Smart Grid: A New Paradigm for Power Delivery

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Topics

- Elements of Smart Grid
- Implementation of DOE Smart Grid Project at IIT
- Conclusions
Electric Grid is a Complex System with Unique Characteristics

Physically

- Not holistically designed, evolved incrementally in response to local load growth.
  - 30,000 Transmission paths; over 160,000 miles of transmission line
  - 14,000 Transmission substations
  - Distribution grid connects these substations with over 100 million loads
- Diverse industry without a common voice
  - 3,170 traditional electric utilities
  - 239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 Federal electric utilities

Technically

- Electricity flows along paths with lowest impedance; yet the grid is operated in a decentralized manner by over 140 control areas
- Demand is uncontrolled; electricity production is the ultimate “just-in-time” process
Interdependent Infrastructures

- Water
- Transportation
- Oil
- Telecom
- Natural Gas
- Electric Power
Innovations in Electricity Infrastructure

- **Supply Adequacy and Economics:** Applications of renewable energy, storage technologies for enhancing the security, coordination of renewable and storage supplies, carbon footprints

- **Transmission Expansion and Security:** Expansion planning of transmission facilities, coordination of energy infrastructures, superconductors, HVDC, physical and cyber security, wide area measurements, PMUs

- **Smart Grid:** Energy efficiency, price response, peak load reduction, distribution automation, new building technologies, smart metering, sensors, communication and control techniques
What is a Smart Grid?

- Smart grid is a response to economic, security, and environmental mandates placed on energy supply and delivery.

- Smart grid provides access points that can be identified, much like computer devices, with an IP address on the internet.

- Smart grid uses the internet protocol to shuttle information back and forth between the utility and customers.

- With two-way communications between consumers and suppliers, both parties can get far more control over the grid consumption, and physical and cyber security.
Consumer's Dilemma

- Today, most consumers know little about costs that show up on their electricity bills except that they are higher during hot and cold months.

- Few consumers realize that the true price of electricity varies continuously in response to supply and demand, and that electricity bills are mostly calculated based on average prices.

- Since consumers do not adjust energy use in response to high prices, they are likely to use electricity at peak hours more than what they need to — and thus pay more than what they would have to.
Elements of Smart Grid

- Distribution automation
  - Self-healing distribution systems
    - Rapidly detect, respond, restore, and communicate

- Self-sustaining on-site generation with storage
  - Provides alternative supply of energy

- Leveraging lower carbon generation sources
  - Solar PV, natural gas, wind, hydro, geothermal, biofuel,

- Demand response / empower consumers
  - Smart meters
  - Real-time pricing of electricity
Power Systems and Smart Grid

Smart Grid with integrated information/communication/power infrastructure

- Generation
  - Renewables Integration

- Transmission
  - Wide-area Monitoring and Control

- Substation
  - Substation Automation

- Distribution
  - Distribution Automation Microgrids

- Consumer
  - AMI
  - EV/PHEV Integration

- DER Integration
- Condition Monitoring
- Asset Optimization
- Workforce Effectiveness
Advanced Metering Infrastructure (AMI)

- AMI combines three core components
  - Smart sensors at customer premises,
  - Two-way communications,
  - Master controller for managing and metering hourly energy use

- Smart sensors installed at consumer premises measure, monitor, and help manage energy use

- Two-way communication links include cellular networks, satellite, and radio frequency networks
  - AMI revolutionizes electric outage detection and restoration by providing utilities with customer outage information

- Master controller uses the hourly price information to provide consumers with real time data to ensure a seamless consumer experience.
Business of Smart Grid

- Smart grid technologies would reduce power disturbance costs to the U.S. economy by $49 billion per year
- Smart grid would reduce the need for massive infrastructure investments by $100 billion over the next 20 years
- Deployment of smart grid allows consumers to easily control and lower their power consumption
  - It could add $5 - $7 billion per year back into the U.S. economy by 2015 and $15 - $20 billion per year by 2020
Perfect Power at Illinois Institute of Technology

- Funded by the U.S. Department of Energy
- $12M ($7M from DOE, $5M Cost Share)
- 5 year project
- Located at Illinois Institute of Technology (IIT)
- Involves the entire campus
- Partners: IIT, Exelon, S&C, Schweitzer, Endurant
Vision for Perfect Power

“The perfect power system will ensure absolute and universal availability of energy in the quantity and quality necessary to meet every consumer’s needs. It is a system that never fails the consumer.”

Bob Galvin
Elements of Perfect Power

- Distribution automation
- On-site generation: gas unit, back-up power
- Leveraging lower carbon generation: renewables
- Demand response / empowering the campus
DOE/IIT Project Goals

- 50% peak demand reduction
- 20% permanent demand reduction
- Demonstrate the value of Perfect Power
  - Cost avoidance and savings in outage costs
  - Deferral of planned substations
- New products and commercialization
- Replicable to larger cities
- Promotion of energy efficiency and cleaner cities
Why would IIT Need Perfect Power?

- At least three power outages per year
  - Costs = up to $500,000 annually in restoration costs, lost productivity and ruined experiments
- Electricity costs were doubled within the last decade
- Addition of two new resident halls require more power
- Campus electricity infrastructure would need to be upgraded
- Electricity demand is growing with increased student population
- Installation of additional building equipment adds to energy use
- Renegotiating electricity contract will allow real-time pricing
IIT Before Perfect Power

Existing IIT Distribution System:

Connected To South Substation

North Substation

Feeder
Secondary Feeder
Switch
Fault
IIT with Perfect Power
No Additional Substations—Perfect Power
DOE’s Perfect Power Research Scope

- Distribution Automation Recovery
- Intelligent Perfect Power Controller
- Advanced Zigbee Technology
- Buried Cable Fault Detection
perfect power
at iit

PERFECTING POWER FOR A SECURE, SUSTAINABLE ENERGY FUTURE
PERFECT POWER

HOW THE MICROGRID REVOLUTION WILL UNLEASH CLEANER, GREENER, AND MORE ABUNDANT ENERGY

ROBERT CALVIN AND KURT YEAGER
WITH JAY STULLER