U.S. DOE Office of Electricity and Energy Reliability Energy Storage Program at Sandia National Laboratories

Summary of Accomplishments and Impacts for FY18
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Introduction

Energy storage can play a key role in creating a resilient, reliable, and secure U.S. electric grid. Currently, grid energy storage technology is being deployed for selected applications, and further cost reductions and performance improvements are needed to make energy storage cost effective across all applications in the electricity infrastructure. Sandia National Laboratories’ Energy Storage Program is focused on making energy storage cost effective through research and development (R&D) in new battery technology development and advancements in power electronics and power conversion systems, improving the safety and reliability of energy storage systems, and enabling the deployment of new energy storage technologies in the electric grid. During FY18, Sandia executed R&D work supported by U.S. Department of Energy’s (DOE) Office of Electricity Delivery and Energy Reliability – Energy Storage Program under the leadership of Dr. Imre Gyuk. This document summarizes the impact of Sandia’s contributions through notable accomplishments, journal publications, patents, and technical conferences and presentations.

Notable Accomplishments

During this period, Sandia contributed to multiple energy storage system installations, received prestigious professional and technical recognition, including an R&D100 Award, and organized the 2018 ESSAT Conference and other technical symposium. Brief descriptions of these and other selected accomplishments are provided on pages 6 through 9.

Publications

Sandia researchers produced a large number of energy storage-related publications, including more than 30 published peer-reviewed journal papers. A list of publications is provided on pages 12 through 16.

Patents

Sandia’s efforts have produced a number of patents and applications on topics that include redox flow batteries, sodium ion batteries, lithium primary batteries, and control systems. Five granted patents and three patent applications have been filed and are listed on page 18.

Technical Conferences and Presentations

Sandia researchers were invited to talk at multiple conferences, contributed to 15 conference papers, participated in webinars and on conference panels, and organized symposiums. These technical conference contributions and additional presentations are listed on pages 20 through 26.
Notable Accomplishments
Awards

**R&D 100 Award Winner, “Control System for Active Damping of Inter-Area Oscillations”**

November 2017 - Today, electric power grids operate well below transmission capacity to avoid widespread outages due to inter-area oscillations. This new R&D 100 award-winning control system, funded by DOE OE and Bonneville Power Administration and developed by Sandia National Laboratories and Montana Tech, improves electric power grid reliability by continuously damping inter-area oscillations, allowing greater power transfer. This control system is the first successful grid demonstration of feedback control, making it a game changer in efforts to transform the existing grid into the future smart grid.

Events

**Materials Research Society Fall 2017 “Symposium ES5: Materials and Design for Resilient Energy Storage”**

November 2017 - Dr. Summer Ferreira led the organization of a three day symposium on energy storage safety at the MRS Fall meeting. This symposium with over 60 technical papers focused on advanced research on the interplay of materials properties, cell performance and response, and failure behavior of the safety of energy storage systems. In addition, working with Prof. Partha Mukherjee of Purdue University, a half day tutorial covering the materials and design of electrochemical energy storage was organized.


April 2018 - The sodium battery project team lead, Dr. Erik Spoerke, continued to engage the solid-state ion conductor community through the organization symposia at two international conferences in 2018. The first, “Ion Conducting Ceramics,” at the 2018 Conference on Electronics and Advanced Materials completed its fourth successful iteration, since Dr. Spoerke cofounded the symposium in 2015. This relatively intimate meeting engaged approximately two dozen experts from around the world in solid state physics, ceramic processing, and ionic materials for a one-day session in January in Orlando, FL. Dr. Spoerke was the lead organizer for the second symposium, “Next Generation Solid-State Super Ion Conductors” at the 2018 Spring meeting of the Materials Research Society, which brought together experts from Asia, Europe, and North America to discuss computational studies, synthetic processing, and functional performance of ceramic, composite, and polymer-
based solid-state ion conductors. This highly condensed, well-attended symposium was a popular addition that complemented several other symposia on energy storage and ionic materials at the relatively large Materials Research Society Meeting in April in Phoenix, AZ.

**Enabling Advanced Power Electronics Technologies for the Next Generation Electric Utility Grid Workshop**

July 2018 - The role of power electronics in the utility grid is continually expanding. As converter design processes mature and new advanced materials become available, the pace of industry adoption is poised to accelerate. Looking forward, we can envision a future in which power electronics are as integral to grid functionality as the transformer is today. The Enabling Advanced Power Electronics Technologies for the Next Generation Electric Utility Grid Workshop was organized by Sandia National Laboratories and held in Albuquerque, New Mexico, July 17-18, 2018. The workshop was a great success. It brought together more than 60 world leaders in power electronics R&D from across the nation, national laboratories and industry. The workshop helped attendees to gain a broader understanding of power electronics R&D needs—from materials to systems—for the next generation electric utility grid. A Sandia report was published that summarizes discussions and presentations from the workshop and identifies opportunities for future efforts.

**2017 Electrical Energy Storage Applications and Technologies (EESAT)**

October 2017 - The 10th Biennial Electrical Energy Storage Applications and Technologies (EESAT) Conference was held October 11-13, 2017 at the Westin Hotel—Gaslamp District, in San Diego, California (USA). The 2017 EESAT Conference theme was Energy Storage: Evolution and Revolution. This provided a platform to: revisit research and development, technologies, applications, and projects that have helped to shape the science and industry of energy storage; and make presentations about new directions for energy storage and how it can address challenges of the smarter, more modern electricity grid. Over 100 attendees participated. Presentations covered advances in material science, electrochemistry, grid modernization, power electronics, demonstration projects, modeling, and recent breakthroughs in energy storage technologies. David Schoenwald (SNL) and Patrick Balducci (PNNL) served as technical co-chairs for the event. Jacquelynne Hernandez (SNL) was the event coordinator. The meeting was held in conjunction with the 2017 DOE Energy Storage program peer review.
Release of QuEST software Suite

This past year, the SNL energy storage software tool team developed the initial release version of QuEST, a Python-based, open source energy storage software suite. The launch version includes QuESt Data Manager, an application for obtaining market data from ISO/RTO sources, as well as QuESt Valuation, an application for performing energy storage system valuation (revenue estimation) in different market areas. Three different market areas (ERCOT, PJM, MISO) are initially supported, but support for the remaining market areas in the USA are in rapid development. As research and development in the energy storage program with SNL and its various partners continues, more applications will be developed and implemented in QuESt so that it will become a one stop shop for energy storage analysis.

2018 U.S. DOE Energy Storage Financing Summit: Advancing Energy Storage Contracting

January 2018 - On January 18th, 2018 Mustang Prairie Energy in Partnership with the U.S. Department of Energy organized a one-day financial summit in Manhattan with approximately 75 attendees. Speakers included representatives from the U.S. Department of Energy and industry experts who have experience with the challenges and opportunities of investing in energy storage projects. The summit was part of a U.S. Department of Energy sponsored study to identifying the impact of performance on project financing for energy storage projects. This study’s goal is to understand the current challenges facing energy storage project financing, and gain insights into how de-risking the performance issues in the solar, wind and energy efficiency markets benefited these markets, and what strategies could be successful in the energy storage market. This series of studies are part of the U.S. Department of Energy’s effort to promote market development through reducing barriers to entry, reducing transaction costs, and promoting wider access to low cost capital.

Presentation at Gordon Research Conference – Energy Storage Safety

February 2018 - Dr. Summer Ferreira presented an invited talk at the Batteries Gordon Research Conference “Battery Failure from a Materials, Electrochemical and Thermal Modeling Perspective” February 25-March 2, 2018, Ventura California. In this talk she covered the evaluations carried out at Sandia National Laboratories, and with Sandia’s collaborators in the area of safety research into lithium ion battery technologies, from the materials perspective through cell and string level abuse in the laboratory. The discussion further incorporated current developments of sophisticated thermal models that are able to capture the key signature temperatures and thermal releases being developed at Sandia under the Energy Storage System Safety thrust.
Flow Battery Symposium, 2018 Materials Research Society (MRS) Spring Meeting & Exhibit
April 2018 - Sandia National Laboratories co-chaired a symposium on reduction-oxidation (redox) flow batteries at the Spring 2018 Materials Research Society International Meeting in Phoenix, Arizona. Travis Anderson, a Sandia researcher and chemist, co-chaired this opportunity for researchers—from students and postdoctoral fellows, to Nobel and Kavli Prize Laureates—to exchange technical information. Speakers (including sixteen invited) from around the World presented in six sessions on topics ranging from aqueous and non-aqueous chemistries to solar flow batteries and systems integration. The symposium allowed subject matter experts from Industry, Academia, and National Laboratories to come together and exchange ideas and establish fruitful collaborations.
Publications
Journal Publications


20. F. A. Mier, M. J. Hargather, and S. R. Ferreira “Experimental quantification of vent mechanism flow parameters in 18650 format lithium ion batteries,” Journal of Fluids Engineering, submitted 2018


Conference Papers and Proceedings


13. F. Wilches-Bernal, D. A. Copp, I. Gravagne, and D. A. Schoenwald “Stability Criteria for Power Systems with Damping Control and Asymmetric Feedback Delays,” In the proceedings of the North American Power Symposium (NAPS), North Dakota State University, Fargo, ND, September 9-11, 2018


**Other Publications**


Patents
**Patents**

**Issued**

1. C. Fujimoto “Halo-Containing Anion Exchange Membranes and Methods Thereof” U. S. Patent 2018/0194892, Issued July 12, 2018


**Applications**


3. C. Fujimoto “Block Copolymers including Poly(phenylene) and Methods Thereof” Appl. No.: 15/908,507 (February 28, 2018)

**Sandia Technical Advances (Patent applications to be filed)**


Technical Conferences and Presentations
Technical Conferences

Invited Talks

1. S. Atcitty, “Role of Power Electronics and Power Conversion Systems in Grid-Tied Storage”, UT Austin Technical Seminar to the Power Electronics Group, Jan 19, 2018

2. S. Atcitty, “National Laboratory and American Indian Perspectives on Alternative Energy, Distributed Energy Resources and the Environment,” Keynote presentation on alternative energy resources and its positive impact on the environment at the Navajo Nation Environmental Protection Agency Conference, Flagstaff, AZ, June 20-22, 2018

3. S. Atcitty, “Role of Power Electronics and Power Conversion Systems in Grid-Tied Storage”, UT Austin Technical Seminar to the Power Electronics Group, Jan 19, 2018

4. R. H. Byrne “Energy Storage,” University of New Mexico Graduate Seminar, Albuquerque, NM November 17, 2017


6. R. H. Byrne “Solar + Energy Storage Controls,” EPRI-SNL PV Symposium, Albuquerque, NM, May 1- 3, 2018

7. R. H. Byrne “Designing Storage to Provide Multiple Benefits,” Intersolar 2018, San Francisco, CA, July 8-12, 2018


12. B. R. Chalamala “Energy Storage and the Grid of the Future,” Hart Center Lecture, Hart Center for Engineering Leadership, Southern Methodist University, Dallas, TX, February 28, 2018

13. B.R. Chalamala “Energy Storage and Grid of the Future,” Mechanical Engineering and Energy Engineering Department, University of North Texas, March 1, 2018


19. J. C. Hewson “Modeling the limits of thermal runaway in Li-ion packs and designing tests to measure those limits,” Joint Army Navy NASA Air Force meeting, Special Fire Science Session, December 4, 2017


22. J. Lamb “Evaluating the impact of initiation methods on propagating thermal runaway in lithium ion batteries,” Fall ECS and AIMES 2018, Cancun, Mexico, September 30, 2018

23. T. N. Lambert, J. Duay, R. Aidun and J. E Ortiz-Santiago “Development of Anodic Stripping Voltammetry in Alkaline Electrolyte with Applications toward Screening Metal Ion Diffusion Selectivity in Battery Separators” 17th International Conference on Electroanalysis (ESEAC 2018) Rhodes, Greece, June 3-7, 2018


**Contributed Technical Presentations**

1. S. Atcitty, “MSI Update on Tribal Ecology using Advanced Manufacturing, Education, & Drones,” Technical presentation and program update on Tribal College and Universities Advanced Manufacturing Project at the NNSA Minority Serving Institute Program meeting, Atlanta, GA, April 23-25, 2018


5. D. Borneo “EWEB Case Study”, IEEE PES Meeting, Portland, OR, May 2018


7. D. Borneo “Perspectives of ES”, Portland OR, Utility Resource Planners meeting, June 2018


11. J. C. Hewson “Energy storage material choices to avoid thermal runaway in lithium-ion batteries,” Material Research Society Fall Meeting, November 29, 2017


28. B. Schenkman and R. Byrne “Opportunities for Energy Storage to Provide Spinning Reserve in Cordova, Alaska,” SPEEDAM 2018, Italy, June 21, 2018

29. D. A. Schoenwald, Presentation to Joint Synchronized Information Subcommittee, WECC Headquarters, Salt Lake City, UT, May 17, 2018


42. L. Torres-Castro, J. Lamb, M. Karulkar, J. Stanley, and C. Grosso “Investigations of the structural and electrochemical properties of overcharged Li-ion batteries”, 233rd Electrochemical Society Meeting, Seattle, WA, May 13-17, 2018

43. L. Torres-Castro, J. Lamb and M. Karulkar “Investigations of the Structural and Electrochemical Properties of Overheated Li-Ion Batteries and Its Effects in Single Cells Vs. Multi-Cells Packs,” 234th ECS and AIMES meeting 2018; Cancun, Mexico, September 30, 2018

44. L. Torres-Castro, J. Lamb, L. A. Steele, J. Quintana, C. Grosso and J. Stanley “Mitigation Techniques for Failure Propagation in Li-ion Batteries,” 2017 Peer Review & ESSAT Conference; San Diego, CA, October 9, 2017

Additional Presentations

Tutorials


5. Imre Gyuk, Vince Sprenkle, Babu Chalamala, Ray Byrne, David Copp and Dan Borneo, Grid Energy Storage Tutorial, National Rural Electric Coop Association, Arlington, VA, February 8, 2018

6. J. McDowall, B. Chalamala and R. Schubert, Focus on Advanced Battery Technologies, Tutorial Lectures at 2018 Battcon, Nashville, TN, April 22, 2018

**Webinars**


3. R. H. Byrne, “Sterling Municipal Light Department Analysis,” CESA webinar, March 7, 2018


**Seminar Presentations**

1. S. Atcitty, “Role of WBG Devices for Grid-tied Storage”, Ohio State University Technical Seminar, Sept 12, 2018


4. D. A. Copp, “From the Power Grid to Diabetes: Solving Problems with Control and Optimization,” University of New Mexico (UNM), ECE Department Graduate Seminar, March 9, 2018

5. D. A. Schoenwald, Invited seminar to the Department of Electrical Engineering, The Ohio State University, “Control System Design for Active Damping of Large-Scale Power Grids,” December 4, 2017