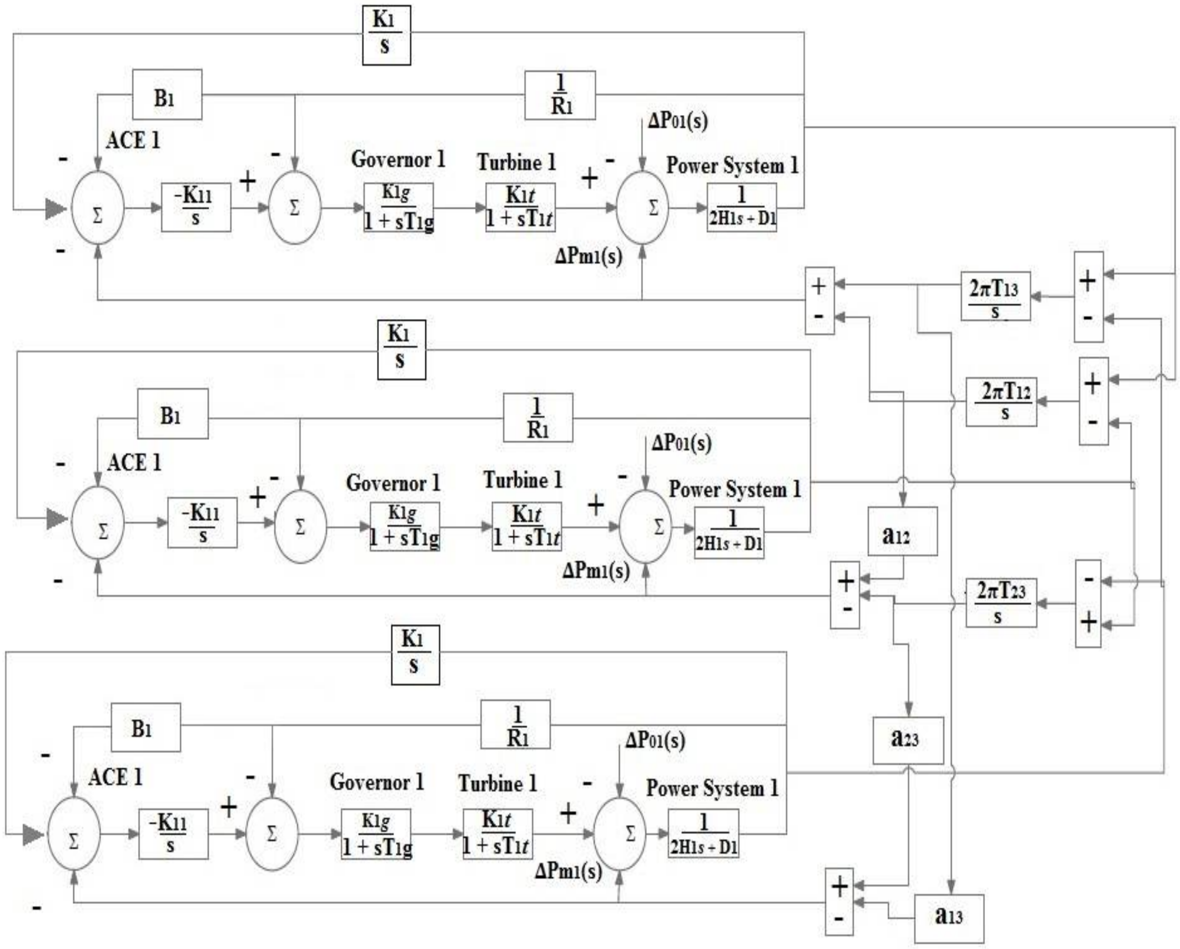

Fig. 3 - Model of Three Area System by using secondary loop

V. SIMULATION RESULTS OF TWO AREA SYSTEMS

Table 1 – System parameters for Two Area Systems

Name	Kg	Tg(s)	Kt	Tt(s)	H(s)	D(p.u.MH/Hz)	1/R	B
Area 1	1	0.2	1	0.5	5	0.6	20	20.6
Area 2	1	0.3	1	0.6	4	0.9	16	16.9

We have taken the values of the different parameters used in Automatic Load Frequency simulink model as shown in Table 1 for modelling purpose to obtain the desired results for Two Area Systems.

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A. FUZZY PI CONTROLLER

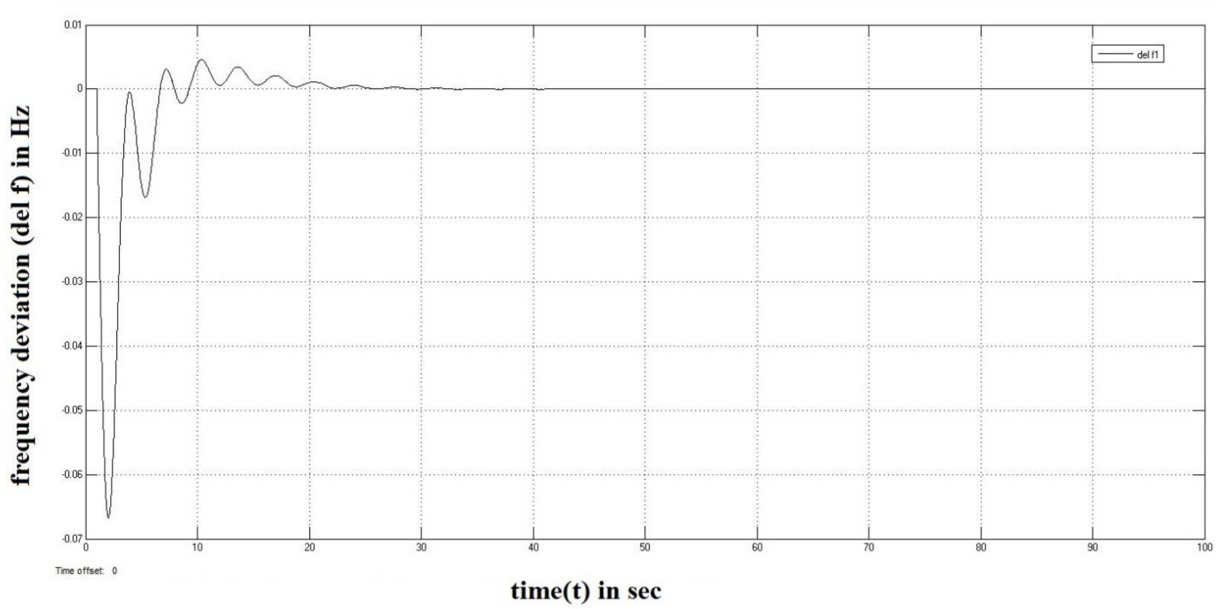

Fig. 4 - Frequency deviation vs. time for Area 1 of Two Area System using Fuzzy PI Controller

In Fig. 4, Automatic Load Frequency model is implemented through Fuzzy PI controller. The plot in Fig. 4 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for frequency deviation vs. time with secondary loop for Two Area systems for area 1.

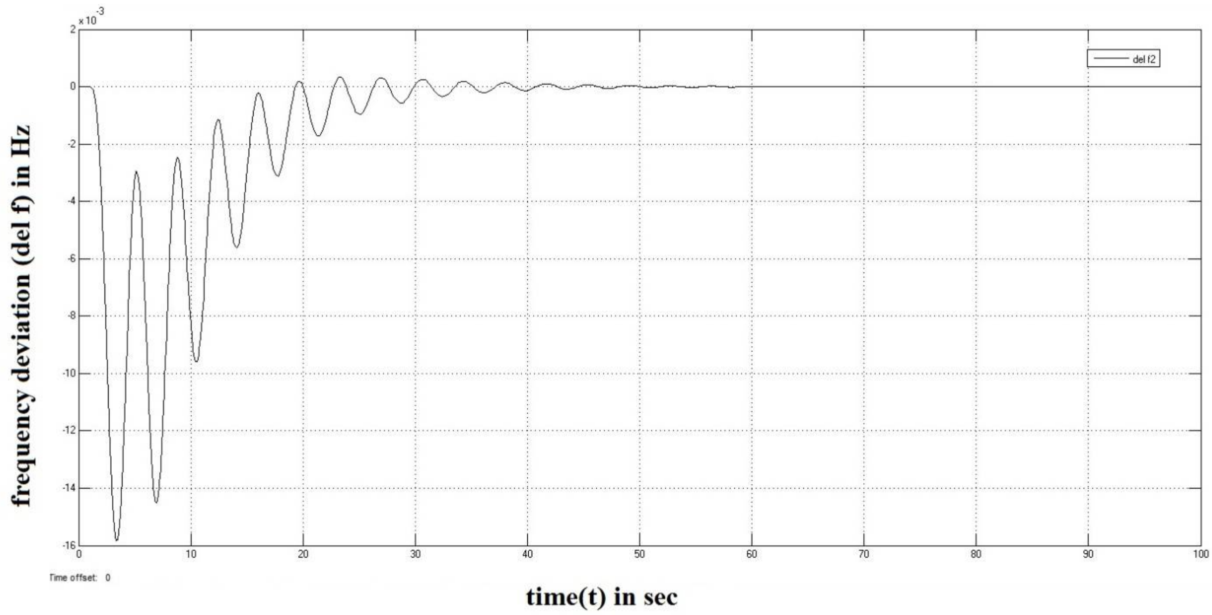

Fig. 5 - Frequency deviation vs. time for Area 2 of Two Area System using Fuzzy PI Controller

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In Fig. 5, Automatic Load Frequency model is implemented through Fuzzy PI controller. The plot in Fig. 5 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for frequency deviation vs. time with secondary loop for Two Area systems for area 2.

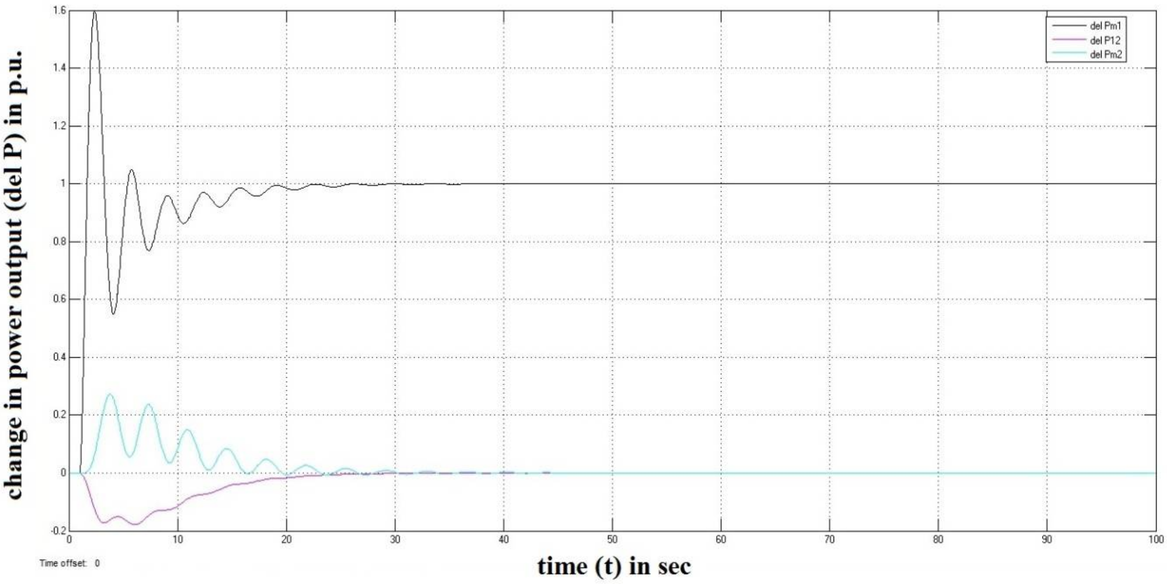

Fig. 6 - Change in power output vs. time for Two Area System using Fuzzy PI Controller

In Fig. 6, Automatic Load Frequency model is implemented through Fuzzy PI controller. The plot in Fig. 6 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in power output vs. time with secondary loop for Two Area systems.

B. ARTIFICIAL NEURAL NETWORK

The training methods available here were trainlm, trainrp, trainscg and trainbr. Out of them, the training method used is trainlm(Levenberg-Marquardt). The network which is going to be trained is supervised using a feedforwardnet algorithm. The performance is evaluated using Mean Squared Error method. The maximum number of epochs allowed is 1000.

The maximum number of validation checks during simulation time is also 1000. The topology used to generate custom Neural Network is gensim. Plots of Error Histogram, Performance and Training State need to be regularly inspected during the train period of the Neural Network.

While designing the Neural Network for Two Area System, the number of hidden layers deployed in this custom Neural Network is 4. The number of neurons present in each of the hidden layers is 2.

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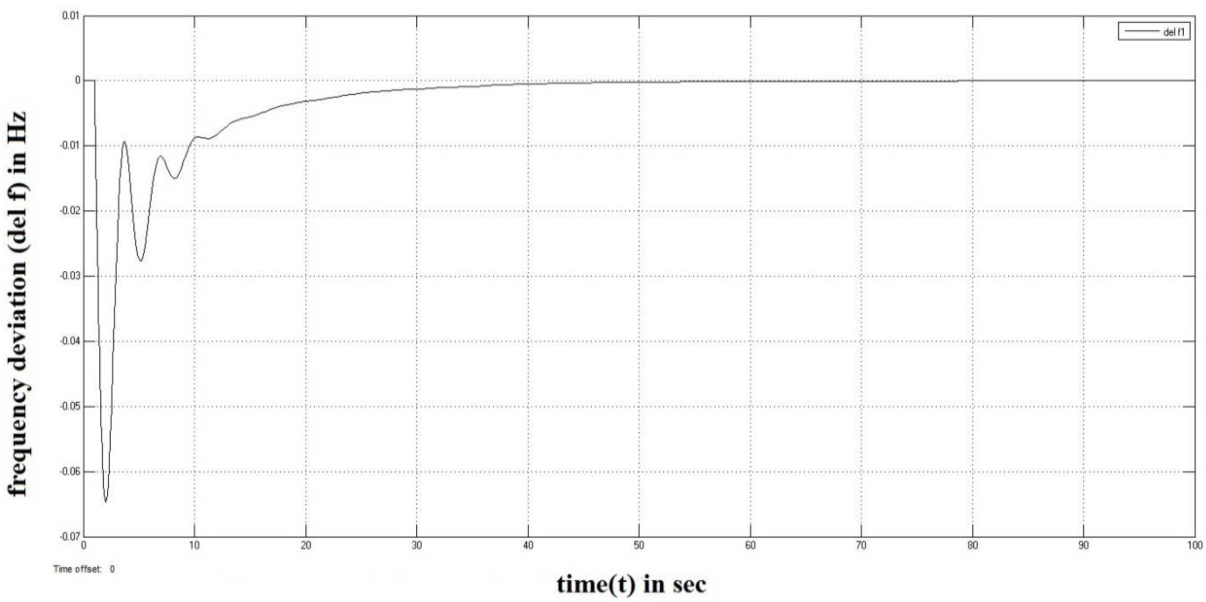

Fig. 7 - Frequency deviation vs. time for Area 1 of Two Area System using Neural Network

In Fig. 7, Automatic Load Frequency model is implemented through Neural Network. The plot in Fig. 7 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Two Area systems for area 1.

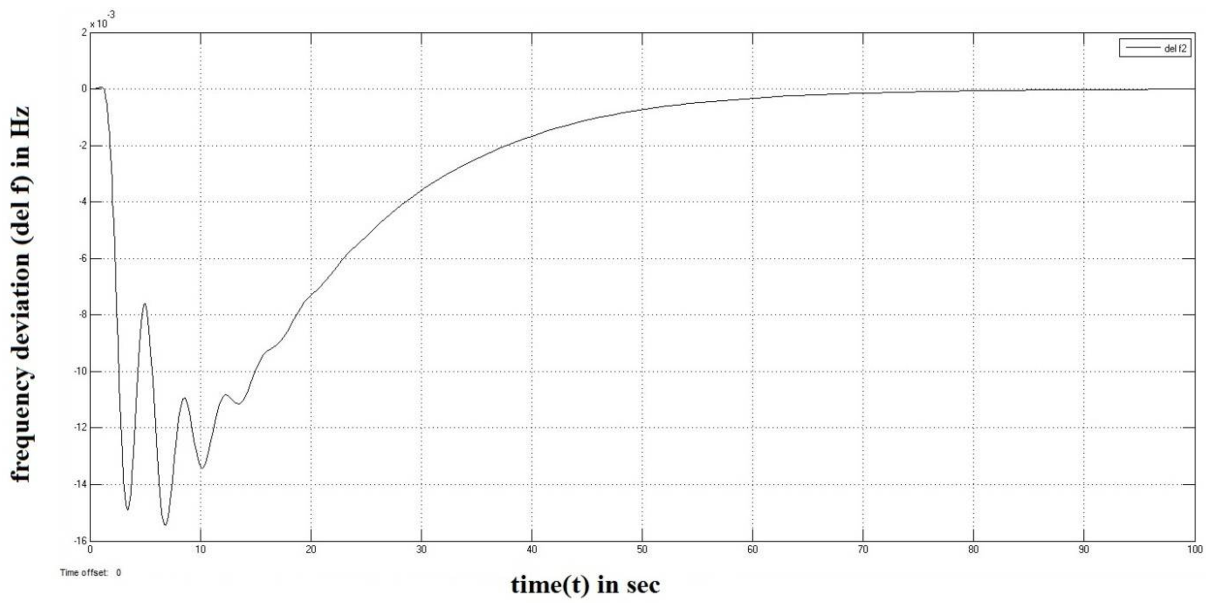

Fig. 8 - Frequency deviation vs. time for Area 2 of Two Area System using Neural Network

In Fig. 8, Automatic Load Frequency model is implemented through Neural Network. The plot in Fig. 8 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation

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in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Two Area systems for area 2.

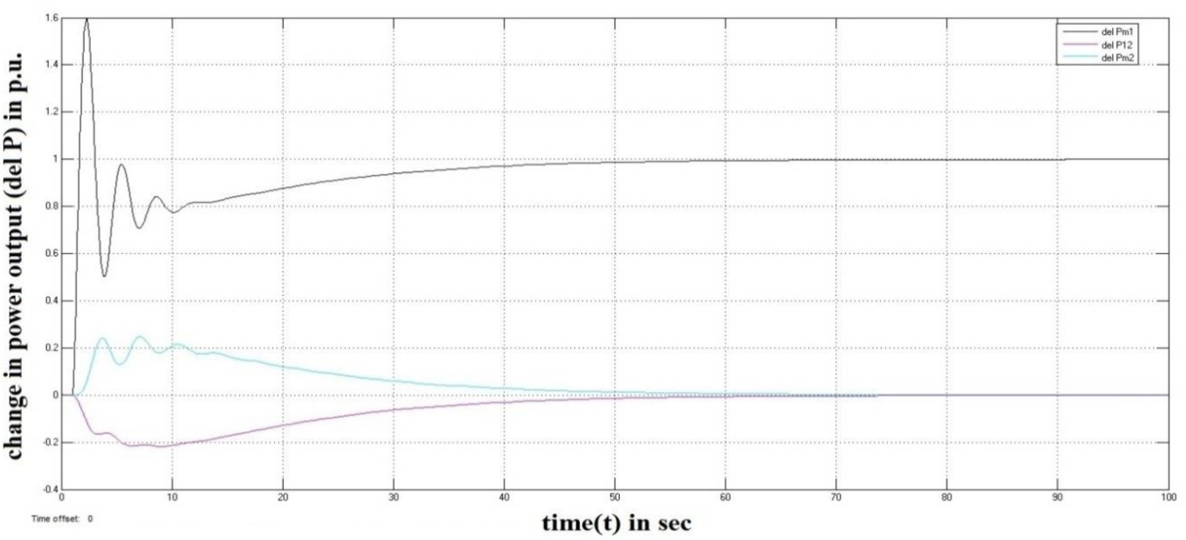

Fig. 9 - Change in power output vs. time for Two Area System using Neural Network

In Fig. 9, Automatic Load Frequency model is implemented through Neural Network. The plot in Fig. 9 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in power output vs. time with secondary loop for Two Area systems.

C. PI CONTROLLER

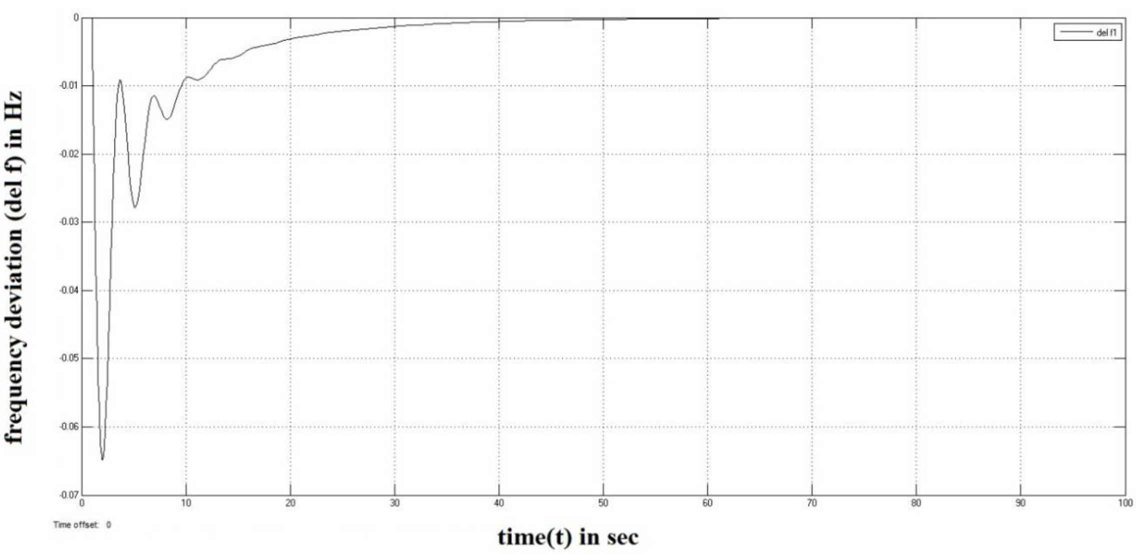

Fig. 10 - Frequency deviation vs. time for Area 1 of Two Area System using PI Controller

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In Fig. 10, Automatic Load Frequency model is implemented through PI controller. The plot in Fig. 10 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Two Area systems for area 1.

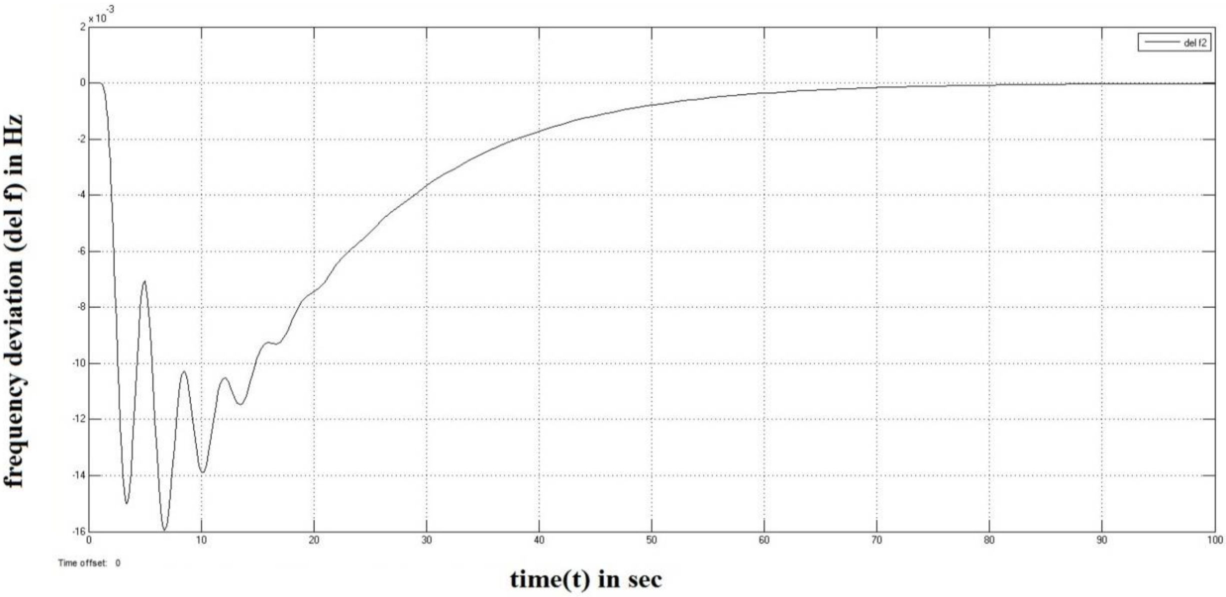

Fig. 11 - Frequency deviation vs. time for Area 2 of Two Area System using PI Controller

In Fig. 11, Automatic Load Frequency model is implemented through PI controller. The plot in Fig. 11 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in power output vs. time with secondary loop for Two Area systems for area 2.

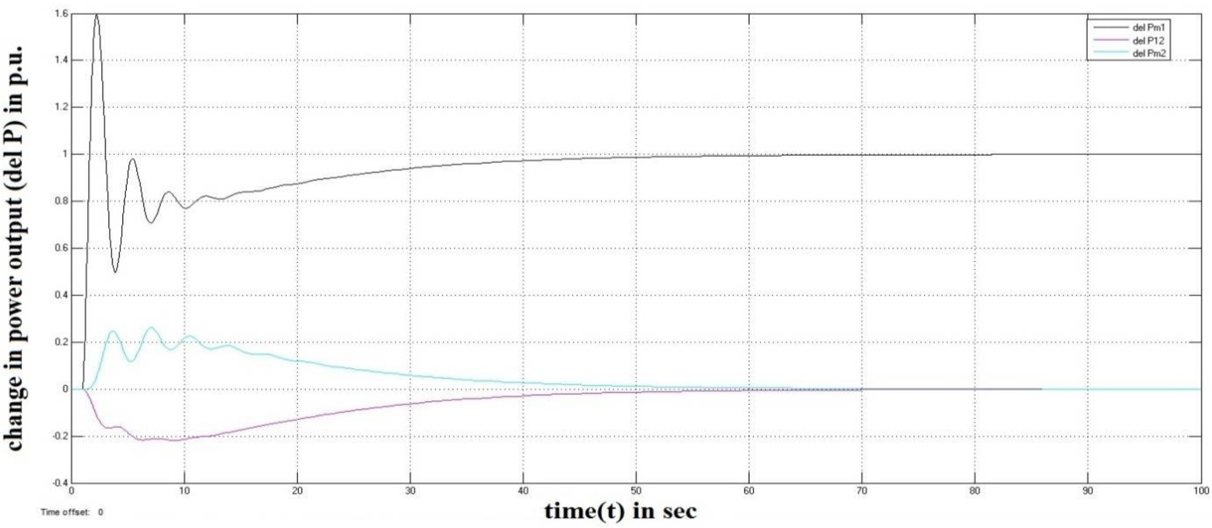

Fig. 12 - Change in power output vs. time for Two Area System using PI Controller

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In Fig. 12, Automatic Load Frequency model is implemented through Fuzzy PI controller. The plot in Fig. 12 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in power output vs. time with secondary loop for Two Area systems.

VI. SIMULATION RESULTS OF THREE AREA SYSTEMS

Table 2 – System parameters for Three Area Systems

Name	Kg	Tg(s)	Kt	Tt(s)	H(s)	D(p.u.MW/Hz)	1/R	B
Area 1	1	0.08	1	0.3	11	1	1.7	0.326
Area 2	1	0.08	1	0.3	11	1	1.7	0.326
Area 3	1	0.08	1	0.3	11	1	1.7	0.326

We have taken the values of the different parameters used in Automatic Load Frequency simulink model as shown in Table 2 for modelling purpose to obtain the desired results for Three Area Systems.

A. FUZZY LOGIC CONTROLLER

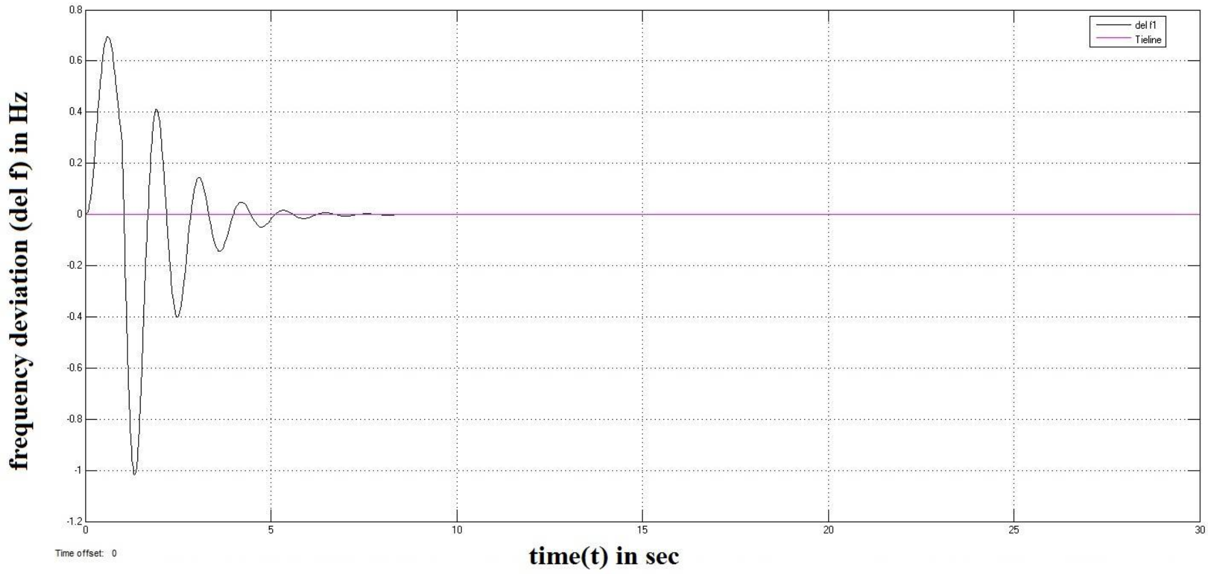

Fig. 13 - Frequency deviation vs. time for Area 1 of Three Area System using Fuzzy Logic

In Fig. 13, Automatic Load Frequency model is implemented through Fuzzy Logic. The plot in Fig. 13 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 1.

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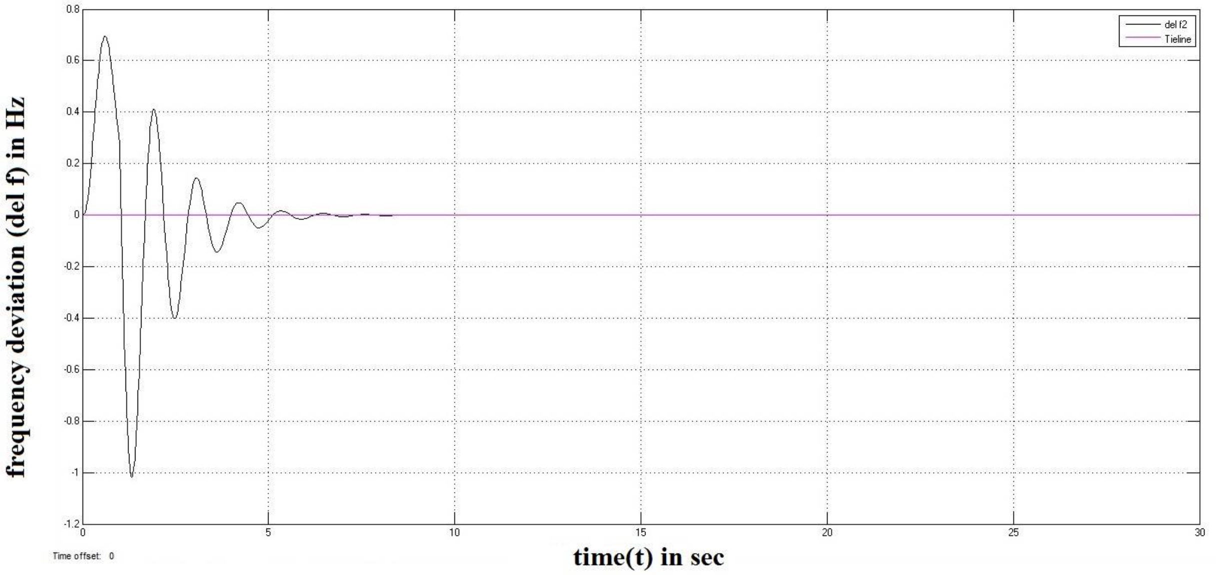

Fig. 14 - Frequency deviation vs. time for Area 2 of Three Area System using Fuzzy Logic

In Fig. 14, Automatic Load Frequency model is implemented through Fuzzy Logic. The plot in Fig. 14 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 2.

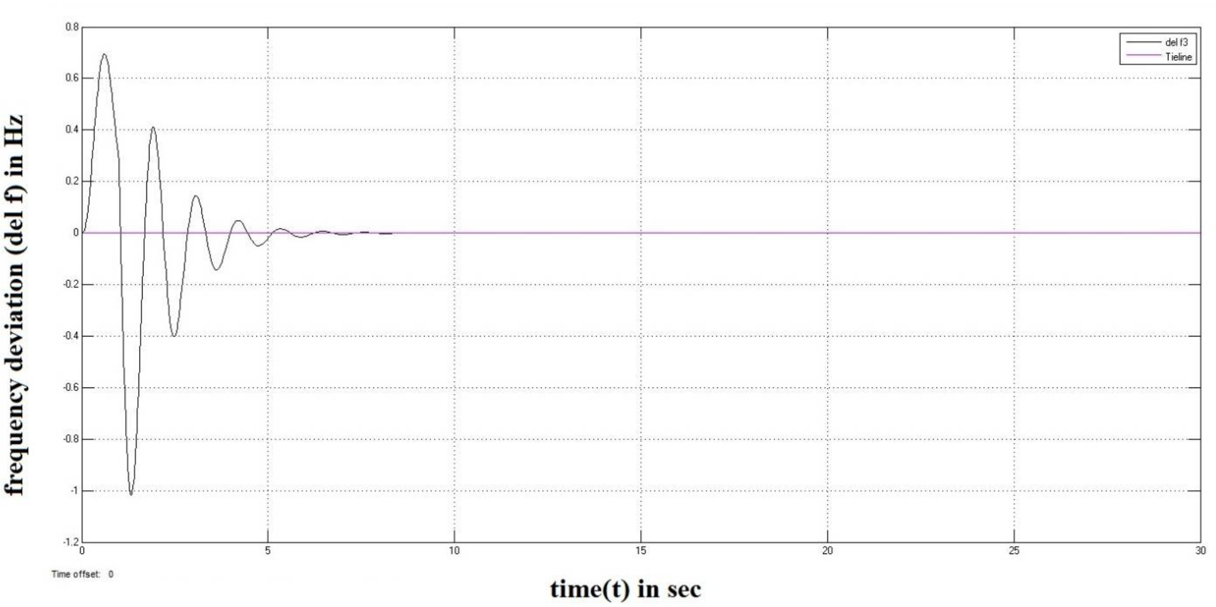

Fig. 15 - Frequency deviation vs. time for Area 3 of Three Area System using Fuzzy Logic

In Fig. 15, Automatic Load Frequency model is implemented through Fuzzy Logic. The plot in Fig. 15 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation

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in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 3.

B. ARTIFICIAL NEURAL NETWORK

The training methods available here were trainlm, trainrp, trainscg and trainbr. Out of them, the training method used is trainlm(Levenberg-Marquardt). The network which is going to be trained is supervised using a feedforwardnet algorithm. The performance is evaluated using Mean Squared Error method. The maximum number of epochs allowed is 1000.

The maximum number of validation checks during simulation time is also 1000. The topology used to generate custom Neural Network is gensim. Plots of Error Histogram, Performance and Training State need to be regularly inspected during the train period of the Neural Network.

While designing the Neural Network for Three Area System, the number of hidden layers deployed in this custom Neural Network is 2. The number of neurons present in each of the hidden layers is 10.

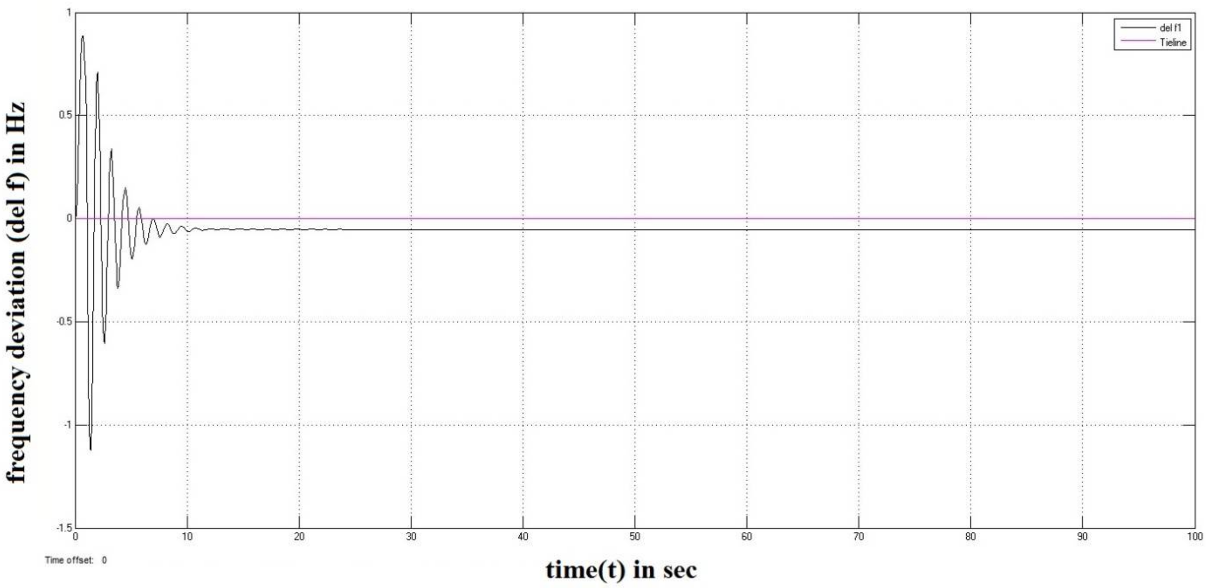

Fig. 16 - Frequency deviation vs. time for Area 1 of Three Area System using Neural Network

In Fig. 16, Automatic Load Frequency model is implemented through Neural Network. The plot in Fig. 16 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 1.

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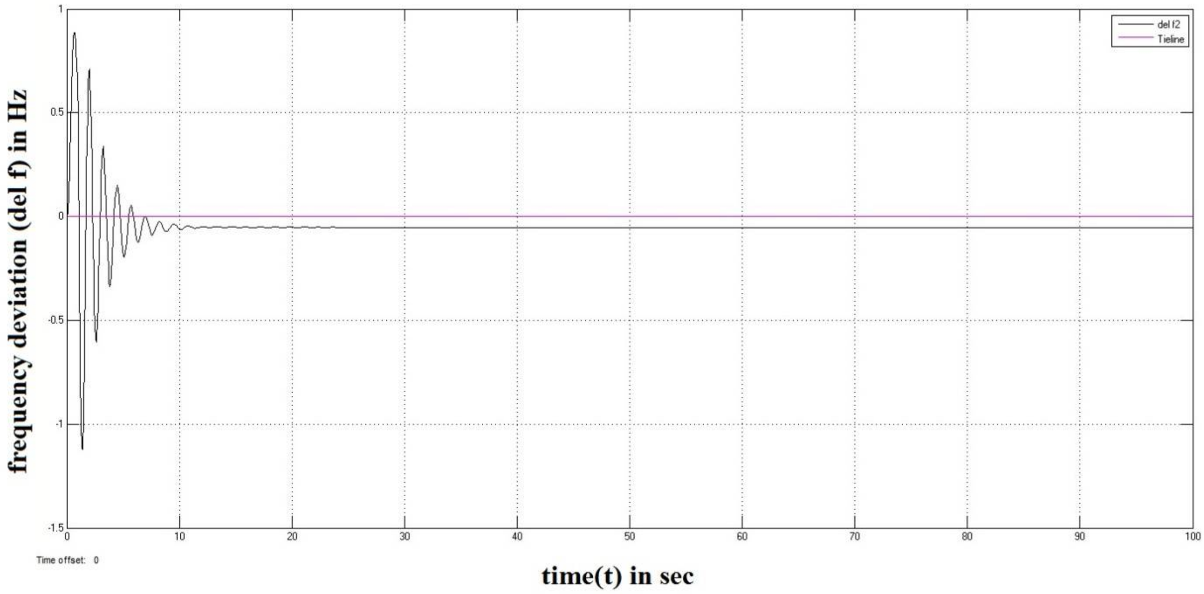

Fig. 17 - Frequency deviation vs. time for Area 2 of Three Area System using Neural Network

In Fig. 17, Automatic Load Frequency model is implemented through Neural Network. The plot in Fig. 17 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 2.

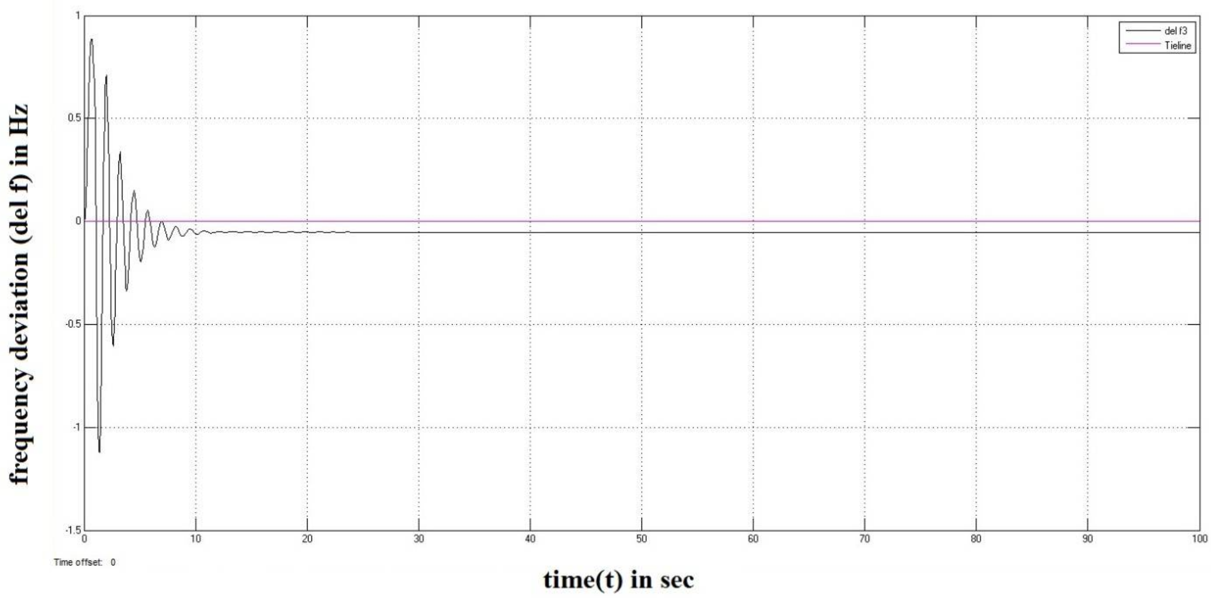

Fig. 18 - Frequency deviation vs. time for Area 3 of Three Area System using Neural Network

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In Fig. 18, Automatic Load Frequency model is implemented through Neural Network. The plot in Fig. 18 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 3.

C. PI CONTROLLER

As the name depicts, it is a combination of proportional and an integral controller. The output which is also known the actuating signal is equal to the summation of proportional and integral of the error signal. In a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal.

Advantages and disadvantages are the combinations of the advantages and disadvantages of proportional and integral controllers.

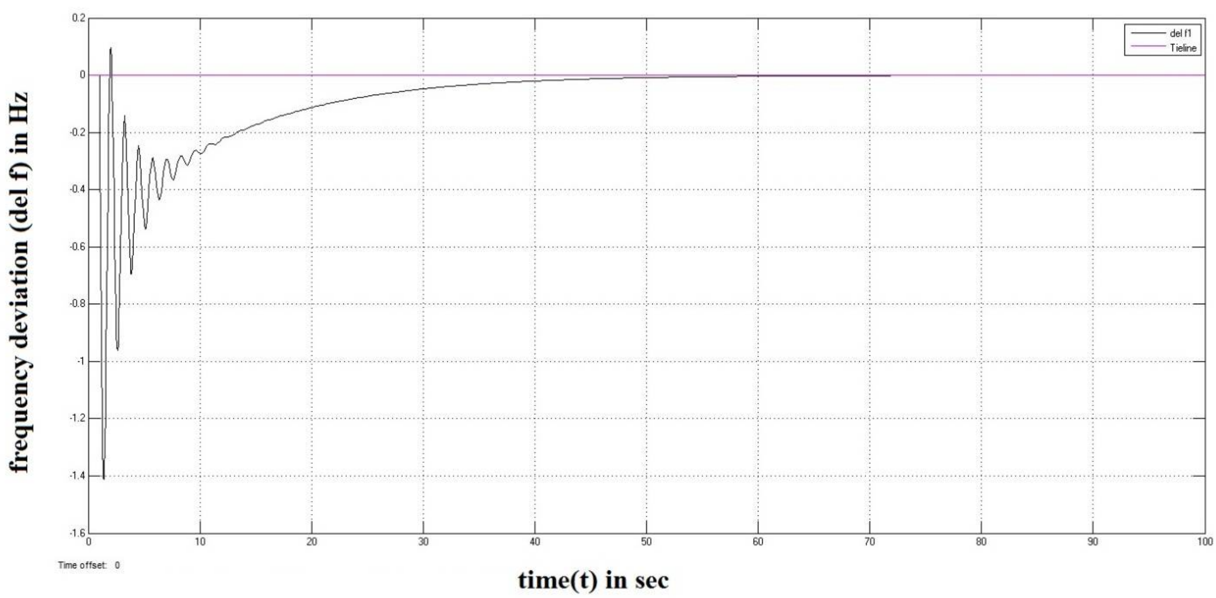

Fig. 19 - Frequency deviation vs. time for Area 1 of Three Area System using PI Controller

In Fig. 19, Automatic Load Frequency model is implemented through PI controller. The plot in Fig. 19 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 1.

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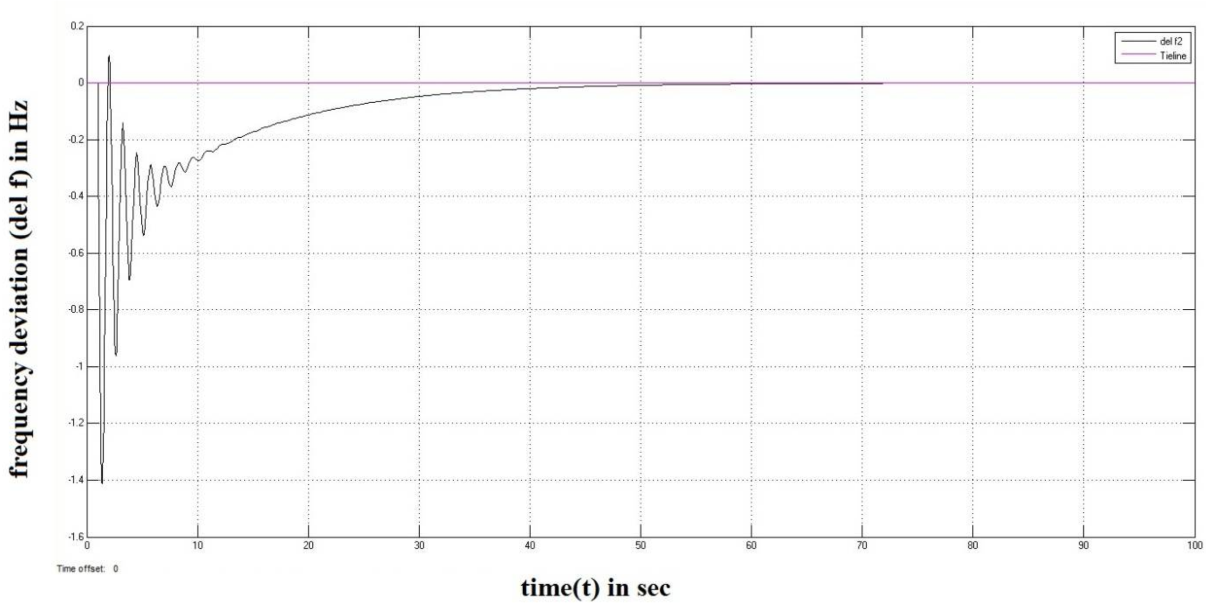

Fig. 20 - Frequency deviation vs. time for Area 2 of Three Area System using PI Controller

In Fig. 20, Automatic Load Frequency model is implemented through PI controller. The plot in Fig. 20 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 2.

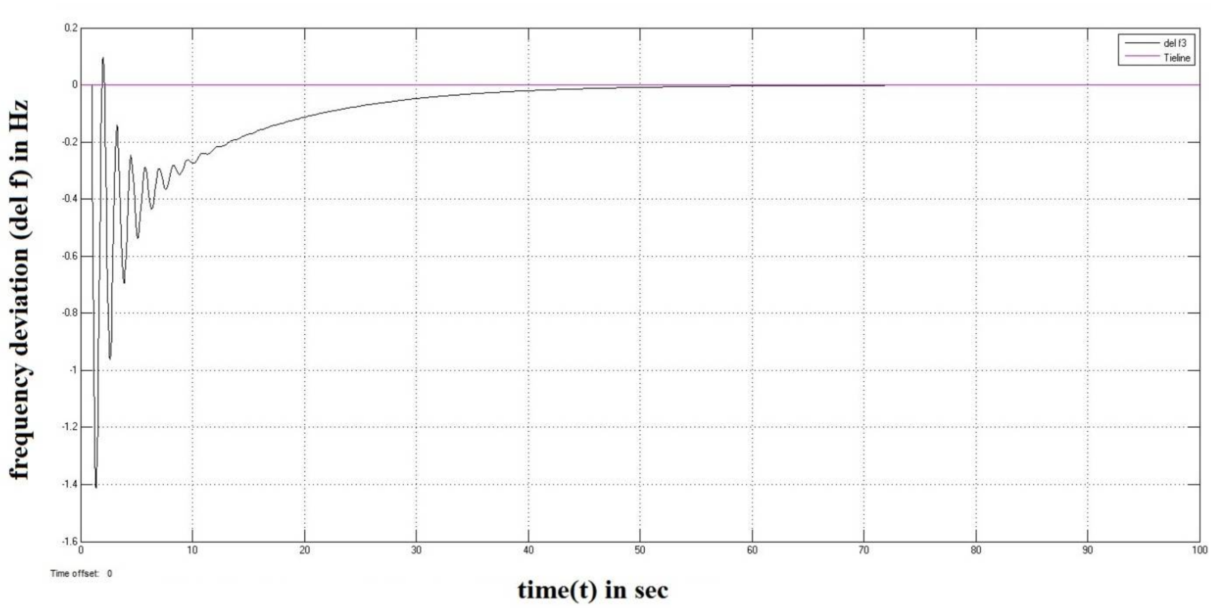

Fig. 21 - Frequency deviation vs. time for Area 3 of Three Area System using PI Controller

In Fig. 21, Automatic Load Frequency model is implemented through PI controller. The plot in Fig. 21 which is obtained by simulating the model shows that the change in load causes alteration in rotor speed which causes deviation in frequency and is undesirable. It is the graph for change in frequency deviation vs. time with secondary loop for Three Area systems for area 3.

VII. RESULTS AND DISCUSSION

The above simulations depicts that the deviation in frequency of the isolated system has more ripples and its counterpart has fewer ripples.

In case of Two Area Systems, we have studied the effects of Fuzzy PI controller, Artificial Neural Network, PI controller with respect to Load Frequency Control. The best dynamic response and reduction in the oscillation of frequency deviation was given by Fuzzy PI controller over Neural Network and PI controller when we consider factors like settling time and peak overshoot. The equilibrium state was attained to its quickest in case of Fuzzy PI controller. We can conclude from the simulation results that the inclusion of Fuzzy PI Controller is an effectual and efficient method of Load Frequency Control.

In case of Three Area Systems, we have studied the effects of Fuzzy Logic controller, Artificial Neural Network, PI controller with respect to Load Frequency Control. The best dynamic response and reduction in the oscillation of frequency deviation was given by Fuzzy Logic controller over Neural Network and PI controller when we consider factors like settling time and peak overshoot. The equilibrium state was attained to its quickest in case of Fuzzy Logic controller. We can conclude from the simulation results that the inclusion of Fuzzy Logic Controller is an effectual and efficient method of Load Frequency Control.

VIII.CONCLUSION

There's unveiling of optimization techniques i.e. Fuzzy Logic and Neural Network to vary the values of the several parameters present in the power system under inspection so it can deal with the variations in the load demand. As a result of which, minute changes in the frequency and the tie line power is reduced and the stability of the system is maintained. Simulation results depict that Artificial Intelligence technique has quicker convergence characteristics. The fuzzy control technique also has some shortcomings of selecting proper membership functions and defuzzification problem. ANN controller has difficulty while training of neural network and activation function. There is a requirement of such controller which has both properties fuzzy and neural then a hybrid neuro-fuzzy controller is sought.

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