Load frequency control for diverse sources of interconnected two area power system:an adaptive fuzzy approach

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***Abstract*—This paper addresses adaptive fuzzy logic controller for load frequency control of a multi-source two area power system with different power generation sources viz hydro gas & thermal power plant. Expert knowledge is required for conventional fuzzy logic control in developing parameters. Whereas in this method rules are tuned online by adaptation algorithm according to operating condition. The robustness of adaptive fuzzy logic controller has been shown by comparing with conventional fuzzy logic controller and integral controller. The comparison is done based on various performance indices like settling times and peak overshoots for 1 percent step load perturbation.**

***Keywords*—Fuzzy Logic Control; Adaptive Fuzzy Logic control. Load Frequency Control;**

I. INTRODUCTION

Generators with same response characteristics for load variations grouped together to meet a particular load demand is called area. Such an areas multiple will present in large scale power system. These areas are interconnected with tie lines these tie lines are used to exchange energy between areas, increases fault level and inter area support in case of abnormal conditions [1-3]. Area may have combination of different sources in this paper each area consists of thermal with reheat type turbine system, hydro, gas power generation. [16].

Conventional control strategy for frequency regulation problem is based on applying corrective signal governor summing point using PI, PID controllers. These controllers acheives zero steady state error but dynamic performance exhibited by these controllers is very poor. More over PI/PID controllers fails to provide best performance over a variety of operating conditions.

Literature survey on LFC shows various control strategies have been employed for load frequency control problem. Optimal state feedback control approaches, suboptimal state feedback controllers are proposed in [4-5]. Adaptive and self-tuning approaches are proposed in [6-7].

Evolutionary algorithms like GA,PSO, optimization, bacterial foraging etc applied by several authors [8-10].

In extensive literature survey LFC shows that LFC with ANN & Fuzzy logic control application providing better performance for load frequency control problems [10-12]. Drawback of conventional fuzzy logic controller is lack of ability of self-tuning. Irrespective of operating condition it computes all fuzzy singleton outputs for fuzzifying crisp output i.e. control action.

This paper suggests AFLC for two area multi-source power system that gains the merits of fuzzy logic control and adaptive control. In this proposed method, the controller initially uses FLC rule base to ensure acceptable performance during the learning stage with the adaptation algorithm the rule base of FLC tuned online for different operating conditions. This method uses reduced rule base compared to conventional fuzzy logic controller [13-15].

II. TWO AREA MODEL

A Multisource two area power system model used in this research is shown in Fig.1. The controller shown in Fig.1 is tie line bias control. Objective of LFC is to reduce area control error to zero.

$$ACE_1 = \Delta P_{tie12} + B_1\Delta f_1$$
$$ACE_2 = \Delta P_{tie21} + B_2\Delta f_2 \qquad (1)$$

An overall satisfactory performance is achieved when B_i is selected to be equal to the frequency bias factor of that area. So

$$B_i = D_i{+}/R_T = D_i{+}1/R_H = D_i{+}1/R_G\,, \quad i = 1,2$$

Controller block in Fig.1 is conventionally PI controller which is replaced with fuzzy logic controller and adaptive fuzzy logic controller. Dynamic responses of three controllers are tested at different operating conditions.

III. FUZZY LOGIC BASED LFC

Mamdani type FLC is used for frequency control. FLC can be divided into three modules. Fuzzifier assigning membership values to inputs and output. In this FLFC fuzzy logic consists two inputs and seven normalized MF's represents the fuzzy set variation from NM to PM (NB,NM,NS,Z,PS,PB,PM) having centroids at -1, -0.5,-0.25,0,0.25,0.5,1 respectively. Fig.2 shows the membership functions for ACE,dACE,U_f..

The variables are normalized by multiplying with respective gains K_e,K_{de} and K_u called shrinking factors so that their values lie between -1 and +1.

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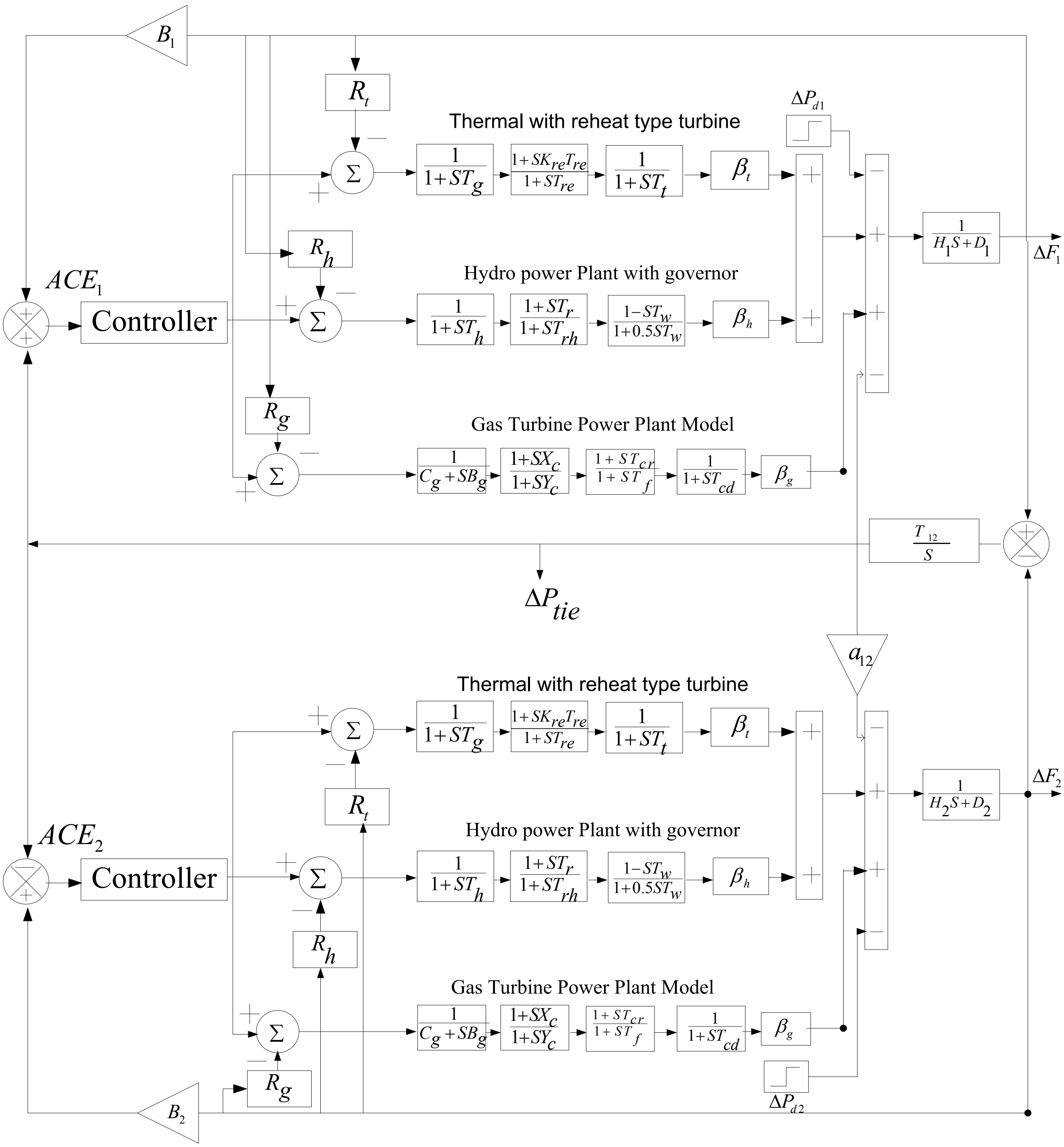

Fig.1 Transfer function model of multi source two area LFC model

Second module is inference engine which consist of rule base. It contains knowledge of linguistic labels and control rule. Table 1 shows rule base for decision making & inferring control action.

Defuzzification is conversion of sum of fuzzy singleton outputs into crisp value which is control action for governor.

$$U_f = \frac{\sum_{j=1}^{N} X_j \theta_j}{\sum_{j=1}^{N} X_j} = \theta^T \varsigma \quad (2)$$

Objective functions is to minimize area control error

$$J = \min\left(\sum_{i=1}^{2} ACE_i\right)$$

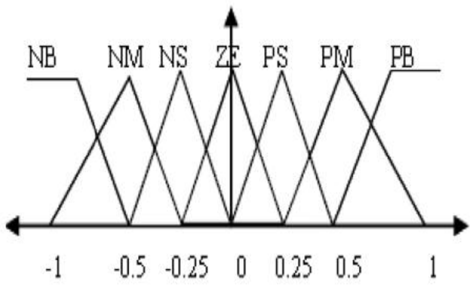

Fig.2 Membership function for ACE,dACE,U_f

IV. Adaptive Fuzzy Logic Based Load Frequency Controller

Implementation of this method is simple and straight forward. AFLFC adapts the membership functions. The inputs for AFLFC are desired data in pattern file that is created from expert knowledge [13]. Output of the AFLFC is membership functions and tunes the membership functions according to the operating condition and computes the consequent parts of the rules in rule base and eq. 2 will be applied to calculate the control signal U_f .

The adaptive algorithm can update its parameters which are MF's shrinking factors K_e,K_{de} and K_u, according to the model file, by using adaptation algorithm. The update rule for each parameter in AFLC could ($1 \leqslant p \leqslant P$) entry of training data could defined as

$$e_p = 0.5(d_k - o_k) \quad (3)$$

Where d_k is the k^{th} component of p^{th} desired output vector o_k is the k^{th} component of actual output. Where e_p is target error, the network is able to reproduce exactly desired output vector in the p^{th} training data pair. Objective is to minimize the error.

$$E = \sum_{p=1}^{p} e_p \quad (4)$$

TABLE I. FUZZY LOGIC RULES

ACE	*dACE*						
	NB	***NM***	***NS***	***ZE***	***PS***	***PM***	***PB***
NB	-1	-1	-1	-1	-0.5	-0.25	0
NM	-1	-1	-1	-0.5	-0.25	0	0.25
NS	-1	-1	-0.5	-0.25	0	0.25	0.5
Z	-1	-0.5	-0.25	0	0.25	0.5	1
PS	-0.5	-0.25	0	0.25	0.5	1	1
PM	-0.25	0	0.25	0.5	1	1	1
PB	0	0.25	0.5	1	1	1	1

Proposed structure consists of two inputs ACE, dACE and one output U_f.Modified rule base for AFLC is shown in Table2. At the beginning, the model file is prepared it contains three variables which are error (ACE), change in error (dACE) and control signal U_f. Each one contains 500 samples (P=500). Then the target error in total measure E is chosen as 0.0001 and program run. Fifty nine epochs have been performed and normalized errors computed as

TABLE II. ADAPTIVE FUZZY LOGIC CONTROLLER RULES

ACE	**dACE**						
	NB	***NM***	***NS***	***ZE***	***PS***	***PM***	***PB***
NB	-0.14	-0.14	-0.14	-0.14	-0.01	-0.001	0
NM	-0.14	-0.14	-0.14	-0.01	-0.001	0	0.001
NS	-0.14	-0.14	-0.01	-0.001	0	0.001	0.01
Z	-0.14	-0.01	-0.001	0	0.001	0.01	0.14
PS	-0.01	-0.001	0	0.001	0.01	0.14	0.14
PM	-0.001	0	0.001	0.01	0.14	0.14	0.14
PB	0	0.001	0.01	0.14	0.14	0.14	0.14

0.00009129. At this condition the relation between ACE, dACE and U_f is shown in Table2.

V. Results & Discussion

In order to verify effectiveness of proposed adaptive fuzzy logic controller, computer simulations are carried out by using MATLAB software. A comparative study among the three controllers adaptive fuzzy logic controller, fuzzy logic controller and integral controller are carried out in this paper by considering 1% step load perturbation in area 1.Frequency response of area 1, area 2 and tie line power are shown in Fig.3,Fig.4,Fig.5 respectively. Comparative study in terms of peak overshoot and settling time are tabulated. In order to test the effectiveness of proposed controller it is tested at different operating conditions like 0.05p.u. and 0.1p.u. step load disturbances on area l.

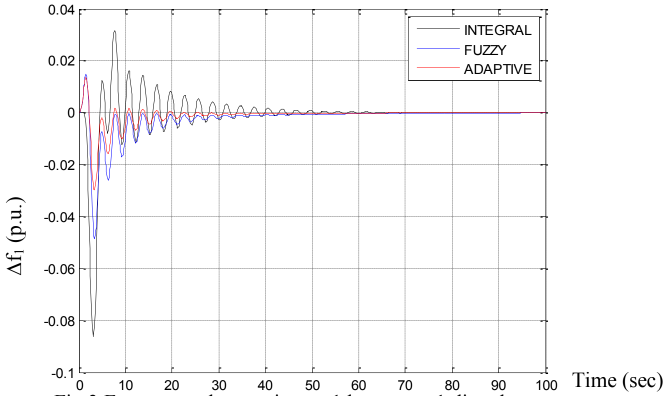

Fig.3 Frequency changes in area1due to area1 disturbance

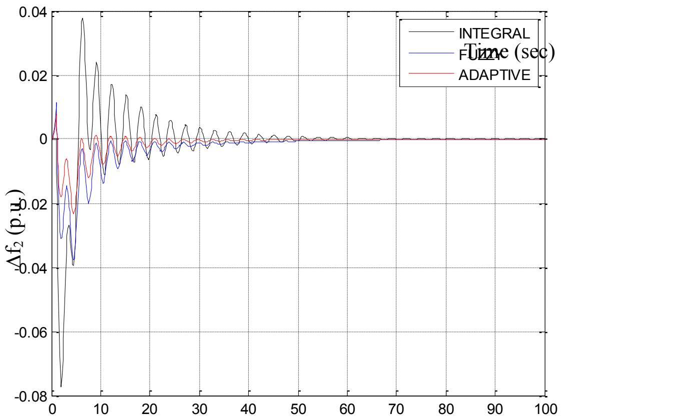

Fig.4 Frequency changes in area 2due to area 1 disturbance

TABLE III COMPARATIVE STUDY OF PEAK OVERSHOOTS

Controller	$\Delta f_1(pu)$	$\Delta f_2(pu)$	$\Delta P_{TIE12}(pu)$
Integral	-0.0861	-0.0772	0.0155
Fuzzy	-0.0486	-0.0375	-0.00595
Adaptive Fuzzy	-0.0298	-0.0235	-0.00542

TABLE IV COMPARATIVE STUDY OF SETTLING TIMES

Controller	$\Delta f_1(sec)$	$\Delta f_2(sec)$	$\Delta P_{TIE12}(sec)$
Integral	70	76	80
Fuzzy	44	50	66
Adaptive Fuzzy	35	40	62

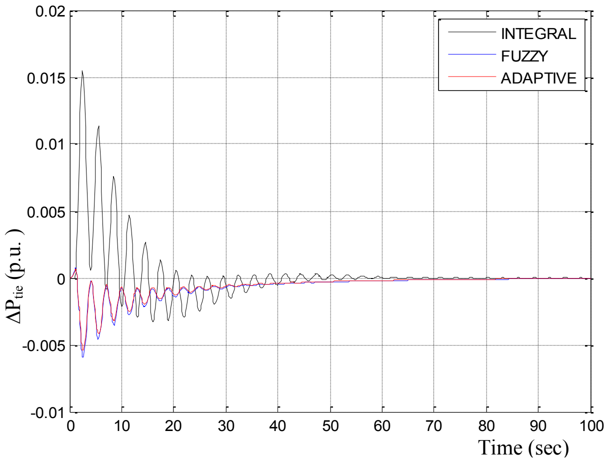

Fig.5 Tie line power changes due to area 1 disturbance

VI. CONCLUSION

This paper studies the frequency and tie line fluctuations in a two area power system controlled by using adaptive fuzzy logic controlled technique. MATLAB simulations have been carried out in order to ensure superiority of proposed control scheme. Proposed controller has been tested for 1% step load perturbation. A comparative study among AFLFC, FLC and integral controllers is carried out. Simulation results shows proposed controller providing better dynamic response compared other two controllers.

APPENDIX: System Parameters

R_t=R_h=R_g=Speed regulation constant=2.4Hz/p.u.;

T_g, T_{re}, T_t = Time constants of governor, reheater, turbine = 0.08s, 10s, 0.3s;

T_r = Reset time of hydro turbine governor =5s;

T_w = Nominal starting time of water in penstock=1s;

β_t = Participation factor of thermal power plant = 0.54;

β_h = Participation factor of hydro power plant =0.326;

β_g = Participation factor of gas power plant = 0.13048;

K_{re} = Steam turbine reheat constant=0.3;

B_1=B_2= Frequency bias factor = 0.4311;

D_1=D_2=Frequency sensitive load coefficient=0.0145 *p.u./Hz*

T_{12} = Synchronizing power coefficient = 0.0433;

H_1 =H_2 = Inertia constant = 5;

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