Trends and Priority Issues for Sustainable Power Grid:

IEEE Quadrennial Energy Review (QER)

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Achieving Electric System Resilience

Large investment required - uniquely critical infrastructure providing an “enabling function”

- Aging Infrastructure
- Reliability, Hardening, Resiliency, Security
- Smart Grid
- Electrical - Natural Gas Interdependency
- Demand side innovations

Complex grid structures require "Smart Grid" solutions

U.S. Outage Cost = $125 Billion/Year (DOE)
Grid Transformation Driver: Smart Grid & Distributed Resources

- **Smart Grid investments**
  - Transmission made smarter with enhanced monitoring, protection, and control with synchrophasors
  - Distribution being transformed with automation and feeder optimization
  - Demand response with smart meters
  - Utility grade battery storage introduced

- **Microgrids and "behind the meter" distributed energy resources require a robust, hybrid T&D grid**
  - Grid connection required for reliability and market reach

Source: NASPI
GAS Exceeds COAL in 2035; 50+ GW COAL Retired
More COAL Retirements Probable; NUCLEAR Stressed

Source: EIA.GOV
Grid Transformation Driver: Renewable Surge

Non-Hydro Renewable Sources Grow 3.2% Annually
Game Changer – Solar Grows 7.5% Annually

Source: EIA.GOV
Proposed Generation in New England is Primarily Gas and Wind

All Proposed Generation
Developers propose >5 GW of gas-fired generation and >3 GW wind; wind is mostly onshore in northern New England and offshore in southern New England.

Wind Proposals
- ME: 3,113 MW
- MA: 480 MW
- VT: 30 MW
- NH: 62 MW
- RI: 30 MW

Source: ISO Generator Interconnection Queue (July 2014); includes FERC Jurisdictional and FERC Non-Jurisdictional projects.
Grid Transformation Driver: Competitive Transmission

FERC Order 1000 in 2011 and clarified in 2012 enabled competitive transmission:

• Ensures regional and transparent planning
• Reinforces "beneficiary pays" cost allocation
• Eliminates rights of first refusal (ROFR) or monopoly status for building transmission unless states mandate ROFR
  – Affects higher voltage, regionally allocated transmission

FERC Order 1000 will lead to increased transmission development and developers
Grid Transformation Driver: Game Changing Events

Super Storm Sandy

Metcalf Substation
Gunshot Damage

- Grid Vulnerabilities Revealed: System and Equipment
- White House, Congress, FERC, NERC focused - Standards
# Industry Response

## Utilities Headed for a Cliff? – Energybiz, Jan/Feb 2014

"There will be companies...supplying 40% or more electricity utilities originally provided .... You'll see the development of a significant number of microgrids that will protect the grid against cyber attack."

*Jim Rogers, former Duke Energy CEO*

## Wall Street Journal interview with J. Wellinghof, former FERC chairman:

“Assault on California Power Station Raises Alarm on Potential for Terrorism”

## Deputy Assistant Energy Secretary D. Ortiz:

“The grid is resilient and disabling many locations would be difficult. FERC’s findings had value ‘as a way of starting a conversation on physical security.’”

## Obama Administration to conduct a Quadrennial Energy Review to focus on a comprehensive strategy for T&D
“Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security.

Achieving these goals requires a comprehensive and integrated energy strategy resulting from interagency dialogue and active engagement of external stakeholders.

To help the Federal Government better meet this responsibility, I am directing the undertaking of a Quadrennial Energy Review.”
U.S. DOE has requested IEEE to provide insights on a specific set of priority issues

- Effects of renewable intermittency on the grid and the potential role of storage
- Business case issues related to microgrids and distributed generation (DG), including rooftop photovoltaics
- The technical implications for the grid of electric vehicle (EV) integration
- The implications and importance of aging infrastructure and the options for addressing these challenges, including asset management
- Recommendations for metrics for addressing Smart Grid issues, especially to help policy makers determine the importance and necessity of protocols
- Skilled workforce issues
- Report cards on the condition and performance of the electric grid
IEEE QER Report is delivered to DOE

• Work started in May 2014
• Draft delivered for review beginning of July
  o IEEE membership and PES Technical Committees
  o NERC, utilities, RTOs, academia, and vendors
  o Industry organizations (e.g. APPA, EEI, UWIG)
• Final report submitted on September 5th 2014

http://www.ieee-pes.org/qer
As the system ages, operating cost increases and reliability decreases - limited resources for wholesale replacements.

- How to manage Smart Grid assets?
- Sound strategy for controlling the symptoms of aging within the utility's overall business plan - maintain *accepted levels of performance*.

The Grid is 40 to 60 years old on average, with 25% of the Grid a performance concern.
Renewable Intermittency and Storage

**Grid Level:** Uncertainty of renewable sources can be tolerated at penetration levels around 30% (system studies and real world experience)

- Traditional power system planning and operations need to be updated
- Energy storage, while a useful and flexible system tool, is not essential as other, often more cost-effective options are available such as fast responding generation and demand response

**Distribution:** High penetration levels of renewable DG creates challenges, requiring

- Battery storage systems
- Advanced power electronics technologies
- Real-time monitoring, control and automation.
Why Microgrids?

• **Capacity, Reliability and Power Quality**
  - A low-cost augmentation/alternative to a utility system
  - Better power quality and outage management for critical, premium and remote customers (e.g., for weather related events)

• **Sustainability** – Enables optimal dispatch of renewables and high customer involvement
  - Emissions reduction
  - Green marketing
  - Community management

• **Cost Savings** – Portfolio of resources managed locally, but optimized on the system level
  - Enables a hedge against fuel cost increase
  - Net-zero model (still relies on the grid)
Optimized Hybrid Microgrids

- Energy Efficiency and Asset Management – lower OPEX:
  - Reduced equipment utilization and losses as generation closer to the load
  - Peak load shaving – in conjunction with market pricing

- Utility grid as backup – Neither the MG nor the traditional system can fulfill all the needs, e.g. serving all the load, all the time
  - They must work synergistically

- New tools and Standards
  - E.g. IEEE 1547 Series of Interconnection Standards for DG integration

- Safety, Life cycle costs, efficiency, reliability, grid resiliency, etc.
RecommendaEons for Microgrids

• Policy should support value creation, with results-based rewards, and not unduly favor either incumbent utilities or non-utility microgrid sponsors
  – Assessing costs should include efficiency, reliability, safety, optimizing life-cycle costs, and resilience for the grid
  – Costs and benefits must be apportioned to each relevant party in a multi-stakeholder microgrid business case to accelerate microgrid adoption
  – Regulatory policy must be reviewed and revised to reward a utility for the costs incurred in planning, operational changes, and the optimal integration of these customer- or utility-owned assets

• Utilities need to review where and how best to accommodate microgrids and DG given existing policy

• Utility business case-, operations- and safety-related lessons learned from utility-sponsored microgrids developed with U.S. DOE participation should be documented and disseminated
Plug-In Electrical Vehicles Market Penetration

- There are about 250,000 PEVs and 20 models on the road (through August 2014)
- Steady increase in sales year over year
Integrating PEV

• Generation and transmission systems can handle millions of plug-in electric vehicles

• Good understanding of technical issues that may arise on the distribution system
  – Potential overloads of distribution transformers and circuits
  – Changes in equipment cooling patterns
  – Inability to accommodate high-power charging in older neighborhoods with legacy distribution infrastructure

Source: “Survey Says: Over 40% of American Drivers Could Use an Electric Vehicle,” Union of Concerned Scientists,
PEV Recommendations 1 (2)

- Promote the development of PEV charging infrastructure and its deployment by cities, states, and businesses, and along the interstate highway system with the support of the federal government

- Fast track standards and research to support higher penetration of PEVs
  - Sizing and implementation guidelines for physical grid equipment
  - Sensors and controls for remote control of charging to better interface with the grid
  - Security of communication
  - Use of the PEV batteries to support electric needs during natural disasters
PEV Recommendations 2 (2)

- Support battery research for transportation focusing on longer range/life and battery chemistries suitable for opportunity charging
- Increase the focus on research to determine
  - Grid sizing to support high penetration of PEV
  - Reduction in losses when charging from roof-top photovoltaics
  - PEV load modeling and forecasting
  - Demographics of PEV locations
- This research will also benefit high penetration of distributed generation
Grid Transformation Headwind: Aging Workforce

- Perfect Storm: Aging Workforce + Aging Assets = Reliability Decline
- Requirement: Programs to attract, train and develop engineers, linemen, station electricians, P&C resources, and other technical resources

The U.S. utility workforce is getting old ...

<table>
<thead>
<tr>
<th>Age Group</th>
<th>U.S. average</th>
<th>Electric power generation and T&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-24</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>25-34</td>
<td>22</td>
<td>21</td>
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<td>45-54</td>
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<td>55-64</td>
<td>16</td>
<td>19</td>
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<tr>
<td>65+</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

~50% of workers will be eligible for retirement in the next 5-10 years

...limiting the labor pool for utilities

- Utility workforce not adequately replenished
- Recession has hurt development effort
- Long training lead times
- Limited utility labor supply
Preventing Blackouts

India Blackout – July 2012
600 million people affected

- Widespread electric outages are a symptom of strategies for grid management
- Analysis of recent disturbances reveals common threads
  - Learn from the past and proven methods to mitigate
  - Blackout propagation should be arrested
  - Restoration time could be reduced

- Wide Area Monitoring Protection and Control (WAMPAC): System Integrity Protection Schemes and Synchronized measurements for Improved Situational Awareness and Control

- Not possible to avoid multiple contingency initiated blackouts

HOWEVER...
Preventing Blackouts

The *Probability*, *Size* and *Impact* of *Wide Area Blackouts* can be *REDUCED* ...... !!
Synchrophasor Deployment
U.S. and Canada 2009

Precise grid measurements (within 1 µs) using GPS signals - Phasor Measurement Units (PMUs)

Dynamic wide-area network view at high speed (e.g., 60 -120 observations/s) for better indication of grid stress

Legend
- Networked
- Installed
- Planned
- Desired

Source: NASPI
Synchrophasor Deployment
U.S. and Canada 2013

1,700 PMUs, most networked, funded by SGIG grants and private sector funds

Source: NASPI
Pacific Gas & Electric Applications

- Situational Awareness, Visualization and Alarming (angles and voltages; overloads and oscillations)
- Voltage Stability Management
- Enhanced Energy Management Systems
  - Adding synchrophasor measurements to existing SE
  - Tracking dynamic changes and contingency analysis
- System Restoration
- Post-Disturbance Event Analysis, including Fault Location
- Operator and Engineering Training, Dispatch Training Simulator
- Provide interfaces with EMS and with third parties
Near-Term Roadmap

**INFRASTRUCTURE**
- Full production-grade system: QA/Staging & Training/Test environments
- Redundant ISO-TO communication network
- Enhanced DQMS
- CIP compliant measures
- Displays sharing with TOs

**APPLICATIONS**
- Fast and accurate post-event analysis
- Generation and Load dynamic model validation
- PhasorPoint operational use
- ROSE operational use
- Online oscillation (< 10Hz) detection and mitigation

**PROCESSES**
- Processes, procedures & training for items in

**Impact**
- HIGH
  - Initial data exchange with some neighbors
  - Initial EMS integration
  - TO expand PMU coverage to lower voltage levels and generation stations
  - Initial ISO-NE access TO DFR/DDR data
- MEDIUM
  - PMU only SE (345 kV) – Feasibility demonstration
  - Online calibration and status monitoring of PMUs
- LOW
  - Initial integration with other ISO-NE systems (e.g. GIS, OMS)

Source: ISO NE
System Testing and Data Conditioning is Critical

- Risk management: Identifies and remedies product and system integration issues
- Fine tuning applications for functionality and performance
- Online Data Conditioning
  - Mitigate bad/missing data
  - Linear State Estimator is used for front end data conditioning (Dominion)
- Transition from development to operation for training future users
  - System simulator
  - Training simulators

Instrumental in gathering the knowledge to provide the industry with direction and a fast track process for maturing the standards such as the IEEE C37.118.2, C37.238, C37.242, C37.244, and IEC-61850-90-5

Source: PG&E
## Synchronized Measurement Progression

<table>
<thead>
<tr>
<th>Before</th>
<th>Products Now</th>
<th>2014</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="First PMU" /></td>
<td><img src="image2" alt="Analog Displays" /></td>
<td><img src="image3" alt="Standard feature" /></td>
<td>Thousands of synchronized measurements world-wide</td>
</tr>
<tr>
<td><img src="image2" alt="Analog Displays" /></td>
<td><img src="image1" alt="First PMU" /></td>
<td>On major interconnections and generators</td>
<td>Integrated in standard business and operational practices</td>
</tr>
<tr>
<td><strong>Before</strong></td>
<td><strong>Products Now</strong></td>
<td><strong>2014</strong></td>
<td><strong>2018</strong></td>
</tr>
<tr>
<td>First PMU</td>
<td>Analog Displays</td>
<td>Standard feature (relays, DFR, controllers, monitors)</td>
<td>Fully integrated with EMS/SCADA or Independent system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>On major interconnections and generators</td>
<td>Higher data rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard SW tools included in EMS/SCADA</td>
<td>Fully in Distribution</td>
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<tr>
<td></td>
<td></td>
<td>Primary use for monitoring, event analysis</td>
<td>Distributed comm. and processing architecture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interoperability standards deployed</td>
<td>Fast Control and Adaptive Protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Some distribution PMUs</td>
<td></td>
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</tbody>
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Future Grid Roadmap

- Demand For Electricity Will Increase
  - Population growth, electric vehicles, use of renewable energy, etc.

- U.S. Fuel Transformation Will Occur
  - Dash to gas, renewable surge, plant retirements

- G, T & D Investment Will Increase
  - Infrastructure **Investment** - Electric utility industry will require up to $2 trillion by 2030, including generation (EEI)

- Grid Will Be Made Smarter, Reliable, Resilient, Secure
  - Advancements in technology and skilled workforce

- Customers Will See Value Beyond Commodity
  - Increased choices, digital age reliability, comfort value

- Societal and U.S. Economic Goals Met
  - Sustainability and support of growing U.S. economy
Thank you

Questions?