# How Does the Smart Grid Measure Up?

## *Metrology Research at NIST Looks for Answers*

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While the electric grid was hailed by the National Academy of Engineering as the greatest engineering achievement of the 20th century, more work remains to modernize the grid to meet the increasing demands of the 21st century economy for cost-effective, highly reliable, resilient, and sustainable electric energy.

The existing U.S. electric power grid is a complex and fragmented assembly of systems and operators. With a collective infrastructure investment of more than $1 trillion, the grid is operated by approximately 3,200 electric utilities, delivering power to over 140 million customers, with equipment and systems provided by hundreds of suppliers. Adding to this complexity are the broad and diverse range of stakeholders, regulatory oversight at the federal and state levels, and the intricate and intertwined markets that influence the flow of energy.

Our present grid system is designed to meet infrequent peak demands and operates at roughly 50 percent system load factor on average, with room for improvement. The reliability of the U.S. grid is less robust than that of some other developed countries, imposing an estimated $80 billion to $100 billion in yearly economic losses to the U.S. economy.

Last year's Superstorm Sandy showed us that grid resiliency must be improved, so that operations can be quickly and systematically restored after widespread outages. Electricity generation accounts for 40 percent of human-caused $CO_2$ emissions, and renewable energy portfolio standards have been enacted in a majority of states to drive more sustainable, clean generation. However, the integration of significant amounts of intermittent renewable energy sources, such as wind and solar, into the electric grid will require a much more dynamic system.

## New Measurement for New System

"Smart Grid" and "grid modernization" are shorthand ways of referring to the electric industry's evolving plans to upgrade the grid infrastructure and address these challenging problems. The big new idea underlying the Smart Grid is the integration of new distributed intelligence, communications, and control technologies into the power grid. The long-term result will be a system of systems that enables two-way flows of energy and information, with communication and control capabilities that will lead to an array of new functionalities and applications.

One of the biggest technical problems is introducing this new operating paradigm into a large, complex system of systems that must continue without interruption. It will require robust, fully-tested solutions based on interoperable and secure equipment and systems.

New measurement science is needed to support grid operators and regulators to adopt Smart Grid technologies at large scale and achieve expected benefits. Technical barriers to the adoption of Smart Grid include the following:

- incomplete standards and testing programs for interoperability of smart grid devices and systems
- the need for better approaches that enhance cybersecurity and privacy,
- lack of validated measurement methods and models that demonstrate the ability of new Smart Grid technologies to cost-effectively improve grid performance without introducing unforeseen instabilities and vulnerabilities

Assessing this broad array of technical barriers and challenges, NIST researchers have identified four key research areas where NIST expertise in metrology can help provide both better understanding and innovative solutions. Here's a very brief summary of the metrology program that NIST is undertaking in Smart Grid.

### METROLOGY FOR SMART GRID SYSTEM PERFORMANCE

**Challenge**
Improving Smart Grid systems-level performance will be challenging because of the lack of coordination and validation of integrated modeling of the multiple interconnected systems and subsystems. These systems and subsystems must operate over a range of different time scales and abstraction levels, and must meet significant physical and cybersecurity requirements.

**Research focus**
This thrust area includes five projects that provide the needed measurement science to support cross-cutting, systems-level analysis, and operational needs. The projects' deliverables will support actionable intelligence and decision-support modeling tools for grid-scale operators, including addressing cybersecurity, understanding of network and timing requirements, and acceptable performance within complex electromagnetic environments.

**Example of research project**
The Smart Grid System Testbed Facility Project is creating a new integrated Smart Grid system measurement testbed that will provide NIST with the initial technical capability to simulate advanced Smart Grid systems and subsystems.

When established, the testbed will become a focal point for internal coordination and collaboration among Smart Grid projects.

### METROLOGY FOR T&D GRID OPERATIONS

**Challenge**
It is difficult to implement distributed sensing and control into transmission and distribution grids because of the need to characterize the dynamic performance of equipment and sensors that are both cost-effective and operational under challenging field environments.

**Research focus**
This thrust area's two projects provide measurement science to support real-time situational awareness needed by grid operators. The projects' focus is to develop standards to support communication of actionable information from grid sensors, and new measurement methods to optimize the capabilities of these sensors to support grid operations.

**Example of research project**
The Wide-Area Monitoring and Control of Smart Grid project addresses measurement science and standards supporting deployment of phasor measurement units and new phasor data concentrators by utilities across the country in transmission grids.

### METROLOGY FOR DISTRIBUTED ENERGY RESOURCES AND MICROGRIDS

**Challenge**
It is difficult to accommodate large amounts of intermittent distributed energy resources into the grid because existing systems were not designed for two-way power flows, and required changes will substantially modify existing operations and safety procedures.

**Research focus**
In this thrust area, the Power Conditioning Systems (PCSs) for Renewables and Storage project addresses key measurement and standards barriers impeding deployment of distribution energy resources.

**Example of research project**
This project will develop metrology and standards to characterize and integrate advanced PCSs with new functionalities (e.g., islanding, ride-through/continued operation, and other enhancements) to support PCS-based distributed generators, storage, and microgrids.

### METROLOGY FOR USER-TO-GRID INTEROPERATION

**Challenge**
A major paradigm shift for the grid is automated management of demand as well as generation to optimize asset utilization and accommodate intermittent variable generation. Significant technical challenges remain to improve the bidirectional interactions between subsystems and the Smart Grid in buildings and commercial and industrial facilities, and to engage residential consumers with actionable information on their energy usage.

**Research focus**
In this thrust area, the Building Integration with Smart Grid project is developing underpinning measurement science necessary to integrate customer facilities with a smart grid, through development of high impact industry standards, industry-run testing and certification processes to support implementations, and new industry best practices.

**Example of research project**
This project includes improving and expanding consumer access to energy usage information in the White House Green Button Initiative, by increasing the consistency of available data and industry implementations. NIST will continue to drive progress with year-long sponsorship of a White House Presidential Innovation Fellow, who started in June 2013.

*Dr. Wollman wrote this article on behalf of the NIST Smart Grid Team. He is Deputy Director of NIST's Smart Grid and Cyber-Physical Systems Program Office.*

## › Why NIST?

Metrology, or measurement science, provides the foundation for research at the National Institute of Standards and Technology (NIST). Through exploration of the very small (quantum computing), very cold (less than a millionth of a degree above absolute zero), and the very accurate (the most stable NIST atomic clock is about 10 billion times more stable than quartz wristwatches), NIST scientists and engineers engage in cutting-edge research, as evidenced by four Nobel Prizes won by NIST scientists in the past two decades.

An agency of the U.S. Department of Commerce, NIST undertakes this science for a good reason—"to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life." NIST has been involved in measurement research and standards development related to the electric grid since the early days of the electric age. Congress established NIST in 1901 in part to meet the needs of electrical instrument makers and manufacturers.

Today, as the electric grid undergoes its most dramatic transformation in a century, more than 20 scientists and engineers are part of the NIST Smart Grid team working on Smart Grid-related projects. NIST laboratories participating in this effort include the Engineering Laboratory (lead laboratory), the Information Technology Laboratory, and the Physical Measurement Laboratory.

For more information, visit the NIST Smart Grid website (*www.nist.gov/smartgrid*).