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Automatic Generation Control in Two-Area Hydro-Thermal and Four Area Non-Reheat Thermal Power Plant using Fuzzy Logic Controller

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Abstract: This paper contributions a fuzzy Logic Controller for Automatic Generation Control (AGC) is considered for both area like two-area hydro-thermal and four area non-reheat thermal power plant. In the modern power association, the AGC of both system has generally consumed in frequency control outstanding to taking the profligate comebacks. The model of hydro-thermal system and four area non-reheat thermal system with fuzzy is simulated in MATLAB/SIMULINK platform. The dynamic reactions of load frequency control by fuzzy and its related determined with PID controller for frequency management. The accomplishment of the projected fuzzy is better-quality the expectations of power system in provisions of settling time, peak undershoot time and peak overshoot time for two area hydro-thermal and four area relation of setting time and peak undershoot time is improved . Proposed Fuzzy Controller is better result offers as compared to PID for both area such as hydro-thermal power plant and four area power plant.

Keywords: Automatic Generation Control (AGC), Fuzzy Logic Controller, Load Frequency Control (LFC), PID Controller, Frequency Deviation, Hydro Power Plant, Thermal Power Plant

I. INTRODUCTION

AGC participation an confident attractiveness in four-area thermal system to remember the inspiration of frequency and tie-line at their professed integrity. If any surprising disorder emerges due to any reason and if the fashioned active power changes the division with load supplication i.e. decreasing or mounting instruction. For a profit of power memory is domineering to reservation the repeated dispense of electrical power to the customer without any volatilities. A power system comprises of a distribution, generation and transmission of electrical strength. Massive consistent measure of essentials products to a problematic power plant which is regularly attached via tie lines. In current epochs, it is gorgeous a difficult occupation to engineer for remaining the augmented power supplication from the fashionable power system. The endangered and dependable procedure of a large consistent two-area system requires the harmonizing between the manufacturing power and load supplication [1].

The quickness difference is acknowledged by the turbine supervisor, which presentations and modifies the controller to modification the mechanical power construction to transport the swiftness to inventive steady-state proportion. The necessity of existence is on vigorous inspiration; though the voltage is on explosive inspiration. The incorporation of active power and frequency is generally recognized as automatic generation control(AGC) [2]. For a success of power system is imperative to reserve the continuous foundation of electric authority to the patron destitute of any disorders. For an firmness, the power structure is to reservation a equipoise amongst load supplication of the consumer and power stimulated of power [3].

The troubling in generation and load supplication is ensued by optimally envisioned controllers for circlet in the plant. The essential determination of a plant is to foundation electric vitality with unimportant incorrigible voltages and frequency. It is imperfect to knowledgeable and continual action of the power plant by protective plant frequency lower compulsory receptions. This frequency deviation container be declined by optimally deliberate PID controller. The AGC is one of the apparatuses that steadiness the active and reactive power supplication, on the supplementary gauge, the controller gadget is to control the change in plant frequency. Concluded the preceding year gumshoes, all accomplished the world are predictable countless soft computing techniques for AGC of system in training to reservation the tie line and plant frequency undertaking at their slight morals. These computing techniques like PSO

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[4], BFOA TLBO [5], QOGWOA [6], FA [7], GA[8], CSA [9]. Fuzzy is unassuming of the knowledgeable commissioner, for administrative the load frequency of plant. Fuzzy is not only progresses the active protest but also condenses the steady state mistake [10]. The optimal approach of a PID for AGC by HSA [11]. A fuzzy-PI for sanitizing the dynamic attending of two amount hydro-power system and expectations have been old-fashioned for concerning PI and Fuzzy-PI [12]. AGC by a fuzzy-PID and the confines of Fuzzy PID improved-superiority by a FA. The AGC of two-area reliable thermal plant comprehensive fuzzy and the paybacks of fuzzy controller accompanying resolute P, PI and PID. The assessed and examination of fuzzy-PID for reliable power system and complementary the belongings of PI, PID and Fuzzy-PID for deformed morals of speed restriction [13], [14].

Controlled on calming the grid firmness of reliable wind power plant ended Fuzzy PID. For gigantic impress demand, supplementary power plant is faithful to alone opposite [15]. A fuzzy-PID for imperative AGC of two-area in assessment of outset quantity limitations [16]. AGC for spread by fuzzy PI, PID. A conversant investigation on AGC of single-area finished fuzzy and flawless administrators [17]. The hypothetical control development with fuzzy, ANN cognizance is accompanying correct and more quickly than supplementary controller and PI grounding unfluctuating for multi-coated dynamical prearrangement [18]-[24]. A Fuzzy-PI for imperative the LFC of four arrangement and for support of representative the demos of fuzzy-PI allied done PI for LFC of spread and the invented of fuzzy-PID are heightened by GA [25]. GA, PSO [26]. LFC in four area power system using fuzzy logic controller [30], NARMA-L2 controller [31], Tuning of PID controller [32], PSO [33].

This paper contributions a learning of LFC of both system such as two-area hydro-thermal and four area power system. The fuzzy controller dramas an imperious attractiveness to achieve better-quality appearances. In this article, Fuzzy have been beneficial to the plant to accomplish the approach planes. This paper is prepared in five parts. The problem preparation through both system clarification in part 2. Proposed fuzzy and PID are accessible in part 3. The performances of procedure in relatives of peak overshoot, peak undershoot and settling time of frequency deviation(ΔF) of hydro-thermal power system and four area thermal power system are proposed fuzzy compared over the PID is designated in part 4. The conclusion of this work is accessible in part 5 and involves of nomenclature and references.

II. PROBLEM PREPARATION

2.1 Two Area Hydro-Thermal Power Plant (System Explanation)

The essential diagram of hydro-power plant is visible in fig. 1. The detailed gears of Hydro-power plant be intelligent to discrete into 4 fundamentals like Penstock, Electrical-Hydraulic servo-system, Turbine, and Generator. The area design of speed governing turbine arrangement of thermal power system is visible in fig. 2. The frequency is restrained when the steam contribution of the Turbine is slow. The steam contribution of the turbine is inspiration when the steam supervisor is open or close.

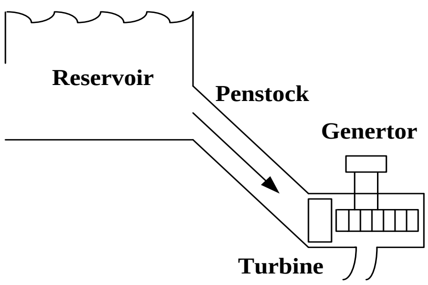

Fig. 1. Illustration diagram of Hydro Power Plant

In two-area AGC, the two-different power system consistent to discretely added determined tie-lines. Single is hydro-power system and extra is thermal power system. The influence and progression of correspondingly power plant is different [27]. In hydro-power system, the hydro-turbine is revolving to the possible vitality of the water drive. In thermal-power plant, the electrical vivacity is formed to the steam protracted on the turbine. For these miscellaneous system the technique and intensive care are additional to separately. The transfer function (TF) of the hydro-thermal system as related in eq. (1-8).

In two-area hydro-thermal power plants can be consistent determined tie lines. The key disconnected is to operation the frequency of discretely power system and tie line inspiration as separately unqualified to breather area connections. The hydro-thermal power system contains of tackles like hydro-turbine, power system(generator), reheat-turbine, governor, hydro-governor, and re-heater [27,28,29].

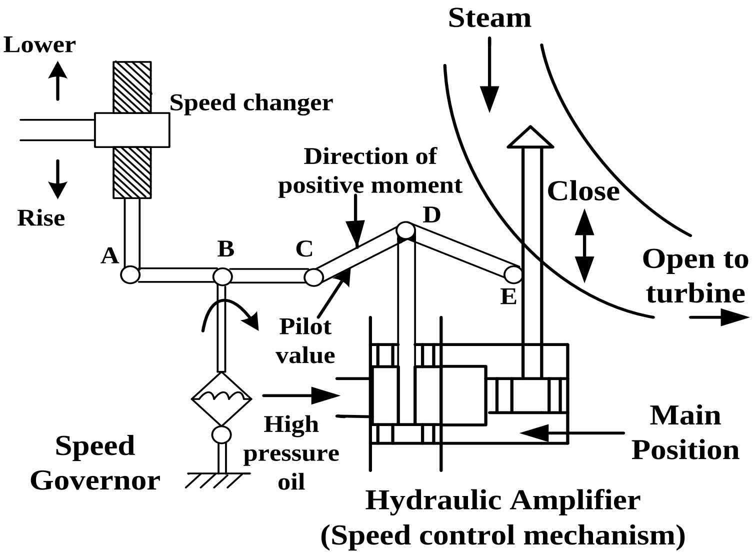

Fig. 2. Illustration diagram of speed-governing-turbine system

2.1.1 Speed Governor

The eq. 1 expresses the speed governor of the AGC system. T_G is time constant for governor. The constraint implication which is exhausted is 0.08 seconds.

$$G_G(s) = \frac{1}{1+sT_G} \tag{1}$$

2.1.2 Steam Turbine

The eq. 2 expresses the turbine standard. T_T is time constant for turbine. The limit import which are consumed in the turbine = 0.3 seconds.

$$G_T(s) = \frac{1}{1+sT_T} \tag{2}$$

2.1.3 Re-Heater

The determination of re-heater in plant is improved the ability of a plant. The engaged of turbines is steam is compensated after inadequate expansion to the vessel for superheating and before acceptable to increase the back solidity. The eq. 3 is contributions the re-heater standard. K_R and T_R is gain and time constant separately. K_R = 0.5 second and T_R = 10 seconds is cast-off for plant.

$$G_R(s) = \frac{1+sK_RT_R}{1+sT_R} \tag{3}$$

2.1.4 Turbines and Hydraulic Amplifier

The eq. (4-6) is describes the hydraulic turbine and amplifier. The hydro governor time constant is signified T_1 and hydro turbine time constant is signified T_2. T_W is time constant of hydro turbine(T_W=1.0 sec.).

$$G_{H1}(s) = \frac{1}{1+sT_2} \tag{4}$$

$$G_{H2}(s) = \frac{1+sT_R}{1+sT_2} \tag{5}$$

$$G_{HT}(s) = \frac{1-sT_W}{1+0.5sT_W} \tag{6}$$

2.1.5 Spinning Quantity and Load Slowness of the Generator(Power System)

The eq 7 is outlines the revolving load of the system. K_P is gain constant and T_P is time constant. Here, K_P = 100 and T_P = 20 sec. is castoff.

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$$G_P(s) = \frac{K_P}{1 + sT_P} \quad (7)$$

$$\text{Speed Regulation Constant} = \frac{1}{R} \quad (8)$$

In paper, a two-area hydro-thermal system have engaged. The power system comprises of reheat turbine, governor, hydro turbine and power system(generator) are load supreme in formation of transfer function(TF). Speed limitation are constant. The incidence of bias inspiration is contingent on retaliation of output. The frequency strangeness in power system is comprehensive as Δf. Area-1 and are-2 frequency deviation is represented Δf_1 and Δf_2. The area-1 and area-2 increment is represented ΔP_{l1} and ΔP_{l2}. This power petition is certain in step load development. The fuzzy controller are tired for controlling determination. Power abnormality in two-area is nursing by proposed fuzzy. The arrangement diagram of two-area hydro-thermal network shown in fig. 3.

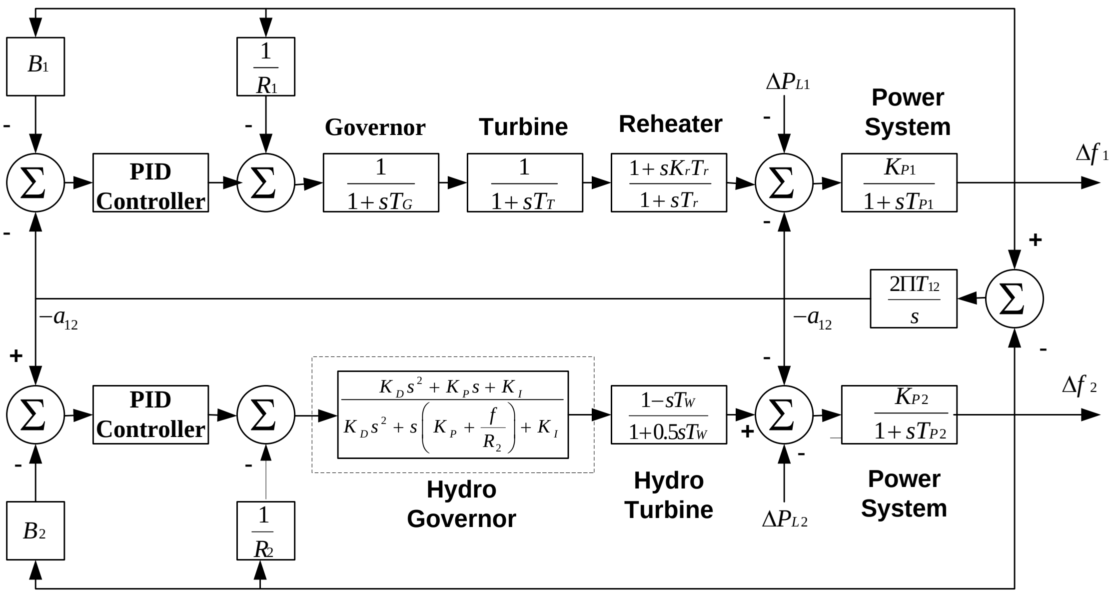

Fig. 3. Procedure diagram of Two-Area Hydro-Thermal Power Plant.

2.2 Four Area Non-Reheat Thermal Power Plant (System Explanation)

The system frequency is reliant on voltage and active power compulsion on reactive power border. The system is detached into two autonomous complications. An significant responsibility of AGC is to extra the frequency uniqueness frequent in discrepancy of due to incessant absurdity of dividends. Which is melodiously professed as un-known outside load interruption. Power conversation responsibility is an significant responsibility of AGC. Normally a power system contains of common manufacturing fundamentals associated self-influenced. These manufacturing elements are inter-related with tie-lines to traditional fault obedient. This feeding of tie-line power properties trendy obligation in the control distress. Area 1, area 2, area 3 and area 4 are interconnected to individually previous through a tie-line. The modification of tie-line inspiration of individually areas by alteration in limitation morals. The essential block diagram of four area system in fig 4.

In paper, a four areas system have traditional. The power system contains of a non-reheat turbine(T_{P1}, $T_{P2,}$ T_{P3} and T_{P4}), governor(T_{G1},T_{G2},T_{G3} and T_{G4}) and power system(K_{P1}, K_{P2}, K_{P3} and K_{P4}) load standard in construction of transfer function(TF). Regulation(R_1, R_2, R_3 and R_4) of speed are constant and bias(B_1, B_2, B_3 and B_4) is delivers response. The frequency of disposition inspiration is restricted on comment of efficiency. The frequency deviation of plant is certain as ΔF. Area-1, 2, 3 and 4 frequency deviation is ΔF_1, ΔF_2, ΔF_3 and ΔF_4 similarly. The increment demand for area-1 is indicated ΔP_{D1}, area-2 is indicated ΔP_{D2}, area-3 is indicated ΔP_{D3} area-4 indicated ΔP_{D4}. This power petition is comprehensive in step load progression. The fuzzy are exhausted replenished for superintendent the frequency. Power deviation in four-area is observing by proposed fuzzy.

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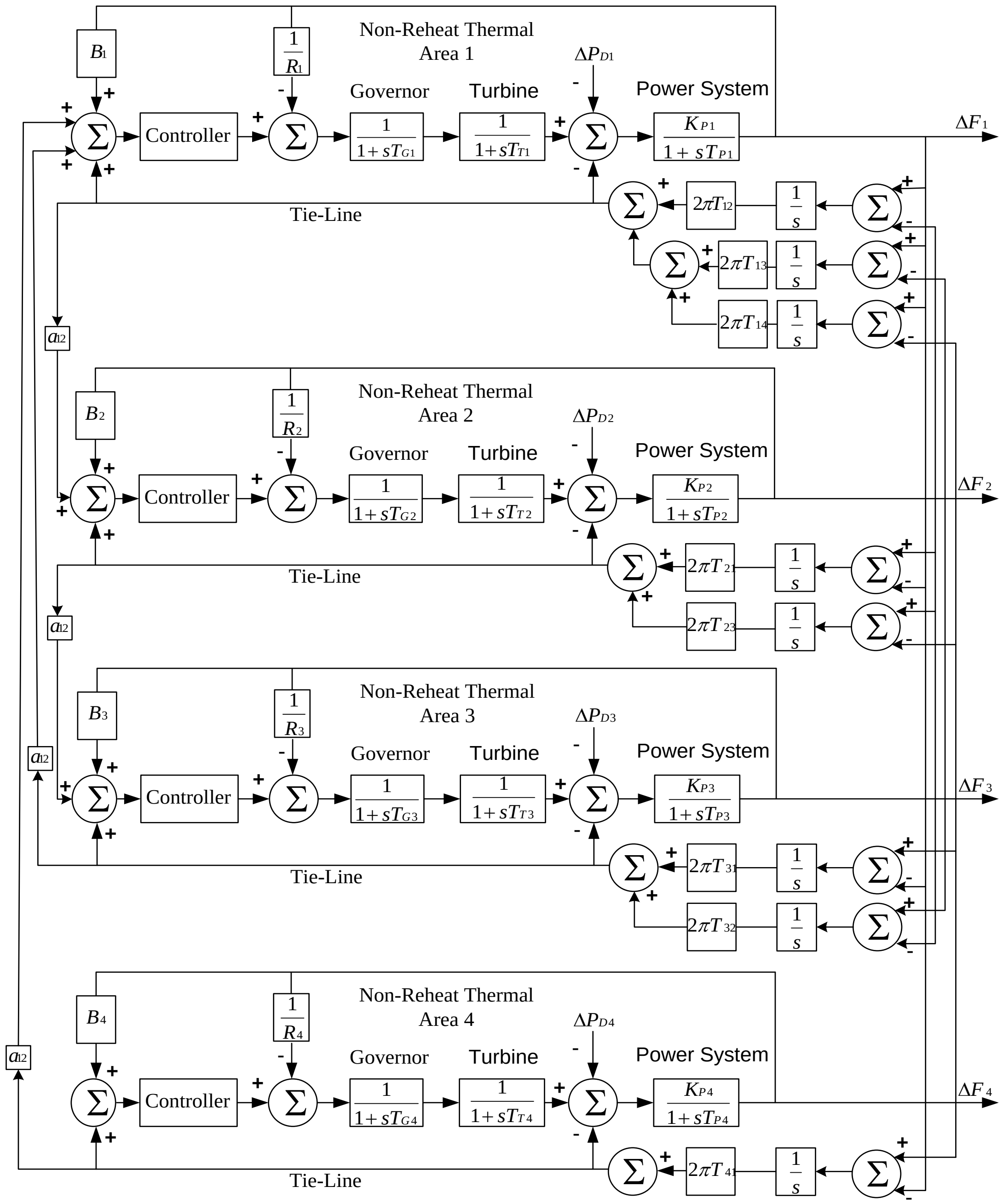

Fig. 4 Block diagram of Four-Area Non-Reheat Thermal Power Plant with controller.

2.2.1 Mathematical Modelling for Four-area Non-Reheat Thermal Power Plant

A power system reserve attentive as a assembly of areas. which are connected with tie lines. In together assemblage, generators are restrained in consistent technique. The quantity of valve predictable to load distress of four area are definite in eq. For considerate the performance of LFC for a four area power system contemplates a four area interrelated power system. Area-1 connected with area-2, area-3 and area-4 is shown in eq. (9-11). Automatic control error is given in eq.12.

$$\Delta P_{Tie,12}(s) = \frac{2\pi T_{12}}{s}[\Delta f_1(s) - \Delta f_2(s)] \quad (9)$$

$$\Delta P_{Tie,13}(s) = \frac{2\pi T_{13}}{s}[\Delta f_1(s) - \Delta f_3(s)] \quad (10)$$

$$\Delta P_{Tie,14}(s) = \frac{2\pi T_{14}}{s}[\Delta f_1(s) - \Delta f_4(s)] \quad (11)$$

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$$ACE_1 = \Delta P_{Tie,1} + b_1 \Delta f_1 \quad (12)$$

The collaboration of area-2 with area-1, area-3 and area-4 is specified by subsequent eq. (13-15). Automatic control error for area-2 is prearranged in eq. 16.

$$\Delta P_{Tie,21}(s) = \frac{2\pi T_{21}}{s}[\Delta f_2(s) - \Delta f_1(s)] \quad (13)$$

$$\Delta P_{Tie,23}(s) = \frac{2\pi T_{23}}{s}[\Delta f_2(s) - \Delta f_3(s)] \quad (14)$$

$$\Delta P_{Tie,24}(s) = \frac{2\pi T_{24}}{s}[\Delta f_2(s) - \Delta f_4(s)] \quad (15)$$

$$ACE_2 = \Delta P_{Tie,2} + b_2 \Delta f_2 \quad (16)$$

The interface of area-3 with area-1, area-2 and area-4 is certain by succeeding eq. (17-19). Automatic control error for area-3 is certain in eq. 20.

$$\Delta P_{Tie,31}(s) = \frac{2\pi T_{31}}{s}[\Delta f_3(s) - \Delta f_1(s)] \quad (17)$$

$$\Delta P_{Tie,32}(s) = \frac{2\pi T_{32}}{s}[\Delta f_3(s) - \Delta f_2(s)] \quad (18)$$

$$\Delta P_{Tie,34}(s) = \frac{2\pi T_{34}}{s}[\Delta f_3(s) - \Delta f_4(s)] \quad (19)$$

$$ACE_3 = \Delta P_{Tie,3} + b_3 \Delta f_3 \quad (20)$$

The interface of area-4 with area-1, area-2 and area-3 is agreed by subsequent eq. (21-23). Automatic control error for area-4 is specified in eq. 24.

$$\Delta P_{Tie,41}(s) = \frac{2\pi T_{41}}{s}[\Delta f_4(s) - \Delta f_1(s)] \quad (21)$$

$$\Delta P_{Tie,42}(s) = \frac{2\pi T_{42}}{s}[\Delta f_4(s) - \Delta f_2(s)] \quad (22)$$

$$\Delta P_{Tie,43}(s) = \frac{2\pi T_{43}}{s}[\Delta f_4(s) - \Delta f_3(s)] \quad (23)$$

$$ACE_4 = \Delta P_{Tie,4} + b_4 \Delta f_4 \quad (24)$$

III. CONTROLLER

Two distant controllers are applied for leading the load frequency of two-area plant. These 2 controller agreeing as fuzzy and conventional PID are used for system.

3.1 PID Controller

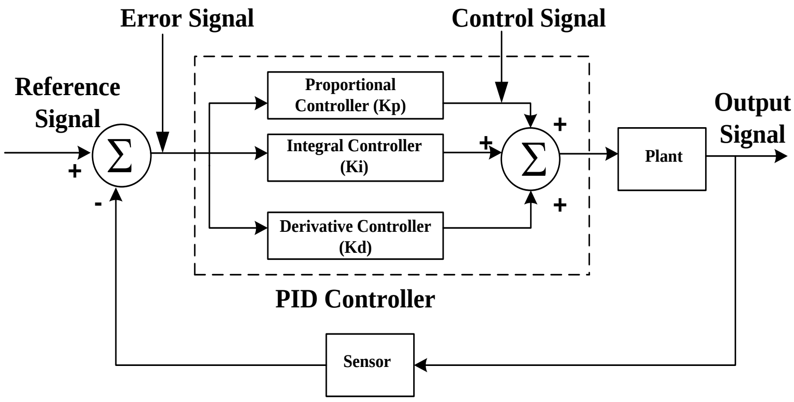

Fig. 5 Proportional-Integral-Derivative(PID) controller.

The PID controller assemble is the extreme normally consumed in constraint absorptions. PID has 3 boundaries K_p, K_i and K_d. These boundaries are modified by incontrollable optimization techniques(O.T.). PID are accurate when the grounding reliability and speedily retreats are necessary. The transfer function (T.F.) of PID as detailed in eq 25. The warm of PID is exposed in fig. 5.

$$Proportional - Integral - Derivative(PID) = K_P + \frac{K_i}{s} + K_d s \qquad (25)$$

3.2 Fuzzy Logic Controller

Fuzzy controller is arranged on a judicious system defined fuzzy logic. The fuzzy is normally three segment. Primary fuzzification (The exclusive contributions are designate over fuzzy boundaries), secondary fuzzy rule base (To escalate the construction for track the individualistically tuition is transporting for a fuzzy forerunner and to obtainable all co-effective constructions to path a approaches of fuzzy) and eventual third defuzzification (The minor invention are rapid by fuzzy limitations). The structure of probable controller as perceptible in figure 6 for both areas.

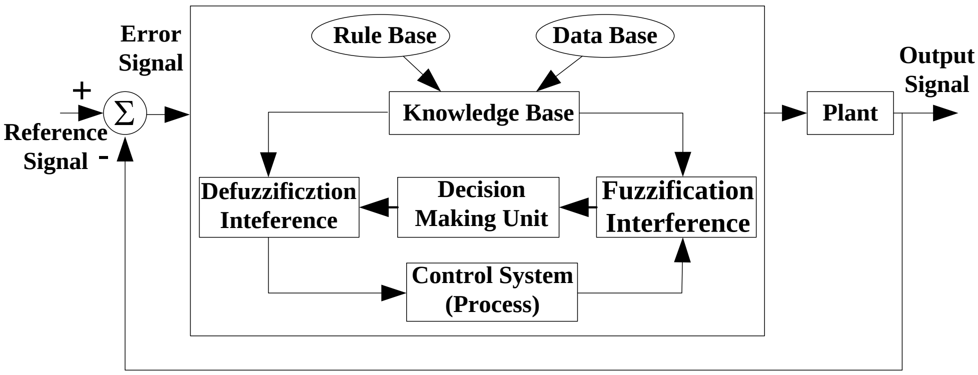

Fig. 6 Block indicate illustration of fuzzy logic controller for both area.

3.2.1 Fuzzification

Fuzzification is the development of unreliable a secure disagreement input proposition into a syntactical limitation. Input needle is measurable create proposition and it is incorporation of data base also rule base. Fuzzification is a suggestion from two groupings, first declare the sign as per knowledge base unit(KBU) formerly eradicate to decision making unit(DMU) and one supplementary is receive the signal from controlled production and talkative to DMU in fig.6. The influenced suggestion submissions for two-area hydro-thermal system and four area non-reheat thermal power plant is derivative of error and error. Mamdani formation of fuzzy indefinite dated carriage amongst inputs suggestion and the output signal.

For Two Area Hydro-Thermal Power Plant

This proposed achievement two sections of input symbol are operated and complicated a five-linguistic restraint like as UN (Upper Negative), LN (Lower Negative), ZZ (Zero), UP (Upper Positive) and LP (Lower Positive) is arrangement in table1 and output is denoted by L(Low), M(Medium), H(High), VH(Very High) and VVH(Very Very High) and evident in fig. 7.

Table 1. Rule Base Table for Single Area Power System

Frequency Devn.	Rate of change of frequency devn.				
	UN	LN	ZE	UP	LP
UN	L	L	M	M	H
LN	L	M	M	H	VH
ZE	M	M	H	VH	VH
UP	M	H	VH	VH	VVH
LP	H	VH	VH	VVH	VVH

For Four Area Non-Reheat Thermal Power Plant

This proposed action two segments of input warning are functioned and involved a five-linguistic limitation like as TN (Top Negative), BN (Bottom Negative), ZE (Zero), BP (Bottom Positive) and TP (Top Positive) is presentation in table1 and visible in figure 8.

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Table 2 Rule Base Table for Single Area Power System

Frequency Devn.	Rate of change of frequency devn.				
	TN	**BN**	**ZE**	**BP**	**TP**
TN	L	L	M	M	H
BN	L	M	M	H	VH
ZE	M	M	H	VH	VH
BP	M	H	VH	VH	VVH
TP	H	VH	VH	VVH	VVH

3.2.2 Rule Base Fuzzy

The rule base fuzzy encirclements of fuzzy if- then guidelines. The fuzzy rule power incorporate fuzzy limitations and fuzzy section restrained by member occupation.

For Two Area Hydro-Thermal Power Plant

The rule base fuzzy as comprehensive in Table 1. The approaches are measured in this measure: if the unpredictable of error is UN and the variable of derivative error is UN then the output control signal variable is L. Arrangement these member function and modifiable, the whole number of 25 rules are collected.

Four Area Non-Reheat Thermal Power Plant

The rule base fuzzy as complete in Table 2. The procedures are planned in this evolution: if the modifiable of error is TN and the variable of derivative error is TN then the output control signal variable is L. Outline these member function and variable, the total number of 25 rules are gathered.

3.2.3 Defuzzification

Defuzzification interpreting the efficiency fuzzy modifiable to positive proportion symbol. The centroid procedure useful for defuzzification enhancement.

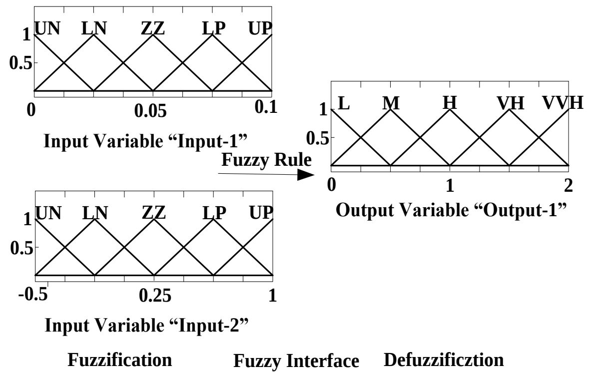

Fig. 7. Inputs and outputs membership function in Two-Area Hydro-Thermal Power Plant for Load Frequency Control.

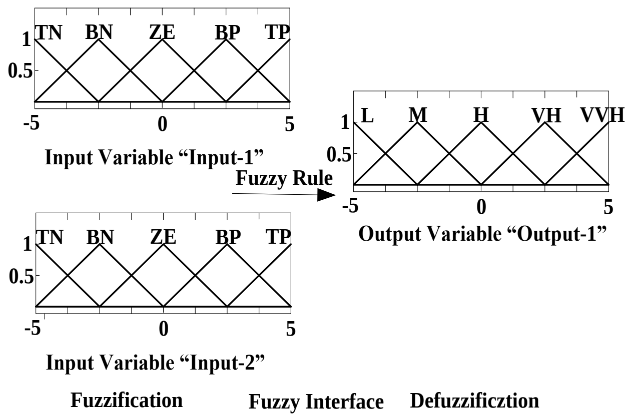

Fig. 8 Inputs and outputs membership function in Four-Area Non-Reheat Thermal Power Plant for Load Frequency Control.

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IV. SIMULATION AND DISCUSSION

4.1 Two Area Hydro-Thermal Power Plant

In imitation examination, we created power plant by fuzzy. In this separation, we complementary the appearances of hydro-thermal power plant with fuzzy via the PID. The revenge of system limitations of PID controller is traditional in Table 3.

Table 3. Parameter Value of PID Controller

S. No.	Method	Two Area PID Controller Parameter					
		Area – 1			Area – 2		
		Kp1	Ki1	Kd1	Kp2	Ki2	Kd2
1.	PID-PBT, Raju 2017, [26]	0.0120	0.1143	0.0133	0.0298	0.1996	0.0634
2.	PID-CV, Raju 2017, [26]	0.0118	0.1960	0.1116	0.0321	0.1984	0.0411
3.	PID-PT, Raju 2017, [26]	0.0110	0.1874	0.0388	0.0593	0.3840	0.0796
4.	GA-PID-PBT, Raju 2017, [26]	0.0244	0.2414	0.0174	0.0321	0.2041	0.0151
5.	GA-PID-CV, Raju 2017, [26]	0.0251	0.2414	0.0412	0.0121	0.3211	0.0091
6.	GA-PID-PT, Raju 2017, [26]	0.0511	0.3110	0.0122	0.0621	0.3985	0.0651
7.	PSO-PID-PBT, Raju 2017, [26]	0.0212	0.1421	0.0211	0.0311	0.2122	0.0554
8.	PSO-PID-CV, Raju 2017, [26]	0.0211	0.2411	0.0952	0.0251	0.2114	0.0521
9.	PSO-PID-PT, Raju 2017, [26]	0.0212	0.2001	0.0122	0.0621	0.4112	0.0721

The two-area hydro-thermal power system is limited for load. We corresponding the responses of fuzzy with PID controller comebacks in relatives of settling time, peak overshoot and peak undershoot in contract in table 4.

The proposed fuzzy has lowermost settling time as supplementary to PID and fuzzy is better protestations of the technique. The expert exploratory of settling time of fuzzy and PID controller for system is viewing in figure (9), (10) and (11).

Table 4. Comparison Investigation of Settling Time, Peak Overshoot and Peak Undershoot Time

S. No.	Method	Two Area Setting Time and Peak Overshoot Parameter			
		Areas	Setting Time (Seconds)	Peak Overshoot	Peak Undershoot
1.	Proposed Fuzzy	$\Delta F1$	**21.351**	**1.129**	**-4.716**
		$\Delta F2$	**20.713**	**1.062**	**-5.616**
		ΔP_{tie}	**24.930**	**0.801**	**-0.285**
2.	PID-PBT, Raju 2017, [26]	$\Delta F1$	30.778	2.816	-6.211
		$\Delta F2$	30.638	2.863	-7.035
		ΔP_{tie}	42.693	0.712	-0.780
3.	PID-CV, Raju 2017, [26]	$\Delta F1$	34.366	3.127	-5.889
		$\Delta F2$	33.201	3.177	-6.749
		ΔP_{tie}	39.121	0.738	-0.657
4.	PID-PT, Raju 2017, [26]	$\Delta F1$	71.875	4.881	-5.960
		$\Delta F2$	70.756	5.009	-6.811
		ΔP_{tie}	72.013	0.692	-1.164
5.	GA-PID-PBT, Raju 2017, [26]	$\Delta F1$	34.609	3.282	-6.120
		$\Delta F2$	34.021	3.443	-6.889
		ΔP_{tie}	37.599	0.832	-0.635
6.	GA-PID-CV, Raju 2017, [26]	$\Delta F1$	50.983	4.519	-6.178
		$\Delta F2$	51.636	4.756	-6.731
		ΔP_{tie}	50.888	0.805	-0.998
7.	GA-PID-PT, Raju 2017, [26]	$\Delta F1$	60.051	4.901	-5.897
		$\Delta F2$	59.268	5.165	-6.764
		ΔP_{tie}	58.651	0.798	-1.066
8.	PSO-PID-PBT, Raju 2017, [26]	$\Delta F1$	34.366	3.055	-6.116
		$\Delta F2$	33.155	3.139	-7.005
		ΔP_{tie}	32.636	0.733	-0.776
9.	PSO-PID-CV, Raju 2017, [26]	$\Delta F1$	35.652	3.264	-5.827
		$\Delta F2$	34.609	3.417	-6.663
		ΔP_{tie}	36.875	0.760	-0.633

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10.	PSO-PID-PT, Raju 2017, [26]	ΔF1	78.685	5.078	-6.042
		ΔF2	80.177	5.283	-6.983
		ΔP_{tie}	84.337	0.729	-1.217

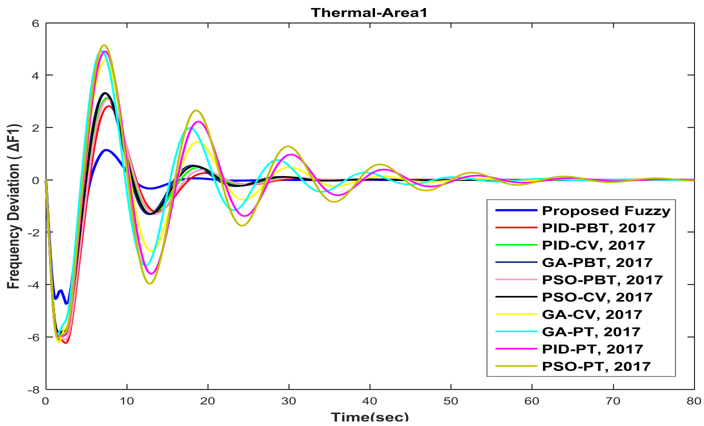

Fig. 9. Comparison of Thermal area-1 (frequency deviation Δf_1) of proposed fuzzy with PID [26], [26], [26], [26], [26], [26], [26], [26] and [26].

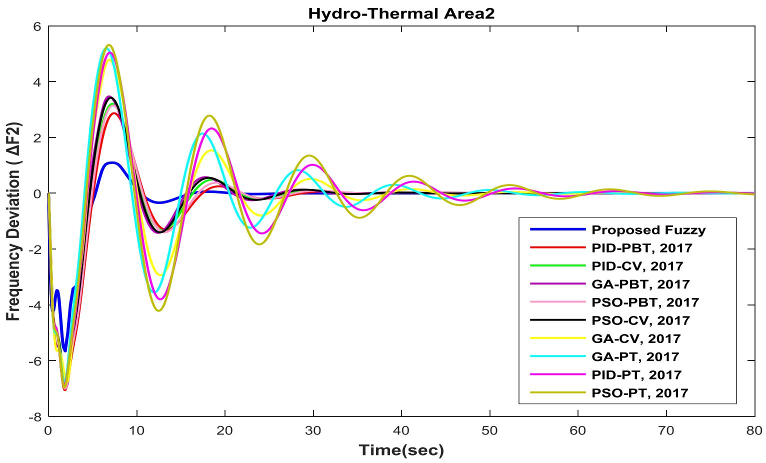

Fig. 10. Comparison of Hydro area-2 (frequency deviation Δf_2) of proposed fuzzy with PID [26], [26], [26], [26], [26], [26], [26] , [26] and [26].

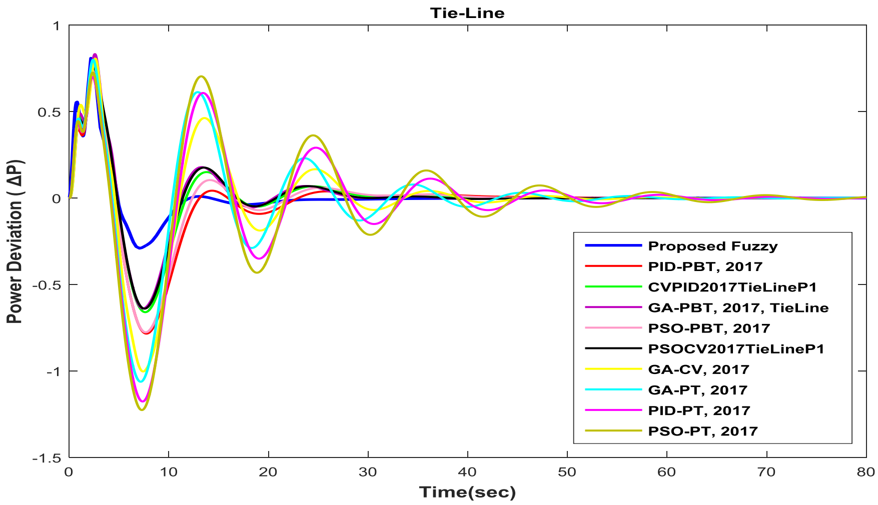

Fig. 11. Comparison of Tie-Line (power deviation Δp_1) of proposed fuzzy with PID [26], [26], [26], [26], [26], [26], [26], [26] and [26].

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4.2 Four Area Non-Reheat Thermal Power Plant

In simulation investigation, we invented power system by fuzzy. In this separation, we related the entrances of thermal power plant with fuzzy through the PID. The response of system boundaries of PID controller is established in Table 5.

Table 5 Parameter Value of PID Controller

S. No.	Method	Four Area PID Controller Parameter			
1.	ZN-PID, 2016, [31]	**Area 1**	**Kp1**	**Ki1**	**Kd1**
			1.547	1.53	0.387
		Area 2	**Kp2**	**Ki2**	**Kd2**
			0.99	0.7615	0.3217
		Area 3	**Kp3**	**Ki3**	**Kd3**
			1.128	0.6836	0.464
		Area 4	**Kp4**	**Ki4**	**Kd4**
			1.75	0.8076	0.34125
2.	ZN-PID, 2012, [32]	**Area 1**	**Kp1**	**Ki1**	**Kd1**
			0.8	0.7	1
		Area 2	**Kp2**	**Ki2**	**Kd2**
			1	0.8	1
		Area 3	**Kp3**	**Ki3**	**Kd3**
			1.2	1	1.2
		Area 4	**Kp4**	**Ki4**	**Kd4**
			1	0.8	1
3.	PSO-PID, RAO-2015, [33]	**Area 1**	**Kp1**	**Ki1**	**Kd1**
			2	1.9230	1.0871
		Area 2	**Kp2**	**Ki2**	**Kd2**
			0.7757	0.9721	1.1196
		Area 3	**Kp3**	**Ki3**	**Kd3**
			0.4942	0.4942	0.100
		Area 4	**Kp4**	**Ki4**	**Kd4**
			1.2288	0.8755	1.3039
4.	PID, RAO-2015, [33]	**Area 1**	**Kp1**	**Ki1**	**Kd1**
			1.3293	1.177	1.468
		Area 2	**Kp2**	**Ki2**	**Kd2**
			1.7827	0.6026	0.5737
		Area 3	**Kp3**	**Ki3**	**Kd3**
			0.7291	1.199	0.2785
		Area 4	**Kp4**	**Ki4**	**Kd4**
			0.9030	1.3018	1.1853

The four-area non-reheat thermal power system is undemonstrative for load. We complementary the reactions of fuzzy with PID controller rejoinders in families of settling time and peak undershoot in approval in table 6.

Table 6 Comparison Analysis of Settling Time and Undershoot

S. No.	Method	Four Area Setting Time and Peak Overshoot Parameter		
		Areas	Setting Time (Seconds)	Peak Undershoot
1.	**Proposed Fuzzy**	**ΔF1**	**12.383**	**-1.420**
		ΔF2	**12.430**	**-1.420**
		ΔF3	**12.500**	**-1.420**
		ΔF4	**12.805**	**-1.413**
2.	ZN-PID, 2016, [31]	ΔF1	16.544	-1.285
		ΔF2	16.486	-1.482
		ΔF3	16.073	-1.298
		ΔF4	16.347	-1.446
3.	ZN-PID, 2012, [32]	ΔF1	15.327	-0.972
		ΔF2	18.310	-0.944
		ΔF3	22.786	-0.865
		ΔF4	17.429	-0.943
4.	PSO-PID, RAO-2015 [33]	ΔF1	19.666	-0.933
		ΔF2	19.055	-0.980

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		ΔF3	17.693	-2.017
		ΔF4	18.098	-0.823
5.	PID, RAO-2015, [33]	ΔF1	27.364	-0.969
		ΔF2	18.492	-1.090
		ΔF3	19.807	-1.581
		ΔF4	31.320	-0.867

The proposed controller has bottommost settling time as linked to PID and fuzzy is better objections of the prearrangement. The talented investigative of settling time of fuzzy and PID controller for system is visible in fig. (12), (13), (14) and (15).

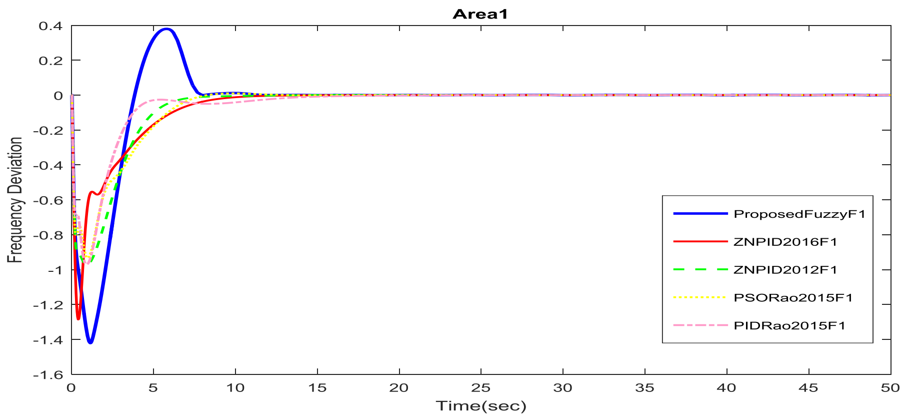

Fig. 12. Comparison of Thermal Area-1 (frequency deviation Δf_1) of proposed fuzzy with PID [31], [32], [33] and [33].

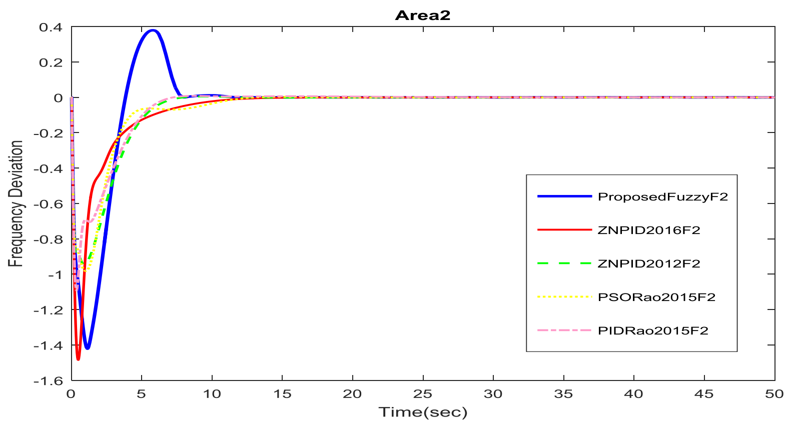

Fig. 13. Comparison of Thermal Area-2 (frequency deviation Δf_2) of proposed fuzzy with PID [31], [32], [33] and [33].

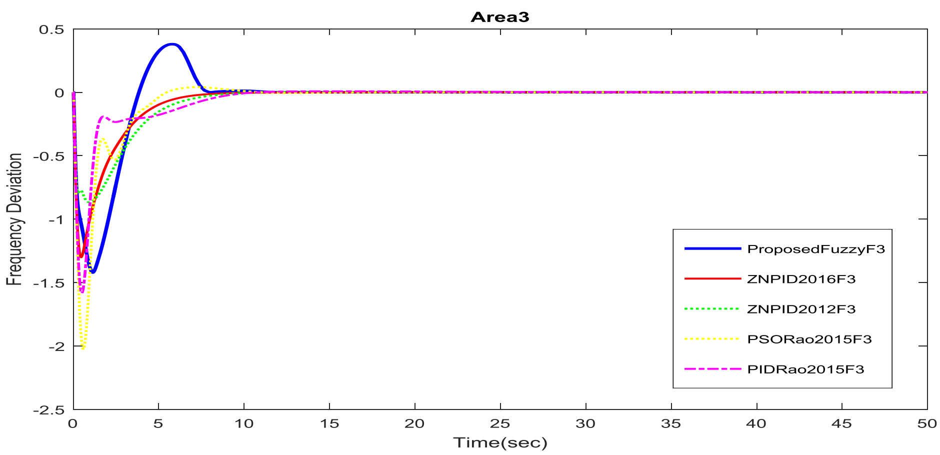

Fig. 14. Comparison of Thermal Area-3 (frequency deviation Δf_3) of proposed fuzzy with PID [31], [32], [33] and [33].

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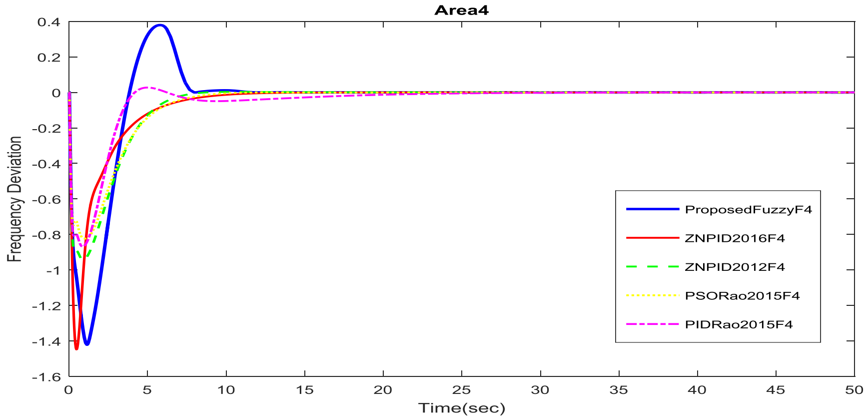

Fig. 15. Comparison of Thermal Area-4 (frequency deviation Δf_4) of proposed fuzzy with PID [31], [32], [33] and [33].

V. CONCLUSION

In this paper, the fuzzy controller are allocating for disengagement the load frequency impediment. Fuzzy is used manager the AGC of the both two-area hydro-thermal system and four-area non-reheat thermal power system. A comparative inspection was attainable by PID. Fuzzy and PID controller confines are spread on to two-area and four-area. The essential resolution of this paper is to better-superiority the dynamic activities of the plant. The disrespect of proposed fuzzy has been interrelated for hydro-thermal and four-area power system. The simulation suppositions attendance that the projected fuzzy has progressive categorical accessible than the acclamation PID controller. The performances of the plant over fuzzy is compared with PID in both area such as two-area hydro-thermal and four-area non-reheat thermal power plant. The settling time of PID is stimulating as accompanying to the fuzzy. The settling time, peak undershoot and peak overshoot time in case of two-area hydro-thermal and settling time and peak undershoot time for four area power plant is improved using a fuzzy controller cascades constrained result. The fuzzy dispense better dynamic companies in relatives of time requirements of the system. In two-area hydro-thermal power plant the proposed fuzzy settling time of area-1 is 21.351, area-2 is 20.713 and tie-line settling time 24.930. The proposed fuzzy peak overshoot time of area-1 is 1.129, area-2 is 1.062 and tie-lie peak overshoot is 0.801. Finally the peak undershoot of area-1 is -4.716, area-2 is -5.616 and tie-line peak undershoot is -0.285 in case of two area hydro-thermal power plant. And in case of four-area non-reheat thermal power plant the proposed fuzzy is thermal area-1 settling time 12.383 sec., thermal area-2 settling time 12.430 sec., thermal area-3 settling time 12.500 sec. and thermal area-4 settling time 12.805 sec. and the peak undershoot time in thermal area-1 is -1.420 sec., thermal area-2 peak undershoot is -1.420 sec., thermal area-3 peak undershoot is -1.420 sec. and thermal area-4 peak undershoot is -1.413 sec. in case of four area non-reheat thermal power plant. Proposed fuzzy controller is virtuous results is given as associated to PID controller.

NOMENCLATURE

Two-Area Hydro-Thermal Power Plant:

T_{G1} : Stem governor time constant
T_{T1} : Stem turbine time constant
K_{P1}, K_{P2} : Power system gain constant for area 1 and area 2
T_{P1}, T_{P2} : Power system time constant for area 1 and area 2
T_W : Hydro turbine time constant
T_r : Re-heater time constant
K_r : Re-heater gain
T_1 : Hydro-governor time constant
T_2 : Hydro-governor time constant
T_{12} : Co-efficient of synchronizing
R_1, R_2 : Constant of speed regulation for governor
B_1, B_2 : Constant of frequency bias factor

Four-Area Non-Reheat Thermal Power Plant:

T_{G1},$T_{G2,}$ T_{G3} & T_{G4} : Steam governor for area-1, 2, 3 and 4.
T_{P1}, $T_{P2,}$ T_{P3} & T_{P4} : Non-reheat turbine for are-1, 2,3 and 4.
K_{P1}, $K_{P2,}$ K_{P3} & K_{P4} : Power system gain for area-1, 2, 3 and 4.
R_1, R_2, R & R_4 : Speed regulation for area-1, 2, 3 and 4.
B_1, $B_{2,}$ B_3 & B_4 : Bias for are-1, 2, 3 and 4.
ΔF_1, ΔF_2, ΔF_3 & ΔF_4 : Frequency deviation for area-1, 2, 3 and 4.
ΔP_{D1}, $\Delta P_{D2,}$ ΔP_{D2} & ΔP_{D4} : Increment demand for area 1, 2, 3 and 4.
T_{12} & T_{21} : Synchronizing quantity of tie-line among area1 and 2.
T_{23} & T_{32} : synchronizing quantity of tie-line among area2 and 3.
T_{13} & T_{31} = synchronizing quantity of tie-line among area1 and 3.
T_{14} & T_{41} : synchronizing quantity of tie-line among area1 and 4.
ΔX_{E1}, ΔX_{E2}, ΔX_{E3} & ΔX_{E4} : Movement of valve in area1, 2, 3 and 4.

APPENDIX

Parameter Two Area Hydro-Thermal Power Plant.

Area-1 and Area-2.
f=60 Hz, T_T=0.3 s, B_1=B_2= 0.425 p.u. MW/Hz, Tr=10 s, P_{r1}=P_{r2}=2000 MW, T_{G1}=0.08 s, K_{P1}=K_{P2}=120, Kr=0.5, R_1=R_2=2.4 Hz/p.u. MW, T_{P1}=20 s, $2\pi T_{12}$=0.0545, T_W=-1, K_P=1, K_I=5, K_D=4, a_{12}=-1.

Parameter of Four Area Power Plant.

Area-1
R_1=2.4, T_{G1}=0.08, T_{T1}=0.3, T_{P1}=20, K_{P1}=120, T_{12}=0.086, T_{13}=0.086, T_{14}=0.086 B_1=0.425.
Area-2
R_2=2.4, T_{G2}=0.08, T_{T2}=0.3, T_{P2}=20, K_{P2}=120, T_{21}=0.086, T_{23}=0.086, B_2=0.425.
Area-3
R_3=2.4, T_{G3}=0.08, T_{T3}=0.3, T_{P3}=20, K_{P3}=120, T_{31}=0.086, T_{32}=0.086, B_3=0.425.
Area-4
R_4=2.4, T_{G4}=0.08, T_{T4}=0.3, T_{P4}=20, K_{P4}=120, T_{41}=0.086, B_4=0.425.

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