U.S. Department of Energy

**Office of Electricity Delivery
and Energy Reliability**

Smart Grid R&D Discussion Forum Draft Report

June 6, 2012

San Diego, California

Introduction

The Smart Grid R&D Program held a one-day discussion forum on June 6, 2012, in San Diego, California, immediately before the biennial Program Peer Review meeting. The purpose was to seek input from people attending the peer review meeting on select R&D areas for incorporation into the 2012 edition of the Smart Grid R&D Multi-Year Program Plan (MYPP). The Smart Grid R&D Program resides within the U.S. Department of Energy (DOE) Office of Electricity Delivery and Energy Reliability (OE).

Three R&D areas of interest to the Program were selected for the one-day forum discussions. They are: Modeling & simulation (M/S); Demand response (DR)/buildings energy management (BEM) integration; and R&D on plug-in electric vehicle (PEV) and/or photovoltaic (PV) integration with electric distribution grid. The selection of the latter two was based on their direct support of integration of demand-side management for improved system efficiency, which is one of the Program's long-term goals. The selection of M/S was based on its crosscutting support to the goal above and also the Program goal for a self-healing distribution grid from grid disturbances for improved reliability.

Due to broad and encompassing applications for M/S, about two thirds of the discussion forum was dedicated to this R&D area, while the remaining time was allocated to the other R&D areas, which were discussed in two concurrent sessions. Read-ahead material for the M/S session was prepared by a multi-laboratory coordinating committee, involving personnel from seven of the DOE national laboratories; it includes a list of M/S capabilities and associated technology readiness levels (TRLs), the context of use of each capability in application areas (such as distribution system planning, design, operations, and analysis), and the definition of each capability and identification of its gap areas. The material was distributed to attendees before the forum and was used during the forum to guide the M/S session discussions. No such preparatory materials were developed for the other sessions, as they were designed to be more exploratory of the needs based on the limited time available.

About 30 people—primarily consisting of principal investigators of the Smart Grid R&D Program projects, national lab managers and researchers, and some guest participants—attended the discussion forum. The agenda, a list of the members of the multi-laboratory committee, and the list of attendance are shown in Appendices 1-3, respectively.

I.   M/S Session Discussions

Identification of M/S Capabilities that Need Further R&D

A master list of the M/S capabilities developed by the multi-laboratory coordinating committee was introduced, followed by two sub-lists: "Pass Capabilities List" and "Fail Capabilities List." Since the TRL range of interest to the Smart Grid R&D Program is between 3 and 7, any capabilities on the master list assessed by the seven national labs (represented in the multi-laboratory coordinating committee) with a medium of TRL in this range are shown on the "Pass" list, whereas any capabilities with a medium of TRL outside of that range are shown in the "Fail" list. Appendix 4 shows the master list, the two sub-lists, and a brief description of each TRL level. In addition, a capability relevance table, also shown in Appendix 4, provides the

mapping results showing the context in which each capability on the "Pass Capabilities List" (in column A) is used, with respect to the seven application areas below (also in row 4):

- Smart grid business case and consumer impacts
- Capacity and asset utilization impacts
- Reliability impacts
- Environmental and carbon impacts
- Alternative control strategies for distribution, distributed resources, and demand response
- Communications network impacts and loss of communication contingencies
- Smart grid impact on distribution planning and engineering design practices

The color-coded cells in the capability relevance table (Appendix 4) show those capabilities assessed by a majority of the seven national labs (i.e., 4-7) as having a primary role in support of the corresponding application areas. For example, "P-5" in the cell found in row 5/column D indicates that the Volt-VAR management capability was assessed by five of the national labs as having a primary role in support of the "Reliability Impacts" analysis.

Attendees were asked to provide input to the master list (any missing capabilities and any changes to the existing list), as well as to the assignments of the capabilities to the "Pass" and "Fail" lists based on assessment of the TRL range. A revised list of M/S capabilities with a TRL range of 3-7 is shown in Table 1, which reflects input from attendees. The capabilities shown in *italics* in Table 1 are new additions from forum attendees.

Table 1. List of Smart Grid M/S Capabilities with a TRL of 3-7, Revised from the Original List with Input from Attendees (not in prioritized order)

Volt-VAR management	Microgrids
Distribution management systems	Hardware-in-the-loop and virtual performance testing
Fault identification and feeder reconfiguration	Forecasts of load/demand response/price/renewables
Integrated power system w. communications network	Uncertainty management and quantification
Smart meters	Probabilistic/stochastic models of reliability and performance
Sensors (SCADA, PMUs, etc.)	Advanced control algorithms
Demand response and customer behavior	Optimization (Planning)
Dispatchable distributed generation	*Interoperability among formerly independent (disparate) models*
Renewable (non-dispatchable) resources	*System models with incompatible time scales (from short to long time span)*
Dispatchable energy storage	*System protection and coordination*
PEV charging	*Model calibration, verification, and validation*
Wholesale and retail market operations	*Modeling lifecycle performance of distribution assets*
Need for, and provision of, ancillary services	*Test cases for availability of measured data for model verification/validation, modeling load profiles (e.g., industrial), etc.*

Prioritization of M/S Capabilities that Need Further R&D

During this session, a description of each capability and associated gap areas (Appendix 5) were discussed, along with the gap areas for the added capabilities shown in *italics* in Table 1. Each representing entity was then asked to vote on seven capabilities deemed to be high priority. A show of hands was used to tally the votes for each capability. The five capabilities receiving the highest vote counts were identified for discussion in the next session.

R&D Definition for Each of the Top-5 Ranked Capabilities

Discussion ensued on each of the five capabilities that garnered the most votes, beginning with the top-voted capability and working down, to further define R&D gaps, milestones, timeframe (1-3 years, 3-5 years, over 5 years), level of effort, and measures of success. Three levels of effort were categorized as follows: High (>$5M in lifecycle DOE investment); Medium ($1-5M in lifecycle DOE investment); and Low (<$1M in lifecycle DOE investment).

R&D definition for each of the top-3 ranked capabilities was carried out, and discussion summaries are provided below. With respect to R&D definition for capability #4, attendees converged on the need to conduct a scoping study to identify its gaps and requirements. Time ran out before discussion could begin on capability #5.

1. **Integrated Power System with Communications Network** (tied with #2 on vote count)

   Gaps: Modeling the effects of latency, traffic volumes, availability and integrity of data (data dropouts), and communication media on power system planning, operations, and reliability. The gaps include protocol conversion, cybersecurity delays, etc.

   Milestones:

   - Review available communication systems developed and practiced by other industries, and adapt them for integration with power system models.
   - Obtain data from priority communication protocols (defined by the SGIP and used in the field) to estimate the effects.
   - Develop interoperable interfaces between communication system and power system models.

   Measures of Success:

   - A framework to facilitate an open, scalable, interoperable, and integrated system model that enables better understanding of interdependency between communication and power system models.
   - Put into practical use by smart grid community (industry, multiple vendors, etc.).

   Timeframe: 3-5 years

   Level of Effort: High

2. **Advanced Control Algorithms** (tied with #1 on vote count)

    Gaps: Develop different M/S platforms for varying time scales to help develop, test, and validate different control algorithms (non-prescriptive but user specifiable) that perform smart grid functions. Real-Time Digital Simulators (RTDS) are an example of such a platform that covers electromagnetic transient phenomena. The gaps include both component and system controls.

    Milestones:

    - Conduct a scoping study on existing platforms for gaps.
    - Prioritize platform development for different ranges of time scales.
    - Develop platform(s).

    Measure of Success:

    - Consistent and uniform simulation results.

    Timeframe: 3-5 years

    Level of Effort: High

3. **Renewable (Non-dispatchable) Resources**

    Gaps: In addition to general improvements needed to fully model real and reactive power (inverter-based equipment), modeling capabilities that need to be established to improve the representation of renewable resources on the distribution system include improved availability of small time-step resource data, ability to create accurate generation profiles from different types of measurement sources and resource configurations, temporal and spatial representation of environmental events such as cloud passage, and protection impacts such as variations in fault current.

    Milestones:

    - Validate the first-generation M/S results of cloud transient effects on PV power output variability.
    - Integrate existing capabilities into the smart grid modeling environment.

    Measures of Success:

    - Conduct first ever demonstration with validation against field results.
    - Model PV controls for mitigation of impacts on high saturation of PV on distribution feeders (with electric vehicles, energy storage).

    Timeframe: 1-3 years

    Level of Effort: TBD

4. **Interoperability among Formerly Independent (Disparate) Models** (tied with #5 on vote count)

   Gaps: Interoperability among data that drives models; interoperability of model components among models; integration of models. A scoping study is needed to define what is required (what questions need to be answered).

5. **Test Cases for Availability of Measured Data for Model Verification and Validation (V&V), Modeling Load Profiles (e.g., Industrial...), etc.** (tied with #4 on vote count)

   No discussion on this capability was possible because of time constraints.

II.   Concurrent Breakout Sessions

Two concurrent sessions were held, each allotted for 1.5 hours, followed by a report-out by a designated session spokesperson for each session. Both sessions were conducted following a similar process that began with framing the session topics, continued with asking each participant to write R&D needs on index cards that were used to discuss/consolidate the needs, and concluded with voting on the needs by each representing entity.

Breakout Session 1: DR/BEM Integration

Table 2 presents related needs organized under group headings along with stand-alone needs in the last column; voting results are also shown.

Table 2. Technology Development R&D Priorities from Breakout Session 1: DR/BEM Integration

● **Indicates number of votes**

DR/BEM Technology Development R&D Priorities
Grid/Building Interface Control   ●●●●●●●●●● (10)
– Market based control of multiple resources in buildings for energy/power/ramp services that is capable of functioning in multiple scales, services, and time horizons
– Evaluate different forms of load set point control using energy targets that are off set (delta) from historical use
– Develop protocols for closed-loop market based control of buildings
– Develop algorithms for managing (closing the loop) between "bid/offer"
– Establish a standard means of expressing grid "needs" (what the building plans to do) to the building "offer" (what it is capable of doing or "bid")
– Develop static and dynamic building load forecasting models to support grid and building owner that include load history, weather, and near-term owner planning
– Develop load optimization methods/techniques (e.g., DR resource optimization) to support both the utility and the building owner (shared burden) that involves the individual building plus wide-area two-way communication and used for load shaping
– Develop ability to establish ownership/where control and smarts are located (device, building, or utility)

DR/BEM Technology Development R&D Priorities (*continued*)
Building Capability ●●●●●●● (8)
– Enhanced granularity in GIS/building modeling to clearly communicate affected regions within a building – Develop ability to identify building assets (especially big buildings like the Empire State building) in building simulations, BEM systems, etc. to assist in determining a building's capabilities – Develop on-line, data-driven methods to determine short-term distributed response capability of large buildings; what can the building do right now?
Predictive Building Load Management ●●●●●●● (8)
– Enhanced granularity in Predictive Load Management through user profiling – Develop fast load management (e.g., fast DR) from building automation system – Improve modeling of response to DR requests (i.e., behavioral modeling) for simulation
Disturbance Control ●●●●●● (7)
– Frequency "droop" control for DR in buildings – Develop distributed control algorithms (GFA-like) to respond to grid events – Improve understanding of how grid disturbances affect building operation to develop cheaper and better control schemes
Standards for Controls and Communications ●●●●● (5)
– Create well-defined communication interfaces between loads and grid (e.g., ASHRAE/NEMA SPC 201 "Facility Smart Grid Information Model, etc.) – Develop technology that supports the communication of price and reliability signals
Other Technology Development R&D Needs
– Develop cheaper and reliable telemetry solutions that support fast DR for ancillary services (area control error (ACE), automated dispatch system (ADS)); achieve 4-6 second telemetry; current capital cost is $5K to $10K, but needs to be below $500 ●●● (3) – Develop user/occupant interaction technology to (1) set constraints for DR and (2) provide active engagement in DR ●● (2) – Develop DR "staging" – setup to mitigate forecast uncertainty ● (1) – Determine how current DOE Buildings Technology Program (BTP) research to reduce energy use affects DR & Grid (coordinate with BTP) – Develop technologies allowing distribution utility to target a certain distribution location to avoid congestion

Breakout Session 2: PV and/or PEV Integration

This session was framed to discuss technology development needs in one to three years in the following areas:

- Hardware
- Software
- Standards conformance and development
- Infrastructures
- Testing
- Analytics
- Communications and control
- Regulatory issues
- Other

Each representing entity was asked to identify its top-2 needs in distribution grid integration of PV, PEV, or both. The compiled list of the top needs is presented in Table 3 (without prioritization).

Table 3. Compiled List of Technology R&D Needs from Breakout Session 2

PV/PEV Needs
– Load / generation prediction for high penetration PV/PEV both at distribution and higher voltages
– Control of microgrids (building, PV, PEV) operated as single units
– Regulatory(tariffs, interconnections, business practices) for microgrid
– Fast, real/reactive control using hardware, using converters or other hardware to control P, Q
– Methods and algorithms that allow thousands of components to coordinate in optimal volt/VAR balance on the grid while many rooftop PV and PEV are actively fluctuating
– Forecast methods and stochastic characterization
– Conformance test procedures for high penetrations of inverter based distribution assets
– Analytics/database to provide inputs for next generation distribution analysis
– Impact on the grid operation: schedule interaction with similar and dissimilar DG; This could happen both at the secondary level reflected on the distribution transformer and the primary level reflected on the substation level and finally at the control center level where thousands of these devices reflect
– More reliable, less dense batteries
– Control strategies for 4-quadrant inverters
– Ride through standards/control strategies
– Protection and control schemes for future grid topologies
– Communication and control of high penetration devices including volt/VAR management
– Algorithm for optimization at home level that has PV and PEV
– Unified infrastructure for plug and play PV/PEV communication and control
– Communication and control for bi-directional energy for local load leveling in commercial and industrial scenarios
– Net zero/self consumption PV/PEV for residential and commercial

PV Needs
– Standards that allow for islanded operation
– Reduce the cost of PV panels
– Energy storage for high penetration of PV, load leveling, and ride through
– PV rates and regulation

PEV Needs
– Standard PEV grid information models (charge required, flexibility in time, charging goal, location, etc.)
– Regulatory incentives for PEV deployment
– Vehicle to grid (V2G) standardization with communication and control functionality
– Smart charging capabilities
– V2G functionality

This was followed by a prioritization process that determined the top-5 R&D needs, which are listed below.

- Forecasting, control, and communication necessary for coordination of PV/PEV at:
    - Microgrids
    - Behind the meter / net-zero / self consumption
    - Secondary (not substation) transformer level
    - Feeder level
    - More detailed analysis, 4-corner testing, deeper dive

- Hardware/software development necessary for P, Q control of PV and PEV (device level and system level)

- Standards and conformance testing processes necessary for high penetration of PV/PEV and Voltage/Frequency ride-through

- Analytics necessary for control and analysis of next generation distribution systems

- Regulatory concerns

Acknowledgment

The DOE would like to acknowledge the support provided by the seven national laboratories represented in the multi-laboratory coordinating committee. Members of the committee, identified in Appendix 2, developed the preparatory materials (Appendices 4 & 5) used to guide the discussions for the M/S sessions. The forum discussions would not have succeeded in addressing all of the agenda topics without professional facilitation by Energetics Inc. for the M/S session and the DR/BEM integration breakout session and without technical facilitation by NREL for the PEV and/or PV integration breakout session.

Preparation of this forum report was coordinated by Energy & Environmental Resources Group, LLC (E2RG). The report content is based on forum session discussions, with breakout session summary descriptions taken from the session notes supplied by the session facilitators. Contributions to this report by all forum participants, via expressed viewpoints during the forum and review comments of the draft report, are duly acknowledged.

Appendices

1. **Forum Agenda**

Smart Grid MYPP
Discussion Forum Age

2. **Members of the Multi-Laboratory Coordinating Committee**

ANL: Guenter Conzelmann and Jianhui Wang

NREL: Dave Corbus

LANL: Scott Backhaus

LBNL: Sila Kiliccote

ORNL: Tom King

PNNL: Rob Pratt (Coordinator of the Multi-Lab Committee)

SNL: Ross Guttromson

3. **List of Attendance**

Forum Attendance
List.docx

4. **Pass Capabilities List, Fail Capabilities List, Capability Relevance, and TRL definitions** (prepared by the multi-laboratory coordinating committee)

MYPP Modeling
Capability Feedback (

5. **Definitions of Smart Grid M/S Capabilities and Associated Gap Areas** (prepared by the multi-laboratory coordinating committee)

Capability Gaps All
Final 06042012.docx