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ROBUST FUZZY LOAD FREQUENCY CONTROLLER FOR A TWO AREA INTERCONNECTED POWER SYSTEM

[1]B. Venkata Prasanth, [2]Dr. S. V. Jayaram Kumar

[1]Associate Professor, Department of Electrical and Electronics Engineering,
N. B. K. R. Institute of Science and Technology,
Vidyanagar, A.P., India.
[2]Professor, Department of Electrical and Electronics Engineering,
J.N.T.U. College of Engineering,
Hyderabad, A.P., India.

E – mail: [1]bvenkataprasanth@yahoo.co.in, [2]svjkumar101@rediffmail.com

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 fuzzy controller designed here consists of two crisp inputs namely deviation of frequency and the other is derivative of frequency deviation. The output of the fuzzy 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 fuzzy controller. The simulated results are obtained for different configurations of the fuzzy 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 fuzzy controller over the other control studies presented in earlier work in terms of fast response (dead beat response for certain configuration of fuzzy controller) with very less undershoots and negligible overshoot with having small state transfer time to reach the final steady state with zero frequency.

Key Words: - *Load frequency control, Fuzzy logic 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].

Studies on two area interconnected power system networks were presented based on conventional techniques. Recently many researchers have applied fuzzy logic controllers to improve the dynamic performance of the system. Fuzzy logic PI, PID controllers were used to damp oscillations resulted from load perturbations [3] – [6].

Subsequently robust load frequency control for uncertain non linear power systems using fuzzy logic approach to quench the transients in frequency deviations and tie line power deviations is presented [7].

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 fuzzy 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

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$\Delta f_1, \Delta \dot{f}_1, \Delta \ddot{f}_1$ *and* $\Delta f_2, \Delta \dot{f}_2, \Delta \ddot{f}_2$ 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 behaviour 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 fuzzy controller. With this aim an attempt is made to improve the transient behaviour of the two – area power system.

The first part of the study is concentrated on the transient behaviour 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 fuzzy controller designed with two crisp inputs namely Δf and derivative of Δf without any integral action. The output of the fuzzy 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 fuzzy controller is incorporated in area 1 the system behaviour is observed. Studies are also conducted to find the response of the system by placing the fuzzy controller in area 2. Studies are also performed to load changes in both areas with fuzzy controllers. The behaviour of the interconnected power system for different load changes are also obtained in all these cases.

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 Δf_1, $\Delta \dot{f}_1$ & $\Delta \ddot{f}_1$ Δf_2, $\Delta \dot{f}_2$ & $\Delta \ddot{f}_2$ as state variables is derived. The dynamic equations are represented in eqn. (1.1).

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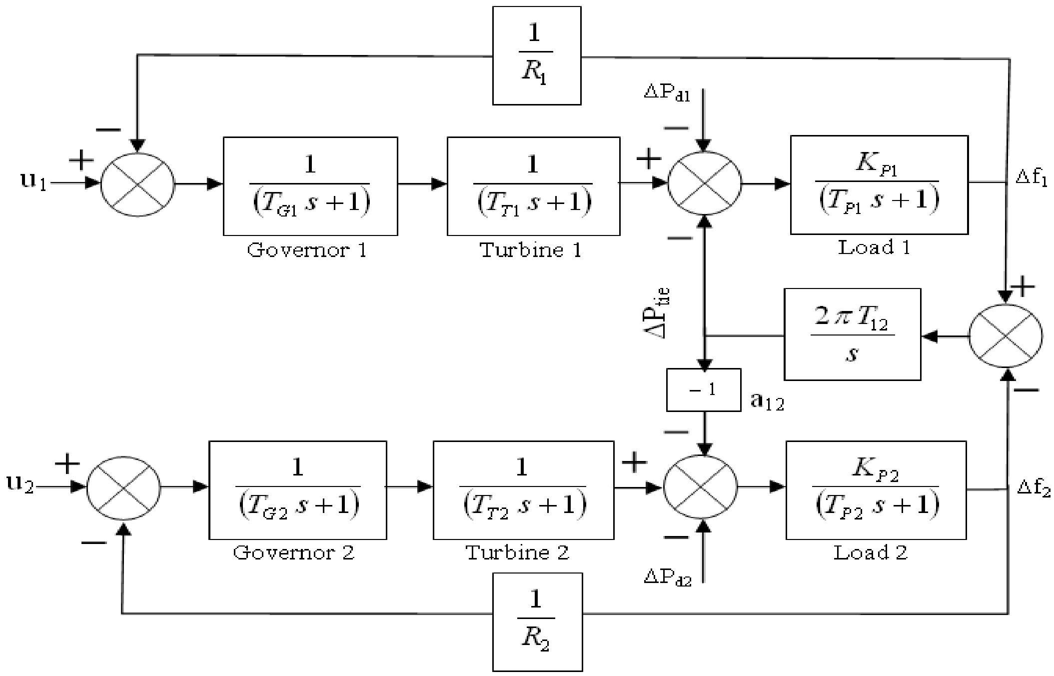

Fig.1: The two area interconnected power system

$$
\left.
\begin{aligned}
\dot{X}_1 &= X_2 \\
\dot{X}_2 &= X_3 \\
\dot{X}_3 &= \frac{1}{T_3}\{-(K_1 + 2\pi T_{12}K_{P1}(T_{G1}+T_{T1}))X_1 - (T_1 + 2\pi T_{12}K_{P1}T_{G1}T_{T1})X_2 \\
&\quad - T_2X_3 + 2\pi T_{12}K_{P1}(T_{G1}+T_{T1})X_4 + 2\pi T_{12}K_{P1}T_{G1}T_{T1}X_5 \\
&\quad + K_{P1}(u_1 - \Delta P_{d1} - X_7)\} \\
\dot{X}_4 &= X_5 \\
\dot{X}_5 &= X_6 \\
\dot{X}_6 &= \frac{1}{T_6}\{-(K_2 + 2\pi a_{12}T_{12}K_{P2}(T_{G2}+T_{T2}))X_4 - (T_4 + 2\pi a_{12}T_{12}K_{P2}T_{G2}T_{T2})X_5 \\
&\quad - T_5X_6 + 2\pi a_{12}T_{12}K_{P2}(T_{G2}+T_{T2})X_1 + 2\pi a_{12}T_{12}K_{P2}T_{G2}T_{T2}X_2 \\
&\quad + K_{P2}(u_2 - \Delta P_{d2} + a_{12}X_7)\} \\
\dot{X}_7 &= 2\pi T_{12}(X_1 - X_4)
\end{aligned}
\right\} \quad (1.1)
$$

Where

$X_1 = f_1,\ X_2 = \dot{f}_1,\ X_3 = \ddot{f}_1,\ X_4 = f_2,\ X_5 = \dot{f}_2,\ X_6 = \ddot{f}_2$ and $X_7 = P_{tie}$

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

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

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3. NEW FUZZY LOGIC CONTROLLER FOR THE INTERCONNECTED POWER SYSTEM

Fuzzy control is based on a logical system called fuzzy logic is much closer in spirit to human thinking and natural language than classical systems [5]. Nowadays fuzzy logic is used in almost all sectors of industry and science. One of them is load frequency control. Because of the complexity and multi – variable conditions of the power system, conventional control methods may not give satisfactory solutions. On the other hand, their robustness and reliability make fuzzy controllers useful in solving a wide range of control problems. The fuzzy controller proposed in this paper is new to the literature because most of the researchers have concentrated their work with different types of fuzzy PI or PID controllers. The model of the fuzzy controller used in this work is as shown in fig.2.

In this proposed work, two input membership functions (Δf *and* $\dot{\Delta f}$) for two crisp inputs and one output membership function for output (u) are defined. First input membership is having the values of $-\frac{\pi}{2}, -\frac{\pi}{4}, 0, \frac{\pi}{4}, \frac{\pi}{2}$ and is shown in fig.3. Second input membership function is having the values $-\frac{\pi}{4}, -\frac{\pi}{8}, 0, \frac{\pi}{8}, \frac{\pi}{4}$ and is shown in fig.4. The output function is having the values of -20, -10, 0, 10, 20 and is shown in fig.5. In addition, defuzzification has been performed by the centre of gravity method in all the studies. After defuzzification, the fuzzy controller output is obtained.

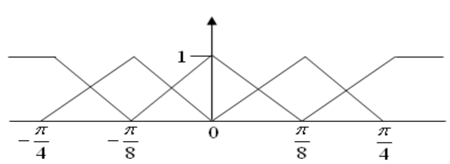

Fig. 4 Membership function for the derivative of error ($\dot{\Delta f}$)

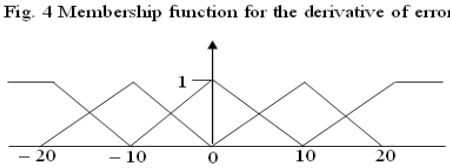

Fig. 5 Membership function for the output (u)

4. SIMULATION STUDY

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

A step load change of 0.01 is assumed in area 1 and the uncontrolled deviations in Δf_1 and Δf_2 are shown in fig.6. Fig.7 shows the tie line power deviations for the same case. The behaviour of the uncontrolled system for $\Delta P_{d1} = 0.02, 0.03, 0.04$ *and* 0.05 are also shown in these figures.

Fig 2: The simple fuzzy controller

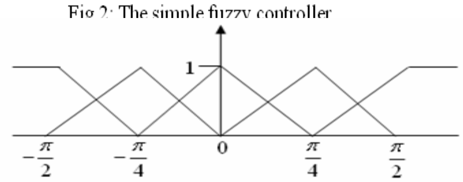

Fig. 3 Membership function for the error (Δf)

The variations of frequencies and tie line power in both the areas for uncontrolled system with equal load changes in both the areas are shown in figures 8 and 9 respectively. With step load changes in area 1 with fuzzy controller placed in area 1, the variations in frequency deviations along with tie line power deviations are obtained and depicted in figures 10 and 11. Figures 12 and 13 show the responses of the system with step load change in area 1 with fuzzy controllers placed in both the areas.

Simulation studies are also conducted assuming equal load disturbances in both the areas placing fuzzy controller in area 1 and also placing fuzzy controllers in both the areas. The corresponding responses are shown in figures 14 to 17.

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	

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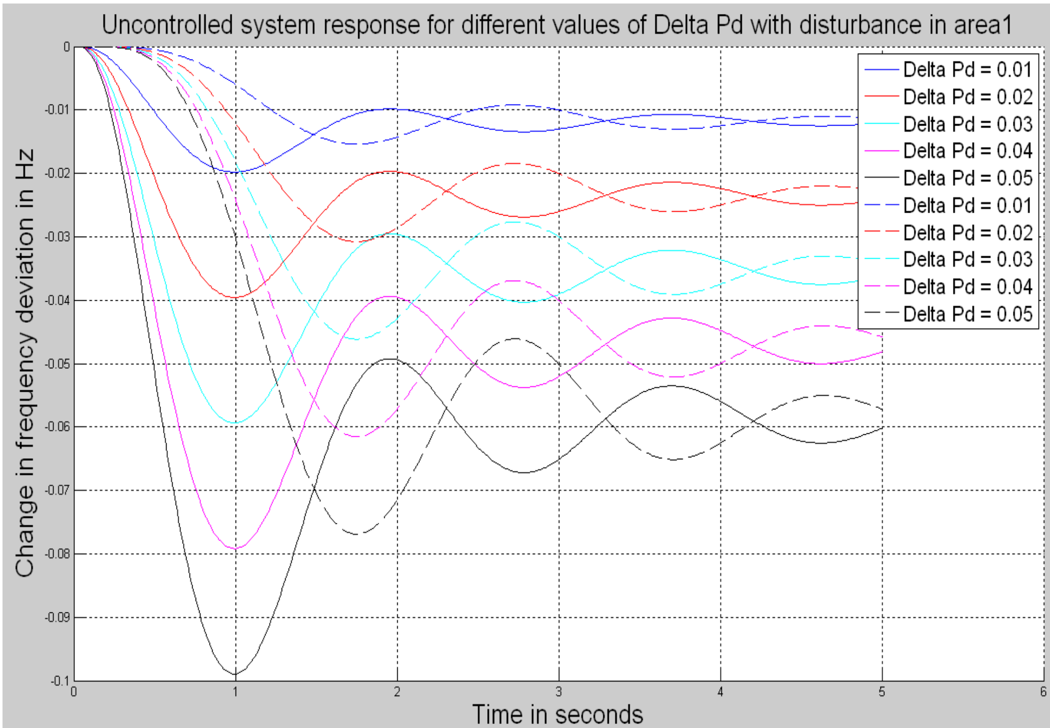

Fig.6: Variation of frequency in area 1 (–) and area 2 (– –)

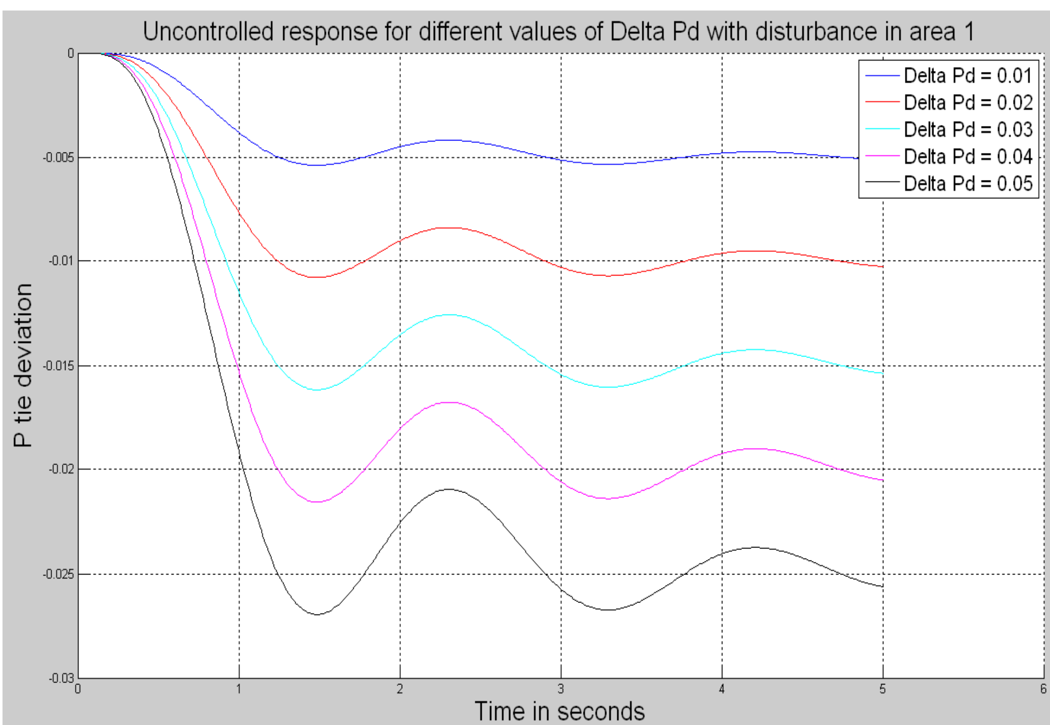

Fig.7: Variation of tie line power deviations

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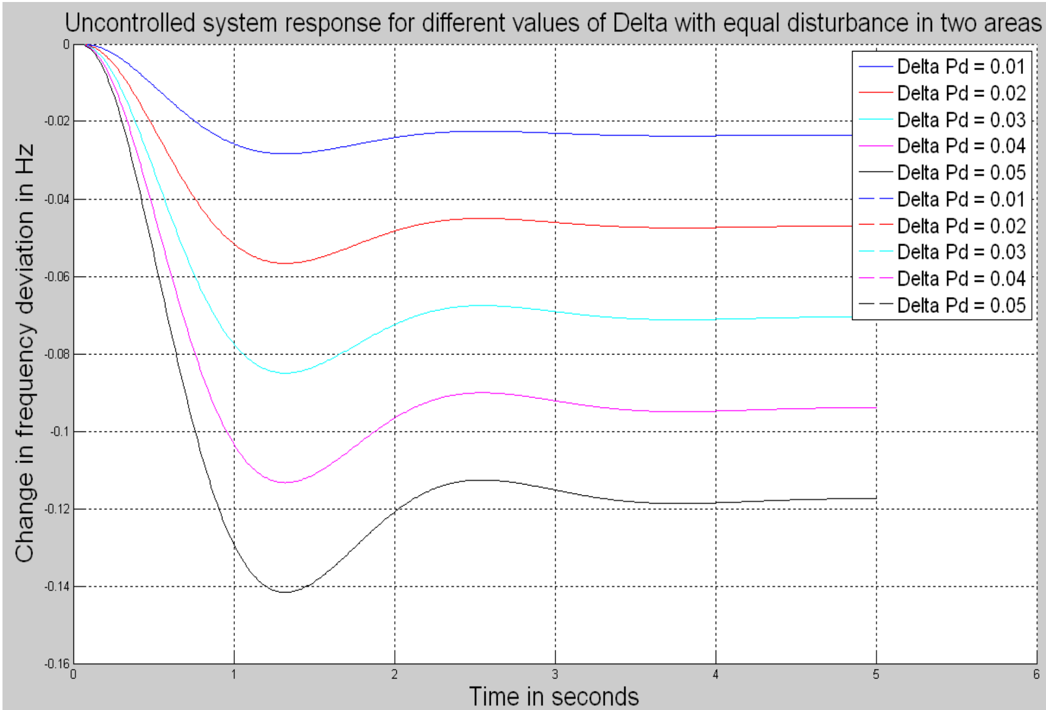

Fig.8: Variation of frequency in area 1 (–) and area 2 (– –)

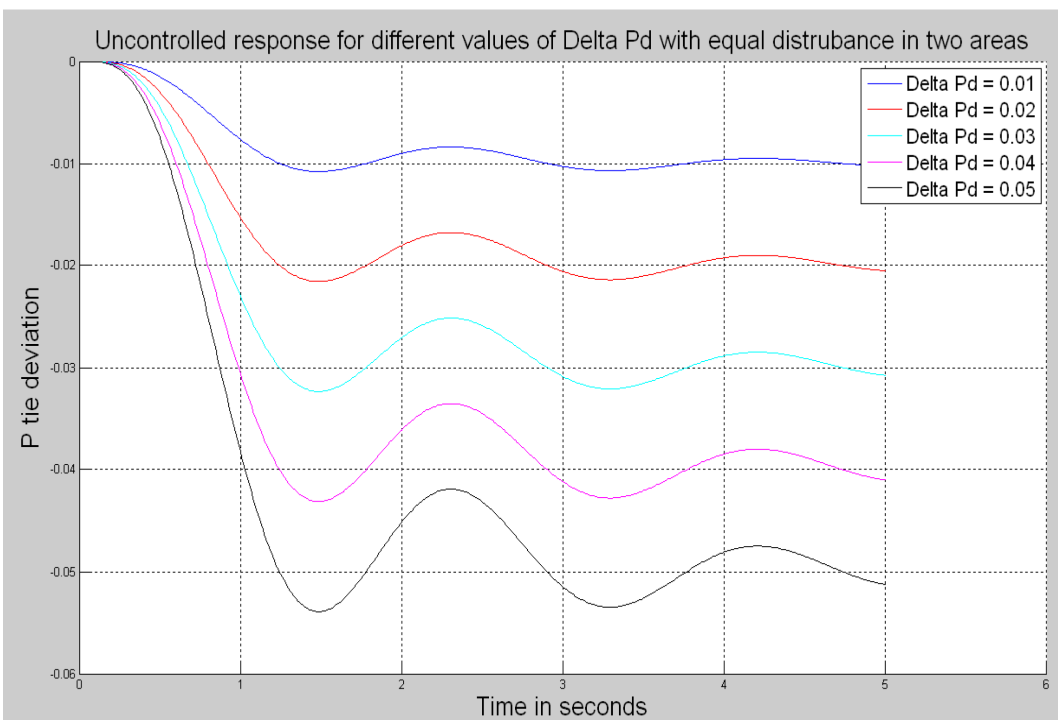

Fig.9: Variation of tie line power deviations

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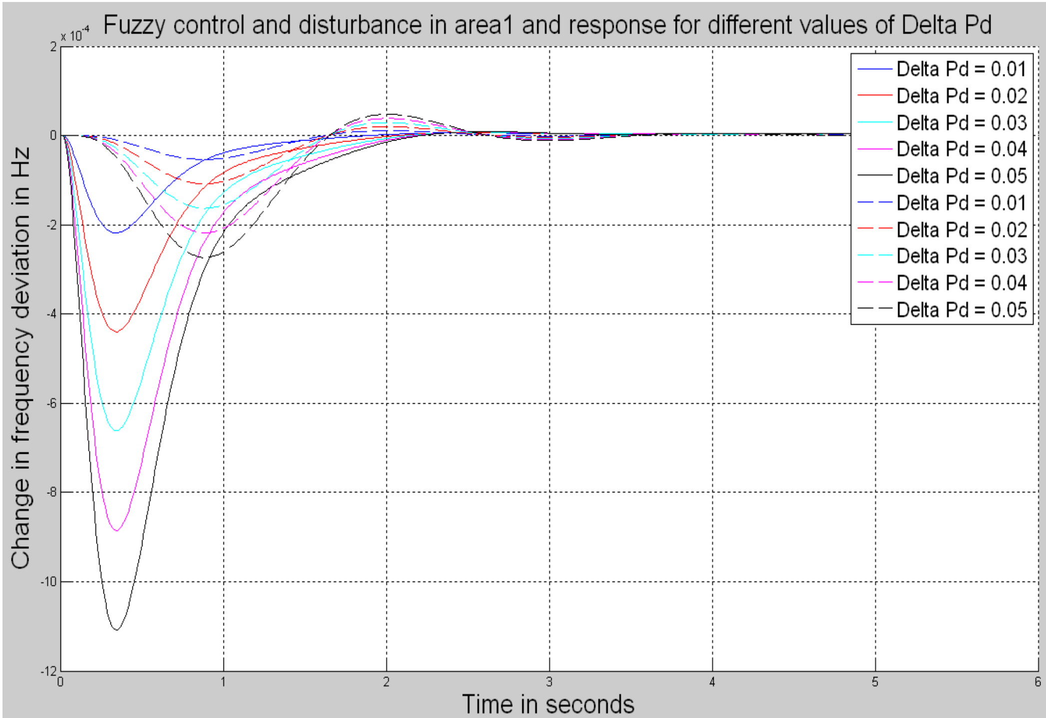

Fig.10: Variation of frequency in area 1 (–) and area 2 (– –)

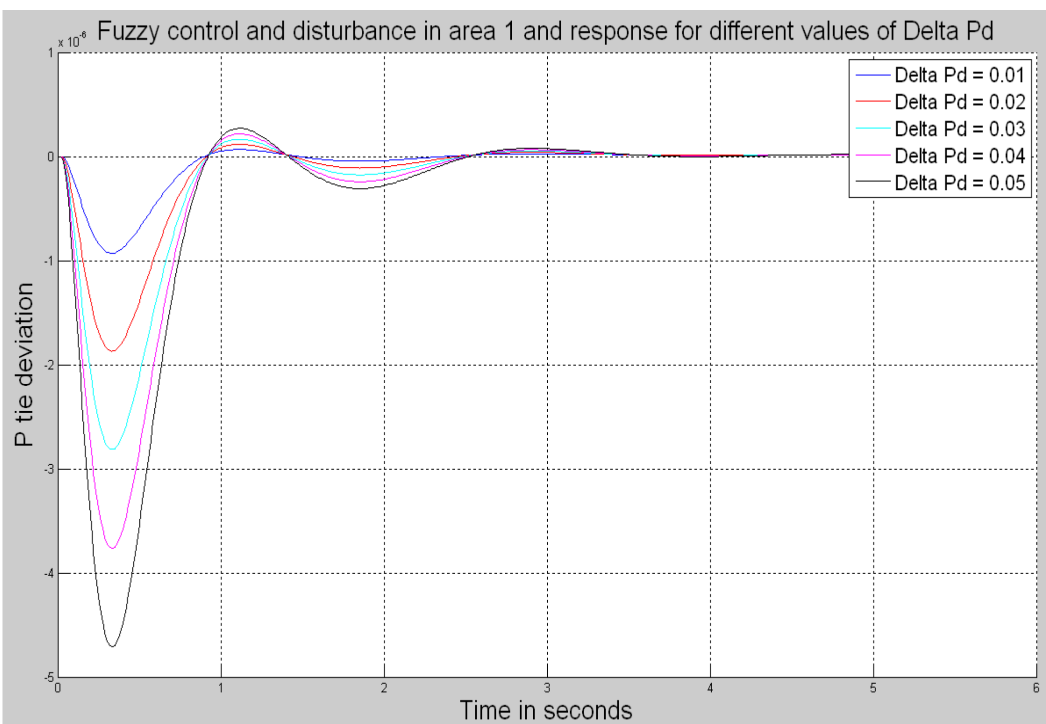

Fig.11: Variation of tie line power deviations

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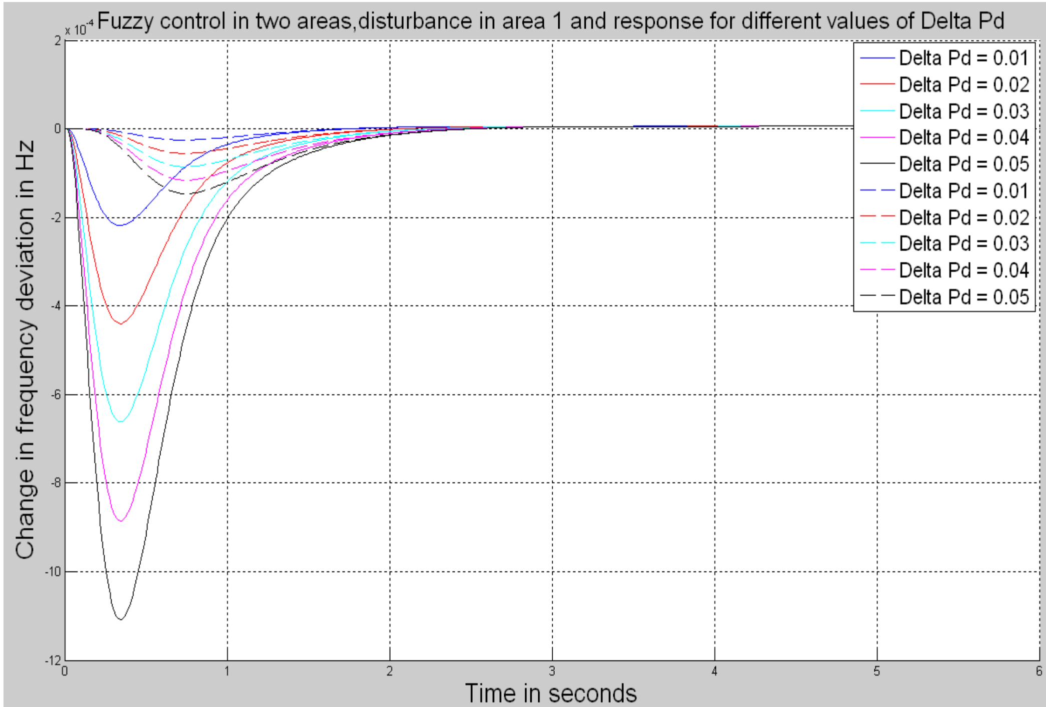

Fig.12: Variation of frequency in area 1 (–) and area 2 (– –)

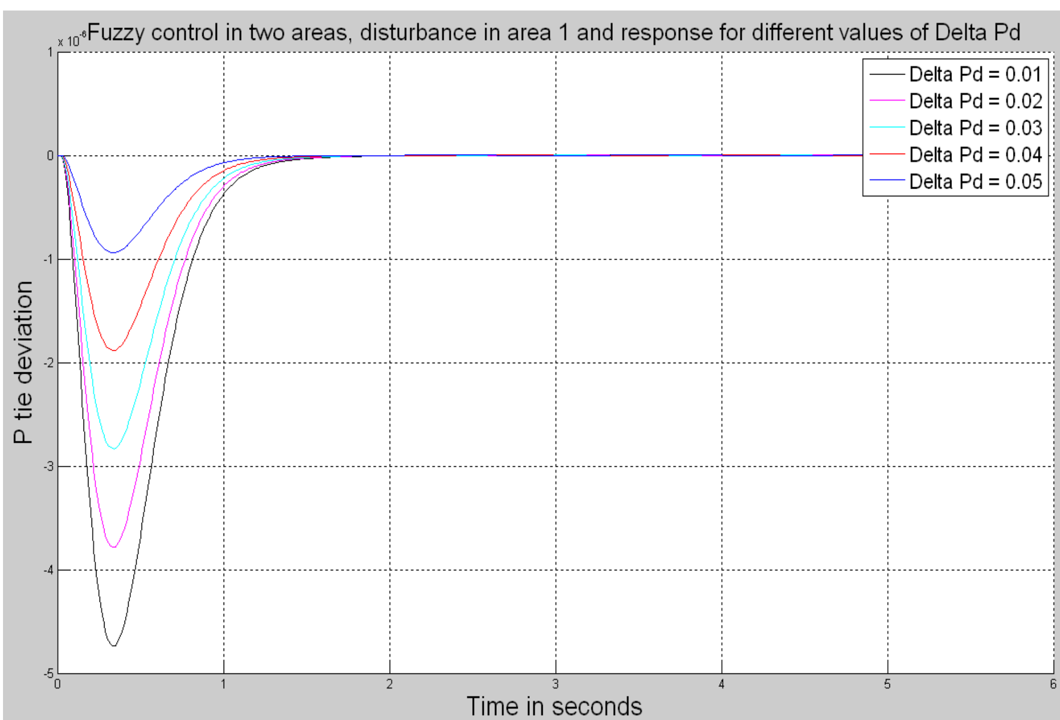

Fig.13: Variation of tie line power deviations

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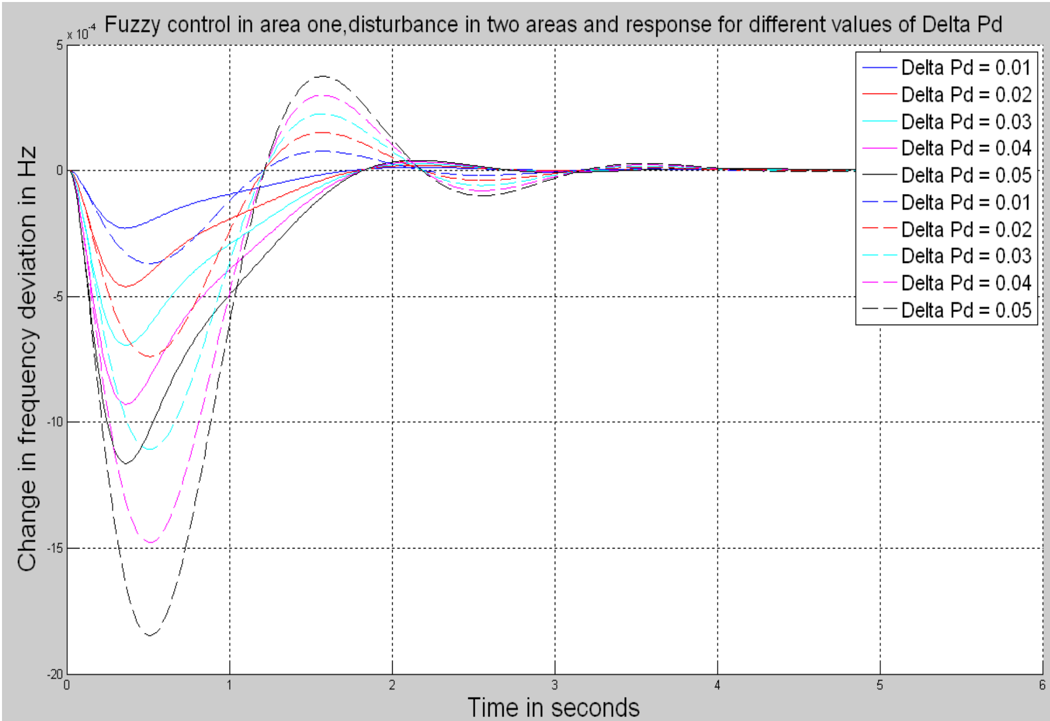

Fig.14: Variation of frequency in area 1 (–) and area 2 (– –)

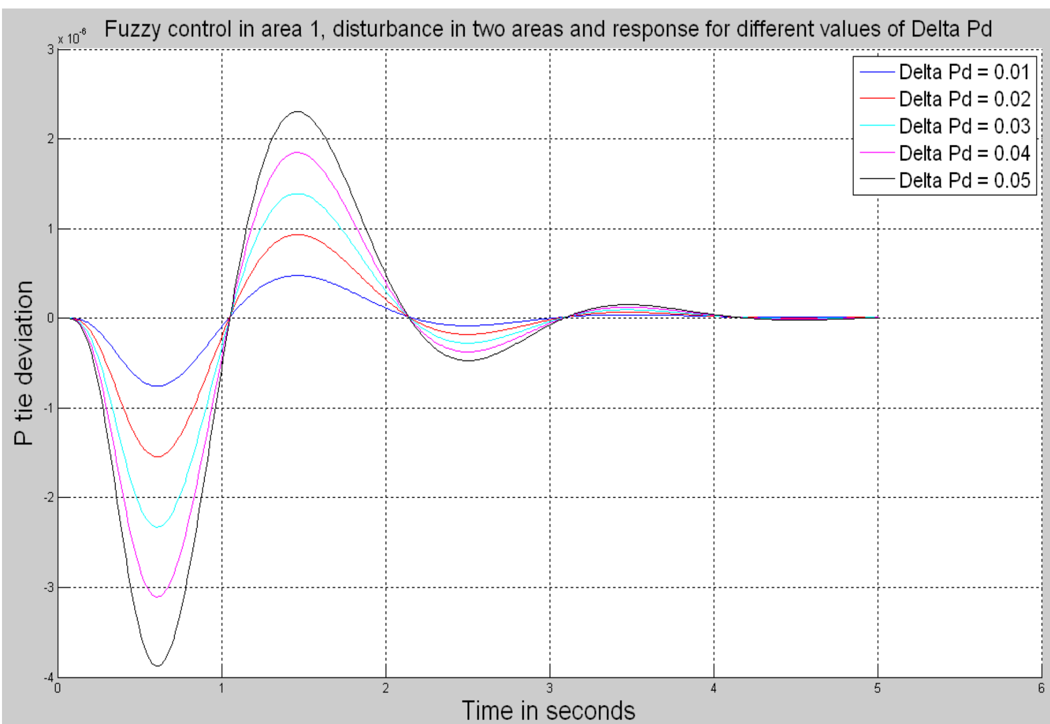

Fig.15: Variation of tie line power deviations

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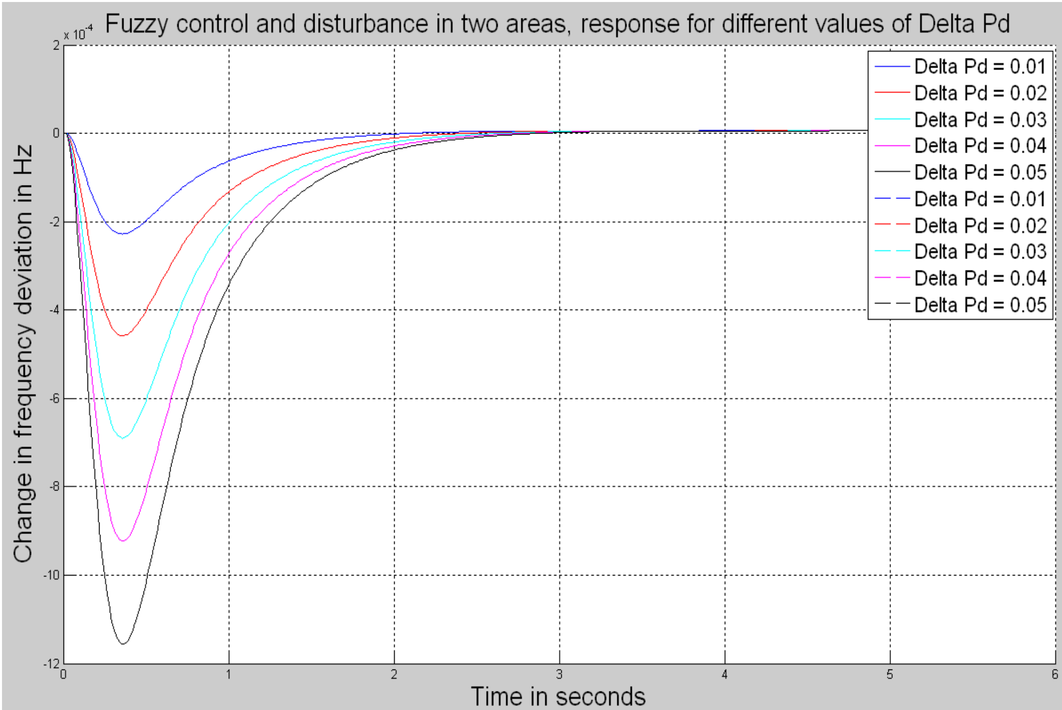

Fig.16: Variation of frequency in area 1 (–) and area 2 (– –)

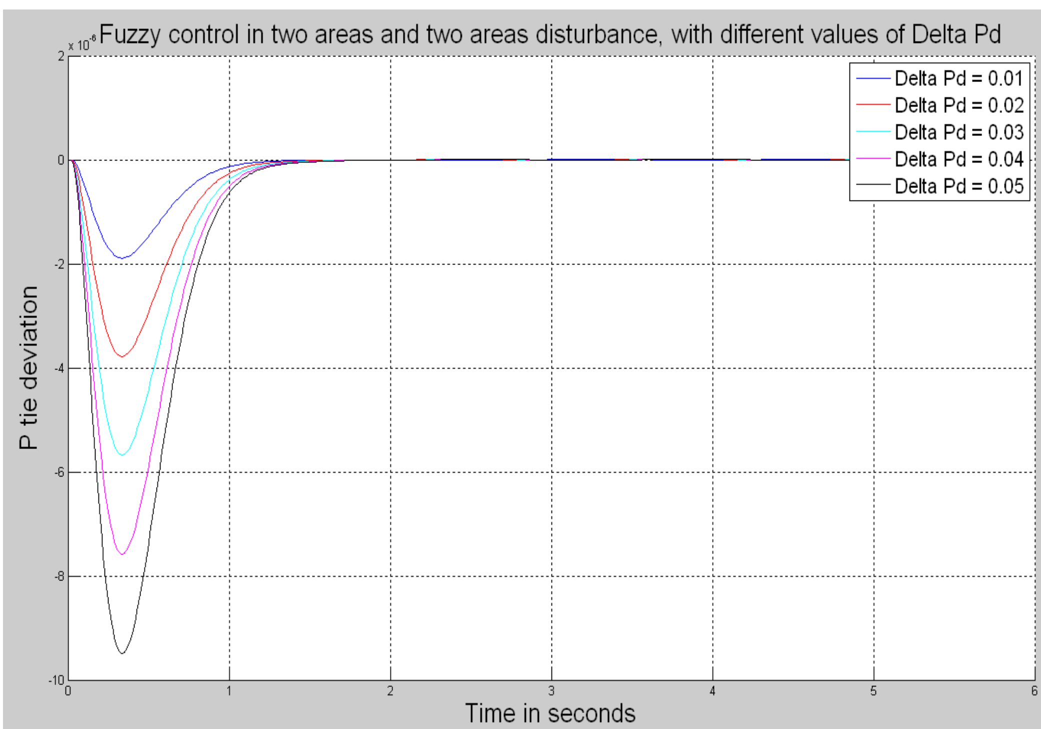

Fig.17: Variation of tie line power deviations

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5. CONCLUSIONS

In case of the uncontrolled studies it is observed that as the load disturbance is increased the static errors are also increasing.

For a load disturbances in area 1 with fuzzy controller placed in area 1 the frequency deviation Δf_1 is non – oscillatory where as the variations of Δf_2 exhibit small over shoot before reaching zero steady state value. The variation of ΔP_{tie} is very small.

When fuzzy controllers are placed in both the areas for a step load change in area 1 it is noticed that variations in Δf_1, Δf_2 and ΔP_{tie} are completely non – oscillatory.

Similar conclusions can be drawn for equal step load changes in both the areas having fuzzy controller in area 1. Dead beat responses are obtained with fuzzy controllers placed in both the areas.

When fuzzy controllers are placed in both the areas the deviations are small and the time of state transfer is least with no oscillations.

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
t_c	=	Switching time in seconds

REFERENCES:

[1] Fosha C.E., Elgerd O.I., The megawatt – frequency control theory, IEEE Trans. Power Appl. Syst. (1970) Vol.89, pp. 563 – 571.

[2] Elgerd O.I., Electrical energy system theory – An introduction, (Mc Graw – Hill, New Delhi, 1983)

[3] Mendal J.M., Fuzzy logic system for engineering, proceedings of the IEEE (1995) Vol.83, No.3, pp. 345 – 377.

[4] Lee CC., fuzzy logic in controller part – II, IEEE Trans. Syst., Man Cybern (1990), Vol. 20 (2), pp. 419 – 435.

[5] Chang CS., Fu W., Area load frequency control using fuzzy gain scheduling of PI controllers, Electrical power system Res (1997), Vol.2, pp. 145 – 152.

[6] Erlugrul C., Ilhan K., Fuzzy logic controller in interconnected electrical power systems for frequency control, Electrical power system (2005), Vol. 37, pp. 542 – 549.

[7] Ho Jae Lee etc., Robust load frequency control for uncertain non linear power systems: A fuzzy logic approach, Information Sciences (2006), Vol. 176, pp. 3520 – 3537.

BIOGRAPHY:

B. Venkata Prasanth received the M.Tech. degree in electrical & electronics engineering from Jawaharlal Nehru Technological University, Ananthapur, India, in 2005. He is a research student of Jawaharlal Nehru Technological University, Hyderabad, India. Currently, he is an Associate Professor at N.B.K.R.I.S.T., Vidyanagar. His interests are in power system control design and dynamic load modeling.

Dr. S. V. Jayaram Kumar received the M.E. degree in electrical engineering from the Andhra University, Vishakapatnam, India, in 1979. He received the Ph.D. degree in electrical engineering from the Indian Institute of Technology, Kanpur, in 2000. Currently, he is a professor at Jawaharlal Nehru Technological University, Hyderabad. His research interests include FACTS and Power System Dynamics.