Synchronized Measurement Data for Frequency Response Analysis

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• We’ve seen (numerous) presentations on both the FNET system and the Frequency Response Analysis Tool (FRAT)...

• Both are huge success stories – advancement in tools and technology from different perspectives...

• Now, let’s spend a few minutes illustrating the *practical value* in these tools to meet the mission and vision of NERC...
  ▪ Improved reliability - Interconnection-wide frequency response analysis
  ▪ Execution of interconnection-wide NERC Reliability Standards

• And let’s touch on where we’re headed...
The University of Tennessee – Knoxville (UTK) administers the Frequency Monitoring Network (FNET)/GridEye system.

- Wide area phasor measurement network built in 2004
- Data collected at distribution level – wall outlets
- Hundreds of Frequency Disturbance Recorders (FDRs) across North America
- Measures synchrophasor data
  - GPS time-synchronized
  - Voltage magnitude, phase angle, frequency
  - Reported at 10 samples per second
  - Transmitted to central data center via Internet
• FNET spans all for interconnections – Eastern, Western, ERCOT, and Quebec
• Measurement location from over 100 FDRs across North America
• FNET data provided to NERC and Electric Power Group (EPG) for detailed analysis for ongoing frequency response analysis

• Use all available FDRs, for each interconnection, to calculate a “median” frequency value at each sample – “system frequency”
Purpose:

1. To require sufficient Frequency Response from the Balancing Authority (BA) to maintain Interconnection Frequency within predefined bounds by arresting frequency deviations and supporting frequency until the frequency is restored to its scheduled value.

2. To provide consistent methods for measuring Frequency Response and determining Frequency Bias Setting.

Applicability:

1. Balancing Authority (BA)
2. Frequency Response Sharing Group (FRSG)

*This presentation focuses on Frequency Response; it does not address Frequency Bias Setting.*
• R1: Each FRSG or BA ... shall achieve annual Frequency Response Measure (FRM) that is equal to or more negative than its Frequency Response Obligation (FRO) to ensure that sufficient Frequency Response is provided by each FRSG or BA ... to maintain Interconnection Frequency Response equal to or more negative than the Interconnection Frequency Response Obligation (IFRO).

**IFRO** – *Interconnection Frequency Response Obligation*

**BA FRO** – *Balancing Authority Frequency Response Obligation*

**BA FRM** – *Balancing Authority Frequency Response Measure*
IFRO: The minimum amount of frequency response that must be maintained by an interconnection.

- Intended to ensure that the “largest contingency” should not trip first-stage of regionally approved UFLS systems within the interconnection.

\[
DF_{\text{Base}} = F_{\text{Start}} - UFLS \\
DF_{\text{CC}} = DF_{\text{Base}} - CC_{\text{Adj}} \\
DF_{\text{CBR}} = \frac{DF_{\text{CC}}}{CB_R} \\
MDF = DF_{\text{CBR}} - BC'_{\text{Adj}} \\
ARLPC = RLPC - CLR \\
IFRO = \frac{ARLPC}{MDF}
\]

“Starting with a statistically determined delta frequency, and accounting for necessary adjustment factors, the IFRO is determined using the resources loss protection criteria less a credit for load reduction to determine a required obligation of frequency response for the interconnection.”
• **BA FRO:** Allocation of IFRO to each BA based on generation and load – annual production and consumption

\[ FRO_{BA} = IFRO \times \frac{Annual\ Gen_{BA} + Annual\ Load_{BA}}{Annual\ Gen_{Tot} + Annual\ Gen_{Tot}} \]

- Annual Gen and Annual Load data acquired from FERC Form 714

• **BA FRM:** Single event frequency response measure (FRM) – change in Net Actual Interchange (on tie lines with other BAs) divided by the change in interconnection frequency.

\[ FRM_{Interconnection} = \frac{MW\ Loss}{0.1\ Hz} \quad FRM_{BA} = \frac{\Delta Interchange_{Net\ Actual}}{0.1\ Hz} \]
• Developed by PNNL under BPA guidance
  ▪ Co-funded by US DOE and BPA
• Released under an open source license
• Frequency Response Monitoring
  ▪ Interconnection-wide
    o Balancing Authority
      – Power Plant (Under development)
      – Individual Unit (Under development)
• Calculates NERC FRM using PMU and/or SCADA data
• Compliance reporting
• Baselining frequency response for interconnection and BA
• Supports different data formats (csv, xml, OSIsoft PI, COMTRADE)
• Statistical Analysis
Frequency Response Analysis Tool: Eastern Interconnection

Database of events

Event Plot

Event Details

Performance Baseline
Baselining & Outlier Identification

**Eastern Interconnection**

**ERCOT Interconnection**

**Quebec Interconnection**

**Western Interconnection**

*IFRO values are from 2014 FRAA Report*
• ERSTF Measure 4:
  - A:B Measure
  - A:C Measure
  - C:B Measure
  - C’:C Measure
  - tC-t0 Measure
  - tC’-tC Measure
  - tC’-t0 Measure
• Frequency Response Analysis
  ▪ Frequency Response Initiative Report -

• Frequency Response Analysis Tool (FRAT)
  ▪ FRAT web page: https://svn.pnl.gov/FRTool
  ▪ pavel.etingov@pnnl.gov

• Relevant NERC Subcommittees
  ▪ Essential Reliability Services Task Force (ERSTF) -
  ▪ Synchronized Measurement Subcommittee (SMS) -
Questions and Answers