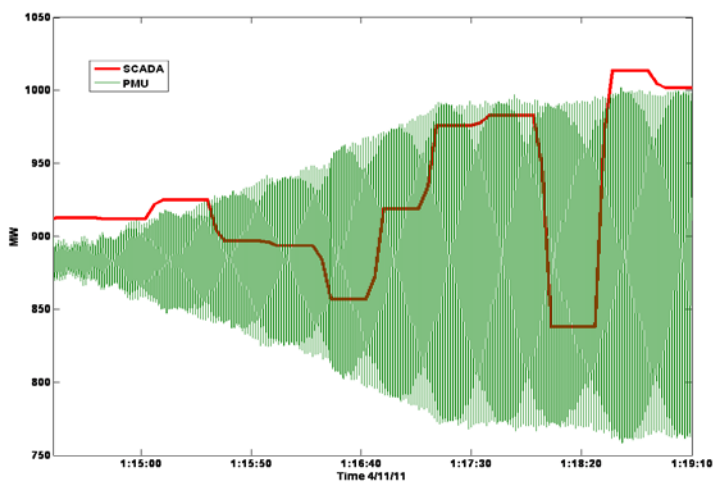
SYNCHROPHASOR TECHNOLOGY FACT SHEET

A synchrophasor is a time-synchronized measurement of a quantity described by a phasor. Like a vector, a phasor has magnitude and phase information. Devices called phasor measurement units (PMU) measure voltage and current and with these measurements calculate parameters such as frequency and phase angle. Data reporting rates are typically 30 to 60 records per second, and may be higher; in contrast, current supervisory control and data acquisition (SCADA) systems often report data every four to six seconds – over a hundred times slower than PMUs.

PMU measurements are time-stamped to an accuracy of a microsecond, synchronized using the timing signal available from global positioning system (GPS) satellites or other equivalent time sources. Measurements taken by PMUs in different locations are therefore accurately synchronized with each other and can be time-aligned, allowing the relative phase angles between different points in the system to be determined as directly-measured quantities. Synchrophasor measurements can thus be combined to provide a precise and comprehensive "view" of an entire interconnection.

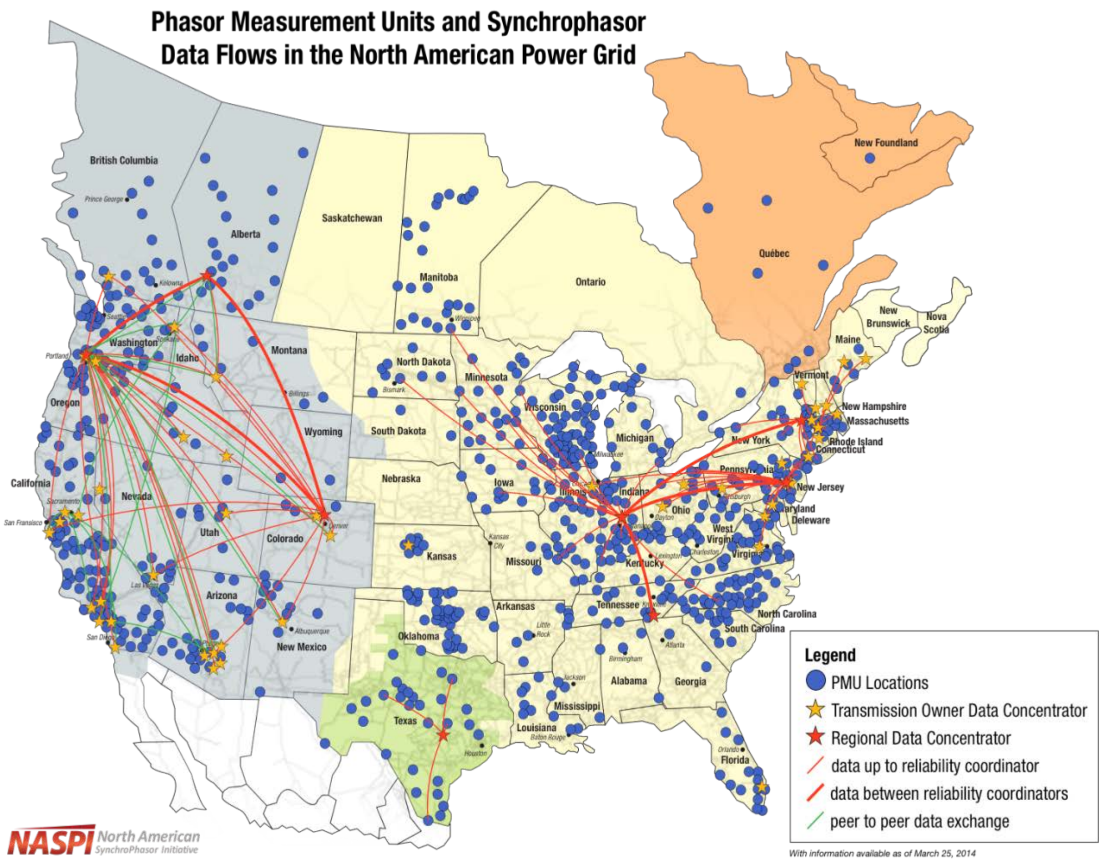
The accurate time resolution of synchrophasor measurements allows unprecedented visibility into system conditions, including rapid identification of details such as oscillations and voltage instability that cannot be seen from SCADA measurements. Complex data networks and sophisticated data analytics and applications convert PMU field data into high-value operational and planning information.

Power plant un-damped oscillations



PMU Deployments and the Federal ARRA Grants

In 2009, there were only 200 research-grade PMUs networked across North America. Today there are almost 1,700 production-grade PMUs deployed across the U.S. and Canada, streaming data and providing almost 100% visibility into the bulk power system. Most were installed using $165 million in federal grants authorized by the American Recovery and Reinvestment Act of 2009, matched by private industry funds. The DOE and industry investments also funded installation of high-speed synchrophasor data networks, development of technology interoperability standards for PMU measurement, functionality and data formats. At the same time, DOE funded a variety of R&D projects to develop advanced synchrophasor data applications and analysis tools.



Principal applications and benefits of synchrophasor technology

<u>Situational awareness and wide-area monitoring</u>: The network of PMUs enable grid operators to see the bulk power system across an entire interconnection, understand grid conditions in real time, and diagnose and react to emerging problems. Analysts believe that synchrophasor-enabled visibility could have prevented the 2003 Northeast and the 1996 Western blackouts. As synchrophasor data quality improves, those data are being integrated

into some existing control room visualization tools based on EMS and SCADA data, gaining acceptance for synchrophasor-enhanced wide-area monitoring.

Real-time operations: Synchrophasor data is being used to improve state estimator models for better understanding of real-time grid conditions. It is being used to detect and address grid oscillations and voltage instability, and integrated with SCADA and EMS data to drive real-time alarms and alerts. Analysts are looking at PMU data to expedite resolution of operating events such as fault location, and quickly diagnose equipment problems such as failing instrument transformers and system imbalances.

More advanced applications use PMU data as an input to Special Protection Systems (SPS) or Remedial Action Schemes (RAS), and can trigger automated equipment controls. PMU data can be used to monitor and manage system islanding and black-start restoration. ERCOT is using PMUs to verify customers' performance in demand response events.

Power system planning: Good dynamic models allow a better understanding of how power systems respond to grid disturbances; better prediction enables better system planning with better grid and financial asset utilization. Synchrophasor data are particularly useful for validating and calibrating models of power plants, FACTS devices and other grid equipment, letting generators and grid operators comply with NERC Modeling standards with better results at lower cost. These data are also being used to improve system models, calibrating state estimators and dynamic system models and simulations. The Western Interconnection of North America has been a leader in using synchrophasor data for planning applications.

Forensic event analysis: Phasor data is invaluable for post-event analysis of disturbances and blackouts. Because synchrophasor data is time-stamped, it can be used to quickly determine the sequence of events in a grid disturbance, and facilitate better model analysis and reconstruction of the disturbance. These enable a faster and deeper understanding of the disturbance causes and inform development of ways to avert such events in the future.

Synchrophasor System Elements

A synchrophasor system begins in the substation. PMUs there collect real-time data, usually from existing potential and current transformers. The PMUs are connected to a high-speed communications system to deliver the data to a phasor data concentrator (PDC). Typically, the PDC performs a number of functions that reject bad data, and package the incoming data into sets based on the time-stamp. The data at the PDC are then relayed on a high-speed wide-area communications network to a higher-capability PDC. PDCs typically feed the aggregated data received into a data archive, and to analytical applications such as wide- area visualization tools, state estimators, and alarm processors. The details of these installations can vary greatly, depending on the complexity and scale of the synchrophasor system, and application requirements dictate the rigor of system redundancy, cyber-security, and other implementation details.

Today PMUs are deployed primarily on the transmission system, but the industry is beginning to explore the use of PMUs at the distribution level for power quality, demand response, microgrid operation, distributed generation integration, and enhanced distribution system visibility.

The international engineering community has recently adopted several key technical interoperability standards pertaining to synchrophasor technology, including IEEE C37.118.1 (phasor measurement units and synchrophasor measurements), IEEE C37.118.2 and IEC 61850-90-5 (synchrophasor data communications and protocols), IEEE PC 37.244 (phasor data concentrator requirements), IEEE C37.238 (use of PTP over Ethernet for power system applications), and IEEE 27.242 (guide for PMU synchronization, testing, and calibration).

The NASPI Task Force on Testing and Certification has recommended that users of synchrophasor measurements require that the PMUs producing those measurements be certified compliant with IEEE C37.118.1. The IEEE Standards Association has developed a synchrophasor conformity assessment program for testing PMU compliance with respect to the IEEE standard.

International synchrophasor technology use

Several nations began deploying PMUs in the 2000s, including several European Transmission System Operators, the Nordic System, and several Latin American utilities. China has built an extensive synchrophasor system in combination with its high voltage power grid and generation build-out, using thie synchrophasor system for wide-area monitoring and dynamic security control. In India, the Power System Operation Corporation Ltd. is building a national-scale wide-area monitoring system with over 1,700 PMUs that will feed a broad suite of real-time grid security applications and off-line uses.

North American SynchroPhasor Initiative

NASPI brings together the utility industry, manufacturers and vendors, academia, national laboratories, government experts and standards-making bodies. This large volunteer community dedicated to synchrophasor technology advancement has collaborated to address and solve technical, institutional, standards development, and other strategic issues and obstacles. NASPI works to accelerate the maturity and capabilities of synchrophasor technology, to improve the reliability and efficiency of the bulk power system. The NASPI Work Group meets twice a year, with financial support from the United States Department of Energy and the Electric Power Research Institute. NASPI has compiled a large collection of synchrophasor resource information and success stories from North American and international sources, available at www.naspi.org.

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Image sources: Map -- NASPI; oscillation -- Dominion Virginia Power; photo -- BPA