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Tutorial Details

Tutorial Title	How Grid Energy Storage Meets the Challenges of a Decarbonized Future
Technical Sponsor	IEEE PES ESSB (Energy Storage and Stationary Battery) committee
Abstract (~150 words)	This multi-presenter tutorial covers the basics of how electrical energy storage supports decarbonization initiatives across the U.S. To cover this topic, the 4-hour tutorial will be divided into four (4) sections, starting with a review of current technologies targeted for this area, e.g., lithium ion, pumped hydro, flow batteries, and long duration energy storage. Next, market application challenges and valuations will be discussed where the focus will be on the duration needed in a decarbonized scenario and market products that may be required to ensure deployment. In the final two sections, focus will shift to engineering of energy storage systems, code compliance, and interconnection – including electrification technologies. The last section will review system safety and reliability.

Summary of Topics and Brief Description of What is Covered by Each Topic

1. A Look at the Battery Energy Storage System (BESS) Technologies needed to support Decarbonized Initiatives (can technologies meet likely duration needs)
 - Energy Storage Evolution: factors driving the need for energy storage for the grid
 - Advanced, Current Technologies
 - Li-ion Batteries: advantages, how they work, various chemistries and their pros and cons, and safety
 - Flow Batteries: advantages/issues/challenges, and the various present and potentially future promising chemistries
 - Traditional Storage Technologies: Review of pumped storage and Advanced Lead-Acid batteries:
 - Long Duration Energy Storage Technologies:
 - Traditional and Emerging Battery Energy Storage Technologies: Sodium batteries (Na-S, NaNiCl), Zn-air, Zn-MnO₂ and emerging technologies. Technology status, and progress



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2. Session 2: Applications and Valuation for Energy Storage to Support Decarbonization
 - Applications/Markets for Short Term / Long Duration Energy Storage for decarbonization – use of current markets of future markets to support deployment
 - Electrification: Role EVs can play in Decarbonization and Grid Support
 - Role of Solar / Storage support Electric Vehicle Charging Infrastructure

3. Session 4: Interconnection, Codes and Regulations
 - Energy Storage System Commissioning: testing protocols, performance metrics, data acquisition, and duty cycle performance
 - Grid Interconnection: Challenges of Interconnectivity and need for standards, IEEE 1547. Integration of distributed energy resources, impacts and solutions
 - Related to vehicle to grid, vehicle to home. Do standards cover these applications?

4. Session 3: A Closer Look at Safety, Codes Compliance
 - Safety and Reliability – Stationary Storage
 - Recent incidents – occurrences and what we know
 - Safety and Reliability of Energy Storage Systems, Fire Hazard Elimination and Suppression
 - Safety Code Compliance
 - Code Compliance for Energy Storage Systems: Relevant codes and regulations, upcoming big changes to the Fire Codes for new battery types, and NFPA 855

Outline with timeslots for each topic.

Moderator: Steve Vechy + Rick

Part 1: Session 1: 8:00 – 9:00 am

Review of Energy Storage Technologies to Support a Decarbonized Future (Babu + Curtis + Rick F)

- Likely requirement needs for energy storage in a decarbonized future (breakdown of hours)
- Review of Advanced battery types — Lithium, Flow batteries (Supply chain issues)
- Review of Traditional technologies – pumped storage and advanced lead acid
- Review of Long Duration energy Storage Technologies (Rick + duration Gap)



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Part 1: Session 2: 9:00 AM to 10:00 AM

Applications and Valuation for Energy Storage to Support Decarbonization (**Ray Byrne, Tu Nguyen**)?

- Applications/Markets for Short Term / Long Duration Energy Storage for decarbonization
- Role of Electrification / Storage
- Role of solar / storage applications
- Q&A
- **Role of storage in data centers, back-up...**

Break – 15 minutes: 10:00 AM to 10:15 AM

Part 2: Session 3: 10:15 AM – 11: 00 AM

Interconnection, Codes and Regulations – **Charlie Vartanian + Michael Ropp**

- Energy Storage System Commissioning: testing protocols, performance metrics, data acquisition, and duty cycle performance
- Grid Interconnection:
- ***Vehicle to grid, vehicle to home. Do standards cover these applications? (Charlie)***

Part 2: Session 4: 11:00 AM – 12:00 pm

A Closer Look at Safety, Codes Compliance (**Chris Searles + Curtis**)

- Safety and Reliability – Stationary Storage
- Safety Code Compliance
- ***Firefighting philosophy still developing***
- ***Stranded Energy?***

Conference Name

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List PES conferences at which this tutorial was previously presented

- This shortened tutorial will be an updated version of recent energy storage tutorials but updated and directed at ability of storage to support a decarbonized future
 - ESSB Committee presented a day long tutorial at 2022 T&D Meeting in New Orleans
 - ESSB Committee presented a day long tutorial at 2018 T&D Meeting in Denver.
 - The committee also presented a full day tutorial at Federal Energy Regulatory Commission (FERC) on Feb 8, 2018, in Washington, DC.
 - A shortened version of this was tutorial was given at ESSB Winter Meeting in Chattanooga in January of 2017.

Instructor Details: Primary Contact Name, affiliation, email address

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Instructor Name, affiliation, email address.

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Instructor Bios (~125 words each bio).

Dr. Ray Byrne is Manager of the Power Systems Department at Sandia National Laboratories. He started his career in robotics, working on tele-robotic vehicles and miniature mobile robots. In the late 1990's his team demonstrated large numbers of cooperative miniature mobile robots as part of a DARPA effort. From 2001-2008 he developed fiber optic links for space applications. For the last ten years, his work has been focused on optimal control of energy storage to maximize benefit to the grid, and grid integration of renewables. One of his energy storage papers received the Prize paper award at the 2016 PES GM. Ray has a B.S., M.S., and PhD in electrical engineering, and an M.S. in financial mathematics. He has been chair of the Albuquerque IEEE section multiple times. He is a Fellow of the IEEE and recipient of the IEEE Millennium Medal.

Dr. Babu Chalamala is Manager of the Energy Storage Technology and Systems Department at Sandia National Laboratories. Prior to joining Sandia, he was a Corporate Fellow at MEMC Electronic Materials/SunEdison for five years, where he led R&D and product development in grid scale energy storage. Before that, he founded two startup companies commercializing large format lithium batteries and digital x-ray sources. Earlier, as a research staff member at Motorola and Texas Instruments, he made contribution to the development of electronic materials and device technologies. He received his B.Tech. degree in Electronics and Communications Engineering from Sri Venkateswara University and his PhD degree in Physics from the University of North Texas. He is a Fellow of the IEEE and Academy of Sciences St Louis, etc.

Jim McDowall has worked in the battery industry since 1977 and is currently with Saft Batteries in the position of Business Development Manager. He is very active in standards work and is currently the Standards Coordinator of the IEEE Stationary Battery Committee and chair of three of its working groups, as well as being a former chair of the parent committee. Jim is also a current member and former chairman of the board of directors of the Electricity Storage Association. He is a member of the Battcon conference technical committee and received ESA Phil Symmons Award and IEEE PES recognition for standards development.

Chris Searles is a 40 year veteran of the battery and dc power industry. He currently holds the position of National Director of Sales, Marketing and Business Development for BAE Batteries USA. He has held previous positions as Product Manager of DC Power Systems for Yuasa-Exide as well as National Director of Business Development for the IS&S Group at Yuasa-Exide. He has also held sales, marketing and management positions at Northern Telecom, IT&T Power Systems and Argus Technologies. Chris is the chair of the IEEE PES ESSB.

Dr. Ralph D. Masiello is Senior Advisor at Quanta Technology. He worked on early applications of modern control and estimation theory for electric power systems and developments of the first state estimators for transmission operations. He also led the teams that developed the early commercial ISO systems for market and reliability operations. He chaired the US DOE Energy Advisory Committee



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Storage Subcommittee 2009-2013 and has been responsible for the development of analytical solutions for applying energy storage to wholesale, transmission, and distribution applications. Dr. Masiello was the chaired the DNV GL department of Energy Advisory Americas and developed Smart Grid and automation roadmaps for several US ISOs as well as the California Energy Commission. Dr. Masiello also served as the General Manager of ABB Systems Control and has recently been involved with energy deregulation projects in Australia, Singapore, Taiwan, the UK, Canada. Dr. Masiello is a Life Fellow of the IEEE, Member of the US National Academy of Engineering. He received the 2009 IEEE Power Engineering Concordia award for Power System Engineering. He received his B.S., M.S., and Ph.D. from the Massachusetts Institute of Technology in Electrical Engineering.

Dr. Tu Nguyen is a Senior Member of the Technical Staff at Sandia National Laboratories. He received his B.S degree in Power Systems from Hanoi University of Science and Technology, Vietnam in 2007 and his Ph.D. degree from Missouri University of Science and Technology in 2014. He worked as a Power Transformer Test Engineer in ABB High Voltage Test Department in Vietnam from 2008 to 2009. Before joining Sandia National Laboratories in September 2016, he worked as a Postdoctoral Research Associate at University of Washington. He is currently an Editor for IEEE Transactions of Sustainable Energy. His research interests include energy storage economics, microgrid modeling and analysis, and the integration of distributed resources into power grids.

Dr. Yuliya Preger is a Senior Member of Technical Staff at Sandia National Labs. Her current work is centered on the safety and reliability of lithium ion batteries for grid-level energy storage applications. This work ranges from high precision analysis of cell level cycling and thermal characterization of cell components to development of new module arrangements in conjunction with new power electronics architectures. She earned her PhD in Chemical Engineering in 2018 at the University of Wisconsin-Madison and her BS in Chemical Engineering in 2013 from MIT.

Charlie Vartanian is a Senior Advisor in Grid Modernization at Pacific Northwest National Laboratory. He was previously Generation Sales Manager at Mitsubishi Electric Power Products, Inc (MEPPI), a North American based provider of power equipment and turnkey power projects. His current focus is on advanced grid products including energy storage and grid-scale PV solutions. Charlie has over 25 years of power industry experience developing and marketing advanced grid solutions, performing electric system studies, and contributing to technical standards development. He's previously worked for DNV KEMA, Enron Energy Services, the California Energy Commission, and Southern California Edison (SCE). During his 15 years at SCE, Charlie's activities spanned traditional T&D planning through R&D. Charlie is a licensed electrical PE and a Senior IEEE member. Charlie received his BSEE from Cal Poly Pomona, and his MSEE from USC.

Richard Fioravanti is a Director for Transportation Electrification and brings over 25 years of experience working with emerging energy technologies in both commercial and consulting roles. He has worked



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with major manufacturers, utilities, state/federal agencies, and developers to understand and deploy advanced energy systems. He currently focuses his efforts on electric transportation, EV infrastructure, and technology electrification - evaluating electricity grid impacts and linking the technologies to grid modernization, utility of the future initiatives. For electrification, he is currently leading efforts to examine load impacts for airport and seaport electrification. Mr. Fioravanti also was a founding Board Member of New York BEST (Battery and Energy Storage Technology Consortium) and served on their Board for five years. In this role, he helped create the NY-BEST Energy Storage testing lab for the organization. He has authored several papers on advanced storage technologies and has been cited frequently as a leader in his field.