# Synchrophasor Technology at BPA: from Wide-Area Monitoring to Wide-Area Control

Presented by Jeff Dagle (PNNL)
on behalf of BPA

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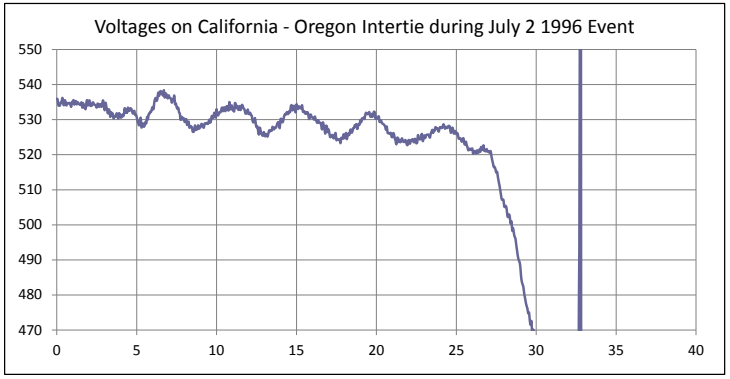
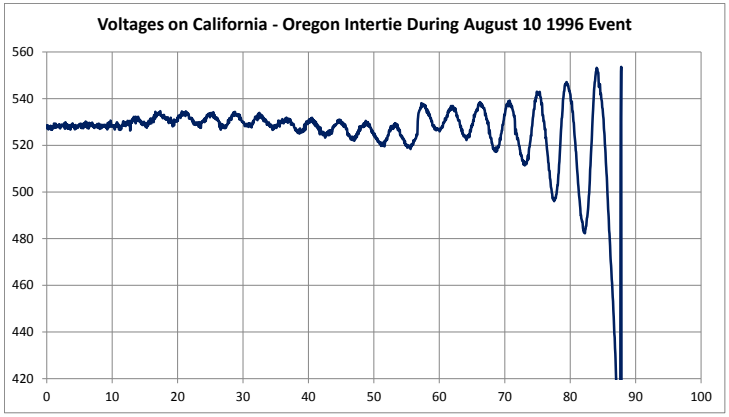
# History of Synchrophasors at BPA

- BPA was one of the early adopters of the synchrophasor technology in early 1990s
- PMU coverage and networking greatly expanded following 1996 outages
- Utilities researched, prototyped and deployed several PMU applications for engineering analysis
- However, the original PMU network was not reliable or secure for grid operations



# 2010 Synchrophasor Investment Project

BPA initiated a capital investment project in 2010 to build a secure, reliable, control-grade synchrophasor network:

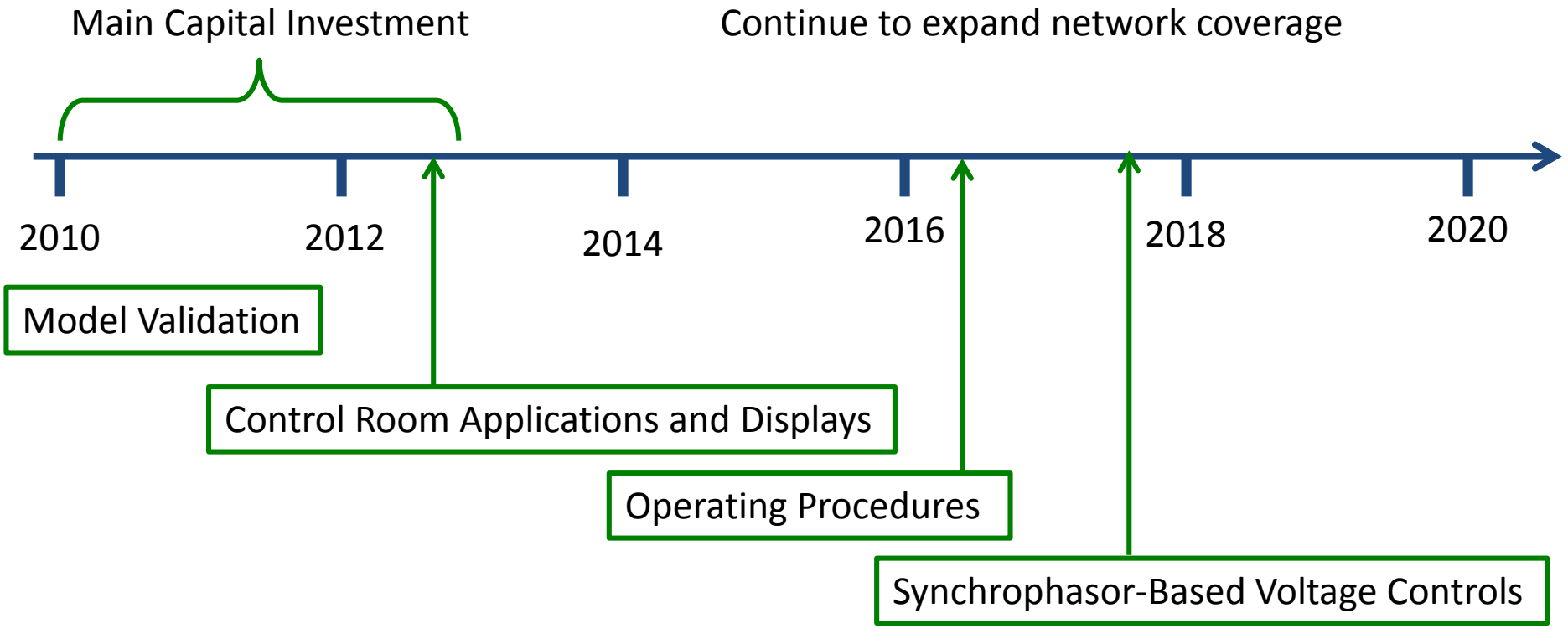
- "Control" PMUs
  - Fully redundant architecture
  - 50 sites
  - 142 PMUs (71 redundant pairs)
- "Data" PMUs
  - 15 wind sites
  - 20 PMUs (non-redundant)
- More than 4,000 signals
- 270,000 measurements per second!!!
- >100 GB of data per day

# Platt's Global Energy Award

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


https://www.bpa.gov/news/newsroom/releases/Documents/20131213-PR-39-13-BPA-wins-Platts-Global-Energy-Award-for-grid-optimization.pdf

# Building on Success




*Linear State Estimator

*PDCI Modulation Controller

*Archive Walker Data Analytics

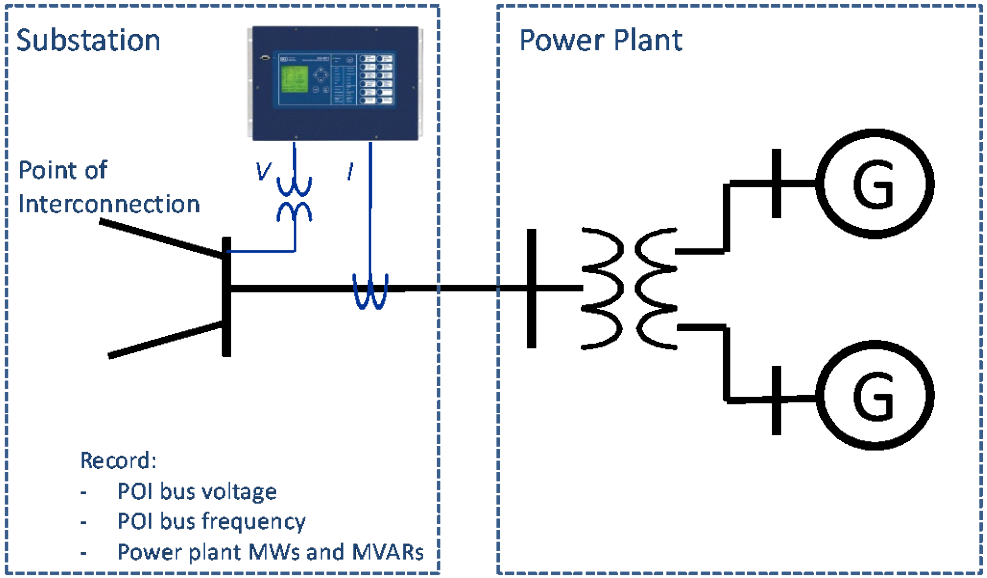
*Big Data Analytics

* Research projects

# Model Validation

# Power Plant Model Validation

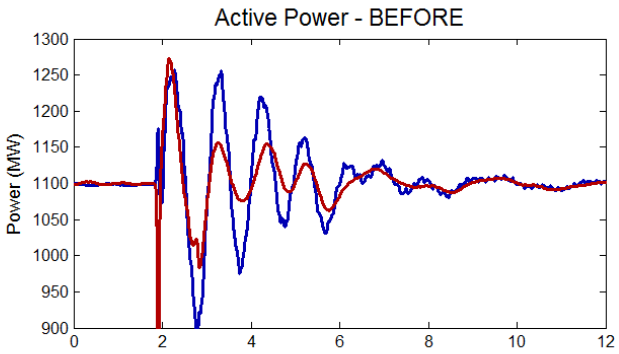
- NERC MOD Standards require verification of power plant models
- Disturbance-based model verification is a cost-effective method of compliance for the Standards
- In 2000, BPA adopted this approach

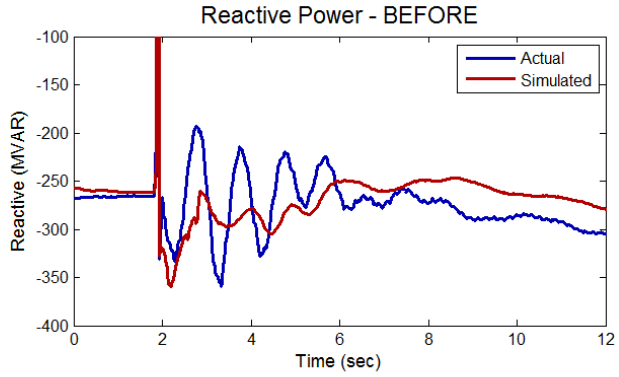



- Today more than 20 GWs of generating capacity have PMU monitoring
- 15 wind power plants have PMUs
- Tools are developed and used to validate and calibrate models

# Power Plant Model Verification and Compliance with MOD-026/27 Standards

BEFORE

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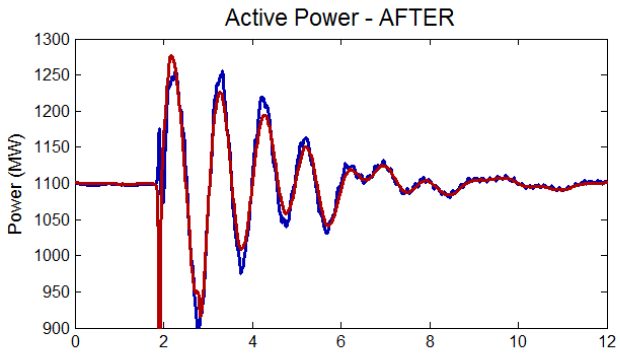
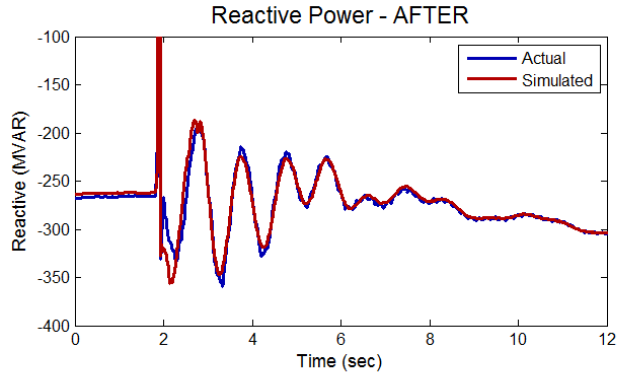
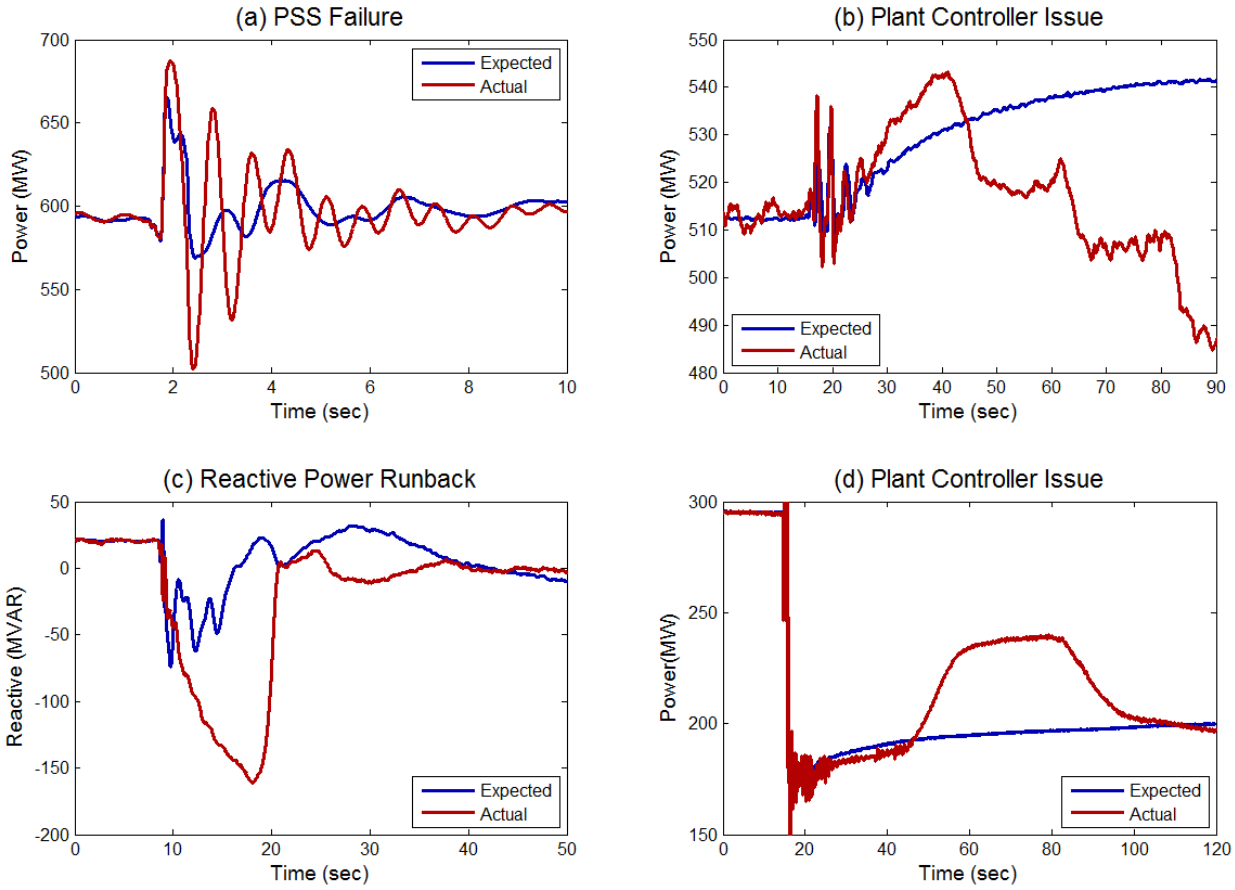


# Power Plant Performance and Condition Monitoring

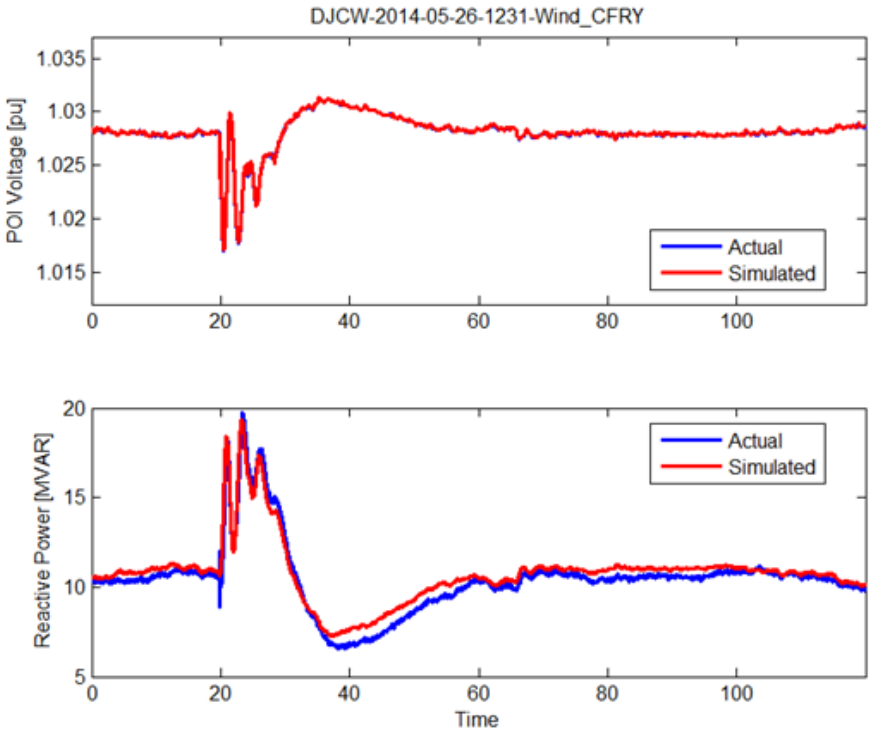
Now, that BPA models have been calibrated and validated, PMU recordings are used as “clinical” health check-up  of generator controls.
PMU-based tools detected several control performance anomalies, a few are shown below:



# Wind Power Plant Monitoring

- BPA has extensive PMU coverage at wind power plants
- BPA has been working with wind generation manufacturers and wind power plant operators on developing wind model data sets
- Significant model improvements have been achieved

2017 NW Wind Power Plant Modeling Workshop: https://transmission.bpa.gov/Business/Operations/GridModeling/default.aspx

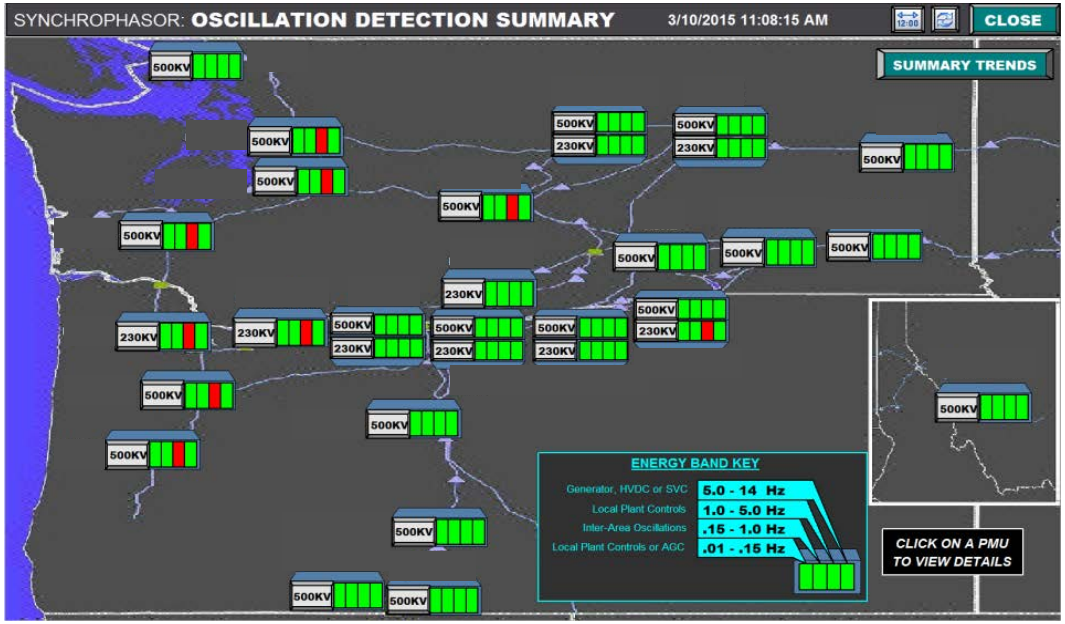


# Control Room

# Control Room: Oscillation Detection

BPA deployed several PMU applications and displays in its control room in October 2013

**Oscillation Detection Application**



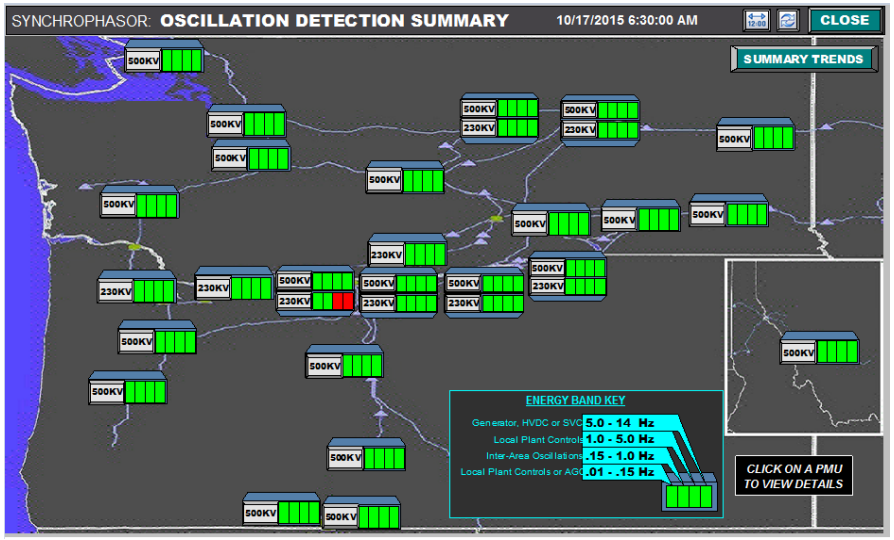

Scans 100+ signals for signs of growing or sustained power oscillations

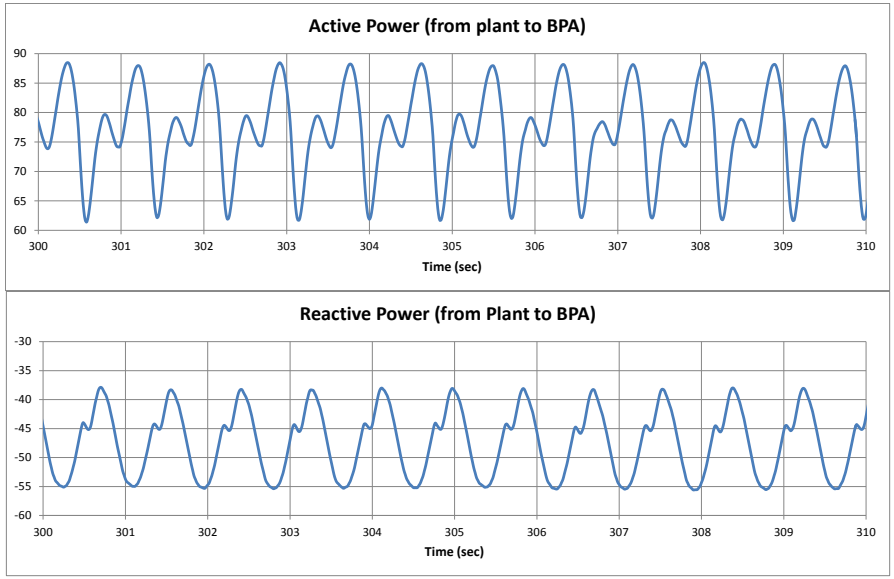
Alarms dispatchers when an oscillation is detected

Several dispatcher training sessions have been performed

Operating procedures went in effect on June 1, 2016

# Oscillation Detection Application Helps Correct Generator Controller Settings




Multiple instances of oscillations were detected at a hydro-power under light load conditions

Oscillation magnitude was as much as 30% of the generator's power

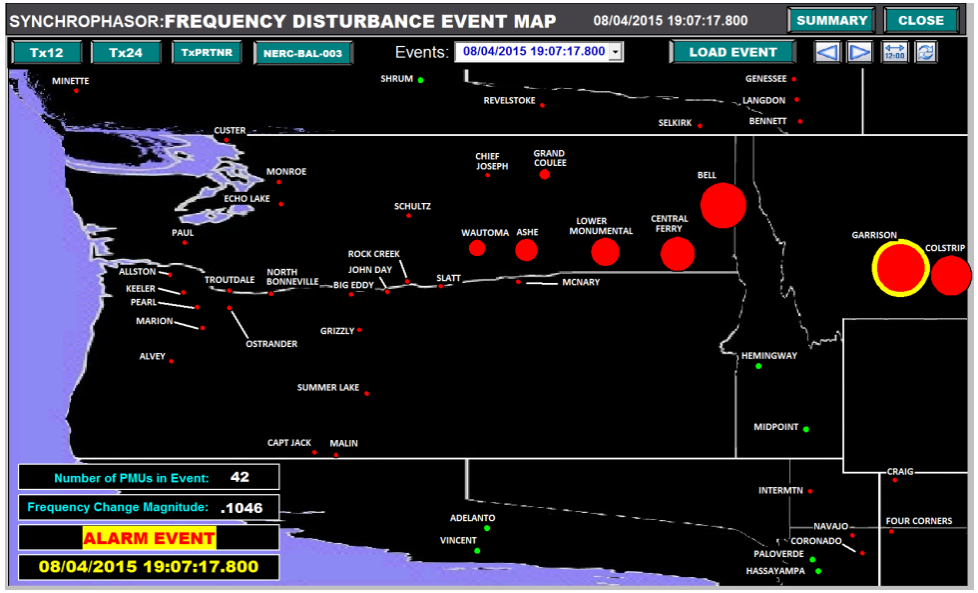
The oscillations are linked to control interactions between generator PSS and UEL

BPA notified plant engineering

UEL was re-tuned, no similar oscillation was detected since

# 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


BPA deployed a suite of applications for frequency response analysis for NERC BAL-003-1 Frequency Response Standard

# Automated Controls

*"It is time to move forward from wide area monitoring to wide area controls"*
-- Vickie VanZandt, 2007

# Automated Voltage Controls

- 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 multiple substations to switch shunt reactors and capacitors
  - And it is all done in less that half a second !!!
- WECC approved the control scheme as a safety net
- In-service since April 2017
- Controls are used to mitigate voltage stability issues associated with dynamic transfers

# Value Proposition

- BPA worked with Alison Silverstein to develop value proposition of BPA investment in the synchrophasor technology (based on NASPI metrics)

Report at:
https://www.bpa.gov/Doing%20Business/TechnologyInnovation/Documents/SYNCHROPHASORS%20AT%20BPA%20Nov%202017.pdf

# Technology Innovation

# Technology Innovation Projects

- BPA is collaborating with National Labs (PNNL and Sandia) on the next generation of synchrophasor applications

- Big Data Analytics – analyzing high volume of synchrophasor data for any early signs of equipment or system issues
  - Successful demonstration of Archive Walker application with Pacific Northwest National Laboratory
  - Distributed computing/storage architecture

- PDCI Modulation Controller to dampen inter-area power oscillations
  - Successful demonstration with Sandia National Laboratory on using PDCI controller to improve damping of north-south power oscillations
  - Considering commercialization

# Distributed Computing

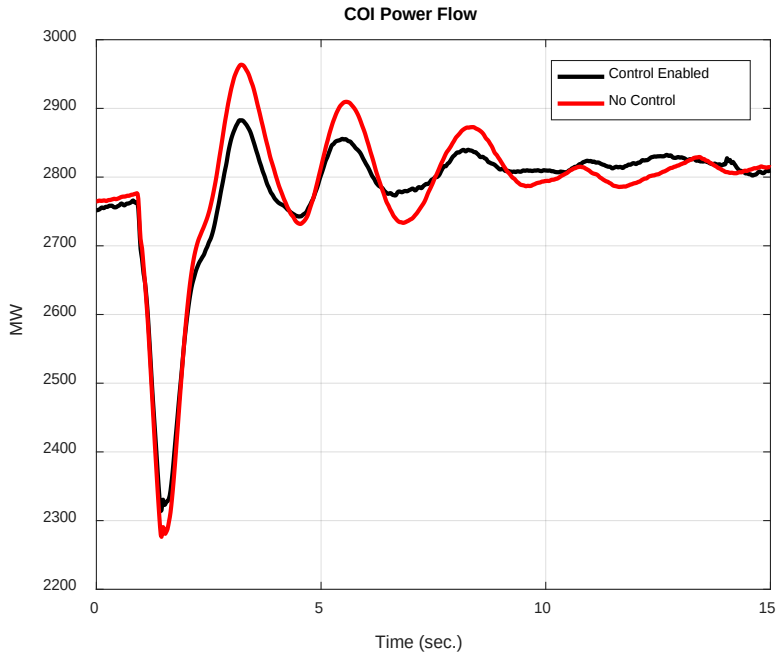
- Process multiple files in parallel on cluster
- Apache Spark computing platform on Linux OS
- Hadoop file structure
  - Hierarchical data format, version 5 (HDF5)
  - Generic time-series information
  - Support for unlimited data types
- Built-in lossless compression
  - 20-25% savings on BPA PMU data

- Performance:
  - Conventional architecture: **1 month of data** processed in 7.5 hours
  - Distributed architecture **1 year of data** processed in 3.6 minutes
  - 150 times improvement !!!

# PDCI Modulation

- Modulation controller and supervisory controls are developed and prototyped as a collaboration between Sandia National Labs, Montana Tech and BPA

- Controls were tested successfully in close-loop operation, including several system tests and a 30-day continuous operation
- Tests show improvement in oscillation damping of about 4%




System test performed with modulation controller enabled and controller off

# BPA Contacts

- Ashley Donahoo – Control Room applications
- Tony Faris (lead) – Synchrophasor Lab, distributed computing
- Dmitry Kosterev – Planning applications and controls
- Gordon Matthews – Technology Innovation Office

# Thank You