Guest Editorial Special Section on Hybrid Electric and Fuel Cell Vehicles

THERE are more than 70 million vehicles manufactured every year worldwide including passenger automobiles, sport utility vehicles, vans, trucks, buses, heavy-duty vehicles, and military applications. With the requirements for reducing the emissions and improving the fuel economy, the automotive companies are developing hybrid and fuel cell systems for propulsion. In addition, the increasing use of electrical and electronic features to improve vehicle performance, passenger comfort, safety, and convenience has resulted in the growth of electrical loads in the vehicle. Hence, the fuel cells are also being investigated as an auxiliary power unit for on-board power generation. There is a lot of interest in academia and in the transportation related industries to advance the state-of-the-art in the areas of hybrid and fuel cell based vehicle technologies.

This special section focuses on the state-of-the-art research and development as well as future trends in the areas of hybrid electric vehicles (HEVs) and fuel cell vehicles (FCVs). We received a total of 22 paper submissions. All 22 submissions were of exceptionally high quality. Unfortunately, we have been able to accept only 10 papers published in this special section due to the space limitations. The first paper by Emadi, Rajashekara, Williamson, and Lukic is a review paper presenting a topological overview of hybrid electric and fuel cell vehicular power system architectures and configurations.

The second paper by Koot, Kessels, de Jager, Heemels, van den Bosch, and Steinbuch deals with the overall energy management strategies of vehicular electrical systems. It presents a comprehensive study of the entire electrical system to improve fuel economy and emissions by optimizing the generation and storage of the electrical energy. The third paper by Bingham, Stone, Bentley, and Bhangu from the University of Sheffield introduces the application of state-estimation techniques for the real-time prediction of state-of-charge and state-of-health of batteries for HEVs.

The next three papers are on the applications and evaluation of electric machines in automotive systems, including the traction load. The fourth paper by Edrington, Krishnamurthy, and Fahimi pioneers the bipolar switched reluctance machine (SRM) technology for automotive applications. Advantages of this proposed technology include its cost-effectiveness, wide speed range, and robustness. The fifth paper by Wang, Xia, and Howe presents a novel permanent-magnet brushless machine for automotive applications such as torque boosting at low engine speeds for vehicles with downsized internal combustion engines. The sixth paper by Oh from Korea University of Technology and Education presents the hardware-in-the-loop (HIL) concept to test and evaluate individual components such as electric motors in real vehicle environment without installing the component in actual vehicle and implementing the entire drive train.

The next two papers deal with the modeling and simulation issues. The seventh paper by Amrhein and Krein from the University of Illinois at Urbana-Champaign presents dynamic simulations for analysis of HEV system and sub-system interactions including power electronics. The eighth paper by Filippa, Mi, Shen, and Stevenson presents the application of bond graphs in modeling of automotive systems. A bond graph model of a hybrid electric power train test cell is explained in detail.

The ninth paper by Gao from Mississippi State University compares fuel cell-battery and fuel cell-ultracapacitor hybrid power trains. It explains that ultracapacitors can more effectively assist the fuel cell to meet the power demands and improve performance and fuel economy. The last paper by Williamson and Emadi from Illinois Institute of Technology presents a comparative assessment of hybrid electric and fuel cell vehicles based on comprehensive well-to-wheels efficiency analysis.

We hope that this special section serves as an incentive for initiating new research in the area of hybrid electric and fuel cell vehicle technologies, and motivates the new engineers to work in the area of automotive systems. We would like to thank Prof. Tan F. Wong, IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY Editor-in-Chief, from the University of Florida, for his support. We would also like to thank Prof. Babak Fahimi from the University of Texas at Arlington and Dr. Abul Masrur from the U.S. Army Tank-Automotive and Armaments Command as the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY liaisons. We are also grateful to our reviewers who dedicated their time in reviewing the submitted papers and provided many good suggestions to the authors.

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He is the Director of Grainger Power Electronics and Motor Drives Laboratories at Illinois Institute of Technology (IIT), Chicago, where he has established research and teaching facilities as well as courses in power electronics, motor drives, and vehicular power systems. He is also the Co-Founder and Co-Director of the IIT Consortium on Advanced Automotive Systems (ICAAS). He is an Associate Editor of IEEE TRANSACTIONS ON POWER ELECTRONICS, an Associate Editor of IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, and an Associate Editor of IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY. He is the general chair of the *2005 IEEE Vehicle Power and Propulsion (VPP) and SAE Future Technology Transportation (FTT) Joint Conference*. He is the principal author of over 150 journal and conference papers as well as three books including *Vehicular Electric Power Systems: Land, Sea, Air, and Space Vehicles* (New York City, NY: Marcel Dekker, 2003), *Energy Efficient Electric Motors: Selection and Applications* (New York City, NY: Marcel Dekker, 2004), and *Uninterruptible Power Supplies and Active Filters* (Boca Raton, FL: CRC, 2004). He is also the co-author of *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design* (Boca Raton, FL: CRC, 2004). He is also the editor of the *Handbook of Automotive Power Electronics and Motor Drives* (Boca Raton, FL: CRC, 2005). His main research interests include modeling, analysis, design, and control of power electronic converters/systems and motor drives. His areas of interest also include integrated converters, vehicular power systems, and hybrid electric and fuel cell vehicles.

Dr. Emadi has been named the Eta Kappa Nu Outstanding Young Electrical Engineer of the Year 2003 by virtue of his outstanding contributions to hybrid electric vehicle conversion, for excellence in teaching, and for his involvement in student activities. He also received the Ralph R. Teetor Educational Award from the Society of Automotive Engineers (SAE) in 2005. He is the recipient of the 2002 University Excellence in Teaching Award from IIT as well as the 2004 Sigma Xi/IIT Award for Excellence in University Research. He directed a team of students to design and build a novel low-cost brushless dc motor drive for residential applications, which won the First Place Overall Award of the 2003 IEEE/DOE/DOD International Future Energy Challenge for Motor Competition.

Kaushik Rajashekara (M'86–SM'89–F'99) received the B.Sc. degree from Bangalore University, India, in 1971. He also received the B.Eng., the M.Eng., and Ph.D. degrees from the Indian Institute of Science, Bangalore, India, in 1974, 1977, and 1983, respectively.

From 1977 to 1985, he worked as an Assistant Professor/ Senior Scientific Officer in Indian Institute of Science. In 1978 and 1984–1985, he worked at Asea Brown Boveri, Switzerland, on power electronics systems. In 1982, he was a Visiting Scientist at the Technical University of Dresden, Germany. From 1985 to 1987, he was a Visiting Associate Professor at the University of Quebec, Canada, working on Photovoltaic utility interactive systems. From 1987 to 1989, he worked at Viteq Corporation, USA, in the area of uninterrupted power supplies for computers. In July 1989, he joined the Delco Remy division of General Motors, and presently he is the Chief Scientist for Propulsion, Fuel Cell and Energy Systems at Delphi Corporation, Kokomo, IN. He is working on the development of fuel cell based systems for automotive, stationary power, and aerospace applications. He has done extensive research in the area of power conversion for transportation, propulsion systems for electric, hybrid, and fuel cell vehicles, and fuel cells for transportation and power generation applications. He has published more than 70 papers. He has 19 patents and 10 more that are pending. He is the co-editor of the IEEE Press book on *Sensorless Control of AC Motor Drives* (1996). He has contributed two chapters on power converters for the *Electrical Engineering Handbook* (Boca Raton, FL: CRC, 1993), one chapter on "Power Electronics" for the *Engineering Handbook* (Boca Raton, FL: CRC, 1995), and one chapter on "Power Electronics" for the *Electric Power Engineering Handbook* (Boca Raton, FL: CRC, 2000).

Dr. Rajashekara was elected to the Fellow of IEEE for his contributions to the advancement of propulsion systems for electric and hybrid vehicles. He was also inducted into the Delphi Innovation Hall of Fame in 1999. He has given seminars in many universities across Asia and Europe. In addition, he has conducted one-day tutorial courses in various conferences. He has also given invited speeches in several local IEEE Chapters. He is the past Chairman of the Power Electronics Devices and Components committee of the *IEEE Industry Applications Society*.