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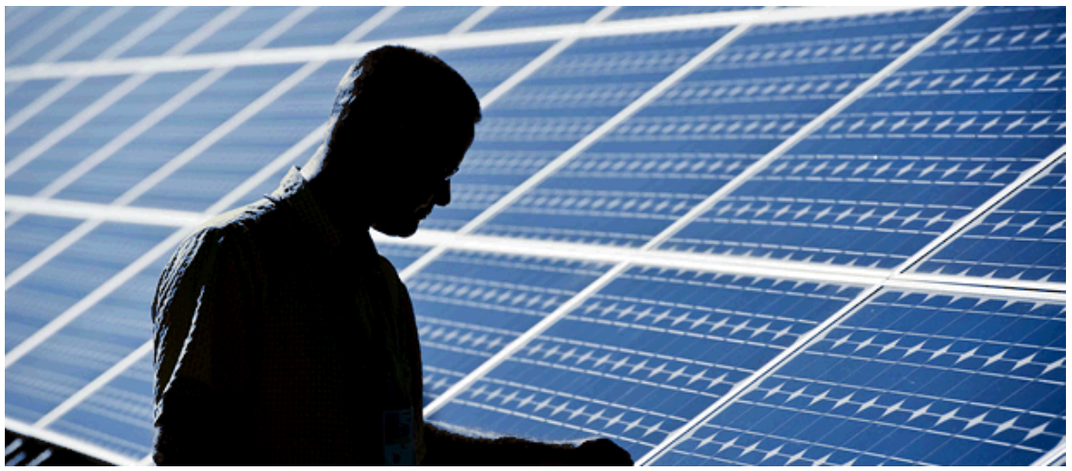

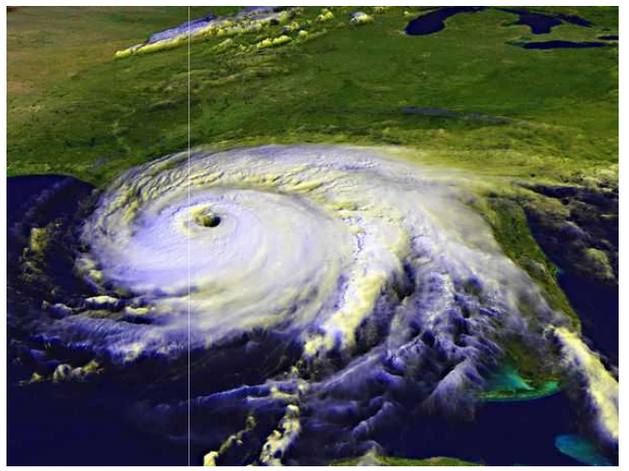

Energy Storage Systems Research Program: Sandia National Laboratories

David M. Rose

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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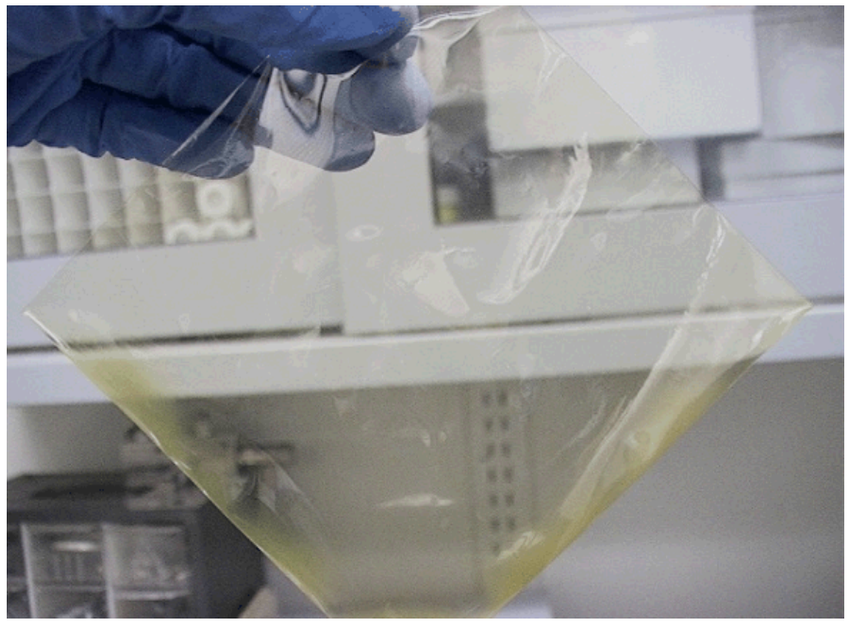
Advanced Membranes for Flow Batteries

Sandia National Laboratories

Reducing material costs and improving performance of flow battery by replacing fluorine (Nafion) membranes with hydrocarbon-based (polymer) membranes.

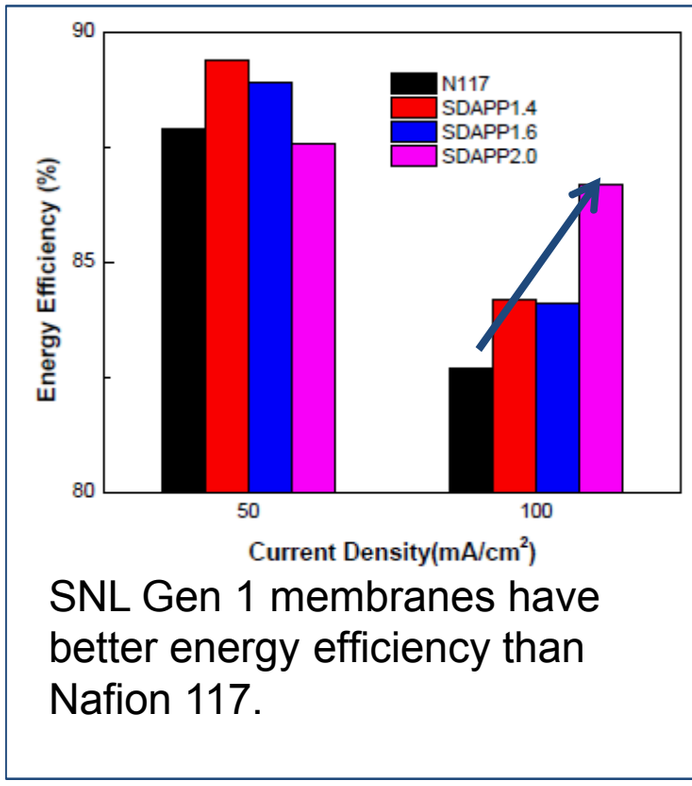


SNL Gen 1 membrane made by vacuum casting

Leveraging extensive IP and expertise in developing polymer membranes for fuel cells.

Collaboration between labs:

- **SNL - separator development**
- **PNNL - flow battery testing**
- **ORNL - fundamental transport**



SNL Gen 1 membranes have better energy efficiency than Nafion 117.

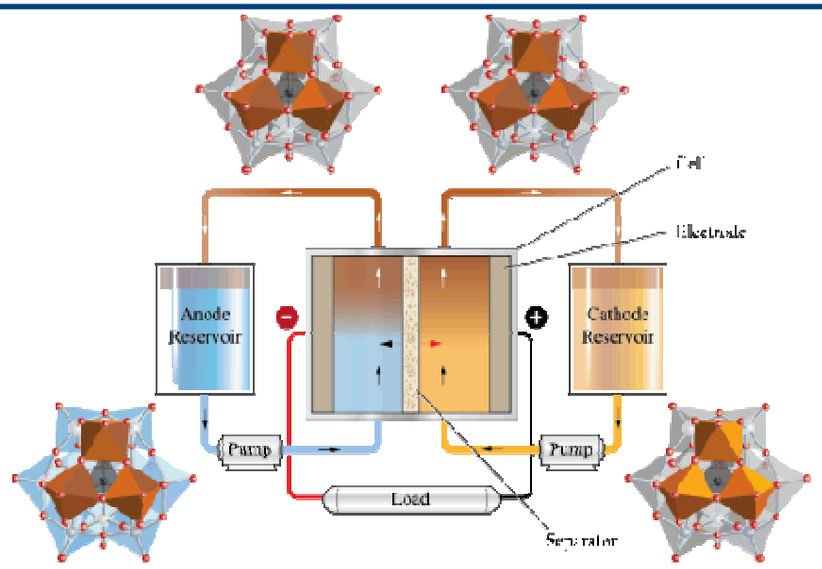
FY13 Accomplishments:

- Evaluated 1st generation fuel cell membranes in vanadium flow batteries and found good selectivity, efficiency and durability
- Developed 2nd generation membranes specifically for flow batteries with enhanced ion selectivity and durability
- Submitted technical advance and pursuing a patent on 2nd generation membranes

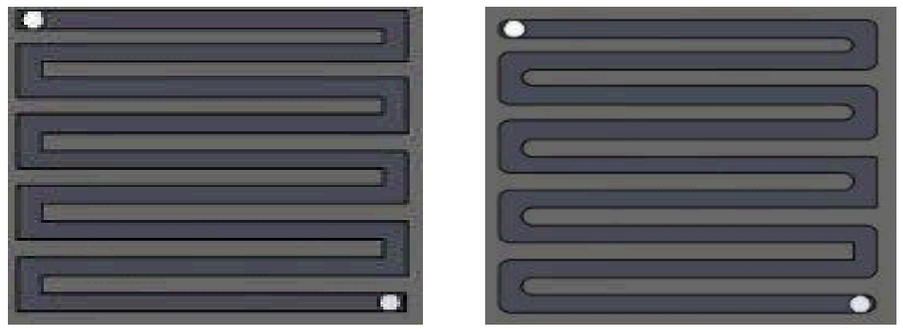
Ionic Liquid Flow Battery

Sandia National Laboratories

Ionic liquid flow batteries offer the potential of high energy densities compared to aqueous flow batteries due to larger voltage windows, but are limited by their high viscosity. SNL is revolutionizing flow batteries through new multivalent solutions and cell designs.



New multivalent anode/cathode particles (Vanadium-tungsten oxide cluster), for lower particle densities in solution (↓ viscosity, ↑ energy density)



Upper and lower 3D prototype chips

New rapid prototyping platform made with 3D printing to quickly evaluate membranes, solutions and cell designs

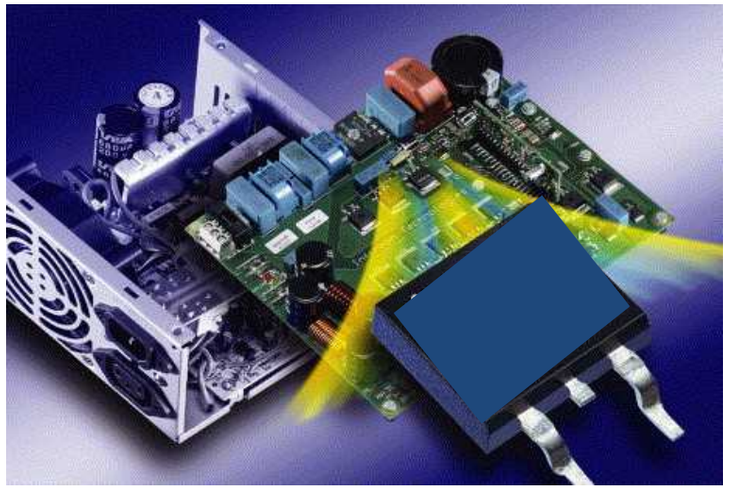
FY13 Accomplishments

- As of FY13, published 6 articles and 12 conference papers
  - Publication in March 2013 *Journal of Power Sources* was cited by *JPS* as one of the most downloaded articles of the week
- Developed new three-electron redox multivalent solution using new prototyping platform
- Demonstrated redox multivalent battery solution with >50% improvement in utilization of the active battery material

Power Electronics

Sandia National Laboratories

Using wide bandgap semiconductor devices, advanced topologies, and controls to significantly reduce installed cost and footprint, improve control capability, and increase reliability

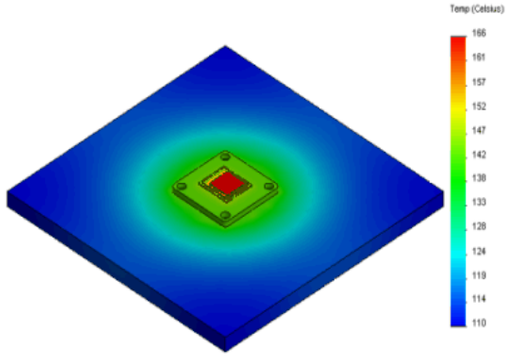


Arkansas Power Electronics International
15kV Discrete SiC Package

Recognition

- Four R&D100 Awards
- Three U.S. Patents
- Over 40 technical publications
- Stan Atcitty received Presidential Early Career Award for Scientists and Engineers

P_{dis} = 200 W, Max Temperature = 166 °C



FY13 Accomplishments

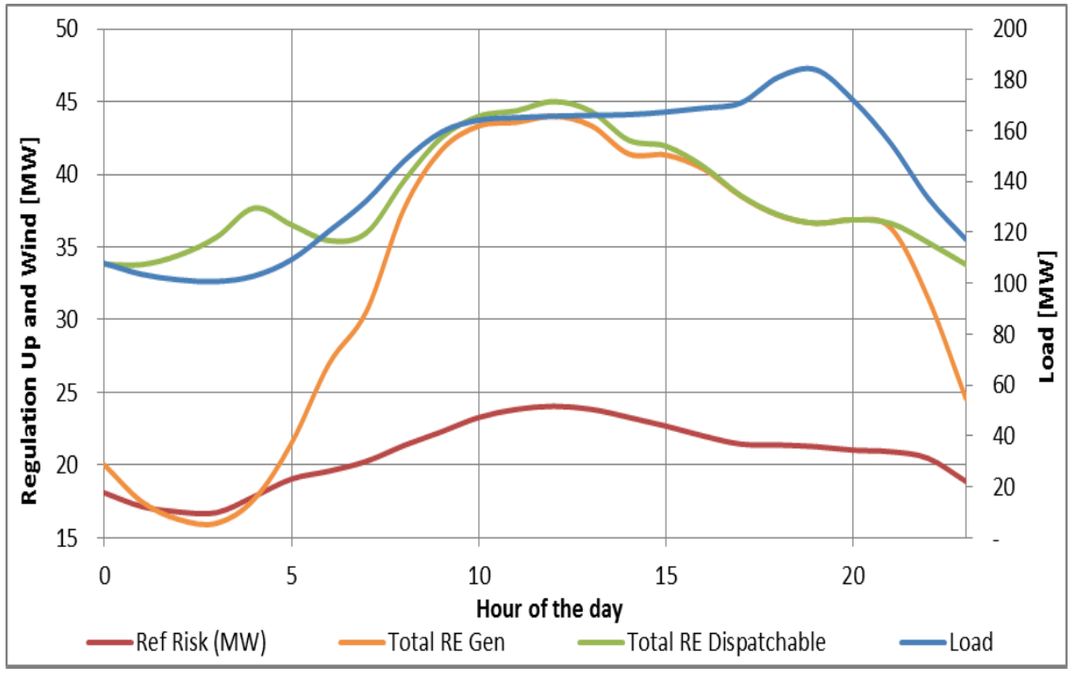
- Developed World's first high voltage (15kV at 100 amps), high temp SiC half bridge module
- Designed a 1.2kV SiC Junction gate Field-Effect Transistor (JFET)
- Developed specifications advanced transformer core material for use in high frequency power conversion system designs

Modeling and Analysis System Studies

Determining the cost effectiveness of grid-level storage as compared to alternatives to supply energy & reserves, determining the optimal locations in which to implement grid-level storage and quantifying the benefits of storage within calculated operating reserves.

FY13 Accomplishments:

- Market Design Project: Report on new market design concept released in April 2013. A survey was released as a SAND report in September 2012.
- Southern Company Project: Report on storage study for Southern Company released in March 2013.
- NV Energy Project: Report on storage study for NV Energy released in June 2013.
- Maui Energy Project: SAND report, entitled "Maui Energy Storage Study," released in December 2012.



Jim Ellison, Ben Karlson, Dhruv Bhatnagar, Abbas Akhil , Sandia National Labs

Energy Storage System Demonstrations and Testing

Sandia National Laboratories

Regulators and utilities need assistance in determine how to utilize these systems to maximize return on investment (ROI). This project helps to ensure ROI and facilitate adoption via improving confidence in safety, reliability, performance and cost effectiveness.

Two Pronged Approach:

Energy Storage Test Pad (ESTP) – 1MW test pad at SNL to controllably test and evaluate the safety, reliability and performance of ES systems.

Field Demonstrations - Assist in the selection, installation, optimization and analysis of performance of systems providing verified ROI evaluations of technologies.

FY13 Accomplishments

- Tested 4 grid scale systems at ESTP and provided key information to the manufacturers, which resulted in system redesigns in all cases
- Provided support and analysis of >10 fielded energy storage systems (Texas Tech, Sunpower, UCSD, etc.)
- Developed standardized duty cycle testing protocol that is being implemented by utilities in system selection.

Questions?

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