PERSONAL transportation offers people freedom, but this choice of freedom creates a conflict with growing environmental concerns and the sustainability of humanity’s use of natural resources. Hybrid electric vehicles (HEVs) improve fuel efficiency by optimizing powertrain operation and recovering kinetic energy during braking, hence reducing liquid fuel consumption in the transportation sector. Electric vehicles (EVs) and plug-in HEVs (PHEVs) further reduce fuel consumption by using grid electricity.

Electricity can be utilized more efficiently than the combustion process in a car. Well-to-wheel studies show that even if the electricity is generated from petroleum, the distance that can be driven when consuming one gallon of gasoline is 108 mi (equivalent) in an electric car compared with 33 mi in a conventional car that is driven by an internal combustion engine. Future electricity can be generated through renewable sources, such as hydroelectric, wind, sun, and biomass, which offer ultimate sustainability.

High cost, limited driving range, and long charging time are the main challenges for battery-powered EVs. HEVs use both an internal combustion engine and an electric motor to drive the vehicle, thereby overcoming the cost and range issues of a pure EV with no need to be plugged in to charge. The fuel consumption of HEVs can be significantly reduced as compared with conventional gasoline engine-powered vehicles. However, the vehicle still operates on gasoline/diesel fuel.

PHEVs are equipped with a larger battery pack and a larger sized electric motor compared with HEVs. PHEVs can be charged from the grid and driven for a limited distance (for example, 20–40 mi) using electricity, which is referred to as the charge-depletion mode operation. Once the battery energy has been depleted, it operates in a way that is similar to a regular HEV, which is referred to as the charge-sustain mode operation or the extended-range operation. Since most personal vehicles are for commuting and most of them are only driven for a limited range daily, a significant amount of fossil fuel can be displaced by deploying PHEVs. In an extended-range operation, a PHEV works similarly to an HEV by using the onboard electric motor and battery to optimize the engine and vehicle system operation to achieve higher fuel efficiency. Due to the larger battery power and energy capacity, a PHEV can recover more kinetic energy during braking, thereby further increasing the fuel efficiency.

EVs, HEVs, and PHEVs provide many advantages and challenges. The Annual IEEE Vehicle Power and Propulsion Conference (VPPC), which is sponsored by the IEEE Vehicular Technology and Power Electronics Societies, is designed to tackle these challenges. On September 7–11, 2009, the fifth IEEE VPPC was held in Dearborn, MI, which is the heartland of the automotive industry. It was attended by 430 people from academia, industry, and the government from over 50 countries. There were 435 papers submitted and 290 accepted to present at the conference.

To further promote excellence of research in vehicle power and propulsion in EVs, HEVs, and PHEVs, and in conjunction with the 2009 VPPC, a Special Section in the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY has been organized to focus on state-of-the-art research and development, as well as future trends in the modeling, design, control, and optimization of advanced power and propulsion systems for EVs, HEVs, and PHEVs. We are pleased to include six papers in this Special Section (out of 20 submissions). These papers range from powertrain optimization to energy storage to motor drives and from power converter design to system optimization. The research outcomes in some papers are supported with experimental data.

The paper entitled “Hybrid Electric Vehicle Based on Bidirectional Z-Source Nine-Switch Inverter” by Dehghan et al. uses a bidirectional z-source nine-switch inverter to replace the conventional several two-terminal converters in an HEV to reduce size and cost. The performance and the operation of the converter are discussed and analyzed in detail. The authors indicate that device rating must be increased, and the efficiency of the proposed converter is constrained, which will need to be studied in the future.

The paper entitled “Simulation Model of a Military HEV with a Highly Redundant Architecture” by Boulon et al. uses a graphical description [energetic macroscopic representation (EMR)] to develop the model of a heavy-duty military HEV in a systematic approach. The simulation model is, thus, described and validated from experimental results. Due to its functional approach, the EMR highlights the energetic nodes of the system and is useful in understanding the power flows in an HEV. The coupling elements highlight the power distributions and interactions between the different subsystems. Inversion-based control of the vehicle, however, is not studied in the paper. In the future studies, the inputs of the vehicle control can be tuned based on the EMR models to obtain an optimized behavior of the system.

The paper entitled “Effects of Common Mode Active Filtering in Induction Motor Drives for Electric Vehicles” by Di Piazza et al. studies the active common-mode (CM) voltage compensation in an induction motor drive, where the inverter is supplied by a dc source, which is typical of vehicle applications. The CM voltage at the motor terminals generates a shaft voltage through the motor air gap with a possible bearing current that endangers the motor reliability and reduces its lifetime.
CM voltage filtering can mitigate this issue. The proposed CM voltage filter was simulated and validated through experiments by the authors.

The paper entitled “Phase-Redundant Based Reliable Direct AC/AC Converter Drive for Series Hybrid Off-Highway Heavy Electric Vehicles” by Kwak et al. investigates a direct ac/dc converter for an off-highway heavy-duty vehicle. The proposed converter can directly drive traction motors from the generator with no intermediate dc conversion. In addition, a phase-redundant matrix converter structure with a backup leg and a control scheme is proposed to guarantee reliable and safe vehicle operations by providing continuous disturbance-free operations against converter faults. Fault-diagnosis techniques using line-to-line voltages, as well as phase voltages, are presented not only to detect system malfunctions but to locate a failed switching device among 18 switching components as well. Appropriate reconfiguration structure and control actions with accurate knowledge about fault occurrence can avoid propagation of fault, which may lead to catastrophic system failure.

The paper entitled “An Online Power Balancing Strategy for a Parallel Hybrid Electric Vehicle Assisted by an Integrated Starter Generator” by Adhikari et al. proposes an online power flow control strategy for fully hybridized HEVs based on the concept of power balancing strategy (PBS), which controls the internal combustion engine within its peak-efficiency region by using the electric system. A new HEV architecture is introduced with the engine assisted by an integrated starter generator (ISG), in which the ISG supports the downsized electric motor/generator to maintain the electric system’s efficiency close to its peak efficiency and, therefore, to enhance the fuel-saving capability of the PBS controller.

The paper entitled “Modeling and Control of Fuel Cell/Supercapacitor Hybrid Source Based on Differential Flatness-Control” by Thounthong et al. utilizes an energy-storage device composed of a supercapacitor bank for future EVs with a hydrogen fuel cell (FC) as the main power source. The study mainly focuses on the innovative control law based on flatness properties for an FC/supercapacitor hybrid power source. A simple solution to the hybrid energy-management and stabilization problems is proposed to improve the robustness, stability, and efficiency of the FC/supercapacitor hybrid power source. Experimental results validate the developed algorithm.

We hope that this Special Section will serve as an enticement for instigating new research in the area of vehicle power and propulsion systems and inspire new engineers to work in the area. We are grateful to all the authors for making this Special Section possible and to all the reviewers for dedicating their time to reviewing the submitted papers and providing many constructive comments and suggestions to the authors. We would like to thank the Board of Governors of the IEEE Vehicular Technology Society and the VPPC Steering Committee for their strong support. We thank Prof. W. Zhuang, the Editor-in-Chief of the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, from the University of Waterloo, for her hard work in getting the Special Section published early.

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Dr. Mi was a recipient of the 2009 Distinguished Research Award from the University of Michigan, Dearborn, the 2007 SAE Environmental Excellence in Transportation Award for “Innovative Education and Training Program in Electric, Hybrid and Fuel Cell Vehicles,” the 2005 Distinguished Teaching Award from the University of Michigan, the IEEE Region 4 Outstanding Engineer Award, and the IEEE Southeastern Michigan Section Outstanding Professional 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 the 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.” He is an Associate Editor for the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY and the IEEE TRANSACTIONS ON POWER ELECTRONICS LETTERS and a member of the editorial board of the IET Electrical Systems in Transportation. He was an Associate Editor for the Journal of Circuits, Systems, and Computers (2007–2009), a member of the editorial board of the International Journal of Electric and Hybrid Vehicles (2006–2009), a Guest Editor for the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY Special Issue on Vehicle Power and Propulsion (2009–2010), and a Guest Editor for the International Journal of Power Electronics Special Issue on Vehicular Power Electronics and Motor Drives (2009–2010). He was also the Vice Chair (2006–2007) and the Chair (2008) of the IEEE Southeastern Michigan Section. He was the General Chair of the Fifth IEEE International Vehicle Power and Propulsion Conference held in Dearborn on September 7–11, 2009. He served on the review panel for the NSF, the U.S. Department of Energy (2007–2010), and the Natural Sciences and Engineering Research Council of Canada (2010).

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Dr. Peng has received many awards, including the 1991 First Prize Paper Award from the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS and the 1990 Best Paper Award from the Transactions of the Institution of Electrical Engineers of Japan (the Promotion Award of Electrical Academy). He has served in the IEEE Power Electronics Society in many capacities, such as the Chair of the Technical Committee, an Associate Editor for the IEEE TRANSACTIONS ON POWER ELECTRONICS, Regions 1–6 Liaison, an AdCom Member-at-Large, etc. He is an IEEE/Industry Applications Society Distinguished Lecturer for the 2010–2011 term.