# Summary Results of Electricity Distribution System Challenges & Opportunities

From Breakout Group Sessions

Electricity Distribution Workshop
Sheraton Crystal City, Arlington, Virginia
September 26, 2012

# Red Team

Results

# Top Challenges

- Communication
- System Awareness & Modeling
- Standards and Interoperability

# Challenges

- Need a national scale Grid Operating System (Grid OS) including microgrids – a uniform framework towards operating all of the nation's distribution grids using a collaborative approach
  - DOE needs to develop an advanced SCADA system definition given to system operators

- Bring information together from various sources – differing protocols, lack of a data service bus, automated processes

- Lack of a standard communication protocols, data formats/interfaces

- A common modeling and simulation approach with linkages between different tools

# Challenges

- Grid-friendly standards for all technologies
- Application-needs drive data-needs that drive communication technology
- Low cost sensors, interoperable with grid operating systems
  - Safety, security & survivability
- Distribution system optimization across different technologies
  - With parameterized node definitions
  - Identifying opportunities to synergize between resources (various types of generators)
- Cultural differences in communicating challenges to regulators

# Opportunities

- Lack of a standard communication protocols, data formats/interfaces
  - Facilitation by DOE to enable the adoption of common communication models
  - DOE enables demonstration projects to showcase interoperability standards
    - Through IEC 61850
  - Enable adoption of standard data transfer and sensor protocols
  - Leverage learnings from existing “big data” issues in other applications

- Convening all stakeholder standards institutions in a common forum to create standards for the distribution grid

# Opportunities

- Distribution system optimization across different technologies
  - With parameterized node definitions
  - Identifying opportunities to synergize between resources (various types of generators)
  - Integrating dispatchable renewables - weather forecast data
    - Predictive algorithms to dispatch storage in advance of weather patterns
  - DOE needs to do research in collection, storage, management, and analysis of large amounts of data
  - Whitepaper on DMS to define baseline, gaps and roadmap
  - Drivers for distribution system optimization include real-time pricing, reliability, utility business models

# Orange Team

Results

# Top Challenges

- System Architectures & Controls
- Modeling & Simulations
- Data & Communications
- Codes and Standards
- Valuation

# Challenges

- System Architectures
  - Hierarchical distributed control systems
  - Demonstrating hierarchies for control and communications
  - Centralized versus decentralized; Transmission & Distribution
  - Need for foundational research for control over time and space (across large numbers of components/devices)
  - Different technologies at different maturities—need to accommodate all
  - EMS and DMS; Building energy management system (DMS, micro-EMS)
- Modeling and simulations for new architectures and tech
  - Variability and uncertainty, impacts, climate dependence
  - Planning tools, analyses, operator tools – forecasting (validate technology function & cost on a system level)
  - Latency and communication requirements

# Challenges

- Data and communications requirements
  - Standardized communications protocol among DER & energy consuming devices
  - Comprehensive database of technologies, latencies,
  - Visibility and the data to system operators (different time scales, spatial)
- Protection and safety
  - System operation under the loss of communications, etc. (revert to safe operating mode)
  - Standardization at the national level
  - Two way flows and relays
- Physical requirements for functionality
  - Moving from legacy systems to newer technology
- Codes, standards, and interoperability – flexibility, security
- Understanding cost/benefits to all stakeholders

# Opportunities

- **System Architectures and Control Structures (e.g., Hierarchical distributed control systems)**
  - Basic science/foundational control theory advancements for systems of multiple temporal and spatial scales and with significant uncertainty
  - Focused demonstration projects to validate the above
  - End-to-end demonstrations (in different markets, including value and impacts to all relevant stakeholders)
  - Power electronics flow controllers and new architectures they enable (e.g., flow control interconnected microgrids, AC/DC)
  - EMS and DMS, micro-EMS implementing new architectures

# Opportunities

- **Modeling and simulation for new architectures and technologies (planning tools, analyses, operator tools – forecasting; validate technology function & cost on a system level)**
  - Low cost sensors (e.g., "distribution PMU") and/or intrinsic sensors on distribution systems with visibility to different stakeholders
  - Comprehensive analysis of sensor data needs and value proposition
  - State estimation tools for distribution systems
  - Self-adaptive, self-calibrating, real-time model of distribution feeder (from utility data) including "plug and play"
  - Planning tools for storage, demand response, smart inverters, and related components in the distribution system (interface existing models, plus emerging technologies)
  - Validation of existing tools
  - Workforce training tools with new models and operational practices

# Opportunities

- **Data and communication technologies**
  - comprehensive performance database of existing technologies (e.g., response times, bandwidth, latencies)
  - standardized /harmonize communications protocol among DER & energy consuming devices
  - development of analytics to convert data into actionable information for various stakeholders
  - facilitate & analyze delivery of prices and reliability information/signal to end-use devices and users

- **Mapping ARRA outcomes against all these challenges and the analysis of results**

# Yellow Team

Results

# Top Challenges

- Flexibility
- System Understanding & Knowledge
- Visibility

# Challenges

## Flexibility

- MV DC to interconnect distribution components –new capability
- Maintaining safety while incorporating flexibility
- Storage integrated with renewable operations in design phase
- Optimal use of existing distribution assets – new perspectives
- Open framework for allowing innovation from all participants
- Power electronics integration of grid features while maintaining efficiency and cost
- Expand tools/equipment and features from planning to the operating environment
- Retail structure that incentivizes new behavior
- Accommodating electrical islands at scales in campus and distribution system level

# Challenges

## Flexibility

- Common signaling and reward methods to extract ancillary services from distribution level assets
- Relax policies to accommodate microgrids
- Proper allocation of costs and values for flexibility
- Integrated demand side management perspective of the system including DG, loads, RE, Energy efficiency, DR, energy storage
- Balance between open framework and security/reliability
- Understanding implications of 2 way power flow to physical hardware and operational approaches
- **Reconfigurable electronics**
- Standard backbone; interoperability for data streams

**Challenges**

# Flexibility Summary

| | |
|---|---|
| Electronics Development | Low cost multifunctional electronics and ability to accommodate communications and control features in existing systems assessing value. |
| Value identification and compensation methods | Value alignment with system operation<br>Modeling methods<br>Establishing market methods for ancillary services in the distribution network (models) |
| Active distribution system operation approaches | Better operational distribution system modeling.<br>Extracting data streams to feed models.<br>State estimation applied to distribution and interoperability<br>Integrated demand side management<br>Assessment of scalability of technologies. |
| Improve flexibility while maintaining safety and providing acceptable reliability and security | Through applicable standards, codes, and policies.<br>Potentially through microgrid and other solutions deployment.<br>Methods and metrics for evaluating approach.<br>Cyber methods incorporated in design stage. |

# Challenges

## Understanding & Knowledge

- Multi dimensional visual analytic tools
- High res weather forecasting and load forecasting tools to identify potential flex
- Training approaches
- Cyber threat identification and awareness
- Evaluation of increased flexibility on emissions
- Information latency and its impact on controls and benefits
- Validation of data and management of volume
- Validate DG penetration threshold level that triggers extensive studies
- Future proofing communications attributes to enable broader applications

# Challenges

## Understanding & Knowledge

- Managing mobile assets in distribution networks
- Addressing ability to respond with differences in time scales of monitoring and data streams
- Mix of EVs, FCVs – quantifying the difference in the potential of each to participate in grid operations
- Interconnect requirements database that is inclusive of all regions to enable tech development
- A way to better share knowledge and data across regions about solutions and tests

# Challenges

## Understanding & Knowledge

- Expanding ability to accommodate many degrees of freedom
- What data is needed and how to utilize for multiple applications
- Extracting power analysis data from distributed power electronics to be used to standardize real time grid status

**Challenges**

# Knowledge Summary

| | |
|---|---|
| Data<br>-Amount<br>-Types<br>-Quality/validation<br>-Resolution<br>-Architecture interop<br>-security | Analytic information compression with the ability to identify errors and fill holes<br>Interoperability protocols<br>Case studies on best practices of data application<br>State analysis to reduce the amount of data needed at different levels<br>Analytical tools to identify good and bad data sets<br>Info sharing/best practices with other agencies |
| Forecasting scenarios of EVs, FCVs, Energy storage, demand response, etc. and related market models | Scenario analysis and component modeling<br>Customer response<br>Coordination and planning of demonstrations<br>Characterization of devices<br>Expanded distribution level analysis |
| Interaction between component modeling and distribution system modeling | Convene standardization of information sharing<br>Initiate integration from component, to building, to distribution system<br>Evolving penetration scenarios integrated in the modeling to better understand the impacts<br>Leverage DOD simulation and interface standards<br>Develop decision model structure supporting key outcomes<br>Develop means for integrating future elements |

# Challenges

## Visibility

- Situational Awareness: Integrated view for ongoing monitoring- significant components. Where are the small scale assets? What is their availability? Visibility into when DG and DR is coming on and off. Cause and effect between knowns and unknowns. Visibility into restoration effort. Coordinate around a microgrid and for the overall infrastructure reconnection.
- Data Access: Who is the keeper/owner of the information? Where can the info be found. Proprietary/ Territory/ Privacy/ Jurisdictional issues. Security.
- What do we need to visualize? How do we deploy the minimum set of sensors to achieve the objective? Machine to machine visibility- bandwidth constrained. Man to machine- cognitive distilling of information.

# Challenges

## Visibility

- Visualize weak links in the grid.  Identify highly localized weaknesses for upgrade.
- Delivering comprehensible market signals to mobile resources (e.g. finding cheapest gas).
- Making very large amounts of data actionable.
- Modeling a very complex system and making it easy to use. Computation time creates lag in response.

**Challenges**

# Visibility Summary

| | |
|---|---|
| Situational Awareness: Integrated view for ongoing monitoring- significant components. Where are the small scale assets? What is their availability? Visibility into when DG and DR is coming on and off. Cause and effect between knowns and unknowns. Visibility into restoration effort. Coordinate around a microgrid and for the overall infrastructure reconnection. | • Better tools (e.g. distribution state estimator). Interoperability of components into existing tools. Demonstration and deployment for qualification.<br>• Making large amounts of data actionable.<br>• Identify gaps in what data is available. Data management systems.<br>• Algorithms for identifying and predicting grid performance and establishing system autonomy.<br>• Adaptive query on data for better understanding cause and effect. Deployable (temporary) sensors to identify data gaps. |
| Data Access: Who is the keeper/owner of the information? Where can the info be found. Proprietary/ Territory/ Privacy/ Jurisdictional issues. Security. | • What is the data for? Identify what data needs to be secured.<br>• NDA. Limiting scope to necessary circuits.<br>• Use of surrogate data or aggregate. (develop understanding of good surrogate data)<br>• Develop paradigm for data access.<br>• DOE could be an aggregator and convener for data dissemination.<br>• Avoid lack of data availability (e.g. private meter data). |
| What do we need to visualize? How do we deploy the minimum set of sensors to achieve the objective? Machine to machine visibility- bandwidth constrained. Man to machine- cognitive distilling of information. | Development of low-cost mobile sensors.<br>Research in algorithms for cognitive networks.<br>Research into smarter sensors to reduce number of sensors.<br>Understanding spatial and temporal resolution of data needed.<br>Education and development of best practices for operators to utilize visibility tools |

# Green Team

Results

# Top Challenges

- Data Exchange and Information Sharing
- Data Management, Modeling & Visualization
- Distribution Topology
  - 1) Higher resolution; 2) Communication Architecture
  - 3) Migration from Radial to Network 4) Protection & Controls
    5) Cyber and Cyber-Physical Security
- Grid Flexibility = “Adaptive Grid”
  - Adaptive at different scales
  - Advanced technologies
- Need for optimization tools – link to risk management, technology options

# Challenges

## Data Exchange & 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

# Challenges

## 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

# Challenges

## Distribution Topology

1) Higher resolution 2) Communication Architecture 3) Migration from Radial to Network
4) Protection & Controls 5) Cyber and Cyber-Physical Security

- 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

# Challenges

## Grid Flexibility – “Adaptive Grid”

- 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

# Opportunities

**These opportunities cross-cut all challenges and should be addressed within all appropriate opportunities**

- 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; technology 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 Team

Results

# Top Challenges

- Business Case
- Communication & Controls
- Tools, Modeling & Simulation
- System Alignment

# Challenges

1. Business case, determining, monetizing and allocating value across appropriate scales and participants in grid
2. Reliable, secure, two-way communication and control across the grid spectrum (vehicles, storage, buildings, RE integration, and feeder to transmission scale).
3. Tools to enable systems-level modeling and simulation and turn this into information for decision-making across scales (and reduce risk to business case) – System of systems approach
3. Ensuring alignment of policy, consumer needs, utility needs, economics, technical solutions

# Opportunities

**Business Case:**

Determining, monetizing and allocating value across appropriate scales and participants in the electrical grid

- DOE: Analysis to define value propositions at all levels of interaction across regions
- Education and outreach
  - Regulators, policymakers, customer education and outreach
- Buildings, vehicles, RE, storage: Develop multiple simultaneous value propositions such as DR, improved EE, maintenance and mgmt services via investment in infrastructure
  - DOE: Short term – implement existing controls
  - DOE: Long term – develop new controls paradigm

# Opportunities

## Business Case:

Determining, monetizing and allocating value across appropriate scales and participants in the electrical grid

- DOE: Help reduce risk to utilities and 3rd party aggregators
  - Help define system and value streams
  - Improve modeling and understanding of system of system approach/synergies
  - Quantify ancillary services value for a given market
  - Operability and reliability testing: DOE a convener to enable integration across technologies
- DOE: Facilitate availability of accurate, high-fidelity data

# Opportunities

## Communication & Controls

Reliable, Secure, "Two-Way"

- DOE: Ensure coordination not duplication with existing activities (i.e., SGIP)
- Identify criteria for security based upon system needs
- Establish redundant pathways to ensure reliability of transmission, power flows, storage, etc., and data and information
- DOE: Demo projects to facilitate customer acceptance and try out variety of business models and value propositions
- 3rd party testing and certification of adequate cybersecurity and communications interoperability (i.e., Energy Star-like process)

# Opportunities

## Tools

Enabling Systems-level Simulation to Inform Decision-making

- Improve interfaces of existing modeling platforms; improve training, documentation; data format translation and standardization
- 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)
- Model validation
- Improve (reliability, speed) tools for system modeling of DG or loads for planning

# Opportunities

## Tools

Enabling Systems-level Simulation to Inform Decision-making

- DOE: Integrate additional energy system components for contingency analysis tool (i.e., transportation, natural gas ‘grid’, etc.)
  - Planning, risk analysis, interfaces between system components
- Uncertainty quantification
- Interactive threat analysis (i.e., two correlated or uncorrelated events occur simultaneously)
- DOE:  Provide modeling data inputs and databases

# Opportunities

## System Alignment

Enabling Systems-level Simulation to Inform Decision-making through alignment of policy, consumer needs, utility needs, economics, and technical solutions

- Example: data privacy and aggregation
  - Establish algorithms for data aggregation that removes privacy concerns while still providing necessary information at relevant scales
  - 3rd party access to data maintains appropriate privacy/security as required
  - Develop clarity around ownership of data

# Overall Themes

Dr. Anjan Bose, Grid Tech Team

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