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Comparative Analysis of PI & Fuzzy Based Cntroller For Load Frequency Control of Thermal-Thermal & Thermal: Hydro System

[I]Ratnesh Chaturvedi, [II]Dr. Bharti Dwivedi
[I]M.Tech Student, Institute of Engineering & Technology Lucknow, India
[II]Professor Dept. of Electrical Engineering Institute of Engineering & Technology Lucknow, India
[I]naman.en@gmail.com, [II]bharti_dwivedi@yahoo.com

ABSTRACT

This paper presents the effectiveness of Fuzzy controller over conventional PI controller for load frequency control. The main disadvantage of PI controller is slow acting and does not efficiently handles system nonlinearities. Due to change in load, system frequency deviates from nominal value. System Collapse is one of the main reasons due to high deviation in frequency. Fuzzy controller is an accurate and fast acting controller, which improve dynamic performance (settling time, peak overshoot) and reduce the oscillation frequency. In this paper, peak overshoot, settling time and frequency deviation is compared.

Keywords

Fuzzy Logic Controller, PI Controller, Thermal Power Plant, Load Frequency Control, Automatic Gain Control

I. Introduction

In actual power system operations, the load is changing continuously and randomly. As the ability of the generation to track the changing load is limited due to physical/technical considerations, this results an imbalance between the actual and the scheduled generation quantities. This imbalance leads to a frequency deviation. Maximum allowable change in frequency should be ± 0.5Hz[1]. Due to change in frequency there is change in the speed of motors. It is necessary to maintain the frequency for smooth running of power stations in parallel. In modern large system manual regulation is not possible .Load Frequency Control (LFC) is a part of Automatic Generation Control (AGC).The main objective of AGC is to maintain the system frequency at nominal value[1]. Power system is divided into different control areas. These control areas are connected by tie lines. Frequency should remain constant throughout the control areas [2]. Frequency of the system depends on active power demand. Various types of load frequency controller are used to maintain the system frequency at nominal value. PI Controller is widely employed. It is simple for implementation but its settling time is more and produces large frequency deviation. A number of state feedback controllers based on linear optimum control technique have been proposed to achieve better performance. Fixed gain controllers work at nominal operating condition but its performance over a wide range operating condition is not satisfactory. Fuzzy controller shows good result over the conventional controller especially in complex and nonlinearities associated system[3]. In this paper performance analysis of PI and Fuzzy controller for two area interconnected thermal-thermal and thermal hydro plant is proposed.

Two Area Controls:

In two area system, two single area is connected through a tie line. Power is transferred though tie line [5,7]. The control objective is to regulate the frequency of each area and to simultaneously the tie line power s per inter-area power contracts. Each control areas is represented by an equivalent turbine, generator and governor [4].

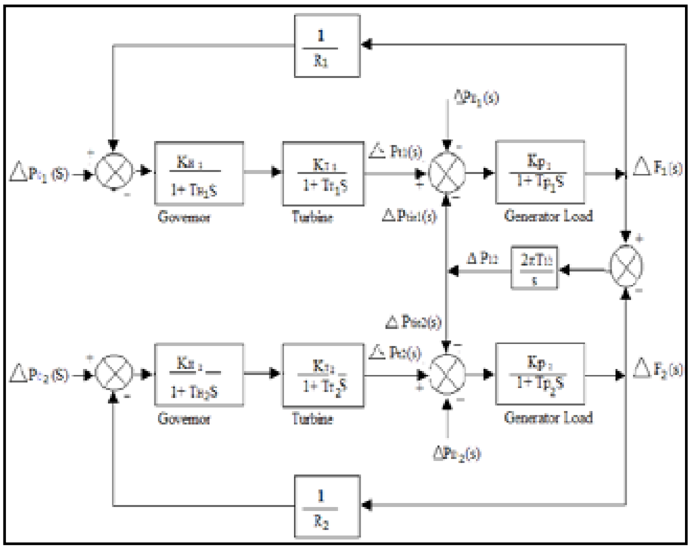

Fig. 1: Block Diagram of Two Area Power System (Thermal-Thermal)

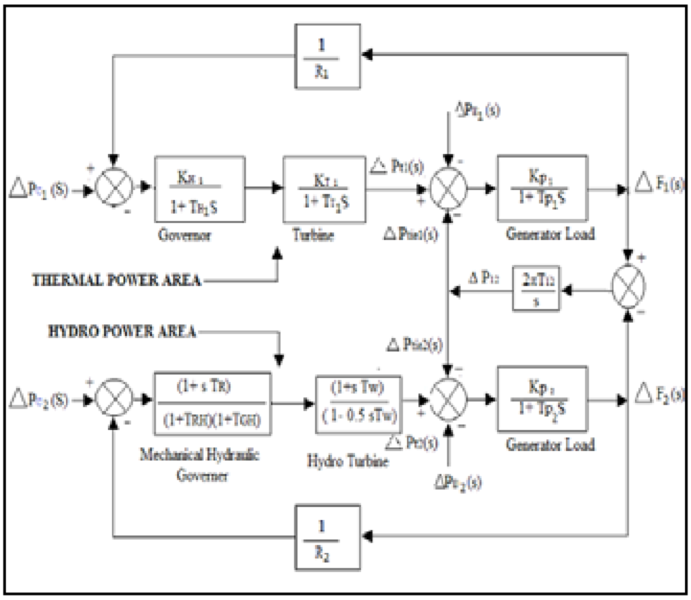

Fig. 2: Block Diagram of Two Area Power System (Thermal-Hydro)

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II. Modeling of the Tie-Line

The well known power transfer equation is $P_{12} = \frac{|V_1||V_2|}{x}\sin(\psi_1 - \psi_2)$ (1)

Where ψ_1 and ψ_2 are the angles of end voltages V_1 and V_2 respectively.

The tie line power changes for small deviation in the angles are given by the amount.

$$\Delta P_{12} \approx \frac{|V_1||V_2|}{x}\cos(\psi_1 - \psi_2)(\Delta\psi_1 - \Delta\psi_2) \quad (2)$$

Analogous to the concept of "electric stiffness" of synchronous machines we define the "synchronous coefficient" of a line

$$T^0 \approx \frac{|V_1||V_2|}{x}\cos(\psi_1 - \psi_2) \quad (3)$$

Thus the equation can be written as

$$\Delta P_{12} = T^0(\Delta\psi_1 - \Delta\psi_2) \quad (4)$$

The frequentation deviation is related to the reference angle by the formula

$$\Delta f = \frac{1}{2\pi}\frac{d(\Delta\psi_1 - \Delta\psi_2)}{dt} = \frac{1}{2\pi}\frac{d(\Delta s)}{dt} \quad (5)$$

or

$$\frac{d(\Delta s)}{dt} = 2\pi\Delta f$$

or

$$\Delta\psi = 2\ 2\pi\int_0^t \Delta f dt$$

Thus the equation can be written as

$$\Delta P_{12} = 2\pi T^0\left(\int_0^t \Delta f_1\, dt - \int_0^t \Delta f_2 dt\right) \quad (6)$$

Taking Laplace transform of equation (6)

$$\Delta P_{12}(s) = \frac{2\pi T^0}{s}(\Delta f_1(s) - \Delta f_2(s)) \quad (7)$$

Similarly the incremented tie line power expected from area 2 is given by

$$\Delta P_{12}(s) = \frac{2\pi T^0}{s}(\Delta f_2(s) - \Delta f_1(s)) \quad (8)$$

The power balance equation for single area can be given by

$$\Delta P_T - \Delta P_E = \frac{2H_1}{f_0}\frac{d(\Delta f_1)}{dt} + B\Delta f_1 \quad (9)$$

So for the double area, the same equation should be modified as follows

Taing laplace of equation (9)

$$[\Delta P_{T1}(s) - \Delta P_{E1}(s) - \Delta P_{12}(s)] = \frac{2H_1}{f_0}s\Delta f_1(s) + B_1\Delta f_1(s)$$

$$\Delta P_{T1} - \Delta P_{E1} = \frac{2H_1}{f_0}\frac{d(\Delta f_1)}{dt} + B_1\Delta f_1 + \Delta P_{12} \quad (10)$$

$$= \frac{2H_1}{f_0}s\Delta f_1(s)\left(\frac{1}{B_1}s + 1\right)$$

If

$$\frac{2H_1 B_1}{f_0} = \frac{1}{K^{PI}}$$

$$\frac{1}{B_1} = T_{PI}$$

Taking laplace Transform of equation (9) and reorganizing, we get

$$\Delta f_1(s) = G_{P1}(s)[\Delta P_{T1}(s) - \Delta P_{E1}(s) - \Delta P_{12}(s)]$$ where,

$$G_{P1}(s) = \frac{K_{PI}}{1 + sT_{PI}}$$

III. Fuzzy Logic Controller

Fuzzy logic controller has three stages-

1. Fuzzification interface
2. Inference rule engine
3. Defuzzification interface

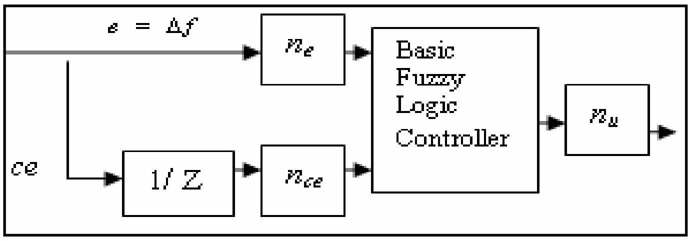


Fig. 3: Block Diagram of Fuzzy Logic Controller

Fuzzy logic controller respond to variable error(e) and change of error (ce).

Global function of FLC is written as ΔP_c=F[n_c e(k)], n_{ce} ce(k)]. Where n_e, n_{ce} and n_u are known as error, change of error scaling gains and output control gain respectively.

A label set corresponding to linguistic variables of the input control signals, e (k) and ce (k), with a sampling time of 0.01 sec is as follows L(e, ce) = { NB, NM, ZE, PM, PB}, (2)

Where, NB = Negative Big, NM = Negative Medium, ZE = Zero, PM = Positive Medium, PB= Positive Big

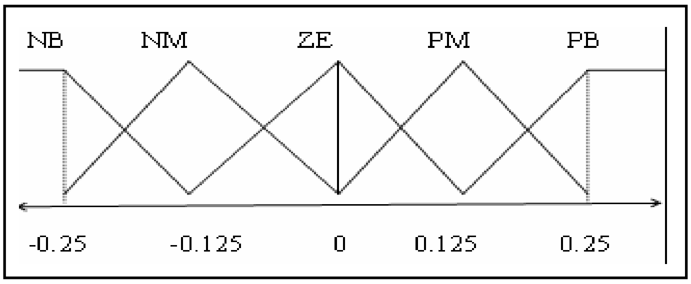


Fig. 4: Membership Function for the Control Input Variables

Table of Fuzzy interference rule for fuzzy logic controller-

Input	e(k)					
		NB	NM	ZE	PM	PB
ce(k)	NB	NB	NB	NM	NM	ZE
	NM	NB	NB	ZM	ZE	ZE
	ZE	NM	NM	ZE	PM	PM
	PM	ZE	PM	PM	PB	PB
	PB	ZE	ZE	PM	PB	PB

IV. Simulation and Results:

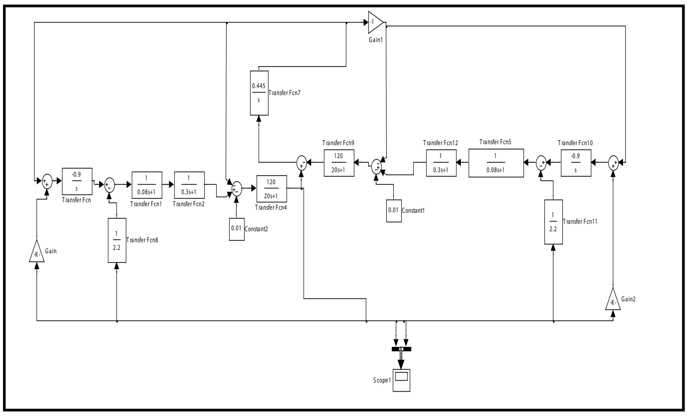
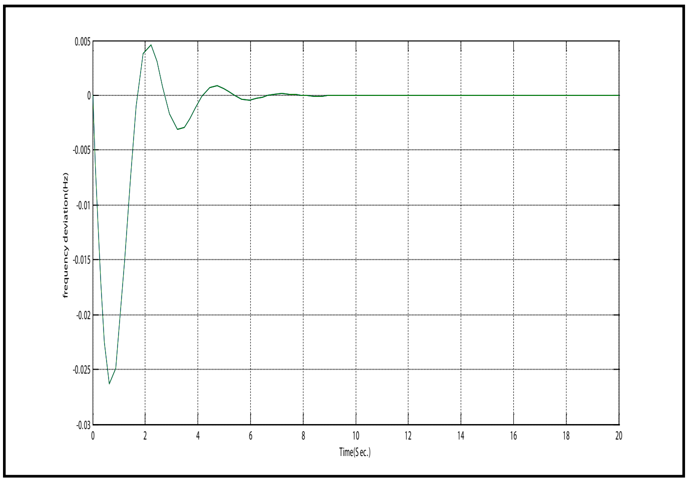


Fig. 5: Simulink Model of Two Area Thermal Thermal Plant With PI Controller



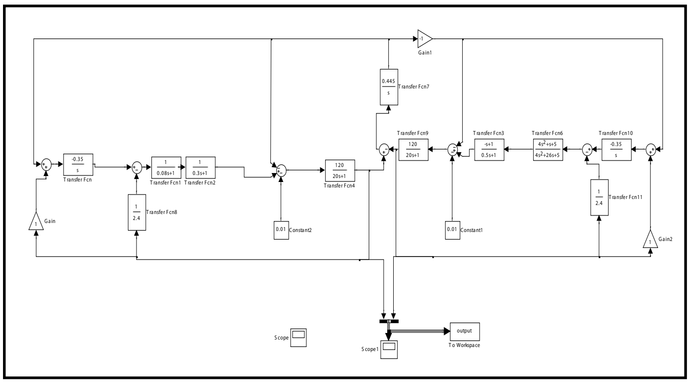
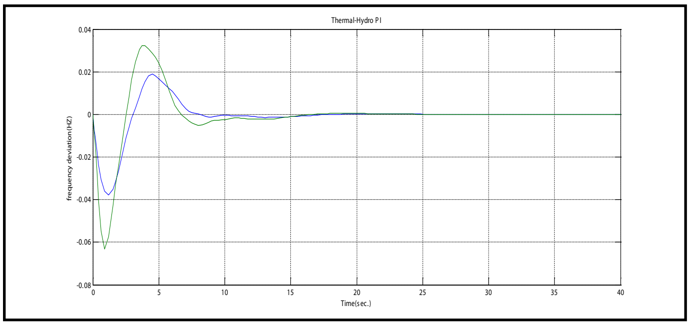


Fig. 6: Simulink Model of Two Area Thermal Hydro Plant With PI Controller



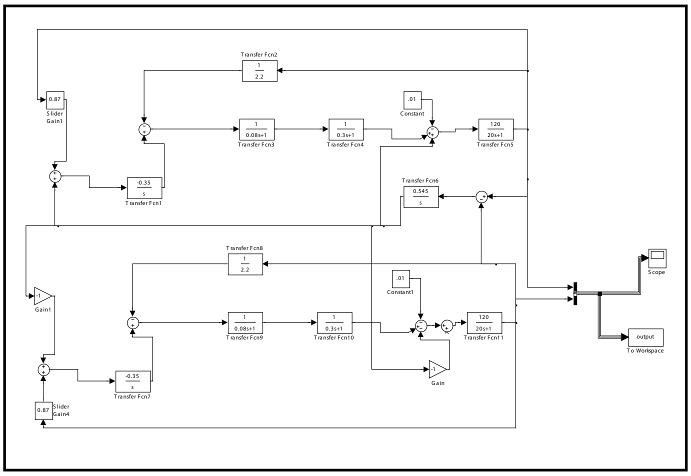
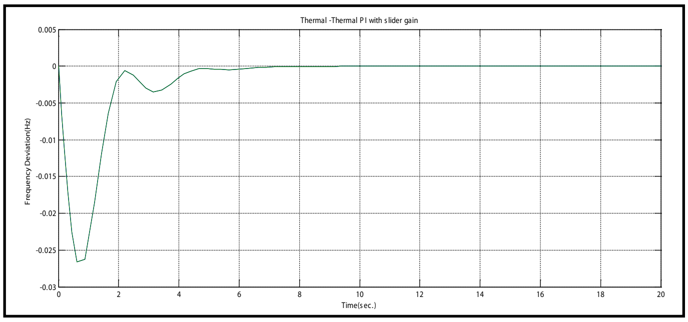


Fig. 7: Simulink Model of Two Area Thermal Thermal Plant With Slider Gain PI Controller



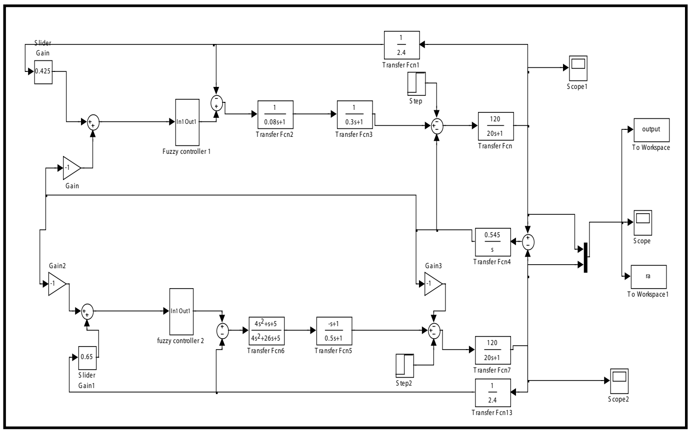
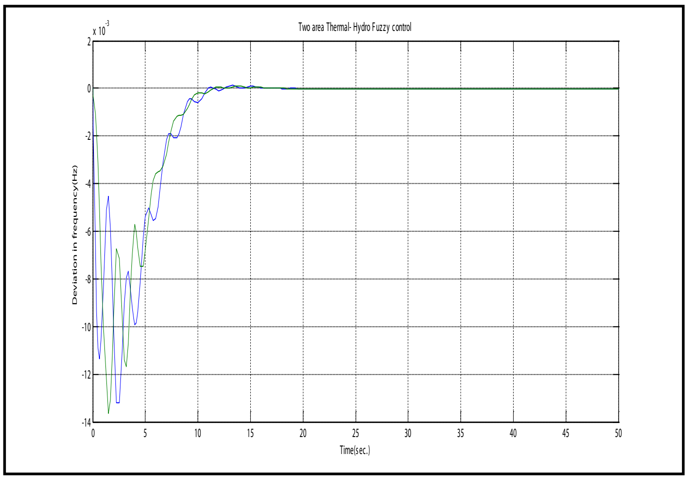


Fig. 8: Simulink Model of Two Area Thermal Hydro Plant With Fuzzy Controller



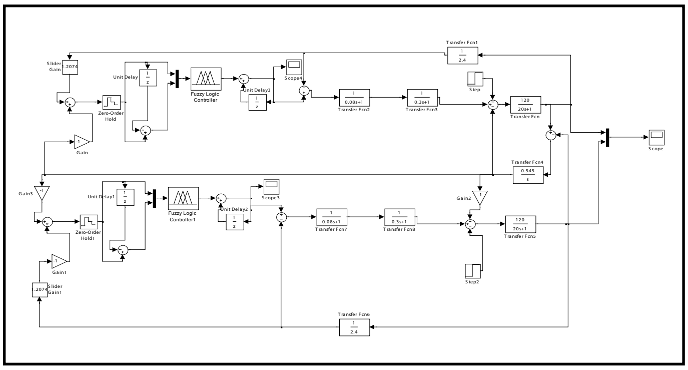
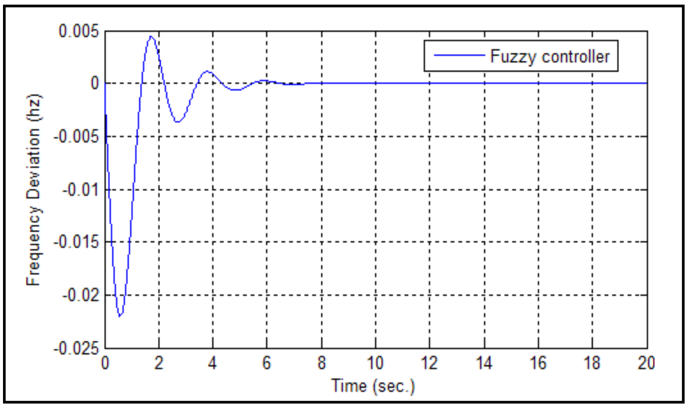


Fig. 9: Simulink Model of Two Area Thermal Thermal Plant With Fuzzy Controller



V. Comparative Results

Table 1:

Cases of simulation	Steady state error	Settling time	+vePeak over shoot
Thermal-Thermal PI	0	11	0.05
Thermal-Hydro PI	0	23	0.03
Thermal-Thermal Fuzzy	0	7	0.02
Thermal-Hydro Fuzzy	0	17	0

VI. Conclusion

From the above MATLAB /Simulink result, it shows that with the implementation of fuzzy controller settling time reduced,oscillation reduced and provide better dynamic performance.

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