Synchrophasor Technology and the DOE

By Phil Overholt, David Ortiz, and Alison Silverstein

SYNCHROPHASOR TECHNOLOGY HAS GROWN from a handful of phasor measurement units (PMUs) in the U.S. Pacific Northwest to a continental network of almost 2,000 PMUs in the past decade, which has helped to improve reliability of the North American electric bulk power grid. This progress is due in large part to research and deployment investments that the U.S. Department of Energy (DOE) has been making since the late 1990s to accelerate the development, adoption, and maturity of this valuable technology. The DOE's early vision was that better real-time tools could improve grid reliability and prevent blackouts; today, the entire industry recognizes that synchrophasor technology can improve grid planning and investment decisions, enhance operational reliability, facilitate renewables integration, and reduce many operating and asset costs.

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Digital Object Identifier 10.1109/MPE.2015.2431211
Date of publication: 18 August 2015

The DOE's investments in synchrophasor technology have demonstrated a strong set of uses, bringing the value of PMUs to light. These investments, combined with extensive industry effort, have produced technical standards and built a community of synchrophasor users and adherents through the North American Synchrophasor Initiative (NASPI).

Early Research Initiatives

The DOE, the Electric Power Research Institute (EPRI), the Bonneville Power Administration, and the Western Area Power Administration funded and hosted the first PMU-based wide-area measurement and monitoring system (WAMS) in the 1990s to enhance real-time situational awareness. The DOE then provided continuing funding to develop several key applications, including tools for more sophisticated real-time WAMS, mode monitoring, oscillation detection, and pattern recognition tools.

Exciting Opportunities Lie Ahead in Development and Deployment

The United States–Canada blackout of 2003 was a stark reminder of the need for better situational awareness into the bulk electric system. After the 2003 blackout investigation report recommended the deployment of synchrophasor technology to help prevent future occurrences, the DOE redoubled its investments in synchrophasor R&D and formed the Eastern Interconnection Phasor Project (EIPP) in 2003 to focus early industry efforts. These activities were coordinated by the Consortium for Electric Reliability Technology Solutions. (The Consortium for Electric Reliability Technology Solutions, http://certs.lbl.gov, is a national laboratory, university, and industry research consortium that was formed in 1998.) The DOE also funded a synchrometrology laboratory at the National Institute for Standards and Technology (NIST), to perform PMU testing. Between 2005 and 2014, the DOE funded over US$65 million in research, development, and demonstration projects to advance phasor data analytical tools, automated controls using phasor data, and synchrophasor communications network design.

Deploying Devices and Networks

In 2009, there were fewer than 500 research-grade PMUs installed across North America's transmission grid. Few were networked to deliver real-time data, and none were used for real-time situational awareness. Today, thanks to private industry and federal investments (see Figure 1), there are almost 2,000 commercial-grade PMUs installed across the continent, delivering real-time grid condition data into control rooms and engineering applications.

The rapid advances in PMU capability, availability, and connectivity were all spurred in 2009 by the American Reinvestment and Recovery Act, which funded federal Smart Grid Investment Grants and Smart Grid Demonstration Projects with matching private funds. Eleven of these projects, involving over 80 utilities and reliability coordinators, focused on deploying PMUs and synchrophasor applications and communications systems; another two projects included PMUs among a broader suite of transmission and distribution automation efforts. These projects committed over US$325 million in direct federal and private funds to PMU technology. And since those initial commitments were made, private sector investments in synchrophasor technology have grown markedly.

Together, these synchrophasor projects led to a common set of requirements for PMU performance and created "market pull" for vendors to create new devices to meet those performance requirements. They tested much of the NASPI synchrophasor technology road map, created synchrophasor communications networks across much of the nation, established a cybersecurity foundation for these networks,

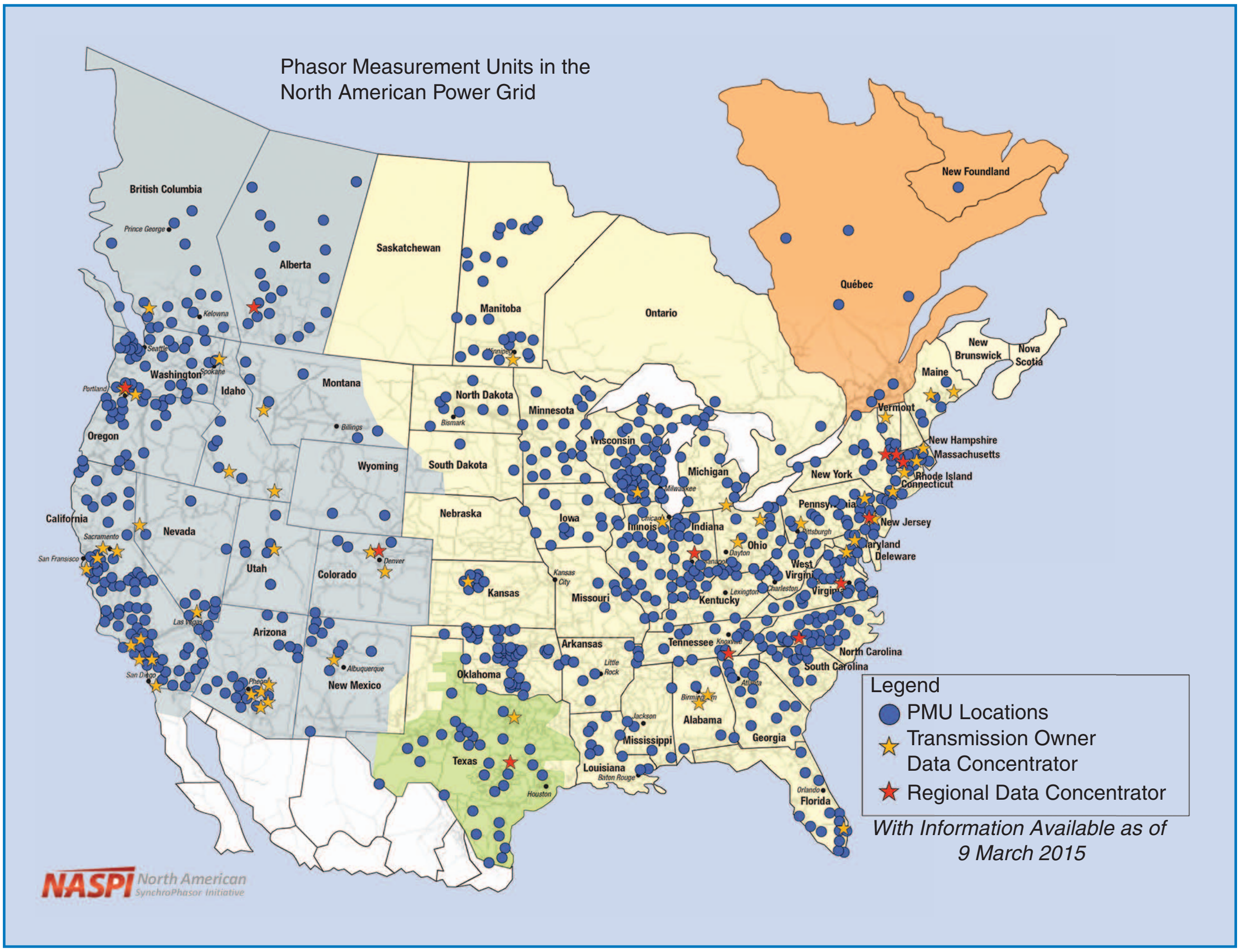

figure 1. Phasor measurement units in the North American grid. (Source: North American Synchrophasor Initiative, March 2015, used with permission.)

and funded the development and adoption of analytical tools to use high-speed PMU data in high-value ways.

The DOE's R&D efforts have continued. In 2014, the DOE awarded US$10.65 million to six utility and reliability coordinator partners for synchrophasor projects that will move precommercial applications to production-grade tools within two years. Current synchrophasor R&D priorities include demonstrating the value of synchrophasor technology for asset owners, using "big data" techniques on PMU data for pattern recognition and grid condition baselining, assuring end-to-end data quality of delivered PMU data, and moving more synchrophasor applications into trusted use in North American control rooms and planning departments.

It Takes a Village...

The DOE also has been investing in the institutional side of technology adoption. In 2007, the DOE and the North American Electric Reliability Corporation created NASPI from the EIPP. NASPI, which began with 150 members across the United States and Canada, is a collaborative effort with industry, academia, and vendors to foster the development and adoption of synchrophasor technology. Today the group has over 1,000 members, and its semiannual meetings draw attendees and presentations from North America, South America, Europe, and Asia.

It was clear to NASPI members early on that an interconnection-wide information system would need an interoperable communications network and interoperable technical standards. To that end, NASPI members worked with the DOE and federally funded researchers to develop a network architecture, NASPInet, to guide future synchrophasor data communications. Several of the synchrophasor smart grid projects implemented use these NASPInet concepts today.

One of the DOE's most effective technology acceleration measures was to expedite the development of technical interoperability standards. Beginning in 2007, NASPI members began working to update IEEE Standard 37.118-2005 and other key standards. In 2009, the DOE awarded US$10 million in Recovery Act funds to NIST to develop a smart grid interoperability framework and protocols for all smart grid devices and systems. NASPI members led and participated in the NIST-coordinated effort that addressed synchrophasor standards. Today NASPI members have

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created, and the IEEE and International Electrotechnical Commission (IEC) have adopted, a suite of standards and guides covering synchrophasors, including PMU functionality for static and dynamic measurements, PMU data, phasor accuracy, phasor data concentrator functions, PMU testing, and time synchronization.

NASPI works to build a community of knowledge around synchrophasor technology. Its members are generous in sharing their time and information about synchrophasor technology successes and lessons learned. NASPI has identified obstacles to advancing synchrophasor technologies and applications and worked to build consensus around effective, objective solutions to technical and commercial challenges. The group has tackled the challenges of cybersecurity, GPS timing vulnerability, and delivered data quality. NASPI and its members document and share information within and outside the community, offering technical workshops and tutorials on IEC 61850 (substation automation); synchrophasor-based model validation; the use of synchrophasor data to measure renewable resource performance; comparing synchrophasor-based tools for grid visualization, oscillation detection, and voltage stability; and using PMU data for state estimation.

The U.S. national laboratories are leaders in many aspects and uses of synchrophasor technology. The Pacific Northwest National Laboratory provides technical and administrative assistance to NASPI and hosts its website (www.naspi.org). In 2014, the DOE assumed NASPI funding from NERC, with logistical assistance from EPRI.

Synchrophasor technology, with its links to high-speed communications networking, advanced analytics, and big data applications, is an appealing topic for young engineering students, and in 2012 the DOE issued grants to seven universities for synchrophasor education. That same year, the National Science Foundation and the DOE created the Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks (CURENT) at the University of Tennessee, Knoxville, which is conducting extensive research and education on synchrophasors and related topics.

Realizing the Value of Synchrophasor Investments

Thanks to the long-standing partnership between the private sector and the DOE to advance synchrophasor technology, this young technology (by industry standards) is already yielding great value for the grid. PMU data are being integrated into wide-area visualization tools and state estimators to enhance situational awareness and grid reliability. PMU-based oscillation detection and voltage stability tools are operational in many control rooms, where they can inform alarms and alerts, limit-setting, and real-time event responses. In some cases these synchrophasor-based limits allow greater use of existing assets without compromising reliability.

PMU applications are creating enduring value. Static and dynamic power plant and grid models validated with synchrophasor data can be updated continuously, avoiding costly power plant testing. These model-validation efforts are also creating insights into how intermittent resources interact with the bulk power system so operators and engineers can integrate the renewables with greater reliability and lower cost. And PMU data are widely recognized for revolutionizing forensic analysis of grid events, enabling investigators to determine “what happened” within hours rather than months of the incident.

Researchers are beginning to look at PMU data to spot “signatures” of equipment misoperation and imminent failure, which help to avert costly and damaging equipment failures and customer outages. Others are investigating how to use PMU data for early indicators of ground-induced currents from geomagnetic disturbances, which would enable more proactive asset management to protect the grid against geomagnetic overload. And the DOE is funding several efforts to look at how PMUs could be used for monitoring, insight, and control at the distribution level as well as transmission.

Thanks to the accelerated development and deployment of synchrophasor technology, the electric industry is realizing real improvements in grid reliability and efficiency. Many exciting value opportunities lie ahead.

For Further Reading

NASPI. (2015, 29 June). [Online]. Available: http://www.naspi.org

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