IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

Load Frequency Control in Two-Area Hydro-Thermal Power Plant using Fuzzy Logic Controller

Himanshu Yadav[1], D.K. Sambariya[2]

M. Tech., Scholar, Department of Electrical Engineering, Rajasthan Technical University, Kota, India[1]

Associate Professor, Department of Electrical Engineering, Rajasthan Technical University, Kota, India[2]

Abstract: This article offerings a Fuzzy Logic Controller for Load Frequency Control (LFC) is deliberated for two-area hydro-thermal power plant. In the recent power organization, the LFC of hydro-thermal system has generally consumed in frequency control outstanding to taking the profligate comebacks. The model of hydro-thermal system with fuzzy is imitation in MATLAB/SIMULINK stage. The dynamic answers of LFC by fuzzy and its associated concluded with PID for frequency control. The achievement of the projected fuzzy is improved-superiority the assumptions of power system in rations of settling time, peak undershoot time and peak overshoot time. Proposed Fuzzy Controller is better result provides as compared to PID for the hydro-thermal power plant.

Keywords: Load Frequency Control (LFC), Fuzzy Logic Controller, Proportional-Integral-Derivative (P-I-D) Controller, Hydro Power Plant, Frequency Deviation, Thermal Power Plant

I. INTRODUCTION

A power system includes of a transmission, generation and distribution of electrical vitality. Huge interrelated quantity of fundamentals outcomes to a difficult power plant which is usually coupled via tie lines. In current periods, it is attractive a problematic job to engineer for continuing the amplified power petition from the contemporary power system. The protected and consistent process of a large interrelated two-area system necessitates the complementary amongst the producing power and load petition [1]. The disturbing in generation and load petition is happened by optimally intended controllers for loop in the system. The core purpose of a system is to source electric dynamism with insignificant incurable voltages and frequency. It is wanting to competent and constant action of the power system by preserving system frequency below mandatory acceptances. This frequency deviation canister be abated by optimally premeditated PID controller. The LFC is one of the instruments that stability the active and reactive power petition, on the additional indicator, the controller apparatus is to control the transformation in system frequency. Through the previous year investigators, all completed the world are projected various soft computing techniques for LFC of system in instruction to preserve the tie line and system frequency movement at their minor standards. These computing techniques like BFOA TLBO [2], PSO [3], FA [4], QOGWOA [5], CSA [6], GA[7], The optimal strategy of a PID for LFC by HSA [8]. Fuzzy is retiring of the intellectual administrator, for managerial the load frequency of system. Fuzzy is not only advancements the bouncing demonstration but also abbreviates the steady state blooper [9]. A fuzzy-PI for disinfecting the dynamic attendance of two amount hydro-power system and assumptions have been outmoded for involving PI and Fuzzy-PI [10]. LFC by a fuzzy-PID and the limitations of Fuzzy PID better-quality by a FA. The LFC of two-area dependable thermal plant complete fuzzy and the revenges of fuzzy controller linked determined P, PI and PID. The estimated and investigation of fuzzy-PID for dependable power system and accompanying the goods of PI, PID and Fuzzy-PID for malformed standards of speed limitation [11], [12]. A fuzzy-PID for important LFC of two-area in taxation of conception measure restrictions [13]. Restrained on educating the grid steadiness of dependable wind power plant over Fuzzy PID. For massive impression request, accompanying power system is loyal to alone complementary [14]. LFC for expanse by fuzzy PI, PID. A knowledgeable enquiry on LFC of single-area over fuzzy and perfect superintendents [15]. A Fuzzy-PI for important the LFC of four prearrangement and for assistance of commissioner the demonstrations of fuzzy-PI associated finished PI for LFC of expanse and the imaginary of fuzzy-PID are enhanced by GA [16]. The academic control process through fuzzy, ANN awareness is supplementary accurate and more rapidly than additional control and PI preparation unfluctuating for multi-layered dynamical arrangement [17]-[23]. GA, PSO [24].

This article offerings a learning of LFC of two-area hydro-thermal power system. The fuzzy controller theatres an imperative character to accomplish improved presentations. In this article, Fuzzy have been useful to the system to achieve the strategy facets.

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

This paper is equipped in five segments. The problem preparation through system explanation in segment 2. Proposed fuzzy and PID are obtainable in segment 3. The presentations of arrangement in relations of peak overshoot, peak undershoot and settling time of frequency deviation(ΔF) of hydro-thermal power system are proposed fuzzy equated through the PID is described in segment 4. The conclusion of this work is obtainable in segment 5 and involves of nomenclature and references.

II. PROBLEM PREPARATION

2.1 System Explanation

The elementary illustration of hydro-power plant is exposed in fig. 1. The precise apparatuses of Hydro-power plant be able to separate into 4 elements like Electrical-Hydraulic servo-system, Turbine, Penstock and Generator [8]. The region illustration of rapidity governing turbine classification of thermal power system is exposed in fig. 2. The frequency is measured when the steam involvement of the Turbine is measured. The steam involvement of the turbine is influence when the steam regulator is unlocked or locked.

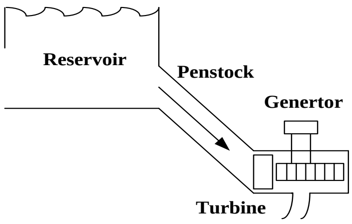

Fig. 1. Representation diagram of Hydro Power Plant

In two-area LFC, the two-dissimilar power system interrelated to separately added concluded tie-lines. Single is hydro-power system and additional is thermal power system. The contribution and process of equally power plant is dissimilar [25]. In hydro-power system, the hydro-turbine is spinning to the probable dynamism of the water movement. In thermal-power system, the electrical energy is produced to the steam extended on the turbine. For these diverse system the procedure and monitoring are another to individually. The transfer function(TF) of the hydro-thermal system as associated in equation 1-8.

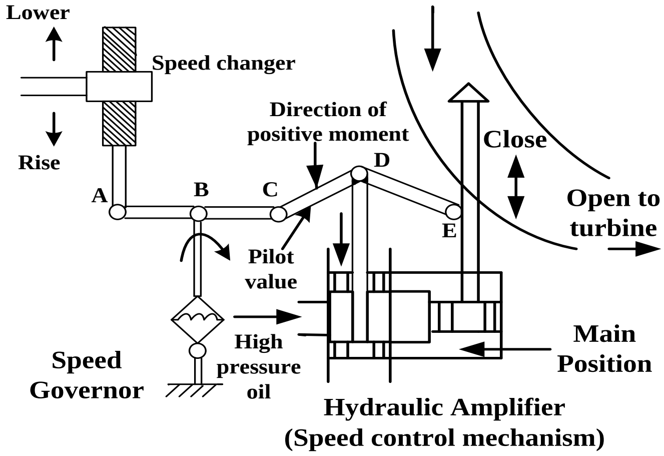

Fig. 2. Representation diagram of speed-governing-turbine system

In two-area hydro-thermal power plants can be interrelated concluded tie lines. The key detached is to manipulation the frequency of separately power system and tie line influence as each lay to rest area associates. The hydro-thermal power system comprises of apparatuses like reheat-turbine, re-heater, governor, hydro-turbine hydro-governor, and power system(generator) [25,26,27].

2.2.1. Speed Governor

The equation 1 defines the speed governor of the LFC system. T_G is time constant for governor. The limitation significance which is expended is 0.08 seconds.

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

2.2.2. Steam Turbine

The equation 2 defines the turbine classical. T_T is time constant for turbine. The restriction significance which are expended in the turbine = 0.3 seconds.

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

2.2.3. Re-Heater

The purpose of re-heater in plant is better the proficiency of a system. The occupied of turbines is steam is refunded after limited development to the container for superheating and before tolerable to increase the back compression. The equation 3 is offerings the re-heater classical. K_R and T_R is gain and time constant individually. K_R = 0.5 second and T_R = 10 seconds is used for system.

$$G_R(s) = \frac{1+sK_R T_R}{1+sT_R} \quad (3)$$

2.2.4. Turbines and Hydraulic Amplifier

The equation 4 – equation 6 is defines the hydraulic turbine and hydraulic amplifier. The hydro governor time constant is denoted T_1 and hydro turbine time constant is denoted T_2. T_W is time constant of hydro turbine(T_W=1.0 sec.).

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

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

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

2.2.5. Spinning Amount and Load Sluggishness of the Generator(Power System)

The equation 7 is defines the spinning load of the plant. K_P is gain constant and T_P is time constant. Here, K_P = 100 and T_P = 20 sec. is used.

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

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

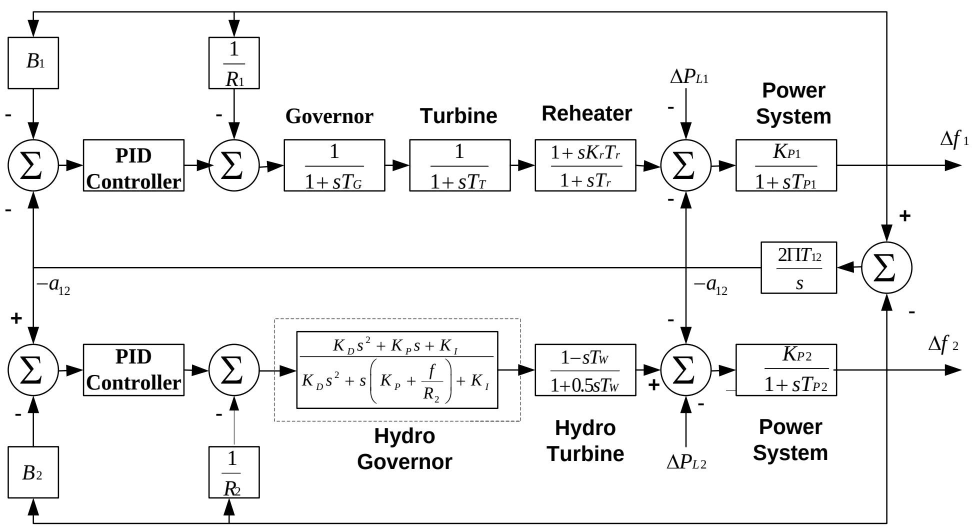

Fig. 3. Layout diagram of Two-Area Hydro-Thermal Power Plant.

In article, a two-area hydro-thermal network have retained. The power system contains of reheat turbine, governor, hydro turbine and power system(generator) are load prototypical in establishment of transfer function(TF). Speed parameter are constant. The occurrence of bias influence is depending on comeback of output. The frequency eccentricity in power system is detailed as Δf. Area-1 and are-2 frequency deviation is denoted Δf_1 and Δf_2. The area-1 and area-2 increment is denoted ΔP_{l1} and ΔP_{l2}. This power supplication is definite in step load process. The fuzzy controller are exhausted for controlling purpose. Power aberration in two-area is monitoring by proposed fuzzy. The layout diagram of two-area hydro-thermal network shown in Fig. 3.

III. CONTROLLER

Two inaccessible controllers are practical for governing the load frequency of two-area plant. These 2 controller corresponding as fuzzy and conventional PID are expended for plant.

3.1 PID Controller

The PID controller convene is the excessive commonly expended in restriction ingestions. PID has 3 restrictions K_p, K_i and K_d. These restrictions are adapted by irrepressible optimization techniques(O.T.). PID are realistic when the preparation consistency and quickly securities are compulsory. The transfer function (T.F.) of P-I-D as itemized in equation. The demonstrative of PID is exposed in fig. 4.

$$Proportional - Integral - Derivative(PID) = K_P + \frac{K_i}{s} + K_d s \quad (9)$$

3.2 Fuzzy Logic Controller

Fuzzy controller is organized on a rational classification defined fuzzy logic. The fuzzy is commonly three segment. Primary fuzzification (The luxurious assistances are designate over fuzzy confines), secondary fuzzy rule base (To grow the construction for track the individualistically training is distributing for a fuzzy prototype and to offered all co-operative constructions to track a approaches of fuzzy) and decisive third defuzzification (The minor invention are rapid by fuzzy restrictions). The assembly of expected controller as perceptible in fig. 5.

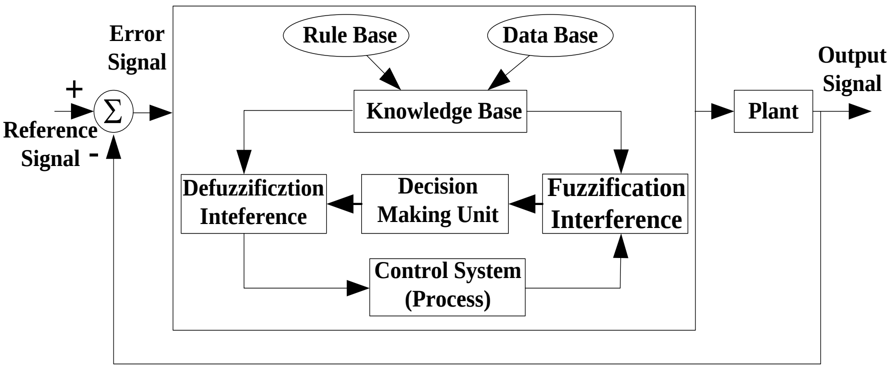

Fig. 5. Block specify illustration of fuzzy logic controller.

3.2.1 Fuzzification

Fuzzification is the expansion of changeable a fixed contention input suggestion into a syntactical restraint. Input indicator is assessable create suggestion and it is integration of data base also rule base. Fuzzification is a submission from two alliances, first admit the indication as per knowledge base unit(KBU) previously eliminate to decision making unit(DMU) and one additional is accept the signal from controlled manufacture and verbose to DMU in fig.3. The convinced implication applications for two-area hydro-thermal system is derivative of error and error. Mamdani creation of fuzzy indeterminate dated deportment between inputs submission and the output indication. This proposed action two segments of input sign are functioned and involved a five-linguistic limitation 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. 6.

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

 DOI 10.17148/IJIREEICE.2019.7702

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

3.2.2 Rule Base Fuzzy

The rule base fuzzy embraces of fuzzy if- then directions. The fuzzy rule power encompass fuzzy boundaries and fuzzy segment undemonstrative by member profession. The rule base fuzzy as inclusive in Table 1. The strategies are considered in this movement: if the changeable of error is UN and the variable of derivative error is UN then the output control signal variable is L. Layout these member function and adjustable, the complete number of 25 rules are accumulated.

3.2.3 Defuzzification

Defuzzification construing the productivity fuzzy regulating to positive rate emblem. The centroid technique beneficial for defuzzification improvement.

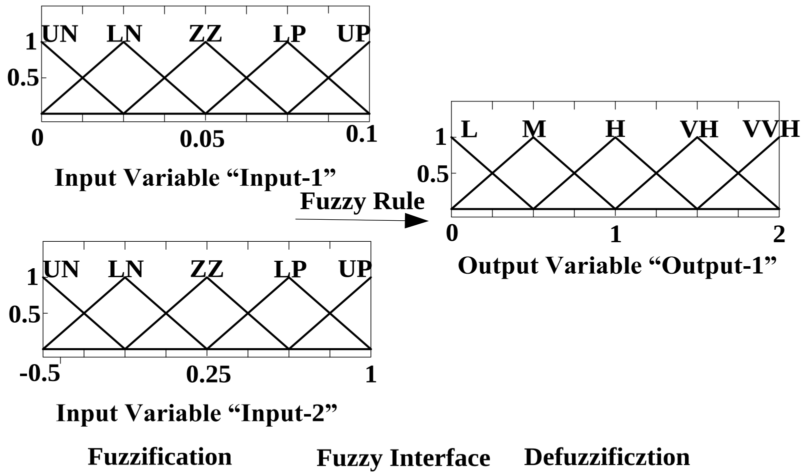

Fig. 6. Inputs and outputs membership function for LFC.

IV. SIMULATION AND DISCUSSION

In simulation investigation, we invented power plant by fuzzy. In this dissection, we accompanying the attendances of hydro-thermal power plant with fuzzy via the PID. The retaliation of system boundaries of PID controller is established in Table 2.

Table 2. 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, [24]	0.0120	0.1143	0.0133	0.0298	0.1996	0.0634
2.	PID-CV, Raju 2017, [24]	0.0118	0.1960	0.1116	0.0321	0.1984	0.0411
3.	PID-PT, Raju 2017, [24]	0.0110	0.1874	0.0388	0.0593	0.3840	0.0796
4.	GA-PID-PBT, Raju 2017, [24]	0.0244	0.2414	0.0174	0.0321	0.2041	0.0151
5.	GA-PID-CV, Raju 2017, [24]	0.0251	0.2414	0.0412	0.0121	0.3211	0.0091
6.	GA-PID-PT, Raju 2017, [24]	0.0511	0.3110	0.0122	0.0621	0.3985	0.0651
7.	PSO-PID-PBT, Raju 2017, [24]	0.0212	0.1421	0.0211	0.0311	0.2122	0.0554
8.	PSO-PID-CV, Raju 2017, [24]	0.0211	0.2411	0.0952	0.0251	0.2114	0.0521
9.	PSO-PID-PT, Raju 2017, [24]	0.0212	0.2001	0.0122	0.0621	0.4112	0.0721

The two-area hydro-thermal power system is confined for load. We complementary the reactions of fuzzy with PID controller rejoinders in relations of settling time, peak overshoot and peak undershoot in agreement in table 3.

The proposed fuzzy has lowest settling time as accompanying to PID and fuzzy is better objections of the procedure. The proficient investigative of settling time of fuzzy and PID controller for system is showing in Figure (7), (8), (9), (10), (11), (12), (13), (14) and (15).

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

Table 3. Comparison analysis 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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	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, [24]	$\Delta F1$	35.652	3.264	-5.827
		$\Delta F2$	34.609	3.417	-6.663
		ΔP_{tie}	36.875	0.760	-0.633
10.	PSO-PID-PT, Raju 2017, [24]	$\Delta F1$	78.685	5.078	-6.042
		$\Delta F2$	80.177	5.283	-6.983
		ΔP_{tie}	84.337	0.729	-1.217

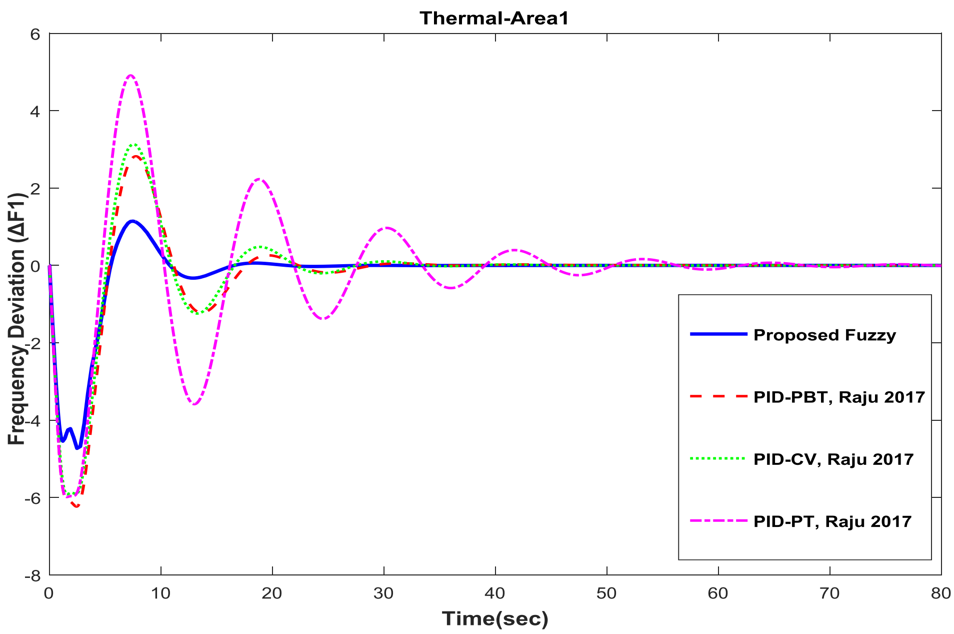

Fig. 7. Comparison of hydro-thermal area-1 (frequency deviation Δf_1) of proposed fuzzy with PID [24], [24] and [24].

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

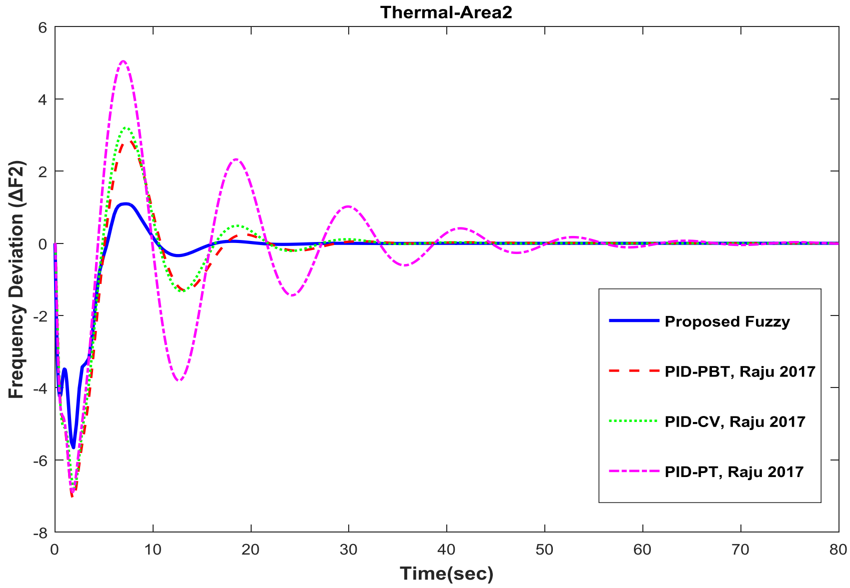

Fig. 8. Comparison of hydro-thermal area-2 (frequency deviation Δf_2) of proposed fuzzy with PID [24], [24] and [24].

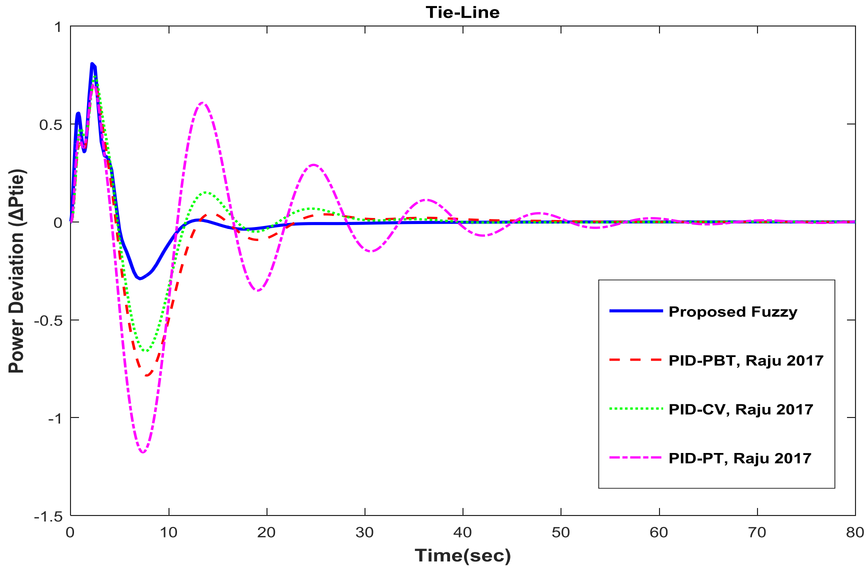

Fig. 9. Comparison of tie-line of proposed fuzzy with PID [24], [24] and [24].

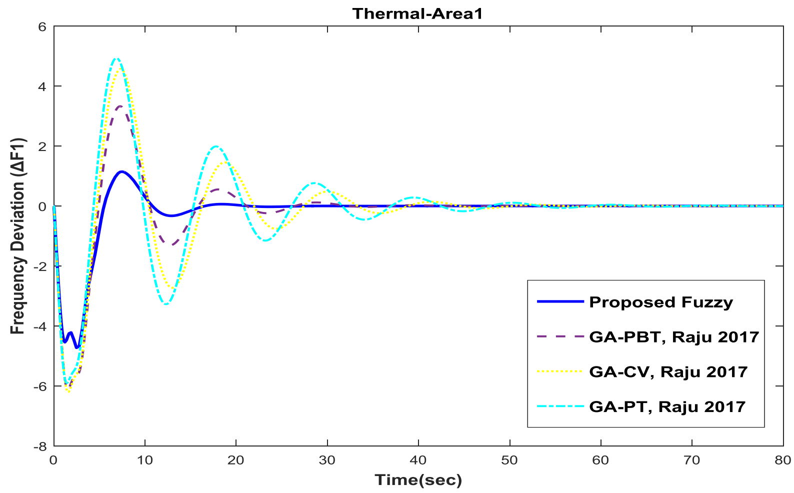

Fig. 10. Comparison of hydro-thermal area-1 (frequency deviation Δf_1) of proposed fuzzy with PID [24], [24] and [24].

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

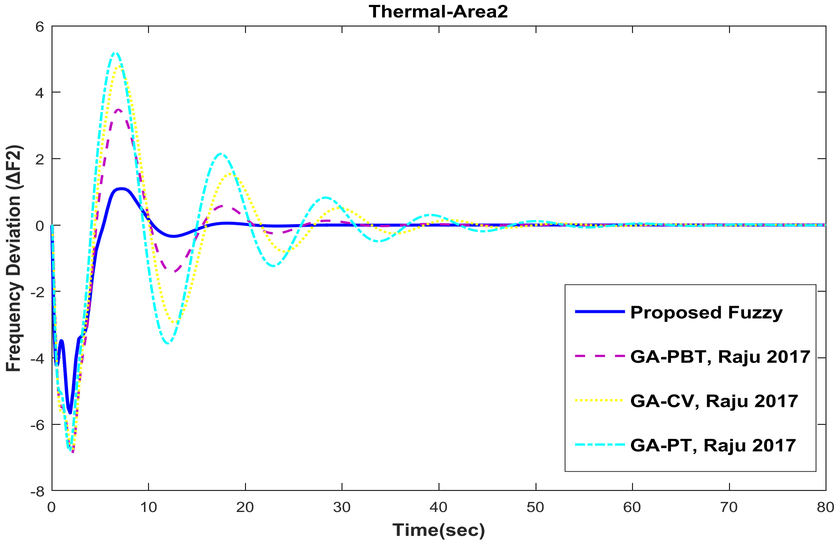

Fig. 11. Comparison of hydro-thermal area-2 (frequency deviation Δf_2) of proposed fuzzy with PID [24], [24] and [24].

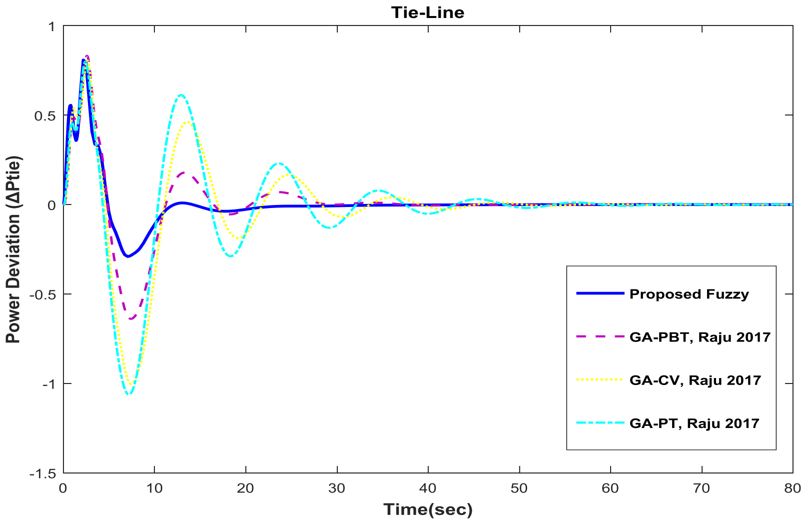

Fig. 12. Comparison of tie-line of proposed fuzzy with PID [24], [24] and [24].

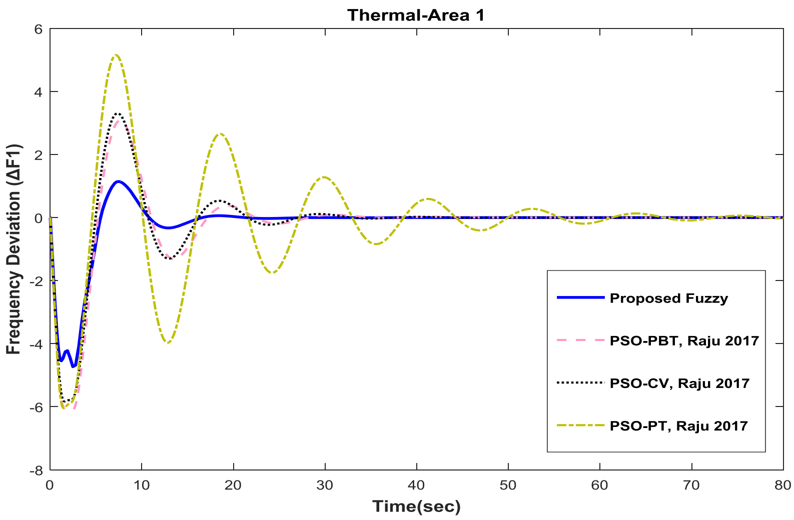

Fig. 13. Comparison of hydro-thermal area-1 (frequency deviation Δf_1) of proposed fuzzy with PID [24], [24] and [24].

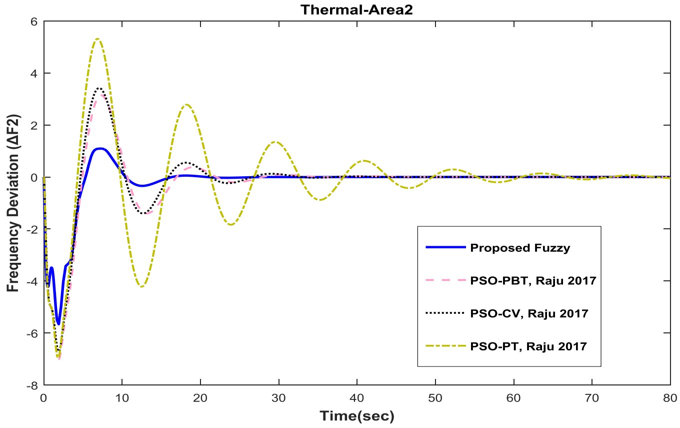

Fig. 14. Comparison of hydro-thermal area-2 (frequency deviation Δf_2) of proposed fuzzy with PID [24], [24] and [24].

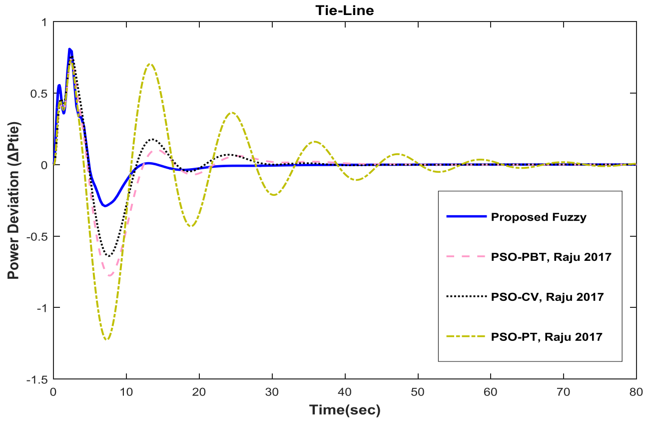

Fig. 15. Comparison of tie-line of proposed fuzzy with PID [24], [24] and [24].

V. CONCLUSION

In this article, the fuzzy controller are distributing for extrication the load frequency complication. Fuzzy is used administrator the LFC of the two-area hydro-thermal system. A proportional reconnaissance was obtainable by PID. Fuzzy and PID controller limitations are spread on to two-area. The indispensable purpose of this article is to better-quality the dynamic accomplishments of the system. The contemptuousness of proposed fuzzy has been interconnected for hydro-thermal power system. The simulation conclusions appearance that the proposed fuzzy has advanced resounding obtainable than the commendation PID controller. The executions of the system over fuzzy is compared through PID. The settling time of PID is exciting as linked to the fuzzy. The settling time, peak undershoot and peak overshoot time of two-area hydro-thermal power plant is better using a fuzzy controller fountains restricted result. The fuzzy distribute better dynamic presences in relations of time provisions of the system. 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. The proposed controller is good results is given as compared to PID.

NOMENCLATURE

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

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 7, Issue 7, July 2019

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

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.

REFERENCES

[1]. B. Mohanty and P. K. Hota, "Load Frequency Control of Nonlinear Interconnected Hydro-Thermal System Using Differential Evolution Technique," World Academy of Science, Engineering and Technology, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering, vol. 8, pp. 453-460, 2014.
[2]. R. K. Sahu, S. Panda, U. K. Rout, and D. K. Sahoo, "Teaching learning based optimization algorithm for automatic generation control of power system using 2-DOF PID controller," International Journal of Electrical Power and Energy Systems, vol. 77, pp. 287-301, 2016.
[3]. D. Lakshmi, A. P. Fathima, and R. Muthu, "PSO Based Load Frequency Control For Single Area Power System," International Journal of Scientific & Engineering Research, vol. 5, pp. 12-17, 2014.
[4]. K. Naidu, H. Mokhlis, & A. Bakar, "Application of Firefly Algorithm (FA) based optimization in load frequency control for interconnected reheat thermal power system," in Applied Electrical Engg & Computing Technologies (AEECT), 2013 IEEE Jordan Conf on, 2013, pp. 1-5.
[5]. D. Guha, P. K. Roy, and S. Banerjee, "Load frequency control of large scale power system using quasi-oppositional grey wolf optimization algorithm," Engineering Science and Technology, an International Journal, vol. 19, pp. 1693-1713, 2016.
[6]. S. Debbarma, A. Nath, U. Sarma, and L. C. Saikia, "Cuckoo search algorithm based two degree of freedom controller for multi-area thermal system," in 2015 International Conference on Energy, Power and Environment: Towards Sustainable Growth (ICEPE), 2015, pp. 1-6.
[7]. E. S. Ali and S. M. Abd-Elazim, "BFOA based design of PID controller for two area Load Frequency Control with nonlinearities," International Journal of Electrical Power & Energy Systems, vol. 51, pp. 224-231, 2013.
[8]. D. K. Sambariya and S. Shringi, "Optimal Design of PID Controller for Load Frequency Control using Harmony Search Algorithm," Indonesian Journal of Electrical Engineering and Computer Science, vol. 5, pp. 19-32, 2017.
[9]. D. K. Sambariya and R. Fagna, "A novel Elephant Herding Optimization based PID controller design for Load frequency control in power system," in 2017 International Conference on Computer, Communications and Electronics (Comptelix), 2017, pp. 595-600.
[10]. R. Kashyap, S. Sankeswari, and B. Patil, "Load Frequency Control using fuzzy PI controller generation of interconnected hydropower system," International Journal of Emerging Technology and Advanced Engineering, vol. 3, pp. 655-659, 2013.
[11]. K. V. Kumar and V. Ganesh, "Fuzzy Logic Controller Based Load Frequency Control of Two Area Inter connected Thermal Power System."
[12]. P. C. Pradhan, R. K. Sahu, and S. Panda, "Firefly algorithm optimized fuzzy PID controller for AGC of multi-area multi-source power systems with UPFC and SMES," Engineering Science and Technology, an International Journal, vol. 19, pp. 338-354, 2016.
[13]. Sathans and S. Akhilesh, "Fuzzy Pid Controller for Load Frequency Control of Two-Area Power System Considering Generation Rate Constraint," INTERNATIONAL JOURNAL OF ELECTRICAL SYSTEMS AND CONTROL vol. 3, pp. 43-48, 2011.
[14]. E.A.Daood and A.Bhardwaj, "Automatic load frequency control of Three-area power System using ANN controller with Parallel Ac/Dc Link."
[15]. N. S. N., "A single area load frequency control: a comparative study based on pi, optimal and fuzzy logic controllers," American Journal Of Scientific And Industrial Research, 2011.
[16]. D. K. Sambariya, R. Gupta, and V. Vishnoi, "Robust Fuzzy Logic Based Power System Stabilizer," in National Conference on Communication, Control and Bioinformatics, (NCCB 2006), 2006, pp. FZ-09 (1-6).
[17]. D. K. Sambariya, "Power System Stabilizer with Fuzzy Logic for Multi-Machine System," in National Conference on Power and Energy Systems, (NCPES-2011), 2011, pp. 200-204.
[18]. D. K. Sambariya and R. Gupta, "Fuzzy Logic Based Robust Multi-Machine Power System Stabilizer," in International Conference on Computer Applications in Electrical Engineering Recent Advances, (CERA-2005) 2005, pp. 436-442.
[19]. D. K. Sambariya, R. Gupta, and A. K. Sharma, "Simulation of Fuzzy Logic Power System Stabilizer," IEE Sponsored National Conference on Power Engineering Practices & Energy Management, (PEPEM 2005) pp. 32-35, January 28-29, 2005 2005.
[20]. D. K. Sambariya and R. Prasad, "Optimal Tuning of Fuzzy Logic Power System Stabilizer Using Harmony Search Algorithm," International Journal of Fuzzy Systems, vol. 17, pp. 457-470, September 2015 2015.
[21]. D. K. Sambariya, "Power system stabilizer design using compressed rule base of fuzzy logic controller," Journal of Electrical and Electronic Engineering, vol. 3, pp. 52-64, July 1, 2015 2015.
[22]. R. Gupta, D. K. Sambariya, and R. Gunjan, "Fuzzy Logic based Robust Power System Stabilizer for Multi-Machine Power System," in IEEE International Conference on Industrial Technology, ICIT 2006., 2006, pp. 1037-1042.
[23]. D. K. Sambariya and V. Nath, "Load Frequency Control Using Fuzzy Logic Based Controller for Multi-area Power System," British Journal of Mathematics & Computer Science, vol. 13, pp. 1-19, December 28, 2015.
[24]. M. Raju, L. C. Saikia, N. Sinha & D. Saha, "Application of antlion optimizer technique in restructured automatic generation control of two-area hydro-thermal system considering governor dead band," 2017 Innovations in Power & Advanced Computing Technologies (i-PACT), Vellore, 2017, pp. 1-6.
[25]. V. Nath and D. K. Sambariya, "Design and performance analysis of adaptive neuro fuzzy controller for load frequency control of multiarea power system," in 10th International Conference on Intelligent Systems and Control (ISCO 2016), Karpagam College of Engineering, Tamilnadu, India, 2016, pp. 359-365.
[26]. V. Nath and D. K. Sambariya, "Analysis of AGC and AVR for Single Area and Double Area Power System Using Fuzzy Logic Control," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 4, pp. 6501-6511, July 2015.
[27]. D. K. Sambariya and V. Nath, "Optimal Control of Automatic Generation with Automatic Voltage Regulator Using Particle Swarm Optimization," Universal Journal of Control and Automation, vol. 3, pp. 63-71, December 2015.