NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Synchronized Measurement Data for Frequency Response Analysis

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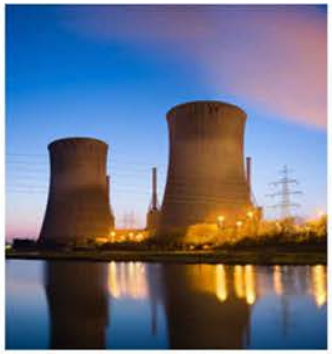
RELIABILITY | ACCOUNTABILITY

Success Using FNET and FRAT for Frequency Response Analysis

- 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…

Data Source – FNET System

- 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 Data for Frequency Response Analysis

- 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"

BAL-003-1: Frequency Response and Frequency Bias Setting

- 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.*

BAL-003-1 Requirement 1

- 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*

Interconnection Frequency Response Obligation (IFRO)

- **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.

$$DF_{Base} = F_{Start} - UFLS$$

$$DF_{CC} = DF_{Base} - CC_{Adj}$$

$$DF_{CBR} = \frac{DF_{CC}}{CB_R}$$

$$MDF = DF_{CBR} - BC'_{Adj}$$

$$ARLPC = RLPC - CLR$$

$$IFRO = \frac{ARLPC}{MDF}$$

"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.

Balancing Authority Frequency Response Obligation (BA FRO)

- **BA FRO:** Allocation of IFRO to each BA based on generation and load – annual production and consumption

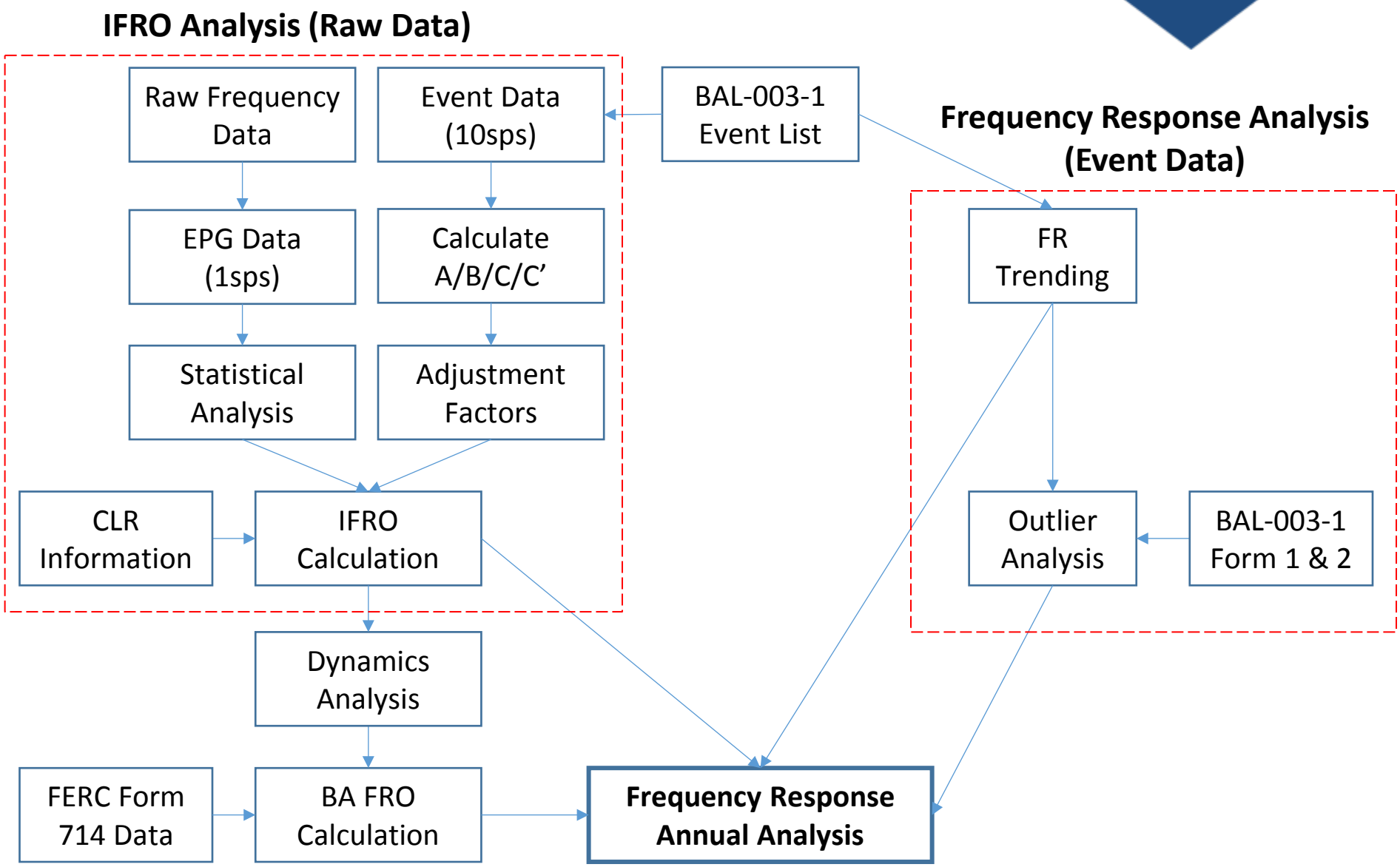
$$FRO_{BA} = IFRO * \frac{Annual\ Gen_{BA} + Annual\ Load_{BA}}{Annual\ Gen_{Tot} + Annual\ Gen_{Tot}}$$

  - 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.

$$FRM_{Interconnection} = \frac{MW\ Loss}{0.1\ Hz} \qquad FRM_{BA} = \frac{\Delta Interchange_{Net\ Actual}}{0.1\ Hz}$$

Bringing the Pieces Together



Frequency Response Analysis Tool (FRAT)

- Developed by PNNL under BPA guidance
  - Co-funded by US DOE and BPA
- Released under an open source license
- Frequency Response Monitoring
  - Interconnection-wide
    - 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

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Database of events

Event Plot

Events DataBase

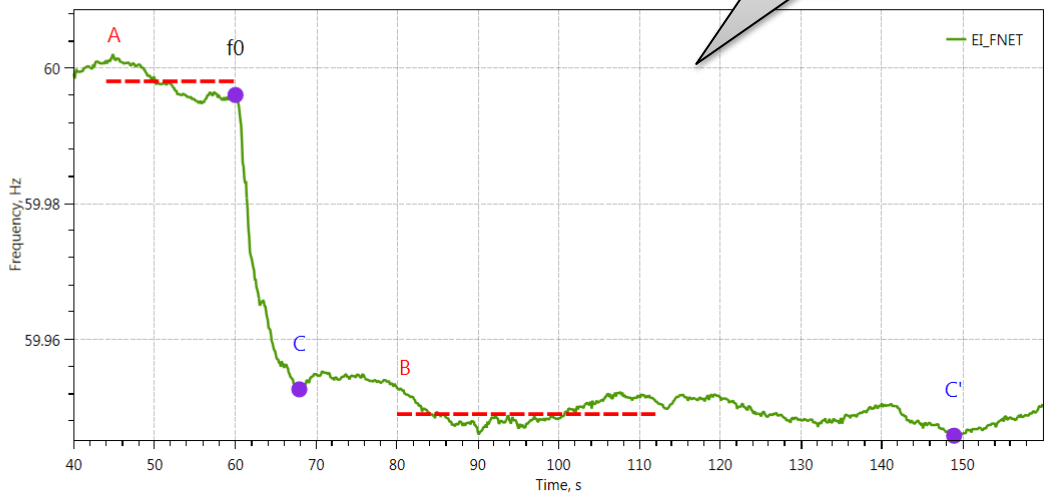
Event Name	Date	Time	Disturban	FRM NERC	FRM BA
20120113-200257E	01/13/12	20:02:57	524	1455.556	0
20120130-160157E	01/30/12	16:01:57	1152	2504.348	0
20120302-195319E	03/02/12	19:53:19	1300	1884.058	0
20120323-182826E	03/23/12	18:28:26	1228	2117.241	0
20120414-174650E	04/14/12	17:46:50	1800	2535.211	0
20120430-140241E	04/30/12	14:02:41	1237	2132.759	0
20120504-173404E	05/04/12	17:34:04	1300	2363.636	0
20120521-195215E	05/21/12	19:52:15	903	2052.273	0
20120626-175002E	06/26/12	17:50:02	1320	2062.5	0
20120702-025225E	07/02/12	02:52:25	1200	2142.857	0
20120803-124122E	08/03/12	12:41:22	1186	3488.235	0
20120828-073034E	08/28/12	07:30:34	1150	2346.939	0
20120909-145954E	09/09/12	14:59:54	540	1285.714	0
20120915-055418E	09/15/12	05:54:18	694	1285.185	0
20120922-193805E	09/22/12	19:38:05	189	460.976	0
20121023-222807E	10/23/12	22:28:07	1234	2742.222	0
20121030-050928E	10/30/12	05:09:28	0	0	0
20121109-061752E	11/09/12	06:17:52	1165	2284.314	0
20121111-085431E	11/11/12	08:54:31	1013	2110.417	0
20121229-061816E	12/29/12	06:18:16	1300	1940.299	0

Event Plot

SubPlots: Frequency, Active Power, Voltage, Reactive Power

Performance Points: NERC, F0, FC, Fsettling, F20/30/60/90

Legend: EIFNET, Mean Freq



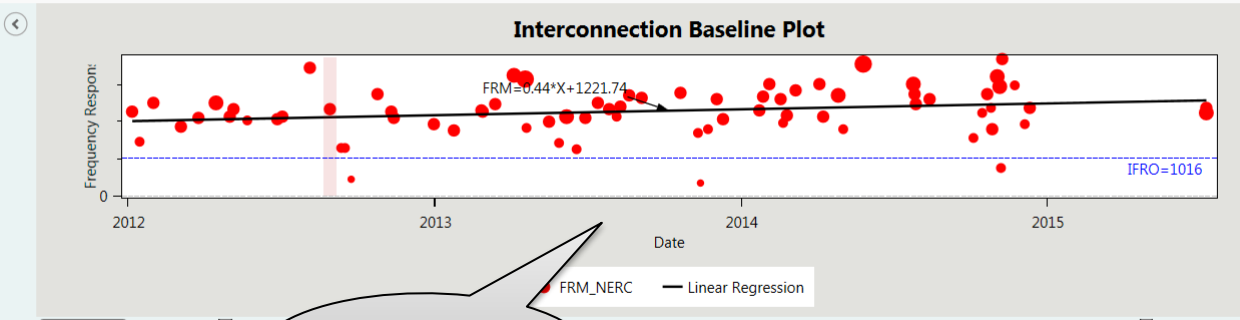
Event Characteristics

- Event Description
- Load/Generation
- Time/Frequency
- NERC Performance

Interconnection		Balancing Authority	
FA NERC	59.998	PA Interchange	0
FB NERC	59.949	PB Interchange	0
FC NERC	59.953	FRM BA	0
FC' NERC	59.946	PA Generation	0
FRM NERC	2346.939	PB Generation	0
		FR Gen BA	0

- Additional Performance Indexes

Interconnection Baseline Plot



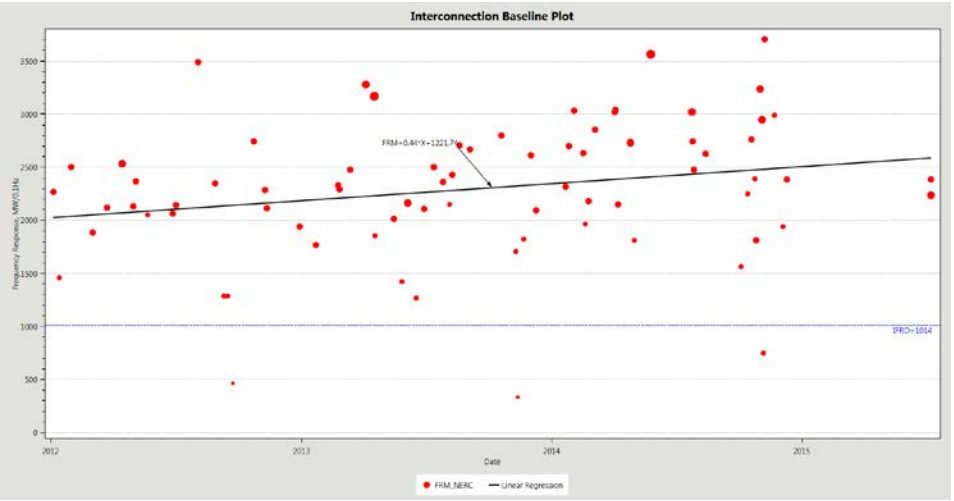
Interconnection Baseline Plot | BA Base

Event Details

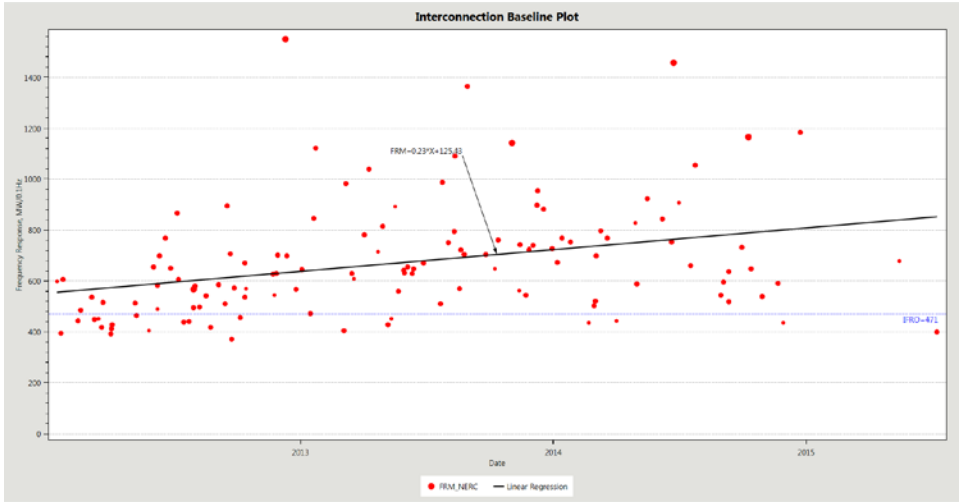
Performance Baseline

Baselining & Outlier Identification

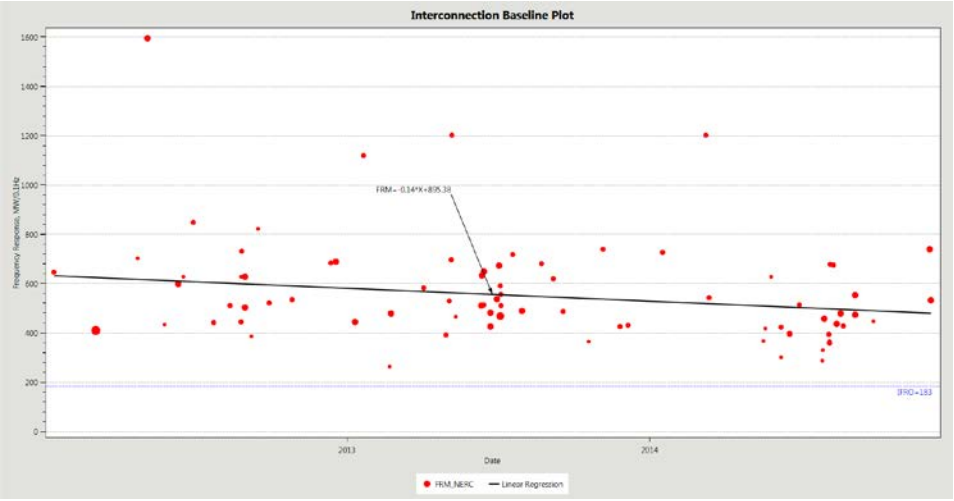
Eastern Interconnection



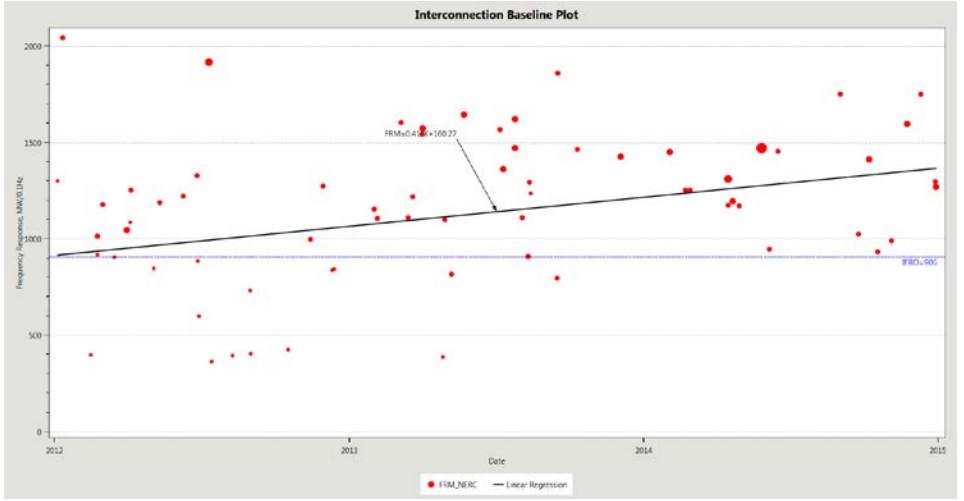
ERCOT Interconnection



Quebec Interconnection

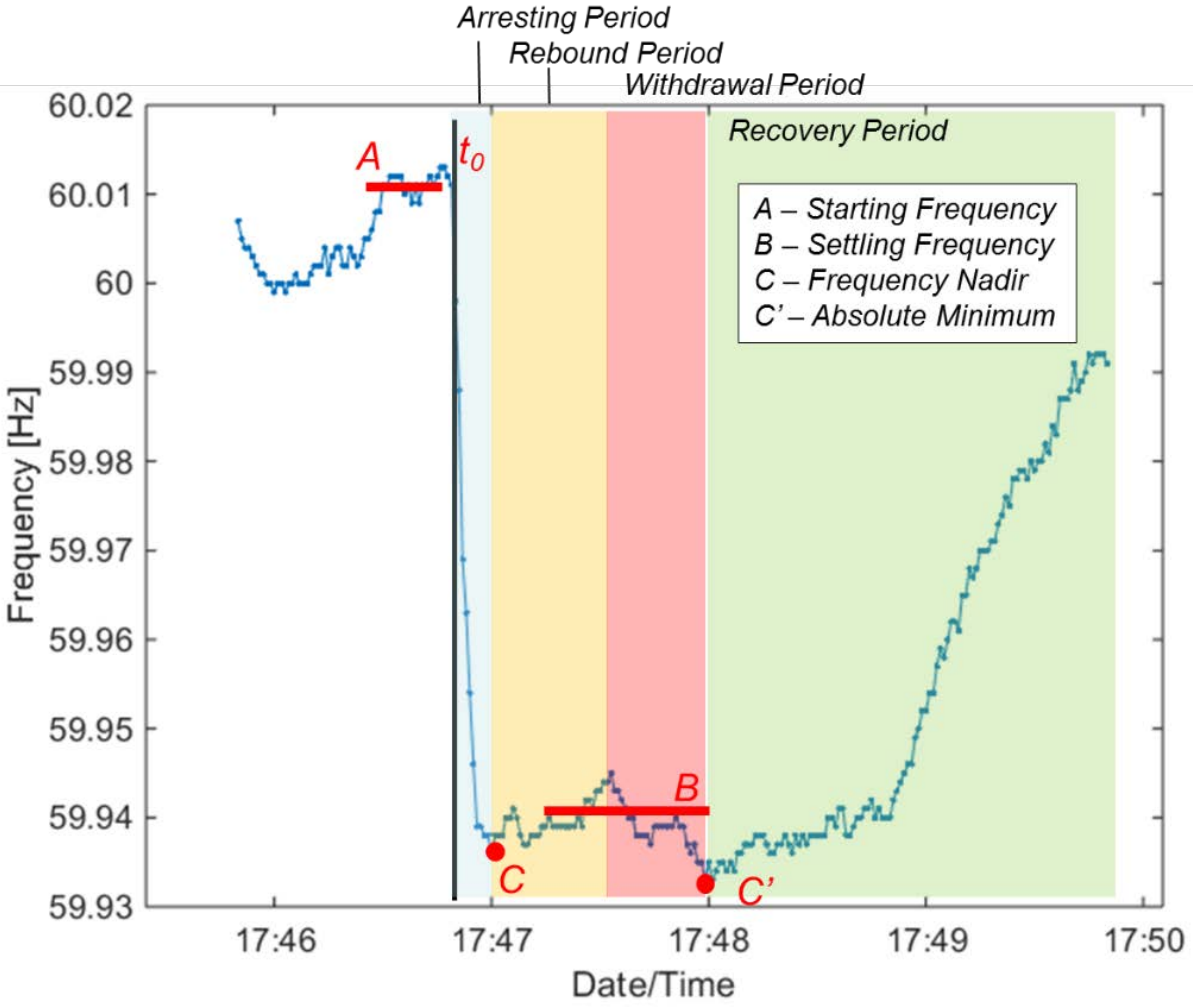


Western Interconnection



**IFRO values are from 2014 FRAA Report*

NERC Essential Reliability Services Task Force (ERSTF)



- ERSTF Measure 4:
  - A:B Measure
  - A:C Measure
  - C:B Measure
  - C’:C Measure
  - tC-t0 Measure
  - tC’-tC Measure
  - tC’-t0 Measure

References

- Frequency Response Analysis
  - Frequency Response Initiative Report - http://www.nerc.com/docs/pc/FRI_Report_10-30-12_Master_w-appendices.pdf
  - BAL-003-1 - http://www.nerc.com/_layouts/PrintStandard.aspx?standardnumber=BAL-003-1&title=Frequency Response and Frequency Bias Setting
- 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) - http://www.nerc.com/comm/Other/Pages/Essential-Reliability-Services-Task-Force-(ERSTF).aspx
  - Resource Subcommittee (RS) - http://www.nerc.com/comm/OC/Pages/Resources-Subcommittee-(RS)-2013.aspx
  - Synchronized Measurement Subcommittee (SMS) - http://www.nerc.com/comm/PC/Pages/Synchronized-Measurement-Subcommittee-(SMS)-Scope.aspx

Questions and Answers