Abstract-- This paper studies control of load frequency in single area power system with PID controller. In this study, PID parameters are improved using the multi-objective genetic algorithm technique. The proposed controller compared with a conventional PID controllers tuned by Ziegler-Nicholas technique, Particle Swarm Optimization (PSO). The effectiveness of the anticipated scheme is confirmed through the comparison of steady state response characteristics. For this study, MATLAB-Simulink software is used.

Keywords-- Load Frequency Control, Single Area Power System, PID Controller, Multi-Objective Genetic Algorithm

I. INTRODUCTION

Frequency is a key stability criterion in power systems. To provide the stability, active power balance and constant frequency are required. Frequency depends on active power balance. If any change occurs in active power demand/generation in power systems, frequency cannot be held in its rated value. So oscillations increase in both power and frequency. Thus, system subjects to a serious instability problem. To improve the stability of the power networks, it is necessary to design a Load Frequency Control (LFC) system that controls the power generation and active power [1].

Generally, ordinary LFC systems are designed with Proportional-Integral (PI) controllers. However, since the "I" control parameters are usually tuned; it is incapable of obtaining good dynamic performance for various load and system changes. Many studies have been carried out in the past on this important issue in power systems, which is the load frequency control. As stated in some literature [2], some control strategies have been suggested based on the conventional linear control theory. These controllers may be inappropriate in some operating conditions. This could be due to the complexity of the power systems such as nonlinear load characteristics and variable operating points.

In this study, multi-objective genetic algorithm is used to determine the parameters of a PID controller according to the system dynamics.

II. OVERVIEW ON GENETIC ALGORITHM

The Genetic Algorithm (GA) is an optimization and search technique based on the principles of genetics and natural selection. The GA allows a population composed of many individuals to evolve under specified selection rules to a state that maximizes the “fitness” (i.e., minimizes the cost function) [3].

The GA begins, like any other optimization algorithm, by defining the optimization variables, the cost function, and the cost. It ends like other optimization algorithms too, by testing for convergence; a flow chart of the components of the GA is shown in Figure 1.

Selecting Genetic Algorithm parameters like mutation rate, and population size is very difficult due to the many possible variations in the algorithm and cost function. A Genetic Algorithm relies on random number generators for creating the population, mating, and mutation. A different random number seed produces different results. In addition there are various types of crossovers and mutations, as well as other possibilities, like chromosome aging and Gray codes. Comparing all the different options and averaging the results to reduce random variations for a wide range of cost functions is a daunting task. Plus the results may be highly dependent on the cost function analyzed.
III. MULTI-OBJECTIVE GA

Multi objective formulations are realistic models for many complex engineering optimization problems. As soon as there are many (possibly conflicting) objectives to be optimized simultaneously, there is no longer a single optimal solution but rather a whole set of possible solutions of equivalent quality [4].

A reasonable solution to a multi objective problem is to investigate a set of solutions, each of which satisfies the objectives at an acceptable level without being dominated by any other solution.

Being a population based approach, GA are well suited to solve multi-objective optimization problems. A generic single-objective GA can be modified to find a set of multiple non-dominated solutions in a single run. The ability of GA to simultaneously search different regions of a solution space makes it possible to find a diverse set of solutions for difficult problems with non-convex, discontinuous and multi-modal solutions spaces. The cross over operator of GA may exploit structures of good solutions with respect to different objectives to create new non-dominated solutions [5].

The goal of MOO is to find as many of these solutions as possible. If reallocation of resources cannot improve one cost without raising another cost, then the solution is Pareto optimal. A Pareto GA returns a population with many members on the Pareto front. The population is ordered based on dominance. Several different algorithms have been proposed and successfully applied to various problems such as [5]: Vector Evaluated GA (VEGA), Multi Objective GA (MOGA), A Non-Dominated Sorting GA (NSGA) and Non-Dominated Sorting GA (NSGA II) which is used in the proposed research.

IV. PROBLEM FORMULATION

Non-reheat type single area thermal generating system represents by block diagram of closed loop controlled system model. As shown in Figure 2, \( f \) is the system frequency (Hz), \( R \) is regulation constant (Hz/unit), \( T_p \) is speed governor time constant (sec), \( T_i \) is turbine time constant (sec), \( H \) is inertia constant (s) and \( D \) is area parameter (Mw/Hz).

Basically, electric power system components are non-linear; therefore a linearization around a nominal operating point is usually performed to get a linear system model which is used in the controller design process. The operating conditions of power systems are continuously varying. Accordingly, the real plant usually differs from the assumed one. Therefore, classical algorithms to design a Load Frequency Control (LFC) using an assumed plant may not ensure the stability of the overall real system.

For the single area non-reheat thermal system considered in this study, the conventional Proportional integral (PI) controller was replaced by a PID controller with the following structure:

\[
G_c(s) = K_p + \frac{K_i}{s} + K_ds
\]  

Where \( K_p \) is proportional gain, \( K_i \) and \( K_d \) are integral and derivative time constants, respectively.

In this simulation, the objective is to minimize the cost function. For this reason the objective function is chosen as the Integral Square Error (ISE). The ISE squares the error to remove negative error components.

\[
ISE = \sum_{k=1}^{n} e^2(k)
\]

Define cost function
Select GA parameters

Generate initial population

Find cost for each chromosome
Select mates
Crossover
Mutation

Convergence
Check
No

Yes
Done

Figure 1: Flow Chart of Genetic Algorithm

In this simulation, the objective is to minimize the cost function. For this reason the objective function is chosen as the Integral Square Error (ISE). The ISE squares the error to remove negative error components.
\[ ISE = \sum_{k=1}^{\infty} e^2(k) \]  

Where \( e(t) \) represents the deviation in the frequency \( \Delta f \). The minimization fitness function becomes

\[
fitness = ISE + \alpha \times P.O + \beta \times T_s
\]  

Where \( P.O \) is the percentage overshoot, \( T_s \) is the settling time (sec.), and \( \alpha \) and \( \beta \) are positive real numbers taken normally as 0.5 and 0.5.

The control signal for the conventional PID controller in the sense of ISE only can be given in the following equation.

\[
U_i(s) = - G_e(s) \times ISE
\]

\[
U_i(s) = \left( K_p + \frac{K_i}{s} + K_d s \right) \left( \sum_{k=1}^{q} e^2(k) \right)
\]

Based on these objectives; the multi-objective optimization problem can be stated as:

**Minimize fitness**

Subjected to:

\[
K_p^{\text{min}} \leq K_p \leq K_p^{\text{max}}
\]

\[
K_i^{\text{min}} \leq K_i \leq K_i^{\text{max}}
\]

\[
K_d^{\text{min}} \leq K_d \leq K_d^{\text{max}}
\]

Where \( K_p, K_i, K_d \) are the PID controller parameters.

The performance of the multi-objective genetic algorithm based PID controller was compared with the PSO based self tuning PID controller developed in [6], the conventionally tuned PID controller (Ziegler-Nichols method), and conventional PI controller.

V. RESULTS AND DISCUSSIONS

By using multi-objective genetic algorithm technique in conjunction with equation (1)-(5), optimal controller parameters were obtained as shown in Table 1.

Table 1: PID Controller Parameters using Genetic Algorithm Technique

<table>
<thead>
<tr>
<th>PID parameters</th>
<th>( K_p )</th>
<th>( K_i )</th>
<th>( K_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>values</td>
<td>3.8192</td>
<td>2.2784</td>
<td>4.0498</td>
</tr>
</tbody>
</table>
Table 2: Comparison between Proposed Genetic based PID, PSO based PID, Ziegler-Nichols Tuned PID & Conventional PI Controller.

<table>
<thead>
<tr>
<th>Controller</th>
<th>Settling Time</th>
<th>Peak Overshoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Genetic-PID</td>
<td>3.5</td>
<td>0.002400</td>
</tr>
<tr>
<td>PSO based PID</td>
<td>11.5</td>
<td>0.002662</td>
</tr>
<tr>
<td>Ziegler-Nichols PID</td>
<td>17.3</td>
<td>0.009763</td>
</tr>
<tr>
<td>Conventional PI</td>
<td>13.5</td>
<td>0.027350</td>
</tr>
</tbody>
</table>

Figure 4 shows time response with the conventionally tuned PID controller (Ziegler-Nichols method) and the conventional PI controller.

Figure 5 shows time response with PSO based PID controller; System was simulated for 20 seconds with step change of 0.01 p.u.

Figure 6 shows the time domain performance of the system under the proposed multi-objective genetic algorithm based PID controller with step change of 0.05 p.u.

At the simulation, the multi-objective genetic algorithm was run for 1000 generations with a population size of 100; As seen in the time response, the genetic algorithm tuned controller gives better performance in terms of overshoot and settling time.

This shows the efficiency of the multi-objective genetic algorithm tuned PID controller over the performance of the PSO based controller, the conventionally tuned PID controller (Ziegler-Nichols method) and conventional PI controller.

VI. CONCLUSION

In this proposed study, a new multi-objective genetic algorithm based PID has been investigated for automatic load frequency control of a single area power system. For this purpose, first, more adaptive tuning mechanism for the PID controller parameters is obtained. It has been shown that the proposed control algorithm is effective and provides significant improvement in system performance. Therefore, the proposed multi-objective genetic algorithm based PID controller is recommended to generate good quality and reliable electric energy. In addition, the proposed controller is very simple and easy to implement since it does not require many information about system parameters. Comparison of the proposed multi-objective genetic algorithm based PID controller with conventional PID controllers was presented.
REFERENCES


