Grid-Scale Energy Storage Demonstration for Ancillary Services Using UltraBattery®
PJM Frequency Regulation
3 MW Frequency Regulation Installed at EPM

3.6 MW BES System for 3MW of Frequency Regulation

4 x UltraBattery® strings

900 kW Inverter

BESS Master Controller

13.8 kV

Electrical Single Line Diagram

PJM Frequency Regulation Project
Communications Framework

Secure Communications Framework

Control Interface RTU

Internet (encrypted)

PJM Control Input Signals

Via Modbus over TCP/IP

BESS

System Control Processor

Master and Subsystem Controllers

UltraBattery® Storage Blocks

Battery Management and Monitoring System

Power Conversion System [Dynapower]

BMM feeds back:
- Temperature
- State of Charge
- Voltage

PJM Grid
PJM System Performance

PJM Request and BESS Response for Aug 5, 2013

String SOC – Aug 5, 2013

String Voltages – Aug 5, 2013
Regulation Services on PJM

Revenue of 1MW Regulation Plant Operated Continuously With 100% PJM Performance Score

- Regulation Market Capability Clearing Price (RMCCP)
- Regulation Market Performance Clearing Price (RMPCP)

PJM introduces performance payments

PJM introduces performance mileage modifier
Regulation Services on PJM

<table>
<thead>
<tr>
<th>Traditional Regulation</th>
<th>Daily Mileage</th>
<th>Mileage Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>141.7 MW</td>
<td>1.0</td>
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<table>
<thead>
<tr>
<th>Dynamic Regulation</th>
<th>Daily Mileage</th>
<th>Mileage Ratio</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>434.3 MW</td>
<td>3.1</td>
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### PJM System Performance

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
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<tbody>
<tr>
<td>Energy (Capacity at Rated Power - 100% Capacity)</td>
<td>2.2 MWh</td>
</tr>
<tr>
<td>Used Partial State of Charge Energy Band</td>
<td>0.5 MWh</td>
</tr>
<tr>
<td>Daily MWh Throughput (Charge + Discharge) per MW</td>
<td>≈ 6.5</td>
</tr>
<tr>
<td>Total MWh Throughput (Charge + Discharge) to Date</td>
<td>≈ 5.5 GWh</td>
</tr>
<tr>
<td>Total Number of Hours of 1 MW Reg. Service Supplied to PJM</td>
<td>≈ 20,000</td>
</tr>
<tr>
<td>Average Hourly Price Since October 2012</td>
<td>≈ $48/MW</td>
</tr>
<tr>
<td>DC-DC Efficiency (Rate Dependent)</td>
<td>≈ 92%</td>
</tr>
<tr>
<td>AC-AC Efficiency (13.2kV Revenue Meter)</td>
<td>≈ 82%</td>
</tr>
<tr>
<td>Parasitic Losses</td>
<td>≈ 8.5%</td>
</tr>
<tr>
<td>Current Average Operational Availability</td>
<td>≈ 90%</td>
</tr>
</tbody>
</table>
PJM System Performance
PJM System Performance
UltraBattery Technology: Understanding & Breakthrough

Original batteries [UB 95-33]
0.7 – 0.9 C 1

New UltraRax & UltraFlex batteries [UB 145 ET]
1.4 C 1

2x Power
Higher Efficiency
Even temperature

Value $/kW↑
Cost $/kW↓
EPM funding additional projects to demonstrate UltraBattery performance

Storage Facility #1:
- 3MW Frequency
- Regulation
- 2x Power
Multi-Purpose Storage System

Storage Facility #2:

- 100 kW Frequency Regulation
- 250kW UPS/Back-up
Multi-Purpose Storage System

Storage Facility #3:

- 200 kW Frequency Regulation
- 200 kWh Demand Management
- 200 kW UPS/Back-up
THANK YOU

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PJM Frequency Regulation