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Load Frequency Control of Multi Area Hydro Thermal Power System using Hybrid Controllers

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Abstract: Load frequency control (LFC) play a very important role to provide quality of power in interconnected power systems. In this paper hybrid controllers are used to minimize frequency variation as well as tie line power utilization of multi area power system which includes two non-reheated thermal and one hydro system. Hybrid Fuzzy Tilt Integral Derivative (HFTID), 2DOF–proportional-integral (2DOF–PI), 2DOF Proportional – Integral- Derivative (2DOF – PID), 2DOF-Integral plus double derivative (2DOF-IDD) and fuzzy logic controllers are used to control the frequency & tie line power of multi area power system. The main motivation of this paper is to minimize frequency variations and tie line power utilization with minimum peak overshoot and settling time. Hybrid Fuzzy integral plus double derivative (HFIDD) controller is proposed in order to minimize load frequency variation and tie line power utilization. A system involving two non-reheated thermal and one hydro power generation is modeled using MATLAB simulation.

Keywords: Fuzzy logic controller (FLC), Hybrid fuzzy integral plus double derivative (HFIDD), Hybrid fuzzy Tilt integral derivative (HFTID) & integral plus double derivative (IDD) Controllers.

1. INTRODUCTION

The objective of load frequency control (LFC) in an inter-connected power system is to minimize the frequency variation of each area within limits and keep tie-line power flows within some pre-specified tolerances [1]. Unique techniques of Load Frequency control are used to improve Reliability [l]. The purpose of the LFC to maintain zero steady state error in a multi area Interconnected power system and satisfy the preferred dispatch conditions [2]. because of load changes the power flows in tie-lines produce change in frequency due to the unequal technology and demand of the power . For any power system, reliability and quality are two important factors. Load frequency control play an important role to maintain the reliability and quality of power system [4]. A control strategy is needed that not only maintains constancy of frequency and desired tie line power flow but also achieves zero steady state error and inadvertent interchange. Among the various types of load frequency controllers, the most widely used the conventional (2DOF – PI), (2DOF – PID). Due to high peak overshoot and settling time, conventional (2DOF – PI), (2DOF – PID) and Fuzzy Logic controllers are not preferred for large power system. The main motivation of this paper is to minimize variation frequency & tie line power response with minimum peak overshoot and settling time. The output frequency response with Hybrid Fuzzy Tilt Integral Derivative(HFTID), Hybrid Fuzzy integral plus double derivative(HFIDD) and Integral plus double derivative (IDD) controller indicates that Hybrid Fuzzy Tilt Integral Derivative(HFTID) is better Compare to Hybrid Fuzzy integral plus double derivative (HFIDD) controller and Integral plus double derivative (IDD) controllers.

2. DIFFERENT TYPES OF 2DOF CONTROLLERS

In the power system the 2DOF controllers are of many types. In this paper following three type of 2DOF controllers are used.

2.1. 2DOF-PI Controller

Conventional 2DOF-proportional plus integral (2DOF-PI) controller makes the system response to be steady state in the farm of frequency deviation, but it exhibits poor dynamic performance (such as no. of oscillation and more settling time) as discussed in equation (1) .

$$U(t) = k_p e(t) + k_i \int_0^t e(\tau)\, d\tau \qquad (1)$$

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2.2. 2DOF-PID Controller

A 2DOF-Proportional – Integral – Derivative (2DOF-PID) Controller is a control closed loop feedback mechanism system as discussed in (equation 2). It is widely used in industrial control System as shown in Fig. 1. It exhibits good dynamic performance (such as no. of oscillations and setting time) and is better as compared to 2DOF-PI Controller.

$$U(t)=k_p e(t)+k_i\int_0^t e(\tau)d\tau+k_d\frac{de}{dt} \qquad (2)$$

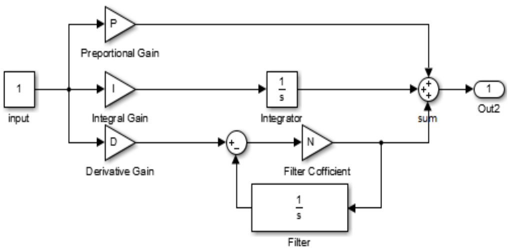

Fig -1 PID Controller Simulation Diagram

2.3. Fuzzy Logic Controller (FLC)

In the present scenario Fuzzy Logic Control system applications become very useful. The Fuzzy logic controller is framed by the combination of different interfaces named as Fuzzification interface, the inference rules design interface and defuzzification interface. It exhibits very good dynamic performance and is better as compared to 2DOF-PI and 2DOF-PID controller.

Table-1 Fuzzy logic rules for HFTID controller.

MBF	NL	NM	NS	Z	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	Z
NM	NL	NL	NL	NM	NS	Z	PS
NS	NL	NL	NM	NS	Z	PS	PM
Z	NL	NM	NS	Z	PS	PM	PL
PS	NM	NS	Z	PS	PM	PL	PL
P	NS	Z	PS	PM	PL	PL	PL
PL	Z	PS	PM	PL	PL	PL	PL

A linguistic variable which implies inputs and outputs have been classified as 'Negative Large'(NL), 'Negative Medium'(NM), 'Negative Short'(NS), 'Zero'(Z), Positive Short'(PL), 'Positive Medium'(PM), 'Positive Large'(PL). Each control input has seven Fuzzy set so that total 49 Fuzzy set are there [8]. These MFs are shown in fig-2.

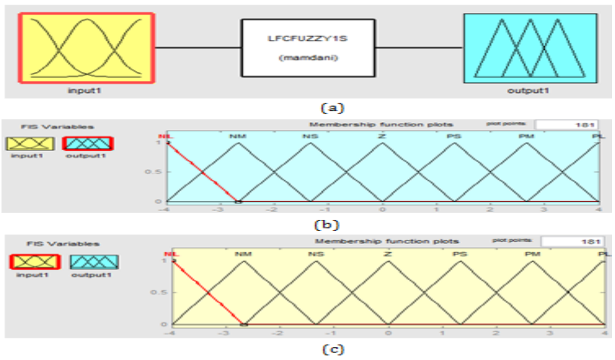

Fig-2 Membership function of output

2.4. 2DOF-IDD Controller

A new 2DOF controller named as 2DOF – Integral double derivative (2DOF – IDD) is proposed for first time whose structure is shown in Fig. 3c called as two degree of freedom – Integral-Double-Derivative (2DOF – IDD) controller. The controlling values C(s) and F(s) of 2DOF – IDD controller are given by the following equation:

$$C(s) = \frac{(K_{DD}N)s^2 + (K_I)s + K_I N}{s(s+N)} \quad (3)$$

$$F(s) = \frac{(cK_{DD}N)s^2 + (K_I)s + K_I N}{(K_{DD}N)S^2 + (K_I)s + K_I N} \quad (4)$$

Where:-
K_I & K_{DD} =integral and double derivative gain
N = derivative filter coefficient

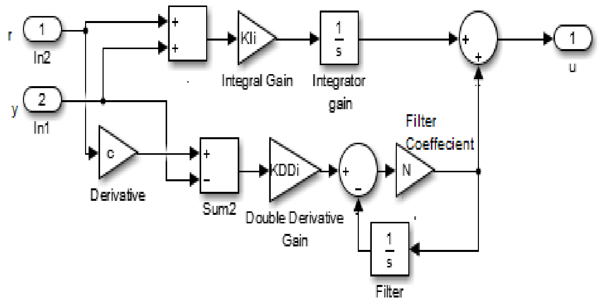

Fig -3 IDD Controller Simulation Diagram

3. DIFFERENT TYPES OF HYBRID CONTROLLER

3.1. Hybrid-Fuzzy-TID Controller

A hybrid fuzzy-tid (tilt-integral- derivative) controller is a new approach to get the better result as compare to the PI, PID ,IDD , HFIDD and fuzzy controller. in a PID type compensator, where the proportional compensating unit is replaced by a compensator designed to have a transfer function denoted by 1/s (1/n). this is called 'tilt' compensator. it provides a feedback gain as a function of frequency which is tilted or shaped with respect to the gain\frequency of a conventional or proportional unit. so the entire compensator is here in referred to as a tilt-integral derivative (TID) compensator[5]. here 'n' is a non zero real number, preferably between 2 and 3. TID have several advantages also that it is ease in tuning, universal w.r.t the plants with different bandwidths, the phase and slope of the gain response are both rendered frequency independent, thus ensuring that the compensator is substantially universal. to get the better output made a hybrid simulation model consist of fuzzy logic controller (FLC) and TID is shown in fig.5 and the graphical representation is shown in fig.4

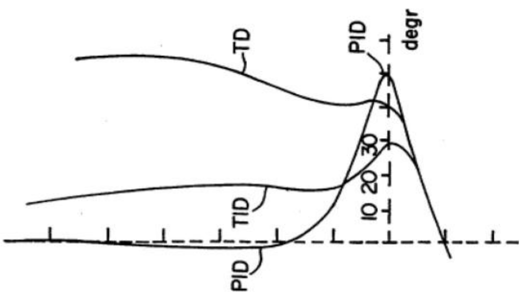

Fig. – 4 Graphical representation of PID and TID.

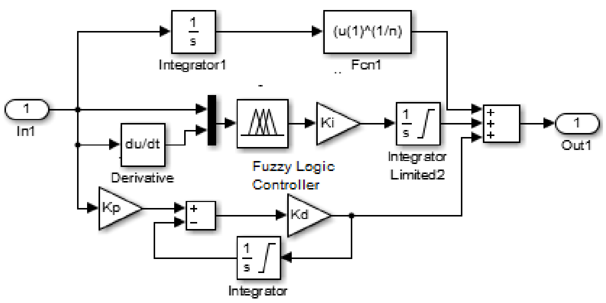

Fig.-5 Simulation Model Of Fuzzy-TID Controller

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3.2. Hybrid Fuzzy Logic Integral double derivative (HFIDD) Controller

A new controller HFIDD named as Hybrid Fuzzy Logic Integral double derivative (HFIDD) is proposed for first time. The HFIDD controller is the combination of Fuzzy Logic and Integral double derivative controllers. It is a new approach to get the better result as compare to the 2DOF-PI, 2DOF-PID, 2DOF-IDD and fuzzy controller. The simulation model of HFTIDD is shown in fig-6.

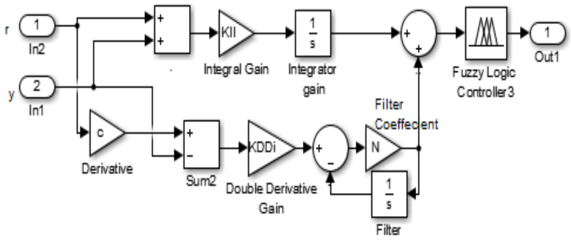

Fig -6 HFIDD Controller Simulation Diagram

4. PROPOSED CONTROL STRATEGY

The proposed power system with three areas having two Non Reheat Turbine and one Hydro Turbine are consider in Simulation study with time delays using 2DOF – Proportional-Integral (2DOF – PI), 2DOF Proportional – Integral-Derivative (2DOF – PID) and Fuzzy Logic Controller (FLC). These three areas are connected with the help of tie-line. 2DOF-PID gives better results as compare to (2DOF-PI) Controller. but FLC provides fast response, adequate disturbance rejection and it provides also effective result for complex and Non-linear model. The output frequency response with Hybrid Fuzzy Tilt Integral Derivative(HFTID), Hybrid Fuzzy integral plus double derivative(HFIDD) and 2DOF-Integral plus double derivative (2DOF-IDD) controller indicates that Hybrid Fuzzy Tilt Integral Derivative (HFTID) is very much better Compare to Hybrid Fuzzy integral plus double derivative (HFIDD) controller and 2DOF-Integral plus double derivative (2DOF-IDD) controllers. These controller improves effectively the damping of the oscillations after the load deviation in one of the interconnected system area compared to Conventional Controllers. So proposed three area Simulation models for (2DOF-IDD) Controller,& HFTID and HFIDD Controller in Fig-7, fig-8 and fig-9 respectively.

4.1. Tie - Line Control

The Power transfer equation through tie-line is

$$P_{tieflow} = 1/X_{tie}(\Phi_1 - \Phi_2) \quad (5)$$

This tie flow is a steady state quantity.
Where frequency change Δω is

$$\Delta\omega = [\Delta PL1]/[1/R1+1/R2+D1+D2] \quad (6)$$

Tie-line power in terms of Δω is

$$\Delta Ptie = \Delta\omega\left(1/R_2 + D_2\right) \quad (7)$$

The new tie flow is determined by the net change in load and generator in each area[l]. Do not need to know the tie stiffness to determine this new tie flow, although the tie stiffness will determine that how much difference in phase angle across the tie will result from the new tie flow. Tie-line bias control is used to eliminate steady state error in frequency in tie line power flow [7].

ACE1 = area control error of area 1
ACE2 = area control error of area 2
ACE3 = area control error of area 3

In this control ACE1, ACE2, and ACE3 are made linear combination of frequency and tie-line power error.

$$ACE_1 = \Delta P_{12} + b_1\Delta f_1 \quad (8)$$

$$ACE_2 = \Delta P_{21} + b_2\Delta f_2 \quad (9)$$

$$ACE_3 = \Delta P_{31} + b_3\Delta f_3 \quad (10)$$

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Where b1, b2 and b3 are called area frequency bias of areal, area2 and area3 respectively. In three area Hydro Non Reheated Thermal control system used a model, there are Generator, Turbine & Governor model. To Simulate this model have to define the value of Turbine, Generator, Governor and others parameters at which model depends. These parameters are defined in APPENDIX 1.

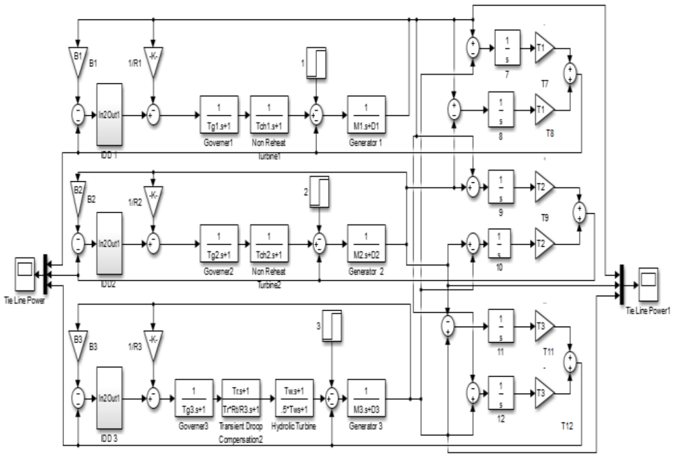

Fig-7 Simulation model with IDD Controller

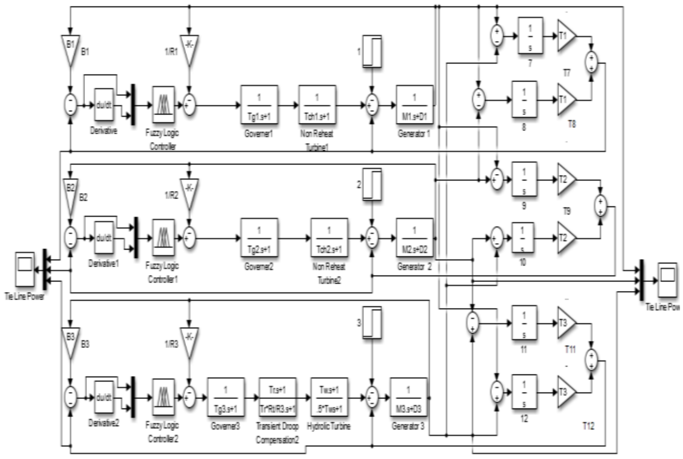

Fig-8 Simulation model with HFTID Controller

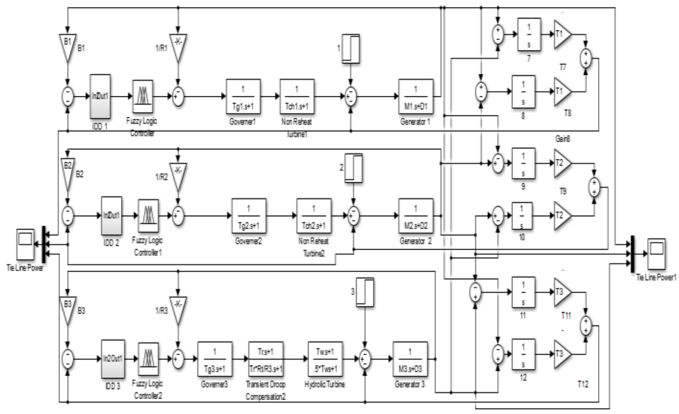

Fig-9 Simulation model with HFIDD Controller

5. SIMULATION ANALYSIS AND RESULTS

A three area system model is developed for multi area concept. In three area system, thermal non-Reheated system is taken as area 1 & area2 and Hydro system, area3. In this presented work, multi- areas Two Non Reheated Thermal and

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one Hydro power system have been developed by using fuzzy logic, HFTID, HFIDD and 2DOF-PI, 2DOF-PID & 2DOF-IDD controllers to illustrate the performance of load frequency control using MATLAB/SIMULINK package. The Tie Line power of IDD, HFTID and HFIDD Controllers is shown in figures 10, 12 & 13 and the output frequency response with minimum peak overshoot and settling time of three area is shown in fig-14,15 & 16. It is observed that proposed fuzzy fuzzy-tid (HFTID) controller gives better performances.

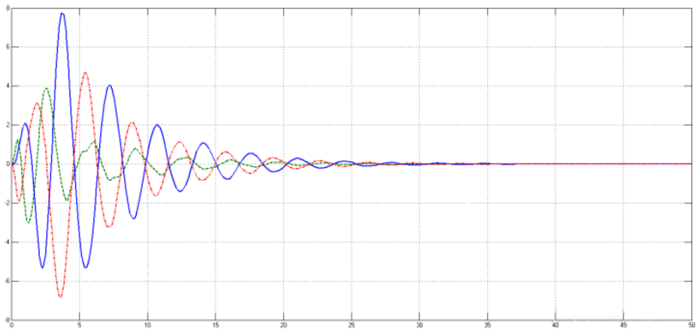

Fig-10 Simulation result of Tie line power for Hydro Thermal system With IDD

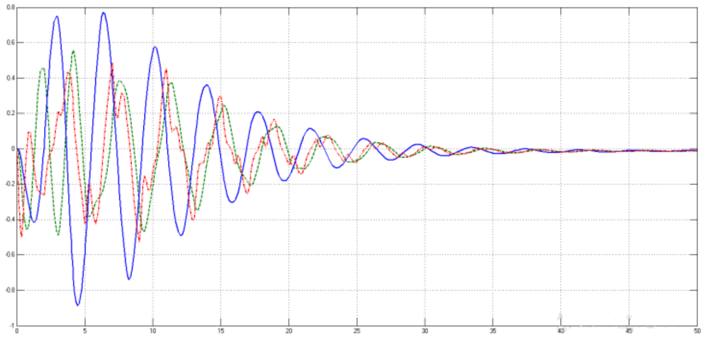

Fig-11 Simulation Output result of Hydro Thermal Power System with IDD Controller

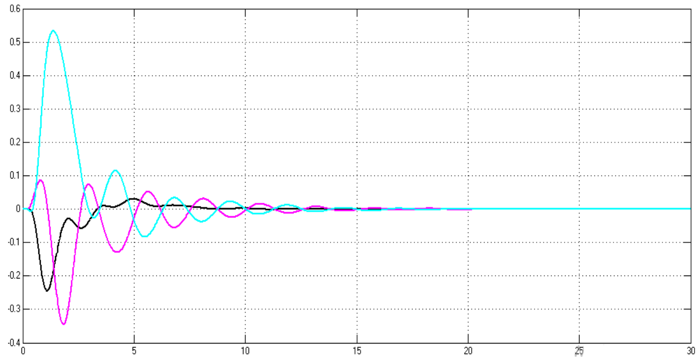

Fig-12 Simulation result of Tie line power for Hydro Thermal Power system With HFTID

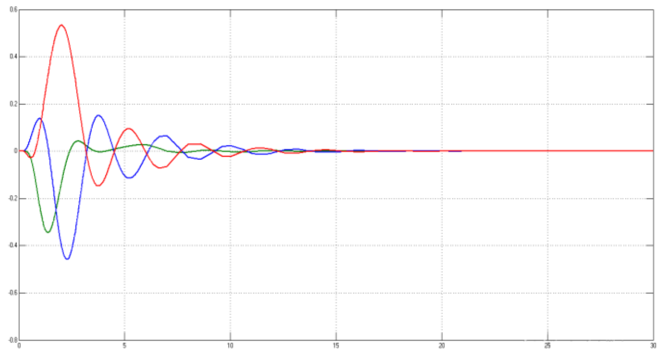

Fig-13 Simulation result for Hydro Thermal Power system with HFIDD Controller

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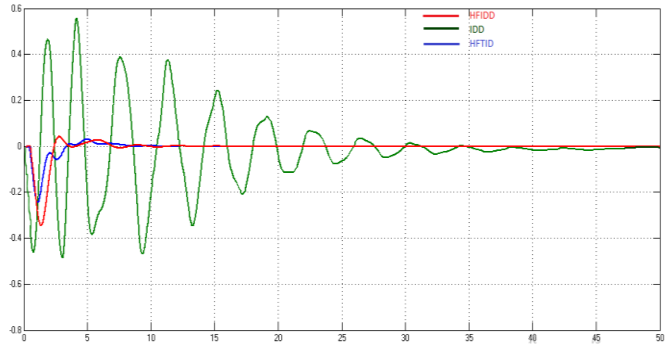

Fig-14 Simulation result of Tie line power for Non-reheated thermal 1system

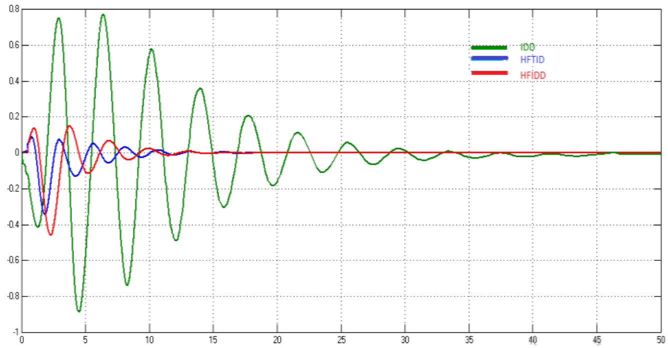

Fig-15 Simulation result of Tie line power for non-Reheated Thermal 2 system

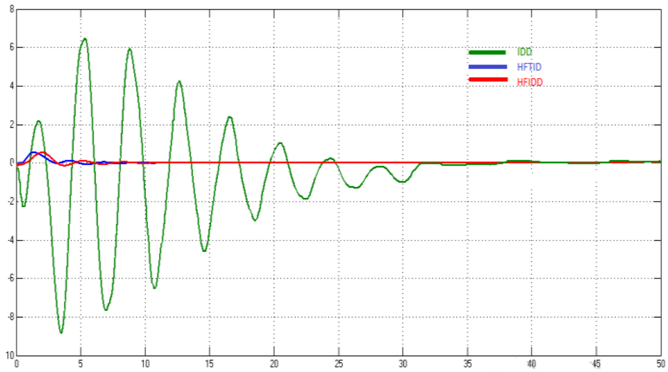

Fig-16 Simulation result of Tie line power for Hydraulic system

Controllers	Settling time (s)			Peak overshoot			Peak undershoot		
	AREA1 Fig-14	AREA2 Fig-15	AREA3 Fig-16	AREA1 Fig-14	AREA2 Fig-15	AREA3 Fig-16	AREA1 Fig-14	AREA2 Fig-15	AREA3 Fig-16
IDD	48	45	36	0.56	0.78	6.5	-0.49	-0.9	-8.9
HFIDD	12.6	19	11	0.041	0.15	0.53	-0.34	-0.45	-0.15
HFTID	11.9	18	10	0.031	0.08	0.52	-0.25	-0.34	-0.09

Table -2 Values of setting time, peak overshoot and peak undershoot

6. CONCLUSION

Load frequency control is very important for interconnected power system due to continue varying load. Comparison of load frequency control using different controllers like 2DOF – Integral double derivative (2DOF-IDD), hybrid Fuzzy - tilt integral derivative controller (HFTID) and Hybrid Fuzzy Logic Integral double derivative (HFIDD) has been given. It is observed that HFTID responses fast to settle the frequency deviation in comparison of other controllers. Simulation studies have been carried out using MATLAB. It is seen from the simulations that, the proposed controller results in less peak overshoots as well as less settling time.

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APPENDIX 1

M_3= 6,D_1 = 1 ,D_2= 1,D_3= 1,Tch_1 =0.3,Tg_1 =0.1, T_{21} = 0.06 ,Tg_3= 0.2, Tw = 1,Rt = 0.38,R_1 = 0.08,R_2= 0.08, ,M_2 = 10, R_3= 0.05, Tr = 5, T_1 = 15,T_2 =15,T_3=15,B_1 =(1/R_1)+D1,B_2 =(1/R_1)+D_1,B3 = (1/R3)+D3,T_{12}= 0.06, M1= 10,T_{13}= 0.08,T_{23}= 0.06,T_{31} = 0.08,T_{32} = 0.06,K_p=0.031,K_i=0.10,K_{DD}=0.099,N=30,b=0.017.

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