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Smart Grid R&D Perspectives from the US

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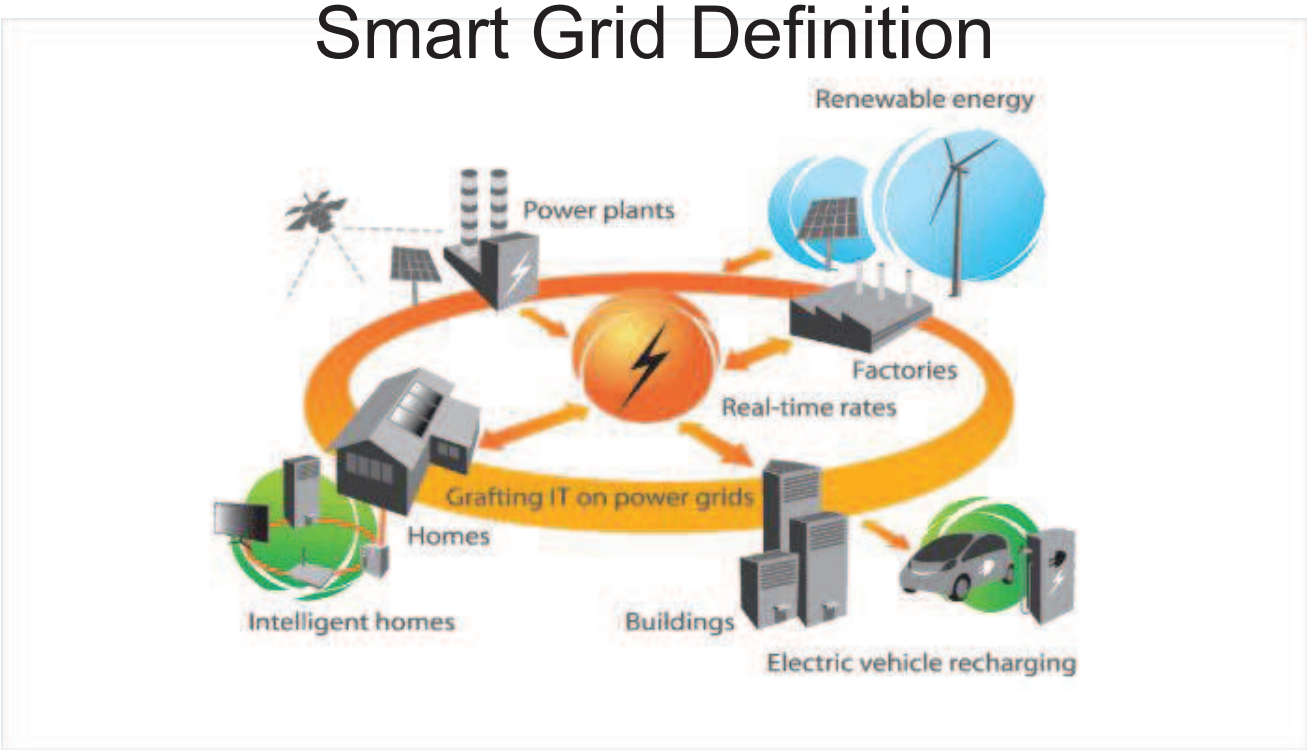
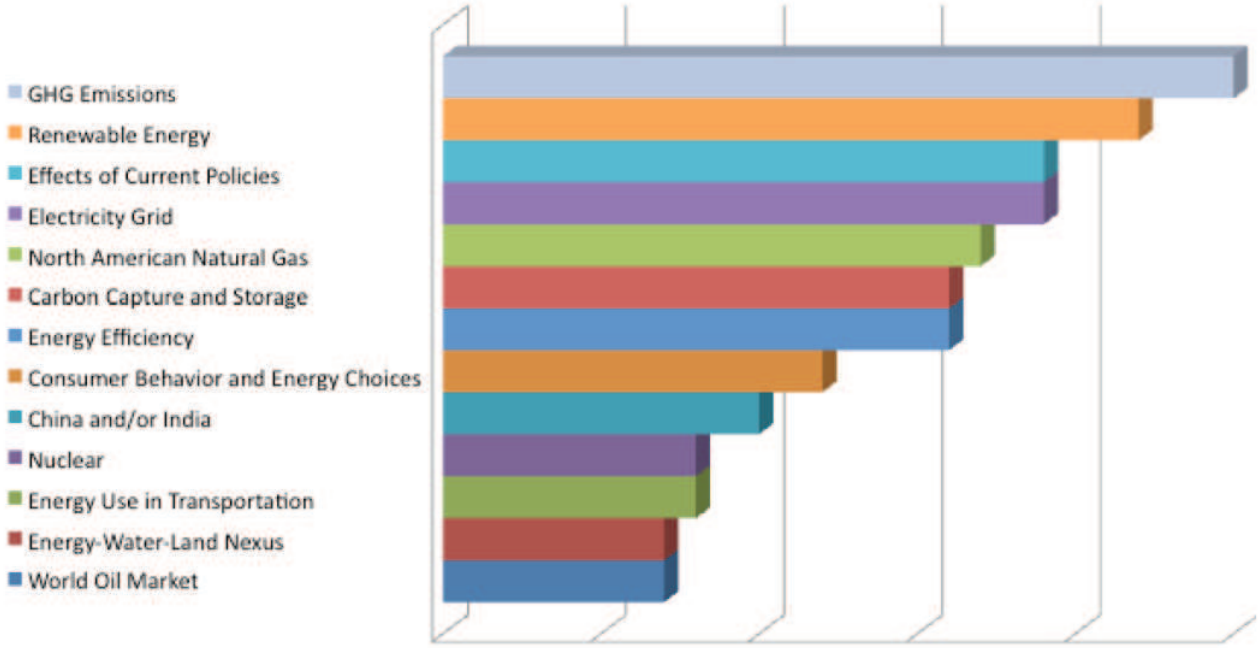
Smart Grid Definition



〈 The definition of Smart grid 〉

Source: http://smartgrid.jeju.go.kr/eng/images/sub01/definition.gif

2010 US Energy Policy Survey



Source: Brown et al.: Perspectives on Energy Policy and Economic Research: Results of a Survey

Smart Grid Technologies

- Integrated communications
- Sensing and measurement
- AMI and Smart meters
- Phasor measurement units (Synchrophasors)
- Advanced components
- Advanced control (real-time)
- Improved interfaces and decision support
- Smart power generation

Source: wikipedia.com

Some Research Activities

- ***IntelliGrid*** – Created by the Electric Power Research Institute (EPRI).
- The IntelliGrid Consortium is a public/private partnership that integrates and optimizes global research efforts, funds technology R&D, works to integrate technologies, and disseminates technical information.
- IntelliGrid architecture provides tools and recommendations for standards and technologies for utility use in designing IT-based systems, such as advanced metering, distribution automation, and demand response.
- Several utilities have applied IntelliGrid architecture including Southern California Edison, Long Island Power Authority, Salt River Project, and TXU Electric Delivery.

Source: wikipedia.com

Some Research Activities

- Modern Grid Initiative (MGI) is a collaborative effort between the U.S. Department of Energy (DOE), the National Energy Technology Laboratory(NETL), utilities, consumers, researchers, and other grid stakeholders to develop a common, national vision to modernize the U.S. electrical grid.
- MGI supports demonstrations of key systems and technologies that serve as the foundation for an integrated, modern power grid.
- DOE's Office of Electricity Delivery and Energy Reliability (OE) sponsors the initiative, which builds upon Grid 2030 and the National Electricity Delivery Technologies Roadmap and is aligned with other programs such as GridWise and GridWorks.

Source: wikipedia.com

Some Research Activities

- ***Grid 2030*** – Grid 2030 is a joint vision statement for the U.S. electrical system developed by the electric utility industry, equipment manufacturers, information technology providers, federal and state government agencies, interest groups, universities, and national laboratories.
- It covers generation, transmission, distribution, storage, and end-use. The National Electric Delivery Technologies Roadmap is the implementation document for the Grid 2030 vision.
- The Roadmap outlines the key issues and challenges for modernizing the grid and suggests paths that government and industry can take to build America's future electric delivery system.

Source: wikipedia.com

Some Research Activities

- GridWise – A DOE OE program focused on developing information technology to modernize the U.S. electrical grid.
- Working with the GridWise Alliance, the program invests in communications architecture and standards; simulation and analysis tools; smart technologies; test beds and demonstration projects; and new regulatory, institutional, and market frameworks.
- The GridWise Alliance is a consortium of public and private electricity sector stakeholders, providing a forum for idea exchanges, cooperative efforts, and meetings with policy makers at federal and state levels.

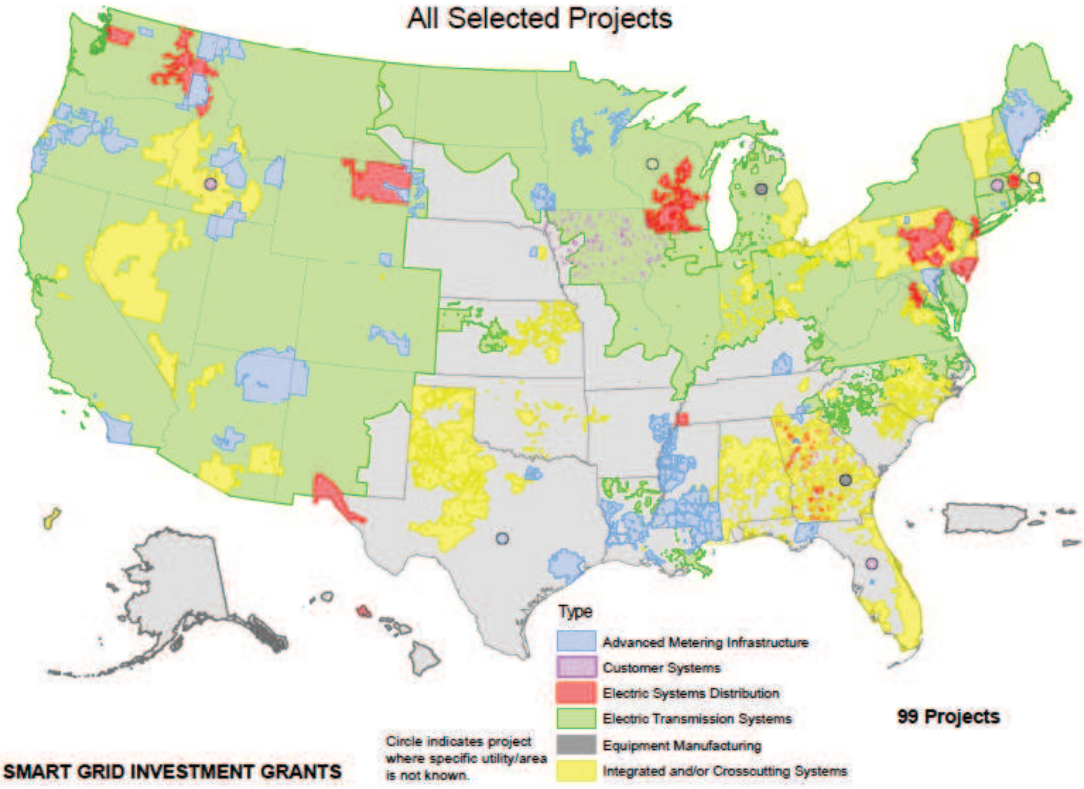
Source: wikipedia.com

Some Research Activities

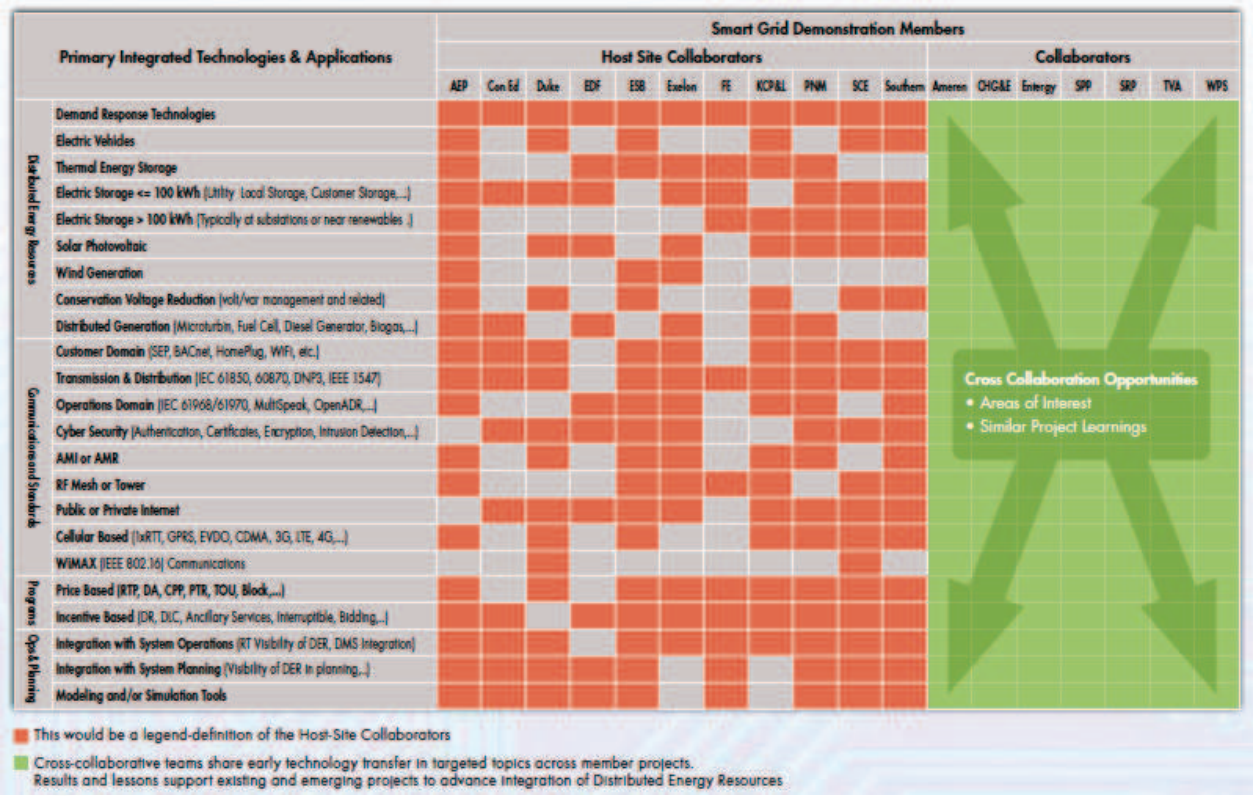
- ***GridWorks*** – A DOE OE program focused on improving the reliability of the electric system through modernizing key grid components such as cables and conductors, substations and protective systems, and power electronics.

- The program's focus includes coordinating efforts on high temperature superconducting systems, transmission reliability technologies, electric distribution technologies, energy storage devices, and GridWise systems.

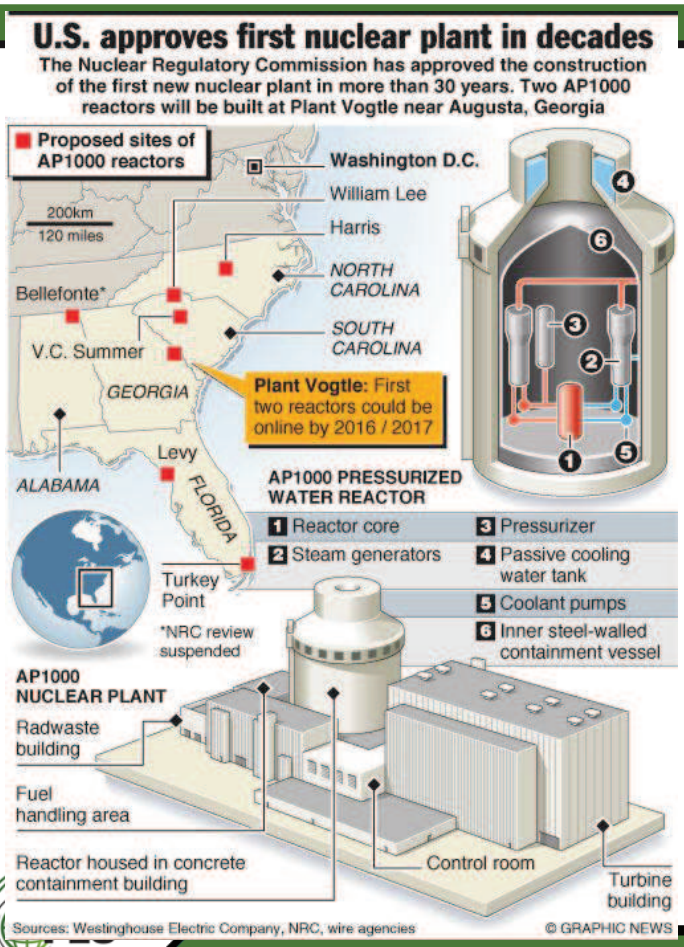
Source: wikipedia.com



Source: wikipedia.com



Source: EPRI

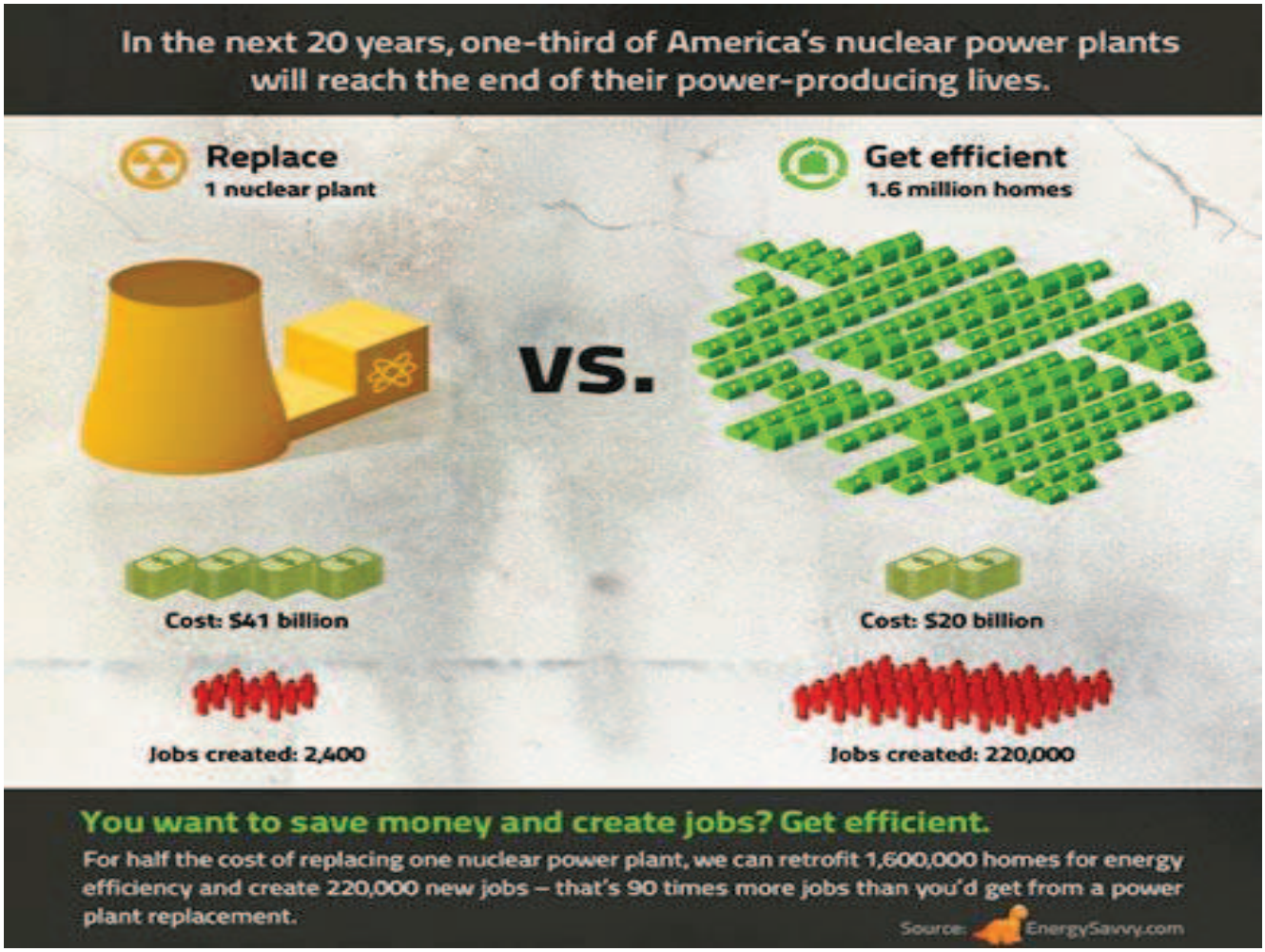


Five new nuclear reactors approved in US (for the first time in 34 years):

Plant Vogtle (GA, two reactors)

Summer (SC, two reactors)

Watts Bar II TN, (one reactor)



Utility Perspective

- Wide area (broader) regional markets
- Wide area transmission planning
- Wide area monitoring of real-time system behavior
- Developing a new generation of critical thinkers in fields of energy and computing

Source: Dejan Sobajic, New York ISO

Transmission Planning

- Calibration of Dynamic System Models (DOE ARRA)
  - Development of a systematic process and qualified staff
  - Increased confidence in conclusions of dynamic system studies
  - Prerequisite for wide area real time system controls
- Controlled System Separation (DOE ARRA)
  - Development and testing of online algorithms for CSS taking advantage of time-synchronized dynamic system data
- Modeling using Dynamic Phasors
  - Bridging the gap between electromagnetic and electromechanical simulations
  - Analysis and control of periodic steady-states.

Source: Dejan Sobajic, New York ISO

System Operations

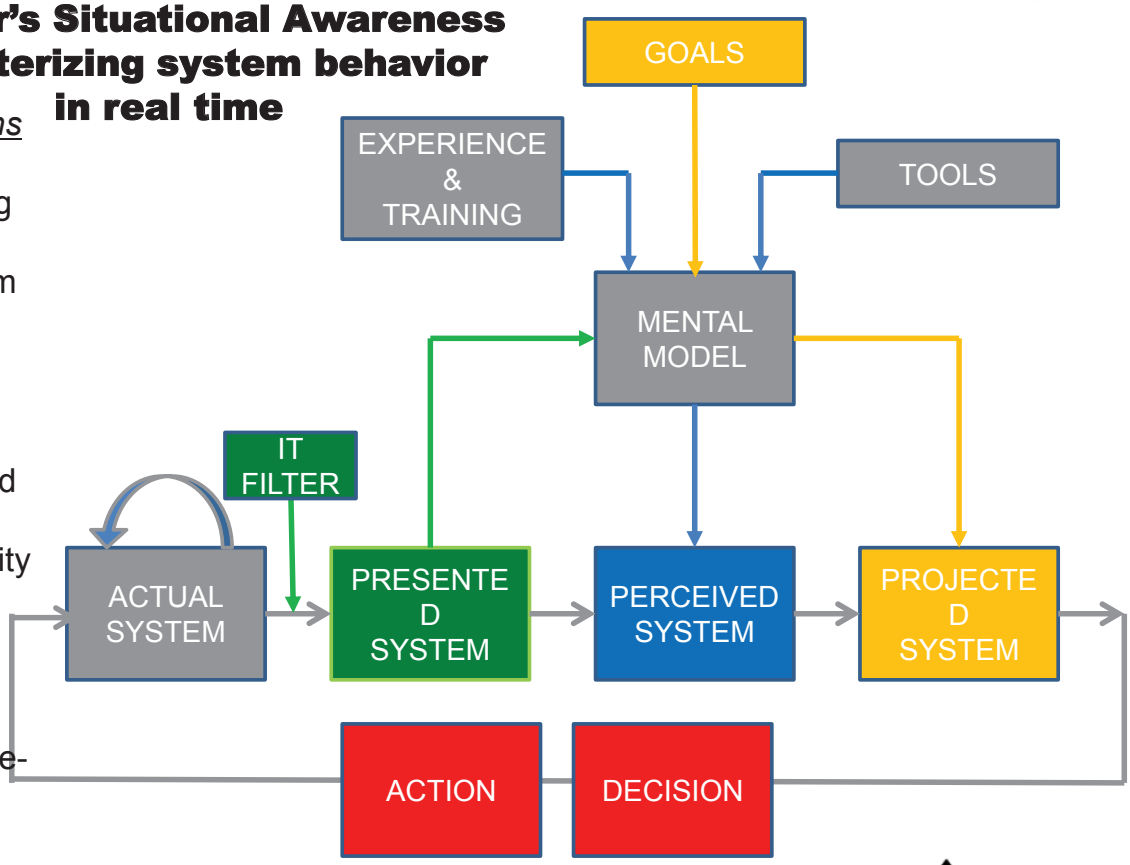
- Monitoring and Control of Voltage Profile in the Grid (DOE ARRA)
  - 800MVar of installed smart-grid enabled capacitor banks
  - Maximum Loadability Monitor
- Enhanced Operator's Wide Area Situational Awareness (DOE ARRA)
  - Maintain the 'big picture' and think ahead
  - Situational awareness is a function of time
  - Situational awareness
    - Individual
    - Shared (ISO-TO, ISO-ISO)

Source: Dejan Sobajic, New York ISO

Operator's Situational Awareness Characterizing system behavior in real time

SA Demons

- Attention narrowing
- Limited short term memory
- Fatigue
- Data overload
- Misplaced salience
- Complexity creep
- Errant mental models
- Out-of-the-loop

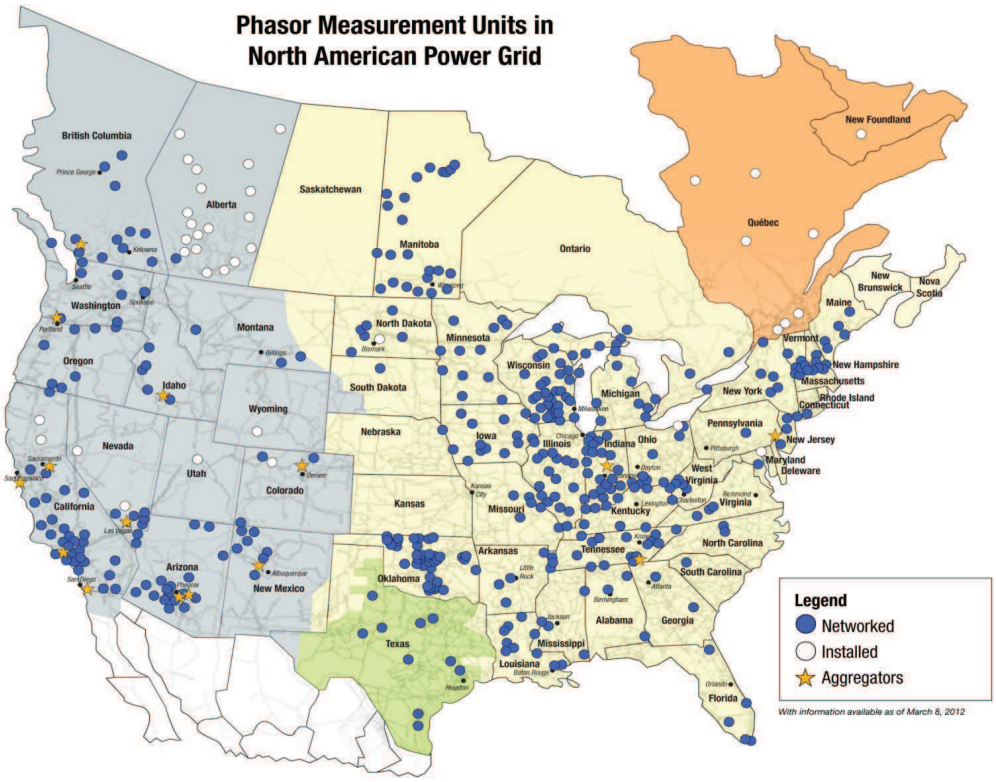


Source: Dejan Sobajic, New York ISO

Next Generation of Critical Thinkers

- Companies are interested in supporting new power programs at local universities
- Funding internship programs
- Re-examine roles of IEEE, EPRI, PSERC, etc… in this process

Source: Dejan Sobajic, New York ISO



Source: U.S. Energy Information Administration

Approved IEEE Smart Grid Standards

1020-2011 IEEE Guide for Control of Small (100 kVA to 5 MVA) Hydroelectric Power Plants

1031-2011 IEEE Guide for the Functional Specification of Transmission Static Var Compensators

1127-1998 IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility

1366-2012 IEEE Guide for Electric Power Distribution Reliability Indices

1138-2009 IEEE Standard for Testing and Performance for Optical Ground Wire (OPGW) for Use on Electric Utility Power Lines

1159.3-2003 IEEE Recommended Practice for the Transfer of Power Quality Data

1222-2003 IEEE Standard for All-Dielectric Self-Supporting Fiber Optic Cable

1247-2005 IEEE Standard for Interrupter Switches for Alternating Current Rated Above 1000 Volts

1250-1995 IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

1250-2011 IEEE Guide for Identifying and Improving Voltage Quality in Power Systems

1325-1996 IEEE Recommended Practice for Reporting Field Failure Data for Power Circuit Breakers

Approved IEEE Smart Grid Standards

1379-2000 IEEE Recommended Practice for Data Communications Between Remote Terminal Units and Intelligent Electronic Devices in a Substation

1402-2000 IEEE Guide for Electric Power Substation Physical and Electronic Security

1409-2012 IEEE Guide for the Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV Through 38 kV

1453-2004 IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

1459–2010 IEEE Standard Definitions for the Measurement of Electric Power Quantities under Sinusoidal Non-Sinusoidal Balanced or Unbalanced Conditions

1471-2000 IEEE Recommended Practice for Architectural Description for Software- Intensive Systems

1547-2003 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

1547.1-2005 IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

1547.2-2008 IEEE Application Guide for IEEE Std 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

1547.3-2007 IEEE Guide For Monitoring, Information Exchange, and Control of Distributed Resources Interconnected With Electric Power Systems

1547.4-2011 IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

Approved IEEE Smart Grid Standards

1547.6-2011 IEEE Recommended Practice For Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks

1590-2009 IEEE Recommended Practice for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Using Optical Fiber Systems

1591.1-2012 IEEE Standard for Testing and Performance of Hardware for Optical Groundwire (OPGW)

1591.3-2011 IEEE Standard for Qualifying Hardware for Helically-Applied Fiber Optic Cable Systems (WRAP Cable)

1615-2007 IEEE Recommended Practice for Network Communication in Electric Power Substations

1646-2004 IEEE Standard Communication Delivery Time Performance Requirements for Electric Power Substation Automation

1675-2008 IEEE Standard for Broadband over Power Line Hardware

1686-2007 IEEE Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities

1701-2011 IEEE Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables Systems with Electric Power Systems

1702-2011 IEEE Standard for Telephone Modem Communication Protocol to Complement the Utility Industry End Device Data Tables

1703-2012 - IEEE Standard for Local Area Network/Wide Area Network (LAN/WAN) Node Communication Protocol to Complement the Utility Industry End Device Data Tables

1711-2010 IEEE Trial Use Standard for a Cryptographic Protocol for Cyber Security of Substation Serial Links

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1775-2010 IEEE Standard for Powerline Communication Equipment - Electromagnetic Compatibility (EMC) Requirements - Testing and Measurement Methods

1808-2011 - IEEE Guide for Collecting and Managing Transmission Line Inspection and Maintenance Data

1815-2010 IEEE Standard for Electric Power Systems Communications -- Distributed Network Protocol (DNP3)

1901-2010 IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications

2030-2011 IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads

367-1996 IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault

487-2007 IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Stations

644-1994 IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines

656-1992 IEEE Standard for the Measurement of Audible Noise from Overhead Transmission Lines

80-2000 IEEE Guide for Safety in AC Substation Grounding

802-2001 IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture

802.1AB-2009 - IEEE Standard for Local and Metropolitan Area Networks - Station and Media Access Control Connectivity Discovery

Approved IEEE Smart Grid Standards

802.11-2007 IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY)

802.11-2012 IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (P

802.15.1-2005 IEEE Standard for Information Technology - telecommunications and information exchange Systems between systems - Local and metropolitan area networks-Specific requirements - Part 15.1a: Wireless Medium Access Control (MAC) and Physical Layer

802.15.4-2006 IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY)

802.15.4g-2012 IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY)

802.16-2012 IEEE Approved Draft Standard for local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems

802.2-1998 Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 2: Logcal Link Control

802.20-2008 - IEEE Standard for Local and Metropolitan Area Networks - Part 20: Air Interface for Mobile Broadband Wireless Access Systems Supporting Vehicular Mobility -- Physical and Media Access Control Layer Specification

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802.20.2-2010 - IEEE Standard for Conformance to IEEE 802.20 Systems--Protocol Implementation Conformance Statement (PICS) Proforma

802.3-2005 - IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Acc

81-1983 IEEE Guide for Measuring Earth Resistivity Ground Impedance and Earth Surface Potentials of a Ground System Part 1: Normal Measurements

81.2-1991 IEEE Guide for Measurement of Impedance and Safety Characteristics of Large Extended or Interconnected Grounding Systems

C37.1-2007 IEEE Standard for SCADA and Automation Systems

C37.13-2008 IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

C37.100-1992 IEEE Standard Definitions for Power Switchgear

C37.101-2006 IEEE Guide for Generator Ground Protection

C37.101-2006/Cor 1-2007 - IEEE Guide for Generator Ground Protection - Corrigendum 1: Annex A.2 Phasor Analysis (Informative)

C37.102-2006 IEEE Guide for AC Generator Protection

C37.104-2002 IEEE Guide for Automatic Reclosing of Line Circuit Breakers for AC Distribution and Transmission Lines

C37.106-2003 IEEE Guide for Abnormal Frequency Protection for Power Generating Plants

Approved IEEE Smart Grid Standards

C37.111-1999 IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems

C37.112-1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays

C37.114-2004 IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines

C37.115-2003 IEEE Standard Test Method for Use in the Evaluation of Message Communications Between Intelligent Electronic Devices in an Integrated Substation Protection Control and Data Acquisition System

C37.116-2007 IEEE Guide for Protective Relay Application to Transmission-Line Series Capacitor Banks

C37.117-2007 IEEE Guide for the Application of Protective Relays Used for Abnormal Frequency Load Shedding and Restoration

C37.118-2005 IEEE Standard for Synchrophasors for Power Systems

C37.118.1-2011 IEEE Standard for Synchrophasor Measurements for Power Systems

C37.118.2-2011 IEEE Standard for Synchrophasor Data Transfer for Power Systems

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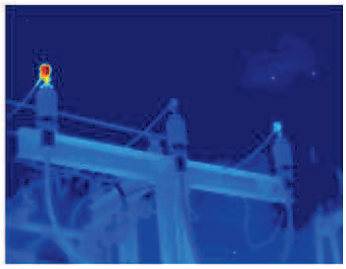
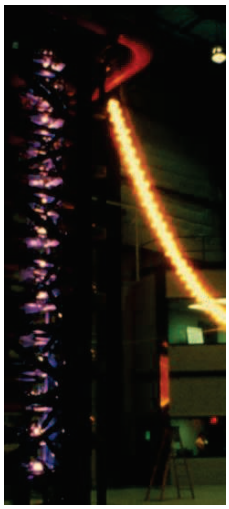
Energy at Georgia Tech



- Electric Energy Technical Interest Group
- NEETRAC
  - National Electric Energy Testing Research and Application Center
- IPIC
  - Intelligent Power Infrastructure Consortium
- UCEP
  - University Center of Excellence in Photovoltaic Research
- Brook Byers Sustainable Technologies Institute (Interactions between Critical Infrastructures, Sustainable Design of Urban Infrastructures)
- Strategic Energy Initiative (SEI): Building Technologies, Carbon Management, Lighting, Combustion, System Design & Optimization
- GTRI: Fuel Cells/Alternative Energy, Energy Efficiency, Energy and Environmental Modeling



Research Centers

- $4-5M Consortium
  Utilities
  Manufacturers
  End Users
  Academia
- EV Research
  200 HP Dynamometer
  125 kW DC Test System
  EV Virtual Testbed
  EV Charger Power Quality
- Materials
  1,000 sq. ft. Solar Cell Fabrication Facility
- Systems
  340 kW PV Array on GT Olympic Natatorium Roof
- Suniva, Inc.
  18% efficient commercial PV cells

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Conclusions

- Tremendous amount of work is ongoing, both R and D
- Future intensity greatly depends on federal funding initiatives
- Government agencies are stepping in as venture capitalists
- The industry is rapidly changing, embracing new technologies
- The future: long on growth, short on ability to forecast short-term