Nickel-Zinc Flow Battery

Martin Klein
Visiting Professor,
City College of New York, CUNY

Prof. Sanjoy Banerjee
Prof. Dan Steingart
Dr. Yasumasa Ito
Robert Plivelich
Michael Nyce

E-mail: bipolarbat@aol.com
Tel: 212-772-1175 Cell: 917-331-4334

Presentation: Nov 9, 2010
2010 Advanced Energy Conference
The CUNY Energy Institute Overview

CITY UNIVERSITY OVERVIEW
• FOUNDED 1847 (THE LARGEST URBAN PUBLIC UNIVERSITY)
• TWENTY THREE COLLEGES AND INSTITUTES IN NEW YORK CITY
• SERVING MORE THAN 480,000 STUDENTS, INCLUDING DEGREE, CONTINUING EDUCATION AND GRADUATE STUDENTS
• ENGINEERING SCHOOL LOCATED AT THE CCNY CAMPUS, 138ST & CONVENT AVE

CITY UNIVERSITY ENERGY INSTITUTE
• FOUNDED 2008, AFFILIATED WITH THE CHEM ENG DEPT AT CCNY

➢ ENERGY INSTITUTE MISSION
• R&D OF ADVANCED SUSTAINABLE ENERGY TECHNOLOGIES
• EDUCATE AND MENTOR THE NEXT GENERATION OF ENERGY SCIENTISTS AND ENGINEERS

➢ AREAS OF FOCUS
• ELECROCHEMICAL ENERGY STORAGE
• NUCLEAR
• OIL & GAS

➢ FUNDING BACKLOG
$10 MILLION OPERATION and $4 MILLION CONSTRUCTION
Nickel Zinc batteries have been proven to be safe, low cost, and scalable. The remaining challenge involves increasing the cycle life.
Nickel-Zinc System

ADVANTAGES

• AVAILABLE ABUNDANT MATERIALS
• LOW COST MATERIALS, THEORETICALLY $32.2/KWHR
  (Based on current metals price, Ni: $11/lbs, Zn: $1.1/lbs)
• HIGH ENERGY DENSITY, THEORETICALLY 334WHR/KG
• LOW TOXICITY MATERIALS
• AMBIENT TEMPERATURE OPERATION
• AQUEOUS NON FLAMMABLE ELECTROLYTE
• SCALABLE
• MANUFACTURABLE

HISTORIC DISADVANTAGE

• POOR CYCLE LIFE LIMITED BY ZINC ELECTRODE SHAPE CHANGE AND DENDRITIC GROWTH
Positive: \( 2\text{NiOOH} + 2\text{H}_2\text{O} + 2e^- = 2\text{Ni(OH)}_2 + 2\text{OH}^- \)

Negative: \( \text{Zn} + 4\text{OH}^- = \text{Zn(OH)}_4^{2-} + 2e^- \)

( \( \text{Zn(OH)}_4^{2-} = \text{ZnO} + \text{H}_2\text{O} + 2\text{OH}^- \) )

Overall: \( \text{Zn} + 2\text{OH}^- + 2\text{H}_2\text{O} + 2\text{NiOOH} = 2\text{Ni(OH)}_2 + \text{Zn(OH)}_4^{2-} \)
Zinc Dendrites on Repeated Cycling

1st charge

1st discharge

5th charge

5th discharge

9th charge

Nickel

Zinc

3mm
Reconditioning (slow and deep discharging)

3mm

t= 0 min

t= 90 min

t= 180 min

Subsequent cycle
Performance of the 6 Wh Battery

![Graph showing Performance of the 6 Wh Battery](image)
Scale Up

Voltage

- Multiple cells in series
- 2.5 kWh (48V-55Ah)
- 32 cells
- 23 electrodes per cell

Capacity

- Large capacity per cell
- 1.6 kWh (1.6V-1000Ah)
- 101 electrodes per cell
Conclusions

• FLOW ASSISTED NICKEL ZINC APPROACH OVERCOMES CYCLE LIFE LIMITS OF TRADITIONAL STATIC NI-ZN SYSTEMS

• 2000 STABLE DEEP CYCLES HAVE BEEN DEMONSTRATED IN SMALL CELLS

• PERIODIC CONDITIONING CYCLES RENEWS ZINC ELECTRODE

• THE TECHNOLOGY HAS BEEN SCALED TO A 48 VOLT 3KWHR SYSTEM

• CELLS HAVE BEEN SCALED FROM 50AHR TO 100AHR TO 800AHR

• ELECTROLYTE CIRCULATION ENABLES THERMALLY STABLE OPERATION OF LARGE CELLS AND ELECTROLYTE MAINTENANCE AS REQUIRED
Project Plan

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008/10</td>
<td>Project start</td>
<td>6Wh</td>
</tr>
<tr>
<td>2009</td>
<td>100Wh</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>2kWh</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>50kWh (Smart grid)</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>200kWh</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>1MWh</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>10MWh (Power sub-station)</td>
<td></td>
</tr>
</tbody>
</table>

Projected cost $250/KWHR  Battery life 10+ years  Roundtrip efficiency 80%+