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Tutorial Title

Advanced Data-driven and Digital-twin Enabled Power-electronics-intensive Battery Management Systems and Fast Charging

Instructor Team

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Abstract

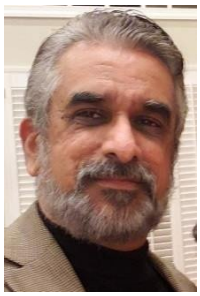
As electrified transport systems proliferate, Lithium-ion batteries (LIBs) are increasingly becoming the critical element in the immediate and long-term technical and commercial success of these programs. Understanding battery technology and its role in applications are becoming crucial. While there have been many articles published on battery elements and systems, this tutorial approaches the problem from a technical as well as from a user mindset. Primarily, range anxiety and reliability aspects are a bottleneck for the wide adoption of EVs. The internal characteristics of LIBs are highly nonlinear and extremely sensitive to 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. The reliable operation of BMS requires detailed information on the voltage, current, temperature, and aging profile of each cell. Moreover, important battery states like the state of charge, health, and remaining useful life cannot be directly measured with physical sensors. Therefore, intelligent state estimation techniques such as artificial intelligence (AI), machine learning (ML), and deep learning (DL)- based techniques will be discussed in this short course.

Now, as high-resolution data is the backbone of any data-driven technique and collecting and processing high-resolution data needs the IoT for accessing advanced platforms such as cloud computing and data storage. All these aspects will be discussed with examples in this tutorial. Furthermore, the application of microcomputers and new-gen computing platforms, such as edge-computing and fog-computing will also be discussed. Recently, with the introduction of fast charging, the issues of range anxiety and long charging times have been somewhat minimized.

However, there has been a high risk of thermal runaway and other safety issues due to this. To ensure effective BMS operation, superfast data acquisition, processing, and control based on accurate battery state are of utmost importance. Here, a recently patented digital-twin-based battery safety framework powered by DL will be introduced. In addition, fast charging and active cell balancing have a significant negative impact on battery health, thus some of our recent developments such as constant temperature constant voltage (CTCV) charging and modular multilevel converter (MMC) based cell balancing and protection techniques aside from the application of reconfigurable battery pack and its application in fast charging and EV battery management will also be covered in this tutorial. The application of data-driven techniques and electromagnetic impedance spectroscopy will be discussed for battery diagnosis, remaining useful life prediction, and remaining useful capacity prediction. A special emphasis will be given to the state estimation of unknown old batteries and second-life LIBs. Furthermore, insights on health-conscious BMS and ways to extend battery useful life will be discussed based on our recent research and development. The application of higher-order cell electrical and thermal modeling in battery emulator development will also be covered in sufficient detail. Finally, recent R&D issues, challenges, and case studies of existing BMS methods and thermal management systems will be explained.

Instructor Biography

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.



Uday Deshpande (Senior Member, IEEE) is currently the CTO of D&V Electronics, a maker of special test equipment used in automotive, military, and defense applications for testing electrical systems and EV components. Prior to joining D&V, He held global engineering leadership positions in companies such as CNH Industrial, Ingersoll Rand, General Atomics, and Black & Decker. He has worked on projects from electric power steering to electric drivetrains in automotive, on electromagnetic aircraft launch and recovery systems, electrification and autonomy for agriculture equipment, and connected products and services. His areas of technical focus are electrical and electromechanical systems and their
applications. He was the Co-General Chair of ECCE 2011, in Phoenix, AZ. He is the Past Chair of the Industrial Drives Committee of the IEEE IAS
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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.