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/ FTE for fiscal year 2016 from the FY 2017 Congressional Budget.
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
- 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.
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

Output
RMS Energy

Preprocess→BP Filter→Average Filter→\( \sqrt{\text{Average}} \)→Oscillation Magnitude

Restrict the signal to the particular frequency band
Calculate the RMS Value of the Oscillation

Inputs
Derived Signal
How are oscillations detected?

The magnitude of the oscillation is calculated in 4 frequency bands:

- **BAND 1:** Cause > Local Plant Controls or AGC -- 0.1 Hz
- **BAND 2:** Cause > Inter-Area Oscillations -- 1 Hz shown
- **BAND 3:** Cause > Local Plant Controls -- 5 Hz shown
- **BAND 4:** Cause > Generators, HVDC, SVC -- 14 Hz shown

Oscillation Energy Calculator Module

PMU Measurement (one of 136)
How are oscillations detected?

**Step 2**

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

- 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**

- **Band 1**: Governor, AGC, mechanical
- **Band 2**: Inter-area power oscillations
- **Band 3**: Local oscillations
- **Band 4**: Control-electrical, Torsional, SSR

Oscillation Frequency (Hz)

- 0.1
- 1
- 10

Oscillation Period (sec)

- 10
- 1
- 0.1
- 11
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 1\textsuperscript{st}, 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 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

Power Plant Active Power
Central Oregon Plant Oscillation
Central Oregon Plant Oscillation

SYNCHROPHASOR: OSCILLATION DETECTION SUMMARY

ENERGY BAND KEY
- Generator, HVDC or SVC: 5.0 - 14 Hz
- Local Plant Controls: 1.0 - 5.0 Hz
- Inter-Area Oscillations: 0.15 - 1.0 Hz
- Local Plant Controls or AGC: 0.01 - 0.15 Hz

CLICK ON A PMU TO VIEW DETAILS
Central Oregon Plant Oscillation
Central Oregon Plant Oscillation

![Graph showing Active Power and Reactive Power oscillations over time.](image)
PDCI Oscillation
PDCI Oscillation

500-kV Bus Voltage

Active Power

Reactive Power
Questions