

Comparative Study of Two-Area and Four-Area Load Frequency Control Using Pid Controller

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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.

INTRODUCTION

Load-frequency control is important in electrical power System design and operation. The loading in a Power system is never constant. To ensure the quality of the power supply, it is necessary to design a load frequency Control system which deals with the control of loading of the generators depending on the frequency. In the context of a multi-area power system, each area has to be equipped with one local load-frequency Controller. The purpose of the local controller is to maintain the area's frequency as well as the power flowing in/out of the area. There has been continuing interest in designing these load-frequency controllers for the past 20 years. Many control strategies for load frequency control have been proposed since the 1970s. If the Problems have been considered, a suitable set of local load-

frequency controllers is normally obtained via tedious field testing and tuning.

A robust decentralized control concept [13-16] is utilized for the design of a robust decentralized load-frequency Controller (RDLFC). The RDLFC is thus made-up of N local load-frequency controllers (i.e. no measurements from other areas are required). In our new controller-design approach, the RDLFC is realized by solving N decoupled Riccati equations. The originally derived N Riccati equations are interlinked, and are separated using our proposed technique. The overall power system, using the RDLFC, will be asymptotically stable for all admissible parametric uncertainties.

The problem of controlling the real power output of generating units in response to changes in system frequency and tie-line power interchange

within specified limits is known as load frequency control (LFC) [1]. Due to the increased complexity of modern power systems, advanced control methods were proposed in LFC, e.g., optimal control [2]–[4]; variable structure control [5]; adaptive and self-tuning control [6], [7]; intelligent control [8], [9]; and robust control [10]–[14].

Recently, LFC under new deregulation market [16], [17], LFC with communication delay [18], and LFC with new energy systems [19], [20] received much attention. See [21] and [22] for a complete review of recent philosophies in AGC. Improved performance might be expected from the advanced control methods, however, these methods require either information on the system states or an efficient online identifier thus may be difficult to apply in practice. A unified method to design and tune PID load frequency controller for power systems with non-reheat, reheat and hydro turbines will be discussed.

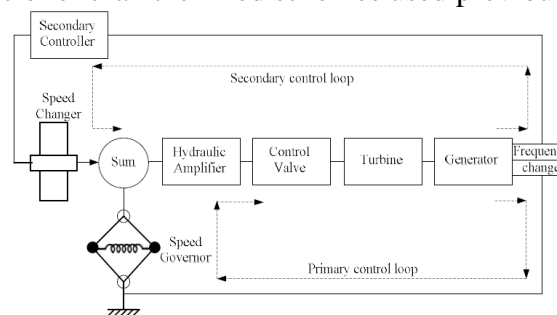
LOAD FREQUENCY CONTROL

This chapter in brief portrays electrical power system networks and their use in transferring electrical energy from its source of generation to the centers of consumer load. The state-space approach determines an optimal controller using linear optimal control theory. The parameters calculated by the optimal controller are strongly dependent, on the coefficients of the quadratic performance index. The main problem with the linear optimal control approach is the fact that no practical guide lines exist on the selection of the coefficients of the performance index.

The load Frequency Control problem of an interconnected power system is a well defined problem. The system is divided into groups of generators which are interconnected by tie--lines. Each group of generators is called an area, and each area must be able to meet its own load changes and any import or export targets set by the controllers in advance. Each area has its own response characteristics which relate the area frequency and total generation for load changes on the specific area. This curve is the regulation curve of an area and represents the area gain (in MW /Hz). The area gain or regulation is a direct measure of the effects of all the governors on the prime movers within the area, and plays an important part in the steady-state and dynamic performance of the system.

The normal procedure used in the design of L.F.C. functions is to construct a linear system model with fixed parameters. This is obtained by linearizing the system around an operating point; however, this approach is not strictly correct as the system response characteristics tend to be non-linear. Power system parameters, are a function of the operating point. Hence, as the operating conditions change, the calculated operating point will no longer be optimal. To keep the system performance near to optimum, a way of tracking the operating conditions of the system is required which will enable the continuous updating of the system parameters. The control signal can then be computed based on an optimal approach using the newly updated parameters.

Load changes in the system are random in magnitude and time. To control the transient response effectively and to take into account the sensitivity problem of L.F.C. in interconnected power systems the use of self-tuning controllers is considered. It seems more appropriate to consider the system as a stochastic system and to improve control performance, design an adaptive stochastic controller than the fixed schemes used previously.



Schematic diagram of load frequency control

MULTI-AREA POWER SYSTEM MODEL

In a two area interconnected power system, where the two areas are connected through tie lines, the control area are supplied by each area and the power flow is allowed by the tie lines among the areas. Whereas, the output frequencies of all the areas are affected due to a small change in load in any of the areas so as the tie line power flow are affected. So the transient situation information's of all other areas are needed by the control system of each area to restore the pre defined values of tie line powers and area frequency. Each output frequency finds the information about its own area and the tie line power deviation finds the information about the other areas. For example in a two area power system, the information can be written as $B_i \Delta f_i + \Delta P_{tie}$. B = frequency bias, f = predefined frequency and P_{tie} 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 area power system generally incorporates proper control system, by which the area frequencies could brought back to its predefined value or very nearer to its predefined value so as the tie line power, when the is sudden change in load occurs.

P-I-D CONTROLLER

The electricity souk has experienced vast setbacks in delivering on swear of deregulation. Based on theory, deregulating the electricity souk would boost the efficiency of the industry by producing electricity at lesser costs and passing those cost investments on to consumers. For an electric production, deregulation means the production portion of electricity service will be unbolt to competition. However, the distribution and transmission of the electricity will be continuing for regulation and our local service company will carry on distributing electricity for us and providing customer services. The generation of electricity is being deregulated, which means we will have the opportunity to shop around for the electricity generation supplier of choice.

LFC PID CONTROLLER

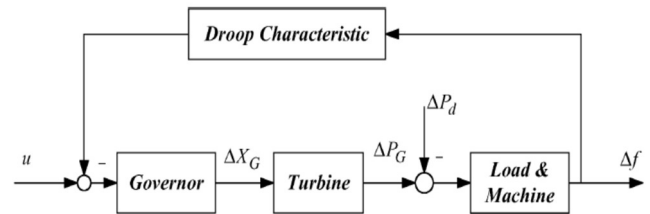
The largest part used control strategy in industry is P-I-D controller. It is used for various control problems such as automated systems or plants. A PID-Controller includes three different fundamentals, which is why it is at times called a three term controller. Proportional control, Integral control and Derivative control is the expansion of PID.

To meet up different design specifications for the system, PID control is able to put into operation. These can include the settling and rise time plus the accuracy and overshoot of the system step response. The three stipulations should be measured separately to realize the function of a feedback controller for PID.

- Proportional Control: to supply the driving input to the process, the Proportional control is a chaste gain tuning acting on the error gesture. The system speed can be adjusted using the P-term from the PID controller.
- Integral Control: by preamble of an integrator, an Integral control is employed. To get the control system desired accuracy, an Integral control is used
- Derivative Control: to enhance the damping in the system, Derivative deed is usually introduced. The derivative term also magnifies

the presented noise which can cause evils together with instability.

Primarily we can well thought-out with a single generator supply of an isolated power system.



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 $u = -K(s) \Delta f$, where $K(s)$ has the form

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

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.

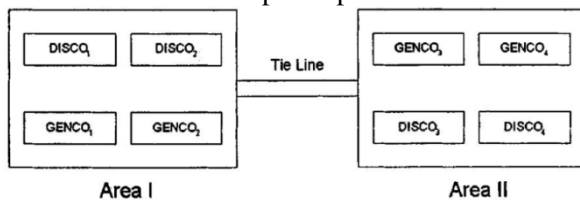
DISCO PARTICIPATION MATRIX

The participation factor indicates the amount of participation of a generator unit in the Automatic Generation Control (AGC) system. Following a load disturbance within the control area, the produced appropriate supplementary control signal is distributed among generator units in proportion to their participation, to make generation follow the load. In a given control area, the sum of participation factors is equal to 1.

In a competitive environment, AGC participation factors are actually time dependent variables and must be computed dynamically by an independent organization based on bid prices, availability, congestion problems, costs, and other related issues.

In the restructured environment, Generating Companies (GENCOs) sell power at competitive prices to various Distributing Companies (DISCOs). Thus,

DISCOs have the independence to prefer the GENCOs for contracts. They may or may not have agreement with the GENCOs in their individual area. This makes various combinations of GENCO-DISCO agreement possible put into practice. The thought of a “DISCO participation matrix” (DPM) is initiate to make the apparition of agreement easier [9]. DPM is a matrix with the number of GENCOs is equal to the number of rows and the number of DISCOs equal to the number of columns in the system. Every entry in this matrix can be attention of as a part of a full amount of load constricted by a DISCO (column) toward a GENCO (row). Therefore, the entry equivalent to the part of the entire load power constricted by DISCO from a GENCO. The sum of all the entries in a column in this matrix is unity. DPM illustrate the involvement of a DISCO in a contract with a GENCO; hence the name “DISCO participation matrix.”

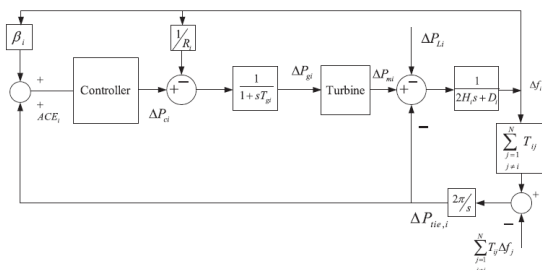


Schematic of a Two-Area System in Restructured Environment

SIMULATION RESULTS

PROPOSED TOPOLOGY

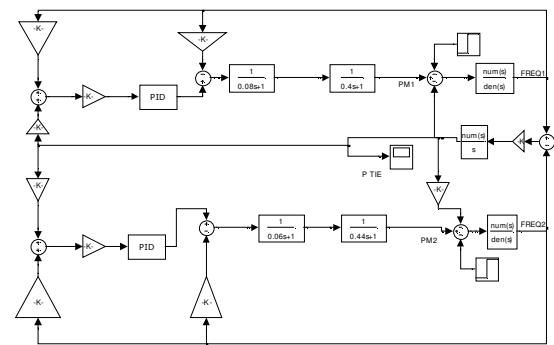
The block diagram for single-area power system with a simplified non-reheat steam turbine is shown in Fig. 5.1.



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.



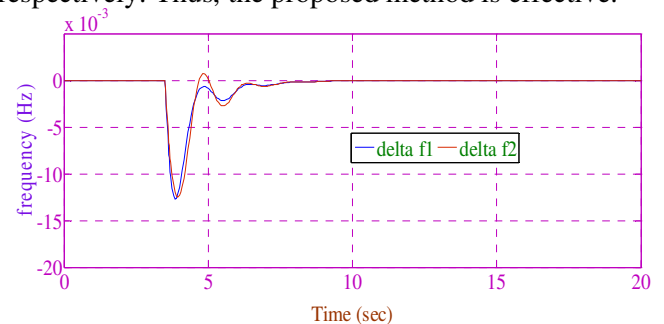
Matlab simulink model of two area power system

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.

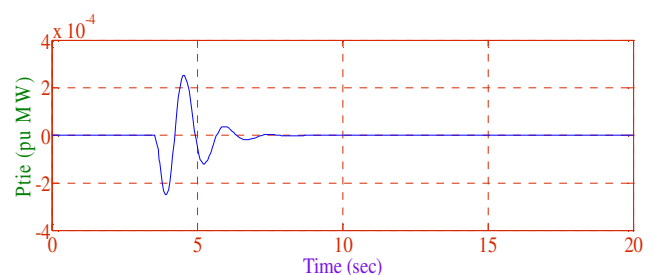
Table 5.1 Parameters of a two area LFC power system with non-reheated turbines

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

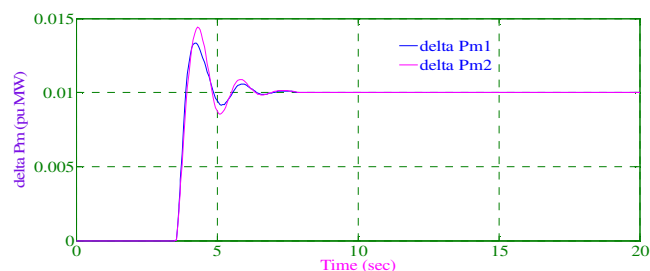
When $t \geq 3s$, there are load demands $\Delta P_{L1} = \Delta P_{L2} = 0.01$ p.u.MW for the two Areas 1 and 2, respectively. It is necessary to point out that the overshoot and responding speed of $\Delta P_{tie,i}$ are small and fast, respectively. Thus, the proposed method is effective.



Frequency response for LFC two-area with non reheated turbine

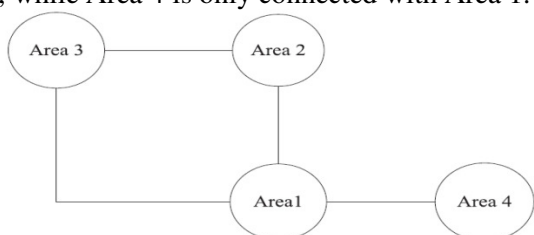


P_{tie} line response for LFC two-area with non reheated turbine



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.



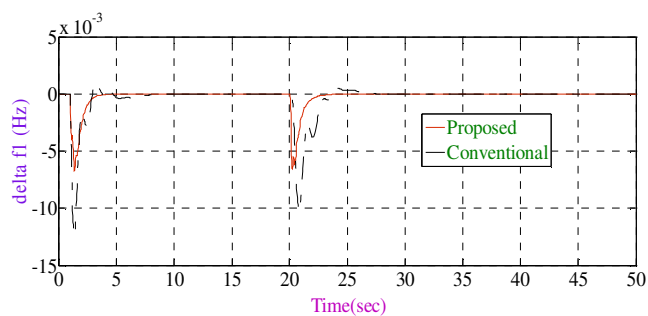
Simplified diagram of a four-area power system

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

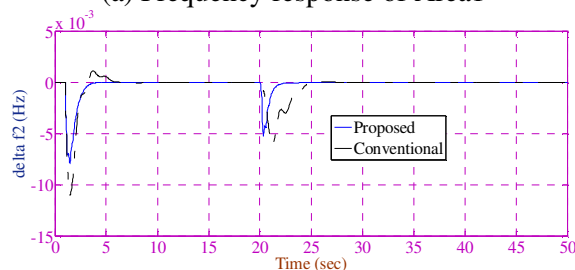
Area	R (Hz/p.u MW)	T_g (s)	T_t (s)	T_p (s)	K_p
Area1	2.4	0.08	0.3	20	120
Area 2	2.7	0.072	0.33	25	112.5
Area 3	2.5	0.07	0.35	20	125
Area 4	2.0	0.085	0.375	15	115

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.

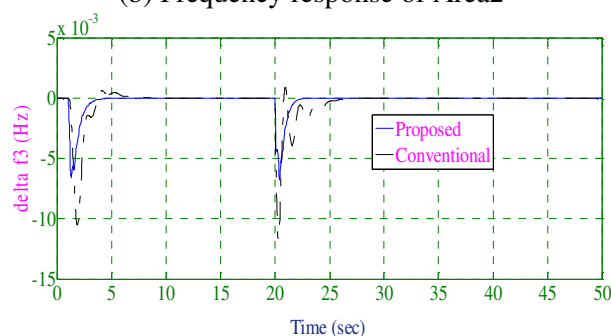
In the Figs. 5.7 and 5.8, the four-area LFC system faces the demand loads $\Delta P_{L1} = \Delta P_{L2} = 0.01$ p.u. MW at time $t \geq 1$ s and $\Delta P_{L3} = \Delta P_{L4} = 0.01$ p.u. MW at time $t \geq 20$ s, respectively. The solid lines of the proposed method quickly and smoothly approach to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



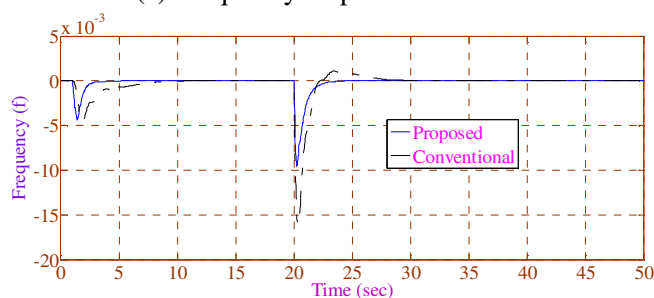
(a) Frequency response of Area1



(b) Frequency response of Area2

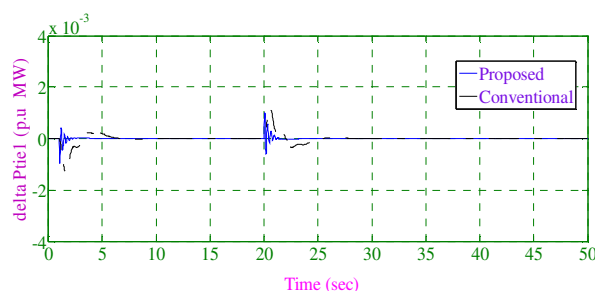


(c) Frequency response of Area3

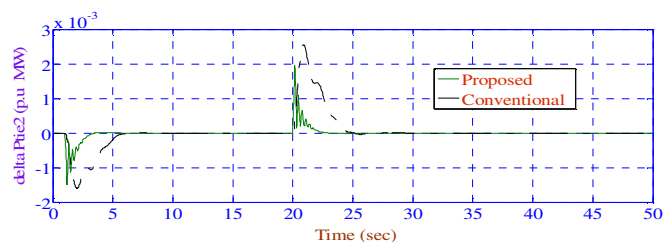


(d) Frequency response of Area4

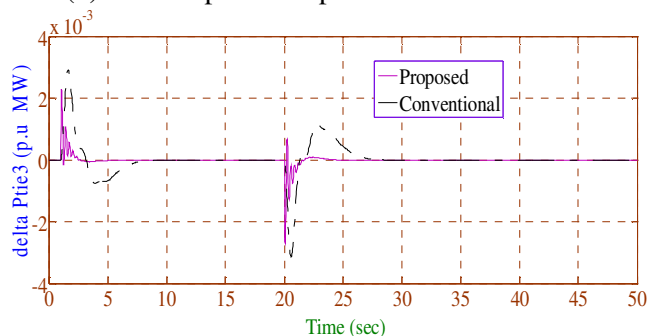
Frequency response curves of four area power system with non-reheated turbines



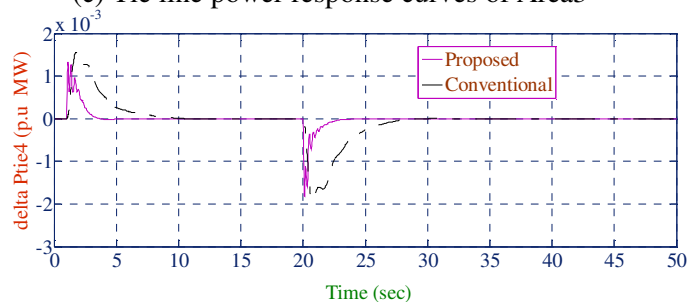
(a) Tie line power response curves of Area1



(b) Tie line power response curves of Area2



(c) Tie line power response curves of Area3

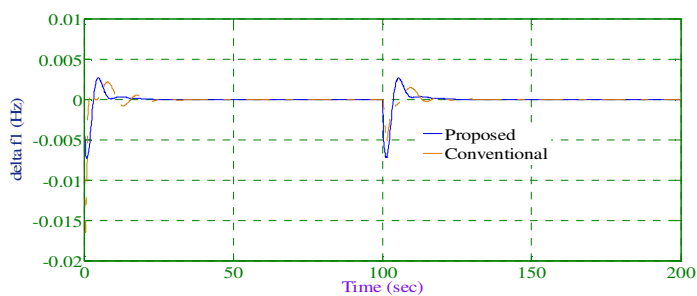


(d) Tie line power response curves of Area4

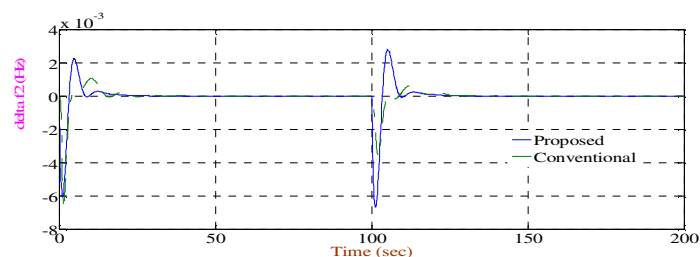
Tie line power response curves of four area power system with non-reheated turbines

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

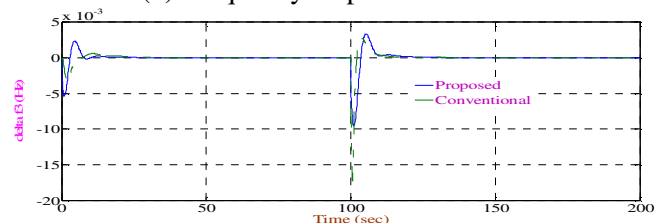
Area	R (Hz/p.u MW)	T_g (s)	T_t (s)	T_p (s)	K_p
Area1	2.4	0.08	0.3	20	120
Area 2	2.7	0.072	0.33	25	112.5
Area 3	2.5	0.07	0.35	20	125
Area 4	2.0	0.085	0.375	15	115



(a) Frequency response of Area1



(b) Frequency response of Area2



(c) Frequency response of Area3

CONCLUSIONS

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 Δf_i 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 $\Delta P_{tie,i}$.

FUTURESCOPE

In future work, it is interesting to apply the proposed method with some practical constraints and intelligent methods to do some researches on the multi-area LFC power system.

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