QUANTA TECHNOLOGY
Smart Solutions, Practical Results

Trends and Priority Issues for Sustainable Power Grid:

IEEE Quadrennial Energy Review (QER)

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November 5, 2014

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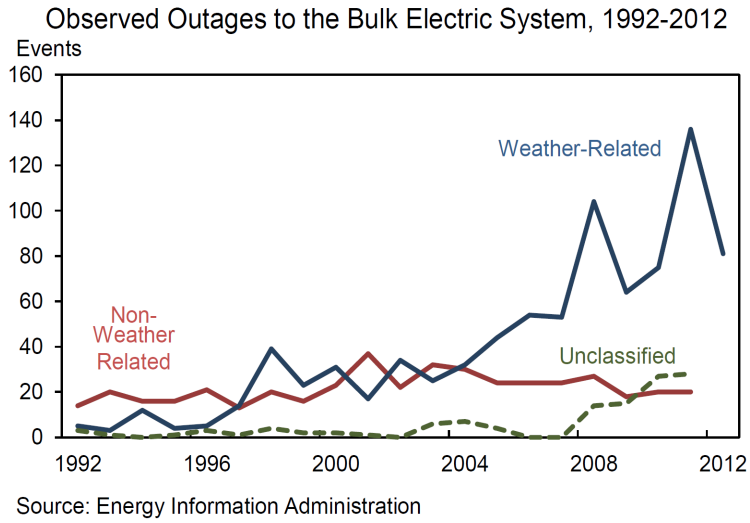
Achieving Electric System Resilience

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

Complex grid structures require "Smart Grid" solutions

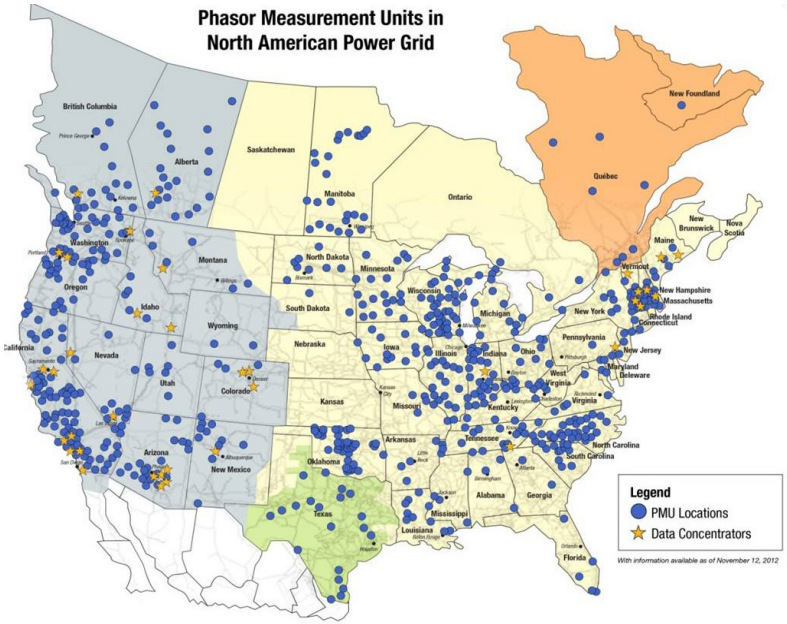
- Aging Infrastructure
- Reliability, Hardening, Resiliency, Security
- Smart Grid
- Electrical - Natural Gas Interdependency
- Demand side innovations



U.S. Outage Cost = $125 Billion/Year (DOE)

Grid Transformation Driver: Smart Grid & Distributed Resources

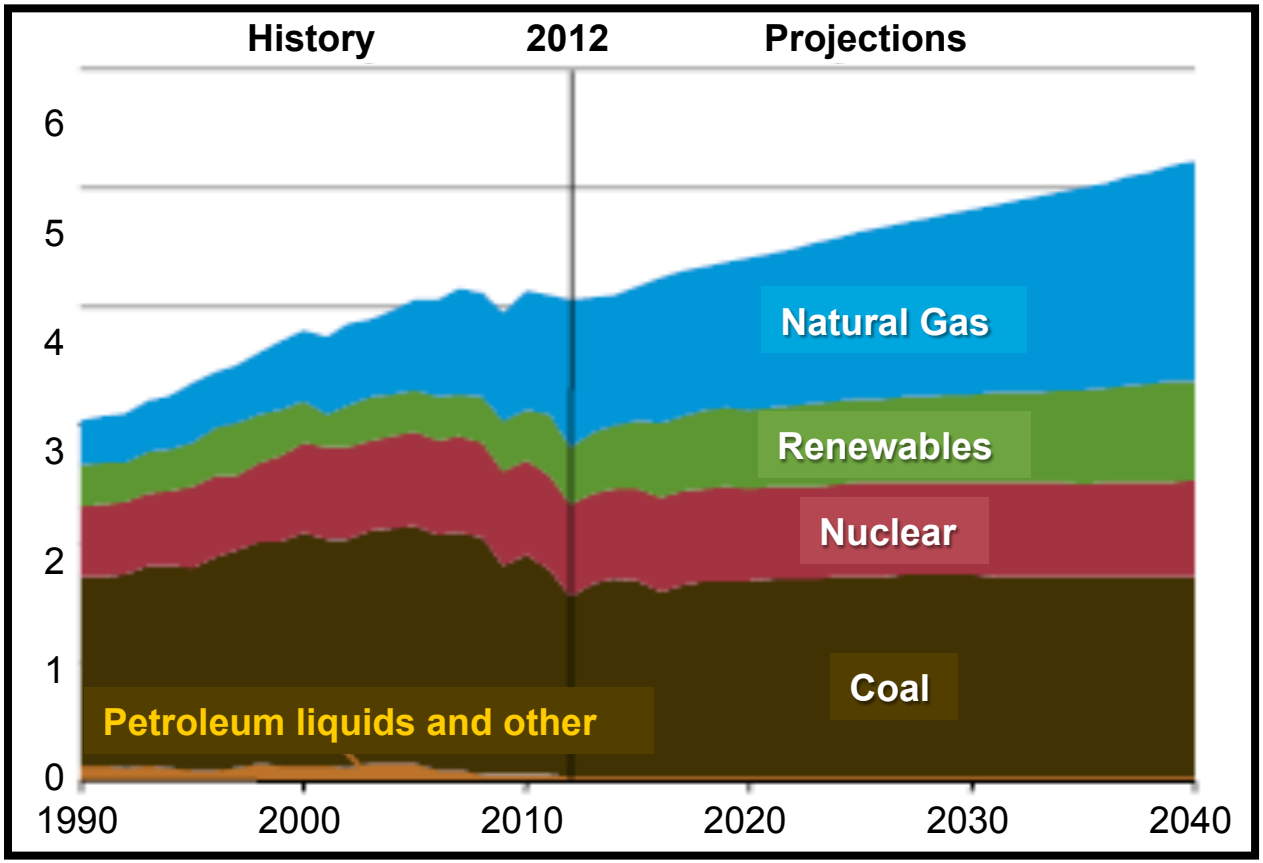
- **Smart Grid investments**
  - Transmission made smarter with enhanced monitoring, protection, and control with synchrophasors
  - Distribution being transformed with automation and feeder optimization
  - Demand response with smart meters
  - Utility grade battery storage introduced



Source: NASPI

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

Grid Transformation Driver: U.S. Fuel Transformation



Source: EIA.GOV

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

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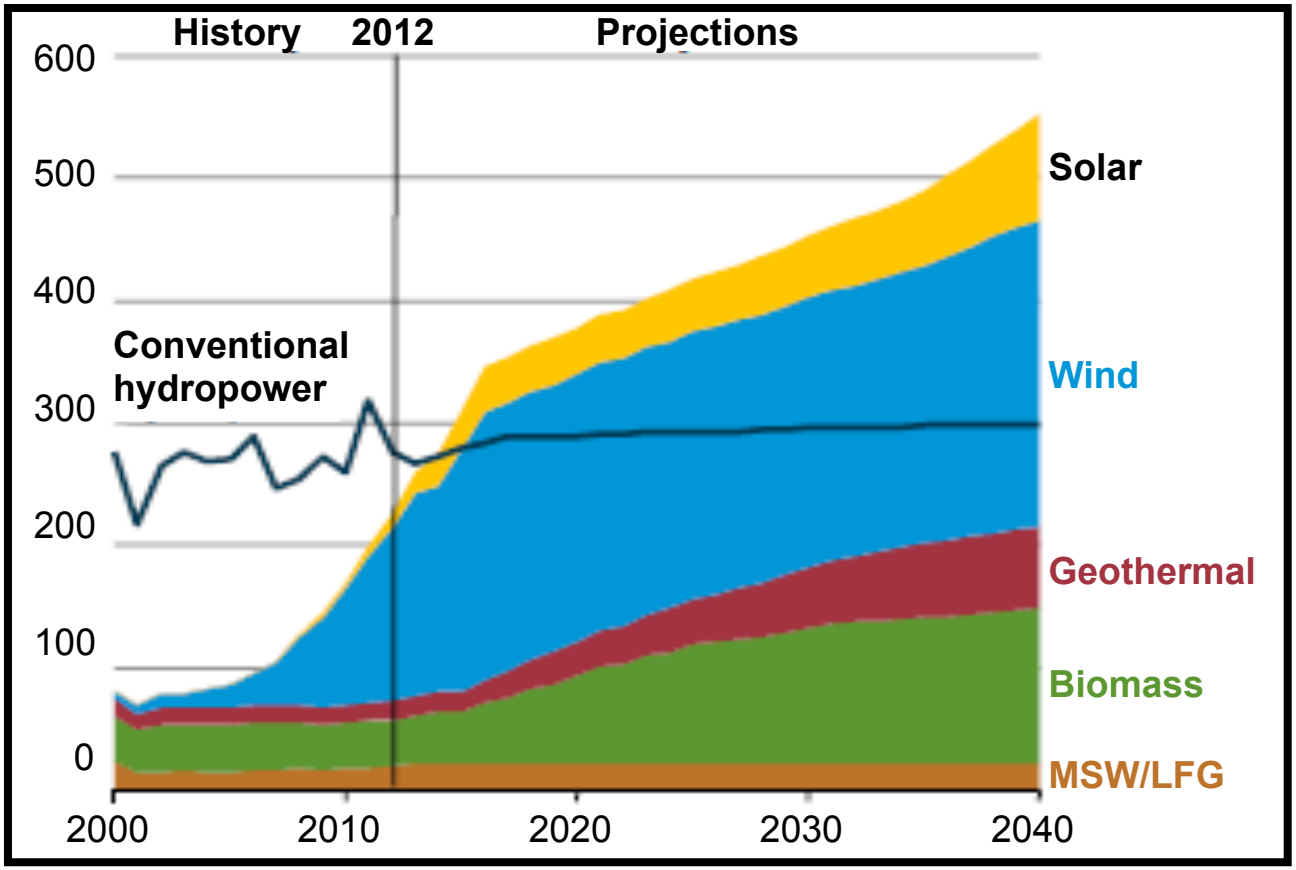
Grid Transformation Driver: Renewable Surge

Billion kWhs

Includes Distributed Resources



Source: EIA.GOV

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

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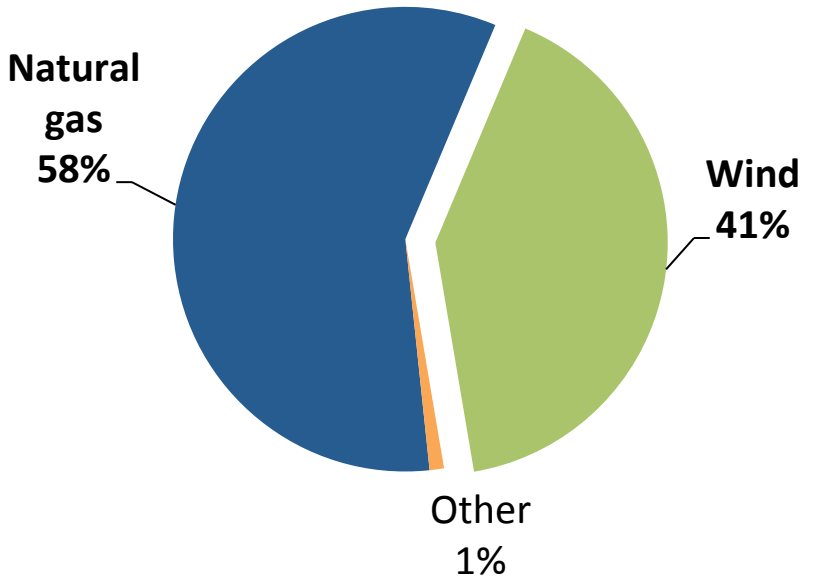
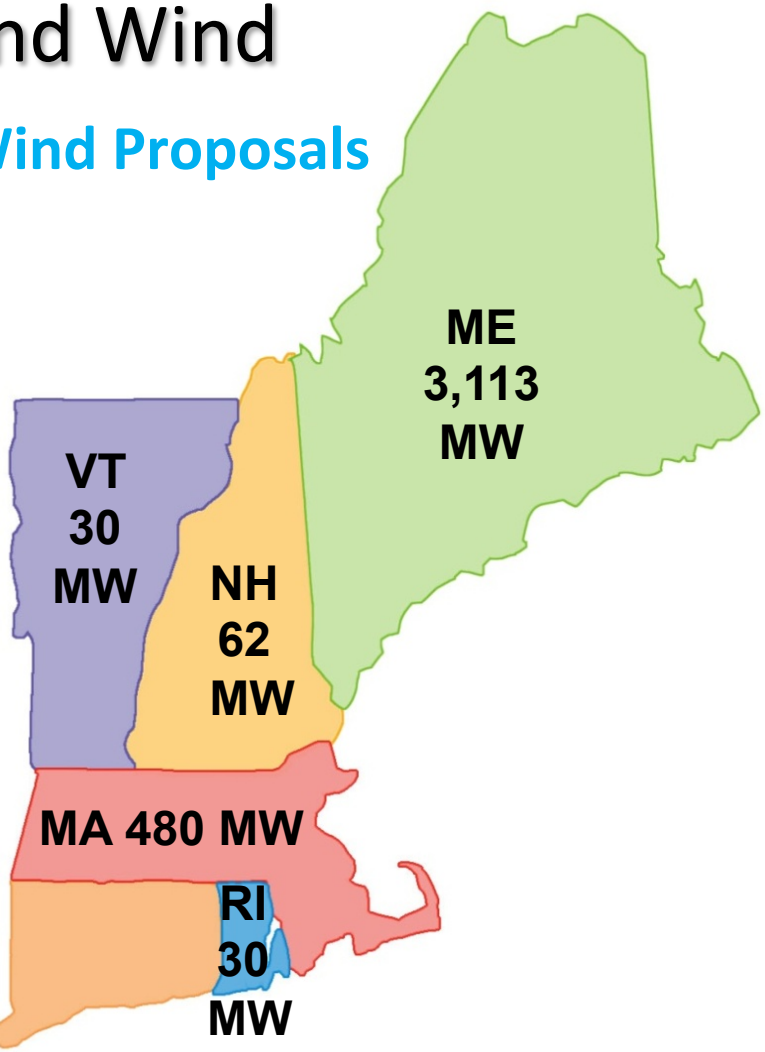
Proposed Generation in New England is Primarily Gas and Wind

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



Source: ISO Generator Interconnection Queue (July 2014); includes FERC Jurisdictional and FERC Non-Jurisdictional projects.

Grid Transformation Driver: Competitive Transmission

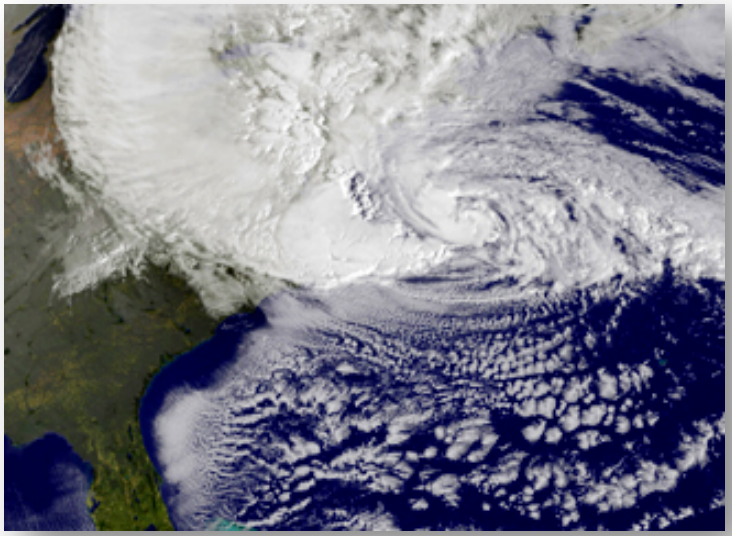
FERC Order 1000 in 2011 and clarified in 2012 enabled competitive transmission:

- 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

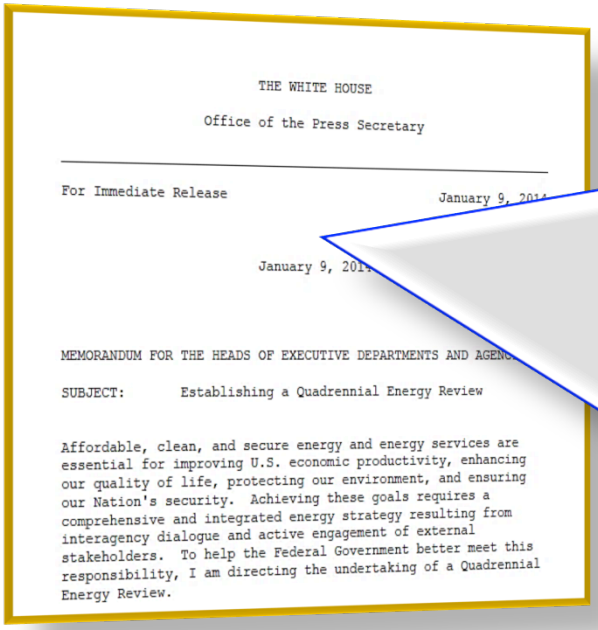
"There will be companies…supplying 40% or more electricity utilities originally provided …. You'll see the development of a significant number of microgrids that will protect the grid against cyber attack."

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

Quadrennial Energy Review



THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release January 9, 201

January 9, 201

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGEN

SUBJECT: Establishing a Quadrennial Energy Review

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.

President Barack Obama
January 9, 2014

"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.

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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

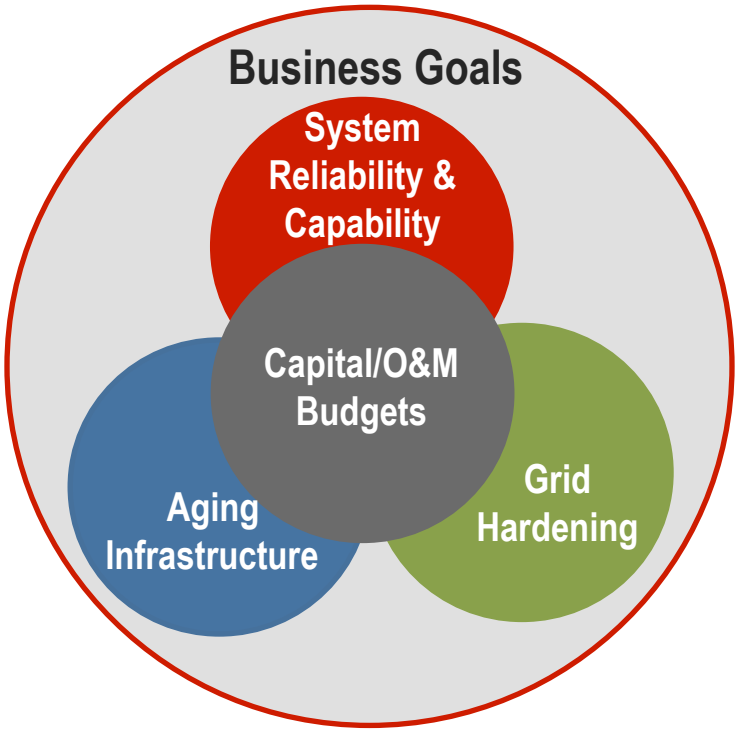
IEEE QER Report is delivered to DOE

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

http://www.ieee-pes.org/qer

Holistic Asset Management

Asset Management: Predictability of Cost & Reliability

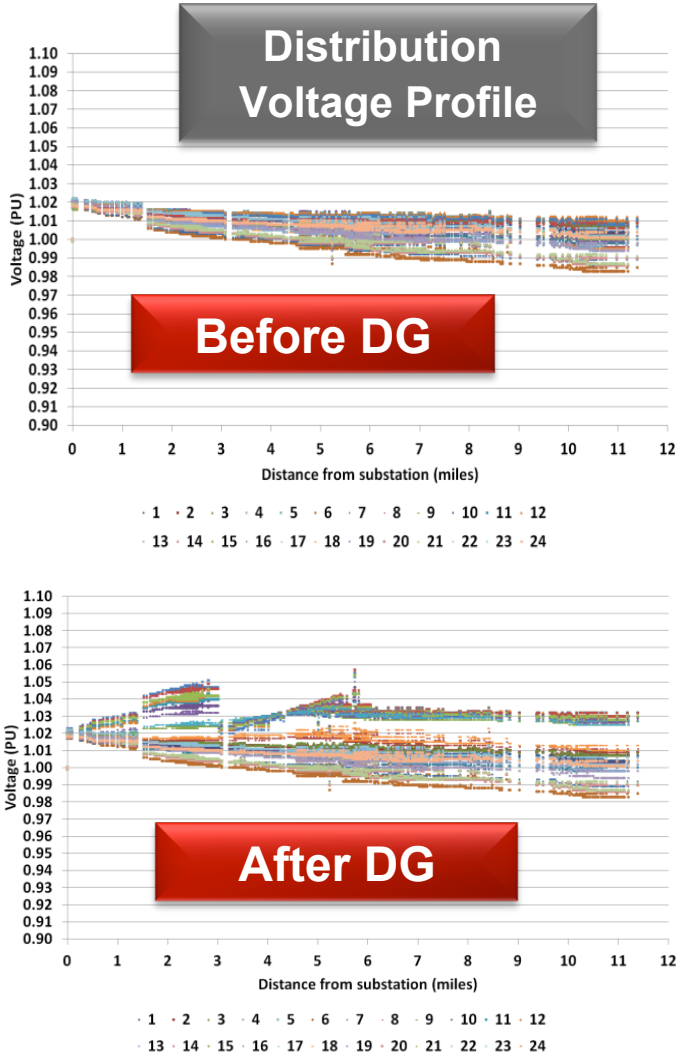


The Grid is 40 to 60 years old on average, with 25% of the Grid a performance concern.

- As system ages, operating cost increases and reliability decrease - 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*

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.

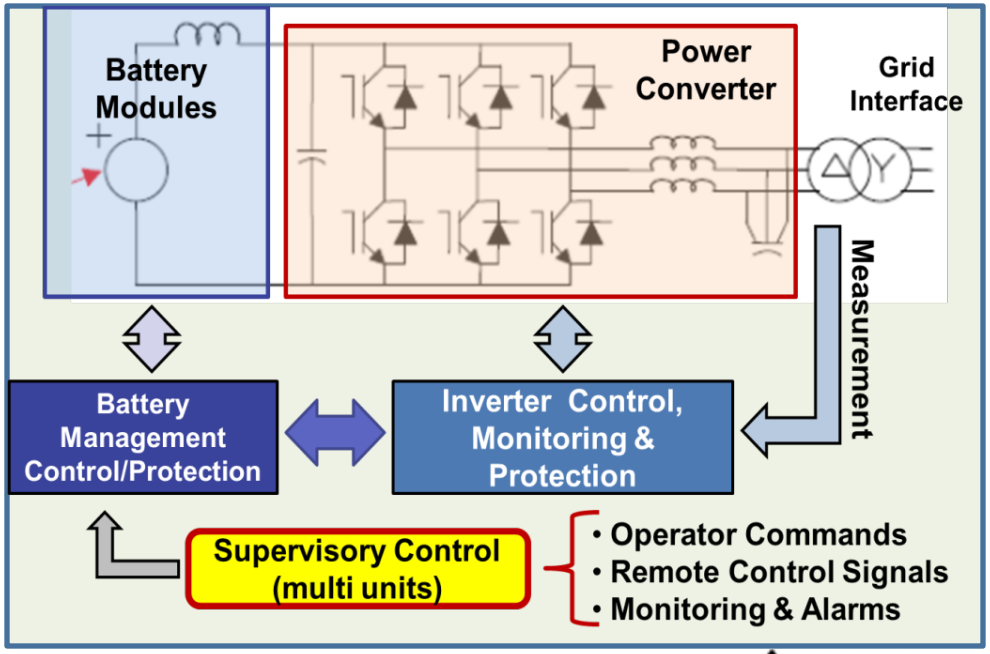


Why Microgrids?

- **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.

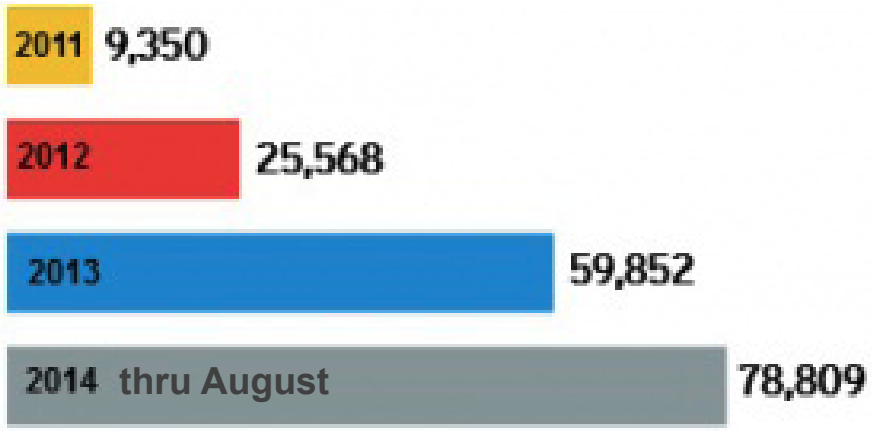


Recommendations for Microgrids

- 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

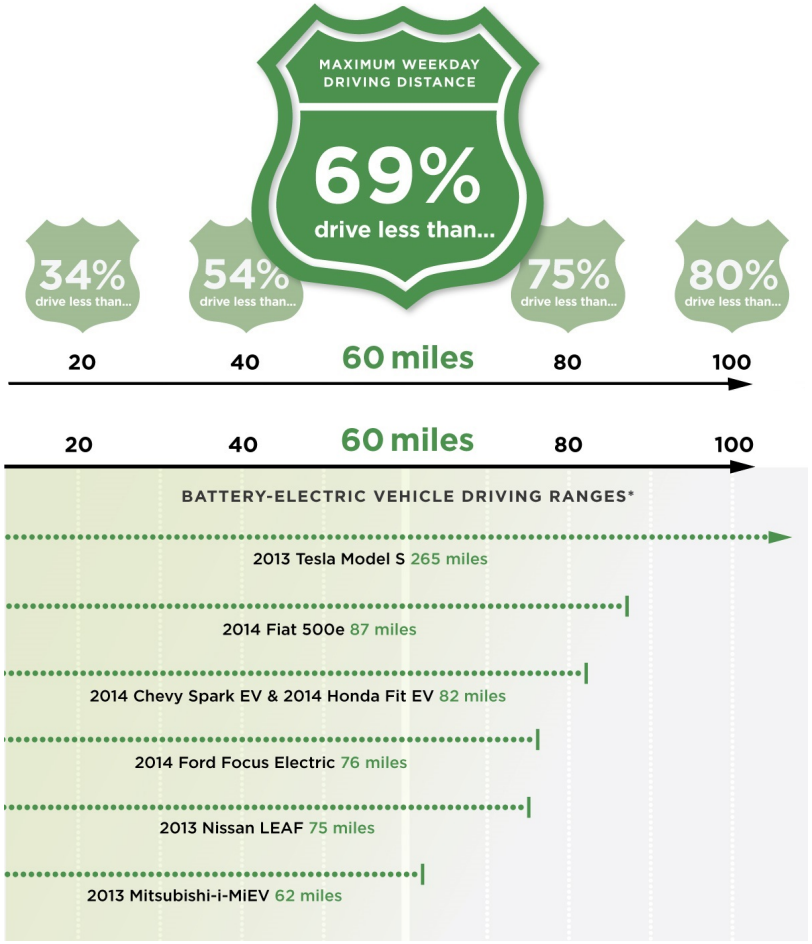
Plug-In Electrical Vehicles Market Penetration

- 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

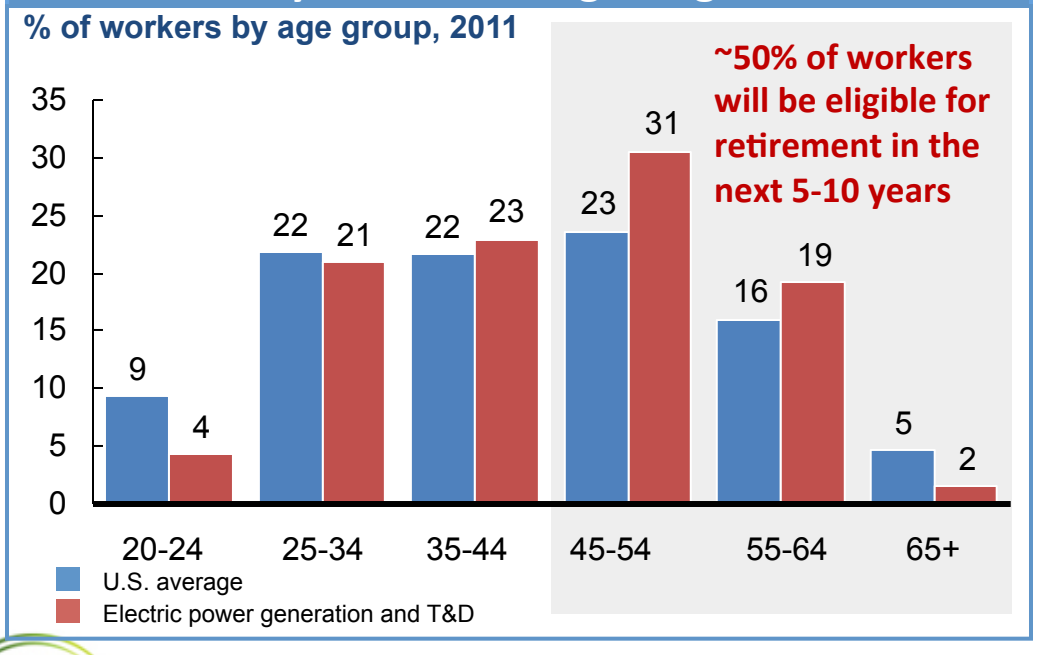
PEV Recommendations 2 (2)

- 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 …



…limiting the labor pool for utilities

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

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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

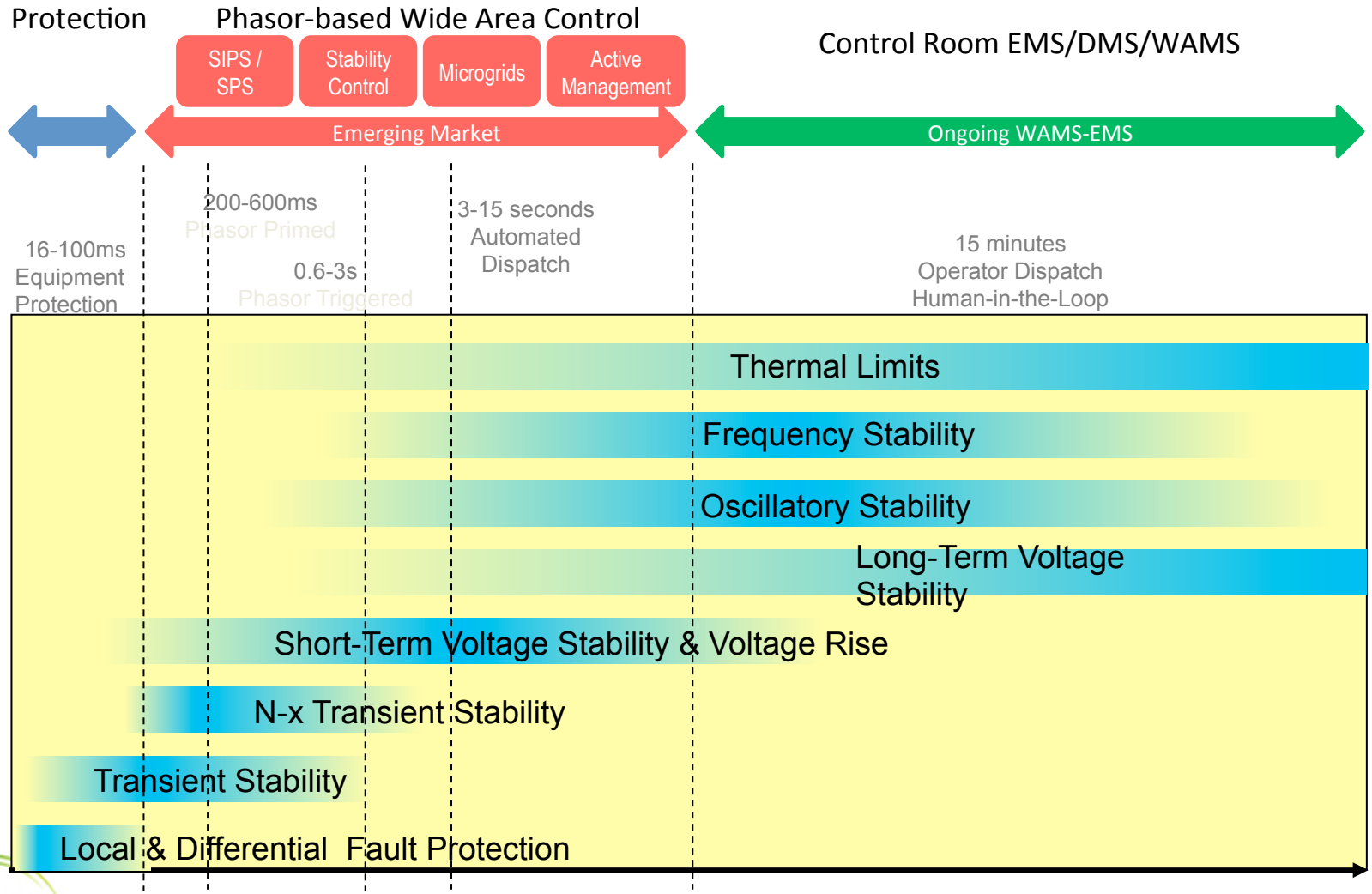
Wide Area Blackouts

can be

REDUCED …… !!

Bridging the Control Gap - Finally!

Timeframes of Grid Management

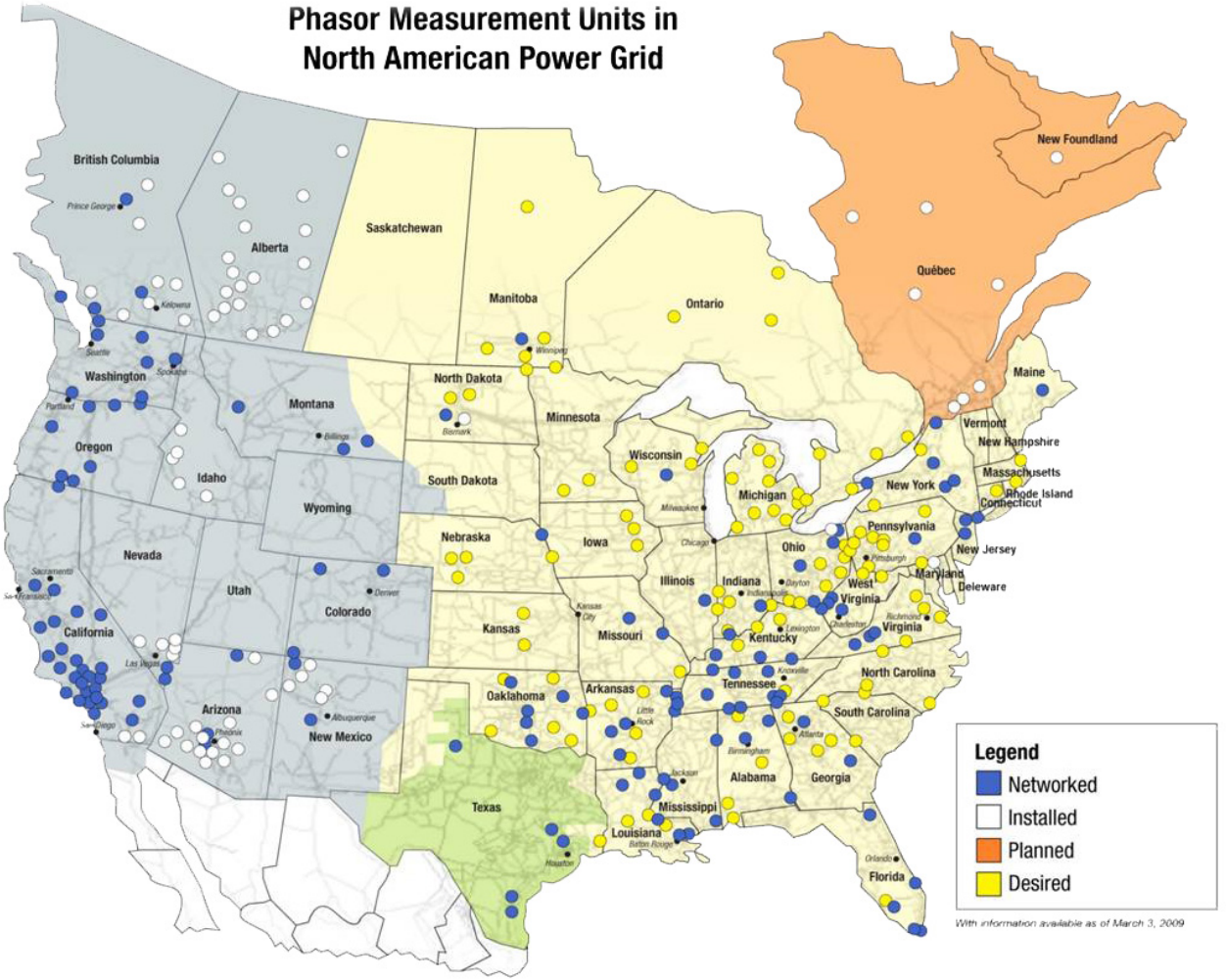


Synchrophasor Deployment

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

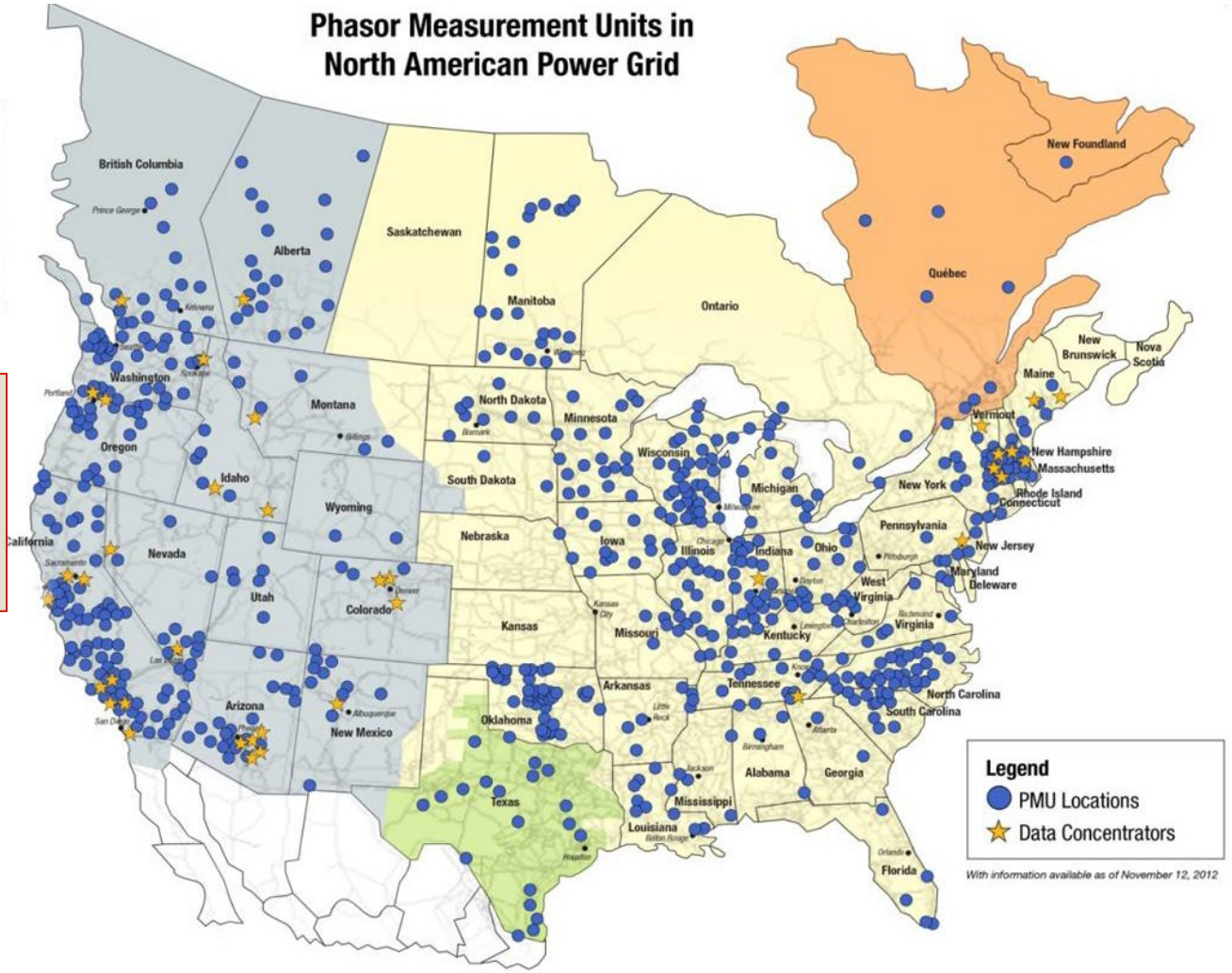


Source: NASPI

Synchrophasor Deployment

U.S. and Canada 2013

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

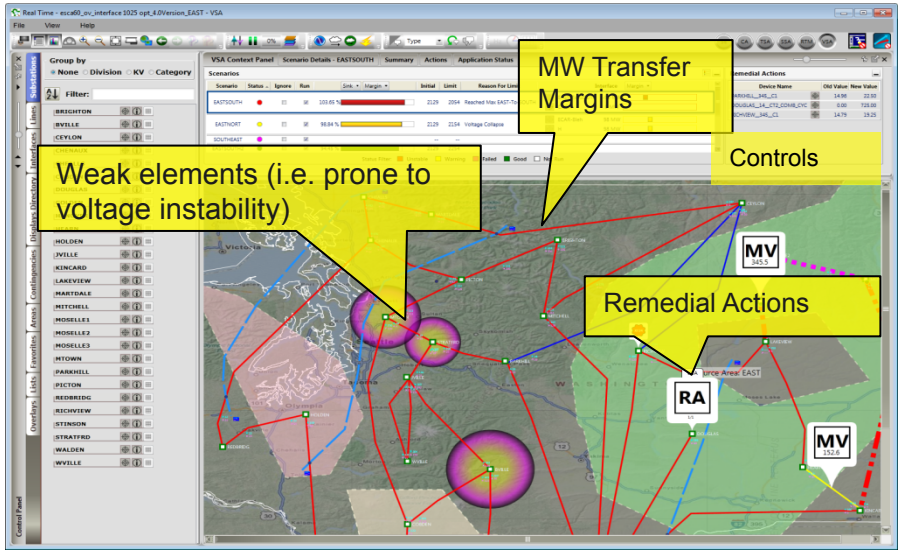


Source: NASPI

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

Impact

	INFRASTRUCTURE	APPLICATIONS	PROCESSES
HIGH	▪ Full production-grade system: QA/Staging & Training/Test environments ▪ Redundant ISO-TO communication network ▪ Enhanced DQMS ▪ CIP compliant measures ▪ Displays sharing with TOs	1 ▪ 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, procedures & training for items in 1
MEDIUM	▪ 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	▪ 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

Proof-of-Concept Facility

Source: PG&E

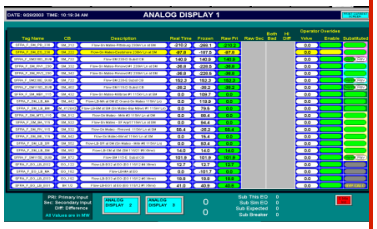
Instrumental in gathering the knowledge to provide the industry with direction and a fast track process for maturing the standards such as the IEEE C37.118.2, C37.238, C37.242, C37.244, and IEC-61850-90-5

- 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

Synchronized Measurement Progression

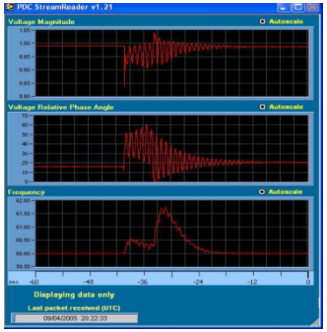
Before

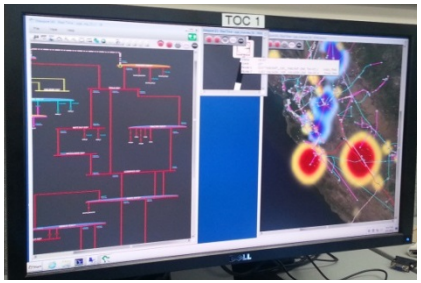
First PMU



Analog Displays

Products Now





2014

Standard feature (relays, DFR, controllers, monitors)

On major interconnections and generators

Standard SW tools included in EMS/ SCADA

Primary use for monitoring, event analysis

Interoperability standards deployed

Some distribution PMUs

Improvements in communication infrastructure

2018

Thousands of synchronized measurements world-wide

Integrated in standard business and operational practices

Fully integrated with EMS/SCADA or Independent system

Higher data rates

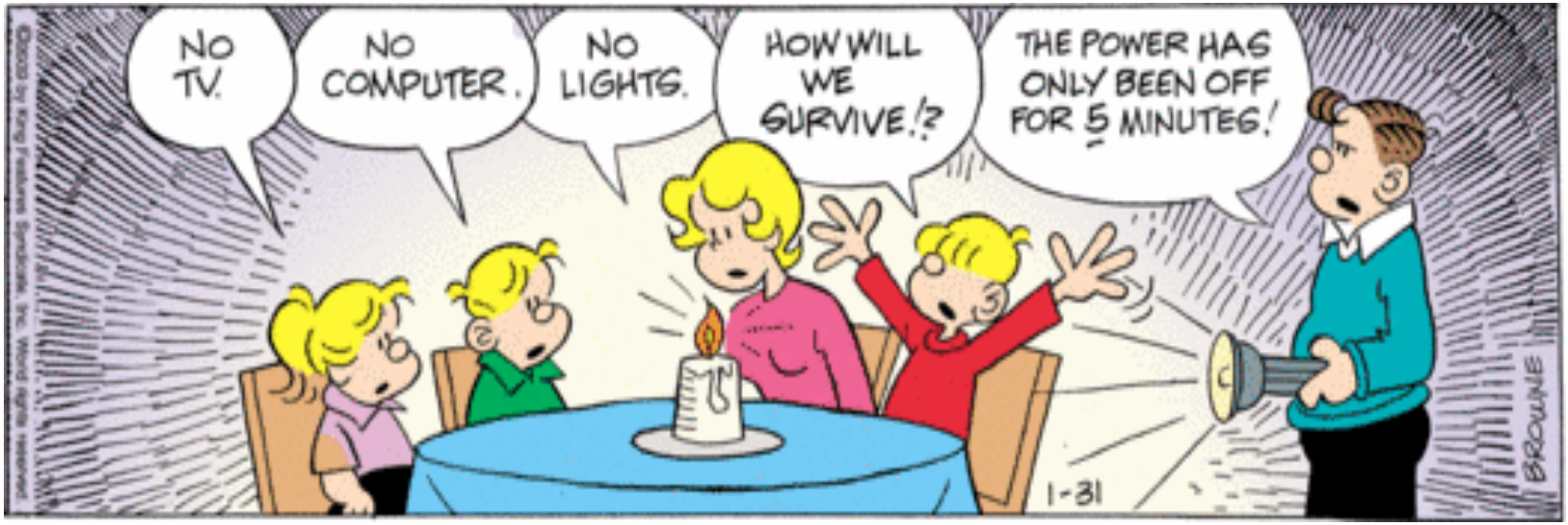
Fully in Distribution

Distributed comm. and processing architecture

Fast Control and Adaptive Protection

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?