Suite of Open-Source Applications and Models for Advanced Synchrophasor Analysis

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Project Team

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  – James O’Brien

• LBNL
  – Joe Eto
  – Ciaran Roberts
  – Emma Stewart (currently with LLNL)

• Partners
  – BPA
  – NERC
  – WECC
  – University of Wisconsin-Madison (Bernie Lesieutre)
Overall project objective

• Develop and advance applications of phasor measurement units (PMUs) and synchrophasor data for power system planning, modeling, and analysis.
• Create building blocks and solutions for future and third-party applications.
• Address oscillation analysis, frequency response, model validation and calibration, load modeling, and other important power-grid-related issues.
• Enable adoption of PMU technology by a wider range of electrical utilities.
Applications built on the open source platform

Frequency Response Analysis Tool (FRAT 2.0)

Power Plant Model Validation Tool (PPMV 2.0)

Oscillation Baselining and Analysis Tool (OBAT 1.0)

Load model Data Tool (LMDT 2.0)
Open Source Framework

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

- Available:
  - PI database reader
  - JSIS CSV reader
  - PDAT reader
  - COMTRADE reader

- Under development:
  - Event detection
  - Data validation
PDAT reader

• Read information from PDAT files.
  – PDAT format developed by BPA.
  – Based on IEEE Std. C37.118.2-2011.
  – Binary files.
  – Each file contains 1 minute of data.
  – PNNL receives PMU data stream from Bonneville Power Administration.

• User friendly GUI.

• Export data to CSV and COMTRADE.

• Configurable presets:
  – PMU/signal names
  – Time shift
  – Scale
  – Offset
OSIsoft PI database

- New version includes multiple improvements.
- Read information from OSIsoft PI database server.
- Time series alignment.
- Configurable presets:
  - PI tag
  - Time shift
  - Scale
  - Offset
- Support simple math operations:
  - Sum of several signals.
  - P and Q calculation.
Oscillation Baselining and Analysis Tool

- Standalone Windows application.
- Released under an open source license on 05/01/2017.
- Based on the open platform for engineering application.
- Interaction with external MATLAB analytical modules for oscillation analysis through COM interface.
- Three analytical methods have been implemented:
  - VARPRO (provided by Bernie Lesieutre)
  - Prony
  - Matrix pencil
- Connectivity to different data sources.
- Database of events.
- Event baselining.
- Advanced visualization.
- Automatic reporting.
OBAT Conceptual Design

Proposed Baselining Application

Application Database

- Events database
- Event Analysis Results
- XML

Common Data Exchange Protocol

Ring down analysis applications

- PNNL
- Montana Tech
- University of Wisconsin-Madison
- ...

PMU measurements

- PI
- CSV
- MATLAB

Data Reader

Baselining Application (analytical engine)

- Advanced visualization
- Statistics
- Reports
OBAT - visualization

Event plot

Mode shape

Map

XML based configuration

Baselining
Frequency Response Analysis Tool

- Developed under NERC and BPA guidance.
- Frequency response monitoring:
  - Interconnection
    - Balancing Authority
    - Power Plant
- Calculates NERC FRM using PMU and SCADA measurements according to BAL-003 standard.
- Compliance reporting.
- Baselining frequency response for interconnection and BA.
- Supporting different data formats (csv, xml, OSIsoft PI, COMTRADE).
- Statistical Analysis.
- Advanced visualization.
FRAT 2.2

- LBNL prepared a review of international practices for managing frequency response.
- Multiple improvements and modifications based on NERC guidance.
- New visualization capabilities:
  - Animated heat map
  - Path flows
- New reporting capabilities based on NERC feedback.

Animated video created using FRAT (Illustrative example, synthetic data).
Power Plant Model Validation Tool

- Supports GE PSLF and Siemens/PTI PSS®E Play-In function for generator model validation.
- Maintains the database of model validation studies (projects).
- Maintains the database of the historic events.
- Maintains the database of the power plants.
- Advanced visualization capabilities.
- Automatically generates reports.
- Performs sensitivity analysis
- Supports interface to external model calibration modules.
New features in PPMV 2.2

Sensitivity Analysis

Comparison PSLF and PSS®E model validation results

Python scripts for PSS®E
Load Model Data Tool

- Fully redesigned GUI.
- Advanced functionality.
- New visualization capabilities.
- Database of load models for different climate zones.
- Configurable presets for each climate zone.
- Generating .dyd and .dyr dynamic records.
Composite Load Model Validation

- LBNL collected micro PMU data for multiple events.
- PNNL set up a simple two-bus system to compare simulated PQ of composite load model and measured PQ in response to played-in voltage and frequency.
- Developed EPCL code to run play-in events in batch mode.
  - Pre-process original play-in event data file.
  - Extract initial bus voltage and load PQ measurements from play-in data file.
  - Adjust and re-solve power flow raw file.
  - Run dynamic simulations with played-in voltages and frequencies at the load terminal.

\[
Z = 0.0001 + 0.001j \text{ pu}
\]

Climate Zone: DSW
Season: Winter day
Hour = 21
Major accomplishments

- Industry-grade, open-source power system analytical tools and software modules have been developed.
  - Power Plant Model Validation Tool (*new version*)
  - Frequency Response Analysis Tool (*new version*)
  - Oscillation Baselining and Analysis Tool
  - Load model data tool (*new version*)
  - Date readers (JSIS CSV, COMTRADE, PDAT, OSIsoft PI)
  - Outcomes of the project were leveraged by the BPA TI projects (e.g., Archive walker application).

- All tools are based on the common open platform and data formats.

- Developed tools have been used by many organizations and electrical utilities including: NERC, WECC, BPA, PG&E, SCE, SPP, BC Hydro, PacifiCorp, CAISO, SRP, and many more.
## Deliverables

<table>
<thead>
<tr>
<th>Significant Milestones</th>
<th>Date</th>
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<tbody>
<tr>
<td>Prototype of the Oscillation Analysis and Baselining Tool (OBAT)</td>
<td>12/15/2016</td>
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<td>PPMV 2.2 (with Siemens/PTI PSSE support)</td>
<td>3/15/2017</td>
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<tr>
<td>FRAT 2.2</td>
<td>5/1/2017</td>
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<tr>
<td>OBAT version 1.0 released under an open source license</td>
<td>5/1/2017</td>
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<tr>
<td>LMDT 2.1</td>
<td>5/1/2017</td>
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<td>Release the open source framework for PMU analysis</td>
<td>9/30/2017</td>
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Publications/Presentations

- Tools presented at multiple events, including IEEE conferences, NASPI meetings, NERC and WECC working groups, webinars to electrical utilities.

- Selected list of presentations:
  - Etingov P, “PPMV tool presentation” at the NASPI Technical Workshop - Model Verification Tools, 2016, Seattle
  - Etingov P., Liu Y., Zhang Y. "Load Model Data Tool Development" , WECC MVWG, Portland, 2017
  - Etingov P. “PPMV 2.0 presentation”, WECC MVWG, Portland, 2017
  - Etingov P. “Power Plant Model Validation”, WECC JSIS, Portland, 2017
  - Jim Follum, Frank Tuffner and Pavel Etingov, “Oscillation analysis and baselining”, WECC JSIS, Portland 2017
  - Etingov P. “Oscillation baselining and analysis tool”, NERC SMS, Atlanta, 2016
  - Etingov P. “Power Plant Model Validation Tool”, NERC SMS, Atlanta, 2016
  - Etingov P. “Update on Oscillation baselining and analysis tool”, NERC SMS, Little Rock, 2017
  - Etingov P. “Update Power Plant Model Validation Tool”, NERC SMS, Little Rock, 2017
Publications related to the project

• Published one journal paper and two conference papers:

• Submitted one journal paper and two conference paper:
On-line Resources

• FRAT
  https://svn.pnl.gov/FRTool

• PPMV
  https://svn.pnl.gov/PPMV

• LMDT
  https://svn.pnl.gov/LoadTool

• OBAT
  https://svn.pnl.gov/OBAT
Future plans

- Continue enhancement of the open source tools and developing new software tools and modules.
- Transition from off-line to near-real time analysis functionality.
- Expanding analytical capabilities based on user feedback.
- Industry outreach, working closely with NERC, WECC, BPA and other electrical utilities to promote nationwide dissemination of the tools.