Guest Editorial: Special Section on Information and Control Technologies in the Electrification of Transportation

ECONOMIC and environmental incentives, as well as advances in information and control technologies, are reshaping the traditional view of transportation systems. The emergence of plug-in hybrid electric vehicles (PHEVs) and plug-in electric vehicles (PEVs) has shown that electrification is a clear trend to improve performance, efficiency, and sustainability of transportation systems since electricity is becoming cleaner, greener, and more affordable through the introduction of renewable sources. With the introduction of advanced electric vehicles (EVs) into the transportation systems, there is an in-depth need to address the potential communication and control challenges posed by the penetration of these vehicles to the electricity grid, maintaining battery performance and managing the interaction between the battery and combustion engine in HEVs. Currently, the electrification of transportation is increasingly taking advantage of the opportunities afforded by advancement of information and control technologies to offer new and original functions and solutions.

This Special Section on "Information and Control Technologies in the Electrification of Transportation" is focused on the development, adoption, and application of information and control technologies for transportation electrification. Topics that were announced to be addressed in this section included, but were not limited to, the following research areas and technologies: 1) information and control technologies for PHEVs and PEVs; 2) vehicle-to-grid (V2G) and vehicle-to-home (V2H) interface, communication, and applications; 3) energy management systems for controlling the charging process of plug-in vehicles; 4) charge/depletion control for hybrid plug-in vehicles; 5) energy/battery management systems; 6) charging stations; level I, II, and III charging; wireless charging; fast and opportunity charging; 7) energy storage; hybrid battery/ultra-capacitor energy storage systems (ESSs); 8) network integration in transportation systems (heterogeneous networks and wired/wireless); 9) mass transit/public transportation electrification: standards; modeling, and simulations; 10) vehicle-grid communication and control; 11) security, reliability, and availability of electrified transportation systems.

We received many papers from different research groups and variety of perspectives for this section. After a thorough evaluation of the papers by reviewers, the editorial board chose seven papers to appear in this section. These papers, as will be explained in more details in the following, are well-written representatives of the state-of-the-art information and control technologies in the area.

First, the large-scale integration of EVs has potential challenges and benefits for the grid. On one hand, it may increase the peak demand and destabilize the grid. On the other hand, the grid can actually benefit from the EVs by treating them as a flexible load and thus optimize the load profile. To address this issue, in [1], cooperative distributed demand management is proposed for community charging of PHEV/PEVs. To avoid overloads and maximize customer preferences in terms of the time and cost of charging, a constrained nonlinear optimization problem is formulated and solved using Karush–Kuhn–Tucker (KKT) conditions and consensus networks in a distributed fashion. The global optimal power allocation under all local and global constraints is reached through peer-to-peer coordination of charging stations. Thus, the need for a central control unit is eliminated. Using the method, single-node congestion is avoided when the size of the problem is increased and the system gains robustness against single-link/node failures. Furthermore, via Monte Carlo simulations, the proposed distributed method is shown to be scalable with the number of charging points and returns solutions, which are comparable to centralized optimization algorithms with a maximum of 2% suboptimality.

In [2], the integration of PHEVs in microgrids is discussed considering the optimal number of parking numbers under optimal scheduling of PHEVs. Due to uncertainty of the solar energy, the radial basis function network (RBFN) techniques are used for forecasting photovoltaic (PV) power output. Again, Monte Carlo simulation is deployed to deal with the uncertainties in the daily driving range of the PHEVs, load values, and electricity market price. Finally, genetic algorithm (GA) method is used to minimize the total cost.

Information and control technologies are important for EVs to operate effectively and optimize their integration with the grid. A mobile information system denominated as vehicle-to-anything application (V2Anything App) and its conceptual aspects are described in [3]. The application aims at giving relevant information to EV drivers, by supporting the integration of several sources of data in a mobile application, thus contributing to the deployment of the electric mobility process. The V2Anything App provides recommendations to the drivers about the EV range autonomy, location of battery charging stations, information of the electricity market, and

also a route planner taking into account public transportations and car or bike sharing systems. The proposed application includes an information and communication technology (ICT) platform, recommender systems, data integration systems, driver profile, and personalized range prediction. Thus, it is possible to deliver relevant information to the EV drivers related with the electric mobility process, electricity market, public transportation, and EV performance.

In [4], an energy management and driving strategy (EMDS) is proposed for maximizing the travel distance of in-wheel motor and pure electric ground vehicles (EGVs). The EMDS is based on terrain information and incorporates the actuator efficiency. Unlike conducting energy optimization under given vehicle speed profiles that are specified *a priori* in most literature, the optimally varied vehicle velocity and globally optimal in-wheel motor actuation torque distributions are simultaneously obtained to minimize the EGV energy consumption by employing the dynamic programming method. The CarSim-MATLAB/Simulink cosimulation results validate the minimized power consumption using the EMDS design. The simulation also shows that the driving strategy derived from the EMDS can be potentially utilized as an energy-optimal speed reference for other real-time implementable methods.

ESS is a fundamental building block of EVs. A model-based dynamic peak-power evaluation is discussed in [5] for LiNMC and LiFePO$_4$ batteries. The peak-power estimation method incorporates an explicit prediction horizon and design constraints on the battery current, voltage, and state of charge (SOC). The discharge and charge peak powers are quantitatively assessed under different dynamic characterization tests, in which a comparison with the conventional partnership for new generation vehicles (PNGVs)–hybrid pulse power characterization (HPPC) method and approaches using the less accurate models is conducted. The robustness of the peak-power estimation approach against varying battery temperatures and aging levels is then investigated; and finally, the methods to improve the credibility of the peak-power assessment in the context of battery degradation are explored.

In [6], a supervisory power splitting approach is proposed for a battery–ultracapacitor vehicle with two propulsion machines. Electrification of vehicles needs high-power sources, which should satisfy the power requirements during acceleration and efficiently retrieve energy during deceleration, while avoiding performance and lifecycle deterioration of such sources. In addition, the limited space under the hood eliminates the possibility of utilizing large volume high-power propulsion machines. The proposed energy management strategy is based on a fuzzy logic supervisory wavelet-transform frequency decoupling. The strategy is then implemented in the powertrain, which uses two propulsion machines rated at different power levels and the battery–ultracapacitor hybrid ESS. The control and energy management strategy guarantees that the battery and ultracapacitor provide the base and transient-free power, respectively, while SOC of ultracapacitor is maintained at an optimal value. The torque demand is split among the propulsion machines by solving the formulated unconstrained optimization problem. With the proposed hybrid ESS and energy/power decoupling strategy, power density of the ESS, vehicle performance, and battery lifetime can be improved.

Besides the conventional conductive charging, wireless charging, or noncontacting charging, is also possible. Wireless power transfer (WPT) has attracted an ever-increasing interest from both industry and academics over the past few years. Its applications vary from small power devices such as mobile phones and tablets to high power EVs; and from small transfer distance of centimeters to large distance of tens of centimeters. In [7], a cascaded boost-buck converter is proposed for high-efficiency WPT systems. In order to achieve a high-efficiency WPT system, each circuit should function at a high efficiency along with proper impedance matching techniques to minimize the power reflection due to impedance mismatch. Analysis on the system efficiency is first conducted to determine the optimal impedance requirement for coils, rectifier, and dc–dc converter. Then, the cascaded boost-buck dc–dc converter is controlled to provide the optimal impedance matching in WPT system for various loads including resistive load, ultracapacitors, and batteries. The proposed MHz WPT system can achieve total system efficiency of over 70% in experiment.

To conclude, the electrification of transportation is a rapidly evolving area with a growing need for ground-breaking research on information and control technologies. Realization of communication and telemetric systems tailored to the EV requirements is an important step to prepare the infrastructure to implement advanced control and management algorithms. Advanced energy management including smart battery management and battery/alternative storages energy/power management is a crucial need to guarantee safe, reliable, and efficient performance of PEV/PHEVs. Moreover, it is critical from the viewpoint of grid to prepare the charging infrastructure to provide reliable green electricity for the vehicle with integrating renewable energies into the grid, as well as to make revolutionary services such as WPT and V2G available. These services still require tremendous effort from the communication and control side to be reliable, secure, and efficient. Guest Editors expect that these papers would stimulate further studies and serve as references for the researchers working in the area of transportation electrification.

MO-YUEN CHOW, *Guest Editor*
Department of Electrical and Computer Engineering
North Carolina State University
Raleigh, NC 27606 USA
e-mail: chow@ncsu.edu

FEDERICO BARONTI, *Guest Editor*
Department of Information Engineering
University of Pisa
16-56122 Pisa, Italy
e-mail: f.baronti@iet.unipi.it

SHELDON S. WILLIAMSON, *Guest Editor*
Department of Electrical and Computer Engineering
Concordia University
MONTREAL, QC H3G 2W1, Canada
e-mail: sheldon@ece.concordia.ca

CHENGBIN MA, *Guest Editor*
University of Michigan–SJTU Joint Institute
Shanghai Jiao Tong University
Shanghai 200240, China
e-mail: chbma@sjtu.edu.cn

REFERENCES

[1] N. Rahbari-Asr and M.-Y. Chow, "Cooperative distributed demand management for community charging of PHEV/PEVs based on KKT conditions and consensus networks," *IEEE Trans. Ind. Informat.*, to be published.

[2] C. Chen and S. Duan, "Optimal integration of plug-in hybrid electric vehicles in microgrids," *IEEE Trans. Ind. Informat.*, to be published.

[3] J. C. Ferreira, V. Monteiro, and J. L. Afonso, "Vehicle-to-anything application (V2Anything App) for electric vehicles," *IEEE Trans. Ind. Informat.*, to be published.

[4] Y. Chen, X. Li, C. Wiet, and J. Wang, "Energy management and driving strategy for in-wheel motor electric ground vehicles with terrain profile preview," *IEEE Trans. Ind. Informat.*, to be published.

[5] X. Hu, R. Xiong, and B. Egardt, "Model-based dynamic power assessment of lithium-ion batteries considering different operating conditions," *IEEE Trans. Ind. Informat.*, to be published.

[6] S. Dusmez and A. Khaligh, "A supervisory power splitting approach for a new ultracapacitor-battery vehicle deploying two propulsion machines," *IEEE Trans. Ind. Informat.*, to be published.

[7] M. Fu, C. Ma, and X. Zhu, "A cascaded boost-buck converter for high efficiency wireless power transfer systems," *IEEE Trans. Ind. Informat.*, to be published.

Mo-Yuen Chow (S'81–M'82–SM'93–F'07) received the B.S. degree in electrical and computer engineering from the University of Wisconsin–Madison, Madison, WI, USA, in 1982, and the M.Eng. and Ph.D. degrees in electrical and computer engineering from Cornell University, Ithaca, NY, USA, in 1983 and 1987, respectively.

He joined the Department of Electrical and Computer Engineering, North Carolina State University, Raleigh, NC, USA, as an Assistant Professor in 1987, where he became an Associate Professor in 1993 and has been a Professor since 1999, and established the Advanced Diagnosis and Control Laboratory. He is a Changjiang Scholar and a Visiting Professor with Zhejiang University, Zhejiang, China. He is a Distinguished Lecturer of the IEEE Industrial Electronics Society (IES). He has published one book, several book chapters, and more than 200 journal and conference articles. His research interests include distributed control, big data, and fault management on smart grids, batteries, and robotic systems.

Dr. Chow is a Co-Editor-in-Chief of the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS and was Editor-in-Chief of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS from 2010 to 2012. He has received the IEEE Region-3 Joseph M. Biedenbach Outstanding Engineering Educator Award, the IEEE East North Carolina Section (ENCS) Outstanding Engineering Educator Award, the IEEE ENCS Service Award, and the IEEE IES Anthony J. Hornfeck Service Award.

Federico Baronti (M'08) received the M.Sc. and Ph.D. degrees in electronic engineering from the University of Pisa, Pisa, Italy, in 2001 and 2005, respectively.

Currently, he is working as an Assistant Professor with the Department of Information Engineering, University of Pisa. His research interests include the design of embedded electronic systems for biomedical, automotive, and marine applications.

Sheldon S. Williamson (S'01–M'06) received the B.E. degree in electrical engineering with high distinction 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.

Since June 2006, he has been with Concordia University, Montreal, QC, Canada, where he is currently an Associate Professor with the Department of Electrical and Computer Engineering. He serves as a Distinguished Lecturer of the IEEE Vehicular Technology Society. His research interests include the study and analysis of electric drive trains for electric, hybrid electric, plug-in hybrid electric, fuel cell vehicles, 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 serves as an Associate Editor for the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS and the IEEE TRANSACTIONS ON POWER ELECTRONICS.

Chengbin Ma (M'05) received the B.S.E.E. degree in electrical and computer engineering from the East China University of Science and Technology, Shanghai, China, in 1997, and the M.S. and Ph.D. degrees in the electrical engineering from the University of Tokyo, Tokyo, Japan, in 2001 and 2004, respectively.

He is an Assistant Professor of Electrical and Computer Engineering at the University of Michigan–Shanghai Jiao Tong University Joint Institute, Shanghai Jiao Tong University, Shanghai, China. Between 2006 and 2008, he held a Postdoctoral position with the Department of Mechanical and Aeronautical Engineering, University of California at Davis, Davis, CA, USA. From 2004 to 2006, he was an R&D Researcher with Servo Laboratory, Fanuc Limited, Yamanashi, Japan. His research interests include modeling and control of networked hybrid energy systems, wireless power transfer, control of electromagnetic suspension for maglev trains, and electric vehicle dynamics.