Quadrennial Technology Review: Grid Technology – Introduction

Scottsdale, Arizona

May 23, 2011

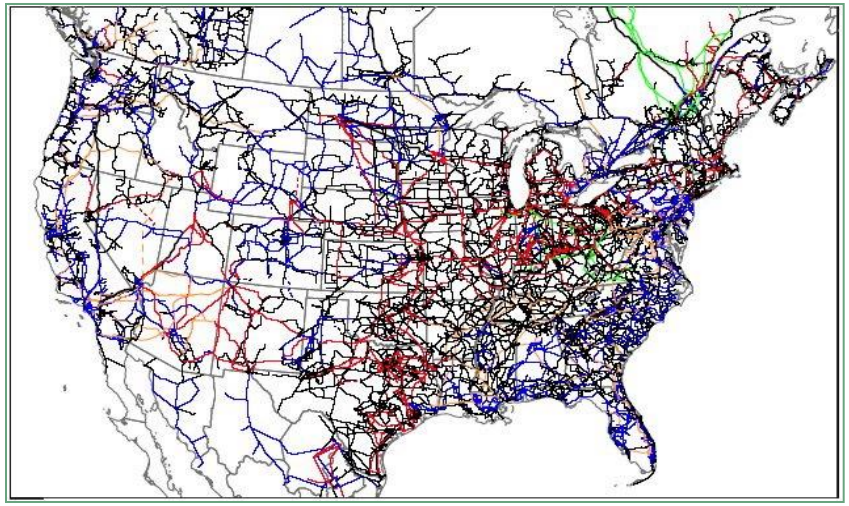
Electricity's Role in Society

Electricity plays a vital role to our economy and national security. Most Americans can not describe what it is or where it comes from. Yet, we know the impact that electricity plays on nearly all aspects of our lives: *national security; health and welfare; communications; finance; transportation; food and water supply; heating, cooling, and lighting; computers and electronics; commercial enterprise; and even entertainment and leisure.*

Unique Characteristics of a Complex System of Systems

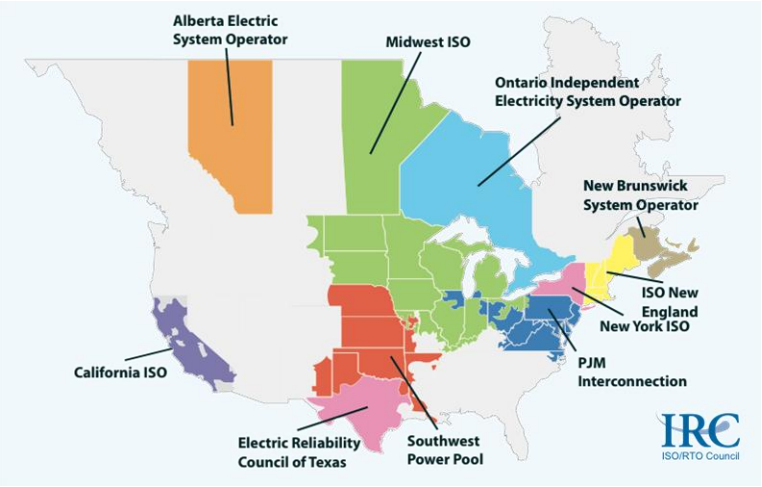
<u>Physically</u>

- Grid developed incrementally without a holistic design. Today, there are:
  - Over 180,000 miles of transmission lines
  - 15,000 transmission substations
  - Distribution grid connects these substations with over 100 million loads
- Industry is fragmented w/o a common voice
  - 3,170 traditional electric utilities
  - 239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 Federal electric utilities



<u>Operationally</u>

- Electricity flows within three major interconnections along paths of lowest impedance; yet the grid is operated in a decentralized manner by over 140 control areas
- Demand is uncontrolled; electricity is the ultimate “just-in-time” production process



The Grid Faces Simultaneous Challenges

2009		2035
51% coal 19% nuclear 20% natural gas 3% oil 6% hydro 1% other renewable	**Changing Supply Mix** Requires additional transmission Requires control/communications	30-60% coal 20-40% nuclear 10-20% natural gas 1-2% oil 10-20% renewable
3653 billion kWh Hybrids, No PHEVs Electrically-sensitive equipment (limited consideration - PQ)	**Demand Transformation** Expanding Digital Economy Power quality needs Demand growth	5168 billion kWh Load curves – increased peaking Plug-in hybrids (could increase demand 25%) More electrically sensitive equipment (2.5x)*
140 control areas Energy Mgt Systems (<1%) 180,000 miles wires ~10 million DG units	**Complexity of Grid** Expanding footprint Overlay of markets Operating "closer to the edge"	Nodes within control area increase 5-10x Energy Mgt Systems (70%) Additional 30,000 miles needed ~ 22 million DG units (2.5x increase)
Blackouts Aging Infrastructure Vulnerability of assets	**Vulnerability of Energy Infrastructure** Interdependencies of electric and energy systems	Infrastructure protection Increased globalization Materials and resource limitations All-hazard risks will continue to increase

** RAND Digital Study, 2001*

Consequences to the Nation are Substantial

Capacity

Electric power flows expected to grow 50% by 2035

Options to meet projected demand:

- New 'right of ways'
- More power flow from existing paths

Congestion

T&D line are operated at capacity limits in some areas costing ratepayers ~ $2B/yr

Power is provided by more expensive local generation capability

Major Disruptions

Major, widespread outages cost the nation over $1 billion/yr on average

August 2003 outage cost an estimated $10B

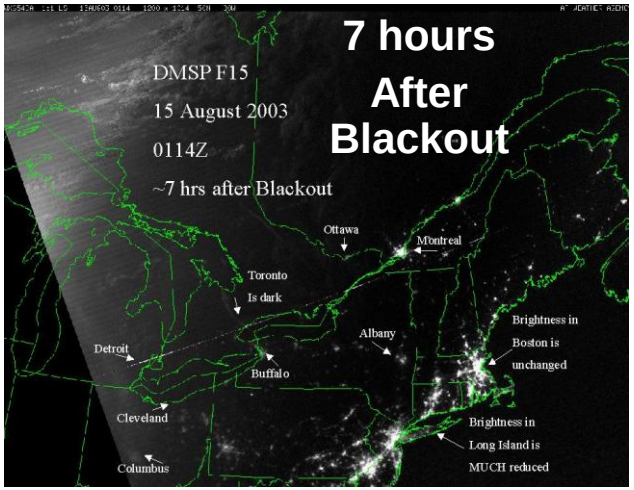
Power Quality & Momentary Outages

Short localized outages result in losses as high as $80 billion/yr*

National Security Implications

Potential for increased vulnerability

Interdependency of critical energy systems



** Input from EPRI, LBNL Study, Rand*

Technologies, Markets, and Policies are Intricately Linked

- Policies drive markets which drives technology
- When finding solutions to challenges, all aspects need to be considered simultaneously

The Grid

Policies
state RPS, federal CES, FERC, PUC's, environmental regulations, siting, etc.

Markets
business models, cost allocation, wholesale power trading, utilities, vendors, etc.

Technologies
generation, infrastructure, smart grid, electric vehicles, storage, etc.

Changing the Perspective

20th Century Grid: Electrifying America

- Current attributes (electricity as a commodity)
  - Reliable
  - Accessible to all
  - Low cost
  - Safe and Secure

21st Century Grid: Enabling an Electricity Service Economy

- Previous attributes plus
- New attributes (electricity as a service)
  - Provides access to low carbon generation
  - Delivers the desired power quality when it is desired
  - Enables customer participation into electricity markets (demand response)
  - Provides customer flexibility to use new technologies (electric vehicles, distributed generation, energy management system, etc.)
  - Provides dynamic protection, privacy, and cyber security

Addressing the Needs

- The system has been engineered for 120 years; *How do we use goal oriented science to understand the science behind the system?*
- We have a system with underutilized capacity; *How can we make this a competitive advantage? How can we remove its constraints?*
- Uncertainty is increasing in many domains (temporal, spatial, etc.); *How can we design flexibility into the system to handle this variability?*
- New technologies are coming online (generation, EV's, storage, etc.); *How does the grid become an effective enabler of these technologies? What are the impacts of these technologies?*
- Consumers will become active participants in the grid; *How and to what degree will the customer be impacted and engaged?*
- Two-way power flow will be needed; *How do we modify the system to accommodate this? Can we control power flow in new ways?*
- Electricity is treated as a commodity; *How do we move to treating electricity as a service?*

National Energy Goals Depend on Transformation of the Grid

U.S. DEPARTMENT OF ENERGY STRATEGIC PLAN 2011: TRANSFORMING OUR ENERGY SYSTEMS

Modernize the Grid

- Enable better understanding and control of our electrical grid by installing more than 1000 synchrophasor measurement units by 2013
- Deploy more than 26 million smart meters in American homes and businesses by 2013
- Reduce utility-scale energy storage costs 30% by 2015

But this is only a start… there are many other activities and directions we need to pursue