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Design of FGSPI Controller Based Combined LFC and AVR of Two Area Interconnected Power Generating System

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Abstract - This work presents the Fuzzy Gain Scheduled proportional-integral controller (FGSPIC) parameters of Load Frequency Control (LFC) and Automatic Voltage Regulator (AVR) for two area interconnected power system. The proposed controller is used to tune the LFC and AVR .The LFC loop controls real power &frequency and AVR loop controls reactive power & voltage. To maintain the system parameters of the given system at nominal value, FGSPIC is proposed. This paper is proposed to show the interaction between the LFC and the AVR loops. The system with its control method is going to implement in MATLAB software. Also, a conventional proportional and integral (PI) controller was used to control the same for the performance comparison. Two performance criteria were utilized for the comparison. The proposed method had superior features like, stable convergence characteristics, easy implementation and good computational efficiency.

Key Words – Automatic Voltage Regulator (AVR), Load Frequency Control (LFC), Fuzzy Gain Scheduled Proportional-Integral Controller (FGSPIC).

I. INTRODUCTION

In recent years electricity has been used to power more sophisticated and technically complex manufacturing processes, and a variety of high-technology consumer goods. These products and process are sensitive not only to the continuity of power supply but also on the quality of power supply such as voltage and frequency. In power system, both active and reactive power demands are never steady they continuously change with the rising or falling trend. The changes in real power affect the system frequency, while reactive power is less sensitive to changes in frequency and is mainly dependent on Changes in voltage magnitude [1]. The main purpose of system generation control is to balance the system generation against the load and losses so that the desired frequency and power interchanges between neighboring systems are maintained. The two main control loops of a generation are Load Frequency Controller (LFC) and Automatic Voltage Regulator (AVR).The turbine fed by controllable rate of steam and the Automatic Generation Control method deals with frequency through the LFC loop and with voltage through the AVR loop, where the main purposes of these controllers are to maintain levels of voltage and frequency at the acceptable values [2]. The main goal of LFC and AVR in the power systems is to protect the balance between production and consumption and to maintain zero steady state errors in an interconnected power system [3].

Many investigations in the area of LFC and AVR of an isolated power system have been reported and a number of control schemes like integral (I), Proportional and Integral (PI), Proportional, Integral and Derivative (PID) control have been proposed to achieve improved performance [4-6]. The conventional method exhibits relatively poor dynamic performance as evidenced by large overshoot and transient frequency oscillations [7].These conventional fixed gain controllers based on classical control theories in literature are insufficient because of change in operating points during a daily cycle[8,9].

Fuzzy controllers are increasingly being accepted by engineers and scientists alike as a viable alternative for classic controllers. Fuzzy controllers closely imitate human control process. Human responses to stimuli are not governed by transfer function and neither are those from fuzzy controllers [10]. Due to rising and falling power demand, the real and reactive power balance is harmful effects and hence frequency and voltage deviated from its rated value. In order to maintain the system parameters of the given system at nominal value, FGSPIC is proposed [3]. The FGSPIC was developed to regulate and improve the frequency and also control the voltage and reactive power flow, thereby enhancement of system stability.

Fuzzy gain scheduling of PI controllers have been proposed to solve power system problems, and developed different fuzzy rules for the proportional and integral gains separately. Two performance criteria were utilized for the comparison of the proposed FGSPI controller with the conventional PI controller. First, settling times and overshoots. Later, the study state error was calculated to compare. The comparison results suggest that the overshoots and settling time with the proposed FGSPI controller was better than the rest.

II. MODELING OF THE PLANT

A. Basic Generation Control Loops

In an interconnected power system, LFC and AVR Equipment is installed for each generator. The schematic diagram of the voltage and frequency control loop is represented in Fig.1.

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The controllers are set for a particular operating condition and take care of small changes in load demand to maintain the frequency and voltage magnitude within the specified limits.

Small changes in real power are mainly dependent on changes in rotor angle δ and, thus, the frequency f. The reactive power is mainly dependent on the voltage magnitude (i.e. on the generator excitation). Change in angle δ is caused by momentary change in generator speed. Therefore, load frequency and excitation voltage controls are non-interactive for small changes and can be modeled and analyzed independently. Furthermore, excitation control is fast acting while the power frequency control is slow acting since, the major time constant contributed by the turbine and generator moment of inertia-time constant is much larger than that of the generator field. Thus, the cross-coupling between the LFC loop and the AVR is negligible, and the load frequency and excitation voltage control are analyzed independently [1]. But in the practical systems, during dynamic perturbations, exists some interaction between these two control channels [11].

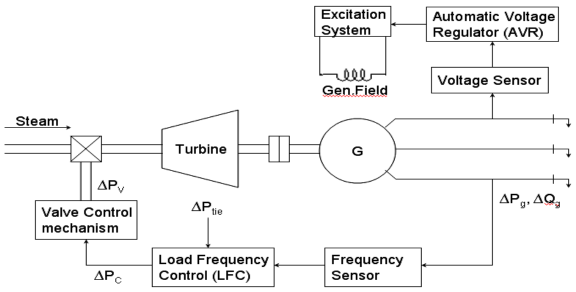


Fig (1): Schematic Diagram of LFC and AVR of A Synchronous Generator

B. Load Frequency Control (LFC)

The aim of LFC is to maintain real power balance in the system through control of system frequency. Whenever the real power demand changes, a frequency change occurs. The change in frequency and tie – line power are sensed, which is a measure of the change in rotor angle δ , i.e., the error $\Delta\delta$ to be corrected. The error signal, i.e. ΔF and ΔP_{tie} are amplified, mixed, and transformed into a real power command signal ΔP_V , which is sent to turbine governor. The governor operates to restore the balance between the input and output by changing the turbine output, which will change the values of ΔF and ΔP_{tie} within the specified tolerance .This method is also referred as Megawatt frequency or Power-frequency (P-F) control [12].

C. Automatic Voltage Regulator (AVR)

The aim of this control is to maintain the system voltage between limits by adjusting the excitation of the machines. The input signals for voltage control are error of terminal voltage and its derivative. Whenever the reactive power load changes a drop in the terminal voltage magnitude resulted. The voltage magnitude is sensed through a potential transformer in one phase. This voltage is rectified and compared to a dc set point signal. The amplified error signal controls the exciter field and increases the exciter terminal voltage .Thus, the generator field current is increased, which results in an increase in the generated emf.The reactive power generation is increased in a new equilibrium, raising the terminal voltage to the desired value. The change of excitation maintains the VAR balance in the network. This method is also referred as Megawatt Volt Amp Reactive (MVAR) control or Reactive-Voltage (QV) control [12].The models of LFC and AVR in single area with PI controller are shown in Fig.2 and Fig.3 respectively.

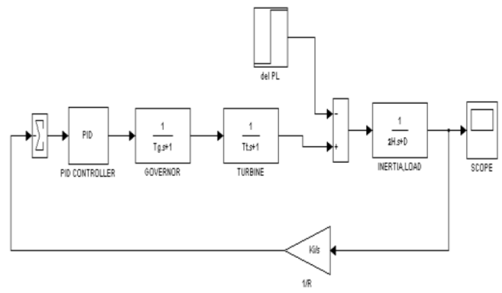


Fig (2): Simulink Model of LFC with PI Controller

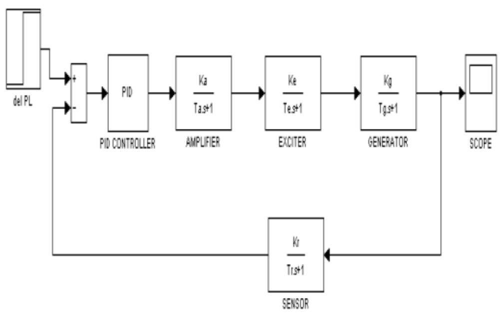


Fig (3): Simulink Model of AVR with PI Controller

III. CONVENTIONAL PI CONTROLLER

The proportional plus integral controller (PIcontroller) produces an output signal consisting of two terms-one proportional to error signal and the other proportional to the integral of error signal. The transfer function of PI controller is

$$K_P\left[1+\frac{1}{T_{is}}\right] \quad \text{Or} \quad K_P\left[\frac{T_{is}+1}{T_{is}}\right] \qquad (1)$$

Where K_P is equal to proportional gain and T_i is equal to integral time. A typical conventional PI control system is shown in Fig. 4.

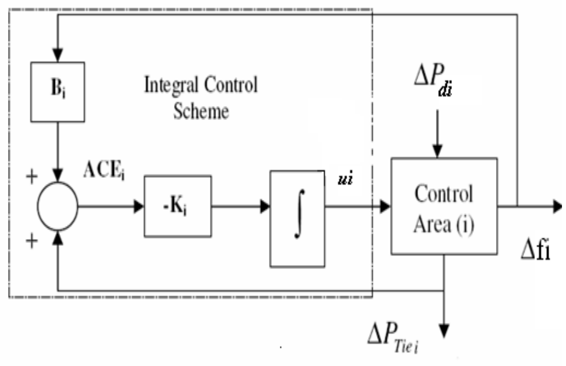


Fig (4): Conventional PI Controller

Conventional proportional plus integral controller (PI) provides zero steady state frequency deviation, but it exhibits poor dynamic performance (such as more number of oscillation and more settling time) [13].

IV. FUZZY GAIN SCHEDULED PI CONTROLLER

Gain scheduling is a technique commonly used in designing controllers for systems whose dynamics change nonlinearly with operating conditions [14]. It is normally used when the relationship between the system dynamics and operating conditions are known, and for which a single linear time-invariant model is insufficient [15].

In the present study, the gain scheduling is done based on the frequency deviation step response of the system for different values of K_i. A higher value of K_i results in reduction of maximum deviation of the system frequency but the system oscillates for longer times, whereas decreasing the value of K_i yields relatively higher maximum frequency deviation at the beginning but provides effective damping in the later cycles. This necessitates a variable K_i; therefore, higher values of K_i are scheduled at the initial stage and then changed gradually depending on the system frequency changes [16].In this paper, we use this technique to schedule the parameters of the PI controller according to change of the new area control error ACE and ΔACE, as shown in Fig.5.

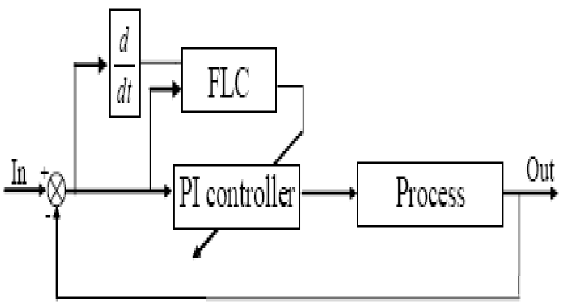
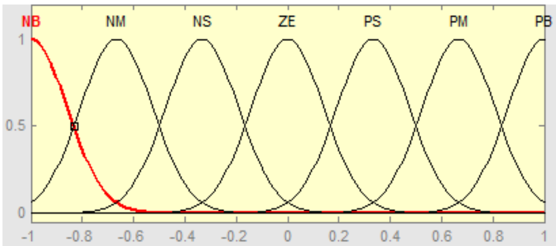
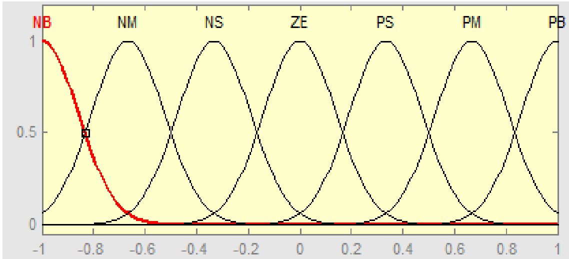


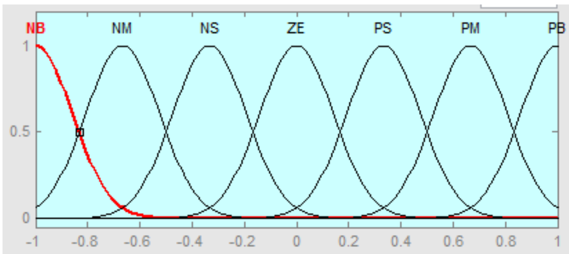
Fig (5): The Scheme of Fuzzy Gain Scheduling



(a)



(b)



(c)

Fig (6): Membership Functions for FGPI Controller of

(a) ACE **(b)** ΔACE **(c)**, K_I.

Table 1
Fuzzy Logic Rules for FGPI Controller

ACE \ ΔACE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

For the proposed controller, the Mamdani fuzzy inference engine was selected and realized by Gaussian membership functions for each of the three linguistic variables (ACEi,d/dt(ACEi),,Ki) with suitable choice of intervals of the membership functions as shown in Fig.6, where ACEi and d/dt(ACEi) act as the inputs of the controller and ,K_i is the output of the controller.Defuzzification has been performed using “Center of Area Method”. The appropriate fuzzy rules, as used in our study, for the FGSPI Controller are given in Table.1.

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V. SIMULATION RESULTS

A two area system connected by a tie-line with combined LFC and AVR parameters are simulated using conventional PI and the proposed FGSPI Controllers. The frequency V_s time responses for control input in area1 and area2 is shown in Fig.7 and Fig.8.Similarly the frequency deviation responses in area1 and area2 is shown in Fig.9 and Fig.10.Now all the two area systems can be connected to single tie-line and frequency V_s response can be obtained as shown in Fig.11.All these graphs are shown for a change in load of 0.01 p.u.

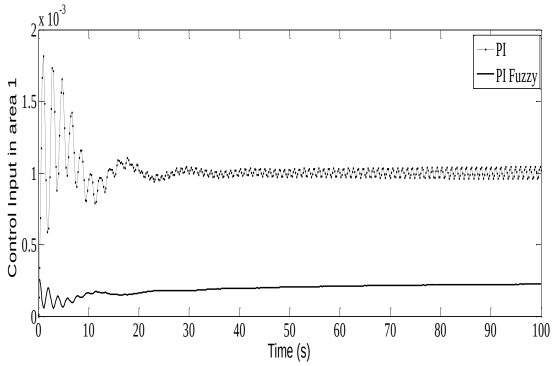

Fig (7): Frequency Vs Time Response for Control Input in Area 1

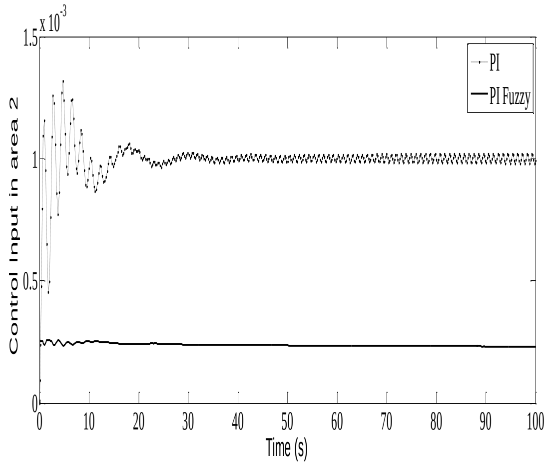

Fig (8): Frequency Vs Time Response for Control Input in Area 2

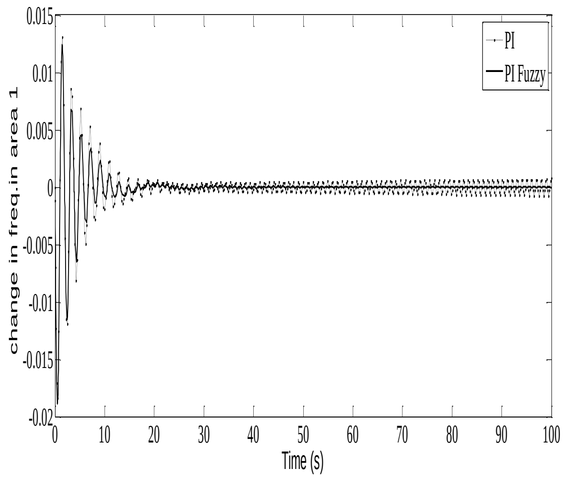

Fig (9): Frequency Deviation Response of Area1

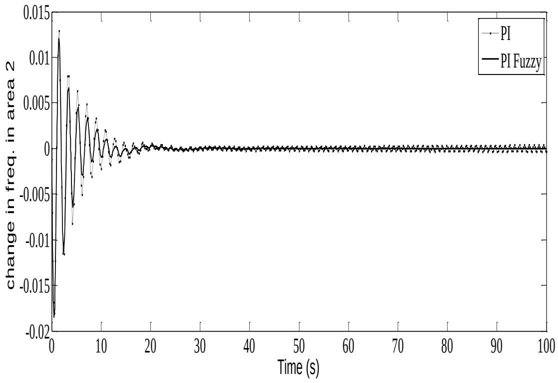

Fig (10): Frequency Deviation Response of Area2

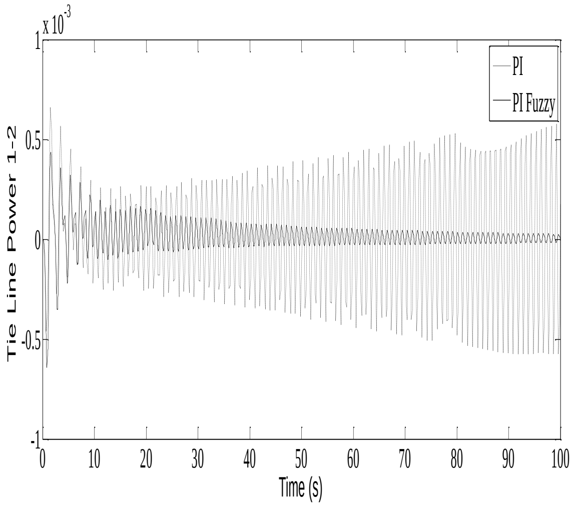

Fig (11): Tie-line Power Deviation of Two Area System

Table 2
Performance Comparison of Controllers for Frequency Deviation of Two Area System

Methods	Settling time (Sec)		Overshoot (Hz)		Steady State Error		
	Area1	Area2	Area1	Area2	Area1	Area2	ΔP_{tie}
PI Controller	99	97	0.013	0.0129	0.000188	-0.00009664	-0.0002074
FGPI Controller	20	19	0.0123	0.012	-0.0000032	0.00000145	0.0000039

Here, settling times, overshoots and steady state error of frequency deviation of the controllers were compared against each other. Similarly the terminal voltage graph is shown in Fig.12 and Fig.13. The comparison results with change in load of 0.01 p.u are provided in Table.2. and Table.3.

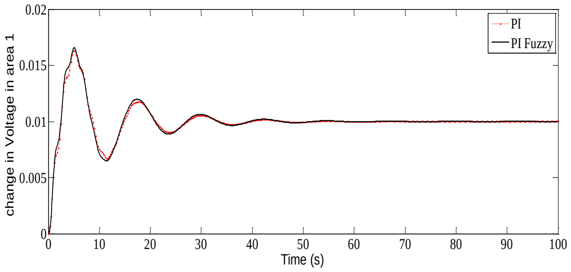

Fig (12): Terminal Voltage Response of Area 1

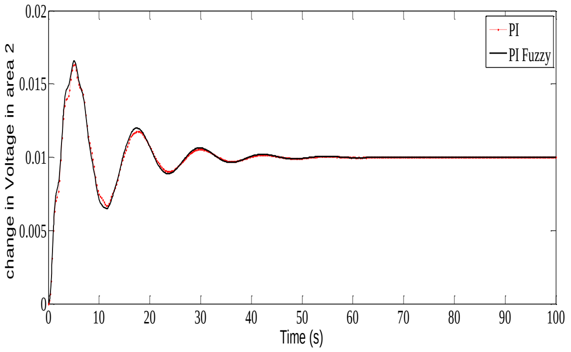

Fig (13): Terminal Voltage Response of Area 2

Table 3
Performance Comparison of Terminal Voltage Response of Controllers in Two Area System

Methods	Settling time (Sec)		Overshoot (Hz)	
	Area1	Area2	Area1	Area2
PI Controller	65	64	0.017	0.0169
FGPI Controller	42	40	0.0163	0.0162

VI. CONCLUSION

The quality of the power supply is determined by the constancy of frequency and voltage. In this paper a new combined model of interaction between LFC and AVR loops is proposed. The choice of values for the governor regulation parameter R and the exciter speed stabilizer gain has significant effect on the damping of intersystem oscillations as well as area frequencies. The simulation results revealed that the proposed FGSPI Controller can search the optimal parameters of LFC and AVR quickly & efficiently and also shows enhanced performance characteristics when compared to conventional controllers.

REFERENCES

1. A.Soundarrajan, Member ,IAENG, Dr.S.Sumathi, C.Sundar, "Particle Swarm Optimization Based LFC and AVR of Autonomous Power Generating System ", IAENG International journal of computer science , 2010.
2. Elyas Rakhshani, Kumars Rouzbehi and Sedigheh Sadeh , "A New Combined Model for Simulation of Mutual Effects Between LFC and AVR Loops", IEEE Transactions on power system, 2009.
3. Ertugrul Cam and Ilhan Kocaarslan, " A Fuzzy Gain Scheduling PI Controller Application for an Interconnected Electrical Power System" , Electrical power systems research 73,264-274 2004.
4. H.D. Mathur and S. Ghosh, "A Comprehensive Analysis of Intelligent Control for Load Frequency Control", IEEE Power india conference, 2006.
5. D.M. Vinod Kumar, "Intelligent Controllers for Automatic Generation Control", IEEE Transactions on global connectivity in energy, computer, communication and control, 1988, pp557-574.
6. P. Kundur, "Power System Stability and Control", Tata Megraw Hill,Newyork, 1994.
7. M.S. Anower , "Fuzzy Frequency Controller for an AGC for the Improvement of Power System Dynamics", 4th International conference on electrical & computer engineering, 2006.
8. H.L. Zeynelgil, A. Demiroren, N.S. Sengor, "The Application of ANN Technique for Automatic Generation Control for Multi-Area Power System", Electric power and energy systems, pp345-354, 2002.
9. H.D. Mathur and H.V. Manjunnath, "Frequency Stabilization using Fuzzy Logic Based Controller for Multi-Area Power System", The south pacific journal of natural science, pp22-30, 2007.
10. A.R. Hasan, T.S. Martis , "Design and Implementation of a Fuzzy Based Automatic Voltage Regulator for a Synchronous Generator",IEEE Transactions on energy conversion, 1994.
11. Parveen Dabur, Naresh Kumar Yadav and Vijay Kumar, "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, 2011.
12. Hadi Saadat, eds 1999. "Power System Analysis", Mcgraw-Hill International edition , 2005.
13. A. Khodabakhshian and N. Golbon, "Robust Load Frequency Controller Design for Hydro Power Systems",IEEE conference on control applications,pp28-31, 2005.
14. J. Talaq, F. Al-Basri, "Adaptive Fuzzy Gain Scheduling for Load Frequency Control", IEEE Transactions in power system,pp145-150, 1999.
15. Parveen Dabur, Naresh Kumar Yadav and Vijay Kumar, "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, 2011.
16. A. Sreenath, Y.R. Atre, D.R. Patil, "Two Area Load Frequency Control with Fuzzy Gain Scheduling of PI Controller", First International conference on emerging trends in engineering and technology, 2008.
17. Sayed Mojtaba , "Load Frequency Control in Multi Area Electric Power System Using Genetic Scaled Fuzzy Logic", International Journal of the physical science, pp377-385, 2011.
18. N. Ndubisi Samuel, "An Intelligent Fuzzy Logic Controller Applied to Multi-Area Load Frequency Control", American journal of scientific and industrial research, 2010.