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ANALOGY BETWEEN SELF TUNING FUZZY AND ANN BASED PI–CONTROLLERS FOR AGC AND LOAD FREQUENCY CONTROL IN DEREGULATED MULTI-AREA POWER SYSTEM

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ABSTRACT

This paper work presents, design and comparative analysis of Automatic load frequency control of two area power system using self tuned Fuzzy based PI Control and Artificial Neural Network (ANN) base PI Control. Generation control is becoming more important in analysis of better load demand & reducing generating resources. Whenever demand of load increases, will cause serious threats to reliable operation of power systems. As we all that maintaining power system frequency at steady value is very essential for the quality of the power generating equipment and the utilization equipment at the customer end. In this paper area-1 and area-2 consists of different GENC0'S and DISCOM'S under deregulated market. In this anticipated proposal, the combination of most complicated system are interconnected which increases the nonlinearity of the system. The main objective of automatic generation control is to maintain the balance between the generation and demand of a particular power system. The performances of the controllers are simulated using MATLAB/SIMULINK package. A comparison of self-tuned PI controller, Fuzzy controller and ANN based controller methods for LFC shows the superiority of proposed ANN based approach over self tuned Fuzzy based PI-controller and conventional PI controller for similar conditions. To improve the performance of PI, Fuzzy and neural controller in deregulated scenario sliding surface is included. The simulation results also tabulated as a comparative dynamic performance of two area deregulated power system in the view of settling time, area control error (ACE) and peak over shoot and also values are tabulated.

Keywords: Automatic generation control (AGC), Load frequency control (LFC), Area control error (ACE), Contract Participation Factor (CPF), DISCO Participation Matrix (DPM)

1. INTRODUCTION

Automatic Generation Control (AGC) or Load Frequency Control is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. AGC is a feedback control system adjusting a generator output power to remain defined frequency. The interconnected power system is divided into two control areas; all generators are assumed to form a coherent group (Grass G et al, 2001). Load Frequency Control (LFC) is being used for several years as part of the Automatic Generation Control (AGC) scheme in electric power systems. One of the objectives of AGC is to maintain the system frequency at nominal value (50 hz). In the steady state operation of power system, the load demand is increased or decreased in the form of Kinetic Energy stored in generator prime mover set, which results the variation of speed and frequency accordingly. Therefore, the control of load frequency is essential to have safe operation of the power system

A control strategy is needed that not only maintains constancy of frequency and desired tie-power flow but also achieves zero steady state error and inadvertent interchange. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller. The PI controller is very simple for implementation and gives better dynamic response, but their performances deteriorate when the complexity in the system increases due to disturbances like load variation boiler dynamics (Talaq J et al, 1999) ,(Arvindan P et al, 2009). Therefore, there is need of a controller which can overcome this problem. The controllers like Fuzzy and Neural control approaches are more suitable in this respect. Fuzzy system has been applied to the load frequency control problems with rather promising results (Nanda J et al, 2003). The salient feature of these techniques is that they provide a model- free description of control systems and do not require model identification.

The fuzzy controller offers better performance over the conventional controllers, especially, in complex and nonlinearities associated with the system. Self tuned Fuzzy Controller to the two area interconnected deregulated power system is demonstrated good dynamics only when selecting the specific number of membership function, so that the method had limitation. To overcome this self tuned Artificial Neural Network (ANN) controller, which is an advance sliding mode control configuration, is used because the controller provides faster control than the others. In SMC, the task of the control system is firstly to drive (reaching phase), and then to keep the system state on the desired sliding surface (sliding phase). The first step in applying SMC algorithm is choosing an appropriate sliding surface. The sliding surface is a sub-manifold in the state space and it specifies the desired system behavior.

The second step is choosing an appropriate control law. The chosen control law makes the system state to the sliding surface and then keeps it on the sliding surface. There are two main advantages of this approach.

Firstly, the dynamics of the system in sliding mode are determined only with parameters of the chosen sliding surface. Secondly, the system's dynamics in sliding mode are insensitive to particular class of uncertainties.

2. ANALYSIS OF DEREGULATED POWER SYSTEM:

In most of the studies earlier the researchers have used the dynamic model of the power system A dynamic model with state variables is derived. DISCOM1, DISCOM2, DISCOM3 and DISCOM4 are the four distribution companies and GENCO1, GENCO2, GENCO3 and GENCO4 are the four Generating companies used in the two deregulated system represented below. Here the load distribution is based on the contracted participation factors represented in Disco Participation Matrix (DPM). Here in this case it of two area we need area participation matrix also that is also mentioned and care should be taken the total sum must be equal to one.

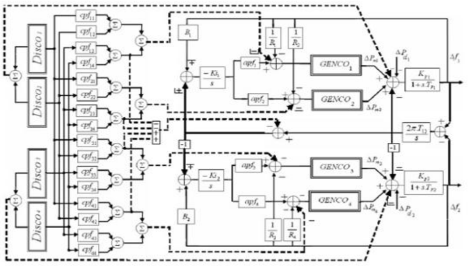


Fig 1 : Two area Deregulated system

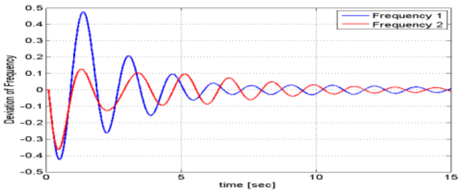


Fig 2: Response Of The Two Area Deregulated System Without Controller

3. CONTROL METHODOLOGY FOR LFC PROBLEM :

3.1 PI Controller

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically.

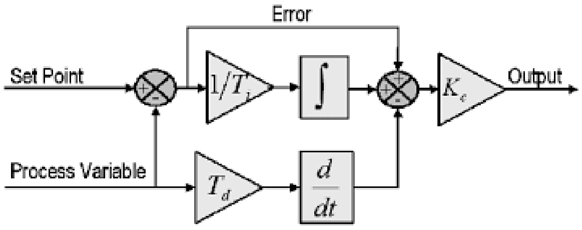


Fig 3.1: Designing model of PI controller

As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt \ + \ A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_i \int_0^t e(t)dt \ + \ K_p e(t)$$

Where K_i and k_p proportional constant and integral constant respectively.

For a step change of load demand, small values of *K*p give rise to stable responses but gives higher steady-state errors. Larger values of *K*p we obtained superior steady-state performance, but poor transient response. A common way of reducing the steady state error is by incorporating integral action into the controller.

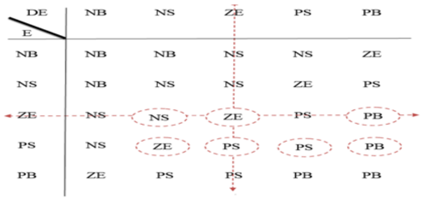
3.2. FUZZY BASED PI-CONTROLLER

The concepts of fuzzy-set theory and fuzzy logic can be employed in the modeling of systems in a number of ways. Example of fuzzy systems are rule-based fuzzy systems, fuzzy models using cell structures. Systems where the relationships between variables are represented by a means of fuzzy if-then rules of the form:

"If antecedent proposition ***then*** consequent proposition".

There are two principal approaches to the derivation of fuzzy control rules. The first is a heuristic method in which a collection of fuzzy control rules is formed by analyzing the behavior of a controlled process. The control rules are derived in such a way that the deviation from a desired state can be corrected and the control objective can be achieved. The derivation is purely heuristic in nature and relies on the qualitative knowledge of process behavior.

The second approach is basically a deterministic method which can systematically determine the linguistic structure and/or parameters of the fuzzy control rules that satisfy the control objectives and constraints. Fuzzy control methods are critical for meeting the demands of complex nonlinear systems. They bestow robust, adaptive, and self-correcting character to complex systems that demand high stability and functionality beyond the capabilities of traditional methods. A thorough treatise on the theory of fuzzy logic control is out of place on the design bench. That is why Fuzzy Controller Design: Theory and Applications offers laboratory- and industry-tested algorithms, techniques, and formulations of real-world problems for immediate implementation.



DE / E	NB	NS	ZE	PS	PB
NB	NB	NB	NS	NS	ZE
NS	NB	NS	NS	ZE	PS
ZE	NS	NS	ZE	PS	PB
PS	NS	ZE	PS	PS	PB
PB	ZE	PS	PS	PB	PB

Fig3.2: Rule Justification using a Linguistic phase plane

Table 1: Prototype of Fuzzy Control Rules with Term Sets (NB, N, ZE, P, PB)

Rule No.	E	DE	CI	Reference Point
1	PB	ZE	PB	A
2	P	ZE	P	e, i
3	ZE	NB	NB	B
4	ZE	N	N	f, j
5	NB	ZE	NB	C
6	N	ZE	N	g, k
7	ZE	PB	PB	D
8	ZE	P	P	h, l
9	ZE	ZE	ZE	set point

The structure of the Fuzzy PI controller with membership function is presented in Fig3.3. The controller is working after the error **e** between the input variable reference and the feedback variable Control Error (CE).After rule fuzzification simulink model fuzzy based pi controller is shown in fig 3.2

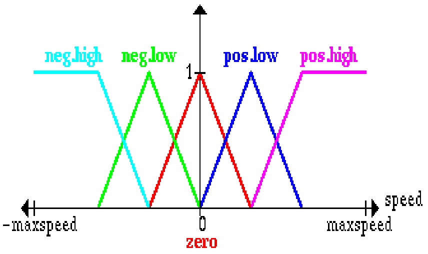


Fig 3.3: Membership function of fuzzy control

Finally, by using rule base resultant combined fuzzy subsets instead of the controller output are converted to the crisp values using the central of area (COA) defuzzified scheme.

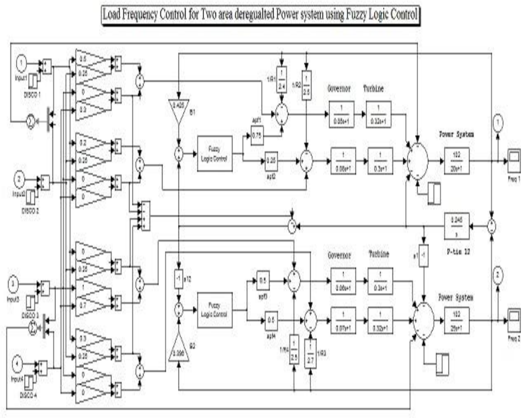


Fig3.4: Fuzzy control of two area system for FLC.

3.3. ANN BASED PI-CONTROLLER

An artificial neural network as defined by Hect-Nielsen is a parallel, distributed information processing structure consisting of processing elements interconnected via unidirectional signal channels called connections or ***weights.*** Each processing element or ***neuron*** has a single output connection that branches (fans out) into as many collateral connections as desired; each carries the same signal -the processing output signal. The processing element output signal can be of any mathematical type desired.

The information processing that goes on within each processing element can be defined arbitrarily with the restriction that it must be completely local; that is, it must depend only on the current values of the input signals arriving at the processing element via impinging connections and on values stored in the processing element's local memory. Neural systems encode sampled information in a parallel-distributed framework. The ANN based controllers can be divided in two categories. The proposed network has been trained by using the learning performance. Learning algorithms causes the adjustment of the weights so that the controlled system gives the desired response.

The first category is the controllers with off-line learning. first the learning is performed, and then the trained ANN is implemented to the process which is under control. Generally, the off-line method is applicable to a process with explicit mathematical formulation. The second category includes the controllers that use online learning. Chen has investigated on-line learning for adaptive control, although his method is only applicable to single input, single output linearized systems. It is shown that the learning process makes this controller an adaptive one. On-line learning has been successfully used for underwater vehicle control as reported.

The proposed learning algorithm and the network architecture provide stable and accurate tracking performance. For the on-line learning method, the mathematical formulation of the process under the control is needed. Schiffmann have reported a comparative study for an ANN on-line controller and a P-I controller.

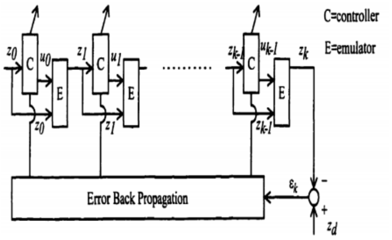


Fig 4.1: Online training of ANN controller

The results show that the ANN controller is very effective. This simulation consists of ANN control for load frequency control the control block consist of following subsystem.

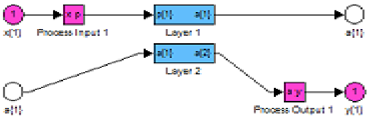


Fig4.2: ANN control scheme

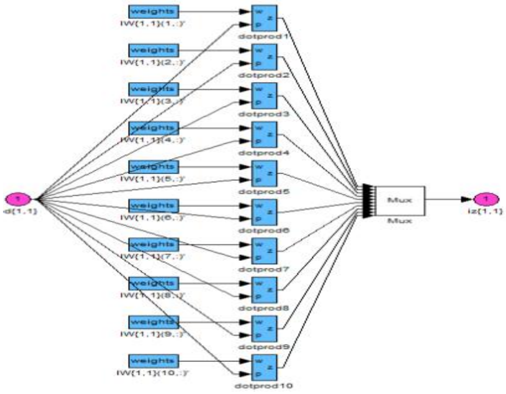


Fig4.3: Hidden layer of self tuned ANN-controller

The output of any hidden or output neuron is calculated from a weighted sum of the inputs to that neuron. In addition to the inputs to each processing neuron, a bias level ***B*** (usually equal to one) may also be applied to each neuron. The bias is connected with an adjustable weight to each hidden and output neuron. The sigmoid function used for this study has an input to output function given by

$$g[h] = \frac{1}{1+\exp(-2\beta h)}$$

Once the plant model is obtained, a candidate ANN controller is now designed to match the desired control characteristic of a conventional controller. After training, the ANN controller will mimic the conventional controller from which the training was derived. However, the performance of the off-line ANN controller can only be as good as that of the conventional one.

MATLAB/SIMULINK model of Artificial Neural Network (ANN) based PI-controller is shown below figure4.3,

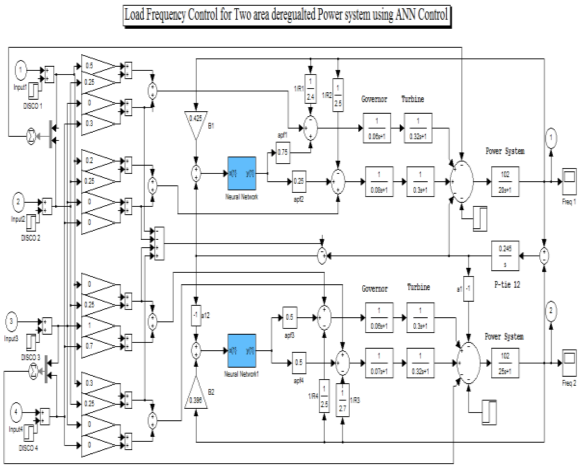


Fig 4.3: Simulink Model of self tuned ANN Controller

4. SIMULATION RESULTS OF TWO AREA DEREGULATED POWESYSTEM WITH DIFFERENT CONTROLLERS:

A two-area system is used to illustrate the behavior of the proposed LFC scheme. Consider a case where all the DISCOs contract with the GENCOs for power as per the following DPM:

In this scenario, DISCOs have the freedom to have a contract with any GENCO in their or other areas. So all the DISCOs contract with the GENCOs for power base on following *DPM*:

$$DPM = \begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix}$$

It is considered that DISCO demands

$$\Delta P_{m1} = 0.105\ pu\ MW,\quad \Delta P_{m2} = 0.045\ pu\ MW,$$
$$\Delta P_{m3} = 0.195\ pu\ MW,\quad \Delta P_{m2} = 0.055\ pu\ MW$$

Here the simulation results of the 13 parameters of the system are drawn by comparing their responses with the proposed controller.

Thy dynamic response of different controllers for two-area deregulated power system is shown below,

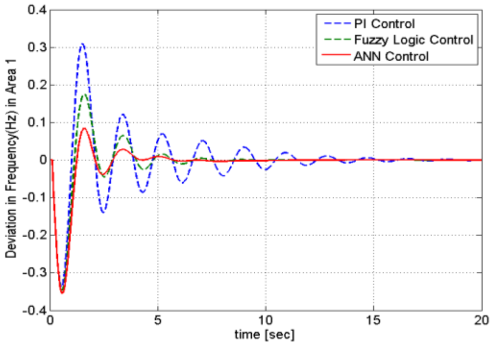


Figure5.1 Deviation of Frequency (Hz) in area1

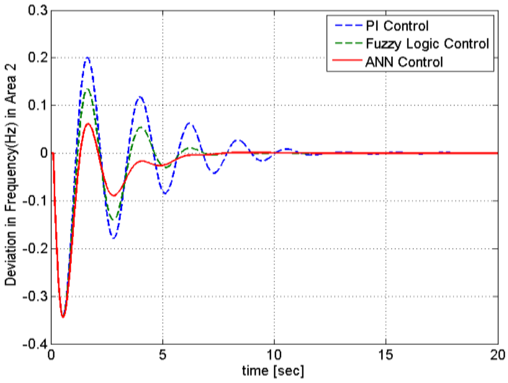


Figure5.2 Deviation of Frequency (Hz) in area2

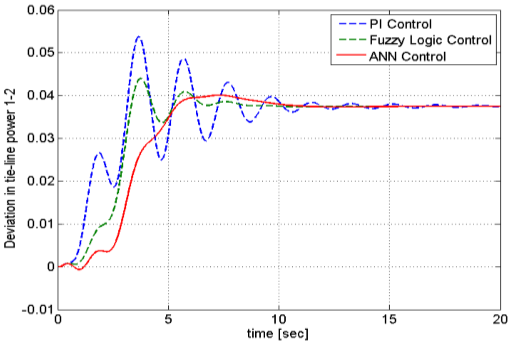


Figure5.3 Deviation of Tie-Line power flow (pu)

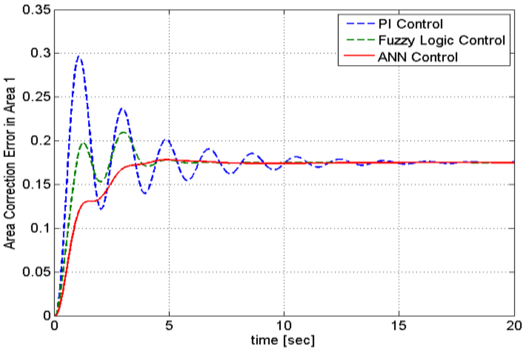


Figure5.4 Deviation of ACE in area 1

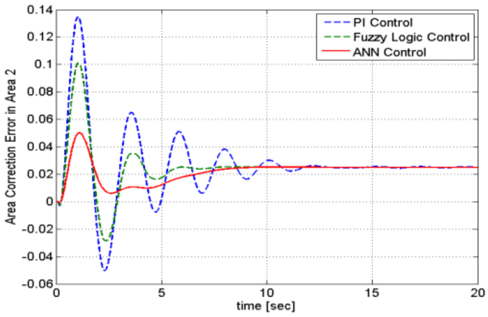


Figure5.5 Deviation of ACE in area 2

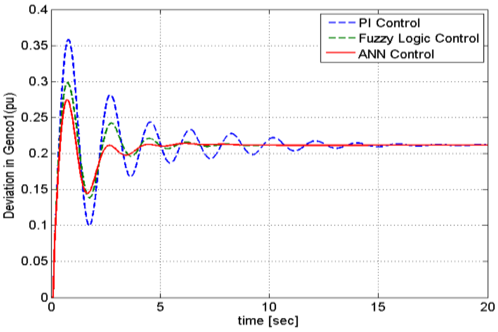


Figure5.6 Deviation of GENCO1 power (pu)

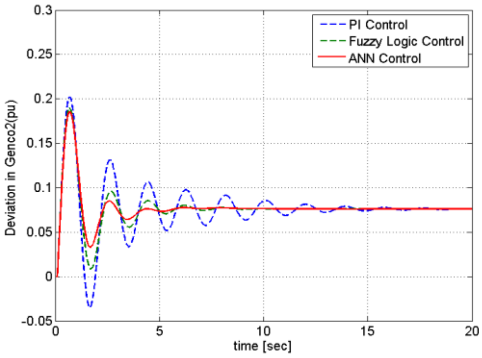


Figure5.7 Deviation of GENCO2 power (pu)

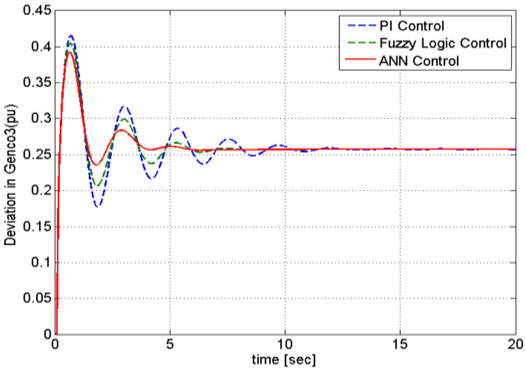


Figure5.8 Deviation of GENCO3 power (pu)

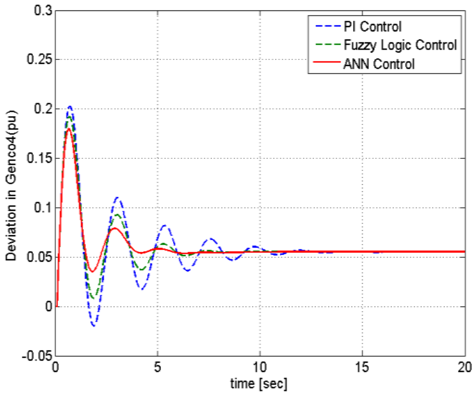


Figure5.9 Deviation of GENCO4 power (pu)

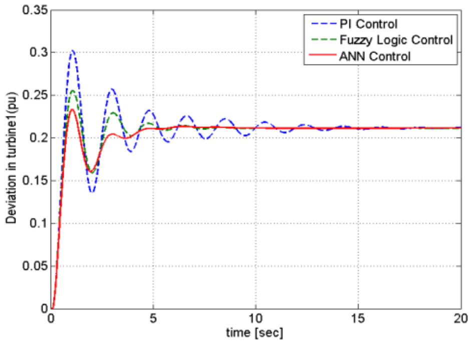


Figure7.10 Deviation of TURBINE1 power (pu)

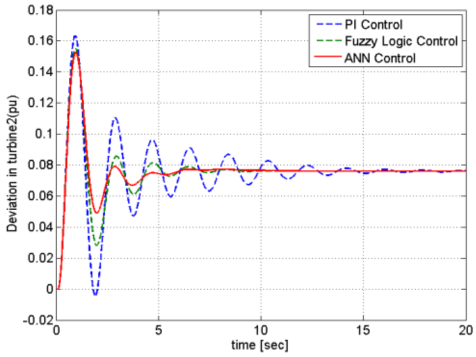


Figure6.11 Deviation of TURBINE2 power (pu)

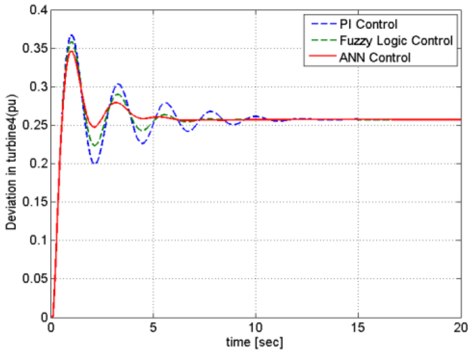


Figure6.12 Deviation of TURBINE3 power (pu)

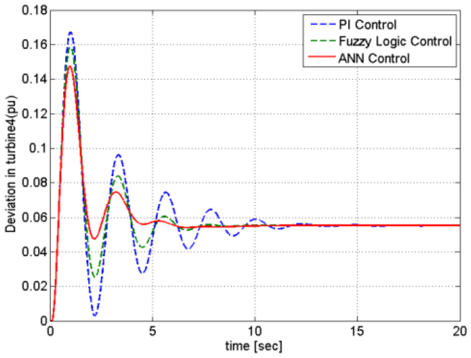


Figure5.13 Deviation of TURBINE4 power (Pu)

5. CONCLUSIONS

The above simulation results shows that performance of integral controller, Fuzzy based PI Controller and Artificial-neural network based PI-Controller for a two area deregulated system has been investigated. It has been observed that for load changes in power system the integral is capable of bringing better dynamic response of the system to some extent. But the conventional design approach requires a deep understanding of the system, exact mathematical models and precise numerical values.

Table-I: Comparative Study of Settling Time

Controllers	ΔF1 Area 1 (sec)	ΔF1 Area 2 (sec)	ΔP tie (sec)	ACE1 (sec)	ACE2 (sec)
PI	17.2	11.5	20	18	17.7
FUZZY	8.55	7.6	14	7	9.4
ANN	6.2	6	11	5.4	9.2

Table-II: Comparative Study of Peak Overshoot

Controllers	ΔF1 Area 1 (pu)	ΔF1 Area-2 (pu)	ΔP tie Line 1-2 (pu)
PI	-0.38	-0.35	0.056
FUZZY	-0.36	-0.34	0.045
ANN	-0.34	-0.33	0.040

Form the above table-I and II. It is clear that comparison of dynamic responses obtained in deregulated system reveals that ANN controller with sliding gain provides better settling performance rather than Fuzzy and PI controllers. Therefore, the sliding control approach of self-tuning ANN based PI-controller concept is more accurate and faster than the fuzzy control and conventional PI control scheme even for complex dynamical system to analyze ALFC.

6. APPENDEX:

Both the areas are having their governor, turbine and power system time constants are as follows. Speed regulation and power system gain values of the system are shown in the given table:

Table IV: Parameters of the GENCOs

GENCO Parameters	Area1		Area2	
	GENCO1	GENCO2	GENCO3	GENCO4
R(Hz/pu)	2.4	2.5	2.5	2.7
Tg(s)	0.6	0.8	0.6	0.7
Tt(s)	0.2	0.3	0.3	0.2

Table V: Parameters of the Control Areas

Control Area Parameters	Area1	Area2
Kp(pu/Hz)	102	102
Tp(s)	20	25
Bi	0.425	0.396
Tij(pu/Hz)	0.245	

REFERENCES:

[1]. Kocaarslan and E. Cam, “Fuzzy logic controller in interconnected electrical power systems for load-frequency control,” Electrical Power and Energy Systems, vol. 27, no. 8, pp. 542-549, 2005.

[2]. V.D.M. Kumar, “Intelligent controllers for automatic generation control,” IEEE Region 10 International Conference on Global Connectivity in Energy, Computer, Communication and Control, TENCON ‘98, vol. 2, pp. 557-574, 1998.

[3]. G. Monsees, “Discrete-time sliding mode control,” Ph.D. dissertation, Delft University of Technology, Netherlands, 2002.

[4]. A.KhakiSedigh, Modern Control Systems, University of Tehran Press, 2003.

[5]. F. Liu, Y.H.Song, J.Ma, S.Mei and Q Lu, “Optimal Load Frequency Control in restructured power Systems,” IEE Proceedings Generation, Transmission and Distribution, vol. 150, no. 1, pp. 87-95, Jan. 2003

[6]. B. Stojkovi´ , “An original approach for load-frequency control – thecwinning solution in the second UCTE synchronous zone,” Electric Power Systems Research, vol. 69, no. 1, pp. 59–68, April 2004.

[7]. System and Control by stanislaw h. zak

[8]. F.L. Lewis and V.L. Syrmos, Optimal control, Prentice Hall, Englewood Cliffs, New Jersey, 1995.

[9]. J.Kumar, Kah-Hoe Ng and G. Sheble, “AGC Simulator for price-based Operation Part 1: A model, “IEEE Trans. On Power Systems, vol. 12, no. 2, May. 1997.

[10]. C. Edwards and S. Spurgeon, Sliding Mode Control: Theory and Applications. Taylor and Francis, 1998.