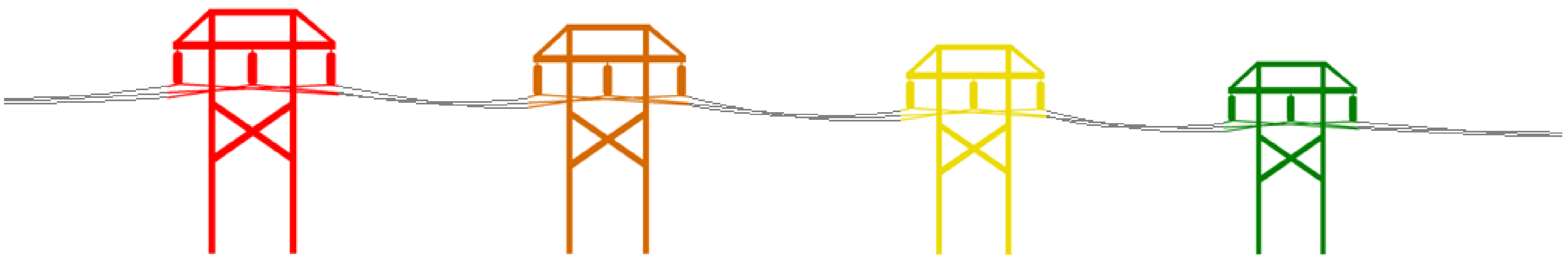
The Electricity Transmission System

Opportunities to Overcome Key Challenges

Summary Results of
Breakout Group Discussions



Electricity Transmission Workshop
Double Tree Crystal City, Arlington, Virginia
November 2, 2012

Breakout Group Discussion Overview

Opportunities to Overcome Key Challenges

Each of the four breakout groups prioritized the critical issues facing the grid from the list of synthesized challenges identified in the first breakout session of the workshop. Focusing on these top priorities, each group proposed specific R&D activities and initiatives that DOE can pursue to overcome these challenges and address existing gaps.

Summary of Synthesized Challenges

A. Need improved understanding of the availability, utility, maintenance, exchange, and security of data and associated requirements.

B. How to synthesize, process, integrate, visualize, and validate data for actionable intelligence?

C. What are the ICT/sensor systems needed for the future grid and advanced applications?

D. Lack of validated models and simulation algorithms to explore new dynamics, concepts, and technologies.

E. Lack of adequate tools for grid operators and planners to perform credible analyses over multiple scales for the future grid.

Summary of Synthesized Challenges

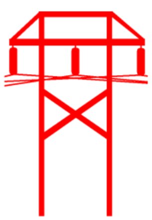
F. Lack of metrics and definitions for grid flexibility.

G. How to value, evaluate, and control various technologies for flexibility on a level playing field?

H. Need advanced technologies for grid flexibility and mechanism to extract flexibility from existing assets.

I. Need new grid architectures including information, control, communication, and physical.

Group 1



Key Challenges – Overview & Revision

Group 1

1. Addressing the varying temporal and spatial issues associated with collecting data, processing it, and presenting stakeholders with relevant, actionable information
2. Need improved understanding of the availability, utility, maintenance, exchange, and security of data and associated requirements
3. What are the ICT/sensor systems needed for the future grid and advanced applications?
4. Lack of adequate tools for grid operators and planners to perform credible analyses over multiple scales for the future grid
5. How to value, evaluate, and control various technologies for flexibility on a level playing field (Lack of metrics and definitions for grid flexibility)
6. Need advanced technologies for grid flexibility (responsiveness) and mechanisms to extract flexibility from existing assets
7. Need new grid concepts and architectures - including information, control, communication, and hardware – to enhance resiliency, response and restoration

Opportunities

Key Challenge - 1

Addressing the varying temporal and spatial issues associated with collecting data, processing it, and presenting stakeholders with relevant, actionable information.

Specific R&D Activities & Initiatives

A. Research to design and develop **data structures** that can accommodate broad time scales, geospatial aspects and system status
   i. Research to ensure that data **dissemination and control** is consistent when data is transferred to partners
   ii. Ongoing dialogue to develop **standards for metadata**, data collection and dissemination

B. Develop cyber security solutions to **build trust** in data security among partners – needs to be continual to balance evolving threat and performance specifications

C. Develop and demonstrate **data fusion capabilities** to assimilate data in real-time using existing data streams (e.g. grid status, weather) to realize a high fidelity, **holistic view** of the system and share real-time information with operators

Opportunities

Key Challenge - 1

Addressing the varying temporal and spatial issues associated with collecting data, processing it, and presenting stakeholders with relevant, actionable information.

Specific R&D Activities & Initiatives

D. Refine existing models and develop and validate new models with the **flexibility to incorporate new technologies** as they are developed (Supercon FCLs, Storage, DG)

E. Develop a **foundational modeling platform** or ensemble that can integrate existing models for a wider system view

   i. **Consolidate modeling** for planning and operations that encompass both transmission and generation

   ii. Develop **simpler user interfaces** for models without sacrificing power and fidelity

Opportunities

Key Challenge - 2

Need advanced technologies for grid flexibility (responsiveness) and mechanisms to extract flexibility from existing assets

Specific R&D Activities & Initiatives

A. Assess the current abilities and limitations of the system (**baseline**)
   i. Study **current responsiveness** of markets, technologies and physical structures
   ii. Develop **regional flexibility cost/supply curve** of options and potential

B. Develop **consistent rating standards** for resource measurement, assets and flexibility

C. Conduct **regional transmission expansion studies** to include new technologies such as
   i. Research into increasing power densities in **existing rights of way** (e.g. railroads, reconductoring, dynamic line ratings, 6-phase)
   ii. **Scenario analysis of future possibilities** including alternative vehicles and DG ubiquity necessitating decrease in physical transmission infrastructure
   iii. Combination of AC with DC offset, near DC frequency operation
   iv. Research into development of offshore transmission

Opportunities

Key Challenge - 2

Need advanced technologies for grid flexibility (responsiveness) and mechanisms to extract flexibility from existing assets

Specific R&D Activities & Initiatives

D. Increased research into lowering the cost and increasing the reliability of grid-scale energy storage and demand response
   i. Research into **lowering the response time** of grid-scale storage on the transmission system (e.g. pumped storage, dispatchable loads)

E. Research into operating on a **wider bandwidth** of the nominal system frequency

F. Research into modeling aggregated distribution system data to **increase visibility and control of distribution operations** for transmission operations (e.g. price and other consumer market signals)

Opportunities

Key Challenge - 3

Need new grid concepts and architectures—including information, control, communication, and hardware—to enhance resiliency, response and restoration

Specific R&D Activities & Initiatives

A. RD&D of advanced system design concepts and architectures such as:
   - **i.** **HVDC loops** - High capacity lines (under/above ground), high capacity, low loss circuit breakers
   - ii. Extensive microgrids

B. Research into control architectures for fundamental changes in design and operation principles
   - i. Hierarchical distributed control systems

C. RD&D to **leverage recently installed PMUs** for enhanced grid analysis and control
   - i. Wide area control algorithms to improve transient and small signal stability

Opportunities

Key Challenge - 3

Need new grid concepts and architectures—including information, control, communication, and hardware—to enhance resiliency, response and restoration

Specific R&D Activities & Initiatives

D. Research into new **cost-effective two-way communications** techniques and technologies

E. Development of next generation **energy management systems** for better control of system operations **inclusive** of relevant data sets (e.g. weather)

F. Development of next generation **conductors** (e.g.. sodium)

G. Investigate **wide-area communication networks** that can guarantee acceptable levels of determinism in transport

Group 2

Key Challenges – Overview & Revision

Group 2

Information

1. Need improved understanding of the availability, utility, maintenance, exchange, and security of data and associated requirements
2. How to synthesize, process, integrate, visualize, and validate data for actionable *information and* intelligence
3. What are the *Information Communications Technologies* (ICT), sensor systems *and actuators* needed for the future grid and advanced applications

Models & Tools

4. Lack of validated models and simulation algorithms, *as well as process and organization,* to explore *systems* dynamics *(physical, policy, markets)*, concepts, and technologies
5. Lack of adequate tools *(including visualization) and appropriate computing resources* for grid operators, planners, decision makers, investors and other stakeholders to perform credible analyses over multiple scales *(temporal, spatial, scenarios)*

Metrics & Valuation

6. Lack of metrics and definitions for *all key attributes of* grid *performance objectives, including* flexibility, resiliency, value, etc.

6. How to value, evaluate, and control various technologies for *key attributes of grid performance,* including flexibility, on a level playing field

7. Need advanced technologies *and processes to extract value, including* flexibility, from existing assets

System Architecture

8. Need new grid architectures *spanning both transmission and distribution,* including information, control, communication, and physical *infrastructures*

Opportunities

Group 2

Key Challenge - 1

Information

Specific R&D Activities & Initiatives

A. Define data applications, categories, sources and destinations, and identify existing barriers that need to be removed to allow for seamless data exchange

   i. Near-term application/example: synchrophasor deployment

B. Develop data/information sharing protocols and mechanisms for data that covers a large cross-section of the electric industry

   i. Facilitate the creation of data repositories for valuable, sanitized, publicly accessible data (e.g., from DOE demonstration/research projects)

   ii. Data confidentiality is currently institutionalized (FERC, NERC)

   iii. Some data can be shared (physical attributes, time-delayed operational data) and some not (market sensitive data)

Opportunities

Key Challenge - 1

Information

Specific R&D Activities & Initiatives

C. Promote information interoperability across all system layers through standards (e.g., IEC 61850)

D. Leverage existing demonstration and research projects (publicly and privately funded)

   i. Communication is key: what does the public get from all this investment?

Opportunities

Key Challenge - 2

Models & Tools

Specific R&D Activities & Initiatives

A. Identify critical modeling *needs* and applications
   i. Fundamental, on-going
   ii. Many types of models; some are critical, some not

B. Validate and verify critical models

C. Promote standardized modeling environments and model interfaces
   i. Shepherd model coordination efforts, but implemented under a non-government institution

D. Define attributes for models and modeling tools
   i. Scalable, consistent across transmission & distribution, operations & planning

Opportunities

Key Challenge - 2

Models & Tools

Specific R&D Activities & Initiatives

E. Develop approaches and tools for specific applications to support decision making under uncertainty (planning, operations, regulatory, policy, etc.)

i. Need to make this a practical option: need data, tools For example, DOE could help find/define practical application beyond resource adequacy

ii. Develop theory, methods and tools to quantify the operational and resource adequacy value of transmission

Opportunities

Key Challenge - 3

Metrics & Valuation

Specific R&D Activities & Initiatives

A. Identify key grid performance attributes (reliability, cost, flexibility, resilience, scalability, adequacy) and how to measure them
   i. Metrics are fundamental; valuation is context-dependent
   ii. Define appropriate ways to report performance metrics that are probabilistic in nature
   iii. Characterize regional differences in the definitions (even though there are differences in philosophies based on history, reality)

B. Address emerging critical gap to maintain process to deal with development of reliability standards, metrics, technologies
   i. NERC function is increasingly standards enforcement
   ii. DOE can fulfill some of this role

Opportunities

Key Challenge - 3

Metrics & Valuation

Specific R&D Activities & Initiatives

C. Develop frameworks and metrics to more clearly understand tradeoff among competing factors/options, including cost-effectiveness, reliability, system architectures
   i. Related to probabilistic/stochastic approaches
   ii. Need to understand what we are trying to manage; from this, metrics can be developed

D. Develop metrics to assign value associated with new and existing technologies
   i. Apply to existing demonstration projects and expand scope and scale of demonstrations

Opportunities

Key Challenge - 4

System Architectures

Specific R&D Activities & Initiatives

A. Work on analysis tools, simulators to study various options cyber-physical architectures
   i. What is the right architecture?
   ii. What are the actors and their roles?
   iii. What is the appropriate information exchange?
   iv. What are the types of transactions/controls?
   v. What types of resources are optimal?

B. Study potential value of adaptive islanding to improve resilience and security
   i. Strategy of last resort; fail-safe

C. Develop new ways of protections & controls; leverage new technology like fiber optics

D. Research co-optimized management of infrastructure
   i. Include demand response, dynamic line rating, AC/DC networks, corridors for major transmission overlay, etc.

Group 3

Key Challenges – Overview & Revision

1. Understanding Data Requirements
   e.g. availability, utility, temporal & spatial, maintenance, exchange, and security

2. Lack of Adequate Tools (e.g. visualization, models, algorithms) <u>for grid operators and planners</u> to perform credible analyses over multiple scales

3. New Grid Architectures
   Need to explore new grid architectures including information, control, communication, market, and physical

Opportunities

Key Challenge - 1

Understanding Data Requirements

(e.g. availability, utility, temporal & spatial, maintenance, exchange, and security)

Specific R&D Activities & Initiatives

A. Create a matrix to map data requirements to applications

B. Support development of standard process and format for sharing of data

C. Support development of standards for data validation (e.g. bringing PMU data under IEC standards)

D. Support adoption of CIM; create test beds and grid models based on IEC standards

E. Define level of cyber security needs for data transfer and for different data types

Opportunities

Key Challenge - 2

Lack of Adequate Tools

(e.g. visualization, models, algorithms) for grid operators and planners to perform credible analyses over multiple scales

Specific R&D Activities & Initiatives

A. Facilitate collaboration among researchers, operators, and vendors to transition research models to real-time operations

B. Assess and improve processes for two-way knowledge transfer between research and implementation

C. Support development of contingency analysis tools that incorporate DERs and loads

D. Support development of fast algorithms for system identification

E. Assess capabilities of existing tools and models to deal with future power systems uncertainties. E.g. develop next generation EMS

Opportunities

Group 3

Key Challenge - 3

New Grid Architectures

Need to explore new grid architectures including information, control, communication, market, and physical

Specific R&D Activities & Initiatives

A. Develop potential future architectures (e.g. centralized vs. agent-based, AC vs. DC) and compare pros and cons

B. Create a software platform that include cyber and physical architecture to allow researchers to create and evaluate different architectures

C. Support creative technical ways to cut down delays in transmission permitting, land acquisition; e.g. UG, railroad

D. Encourage continued collaboration among DOE offices and other federal and state agencies (e.g. DOD)

E. Support development of metrics for grid flexibility

Group 4

Key Challenges – Overview & Revision

1. Advanced Models and Operational Tools

2. Metrics for Flexibility and Enhanced Reliability

3. New Grid Architecture Paradigms

4. Big Data: “The Final Frontier”

Opportunities

Key Challenge - 1

Advanced Models and Operational Tools

- *How to synthesize, process, integrate, visualize, and validate data for actionable intelligence*
- *Lack of validated models (and methodology) and simulation algorithms to explore new dynamics, concepts, and technologies*
- *Lack of adequate tools for grid operators and planners to perform credible analyses over multiple scales for the future grid*

Specific R&D Activities & Initiatives

A. Develop high performance computational methods for large, high resolution models of future grid (close to real time)

B. R&D program to transition grid tools to parallel computational architectures

C. Develop central data monitoring / sharing function to track vulnerabilities

D. Research to ID requisite data/model fidelity to virtualize full grid simulation (power, markets, loads, extreme events)

E. Develop advanced methods and metrics for forecasting tools (weather, load, generation, fuel supply, other infrastructure interdependencies)

F. Ops and planning utilization of forecasts

Opportunities

Key Challenge - 1

Advanced Models and Operational Tools

Specific R&D Activities & Initiatives

F. Develop integration/interoperability strategies and methods for grid modeling suites (validation, verification)

G. Develop enhanced impact valuation tools to inform policy and business decisions (better reflect emerging public goods benefits from future grid)

H. Develop a platform to model and evaluate communication platforms

I. Research design and operation of data platform contingencies to enable future ops, control and cyber security of grid

J. Develop national test bed to simulate cyber-physical system of future grid (super size)
   i. Federation with lab / academic resources

K. Multi-scale modeling platform development (temporal, spatial, physics)

L. R&D to enhance cyber resilience of grid

Opportunities

Key Challenge - 2

Metrics for Flexibility and Enhanced Reliability

- *Develop metrics and definitions for grid flexibility / Enhance metrics for reliability in emerging grid*

Specific R&D Activities & Initiatives

A. Define flexibility requirements for future grid
   i. Accommodate increased intermittent gen (includes geospatial diversity)
   ii. Accommodate intelligent, response load
   iii. Adapt to changes in fuel / gen mix
   iv. Deliver customer needs in reliability, quality, cost
   v. New business models

B. Evaluate common fault risks of interdependent infrastructures

Opportunities

Group 4

Key Challenge - 3

New Grid Architecture Paradigms

- *Need new grid architectures: info, control, communication, & physical (system, holistic, stochastic)*

Specific R&D Activities & Initiatives

A. Frame vision for future grid (2050)

B. Innovations in balancing area coordination for ops and interconnection level planning

C. Develop methods for cost/benefit analysis of BA innovations/changes

D. Develop operations/control methods for dynamic/stochastic grid of future that meet desired attributes / outcomes

E. Research of distributed, hierarchical control (vs. traditional)

F. Develop advanced cost-effective controllable devices / controllable transmission (e.g. DC)

Opportunities

Key Challenge - 3

New Grid Architecture Paradigms

- *Need new grid architectures: info, control, communication, & physical (system, holistic, stochastic)*

Specific R&D Activities & Initiatives

G. Develop transactive control concepts to engage demand and distributed resources optimally

H. Develop inherently cyber / physical secure grid architecture

I. Establish research on load characterization and consumer elasticity

J. Research interdependency of grid with NG, water and communications systems

K. Research system reliability impacts (e.g. VAR, inertia) of fuel / generation scenarios of future

L. Develop “grid friendly” standards for devices to fulfill “desired attributes” of future grid (e.g. loads, generators, storage, etc.) (reactive power, frequency response, ramping, voltage collapse)

Opportunities

Key Challenge - 4

Big Data: "The Final Frontier"

- *What are the ICT/sensor systems needed for the future grid and advanced applications?*
- *Need improved understanding of the availability, utility, maintenance, exchange, and security of data and associated requirements*

Specific R&D Activities & Initiatives

A. Develop enhanced (speed, quality, significance) data analytics to inform operations and planning

B. Develop open data sets for planning, operations, R&D, policy analysis (standardization for data exchange)

C. Develop advanced data management concepts for quality, curation, validation and delivery

D. Develop test bed for advanced data networks for testing, interoperability

E. Develop next generation information networks for high speed time-synchronous data to real-time operations and control (NASPInet and beyond)

F. Develop advanced visualization for real-time tools

G. Develop "plug and play" data acquisition technologies that are "all hazards" resilient

E N D