Synchrophasor Technology at BPA: from wide-area monitoring ... to wide-area control
BPA Overview

- Bonneville Power Administration (BPA) is a federal Power Marketing Agency in Pacific Northwest
- BPA markets power from 31 Federal dams and the Columbia Generating Station Nuclear Plant
- 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)
BPA History

• The U.S. Government built Bonneville and Grand Coulee Dams in the 1930s and 1940s.
• Congress created BPA in 1937 to deliver and sell the power from Bonneville Dam.

• Major construction from the 1940s through the 1960s created networks and loops of high-voltage wire touching most parts of BPA's service territory. During that time, Congress authorized BPA to sell and deliver power from more federal dams on the Columbia and its tributaries.

• BPA constructed AC and DC interties between Pacific Northwest and California in late 1960s.

Hydro generation powered aluminum plants in the Northwest during WWII.
About BPA

• About one-third of the power consumed in the Pacific Northwest comes from BPA. Northwest utilities and a few large industries buy BPA power; utilities resell it to homes, businesses, and other consumers.

• BPA operates and owns one of the nation’s largest high voltage transmission systems 15,000 miles of transmission, including 4,735 miles of 500-kV lines

• BPA includes:
  – Power Services
  – Transmission Services
  – Energy Efficiency
  – Fish and Wildlife

• Dams and power plants are operated by US Army Corps of Engineers and US Bureau of Reclamation (Grand Coulee Dam)

• Interested in a job at BPA? Visit www.usajobs.gov
Syncrophasor Technology

- Synchrophasors are precise time-synchronized measurements system voltages, frequencies, power, currents and angles
- Synchrophasors provide an unprecedented wide-area view of the power system dynamic state
- Every modern digital relay is PMU-capable

### Phasor Measurement Units vs Conventional SCADA

<table>
<thead>
<tr>
<th>Phasor Measurement Units</th>
<th>Conventional SCADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>High time resolution: 30 to 120 samples per second</td>
<td>Scanned every 2 to 4 seconds</td>
</tr>
<tr>
<td>Data is time synchronized at the source</td>
<td>Time stamped in the control center</td>
</tr>
</tbody>
</table>
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
2010 Synchrophasor Investment Project

BPA initiated a capital investment project in 2010 to build a secure and reliable synchrophasor network:

- 5-year, $35M project
- Part of DOE Smart Grid Program

- “Control” PMUs
  - Fully redundant architecture
  - 32 substations
  - 110 PMUs (55 redundant pairs)
- “Data” PMUs
  - 15 wind sites
- Total of 3,322 signals
Western Interconnection Synchrophasor Program

BPA project is a key part of Western Interconnection Synchrophasor Program (WISP), a $108+M investment managed and led by Peak RC

Interconnection-wide visibility

19 participants exchanging real-time data

BPA receives streaming PMU data from 12 other utilities (total of 752 signals)

BPA sends its data to 8 other operating entities, including California ISO and Peak RC
Transmission Smart Grid: US DOE Stimulus for PMUs

- **WECC WISP**: 300+ PMUs ($108M): *WECC RC, PG&E, BPA, SCE, CISO, PAC, SRP, IPC, NVE*
- **PJM**: 90 PMUs ($28M)
- **NY ISO**: 35 PMUs ($74M)
- **MISO**: 150 PMUs ($35M)
- **ATC**: 5 PMUs ($28M)
- **Entergy**: 18 PMUs ($10M)
- **ISO New England**: 30 PMUs ($9M)
- **Duke Energy**: 45 PMUs ($8M)
- **Midwest Energy**: 1 sub ($1.5M)

Source: NASPI (www.naspi.org)
Typical Control Room Architecture

- **Phasor Data Concentrator***
  - Utility PMUs
  - 54 PMUs, 60sps
  - WISP Phasor Gateway
  - Wide-Area Network Inter-utility Data Exchange
  - 2sec

- **Historian**
  - ~18 Kmps

- **Application Server**
  - ~200 Kmps

- **Energy Management System**
  - Alarms

- **Client Visualization**
Western Interconnection Synchrophasor Program

19 participants exchanging data on WISP WAN
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
  • Five Application displays on dispatcher video wall (Oscillation Detection, Mode Meter, Islanding Detection, MW flow, Frequency disturbance)
  • State estimation

• **Wide-Area Controls**
Engineering: Model Validation

- WECC and BPA has 17+ year history of power plant model validation using PMU data
- Cost-effective method of compliance with NERC MOD Reliability Standards

- Improved model accuracy, leading to better planning and operational decisions
- Today more than 20 GW of generating capacity have PMU monitoring
- BPA expanded model validation to wind generation
Engineering: System Model Validation

- Accurate power system models are required for reliable and economic power system operations.
- Periodic system model validation against system events is required to ensure models are accurate and up to date.

Western interconnection models in 2015:
- much better

- Peak RC constructs an interconnection-wide power system model based on real-time state estimator data.
- Peak RC, WECC and BPA has started performing regular model validation studies.
- PMU data is used for model validation.
Engineering: Detecting Control Abnormalities

PMU monitoring provides detection of generator control abnormalities

Stabilizer failure

Unexpected action from plant MW controller

Abnormal runback in reactive power
Engineering: Oscillation Analysis

Power systems oscillate

(a) High resolution

(b) synchronized

and (c) wide-area PMU data is required for understanding oscillation risks and developing detection tools and counter-measures

California – Oregon Intertie

Montana - Northwest Intertie
BPA perform system tests three times per year to stimulate power oscillations under controlled conditions.

1,400 MW braking resistor is applied for half a second to “ping” the power system.

Wide-area data is analyzed to understand the inter-actions among the generators in the Western Interconnection.
Control Room: Oscillation Detection

BPA deployed Oscillation Detection in its control room in October 2013

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

Alarms dispatchers when an oscillation is detected

Dispatcher training sessions are performed
Oscillation Detection Success Stories

BPA detected sustained power oscillations coming from a wind power plant when power output reached about 90% of plant capacity

BPA worked with plant owner and wind turbine manufacturer to fix the problem

Wind Ramp Before

80 MVAR peak to peak oscillation

Wind Ramp After
Control Room: Frequency Event Detection

BPA deployed Frequency Event Detection in its control room in 2014

Frequency and power charts are auto-generated

Map shows where frequency event originated
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 several substations to switch shunt reactors and capacitors
  • And it is all done in less that half a second !!!

• WECC approved the synchrophasor control scheme as a safety net

• Scheduled to be in service in 2016
Leading Edge Research: PDCI Modulation

- BPA Technology Innovation Office sponsors a joint project with DOE and Sandia NL to demonstrate active power modulation to dampen the inter-area power oscillations
- Modulate power of Pacific DC Intertie to dampen North-South oscillations on Pacific AC Intertie
- **DO NO HARM** is the paramount principle
Changing Nature of Electrical Loads

- Resistive Cooking
- Resistive Heating
- Incandescent Lighting
- Distributed Generation
- Power Electronics
- Data Centers
- AC and Heat Pumps
- EV Chargers
Next Frontier: Distribution Monitoring

Synchro-phasor data help transmission planners better understand the implications of changing electrical loads, so that they can make timely and appropriate capital investments.

Delayed voltage recovery due to residential air-conditioner stalling during a transmission fault.

Load Model development in the West

DOE sponsors efforts to deploy disturbance monitoring equipment in distribution systems to better understand load and DG impact on system stability.

Point-on-wave data is required.
Future Research Needs

Big Data Analytics – analyzing high volume of synchrophasor data for any early signs of equipment or system issues

Moving from post-event analysis to predictive applications

Building intelligence and situational awareness levels

Wide-area controls
Platt’s Global Energy Award

International recognition:

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