ANALYSIS OF LOAD FREQUENCY CONTROL USING PROPORTIONAL PLUS INTEGRAL (PI) CONTROLLER TUNED WITH PARTICLE SWARM OPTIMIZATION (PSO) IN TWO AREA POWER SYSTEM

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Abstract

Often a major problem is being taken placed in a Two area inter connected power system such that sudden change in supplying the power to the load due to dynamic change in load at the load end. The dynamic change in the power causes change in the frequency which leads to the unstable in power system. Hence to improve the performance of power and to keep the deviations in the frequency within the permissible limits; A new technique or an algorithm has been proposed namely Particle Swam Optimization (PSO).The PSO is used for tuning of Proportional plus Integral (PI) controller in order to optimize the gain values of the controller which helps in minimizing the error function of the frequency. In order to improvise the performance of power of a power system, error function is minimized. The objective function taken into consideration over here is Integral Time multiplied with Absolute Error (ITAE). The reason for choosing this algorithm over other recent well known algorithms and techniques such as Bacteria Foraging Optimization Algorithm (BFOA), Genetic Algorithm (GA), Conventional PI controllers and *Linear Quadratic Regulator* (LQR) method. In this paper, Tuning of controller was done in order to obtain the gain values, controller parameters with the help of PSO such that the desired frequency in the neighboring systems are maintained within specific values. The simulation results of PSO based PI Controller are shown as compared with conventional and LQR methods in the plots for the Two Area Inter Connected Power System by using MAT Lab. All the Controllers should maintain the property of being sensitive against the changes in the frequency and load. Tuning of the controllers based on PSO algorithm is justified by making a comparison with Conventional method and Linear Quadratic Regulator (LQR) method.

Keywords— Load Frequency Control (LFC),Linear Quadratic Regulator(LQR), Bacterial Foraging Optimization (BFO), Particle Swarm Optimization (PSO)),Proportional-Integral(PI), IntegralTime multiplied with Absolute Error(ITAE) ,Matrix Laboratory(Mat lab).

I.INTRODUCTION

The conventional strategy for LFC may not be achievable effectively. In this context, we go for powerful control ,the auxiliary unpredictability emerges and rebuilding of the framework is basically initiated. To dodge this issue, the astute control plans are utilized, which include delicate figuring methods. As the course of action of the present day control framework is mind boggling, the swaying acquired is exposed to any aggravation impact which may spread to wide zones provoking force framework power outage. An advanced control approach, for example, ideal control ought to be utilized. Techniques used to tune controller parameters are basic parts for the heap recurrence control, the parameters of the controller ought to be tuned with appropriate systems. In a multi area power system, a sudden burden of load in any area causes the deviation of frequencies of every area of the system as well as the tie line powers. In such circumstances, LFC [1] also known as automatic generation control (AGC), the main motive of which is to control frequency in each area as much as possible ought to provide its own load demand and transfer of power through tie line which must be done only in the case of the demand of that area being lower than the generation of the units in the specified area. All control areas should respond to the changes in load frequency contro[2] and ensure zero steady-state errors of frequencies. Over the past decades, many researchers [3] have applied different control approaches, such as traditional control,optimum state response control and robust control to the LFC problem in order to achieve better results. All of these approaches have proved to be unsatisfactory due to the fundamentally nonlinear nature and random operational situations of power system. Several researchers [4, 5] have efficiently applied the intelligent control methodology to LFC problem. The further research in this area has been carried out by use of various optimization techniques such as Genetic Algorithm (GA) which is robust and adaptive method is used to solve search and optimization problem but its complexity in coding makes GA difficult to be implemented as well as its convergence speed.

In this study, some of the well known optimization techniques have been used for tuning the gain values of Proportional-Integral (PI) controller to get the optimal solution. One of the main driving forces of BFO is that during the process of chemo taxis, the BFO depends on random search directions which may lead to delay in reaching the global solution. Bacteria Foraging Optimization (BFO) Algorithm which is another technique to keep the frequency within permissible limits by tuning the gains of controller [5]. Selection procedure in this process tends to eliminate animals with poor foraging schemes and favor the transmission of genes of animals having successful foraging schemes since they are more likely to give success. As it is a process which deals with reproduction process which produces a population of N individuals leading to large number of parameters to be set which adds to its drawback. This leads to another algorithm that is Particle Swarm Optimization (PSO) a population based technique first described by James Kennedy and Russell C.J Eberhart (1995). This applies the concept of social interaction to problem solving. We proposed a new technique called PSO.

This paper is organized in six sections; the first section is the introduction part which is explained above. In section second, two area interconnected power system is shown. Section three gives an overview of different optimization techniques that help us to understand how these techniques work. Section four is dedicated to tuning of controller on the basis of which we compare all the optimization techniques and simulation results that have been used in this article. Section fifth contains the conclusion. In the last section future scope is given .

II.INTERCONNECTED POWER SYSTEM

The problems of frequency control of interconnected areas are more important than those of single area systems. Reasons to hold frequency constant are:

1. If normal frequency is 50 Hertz and the turbine run at speeds corresponding to ±2.5 Hertz then the blades of the turbine are likely to get damaged.
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3. The electrically operated clocks are driven by the synchronous motors. The accuracy of these clocks dependent on the frequency as well as the integral of this frequency error. Nowadays power systems are connected to neighboring areas.

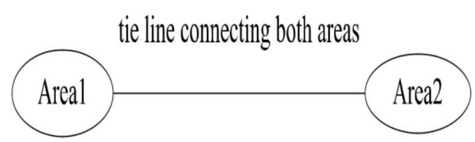

Fig.1

Figure 1: Two areas connected by tie-line

Tie-line allows the flow of electric power between areas. Introduction of tie-line power leads to introduction of an error called tie-line power exchange error. When there is load change in an area, that area will get energy with the help of tie-lines from other areas. The power flow through different tie lines are planned or set i.e. $area_i$ may give a specific amount of power to $area_j$ while taking another specified amount from k^{th} area. Hence LFC also needs to control the tie-line power exchange error. It is said that information regarding local area can be obtained in the tie-line power fluctuations. Therefore the tie-line power is observed and the resulting tie-line power is given back into both areas for a two area system. Also interconnection of the power systems leads to large increase in the order of the system. As a result, when modeling such complex high-order power systems, the model and parameter approximations cannot be avoided [2].Hence LFC has two main objectives: To keep the frequency constant against any load change & Flow of power in the tie-line must be maintained to its desirable value in each area.

III.OPTIMIZATION TECHNIQUES

A)LQR based controlling techniques:

Optimal control design for the linear systems with quadratic performance Linear Quadratic Regulator (LQR) is established [\. The purpose of optimal regulator design is to determine the optimal control rule. There are several competing objectives that need to be simultaneously satisfied (system step response, rise time, overshoot, disturbance rejection, or integral absolute error). These objectives are imbedded in system's Eigen values that are measures of system stability and robustness. Ray *et al.* proposed a combination of 'Matching conditions' and Lyapunov stability

B)Genetic Algorithm approach

A newly intelligent control technique is the genetic algorithms based load frequency controller. Genetic algorithms (GA) are global search techniques, based on the operations observed in natural selection and genetics. They operate on a population of current approximations . The individuals initially drawn at random, from which improvement is sought. Individuals are encoded as strings (chromosomes) constructed over some particular alphabet, e.g., the binary alphabet {0, 1}, so that chromosomes values are uniquely mapped onto the decision variable domain. Once the decision variable domain representation of the current population is calculated, individual performance is assumed according to the objective function which characterizes the problem to be solved. It is also possible to use the variable parameters directly to represent the chromosomes in the GA solution.

C)Bacterial Foraging Algorithm

BFO is used to search for perfect controller parameters. By limiting the time space target work, in which the deviations in the recurrence and tie line control are incorporated; soundness and execution of the framework moved forward. The survival of species in any trademark transformative strategy depends on their wellbeing criteria, which relies on their sustenance looking and motile lead. The law of improvement supporting those species who have better sustenance looking limit with respect to and either wipes out or reshapes those with poor chase limit. The characteristics of those species who are more grounded gets e caused in the advancement chain since they bunches ability to reproduce far superior species in future. So an indisputable understanding and showing of looking behavior in prompts its application in any

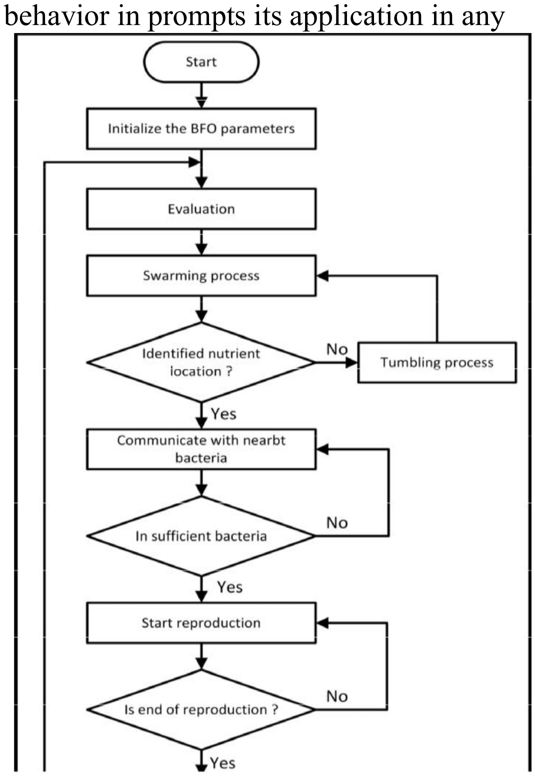

Fig.2

The Bacterial Foraging strategy which can be explained by four processes, namely chemo taxis, swarming, reproduction, and Elimination–dispersal. Here in Fig. 2 step of bacterial foraging optimization has been given to show how the technique work. The detailed mathematical derivations as well as theoretical aspect of this new concept are presented in [11] and [12]

FLOW CHART OF PSO ALGORITHM

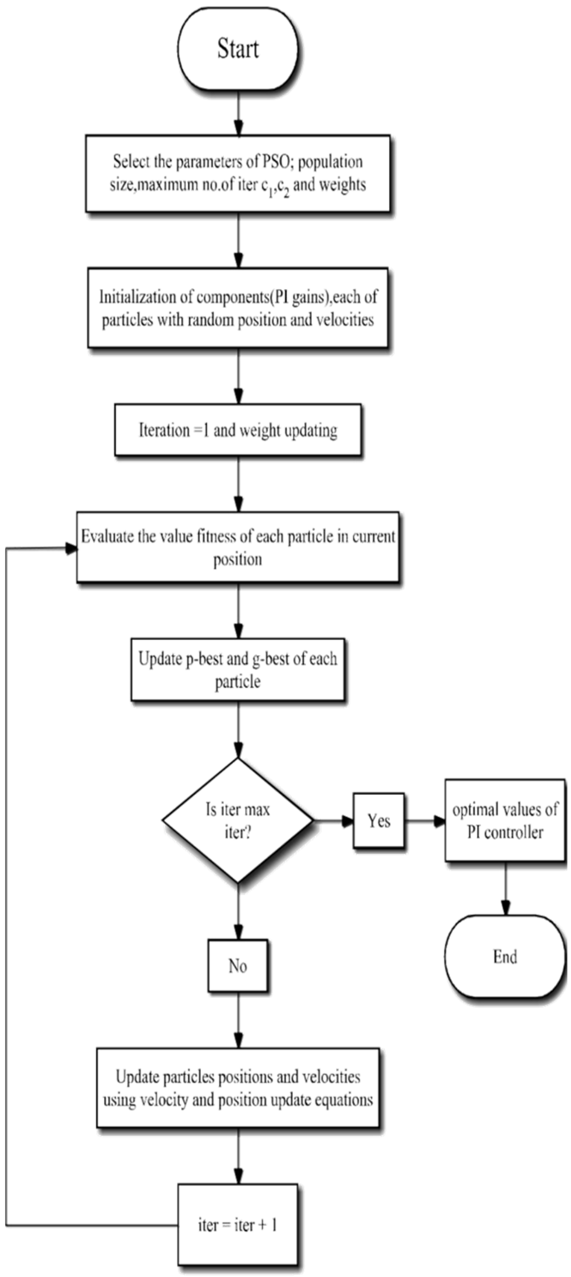

Fig.3

D) PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) originated by James Kennedy and R.C. Eberhart in 1995 It is a stochastic (connection of random variable) evolutionary computation method used to explore search space. This technique is based on swarm's intelligence and movement. As this is based on swarm behavior, is a population based technique. The bird generally follows the shortest path for food searching. Based on this behavior, this algorithm is developed. It uses a number of particles where every particle is considered as a point in N-dimensional space. Each particle keeps on accelerating in the search space depending on the knowledge it has about the appreciable solution comparing its own best value and the best value of swarm obtained so far It is well described by the concept of social interaction because each particle search in a particular direction and by interaction the bird with best location so far and then tries to reach that location by adjusting their velocity this require intelligence.

Advantages of PSO over above two algorithms:

Few parameters need adjustment so easy to perform unlike BFO algorithm. Only algorithm that does not implement the survival of the fittest hence entire population is member throughout the process. PSO unlike GA is not affected by size of the problem. The shortcoming of GA i.e. premature convergence is overcome by PSO. This is quite easy and simple to implement as it consist of two equations only. Even for large problems less than hundred iterations are required.

IV.TUNING OF CONTROLLER

The selection procedure of controller parameters such that it fulfills desired performance demands is known as tuning of controller. The need to tune controller is for fast response and to have good stability. Ziegler-Nichols (Z-N) first proposed tuning rules of controller. What leads to development of other tuning methods after Z-N method is that it involves trial and error procedure which is not desirable, not applicable to open loop unstable processes. After that a lot of new techniques were developed analytical tuning; amigo tuning; optimization methods etc. Nowadays optimization based methods are getting fame

Where, v^k = velocity of agent i at iteration k
c_i =weighing factor
$rand_i$ =random number between 0-1
$pbest_i$ =p-best of agent i
s^k =current position of agent i at iteration k
$_i$In equation 3.1, the first term wv_i^k is inertia component responsible for movement of particle in the direction it was previously heading. 'w' has a vital impact on speed if its value is less then it speed up the convergence otherwise encourage exploration. Second term: c rand pbest s^k is the cognitive component acts as particle's memory. 1 1 i I move to best region found so far by the swarm.
Once the calculation for velocity of each particle is done then position can be updated using equation of position modification. Position modification equation: Where, $s_i^{k\ 1}$, s_i^k are modified and current search points respectively $v_i^{k\ \square 1}$ = modified velocity This process is repeated unless and until some stopping criteria is fulfilled.

PSO BASED CONTROLLER DESIGN

Step1: The initial particles are set to some linear position in the range of K_p and K_i.
Step2: Their velocities are set to zero.
Step3: Initial ITAE is set to some values.
Step4: Evaluate the ITAE for the particles at their corresponding positions.
Step5: Initialize p_{best} for each particle.
Step6: Find g_{best} based on minimum ITAE.
Step7: Start iteration 1.
Step8: Update the positions.
Step9: Then calculate ITAE at their corresponding position.
Step10: Acordingly update p_{best} and g_{best} based on ITAE.
Step11: Update velocity.
Step12: Iteration=iteration+1.
Step13: If iteratio<=maximum iteration, go to step 8 otherwise continue.
Step14: The obtained g_{best} is the optimum set of parameters of PI controller.

BASIC CONTROL LOOP:

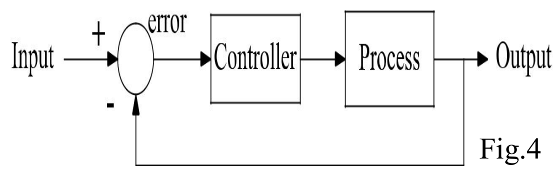

Fig.4

SELECTION OF CONTROLLER:

Guidelines for selection of controller:
In case of Proportional Controller easy to tune but usually introduces steady state error. It is recommended where transfer functions having a single dominating pole or a pole at origin. Integral Controller is effective for high order systems with all the time constants of same magnitude. It does not exhibit steady state error, but is relatively slow responding. Proportional plus Integral (P-I) Controller having much faster response than alone integral action also does not cause offset. Proportional plus Derivative (P-D) Controller is effective for systems whose time constants are large. It results in a minimum offset and much rapid response in comparison to only proportional one. Tuning of P-I-D Controller is difficult. It is mostly used in controlling slow variables, like pH, temperature, etc. Here PI controller is taken into consideration. The working of PI controller is that it monitors the error between a desired set point and a process variable. P-I controller is weighted sum of two time functions.
K_p: Effect of present error value on the control mechanism
K_i: reaction based on the area under error-time curve
Adjusting or controlling the process is the foremost issue that is considered in the process industry. In order to make the controllers work suitably, they need be tuned properly. Tuning of controllers can be

done in several ways. In order to get the optimal solution, conventional objective function is taken

TWO AREA INTER CONNECTED POWER SYSTEM

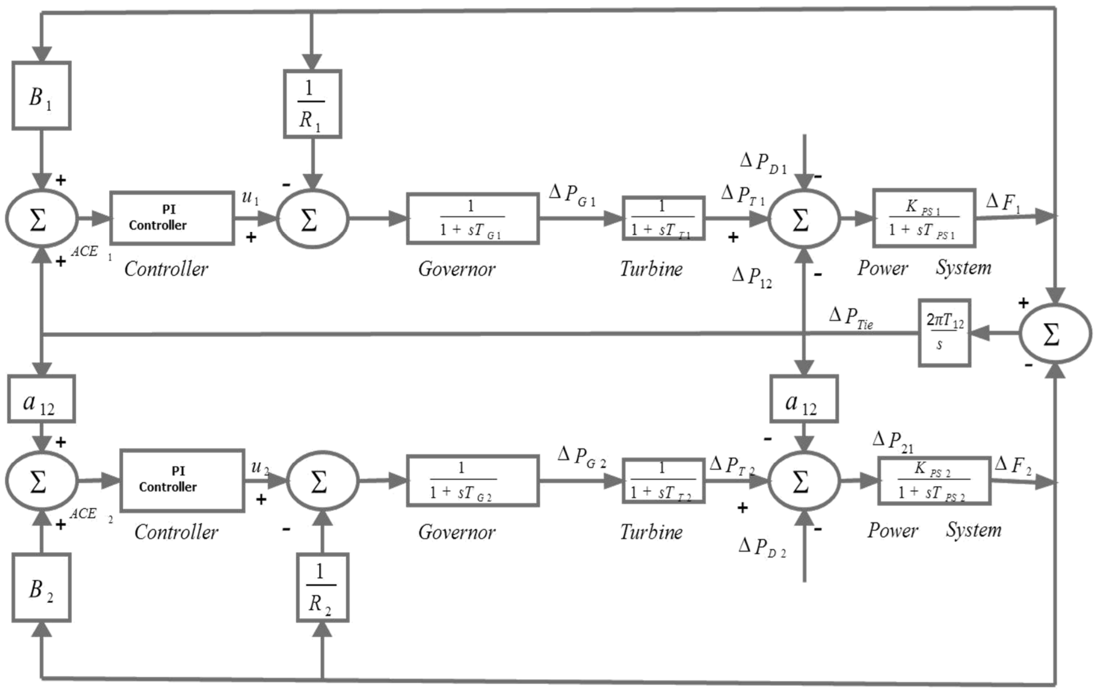

Fig.5

Parameters of Two-Area System

Parameter	Value
B_1, B_2	0.425 p.u. MW/Hz
R_1,R_2	2.4 Hz/p.u.
TG1,TG2	0.08 s.
TT1, TT2	0.2 s.
TPS1,TPS2	20 s.
T12	0.0707 p.u.
KPS1,KPS2	120 Hz/p.u.
a12	-1

Parameter values tuned for PSO Algorithm

Parameters	Values
Population Size	11
Numbers of iterations	50
Inertia Weight (w)	0.8
Cognitive Coefficient (C_1)	2
Social Coefficient (C_2)	2

Error values for corresponding methods

Method	Kp	Ki	Error
Conventional	0.60	-0.75	7.6
LQR	Optimal K is given below		2.8
PSO	0.0563	-0.7302	0.7

Where, the optimal K is given in the matrix below:

K =

0.5604	0.5724	0.2057	0.2271	0.1919	0.0644	1.0027	0.9986	0.3376
0.2450	0.1972	0.0644	0.6029	0.5917	0.2121	1.9131	0.3376	0.9986

In the below figure error of the three methods are compared and shown in the plot.
Error obtained by three used method:

Case1: A step load change in area-1 only
A step load 10% rise in area-1 (dP_{D1}) is given & the deviation in frequency of area1 df_1 , the Deviation in frequency of area-2 df_2 and the tie line power signal of the system are shown in change in frequency of area-1 for 0.1 p.u change in area-1 Time(secs) on x-Axis. Change in frequency on Y-axis in Hz.

Fig.Change in frequency of area-1 for 0.1 p.u change in area-1(below)

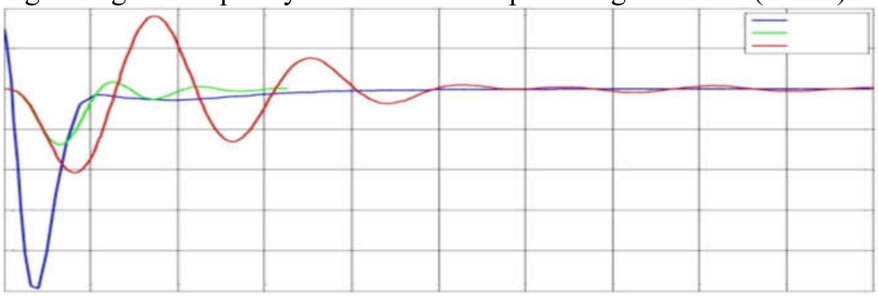

Fig.6

Case2: Step load change in area-1 and area-2 simultaneously In this case, 10% step load rise in demand of first area and 15% step load rise in demand of second area respectively are applied. The response of the system is shown in Figs.

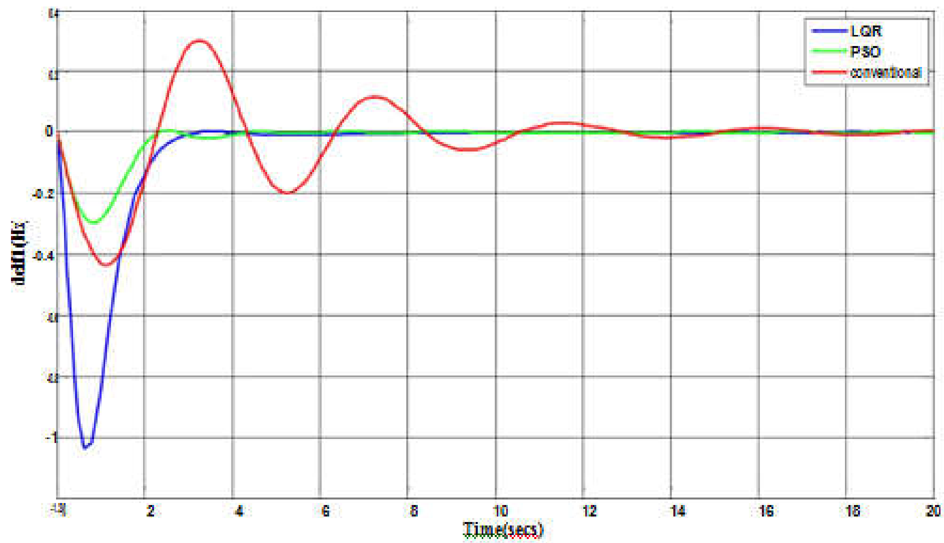

Fig.7

Figure .Change in frequency of first area for 0.1 p.u change in area-1 & 0.15 p.u for area-2

Case3:Simulation Results for both the areas

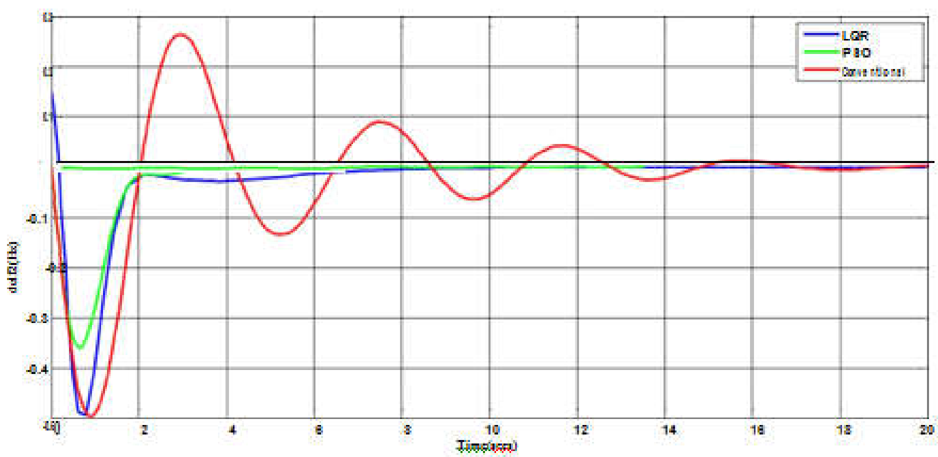

Fig.8

Fig:Change in frequency of second area for 0.1 p.u change in area-1 & 0.15 p.u for area2

V.CONCLUSION:

Controlling of power systems in order to meet the demands of consumers is a challenging task that motivates to design optimum controllers. They should have the capability of monitoring the power system like maintenance of frequency and voltage in no time. Many optimization techniques are used in the design of controllers. In this paper, PSO is used to tune parameters of proportional-plus-integral controller. A two-area system is taken into consideration to show this method. The integral of time multiplied absolute error is used as objective function. Different plots of frequency deviation were obtained by varying the load demand of areas. Effects of parameter variation on system response are also plotted and observed. Its superiority over other methods used to tune the controller is justified by comparing the error values through plots.

VI. FUTURE SCOPE

In this work only PSO algorithm is used to obtain the gain values of controllers for two-area interconnected systems. So it can be implemented for multi area power system with different algorithms and controllers which may helps to obtain better results than the proposed system.

VII. REFERENCES:

[1] O. I. Elgerd, Electric Energy Systems Theory: An Introduction. New

[2] Surya Prakash and S.K. Sinha, "Load frequency control of three area interconnected hydro-thermal reheat power system using artificial intelligence and PI controllers", International Journal of Engineering, Science and Technology, Vol. 4, No. 1, pp. 23-37, 2011.

[3] D. Das, M. L. Kothari, D.P. Kothari and J. Nanda, "Variable structure control strategy to automatic generation control of interconnected reheat thermal systems," IEE Proceedings Control Theory Applications; 138(6):579-85, 1991.

[4] Ibhan Kocaarslan and Ertugrul Cam, "Fuzzy logic controller in interconnected electric power systems for load-frequency control," Electrical Power and Energy Systems, Vol. 27, pp. 542-549, 2005.

[5] L. H. Hassan, H. A. F. Mohamed, M. Moghavvemi and S. S. Yang, "Automatic generation control of power system with fuzzy gain scheduling integral and derivative controllers," International Journal of Power, Energy and Artificial Intelligence, No.1, Vol. 1 August 2008.

[6] C. T. Pan, and C. M. Liaw, "An adaptive controller for power system and load frequency control," IEEE Transactions on Power Systems, Vol. 4(1), pp. 122–128, Feb 1989.

[7] Kundur P, "Power system stability and control", IEEE Press, McGraw Hill; 1994.

[8] Hadi Saadat "Power System Analysis", ,McGraw Hill; 2002.

[9] Allen J Wood and Bruce F Wollenberg. "Power Generation Operation & Control"Wiley Publication, NewYork, 1996

[10] K. M. Passino, "Biomimicry of bacterial foraging for distributed optimization and control", IEEE Control Systems, Vol. 22(3), pp. 52–67, Jun 2002.

[11] T. Datta, I. S. Misra, B. B. Mangaraj and S. Imtia "Improved Adaptive Bacteria Foraging Algorithm In Optimization Of Antenna Array For Faster Convergence", Progress In Electromagnetics Research C, Vol. 1, pp. 143–157, 2008.

[12] R. N. Ray, D. Chatterjee and S. K. Gowami, "A PSO based Optimal Switching Technique for Voltage Harmonic Reduction of Multilevel Inverter", Expert Systems with Applications, Vol. 37(12), pp. 7796-7801, Dec-2010

[13] J. Kennedy and R. C. Eberhart, "Particle swarm optimization", IEEE Proceedings of International Conference on Neural Networks, IV, Piscataway, NJ, pp. 1942- 1948,1995.

[14] R. Poli, "An analysis of publications on particle swarm optimization applications", Technical Report CSM-469 (Department of Computer Science, University of Essex, UK). (2007).

[15] Hai Shen, Yun long Zhu, Xiao ming Zhou, Haifeng Guo and Chunguang Chang, "Bacterial Foraging Optimization Algorithm with Particle Swarm Optimization Strategy for Global Numerical Optimization", Genetic and evolutionary computation conference, Shanghai, Jun 2009.

[16] W. M. Korani, "Bacterial foraging oriented by particle swarm optimization strategy for PID tuning", Proceedings of the 2008 GECCO conference companion on Genetic and evolutionary computation, Atlanta, GA, USA, pp. 12-16, 2008.

[17] Liu Xiaolong, Yang Ping and Li Rongjun, "The bacterial foraging algorithm for global optimization based on PSO," IEEE international conference on intelligent computing and intelligent systems,Xiamen, pp 22-27, Oct 2010.

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