Modeling and simulation of Load Frequency Control in Automatic Generation Control using Genetic Algorithms Technique

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ABSTRACT-

The automatic generation control (AGC) process performs the task of adjusting system generation to meet the load demand and regulating at the large system frequency changes. In most of the previous works on interconnected systems, tie-line bias control strategy has been widely accepted by utilities. In this method, area control error (ACE) is calculated through feedback for each area and control action is taken to regulate ACE to zero. The problems of frequency control of interconnected areas are more important than those of isolated (single) areas.

Practically all power systems today are tied together with neighboring areas and the problem of automatic generation control becomes a joint undertaking. Consequently secure, economic and stable operation of a power system requires improved and innovative methods of control. Intelligent control techniques provide a high adoption to changing conditions and have ability to make decisions quickly by processing imprecise information. Some of these techniques are rule based logic programming; model based reasoning and computational approaches like Particle swarm optimization, genetic algorithms, fuzzy sets, artificial neural networks, evolutionary programming. In this research work, the genetic algorithms controlling technique has been used for AGC of interconnected power systems. The effectiveness of the genetic algorithms is tested on a double machine generating system operating with AGC for several of operating points. These systems are comparing for without and with genetic algorithms. This comparison shows that genetic algorithms give efficient output.

Keywords- ACE, AGC, LFC, GA method

I. INTRODUCTION

Maintaining power system frequency at constant value is very important for the protection of the power generating equipment and the utilization equipment at the customer end. The job of automatic frequency regulation is achieved by governing systems of individual turbine-generators and automatic generation control (AGC) or load frequency control (LFC) system of the power system.

The objective of the AGC in an interconnected power system is to maintain the frequency of each area and to keep tie-line power close to the scheduled values by adjusting the MW outputs of AGC generators so as to accommodate fluctuating load demands. An interconnected power system consists of control areas which are connected to each other by tie lines. In a control area, all the generators speed up or slow down together to maintain the frequency and relative power angles to scheduled values in static as well as dynamic conditions. Thus, an AGC scheme for an interconnected power system basically incorporates suitable control system, which can bring the area frequencies and tie line powers back to nominal or very close to nominal values effectively after the load perturbations. A perturbation like adding a block of load in a single area power system operating at nominal value of frequency creates the power mismatch in generation and demand. As two area interconnected power system connected through a tie line is shown in fig.1 each area feeds its control area and tie line allows electric power to flow between the areas. An interconnected power system may consist of any number of subsystems or areas.
II. OBJECTIVE FUNCTION

The objective of the thesis is to use the PSO algorithm in order to obtain optimal PID controller settings for a two area load frequency system. Every possible controller setting represents a particle in the search space, which changes its parameters: proportionality constant, $K_p$, integral constant, $K_i$, and derivative constant $K_d$ in order to minimize the error function. The error function used here is Integral Time of Absolute errors (ITAE), Integral. The equations are:

\[ J = \int_{t_0}^{t_1} (|\Delta f_1| + |\Delta f_2| + |\Delta p_{tie}|). t \]

\[ \Delta f_1 \text{min} \leq \Delta f_1 \leq \Delta f_1 \text{max} \]  

\[ \Delta f_2 \text{min} \leq \Delta f_2 \leq \Delta f_2 \text{max} \]  

\[ \Delta p_{tie} \text{min} \leq \Delta p_{tie} \leq \Delta p_{tie} \text{max} \]

III. AUTOMATIC GENERATION CONTROL

The main part of power system operation and control is to maintain continuous supply of power with an acceptable quality, to all the consumers in the system. The system will be in equilibrium, when there is a balance between the power demand and the power generated. As the power in AC form has real and reactive components: the real power balance; as well as the reactive power balance to be achieved. There are two basic control mechanisms used to achieve reactive power balance (acceptable voltage profile) and real power balance (acceptable frequency values). The former is called the automatic voltage regulator (AVR) and the latter is called the automatic load frequency control (ALFC) or automatic generation control (AGC).

The primary components to consider are the synchronous generators, the prime movers (hydraulic and steam turbines), the speed-governing system, which includes the governor and the load reference actuator (speed changer), the unit controller and the AGC system (as shown in fig. 2.)

The ALFC loop shown in fig. 3 is called the primary ALFC loop. It achieves the primary goal of real power balance by adjusting the turbine output $\Delta P_m$ to match the change in load demand $\Delta P_D$. All the participating generating units contribute to the change in generation. But a change in load results in a steady state frequency deviation $\Delta f$. The restoration of the frequency to the nominal value requires an additional control loop called the supplementary loop. This objective is met by using integral controller which makes the frequency deviation zero. The ALFC with the supplementary loop is generally called the AGC.
A. AGC in a Single Area System

In a single area system, there is no tie-line schedule to be maintained. Thus the function of the AGC is only to bring the frequency to the nominal value. This will be achieved using the supplementary loop which uses the integral controller to change the reference power setting so as to change the speed set point. The integral controller gain $K_R$ needs to be adjusted for satisfactory response (in terms of overshoot, settling time) of the system. Although each generator will be having a separate speed governor, all the generators in the control area are replaced by a single equivalent generator, and the ALFC for the area corresponds to this equivalent generator.

B. AGC in a Multi Area System

In an interconnected (multi area) system, there will be one ALFC loop for each control area (located at the EDC of that area).

Consider a change in load $\Delta P_{D1}$ in area1. The steady state frequency deviation $\Delta f$ is the same for both the areas. That is $\Delta f = \Delta f_1 = \Delta f_2$. Thus, for area1, we have

$$\Delta P_{m1} - \Delta P_{D1} - \Delta P_{12} = D_1 \Delta f$$  \hspace{1cm} (6)

Where, $\Delta P_{12}$ is the tie line power flow from area1 to area2 and for area2

$$\Delta P_{m2} + \Delta P_{12} = D_2 \Delta f$$  \hspace{1cm} (7)

The mechanical power depends on regulation. Hence

$$\Delta P_{m1} = -\Delta f \frac{1}{R_1} \quad \text{and} \quad \Delta P_{m2} = -\Delta f \frac{1}{R_2}$$  \hspace{1cm} (8)

Substituting these equations, yields

$$\left( \frac{1}{R_1} + D_1 \right) \Delta f = -\Delta P_{12} - \Delta P_{D1} \quad \text{And}$$

$$\left( \frac{1}{R_2} + D_2 \right) \Delta f = \Delta P_{12}$$  \hspace{1cm} (9)

Solving for $\Delta f$, we get

$$\Delta f = \frac{-\Delta P_{D1}}{\left(1/R_1 + D_1\right) + \left(1/R_2 + D_2\right)} = -\frac{\Delta P_{D1}}{\beta_1 + \beta_2}$$  \hspace{1cm} (10)

And

$$\Delta P_{12} = -\frac{\Delta P_{D1} \beta_2}{\beta_1 + \beta_2}$$ \hspace{1cm} (11)

Where, $\beta_1$ and $\beta_2$ are the composite frequency response characteristic of area1 and area2 respectively. An increase of load in area1 by $\Delta P_{D1}$ results in a frequency reduction in both areas and a tie-line flow of $\Delta P_{12}$. A positive $\Delta P_{12}$ is indicative of flow from area1 to area2 while a negative $\Delta P_{12}$ means flow from area2 to area1. Similarly, for a change in area2 load by $\Delta P_{D2}$, Then
\[ \Delta f = -\frac{\Delta P_{D2}}{\beta_1 + \beta_2} \]  
\[ \text{And}\quad \Delta P_{12} = -\Delta P_{21} = \frac{-\Delta P_{D2}\beta_1}{\beta_1 + \beta_2} \]  
(12)
(13)

For area 1: \( \Delta C_1 = \Delta P_{12} + \beta_1 \Delta f \)  
(14)

For area 2: \( \Delta C_2 = \Delta P_{21} + \beta_2 \Delta f \)  
(15)

**IV. Need of Intelligent Control Techniques**

Intelligent control techniques are of great help in implementation of AGC for power systems. Some of these techniques are rule based logic programming; model based reasoning, computational approaches like fuzzy sets, artificial neural networks, evolutionary programming and genetic algorithms. In this work, the Particle swarm optimization controller technique has been used for AGC of interconnected power systems.

**A. Tuning of PI using Genetic Algorithms technique**

Genetic Algorithm is an extensive application widely used to solving globally optimized searching problems. The closed form optimization technique cannot be applied to some optimization problems then a genetic algorithm is a better option. Genetic Algorithm find out too many points in the given space for single parameter hence it is more closely to converge towards global minimum solution.

Genetic Algorithm is used to find out optimal parameters of PI controller. Genetic Algorithm is powerful searching method based on the mechanics belongs to natural selection and natural genetics.

Genetic algorithm based on a population of strings, searching many parallel peaks, opposition to a single point.

- Genetic Algorithm used strings of characters which defining set of parameter.
- Genetic Algorithm follows probabilistic transition rules rather than deterministic rules.
- Genetic Algorithm directly utilized objective function information & not required derivatives or other auxiliary knowledge.

GA method is applied to find out the optimal settings of controller. Genetic algorithm optimization technique is used to minimize performance index which is integral error (AIE) type. Speed deviation has been chosen as an error function. Objective function given is

Minimize \( J_e = \int_0^\infty |e(t)|\,dt \)  
(16)
V. SIMULATION AND RESULTS OF AGC TECHNIQUE

A. Thermal–Thermal system with and without Tie line, and GA Technique

The area1 and area2 interconnected by tie line bias. Frequency deviation of area1, area2 and deviation tie line bias achieve by MATLAB implementation. We use PI controller and connected to multiport switch and analysis without tie line bias control, with tie line bias control, GA tuned method used.

Fig. 6 MATLAB Diagram of Two Area (Thermal-Thermal System) Load Frequency Control

Case-1 Comparison analysis of Deviation in frequency, tie line, for area1, area2 without tie line, with tie line and tie line bias control tuned by GA for a step load of 1% at area1

Fig. 6 to 8 shows the change in frequency deviation $\Delta f_1$, $\Delta f_2$ and deviation in tie line $P_{tie}$ for area1 and area2 a step load of 1% at area1 for without tie line, with tie line, tie line bias control tuned by GA. Analysis and calculates the different parameters maximum deviation, settling time, rise time. The PI tuned GA show better result than tie line bias control.

Fig.6: Change in frequency in area1 without, with tie line bias control and with tie line bias control tuned by GA for a step load of 1% at area1

Fig.7: Change in frequency in area2 without, with tie line bias control and with tie line bias control tuned by GA for a step load of 1% at area1

Fig.8: Deviation in tie line without, with tie line bias control and with tie line bias control tuned by GA for a step load of 1% at area1
Case-2 Comparison analysis of Deviation in frequency, tie line, for area1, area2 without tie line, with tie line and tie line bias control tuned by GA for a step load of 1% at area2

Fig. 9 to 11 shows the change in frequency deviation $\Delta f_1$, $\Delta f_2$ and deviation in tie line $P_{tie}$ for area1 and area2 a step load of 1% at area1 for without tie line, with tie line, tie line bias control tuned by GA. Analysis and calculates the different parameters maximum deviation, settling time, rise time. The PI tuned GA show better result than tie line bias control.

Fig.9: Change in frequency in area1 without, with tie line bias control and with tie line bias control tuned by GA for a step load of 1% at area2

Fig.10: Change in frequency in area2 without, with tie line bias control and with tie line bias control tuned by GA for a step load of 1% at area2

Fig.11 Deviation in tie line without with tie line bias control and with tie line bias control tuned by GA for a step load of 1% at area2

B. Comparison Table and discussion for with tie line and for tie line bias control tuned by GA for a step load of 1% at area1 and area2

Table-1 System performance for without tie line, with tie line and PI tuned GA controller for 1% load at area1

<table>
<thead>
<tr>
<th>Controller</th>
<th>Change in frequency</th>
<th>Change in frequency</th>
<th>Change in tie line power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in area1</td>
<td>in area2</td>
<td></td>
</tr>
<tr>
<td>Setting time (sec.)</td>
<td>Max. deviation (p.u)</td>
<td>Setting time (sec.)</td>
<td>Max. deviation (p.u)</td>
</tr>
<tr>
<td>Tie line bias control</td>
<td>60.524 7</td>
<td>0.0232</td>
<td>66.71 09</td>
</tr>
<tr>
<td>GA PI</td>
<td>8.4213 .0225</td>
<td>9.418 5</td>
<td>0.0167</td>
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</tbody>
</table>

Table-2 System performance for without tie line, with tie line and PI tuned GA controller for 1% load at area2
VI CONCLUSION

Load frequency controller comparison with and without tie line bias controller, GA technique defined. As the effect of tunable parameters of GA technique present in both the areas of the two area system is better. In thermal-thermal system stability can be comes faster. The optimal scaling and membership function width parameter are used in system observation give better dynamic results in case load change occurred in both areas in the system. The peak deviation and amplitude of oscillation increases and settling time almost constant. The parameter of controller is managed by GA is give more efficient output. It gives less distortion in output frequency and gives more output power in fewer time limits. Less time to settle the excursions of system state variables within acceptable limits. The system response rise time, maximum deviation and settling time of improve when prefer PI tuned GA technique.

VII REFERENCES


<table>
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<td>Max. deviation (p.u)</td>
<td>Setting time (sec.)</td>
</tr>
<tr>
<td>Tie line bias control</td>
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<td>GA PI</td>
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