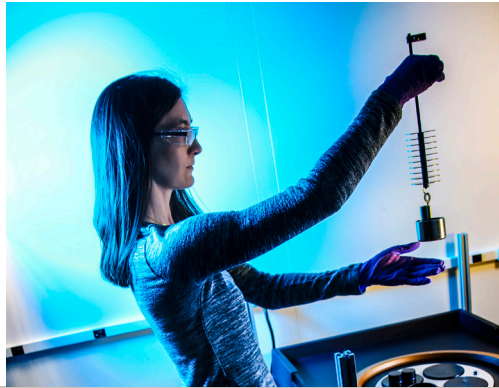


Exceptional service in the national interest



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

Summary of Accomplishments and Impacts for FY18



**U.S. DEPARTMENT OF
ENERGY**

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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

9

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

31

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

11

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

85

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.



2018 Conference on Electronic and Advanced Materials

“Symposium S5: Ion Conducting Ceramics” and 2018 Materials Research Society Spring Meeting “Symposium EN21: Next-Generation Solid-State Super Ion Conductors”

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

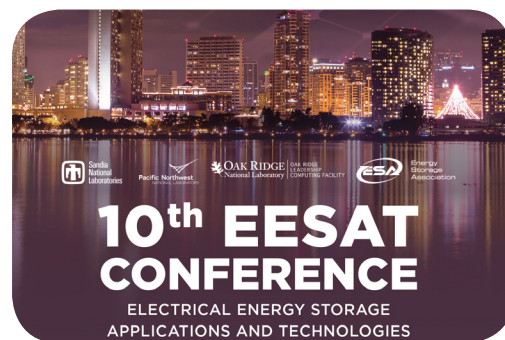
electronics R&D from across the nation, national laboratories and industry. The workshop helped attendees to gain a broader understanding of power electronics R&D needs—from materials to systems—for the next generation electric utility grid. A Sandia report was published that summarizes discussions and 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.



Richard Baxter, President,
Mustang Prairie Energy

Presentation at Gordon Research Conference – Energy Storage Safety



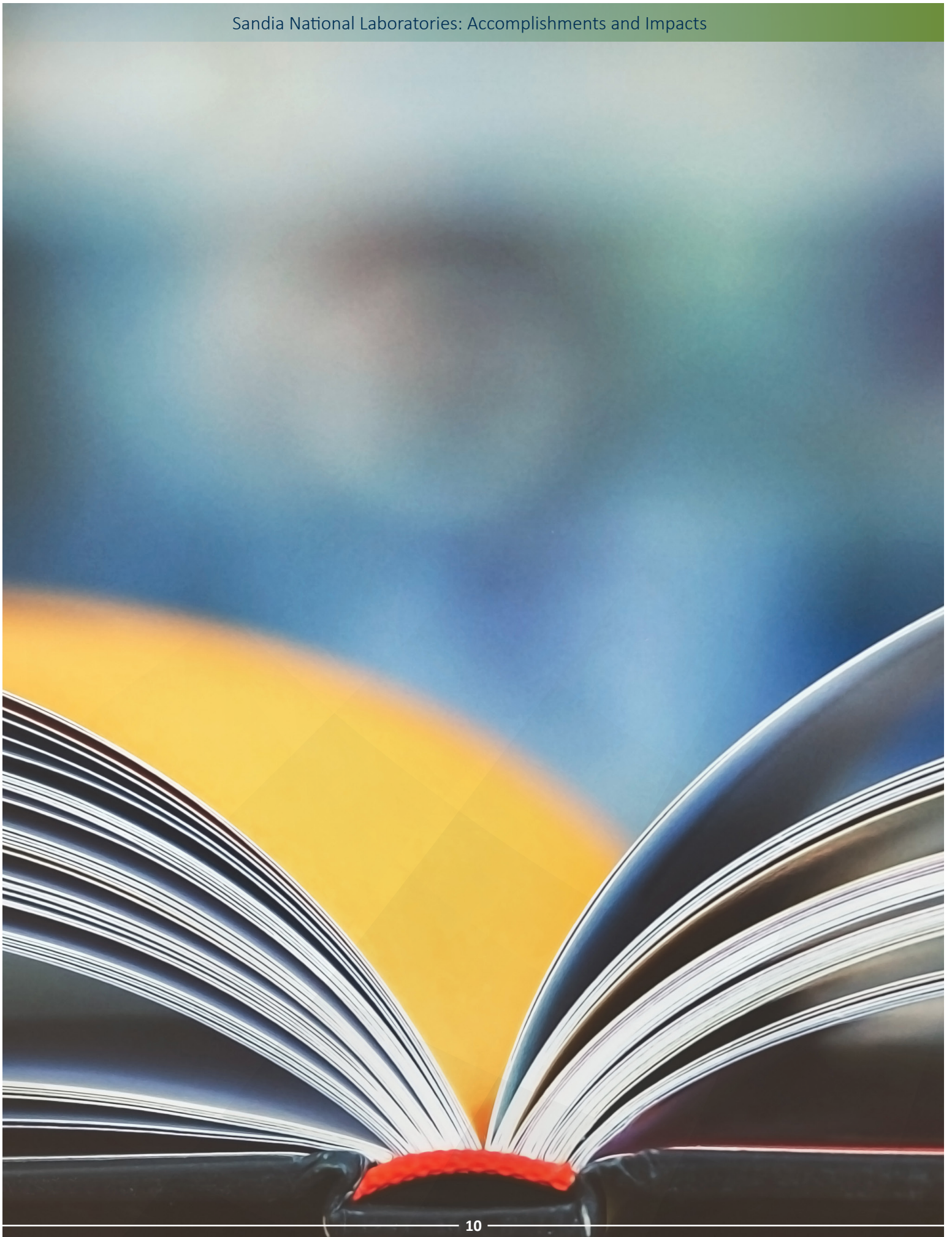
February 2018 - Dr. Summer Ferreira presented an invited talk at the Batteries Gordon Research Conference "Battery Failure from a Materials, Electrochemical and Thermal Modeling Perspective" February 25-March 2, 2018, Ventura California. In this talk she covered the evaluations carried out at Sandia 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.

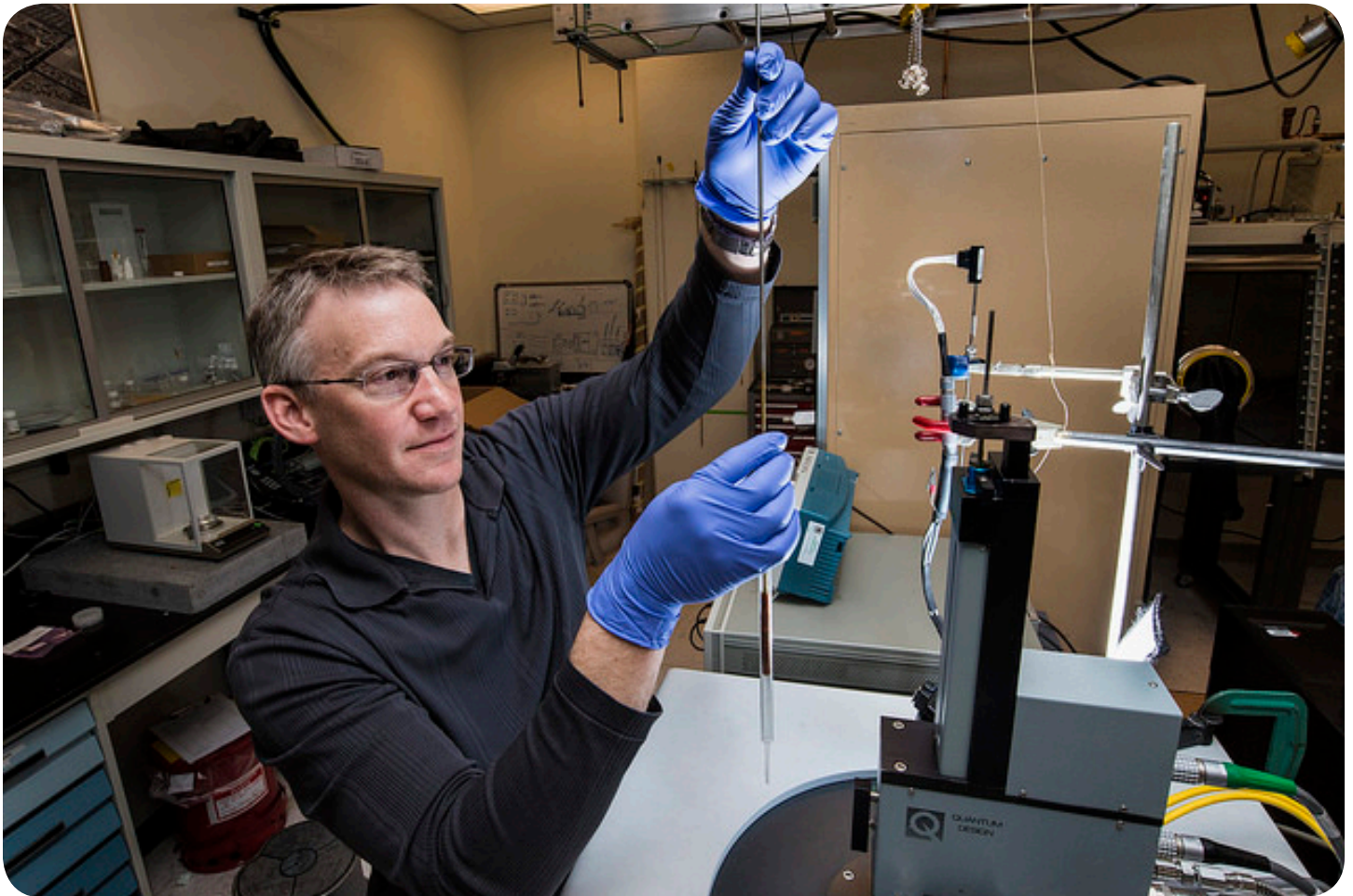
Flow Battery Symposium, 2018 Materials Research Society (MRS) Spring Meeting & Exhibit

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

1. E. Allcorn, G. Nagasubramanian, H. D. Pratt III, E. Spoerke, and D. Ingersoll “Elimination of active species crossover in a room temperature, neutral pH, aqueous flow battery using a ceramic NaSi-CON membrane,” *Journal of Power Sources*, Volume 378, Pages 353-361, February 2018.
2. R. Baxter, I. Gyuk, R. H. Byrne, and B. R. Chalamala “Engineering Energy-Storage Projects: Applications and Financial Aspects,” *IEEE Electrification*, vol. 6, no. 3, September 2018. doi: 10.1109/MELE.2018.2849834
3. A. J. Collin, A. J. Nambiar, D. Bould, B. Whitby, M. A. Moonem, B. Schenkman, S. Atcitty, P. Chainho, and A. E. Kiprakis “Electrical Components for Marine Renewable Energy Arrays: A Techno-Economic Review,” *Energies*, volume 10, issue 12, p. 1973, 2017
4. J. Duay, T. N. Lambert and R. Aidun “Stripping Voltammetry for the Real Time Determination of Zinc Membrane Diffusion Coefficients in High pH: Towards Rapid Screening of Alkaline Battery Separators” *Electroanalysis*, volume 29, issue 10, October 2017, pages 2261-2267. <http://dx.doi.org/10.1002/elan.201700337>
5. J. Duay, M. Kelly and T. N. Lambert “Evaluation of a ceramic separator for use in rechargeable alkaline Zn/MnO₂ batteries” *Journal of Power Sources*, Volume 395, 15 August 2018, Pages 430-438
6. M. A. Elizondo, R. Fan, H. Kirkham, M. Ghosal, F. Wilches-Bernal, D. Schoenwald, and J. Lian “Interarea Oscillation Damping Control Using High Voltage DC Transmission: A Survey,” *IEEE Transactions on Power Systems*, DOI: 10.1109/TPWRS.2018.2832227, 2 May 2018.
7. J. F. Ellison, L. J. Rashkin, J. Serio, and R. H. Byrne “The benefits of grid-scale storage on Oahu,” *Journal of Energy Storage*, Volume 15, February 2018, Pages 336-344
8. D. G. Enos, S. R. Ferreira, H. M. Barkholtz, W. Baca, and S. Fenstermacher “Understanding Function and Performance of Carbon Additives in Lead-Acid Batteries,” *Journal of The Electrochemical Society*, vol. 164, no. 13, pp. A3276-A3284, 2017, doi: 10.1149/2.1031713jes
9. M. Kelly, J. Duay, T. N. Lambert, and R. Aidun “Impact of Triethanolamine as an Additive for Rechargeable Alkaline Zn/MnO₂ Batteries under Limited Depth of Discharge Conditions” *Journal of the Electrochemical Society*, 2017, 164 (14) A3684-A3691. DOI:10.1149/2.0641714jes
10. E. A. Paisley, M. T. Brumbach, C. T. Shelton, A. A. Allerman, S. Atcitty, C. M. Rost, J. A. Ohlhausen, B. L. Doyle, Z. Sitar, J.-P. Maria, and J. F. Ihlefeld “Nitride surface chemistry influence on band offsets at epitaxial oxide/GaN interfaces,” *Applied Physics Letters*, Volume 112, Issue 9, January 2018, DOI: 10.1063/1.5013605
11. D. Rosewater, S. Ferreira, D. Schoenwald, J. Hawkins, and S. Santoso “Battery Energy Storage State-of-Charge Forecasting: Models, Optimization, and Accuracy,” *IEEE Transactions on Smart Grid*, DOI: 10.1109/TSG.2018.2798165, 25 January 2018

12. O. Slobodyan, T. Smith, J. Flicker, S. Sandoval, C. Matthews, M. van Heukelom, R. Kaplar, and S. Atcitty, "Hard-Switching Reliability Studies of 1200 V Vertical GaN PiN Diodes," accepted to MRS Communications (2018)
13. L. J. Small, J. S. Wheeler, J. F. Ihlefeld, P. G. Clem, and E. D. Spoerke "Enhanced alkaline stability in a hafnium-substituted NaSICON ion conductor," *Journal of Materials Chemistry A*, vol. 6, pp. 9691-9698, 2018, DOI: 10.1039/C7TA09924J
14. D. Stenclik, P. Denholm, and B. Chalamala "Maintaining Balance: The Increasing Role of Energy Storage for Renewable Integration," *IEEE Power and Energy Magazine*, vol. 15, no. 6, pp. 31-39, Nov.-Dec. 2017. doi: 10.1109/MPE.2017.2729098
15. L. A. Trujillo-Guajardo, J. Rodriguez-Maldonado, M. A. Moonem, and M. A. Platas-Garza "A Multiresolution Taylor–Kalman Approach for Broken Rotor Bar Detection in Cage Induction Motors," *IEEE Transactions on Instrumentation and Measurement*, vol. 67, no. 6, pp. 1317-1328, June 2018
16. D. A. Copp, T. A. Nguyen, and R. H. Byrne "Real-Time Energy Management of Energy Storage with Stochastic Loads and Generation in Markets," *IEEE Transactions on Smart Grid*, submitted August 2018
17. Cy Fujimoto, Eric Sorte, Cassandra Poirier, Nelson Bell, Eun Joo Park, Sandip Maurya, Kwan-Soo Lee, Yu Seung Kim "Acid-Catalyzed Benzoylation: A Facile Way to Functionalize Diels-Alder Poly(phenylene)s," *Journal of Polymer Science, Part A: Polymer Chemistry*, submitted 2018
18. C. Lackner, F. Wilches-Bernal, B. Pierre, and D. Schoenwald "A Tool to Characterize Delays and Packet Losses in Power Systems with Synchrophasor Data," *IEEE Power and Technology Systems Journal*, August 2018
19. S. B. Lee, H. D. Pratt III, T. M. Anderson, V. Ramadesigan, K. Mitra, B. R. Chalamala, and V. R. Subramanian "Open Data, Models, and Codes for Static Redox Flow Batteries," *Journal of Electrochemical Society*, submitted, July 2018
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
21. T. C. Monson, B. Zheng, R. E. Delany, C. J. Pearce, Y. Zhou, S. Atcitty, and E. J. Lavernia "Soft magnetic multi-layered FeSiCrB-FexN metallic glass composites fabricated via spark plasma sintering," in review at *IEEE Magnetics Letters*.
22. T. A. Nguyen, D. A. Copp, R. H. Byrne, and B. R. Chalamala "Optimal Market Participation of Energy Storage Systems Incorporating Nonlinear Models," *IEEE Transactions on Power Systems*, submitted August 2018

23. S. J. Percival, L. J. Small, and E. D. Spörke “Electrochemistry of the NaI-AlCl₃ Molten Salt System for Use as Catholyte in Sodium Metal Batteries.” *Journal of The Electrochemical Society* (2018)
24. D. Rosewater, R. Baldick and S. Santoso “Optimal Control of Battery Energy Storage: Reducing and Shaping Model Uncertainty to Improve Control Performance” Submitted to *IEEE Transactions on Smart Grid*
25. D. Rosewater, R. Byrne, and S. Santoso “A Novel Sliding-Window Algorithm for On-Line Estimation of Energy Storage Model Parameters” Submitted to *IEEE Power Engineering Letters*, submitted June 2018
26. R. C. Shurtz, J. D. Engerer, and J. C. Hewson “Predicting high-temperature decomposition of lithiated graphite: I. Review of phenomena and a comprehensive model,” *Journal of the Electrochemical Society*, submitted September 2018
27. R. C. Shurtz, J. D. Engerer, and J. C. Hewson “Predicting high-temperature decomposition of lithiated graphite: II. Passivation layer evolution and the role of surface area,” *Journal of the Electrochemical Society*, submitted September 2018
28. J. M. Silveyra, E. Ferrara, D. L. Huber, and T. C. Monson “Soft magnetic materials for a sustainable and electrified world,” in review at *Science*
29. Robb Thomson, David A. Copp, Tu A. Nguyen, Ricky Concepcion, Raymond H. Byrne, and Babu R. Chalamala “On the Role of Energy Storage in the Operation of Future Fossil-Free Utilities,” *Applied Energy*, submitted 2018
30. Y. Tian, A. Bera, J. Mitra, B. R. Chalamala, and R. H. Byrne “Effect of Operating Strategies on the Longevity of Lithium-ion Battery Energy Storage Systems,” *IEEE Tran. Industry Applications*, under review, submitted June 2018
31. I. Vasiliev, B. A. Magar, J. Duay, T. N. Lambert, and B. R. Chalamala “Ab Initio Studies of Hydrogen Ion Insertion into β , γ -R and γ -MnO₂ Polymorphs and the Implications for Shallow-Cycled Rechargeable Zn/MnO₂ Batteries,” *Journal of the Electrochemical Society*, submitted, July 2018

Conference Papers and Proceedings

1. R. H. Byrne, T. A. Nguyen, D. A. Copp, R. J. Concepcion, B. R. Chalamala, and I. Gyuk “Opportunities for Energy Storage in CAISO: Day-Ahead and Real-Time Market Arbitrage,” in the proceedings of the 2018 IEEE Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM 2018), Amalfi, Italy, June 2018
2. D. A. Copp, T. A. Nguyen, and R. H. Byrne “Optimal Sizing of Behind-the-Meter Energy Storage with Stochastic Load and PV Generation for Islanded Operation,” in the proceedings of the 2018 IEEE Power and Energy Society General Meeting, Portland, OR, August 2018

3. D. A. Copp, F. Wilches-Bernal, D. A. Schoenwald, and I. Gyuk “Power System Damping Control via Power Injections from Distributed Energy Storage,” in the proceedings of the International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), 2018
4. R. Fan, M. Elizondo, H. Kirkham, F. Wilches-Bernal, J. Lian, and D. Schoenwald “Oscillation Damping Control Using Multiple High Voltage DC Transmission Lines: Controllability Exploration,” 2018 IEEE PES T&D Conference & Exposition, Denver, CO, April 16-19, 2018
5. C. Lackner, T. A. Nguyen, R. H. Byrne and F. Wiegandt “Energy Storage Participation in the German Secondary Regulation Market,” in the proceedings of the 2018 IEEE/PES Transmission and Distribution Conference and Exposition, Denver, CO, April 16-19, 2018, DOI: 10.1109/TDC.2018.8440484
6. F. A. Mier, M. Hargather, and S. Ferreira “Determining the Internal Pressure in 18650 Format Lithium Batteries Under Thermal Abuse,” Electrical Energy Storage Applications and Technologies (EESAT) Conference 2017, San Diego, CA, October 10-13, 2017
7. T. A. Nguyen and R. H. Byrne “Optimal Time-of-Use Management with Power Factor Correction Using Behind-the-Meter Energy Storage Systems,” in the proceedings of the 2018 IEEE Power and Energy Society General Meeting, Portland, OR, August 2018
8. T. A. Nguyen, R. H. Byrne, B. R. Chalamala and I. Gyuk “Maximizing the Revenue of Energy Storage Systems in Market Areas Considering Nonlinear Storage Efficiencies,” in the proceedings of the 2018 IEEE Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM 2018), Amalfi, Italy, June 2018, pp. 55-62. doi: 10.1109/SPEEDAM.2018.8445321
9. B. Pilvelait, D. Lackey, B. Cameron, J. McCarthy, G. Castelino, and C. Palombini “Feasibility Analysis and Testing of a Utility Grade Advanced Power Inverter (API),” Electrical Energy Storage Applications and Technologies (EESAT) Conference 2017, San Diego, CA, October 10-13, 2017
10. N. Pragallapati, S. J. Ranade, M. A. Moonem and S. Atcitty “Distributed Power Processing based Cell-level Battery Energy Storage System,” 2018 9th IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG), pp. 1-7, Charlotte, NC, June 25-28, 2018
11. D. Rosewater, Q. Nguyen, and S. Santoso “Optimal Field Voltage and Energy Storage Control for Stabilizing Synchronous Generators on Flexible AC Transmission Systems,” 2018 IEEE PES T&D Conference & Exposition, Denver, CO, April 16-19, 2018
12. O. Slobodyan, S. Sandoval, J. Flicker, R. Kaplar, C. Matthews, M. van Heukelom, and S. Atcitty “Switching Reliability Characterization of Vertical GaN PiN Diodes,” Electrical Energy Storage Applications and Technologies (EESAT) Conference 2017, San Diego, CA, October 10-13, 2017
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

14. F. Wilches-Bernal, B. J. Pierre, D. A. Schoenwald, R. T. Elliott, and D. J. Trudnowski “Time Synchronization in Wide Area Damping Control of Power Systems,” 2018 IEEE International Conference on Probabilistic Methods Applied to Power Systems (PMAPS), Boise, ID, June 24-28, 2018
15. F. Wilches-Bernal, D. Schoenwald, R. Fan, M. Elizondo, and H. Kirkham “Analysis of the Effect of Communication Latencies on HVDC-Based Damping Control,” 2018 IEEE/PES Transmission and Distribution Conference and Exposition (T&D), Denver, CO, April 16-19, 2018

Other Publications

1. Richard Baxter, “Energy Storage Financing: Performance Impacts on Project Financing,” SAND2018-10110, September 2018
2. B. R. Chalamala, S. R. Ferreira, R. H. Byrne, D. Borneo and I. Gyuk, “Batteries for Stationary Energy Storage Applications,” Chapter 27 in Linden’s Handbook of Batteries, 5th Edition, McGraw-Hill Professional Publishing, New York, NY, 2018
3. J. C. Hewson, J. Lamb and W. J. Lee, “Electrochemical energy storage and safety,” in Battery Storage Systems. IEEE white paper, 2018
4. S. B. Lee, H. D. Pratt III, T. M. Anderson, K. Mitra, B. R. Chalamala, and V. R. Subramanian, “Estimation of Transport and Kinetic Parameters of Vanadium Redox Batteries Using Static Cells,” ECS Transactions, vol. 85, no. 5, pp. 43-64, 2018
5. T. C. Monson, Guest Editor for the Journal of Materials Research, Focus Issue: Soft Magnetic Materials: Synthesis, Characterization, and Applications, Volume 33, Issue 15, 13 August 2018
6. L. J. Small, H. Pratt, C. Staiger, R. I. Martin, T. M. Anderson, B. Chalamala, T. Soundappan, M. Tiwari, and V. R. Subramanian, “Vanadium Flow Battery Electrolyte Synthesis via Chemical Reduction of V₂O₅ in Aqueous HCl and H₂SO₄,” Sandia National Laboratories Report, SAND2017-0875, 2017
7. J. Vandermeer, B. Schenkman, M. Baca, M. Mueller-Stoffels, and C. Koplin, “Cordova Electric Cooperative Energy Storage Evaluation,” Sandia National Laboratories, SAND2017-13084

Patents



Patents

Issued

1. C. Fujimoto “Halo-Containing Anion Exchange Membranes and Methods Thereof” U. S. Patent 2018/0194892, Issued July 12, 2018
2. C. Fujimoto, K. W. Lee and Y. S. Kim “Poly(phenylene) Based Anion Exchange Polymers and Methods Thereof” U. S. Patent 2018/10,053,535, Issued August 21, 2018
3. D. A. Schoenwald, B. J. Pierre, F. Wilches-Bernal, R. T. Elliott, R. H. Byrne, J. C. Neely, D. J. Trudnowski “Systems and Methods for Active Damping Control of Inter-Area Oscillations in Large-Scale Interconnected Power Systems,” Patent Application: 15/926,658 (March 20, 2018)
4. T. Monson, E. J. Laverne, B. Zheng and Y. Zhou, “Method to Synthesize Bulk Iron Nitride” US Patent number: 9963344, May 8, 2018
5. E. D. Spoerke, P. G. Clem, J. S. Wheeler, L. J. Small, and J. Ihlefeld, “Cation-enhanced chemical stability of ion-conducting zirconium-based ceramics” US Patent No: 9988312, Issued June 5, 2018

Applications

1. S. A. Atcitty, M. A. Moonem, and B.R. Chalamala, “Cell-level micro-dual active bridge controller for precise energy storage management,” Patent Application: 15/875,460 (January 19, 2018)
2. Non-provisional patent application filed, “SYSTEMS AND METHODS FOR ACTIVE DAMPING CONTROL OF INTER-AREA OSCILLATIONS IN LARGE-SCALE INTERCONNECTED POWER SYSTEMS,” Patent Application: 15926658, filed March 20, 2018. Submitted by Schoenwald
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)

1. S. Atcitty, M. A. Moonem, J. Mueller, and B. Chalamala, “Distributed Storage for Photovoltaic Systems” SD#14834 (August 30, 2018)
2. J. A. Bock, E. D. Spoerke, H. Brown-Shaklee, and L. J. Small. “Solution-Assisted Densification of Sodium Ion Conducting Ceramics.” SD# 14673 (September 2018)
3. S. J. Percival, L. J. Small, and E. D. Spoerke. “Molten Inorganic Electrolytes for Low Temperature Sodium Batteries.” Sandia Technical Advance, SD# 14842 (September 2018)

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
5. R. H. Byrne "Energy Storage Overview," The Energy Council's 2017 Global Energy and Environmental Issue Conference, Banff, Alberta, Canada, December 8-9, 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
8. B. R. Chalamala "Energy Storage and the Future Electric Grid," IEEE Phoenix Section, Life Member Affinity Group Lecture, Tempe, AZ, October 17, 2017
9. B. R. Chalamala "Role of DOE Energy Storage Program," 2018 U.S. DOE Energy Storage Financing Summit: Advancing Energy Storage Contracting, New York, NY, January 18, 2018
10. B. R. Chalamala "Manufacturing of Silicon Materials for Microelectronics and PV," IEEE/Sigma Xi/ UNM Science & Society Distinguished Public Lecture, Albuquerque, NM, February 15, 2018
11. B. R. Chalamala "Emerging Energy Storage Technologies, Integration, Safety and Standards, IEEE Innovative Smart Grid Technologies Conference, Washington, DC, February 22, 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
14. B.R. Chalamala "Safety of Grid Energy Storage Systems," 2018 IEEE IAS Electrical Safety Workshop, Ft. Worth, TX, March 19, 2018

15. B.R. Chalamala “DOE System Test Facilities – Grid Energy Storage,” DOE Innovation XLab Summit on Energy Storage, Stanford, CA, Sept 19-20, 2018
16. B.R. Chalamala, T. Nguyen, D. Copp and R.A. Byrne “Advances in Grid Energy Storage Technology,” IEEE Workshop on Electronic Power Transmission and Distribution, November 7 - 9, 2017, Aalborg, Denmark
17. B.R. Chalamala, E. Spoerke, L. Small, T. Lambert, J. Duay, and T. Anderson “Engineering Interfaces in Large Format Batteries for Grid Energy Storage,” 2017 Materials Research Society Fall Meeting, Boston, MA., Nov 26-Dec 1, 2017
18. S. Ferreira “Battery Failure from a Materials, Electrochemical and Thermal Modeling Perspective,” Batteries Gordon Research Conference, Ventura, CA, February 25-March 2, 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
20. R. J. Kaplar, O. Slobodyan, J. Flicker, S. Sandoval, C. Matthews, M. van Heukelom, T. Smith, S. Atcitty, S. Khalil, and S. Bahl “Hard-Switching Reliability Studies of 1200 V Vertical GaN PiN Diodes,” 2018 Materials Research Society (MRS) Spring Meeting & Exhibit, Phoenix, AZ, April 2-6, 2018
21. J. Lamb “Understanding Battery Safety Through Abuse Testing,” PNNL Energy Storage Systems Safety and Reliability Forum 2018, Seattle, WA, March 28-29, 2018
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
24. L. J. Small, S. Percival, and E. D. Spoerke “Improving Solid State Sodium Ion Conductors for Next Generation Energy Storage.” 2018 Spring Materials Research Society Meeting, Phoenix, AZ. April 2-6, 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

2. S. Atcitty “Role of Power Electronics in Grid-tied Energy Storage Systems,” keynote presentation at the 2018 IEEE Power and Energy Conference at Illinois, Feb 22-23, 2018.
3. S. Atcitty, and M. Smith “System Availability and Sustainment,” Energy Storage Systems Safety and Reliability Forum 2018, Seattle, WA, March 28-29, 2018
4. H. Barkholtz, S. Ivanov, J. Langendorf, J. Lamb, B. Chalamala, and S. Ferreira, ES05.03.17 “Thermal Stability of Commercial Lithium-Ion Batteries as a Function of Cathode Chemistry and State of Charge,” 2017 Materials Research Society (MRS) Fall Meeting & Exhibit, Boston, MA, Nov 26-Dec 1, 2017
5. D. Borneo “EWEB Case Study”, IEEE PES Meeting, Portland, OR, May 2018
6. D. Borneo “Safety Considerations for ES installations,” PNNL Energy Storage Systems Safety and Reliability Forum 2018, Seattle, WA, March 28-29, 2018
7. D. Borneo “Perspectives of ES”, Portland OR, Utility Resource Planners meeting, June 2018
8. D. A. Copp, F. Wilches-Bernal, D. A. Schoenwald, and I. Gyuk “Power System Damping Control via Injections from Distributed Energy Storage,” International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), 2018
9. J. Duay, T. N. Lambert, and M. Kelly “Evaluation of a Ceramic Separator for Use in Rechargeable Alkaline Zn/MnO₂ Batteries” 2018 Materials Research Society (MRS) Spring Meeting & Exhibit, Phoenix, AZ, April 2-6, 2018
10. J. Duay, T. N. Lambert and R. Aidun “Screening of Alkaline Zinc Battery Separators using Anodic Stripping Voltammetry” Electrical Energy Storage Applications and Technologies Meeting, San Diego, CA, October 11-13, 2017
11. J. C. Hewson “Energy storage material choices to avoid thermal runaway in lithium-ion batteries,” Material Research Society Fall Meeting, November 29, 2017
12. J. C. Hewson and R. Shurtz “Computer modeling to understand and prevent initial and cascading thermal runaway,” Electrical Energy Storage Applications and Technologies, San Diego, CA, October 12, 2017
13. R. J. Kaplar, O. Slobodyan, J. Flicker, S. Sandoval, C. Matthews, M. van Heukelon, S. Atcitty, O. Aktas, and I. Kizilyalli “Hard-Switching Reliability Studies of 1200V Vertical GaN PiN Diodes,” 2018 Materials Research Society (MRS) Spring Meeting & Exhibit, Phoenix, AZ, April 2-6, 2018
14. M. Kelly, J. Duay, T. N. Lambert and R. Aidun “Evaluation of Triethanolamine as an Additive to Improve Alkaline Zn/MnO₂ Battery Rechargeability Under Limited Depth of Discharge Conditions” 2018 Materials Research Society (MRS) Spring Meeting & Exhibit, Phoenix, AZ, April 2-6, 2018

15. M. Kelly, J. Duay, T. N. Lambert and R. Aidun “Improving Alkaline Zn/MnO₂ Battery Cycle-ability Under Limited Depth of Discharge Conditions with a Triethanolamine Additive” 29th Annual Rio Grande Symposium on Advanced Materials, Albuquerque, NM, October 9, 2017
16. J. Lamb, L. Torres-Castro, L. A. Steele, C. Grosso, J. Quintana, J. Stanley, S. Ferreira and J. Hewson “Consequences, mitigation and detection of propagating battery failure,” 2017 Materials Research Society (MRS) Fall Meeting & Exhibit, Boston, MA, Nov 26-Dec 1, 2017
17. J. Lamb, L. Torres-Castro, M. Karulkar, J. Stanley, and C. Grosso “Examining and Controlling the Behavior of Thermal Runaway in Multi Cell Systems”, 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 2018
18. T. N. Lambert, J. Duay and J. E. Ortiz-Santiago “Development of Anodic Stripping Voltammetry in Alkaline Electrolyte and Application for Screening Zincate Diffusion Selectivity in Battery Separators” 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 2018
19. S. B. Lee, H. D. Pratt III, T. M. Anderson, K. Mitra, B. R. Chalamala, and V. R. Subramanian “Estimation of Transport and Kinetic Parameters of Vanadium Redox Batteries Using Static Cells and Electrochemical Models,” 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 2018
20. B.A. Magar, T. Lambert, J. Duay, B. Chalamala, and I. Vasiliev “First-Principles Study of Hydrogen Trapping in Electrolytic Manganese Dioxide,” Annual Meeting of the APS Four Corners Section, Fort Collins, CO, October 20, 2017
21. B. A. Magar, T. Lambert, J. Duay, B. Chalamala, and I. Vasiliev “Discharge Mechanism of the γ -MnO₂ Electrode in Shallow-Cycled Zn/MnO₂ Batteries: An Ab Initio Study,” American Physical Society March Meeting, Los Angeles, CA, March 6, 2018
22. S. Maurya, H. T. Chung, C. Fujimoto, I. Matanovic, and Y. S. Kim “Why Pt-Ru Catalyst Works Better for Alkaline Hydrogen Oxidation Reaction” 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 2018
23. T. C. Monson, B. Zheng, Y. Zhou, E. J. Lavernia, T. E. Stevens, and S. Atcitty “Optimizing the soft magnetic behavior of iron nitride,” American Physical Society March Meeting, Los Angeles, March 2018
24. T. C. Monson, T. E. Stevens, C. J. Pearce, R. E. Lewis, M. A. Rodriguez, S. Dickens, B. B. McKenzie, and S. Atcitty “Synthesis of γ' -Fe₄N, a new soft magnetic material for inductors and transformers,” Enabling Advanced Power Electronics Technologies for the Next Generation Electric Utility Grid Workshop, Albuquerque, NM, July 17-18, 2018
25. M. A. Moonem and S. Atcitty “Power Electronics in Grid-tied Energy Storage Systems,” Enabling Advanced Power Electronics Technologies for the Next Generation Electric Utility Grid Workshop, Albuquerque, NM, July 17-18, 2018

26. S. Percival, L. J. Small, E. Allcorn, and E. D. Spoecke “Electrochemical Assessment of Molten NaI-AlCl₃ Catholytes for Sodium Batteries,” 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 2018
27. B. J. Pierre, F. Wilches-Bernal, D. A. Schoenwald, R. T. Elliott, R. H. Byrne, J. C. Neely, and D. J. Trudnowski “The Pacific DC Intertie Wide Area Damping Controller Utilizing Real-Time PMU Feedback,” North American Synchrophasor Initiative (NASPI) Spring Meeting, Albuquerque, NM, April 24-26, 2018
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
30. R. Shurtz and J. C. Hewson “Modeling Cascading Failure of Thermal Runaway in Stacks of Li-Ion Pouch Cells with Variation in Cooling Attributes,” 233rd Electrochemical Society Meeting in Seattle, Washington, May 15, 2018
31. R. Shurtz and J. C. Hewson “Modeling Thermochemical Sources for a Broader Range of Materials and Conditions,” 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 2018
32. O. Slobodyan, T. Smith, J. Flicker, S. Sandoval, C. Matthews, M. van Heukelom, R. Kaplar, and S. Atcitty, “Hard-Switching Reliability Studies of 1200 V Vertical GaN PiN Diodes,” Enabling Advanced Power Electronics Technologies for the Next Generation Electric Utility Grid Workshop, Albuquerque, NM, July 17-18, 2018
33. L. J. Small, H. D. Pratt, C. L. Staiger, and T. M. Anderson “Chemically Mediated Redox Flow Batteries for Modular Energy Storage,” 2018 Spring Materials Research Society Meeting, Phoenix, AZ, April 2-6, 2018
34. L. J. Small, S. Percival, E. Allcorn, and E. D. Spoecke “Molten NaI-AlCl₃ Catholytes for Use in a Sodium Battery,” Electrical Energy Storage Applications and Technologies 2017, San Diego, CA, Oct 11-13, 2017.
35. L. J. Small, S. Percival, J. Lamb, E. Allcorn, and E. D. Spoecke “Intermediate Temperature Sodium Batteries Enabled by an Inorganic Molten Catholyte,” 233nd Electrochemical Society Meeting. Seattle, WA. May 13-17, 2018.
36. E. D. Spoecke, L. J. Small, S. Bhavaraju, A. Eccleston, E. Allcorn, J. Lamb, and P. Clem “A Materials Chemistry Approach to Safe, Effective Sodium Batteries,” 2017 Fall Materials Research Society Meeting, Boston, MA. Nov. 26-Dec. 1, 2017
37. E. D. Spoecke, L. J. Small, J. Lamb, P. Clem, D. Ingersoll, S. Bhavaraju, and A. Eccleston “Advancing Sodium-Based Batteries for Grid-Scale Energy Storage,” 232nd Electrochemical Society Meeting. National Harbor, MD. Oct. 1-5, 2017

38. E. D. Spoeke, L. Small, S. Percival, J. Lamb, P. Clem, D. Ingersoll, S. Bhavaraju, and A. Eccleston “Sodium-Based Batteries: Toward Meeting Next Generation Challenges in Grid-Scale Energy Storage.” Electrical Energy Storage Applications and Technologies 2017, San Diego, CA, Oct 11-13, 2017
39. E. D. Spoeke, L. J. Small, S. Percival, P. Lu, and J. Ihlefeld “Relating NaSICON Chemistry and Microstructure to Ion Conducting Ceramic Separator Performance,” 2018 Spring Materials Research Society Meeting, Phoenix, AZ. April 2-6, 2018
40. T. E. Stevens, C. J. Pearce, M. A. Rodriguez, S. Dickens, B. B. McKenzie, S. Atcitty, and T. C. Monson “Synthesis of γ' -Fe₄N, a new soft magnetic material for inductors and transformers” 255th ACS National Meeting and Exposition, New Orleans, 2018
41. T. E. Stevens, C. J. Pearce, M. A. Rodriguez, S. Dickens, B. B. McKenzie, S. Atcitty, and T. C. Monson “Synthesis of γ' -Fe₄N, a new soft magnetic material for inductors and transformers” 233rd Electrochemical Society (ECS) Meeting, Seattle, WA, May 13-17, 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

1. Babu Chalamala and Vincent Sprenkle “[Tutorial ES04: Grid-Scale Energy Storage Materials and Systems](#),” 2017 Materials Research Society (MRS) Fall Meeting & Exhibit, Boston, MA, Nov 26-Dec 1, 2017
2. Dan Borneo, Ray Byrne, Babu Chalamala, David Copp, Tu Nguyen, Jim McDowall, Randy Schubert, Chris Searles, Vince Sprenkle, and Charlie Vartanian, Energy Storage Tutorial, TUT-07, IEEE T&D Conference, Denver, CO, April 16, 2018
3. S. Ferreira, H. Barkholtz, Partha Mukherjee Tutorial ES05 “Energy Storage System Materials and Design Safety Considerations—A Materials Perspective,” 2017 Materials Research Society (MRS) Fall Meeting & Exhibit, Boston, MA, Nov 26-Dec 1, 2017

4. Imre Gyuk, Vince Sprenkle, Babu Chalamala, Ray Byrne, David Copp and Dan Borneo, The Evolution of Energy Storage: Factors Driving the Need for Energy Storage and Its Effect on the Grid, IEEE Tutorial Program for staff of Federal Energy Regulatory Commission (FERC), Washington, DC, February 7, 2018
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

1. D. Borneo "[Microgrid Resiliency](#)," CESA Webinar, October 24, 2017
2. D. Borneo, "Engineering, Procurement, and Construct Issues in ES Projects," Webinar, Energy Storage Week, March 2018
3. R. H. Byrne, "Sterling Municipal Light Department Analysis," CESA webinar, March 7, 2018
4. D. A. Copp, "[Distributed Control for Improving Power System Stability](#)," IEEE Smart Grid Webinar, April 12, 2018 online: <http://resourcecenter.smartgrid.ieee.org/sg/product/education/SGWEB0080>
5. T. A. Nguyen "[Maximizing the Cost Savings for Utility Customers Using Behind-the-Meter Energy Storage](#)," at IEEE Smart Grid Webinar, May 2018, online: <http://resourcecenter.smartgrid.ieee.org/sg/product/education/SGWEB0083>
6. T. A. Nguyen "[Rate Design Trends for Behind-the-Meter Storage](#)," at Sandia & Strategen's Energy Storage Webinar Series, Jul 2018, online: <https://www.strategen.com/webinar-4>.

Seminar Presentations

1. S. Atcitty, "Role of WBG Devices for Grid-tied Storage", Ohio State University Technical Seminar, Sept 12, 2018
2. (Invited) B. R. Chalamala, "Energy Storage and Modernization of the Electric Grid," Department of Chemical Engineering Seminar, City University of New York, New York, NY, December 11, 2017
3. D. A. Copp, "From the Power Grid to Diabetes: Solving Problems with Control and Optimization," Northern Arizona University (NAU), Technical Seminar, November 21, 2017
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



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