



Practical Aspects in Modern Design Process of Electric Motors

Abstract:

There is currently wide and renewed interest in the research and development of electrical machines. On-going efforts are fueled by the need for the new generations of “green” products, such as hybrid and electric vehicles, wind power generators and ultra high-efficiency home appliances.

The tutorial covers from an industrial perspective some of the latest developments in the subject area and includes timely topics such as heating and ventilation, the effect of manufacturing tolerances, the influence of fabrication processes on material properties, the unbalanced magnetic pull and the torque ripple due to eccentricity, manufacturing technologies like segmented stators for brushless PM machines and die-cast copper rotors for induction motors, the role of computer aided engineering in the industrial environment.

The fundamental theory of brushless DC, inverter and line-fed synchronous PM, induction and switched reluctance machines is briefly reviewed. The relative merits of each machine type are discussed. The state of the art topologies and the emerging trends are also presented. Particular emphasis is placed on the possible shortage of NdFeB magnets and on potential alternatives for rare-earth free or even magnet free solutions.

The presentation includes the main aspects of power electronics and controls directly affecting the electric machines. Topics such as the risk for PM demagnetization, the effect of switching frequency, supplementary losses and heating are discussed.

Design procedures that include a multi-physics approach encompassing the electromagnetic and the thermal field together with the mechanical stress are described. The electromagnetic methods range from analytical closed-form techniques to ultra-fast simplified FEA and time stepping transient FEA. A lumped parameter model is preferred for the thermal study. Extensive details are provided for the thermal analysis of electric machines, which is a topic less covered in the published literature.

Many examples are provided from a variety of industries ranging from very small motors for house hold appliances, to fans and pumps that account for the largest proportion of energy consumption and go all the way to some of the largest traction motors and generators developed for renewable and alternative energy applications. A discussion of the trends and anticipated industry developments is also included.

The course topics are structured as follows:

- (I) Efficient multi-physics analysis of electrical motors
- (II) Thermal analysis of electrical machines – the neglected design aspect
- (III) Application example – Interior permanent magnet motor
- (IV) Manufacturing process effects on the electrical motors design procedures

Lead Instructors:

Title: **Dr**

Name: **David A. Staton**

Affiliation: **Motor Design Ltd.**

Street Address: **4 Scotland Street**

City / State / Zip Code: **Ellesmere / United Kingdom / SY12 0EG**

Telephone / FAX: **+ 44 1691 623305**

E-Mail Address: **dave.staton@motor-design.com**

Title: **Dr**

Name: **Dan M. Ionel**

Affiliation: **Vestas R&D Technology Americas Inc./ Marquette University, USA**

Street Address: **634 West Main Street, Suite 203**

City / State / Zip Code: **Madison, WI 53703**

Telephone / FAX: **+1 773 628 6438**

E-Mail Address: **daion@vestas.com**

Other Instructors:

Dr. David G. Dorrell	University of Technology Sydney, Australia	ddorrell@eng.uts.edu.au
Dr. Gianmario Pellegrino	Politecnico di Torino, Italy	gianmario.pellegrino@polito.it

Instructor Bios

Dr. Dan M. Ionel - (M'91–SM'01) has more than 20 years of experience with electrical machines. He received the M.Eng. and Ph.D. degrees in electrical engineering from the University “Politehnica” of Bucharest, Bucharest, Romania. His doctoral program included a Leverhulme Visiting Fellowship at the University of Bath, England, U.K. He was a Postdoctoral Researcher with the SPEED Laboratory, University of Glasgow, Glasgow, U.K. He is currently the Chief Scientist with Vestas Technology R&D Americas, Madison, WI. He is also currently an Adjunct Professor in the Department of Electrical and Computer Engineering, Marquette University, Milwaukee, WI. Earlier in his career he was with the Research Institute for Electrical Machines (ICPEME), Bucharest, with Invensys Brook Crompton Company, Huddersfield, U.K., and with A.O. Smith Corporation, Milwaukee, WI. He has published more than 75 journal and conference papers, including a first prize winner of the IEEE Industry Applications Society Electric Machines Committee. He holds more than 25 patents, including a medal winner at the Geneva Invention Fair. Dr. Ionel is the Vice-Chair of the IEEE Power and Energy Society Electric Motor Subcommittee and an Associate Editor of the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS.

Dr. David Staton (M'95) did his PhD in computer aided design of electric motors at Sheffield University in the mid 1980's. Since then he has worked on motor design and in particular development of motor design software at Thorn EMI, the SPEED Laboratory at Glasgow University and Control Techniques who are part of Emerson Electric. At the SPEED labs he helped to develop the SPEED software which is used to design electric motors by some of the leading electric motor manufacturers worldwide. In 1999 he founded Motor Design Ltd focusing on development of thermal analysis software for electrical machines. Motor Design Ltd develops a software package called Motor-CAD that helps simplify thermal analysis of electric motors and generators. The company also market SPEED software, the FLUX finite element software and PORTUNUS system simulation software – for which they have also developed a heat transfer and flow network library. Motor-CAD is very well integrated with these other electric motor and drive simulation packages. More recently Motor Design Ltd. have developed two new software packages called Eff-MAP and Motor-FLOW. These are used to calculate and plot efficiency maps and help automate the design process, Motor Design Ltd also supply design consultancy and machine design training services.

Dr. David G. Dorrell (M'95, SM'08) is a native of St Helens, UK, and has a BEng (Hons) degree (1988), MSc degree (1989) and PhD degree (1993). He has held lecturing positions with Robert Gordon University and University of Reading, UK. He was a Senior Lecturer with The University of Glasgow, UK, for several years. In 2008 he took up a post with The University of Technology Sydney, Australia, and he was promoted to Associate Professor in 2009. He is also an Adjunct Associate Professor with The National Cheng Kung University, Taiwan. His research interests cover the design and analysis of various electrical machines and also renewable energy systems with over 150 technical publications to his name. He is a Chartered Engineer in the UK and a Fellow of the Institution of Engineering and Technology.

Dr. Gianmario Pellegrino (M'06) received the M.Sc. and Ph.D. degrees in electrical engineering from Politecnico di Torino, Torino, Italy, in 1998 and 2002 respectively. He has more than ten years experience in electrical motor and drives design and control. He has been with the Electrical Engineering Department of Politecnico di Torino since 2002, first as a Research Fellow and currently as an Assistant Professor. He has been involved in He has been a visiting researcher at Aalborg University, Aalborg, Denmark in 2002 and a visiting fellow at Nottingham University, Nottingham, UK in 2010/2011. He has been working with industry for prototype and commercial machines and drives since 1997. He is author of more than 60 journal and conference papers and one patent. He is the recipient of ICEM best paper award, ICEM 2010 and the third prize paper award from IEEE IAS EMC in 2009. He is an Associate Editor of the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS.