Flow Battery Solution for Smart Grid Renewable Energy Applications

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Area of Interest

- Clean, renewable-energy-based National Smart Grid
- Energy storage
  - Safe, reliable, cost-effective
  - Utility-scale, national deployment
  - Scalable to specific power levels required by renewable energy technologies
  - Environmentally advantageous
## Problem

- **Irrigation wants reliable, low cost power**
  - Remote locations, critical demand concurrent with highest stress in grid

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Problems</th>
<th>Impact of Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid electric connection</td>
<td>Service (to remote loc.) Reliability, Cost</td>
<td>Shift demand off peak: cost down, reliability up</td>
</tr>
<tr>
<td>On-site diesel generation</td>
<td>Emissions, fuel cost, maintenance</td>
<td>None</td>
</tr>
<tr>
<td>Grid electric + PV</td>
<td>Low value of off-peak PV generation, utility demand charges</td>
<td>Energy costs reduced Reliability increased Grid emissions reduced</td>
</tr>
<tr>
<td>Diesel + PV</td>
<td>Emissions, fuel costs, PV offset limited by sun</td>
<td>Enabling Energy costs reduced Emissions reduced</td>
</tr>
</tbody>
</table>
Project Objectives

- Advance a technology that will become an essential building block of a renewable-energy-based Smart Grid
- Integrate an advanced, innovative Battery Energy Storage System with an intermittent renewable energy source
- Reduce electricity costs and environmental impacts for large energy users, such as agricultural irrigation
**Project Description**

- **Scope**: Demonstration of EnerVault’s Vault-20 Battery Energy Storage System (250 kW, 1 MWh)
- **Duration**: Three years, through January 2013
- **Result**: Deployment of a Vault-20 beta system with a 180 kW dual tracking PV array in CA
- **Team**: Project team includes Montpelier Nut Company and JKB Energy
Project Phases

- **Phase 1, Dec. 2009 – Oct. 2011**
  - Develop EnerVault’s energy storage technology into a 40 kW utility-scale system building block
  - Complete preliminary design of the Vault-20 system

- **Phase 2, Oct. 2011 – May, 2012**
  - Build 250 kW, 1 MWh Vault-20 beta system
    - Final design and full system integration
    - Power conditioning system, controls, and tanks
  - Complete off-site testing in Albuquerque, NM

- **Phase 3, May 2012 – Jan. 2013**
  - Commission and demonstrate Vault-20 system
Features & Benefits

- Safety
  - Liquid reactants
  - Minimal vulnerability
  - No thermal runaway

- Reliability
  - Dissolved reactants
  - Less complex design
  - Simpler controls

- Cost Effectiveness
  - Low-cost design
  - Low-cost materials
  - Low-cost reactants
**Known Chemistry, Radical Design**

- **Engineered Cascade**
  - Developed by EnerVault
- **US Patent # 7,820,321**
  - USPTO Greentech program

**Distinctive features**
- Balances coulombic and voltaic efficiencies
- Simplified controls
- Steady DC voltage
- Macroscopic state-of-charge indicator

<table>
<thead>
<tr>
<th>SOC</th>
<th>NE</th>
<th>SEP</th>
<th>PE</th>
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</thead>
<tbody>
<tr>
<td>97%</td>
<td>C-1</td>
<td>S-1</td>
<td>C-4</td>
</tr>
<tr>
<td>71%</td>
<td>C-2</td>
<td>S-2</td>
<td>C-4</td>
</tr>
<tr>
<td>47%</td>
<td>C-2</td>
<td>S-3</td>
<td>C-5</td>
</tr>
<tr>
<td>25%</td>
<td>C-3</td>
<td>S-4</td>
<td>C-5</td>
</tr>
<tr>
<td>5%</td>
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</table>
Design Validation

<table>
<thead>
<tr>
<th></th>
<th>Legacy Cell</th>
<th>Standard Cascade</th>
<th>EnerVault Cascade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Efficiency [%]</td>
<td>76</td>
<td>76</td>
<td>80</td>
</tr>
<tr>
<td>Energy Efficiency [%]</td>
<td>67</td>
<td>67</td>
<td>70</td>
</tr>
</tbody>
</table>

**Legacy Design**

Type 1: Low Resistance
Type 2: Low Crossover

**EnerVault Cascade Design**

- **Charge**
- **Discharge**

**Power Density (MW/cm²)**

**Type 1 Cell Shows Improved Voltage at Lo SOC**
Progress

10x cell footprint

20x power

prototype scale

system simulator
Benefits of Vault-20

- Match for application
  - Thermally robust
  - Improved efficiency curve
  - Electrolyte is permanent asset
  - Low incremental cost of added kWh

- Potential annual benefits
  > $100,000 savings
  > 100 tonnes (CO$_2$)$_e$
  > 60,000 gallons H$_2$O
Summary

- Our project demonstrates the use of a radically-different flow battery technology in a large-scale renewable energy application.
- EnerVault engineered cascade design validated.
- Scale-up progressing according to plan.
- Detailed project plan baselined; actual costs and progress are being captured.
- Successful demonstration of the Vault-20 system in this application provides pathway to broad deployment for smart grid and renewable generation.
## Future Tasks

### Phase 1 Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Description</th>
<th>Date</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4</td>
<td>Achieve Initial Performance Targets</td>
<td>5/30/2010</td>
<td>Achieve 0.8 kW/m²</td>
</tr>
<tr>
<td>5.2</td>
<td>2-5 kW Prototype System Demo</td>
<td>2/1/2011</td>
<td>Achieve 2 kW at 70% Roundtrip Efficiency for 20 cycles</td>
</tr>
<tr>
<td>6.3</td>
<td>Demonstrate Full Scale Stack Design</td>
<td>5/31/2011</td>
<td>Achieve 1.0 kW/m²</td>
</tr>
<tr>
<td>6.7</td>
<td>Operation of 40 kW Alpha stack for 1 month</td>
<td>10/20/2011</td>
<td>Achieve 85% DC Roundtrip Efficiency for 30 cycles</td>
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</tbody>
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Q & A