Load Frequency and Voltage control of Two Area Interconnected power Using PID controller and Fuzzy controller

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Abstract – This paper presents the frequency control and voltage control of two area Interconnected power system using PID controller and fuzzy controller. Effectiveness of Fuzzy controller over pid controller is shown. For this MATLAB offers simulation applications and models in simulink. LFC controls the Frequency and AVR maintains the Voltage and thereby Active and Reactive Power Flows in the system. A Step Disturbance is applied in the area 1 and the response of the system is analyzed by analyzing the frequency, tie line power flow and voltage.

***Key Words*:** Load Frequency Control (LFC), Automatic Voltage Regulator (AVR),PID controller, Fuzzy controller, Tie line control, Interconnected system

1. INTRODUCTION

Now a days Stability of the Power system has been identified as an important problem. It is always Known that power system Demand and Load are not constant. They will Keep on Changing. In Order to get effective operation of the power system, the power generated should change in according to load disturbance. In the Interconnected Power system, every subsystem is required to control the power output of its installed generators in response to changes in system frequency. This is called as Load Frequency Control. It is also essential to maintain Voltage at specified level. This is done by using Automatic Voltage Regulator. [1][2]. The frequency and real power is adjusted by speed governor in the generating stations and it will hold the values at specified limits. Excitation Control will regulate the voltage and reactive power at specified values. This Excitation control is equipped with generator in the Generating station.

There is a negligible cross coupling between LFC and AVR block because of this continuous control of frequency and voltage is possible. The reason of negligible cross coupling between the block is due to the fact that the time constant of the excitation system is much smaller than the time constant of the prime mover and also the transient of excitation system decay much faster and does not affect the LFC dynamic

Interconnected power system were formed in order to meet the needs of energy that are for both suppliers and consumers. Number of adjustments and arrangements are required to the linking up interconnected electrical power systems. All the subsystems that connect the whole system must be stable internally and the overall system frequency and voltage can be controlled should be same with each other [1].

PID controller is tuned by the trial and error method and the results are compared with fuzzy logic controller. The main objective of this paper is to suppress all the functions of the system due to the applied step disturbance and get back the frequency and voltage at nominal values. In this study, Fuzzy logic controller and Proportional Integral Derivative (PID) control perspectives have been applied in two field coupled power system with variable frequency control model and voltage control model to eliminate the frequency and voltage fluctuations experienced in electric energy.

PID is preferred because of its reliability, simplicity and low cost and also it is easy to operate. But the major disadvantage of pid is the proportional and derivative kick which causes sharp spikes and sudden overshoots. To overcome this Fuzzy logic controller is used, as it gives better results and reduce overshoot.

2. LINEARIZED MODEL OF THE SYSTEM

2.1. Load Frequency Control (LFC)

Load frequency control of an interconnected power system means the interconnection of more than one control area through tie lines. Sudden load variation in any control area of an interconnected power system will lead to both frequency change and tie line power deviation..

The LFC loop regulates the real power output and the corresponding frequency of the generator power output. The primary LFC loop senses the turbine speed and controls the operation of the control valves of turbine power input via the speed governor. This loop is relatively faster than the secondary LFC loop which senses the electrical frequency of the generator output and maintains proper power interchange with the interconnections. This loop is slower in response and is insensitive to rapid load and frequency changes.

The main objective of LFC is:

1. To maintain the real frequency and the desired power output (megawatt) in the interconnected power system.

2. To control the change in tie line power between control areas

2.2 Automatic Voltage Regulator (AVR)

The automatic voltage regulator is used to regulate the voltage. It takes the fluctuate voltage and changes them into a constant voltage. The fluctuation in the voltage mainly occurs due to the variation in load on the supply system. The variation in voltage damages the equipment of the power system. The variation in the voltage can be controlled by installing the voltage control equipment at several places likes near the transformers, generator, feeders, etc., The voltage regulator is provided in more than one point in the power system for controlling the voltage variations Magnitude of the terminal voltage of the generator is controlled by the AVR loop.

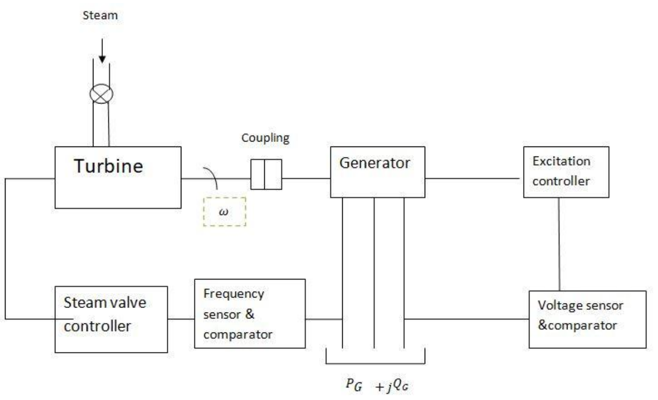

Fig.1. Block diagram of LFC and AVR

3. CONTROLLERS

3.1 PID controller: Pid controller is also known as three term controller. It is a control loop mechanism employing feedback that is widely used in industrial control.

It is one kind of device used to control different process variables like Pressure, flow, temperature and speed in industrial applications. In this controller a control loop feedback device is used to regulate all the process variables.

3.1.2 Mathematical model:

$$u(t) = k_p\, e(t) + k_i \int e(t)\, dt + k_d \frac{de(t)}{dt}$$

where

u(t) =PID control variable
k_p =Proportional gain
k_i = Integral gain
k_d = Derivative gain
e(t) =error value
dt =change in time

3.1.3 Tuning of PID controller

Tuning of PID controller is done by three steps which are as follows:

Step 1: Set K_D and K_I to zero. By trial and error select K_P that results in a stable oscillatory performance. In case of multi input system, select K_P that results near to critical damping.

Step 2: Vary K_D with K_P fixed so as to reduce the oscillations and result in reasonable overshoot and settling time.

Step 3: Till here the transients are taken care of. For the steady state performance vary K_I with K_P and K_D fixed such that there is zero steady state error in minimum time.

This completes the tuning of the PID controller

4. FUZZY LOGIC CONTROLLER

Fuzzy logic controller has lot of applications in power system. FLC works on the basis of knowledge acquisition process. A fuzzy system has a membership function associated with each fuzzy set and here fuzzy IF-THEN rule is used for controlling the process. The horizontal range of membership function is obtained by optimization of error generated by PID controller. In this given system the LFC comprises of sudden load variations in the power system which results in frequency and voltage change and this should be in permissible limits

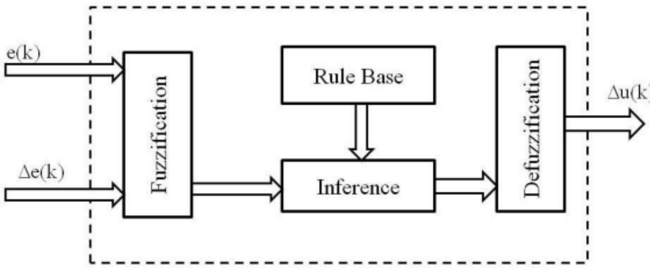

Fig.2. Block Diagram of Fuzzy logic controller

Fuzzification:

- It is the way of converting real-valued variable into fuzzy variable.

Rule Base :

- The rule-base used is IF-THEN rule it consists of a set of rules. The rule base is a combination of a set of fuzzy rules. The information is carried out by the membership functions.

Defuzzification

- It is the way of converting the fuzzy variable into the real value which is known as crisp-value due to this it is used in the controlling process. The block diagram rep-representation of de-fuzzification is given below. The controlling action of FLC is decided by the fuzzy rule base.

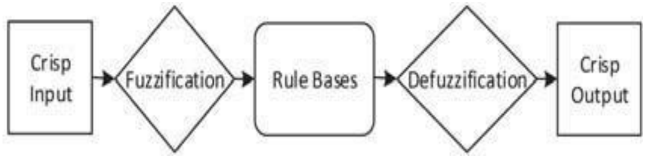

Fig.3. Main steps of Fuzzy control

Table -1: Fuzzy Rule Base

ACE ΔACE	HN	MN	LN	Z	LP	MP	HP
HN	HP	HP	HP	MP	MP	LP	Z
MN	HP	MP	MP	MP	LP	Z	LN
LN	HP	MP	LP	LP	Z	LN	MN
Z	MP	MP	LP	Z	LN	MN	MN
LP	HP	LP	Z	LN	LN	MN	HN
MP	LP	Z	LN	MN	MN	MN	HN
HP	Z	LN	MN	MN	HN	HN	HN

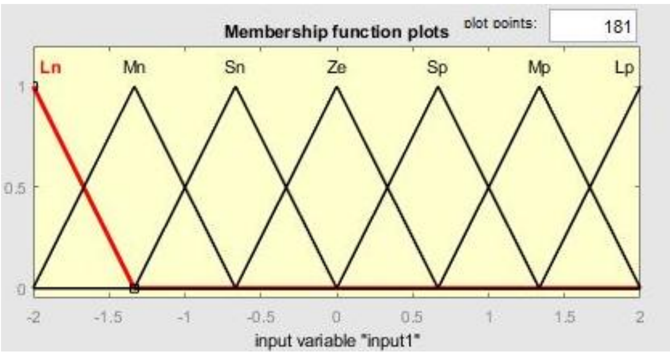

Fig.5. Input 1

- Two inputs will be given i.e., INPUT 1(ERROR) INPUT 2 (CHANGE IN ERROR)

- Here Triangular Membership Functions is taken

- The input variables are determined by assigning a single fuzzy set, a set with membership function (A),and a zero at another location.

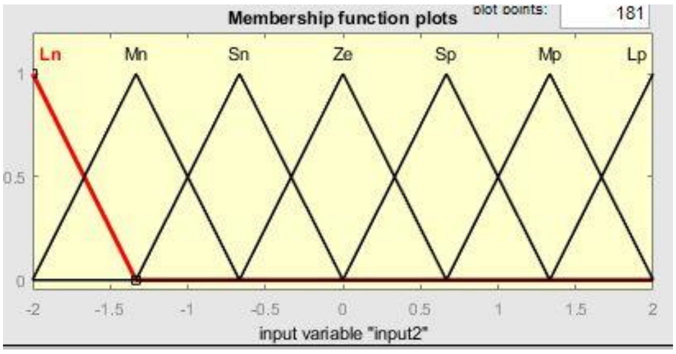

Fig.6. Input 2

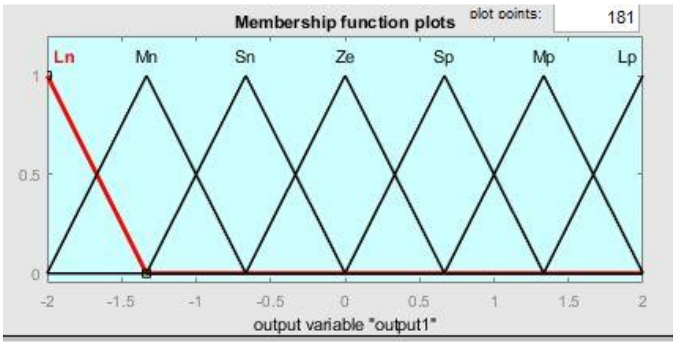

Fig -7: Output

If the output variable is a fuzzy set, the maximum min and fuzzy relation with the composition expresses the desired control action. The fuzzy set of the output variable is solved by blurring to obtain a clear numerical value by the centroid method. The fuzzy rule base, as shown in Table -1, consists of a collection of form based on the fuzzy base rule IF-THEN principle.

4. Simulation Results

In this paper, basically a comparison between PID and fuzzy controllers is presented in four different scenarios. The comparison of PID and fuzzy will be in the most important factors from which we can determine the best controller such as settling time (ts), maximum over shoot (O.S%) oscillation and steady state error (SSE) as will be confirmed in different simulated scenarios

The dynamic performance of the system was measured interms of the following system parameters:

Δf_1 : Frequency deviation in Area 1

Δf_2 : Frequency deviation in Area 2

ΔACE_1 : Area control error in Area 1

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ΔACE_2 : Area control error in Area 2

ΔP_{TIE} : Change in tie line power flow

ΔV_1 : Voltage deviation in Area 1

ΔV_2 : Voltage deviation in Area

TABLE 2.

SIMULATON PARAMETERS FOR LFC SYSTEM

Quantity	Area 1	Area 2
Load Change	ΔP_{L1}=0.1875 p.u.	-
Load change in MW	ΔP_{L1} = 187.5 MW	-
Base Power	1000MW	1000MW
Governor time constant	tg1 = 0.2 sec	tg2 = 0.2 sec
Turbine time constant	t1 = 0.5 sec	t2 = 0.5 sec
Load damping constant	D_1 = 0.8	D_2 = 0.8

Quantity	Area 1	Area 2
Load Change	ΔP_{L1} = 0.1875 p.u.	-
Generator inertia constant	H_1 = 5 MW/MVA	H_2 = 5 MW/MVA
Governor speed regulation	R_1 = 0.05 Hz/p.u.	R_2 = 0.05 Hz/p.u.
Frequency bias factor	B_1 = 20.8 p.u. MW/Hz	B_2 = 20.8 p.u. MW/Hz
Tie line constant	a12 = 1	-
Tie line synchronizing coefficient	T_{12} = 0.0867 p.u	-

TABLE 3.

SIMULATON PARAMETERS FOR AVR SYSTEM

Quantity	Area - 1	Area - 2
Amplifier gain	K_{A1} = 10	K_{A2} = 10
Amplifier time constant	τ_{A1} = 0.1 sec	τ_{A2} = 0.1 sec
Exciter gain	K_{E1} = 1	K_{E2} = 1
Exciter time constant	τ_{E1} = 0.4 sec	τ_{E2} = 0.4 sec
Generator gain	K_{G1} = 0.8	K_{G2} = 0.8
Generator time constant	τ_{G1} = 1.4 sec	τ_{G2} = 1.4 sec
Sensor gain	K_{R1} = 1	K_{R2} = 1
Sensor time constant	τ_{R1} = 0.05 sec	τ_{R2} = 0.05 sec

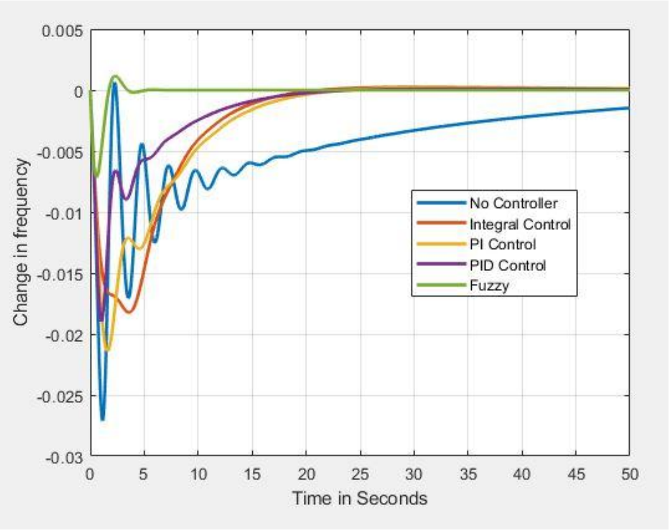

Fig.8. Frequency Deviation response of Area 1

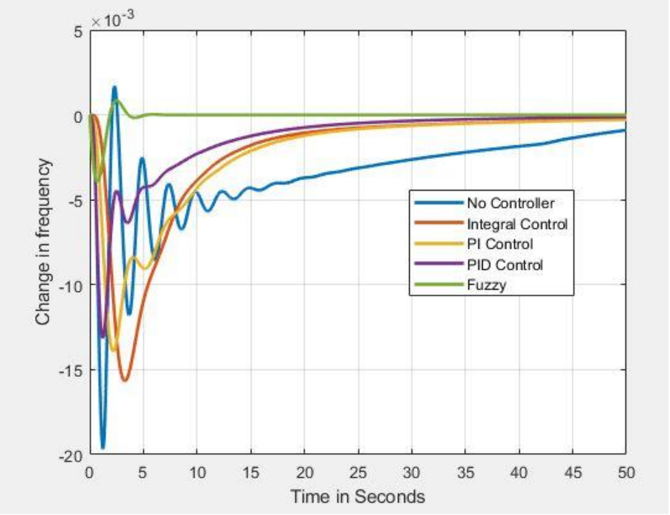

Fig.9. Frequency deviation response of Area 2

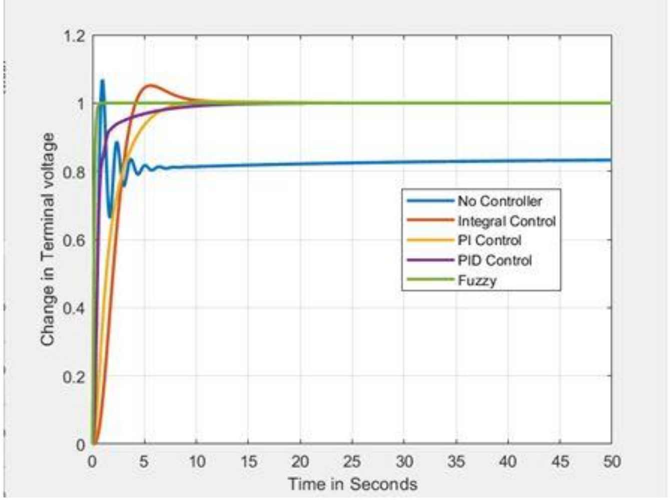

Fig.10. Terminal Voltage response of Area1

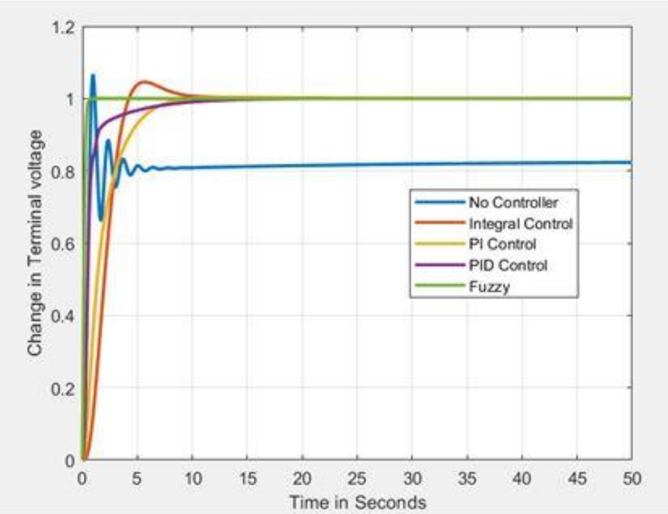

Fig.10. Terminal Voltage response of Area 2

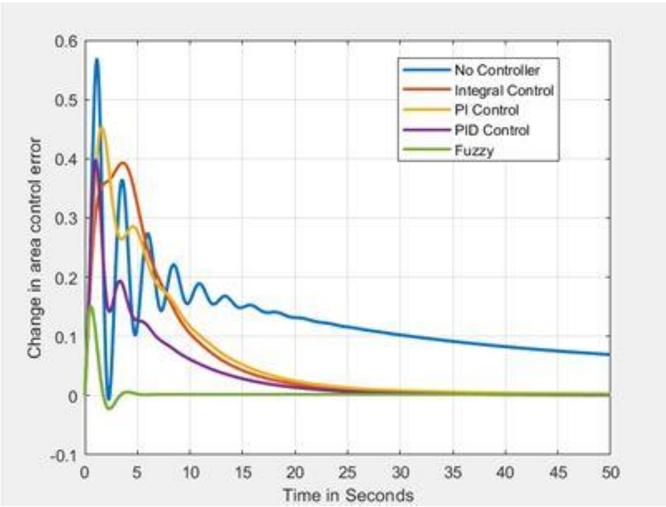

Fig.11. Change in Area Control error for Area 1

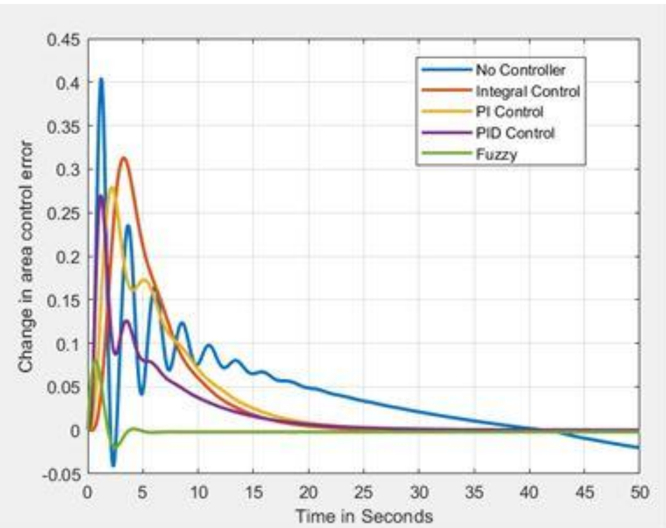

Fig.12. Change in Area Control error for Area 2

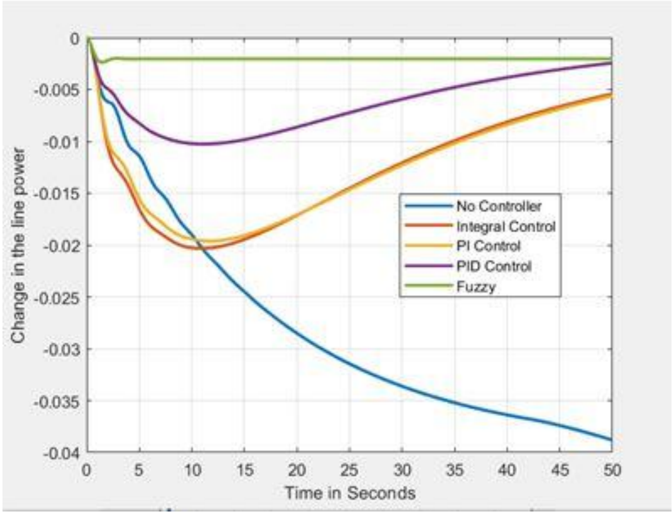

Fig.13. Tie line power deviation response

The terminal voltage response for Area 1 and Area 2 is shown in Fig. 9 and Fig. 10 respectively. The change in Area control error for Area 1 and Area 2 is shown in Fig. 11 and Fig. 12 respectively. The change in frequency for Area 1 and Area 2 is shown in Fig. 8 and Fig. 9 respectively. The change in Tie line power flow is shown in Fig. 13. Further comparison of use FUZZY controller, Integral Controller, PI controller, PID controller and system operation without any controller is shown in the respective figures.

5. CONCLUSION

Response of the system is observed for a 0.18 p.u. Step load change. The use of Fuzzy controller results in smaller peak, overshoot and lesser settling time with zero steady state error as compared to PID controller, PI controller and integral control and when the system has no control.

6. References:

[1] A.J. Wood and B.F. Wollenberg, "Power Generation, Operation and Control", pp. 363-365, John Wiley and Sons, New York, 1984.

[2] Kothari D.P.,andNagrath I.J., 2011. "Power System Engineering" 2nd Edition, Tenth reprint, Tata McGraw-Hill publication, pp. 409-430.

[3] Saadat, H., 2002. "Power System Analysis", Fifteenth reprint edition, Tata McGraw-Hill publication, pp. 527-569.

[4] Apostolopoulou, D., Sauer, P.W., Dominguez-Garcia, A.D., 2014. "Automatic Generation Control and its Implementationin Real Time", IEEE, pp. 2444-2453, 2014.

[5] Dabur, P., Yadav, N.K., and Tayal, V.K., April 2011. "Matlab Design and Simulation of AGC and AVR for Multi Area Power System and Demand Side Management," International Journal of Computer and Electrical Engineering, Vol. 3, No. 2, 1793-8163.

[6] Gaing, Z.L., June 2004. "A Particle Swarm Optimization Approach for Optimum Design of PID Controller in AVR System," IEEE transactions on energy conversion, Vol. 19, No. 2, June 2004.

[7] Kouba, N. EL Y., Meena, M., Hasni, M., Boudour, M., 2015. "Optimal Control of Frequency and Voltage Variations Using PID Controller based on Particle Swarm Optimization," IEEE, pp. 424-429, April 2015.

[8] Parmar, K.P., Majhi, S. and Kothari, D.P., January 2011. "Optimal Load Frequency Control of An Interconnected Power System," MIT International Journal of Electrical and Instrumentation Engineering Vol. 1, No. 1, pp. 1-5. ISSN No.2230-7656.

[9] A. Demiroren and E. Yeşil, "Automatic Generation Control withFuzzy Logic Controllers in the Power System Including SMES Units", Electrical Power and Energy Systems, vol.26, pp.291-305, 2004. DOI: 10.1016/j.ijepes.2003.10.016.

[10] O. A. Mousavı, On Voltage and Frequency Control in Multi-Area Power Systems Security Thèse No 6053 (2014) École Polytechnıque Fédérale De Lausanne Présentée Le 21 Mars 2014 À La Faculté Des Scıences Et Technıques De L'ıngénıeur Groupe De Scıentıfıques Stı Programme Doctoral En Génıe Électrıque Suisse.

[11] A.Anilkumar, N.V.Srikanth, "TeachingTeaching - Learning Optimization Based Adaptive Learning Optimization Based Adaptive Learning Optimization Based Adaptive Learning Optimization Based

[12] Adaptive Fuzzy Logic Controller for Frequency Control in an Fuzzy Logic Controller for Frequency Control in an Autonomous Microgrid

[13] Soundarrajan, A., Sumathi, S. and Sundar, C., 2010. "Particle Swarm Optimization Based LFC and AVR of Autonomous Power Generating System", International Journal of Computer Science, Feb 2010.

[14] Jeevithavenkatachalam and Rajalaxmi, S., 2013."Automatic generation control of two area interconnected power system using particle swarm optimization", IOSR Journal of Electrical and Electronics Engineering, ISSN: 2278-1676, Vol. 6, No. 1, pp. 28-36, May 2013.

[15] Chakrabarti, A. and Halder, S., 2010. "'Power system Analysis-Operation & Control", PHI New Delhi, 3rd Edition,pp. 469-506, 2010.

[16] Ang, K. H., Chong, G. and Li, Y., *Jully 2005*. "PID Control System Analysis, Design, and Technology" *IEEE transactions on Control Systems Technology, Vol. 13, No. 4*.

[17] Nagendra, M. and Krishnarayalu, M.S., 2012. "PID Controller Tuning using Simulink for Multi Area Power Systems," International Journal of Engineering Research andTechnology, Vol. 1, Issue 7, ISSN: 2278-0181, September 2012.

[18] H.Bevrani and T.Hiyama, Intelligent Automatic Generation Control(CRC Press,2011).

[19] D.P.Kothari and I.J.Nagrath, Modern Power System Analysis, 4th ed.(McGraw Hill, New Delhi,2011)