Life Cycle Testing and Evaluation of Energy Storage Devices

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September 28, 2012
SNL Energy Storage System Analysis Laboratory

Mission:
Provide reliable, independent, third party testing and verification of advanced energy technologies for cells to MW systems

Problem:
• Current testing methods are inconsistent and the results confusing
• Potential storage customers, i.e. utilities, without experience in storage, are reluctant consumers.

Approach:
Develop advances through:
• exploration of test protocols, through direct research and standards activities
• high precision testing

Provide ongoing:
• expertise in testing programs to customers
• verification of specific technologies
SNL Energy Storage System Analysis Laboratory

Providing reliable, independent, third party testing and verification of advanced energy technologies for cell to MW systems

Testing Capabilities Include:

Expertise to design test plans to fit technologies and their potential applications

Cell, Battery and Module Testing
- 14 channels from 36 V, 25 A to 72 V, 1000 A for battery to module-scale tests
- Over 125 channels; 0 V to 10 V, 3 A to 100+ A for cell tests
- Potentiostat/galvanostats for spectral impedance
- Multimeters, shunts and power supply for high precision testing
- Temperature chambers
- IR camera

System Testing
- Scalable from 5 KW to 1 MW, 480 VAC, 3 phase
- 1 MW/1 MVAR load bank for either parallel microgrid, or series UPS operations
- Subcycle metering in feeder breakers for system identification and transient analysis
Standards Activities

DOE Performance Protocol
• Working closely with PNNL, and have input from utility and manufacturing side

IEC
• CENELEC Workshop Agreement for Flow Batteries
• International Standard IEC 61427-2 Secondary Cells and batteries for renewable energy storage – Part 2: On-grid applications

Last Peer Review saw repeated calls for standard language and testing, with definitions. In response standards development has been a large priority in the past year
Cycling protocols employed in testing

VRLA Life cycle data S. Drouilhet, B.L. Johnson, 1997 NREL
Waveform Testing

State of the Art: Frequency Regulation

State of the Art: Load Leveling

Stacked Applications: Working with KEMA

Stochastic Application Modeling:
Future Projects

CUNY: Ni-Zn Flow battery modules August 2013

AllCell: Test Program under consideration

Encell: Testing anticipated February 2012

Altairnano: Generation II 13 Ah cells; Generation III 14 Ah

LiFe Batt: Cost share agreement for testing new generation

3rd party testing open to researchers and manufacturers in FY 2013
Summary of completed testing activities

East Penn

East Penn Ultrabattery® Module
20,347 5% PSOC utility cycles
422 Days and 229 PV deep discharge cycles

Furukawa

Furukawa Ultrabattery® Module
7,012 5% PSOC utility cycles
498 Days and 280 PV deep discharge cycles
Ultrabattery® performs much longer than VRLA

**PSOC Utility Cycling**

- **East Penn Ultrabattery®**
  - 5% DOD cycle
- **Furukawa Ultrabattery®**
  - 5% DOD cycle
- **VRLA Battery**
  - 10% DOD cycle

- Filled symbols (●) cycled at 400 A
- Open symbols (○□) cycled at 300 A

* VRLA After Recovery

- **Furukawa Ultrabattery®** operated at elevated temperatures, likely leading to thermally activated degradation
- **East Penn Ultrabattery®** ran for more than 20,000 cycles without recovering the battery
Ultrabatteries® also perform much longer in energy applications than VRLA.

Even at 40 day deficit charge, Ultrabatteries® have performance far surpassing traditional VRLA batteries even with as low as a 7 day deficit charge (without recovery by taper charge).
Ongoing testing activities

**Cell Level Testing**
- East Penn Advanced Battery Cells
  (D. Enos 10:50 AM Thur.)
- Altairnano Lithium-titanate oxide cells
  40,000 10% PSOC
- International Battery Li-FePO₄ Cells
  20,000+ 10% PSOC

**Module Level Testing**
- RedFlow 10kWh Zn-Br flow battery module and system
  (D. Rose)
International battery cell at 27K+ cycles

International battery Li-ion FePO₄ large format prismatic 160 Ah cells

0.6C 10% Utility cycles

80% Initial Capacity

0.6C Utility PSOC cycle
10% SOC cycles at 100 A

15% capacity loss after 27,000+ cycles
## Altairnano Characterization

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<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td><strong>Capacity (Ah)</strong></td>
<td>12.58</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Voc (V)</strong></td>
<td>2.531</td>
<td>0.006</td>
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<tr>
<td><strong>R (µΩ)</strong></td>
<td>2642</td>
<td>147</td>
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<tr>
<td><strong>Mass (kg)</strong></td>
<td>0.367</td>
<td>0.001</td>
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<tr>
<td><strong>3 Month Self Discharge</strong></td>
<td>4.825%</td>
<td>0.025%</td>
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</tbody>
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Lithium-titanate oxide cells
Altairnano Cycle-Life

94% of initial capacity after 36K 10% PSOC utility 2C cycles without rests

97.6% of initial capacity after 4,000 10% PSOC utility 4C cycles
Summary/conclusions to date

- Current advanced batteries are completing over 10,000 10% cycles with little loss in capacity, currently at over 40,000 cycles for Altairnano.

- Anticipate longer testing to reach EOL so we are exploring testing paths. More aggressive tests, and varied protocols including stacked testing under investigation.

- Participation in standards activities is becoming a priority; as we heard at last Peer Review a recurring call for standard language and testing.

Contact Information:

To take advantage of Sandia testing services or consultation:

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With grateful acknowledgment of Dr. Imre Gyuk for support of storage testing