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Department of CIVIL, CSE, ECE, EEE, MECHNICAL Engg. and S&H of Muthayammal College of Engineering, Rasipuram, Tamilnadu, India

Load Frequency Control of Multi-Area Power Systems Using PI, PID, and Fuzzy Logic Controlling Techniques

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***Abstract*— Automatic Generation Control (AGC) or Load Frequency Control is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. AGC is a feedback control system adjusting a generator output power to remain defined frequency. One of the objectives of AGC is to maintain the system frequency at nominal value In the steady state operation of power system .An extended power system can be divided into a number of load frequency control areas interconnected by means of tie lines. Without loss of generality one can consider a three- area case connected by tie line. Here we are considering system, which is integration of two thermal power systems with hydro power system. That is area-1 and area-2 consists of thermal reheat power plant whereas area-3 consists of hydro power plant. The performance analysis of load frequency control for multi area inter connected system will be done in MATLAB/SIMULINK environment. As integration of multi area effects performance of system study of different characteristics using controllers like conventional PI ,PID, artificial intelligence FUZZY LOGIC controlling techniques are necessary in order to determine the effective gains of controller in efficient manner. And this knowledge about dynamic response characteristics will give us idea of controlling techniques that we need to implement for obtaining required frequency response at tie line stations.**

***Keywords*— load frequency control, multi area power system proportional Integral, proportional integral derivative controlling techniques, fuzzy logic.**

I. INTRODUCTION

Load Frequency Control is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. AGC is a feedback control system adjusting a generator output power to remain defined frequency[2][5]. Load frequency control is the basis of many advanced concepts of the large. The dynamic behaviour of many industrial plants is heavily influenced by disturbances and, in particular, by changes in the operating point. This is typically the case for power systems The control strategy of PI and PID control The reason PID controllers are so popular is that using PID gives the designer a larger number of options and those options mean that there are more possibilitie for changing the dynamics of the system in a way that helps the designer[5]. If the designer works it right we can get the advantages of several effects. Frequency deviation and tie line power deviation are the two prime parameters with respect to LFC. In interconnected power system, load variations in any areas disturb the frequency and tie-line power of other interconnected areas [3]. The fuzzy controller offers better performance over the conventional controllers, especially, in complex and nonlinearities associated with the two regions interconnected reheat thermal and hydro power system.

II. AGC IN THE MULTIAREA SYSTEM

All generators are supposed to constitute a coherent group in each control area[2]. From experiments, it can be seen that each area needs its system frequency and tie line power flow to be controlled.

The real power transferred over the tie line is given by:
Where X12= X1+Xtie+X2 (1)

From eqn.(1)For a small deviation in the tie-line flow

$$\frac{dp12}{d\delta 12} * \Delta\delta 12 = \Delta p12 = Ps\Delta\delta_{12} \quad (2)$$

The tie-line power deviation then takes on the form

$$\Delta P12 = Ps\,(\Delta\delta_1 - \Delta\delta_2) \quad (3)$$

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III. CONTROLLING METHODOLOGIES

In this paper there are two controlling methodologies mentioned. They are:

1. Conventional control
2. Fuzzy logic control.

Fuzzy logic controller :

Fuzzy set theory and fuzzy logic constitute the rules of a nonlinear mapping. The use of fuzzy sets provide a basis for a systematic way for the application of uncertain and indefinite models. Fuzzy control is based on a logical system called fuzzy logic is much closer in spirit to human. By taking ACE as the system output, the control vector for a conventional PI controller can be given as.

ACE(k) \ ΔACE(k)	LN	MN	SN	Z	SP	MP	LP
LN	LP	LP	LP	MP	MP	SP	Z
MN	LP	MP	MP	MP	SP	ZE	SN
SN	LP	MP	SP	SP	Z	SN	MN
Z	MP	MP	SP	Z	SN	MN	MN
SP	MP	SP	Z	SN	SN	MN	LN
MP	SP	Z	SN	MN	MN	MN	LN
LP	Z	SN	MN	MN	LN	LN	LN

LN: large negative, MN: medium negative, SN: small negative, Z: zero, SP: Small positive, MP: medium positive and LP: large positive.

Table1. Fuzzy rules for ACE(k) and ΔACE(k)

As will be shown in the simulation results, the conventional PI controller results in a large overshoot and a long settling time Also, settling time for the control parameters is very long. According to many researchers, there are some reasons for the present popularity of fuzzy logic control. First of all, fuzzy logic can be easily applied for most applications in industry.

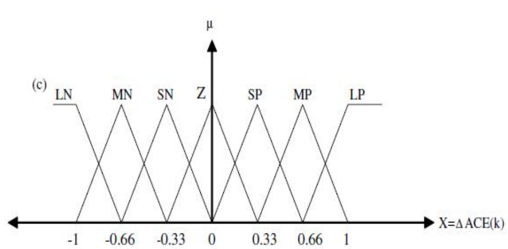

Fig. 1 Membership functions of (a) ACE, (b) ΔACE and (c) Kp, Ki .

Multi stage fuzzy PID controller:

Multi stage fuzzy PID controller with fuzzy switch is a type of controller where the PD controller becomes active depending on certain conditions. The resulting structure is a controller using two-dimensional inference engines (rule base) to reasonably perform the task of a three-dimensional controller. The proposed method requires fewer resources to operate and its role in the system response is more apparent, i.e. it is easier to understand the effect of a two dimensional controller than a three-dimensional one. So, three dimensional controller can partitions into two dimensional one.

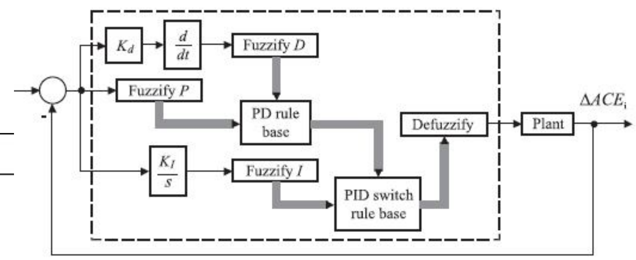

Fig. 2 The proposed multi stage fuzzy PID controller.

e \ Δe	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PS	PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

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$\int e$ \ PD Values	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NM	NS	NB	PS	PM	PB
NM	NB	NM	NS	NM	PS	PM	PB
NS	NB	NM	NS	NS	PS	PM	PB
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NB	NM	NS	PS	PS	PM	PB
PM	NB	NM	NS	PM	PS	PM	PB
PB	NB	NM	NS	PB	PS	PM	PB

Table 2 : PID rule base

Conventional PID controller:
One of the most widely used control methods in thermal and hydro power station governing systems is the conventional PI type controller. Proportional controller is used to reach the steady state condition much quicker because of the faster transient response with proportional controller. The proportional term of the controller produces a control signal proportional to the error in the system, so that u (t) = *K*p e (t). Typically, given a step change of load demand, low values of *K*p give rise to stable responses with large steady-state errors. Higher values of *K*p give better steady-state performance, but worse transient response. Therefore, the higher value of *K*p is used to reduce the steady state error, although increasing the gain *K*p decreases the system time constant and damping. Therefore it is evident to choose the optimum value of *K*p. The proportional action can never eliminate the steady state error in the system because some (small) error must be present in order to produce a control output. A common way of reducing the steady state error is by incorporating integral action into the controller

III. POWER SYSTEM INVESTIGATED

A three area extended thermal-hydro interconnected system can be used to analyze dynamic analysis of the system for 1%step disturbance is as shown in figure1,with following specifications.

f = 50 Hz, R1 =R2= R3=2.4 Hz/ per unit MW,
Tg1=Tg2 = 0.08 sec, Tp1=Tp2=Tp3=20 sec;
P tie, max = 200 MW ; Tr = 10 sec ;
Kr = 0.5, H1 =H2 =H3= 5 sec ;
Pr1 = Pr2 =Pr3=2000MW;Tt1=Tt2 = 0.3 sec ;
Kp1=Kp2=Kp3 = 120 Hz.p.u /MW ;
Kd =4.0;Ki = 5.0 Tw = 1.0 sec;
D1 =D2=D3= 8.33 * 10-3 p.u MW/Hz.;
B1=B2=B3=0.425p.u.MW/Hz;
a1=a2=a3=0.545;
a=2*pi*T12=2*pi*T23=2*pi*T31=0.545
delPd=0.01;

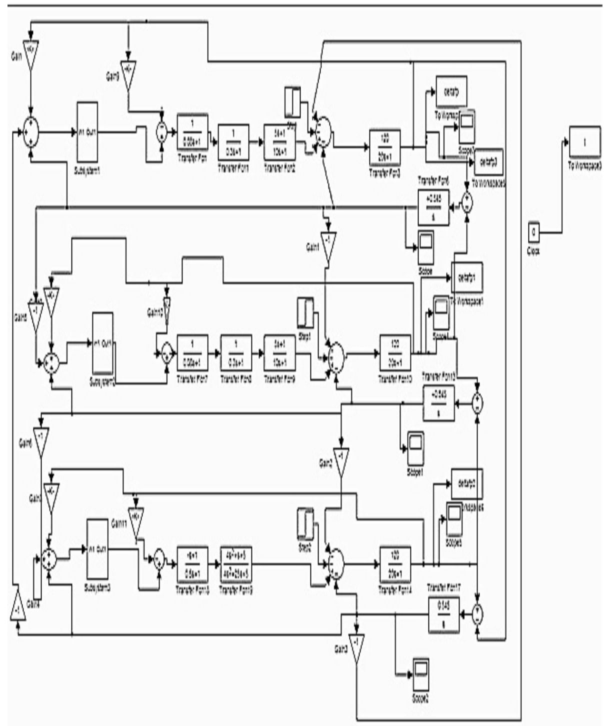

Fig. 3 Simulink model of hydro thermal re-heat energy three area interconnected system.

V.RESULTS AND DISCUSSIONS

The simulation of considered system for PI,PID and FUZZY PID are obtained as shown in below figures and from those corresponding conclusions can be made from the respected results of variable controllers.

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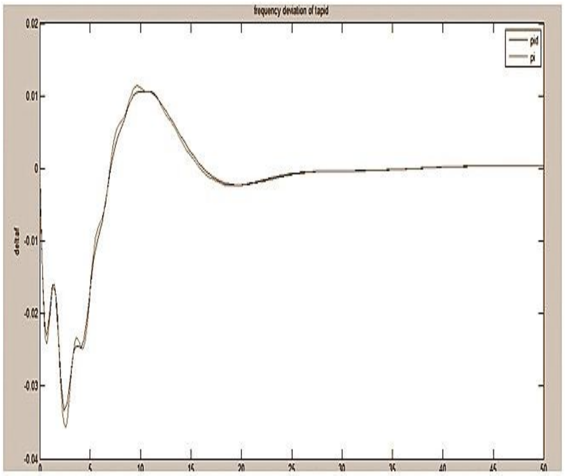

Fig 4:Comparison graph of thermal power plant for PID to PI controller.

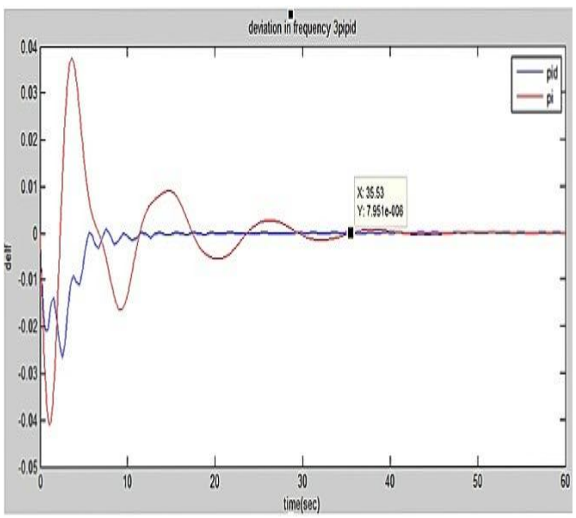

Fig. 5 Comparison graph of change in frequency of hydro-thermal power plant for PID to PI controller.

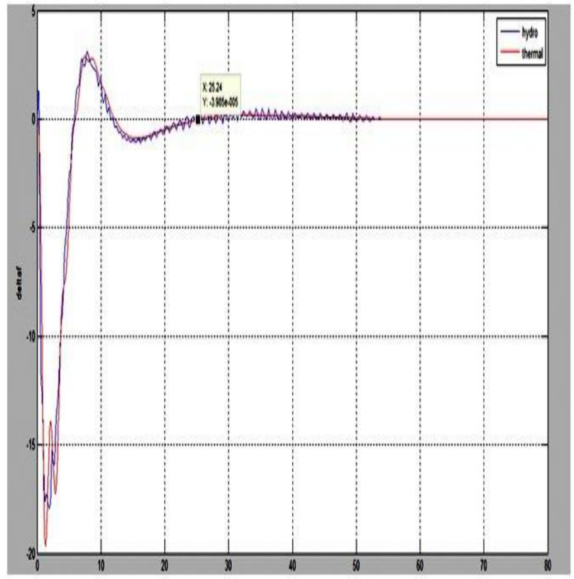

Fig 6 Comparison of Change in frequency of hydro-thermal power plant

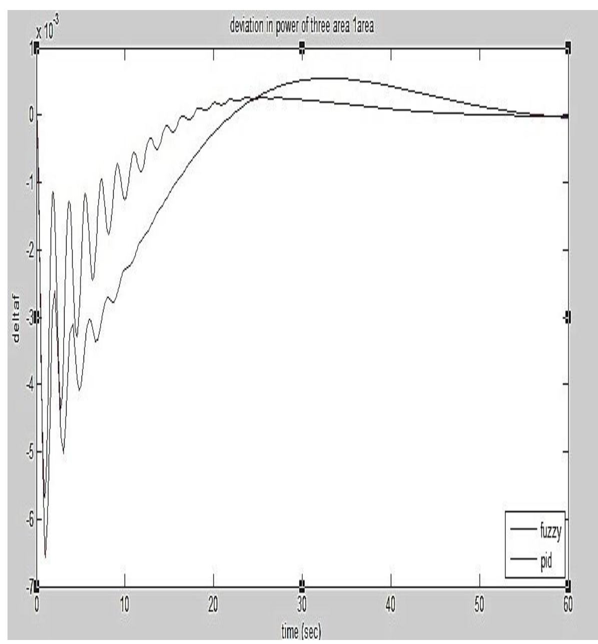

Fig. 7 Comparison graph of power deviation hydro thermal power plant with fuzzy PID and conventional PID.

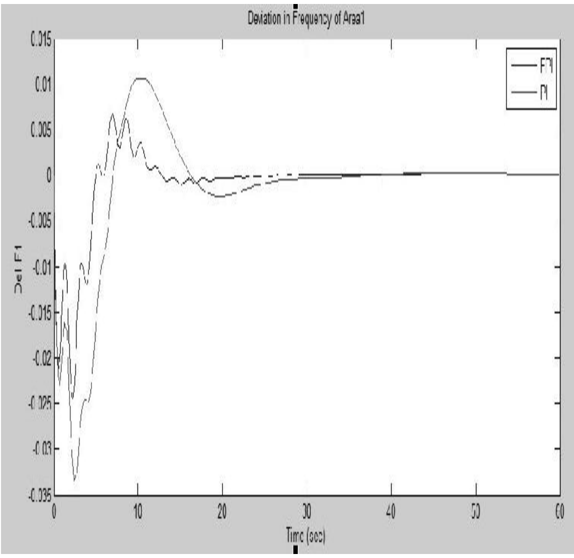

Fig.8 comparison graph of hydro thermal power plant for fuzzy pi to conventional pi.

Controller	Steady state	Peak over shoot
PI	X=35.53,Y=0.00007	X=3.802;Y=0.00007
PID	X=21.73,Y=0.000042	X=5.95;Y=0.00004
Fuzzy PID	X=29.17Y=0.000127	X=8.218 Y=0.0003
Fuzzy PI	X=27.8 Y=0.000113	X=6.763;Y=0.0061

Table3. Comparison results for PI,PID and FUZZY LOGIC controllers with 1%step change in steady state and peak overshoot aspects of considered system.

Controller	Steady state	Peak over shoot
PI	X=38.63,Y=0.0001059	X=10.28;Y=0.0108
PID	X=34.57,Y=0.000114	X=9.67;Y=0.0011
Fuzzy PID	X=29.17Y=0.000127	X=0.841 Y=0.0001042
Fuzzy PI	X= 40.19Y=0.0024	X=8 Y=0.0129

Table4. Comparison results for PI,PID and FUZZY LOGIC controllers with 1%step change in steady state and peak overshoot aspects of considered system. For three area interconnected thermal system.

Form the above tables it is clear that responses obtained, reveals that FUZZY PID gives better Settling performance than PID and PI controller. Therefore, the intelligent control approach using FUZZY PID concept is more accurate and faster than the conventional PI control scheme even for complex dynamical system. it is clear that responses obtained, reveals that PID better Settling performance than PI. Therefore, the intelligent control approach using PID concept is more accurate and faster Than the conventional PI control scheme even for complex dynamical system.

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