Flow Battery Energy Storage Systems

Kotzebue Electric Association
Alaska Center for Energy and Power
Kotzebue

- Isolated community of 3500 people
- Not connected to roads or grid
- Electric power from diesel generators
- Started testing wind power to reduce diesel consumption
- First demonstrations of commercial utility scale wind turbines in Alaska
Kotzebue

- Average Load 2500kW
- Installed Wind Capacity 1.14MW
- Plans to increase wind capacity to 4 MW
- Vanadium Red-ox Flow Battery from Prudent Energy
  - Phase One: Battery Power 600kW and Battery Storage 1800kWh
  - Phase Two: Battery Power 1800kW and Battery Storage 2700kWh
- Waste Heat Recovery with 150kW Ammonia Power Cycle Power Plant
An average of 8% of Kotzebue’s electricity comes from the wind plant.

Installed capacity of 1.14 MW:

- 15 Entegrity (66 kW)
- 1 North Wind 100 (100 kW)
- 1 Vestas (65 kW)
Kotzebue Energy Profile

Total: $5,860

- Heat: $1,806
- Transportation: $579
- Electricity: $3,475
The Future

Vision Statement

- KEA will hold a statewide leadership role in energy innovation and environmental stewardship while providing secure and reliable power to its members in a manner that is sustainable economically, socially, and environmentally.

Mission Statement

Affordable electricity is essential to the economic viability of Alaska villages. KEA will:

- Provide reliable electricity at the lowest cost possible to its members
- Provide employment opportunities and job training to Alaskans
- Promote research, development, and demonstration of clean and renewable energy technologies
- Promote energy efficiency and conservation
Wind Expansion: Summer 2010

Increase Wind Capacity from 1.14 MW to 2.94 MW. Almost tripling the wind capacity will increase the average penetration from 10 to 30% and the instantaneous penetration could exceed 100%.

Funding

$4 million through AEA Round One CREBS
Need for Energy Storage

- Need to stabilize the power coming out of wind turbines (second by second stability, flywheels and super capacitors might also work)
- Ability to operate system in diesel off mode
- Ability to store energy from high wind events to use later (increased fuel savings—only batteries will work)
- Also allow operation of diesel generators in zones of maximum efficiency
Why do this in Kotzebue?

• Commitment of KEA to testing and developing new technologies
• KEA small and isolated enough to be typical of Alaskan villages, but large enough to support testing activities
• KEA already has wind farm and SCADA system, ideal site for testing batteries
• Experience learned in wind projects—Alaska needs to invest in these technologies to prove that it is a viable market—
  — willing to try new things, and take risks
  — Willing to work with manufactures to address issues that arise
  — Can provide an adequate market for these products (like the Northwind 100 experience)
Battery Evaluations

Cons
- Decreased Efficiency
- Cost & Lifetime

Pros
- Reliability
- Diesel Reduction
- Increased Performance
New Battery Systems That Might Work

• Vanadium Flow batteries
  – VRB test at UAF, discussions with KEA about larger battery system
  – Prudent Energy has replaced VRB
  – CellStrom is the European supplier of same technology

• Zinc Bromide Flow batteries
  – Premium Power is marketing units
  – ZBB also, but not currently shipping units

• Sodium Sulfur Battery
  – NGK developed battery in Japan, now shipping units to US for testing
<table>
<thead>
<tr>
<th>Method</th>
<th>$/kWh</th>
<th>Power (MW)</th>
<th>Efficiency</th>
<th>Lifetime (hours)</th>
<th>Discharge Time (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumped Hydro</td>
<td>250-260</td>
<td>20-2,400</td>
<td>76-83%</td>
<td>11,000+</td>
<td>10</td>
</tr>
<tr>
<td>Compressed Air</td>
<td>550-650</td>
<td>110-290</td>
<td>50-75%</td>
<td>11,000+</td>
<td>10</td>
</tr>
<tr>
<td>NaS (NGK)</td>
<td>2,500-4,500</td>
<td>.05-50</td>
<td>70-80%</td>
<td>3,000+</td>
<td>7</td>
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<tr>
<td>Ni-Cad</td>
<td>610-1,700</td>
<td>.01-27</td>
<td>60-65%</td>
<td>1,000+</td>
<td>4</td>
</tr>
<tr>
<td>Premium Power</td>
<td>350-400</td>
<td>.5</td>
<td>70%</td>
<td>30 years</td>
<td>5</td>
</tr>
<tr>
<td>ZBB</td>
<td>1,070</td>
<td>.5</td>
<td>77-78%</td>
<td>+2,000 cycles</td>
<td>varies</td>
</tr>
<tr>
<td>Prudent Energy</td>
<td>1637</td>
<td>Varies</td>
<td>85%</td>
<td>10,000+ cycles</td>
<td>varies</td>
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</tbody>
</table>
## Power Stability (kW) Comparison

<table>
<thead>
<tr>
<th>Method</th>
<th>$/kW</th>
<th>Power (MW)</th>
<th>Efficiency</th>
<th>Lifetime (hours)</th>
<th>Discharge Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Acid</td>
<td>1,050-1,890</td>
<td>0.01-10</td>
<td>70-75%</td>
<td>250+</td>
<td>15</td>
</tr>
<tr>
<td>Flywheels</td>
<td>2,500-4,000</td>
<td>0.5-1</td>
<td>90-95%</td>
<td>500,000+</td>
<td>15</td>
</tr>
<tr>
<td>Super Capacitors</td>
<td>n/a</td>
<td>0.003-.01</td>
<td>90-98%</td>
<td>500,000+</td>
<td>Seconds</td>
</tr>
<tr>
<td>NaS Batteries</td>
<td>3,000-4,000</td>
<td>0.05-50</td>
<td>70-80%</td>
<td>3,000+</td>
<td>300</td>
</tr>
<tr>
<td>Li-Ion Batteries</td>
<td>1,000-4,500</td>
<td>0.005-1</td>
<td>90-95%</td>
<td>20,000+</td>
<td>15</td>
</tr>
<tr>
<td>Lead Acid</td>
<td>1,050-1,890</td>
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</tbody>
</table>
Zinc Bromide Technology
Premium Power
Premium Power-Zinc Bromide

Energy Storage Systems

Thermal Management System

Power Conditioning Systems & System Controller

TransFlow 2000 – Main Subsystems
### Premium Power

<table>
<thead>
<tr>
<th>Performance:</th>
<th></th>
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<tbody>
<tr>
<td><strong>Energy Storage Capacity:</strong></td>
<td>2.8 MWh</td>
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<tr>
<td><strong>Voltage Input (3-Phase):</strong></td>
<td>480VAC, 60Hz</td>
</tr>
<tr>
<td><strong>Voltage Output (3-Phase):</strong></td>
<td>480VAC, 60Hz</td>
</tr>
<tr>
<td><strong>Maximum Continuous Power Delivery:</strong></td>
<td>500kW</td>
</tr>
<tr>
<td><strong>Power Factor (Input):</strong></td>
<td>+/- 0.95</td>
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<tr>
<td><strong>Voltage Harmonics:</strong></td>
<td>Approx. 1.5% THD</td>
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</table>
Vanadium Red-Ox Technology
Performance and Energy

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Nominal rated charge power (15 – 80 % SOC)</td>
<td>10 kW</td>
</tr>
<tr>
<td>Nominal rated discharge power (15 – 95 % SOC)</td>
<td>10 kW</td>
</tr>
<tr>
<td>Nominal rated energy (15 – 95 % SOC)</td>
<td>100 kWh</td>
</tr>
</tbody>
</table>
The wind doesn’t always blow when you need it.

With Prudent Energy, it doesn’t have to.
Sodium Sulfur Batteries, NGK
Sodium Sulfur Batteries, NGK
Is this a good investment?

• If wind or other renewable energy is to be used in Alaska’s remote communities, energy storage is an important part of the system

• New batteries are being developed, but they are not yet truly commercial
  – Performance is not well understood, especially issues of lifetime and degradation
  – Capital and installation costs are not yet completely defined (they might go down, they might go up)
  – O&M Costs are not known

• The only way we can understand these issues is by purchasing and testing these batteries
Which battery should we buy?

• Every battery we can get our hands on
  – It provides Alaskans with information they need to make decisions about how to invest funds to maximize return.
  – It tells the battery manufacturers that we are an important market.
  – It allows us to make sure that future products work in our environment.