The Power to Sustain Warfighter Dominance

Optimizing Generator Efficiency with Energy Storage Technologies

Presented by

Doug Moorehead
President, Earl Energy
Earl Energy Overview

• Earl Energy is an energy systems engineering and product development firm, owned and led by veterans and headquartered in Portsmouth, VA
• We design, build, test, install, and service military power generation and energy management systems
• Affiliated with Earl Industries, a diversified industrial defense contractor with 900 employees and a global footprint
• 15 years of shipboard electrical power and control systems experience
• Expertise in electrical control panels, switchboards, power distribution, and full-scale automation systems
• Preferred power and controls vendor for Military Sealift Command

Doug Moorehead, President and Principal Investigator
• Director of Automotive and Grid-Level Energy Storage at A123 Systems, Inc.
• Original patent holder of A123 Systems, Inc. founding intellectual property
• Bachelor of Science, United States Naval Academy
• Master of Science in Materials and Engineering, Massachusetts Institute of Technology
• Master of Business Administration, Harvard Business School
• U.S. Navy SEAL, 9 years, Combat Veteran
**Generator Inefficiency & the Hybridization Solution**

- Battlefield diesel generators typically operate at low load factors, resulting in **exponentially** higher:
  - Fuel consumption
  - Maintenance costs
  - Physical depreciation of the generator
  - Hazardous emissions of NOx, SOx, PM, and GHGs
- Through plug-and-play integration of small, high-performance energy storage systems, existing battlefield generators can be hybridized
  - Reduces generator runtime by 60-90%, with corresponding reduction in fuel consumption, maintenance and MTBF
  - Maintains 100% power reliability
  - Improves power quality
  - Increases overall sustainability of existing genset inventory and deployed power systems

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**Diesel Fuel Consumption (Source: EPA)**

Battlefield diesel gensets operate at 10-25% load, where energy, maintenance and replacement costs are 20-50% higher.

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**Typical Genset Load Profile**

Infrequent need for even 50% capacity

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**Hybridized Genset Load Profile**

Genset is off most of the time

Genset only runs at optimal efficiency
Earl Energy FlexGen Development Roadmap

**Capabilities**

- 18kW rated power
- 3x 120VAC, 3-phase outputs
- 5kW integrated PV
- AC & 3x DC inputs
- Integrated energy storage
- Dynamic load mgmt/shedding
- Automatic genset start/stop

### Initial USMC Testing
- **EarlCON**
  - Aug 2010

### USMC Operational Testing
- **FlexGen 3kW**
  - May 2011

### Deployment to Afghanistan
- **Lithium ion Prototype**
  - Aug 2011

### USMC Operational Testing
- **FlexGen 35kW 60kW 100kW**
  - May 2011

### Deployment to Afghanistan
- **DHS Unit**
  - Sep 2011

- 3kW rated power
- Integrated lithium ion energy storage
- AC & 3x DC inputs
- Automatic genset start/stop
- Man-portable

- 35, 60 and 100kW rated power
- 2x AC & 3x DC inputs
- Integrated lithium ion energy storage
- Automatic 2x input genset paralleling/phase matching
- Automatic genset start/stop
Why Now?

• Energy storage and large-scale power conversion technology have benefitted from 5+ years of significant government and private investment resulting in lower costs and improved performance, reliability, and safety.
• In a number of large markets, the costs of hybridization are now competitive economically with traditional power systems.
Business Case Analysis

- 5kW EARLCON with integrated energy storage participated in Aug 2010 ExFOB Phase IV in Twentynine Palms, CA
  - NSWC test results confirmed 93% reduction in fuel consumption of 6kW generator
  - Excluding renewable power sources, hybridization of generator alone reduced fuel consumption by 60%
- USMC MARCORSYSCOM issued sole source contract for 2x EARLCONs in Feb 2011 to power battalion-level Combat Operations Centers (COC)

- FlexGen generator hybridization of a 3kW Tactical Quiet Generator (TQG) delivers a cash payback period of 4-5 months and total savings of $68,000 over the 9-year life of the system
- Enables the TQG to turn off for 20-21 hours per day
- Reduces maintenance, emissions, sound, and vibration by ~80%
- Extends generator replacement cycle by 4x to approximately 5 years
- Our financial analysis excludes the positive financial and competitive impacts of the reductions in emissions, sound, and vibration
- The primary drivers of payback are electrical load profile, fuel consumption, and fuel cost

Key Assumptions
- Genset price: $10,400; no salvage value
- Genset lifecycle: 10,000 hours
- Genset annual maintenance: $2,500
- 24/365 operation
- Diesel fuel cost: $7.50-$30/gal
- Hybridization system lifecycle: 9 years
- Battery service: 18 months

Example - 3kW TQG at $7.50 ADP

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Generator Power Output</td>
<td>4,011 kWh</td>
</tr>
<tr>
<td>Cost of Power at Optimal Power Factor</td>
<td>$ 1.95</td>
</tr>
<tr>
<td>Annual Cost of Power at Optimal Power Factor</td>
<td>$ 7,828</td>
</tr>
<tr>
<td>Actual Cost per kWh (incl. fuel &amp; maint.)</td>
<td>$ 5.28</td>
</tr>
<tr>
<td>Observed Annual Cost of Power</td>
<td>$ 21,168</td>
</tr>
<tr>
<td>Annual Cost of Generator Inefficiency</td>
<td>$ 13,340</td>
</tr>
<tr>
<td>Production Cost of 3kW Hybridization System</td>
<td>$ 5,750</td>
</tr>
<tr>
<td>Payback period (months)</td>
<td>5.2</td>
</tr>
</tbody>
</table>
The market for generator hybridization is large, spanning multiple customer segments, identified by the following characteristics:

- **High fuel delivery costs** – battlefield, remote locations, at sea
- **High maintenance costs** – dangerous, harsh or remote locations, at sea, highly technical equipment, mission-oriented power systems
- **High generator utilization rates** – where gensets provide prime power, where engineers factor in excess capacity as a rule
- **Emissions restrictions/incentives** – European markets tax carbon emissions, in-port vessels, harbor dredging
- **Silent and low vibration power** – military operational security, luxury yachts, highly instrumented equipment
- **Clean, high quality power** – sensitive instrumentation
- **Mission-critical power** – uninterruptible power supplies

**Inform**
- Energy surveys
- Identify/quantify inefficiencies
- Collect configuration data

**Reliability**
- Put products in customers’ hands
- Flawless field service/support

**Endorsement**
- Third party validation
- Ports, EPA, IMO, NGOs

**Measure**
- Prove business case
- Improve product design
Thank You

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