Power electronics based grid integration technology for energy storage application

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Work Funded under Grid Modernization Laboratory Call

The vision of DOE’s Grid Modernization Initiative (GMI) is:

• A future grid that will:
  ✓ solve the challenges of seamlessly integrating conventional and renewable sources, storage, and central and distributed generation.
  ✓ A future grid that will deliver resilient, reliable, flexible, secure, sustainable, and affordable electricity to consumers where they want it, when they want it, how they want it.
Project Objectives

• General Project Objectives:
  – Broadening the customer base with a low cost energy storage solution.
  – Integrated energy system to increase value of storage.
  – Overcoming secondary-use energy storage challenges.

• Deliverable: Deployment of the system
Overall Approach

3 year Project: Full system completed and under deployment

Year 1: Design

Year 2: Prototype

Year 3: Full design and deployment
Overall Architecture

Supporting Integration Functionality (ORNL)

- AGENT PLATFORM
  - RASPBERRY PI 3
  - INTEL NUC
- INTERFACE AGENT
- MESSAGE BUS
- CONVERTER AGENT
- INTEL AGENT
- BMS AGENT

Power Conditioning System (ORNL)

- INVERTER CONTROLLER
- Ethernet: API-UDP
- Communications
- Control Logic
- Control to PWM
- SWITCH MODULES
- HEAT SINK

Battery System (SNT)

- Serial Ethernet CAN/MODBUS
- BMS
- BATTERIES
## Specifications

### ELECTRICAL

<table>
<thead>
<tr>
<th></th>
<th>Inverter</th>
<th>Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Peak</td>
<td>12 kW</td>
<td>14 kW</td>
</tr>
<tr>
<td>- Continuous</td>
<td>10 kW</td>
<td>10 kW</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 kWh</td>
<td></td>
</tr>
<tr>
<td><strong>AC (Roundtrip) Efficiency</strong></td>
<td>~90%</td>
<td></td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>240 VAC +/- 2%</td>
<td></td>
</tr>
<tr>
<td><strong>Current THD</strong></td>
<td>&lt; 5% THD</td>
<td></td>
</tr>
<tr>
<td><strong>Self-Discharge</strong></td>
<td>&lt; 1% of stored energy over 48 hours</td>
<td></td>
</tr>
<tr>
<td><strong>Response Time</strong></td>
<td>1000 W/s – Ramp from 0 to 100% of rated discharge in &lt; 10s</td>
<td></td>
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</tbody>
</table>

### GENERAL

<table>
<thead>
<tr>
<th></th>
<th>Inverter</th>
<th>Battery: 850 Lbs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions</strong></td>
<td>45” W x 65” H x 40” D</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Installed Weight</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ambient Temperature</strong></td>
<td></td>
<td>0°C to 45°C</td>
<td></td>
</tr>
<tr>
<td><strong>Design Life</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Audible Noise</strong></td>
<td></td>
<td>70 dB at 1 meter</td>
<td></td>
</tr>
<tr>
<td><strong>End of Life Disposal</strong></td>
<td></td>
<td>Batteries reclaimed and recycled by Spiers New Technologies</td>
<td></td>
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</table>

### CODES AND STANDARDS*

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<tr>
<td><strong>Interconnection</strong></td>
<td>UL1741</td>
</tr>
<tr>
<td><strong>Electric Energy Storage</strong></td>
<td></td>
</tr>
<tr>
<td><strong>National Electric Code</strong></td>
<td>NFPA 70</td>
</tr>
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</table>

- Full design specifications developed.
- System designed to conform to these standards: pending a third-party verification service.
Power Conditioning System (PCS) 2.0
• Targeted lower cost Digital signal processor equipment and components (compared to previous NI version)
Grid Tied Tests of PCS 2.0

- Grid Emulator and passive load bank were utilized to respectively represent the grid connecting to the house loads
- Evaluated the basic functionalities of hardware architecture
- Operated continuously in open loop mode to ensure Habitat Generation II thermal design

DC Voltage: 440 V  Total Power: 11.53 kW

Front control panel of DC power supply (Left) and experimental waveforms captured by the oscilloscope during the continuous open loop operation tests (Right)
Final Prototype

• Battery system incorporates self protection and controls
• Include contactors with status feedback
• Incorporated new Battery Management System (BMS) with multiple communication interfaces.
Testbed

Software section

Hardware section

RestAPI

POST

GET

COMP

NETWORK SWITCH

COMP

Battery and BMS

Energy Storage System

Master Controller and Optimizer

Manual Control

Optimization and Dispatch

Use Case Test/Demos

Grid Emulator

Grid Emulator 100 kW

ES System 10 kW

PNNL/SNL protocols

OE ES program
Summary of Accomplishments: FY18

• Completed the new version of the hardware interface for the battery system

• Completed the software interface design and development

• The prototype was integrated with two battery units with different BMS systems

• The prototype was tested for bidirectional operation with a grid emulator up to 10 kW.

• Generated a reference design for the BMS systems
FY19 and Future Work

• Complete the deployment process

• Long runs and data collection at site.

• Evaluate achievable economic return

• Develop advance BMS systems with new technologies
  • New semiconductor devices
  • New multi chemistry energy storage systems
Acknowledgment and Collaboration

This work is supported by Dr. Imre Gyuk, Manager, Energy Storage Program, Office of Electricity Delivery and Reliability, Department of Energy.
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