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Oscillation Baseline and Analysis Tool

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Pacific Northwest National Laboratory

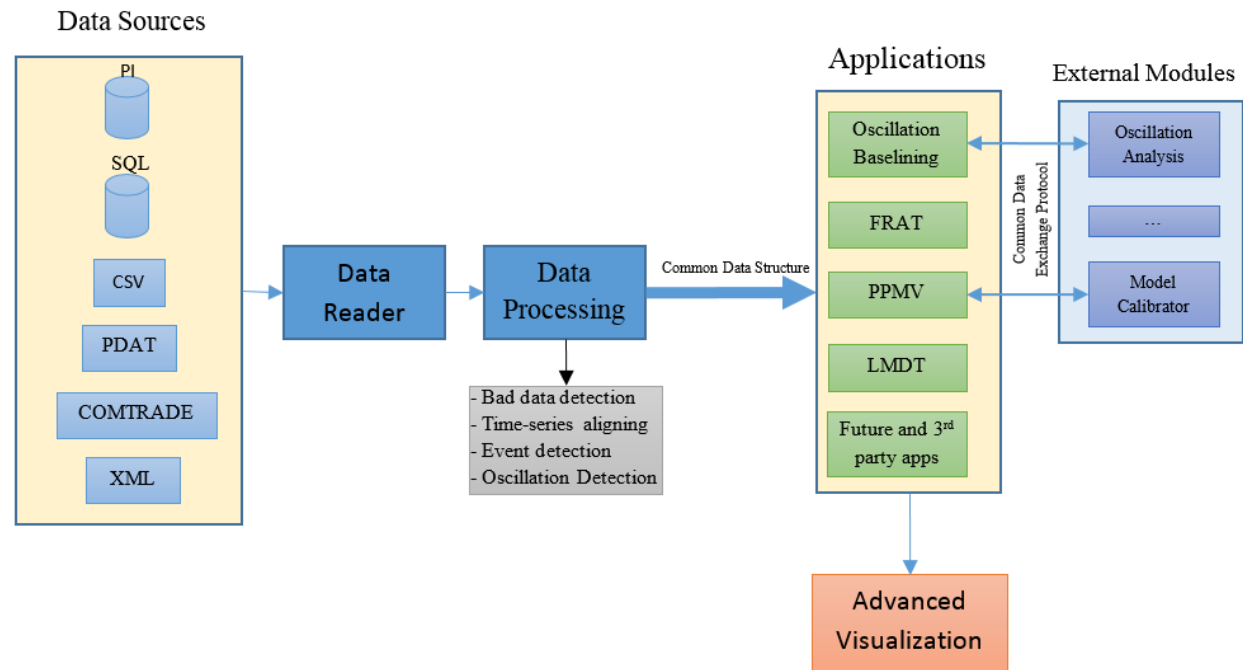
DMITRY KOSTEREV, GORDON MATTHEWS
Bonneville Power Administration

BERNIE LESIEUTRE
University of Wisconsin-Madison

NASPI Work Group Meeting, Seattle, October 19-20, 2016

Open Platform for Engineering Applications

- ▶ Development is funded by the DOE through GMLC program and by Bonneville Power Administration
- ▶ 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



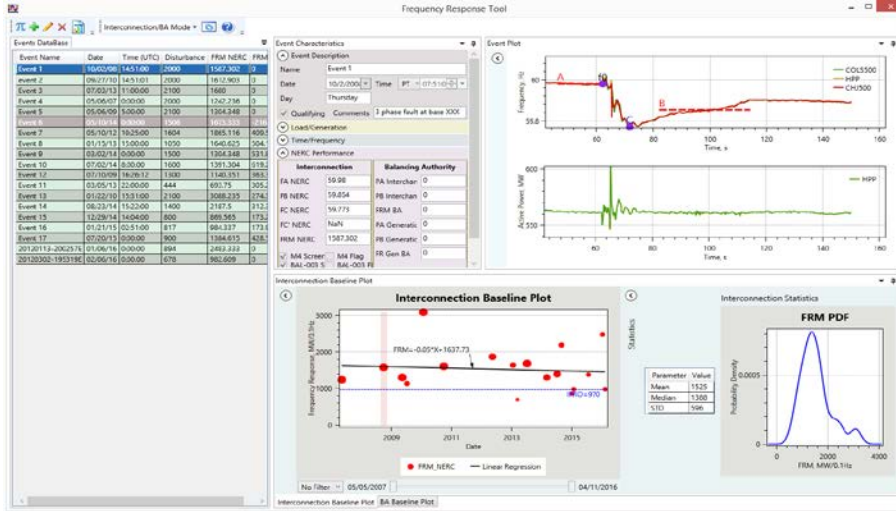
Applications based on the Open Platform for Engineering Applications



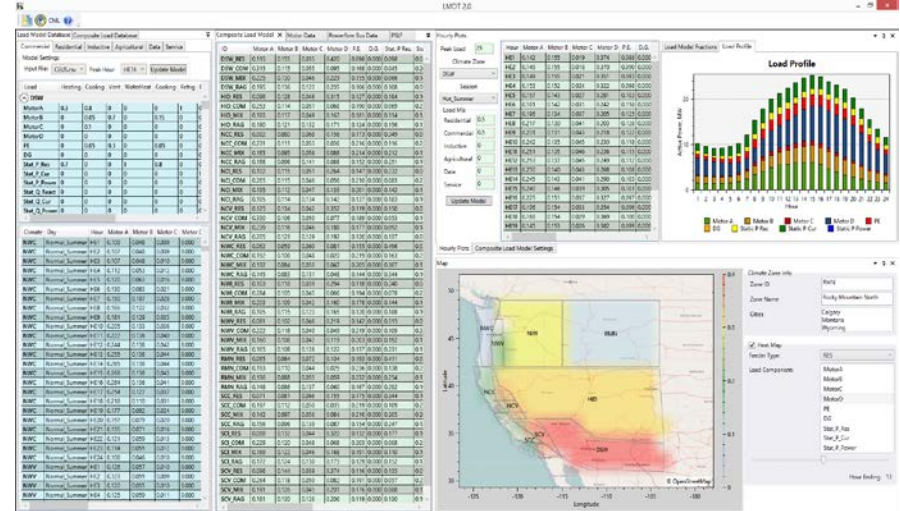
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► Frequency Response Analysis Tool (FRAT 2.0)



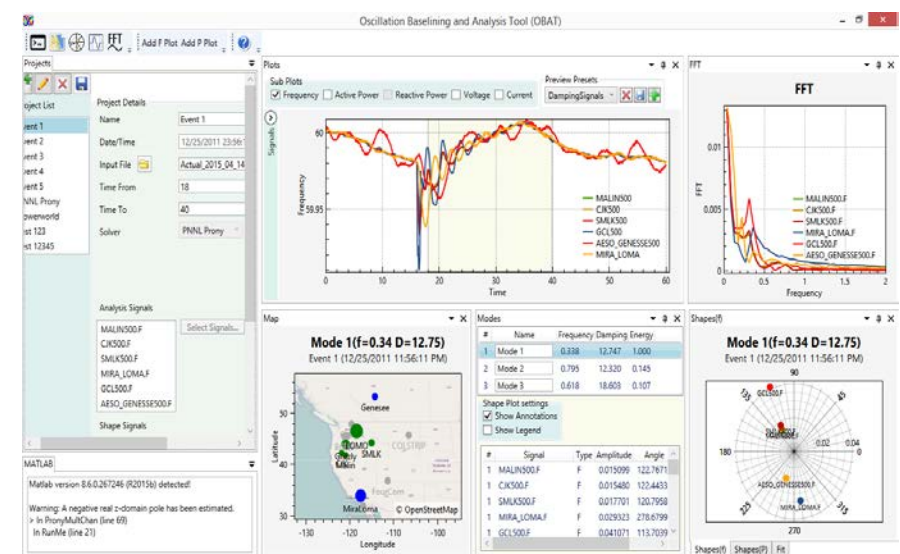
► Load model Data Tool (LMDT 2.0)



► Power Plant Model Validation Tool (PPMV 2.0)



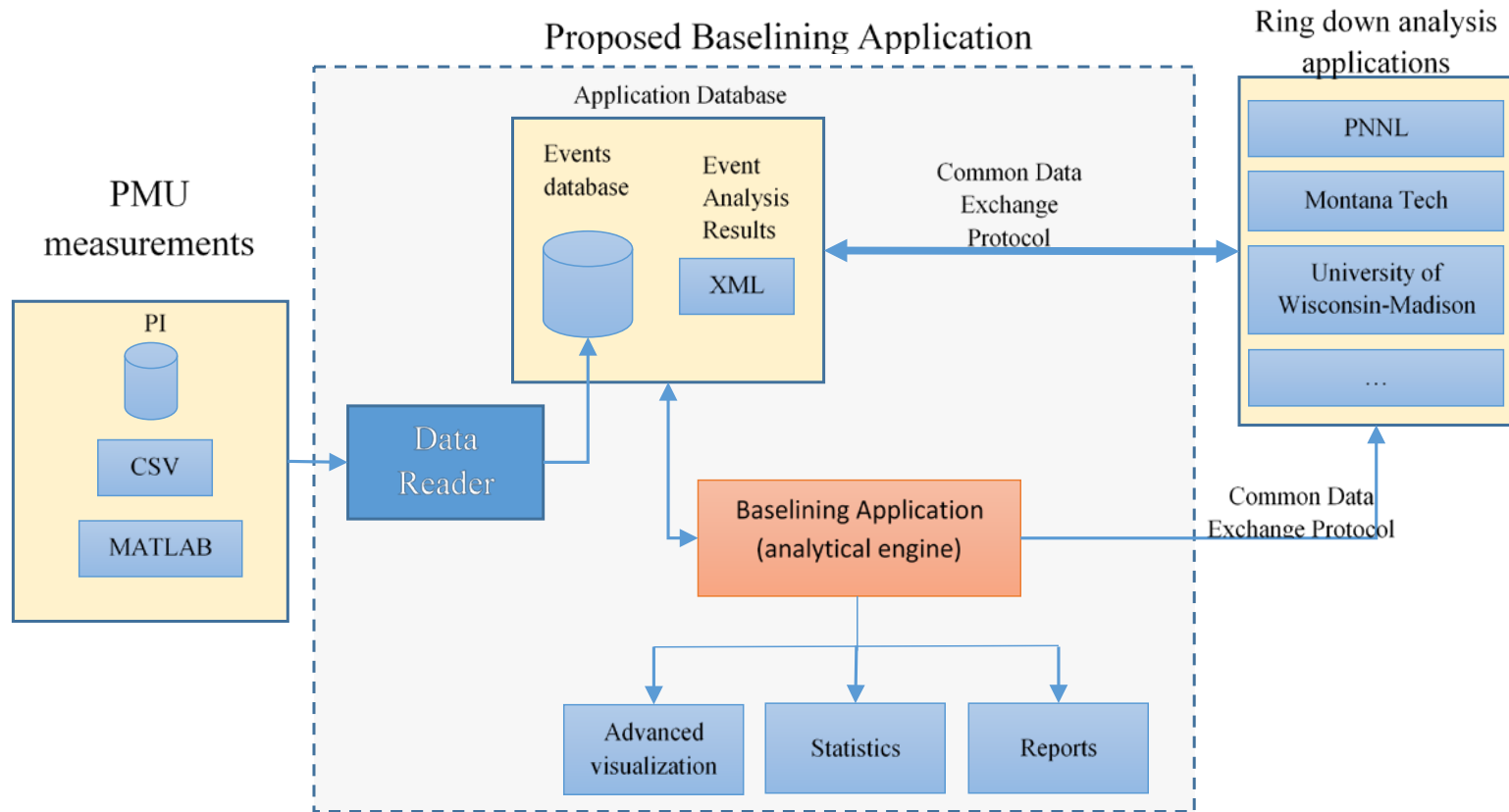
► Oscillation Baseline and Analysis Tool (OBAT)



Oscillation Baselining and Analysis Tool

- ▶ Standalone Windows application
- ▶ Will be released under an open source license
- ▶ Based on the open platform for engineering application
- ▶ Interaction with external MATLAB analytical modules for oscillation analysis (e.g., VARPRO and Prony) through MATLAB COM interface
- ▶ Connectivity to different data sources
- ▶ Database of events
- ▶ Event baselining
- ▶ Advanced visualization
- ▶ Automatic reporting

OBAT Conceptual Design



OBAT Graphical User Interface (GUI)

Oscillation Baseline and Analysis Tool (OBAT)

Projects

Project List

Project Details

Name: [Blank]

Date/Time: [Blank]

Input File: [Blank]

Time From: 19

Time To: 30

Solver: PNNL Prony

Damping Threshold: 20 %

Analysis Signals

Select Signals...

- ADELANTO500.F
- AESO_GENESSE500.F
- AESO_SUNDANCE240.F
- BCH_CBK500.F
- BCH_GMS500.F
- BCH_ING500.F
- BCH_MCA500.F

Shape Signals

Select Signals...

Signals for baselining

Name	Value
COI	2,651.400
Montana-Northwest	778.000
BC-Alberta	19.462

Event Description

Run Analysis

MATLAB

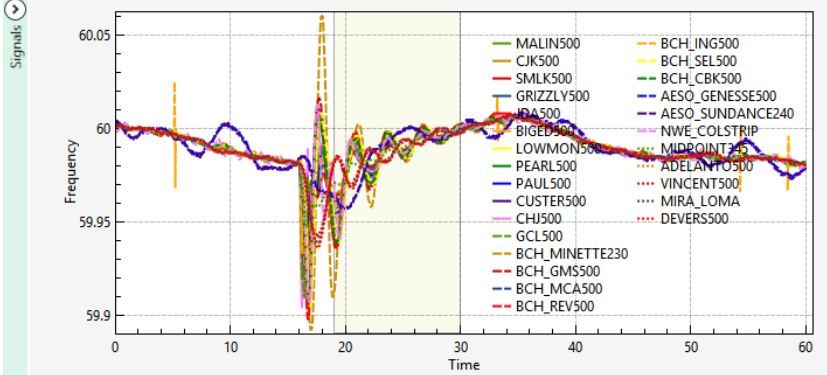
Matlab version 8.6.0.267246 (R2015b) detected!

Plots

Sub Plots

Frequency Active Power Reactive Power Voltage Current

Preview Presets: AnalysisSignals

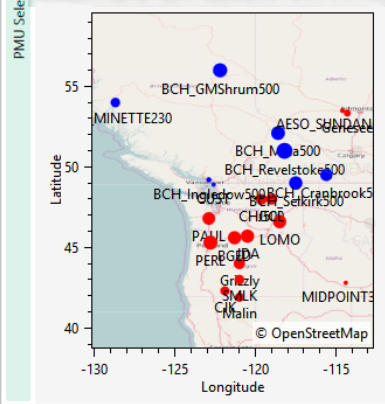


Plots: FFT Baseline

Map

PMU Selection

Montana (f=0.82 D=10.68)



Modes

#	Name	Frequency	Damping	Energy
1	North-South B	0.334	10.939	1.000
2	British Columbia	0.604	12.898	0.128
3	Montana	0.824	10.675	0.026

Shape Plot settings

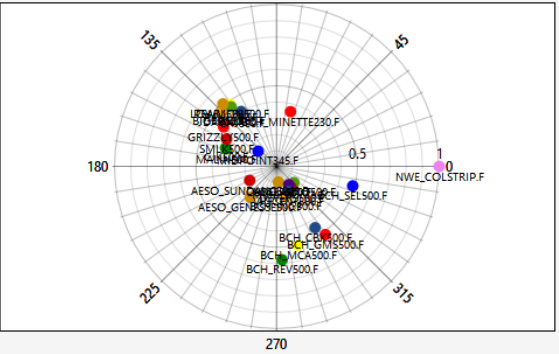
Show Annotations

Show Legend

#	Signal	Type	Amplitude	Angle	Display
3	ADELANTO500.F	F	0.14578	-42.98658	<input checked="" type="checkbox"/>
3	AESO_GENESSE500.F	F	0.25061	-130.1804	<input checked="" type="checkbox"/>
3	AESO_SUNDANCE240.F	F	0.18673	-152.5547	<input checked="" type="checkbox"/>
3	BCH_CBK500.F	F	0.44503	-57.90805	<input checked="" type="checkbox"/>
3	BCH_GMS500.F	F	0.51518	-54.41438	<input checked="" type="checkbox"/>
3	BCH_ING500.F	F	0.19053	-72.32819	<input checked="" type="checkbox"/>
3	BCH_MCA500.F	F	0.50183	-74.78332	<input checked="" type="checkbox"/>
3	BCH_REV500.F	F	0.57527	-86.60023	<input checked="" type="checkbox"/>
3	BCH_SEL500.F	F	0.48297	-14.35648	<input checked="" type="checkbox"/>
3	BIGED500.F	F	0.48005	134.83775	<input checked="" type="checkbox"/>

Shapes(f)

Montana (f=0.82 D=10.68)



Shapes(f) Shapes(P) Shapes(A) Fit

GUI – Projects panel

- ▶ List of events
- ▶ Add/modify/delete events
- ▶ Event info
- ▶ Starting/Ending time
- ▶ Oscillation Analysis Method (Solver)
- ▶ List of signals for mode analysis
- ▶ List of signals for mode shape calculation
- ▶ List of signals for baselining

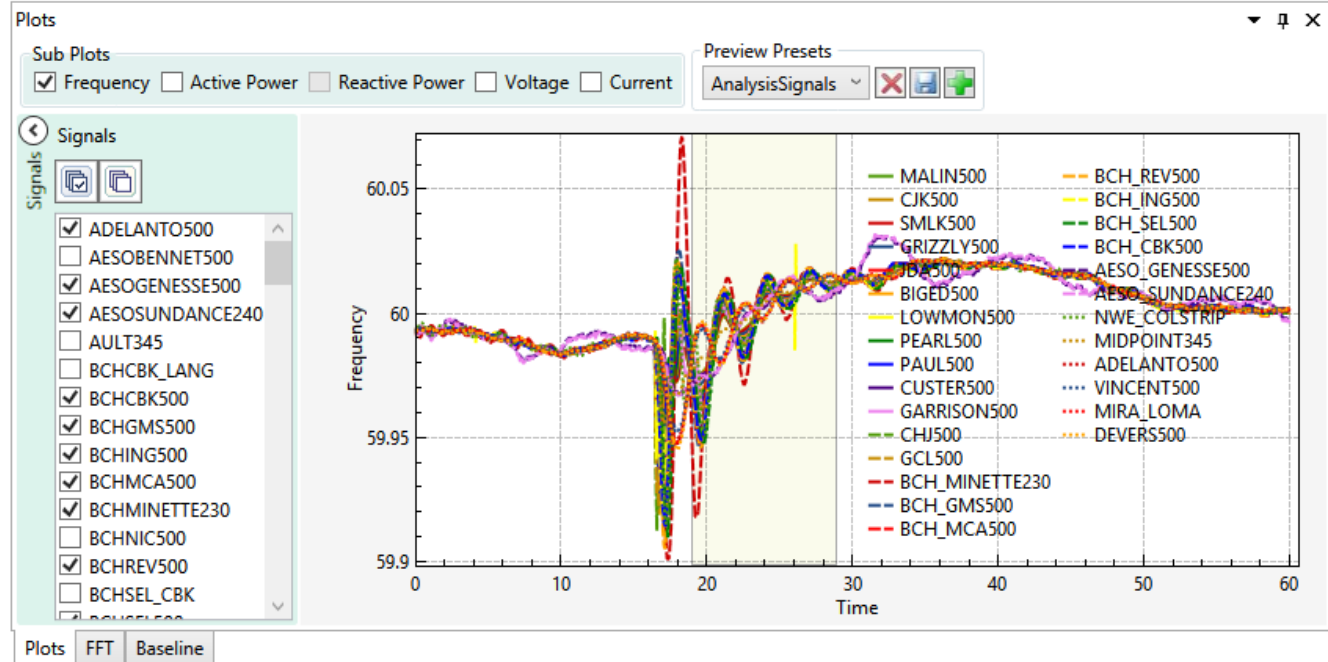
The screenshot displays the 'Projects' panel in a software application. On the left, a 'Project List' shows 'Event1' and 'Event2', with 'Event2' selected. The main area is titled 'Project Details' and contains the following fields and sections:

- Name:** Event2
- Date/Time:** 06/29/2016 23:00:59, UTC Offset + 2
- Input File:** Event2.csv
- Time From:** 18
- Time To:** 45
- Solver:** VARPRO
- Damping Threshold:** 20 %
- VARPRO Section:**
 - Polynomial Order: 0
 - Number Modes: 0 (Not used when initial values are entered below)
 - Table with columns: Frequency, Damping, Delete?
 - Row 1: 0.380, 10.072, [checkbox]
 - Buttons: Use Current Estimates, [X], [+], [Save]
- Analysis Signals:** Select Signals... [dropdown] [+]
- Shape Signals:** Select Signals... [dropdown] [+]
- Signals for baselining:**

Name	Value
Path ABC	745.881
Path XYZ	4,004.534
- Event Description:** [text field]
- Run Analysis:** [button]

GUI – Event Preview

- ▶ Subplots for F,P,Q,V,I
- ▶ Configurable preview presets
- ▶ List of available signals
- ▶ Multiple subplots



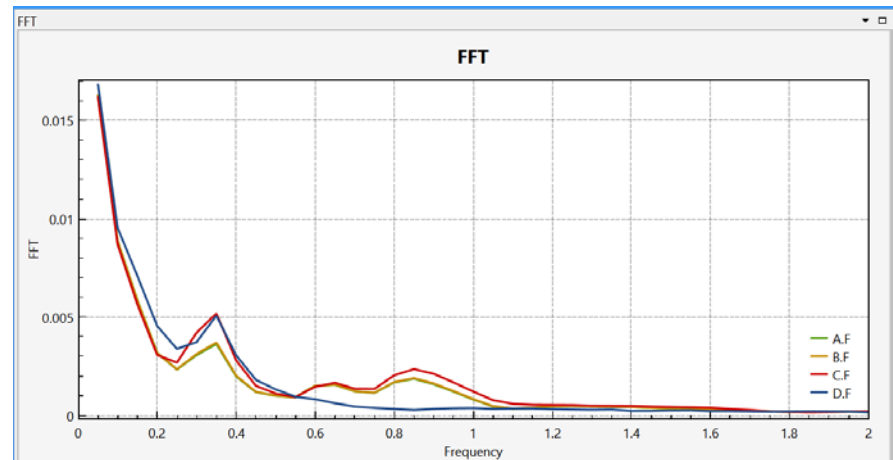
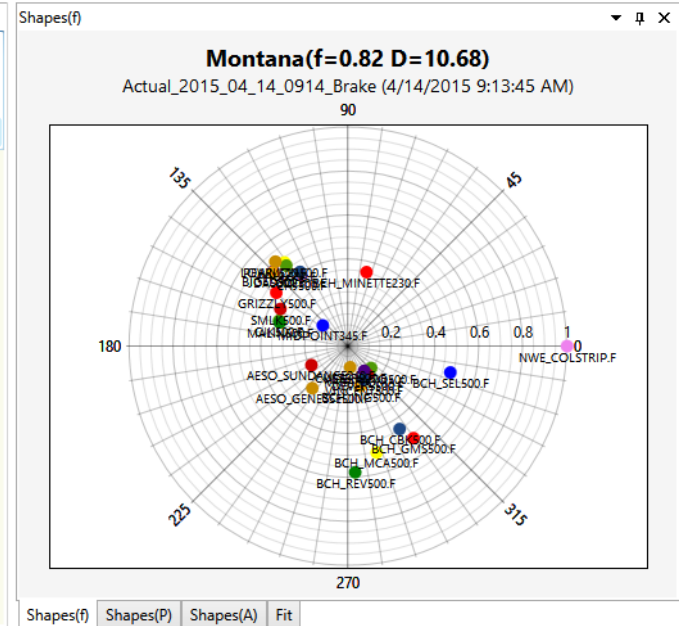
GUI – Modes & Mode Shapes

- ▶ Modes list
 - Name
 - Frequency
 - Damping
 - Energy
- ▶ Mode shapes
 - Amplitude
 - Angle
- ▶ FFT analysis

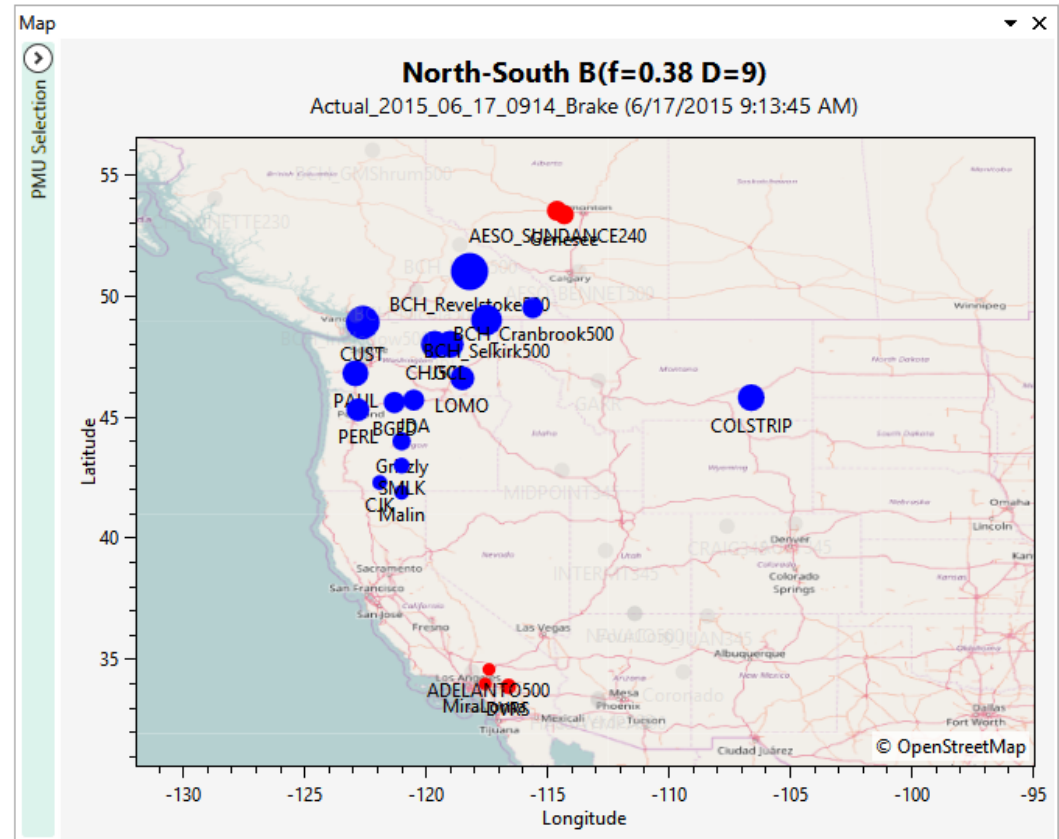
#	Name	Frequency	Damping	Energy
1	North-South B	0.334	10.939	1.000
2	British Columbia	0.604	12.898	0.128
3	Montana	0.824	10.675	0.026

Shape Plot settings
 Show Annotations
 Show Legend

#	Signal	Type	Amplitude	Angle	Display
3	ADELANTO500.F	F	0.14578	-42.98658	<input checked="" type="checkbox"/>
3	AESO_GENESSE500.F	F	0.25061	-130.1804	<input checked="" type="checkbox"/>
3	AESO_SUNDANCE240.F	F	0.18673	-152.5547	<input checked="" type="checkbox"/>
3	BCH_CBK500.F	F	0.44503	-57.90805	<input checked="" type="checkbox"/>
3	BCH_GMS500.F	F	0.51518	-54.41438	<input checked="" type="checkbox"/>
3	BCH_ING500.F	F	0.19053	-72.32819	<input checked="" type="checkbox"/>
3	BCH_MCA500.F	F	0.50183	-74.78332	<input checked="" type="checkbox"/>
3	BCH_REV500.F	F	0.57527	-86.60023	<input checked="" type="checkbox"/>
3	BCH_SEL500.F	F	0.48297	-14.35648	<input checked="" type="checkbox"/>
3	BIGED500.F	F	0.48005	134.83775	<input checked="" type="checkbox"/>
3	CHJ500.F	F	0.38612	122.98294	<input checked="" type="checkbox"/>
3	CJK500.F	F	0.33402	159.65758	<input checked="" type="checkbox"/>
3	CUSTER500.F	F	0.09658	-83.32962	<input checked="" type="checkbox"/>



- ▶ Display information for user selected mode
- ▶ PMU location
- ▶ Size of circles is proportional to mode shape magnitude
- ▶ Color depends on mode shape phase



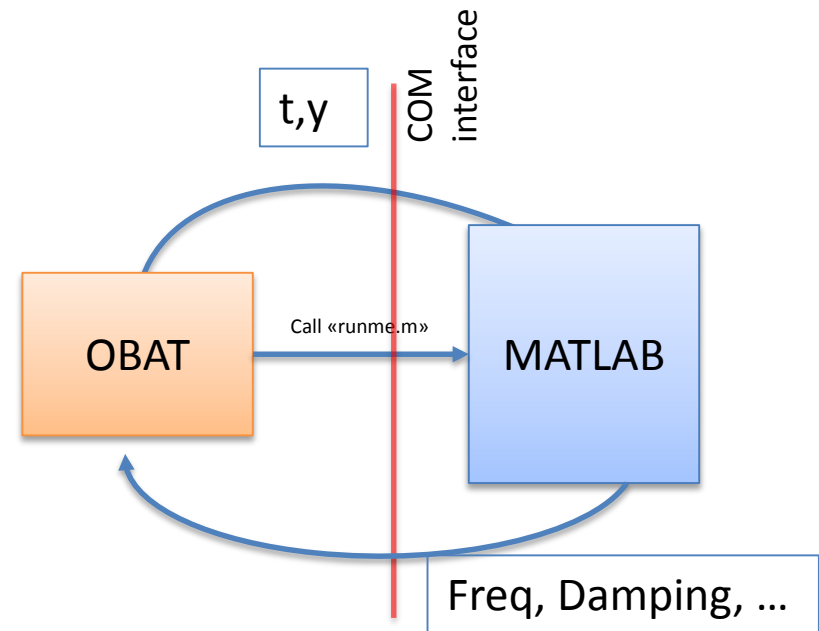
Oscillation event description

- ▶ Based on XML
- ▶ Parameters list can be extended
- ▶ Simplifies oscillation event information exchange between different organizations
- ▶ Will include the following information:
 - Event basic information (name, time, input file name, etc.)
 - List of signals used for analysis
 - Modes(name, frequency, damping, mode shapes, etc.)

```
- <Event Name="Event2">
  <Tstart>5</Tstart>
  <Tend>45</Tend>
  <InputFile>Event2.csv</InputFile>
  <Solver>VARPRO</Solver>
  - <Signals>
    <Signal>A</Signal>
    <Signal>B</Signal>
    <Signal>C</Signal>
  </Signals>
  - <Modes>
    - <Mode>
      <ID>1</ID>
      <Name>Mode 1</Name>
      <Frequency>0.37802</Frequency>
      <Damping>1.03616</Damping>
      - <ModeShapes>
        - <Signal Name="A">
          <Amplitude>0.00389</Amplitude>
          <Angle>66.38118</Angle>
        </Signal>
        - <Signal Name="B">
          <Amplitude>0.00391</Amplitude>
          <Angle>66.41947</Angle>
        </Signal>
        - <Signal Name="C">
          <Amplitude>0.00419</Amplitude>
          <Angle>67.69662</Angle>
        </Signal>
      </ModeShapes>
    </Mode>
    - <Mode>
      <ID>2</ID>
      <Name>Mode 2</Name>
      <Frequency>0.06316</Frequency>
      <Damping>3.0263</Damping>
      - <ModeShapes>
        - <Signal Name="A">
          <Amplitude>0.01537</Amplitude>
          <Angle>199.65433</Angle>
        </Signal>
        - <Signal Name="B">
          <Amplitude>0.01537</Amplitude>
          <Angle>199.6545</Angle>
        </Signal>
        - <Signal Name="C">
          <Amplitude>0.01531</Amplitude>
          <Angle>199.61553</Angle>
        </Signal>
      </ModeShapes>
    </Mode>
  </Modes>
</Event>
```

Integration with MATLAB

- ▶ Define naming convention for input/output parameters
- ▶ Input parameters:
 - t- Time (vector)
 - y – measurement values (matrix)
- ▶ Output parameters:
 - Freq – frequency values (vector)
 - Damping – damping values (vector)
 - A – mode shape amplitude values (matrix)
 - theta – mode shape phase values (matrix)



Folders structure



[Freq,Damping,A, theta] =
callVarpro (t, y)

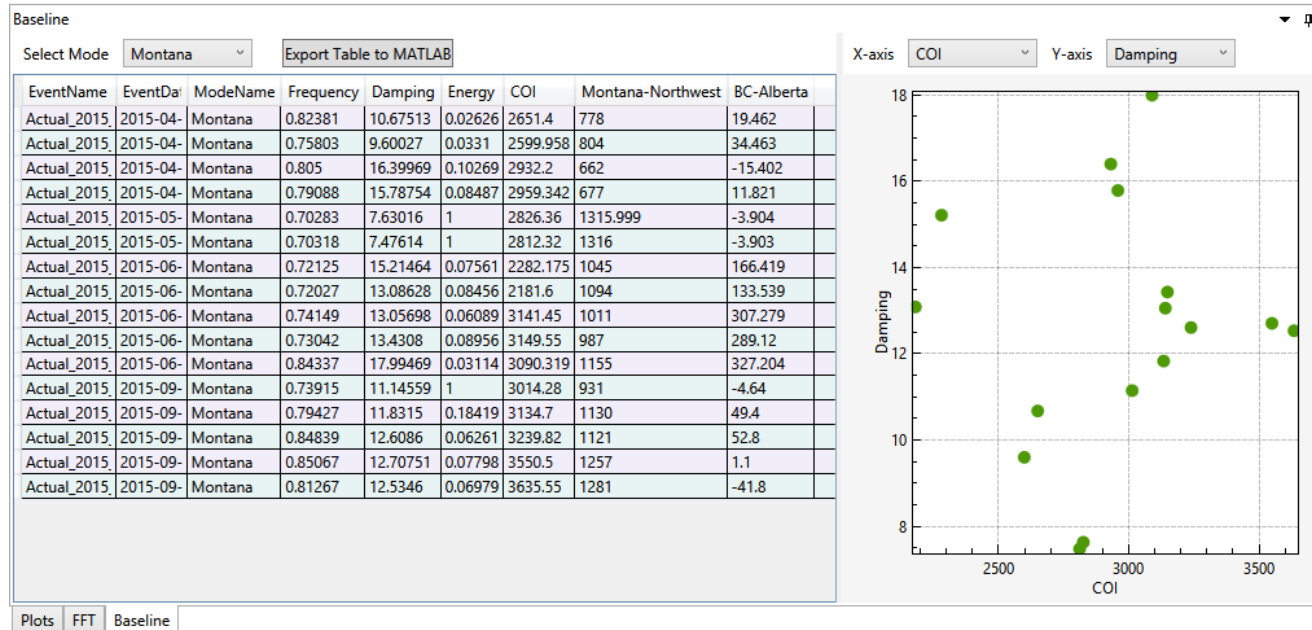
[Freq,Damping,A, theta] =
callSolverX (t, y)

- ▶ Configurable presets for automatic mode identification
 - Mode shape based on a set of signals
 - Frequency range

```
<Mode Name="Montana">  
  <fmin>0.65</fmin>  
  <fmax>0.85</fmax>  
  <Cluster1>  
    <SetA>  
      <PMU>NWE_COLSTRIP</PMU>  
      <PMU>GARRISON500</PMU>  
    </SetA>  
    <SetB></SetB>  
  </Cluster1>  
  <Cluster2>  
    <SetA>  
      <PMU>CHJ500</PMU>  
      <PMU>GCL500</PMU>  
      <PMU>JDA500</PMU>  
      <PMU>BIGED500</PMU>  
    </SetA>  
    <SetB></SetB>  
  </Cluster2>  
</Mode>
```

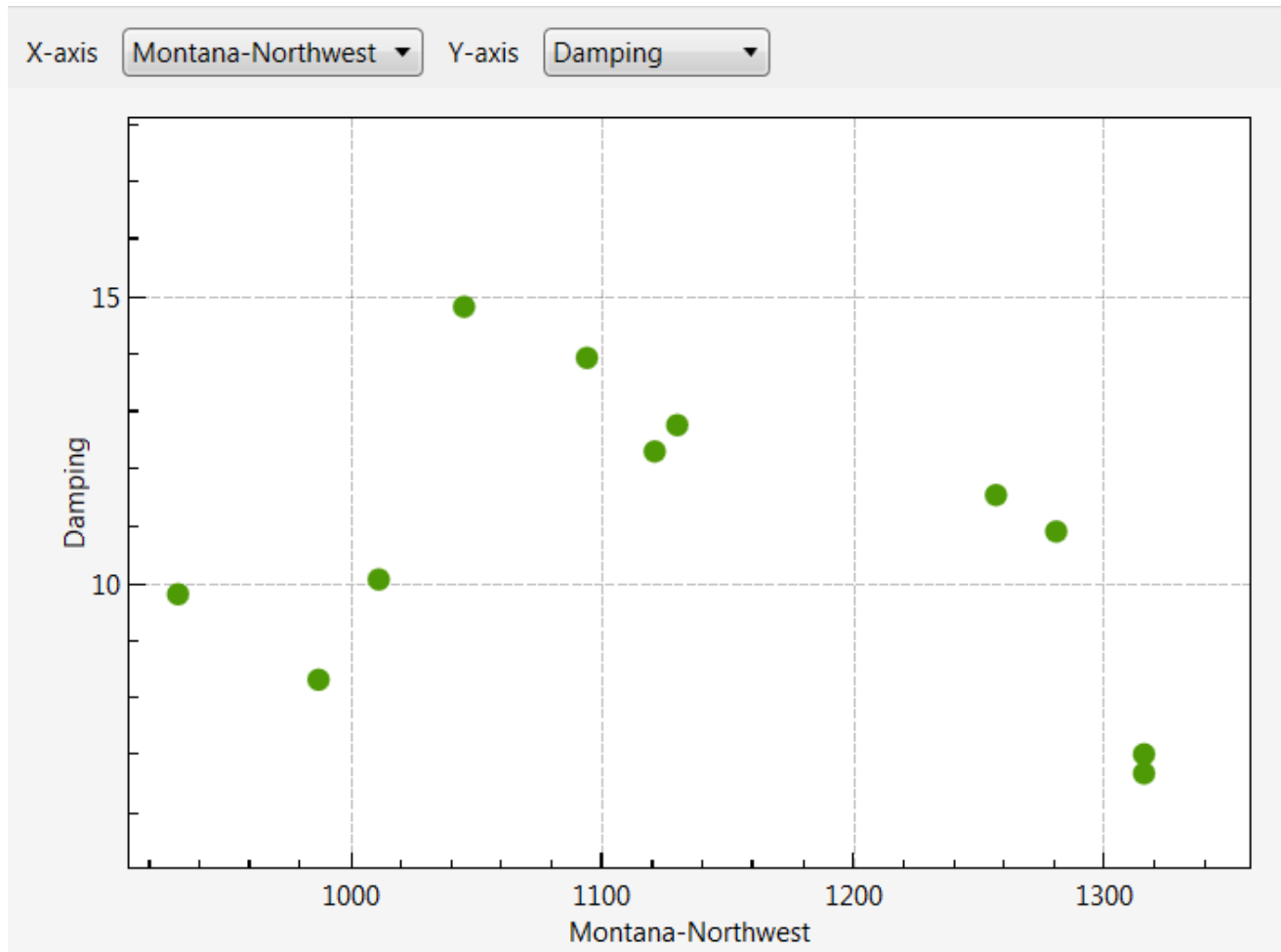
Oscillation Baseline

- ▶ Configurable set of signals used for baselining
- ▶ Select events in the database with particular mode
- ▶ Export results to MATLAB for analysis
- ▶ Plot oscillation characteristics vs. system operating conditions

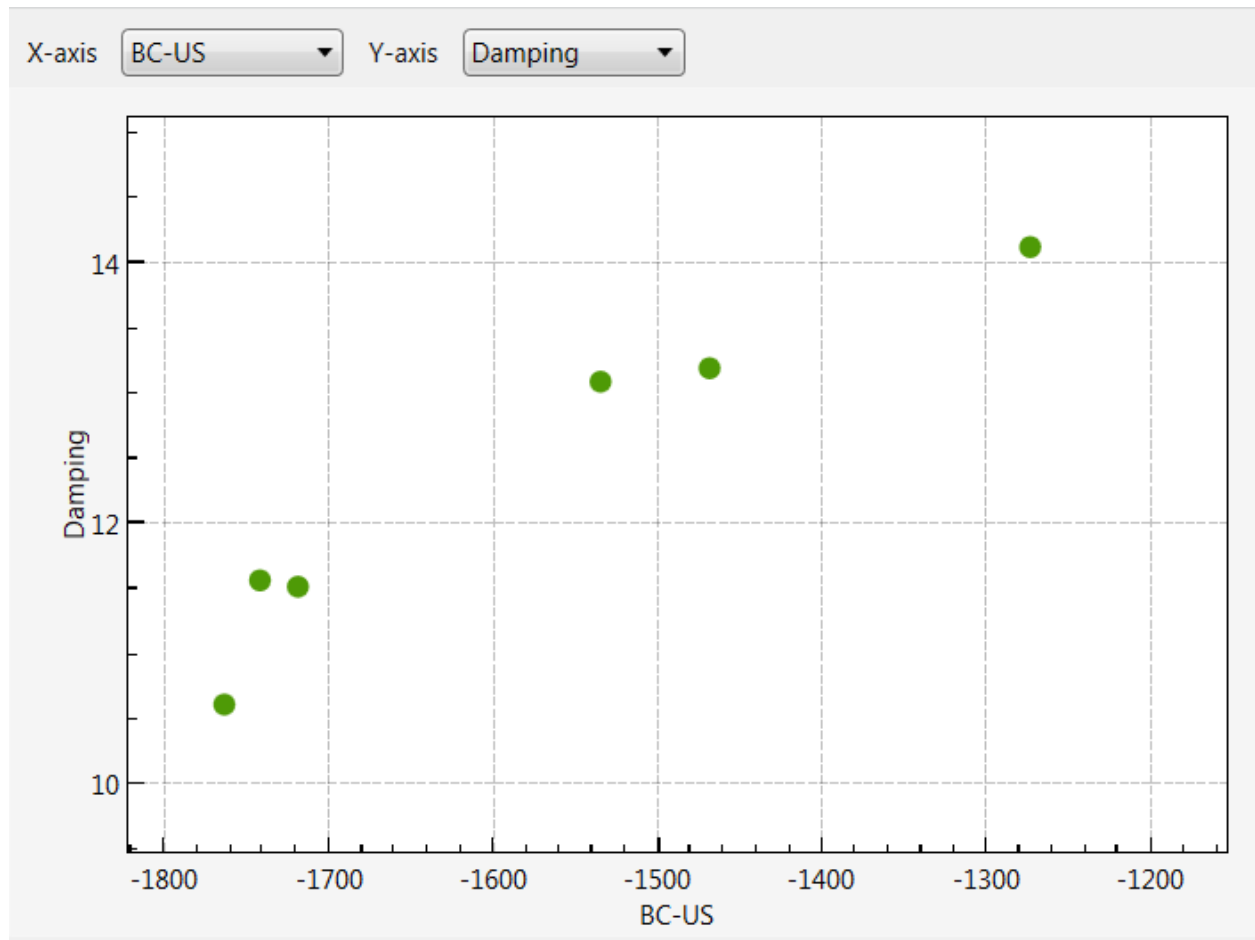


```
<Baseline>  
  <Parameter Name="COI">  
    <Signal>PATH.COI</Signal>  
  </Parameter>  
  <Parameter Name="Montana-Northwest">  
    <Signal>PATH.MT-NW</Signal>  
  </Parameter>  
  <Parameter Name="BC-Alberta">  
    <Signal>PATH.BC-ALB</Signal>  
  </Parameter>  
</Baseline>
```


▶ Montana mode



▶ British Columbia mode



- ▶ <https://svn.pnl.gov/OBAT>
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 - james.follum@pnnl.gov