by Joel Scruggs

Synchrophasor breakthroughs mark quantum leap in grid reliability

On September 8, 2011, grid operators didn't realize what was happening until it was too late. In just 11 minutes, an outage in Arizona triggered a series of events on five separate power systems that left nearly 7 million people across much of Southern California and western Arizona in the dark. A lack of information sharing among transmission operators was one of the causes cited for the blackout.

A few years after the largest blackout in California history, smart-grid devices known as phasor measurement units, or synchrophasors, are opening the eyes of grid operators across the West. And engineers at the Bonneville Power Administration (BPA) are taking the technology to new levels.

PMUs are shoebox-sized devices that take precise current, frequency, and voltage readings that are time-stamped using GPS. They crank out power system parameters 100 times faster than the industry standard supervisory control and data acquisition (SCADA) systems, which produce readings every two to four seconds. This massive boost in resolution is akin to making the technology leap from black-and-white to ultra-high-definition television.

In 2013, BPA completed the build out of the largest, most sophisticated synchrophasor network in North America as part of a three-year, $32 million investment to enhance the Northwest's generation and transmission systems. The network includes 126 PMUs at 50 substations and wind generation sites that transmit 60 times a second over a high-speed broadband network to BPA's control centers. The result is a hyper-feed of power system data that provides BPA operators real-time intelligence so they can react more quickly to system disturbances and take actions to avoid a blackout or prevent a disturbance from cascading.

"It gives us an unprecedented view of the dynamic state of the Northwest power system and significantly improves our wide-area situational awareness," said Richard Shaheen, senior vice president of Transmission Services.

BPA was the largest contributor to the Western Interconnection Synchrophasor Program (WISP), in which 19 utilities partnered with the Department of Energy to build a network of more than 600 PMUs across the western grid. Today, through a dedicated, secure network, BPA shares synchrophasor data with 11 utilities, furthering the understanding of the status and condition of the interconnection well beyond BPA's borders.

"It was a true industry game-changer," said Vickie VanZandt, WISP synchrophasor program manager and former senior vice president of Transmission Services at BPA. "Not only did BPA and its WISP partners make the Western Interconnection more reliable and secure, they facilitated a whole new level of cooperation."

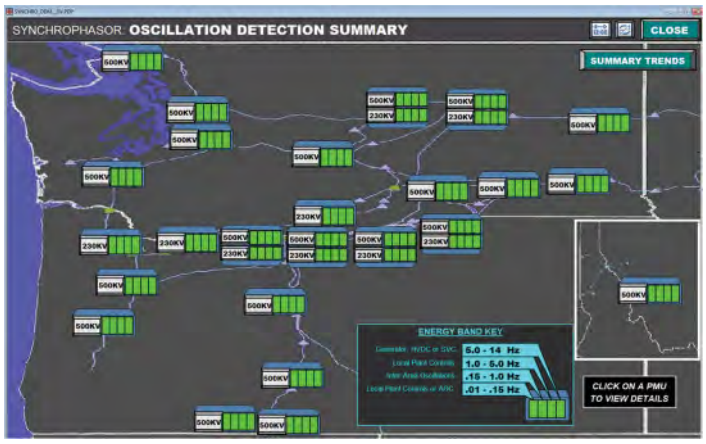
The outcome is a clearer view of all the transmission systems from Canada to Mexico.

"Now our operators can see more precisely how all the interconnected power systems in the West are responding to changes and disturbances in the grid," said engineer Nick Leitschuh, project manager for synchrophasor applications in BPA's control centers.

In 2013, BPA completed the build out of the largest, most sophisticated synchrophasor network in North America. It now receives readings from 126 phasor measurement units at 50 key substations and large wind generation sites, giving operators a more dynamic view of the Northwest power system. Photos provided by BPA.

BPA operates the only fully redundant synchrophasor network in the West. With at least two PMUs at each site and an encrypted data link between its control centers, two streams of data are always available. So if one stream is interrupted or erroneous, the system automatically uses the other feed.

At 200,000 measurements per second, BPA accumulates terabytes of power system data every month. Because there weren't any suitable off-the-shelf products, BPA engineers developed tools and techniques to manage and analyze the avalanche of real-time data. In-house applications, operating on a subset of the data, run a suite of customizable, real-time analytics and visualization displays.



Low-frequency power variations can make the grid unstable, limit the transfer of power, and even cause system separation if they go unchecked. BPA's oscillation detection application monitors 136 synchrophasor measurements for excessive oscillations on the system.

BPA has also been an industry leader in using disturbance recordings for power plant model validation and performance monitoring. With a quick glance at a display, BPA staff monitors the dynamic performance of 115 power generators connected to its system. This visibility allows BPA to detect a failure before it escalates into a system-wide disturbance. Furthermore, BPA discovered that synchrophasors can be used to validate the actual performance of a generator unit against its modeled performance. That can avoid the need to take generating units offline to run costly baseline tests.

"We can use synchrophasor data to validate and calibrate dynamic models," said Dmitry Kosterev, a BPA electrical engineer. "That means we can avoid staged tests and reduce the costs of compliance with NERC [North American Electric Reliability Corporation] reliability standards."

Scaled up, the synchrophasor method of testing without taking the units offline could unlock hundreds of millions of dollars in revenue lost during such testing. BPA is also leading industry outreach with its model validation application by sharing the application and knowledge with other utilities in the Western Interconnection.

With more than 4,500 megawatts of wind-generating capacity connected to its grid, another focus for BPA is improving dynamic monitoring of wind generation facilities. To date, BPA has installed PMUs at nine wind plants and is partnering with DOE and the Utility Wind Integration Group in data analysis. In one case, the monitoring uncovered a performance issue that could have damaged a wind turbine if left unaddressed. The turbine blades had been continually tilting back and forth for six hours, causing unnecessary wear and tear on the equipment and diminishing its efficiency.

Another benefit of synchrophasor technology is the detection of power oscillations. Low-frequency power variations among parts of the interconnection can make the grid unstable, limit the transfer of power, and even cause system separation if they go unchecked. BPA's oscillation detection application monitors 136 synchrophasor measurements for excessive oscillations on the system. While BPA expects the detection capability will help operators avoid at least one large-scale outage in the next 40 years, it has already detected a handful of significant oscillations. In October, PMU data pointed BPA engineers to a local oscillation at a hydropower plant. At partial loads, hydro generators go through a "rough zone" that lasts 15 to 30 seconds during loading and unloading. BPA noticed a generator was continuously operating in the "rough zone," which can cause earthquake-like shaking around the unit and lead to additional wear and tear or even catastrophic failure.

"Our dispatcher contacted the plant owner, who was unaware of the controller error problem," Leitschuh explained.

BPA continues to expand the use of synchrophasors. Recently, engineers introduced a new application that identifies the sources of frequency disturbances (abrupt drops or increases from 60 hertz) in the Western Electricity Coordinating Council (WECC) service territory. This lets dispatchers know if a disturbance, such as a generator or line loss, originated inside or outside of BPA's balancing area. By the end of next September, BPA expects to launch new remedial action schemes (RAS) using synchrophasor measurements to trigger uncommanded operation of equipment on the system. This advance could result in an additional 100 megawatts of voltage stability margin on the interties, reduce the required amount of load shedding, and minimize the outage area in the event of a fault. Another goal is to set up a formal notification process for alerting generator owners to oscillation issues.

"We have the only synchrophasor network in the country designed to take split-second actions when a problem is detected," said Lawrence Carter, electrical engineer and senior project manager of BPA's synchrophasor program. "Eventually, we will use PMU measurements to initiate automatic protective measures that would prevent or limit outages."

With its PMU coverage, BPA's better equipped to respond to disturbances and equipment failures than ever before, ultimately improving grid reliability, utilization of transmission assets, and enabling better integration of renewable generation.

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