Tehachapi Wind Energy Storage Project

2014 DOE/OE Energy Storage Systems Program Peer Review
September 17-19 2014

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Advanced Technology
Southern California Edison
Southern California Edison

- 14 million customers: one of the largest utilities in US
- 125 years of service
- Award-winning energy efficiency and demand response programs

Committed to safely providing, reliable and affordable electric service
SCE Advanced Technology Focus

• Implementing government policies and regulations and improving current utility operations

• Enabling customer adoption of new energy technologies

• Acquiring a deep understanding of the performance and controls of distributed resources

• Investing in next generation infrastructure to enable utilities to be the “optimizer” of distributed resources
Project Objectives

• Test Battery Energy Storage System as a system reliability and/or market driven device
  – Demonstrate the performance of a lithium-ion Battery Energy Storage System (BESS) for 13 specific operational uses, both individually and bundled
  – Share data and results with CAISO, CEC, CPUC, DOE, and other interested parties
  – Assist in the integration of large-scale variable energy resources

• Integrate battery storage technology into SCE’s grid
  – Test and demonstrate smart inverter technology
  – Assess performance and life cycle of grid-connected lithium-ion BESS
  – Expand expertise in energy storage technologies and operations
Tehachapi Storage Project (TSP) Facility

- Located in the Tehachapi area, California’s largest wind resource
- Massive wind development potential (up to 4,500 MW) driving grid infrastructure
- Installed at SCE’s Monolith Substation
- 6,300 ft² building
- Connected at sub-transmission level through a 12/66 kV transformer
TSP Layout

12kV/66kV transformer

BESS Building

PCS units
Project Timeline

02/09/2010 – Project Started
10/13/2010 – DOE Contract Signed
02/28/2011 – Original Vendor Contract Signed
10/16/2012 – Original Vendor Filed for Bankruptcy
03/27/2013 – New Vendor Contract Signed
07/18/2014 – System Commissioning/Acceptance Completed
System Specifications

- **Battery Storage System**
  - Li-Ion
  - Manufactured by LG Chem.
  - 32MWh usable

- **Power Conversion System**
  - 9MVA
  - 12kV connected
  - Manufactured by ABB
System Configuration

How to get 32MWh from 60Wh battery cells?

<table>
<thead>
<tr>
<th></th>
<th>Cell</th>
<th>Module</th>
<th>Rack</th>
<th>Section</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity</strong></td>
<td>609 k</td>
<td>10,872</td>
<td>604</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>3.7 V</td>
<td>52 V</td>
<td>930 V</td>
<td>930 V</td>
<td>930 V</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>60 Wh</td>
<td>3.2 kWh</td>
<td>58 kWh</td>
<td>8.7 MWh</td>
<td>32 MWh</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>380 g</td>
<td>40 kg</td>
<td>950 kg</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
13 Operational Uses

• Transmission
  – Provide voltage support/grid stabilization
  – Decrease transmission losses
  – Diminish congestion
  – Increase system reliability
  – Defer transmission investment
  – Enhance value and effectiveness of renewable energy-related transmission

• System
  – Provide system capacity/resource adequacy
  – Integrate renewable energy (smoothing)
  – Shift wind generation output

• Market
  – Frequency signal/response
  – Spin/non-spin/replacement reserves
  – Ramp management
  – Energy price arbitrage
8 Core Tests

1) Provide steady state voltage regulation and dynamic voltage support at the local 66 kV bus
2) Perform Test 1 while operating under any mode and performing real power injection/absorption required under such mode
3) Charge during periods of high line loading and discharge during low line loading under SCE system operator control
4) Charge during off-peak periods and discharge during on-peak periods under SCE system operator control
5) Charge and discharge seconds-to-minutes as needed to firm and shape intermittent generation in response to a real-time signal
6) Respond to CAISO control signals to provide frequency regulation
7) Respond to CAISO market awards to provide energy and spin/non-spin reserves
8) Follow a CAISO market signal for energy price
## Deployment Challenges

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Resolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction &amp; Site Constraints</td>
<td>• Made scheduling a priority; deliveries, tasks, crew sizes, and trash disposal</td>
</tr>
<tr>
<td>Insects and Rodents</td>
<td>• Installed extra door seals</td>
</tr>
<tr>
<td></td>
<td>• Installed traps</td>
</tr>
<tr>
<td></td>
<td>• Installed sonic repellers</td>
</tr>
<tr>
<td>Weather Conditions &amp; Schedule Impacts</td>
<td>• Checked weather forecasts daily and scheduled travel, construction crews, &amp; tasks accordingly</td>
</tr>
</tbody>
</table>
## Deployment Challenges (cont.)

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Resolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale and Complexity of System</td>
<td>• Managed project onsite, real-time, in-person</td>
</tr>
<tr>
<td></td>
<td>• Communicated continually across teams</td>
</tr>
<tr>
<td></td>
<td>• Implemented additional training, quality inspections and checks</td>
</tr>
<tr>
<td>Number and Breadth of Stakeholders</td>
<td>• Continued constant stakeholder engagement and collaborative efforts</td>
</tr>
<tr>
<td>Complexity of Interconnection Process</td>
<td>• Remained flexible, engaged, &amp; supportive</td>
</tr>
</tbody>
</table>
System Validation Challenges

• Large energy storage systems are modular
  – Comprised of AC and DC subsystems
  – Scaled by adding additional components in series/parallel
  – Multiple manufacturers
  – Requires integration
  – Increased likelihood of problems

• Utilities need to assess safety and reliability prior to field deployment

• Issues with testing large systems in the field
  – Grid/personnel safety
  – Geographic distance
  – Need to exchange significant power at will
  – Hardware/firmware/software problems can take many months to solve
System Validation Approach: Mini-System Lab Testing

Mini-System enables subscale testing in the lab before full-scale operation of the BESS at Monolith Substation

<table>
<thead>
<tr>
<th></th>
<th>Mini-System</th>
<th>Full System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footprint</td>
<td>77 ft²</td>
<td>6300 ft² building</td>
</tr>
<tr>
<td>Power</td>
<td>30 kW</td>
<td>8 MW</td>
</tr>
<tr>
<td>Energy</td>
<td>116 kWh</td>
<td>32 MWh</td>
</tr>
<tr>
<td>Power Conversion System</td>
<td>One Mini-Cabinet</td>
<td>Two 40-foot containers</td>
</tr>
<tr>
<td>Sections</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Banks</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>Racks</td>
<td>2</td>
<td>604</td>
</tr>
<tr>
<td>Modules</td>
<td>36</td>
<td>10,872</td>
</tr>
<tr>
<td>Cells</td>
<td>2,016</td>
<td>608,832</td>
</tr>
</tbody>
</table>
## Mini-System Testing Key Findings

<table>
<thead>
<tr>
<th>Key Findings</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovered and resolved critical operation aspects regarding the battery system and PCS</td>
<td>Enabled operational aspects to be resolved quickly</td>
</tr>
<tr>
<td>Several iterations of software/firmware upgrades were required</td>
<td>Significant time and resources saved due to upgrades performed in the lab at subscale level versus full-scale at remote substation location</td>
</tr>
<tr>
<td>24/7 operation for more than 4 months prior to full system commissioning yielded feedback to implement many additional functional upgrades</td>
<td>System operation and features have been enhanced (optimized control algorithms &amp; graphic user interface)</td>
</tr>
</tbody>
</table>
## Pre-Operation Challenges

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Resolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>System integration between all components; Sub-components may be mature but system integration is not</td>
<td>Assess safety and reliability prior to field deployment</td>
</tr>
<tr>
<td>System Acceptance Testing (SAT) is impractical on site</td>
<td>Introduced multi-step Acceptance Testing based on lab evaluation of:</td>
</tr>
<tr>
<td></td>
<td>• Communication system by SCE IT group</td>
</tr>
<tr>
<td></td>
<td>• PCS controller on the RTDS (Real Time Digital Simulator)</td>
</tr>
<tr>
<td></td>
<td>• Mini-system</td>
</tr>
<tr>
<td>Framework around control ownership in a non-vertically-integrated utility:</td>
<td>Engage stakeholders and identify requirements to be completed for (inter)connection and deployment</td>
</tr>
</tbody>
</table>
Initial Operation

Full Discharge:
- 8MW - 4 hours
- 32MWh
Final Thoughts

• Installation, deployment and initial operation of large-scale ESS has:
  – Provided key learning to facilitate future deployments
  – Demonstrated the benefits of Mini-System testing

• Close collaboration between utility and turnkey system provider has accelerated lessons learned
Questions?