GRID INTEGRATION OF SOLAR ENERGY WORKSHOP

OCTOBER 29, 2015

OVERVIEW

The U.S. Department of Energy's SunShot Initiative is a collaborative national effort that aggressively drives innovation to make solar energy cost-competitive with traditional energy sources by 2020. SunShot's strategic research and development programs support efforts by private companies, universities, and national laboratories to drive down the cost of solar electricity to $0.06 per kilowatt-hour, and to enable the safe, reliable, and cost-effective integration of large scale solar generation onto the U.S. electric power grid.

The Systems Integration program of the SunShot Initiative envisions that hundreds of gigawatts of variable solar (photovoltaics (PV) and concentrated solar power) generation will be interconnected to the grid as the solar industry moves toward achieving the SunShot goal. Therefore, it becomes imperative to identify the associated technical, economic, and regulatory challenges, and to develop impactful solutions in order to ensure compatibility with the existing grid and smooth transition to a secure, reliable, and resilient grid of the future.

The purpose of this workshop is for participants to identify critical challenges and opportunities associated with integrating high levels of solar energy into the electric grid, assess state of the art technologies, and propose a set of solutions that will address the near and long-term R&D needs. The workshop will cover three technical areas that represent potential for transformative and cost-effective solutions to these challenges: 1) Design & Modeling; 2) Sensing, Communication & Data Analytics; and 3) Operations & Control. The DOE SunShot team will collect and analyze ideas, opinions, and comments from this workshop as valuable inputs to the development of research roadmaps and future funding opportunities. Participants are encouraged to provide additional feedback after the workshop as well.

BACKGROUND

The U.S. installed 1,393 MW of solar PV in Q2 2015, reaching a milestone of over 20 GW of cumulative installed solar, and is projected to continue installing solar at an accelerating pace.[1] The historical grid paradigm, conceived around central power generation with unidirectional power flow to distributed loads, increasingly represents an insufficient framework for high-penetration scenarios of solar power. Introducing a significant amount of PV closer to the customer load creates two-way power flow, potentially creating technical and regulatory challenges that affect the reliability and safety of the power system (Figure 1). These challenges include voltage and VAR regulation, unintentional islanding, power quality issues, protection coordination, sufficiency of distribution modeling tools, distribution system visibility and control, and creation and adherence to codes and standards.

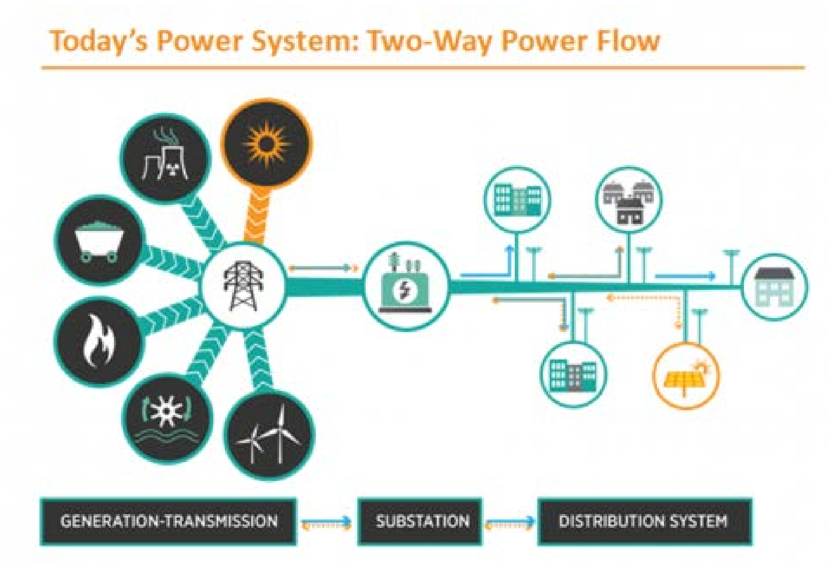

Figure 1. Two-Way Power Flow

Solar generation variation can cause feeder and substation voltage variations in both temporal and spatial patterns that are very different from historical values. Voltage variability due to the transient nature of solar resource can impact service quality and complicate voltage regulator operations significantly. Inability to deal effectively with such variations limits the amount of PV generation a distribution feeder can accommodate[2].

[1] Greentech Media Research, Solar Energy Industries Association, "Solar Market Insight Report 2015 Q2", accessed October 2015

[2] R. Uliski, "Measuring Smart Distribution", Electric Light and Power, http://www.elp.com/articles/powergrid_international/print/volume-16/issue-9/features/measuring-smrt-distribution.html, accessed August 2014

While the bulk power system is well monitored and controlled by system operators, very little visibility or control is available at the distribution level for solar installations, particularly those that are behind-the-meter. To effectively inform grid operations, visibility of solar generators is required at multiple spatial and temporal scales. Existing communication technologies will need to be leveraged as well as new communication and control architectures in order to collect, store, visualize, and interpret real time operations data, which is growing at an exponential rate. Network latency, availability, and scalability are key issues that need to be addressed in order to adequately and cost-effectively monitor and manage the impact of distributed solar. As illustrated in the conceptual diagram below, the transformation of the electric grid from a centralized and hierarchical network architecture to a more distributed one adds significant system complexity. Communication needs vary greatly depending on the type of applications, locations, and topologies of the power systems. Both communication technologies and solar grid integration applications are evolving rapidly, therefore the capabilities developed today need to be able to adapt and meet the future challenges.

Figure 3. Concept of Future Grid Communication

Please visit http://energy.gov/eere/sunshot/systems-integration for more information on the SunShot Systems Integration program and its grid performance and reliability, and grid communication goals and efforts.

TRANSFORMATIVE SOLUTION FRAMEWORK

The goal is to create a transformative, cost-effective, secure, reliable, resilient, and integrated solution with real-time vulnerability assessment and optimization tools (both hardware and software) for distribution planning and operation. The solution should be able to dynamically manage the variability, uncertainty, and distributed nature of more than 100% (peak load) solar penetration. Such a solution should result in significant cost and time reductions in the grid integration of solar energy.

The grid solution mentioned above should demonstrate certain characteristics. It should be:

1. CONFIGURABLE: The grid solution must be able to dynamically adapt to changing operating environments.
   - A separable grid topology with independently functioning parts. Ideally, the parts should be able to island and recombine at various levels of spatial and temporal granularity.
   - A fractal grid structure that potentially allows any grid segment to be isolated and operated in a similar manner, regardless of scale.
2. VISIBLE: The grid solution must be constantly aware of its state.
   - Real-time visibility to enable the continuous acquisition of large amounts of distributed system information.
   - Automatic data management and data availability to other parts of the system.
   - Employment of event-driven principles to allow judicious data sharing by intelligent and inexpensive monitors that only send alerts when there is an issue, thereby minimizing network traffic.
   - Optimization of sensor placement to minimize installation costs while maximizing the usefulness of the data.
3. INTELLIGENT: The grid solution must ideally be able to function autonomously without human intervention and have the flexibility to respond to local or central control.
   - Locally and globally adaptive, able to operate independently, possess decision-making capabilities at any level, and ideally be self-healing.
   - Optimization of generation, demand response, energy storage, and other distributed assets with load and solar forecasting ability to provide optimal allocation of energy and ancillary services.
   - Ability to handle massive data influx from disparate systems such as distribution feeder sensors, SCADA, GIS, CIS (Customer Information System), AMI, OMS (Outage Management Systems), etc.
4. INTEROPERABLE: The grid solution must be compatible and technology agnostic, allowing for seamless integration with distribution utility systems.
   - Abide by standard protocols that satisfy communication and control capabilities as required by the electric distribution utilities.
   - All components designed to be compliant with applicable ANSI, UL, NEC and OSHA standards.
   - Enable faster PV interconnection processing and reliable integration.
   - Leverage existing hardware and software systems to the extent possible.

WORKSHOP BREAKOUT SESSIONS

BREAKOUT SESSION 1

Breakout Session 1 will focus on addressing the following questions under three categories:

- **Design & Modeling**: Current and future grid design and modeling efforts needed to enable seamless integration of distributed solar at 100s of GW of solar deployment. Innovative breakthroughs in modernizing the grid while leveraging existing grid infrastructure. Power systems modeling and tools for assessing grid operations under these new operating conditions.
- **Sensing, Communication & Data Analytics**: Adoption of advanced sensing technology to enable real-time grid visibility, innovative grid communication systems for optimizing grid operations, and data analytics to understand the limitations, opportunities, and implications of big data for the grid.
- **Operations & Control**: Grid operation and state-of-the-art control methodologies that set the stage for the future of real-time, intelligent grid control.

1. What grid architectural objectives are required to achieve seamless, real-time integration of 100s of GW of solar at the $0.06/kWh SunShot goal?
2. What technology breakthroughs are required to achieve seamless, real-time integration of 100s of GW of solar at the $0.06/kWh SunShot goal?
3. What lessons learned from other industries can be leveraged towards achieving the breakthroughs in question #2? What other industries that historically haven't been involved in grid integration challenges need to be involved to achieve these goals?
4. How can existing standards be leveraged and what new standards should be implemented to achieve seamless, real-time integration of solar energy into the grid?
5. Are there other major concerns that need to be addressed to effectively achieve 100s GWs of solar energy on the electric grid?

BREAKOUT SESSION 2

Breakout Session 2 will bring together experts from the three broad categories in Session 1 to answer the following questions:

1. How can the solutions from the individual focus areas in Breakout Session 1 be combined as a system-level approach to achieve seamless, real-time integration of 100s of GW of solar energy into the electric grid at SunShot cost targets?
2. How would you construct a scalable demonstration for testing of solutions?
3. What regulatory challenges will need to be addressed to achieve the goal of seamless, real-time integration of 100s of GW of solar energy into the electric grid at SunShot cost targets?
4. How do you measure progress toward these solutions? What metrics should be used?