Progress in Grid Scale Flow Batteries

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FlowBat 03–07-12
Without technological breakthroughs in efficient, large scale Energy Storage, it will be difficult to rely on intermittent renewables for much more than 20-30% of our Electricity.  
  
  Secretary Chu, Feb. 2010

The need for regulation services can dramatically increase as the amount of variable renewable resources is increased. Local storage is among the best means to ensure we can reliably integrate renewable energy resources into the grid.

  Chairman Wellinghoff, FERC, March 2010

Transmission and storage capacity are key issues for energy resource planning. If you like wind power, you have to love transmission and storage.

  Terry Boston, CEO, PJM, June 2010
Worldwide installed storage capacity for electrical energy

110,000 MW$_e$

- Pumped Hydro: 19,500 MW$_e$
  - in US: -

- Compressed Air Energy Storage: 477 MW$_e$
- Sodium-Sulfur Battery: 200 MW$_e$
- Lead-Acid Battery: 125 MW$_e$
- Nickel-Cadmium Battery: 26 MW$_e$
- Redox-Flow Battery: 11 MW$_e$

Source: Fraunhofer Institute

Note: Pumped hydro represents 2.5 percent of U.S. electrical baseload capacity.
Some Large Energy Storage Projects:

27MW / 7MWh 1995 Fairbanks, AL
34MW / 245MWh 2008 Rokkasho, Japan
20MW / 5MWh 2011 Stephentown, NY
32MW / 8MWh 2011 Laurel Mountain, WV
14MW / 63 MWh 2011 Hebei, China
8MW / 32MWh 2012 Tehachapi, CA
25MW / 75MWh 2013 Modesto, CA

Annual new Deployment

2011 : 121MW → 2021 : 2,353MW

(Pike Research)
29 States have Renewable Portfolio Standards (RPS) Requiring 10-40% Renewables

On Peak Wind - the Reality!

Cost effective Energy Storage yields better Asset Utilization
Renewables (not capacity factor adjusted)

- Wind
- Wind (proj)
- Solar PV
- Solar PV (proj)
- Hydro
- Hydro (proj)
- World Consumption

G. Gyuk 2011
Flow Battery Research
at PNNL and Sandia
Redox Couples for Flow Batteries, Sandia

Sandia has developed a New Class of electroactive metal-containing ionic liquids (“MetILs”)

Materials research and development for:
1. Multi-functional materials act as both electrolyte and energy storage medium for high energy density
2. Low cost, Safety, Environmentally benign
3. Cost effective scale-up options

FY10: 12 MetILs synthesized and tested:
• Found 3 with high ionic conductivity & viscosity
• One with low ionic conductivity & viscosity
• One with high ionic conductivity & low viscosity: Ce(NH$_2$C$_2$H$_4$OH)$_8$(CF$_3$SO$_3$)$_3$

FY11: investigate effects of tailored molecular structures on viscosity, ionic conductivity, and electrochemical performance by
• Incorporating aromatic ligands into cation
• Altering the size of the anion
FY12: Test 5 MetIL for ionic conductivity and electrochemical reversibility; test best candidates in benchtop flow battery prototype
New Generation Redox Flow Batteries, PNNL

Developed new generation redox flow battery (RFB) that can demonstrate substantial improvement in performance and economics, to accelerate its commercialization and market penetration, via collaborations with industries and universities.

**FY11 Accomplishments**
- Developed 3rd gen all vanadium RFB that demonstrated >70% increase in capacity, >80% better temp. range and 2x power at >75% efficiency.
- Discovered Fe/V redox couples for further reduction in capital cost by using low cost materials and elimination of gas evolution.

**FY 12 Plan**
- Develop novel scalable cell design
- Component integration
- Build 1 kW/4 kWh bench top system
- Five U.S. Patents filed
- Technology Transfer to Industry
Anderson et al., Synthesis of Ionic Liquids Containing Cu, Mn, or Zn Coordination Cations

Sandia, Nov. 2011

Liyu Li et al., Stable Vanadium Redox Flow Battery with High Energy; 1, 394-400, 2011

PNNL, May 2011
ARRA Stimulus Funding for Storage Demonstration Projects ($185M)

A ten-fold Increase in Power Scale!

Large Battery System (3 projects, 53MW)
Compressed Air (2 projects, 450MW)
Frequency Regulation (20MW)
Distributed Projects (5 projects, 9MW)
Technology Development (5 projects)

533MW - $585M Costshare!
Three ARRA Storage Applications using Flywheels, PbC, an Li-Ion

DOE Loan Guarantee – AES / A123: 20MW Lithium Ion Battery for Frequency Regulation in NY-ISO. 8MW on Line!
5 Distributed Projects = 9 MW
Peak Shaving, Energy Management

ARRA – Public Service NM:
500kW, 2.5MWh for smoothing of 500kW PV installation; Using EastPenn Lead-Carbon Technology

Commissioned Sep. 24, 2011
American Electric Power, Community Energy Storage ARRA Project in Columbus, OH

A fleet of 80 units,
25 kW/1 hour each
2 MW Peak shaving for a 6.8 MW Peak

International Battery,
Entire Unit
Four ARRA Storage Applications using Flow Batteries
ARRA- Primus Power:
25MW / 3hr battery plant for the Modesto, CA Irrigation District, firming 50MW of Wind, replacing $75M of Gas fired Generation.

Totally sealed battery module
With a Zn-Halogen electrolyte and zinc and tungsten electrodes
ARRA Distributed Project:

Installation of 5 Transflow 2000 500kW ZnBr Battery Systems at locations within SMUD and National Grid Utility Districts:

- 2 units at a substation in Syracuse
- 1 unit at Syracuse University
- 1 unit at SMUD HQ microgrid
- 1 unit at SMUD Solar Smart Homes Project
Ashlawn VanCharg™ Battery for the City of Painesville, Ohio

- US Produced Vanadium Redox Flow Battery for Bulk Storage/Peak Shaving scheduled for startup later this year.
- 8 MW Hour redox flow battery (1MW 8 hours)
- To be installed at Painesville Municipal Electric Plant (PMEP), a 32 MW coal fired facility to help maintain its daily power output requirements more efficiently while reducing carbon footprint.
- Assists Ashlawn in Establishing US Vanadium Redox Battery Manufacturing Base
  - Stack components/stack fabrication
  - Electrolyte
  - Power Conditioning System
- Demonstrates Efficacy/Reliability of latest Vanadium Redox Flow Battery Design
- Leverages technology insertions from National Labs
- Creates Advanced Energy Manufacturing Jobs
ARRA - Enervault:
250kW/4hr  Fe-Cr Flow Battery for PV

PV: 300 kW  
Storage: 250 KW  
Peak output: 450kW  
Storage Cost: +16%  
Storage Value: +84%

Tracking PV in Almond Grove

Flow Battery Prototype

Leveraging PV with Storage
New Electrolytes
New Electrodes
New Membranes
New Stack Topologies

Think Cheep! Think Durable!
Think Safe! Think Small!

Remember PC Systems
Remember Hydraulics

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(Pike Research)