Multi-Objective Design of Load Frequency Problem Using Genetic Algorithm based PID Controller

Ch. Rajani
M.Tech Student Scholar
Department of Electrical & Electronics Engineering,
QIS College of Engineering, Ongole, A.P,India

Karimulla Peerla Shaik
Assistant Professor
Department of Electrical & Electronics Engineering,
QIS College of Engineering, Ongole, A.P, India

B.Venkata Prasanth
Prof In EEE
Department of Electrical & Electronics Engineering,
QIS College of Engineering, Ongole, A.P,India

Abstract— In this paper, Genetic Algorithm (GA) based proportional integral (PID) type controller is proposed to solve the Decentralized load frequency control (LFC) problem for multi-area power system that operates under deregulation based on the bilateral policy scheme. A decentralized PID tuning method is proposed by assuming that the tie-line power flows are disconnected. In each control area, the effects of the possible contracts are treated as a set of new input signals in a modified traditional dynamical model. The salient advantage of this strategy is its high insensitivity to large load changes and disturbances in the presence of plant parameter variations and system nonlinearities. This developed strategy leads to a flexible controller with simple structure that is easy to implement, and therefore, it can be useful for the real world power systems. The proposed method is tested on a three area power system with different contracted scenarios under various operating conditions to illustrate the GA based PID controller robust performance. The analysis for this evaluation by using Matlab Environment.

Index Terms— Automatic Generation Control (AGC), Genetic Algorithm (GA), Load Frequency Control (LFC), Proportional Integral Derivative (PID).

I. INTRODUCTION

Large scale power systems are normally managed by viewing them as being made up of control areas with interconnections between them. Each control area must meet its own demand and its scheduled interchange power. Any mismatch between the generation and load can be observed by means of a deviation in frequency [1]. This balancing between load and generation can be achieved by using Automatic Generation Control (AGC). The engineering aspects of planning and operation have been reformulated in a restructured power system in recent years although essential ideas remain the same. To improve the efficiency in the operation of the power system some major changes into the structure of electric power utilities have been introduced by means of deregulating the industry and opening it up to private competition. The utilities no longer own generation, transmission, and distribution; instead, there are three different entities, viz., GENCO (Generation Companies), TRANSCO (Transmission Companies) and DISCOs (Distribution Companies). As there are several GENCOs and DISCOs in the deregulated structure, a DISCO has the freedom to have a contract with any GENCO for transaction of power. A DISCO may have a contract with a GENCO in another control area. Such transactions are called “bilateral transactions.” 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. One of the most profitable ancillary services is the load frequency control. The main goal of the LFC is to maintain zero steady state errors for frequency deviation and minimize unscheduled tie-line power flows between neighboring control areas.

Significance of AGC in deregulated environment is three-fold:
(i) To achieve zero static frequency;
(ii) To distribute generation among areas so that interconnected tie line flows match a prescribed schedule; and
(iii) To balance the total generation against the total load and tie line power exchanges. In the deregulated environment, control is highly decentralized.

Frequency changes in large scale power systems are a direct result of the imbalance between the electrical load and the power supplied by connected generators [1]. Therefore load–frequency control is one of the important power system control problems which have been considerable research works for it [1–3]. Usually, the load frequency controllers used in the industry are PI type and are tuned online based on trial-and-error approaches. Also recently, several approaches based on modern control theory have been applied to the LFC design problem and there has been continuing interest in designing load–frequency controllers with better performance using various decentralized robust and optimal control methods during the last two decades [4–10]. One of the modern control techniques which has been applied to the LFC problem is H1 optimization technique [9,10]. However, the
importance and difficulties in the selection of H1 weighting functions have been reported.

Moreover, the pole-zero cancellation phenomenon associated with this approach produces closed loop poles whose damping is directly dependent on the open loop system (nominal system) [11]. On the other hand, the order of the H1-based controllers is as high as that of the plant. This gives rise to complex structure of such controllers and reduces their applicability. Then despite the potential of modern control techniques with different structures, power system utilities prefer the online tuned PI and PID controller’s. The reasons behind that might be the ease of online tuning and the lack of assurance of the stability related to some adaptive or variable structure techniques. One of the optimization techniques that is used for tuning the PID controller parameters is Genetic algorithm (GA) [12,13]. The advantage of the GA technique is that it is independent of the complexity of the performance index considered. It suffices to specify the objective function and to place finite bounds on the optimized parameters. However, in practice this approach is not capable in problems with multiple objective functions like multi-area power systems with more than one PID controller. In this paper, the LFC problem in multi-area power system is formulated as a multi-objective optimization problem and GA is employed to solve it.

II. MULTI-OBJECTIVE DESIGN

Many real-world power system problems involve simultaneous optimization of multiple objectives. In certain cases, objective functions may be optimized separately from each other and insight gained concerning the best that can be achieved in each performance dimension. However, suitable solutions to the overall problem can seldom be found in this way. Instead, multi-objective optimization (MO) solution seeks to optimize the components of a vector-valued cost function. Unlike single objective optimization, the solution to this problem is not a single point, but a family of points known as pare to-optimal (PO) set. Each point in this surface is optimal in the sense that no improvement can be achieved in one cost vector component that does not lead to degradation in at least one of the remaining components [14].

In an MOP, there may not exist one solution that is best with respect to all objectives. In view of the fact that none of the solutions in the non-dominated set is absolutely better than any other, any one of them is an acceptable solution [15]. The choice of one solution over the other requires using an optimization technique. Conventional optimization techniques, such as gradient and simplex based methods, and also less conventional ones, such as simulated annealing, are difficult to extend to the true multi-objective optimization case, because they were not designed with multiple solutions in mind. Evolutionary algorithms (EAs), however, have been recognized to be possibly well-suited to multi-objective optimization since early in their development. Multiple individuals can search for multiple solutions in parallel, eventually taking advantage of any similarities available in the family of possible solutions to the problem. The ability to handle complex problems, involving features such as discontinuities, multimodality, disjoint feasible spaces and noisy function evaluations, reinforces the potential effectiveness of EAs in multi-objective search and optimization, which is perhaps a problem area where evolutionary computation really distinguishes itself from its competitors [15]. One of the evolutionary computation techniques that work well with a population of points is GA. It is expected that they can find the Pareto-optimal front easily by maintaining a population of solutions, and search for many non-inferior solutions in parallel. This characteristic makes GAs very attractive for solving Multi-objective optimization problems.

In an isolated power system, the LFC task is limited to restore the system frequency to the specified nominal value. In order to generalize the isolated LFC model for interconnected power systems, the control area concept needs to be used as it is a coherent area consisting of a group of generators and loads, where all the generators respond to changes in load or speed changer settings, in unison [16].

Fig. 1. A Three-Control Area Power System.

Therefore, a large-scale power system consists of a number of interconnected control areas. Fig. 1 shows the block diagram of a three-control area power system, which includes 3 Gencos in each control area. Following a load disturbance within a control area, the frequency of that area experiences a transient change, the feedback mechanism comes into play and generates appropriate rise/lower signal to make generation follow the load [16]. In the steady state, the generation is matched with the load, driving the tie-line power (DPtie) and frequency deviations (DF) to zero. The balance between connected control areas is achieved by detecting the frequency and tie-line power deviations to generate area control error (ACE) signal. The ACE for each control area can be expressed as a linear combination of tie-line power change and frequency deviation as follow [16]:

\[ \text{ACE}_i = \beta_i \Delta f_i + \Delta P_{\text{tie}-i} \]  

(1)

III. PROBLEM FORMULATION

A multi-area power system comprises areas that are interconnected by high-voltage transmission lines or tie-lines. The trend of frequency measured in each control area is an indicator of the trend of the mismatch power in the interconnection and not in the control area alone. The LFC system in each control area of an interconnected power system should control the interchange power with the other control areas as well as its local frequency [16]. According to above
discussions, the main objectives for the LFC problem in a multi-area power system can be expressed as follow. If the disturbance magnitude is greater than the available power reserve (supplementary control) i.e. PC < PL, the frequency deviation and tie line power changes do not converge to zero in steady state [16]. Therefore, the main goal of the LFC system in a multi-area power system is to converge each area’s ACE signal to zero in steady state in the presence of load disturbance, and the Multi-objective problem is reduced to optimize the PID controllers parameters, such that the ACE signals converge to zero in encountering the load disturbance too. According to the above explanation, to have some degree of relative stability in all areas of a multi-area power system, the parameters of the PID controllers may be selected so as to minimize the objective function (2).

Which ObjFnci is the objective function of power area i, k is equal with the simulation time (s) and [ACEit] is the absolute value of ACE signal of area i at time t.

$$\text{ObjFnci} = \sum_{t=0}^{K} |\text{ACEit}|$$  \hspace{1cm} (2)

To minimize the mentioned objective function in a multi-area power system with n areas, a vector-valued cost function (3) has been defined, which the multi-objective optimization solution seeks to optimize it by determining a set of non-dominated solution points which the choice of one solution over the other is done by GA.

$$[\text{ObjFnc}_{1}, \ldots, \text{ObjFnc}_{i}, \ldots, \text{ObjFnc}_{n}]$$  \hspace{1cm} (3)

To implement the above solution, a simulation study is provided in the Optimization Toolbox of MATLAB software. In this simulation the following design criteria have been considered for simplicity through the process of applying GA to the MOP:
1. The population and individual representation has to be able to declare all candidate solutions.
2. The LFC problem includes specific constraints, then it has to be guaranteed that any produced individual by the crossover and mutation presents a valid candidate solution, otherwise it has to be repaired to a feasible one. Fitness function of the GA problem based on the vector objective function (3), is as follows

$$[\text{ObjFnc}_{1}, \ldots, \text{ObjFnc}_{i}, \ldots, \text{ObjFnc}_{n}] = \text{FitnessFunction}(\ldots).$$  \hspace{1cm} (4)

Here GA is a technique used to tune PID controller parameters based on the optimum values gained for the vector-valued cost function (3). The basic line of the algorithm is derived from a steady state genetic algorithm, where only one replacement occurs per generation. Also when defining the initial population of GA individuals and designing the crossover and mutation operators, the need for the repair function is necessary to make a high correlation between parents and offspring. Finally to reach a good combination of individuals, GA operators are defined as follow [15].

$$[\{K_{1}, P_{1}\}, \ldots, \{K_{i}, P_{i}\}, \ldots, \{K_{n}, P_{n}\}]$$  \hspace{1cm} (5)

Eq. (5) shows the GA individual vector whose elements present PID controller parameters.

Which (Ki, Pi, Di) are PID parameters related to area i. Initial solutions to the above individuals are generated using a uniform random number of PID controller parameters between [-1, 1] (since the most PI Dcontroller parameters are between [-1,1], the initial population is spread along the search space [-1,1]). Also an m x n matrix presents the whole GA population, (m rows correspond to m individuals and n columns present individual elements). To initialize individuals at random, we start with an empty matrix, and fill it with PID parameters generated using a uniform random number.

In each generation phase, individuals (PID parameters) are applied to the specified multi-area model and the model is simulated for appropriate seconds. After the simulation terminated different control area ACE signals will produce the individual fitness according to (4). Then two different individuals have been selected based on the roulette wheel selection. The crossover and mutation operators are then applied. The crossover is applied on both selected parents and offspring. Finally to reach a good combination of individuals, GA operators are applied.

A. About GA Technique

Here GA is a technique used to tune PID controller parameters based on the optimum values gained for the vector-valued cost function (3). The basic line of the algorithm is derived from a steady state genetic algorithm, where only one replacement occurs per generation. Also when defining initial population of GA individuals and designing the crossover and mutation operators, the need for there pair function is necessary to make a high correlation between parents and offspring. Finally to reach
a good combination of individuals, GA operators are defined as follow

**Initialization**

Eq. (6) shows the GA individual vector whose elements present PIDcontroller parameters.

\[(K1,P1,D1),..., (Ki, Pi, Di), ..., (Kn, Pn, Dn)\] ...(6)

which (Ki, Pi, Di) are PID parameters related to area i. Initial solutions to the above individuals are generated using a uniform random number of PID controller parameters between [-1, 1] (since the most PID controller parameters are between [-1, 1], the initial population is spread along the search space [-1,1]). Also an m x n matrix presents the whole GA population, (m rows correspond to m individuals and n columns present individual elements). To initialize individuals at random, we start with an empty matrix, and fill it with PI parameters generated using a uniform random number.

**Selection, mutation and crossover**

In each generation phase, individuals (PID parameters) are applied to the specified multi-area model and the model is simulated for appropriate seconds. After the simulation terminated different control area ACE signals will produce the individual fitness according to (4). Then two different individuals have been selected based on the roulette wheel selection. The crossover and mutation operators are then applied. The crossover is applied on both selected individuals, generating two children. The mutation is applied uniformly on the best individual. The best resulting individual is integrated into the population, replacing the worst ranked individual in the population. The above procedure has run for many generations until gain to the minimum value of the fitness functions (Fig. 2 presents the model of the applied GA algorithm). In some cases mutation operator will change the individual in such a way that we cannot guarantee the individual to be still legal. Then, the repair function has to be applied and guarantee that each individual parameters are randomly generated in [-1, 1] and also there is not any repetitive individual.

**IV. SIMULATION RESULTS**

The performance of the closed-loop system using the linear robust PID controllers [9,10] compared to the well tuned PID controllers with multi-objective optimization for the various possible load disturbances, here simulation results is carried out in cases 1). Pool Co Based Transcations, 2). Combination of Pool Co And Bilateral Based Transcations, 3). Combination Of Pool Co And Bilateral Based Transcations With Contract Violation.

**Case 1: Pool Co Based Transcations**

![Fig.3 Modified control Area in Deregulated environment](image)

To illustrate the robustness of the proposed control strategy against contract variations, simulations are performed for three scenarios of possible contract under various operating conditions and large load demand. In the three area system of deregulated environment, each area has two Genco’s and two Disco’s in it. Let Genco1,1,Genco2,1, Disco1,1, Disco1,2 be in area 1, Genco1,2,Genco2,2, Disco1,2, Disco2,2 be in area 2, Genco1,3,Genco2,3, Disco1,3, Disco2,3 be in area 3. The Genco’s parameters and control parameters used for each area is given in appendix. GA based PID tuning methods is used to design decentralized load frequency controllers for the deregulated environment systems. For GA based PID tuning, population size is 15, maximum generation 100 has been taken. Decentralized load frequency controller and the GA based PID tuning method are simulated using MATLAB software package tool.

The Genco’s ACE participation factor, un-contracted and contracted load demand of Disco’s in each area for scenario 1 is given in table 1.

<table>
<thead>
<tr>
<th></th>
<th>1-1</th>
<th>2-1</th>
<th>1-2</th>
<th>2-2</th>
<th>1-3</th>
<th>2-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participation factor of Disco j in area i[αji]</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Un controlled demand of Disco j in area I in p.u. mw[ΔP(j,i)]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Load demand of Disco j in area I in p.u. mw [ΔP(j,i)]</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Based on the considered scenario 1 load demand and AGPM, the demand signals for each area are given below:

\[ \Delta P_{LOC1} \text{ for area 1 } = 0.2 \text{ pu MW} \]
\[ \Delta P_{LOC2} \text{ for area 2 } = 0.2 \text{ pu MW} \]
\[ \Delta P_{LOC3} \text{ for area 3 } = 0.0 \text{ pu MW} \]

\[ \Delta P_{d1} \text{ for area 1 } = 0.2 \text{ pu MW} \]
\[ \Delta P_{d2} \text{ for area 2 } = 0.2 \text{ pu MW} \]
\[ \Delta P_{d3} \text{ for area 3 } = 0.0 \text{ pu MW} \]

Similarly, the scheduled power tie line power flow deviation \( \Sigma i \) for each area are calculated from equation are given below:

\[ \Sigma_1 = 0 \text{ pu Mw} \]
\[ \Sigma_2 = 0 \text{ pu Mw} \]
\[ \Sigma_3 = 0 \text{ pu Mw} \]

The contracted load demand of Genco \( j \) from other area \( \rho_{ji} \) (pu Mw) are calculated from equation are given below:

\[ \rho_{1,1} = 0.11 \]
\[ \rho_{1,2} = 0.09 \]
\[ \rho_{1,3} = 0.1 \]
\[ \rho_{2,1} = 0.1 \]
\[ \rho_{2,2} = 0.0 \]
\[ \rho_{2,3} = 0.0 \]

The design decentralized load frequency controller model block diagram for scenario 1 is given in fig.4.

These optimized PID controller gain value quickly driven back the frequency deviation to zero and also driven back the tie line power deviation to their steady state value with very small settling time and overshoot.

<table>
<thead>
<tr>
<th>AREA 1</th>
<th>P</th>
<th>I</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.3929</td>
<td>0.02352</td>
<td>1.1399</td>
</tr>
<tr>
<td>AREA 2</td>
<td>1.7097</td>
<td>0.10463</td>
<td>1.4128</td>
</tr>
<tr>
<td>AREA 3</td>
<td>1.7018</td>
<td>1.901</td>
<td>0.5767</td>
</tr>
</tbody>
</table>

The convergence graph based on performance index is shown in fig 4.
Since there are no contracts between areas, the steady state power flow over the tie line are zero. Also the actual generated powers of the Genco’s according to equation properly converge to the desired value in the steady state with small settling time and overshoot. That is

\[ \Delta P_{m1-3} = 0.11 \text{ pu Mw} \]
\[ \Delta P_{m2-1} = 0.09 \text{ pu Mw} \]
\[ \Delta P_{m2-3} = 0.1 \text{ pu Mw} \]

\[ \Delta P_{m2-2} = 0.1 \text{ pu Mw} \]
\[ \Delta P_{m1-2} = 0.0 \text{ pu Mw} \]
\[ \Delta P_{m2-3} = 0.0 \text{ pu Mw} \]
Case 2: Combination of Pool Co And Bilateral Based Transcations

It is assumed that a large step load of 0.1 pu MW is demanded by each Disco in the areas. The Genco ACE participation factor, uncontracted and contracted load demand of disco’s in each area for scenario 2 is given in table III.

<table>
<thead>
<tr>
<th>Table III Demand signals for scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE Participation factor of Disco j in area i[j][j]</td>
</tr>
<tr>
<td>Un controlled demand of Disco j in area I in p.u. mw[∆PULj-i]</td>
</tr>
<tr>
<td>Load demand of Disco j in area I in p.u. mw [∆PLj-i]</td>
</tr>
<tr>
<td>Total demand signal in each area.</td>
</tr>
<tr>
<td>∆PLOC1 for area 1 = 0.2 pu MW</td>
</tr>
<tr>
<td>∆PLOC2 for area 2 = 0.2 pu MW</td>
</tr>
<tr>
<td>∆PLOC3 for area 3 = 0.0 pu MW</td>
</tr>
<tr>
<td>∆PD1 for area 1 = 0.2 pu MW</td>
</tr>
<tr>
<td>∆PD2 for area 2 = 0.2 pu MW</td>
</tr>
<tr>
<td>∆PD3 for area 3 = 0.2 pu MW</td>
</tr>
</tbody>
</table>

Based on the considered scenario 2 load demand and AGPM, the demand signals for each area are given below:

\[
\Delta P_{LOC1} \text{ for area 1 } = 0.2 \text{ pu MW} \\
\Delta P_{LOC2} \text{ for area 2 } = 0.2 \text{ pu MW} \\
\Delta P_{LOC3} \text{ for area 3 } = 0.0 \text{ pu MW} \\
\Delta P_{D1} \text{ for area 1 } = 0.2 \text{ pu MW} \\
\Delta P_{D2} \text{ for area 2 } = 0.2 \text{ pu MW} \\
\Delta P_{D3} \text{ for area 3 } = 0.2 \text{ pu MW} \\
\]

Similarly the scheduled power tie line power flow deviation \(\sum_i\) for each area are calculated from equation are given below:

\[
\sum_1 = 0 \text{ pu Mw} \\
\sum_2 = 0.025 \text{ pu Mw} \\
\sum_3 = -0.025 \text{ pu Mw} \\
\]

Using the proposed GA based PID method, the optimized PID gain value for each area based on the minimum performance index value (ITAE) of 81.5407 is given in table IV.

<p>| Table 7.4 Optimized PID Gain Value For Three Area System |</p>
<table>
<thead>
<tr>
<th>P</th>
<th>I</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA 1</td>
<td>1.3929</td>
<td>0.02352</td>
</tr>
<tr>
<td>AREA 2</td>
<td>1.7097</td>
<td>0.10463</td>
</tr>
<tr>
<td>AREA 3</td>
<td>1.7018</td>
<td>1.901</td>
</tr>
</tbody>
</table>

The convergence graph based on performance index is shown in fig.17.

These optimized PID controller gain value quickly driven back the frequency deviation to zero and also driven back the tie line power deviation to their steady state value with very small settling time and overshoot.
It is observed that the deviations of the scheduled tie line flow are not zero due to the contract in the deregulated environment. The steady state of $\Delta P_{tie,i}$ should be,

$\Delta P_{tie,1} = 0$ pu Mw

$\Delta P_{tie,2} = 0.025$ pu Mw

$\Delta P_{tie,3} = -0.025$ pu Mw

The actual generated powers of the Genco’s according to equation, properly converge to the desired value in the steady state with small settling time and overshoot. That is

$\Delta P_{m1,1} = 0.1$ pu Mw

$\Delta P_{m2,1} = 0.1$ pu Mw

$\Delta P_{m1,2} = 0.075$ pu Mw

$\Delta P_{m2,2} = 0.15$ pu Mw

$\Delta P_{m1,3} = 0.075$ pu Mw

$\Delta P_{m2,3} = 0.1$ pu Mw
Case 3: Combination Of Pool Co And Bilateral Based Transactions With Contract Violation.

In this case, Disco’s may violate a contract by demanding more power than the specified in the contract. This excess power is reflected as a located load of the area (uncontracted demand). Consider scenario 2 again, it is assumed that in addition to the specified contracted load demands, Disco in area 1, Disco 1 in area 2 and Disco 2 in area 3 demand are 0.05, 0.04 and 0.03 pu Mw as large uncontracted loads respectively. The purpose of this scenario is to test the effectiveness of the proposed controller against uncertainties and large load disturbance.

The Genco ACE participation factor, uncontracted and contracted load demand of Disco’s in each area for scenario 2 is given in table V.

<table>
<thead>
<tr>
<th>Table V Demand signals for scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACE Participation factor of Disco j in area i [α_\text{ji}]</td>
</tr>
<tr>
<td>Un controlled demand of Disco j in area I in p.u. mw [\Delta P_{UL,i}]</td>
</tr>
<tr>
<td>Load demand of Disco j in area I in p.u. mw [\Delta P_{L,i}]</td>
</tr>
</tbody>
</table>
Based on the considered scenario 3 load demand and AGPM, the demand signals for each area are given below

\[ \Delta P_{\text{LOC2}} \text{ for area 2} = 0.20 \text{ pu MW} \]
\[ \Delta P_{\text{LOC3}} \text{ for area 3} = 0.20 \text{ pu MW} \]
\[ \Delta P_{d1} \text{ for area 1} = 0.25 \text{ pu MW} \]
\[ \Delta P_{d2} \text{ for area 2} = 0.24 \text{ pu MW} \]
\[ \Delta P_{d3} \text{ for area 3} = 0.23 \text{ pu MW} \]

Similarly the scheduled power tie line power flow deviation (\(\sum_i\)) for each area are calculated from equation are given below

\[ \sum_1 = 0 \text{ pu Mw} \]
\[ \sum_2 = 0.025 \text{ pu Mw} \]
\[ \sum_3 = -0.025 \text{ pu Mw} \]

The contracted load demand of Genco \(j\) from other area \(\rho_{j1}\) (pu Mw) are calculated from equation are given below

\[ \rho_{1,1} = 0.1 \]
\[ \rho_{1,2} = 0.075 \]
\[ \rho_{1,3} = 0.075 \]
\[ \rho_{2,1} = 0.1 \]
\[ \rho_{2,2} = 0.15 \]
\[ \rho_{2,3} = 0.1 \]

Using the proposed GA based PID Method, the optimized PID gain value for each area based on the minimum performance index value (ITAE) of \(165.7161\) is given in table VI.

<table>
<thead>
<tr>
<th>AREA</th>
<th>P</th>
<th>I</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA1</td>
<td>1.797655</td>
<td>1.18994</td>
<td>0.647514</td>
</tr>
<tr>
<td>AREA2</td>
<td>1.662234</td>
<td>0.749171</td>
<td>0.617492</td>
</tr>
<tr>
<td>AREA3</td>
<td>1.255921</td>
<td>1.942498</td>
<td>0.387357</td>
</tr>
</tbody>
</table>

The convergence graph based on performance index is shown in fig. 30.
From the above figures it is illustrated that the uncertainties and large load demand affect the power system response in large manner without controlled and this power system response, has been quickly driven back to zero using GA based PID gain value. The actual generated powers of the Genco’s according to equation properly converge to the desired value in the steady state with small settling time and overshoot. That is

- $\Delta P_{m1,1} = 0.125 \text{ pu Mw}$
- $\Delta P_{m2,1} = 0.125 \text{ pu Mw}$
- $\Delta P_{m1,2} = 0.095 \text{ pu Mw}$
- $\Delta P_{m2,2} = 0.17 \text{ pu Mw}$
- $\Delta P_{m1,3} = 0.090 \text{ pu Mw}$
- $\Delta P_{m2,3} = 0.115 \text{ pu Mw}$

This is verified using the above figures the generated powers of the Genco’s properly reach their desired values using the proposed strategy.
The simulation results show the proposed GA based PID controller tracks the load change and achieves good robust performance for a wide range of load disturbances and possible contracted scenarios in the presence of system non-linear ness.

V. CONCLUSION

A GA based PID type controller for the AGC problem in deregulated power systems is proposed using the modified AGC scheme in this paper. This control strategy is chosen because of the increasing complexity and changing structure of deregulated power systems. This newly developed control strategy combines the advantages of the GA based PID and integral controllers for achieving the desired level of robust performance, such as precise reference frequency tracking and disturbance attenuation under a wide range of area load changes and disturbances. Moreover, it has a simple structure and is easy to implement, which makes it ideally useful for the real world power systems. The GA-PID controller was tested on a three area deregulated power system to demonstrate its robust performance for the three possible contracted scenarios under different operating conditions. Simulation results show that the proposed strategy is very effective and guarantees good robust performance against parametric uncertainties, load changes. The system performance characteristics in terms of ‘ITAE’ indices reveal that the proposed GA PID is a promising control scheme for the AGC problem. Thus, it is recommended to generate good quality and reliable electric energy in deregulated power systems.

REFERENCES