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IECON 2023 Tutorial Proposal

Title of the Proposal: Integration of New Data-driven Battery Management Systems with Health-conscious Fast Charging Methods for Future E-mobility

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Brief description:

The transition to sustainable e-mobility is a complex process that requires the development of both battery technology and charging infrastructure. A significant development in these two major domains is extremely essential to alleviate some of the major bottlenecks towards transiting to sustainable e-mobility. While battery technology plays a crucial role in determining the range, cost, and performance of electric vehicles (EVs), charging infrastructure is essential for enabling long-distance travel and reducing range anxiety.

Advancements in battery technology have already made electric vehicles more viable as a transportation option. Lithium-ion batteries (LIB), for instance, have become smaller, lighter, and more powerful, allowing for longer driving ranges and faster acceleration. However, the internal characteristics of LIB are highly nonlinear and extremely sensitive to the operating and environmental parameters. Therefore, an intelligent safety framework and smart battery management systems (BMS) are extremely essential to ensure safe, reliable, and longer battery life. Furthermore, it is noticed that the frequent incident of fire in electric vehicles (EVs) is primarily due to ineffective BMS, especially poor thermal management control. New battery chemistries, such as solid-state batteries, could potentially offer even greater improvements in performance and safety. Therefore, recent advances in battery technology, BMS, and thermal management of batteries will be explained in significant detail along with the current issues, challenges and future research scopes. Recent advancements such as the application of artificial intelligence, machine learning, digital-twin, internet of things, cloud computing, and wireless BMS will also be covered in this tutorial.

Another, import aspects of achieving sustainable e-mobility is the charging infrastructure development. Without adequate charging infrastructure, EVs may still face significant limitations even after adding more capacity and high-tech batteries. Adding more batteries will increase the range but also increase the weight and cost of the vehicle. Moreover, the replacement cost of the vehicle will also be more, resulting in a higher total ownership cost of EVs. EV drivers need access to a network of charging stations that can support long-distance travel and charging times that are comparable to refuelling times for gasoline vehicles. Failing to do that, EVs will never attract more users and the future of EVs will be questionable. This requires the deployment of high-speed and an adequate number of charging stations. Therefore, recent developments, issues and challenges of EV charging including wireless charging, DC fast charging along with the potential options to improve charging infrastructure development will be comprehensively discussed in the tutorial.
To achieve a sustainable e-mobility future, it is necessary to continue to invest in both battery technology and charging infrastructure. While at the same time, the development of widespread, fast, and affordable charging infrastructure will enable the wide adoption of EVs. Thus, finally, a comparative analysis and debate through Q&A among the audience will be conducted to provide an interactive platform and brainstorming session to obtain a view of the industry.

Duration: 3 Hours

Outline:

Sl. No.	Topics	Subtopics	Time Allocation and Instructor
1	**Battery Tech for EVs**	• Broad review of emerging storage systems for electric and plug-in hybrid vehicles including the superiority of lithium-ion battery. • Recent developments in battery technology including Solid-state batteries, Lithium-sulfur batteries, Sodium-ion batteries, Zinc-air batteries and their potential in EV applications • Hybrid storage systems such as battery-battery hybrid, battery supercapacitor hybrid and their role in alleviating the current challenges in wide adoption of EVs • Current issues and challenges to industries, promising new energy storage technologies for EVs and future research areas.	45 Minutes

2	**Lithium-ion Battery and Battery Management System**	• Broad review of a lithium-ion battery management system • Typical components of the battery management system • Classification of Battery Management System and their application in Real-Life • Advanced state estimation powered by AI/ML including state of charge, state of health, remaining useful life, and state of temperature • Fault Diagnose and safety features of battery management system • BMS for Second-Life Application of battery • Power electronics converter associated with battery management systems • Use of advanced technology such as digital twin, IoT, cloud computing in BMS • Wireless BMS for high power battery pack • Current practice and challenges and issues associated with the developments on battery management systems • Role of advanced BMS in solving the issues related to range anxiety, battery life and safety including thermal safety.	45 minutes
3	**Health-Conscious Fast charging of Lithium-Ion Battery**	• Overview of different battery charging techniques • Necessity and evolution of DC-fast charging and wireless charging • Different Standards and protocols of charging • Drawbacks of conventional charging techniques • Recent Development in Fast Charge Techniques • Fast charging techniques, standards, and protocols • Practical application, case studies of DC-fast charging and wireless charging • Limitation of fast charging and wireless charging and scope of research and development • Impacts of DC fast charging in battery health and cycle life • Safety issues (fire and catastrophic failure) of the battery due to fast charging	45 Minutes

		• Conventional charging algorithms and health-conscious fast charging algorithms • Poor thermal management control issues and solutions • Recent developments and practical applications with examples and case studies	
4	**Charging Infrastructure Development**	• Different types of charging stations • Smart charging technology • Current status of charging infrastructure development • Discussing the current issues and challenges in charging infrastructure development • Discussion on increasing the number of charging stations and suitable location • Public-private partnerships and its role in charging infrastructure development • Debate on Battery Tech vs. Charging Infrastructure: Driving towards a sustainable e-mobility future among the audience.	45 Minutes

Brief CV:

Akash Samanta (*Student Member*, *IEEE*) received B. Tech degree (1st class) in Electrical Engineering from the West Bengal University of Technology in 2012. He also received M. Tech (1st class) and MBA (1st class) degree in Electrical Engineering and Energy Management from the University of Calcutta in 2018 and 2014 respectively. From 2014 to 2018 he was a Project Officer and Solar Energy Master Trainer with the Department of Energy Management, Indian Institute of Social Welfare and Business Management, Kolkata, India. He is currently a Doctoral Research Scholar with the Department of Electrical, Computer, and Software Engineering at Ontario Tech University, Oshawa, ON, Canada. His research interest includes electric energy storage systems, battery management systems, power electronics converters, and the application of machine learning and artificial intelligence in the related field. He conducted tutorials, special sessions, and short courses at several flagship IEEE conferences such as IECON, SPEC, and ITEC.

Sheldon Williamson (Fellow, IEEE) received the B.E. degree (Hons.) in electrical engineering from the University of Mumbai, Mumbai, India, in 1999, and the M.S. and Ph.D. degrees (Hons.) in electrical engineering from the Illinois Institute of Technology, Chicago, IL, USA, in 2002 and 2006, respectively. He is currently a Professor with the Department of Electrical, Computer and Software Engineering and the Director of Smart Transportation Electrification and Energy Research (STEER) Group, Faculty of Engineering and Applied Sciences, Ontario Tech University, Oshawa, ON, Canada. His current research interests include advanced power electronics, electric energy storage systems, and motor drives for transportation electrification. He holds the prestigious NSERC Canada Research Chair position in electric energy storage systems for transportation electrification. He conducted tutorials, special sessions, and short courses several flagship IEEE conferences such as APEC, ECCE, IECON, SPEC.

Relevant publications

1. A. Samanta and S. Williamson, “Machine Learning-based Remaining Useful Life Prediction Techniques for Lithium-ion Battery Management Systems: A Comprehensive Review,” IEEJ Journal of Industry Applications, p. 22004793, 2023, doi: 10.1541/IEEJJIA.22004793.
2. A. Samanta, A. Huynh, E. Rutovic and S. Williamson, "Rapid Thermal Modeling and Discharge Characterization for Accurate Lithium-ion Battery Core Temperature Estimation," IECON 2022 – 48th Annual Conference of the IEEE Industrial Electronics Society, Brussels, Belgium, 2022, pp. 1-6, doi: 10.1109/IECON49645.2022.9968451.
3. S. Surya, A. Samanta, V. Marcis and S. Williamson, "Hybrid Electrical Circuit Model and Deep Learning-Based Core Temperature Estimation of Lithium-Ion Battery Cell," in IEEE Transactions on Transportation Electrification, vol. 8, no. 3, pp. 3816-3824, Sept. 2022, doi: 10.1109/TTE.2022.3170359.
4. A. Samanta, A. Huynh, M. Sharma, V. Marcis and S. Williamson, "Supercapacitor and Bidirectional DC-DC Converter-based Active Charge Balancing Scheme for Lithium-ion Batteries," 2022 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 2022, pp. 1-7, doi: 10.1109/ECCE50734.2022.9947732.
5. A. Samanta, M. Sharma and S. Williamson, "A Supercapacitor and Fuzzy-PID Controller-based Active Charge Balancing Scheme for Lithium-ion Batteries," IECON 2022 – 48th Annual Conference of the IEEE Industrial Electronics Society, Brussels, Belgium, 2022, pp. 1-6, doi: 10.1109/IECON49645.2022.9969110.
6. A. Golder and S. S. Williamson, "Energy Management Systems for Electric Vehicle Charging Stations: A Review," IECON 2022 – 48th Annual Conference of the IEEE Industrial Electronics Society, Brussels, Belgium, 2022, pp. 1-6, doi: 10.1109/IECON49645.2022.9968614.
7. A. Samanta and S. S. Williamson, “A comprehensive review of lithium-ion cell temperature estimation techniques applicable to health-conscious fast charging and smart

battery management systems," Energies (Basel), vol. 14, no. 18, pp. 1–25, Sep. 2021, doi: 10.3390/en14185960.

8. A. Samanta and S. Chowdhuri, "Active Cell Balancing of Lithium-ion Battery Pack Using Dual DC-DC Converter and Auxiliary Lead-acid Battery," J Energy Storage, vol. 33, Jan. 2021, doi: 10.1016/j.est.2020.102109.
9. V. A. Marcis, A. Kelkar and S. S. Williamson, "Electrical Circuit Modeling of a 18650 Lithium-Ion Cell for Charging Protocol Testing for Transportation Electrification Applications," 2020 IEEE Transportation Electrification Conference & Expo (ITEC), Chicago, IL, USA, 2020, pp. 169-174, doi: 10.1109/ITEC48692.2020.9161522.
10. V. A. Marcis, A. V. J. S. Praneeth, L. Patnaik and S. S. Williamson, "Analysis of CT-CV Charging Technique for Lithium-ion and NCM 18650 Cells Over Temperature Range," 2020 IEEE International Conference on Industrial Technology (ICIT), Buenos Aires, Argentina, 2020, pp. 947-952, doi: 10.1109/ICIT45562.2020.9067186.
11. A. V. J. S. Praneeth, N. Yalla and S. S. Williamson, "DC–DC Converter with Reduced Circulating Current in On-board Battery Chargers for Electric Transportation," 2019 IEEE Transportation Electrification Conference (ITEC-India), Bengaluru, India, 2019, pp. 1-6, doi: 10.1109/ITEC-India48457.2019.ITECINDIA2019-283.