VRB Flow Battery

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Electrical energy storage—the holy grail of renewables

- People expect energy when they want it—
- Renewables such as solar or wind are sometimes abundant and sometimes scarce
- We often want energy when the renewables are scarce
  - Light at night,
  - heat in the winter
- Storage makes renewables “dispatchable”

Basic battery calculation

- A lead acid battery storage system cost about $200 per kW-hour storage
- Lead Acid batteries fail after about 1000 cycles (typical)
- Cost to store 1 kW-hr is $200/1000 = $.20 per kW-hr
- Cost of coal to generate 1 kW-hr is about $.02

What is a flow battery?

- A battery where the energy is stored in the chemical state of liquids
- Total energy storage depends on size of tanks to hold liquid
- Electrolyte is a solid, allowing diffusion of ions between two liquids (nafion, same material as PEM fuel cells)
- Flow requires pumps, valves, etc, to manage the two liquids

Project History

- First heard of VRB flow battery at Wind Diesel Conference in Girdwood in 2004
- No funding—but this is a critical technology for enabling wind in Alaska
- Kotzebue Electric Association interested in larger unit to integrate with wind turbines

VRB flow battery

- Company located out of Vancouver, BC
- Using technology first patented in New Zealand in the 1980's
- Japanese successfully demonstrated large system on wind farm for 8+ years
- Business plan centers on cost reductions necessary to commercialize technology
- VRB is committed to reducing costs from the start by using commercial purity off the shelf materials for entire system

Advantages of VRB flow battery

- Total energy storage limited only by size of liquid tanks
- Absence of solid phase eliminates site for degradation
- Deep charge/discharge cycles possible
  - 80% discharge vs. 20% for lead acid)
- Very high cycle count advertised (14,000 cycles, based on demonstration in Japan)

Disadvantages of VRB Flow battery

- Solid deposition of Vanadium metal in felts if charge rates too high
- Balance of plant issues (pumps, pipes, valves, control system, inverter/charger) create special challenges
- Leaks?
- Ultimate cost of commercial systems unknown at this point


VRB Power Systems
INCORPORATED
VRB Energy Storage System

Laboratory Testing Program at UAF

- VRB unit delivered to UAF in summer of 2006
- Experimental plan—
  - run the battery
  - measure energy in and energy out
  - Log failures
- Deep cycles to test degradation under chemically aggressive conditions.
- Focus mostly on the DC performance of the battery

VRB Battery Specifications

- 10 kW-hr battery (determined by tanks)
- 3.3 kW maximum power (upgraded to 8 kW) (determined by stack size)
- 80% efficiency verbal (2 years ago)
- 70-78% DC efficiency on spec sheet
- 13,000 cycles before failure
- Need 15 years to test for full charge/discharge cycles to test to 13,000 cycles

Economic Analysis

- Cost of $15,000 (pre-commercial testing unit—now $27,000 for 10kW commercial units)
- Simple economic calculation—15,000 cycles at 10 kW-hr per cycle gives a total of 150,000 kW-hrs total lifetime energy storage, or $.10 per kW-hour
- Economics depend strongly on battery life and O&M costs
- Leverage from system dynamics issues (not yet studied)

Failure log

- Initial leaks traceable to bad plastic unions (still some seepage—all unions leak)
- Stack failure (heat warping plastic in stack)—Stack was replaced (fall 2006)
- Electrolyte replacement by VRB (fall 2006)
- Leaks and second stack failure on end plate (spring 2007), stack replaced
- Tank leak leads to decision to replace unit with new 8.3kW system (and new stack)
- Unit replaced, start-up in Fairbanks October 2008, UAF down time for DAQ

Failure log (cont.)

- Stack Failure on new unit traceable to a manufacturing defect after only 23 cycles
- Stack replaced 1/2/2008, ran for 276 cycles until breaker failure on lab circuit on 3/21/08, restarted 3/28/08
- Failure of DC contactor traceable to manufacturing defect on 4/30/08
- Pump head seizure due to manufacturing defect of pump impeller on 6/29/08
- Unit currently experiencing as yet undiagnosed shutdowns (2 in past 2 weeks)
- Total of 9200 hours on systems.
- All these issues were taken care of in a prompt and professional manner by VRB
- Net result of all these issues convinces me that VRB is serious about making these units succeed

Efficiency

- Efficiency is a function of two things: the electrochemical efficiency and the parasitic losses
- Parasitic losses are due to pumps and control system electrical consumption
- Faster charge/discharge cycles result in higher overall efficiency
- Balancing a wind/diesel system would result in lower efficiency
- DC power efficiency of about 72%
- Parasitic and inverter losses reduce this to about 60%

Conclusions (to this point)

- VRB Batteries exist
- VRB is a great company to work with, great service
- Product works well, but is still a developmental product
- Ultimate economics will depend on long term performance
- Field demonstrations required

Questions?

Ammonia Storage

- AP&T interest in converting excess hydro to ammonia for use in Diesel generators
- Provided quote from large international user of excess electricity to ammonia for equipment, and value of bulk ammonia
- Calculation shows that even if the electricity is free, value of ammonia does not provided payback for capital on ammonia plant ($675K ammonia vs $910K income needed for capital)
- Also shows that the cost per MMBtu of ammonia is still higher than diesel fuel ($38 vs $25)
- But the numbers are close with diesel fuel at $3.50 a gallon, ammonia at $610 per ton
- If diesel fuel goes to $10 per gallon, we have a winner

Alaska Center For Energy and Power (ACEP)

- Gwen Holdman working as Administrative Director
- Three branches
  - – Oil and Gas field of the future
  - – Power for economic development (Mines)
  - – Village Scale power
- My interest is in the village power end

The Procurement Experiment

- Can we buy a flow battery?
- How much will it cost?
- Will the company deliver the unit on time?
- Will the company support the product in the field?
- Will the product perform as advertised?
  - Compare actual performance to specs on quote

Results of the Procurement Experiment

- The “Purchase Order” was interesting due to several intellectual property clauses that are not standard for the US
  - UAF owns no IP inside the unit, or to improvements
  - UAF owns the operating data (energy in/energy out, availability, etc.)
  - Unit remains the property of VRB—we only own a license to operate it.
- Flow batteries are being built and delivered
- Unit was delivered several months later that initially quoted (a very good result)