Eaton is a leading power management company.

We help the world use electrical, fluid and mechanical power more reliably, efficiently, safely and sustainably.

Aerospace – Electrical – Hydraulics – Vehicle
Today’s utilities are under extreme pressure to improve reliability, drive operational efficiencies and reduce costs.

Our solutions help you achieve:
• An adaptable, secure and responsive infrastructure
• Consistent distribution of reliable, efficient and high-quality power
• Enhanced safety to protect people, property and the environment
Industry drivers:

- **Regulations**: less emissions, more renewables, higher resiliency, new utility generation / delivery business models (financial incentives)
- **Power outages** becoming alarmingly more frequent and widespread
- **PV & storage competitiveness** rapidly improving
- **Customers** demanding less outages and faster response
- **Digital Economy** requiring higher power quality
- **Natural Gas availability** redefining generation options
The challenge of providing continuous power

The nation’s hardened IT and communication infrastructure rests on a fragile foundation…the grid

- What can cause a utility grid failure?
  - Natural disasters (Super Storm Sandy and Hurricane Katrina)
  - Cyber attack
  - Solar flares (Canada 1989)
  - Circuit overload/failure (2003 Northeast blackout)
  - Sabotage (PGE Santa Clara, CA substation shooting)
- The new threat - Electronic Pulse Detonation (EMP)
  - The risk of a long term, widespread grid outage; theoretical has become real
- Grid technology is the “Achilles heel”
  - Energy dependence is a well known critical vulnerability
  - Reliance on internet-based smart grid technology increases risk
Cornerstone for implementing local power generation that manages critical infrastructure/assets through microgrid applications.

- **Goal**: The ability to create energy islands for the *long-term operation* of critical infrastructure is a *must* to provide the level of supply security necessary to ensure continued mission critical operations as well as life sustaining support.
- **Identify critical sites**: Operational readiness; Islands of refuge
- **Leverage proven microgrid technology**: Demonstration projects prove the viability of the solution.
- **Budget and financing**: Move budgets to grid-tied optimized power generation assets; Engage private financier’s to offset costs; Leverage grants
- **Engage private public partners**: state, local community, utility, financial, federal, energy surety providers

Energy surety defined
Early DoD Vision for “Operational” Energy

“By 2025 all installations will be able to sustain critical mission capabilities for a minimum period of 6 months without reliance in the off-post commercial power grids or fuel supplies,” 2006/2007 Defense Science Board Key Facility Energy Strategy Recommendations

…all installations by 2025 “will be able to achieve Net-Zero energy status, i.e., will produce as much energy as they consume,” according to a senior Army Corps of Engineers energy expert, Tom Hartranft, chief of the energy branch for the Corps’ Engineer Research and Development Center-Construction Engineering Research Lab.
Microgrid introduction…
Megatrends impacting the US electrical grid

- Solar / Wind
- Grid instability
- Earthquakes
-Storm Surge

- Cyber Security
- Retiring Plants

- Aging Grid
- Storm Surge
- Hurricanes
A commercial microgrid is defined as: An aggregation of electrical loads and generation. These systems are characterized by the operation of distributed generation sources (often including renewable) and servicing multiple, prioritized, loads.

Commercial Microgrid Characteristics

• **Multiple Generators:**
  - Locally dispatchable for microgrid loads
  - Excess generation available for peak shaving

• **Non-utility owned distribution grid:**
  - Interconnected with utility owned distribution
  - Load management

• **Feeder with utility sensing**
  - Intentional islanding
  - Synchronized reconnection to utility
The military microgrid is defined as:
A scalable onsite power grid architecture as an aggregation of load, supply and energy storage interconnection points and controllers, networked along low voltage distribution feeders. The System provides organic generation with integrated renewable sources. This ensures continuous service irrespective of demand or commercial grid state; Peak shaving / high demand (export power), Off peak / normal demand (import power) and Commercial power disruption (intentional islanding)

Military Microgrid Characteristics

• Scalability:
  • Plug and play DG sources
  • Modular control system that scales to operation

• Adaptability:
  • Coordinated fault isolation
  • Dynamic load shedding

• Local Control
  • Real time source dispatching
  • Discretionary load prioritization
Military Microgrid Characteristics

- **Energy Storage:**
  - Power Quality
  - Extended islanded operation
  - Exploitation of renewable source

- **Security, Reliability and Sustainability:**
  - Reduced dependence on external power
  - Optimized use of DG sources
  - Integrated and dispatchable renewable sources
The Microgrid Energy System Concept

A group of generating assets and defined loads that can operate within the utility grid or islanded from the grid, as a self-sufficient stand alone application.

Local “Grid Within a Grid”
- Delivers Power Resilience, Reliability and Uptime

Distributed Energy Sources
- Backup Generation
- In-House Co-Gen
- CHP (Combined Heat and Power)
- On-Site Renewables and Fuel Cells
- Energy Storage (Batteries)

Microgrid Applications
- Islanding & Synchronization
- Black Start
- Generation/Load Balance Control
- Battery Energy Storage & Frequency Regulation

Requires Control System “Glue” to Achieve System Performance
## Microgrid System Considerations

<table>
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<th>Operation Mode</th>
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<th>Loads (P, Q)</th>
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<td>Planned Outage, Storm Anticipation</td>
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<td>Y</td>
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<td></td>
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<td>Y</td>
<td>Y</td>
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<tr>
<td></td>
<td>Demand Response</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Power Quality (Utility)</td>
<td>Utility – maintain PQ Index (SAIFI, SAIDI)</td>
<td>Y</td>
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<td>Y, Y</td>
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<td>Enable High Penetration of Renewables</td>
<td>Ramp Rate Control</td>
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<td>Energy Arbitrage</td>
<td>Export/import with real time pricing</td>
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<td>Resilient power system</td>
<td>Ability to support critical loads</td>
<td>y</td>
<td>Y</td>
<td>Y, Y, Y</td>
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<tr>
<td>Black Start</td>
<td>Microgrid to wake-up from a dead bus</td>
<td>Y</td>
<td>y</td>
<td>Y, y, y</td>
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<tr>
<td>Cost of ownership</td>
<td>Managing resources – lowest cost</td>
<td>Y</td>
<td>y</td>
<td>Y, y, Y</td>
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<tr>
<td>Enterprise Integration</td>
<td>Ability to provide cost, reliability data to enterprise and manage resources</td>
<td>Y</td>
<td>Y</td>
<td>Y, Y, Y</td>
</tr>
<tr>
<td>Ancillary Services</td>
<td>Voltage Regulation, Frequency Regulation</td>
<td>Y</td>
<td>y</td>
<td>Y, y, Y</td>
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Eaton’s Microgrid Energy System leverages a broad product and service portfolio

- Hardened controllers
- Optional redundancy
- IEC 61850 comms modules
- Cyber security
- Yukon Visual T&D HMI
- Relays
- Smart MV
- Grid-tie Connection
- Reclosers
- Breakers
- Switchgear
- Switchboards/Panel Boards
- Transformers
- Regulators
- Services
- Smart Inverter Suite
- 500kW-2.5 MW
- Smart interface
- PV and energy storage integration
- Supporting Electrics
- LV Load Control
- Automation and Project Services
- Turn-key supply
- Total project management
- System design/integration/testing
- Lifecycle services
- System Optimization Software
- Overlay supervisory control
- Microgrid/Power System expertise
- CYME dist. system optimization modeling
- Demand Response for gen. / load balance
- Utility Automation Products
- Critical Loads
- Wind
- Battery
- Backup Generation
- Solar
- In-House Co-Gen
Eaton Microgrid Development and Test Facility

**Equipment Available**

1. 100kW Natural gas generator
2. 125kW Diesel generator
3. 60kW Energy storage
4. 25kW PV
5. Two 125kVA Inverters
6. Load banks
7. Weather station
8. System-in-the-loop
Institution/campus segment: military base experience transferable to commercial segments

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
Utility segment: project experience with storage & microgrid

Project Focus: Utility feeder reliability for commercial and residential customers

Solution developments:
1. Control 20 inverters and batteries to provide 5 MW of energy storage in both grid-connected and islanded modes
2. Design of electric power distribution and controls to connect energy storage system to utility grid
3. Islanding without loss of power and reconnection to the grid
4. Interface to diesel generators, solar pv and wind on the same electrical grid

Eaton provides the “glue” to seamlessly connect and island the microgrid
# Energy Storage Applications

<table>
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<th>Driver</th>
<th>Description</th>
<th>Detail</th>
<th>Business Focus</th>
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</thead>
<tbody>
<tr>
<td>Energy Storage Regulations</td>
<td>Fills need for grid storage to complement intermittent renewables</td>
<td>California AB 2514- IOUs to install 1400 MW by 2020 to mate with 33% RPS reg. 400 MW in 2015</td>
<td>California- Battery installations</td>
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<tr>
<td>Resiliency Regulations</td>
<td>Limits outages due to natural events (weather)</td>
<td>NY REV, numerous state programs &amp; regs to implement microgrids</td>
<td>East Coast Sandy States- CT, Mass., NJ, NY, MD</td>
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<tr>
<td>Frequency Regulation</td>
<td>Supplants loss of coal-fired base load power plants</td>
<td>PJM- Wholesale price creates viable business case for short duration ES. ERCOT emerging</td>
<td>PJM territory- OH, PA, KY WV, VA, NJ; Ontario; ERCOT- TX</td>
</tr>
<tr>
<td>Dependency on imported fossil fuels</td>
<td>Need to embrace renewables to offset high fossil cost &amp; environmental impact</td>
<td>Impacts remote and island grid environments using renewables and ES to minimize diesel use</td>
<td>HI, PR, AK, Canada</td>
</tr>
<tr>
<td>Need for energy surety and independence</td>
<td>Military and government drive for energy surety at key bases and facilities</td>
<td>Military bases and mission-critical facilities critical to national defense</td>
<td>DOD bases and key facilities</td>
</tr>
</tbody>
</table>
Seamless Islanding on a Power Outage

Bus Real Power (kW)

- G1_KW
- SI_KW
- Ren_KW
- Util_KW

Static Switch Opens

Energy Storage Supports Microgrid Bus

Power From Utility

Time of Day

8:34:13 8:34:22 8:34:31 8:34:39 8:34:48 8:34:57 8:35:05 8:35:14 8:35:23 8:35:31
Photovoltaics are Growing but they are Intermittent

Plot showing the Global Horizontal Irradiation (GHI) profile at Mayaguez Puerto Rico

Incremental annual solar power capacity* (MW)

- 46% Residential
- 30% Commercial
- 41% Utility

37% CAGR

Compound annual growth rate (CAGR) 2011–2016

2011: 1,890
2012: 3,328
2013E: 4,375
2014E: 5,306
2015E: 7,045
2016E: 9,186
Energy Storage Supports Dynamics of Renewables

Energy Storage Supports Bus During Solar Variations

Static Switch Opens
Static Switch Closes (Utility Recovers)
Critical Infrastructure Microgrid Design Considerations

- Waste water treatment plant with approximately 1MW spare capacity
- Green line is Feeder-2 that will be islanded and operated as a microgrid.
- New recloser with remote controls for islanding Feeder-2
- Shelter BLDG 6007
- Building 5900 with microgrid with 480kW Natural Gas powered engines and 400kW Energy Storage
Design, build and maintain an automated, secure and cost-effective grid

- **Transform**, protect, connect and build the electric power system backbone
- Manage complex, integrated automated solutions and turnkey projects
- Optimize asset efficiency and reduce system operating costs
- Leverage utility application design and project management expertise
Thank you!

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