U.S. Department of Energy

Grid Tech Team

Electricity Distribution System Workshop

Discussion Summary

September 24-26, 2012

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Other referenced documents are available online at:
http://energy.gov/oe/downloads/gtt-2012-distribution-workshop-documents

INTRODUCTION

This report summarizes the inputs provided by external stakeholders and the associated discussions during the Electricity Distribution System Workshop, held in Arlington, Virginia, September 24-26, 2012.[1] Participants prepared for the workshop by reviewing the U.S. Department of Energy's *Action Plan Addressing the Electricity Distribution System* (available online). The Action Plan provides a context of on-going research and development activities in technology-specific areas. It also describes current efforts addressing the overall grid from a holistic systems perspective. The Action Plan raises issues and proposes questions that served as a departure point for discussions at the workshop.

This Discussion Summary report is an important part of the process of developing a comprehensive research roadmap for grid integration at the distribution level. This process involves engaging key stakeholders to identify opportunities and challenges, R&D needs, and priorities for action. Participants in the workshop helped target specific issues associated with grid integration and modernization. This material, along with the Action Plan and other inputs, will help guide DOE decisions on research and development investments over the next five years.

Participants from this workshop, other stakeholders, and the public at large are encouraged to provide additional input to this ongoing process. This document will be released in draft form with a formal request for information.

[1] This report summarizes inputs and discussions at a workshop sponsored by the United States Department of Energy. While this report is believed to be an accurate summary, neither the United States Government nor the Department of Energy, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information provided in this report.

EXECUTIVE SUMMARY

Process

The Distribution Workshop involved a diverse group of electricity-sector experts with interest in a modernized electricity distribution system. The workshop included two breakout sessions, whereby smaller groups (of approximately 20 people) brainstormed to identify and propose solutions to various issues. These breakout sessions addressed the questions proposed in the DOE Action Plan, validated assumptions, and offered perspectives on the challenges and opportunities associated with an advanced electricity distribution system. It is important to note that these sessions were not in any way trying to build agreement or consensus around any particular ideas or proposals. The discussions of these breakout groups are the results from the workshop reported here.

Workshop Breakout Sessions

1) Technology-Specific Issues

2) Holistic-System Issues

The first breakout session was organized around technology-specific issues. The goal of this session was to identify the significant challenges and opportunities that apply to particular technologies. The five separate breakout sessions covered the following topics.

- Distributed Generation: Variable
- Distributed Generation: Dispatchable
- Smart Grid Technologies & Distributed Energy Storage
- Plug-in Electric Vehicles (PEVs) and Fuel Cell Electric Vehicles (FCEVs)
- Residential, Commercial, and Industrial Building Loads

The second breakout session took all the experts from the previous technology-specific groups and mixed them evenly into five new groups, which were labeled by color. This resulted in each of the holistic-system groups consisting of representatives from each of the various technology areas. The focus of discussions in this session was to break out of technology-specific “silos” and take a system-of-systems look at the challenges and opportunities facing the electricity distribution system. The findings and results from both the technology-specific and the holistic-system perspectives are important to the Grid Tech Team and the development of an R&D roadmap for grid integration.

The reports from both breakout sessions were assembled and presented internally to all the attendees. In the days following the workshop, the moderators and note-takers drafted more formalized reports and submitted them to the DOE Grid Tech Team (GTT) for review. The GTT used those reports to refine the findings, which are described in this document.

Common Themes

The findings of this workshop consist of the common themes that were presented by groups in both the technology-specific and holistic-system breakout sessions. These themes represent the most critical challenges and opportunities associated with a modernized distribution system identified in the workshop. The themes were captured in the following five categories:

- Modeling, Simulation & Optimization
- Advanced Components, Controls & Interoperability
- Communications & Database Architecture
- Protocols, Codes & Standards
- Business Case, Demonstrations, Risk & Valuation

Modeling, Simulation & Optimization

Accurate modeling and simulation of the distribution system is critical to improving the informational, knowledge, and physical aspects of the grid. Models and simulators can enable a system-of-systems approach to the development and modernization of grid infrastructure.

Currently, there are no modeling packages that can simultaneously simulate the power, voltage response, communications, latencies and dynamics that are crucial to the system in real time.

The workshop groups identified opportunities to improve modeling on multiple levels including system planning, operations, and business. Improved models need to account for the interactions and dynamic response of the range of technologies discussed in the technology-specific breakout groups, listed above, and their impacts on the distribution grid, including possible bi-directional power flow, and with the larger transmission grid. These capabilities will help enable infrastructure development and distribution system operation with these many future technology opportunities and demand requirements.

Comprehensive modeling, simulation and optimization tools must also be open, cross-platform, and inter-operable. These models will need to rely on common databases, usable by multiple software programs. They will comprise service-oriented architectures that offer real-time applications opportunities. Models with these capabilities could be used to help evaluate the risks and benefits of the system so that stakeholders can optimize their business decisions and efficiently manage resources.

Advanced Components, Controls & Interoperability

The modernized distribution system will require upgraded tools to synchronize and manage its integrated resources. These tools should facilitate dynamic control of the system and promote interoperability. Controls need to be calibrated and responsive to all aspects of the system, including recharging electric vehicles, distributed energy storage, building and industrial loads, demand response, variable resource integration, dispatchable distributed generation, and linkages with transmission. Control systems must also factor in data collection, local distribution management systems, and effects on both sides of interconnections.

Tools and structures that improve system control must account for the various components of the system. Advanced components will play an important role in synchronizing technological compatibilities and improving end-user interfaces. Interoperability is key to ensuring that data from these tools can be assimilated into grid operations software, models and simulators. Participants in the workshop suggested a need for a maturity model designed to facilitate the interoperability of these control tools and structures.

There is an imperative need for interoperability between software tools. There are a number of models that are commercially available and it would be useful to bridge these tools to improve system understanding. A well-controlled and interoperable distribution system would greatly contribute to the safety, security, and reliability of the grid.

Communications & Database Architecture

Communications and database architecture is a very broad topic as it relates to the grid. Generally it includes cyber-security, data collection, storage, and conversion of data to information. The current system is replete with complex issues regarding the system's physical infrastructure, standards, data analytics, and technical nuances of the devices communicating with one another.

Data and communications are intimately connected with system and control architectures. The collection, storage, use, and communication of large volumes of data create a tangle of privacy and security issues. Individual devices and entire organizations, for example, maintain proprietary data and protocols that may sometimes conflict with effective communication throughout the grid.

Further, there is a substantial skills gap for current and future power system engineers who are unfamiliar with updated communication technologies.

Protocols, Codes & Standards

There is currently a lack of open source protocols, codes and standards in some areas that are necessary to develop an interoperable and flexible distribution system. Standardized interfaces between tools can enable accurate modeling of entire networks, which would yield valuable information for all stakeholders.

Research is needed on new standards, codes, and policies, and the refinement of metrics that can be used to evaluate standards and codes to ensure reliability and safety. It was suggested that DOE increase its involvement in standards-forming activities in concert with other organizations like IEEE, NEC, and IBC, and also strengthen its collaboration with international bodies to refine complementary standards. Of course, any proposed change in protocols, codes and standards must consider the process for stakeholders to provide input, understand, adapt, and comply.

Business Case, Demonstrations, Risk & Valuation

A key holistic-system challenge that was identified by many of the workshop groups was the need to improve the visibility and understanding of the grid in a quantifiable way. As it stands now, the system struggles with many issues, some of which include:

- A lack of captured value for grid services and opportunities,
- The lack of true valuation of potential niches (e.g., potentially stranded utility distribution and interconnection assets) that could allow other technologies to participate in the market,
- A need for risk analysis of integration into the various regional, state, and local markets, and
- Understanding the economic viability of microgrids from a utility perspective.

Formulating clear business cases includes identifying, monetizing, and allocating value streams across appropriate scales and among participants in the grid. A holistic systems-approach to grid integration is a very abstract concept for consumers, regulators, businesses, and utilities alike. At the workshop, there was a clarion call for tools that could optimize the mix of various resources and clearly quantify, in dollar amounts, their associated costs and benefits. There was also a call for end-to-end demonstrations to augment simulation and modeling and serve as proving grounds. This would dramatically improve the ability for stakeholders to make informed business decisions in the distribution marketplace. This will, in turn, unlock new markets and enable the deployment and integration of new technologies into the grid.

Summary

The Distribution Workshop distilled the innumerable complexities of a modernized distribution system into five common themes, which can help focus the DOE and stakeholders' attention. These common themes supplement the more detailed discussion topics that, in the following section, outline the specific challenges and opportunities associated with modernizing the electricity distribution system.

Discussion Topic Tables

Technology-Specific Issues

Tech Area	Research Topic	Gaps & Barriers	Possible R&D Approaches
Variable Distributed Generation	Interconnection Process	Need uniform, consistent, and transparent DG interconnection requirements, analyses and processes that are based on sound engineering principles	Support the use of interconnection models
			Support the development of a streamlined interconnection approval process
			Determine, validate, & test the right data and the right amount of data for DG interconnection studies
			Convene technical fora to share best practices
			Provide technical info & help to regulators
	Modeling & Simulation	Need dynamic system models and algorithms necessary to evaluate impacts of variable DG on the grid.	Develop dynamic feeder models
			Develop dynamic models for DG systems at the appropriate level of detail
			Develop better resource models to characterize and forecast output variability
			Develop dynamic models to characterize the interaction between DG and grid control
			Validate dynamic models through field testing
			Convene technical fora and workshops
	Data	Need uniform and transparent data models for DG planning and operation	Develop transparent framework for data requirements in DG planning and operation.
			Develop uniform processes for the collection, storage, and exchange of data
			Support data harmonization and standardization
			Support implementation & demo projects
			Develop open databases
			Convene technical workshops to share results
	Communication & Data Integration	Need enterprise tools to automate data exchange between software systems and promote interoperability	Develop and integrate modern enterprise tools to automate data sharing among different systems.
			Develop tools that can bridge between distribution and transmission grids
			Develop user friendly tools (e.g. easy button) for that focus on actionable intelligence to avoid info overload.
			Promote standard protocols, open interfaces, and information models for interoperability.
			Engage distribution planning and operation software vendors to develop new tools
			Disseminate data interoperability best practices
	Markets & Regulations	Need market and technology evaluation tools to inform and educate stakeholders	Develop benchmarks and metrics to quantify the various cost & value components in DG
			Develop market comparison tools
			Develop technology assessment tools
			Support implementation & demo projects
			Engage & inform stakeholders on best practices
	Standards & Codes	Need increased support for code and standard development to accelerate the processes	Convene fora for development of DG standards
			Support the use and validation of codes & standards
			Interact with regulators, utilities, & end users
			Collaborate with international standards bodies
			Engage software and hardware vendors

Tech Area	Research Topic	Gaps & Barriers	Possible R&D Approaches
Dispatchable Distributed Generation	Protection, Reliability & Safety	Need for adaptive protection schemes accounting for ever-evolving grid with bi-directional flow	Develop of low-cost protective equipment
			Develop low inertia devices to characterize and discriminate between faults and loads
			Identify all critical parameters on the grid and DDG side to model for safety
			Develop standard protection schemes for islanded systems
		Must ensure reliability and safety of distributed resources from a system operator perspective	Conduct research into improving analytics to identify health of the system
			Test, evaluate and validate candidate pilot systems in a simulated, relevant environment prior to deploying to the grid
			Develop standard metrics to evaluate reliability, availability, and system performance
			Develop remote diagnostics for DG systems
	Communication, Data & Information	Need for managing two-way (power and communication) flows in a diverse regulatory environment	Develop faster signal response from meters
			Develop interface standards for data & power
			Develop power flow algorithms for EMS & DMS
			Develop power flow control technologies, including interface technologies (e.g. inverters)
			Develop tools to mitigate voltage variations
			Integrate communications into power electronics
	Technology-Specific Research & Development	Need for energy storage (thermal, electrical, hydrogen, mechanical) to be further developed to effectively utilize dispatchable systems	Analyze storage use optimization (reliability, economics, efficiency) with the value proposition
			Develop and demonstrate biomass-based hydrogen for use as grid storage
			Research storage system cost reduction
			Conduct Verification and validation of storage system performance and efficiency
			Develop small-scale dispersed storage and mobile storage in support of DDG
		Need for improved dispatchability, response times, and cycling of distributed generation	Research to improve charge/discharge cycles
			Develop fuel cell hybrid systems
			Materials research to support high temp systems capable of cycling (SOFC)
			Research to characterize performance of systems in a cycling environment
			Develop tools to optimize cycling/dispatch

Tech Area	Research Topic	Gaps & Barriers	Possible R&D Approaches
Smart Grid	System Architecture & Technologies	Need for engineering use cases to help demonstrate value and duplicate successful technology solutions	Generate/document baseline engineering use cases (e.g. from DOE SG demos, EPRI, international) that identify impacts on system control, architecture issues, and lessons learned
			Develop library of broadly applicable scenarios (e.g. microgrids, EV, high penetration of RE, aggregators, AMI deployment) that includes business models, value streams, cost allocations, and requirements
			Leverage SGIP to expand upon standards use cases
			Generate reference architectures from requirements for various use cases
		System architectures for the future grid will be fundamentally different, an understanding of the future grid landscape is needed	Convene stakeholders that can establish future directions for system/management architectures
			Evaluate the pros and cons of architectures in different scenarios with various control systems
			Extrapolate lessons learned from microgrids to be used in the distribution system
			Determine data exchange needs and collection requirements at various levels
			Improve interconnection of transmission & distribution systems
	Protection, Reliability, & Safety	New protection technologies and schemes are needed for the future grid	Investigate technologies needed to accommodate two-way power flows
			Investigate continued system operations in the event of losses (e.g. communications)
	Modeling & Simulation	Need for next generation modeling and simulation tools that can more accurately capture the system	Research advances in modeling tools & computing methods to span the timescales of simulations (ms to hours) and to handle uncertainties
			Develop calibrated and validated technical models for components and full systems through use of existing or new data
			Develop tools to simultaneously model dynamic system/component responses and communications
			Develop models for reliability and prices to demonstrate value of technologies and tools
			Convene vendors and users to improve data exchange needs and requirements
			Improve visualization tools to inform decisions
			Establish distribution simulators & training tools
	Workforce Development	Workers will be unfamiliar with the rapid adoption of new technologies	Support education & workforce training for current and future power system engineers
			Support the development of curricula and partnerships between industry and universities, community colleges, and other institutions
	Communications, Data & Information	Requirements and standards for communications and data are fairly open-ended	Help establish communication requirements for various components in different configurations
			Develop conformance testing and certification for interoperability, including cyber-security
			Define requirements for data collection, storage, conversion to info base on use-cases & goals.
			Develop data and communication for future needs

Tech Area	Research Topic	Gaps & Barriers	Possible R&D Approaches
Electric Vehicles	System Analysis Tools	Lack of understanding EV charging and electrolyzer impact on grid, of charge rates on EV acceptance	Identify knowledge gaps to develop tools at component and grid interface levels
			Data collaboration between DOE and OEM
			Conduct telematics demonstrations which would include all stakeholders including third parties, such as OEMs and utilities working collaboratively
			Develop models, complementary to the demonstrations, spanning the grid to understand bi-directional power flow.
			Validate models with data gleaned from demonstrations
	Market Analysis	Lack of understanding the monetary value of ancillary services provided by EVs and electrolyzers	Evaluate existing ARRA demonstrations, such as the Northwest Demo, to understand the value of ancillary services
			Modify existing small fleet demonstrations to include ancillary service investigation
			Research and analyze potential service market for frequency regulation, demand response that's good for the battery/electrolyzer, start/stop charging and electrolyzer operation to determine the level of impact in each area
	Technology-Specific Research & Development	Need for development of new batteries to improve energy density and charge rate while reducing cost. Lack of understanding of the operating envelope of previously used batteries and how new chemistries perform	Develop new battery technologies with improved energy density and charge rate
			Research cost reduction methods for new and existing battery technologies
			Accelerate current testing. Open applied battery program to more participants
		Need for an understanding of electrolyzer efficiency in large stacks, improvement in system efficiency, cost reduction, and system size	Research PEM electrolyzer scale-up
		Need for bi-directional power and communication to identify low cost solutions and maintain grid stability	Research higher efficiency operations
			Develop lower cost membranes, catalysts, & stacks
			Research improved hydrogen purification
			Research higher pressure operation
			Develop power electronics with bi-directional power and communication capabilities

Tech Area	Research Topic	Gaps & Barriers	Possible R&D Approaches
Buildings	Interoperability	Building resiliency: Lack of understanding of relationship between building performance and grid operations	Analysis on measured characteristics.
			Develop models to understand characteristics of how buildings can/do interact with the grid
			Catalog systems and solutions map to characterizations
	Sensors & Controls	Lack of technical infrastructure (controls/sensors) in buildings	Identify the ideal characteristics of building control solutions, for all building types
			Develop and deploy low cost, plug & play solutions of cognitive, secure, standardized, and scalable infrastructure for building ops and grid interaction
			Develop/deploy low cost, application specific sensors
	Standards & Code Development	Lack of uniform, national specifications for integration and interconnection applicable to behind the meter assets, beyond IEEE1547	Develop, alongside industry, a national standard for integration and interconnection, taking into account safety, reliability, and future markets
	Markets & Regulations	Lack of business case to achieve solution on both building and grid sides	Develop model business plans to identify and monetize potential and existing value streams across the ISO, utilities, end users, and other market actors
			Develop analytic tools, demos, and pilots
			Maintain adherence to rules/regulations throughout development of models, tools, and demonstrations
	Communications	Lack of adequate information and communications systems to communicate energy and other valuable information between all interfaces of buildings and grid	Survey existing communications systems and infrastructures
			Develop, deploy, and/or integrate the existing communications interfaces
			Standardize measures for communicating/signaling
			Develop common lexicon for communicating info
			Include cyber-security measures throughout each communications development project

Holistic-System Issues

Research Topic	Gaps & Barriers	Possible R&D Approaches
Communication Protocols, Data Formats, & Interfaces	The distribution network is historically a "closed" system, but must become an IT-like "open" system with a common data service bus, while maintaining reliability and sufficient cyber protections	Establish algorithms for data aggregation that removes privacy concerns while providing necessary information at relevant scales
		Develop best practices in cyber-security through inter-agency collaboration
		3rd party testing and certification of adequate cyber-security and communications interoperability
		Develop an open data exchange infrastructure for grid operation and support of transactions
		Engage in development of advanced SCADA system definition and work with utilities and system operators for acceptance and demonstration
	No actionable cost-effective communication technologies	Leverage lessons learned from existing "big data" issues in other applications
		Develop mechanisms and devices to get the right information (e.g. price) to the right stakeholder (e.g. consumer/user) at the right time
		Develop analytical tools for data assessment and filtering
	Existing data streams do not adequately support visibility of the distribution system nor are they fully transparent	Develop low-cost sensors and associated optimal placement algorithms
		Develop methodologies for extracting currently under-utilized data streams from the sensors in already deployed technologies (power electronics, AMI)
		Facilitate the delivery of pricing, reliability, and other information to end-users and relevant stakeholders
		Common database that multiple software programs can pull from
	Comparison of available communications technologies for informing system design is cumbersome	Compile database of the technical specifications (latency, bandwidth, etc.) of existing and future communications technologies
		Document communications and functional requirements for technologies that can enable new grid capabilities
	Divergent communications standards and protocols between different technology areas	Facilitate standardization and harmonization of protocols and communication across relevant technology areas
		Enabling demonstration projects to showcase interoperability standards

Research Topic	Gaps & Barriers	Possible R&D Approaches
Modeling & Simulation	Common platform for consistent input data development is needed across models, formats, and vendors	Development of non-proprietary generic, but accurate, component models using proprietary manufacturer data
		Develop complete simulation models that are open, cross-platform, and vendor neutral.
		Facilitate standardization and interoperability between software tools as the system grows in complexity and layers of hierarchy
	Lack of an uniform decision support system for distribution grid planning and operations	Develop real-time weather and demand forecasting models
		Use of service oriented architectures for real time applications
		Develop look ahead (faster than real-time) simulation
		Develop validated state estimators for common dist. network topologies
	Workforce training tools do not exist for emerging planning and operational software and practices	Interactive scenario and threat analysis
		Study past failures and understand system dynamics
		Improve interfaces of existing modeling platforms
		Develop & deploy workforce training tools for new software & practices
	Current planning tools do not include emerging technologies in the mix of available strategies for system design	Develop adaptable system models that quickly determine allowable renewable penetration levels
		Develop planning tools that incorporate emerging technologies and control architectures
	Cost, complexity of measuring a large number of geographically distributed nodes impedes system visibility Need for parameterized node definitions (describing a node in terms of its capabilities in handling distributed generation)	Conduct demonstration projects confirming modeling & analysis efforts
		Develop visualization & decision support tools, (e.g. video game industry)
		Validate and demonstrate existing and emerging tools
		Develop self-adaptive, self-calibrating feeder models that update via measurements and "plug-and-play" handshake data
		Develop algorithms to create cognitive networks of devices and sensors, for identifying and predicting grid performance
		Develop adaptive query methods to make big data actionable
Grid Standards Development	Need for a uniform set of standards that enable easier integration of distributed generation onto the grid	Conduct research to inform standards, codes, and policies
	Need to define a set of characteristics that all distributed generation should have to interact with the grid	Develop metrics to evaluate standards and codes
	Need for more information on the latest technologies	Create a forum to facilitate the discussion with all appropriate stakeholders for standard development
Grid Sensing & Monitoring	Lack of low-cost interoperable sensors that can measure distribution network data.	Develop temporary, mobile sensors
		Conduct demonstration and deployment for qualification
	Need to package multiple sensors as one element for integrating onto existing grid	Conduct development, demonstration and deployment for qualification

Research Topic	Gaps & Barriers	Possible R&D Approaches
Grid Interoperability, Optimization, & Efficiency	Need to optimize the operation of the distribution grid	Develop optimization tools with various criteria such as central vs. DG, technology options, value proposition, risk management for security
		Pilot demonstrating end-to-end system interoperability, from generation to end-use, including microgrid
	Need for metrics to assess optimality of grid operations	Develop metrics to ensure that cost and value proposition are quantifiable and factored into evaluation
	Identify opportunities to operate various distributed generation resources in a synergistic fashion	Develop new EMS and DMS power system algorithms for new distribution system topologies
		Develop DMS that communicates with grid operator
		Assess scalability of technologies for accessibility to markets and systems
	Need predictive algorithms to dispatch distributed generation and energy storage in advance of weather patterns	Integrate the operation of dispatchable renewables with weather forecasts, collection, storage, management and analysis of large amounts of data
	Need to integrate building controls with distribution operators for improved demand response capabilities	Develop a new building controls paradigm and implement existing controls
Market Structures, Regulation, & Policy	Lack of common signaling for ancillary service needs and a lack of incentive structure for system operators and generators to provide them	Develop models of ancillary service values/benefits
		Define value propositions at all levels of interaction across regions
		Develop multiple simultaneous value propositions such as DR, improved EE, maintenance & management services via investment in infrastructure
	Need to clarify technical information for regulators	Programs for education and interaction among regulators, policymakers, customers, and industry
Grid Technology & Equipment Development	Current infrastructure doesn't allow for communication adaptability	Research low cost multi-functional power electronics that can accommodate communication and control features
		Demonstrate the integration of microgrid characteristics (demos, best practices, lessons learned, ancillary services) into planning and design
	Need for future-proofing all components and technologies	Develop upgradable power electronic interfaces, (power flow controllers, inverters with upgradable firmware for selective harmonic reduction)
Protection, Reliability, & Safety	Reliability and safety must maintain or improve upon current levels as new technologies are integrated into the grid	Develop and demonstrate fault-tolerant and self-healing distribution systems for different applications
		Demonstrate and study the interactions between centralized and autonomous controllers – "loosely decentralized controller"
		Develop mechanism (manual vs. automated) to respond to actions while ensuring reliable operations of distribution system
		Develop and demonstrate adaptive protection systems for flexible grids
		Develop standards of optimization and reliability to business models
		Establish redundant pathways to ensure reliability of transmission, power flows, storage, etc., and data and info
		Create metrics to measure reliability of microgrid, generation, and storage technologies

Research Topic	Gaps & Barriers	Possible R&D Approaches
System Architectures & Control Structures	Alternatives to traditional radial topologies have not been fully analyzed and explored	Analyze visibility, controllability, communications, cost, reliability, and operational implications of potential new topologies, including more tightly coupled networks, networks that enable intentional islanding, and AC/DC configurations
		Develop power electronics-based flow controllers and analyze the topologies and architectures that they enable
		Develop EMS, DMS, or similar that enable new architectures
	Emerging system architectures and control strategies unproven	Perform end-to-end demonstrations that capture cost and value to all relevant stakeholders, including stakeholder behaviors and in different markets
		Leverage lessons learned from existing projects
	Control theory and practice does not adequately cover systems of multiple temporal and spatial scales with significant uncertainty and increased DER	Foundational control theory research to span the multiples scales and to handle uncertainty
		Develop control strategies for new system architectures including ones that can accommodate anti-islanding with increased DER

Conclusion & Next Steps

The Distribution Workshop generated highly productive discussions among electricity sector stakeholders. The synthesized results from the breakout sessions offer a thorough perspective on the opportunities and challenges associated with modernizing the grid. However, the one area that was noticeably lacking in the workshop discussions was energy storage. It is likely that this topic was not covered in sufficient detail because of the structure of the workshop. Energy storage was originally intended to be the focus of its own breakout group session. Instead, it was combined with the Smart Grid discussion. Though there was some conversation on the topic, unfortunately, it was not addressed adequately enough to reflect stakeholders' keen interests in behind-the-meter and distributed energy storage technologies.

Moving forward, the summary of these discussions presented here will help target key challenges and opportunities associated with grid-integration at the distribution level. The information gleaned from the workshop, as described in this document, together with the DOE Action Plan (available online) and other inputs, will play an important role as reference material to inform the development of a research and development roadmap for DOE and help guide R&D investments over the next five years.

Participants from this workshop, other stakeholders, and the general public at large are encouraged to provide additional input to this process. This document will be released in draft form with a formal request for information. These discussion summaries, along with other inputs to the road mapping process will help reinforce the broader efforts of the Grid Tech Team and enable DOE to support the research and development of solutions to achieve a 21st century distribution system.

Breakout Session Summaries

TECHNOLOGY-SPECIFIC ISSUES

TECH GROUP: Distributed Generation – Variable

Overview

The session began with a discussion the integration of variable distributed generation to the distribution network. Variable distributed generation includes resources that are subject to changing environmental conditions, such as wind or solar power for example. The breakout group generated a list of challenges and opportunities associated with modernizing the distribution system.

Key Opportunities & Challenges

As the market share of variable DG grows, concerns about their potential impacts on the operation of the distribution system are likely to increasingly emerge. This is due to their variable, non-dispatchable nature and because the distribution system was not originally planned for multi-directional power flow. Therefore, higher penetration of variable energy resources (VER) and larger plant sizes force many interconnection requests into supplemental studies that often create delays and increase costs.

While there are valuable lessons that can be learned from other countries such as Europe, there are many unique challenges in the U.S. due to the many and varying regulatory landscapes in the energy markets. The DOE and industry urgently need a set of uniform, consistent, and transparent methodologies and tools in determining and communicating the true costs and values of owning and operating variable DGs to stakeholders – utilities, end users, and regulators.

In addition to the three categories of challenges identified in the Action Plan, namely, a) Technical Challenges, b) Impact Studies, and c) Distribution Management Systems, the group has raised and discussed the following specific challenges during the breakout session:

- Burdensome and varying interconnection processes;
- Lack of tools for planning and operation of variable DG on the distribution grid;
- Lack of methodologies and tools in determining and communicating the true cost and value of variable DG to stakeholders;
- Lack of robust, low cost, resilient, secure communication system for visibility and control of variable DG; and
- Lack of interoperability of software and hardware systems.

Breakout Discussion and Conclusions

1) Burdensome and Varying Interconnection Processes

Existing variable DG interconnection requirements and processes are cumbersome, varying from jurisdiction to jurisdiction, and often confusing to variable DG developers and end users. There is a lack of well-defined triggers for interconnection studies that are based on rigorous and sound engineering principles.

While current practices include data gathering and system modeling steps, there is a need to identify the right data and models (at the appropriate level of detail) for variable DG interconnection studies. These include, but are not limited to, feeder and load data, information on certified equipment that are easy to access, and better resource information to characterize variable DG. What is implied here is that the data and models required should be sufficient but not overbearing.

There is a need to develop **uniform, consistent, and transparent** technical analyses and streamlined interconnection processes that are based on sound engineering principles, with consideration of regional differences. These analyses and processes should be validated and shared through case studies and best practices.

2) Lack of Tools for Planning and Operation of Variable DG on the Distribution Grid

Due to the distributed and dynamic nature of variable DGs, traditional static analyses processes and tools used in impact studies are not sufficient. There is an urgent need to integrate existing tools and develop new tools to help more accurately evaluate impacts of variable DG on the grid. It is also critical to publish the results from these efforts and disseminate the findings.

Models - Rather than treating variable DG as negative loads, there is a need to develop dynamic models and algorithms for variable DG resources, grid devices, protection schemes, and power flows to capture the interaction between variable DGs and the grid. There is a need to develop real time (e.g. 15-minute) resource forecasting and predicative analyses capability.

Data - The type, accuracy, granularity, and timeliness of data are critical in impact studies and grid operation, but often cause confusion. There is a need to develop generic and transparent processes on the definition and collection of the right data and the right amount of data. It was suggested that data sharing should be encouraged to inspire and validate new ideas.

Interoperability - Traditionally engineering tools are stove piped, making it hard to exchange data between software systems. There is a need to develop modern enterprise-grade tools (vs. islanded tools) and open interfaces (e.g. APIs) to integrate dynamic grid components such as variable DG. These tools should promote interoperability and data sharing using standard-based methods such as Common Information Model (CIM), and leverage on existing industry efforts and standard activities at IEEE, NIST, and IEC. It was suggested that there is a need for a maturity model for the capability and convergence of these tools. And last, the tools need to bridge between distribution and transmission grids.

Education – It was pointed out that there are many existing tools that are not used or underused by practicing engineers because of the lack of training. There is a need to increase DOE's facilitation role (e.g. hosting workshops) and help the adoption of available tools. It is desirable to develop easy buttons for operators and planners so that they will be more likely to use these tools.

3) Lack of Tools to Assess the Cost and Value of Variable DG

During the planning stage, it is often difficult to determine and communicate the true cost and value of variable DG to stakeholders, including utilities, end users, and regulators.

There is a need to develop uniform, consistent, and transparent methodologies and tools to analyze the costs and values of variable DG in order to guide system planning and operation. As a start, the various cost components of variable DG integration should be quantified. In the meantime, variable DG should be treated as system resources (rather than negative loads) to unlock their potential values to the grid. For comparison, the do-nothing scenario should be analyzed as a baseline in contrast to deploying new technologies for mitigating variable DG integration impacts.

It was suggested that the industry should have more interaction with the PUCs and engage in more customer education.

Understanding of rate structures was considered important. There is a need to develop comparison tools that integrate rate cases and rate structures with variable DG installations to help inform regulators. Having a clearer picture, the regulators may be able to devise new market mechanisms to incentivize utilities and end users in deploying more variable DG.

4) Lack of Robust, Low Cost, Resilient, Secure Communication Systems for Visibility and Control of Variable DG

The group agreed that communication infrastructure upgrades are necessary for the visibility and optimal control of DG resources. While many communication and networking technologies exist in today's market, there are few systems that have all the attributes (robust, lower cost, resilient, and secure) required in the electric grid.

There is a need to develop comparison tools to evaluate cost-effective communication options. First, communication network requirements (e.g. latency, bandwidth, security, etc.) should be driven by the specific needs of the DG applications. For example, DG monitoring-only applications will have less stringent requirements on latency compared with DG control applications. Once the baseline requirements are determined, future expandability and upgradability may be taken into consideration for the final planning. These tools will provide the planners with a clearer picture of the available communication technologies for optimal trade-off between cost and functionality.

5) Lack of System Interoperability

Many software and hardware systems used in DG installations do not interoperate with the electric grid. There are on-going activities in codes and standards development that are mostly led by volunteers and progress slowly. There is a need for more support to accelerate the processes.

It was agreed that validations of standards in the laboratory and in the field are important, and the results should be published to better inform and educate stakeholders – particularly state regulators and code officials.

It was suggested that DOE increase its involvement in standard activities (e.g. IEEE, NEC, and IBC), and strengthen its collaboration with international standard bodies to harmonize standards.

R&D Opportunities

1) Develop DG Interconnection Requirements and Processes that are Uniform, Consistent, and Transparent

- Identify and develop the variable DG resource and feeder models at the appropriate level of detail;
- Identify the right data and the right amount of data for DG interconnection studies.
    - For example, feeder and load data, information on certified equipment, and better resource information should be collected to characterize variable DG and the distribution grid it is connected to;
- Support the development of a timely, streamlined process;
- Validate the technical analyses and interconnection through lab and in field testing; and
- Develop technical forums to share case studies and best practices.

2) Develop Dynamic System Models and Algorithms for Variable DG

- Develop dynamic models for feeder topology and control algorithms;
- Develop dynamic models for DG systems and devices, particularly the power electronic capabilities;
- Develop better resource models to characterize DG output variability;
- Develop dynamic models to characterize the interaction between DG and traditional grid control functionalities – e.g. Volt/VAR control, protection schemes, anti-islanding;

- Develop control coordination algorithms and harmonize DG control and traditional grid control;
- Develop real time (e.g. 15-minute) resource forecasting and predicative analyses capabilities;
- Validate the dynamic models and algorithms through lab testing and field demonstrations; and
- Develop technical forum to share the results and educate distribution engineers.

3) Develop Uniform and Transparent Data Models for Variable DG

- Develop generic and transparent framework to define the type, accuracy, granularity, and timeliness of data necessary for applications in DG planning and operation. The data requirements are driving the business processes;
- Develop uniform, consistent, and transparent processes for the collection, storage, and exchange of data among various systems;
- Develop and support the harmonization of information models (e.g. GIS, CIM) for better data sharing and interoperability;
- Develop open databases that are made available to the wider community in order to spur innovative ideas and to validate new concepts; and
- Publish results and disseminate findings.

4) Develop and Integrate Enterprise Tools to Automate Data Exchange

- Develop and integrate modern enterprise tools to automate data sharing among different systems. This becomes increasingly important as the electric grid is adding more and more intelligent components such as DG;
- Develop tools that can bridge between distribution and transmission grids;
- Develop a capability maturity model (CMM) to easily evaluate the capabilities of these tools;
- Develop simple-to-use (e.g. easy button) and user friendly tools for operators and planners and focus on actionable intelligence and avoid information overload; and
- Promote standard protocols, open interfaces, and information models for interoperability.

5) Develop Market and Technology Evaluation Tools to Inform Stakeholders

- Develop benchmarks and metrics to quantify the various cost and value components of DG integration (e.g. interconnection cost, ancillary service benefit);
- Develop market comparison tools that integrate rate cases and rate structures in DG planning. These tools help regulators (i.e. PUCs) to devise effective market mechanisms to incentivize DG;
- Develop tools to evaluate cost-effective communication options; and
- Develop tools to evaluate new technologies in DG integration planning.

6) Enhance Support for Codes and Standards Development

- More support for code and standard development to accelerate the processes. Convene a common forum for DG standards;
- Validation of standards in the laboratory and in the field;
- Evaluation of DOE involvement in additional standard activities (NEC, IBC);
- Better inform / educate state regulators, code officials, utilities, and end users; and
- More collaboration with international standard bodies for standard harmonization.

TABLE 1 – DISTRIBUTED GENERATION: VARIABLE

Research Topic	Gaps & Barriers	Possible R&D Approaches
Develop uniform, consistent, and transparent DG interconnection requirements, analyses and processes based on sound engineering principles.	• interconnection processes • Impact studies • determining and communicating cost and value	• support the use of uniform data and system models • Support the development of a streamlined process • validation and testing • convene technical fora to inform / share best practices • more interaction with regulators
Develop dynamic system models and algorithms necessary to evaluate impacts of variable DG on the grid.	• interconnection processes • technical challenges • Impact studies • distribution management system • planning and operation tools	• fund direct R&D activities in the development of system models and algorithms • validation and testing • convene technical fora and workshops to inform / share results
Develop uniform and transparent data models for DG planning and operation	• interconnection processes • planning and operation tools • technical challenges • Impact studies • distribution management system • communication system options • interoperability	• fund direct R&D activities in the development of data models • support various standard activities in data harmonization • support implementation and demonstration projects • develop open databases • inform / share results
Develop and integrate enterprise tools (vs. islanded tools) to automate data exchange between software systems	• interconnection processes • planning and operation tools • distribution management system • communication system options • interoperability	• support implementation and demonstration projects • support various standard activities in data harmonization • engage software vendors • share best practices
Develop market and technology evaluation tools to inform and educate stakeholders	• interconnection processes • determining and communicating cost and value • communication system options	• fund direct R&D activities to develop benchmarks and metrics to quantify the various cost and value components in DG • support development of market comparison tools • support development of technology assessment tools • support implementation and demonstration projects • engage /educate stakeholders & share best practices
More support for code and standard development to accelerate the processes	• interconnection processes • planning and operation tools • interoperability	• convene a forums for development of DG standards • validation of standards • more interaction with regulators, code officials, utilities, and end users • more collaboration with international standard bodies for standard harmonization • engage software and hardware vendors

TECH GROUP: Distributed Generation – Dispatchable

Overview

This session focused on brainstorming the technological challenges of integrating dispatchable distributed generation (DDG) into the distribution system and identifying potential opportunities for DOE to assist the industry in overcoming these challenges. Discussion began by each participant identifying a single challenge in a round-robin fashion. These challenges were then categorized into four key areas of opportunity and voted on to prioritize the challenges in each category by level of importance. The session participants then brainstormed opportunities for DOE involvement in addressing the five highest priority challenges.

For the purpose of this discussion, dispatchable generation was defined as any generator, ranging between 5kW and 20MW in size, which has on-off capabilities that could be commanded by an ISO to turn on, off, derate or increase power production on a time scale compatible with dispatchable time response requirements (minutes). The size limitation was imposed to distinguish distribution-level generation from transmission-level generation thereby limiting the scope of the workshop sufficiently to produce targeted results. These generator technologies can include, but are not limited to, battery storage, conventional generators, and alternate energy devices powered by renewable resources such as hydrogen and biomass or non-renewable resources such as fossil fuels. Examples of such devices include, but are not limited to fuel cells, micro-turbines, and flywheels. Dispatchable generators connected to the distribution system can act as energy exporters and can provide reactive power support and other ancillary services. For the purpose of this session, no restriction was placed on the ownership of the generators and the group considered ownership by a utility, third party entity, or a consumer.

Discussion Summary

Participants in this session identified numerous challenges facing the integration of dispatchable generation into the distribution system. These challenges were categorized into four key areas of opportunity for DOE and industry advancement:

(1) Economic and market issues;

(2) Communication, data, and information;

(3) Equipment protection, reliability, and safety;

(4) Equipment-specific research needs.

1) Economic and Market Issues

Although participants identified economic and market issues to be important topics, these issues were outside the scope of the workshop and thus not expanded upon. Market challenges included: a lack of captured value for grid services on the part of DDG operators, the lack of acknowledgement and true valuation of DDG participation in the market, a need for economic analysis of integration into the various regional, state, and local markets, and understanding the economic viability of microgrids from a utility perspective. These challenges were recorded as items to be expanded upon in a future workshop that will focus on addressing market issues.

2) Communication, Data, and Information

The ever-increasing complexity of the distribution system has created a clear need for interoperability between consumers, retail producers, and system operators. The need for two-way flow of both power and data is a key challenge in advancing dispatchable distributed generation in a reliable and safe manner. System operators are currently managing their networks with limited visibility into the operation of the distributed resources they are interconnected with. This lack of communication between operators and distributed resources limits both the value of the resources and the operating efficiency of the distribution grid.

Distributed resources can also benefit from the development of communication and data exchange in a microgrid setting. Through proper communication, a microgrid can utilize dispatchable generation, energy storage, and demand response to self-regulate large penetrations of variable renewable generation (such as wind and PV) without affecting distribution system reliability.

3) Equipment Protection, Reliability, Safety

DDG is creating bi-directional power flow challenges on a distribution system that was traditionally designed for one-way power flows. Participants in this session identified a need for the development of adaptive protection schemes and technologies that could allow for dispatchable generation integration through the system without significant hardware upgrades being required. This potential for bi-directional power flow also creates safety concerns where microgrids are interconnected that can become islanded during a power loss event.

System operators are currently unable to fully evaluate the reliability and power quality impact of distributed resources on their systems. DDG technologies can provide power support services, such as frequency and voltage regulation, and in some cases reactive power support, to operators; however these services, as yet, are not properly valued and appropriate standards are not in place to allow these technologies to reliably provide such services. In addition, traditional voltage regulation technologies are proving inadequate in regulating the distribution network as more distributed generation integration is creating a bi-directional power flow environment.

4) Equipment-Specific Research Needs

Participants in this session identified several challenges that could be resolved through development of dispatchable generation equipment technology and understanding. Energy storage, including thermal, mechanical, and electrical, needs further development to reduce cost, increase efficiency, and improve rapid cycling abilities. Understanding the value proposition of these technologies is also important to inform industry targets. There is also a need for consumers and system operators to better understand the costs and impacts associated with cycling various generation technologies to better inform dispatch priorities. For instance, rapid, frequent load cycling may affect the lifetime of certain systems and may not be desired on the part of the system operator, in effect setting up a conflict between the grid operator and the DDG owner, each having different goals for the equipment. In cases where the DDG system is also a combined heat and power (CHP) system, additional constraints on the dispatchability of the system may be put in place to ensure reliable delivery of its heat load as a priority over grid support.

A greater understanding of how dispatchable generation can benefit other technologies is also needed. This includes examining the necessary levels and technology mixes of dispatchable, distributed spinning or hot reserves that must be present on the distribution system to maximize variable renewable generation, as well as accurately matching thermal and power loads to fully utilize CHP capabilities.

Opportunities

There were five gaps and barriers identified as being key hurdles for the advancement of DDG on the grid. These barriers included: reliability and protection, energy storage and generator cycling, grid communication and interoperability. Potential DOE actions include researching new technologies, refining existing technologies, developing standards, and creating demonstration projects. DOE's role in this area remained specifically technology-centric. The barriers are listed in the following table.

TABLE 2 – DISTRIBUTED GENERATION: DISPATCHABLE

Research Topic	Gaps & Barriers	Possible R&D Approaches
Equipment Protection, Reliability, & Safety	Evaluating the reliability of distributed resources from a system operator perspective	• Research to improve analytics to identify health of the system • Test, evaluate and validate candidate pilot systems in a simulated, relevant environment prior to deploying to the grid. • Develop standard metrics to evaluate reliability, availability, and system performance • Develop remote diagnostics for DG systems
Equipment-Specific	Energy storage (thermal, electrical, hydrogen, mechanical) to effectively utilize dispatchable systems	• Analyze storage use optimization (reliability, economics, efficiency) with the value proposition • Develop and demonstrate biomass-based hydrogen for use as grid storage • Research into storage system cost reduction • Verify and validate storage system performance and efficiency • Develop small-scale dispersed storage and mobile storage in support of DDG
Equipment-Specific	Improving dispatchability, response times, and cycling of distributed generation	• Improve power response time • Develop fuel cell hybrid systems • Materials research to support high temperature systems capable of cycling (SOFC) • Research to characterize performance of systems in a cycling environment • Develop tools to optimize cycling/dispatch
Communication, Data, & Information	Managing two-way (power and communication) flows in a diverse regulatory environment	• Develop faster signal response from meters • Develop interface standards for both data and power • Develop new power flow algorithms for EMS and DMS • Research new equipment to mitigate voltage fluctuations • Integrate communications into power electronics devices
Equipment Protection, Reliability, & Safety	Adaptive protection	• Develop low-cost protective equipment • Research into low inertia devices to characterize and discriminate between faults and loads • Identify all critical parameters on the grid and DDG side to model for safety • Develop standard protection schemes for islanded systems

TECH GROUP: Smart Grid Technologies & Distributed Energy Storage

Overview

The session began with a discussion of the purpose of the breakout, which was the integration of smart grid technologies and storage on the distribution system necessary to enable the deployment of the full range of distributed energy resources. The desired outcomes were activities that DOE could pursue to overcome key challenges within a 5-year time frame. Despite the combined session with storage, the bulk of the discussions were around smart grid technologies. A list of challenges to achieving the future vision described was generated and then prioritized. R&D activities and initiatives that would help overcome the challenges selected were then identified.

Discussion Summary

1) General Comments

“Smart grid” is a nebulous term that is used differently by different groups. The fundamental purpose of these technologies is to help manage the grid. On the other hand, new technologies such as energy storage could serve as a key enabler to increasing the amount of variable renewables into distribution systems. Despite its usefulness, storage is typically not included into planning from the beginning, i.e. understanding and determining how much will be needed to integrate a certain amount of renewables on the distribution system. In general, a holistic perspective is needed to modernize the grid including the physical, information, business, technology, and policy aspects. In particular, policy must be carefully set to avoid unintended consequences and negative reactions. The blurring of transmission and distribution systems and the associated interactions and coupling will also need to be taken into account. There is also an opportunity to generate ARRA case studies so others may learn from successes and mistakes. Many AMIs were deployed but the system architectures needed to leverage the data does not exist yet and remains an issue.

2) System Architectures, Microgrids & Controls

Improved coordination between the multiple technologies being deployed is necessary to increase grid reliability. The discussion on microgrids suggested they could potentially decrease reliability, or potentially maintain or increase reliability if deployed properly. To achieve the successful integration of microgrids, clearly defined control systems that factor in data collection, interactions on either side of the point of common coupling, and local distribution management systems must be designed. It will also be important to determine who will monitor the microgrids, who would be responsible for repairs, and who would manage other interactions such as the purchase of power and balancing requirements. A more granular (lower level) of control in the grid hierarchy will be needed to ensure seamless operations. The internet provides a good example of how a combination of centralized and decentralized control could work. There may be opportunities to learn lesson from the internet and apply it to the smart grid.

3) Data, Communications, and Interoperability

As the smart grid evolves, there will be more and more elements that will be producing data. There are many questions regarding how to organize the data, who will own it, what type is needed and how much, and where should it be stored (local or centralized). Current data infrastructures are insufficient to support the increase in data but it is difficult to plan for future needs since the data requirements are unknown. There is an opportunity to define the requirements needed to perform the grid functions desired. In terms of infrastructure, some small utilities are using the cloud to handle data and processing, but there are other that wish to decouple the electric grid from the internet. Additionally, there are concerns with data privacy and cyber security when using the cloud, but it should be possible to learn lessons and best practices from other industries such as banking.

There are also concerns with communication systems for the grid since they were not designed for real time data. Transparency for data, especially prices, and getting the information to the right person will be needed in the future. Currently, there has been trouble with getting data from one point to another in a reliable manner. There are also issues with processing the data (e.g., management, storage, data analytics, and state estimation), raising questions such as whether utilities will need super computers in the near future. The interface of data with the control system is also not well established, requiring more interoperability including 2-way communication with loads. New measurement and monitoring tools for the various loads and new technologies will need to be factored in. Moving these concepts from implementation to demonstration and full deployment is also a challenge.

4) Safety and Evolving Technologies

Fundamentally, we need a system that is safe, secure, and resilient (survivable) that can handle growing uncertainties. Currently, ISOs/RTOs and balancing authorities are responsible for managing the grid, a dynamic system designed for one-way power flows. With the potential of two-way flows, new protection schemes and ways to make the grid more dynamic and adaptive will be needed along with new responsible entities. New distribution technologies will be introduced, mostly by third parties, and knowledge of where and when they are integrating is needed to ensure safety. New protection devices, smart converters, and education are needed to mitigate impacts of new technologies such as line feeds from EV’s and remote connect and disconnect of appliances in demand response. Utilities will not adopt or allow new technologies if they are not safe.

Since “smart grid” (measurement, information, and control) technologies are evolving so rapidly, it is important to design the system to be flexible enough to accommodate these changes. There needs to be an awareness of the obsolescence curve of technologies to ensure that hardware and software innovations can evolve or adapt. We need to be able to add new capabilities and functionalities that are also scalable. There also needs to be consideration for legacy components. New technologies with old infrastructure will still present vulnerabilities to wind and weather. It is possible to underground lines to improve reliability but it is expensive; new technologies that can help find failures could lower costs.

5) Value Proposition and Modeling

Despite the advantages of these new technologies, key questions remain: What is the value proposition? Is there a market for them? There are two basic customers, the utilities and the consumers, that will need to interact and both extract value from the new technologies. It is also important to note that different market structures will provide different value propositions which will ultimately drive the type of solutions adopted. New markets that open up opportunities for all entities to produce and consume power are desirable. Transparent prices can transform the way the grid is managed and operated but it is currently unclear how this would be done. Regulations are also a key factor since they present hurdles for the integration of resources. Regulatory rules that level the playing field for all different technologies are desired since it is very difficult to predict impacts of prescribed solutions.

Utility business models are also an issue since they are currently paid for delivering energy. Short term fixes are put into place to accommodate solar panels, but the distribution infrastructure must remain to supply energy when the sun doesn’t shine. The accommodation and allocation of costs to all those involved is a difficult question. A potential option is to issue a connection fee and a use fee like internet service providers. Third party businesses who offer consumers energy optimization services will also impact the utility business model. There are opportunities for improved modeling on multiple levels such as business, planning, and systems operation. There is also a need for accurate data on where new technologies should be integrated into the system since they will impact the accuracy of models.

Opportunities for DOE

Out of the various challenges identified above, use cases, system architecture, communications, the interface between distribution and transmission, and protection were identified as being the most critical opportunities for DOE. Discussions primarily focused on use cases to help implement and demonstrate the value of smart grid technologies (including storage), system architectures to ensure various technologies can work together seamlessly, and communications (interoperability, cyber security, etc.) that are fundamental to the achieving a smarter grid. The interface between distribution and transmission is a topic that spans the three areas discussed while there was insufficient time to properly address grid protection. Consideration for protection schemes that allow for dynamic and adaptive two-way power flows and continued system operations in the event of communication losses are critical.

1) Engineering Use Cases

Use cases for various smart grid scenarios (microgrids, deployment of EV, aggregators, etc.) would be extremely helpful in accelerating the deployment of smart grid technologies. Scenarios that define characteristics and requirements needed, lay out market and regulatory conditions, and provide a business model can facilitate the replication of successes. Methods for determining value to different stakeholders (especially reflecting regional differences) along with cost allocation, equations for calculating prices, and metrics are also important aspects to include. Since there are many scenarios that can define use cases, it would be useful to determine a set of common cases that is broadly applicable. An additional benefit of use cases is that information can be extracted to conduct simulations and validate models.

The Smart Grid Demonstration Projects (SGDP) would make a good set of baseline base cases, especially for the deployment of AMI. For example, an area with 6 million customers may be adequately covered with 5-10 strategically placed AMI instead of 6 million. This use case should include details for demonstrating benefits and optimal management of the system. A centralized library of use cases for current projects nationally and internationally (EPRI, Renewable Distribution System Integration (RDSI), German, Japan, etc.) that also captures best practices and lessons learned will help determine what options are available and identify gaps. A starting point would be to leverage the work being done with the Smart Grid Interoperability Panel (primarily standards) and expand upon it. Another useful suggestion was to generate reference system architectures in which to build use cases upon. Engineering use cases are the preferred format since power system engineers will appreciate and utilize the information. Some information is already available at smartgrid.gov but may not be in a useful format.

2) System Architectures

There is awareness that a fundamental change will be needed in system architectures such as moving to the hierarchal management of distributed control systems. Some projects in the Green Electricity Network Integration (GENI) initiative can be disruptive but there is uncertainty in what the industry is ready for. The broader question was the role of DOE in this space since utilities will not be receptive to an architecture that is forced upon them. A competing thought was that a DOE defined architecture would help drive companies to solutions since there is currently a scattering of R&D activities. A basic framework that can help set the direction for industry into the future, establish a big picture, and catalyze R&D across the country would be useful. Additionally, DOE can serve as a convener of groups, help identify key challenges, define competing architectures and evaluate their pros and cons (e.g. application of different control systems), and taking lessons learned from microgrids and extending their applicability to distribution system operators.

Simulations and models were discussed as a subset of system architectures since they are necessary to transition to new designs. With distributed system architectures, the data needs for big systems and small systems will be different and will impact the modeling requirements. Another issue is that the time scales that current technologies operate at are much faster than what is possible in models. Ultimately, there are no modeling packages that can currently capture power, voltage response, communications, latencies, and dynamics simultaneously. Reliability models and price models are also desired and can build off the other model improvements. There is recognition that fundamental advances in simulation tools and computational methods are needed to better capture the nature of the evolving system. Utilizing stochastic methods to capture growing uncertainties would be another advancement desired.

Another aspect of modeling and simulator tools is the adoption of these new technologies by industry. Validation is a big issue but new data streams could be used to calibrate models. There are concerns that DOE investment in new tools should not compete with vendors that develop these tools. DOE can help through pilot scale demonstrations and extending the models into training tools for distribution engineers. Transmission operators have sophisticated tools and there is an opportunity to take lessons learned and implement it on the distribution level. DOE can also serve to convene developers of software and the data community to promote innovation. These new tools should help the operator make decisions and not be prescriptive through better visualization. It is important to keep in mind that utilities won't adopt technologies unless value and positive impact can be shown, such as with PMU adoption.

3) Communications

Communications was a broad topic that included cyber security, data collection, storage of the data, conversion of data to information, the infrastructure required, standards, big data analytics, and devices communicating with one another. Within this umbrella, DOE can add value through supporting testing and certification, potentially at national labs, since it is fairly open-ended today. Another aspect is along the line of cyber security since many utilities don't know where their equipment chips and software were developed. This poses a security threat and DOE can help to expose and mitigate vulnerabilities. There was a concern that product vendors are already dealing with many issues and may be overwhelmed with implementing new standards.

Another issue is with too much data since it is hard to determine what is needed. Helping establish the data requirement needed for specific functions desired would be useful. This can also extend to the communication requirements for various components and could be captured in the use cases. The workforce aspect of communications should also not be neglected. There is a skill gap for current and future power system engineers who may not be exposed to communication technologies. Education, workforce training, and curriculum development could also be roles for the Department of Energy.

TABLE 3 – SMART GRID TECHNOLOGIES & DISTRIBUTED ENERGY STORAGE

Research Topic	Gaps & Barriers	Possible R&D Approaches
Protection, Reliability, & Safety	Protection technologies and schemes for the future grid	• Investigate technologies needed to accommodate two-way power flows • Investigate continued system operations in the event of losses (e.g. communications)
Risk, Business Case, & Valuation	Engineering use cases to help demonstrate value and duplicate successful technology solutions	• Generate/document baseline engineering use cases (e.g. from DOE SG demos, EPRI, international) that identifies impacts on system control, architecture issues, and lessons learned • Develop library of broadly applicable scenarios (e.g. microgrids, EV, high penetration of RE, aggregators, AMI deployment, distributed storage) that includes business models, value streams, cost allocations, and functional requirements • Leverage work done with the SGIP to expand upon standards use cases • Generate reference architectures from requirements for various use cases
System Architectures & Equipment	System architectures for the future grid will be fundamentally different	• Convene industry stakeholders that can establish future directions for new system/management architectures • Evaluate the pros and cons of different architectures in different scenarios, especially with various control systems • Expand concepts and lessons learned from microgrids to be used in the distribution system • Determine data exchange and collection requirements at various levels • Explore the intersection between transmission and distribution
Modeling, Simulation, & Tools	Next generation modeling and simulation tools that can more accurately capture the system	• Fundamental advances in modeling tools and computational methods to span the timescales of simulations (ms to hours) and to handle growing uncertainties (e.g., stochastics) • Calibrated and validated technical models for components and full systems through use of existing or new data • Tools to simultaneously model dynamic system/component responses and communications (including latencies) • Models for reliability & prices to demonstrate value of technologies (such as storage) & tools • Convene vendors & users to improve data exchange needs & requirements • Improve visualization tools to help inform operator decisions • Establish distribution scale simulators and training tools
Communication, Data, & Information	Requirements and standards for communications and data are fairly open-ended	• Help establish communication requirements for various components under various configurations • Develop conformance testing and certification for interoperability, including cyber security • Define requirements for data collection, storage, conversion to information base on use cases, desired outcomes, etc. • Develop data & communication infrastructures for future needs
Workforce Development	Knowledge gap with rapid adoption of communication technologies	• Support education and workforce training programs for current and future power system engineers • Support the development of curricula and partnerships between industry and universities, community colleges, and other institutions

TECH GROUP: Plug-in Electric Vehicles & Fuel Cell Electric Vehicles

Overview

This breakout group was composed of experts in fuel cells and batteries from a cross-section of stake holders. The discussions focused on two major questions: 1) “What are the most important technical challenges to overcome in achieving the vision for the electric grid” with the assumption of up to five years of R&D and commercialization within the next ten to twenty years. (2) The second question discussed was “What are the most important technology development opportunities/activities to pursue in addressing the challenges to achieve the vision for the electric grid?” The approach to answering the first question was to allow each participant to voice their top priority. After each member was able to share their top priority, there was a spirited discussion of the points and the top five were identified. The group then discussed the second question in the context of the top priorities identified.

Discussion Summary

1) Opportunities & Challenges

The plug-in electric and fuel cell electric vehicles breakout group identified eight opportunities and challenges that need to be addressed. The first five listed below were presented to the workshop during the report out session. The remaining three items, although important, were not considered as critical by the group.

I. Cost

II. Batteries, fuel cells, and electrolyzer development

III. Future proofing and flexibility

IV. Variability and uncertainty

V. Unintended consequences

VI. DC metering.

VII. Charging and filling station siting and ownership as well as battery ownership for EV and PEV.

VIII. Consumer future expectations in ten to twenty years.

I. Cost

The cost issues were primarily presented by OEM's, utilities and third parties. The concerns for OEM's were for the high cost of batteries and fuel cells, high cost of the cars, and that additional features (e.g., communications capabilities, bidirectional power flow) would add to the cost of the car. There was some discussion on how to grow the market demand and how the limited charging and hydrogen fueling infrastructure hinders the market. Many concerns seem to deal with understanding the markets rather than technical issues. Interestingly, some utilities are willing to take ownership of the vehicle batteries, charging stations, and hydrogen fueling stations. The batteries could be rented to customers to offset the high cost, for example. This would significantly decrease vehicle ownership cost.

II. Batteries, Fuel Cells, and Electrolyzer Development

Batteries, fuel cells, and electrolyzers need varying degrees of research and development to improve technical specifications. In the near term, the battery technologies are acceptable in performance for providing power to move a vehicle; however, it was generally thought that the current battery life would be significantly impacted by bi-directional power flow and fast charging. The DOE and industry are developing many new battery chemistries and there is still uncertainty about which will be successful. There is concern that while a great deal of effort is being put forth on developing new battery chemistries and technologies, a similar increase in support for testing these new batteries has not occurred. In other words, support for testing has not kept pace with new technology development.

Similarly, software and hardware would need to be developed to allow energy storage systems within plug in vehicles to provide services to the grid. There was some discussion of the possibility of using the software and hardware to give the utilities control—if consumers allow it—to determine when individual vehicles would be charged. The same software could be applied to the operation of electrolyzers for hydrogen generation at hydrogen filling stations. Depending on the station size, electrolyzers could require 1-2MW or more, and could be used to provide ancillary services through direct load control. With proper on-site hydrogen tank sizing, the electrolyzers could operate at night when the demand and locational marginal price for electricity is low. Current PEM [Proton Exchange Membrane] electrolyzers are typically small, less than 10 kg/day (20 to 40 kW) and would need to be scaled up to meet large scale 1000 kg/day (MW scale system) refueling station needs.

In addition to scaling the current technology up, development would need to be done to increase efficiency of the electrolyzer stack and system. Power electronics development is also needed to help manage the flow of power between the grid and the technology.

Finally, the hydrogen compressor is another large power consumer at hydrogen fueling stations. Its efficiency and durability need to increase and for a lower cost. A stationary FCV is essentially an 80 kW power plant that could provide peak power to single or multiple residences given the proper incentives, hardware and software. Developing higher pressure electrolyzers will also contribute to lower compression cost, both in terms of capital and energy.

III. Future-Proofing and Flexibility

Future proofing and flexibility refers to intelligent charging and electrolyzer use to meet customer expectations, maximize life, and maintaining grid stability in the near term and in the future. In addition to the hardware and software development required, considerable work needs to be done in order to develop models to predict the impact on the grid. The DOE has collected considerable data and an analysis needs to be done to determine if the data is sufficient. If not, then additional data should be collected.

IV. Variability & Uncertainty

There is a great deal of uncertainty in how the U.S. fleet will be electrified, how long the process will take, what mix of technologies for cars (EV, PHEV, FCV) will emerge, what mix of fueling technologies will exist (regular chargers, fast chargers, hydrogen fueling stations), and how the future grid will transform. Additionally, codes, standards, and regulations for all these various technologies are still evolving.

V. Unintended Consequences

The fifth top priority and challenge identified dealt with trying to minimize unintended consequences of increasing the number of EV's and PHEV's and using large scale electrolysis to generate hydrogen at fueling stations. The concerns went beyond the vehicles to the need for better understanding of what the future grid mix will be and what ancillary services will be required.

The four remaining topics identified and discussed dealt mostly with policy. For example, the DC metering discussion focused on the fact that most of the US grid is AC with very little DC and in some areas, like California, DC power is not allowed. Identifying where charging stations and hydrogen fueling stations should be located and who should pay for them is not an entirely technical challenge.

Finally, there was a discussion on interoperability standards for charging stations. DOE is already working with the Society of Automotive Engineers and the National Electrical Manufacturers Association to develop some standards such as the IEC15118.

2) Component Development, Demonstrations, and Modeling

I. Component Development

Discussions for the second question centered primarily on component development (battery, electrolyzer, power electronics), modeling and demonstrations. The work on component development is well documented by the different program offices. The focus should be on lowering cost and improving performance of batteries, scaling electrolyzers to larger sizes while reducing costs, and development of the hardware and software to improve interaction with the grid in order to achieve the ancillary services desired.

II. Demonstrations

Demonstrations were identified as a way to gain the necessary information to develop models and to validate the models currently developed. The DOE has already sponsored and is currently sponsoring many demonstrations. It's recommended that there be improved coordination between OE and EERE to determine if the information being gathered is the right quality and frequency needed to be able to develop the models grid engineers need in order to predict the impact of EVs and hydrogen fueling stations on the distribution system. In addition, there are several ARRA projects that are exploring ancillary services, but none of those projects have vehicles or electrolyzers involved. Some of those projects may benefit by the inclusion of vehicles.

III. Modeling

Finally, modeling was identified as a way to be able to address many of the challenges identified. GridLAB-D has been identified as a powerful tool in understanding and predicting grid behavior. However, more accurate EV component models are needed and those models need to be integrated into larger grid models. From a distribution planning perspective there is not a lumped model. These models should build on legacy systems that are already available. The models need to be able to account for bi-directional power flow, dynamic responses, interoperability, different markets, to match infrastructure to future opportunities and needs. The DOE and OEM's indicated that they have data which they can make available to aid in model development. In addition to using the models to better understand grid operations, the models should be used to help monetize the benefits so stakeholders can understand the full value of these efforts as they relate to all aspects of the grid.

TABLE 4 – PLUG-IN ELECTRIC VEHICLES & FUEL CELL ELECTRIC VEHICLES

Research Topic	Gaps & Barriers	Possible R&D Approaches
Battery development	Energy density, cost, high rate charging	
Electrolyzer	Current systems are too small, efficiency of large stacks has not been demonstrated, System efficiency needs to be improved, Capital cost needs to be reduced	improved hydrogen drying efficiency (purification)"Higher pressure operation Lower cost membranes, catalysts, and stacks. Higher efficiency operation PEM electrolyzer scale up
Power electronics	Lack of bi-direction power, communication with grid to ID low cost or how to stabilize the grid	Flexible power converters to enable connection of electrolyzers to various power sources
System analysis tools	Lack of understanding EV charging / electrolyzer impact on grid. Lack of understanding of the effect of charge rates on EV acceptance	1) Determine what information is needed to develop the tools. - Component level - Grid interaction level 2) Use DOE and OEM current data. 3) Get the missing data through appropriate demonstrations which would include all stakeholders including 3rd parties. Demonstrations could include – OEM- Utility- telematics and complimentary modeling spanning the grid to understand bi-directional power flow. 4) Develop tools 5) Validation. This can be done using the demonstration data.
Ancillary service value	Lack of understanding the monetary value of ancillary services provided by EV's and electrolyzers	1) Use existing ARRA demonstrations to understand the value of ancillary services. The Northwest Demo is looking at impacts of smart meters on the grid, can smart chargers be included? 2) Currently there are some small fleet demonstrations. Can these demonstrations be modified to include ancillary services investigation? Example services to be examined frequency regulation, demand response that's good for the battery/electrolyzer, start/stop charging and electrolyzer operation. 3) Use models developed to determine what level of impact the EV and electrolyzers can have
Battery pack testing	Insufficient understanding of how the new chemistries perform	Accelerate current testing. Open applied battery program to more participants.

TECH GROUP: Residential, Commercial, and Industrial Buildings Loads

The discussions from this breakout group were simply captured in the tables below. The first table summarizes the challenges while the second table lists opportunities.

TABLE 5 – BARRIERS FOR BUILDING LOADS

Research Topic	Gaps & Barriers	Possible R&D Approaches
Business case	• Market for flexibility to the grid. Not just $/kWh. Link pricing structures to grid reliability and resiliency. Monetize each product & service to allow for flexible pricing. • Capture monetized savings/value (energy and non-energy service) and communicate back. Incorporate load/payback solutions (aggregation, shared cost, etc.) Demonstrate how building could respond to value proposition for all parties. • Work with aggregating loads to achieve fast payback aggregation control>coupling loads of buildings and cities. • Tackle market barriers for and determine value of ancillary services for demand response	• Determine market players and then target business case to each individually. • Need to determine data that we need by stakeholder (operator, owner, and consumer). • Monitor value of distribution system. • Determine penetration of EVs/PVs/building demand response. • Find value in demand response from buildings • Value propositions for all technologies and market players. • Need to be able to aggregate freely to scale
Incentives	• Create incentive for utility to offer dynamic pricing. Separate ancillary services pricing (currently is buried in business). • Solve for split incentives (owner/non-owner). Show value from Energy efficiency and monetary perspective. • Leverage building automated systems, self-correcting controls and transactive controls to demand response. • Leveraging existing systems to demonstrate the value of EE and demand response. • Develop infrastructure for small buildings and leverage to do more in future. • Value to the consumer in terms of reliability and price. • What does the customer value/ how are you trying to deliver it to them.	• Need to understand utility business • Monetization of transactions is muddled by scale. • All metrics need to match to make shared financial incentive.
Flexibility	• Need systematic signaling that works across different regulatory environments. • Need flexibility of grid between residential and commercial. • Need cognitive network and controls at all levels.	• Need to distill data to make for an efficient communication. Determine frequency of data collection etc.

Research Topic	Gaps & Barriers	Possible R&D Approaches
Automated response at scale and speed	• Need fast response, faster than combustion turbine, to participate in ancillary services. • Fast, automatic, certain, to scale. Highly transactive controls. • Need to tailor behind the building technologies to adhere to response speed targets	• Need target to determine what the response speed should be, could use sub metering to understand the time scale. • Need latency tests and controls response test from bottom up. • Understand resources available in buildings and make them available to the grid.
Barrier to scale/lack of infrastructure	• Package of cost effective control solutions (including controls and sensors) for small and medium buildings. • Need open standard scalable controls.	• Must ensure persistence on energy efficiency
Reliability	• Prescreening of buildings- need methodology to discover which to work on. • Determine technology on the building side that would make up for drops on the grid	• Determine how buildings respond to disturbances and how they degrade overtime. • Look for more rolling voltage reduction. • Understand which region/building can handle the variations. • More info/models on peak load, buildings actual performance.
Interaction	• Study/models on characteristics of building to grid interaction. • Understand and catalog systems and solutions map to characterizations. Prescreening methods. • Catalog Demand Response functions of buildings.	• Determine which measurements can realistically be taken.
Specifications & standards for grid connection	• Determine reactive power capability.	• Need interconnection & equipment specifications. • Need clear national/state specifications
Differing market rules between ISOs	• National standard.	
Complexity	• Demystify process and technology for the stakeholders. Facilitate adoption.	
Regulate for market structure	• Need a standard for communicating/signaling. Need a common lexicon for communicating info.	• Building loads do not depend on infrastructure, therefore we have to optimize by market.
Regulatory barriers	• Survey all legislation/policy/rules to find barriers.	•

TABLE 6 – OPPORTUNITIES FOR BUILDING LOADS

Research Topic	Gaps & Barriers	Possible R&D Approaches
Interaction	• Building resiliency: Lack of understanding of relationship between building performance and grid operations.	• Develop models to understand characteristics of how buildings can/do interact with the grid. Analysis on measured characteristics. Catalog systems and solutions map to characterizations.
Automated Response at Scale and Speed	• Lack of technical infrastructure (controls/sensors) in buildings.	• Identify the ideal characteristics of building control solutions, for all building types. Develop and deploy low cost, plug & play, packaged solutions of cognitive, secure, standardized, and scalable infrastructure for building operations and grid interaction. Develop/deploy low cost, application specific sensors.
Specifications & Standards for Grid Connection	• Lack of adequate information and communications systems to communicate energy and other valuable information between all interfaces of buildings and grid.	• Survey of existing communications systems and infrastructures. Appropriately develop, deploy, and/or integrate the existing communications interfaces between building and grid. Standardize measures for communicating/signaling. Common lexicon for communicating info. Security implied
Information & Modeling	• Lack of business case to achieve solution on both sides.	• Develop model business plans to identify and monetize potential and existing value streams across the ISO, utilities, end users, and other market actors. Develop analytic tools, demos, and pilots to achieve goals. Implied adherence to rules/regulations.
Specifications & Standards for Grid Connection	• Lack of uniform, national specifications for integration and interconnection applicable to behind the meter assets. Beyond 1547.	• Work with the market to develop a national standard for integration and interconnection taking into account safety, reliability, and future markets.

Breakout Session Summaries

HOLISTIC-SYSTEM ISSUES

RED GROUP

Overview

In this session, the participants identified key challenges to the grid integration of all of the various technologies and their abilities to inter-operate while ensuring a safe, reliable, and cost-effective system, building from the challenges discussed in the morning sessions that were based on various types of distributed generation. The discussion in this session was more holistic and systems-based with the goal of identifying R&D activities and initiatives for overcoming key grid integration challenges. The participants' discussions were channeled by the facilitator to address the following key questions using the GTT "Venn Diagram" as a framework:

Grid Flexibility

What R&D advances could be made in the physical domain (component technologies, inverters, power flow controllers, transformers, cable and conductors, protection device, etc.) to increase the flexibility/controllability of the grid? What are the characteristics and functionalities needed to address the challenges identified and ensure a safe, reliable, cost-effective system?

Grid Visibility

What R&D advances could be made in the informational domain (sensors and relays, AMIs, PMUs, end-use energy management systems, communications hardware and protocols, etc.) to increase the visibility/controllability of the grid? What are the characteristics and functionalities needed to address the challenges identified and ensure a safe, reliable, cost-effective system?

Grid Understanding

What R&D advances could be made in the knowledge domain (databases, planning tools, models and simulators, analyses and assessments, etc.) to increase the understanding/controllability of the grid? What are the characteristics and functionalities needed to address the challenges identified and ensure a safe, reliable, and cost-effective system?

Key Challenges

The participants discussed various aspects and issues of distributed generation and its impact on the grid. In the first part of the afternoon session, these discussions also included the challenges for the distribution system in its current form, to absorb large amounts of distributed generation while continuing to operate in a reliable manner. After engaging in wide-ranging discussion on grid integration of distributed generation, the participants coalesced around the following key challenges:

1) Integrating Information From a Variety of Sources

While discussing this challenge, the participants noted that there is considerable amount of information (including data) that tends to come from a variety of sources – especially at the distribution level. Examples include data regarding the anticipated characteristics of distributed generation gleaned through interconnection studies, data on the performance of the distribution system from the utilities, data from meters (smart or otherwise) installed at power consumption sites, data at the substation level from SCADA and transmission sources, power market data from ISOs, retail rates/billing data from utilities etc. These data need to be analyzed and integrated as appropriate for a holistic view of ALL aspects of the distribution system. However, each of the data mentioned as examples above come from various sources, with differing temporal and spatial granularities, various levels of automation in data transmission, collection & storage, and under different formats and protocols. The participants noted the lack of a "common data service bus" to assist in data transmittal and integration. The key challenge is then to devise ways and means to provide for consistent and sustainable processes for integration of such data in a manner that is conducive to analysis and decision making, thus impacting the evolution of distributed generation on the grid.

2) Creating Standard Communication Protocols, Data Formats / Interfaces

This challenge is closely tied to the one above and points at the key gap that prevents information integration. The communication protocols are currently insufficient or completely absent for transfer of most data in the distribution grid space, from one entity to another. The key challenge identified by participants in this case is that, while the once-unidirectional (supply from substation to consumers) distribution grid is now becoming significantly bi-directional with a fast-growing number of consumers installing distributed generation, the associated need for bi-directional data transfer/formats and communication interfaces/protocols remains a gap that needs to be addressed for successful penetration of distributed generation. Other challenges identified by participants are the need for communication technologies to be cost-effective, and the need for transformation of the distribution network from a historically "closed" system to an IT-like "open" system, while maintaining reliability and sufficient cyber protections.

3) Linking Different Tools With a Common Modeling and Simulation Approach

A variety of analyses are performed to study the impact of distributed generation on the power grid, and to simulate the operation of the distribution system to evaluate its reliability and efficiency. Some of these analyses are steady state and transient power flow studies, interconnection studies, short circuit studies, and system stability studies. Others include analysis of demand response behavior, consumer electricity usage patterns, distributed generation operations and variability assessments, forecasts of solar generation and load demands etc. Almost of all of these analyses use individual models and customized data inputs to simulate the desired system operations.

The participants felt that there is significant potential to link at least some of these models, and such an effort, while challenging due to various existing models, formats and vendors, will provide a much-needed common platform for consistent input data development, and pave the way for a holistic analysis of the entire distribution grid. Linking the models and data will also enable the studies needed from a single data and model platform, facilitating easier analyses processes for interconnecting distributed generation. The goal identified by participants in addressing this challenge, is for these linked models and tools to contribute to the creation of a uniform decision support system for distribution grid planning and operations.

4) Creating Grid-Friendly Standards for All Technologies

Each distributed generation technology – either dispatchable or variable, has evolved at a different pace, with varying rates of adoption among the consumers and utilities. During this session, participants expressed the need for a uniform set of standards that enable easier integration (from the viewpoint of distribution system operations and grid impact) of all types of distributed generation onto the grid.

These standards would ideally define the set of characteristics that all distributed generation should possess, in terms of their interaction with the grid. Examples of such standards include voltage ride through, frequency response, reactive power support, real power controllability, ramp up/down rate constraints etc. The issue is that while such standards exist currently, they are neither uniformly applied to all parts of the distribution grid, nor are they applicable to all forms of distributed generation.

Therefore, the key challenge is to enable the development of uniform grid standards that are universally applicable to all forms of distributed generation. Additional challenges include future-proofing all components and technologies (e.g., inverters with upgradable firmware), and the need for more information on the latest and future technologies.

5) Developing Low Cost Sensors, Interoperable with Grid Operating Systems

The participants recognized and discussed hardware, software, process, and institutional challenges during this session. One such challenge identified as a key issue, was the lack of low cost sensors that can enable measurement of data in the distribution grid. These sensors are needed increasingly as distributed generation becomes more prevalent, to measure system parameters closer to the location of each distributed generator, as well as at other locations on the distribution network. The requirement for these sensors to be low cost is due to the fact that a large number of them will be needed at a dispersed set of locations to measure various parameters of the grid and understand how they vary temporally and spatially, due to changes in load, distributed generation, and location.

Further, a fundamental requirement mentioned by the participants is that these sensors need to be interoperable and capable of being fully integrated into the distribution grid operating systems. Such interoperability is key to ensuring that the data from these sensors can be assimilated into the distribution grid operations software, models and simulation tools. Implementing such a sensor network, the participants felt, can have a measurable impact on the safety, security, and survivability of the distribution grid in the event of a disruption. Other associated challenges identified by the participants include the fact that current distribution poles may not be able to support additional sensors, and the need for packaging multiple sensors into a single component.

6) Optimizing the Distribution System Across Different Technologies

As new and different technologies get added to the distribution grid including consumer installed distributed generation, the session participants felt that there is a definite need to optimize the operation of the distribution grid. The challenge that was identified included optimization across different technologies; i.e., how does a utility operate the grid in an optimized fashion considering the capabilities and limitations of the various types of distributed generation? It was acknowledged during the discussions that the drivers for distribution system optimization include real-time pricing, reliability, and utility business models.

One of the open questions not fully addressed in this discussion was about the key metrics that should be used to assess the optimality of the distributed grid operation. However, the participants opined that two key needs while optimizing the operation of the distribution grid include:

- parameterized node definitions (describing a node in terms of its capabilities in handling distributed generation), and
- identifying opportunities to operate various types of distributed generation resources in a synergistic fashion; exploiting the interaction between them in a way that benefits the grid.

7) Cultural Differences in Communicating Challenges to Regulators

An almost universally agreed-upon challenge among participants during the session was the cultural differences that serve as a barrier to successful communication between regulators and other stakeholders in distributed generation. The cultural differences referred to by the participants in this case was primarily due to the fact that regulators focus on issues that could be somewhat different than a more technically inclined stakeholder. Therefore, messages that do not address the key focus areas of the regulators tend to be less impactful than desired.

Further, due to the differing priorities and focus areas of each stakeholder, the messages are not crafted in a fashion that can be easily interpreted by the regulators and other decision makers. The participants felt that this challenge of proper communication is one of the key barriers to widespread adoption of distributed generation.

8) Convening All Stakeholder Standards Institutions in a Common Forum

The need to convene all the stakeholder standards institutions in a common forum was expressed by many participants to be a particularly key challenge that should be addressed. The reason for convening these institutions, the participants felt, is to create standards for planning and operation of the distribution grid of the future. The key issue is that, as various technologies get added to the existing distribution grid, standards institutions that were not previously part of the evolution of the distribution grid, now need to get involved. As an example, the installation of “smart” equipment (such as smart meters) has integrated the Information Technology and Communication networks with the power system distribution grid operations. Therefore, organizations such as NIST should now work with utilities and other stakeholders (such as IEEE) in creating standards for such “smart” equipment, and their integration with existing components of the distribution grid (and are doing so).

The challenge in this case, is to create a forum to facilitate the discussions with all the appropriate stakeholders so that, everyone can understand the capabilities of both the existing grid and the new components that are being added, in order to create holistic and comprehensive standards for operating the entire distribution grid in a reliable and optimal fashion.

9) Creating a Uniform Framework Towards Operating All Distribution Grids

One of the more ambitious challenges mentioned by participants was the need for a national scale grid operating system (Grid OS). This operating system is viewed by the participants to be a uniform framework that will guide the operation of all of the nation’s distribution grids. The framework will need to be developed and implemented using a collaborative approach (similar to NERC or IEEE standards activities).

The challenge in creating such a framework is the extremely fragmented and regional nature of the distribution utilities. While the regional nature of the utilities is a function of both the unique regional characteristics and the legacy of defined service territories in which the utilities operate, the concept put forth by the participants was to explore the creation of a framework that combines the common aspects of distribution grid operation, recognizing that the overall goals for all distribution system utilities is the same – to operate the distribution grid in a safe, secure, reliable and cost-effective fashion, while incorporating new technologies including distributed generation.

R & D Opportunities

In the latter part of the afternoon session, the participants discussed the challenges described earlier, with the goal of identifying a few key opportunities for research and development, with particular focus on the possible contribution by DOE for meeting each challenge. Due to time constraints, all the challenges described above could not be discussed in detail, however, the following R&D opportunities were identified for four key challenges:

1) Optimizing the Distribution System Across Different Technologies

Key R&D opportunities identified for addressing this challenge includes integrating the operation of dispatchable renewables with weather forecast data to optimize their operation. A gap identified is the need for predictive algorithms to dispatch energy storage in advance of weather patterns. Specifically for DOE activities, suggestions were made by participants for research in collection, storage, management and analysis of large amounts of data, and for creating a whitepaper on Distribution Management Systems (DMS) that will define baseline, gaps and a roadmap. Additional suggestions included assisting in developing standards that tie optimization and reliability to utility business models.

2) Creating a Uniform Framework Towards Operating All Distribution Grids

While the decision to adopt a uniform framework for distribution grid operation may be outside DOE's influence or purview, the participants nevertheless suggested that DOE can engage in the development of an advanced SCADA system definition and work with utilities and system operators for acceptance and demonstration. Participants stressed a collaborative approach for this activity.

3) Creating Standard Communication Protocols, Data Formats/Interfaces

It was noted by the participants that application needs drive data needs that drive communication technology. It was also mentioned that currently, the industry is working with NEMA to establish communication standards for smart grid– similar collaboration with DOE is needed. Therefore, R&D-type activities for DOE that were suggested by the participants include:

- Facilitation by DOE to enable the adoption of common communication models
- Enabling demonstration projects to showcase interoperability standards
  - Possibly through IEC 61850
- Enable adoption of standard data transfer and sensor protocols
- Leverage learning from existing "big data" issues in other applications

TABLE A – RED GROUP

Research Topic	Gaps & Barriers	Possible R&D Approaches
Integrating Information from a Variety of Sources	• Differing protocols, lack of a data service bus, automated processes	
Creating Standard Communication Protocols, Data Formats & Interfaces	• Need for bi-directional data transfer/formats and communication interfaces/protocols, cost-effective communication technologies, transformation of the distribution network from a historically "closed" system to an IT-like "open" system, while maintaining reliability and sufficient cyber protections	• Facilitation by DOE to enable the adoption of common communication models, Enabling demonstration projects to showcase interoperability standards, Leverage learning from existing "big data" issues in other applications
Linking different tools with a common modeling and simulation approach	• Various existing models, formats and vendors, much-needed common platform for consistent input data development. • Lack of an uniform decision support system for distribution grid planning and operations	
Creating Grid-Friendly Standards for all Technologies	• Need for a uniform set of standards that enable easier integration of distributed generation onto the grid, define the set of characteristics that all distributed generation should possess for interaction with the grid, need for future-proofing all components and technologies (e.g.: inverters with upgradable firmware), and the need for more information on the latest and future technologies	
Developing Low Cost Sensors, Interoperable with Grid Operating Systems	• lack of low cost inter-operable sensors that can enable measurement of data in the distribution grid, current distribution poles may not be able to support additional sensors, need for packaging multiple sensors into a single component	
Optimizing the Distribution System Across Different Technologies	• Need to optimize the operation of the distribution grid, • Key metrics that should be used to assess the optimality of the distributed grid operation, parameterized node definitions (describing a node in terms of its capabilities in handling distributed generation), identifying opportunities to operate various types of distributed generation resources in a synergistic fashion, need for predictive algorithms to dispatch energy storage in advance of weather patterns	• Integrating operation of dispatchable renewables with weather forecasts, collection, storage, management and analysis of large amounts of data, creating a whitepaper on DMS that will define baseline, gaps and a roadmap, assisting in development of standards that tie optimization and reliability to utility business models

Research Topic	Gaps & Barriers	Possible R&D Approaches
Cultural Differences in Communicating Challenges to Regulators	• Regulators focus on issues that could be somewhat different than a more technically inclined stakeholder, messages that do not address the key focus areas of the regulators tend to be less impactful than desired, messages are not crafted in a fashion that can be easily interpreted by the regulators and decision makers	
Convening all Stakeholder Standards Institutions in a Common Forum	• Create standards for planning and operation of the distribution grid of the future, as various technologies get added to the existing grid, institutions that were not previously part of the evolution of the distribution grid, now need to get involved, create a forum to facilitate the discussions with all the appropriate stakeholders	
Creating a Uniform Framework Towards Operating all Distribution Grids	• extremely fragmented and regional nature of the distribution utilities, a framework that combines the common aspects of distribution grid operation	• engage in development of advanced SCADA system definition and work with utilities and system operators for acceptance and demonstration

ORANGE GROUP

Overview

This session sought to identify specific needs and opportunities associated with systems-level challenges with integrating various emerging grid technologies, specifically on technical gaps and prospects for the electricity distribution system and its interfaces with the transmission system and with end-users. The discussion began by walking through a list of challenges compiled by the facilitator identified in the report-outs from the technology-specific breakout sessions. Through discussion, the group amended and consolidated the list of challenges and prioritized three topical areas. Finally, the group utilized the GTT framework to generate possible R&D activities, exploring the requirements and enhancements needed in grid flexibility, grid visibility, and grid understanding, pertaining to each of the gap areas. Prompting questions used to facilitate the brainstorming of potential R&D activities are restated below:

- ***Grid Visibility***
  What R&D advances could be made in the informational domain (sensors and relays, AMIs, PMUs, end-use energy management systems, communications hardware and protocols, etc.) to increase the visibility and controllability of the grid? What are the characteristics and functionalities needed to address the challenges identified and ensure a safe, reliable, cost-effective holistically integrated system?

- ***Grid Understanding***
  What R&D advances could be made in the knowledge domain (databases, planning tools, models and simulators, analyses and assessments, etc.) to increase the understanding and controllability of the grid? What are the characteristics and functionalities needed to address the challenges identified?

- ***Grid Flexibility***
  What R&D advances could be made in the physical domain (component technologies, inverters, power flow controllers, transformers, cable and conductors, protection device, etc.) to increase the flexibility and controllability of the grid? What are the characteristics and functionalities needed to address the challenges identified and ensure a safe, reliable, cost-effective system?

Discussion Summary

Building on the initial list of challenges identified, the group primarily focused discussions on system and control architectures, data and communications, and protection and safety. Understanding the cost and benefits of new technologies, including new architectures and operational paradigms, to every stakeholder was a major challenge that was added to the initial list but was not discussed in detail. One key aspect is that different technologies are at different levels of maturity, making comparison and comprehensive demonstrations difficult. Additionally, there is a lack of validated methods to effectively determine cost allocations. Codes, standards, and interoperability as well as modeling and simulation were also recognized as being very important but preliminary discussion did not expand on these topics.

1. System and Control Architectures

There is awareness that existing system and control architectures will not adequately provide for the safe, reliable, resilient, and robust operation of a modern distribution system with high penetrations of emerging distributed energy technologies. With the need for new architectures (e.g., hierarchal distributed control systems) and the associated uncertainties, future proofing should be a guiding principle to ensure that systems will be extendible, adaptable, and modular. One example is with the power electronic interfaces of distributed energy resources connecting to the grid. There are many similarities between the various technologies with differences only on the constraints on the DC side. Future architecture should be able to accommodate these differences while leveraging the similarities. It may be possible to extend lessons learned from the vehicle industry since cars now have 100+ communicating sensors and CPU's. All these various smart devices work together to ensure a safe, reliable vehicle.

Intentional islanding and anti-islanding is an important future application that will need to be considered. It has been utilized in Japan recently, demonstrating value and the possibility of moving towards a more flexible and reconfigurable system. Another application to consider is the use of building energy management systems (BEMS), and other management systems such as those for microgrids, to provide a more sophisticated response than simply reducing real power consumption. There are resistive, capacitive, and inductive elements within buildings that can be dynamically modulated to provide value to the system. To achieve these applications, it is necessary to develop or select the appropriate communications and control architectures that span from BEMS on up to the ISO. Another challenge is the fundamental advances in control theory and strategies needed for multi-scale systems that span many orders in space and time.

2. Data and Communications

Data and communications are intimately connected with system and control architectures. Desired control functions will dictate the data and communication requirements while constraints on communication systems will limit what can be achieved. The multiple timescales and quantities of data introduce additional challenges to the system architecture and control challenges. A more complete understanding of functional requirements and the associated communication needs is desirable. There also needs to be advances in sensors and data technologies to achieve the visibility desired in the distribution system. Currently, it is not possible to validate the commitment of distributed resources if utilities move to economic dispatch and associated production cost modeling.

3. Protection and Safety

Emerging grid paradigms will require protection systems that don't yet exist or are not yet mature. Within this topic area, there needs to be consideration for power electronics and protection equipment that can still operate when there is a loss of communication with central operations and control. Another challenge is the major gap in understanding of how to transition from a world with no smart grid to a full smart grid while ensuring that the system operates safely and reliably at every intermediate point. Demonstrating safety and robustness of new technologies is a fundamental need but there is recognition that this will take time. There are similarities with the commercial airline industry where it took 20 years to fully accept autopilot. Time is needed to build confidence in controls when responsibility is taken away from an operator.

Opportunities for DOE

After further discussions, the group selected system architectures and control structures, modeling and simulation for new architectures and technologies - including planning and operational tools, and data and communication technologies as priority areas. These topics were discussed in detail to identify specific R&D activities that DOE could pursue to address these challenges. A general comment was to leverage the information from ARRA demonstration projects and map it against the needs identified in this session.

1. System Architectures and Control Structures

As discussed above, one of the major challenges is new system and control architectures for the future grid. There is an opportunity for the development of fundamental control theory that can accommodate systems that span multiple scales in time and space, including substantial uncertainty. Demonstration of new system and control architectures is also another critical need that will require careful design to ensure that results are compelling and will push the envelope of what is possible. Ideally, these demonstrations should be scalable, include a diverse mix of generation, loads, and other distributed resources, and have end-to-end market relevance. It should also be comprehensive and include the behaviors of all stakeholders and the value provided to them, especially customers participating with loads and resources. A current project to draw from is the deployment of 40 EV's at an Air Force Base in LA that directly participates in the CAISO regulation market.

Investment in power electronics that will be needed in the future distribution system is also important. From smart inverters to power flow controllers, new capabilities enabled by these technologies can broaden the range of possible system architectures (e.g. AC/DC hybrid configurations) and operational strategies (e.g., partial islanding). Another aspect would be the EMS, DMS, micro-EMS, and other control systems implementing the new system architecture. A clear gap in understanding is how users interface with the electric power system but near-term analytics of the ARRA projects may provide some insights.

2. Modeling and Simulation for New Architectures and Technologies

There is currently a lack of validated static and dynamic models for emerging technologies and associated planning and operational tools that include new control strategies. Improvements in models for various technologies will help to perform state estimation on the distribution system. As a result, investigation of limitations due to current topologies (radial vs. networked) can be conducted and necessary sensor deployments can be identified. Advanced models and state estimators can lead to model-driven control as well as planning tools that can provide optimal solutions with a given mix of resources and available equipment based on value proposition. Another possibility would be self-adapting, self-calibrating, real-time models of distribution feeders (e.g., "plug and play") if properly coupled with utility and sensor data. A fundamental need is the validation of these new tools and capabilities in addition to existing tools. Benchmarking these tools with standardized use cases would also be very valuable. These new planning and operational tools should also be used to train the next-generation workforce. There are advances in operational tools and capabilities but the current training simulators don't utilize the same advances, limiting familiarity with actual operations.

A key opportunity for DOE is to support interoperability between software tools. There are a number of models that are commercially available and it would be useful to bridge these tools to improve system understanding. One example is to interface EnergyPlus with OpenDSS which could allow for the simulation of building systems with the distribution network. As the system grows in complexity including additional layers of hierarchy, software tools and simulators that can span the various layers will be critically important. Standardized interfaces between tools can enable the modeling of the entire system without developing a "master" simulator that captures every aspect of the power system. Another facet of modeling and simulation is the availability of low cost sensors that can be used to support state estimation functions which is discussed more in the next topical area.

3. Data and Communication Technologies

The increased adoption of information and communication technologies into the grid present opportunities for new functions and capabilities but there are no clear guidelines to help determine what technologies are needed, what type of data is needed, what amount of both are needed, and what the value proposition is for specific applications. Mapping technical specifications for current and future technologies against the requirements and value for desired functionalities would be very useful.

Additionally, a comprehensive performance database that captures technical characteristics (e.g., response times, bandwidths, latencies) of communication technologies will facilitate the appropriate selection for demonstrations projects or deployment. This database can identify gaps and inform further developments needed based on emerging system architectures and control strategies. In addition to the clear role of helping to standardize or harmonize communication protocols among energy management systems, distributed energy resources, and energy consuming devices, DOE can also develop analytics to convert data into actionable information for various stakeholders.

Availability of low cost sensors that satisfy the communication and functional requirements for new capabilities is another need. The optimal placement of sensors, the sampling and reporting frequencies, and the speed of data transfer are important aspects to determine. Identifying opportunities to leverage infrastructure and hardware that have been deployed to increase the visibility of the system would also be useful. For example, it may be possible to increase the sampling speed of sensors (e.g., AMI) to extract more useful information or to access intrinsic sensor capabilities of existing hardware that have never been utilized before. Participants indicated that DOE could also help facilitate the delivery of prices, reliability information, and/or control signals to end-use devices and users and to analyze the value proposition of this data transparency.

TABLE B – ORANGE GROUP

Research Topic	Gaps & Barriers	Possible R&D Approaches
System Architectures and Control Structures	Alternatives to traditional radial topologies have not been fully analyzed and explored	• Analyze visibility, controllability, communications, cost, reliability, and operational implications of potential new topologies, including more tightly coupled networks, networks that enable intentional islanding, and AC/DC configurations • Develop power electronics-based flow controllers and analyze the topologies and architectures that they enable • Development of EMS, DMS, or similar that enable new architectures
	Emerging system architectures and control strategies unproven	• Perform end-to-end demonstrations that capture cost and value to all relevant stakeholders, including stakeholder behaviors and in different markets • Leverage lessons learned from existing projects
	Control theory and practice does not adequately cover systems of multiple temporal and spatial scales with significant uncertainty and increased DER	• Foundational control theory research to span the multiples scales and to handle uncertainty • Development of control strategies for new system architectures including ones that can accommodate anti-islanding with increased DER
Modeling and Simulation for New Architectures and Technologies	Cost, complexity of measuring a large number of geographically distributed nodes impedes system visibility	• Develop validated state estimators for common distribution network topologies • Develop self-adaptive, self-calibrating feeder models that update via measurements and "plug-and-play" handshake data
	Current planning tools to do not include emerging technologies in the mix of available strategies for system design	• Develop planning tools that incorporate emerging technologies and control architectures • Validate and demonstrate existing and emerging tools
	Workforce training tools do not exist for emerging planning and operational software and practices	• Develop and deploy workforce training tools for new software and practices
	Lack of interoperability between disparate software tools	• Facilitate standardization and interoperability between software tools (e.g., between OpenDSS and EnergyPlus) as system grows in complexity and layers of hierarchy
Data and Communication Technologies	Existing data streams do not adequately support observability of the distribution system nor are they fully transparent	• Develop low-cost sensors and associated optimal placement algorithms • Develop methodologies for extracting currently under-utilized data streams from the sensors in already deployed technologies (power electronics, AMI) • Facilitate the delivery of pricing, reliability, and other information to end-users and relevant stakeholders
	Comparison of available communications technologies for informing system design is cumbersome	• Compile database of the technical specifications (latency, bandwidth, etc.) of existing and future communications technologies • Document communications and functional requirements for technologies that can enable new grid capabilities
	Divergent communications standards and protocols between different technology areas	• Facilitate standardization and harmonization of protocols across relevant technology areas

YELLOW GROUP

Overview

This session focused on identifying challenges and opportunities of the distribution grid from a 'system of systems' perspective and identified activities that DOE could pursue to realize these opportunities. The discussion was segmented into three categories – Grid Flexibility, Grid Visibility, and Grid Understanding – as defined in the Action Plan. Participants each identified a single challenge, condensed these challenges, and then determined possible activities DOE could undertake to overcome these challenges for each category. A brief report was then presented to the general session the following day.

Discussion Summary – Challenges

Session participants identified number of challenges in each strategic focus area. The challenges discussed are summarized below, followed by a table of specific opportunities and challenges.

- ***Grid Flexibility***

Equipment Development

Participants identified equipment as a hurdle for increased flexibility on the grid. Power electronics have the potential to be implemented and continuously reconfigured as the distribution grid evolves. Storage can improve flexibility and increase feasible penetration levels for variable renewable energy, but is not currently cost competitive. Distribution voltage DC interconnections could be utilized over longer distances (approximately 200 miles) to interconnect distribution systems, aiding in voltage regulation and increasing feeder flexibility; however this technology is not currently financially feasible.

Active Distribution System Operation

One of the most highly discussed challenges among participants was the need for interoperability and clear communication among interconnected devices and operators. There is currently a lack of open source standards, communications, or interconnection frameworks that could allow for the interoperability necessary to develop an active, flexible distribution system. Individual devices and organizations maintain proprietary data and protocols that prevent a means of effective communication throughout the grid. Development of a fully accessible, yet secure, communication standard would allow complete interoperability among generators, consumers, and system operators.

Value Identification and Compensation

Generating units currently being integrated into distribution systems have grid support capabilities (i.e. ancillary service capabilities) that are not being fully utilized. There is a lack of common signaling for ancillary service needs and a lack of incentive structure for providing these services between system operators and generators. Power quality on the distribution system can be improved by optimizing the use of existing assets and properly incentivizing efficient customer behavior and ancillary service capabilities.

Improving Flexibility While Maintaining Reliability and Safety

Reliability and safety standards for the distribution system are of utmost importance as we work to improve grid flexibility. Two-way power flows caused by the integration of distributed generation and islanded microgrid systems creates reliability and safety challenges that may not be addressed by current standards. As the distribution topology evolves and the need for flexibility increases reliability and safety standards must be adapted and improved.

- ***Grid Understanding***

Data Collection and Use

The collection, transferring, and utilizing of data is vital in understanding the rapidly evolving complexities of the distribution system. There is a clear need to understand the necessary resolution, duration, and maximum latency of data required to conduct real time distribution grid operation. The proper means of collecting data to be used collaboratively by multiple resources and operators, in a secure manner, does not currently exist. Cyber-security must also be incorporated at every stage of design of new technologies and tools that may be developed to meet these data challenges.

Forecasting Scenarios and Market Models

As new technologies are developed and implemented into the distribution system, advanced forecasting and modeling tools will be needed to maintain grid stability. High resolution weather and load forecasting tools will be needed to properly balance weather-sensitive generation (such as wind, PV) with loads within the same system. Measurement devices will need to be adaptable and communicable. As new mobile assets such as electric vehicles grow in number, proper scenario modeling must be done to understand the amount, behavior, and effects of such technologies on the system and to inform infrastructure development.

Component and Distribution System Modeling

Component modeling and distribution system modeling need to have improved integration in order to fully understand the effects of loads and resources on the system. Adaptive component and system models need to be created that can quickly validate maximum renewable penetration levels on feeders to reduce the processing time for interconnection applications for utilities. Power analysis tools also need to be developed to utilize new and existing sensor hardware to develop a proper understanding of real-time grid status.

• ***Grid Visibility***

Situational Awareness

The need to improve the visibility of grid behavior during events is vital to maintaining grid reliability and safety. There is a need for predictive models that can operate in real time utilizing sensors and resources during events that can examine cause and effect to determine necessary operator actions. There is also a current inability to determine best-use resources in real time under different market and environmental scenarios. Efforts to improve visibility can help immensely during emergency situations to identify trouble spots and improve deployment and response time during system restoration.

Data Access

While the need for data sharing among operators, resources, and consumers is clear, proper access to this data is an issue. Information must flow to improve visibility among all parties throughout the grid; however, proprietary data cannot be freely shared. A secure means of sharing data, and sharing the right amount and type of data, must be developed to prevent dissemination of proprietary information.

Data Visualization

The collection and dissemination of data among grid participants will not prove effective unless there are proper tools to organize and visualize this data. These tools can be used to create an aggregate vision of loads and resources that allows for easy identification of weak links and appropriate operational actions within the distribution system. Data must be filtered to remove unnecessary information and then visualized in a manner that easily represents system operations.

Discussion Summary –Opportunities

Session participants identified a number of opportunities in each challenge area. These opportunities have been summarized and listed in the table below.

- ***Grid Flexibility***

Equipment Development

Research into low cost, multifunctional power electronics was the single most effective equipment development opportunity identified by the session participants. Incorporating power electronics capable of both communication and power control into existing equipment would eliminate many of the equipment challenges to grid flexibility without requiring a complete infrastructure overhaul.

Active Distribution System Operation

A number of opportunities exist for DOE to advance an active distribution system. Enhanced tools can be developed that enable real-time system modeling that incorporate state estimation abilities. Incorporating demand side management and creating standardized communication protocols can provide the necessary data to feed these models. The technologies necessary to allow for this monitoring and communication must be scaled between the distribution grid and the end user; DOE can assess the scalability of such technologies.

Value Identification and Compensation

DOE can conduct analysis into true ancillary service values under existing and potential new, markets and distribution system architectures. Models can be developed to accurately demonstrate costs and benefits of utilizing various grid connected resources to provide grid support. This analysis and modeling can be used by market entities to inform incentive structures for ancillary services provided by interconnected resources.

Improving Flexibility While Maintaining Reliability and Safety

Research into new standards, codes, and policies can be conducted by DOE that allows for power electronics to play a more active role in grid support. Metrics can also be developed to evaluate the standards and codes to ensure adequacy in maintaining reliability and safety.

- ***Grid Understanding***

Data Collection and Use

The DOE opportunities for data collection and use include tools, protocols, and cyber-security development. DOE can research communication protocols that allow complete interoperability between devices, resources, and grid operators. Analytical tools can also be developed to reduce the volume of data needed for monitoring and modeling the system, with the ability to identify erroneous or missing data implemented into these tools. DOE can also work with other public agencies such as DOD to develop best practices in data sharing and security.

Forecasting Scenarios and Market Models

The development of scenario and component modeling, and demonstration projects that confirm these models with real-world data, was identified as an opportunity for DOE involvement. Collection of sensor data during weather and grid events can be utilized to develop an understanding of customer response, which can inform expanded analysis of distribution system scenarios.

Component and Distribution System Modeling

DOE's position as a public entity allows it to collect proprietary information from manufacturers and develop non-proprietary component models that can be used universally throughout the industry without releasing trade-secrets. These types of technology-specific models that demonstrate true device behavior are currently lacking in the industry. Adaptable system models can also be developed that can quickly and accurately determine maximum renewable penetration levels on feeders, significantly reducing interconnection processing periods.

- ***Grid Visibility***

Situational Awareness

DOE can have a role in overcoming a number of situational awareness challenges. An adaptive query method can be developed that allows large amounts of data to be actionable by changing the level and resolution of data being utilized based on situational aspects. Research into temporary, mobile sensors can be conducted. Algorithms can be developed that further automate grid system operation and predict grid performance. These tools and technologies can also be incorporated into demonstration projects to verify real-world performance and value.

Data Access

Similar to DOE's ability to overcome data collection hurdles, a number of non-disclosure agreements can be put in place with competing entities to develop generic component models from proprietary data that more mirror real-world operation. DOE can also provide a neutral role in determining what industry data should be shared and how to protect all business interests involved.

Data Visualization

Data visualization opportunities include development of the technologies that monitor the grid, the tools that utilize the data, and the workforce that works with the tools. Research can be done to develop algorithms for cognitive networks for sensors and systems. These algorithms, when implemented with low-cost, mobile sensors can be used to fully understand the real-time operation of the grid. However, workforce education and development of best practices for operators is vital to utilizing the tools DOE can create. Without a properly informed workforce, little benefit will be seen from developing new technologies to visualize the grid.

TABLE C – YELLOW GROUP

Research Topic	Gaps & Barriers	Possible R&D Approaches
Flexibility	Equipment Development	• Research low cost multifunctional power electronics that can accommodate communication and control features
	Active Distribution System Operation	• Develop demand side management system that communicates with grid operator • Assess scalability of grid technologies for accessibility to all markets and systems • Develop real-time weather and demand forecasting models
	Value Identification and Compensation Methods	• Develop models of ancillary service values/benefits
	Improving Flexibility While Maintaining Reliability and Safety	• Research to inform standards, codes, and policies to utilize power electronics • Develop metrics to evaluate standards and codes
Understanding	Data Collection and Use	• Develop standardized communication/interoperability protocols • Develop analytical tools for data assessment and filtering • Develop best practices in cyber security through interagency collaboration
	Forecasting Scenarios and Market Models	• Scenario analysis and component modeling • Demonstration projects confirming modeling and analysis efforts • Data collection and analysis of consumer response during grid events
	Component and Distribution System Modeling	• Develop generic, but accurate, component models using manufacturer data • Develop adaptable system models that quickly determine renewable penetration levels
Visibility	Situational Awareness	• Develop temporary, mobile sensors • Research algorithms for identifying and predicting grid performance and establishing system autonomy • Develop adaptive query methods to make large amounts of data actionable • Demonstration and deployment for qualification
	Data Access	• Collect data from proprietary sources for model development and nonproprietary dissemination
	Data Visualization	• Develop algorithms to create cognitive networks of devices and sensors • Workforce education and development

GREEN GROUP

Overview

After organizing into the breakout session, the group was presented with the session objectives which included identifying top challenges from the grid perspective and, ultimately, key opportunities to address those challenges. Clarifying questions regarding the GTT's framework were addressed and the Action Plan document referenced. The discussion was limited to the technical challenges and opportunities, but any institutional topics were captured by the scribes for later consideration by the GTT.

Starting with the list of challenges and opportunities from the technology-specific morning breakout sessions, the group was tasked with reconsidering those captured during the morning session readouts, a brief summary of which was provided, from the grid perspective rather than from each specific technology. The group identified and organized its challenges around five key themes. It then proceeded to examine each of the key challenge themes for potential opportunities that would make great strides in the corresponding R&D spaces. Any challenges or opportunities discussed which were considered cross-cutting or institutionally focused were captured as a cross-cutting opportunity or an institutional consideration which should parallel any future R&D efforts, respectively. The refined challenges and opportunities were presented by a volunteer spokesperson.

Discussion Summary

The group discussion on key challenges ran the gamut of hardware, data management, modeling, microgrids, and security, among other topics. The discussion honed in on five specific challenge areas: (1) data exchange and information sharing; (2) data management, modeling, and visualization; (3) distribution topology; (4) grid flexibility; and, (5) and the general, cross-cutting need for optimization tools. This section synthesizes the challenge-focused discussions.

1. Data Exchange and Information Sharing

The group targeted this theme towards the need to rethink and possibly redesign how our legacy distribution equipment, which was designed and has been traditionally utilized for one-way flow of electricity. The "new" system needs to handle the bidirectional flow of electricity and information. Current power flow algorithms are insufficient to capture this enhanced role of the distribution system and provide greater visibility in both directions. Further, data management and utilization of increased quantities and types of data also creates a challenge in this space by adding overhead and increasing the burden on the system to ensure that the data are being sent and stored securely, being directed to the right data consumers, at each interface, and being translated or processed such that the data are usable for those consumers.

Ensuring that the right (validated) data get to the right user requires some form of standardized or common information exchange (such as a standard, protocol, or specifically designed infrastructure), which will be difficult to develop and impose on the industry broadly. The group believes that overcoming these data exchange and information sharing challenges will enable greater grid visibility and grid understanding.

2. *Data Management, Modeling, and Visualization*

This theme was targeted toward the need for more comprehensive models, open and integrated data sets which describe system components, and the infrastructure needed to manage the diverse data expected from the "new" system. To distinguish from the previous section on data exchange, here we are focused not with the "raw" data or algorithms, but with how that data is used in the context of the system. Under this theme, in addition to getting the right data to the right user as described earlier, how that information is structured and re-integrated back into the system, e.g., simulation, visualization, and optimization tools, for greater visibility and flexibility is a challenge.

At present there are numerous independent models which utilize various data types and information. While these models need not follow a centralized structure, they should be open and accessible by the right users and they need to be effectively visualized for better understanding and decision-making with respect to the distribution system. The group noted that, ideally, an all-encompassing, open, comprehensive model for the distribution system would certainly improve grid visibility, understanding, and flexibility.

However, heavy research into computing capabilities would be necessary to run such a model and such a model would need to be validated, yielding a chicken-and-egg situation where we need the data and the physical capabilities together to do so. Moreover, with the changing dynamics (and sometimes characteristics) of the distribution system, any simulation model that is developed would need to be continuously updated and improved to ensure it was accurately accounting for any improvements and changes to the topology of the distribution system.

Further, with respect to data management, security and storage infrastructures (whether centrally located or regionally accessible) are necessary elements to improve the use of these data in simulation, visualization and optimization models. In essence, achieving access to the right universal data, whether for an all-encompassing model or for a series of models capable of being linked, and the ability to apply that data in such models, especially in a predictive (faster-than-real-time) context, would help improve grid visibility, flexibility and understanding.

3. *Distribution Topology*

In establishing this theme, the group discussed many facets of distribution topology and settled on five specific areas: (1) higher resolution; (2) communications architecture; (3) migration from radial to network; (4) protection and controls; and, (5) security (cyber and cyber-physical).

The evolution of this theme started with consideration of various technologies, e.g., buildings, microgrids, which might be utilized to provide ancillary services or be considered subcomponents of the greater distribution grid system. More specifically, the need for the grid to be capable of assessing applications of these technologies to be seen as sources rather than simply end users; for example, future buildings which respond on a minute-level time scale and are capable of providing ancillary services or microgrids, which can also be used as "pilot scale" demonstrations for technologies, that are viewed as subcomponents which may be integrated into the design of the "modernized" distribution grid. Further, it was noted that, with this "modernized" view of these technologies, a more meshed/networked topography evolves from a conventional radial topography.

In fact, as the group noted, we are getting to this new topography presently and it too has challenges. Appropriate protection schemes and necessary hardware to protect and operate a new, looped topography do not currently exist. Additionally, security (both cyber and physical) is yet another layer (or layer of layers) which need(s) to be considered to ensure reliable, resilient and secure operation of the distribution system.

As noted above, data exchange and information sharing are important elements for the successful and effective operation of our future distribution grid. Establishing the corresponding communications system is a necessary stepping stone to overcoming that challenge. This also requires allowing the "modernized" distribution topology and implementation to be operated and modernized more proactively (e.g., improved contingency preparation rather than crisis management through better grid visibility and strategically focusing upgrade investments through better grid understanding). By addressing these facets of distribution topology and identifying "practices of note," great strides in grid flexibility, visibility and understanding can be accomplished, paving the way for future technologies and operational improvements.

4. *Grid Flexibility*

The group, for this theme, concluded that "grid flexibility" equals "an adaptive grid" with the underlying context being that such a grid can handle anything that is thrown at it, at whatever frequency or from whatever location it is thrown. That said, the group recognized that establishing such an adaptive grid requires success with many of the above-summarized challenge themes. Specifically, being sufficiently flexible to utilize technologies in unconventional roles (e.g., buildings as ancillary service providers, microgrids as functional distribution grid system subcomponents) and able to utilize adaptive protection schemes and system architecture for both security and operational control.

Further, in capturing another topological facet, an adaptive grid should also be capable of communicating and responding to appropriate data at desired frequencies, including at the consumer engagement level (e.g., consumer decisions based on in-house price signals). R&D targeted to enable such grid flexibility in order to achieve a universally-adaptive grid will enhance the current distribution grid system's flexibility, in addition to providing insight to grid understanding and visibility needs.

5. General, Cross-cutting need for Optimization Tools

Throughout its discussion, the group identified several cross-cutting challenges which should be considered broadly as each of the above-discussed more-focused challenge themes is addressed. The overarching connection for many of these cross-cutting challenges was the need for optimization tools which account for several different and important decision-making factors. Some specific examples include risk management, evaluation of technology options – including cost and value proposition – and evaluation of central versus distributed generation. Emphasis was on the need for costs to always be considered in decision-making and the need to be able to quantify benefits and the value proposition, at every step of the way, not just at the conclusion of a technology's production cycle. Additionally, the group noted that more demonstrations are needed to show how new technologies or new roles for established technologies can be used in a "modernized" distribution system. Two specific, recurring examples of newly positioned technologies are microgrids as a subcomponent and buildings as ancillary service providers. Such demonstrations also provide the opportunity to identify "practices of note" and testing of the next generation of controls, as well as newly developed optimization tools for risk assessment and cost-benefit analysis to ensure the right balance between cost and technology. Addressing these challenges will help advance grid flexibility and understanding as well as better inform decision-makers.

Key Opportunities

In addition to identifying top challenges from the perspective of the distribution grid, the group identified corresponding R&D opportunities to help address the challenges which would greatly increase the progress in the corresponding space. These opportunities are tabulated below and, in the sections that follow, a synopsis of the discussions around these opportunities is provided.

1. Data Exchange and Information Sharing

In discussing how to overcome the challenges associated with data exchange and information sharing, the group determined that two key areas would help move this space forward greatly: (1) developing an open data exchange infrastructure for grid operation and (2) developing mechanisms and devices which would enable getting the right information to the right user at the right time, at each interface. An open data exchange infrastructure, as contemplated by the group, should provide and exchange information across the grid. Appropriate data should also be used to model equipment and subsystems such that these representative data models are vendor-neutral and cross-platform and can be used in system modeling and visualization.

Upon further consideration of what would be needed to establish an open data exchange infrastructure, the group identified existing protocols that could be incorporated, either directly or used as examples, e.g., IEC 61850. However, the group also noted that if protocols are used to protect data sensitivity, then security measures should be used because of potential conflicts.

The benefits and value propositions for the different approaches should be considered when determining which manner of protection is appropriate. NASPInet was identified as an example of the type of data communications infrastructure that is needed to ensure that the right information can, securely, get to the right user. The group noted that, while the concepts underlying NASPInet would be a good start, additional hardware and devices would likely need to be developed to facilitate data exchange or information sharing. Progress toward these opportunities would improve grid understanding and visibility.

2. *Data Management, Modeling, and Visualization*

To make progress addressing data management, modeling, and visualization, the group concluded that comprehensive simulation models that are open, cross-platform, and vendor-neutral would be extremely valuable. These models would rely on a common database, usable by multiple software programs, and would comprise service-oriented architectures offering real-time applications opportunities. Further, these models should have look-ahead capabilities providing “faster than real-time” simulations and be informed by past failures and improved understanding of system dynamics. As noted above, the comprehensive models envisioned will require improved computing capabilities such as parallel processing, as compared to today’s serial processing, and the development of new algorithms. With these models, visualization and decision support tools can be developed to improve usability for operators, planners, and policy makers. However, when developing these tools, the group noted that, with so much information available, they must be developed to effectively visualize the data and provide useful information and lead to better-informed decisions; insights may be drawn from leveraging the gaming industry.

3. *Distribution Topology*

As described above, this challenge theme, as devised by the group, comprises five specific facets. In identifying opportunities targeting these facets, the group discussed the need for diagnostic tools which sufficiently capture the dynamic nature of the distribution grid system. Additionally, there is a need for development and demonstration of appropriate adaptive protection schemes, systems and components for a modern, flexible grid. Here, the group noted that these protection elements refer not to cyber-security, but to the protection of the devices which comprise the grid and are integrated into control devices.

Cyber and physical security must also be considered, potentially in the context of a contingency preparation tool (as opposed to crisis management) to allow for more proactive security of the grid and its information. Another opportunity discussed was the need for a configuration management tool to help, for example, evaluate legacy vs. new grid topology, simulate grid components for reliability and manage network growth. Recognizing that the distribution grid is dynamic, the group also noted that a new EMS and DMS are needed to accommodate these dynamics. All of these opportunities will inform distribution topology decisions, leading to improved understanding, visibility and flexibility of the distribution grid system.

4. *Grid Flexibility*

In this challenge theme, the focus was on establishing an adaptive grid. Building the adaptive characteristic into the grid's topology, simulation and management will require panoply of advancements. During this session, the group focused on some of the key opportunities that would make progress toward achieving an adaptive grid.

Grid operation and configuration were discussed, yielding the suggestion that islanding mode be employed along with fault-tolerant and self-healing technologies. Additionally, advancements in power electronics interfaces, including inverters, controls, protection, power flow, selective harmonic reductions, etc., are needed, along with complementary demonstrations.

Another technology ripe for improvement is autonomous controllers, which need to demonstrate a higher level of ability, as "loosely decentralized controllers" in comparison with centralized control. From the user perspective, in addition to having the infrastructure in place to ensure that information can get to the user, devices and mechanisms which allow the user to act or respond, e.g., based on price data, are needed.

The group also discussed advancements in adaptive relays where the technology concept is built around understanding the grid through measurements; with such technology, when the system changes, it is measured and then the protective controls are adapted – which is very different from a set it and forget it mindset. Achieving these opportunities will enable greater flexibility of the grid and, in conjunction with improved data exchange and management, will increase grid visibility and understanding.

5. *General, Cross-Cutting need for Optimization Tools*

Throughout discussions on the above-summarized challenge themes, the group identified, and often reiterated, the importance of some specific capabilities and opportunities. Namely, the need for more demonstration of new technologies and the need for improved optimization tools. Through demonstrations, it was noted that lessons can be learned and applied, better informing the next phase in the production/commercialization lifecycle.

Further, demonstrations of new technologies, and existing technologies in new roles, can help identify additional data and data management/utilization needs and opportunities. One such example discussed was using buildings as ancillary services: currently they are able to respond on an hourly time-scale, but future buildings could respond as quickly as on the minute time-scale; in this capacity, there is a need to understand the need for, develop, and demonstrate the next generation of controls, cyber and physical security protocols and technologies, etc. And, as was stressed vehemently by the group, cost, value proposition and risk are very important factors that need to be captured by optimization tools to ensure that the right mix between cost and technology is achieved when decisions are made.

These three factors parallel any technology advancements and can be analyzed, at least at "pilot scale" through the use of demonstrations which can be optimized through the use of strategically designed tools. While opportunities around increasing demonstrations and optimization tools will help advance grid understanding and flexibility, the outcomes of these opportunities are also very important to better inform technology option decisions at all levels of the distribution grid system (and in the electricity system as a whole).

TABLE D – GREEN GROUP

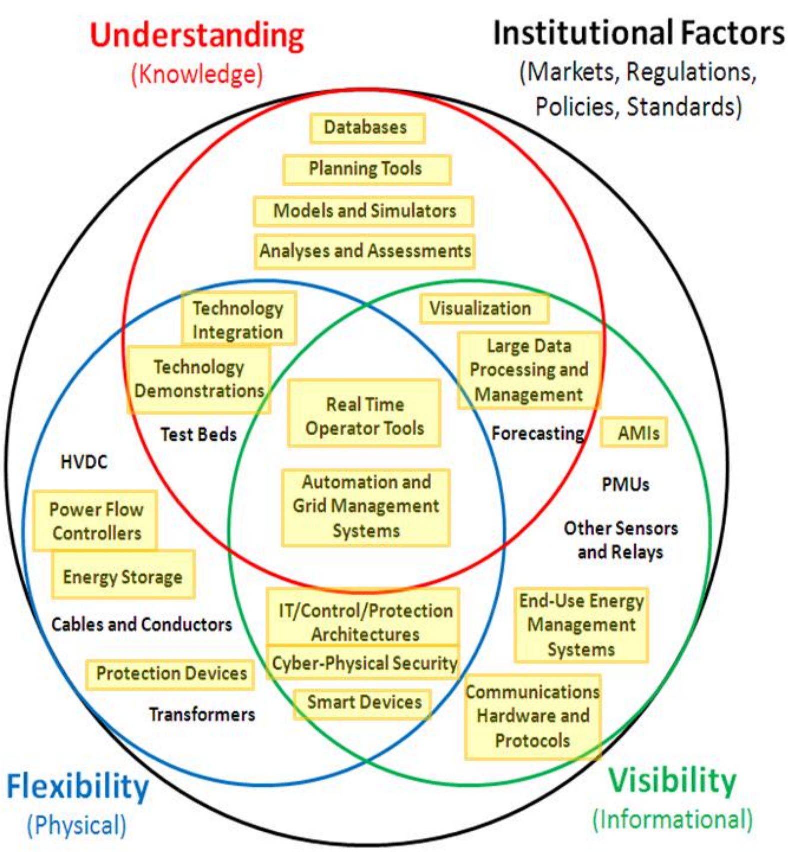
Research Topic	Gaps & Barriers	Possible R&D Opportunities
Communication & Information	Data exchange and information sharing	▪ Develop an open data exchange infrastructure for grid operation and support of transactions ○ Incorporate (informed by) existing protocols ○ Provide exchange of information across grid ○ Develop data models (data structure) for equipment and subsystems (vendor neutral and cross platform) ▪ Develop mechanisms and devices to get the right information (e.g. price) to the right stakeholder (e.g. consumer/user) at the right time
	Data management, modeling & visualization	▪ Develop comprehensive simulation models (open, cross-platform, vendor neutral) ○ Common database that multiple software programs can pull from ○ Use of service oriented architectures for real time applications ▪ Develop look ahead (faster than real-time) simulation ○ Study of past failures and understand system dynamics ▪ Utilize parallel processing and develop new algorithms ▪ Develop visualization and decision support tools, e.g. leverage gaming industry
Communication	Distribution topology… 1) higher resolution; 2) communication architecture 3) migration from radial to network 4) protection & controls security, cyber and cyber-physical	▪ Introduce and deploy a broad array of diagnostic tools ▪ Leverage characteristics of microgrids (demos, "practices of note", lessons learned, ancillary services), e.g., ○ Integrate MG into distribution planning and design ○ How does MG meet reliability requirements ▪ Develop configuration management tool (legacy vs. new) ▪ Develop of contingency management tool ▪ Develop of new EMS and DMS power system algorithms for new distribution system topologies ▪ Develop and demonstrate adaptive protection systems for flexible grids
Flexibility	Grid Flexibility = "adaptive grid" • Adaptive at different scales Advanced technologies	▪ Develop and demonstrate fault-tolerant and self-healing distribution systems for different applications ▪ Develop power electronic interfaces, e.g., power flow controllers, selective harmonic reduction ▪ Demonstrate and study the interactions between centralized and autonomous controllers – "loosely decentralized controller" ▪ Develop mechanisms and devices to get the right information (e.g. price) to the right stakeholder (e.g. consumer/user) at the right time ○ Also, need mechanism (manual vs. automated) to respond to the decision/action (*link to data exchange*) while ensuring reliable operations of distribution system
Management Tools	Need for optimization tools – link to risk management, technology options	▪ Ensure that cost and value proposition are quantifiable and factored into evaluation ○ Quantify benefits and values ▪ Develop optimization tools – various criteria such as central vs. DG; tech options; value proposition; risk management for security, etc. ▪ Demonstration – end-to-end from generation to end-use, including microgrid ○ Leverage concept of microgrid for pilot scale demo ○ Productize and Commercialize

BLUE GROUP

Overview

This report summarizes the work done by the "Blue" Group during the holistic-system breakout sessions. The group consisted of 18 members representing private industry, national labs, utilities, research institutions, and government agencies.

The purpose of the discussion was to identify the key challenges and opportunities with integrating disparate technologies onto a cohesive 21st century grid, while maintaining the reliability and security of the system. In the cross-cutting analysis, the group keyed in on several of the topics that were identified by DOE's Grid Tech Team as the primary realms of grid integration: understanding, visibility, and flexibility.



The group touched on a number of key issues, keeping well within the framework of the Grid Tech Team's Venn diagram of the challenges confronting grid integration. The diagram to the left shows all of the sub-topics in that framework. The topics that were addressed in the breakout session are highlighted on the chart. As seen, the group's collaboration was rather comprehensive in addressing broad institutional factors of markets, regulations, policies and standards. The discussion appeared to have leaned slightly more towards the "visibility" & "understanding" aspects of the grid, though, giving comparatively less emphasis on its physical flexibility.

Discussion Summary

The group distilled its discussion into four key challenge areas for the distribution system:

1) Formulating business cases

2) Establishing communication and control infrastructure

3) Developing tools for modeling and simulation

4) Aligning policies with holistic systems

Formulating business cases includes identifying, monetizing, and allocating value streams across appropriate scales and among participants in the grid. A holistic systems-approach to grid integration is a very abstract concept for consumers, regulators, businesses, and utilities alike. Clearly identifying the value of various integrated systems to each (or all) of these parties will help them better understand the risks and rewards associated with a modernized distribution system. Further, this approach – clearly defining value streams for all aspects of the grid – will unlock new markets and enable the adoption of new technologies.

Communication and control infrastructure is a critical component of an integrated distribution system. Two-way communication capabilities must first and foremost be reliable and secure. Controls need to be calibrated and responsive to all aspects of the system, including vehicles, storage, buildings, variable resource integration, dispatchable distributed generation, and feeders to transmission.

Modeling and simulation of the distribution system are essential tools to enhance the understanding, visibility, and flexibility of the grid. Such tools enable a system-of-systems approach to the development and modernization of grid infrastructure, providing essential information to inform the business cases for risk-managers, planners and decision makers.

Finally, a fully integrated distribution system must include a suite of policies that are aligned with economic incentives, consumer and utility needs, and technical solutions. Though the policy landscape was outside the purview of this workshop, the importance of its impact on the system cannot be overstated.

TABLE E – BLUE GROUP

Research Topic	Gaps & Barriers	Possible R&D Approaches
Business Case	Valuation & Monetization	Conduct analysis to define value propositions at all levels of interaction across regions
	Education & Outreach	Programs for education and interaction among regulators, policymakers, customers, and industry
	Buildings, Vehicles, RE, & Storage	Develop multiple simultaneous value propositions such as DR, improved EE, maintenance and management services via investment in infrastructure
		Implement existing controls
		Develop a new controls paradigm
	Reducing Risk to 3rd Party Aggregators	Help identify and define system and value streams
		Improve modeling and understanding of systems and synergies
		Quantify the value of ancillary services for a given market
		Operability and Reliability Testing: DOE can act as a convener to enable integration across technologies
	Data Availability	DOE: facilitate the availability of accurate, high fidelity data
Communication & Control	Anti-Redundancy of Effort	Ensure coordination and not duplication of existing activities (like SGIP)
	Security	Identify criteria for security based upon system needs
	Reliability	Establish redundant pathways to ensure reliability of transmission, power flows, storage, etc., and data and information
	Demonstrations	Demonstrate projects to facilitate customer acceptance and try out a variety of business models and value propositions
	Certification & Standardization	3rd party testing and certification of adequate cyber-security and communications interoperability (i.e., Energy Star-like process)
Tools & Systems Simulation	Interfaces	Improve interfaces of existing modeling platforms; improve training, documentation; data format translation and standardization
	Scalability	Improve ability to model across scales and between components (i.e., buildings <-> grid; T <-> D; operations <-> planning; forecasting <-> planning; models need to talk to each other)
	Planning & Contingencies	DOE: Integrate additional energy system components for contingency analysis tool (i.e., transportation, natural gas 'grid', etc.) Planning, risk analysis, interfaces between system components
		Improve (reliability, speed) tools for system modeling of DG or loads for planning
	Valuation	Quantify uncertainty
	Security	Interactive threat analysis (i.e., two correlated or uncorrelated events occur simultaneously)
	Data Collection	DOE: Provide modeling data inputs and databases
Policy Alignment	Data Privacy & Aggregation	Establish algorithms for data aggregation that removes privacy concerns while providing necessary information at relevant scales
		3rd party access to data maintains appropriate privacy/security
		Develop clarity around ownership of data

CONCLUSION & NEXT STEPS

The Distribution Workshop was a productive engagement with electricity-sector stakeholders, and produced very thoughtful outputs. The information gleaned from the workshop, as described in this document, will play an important role to inform the development of a research and development roadmap. These findings identify key challenges and opportunities associated with grid-integration.

This document does not complete DOE's collection of input regarding the modernization of the electricity distribution grid. This document, along with the DOE Action Plan and other reference inputs will inform the decision-making process to help guide research and development investments over the next five years.

Participants from this workshop, other stakeholders, and the general public at large are encouraged to provide input to this process. This document will be released in draft form with a formal request for information. These and other inputs to the road mapping process will help support the broader efforts of the Grid Tech Team to identify key research and development activities to achieve a 21st century distribution system.

APPENDIX A: PUBLIC COMMENTS

Process

The participants at the Distribution Workshop represented a broad cross-section of stakeholders in the grid space. While their wide-ranging perspectives provided a thorough analysis of the topics discussed at the Workshop, their contributions were not exhaustive. Recognizing this, the DOE made the Distribution Workshop Discussion Summary Report available for public review for a period of 30 days in March, 2013. This period began with a public notification that was announced in the Federal Register. Concurrently, the DOE sent email notifications to the original workshop invitees and also encouraged sharing and forwarding this notification to extend the outreach to the greatest extent possible. DOE's intent was for the widest-possible solicitation of input on the following questions:

1) Are there any issues in the discussion summary documents that require particular consideration? Are there any issues in the discussion summary documents that do not warrant further consideration? Please provide any examples or information that further supports your comment.

2) Are there crucial challenges or opportunities associated with the Electricity Distribution or Transmission System (or both) that are not sufficiently represented in these documents?

Comments & Response

During the comment period, anyone with an interest in this topic or these documents was able to submit their input in a variety of ways. DOE established systems to collect comments via regular mail, email, or online at the Grid Tech Team Website. DOE received a total of five comments, which are included below (with formatting changes only and in order of increasing length).

Submitted Public Comment	GTT Response
The Electricity Distribution System Workshop report provides a good analysis of the proceedings at the Grid Integration Workshop. I see no issues in the report.	No response required.
When energy storage is discussed, mechanical storage systems such as flywheels should be included. When cost reductions, response times, charge/discharge cycles are mentioned, the value proposition needs to be more explicit to inform the industry of the targets.	This comment is incorporated in the Discussion Topic Tables on page 9, in the Dispatchable Generation discussion summary on page 25, and the Table 2 on page 27.

Submitted Public Comment	GTT Response
I agreed with many of the needs identified in the workshop proceedings. Among them: • Better visualization of grid state • Interoperability testing of proprietary technologies, side-by-side • Standard, open-source communications protocols • Better communication and visibility of distributed generation technologies • Better models and simulation at faster than real time in order to better understand the impact of renewable and distributed generation. • The need for energy storage to increase grid flexibility • The need to maximize the capture of value from ancillary services, especially of non-traditional generation sources and dispatchable loads. Many of these challenges will not or cannot be met by private companies in the utility industry alone. It is proper that DOE should use the resources and expertise at its disposal in order to effectuate change in the areas above.	No response required.
I have the following comments on the Tech Group section for Plug-in Electric Vehicles and Fuel Cell Electric Vehicles: (i) In Section II, the statement that "current electrolyzers are typically small..." is not accurate. The following statement is more reflective of the current state of technology: "Commercial PEM [Proton Exchange Membrane] electrolyzers are currently available at the 200 kW scale, and MW scale systems are in development." (ii) In the paragraph that immediately following item 1, the correct statement is "Power electronics development is also needed, particularly to aid in renewable system integration." (iii) The paragraph talking about the power consumption of hydrogen compression should also include the following statement: "Developing higher pressure electrolyzers will also contribute to lower compression cost, both in terms of capital and energy. (iv) Under the section "Component Development, Demonstrations, and Modeling", subsection II (Demonstrations), the last 2 sentences should read as follows: "In addition, there are several ARRA projects that are exploring ancillary services, but none of those projects have vehicles or electrolyzers involved. Some of those projects may benefit by the inclusion of vehicles and electrolyzers." (v) In Table 4, under the "Electrolyzer" research topic, the first bullet under "possible R&D approaches" should read "improved hydrogen drying efficiency". (vi) In Table 4, under the "Power Electronics" research topic, the following "possible R&D approach" should be added: "DC to DC power conversion to enable electrolyzers tied directly to renewable power sources".	Comments (i) (ii) (iii) and (iv) are incorporated in the Plug-in Electric Vehicles & Fuel Cell Electric Vehicles discussion summary on page 36-38. Comments (v) and (vi) are incorporated in Table 4 on page 39.

Submitted Public Comment	GTT Response
In the Distribution workshop, energy storage was included in the breakout session titled Smart Grid Technologies & Distributed Energy Storage. One of the specific R&D needs identified was for energy storage technologies to be further developed to become more dispatchable on a small scale. There are already a number of projects on the community scale that are testing that functionality. Building from the data gathered for those projects, the ESA [Energy Storage Association] believes we will be able to rapidly scale and deploy community-based systems without need for significant increased technology R&D. We would recommend, however, that DOE include these projects in modeling such that utilities and regulators can build those assumptions into the rate case process. In addition, under customer-sited categories of use cases (developed in California) – customer bill management, utility controlled, permanent load shifting– energy storage can serve as a component within demand response and energy efficiency strategies. One of the comments made by the Distribution team was that insufficient discussion was held on the benefits of energy storage to the distribution side of the grid. Since it was combined with smart grid, the conversation was evidently diluted and did not focus on energy storage specifically. The ESA agrees with this comment and recommends that energy storage be revisited in the Distribution setting and that industry have the opportunity to participate in those discussions.	This comment is incorporated in the Opportunities for DOE section on page 30 and in Table 3 on page 33.