

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

NASPI Work Group Meeting

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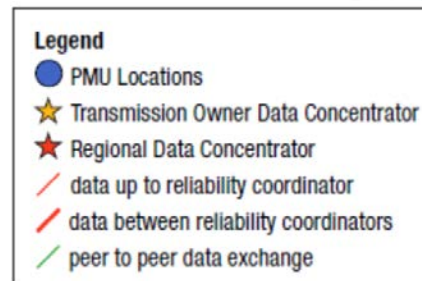


PEAKRELIABILITY
assuring the wide area view

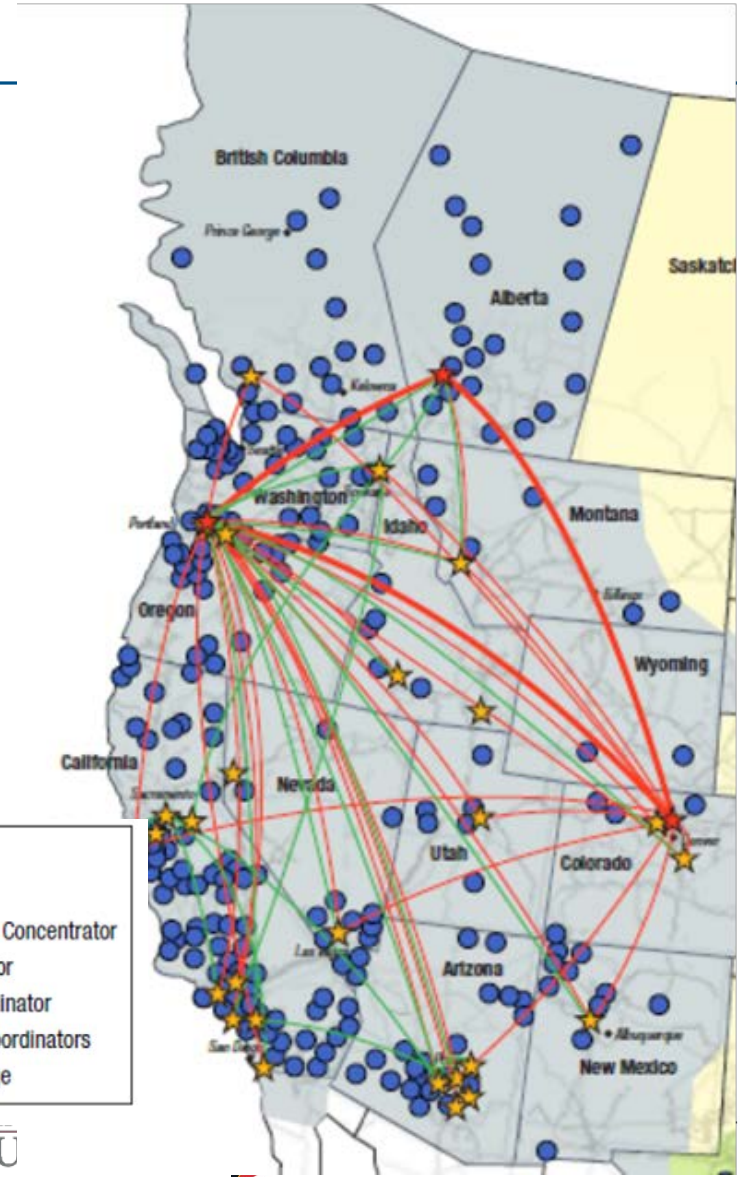
Peak Reliability (formerly WECC RC) Synchrophasor Effort

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)

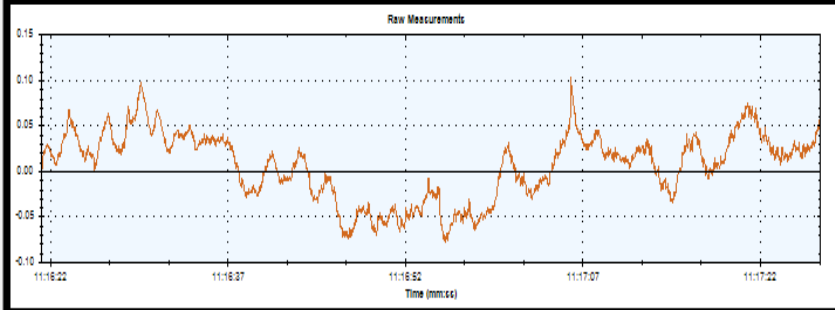
WSU Online Oscillation Monitoring System

- 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

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

- 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

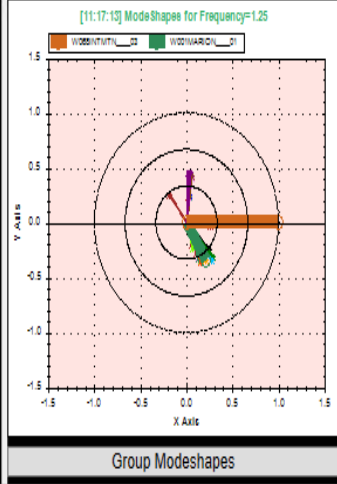
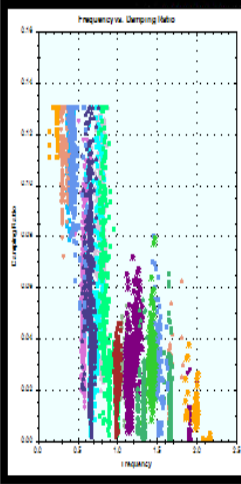
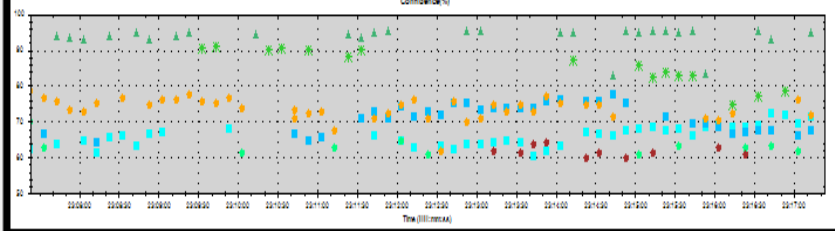
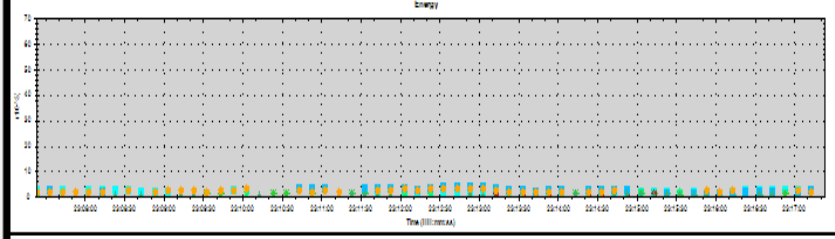
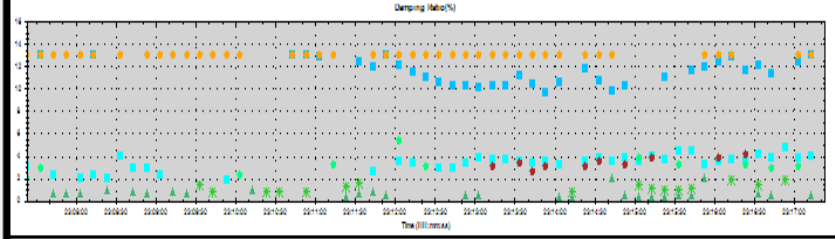
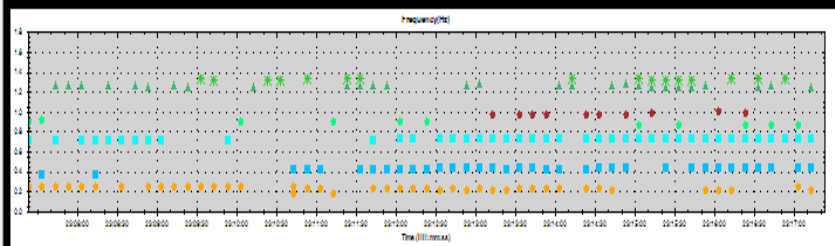


Frequency(Hz)	Damping Ratio(%)	Confidence(%)	Energy
Damping Analysis Engine			
0.21	13.00	71.66	2,153.26
0.44	13.00	67.74	2,504.86
0.73	3.98	71.48	2,564.71
1.25	0.49	95.01	1,318.12

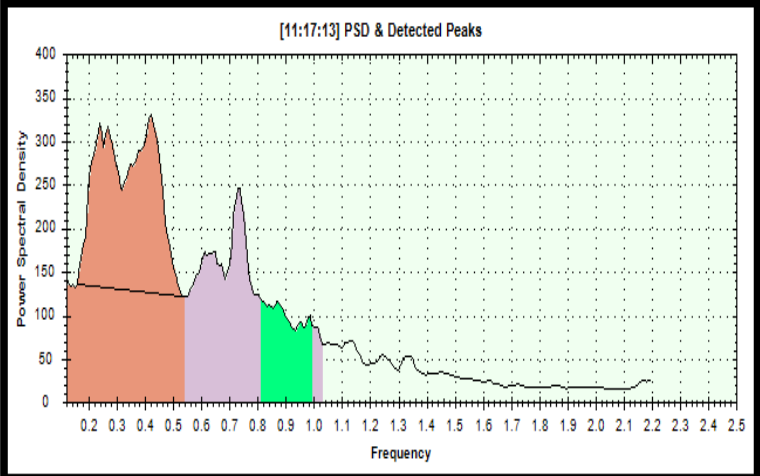
Frequency Last Time

Damping Analysis Engine

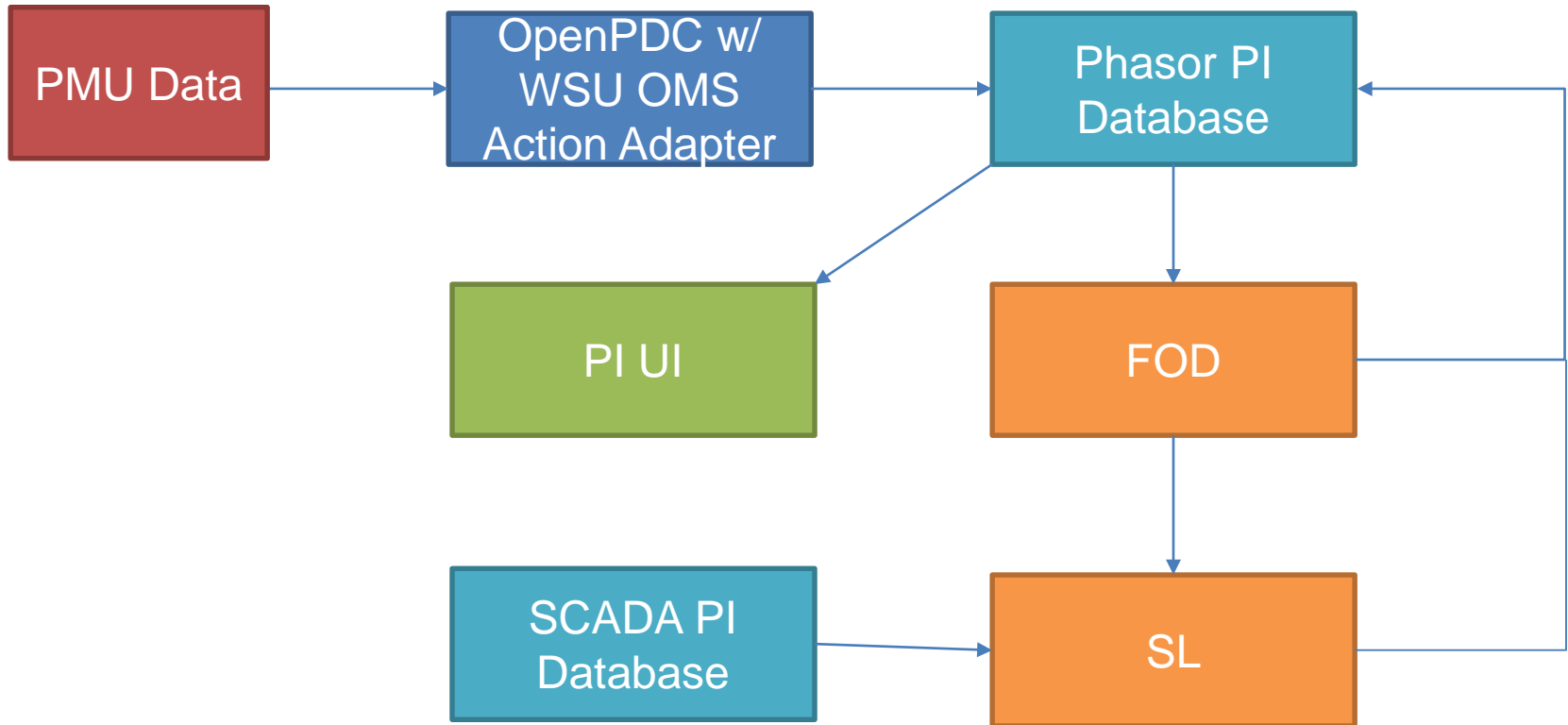
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<input checked="" type="checkbox"/> 1.26	23:17:13
<input checked="" type="checkbox"/> 0.99	23:16:23
<input checked="" type="checkbox"/> 0.88	23:17:03
<input checked="" type="checkbox"/> 0.74	23:17:13
<input checked="" type="checkbox"/> 0.44	23:17:13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

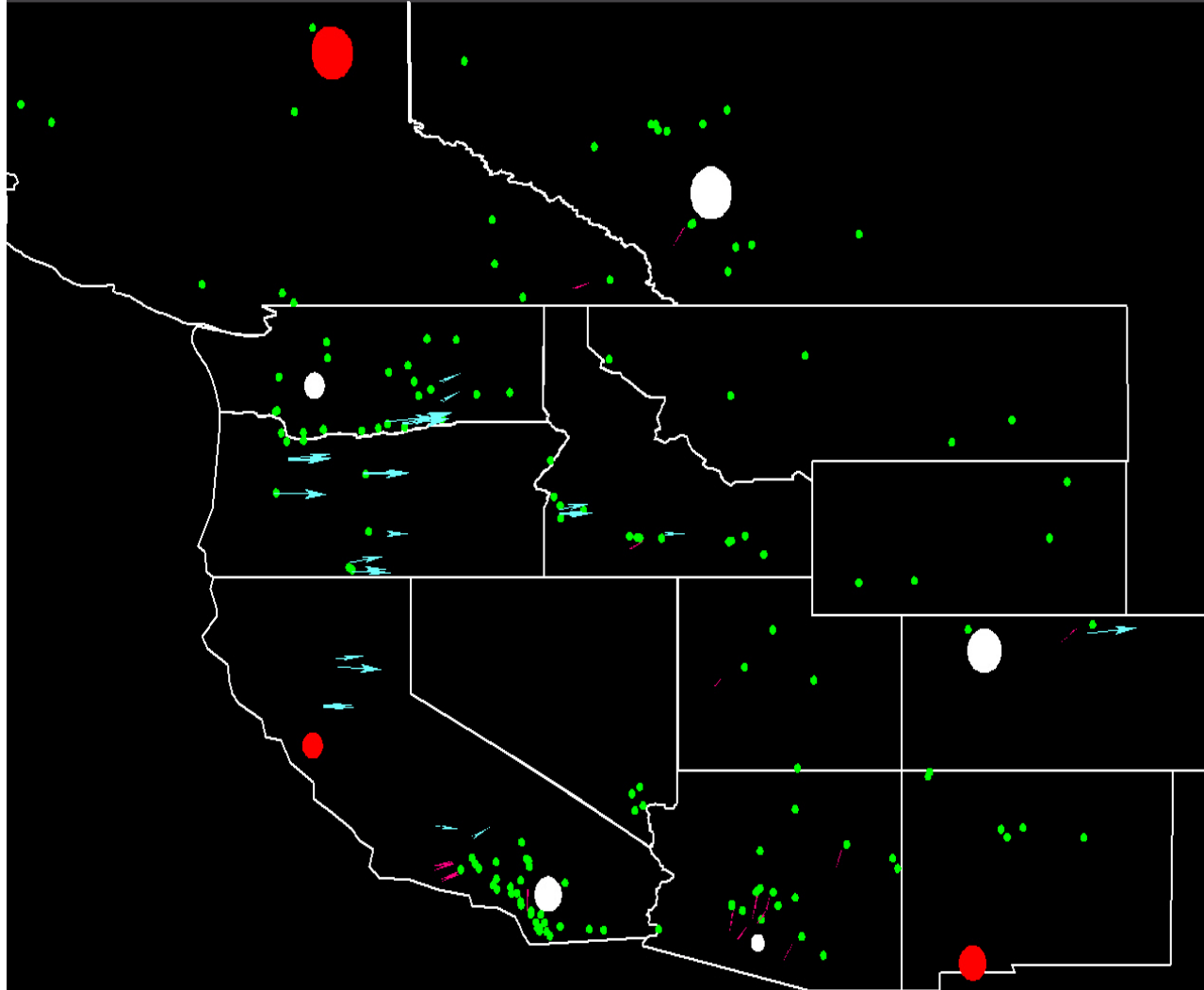
FODSL User Interface (Initial Design)

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

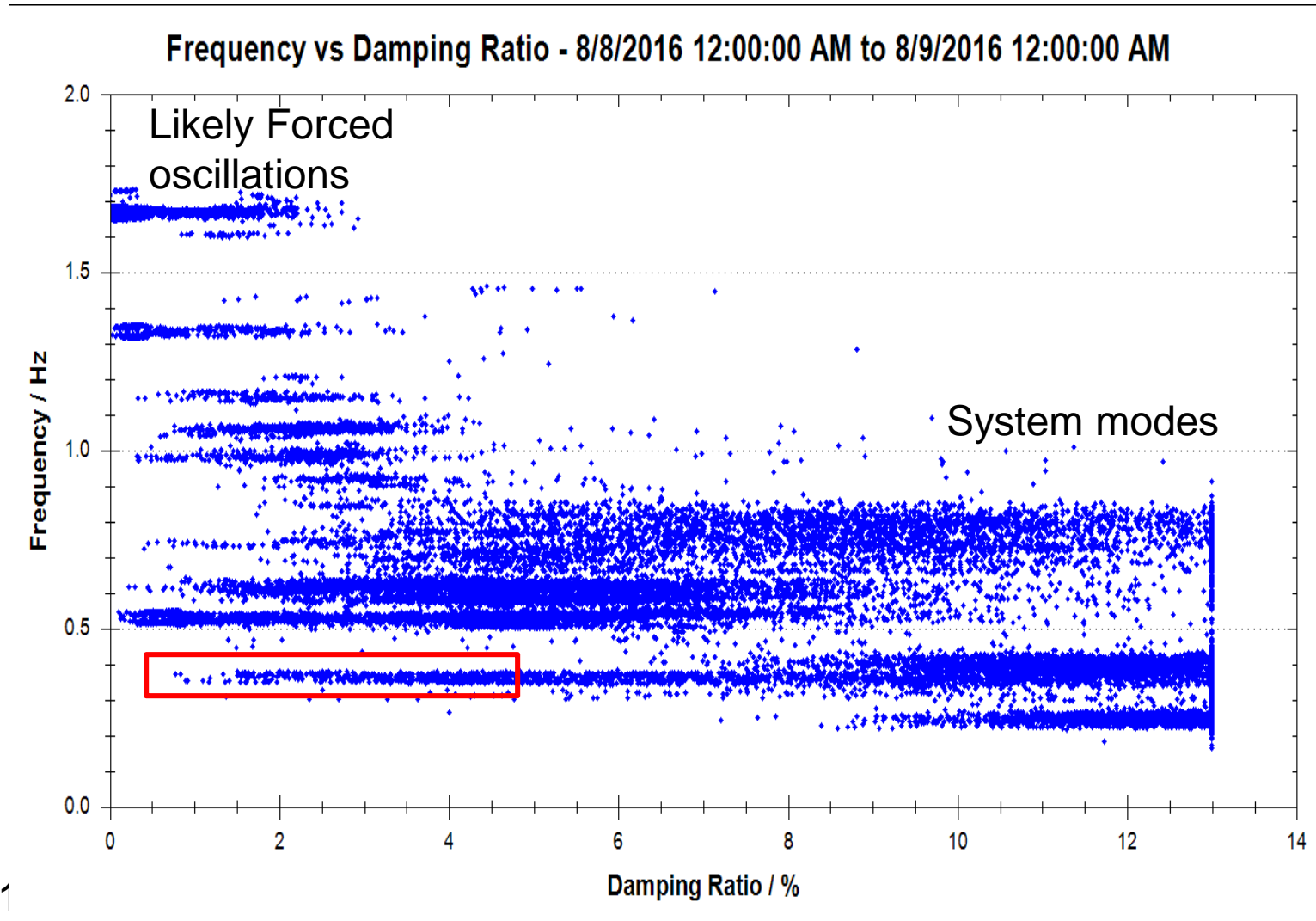
Start Time
End Time
Frequency
Energy
Confidence Level
Damping Ratio

Start Time
End Time
Frequency
Energy
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End Time
Frequency
Energy
Confidence Level
Damping Ratio

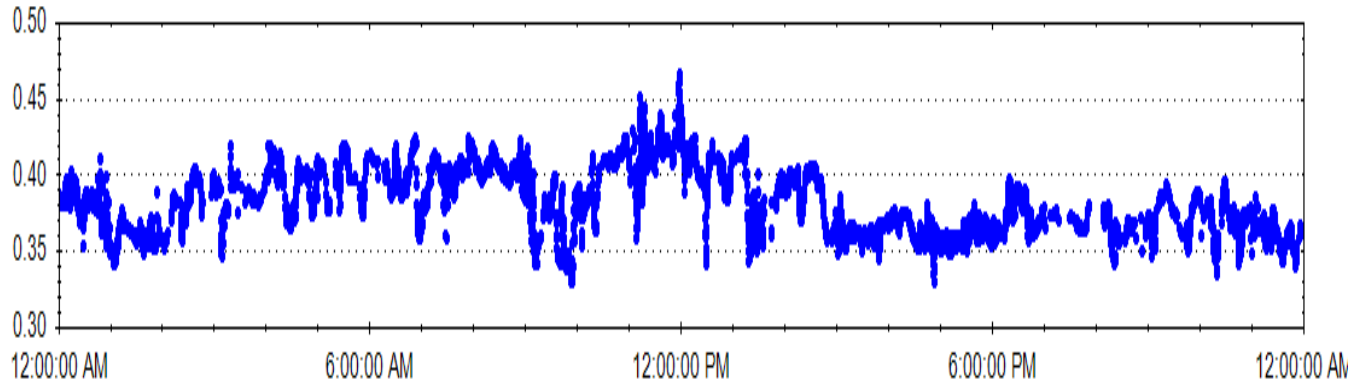
For illustration purpose only

Use Case



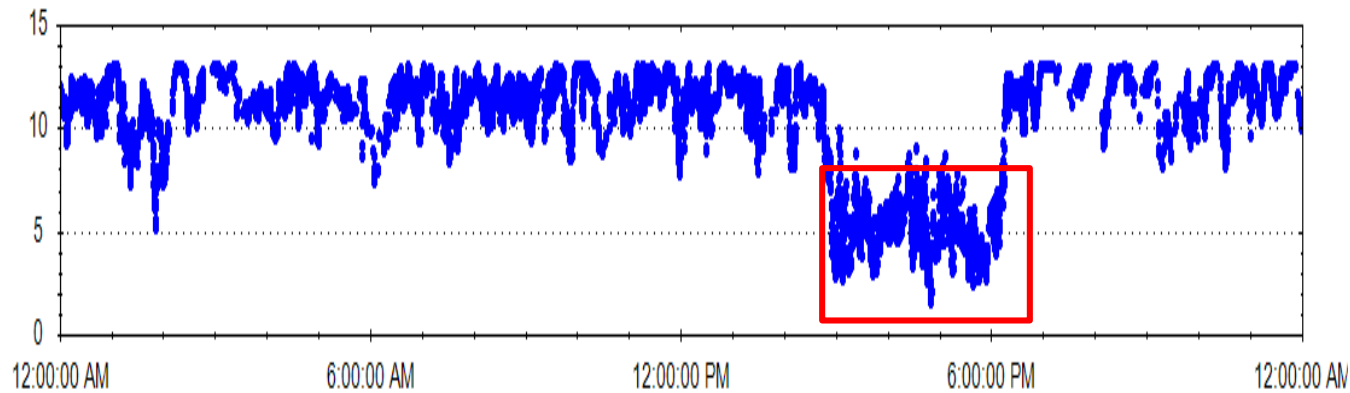
Use Case

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%.

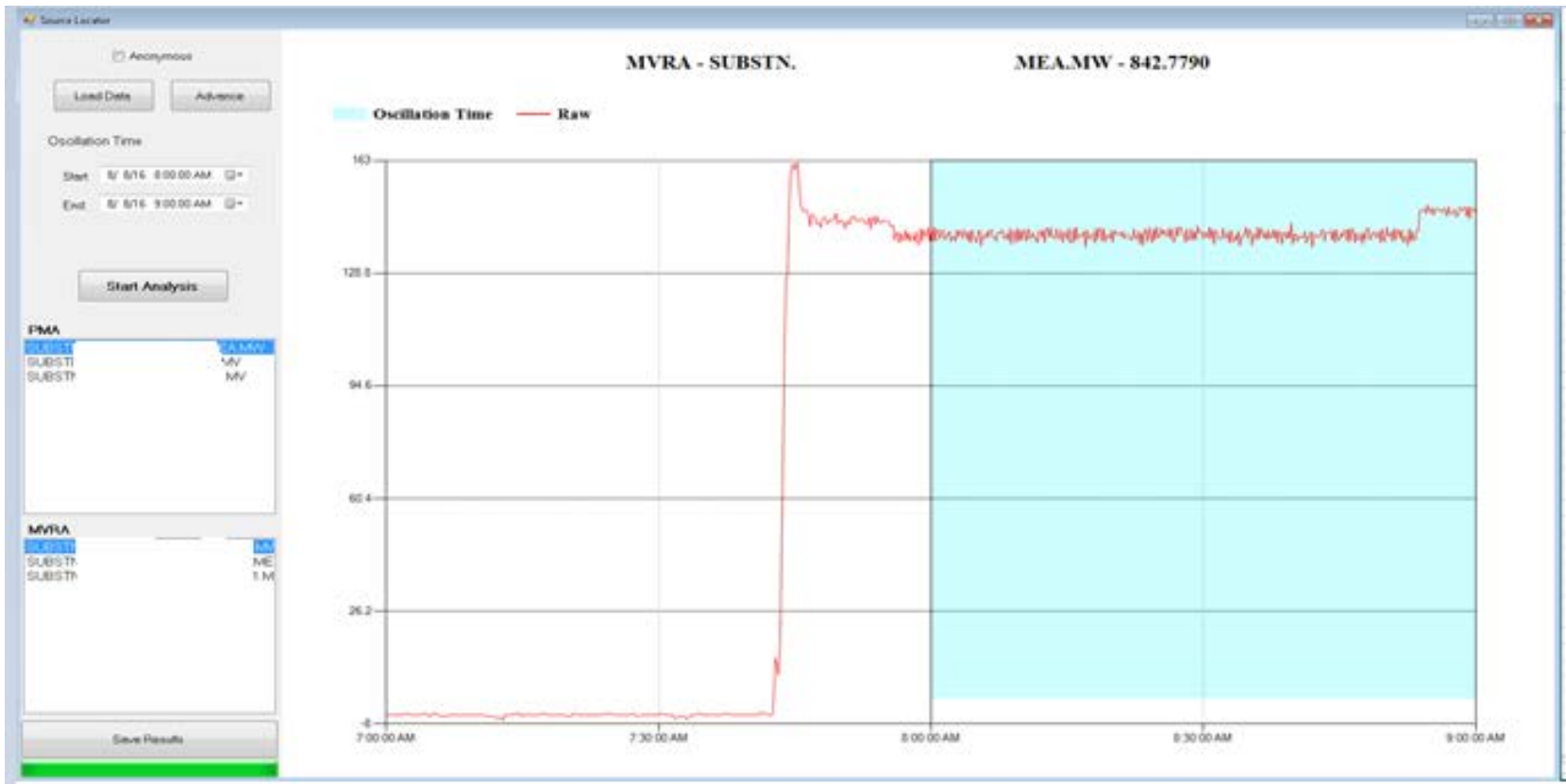
Damping Ratio / % - 8/8/2016 12:00:00 AM to 8/9/2016 12:00:00 AM Mean: 10.1481, STD: 2.7364



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

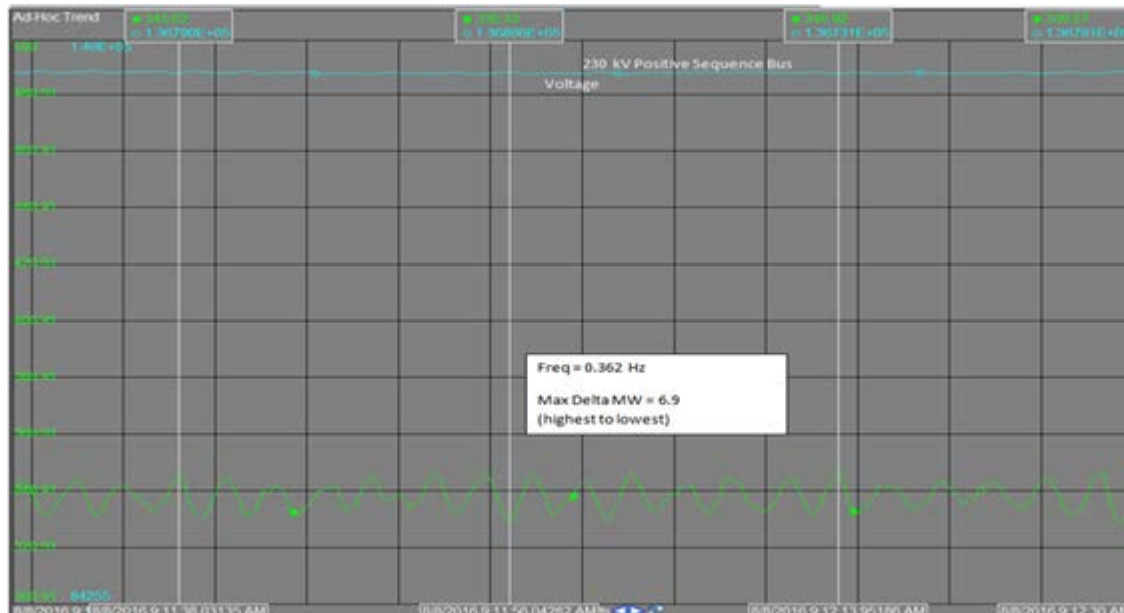
Use Case

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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