Tutorial ECCE Europe EPE'13

Battery Management Systems for Electric Drive Vehicles and Grid Storage

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Scope: Electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) have attracted worldwide attentions because their capabilities to displace petroleum usage and improve energy and environment sustainability. One of the key constraints for mass market penetration of EV and PHEV is the high cost of the battery system as well as the safety and reliability concerns of the battery system. Battery management systems deal with these issues effectively to ensure safe and reliable operation of the battery system, extend the life of battery, and maximize the drive range. On the other hand, power electronics are widely used in EV and PHEV battery systems, such as battery charger, battery control units (DC-DC converter), battery cell balancing circuits, and battery protection circuits. These power electronics units must address the unique characteristics of different batteries and assure safe operation of the battery system, and effectively work with the battery management system (BMS). Proper design of the BMS and associated micro and power electronic circuits can help optimize the system efficiency and reduce cost while extend the life expectance and increase safety of the battery system.

This course covers four main topics: (1). Energy storage system basics for power electronic engineers with focus on lithium ion batteries; (2). Battery management systems; (3). The application of power electronics in the battery system of an EV and PHEV, including on board and off board battery charger, DC-DC converter, battery monitoring, control, balancing, and protection circuits. (4). Battery safety basics. (5) Battery modeling and parameter identification; (6) battery diagnostics and prognostics. (7). Wireless charging of electric vehicle. The seminar will focus on the unique aspects of these power electronic circuits in EV and PHEV applications. Conductive, inductive, and wireless chargers will be discussed. Vehicle to grid (V2G) concepts and grid energy storage will be briefly introduced.

Benefits: the objective is to provide power electronics engineers and students the knowledge they need to work in the area of batteries in electric drive vehicles and grid storage.

See last two pages for list of topics covered in this seminar.

Who Should Attend
Student, faculty, engineers who work in power electronics, hybrid electric vehicle and related area and like to know more about batteries and battery management.

Technical Level: This tutorial cover some basics of battery management to advanced topics in BMS.

About the Instructor: Chris Mi is a fellow of IEEE, Professor of Electrical and Computer Engineering at the University of Michigan, Dearborn, and the Director of the newly established DOE GATE Center for Electric Drive Transportation. He received the B.S. and M.S. degrees from Northwestern Polytechnical University, Xi'an, China, and the Ph.D. degree from the University of Toronto, Toronto, ON, Canada, all in electrical engineering. Previously he was an Electrical Engineer with General Electric Canada Inc. He was the President and the Chief Technical Officer of 1Power Solutions, Inc. from 2008 to 2010.

His research interests are in electric and hybrid vehicles. He has taught tutorials and seminars on the subject of HEVs/PHEVs for the Society of Automotive Engineers (SAE), the IEEE, workshops sponsored by the National Science Foundation (NSF), and the National Society of Professional Engineers. He has delivered courses to major automotive OEMs and suppliers, including GM, Ford, Chrysler, Honda, Tyco Electronics, A&D Technology, Johnson Controls, Quantum Technology, Delphi, and the European Ph.D School. He has offered tutorials in many countries, including the U.S., China, Korea, Singapore, Italy, and Mexico. He has published more than 100 articles and delivered 30 invited talks and keynote speeches. He has also served as a panelist in major IEEE and SAE conferences.

Dr. Mi is the recipient of "Distinguished Teaching Award" and "Distinguished Research Award" of University of Michigan Dearborn. He is a recipient of the 2007 IEEE Region 4 "Outstanding Engineer Award," "IEEE Southeastern Michigan Section Outstanding Professional Award." and the "SAE Environmental Excellence in Transportation (E2T) Award." He was also a recipient of the National Innovation Award (国家发明奖二等奖) and the Government Special Allowance Award (政府特殊津贴) from the China Central Government. In December 2007, he became a Member of Eta Kappa Nu, which is the Electrical and Computer Engineering Honor Society, for being "a leader in education and an example of good moral character."

Dr. Mi was the Chair (2008-2009) and Vice Chair (2006-2007) of the IEEE Southeastern Michigan Section. Dr. Mi was the general Chair of the 5th IEEE Vehicle Power and Propulsion Conference held in Dearborn, Michigan, USA in September 6-11, 2009. Dr. Mi is Associate Editor of IEEE Transactions on Vehicular Technology and IEEE Transactions on Power Electronics – Letters, Associate Editor of IEEE Transactions on Industry Applications, Senior Editor, IEEE Vehicular Technology Magazine, Guest Editor, International Journal of Power Electronics, Editorial Board, International Journal of Electric and Hybrid Vehicles, Editorial Board, IET Electrical Systems in Transportation, and Associate Editor of Journal of Circuits, Systems, and Computers (2007-2009). He served on the review panel for the NSF, the U.S. Department of Energy (2007–2010), the Natural Sciences and Engineering Research Council of Canada (2010), Hong Kong Research Grants Council, French Centre National de la Recherche Scientifique, Agency for Innovation by Science and Technology in Flanders (Belgium), and the Danish Research Council. He is the topic chair for the 2011 IEEE International Future Energy Challenge, and the General Chair for the 2013 IEEE International Future Energy Challenge. Dr. Chris Mi is a Distinguished Lecturer (DL) of the IEEE Vehicular Technology Society.

Contents Outline

1. Energy Storage Options and Battery Basics for EV and PHEV (14h)
   - Battery parameters – capacity, SOC, discharge rate, internal impedance
   - Battery characteristics
   - Lithium ion batteries
   - Ultracapacitors
   - Flywheels
   - Hybrid energy storage systems
   - EV/PHEV battery pack sizing example
2. Battery Management Systems (14h30)
   - Current monitoring
   - Voltage monitoring
   - Temperature monitoring and cooling system control
   - SOC calculation
   - SOH - concepts, method, measurements
   - Cell balancing
     - Passive balancing
     - Capacitive balancing
     - Inductive balancing
     - Power electronics based balancing
3. Application of Power Electronics in Battery Control and Management (15h)
   - SAE J1772 standard and level of chargers
   - Battery charger
   - DC-DC converter
   - Conductive charger
   - Inductive charger
   - Wireless charger
   - Power factor correction
   - Grid isolation
   - Charger design/optimization example
   - Battery charge algorithms

  - Constant current charging
  - Constant voltage charging
  - Pulsed charging
  - Fast charging
  - Charge balancing
- V2G concepts and V2G functions
- Bidirectional chargers
- 14V battery charger
- Principle of DC-DC converter in EV/PHEV
- Bidirectional DC-DC converter for battery management
- DC-DC converter for hybrid energy storage systems

4. Battery Safety Basics (15h30)
   - Battery hazards, sources, facts, and risks
   - Causes of battery hazards
   - Prevention of battery hazards
   - Safety procedures in handling EV systems
   - Codes and Regulations
   - First aid procedures
   - Fire prevention
5. Battery Modeling and Parameter Identification (16h)
   - Battery models
   - Parameter identification
6. Battery Diagnostics and Prognostics (16h30)
   - Definition of battery health
   - Diagnostics
   - Prognostics
   - Sensitivity and specificity
7. Wireless power transfer for EV battery charging (17h)
   - Principle
   - Resonant frequency
   - Efficiency, sensitivity, future trend