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Multi-machines Power System Stability using Fuzz-PD+I and ANFIS

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Abstract:
In this paper, ANFIS and FuzzyPD+Icontrollers are proposed to control a power system to enhance the oscillations in the two areas power system. The main goal is to minimize the transient deviations and steady-state error to minimum value. Power System Stabilizers (PSSs) are added to excite system or control loop of the generating unit to enhance the damping during oscillations. The results of different hybrid control strategy are compared. The simulations are adopted using MATLAB/Simulink software package, the simulation results shown that the performance of ANFIS controller is the better one.

Keywords:
*(ANFIS, fuzzy PD+I)controller**,**Tie-Line,powerdeviation**.***

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I. Introduction

The electric power systems have recently grown very fast, the load dispatch centers should continually determine the load planning and dispatching without violating the system constraints to ensure and reliable suppliers to all consumers. Utilities try to predict the future energy demand in their areas and develop new generation strategies accordingly to account risks due to extensive interconnection on system stability especially in deregulated electricity markets[1, 2].While the requestof electric power growing fast, under these conditions, the power engineers have had to confront some major operating problems such as transient instability, poor damping of oscillations and poor voltage regulation. While the generator excitation controllers are helpful in achieving rotor angle stability, with excitation control alone system stability may not be maintained if a large fault occurs close to the generator terminal[3][4].

Oscillations of generator angle associated with transmission system disturbances and can occur due to emergence states. Depending on the characteristics of the power system, the oscillations may last for 3-20 seconds after a severe fault. It is essential to damp the oscillations as quickly as possible because they cause mechanical wear in power plants and many cause power quality problems. [5].

For thatreliable operation requires fast tools to monitor system stability that can process a wide kind of network connectivity and generation dispatches during normal and ub-normal operation. Secure operation is accomplished with the ability of power system to withstand sudden disturbances, and supply the power to all consumers at satisfactory frequency and voltages. In addition, the system operation must be controlled to stay within acceptable system operating limits such as the ranges of line flows and generators loading rate to maintain operating reliability. When these limits are seriously perturbed the system may suffer from frequency collapse, voltage instability, generators rotor angle instabilities, or system islanding.

developing real-time design and adaptive –neuro-fuzzy for online monitoring and enhancing of system dynamic stability are the main targets of the paper. The online monitoring of electric power system becomes more and more important to evaluate and enhance the performance of system operation at all levels of loading due to excessive number of possible contingencies. Pursuing system security is the main responsibility of ISO, which must be managed ahead of time by coordinating power transactions in a suitable manner to keep the system security at all operating conditions. which increase the risk to lose of synchronism during abnormal conditions due to system instability, the behavior of the online connected generators should be monitored continuously to keep in synchronism.

II. Power system model

Power systems are separated into various areas. The transmission lines which connect an area to its neighboring area are called tie-lines. The Power sharing between two areas is done through these tie-lines. Load frequency control, its name signifies that it regulates the power flow between different areas while keeping the frequency constant [6]. The mainindependent ofAutomatic Generator Control (AGC) are to regulate frequency to the specified nominal value and to maintain the inter change power between control areas at the scheduled values by modifying the output of selected generator. These objectives can be met by monitoring the area control error (ACE) for each area. The ACE for each area is consisting of a linear combination of frequency and tie-line error. its unit is MW and given by [7]:

$ACE_1 = -\Delta p_{ti} - B_1 \Delta \omega$ ……………… ……………….. (.1)

$ACE_2 = \Delta p_{ti} - B_2 \Delta \omega$ ……………………………….. (2)

Where:

Δω : rotor speed deviation

Δp_{ti} :ti-power deviation

Tie power flow was defined as going from area1 to area2.

$B_1 = \frac{1}{R_1} + D_1$ ………………………………………. (3)

$B_2 = \frac{1}{R_1} + D_2$ ……………………………………….. (4)

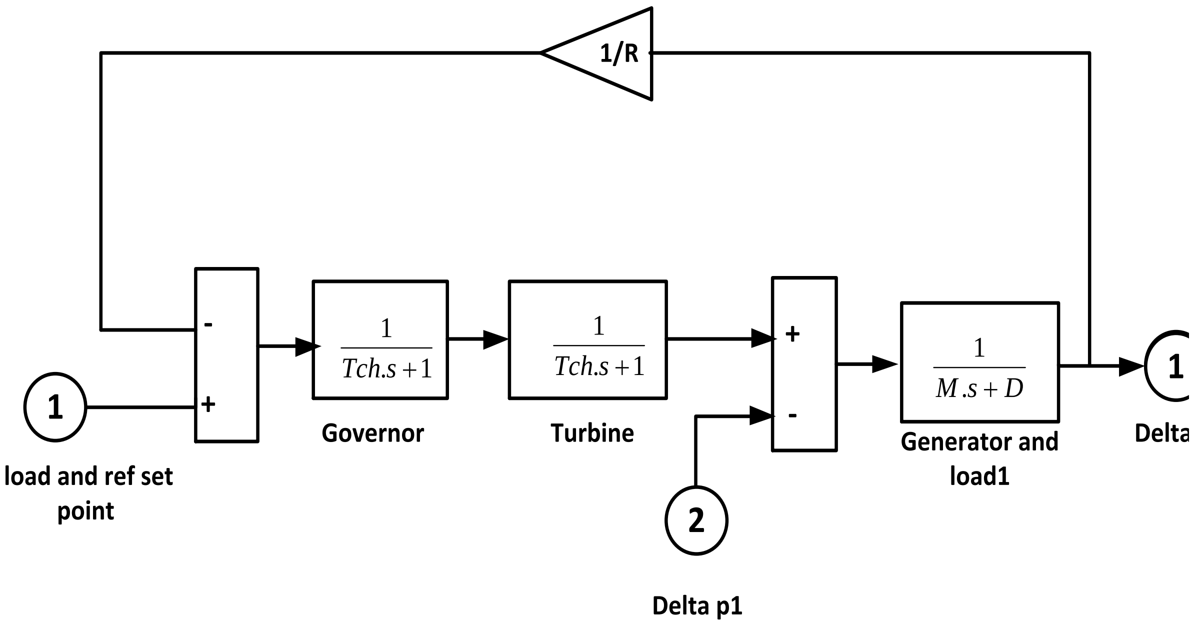
Where:

1/R: Net gain

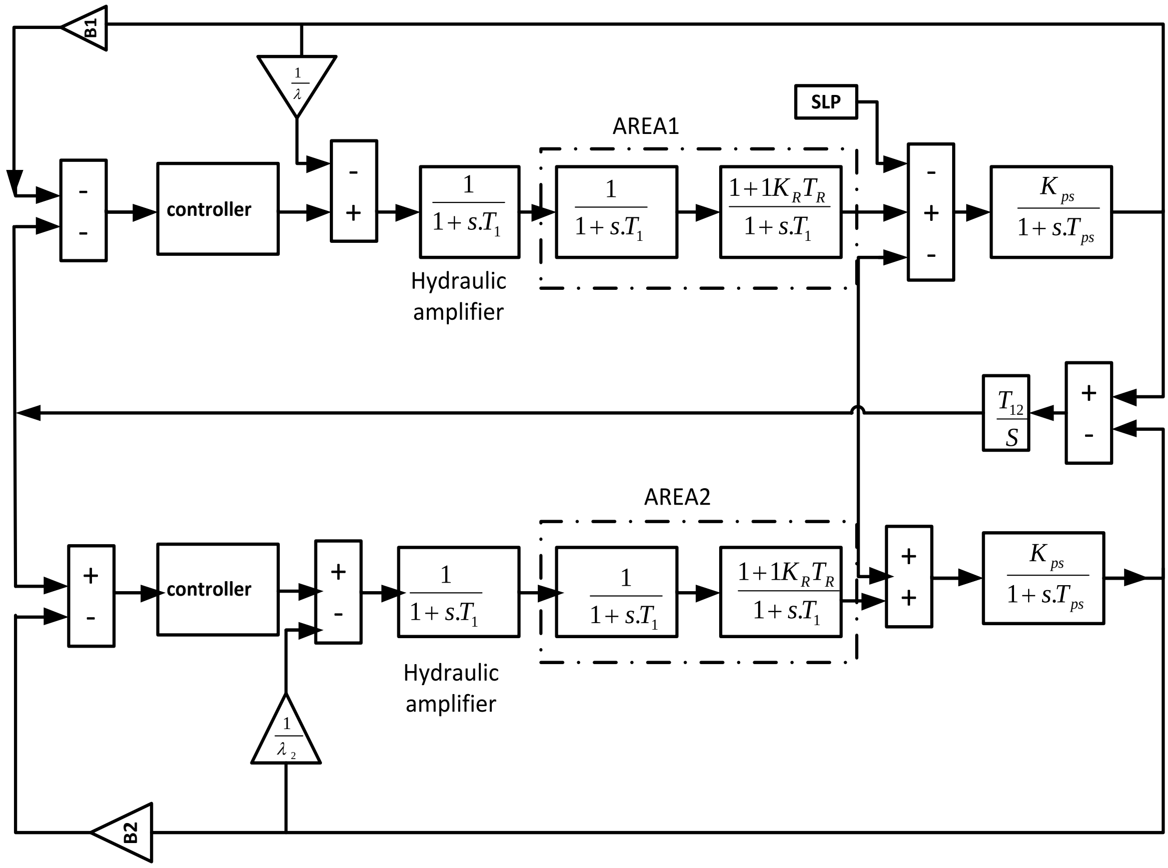
B_1, B_2: frequency bias factors in MW/Hz

D: load constant

Figure (1) showthe Simulink model of an isolated power system (turbine, generator and governor),figure(2) show the block diagramoftwo areas interconnected, it consist of two power generating stations connected by ti-line.



Figure(1): Simulink model of isolated power system



Figure(2) block diagram for two areas power system

3. Controller stretcher and objective:

To control the oscillations, (PID , fuzzy PD+I and ANFIS) controllers are provided in each area.

3.1 Theproportional-Integral-Derivative controller (PID controller):

The PID controller as shown in figure (3),is a common feedback loop component in manufacturing control systems. The controller takes a measured value from a process or other apparatus and compares it with a reference set point value,the difference (or "error" signal) is then used to adjust some input to the process in order to brink the process measured value back to its desired set point. The PID controller gives combined effect of three controllers that is proportional, integral and derivative hence it is most widely used controller in the industry. it can be divided into two categories; Analogue (continuous) or digital (discrete) PID controller[8, 9] . Mathematically the control signal is given by $u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt}$…………………………………. (5)

The tuning parameter K_p , K_i and K_d are the proportional , integral and derivative gains respectively.

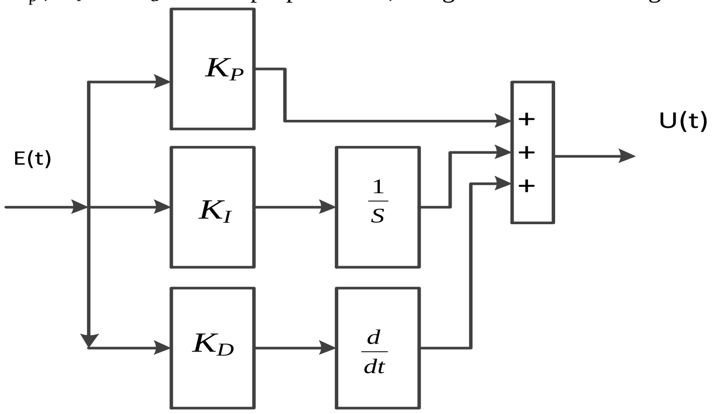


Figure (3)The PID controller

3.2 Fuzzy Controller

Fuzzy logic control is a powerful tool used in various power system applications. The application of fuzzy logic control technique appears to be most suitable one whenever a well-defined control objective cannot be specified, the system to be controlled is a complex, or mathematical model is not available[10, 11]

Fuzzy control is a control method based on fuzzy logic. Itcan bedescribedsimply as computingwithwordratherthannumbers'', fuzzy control can be described simply as ''control with sentences rather than equations''. Fuzzy logic converts complex problems into simpler problems using approximate. The system is described by fuzzy rules and membership function using human type language and linguistic variable. Thus, one can effectively use his/her knowledge to describe the system behavior. A description can effectively model the uncertainty and nonlinearity of a system.

3.2.1Structure of fuzzy logic controller

There are specific components characteristic of fuzzy controller to support a design procedure-processing block. Figure (4)represent a block diagram of the fuzzy controller.

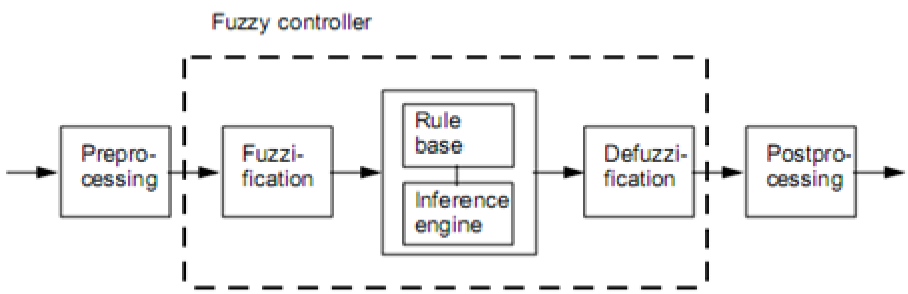
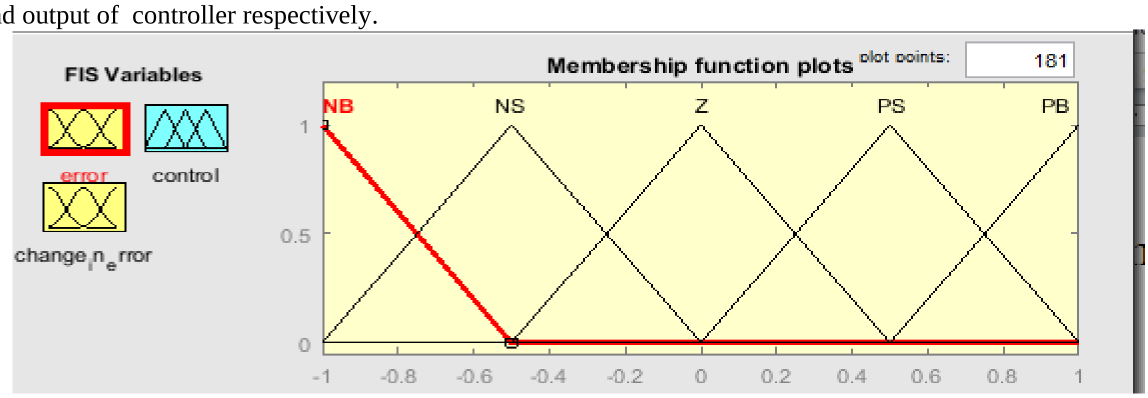


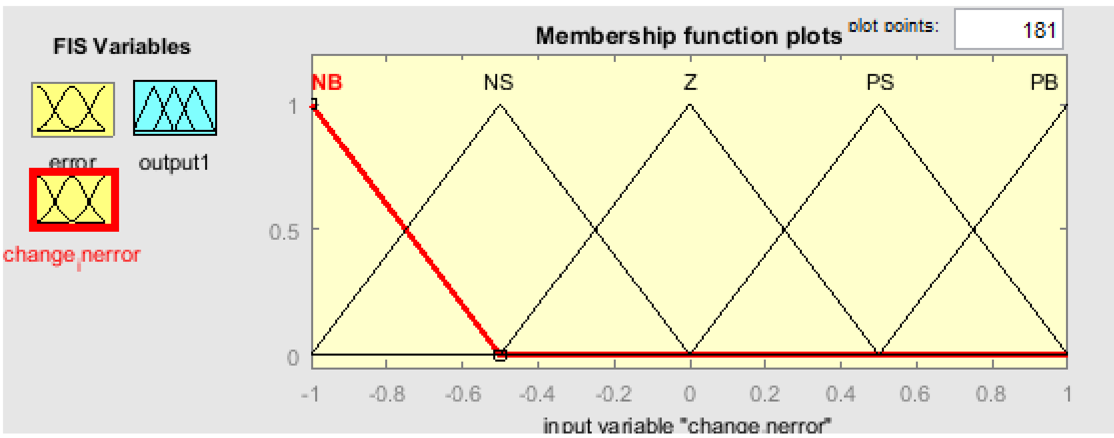
Figure (4): Blocks of fuzzy controller

III. Fuzzy-PD+I Controller

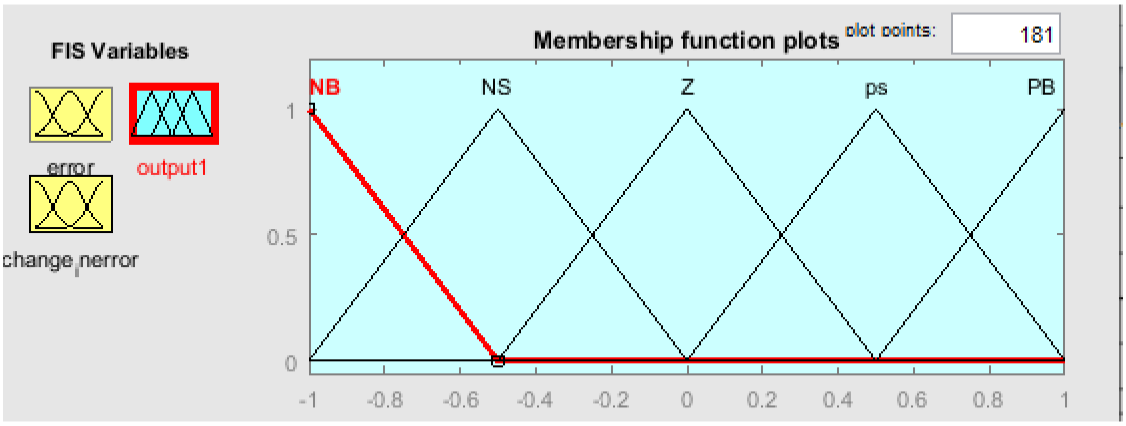
The input- output membership function ofFuzzyPD+I controller shown in figure (5-a,b,c) error, change in error and output of controller respectively.



(a)



(b)



(c)

Figure (.5a.b.c)Input and Output Membership functions Fuzzy-PD+I controller

Table(1)shown the rule base offuzzy Logic controller.

Table 1. Rule base of Fuzzy Logic Controller

e \ Ce	NB	NS	Z	PS	PB
NB	NB	NB	NS	NS	Z
NS	NB	NS	NS	Z	PS
Z	NS	NS	Z	PS	PS
PS	NS	Z	PS	PS	PB
PB	Z	PS	PS	PB	PB

For the fuzzy gain scheduled proportion, integral and derivative controller the Manmdani fuzzy inference engine was chosen and implemented by triangular membership functions for each variable with appropriate selection of intervals of the membership functions given.

IV. Adaptive Neuro Fuzzy Inference System (ANFIS)

Theadaptive network based fuzzy inference system (ANFIS) is a data driven procedurerepresenting a neural network approach for the solution of function approximation problems.

Here a fuzzy inference system comprises of the fuzzy model proposed by Takagi- Sugeno to formalize a systematic approach to generate fuzzy rules from an input output data set [12-14].

5.1ANFIS Structure:

Adaptive neuro-fuzzy inference system is one of method based on artificial intelligent. The ANFIS method function is same as the fuzzy rule based on Sugeno algorithm,it is consist of premise and consequence parameters. the ANFIS network consist of two inputs and one output. For a first order of sugeno fuzzy model , distinctive rule set are expressed as[16]:

$$\text{if } x_1 = A_{1i}\, AND x_2 = A_{2i} THEN\ y = B_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

since the output does not depend directly on the input, takagi and sugeno proposed their fuzzy inference mechanism as:

$$\text{if } x_1 = A_{1i}\, AND x_2 = A_{2i} THEN\ y_i = f_i(x_1, x_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

When there is no predetermined model structure describing the system, the FIS can be expanded as a Neuro-Fuzzy system. In this study , a takagi – sugeno FIS is adapted to the ANFIS as it is more effective for system identification. A takagi –sugeno FIS structure can be generated by one of the following methods:

- ANFIS(Adaptive NN based Fuzzy Inference system)
- Genfis2(Cluster based generation of FIS)
- RENO(Regularized Numerical Optimization)

Atypical ANFIS structure for two inputs, each with five membership functions, is shown in figure (6).The 5 layer of the ANFIS are connected by weights. The first layer is called input layer, it receives the input data, which are mapped in to membership functions, these membership functions determine the membership of a given input to the corresponding class. The second layer of neurons represent associations between input and output, which are called fuzzy rules, in the third layer, the output are normalized and passed to the fourth layer. Based on these pre-determined rules, the output data are mapped in the fourth layer to output membership functions. The output are added in the fifth layer and result finally in a single valued output[17].

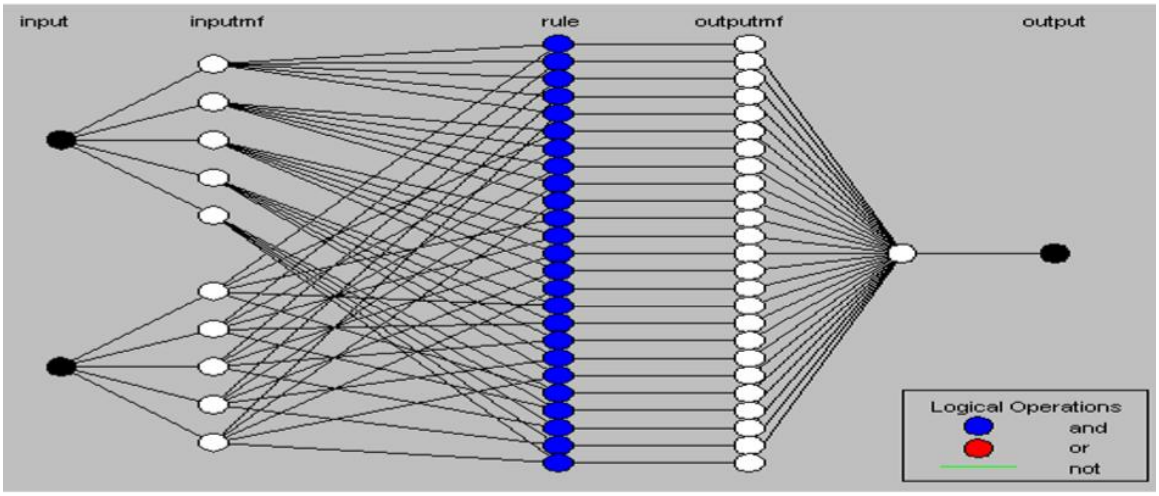


Figure (6): ANFIS Structure with 2 input 1 output and 5 membership functions for each input.

5.2ANFIS Training:

In this work, both membership functions and the inference system are optimized using ANFIS technology.

Appendix: Numerical values of the two-areas power system model

The interconnected power system consists of two areas. Two control areas are treated as identical.

Table (2) : Parameters of the systems

Parameter	**$Area_1$**	**$Area_2$**
Governor Time Constant (T_G)	T_{G1} = 0.2 sec	T_{G2} = 0.3 sec
Turbine Time constant (T_{CH})	T_{CH1} = 0.5 sec	T_{CH2} = 0.6sec
Governor Speed Regulation (R)	R_1 = 0.05P.u	R_2 = 0.0625p.u
Load Damping Constant (D)	D_1 = 0.8 p.u	D_2 = 0.9 p.u
Inertia Constant (H)	H_1 = 5 sec	H_2 = 4 sec
Load Change (Δp_l)	Δp_{l1} = 0.2 p.u	Δp_{l2} = 0
Synchronizing Power Coefficient (T)	T = 2 p.u	T = 2 p.u

V. Simulation Results and Discussion:

Here used MATLAB Simulink program and fuzzy logic toolbox to build the model with two areas steam turbine .

In the simulation a step load increase in area1 of power system ,first used fuzzy PD+I controller then ANFIS controller.

The simulation results from the proposed controllers were compered.

Figure (7) represent frequency deviation response of area1without controller.

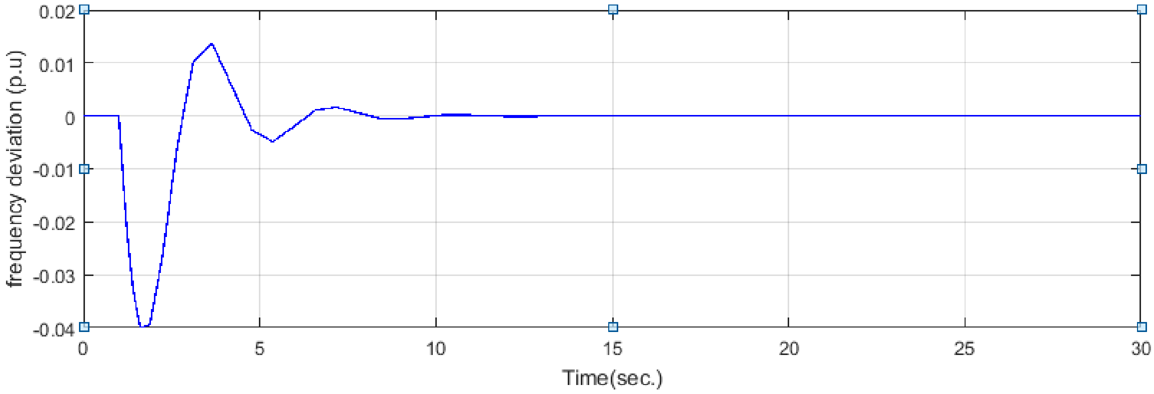


Figure (7): Frequency deviation response of area1without controller.

From the step response, the steady-state frequency deviation is not zero, and the frequency return to nominal value in 9.5 second with over shoo t 0.015 (p.u)and andershoot-0.04 (p.u).
Figure (8) represent frequency deviation response of area1with FuzzyPD+I controller.

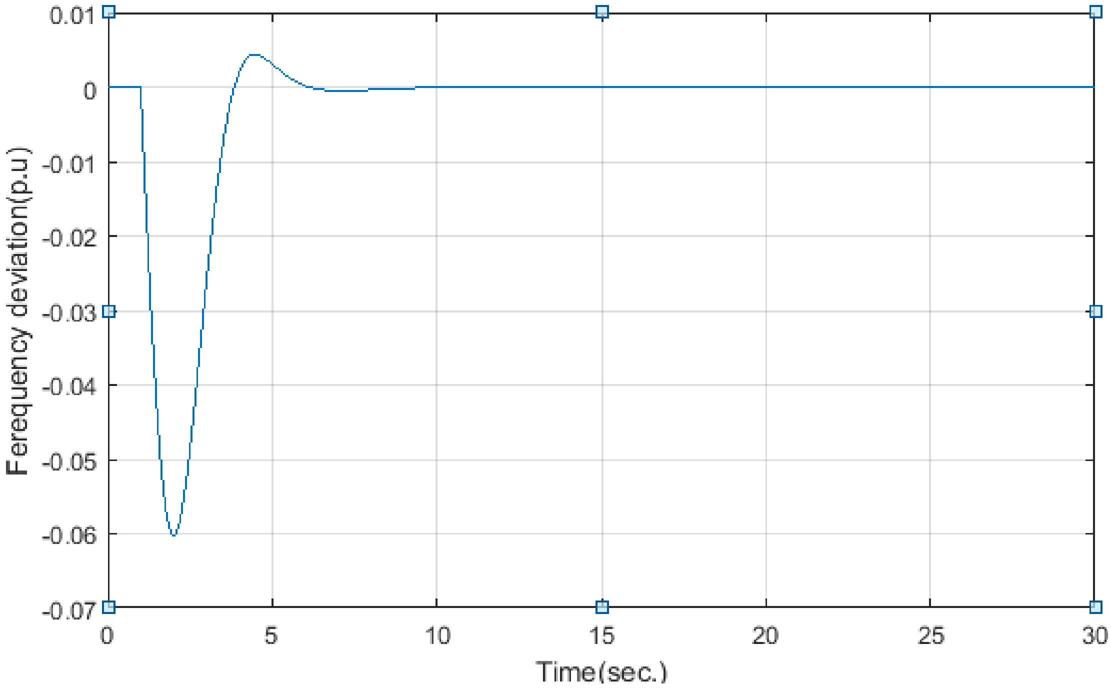
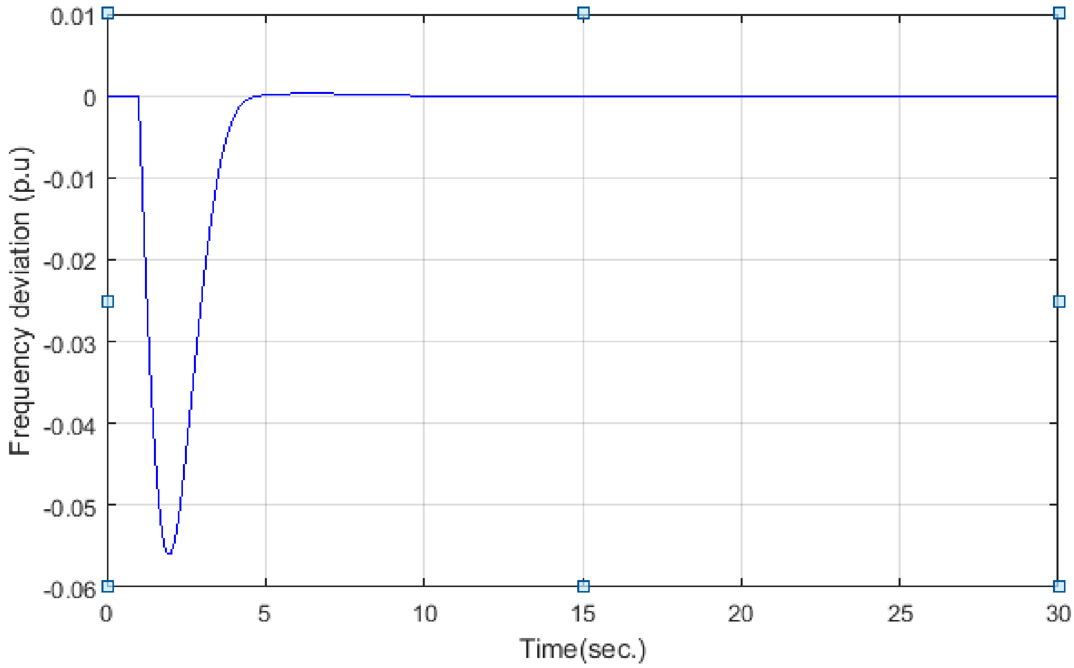


Figure (8)Area1 power deviation response with the fuzzy- PD+I controller.

Figure (9) represent frequency deviation response of area1with ANFIS controller.



Figure(9)Frequency deviation response of area1 ANFIS controller.

It shows that the behavior characteristic of the response was improved, neither overshoot. Table(2) shown the cooperation responses of area1

Table 1: cooperation responses of Area1

Parameters	Fuzzy-PD+I Controller	ANFIS-PID Controller
Peak Undershoot (p.u)	- 0.06	-0.05
Peak Overshoot (p.u)	0.005	0.00
Settling Time (Sec)	7	4

Figure (10) represent frequency deviation response of area2 without controller.

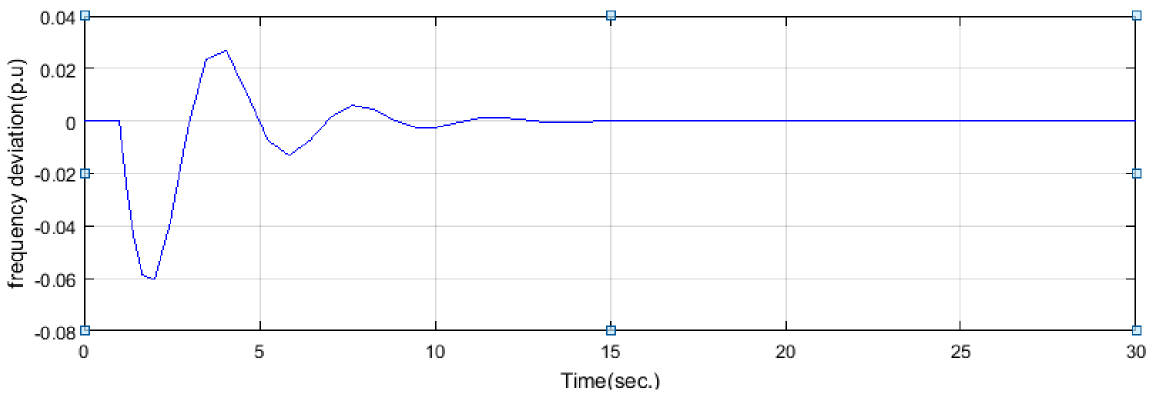


Figure (10): Frequency deviation response of area2 without controller

From the step response, the steady-state frequency deviation is not zero, and the frequency return to nominal value in 12.5second with over shoo t 0.029 (p.u) and undershoot -0.06 (p.u).
Figure (11) represent frequency deviation response of area2with FuzzyPD+I controller.

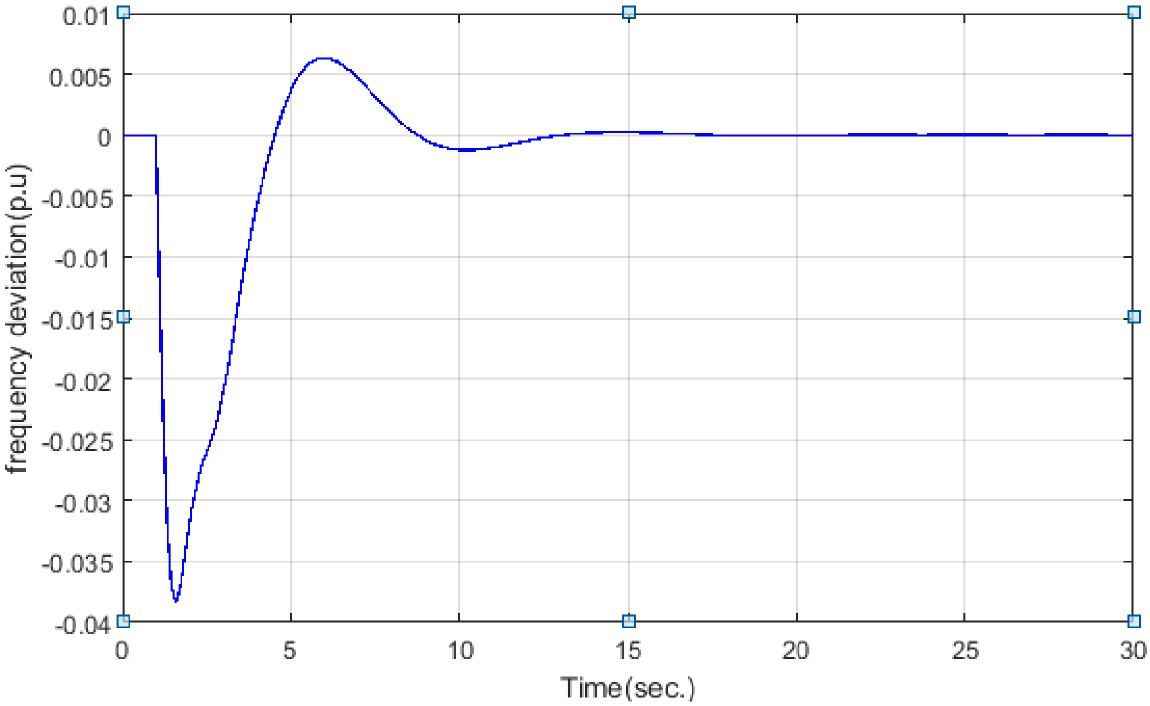
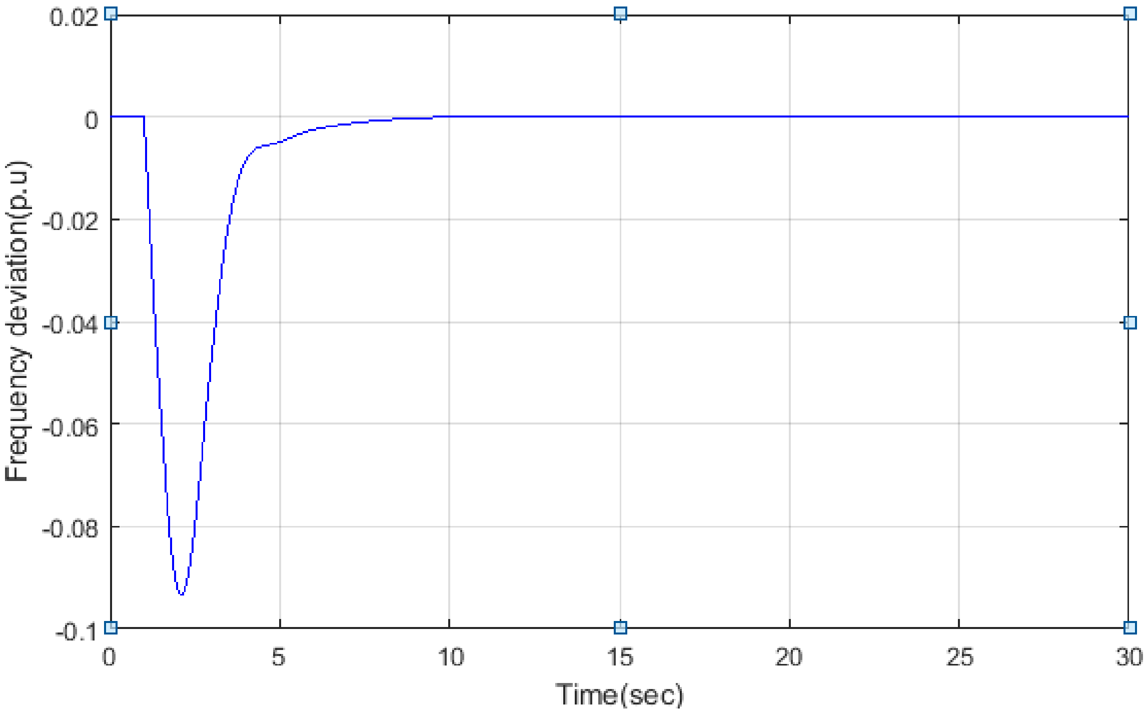


Figure (11): Frequency deviation response of area2 with fuzz-PD+I controller

From the step response, the steady-state frequency deviation is zero, and the frequency return to nominal value in 11.5second with over shoo t 0.006 (p.u) and under shoot-0.038 (p.u).
Figure (12) represent frequency deviation response of area2with ANFIS controller..



Figure(14) Frequency deviation response of area2 with FPD+I controller

The controller forced the steady-state error to zero, neither overshoot. Table(3) shown the cooperation responses of area2

Table3:steady-state responses of Area2

Parameters	Fuzzy-PD+I Controller	ANFIS-PID Controller
Peak Undershoot (p.u)	- 0.038	-0.085
Peak Overshoot (p.u)	0.006	0.00
Settling Time (Sec)	11	7.5

Figure (13) represent frequency deviation response of area12without controller..

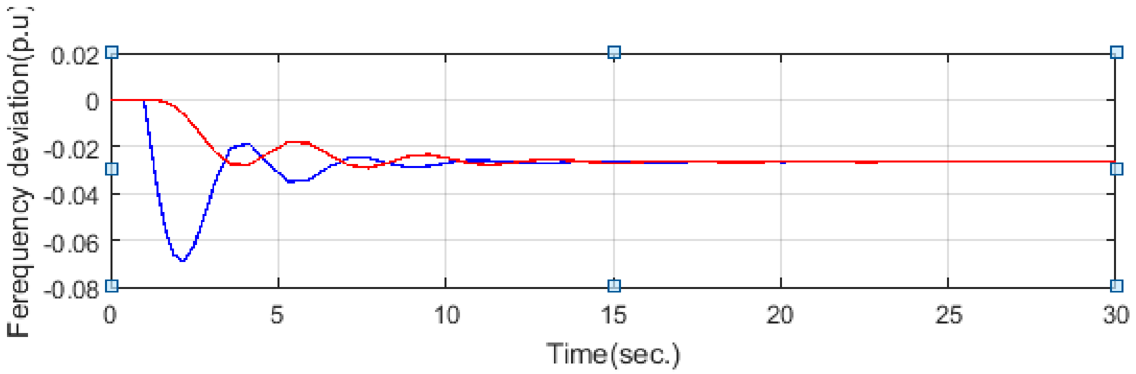
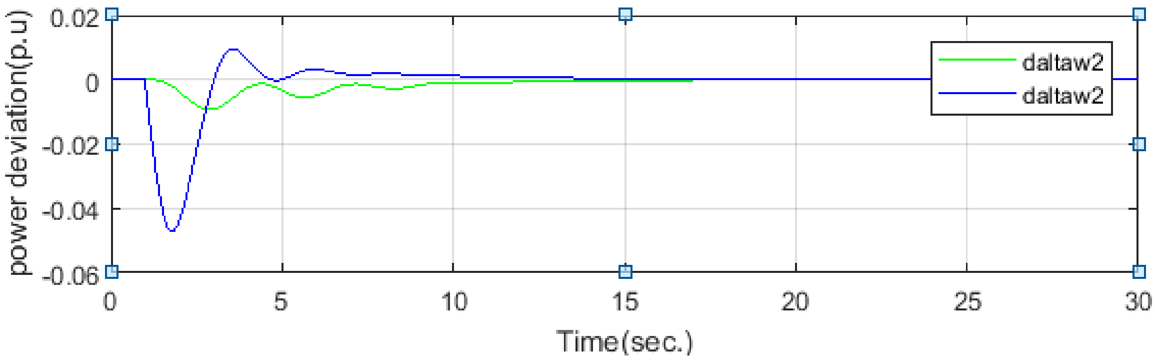


Figure (13): Frequency deviation response ofarea12 without controller.
From the step response, the steady-state frequency deviation is not zero, and the frequency return to nominal value in 14 second for the two areas.

Figure (14) represent frequency deviation response of area2with fuzzy-PD+I controller.



Figure(15):Area12 frequency deviation response with fuzzy-PD+I controller.

From the step response, the steady-state frequency deviation is zero, and the frequency return to nominal value in 12 second for the two areas .

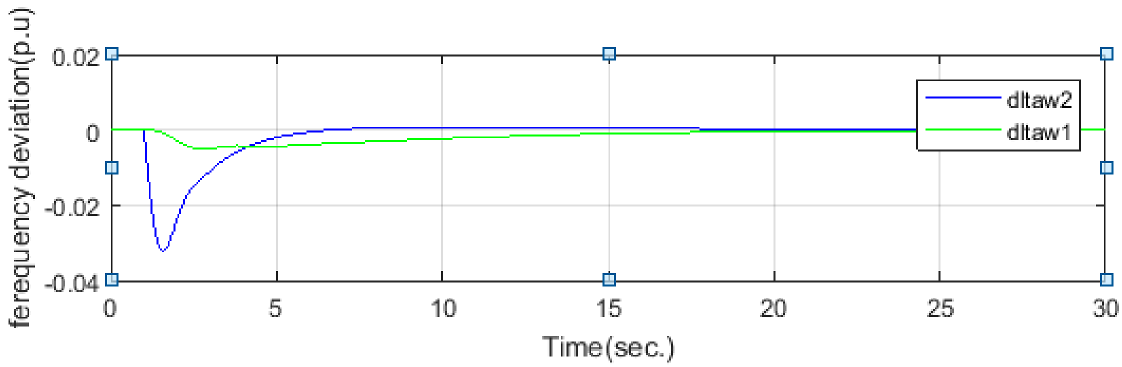
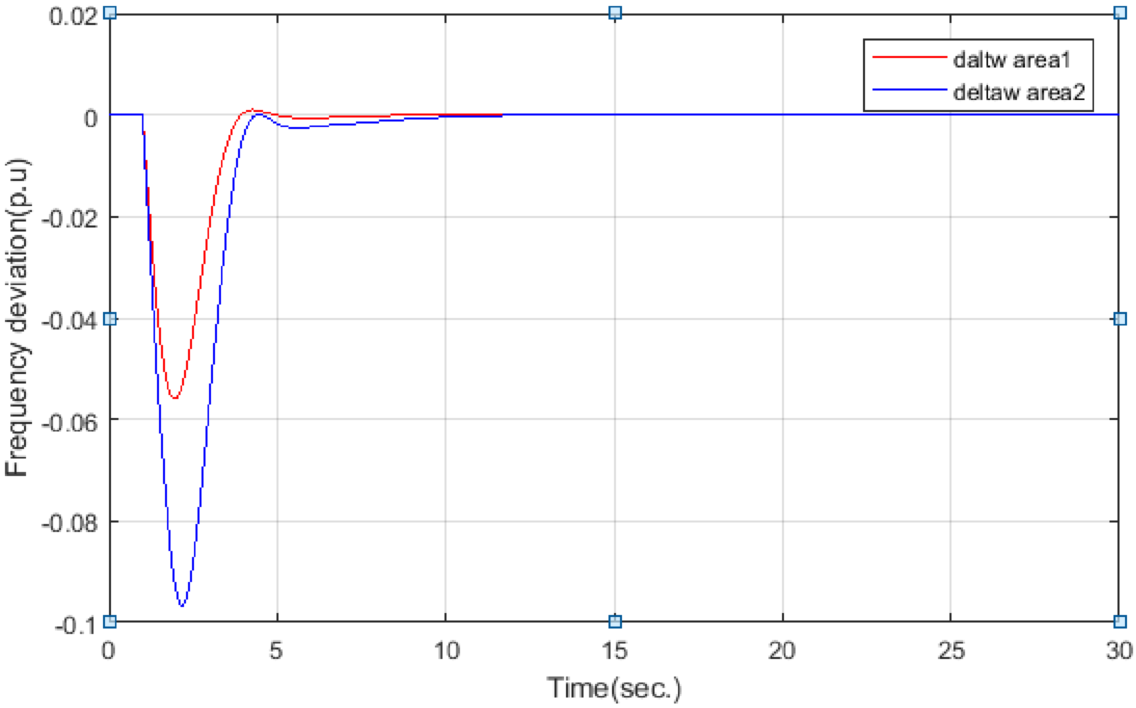


Figure17:Area12 frequency deviation response with ANFIS controller.

From the step response, the steady-state frequency deviation is zero, and the frequency return to nominal value in 9second without overshoot.

The power change in area1 is observed by generation in area1, generation in area2 change a little in the transient period and then return to nominalvalue in steady-stat. The tie-line power flow appears as a loadincrease in one area and a load decrease in the other area depending on the direction of the flow. The direction of flow is dictated by the phase angle difference.



ANFIS

VI. Conclusion:

This paper present billed and application of fuzzy PD+I and ANFIS controllers to investigation of power system. It is observed with significant improvements of dynamic responses are obtained with coordinated.The controllers are design for single machine and multi-machine power system. Speed deviation of synchronous generator were taken as the input signals to controllers . The performance of the power system with ANFIS controller is effective for all test conditions . It was also shown in the simulation results that the ANFIS controller decrease both maximum-overshoot and settling time when was compared with the fuzzy PD+I controllers .It is observed that significant improvements of dynamic responses are obtained with coordinated application of the controllers. Finally, sensitivity analysis is carried out to show the robustness ANFIS controllerwith varying small oscillations from the nominal values. It is observed from simulation results that proposed controllers performed improve the response of the power system.

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