

Automatic Generation Control of Power System with Fuzzy Gain Scheduling Integral and Derivative Controller

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Abstract— This paper presents a new Fuzzy Gain Scheduled Integral and Derivative (FGID) controller for Automatic Generation Control (AGC) of a two area non-reheat power system. Simulation results show that the proposed control scheme is suitable for damping the frequency oscillation due to load disturbance effects. The proposed controller is compared against other controllers using settling times, overshoots, and undershoots of the frequency deviations. The results show that the proposed controller outperforms other schemes. Best dynamic responses are obtained when compared with Fuzzy Gain Scheduling of Proportional and Integral (FGPI) controller, fuzzy controller, and Conventional Proportional and Integral (PI) controller.

Keywords – Automatic generation control, fuzzy logic control, power system.

I. INTRODUCTION

In steady state, the output of the generators at any instant will exactly equal the load on the system and all the generating units operate synchronously at the same frequency.

Immediately after a change in the total power demand, the flywheel governor of the synchronous machine try to return the system to the initial frequency but it is unable to do that. Therefore, the system needs to use supplementary control i.e. AGC to eliminate the deviation in frequency [1].

In the interconnected power system, the supplementary control is added to the system to compliment the primary control to eliminate the frequency and net tie-line interchange deviations. The following objectives are considered due to the load perturbations:

- (1) maintain frequency of each area and the net tie-line power at scheduled value.
- (2) each area regulates its own load changes.

In conventional studies, frequency oscillations of the system are minimized by using conventional linear controllers [2, 3]. However, they resulted in longer settling times and higher oscillations.

Power system is a nonlinear, complex system and is subjected to different kinds of events. Therefore, it is difficult to effectively solve the significant power system control problems depending only on the conventional approaches. As a way to solve these problems, gain scheduling controllers as a type of adaptive controller had been used for AGC by many researchers, [4]. It gave better

performance than conventional control methods but the dynamic response may be unstable because of the abruptness in system parameters. In addition, it is difficult to design a linear time invariant models for different operating points [5].

Recently many researchers applied intelligent techniques (i.e neural network, fuzzy logic, optimization algorithms, etc.) to solve the load frequency control problem [6-9]. FGPI controllers were proposed by different researchers, [4, 5]. A FGPI controller proposed by [5] with seven triangular membership functions. This controller gave better dynamic performance when compared with three different controllers. In this study, instead of the FGPI controller, the FGID controller is suggested. The results of the proposed controller are compared against the conventional controller, Fuzzy Logic Controller (FLC) and the two PGPI controllers proposed by [4] and [5] respectively. Settling times, overshoots, and undershoots of the frequency deviations are used for comparison. The results demonstrate that the proposed controller provides better performance than other types of controllers.

II. MODELING FOR AGC OF A TWO AREA POWER SYSTEM

The system considered in this study is consisting of two control area connected by a tie-line as shown in Fig. 1. Each control area is containing non-reheat turbine type thermal unit. Detailed block diagram of a single area power system is shown in Fig. 2.

The system can be represented in the state-space form by the following equation:

$$\dot{x}(t) = Ax(t) + Bu(t) + \Gamma \Delta P_d(t) \quad (1)$$

where A is the state matrix, B , and Γ are input and disturbance matrices, u and ΔP_d are input and disturbance vectors.

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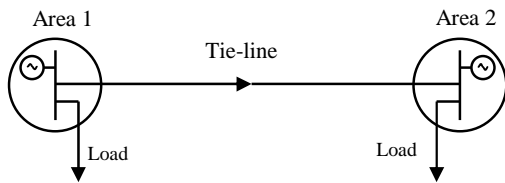


Fig. 1. General diagram of a two-area power system.

Also $x(t)$ is the state vector, given as

$$x(t) = [x_1 \ x_2 \ \dots \ x_7]^T = [\Delta f_i \ \Delta P_{gi} \ \Delta X_{Ei} \ \Delta P_{tie}]^T$$

where Δf_i is increment frequency deviation of area i , ΔP_{gi} is mechanical power deviation of area i , ΔX_{Ei} is increment change in governor valve position of area i , ΔP_{tie} is tie-line increment power deviation, i is area index 1, 2, $u(t) = [u_1 \ u_2]^T$, and $\Delta P_d = [\Delta P_{d1} \ \Delta P_{d2}]^T$.

First control area is interconnected with tie-line to other control area. The i -th control area net interchange equals the megawatts on outgoing tie-line. To maintain frequency of each area and the net tie-line power at scheduled value, the Area Control Error (ACE) of i -th area is minimized to zero.

$$ACE_i = \sum_{j=1}^m \Delta P_{tie,ij} + b_i \Delta f_i \quad (2)$$

where b_i is frequency bias coefficient of i -th area, and $\Delta P_{tie,ij}$ is tie-line interchange error between the i -th and j -th areas.

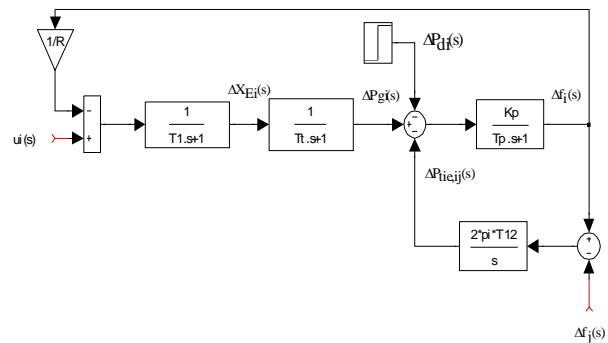


Fig. 2. Detailed block diagram of a single-area model.

Detailed block diagram of the two-area interconnected power system including controllers is shown in Fig. 3.

III. THE FGID CONTROLLER

Fuzzy logic is derived from fuzzy set theory where infinite number of memberships is allowed. The degree of each member ship for each element is indicated by a number in the interval [0 1], [10]. While traditional controllers are linear, fuzzy logic controllers are nonlinear. Moreover, fuzzy logic controllers do not need a controlled plant model, and not sensitive to plant parameter variations. By using fuzzy logic the human experience can be used in the design of the controller.

Fuzzy logic controllers are rule-based controllers. The rules of the system are written in natural language and translated into fuzzy logic.

A basic structure of a fuzzy logic system is shown in Fig. 4 [11].

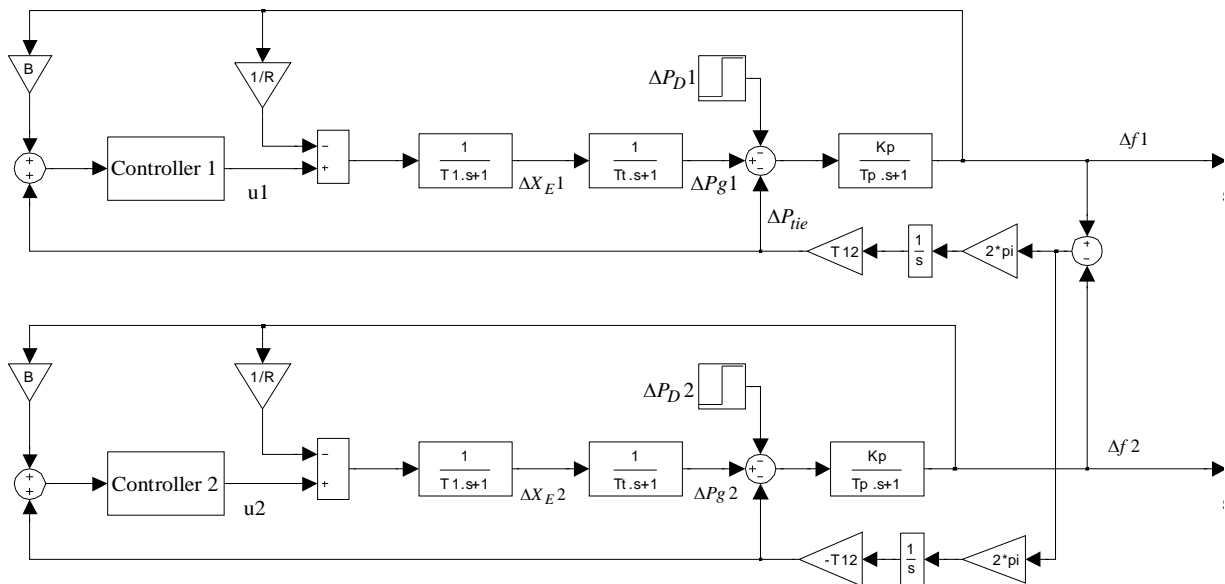


Fig. 3 Two-area power system including controllers

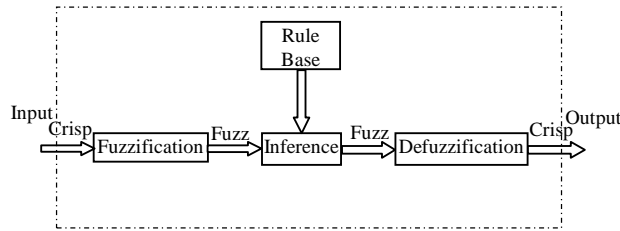


Fig. 4. Basic structure of a fuzzy logic system.

The control structure for the conventional ID controller is in the following form:

$$u_i(t) = -K_I \int e_i(t)dt - K_D \dot{e}_i(t) \quad (3)$$

where $e_i = ACE_i$, K_I and K_D are the integral and derivative controller gains.

The correlation between the conventional controller and fuzzy logic system is chosen to improve the performance of the conventional controller. Here the gains of the ID controller are modified according to the disturbances.

The Mamdani fuzzy inference engine was selected and the range of the controller is chosen properly to improve outputs responses of the system. Here, error and its time derivative are used as inputs to the controller. Seven triangle membership functions are employed for the inference mechanisms i.e. Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), and Positive Big (PB). The membership functions of the e , \dot{e} , K_I , and K_D for the proposed controller are shown in Fig. 5.

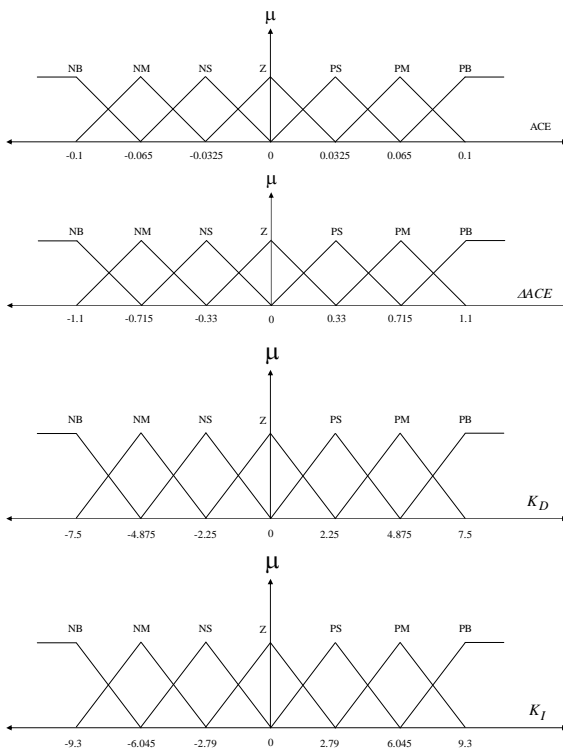


Fig. 5 Membership functions for the proposed controller of error ,errors time derivative , K_D , and K_I

TABLE I
FUZZY LOGIC RULES FOR THE PROPOSED CONTROLLER

		\dot{e}						
		NB	NM	NS	Z	PS	PM	PB
e	NB	PB	PB	PB	PM	PM	PS	Z
	NM	PB	PM	PM	PM	PS	Z	NS
	NS	PB	PM	PS	PS	Z	NS	NM
	Z	PM	PM	PS	Z	NS	NM	NM
	PS	PM	PS	Z	NS	NS	NM	NB
	PM	PS	Z	NS	NM	NM	NM	NB
	PB	Z	NS	NM	NM	NB	NB	NB

The fuzzy rules of the gains K_P and K_I are in the form:

If e is L_n and \dot{e} is M_n Then Gain is Z_n (4)

where L_n , M_n , and Z_n are fuzzy sets, and n is number of rules. In this study 49 rules are used. The set of fuzzy rules are given in TABLE I. The centroid method is used in defuzzification process.

IV. SIMULATION RESULTS AND DISCUSSION

The proposed approach was applied to two-area non-reheat interconnected power system. To study and analyze the effect of a load change on the system response, a 1% step load change is assumed to take place in area 1 and area 2. The performance of the proposed controller is compared with conventional controller, FLC, and the two PGPI controllers proposed by [4] and [5] respectively.

In this paper, the simulation is implemented by using MATLAB Simulink program and MATLAB Fuzzy Logic toolbox. The data of the system are given in the Appendix.

The proposed controller gains are changing during disturbances as shown in Fig. 6 and Fig. 7. The generator output power responses of both areas and the tie-line power response are shown in Fig. 8. The figure demonstrates that each area regulates its own load fluctuations. The frequency response of the area 1 after the load change is shown in Fig. 9.

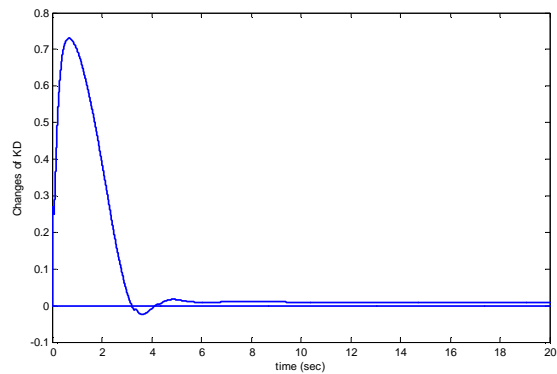


Fig. 6. Changes of the K_D of the proposed controller for the two-area power system.

As mentioned before, settling times, overshoots, and undershoots of the frequency deviations are used for comparison. Fig. 9 shows the settling time for 5% band of

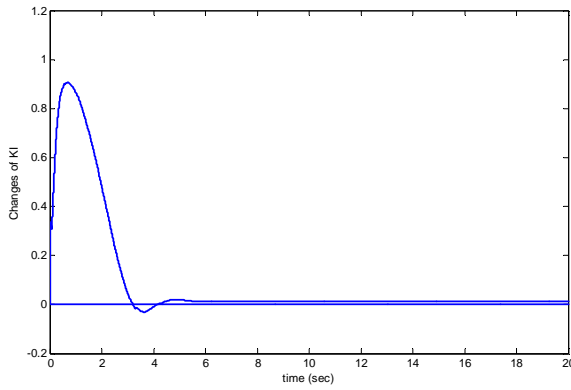


Fig.7. Changes of the K_I of the proposed controller for the two-area power system

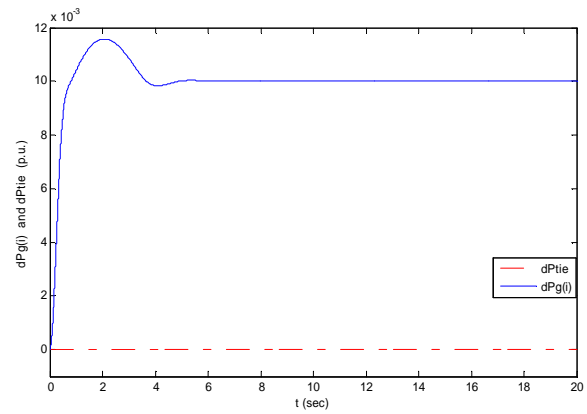


Fig. 8 Generator output response of the area 1 and area 2, and tie-line power deviation response.

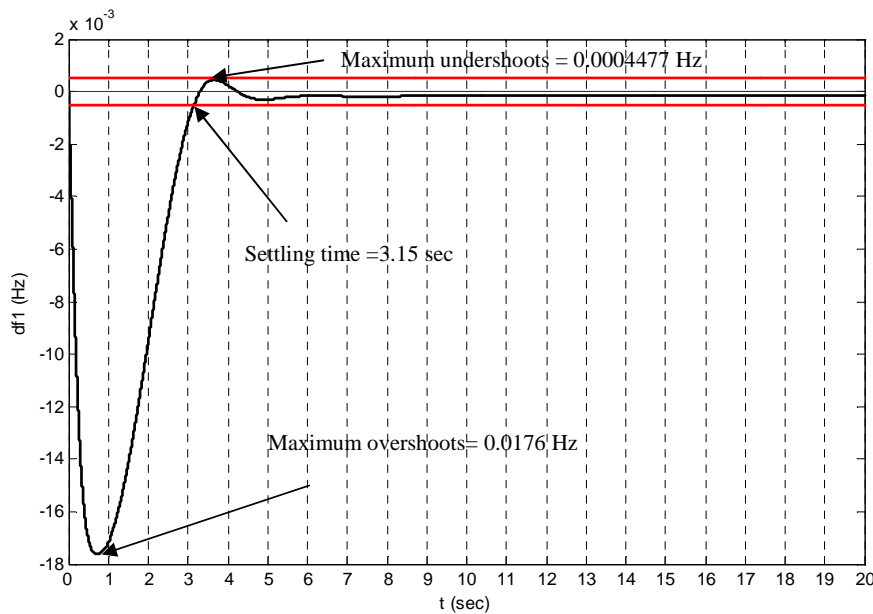


Fig. 9 Frequency deviations response of area 1.

TABLE II
COMPARISON OF SETTLING TIME, OVERSHOOTS,
UNDERSHOOTS FOR THE FREQUENCY DEVIATION OF AREA 1

Type of controller	Settling time (sec)	Maximum overshoots	Maximum undershoots
The proposed FGID controller	3.15	-0.0176	0.000477
FGPI controller [5]	3.47	-0.0194	0.008
Conventional PI [5]	4.37	-0.0271	0.0005
FGPI [4]	7.21	-0.0226	0.0106
FLC [5]	17.13	-0.0152	-

the step load change, maximum overshoots, and maximum undershoots of the proposed controller.

The comparison results against other controllers are summarized in TABLE II which reveals that settling time of the proposed controller has the shortest time. Also, the

overshoots, and undershoots of the proposed controller are the lowest among all methods.

V. CONCLUSION

In this paper, a new Fuzzy Gains Scheduled Integral and Derivative controller was developed for AGC of two-area non-reheat thermal power system.

The information about the parameters of the system are not important. So this controller is very simple to be implemented like other types of fuzzy gain schedule controllers.

The proposed controller was compared with other controllers using settling time, overshoots and undershoots for the frequency deviations. The simulation results demonstrate that the FGID provides better performance.

As an overall conclusion, this paper illustrated that the proposed FGID controller is more suitable for implementation on a two-area power system compared to FGPI controllers.

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APPENDIX

Two-area non-reheat thermal parameters:

$T_1 = 0.08$, $R_1 = 2.4$, $B = 0.425$, $T_{12} = 0.086$, $T_p = 20$,

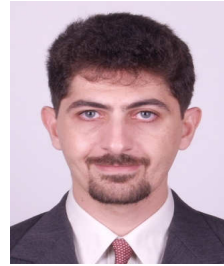
$T_t = 0.3$, $K_p = 120$.

VII. BIOGRAPHIES



especially monitoring, stability and power system control.

Mr. Lokman H. Hassan received his MSc in Power Engineering from the University of Technology, Baghdad in 2002. He worked as a project engineer for seven years before he became a lecturer in the Electrical and Computer Department, University of Dohuk, Kurdistan of Iraq. Currently, he is pursuing his PhD in Power Systems and Control at the Department of Electrical Engineering in University of Malaya. His most important research concern is control systems design



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sensory interface electronics in industrial, commercial, scientific, transportation, and biomedical systems.

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Dr S. S. Yang was born in 1971 and received his early education in Malaysia. He graduated with a BEng.(Hons) in Electrical and Electronics Engineering from the University of Sunderland, UK, MSc in Control Engineering from the University of Bradford, UK and PhD in Fault Tolerant Control Systems from Brunel University of West London, UK in 1992, 1995 and 2004 respectively. He is currently serving as a lecturer at the Department of Electrical