Middle-East Journal of Scientific Research 25 (6): 1308-1314, 2017
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2017.1308.1314

Flower Pollination Algorithm Based Decentralized Load-Frequency Controller for a Two-Area Interconnected Restructured Power System Considering Gas Turbine Unit

[1]G. Ganesan @ Subramanian, [2]I.A. Chidambaram and [3]J. Samuel Manoharan

[1]Research Scholar, Department of Electrical Engineering, Annamalai University, Annamalainagar, Tamil Nadu
[2]Professor, Department of Electrical Engineering, Annamalai University, Annamalainagar, Tamil Nadu
[3]Professor, Department of Electronics & Communication Engineering, Bharathiyar College of Engineering & Technology, Karaikal, Pondicherry

Abstract: This paper deals with the design implementation of a decentralized load-frequency controllers for a two-area thermal reheat interconnected restructured power system without and with Heavy Duty Gas Turbine (HDGT) unit. Area-I is considered to have two GENCOS and two DISCOS and area II with two GENCOS and two DISCOS. A new nature-inspired algorithm based on the characteristics of pollination process of flowers plants namely Flower Pollination Algorithm (FPA) has been adopted to tune the PI controllers in order to restore the frequency and the net interchanges to their desired values for each control area in the shortest possible time. The optimal controller gains Proportional gain (K_P) and Integral gain (K_I) are obtained from the performance index curves based on Integral Square Error (ISE) criterion for the AGC problem which are optimized through FPA in order to achieve the optimal transient response of the system under different types of possible transactions in restructured environment. The simulation results reveal that an improved dynamic response of the system can be obtained following a small load disturbance in the bilateral trades for the restructured power system considered with HDGT than that of the system without HDGT unit considered with the same Disco participation matrix.

Key words: Flower Pollination Algorithm (FPA) · Load- Frequency Control (LFC) · DISCO Participation Matrix · Area Participation Factor · Heavy Duty Gas Turbine

INTRODUCTION

Load-frequency control (LFC) plays a paramount role for the reliability of power system. Based on two objectives, frequency and tie- line power exchanges are weighted together by a linear combination to a single variable called ACE which is used as the control signal in the LFC problem [1-3]. As the LFC system is responsible for the frequency control and power exchange for any sudden load perturbation which may cause larger deviations in tie-line power exchanges and the frequency. The main task of the LFC is to provide optimum control signals to regulate not only the real power within a prescribed area in response to changes in area frequency but also the tie-line loading so as to maintain at the prescribed values by adopting various control strategies [4]. The active power control of a multi-area interconnected power system be ensured effectively by

- Counteracting the load fluctuation to keep the intra-area active power balance
- Stabilizing the system frequency to the rated value
- Regulating the inter-area tie-line power to the scheduled value.

In addition, the LFC should be capable of realizing the inter-area power support in emergencies (power shortage existing in a certain area). Therefore, the LFC is particularly important for the reliable and stable operation of the power system.

Corresponding Author: G. Ganesan @ Subramanian, Research Scholar, Department of Electrical Engineering, Annamalai University, Annamalainagar, Tamil Nadu, India.

Presently worldwide, the electric power industry has evolutionary changes from vertically integrated utility scenario to restructured scenario. In restructured environment there is no a single utility owned and operated generation, transmission and distribution systems. So the power is provided at regulated rates in a deregulated scenario, where, competitive companies sell unbundled power at lower rates. Many research studies have been made for the LFC in a deregulated environment over the last decades [4, 5]. These studies were made to modify the conventional LFC system by taking into account of the effect of bilateral contracts on the dynamics and to ensure a better dynamic transient response of system under competitive environment. The conventional control strategy for the LFC problem be enhanced effectively by incorporating Proportional and Integral Controllers in an optimal manner for the deregulated system which has got the combination of Generation companies (GENCOs), Distribution companies (DISCOs), Transmission companies (TRANSCOs) and Independent system operators (ISO). All the transactions have to be cleared through an impartial entity called an independent system operator (ISO). The ISO has to control a number of so-called ancillary services, one of which is AGC. The unbiased entity, ISO, has to control many ancillary services, one of them is LFC. In deregulated environment, 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.

The LFC design methodologies implemented so far mainly aim for the frequency stabilization and the ensuring zero ACE in each control area. In this pattern, the ACE control may conflict with the system frequency recovery even though optimal decentralized controllers are implemented. In view of the drawback in the restructured scenario this paper proposes a design methodology by incorporating Heavy Duty Gas Turbine unit [6-10] along with the two-area thermal restructured power system. For the past two decades, major hike in power demand has been seen from the industrial and domestic side all around the world. In order to meet this demand major changes have been made in power system to improve the efficiency and to increase the power generating capabilities. Various control methodologies [11-14] were adopted to tune the Proportional and Integral Controllers (PI controllers) like bacterial foraging technique, ant, bee colony algorithms and due to computational complexity those algorithms are found to inferior and a new nature-inspired algorithm based on the characteristics of pollination process of flowers plants namely Flower Pollination Algorithm (FPA) has been proposed. This algorithm is one of the most promising less computational complex solution methodologies [15-19]. From the biological evolution point of view, the objective of the flower pollination is the survival of the fittest and the optimal reproduction of plants in terms of numbers as well as the fittest. The basic idea of flower pollination in the context of bees and clustering was investigated before, but in this paper discusses the completely new optimization strategy solely based on the flower pollination characteristics.

This paper proposes a conceptually computational methodology for ensuring better steady state response of the system. In this study without and with the incorporation of the HDGT to the two-area thermal restructured power system has been considered for poolco, bilateral and contract violation transactions. From the simulated results it is observed that the system with HDGT units ensures improved steady state parameters which provides and ensures a good margin of stability.

Mathematical Modelling and Implementation of FPA: The system investigated consists of two generating areas of equal size which means identical areas. Out of which in case one in area 1 both GENCOs are thermal-thermal interconnected power system and in area 2 also both Thermal-thermal interconnected power system but in case two area 1 comprises a reheat thermal-thermal system with two GENCOs and Area 2 comprising two GENCOs of thermal and - heavy duty gas turbine system. Figure 1 shows the new transfer function LFC model with single stage reheat turbine in heavy duty gas system area are considered for deregulated environment. The nominal system parameters are given in the appendix.

Design Formulation: A formulation of the block diagram for a two area LFC system in the deregulated scenario has been presented here. Whenever a load demanded by a DISCO changes, it is reflected as a local load in the area to which this DISCO belongs [1]. This corresponds to the local loads $\Delta PL1$ and $\Delta PL2$ should be reflected in the deregulated LFC system block diagram at the point of input to the power system block. As there are many GENCOs in each area, ACE signal has to be distributed among them in proportion to their participation in the LFC. [3]

Coefficients that distribute ACE to several GENCOs are termed as "ACE participation factors" (APF's). Note: Σmj=1 APF j=1 where 'm' is the number of GENCOs.

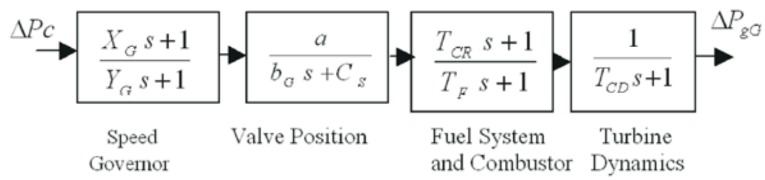

Fig. 1: Transfer Function representation of a Heavy Duty Gas Turbine (HDGT)

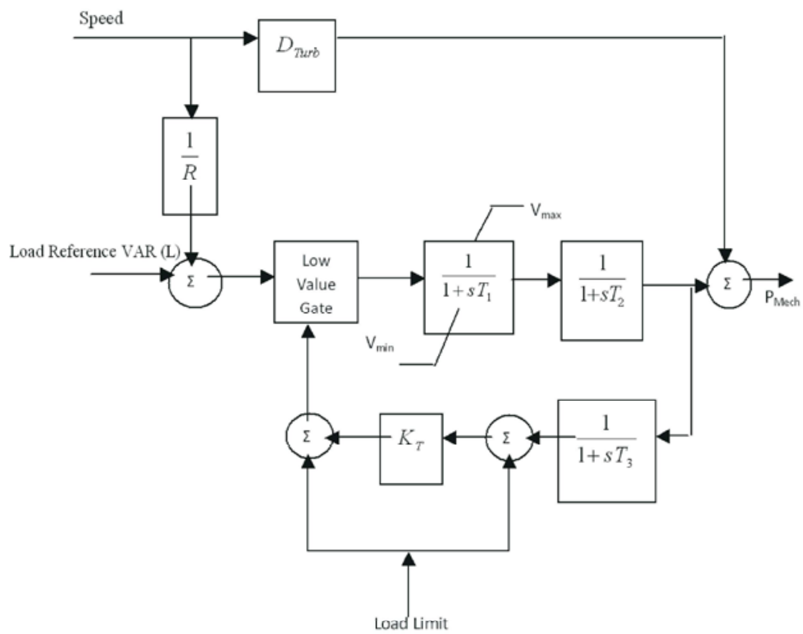

Fig. 2: Gas turbine

Unlike in the traditional LFC system, a DISCO asks/demands a particular GENCO or GENCOs for load power [5]. These demands must be reflected in the dynamics of the system. Turbine and governor units must respond to this power demand. Thus, as a particular set of GENCOs are supposed to follow the load demanded by a DISCO, information signals must flow from a DISCO to a particular GENCO specifying corresponding demands. Here, we introduce the information signals which were absent in the traditional scenario. The demands are specified by cpfs (elements of DPM) and the p.u MW load of a DISCO. These signals carry information as to which GENCO has to follow a load demanded by which DISCO [6-8]. The scheduled steady state power flow on the tie line is given as

$\Delta p_{tie1\text{-}2,\ scheduled}$ = (demand of DISCOs in area II from GENCOs in area I) - (demand of DISCOs in area I from GENCOs in area II) (1)

At any given time, the tie line power error, ΔPtie1-2,error is defined as

$$\Delta P_{tie1-2error} = (\Delta P_{tie1-2actual}) - (\Delta P_{tie1-2,scheduled}) \quad (2)$$

Δptie1-2,error vanishes in the steady state as the actual tie line power flow reaches the scheduled power flow. This error signal is used to generate the respective ACE signals as in the traditional scenario.

$$ACE_1 = (B_1 \Delta f_1) + (\Delta P_{tie1-2,eror})$$
$$ACE_2 = (B_2 \Delta f_2) + (\Delta P_{tie2-2,eror}) \quad (3)$$

where

$$\Delta P_{tie1-2error} = \mathrm{P_{r1}/P_{r2}}\ \Delta P_{tie1-2,error} \quad (4)$$

and Pr1, Pr2 are the rated powers of areas I and II, respectively. Therefore,

$$ACE_2 = (B_2 \Delta f_2) + (\propto_{12}\ \Delta P_{tie1-2,error}) \quad (5)$$

where, α12 = Pr1/Pr2

Algorithm:
Step 1: Objective min or max function f (x), x = (K_P, $K_{I,..,}K_n$)
Step 2: Initialize a population of n flowers/pollen gametes with random solutions
Step 3: Find the best solution in the initial population
Step 4: Define a switch probability p ◎ [0, 1]
Step 5: while (t < Max Generation)
Step 6: for i = 1: n (all n flowers in the population)
Step 7: if rand < p
Step 8: Draw a (d-dimensional) step vector L which obeys aL´evy distribution
Step 9: Global pollination via $x_i^{t+1} = x_i^t + L\,(B - x_i^t)$
Step 10: else
Step 11: Draw □ from a uniform distribution in [0,1]
Step 12: Do Local pollination via $x_i^{t+1} = x_i^t + U\,(x_j^t - x_k^t)$
Step 13: end if; otherwise go to step 14
Step 14: Evaluate new solutions
Step 15: if new solutions are better, update them in the population
Step 16: end for
Step 17: Find the current best solution B
Step 18: end while
Step 19: Output the best solution found

Simulation of Thermal – Heavy Duty Gas Turbine: The block LFC with deregulated thermal – heavy duty gas turbine power systems [20] is shown in Fig.3 and Hydrothermal system in Fig. 4

The optimum value of PI controllers using integral square error technique is as follows

$$J = \int ((\Delta P_{2tie(1-2)}) + \Delta f_{21} + \Delta f_{22})dt \qquad (6)$$

where,
dt = small time interval during sample,
$\Delta_{Ptie\,(1-2)}$ = change in tie-line power,
Δ_{f1},Δ_{f2} = change in frequency area 1 & area 2 respectively.

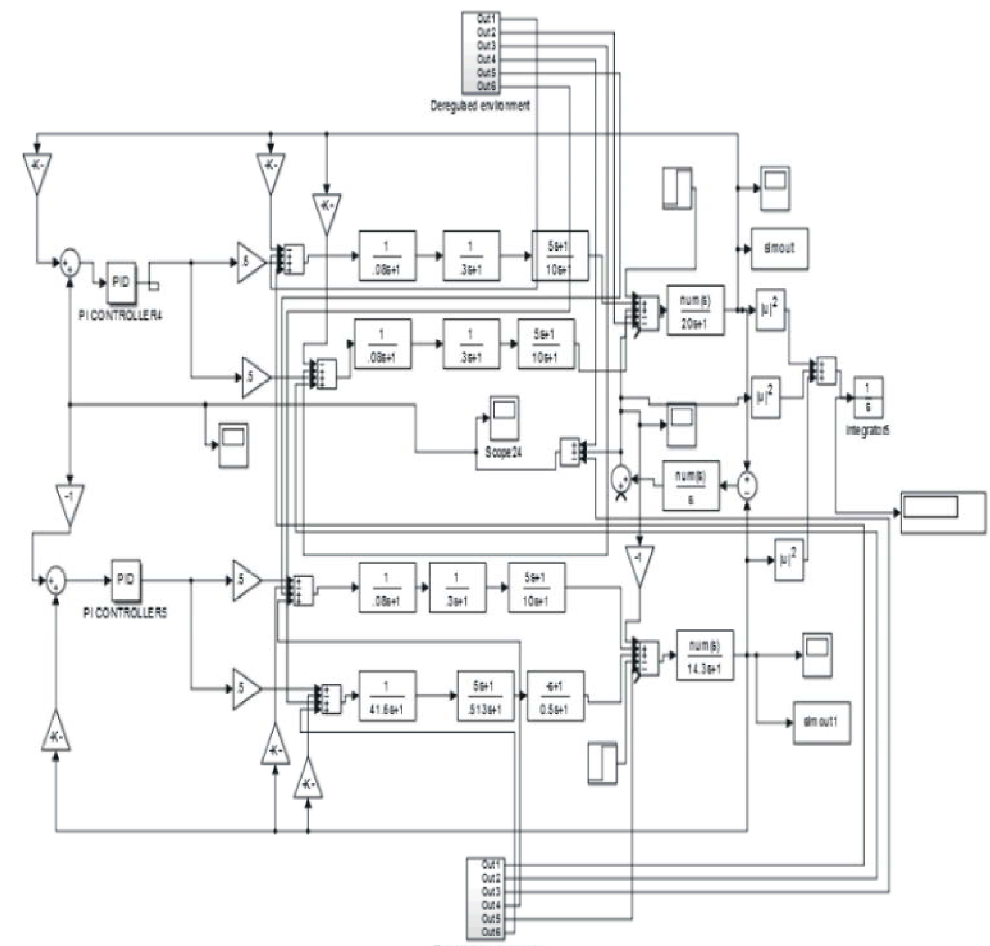

Fig. 3: Simulation Diagram of Load-Frequency Controller for Deregulated Hydro-Thermal Power Systems

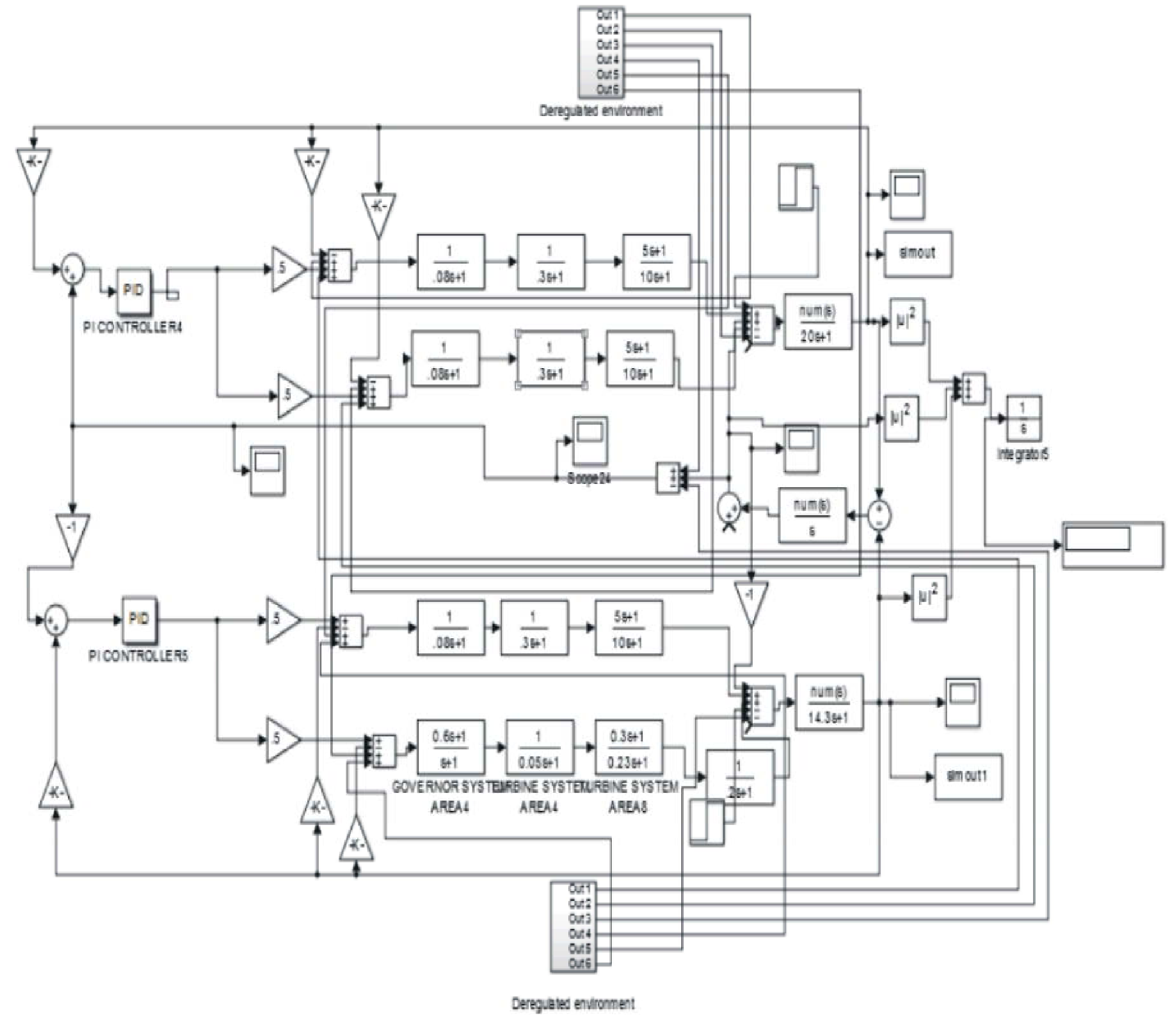

Fig. 4: Simulation Diagram of Load-Frequency Controller for Deregulated Thermal-Heavy duty gas turbine Power Systems

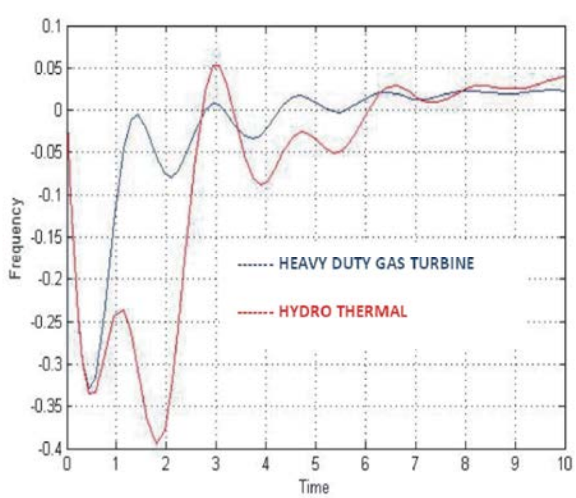

Fig. 5: Change in frequency of Area – I for Heavy duty gas turbine unit and Hydrothermal system.

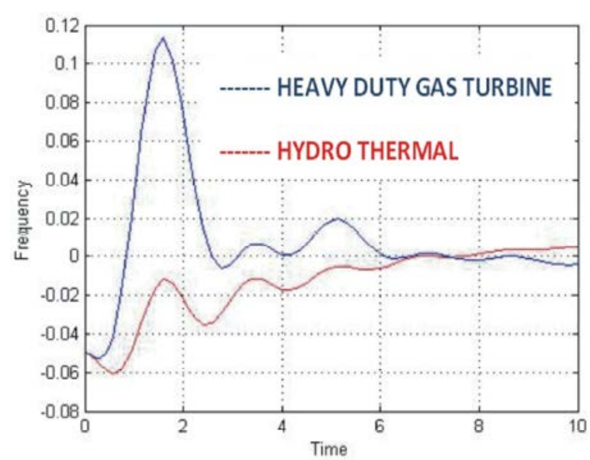

Fig. 6: Change in frequency of tie line of Area – I and Area – II of Heavy duty gas turbine unit and Hydrothermal system.

Table 1: Optimum Gain Values

		With Flower Pollination Algorithm		Without Flower Pollination Algorithm	
Plant	Controller	K_P	K_I	K_P	K_I
Thermal -Thermal RPS without HDGT unit	PI controller	0.3801	0.2504	0.3903	0.2812
Thermal - Thermal RPS with HDGT unit		0.1208	0.1585	0.1782	0.2006
Thermal -Thermal RPS without Hydro unit		0.3884	0.1322	0.3942	0.1690
Thermal -Thermal RPS with Hydro unit		0.1210	0.1757	0.1293	0.1791

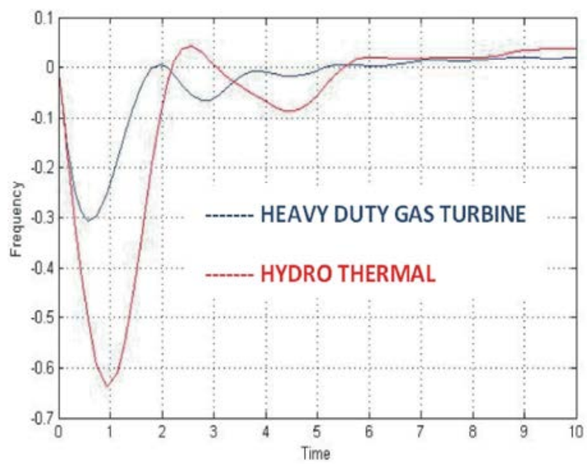

Fig. 7: Change in frequency of Area – II in Heavy duty gas turbine unit and Hydrothermal system.

Simulation Results and Discussions: The simulation results obtained shown in Table. 1 using Flower Pollination Algorithm reveals that the dynamic response of the system of the two-area interconnected Restructured Power System (RPS) with HDGT ensures a better dynamic response than that of the RPS without HDGT unit. Integral square Error (ISE) technique is used to obtain the optimum PID-controller gains.

CONCLUSION

An improved version of Load frequency control in an interconnected Heavy duty Gas turbine -thermal power system under the deregulation scenario is presented. An effective method of adjusting generation to minimize frequency deviations and regulate Tie-line power flow is shown. The simulation results reveals that the improved dynamic performance for various cases. However the system as well as retaining the fundamental LFC concepts, is significantly improved. It provides stability and reliability of electric power supply with good quality.

Appendix:

A1. Data for the interconnected two-area thermal power system [22]
Rating of each area = 2000 MW.
Base power = 2000 MVA.
f = 60 Hz.
R1 = R2 = 2.4 Hz/p.u MW.
Tg1 = Tg2 = 0.08 s.
Tt1 = Tt2 = 0.3 s.
Tp1 = Tp2 = 20 s.
Kp1 = Kp2 = 120 Hz/p.u MW.
B1 = B2 = 0.425 p.u MW/Hz.

A2. Data for Heavy Duty Gas Turbine unit [23]
T_{GH} = 0.2 sec, X_G = 0.6 sec, Y_G = 1.1 sec
C_g=1, b_g= 0.049 sec, T_F = 0.239 sec,
T_{CR}=0.3 sec, T_{CD}=0.2 sec,
R_g=2.4 HZ/pu.MW

REFERENCES

1. Ramakrishna, K.S.S., Pawan Sharma and T.S. Bhatti, 2010. Automatic generation control of interconnected power system with diverse sources of power generation, International Journal of Engineering, Science and Technology, 2(5): 51-65.
2. Anu Chaudhary, Mohan Kashyap and Satish Kansal, 2016. Automatic Generation Control - A Review, IJSRSET Themed Section: Engineering and Technology, 2(2): 81-84, 2016. Print ISSN: 2395-1990; Online ISSN: 2394-4099.
3. Ibraheem and Omveer Singh, 2014. Current Philosophies of Intelligent Techniques based AGC for Interconnected Power Systems, International Journal of Energy Engineering (IJEE), 4(3) 141-150.
4. Shashi Kant Pandey, Soumya R. Mohanty, Nand Kishor, 2013. A literature survey on load–frequency control for conventional and distribution generation power systems, Renewable and Sustainable Energy Reviews, 25: 318-334.

5. Sadia Firdous and Mohammed Abdul Rahman Uzair, 2015. Load Frequency Control Techniques, International Journal of Science, Engineering and Technology Research (IJSETR), 4(8): 2887-2893, ISSN: 2278 – 7798
6. Soon Kiat Yee, Jovica V. Milanovic and F. Michael Hughes, 2008. Overview and Comparative Analysis of Gas Turbine Models for System Stability Studies, IEEE Transactions on Power Systems, 23(1): 108-118.
7. Hajagos, L.M. and G.R. Berube, 2001. Utility Experience with Gas Turbine Testing and Modeling, IEEE Transactions on Power Engineering Society, Winter Meeting, 2: 671-677.
8. Shalan, H.E.M.A., M.A. Moustafa Hassan and A.B.G. Bahgat, 2010. Comparative Study On Modelling Of Gas Turbines In Combined Cycle Power Plants, Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, pp-970-976, 2010.
9. Rowen, W., 1988. Operating characteristics of heavy-duty gas turbines in utility service, Proceedings of Gas Turbine and Aero engine Congress: Paper 88 GT 150, June 6–9, 1988 Amsterdam, Netherlands.
10. Hajagos, L.M. and G.R. Berube, 2001. Utility experience with gas turbine testing and modelling, Power Engineering Society Winter Meeting, 2: 671-677.
11. Osman Hegazy, Omar S. Soliman and Mustafa Abdul Salam, 2015. Comparative Study between FPA, BA, MCS, ABC and PSO Algorithms in Training and Optimizing of LS-SVM for Stock Market Prediction, International Journal of Advanced Computer Research, 5(18).
12. Chidambaram, I.A. and B. Paramasivam, 2013. Optimized load-frequency simulation in restructured power system with redox flow batteries and interline power flow controller, International Journal on Electric Power and Energy Systems, 50: 9-24.
13. Ajitha Priyadarsini, S., P. Melba Mary and M. Willjuice Iruthayarajan, 2017. Automatic Generation Control in Deregulated Power System Using Genetic Algorithm Optimized Fuzzy Controller, An International Journal on Applied Mathematics & Information Sciences, Vol. 11, No. 2, pp.479-487, 2017, http://dx.doi.org/10.18576/amis/110217
14. Fatemeh Daneshfar, 2013. Load-Frequency Control in a Deregulated Environment Based on Reinforcement Learning, Journal of Control and Systems Engineering Jun. 2013, Vol. 1 Issue. 1, pp. 9-16, DOI: 10.18005/JCSE0102001.
15. £ukasik, S. and P. Kowalski, 2015. Study of Flower Pollination Algorithm for Continuous Optimization, Advances in Intelligent Systems and Computing, 322: 451-459.
16. Yang, X.S., 2012. Flower pollination algorithm for global optimization, in: Unconventional Computation and Natural Computation, Lecture Notes in Computer Science, 7445: 240-249.
17. Mohamed Abdel-Baset and Ibrahim M. Hezam, 2005. An Effective Hybrid Flower Pollination and Genetic Algorithm for Constrained Optimization Problems, International Journal Advanced Engineering Technology and Application, 3: 27-34.
18. Er. Man Mehak Sidhu and Er.Shivani Mehta, 2015. Pollination Based Optimization for Economic Load Dispatch Problem, International Journal of Research in Advent Technology, 3(4)E-ISSN: 2321-9637.
19. Kirandeep Kaur, Khushal Thakur and Anmol Goyal, 2015. Flower Pollination Algorithm (FPA) Optimization based Multiuser Detection for DS-UWB Communication System, International Journal of Research in Electronics and Computer Engineering (IJRECE), 3(2): 159-164.
20. Das, D., 2006. Electrical Power systems, New age international publishers, New Delhi, 2006.
21. Shalan, H.E.M.A., M.A. Moustafa Hassan and A.B.G. Bahgat, 2010. Comparative Study On Modelling Of Gas Turbines InCombined Cycle Power Plants, Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10), Cairo University, Egypt, December 19-21, pp-970-976, 2010.
22. Chidambaram, I.A. and B. Paramasivam, 2013. Optimized load-frequency simulation in restructured power system with redox flow batteries and interline power flow controller. International Journal on Electric Power and Energy Systems, 50: 9-24.
23. Hajagos, L.M. and G.R. Berube, 2001. Utility experience with gas turbine testing and modelling, Power Engineering Society Winter Meeting, 2: 671-677.