

Real-time Forced Oscillation Detection and Source Location in the Western Interconnection

NASPI Work Group Meeting

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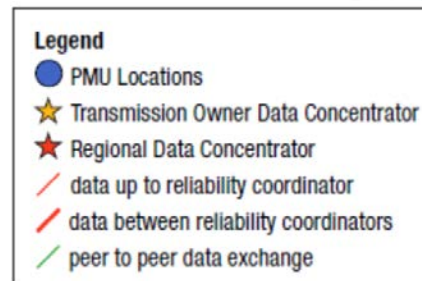


PEAKRELIABILITY
assuring the wide area view

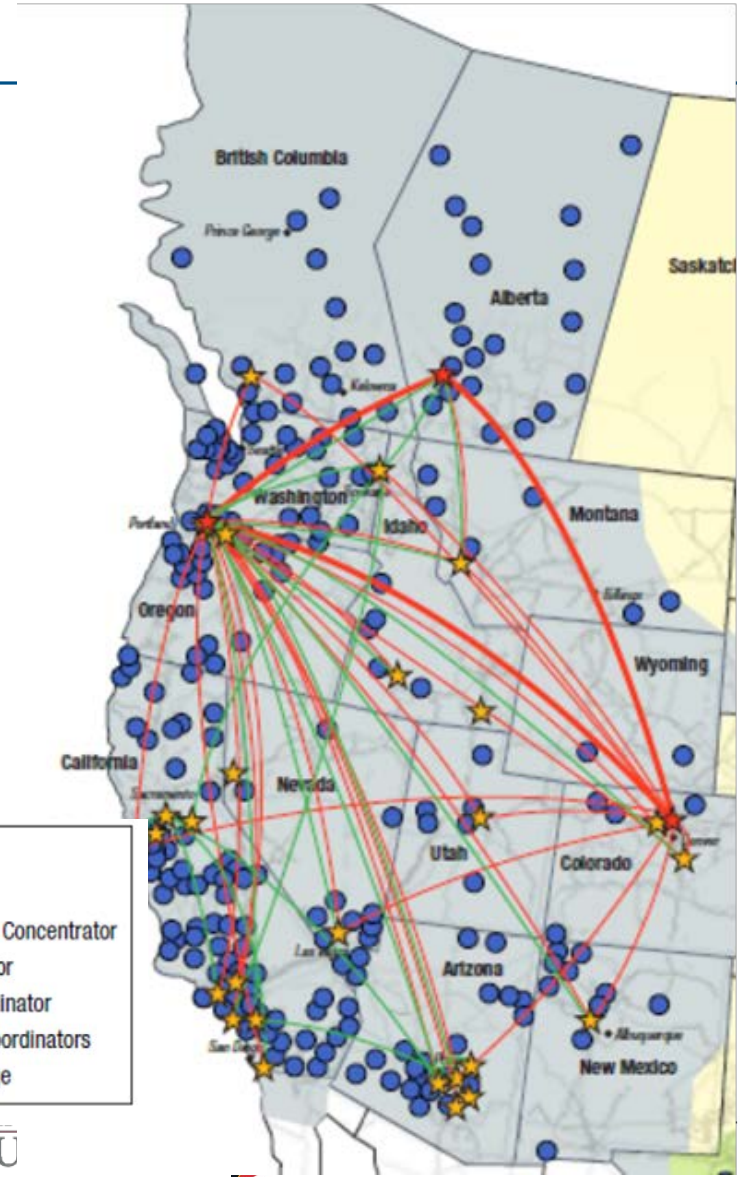
Peak Reliability (formerly WECC RC) Synchrophasor Effort

WISP/PRSP Accomplishments:

- 600+ Phasor Measurement Units
- 70+ Phasor Data Concentrators
- WAN Communication Infrastructure
- Data Center(s) and Information Technology Infrastructure
- Advanced Transmission Software Applications
- Control Room Solution use case development



With information available as of March 20, 2014



Overview of Oscillation Monitoring Implementation Status

- Peak is receiving 300+ PMU data from 16 Western Interconnection Entities
- Synchrophasor Applications:
 - GPA OpenPDC (in Prod)
 - GE PhasorPoint incorporating Montana Tech Modal Analysis Software (MAS) (in Prod)
 - WSU Oscillation Monitoring System (in Test)
 - OSIsoft PI Data System (in Prod)



Motivation of RT-FODSL

- Forced Oscillations in the system (equipment malfunction, poor control designs, and abnormal operating conditions of power plant)
- Persistent Forced Oscillations with high oscillation amplitude could cause damage to local power plant
- Forced Oscillation with low oscillation frequency could potentially resonate with system modes to trigger wide area oscillations
- Real-time monitoring is needed in control room



Motivation of RT-FODSL (cont'd)

- Two steps:
 - Forced Oscillation Detection (PMU data)
 - Oscillation Source Location (SCADA data)
- PMU data has poor coverage for monitoring generation plants
- Peak receives SCADA measurements of 3000 generators via ICCP
- **RT-FODSL: PMU-SCADA hybrid tool**

Forced Oscillation Detection

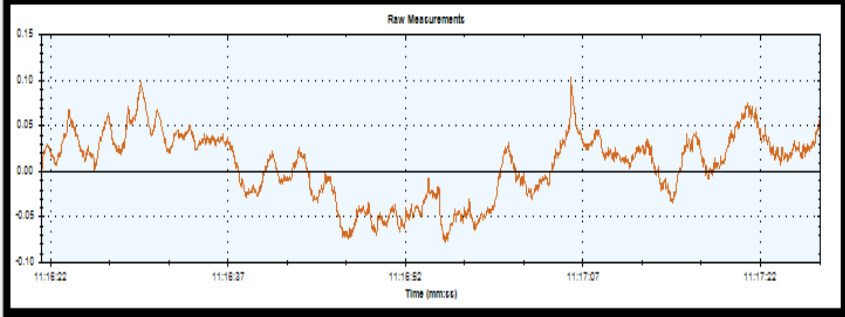
- Characteristics of Forced Oscillations
 - Sustained oscillations
 - Near zero damping ratio
 - Mostly fixed oscillation frequency
 - High oscillation energy
 - Persistent until source mechanism mitigated
- WSU online Oscillation Monitoring Tool
 - Fast Frequency Domain Decomposition (FFDD)
 - Fast Stochastic Subspace Identification (FSSI)

WSU Online Oscillation Monitoring System

- Use all available PMU signals (voltage magnitudes chosen by Peak)
- Automatically detected dominant modes (frequency, damping ratio, mode shape, energy, confidence level)
- 1 minute moving window
- Updated every 10 seconds

Messages About

- Tag
- Normal W001ALLSTON_01-P
 - Normal W001ALLSTON_01-P
 - Normal W001ALVEY_01-PA
 - Normal W001ALVEY_01-PA
 - Normal W001ASHE_01-PA
 - Normal W001ASHE_01-PA
 - Normal W001BELL_01-PA



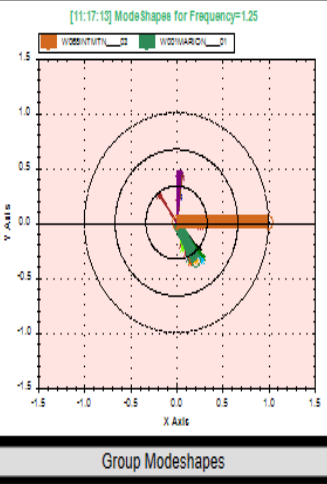
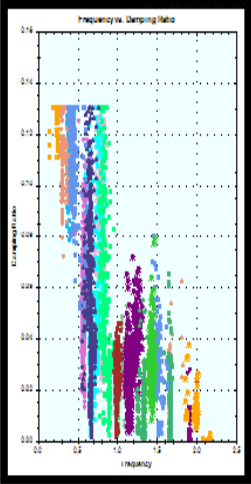
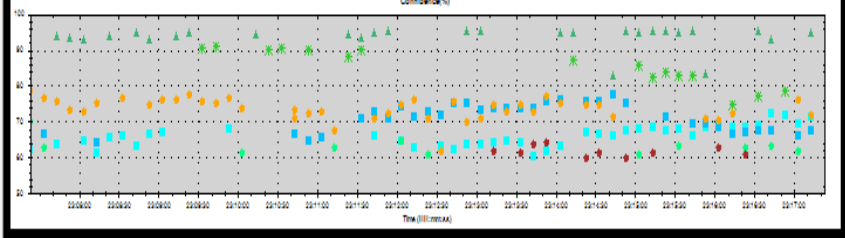
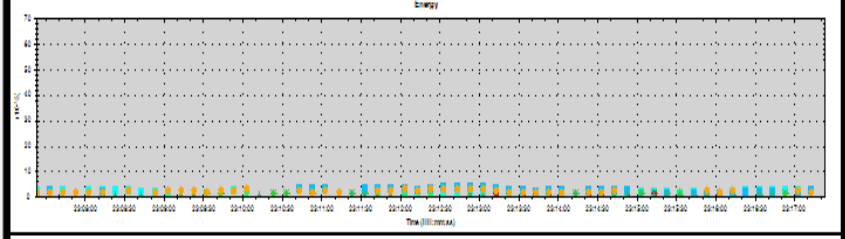
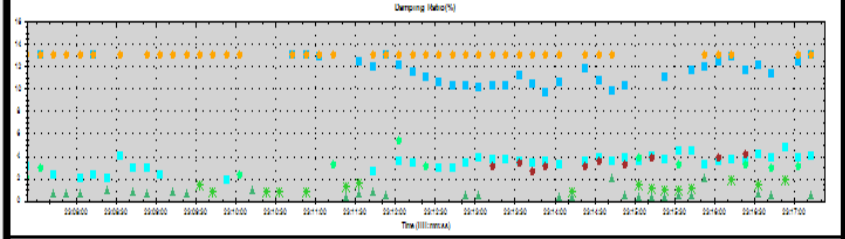
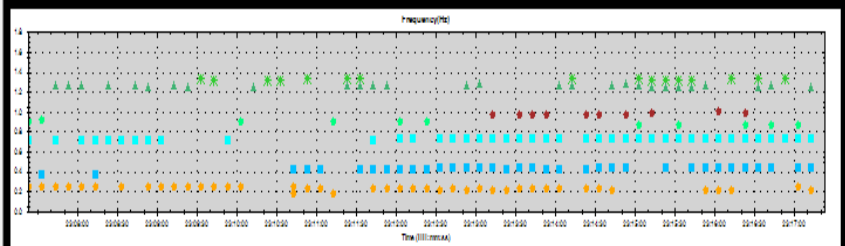
Monday, March 13, 2017 23:16:13 ~ 23:17:13

Frequency(Hz)	Damping Ratio(%)	Confidence(%)	Energy
Damping Analysis Engine			
0.21	13.00	71.66	2,153.26
0.44	13.00	67.74	2,504.86
0.73	3.98	71.48	2,564.71
1.25	0.49	95.01	1,318.12

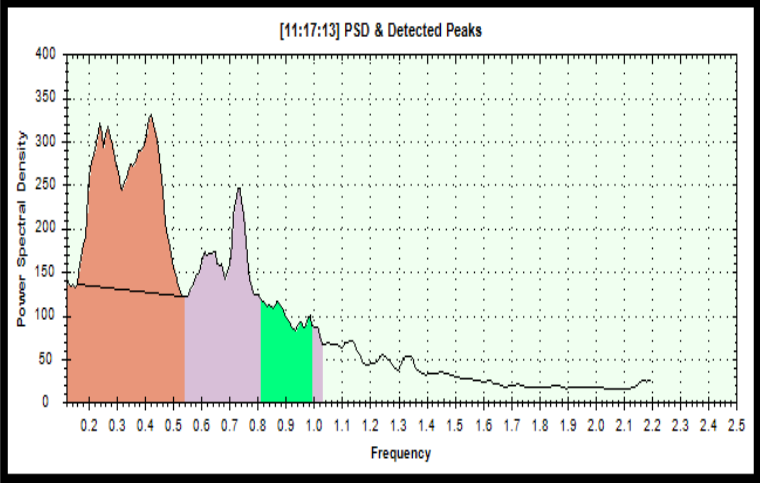
Frequency Last Time

Damping Analysis Engine

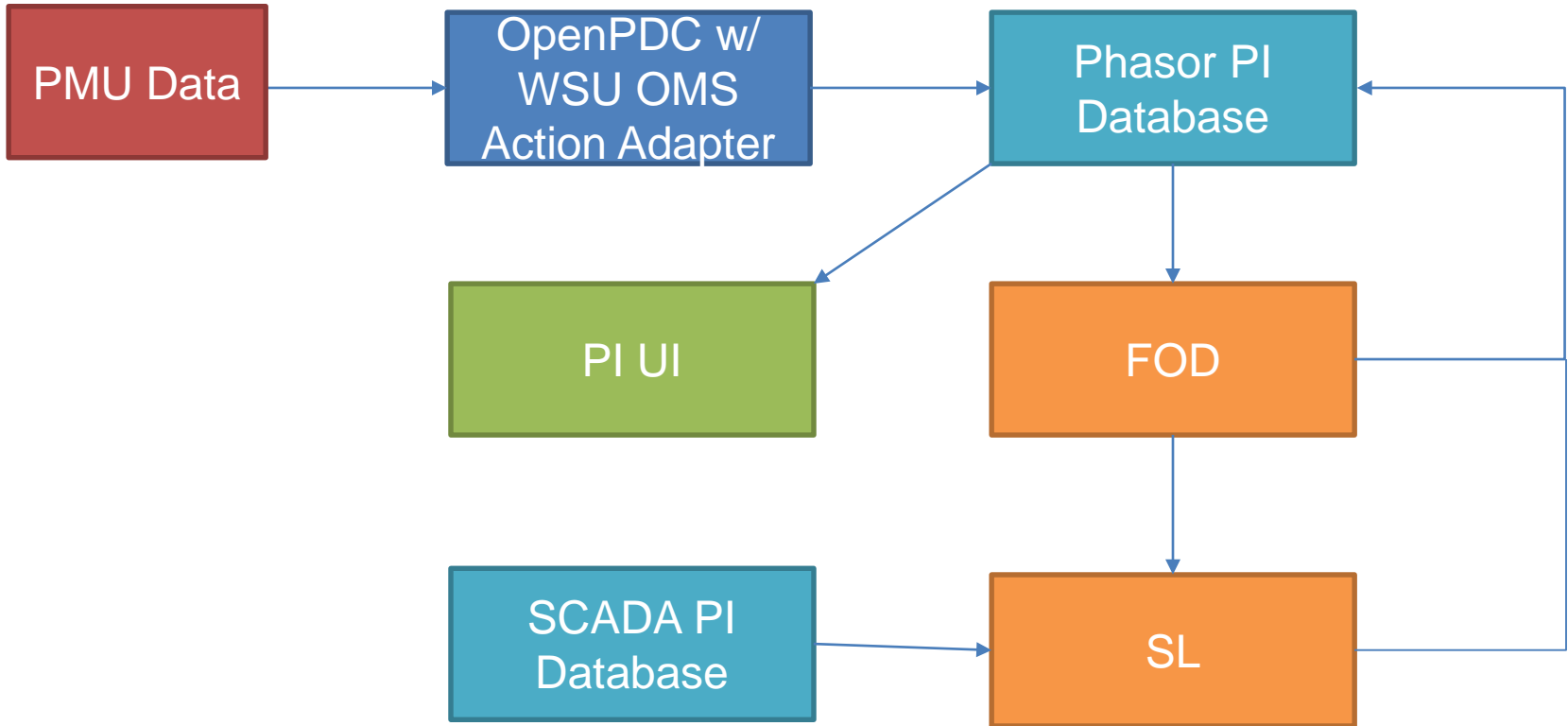
<input checked="" type="checkbox"/> 1.33	23:16:53
<input checked="" type="checkbox"/> 1.26	23:17:13
<input checked="" type="checkbox"/> 0.99	23:16:23
<input checked="" type="checkbox"/> 0.88	23:17:03
<input checked="" type="checkbox"/> 0.74	23:17:13
<input checked="" type="checkbox"/> 0.44	23:17:13
<input checked="" type="checkbox"/> 0.23	23:17:13



- Tag
- W068INTMTN
 - W001MARION
 - W106GENESE
 - W106SUNNYBRI
 - W001OSTRND
 - W106SUNNYBRI
 - W001PEARL
 - W106SUNNYBRI
 - W001MARION
 - W001BIG_EDDY
 - W001BIG_EDDY
 - W001JOHN_DAY
 - W001JOHN_DAY



RT-FODSL Data Flow



Forced Oscillation Detection

- Post-processing of FFDD estimates
- Runs every 1 minute
- Builds 5 minutes buffer (of OMS results)
- Group them by oscillation frequency
- Crosscheck rules:
 - Persistent? High energy?
 - Low damping?
 - High estimation confidence?

Oscillation Source Location

- Triggered by FOD
- Inputs are oscillation start and end times
- Retrieve all generator MW and MVAR SCADA data
- Two algorithms are used to analyze:
 - PMA* (Pattern Mining Algorithm)
 - MVRA* (Maximal Variance Ratio Algorithm)

*J. O'Brien, T. Wu, V. Venkatasubramanian, H. Zhang, Source Location of Forced Oscillations "Using Synchrophasor and SCADA Data", Proceedings of the 50th Hawaii International Conference on System Sciences, 2017

Pattern Mining Algorithm

- Calculate the ranking index K_{PMA} based on the number of the **high-amplitude** peaks in the raw measurements for each channel
- Select Top 5 channels according to the ranking index

Maximal Variance Ratio Algorithm

- Two key factors are considered when calculating the ranking index K_{MVRA}
 - Number of times the data values cross their mean value within the oscillation window, which indicates how much the data is showing sustained oscillations.
 - Average of standard deviations from multiple moving windows of the SCADA signal, which is a measure of the oscillation amplitude.

FODSL User Interface

- A GIS based overview to present:
 - Forced Oscillation Detector
 - Start/end time, oscillation frequency, damping ratio, oscillation energy, confidence level
 - Average normalized mode shape, length = magnitude, east = 0 degree angle
 - Oscillation Source Locator
 - PMA result (red), MVRA result (white)
 - Area = ranking index

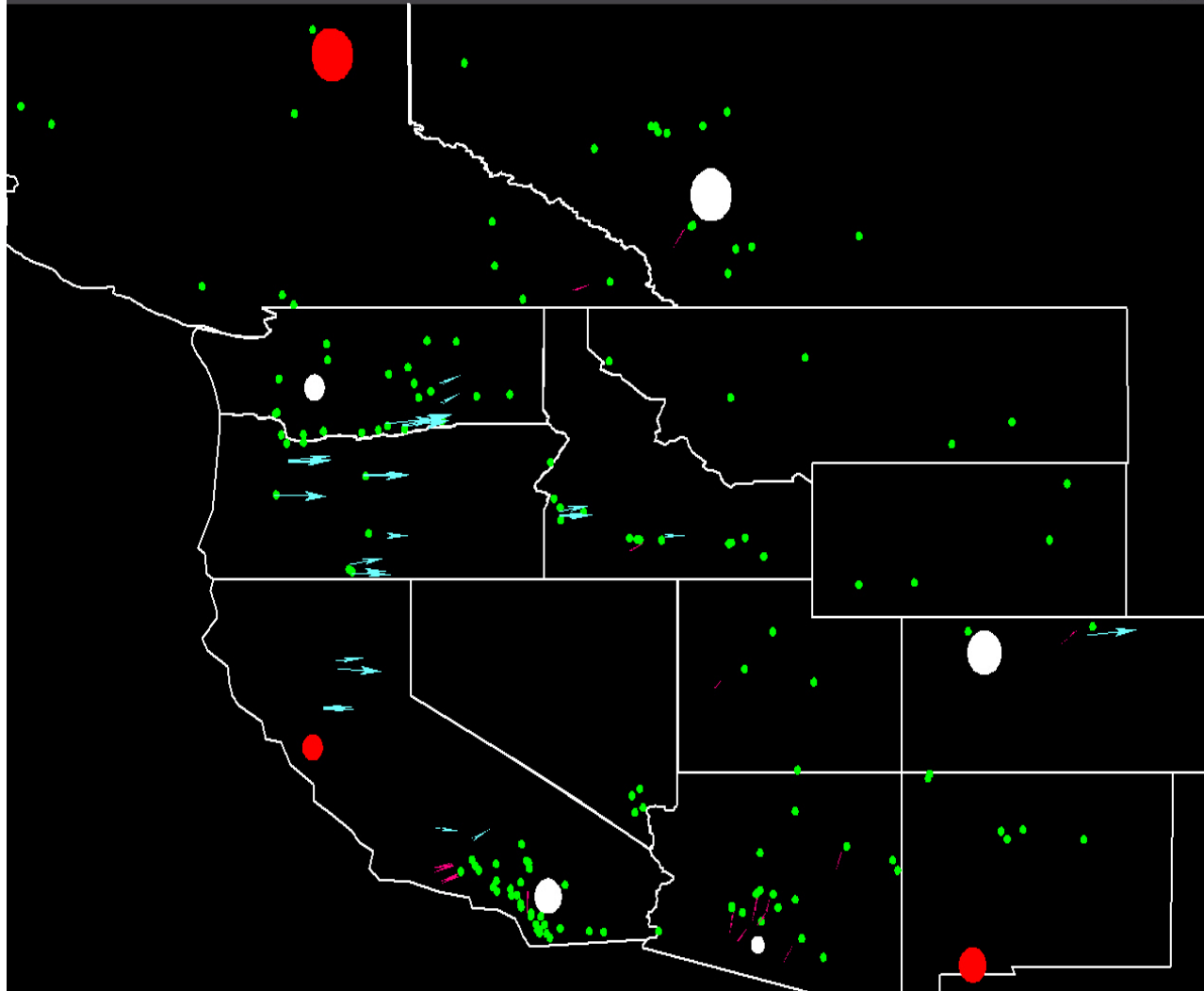
FODSL User Interface (Initial Design)

OSCILLATION DETECTION SUMMARY

Display time: 3/9/2017 2:09:16 PM

CLOSE

- PMUs
- Generator (MVRA)
- Generator (PMA)



Start Time 3/9/2017 2:09:16 PM
End Time 3/9/2017 2:38:06 PM
Frequency 1.66
Energy 1682.46
Confidence Level 95.20
Damping Ratio 0.077

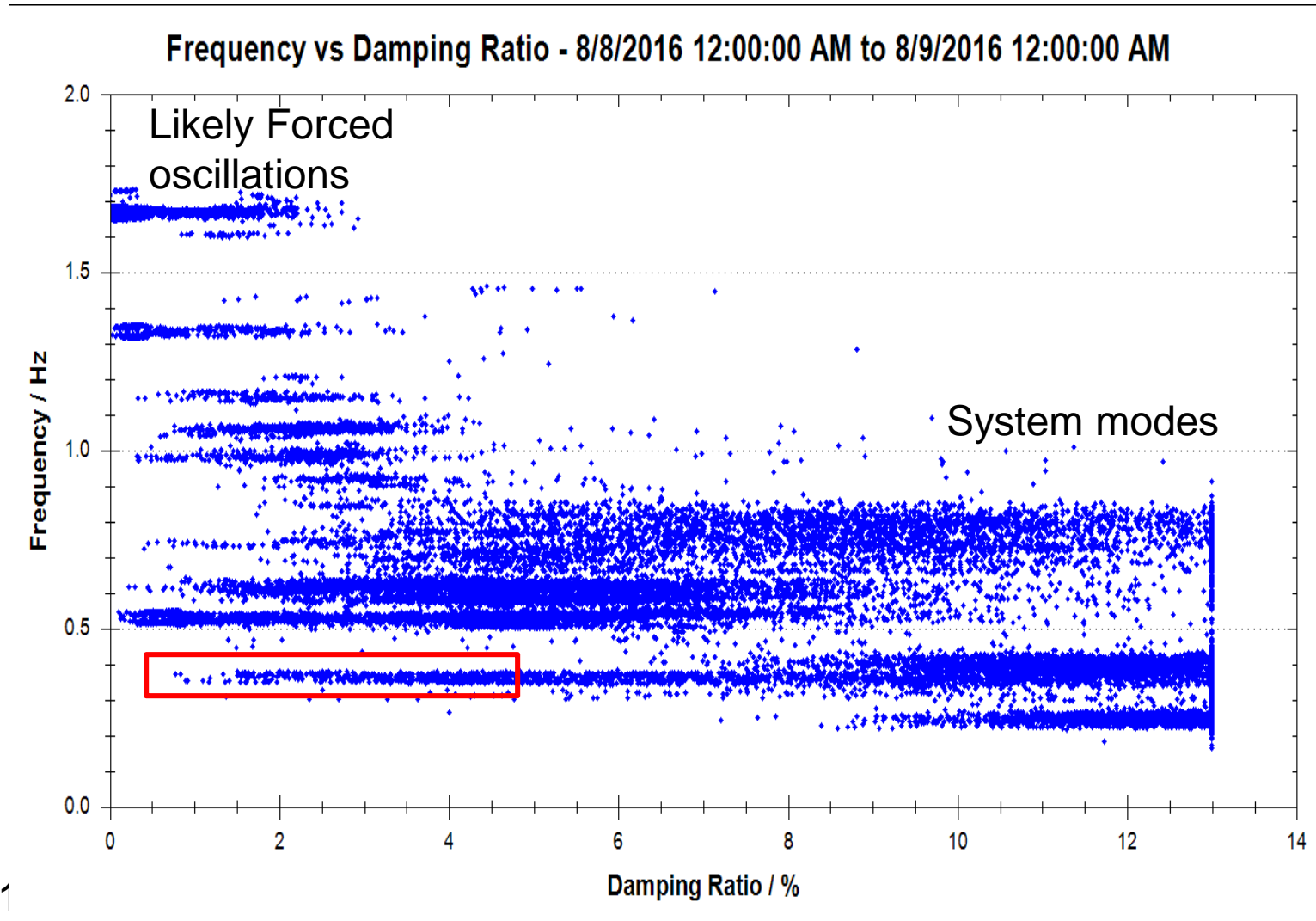
Start Time
End Time
Frequency
Energy
Confidence Level
Damping Ratio

Start Time
End Time
Frequency
Energy
Confidence Level
Damping Ratio

Start Time
End Time
Frequency
Energy
Confidence Level
Damping Ratio

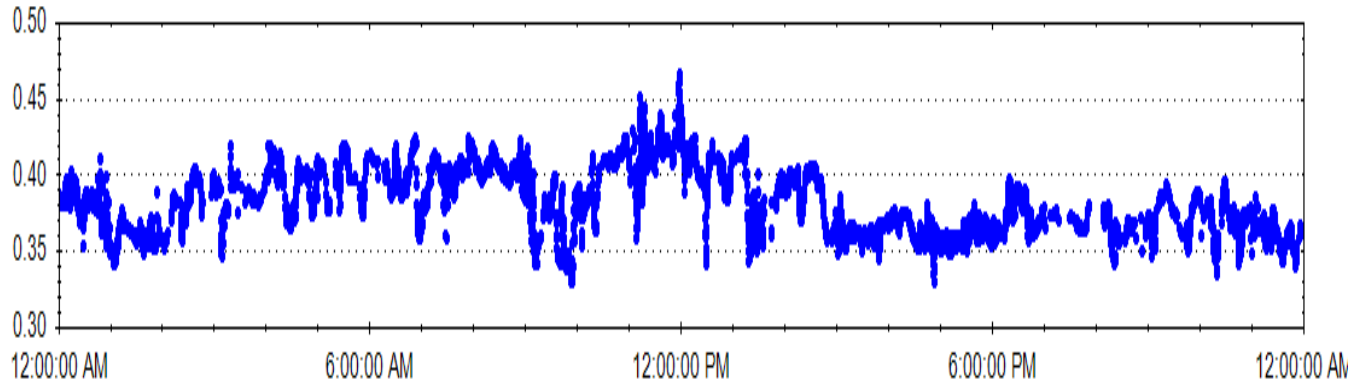
For illustration purpose only

Use Case



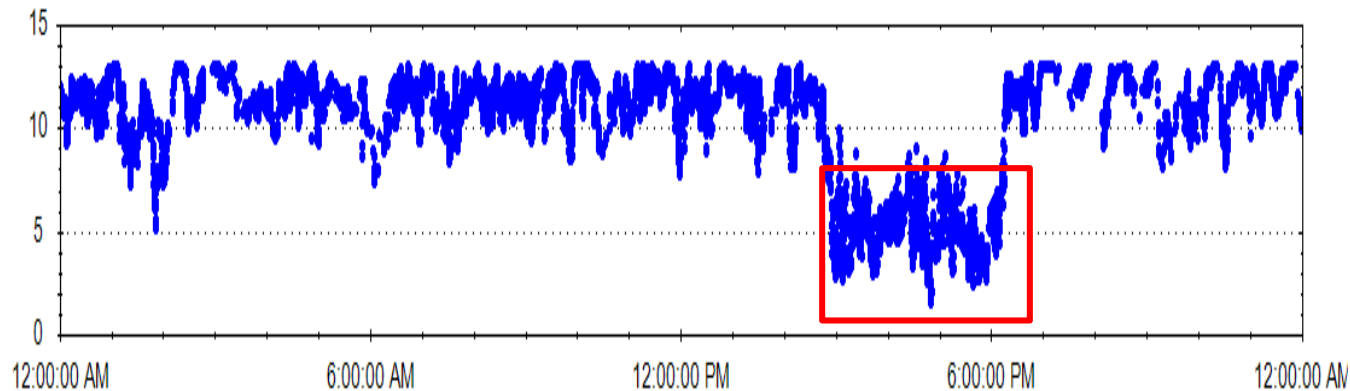
Use Case

Frequency / Hz - 8/8/2016 12:00:00 AM to 8/9/2016 12:00:00 AM Mean: 0.3801, STD: 0.0215



Freq of N-S mode is around 0.4 Hz.
Damping ratio for N-S mode is normally above 10%.

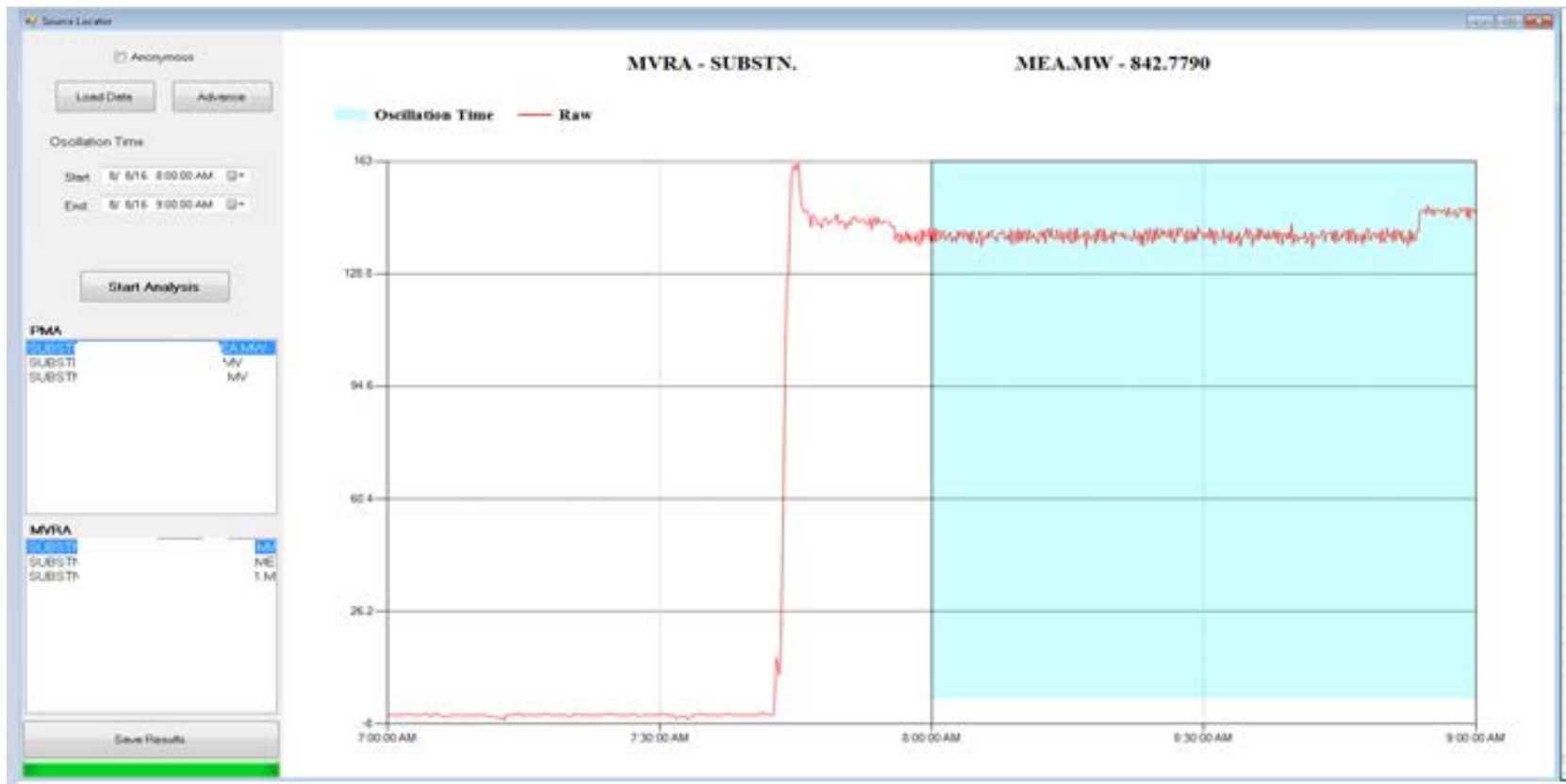
Damping Ratio / % - 8/8/2016 12:00:00 AM to 8/9/2016 12:00:00 AM Mean: 10.1481, STD: 2.7364



Likely there is a forced oscillation at near 0.4 Hz that “drags” the estimate of the damping ratio down.

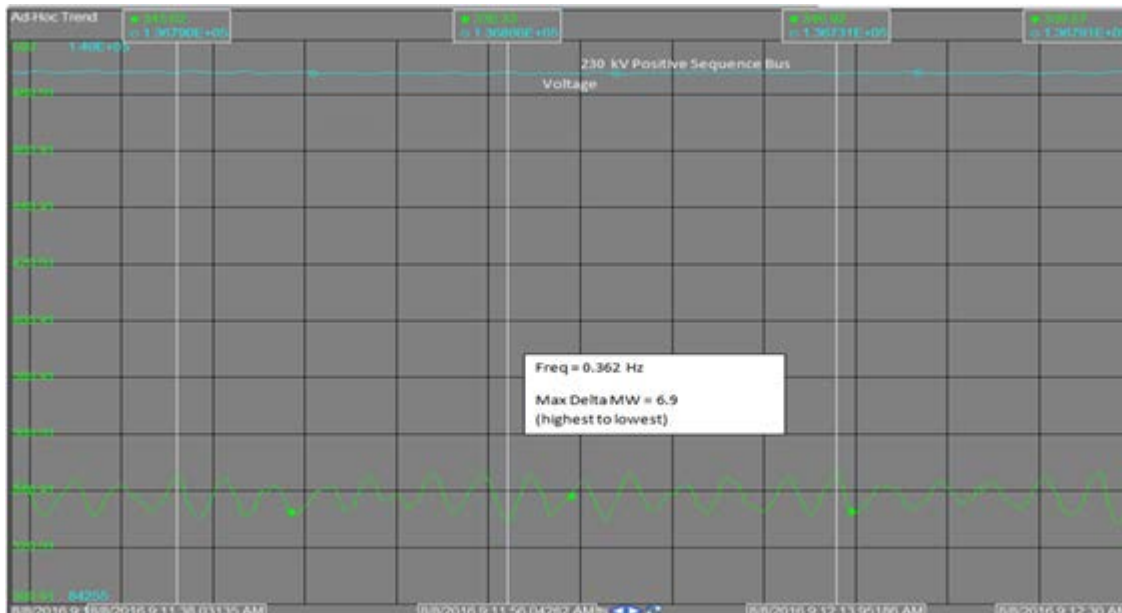
Use Case

SCADA based MVRA pointed to a hydro generator.



Use Case


This entity was contacted to confirm this event. The generator was operating in the rough zone during that time period.



Ongoing Efforts

- Test/tune parameters for PMA and MVRA and add new and more advanced algorithm for SCADA oscillation source location
- Collaborate with entities for results validation
- Including FSSI for resonance analysis of forced oscillation and system mode
- Adding playback features in UI
- PMU data and SCADA data trend plots
- Operation Staff Training





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