# LOAD FREQUENCY CONTROL OF TWO AREA POWER SYSTEM WITH INTEGRAL PROPORTIONAL-INTEGRAL AND PID CONTROLLER

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## Abstract

*This paper has discussion on two area load frequency control with Integral (I), Proportional Integral (PI) and Proportional-Integral-Derivative (PID) controller. This is basic paper on two area load frequency control which presents comparative analysis of these controllers with the effects of gain factors of these controllers on frequency deviation. First, system is discussed with and without integral controller then I is replaced with PI & after that with PID to get the results from these controllers to make the comparative analysis. Analysis is based on MATLAB/SIMULINK 2010a.*

***Keywords—*** *Two-area, Integral (I) Controller Proportion-Integral (PI) Controller, Proportional-Integral-Derivative (PID) Controller, Load Frequency Control (LFC), Area Control Error (ACE), Tie-line Power Deviation, Frequency Deviation*

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## 1. INTRODUCTION

Load is not constant on any power system. Its variation takes place with time. Frequency deviation results from active power mismatch in the system and voltage variation results from reactive power mismatch in the system. Performance of many machines deteriorates when frequency differs from nominal value. It can be observed that during load disturbance system frequency goes down, under such conditions there is need to increase real power generation. For increasing real power generation some constraints known as generation rate constrains, are also taken into account. For reliable system operation frequency variation limit is +/- 0.5Hz [2]. When load side real power demand dominates the generation side real power then frequency comes down from its nominal value at generation side and vice-versa. When real power generation equalizes to active load demand plus losses then system operates at its nominal frequency. Change in active power generation is done at generation side, only under emergency conditions it is done at load side [7]. In case of interconnected systems, whenever there is load disturbance in any area then power flows from other areas to supply the demand which helps in reduction of frequency deviation of that particular area in which disturbance has occurred. Proportional-integral-derivative controller (PID) is effective in reducing transients during disturbance along with overshoots [3]. For the ease of analysis an equivalent governor, an equivalent turbine and an equivalent generator load model is used for the entire system which is known by a particular area, e.g. area-1.

## 2. TWO AREA SYSTEM

A two area system has two areas connected through a tie-line. Area-1 represents equivalent governor, turbine and generator load model of the entire system. Area-2 represents equivalent model of another entire system. Tie-line power flows due to frequency deviations. For any load change, all the generating units respond simultaneously to maintain coherency. This type of coherent area is known as control area where frequency is same under both static and dynamic conditions. Fig.1 shows the block diagram of two area power system without integral controller and Fig.2 shows the block diagram of two area system with integral controller. System should be operated around nominal frequency because [8] -

1. Three phase AC motors will not give good performance as their speed directly depends on the frequency.
2. Turbine blades are likely to be damaged if frequency goes beyond specified limits [47.5 52.5].
3. Electric clocks are operated by synchronous motors. Clocks will give error for any deviation in the frequency.
4. Saturation problem will arise in power transformers under constant voltage mode operation if frequency goes down.
5. Blast of fans like ID & FD in a thermal plant causes reduction in generation for which proper load shedding is required otherwise it is likely to shut down.

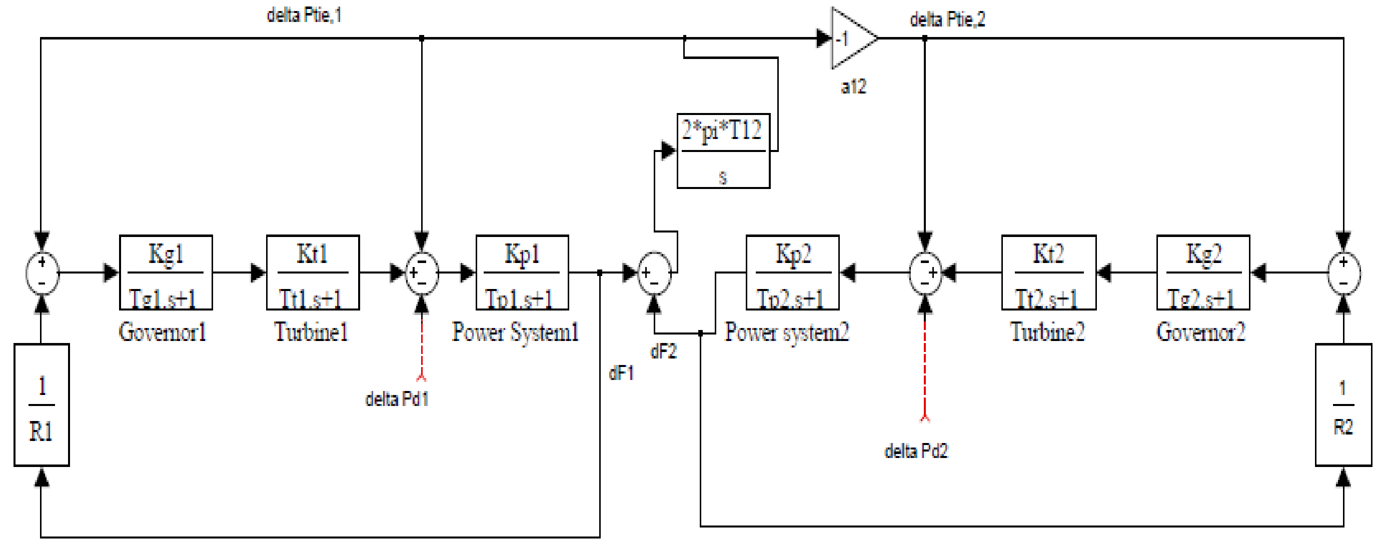


**Fig.1:** Block diagram of two area system without integral controller

It is assumed that area-1 has surplus power. Therefore, power out of area-1 can be given as-

$$P_{tie,1} = (|V_1||V_2|/X_{12})\mathrm{Sin}(\delta_1-\delta_2)$$

Here $\delta_1$, $\delta_2$ are angles of $V_1$ and $V_2$ which are end voltages of equivalent machines of area-1 and area-2 respectively.

For $\Delta f_1$ and $\Delta f_2$, change in tie-line power can be given by [2]-

$\Delta P_{tie,1}$ (pu) = $2\pi T_{12} (\int\Delta f_1 dt-\int\Delta f_2 dt)$

$\Delta P_{tie,2}$ (pu) = $2\pi T_{21} (\int\Delta f_2 dt -\int\Delta f_1 dt)$

Synchronizing coefficients $T_{12}$ and $T_{21}$ are given as [2]-

$T_{12} = (|V_1||V_2|/(P_{r1}X_{12}))\mathrm{Cos}(\delta_1-\delta_2)$

$T_{21} = (|V_1||V_2|/(P_{r2}X_{21}))\mathrm{Cos}(\delta_2-\delta_1) = (P_{r1}/P_{r2})T_{12} = -a_{12}T_{12}$, $a_{12} = (-P_{r1}/P_{r2})$

$P_{r1}$ is rated power (MW) of area-1 and $P_{r2}$ is rated power (MW) of area-2. Base power is given in MVA.

Tie-line power deviations are given as [2]-

$\Delta P_{tie,1}(s) = (2\pi T_{12}/s)[\Delta F_1(s) - \Delta F_2(s)]$

$\Delta P_{tie,2}(s) = a_{12} (-2\pi T_{12}/s)[\Delta F_1(s) -\Delta F_2(s)]$

Area control errors for area-1 and area-2 are given as [2]-

$ACE_1(s) = \Delta P_{tie,1}(s) + b_1\Delta F_1(s)$

$ACE_2(s) = \Delta P_{tie,2}(s) + b_2\Delta F_2(s)$ where $b_1$, $b_2$ are frequency bias constants.

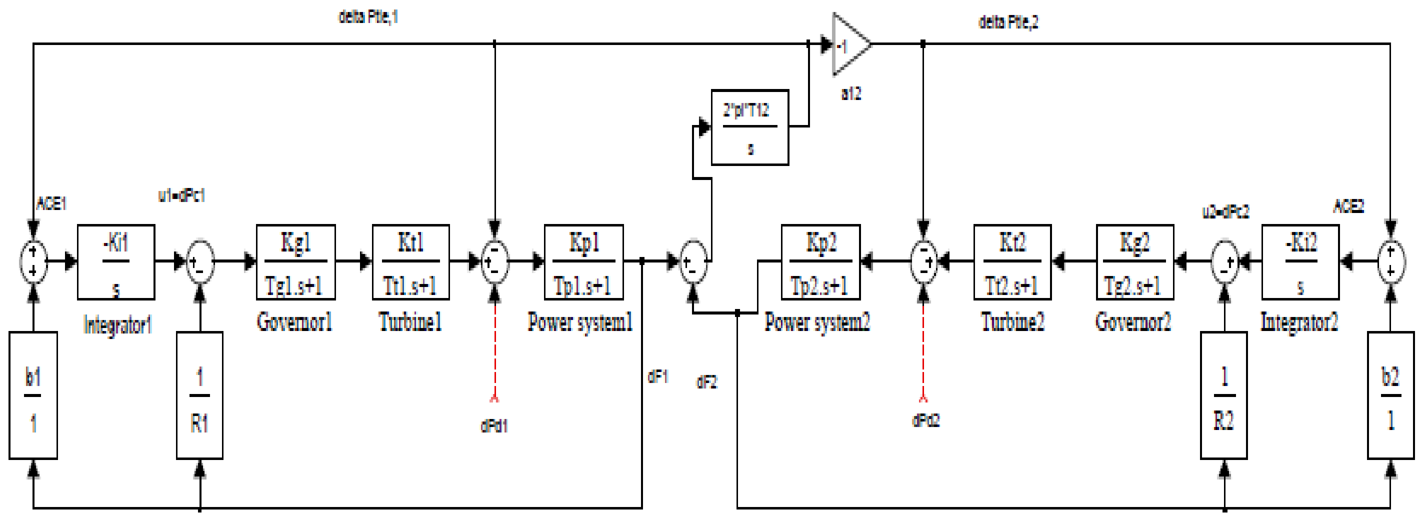


**Fig.2:** Block diagram of two area system with integral controller

Frequency deviations can be written as [2]-

$$\Delta F_1(s) = [\Delta P_{G1}(s)-\Delta P_{D1}(s)-\Delta P_{tie,1}(s)]K_{p1}/(1+T_{P1}s)$$

$$\Delta F_2(s) = [\Delta P_{G2}(s)-\Delta P_{D2}(s)-\Delta P_{tie,2}(s)]K_{p2}/(1+T_{P2}s)$$

Where $K_p$ =1/B=Power system gain and $T_p$ = 2H/(Bf) = Power system time constant.

## 3. PID CONTROL

Transfer function of PID controller can be written as-

$$G(s) = K_p + K_i/s + K_d.s$$

Gain $K_p$ affects mainly overshoot, $K_i$ affects mainly settling time & it can also be observed that when overshoot reduces then settling time increases with I and PI. $K_d$ has impact on both overshoot and transients. Integral controller has only one gain $K_i$ and its value can be obtained by trial & error method. When gain $K_p$ is introduced along with $K_i$ then it becomes PI controller ($K_p + K_i/s$). When we go I to PI then overshoot reduces but settling time increases. PI is reduced form of PID. In PID controller due to damping factor $K_d$, it gives least overshoot, least settling time and least transients among these controllers with proper tuning of parameters. These three controllers provide their best results only at a particular operating point corresponding to given system parameters with the chosen gain factors ($K_p$, $K_i$, $K_d$). Under dynamic conditions it may be that system parameters are different, in that case these controllers don't provide their best results. To overcome this type of problems, fuzzy logic based controllers are in use these days where system robustness and reliability are more important. With these controllers (I, PI, PID) due to introduction of a pole at origin by the term 1/s, steady state error is reduced. In PID controller due to derivative term, a zero is added in the open loop transfer function. It helps in the reduction of both transients and overshoots with proper tuning of all the parameters of the controller [3]. Tuning of parameters can be done easily by trial & error method using permutation-combinations. In case of integral controller, $K_i$ should be less than its critical value for damped and non-oscillatory response. Critical value of gain is given by-

$$K_{crit} = (1/4)T_{ps}K_{ps}(1+ K_{ps}/R)^2 = \text{Critical value of gain}$$

Area control error (ACE) is the input to each controller and real power command signal $\Delta P_C$ is obtained after the controller action which is input to the speed changer of that area. For Integral controller-

$$\Delta P_{C1} = -K_{i1}\int(ACE_1)dt \quad \& \quad \Delta P_{C2} = -K_{i2}\int(ACE_2)dt$$

For PI controller-

$$\Delta P_{C1} = K_{p1} + K_{i1}\int(ACE_1)dt \quad \& \quad \Delta P_{C2} = K_{p2} + K_{i2}\int(ACE_2)dt$$

For PID controller-

$$\Delta P_{C1} = K_{p1} + K_{i1}\int(ACE_1)dt + K_{d1}\, d(ACE_1)/dt$$

$$\Delta P_{C2} = K_{p2} + K_{i2}\int(ACE_2)dt + K_{d2}\, d(ACE_2)/dt$$

Where $\Delta P_{C1}$, $\Delta P_{C2}$ are real power command signals of area-1 and area-2 respectively. Ki1 & Ki2 are integral gains, $K_{p1}$ & $K_{p2}$ are proportional gains and $K_{d1}$, $K_{d2}$ are derivative gains of area-1 & area-2 respectively.

## 4. SIMULATION & RESULTS

Simulation model of the system without Integral controller is shown in Fig.3 and Fig.4 shows the simulation model of the system with integral controller. For a step load disturbance of 0.05pu in area-1, these results were obtained for the given controllers. Fig.5 to Fig.7 show the frequency deviation and Fig.8 to Fig.10 show incremental turbine power outputs ($\Delta P_{m1}$, $\Delta P_{m2}$) and tie-line power deviations with the given controllers.

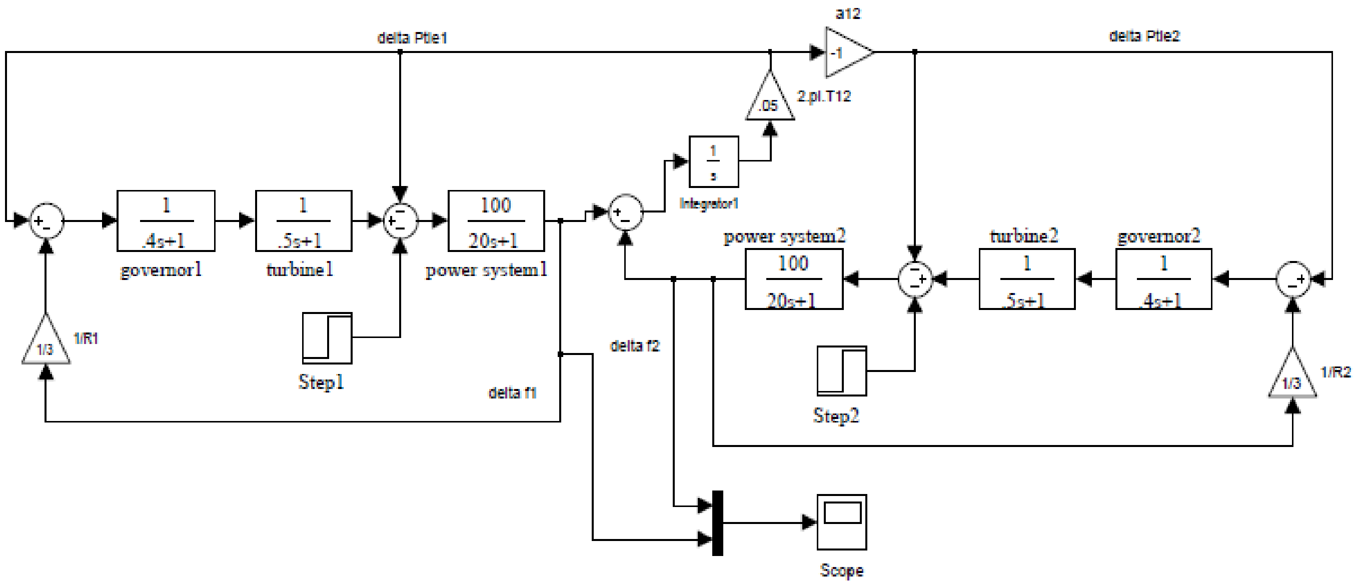


**Fig.3:** Simulation model of the system without integral controller

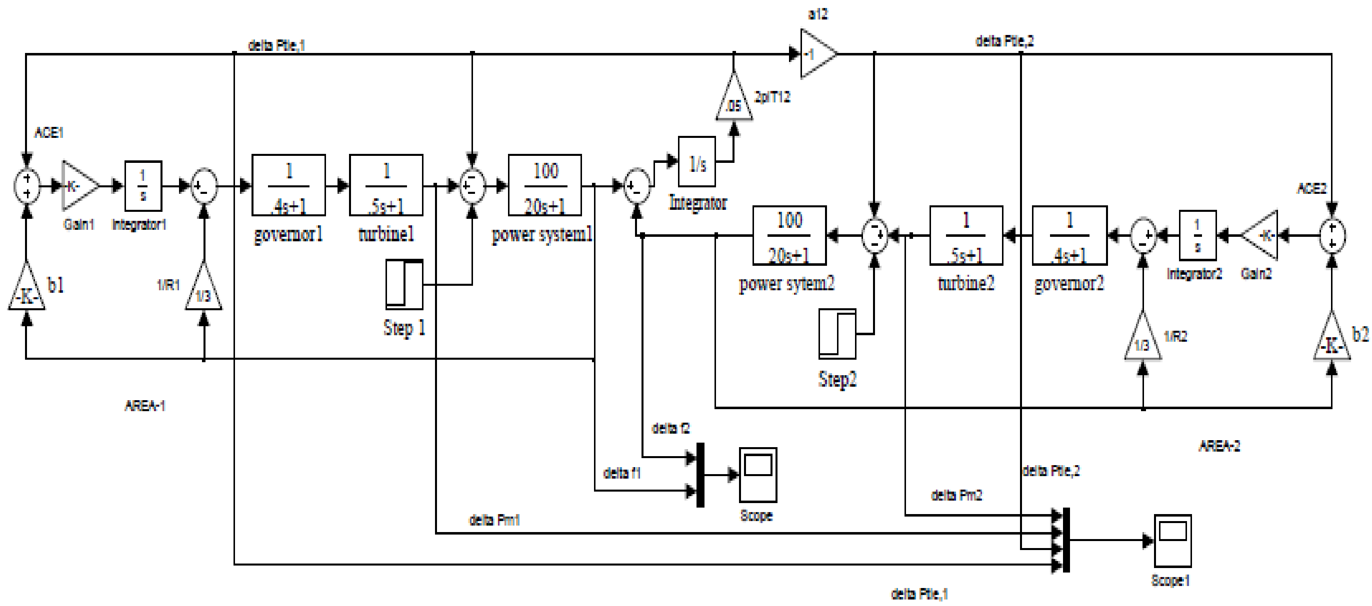

**Fig.4:** Simulation model of the system with integral controller

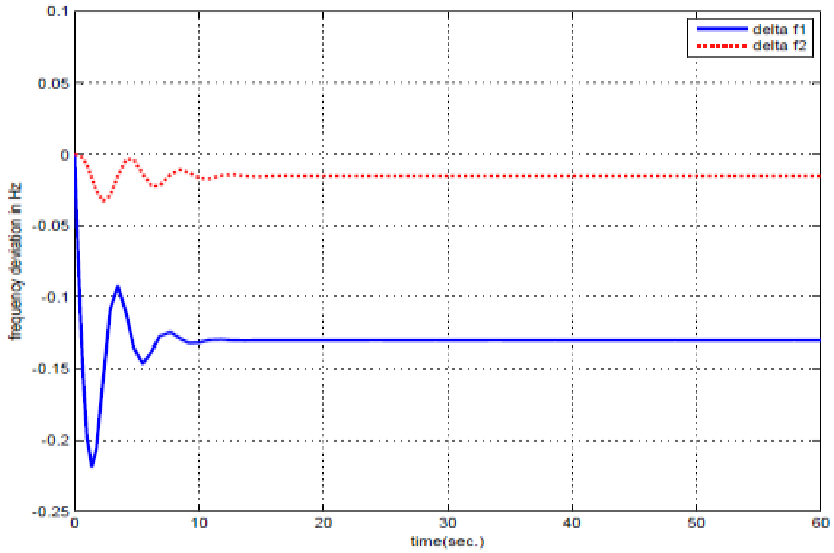

**Fig.5:** Frequency deviation v/s time without I controller

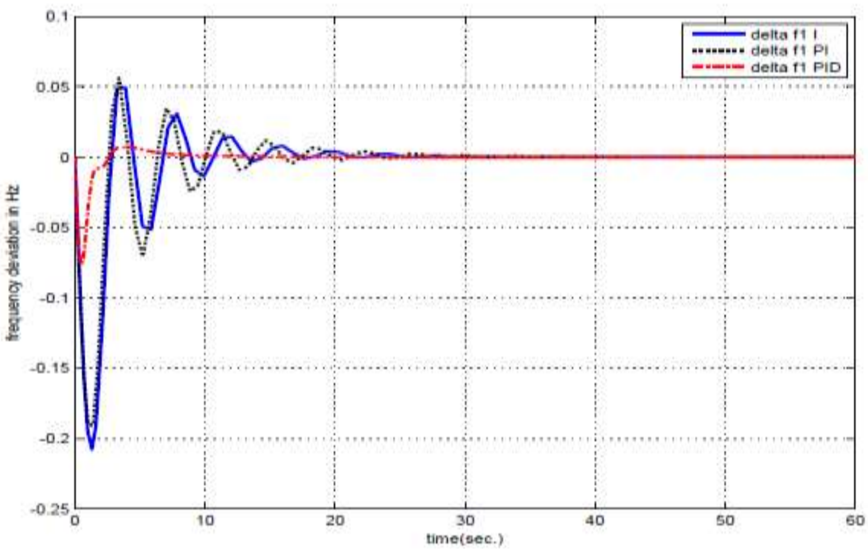

**Fig.6:** Frequency deviation v/s time for area-1

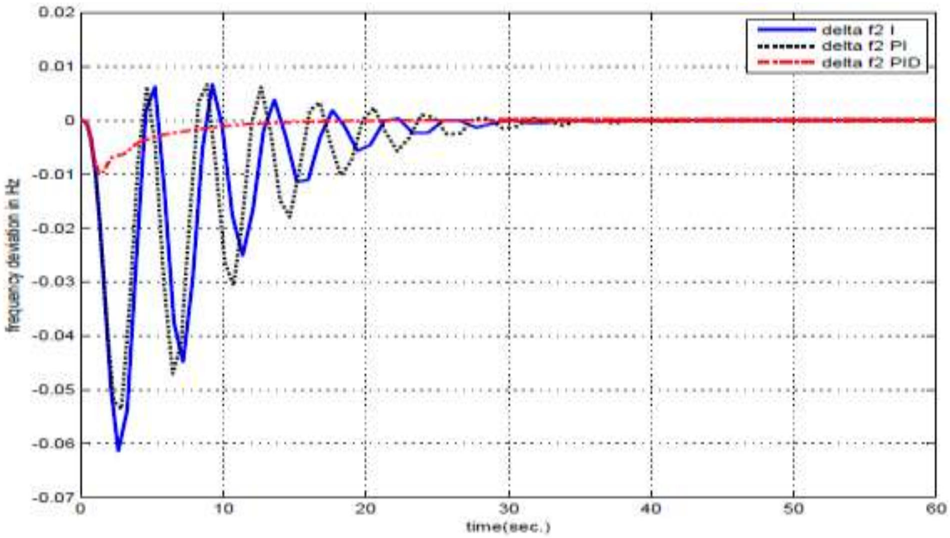


**Fig.7:** Frequency deviation v/s time for area-2

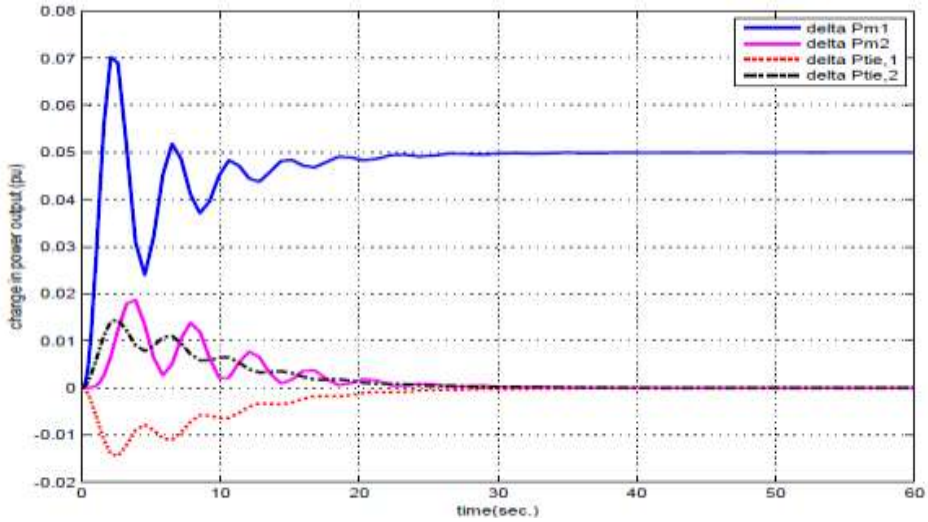


**Fig.8:** Change in power output v/s time with I

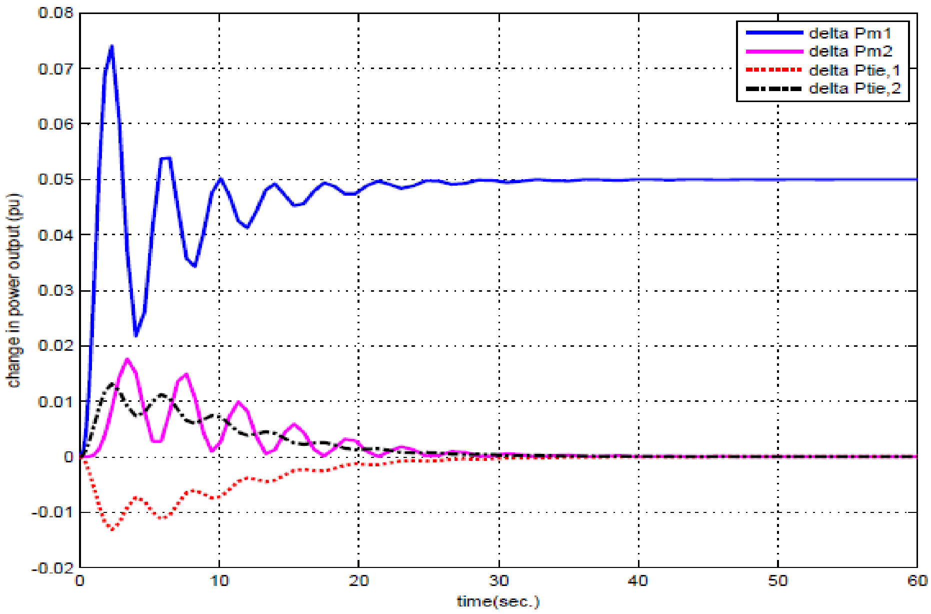


**Fig.9:** Change in power output v/s time with PI

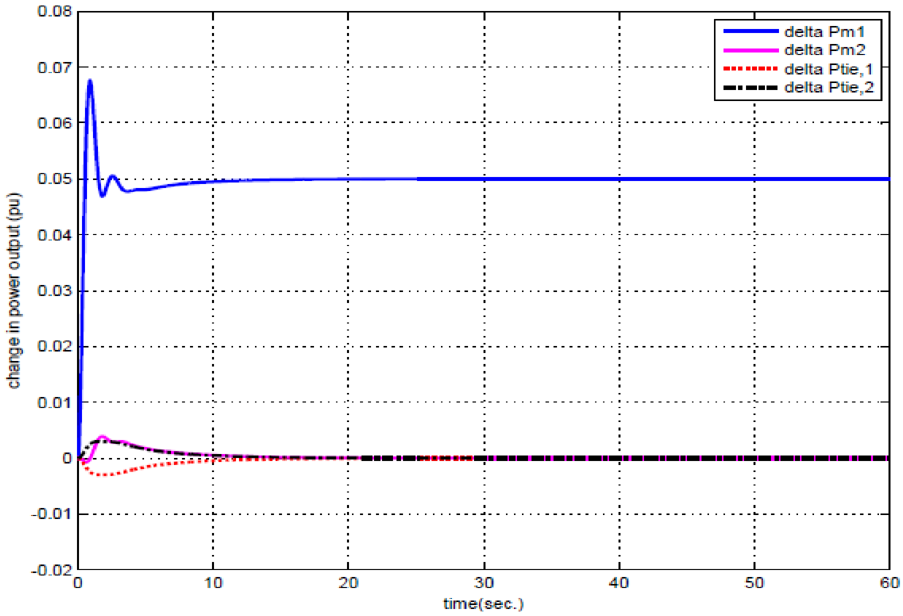


**Fig.10:** Change in Power output v/s time with PID

## 5. CONCLUSION

In this study, performance of I, PI and PID controller has been compared in terms of overshoot, settling time and steady state error for the frequency deviation of two area power system. PID controller gives better results with least overshoot and least settling time. It can be observed that under steady state condition, incremental turbine power output of that area in which disturbance was given, becomes equal to the load disturbance and that of other area becomes zero along with zero tie-line power deviation with these controllers. Analysis is given below in Table 1.

**Table 1:** Frequency deviation analysis for area-1 and area-2

| Parameter for $\Delta f_1$ | Without controller | With I | With PI | With PID |
|---|---|---|---|---|
| Overshoot (Hz) | -0.22 | -0.208 | -0.190 | -0.075 |
| Settling time(sec.) | 14 | 30 | 33 | 22 |
| Steady state error (Hz) | -0.13 | 0 | 0 | 0 |
| Parameter for $\Delta f_2$ | | | | |
| Overshoot (Hz) | -0.033 | -0.061 | -0.054 | -0.01 |
| Settling time(sec.) | 20 | 40 | 44 | 25 |
| Steady state error (Hz) | -0.015 | 0 | 0 | 0 |

## APPENDIX

The Nominal system parameters are: f=50Hz, $T_{g1}$ = $T_{g2}$ = 0.4s,

$T_{t1}$ = $T_{t2}$ = 0.5s, $K_{p1}$ = $K_{p2}$ = 100Hz/puMW, $T_{p1}$ = $T_{p2}$ = 20s,

$R_1$ = $R_2$ = 3Hz/puMW, $b_1$ = $b_2$ = 0.425puMW/Hz, $a_{12}$ = -1,

$K_{i1}$ = $K_{i2}$ = 0.2 for I, $K_{p1}$= $K_{p2}$= -0.13 & $K_{i1}$= $K_{i2}$= -0.2 for PI , $K_{p1}$=$K_{i1}$=$K_{d1}$ = -1.4 = $K_{p2}$=$K_{i2}$=$K_{d2}$ for PID, $\Delta P_{L1}$ = 0.05pu, $\Delta P_{L2}$=0.00pu

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