OPTIMIZATION OF LOAD FREQUENCY CONTROL FOR TWO AREA SYSTEM USING PARTICLE SWARM OPTIMIZATION

K.Balaji[1], S.Neelan[2]

[1]U.G Student, Department of EEE, IFET College of Engineering, Villupuram-605108
[2] Assistant Professor, Department of EEE, IFET College of Engineering, Villupuram-605108

ABSTRACT

This paper presents a practical model for optimization of the load frequency control of a two area system. The proposed model is framed with the thermal generating units and it is a non-linear power system. For design and analysis of the proposed method the Proportional Integral Derivative (PID) controller is used. A unique objective function is formulated which considering the transient specifications. A Particle Swarm Optimization (PSO) algorithm is used to obtain the best control parameters. The results and characteristics are show that the proposed model gives better performances.

Keywords-*two area power system; load frequency control; PID controller; particle swarm optimization.*

I. INTRODUCTION

Load frequency control is used to maintain the system frequency and the interconnected area tie-line power as close as constant values. The control of frequency and tie-line power is commonly known as Load Frequency Control (LFC). The frequency of a system is depend upon the active power balance. In an interconnected power system, the generation of power within each area has to be controlled so as to maintain the scheduled power interchange. In recent days, smart grids are mostly used which predicts the actions of all suppliers, consumers in order to effectively deliver the reliable, economic electricity services. By controlling the loads as well as governor actions at the generating stations the regulation of frequency can be achieved.

In LFC there are two different control actions they are, 1.Primary Control and 2.Supplementary Control. Speed is directly proportional to the load. So when load changes the primary speed also changes. The initial re-adjustment of the frequency and tie-line power of governor was done by primary speed control. The governor will try to minimize the frequency and tie-line power deviation to zero by manipulating the input to the turbine unit. After the primary control the supplementary control is used. The supplementary control action is used to minimize the frequency deviation of the system to zero by integral control action[1]. The controller parameters of the P,PI and PID controller are tuned based on Ziegler-Nichols method for the Distributed Generation System (DSG) was developed in[2]. A multi area adaptive LFC based on Self-Tuning Regulator (STR) for Automatic Generator Control Stimulator (AGCS) was investigated in Alieza et al. A new robust optimal MISO-PID controller for LFC used in [2]. For LFC system the controllers are designed so far using traditional and advanced control techniques are model based controller. Load frequency control is employed to allow an area to meet its own load demands, then to assist in returning the steady state frequency of the system, Δf to zero[3]. To keep the system frequency stable the Load Frequency Control operates with a response time of a few seconds. As the load changes, speed or frequency of the generator also changes. The speed governor helps to compensate the active power generation with the demand through controlling throttle valves which monitor the steam input to the turbine. The Automatic Generation Control (AGC) in interconnected power system under deregulated environment to control the tie line power of the interconnected hydro-thermal power system in which thermal reheated turbine is used [6]. The design and analysis issues in Load Frequency Control (LFC) for a power system entity that participates in an interconnection used in[8]. The concept of Distribution Companies (DISCO) participation matrix to stimulate the bilateral contracts is introduced and reflected in the two-area block diagram. Genetic Algorithms (GAs) optimization is used to tune the control parameters of the Proportional Integral (PI) controller [9].Sufficient conditions for feasibility are derived for a general class of convex regions of the complex plane. These conditions are expressed in terms of linear matrix inequalities (LMI's), and our formulation is therefore numerically tractable via LMI optimization. The AGC schemes based on power system models and control strategies are reviewed. The optimal output feedback regulator is proposed. In the output feedback method, only the measurable state variables within each control area are required to use for feedback. Robust decentralized power system stabilizer (PSS) design approaches for power system that can be expressed as minimizing a linear objective function under linear matrix inequality (LMI) in tandem with bilinear matrix inequality (BMI) constraints. For automatic generation control within a restructured environment considering effects of contracts between DISCOs and GENCOs to make power system network in normal state where, GENCO used are hydro plants as well as thermal plants.

The controller parameters of PID controller are K_p, K_i and K_d must be designed in such a way that it ensures reliable, safe and uninterrupted power supply. The conventional approaches provide very poor performances for large area network and also it provide generation rate constraint, governor dead band, time delay etc. Soft computing techniques are not model specific but it is robust in nature and can give multiple solutions. Soft computing techniques can give highly satisfactory results under critical situation and security constraints. In this paper a two area thermal-thermal power system is considered for the design purpose. To optimize the PID gains the PSO algorithm is developed. A novel objective function is designed to calculate the optimal controller gains more accurately in less time.

(IJRST) 2015, Vol. No. 5, Issue No. II, Apr-Jun **ISSN: 2249-0604**

II. EXISTING SYSTEM

In the existing system P,PI controller is used to enhance power system stability. Not fully reliable always as it is incapable of obtaining good dynamic performance for a wide range of operating conditions.

(a).LFC model

Consider the non-reheat thermal power system shown fig.1. The basic block of power generating consists of Governor, Turbine and Generator. The speed governor is used maintain the speed and active power of the system with the demand by controlling the throttle valves which monitors how much amount of steam is used in turbine unit. The governor is also used- to sense the frequency bias which is caused by load change and cancel it by varying the input of the turbine unit i.e. increasing or decreasing the steam value. The turbine unit is used to transform the energy such as steam or water into mechanical energy received which is applied to the generator unit. The mechanical power received from the turbine unit into electrical power by using generator unit. The LFC is focused on the rotor speed of the generator instead of transform the energy. The blocks are: non-reheat steam turbine=$1/(T_t s+1)$; load and machine =$1/(T_p s+1)$; governor=$1/(T_g s+1)$;

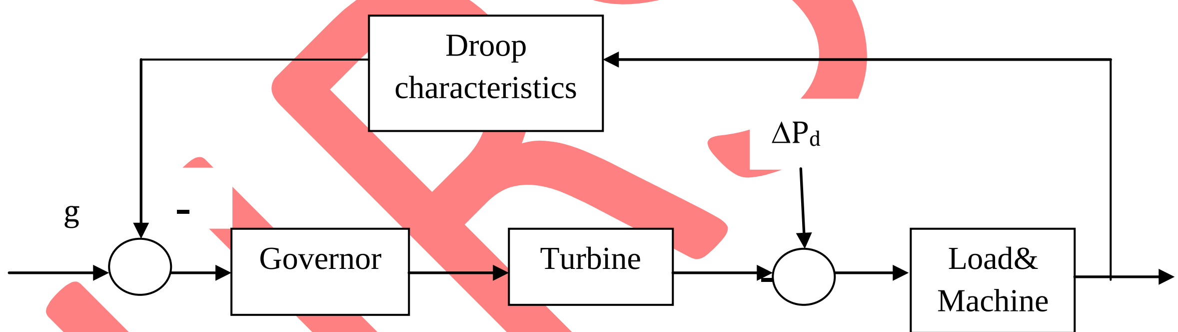

Figure.1. Single area system model.

From the above block diagram, T_g is the governor time constant and Tt is the turbine time constant. Kp =1/D and Tp=2H/fD where D is the ratio of load changes percentage to the percentage change in frequency and H is the inertia coefficient of generator. ΔPd is the change in demand.

B. SYSTEM UNDER STUDY

For example considered the two area system for LFC analysis of multiple area system. The main objectives of the LFC method are to keep the system frequency at nominal value, to provide load sharing between generators proportionality and to maintain the power exchange between the generators at schedule value. In an interconnected system each area can be connected via tie line, the power exchange between area are done through this tie line. When there is change in power of area one, that will be met by the increase in generation in all areas associated with a change in the tie line power and a reduction in frequency. But the normal operating state of the power system is that the demand of each area will be satisfied at a normal frequency and each area will absorb its own load changes. There will be area control error (ACE) for each area and this area will try to reduce its own ACE to zero.

The ACE of each area is the linear combination of the frequency and tie line error, i.e.

ACE = Frequency error + Tie line error.

A governor dead band is defined as the total magnitude of a sustained speed change where there is no change in valve position of the turbine.

III. PROPOSED SYSTEM

In the proposed methodology the load frequency control of two area system by using PSO along with PID Controller. Proportional Integral Derivative (PID) is the controller in that controller, Proportional part mainly reduces the error response to disturbances, the integral part minimizes the steady-state error and the Derivative part increases the transient response and the stability of the system. Due to its clear functionality, applicability, Robust performance and simplicity PID controller is used in industry. It is clear from above discussions that a suitable combination of proportional, integral and derivative actions can provide all the desired performances of a closed loop system. The transfer function of a P-I-D controller is given by:

$$C(s) = K_p\left(1 + \tau_d s + \frac{1}{\tau_i s}\right) \tag{1}$$

The order of the controller is low, but this controller has universal applicability; it can be used in any type of SISO system, e.g. linear, nonlinear, time delay etc. Many of the MIMO systems are first decoupled into several SISO loops and PID controllers are designed for each loop. PID controllers have also been found to be robust, and that is the reason, it finds wide acceptability for industrial processes. However, for proper use, a controller has to be tuned for a particular process; i.e. selection of P,I,D parameters are very important and process dependent. Unless the parameters are properly chosen, a controller may cause instability to the closed loop system.

The transfer function of PID controller is,

$$G_{MD}(s) = \frac{Y(s)}{E(s)} = K_p + \left(\frac{K_i}{s}\right) + K_d s \tag{2}$$

Where K_p is the proportional gain, K_i is the integral gain and K_d is the derivative gain. The required output should have the no overshoot, minimum settling time and zero steady state error. By using the PSO algorithm the parameters of the PID controller have been designed.

IV. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a population based stochastic optimization technique which is introduced by Kennedy and Eberhart in 1995. The introduction of particle swarm optimization (PSO) as a new method for global optimization many researchers have expanded on the original idea with alterations ranging from minor parameter adjustments to complete re-workings of the algorithm. Others have used PSO for comparison testing of other global optimization algorithms, including genetic algorithms and differential evolution. The PSO field has expanded dramatically since its inception, but to this point there has been little to no consensus as to what constitutes the "standard" or "canonical" PSO algorithm. Despite regular usage of the term, the actual implementation of this undefined standard varies widely between publications. Also troublesome is the fact that many of the variations on the particle swarm algorithm that are used for comparison testing do not take into account some of the major developments that have taken place since the original algorithm was proposed.

This computational technique is developed inspired by social behavior of bird flocking or fish schooling. In this technique, a group of random particles (solutions) are generated. According to fitness value the best solution is determined in the current iteration and also the best fitness value is stored. The best solution is known as pbest. Another best fitness value is also tracked in the iterations obtained so far. This best fitness value is a global best and its corresponding particle (solution) is called gbest. In every iteration all the particles will be updated by following the best previous position (pbest) and best particle among all the particles (gbest) in the swarm. The each particle updates its velocity and positions with following equations:

$$v_i^{k+1} = w^* v_i^k + c1^* rand()^* (pbest_i^k - x_i^k) + c2^* rand() * (gbest_i^k - x_i^k)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \qquad (3)\&(4)$$

where i = 1, …n and n is the size of the swarm, k represent the no. of iteration.

x_i^k: current position of i^{th} particle at k^{th} generation.

v_i^k: current velocity of i^{th} particle at k^{th} generation.

$pbest_i^k$: pbest of i^{th} particle for k^{th} generation.

$gbest_i^k$: gbest of i^{th} particle considering the whole generation. i.e. upto the k^{th} generation .

v_i^{k+1}: updated velocity of i^{th} particle.

w: inertia weight for ith particle.

c1 & c2 : constriction factors .

$rand()$: random number between 0 and 1.

For obtaining optimized value, if c1 & c2 are not properly selected according to the problem, the PSO system might not converge at all. Normally c1 and c2 are equal and ranges from 0 to 4.

(IJRST) 2015, Vol. No. 5, Issue No. II, Apr-Jun **ISSN: 2249-0604**

Inertia weight is another important factor for swarm optimization problems. Inertia weight (w) must not be constant for better results. It is randomly selected within a certain range. Random selection of w provides successful tracking for a dynamic optimization problem. The inertia weight w is determined according to the following equation:

$$w = wmax - \frac{(wmax - wmin) * present\ iteration}{maximum\ iteration} \tag{5}$$

V. CONTROL STRATEGY

The error input to the controllers are the respective area control errors (ACE) given by:

$$ACE_i = B_i \Delta f_i + \Delta P_{tie} \tag{6}$$

where i = 1,2, B_i = frequency bias factor = (1/ R_i)+D_i

Control input to the power system is obtained by use of PID controller together with the area control errors ACE1 and ACE2.

Control input to the power system is obtained by use of PID controller together with the area control errors ACE1 and ACE2. The control input of the power system u1 and u2 are the output of the controllers and these are obtained as

$$u_1 = K_{p1} ACE_1 + K_{i1} \int ACE_1 dt + \frac{K_{d1} d(ACE_1)}{dt} \tag{7}$$

$$u_2 = K_{p2} ACE_2 + K_{i2} \int ACE_2 dt + \frac{K_{d2} d(ACE_1)}{dt} \tag{8}$$

In LFC system, in order to convergence to the optimal solution, two different unique objective functions are formulated. The objective functions are derived considering steady state and transient response specifications and proper selection of weighting factors. Wrong selection of weighting factors leads to incompatible numerical value of each term of objective functions which gives erroneous result. To meet the design specifications, following objective functions are used.

$$J_1 = (e_1 + M_{p1}) * 10^{-04} + (SSE_1) \tag{9}$$

$$J_2 = (e_2 + M_{p2}) * 10^{-04} + (SSE_2) \tag{10}$$

Where e1 and e2 = square integral of ACE1 and ACE2, M p1 and Mp2= Maximum overshoot of area-1 and 2 and SSE1 and SSE2 = Steady state error of area-1 and 2.

In this paper, multi objective optimization using PSO algorithm is used to tune the PID control parameters. In multi objective optimization, simultaneous optimization of multiple objectives is carried out. Unlike single objective optimization, the solution is not a single point, but a group of solutions are obtained which may be useful for design and analysis.

The observations show that the proposed control strategy with developed objective function produces good dynamic performances of the considered power system.

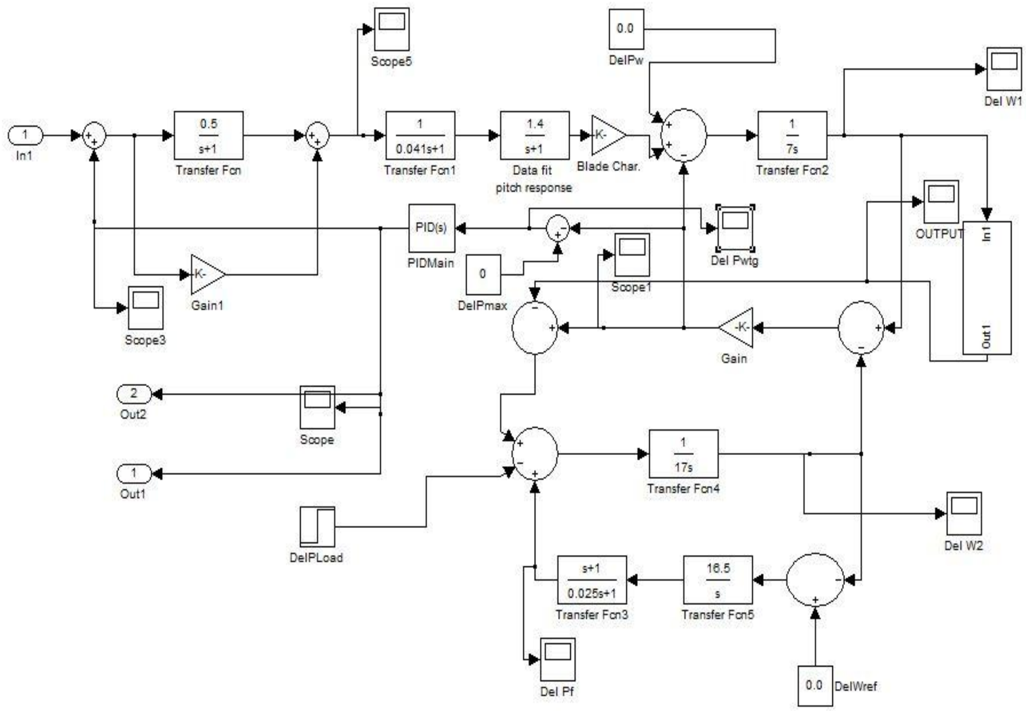

Figure 2 : Simulation Diagram

VI.RESULT AND DISCUSSION

The simulation is carried out by MATLAB 7.9 software run on a PC of dual core processor with 2 GHz speed and RAM of 4 GB. For two area system the population size is chosen as 50 and the maximum number of iterations for optimization process is 50. The constriction factors c1 and c2 are chosen as c1=c2=2.05. The simulation is realized in case of step load change, ΔPL = 0.2 pu MW in area-1, occurring at t = 1 sec and the frequency change in area-1, area-2 and tie-line power change is observed. Settling Time=11.944, Over shoot=20980.0699, Under shoot=8837.1612. The observations show that the proposed control strategy with developed objective function produces good dynamic performances of the considered power system. Specially, the proposed objective function extract better solution. The proposed PSO based PID controller with the derived cost function gives better control performance by minimizing frequency and tie line power deviation to zero. There is no oscillation in the transient part this make the system relatively more stable one. The proposed method yields true optimal gains, minimum settling time and zero overshoot of the transient responses shown in Figure 3(a) – 3 (e) *(a) Simulation Results*

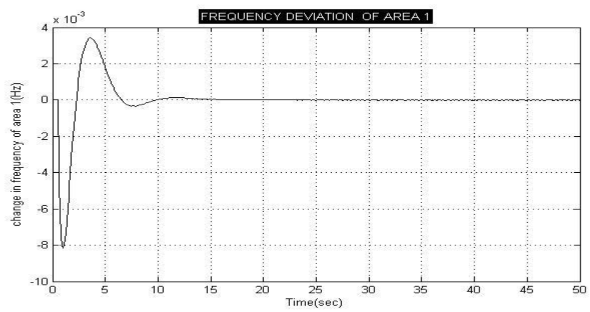

Figure 3(a) : Frequency deviation of area-1

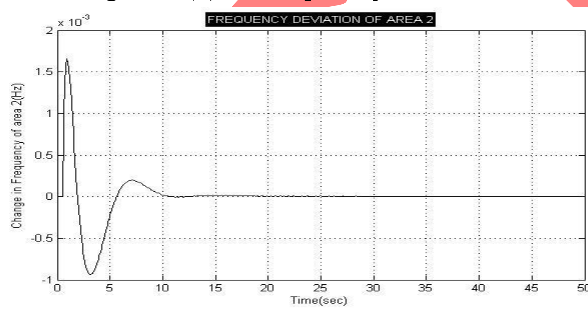

Figure 3(b) : Frequency deviation of area-2

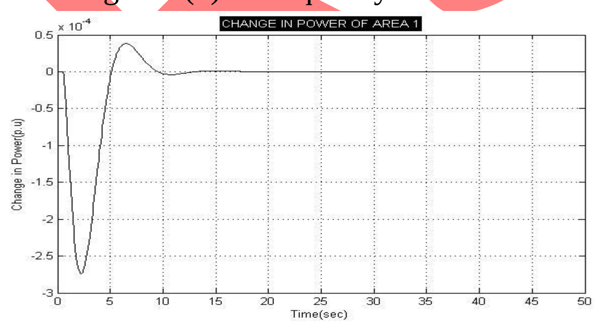

Figure 3(c) : Power deviation of area-1

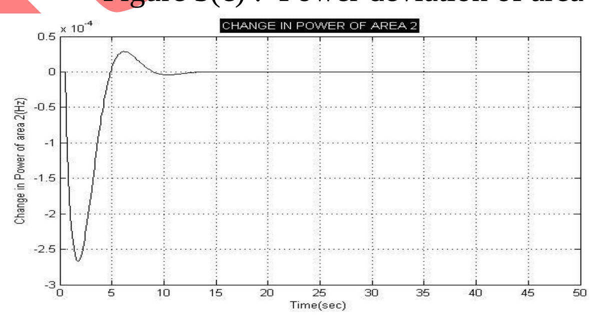

Figure 3(d) : Power deviation of area-2

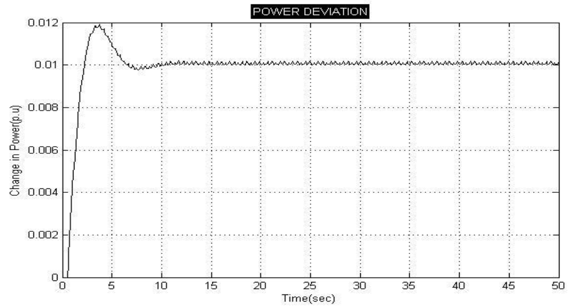

Figure 3(e) : Tie-line Power deviation

VII. CONCLUSION

In this paper, PSO based PID controller design using optimization has been proposed for the LFC. A two area power system with governor dead band has been considered to demonstrate the proposed methodology. By considering the transient specifications and appropriate selection of weighting factors the objective functions are uniquely formulated.
The proposed method gives a very good transient and steady state responsibilities for frequency and tie line power deviation. The simulation results are also proves that.

REFERENCES

[1] P. Kundur, Power system stability and control, McGraw-Hill, New York, 1994.

[2] G. Mallesham,S. Mishra, and A.N. Jha, "Maiden application of Ziegler-Nichols method to AGC of distributed generation system", Power Systems Conference and Exposition, PSCE '09, IEEE/PES, pp.1-7, March 2009.

[3] M tankovi , G admor, and akharuk, n robust control analysis and design for load frequency regulation", IEEE Transactions on Power Systems , vol.13, no.2, pp.449-455, May 1998.

[4] Khodabakhshian, and M Edrisi, " new robust PID load frequency controller", Control Engineering Practice, vol. 16, issue 9, pp. 1069-1080, September 2008.

[5] Wen an,and Hong Zhou, "Robust analysis of decentralized load frequency control for multi-area power systems", International Journal of Electrical Power & Energy Systems, vol. 43, issue 1, pp. 996-1005, December 2012.

[6] R.R. Shoults, and J.A. Jativa Ibarra, "Multi-area adaptive LFC developed for a comprehensive AGC simulator," IEEE Transactions on Power Systems , vol.8, no.2, pp.541-547, May 1993.

[7] Alireza Yazdizadeh, Mohammad Hossein Ramezani, and Ehsan Hamedrahmat, “Decentralized load frequency control using a new robust optimal MI PID controller”, International Journal of Electrical Power & Energy Systems, vol.35, issue 1, pp. 57-65, February 2012.

[8] D. Rerkpreedapong, A. Hasanovic, and A. Feliachi, A., "Robust load frequency control using genetic algorithms and linear matrix inequalities", IEEE Transactions on Power Systems, vol.18, no.2, pp.855-861, May 2003.

[9] Yao Zhang, Lili Dong, and Zhiqiang Gao, "Load frequency control for multiple-area power systems," American Control Conference, ACC '09, pp.2773-2778, June 2009.

[10] Lili Dong, Yao Zhang, and Zhiqiang Gao, “ robust decentralized load frequency controller for interconnected power systems”, I Transactions, vol. 51, issue 3, pp. 410-419, May 2012.

[11] Ho Jae Lee, Jin Bae Park, and Young Hoon Joo, “Robust load frequency control for uncertain nonlinear power systems: A fuzzy logic approach”, Information sciences, vol. 176, issue 23, pp. 3520-3537, December 2006.

[12] H. Bevrani, and P.R. Daneshmand, "Fuzzy logic based load frequency control concerning high penetration of wind turbines", IEEE Systems Journal , vol.6, no.1, pp.173-180, March 2012.

[13] J. Talaq, and F. Al-Basri, "Adaptive fuzzy gain scheduling for load frequency control", IEEE Transactions on Power Systems , vol.14, no.1, pp.145-150, Feb 1999.

[14] Li Pingkang, Zhu Hengjun, and Li Yuyun, "Genetic algorithm optimization for AGC of multi-area power systems," 2002 IEEE Region 10 Technical Conference on Computers, Communications, Control and Power Engineering , vol.3, pp.1818-1821, Oct. 2002.

[15] Fatemeh Daneshfar, Hassan Bevrani, “Multiobjective design of load frequency control using genetic algorithms”, International Journal of Electrical Power & Energy Systems, vol. 42, issue 1, pp. 257-263, November 2012.