Eaton’s Intelligent Grid Solutions
Microgrid & Energy Storage Systems

Engineering services…
supporting innovative methods to improve power distribution system resiliency

Energy Supply Task Force
NCSL-Capital Forum, Dec. 8th, 2015

Electrical Engineering Services & Systems Division

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• Megatrends, MicroGrids & Segment Drivers
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• Bidirectional Inverter / PGE & Military MicroGrid
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• Controls & Cybersecurity: SMP Gateway (EAS)
• Battery Technology Considerations & Monitoring
• Distributed Generation Options
• MicroGrid Feasibility Study & Implementation
• Government / State Initiatives
• Grid Power Distribution History
Edison’s Pearl Street Station, the first central power plant on September 4th, 1882, was located on Pearl Street in Manhattan. It served 85 customers, supplying 400 lamps.

By the end of the 1880s, many cities had small central stations that each served only a few city blocks by competing electrical power producers.

1895, Westinghouse built an AC hydro-electric power plant at Niagara Falls, sending electricity to Buffalo, 20 miles away.

The Great Depression reduced demand and many electrical companies went under; and many of the New Deal projects centered around the building of massive electricity generation plants, including the Hoover Hydro-electric Dam (1936), and the hydro-electric dams within the TVA.

Samuel Insull: Father of IOUs? Convicted of Fraud …

By the 1930s regulated electric utilities were well-established. The efficiency of generators & transformers improved, and transmission voltages increased resulting in large fossil fuel plants, followed by Nuclear Mega-Plants.

In 1978 the Public Utilities Regulatory Policies passed, making it possible for power plants owned by non-utilities to sell electricity too.
The last 50 Years

The Interconnected Grid

1965 Blackout
Relay Miss-operation and the inability to quickly Island Grid Sections → 30M people affected

New York City blackout of 1977, which resulted in the looting of over 1,600 stores and the setting of over 1,000 fires across the five boroughs.

2003 Blackout
Multiple Causes → 50M people affected

Increasing Grid Outages

Figure 4. Historical analysis of United States outages (1991–2005). Source: Massoud Amin. (Data courtesy of NERC’s Disturbance Analysis Working Group database.)
The last 5 Years

“What happens if Hoboken goes dark? Mayor hopes a $50M microgrid will illuminate vital buildings”

HOBOKEN — Two years ago, all of Hoboken went dark, but city officials hope a $50 million microgrid will keep the city lit if another storm of Hurricane Sandy’s caliber strikes.

The city is hosting a series of expert panels Wednesday at Stevens Institute of Technology in hopes of sparking interest in financial backers for the $50 million project. The proposed microgrid would power roughly 50 buildings in the city in cases of mass outages.

Mayor Dawn Zimmer said that the microgrid would target emergency buildings—the police department, hospital and pharmacies—and the city’s most vulnerable residents, such as senior citizens and the Hoboken Housing Authority.

53 gained “Super-user” privileges on DOE computers.

19 successful attacks in 4 years on Nuclear Weapons Stockpile Computers
Hawaii last year led the nation in the portion of its electricity that comes from solar, with 2.6 percent. "We can't allow circuits to become dangerous," said Peter Rosegg, a utility spokesman. "We can't allow circuits to become unreliable because there's too much PV on those circuits."

Renewables: Wind Profile

Wind Generator Control

Lessons from Katrina and Sandy…

**Katrina and the Louisiana Superdome:**
- Air conditioning in the arena failed immediately
- Some lighting was maintained via an emergency generator, but quickly failed.
- Backup generation faltered
- City's water supply held on a bit longer but finally gave out…toilets in the Dome became inoperable and began to overflow

**New York City Post-Sandy:**
- City deployed as many generators as it could source to meet a demand that significantly exceeded supply
- City’s shelters not intended to support refugees for more than 3 days…far shorter than duration of impact from events like Sandy
- Elderly/sick in high rise buildings could not evacuate without elevators
• Megatrends, MicroGrids & Segment Drivers
Megatrends Impacting today’s US power grid

- **Solar / Wind**
  - Grid instability

- **Earthquakes**

- **Disasters**
  - Hurricanes
  - Storm Surge

- **Aging Grid**

- **Cyber Security**

- **System Outages**

- **Retiring Plants**
MicroGrid: What’s out there …

Historical Typical Power Grid

Simplified MicroGrid

One Way Power Flow

http://electricalengineeringdesigns.blogspot.com/2012/05/transmission-and-distribution-system.html


Energy Surety MicroGrid™
MicroGrid: What’s out there …

Navy’s Green MicroGrid


Map of U.S. Operational Microgrid Deployments

124 microgrids* are currently in operation, with a total generation capacity of 1,169 MW

48% of operational microgrids are located in Northeast (29%) and West Coast (19%) states

Regional hotspots include California (23), Alaska (12), New York (10), and Hawaii (8).
Our Grid: General Security ?
As renewables grow, states & utilities add storage regulations

- **New York** - Reforming the Energy Vision (REV) Order - distributed generation
- **Mid Atlantic** - PJM Frequency Regulation program
- **California** - Solar PV has reached 5% of total electricity generation and growing
- **California** – AB 2514 Energy Storage Systems requires 1.3 GW of storage by 2020
- **Hawaii** - HECO Ramp Rate Control requirements
- **Texas** - ERCOT Frequency Regulation proposal
- **Puerto Rico** - PREPA Ramp Rate Control requirements

Source: GTM Research / Solar Energy Industry Association

California - Solar PV has reached 5% of total electricity generation and growing

California – AB 2514 Energy Storage Systems requires 1.3 GW of storage by 2020

Hawaii - HECO Ramp Rate Control requirements

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Puerto Rico - PREPA Ramp Rate Control requirements
Early focus areas for energy storage & microgrids

- PJM – Now Frequency Regulation
- NY / NE – Emerging Microgrid / Resiliency
- Government & Campus – Emerging Microgrid / Resiliency
- ERCOT – Emerging Frequency Regulation
- California - Now - Energy Storage
Eaton’s Power Xpert Energy Optimizer™
MIT Lincoln Lab Microgrid Demonstration

Eaton’s MIT Lincoln Lab
Microgrid Demo

MIT Lincoln Lab Microgrid
Hardware-in-the-Loop Simulator

Eaton’s Principal Engineer,
Vijay Bhavaraju addresses a
audience of over 150 attendees
concerning Microgrids
Portland General Electric MicroGrid

PGE Salem High Reliability Zone

The Yellow line is a 2.5 mile 12kV over head line
Military MicroGrid by Eaton

Project Focus: Energy Surety / Resiliency for a military campus

Solution developments:
1. Manage multiple generation sources – natural gas generators, solar pv, wind, battery storage
2. Optimized capital and operating costs via microgrid system design
3. Seamless islanding and reconnection to the grid

Eaton provides the “glue” to seamlessly connect and island the microgrid
• Battery Technology Considerations & Monitoring
Battery Storage Pricing

Source: Boston Consulting 2012
# Battery Technology – Qualitative Comparison

<table>
<thead>
<tr>
<th></th>
<th>Lithium-ion</th>
<th>Sodium Sulphur</th>
<th>Advanced Lead Acid</th>
<th>Flow Battery</th>
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</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
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<td><strong>Environment Friendly</strong></td>
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<td><strong>Commercial Maturity</strong></td>
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<td><strong>Technical Complexity</strong></td>
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<td><strong>Portability</strong></td>
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## Key Thoughts on Qualitative Attributes

- **Lithium-ion** batteries are lightweight with a minimal plant footprint and total weight per system thereby making any MW-sized system easily transportable.

- **Sodium-Sulfur** batteries must operate at extremely high temperatures and can explode if they come into contact with water, making them a safety hazard if not handled properly. Consumers dislike the prospect of batteries located close to residential or highly populated areas.

- **Lead acid** batteries are the most mature electrochemical energy storage system. They exhibit a low capital cost and high technical maturity. High potential of environmental hazards has a negative impact on the adoption rate.

- **Flow** batteries are rather complicated in comparison with standard batteries as they may require pumps, sensors, control units and secondary containment vessels.
Battery Monitoring

http://www.hazards.co/calorimeters/battery-thermal-runaway-testing/arctype-btc/runaway-liion-battery-explosion-during-chargingdischarging/


• Multiple Distributed Generation Options
Distributed Generation Solutions

District Distributed Power
1. Combined Heat & Power
2. Combined with Renewable Energy
3. Power Generation for remote area

On-site power
1. Reduction of Power line Cost
2. Reduction of Power Line loss
3. Smart Energy Management
4. Mechanical Drive (Oil & Gas)
## Distributed Generation Solutions

<table>
<thead>
<tr>
<th>Area</th>
<th>Energy</th>
<th>Typical Products</th>
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<tbody>
<tr>
<td></td>
<td>Hot Water</td>
<td></td>
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<td></td>
<td>Chilled Water</td>
<td></td>
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<tr>
<td>2. Hospital / University/Hotel</td>
<td>Electricity</td>
<td>Reci. Engine Chiller Boiler</td>
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<tr>
<td></td>
<td>Hot Water</td>
<td></td>
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<td></td>
<td>Chilled Water</td>
<td></td>
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<tr>
<td>3. Factory / Industrial Complex</td>
<td>Electricity</td>
<td>Aero GT</td>
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<tr>
<td></td>
<td>Steam</td>
<td>Reci. Engine Chiller Boiler</td>
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<td></td>
<td>Hot Water</td>
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<td></td>
<td>Chilled Water</td>
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<tr>
<td>4. Grid Island Area / Mountain area, Desert area, Isolate Island</td>
<td>Electricity</td>
<td>Aero GT</td>
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<tr>
<td></td>
<td>Hot Water</td>
<td>Reci. Engine Chiller/Boiler ORC</td>
</tr>
<tr>
<td></td>
<td>Chilled Water</td>
<td>Solar/Wind/ESS</td>
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• Government / State Initiatives
State of New York Programs
NY Prize Community Grid Competition (NY Prize): Grant Program $40M
(New York State Energy Research and Development Authority)

The NY Prize competition is comprised of three (3) stages (Separate RFP’s)

- **Stage 1: Feasibility Assessments (Max $100K/award)** - Engineering assessments and the feasibility of installing/operating a community MicroGrid.
  - Awards given in June 2015: $100,000 each to 83 communities across the state to support innovative microgrid projects.
- **Stage 2: Audit-Grade Detailed Engineering Design and Financial /Business Plan**
  - Open for proposals due October 2015 through February 2016 (estimate)
  - Note: Participation in stage 1 is not a pre-requisite to participation in stage 2.
  - 25% cost share
- **Stage 3: MicroGrid Build-out and Operation ($25M total awards). Estimating 5-7 awards.**
  - Proposals due July 2016 through December 2017 (estimate).

**Eligibility/Focus of the Grant:**
- Community grids encompassing no less than one facility providing a critical service.
  - Facilities meeting this requirement include: Wastewater Treatment Plants, Hospitals, Universities, Facility of Refuge or Shelters, Schools (K-12), Police Departments, Libraries, Hospitals and Fire Stations
- Connected to multiple, controlled buildings that act as a group of interconnected loads and distributed energy resources.
- Clearly defined electrical boundary and act as a single controllable entity.
- Can connect and disconnect grid and operate in both grid-connected or island mode.

**Purpose/Objective:**
- To promote the design and build of community grids that improve local electrical distribution system performance and resiliency in both a normal operating configuration as well as during times of electrical grid outages.
- Encouraging broad private and public sector participation (including local distribution utilities, governments and third parties)
"Staff White Paper on Ratemaking and Utility Business Models," commonly referred "Track Two"

The Track Two proposal seeks to identify changes to utility rates and business models that can leverage market forces to facilitate the transition to a more innovative and cost-effective electric system. Key principles Include:

- Align earning opportunities with customer value
- Maintain flexibility [Ratemaking structure Allow for future adaptation to evolving markets and technologies]
- Provide accurate and appropriate value signals
- Maintain a sound electric industry
- Shift balance of regulatory incentives to market incentives
- Achieve public policy objectives [that promote a reliable, resilient, affordable, and clean energy system]

The white paper presents specific reforms that could be considered to create better-aligned rates for customers and business models for utilities: Utility business model reforms including opportunities for market-based earnings

- **Market-based earnings (MBEs):** Allowing utilities to provide new services that support DER provider access to the distribution system
- **Earnings impact mechanisms (EIMs):** Performance incentives based on achieving customer-oriented objectives and outcomes (e.g., peak reduction, energy efficiency, customer engagement, affordability, interconnection, etc.)
- **Incremental ratemaking reforms to utility revenue model**
- **Rate design reforms to reflect the needs of the evolving energy marketplace**
- **Demand charge:** Proposes a peak-coincident demand charge in place of some portion of existing volumetric or fixed customer charges.
- **Time-of-use rates:** TOU rates better reflect the actual cost of consuming electricity at a given time. Increased use of TOU rates, either as an opt-in or default rate.
- **Smart home rate:** An opt-in rate to encourage customers to actively participate in the market in the near term and to give active customers more accurate and unbundled price signals for delivery costs, energy costs, ancillary services costs, etc.
- **Commercial and industrial rates:** More closely align commercial and industrial rates with actual costs
- **Standby service tariff:** A rate for self-generating customers that can demonstrate reduced reliance on the grid.
- **Low-income customer rates:** Being addressed in a separate NYS PSC proceeding (Case Number 14-M-0565).
- **Net metering:** The white paper recommends a continuation of net metering rates.

Public comments be submitted November 15, 2015
State of Connecticut Grant Program
MicroGrid Grant and Loan Pilot Program
(Department of Energy and Environmental Protection)

**Funding:** Energy Resiliency Grants $30M
- Round 1 ($18M): Nine (9) Awards
- Round 2 ($5M): Two (2) awards (more stringent guidelines – less awards)
  - Projects not funded in Rounds 1 and 2 are encouraged to participate in future rounds of funding
- Round 3 (Late 2015 RFP)
- Program Funded Elements: Grants and loans awarded to selected projects to assist with cost of design, engineering services, interconnection infrastructure

**Eligibility/Focus of the Grant:**
- Eligibility: Municipalities, electric distribution companies, municipal electric utilities, energy improvement districts, private entities.
- Focus of the Grant: Critical Facilities including hospital, police station, fire station, WTP/WWTP, public shelter, correctional facility, commercial area of a municipality, municipal center, critical areas as defined by DEEP (communications towers, ports, others)

**Purpose/Objective:** Projects that support local distributed energy generation for critical facilities during times of large electric grid outage.
- Support the identified critical facilities during times of electricity grid outages.
- Continuously operate for a minimum of four weeks,
- Access to uninterruptable fuel resources either on site or delivered for a min. of 2 wks.
- Plan to secure additional fuel resources beyond two weeks - storm preparation/mgt.
State of New Jersey Financing Program
Community Development Block Grant-Disaster Recovery
(Board of Public Utilities and the NJ Economic Development Authority)

**Funding:** Financing Programs $200M
- The Energy Resiliency Bank (ERB) was created to assist eligible facilities with the substantial upfront costs in order to encourage wider adoption of resilient technologies.
- The ERB will finance the design, acquisition, construction, and installation of distributed energy resources that will improve and increase the energy resiliency critical facilities.
- First Round ($65M): Projects for (WWTP) and (WTP) – First phase completed last year.
  - The total available budget for electricity storage equipment such as batteries to store onsite renewable electricity production is $5 million, and each project will be limited to a cap of $500,000 for electricity storage equipment.
- Second Round: Communities identified to move forward with final proposal from Round One

**Eligibility/Focus of the Grant:**
- The ERB is focusing on existing commercially available and cost effective DER technologies, including CHP, fuel cells, and renewable technologies (PV)

**Purpose/Objective:**
- Purpose: Financing to develop/enhance distributed energy resource (DER) technologies at critical facilities (directly/indirectly impacted by Superstorm Sandy/other).
- Objectives: DER technologies with islanding and blackstart capabilities that allow facilities to continue to operate despite failures of the larger power grid.
- The DER technologies to be financed (but are not limited to):
  - CHP: Using gas turbines, reciprocating internal combustion (IC) engines, or micro turbines and include thermal storage;
  - Fuel cells with and without heat recovery; and
  - Upgrades to solar panel systems with off-grid inverters and storage systems.
  - The ERB will not finance the cost for installation of solar PV panels or for any balance-of-system equipment related to solar PV panels.
State of Massachusetts Grant Program
Community Clean Energy Resiliency Initiative
(Department of Energy Resources)

Funding: Energy Resiliency Grants $40M
- $7.4M first round (6 community awards)
- $18.4M second round (13 community awards)
  - In round 1 and 2 there were 27 applicants awarded funding for technical assistance
- Projects will continued to be evaluated and funded through 2015
- Program Funded Elements: Technical assistance or direct program implementation

Eligibility/Focus of the Grant:
- Eligibility: Single municipality, joint applications (multiple municipalities), regional planning agencies, regional districts (WTP/WWTP, school, etc.), public/private partnerships
- Focus of the Grant - Critical Facilities: Buildings or structures where loss of electrical service would result in disruption of a critical public safety life sustaining function, i.e. life safety resources, lifeline resources and community resources

Purpose/Objective: Implement clean energy technologies and improve resiliency at critical facilities
- Clean energy generation and/or Energy storage
- Energy management systems (enable load shedding used to isolate and serve critical loads during an event
- Technology used for DG operation in island mode
- Single building facilities or microgrids
Legislative Recommendations

1) Support Microgrid Feasibility Studies (NY – NYSERDA Program- Ph1)
2) Fund further resiliency of natural gas distribution systems
3) Provide incentives for battery storage power generation (Utilities)
Eaton MicroGrid Resources

Eaton MicroGrid Presentation  www.eaton.com/microgrid  Eaton MicroGrid Proposal

Eaton Video

PGE Video

Eaton
Electrical Engineering Services & Systems

Field Services
24/7 Emergency Response
Acceptance Testing
Startup Commissioning
Maintenance Service Contracts

Power System Engineering
Studies:
- Arc Flash
- Microgrid
- Short Circuit
- Overcurrent
- Harmonic
- Load Flow
- Motor Starting

Power System Automation
Protection & Control Systems
Dashboards
Foreseer /EPMS
Power pert Enterprise Solutions
Metering

Turnkey Projects
Project Management
Engineer, Procure & Construct (EPC)
Local Support, Crisis Response
MicroGrids
Battery Storage

Aftermarket & Life Extension
MV & LV Power Circuit Breaker Replacement
Equipment Rebuild & Reconditioning
Life Extension & Modernization

Total Life Cycle Solutions by Eaton