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Load Frequency Control of Multi Source Realistic Power System with Intelligent Controllers

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ABSTRACT

Load frequency control is a virtual challenging problem in a realistic complex power system network. Power demand on the grid is unpredictably varying in nature and consequently grid frequency also varies. To reduce frequency fluctuations on the grid, the renewable energy resources are interfaced with the grid. Renewable resources are abundant and Eco-friendly, but the power generation from these sources is intermittent in nature. In this paper two areas are considered, each area has hydro plant, Thermal with reheat turbine, Gas plant and Wind plant. The integration of Renewable energy system with conventional systems is difficult, and hence an advanced intelligent controller are required. Here an attempt is made to design a controller which control the deviations in frequency and tie line power by using Area Control error (ACE). Application of an advanced intelligent controller improves the performance of Automatic Generation Control (AGC) by reducing the frequency deviations. The frequency errors such as ITAE, ITSE, IAE, ISE which should be minimum for better controlling. The steady state error and settling time shows the satisfactory performance of the prescribed controller.

Index Terms: Automatic Generation Control (AGC), Artificial Intelligent Controllers (AI), ISTE, ITAE,AFGT, ITSE.

1. INTRODUCTION

The power system having major problems in the areas power flow analysis, automatic generation control (AGC), power system maintenance. In that to perform successful operation of interconnected power system network AGC plays a vital role. The AGC concentrates on frequency controlling in interconnected areas and tie line power controlling with respective their contracts between control areas and power demand on the areas. Load frequency control which is a problem at every instant of time the power generation and power demand on the network be equal. Then the frequency of entire system with in the allowable limits. Loss of frequency controlling leads to out of synchronism of power system then system will shut down, world get into dark. To control the frequency most commonly used techniques are categorised as classical methods, adaptive and variable structure methods, robust control approaches, intelligent techniques and digital control [1-5]. Present scenario majorly working on intelligent techniques, algorithms, soft computing techniques are using to control the power system frequency. Neural networks are generalized models of human brains. These networks are capable of understanding realistic problems and provides better solutions. These controllers are stores previous data and gives better solution to the problems by analysing present and past data. In soft computing techniques FUZZY, ANFIS are trending controllers. Fuzzy has advantage that simple fuzzy rules solves the realistic complex network problem with considerable accuracy. Fuzzy controller accuracy depends on the number of membership functions, their ranges and fuzzy rules [6-7].

To enhance the fuzzy controller advantages proportional integral derivative (PID) control concepts incorporated in the fuzzy applications such as FUZZY PI (velocity type of control), FUZZY PD (position

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type of control) and FUZZY PID (acceleration type of control) controllers designed to alleviate frequency fluctuations [8]. Prescribed fuzzy controllers used in various applications as speed, torque control of BLDC motor at various loading conditions. These controllers have self-tuning capability [9]. Advantages of fuzzy and artificial neural networks incorporated in a single controller which is ANFIS controller. The controller having optimum choosing of operating point. The controller has greater advantage that self-generated rules according to problem and data. The ANFIS having best tracking of power system parameter controlling [10-12].

Multi source power more reliable in inter connected systems. The cost of unit power generation is reduced, power production from the plants in an economical manner. The power losses reduced by the tie line power exchange [6]. Generally thermal plants are operated as base load plants. These plants continuously running irrespective of load demand. Due to some faults in the power system the frequency vary larger

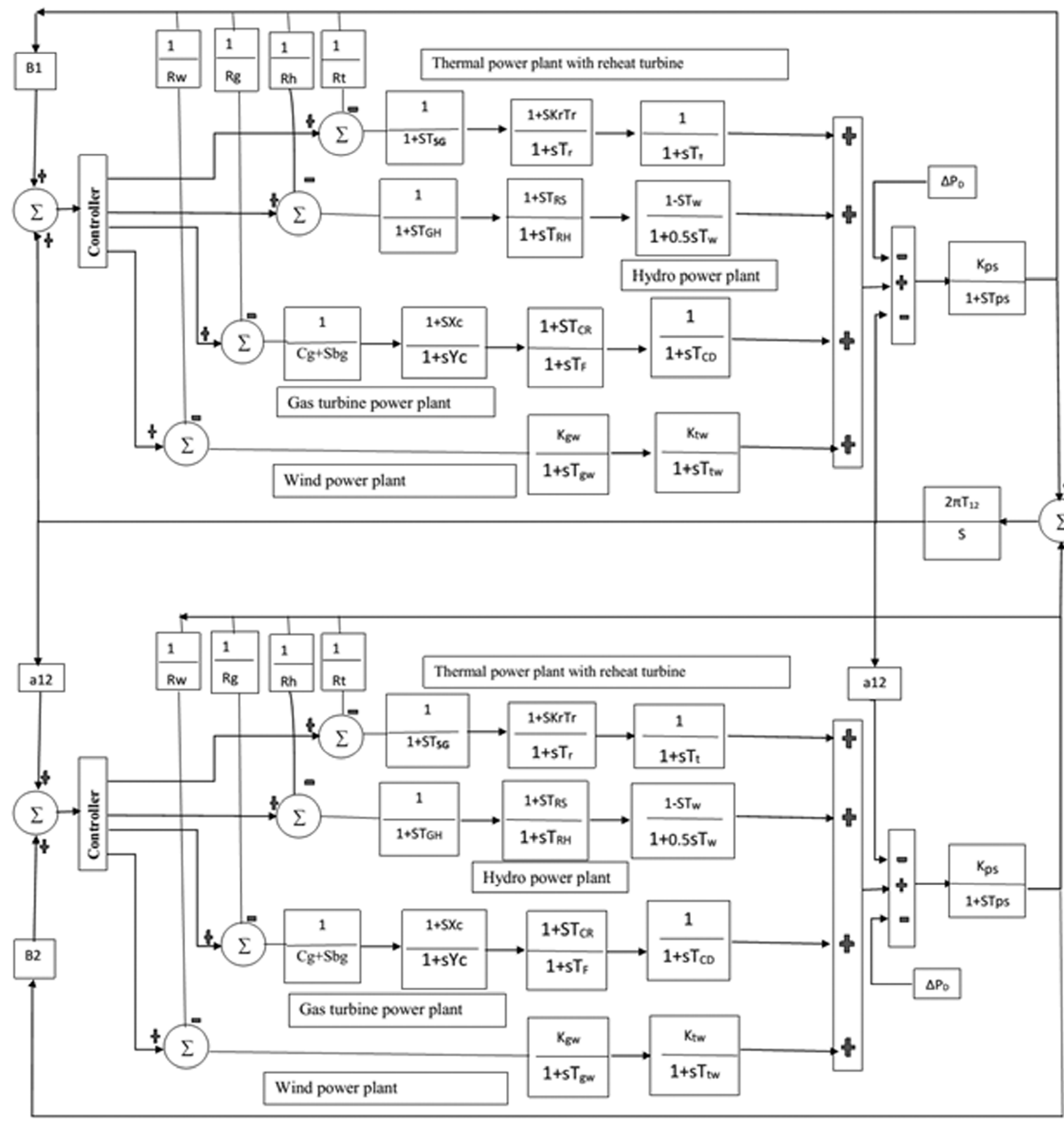

Figure 1: Transfer function model block diagram of multi sources.

otherwise the frequency variations with in the acceptable limits [8]. The hydro plants are operated as both peak and base load plants depending upon water availability, plant capacity and load demand [9]. Gas and diesel plants are operated as peak load plants. The integration of these plants with grid is complex due to different factors affect the individual plant performances. The frequency controlling also complex. For short span of load disturbances the energy storage systems are helpful to meet the power demand. The energy systems like SMES, BES, CES, and RFB have been used in load frequency control systems [6].

2. AI CONTROLLERS

AI controllers provide best parameter optimization in the enlarge power system. These controllers are self-tuned according to the parameter variations. These are directly resembles the human brain.

2.1. Fuzzy controller

Fuzzy aspects are derived from classical set theory. These controllers more realistic than other conventional controllers (P, PI, PID), the designing of fuzzy controller easy. Fuzzy controller have two inputs and one output. Each input having 7 trapezoidal membership functions. The sugeno rule baseis adopted here. The membership function ranges are ACE [-0.475 0.3455], ΔACE [-0.4 0.99] and output [0 1].

2.2. ANFIS-PD Controller

To enhance the dynamic performance of the plant ANFIS-PD controller is designed. The ANFIS-PD controller provides finite optimum tracking operating point to the system. Inputs 1 & 2 having 5 triangle membership functions, Output having 25 functions. The membership function ranges are ACE [-1 1], ΔACE [-2.193 2.5], and output [-2.206 1.864].

The training data (ACE, ΔACE) given to controller and trained then it generate the sugeno rule base with optimum output range. ANFIS-PD structure shown below.

2.3. Adaptive Fuzzy Gain Tuner

The controller have two inputs ,Area control error (ACE) and change in Area control error (ΔACE) and four outputs i.e. the constants of proportional gain K_p, integral gain K_i, derivative gain K_d and saturation

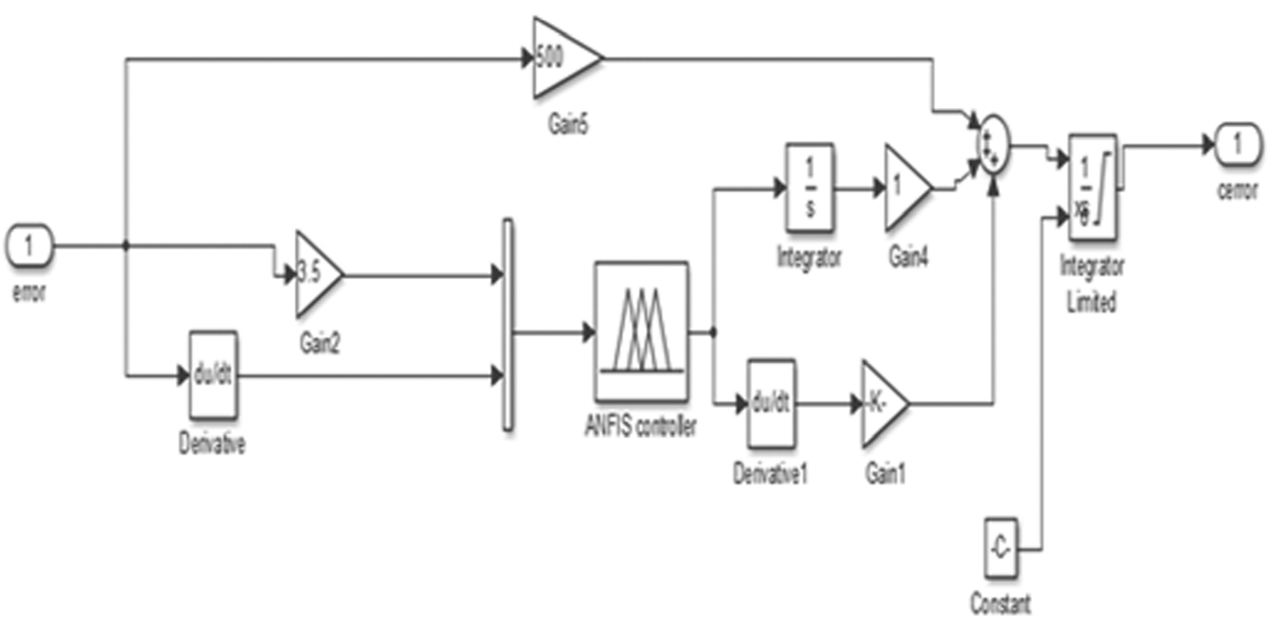

Figure 2: ANFIS-PD rule base structure.

constant Kc. Each input and outputs having 5 gauss bell membership functions. The membership function rages ACE [-1 1], ACE [-1 1], K_p [-7.5 2.5], Ki [-130 0.15], K_d [-0.75 0.1] and Kc [-0.1 0.1].

3. SIMULATION AND RESULTS

The two area power systems has been modelled in Matlab/Simulink environment. The area 1 consist of a Thermal plant with reheat turbine, hydro power plant, gas plant and wind plant. The area 2 consist of a Thermal plant with reheat turbine, hydro power plant, gas plant and wind plant. Bothe area1 are area 2 are interconnected with the tie power for exchange of active power. The performance of proposed controller has checked by comparing with other controller in the terms of time domain specifications. From the results, it is ensured that the dynamic performance has been improved.

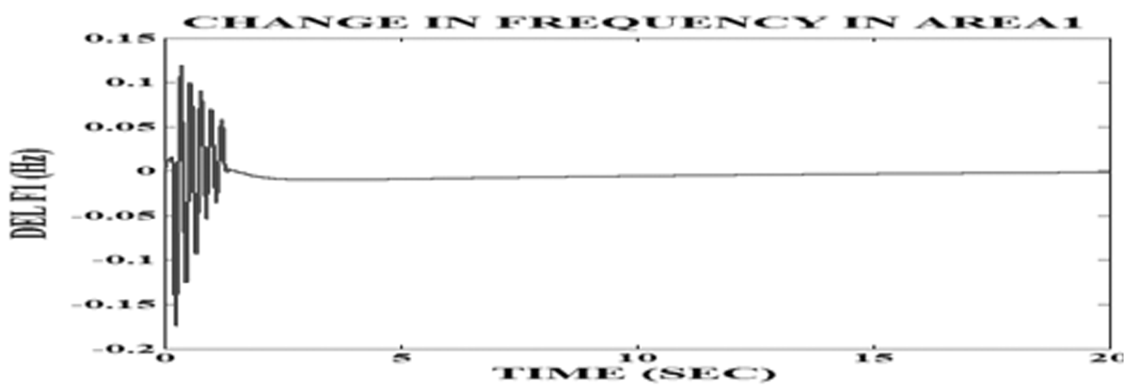

Figure 3: Frequency deviation of area1 at 20% and 30% loading in Control areas 1 & 2 with fuzzy.

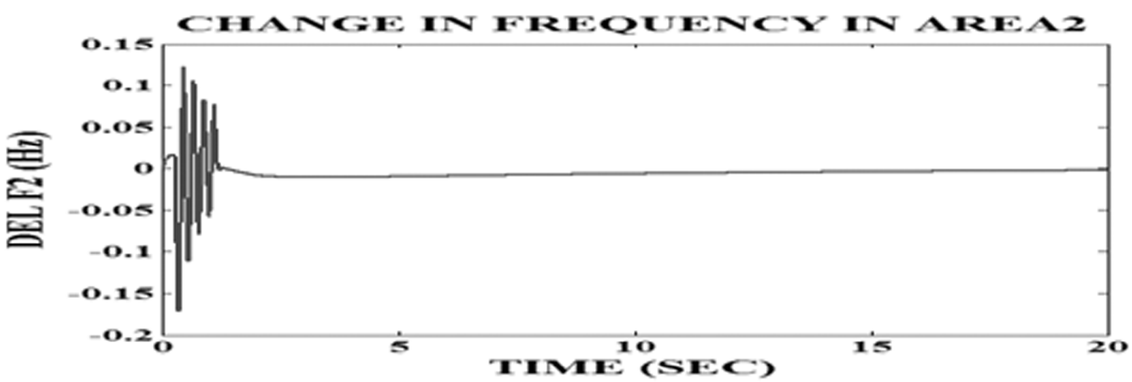

Figure 4: Frequency deviation of area2 at 20% and 30% loading in Control areas 1 & 2 with fuzzy.

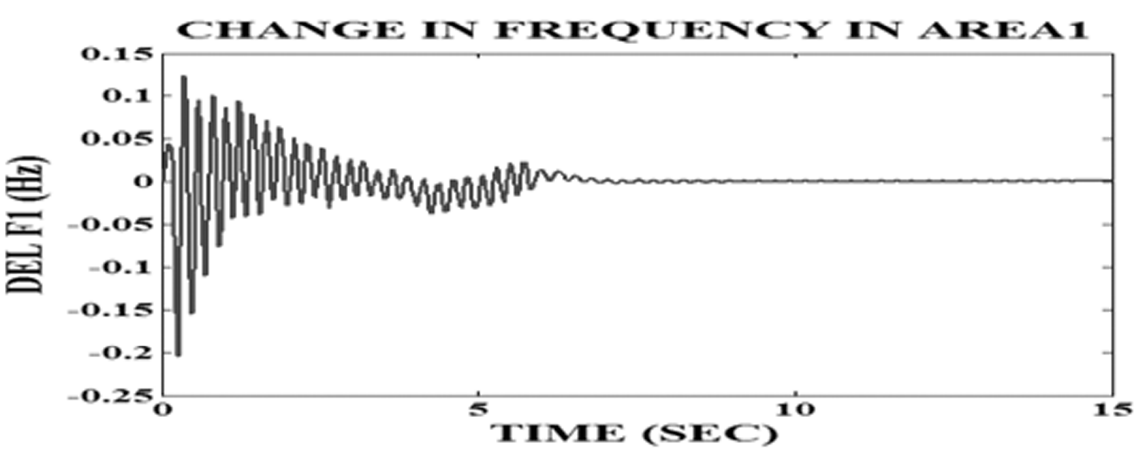

Figure 5: Frequency deviation of area1 at 20% and 30% loading in Control areas 1 & 2 with ANFIS-PD.

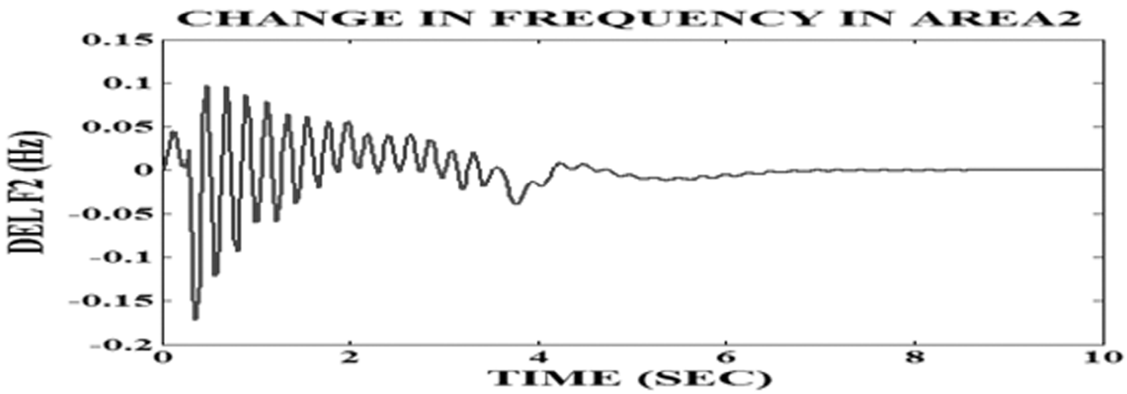

Figure 6: Frequency deviation of area2 at 20% and 30% loading in Control areas 1 & 2 with ANFIS-PD.

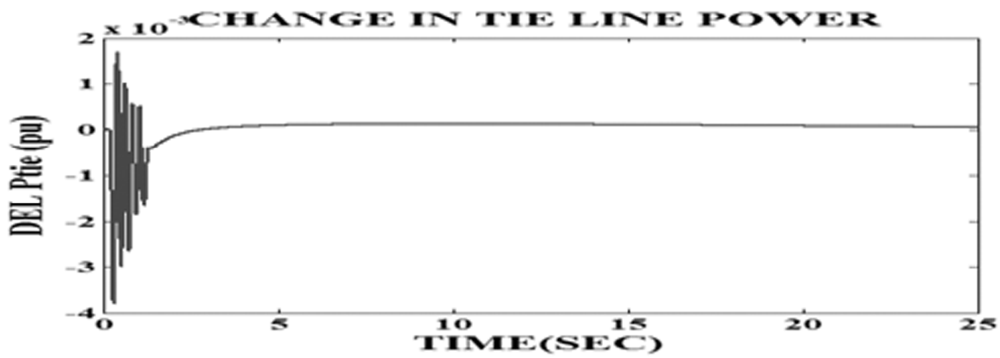

Figure 7: Deviation in the Tie line power withFUZZY controller at 20% and 30% loading in control areas 1&2.

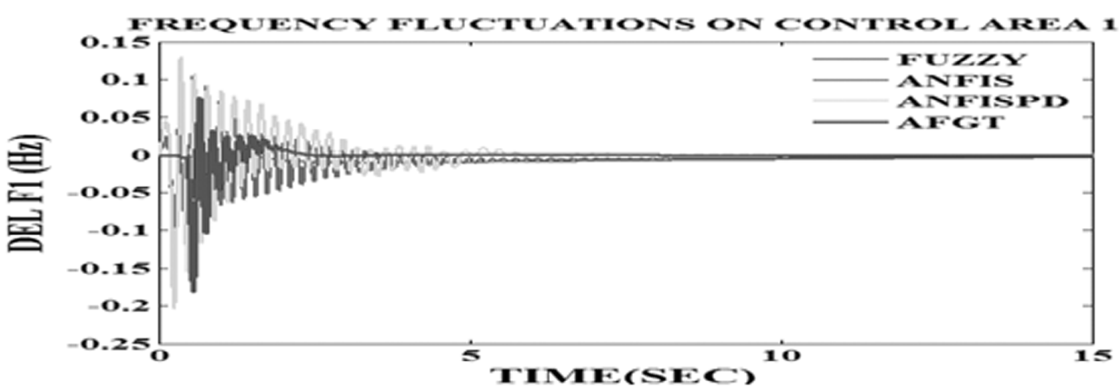

Figure 8: Frequency deviation of area1 at 20% and 30% loading in Control areas 1 & 2 with fuzzy, Anfis, Anfis-pd and adaptive fuzzy gain tuner.

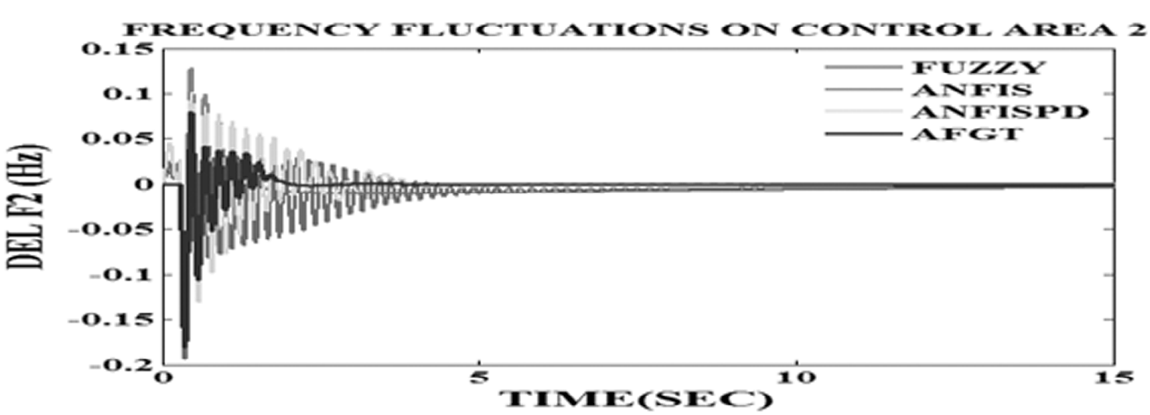

Figure 9: Frequency deviation of area2 at 20% and 30% loading in Control areas 1 & 2 with fuzzy, Anfis, Anfis-pd and adaptive fuzzy gain tuner.

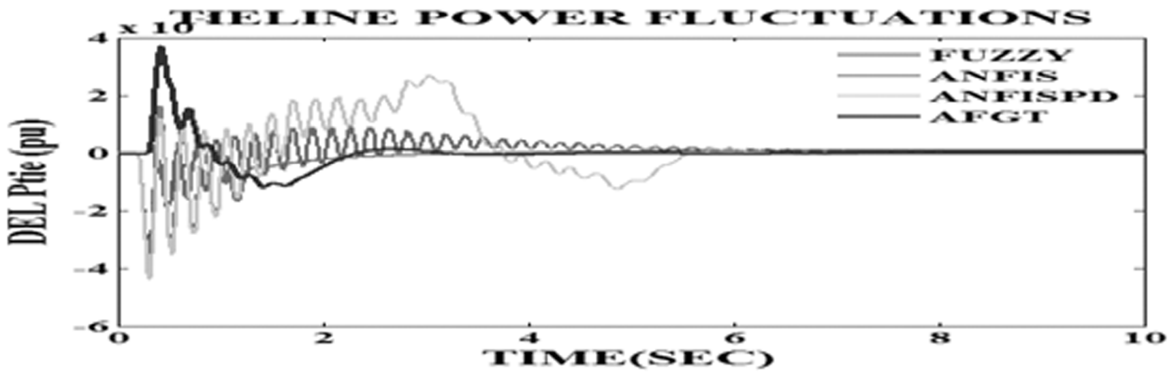

Figure 10: Tie line power deviation with fuzzy, Anfis, Anfis-pd and Adaptive Fuzzy Gain Tuner controller at 20% and 30% loading in control areas 1 & 2.

Fig. 7, 8 & 9 reveals that the comparison of frequency fluctuations in control areas 1&2, tie line power deviations with artificial intelligent (Fuzzy, Anfis, AnfisPD, Adaptive Fuzzy Gain Tuner) controllers. The control areas 1 & 2 loaded 20%, 30% respectively.Adaptive fuzzy online gain tuner controller having better performance than all prescribed controllers. AFGT controller provides lesser settling time for frequency's in control area 1 & 2 and tie line power.

3.1. Performance evaluation

Table 1
Time Domain Specifications of ΔF1 at 20% and 30% loadings in control areas 1 & 2.

Controller	T_r *(Sec)*	T_p *(Sec)*	T_s*(Sec)*
FUZZY	0.0063	0.2555	15.997
ANFIS	0.0025	0.2579	11.3699
ANFIS-PD	0.0090	0.2627	6.5753
Adaptive Fuzzy Gain Tuner	$2.86e^{-06}$	0.2587	1.8331

Table 2
Time Domain Specifications of ΔF2at20% and 30% loadings in control areas 1 & 2.

Controller	T_r *(Sec)*	T_p *(Sec)*	T_s *(Sec)*
FUZZY	0.0064	0.3509	16.1381
ANFIS	0.0025	0.3619	10.5533
ANFIS-PD	0.0090	0.3643	6.6303
Adaptive Fuzzy Gain Tuner	$2.73e^{-06}$	0.3590	1.9583

Table 3
Time Domain Specifications for Tie Line Power at 20% and 30% loadings in control areas 1 & 2.

Controller	T_r *(Sec)*	T_p *(Sec)*	T_s *(Sec)*
FUZZY	$2.23e^{-04}$	0.3125	13.524
ANFIS	$2.25e^{-04}$	0.3099	6.7179
ANFIS-PD	0.2903	5.2392	8.2393
Adaptive Fuzzy Gain Tuner	$2.865e^{-06}$	0.2587	1.833

Table 4
Error Performance for ΔF1

Controller	*ITSE*	*ITAE*	*IAE*	*ISE*
FUZZY	$7.89e^{-03}$	$1.118e^{0}$	$1.76e^{-01}$	$5.97e^{-03}$
ANFIS	$7.59e^{-03}$	$8.48e^{-01}$	$1.66e^{-01}$	$5.51e^{-03}$
ANFIS-PD	$1.22e^{-02}$	$7.62e^{-01}$	$1.96e^{-01}$	$1.08e^{-02}$
Adaptive Fuzzy Gain Tuner	$1.36e^{-03}$	$5.53e^{-02}$	$4.97e^{-02}$	$3.33e^{-03}$

Table 5
Error Performance for ΔF2

Controller	*ITSE*	*ITAE*	*IAE*	*ISE*
FUZZY	$8.67e^{-03}$	$1.142e^{0}$	$1.80e^{-01}$	$6.10e^{-03}$
ANFIS	$8.66e^{-03}$	$8.60e^{-01}$	$1.71e^{-01}$	$6.73e^{-03}$
ANFIS-PD	$9.04e^{-02}$	$6.73e^{-01}$	$1.63e^{-01}$	$7.76e^{-02}$
Adaptive Fuzzy Gain Tuner	$1.69e^{-03}$	$5.90e^{-02}$	$4.95e^{-02}$	$3.42e^{-03}$

4. CONCLUSION

This paper reveals multi source load frequency with artificial intelligent controllers. The dynamic performance of multi-source generation load frequency achieved by Fuzzy, ANFIS, ANFIS-PD and Adaptive Fuzzy Gain Tuner. Performance evaluation shows that the AFGT improve the dynamic performance of the two area interconnected power with change in the load in Area1 and Area2 . Error evaluation reveals AFGT offers great reduction of errors and frequency, tie line power fluctuations.

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