

Keynote Speech on “The Evolution of the EV Powertrain from 1990 to Today”

by

Prof. John Hayes

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Abstract: In this keynote, the speaker reviews the evolution of the electric car from the late 1980s to 2025. He discusses the powertrain developments of the battery chemistries, semiconductors, machines and drives, all technologies of interest to the power electronics engineer. The author discusses the developments of the first modern production electric vehicle, the General Motors EV1, and the first modern production hybrid electric vehicle, the Toyota Prius. These vehicles were propelled by insulated-gate bipolar transistor (IGBT) inverters powering the induction motor for the EV1 and the interior-permanent magnet (IPM) motor for the Prius. By 2025, the IPM motor is the most common production technology with the induction machine filling a niche role for all-wheel-drive applications. The electrically-excited synchronous machine competes as a magnet-free technology. Everything had been transformed for battery technology and we'll explore the shifts from lead-acid in the 1996 GM EV1 and nickel metal hybrid in the 1997 Toyota Prius to the modern lithium-ion cells, modules and packs with cobalt, nickel, iron and manganese based cathode chemistries. With these batteries has come the need for higher voltages. Thus, the power semiconductors have shifted from just IGBT to silicon carbide MOSFET. Similarly, the high –power high-voltage battery packs can be rapidly charged with charging levels into hundreds of thousands of kilowatts.



About the Speaker:

Dr. John G. Hayes is an associate professor specializing in electric vehicles, energy systems, power electronics and drives. He received the B.E. degree from University College Cork (UCC), the M.S.E.E. degree from the University of Minnesota, Minneapolis - St. Paul, the M.B.A. degree from California Lutheran University, and the Ph.D. from University College, Cork in 1986, 1989, 1993 and 1998, respectively. From 1986 to 1988, John held a research fellowship for power electronics under Prof. Ned Mohan at the University of Minnesota. From 1988 to 1990, he worked at Power One Inc. (now ABB Solar), of Camarillo, CA, designing linear and switching ac-dc power converters.

In 1990, He joined General Motors Advanced Technology Vehicle (formerly Hughes Aircraft Company and Delco Electronics), in Culver City, and later Torrance, CA, where he worked extensively as a design engineer and technical manager in the fields of propulsion drives and battery charging for electric vehicles, especially for heavy-duty vehicles and the General Motors EV1 electric car. From 1995 to 1997, he pursued a PhD part-time as a Howard Hughes Corporate Fellow while continuing to work as a design engineer at GM. Subsequently, he worked as a technical manager on EV battery chargers and infrastructure. John led a technical team collaborating with Toyota Motor Company to revise the EV inductive charging standard SAE J1772.

John joined the academic staff at UCC as a lecturer in 2000 and currently teaches power engineering and power electronics and drives. His research interests are power electronics, machines, and magnetics for automotive, industrial and renewable energy applications. John directs the Power Electronics Research Laboratory (PERL) at UCC. The focus of PERL in recent years has been on industrial collaborations with global leaders, such as Analog Devices, Collins Aerospace, General Motors, Moog, and SMA Magnetics.

John's most recent PhD students are in the fields of heavy-duty off-road vehicles and hybrid electric aircraft. John is the lead author, with co-author Dr. Abas Goodarzi, former CEO of US Hybrid in Los Angeles, of an EV textbook for university students and for industry reference. The book is titled "**Electric Powertrain: Energy Systems, Power Electronics and Drives for Electric, Hybrid and Fuel Cell Vehicles**". The publisher is John Wiley & Sons and the book was released in January 2018. The Chinese language edition 电驱动系统——混动、纯电动与燃料电池汽车的能量系统、功率电子和传动, ISBN 978-7-111-67290-6, was published by China Machine Press in May 2021.

Research Interests: Building energy efficiency enhancement, Condition monitoring and predictive maintenance, High-performance control of motor drives and power electronic converters