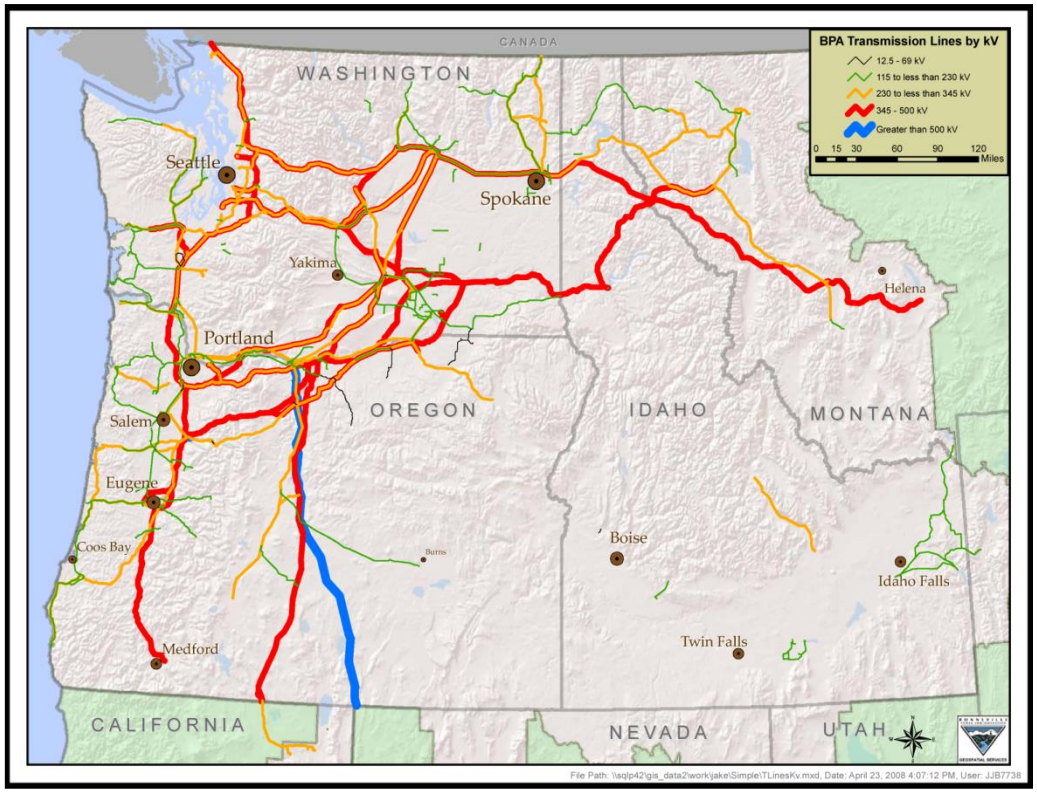
Synchrophasor Technology at BPA: From Wide Area Monitoring to Wide Area Control

DOE Energy Advisory Committee
October 2019
Arlington, VA

BPA Overview

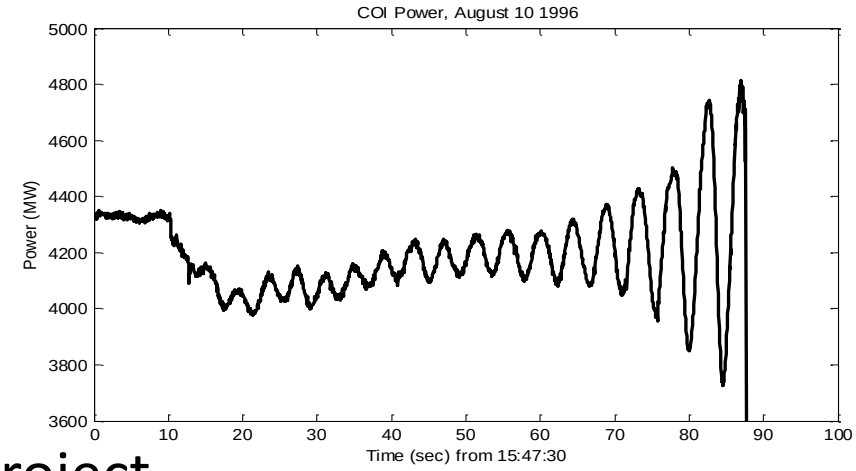


- Bonneville Power Administration (BPA) is a federal Power Marketing Agency in Pacific Northwest
- BPA markets power from 31 Federal dams (22 GW) and the Columbia Generating Station Nuclear Plant (1 GW)
- BPA operates more than 15,000 miles of transmission, including 4,735 miles of 500-kV lines

- BPA operates several large paths in the Western Interconnection – California Oregon AC Intertie (4,800 MW), Pacific HVDC Intertie (3,100 MW), Northern Intertie (3,100 MW), and Montana Intertie (2,200 MW)

History of Syncrophasors 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



- 2010 Synchrophasor investment project
  - 5-year, $35M project
  - Part of DOE Smart Grid Program
- Present-Day Synchrophasor Statistics
  - 148 “Control” PMUs (74 fully redundant pairs, 54 sites)
  - 25 “Data” PMUs (not redundant)
  - Exchange real time PMU data with 14 operating entities

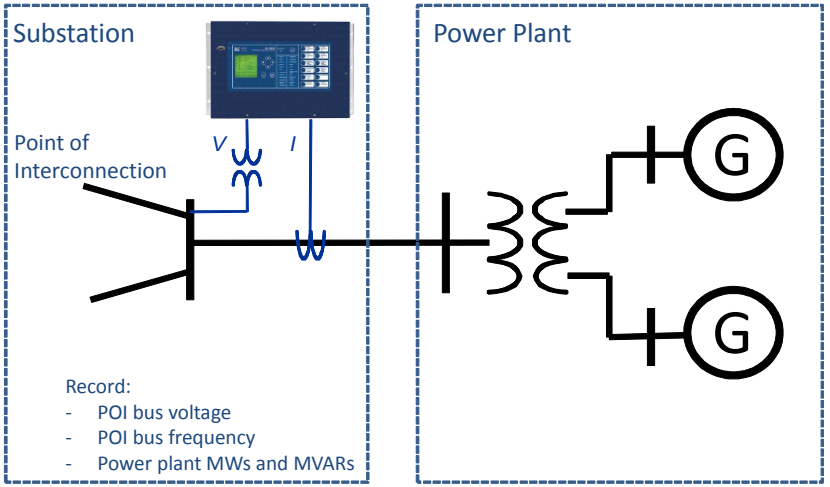
Applications

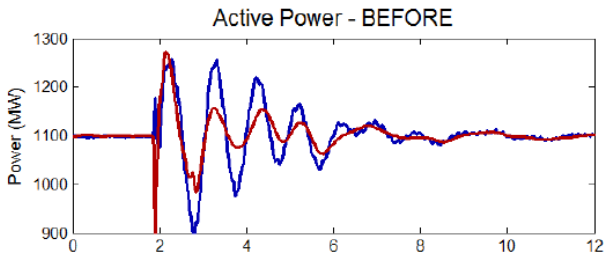
The value of the technology investment is unlocked through the deployment of applications:

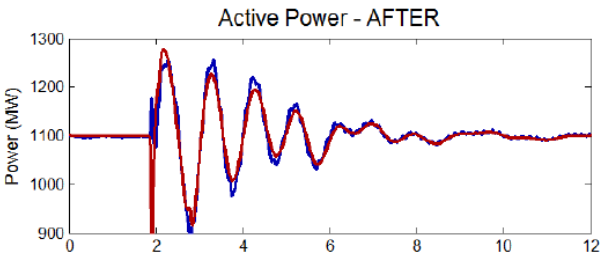
- **Engineering Analysis**
  - Event analysis, model validation, performance baselining
- **Control Room** – the primary focus of the investment project to bring Synchrophasor data in the Control Room
  - Four Application displays on dispatcher video wall (Oscillation Detection, Mode Meter, Islanding Detection, Frequency disturbance)
  - State estimation
- **Wide-Area Controls**
  - Reactive insert RAS

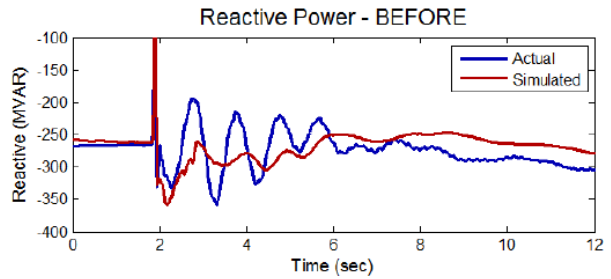
Engineering: Model Validation

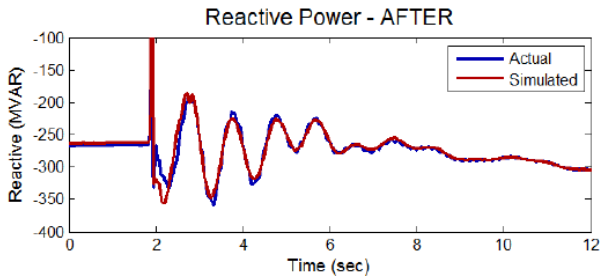
- WECC and BPA has 20+ year history of power plant model validation using PMU data
- Cost-effective method of compliance with NERC MOD Reliability Standards







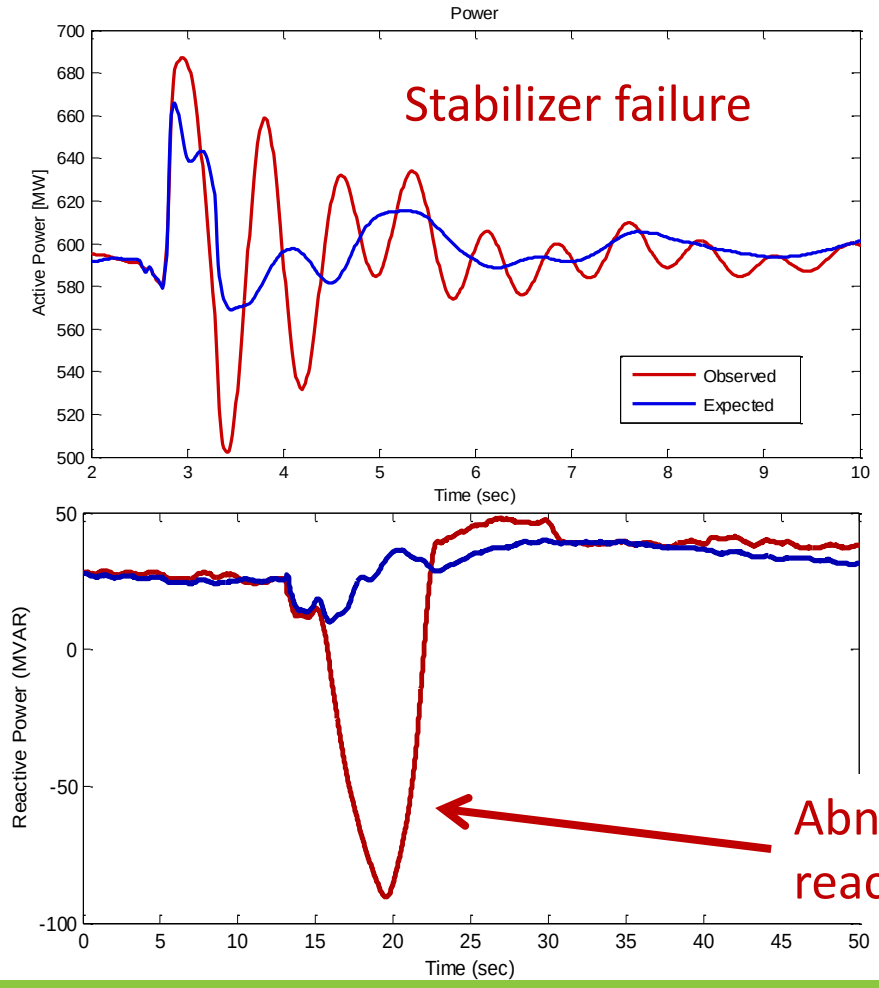




- Today more than 20 GW of generating capacity have PMU monitoring
- PMU's are Standard for new large generator and load interconnections

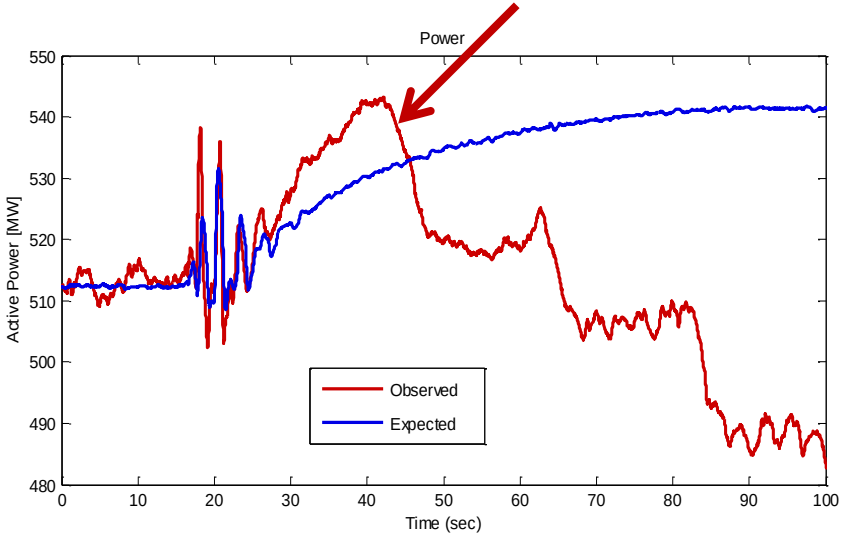
Engineering: Detecting Control Abnormalities

PMU monitoring provides detection of generator control abnormalities



Abnormal runback in reactive power

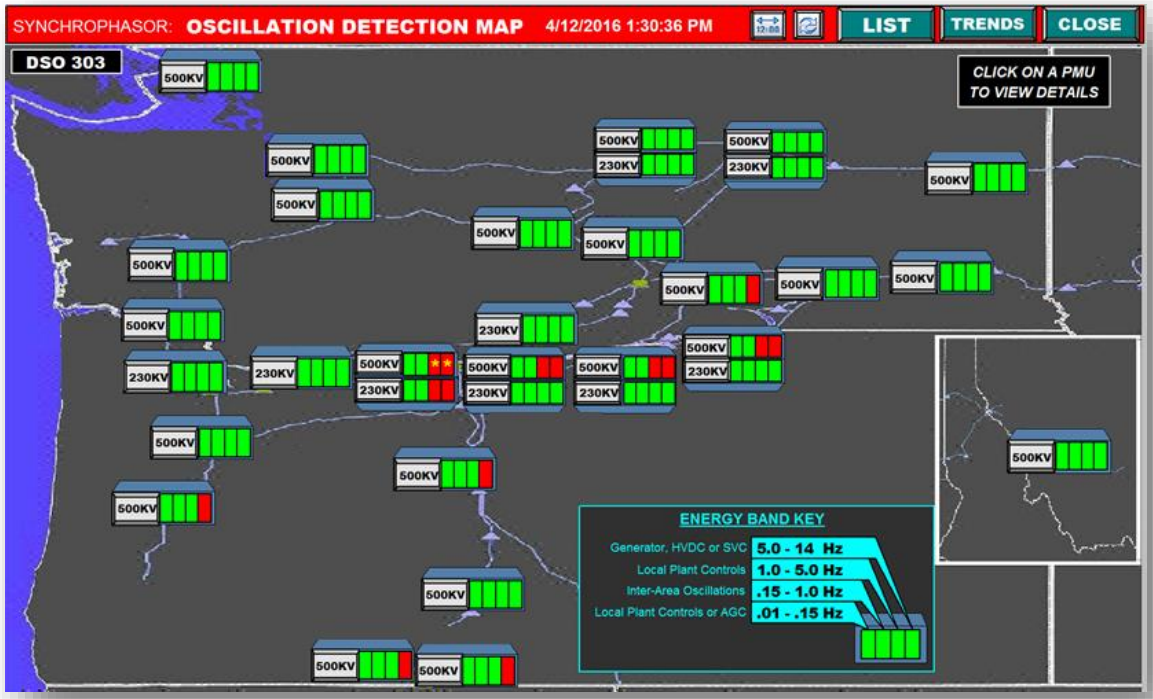
Unexpected action from plant MW controller



Control Room: Oscillation Detection

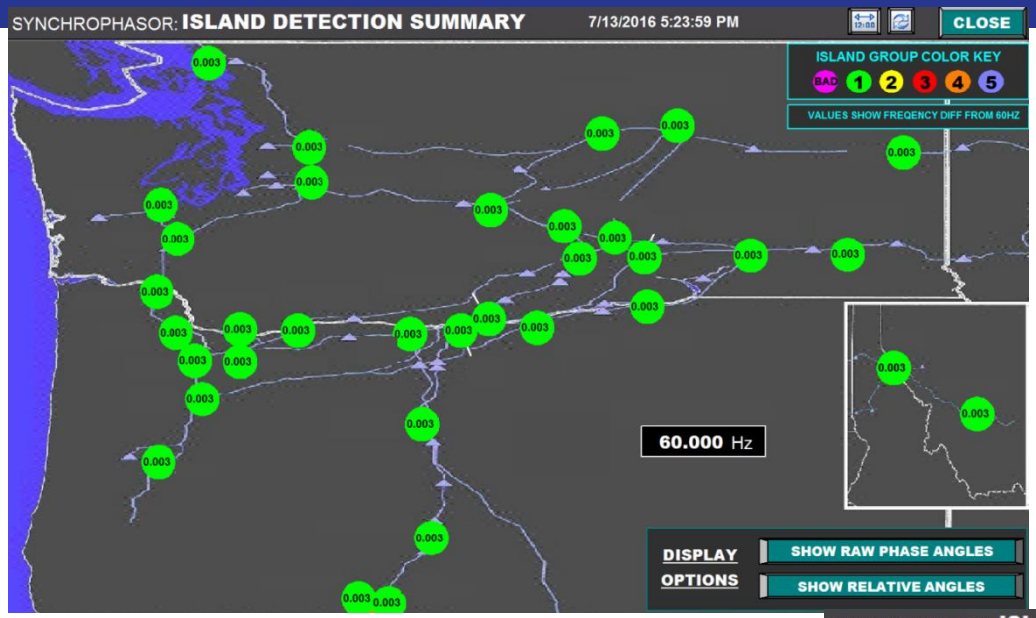
"Oscillation detection is the premier application of synchrophasor technology" --- Vickie Van Zandt

BPA deployed Oscillation Detection in its control room in October 2013



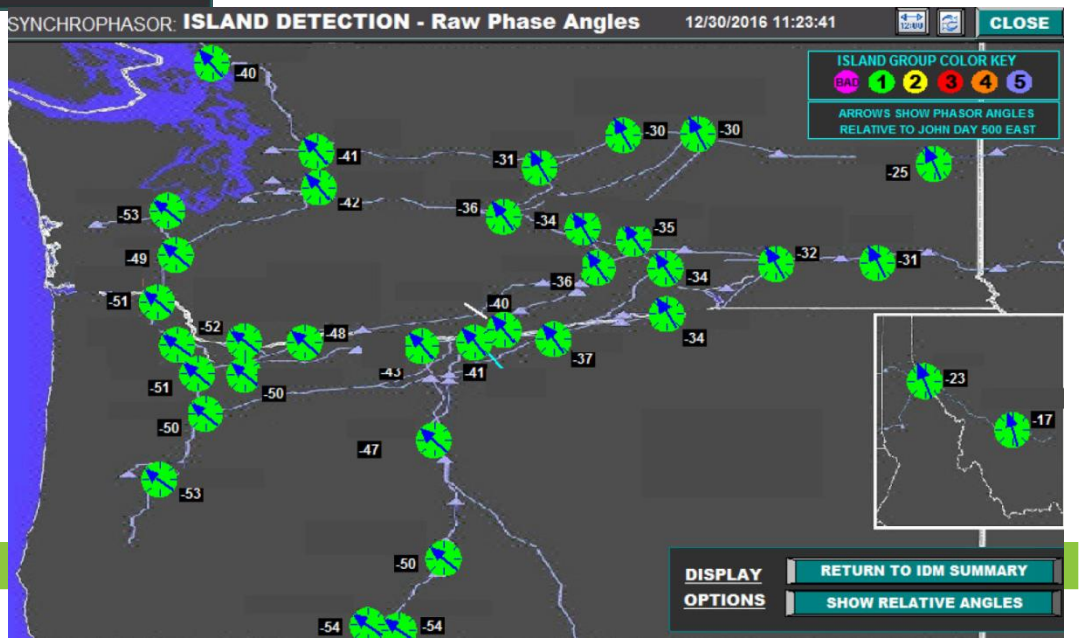
- Scans 100+ signals for signs of growing or sustained power oscillations
- Operating procedures are developed
- Dispatcher training sessions are performed
- Alarms dispatchers when an oscillation is detected

Control Room: Island Detection



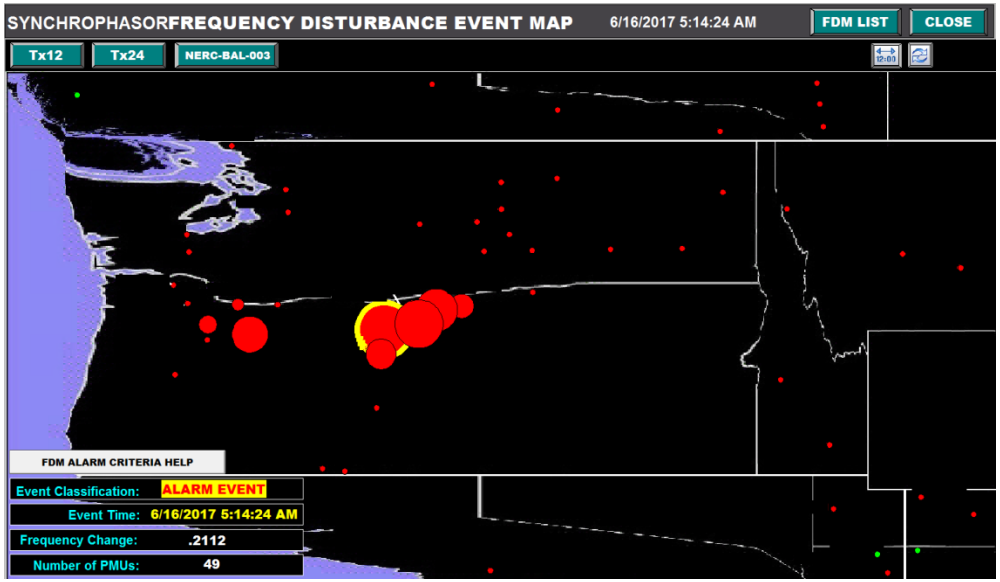
Can quickly see if any islands form, and see what island frequency is. Here there are no islands.

Can see raw phase angles, useful to see if the angle is safe for line reclosing



Control Room: Frequency Event Detection

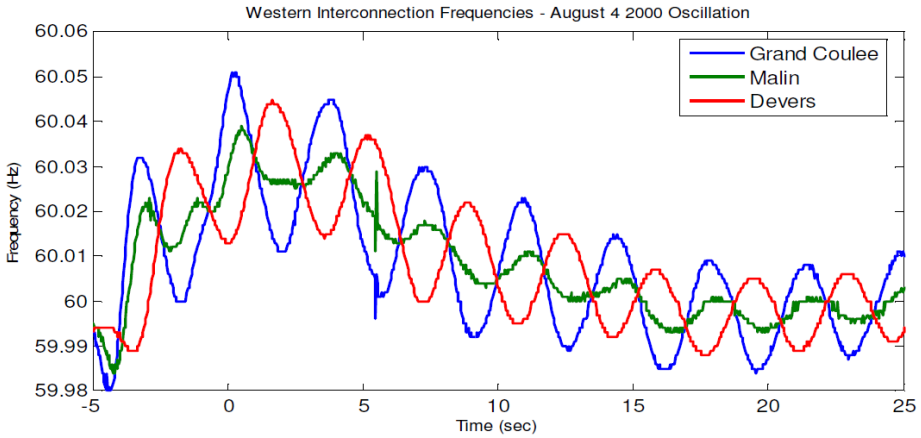
BPA deployed Frequency Event Detection in its control room in 2014



Map shows where frequency event originated

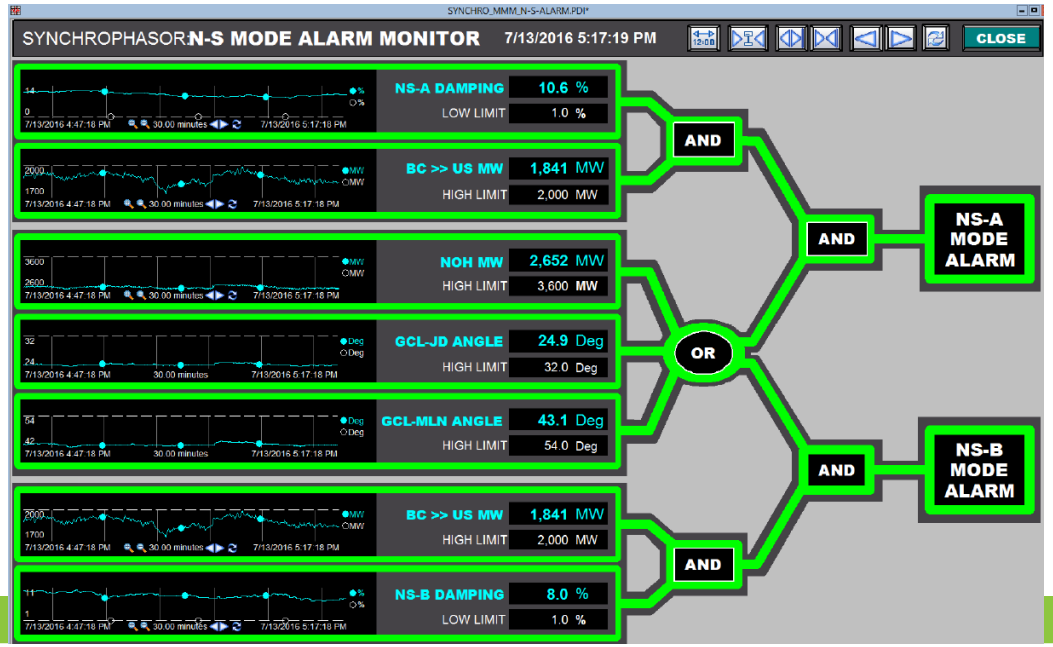
Frequency and power charts are auto-generated

Control Room: Mode Meter / Low Damping Detection



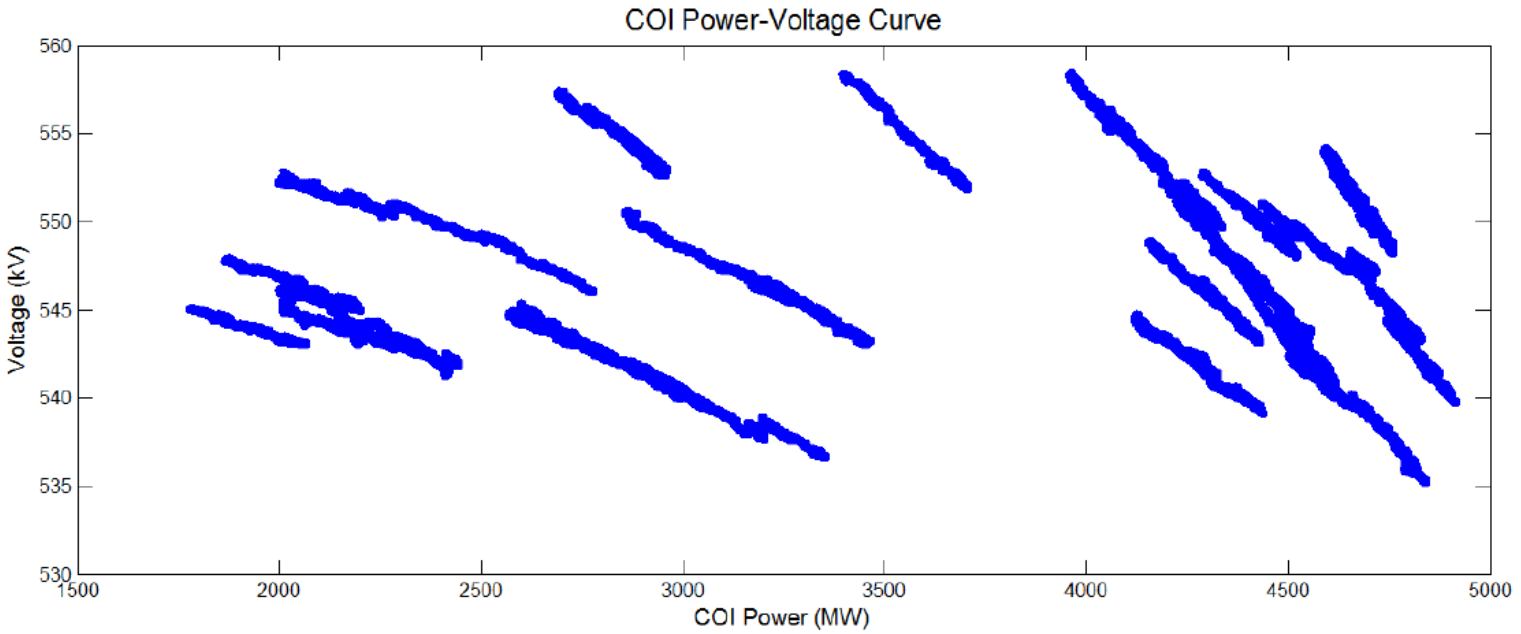
- There are 5 well known wide area oscillation modes in WECC
- One of them was excited in August 2000 due to high system stress

- Mode meter detects system conditions when the grid is vulnerable to exciting these modes
- Currently dispatchers do not take action, but orders are under development.



Automated Controls: SP RAS

- BPA developed a wide-area voltage control scheme that uses real-time synchrophasor information
  - PMU measurements are streamed from several substations to BPA control centers
  - Control algorithm assess stability risk in real time
  - Control signal is sent to several substations to switch shunt reactors and capacitors
- SP RAS went operational in May 2017
- WECC approved the synchrophasor RAS as a safety net first in 2015, and as a wide-area protection scheme in 2018
- Allows for RAS action due to events outside of BPA's system (i.e. large generation loss in the Desert Southwest)

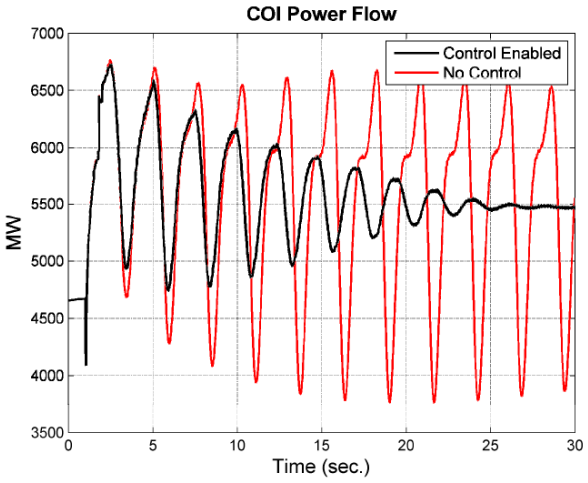


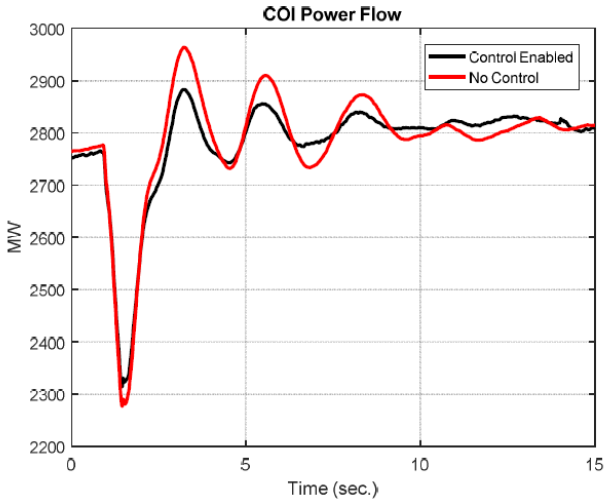
Keys To Success

- International Recognition
  - BPA's synchrophasor project received 2013 Platt's Global Energy Award for Industry Leadership in Grid Optimization
- Reasons for Success
  - Institutional knowledge and expertise within the organization
  - Clear vision of the project objectives and superb project management and execution team
  - Early engagement of stakeholders and product owners (several dispatcher trainings on oscillations, DSO development, additional training)
  - Strong executive support

Looking Forward

- Big Data Analytics
  - Distributed Computing and Storage
    - 86 TB (9 nodes x 9.6 TB)
    - Benchmark tests show 150x speed compared to single thread
  - Sliding window algorithms for event detection





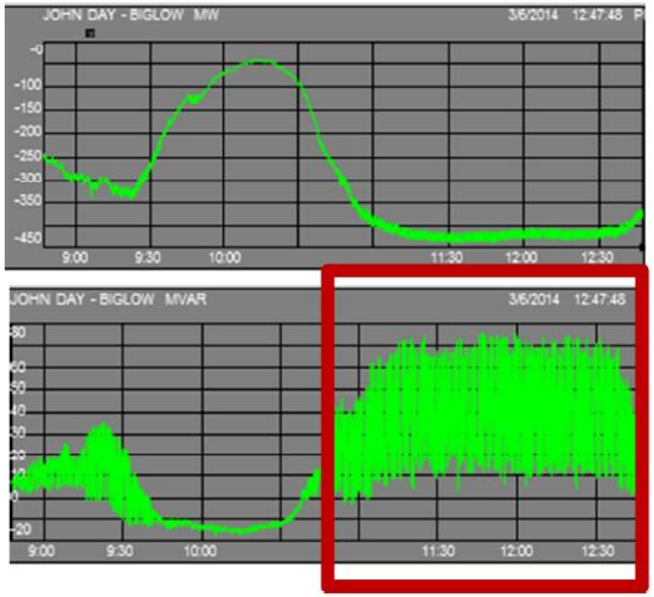
- Damping Controller
  - Research project with Montana Tech, Sandia National Labs, and BPA
  - Modulate the Pacific DC intertie to dampen oscillations on the parallel California Oregon AC intertie
  - A successful closed loop test was performed on the real system in 2016; demonstrated measurable improvement in damping

Thank You

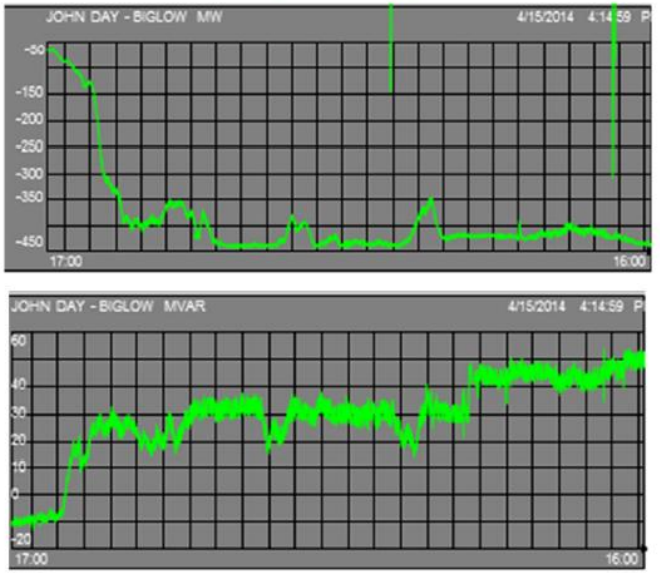
Extra Slides for Discussion

Local Oscillation Detection

Wind Ramp in March 2014



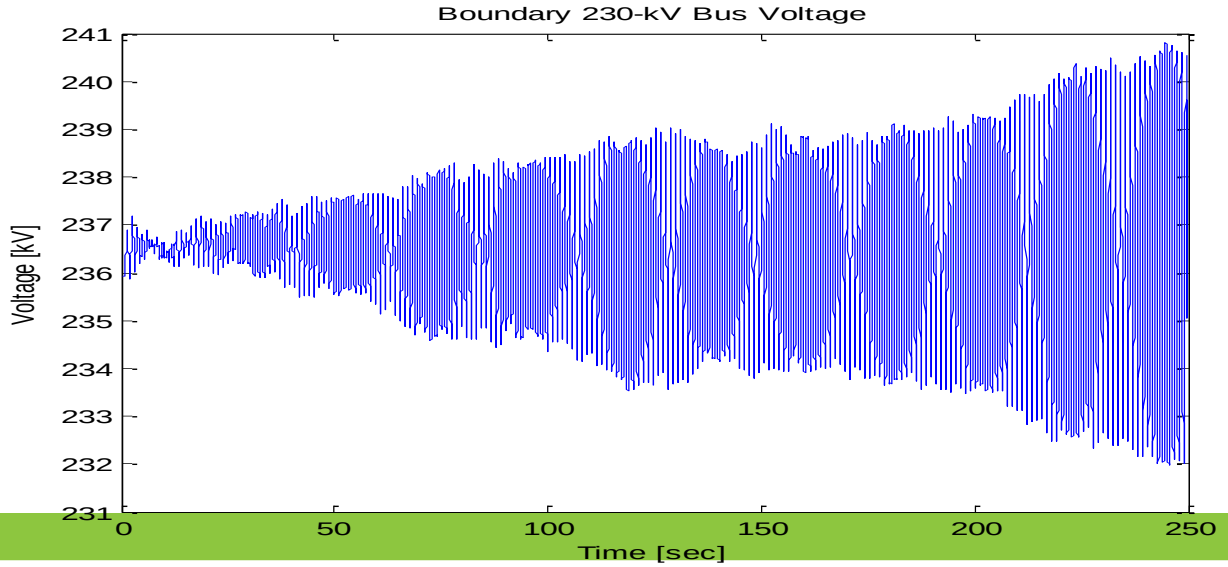
Wind Ramp in April 2014



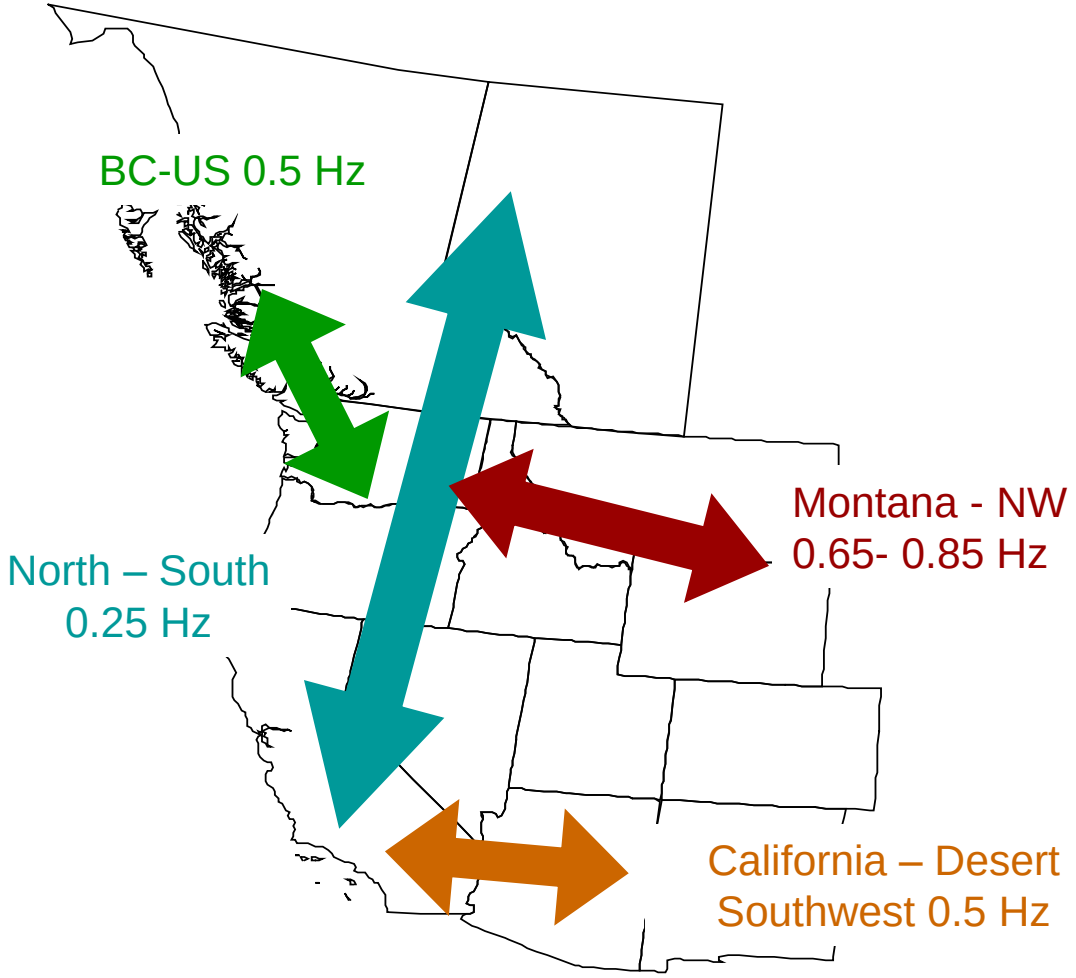
Wind ramps prior to a controller upgrade in April 2014 showed a 70 MVAR oscillation in reactive power (left). Wind power ramps after the upgrade show oscillation activity greatly diminished (right).

Local Oscillation Detection

- Boundary – Nelway 230-kV was out of service
- One of Boundary – Bell 230-kV lines was out of service
- SCL started ramping up Boundary generation
- Boundary power oscillations started building up
- SCL thought AGC problem, ramp down, rebooted AGC
- Ramped generation back up, the oscillation re-appeared



WECC has 4 wide area modes



North – South

Montana – NW

BC – US

California - DSW

Wide Area Forced Oscillation

- November 30, 2005
- Nova Joffre (generator in Alberta) had steam supply instability, resulting in power oscillation at the inter-area frequency, about 0.28 Hz
- 20 MW oscillation at Nova Joffre plant resulted in 160 MW oscillation on COI