Frequency Response Analysis Tool

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Project Objectives

• Federal Energy Regulatory Commission (FERC) defines in RM13-11: “Frequency response is a measure of an Interconnection’s ability to stabilize frequency immediately following the sudden loss of generation or load, and is a critical component of the reliable operation of the Bulk-Power System, particularly during disturbances and recoveries.”

• North American Electric Reliability Corporation (NERC) developed Frequency Response BAL-003-1 Standard, FERC approved the standard with effective date April 1st 2015.

• The frequency response measure (FRM) can be computed from the single event frequency response data (SEFRD).
Project Objectives

• The main objective of the project is to continue enhancements of the Frequency Response Analysis Tool (FRAT)

• FRAT application:
  – Released under an open source license
  – The tool calculates Frequency Response Measure (FRM) according to NERC BAL-003 standard.
  – The tool archives the historical events and baselines the system performance.
  – The tool automatically generates NERC Frequency Response Survey (FRS) reports
  – The tool has built in statistical analysis and advanced visualization capabilities
Frequency Response Analysis Tool

- Developed under Bonneville Power Administration (BPA) and WECC JSIS technical guidance
- **Frequency response monitoring**
  - Interconnection
    - Balancing Authority
      - Power Plant
- Calculation NERC FRM using PMU and SCADA measurements
- Compliance reporting
- Baselining frequency response for interconnection and BA
- Supporting different data sources (csv, xml, OSIsoft PI, COMTRADE)
- Statistical Analysis
Past major accomplishments

- FRAT (version 1.0) was released under an open source license in 2013
- FRAT (version 2.0) was released under an open source license in September 2014
- Received positive feedback from multiple industrial users including BPA, NERC, and WECC JSIS
- Development was funded by DOE and BPA
FRAT 2.0

- Standalone Windows application
- New analytical functions including:
  - Calculation of the interconnection and balancing authority frequency response measure (FRM) according to the NERC BAL-003-01 Standard
  - Calculation of the power plant frequency response
  - Statistical analysis
- Redesigned user interface based on WPF framework
- Advanced visualization
- Automated reporting capabilities
- Support of different data sources
Technical Accomplishments FY16

• New version is expanded to national use;
• Multiple improvements based on NERC feedback
  – Time zones support
  – NERC BAL-003 and M4 events screening
  – Point C’ calculation
• GUI improvements
• New reporting capabilities
• Connectivity to OSIsoft PI database.
FRAT use at BPA

• Bonneville Power Administration (BPA) is one of the early users of FRAT
• BPA provides feedback on the application development
• BPA uses frequency response baseline developed by FRAT for preparing its filings in response to FERC NOPR on BAL-003-1
• BPA uses the application for baselining its BA frequency response and determining the inventory of its frequency responsive reserves
• BPA uses the application to monitor the impact of renewable generation on its frequency response performance
FRAT use at NERC

- NERC worked closely with PNNL to make improvements to the FRAT for interconnection-wide frequency response analysis
- NERC using FRAT for event tracking for BAL-003-1 and ALR 1-12 (M4) events
- NERC using FRAT to generate the database of performance values for frequency response events for each of the four interconnections
- NERC using FRAT for determination of BAL-003-1 factors
  - Interconnection Frequency Response Obligation (IFRO)
  - Balancing Authority Frequency Response Obligations (BA FRO)
FRAT use at NERC

*IFRO values are from 2014 FRAA Report

Eastern Interconnection

ERCOT

Quebec Interconnection

Western Interconnection
FRAT main GUI
Interconnection Performance

Interconnection Baseline Plot

Interconnection Statistics

Parameter | Value
--- | ---
Mean | 1453
Median | 1443
STD | 309

FRM PDF

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Balancing Authority Performance

*Interchange response is measured for compliance with NERC BAL-003-1
Generation response is calculated to determine how much frequency response to acquire
Baselining
OSIsoft PI database support

- Read information from PI server
- Configurable presets
- Time-series aligning
- Simple math operations (Sum of several signals, P and Q calculation)
Automated reporting

User defined reporting range

Export to Excel
### Interconnection Frequency Response Analysis Report

**Event 1**
- **Event Name**: Event 1
- **Event Date**: 1/10/2014
- **Event Time (UTC)**: 01:00:00
- **Event Time (Local)**: 01/09/2014 00:00:00
- **Time Zone**: Pacific Standard Time
- **Disturbance**: Value A 59.0, Value B 59.8

**Event 2**
- **Event Name**: Event 2
- **Event Date**: 1/11/2014
- **Event Time (UTC)**: 01:00:00
- **Event Time (Local)**: 01/10/2014 00:00:00
- **Time Zone**: Pacific Standard Time
- **Disturbance**: Value A 59.0, Value B 59.8

**Event 3**
- **Event Name**: Event 3
- **Event Date**: 1/12/2014
- **Event Time (UTC)**: 01:00:00
- **Event Time (Local)**: 01/11/2014 00:00:00
- **Time Zone**: Pacific Standard Time
- **Disturbance**: Value A 59.0, Value B 59.8

**Event 4**
- **Event Name**: Event 4
- **Event Date**: 1/13/2014
- **Event Time (UTC)**: 01:00:00
- **Event Time (Local)**: 01/12/2014 00:00:00
- **Time Zone**: Pacific Standard Time
- **Disturbance**: Value A 59.0, Value B 59.8

**Event 5**
- **Event Name**: Event 5
- **Event Date**: 1/14/2014
- **Event Time (UTC)**: 01:00:00
- **Event Time (Local)**: 01/13/2014 00:00:00
- **Time Zone**: Pacific Standard Time
- **Disturbance**: Value A 59.0, Value B 59.8

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Deliverables FY16

- Conference paper will be presented at IEEE General meeting in July 2016.
- Latest version of the Frequency Response Analysis Tool and software documentation. Available at:
  - PNNL web page: https://svn.pnl.gov/FRTool
  - NASPI software exchange portal

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<thead>
<tr>
<th>#</th>
<th>Milestone/Deliverable</th>
<th>Target Date</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Tool specification</td>
<td>December 2014 (completed)</td>
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<tr>
<td>2</td>
<td>Prototype version of the tool</td>
<td>March 2015 (completed)</td>
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<tr>
<td>3</td>
<td>Incorporate user feedback and revise prototype</td>
<td>September 2015 (completed)</td>
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<tr>
<td>4</td>
<td>Final tool release</td>
<td>December 2015 (completed)</td>
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Industry Outreach

The FRAT application has been presented at multiple industrial events including:

- NERC Synchronized Measurement Subcommittee (SMS)
- NASPI working group meeting
- GIGRE Grid of the Future Symposium
- WECC Joint Synchronized Information Subcommittee (JSIS)
- WECC Modeling and Validation Work Group (MVWG)
- Webinars for different electrical utilities
- IEEE General Meeting (to be presented)
Risk factors

• Risk factors are low.
• Feedback and guidance from industrial users are very important for the success of the project.
Future plans

Completed Projects

- FRAT – Frequency Response Analysis Tool
- PPMV – Power Plant Model Validation Tool
- LMDT – Load Modeling Data Tool
- FOD – Forced Oscillation Detection
- OBAT – Oscillation Baselining and Analysis Tool

GMLC Open Source Suite for PMU analysis

- Data Readers
- Event Detection
- Load Modeling
- Machine Learning
- Oscillation project

FRAT – Frequency Response Analysis Tool
PPMV – Power Plant Model Validation Tool
LMDT – Load Modeling Data Tool
FOD – Forced Oscillation Detection
OBAT – Oscillation Baselining and Analysis Tool
Open Platform for Engineering Applications

- Based on Open Source Components
  - Extended WPF Toolkit™
  - OxyPlot
  - Math.NET
- Create building blocks and solutions for future and 3rd party applications
- Common data structure and data exchange protocols
- Support external modules/solvers
  - Oscillation Analysis
  - Model Calibration