Chapter 6

Simulation Results and Analysis - Three Area System

6.1 Introduction

This chapter presents results of various cases of three area interconnected power system. Three area interconnection has more complications as compared to two area interconnected power system. Fuzzy logic based integral control strategy is implemented in this study of three area ring type connected power system.

The data used for the study are from IEEE standard data, given in appendix B. Results are arranged in the following sequence.

- Three area with non-reheat turbines and disturbance in area 1.
- Three area with non-reheat turbines and disturbance in area 1 and area 2.
- Three area with non-reheat turbines and disturbance in area 1, area 2 and area 3.
- Three area with non-reheat turbines but with different parameters and disturbance in area 1
- Three area with reheat turbines and GRC and disturbance are as follows:
    - Disturbance in area 1.
    - Disturbance in area 2.
    - Disturbance in area 1 and area 2.
    - Disturbance in area 1 and area 3.
- Three area with two non-reheat and one hydro turbine.
- Three area with one reheat, one non-reheat and one hydro.

All above mentioned models with different combinations are given in chapter 3.

6.2 Three Area System with Non-Reheat Turbines

This case of three area system, where all thermal turbines are non-reheat type, is controlled by fuzzy logic based integral controller. The dynamic responses are noted for step disturbance of 1%. Figure 6.1 shows system response when only area 1 is subjected to sudden disturbance and in this case peakovershoot for area 1 is –0.0194 Hz while the settling time is 6.54 seconds for area 1. Figures show variations in change in frequency of all three area and change in tie-line power between area 1 and area 2.

Figures 6.2 and 6.3 are showing responses when two areas and all three areas are experiencing sudden disturbance respectively. It has been observed that peakovershoot along with settling time remain within limits. Tie line deviation, in case of disturbance in all three areas, remains stable initially and gets oscillatory in between and latter gets settled again because of cumulative effect of all disturbances in all the areas but robustness of controller does not let system unstable. On the other hand overall system response in third case is less oscillatory as compared to other two. The amount of disturbance is kept same in all the three cases i.e. 1 % and results are shown in table 6.1.

Table 6.1: Deviations with proposed controller in three area system

Different Cases	Settling time for 5 % tolerance band (s)	Peakovershoot (Hz)
Disturbance in area 1	6.5421	-0.0194
Disturbance in area 1 & 2	6.5703	-0.0234
Disturbance in area 1, 2 & 3	8.6514	-0.0297

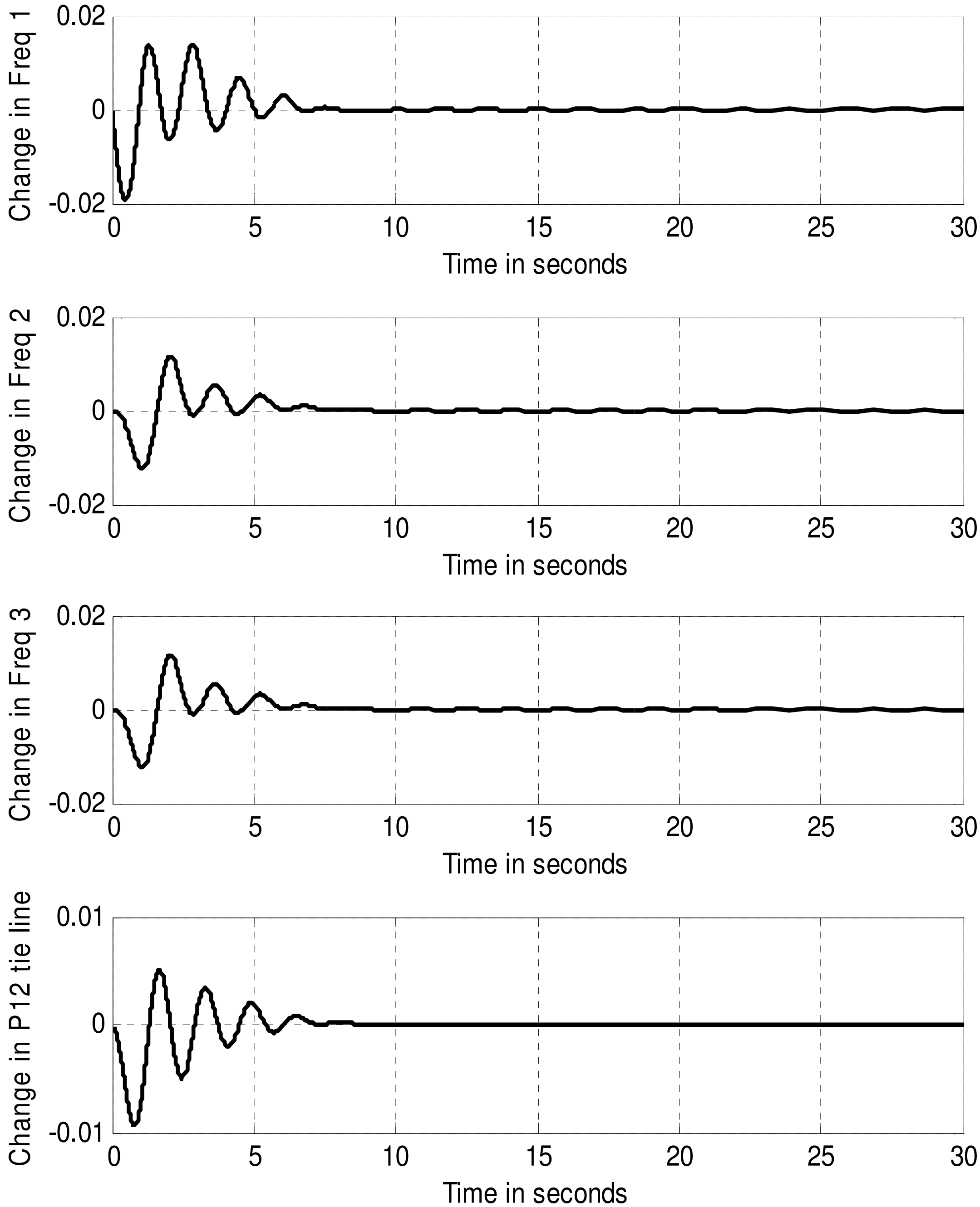

Figure 6.1: System responses for step disturbance in load of 1 % in area 1

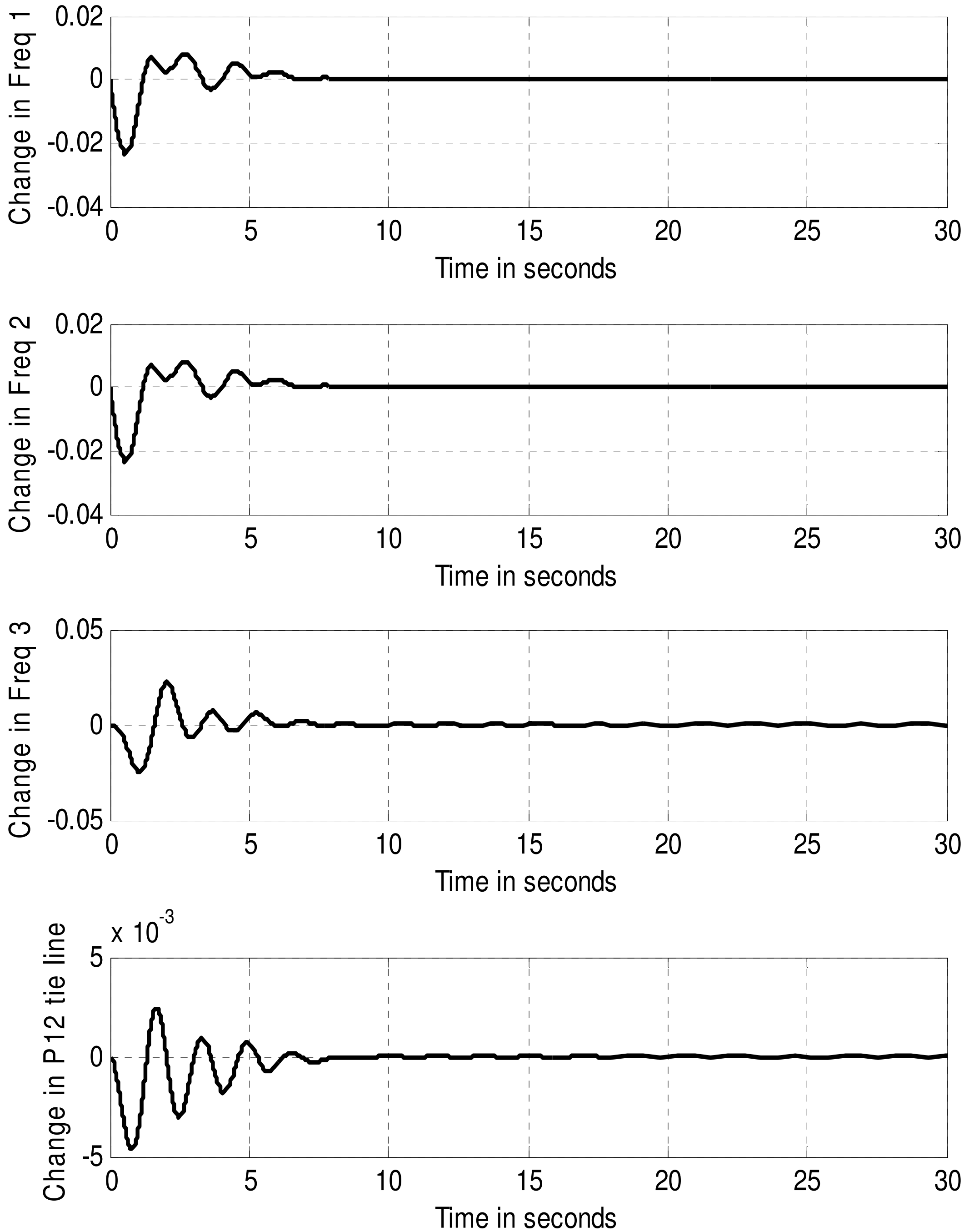

Figure 6.2: System responses for step disturbance of 1 % in load in each area 1 and area 2

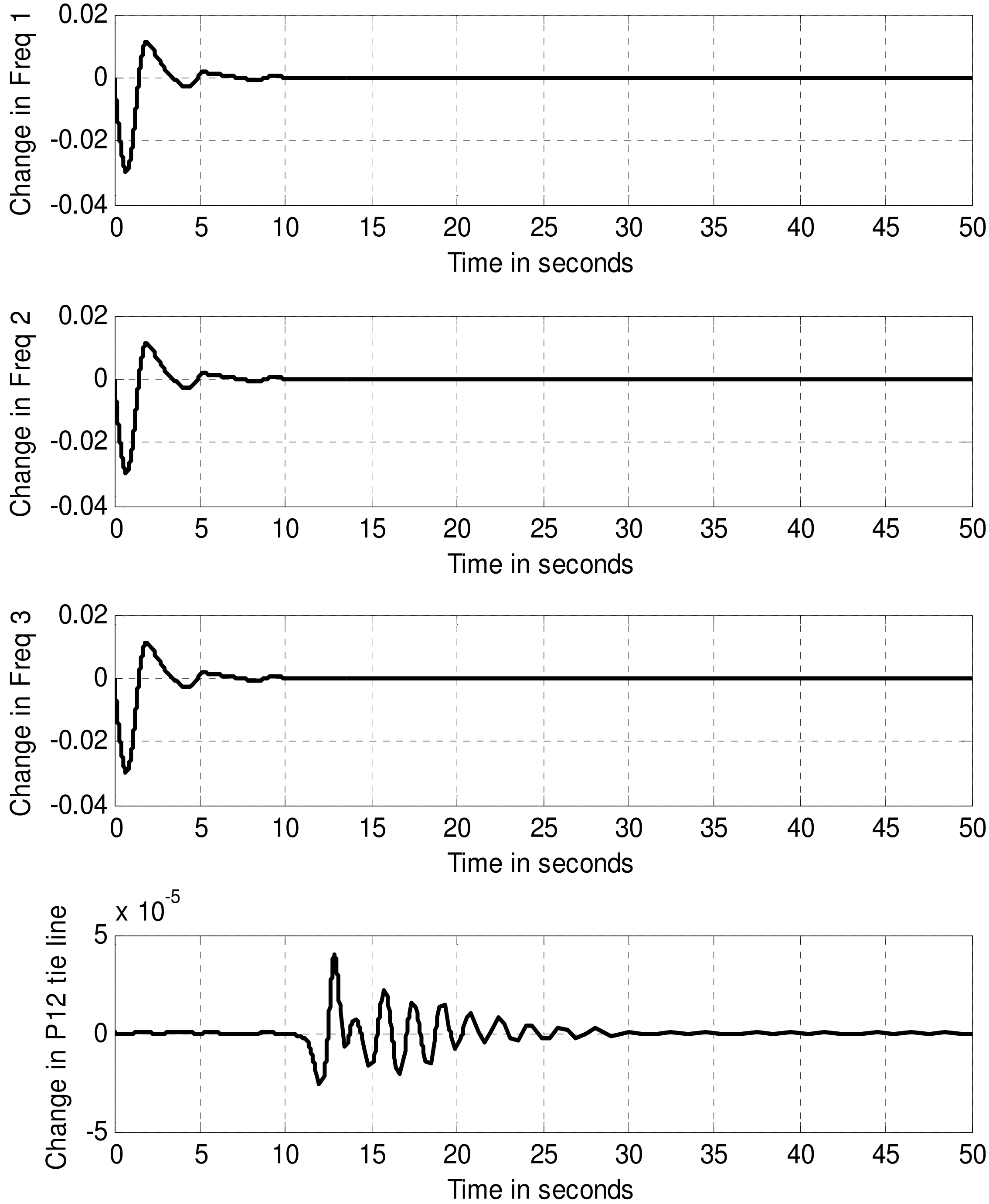

Figure 6.3: System responses for step disturbance of 1 % in each area 1, area 2 and area 3

6.3 Three Area System with Non-Reheat Turbines but with Different Parameters and Disturbance in Area 1

This analysis of three area system with different parameters is carried out to compare the proposed method with results of [94]. The parameters taken are: Power system time constant t_p= 11, tie-line constant t_{12}= 0.14, and frequency bias coefficient b = 0.12. Figure 6.4 is showing the system response and it is observed that settling time is better i.e. 8.23 seconds as compared to 9 seconds.

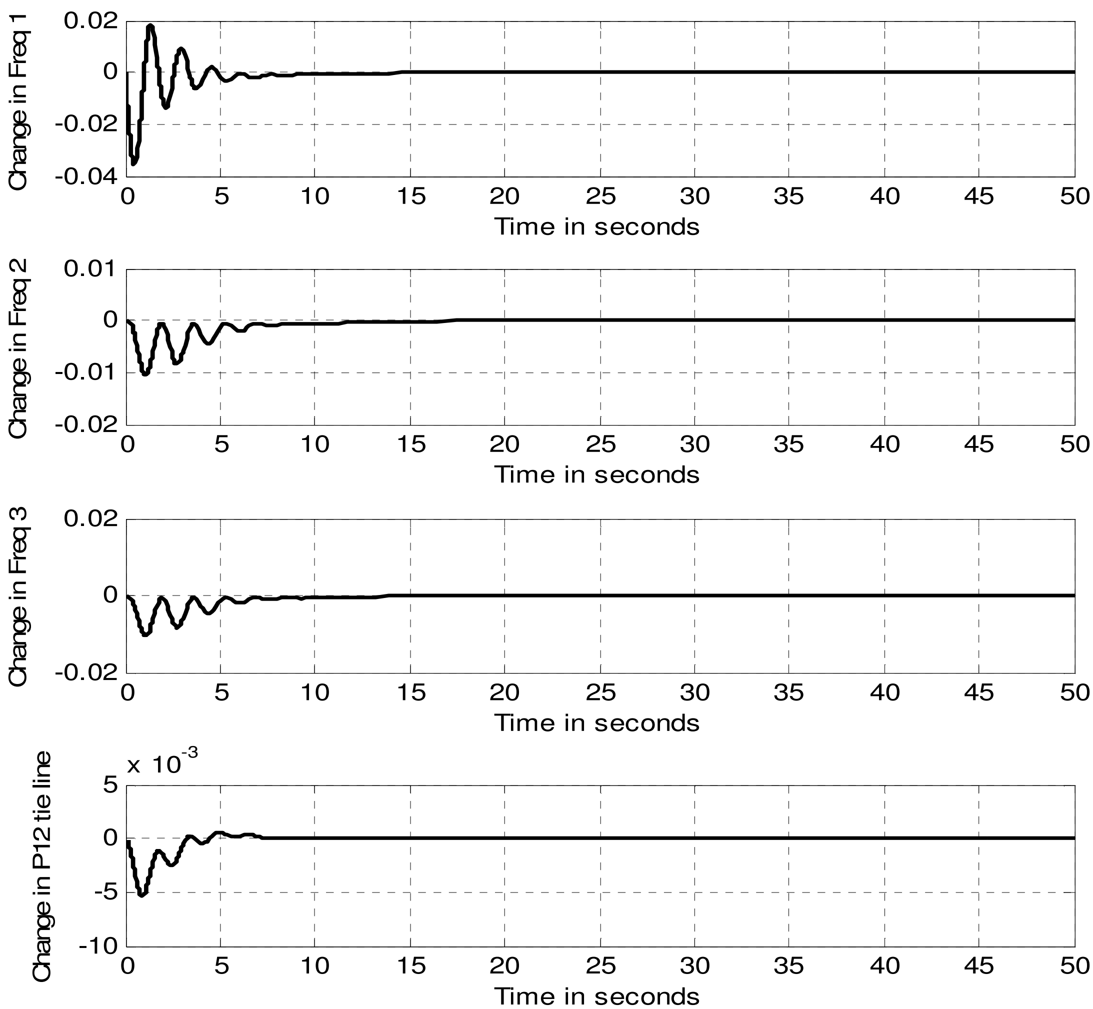

Figure 6.4: Three area system responses for 1 % disturbance.

6.4 Three Area with Reheat Turbines and GRC

A case with reheat turbine as well as generation rate constraints is studied and simulated with proposed control strategy and results are compared with [112]. The parameters taken are same as in this paper and various cases analyzed on the basis of load change in different areas. Figure 6.5 shows the responses when area 1 is subjected to disturbance of -0.01 p.u.

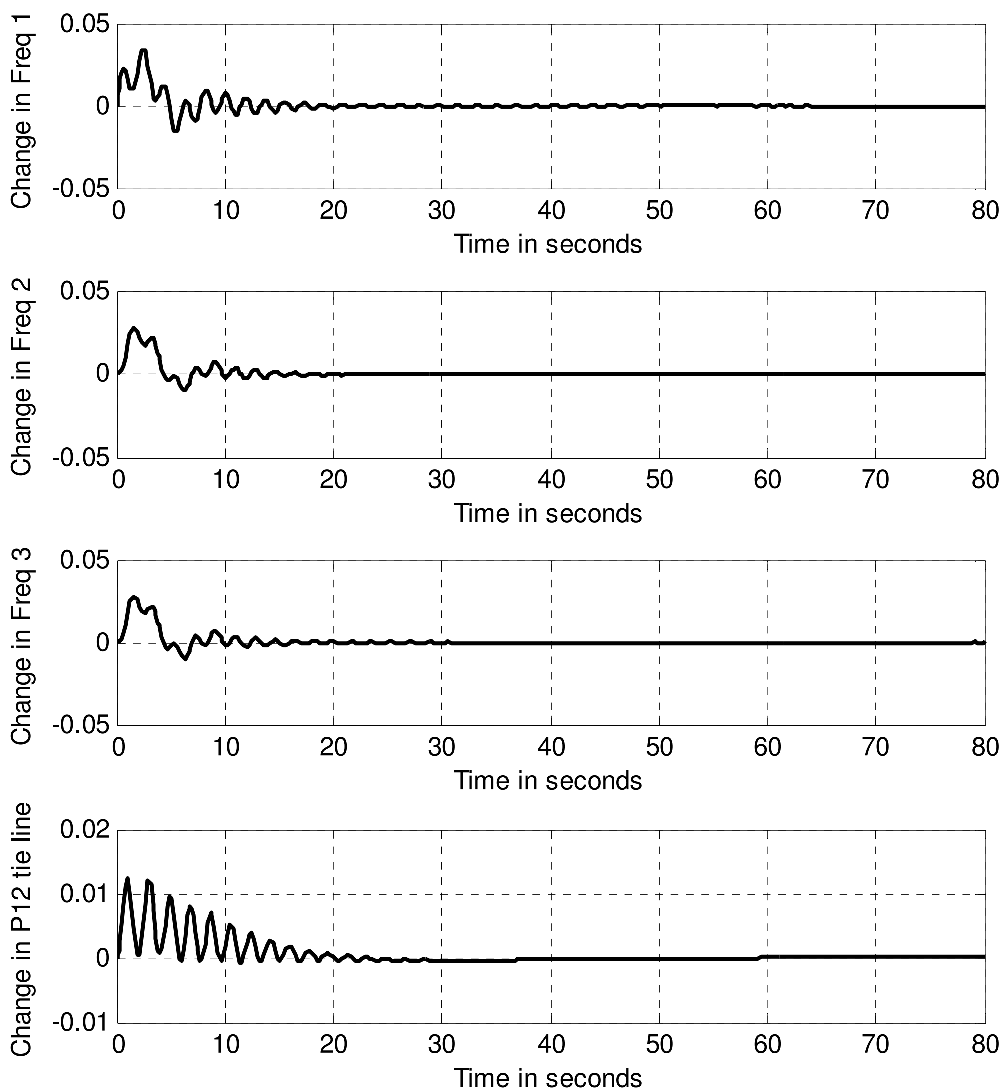

Figure 6.5: Responses of the power system for load changes ΔP_{d1}= -0.01 p.u. MW

In figure 6.6 is presented the responses due to disturbance of 1 % in area 2 only. Variation in frequency of area 2 is more oscillatory than others since disturbance in this area settles fast with the proposed method of control.

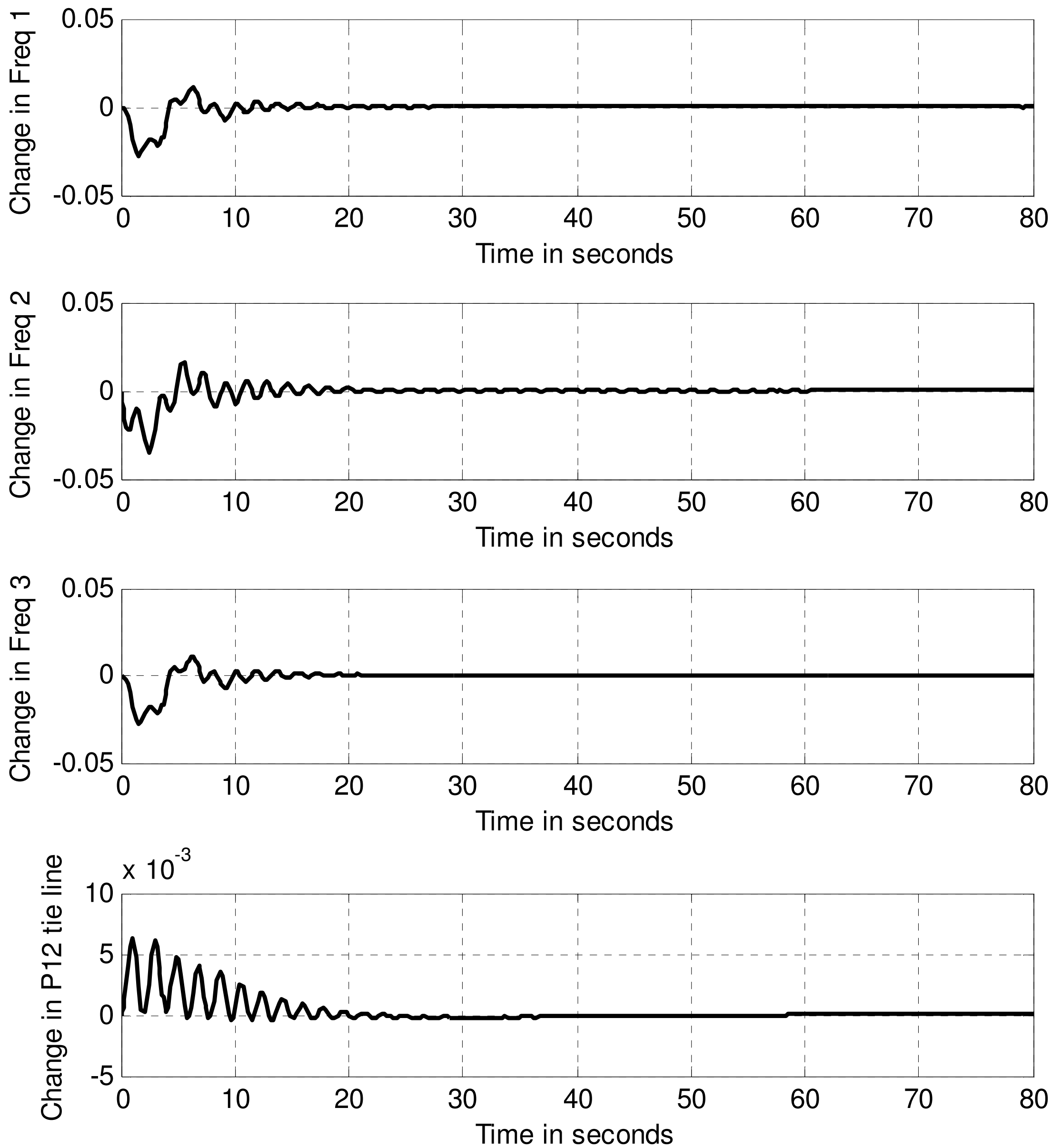

Figure 6.6: Responses of the power system for load changes ΔP_{d2}= 0.01 p.u. MW

Responses of change in mechanical power output from turbine in all the three areas are also noted and shown in figure 6.7. Area 1 and area 3 are finally settling at zero and area 2 is setting at 0.01 p.u. because of disturbance in it.

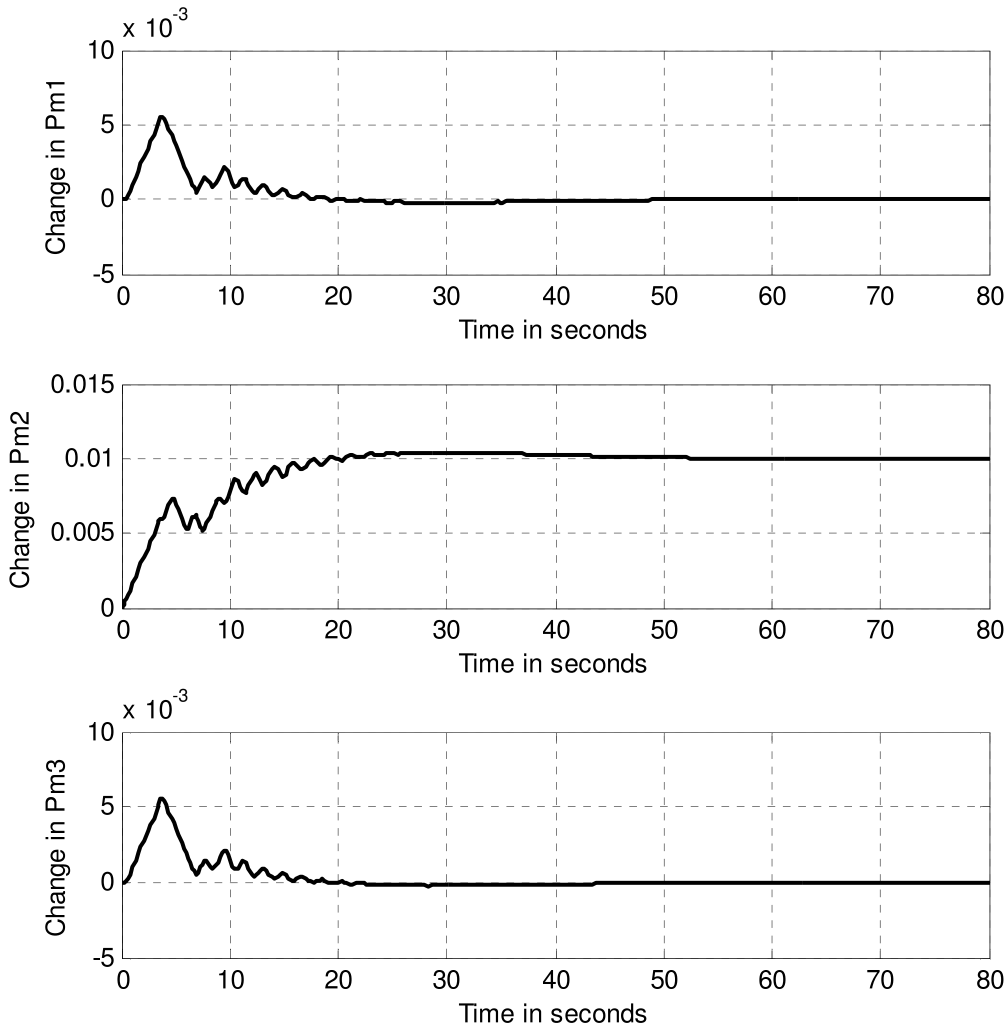

Figure 6.7: Mechanical power output variations in different areas on load change in area 2

In figure 6.8 is presented the responses on disturbances of 0.004 p.u. MW in area 1 and -0.007 p.u. MW in area 2. Variations in frequency and tie-line power along with mechanical power output (figure 6.9) are observed. Results obtained are better when compared to results with PI controller technique given in [112].

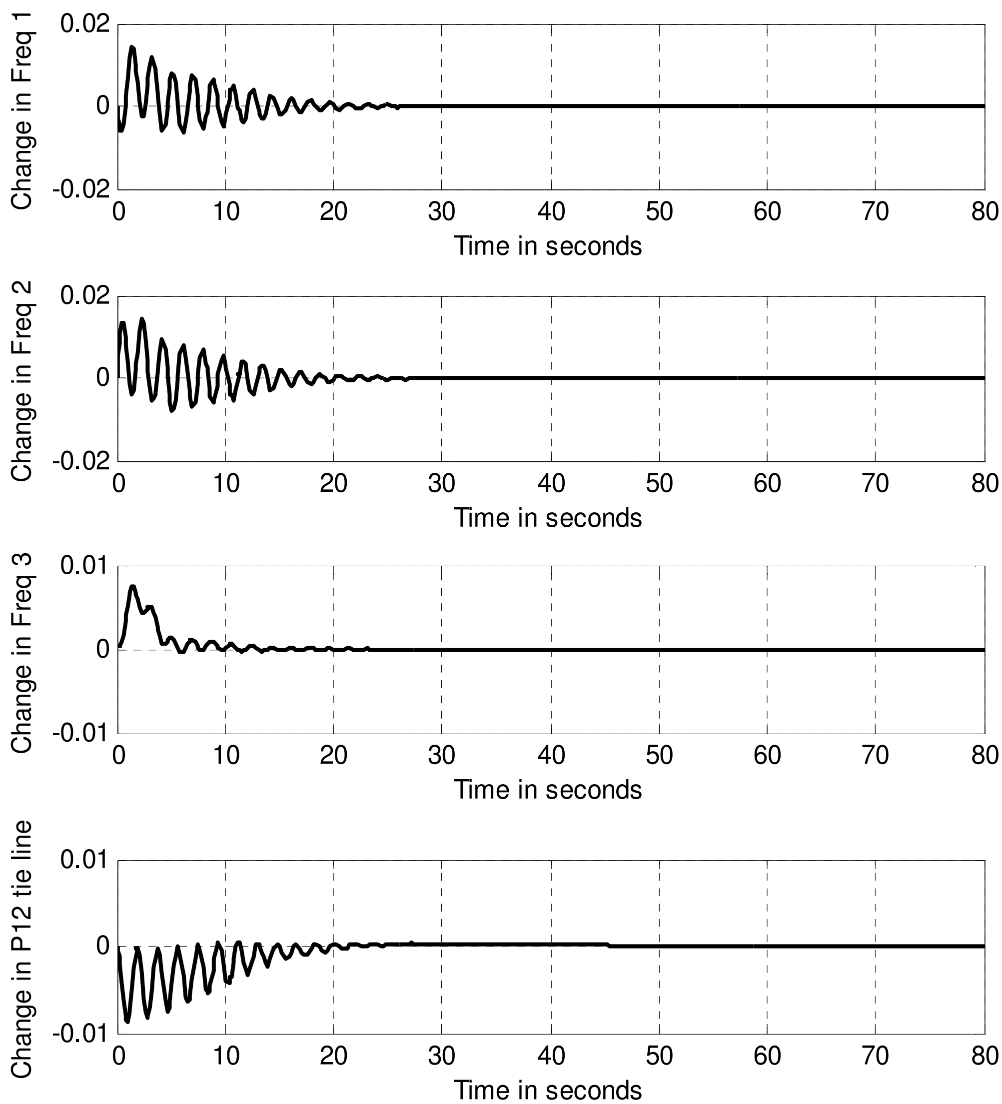

Figure 6.8: Responses of the power system for load changes ΔP_{d1}= 0.004 p.u. MW, ΔP_{d2}= -0.007 p.u. MW

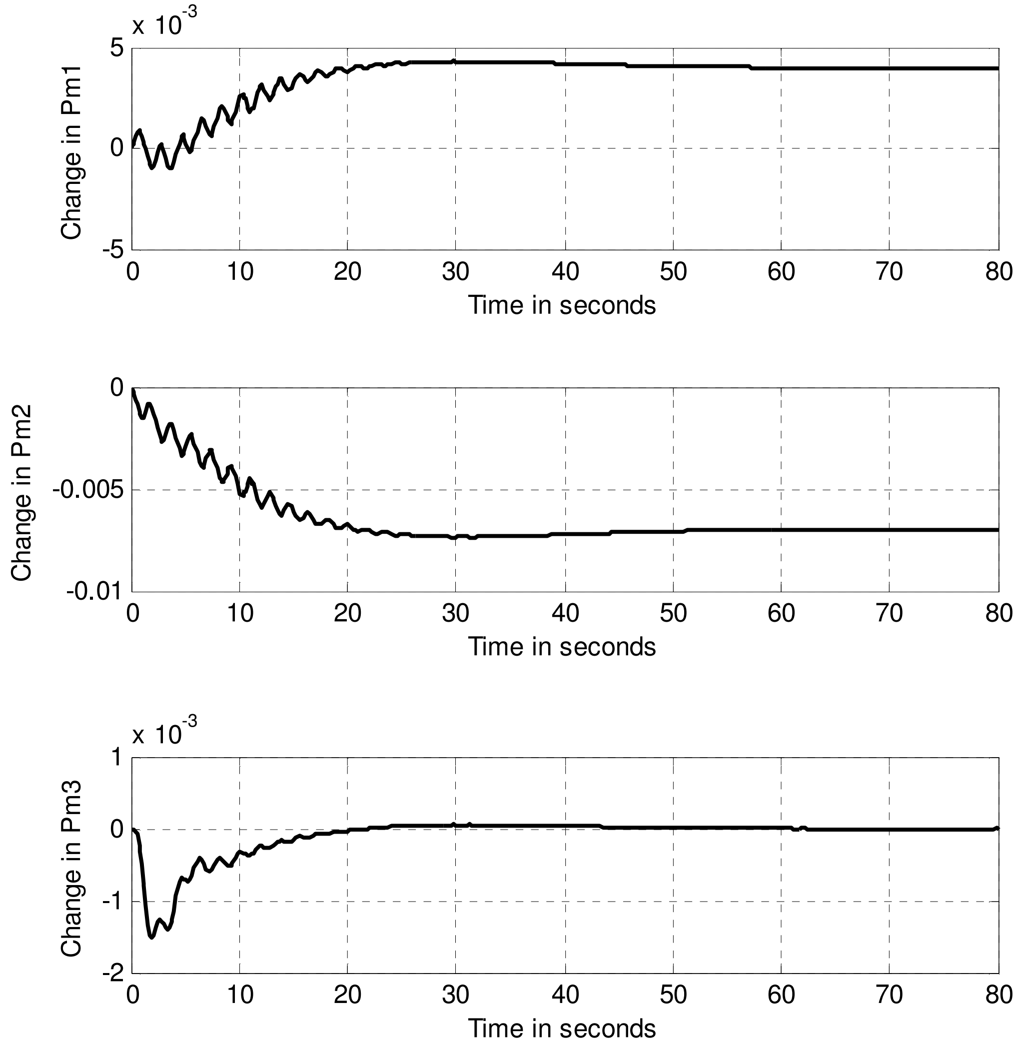

Figure 6.9: Responses of the mechanical power output for load changes ΔP_{d1}= 0.004 p.u. MW, ΔP_{d2}= -0.007 p.u. MW

Similarly, system responses are noted for load changes ΔP_{d1}= -0.008 p.u. MW, ΔP_{d2} = 0.003 p.u. MW as shown in figure 6.10 and 6.11. Results are found better than PI controller results. The amount of disturbances in different areas is taken same as in [112] to compare the results on the same platform.

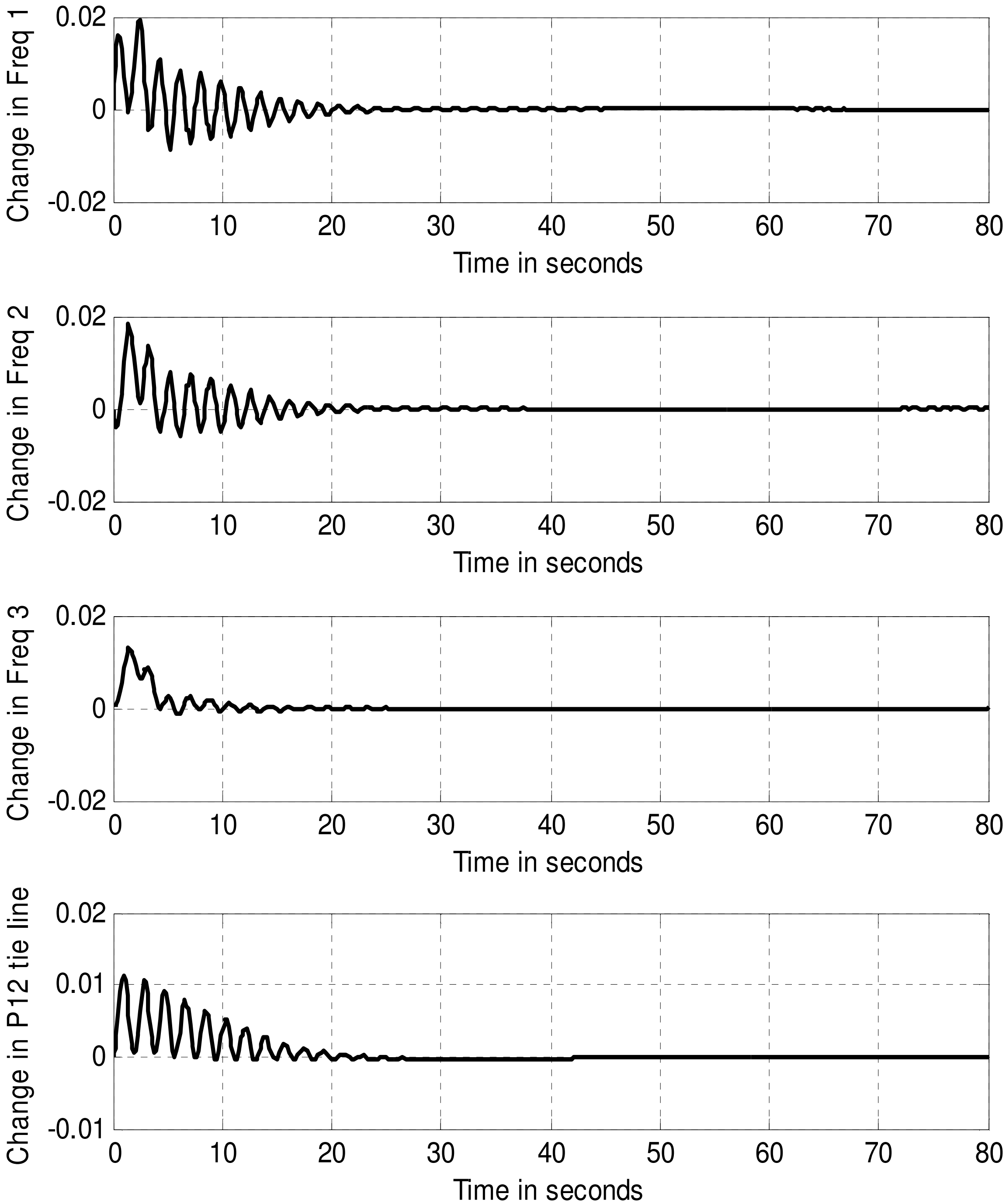

Figure 6.10: Responses of the power system for load changes ΔP_{d1}= -0.008 p.u. MW, ΔP_{d2} = 0.003 p.u. MW

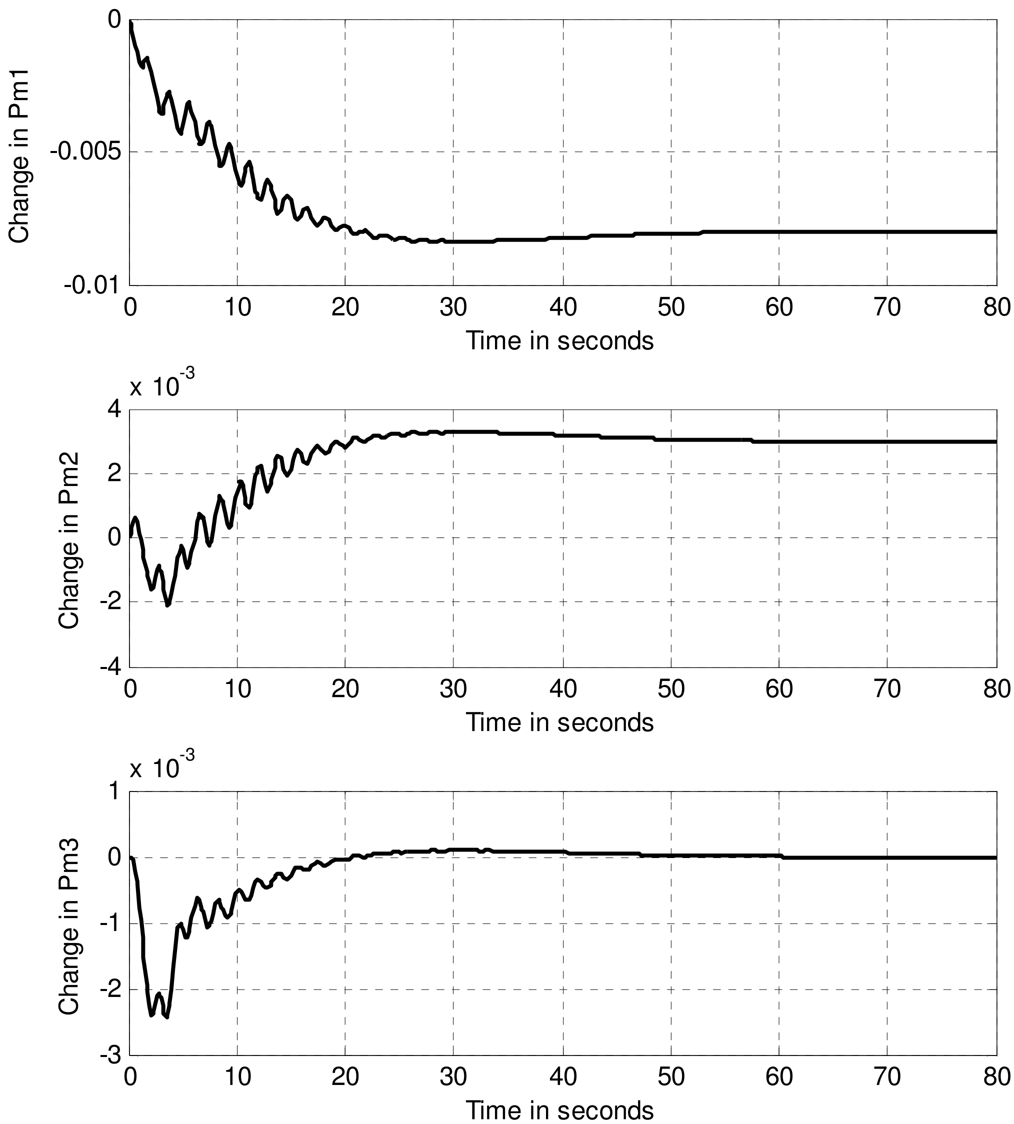

Figure 6.11: Responses of the mechanical power output for load changes ΔP_{d1}= -0.008 p.u. MW, ΔP_{d2} = 0.003 p.u. MW

Responses of the three area interconnected power system by proposed controller with load change in area 1 and area 3 of -0.01 p.u. MW are shown in figure 6.12 and 6.13. The responses are better and having less oscillations as compared to [112].

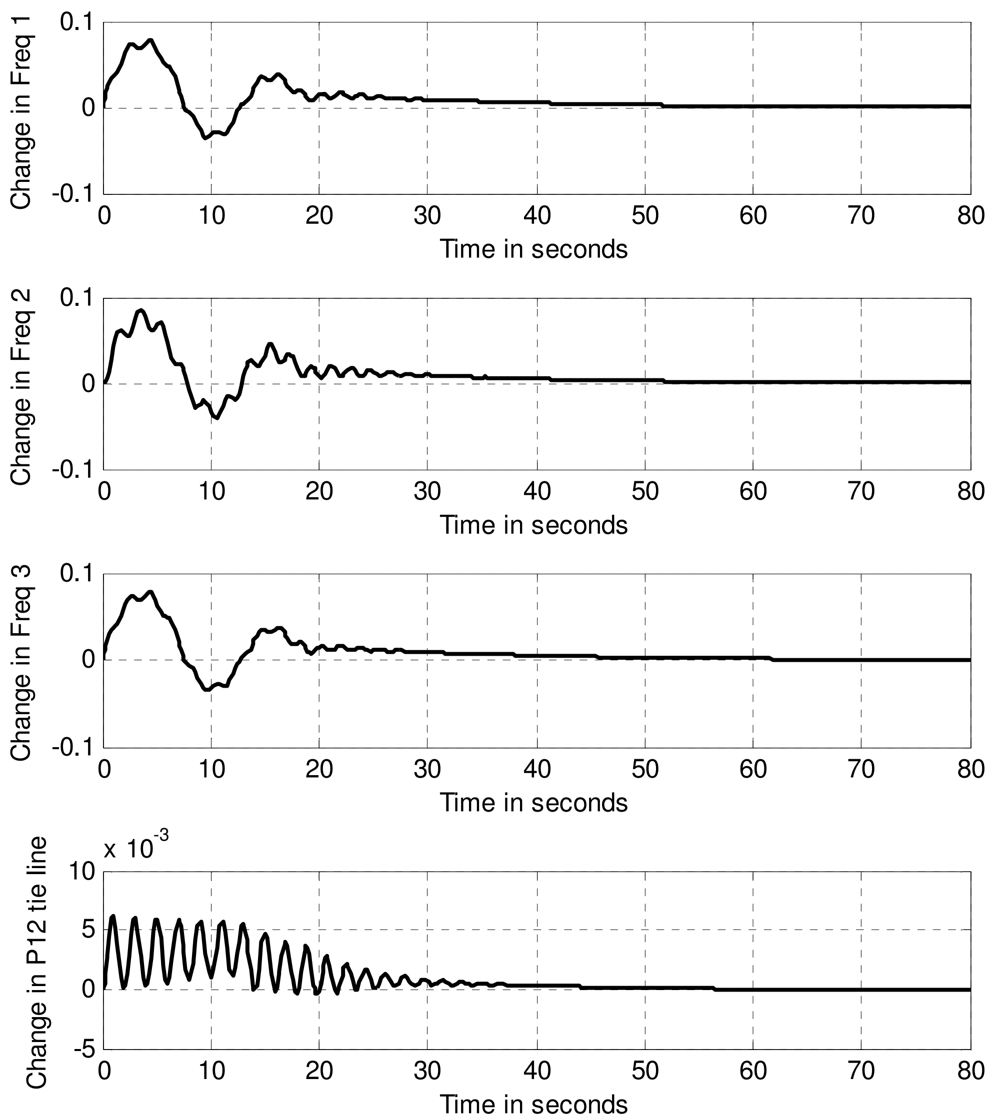

Figure 6.12: Responses for load changes ΔP_{d1}= -0.01 p.u. MW, ΔP_{d3} = -0.01 p.u. MW

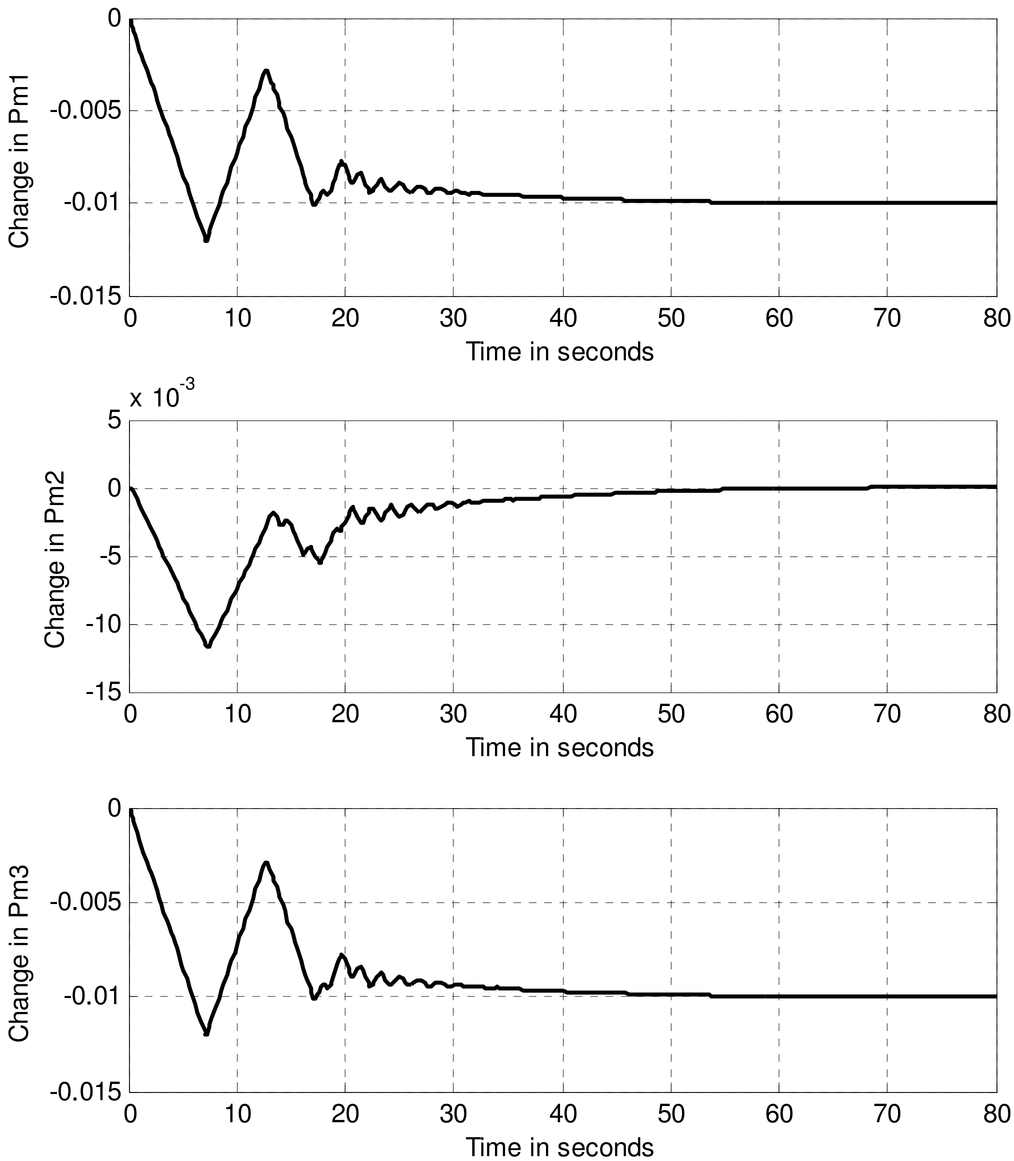

Figure 6.13: Responses of mechanical power output of each area for load changes ΔP_{d1}= -0.01 p.u. MW, ΔP_{d3} = -0.01 p.u. MW

6.5 Three Area with Two Non-Reheat Turbines and One Hydro Turbine

Another analysis is carried out on a different combination where two areas are equipped with non-reheat turbine and one with hydro turbine. The proposed controller is employed to control the frequency and tie-line power deviations. Results obtained are found satisfactory in terms of dynamic response. Variations in figure 6.14 show less oscillations and fast settlement to steady state value.

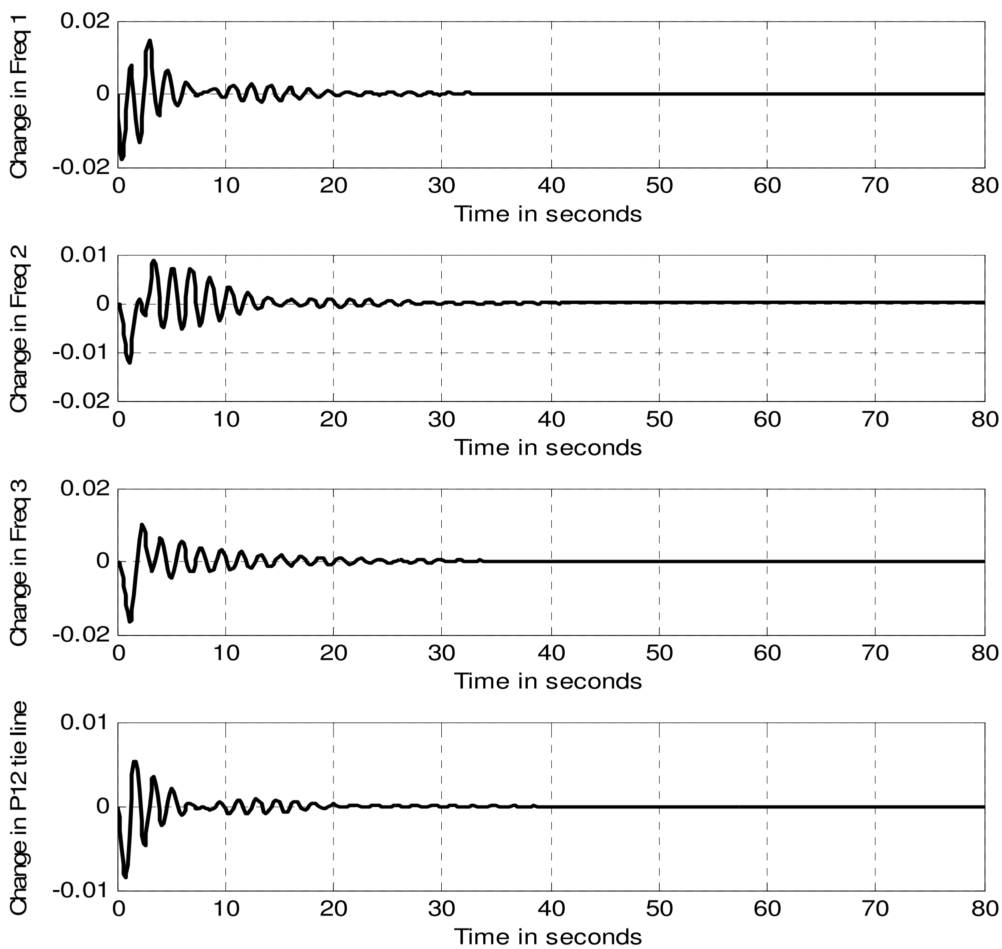

Figure 6.14: Responses of system with two non-reheat and one hydro turbine when area 1is subjected to load change of 1%

6.6 Three Area with Non-Reheat, Reheat and Hydro Turbine

This analysis is carried out on a combination where each area is equipped with different turbine i.e. one non-reheat, one reheat and one with hydro turbine. The proposed controller is employed to control the frequency. Results obtained are found satisfactory in terms of dynamic response. Variations in figure 6.15 show less oscillations and fast settlement to steady state value. Area 1 is subjected to a disturbance of 1 %.

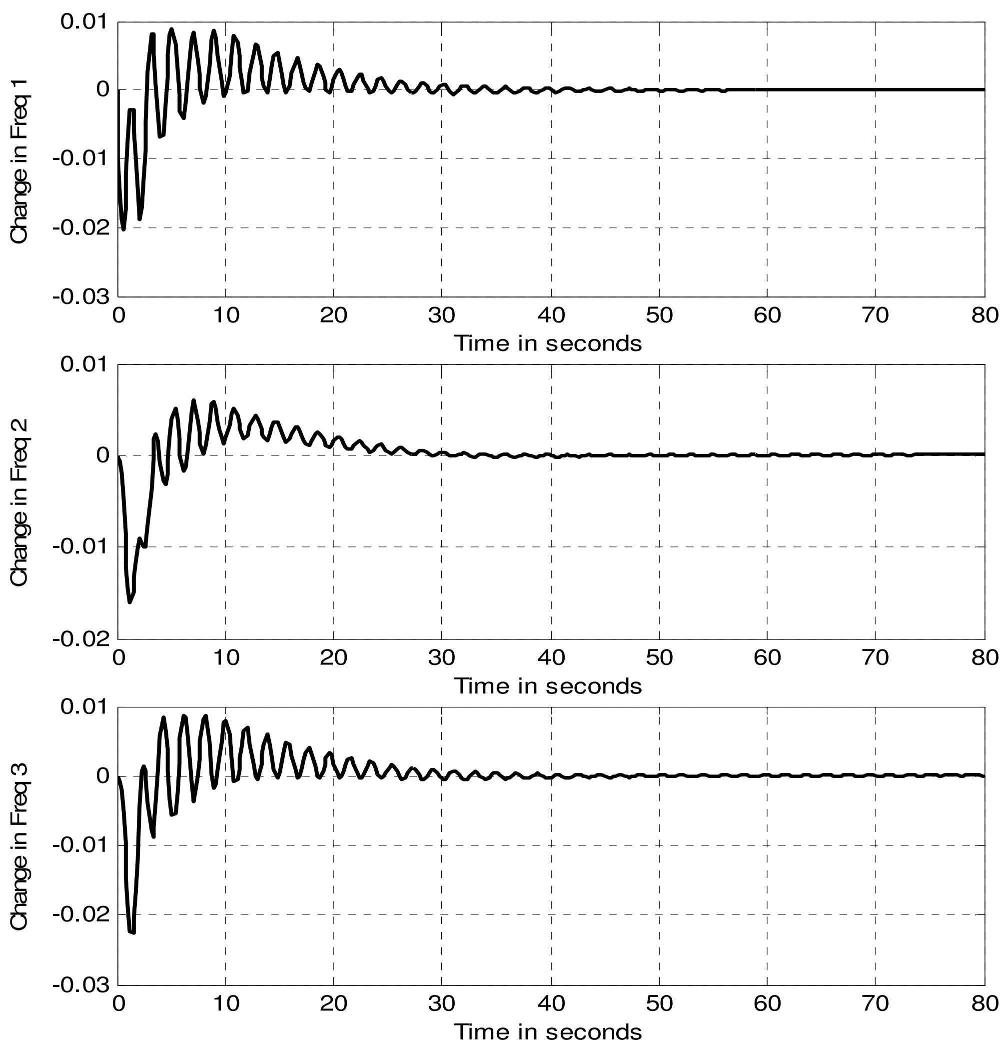

Figure 6.15: System responses of mixed three area power system (area 1 subjected to load change of 1%)

Figure 6.15 is shown the responses when only one area i.e. area with non-reheat is disturbed while responses, when two areas i.e. one area with non-reheat and one with reheat are simultaneously disturbed with same amount of load change, are shown in figure 6.16.

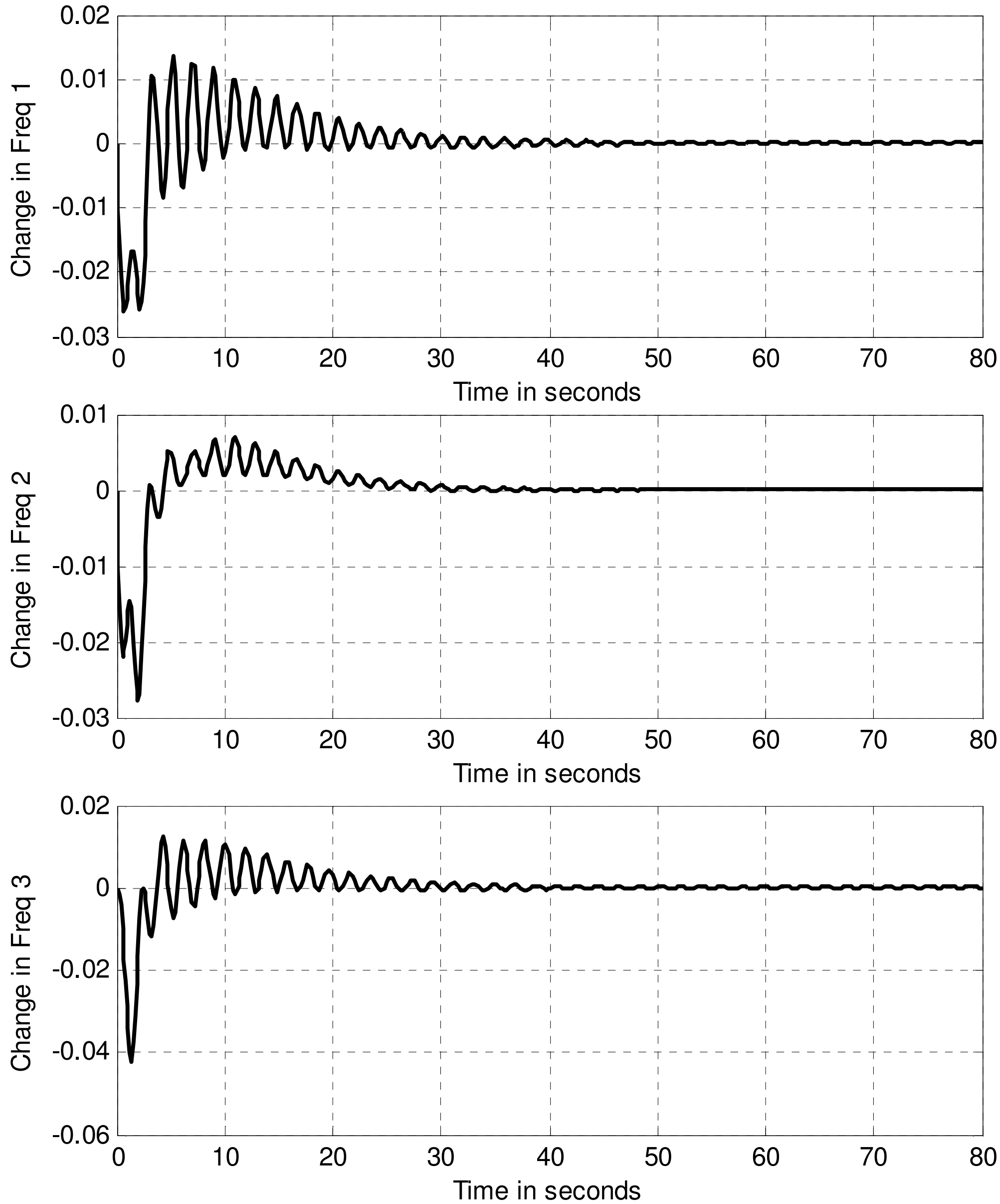

Figure 6.16: System responses of mixed three area power system (area 1 and area 2 are subjected to load change of 1%)

6.7 Summary

In this chapter presented the complete results of various cases of three area interconnected power system. Three area system considered is a ring connected system. Results of non-reheat system, reheat system with GRC and mixed system consisting of non-reheat, reheat and hydro turbine are presented. Robustness was also checked by means of applying different load changes to different areas and found that system is achieving steady state position within permissible time frame. Frequency deviations, tie-line deviations and changes in mechanical power output are plotted. Results are compared with suitable references for comparative study.