Load Frequency Control of Multi Area Power System using Different Intelligent Controllers

Anoop Kumar Singh, Sudhir Kumar Srivastava, Vikas Pandey

***ABSTRACT-** In power system engineering exact load prediction is difficult task because a continuous load changing in power systems network that disturb the frequency directly. If the frequency is deviate from its limit, there show a severe effect on power system. So load frequency controller (LFC) is designed and if it working properly, the frequency is quickly returned to the normal operating point that means steady state error become zero. There are two types of controllers used in this paper which are Fuzzy controllers and GA-PID (pid controller tuned by genetic algorithm) controllers. The performance of GA-PID controller is quite fast and efficient. The result shows an improved performance in terms of rise time, settling time, steady state error and overshoot. In this paper we use linear single area (thermal) and two area (thermal-thermal) model for simplification. The effectiveness of the proposed controller is confirmed via extensive study using MATLAB/SIMULINK software. Simulation results are carried out by 10% system disturbances in both of one and two areas power system.*

***Keywords:** Fuzzy controller, genetic algorithm, load frequency control, PID controller.*

I. INTRODUCTION

In a interconnected power systems, changes in the load directly affect the frequency. Load frequency control is a play the important role in the operation of power systems. In power system the prediction of load at a particular time is difficult so load is varying continuously that causes fluctuates frequency randomly & continuously. Load Frequency Control is define as a necessary action by which a balance between power demand and power generation is maintained. Changes in the power demand affect the frequency of the power system as well as the tie-line power flow between control areas [1]. Therefore, the main objectives of the LFC are to keep the system frequency at the scheduled value which is normally 50 Hz, and maintain the net tie-line power flow at the contracted level. There has been continuing interest in designing of load-frequency controllers with better performance during past 40 years. There are control strategies for LFC have been proposed since the 1970s [2]. In this paper a linear model is used for simplification are given in fig.no.1 and around a nominal operating point is used in the load frequency controller design. However in power system many components are nonlinear, so the operating conditions of power systems are continuously changing. Therefore robustness becomes a main issue in the attempt to design a controller to satisfy the basic requirements for zero steady state and acceptable transient frequency deviations.

Revised Version Manuscript Received on January 13, 2016.

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For this reason, many control approaches have been developed for the load frequency control. Among them, pid controllers, various adaptive controller, intelligent controller (fuzzy, neural and genetic)[3]. In this paper, because of the inherent nonlinearity of power systems an intelligent controller GA-PID and FUZZY is used. In fuzzy logic controller we use seven membership functions which is triangular type. By using of fuzzy logic controller Zero steady-state frequency deviation can be achieved but its dynamic performance is unsatisfactory.GA-PID method improves the dynamic performance when compared with the fuzzy logic controller. In below load frequency model is given [4].

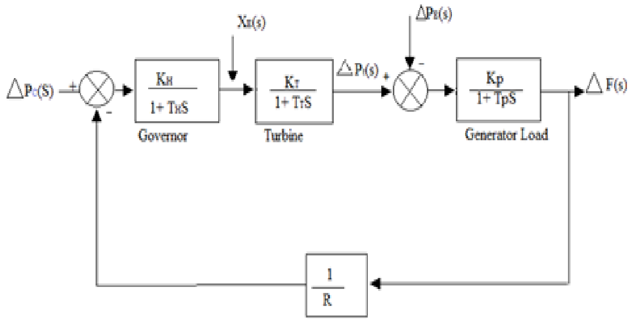

Fig.1 Linear Model of The Power System

ΔP_E = sudden load change (p.u.MW), K_P = electric system gain, K_H = gain of speed governor T_P = electric system time constant (s), T_T = turbine time constant (s), T_H = governor time constant (s), R = speed regulation due to governor action (Hz/p.u.MW),ΔF(S) = incremental freq. deviation (Hz),ΔP_t (S) = incremental change in generator (p.u.MW), $X_E(S)$ = incremental change in governor valve position.

II. MATHEMATICAL MODELING

(A) Speed Governor Model

Assume that the system is initially operating under steady state condition. The linkage mechanism is govern the modelling of governor. Thus the nominal conditions are Power delivered = P_G^0, Frequency = f^0, Steam valve position = X_E^0

Let the point A on the linkage mechanism which is given in page no.292 [5] be moved downwards a small distance ΔX_A.

$$\Delta X_A = K \Delta P_C,$$

Where ΔP_c is the increased power.

The pilot valve moves upwards, high pressure oil on the top of main piston moving it downwards; the steam valve opening consequently increases that means turbine generator speed increases [5]. Thus the net movement of link point C is

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$$\Delta X_C = -K_1 K_C \Delta P_C + K_2 \Delta P_C$$
$$\Delta X_D = K_3 \Delta X_C + K_4 \Delta X_E$$

Now if an assumption is made that the flow of oil into the servo-motor is proportional to position ΔX_D of the pilot valve V , then the movement ΔX_E of the piston can be expressed as-

$$\Delta X_E = K_5 \int (-\Delta X_D)\, dt$$

Taking Laplace transform of these equation and eliminating $X_C(s)$ and $\Delta X_D(s)$

$$\Delta X_E(s) = \left[\Delta P_C(s) - \frac{1}{R}\Delta f(s)\right]\frac{K_H}{1 + sT_H}$$

Where R = speed regulation of the governor

K_H = Gain of speed governor

T_H = time const. of speed governo

B) Modelling of Turbines:

The steam chest and inlet piping to the all compounded turbines introduce delays between valve movement and change the steam flow.

The continuity equation is

$$\frac{dw}{dt} = Q_{in} - Q_{out}$$

Where w is the weight of the steam in volume (m^3), t is time in seconds and Q_{in} and Q_{out} are flows assuming the weight flow out of the vessel is proportional to pressure in the vessel.

$$Q_{out} = \frac{P}{P_0} Q_0 \quad \frac{dQ_{out}}{dt} = \frac{Q_0}{P_0}\frac{dP}{dt}$$

Where

P= variable vessel pressure

P_0= steady state vessel

Q_0 =steady state weight flow out at P_0

Thus $$\frac{dw}{dt} = \frac{\partial w}{\partial p}\frac{dP}{dt} = v\frac{\partial}{\partial P}\frac{1}{v}\frac{dP}{dt}$$

Where ν is specific volume (m^3/wt) of steam in vessel.

$$Q_{in} - Q_{out} = \frac{P_0}{Q_0} v \frac{\partial}{\partial P}\left(\frac{1}{v}\right)$$

Let

$$T_T = \frac{P_0}{Q_0} v \frac{\partial}{\partial P}\left(\frac{1}{v}\right)$$

Then

$$\frac{Q_{out}}{Q_{in}} = \frac{1}{sT_T + 1}$$

(C) Generator Load Model`

The increment in power input to the generator load system is ΔP_T-ΔP_E. This increment in power input to the system will be absorbed by the system in two ways.

1. By increasing the kinetic energy W_{Kin} in the rotor generator at the rate $\frac{d(W_{Kin})}{dt}$.

2. By an increased local consumption.

Thus this surplus power can be expressed as

$$\Delta P_T - \Delta P_E = \frac{dW_{Kin}}{dt} + B\Delta f$$

Where B is called damping coefficient.

$$\Delta P_T - \Delta P_E = \frac{2W_{Kin}}{f_0} + B\Delta f$$

By dividing this equation by the generator rating P_r and by introducing the H(per unit inertia constant). So incremented power becomes in

Laplace transform

$$\Delta P_T(s) - \Delta P_E(s) = \frac{2H}{f_0} s\Delta f(s) + B\Delta f(s)$$

Or it can be written as

$$\Delta f(s) = G_P(s)\left[\Delta P_T(s) - \Delta P_E(s)\right]$$

where $G_P = \frac{K_P}{1 + sT_P}$

$$T_P = \frac{2H}{f_0 B} = \text{Power system time constant}$$

$$K_P = \frac{1}{B} = \text{Power system gain}$$

(D) Modelling of Tie line

In these day power systems are divided into various areas. For example in India , there are five regional grids, e.g., Eastern Region, Western Region etc. Each of these areas is generally interconnected to its neighbouring areas. The transmission lines that connect an area to its neighbouring area are called tie-lines .

During normal condition, the real power transferred over the tie line is given by

$$P_{tie1} = \frac{|V_1||V_2|}{X}\sin(\delta 12)$$

Where X= $X_1 + X_{tie} + X_2$ and $\delta_{12} = \delta_1 - \delta_2$ are the angles of end voltages V_1 and V_2 respectively.

Analogous to the concept of “electric stiffness” of synchronous machines we define the “synchronous coefficient” of a line

$$T_{12} \approx \frac{|V_1||V_2|}{X}\cos(\delta_{12})$$

Thus the equation can be written as

$$\Delta P_{tie1} = T_{12}(\Delta\delta_{12})$$

III. INTELLIGENT CONTROLLER

(A) Fuzzy Logic Control System

The proposed model of a LFC is shown in Fig. 1. The model consists of regulator, turbine and generator load. The adaptive fuzzy controller is used to control the deviation of the frequency. There are two inputs and one output of the fuzzy controller. The first input is the error between reference value that is desired output value. The second input is the derivative of the error.

The inputs and output are multiplied by the scaling factors KI, K2 and K3, respectively. The design of the fuzzy controller depends on information about the system behaviour or experience of a human expert. The fuzzification stage is determined by the choice of the range, shape and number of the membership functions.

The output membership functions are chosen to be nonuniformly distributed seven triangular functions in order to minimize the computation time[6]. The range of the input and output membership functions is chosen in [-0.25 to +0.25). Input scaling factors are used to normalize the input magnitude.

The membership functions of the input and output variables are shown in fig.2 & Fuzzy rule in fig.3.

	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	EZ
NM	PB	PM	PM	PM	PS	ZE	NS
NS	PB	PM	PS	PS	ZE	NS	NM
ZE	PM	PM	PS	ZE	NS	MN	NM
PS	PM	PS	ZE	NS	NS	MN	NB
PM	PS	ZE	NS	NM	NM	MN	NB
PB	ZE	NS	NM	NM	NB	NB	NB

Fig.2 Fuzzy Rule

Where NB = negative big, NM= negative medium, NS=negative small, ZE= zero, PS= positive small, PM= positive medium, PB= positive big

The fuzzy controller is used the max-min inference method that called as the Mamdani type inference. Defuzzification method is chosen as centre of gravity method. The input and output scaling factors must be adjusted in order to make the fuzzy controller more sensitive to changes in the system[7].

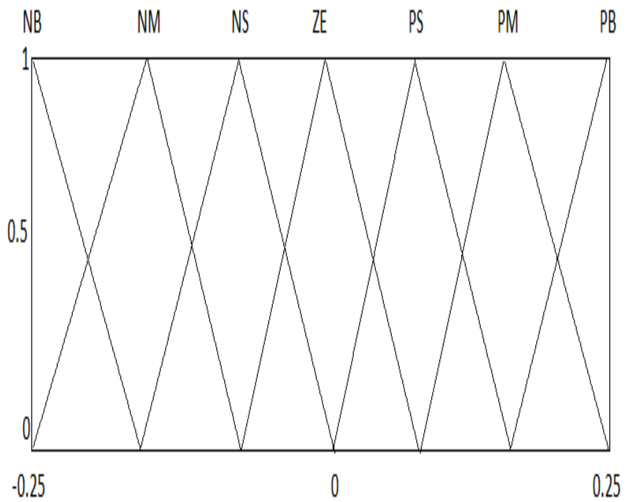

Fig.3 Membership Function for Error and Derivative for the Error

In the proposed algorithm, many simulations have been performed to find optimum values of the scaling factors. Thus, the appropriate values of the scaling factors have chosen in different load conditions.

(B) Genetic Algorithm

In the field of artificial intelligence genetic algorithms is a search heuristic method that mimics the process of natural evolution. Genetic algorithm is belong to the longer class of evolutionary algorithm. It is one of the methods used for optimization. The John Holland formally introduce the genetic algorithm in the 1970 at the University of Michigan. Genetic Algorithms are search and optimization techniques inspired by two biological principles namely the process of natural selection and the mechanics of natural genetics. GAs manipulate not just one potential solution to a problem but a collection of potential solutions. This is known as population. There is no particular specified rule with regards to the no. Of population size adopt. The potential solution in the population is called chromosome[8]. A fitness function is a particular type of objective function that is used to summarise, as a single figure of merit how close a given design solution is to achieving the set aims. There are three main stages of a genetic algorithm, that's reproduction, crossover and mutation.

Reproduction

Parents are selected at random with selection chances biased on relation to evaluations. A fit chromosome has a higher probability of being selected for reproduction. The size of the section is proportional to the fitness of the individual. This continues until the selection criterion has been met.

Crossover Cross over is a process of taking more than one parent solutions and producing a child solution from them. The crossover operations swaps certain parts of the two selected strings in a bid to capture the good parts of old chromosomes and create better new ones.

Mutation- mutation is a type of genetic operator that is used for maintain genetic diversity from one generation of a population to the next. A mutation serves as a safeguard against a premature loss of important genetic material and is done by random alteration of a binary digit at random location.

Adaptation of pid controller

The transfer function of pid controller is

$$G_C(S) = K_p + \frac{K_i}{s} + K_d S$$

Where kp is proportional gain, k_i and k_d are integral and derivative time constants respectively. In this simulation, the objective is to minimize the fitness function. For this reason the objective function is chosen as the Integral Absolute Error (IAE).

$$IAE = \int |e|\, dt$$

The minimization fitness function becomes

$$f = \frac{1}{ISE}$$

The control signal for the conventional PID controller can be given in the following equations.

$$U_{PID}(S) = \left(K_p + \frac{K_i}{S} + K_d(S)\right)\left(\frac{1}{\int |e|\, dt}\right)$$

In this paper the no. of variables is three (K_p , K_i ,K_d),the population type is double vector , population size is 20 , the initial range of variable is [0.5– 10]. The mutation function is Gaussian, the crossover function is scattered , the stopping rules is the no of generation is 150 , and the stall time limit is 500 sec[9],[10].

IV. SIMULATION RESULT

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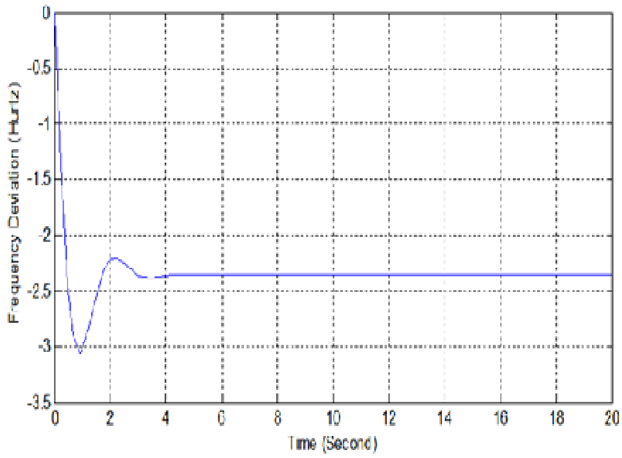

FIG.4 Single Area Uncontrolled

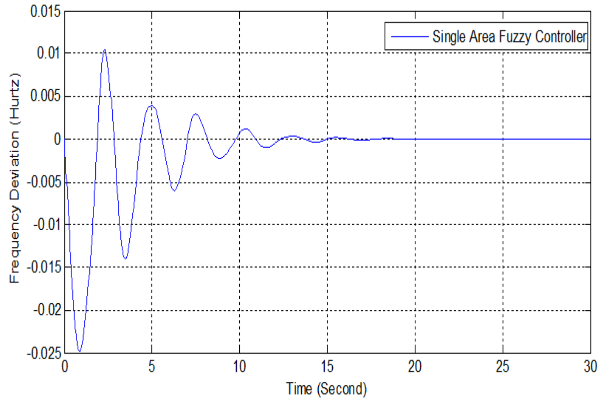

FIG.5 fuzzy logic Controller for Single Area

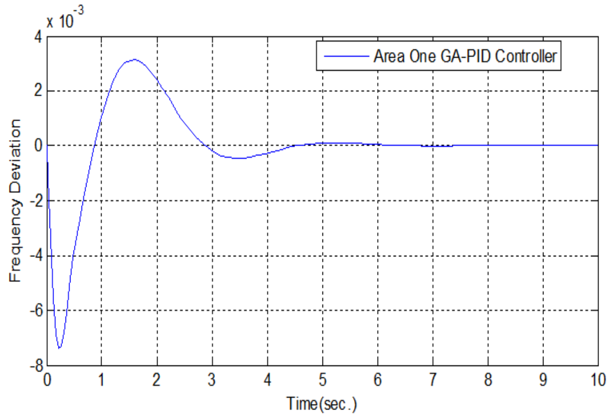

FIG.6 GA-PID Controller for Single Area

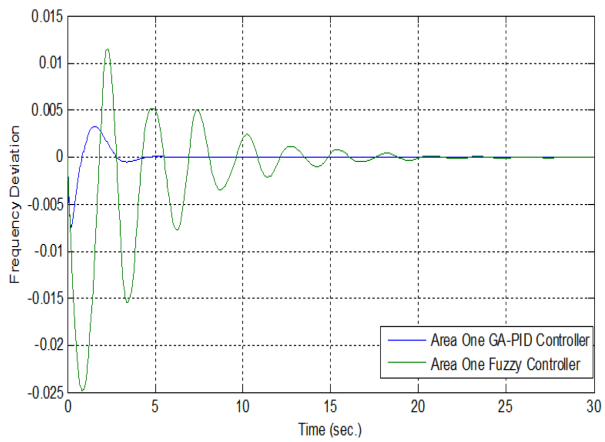

FIG.7 Comparison between fuzzy logic controller and GA-PID controller

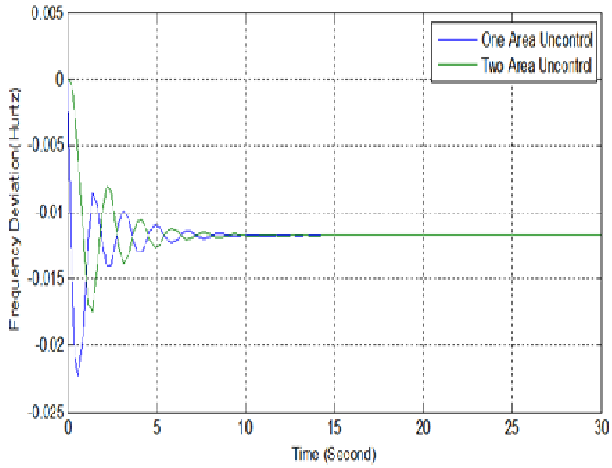

FIG. 8 Two Area Uncontrolled

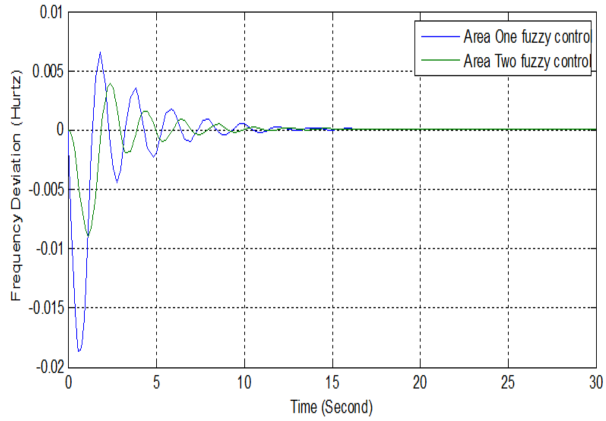

FIG.9 fuzzy logic controller for two area

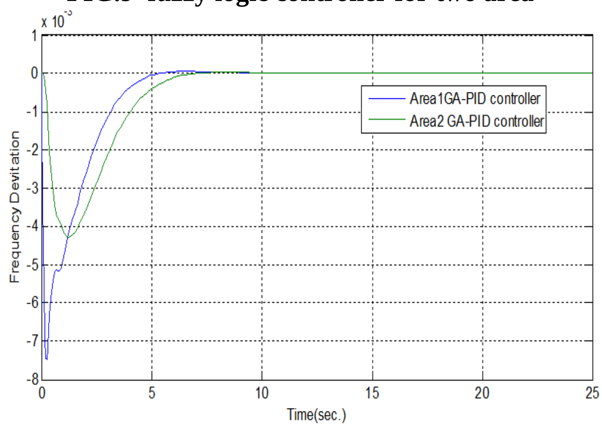

FIG.10 GA-PID controller for two area

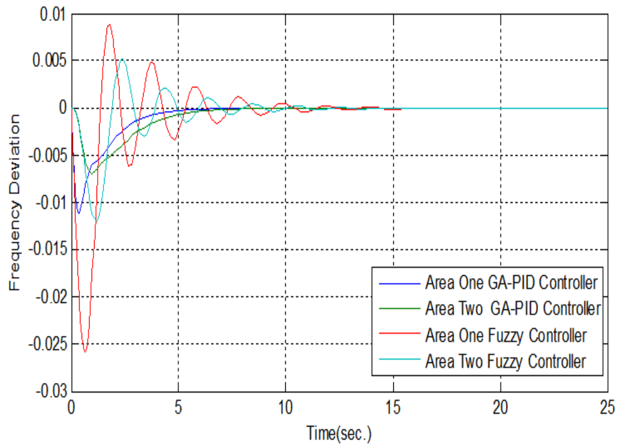

FIG.11 Comparison between fuzzy logic and GA-PID

V. CONCLUTSION

This paper has described a optimal control technique that has been applied to the non-linear LFC problem and hence is able is to improve the performance of a power system and the quality of supply. As the results shown by figure 4to 11, it is clearly observed that the performance regarding the overshoot and settling time of GA-PID controller is much better than the Fuzzy controller. By using GA-PID controller the settling time is reduced much and also there is no steady state error. Hence it has been concluded that the GA-PID controller shows its effectiveness over the Fuzzy controller.

REFERENCE

1. Dulpichet Rerkpreedapong , Ali Feliachi , N. Atic "Economy Oriented Model Predictive Load Frequency Control " USDOEEPSCOR WV State Implementation Award IEEE 2003
2. Y. Wang, R. Zhou, C. "Wen Robust; load-frequency controller design for power systems" IEE PROCEEDINGS-C. Val 140. No I , JANUARY 1993
3. Pan C. T. and C. M. Liaw, **"An** adaptive controller for power system load frequency control", IEEE Trans. On Power Systems, Vo1.4, No.1, PP.122-128, 1988.
4. Saadat, Hadi; " Power System Analysis" McGraw-Hill,1999
5. Nagrath I.J. and Kothari D.P.; "Modern Power System Analysis " McGraw-Hill,2004,New Delhi
6. R. C. Bansa, "Bibliography on the fuzzy set theory applications in power systems (1994-2001)", IEEE Transactions on Power Systems, vol. 18 (4), pp. 1291-1299, November 2003.
7. J. Bih, "Paradigm shift - an introduction to fuzzy logic", IEEE Potentials, vol. 25 (1), pp. 6-21, 2006.
8. K. Krishnakumar and D. E.Goldberg, .Control System Optimization Using Genetic Algorithms., Journal of Guidance, Control and Dynamics, Vol. 15, No. 3, pp. 735-740, 1992.
9. T O.Mahony, C J Downing and K Fatla, .Genetic Algorithm for PID Parameter Optimization: Minimizing Error Criteria., Process Control and Instrumentation 2000 26-28 July 2000, University of Stracthclyde, pg 148-153, July 2000.
10. Varsek, T. Urbacic and B. Filipic, .Genetic Algorithms in Controller Design and Tuning., IEEE Trans. Sys.Man and Cyber, Vol. 23, No. 5, pp1330-1339, 1993