# Load Frequency Control of Three Different Area Interconnected Power Station using Pi Controller

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**Abstract :**
*This paper present analysis on dynamic performance of Load Frequency Control (LFC) of three area interconnected thermal-hudro-nuclear power station by the use of PI Controller. In this paper area-1, area-2 and area-3 consists of hydro, nuclear power plants whereas area-3 consists of thermal power plant. In this proposed scheme, the combination of most complicated system like thermal, hydro plant and nuclear plant are interconnected which increases the nonlinearity of the system. The performances of the controllers are simulated using MATLAB/SIMULINK package. The simulation results also tabulated as a comparative performance in view of frequency deviation by three different interconnected power plants.*

**Keywords:** *Load Frequency Control (LFC), Tie line Control, PI controller, MATLAB / SIMULINK.*

## I. INTRODUCTION

Automatic Load Frequency Control (ALFC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. ALFC is a feedback control system adjusting a generator output power to remain defined frequency[1]. The interconnected power system is divided into three control areas, all generators are assumed to form a coherent group (Grass Getal, 2001). Load Frequency Control (LFC) is being used for several years as part of the Automatic Generation Control (AGC) scheme in electric power systems[3.4]. One of the objectives of AGC is to maintain the system frequency at nominal value (50 hz). In the steady state operation of power system, the load demand is increased or decreased in the form of Kinetic Energy stored in generator prime mover set, which results the variation of speed and frequency accordingly. Therefore, the control of load frequency is essential to have safe operation of the power system [6]

A control strategy is needed that not only maintains constancy of frequency and desired tie-power flow but also achieves zero steady state error and inadvertent interchange. Among the various types of load frequency controllers, the most widely employed is the conventional proportional integral (PI) controller. The PI controller is very simple for implementation and gives better dynamic response. In LFC pertains to interconnected system and relatively lesser attention has been devoted to the LFC of three area interconnected hydro-thermal-nuclear system[3]. The PI controller offers better performance especially, in complex and nonlinearities associated system. In this paper, the performance evaluation based on PI controller for three area interconnected thermal-hydro-nuclear power plant is proposed [4].

## II. MODELLING OF THREE DIFFERENT AREA INTERCONNECTED WITH TIE LINE CONTROL

To illustrate LFC system behavior in a multi-area power system, consider three different interconnected control areas as shown in Figure.1. The system dynamics response following a simulations 0.01 pu load step disturbance in control areas[8]. If disturbance is given to any one of the three areas, the power to compensate the tie-line power change initially comes from all the three areas and frequency drops in all the areas and this drop of frequency is sensed by the speed governors of the three areas. However, after a few seconds (steady state), additional power against the local load changes come only from that disturbed area[10].


**Figure.1 Representation of Interconnected Three Different Area with Tie line**

In real time power system many loads are connected to many generators located in different regions (areas). This may be assumed as extended power system which can be divided into number of load frequency control areas interconnected by means of tie lines sIn these areas load changes and abnormal conditions lead to mismatches in frequency and scheduled power interchanges through tie line between areas. These mismatches have to be corrected by Governor Control, which is defined as the regulation of the power output of generators within a prescribed area. The key assumptions in the classical Governor Control problem are:

i. The steady state frequency error following a step load change should vanish. The transient frequency and time errors should be reduced.
ii. The static change in the tie line power following a step load in any area should be zero, provided each area can accommodate its own load change.
iii. Any area in need of power during an emergency should be assisted from other areas.

The power transfer equation through tie line is ,

$$P_{12} = \frac{|V_1||V_2|}{x} \sin(\delta_1 - \delta_2) \quad (1)$$

Considering area 1 has surplus power and transfers to area 2

$P_{12}$ = Power transferred from area 1 to 2 through tie line.

$$P_{12} = \frac{|V_1||V_2|}{X_{12}} . \mathrm{Sin}(\delta 1 - \delta 2)$$

(2)

Where

$\delta_1$, $\delta_2$and$\delta_3$= Power angles of end voltages

$V_1$, $V_2$and $V_3$of equivalent machine of the three areas respectively.

$X_{12}$ = reactance of tie line.

The order of the subscripts indicates that the tie line power is define positive in direction 1 to 2. For small deviation in the anglesand the tie line power changes with the amount i.e. small deviation in $\delta_1$ , $\delta_2$ and $\delta_3$ changes by $\delta 1$, $\delta 2$, and $\delta_3$

Power P12 changes to P12 + $P$ 12.

Therefore, Power transferred from Area 1 to Area 2 as given in [10]] is

**C**hange in the tie line power between area 1 and 2

$$\Delta P_{tie,1-2} = \frac{2\pi}{s} T_{12}(\Delta f_1(s) - \Delta f_2(s)) \quad (3)$$

**C**hange in the tie line power between area 1 and 3

$$\Delta P_{tie,1-3} = \frac{2\pi}{s} T_{13}(\Delta f_1(s) - \Delta f_3(s)) \quad (4)$$

**C**hange in the tie line power between area 2 and 3

$$\Delta P_{tie,2-3} = \frac{2\pi}{s} T_{23}(\Delta f_2(s) - \Delta f_3(s)) \quad (5)$$

Where

$T_{ij}$ -Tie line power between $i^{th}$and$j^{th}$areas.

$f_i$ - Frequency of $i^{th}$area.

So the total tie line power change between area 1 and the other two areas can be calculated as

$$\Delta P_{tie,1} = \Delta P_{tie,1-2} + \Delta P_{tie,1-3} = \frac{2\pi}{s}\left(\sum_{j=2,3} T_{1j}\Delta f_1 - \sum_{j=2,3} T_{1j}\Delta f_j\right) \quad (6)$$

Similarly for N control areas, the total tie line power change between area 1 and other area is (as shown in Figure.2)

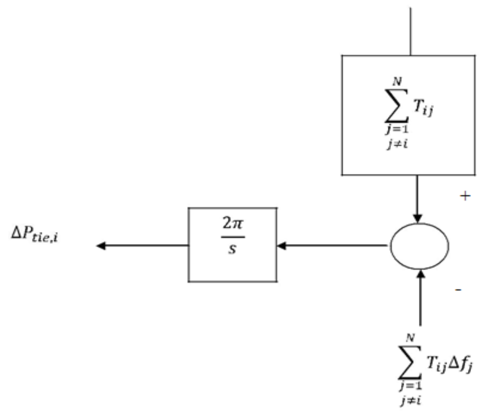


**Figure.2 Block Diagram Representation for tie-line Power Change of Control Area i in N Control Area Power System**

$$\Delta P_{tie,i} = \sum_{j=1, j\neq i}^{N} \Delta P_{tie,i-j} = \frac{2\pi}{s}\left(\sum_{j=1, j\neq i}^{N} T_{ij}\Delta f_i - \sum_{j=1, j\neq i}^{N} T_{ij}\Delta f_j\right) \quad (7)$$

Therefore three area system can be modeled as shown in Figure 3.

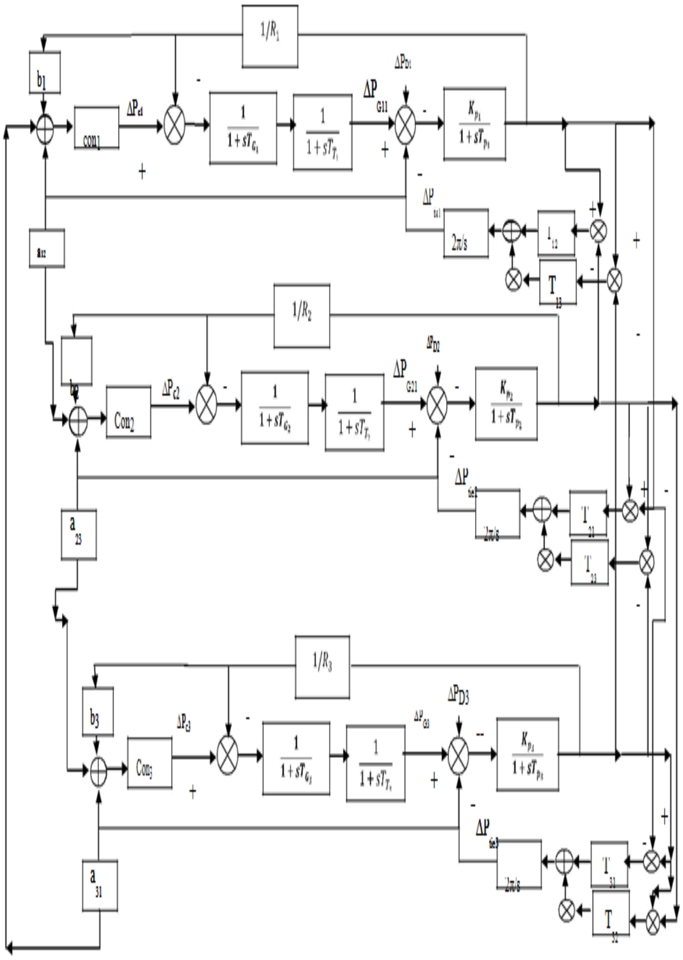

**Figure 3. Simulink Model of Interconnected Three Different Area with Tie line Control**

## III. PI CONTROL METHODOLOGY

Most common controllers available commercially are the proportional integral (PI) and proportional integral derivative (PID) controller [13]. The PI controllers are used to improve the dynamic response as well as to reduce or eliminate the steady state error [14]. The derivative controller adds a finite zero to the open loop plant transfer function and improves the transient response. PI is made up of two main components i.e. proportional and integral.

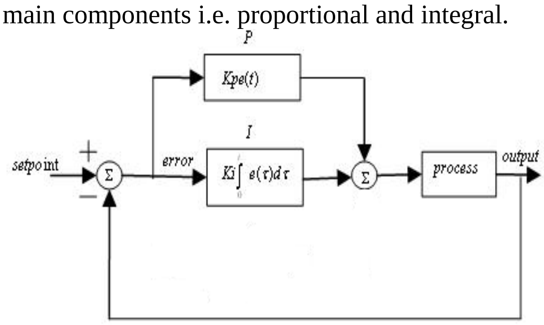


**Figure 4: Block Diagram of a PI Controller.**

This controller is one of the most popular in industry. The proportional gain provides stability and high frequency response[15]. The integral term insures that the average error is driven to zero. Advantages of PI include that only two gains must be tuned, that there is no long-term error, and that the method normally provides highly responsive systems. The predominant weakness is that PI controllers often produce excessive overshoot to a step command. The PI controller is characterized by the transfer function

$$G_c(s) = K_p(1 + \frac{1}{sT_i}) \quad (8)$$

### A. *Proportional Gain ($K_p$)*

Larger values typically mean faster response since the larger the error, the larger the Proportional term compensation. An excessively large proportional gain will lead to process instability and oscillation.

### B. *Integral Gain ($K_i$)*

Larger values imply steady state errors are eliminated more quickly. The trade-off is larger overshoot: any negative error integrated during transient response must be integrated away by positive error before we reach steady state.

The PI controller is a lag compensator. It possesses a zero at s = $-1/T_i$ and a pole at s = 0. Thus, the characteristic of the PI controller is infinite gain at zero frequency. This improves the steady-state characteristics [12]. However, inclusion of the PI control action in the system increases the type number of the compensated system by 1, and this causes the compensated system to be less stable or even makes the system unstable. Therefore, the values of $K_p$ and $T_i$ must be chosen carefully to ensure a proper transient response. By properly designing the PI controller, it is possible to make the transient response to a step input exhibit relatively small or no overshoot. The speed of response, however, becomes much slower [16].

## IV. SIMULATION AND RESULTS

A three area system model is developed for multi-area concept. In three area system hydro system is taken as area 1 and nuclear system is taken as area 2 and thermal system is taken as area 3. This three area system is simulated for 1% disturbance in thermal system. This three area system is modeled without nonlinearities [15]. The performance offrequency deviation using PI controller is tested and compared for three area system. A three area Hydro-Nuclear-Thermal system is shown in Figure 5 [16]. Simulated and compared frequency responses of three different power plants are shown in Figure-6 to 9. Table. I show that performs frequency deviation using PI controller for different three areas.

### *A. Simulation of Three Different Interconnected Power Plant*

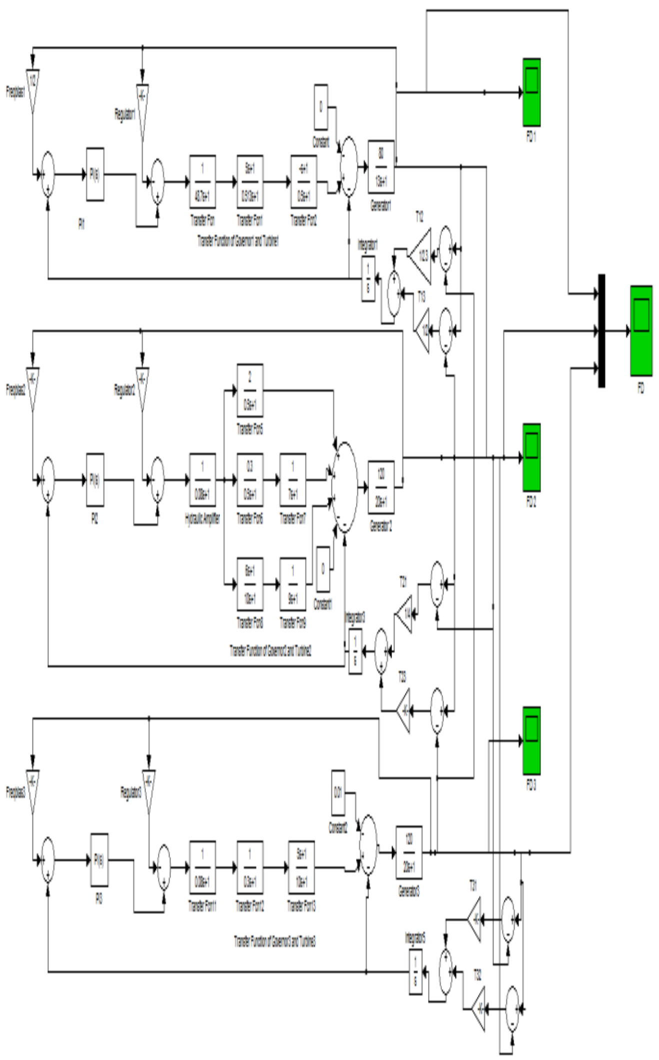

**Fig. 5 Simulation on Three Different Area Interconnected Hydro-Nuclear-Thermal Power Station using PI Controllers**

### *B. Analysis of Three Different Interconnected Power Plant*

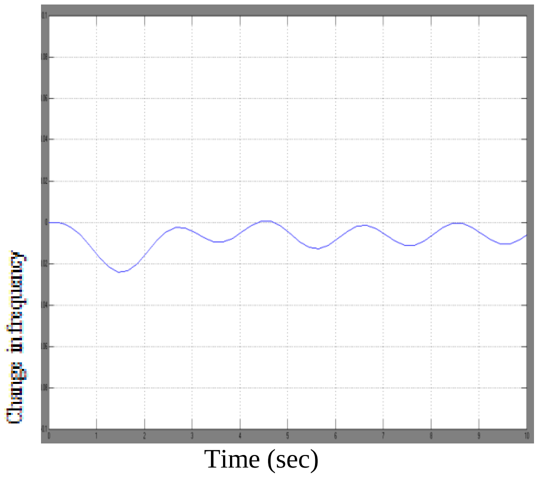


**Fig.6 Frequency Deviation for Hydro PS With PI Controller**

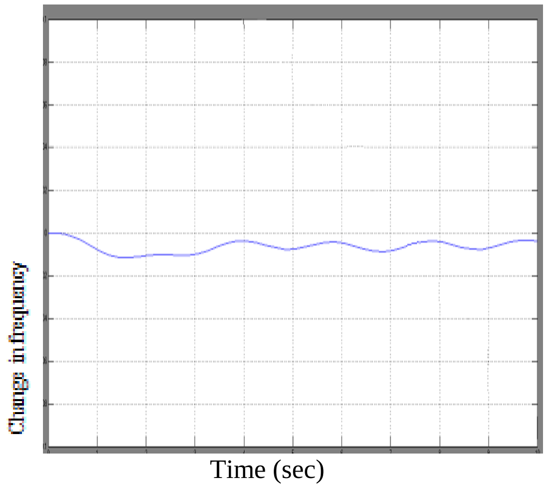


**Fig.7 Frequency Deviation for Nuclear PS With PI Controller**

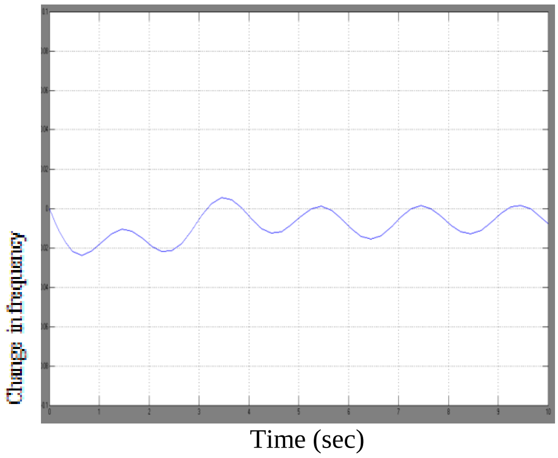


**Fig.8 Frequency Deviation for Thermal PS With PI Controller**

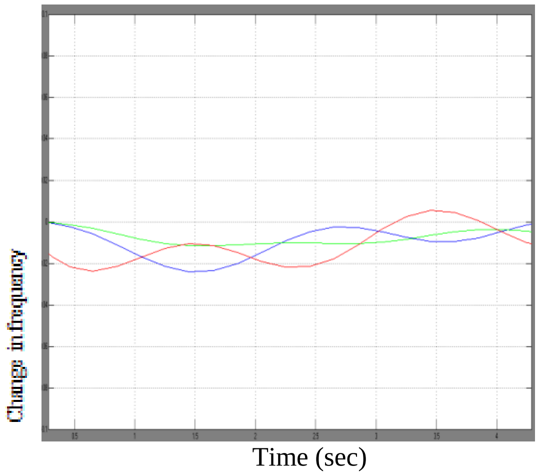


**Fig.9 Frequency Deviation for Three Combined PSWith PI Controller**

### C. *Tables*

| Sr. No. | Three Different Stations | Frequency Deviation Δf |
|---|---|---|
| 1 | Hydro Power Station | -0.022 Hz |
| 2 | Nuclear Power Station | -0.012 Hz |
| 3 | Thermal Power Station | -0.023 Hz |

**Table I Results of Frequency Deviation for Three Different Power Plants**

## V. CONCLUSION

In this paper three different area thermal, hydro and nuclear systems have been modeled and these areas are simulated in Simulink environment. All these aforesaid systems are controlled with conventional PI controller [18,19]. The performance of PI controller has been compared frequency deviation of three different power plants. From table. I it is found that PI controller show the best performance of settling time less frequency deviation and minimum oscillations.

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