Improved PI using GSA algorithm for LFC of Two Area Thermal Power System

Deepak Sharma¹, Mahendra Kumar², Alok Kumar Singh³

¹,³Department of Electrical Engg., JIT, Jaipur, ²University Department of Electronics Engg, RTU Kota
Email: deepakakshay89@gmail.com, miresearchlab@gmail.com, mtech.jitjaipur103@gmail.com

ABSTRACT
This research paper contains an elaborate presentation of control scheme for ‘Load Frequency Control’. Various attempts have been taken to investigate the load frequency control scenario, because of the main problem of controlling the real power output of generating units according to change in system frequency and tie-line power interchange within specific limits, is known as load frequency control [LFC]. The main objectives of LFC are to avoid any steady state errors of frequency and tie-line exchange variations, high damping of frequency oscillations, and decreasing overshoot of the disturbances so that the system can achieve stability. This paper presents I-Controller and PI-Controller tuning based on Gravitational Search Algorithm (GSA) for better frequency response. This type of controller is used to reduce steady state error and to control them To control the uncontrolled case of oscillations and to give better performance of dynamic response.
Keywords: Damping controller; GSA; Low frequency oscillations; PI Controller.

I. INTRODUCTION
In actual power system, the load is changing continuously as well as randomly. Thus, the real and reactive power demands; on the power system are never steady, but are constantly varying with the rising or falling trend. The real and reactive power generations must alter according to the load perturbations. Load frequency control is essential for successful operation of power systems, especially interconnected power systems, without it the power in distribution system might not be controlled within the required limit band. To achieve this, it became necessary to automatically regulate the operations of mainstream valves in accordance with a suitable control strategy, which in turn will control the real power output of electric generators [1]. Thus the main objectives of the power system is to maintain uninterrupted supply of power with an satisfactory quality, to all the consumers. In case of an interconnected power system, which have two or more areas connected through tie lines; each area supplies its control area and tie lines allow electric power to flow among the areas.
However, load trepidation in any of the areas affects output frequencies of all the areas as well as the power flow on tie lines. Hence, the control coordination of each area needs data about transient situation in all the other areas to reinstate the insignificant values of area frequencies and tie line powers. The information about each area found in its output frequency and the information about other areas is in the deviation of tie line powers. For example, for a two area interconnected power system, this information is taken as

\[ \text{ACE} = \Delta P_{\text{tie}} + b \Delta f \]

Where, \( b = \) area frequency bias, \( \Delta f = \) nominal frequency, \( \Delta P_{\text{tie}} = \) tie line power. The area control error (ACE); fed as input to the integral controller of corresponding area [2]. Thus, an AGC scheme for an interconnected power system integrates 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. Literature shows that Concordia et al [2] studied effect of speed governor dead band on tie-line power and frequency control performance. Elgerd [3] developed a dynamic system model of the multi area electric energy system. This system is suitable for the study of the megawatt-frequency control problem. Concordia, Kirchmayer and Cohn [4],[5],[6] has analyzed the AGC problem of two equal area thermal, hydro and hydro-thermal systems. Bohn and Miniesy [7] have studied the optimum LFC of a two-area interconnected power system by making the use of differential approximation and a Luenberger observer and by introducing an adaptive observer for identification of unmeasured states and unknown deterministic demands, respectively. Automatic Generation Control is an ancillary service which plays an important role in the power
system. It maintains the tie line power and scheduled system frequency during normal operating condition and also during small perturbation. The last lap of twentieth century has witnessed many research articles relating to power system control schemes based on intelligent techniques to overcome the drawbacks of the existing schemes [8-9]. Rest of this paper is organized as follows. System description is explained in Section II. Section III gives detailed explanation about the GSA algorithm. In section IV, the experimental setup, results and corresponding performance evaluations are given. Finally, section V concludes the paper.

II. SYSTEM DESCRIPTION

The large-scale power systems are normally composed of control areas (i.e. multi-area) or regions representing for contractual energy exchange between areas and provide inter-area support in case of abnormal conditions. Without loss of generality we shall consider a two-area case connected by a single line as illustrated in Figure 2. The concepts and theory of two-area power system is also applicable to other multi-area power systems [8].

![Figure 1: Two interconnected control areas (single tie line)](image1)

![Figure 2: Transfer function model of two-area Thermal-Thermal system](image2)

III. GRAVITATIONAL SEARCH ALGORITHM

The GSA could be considered as an isolated system of masses. It is like a small artificial world of masses obeying the Newtonian laws of gravitation and motion. More precisely, masses obey the following laws [9-10]:

**Law of gravity:** Each particle attracts every other particle and the gravitational force between two particles is directly proportional to the product of their masses and inversely proportional to the distance between them, \( R \) (\( R \) instead of \( R^2 \)).

**Law of motion:** The current velocity of any mass is equal to the sum of the fraction of its previous velocity and the variation in the velocity. Variation in the velocity or acceleration of any mass is equal to the force acted on the system divided by mass of inertia.

Now, consider a system with \( N \) agents (masses). We define the position of the \( i^{th} \) agent by:

\[
X_i = \left( x_{i1}, x_{i2}, \ldots, x_{in} \right)
\]

for \( i = 1, 2, \ldots, N \).

Where \( x_{id} \) presents the position of \( i^{th} \) agent in the \( d^{th} \) dimension.

At a specific time \( \tau \), define the force acting on mass \( \text{‘}i\text{’} \) from mass \( \text{‘}j\text{’} \) as following:

\[
F_{ij}^d(t) = G(t) \frac{M_{pi}(t) \times M_{pj}(t)}{R_{ij}(t)} \left( x_{jd}(t) - x_{id}(t) \right)
\]

Where:
- \( M_{pj} \) – Active gravitational mass related to agent \( j \).
- \( M_{pi} \) – Passive gravitational mass related to agent \( i \).
- \( G(t) \) – Gravitational constant at time \( t \).
- \( E \) - Small constant.
- \( R_{ij}(t) \) - Euclidian distance between two agents \( i \) and \( j \):

\[
R_{ij}(t) = \left| X_i(t) - X_j(t) \right|_2^n
\]

To give a stochastic characteristic to our algorithm, we suppose that the total force that acts on agent \( i \) in a dimension \( d \) be a randomly weighted sum of \( d_{th} \) components of the forces exerted from other agents:

\[
F_{i}^d(t) = \sum_{j=1, j\neq i}^{N} \text{rand} \times F_{ij}^d(t)
\]

(4.a)

\[
F_{i}^d(t) = \sum_{j=k_{best}, j\neq i}^{N} \text{rand} \times F_{ij}^d(t)
\]

(4.b)

Where \( \text{rand} \), is a random number in the interval [0, 1]. \( K_{best} \) is the set of first \( K \) agents with the best fitness value and biggest mass.

To improve the performance of GSA by controlling exploration and exploitation only the \( K_{best} \) agents will attract the others. \( K_{best} \) is a function of time, with the initial value \( K_0 \) at the beginning and decreasing with time.

Hence, by the law of motion, the acceleration of the agent \( i \) at time \( t \), and in direction \( d^{th} \), \( a_{id}^d(t) \) is given as follows:
\[ a_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \]

Where: \( M_{ii} \) is the Inertial Mass of \( i \)th agent. Furthermore, the next velocity of an agent is considered as a fraction of its current velocity added to its acceleration. Therefore, its position and its velocity could be calculated as follows:

\[ V_i^d(t+1) = \text{rand}_i \times V_i^d(t) + a_i^d(t) \] (6)

\[ X_i^d(t+1) = X_i^d(t) + V_i^d(t+1) \] (7)

The gravitational constant, \( G \), is initialized at the beginning and will be reduced with time to control the search accuracy. In other words, \( G \) is a function initial value \( G(0) \) and time \( t \):

\[ G(t) = G(G_0, t) \] (8)

We update the gravitational and inertial masses by the following equations:

\[ M_{ii} = M_{pi} = M_{ii} = M_i; \quad i = 1; 2; \ldots ; N; \]

\[ m_j(t) = \frac{f_{ij}(t) - \text{worst}(t)}{\text{best}(t) - \text{worst}(t)} \] (9)

\[ M_j(t) = \frac{m_j(t)}{\sum_{j=1}^{N} m_j(t)} \] (10)

Where: \( \text{fit}(t) \): Fitness value of the agent \( i \) at time \( t \) and \( \text{worst}(t) \) and \( \text{best}(t) \) are defined as follows (for a minimization problem):

\[ \text{best}(t) = \min_{j \in \{1 \ldots N\}} \text{fit}(j) \] (11)

\[ \text{worst}(t) = \max_{j \in \{1 \ldots N\}} \text{fit}(j) \] (12)

Pictorial representation of GSA algorithm is depicted in figure 3. Stopping criterion for this paper is considered as maximum iteration.

**IV. SIMULATION RESULTS**

The objective in this paper is to find a systematic tuning procedure using GSA for load frequency control. Simulations Model performed with no controller, with I and PI controller. GSA based controllers are applied to two-area electrical power system by applying 0.01 p.u. step load disturbance to area 1. Figure 4 to Figure 5 show the dynamic responses of frequency deviations in two areas (i.e., \( \Delta f_1 \) and \( \Delta f_2 \)) and the tie line power deviation (\( \Delta P_{tie} \)) for the two area Thermal-Thermal power system for sample values of area load disturbances. These figures show the performance of GSA based controller compares with open loop and integral controllers on same scale. These graph concluded that GSA based integral and PI controller give less settling time and low peak overshoot. The overall results without controller, with integral and PI controller and with GSA based integral and PI controllers applied to two-area Thermal-Thermal power system are summarized in Table 1. Table 2 shows the settling time (Ts) in case of GSA based integral controller is better than the conventional integral controller.

**Table 1**

<table>
<thead>
<tr>
<th>Controller</th>
<th>( K_p )</th>
<th>( K_i )</th>
<th>( K_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>-0.3294</td>
<td>-0.4937</td>
<td>-0.4937</td>
</tr>
<tr>
<td>PI</td>
<td>-0.3294</td>
<td>0.5025</td>
<td>0.5025</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Settling Time of Two-area Thermal-Thermal system</th>
<th>Settling Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>With PI-controller</td>
<td>12s 12s 12s</td>
</tr>
<tr>
<td>I-GSA controller</td>
<td>14s 14s 14s</td>
</tr>
<tr>
<td>PI-GSA controller</td>
<td>8s 8s 8s</td>
</tr>
</tbody>
</table>

**V. CONCLUSION**

GSA Algorithm emerged as a possible solution for many search and optimization problems. GSA may be viewed as an evolutionary process where in the population of feasible solutions to the optimization problem evolves over a sequence of iterations. It
can be well applied for getting optimized value of Kp and Ki which provide better tuning of controllers to minimized the frequency deviation and tie-line power deviation to settle at steady state. Simulation is carried out using MATLAB to get the output response of the system. In the proposed method, As graph shows GSA Controller gives better result as compare to conventional controller.

REFERENCES


Appendix
The nominal parameters and the operating condition of the system are given below [8].

Test Function for Tuning of I and PI controller:

function J=test_functions(L,F_index,dim)
% Insert your own objective function with a new F_index.
J=(abs(delf1)+ abs(delf2)+ abs(delplie))^2
J=min(J);
end

Simulation Data for I-Controller:

Simulation Parameters:

Tg1=0.08
T1=0.3
Tp1=20
Tg2=0.08
Tt2=0.3
Tp2=20
Kp1=120
Kp2=120
R1=2.4
R2=2.4
B1=0.425
B2=0.425
T12=0.086
a12=1
Ki1=-0.4937
Ki2=-0.4937

Simulation Data for PI-Controller:

Simulation Parameters:

Tg1=0.08
T1=0.30
Tp1=20
Tg2 = 0.08
Tt2 = 0.3
Tp2 = 20
Kp1 = 120
Kp2 = 120
R1 = 2.4
R2 = 2.4
B1 = 0.425
B2 = 0.425
T12 = 0.545
a12 = -1
Ki1 = -0.3294
Ki2 = -0.3294
Kp3 = 0.5025
Kp4 = 0.5025

Fig. 4: Simulated results for I controller with Two area Power system
Fig.5: Simulated results for PI controller with Two area Power system