Distributed Generation and Microgrids – Utility Life or Death?

Potential Threats to Current Utility Business Model

- Distributed Generation
  - Disruptive, especially if behind the meter (rooftop PV)
  - But, still can’t send your excess next door to your neighbor
- Microgrids
  - Disruptive, especially if generation included (natural gas, renewables)
  - But, expensive today compared to utility-scale alternatives
Almost every customer has two energy delivery systems...

- NRG CEO David Crane
  - Apparently, Mr. Crane has said that he thinks only one is necessary, so...
  - "Does the grid just become a backup system the way the post office is effectively a backup system for Federal Express and UPS for high-value mail?"
  - "Or do we actually get to the point where we are tearing down the grid because it’s actually not being used at all?"

Electric Utility has an Exclusive Franchise

NYC: 1888

US Transmission: 2014
### ComEd Executives Speak…

- “Reports of my death are greatly exaggerated.”
- Popular misquotation comes from a piece by Mark Twain that appeared in the New York Journal of 2 June 1897 called "The report of my death was an exaggeration".
- Takeaway: The utility and the grid are here to stay.

### Distribution Utility of the Future

- Four Business Models (regulatory issues are tough; technology is easier)
  - Business as usual (status quo)
  - Enhanced utility (more technology, more iron, similar rules)
  - Network provider (regulatory innovation, e.g., NY “Reforming the Energy Vision”, utility-owned public purpose microgrids)
  - Full-service (back to owning generation & wires)
Personal computing infrastructure is moving into the cloud (backup, storage, applications, streaming music vs. purchasing CDs)

- People want **access to services**, rather than buy (and maintain and store stuff)
- Why would a typical home-owner (house, condo, etc.) want to take on DG or MG?
Resiliency: 2011 Storms - There goes the budget!

- Daybreak, Monday, July 11, 2011
- 850,000+ customers knocked off-line
  - Nearly 25% of all ComEd customers
- Intense lightning and high winds
- Extensive tree damage and downed power lines
- Restoration for last 1% of outaged customers stretched into Saturday...
- ComEd restoration cost > $80 million
  - More than twice annual storm restoration budget

Intergovern. Panel on Climate Change - Electricity is Best Carrier

[Diagram showing the comparison of different energy carriers based on Accessibility, Availability, and Acceptability.]

IPCC Climate Change 2007: Working Group III: Mitigation of Climate Change – Fig 4-17
Power Systems and Smart Grid

- Generation
  - Renewables Integration
- Transmission
  - Wide-area Monitoring and Control
- Substation
  - Substation Automation
- Distribution
  - Distribution Automation Microgrids
- Consumer
  - EV/PHEV Integration

Smart Grid with integrated information/communication/power infrastructure

DER Integration  Condition Monitoring  Asset Optimization  Workforce Effectiveness

How Micro-Grids Add Value

Clark Gellings
Electric Power Research Inst.

The individual value sources can grow or shrink depending on the application.

- Added Security
- T&D elements and/or released capacity
- Emissions reductions
- Efficiency/reduced losses and Conservation values
- Reliability value (enhanced process productivity)
- Thermal Energy (usable-value)
- Electrical Energy Produced

Central station, T&D based approach

$Net Value$

Cost

Multi-energy based approach

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“My friend has this problem...”

- 2004-2006: 12 outages (partial, total)
  - Annual costs up to $500k
  - Restoration costs, lost productivity, ruined experiments
- Aging infrastructure
  - Cable failures, switchgear failures, manual (3-5 hr outage)
- Increasing demand and carbon
  - More students, residence halls, faculty, research
  - $5M substation planned

http://www.iit.edu/perfect_power

IIT Perfect Power Solution

- 2006 -- Galvin Electricity Initiative
  - http://www.galvinpower.org
- 2007 -- US Department of Energy Solicitation
  - Renewable and Distributed Systems Integration Program
- 2008 -- Five year project began
  - S&C High Reliability Distribution System: Vista, SEL 351, fiber loop
  - Distributed Resources (8 MW gas, 8 kW wind, 20 kW solar, storage)
  - Perfect Power Controller (Intelligent Power Solutions)
  - ZigBee Load Control
  - Demand Response, Ancillary Services, Markets
- 2010 -- Smart Grid Center
  - Smart networks, buildings, vehicles, storage, renewables
Investment & Benefits

- Investment
  - $12M DOE, IIT, S&C Electric, Intelligent Power Solutions

- Benefits:
  - Improved reliability and safety (HRDS)
  - Lower peak power via demand response and energy efficiency
  - Defer $5M substation (IIT) and $2M substation upgrade (ComEd)
  - Reduced energy costs and new revenue stream for ancillary services
  - Reduced energy usage and reduced carbon footprint
  - Living laboratory
## Perfect Power at Illinois Institute of Technology

- Funded by the U.S. Department of Energy ($12M)
- Located at Illinois Institute of Technology (IIT)
- Involves the entire campus
- Partners: IIT, S&C Electric, Intelligent Power Solutions, ComEd/Exelon

“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

## DOE/IIT Perfect Power Project Goals

- 50% peak demand reduction (load control, generation, storage)
- 20% permanent demand reduction (energy efficiency)
- Demonstrate the value of Perfect Power
  - Outage cost avoidance
  - Deferral of planned substations
- Provide the proof-of-concept for replication in larger grids
- Develop new products for commercialization
- Promote energy efficiency and cleaner cities
Elements of IIT Microgrid

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

- Self-sustaining on-site generation with storage
  - Provides alternative supply of energy (Combined-cycle gas)
  - Leveraging lower carbon generation sources (PV, wind)

- Demand response / empower consumers
  - Smart meters
  - Real-time pricing of electricity

Multi-agent System (MAS) in Advanced Distribution Automation

- Fault detection, location and isolation, then reconfiguration
- Agents send messages and make decisions
- Communication latency - critical!
IIT Perfect Power - Advanced Distribution Automation

- Create agent-based architecture to provide transaction capabilities that control transport, including
  - Fault detection, location and isolation;
  - Service restoration;
  - Integration of distributed resources (generation & storage);
  - Feeder reconfiguration;
  - Volt/VAR management; and
  - Emergency response (shed non-critical loads).

- dNetSim 3-ph unbalanced distribution simulator
- JADE agents: breaker, sectionalizer, switch, generator, storage

Smart Home

![Smart Home Diagram]

- ZigBee
- Utility Price Signals
- Compressor
- Pool Pump
- Smart Thermostat
- Water Heater
- CenterPoint Energy

![Intelligent Energy Management System Diagram]
**IIT Microgrid – Building Example**

- NORTH SUBSTATION
- HOT WATER

**Demand**

- # of Hours at the Demand Level

**Flatten the Curve – Improve Asset Utilization**

- Demand Response
- Price Transparency
- Ancillary Service Payments

- Price Transparency
- Electric Vehicles

**# of Hours at the Demand Level**

- Greg Rouse
Intelligent Power Solutions
Microgrid Master Controller

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Perfect Power Benefits to IIT

- Reduced energy costs
- Improved power reliability and quality
- Reduced need for scheduled upgrades
- Reduce IIT’s carbon footprint
- Expanded education and research
12 PMUs to be installed on IIT main campus
- Voltage and current phasors recorded 60 times per second at each location
- Database archive and analysis
- Real-time situational awareness
- Detailed load models
- Partnership with Korea Electrotechnology Research Institute (KERI) and Procom
Resiliency – big opportunities

- DOE Microgrid Workshop at IIT 2012
  - Microgrid architecture, modeling, optimization
  - Microgrid dynamics, protection and control

- DOE Advanced Grid Modeling Workshop 2013
  - Synchrophasors (faster monitoring, “30 fps”)
  - High fidelity “faster than real-time” dynamics simulation
  - Wide-area control (autonomous, decentralized?)
Infrastructure Security includes Cybersecurity

Cybersecurity: protect cyber assets from bad actors
Infrastructure Security: protect all assets from bad [actors, weather, luck, etc.]

What needs to be protected?

<table>
<thead>
<tr>
<th>CYBERSECURITY</th>
<th>INFRASTRUCTURE SECURITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication systems</td>
<td>Generators</td>
</tr>
<tr>
<td>Sensors/Meters</td>
<td>Transformers</td>
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<tr>
<td>Control equipment</td>
<td>Transmission lines</td>
</tr>
<tr>
<td></td>
<td>Substations</td>
</tr>
</tbody>
</table>
Brave New World of Electric Power

- **Old World**
  - High barrier to entry
  - Heavy equipment (transformers, generators, conductors)
  - Capital intensive build-out (30-60 years ago)
    - Today: $600 billion in assets (roughly 70% in generation, 20% in distribution, 10% in transmission)

- **New World**
  - Opportunities with various barriers
  - Monitoring & control of existing and new equipment
  - Technology intensive optimization (engineering, IT, markets)
  - Examples: Silver Spring Networks, EnerNOC, Intelligent Generation (startup at IIT Incubator), many more...

www.iit.edu/perfect_power
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- ieee-pes.org - Workforce Collaborative
- globalsmartgridfederation.org

Questions?

"Go around asking a lot of damn fool questions and taking chances. Only through curiosity can we discover opportunities, and only by gambling can we take advantage of them."

- Clarence Birdseye, American inventor, entrepreneur and naturalist