ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 128-133 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

GENETIC ALGORITHM BASED DECENTRALIZED LOAD FREQUENCY CONTROL IN DEREGULATED ENVIRONMENT

S.Baghya shree [a], S.Somaselvakumar [b]
[a] Assistant Professor, University college of Engineering, Dindigul
[b] PG Scholar, Anna university, Regional Centre, Madurai
baghya_shree@yahoo.com somaselvakumar@yahoo.com

Abstract- ***In this paper, Real Coded Genetic Algorithm (RGA) based Proportional Integral Derivative (PID) controller tuning method is proposed to improve the dynamics of the Decentralized Load frequency control (DLFC) in the deregulated electricity market. Due to the intense electricity trade in the deregulated system, the dynamics of the Load frequency control (LFC) such as transient response of frequency and tie-line power oscillations are greatly affected. Optimization of Load Frequency controller parameters such as gain and bias factor may improve the LFC dynamics by rapidly reestablishing the frequency and tie line power deviation within its nominal values. In this paper, the general transfer function model of LFC for decentralized control design of interconnected multi-area deregulated power systems is derived first, and then Real Coded Genetic Algorithm(RGA) based PID tuning method is used to design the optimal local load frequency controllers. A decentralized PID tuning method is proposed by assuming that the tie-line power flows are disconnected. The proposed method is tested on the five area deregulated power system with different electricity contracted scenarios under various operating conditions in terms of optimizing the local PID Controller gains .***

Index Terms – Load frequency control, Genetic Algorithm

1. INTRODUCTION

Frequency control is one of the most profitable auxiliary services for power systems through maintaining short-term balance of energy and frequency of the power systems. Frequency control is usually accomplished through generator governor response (primary frequency regulation) and load frequency control (LFC). The goal of LFC is to reestablish primary frequency regulation capacity, return the frequency to its nominal value and minimize un scheduled tie-line power flows between neighboring control areas.

In 1996 the US Federal Energy Regulatory Commission (FERC) issued Order 888, a ruling on open access transmission, nowknown as electricity deregulation, or restructuring. The ruling intended to increase competition in wholesale power markets. Large vertically integrated utilities providing power at regulated rates are being restructured to incorporate competitive companies selling unbundled power. Consumers were supposed to benefit from lower rates as a result of serious competitive bulk power markets. New players with different and sometimes opposing objectives have emerged. The already complex engineering system has to include economics, business, social and environmental aspects. Deregulation is affecting all business aspects of the power industry from generation to transmission. With increasing size and complexity of the restructured power systems, significant uncertainties and disturbances in power system control and operation are introduced. It is desirable that the novel control strategies be developed to achieve LFC goals and maintain reliability of the electric power system in an adequate level.

2. MULTI AREA LFC MODEL IN DEREGULATED ENVIRONMENTS

In the competitive environment of power systems, the vertically integrated utility (VIU) no longer exists. A deregulated system will consist of generation companies (GENCOs), distribution companies (DISCOs), transmission companies (TRANSCOs) and independent system operator (ISO). In the system, any GENCO in any area may supply DISCOs in its user pool and DISCOs in other areas through tie-lines between areas. In another word, for restructured systems having several GENCOs and DISCOs, any DISCO may contract with any GENCO in another control area independently. This case is called as 'bilateral transactions'. The transactions have to be implemented through an independent system operator. The impartial entity, ISO, has to control many ancillary services, one of which is automatic generation control (AGC), and LFC is regarded as the secondary level of AGC .In deregulated environments, any DISCO has the liberty to buy power at competitive prices from different GENCOs, which may or may not have contract in the same area as the DISCO. Thus there can be various combinations of possible contract scenarios between DISCOs and GENCOs. The concept of an 'Augmented Generation Participation Matrix' (AGPM) is used to express the possible contracts. The AGPM shows the participation factor of a GENCO in the load following contract with a DISCO. An AGPM for a large-scale power system with N control areas has the following Structure

$$AGPM = \begin{pmatrix} AGPM_{11} & \cdots\cdots & AGPM_{1N} \\ \vdots & \vdots & \vdots \\ AGPM_{N1} & \cdots\cdots & AGP_{NN} \end{pmatrix}$$

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 128-133 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

$$AGPM_{ij} = \begin{pmatrix} gpf_{(s_i+1)(z_j+1)} & \ldots\ldots & gpf_{(s_i+1)(z_j+m_j)} \\ \vdots & \ddots & \vdots \\ gpf_{(s_i+n_i)(z_j+1)} & \ldots\ldots & gpf_{(s_i+n_i)(z_j+m_j)} \end{pmatrix}$$

for i, j = 1,…N and $S_i = \sum_{k=1}^{i-1} n_j$,

$Z_j = \sum_{k=1}^{i-1} mj$, $S_1 = Z_1 = 0$

In the above, n_i and m_j are the number of GENCOs and DISCOs in area I and gpf_{ij} refers to ' generation participation factor' and shows the participation factor of GENCO I in the total following requirement of DISCO j based on the possible contract. The sum of all entries in each column of an AGPM is unity. The block diagram of the decentralized LFC design scheme for a Five area deregulated power system is shown in fig.

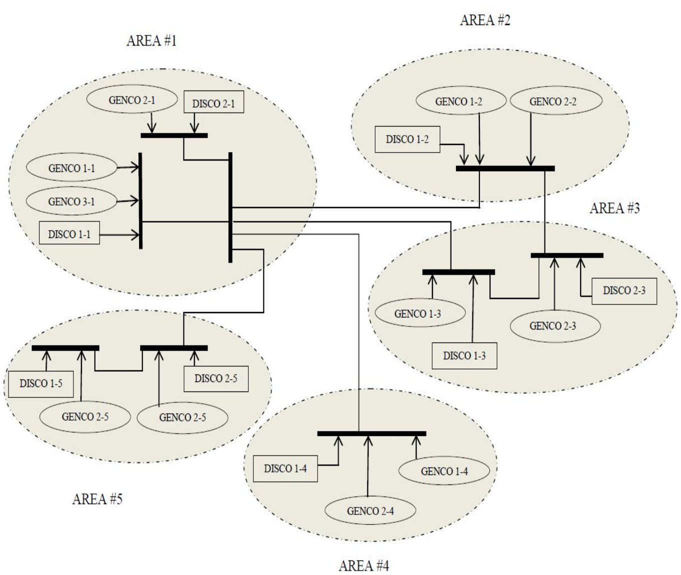


Fig 1: Five area model Diagram

3. PID CONTROLLER DESIGN:

A Proportional–Integral–Derivative (PID) controller is a three-term controller that has a long history in the automatic control field, starting from the beginning of the last century (Bennett, 2000). Owing to its intuitiveness and its relative simplicity, in addition to satisfactory performance which it is able to provide with a wide range of processes, it has become in practice the standard controller in industrial settings. It has been evolving along with the progress of the technology and nowadays it is very often implemented in

Process type	$H_{psf}(s)$ (process)	K_p	T_i	T_d
Integrator + delay	$\frac{K}{s}e^{-\tau s}$	$\frac{1}{K(T_C+\tau)}$	$c(T_C+\tau)$	0
Time-constant + delay	$\frac{K}{Ts+1}e^{-\tau s}$	$\frac{T}{K(T_C+\tau)}$	$\min[T, c(T_C+\tau)]$	0
Integr + time-const + del.	$\frac{K}{(Ts+1)s}e^{-\tau s}$	$\frac{1}{K(T_C+\tau)}$	$c(T_C+\tau)$	T
Two time-const + delay	$\frac{K}{(T_1s+1)(T_2s+1)}e^{-\tau s}$	$\frac{T_1}{K(T_C+\tau)}$	$\min[T_1, c(T_C+\tau)]$	T_2
Double integrator + delay	$\frac{K}{s^2}e^{-\tau s}$	$\frac{1}{4K(T_C+\tau)^2}$	$4(T_C+\tau)$	$4(T_C+\tau)$

Table3.1: Skogestad's formulas for PID tuning

digital form rather than with pneumatic or electrical components. It can be found in virtually all kinds of control equipment's, either as a stand-alone (single-station)controller or as a functional block in Programmable Logic Controllers (PLCs)and Distributed Control Systems (DCSs). Actually, the new potentialities offered by the development of the digital technology and of the software packages has led to a significant growth of the research in the PID control field new effective tools have been devised for the improvement of the analysis and design methods of the basic algorithm as well as for the improvement of the additional functionalities that are implemented with the basic algorithm in order to increase its performance and its ease of use.

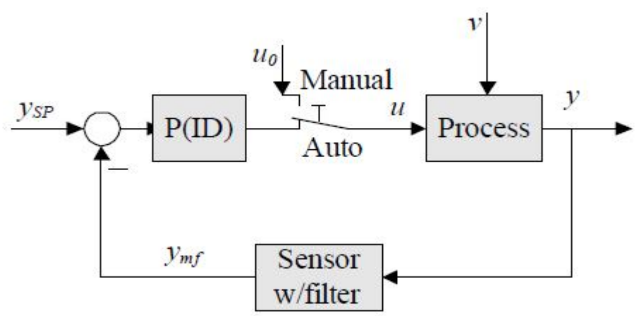


Fig 2: Diagram of PID controller

3.1 PERFORMANCE INDEX

True optimal nominal performance for nominal system parameters (Tp,T12 and B) means minimum undershoot (US) , minimum overshoot(OS),minimum settling time(ts) of Deltaf1,Deltaf2 of area 1 and area2 and tie line power floe deviation(Delta Ptie),minimum overall oscillations of the responses and good damping.

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 128-133 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

The following summed square error(SE) objective function, figure of demerit, ‘‘FDM’’ is adopted, FDM = ∑((Deltaf1)2+(Deltaf2)2+(DeltaPtie)2) for 100 samples over a time span of 20s.

To demonstrate robustness of the proposed control strategy , the performance indexes of integration time absolute error(ITAE) based on ACE is being used as,

$$ITAE = 1000 \int_{10}^{20} t[ACE1]\, d$$

4. *OVERVIEW OF GA*:

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. The basic concept of GAs is designed to simulate processes in natural system necessary for evolution, specifically those that follow the principles first laid down by Charles Darwin of survival of the fittest. As such they represent an intelligent exploitation of a random search within a defined search space, which is very effective at finding optimal solution to complex – real world problemsTo use a genetic algorithm, we must represent a solution to our problem as a genome (or chromosome). The genetic algorithm then creates a population of solutions and applies genetic operators such as mutation and crossover to evolve the solutions in order to find the best one(s).They operate on string structures. The String is a combination of binary digits representing a coding of the control parameters for a given problem. Many such Strings structures are considered simultaneously, with the most fit of these structures receiving exponentially increasing opportunities to pass on genetically important material to successive generation of string structures. In this way, Genetic algorithms search for many points in the search space at once, and yet continually narrow the focus of the search to the areas of the observed best performance.

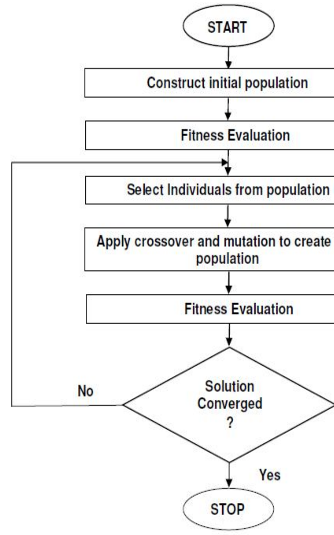


Fig 3: Genetic Algorithm flowchart

4. 4 ALGORITHM FOR GA BASED PID TUNING

The step by step algorithm for the method is explained as follows:

Step1: The intial Population matrix of N X 15 are generated by selecting a value with a probability over the search space (Gmin=0 , Gmax=10).

Step2: Simulating the Decentralized LFC block model by substituting each Chromosome values in the Gain parameter of PID controller and calculate Performance index using Integral Time Absolute error (ITAE) for each Chromosome which is taken as fitness value.

Step3: Select the best Parent from the population pool using roulette wheel selection Method.

Step4: Reproduce child for next Generation using three-point Crossover method.

Step5: Mutated the child for diversification and non-repeatability using Simple Mutation Method.

Step6: Select 20%of best Parent and 80%of best child for creating next population pool.

Step7: Check the iteration exceeds maximum iteration.

Step8:If yes Go to step2,otherwise the print best fitness value and best PID Gain values

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 128-133 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

5. SIMULATION RESULTS:

To illustrate the robustness of the proposed control strategy against contrast variations, simulations are performed for three scenarios of possible contracts under various operating conditions and large load demands.

5.1 SCENARIO 1:POOLCO BASED TRANSACTIONS

In this scenario, GENCOs participate only in load following control of their areas. It is assumed that a large step load of 0.1 pu is demanded by each DISCO in areas 1,2,3,4,5. Using the proposed method, the frequency deviation of all areas and the tie line power are quickly driven back to zero and have very small overshoot.

5.2 SCENARIO 2: COMBINATION OF POOL CO AND BILATERAL BASED TRANSACTIONS.

In this scenario, Disco's have the freedom to have a contract with any Genco in their two other areas. Consider that all the Disco's contract with available Genco's for power as per the following AGPM. All the Genco's participate in the LFC task. It is assumed that a large step load of 0.1 pu Mw is demanded by each Disco in the areas. Using the proposed method, the frequency deviation of all areas and the tie line power are quickly driven back to zero and have very small overshoot.

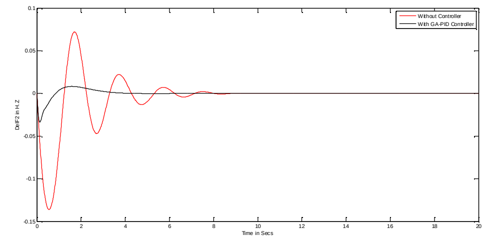
5.3 SCENARIO 3: COMBINATION OF POOL CO AND BILATERAL BASED TRANSACTIONS WITH CONTRACT VIOLATION.

In this case, Disco's may violate a contract by demanding more power than the specified in the contract. This excess power is reflected as a located load of the area(un contracted demand). Consider scenario 2 again, it is assumed that in addition to the specified contracted load demands, Disco in area 1, Disco 1 in area 2 and Disco 2 in area 3, Disco 1 in area 4 and Disco 1 in area 5 as large un contracted loads respectively.

The purpose of these scenarios is to test the effectiveness of the proposed controller against uncertainties and large load disturbances

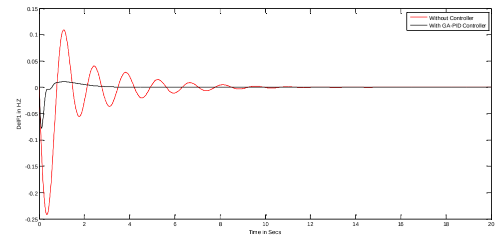
The simulation results show that proposed GA based PID controller tracks the load change and achieves good robust performance better for a wide range of load disturbances and possible contracted scenarios in the presence of plant parameters changes and nonlinearities.

$\Delta f_{1(hz)}$



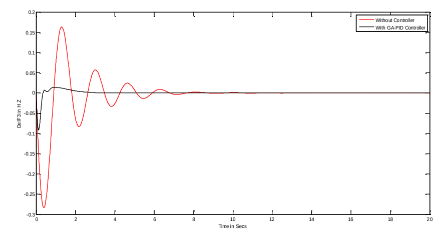
Time (sec)

$\Delta f_{2(hz)}$



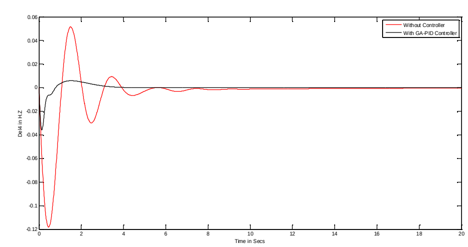
Time(sec)

$\Delta f_{3(hz)}$



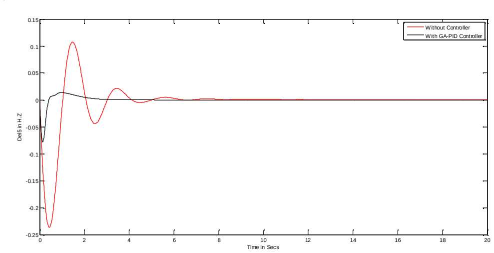
$\Delta f_{4(hz)}$

Time(sec)



Time(sec)

$\Delta f_{5(hz)}$



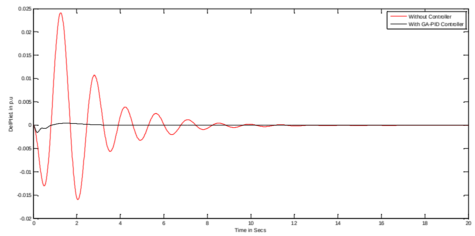
Time(sec)

Fig 4: (a) Frequency deviations for all scenarios

ISSN 2278-3091

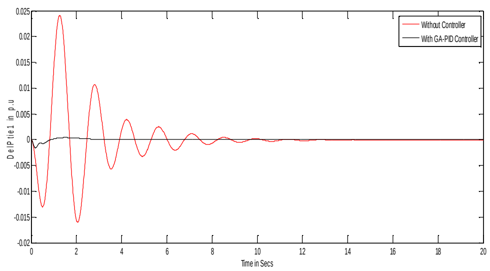
International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 128-133 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

$\Delta P_{tie1(puMW)}$



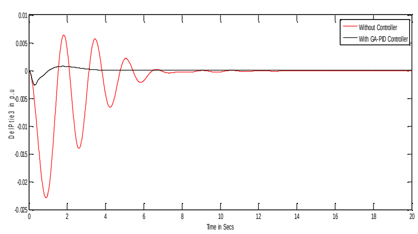
Time (sec)

$\Delta P_{tie2(puMW)}$

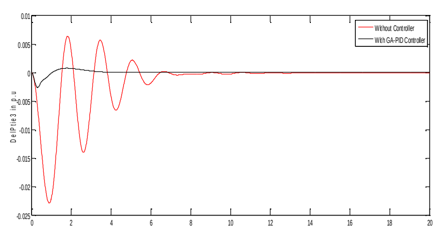


Time (sec)

$\Delta P_{tie3(puMW)}$

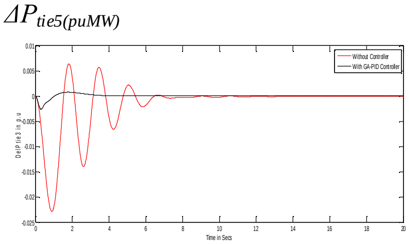


$\Delta P_{tie4(puMW)}$ *Time (sec)*



Time (sec)

$\Delta P_{tie5(puMW)}$



Time (sec)

Fig 5: (b) Tie - line power flows changes for all scenarios

6. CONCLUSION

The effectiveness and robustness of the proposed controller by GA algorithm was tested with different scenarios on five areas power system under possible contracts. Using ITAE as performance criteria the PID controller parameters are optimized using Evolutionary Genetic algorithm. From simulation results the dynamic response obtained for various operating conditions, it is inferred that the implementation of PID controller optimized by Evolutionary GA Algorithm results in an appreciable improvement in dynamics of frequency and tie-line oscillations, reduction in magnitude of overshoot, converging to the nominal values at steady state within convincible settling time. The simulation results show the ability of the controller to track the load fluctuations effectively and holding the frequency of GENCOs and tie-line power in the interconnectors at their nominal values. From the convergence characteristics it is inferred that the proposed algorithm converges rapidly to the optimal solution with in less number of iterations. The overall performance of PID controller tuned by the proposed algorithm exhibits improved dynamic performance over conventional PID controller over a wide range of operating conditions.

REFERENCES

[1] Ibrabeem PK, Kothari DP. Recent philosophies of automatic generation controlstrategies in power systems. IEEE Trans Power Syst 2005;20(1):346–57.

[2] Shayeghi H, Shayanfar HA, Jalili A. Load frequency control strategies: a stateof-the-art survey for the researcher. Energy Convers Manage 2009;50(2):344–53.

[3] Christie RD, Bose A. Load frequency control issues in power system operationsafter deregulation. IEEE Trans Power Syst 1996;11(3):1191–200.

[4] Donde V, Pai A, Hiskens IA. Simulation and optimization in an AGC system afterderegulation. IEEE Trans Power Syst 2001;16(3):481–9.

[5] Bhatt P, Roy R, Ghoshal S. Optimized multi area AGC simulation in restructuredpower systems. Int J Electr Power Energy Syst 2010;32(4):311–22.

[6] Abraham RJ, Das D, Patra A. Load following in a bilateral market with localcontrollers. Int J Electr Power Energy Syst 2011;33(10):1648–57.

[7] Liu F, Song YH, Ma J, Mei S, Lu Q. Optimal load-frequency control inrestructured power systems. IEE Proc Gen Trans Distrib 2003;150(1):87–95.

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.2, Pages : 128-133 (2013)
Special Issue of NCRTECE 2013 - Held during 8-9 February, 2013 in SMK Fomra Institute of Technology, OMR, Thaiyur, Kelambakkam, Chennai

[8] Rerkpreedapong D, Feliache A. Decentralized load frequency control for loadfollowing services. In: IEEE Proc Power Engineering Society Winter Meeting;2002. p. 1252–7.

[9] Sedghisigarchi K, Feliache A, Davari A. Decentralized load frequency control ina deregulated environment using disturbance accommodation control theory.In: Proc 34th SoutheasternSymp System Theory; 2002. p. 302–6.

[10] Menniti D, Pinnarelli A, Scordino N. Using a FACTS device controlled by adecentralized control law to damp the transient frequency deviation in aderegulated electric power system. Electric Power Syst Res 2004;72(3):289–98.

[11] Ghoshal SP. Multi area frequency and tie line power flow control with fuzzylogic based integral gain scheduling. J Inst Eng 2003;84:135–41.

[12] Barjeev T, Srivastava SC. A fuzzy logic based load frequency controller in acompetitive electricity environment. In: IEEE Power Engineering SocietyGeneral Meeting; 2003.

[13] Bevrani H. A novel approach for power system load frequency controllerdesign. In: IEEE/PES Transmission and Distribution Conference and Exhibition;2002. p. 184–9.

[14] Shayeghi H, Shayanfar HA, Jalili A. Multi-stage fuzzy PID power systemautomatic generation controller in deregulated environments. Energy ConversManage 2006;47:2829–45.

[15] Demiroren A, Zeynelgil HL. GA application to optimization of AGC in threearea power system after deregulation. Int J Electr Power Energy Syst2007;29:230–40.

[16] Lim KY, Wang Y, Zhou R. Robust decentralized load-frequency control ofmulti-area power systems. IEE Proc Part C 1996;143:377–86.

[17] Shayeghi H, Shayanfar HA. Decentralized robust AGC based on structuredsingular values. J ElectrEng 2006;57:305–17.

[18] Bevrani H, Mitani Y, Tsuji K. Robust decentralized AGC in a restructured power system. Energy Convers Manage 2004;45:2297–312.

[19] Bevrani H, Mitani Y, Tsuji K, Bevrani H. Bilateral based robust load frequencycontrol. Energy Convers Manage 2005;46(7–8):1129–46.

[20] Shayeghi H, Shayanfar HA. Design of decentralized robust LFC in a competitive electricity environment. J ElectrEng 2005;56(9–10):225–36.

[21] Shayeghi H. A robust decentralized power system load frequency contro. JElectrEng 2008;59(6):281–93.

[22] Rakhshani E, Sadeh J. Practical viewpoints on load frequency control problemin a deregulated power system. Energy Convers Manage 2010;51(6):1148–56.

[23] Tan W. Tuning of PID load frequency controller for power systems. EnergyConvers Manage 2009;50(6):1465–72.

[24] Tan W. Unified tuning of PID load frequency controller for power systems viaIMC. IEEE Trans Power Syst 2010;25(1):341–50.

[25] Tan W. Decentralized load frequency controller analysis and tuning formulti-area power systems. Energy Convers Manage 2011;52(5):2015–23.

[26] Tan W, Xu Z. Robust analysis and design of load frequency controller for powersystems. Electric Power Syst Res 2009;79(5):846–53.

S.Baghya shree received the B.E in Electrical and Electronics Engineering from the Thirumlai engineering college ,Kanchipuram in 2005,and M.E Degree in Power systems in 2009 in College of engg,Guindy, Anna university, Chennai. She is currently pursuing the Ph.D degree at Anna University, Chennai. She is Assistant Professor in Electrical & Electronic Engineering Department, University College of Engineering, Dindigul. His areas of interest are AGC, Power system operation & control.

S.Somaselvakumar received the B.E in Electrical and Electronics Engineering from the Raja college of engg & Tech, Madurai, in 2007,and MBA Degree in personnel in 2010 Kamaraj University,Madurai .He is currently pursuing the M.E Degree in Power management in Regional centre of Anna university, Chennai. His areas of interest are Transmission congestion Management and Power system stability.