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

- Oil
  - Fuel for Generators, Lubricants
  - Power for Pumping Stations, Storage, Control Systems
  - Fuel Transport, Shipping

- Electric Power
  - Power for Switches
  - Water for Production, Cooling, Emissions Reduction
  - Fuel for Generators
  - Power for Signalining, Switches

- Natural Gas
  - Fuel for Generators
  - Power for Compressors, Storage, Control Systems
  - Fuel Transport, Shipping

- Water
  - Water for Production, Cooling, Emissions Reduction
  - SCADA, Communications

- Telecom
  - SCADA, Communications
  - Shipping
  - Oil
    - Fuel for Generators, Lubricants
    - Power for Pumping Stations, Storage, Control Systems
    - Fuel Transport, Shipping
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.
Behavior of a Demand in a Vertically integrated Power Market

Response of a Demand to Price Signals
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
Smart Grid - Consumer Opportunities

Energy efficiency and demand response is a driver that will greatly accelerate the creation of a smart grid
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
Savings Outweigh the Lifecycle Costs

<table>
<thead>
<tr>
<th>PERFECT POWER COSTS</th>
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<tbody>
<tr>
<td><strong>BENEFIT</strong></td>
<td><strong>COST</strong></td>
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<tr>
<td>Redundant cabling</td>
<td>$1.5M</td>
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<tr>
<td>Intelligent switches and meters</td>
<td>$5M</td>
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<tr>
<td>Solar PV, UPS, storage</td>
<td>$600,000</td>
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<tr>
<td>On-site generation</td>
<td>$1M</td>
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<tr>
<td>Communications and controls</td>
<td>$1.4M</td>
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<tr>
<td>Substation recommissioning and automation</td>
<td>$2.5M</td>
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<tr>
<td><strong>TOTAL SYSTEM COSTS</strong></td>
<td><strong>$12M</strong></td>
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<tr>
<th>IIT SAVINGS/COST AVOIDANCE</th>
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<tbody>
<tr>
<td><strong>BENEFIT</strong></td>
<td><strong>PERIOD</strong></td>
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<tr>
<td>Avoided IIT distribution upgrades</td>
<td>One time</td>
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<tr>
<td><strong>TOTAL ONE-TIME SAVINGS</strong></td>
<td><strong>$5M</strong></td>
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<tr>
<td>Electricity cost reduction</td>
<td>Annual</td>
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<td>• Real-time pricing</td>
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<tr>
<td>Demand response</td>
<td>Annual</td>
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<td>Outage costs</td>
<td>Annual</td>
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<tr>
<td>Capacity payments</td>
<td>Annual</td>
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<tr>
<td><strong>TOTAL ANNUAL SAVINGS</strong></td>
<td><strong>$1.3M</strong></td>
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<td>Simple payback period</td>
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IIT Before Perfect Power

Existing IIT Distribution System:

Connected To South Substation

- Feeder
- Secondary Feeder
- Switch
- Fault
Even with Faults, Perfect Power Stays On
N - North Site Substation
S – South site Substation
No Additional Substations—Perfect Power
Look of Perfect Power at IIT

Perfect Power System at IIT’s Siegel Hall
Perfect Power Benefits to IIT

- Reduced energy costs
- Improved power reliability and quality
- Reduced need for scheduled upgrades
- Reduce IIT’s carbon footprint
- Cost and infrastructure benefits for ComEd
- Expanded education and research
- Improved campus safety and security
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
How the microgrid revolution will unleash cleaner, greener, and more abundant energy

PERFECT POWER

ROBERT GALVIN
AND KURT YEAGER
WITH JAY STULLER