AUTOMATIC GENERATION CONTROL OF REHEAT THERMAL GENERATING UNIT THROUGH CONVENTIONAL AND INTELLIGENT TECHNIQUE

Ashish Dhamanda¹, A.K. Bhardwaj²

¹,²Department of Electrical Engineering, SSET, SHIATS, Allahabad, U.P, India

ABSTRACT

This paper deals with the dynamic performance of automatic generation control of single reheat type turbine in isolated thermal area by Intelligent Controller (Fuzzy), conventional (P, I, PI & PID) controller and without controller. The dynamical response of thermal generating unit is improved by proposed controller. In this paper intelligent controller (fuzzy) are proposed for improving performance and their dynamic responses are compared with the conventional controller and without controller. The results indicate that the proposed controller exhibit better performance and satisfy the automatic generation control requirements with a reasonable dynamic response. The performances of the controllers are simulated using MATLAB/SIMULINK software.

Keywords: Proportional (P), Integral (I), Proportional Plus Integral (PI), Proportional Plus Integral Plus Derivative (PID), Automatic Generation Control (AGC).

I. INTRODUCTION

AUTOMATIC Generation Control (AGC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. AGC with load following is treated as an ancillary service that is essential for maintaining the electrical system reliability at an adequate level [12] recent years, major changes have been introduced into the structure of electric power utilities all around the world. The successful operation in power system requires the matching of total generation with total load demand and associated system losses. As the demand deviates from its normal value with an unpredictable small amount, the operating point of power system changes, and hence, system may experience deviations in nominal system frequency which may yield undesirable effects. So the objective of AGC in isolated single area thermal generating unit is to maintain the system frequency at nominal value (60 Hz). [4], [5].
A control strategy is needed to maintain constancy of frequency also achieves zero steady state error. Various types of conventional controller (like P, I, PI & PID) employed to solve AGC problem and these controller gives the good response, reduces the oscillation & steady state error but the intelligent controller (fuzzy) gives the better result over the conventional controller.

A literature survey shows that the load frequency control (LFC) of power systems has been investigated by many researchers over the past decades [13]. Most of the earlier works in the area of AGC pertain to thermal systems with non-reheat type turbines with different controller but relatively lesser attention has been devoted to the comparison of without controller and several conventional controllers with fuzzy controller. A single area Thermal Power system incorporating reheat type turbine and linearized models of governors, non-reheat turbines and reheat turbines are taken for simulation of the system.

II. AGC IN THERMAL GENERATION SYSTEM

The role of AGC in single area power system is to maintain the system frequency at nominal value after some kind of perturbation arises in the system.

To maintain the electrical power system in normal operating state, the generated power should match with power demand plus associated losses. However, in practical power system, the load is continuously changing with respect to time. Therefore, the power balance equilibrium cannot be satisfied in abnormal state. In primary control action also called without controller, when the power system is said to be at stable state, primary control action takes place within an area to suppress frequency oscillations. On the other hand, when the load fluctuations are more, primary control action are not adequate to control.

To overcome the problem of primary control action, the secondary control action also called with controller, need to apply these controllers are set for a particular operating condition and they take care of small changes condition and they take care of small changes in load demand without exceeding the prescribed limits of frequency. These control action comprises of different controller like conventional and intelligent etc. [2], [3], [8], [9], [11].

The model of without controller and with controller is shown below in fig. 1 and fig. 2.

Fig. 1: Single Area Model of Thermal Generation System without Controller

Fig. 2: Single Area Model of Thermal Generation System with Controller
Let us consider the problem of controlling the power output of the generators of a closely knit electric area so as to maintain the scheduled frequency. All the generators in such an area constitute a coherent group so that all the generators speed up and slow down together maintaining their relative power angles. Such an area is defined as a control area. To understand the AGC problem of frequency control, let us consider a single turbo-generator system supplying an isolated load. [2]

To simplicity the frequency-domain analyses, transfer functions are used to model each component of the area. [4]

**Transfer function of governor is**

\[
\frac{K_{sg}}{T_{sg} s + 1}
\]

(1)

**Transfer function of turbine is**

\[
\frac{K_{t}}{T_{t} s + 1}
\]

(2)

**Transfer function of Reheat turbine is**

\[
\frac{K_{r} T_{r} s + 1}{T_{r} s + 1}
\]

(3)

**Transfer function of generator is**

\[
\frac{K_{ps}}{T_{ps} s + 1}
\]

(4)

Dynamic response of automatic frequency control loop is

\[
\Delta F(s) = -\frac{K_{ps}}{1 + T_{ps} s} \frac{\Delta P_D}{s}
\]

(5)

This equation can be written as, [3]

\[
\Delta F(s) = -\Delta P_D \frac{R K_{ps}}{R + K_{ps}} \left( \frac{1}{s} - \frac{1}{s + \frac{R K_{ps}}{R T_{ps}}} \right)
\]

(6)

**III. CONTROL METHODOLOGY**

Controller determines the value of controlled variable, compare the actual value to the desired value (reference input), determines the deviation and produces a control signal that will reduce the deviation to zero or to a smallest possible value. In automatic generation control of thermal generating unit need to control or maintain the frequency constancy, reduced oscillation and zero steady state error, so following types of controller are used, [10].

**A. Conventional Controller**

These controllers are using from many year back for controlling such action with maintaining their performance.

The controllers which are using in this control action are as

**Proportional Controller (P)**

In this controller there is a continuous linear relation between the outputs (control area) to input.
Control Area Input = $K_p \text{ Error Signal}$  

**Integral Controller (I)**

In this controller the output of the controller is changed at a rate which is proportional to the input

Control Area Input = $K_i \int \text{Error Signal}$  

**Proportional Plus Integral Controller (PI)**

This is a combination of proportional and integral control action.

Control Area Input = $K_p + K_i \int \text{Error Signal}$
Control Area Input = \( K_p \) Error Signal + \( K_p K_i \int \) Error Signal \hspace{1cm} (9)

**Proportional Plus Integral Plus Derivative Controller (PID)**

This is a combination of proportional, integral and derivative controller so called three action controller.

\[
\text{Control Area Input} = K_p \text{ Error Signal} + K_p K_i \int \text{Error Signal} + K_p K_d \frac{d}{dt} \text{Error Signal} \quad (10)
\]

**B. Intelligent (fuzzy logic) Controller**

Fuzzy set theory and fuzzy logic establish the rules of a nonlinear mapping. There has been extensive use of fuzzy logic in control applications. One of its main advantages is that controller parameters can be changed very quickly depending on the system dynamics because no parameter estimation is required in designing controller for nonlinear systems. Fuzzy logic controller is shown below, [6].

The inputs of the proposed fuzzy controller are e, and rate of change in ce. The appropriate membership function and fuzzy rule base is shown in below, where 7 membership function, NB, NM, NS, Z, PS, PM, and PB represent negative big, negative medium, negative small, zero, positive small, positive medium, and positive big, respectively make 49 (7×7) rule.[7]
IV. SIMULATION RESULTS

All the results are carried out by using MATLAB/Simulink to investigate the performance of single area reheat thermal system. The power system parameters are given in appendix. The step load disturbance of 0.01 p.u. was applied in single area for all the cases and deviations in frequency were investigated. The AGC performance through without and conventional controllers is compared with intelligent controller. The change in frequency deviation under the load disturbances of 0.01 p.u. in single area are shown in fig 9 to fig 14. From combined responses and comparative value of settling time shown in fig 15 and table II, it is observed that the intelligent (fuzzy) controller improve the dynamic performance of the system as compared to the without and conventional controllers.
Fig. 9: Frequency Response without Controller

Fig. 10: Frequency Response with P Controller

Fig. 11: Frequency Response with I Controller
Fig. 12: Frequency Response with PI Controller

Fig. 13: Frequency Response with PID Controller

Fig. 14: Frequency Response with Fuzzy Controller
This paper investigates the automatic generation control of single area reheat thermal power system. To demonstrate the effectiveness of proposed controller, the control strategy based on intelligent and conventional P, I, PI, PID technique is applied. The performance of these controllers is evaluated through the simulation. The results are tabulated in Table II respectively.

The results of proposed controller have been compared with conventional and without controllers and it show that the proposed technique give good dynamic performances. So it can be concluded that the fuzzy controller give better settling performance than the conventional controllers.

**TABLE II:** Comparative value of settling time

<table>
<thead>
<tr>
<th>Controllers</th>
<th>Settling Time (Sec)</th>
<th>Steady State Error (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without</td>
<td>30</td>
<td>-0.0235</td>
</tr>
<tr>
<td>P</td>
<td>29</td>
<td>-0.011</td>
</tr>
<tr>
<td>I</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>PI</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>PID</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Fuzzy</td>
<td>23</td>
<td>0</td>
</tr>
</tbody>
</table>

**V. CONCLUSIONS**

This paper investigates the automatic generation control of single area reheat thermal power system. To demonstrate the effectiveness of proposed controller, the control strategy based on intelligent and conventional P, I, PI, PID technique is applied. The performance of these controllers is evaluated through the simulation. The results are tabulated in Table II respectively.

The results of proposed controller have been compared with conventional and without controllers and it show that the proposed technique give good dynamic performances. So it can be concluded that the fuzzy controller give better settling performance than the conventional controllers.
VI. APPENDIX

Power System Parameters are as follows:

\[ f = 60\text{Hz}; \quad R = 2.4\text{Hz/p.uMW}; \quad T_{sg} = 0.08\text{Sec}; \quad T_{ps} = 20\text{Sec}; \quad T_t = 0.3\text{ Sec}; \quad T_r = 10\text{Sec}; \quad K_r = 0.5\text{TU}; \]
\[ H = 5\text{MW-S/MVA}; \quad P_{ri} = 2000\text{MW}, \quad K_{ps} = 120\text{ Hz.p.u/MW}; \quad K_{sg} = K_t = 1; \quad D = 8.33 \times 10^{-3}\text{p.uMW/Hz}; \]
\[ B_i = 0.425\text{p.u.MW/Hz}; \quad \Delta P_{Di} = 0.01\text{p.u.} \]

NOMENCLATURE

AGC    Automatic Generation Control
\[ P_{ri} \]    Rated power capacity of area i
\[ f \]    Nominal system frequency
\[ \Delta f \]    Change in supply frequency
\[ D_i \]    System damping area i
\[ T_{sg} \]    Speed governor time constant
\[ T_t \]    Steam turbine time constant
\[ T_{ps} \]    Power system time constant
\[ K_{sg} \]    Speed governor gain constant
\[ K_t \]    Steam turbine gain constant
\[ K_{ps} \]    Power system gain constant
\[ b_i \]    Frequency bias parameter
\[ \Delta P_{Di} \]    Incremental load change in area i
\[ i \]    Subscript referring to area 1 2 3 etc.
\[ H \]    Inertia constant
\[ R \]    Speed regulation of governor

VII. ACKNOWLEDGEMENT

This work is supported by electrical engineering department, Sam Higginbottom Institute of Agriculture Technology and Sciences. Allahabad, India.

VIII. REFERENCES


IX. AUTHORS BIOGRAPHIES

AshishDhamanda Allahabad received his B.Tech degree in Electrical Engineering from GKV Haridwar in 2009. He obtained his M.Tech degree in Electrical and Electronics Engg from SHIATS Allahabad India in 2012. Presently he is Pursuing Ph.D in Electrical Engg. From SHIATS Deemed University Allahabad India.

Dr. A. K. Bhardwaj Allahabad received his B.Tech degree from JMI New Delhi in 1998; He obtained his M.Tech degree in Energy and Env. Mgt. from IIT New Delhi in 2005. He completed his Ph.D in Electrical Engg. From SHIATS Allahabad, India in 2010. Presently he is working as an Associate Professor and HOD in Electrical Engg. Department. SSET, SHIATS Deemed University Allahabad India.