IEEE NTC 2010 at Boeing

The Smart Grid: Applications, Technologies and Standards

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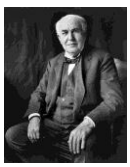
Renton, WA

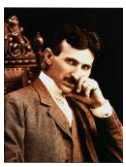
The Presenter

Part 1
Who Needs a "Smart Grid"?

Is the existing grid dumb?



Thomas Edison



Nikola Tesla

George Westinghouse

Samuel Insull

Grand Engineering Achievements of the 20th Century

1. **Electrification**

U.S. Power System at a Glance

- +15,000 Generating units
- +3,800 TWh per year
- Average cost: 9.74 cents/kWh

49%

20%

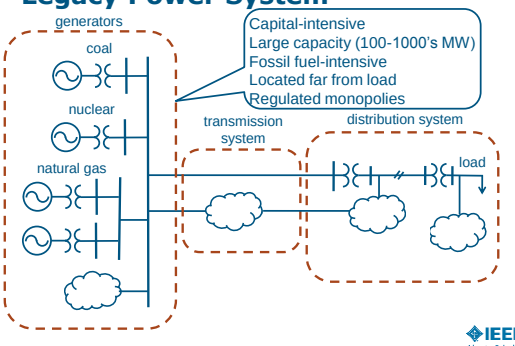
19%

U.S. Power System at a Glance

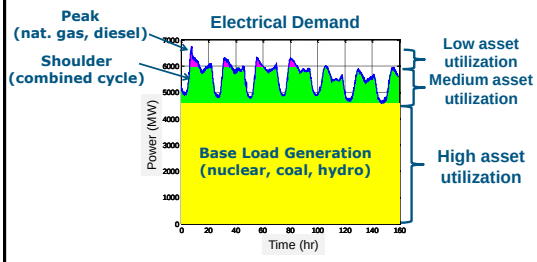
- +160,000 miles of high voltage transmission lines
- Up to 765,000 Volts
- +99% availability

Source: http://www.eia.doe.gov/cneaf/electricity/page/fact_sheets/transmission.html

Legacy Power System



Legacy Power System



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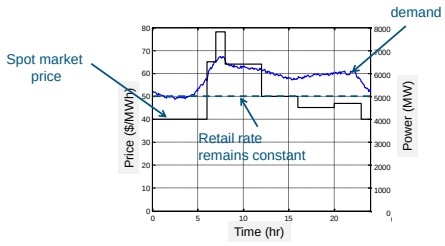
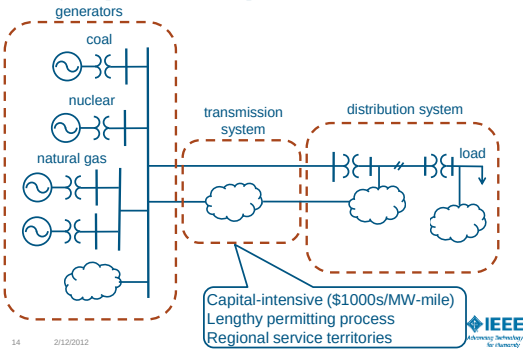
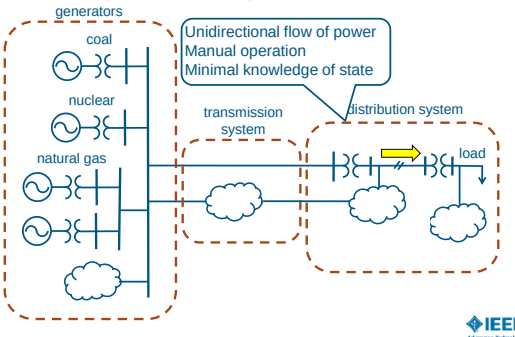


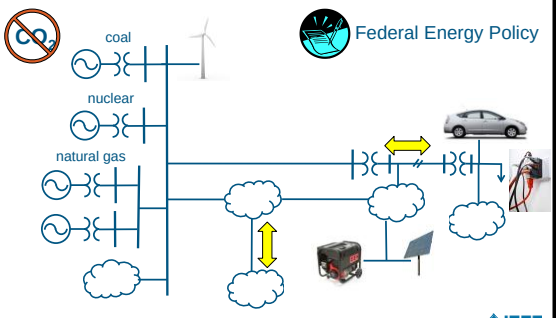
Legacy Power System



Legacy Power System



Emerging Power System



Part 1: Summary

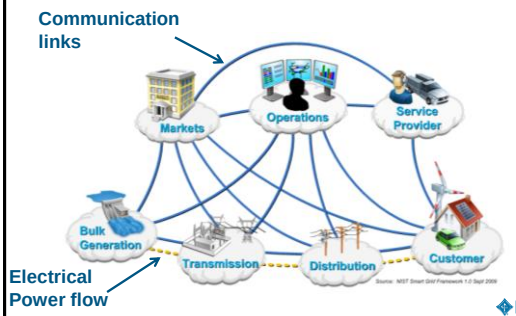
- The legacy power system is a well engineered machine
- Changes in generation characteristics, transmission expectations and new devices in distribution system push the power system to its limits
- To maintain reliability, economy and allow for growth a modernization of the power system is needed

Part 2
The Promise of a Smarter Grid

The Smart Grid is…

A common theme in the various definitions of the Smart Grid is the increased interaction of the power system with communication networks and information technologies to supply electrical energy in a more reliable, efficient, secure, and environmentally neutral manner.

Smart Grid Domains



Smart Grid Functions

A Smart Grid should be able to:

(1) develop, store, send and receive digital information through one or a combination of devices and technologies.

(2) develop, store, send and receive digital information to or from a computer or other control device.

(3) measure, monitor and report electricity use and power quality characteristics.

(4) sense and localize disruptions on the grid and communicate such information for reliability and security purposes.

Smart Grid Functions Cont.

A Smart Grid should be able to:

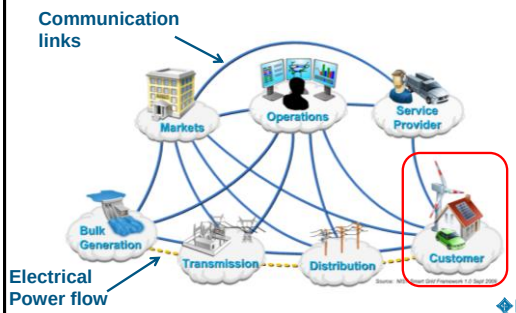
(5) detect, prevent, communicate with regard to, respond to, or recover from system security threats.

(6) have any appliance or machine to respond to signals, measurements, or communications automatically or in a manner programmed by its owner or operator.

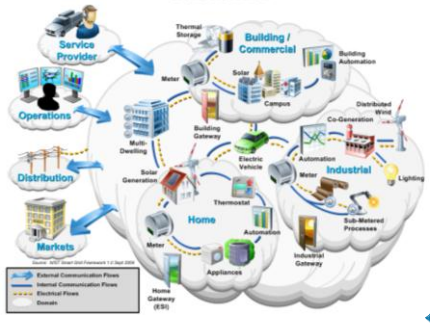
(7) use digital information to operate functionalities on the electric utility without human interaction.

(8) use digital controls to manage and modify electricity demand, enable congestion management, assist in voltage control, provide operating reserves, and provide frequency regulation.

Smart Grid Domains



Customer Domain



Smart Grid Technologies

- Smart Appliances
  - Two-way communication
    - Zigbee, powerline communication (PLC)
  - Remotely controllable
  - Owner-programmable

Smart Grid Technologies

- Home Area Network (HAN)
  - Communication between smart appliances and controller
  - Interfaces with smart meter

Smart Grid Technologies

- Advanced Metering Infrastructure (AMI) with Smart Meters
  - Two-way communication with utility
  - Real-time energy usage
  - Time-dependent price signals
  - Power quality characteristics
  - Control signals

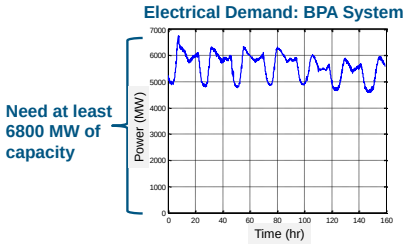
Consumer Empowerment

- Consumers can respond to price signals
- Known as Demand Response
- Examples:
  - laundry done at night to avoid high prices
  - informed comfort versus cost tradeoff decisions for air conditioning, etc.

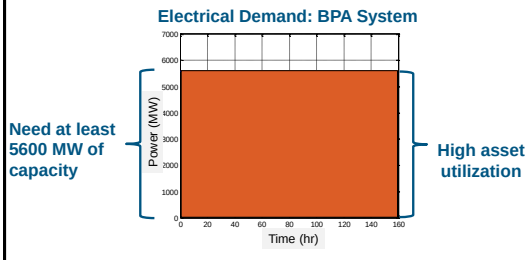
Enhanced Asset Utilization

- Price-sensitive demand could result in reshaped load profile
- Better utilization of assets

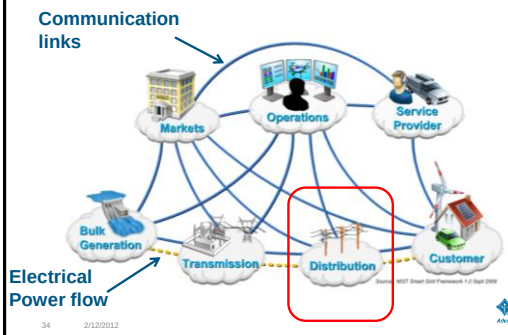
Enhanced Asset Utilization



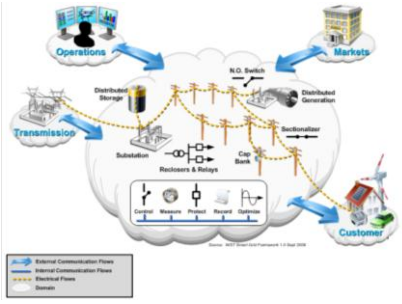
Enhanced Asset Utilization



Smart Grid Domains



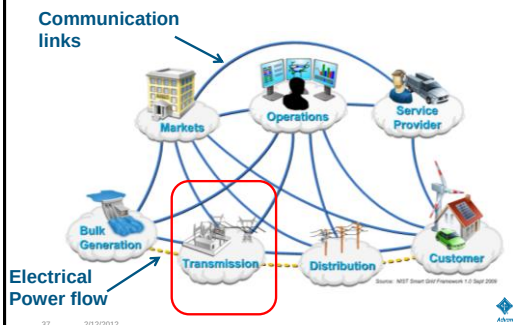
Distribution Domain



Smart Grid Technologies

- Automated substation/distribution devices
  - Transformers
  - Capacitor banks
  - Switches
  - Sectionalizers
- Remote power-harvesting sensors
- Control of distributed generation

Smart Grid Domains



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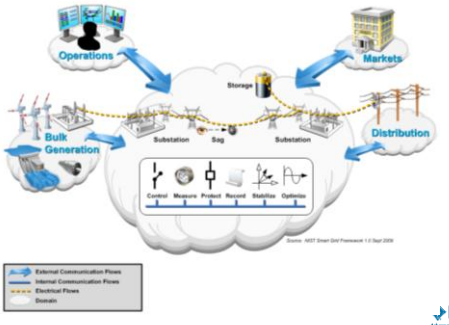
Transmission Domain



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Smart Grid Technologies

- Phasor Measurement Units (PMU)
  - Voltage magnitude and phase measurement
  - Rely on GPS technology to synchronize several PMU readings, leading to enhanced knowledge of system state

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Smart Grid Technologies

- Remote power-harvesting sensors
- Video sagometers
  - Detect when transmission lines are overloaded
  - Dynamic line ratings

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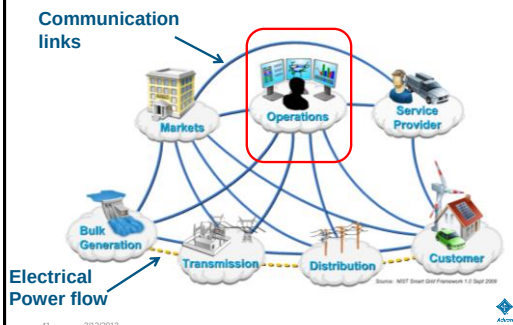
Smart Grid Domains



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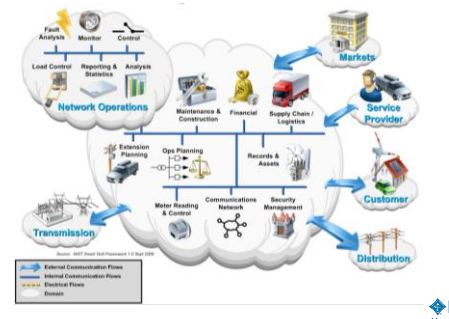
Operations Domain



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Improved Operations

- More secure
- Higher reliability
- Greater power quality
- More efficient delivery of energy
- Improved ability to integrate renewable and distributed generation resources

Part 2: Summary

- Consumer Empowerment
- Enhanced Asset Utilization
- Greater Awareness
- Improved Ability to Meet Operational Objectives (emissions, reliability, etc)

Part 3
Realizing the Smart Grid

The Smart Grid is a Work in Progress

- Standards
- Legislation
- Pilot Projects

Smart Grid Standards

- Key challenge is grid interoperability
- Interoperability framework: "shall be flexible, uniform, and technology neutral"
- Goal: plug-and-play
- Standards and Protocols are needed

Smart Grid Standards

- Standard development organizations
  - IEEE
  - International Telecommunication Union
  - International Organization for Standardization
  - International Electrotechnical Commission
  - German Standards Institute

Smart Grid Standards

- Standards alliances
  - HomePlug Powerline Alliance
  - Z-Wave Alliance
  - Zigbee Alliance

Key IEEE Smart Grid Standards

- +100 existing Smart Grid standards and standards under development
- See http://smartgrid.ieee.org/standards for a complete list

Key IEEE Smart Grid Standards

- **IEEE C37.118**
  Defines phasor measurement unit performance specifications and communications.
- **IEEE 1547 Suite**
  Defines physical and electrical interconnections between utility and distributed generation and storage.
- **IEEE 1588**
  For time management and clock synchronization across the smart grid for equipment needing consistent time management.
- **IEEE 1686-2007**
  Covers intelligent electronic device security capabilities, including the access, operation, configuration, firmware revision, and data retrieval.

Source: http://www.smartgrid.gov/standards/existing

IEEE P2030

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

Key Legislation in the U.S.

- Energy Independence and Security Act of 2007 (EISA)
  - Establishes a federal policy to modernize the power system
  - Forms a Smart Grid Advisory Committee and Smart Grid Taskforce
- American Recovery and Reinvestment Act of 2009
  - Allocates $4.5B specifically for Smart Grid

Smart Grid Case Studies

- +100 projects funded by Federal Government
- Xcel Energy—SmartGrid City
- Southern California Edison—SmartConnect
- Hawaiian Electric
- GridWise™ Demonstration Project

SmartGridCity—Boulder, CO

- Started in 2008
- +20,000 smart metered customers
- Smart Grid infrastructure
  - Communication
  - Sensing
  - Automation

SmartGridCity—Boulder, CO

- *It's so smart that the number of customer-voltage complaints — about either surges or drops — went from 70 in 2007 to zero so far this year.*
- *It's so smart that it identified a transformer that was overloaded and needed to be replaced — before it got fried.*

Source: Mark Jaffe, Boulder's SmartGridCity brings Xcel up to speed on electric picture, *The Denver Post, Sept. 9, 2009.*

SmartGridCity—Boulder, CO

- Original Project Cost: $15.3 million
- Revised Project Cost: $42.1 million
- Only 43% of residents have meters
- Tried to pass on costs through rate increase
- Trouble in installing communication network due to…

Southern California Edison—SmartConnect

- Installing smart meters
  - +1 million meters installed
  - +5 million target by 2012
- Customers can view energy usage the next day from a computer, cell phone, or other device
- Pricing plans, programs and services
- Meters will communicate with smart thermostats, appliances and other devices.

Southern California Edison—SmartConnect

- Estimated reduced demand 1000 MW
- Cost $1.63 billion
- Consumer benefits $9—304 million
- Some consumer opposition as it is paid by rate payers

Hawaiian Electric

- Envisioned $115 million project reaching 451,000 locations
- Pilot Project: 9,400 smart meters
- Proposed Expanded Pilot:
  - 5,000 new meters
  - Cost $1.35 million
- Denied by Hawaiian PUC

Hawaiian Electric

Our office was concerned that the investment would be made but ratepayers wouldn't see the benefits.

-Dean Nishina, Executive Director,
State Division of Consumer Advocacy

GridWise™ Demonstration Project

- Pacific Northwest National Laboratories and regional utilities and industry
- Olympic Peninsula of Washington State
- March 2006 through March 2007
- Tested smart appliance technology and demand-response of customers

GridWise™ Demonstration Project

- Key Results and Findings:
  - Showed feasibility of internet-based coordination of customer demand response
  - Peak load reduced by 15%
  - High customer adoption rate if the human interface is made simple
  - 10% reduction on electricity bills
  - Regulatory rather than technical barriers are most significant

Observations

- What is the business case?
- Customer benefits are poorly quantified
- Electricity is relatively inexpensive and people will pay for convenience
- Customers resent being treated like lab rats
- Smart Grid is not only Smart Meters!
- Working with regulators is key

Summary

- Smart Grid is a way of modernizing the power system
- Increased interaction of power system, communications and IT
- Still a work in progress, many obstacles ahead

I have not failed. I've just found 10,000 ways that won't work.

-Thomas Edison

IEEE Smart Grid

- Cross-society effort
- Transactions on Smart Grid launched June 2010
- IEEE Smart Grid web portal

http://smartgrid.ieee.org/

Selected References

[1] E. Lightner and S. E. Widergren, "An Orderly Transition to a Transformed Electricity System," *IEEE Transactions on Smart Grid*, Vol. 1., No. 1., Jun. 2010

[2] J. Giri, D. Sun and R. Avila-Rosales, "Wanted: A More Intelligent Grid", *Power & Energy Magazine*, Vol. 7, No. 2, March/April 2009.

[3] A. Ipakchi and F. Albuyeh, "Grid of the Future", *Power & Energy Magazine*, Vol. 7, No. 2, March/April 2009.

[4] F. Butler, "A Call to Order", *Power & Energy Magazine*, Vol. 7, No. 2, March/April 2009.

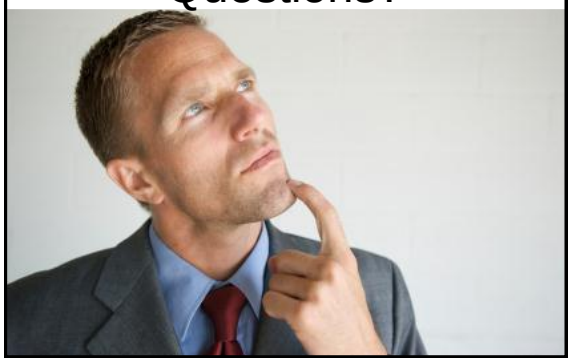
[5] United States Congress, Energy Independence and Security Act, 2007.

[6] United States Congress , American Recovery and Reinvestment Act, 2009.

[7] GridWise Demonstration Project Fact Sheet, http://gridwise.pnl.gov/docs/pnnl_gridwiseoverview.pdf

[8] IEEE Smart Grid Web Portal, http://smartgrid.ieee.org/

Questions?



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