A REVIEW ON CONTROL STRATEGIES FOR LFC IN DEREGULATED SCENARIO

By

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ABSTRACT

In power system studies, Load frequency control is an important issue to supply sufficient and reliable electric power with good quality. The main objective of LFC is to maintain load frequency and tie-line power flow within permissible limits by adjusting megawatt output of LFC generators, so as to accommodate fluctuating load demands. This paper presents a brief review of different control techniques to researchers on design of LFC controllers in deregulated environment. The overview of different control strategies are explained in brief, such as Classical and Modern feedback controllers, Adaptive, Intelligent and Robust control strategies along with their relative advantages and disadvantages. Finally, incorporating Facts devices and Energy storage devices in the investigation of LFC problem have also been discussed.

Keywords: LFC, Deregulated Power System, Robust Control, Intelligent Controller, Adaptive Control, Ancillary Service.

INTRODUCTION

In power system any sudden load disturbance causes deviation of frequency and tie line power exchange. Therefore, the load frequency control is plays crucial role in power system operation and control for supplying quality and continuity of power to the consumer. The main objective of LFC is to maintain load frequency and tie-line power flow within permissible limits by adjusting the steam input of generators so as to accommodate as per the requirement of fluctuating load demands.

In recent years, Electric power industry is transformed to deregulated environment. Because of privatisation of power sector, the world is moving towards deregulation of power industry. It is necessary to provide better service, quality and continuity of supply, so that the power industry is undergoing significant electrical reforms which adversely affect economy of the country. In deregulated industry, there are more number of pool players and buyers. Consumer has the opportunity to select better service provider among the pool.

Open Market Environment is the collection of unrestricted rules and economic benefits provided to sellers to provide better service and reliable supply. Power system under restructured scenario consists of GENCO's, TRANSCO's and ISO's.

In this paper, different control strategies have been discussed such as conventional, Modern Feedback controllers, Adaptive controllers, intelligent controllers, robust controllers and investigated LFC problem in deregulated environment with different ancillaries. In this paper, the salient features of each control strategy are thoroughly discussed and their relative advantages and disadvantages are discussed.

In this paper, section1 represents the modelling of deregulated system for LFC problem. In section2 various control techniques for LFC are described. In section3, control strategies for LFC problem in deregulated environment with different ancillaries are discussed. In section4, LFC schemes with HVDC link are discussed.

1. Mathematical Modelling of Restructured P ower System for Load Frequency Control

In the open market environment of the power system the Vertically Integrated Utility (VIU) no longer exists. Deregulated system consists of GENCOs, DISCOs, transmission companies and Independent System Operators (ISO). However the common goal is to keep frequency constant. In this paper deregulated system contains two areas. Each area consists of two generators and also two discos as shown in Figure1. The block diagram of generalized LFC scheme for a two area deregulated

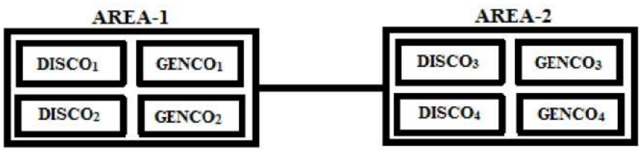

Figure 1. Configuration of two-area Power System

thermal plants is shown in Figure 2. A DISCO can contact individually with any GENCO for power and these transactions are made under the supervision of ISO.

In this open market scenario, any GENCO in one area may supply DISCOs in the same area as well as DISCOs in other areas. In other words, for restructured system having more number of GENCOS and DISCOs, any DISCO may contract with any GENCO in another control area independently. This is called as "bilateral transaction". These transactions made through an Independent System Operator (ISO). The main purpose of ISO is to control many ancillary services, one of them is LFC. In deregulated environment, any DISCO has the liberty to purchase MW power at competitive price from different GENCOs, which may or may not have contract with the same area as the DISCO.

For practice, GENCO–DISCO contracts are represented with 'DISCO Participation Matrix' (DPM). Essentially, DPM gives the participation of a DISCO in contract with a GENCO. In DPM, the number of rows is equal to the number of GENCOs and the number of columns is equal to the number of DISCOs in the system. Any entry of this matrix is a fraction of total load power contracted by a DISCO toward a GENCO. As a result, total of entries of column belonging to DISCO1 of DPM is Σ cpfij=1. The corresponding DPM to the considered power system having two areas and each of them including two DISCOs and two GENCOSs is given as follows.

1.1 DISCO Participation Matrix

$$DPM = \begin{bmatrix} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{bmatrix}$$

Where cpfs represent "contract participation factor". For example, the fraction of the total load power contracted by DISCO1 from GENCO2 is represented by (2, 1) entry. Off-

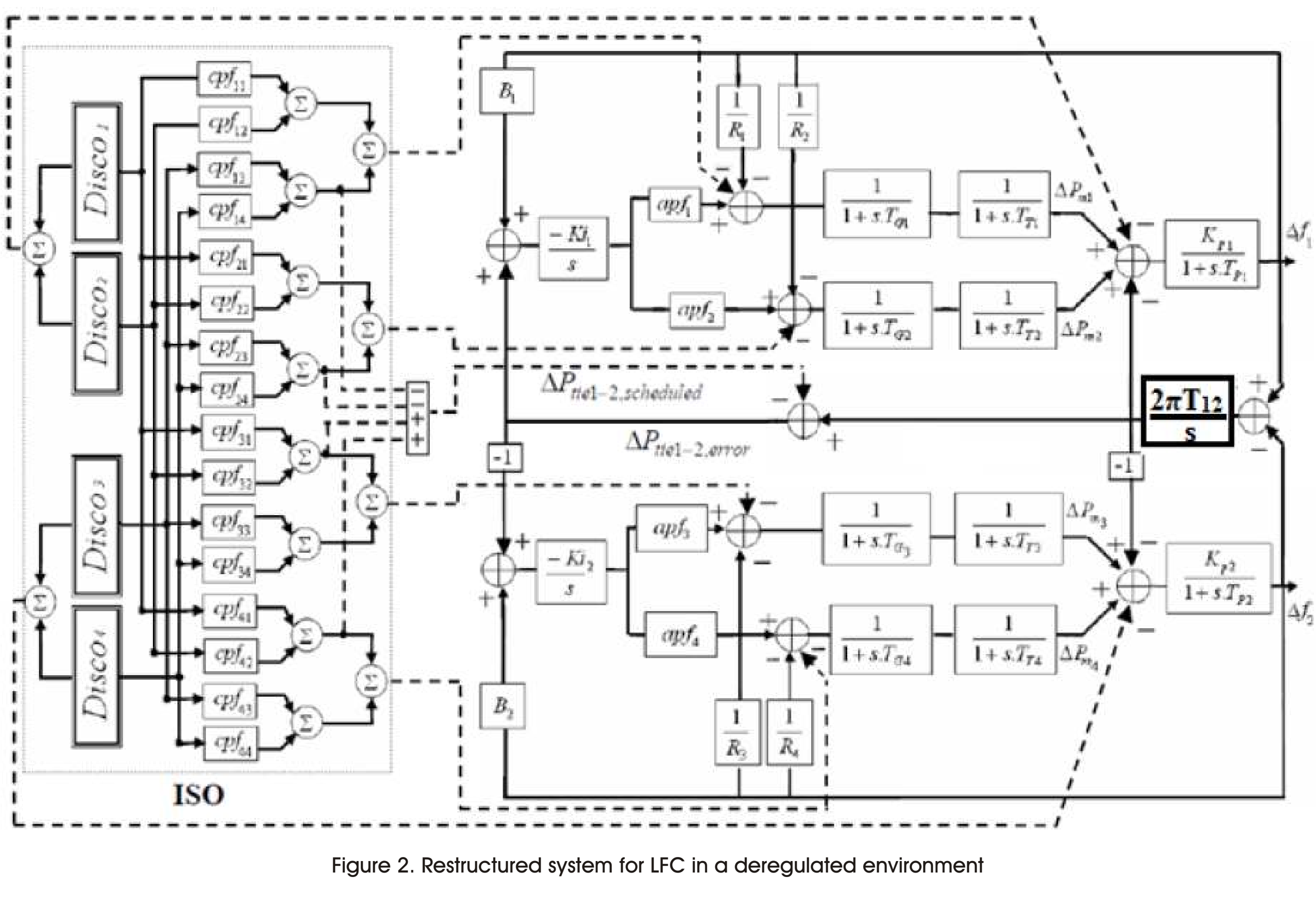

Figure 2. Restructured system for LFC in a deregulated environment

diagonal blocks correspond to demands of the DISCOs in one area to the GENCOs in another area. In the deregulated case, when the load demanded by a DISCO changes, a local load change is observed in the area of the DISCO. Since there are a lot of GENCOs in each area, area control error (ACE) signal must be shared by these GENCOs in proportion to their contributions. The coefficients, which represent this sharing, are called as "ACE participation factors (apf) and $\Sigma^{M}_{j=1} apf_{ij} = 1$ where 'm' is the number of GENCOs in each area. As different from conventional AGC systems, any DISCO can demand power from all of the GENCOs. These demands are determined by cpfs, which are contract participation factors, as load of the DISCO.

Where cpfs represent contact participation factor and which represents bilateral contact between different GENCOs and DISCOs. The actual steady state power flows on the tie line are given as:

$$\Delta P_{tie1-2\,scheduled} = \Sigma_{j=1}^{2} \Sigma_{j=3}^{4} cpfij\ \Delta PL - \Sigma_{j=3}^{4} \Sigma_{j=1}^{2} cpfij \qquad [1]$$

$$\Delta P_{tie1-2error} = \Delta P_{tie1-2schedule} - \Delta P_{tie1-2actual} \qquad [2]$$

The dotted and dashed lines in Figure 2 shows the demand signals based on the possible contracts between GENCOS and DISCOs that carry information as to which GENCO have to follow a load demanded by that DISCO. These new information signals were absent in the traditional LFC scheme. As there are many GENCOS in each area, the ACE signal has to be distributed among them due to their ACE participation factor in the LFC task and

$$\sum_{j=1}^{ni} apf_{ji} = 1 \qquad [3]$$

The equation for area control error(ACE)

$$ACE_i = B_i \Delta f_{ierror} + \Delta P_{ierror} \quad i = 1, 2, \qquad [4]$$

Equations of two area power system with thermal plants are given in state space representation.

$$\dot{x} = Ax + Bu \qquad [5]$$

$$y = cx$$

$$u = [\Delta P_{L1}\ \Delta P_{L2}\ \Delta P_{L3}\ \Delta P_{L4}]^T \qquad [6]$$

$$x = [\Delta f_1\ \Delta f_2\ \Delta P_{G1}\ \Delta P_{G2}\ \Delta P_{G3}\ \Delta P_{G4}\ \Delta P_{m1}\ \Delta P_{m2}\ \Delta P_{m3} \qquad [7]$$

$$\Delta P_{m4}\ \int ACE_1\ \int ACE_2\ P_{tie1-2}]^T \qquad [8]$$

2. Control Techniques For LFC in Deregulated Environment

Basically various control methods proposed by authors are categorised as (i) Conventional and Modern feedback controllers, (ii) Adaptive control methods, (iii) ANN control approach, (iv) Robust control techniques.

2.1 Conventional and modern feedback control approach

In olden days, using conventional control methods like PI controller for LFC problem, the dynamic response of the system is not in steady state for longer time and it has more overshot and more settling time. Because of this reason many authors proposed modern optimal feedback theory based LFC schemes appeared in the literatures [1],[2], [3].

In 2008, Sadeh.J, Rakhshani.E [3] discussed optimal output feedback method for LFC problem in multi area deregulated power system and demonstrated the effectiveness of output feedback controller compared to conventional PI controller. The only disadvantage with optimal output feedback method is that all state variables are not available for feedback. So, Sadeh.J, Rakhshani.E [4, 5, 6] proposed a reduced order observer based controller for LFC problem. In these papers the proposed observer based controller gives good dynamic response compared to optimal state feedback controller. The only disadvantage with this method is all state variables are not available for measurement of feedback parameters.

2.2 Adaptive control methods

In last three decades Adaptive control techniques have been a area of researchers. Adaptive control system can be divide into two parts one is self-tuning controllers and modern reference controllers. The main functional aim of the adaptive control technique is to make the system control less sensitive to parametric variations when system is subjected to sudden disturbance.

In 2003, the authors Barjeev Tyagi, Srivastava.S.C [7] presented the design of fuzzy logic based controller for LFC in a deregulated environment. This proposed controller has been applied on a 75 bus Indian power system and the results are compared with those obtained by using classical integral controller. Later in 2006 the authors A. Demiroren, and H.L. Zeynelgil [8] investigated on Genetic Algorithm (GA) approach, which was used for optimization of integral gain and bias factors, is applied to three-area power system after deregulation. The performance of the system is demonstrated for different operating cases in terms of conventional control gains and bias factors optimised using real coded GA.

In 2011, E.S.Ali and S.M. Abd-Elazim[9] developed a novel algorithm for optimization and control, proposed BFOA based controller and tested on two area non-reheat thermal system. The performance of the proposed controller has been evaluated with the performance of conventional PI controller and PI controller tuned by genetic algorithm (GA) in order to demonstrate the superior efficiency of proposed BFOA in tuning PI controller.In the same year, Abedinia.O, Naderi.M.S, Ghasemi[10] suggested a honey bee matting optimization based fuzzy(HBMOF) controller is developed for load frequency control problem in deregulated environment. The effectiveness of proposed method is demonstrated on a deregulated system with possible contact scenario under large load disturbances in comparison with PSO, GA fuzzy controllers.

In 2012, authors Abedinia.O, Amjady.N and Naderi.M.S [11] suggested a Multi stage Fuzzy (MSF) PID controller based on a Strength Pareto Honey Bee Mating Optimisation (SPHBMO) as a solution for LFC problem in deregulated environment. The objective of this LFC controller was to minimise the transient deviation caused due to small load perturbations which continuously disturb the power system. The results of this proposed method are compared with that of classical fuzzy PID controller. In the same year, Debbarma.S and Saikia.L.C [12] developed a Bacterial Foraging (BF) based fractional order PID (FOPID) controller for LFC problem and proposed controller is tested on a two equal area thermal system considering single stage reheats turbine and approximate Generator rate constant.

In 2012 Srinivasa Rao .C[18] described the analysis of load frequency control problem under deregulated environment by considering adaptive neuron fuzzy interference systems (ANFIS).

2.3 Intelligent Approach

In practise, because of non-linear behaviour of power systems, it is transformed to reduced order linear model without changing system characteristics. However, these models are valid only within certain specific operating ranges, and a different model may be required in the wake of changing operating conditions or the control system should adopt the new system model parameters. On the other hand, due to the nonlinearity and more number of parameters of the power system, classical and non-flexible LFC control strategies not give satisfactory solution. Thus, for the purpose of evaluating the performance of such systems, a flexible method was developed. In last few decades, researchers developed modern intelligent methods such as ANNs, Fuzzy logic and GAs have solved the above discussed problems in a effective manner.

The human understanding capability to control nonlinear complex systems has encouraged researchers to pattern controls on human neural network systems. ANNs, with their massive parallelism and ability to track any type of nonlinearities due to parameter variations. Because of this, now a day's these techniques are widely used in the area of non-linear control problems, certainly when the system is operating within and beyond the non-linear range.

Now-a-days Fuzzy logic is widely used in alldomains of industry and science. One among is power system and control. On the other hand, their robustness and reliability make fuzzy controllers useful for solving control problems in power systems. Unlike traditional control theory, which is essentially based on mathematical models of controlled plants, the fuzzy control methodology tries to establish the controller directly from domain experts or operators who are controlling the system manually and successfully. To consider various power system aspects, many studies have been reported for design of a fuzzy logic based LFC controllers.

In 2005 Le-Ren Chang-Chien Chien-Sheng Lo Ko-Shien Lee [13],demonstrated the features of Artificial-neural network base system control error(ANNSCE) model in tracking a single area's dynamics in gauging the various impacts on the dynamic LFC problem and identifying system dynamics that may be further used as reference in controlling supplementing LFC logic.

In 2006 Bevrani, Hassan, Hiyama, Takashi, Mitani, Yasunori, Tsuji, Kiichiro, & Teshnehlab, Mohammad [14] proposed a new control strategy based on artificial flexible neural networks (FNNs) for LFC problem for large scale power systems in deregulated environment. This proposed controller reduces the effect of disturbances and achieves acceptable frequency regulation in the presence of load variations and line disturbances.

In 2008 S.H. Hosseini, A.H. Etemadi[15]described a control scheme based on Artificial Neuro-Fuzzy Interference System(ANFIS) for LFC problem in deregulated environment. The efficiency of the proposed ANN controller was demonstrated on power system in deregulated environment.

In 2010 a new adaptive controller based on unsupervised learning approach, named Feedback Error Learning (FEL) was proposed by Sabahi. K, Narimani. E.Faramarzi. A [16] for LFC problem in restructured scenario. In the FEL strategy Feed forward and feedback controllers are used for the control of system parameters. Simultaneously the feedback controller contains a classical PID controller and Feed forward controller is a neural network based controller. In [16] Dynamic Neural Network (DNN) is used as a feed forward controller.

An intelligent Fuzzy Gain Scheduled Proportional Integral (FGSPI) controller was proposed for LFC problem in deregulated environment in 2011 [17] by Sathans.S, Swarup.A. The proposed FGSPI controller was compared against conventional PI controller, State Feedback Linear Quadratic Regulator (LQR) controller. This proposed intelligent controller gives better performance than conventional controller.

2.4 Robust Controller approach for LFC problem in Deregulated Environment

In power system, each control area contains different kinds of uncertainties and disturbances due to change in system parameters. The optimal LFC regulators designed based on normal system parameters values is certainly not suitable for LFC problem. This could result in a degraded system dynamic performance and sometimes also in the loss of system stability, thus considerable efforts have been made to design LFC controllers with better performance to cope with system parametric changes using various robust methods.

In robust control approaches, the control objective is to design load frequency controller to not only meet normal stability and normal performance requirement, but also guarantee in robust stability and robust performance. It should be noted that in robust control design approaches, it is possible to use the physical understanding of power system and consider the uncertainties for the synthesis procedure. However, the large model order, uncertain connection between subsystem broad parameter variations and elaborated organisational structure of power systems preclude the direct application of standard robust control methodology.

In 1996,Ali Feliachi[19] discussed the design of robust H∞ load frequency controller for electric power systems in deregulated environment and also the design of a reduced H∞ load frequency controller[20] for interconnected large scale Electric power system in deregulated environment. In 1999 H. Bevrani [21] developed a robust load frequency controller for LFC problem in deregulated environment based on □-synthesis approach.

In 2004 H. Bevrani, Y. Mitani, K. Tsuji addressed a new decentralised robust controlled strategy [22] to adopt well tested classical LFC system to change the environment of power system operation under deregulation based on bilateral LFC scheme. In this paper author formulated LFC problem as a multi objective control problem and the mixed H2 /H∞ control technique is used to synthesize the desired robust controllers for LFC design in multi-area deregulated power system. The effectiveness of propose control strategy was compared with pure H∞ controller. This proposed method minimises the effect of disturbances and maintain robust performance.

In [23] authors Bevrani.H, Mitani.Y and Tsuji. K demonstrated the design and effectiveness of PI based multi objective robust load frequency controller for electrical power system in restructured scenario. In [24] H. Bevrani, Y. Mitani, and K. Tsuji suggested a robust decentralised controller for LFC problem in Deregulated Environment.

In 2007 H. Shayeghi, H.A. Shayanfar, O.P. Malik suggested Decentralised Radial Basis Function Neural Network (RBFNN) based controller [25] for LFC problem in deregulated power system. This newly developed ANN-Robust controlled strategy combines the advantage of neural networks and mixed H2 /H∞ control techniques to prove robust performance and lead to a flexible controller with simple structure that is easy to implement. The effectiveness of proposed method is demonstrated on a three-area deregulated system. This proposed controller gives more robust performance compared with mixed H2 /H∞ controllers in the presence of plant parameter changes and system non-linearities.

In 2009 authors Rezvantalab. J, Kazemi. M.Hand Seddigh. A.K suggested a novel robust decentralised controller using Quantitative Feedback Theory (QFT) [26] to solve LFC problem in a restructured power system that operates under deregulated environment. The effectiveness of proposed control technique is tested on a two-area power system. This proposed gave a good robust performance when compared with conventional integral controller.

3. Various Control Strategies for LFC problem in Deregulated Environment with Different Ancillary Services

Ancillary services are the services available in support to the basic services of generating real power and injecting it into the interconnected system. They are essential to the power system security, management, facilitate trading in electricity an ensure that electricity supplies are available,reliable and qualitatively acceptable. These ancillary services [29] are usually fact devices which are connected in series with interconnected tie-line for the purpose of better LFC performance, reactive power management, voltage control of deregulated power system.

In 1999, Ngamroo. I, Mitani.Y, Tsuji. K proposed, a new robust control strategy for load frequency control [27] for load frequency control for two area deregulated system where Solid State Phase Shifter (SSPS) is used as an ancillary service which is connected in series with tie-line. The effectiveness of proposed H∞ , phase shifter for LFC is confirmed in a two area power system with several system uncertainties and sudden load disturbances.

Authors Kazemi.A and Andami.H suggested influences of fact devices [28] on deregulated electric power systems and their technical and economic benefits.

In 2008, authors H. Shayeghia, A. Jalilib and H.A. Shayanfarc presented a new robust decentralised controller based on mixed H2 /H∞ control technique [30] for load frequency control problem including super conducting Magnetic Energy Storage (SMES) in a deregulated electricity environment. This newly developed design strategy combines advantage of H2 and H∞ control syntheses and give powerful multi-object design addressed by the Linear Matrix Inequality (LMI) technique. This proposed control strategy with SMES unit improves Dynamic performance of system against parametric uncertainties and wide range of load disturbances.

In [31] authors, H. Shayeghi , H.A. Shayanfar and A. Jalili, described a Particle Swarm optimisation (PSO) based tuning of PID controller parameters for load frequency control in multi area deregulated system introducing Thyristor Controlled Phase Shifter(TCPS) used as an ancillary service. The effectiveness of this proposed control strategy is tested on a three-area restructured power system under different operating conditions and system nonlinearities. Analysis reveals that TCPS is quite capable of suppressing the frequency and tie-line power oscillations effectively compared to that obtained without TCPS for a wide range of parametric changes, larger load demands and disturbances even in the presence of system nonlinearities.

In [32] authors, Praghnesh Bhatt and Ranjit Roy, S. P. Goshen, investigated the effect of ofStatic Synchronous Series Compensator(SSSC) in series with tie-line and SMES at the terminals of each control area. In the design of controller, the parameters of SSCS and SMES controllers are optimised through Craziness Based Particle Swarm optimization algorithm in order to have optimal transient response of the system under different transactions in competitive electricity market.

4. LFC Schemes In Deregulated Environment with HVDC Link

Two control areas with different operating frequencies can be interconnected with HVDC link (Asynchronous tie-line).

Iauthors Kumar.T.A, Krishna.V.S, Ramana.N.V, demonstrated the dynamic performance of Three-area thermal deregulated system interconnected with AC tie-line parallel with HVDC link. This interconnection gives better dynamic response compared to the same system when interconnected with AC tie-line.

Authors Ibraheem, Prabhat Kumar, Naimul Hasana & Yadav

Singh described the design of optimal load frequency controller [34] designed for LFC problem in deregulated environment for two control areas connected with AC tie-line in parallel with HVDC link.

Conclusion

Load frequency control is one of the profitable ancillary services in deregulated power system. The goal of LFC is to achieve zero steady state error and maintain scheduled frequency due to sudden change in load demands. This paper is mainly concentrated on the recent research in the area of LFC controllers design. In the literature, various control methods, their salient features and relative advantages and disadvantages are described.

It can be concluded that each control strategy has certain salient features, relative advantages and disadvantages when compared to other control strategies. So, there are no particular rules that a particular technique is more suitable for LFC problem. It can be expected that all the control strategies discussed in this paper provides a route map (path) for researchers for LFC problem in deregulated environment.

Nomenclature

ACE	Area Control Error
apf	Area control error Participation factor
ANN	Artificial Neural Networks
ANNSCE	Artificial Neural Networks based System Control Error
ANFIS	Artificial Neuro Fuzzy Interference System
B	Frequency Bias
BF	Bacterial Foraging
BFOA	Bacterial Foraging Optimization Algorithm
Cpf	Contract Participation Factor
DISCOs	Distribution Companies
DPM	DISCO Participation Matrix
DNN	Dynamic Neural Network
f	Area frequency
FOPID	Fractional Order PID
FNN	Flexible Neural Networks
FEL	Feedback Error Learning
FGSPI	Fuzzy Gain Scheduled Proportional Integral
GENCOs	Generation Companies
GA	Genetic Algorithm
HBMOF	Honey Bee Mating Optimization Based Fuzzy
HVDC	High Voltage Direct Current
ISO	Independent System Operator
K_p	Power system equivalent gain
LFC	Load frequency control
LQR	Linear Quadratic Regulator
LMI	Linear Matrix Inequality
MSF	Multi Stage Fuzzy
P_m	Turbine power output
P_G	Governor Output
P_d	Area load disturbance
PI Controller	Proportional Integral Controller
PSO	Particle Swarm Optimization
QFT	Qualitative Feedback Theory
R	Speed Regulation
RBFNN	Radial Basis Function Neural Network
SPHBMO	Strength Pareto Honey Bee Mating Optimization
SSPS	Solid State Phase Shifter
SMES	Superconducting Magnetic Energy Storage
SSSC	Static Synchronous Series Compensator
T_t	Turbine Time Constant
T_g	Governor Time Constant
T_p	Power system equivalent time constant
T_{12}	Tie line synchronizing coefficient between areas1-2.
TRANSCO	Transmission system
TCPS	Thyristor controlled Phase shifter
VIU	Vertically Integrated Utilities

References

[1]. Vaibhav Donde, M., Pai, A., & Hiskens. (2001). Simulation and Optimization in an AGC System after

Deregulation, *IEEE Transactions on power systems,* Vol. 16, No.3.

[2]. **Liu, F., Song Y. H., J. Ma., S. Mei., & Q. Lu. (2003).** Optimal load-frequency control in restructured power systems, Generation, Transmission and Distribution, *IEEE Proceedings,* 2003. Vol. 150.

[3]. **Sadeh, J., & Rakhshani, E. (2008).** Multi-area load frequency control in a deregulated power system using optimal output feedback method, Electricity Market, 2008. *5th International Conference on European*.

[4]. **Sadeh, J., & Rakhshani, E. (2008).** Simulation of two-area AGC system in a competitive environment using reduced-order observer method, Electricity Market, EEM. 5th *International Conference on European*.

[5]. **Sadeh, J., & Rakhshani, E. (2009).** A Reduced- Order Estimator with Prescribed Degree of Stability for Two-Area LFC System in a Deregulated Environment, *Power Systems Conference and Exposition, PSCE '09,IEEE/PES*.

[6]. **Sadeh, J., & Rakhshani, E. (2010).** Practical viewpoints on load frequency control problem in a deregulated power system, *Energy Conversion and Management,* Volume 51, Issue 6, Pages 1148–1156.

[7]. **Barjeev, Tyagi, & Srivastava, S.C. (2003).** A fuzzy logic based load frequency controller in a competitive electricity environment, *Power Engineering Society General Meeting, IEEE,* Volume: 2.

[8]. **Demiroren, A., & Zeynelgil, H. L. (2007).** GA application to optimization of AGC in three-area power system after deregulation, Elsevier, *International Journal of Electrical Power & Energy Systems*, Volume 29, Issue 3, Pages 230–240.

[9]. **Ali, E. S., & Abd Elazim, S. M. (2011).** Bacteria foraging optimization algorithm based load requency controller for interconnected power system, Elsevier, *International Journal of Electrical Power & Energy Systems.* Volume 33, Issue 3, Pages 633–638.

[10]. **Abedinia, O., Naderi, M. S., & Ghasemi. (2011).** A Robust LFC in deregulated environment: Fuzzy PID using HBMO, *10th International Conference on Environment and Electrical Engineering (EEEIC),* Publication Page(s): 1 – 4.

[11]. **Abedinia, O., Amjady, N., & Naderi, M. S. (2012).** Multi-stage Fuzzy PID Load Frequency Control via SPHBMO in deregulated environment, *11th International Conference on Environment and Electrical Engineering (EEEIC),* Page(s): 473 – 478.

[12]. **Debbarma. S., & Saikia. L. C. (2012).** Bacterial foraging based FOPID controller in AGC of an interconnected two-area reheat thermal system under deregulated environment, Advances in Engineering, *International Conference on Science and Management (ICAESM),* Publication, Page(s): 303 – 308.

[13]. **Le-Ren Chang-Chien Chien-Sheng Lo Ko- Shien Lee. (2005).** Application of ANN-SCE Model on the Evaluation of Automatic Generation Control Performance, *Proceeding (465) Energy and Power Systems.*

[14]. **Bevrani, Hassan., Hiyama, Takashi., Mitani, Yasunori., Tsuji, Kiichiro., Teshnehlab., & Mohammad. (2006).** Load-frequency regulation under a bilateral LFC scheme using flexible neural networks. *Engineering Intelligent Systems,* 14(2), pp. 109-117.

[15]. **Hosseini, S. H., & Etemadi, A. H. (2008).** Adaptive neuro-fuzzy inference system based automatic generation control, Elsevier, *Electric Power Systems Research* 78 1230–1239.

[16]. **Sabahi, K., Narimani, E., & Faramarzi, A. (2010).** Dynamic neural network for AGC in restructure power system, *IEEE International Conference on Power and Energy (PECon),* Page(s): 594- 599.

[17]. **Sathans, S., & Swarup, A. (2011).** Intelligent Load Frequency Control of Two-Area Interconnected Power System and Comparative Analysis. *2011 International Conference on Communication Systems and Network Technologies (CSNT),* Page(s): 360 – 365.

[18]. **Srinivasa Rao, C. (2012).** Adaptive Neuro Fuzzy based Load Frequency Control of multi area system under open market scenario. Science and Management (ICAESM), *International Conference on Advances in Engineering*, Page(s): 5 – 10.

[19]. **Ali, Feliachi. (1996).** On Load Frequency Control in a Deregulated Environment, *Proceedings of the IEEE International Conference on Control Applications Dearborn,* MI September 15-18; 437-441

[20]. Ali, Feliachi. (1997). Reduced H∞ Load Frequency Controller in a Deregulated Electric Power System Environment, *Proceedings of the 36th Conference on Decision & Control San Diego,* California USA*.

[21]. Bevrani, H. (1999). Robust load frequency controller in a deregulated environment: a μ- synthesis approach. Control Applications. *Proceedings of the IEEE International Conference on control applications,* Page(s): 616-621 Vol. 1.

[22]. Bevrani, H., Mitani, Y., & Tsuji, K. (2004). Robust decentralized AGC in a restructured power system, Elsevier, *Energy Conversion and Management* 45, 2297–2312.

[23]. Bevrani, H., Mitani, Y., Tsuji, K. (2004). Pibased multi-objective load-frequency control in a restructured power system, *SICE Annual Conference,* Volume: 2 Page(s): 1745 – 1750.

[24]. Bevrani, H., Mitani, Y., & Tsuji, K., (2004). Robust Decentralized LFC Design In a Deregulated Environment, *IEEE International Conference on Electric Utility Deregulation, Restructuring and Power Technologies (DRPT2004),* Hong Kong.

[25]. Shayeghi, H., Shayanfar, H. A., & Malik. O. P. (2007). Robust decentralized neural networks based LFC in a deregulated power system, Elsevier, *Electric Power Systems Research,* Volume 77, Issues 3–4, Pages 241– 251.

[26]. Rezvantalab, J., Kazemi, M. H., & Seddigh, A.K. (2009). Multi-area robust decentralized Load Frequency Controller design in a restructured power system using Quantitative Feedback Theory, Electric Power and Energy Conversion Systems, *EPECS '09. International Conference on Publication,* Page(s): 1 – 6.

[27]. Ngamroo, I., Mitani, Y., & Tsuji, K., (1999). Robust Load frequency control by solid-state phase shifter based on $\mathcal{H}\infty$ control design, Power Engineering Society Winter Meeting, *IEEE*, Page(s): 725 - 730, Vol.1.

[28]. Kazemi, A., & Andami, H. (2004). FACTS devices in deregulated electric power systems: a review. *Proceedings of the IEEE International Conference on Electric Utility Deregulation, Restructuring and Power Technologies,* Page(s): 337 - 342, Vol.1.

[29]. Sterpu, S., Bésanger, Y., & Hadj Saïd, N. (2005). Ancillary Services Performance Control in Deregulated Power Systems. *Power Engineering Society General Meeting, IEEE*, Page(s): 3048- 3054 Vol. 3.

[30]. Shayeghia, H., Jalilib, A., & Shayanfarc, H. A. (2008). A robust mixed H2/H∞ based LFC of a eregulated power system including SMES. Elsevier, *Energy Conversion and Management,* Volume 49, Issue 10, Pages 2656–2668.

[31]. Shayeghi, H., Shayanfar, H. A., & Jalili, A., (2009). LFC Design of a Deregulated Power System with TCPS Using PSO. World Academy of Science, Engineering and Technology.

[32]. Praghnesh, Bhatt., Ranjit, Roy., Ghoshal, S. P. (2010). Coordinated Control of SSSC and SMES in Competitive Electricity Market for Load Frequency Control. *IEEE 11th International Conference on Probabilistic Methods Applied to Power Systems (PMAPS),* 14-17, Page(s): 42- 47.

[33]. Kumar. T. A., Krishna. V. S., & Ramana. N. V. (2011). Improvement of dynamic performance of three area thermal system under deregulated environment using AC tie-line parallel with HVDC link, *International Conference on Power and Energy Systems (ICPS),* 22-24, Page(s): 1 – 6.

[34]. Ibraheem, Prabhat Kumar, Naimul Hasana & Yadav Singh, (2012). Optimal Automatic Generation Control of Interconnected Power System with Asynchronous Tie lines under Deregulated Environment, *Electric Power Components and Systems,* Volume 40, Issue 10.

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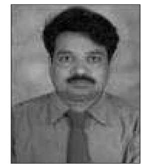

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