Frequency Response Initiative
Industry Advisory – Generator Governor Frequency Response

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Agenda

- Why Primary Frequency Response is important
- Define Primary Frequency Response
- Discuss the NERC Advisory Generator Governor Frequency
- Recommendations for Dead Band and Droop
- Coordination Requirement with Plant DCS
- Step vs. Linear Response
- Frequent Occurring Issues
- Questions
Why Primary Frequency Response Is Important

• Essential for Reliability of the Interconnections
  ▪ Cornerstone for system stability
  ▪ Line of defense to prevent Under Frequency Load Shedding (UFLS)
  ▪ Prevent equipment damage

• Essential for System Restoration
  ▪ Droop response is critical in restoration efforts

• Compliance with NERC Standards BAL-003-1, BAL-001
  ▪ prevent future regulations related to generator frequency response performance

• To accurately predict system events (Transmission Models)
Frequency
• Primary Frequency Response are actions to arrest and stabilize frequency in response to frequency deviations. Primary Response comes from generator governor response, load response (motors) and other devices that provide immediate response based on local (device-level) control.

• Generator Governor Response within 0-10 seconds.

Frequency Point A is the frequency prior to the event
Frequency Point C is the nadir or lowest point
Frequency Point B is the settling frequency
Classic Frequency Excursion Recovery

- Arresting Period
- Rebound Period
- Recovery Period

- A: Initial Point
- B: Nadir
- C: Primary Response Evaluation Period
- D: Secondary Response Control

0-20 seconds: Primary Response Control
20-50 seconds: Secondary Response Control
50-10 minutes: Recovery Period
Generator Response

Generator turbine governors either mechanically or electronically control the primary control valves to the turbine. Steam, Water or Fuel is what is regulated.

Graphic from GE info bulletin PSIB20150212
Current Interconnection Profiles
BAL-003 Field Test - Interconnections 2014 Candidate Events
Profiles Using Frequency Traces for Same 1-Second Median

Current Interconnection Profiles

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Decline in Eastern Interconnection Frequency Response

Eastern Interconnection Mean Primary Frequency Response


Source 2010-2011: Daily Automated Reliability Reports

* 1999 Data Interpolated

MW / 0.1 Hz

Year
Current Eastern Interconnection Frequency Response

No “Point C” to “Point B” Recovery

Response “Withdrawal”
Industry Advisory
Generator Governor Frequency Response

As a result of the Eastern Interconnection Frequency Initiative, the NERC Resources Subcommittee has determined that a significant portion of the Eastern Interconnection generator deadbands or governor control settings inhibit or prevent frequency response. While this specific work was based on the Eastern Interconnection, in the absence of more stringent regional requirements the following good practice and guidance is applicable to all interconnections. The proper setting of deadbands, droop, and other controls to allow for primary frequency response is essential for reliability of the Bulk Electric System (BES) and critical during system restoration. Further, the accuracy of Transmission Planning models are impacted by incorrect governor data. The purpose of this Advisory is to alert the industry of recommended governor deadband and droop settings that will enable generators to provide better frequency response to support the reliable operation of the Bulk Electric System.

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Status: No Reporting is Required – For Information Only
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Distribution: Initial Distribution: Balancing Authority, Generator Owner, Generator Operator, Reliability Coordinator, Transmission Operator, Transmission Planner
Who else will get this alert? >>
What are my responsibilities? >>

- Advisory issued February 5th
- Prompted by NERC Resource Subcommittee
  - Interconnections frequency response has declined
  - Eastern Interconnection Lazy L profile
  - 2010 and 2013 Generator Survey Data

Generator Governor Frequency Response Advisory
What Has Been Learned

- Primary Frequency Response logic typically resides in the turbine controls.
- Dead Bands Vary
  - Many exceed 36 mHz or 2.16 RPM
- Droops Settings Vary
  - Majority Droops reported 5%
• Coordination with plant DCS is a requirement when operating in MW Set Point Coordinated Control.
Frequency 60.000 Hz

Example

Plant level (DCS) Load Control

Plant Load Target (from AGC or other)

- Dead band

- Measured Frequency

- Number of GTs in emissions compliant operation

- Unit gain (MW/Hz)

- Plant frequency bias

- Plant droop gain (MW/Hz)

- Frequency biased Plant Load Target

- PID Integrate plant load error to form GT set point

- Net plant output

- Gas turbine 1 power set point

- Unit A load split %

- Gas turbine 2 power set point

- Unit A load split %

- GT1 power

- GT2 power

- GT1 150 MW

- GT2 150 MW

- 100 MW

- Plant auxiliary load

- Steam turbine power

- Generator

Graphic from GE info bulletin PSIB20150212
Frequency 59.940 Hz

Example

**Plant level (DCS) Load Control**

- **GT1**
  - GT Load Control
  - GT Governor
  - Speed = Load demand
  - Fuel command

- **GT2**
  - GT Load Control
  - GT Governor
  - Speed = Load demand
  - Fuel command

**Plant Load Target** (from AGC or other)

**Unit A load split %**

**Unit B load split %**

**Net plant output**

**Plant auxiliary load**

**400 MW**

**153 MW for little more than 1 second**

**100 MW**

**+/− Dead Band MW**
Frequency 59.940 Hz

Example

Graphic from GE info bulletin PSIB20150212
Frequency 60.000 Hz

Plant level (DCS) Load Control

0 MW

400 MW

400 MW

150 MW

150 MW

100 MW

Graphic from GE info bulletin PSIB20150212
No Frequency Algorithm in DCS

3 - 175 MW GE7FA Gas Mark V1e Turbine

Frequency Algorithm in Plant DCS

3/3/2015
\[ MW_{PrimaryControl} = \left( \frac{HZ_{actual} - 60 + DB}{60 \cdot Droop - DB} \right) \ast \left( Frequency\ Response\ Capacity \right) \ast (-1) \]
Frequency 59.940 Hz

**Plant level (DCS) Load Control**

- Plant Load Target (from AGC or other)
- Frequency bias
- Dead Band MW

**Measured Frequency**

- 60.000 Hz
- Dead Band

**Plant droop gain (MW/Hz)**

- 6 MW
- 400 MW
- 406 MW

**PID**

Integrate plant load error to form unit set point

- Unit demand
- Air and Feed water

**Turbine control panel**

- Control valve demand
- Steam turbine speed

**Generator**

- 406 MW
- Steam turbine power

**Steam Turbine**

**Net plant output**

- Plant auxiliary load

**Graphic from GE info bulletin PSIB20150212**
Figure 42: Frequency Response of 600 MW Unit ±36.0 mHz Deadband and Step Response

Figure 43: Frequency Response of 600 MW Unit ±16.67 mHz Deadband and No-Step Response

• The majority of the Eastern events where frequency declines in excess of 36 mHz is when the interconnections are lightly loaded and the majority of generation is dispatch is less than $P_{max}$.

Source: MYBA_2015_FRS_FORM_19a_Eastern Interconnection_Final
Other issues

- Some units come out of AGC or MW Set Point Control when frequency response is being provided.
- Conventional Steam Turbines operating in sliding pressure or turbine following mode
- Resolution/quality of speed signal
“If I provide primary frequency response I will be penalized.”

- Interconnection frequency events resulting in deviations below the recommended governor deadband settings are infrequent (about 1 / week)
- Primary frequency response is a relatively small amount of energy for a short period
  - Typically provided for about 120 seconds
  - Roughly 0.5% of capacity
- Tariff provisions vary but typically measure dispatch imbalance or deviation charges based on substantially longer time intervals (on the order of 30 to 60 minutes with a tolerance band of 5-10%)
- Tariff provisions typically allow for exemptions or recourse if a generating resource is subject to imbalance or deviation charges due to providing frequency response
- Contact your Transmission Provider for specific tariff information
Requested Next Steps

Fall Outages 2015/ Spring 2016

- Check and add if necessary Frequency Response Algorithm on Frame Gas Turbines
- Check/ Adjust Dead Bands and Droops
- Check Conventional Steam Unit

Note: Need to make sure dead bands and droop are coordinated to be the same in the Plant DCS as Turbine.
• NERC Resource Subcommittee
• North American Generator Forum  www.generatorforum.org
• Original Equipment Manufacturers
• Industry Trade Associations
• Architect /Engineering Firms
• Balancing Authority
Participating Vendors

* - have developed or are developing a related technical guide
Questions and Answers
Appendix Sample Logic for GT

Determine median frequency error (Hz) of good quality frequency signals (see table Quad algorithm above).

If frequency goes below the deadband, this transfer is used for the final calculation of EPRI.

If frequency goes above the deadband, this transfer is used for the final calculation of EPRI.

Last step of EPRI calculation — multiplying by total available capacity for the units that are available.

Available units on and above high limit to begin frequency response.

Available units on and below low limit to begin frequency response.

Determine median frequency error (Hz) of good quality frequency signals (see table Quad algorithm above).

Freq error minus deadband.

Freq error plus deadband all divided by the negative of the denominator.

Mw available for frequency response per GT (favorable to max load).

Freq error minus deadband.

Freq error plus deadband.

Valve open.

Target in Hz

Valve off.

Denominator of EPRI equation.

High limit to begin Feed Resh.

Gain = 8.5

Low limit to begin Feed Resh.

Freq error plus deadband.

Freq error minus deadband.

Mw/unit times number of units available for frequency response.

Determines if the gas turbines are in the correct mode to respond to frequency.

Frequency bias is zeroed out if all speed signals are bad or operator selects to disable it.

Energy conversion valve to output.

Energy conversion valve to output.

Energy conversion valve to output.

Energy conversion valve to output.