LOAD FREQUENCY CONTROL FOR A TWO AREA INTERCONNECTED POWER SYSTEM USING ROBUST GENETIC ALGORITHM CONTROLLER

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ABSTRACT

In this paper a new robust load frequency controller for two area interconnected power system is presented to quench the deviations in frequency and tie line power due to different load disturbances. The dynamic model of the interconnected power system is developed without the integral control. The area control error is also not included. The frequency and derivatives are zero under normal operation and after the disturbance effects are died. Then the problem is restructured as the problem of state transfer from the initial steady state to final steady state without oscillations in less time. The Genetic algorithm (GA) controller designed here consists of two crisp inputs namely deviation of frequency and the other is derivative of frequency deviation. The output of the Genetic algorithm controller is the control input to each area. The studies power system is subjected to a wide range of load disturbances to validate the effective ness of the proposed Genetic algorithm controller. The simulated results are obtained for different configurations of the Genetic algorithm controller like placing in area 1 only and placing area 1 and area 2 for different options of load variations. The digital results prove the present Genetic algorithm controller over the other control studies presented in earlier work in terms of fast response (dead beat response for certain configuration of Genetic algorithm controller) with very less undershoots and negligible overshoot with having small state transfer time to reach the final steady state with zero frequency.

Keywords: - *Load frequency control problem, Genetic algorithm control, Interconnected power system*

1. INTRODUCTION

The modern power systems with industrial and commercial loads need to operate at constant frequency with reliable power. The load frequency control of an interconnected power system is being improved over the last few years. The goals of the LFC are to maintain zero steady state errors in a multi area interconnected power system [1], [2]. The Studies on two area interconnected power system networks were presented based on conventional techniques. Recently many researchers have applied GA controllers to improve the dynamic performance of the system. Subsequently robust load frequency control for uncertain non linear power systems using GA approach to quench the transients in frequency deviations and tie line power deviations is presented [8, 9].

In all these works the basic dynamic model representation of a two area power system given in the reference [2] is considered and the responses of two area power systems are evaluated. These studies using conventional and Genetic algorithm control methods show that the frequency deviations are oscillatory and the total time to reach final steady state is more.

The work reported in this paper deals with the representation of a two – area power system with new state variables. The power system is represented using frequency deviation, rate of frequency deviation and its derivative as variables namely Δf_1, $\Delta \dot{f}_1$ & $\Delta \ddot{f}_1$ and Δf_2, $\Delta \dot{f}_2$ & $\Delta \ddot{f}_2$ of the two areas concerned. It is known that the deviations Δf_1 *and* Δf_2 and their derivatives are zero (initial state) when the system is operating under normal conditions. After a sudden load change in area 1 or in area 2 or in both the areas the frequency deviations are oscillatory with out any control method. However the final steady state deviations of Δf_1 *and* Δf_2 and their derivatives should be zero (final state). The integral action and area control error minimization are not considered in the derivation of the dynamic equations of the interconnected power system in this work.

The so called Load Frequency Control Problem is restructured as a state transfer problem and using a suitable control strategy the system should be transferred from an initial state to the final state without any oscillations (if possible) in frequency deviations and tie line power deviations and thereby the time to reach final steady state is very much reduced. The behavior of the two – area power system for different load changes to predict the variations is a major study with and without the application of the GA controller. With this aim an attempt is made to improve the transient behavior of the two – area power system.

The first part of the study is concentrated on the transient behavior of the uncontrolled system for a range of step load changes for the dynamic model considered here.

The second part of the study is to predict the robustness of the proposed GA controller designed with two crisp inputs namely Δf and derivative of Δf without any integral action. The output of the GA controller is the input given to each area.

The system frequency deviations are zero before any disturbance in the power system. Assuming a step load change in area 1 if the GA controller is incorporated in area 1 the system behavior is observed. Studies are also conducted to find the response of the system by placing the GA controller in area 2. Studies are also performed to load changes in both areas with GA controllers. The behaviors of the interconnected power system for different load changes are also obtained in all these cases.

In this work, we investigate the optimum adjustment of the classical AGC using genetic algorithms [3] and performance indices, namely the integral of time – multiplied absolute value of the error (ITAE) [4], which is given by,

$$S = \int_0^\infty t\left|e(t)\right| dt \qquad ---(1.1)$$

A digital simulation is used in conjunction with the genetic algorithms optimization process to determine the optimum values of the AGC for the performance indices considered. Genetic algorithms are used as parameters search techniques which utilize the genetic operators to find near optimal solutions [5].

2. MODELING OF TWO –AREA INTERCONNECTED POWER SYSTEM

The two area interconnected power system is shown in fig.1, where Δf_1 *and* Δf_2 are the frequency deviations in area 1 and area 2 respectively in Hz. ΔP_{D1} *and* ΔP_{D2} are the load demand increments.

In most of the studies earlier the researchers have used the dynamic model of the power system given by O. I. Elgerd [1]. A dynamic model with $\Delta f_1, \Delta \dot{f}_1$ and $\Delta \ddot{f}_1$ and $\Delta f_2, \Delta \dot{f}_2$ and $\Delta \ddot{f}_2$ as state variables is derived. The dynamic equations are represented in eqn. (1.2).

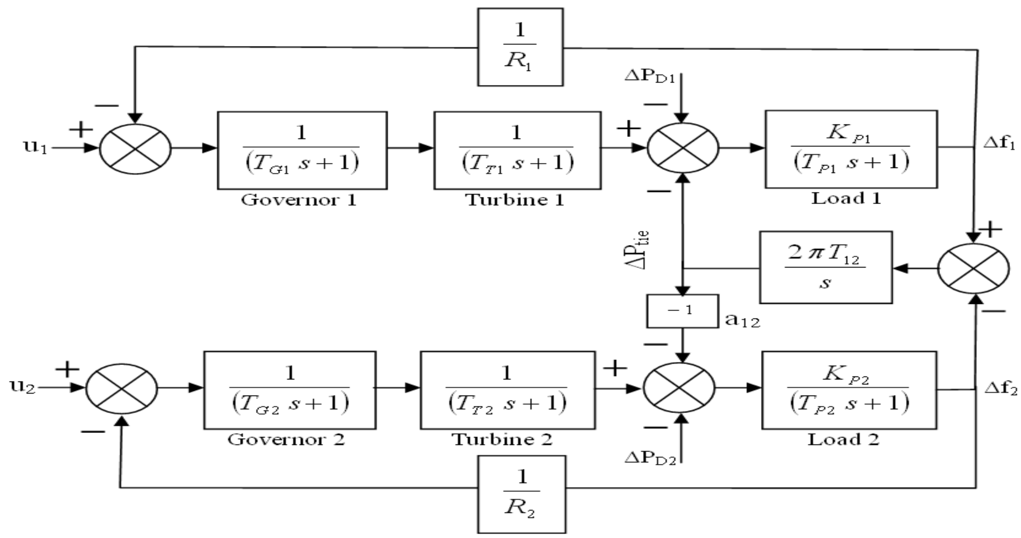

Fig. 1: Two area interconnected power system

$$
\begin{aligned}
\dot{X}_1 &= X_2\\
\dot{X}_2 &= X_3\\
\dot{X}_3 &= \frac{1}{T_3}\Big\{-\big(K_1 + 2\pi\, T_{12}K_{P1}(T_{G1}+T_{T1})\big)X_1 - \big(T_1 + 2\pi\, T_{12}K_{P1}T_{G1}T_{T1}\big)X_2\\
&\qquad - T_2X_3 + 2\pi\, T_{12}K_{P1}\big(T_{G1}+T_{T1}\big)X_4 + 2\pi\, T_{12}K_{P1}T_{G1}T_{T1}\, X_5\\
&\qquad + K_{P1}\big(u_1 - \Delta P_{D1} - X_7\big)\Big\}\\
\dot{X}_4 &= X_5 \qquad\qquad ---(1.2)\\
\dot{X}_5 &= X_6\\
\dot{X}_6 &= \frac{1}{T_6}\Big\{-\big(K_2 + 2\pi\, a_{12}T_{12}K_{P2}(T_{G2}+T_{T2})\big)X_4 - \big(T_4 + 2\pi\, a_{12}T_{12}K_{P2}T_{G2}T_{T2}\big)X_5\\
&\qquad - T_5X_6 + 2\pi\, a_{12}T_{12}K_{P2}\big(T_{G2}+T_{T2}\big)X_1 + 2\pi\, a_{12}T_{12}K_{P2}T_{G2}T_{T2}\, X_2\\
&\qquad + K_{P2}\big(u_2 - \Delta P_{D2} + a_{12}\, X_7\big)\Big\}\\
\dot{X}_7 &= 2\pi\, T_{12}\big(X_1 - X_4\big)
\end{aligned}
$$

Where

$$x_1 = f_1,\ x_2 = \dot{f}_1,\ x_3 = \ddot{f}_1,\ x_4 = f_2,\ x_5 = \dot{f}_2,\ x_6 = \ddot{f}_2 \text{ and } x_7 = P_{tie}$$

$$K_1 = \frac{K_{P1}+R_1}{R_1};T_1 = T_{P1}+T_{G1}+T_{T1};T_2 = T_{P1}T_{G1}+T_{G1}T_{T1}+T_{T1}T_{P1};T_3 = T_{P1}T_{G1}T_{T1}$$

$$K_2 = \frac{K_{P2}+R_2}{R_2};T_4 = T_{P2}+T_{G2}+T_{T2};T_5 = T_{P2}T_{G2}+T_{G2}T_{T2}+T_{T2}T_{P2};T_6 = T_{P2}T_{G2}T_{T2}.$$

3. NEW GENETIC ALGORITHM CONTROLLER FOR THE INTERCONNECTED POWER SYSTEM

Genetic algorithms (GA) are global search techniques, based on the operations observed in natural selection and genetics [6]. They operate on a population of current approximations. The individuals initially drawn at random, from which improvement is sought. Individuals are encoded as strings (chromosomes) constructed over some particular alphabet, e.g., the binary alphabet {0, 1}, so that chromosomes values are uniquely mapped onto the decision variable domain. Once the decision variable domain representation of the current population is calculated, individual performance is assumed according to the objective function which characterizes the problem to be solved. It is also possible to use the variable parameters directly to represent the chromosomes in the GA solution.

At the reproduction stage, a fitness value is derived from the raw individual performance measure given by the objective function, and used to bias the selection process. Highly fit individuals will have increasing opportunities to pass on genetically important material to successive generations. In this way, the genetic algorithms search from many points in the search space at once and yet continually narrow the focus of the search to the areas of the observed best performance.

The selection individuals are then modified through the application of genetic operators, in order to obtain the next generation. Genetic operators manipulate the characters (genes) that constitute the chromosomes directly, following the assumption that certain genes code, on average, for fitter individuals than other genes. Genetic operators can be divided into three main categories [7], reproduction, cross over and mutation.

1. Reproduction: Selects the fittest individuals in the current population to be used in generating the next population.
2. Cross over: Causes pairs, or larger groups of individuals to exchange genetic information with one another.
3. Mutation: Causes individual genetic representations to be changed according to some probabilistic rule.

Genetic algorithms are more likely to converge to global optimal than conventional optimization techniques, since they search from a population of points, and are based on probabilistic transition rules. Conventional optimization techniques are ordinarily based on deterministic hill – climbing methods, which, by definition, will only find local optima. Genetic algorithms can also tolerate discontinuities and noisy function evaluations.

In this study, the optimal values of the parameters $\Delta f_1 (or) \Delta f_2$ and $\Delta\dot{f}_1 (or) \Delta\dot{f}_2$ which minimize an array of different performance indices are easily and accurately computed using a genetic algorithm. In a typical run of the GA, an initial population is randomly generated. This initial population is referred to as the 0^{th} generation. Each individual in the initial population has an associated performance index value. Using the performance index information, the GA then produces a new population. The application of a genetic algorithm involves repetitively performing two steps.

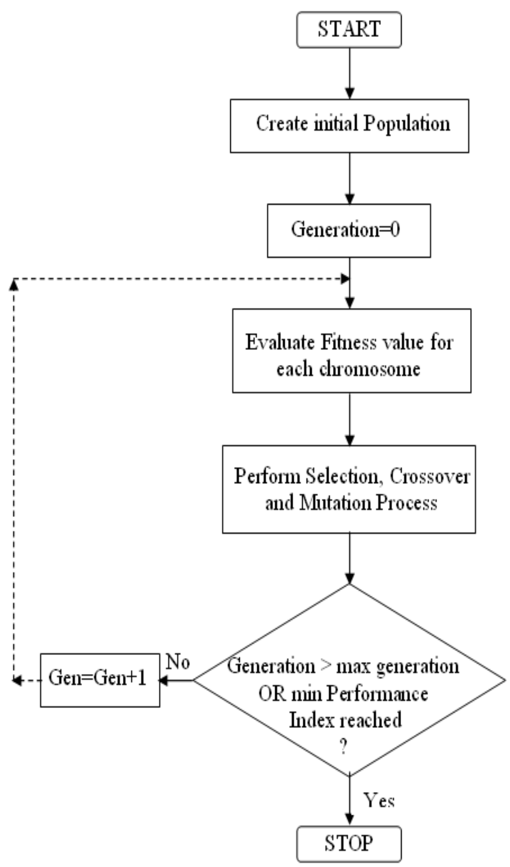

Fig.2. Genetic Algorithm flow chart

1. The calculation of the performance index for each of the individuals in the current population. To do this, the system must be

simulated to obtain the value of the performance index.
2. The genetic algorithm then produces the next generation of individuals using the reproduction, cross over and mutation operators.

These two steps are repeated from generation to generation until the population has converged, producing the optimum parameters. A flow chart of the genetic algorithm optimization procedure is given in fig.2.

4. SIMULATION STUDY

In this paper the GA controller has been applied to a two area power system having the following data.

Table 1: Two area power system parameters

Parameters	Area 1	Area 2
T_P	20 Sec	20 Sec
T_G	0.08 Sec	0.08 Sec
T_T	0.30 Sec	0.30 Sec
R	2.40 Hz / p.u.MW	2.40 Hz / p.u.MW
K_P	120 Hz / p.u.MW	120 Hz / p.u.MW
T_{12}	0.0707 Sec	
a_{12}	– 1	

A step load change of 0.01 is assumed in area 1 and the uncontrolled system responses for various load changes in area 1 with R = 2.4 are obtained. The frequency deviations in area 1 and area2 are shown in fig.3. The tie line power deviations for the same case are shown in fig.4. With step load changes in area 1 with GA controller placed in area 1, the variations in frequency deviations along with tie line power deviations are obtained and depicted in figures 5 and 6. Figures 7 and 8 shows the responses of the system with step load change in area 1 with GA controllers placed in both the areas.

5. CONCLUSIONS

Two area interconnected power system is represented using new state variables namely frequency deviation and its derivative as state variables in both the areas without integral control of frequency in each case.

The static errors of the frequency deviations and tie line power deviations are increasing with increase in load changes without GA controller.

When the controller is placed in area 1 for change of loads in that area the maximum negative overshoot Δf_1 is more compared to that of Δf_2 for a particular load change. Whereas the tie line power deviations are also oscillatory and reaching zero steady state value.

The case study with GA controllers in both the areas for a load change in area 1 indicates that the responses are oscillatory. However the magnitudes of the overshoots are less compared to that of the other case. It is also observed that the values of the maximum overshoots are increasing with increase in load changes. The settling times for frequency deviations and tie line power deviations are less with this scheme. Considering the transient behavior of the interconnected power system the scheme with two GA controllers is a better option.

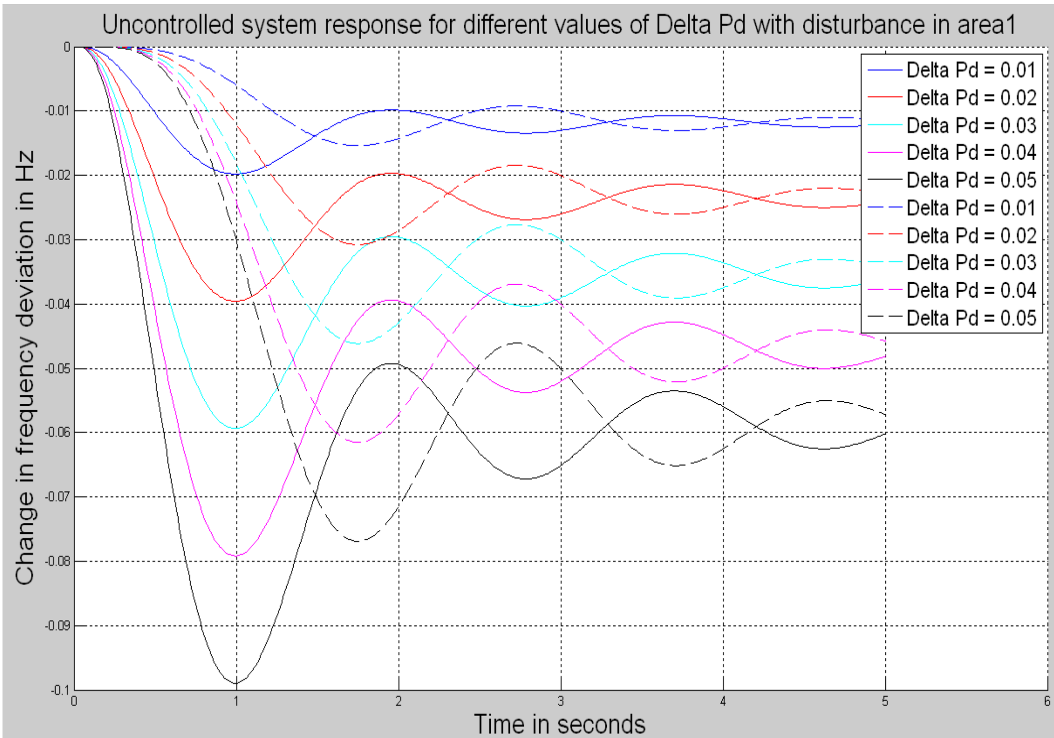

Fig.3: Variation of frequency in area 1 (–) and area 2 (– –)

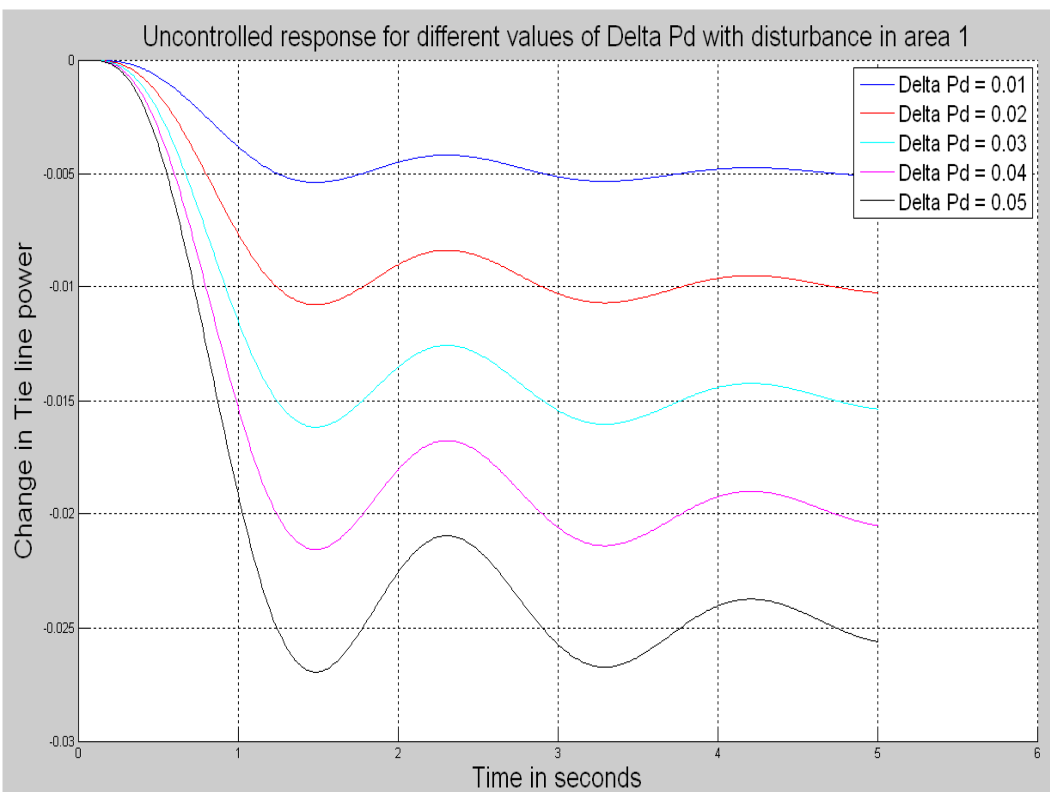

Fig.4: Variation of tie line power deviations

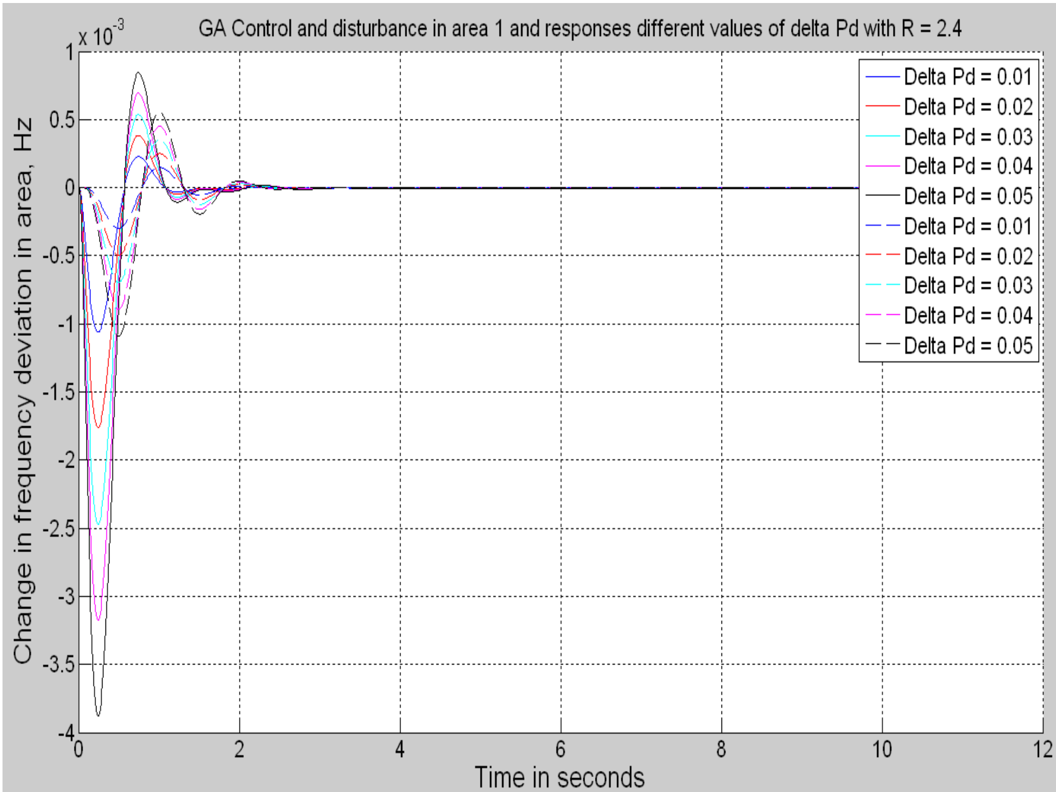

Fig.5: Variation of frequency in area 1 (–) and area 2 (– –)

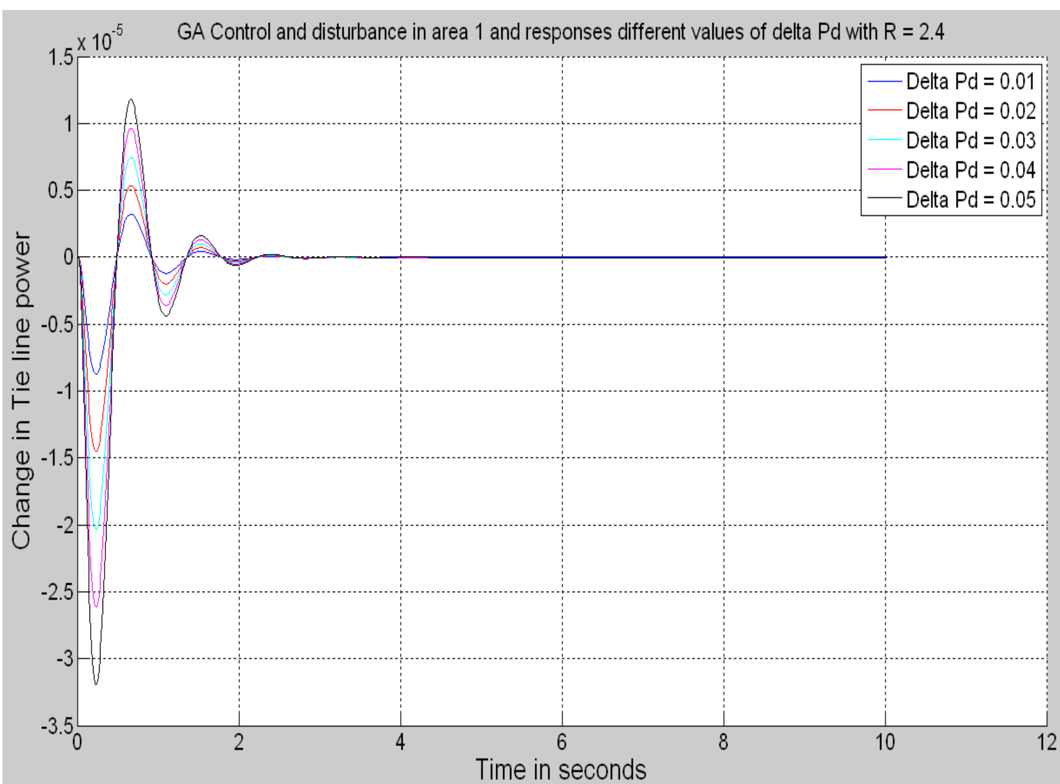

Fig.6: Variation of tie line power deviations

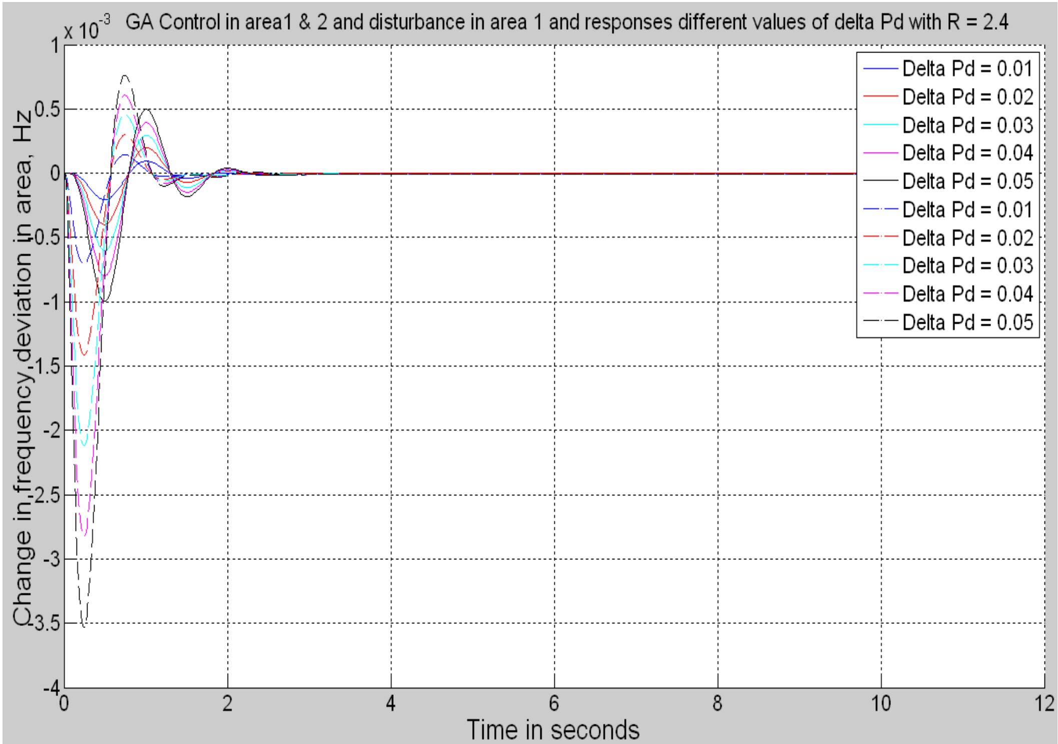

Fig.7: Variation of frequency in area 1 (–) and area 2 (– –)

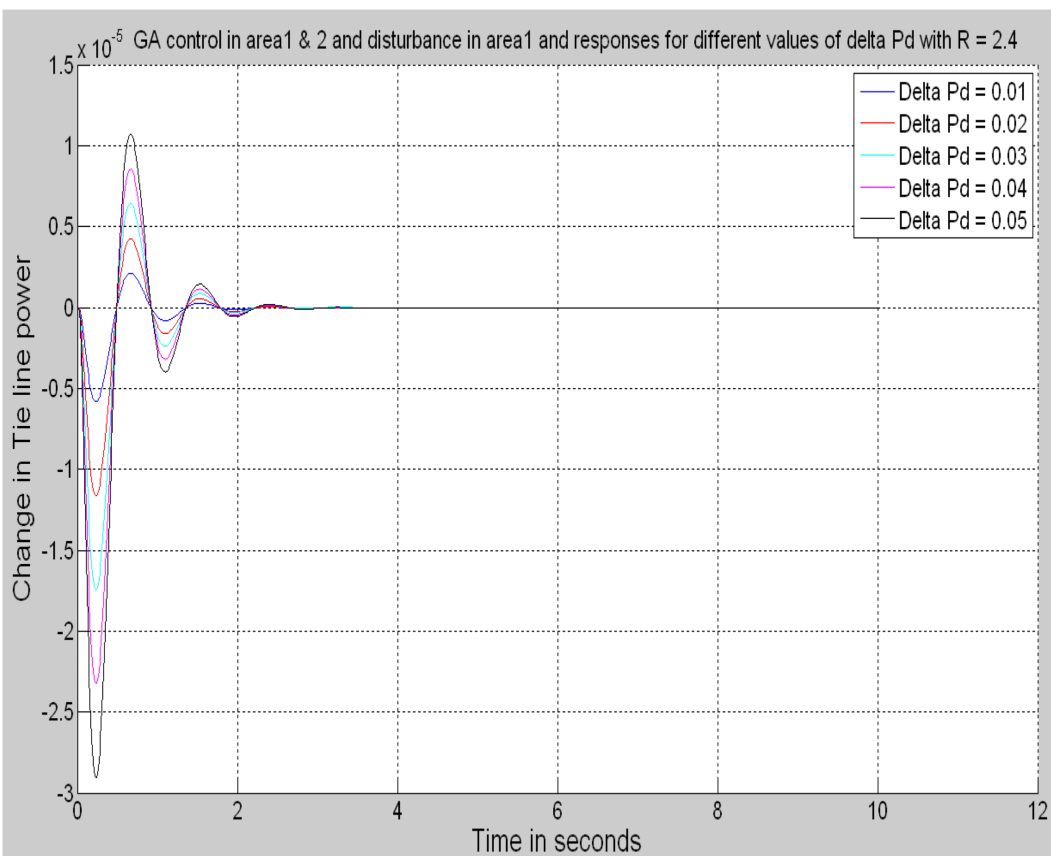

Fig.8: Variation of tie line power deviations

NOMENCLATURE

ΔP_G	=	Generated power derivation, pu MW.
ΔP_D	=	Change in power demand, pu MW.
ΔP_C	=	Change in speed changer position (u), pu MW.
Δf	=	Derivative in frequency, Hz.
K_P	=	Static gain of power system inertia dynamic block, Hz/pu MW.
T_P	=	Time constant of power system inertia dynamic block, sec.
T_G	=	Governor time constant, sec.
T_T	=	Turbine (non reheat type) time constant, sec.
R	=	Speed regulation parameter, Hz/pu MW.

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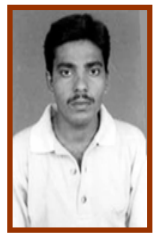
BIOGRAPHY:



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