



IEEE PES Asia-Pacific Power and Energy Engineering Conference

Learning from the Past Going into the Future

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IEEE PES President Elect
President, Quanta Technology



November 16, 2015



Outline

IEEE PES Benefits

Industry Trends

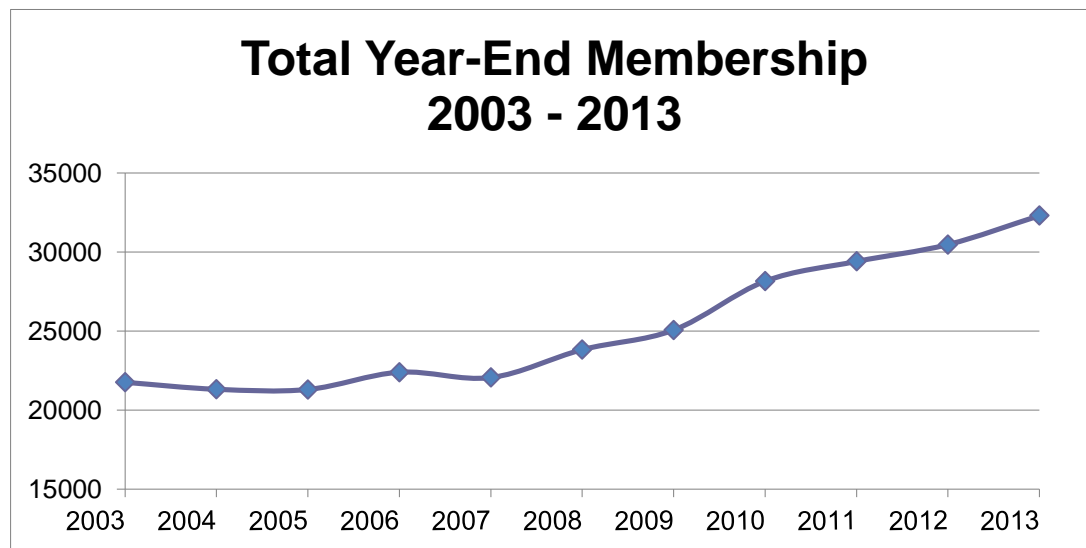
IEEE Quadrennial Energy Review

Grid of The Future

PES Membership – Steady Growth Continues

Going Forward...

- Increase Global Participation
 - Increasing the number of chapters worldwide
 - Publicize technical committee output (standards, tutorials, etc.)
 - Involve more international participants in standards and other committee work through electronic media
 - Hold more technical committee meetings abroad - local meetings
- Increase Industry Participation - Transition members to volunteers
- Promote Products and Services

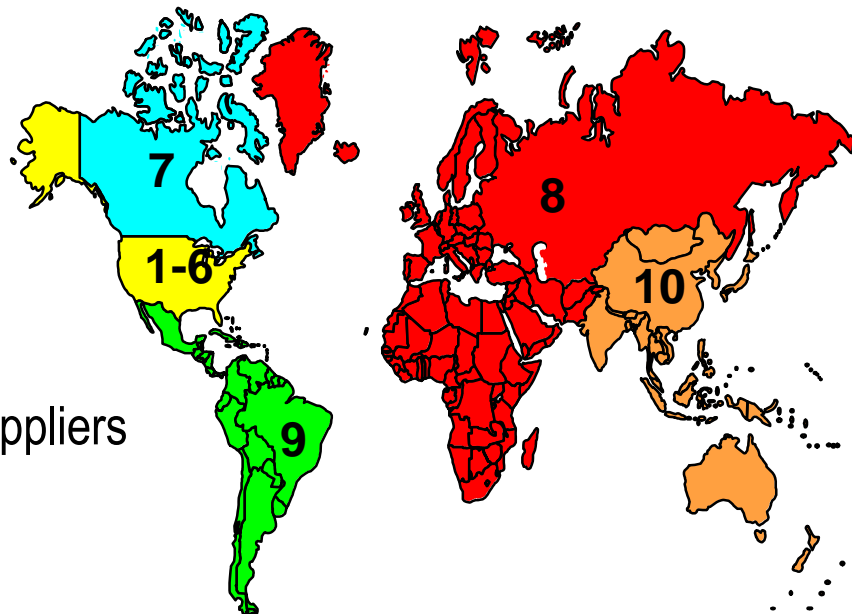


Membership Exceeded 32,000

IEEE PES Membership Depth and Breadth

Benefiting from the strength of our diversity and wide variety of technical backgrounds:

- Utilities, Municipalities and RTOs/ISOs
- Academics and Research
- Equipment Manufacturers and System Suppliers
- Government and Regulatory
- Testing Labs, Consulting and more



Our strength is in attracting wide audiences by creating and implementing new technical ideas and applying best practices through output and initiatives

Benefits of IEEE PES Participation

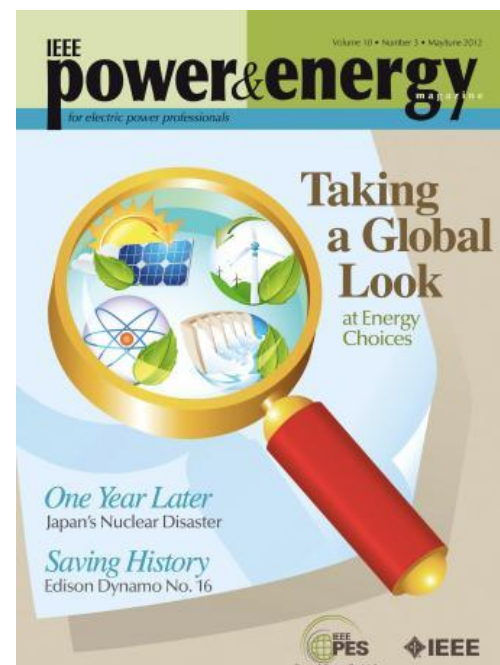
- Learning new skills and technologies and gain information and insight from others through conferences, committee participation, webinars, etc.
 - Cost-effective workforce training, e.g. through attending tutorials
 - Accelerating identification of best practices world-wide for process improvements
- Drive and understand standards and key technical issues: Enhance and protect current and future investments, shape industry practices, gain a voice at the technology table, and influence new developments
 - PES members comprise 10% of overall worldwide IEEE membership but publish app. 50% of all IEEE Standards
- Enabling participants to build a network of professional colleagues for fast access, advice, and problem-solving
- Gain and enhance mentoring, management, and speaking skills

Conferences and Meetings



- Financially Sponsored Conferences around the world
- Partnering for Technically co-sponsored conferences
- International and Regional Scopes
- Emerging Topics

Publications



Education

- **Resources**
 - Tutorials
 - E-Learning Module
 - Plain Talk Courses for Non-Engineers
 - Videos
- **Awards**
 - Increase Senior Member, Fellows, Awards, especially industry and Regions 8, 9 & 10
 - Students
 - Programs – Expanding to Regions 8, 9 & 10
 - Careers and Scholarship Plus

The screenshot shows the IEEE PES website interface. At the top, there are navigation links for IEEE.org, IEEE Xplore Digital Library, IEEE Standards Association, Spectrum Online, and More IEEE Sites. The main header features the IEEE PES logo (Power & Energy Society) and the text "Engineering Electrical Power and Energy". Below the header is a search bar and a navigation menu with categories like About PES, Technical Committees, Meetings & Conferences, Education, Publications, Chapters, Membership, Workforce, and Outreach. The main content area is titled "PES Notable Presentations" and includes a list of presentations from the IEEE PES Transmission & Distribution Conference & Expo (T&D 2012). There are also sidebars for "JOIN PES NOW", "SHOP THE PES STORE", "PES AWARDS", "PAST HIGHLIGHTS", "Related Topics", "Stay up-to-date with the latest advances POWER & ENERGY MAGAZINE", "Society News & Events eNEWS UPDATE", "RECENT ABSTRACTS", and "Announcements".

New Initiatives and Outreach

Community Solutions Initiative -
Low cost, local efforts for electrification
in developing countries

<http://communitysolutionsinitiative.org/>

The banner features the IEEE logo and the text "Lighting Up The World". Below the title are three bullet points: "Sustainability", "Scalable Energy", and "Community Empowerment". The banner is accompanied by three small images: a group of people working on a project, a row of solar panels, and a close-up of a light bulb. Below the banner is a large photograph of a solar panel array mounted on a trailer, with several people standing around it in a rural, hilly area.

19 Technical and 4 Coordinating Committees

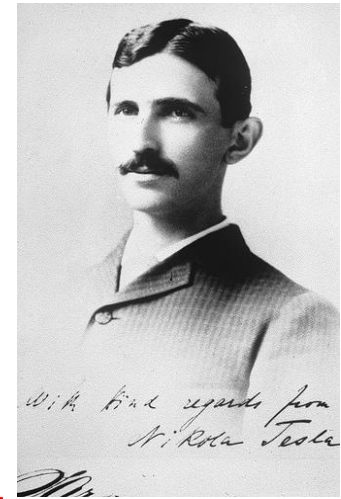
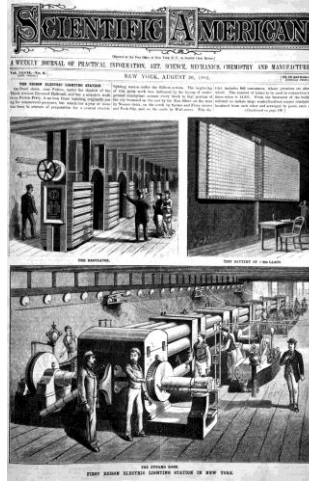
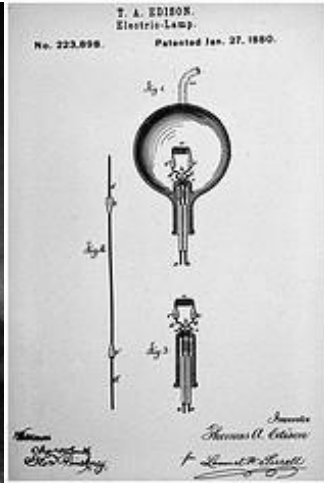
- Electric Machinery
- Energy Development & Power Generation
- Insulated Conductors
- Nuclear Power Engineering
- Power System Analysis, Computing & Economics
- Power System Communications
- Power System Dynamic Performance
- Power System Instrumentation & Measurements
- Power System Operations
- Power System Planning & Implementation
- Power System Relaying
- Stationary Battery
- Substations Committee
- Surge Protective Devices
- Switchgear
- Transformers
- Transmission & Distribution

Coordinating Committees

- Emerging Technologies
- Intelligent Grid
- Marine Systems
- Wind & Solar Power

Standards Coordination

A New Industry: Electric Power & Light



Thomas Edison and his incandescent light patent

Edison's first commercial plant, Pearl St., NY 1882

Samuel Insull built the reliable "power pool", reducing production costs, rates, and increased efficiency

Nikola Tesla, inventor of the induction motor and a comprehensive system for polyphase AC power

- Edison opened his first electric power plant in New York in 1882
Was it a microgrid?
- Within a decade, electric power had spread to every corner of the globe, with many new applications!
- Why was grid interconnected throughout the years?

Cost-effectiveness

Reliability

Safety

IEEE = AIEE + IRE



AIEE (American Institute of Electrical Engineers), established 1884

AIEE elected the following slate of officers on May 13, 1884:

- President: Norvin Green
- Six Vice Presidents: Alexander Graham Bell, Charles A. Gross, Thomas A. Edison, George A. Hamilton, Charles H. Haskins, and Frank L. Pope



IRE (Institute of Radio Engineers), established 1912



AIEE badge, 1893

[Supplement to TRANSACTIONS October 1893]
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
COPPER WIRE TABLE.
 Giving weights, lengths, and resistance of cold, warm, and hot wire, of Matthiessen's standard conductivity, for both A. W. G. (Brown & Sharpe) and B. W. G.

GAUGES	WEIGHT.		LENGTH.			RESISTANCE.		
	30s per 1000 ft.	lbs per 1000 ft.	Per 1000 ft.	Per 1000 ft.	Per 1000 ft.	Per 1000 ft.	Per 1000 ft.	Per 1000 ft.
			50° C.	60° C.	70° C.	50° C.	60° C.	70° C.

which this table has been prepared on as follows—Matthiessen's modified resistivity. Matthiessen's temperature coefficient, specific gravity of copper = 8.9. Resistance in terms of the International unit, defined as a column of pure silver 106.3 cm long, 1 mm diameter, at 100° C. ...
 G. A. HAMILTON, A. E. KENNEDY, Chairman. J. W. LIPP, Jr., Secretary.

First AIEE standard, **1893**



Committee report, 1890



Innovation: Electric Vehicles



- 1891: First successful electric car in the US
- 1893: Different makes exhibited in Chicago
- 1904: ~1/3 of the cars were electrical (photo source: Smithsonian)

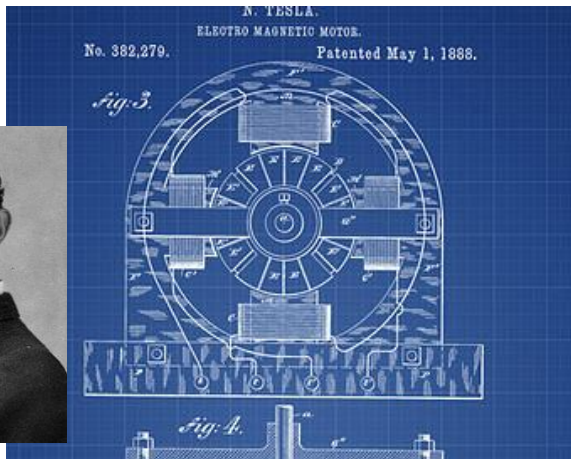
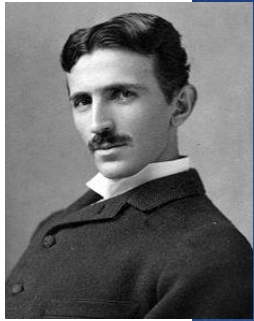
Tesla Motors:

- Leveraged proven technology
- Large financial investments
- Extensive testing
- Realistic expectations
- Sells directly to consumers

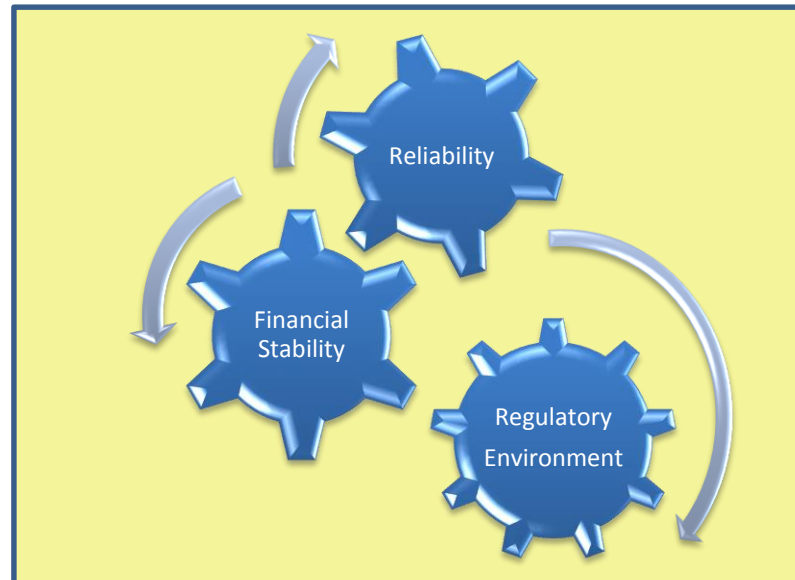
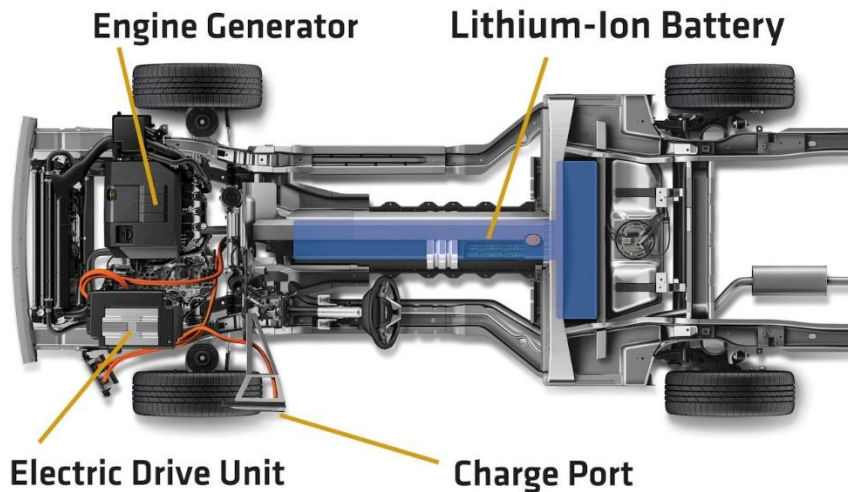
Fisker Automotive:

- Relied on unproven technology & new suppliers
- Limited resources
- Skipped on testing
- Unrealistic pre-order expectations
- Filed for bankruptcy

Engineering for Success



- Highest safety rating
- Zero to 60 mph in 3.2 seconds
- Estimated 270-mile range
- All-Wheel Drive Dual Motor and Autopilot



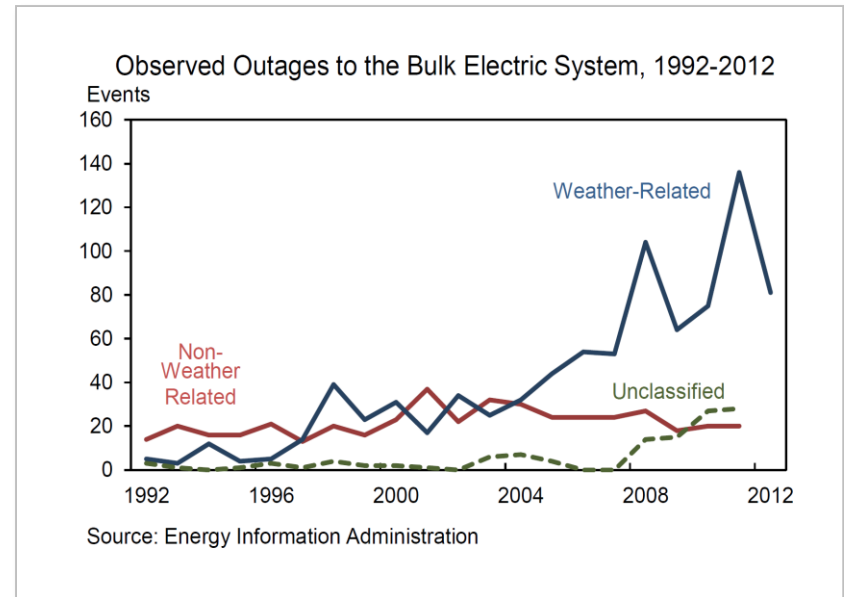
Achieving Grid Resilience

Large investment required - uniquely critical infrastructure providing an "enabling function"

- Asset Management: Aging Infrastructure, Reliability, Hardening, Security (Physical & Cyber)
- Distributed Resources, Microgrids, Electric Vehicles, Storage
- Demand Side Mgmt.
- Distribution Services, Efficiency, and Markets



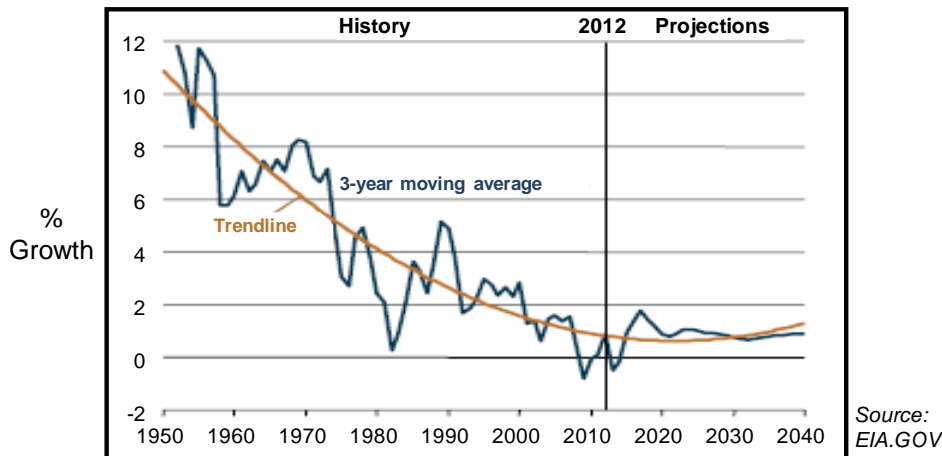
Complex grid structures require "Smart Grid" solutions



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

Grid of the Future: Business Questions

- How to value the use of the T&D system in the presence of renewables?
- Is it cost-effective and appropriate to treat the grid as a “free storage” with no fixed charge for this service?
- What is the future viable utility Business Model? Will there be stranded investment?
- What are the benefits and pre-conditions to implementing DSO?



2012 to 2040 > Typical Home Down 4% (to 11.6 MWh/yr)
2012 to 2040 > Lighting Down 65%

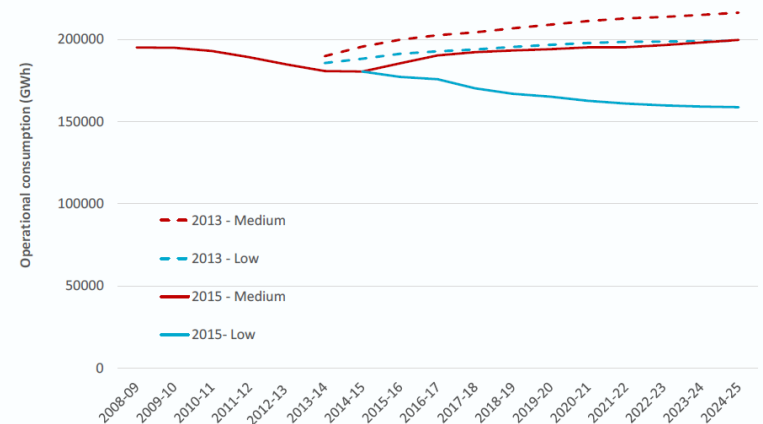
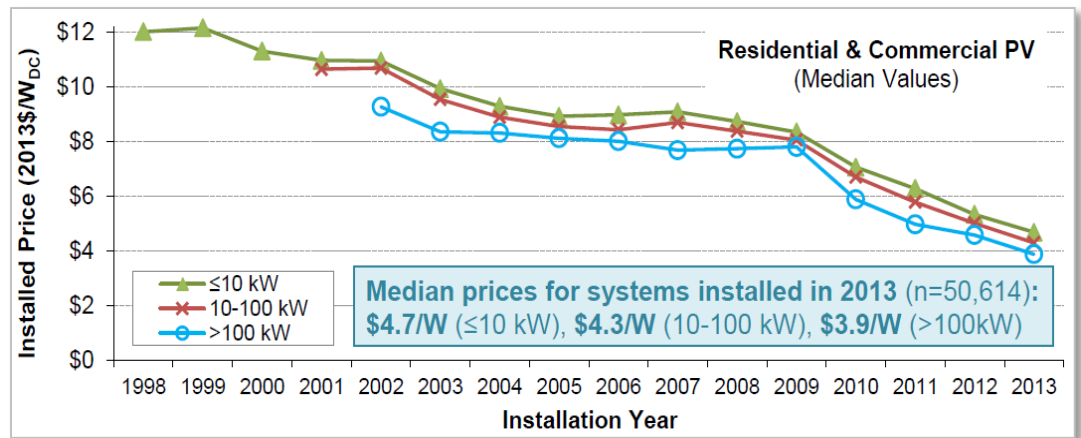


Figure 12: AEMO's 2013 and 2015 medium and low electricity consumption projections

Source: Prof. Simon Bartlett

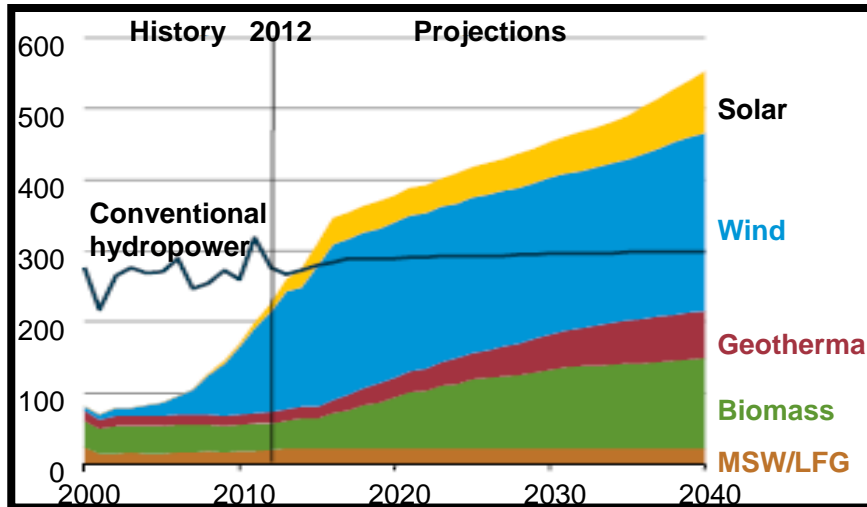
Grid of the Future: Technology Questions

- How would the electric system be designed today using existing technology and knowledge, assuming no existing infrastructure in place?
- How best to deliver remote renewable energy sources to load centers? Is it realistic to build cities close to renewable energy resources?
- Is it more reliable and cost efficient to independently manage local generation (e.g. PV), or to manage these assets in an integrated way?
- Is it more reliable and cost efficient to integrate distributed resources and microgrids?

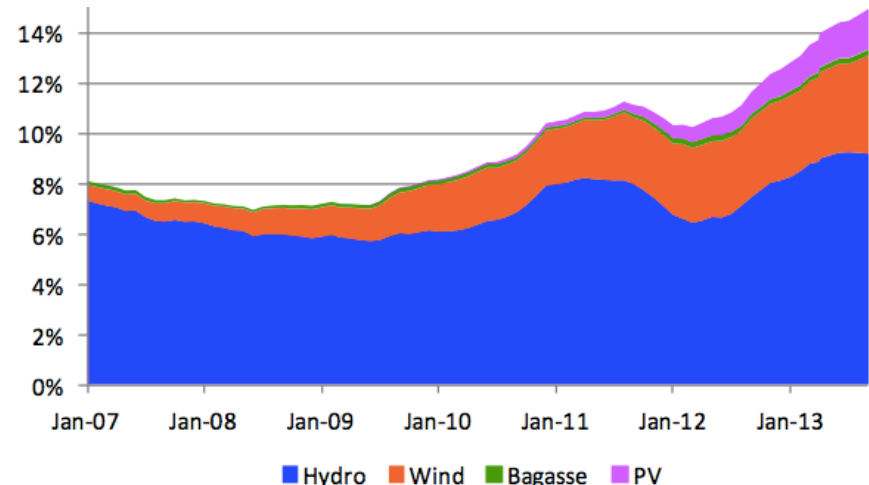


Source: Tracking the Sun VII An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013 http://emp.lbl.gov/sites/all/files/lbnl-6808e_0.pdf

Grid Transformation Drivers



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



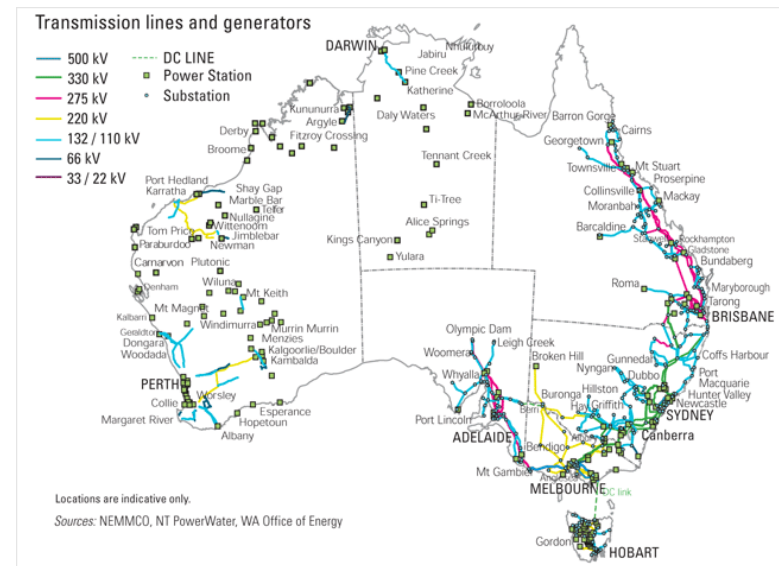
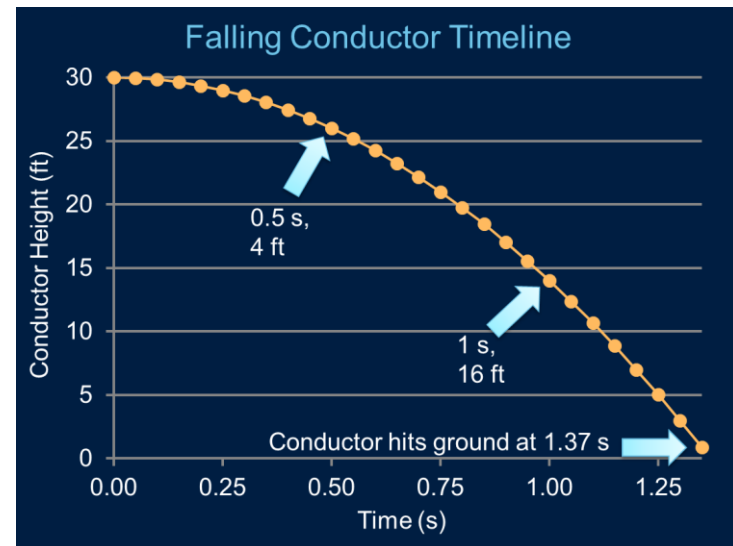
Renewable Sources Growth in Australia, 7% in 8 years

Source: Prof. Simon Bartlett

- Smart Grid Investments
- Microgrids, "behind the meter" distributed energy resources and Electrical Vehicles require a robust, hybrid T&D grid – Grid connection required for reliability and market reach
- Smart Cities - How will electrical system help improve the livability, workability and sustainability

Smart Grid Investments

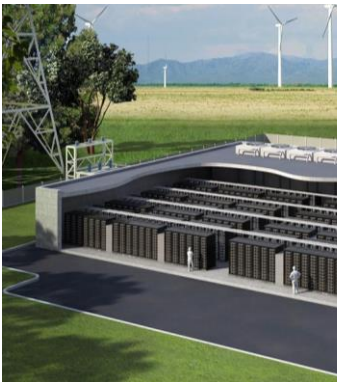
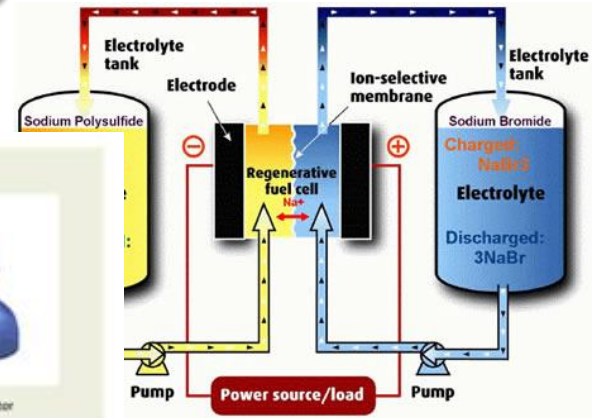
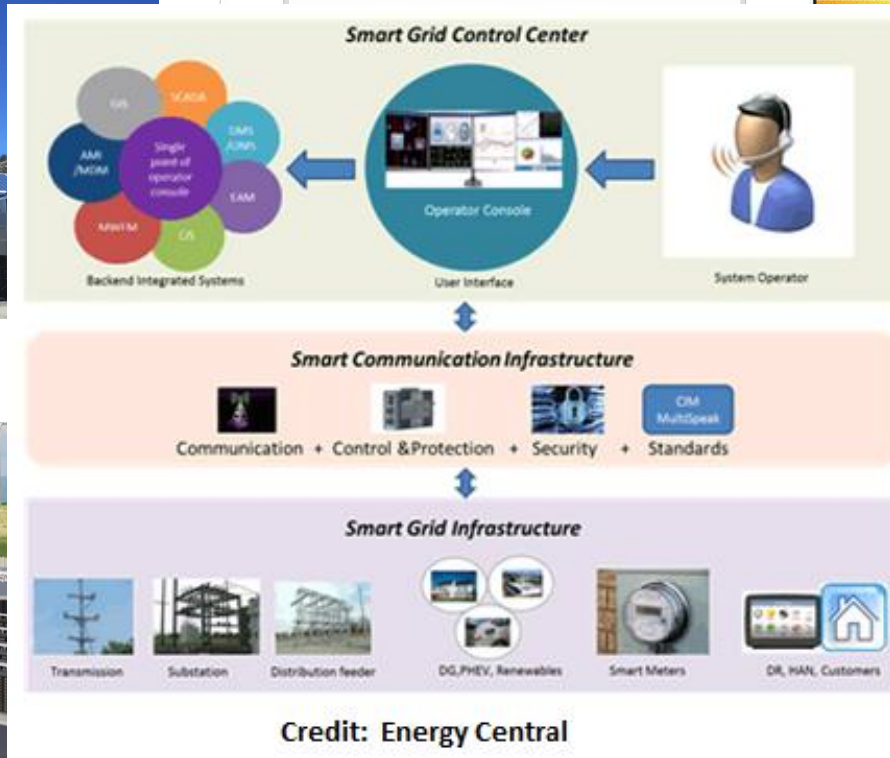
- Transmission made smarter with enhanced monitoring, protection & control
 - Synchronized Phasor Measurements
 - Wide-area protection coordination
- Distribution transformed with automation & feeder optimization
 - Vol-VAR control
 - Catching a conductor before it hits the ground
- Demand response w/smart meters
- Utility grade battery storage



Innovative Technologies

LG Shows Smart Appliances at CES

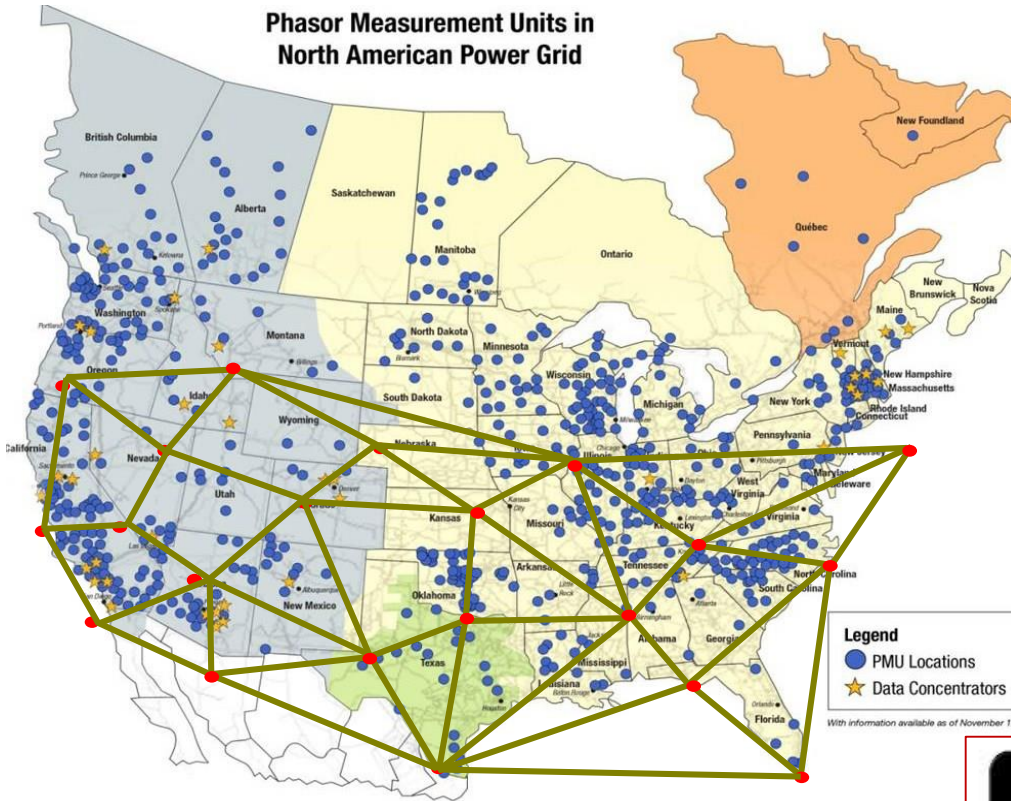
January 4, 2011
By Steven Castle



Next Generation Monitoring and Control

Highly Instrumented Advanced Sensors & Computing

Phasor Measurement Units in North American Power Grid



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

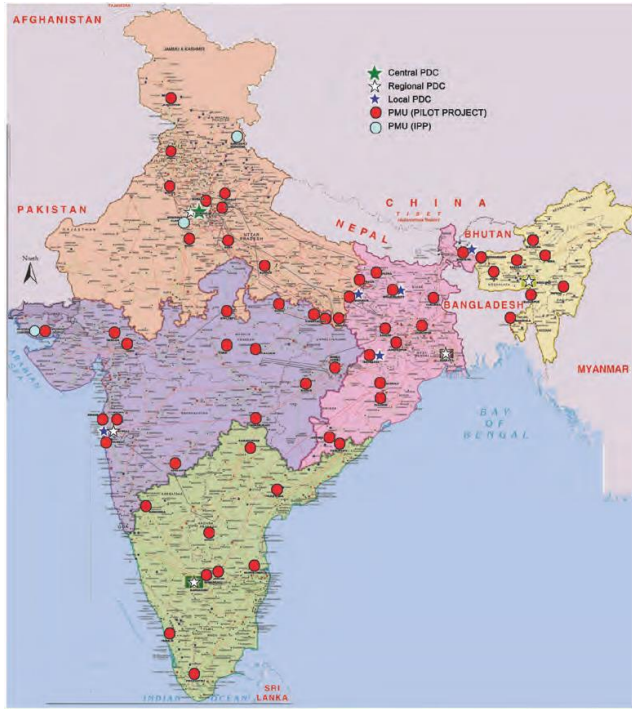
Precise grid measurements (within 1 ms) using GPS signals - Phasor Measurement Units (PMUs)

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

Source: North American Synchro-Phasor Initiative (NASPI)



International Synchophasor Deployment

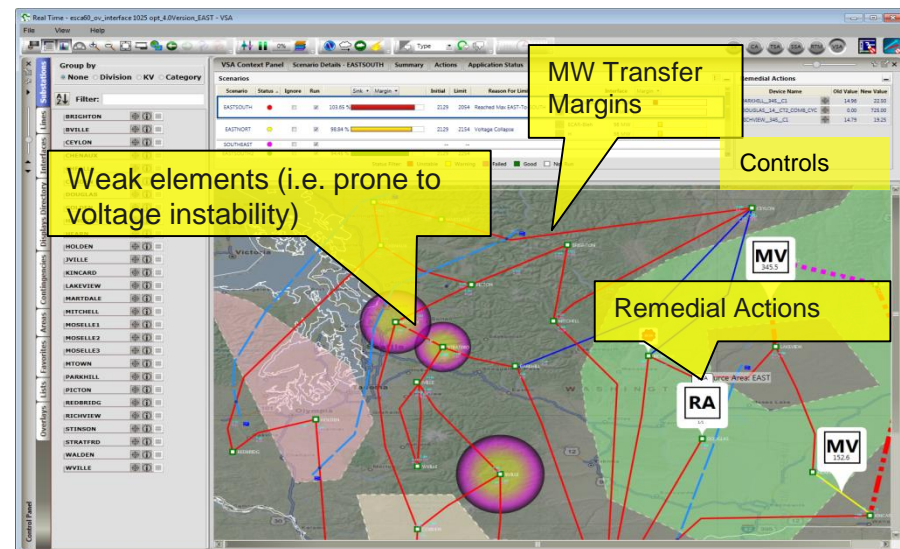
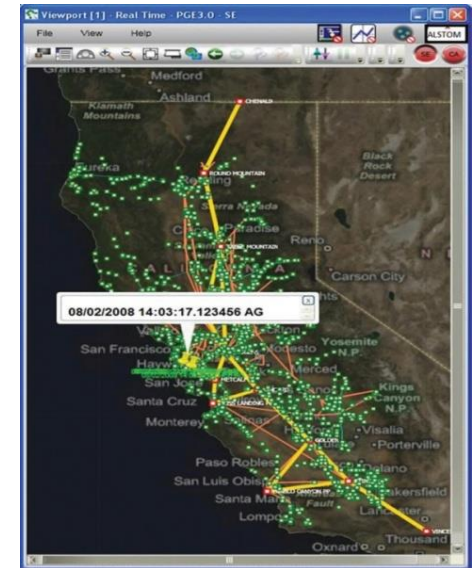


Source: Power system operation India –
"Synchrophasors in India" Dec 2013

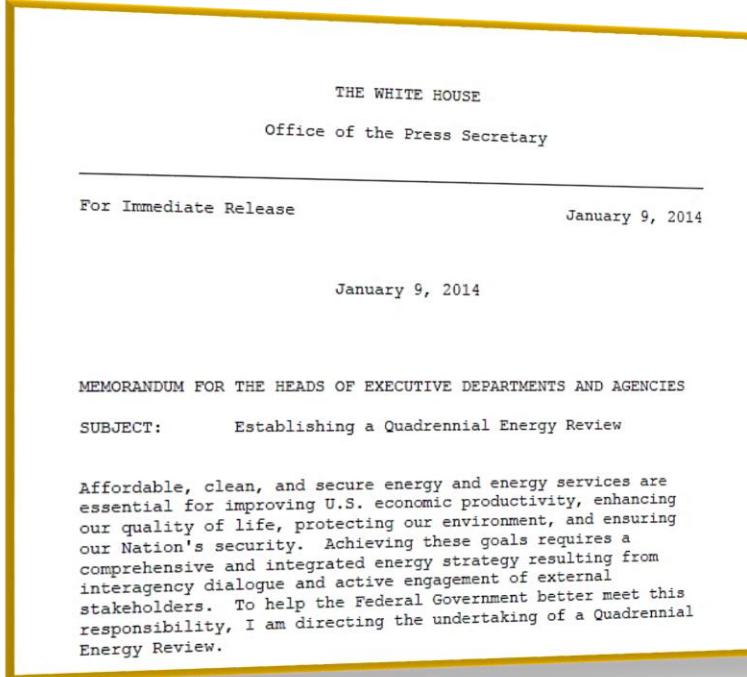
- China has installed PMUs in more than a thousand 500/230 kV substations and number continues to grow
- India is installing 1,732 PMUs
- Latin America
 - Colombia – Deployed applications for improved grid observability and reliability
 - Ecuador – Deployed System Integrity Protection Scheme using PMUs
 - Brazil - ONS is procuring the system
- Europe and Australia have started installations

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



Presidential Memorandum



“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

- **Integrated view** of short-, intermediate-, long-term objectives for Federal energy policy;
- **Outline of legislative** proposals to Congress;
- **Executive actions** (programmatic, regulatory, fiscal, etc.) across multiple agencies;
- **Resource requirements** for RD&D and incentive programs; and
- **Strong analytical base** for decision-making.
- **First year focus** on TS&D infrastructure including: electricity transmission and distribution systems, liquid and gas pipelines, export infrastructure; interdependencies; climate and environment.

Source: DOE

IEEE JOINT TASK FORCE ON QUADRENNIAL ENERGY REVIEW

U.S. DOE has requested IEEE to provide insights on a specific set of priority issues

- The implications and importance of aging infrastructure and the options for addressing these challenges, including asset management
- Effects of renewable intermittency on the grid and the 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
- Recommendations for metrics for Smart Grid issues, determine the importance and necessity of protocols
- Skilled workforce issues

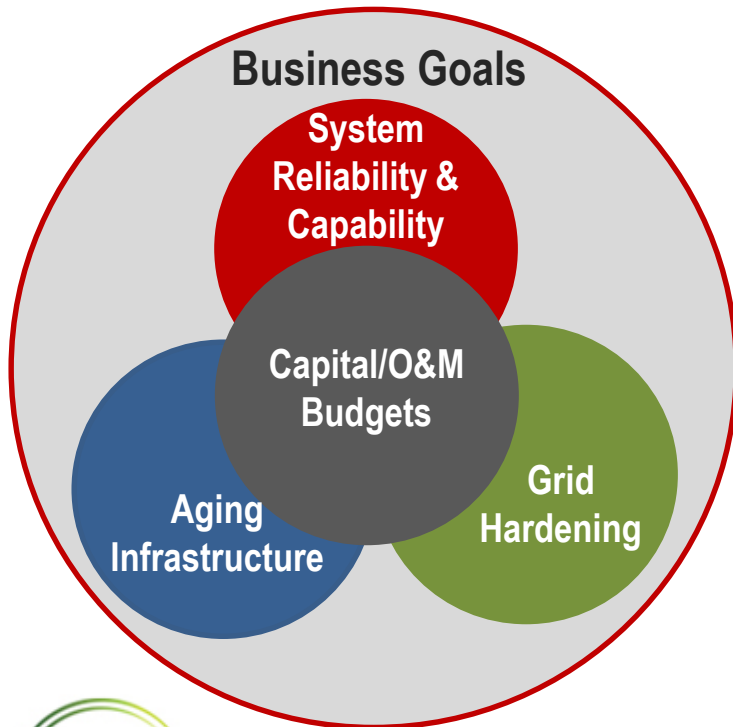
Started in May 2014 and submitted report on September 5th 2014 -

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

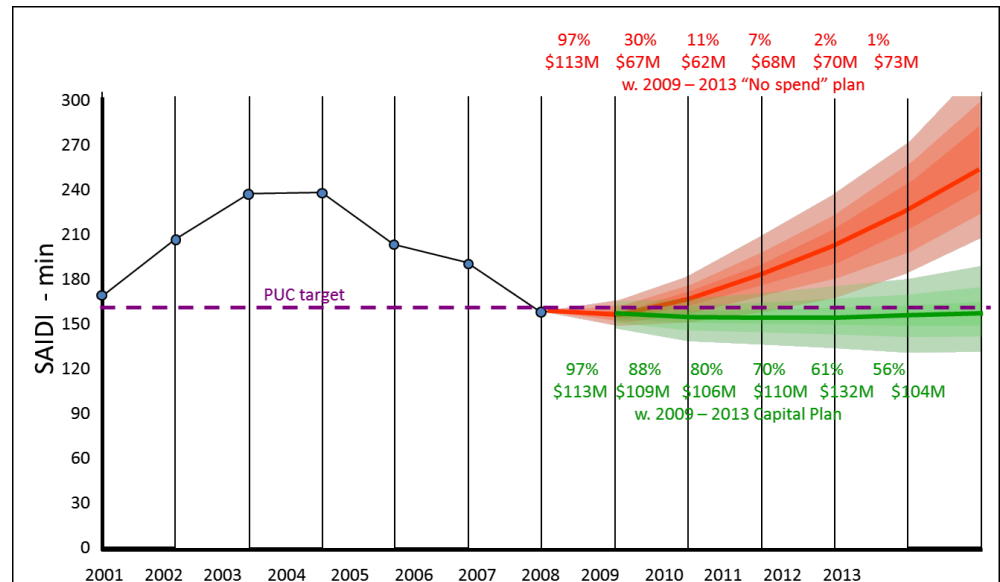
Holistic Asset Management

Average systems 40 to 60 years old - Maintenance needs to double over next 10-20 y

**Asset Management:
Predictability of Cost
& Reliability**

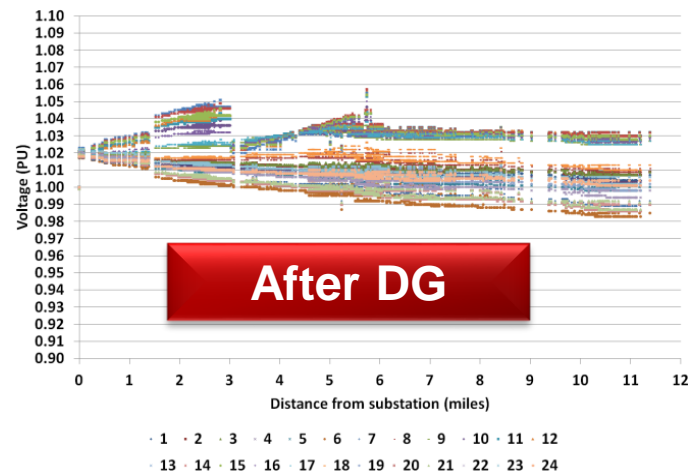
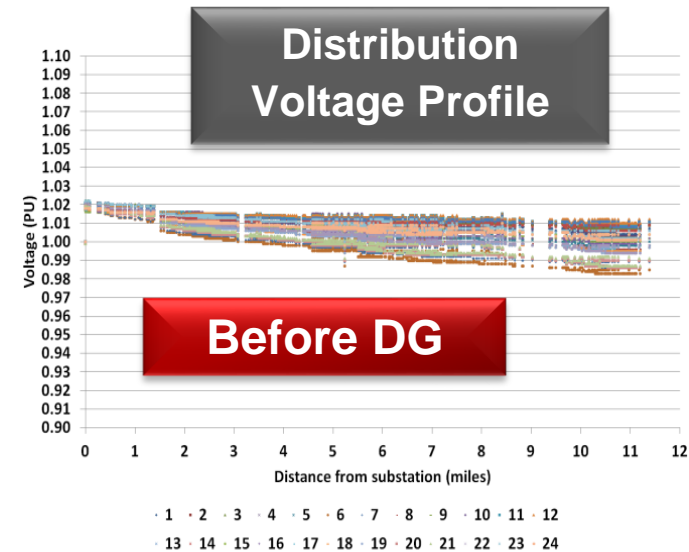


- Many projects competing for more funding than spending plan can provide
- Methodologies to compare and optimize the competing project priorities
- Strategies for Smart Grid assets



Renewable Intermittency and Storage

- **Grid Level:** Uncertainty of renewable sources can be tolerated at penetration levels around 30% (system studies & real world experience)
 - Traditional power system planning and operations need to be updated, incl. cooperation among balancing areas
 - 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 of renewable DG creates challenges; solutions include
 - Low-cost distributed storage systems
 - Advanced power electronics technologies
 - Real-time monitoring, control and automation



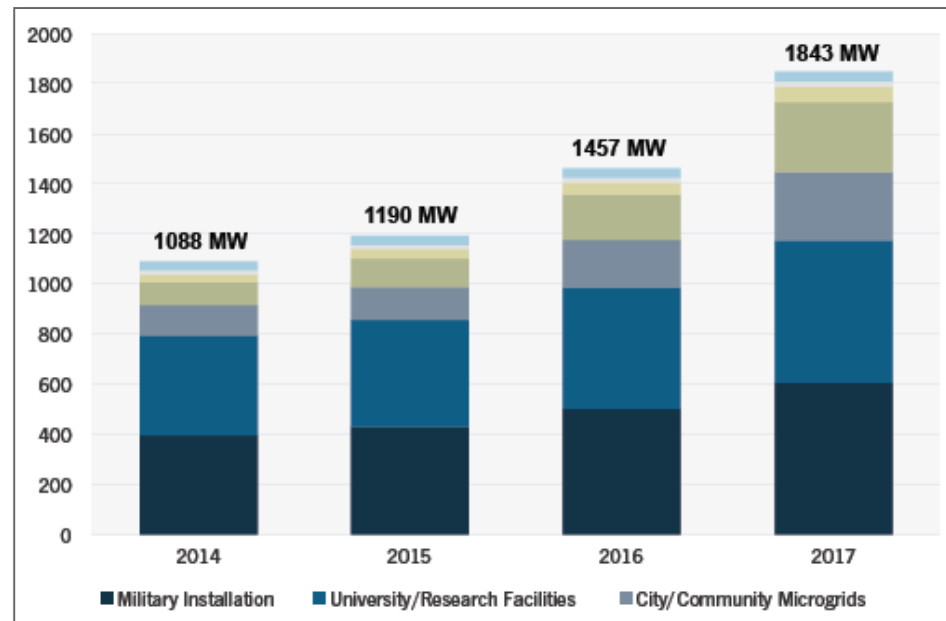
Microgrid Benefits

- **Capacity, Reliability and Power Quality**
 - A low-cost augmentation/alternative to a utility system
 - Controlling power quality and reliability locally
 - Outage management for critical, premium, remote customers (e.g. weather related events)
- **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
- **Sustainability** – Optimal dispatch of renewables and high community involvement
 - Emissions reduction and green marketing
 - Demand-side management
- **Cost Savings** – Portfolio of resources managed locally, but optimized on the system level



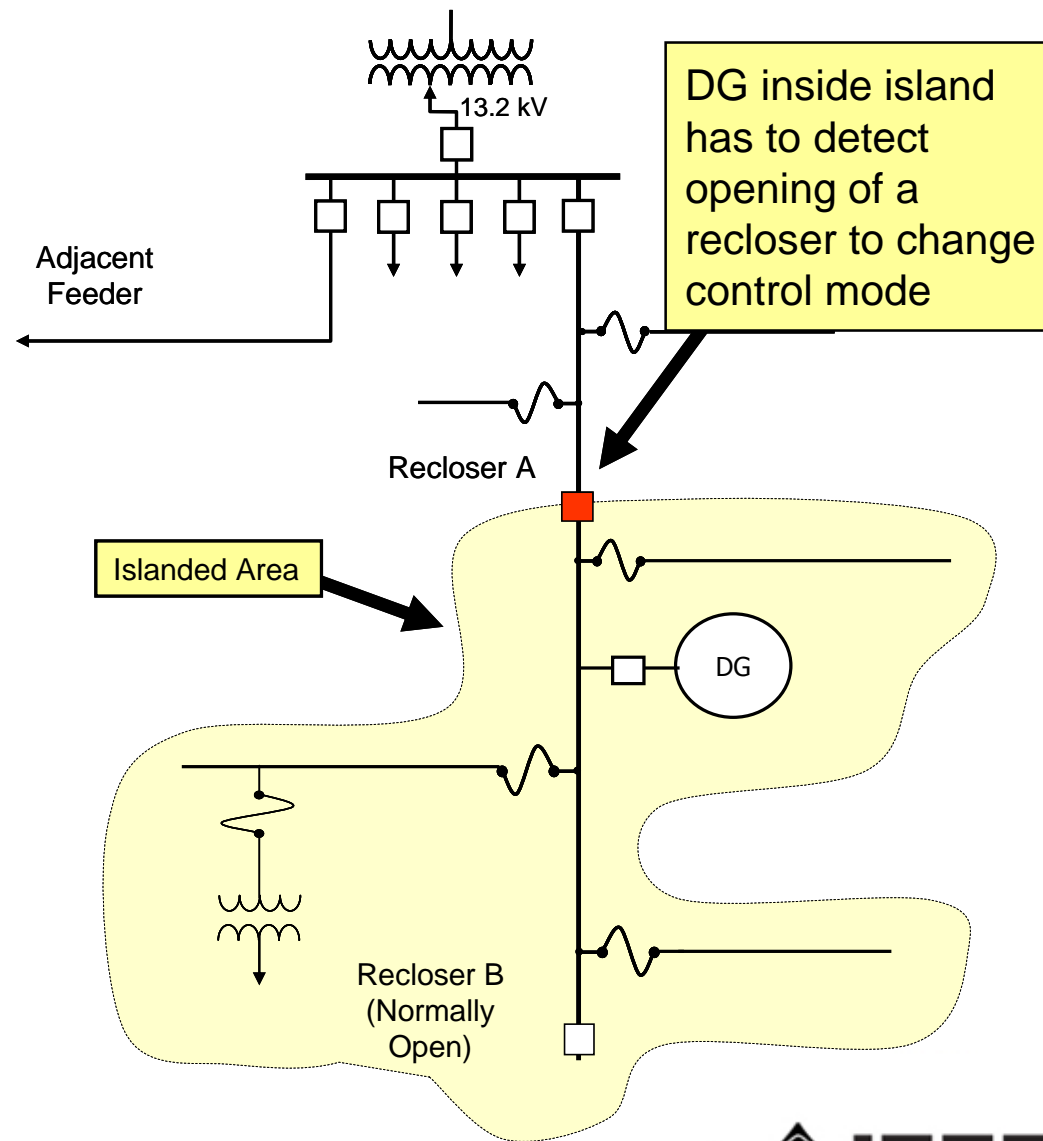
Optimized Hybrid Microgrids

- Utility grid and microgrids must work synergistically to fulfill all the needs - serving all the load all the time
- Assessing costs should include efficiency, reliability, safety, optimizing life-cycle costs, and system resilience
- New tools and Standards, e.g. **IEEE 1547 Series, Microgrid Controller**
 - Frequency regulation
 - Voltage control



Microgrid Protection Aspects

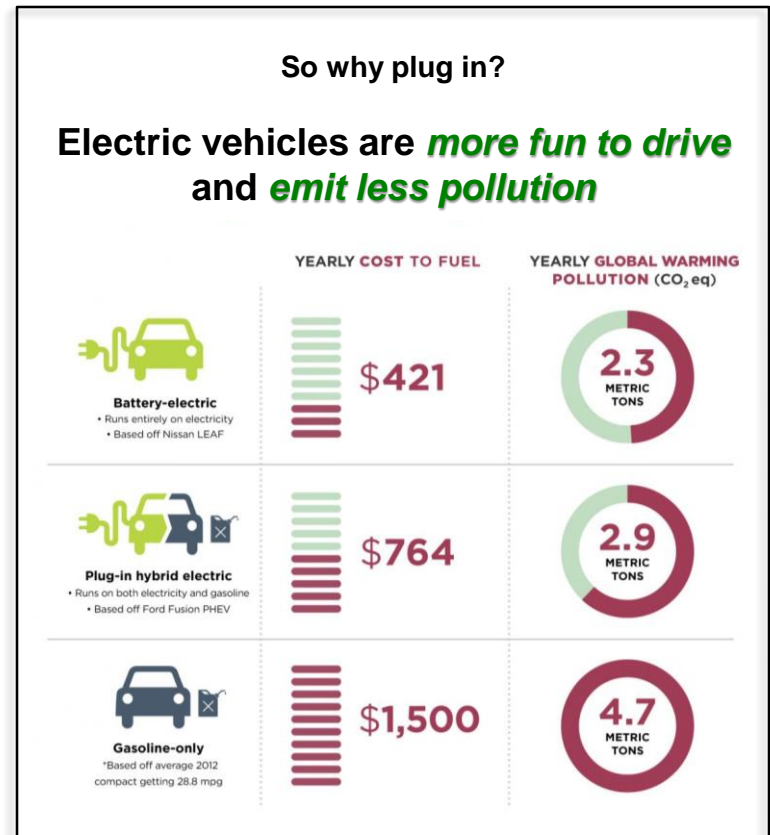
- Grid connected DG protection issues
- Island detection (disconnected from main grid) - Transition issue
- Protection during islanding
 - Not enough short circuit current
 - Re-coordination (change in zones)
- New schemes:
 - Communication based
 - Negative Seq. method
 - PMU based



Integrating PEV

About 330,000 PEVs on the road

- Generation and transmission systems can handle millions of plug-in electric vehicles
- Good understanding of technical issues 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




Adapted from "Survey Says: Over 40% of American Drivers Could Use an Electric Vehicle," Union of Concerned Scientists,

Recommendations

- Charging infrastructure
- Grid interface standards: sizing/implementation for grid equipment, remote control system technology, communications, use of batteries during disasters
- Batteries and power electronics
- Grid/load modeling and forecasting
- Integrated demand response and transactive energy


How long does it take to charge the battery for 32 miles?

Level-1 in 8 hours



\$300 cord comes with all EVs and outlets exist

Level-2 in 2 hours



\$2,000 installed

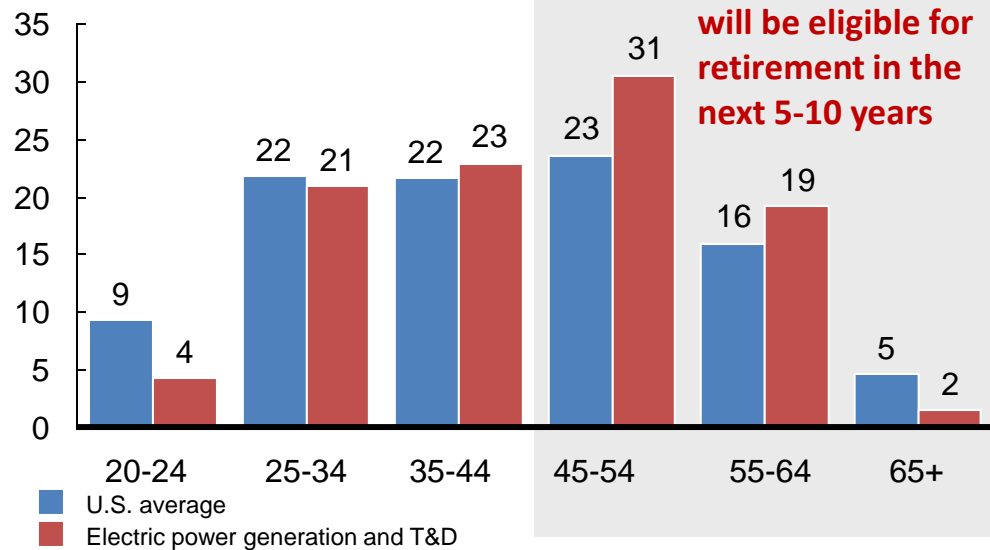
Source: Bob Bruninga, IEEE Transportation Committee, <http://aprs.org/payin-to-plugin.html>

Skilled Workforce

- Perfect Storm: Aging Workforce + Aging Assets = Reliability Decline
- Requirement: Programs to attract, train and develop engineers, linemen, station electricians, protection/control resources, and other technical resources
- Workforce implications and educational or training needs should be considered as integral factors of research and policy initiatives

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

% of workers by age group, 2011



...limiting the labor pool for utilities

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

Critical Needs

- **Software/Models**

- Tools & models for integrated systems analysis & operation

- **Standards**

- Big data handling, stream computing, and analytics
- Interconnection

- **Policy**

- Devices that operate across institutional, regulatory, and information boundaries

Data Analytics: Forensics to Identify Sequence of Events
Example, PG&E: May 30th, 2013



Preparing for the Grid of the Future

- Developing business and technology roadmaps
- Addressing and preparing for various scenarios
- Deploying pilot projects to test and prepare for changes
- Developing and applying industry standards
- Developing a skilled workforce



Source: ComEd

Speed and success will depend on clear and balanced regulatory policies to promote safe, cost-effective, and reliable deployment of technologies

Future Grid Roadmap



Demand For Electricity Will Increase

- ✓ Population growth, electric vehicles, use of renewables, etc.

Fuel Transformation Will Occur

- ✓ Dash to natural gas, renewable surge, plant retirements

G, T & D Investment Will Increase

- ✓ Infrastructure *Investment* – U.S. 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 Economic Goals Met

- ✓ Sustainability and support of growing economy