Department of Electrical Engineering

Subject: Power System Operational and Control (NEE-031) Odd Sem: 2018-19

Innovation in Teaching: Lecture by Demonstration Using Software

1. *Simulation Lecture 1*

Content

a. Visualization of frequency error for step load changes in single area using simulations in MATLAB.

b. Use of PI control in restoring frequency, $\Delta f=0$

c. Also demonstrate that a simple proportional controller cannot reduce Δf to zero.

a. Visualization of frequency error for step load changes in single area

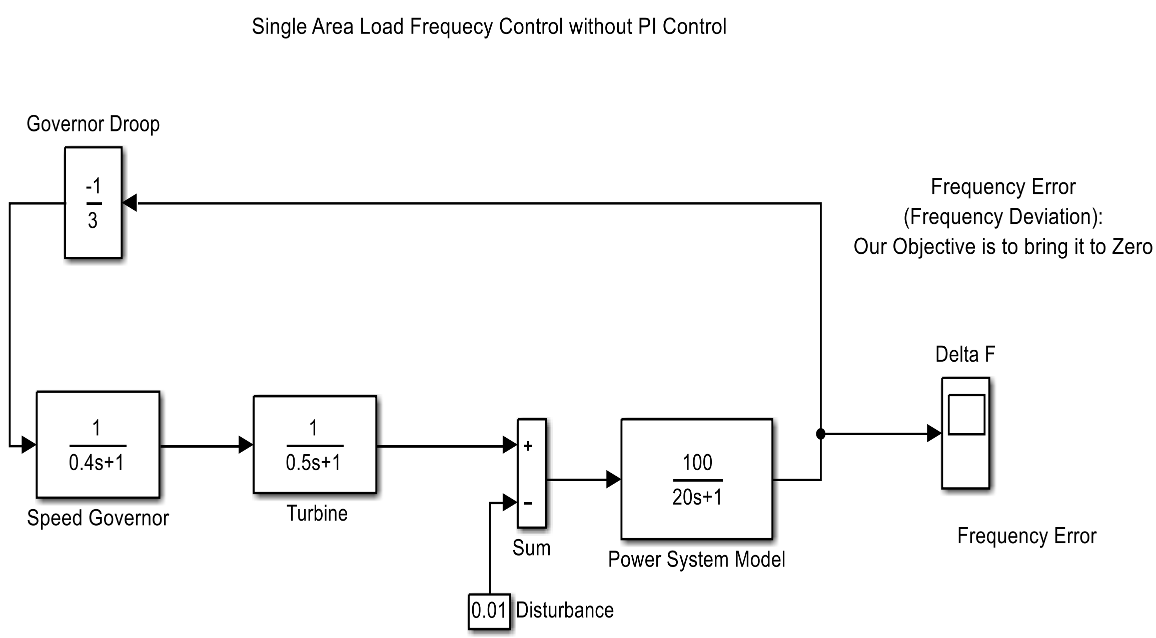

Figure 1: MATLAB Model for Single Area Load Frequency control

System Parameters:

Speed Governor Time Constant Tsg= 0.4s

Turbine Time Constant Tt= 0.5s

Power System Time Constant Tps= 20s

Assuming Ksg×Kt≈ 1

Power System Gain = 100

Speed Regulation R = 3

Load Perturbation ΔP_D= 1% (Step Change)

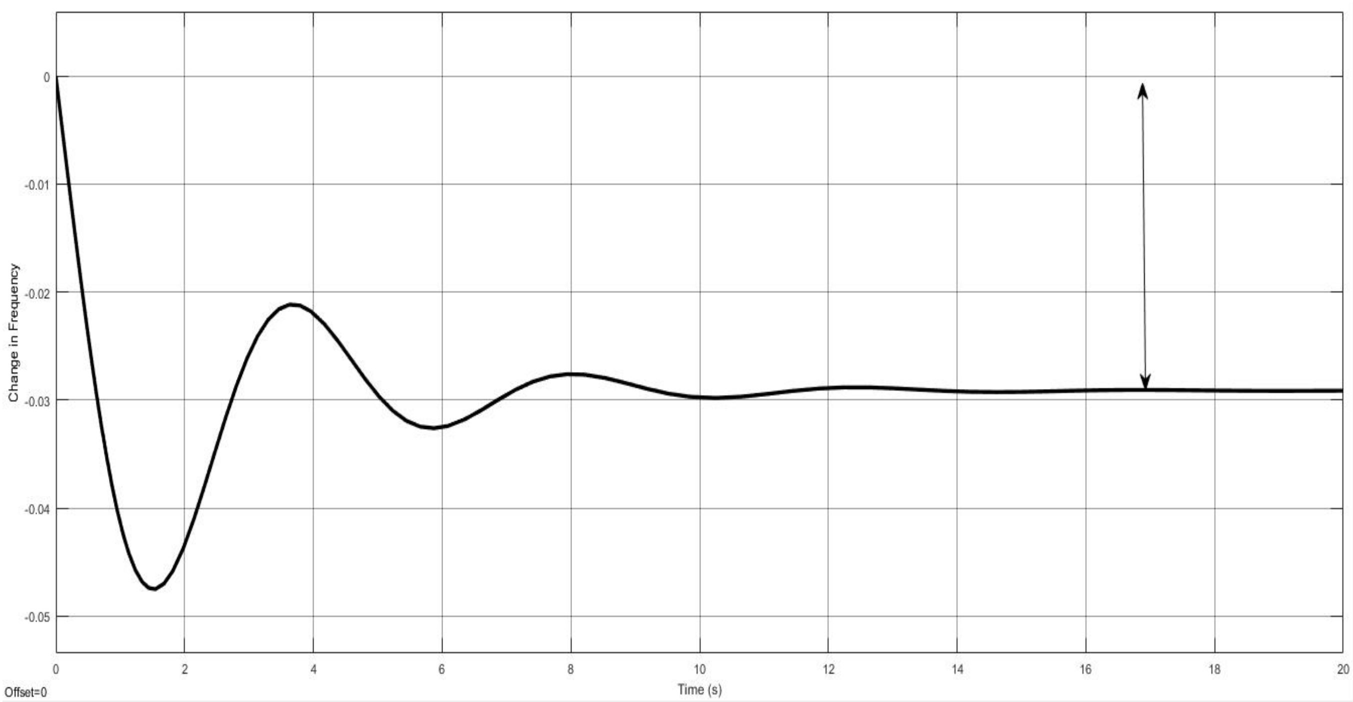

Figure 2: Response showing change in frequency as a result of a step change in load demand

Here, it is observed that for a 1% deviation in load demand a steady state change in frequency is observed to be 2.9 Hz. **[Same as that obtained from theoretical calculations]**

b. Use of PI control in restoring frequency, Δf=0

The frequency norms are very stringent in power system, hence, such a deviation in frequency is intolerable and needs to be restored to the scheduled value. This could be achieved through the use of a PI controller. Using an **integral controller with Ki = 0.09 and a proportional gain Kp = 1** with the above system, we have the MATLAB model as in Figure 3.

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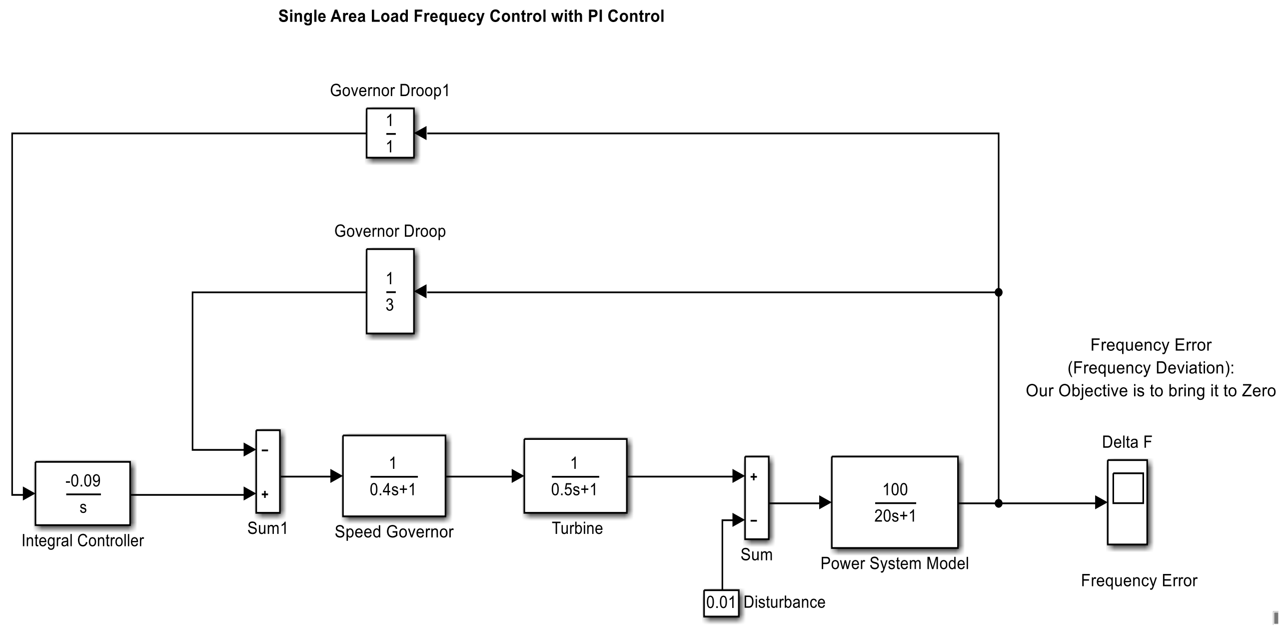

Figure 3: MATLAB Model for Single Area Load Frequency control with PI Controller

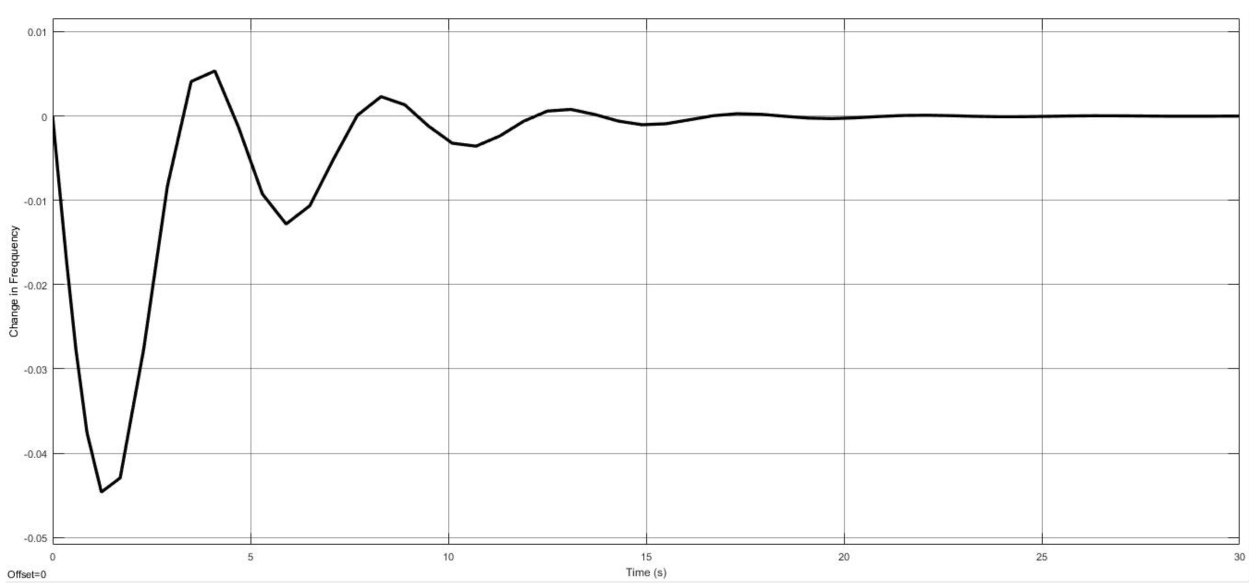

Figure 4: Response showing change in frequency reduced to zero with the use of PI Controller

It can be observed that the use of P+I controller is able to remove errors in frequency introduced by load disturbances. **This correlates with the theoretical derivation showing Δf=0 when PI control is adopted.**

c. Simulation showing a simple proportional controller cannot reduce Δf to zero

Here it is demonstrated that the frequency error cannot be restored with a proportional controller only.

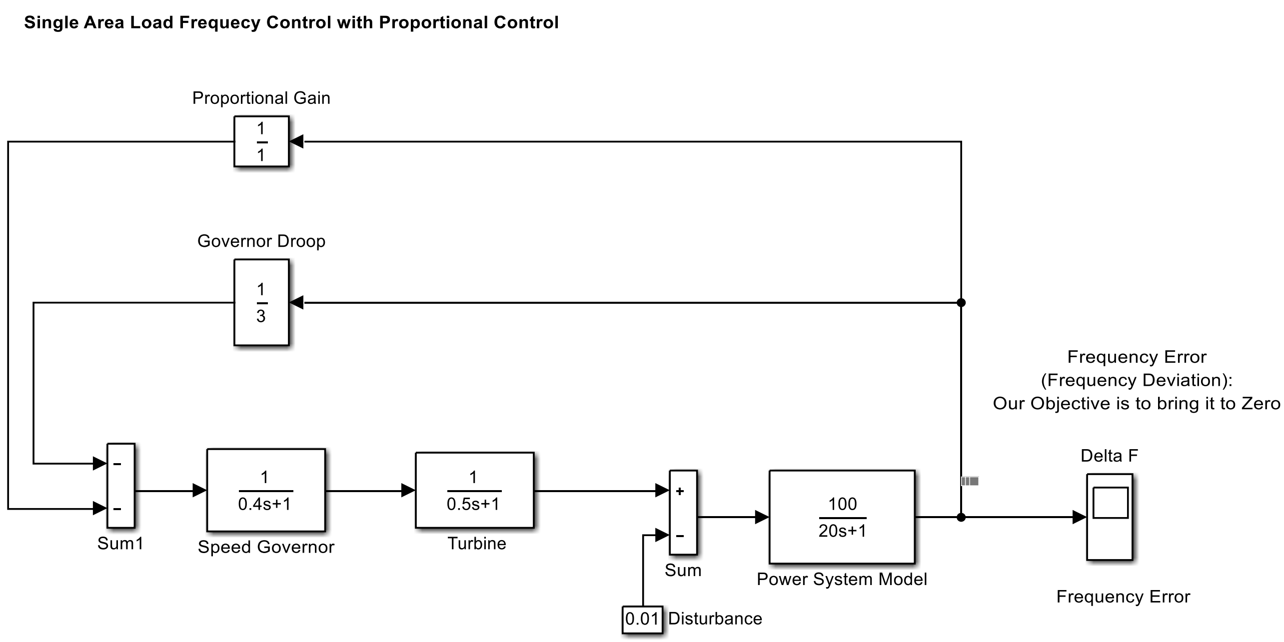

Figure 5: MATLAB Model for Single Area Load Frequency control with Proportional Controller only

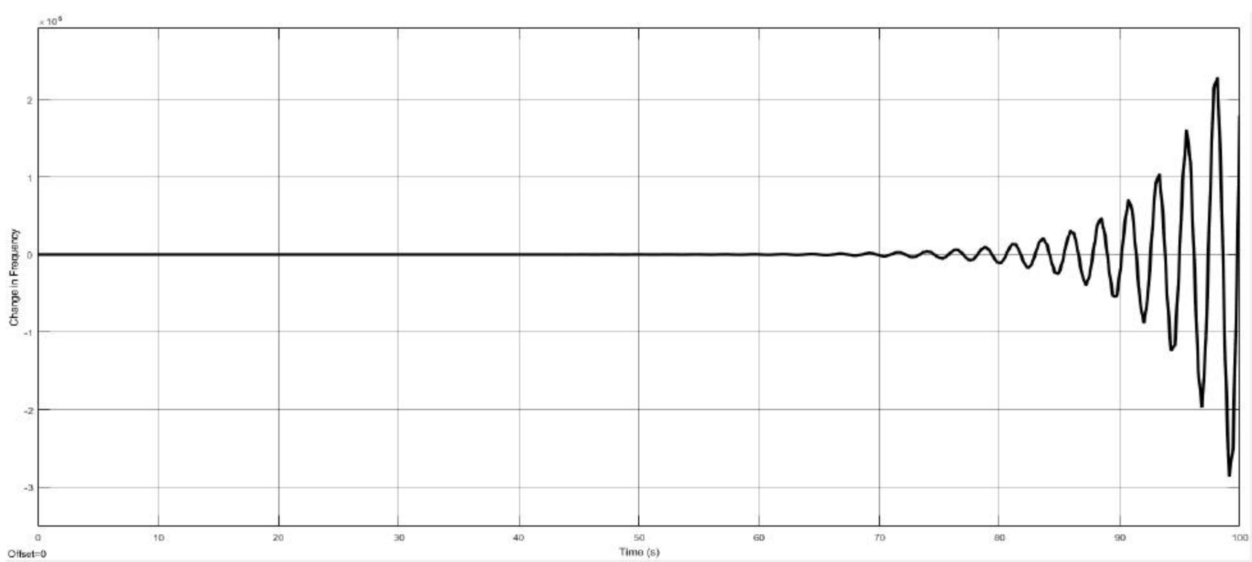

Figure 6: Response showing change in frequency does not reduce to zero with the use of P Controller

2. *Simulation Lecture 2*

Content

Visualization of frequency changes and tie-line power variation for step load changes in two area load frequency control using simulations in MATLAB.

Objective of the demonstration lecture: This lecture through demonstration using MATLAB software aims to give students insight into the dynamics of the two interconnected area load frequency control mechanism subjected to load perturbations.

The approach adopted here involves, first, solving analytically a two area LFC problem using fundamental relations derived in theoretical lectures and secondly, simulating the same system using MATLAB and correlating the simulated outcome with the theoretically determined steady state condition. Such an approach will serve a **two-fold outcome**:

1. Students will learn to apply theoretical equations derived in the classroom to solve realistic LFC problem.
2. They will be able to correlate their answers with the dynamic responses observed through MATLAB simulations. This will validate their answers and lead to better understanding of the phenomena.

Problem Statement

A two area system connected by a tie line has the following parameters, on a base of 1000 MVA.

Area	1	2
Speed Regulation	R_1=0.05	R_2=0.0625
Frequency Sensitive Load Coefficient	D_1=0.6	D_2=0.9
Inertia Constant	H_1=5.5	H_2=5
Governor Time Constant	T_{G1}= 0.25 s	T_{G2}= 0.3 s
Turbine Time Constant	T_{TR1}= 0.5 s	T_{TR2}= 0.5 s

The units are operating at nominal frequency of 50 Hz, when there is a sudden increase in load of area 1 by 150 MW. The synchronizing power coefficient T = 2pu. Obtain the time domain response of $\Delta\omega_1$, $\Delta\omega_2$, ΔP_{m1}, ΔP_{m2} and ΔP_{12}. Repeat for a step change of 150 MW in area 2. If the value of R1 is reduced to 0.01 what is the effect?

Solution:

Theoretical Calculation

Calculating the steady state values. Taking an increase in load in Area-1 by150 MW i.e. 0.15pu

$$\Delta\omega = \frac{-\Delta P_{L1}}{\beta_1+\beta_2} = \frac{-0.15}{\left(\frac{1}{0.05}+0.6\right)+\left(\frac{1}{0.0625}+0.9\right)} = -0.004\, p.u.$$

$$\Delta P_{12} = \frac{-\Delta P_{L1}\beta_2}{\beta_1+\beta_2} = \frac{-0.15\times 16.9}{20.6+16.9} = -0.0676\, pu$$

$$\Delta P_{m1} = \frac{-\Delta\omega}{R_1} = -\frac{-0.004}{0.05} = 0.08\, pu$$

$$\Delta P_{m2} = \frac{-\Delta\omega}{R_2} = -\frac{-0.004}{0.0625} = 0.064\, pu$$

When Load Change of 0.15 pu occurs in Area-2. $\Delta\omega$, ΔP_{m1} and ΔP_{m2} does not change. However, ΔP_{12} will change to:

$$\Delta P_{12} = \frac{-\Delta P_{L2}\beta_1}{\beta_1+\beta_2} = \frac{0.15\times 20.6}{20.6+16.9} = 0.0824\, pu$$

MATLAB Simulation of the given system

Figure 7 below gives the Simulink Model of 2-Area interconnected system. The reference power ($\Delta Pc(s)$) is taken as zero as they are not changed. Parameters of all component are as per the defined problem.

The frequency error of the system for a 0.15pu load disturbance in Area 1 is shown in Fig. 8. It can be observed that the frequency deviation of both areas settle at -0.004 in the steady state. This corroborates the findings of theoretical calculations.

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Fig. 9 gives the change in power levels of the two areas and the tie-line power deviation. The steady state values as obtained from the figure are ΔP_{m1} =0.08 and ΔP_{m2} = 0.064 and ΔP_{12} =0.0676. This is consistent with the findings of the manual calculations.

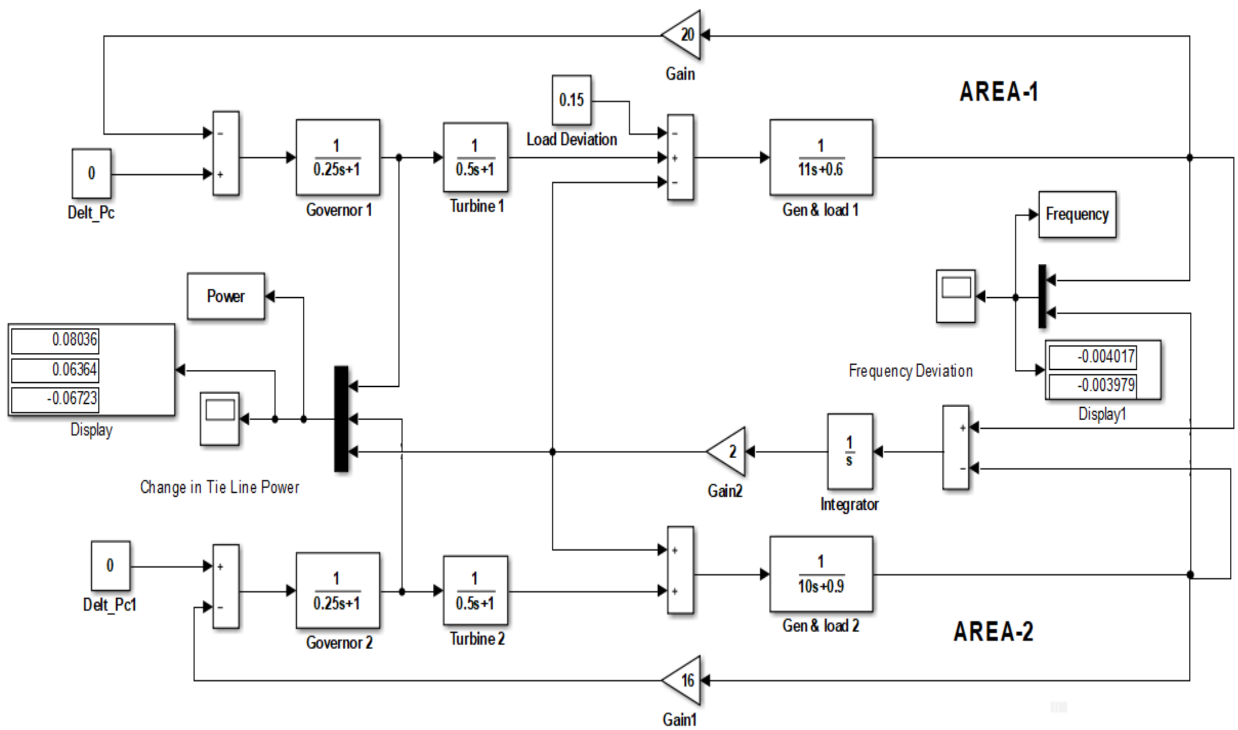

Figure 7: Simulink Model of Two area Sytem

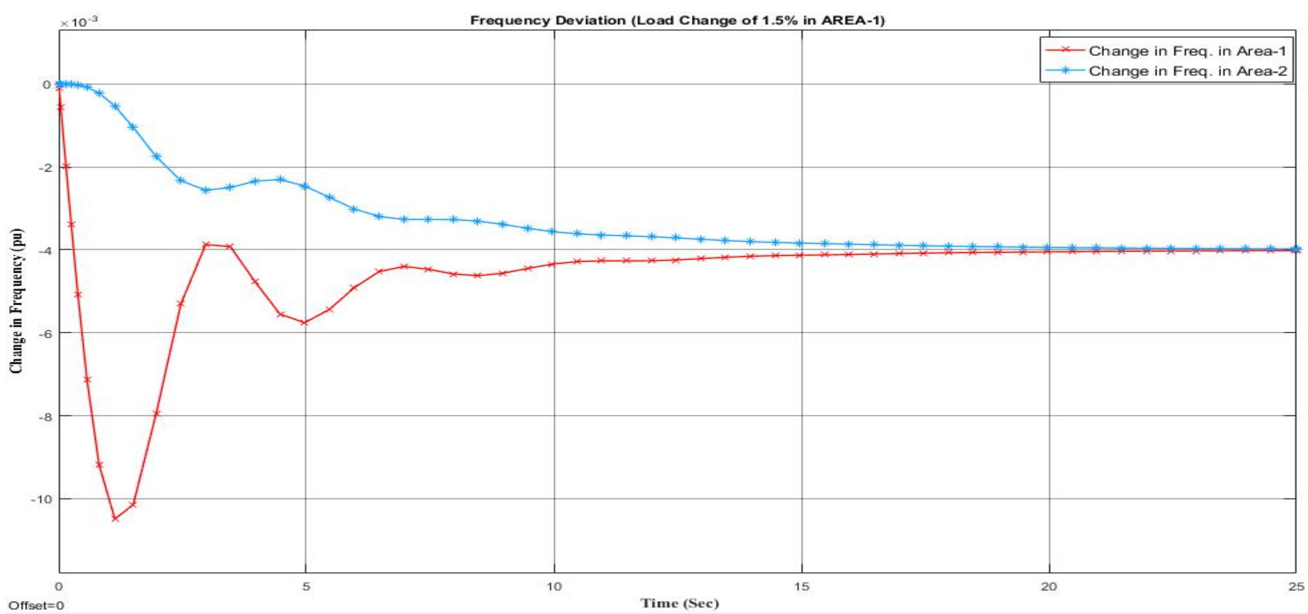

Figure 8: Frequency Deviation for a load perturbation of 0.15pu in Area-1

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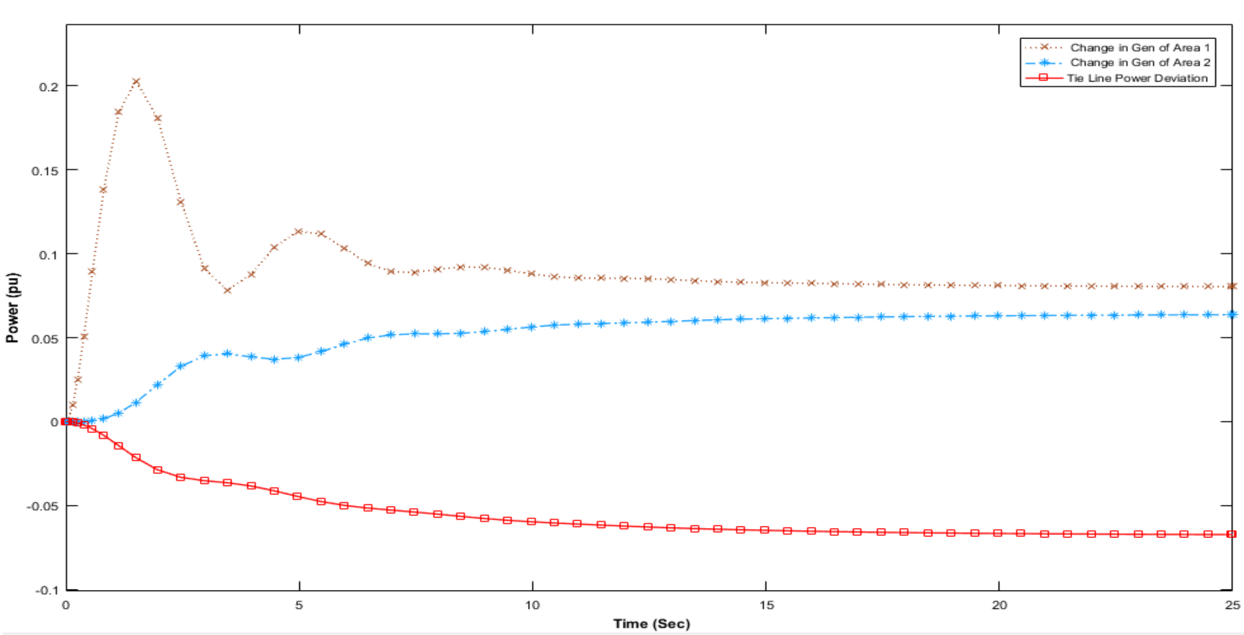

Figure 9: Tie Line Power Deviation for a load perturbation of 0.15pu in Area-1

Conclusion:

1. It is clearly evident that primary control feature is unable to restore frequency to normalcy following a load disturbance i.e. Δf is not equal to zero.
2. Similarly, the deviation in Tie-line power from the scheduled value is finite i.e. ΔP_{12} is not equal to zero.
3. The system requires about 15s to reach steady state values.
4. Power system has very stringent frequency requirements and bilateral agreements on power exchange is strictly regulated. These requirements necessitates the fast reduction in their deviation to zero.
5. In order to maintain scheduled power exchange and system frequency, secondary control feature is mandated.

Test your understanding!

1. Obtain the frequency and Tie-line power variations for a similar load disturbance in Area-2.
2. Design a supplementary control mechanism to reduce frequency and Tie-line deviation to zero.