

# A Novel Method to Improve the LFC in Single Area and Two Areas Power System Using PI Controller

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**Abstract:** This paper presents A novel method to improve the load frequency control in single area and two area power system. This means the load variation on a power system which gives the frequency drift from its nominal value. This gives the quality of electric power, reliable and good, because for minimizing the fluctuations of frequency. This paper is mainly focused on technical issues associated with load frequency control (LFC) in single area and two area power system. In this paper shown the dynamic response of the load frequency control using MATLAB/SIMULINK software. These results are shown and there is no steady state error in frequency fluctuations has been implemented.

**Keywords:** Two area, Tie-line power, LFC, MATLAB, SIMULINK

## 1. Introduction

The main objective of the power system is to maintain the continuous supply of power with good quality and reliable, to all the consumers in the system. The load frequency control is very important for the right operation of interconnected power system. It requires maintenance of a balance between the instantaneous active power produced and consumed. If the production of electric power is larger than consumption, the frequency increases and vice versa. Hence, load frequency control is used to maintain the system frequency at nominal value for supplying good quality power to consumers. The load demand keep on increasing and decreasing during steady state operation of power system. Irrespective of the load change, the tie line flow should be maintained at even value. This requires the manipulation of the operation of valves of the governor with a suitable control strategy so that constant speed can be maintained, and the real power output of the generator be controlled. Hence, an integrator is added, which is automatically adjusts the generation to restore the frequency to its nominal value. Thus the control of real power output of electric generators in this way is termed as "Automatic generation control (AGC)". AGC is basically used to divide the loads among the system, such as to achieve maximum economy and accurate control of the tie line power interchange while maintaining a reasonably uniform frequency during normal period. The frequency control in an inter connected system is accomplished through two automatic controls: primary control and secondary control. The main objective of primary control is to stabilize the system frequency at stationary value following a disturbance, and to maintain the tie line power control areas at scheduled values by adjusting the output of some generators. Secondary control is basically used for automatic restoration of the frequency and the power exchanged between the different areas of the interconnected systems, at their scheduled values (i.e.  $\Delta f = 0$ ,  $\Delta P_i = 0$ ), taking into account control program. Also, their performance deteriorates with the increase in the complexity of the system. Hence, AGC has an importance and is increasing their demand in the inter connected power system. There is a number of control strategies were achieve by the better

performance. Because of this non linearity of power the system parameters and system is suggested by around an operating point. PI control is more advantage and is widely used[1].

## 2. Theory of Load Frequency Control

### 2.1 Frequency Response in Primary Control

The power system consists of a variety of loads of electric devices. Some are sensitive to frequency changes and some are not. The sensitivity depend on composite of the characteristics of speed-load all the devices. The speed load characteristics of a composite load is given by

$$\Delta P_e = \Delta P_L + D\Delta\omega \quad (1)$$

Where,

$\Delta P_L$  = Non frequency sensitive load change

$D\Delta\omega$  = Frequency sensitive load change

$D$  = percentage change in load divided by the percentage change in frequency (Damping factor).

When the system frequency drifts from nominal value (50HZ), the frequency sensitive components in the power system react to this change and the effective load system changes. This process is called load damping. Also, when the sudden increases in the electrical load, the turbine speed and hence the generator frequency begins to decreases. The speed is changes and is sensed by governor and it adjusts the turbine input valve to change mechanical power output so as to takes steady state. This can be done with the help of governed speed droop  $R$ , which is actually the feedback loop gain in the governor. The speed drop is defined as

$$R = \Delta\omega / \Delta P \text{ pu} \quad (2)$$

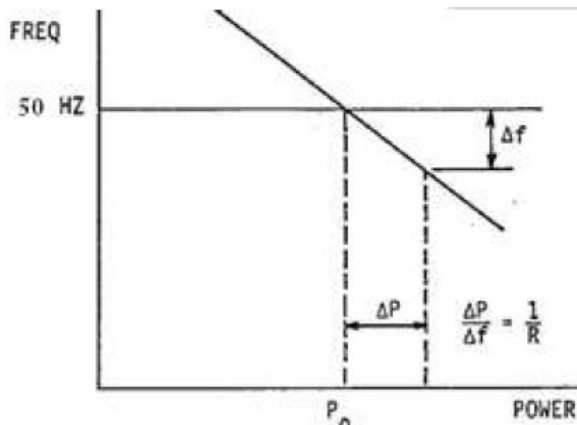
Where,

$\Delta\omega$  = speed deviation

$\Delta P$  = output power [2]

## 2.2 Percent Speed Regulation R

As the load is increased, basically the turbines are used and design for to permit the drop in the speed for stable operation. Due to mismatch in power, speed changes. The governor system senses this change and adjusts and also changes in the power output which in turn valve opening. And it will stop this action and it mismatch the power become zero. But the speed error remains [3]. The steady state characteristics of governor are shown in figure 1. The slope of the curve represents the speed regulation R. it is defined as the ratio of the change in frequency from no load to full load, to change in output power (Valve position).



**Figure 1:** Idle steady state characteristics of governor with speed droop

It can be expressed in percent as:

$$\text{Percent } R = \frac{\text{percent speed or frequency change}}{\text{percent power output change}} \times 100$$

$$= \frac{\omega_{nl} - \omega_{fl}}{\omega_0} \times 100 \quad (3)$$

Where,

$\omega_{nl}$  = steady state speed at no load  
 $\omega_{fl}$  = steady state speed at full load  
 $\omega_0$  = Nominal or rated speed

$$\Delta P_v = \Delta P_{ref} - \frac{1}{R} \Delta \omega \quad (4)$$

These two responses: load damping and governor response; help the system interconnection to become more stable. These responses are mathematically modeled as D and R respectively and are combined into one frequency response characteristic.

$$B = \sum (1/R + D) \quad (5)$$

## 2.3 Automatic generation control

The objectives of AGC are as follows:

- 1) To hold the system frequency at or very close to the nominal value.
- 2) To maintain correct value of interchange power between control areas.
- 3) To maintain each units generation at most economic value.

If the load on the system increased suddenly, the governor can adjust and after the turbine speed drops then the steam

input for the new load. The simple way is frequency brings to its nominal value and restore then it will adds with an integrator. The unit of integrator monitors the over a period of time by average time and overcome the offset. This scheme is known as Automatic generation control (AGC).

## 2.4 Area Control Error

The conventional LFC is composed for an integrator and of a frequency sensor. The frequency error  $\Delta f$  is measured by the frequency sensor and feeds this ERROR signal into the integrator. The input to the integrator is known as the Area control error (ACE). It is defined as the change in area frequency, which forces the steady state frequency error to zero, when used in an integral control loop [5]. The control error for each area consists of frequency and tie line error. Area control error is defined by

$$ACE_i = \sum_{j=1}^n \Delta P_{ij} + K_i \Delta \omega \quad (6)$$

Where,

$i$  = Control area for which ACE is being measured

$\Delta P_{ij}$  = Power interchange areas I and j

$K_i$  = Control area frequency bias coefficient

$\Delta \omega$  = Deviation in frequency

ACE is an error signal consisting of two terms. First term represents the tie-line error in the scheduled power flows. The second term is inter-area assistance in generation from control area to prevent large deviation of inter connection frequency. ACE represents the generation versus load mismatch for the control area and indicates when total generation must be raised or lowered [6]. The ACE signal should be kept from becoming too large should not be allowed to the "drift".

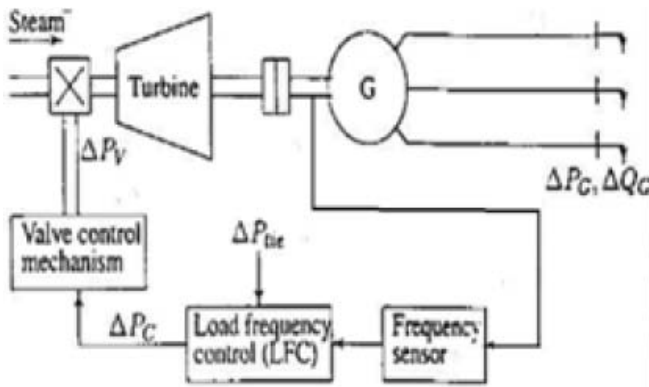
## 2.5 Tie line Bias Control

Extensive powers are composed of control areas which represents coherent groups of generators. The tie-lines are used to exchange energy between these areas and also to provide inter-area support in case of any abnormal condition. Load changes in an area and abnormal conditions, lead to mismatch in required power interchanges between areas [7]. As a result load changes in system and interconnection between generation areas, large tie-line power fluctuations and frequency oscillations take place [8]. Tie-line bias control is a control philosophy which has been developed for load frequency control in a power system. The concept allows each control area to operate to operate its generation and to fulfill areas control obligation, independently by monitoring and controlling the area's ACE.

## 3. Modeling of AGC

In an associated power system, maintenance of power inter change is not an issue. With the primary LFC loop, a change in the power system load will result in a steady state frequency deviation, depending on the governor speed regulation. To make the frequency deviation zero, we must provide a reset action. This is done by introducing an integral controller which acts on the load reference setting

and changes the speed set point. The integral controller increases the system type by 1 which makes the final frequency deviation to zero. The integral controller gain must be adjusted for a satisfactory transient response.



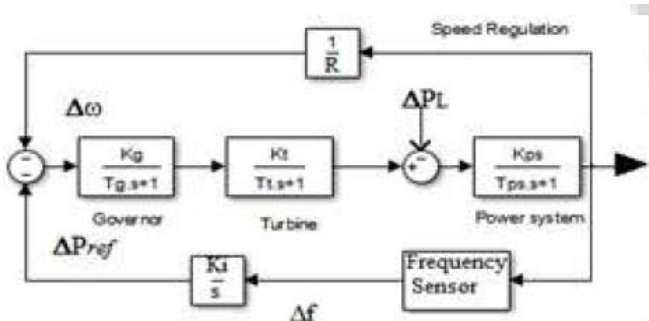
**Figure 2:** Schematic diagram of an LEC of a synchronous generator [10]

The schematic diagram of AGC is shown below. It consists of valve control mechanism, turbine, generator and governor. The change in frequency is compared with a reference speed. A valve controller is used to regulate the steam valve thereby increasing the power output from the generators which results in matching of generation and demand. As a result the frequency is restored to the original value [9]. Based on this, this network can be classified as single area or two area system as discussed below.

The combined block diagram of single area with, governor prime mover – rotating mass/load model is shown in figure 2.

#### 4. Single Area System

The restoration of the frequency to the nominal value requires an additional control loop called the supplementary loop. This loop consists of an integral controller which makes the frequency deviation to zero. The ALFC with the supplementary loop is generally called the AGC as shown in Figure 4. In order to make  $\Delta\omega = 0$ , the speed changer setting is changed in response to  $\Delta\omega(s)$  through an integrator. Thus the integral action results in automatic adjustment of  $\Delta P_{ref}$  so as to make  $\Delta\omega = 0$ .



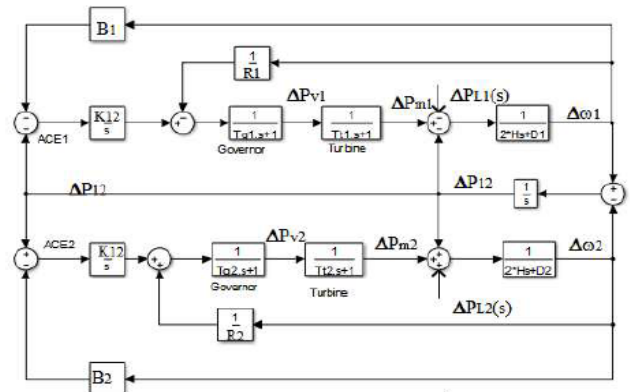
**Figure 3:** Block diagram of single area (PI controller)

#### 5. Two Area System

The block diagram of a simple AGC for a two-area system is shown in figure 4.

ACEs are used as actuating signals to active changes in the reference power set points, and when steady state is reached,  $\Delta P_{12}$  and  $\Delta\omega$  will be zero. Conventional LFC is based up on the tie-line bias control, where each area tends to reduce the area control error (ACE) to zero. The control error for each area tends to consists of linear combination of frequency and tie-line error.

$$ACE_i = \sum n_j = \Delta P_{ij} + K_i \Delta\omega \quad (7)$$

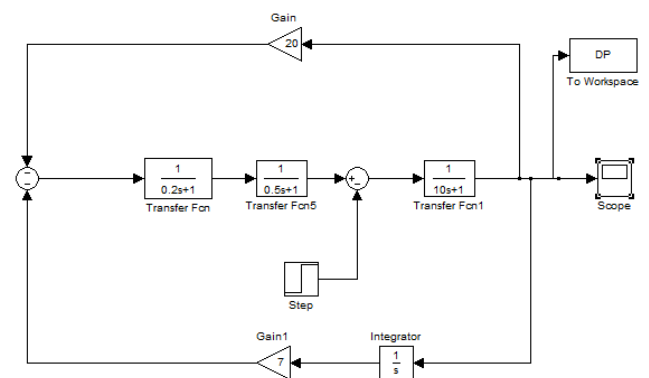


**Figure 4:** Block diagram of Two area system (PI Controller)

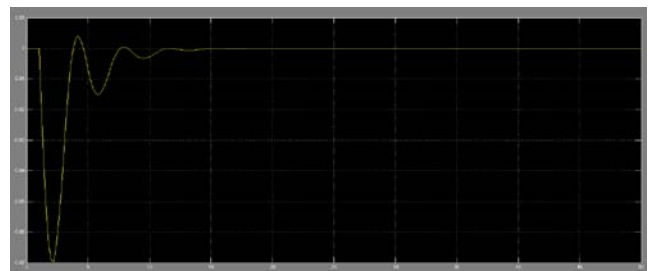
#### 6. Simulation Results

The models of single area and two area system are simulated in SIMULINK.

##### 6.1 Single Area system with PI controller



**Figure 5:** Single area system with PI Controller



**Figure 6:** Simulation result for Single area system with PI controller

## 6.2 Two Area System with PI Controller

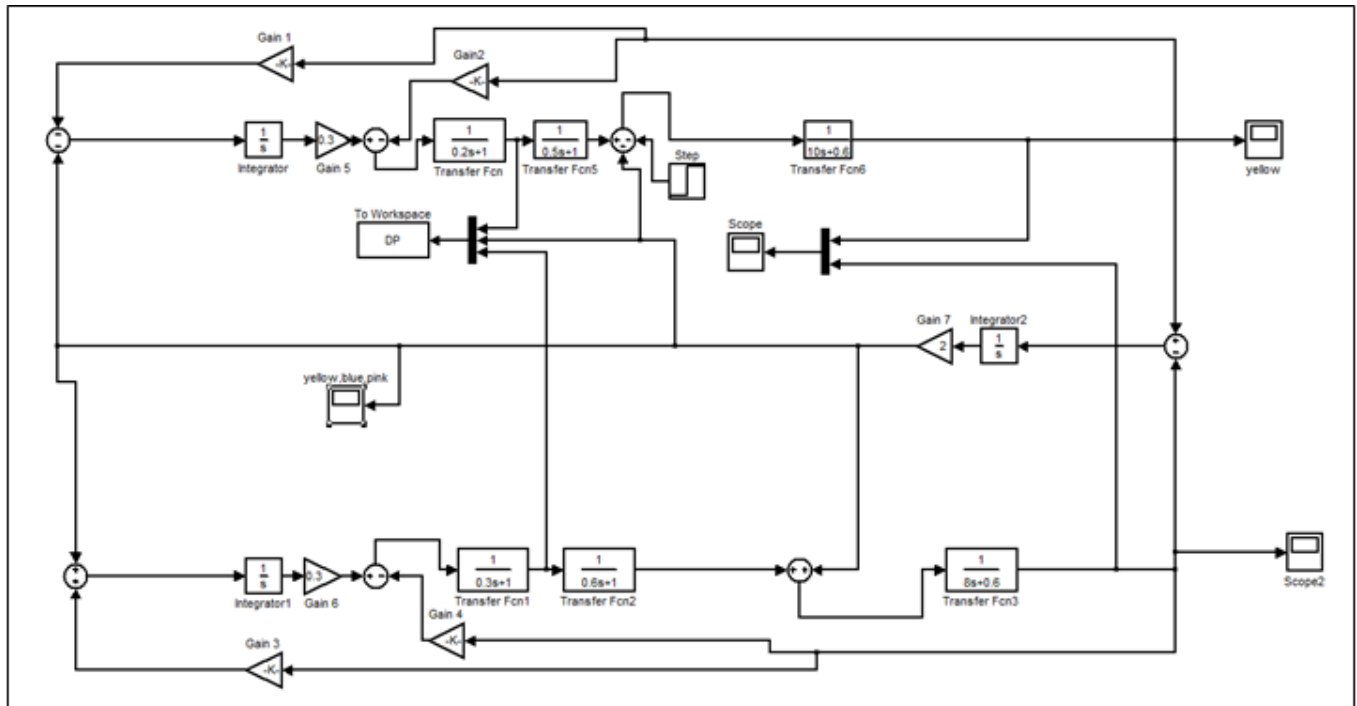


Figure 7: Two area system with PI Controller

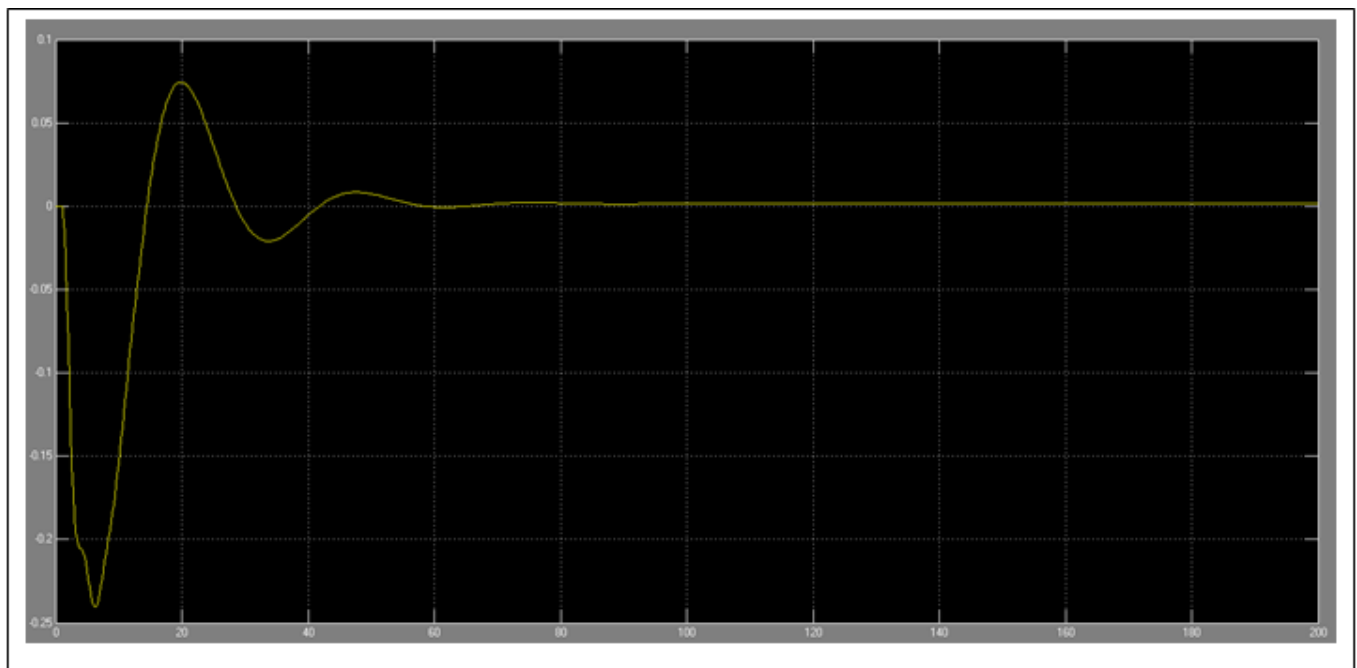


Figure 8: Simulation result for Two area system with PI controller

## 7. Conclusion

A Simulation study of single area and two area system with automatic generation and control is carried out with models developed in SIMULINK and results are shown in this paper. The advantage of interconnection can be understood by comparing the results of single and two area systems. It can be seen that the oscillations due to change in the load in any area is damped down quickly because of tie line power flow. It can also be observed that the dynamic response is mainly governed by the secondary loop and hence its design criteria are extremely vital for efficient implementation.

Also, the dynamic performance of conventional PI controller is compared in single area and two area systems.

## Appendix

Data for interconnected systems are:

$$\begin{aligned} K_{p1} &= 1 \quad K_{p2} = 1 \\ R_1 &= 20.6 \quad R_2 = 16.9 \\ B_1 &= 0.05 \quad B_2 = 0.0625 \\ T_{g1} &= 0.2 \quad T_{g2} = 0.3 \\ T_{t1} &= 0.5 \quad T_{t2} = 0.6 \end{aligned}$$

$$T_{p1}=10 \quad T_{p2}=8$$

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