Zinc|Manganese Dioxide Batteries for Long Duration Energy Storage (LDES) Systems

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DOE Peer Review Meeting
Need of Viable Solutions for LDES

*Key Takeaway: For greater penetration of renewables into the grid we need storage solutions >10+ hours*
Applications Space Overview

Key Takeaway: Aqueous batteries can serve the need for LDES solutions

Active material contribution is higher. Bobbin-type cell designs are a good solution

Inactive contribution like current collectors to the overall cost dominates
Introduction to the Zinc|Manganese Dioxide Chemistry

Key Takeaway: Chemistry has the potential to be a high energy density battery coupled with its safe and non-toxic properties

![Diagram showing the zinc-manganese dioxide chemistry]
Key Takeaway: Reversibility is dictated by which electron is accessed in the MnO$_2$ discharge.
Key Takeaway: UEP cells can provide 1 week of discharge multiple times at high energy efficiency

Cell charged in ~14 hours

168hrs of Discharge

Energy Efficiency ~90%

Citation: UEP data
**Key Takeaway:** Zn-anode batteries are versatile but cathode determines the viability for specific applications

<table>
<thead>
<tr>
<th></th>
<th>UEP</th>
<th>EOS</th>
<th>Zinc8</th>
<th>E-Zn</th>
<th>Zinc Five</th>
<th>ZAF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current Generation</td>
<td>Zn-Br</td>
<td>Zn-air</td>
<td>Zn-air</td>
<td>Zn-Ni</td>
<td>Zn-Ni</td>
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<tr>
<td>Self-Discharge</td>
<td>0.01% per day</td>
<td>1% per hour</td>
<td>N/A</td>
<td>N/A</td>
<td>0.1% per day</td>
<td>0.1% per day</td>
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<tr>
<td>Round Trip Efficiency</td>
<td>80-90%</td>
<td>70-80%</td>
<td>64%</td>
<td>40-50%</td>
<td>71-88%</td>
<td>85%</td>
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<tr>
<td>System Energy Density</td>
<td>&gt;100</td>
<td>11</td>
<td>N/A</td>
<td>N/A</td>
<td>34</td>
<td>N/A</td>
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</tbody>
</table>

Citation: Publicly available data
Safety Study of the UEP’s Battery

Nail Penetration Test

Heat Exposure Test

Overcharge Test

Short Circuit Test

Key Takeaway: UEP cells tested by 3rd party for safety evaluation
Nail Penetration Test

Key Takeaway: Cells did not result heat generation and spillage issues. Passed the nail penetration test

Nail Penetration Test

- Low internal resistance of the cell
- Low chemical spill risk because of the general toughness of the cell
- Low likelihood of adverse chemical reaction
Heat Exposure Test

**Key Takeaway:** Cells did not result in thermal runaway reaction and did not catch on fire. Passed heat exposure test.

**Experimental Design**

**Thermal Runaway Comparison with Lithium-ion**

Melted Down Cell Following Heat Exposure Test, No Fire!

Citation: UEP data, RSC Advances, 2014,4,3633-3642
Short Circuit Test

Key Takeaway: The temperature increase in the cells was not high. They passed the short circuit test.

Shorting results in small Temperature rise but OCV is retained after short is released.
Overcharge

Key Takeaway: Overcharge of the cells results in mostly electrolyte breakdown with no safety related issues. Cells passed overcharge test

Overcharge results in slight temperature increase and H₂ formation

Citation: UEP data
UEP LDES Projects

1. Project with NYSERDA
   1. Title: Deployment of Rechargeable Zinc Alkaline BESS for Long Duration Applications
   2. Size: 0.1MW/1MWh
   3. Collaboration: Hudson Valley Innovation Campus and EPRI
   4. Value: Provide power resilience to end users, reduce need for fossil fuel-based generators, allow for energy reduction through peak demand shaving, and support grid by participating in demand response events

2. 2 other DOE Awards
   1. Title: Demonstration of Rechargeable Zinc Alkaline LDESS for Long Duration Applications in New York State
   2. Size: 2 Systems, Each is 0.3MW/3.6MWh
   3. Collaboration: NYPA and EPRI
   4. Value: Power backup, peak demand management and solar firming
**Key Takeaway:** Bobbin-type cells are the lowest cost cells ($20-$40/kWh). But commercial cells suffer from rechargeability. Improvement in materials (electrode and electrolyte) property and internal cell design important for rechargeability.
UEP Bobbin Project

Dissection of Commercial Cells

Key Takeaway: Learned about the bobbin cell design from various commercial cells. Learned the drawbacks in some designs and we have developed our own assembly process to make rechargeable bobbin cells.
Key Takeaway: Achieved long cycle life cells at various C-rates.

Funded by Sandia (PO #2190188)

Citation: UEP Data
Next Generation Work - 2nd Electron Zn|MnO₂

Key Takeaway: 2nd electron Zn|MnO₂ cells can be used for LDES. Capable of fast charging and cycling multiple times at 100hrs of discharge.

Charge time <10hrs

C/100 discharge rate

Cycle 1
Cycle 5
Cycle 10

Collaboration with CCNY

Check Jungsang Cho Poster
Key Takeaway: Mn HCF cathodes are being studied as cathode candidates for WISE Zn-ion batteries. With H2 corrosion mitigated, these cells can be low-maintenance batteries for LDES.
Looking Ahead

• UEP will manufacture lowest cost Zn|MnO₂ cells

• There will be 3 installation projects for LDES

• Bobbin cells are ahead in their development curve. We will be testing modules made of bobbin cells for LDES application

• 2nd electron cells will be scaled to larger cells and made on the UEP production line for further LDES testing

• WISE-type Zn-anode batteries are early in development. Cathodes have been identified and are being tested for LDES.
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