

Implementation and Operating Experience with Oscillation Detection at Bonneville Power Administration

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Outline

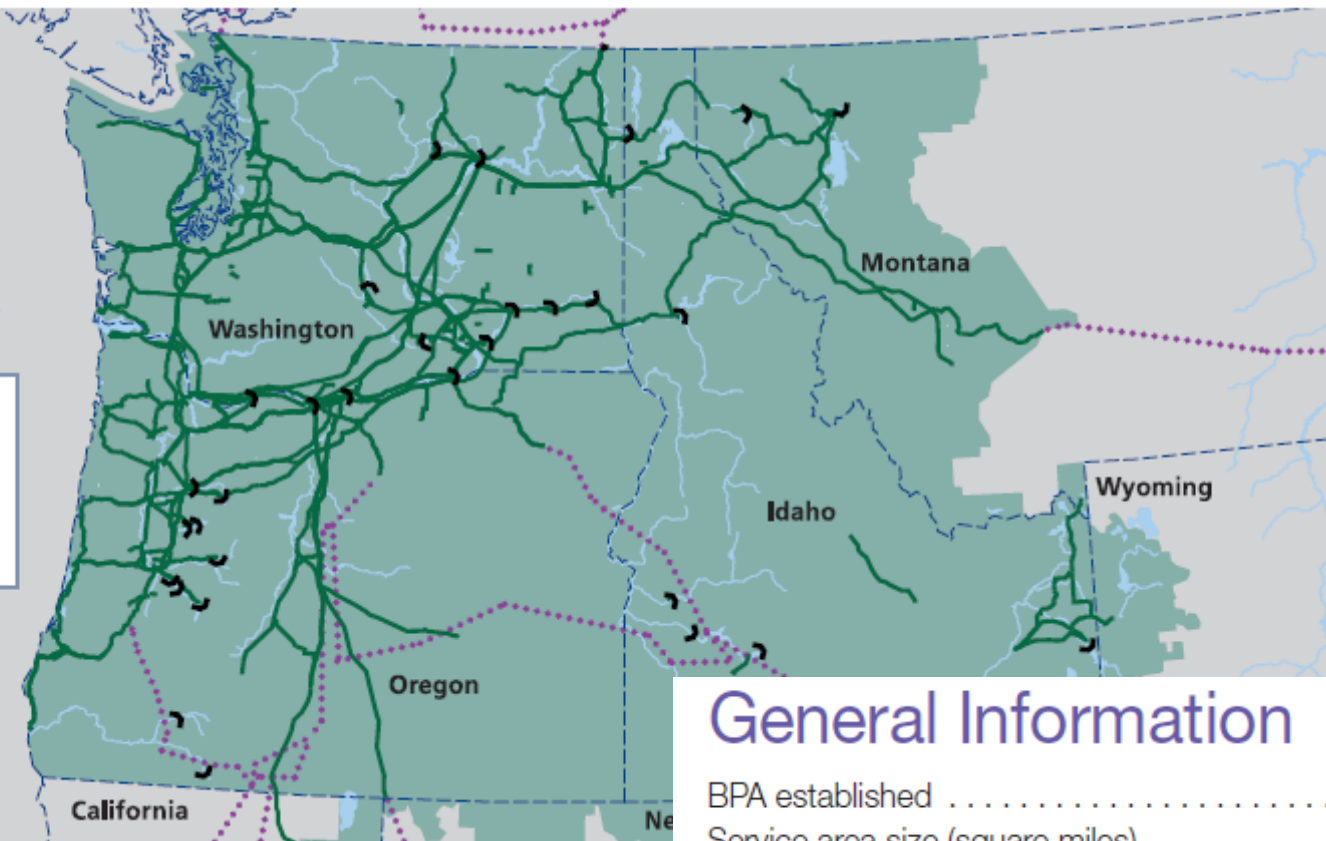
- BPA Synchrophasor Project
- BPA's Oscillation Detection Application
 - Analytics
 - Implementation at BPA
- Oscillation Events

Bonneville Power Administration

Transmission System and Federal Dams

LEGEND

-  BPA Transmission Line
-  Federal Dam
-  Non-BPA Line
-  BPA Service Area



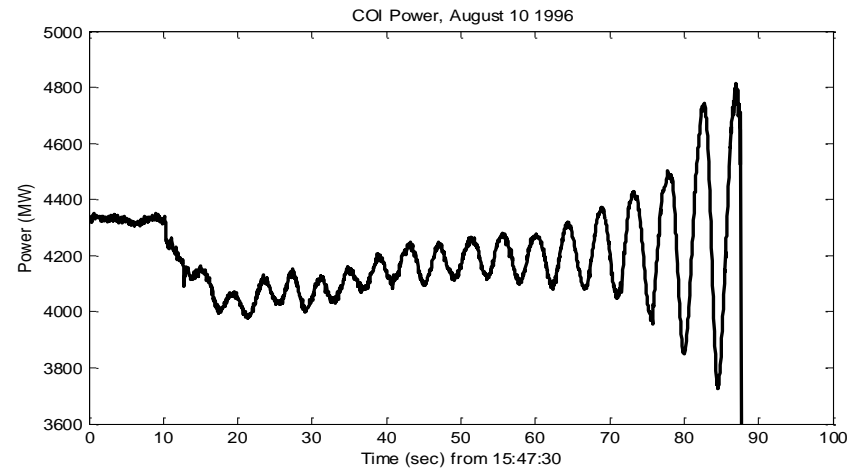
General Information

BPA established	1937
Service area size (square miles)	300,000
Pacific Northwest population	13,278,218
Transmission line (circuit miles)	15,212
BPA substations	261
Employees (FTE)	3,100 ^{1/}

^{1/} FTE for fiscal year 2016 from the FY 2017 Congressional Budget.

History of Synchrophasors at BPA

- BPA has been one of the earliest adopters of synchrophasor technology since early 1990s
- BPA has greatly expanded PMU coverage and networking following 1996 outages
- BPA researched, prototyped and deployed several PMU applications for engineering analysis
- However, that PMU network was research-grade and was not reliable or secure for real-time control room applications.



2010 Synchrophasor Investment Project

- BPA initiated a capital investment project in 2010 to build a secure, reliable, control grade synchrophasor network:
 - 5-year, \$35M project
 - Part of DOE Smart Grid Program
- “Control” PMUs
 - 32 substations
 - 110 PMUs (55 redundant pairs)
- “Data” PMUs
 - 15 wind sites
- Total of 3,322 signals

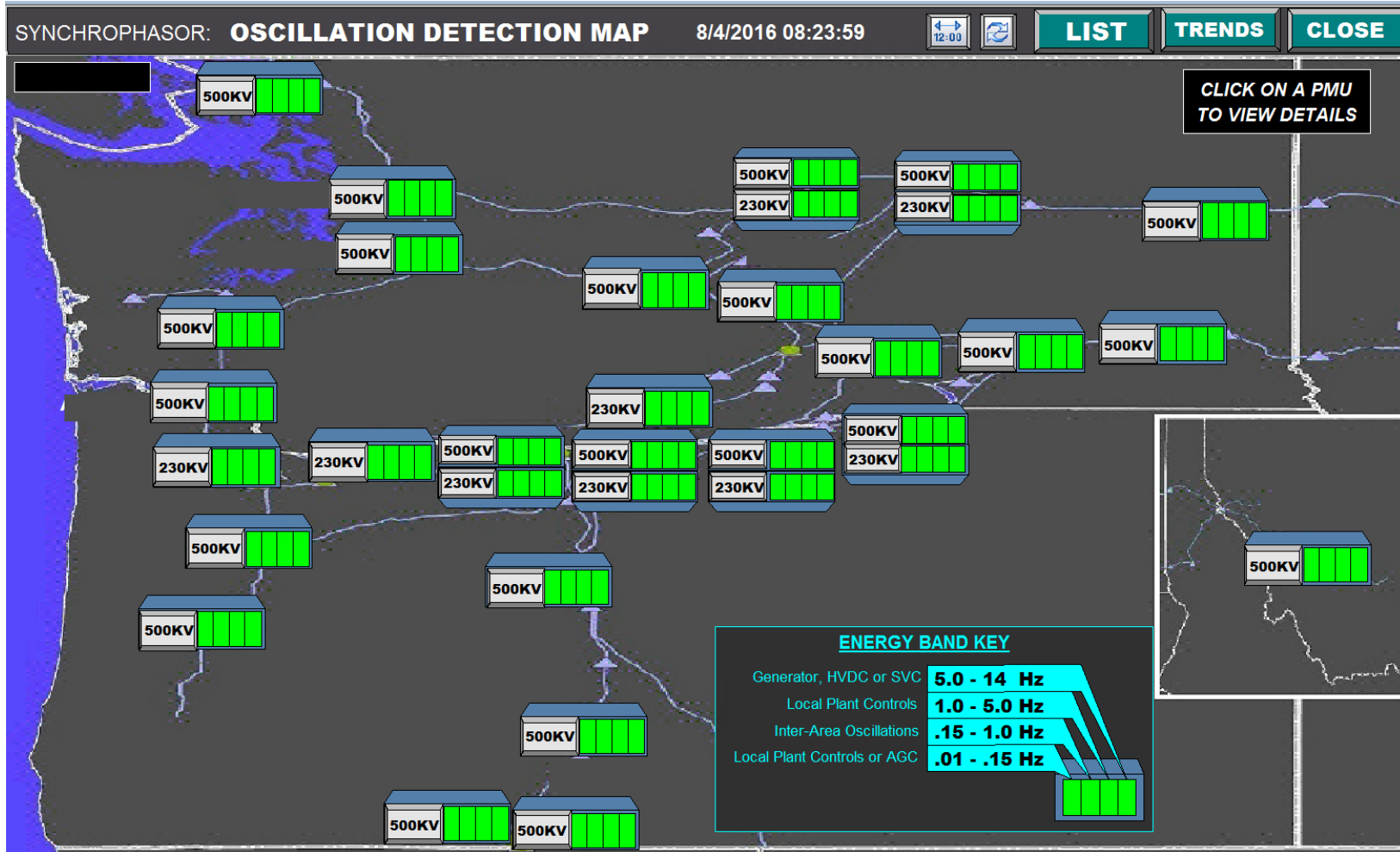


Platt's Global Energy Award

- BPA synchrophasor investment project received 2013 Platt's Global Energy Award for Industry Leadership in Grid Optimization



Oscillation Detection Monitor

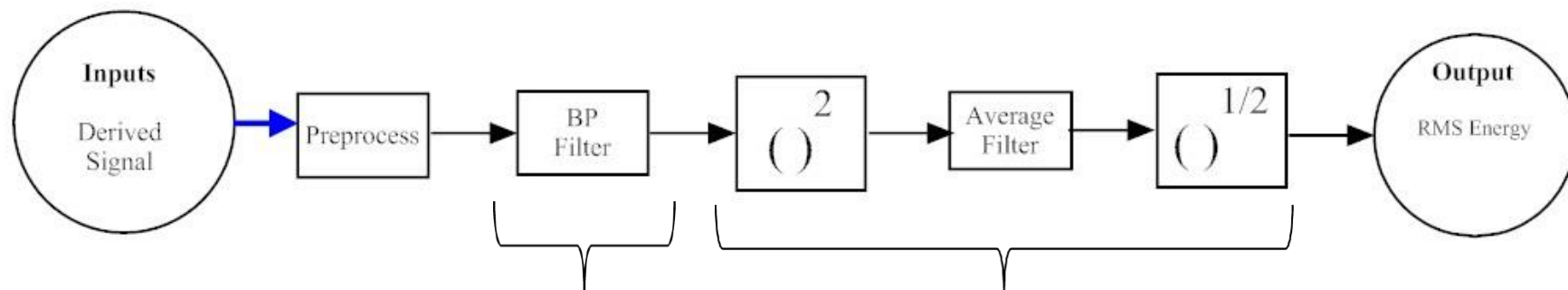


How are the Oscillation Magnitudes Calculated?

For each of the 4 bands, an estimate of the RMS value is calculated

PMU
Measurements

Oscillation
Magnitude

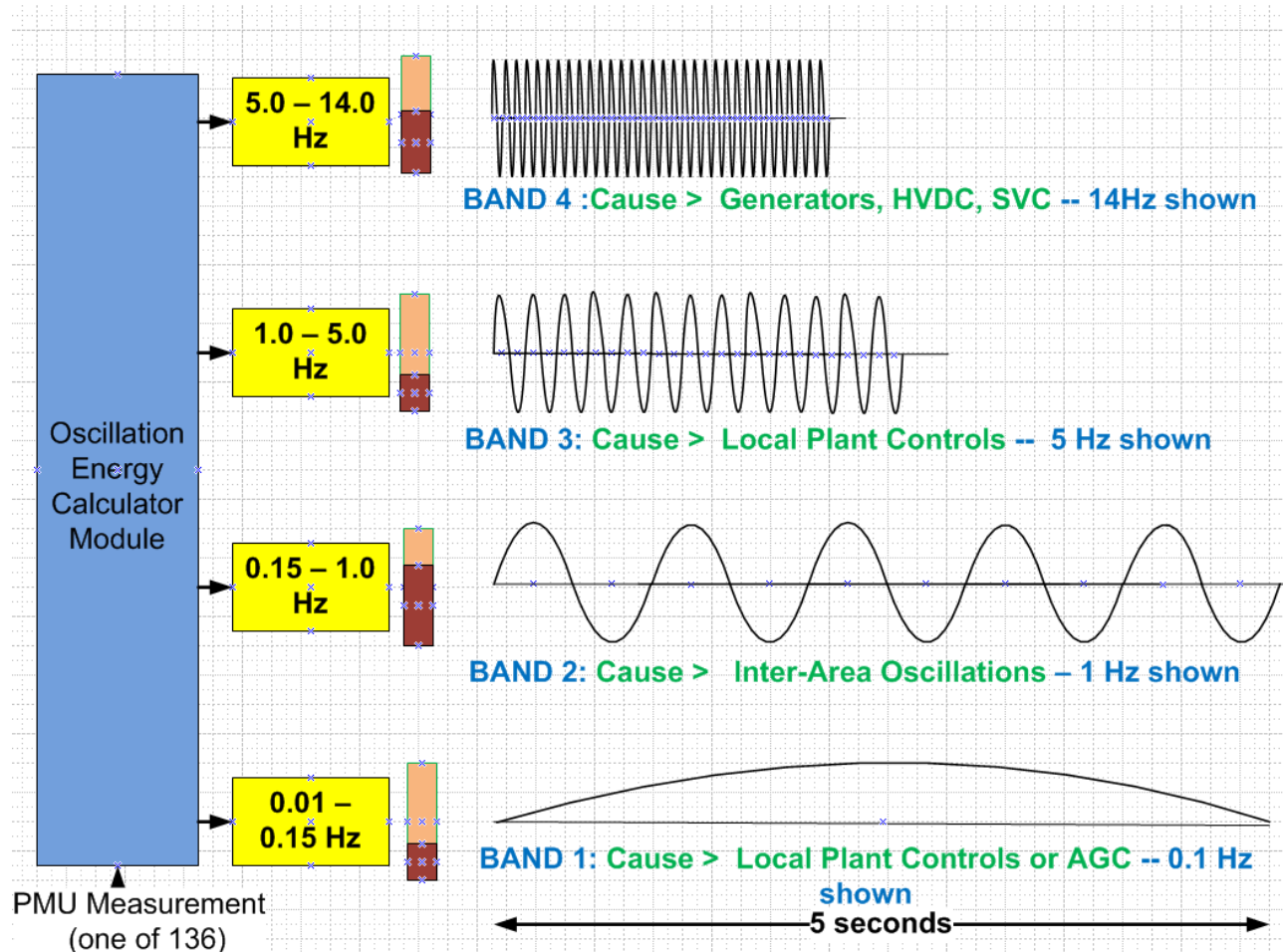


Restrict the signal
to the particular
frequency band

Calculate the
RMS Value
of the Oscillation

How are oscillations detected?

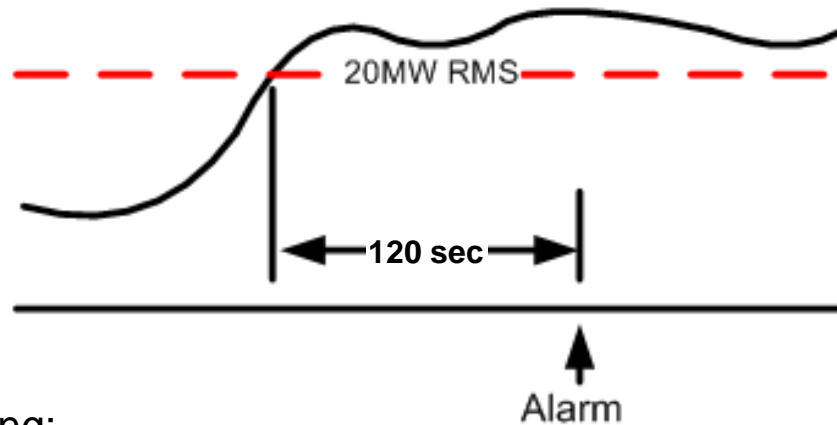
The magnitude of the oscillation is calculated in 4 frequency bands



How are oscillations detected?

Step 2

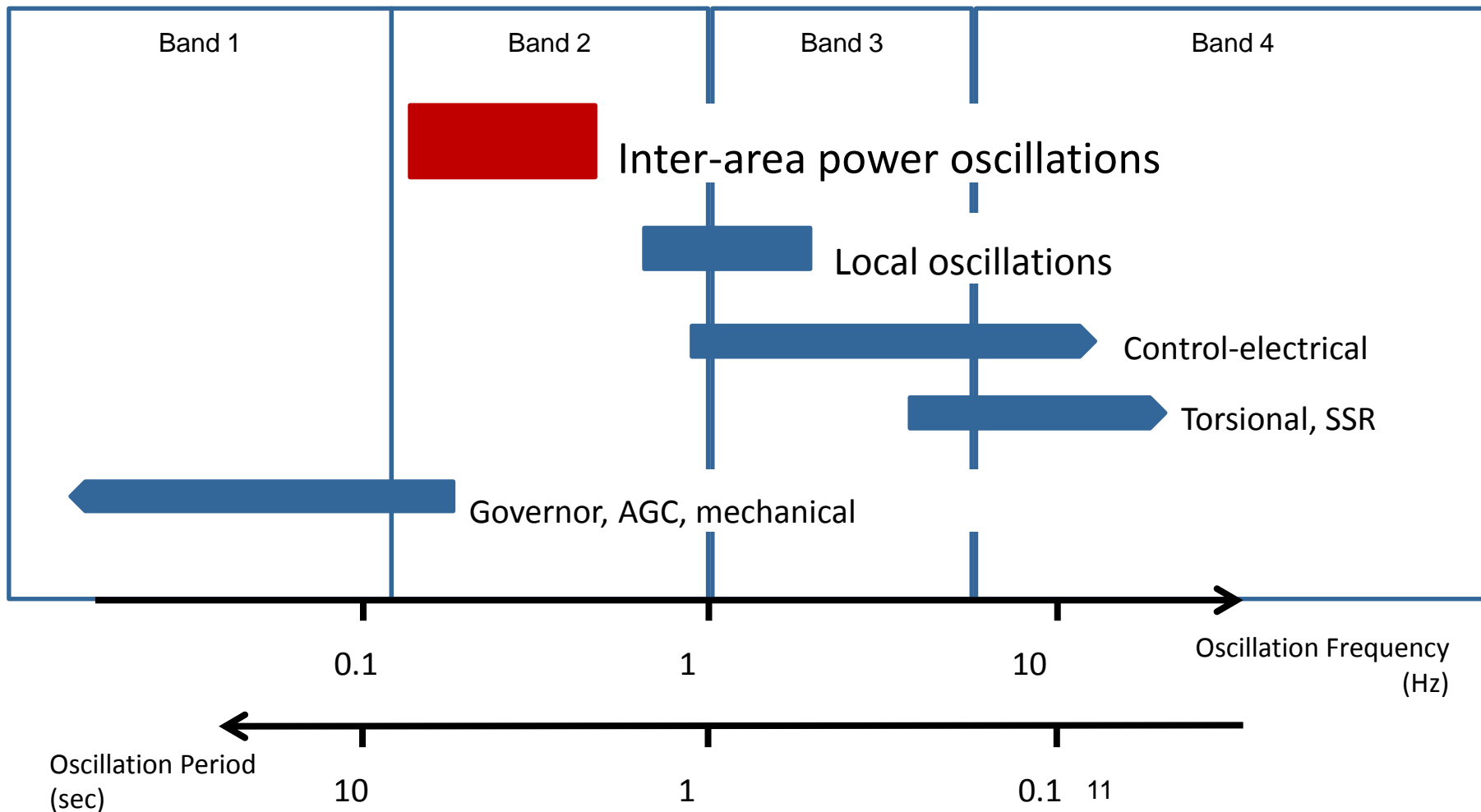
If the oscillation is strong enough, and lasts long enough then an alarm is issued



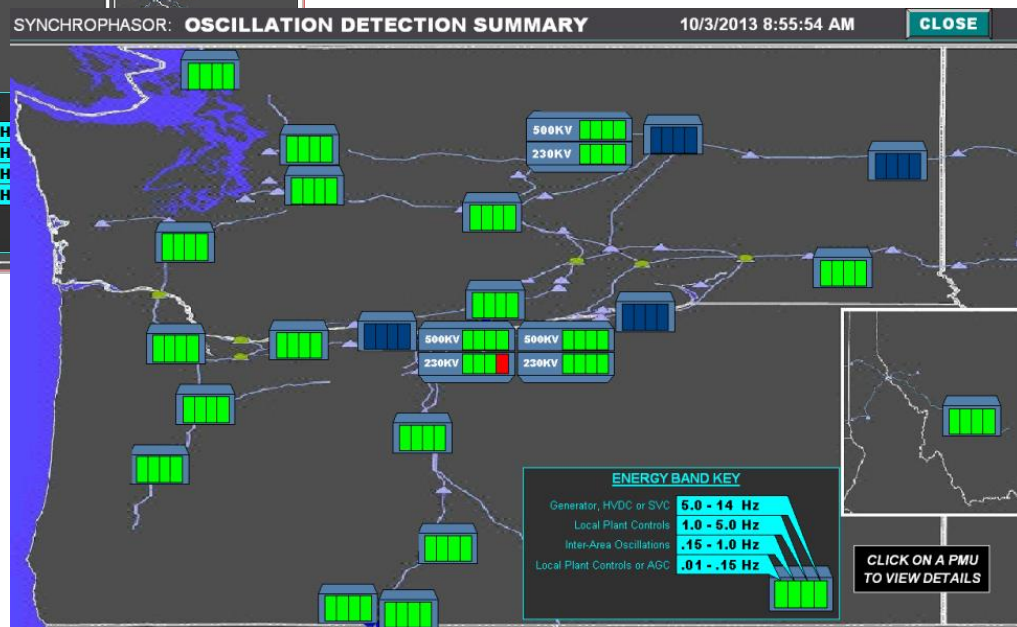
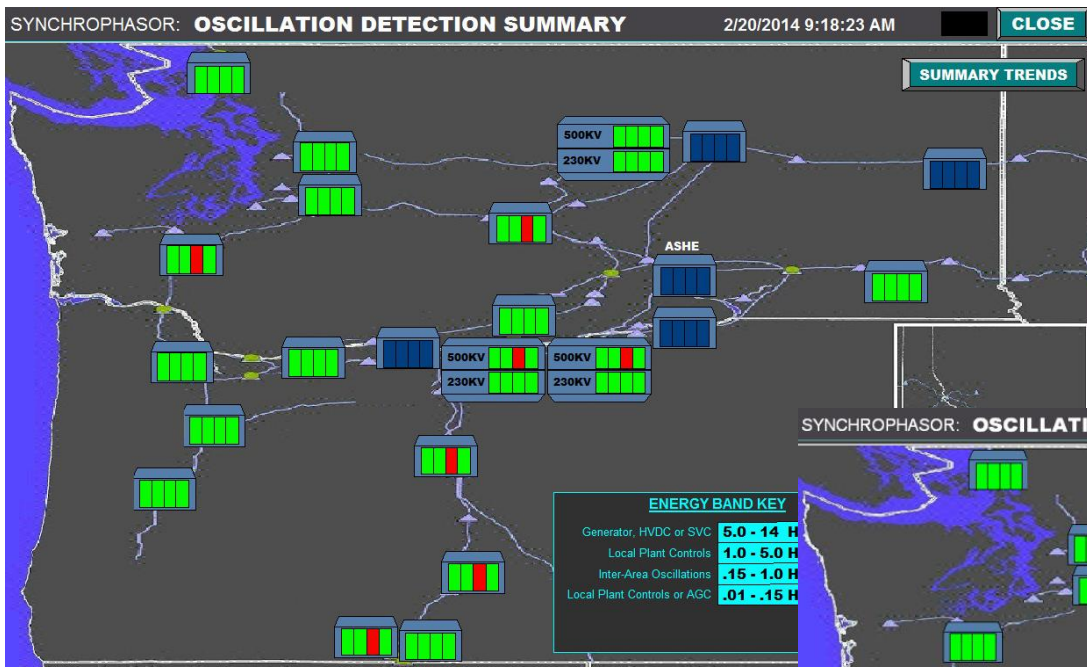
Must persist for this long:

- Band 1 – (0.01- 0.15 Hz) >> 400 seconds
- Band 2 – (0.15 - 1.0 Hz) >> 120 seconds
- Band 3 – (1.0 - 5.0 Hz) >> 120 seconds
- Band 4 – (5.0 - 14.0 Hz) >> 120 seconds

Oscillation Bands



Wide Area vs Local Area



Operational Status

- Monitoring 140 measurement points from 66 PMUs
 - Visibility of previously undetected oscillations
- ODM Map display on video wall of Dispatch floor.
- Full ODM application on all Dispatcher consoles.
- Audible alarms SCADA
- Operational Staff

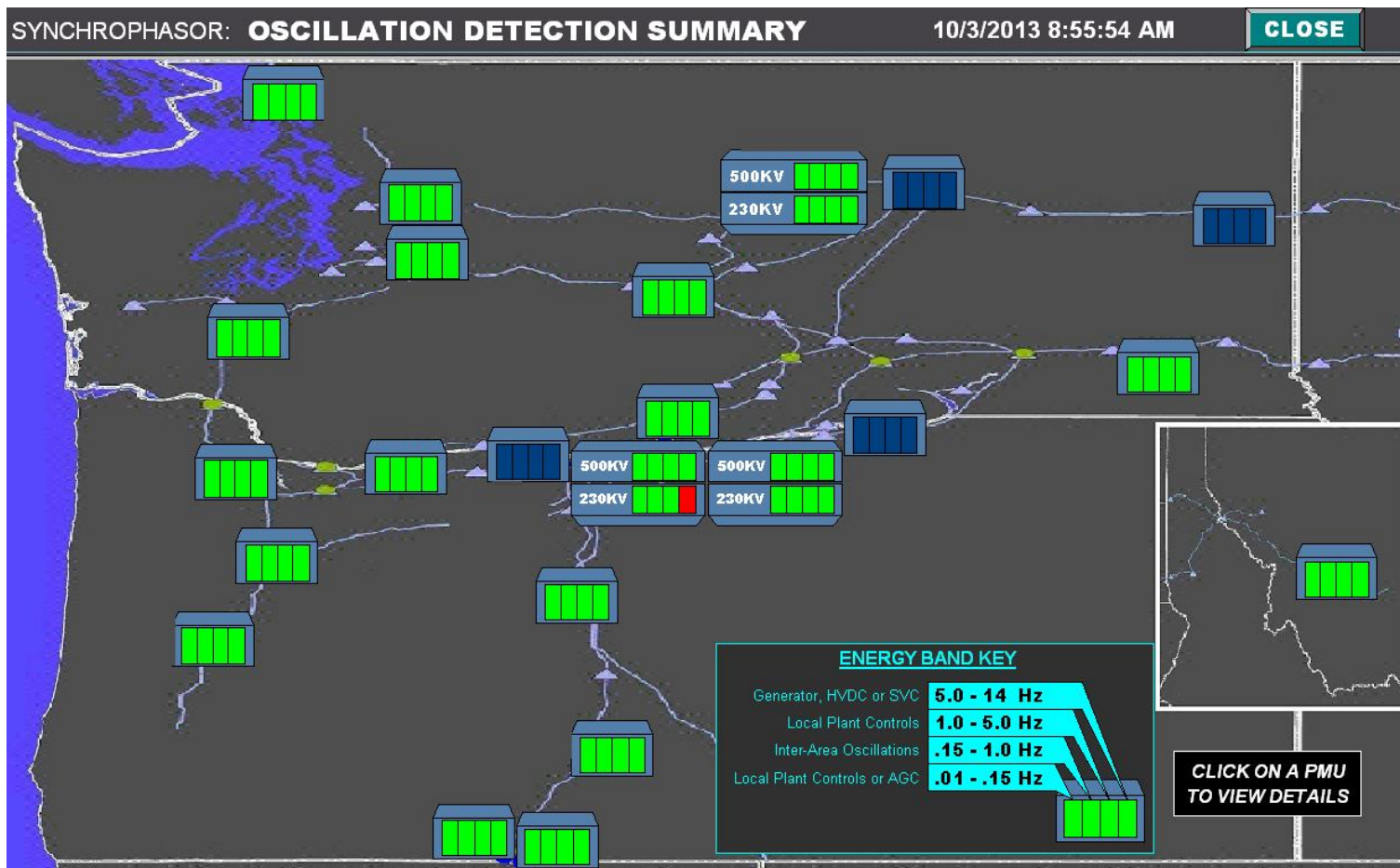
Current Dispatch Standing Orders

- Implemented as of June 1st, 2016
- BPA System Operators must respond to alarms
- Single PMU Site Alarm
 - System Operators contact field staff at alarmed measurement point
- Multiple PMU Sites Alarm
 - System Operators take more proactive approach

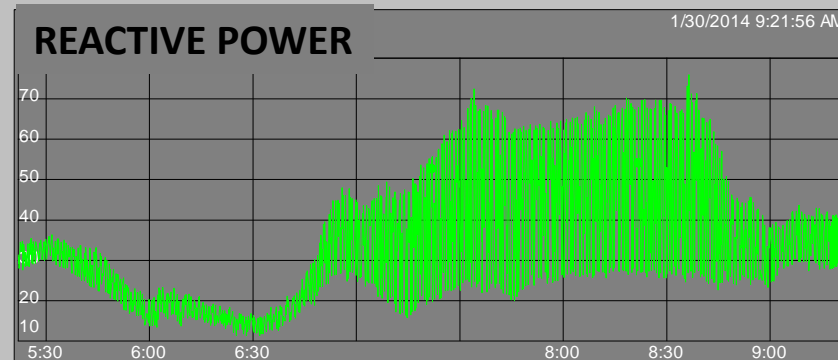
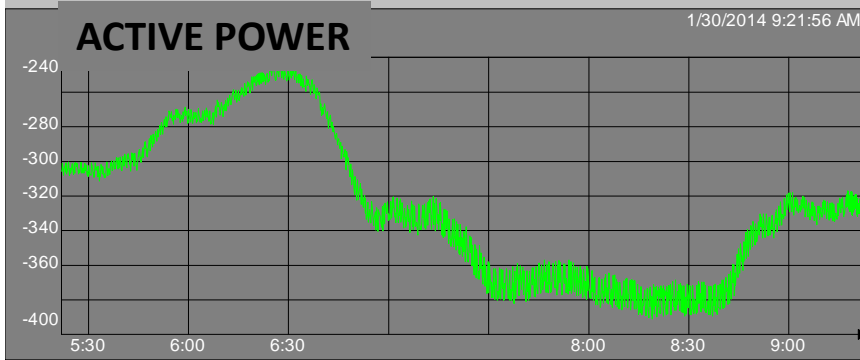
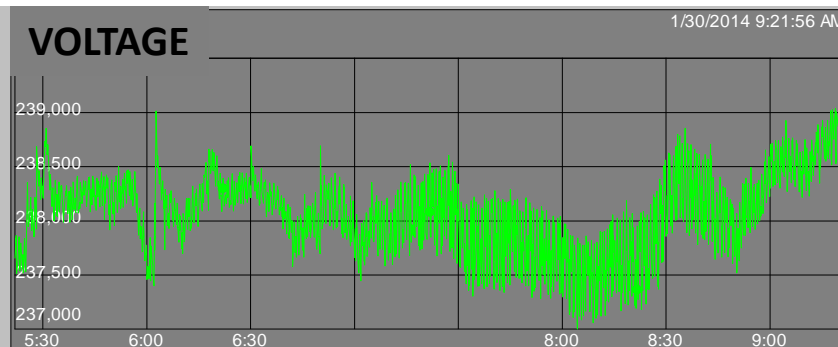
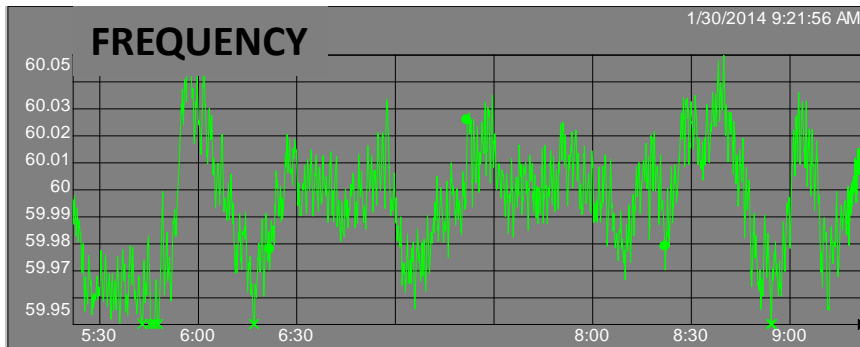
Events

Wind Power Plant High Frequency Oscillations

Wind Power Plant

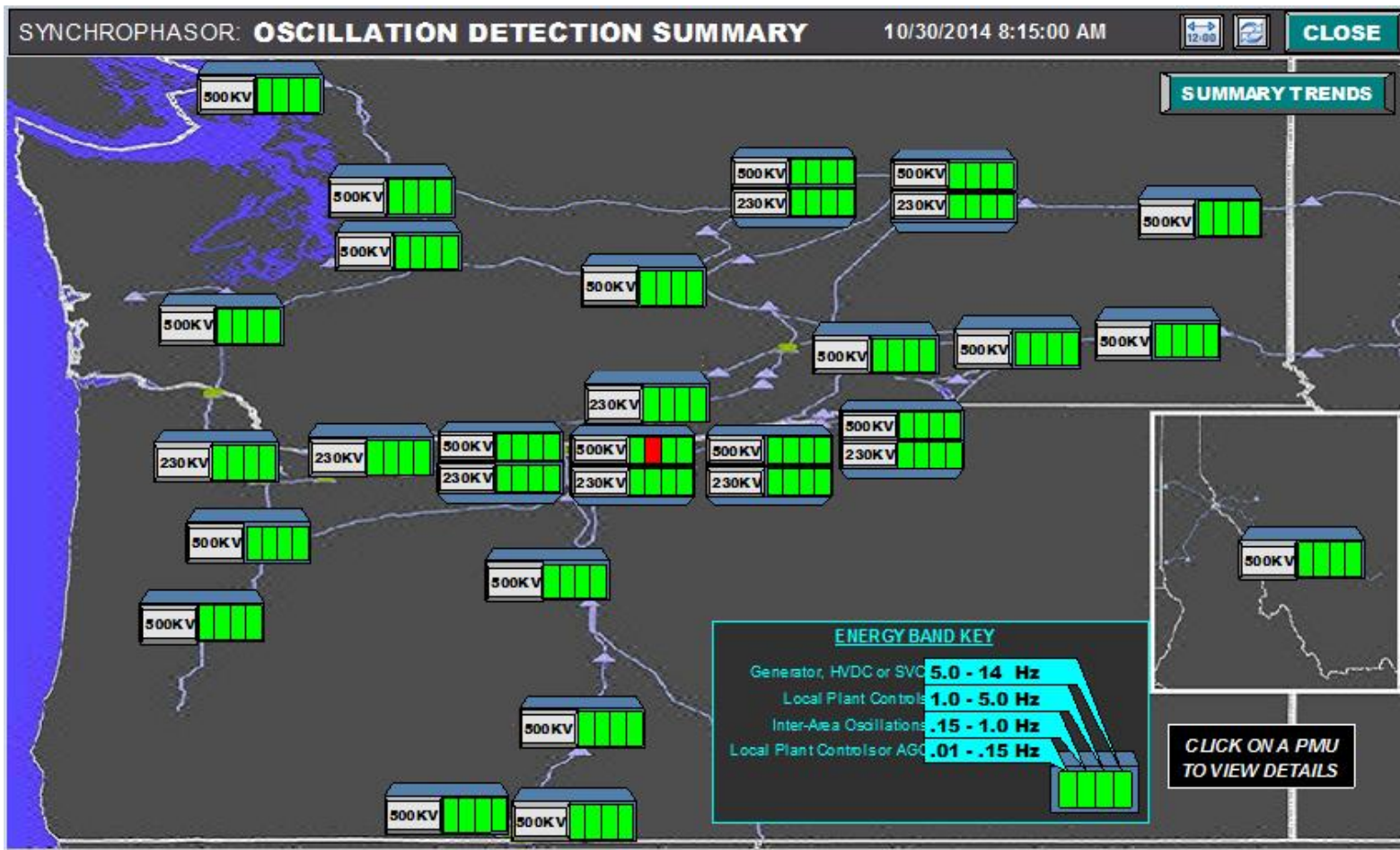


Wind Power Plant

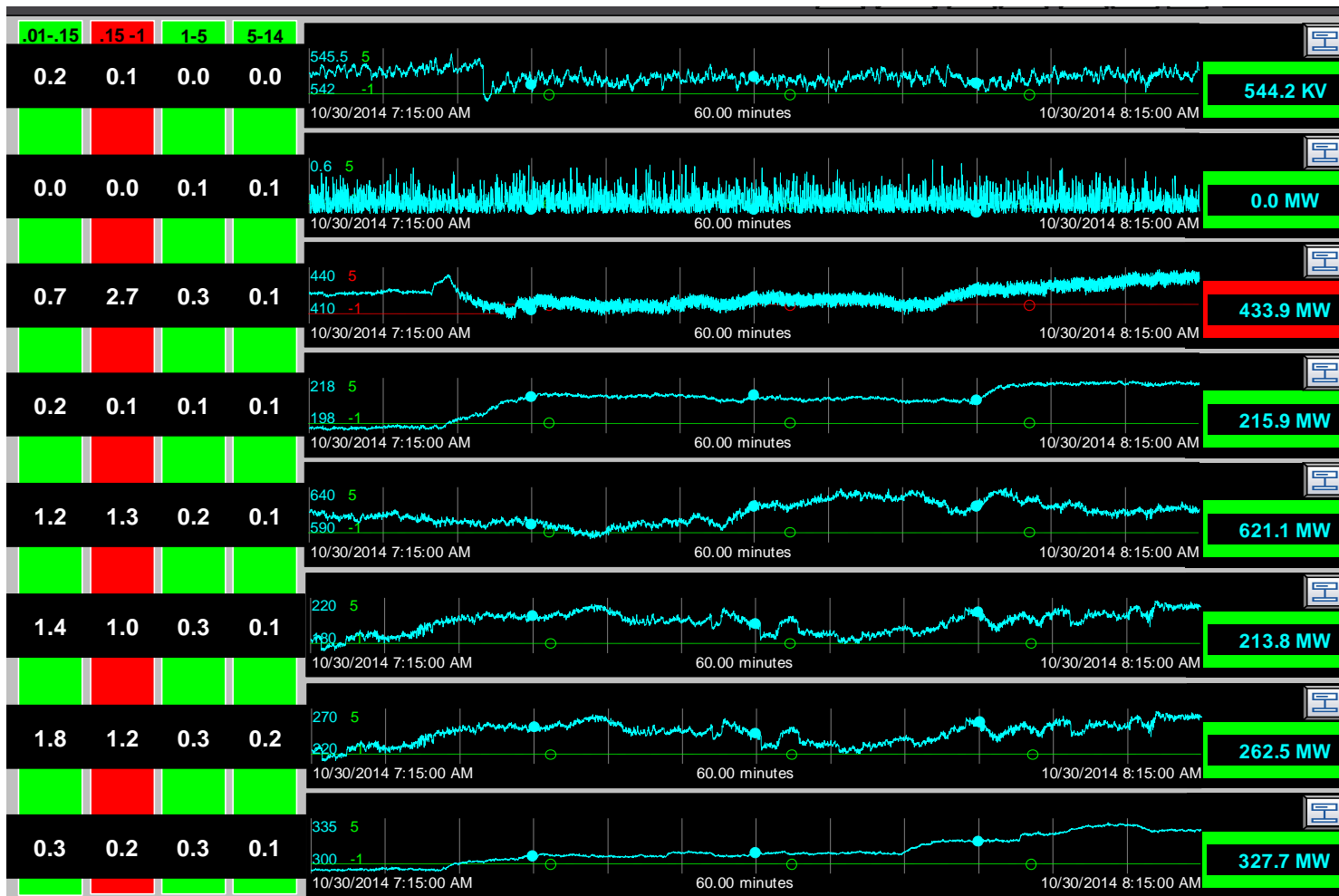


Hydro Generator Event in October 2014

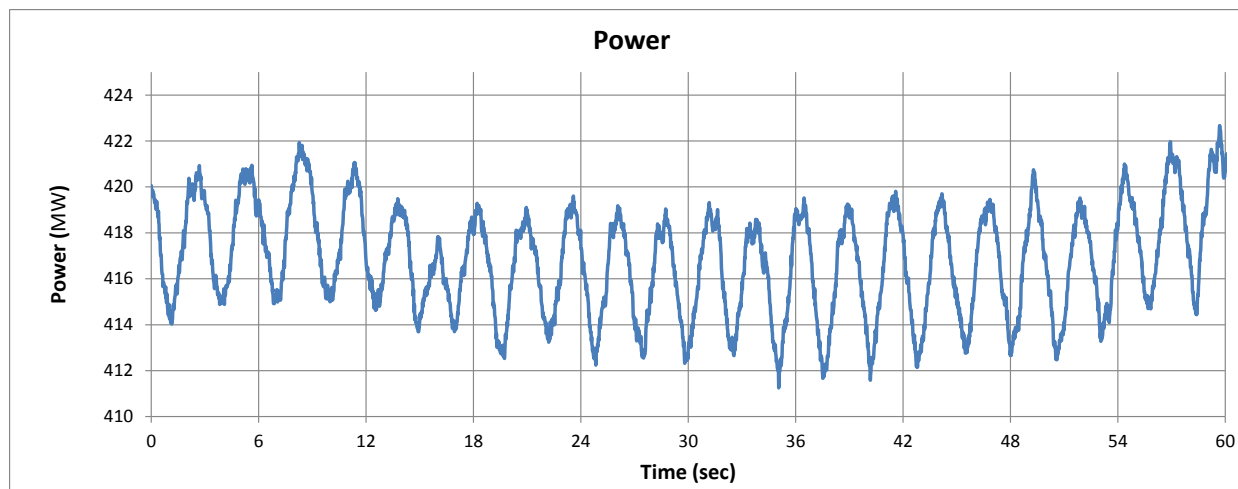
Hydro Event on October 2014



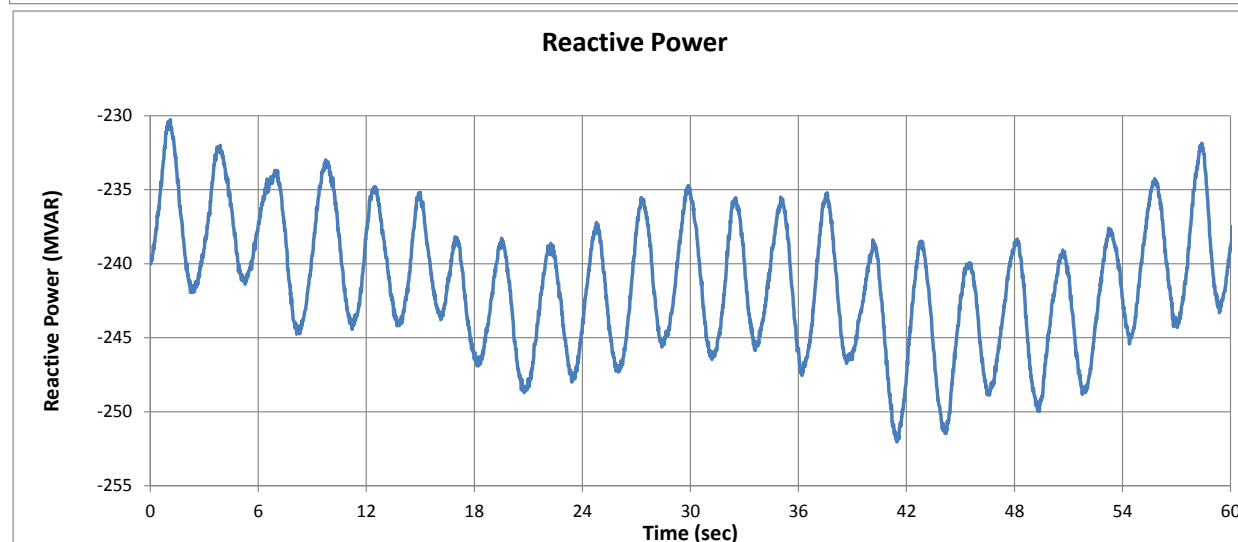
Hydro Generator Event in October 2014



Hydro Generator Event in October 2014

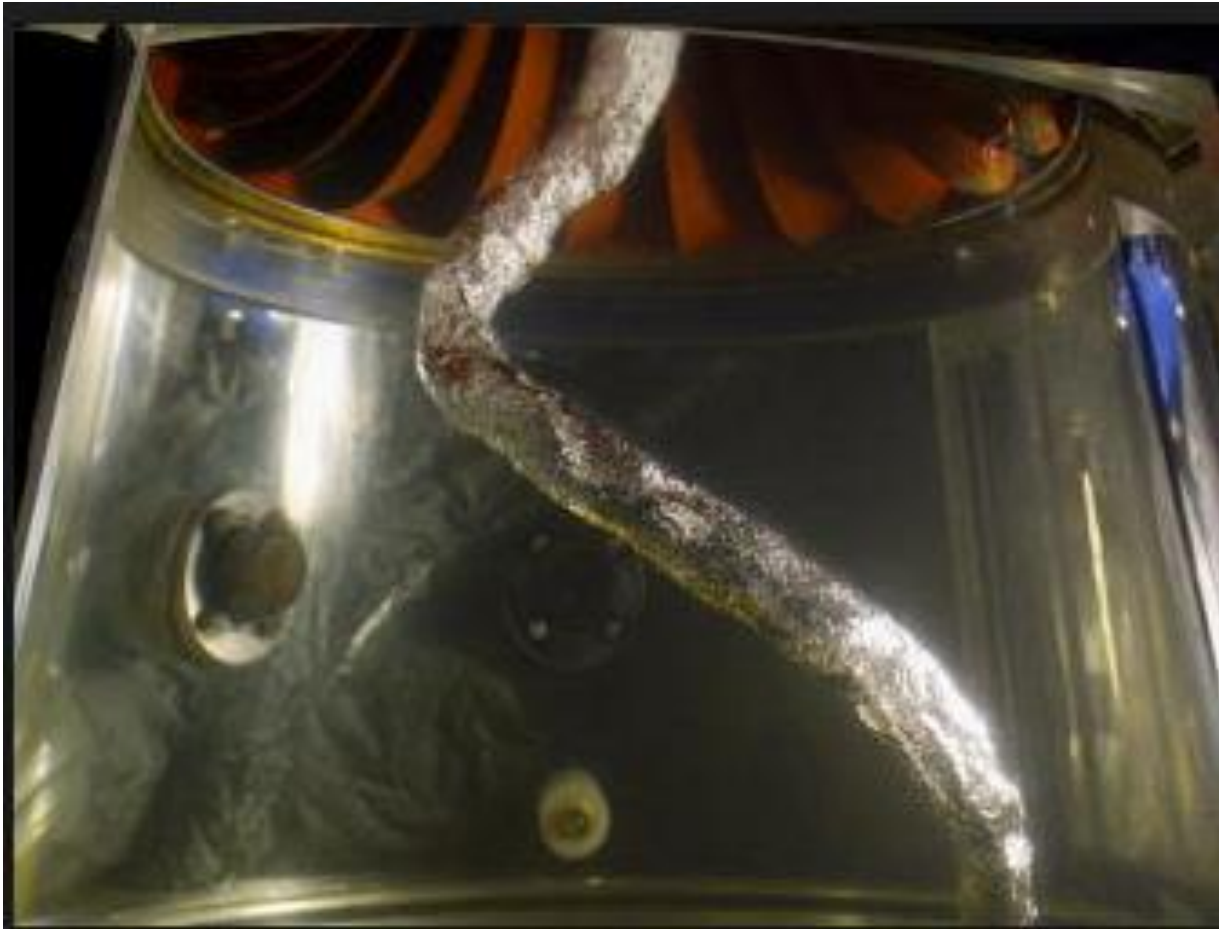


Period of oscillation is 3 seconds, oscillation frequency is 0.33 Hz, seen in both active and reactive power



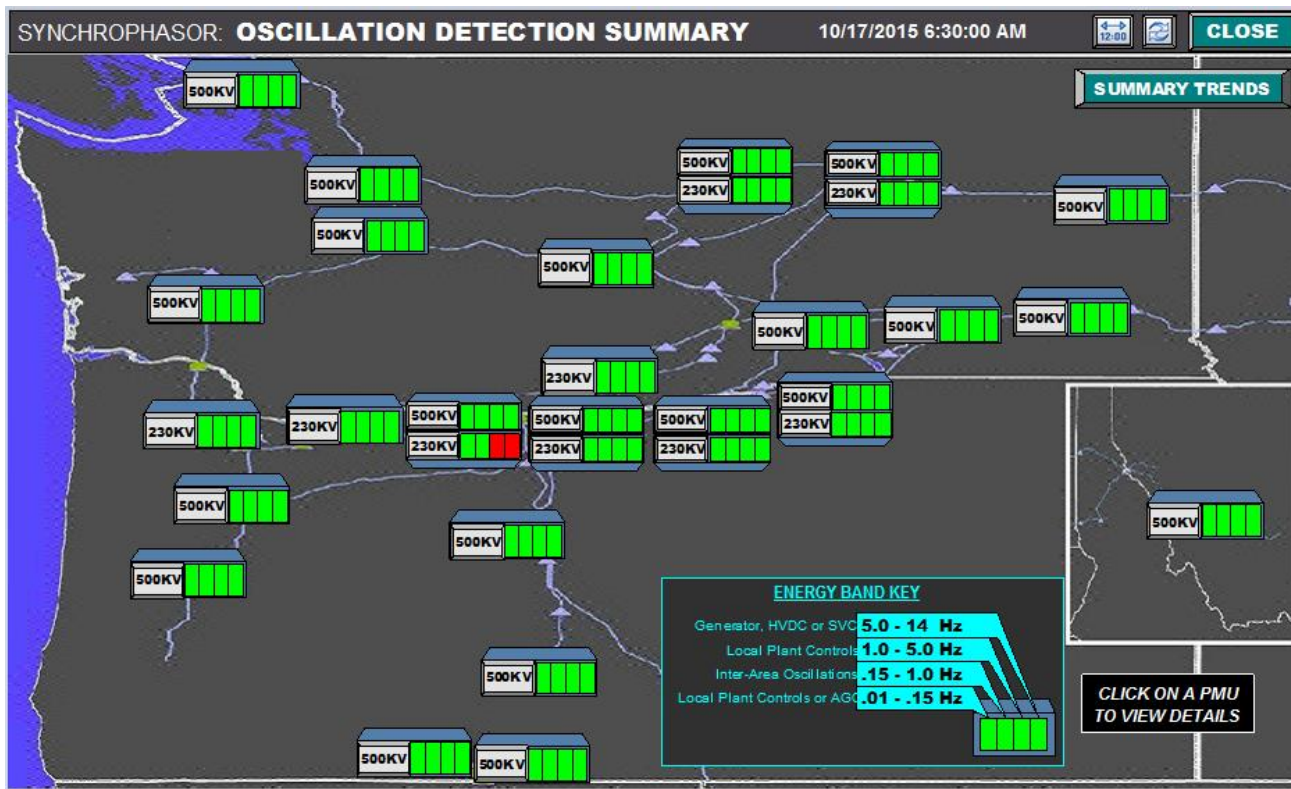
The oscillation is caused by a surging water vortex in one of the turbines operating at a partial load

Water Vortex



Oscillation Event on PowerHouse Line that Occurred on October 2015

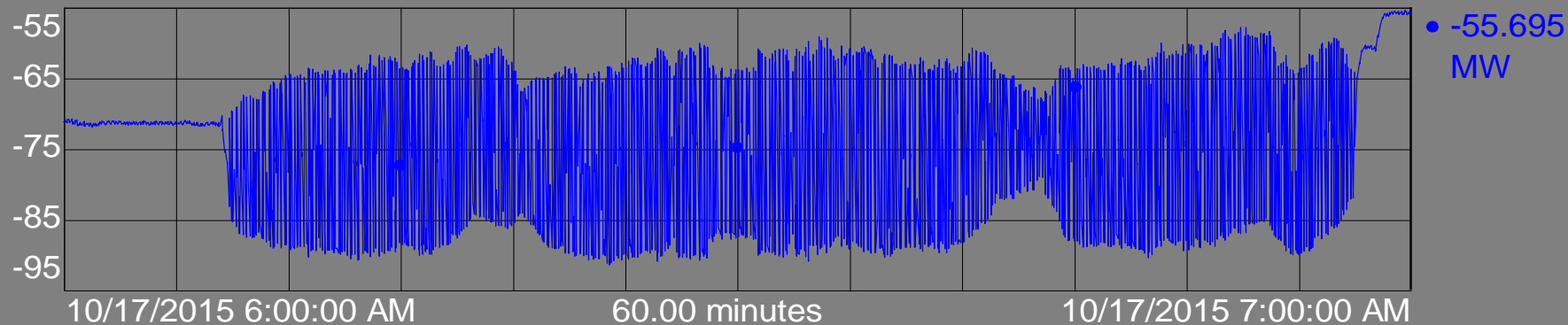
Oscillation Event



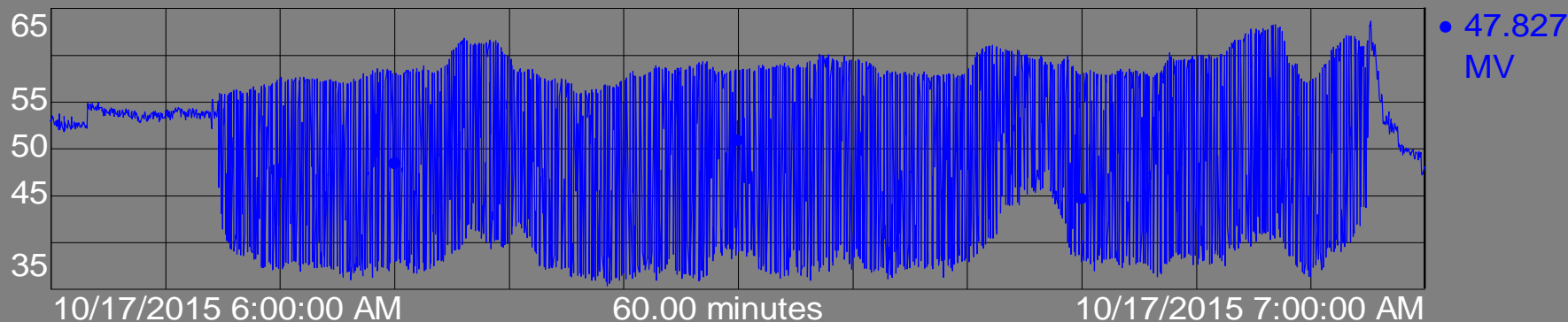
Oscillation Event



THE DALLES PH4 ACTIVE POWER



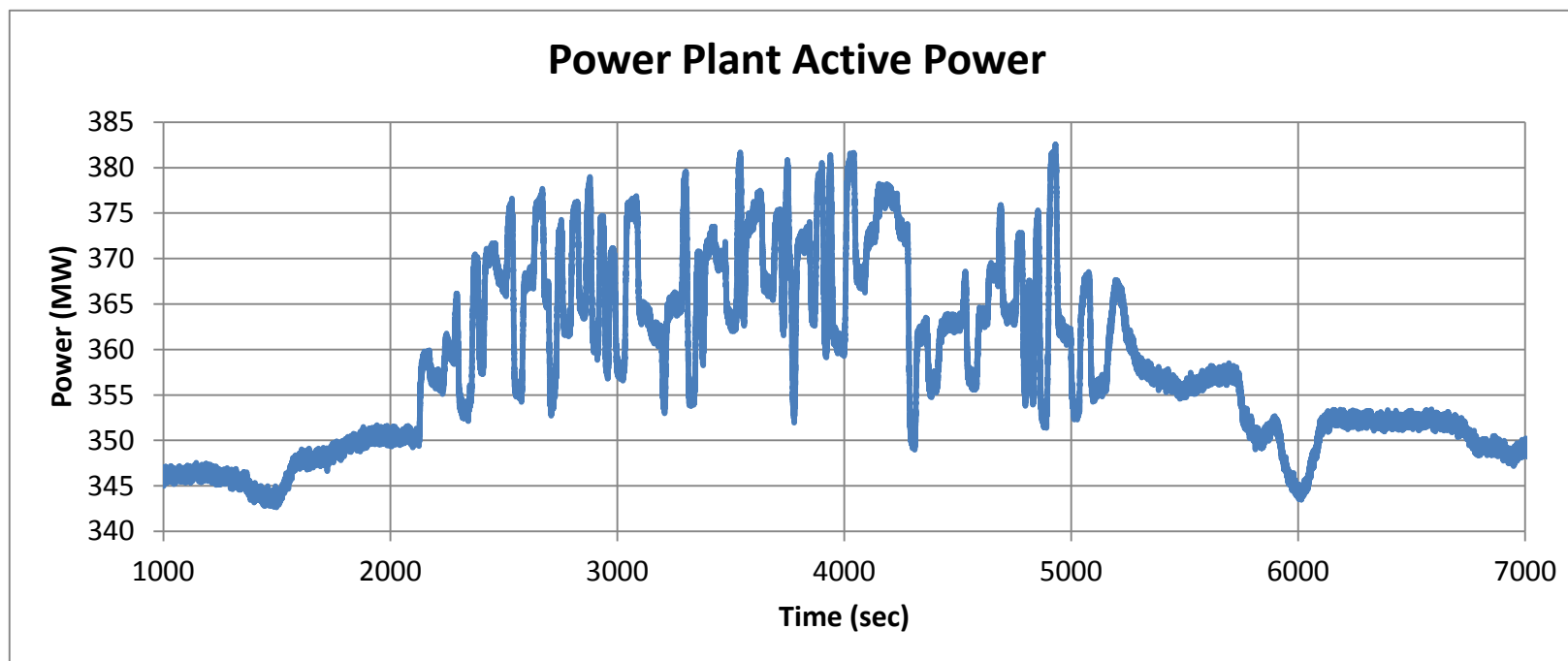
The DALLES PH4 REACTIVE POWER



The oscillation is caused when the Under-Excitation Limiter (UEL) and the PSS started interacting.

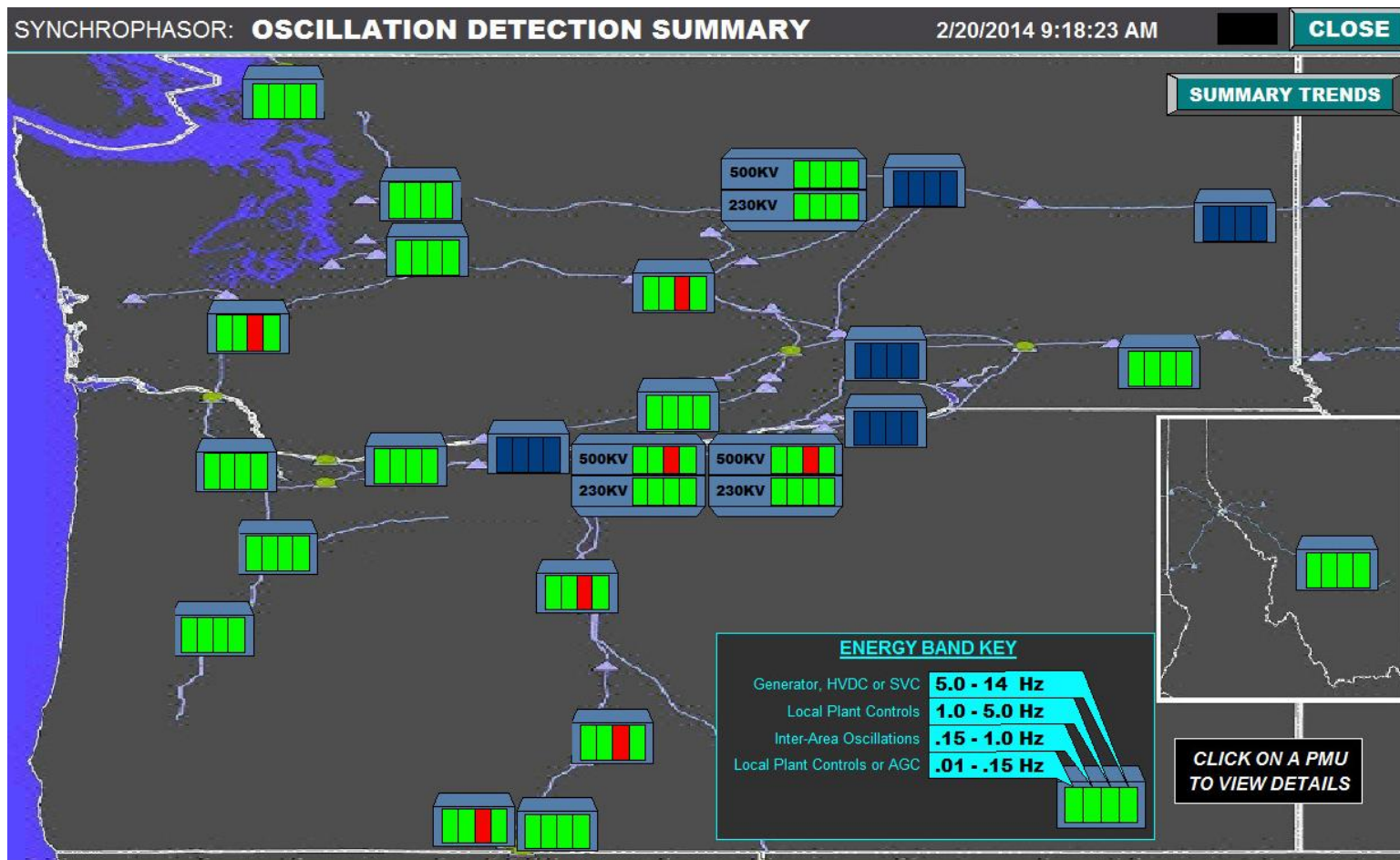
Solution: Move the units out of the UEL area.

Plant Controller Issue

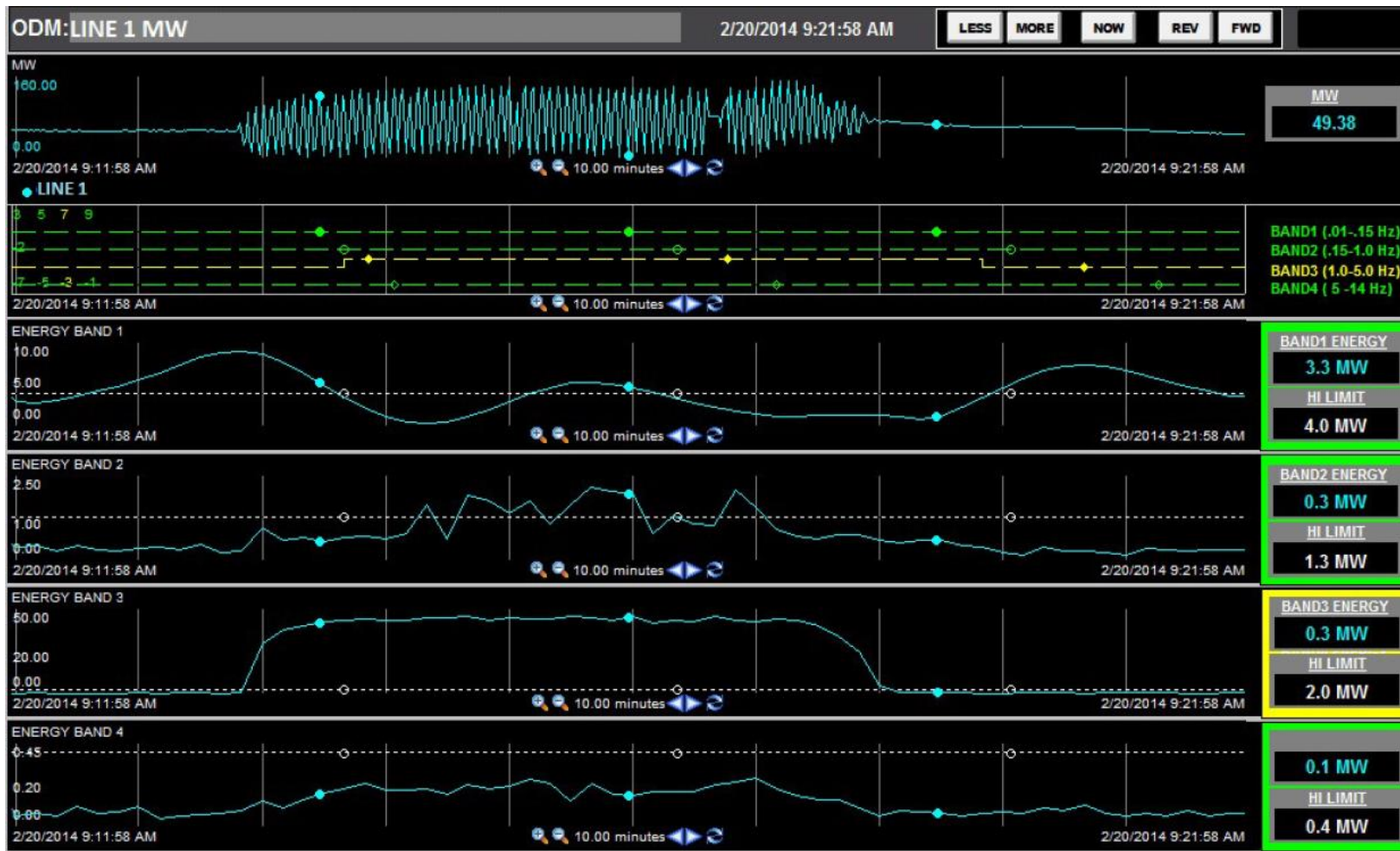


Central Oregon Plant Oscillation

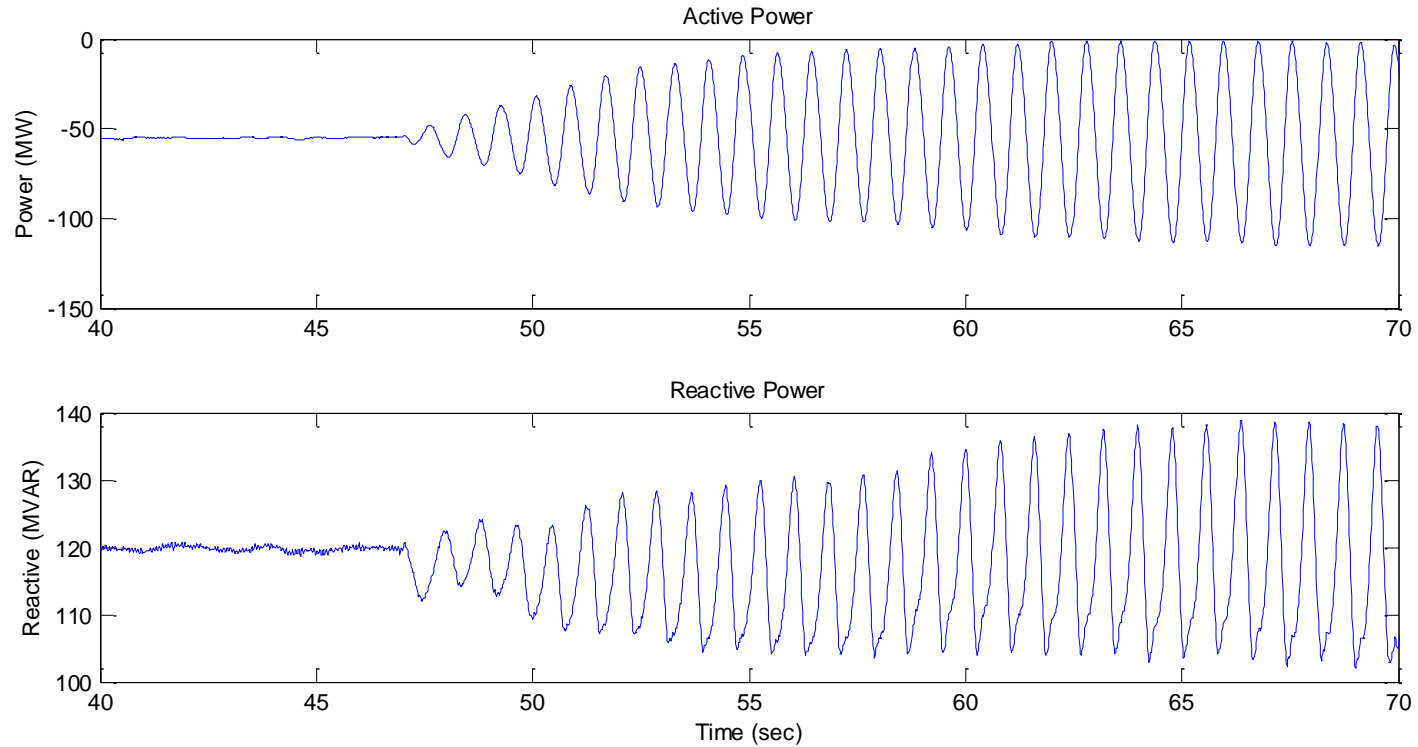
Central Oregon Plant Oscillation



Central Oregon Plant Oscillation

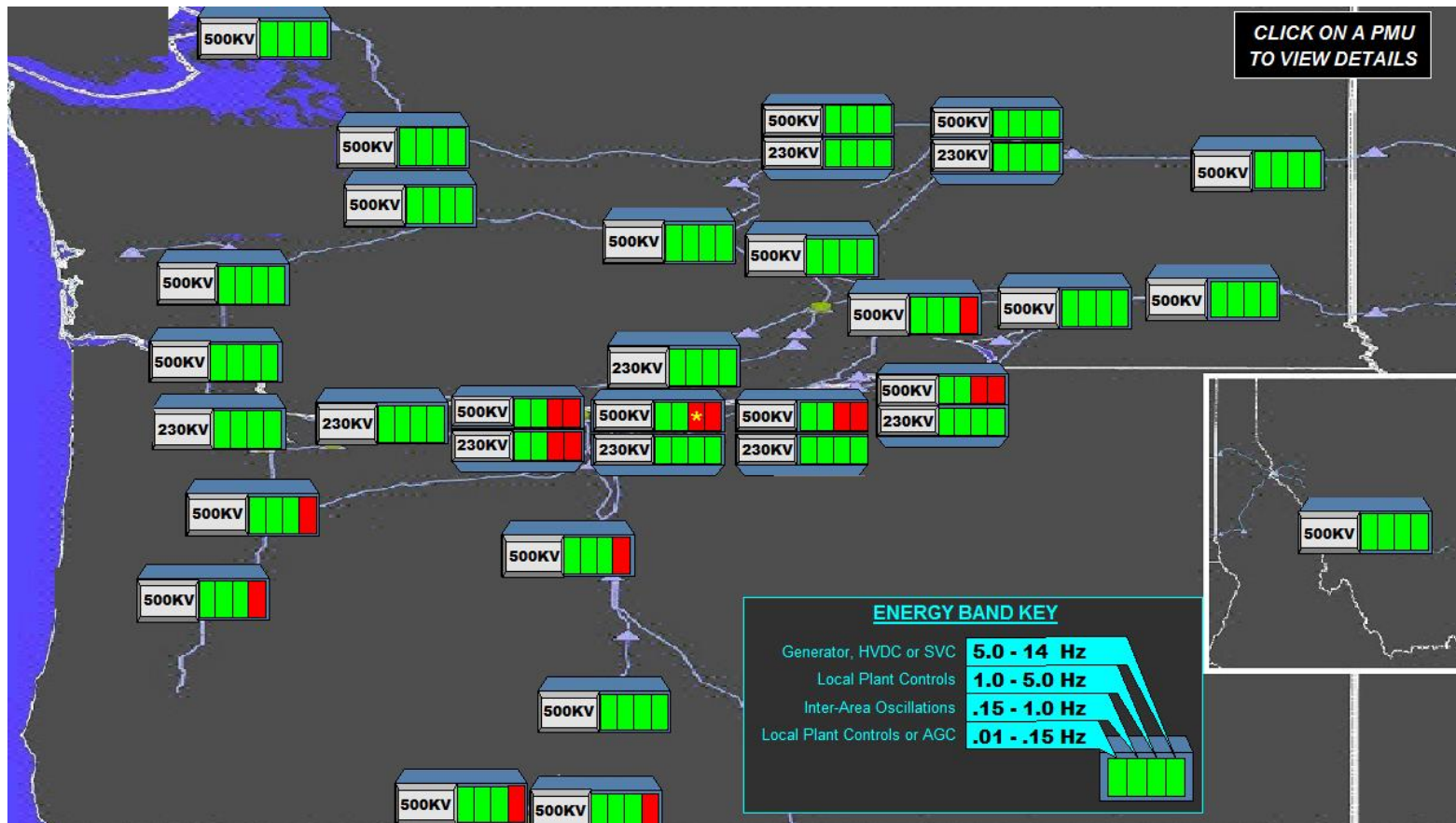


Central Oregon Plant Oscillation

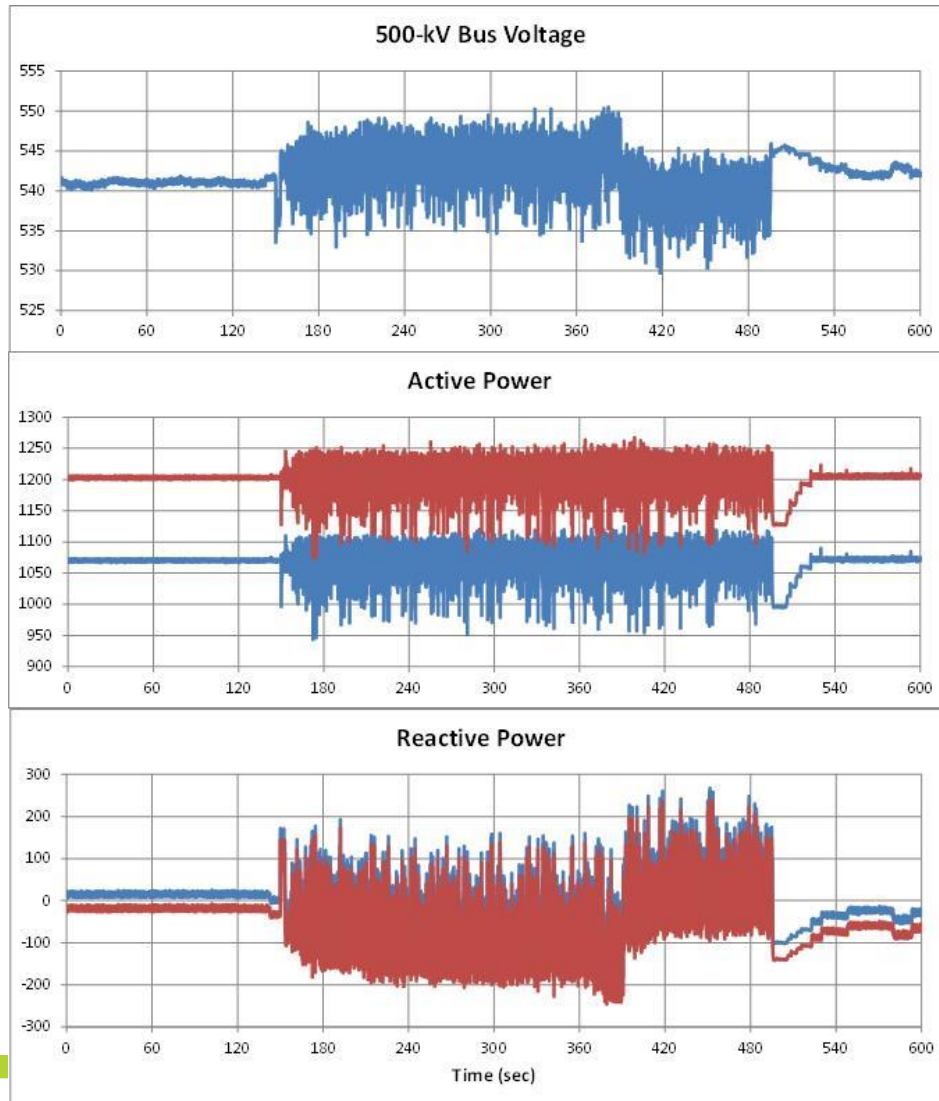


PDCI Oscillation

PDCI Oscillation



PDCI Oscillation



Questions