What’s Driving the Smart Grid?

Joe Miller – Modern Grid Team
October 6, 2008

Funded by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability

Conducted by the National Energy Technology Laboratory
Agenda

- The Smart Grid – a refresher
- “Push” drivers – a case for action
- “Pull” drivers - Smart Grid opportunities
- Some Smart Grid impacts
What is the role of the MGS?

- Define a vision for the Modern Grid
- Reach out to stakeholders for input
- Assist in the identification of benefits and barriers
- Facilitate resolution of issues
- Promote testing of integrated suites of technologies
- Communicate and educate stakeholders

MGS is an “Independent Broker” for the Smart Grid
The Smart Grid – a refresher
It will “Enable active participation by consumers”

- Consumers have access to new information, control and options to engage in electricity markets
  - See what they use, when they use it, and what it costs
  - Manage energy costs
  - Investment in new devices
  - Sell resources for revenue or environmental stewardship

- Grid operators have new resource options
  - Reduce peak load and prices
  - Improve grid reliability

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little price visibility, time-of-use pricing rare, few choices</td>
<td>Full price info, choose from many plans, prices and options, buy and sell, “E-Bay”</td>
</tr>
</tbody>
</table>
It will “Accommodate all generation and storage options”

- Seamlessly integrates all types and sizes of electrical generation and storage systems
- “Plug-and-play” convenience
  - Simplified interconnection processes
  - Universal interoperability standards
- Number of smaller, distributed sources will increase – shift to a more decentralized model
- Large central power plants will continue to play a major role.

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominated by central generation. Little DG, DR, storage or renewables</td>
<td>Many “plug and play” distributed energy resources complement central generation</td>
</tr>
</tbody>
</table>
It will “Enable new products, services and markets”

- Links buyers and sellers – consumer to RTO
- Supports the creation of new electricity markets
  - PHEV and vehicle to grid
  - Brokers, integrators, aggregators, etc.
  - New commercial goods and services
- Provides for consistent market operation across regions

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited wholesale markets, not well integrated</td>
<td>Mature, well-integrated wholesale markets, growth of new electricity markets</td>
</tr>
</tbody>
</table>
It will “Provide power quality for the digital economy”

- Monitors, diagnoses and responds to PQ issues
- Supplies various grades of power quality at different pricing levels
- Greatly reduces consumer losses due to PQ (~$25B/year)
- Quality Control for the grid

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus on outages not power quality</td>
<td>PQ a priority with variety of price/quality options based on needs</td>
</tr>
</tbody>
</table>
It will “Optimize asset utilization and operate efficiently”

- **Operational improvements**
  - Improved load factors and lower system losses
  - Integrated outage management
  - Risk assessment

- **Asset Management improvements**
  - The knowledge to build only what we need
  - Improved maintenance processes
  - Improved resource management processes
  - More power through existing assets

- **Reduction in utility costs (O&M and Capital)**

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited grid information &amp; minimal integration with asset management</td>
<td>Deep integration of grid intelligence with asset management applications</td>
</tr>
</tbody>
</table>
It will “Anticipate & respond to system disturbances”

- Performs continuous self-assessments
- Detects, analyzes, responds to, and restores grid components or network sections
- Handles problems too large or too fast-moving for human intervention
- Self heals - acts as the grid’s “immune system”
- Supports grid reliability, security, and power quality

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protects assets following disruption (e.g. trip relay)</td>
<td>Prevents disruptions, minimizes impact, restores rapidly</td>
</tr>
</tbody>
</table>
It will “Operate resiliently against attack and natural disaster”

- System-wide solution to physical and cyber security
- Reduces threat, vulnerability, consequences
- Deters, detects, mitigates, responds, and restores
- “Fort Knox” image
- Decentralization and self-healing enabled

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerable to terrorists and natural disasters</td>
<td>Deters, detects, mitigates, and restores rapidly and efficiently</td>
</tr>
</tbody>
</table>
In summary:

The Smart Grid will:

- Enable active participation by consumers
- Accommodate all generation and storage options
- Enable new products, services and markets
- Provide power quality for the digital economy
- Optimize asset utilization and operate efficiently
- Anticipate & respond to system disturbances (self-heal)
- Operate resiliently against attack and natural disaster
Smart Grid Technologies

- Sensing and Measurement
- Advanced Control Methods
- Decision Support
- Advanced Components

IC connections indicate interactions or dependencies between the technologies.
Smart Grid Technologies

Sensing and Measurement

Smart meters
Smart sensors
  - Operating parameters
  - Asset Condition
Wide area monitoring systems (WAMS)
Dynamic rating of transmission lines

Advanced Components
Applications that:

- Monitor and collect data from sensors
- Analyze data to diagnose and provide solutions
- Real time and predictive
- Determine and take action autonomously or via operators
- Provide information and solutions to operators
- Integrate with enterprise-wide processes and technologies
Smart Grid Technologies

- Next generation FACTS/PQ devices
- Advanced distributed generation and energy storage
- PHEV - V2G mode
- Fault current limiters
- Superconducting transmission cable & rotating machines
- Microgrids
- Advanced switches and conductors

Advanced Components
Smart Grid Technologies

Sensing and Measurement

Data reduction
Data to information to action
Visualization
Speed of comprehension
System operator training

Advanced Components

Decision Support
Fully Integrated Communications Infrastructure

- Sensing and Measurement
- Advanced Control Methods
- Decision Support
- Advanced Components

- Smart meters
- Smart sensors
- Demand Response
- DG dispatch
- Distribution automation
- Micro-grids
- Markets
- Work force management
- Mobile premises (PHEV's)
Steps to the Smart Grid

- **AMI**
  - AMI empowers the customer and establishes communications to the loads

- **Distribution (ADO)**
  - ADO enables self healing

- **Transmission (ATO)**
  - ATO addresses congestion

- **Asset Management (AAM)**
  - AAM greatly improves the performance of today’s asset management programs
Steps to the Smart Grid

AMI
AMI empowers the customer and establishes communications to the loads

Distribution (ADO)
ADO enables self healing

Advanced Distribution Operations
- Distribution Management System
- Smart sensors
- DER Operations – including PHEV V2G
- Distribution Automation
- Micro-grid operations (AC and DC)
- Advanced protection and control
- Advanced grid components for distribution
Steps to the Smart Grid

Advanced Transmission Operations
Substation Automation
Advanced regional operational applications
Modeling, simulation and visualization tools
Wide Area Measurement System (WAMS)
Hi-speed information processing
Advanced materials and power electronics

Asset Management (AAM)
AAM greatly improves the performance of today’s asset management programs

Transmission (ATO)
ATO addresses congestion
Steps to the Smart Grid

Advanced Asset Management

Integration with other Smart Grid technologies:
- Advanced Outage Management
- System planning (T&D)
- Condition-based maintenance
- Work and resource management
- Customer service
- Geographical Information Systems
- Engineering and operations

AAM greatly improves the performance of today’s asset management programs
## Putting it all together – T, D, & M impacted

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>AMI</th>
<th>ADO</th>
<th>ATO</th>
<th>AAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enables Active Consumer Participation</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accommodates All Generation &amp; Storage Options</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Enables New Products, Services and Markets</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Provides PQ for Digital Economy</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Optimizes Assets &amp; Operates Efficiently</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Anticipates and Responds to System Disturbances</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Operates Resiliently Against Attack and Natural Disaster</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
“Push” drivers – a case for action
Demand for Electricity Is Projected to Increase 30% by 2030

(Billion kilowatthours)

*Electricity demand projections based on expected growth between 2006 and 2030.

Cost of new generation is increasing

<table>
<thead>
<tr>
<th>Generation Type</th>
<th>2003-04 ($/KW)</th>
<th>2008 ($/KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>$1300 - $2300</td>
<td>$4500 - $7500</td>
</tr>
<tr>
<td>Conventional Coal</td>
<td>$1000 - $1600</td>
<td>$1800 - $4000</td>
</tr>
<tr>
<td>IGCC Coal</td>
<td>$1400 - $1800</td>
<td>$1800 - $2000</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>$600 - $700</td>
<td>$900 - $1600</td>
</tr>
<tr>
<td>Combustion Turbine</td>
<td>$300 - $700</td>
<td>$600 - $1000</td>
</tr>
<tr>
<td>Wind</td>
<td>$1000 - $1400</td>
<td>$1400 - $2700</td>
</tr>
<tr>
<td>Geothermal</td>
<td>$1500 - $2500</td>
<td>$2600 - $3600</td>
</tr>
<tr>
<td>Concentrated Solar</td>
<td>$3100 - $5100</td>
<td>$3000 - $5000</td>
</tr>
</tbody>
</table>

Wholesale energy prices are rising

**Forward Market Prices Continue to Climb**

- Midwest ISO (Cinergy) $112.12/MWh +62%
- Massachusetts Hub $141.25/MWh +94%
- New York City $208.51/MWh +123%
- PJM Western Hub $144.38/MWh +79%
- Southern California (SP-15) $139.41/MWh +88%
- Palo Verde $132.95/MWh +76%
- Henry Hub (Gas) $12.99/MMBtu +108%

Sources: Summer electric forwards data is July-August 2008 data from ICE as of 6/16/08. Actual on-peak data for 2007 are from Platts Megawatt Daily. The Henry Hub data is July-August Clearport data from Bloomberg as of 6/16/08.
Retail prices are increasing

Average Retail Price (cents/kwh)

30% increase over last decade

DOE EIA Energy Outlook 2007
Today’s grid - status quo is not an option

- **Aging**
  - 70% of transmission lines are 25 years or older
  - 70% of transformers are 25 years or older
  - 60% of circuit breakers are 30 years or older

- **Outmoded**
  - Designed in the 50s and installed in the 60s and 70s, before the era of the microprocessor.

- **Stressed**
  - Never designed for bulk power shipments

Much of the equipment that makes up the North American grid is reaching the end of its design life.

*EnergyBiz Magazine, Sept. 2005*
Businesses losing billions from interruptions

Primen Study: Up to $135B annually for power interruptions
Other considerations

- 50 coal plants canceled or delayed since January 2007
- Jobs and the economic downturn
- US dependence on foreign energy sources
- Rising oil and gasoline prices
- Climate change
- National security
- Cost of renewable generation more competitive
- Impact of electric vehicles
“Pull” drivers - Smart Grid opportunities

- US policy is to support grid modernization
- Smart Grid System Report
  - Status and prospects of development
  - Regulatory or government barriers
  - Technology Penetration
  - Communications network capabilities, costs, obstacles
  - Recommendations for state and federal policies
- Smart Grid Advisory Committee (thru 2020)
- Smart Grid Task Force (thru 2020)
- Smart Grid Interoperability Framework (NIST)

- **Smart Grid Technology RD&D**
- **Smart Grid Regional Demonstration Initiative**
  - 50% Cost Share
  - $100M per year – 2008-2012
- **Federal Matching Funds**
  - 20% reimbursement for qualifying Smart Grid investments
- **States shall consider:**
  - Requiring utilities to consider Smart Grid solutions including societal benefits
  - Allowing utilities to recover capital, O&M and other costs
  - Allowing recovery of book value of technologically obsolete assets
### Value Proposition

#### Cost to Modernize
- **$165B** over 20 years
  - $127B for Distribution
  - $38B for Transmission
- **~$8.3B per year** (incremental to business-as-usual)
- Current annual investment - $18B

#### Benefit of Modernization
- **$638B - $802B** over 20 years
- Overall benefit to cost ratio is 4:1 to 5:1

Thus, based on the underlying assumptions, this comparison shows that the benefits of the envisioned Future Power Delivery System significantly outweigh the costs. (EPRI, 2004)
Generally speaking...

- Advanced Metering Infrastructure
- Advanced Distribution Operations
- Advanced Transmission Operations

Benefit vs. Cost graph:

- Cost
- Benefit

Advanced Metering Infrastructure
Advanced Distribution Operations
Advanced Transmission Operations
Who are the Smart Grid “benefactors”?

Consumers
- Industrial
- Commercial
- Residential

Others
- EPRI
- Financial Firms
- R&D Organizations

Vendors
- Technology
- Services

Policy & Regulation
- FERC
- PUC’s
- NERC
- NARUC

Government
- Federal
- State
- Local

Utilities
- IOU’s
- Publics
- RTO / ISO
- Power marketers

Advocacy
- EEI
- Rate Payer Groups
- Environmental Groups
Utility Benefits

Operational improvements
- Metering and billing
- Outage management
- Process improvement
- Work force management
- Reduced losses (energy)
- Asset utilization

Asset Management improvements
- System planning
- Maintenance practices
- Engineering

These benefits are expected to improve customer satisfaction and reduce O&M and capital costs.
Consumer Benefits

- Improved reliability
- Improved overall level of service
- Access to information
- Ability to manage energy consumption
- Option to participate in demand response
- Convenient interconnection of distributed generation
- Option to bid (sell) into electricity markets
- Potential to dramatically reduce transportation costs (PHEV)

Consumers have access to information, control and options
Societal Benefits

- Downward pressure on electricity prices through improved operating and market efficiencies, consumer involvement
- Improved reliability leading to reduction in consumer losses (~$135B)
- Increased grid robustness improving grid security
- Reduced losses and emissions through integration of renewables
- New jobs and growth in GDP
- Opportunity to revolutionize the transportation sector through integration of electric vehicles as generation and storage devices

Societal benefits must be included in the value proposition
Imagine a World with 200 million electric vehicles that:

- Connect anywhere
- Provide transportation and act as storage and generators for the grid

And are powered by:

- Clean central station generation
- Renewables and other distributed generation

A shift from gasoline to PHEVs could reduce U.S. petroleum imports by 52% (PNNL – Impact assessment of PHEV’s)
Resulting in:

- Dramatic reduction in tailpipe emissions
- Reduction in petroleum imports of >50%
- Reduction in peak loads – lowering prices for consumers
- Improved grid reliability – decreasing today’s consumer losses of >$125 Billion annually
- Increased grid security – the “Fort Knox” model

But we need a Smart Grid to enable this world
Some Smart Grid Impacts
Change will be constant

- Significant focus on “change management”
- Process and technology “re-engineering”
- Utility business model – “decoupling?”
- More consumer education
- Increased consumer influence
- More accountability (metrics and reports)
- New opportunities
Technical challenges

- Lack of resources to “change” and also “keep the lights on”
- Shortage of skilled human resources
- Incorporating 2-way power flow into operations
- Simplifying interconnection standards while maintaining safety
- More focus on R&D – breakthrough technologies
- Integration of disruptive technologies
- Sharing successes and “lessons learned”
- Getting the communications right
Other considerations

- Management of huge volumes of data
- Conversion of data to information to action
- Autonomous decision making by agents
- Diagnosis time reduced enabling more rapid response by operations
- Human factors engineering

“If you are sure you understand everything that is going on, you are hopelessly confused”

Walter F. Mondale
Questions
Back-up Slides
Regulatory Policies

- **Time based rates** - incentives for consumers to become actively involved
- **Favorable depreciation rules** – recovery of book value for assets that are retired early for “smart grid” reasons
- **Policy changes that provide incentives and remove disincentives to utilities** – investment in a Smart Grid should make business sense
- **Clear cost recovery policies** - uncertain cost recovery increases investment risk
- **Societal benefits** – quantified and included in business cases
Integrated Communications (IC): Overview

An effective, fully-integrated communications infrastructure is an essential component of the modern grid:

- IC creates a dynamic, interactive “mega-infrastructure” for real-time information and power exchange
- IC allows the various intelligent electronic devices (smart meters, control centers, power electronic controllers, protection devices) and users to interact as an integrated system
- Open universal communication standards to enable information to be understood by a wide assortment of senders and receivers (e.g. CIM, IEEE P1901, IEC 61850…)

- Appropriate media to enable information to be transmitted accurately, securely and with the required throughput. Media examples include:
  - Powerline communications (PLC and BPL)
  - Wireless (WiFi, WiMAX, 800 MHz, Satellite, Microwave…)
  - OPGW
  - Fiber
  - Land lines

- Hybrid combinations of the above media, having differing capabilities, will be needed