• Modern Grid Vision
• Modern Grid Deployments
• Case for WV Grid Modernization
• Some Challenges and Risks
• Questions
Modern Grid Vision
The Modern Grid
includes Smart Grid enhancements and more

Attributes of Smart Grid
Senses
Protects
Controls
Automates
Transforms Power

Enhanced Functionality
Generation
Storage
Load

Modern Grid

Communication
The Modern System will have changes in all of these elements, some more than others.
Who are the Beneficiaries?

Utilities (What’s in it for my shareholders?)
• Outage restoration
• Billing
• Operations and maintenance
• Asset utilization

Consumers (What’s in it for me?)
• Improved reliability
• Manage electric power usage
• Energy bill savings (power & transportation)

Society (What’s in it for us?)
• Reduce emissions
• Energy independence
1 project involving 230 automated feeder switches on 75 circuits in an urban area
From Apr 1 – Sep 30 2011

SAIDI improved 24%; average outage duration decreased from 72.3 to 54.6 minutes

Estimated Average Customer Interruption Costs US 2008$ by Customer Type and Duration

<table>
<thead>
<tr>
<th>Customer Type</th>
<th>Interruption Cost Summer Weekday</th>
<th>Interruption Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Momentary 30 mins 1 hr 4 hr 8 hr</td>
</tr>
<tr>
<td>Large C&amp;I</td>
<td>Cost Per Average kWh</td>
<td>$173 $38 $25 $18 $14</td>
</tr>
<tr>
<td>Small C&amp;I</td>
<td>Cost Per Average kWh</td>
<td>$2,401 $556 $373 $307 $272</td>
</tr>
<tr>
<td>Residential</td>
<td>Cost Per Average kWh</td>
<td>$21.6 $4.4 $2.6 $1.3 $0.9</td>
</tr>
</tbody>
</table>

Estimated monetary value of this improvement in reliability based on value-of-service data is $21 million

Sullivan J, Michael, 2009 Estimated Value of Service Reliability for Electric Utility Customers in the US; xxi
Modern Grid Deployments
Modern Grid ARRA Activities
American Recovery and Reinvestment Act ($4.3B)

- **Smart Grid Investment Grants (99 projects)**
  - $3.4 billion Federal; $4.7 billion private sector
  - >800 PMUs covering almost 100% of transmission
  - 6500 distribution automation circuits
  - >15 million smart meters

- **Smart Grid Demonstration Projects (32 projects)**
  - $620 million Federal; $1 billion private sector
  - 16 storage projects
  - 16 regional demonstrations
AMI Improvements in Operational Efficiencies

Results from 15 projects due to automation of metering service tasks and reductions in labor hours and truck rolls

<table>
<thead>
<tr>
<th>Smart Meter Capabilities</th>
<th>O&amp;M Savings</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Remote meter reading</td>
<td>Meter Operations Cost</td>
<td>13-77</td>
</tr>
<tr>
<td>• Remote service connections/disconnections</td>
<td>Vehicle Miles</td>
<td>12-59</td>
</tr>
</tbody>
</table>

Future SGIG examples to provide information on other benefits

<table>
<thead>
<tr>
<th>Smart Meter Capabilities</th>
<th>Expected Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tamper detection and notification</td>
<td>Enables potential recovery of ~1% of revenues that may be lost from meter tampering</td>
</tr>
<tr>
<td>• Outage detection and notification</td>
<td>Enables faster restoration (e.g., PECO avoided 6,000 truck rolls following Superstorm Sandy and accelerated restoration by 2-3 days)</td>
</tr>
<tr>
<td>• Voltage and power quality monitoring</td>
<td>Enables more effective management of voltages for conservation voltage reductions and other VVO applications</td>
</tr>
</tbody>
</table>
### Reliability Improvements from Automated Feeder Switching

**4 Projects involving 1,250 feeders**  
April 1, 2011 through March 31, 2012

<table>
<thead>
<tr>
<th>Index</th>
<th>Description</th>
<th>Weighted Average (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAIFI</td>
<td>System Average Interruption Frequency Index (outages)</td>
<td>-22 % (-11% to -49%)</td>
</tr>
<tr>
<td>MAIFI</td>
<td>Momentary Average Interruption Frequency Index (interruptions)</td>
<td>-22 % (-13% to -35%)</td>
</tr>
<tr>
<td>SAIDI</td>
<td>System Average Interruption Duration Index (minutes)</td>
<td>-18 % (+4% to -56%)</td>
</tr>
<tr>
<td>CAIDI</td>
<td>Customer Average Interruption Duration Index (minutes)</td>
<td>+8 % (+29% to -15%)</td>
</tr>
</tbody>
</table>

Weighted average based on numbers of feeders.
City of Naperville
Empowering Consumers in Illinois

Key Activities
• Naperville’s “Smart Grid Initiative” completes a decade long efforts to automate the city’s entire electric distribution grid.
• Deploys smart meters city wide to all customers.
• Provides consumer education programs to engage public participation in shaping smart grid policies and programs.

Aims and Strategies
• Strengthen reliability and reduce the frequency and duration of power outages.
• Empower consumers to manage their own power consumption and costs to enhance energy efficiency, reduce peak, and reduce power purchase costs from wholesale suppliers.

Results and Benefits
• Distribution automation investments have improved System Average Interruption Duration Index each years since 1991 by from 15% to 55%.
• O&M costs from dispatching repair crews reduced by about 40%.
• Enacted Naperville Smart Grid Consumer Bill of Rights.
• Implemented Smart Grid Ambassadors Program

Facts & Figures
Total Project Budget: $21,988,220
Federal Share: $10,994,110
Distribution Automation: Remaining 6 of 117 circuits
Smart meters: 57,000
Time-based Rates: 1,500 customers targeted

Residents provide feedback on Naperville’s smart grid policies and programs.
Electric Power Board of Chattanooga
Improved System Restoration

Key Activities
- EPB’s Smart Grid Project covers 600 miles throughout 9 counties of Georgia and Tennessee affecting 170,000 customers.
- Installing automated feeder switches, automated circuits, advanced SCADA, AMI, in-home displays, and communications infrastructure.

Aims and Strategies
- Electric Distribution System Automation – installing automated feeder switches and sensor equipment for distribution circuits that can be used to detect faults and automatically switch to reroute power and restore all other customers.
- Communications Infrastructure – includes fiber optic systems that enable two-way communication between the meters, substations, and control office which provides EPB with expanded capabilities and functionality to optimize energy delivery, system reliability, and customer service options.

Results and Benefits
- During the April 2011 storms, three fourths of EPB customers – 129,000 residences and businesses – lost power.
  - Smart switches avoided thousands of hours of outage time due to the devices and automation already installed
  - EPB was able to avoid sending repair crews out 250 times

Integrating Smart Grid Applications
Smart switches help ensure grid reliability and power quality

Facts & Figures
Total Project Budget: $226,707,562
Federal Share: $111,567,606
Equipment Deployed:
- Smart Switches: 1,500
- AMI: 170,000
- Direct LC Devices: 5,000
- HEMS: 5,000
- Thermostats: 5,000
- Automated Circuits: 164

Smart switches help ensure grid reliability and power quality.
Case for WV Grid Modernization
### Key Findings from WG SIP 2009

<table>
<thead>
<tr>
<th>Key Success Factors</th>
<th>Benefits</th>
<th>Annual Benefits (SM)</th>
<th>(All Beneficiaries)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reliability</strong></td>
<td>Reduced Consumer Losses</td>
<td>$898</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduce Power Quality Events</td>
<td>$131</td>
<td></td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Reduce Price of Electricity</td>
<td>$399</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Job Creation</td>
<td>$215</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumer Sales of DER Resources</td>
<td>$175</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased Energy Sales as Exports</td>
<td>$7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced Transmission Congestion</td>
<td>$1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased Transportation Fuels Business</td>
<td>$5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumer Conservation</td>
<td>$20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operational Savings</td>
<td>$194</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Reduced Emissions</td>
<td>$7</td>
<td></td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Reduced Blackout Probability &amp; Dependence on Foreign Oil</td>
<td>$13</td>
<td></td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>Reduce Hazard Exposure</td>
<td>$1</td>
<td></td>
</tr>
</tbody>
</table>
Key Findings from WG SIP 2009
States experienced varying levels of reliability in 2015. A reliable bulk power system does not necessarily mean reliable end-user electricity service because outages often originate on local distribution systems, as reflected in the SAIDI measurements in the map.

Source: “Transforming the Nation’s Electricity Sector: The Second Installment of the QER” January 2017
GMI-4 Final Scoring Graph

GMI-3 Final Scoring vs GMI-4 Final Scoring

- GMI 3 Score
- Final GMI 4 Score
West Virginia GMI Recap

- West Virginia’s overall GMI score rose to 19 in GMI-4.
- This score saw West Virginia ranked 38th overall, down from its ranking of 37th in GMI-3.
Some Challenges and Risks
Challenges for Smart Grid Deployment

Change Management:
• Common vision
• Consumer education and motivation
• Metrics needed for accountability

Regulatory:
• Dynamic rates
• Cost recovery
• Consumer privacy/safety concerns
• Societal benefits in business case

Technical:
• Interoperability and cyber security
• Communications
• Data management
• Central and distributed control
• Two-way protection
Questions?
Extra Slides
## What’s Different with a Modern Grid

<table>
<thead>
<tr>
<th>Current Grid</th>
<th>Modern Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little consumer engagement</td>
<td>Consumer involvement</td>
</tr>
<tr>
<td>Radial system</td>
<td>Networked and integrated system</td>
</tr>
<tr>
<td>One-way power flow</td>
<td>Two-way power flow</td>
</tr>
<tr>
<td>One-way communications</td>
<td>Two-way communications</td>
</tr>
<tr>
<td>Central generation</td>
<td>Mix of central and distributed generation</td>
</tr>
<tr>
<td>Passive control</td>
<td>Active control</td>
</tr>
<tr>
<td>Fixed rates</td>
<td>Dynamic rates</td>
</tr>
<tr>
<td>Separate transmission &amp; distribution</td>
<td>Interaction between T&amp;D</td>
</tr>
<tr>
<td>Little ties with other infrastructures</td>
<td>Potential to transform transportation sector</td>
</tr>
</tbody>
</table>
The Modern Grid will...

1. Enable active participation by consumers
2. Accommodate all generation and storage options
3. Enable new products, services, and markets
4. Provide power quality for the digital economy
5. Optimize asset utilization and operate efficiently
6. Anticipate & respond to system disturbances (self-heal)
7. Operate resiliently against attack and natural disaster
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
  - Increase in variable renewables (e.g., solar and wind farms)
  - Increase in distributed generation (e.g., rooftop PV)
  - Increase in consumer engagement (e.g., demand response)
  - Many more assets to manage and control
Why Modernize the Grid?

• Today’s grid is aging and outmoded

• Unreliability is costing consumers billions of dollars
  • Outages up 285% since 1984 – EIA estimates outage costs at $150 Billion/yr *  * SmartGridNews.com

• 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

• Adverse trends associated with the grid
  ➢ - Costs, reliability, peak loads, asset underutilization, TLRs, grid divorce

• The benefits of a modernized grid are substantial
Modernizing the Grid

Cost to Modernize:
- $338-$476B over 20 years
  - $82-90 B for transmission
  - $232-$339 B for distribution
  - $24-46 B for consumer
- $17-24 B per year

EPRI, 2011

Benefit of Modernization:
- $1294 – 2028 Billion
- Overall benefit-to-cost ratio of 2.8 to 6.0

Previous Studies:
- Benefit to Cost Ratio for West Virginia of 5:1
- Benefit to Cost Ratio for San Diego of 6:1
  - $165 B Cost
  - $638 - $802 B Benefits

# Peak Demand Reduction from AMI, Pricing, and Customer Systems

<table>
<thead>
<tr>
<th>Project Elements</th>
<th>OG&amp;E 770,000 customers</th>
<th>MMLD 11,000 customers</th>
<th>SVE 18,000 customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers Tested</td>
<td>6,000 residential</td>
<td>500 residential</td>
<td>600 mostly residential</td>
</tr>
<tr>
<td>Time-Based Rate(s)</td>
<td>TOU and VPP, w/CPP</td>
<td>CPP</td>
<td>CPP</td>
</tr>
<tr>
<td>Customer Systems</td>
<td>IHDs, PCTs, and Web Portals</td>
<td>Web Portals</td>
<td>Web Portals</td>
</tr>
<tr>
<td>Peak Demand Reduction</td>
<td>Up to 30%</td>
<td>37%</td>
<td>Up to 25%</td>
</tr>
<tr>
<td></td>
<td>1.3 kW/customer</td>
<td>0.74 kW/customer</td>
<td>0.85 kW/customer</td>
</tr>
<tr>
<td></td>
<td>(1.8 kW/customer w/CPP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outcome</td>
<td>Deferral of 210 MW of peak demand by 2014 with 20% participation</td>
<td>Lowers total purchase of peak electricity</td>
<td>Lowers total purchase of peak electricity</td>
</tr>
<tr>
<td>Customer Acceptance</td>
<td>Positive experience, many reduced electricity bills</td>
<td>Positive experience, but did not use the web portals often</td>
<td>Interested in continued participation, many reduced electricity bills</td>
</tr>
</tbody>
</table>
Applying Volt/VAR Optimization to Improve Energy Efficiency

Conservation voltage reduction (CVR) reduces customer voltages along a distribution feeder for lowering peak demands and overall energy consumption.

Example Using SGIG Project Data

<table>
<thead>
<tr>
<th></th>
<th>% Reductions</th>
<th>Potential savings for a 7 MW peak circuit with 53% load factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results averaged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>across 11 circuits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer Energy</td>
<td>2.9%</td>
<td>$75,440 (at $0.08/kWh)</td>
</tr>
<tr>
<td>Reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Demand</td>
<td>3%</td>
<td>943 MWh/year</td>
</tr>
<tr>
<td>Reduction</td>
<td></td>
<td>210 kW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Defer construction of peaking plants</td>
</tr>
</tbody>
</table>

Voltage reduced by adjusting the LTC set-points

Distance along circuit

Customer Voltage

Distribution Source Voltage

“CVR-off” voltage profile

“CVR-on” voltage profile
Top Ten Countries Account for 80% of Global Smart Grid Investment by 2030*

- China
- United States
- India
- Brazil
- France
- Germany
- Spain
- United Kingdom
- Japan
- South Korea

Others
- Italy
- Norway
- Sweden
- Australia
- Russia

* Innovation Observatory
Smart Grid Key Success Factors

The Smart Grid is MORE:

• Reliable
• Secure
• Resilient
• Economic
• Efficient
• Environmentally friendly
• Safe
Smart Grid Principal Characteristics

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
# Context of Smart Grid & Modern Grid

## Smart Grid Technologies
- Two-way communications
- Sensors
- Controls
- Decision support tools
- Components
  - Transformers
  - Power electronics
  - Conductors

## Enhanced Technologies
- Renewable energy resources
- Electric vehicles
- Energy storage
- Distributed generation
- Connected appliances/devices
- Load control/demand response

## Attributes
- Sensing, control, automation, power transformation, protection and communications

## Enhanced Functionality
- Generation, storage, and load

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The Smart Grid should have quantifiable measurements of performance.