Generator Governor and Information Settings Webinar

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September 30, 2010
Survey Instructions

- All generators rated 20 MVA or higher, or plants that aggregate to a total of 75 MVA or greater net rating at point of interconnection (i.e., wind farms, PV farms, etc.), Statement of Compliance Registry Criteria, Rev. 5.0.
- Jointly-owned units – reported by the operating entity.
- Combined-cycle plants – combustion turbines and heat-recovery (steam turbine) units to be reported separately.
- Wind farms – report on a point-of-interconnection basis.
- If operable in more than one interconnection, complete the survey for operation in each of the interconnections.
Frequency Response Concerns

- Frequency Response is declining in Eastern Interconnection
  - Various factors are influencing
  - When is frequency response too low?
- Primary Control Frequency Response is being withdrawn
- Primary inertial generation being supplanted by non-inertial resources – wind, solar, electronically coupled resources
  - What is their response to frequency excursions?
  - What is their susceptibility to tripping during frequency excursions?
- Load characteristics are changing
  - Unknown frequency response characteristics
  - Current modeling is insufficient to analyze the phenomenon
Eastern Interconnection Mean Primary Frequency Response Trend

Source: J. Ingleson & E. Allen, "Tracking the Eastern Interconnection Frequency Governing Characteristic" presented at 2010 IEEE PES
Eastern Interconnection Mean Primary Frequency Response – Projected

Source: J. Ingleton & E. Allen, "Tracking the Eastern Interconnection Frequency Governing Characteristic" presented at 2010 IEEE PES

Linear: \( y = -65.61x + 3777.4 \)

Polynomial: \( y = -2.2698x^2 - 27.024x + 3661.6 \)

* 1999 Data Interpolated
Classic Frequency Excursion Recovery

Frequency (Hz)

Time (Seconds)

Recovery Completed, $T_V$

A = 60.000

B = 59.874

C = 59.812
Frequency Performance

Arresting Period
Rebound Period
Recovery Period

System Frequency

60.00
59.98
59.90

Minutes

0 10 20 30

Power

MW

Primary Frequency Control
[Governor response (and frequency-responsive demand response)]

Secondary Frequency Control
(Generators on Automatic Generation Control)

Tertiary Frequency Control
(Generators through operator dispatch)
Typical Frequency Traces Following a Unit Trip

Typical average response - One Minute View using Phasor data at 10 mSeconds

- EI Typical
- WECC Typical
- ERCOT Typical

2006 data
Frequency Response Basics
(Using a 1400 MW generation loss event as an example)

NERC Frequency Response =
\[
\frac{\text{Generation Loss (MW)}}{\text{Frequency Point A-Frequency Point B}}
\]

Pre Event Frequency

Settling Frequency:
Primary Response is almost all deployed

Frequency Nadir:
Generation and Load Response equals the generation loss

Slope of the dark green line illustrates the System Inertia (Generation and Load). The slope is \(\frac{\Delta P}{(D+2H)}\)

Governor Response
Load Response
Frequency
Inertial Response Variability

**High Inertia**
- **Frequency in HZ**
- **Time in Seconds**
- **Event with 837 MW Trip (March, 2010)** ERCOT Load was 23655 MW with 27,499 MW of total Conventional Generation

**Light Inertia**
- **0.066403 HZ/Sec**
- **0.027438 HZ/Sec**
Frequency Response Basics

- Whys and Wherefores (things to examine)
  - Deadband — currently typical setting is at ±36 mHz
    - ERCOT greatly improved frequency response by reducing deadband to ± 16.6 mHz
  - Sliding pressure controls
  - MW setpoints — limited time of response
  - Blocked governor response
  - Once-through boilers
  - Gas Turbine inverse response
ERCOT Experience
**Governor response** is proportional at the dead-band reaching 5% at 3 Hz deviation

<table>
<thead>
<tr>
<th>Frequency Deviation Hz</th>
<th>Grid Frequency 59.96000 Hz</th>
<th>Frequency Response MW</th>
<th>Droop %</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.04000</td>
<td>4.69287</td>
<td>8.52357%</td>
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<td>-0.01600</td>
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**NERC**

**Dead-band**

**Frequency Grid Frequency**

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<td>-0.03900</td>
<td>7.80000</td>
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<td>-0.03600</td>
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<tr>
<td>-0.01600</td>
<td>0.00000</td>
<td>100.00000%</td>
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**Dead-band**

**Governor response “Steps” to the 5% droop curve at the dead-band**

**Frequency Grid Frequency**

- 0.01666 Hz Dead-Band
  - 600 MW Steam Turbine 5% Droop Setting

- 0.036 Hz Dead-Band
  - Common Industry Implementation
Close up look at +/-0.0166 Hz Dead Band with No Step Implementation
600 MW Generator

Capability (MW) 600.000

Frequency Response

Deadband Setting 0.0166 Hz

No Step response at dead-band.

Hz

MW Change

Droop Setting 5.00%
Close up look at +/-0.036 Hz Dead Band with Step Implementation

600 MW Generator

Frequency Response

Capability (MW) 600.000

Deadband Setting 0.036 Hz

Droop Setting 5.00%

Step response at dead-band.
ERCOT Frequency Profile Comparison

January through August of each Year

One Minute Occurrences

- 59.9 to 60.1

2010 in blue
2008 in red

Comparison of frequency profile from January to August of each year, with a focus on the one-minute occurrences.
January thru August 2008 0.036 db vs. 2010 0.016 db

MW Minute Movement of a 600 MW Unit @ 5% Droop

<table>
<thead>
<tr>
<th>Year</th>
<th>Response</th>
<th>Decrease in MW movement with lower deadband.</th>
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</thead>
<tbody>
<tr>
<td>2010</td>
<td>0.0166 db</td>
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<tr>
<td>2008</td>
<td>0.036 db</td>
<td>23.89%</td>
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</table>

Same 600 MW unit - MW movement due to frequency each year.
Frequency Response Initiative
FRI Objectives

- Coordinate all NERC standards development and performance analysis activities related to frequency response and control
- Identify specific frequency-related reliability factors
- Identify root causes of changes in frequency response
- Identify practices and methods to address root causes
- Consider impacts of integration of new generation technologies (such as wind, solar, and significant nuclear expansion)
FRI Objectives

- Develop metrics and benchmarks to improve frequency response performance tracking
- Share lessons learned with the industry via outreach, alerts, and webinars
- Determine if performance-based frequency response standards are warranted
Near-Term Tasks

- Develop a clear set of terminology for use by NERC and the industry – *Nearing completion*
- Issue a Recommendation (ROP § 810) and survey to collect data and information for analysis
- Analyze current and historical Primary and Secondary Control Response performance – what factors influence that performance
- Develop automated method for determining frequency deviation events to be used for BAs to measure Primary Control Response – *Evaluating CERTS FMA Tool*
- Develop appropriate metrics for tracking frequency performance on each interconnection to monitor trends and performance
- Develop sustainable methods for automatically collecting, trending, and analyzing various elements of frequency response and control for frequency deviation events
Mid-Term Tasks

- Improve transient dynamic models of Primary Control Response for generators and other devices
- Explore and analyze what are appropriate frequency response and control performance requirements to maintain system reliability
- Determine appropriate minimum Bias settings for use in AGC systems as part of an overall Frequency Response and Control strategy
Longer-Term Tasks – 1 to 2 Years

- Develop and implement mid-term dynamic models of Primary Control Response of generators and other devices
  - Research required

- Analyze current Inertial Response performance and determine what factors influence performance

- Examine Primary Control Frequency Response characteristics of electronically-coupled resources and “smart grid” loads
  - Develop load and “generator” models (research required) to properly analyze influence on system behavior in transient, post-transient, and mid-term stability

- Explore how displacement of inertial generation with electronically-coupled resources might influence Inertial Response
Reporting & Ongoing Activities

Ongoing Activities

- Communications / Educational Outreach
  - Technical Reference Documents
  - Webinars / Workshops

- Metrics & Calculations
  - Ongoing determination of frequency events for analysis
  - Quarterly determination of response performance

Reporting on FRI Progress

- Oct. 18, 2010 – Report to FERC
- Dec. 31, 2010 – Report to Board
- February 2011 – Report to Board and FERC
- 2011 & 2012 Quarterly Reports to Board
Question & Answer
1. Unit name and number.

2. Balancing Authority (BA) in which the generator is operated (pull-down).
   a. If operable in more than one, please note all applicable BAs.
   b. If operable in more than one interconnection, complete the survey for operation in each of the interconnections.
3. Unit seasonal Net MW ratings normally reported to NERC for resource adequacy analyses:
   a. Summer Net MW rating
   b. Winter Net MW rating

4. Prime mover (steam turbine, combustion turbine, wind turbine, etc. — pull-down)

5. Fuel type (coal, oil, nuclear, etc. — pull-down)
6. Unit inertia constant (H) as modeled in dynamics analyses – the combined kinetic energy of the generator and prime-mover in watt-seconds at rated speed divided by the VA (Volt-Ampere) base.

7. What are the annual run hours for the unit (data for each of the last 3 years)?

8. What is the continuous MW rating (Pmax) of the unit?
9. What percent of time does the unit run at Pmax or valves wide-open?
   a. 0 to 30 %
   b. 31 % to 60 %
   c. 61 % to 100 %

10. Equipped with a Governor? (Y/N)  
    If not, no further answers are necessary.
11. If yes, is the governor operational? (Y/N with a comment box) If not, please explain.

a. Is the governor normally in operation? (Y/N with a comment box) (even if not normally operated, the data on the governor is still needed)

b. What is the normal governor mode of operation? (pull-down)

c. Is the governor response sustainable for more than one minute if conditions remain outside of the deadband? (Y/N)
11. (continued)

d. Are there any regulatory restrictions regarding the operation of the governor? This should cover nuclear regulation, environmental restrictions (water temperature, emissions), water flow, etc.

e. Does the governor respond beyond the high/low operating limit (boiler blocks)? (Y/N)

f. Is the governor response limited by the rate of change? (Y/N)

g. Are there any other unit-level or plant-level control schemes that would override or limit governor performance? If yes, please explain.
12. Governor Type?

- Electronic (analog electro-hydraulic);
- DEH (digital electro hydraulic);
- Mechanical;
- Other — please specify

13. Governor manufacturer and model?

a. If mixed vendor equipment is installed, please explain.
14. Governor Deadband setting?
   a. Deadband in (+/-) mHz
      i. If in mHz is the deadband centered around a frequency reference (60 Hz or current frequency)?
   b. Deadband in (+/-) RPM
      i. For RPM specify number of machine poles
      ii. If in RPM, is the RPM reference nominal or current RPM?
   c. What is the basis for this setting?
   d. Once activated, what are the conditions for which the governor action is reset?
15. What is the percentage (%) droop setting on the governor?
   
a. What is the basis for the droop setting?

16. Does the unit Frequency Response step into the droop curve or is it linear from the deadband?
17. Prime mover control mode – What is the normally used Turbine Control mode(s)? If more than one is prevalently used, select a primary and explain.

- Turbine manual
- Thermally-limited
- Turbine following
- Boiler following
- Part-load

- Pre-select
- MW set point
- Coordinated control
- Other (please explain)
18. Do market rules restrict or override governor speed controls? (Y/N) If yes, please explain.
For steam generator controls or central station controls:

19. Does the boiler control or combined cycle central station control have a frequency input? (Y/N) If yes, answer the following questions:

a. Deadband in (+/-) mHz
   i. If in mHz is the deadband centered around a frequency reference (60 Hz or current frequency)?

b. Deadband in (+/-) RPM
   i. For RPM specify number of machine poles
   ii. If in RPM, is the RPM reference nominal or current RPM?

c. What is the basis for this setting?
20. Does the control’s Frequency Response step into the droop curve or is it linear from the deadband?

21. What is the steam turbine control mode? (boiler following, turbine following, coordinated control)

22. Do the unit or plant controls over-ride governor speed control or are the control parameters supportive? (Y/N)
23. Does the boiler operate under variable/sliding pressure? (Y/N)

a. What is the control/governor valve position percentage (%) during variable pressure operation?

24. Do unit or plant economic controls over-ride governor speed control? (Y/N)
### Eastern Interconnection

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<th>UTC</th>
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<td>Atlantic Standard</td>
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<tr>
<td>406</td>
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<tr>
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8-16-10 Braidwood Trip

Eastern Interconnection System Frequency - 4 sec scan

Start Date/Time: 1:04:20 CST

8/16/2010 1:06 CST
## Event Performance Data Questions

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<th>Interconnection</th>
<th>Date</th>
<th>Time</th>
<th>Time Zone</th>
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<td>CST</td>
</tr>
<tr>
<td>Texas</td>
<td>8/20/2010</td>
<td>14:25:29</td>
<td>CST</td>
</tr>
<tr>
<td>Québec</td>
<td>12/10/2009</td>
<td>15:09:31</td>
<td>EST</td>
</tr>
</tbody>
</table>
25. Was the unit on-line during the event? (Y/N)

26. Pre-event generation (MW) – Enter the MW output of the generator at the time just before the event began.

27. Post-event generation (MW) – Enter the MW output of the generator after the event that was reflects the response by the governor to the frequency deviation.

28. Time to achieve post-event response (seconds) – Enter the time (in seconds) it took to achieve the MW response in question 27.