A NEW LOAD FREQUENCY CONTROL METHOD OF MULTI-AREA POWER SYSTEM VIA THE VIEWPOINTS OF PORT-HAMILTONIAN SYSTEM AND CASCADE SYSTEM

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ABSTRACT - Traditionally, frequency regulation in power system is achieved by balancing generation and demand through load following, i.e., spinning and non-spinning reserves. The future power grid, on the other hand, is foreseen to have high penetration of renewable energy (RE) power generation, which can be highly variable. In such cases, energy storage and responsive loads show great promise for balancing generation and demand, as they will help to avoid the use of the traditional generation following schemes, which can be costly and/or environmentally unfriendly.

The main goals of Load Frequency control (LFC) are, to maintain the real frequency and the desired power output (megawatt) in the interconnected power system and to control the change in tie line power between control areas. So, a LFC scheme basically incorporates an appropriate control system for an interconnected power system, which is heaving the capability to bring the frequencies of each area and the tie line powers back to original set point values or very nearer to set point values effectively after the load change. This is achieved by the use of conventional controllers. But the conventional controllers are heaving some demerits like; they are very slow in operation, they do not care about the inherent nonlinearities of different power system component, it is very hard to decide the gain of the integrator setting according to changes in the operating point. Advance control system has a lot of advantage over conventional integral controller. They are much faster than integral controllers and also they give better stability response than integral controllers.

In this work, a method based on the Port-Hamiltonian PH system and cascade system that is proposed to design some PID control laws for the multi-area LFC system successfully works out the aforementioned problem. Compared with the existed PID methods for the multi-area LFC system, the proposed method has two advantages, which are the decoupling of total tie-line power flow and the robust disturbance rejection. Finally the test system is simulated with and without reheated turbine in the environment of MATLAB Simulink to validate the advantages and robustness of proposed method.

1 INTRODUCTION

Load-frequency control is essential in electrical power System structure and operation. The loading in a Power system is never steady. To guarantee the quality of the power supply, it is important to structure a load frequency Control system which manages the control of loading of the generators relying upon the frequency. With regards to a multi-region power system, each zone has to be furnished with one nearby load-frequency Controller. The motivation behind the neighborhood controller is to keep up the zone's frequency and also the power streaming in/out of the territory. There has been proceeding with enthusiasm for structuring these load-frequency controllers for as far back as 20 years. Many control techniques for load frequency control have been proposed since the 1970s. On the off chance that the Problems have been considered, a reasonable arrangement of neighborhood load-frequency controllers is typically acquired by means of dull field testing and tuning.

A robust decentralized control idea [13-16] is used for the plan of a robust decentralized load-frequency Controller (RDLFC). The RDLFC is thus comprised of N nearby load-frequency controllers (i.e. no estimations from other zones are required). In our new controller-plan approach, the RDLFC is acknowledged by fathoming N decoupled Riccati conditions. The initially inferred N Riccati conditions are interlinked, and are isolated utilizing our proposed technique. The general power system, utilizing the RDLFC, will be asymptotically steady for all acceptable parametric vulnerabilities.

The issue of controlling the genuine power output of producing units in light of changes in system frequency and tie-line power interchange within indicated limits is known as load frequency control (LFC) [1]. Because of the expanded multifaceted nature of modern power systems, propelled control methods were proposed in LFC, e.g., ideal control [2]– [4]; variable structure control [5]; versatile and self-tuning control [6], [7]; astute control [8], [9]; and robust control [10]–[14]. As of late, LFC under new deregulation advertise [16], [17], LFC with correspondence postpone [18], and LFC with new vitality systems [19], [20] got much consideration. See [21] and [22] for an entire survey of ongoing philosophies in AGC. Enhanced execution might be normal from the propelled control methods, however, these methods require either data on the system states or a proficient online identifier thus might be hard to apply by and by. A bound together method to plan and tune PID load frequency controller for power systems with non-reheat, reheat and hydro turbines will be talked about.

2. LOAD FREQUENCY CONTROL

2.1 CONTROL OBJECTIVES

The principle targets of the Automatic Generation Control (A.G.C.) work are

- To match the generated power to the load demanded by the buyer.
- Adjust the system frequency to the reference set frequency.
- Control the power fare to other zones in the interconnected case to keep to scheduled interchange understandings.
- To control each individual zone to share the generation in the most financial way.
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The initial three destinations are under the control of the L.F.C. and the last includes the utilization of financial dispatch. The system elements must be considered and the entire controller developed from this start position. For the most part there have been two principle sorts of arrangements proposed to the issue of L.F.C. the more conventional arrangements which have been utilized by and by for a long time and the more modern ones have just been proposed without any down to earth executions.

As specified before the conventional controllers utilize the outstanding and comprehended relative in addition to indispensable sort control schemes. These are based on the theory related with servomechanisms which was created in the 1950's. These schemes utilize what is typically named' unconstrained monetary dispatch, that is the control is allowed to do any control activity it considers important without any respect to the financial aspects of this control activity.

2.2 DEFINITION OF GOOD CONTROL

The future improvements for A.G.C. are based on the meaning of how a decent L.F.C. work and monetary dispatch are equipped for acting. This definition is certainly not a very much characterized amount, however there are various properties which must be considered as necessary for the finishing of a decent frequency controller.

- It should be robust m its correspondence with other control work and numerically consistent, it have got the chance to maintain a strategic distance from information multifaceted nature, and it must be decentralized based on territory premise.

- It has got the opportunity to consider the system choking, and place additional emphasis on, system security, power rate breaking points and every day dynamic requirements.

- It must have the capacity to show some financial enhancement in operation, seen directly through a reasonable interface with monetary dispatch, seen indirectly by the reduction of the turning store and control plant edges.

- It must have the capacity to adapt to system drifters, by having expansive security edges, by issuing smooth control commands which enhances the economy, by diminishing the wear and tear on the generation units, the interface between L.F.C. and E.D. must be effectively comprehended.

3. MULTI-AREA POWER SYSTEM MODEL

3.1 INTRODUCTION

In a two zone interconnected power system, where the two territories are associated through tie lines, the control territory are supplied by each region and the power stream is permitted by the tie lines among the regions. Whereas, the output frequencies of the considerable number of regions are influenced because of a little change in load in any of the regions so as the tie line power stream are influenced. So the transient circumstance data's of every single other region are required by the control system of each territory to reestablish the pre characterized values of tie line powers and region frequency. Each output frequency finds the data about its own region and the tie line power deviation finds the data about the other territories. For instance in a two region power system, the data can be composed as $B_i\Delta f_i+\Delta P_{tie}$. B = frequency bias, f = predefined frequency and Ptie is the power in tie line. This is the Area Control Error (ACE) which is the input to the controller.

Thus the load frequency control of a multi zone power system for the most part fuses appropriate control system, by which the territory frequencies could brought back to its predefined esteem or closer to its predefined esteem so as the tie line power, when the is sudden change in load happens.

4. P-I-D CONTROLLER

The power souk has encountered huge misfortunes in conveying on swear of deregulation. Based on theory, deregulating the power souk would boost the effectiveness of the business by delivering power at lesser expenses and passing those cost ventures on to buyers. For an electric creation, deregulation implies the generation segment of power administration will be unbolt to rivalry. However, the distribution and transmission of the power will be proceeding for control and our nearby administration organization will bear on dispersing power for us and giving client administrations. The generation of power is being deregulated, which implies we will have the chance to shop around for the power generation supplier of choice.

4.1 LFC PID CONTROLLER

The biggest part utilized control strategy in industry is P-I-D controller. It is utilized for different control issues such as robotized systems or plants. A PID-Controller incorporates three distinct basics, which is why it is now and again called a three term controller. Corresponding control, Integral control and Derivative control is the development of PID.

To get together extraordinary structure determinations for the system, PID control can put into operation. These can incorporate the settling and rise time in addition to the precision and overshoot of the system step reaction. The three stipulations should be estimated independently to understand the capacity of a criticism controller for PID.

- Proportional Control: to supply the driving input to the procedure, the Proportional control is a chaste gain tuning following up on the blunder signal. The system speed can be balanced utilizing the P-term from the PID controller.
- Integral Control: by preface of an integrator, an Integral control is utilized. To gain the power system wanted precision, an Integral control is utilized

Fundamentally we can well thought-out with a single generator supply of a secluded power system.

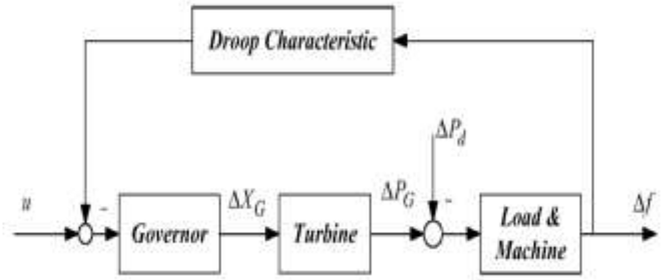


Fig. 1: Linear model of a single area power system

The PID controller tuning is to improve the performance of power system load frequency control. The design control law u = -K(s) Δf, where K(s) has the form

$$K(s) = K_p(1 + \frac{1}{T_i s} + T_d s) \quad (4.1)$$

In general, PID controller is put into practice to decrease the effect of noise. So, for this case K(s) can be written as

$$K(s) = K_p\left(1 + \frac{1}{T_i s} + \frac{T_d s}{N_s + 1}\right) \quad (4.2)$$

Where N is termed as the filter constant

$$K(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\frac{1 - e^{-Ts}}{N_s + 1}\right) \quad (4.3)$$

Where 'T' is an incredibly little sampling rate

In view of the fact that the power system load frequency control deems a little load change, it can be symbolized by the single area model.

5 SIMULATION RESULTS

5.1 INTRODUCTION

In this Chapter, two area and four area power system model of simulation results are presented for non reheated and reheated turbines. In order to validate the proposed topology, simulation is carried out using the MATLAB/SIMULINK.

5.2 PROPOSED TOPOLOGY

The block diagram for single-area power system with a simplified non-reheat steam turbine is shown in Fig. 5.1.

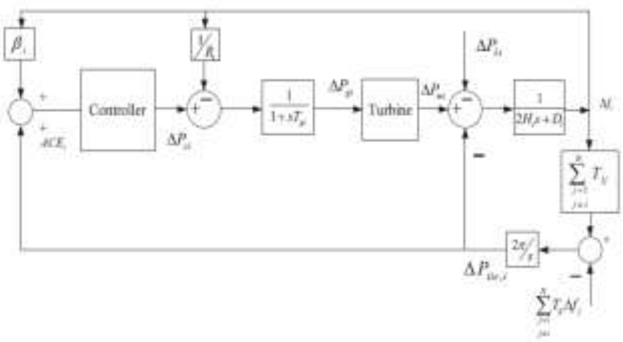


Fig.5.1: Block-diagram representation of a single-area power system model

5.3 SIMULATION RESULT ANALYSIS

In this section, simulations are given to demonstrate the validity and advantage of the proposed method. To prove the validity of the proposed method, a two-area LFC power system (1) with non-reheated turbines is considered, which rates of areas 1 and 2 are 1000 MW and 800 MW, respectively. The synchronizing coefficients $T_{12} = T_{21} = 0.2$ p.u. MW/Hz.

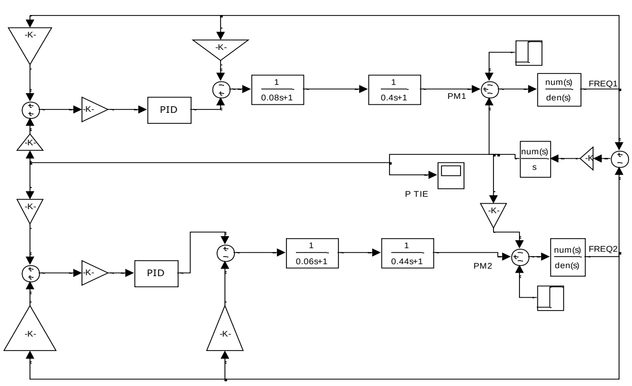


Fig.5.2: MATLAB SIMULINK model of two area power system

Fig.5.2 is simulated for two-area with non reheated turbine model and the parameters used for this area is presented in Table 5.1. The simulations results are shown in Fig.5.3, Fig.5.4 and Fig.5.5.

Table 5.1 Parameters of a two area LFC power system with non-reheated turbines

Area	R (Hz/p.u MW)	T_g (s)	T_t (s)	T_p (s)	K_p
Area1	3	0.08	0.4	11.1133	66.7
Area 2	2.73	0.06	0.44	12.6062	62.5

When $t \geq 3s$, there are load demands $\Delta P_{L1} = \Delta P_{L2} = 0.01$ p.u.MW for the two Areas 1 and 2, respectively. It is necessary to point out that the overshoot and responding speed of $\Delta P_{\mathrm{tie},i}$ are small and fast, respectively. Thus, the proposed method is effective.

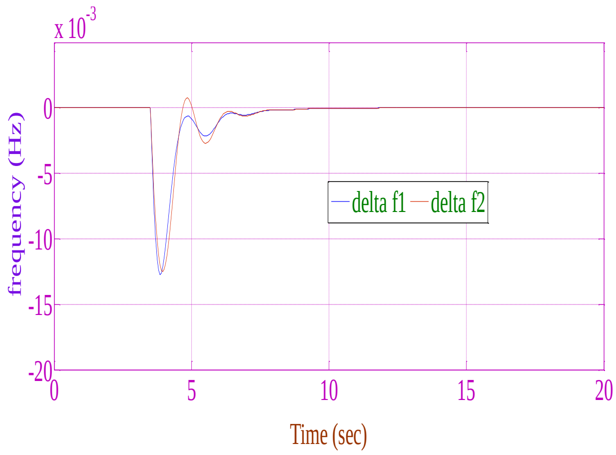


Fig.5.3: Frequency response for LFC two-area with non reheated turbine

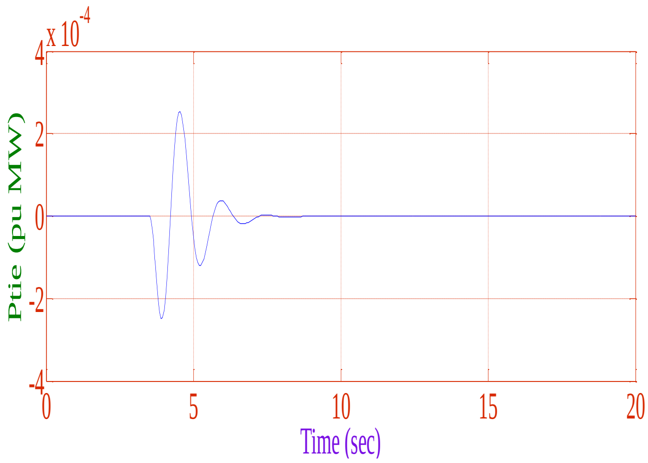


Fig.5.4: P_{tie} line response for LFC two-area with non reheated turbine

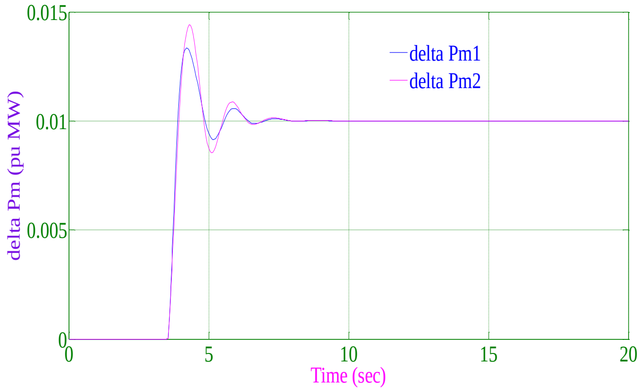


Fig.5.5: Pm responding curves for LFC two-area with non reheated turbine

To prove the advantages of the proposed method, a four area LFC system with non-reheated turbines containing four areas is considered, as shown in Fig. 5.6. Areas 1, 2 and 3 are interconnected with each other, while Area 4 is only connected with Area 1.

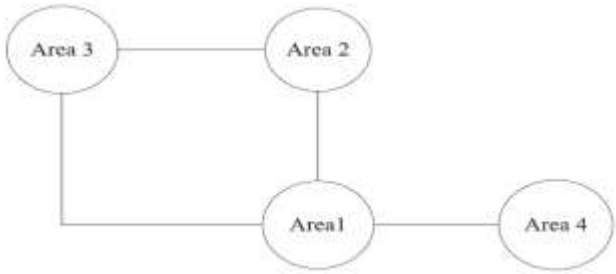


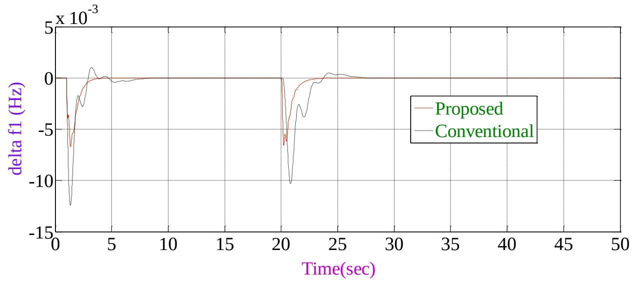
Fig.5.6: Simplified diagram of a four-area power system

Table 5.2 Parameters of a Four-Area LFC System with Non-Reheated Turbines

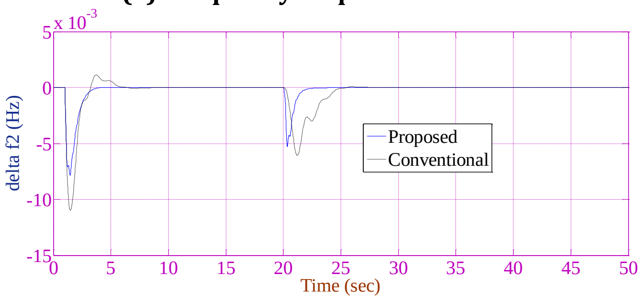
Area	R(Hz/p.u MW)	T_g (s)	T_t (s)	T_p (s)	K_p
Area1	2.4	0.08	0.3	20	120
Area 2	2.7	0.072	0.33	25	112.5
Area 3	2.5	0.07	0.35	20	125
Area 4	2.0	0.085	0.375	15	115

Fig.5.6 is simulated with parameters as shown in Table 5.2 and the response curves related to frequency and tie line power is presented in Fig.5.7 & Fig.5.8.

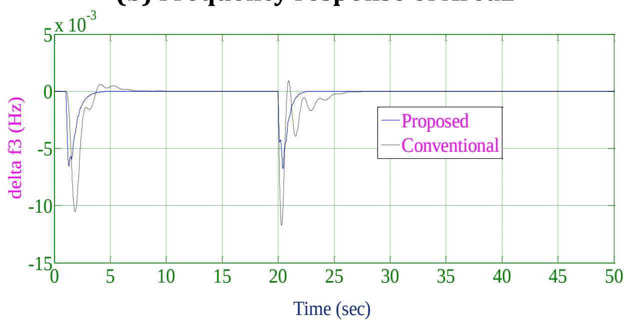
In the Figs. 5.7 and 5.8, the four-area LFC system faces the demand loads $\Delta P_{L1} = \Delta P_{L2} = 0.01$ p.u. MW at time $t \geq 1$ s and $\Delta P_{L3} = \Delta P_{L4} = 0.01$ p.u. MW at time $t \geq 20$ s, respectively. The solid lines of the proposed method quickly and smoothly approach to the system equilibrium. Besides that, the responding speeds and overshoots of the proposed method are better than those of the conventional results.



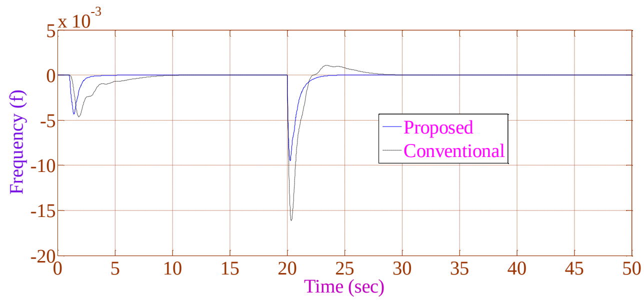
(a) Frequency response of Area1



(b) Frequency response of Area2

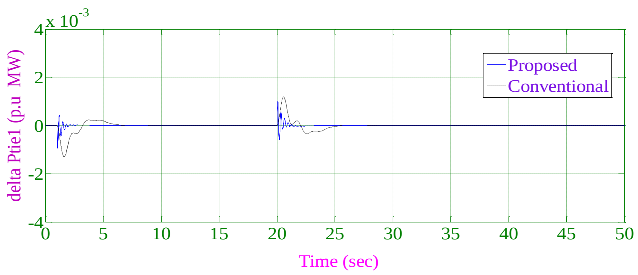


(c) Frequency response of Area3

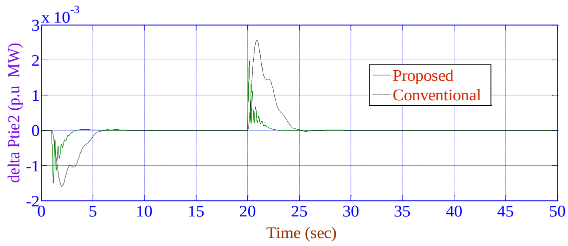


(d) Frequency response of Area4

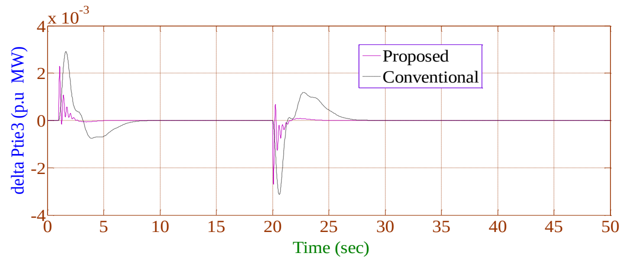
Fig.5.7: Frequency response curves of four area power system with non-reheated turbines



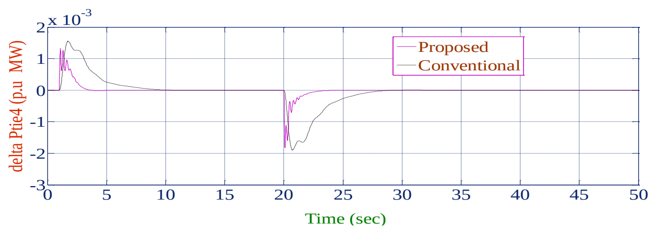
(a) Tie line power response curves of Area1



(b) Tie line power response curves of Area2



(c) Tie line power response curves of Area3

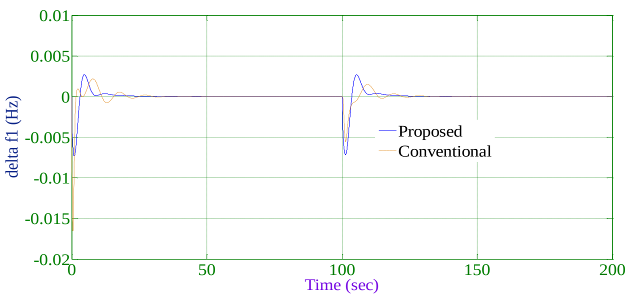


(d) Tie line power response curves of Area4

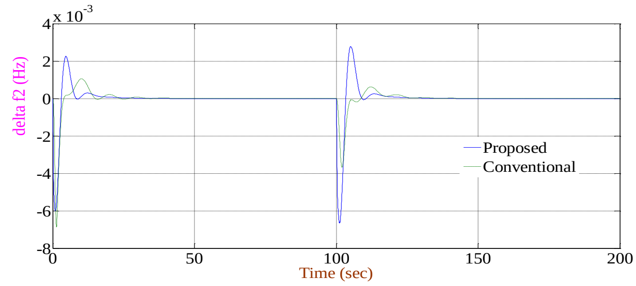
Fig.5.8: Tie line power response curves of four area power system with non-reheated turbines

Table 5.3 Parameters of a Four-Area LFC System with Reheated Turbines

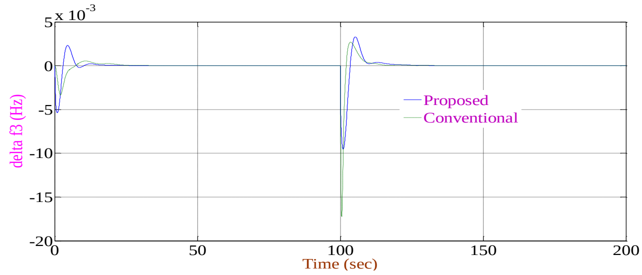
Area	R(Hz/p.u MW)	T_g (s)	T_t (s)	T_p (s)	K_p
Area1	2.4	0.08	0.3	20	120
Area 2	2.7	0.072	0.33	25	112.5
Area 3	2.5	0.07	0.35	20	125
Area 4	2.0	0.085	0.375	15	115



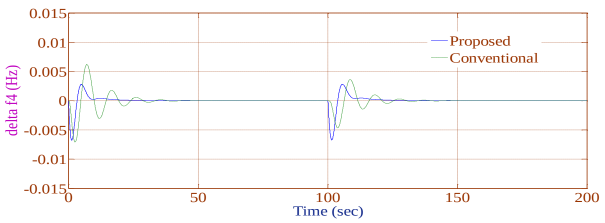
(a) Frequency response of Area1



(b) Frequency response of Area2

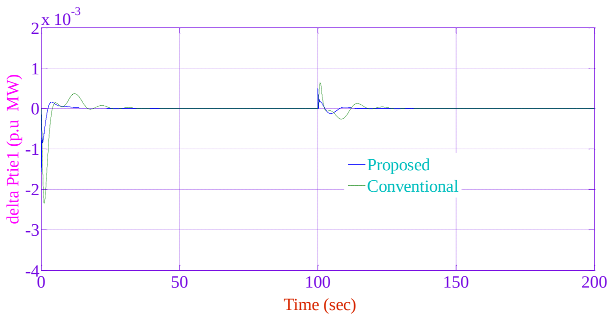


(c) Frequency response of Area3

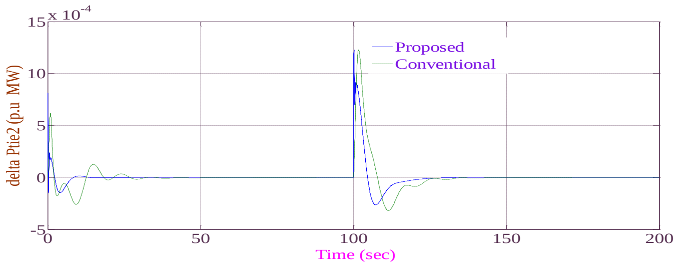


(d) Frequency response of Area4

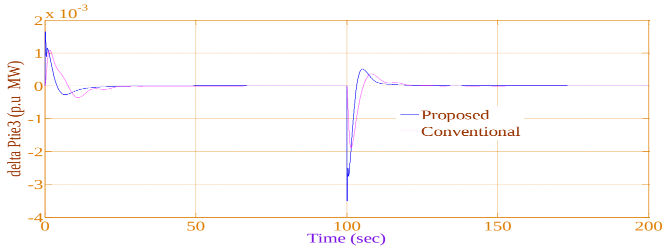
Fig.5.9: Frequency response curves of four area power system with reheated and hydro turbines



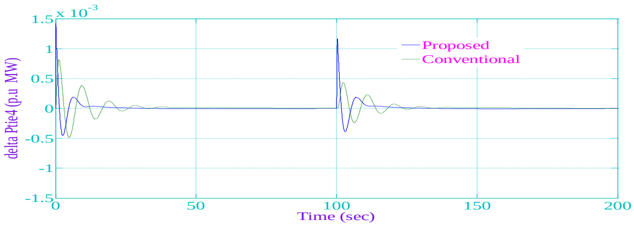
(a) Tie line power response curves of Area1



(b) Tie line power response curves of Area2



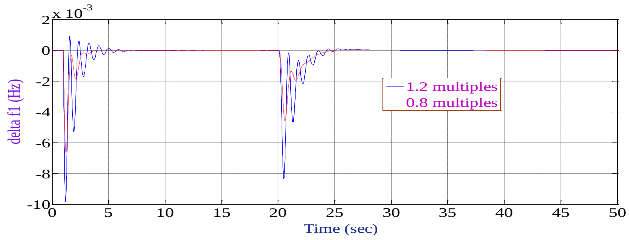
(c) Tie line power response curves of Area3



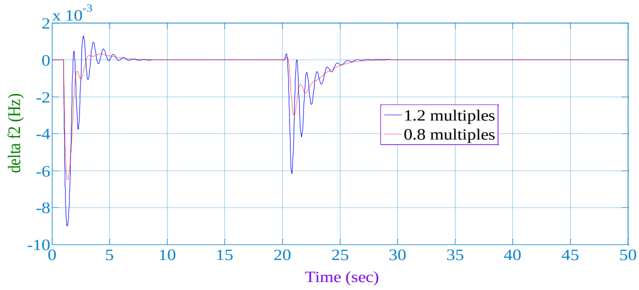
(d) Tie line power response curves of Area4

Fig.5.10: Tie line power response curves of a four-area power system with reheated turbines

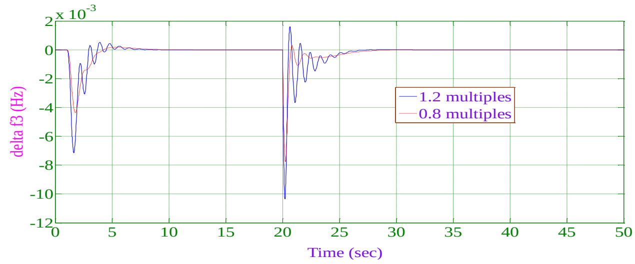
Fig.5.6 is simulated with parameters as shown in Table 5.3 and the response curves related to frequency and tie line power is presented in Fig.5.9 & Fig.5.10. Noting the Fig. 5.6 again, when the non-reheated turbines of the Areas 1, 2 and 3 in the above four-area LFC system are replaced by reheated turbines, while the non-reheated turbine of the Area 4 is replaced by a hydro turbine. Thus, a four-area LFC system with reheated and hydro turbines is considered. When $t = 0$ s and $t = 100$ s, there are step loads $\Delta P_{L1} = 0.01$ p.u.MW and $\Delta P_{L3} = 0.01$ p.u.MW for the Areas 1 and 3, respectively. It is clear that the responding speeds of the proposed method are faster than those of the conventional results.



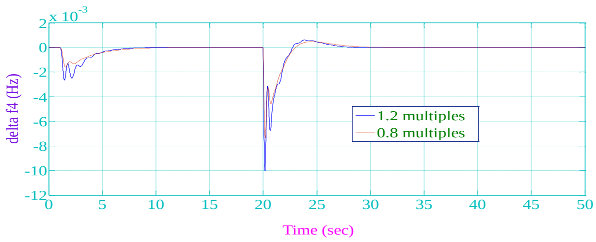
(a) Frequency response of Area1



(b) Frequency response of Area2

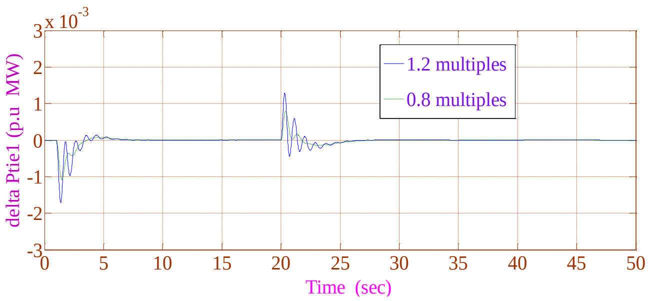


(c) Frequency response of Area3

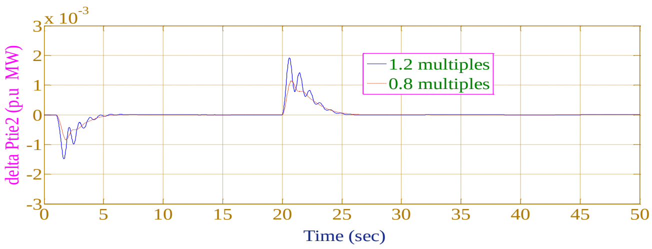


(d) Frequency response of Area4

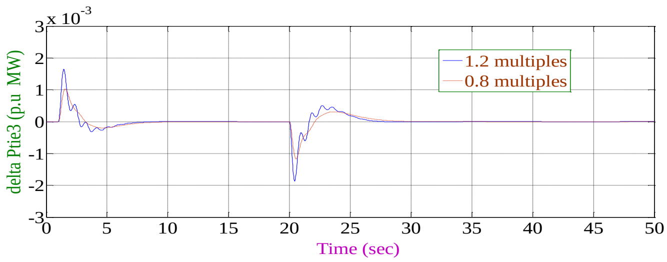
Fig.5.11: Frequency response curves of four-area power system with non-reheated Turbines



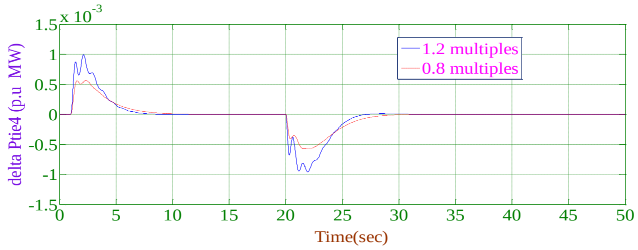
(a) Tie line power response curves of Area1



(b) Tie line power response curves of Area2



(c) Tie line power response curves of Area3



(d) Tie line power response curves of Area4

Fig.5.12: Tie line power response curves of a four-area power system with non reheated turbines

A four-area LFC system with non-reheated turbines that is considered is interconnected as the configuration shown in the Fig.5.6. Namely, the parameters of the four-area LFC system are in the Table 5.2, and the rates of areas are mentioned as before. To test the robustness, the above system is simulated for different parameter variations within ± 20% as shown Figs.5.11 and 5.12. It is clear that the control laws still asymptotically stabilize the four-area LFC system with some varying parameters. Thus, the proposed method is robust.

CONCLUSION

In this thesis, a control method based on the PH system and cascade system for the multi-area LFC system is proposed with two contributions. One is that the proposed method decouples the total tie-line power flow $\Delta P_{tie,i}$, while the other is that the proposed method designs a robust disturbance rejection controller in the same time. In other words, due to the decoupling of $\Delta P_{tie,I}$, the useful part $\int \Delta f_i dt$ of $\Delta P_{tie,i}$ is used as the integral feedback to improve the systemic steady static difference, while the disturbed part $\int \Delta f_j dt$ of $\Delta P_{tie,i}$ is simultaneously robust rejected by the IA method. In short, compared with the traditional methods, the proposed method applies the structure and energy properties of multi-area LFC system to design a control law, which successfully works out the problem on how to effectively utilize the total tie-line power flow $\Delta P_{tie,i}$.

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