National Institute of Standards and Technology (NIST)
Smart Grid Advisory Committee (SGAC)
Report

The electric power grid—and the sectors and organizations that support it—is being dramatically transformed as it is modernized to integrate information technologies and to respond to a wide variety of evolving and disruptive forces. The smart grid, which is already emerging in a number of places around the nation and the world, will continue to evolve in the decades ahead.

The role of NIST's Smart Grid Advisory Committee is to provide input to NIST on the smart grid standards, priorities, and gaps--and on the overall direction, status, and health of the smart grid implementation by the smart grid industry--including identification of issues and needs. With this report, the Committee is providing strategic input to NIST on three key emerging issues that will drive significant change over the next five to ten years: transactive energy, resilience, and distributed energy resources.

This report is based on discussions held at the Committee meeting on June 3-4, 2014. Prior to the meeting, committee members were provided with a set of related white papers and reports (see attached list) and a series of questions (see attached).

Transactive Energy

Transactive energy is an emerging issue that has received increased attention in recent months. With strong drivers from across the energy sector, it raises a number of issues and challenges for the various organizations that play roles in the sector now and in the future. The Smart Grid Federal Advisory Committee discussed various aspects of transactive energy, including definitions, drivers, challenges and potential roles for NIST and other organizations.

<u>Definition</u>

Using an early definition offered by the GridWise Architecture Council (GWAC), transactive energy was initially described as:

> Techniques for managing the generation, consumption, or flow of electric power within an electric power system through the use of economic or market-based constructs while considering grid reliability constraints.

In its discussions, the Committee also used this working definition:

> The ability to interact with every device that connects to the grid using price signals as a basis for monetizing responses.

Drivers

Recent developments in technology, public policy, and users' requests are creating the conditions that have given rise to the concept of transactive energy.
From a technology standpoint, important drivers include the following developments:

- increasing availability of renewable energy (along with implications for power quality, etc.)
    - Energy Information Administration (EIA) data show that 30 gigawatt of renewable resources could be online by 2020 in the U.S.
- declining prices for photovoltaics
- increasing use of electric vehicles
- increasing availability of distributed energy resources (DER) (See also Section 3 of this report)
- increasing capacity for building and facility energy management to optimize users' investments (e.g., building and home automation)
- increasing use of microgrids
  (Note that some of these are similar and/or inter-related.)

From a policy and economic perspective, important drivers include the following:

- renewable energy portfolio requirements now established in many states
- climate change concerns and considerations
- new rate structures
- feed-in tariffs and net metering
- new business models

From the standpoint of the end user, drivers include:

- desire for increased (or exclusive) use of renewable energy
- increasing interest in using building and facility energy management to optimize asset investments

Challenges and Needs

As these developments and drivers expand, a number of challenges and needs are arising for stakeholders across the energy sector. The challenges and needs include the following:

<u>Needs related to technology</u>

- Need for technical definitions and standards
- Need to describe "character and color of electrons" as value-added information
    - e.g., is it renewable energy? is it reactive power? etc.
- Need for measurements ("measurement is the enabler")

- Need for mathematical equations (relationships between measurable units) to support transactions
- Need for better modeling and characterization of variable loads
- Need for better modeling of systems
- Need for utilities to have better "visibility" beyond meter
    - Utilities need more information and structure including voltage, frequency, ramping, and pricing structure
- Need for monitoring and control of new sensors and systems (e.g., response signals, false positives)
- Need for new types of sensors (and define how to capture these data and send the signals to the operators)
- Need for technology development to deal with power quality issues related to harmonics, etc.
- Need for anticipating new technologies

<u>Needs related to cybersecurity</u>

- Need for secure communications, with adaptive protection mechanisms
- Need for secure systems (formed from insecure pieces)
- Need to balance security with operations
- Need to enable "root of trust" in the system

<u>Needs related to economic considerations</u>

- Need for prices to be unbundled between the infrastructure and the commodity
- Need for pricing definitions for a range of actions and attributes:
    - price to connect
    - price to disconnect
    - price for reliability
    - etc.
- Need to define a rate structure that depends on the type of customers based on resources, location, and circumstances
- Need for pricing schemes that include incentives (approved by regulators) for everyone
- Need to be able to measure and model locational marginal pricing (LMP)
- Need economic analyses of different market structures
- Need to deal with time-related issues (forward markets, etc.)
- Need to understand and deal with social science-related questions (behavior of users, etc.)

<u>Needs related to changing roles of stakeholders in evolving electric sector</u>

- Need for "rules on the playground" (current situation is equivalent to the "wild, wild west")
- Need for system-wide changes
- Need for new regulations (e.g.. issues related to rooftop solar)
- Need for new business models

- Need for defining role of utility (especially at distribution level) in this new environment

The committee discussed ways in which the organization of the electric sector is likely to evolve in the future. In developed countries, which have typically used a radial distribution approach, there will be greater use of a more networked distribution approach. The underlying grid as it exists today will still have role in this future. In developing countries, where a strong grid is not yet established, the evolution of microgrids and networks may be decentralized.

Two approaches to guiding this evolution of the electric sector were discussed:

- Incremental approach
- Define desired end result first, then make changes

Transactive energy will affect stakeholders across the entire electric sector, and roles that existing organizations play are likely to evolve. The committee discussed the current activities in SGIP and roles for NIST with respect to transactive energy.

<u>SGIP Activities</u>

The SGIP is currently discussing transactive energy, including a cross-Domain Expert Working Group discussion on the topic which was held at the May 2014 Members meeting. Among the issues being explored are the following:

- Where is the right "home" for this subject within the SGIP organizational structure? (At the present time, a working group has been established within the Smart Grid Architecture Committee.)
- What is the definition of transactive energy?
- What are the requirements and use cases; what standards exist; and where are the gaps?
- How will SGIP coordinate its efforts with other organizations, such as GWAC and NIST?

<u>Role for NIST</u>

The committee's discussion suggested that NIST does have a role to play in the transactive energy arena. It may be appropriate for NIST to work with stakeholders to develop a more widely accepted consensus definition of transactive energy, for example. Several types of pilot projects were discussed as possibilities:

- Cybersecurity
- System-level testing
- Campus-wide pilot with a utility (such as currently being done in Nice, France)
- Incorporate economic considerations into pilot (with assistance of NIST Economic Office)

One possible NIST approach would involve the following:

- Detailing a "strawman" for the pilot
- Hold a workshop to get community feedback

- Conduct pilot at the testbed level

Action Items and Conclusions

The committee encourages NIST:

- To continue to explore the area of transactive energy
- To focus on technical work/interoperability standards rather than policy
- To consider various pilots in this area
- To work with—and in parallel to—other organizations (SGIP, national labs)
- To report back to the committee at its next meeting (in September) on this subject

Resilience

In the months since Superstorm Sandy had a devastating impact on the electric grid and infrastructure of the Northeast in October 2012, resilience has emerged as one of the most important issues facing stakeholders in the electricity sector. Utilities, state regulators, and federal agencies have been working together to collect lessons learned and put in place technologies and policies that will ensure more resilient responses to future disasters.

NIST is one of the federal agencies playing a key role in this process. Earlier in the meeting, Dr. Howard Harary, Acting Director of NIST's Engineering Laboratory, updated the committee on work that NIST has begun to develop a resilience framework that will address the subject as it applies across a number of sectors (http://www.nist.gov/el/building_materials/resilience/). The utility industry is encouraged to be an active participant in that larger effort.

The Advisory Committee discussed resilience from the standpoint of the electricity sector and the smart grid.

Definition

The term "resilience" means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions.

Lessons Learned and Recent Responses

The committee reviewed the progress that has been made in recent months.

On a sector-wide level, the cooperative efforts of key stakeholders have been strengthened through existing and new organizations and processes, including the following:

- An electric sector steering committee (the Electricity Sub-sector Coordinating Council, ESCC) has been established that includes all the major utility trade associations, DOE, DHS, DOD, and other members of the utility space. A key task for this group is to streamline the information exchange between the parties.

- The effectiveness of the Electricity Sector Information Sharing and Analysis Center (ES-ISAC), operated by NERC, has been improved in recent months by streamlining processes.
- Utilities are working with the federal government to use tools for cyber detection and prevention technology (e.g., CRISP, Cyber Risk Information Sharing Program).
- In the important area of physical security, utilities are working with government to identify critical assets, identify processes for hardening them, and establish a process for protecting and maintaining the information.
- One program for testing and improving resilience involves major drills that include key stakeholders. These drills simulate physical and/or cyber disruptions in a major disaster. As a result, communication and other weaknesses are identified and can then be addressed.
    - One example of a major drill in the cybersecurity area was GridEx II, held in November 2013.
- Connectivity and agile technologies can provide both on- and off-grid solutions for resilience.

Challenges

Although there have been improvements made in recent months, as discussed above, there remain a number of significant challenges. The committee discussed challenges in the following areas:

- Standards and metrics
    - Who pays for resilience? How is resilience measured? This can vary from company to company.
    - How do you measure the economic benefits of resilience? How do you measure the cost of not having resilience?
    - General standards and/or metrics for resilience would be helpful. (One measure currently used is the frequency of outages.)
    - If better standards and metrics for resilience were available, this would be helpful when utilities are working with public utility commissions.
    - Benchmarking (e.g., city and building benchmarking) is one useful step toward the development of standards and metrics.
- Modernizing the infrastructure
    - One important way to address issues of resilience is "to build and rebuild smart" (i.e., modernize the infrastructure) including technology to route around down areas, provide backup power at storage and pumping facilities to move fuel through the pipelines or into transport vehicles, and to use microgrids. ("Build and rebuild smart" was offered as an alternate definition for "resilience.")
    - It would be valuable to have a technology gap assessment, based on lessons learned.
    - Critical loads need to be inventoried. Critical loads should have backup generation, and backup (e.g., microgrids) should be provided if not currently available.
    - Connecting new devices to a legacy system can be a challenging job.

  - Do companies need to have a "black start" capability?
- Costs, benefits, and incentives
  - Technologies to improve resilience are available today, but people are not using them, because initial costs are large. However, the technologies can pay for themselves over the long term. Therefore, incentives and education may be necessary to speed the adoption of these better technologies.
  - Government could help drive the development and adoption of new technologies. (A good example is the increasing use of microgrids on military base.)
- Communication between government and industry
  - There is a need to clarify the responsibilities of different agencies, as well as the chain of command.
  - There is a need for allocating crews more efficiently through a national response event and for using best practices.
- Spare parts and transformers
  - Two lessons learned (from Superstorm Sandy, other recent disasters, and drills) are that the federal government does not have an effective spare parts inventory, and industry needs to improve its spare parts inventory.
  - Parts availability may be improving in the case of some utilities.
  - Are modular design solutions helpful? Should we have spares? How can we transport transformers?
  - Regional solutions may be more appropriate than a national solution (e.g., in the case of a transformer reserve).
  - With respect to transformers, there have been some improvements in the technology and the manufacturing process.
- Sensors
  - Are the sensors that we have today sufficient under various conditions? The temperature sensitivity of sensors is one example that may become important as climate changes occur.
- Modeling
  - Modeling techniques, especially those related to timing and time data, can be helpful in "putting things back together."
- Geographic information
  - Smart meters are helpful in providing the exact location of outages.
  - Communication technology and mapping technology are helpful in providing the exact location of crews.
  - It would be helpful to have a "Green Button"-type application that showed consumers which gas stations, groceries, medical, and other key facilities are open during a disaster event and recovery.
- Interdependencies of various industries and sectors
  - Resilience can be affected by the interdependencies of other industries, such as water, fuel, and telecommunication.
  - Greater sharing of information between industries and sectors can be helpful.
    - During Superstorm Sandy, information about the real-time usage and non-usage of cable television was helpful in locating electric outages.
- Geomagnetic storms and other electromagnetic interference events
  - What are potential impacts and associated measurement needs?

  - NIST Boulder is doing work in this area.

Additional Resources on Resilience

- Johan Rockström (Executive Director, Stockholm Resilience Centre, Sweden) presented a study in Davos at the World Economic Forum annual meeting.
- Risk management capability and maturity models are available from DOE, NERC, FERC, and DHS.
- The Distributed Energy Resources Customer Adoption Model (DER-CAM) model from Berkeley may be able to add resilience.

Microgrids

- Microgrid technology (along with energy storage and, more generally, all distributed energy resources) can play an important role in improving resilience. The committee's microgrid discussion, which began as part of the discussion on resilience, expanded to a larger discussion on microgrids. Those comments are included here.
- The microgrid market is bigger in developing countries, where the risk is lower. In developing countries, current grids are not as developed or as reliable as in developed countries.
- At the present time, the business case is not there for microgrid (in the U.S. market). Cost is the number one issue for the domestic microgrid market when selling to business owners.
- Public policies, such as subsidies, can promote microgrid development and adoption (as is currently happening in New York and Connecticut). The federal government is also serving as a driver, especially through the expanded use of microgrids on military bases.
- A California utility recently received approval for a microgrid implementation from the rate case for a community.
- One way for utilities to look at microgrids is as an opportunity for providing a service. Current staff could be repurposed to support utility-side microgrid offerings.
- The SGIP is considering a Priority Action Plan (PAP) proposal related to microgrids. The proposal includes microgrid interaction points and their communication with each other and their functionalities.
- There would be value in having a testbed to validate the commercialization of microgrids.
  - NIST's Smart Grid Testbed, which is currently being built, will be emulating scenarios, performance, and interoperability testing. There is a strong emphasis on microgrids.
  - NIST, with its Testbed, could look at multi-value streams for microgrid with a focus on resilience.
  - Several DOE labs are working on different elements of microgrid technology and development, and NIST is collaborating with those labs.

Distributed Energy Resources (DER)

The committee discussed distributed energy resources (DER), an issue that is receiving increasing attention from utilities, manufacturers, regulators, and energy users. It is subject that will have far-reaching impacts across the electricity sector.

Definition

There are a variety of definitions for DER, and the committee did not commit to just one definition for the purposes of this discussion. The committee also discussed the relationships between DER, backup power, mini-grids, and microgrids. Here are some of the useful definitions and distinctions discussed:

- DER are typically discrete, analog resources (generation, storage, or demand response) that are connected to the grid. They are missing the control mechanisms for load balancing. A distributed energy resource is usually a single unit.
    - With this definition, a microgrid, which does include a controller, is not considered DER, but in fact supervises DER.
    - As complexity is added to a DER-type resource, it becomes more like a microgrid. This is particularly true if the DER exhibits smart grid qualities.
- Back-up generation is generally not considered to be DER, but it is treated as a separate category.
- Two standards that define DER, and which have a broader definition of DER that includes resources within the distribution system (outside of the transmission system), are the following:
    - IEEE 1547 (“Standard for Interconnecting Distributed Resources with Electric Power Systems”)
    - IEC 61850 (“Communication Networks and Systems in Substations”)
- DER with a control mechanism is like a microgrid (size and scale are described in IEEE 1547-4, “Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems”).
- Mini-grids in other countries could also be considered to be DER.
    - A”mini-grid”—as defined by UN, World Bank, and NGOs—is a power system where the produced electricity is fed into a small distribution network that provides a number of end-users with electricity in their premises. Mini-grids are typically off-grid, less than 1 MW in capacity, and utilize diesel, renewable (+battery), or hybrid (combined) fuel sources to produce power. An example of a mini-grid is rooftop solar plus several devices in a system that generates several thousand watts.
    - As mini-grids are aggregated and networked, the system becomes more like a microgrid, and smart grid technology is involved.
- One older definition of DER was any generator (less than 10 MW) connected to the distribution system. That definition is now being broadened to include any resource that is not in the FERC transmission domain.

Challenges

As utilities and the current grid incorporate a greater amount of DER, a number of challenges are emerging, including the following:

- Visibility of DER -- Utilities need to understand the characteristics of the various resources. Can you have a good model that includes overall characteristics and characteristics of individual loads?
- It is a challenge for a utility to integrate all the distributed generation resources (ownership, quality of power, etc.).
- DER or microgrids -- The challenges that utilities face with DER are similar to the challenges they face with microgrids.
- Networks
    - As more and more DER comes online, it may be necessary to operate the system as a network (i.e., a distributed multi-dimensional power flow).
    - The utility feeder can be treated as a bi-directional resource (networking distribution system similar to hosting concept).
    - In certain parts of the country (e.g., New York City), the distribution system will be networked.
    - Capacity of the lines could be an issue for routing power in networked systems (as opposed to hierarchical systems where lines can have lower capacity as they radiate out).
- Voltage and frequency
    - Frequency control can be a revenue source.
    - The voltage and frequency regulation functionalities could be available on the edge of the grid through third party and that could negate utility investment at the generation but need to be able to monetize.
    - As the amount of distributed generation grows, utilities may have to invest more in VARs and frequency management.
    - There are some cost constraints for inverters based on the range of the voltage.
    - It may be the case that the load doesn't care about voltage and frequency any more. Is the necessity for control becoming an outdated historical paradigm?
    - As power electronics become more sophisticated, reliable and capable, new products offered to the grid multiplies.
- Safety of the linemen is the #1 issue for utilities.
- Storage is an important and changing area.

Direct Current (DC) as emerging technology

The committee noted that DC technology and networks are receiving increased attention. (Most of the issues mentioned above relate to alternating current (AC) networks and systems.)

- Standards for DC networks
    - There are few or no standards yet, so more development is needed regarding DC networks and DC devices.

    - IEC has a strategic group that is looking at gaps in standards related to DC in the distribution network.
- Developing countries and DC distribution networks
    - DC technology is of special interest in developing countries, because these countries may not have to deal with an existing infrastructure. (In Liberia, where the existing grid was destroyed in two civil wars, there are now 100 microgrids.)
    - As microgrids in developing countries are connected together and the grid grows, where is the demarcation point for converting AC to DC?
- One current challenge for DC technology is that the DC supply chain is not as robust as the AC supply chain (i.e., parts availability is an issue).
- Manufacturers are watching smart cities and what's going on around the world (South Korea, Australia, and others) including benchmarking for building, and DC is always coming up in the discussions. So, although there is not yet a lot of change on the manufacturer side, they may need to move to DC.
- Navy ships are going to all DC.

Policy-related and economic issues

Although NIST's responsibilities are primarily in areas dealing with technology, there are a number of policy and economic issues related to DER that should be kept in mind, including the following:

- For the foreseeable future, the expectation in developed countries is to have a reliance on the current grid (as opposed to the situation in some developing countries, where other ways of generating and delivering electricity are likely to evolve.)
- Feed-in tariffs could encourage home owners to put in solar but there are issues of selling back to the grid (e.g., capacity issues and also exposure of utility) so there is a need for sound long-term economics.
- At some point, existing incentives (e.g., subsidies, etc.) for DER are likely to disappear. When that happens, these technologies and systems will need to work from a sound economic standpoint.
- California is pushing for net-zero home and building by 2020. This is a policy issue that has a relationship with DER.
- Some utilities (e.g., San Diego Gas & Electric) are doing experiments that include electric vehicles, rooftop solar, and/or microgrids.
- Some utilities (e.g., Georgia Power) are establishing agreements to build, own, and operate solar generation facilities on military bases.
- Some utilities are doing R&D to prepare for a future that includes more emphasis on DER rather than on microgrids.
- Significant differences exist between how different regions of the country are adopting new regulations and technologies related to DER.
- Some utilities are also getting approval from their PUCs to build utility-owned solar.
- GSA is interested in creating a microgrid in Washington, DC.

Key Areas for NIST Consideration

In summarizing the DER-related topics that merit NIST's attention, the committee identified the following:

- The concept of distribution as a distributed multi-dimensional power flow network is of growing importance.
- There is a need for modeling capability that includes economic analysis.
- Direct current (DC) is growing in importance as a technology, and there is a need for standards in this area.
- Storage is an important and changing area.