Content

- AGC in a modern power system
- Fundamentals and Concepts
- Simulation example
- Intelligent AGC
- Key issues

AGC in Modern Power System

SCADA

SCADA/AGC

West Regional Operating Center, WREC, Kermanshah, Iran
Load-Frequency Control

Emergency Operation (Emergency control) $\Delta y$

Off-normal operation (Load-frequency control) $\Delta f$

Normal operation (Primary control) $\Delta f^*$

Frequency deviations and associated operating controls

Frequency operating and control actions

<table>
<thead>
<tr>
<th>Frequency deviation range</th>
<th>Condition</th>
<th>Control action</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta f$</td>
<td>No contingency or load event</td>
<td>Normal operating</td>
</tr>
<tr>
<td>$\Delta f^*$</td>
<td>Generation load or outage event</td>
<td>LFC operating</td>
</tr>
<tr>
<td>$\Delta f$</td>
<td>Severe contingency event</td>
<td>Emergency operating</td>
</tr>
<tr>
<td>$\Delta f^*$</td>
<td>Multiple contingency event</td>
<td>Emergency operating</td>
</tr>
</tbody>
</table>

AGC: Fundamentals & Concepts

Frequency control mechanism

Frequency Response Model

A frequency response model for dynamic performance analysis
AGC characteristics

**Droop characteristic**
The ratio of frequency change to change in output generated power is known as droop or speed regulation, and can be expressed as:

\[
\frac{\Delta f}{\Delta P} = \frac{1}{M_R} = \frac{M}{R_f} = \frac{\Delta P}{\Delta f} = \frac{R_f}{R_L}
\]

Load tracking by generators with different droops

**Area interface**

\[
\Delta P_{\text{Area}} = \sum_{j=1}^{N} \Delta P_{g,j} = \frac{2}{M} \left( \sum_{j=1}^{N} T_{i,j} \Delta f_{i,j} - \sum_{j=1}^{N} T_{j,i} \Delta f_{j,i} \right)
\]

Tie-line power flow control

**Area Control Error (ACE)**

\[
ACE_i = \Delta P_{\text{tie},i} + \beta_i \Delta f_i
\]

where

\[
\beta_i = \frac{1}{R_i} + D_i
\]

Participation factor

\[
\sum_{k=1}^{N} a_{ki} = 1, \quad 0 \leq a_{ki} \leq 1
\]
Rapidly varying components of system signals are almost unobservable due to various filters involved in the System. Hence, the performance of a designed LFC system is dependent on how generation units respond to the control signal.

By changing the input signal, the speed governor may not immediately react until the input reaches a specified value. Governor dead band is defined as the total magnitude of a sustained speed change, within which there is no resulting change in valve position. The maximum value of dead band for governors of large steam turbines is specified as 0.06%.
Simulation Example

Simulation parameters for 3-control area power system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>area 1</th>
<th>area 2</th>
<th>area 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating unit</td>
<td>G1</td>
<td>G2</td>
<td>G3</td>
</tr>
<tr>
<td>Base MVA</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Sensitivity Factor</td>
<td>-0.4</td>
<td>0.5</td>
<td>-0.6</td>
</tr>
<tr>
<td>Range over (pu)</td>
<td>0.2</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Load (pu)</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
</tr>
</tbody>
</table>

System response in control area 1

System response in control area 2

System response in control area 3

Simulation Example

Simultaneous 0.05 pu load step increase in control areas 1 and 2

Intelligent AGC

Fuzzy logic AGC: common structures

A general scheme for fuzzy logic based AGC

A general scheme for adaptive fuzzy logic AGC

Intelligent AGC

Fuzzy PI control scheme
Fuzzy logic for tuning of PI-based AGC system

Intelligent AGC

ANN AGC: common configurations
ANN as main controller to provide control command in the main feedback loop

Intelligent AGC

ANN system as an additional controller in parallel with the existing controller such as PI, to improve the closed-loop performance

Intelligent AGC

GA-based AGC

Data
Optimization Function
GA
Controller (PI, PID, ...)
\( \Delta P_c \)
Control input
\( \Delta P_c \)
Control output
Intelligent AGC

Multi-agent AGC

An agent-based AGC structure

Intelligent AGC

Combined and other intelligent AGC schemes

Some Key Issues:

AGC in a Deregulated Environment

AGC and Renewable Energy Options

AGC and Microgrids