The Smart Grid ??

AEE – National Capital Chapter

Keith Dodrill
US Dept of Energy
National Energy Technology Laboratory
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Topics

• The "Case for Action"
• What is the Smart Grid?
• Key Technology Areas
• The Smart Grid business case
• Challenges and Barriers
• Current Activities
• Summary
Case for Action

- Today’s grid is aging and outmoded
- Unreliability is costing consumers billions of dollars
- Today’s grid is vulnerable to attack and natural disaster
- An extended loss of today’s grid could be catastrophic to our security, economy and quality of life
- Today’s grid does not address the 21st century power supply challenges
- Missed opportunity to enjoy the benefits of a Smart Grid
- Disturbing trends in prices, reliability, peak loads, transmission congestion, & asset utilization

But is it worth it?
The “Market” will create new stresses

**Generation**
- 47%
- 17,342 units

**Transmission**
- 43%
- 164,000 miles

**Distribution**
- 34%
- 3 million miles

**Consumer Systems**
- <1%
- 12.3 M DG
- 25 M residential solar
- 1 M PHEV/PEV
- 10 M PHEV/PEV
- 50 M PHEV/PEV
- 2 M architectural wind
- 5 M building solar
- 1 M PHEV/PEV
- 10 M PHEV/PEV
- 50 M PHEV/PEV
- 100,000 Buildings as PP
- Demand Response Conservation

- 500 wind parks
- 50 solar parks

- 5,000 distributed wind
- 5,000 utility solar

- 5,000 distributed wind
- 5,000 utility solar
What is the Smart Grid?
The Systems View

Key Success Factors

- Performance
- Principal Characteristics
- Key Technology Areas
- Metrics
What’s different with the Smart Grid?

- Decentralized supply and control
- Two-way power flow
- Two-way information flow

Creating the intelligence and capability to optimize:

- Reliability
- Security
- Economics
- Efficiency
- Environment
- Safety

...for all stakeholders

In order to succeed, we must view the Smart Grid as a vision AND as a system...
The Smart Grid is “transactive” and 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

...the enabler
# Smart Grid Domains

<table>
<thead>
<tr>
<th>Domain</th>
<th>Actors in the Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers</td>
<td>The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: home, commercial/building, and industrial.</td>
</tr>
<tr>
<td>Markets</td>
<td>The operators and participants in electricity markets</td>
</tr>
<tr>
<td>Service Providers</td>
<td>The organizations providing services to electrical customers and utilities</td>
</tr>
<tr>
<td>Operations</td>
<td>The managers of the movement of electricity</td>
</tr>
<tr>
<td>Bulk Generation</td>
<td>The generators of electricity in bulk quantities. May also store energy for later distribution.</td>
</tr>
<tr>
<td>Transmission</td>
<td>The carriers of bulk electricity over long distances. May also store and generate electricity.</td>
</tr>
<tr>
<td>Distribution</td>
<td>The distributors of electricity to and from customers. May also store and generate electricity.</td>
</tr>
</tbody>
</table>

*Source: NIST*
## Smart Rates Can Work

<table>
<thead>
<tr>
<th>Customers</th>
<th>Rate Alone</th>
<th>Rate w/Controlling Technology</th>
<th>Rate Alone</th>
<th>Rate w/Controlling Technology</th>
<th>Rate Alone</th>
<th>Rate w/Controlling Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>-16.1%</td>
<td>-23.3%</td>
<td>-10.9%</td>
<td>-17.8%</td>
<td>3.7%</td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>-2.8%</td>
<td>-7.2%</td>
<td>0.0%</td>
<td>-4.1%</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>

*Connecticut L&P Plan-it Wise Results—Reduction in Peak Load*
Key Technology Areas
Smart Grid Key Technology Areas

The Smart Grid is a System.

- Advanced Control Methods
- Integrated Communications
- Decision Support & Improved Interfaces
- Advanced Components
- Sensors and Measurement

The Smart Grid is a System.
Sensors and Measurement

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

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
Decision Support & Improved Interfaces

Data reduction
Data to information to action
Visualization
Speed of comprehension
System operator training
Next generation FACTS/PQ devices
Advanced distributed generation and energy storage
PHEV - V2G mode
Fault current limiters
Superconducting transmission cable & rotating machines
Micro-grids
Advanced switches and conductors
Consider all needs:
- Smart meters
- Smart sensors
- Demand Response
- DG dispatch
- Distribution automation
- Micro-grids
- Markets
- Work force management
- Mobile premises (PHEV’s)
The SG Business Case
EPRI’s Perspective on the 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)
### WV Smart Grid Costs & Benefits

#### PV 20-yr Cost and Benefits ($1000)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Cost</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI</td>
<td>$399</td>
<td>$1,377</td>
</tr>
<tr>
<td>IT</td>
<td>$170</td>
<td>$1,025</td>
</tr>
<tr>
<td>DR</td>
<td>$22</td>
<td>$877</td>
</tr>
<tr>
<td>DMS</td>
<td>$454</td>
<td>$3,286</td>
</tr>
<tr>
<td>DER</td>
<td>$832</td>
<td>$3,671</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,878</strong></td>
<td><strong>$10,236</strong></td>
</tr>
</tbody>
</table>

*Benefit to Cost Ratio for West Virginia – 5:1
Benefit to Cost Ratio for San Diego – 6:1
Benefit to Cost Ratio for US (EPRI 2004) – 4:1 to 5:1*
## WV Smart Grid Annual Benefits

<table>
<thead>
<tr>
<th>Key Success Factors</th>
<th>Benefits</th>
<th>Annual Benefits ($M) (All Beneficiaries)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reliability</strong></td>
<td>Reduced Consumer Losses</td>
<td>$898</td>
</tr>
<tr>
<td></td>
<td>Reduce Power Quality Events</td>
<td>$131</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Reduce Price of Electricity</td>
<td>$399</td>
</tr>
<tr>
<td></td>
<td>Job Creation</td>
<td>$215</td>
</tr>
<tr>
<td></td>
<td>Consumer Sales of DER Resources</td>
<td>$175</td>
</tr>
<tr>
<td></td>
<td>Increased Energy Sales as Exports</td>
<td>$7</td>
</tr>
<tr>
<td></td>
<td>Reduced Transmission Congestion</td>
<td>$1</td>
</tr>
<tr>
<td></td>
<td>Increased Transportation Fuels Business</td>
<td>$5</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Consumer Conservation</td>
<td>$20</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Reduced Blackout Probability &amp; Dependence on Foreign Oil</td>
<td>$13</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Reduce Hazard Exposure</td>
<td>$1</td>
</tr>
</tbody>
</table>
Challenges and Barriers
Many Challenges to Address

- Consumer acceptance
- Culture and education
- Regulatory & policy
- Technical
- Engineering
- System planning
- Operations
- Workforce training and education
Many Stakeholders Involved

- **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

- **Consumers**
  - Industrial
  - Commercial
  - Residential

- **Vendors**
  - Technology
  - Services

- **Others**
  - EPRI
  - Financial Firms
  - R&D Organizations

NATIONAL ENERGY TECHNOLOGY LABORATORY
The Two Big Things…

• **Defining and understanding the business case**
  – Leads to logical implementation
  – Maximizes profitability
  – Minimizes impact to the consumer

• **Consumer education**
  – Needed understanding of the Smart Grid vision
    • consumer benefits
    • societal benefits
    • costs of doing nothing
    • address their concerns and questions

*The consumer will pay for the Smart Grid…*
If we do this right – we can all be winners

- Suppliers
- Consumers
- Society
Current Smart Grid Activities

• **Smart Grid Investment Grants** (100 projects)
  – $3.4 billion Federal; $4.7 billion private sector
  – 850 PMUs covering 100% of transmission
  – 200,000 smart transformers
  – 700 automated substations
  – 40 million smart meters
  – 1 million in-home displays

• **Smart Grid Demonstration Projects** (32 projects)
  – $620 million Federal; $1 billion private sector
  – 16 storage projects
  – 16 regional demonstrations
Summary

- Motivation to move toward national Smart Grid
- Common vision being established for Smart Grid
- Benefits accrue to utilities, consumers & society
- Business case shows 4:1 to 6:1 ROI
- Different approaches to implementing Smart Grid
- Technical, regulatory, consumer & cultural barriers
- DOE ARRA projects create momentum
For More Information

For additional Information:  
www.netl.doe.gov/smartgrid

Federal Smart Grid Website  
www.smartgrid.gov

Smart Grid Information Clearinghouse  
www.sgiclearninghouse.org

Steve Bossart  
National Energy Technology Lab  
304-285-4643  
Steven.Bossart@netl.doe.gov
It will “Enable active participation by consumers”

- **Consumers have access to new information, control and options to engage in electricity markets**
  - Reduce consumption and energy bill
  - Enable new technologies (PHEV, HAN, EMS, smart appliances, etc.)
  - Sell resources for revenue or environmental stewardship
  - Incentives to participate (i.e. smart rates)

- **Grid operators have new resource options**
  - Reduce peak load and prices through demand response
  - Improve grid reliability
  - Ancillary services

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little or no info, limited use of smart pricing, 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
- “Moves the needle” – shifts to a more decentralized model
- Large central power plants will continue to play a major role.

<table>
<thead>
<tr>
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<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**
  - Demand Response
  - Energy, Capacity, Ancillary Services
  - Brokers, integrators, aggregators, etc.
  - In-home devices and applications
- **Provides for consistent market operation across regions**

<table>
<thead>
<tr>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near-zero market interaction at distribution level</td>
<td>Distribution assets and consumers act as resources for transmission, growth of new secondary 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 enabling reduction in O&amp;M and CapEx</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>
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<tr>
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<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—“cyber proof”</td>
</tr>
</tbody>
</table>
Who are the Smart Grid Beneficiaries?

- Utilities
- Consumers
- Society

The value of Smart Grid depends on who you ask!
### Potential Bill Savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated residential bill/year</td>
<td>$1,200</td>
</tr>
<tr>
<td>Expected reduction from EE/DR</td>
<td>10% – 15%</td>
</tr>
<tr>
<td>Potential savings/year</td>
<td>$120 – $180</td>
</tr>
<tr>
<td>Assumed bill increase to pay for smart grid/year</td>
<td>$60 – $120</td>
</tr>
<tr>
<td>Net consumer value/year</td>
<td>$0 – $120</td>
</tr>
</tbody>
</table>

*Positive value but not very compelling!*
Another Example

**Potential Fuel Cost Savings**

<table>
<thead>
<tr>
<th>Assumed miles driven/year</th>
<th>10,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cost (gas)/mile</td>
<td>$0.10 – 0.15</td>
</tr>
<tr>
<td>Fuel cost (PHEV)/mile</td>
<td>$0.03 – 0.05</td>
</tr>
<tr>
<td>Annual fuel cost (gas)</td>
<td>$1,000 – $1,500</td>
</tr>
<tr>
<td>Annual fuel cost (PHEV)</td>
<td>$300 – $500</td>
</tr>
<tr>
<td>Potential fuel cost savings/year</td>
<td>$500 – $1,200</td>
</tr>
<tr>
<td>Premium to purchase PHEV over gas</td>
<td>$4,000 – $10,000</td>
</tr>
</tbody>
</table>

*More compelling but is it enough?*
Societal Value Proposition

Benefits

- Energy independence
- National security
- Downward pressure on electricity prices
- Improved environment
- Growing U.S. economy
- Improved reliability
Implementation sequence can vary

Consumer Enablement

CE empowers the customer and enables grid interaction

Advanced Distribution

AD improves reliability and enables self healing

Advanced Transmission

AT addresses congestion and integrates with RTO’s

Advanced Asset Management

AAM helps utilities reduce costs and operate more efficiently
Current Smart Grid Activities (cont.)

- DOE Renewable & Distributed Systems Integration (9 projects)
- EPRI Smart Grid Demonstrations (6 projects)
- Excel’s Smart Grid City, Boulder, CO
- Smart Grid System Report to Congress
  – http://www.smartgrid.gov/resources