Smart Grid Progress and Challenges: A National Perspective

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National Institute of Standards and Technology

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Texas A&M University
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NIST’ s Mission

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: Basic Stats and Facts

Major assets

- ~ 3,000 employees
- ~ 2,800 associates and facilities users
- ~ 1,300 field staff in partner organizations
- Two main locations: Gaithersburg, Md., and Boulder, Colo.
- Four external collaborative institutes: basic physics, biotech, quantum, and marine science

FY 2012 Appropriations $750.8 M

- MEP ($128.4 M)
- Construction ($55.4 M)
- NIST Labs ($567 M)
NIST Roles in the Smart Grid

- Standards
  - Interoperability
  - Cybersecurity
- Measurement research
  - Metering
  - Wide area situational awareness (synchrophasors)
  - Power electronics
  - Network communications
  - Timing
  - Building energy management
  - Others …
The Electric Grid

“The supreme engineering achievement of the 20th century”
- National Academy of Engineering
North American Electric Grid

US figures:
- 22% of world consumption

- 3,200 electric utility companies
- 17,000 power plants
- 800 gigawatt peak demand
- 165,000 miles of high-voltage lines
- 6 million miles of distribution lines
- 140 million meters
- $1 trillion in assets
- $350 billion annual revenues
Drivers for Grid Modernization

**Greater efficiency** to reduce need for asset replacement and system expansion: $1.5-$2 trillion by 2030

**Increased reliability**: power outages cost the US economy $80 billion/year

**Sustainability**: 29 states have renewable portfolio standards

2011 EPRI study: Smart Grid will cost in the range of $338 - $476 billion over 20 years Resulting benefit estimated at $1.6 - $2 trillion
Smart Grid – A U.S. National Policy

• “It is the policy of the United States to support the modernization of the Nation's electricity [system]… to achieve…a Smart Grid.”


http://www.whitehouse.gov/ostp
## Technology Deployment

### SGIG/SGDP Areas of Smart Grid Technology Deployment

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>• Displays</td>
<td>• Smart meters</td>
<td>• Switches</td>
<td>• Wide area monitoring and visualization</td>
<td>• Energy devices</td>
</tr>
<tr>
<td>• Portals</td>
<td>• Data management</td>
<td>• Feeder optimization</td>
<td>• Synchrophasor Technology</td>
<td>• Software</td>
</tr>
<tr>
<td>• Energy</td>
<td>• Back office integration</td>
<td>• Equipment monitoring</td>
<td>• Energy Storage</td>
<td>• Appliances</td>
</tr>
<tr>
<td>management</td>
<td></td>
<td>• Energy Storage</td>
<td></td>
<td></td>
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<tr>
<td>• Direct load controls</td>
<td></td>
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</tbody>
</table>

- [Image of Display](image1)
- [Image of Smart Meter](image2)
- [Image of Electric Distribution Systems](image3)
- [Image of Electric Transmission Systems](image4)
- [Image of Equipment Manufacturing](image5)
SGIG Deployment Status

SGIG Project Expenditures ($MM)

- Transmission Assets
  - $270
  - $580

- Distribution Assets
  - $1,190
  - $1,960

- AMI and Customer System Assets
  - $3,600
  - $5,290

- 541 out of at least 800 networked phasor measurement units
- 6,544 of about 7,500 automated switches and 10,336 of about 18,500 automated capacitors
- 12.0 of 15.5 million residential and commercial smart meters

* Based on self-reported project target from Recipients.

Reported as of Sept. 2012

Estimated at Completion*
62 SGIG projects (pricing and customer systems offered mostly at pilot scales):

- 56 offering web portals; 46 offering (DLC, PCTs, and/or IHDs)
- 32 offering pricing (TOU, CPP, CPR, VPP)

<table>
<thead>
<tr>
<th>Project Elements</th>
<th>OG&amp;E 770,000 customers</th>
<th>MMLD 11,000 customers</th>
<th>SVE 18,000 customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers Tested</td>
<td>6,000 residential</td>
<td>500 residential</td>
<td>600 mostly residential</td>
</tr>
<tr>
<td>Time-Based Rate(s)</td>
<td>TOU and VPP, w/CPP</td>
<td>CPP</td>
<td>CPP</td>
</tr>
<tr>
<td>Customer Systems</td>
<td>IHDs, PCTs, and Web Portals</td>
<td>Web Portals</td>
<td>Web Portals</td>
</tr>
<tr>
<td>Peak Demand Reduction</td>
<td>Up to 30%</td>
<td>37%</td>
<td>Up to 25%</td>
</tr>
<tr>
<td></td>
<td>1.3 kW/customer</td>
<td>0.74 kW/customer</td>
<td>0.85 kW/customer</td>
</tr>
<tr>
<td></td>
<td>(1.8 kW/customer w/CPP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcome</td>
<td>Deferral of 210 MW of peak demand by 2014 with 20% participation</td>
<td>Lowers total purchase of peak electricity</td>
<td>Lowers total purchase of peak electricity</td>
</tr>
<tr>
<td>Customer Acceptance</td>
<td>Positive experience, many reduced electricity bills</td>
<td>Positive experience, but did not use the web portals often</td>
<td>Interested in continued participation, many reduced electricity bills</td>
</tr>
</tbody>
</table>
48 SGIG projects are applying distribution automation technologies to improve reliability:

- 42 deploying automated feeder switches (1 to > 1000’s of switches)
  - Enables fault location, isolation and service restoration functions (FLISR)
- Multitude of system integration schemes (AMI/OMS/DMS/SCADA/GIS)
  - 26 projects are applying distribution management systems
  - 36 implementing AMI outage notification
  - 22 deploying equipment health sensors

**Initial results from 4 Projects (1,250 feeders) – April 1, 2011 through March 31, 2012**

<table>
<thead>
<tr>
<th>Reliability Index</th>
<th>Description</th>
<th>Weighted Average (Range)</th>
</tr>
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<tbody>
<tr>
<td>SAIFI</td>
<td>System Average Interruption Frequency Index (outages)</td>
<td>-22 % (-11% to -49%)</td>
</tr>
<tr>
<td>MAIFI</td>
<td>Momentary Average Interruption Frequency Index (interruptions)</td>
<td>-22 % (-13% to -35%)</td>
</tr>
<tr>
<td>SAIDI</td>
<td>System Average Interruption Duration Index (minutes)</td>
<td>-18 % (+4% to -56%)</td>
</tr>
<tr>
<td>CAIDI</td>
<td>Customer Average Interruption Duration Index (minutes)</td>
<td>+8 % (+29% to -15%)</td>
</tr>
</tbody>
</table>

Weighted average based on numbers of feeders
Many Devices and Systems Need to Interoperate

- High use of variable renewables
- Distributed generation and microgrids
- Ubiquitous networked sensors
- Smart meters and real time usage data
- Price and DR signals
- Distributed storage
- Bidirectional metering
- Energy management systems
- Smart appliances
- PVs and EVs

NIST Smart Grid Program
Ubiquitous Networked Sensors
Paradigm Shift

Smart Grid

From:
• Vertically integrated monopolies
• Centralized fossil fuel generation
• Limited awareness
• Hierarchical network
• Deterministic control
• Generation to meet demand
• Proprietary architectures and interfaces

To:
• Restructured competitive markets
• More distributed and renewable generation
• Sensors everywhere
• Interconnected microgrids
• Stochastic control
• Responsive demand and generation
• Open standards
Standards for the Grid in U.S. Law

The Energy Independence and Security Act directs NIST “to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…”

- Congress directed that the framework be “flexible, uniform, and technology neutral”
- Use of these standards is a criteria for Dept. of Energy Smart Grid Investment Grants
- Input to federal and state regulators
Standards Come From Many Sources

- International
  - IEC
  - ISO
  - ITU
  - IETF

- Global Consortia
  - IEEE
  - SAE International
  - ZigBee Alliance
  - OGC
  - OASIS

- Regional and National
  - ANSI
  - SAE
  - NFESB
  - NEMA
NIST Plan – and – NIST Framework 2.0

- Release 2 - February 2012
- Release 1 - January 2010
- Smart Grid vision & reference model
- Identifies 100 standards
- Cybersecurity guidelines
- Testing and certification framework
- Provided a foundation for IEC, IEEE, ITU, and other national and regional standardization efforts

NIST Smart Grid Domains

http://www.nist.gov/smartgrid/
Smart Grid Interoperability Panel

- Public-private partnership created in Nov. 2009
- Now a self-sustaining 501(c)3 not-for-profit corporation
- >160 dues-paying member organizations
- International participation
- Web-based collaboration
- Coordinates standards developed by Standards Development Organizations (SDOs)
  - Identifies requirements and prioritizes standards development programs
  - Works with over 20 SDOs including IEC, ISO, ITU, IEEE, …
  - IEC, IEEE and ITU roadmaps are all based on the NIST/SGIP Framework
Green Button: Benefit of Standards

- Enables electricity customers to access their own energy usage information in a consumer- and computer-friendly electronic format from their utility’s secure website.

- Result of collaboration among White House, DOE, NIST, state regulators, utilities, vendors, SGIP, and North American Energy Standards Board.

15+ million consumers have access to Green Button data NOW, and 36+ million will by 2013.

Cybersecurity Guidance and Tools
Smart Grid = Jobs

- 2009 KEMA Study* for GridWise Alliance estimated:
  - 280,000 new jobs in early deployment years
  - 140,000 new jobs in steady state
  - Utilities, their contractors and supply chain

*“The U.S. Smart Grid Revolution: KEMA’s Perspectives for Job Creation”, KEMA publication
Research Needs

• NIST/Colorado U. Workshop
  – August 13-14, 2012
  – 70 invited experts from industry, academia & government

• Considered four fundamental areas:
  – Integration of large utility-scale renewables
  – Integration of distributed generation
  – Energy efficiency, demand response and load control
  – Grid efficiency, reliability, security and stability
Strategic R&D Opportunities – Planning and Operations

Optimize smart grid capabilities for system planning and operations

- Comprehensive models and tools for robust operations and planning
- Tools for operator decision support and situational awareness
- Tools to assure flexibility in electricity generation and the grid
- Control architectures and voltage controls for distributed networks

Develop smart tools and technologies to utilize demand response, load control and energy efficiency

- Evaluation methods and frameworks for EE, DR, and DLC
  - Evaluation, measurement and verification methods
  - Frameworks to relate demand response to business objectives
  - Standardized methods for collecting and managing distribution-level operations data
Strategic R&D Opportunities: Enabling Infrastructure

Communications and Interconnectivity
- Communications and interconnection standards and technologies
- Managing and extracting information from large and disparate data sets

Cybersecurity and Resilience
- Models and topologies for improving security and resilience
  - Cyber-physical design methods, metrics and analytical tools
  - Flexible power system topologies

Investment and Regulatory Frameworks
- Cost-benefit and life cycle models for smart grid
Worldwide Investment in the Grid

- International Energy Agency estimates:
  - $10 trillion over next 20 years
  - 50% in generation
  - 50% in transmission and distribution
  - Does not count customer-side investments

- Significant export opportunity

- NIST and SGIP are collaborating with other countries and regions in international standards-setting through bilateral and multilateral engagements
The Smart Electric Grid is One Example of a New Generation of Cyber-Physical Systems

IBM plunges into the ‘smart grid for water’

by Mariella Lattanzia

IBM is developing a portfolio of IT-related water management technologies, a business that it estimates can total $20 billion within five years. At a water conference next week, IBM and Intel will be forming a working group to study how information and technology can be used to improve water management, according to IBM.

The goal is to stretch out the technical architecture required to more efficiently use fresh water, only one percent of the available water on Earth.

Water systems even in developed countries like the U.S. are notoriously outdated, with faulty pipes—some of them still made of wood—result in 25 percent to 45 percent lost water. That means high-tech approaches, such as using sensors to gauge water quality, are a tough sell to cash-strapped municipalities, most of which are more concerned with maintaining the basic infrastructure.

IBM is betting, though, that fresh water will have more value attached to it from the public, governments, and corporations.

The natural gas grid...the really smart grid

Posted on July 20, 2010 by Dan Gibson

I read a lot of stuff about the “smart grid” but it generally covers only the electric side. Here’s a good article from CleanTechies titled “The Natural Gas Grid – The Other Grid” that has some good information on the natural gas grid. The article brings attention to the industry’s record of safely and reliably delivering natural gas. Some highlights from the article:

- The current demand to update the gas grid is more about reducing utility expenditures, increasing energy conservation, and meeting global climate initiatives and mandates, rather than dealing with failing system integrity issues
- Southern California Gas (SoCalGas) was recently approved by the California Public Utility Commission (CPUC) to implement a $1.05 billion, 5.5 million meter AMI system in Southern California. SoCalGas is the largest gas utility in the United States.
Prediction...

- The Smart Grid will be one of the great engineering achievements of the 21\textsuperscript{st} century