Imperial Journal of Interdisciplinary Research (IJIR)
Vol-3, Issue-7, 2017
ISSN: 2454-1362, http://www.onlinejournal.in

Load Frequency Control of Multi Area Hydro Thermal Power System using 2DOF Controllers

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***Abstract**: This paper presents load Frequency control (LFC) of multi area system controlled by two degree of freedom (2DOF) controller. In this paper Dynamic responses of the system obtained by fuzzy controller are compared with other 2DOF controllers like 2DOF – Proportional-Integral (2DOF – PI), 2DOF Proportional – Integral-Derivative (2DOF – PID. Two Non Reheated Thermal and one Hydro system is connected by way of Tie line. It affords better performance and efficiency. Simulation is executed using different Controllers for unique inputs in MATLAB SIMULINK software.*

***Key Words**: FUZZY LOGIC CONTROLLER (FLC), PI & PID CONTROLLER, HFTID.*

1. Introduction

In the present power device the primary problem is to preserve the ideal frequency control operation of an interconnected power systems and providing the reliable electric power of desirable quality. unique techniques of Load Frequency manipulate 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 [1]. a whole lot of research have been executed on Load Frequency control (LFC) in interconnected power system. exclusive manage techniques had been counseled based totally on the conventional linear control principle and for nonlinear used a gain scheduling controller. in this method, the machine outputs are faster with high quality and parameter estimation is not required as compare to standard Controller. This gives the better result as compare to PI [4]. further to improve result, designed a Hybrid controller, it is Hybrid Fuzzy Tilt-fundamental derivative(HFTID) Controller. TID Controller depends upon a non 0 real range 'n'. TID is a enhance method and it's miles designed with the aid of NASA[5]. So with the help of Simulation effects it has proved that HFTID offers higher results as examine to FLC and PID.

2. Description Of 2DOF Controllers

2.1.P-I Controller

P-I controller is mainly used to do away with the steady nation error because of P controller. however, in phrases of the rate of the response and average stability of the system, it has a negative effect. This controller is mostly utilized in areas where speed of the device isn't always an difficulty. due to the fact P-I controller has no capacity to predict the future errors of the device it can't decrease the rise time and remove the oscillations. If applied, any quantity of I guarantees set point overshoot. PI control is a combination of proportional and integral control.

$$U(t) = k_p e(t) + k_i \int_0^t e(\tau)\, d\tau \quad \text{.........................(1)}$$

Where define:-

τ = Variable of Integration

e = Control error

This shows that proportional-integral control eliminates the step response steady state error and allows for more control over the transient response (compared to only P or only I control) because both the damping ratio and natural frequency can be altered using the gains. For example, it is now possible to reduce the rise time and maximum overshoot simultaneously.

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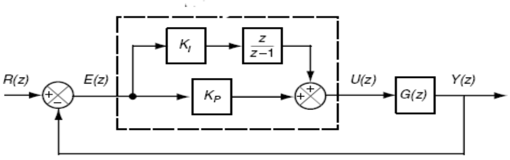

Fig -2.1: PI Controller Block Diagram

2.2. Proportional-Integral-Derivative

The proportional integral derivative (PID) controller is maximum popularly known and used as a comments controller in the subject of complicated system industries. it may offer excellent robust control performance over a wide variety of operating situations of a power system due to its three exclusive modes of operation. The proportional controller mode can reduce the upward push time but is unable to reduce the steady-state error of the response. The higher price of proportional gain may purpose a machine to turn out to be risky however decrease price makes it insensitive or lesser touchy to even large price of error. The derivative control mode complements the system stability by reducing overshoot and enhancing transient reaction. The fundamental control mode of operation may get rid of the regular-nation errors but can also get worse the temporary reaction of a system. The lower price of integral gain value makes a system slow at the same time as the higher cost causes a random increase in the overshoot. therefore, to layout the PID controller, all three gains require special attention to get the control signal with the aid of the trial-and-errors method primarily based on the experience and plant behavior. The block diagram illustration of PID controller for a closed-loop system is proven in figure 2 . A Proportional -integral- derivative (PID Controller) having time period control-The Proportional, The integral and The derivative values denoted by way of P , I and D respectively. PID is a manipulate closed loop remarks mechanism system and it's miles widely utilized in commercial manipulate system[4,6]. In PID the P depends on gift error, I depends on the accumulation of the past mistakes and D is the prediction of the destiny mistakes based on current charge of exchange. To perform top with the industrial technique troubles, the PID Controller must have opsstimally tuned Kp, ki, and Kd values. PID offers first-class result as compare to PI and PD in accuracy, oscillation and stability. The Proportional, integral and derivative phrases are summed to calculate the output of the PID Controller.

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

τ = Variable of Integration e = Control error

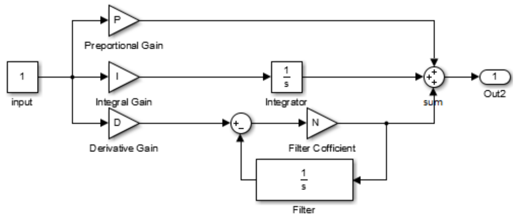

Fig -2.2: PID Controller Simulation Diagram

2.3.Fuzzy Logic Controller (FLC)

In the present scenario Fuzzy Logic Control system applications become important[7]. In Fuzzy logic control there is no need of complex transactions. With the help of human knowledge into a Fuzzy Control system a rule base is obtained and it is used by Fuzzy Inference System (FIS) as shown in Fig.2.3.1. Here, used Mamdani Method, which uses natural language clauses[6]. Fuzzy Logic Control basically consist of three components

a) Fuzzification
b) Rule Base
c)Defuzzification

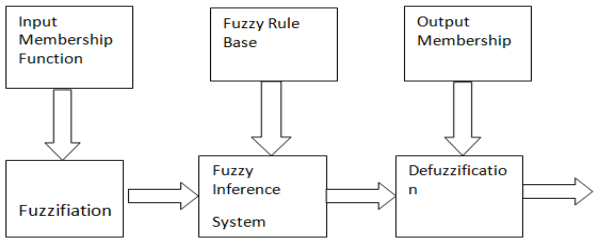

Fig.2.3.1. Basic Configuration of Fuzzy System

a) Fuzzification is a process of making a Crisp quantity into the Fuzzy.
b) Fuzzy values sent to the linguistic control Rule Base and Data Base.
c) Defuzzification is the conversion of a fuzzy Quantity to a crisp quantity.

2.3.1.Fuzzifiation

(a) Measure the values of input Variables
(b) Performs the function of Fuzzification that converts input into suitable values.

Fuzzification is process of making a crisp quantity into the fuzzy .They carry considerable uncertainty .if the form of uncertainty happens to arise because of imprecision, ambiguity, or vagueness, then the variables is probably fuzzy and can be represented by a membership function.

2.3.2.Rule Base

It consists of data and linguistic control rule base.

(a) The data base provides necessary definitions, which are used to define linguistic control rules and fuzzy data, manipulation in an LFC.
(b) The rule base characterizes the control goals and control policy of the domain experts by means of linguistic control rules.

2.3.3. Defuzzification

Defuzzification yields a non –fuzzy control action from an inferred fuzzy control action. For load frequency control the process operator is assumed to respond to variables error (e) and change of error (ce).

The resulting fuzzy set must be converted to a number that can be sent to the process as a control signal. This operation is called defuzzification. The resulting fuzzy set is thus defuzzified into a crisp control signal.

There are several defuzzification methods.

1. Max-membership principle,
2. Centroid method,
3. Weighted average method,
4. Mean–max membership,
5. Centre of sums,
6. Bisector of area, and
7. First of maxima or last of maxima

Table of Fuzzy Rule is shown in Table 1

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.2.3.2

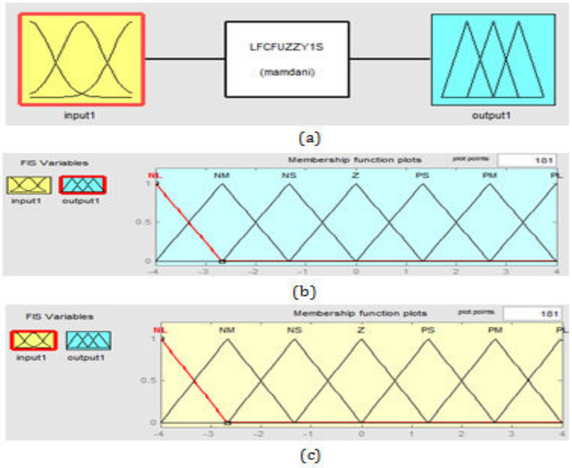

Fig.2.3.2. Membership function of output

2.4. 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. 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-PI) Controller,&(2DOF-PID) controller and Fuzzy Logic Controller (FLC) in Fig.3.1, fig.3.2. and fig.3.3. respectively.

3.1. Tie - Line Control

The Power transfer equation through tie-line is

$$P_{tieflow} = 1/X_{tie}(\Phi_1 - \Phi_2) \quad ....(3)$$

This tie flow is a steady state quantity.
Where frequency change $\Delta\omega$ is

$$\Delta\omega = -[\Delta PL1]/[1/R1+1/R2+D1+D2] \quad ....(4)$$

Tie-line power in terms of $\Delta\omega$ is

$$\Delta Ptie = \Delta\omega(1/R_2 + D_2) \quad ....(5)$$

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.

$$ACE_1 = \Delta P_{12} + b_1 \Delta f_1 \quad \text{......................................(6)}$$

$$ACE_2 = \Delta P_{21} + b_2 \Delta f_2 \quad \text{...........................(7)}$$

$$ACE_3 = \Delta P_{31} + b_3 \Delta f_3 \quad \text{.............................(8)}$$

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.

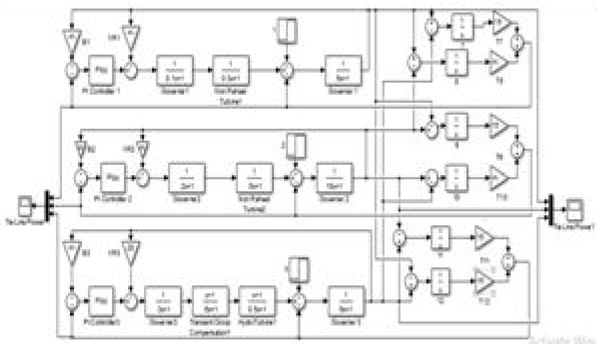

Fig-3.1. Simulation model with PI Controller

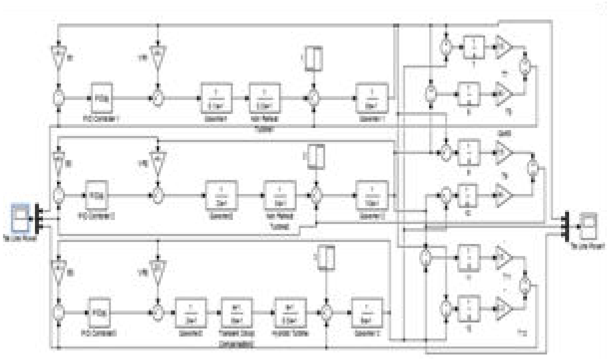

Fig-3.2. Simulation model with PID Controller

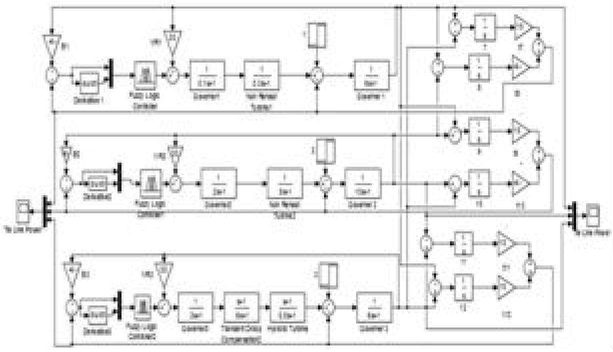

Fig-3.3. Simulation model with FUZZY Controller

4. Simulation Analysis and Results

Simulation results of Thermal Non-Reheated 2, Tie-line power for Non-Reheated 1&2 Thermal System, Tie-line Power for Non-Reheated and Hydro system, areal, Thermal Non Reheated 1 , area2, area3, Hydraulic system are shown in Fig.4.4, Fig.4.5, Fig.4.6., respectively. So the Fuzzy Logic controller(LFC) gives better result as compare to 2DOF – Proportional-Integral (2DOF – PI), & 2DOF Proportional – Integral- Derivative (2DOF – PID) controller stabilize the system in very less time with less oscillation and give fast response.

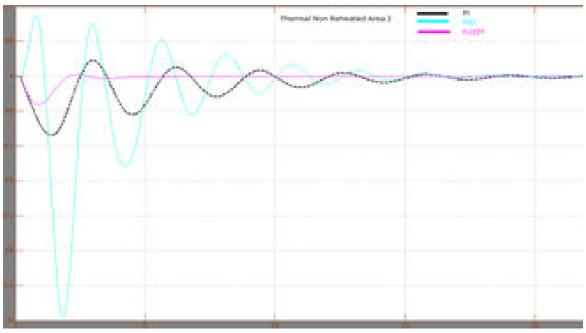

Fig-4.1. Simulation result of Thermal non-Reheated 2 system

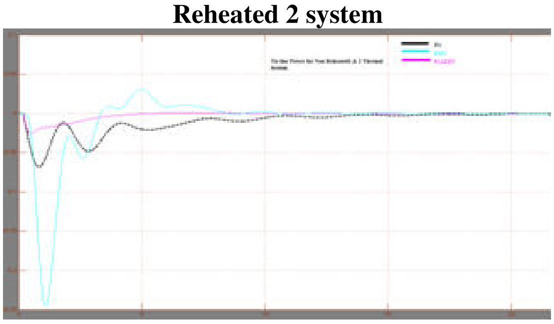

Fig-4.2. Simulation result of Non Reheated I Thermal & Hydraulic system

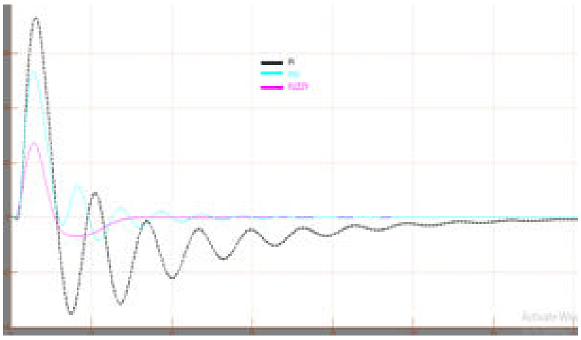

Fig-4.3. Simulation result of Hydraulic system

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

Controllers	Settling time (s)			Peak overshoot			Peak undershoot		
	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3	AREA1	AREA2	AREA3
	Fig. 4.2	Fig.4.1	Fig.4.3	Fig. 4.2	Fig.4.1	Fig.4.3	Fig. 4.2	Fig.4.1	Fig.4.3
PI	26	27	26.3	0.01	0.023	0	-0.068	-0.086	-0.051
PID	17.8	25	24.8	0.031	0.087	0.534	-0.026	-0.345	-0.084
FUZZY	9	6.5	8.3	0.01	0.005	0.002	-0.26	-0.042	-0.023

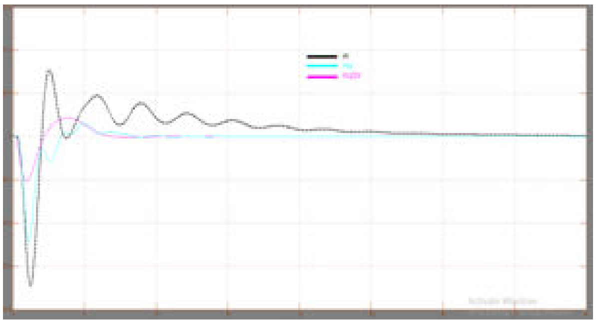

Fig.4.4. Simulation result of Tie line power for Thermal Non-reheated 1system

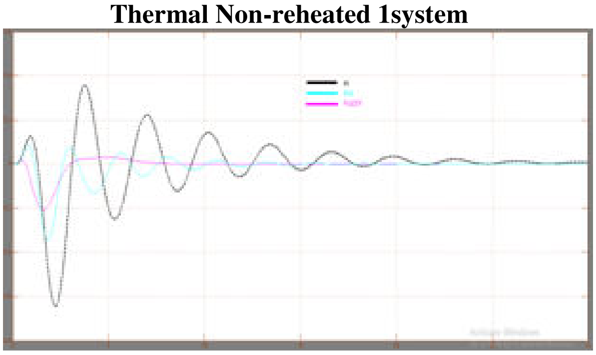

Fig. 4.5. Simulation result of Tie line power for Thermal non-Reheated 2 system

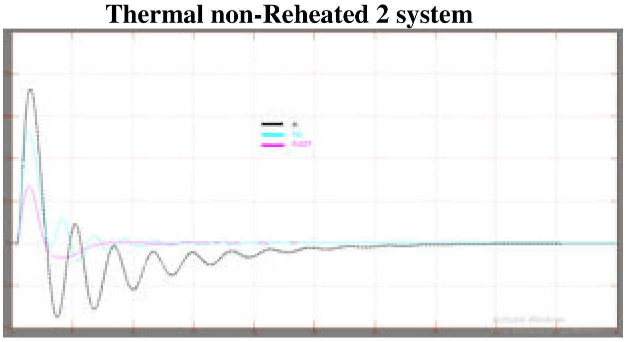

Fig.4.6. Simulation result of Tie line power for Hydraulic system

5.Conclusion

In three area control device having two Non-Reheated Thermal and one Hydro electricity system, after applied the two degree of freedom (2DOF) controller and fuzzy logic controller (FLC). it's been found that FLC given better results and reduce the overshoot and having greater balance as compared with other 2DOF controllers like 2DOF – Proportional-Integral (2DOF – PI), 2DOF Proportional – Integral-Derivative (2DOF – PID) as proven within the Simulation outcomes. FLC additionally improves the general machine performance. HFTID is new approach and it's going to provide higher bring about controlling location in which used best 2DOF & FLC single controller.

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

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