Advanced Electric Energy Storage Systems and Smart Fast Charging for Future Electric Mass Transit Applications

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In order to achieve stringent environmental sustainability goals, the trend in the auto industry is moving towards transportation electrification, by introducing electric and plug-in hybrid electric vehicles (EVs/PHEVs). Hence, it has become imperative to find a solution, to manage energy production and usage accurately, within the context of future transportation electrification and energy storage systems.

Enhancing the life of Lithium-ion (Li-ion) battery packs has been the topic of much interest in the automotive industry. On-board cell-equilization problem of Li-ion batteries will be highlighted in this tutorial. This is a very important topic in the context of EV battery energy storage cost and life/state-of-charge, SOC/state-of-health, SOH monitoring. Li-ion batteries, although popularly proposed, have been highly uneconomic for EV energy storage, overshooting cost requirements by a large margin. They provide a good solution for EV and PHEV applications, but main issues include: cycle life, calendar life, energy density, power density, and lately, safety. These issues can be addressed successfully by using a simple practical approach: a power electronics cell voltage equalizer. The purpose of the second part of this tutorial is to demonstrate the role of power electronics intensive battery management solutions to reach the cost breakpoint of a PHEV/EV. The design and implementation of both inductor-based as well as switched capacitor DC/DC converters for Li-ion battery cell-equilization will be discussed. Finally, the design of a novel DC/DC resonant converter for voltage equalization of EV/PHEV Li-ion battery cells will also be presented.

This presentation will also look at storage and off-board fast charging solutions for future all-electric mass transit applications, such as electric buses, trucks, trains, and trams. In addition, the tutorial will also introduce the concept of fast charging stations and smart on-board energy management for ultracapacitor (UC) powered electric traction. The presentation will depict the proposed possibility of completely eliminating the need for powering electric railway traction systems from overhead or wayside power conductor rails. The usage of wireless/inductive power transfer (IPT) will be described for mass transit applications, such as electric city trams, buses, and trains, solely powered by UCs. The tutorial will present a wireless DC fast charging system that can be installed only at major bus stops, tram stops, or train stations, to achieve charging of on-board UCs in less than 2 minutes. The tutorial will present the sizing/layout of the UC bank (series/parallel modules) and its distinct DC/DC 2-quadrant converter (for regenerative braking and acceleration), as well as the design the power electronic wireless off-board fast charging infrastructure. The tutorial will finally describe the design of the on-board power electronic UC cell voltage/power-management system. This smart and novel on-board DC/DC power electronic energy management converter will help equalize and balance the UC cell voltages.

It must be noted that this tutorial will be particularly useful for engineers and managers with entry-level and medium-level knowledge of automotive power electronics and motor drives. The tutorial would also be appropriate for engineers with entry-level knowledge of power electronics and motor drives applications towards energy storage systems, electric vehicles, and renewable energy systems.
Speaker Biography

Sheldon S. Williamson (S’01–M’06–SM’13) received his Bachelor of Engineering (B.E.) degree in Electrical Engineering with high distinction from University of Mumbai, Mumbai, India, in 1999. He received the Master of Science (M.S.) degree in 2002, and the Doctor of Philosophy (Ph.D.) degree (with Honors) in 2006, both in Electrical Engineering, from the Illinois Institute of Technology, Chicago, IL, specializing in automotive power electronics and motor drives, at the Grainger Power Electronics and Motor Drives Laboratory. Dr. Williamson is an Associate Professor and NSERC Canada Research Chair in Transportation Electrification and Electric Energy Storage Systems, within the Department of Electrical, Computer, and Software Engineering, Faculty of Engineering and Applied Science, at the University of Ontario-Institute of Technology, Oshawa, Ontario. From 2006-2014, Dr. Williamson was with the Department of Electrical and Computer Engineering, at Concordia University, Montreal, Canada. His main research interests include the study and analysis of electric drive trains for electric, hybrid electric, plug-in hybrid electric, and fuel cell vehicles. His research interests also include modeling, analysis, design, and control of power electronic converters and motor drives for land, sea, air, and space vehicles, as well as the power electronic interface and control of renewable energy systems.

Dr. Williamson has offered numerous conference tutorials, lectures, and short courses in the areas of Automotive Power Electronics and Motor Drives. He is the principal author/co-author of over 150 journal and conference papers. He is also the author of 4 chapters in the book entitled, Vehicular Electric Power Systems (Marcel Dekker, 2003). He is also the author of 2 chapters in the book entitled, Energy Efficient Electric Motors (CRC Press, 2004). In addition, Dr. Williamson has been selected as the General Chair for the IEEE Transportation Electrification Conference, to be held in Detroit, Michigan, in June 2014. He also served as the Technical Program Chair for various conferences, including the Annual Conference of the IEEE Industrial Electronics Society (IEEE IECON 2012), the IEEE Vehicle Power and Propulsion Conference (2011), and the IEEE Canada Electrical Power and Energy Conference (2009). Dr. Williamson also served as the Project Coordination and Awards Chair at the 2007 IEEE Canada Electrical Power Conference, Montreal, Canada. He was the Conference Secretary for the 2005 IEEE Vehicle Power and Propulsion Conference, Chicago, Illinois.

Dr. Williamson is also the beneficiary of numerous awards and recognitions. He was the recipient of the prestigious “Paper of the Year” award, for the year 2006, in the field of Automotive Power Electronics, from the IEEE Vehicular Technology Society (IEEE VTS). In addition, he also received the overall “Best Paper” award at the IEEE PELS and VTS Co-sponsored Vehicle Power and Propulsion Conference, in Sept. 2007. He was awarded the “Best Paper” award at the IEEE Canada Electrical Power and Energy Conference, in Halifax, Nova Scotia, Canada, in Aug. 2010. He was awarded the prestigious Sigma Xi/IIT Award for Excellence in University Research, for the academic year 2005-2006. In 2006, he also received the “Best Research Student” award, Ph.D. category, within the ECE Department, at the Illinois Institute of Technology, Chicago.

Dr. Williamson is a Senior Member of the IEEE. He currently serves as a Distinguished Lecturer of the IEEE Vehicular Technology Society (VTS). He also serves as Associate Editor for the IEEE Transactions on Industrial Electronics, IEEE Transactions on Power Electronics, IEEE Transactions on Transportation Electrification, and the IEEE Journal of Emerging and Selected Topics in Power Electronics. He is a member of the IEEE PELS, IES, and VTS. He is also a Member of the IEEE Transportation Technologies Awards Committee.