# IMC Tuning of PID Load Frequency Controller and Comparing Different Configurations for Two Area Power System.

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## ABSTRACT

**The IMC Tuning method of PID load frequency control (LFC) for single area power system is presented and is applied for two identical area power system. The performances of different controllers for variable inputs are compared for the same two area power system with non-reheated turbines. The damping and the negative overshoot of the two area power system can be improved by using an IMC tuned controller. Also it is shown that when both frequency change and tie line power are used as inputs, the results were superior. The effectiveness of the proposed controller is validated by applying a wide range of load disturbances.**

*Keywords* – **Disturbance rejection, internal Model Control (IMC), Load Frequency Control (LFC), PID Tuning.**

## I. INTRODUCTION

Imbalances between load and generation must be corrected within seconds to avoid frequency deviations that might threaten the stability and security of the power system. The problem of controlling the frequency in large power systems by adjusting the production of generating units in response to changes in the load is called load frequency control (LFC). The Objectives of LFC are to provide zero steady-state errors of frequency and tie-line exchange variations, high damping of frequency oscillations and decreasing overshoot of the disturbance so that the system is not to far from the stability.

The above mentioned objectives are carried successfully in previous works by different authors using Fuzzy logic PI and PID controllers[7] &[9], optimal control[2], Variable structure control[3], adaptive and self-tuning control[4] etc. Then the tuning of the PID controller was proposed, after that several tuning rules came in to lime light in which Internal model control (IMC) is one of them. The IMC model is given in the paper [1] for single area and extended it to multi-area, given its performance, robustness.

In this paper the same IMC tuning method is adapted to two-area power system having identical areas with non-reheat turbines and compared with different controller configurations and the system is subjected to different load changes i.e. different cases of load changes in single area, and a case of load change in both areas. Also the new configuration proposed in this paper grasps the advantages of IMC tuning of PID controller and usage of both frequency change and tie-line exchange as inputs to the controller.

Initially the system frequency deviations are zero before any disturbance, a step load change is applied to a single area in first case and system behavior is observed without any controller in both the areas, after that untuned PID controlled is placed in both the areas and the results are compared, then the tuned controller with only frequency change as input is used and the results are observed in comparison with previous ones, finally both frequency change and tie line power exchange due to the load disturbance in area 1 are applied and results are studied. In all the cases it is observed that the negative overshoot is reduced monotonically, and damping of the oscillations is also increased except for the last case we find some oscillations. for the last case it is observed that the steady state error of tie-line exchange is reduced to zero.

## II. IMC DESIGN

The IMC structure (Garcia & Morari, 1982) given in Figure1 is central to our discussions on the design of controllers [8]. Its conceptual usefulness lies in the fact that it allows us to concentrate on the controller design without having to be concerned with control system stability provided that process model $\tilde{P}(s)$ is a perfect representation of stable process *P(s)*. The model shown in the Figure1 has *P(s)* is the plant to be controlled, $\tilde{P}(s)$ is the plant model, and *Q(s)* is the IMC controller to be designed.

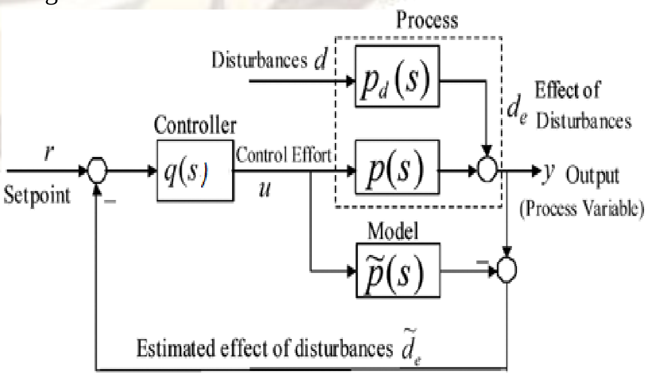


Figure 1. The IMC System.

In the figure 1 'u' represents the control effect, 'r' represents the setpoint and'd' is the disturbance applied to the system. An ideal control system would force the process output to track its setpoint instantaneously and perfectly suppress all disturbances so that they do not affect the output. That is, the ideal controller would accomplish,

$$y(s) = r(s) \qquad (1)$$

and

$$y(s)/d(s) = 0 \qquad (2)$$

from the system equations, the above requires that

$$P(s)q(s) = 1 \text{ and } P^{\sim}(s) = P(s) \qquad (3)$$

thus for perfect control we need perfect model, unfortunately, one never has a perfect model and if the model has any dynamics at all, no controller can perfectly invert the process model. Based on the above concept the plant model is decomposed in to two parts one is invertible part $P_M(s)$ and other is all pass part $P_A(s)$ with unity magnitude. the design procedure is,

1) Designing the setpoint-tracking IMC controller is

$$Q(s) = P_M^{-1}(s)\frac{1}{(\lambda s+1)^r} \qquad (4)$$

Where λ is a tuning parameter such that the desired set point response is $1/(\lambda s + 1)^r$, and r is the relative degree of $P_M(s)$. In order to increase the load disturbance rejection performance a second controller is added to the present system. The TDF-IMC structure is shown in figure 2, and the $Q_d$ design is as follows.

$$Q_d(s) = \frac{\alpha_m s^m + \cdots + \alpha_1 s + 1}{(\lambda_d s+1)^m} \qquad (5)$$

Where $\lambda_d$ is a tuning parameter for disturbance rejection, m is the number of poles of $P^{\sim}(s)$ such that the $Q_d(s)$ needs to be cancel. Suppose $p_1 \ldots\ldots, p_m$ are the poles to be canceled, then $\alpha_1, \ldots. \alpha_m$ should satisfy

$$\{1 - P^{\sim}(s)Q(s)Q_d(s)\}_{s=p_1,\ldots,p_m} = 0 \qquad (6)$$

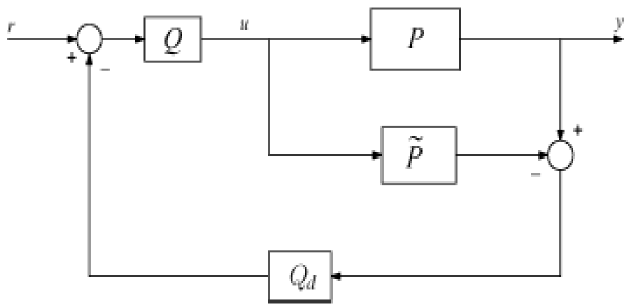


**Figure 2. TDF-IMC System configuration**

The present system can be converted in to a conventional TDF feedback structure shown in figure 3, where the feedback controller K equals

$$K = \frac{QQ_d}{1-P^{\sim}QQ_d}. \qquad (7)$$

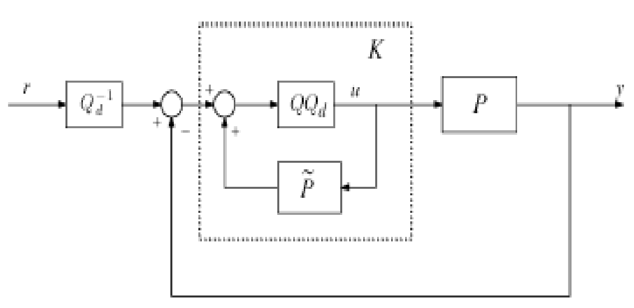


**Figure 3 Equivalent conventional feedback configaration.**

The standard procedure for obtaining PID parameters from IMC controllers is to expand the final controller (7) into McLaren series and get the coefficients of the first three terms, or using a IMCTUNE package as in manual [10] .

## III. LFC-PID DESIGN

Here we consider the case of two area power system where each generator supplying power to a single service area with non- reheat turbines used in generation. As we are tuning PID controllers inorder to improve the performance of LFC system, the control law takes the form, $u = -k(s)\Delta f$, where K(s) takes the form

$$K(s) = K_p(1 + \frac{1}{T_i(s)} + T_d\frac{1-e^{-Ts}}{T} \qquad (8)$$

*Non-reheat turbine:*

The plant for the power system with a non-reheated turbine consists of three parts,

- Governor with dynamics:

$$G_g(s) = \frac{1}{T_G s+1}. \qquad (9)$$

- Turbine with dynamics:

$$G_t(s) = \frac{1}{T_T s+1} \qquad (10)$$

- Load and machine with dynamics:

$$G_p(s) = \frac{K_P}{T_P s+1} \qquad (11)$$

The open-loop transfer function without droop characteristic for load frequency control is

$$P^{\sim}(s) = G_p G_t G_g$$

$$= \frac{K_P}{(T_G s+1)(T_T s+1)(T_P s+1)} \qquad (12)$$

from the above section the setpoint tracking IMC controller takes the form,

$$Q(s) = P^{\sim}(s)^{-1}\frac{1}{(\lambda s+1)^3}$$

$$= \frac{(T_P s+1)(T_T s+1)(T_G s+1)}{K_P(\lambda s+1)^3} \qquad (13)$$

for $Q_d(s)$ we choose, to cancel the pole $s = -\left(\frac{1}{T_p}\right)$.

$$Q_d(s) = \frac{\alpha_1 s+1}{\lambda_d s+1} \qquad (14)$$

then $\alpha_1$ should satisfy the

$$(1 - P^{\sim}(s)Q(s)Q_d(s))_{s=-\frac{1}{T_P}}$$

$$= \left(1 - \frac{\alpha_1 s+1}{(\lambda s+1)^3(\lambda_d s+1)}\right)_{s=-\frac{1}{T_p}} = 0$$

that is $\alpha_1 = T_p\left(1-\left(1-\frac{\lambda}{T_P}\right)^3\left(1-\frac{\lambda_d}{T_P}\right)\right)$.

by choosing suitable parameters $\lambda$ and $\lambda_d$, TDF-IMC controllers *Q(s)* and $Q_d(s)$ can be calculated from (13) and (14). In the case of LFC design with droop characteristics, the plant model is

$$P(s) = \frac{G_g G_t G_p}{1+G_g G_t G_p/R} \qquad (15)$$

## IV. MODEL OF TWO AREA POWER SYSTEM

A two area model is adapted in the work is shown in fig. 4. Each area is assumed to have only one equivalent generator and is equipped with governor- turbine system. The $u_1$ and $u_2$ are the control signals from the controllers we choose. The terms showed in the figure are termed in the Table below.

**Table 1: NOMENCLATURE**

| | |
|---|---|
| $\Delta P_d$ | load disturbance (p.u.MW) |
| $K_P$ | electric system gain |
| $T_P$ | electric system time constant (s) |
| $T_T$ | turbine time constant (s) |
| $T_G$ | governor time constant (s) |
| $R$ | speed regulation due to governor action (Hz/p.u.MW) |
| $T_r$ | constant of reheat turbine |
| $c$ | percentage of the power generated in the reheat portion |
| $T_w$ | time constant of hydro turbine |
| $\Delta f(t)$ | incremental frequency deviation (Hz) |
| $\Delta P_G(t)$ | incremental change in generator output (p.u.MW) |
| $\Delta X_G(t)$ | incremental change in governor valve position |

## V. NUMERICAL STUDIES

for the power system with the non- reheat turbines, the model parameters are given by

$$K_p = 120, T_p = 20, T_T = 0.3, T_G = 0.08, R = 2.4.$$

the plant model with droop characteristics is

$$P(s) = \frac{250}{s^3+15.88s^2+42.46s+106.2} \qquad (15)$$

with λ=0.1 and $\lambda_d$= 0.5, we get the following PID controller,

$$K(s) = 0.8036 + \frac{0.6356}{s} + 0.1832s. \qquad (16)$$

the responses for the uncontrolled, unturned controller, tuned controller, tuned controller with both frequency change and tie line power exchange as inputs are shown in the figures below for load changes of $\Delta P_d$ =0.01, 0.02, 0.03,p.u. in single area and a case of load change in both the areas of $\Delta p_{d1} = 0.01$ and $\Delta p_{d2} = 0.03$ p.u. are studied they show good damping performance as represented.

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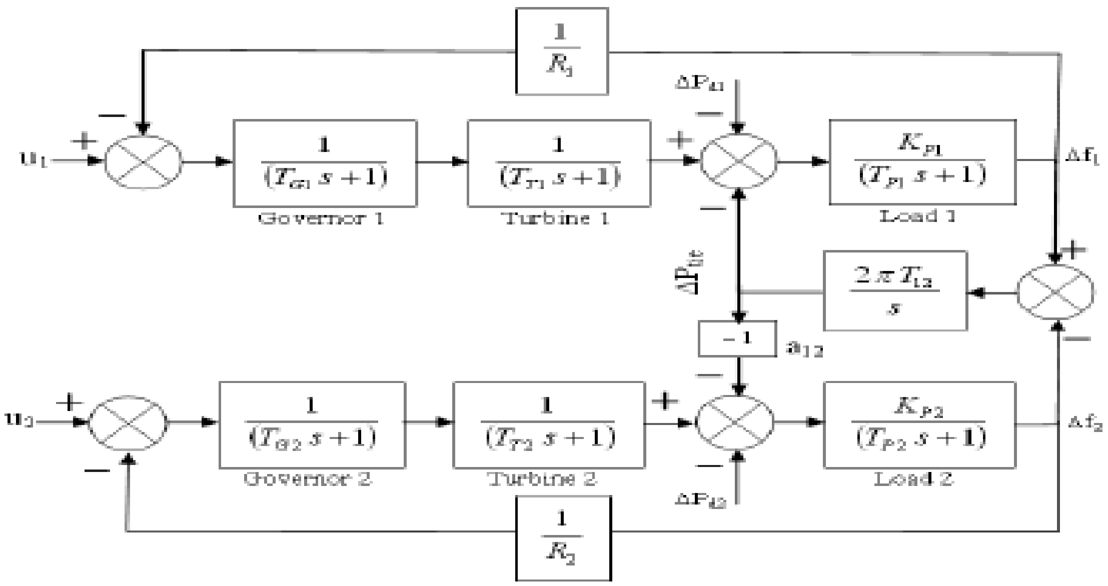



figure 4: Two area power system model.

**Figure 5: delta f of area1 due to load change 0.01 in area 1**

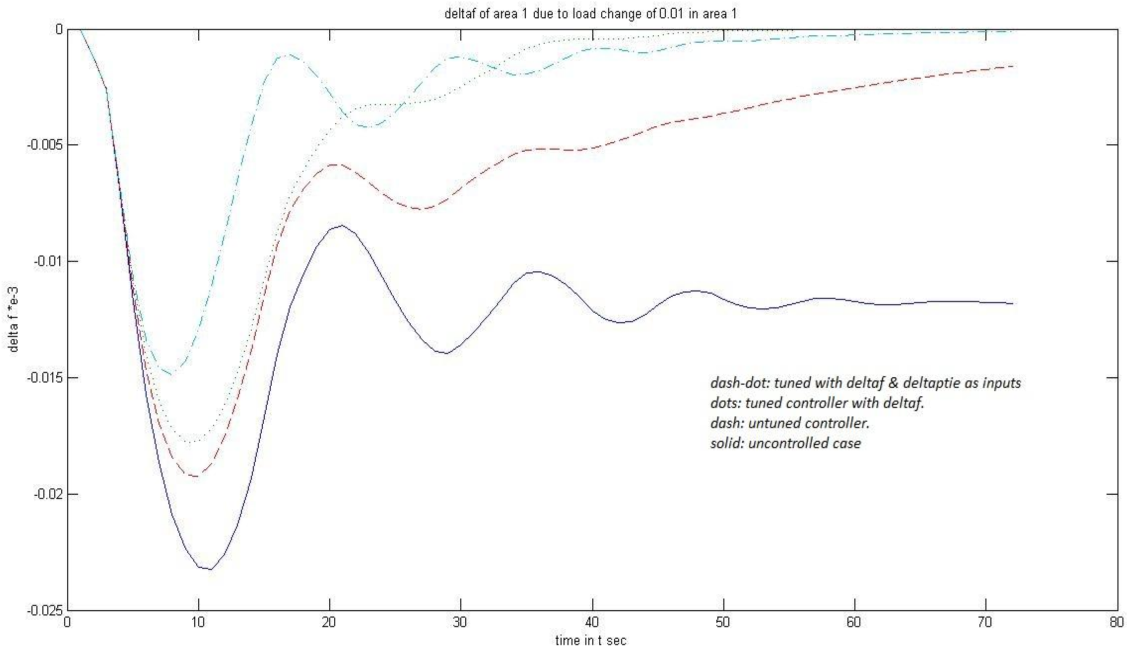



**Figure 6 delta f of area 2 with load change 0.01 in area 1**

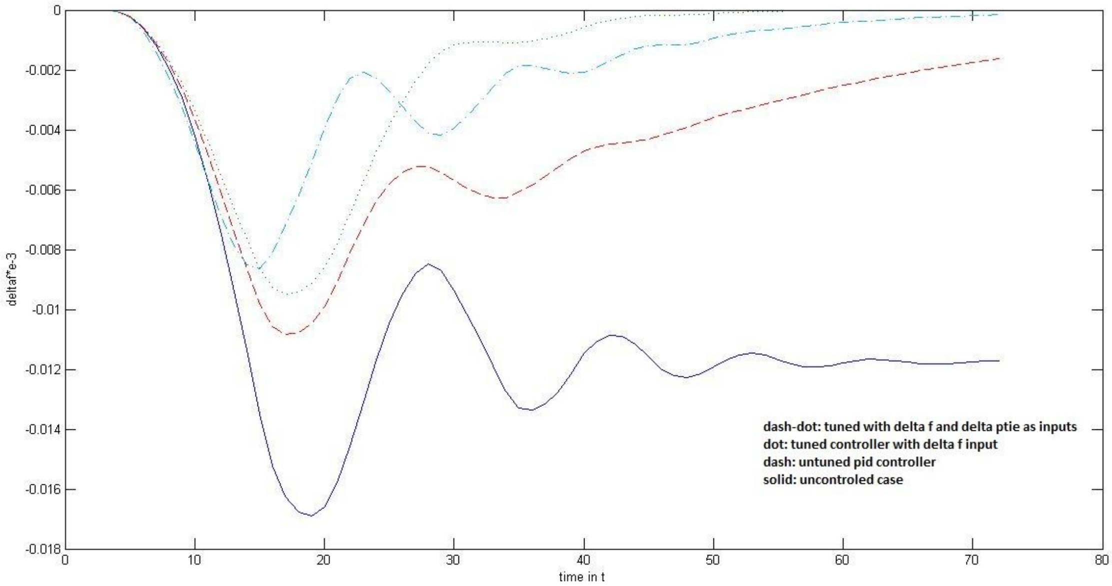



**Figure 7 delta ptie for load change 0.01 in area 1**

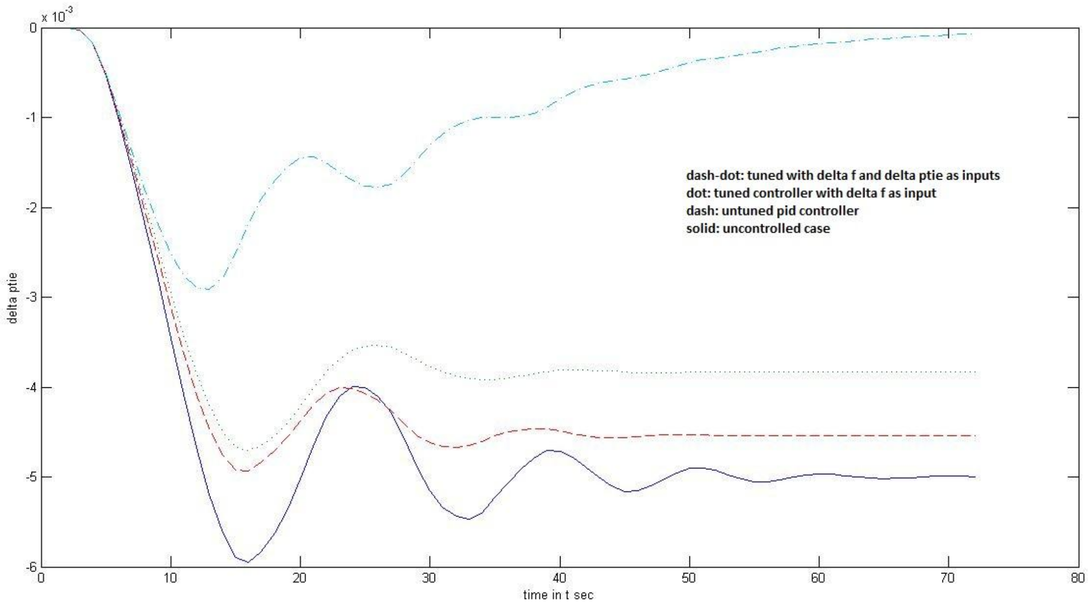


**Figure 8 delta f variation of area 1 due to load change delta pd1=0.01 and delta pd2=0.03 in both areas**

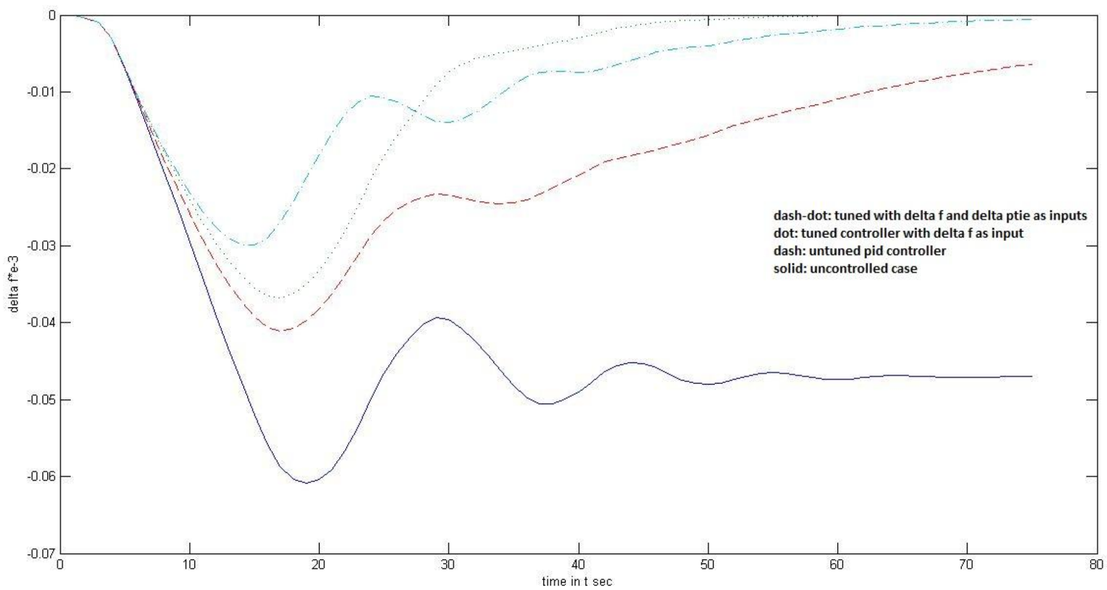



**Figure 9 delta f in area 2 due to load change of delta pd1=0.01 and delta pd2=0.03 in both areas**

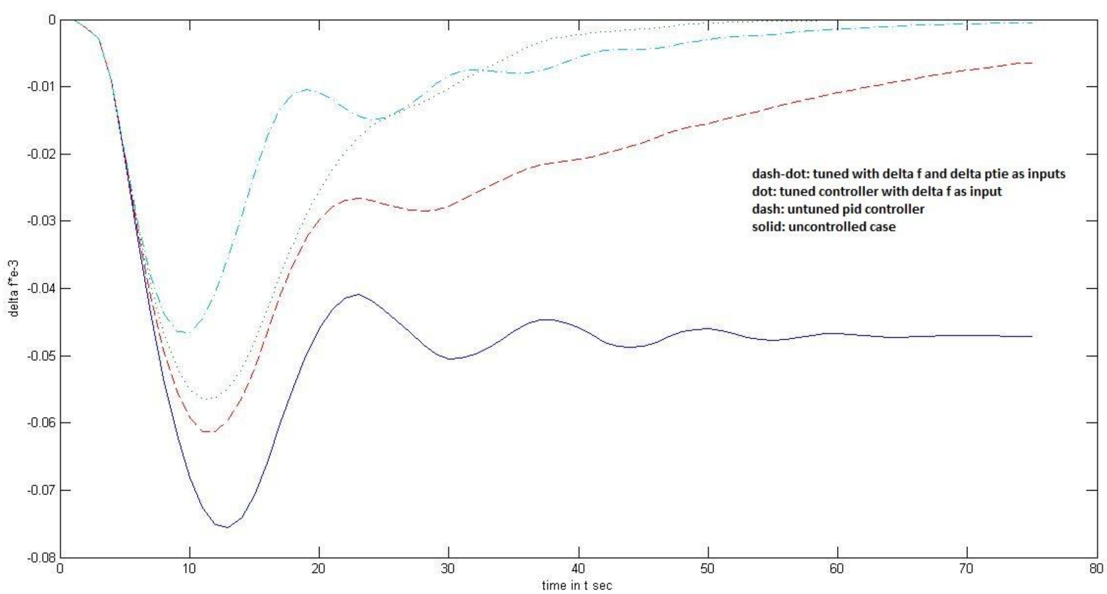
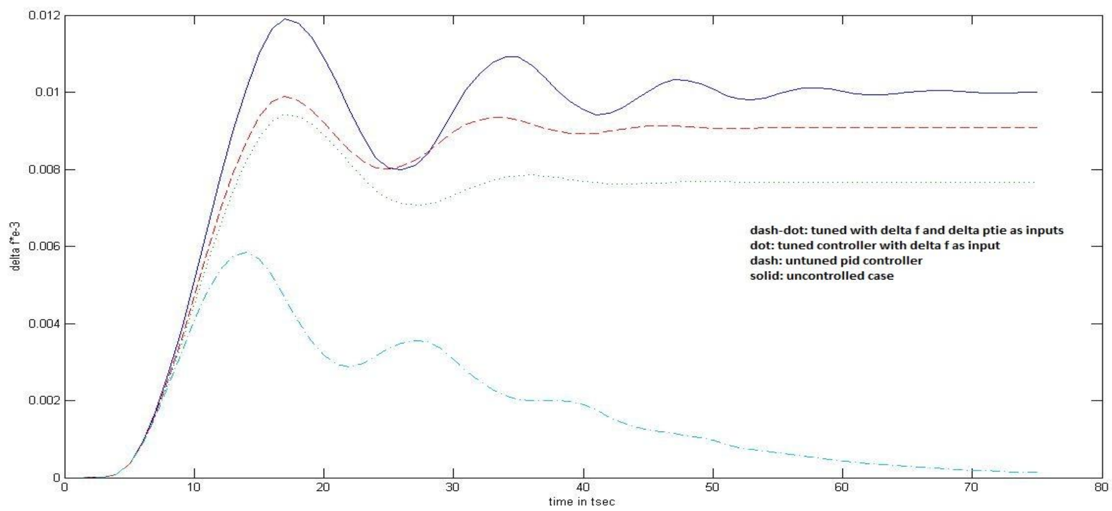


**Figure 10 variation of delta ptie due to load change of delta pd1=0.01 and delta pd2=0.03**




## VI. CONCLUSION.

The load change cases of 1 and 4 are only represented here, remaining are represented in the book its self. As seen from the results, for the uncontrolled case which is represented in solid line has more negative overshoot and more oscillations, which are decreased by applying different controllers and configurations. The better case is achieved when the tuned controller with both frequency change and tie line power change are applied to the control, in that case both steady state error is zero and negative overshoot is reduced when compared with others.

Comparison shows that the proposed controller is more effective in reducing the frequency deviation transients and to keep the interchanged power at the scheduled value. Moreover, the proposed controller type is relatively simple and suitable for practical on-line implementation. the proposed controller gathers the merits of both the TDF-IMC and stabilizing input signals to the controller.

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