# NEW CONTROL STRATEGY FOR LOAD FREQUENCY PROBLEM OF A SINGLE AREA POWER SYSTEM USING FUZZY LOGIC CONTROL

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**ABSTRACT**

This paper deals with a novel method of quenching transients of load frequency of a single area power system. The load frequency power system dynamics are represented by selecting deviation in frequency and its derivatives as variables. The validity of this model was compared in terms of its uncontrolled response obtained in the earlier work [1]. This new model representation is used for further studies in this paper. For a practical single area power system the behavior of uncontrolled system with range of values of regulation constant (R) and for various load disturbances ($\Delta P_d$) are obtained. The responses of single area power system with range of values of load changes for different switching times, Fuzzy control are evaluated. The time of state transfer in general is increasing with increase of load disturbance. When fuzzy control is applied the frequency transients are quenched at much faster rates without any oscillations.

**Keywords:** *Load frequency control, Transient response, Single area power system and Fuzzy logic controller*

## 1. INTRODUCTION

The development of design techniques for load frequency control of a power system in the last few years is very significant. The conventional proportional plus integral control is probably the most commonly used technique. This method does not work well if the parameters are changing for different load conditions. The transient response of the system will have overshoots and undershoots. In recent years many researchers have applied optimal control theory to solve LFC problem [1, 2]. Many researchers have used fuzzy logic controllers for load frequency control of two area power system [5-7] with and without nonlinearities. In their findings it is observed that the transient response is oscillatory and time to reach the steady state is more.

Some other elegant technique is needed to achieve a deadbeat response so that the time to reach the steady state is the least. In this work a single area power system is considered for the study. Most of the researchers have taken the dynamic equations of the single area power system as given by O. I. Elgerd [1]. The work reported here deals with a new model derived with change in frequency ( $\Delta f$ ) and derivative of frequency ( $\dot{\Delta f}$ ) without any integral control and the control parameter (u) being the speed changer position ($\Delta P_C$). The change in frequency and its derivative are taken as crisp values to the fuzzy controller and the output of the controller is ‘u’. An attempt is made in this work by applying fuzzy controller at a predetermined time ($t_c$) of uncontrolled system, the system response is observed. The system responses for range of values of regulation constant (R) for different values of load disturbance ($\Delta P_d$) and $t_c$ are obtained for uncontrolled and with fuzzy controller. It is observed that in all theses studies with fuzzy controller the response of the system is deadbeat in nature and the total time taken to reach final value is $\Delta f = 0$ after disturbance is the least. Since the controller is simple and needs $\Delta f$ and derivative of $\Delta f$ the on line implementation may be easier and convenient.

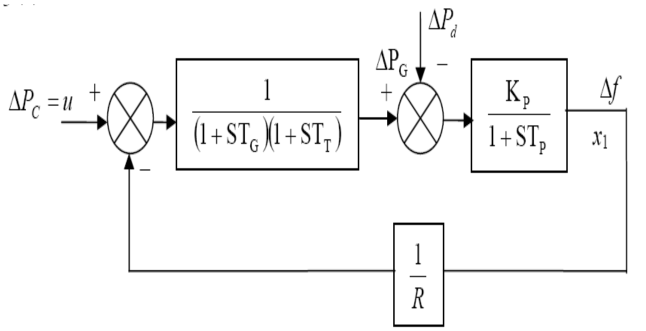


Fig:1 Block diagram of single area power system

## 2. SYSTEM DYNAMICS

The new state variable model is derived by means of block diagram for single area power system shown in fig.1 with the speed changer position is taken as control parameter.

The state variable equations from block diagram are derived as follows:

$$\left(u - \frac{\Delta f}{R}\right) = (1+ST_G)(1+ST_T)\Delta P_G$$
$$= \left[1 + S(T_G T_T) + S^2 T_G T_T\right]\Delta P_G \qquad ---(1.1)$$

$$(\Delta P_G - \Delta P_d) = \frac{\Delta f(1+ST_P)}{K_P}$$
$$\Rightarrow \Delta P_G = \Delta P_d + \frac{\Delta f(1+ST_P)}{K_P} \qquad ---(1.2)$$

Substituting the values of $\Delta P_G$ from equation (1.1) into equation (1.2)

$$\left(u - \frac{\Delta f}{R}\right) = \left[1 + S(T_G T_T) + S^2 T_G T_T\right]\left[\Delta P_d + \Delta f\frac{(1+ST_P)}{K_P}\right]$$

Assuming $\Delta P_d$ is constant, then $\Delta\dot{P}_d, \Delta\ddot{P}_d = 0$ (neglected)

$$K_P\left(u - \frac{\Delta f}{R}\right) = K_P\Delta P_d + T_1\Delta\dot{f} + T_2\Delta\ddot{f} + T_3\Delta\dddot{f} + \Delta f$$

$$\Delta\dddot{f} = \frac{1}{T_3}\left[\frac{-(K_P+R)}{R}\Delta f - T_1\Delta\dot{f} - T_2\Delta\ddot{f} - K_P\Delta P_d + K_P u\right] \qquad ---(1.3)$$

Where

$T_1 = (T_P + T_G + T_T)$
$T_2 = (T_G T_T + T_G T_P + T_P T_T)$
$T_3 = (T_G T_T T_P)$

Let the state variables be

$$\Delta f = x_1 \quad ; \quad \Delta\dot{f} = x_2 \quad ; \quad \Delta\ddot{f} = x_3$$

The system of equations (1.3) is represented in state variable from using phase variables

$$\left.\begin{aligned} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= x_3 \\ \dot{x}_3 &= \frac{1}{T_3}\left[\frac{-x_1(K_P+R)}{R} - T_1 x_2 - T_2 x_3 - K_P\Delta P_d + K_P U\right] \end{aligned}\right\} \quad ---(1.4)$$

## 3. THE LOAD FREQUENCY PROBLEM USING FUZZY CONTROL

In the so called LFC problem before the load disturbance and after the load disturbance the change in frequency is zero by the point A as shown in fig.2. The uncontrolled system behavior (u = 0) is shown as AB for a particular time '$t_c$'.

Now the problem is to transfer the system state from B to A using a suitable control strategy. The physics of the original system demands that a suitable trajectory is 'BCA' as shown in fig.2. From the behaviors of the load frequency control problem the value of the speed changer position is selected as u (control parameter). Fuzzy control techniques are developed to transfer the state from B to A through C. The fuzzification and defuzzification methods for single or multiple techniques are discussed in literature.

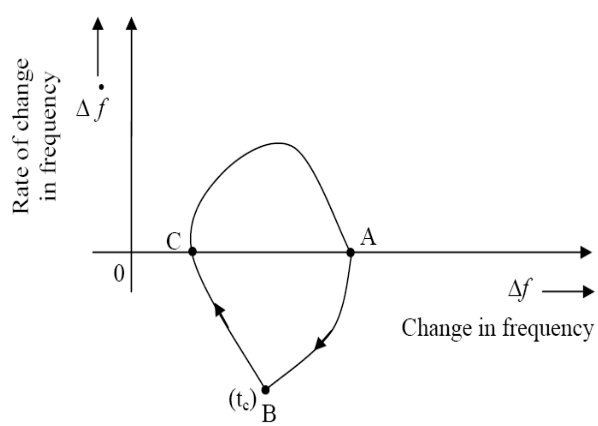


Fig. 2 Phase Plane Trajectory

Fuzzy set theory and fuzzy logic establish the rules of a non linear mapping [3]. The use of fuzzy sets provides a basis for a systematic way for the application of uncertain and indefinite models [4]. Fuzzy control is based on a logical system called fuzzy logic is much closed in spirit to human thinking and natural language than classical logical systems. Nowadays fuzzy logic is used in almost all sectors of industry and science. One of them is load frequency control. The main goal of LFC in power system is to protect the balance between production and consumption. 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.

In this proposed work, two input membership functions ( $\Delta f$ *and* $\Delta\dot{f}$ ) for two crisp inputs and one output membership function for output (u) were defined. First input membership function corresponding to five linguistic variables $\left(-\frac{\pi}{2},-\frac{\pi}{4},0,\frac{\pi}{4},\frac{\pi}{2}\right)$ and is shown in fig.3. Second input membership function corresponding to five linguistic variables $\left(-\frac{\pi}{4},-\frac{\pi}{8},0,\frac{\pi}{8},\frac{\pi}{4}\right)$ and is shown in fig.4. The output membership function corresponding to five linguistic variables $(-20,-10,0,10,20)$ 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.

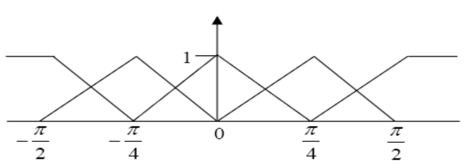


Fig. 3 Membership function for the error ( $\Delta f$ )

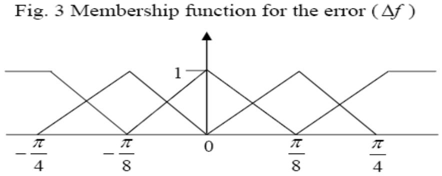


Fig. 4 Membership function for the derivative of error ( $\Delta\dot{f}$ )

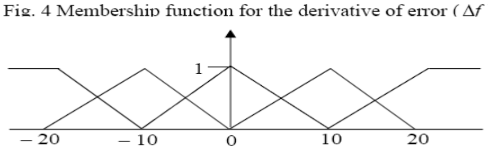


Fig. 5 Membership function for the output (u)

## 4. RESPONSE OF UNCONTROLLED AND CONTROLLED SYSTEM

A practical single area power system having the following data [1] is considered with following data: the numerical data for the system are $K_P$ = 120.0, $T_P$ = 20.0 Sec, $T_G$ = 0.08 Sec, $T_T$ = 0.3 Sec and range of values of regulation constant (R) and $\Delta P_d$. Fig.6 to 9 shows Fuzzy controlled and uncontrolled responses for $t_c$ = 0.5 sec and 1 sec with $\Delta P_d$ = 0.03 and 0.04 for different values of R. The corresponding phase – plane trajectories are depicted in fig.10 to 13. Further studies are also to be conducted to get the response of the system for range of values of control inputs, load changes, regulation constants at different values of '$t_c$'. Table 1 shows the static errors of the uncontrolled system for range of values of $\Delta P_d$ and R. For selected $t_c$ = 0.5 sec and $t_c$ = 1 sec with $\Delta P_d$ = 0.03 and $\Delta P_d$ = 0.04 the times of state transfer (from B to A through C) are tabulated in Table 2 for range of values of R.

**Table 1: Static errors of the uncontrolled system for range of values of $\Delta P_d$ and R**

| Regulation Constant (R) | Static Error with $\Delta P_d$ = 0.03 | Static Error with $\Delta P_d$ = 0.04 |
|---|---|---|
| 1.6 | – 0.04752 | – 0.06316 |
| 1.8 | – 0.0532 | – 0.07094 |
| 2.0 | – 0.05893 | – 0.07869 |
| 2.2 | – 0.06468 | – 0.08641 |
| 2.4 | – 0.07057 | – 0.09412 |
| 2.6 | – 0.07626 | – 0.1018 |
| 2.8 | – 0.08204 | – 0.1094 |

**Table 2: Time of state transfer for different switching times of a controlled system**

| $t_c$ in sec | Regulation Constant (R) | Time of state transfer with $\Delta P_d$ = 0.03 | Time of state transfer With $\Delta P_d$ = 0.04 |
|---|---|---|---|
| 0.5 | 1.6 | 1.98 | 2.08 |
| | 1.8 | 2.36 | 2.44 |
| | 2.0 | 2.6 | 2.75 |
| | 2.2 | 2.82 | 2.95 |
| | 2.4 | 3.08 | 3.27 |
| | 2.6 | 3.23 | 3.58 |
| | 2.8 | 3.45 | 3.87 |
| $t_c$ in sec | Regulation Constant (R) | Time of state transfer With $\Delta P_d$ = 0.03 | Time of state transfer with $\Delta P_d$ = 0.04 |
| 1.0 | 1.6 | 2.28 | 2.48 |
| | 1.8 | 2.7 | 2.98 |
| | 2.0 | 3.15 | 3.27 |
| | 2.2 | 3.46 | 3.56 |
| | 2.4 | 3.83 | 4.01 |
| | 2.6 | 4.11 | 4.29 |
| | 2.8 | 4.39 | 4.56 |

## 5. RESULTS

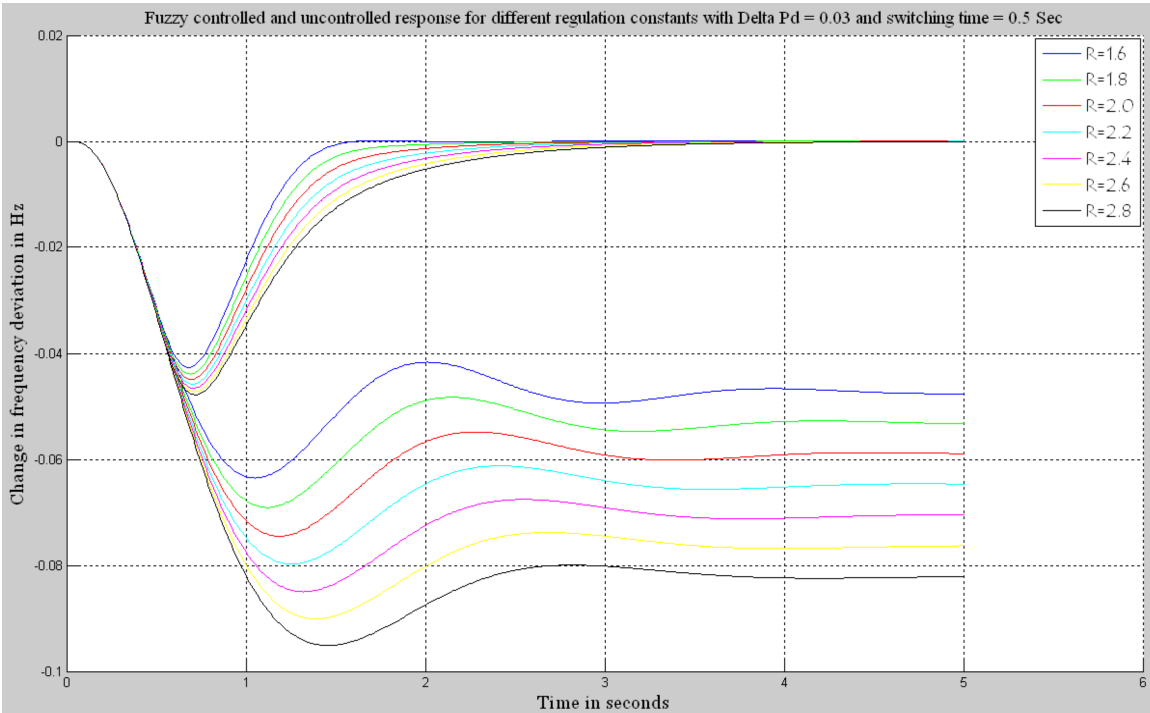


**Fig. 6: Time response of controlled and uncontrolled system with $\Delta P_d$ = 0.03 and $t_c$ = 0.5 Sec**

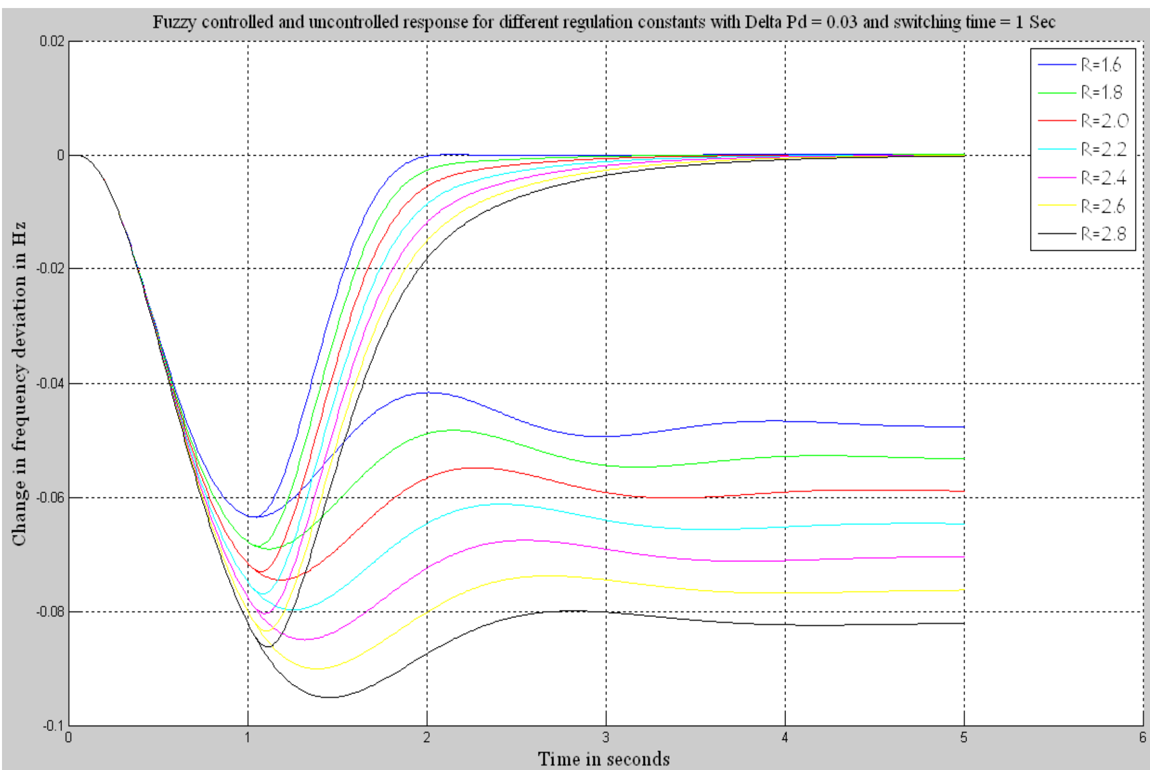


**Fig.7: Time response of controlled and uncontrolled system with $\Delta P_d$ = 0.03 and $t_c$ = 1 Sec**

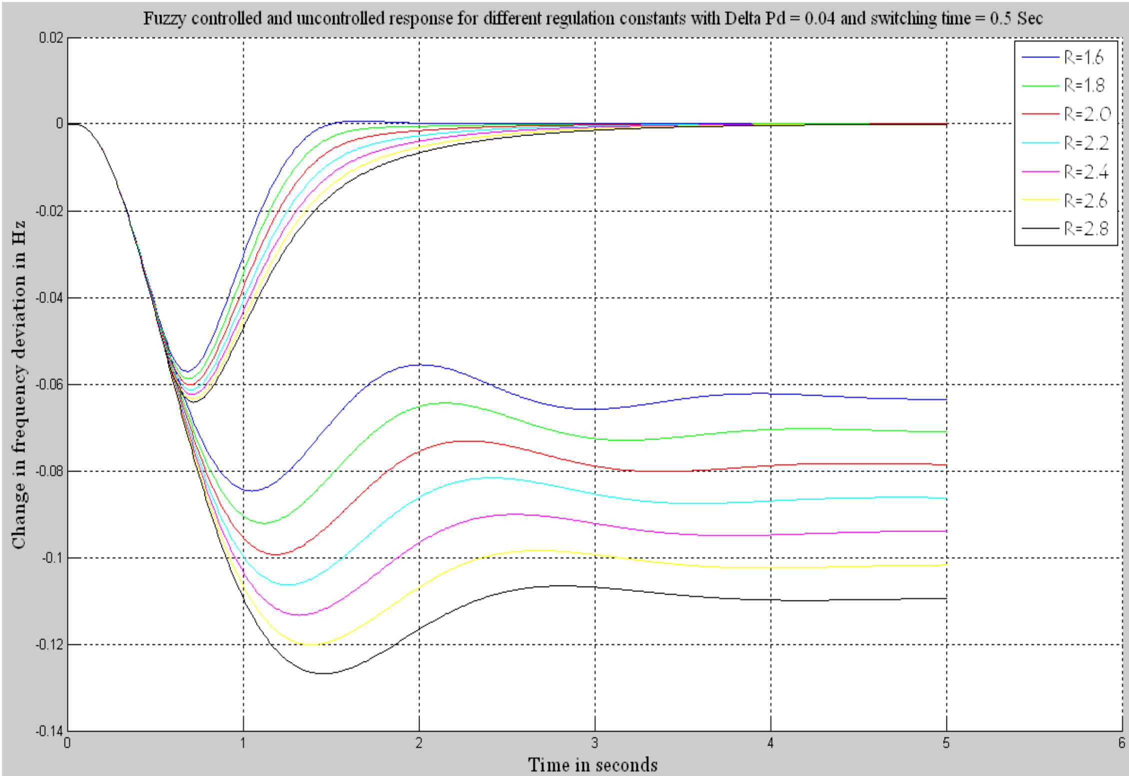


**Fig.8: Time response of controlled and uncontrolled system with $\Delta P_d = 0.04$ and $t_c = 0.5$ Sec**

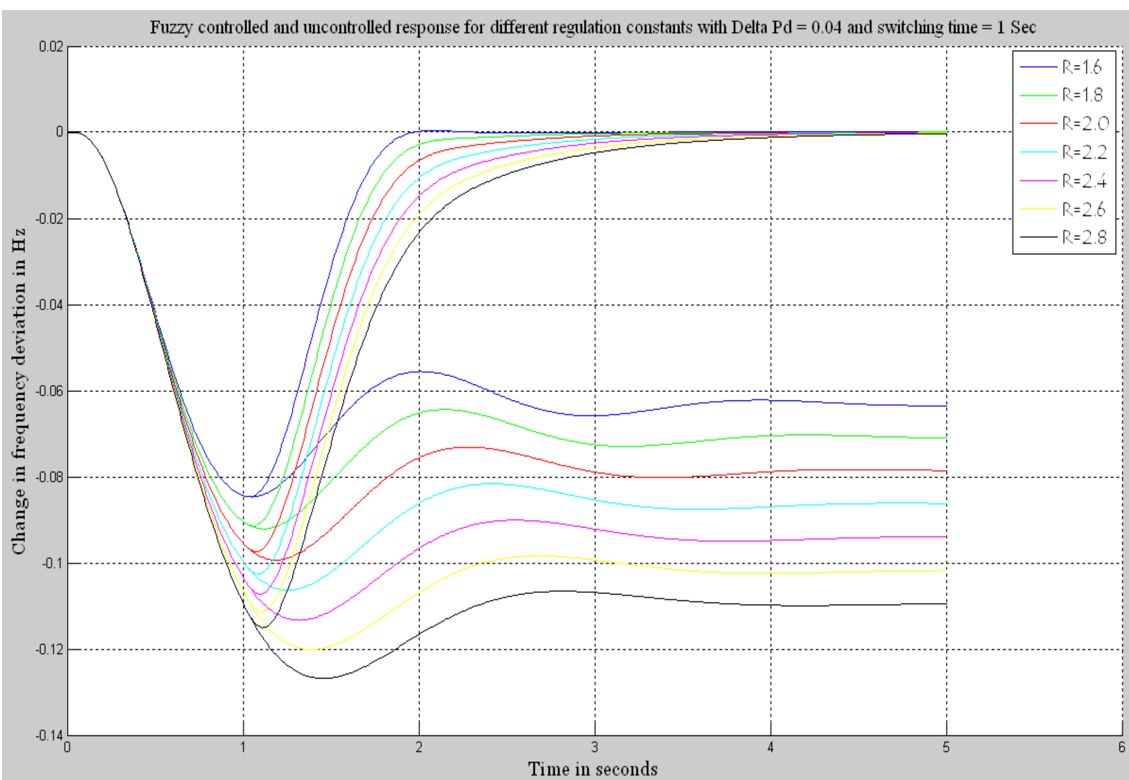


**Fig.9: Time response of controlled and uncontrolled system with $\Delta P_d = 0.04$ and $t_c = 1$ Sec**

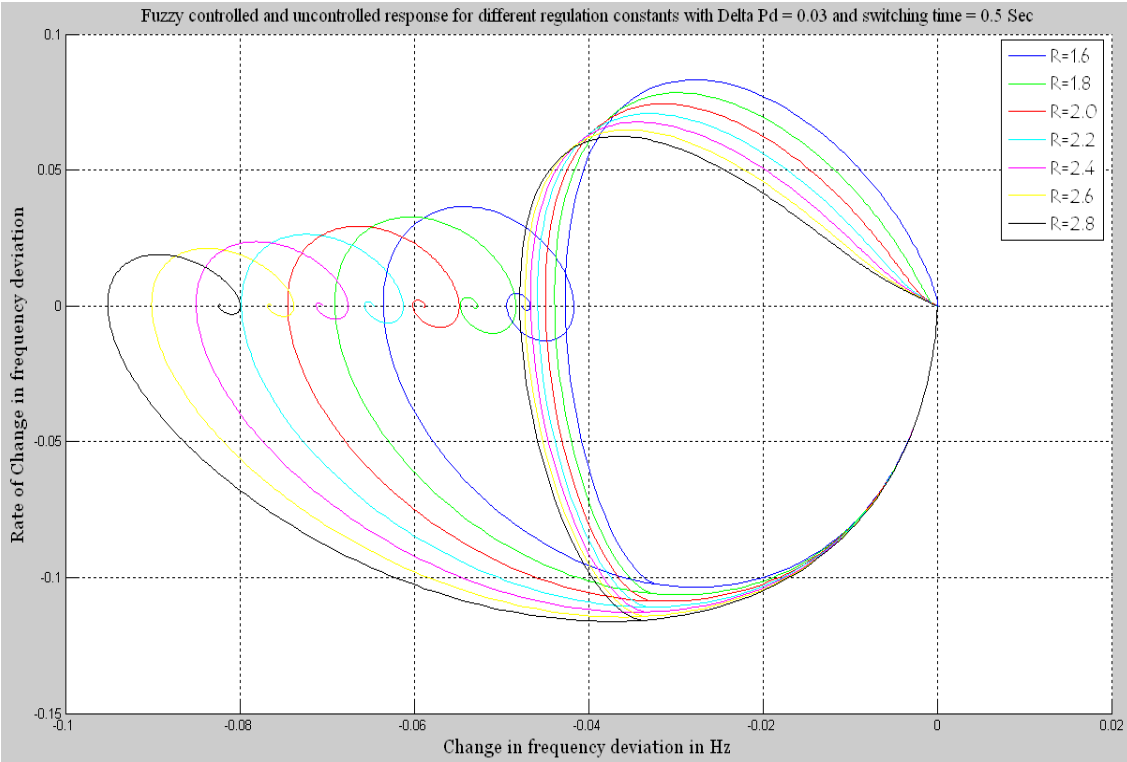


**Fig.10: Phase–plane trajectories of controlled and uncontrolled system with $\Delta P_d$=0.03and $t_c$=0.5 Sec**

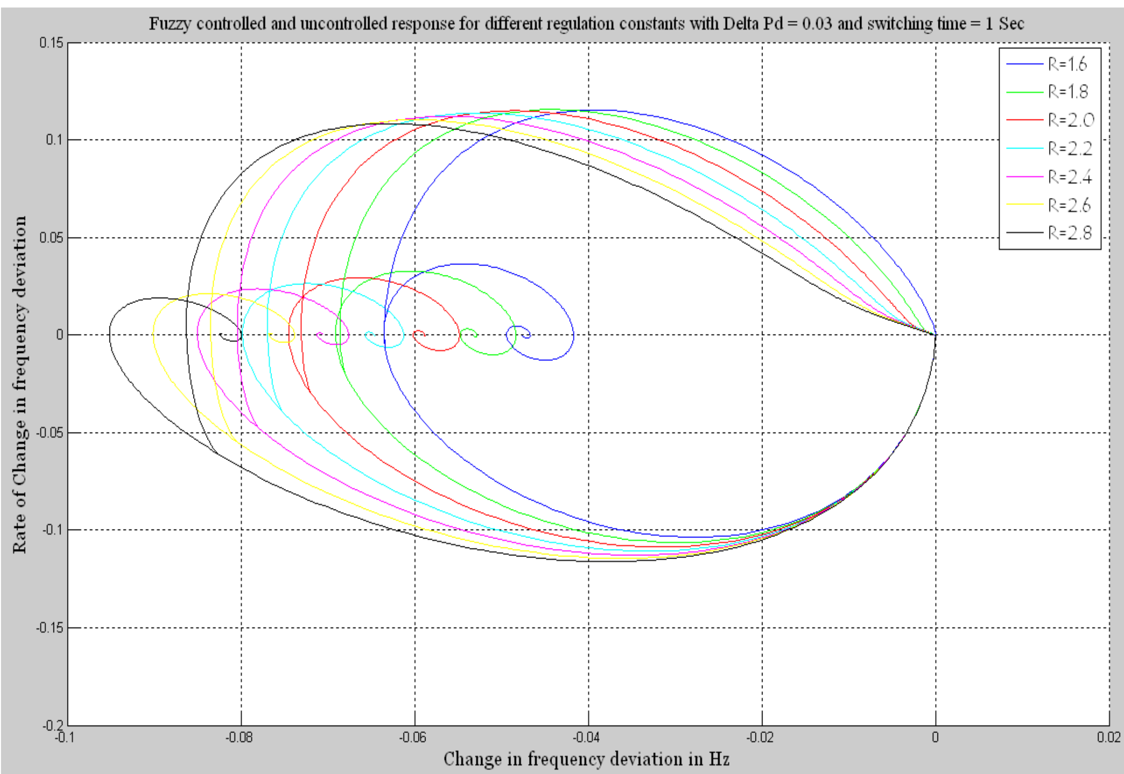


**Fig.11: Phase–plane trajectories of controlled and uncontrolled system with $\Delta P_d$=0.03 and $t_c$ = 1 Sec**

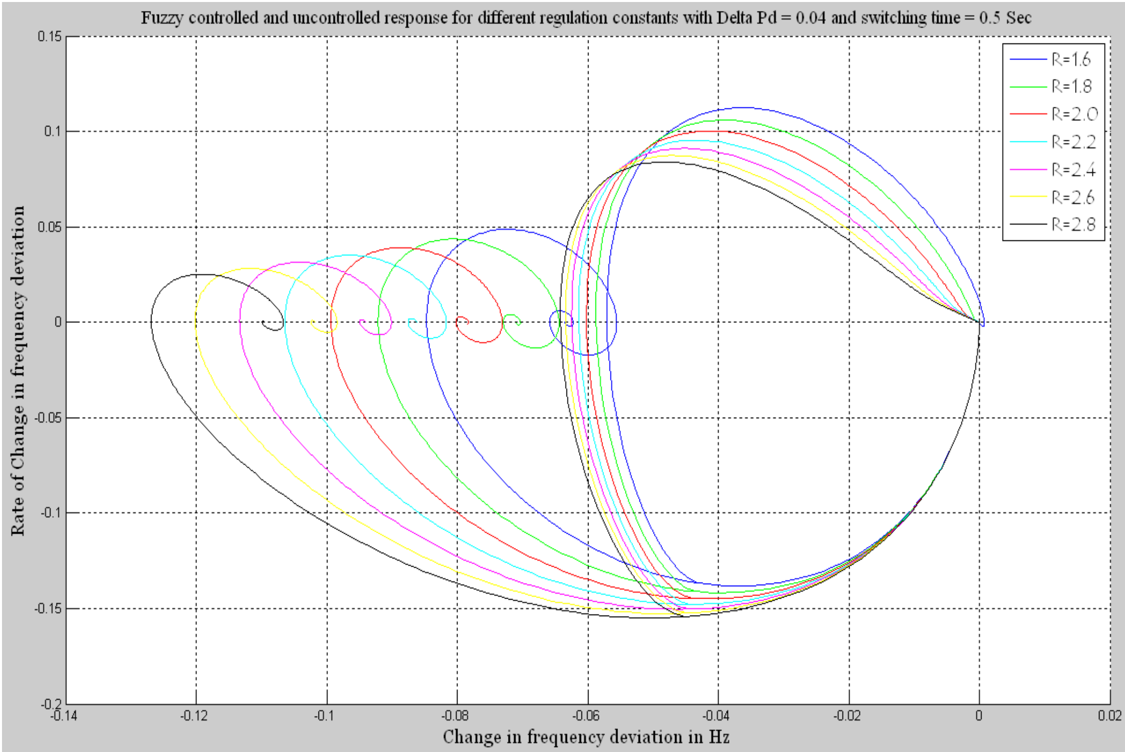


**Fig.12: Phase–plane trajectories of controlled and uncontrolled system with $\Delta P_d$=0.04 and $t_c$=0.5 Sec**

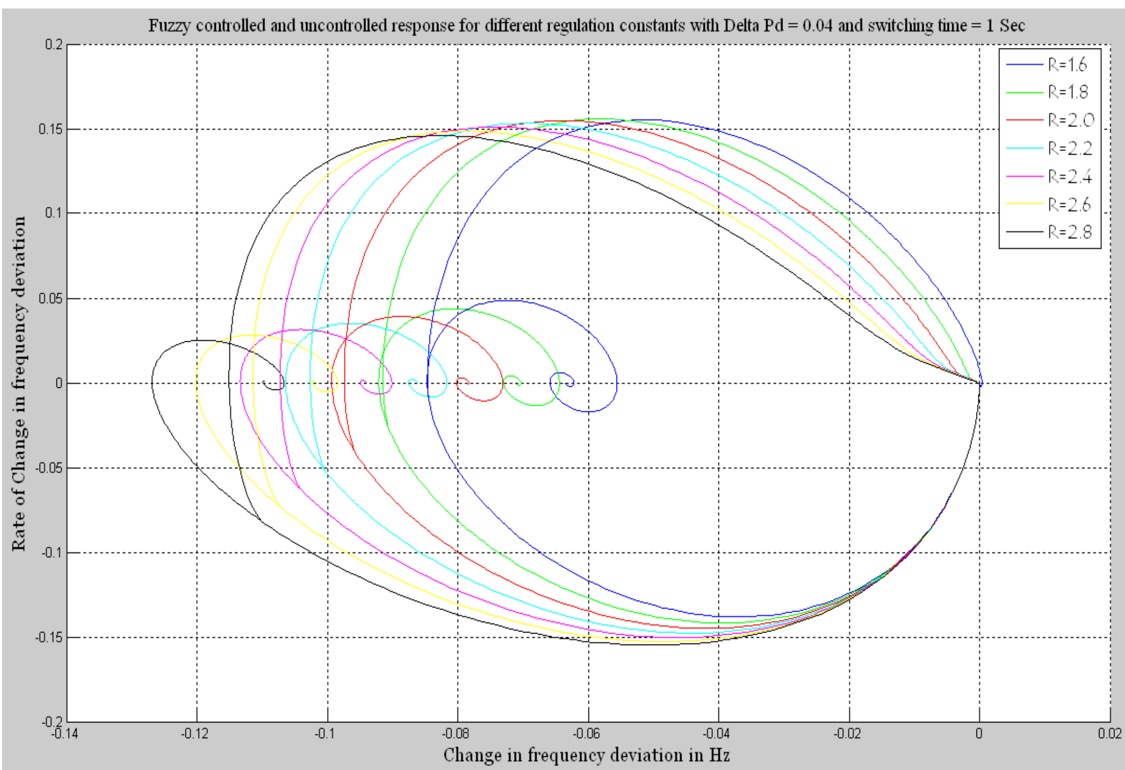


**Fig.13: Phase–plane trajectories of controlled and uncontrolled system with $\Delta P_d$ =0.04 and $t_c$ =1 Sec**

## 6. CONCLUSIONS

A new model of load frequency control using $\Delta f, \frac{d\Delta f}{dt}$ *and* $\frac{d^2\Delta f}{dt^2}$ is developed with $\Delta P_C$ as the control parameter (u). It is observed that the static errors are increasing as the regulation constant is increasing for a particular load change. Fuzzy control studies are conducted on a single area power system for a particular load change ($\Delta P_d = 0.03$) and for a predetermined closing time ($t_c = 0.5\sec$), reveal that the response is dead beat with a less state transfer time. The time of state transfer is increasing with an increase of regulation constant. Similar results are observed for different load changes. It is also noticed that the static error and state transfer times are more with increase in load disturbance.

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## NOMENCLATURE

$\Delta P_G$ =Generated power derivation, pu MW
$\Delta P_d$ =Change in power demand, pu MW
$\Delta P_C$ =Change in speed changer position (u), pu MW
$\Delta f$ =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