Lessons Learned from Microgrid Design Studies in New York

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Agenda

• Background on Microgrids
• Design Process
• NY Prize Competition
• Project Examples
• Key Take-Aways
Microgrids Background
What are Microgrids?

An integrated energy system with distributed energy resources and interconnected loads, operated in parallel with the grid or in an intentional island mode.
Convergence of environment, energy cost/efficiency, security, and system resiliency and reliability prove to be the key drivers for Microgrids . . .
Principal Elements of Microgrids and Minigrids

Supply Side/DER
- Distributed Generation
  - Fuel Cells
  - Gas Turbines
  - Micro-turbines
  - RICE
  - CHP/CCHP
  - Solar PV

- Energy Storage
  - Battery Storage
  - Thermal Storage
    - Heat
    - Cool

Power Delivery
- Distribution infrastructure
  - Lines/cables
  - Transformers
  - Switchgear

- Protection and Relaying
  - Breakers/relays
  - Fuses
  - Reclosers/sectionalizers
  - Coordination

- Automation/Smart Grid
  - Smart devices
  - Dynamic reconfiguration

Demand-Side
- Load/demand
  - Critical loads
  - Discretionary loads
  - Curtailable loads

- Demand Response & Energy Efficiency
  - Event-Responding Demand Response
  - Price Responding Demand Response (Dynamic Pricing)

- Electric Vehicles (EV)

Control and Comms
- Microgrid Controller
  - Monitoring and Visualization
  - DER Dispatch
  - Optimized operation
  - Command & Control

- Communications & IT
  - DERMS/DMS integration

- Cybersecurity

Microcosm of an electric power systems with associated challenges and opportunities
Microgrid Design Process
Design and Analysis Tools

- DER SELECTION, DER DISPATCH
- LOAD & SUPPLY ANALYSIS
- BULK POWER SYSTEM MODELS
- GE CONCORDA SUITE
- DISTRIBUTION ANALYSIS TOOLS
- COMMERCIAL & CUSTOM

Combination of tools and techniques applied to evaluate system technical and economic operation
“Soft” Aspects of Project Development

- **Ownership Model**
  - Utility/NYISO Role
  - Developer/Owner/Operator Role
  - Customers/Tenants Role

- **Regulatory/Policy Challenges**
  - Service Model
  - Market Participation (Retail/Wholesale)

- **Viable Financial Model**
  - Business Case/Justification
  - Financial Model
  - State/Federal Incentives
NY Prize Competition
NY State Energy Plan for 2030

Regulation & Policy

- Reforming of Energy Vision (REV)
- Clean Energy Standards

Guiding Principles

- Fostering more DER
- Market Transformation
- Community Engagement
- Economic Efficiency
- Private Sector Investment
- Innovation and Technology
- Customer Value and Choice

Goals

- 40% reduction in Greenhouse gas (GHG) emissions from 1990
- 50% of electricity generation from renewable energy resources
- 23% decrease in building energy consumption
- 600 Trillion BTU increase in statewide energy efficiency

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Stage 1: Feasibility Study (2015 -2016)

- Qualitative Characterization of the community grid
- Description of Technical, Commercial and Financial Feasibility
- Conceptual Design of Electrical and Communication Infrastructure
- Preliminary commercial structure
- Preliminary financial model
- Identify regulatory/policy hurdles

Stage 2: Detailed Design (2017-2018)

- Detailed Technical/Engineering Design
- Project Valuation and Investment Planning
- Regulatory/Legal, Environmental Assessment
- Development of Formal Commercial Terms/Contractual Relationships
- Final Detailed Project Development and Operational Proposals

Stage 3: Project Buildout (2019+)

- Overall cost and benefits of the project
- Portion of project revenue requirements provided by private sector
- Project’s contribution to public need
- Technical and operational performance
- Demonstrated reliability of microgrid configuration
- Use of clean and renewable generation resource

NY Prize Community Grid Competition

- $100K per 83 projects
- $1M per 11 projects

Funding levels TBD
NY Prize Microgrid Design Elements

Project Features and Technologies

- Power critical facilities in the community during major events
- Use existing and/or new T&D infrastructure to connect loads to disparate sources
- Incorporate a variety of DER (not just diesel)
- Optimize operation using advanced communication and control technologies
- Significant societal benefit predicated on resiliency and reduced fossil fuel use
- Multiple Points of Interconnection (POIs) to the main grid
GE’s Stage 1 Projects

Worked with ten communities and five utilities to develop Stage 1 conceptual designs.
GE’s Stage 2 Projects

Worked with **five** communities and **three** utilities to develop **Stage II** detailed designs.

- Binghamton
- Albany
- Syracuse
- Potsdam
- Freeport

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Impact of Tropical Storm Lee
Downtown Binghamton 2011
Critical Facilities Downtown Between the Two Rivers

Starting point for stage 1 design
## Electrical Layout

### DER
- **Gas Recip Engine**
  - Location: City Hall
  - Energy Source: Natural Gas
  - Capacity: 400 kW

- **3 x Microturbine CHP**
  - Location: City Hall
  - Energy Source: Natural Gas
  - Capacity: 1,000 kW

- **Solar PV**
  - Location: YMCA
  - Energy Source: Solar
  - Capacity: 120 kW

- **Solar PV**
  - Location: BHA
  - Energy Source: Solar
  - Capacity: 203 kW

- **Small Hydro Plant**
  - Location: Rock Bottom Dam
  - Energy Source: Hydro
  - Capacity: 1,250 kW

- **Backup Generator**
  - Location: City Hall
  - Energy Source: Natural Gas
  - Capacity: 250 kW

- **Backup Generator**
  - Location: BHA
  - Energy Source: Natural Gas
  - Capacity: 205 kW

- **Backup Generator**
  - Location: Woodburn Court
  - Energy Source: Diesel
  - Capacity: 230 kW
Control and Comms Layout
Microgrid Dispatch for Normal week in July

Microgrid Dispatch for Emergency week in July
Summary of Benefit-Cost Analysis (Stage 1) Binghamton

<table>
<thead>
<tr>
<th>COST OR BENEFIT CATEGORY</th>
<th>PRESENT VALUE OVER 20 YEARS (2014$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Initial Design and Planning</td>
<td>$1,050,000</td>
</tr>
<tr>
<td>Capital Investments</td>
<td>$4,970,000</td>
</tr>
<tr>
<td>Fixed O&amp;M</td>
<td>$567,000</td>
</tr>
<tr>
<td>Variable O&amp;M (Grid-Connected Mode)</td>
<td>$626,000</td>
</tr>
<tr>
<td>Fuel (Grid-Connected Mode)</td>
<td>$559,000</td>
</tr>
<tr>
<td>Emission Control</td>
<td>$7,930</td>
</tr>
<tr>
<td>Emissions Allowances</td>
<td>$0</td>
</tr>
<tr>
<td>Emissions Damages (Grid-Connected Mode)</td>
<td>$11,700,000</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$19,500,000</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td></td>
</tr>
<tr>
<td>Reduction in Generating Costs</td>
<td>$12,600,000</td>
</tr>
<tr>
<td>Fuel Savings from CHP</td>
<td>$3,310,000</td>
</tr>
<tr>
<td>Generation Capacity Cost Savings</td>
<td>$2,370,000</td>
</tr>
<tr>
<td>Distribution Capacity Cost Savings</td>
<td>$0</td>
</tr>
<tr>
<td>Reliability Improvements</td>
<td>$465,000</td>
</tr>
<tr>
<td>Power Quality Improvements</td>
<td>$0</td>
</tr>
<tr>
<td>Avoided Emissions Allowance Costs</td>
<td>$6,910</td>
</tr>
<tr>
<td>Avoided Emissions Damages</td>
<td>$13,000,000</td>
</tr>
<tr>
<td>Major Power Outage Benefits</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total Benefits</strong></td>
<td>$31,800,000</td>
</tr>
<tr>
<td><strong>Net Benefits</strong></td>
<td>$12,300,000</td>
</tr>
<tr>
<td><strong>Benefit/Cost Ratio</strong></td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Internal Rate of Return</strong></td>
<td>28.4%</td>
</tr>
</tbody>
</table>
Syracuse Project Example
## Syracuse Microgrid Facilities

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Facility/Customer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onondaga Community College</td>
<td>Community College</td>
</tr>
<tr>
<td>SUNY Upstate University Hospital</td>
<td>Hospital</td>
</tr>
<tr>
<td>Van Duyn Center for Rehab and Nursing</td>
<td>Nursing home</td>
</tr>
<tr>
<td>Onondaga County Consolidated 911</td>
<td>911 Emergency Dispatch</td>
</tr>
<tr>
<td>Syracuse Community Police Department</td>
<td>Police</td>
</tr>
<tr>
<td>Onondaga Hill Fire Department</td>
<td>Fire Department</td>
</tr>
<tr>
<td>Betts Branch Onondaga Public Library</td>
<td>Library / Place of Refuge</td>
</tr>
<tr>
<td>Loretto Campus</td>
<td>Senior Housing</td>
</tr>
<tr>
<td>Various Apartment Buildings</td>
<td>Residential Dwellings</td>
</tr>
<tr>
<td>Betts Branch Onondaga Public Library</td>
<td>Library / Place of Refuge</td>
</tr>
<tr>
<td>Onondaga Middle School</td>
<td>School / Place of Refuge</td>
</tr>
<tr>
<td>St. Michaels Church</td>
<td>Place of worship / Place of Refuge</td>
</tr>
<tr>
<td>Mobile Gas Station</td>
<td>Fuel, food, ATM</td>
</tr>
<tr>
<td>Kinney Drugs</td>
<td>Drug Store, Food,</td>
</tr>
<tr>
<td>Over 2,000 Residential &amp; Small Commercial Customers</td>
<td>Various</td>
</tr>
<tr>
<td><strong>TOTAL Microgrid Load:</strong></td>
<td><strong>17.4 MW peak load</strong></td>
</tr>
</tbody>
</table>
Microgrid Facility Layout

- 4 miles across
- Consists of 4 utility-owned feeders
- New switching to divide feeders
- Localized load shedding

Generator
- Open Switch
- Load Shed Switch
- Closed Switch

Facility

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Microgrid Existing Distributed Generation

- **Existing Backup Diesel Gen (2MW)**
- **Existing Backup Diesel Gen (1.5MW)**
- **Existing Backup Diesel Gen (2MW)**
- **Existing WTE Prime Mover (39.6 MW)**
- **Existing PV (21 kW)**

- **Community College**
- **911 Center**
- **Fire Dept**
- **Post Office**
- **School**
- **Police Station**
- **Grocery Store**
- **Healthcare Center**
- **Apartment Towers**
- **Residential**

- Open Switch
- Load Shed Switch
- Closed Switch

- **Prime mover current feeds into transmission**
- **Step up transformer converts 13.8kV to 115kV**
- **Substation serves 2 of 4 feeders in microgrid**
When forming microgrid:
• Prime mover would feed into distribution at 13.2kV
• New transformer to convert 13.8kV to 13.2kV
• Proposed 1 MW CHP at hospital
Microgrid Electrical, Controls and Comms Layout
Challenges with Forming Microgrid

- Microgrid critical facilities spread out over an area of ~4 square miles
- Facilities are normally served by 4 utility feeders from 2 distribution substations
- Over 2,000 residential and small commercial loads (7-9 MW) mixed in with critical facilities
- Primary generation source (WTE Plant) normally connected into the subtransmission system
- Multiple Points of Interconnection (POI) to the utility grid
Microgrid Operation

Normal (“Blue Sky”) Conditions

- OCRRA is connected via the existing 115-kV line to the National Grid transmission system
- OCRRA can sell to the utility or into available NYISO markets; UUHCC will operate to provide its own needs
- Microgrid customers have the current supply options that are available to them

Emergency (“Island”) Conditions

- Medium voltage system is reconfigured to allow OCRRA to directly supply microgrid customers
- OCRRA provides electricity to National Grid for delivery to the microgrid customers at a price
- National Grid or a special purpose entity (“SPE”) is responsible for administering Microgrid operations
Microgrid Dispatch in Normal and Emergency Mode

Microgrid Dispatch to Meet Electrical Load – Normal Weekday

Most of the load is met by utility

Microgrid Dispatch to Meet Electrical Load – Emergency Weekday

100% of load met by microgrid DER
Microgrid Control Hierarchy

Control hierarchy governs operation, transition to island mode, and operation in island mode

- Utility might have ultimate supervisory control over microgrid operation
- Microgrid central controller (MGCC) operates (functionally) below utility operations to monitor and dispatch (but perhaps not in this case)
- Generation control systems responsible for primary voltage/frequency regulation
- Protective relay systems perform autonomously, decoupled from control systems
### Summary of Benefit-Cost Analysis (Stage 1) Syracuse

<table>
<thead>
<tr>
<th>Economic Measure</th>
<th>Scenario 1: 0 days/year</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Benefits - Present Value</td>
<td>$53,200,000</td>
<td>Not Evaluated</td>
</tr>
<tr>
<td>Benefit-Cost Ratio</td>
<td>2.6</td>
<td>Not Evaluated</td>
</tr>
<tr>
<td>Internal Rate of Return</td>
<td>222%</td>
<td>Not Evaluated</td>
</tr>
</tbody>
</table>

#### Graph:
- **Costs**
  - Emissions Damages (Grid-Connected Mode)
  - Emissions Allowance Costs
  - Emission Control Costs
  - Fuel Costs (Grid-Connected Mode)
  - Variable O&M Costs (Grid-Connected Mode)
  - Fixed O&M Costs
  - Capital Investments
  - Initial Design and Planning Costs

- **Benefits**
  - Major Power Outage Benefits
  - Avoided Emission Allowance Costs
  - Power Quality Improvements
  - Reliability Improvements
  - Distribution Capacity Cost Savings
  - Generation Capacity Cost Savings
  - Fuel Savings from CHP
  - Reduction in Generating Costs

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Key Take-Aways
General Observations

• Microgrids bring together diverse engineering disciplines, including distributed generation, renewable resources, demand response, smart grid, and advanced control and communications and energy management systems.

• Key drivers are: customers looking for energy independence/surety; resiliency/reliability in US communities; and electrification of rural areas globally.

• The market is growing; expect to see a four-fold increase over the next five years.

• GE’s role is primarily technology provider, designer/consultant, integrator and enabler.

• Many state, national and global investors are looking to invest in microgrids in the U.S.

• Microgrids can provide significant societal net benefits, as well as hard benefits/returns.

• Resiliency (soft) benefits drive positive BCA scores for many community microgrids.

• Microgrids with CHP and high thermal use loads can have positive BCA even without resiliency benefits.
Lessons Learned

• Analysis/output is only as good as the data/inputs – and data collection takes time!

• Leveraging existing generation assets and distribution infrastructure could reduce investment needs, but adds to operational and commercial complexity

• Utility support is critical to designing a reliable viable microgrid delivery system - some utilities are more supportive than others

• Project value proposition improved significantly with participation of the microgrid assets in the utility DR programs and ISO capacity, energy, and ancillary markets

• Societal benefits are applicable for public funding but do not necessarily move the meter for private investors

• Operations and economics are significantly impacted by the regulatory environment and market conditions

• Developing an economically sustainable commercial structure and business model can be challenging and extremely complex
Thank you!