International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Design of various Automatic Control Topologies for Load Frequency Control of Six Area Hybrid Multi-Generation Power System

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Abstract : ***The automatic load frequency control of six unequal areas hybrid model consist of thermal, reheat thermal plants, hydraulic governor system, nuclear, diesel, gas turbine plants. These generating units are represented from area one to area six. If any disturbance occurs in load results to variation of frequency and tie-line. When the generating area doesn't meet load unit gives abnormal limits in response. This can be solved by the implementation of Proportional integral controller(PI), Artificial Neural Network controller(ANN), Adaptive Neuro Fuzzy Inference System controller (ANFIS).But still there is a chance to achieve better responses can be done by the proposed Genetic Algorithm (GA) based PI controller. In the MAT LAB environment hybrid model is developed. The Step varying input is applied that will leads to creating the disturbances and controlled by applying controller respectively. The evaluation of responses will be carried out by the control strategies of frequency responses and tie-lie power responses in all six areas hybrid model system. This work gives the information about the dynamic responses achieved by GA controller is more efficient than that of existing controllers and evaluated by MATLAB Simulink results.***

Keywords **: ALFC,PI,ANN,ANFIS,GA**

I.INTRODUCTION

The generating units, transmitted units and load centres which are interconnected by the tie lines represents the power system. If there is a change in turbine speed (up or down) of the generator results to the abnormal condition in frequency and tie-line. The Automatic Generation Control (AGC) consists of voltage regulator (AVR) and load frequency control (ALFC) that can minimize the limits of frequency and tie-lie power. The zero steady state can be obtained by ALFC in the hybrid system grid. The transient responses which are obtained by the Proportional and Integral controller is good for linear system. When there is a continuously load variation results to change in the operating point. This can be manually adjusted to the normal position by changing gain value. It is very difficult to adjust the gain value of PI controller.so that nonlinearity increases and problem arises.

Revised Manuscript Received on December 30, 2019.
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To avoid the non-linearity, advanced control technique such as Artificial Neural Network (ANN), fuzzy logic controllers are applied. The membership function of fuzzy logic has some limitations. So that this can overcome by the soft computing techniques like Adoptive Neuro-Fuzzy Inference Control System (ANFIS) which consists of both control strategy of Artificial Neural Network (ANN) and NN. ANFIS strategy is also employed for best results regarding to net profits, variables and analyzing energy production.

In this work the hybrid model represents inter connection of generating areas. That are developed with some controllers like PI, ANN,ANFIS and GA based controller. The dynamic responses are evaluated under MATLAB SIMULINK environment by all control strategies and comparing dynamic responses.

II.THEORITICAL APPROCH

A. Representation of Tie-line :

The equation obtained from first area to second area is represented by

$$P_{12} = \frac{E1\,E2}{X_{12}}(\sin \emptyset_1 - \emptyset_2) \qquad (1)$$

Whereas $\emptyset_1$ *and* $\emptyset_2$ are the torque angles. When there is a small variation of the torque angle ($\Delta\emptyset_1$ *and* $\Delta\emptyset_2$) leads to the variation of the tie-line power Δp_{12} then the power changes to P12+Δp_{12} , E1 and E2 are the end voltages of synchronous machines and the reactance present in between 1 to 2 area is X12 . Due to some abnormal conditions like variation of load results in the deviation of torque angle leads to change in the frequency. The six area hybrid system is developed in the MAT LAB is represented as fig 1.

$$\Delta P_{12}(S) = \frac{2\pi T^*}{S}(\Delta f_1(s) - f_2(s)) \qquad (2)$$

The six-area state variables are given as follows,

$$\Delta P1 = \Delta P12 + a31\ \Delta P31 \qquad (3)$$

$$\Delta P2 = \Delta P23 + a12\ \Delta P12 \qquad (4)$$

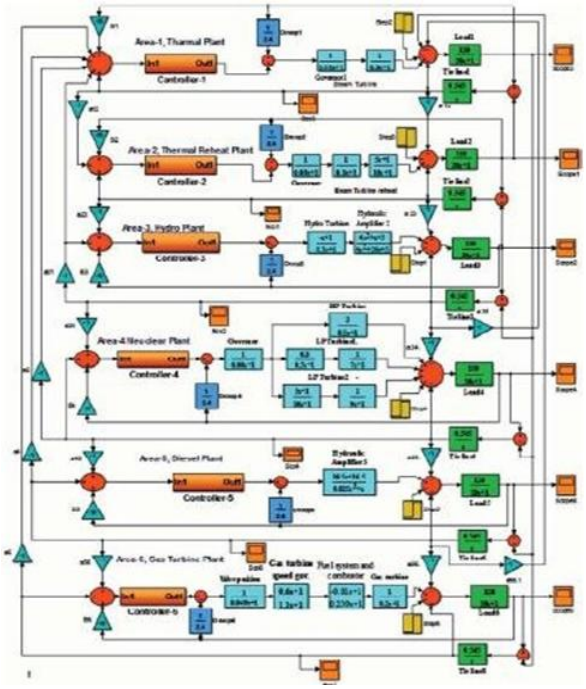

Fig 1: Six Area Hybrid Multi-Generation Model

$\Delta P3 = \Delta P34 + a23 \Delta P23$ (5)

$\Delta P4 = \Delta P45 + a34\ \Delta P34$ (6)

$\Delta P6 = \Delta P56 + a45\ \Delta P45$ (7)

$\Delta P6 = \Delta P61 + a56\ \Delta P56$ (8)

Whereas, ΔP_i is the deviation of power, ΔP_{ij} represents deviation in power from area i to j

$ACE = \Delta P_{12} + b_1\ \Delta f_1$ (9)

$ACE = \Delta P23 + b2\ \Delta f_2$ (10)

$ACE = \Delta P34 + b3\ \Delta f_3$ (11)

$ACE = \Delta P45 + b4\ \Delta f_4$ (12)

$ACE = \Delta P56 + b5\ \Delta f_5$ (13)

$ACE = \Delta P61 + b6\ \Delta f_6$ (14)

Whereas, ACE= area control error, b1-6 = area frequency bias of area one to six

ΔPR_i= deviation of real power demand from area i = one to six. The optimization techniques are applied to reduce abnormal limits of frequency and tie-line response.

III EXISTING CONTROLLERS

A.PROPORTIONAL-INTEGRAL CONTROLLER:

The PI controller provides the error signal which is the difference between set point to that of the output that is obtained. The basic architecture of PI is as shown in fig 2. The parameters of gain value is minimized and given to governor as input. Based on it the operation of generating plant takes place. The transfer function of PI is,

$$G(S) = K_P + \frac{K_I}{s}$$

K**p**,K**i** represents the proportionality constant and integral gain of controller are 0.6 and 0.5.If load changes occurs that will leads to shifting of the operation points takes place. Therefore gain value of the controller is modified repeatedly.

The gain compromises with minimized overshoot and better transient recovery in the dynamic response. It is complicated for continuous tuning the PI parameter such as gain. Then to avoid the continuous tuning, ANN is applied in the place of previous controller.

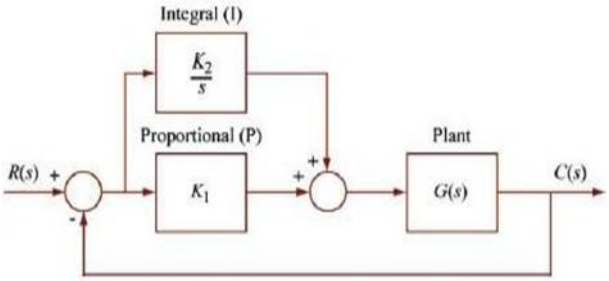

Fig 2: PI Architecture

B.ARTIFICIAL NEURAL NETWORK (ANN)

The Artificial neural network composed of neural network followed by connecting links. The architecture of neural network consists of unknown function and predicted network as shown in the fig.3. The controller is the unknown function. It is tuned that to meet the plant output responses. The basic architecture of ANN is as shown in fig 4. This model consists of hidden layer which compose of 13 neurons, perceptron with five inputs and activation function trainlm is present in between input and output. Power deviation and frequency deviations are inputs to the controller.

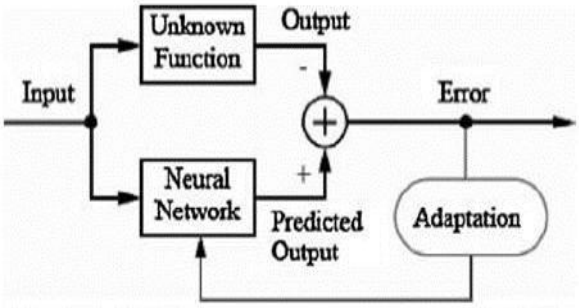

Fig 3: Neural Network

Unit step input causes disturbances created in the model. The obtained output is given as the control signal to the governors.

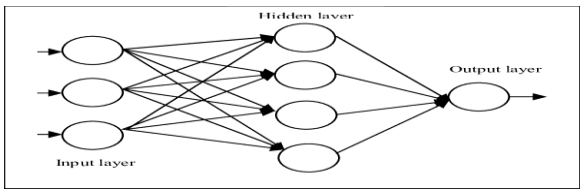

Fig 4: Architecture of Artificial Neural Network

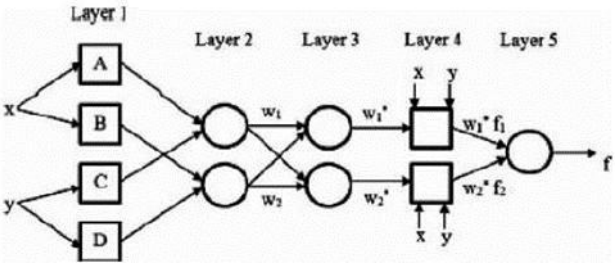

Fig 5: AFNIS Structure

C.ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

It is a soft technique which was introduced by Jang. It consists of three parts namely, fuzzification of input signal. It is followed by the interference consists of knowledge base about the variables and rule base is to make decisions. The last one is defuzzification to convert fuzzy outputs to crisp values and given as the input to the plant. ACE and change in ACE are given to ANFIS controller and the obtained result is given as the control signal.

If x represents A and y represents c, then

$$f_1 = p_1 (x) + q_1 (y) + r_1 \qquad (16)$$

A, B, C, D represents the inputs of the layer one. The membership function which is as show in figure 5 and the node equation is represented as

O = μ (X),

μ (X) represents the membership function

Table 1: Decision table of ANFIS

e\Δe	LOW	MEDIUM	HIGH
LOW	LOW	MEDIUM	HIGH
MEDIUM	MEDIUM	HIGH	HIGH
HIGH	HIGH	HIGH	HIGH

$$f(x;a,b,c) = \frac{1}{1+(\frac{x-c}{a})^{2b}} \qquad (17)$$

Where a,b,c are the parameters of membership function and node in second layer are non-adaptive and multiplied by input signal.

$$W_i = \mu(x) \times \mu(x)_{i+1} \qquad (18)$$

The third layer is rule layer which is non-adaptive and it represents the firing strength as given below,

$$W_I^* = \frac{Wi}{(W1+W2} \qquad (19)$$

The fourth layer is the defuzzification which gives the output value of rule inference.

$$O_i^4 = W_I^* \times f_i = W_I^*(p_i x + q_i y + r_i) \qquad (20)$$

Where p_i, q_i, r are the consequent parameters

Fifth layer is the overall output layer, which adds all the inputs of the forth layer and converts fuzzy into crisp.

$$O_i^4 = \sum_i W_I^* f_i = \frac{\sum_i W_I^* f_i}{\sum_i W_I^*} \qquad (21)$$

Steps to initialize ANFIS in the MATLAB environment:

1. The Simulink hybrid model is developed under MATLAB environment with the selection of proper rule.
2. Collect the data which consists of information about load variation of different generating areas treated as inputs.
3. Fuzzy inference system (FIS) file is created by using "ANFISEDIT" command.
4. With the membership function and FIS is applied to the collected data
5. Before saving the data, evaluate the FIS file with certain number of epochs.

This model is trained with the suitable epochs to avoid abnormal conditions in tie-line power and frequency.

Table2: Parameters of ANFIS is as follows

Nodes	53
Epoch	1000
Data pairs	100
Fuzzy rules	16
Non linear parameters	24
Checking data pairs	100
Linear parameters	16

The implementation of PI controllers in non-linear loads is very difficult. So that implementation of the ANN and ANFIS controller is done. But the responses obtained by the ANFIS is better than that of ANN.

IV PROPOSED TECHNIQUE

GENETIC ALGORITHM:

The GA is a method for solving non-linear problems. It is based on natural selection. The characteristic of GAs makes very attractive for solving multi objective optimization techniques. The use of the controllers to regulate the system frequency and power by controlling the speed of the generators. The proposed GA is used to optimize the gains of the PI controllers for load frequency control of six area hybrid multi-connected power system.

The gain values of the PI controller are optimized by GA technique followed by the initializing population, fitness function, selection, crossover and mutation. Based on roulette wheel selection the different individuals are selected and allow them to crossover and mutation to get the best individuals.

The gain values like K_I,K_P of PI controller are considered. The parameters of GA are population size is about 30, no of iterations are 100, cross over is 90 percent, mutation is 10 percent , number of epochs are 1000 . The PI parameters are applied to the six area hybrid multi-connected network and stimulate the above network to appropriate time period of 150 seconds.

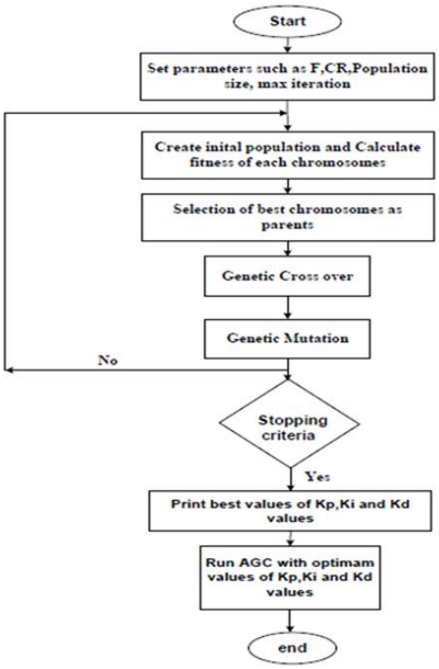

Fig 6 : flow chart of AGC implementation by GA

V SIMULATION AND RESULTS

The transfer function model of six unequal areas is developed by connecting tie-lines.Variation of one percent step load leads to change in frequency and change in tie line power.This is controlled by PI ,ANN,ANFIS and GA based PI controllers. The simulation work was carried out by appling all the above mentioned controllers under the MAT LAB environemt.The comparsion of frequency and tie power was carried out.

FREQUENCY RESPONSE OF SIX AREA HYBRID MULTI-GENERATED

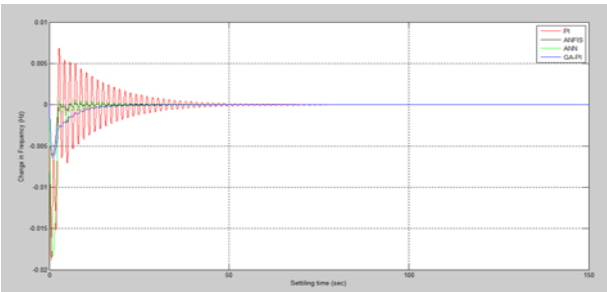

Fig 7: Δf response of area one with respective to Controlling techniques

The fig7 represents dynamic frequency response of thermal plant. By using PI, ANN, ANFIS and GA based PI controllers frequency responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

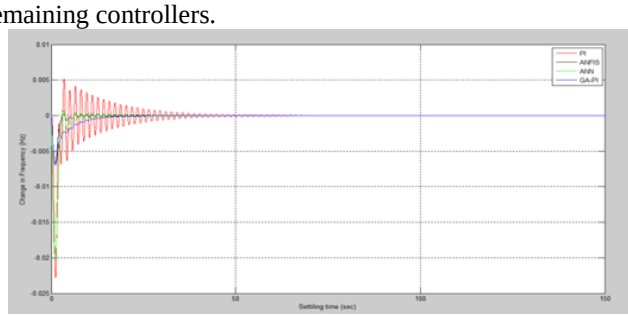

Fig 8: Δf response of area two with respective to Controlling techniques

The fig 8 represents dynamic frequency response of reheat thermal plant. By using PI, ANN, ANFIS and GA based PI controllers frequency responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

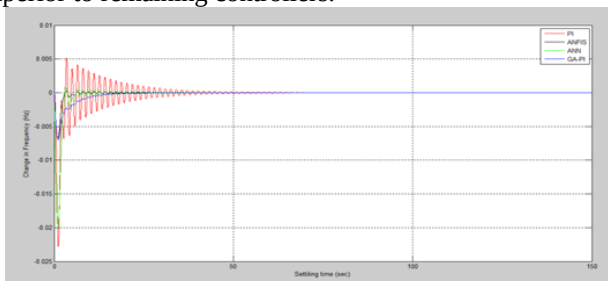

Fig 9: Δf response of area three with respective to Controlling techniques

The fig9 represents dynamic frequency response of hydro plant. By using PI, ANN, ANFIS and GA based PI controllers frequency responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

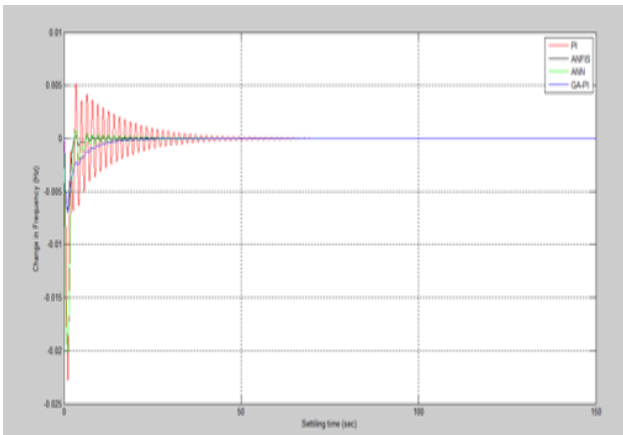

Fig 10: Δf response of area four with respective to Controlling techniques

The fig10 represents dynamic frequency response of nuclear plant. By using PI, ANN, ANFIS and GA based PI controllers frequency responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4.

The settling time achieved by the GA based PI is superior to remaining controllers.

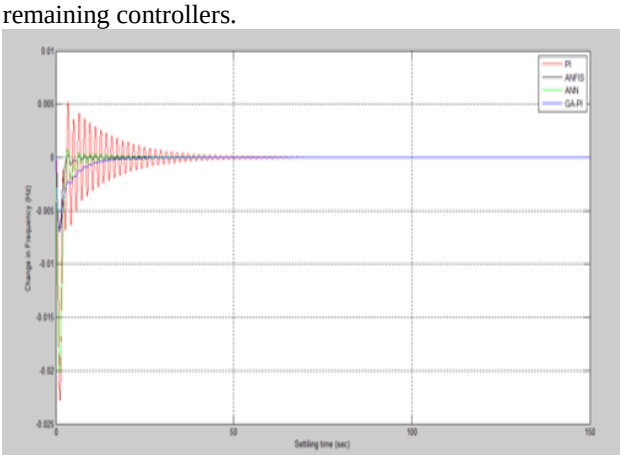

Fig 11: Δf response of area five with respective to Controlling techniques

The fig11 represents dynamic frequency response of diesel plant. By using PI, ANN, ANFIS and GA based PI controllers frequency responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4.The settling time achieved by the GA based PI is superior to remaining controllers.

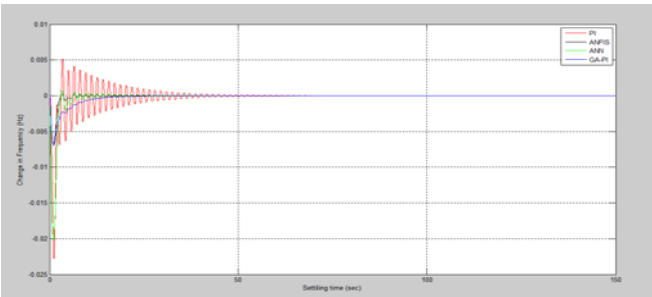

Fig 12: Δf response of area six with respective to Controlling techniques

The fig12 represents dynamic frequency response of gas turbine plant. By using PI, ANN, ANFIS and GA based PI controllers frequency responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4.The settling time achieved by the GA based PI is superior to remaining controllers.

TIE-LINE RESPONSE OFSIX AREA HYBRID MULTI-GENERATED

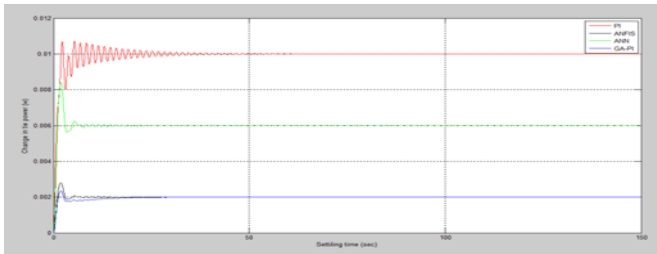

Fig 13: Δp response of area one with respective to Controlling techniques

The fig13 represents dynamic tie line power response of thermal plant. By using PI, ANN, ANFIS and GA based PI controllers tie-line responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

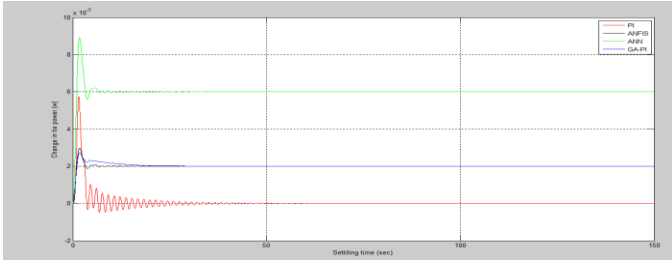

Fig 14: Δp response of area two with respective to Controlling techniques

The fig14 represents dynamic tie line power response of reheat thermal plant. By using PI, ANN, ANFIS and GA based PI controllers tie-line responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

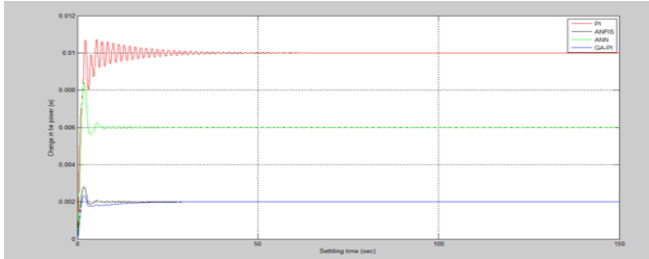

Fig 15: Δp response of area three with respective to Controlling techniques

The fig15 represents dynamic tie line power response of hydro plant. By using PI, ANN, ANFIS and GA based PI controllers tie-line responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

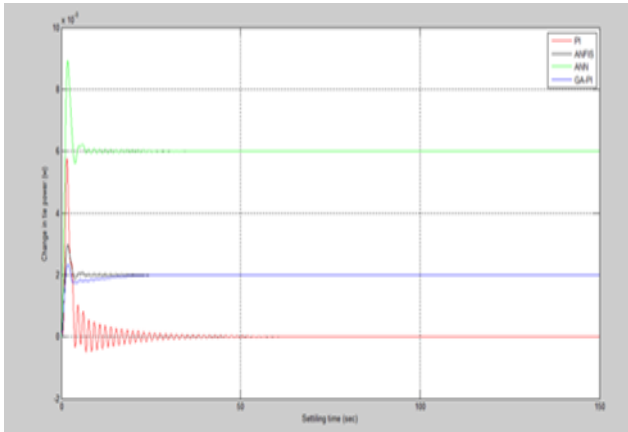

Fig 16:Δp response of area four with respective to Controlling techniques

The fig16 represents dynamic tie line power response of nuclear plant. By using PI, ANN, ANFIS and GA based PI controllers tie-line responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4.The settling time achieved by the GA based PI is superior to remaining controllers.

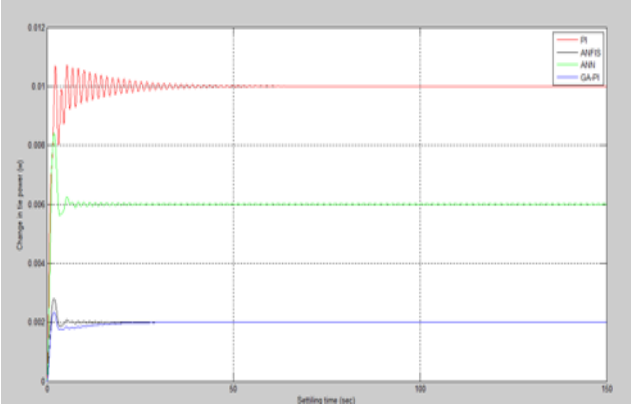

Fig17: Δp response of area five with respective to Controlling techniques

The fig17 represents dynamic tie line power response of diesel plant. By using PI, ANN, ANFIS and GA based PI controllers tie-line responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4.The settling time achieved by the GA based PI is superior to remaining controllers.

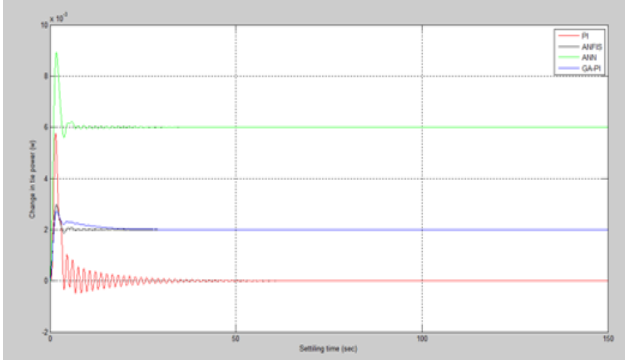

Fig 18: Δp response of area six with respective to Controlling techniques

The fig18 represents dynamic tie line power response of gas turbine plant. By using PI, ANN, ANFIS and GA based PI controllers tie-line responses are obtained. The parameters like settling time and peak overshoot are tabulated in table 3 and 4. The settling time achieved by the GA based PI is superior to remaining controllers.

Table3: comparison of settling time with Respective to applied controllers

AREA	PI (sec)		ANN (sec)		ANFIS (sec)		GA based PI(sec)	
	Δf	Δp	Δf	Δp	Δf	Δp	Δf	Δp
Thermal (1)	75	60	58	45	43	30	28	20
Reheat thermal (2)	65	70	40	38	30	30	27	23
Hydro (3)	68	72	42	52	32	38	28	29
Nuclear (4)	68	64	44	38	34	32	26	24
Diesel (5)	78	68	46	58	32	38	27	25
Gas Turbine (6)	82	71	46	40	38	35	28	27

Table 4: comparison of peak over shoot with respective applied controllers

AREA	PI		ANN		ANFIS		GA based PI	
	Δf(HZ)	Δp (p.u)	Δf(HZ)	Δp (p.u)	Δf(HZ)	Δp(p.u)	Δf(HZ)	Δp(p.u)
Thermal (1)	-0.047	0.003	-0.032	0.0035	-0.0021	0.0032	-0.0025	0.003
Thermal reheat (2)	-0.054	0.0045	-0.05	0.0045	-0.014	0.004	-0.0018	0.0038
Hydro (3)	-0.055	-0.0089	-0.048	0.009	-0.035	0.0065	-0.0019	0.0052
Nuclear (4)	-0.0049	-0.0068	-0.068	0.02	-0.023	0.02	-0.0015	0.021
Diesel (5)	-0.037	-0.0054	-0.0024	0.0045	-0.0025	0.0025	-0.00175	0.023
Gas turbine (6)	-0.034	-0.0065	-0.025	0.03	-0.00247	0.006	-0.0036	0.0053

VI CONCLUSION

In this modern era huge demand for the usage of electrical energy is increasing along the implementation of new controlling techniques. This paper is about implementation of new controlling strategies in six area interconnected hybrid power model, whenever any sudden variation of load results in abnormal conditions in frequency and tie-line power.

This can be avoided by the implementation of some controller techniques such as PI,ANN,ANFIS,GA based PI are used. The six area multi-controlled hybrid model was developed under MATLAB environment. The output responses of all the controllers are compared. There characteristic was tabulated as table 3 and 4.Finally dynamic responses which are obtained by soft controlling technique like GA based PI is more preferable then that of PI ANN ANFIS.

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