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Analysis of synchronous machine using free software

Abstract

The design of competitive and efficient electrical machines remains to date a fascinating engineering challenge. Electrical machines involve a variety of transversal aspects including multiple physical fields, cost and availability of materials and ease of manufacturing. Design goals are also numerous: efficiency, cost, minimum weight, safe operation at high temperature. The new possibilities offered by the rocketing growth of computational power and the availability of CAD software of many kinds have revolutionized the field of electrical machine design. This tutorial introduces to a set of open source tools for the analysis and design of synchronous machine. Some practical example with the analysis of real applications will be shown during the tutorial. Special emphasis is given to electromechanical design of synchronous machine.

Outline

Introduction *Luigi Alberti*

Modern approaches to electrical machine design cannot neglect FE analysis. Also, optimization tools are more and more common practice. Besides the commercial software packages for machine design, free-software represents a new feasible alternative, continuously growing up and becoming user-friendlier thanks to the voluntary contributions of researchers in the field.

Synchronous motor design with FEMM and LUA scripting *Cristian Babetto*

The FEMM software tool is applied to the analysis of a PM machine. After summarizing the basic steps of finite element problem, the concepts of drawing geometry, assigning materials and sources will be given. The importance of grouping some objects will be highlighted. Post-processing of the field solution allowing to determine flux densities, flux linkages, forces, torques will be illustrated. After that, some typical analysis procedures will be described, among the others: alignment of the rotor with the stator phase axis, d- and q-axis flux linkages, search of the MTPA current vector angle, computation of average torque and torque ripple varying the rotor position angle, torque versus current curve and determination of the flux-weakening region. Examples for different machine configurations will be included.

Synchronous motor design using Gmsh and GetDP *Luigi Alberti and Omar Bottesi*

GetDP is a rather general open-source finite-element solver for electromagnetic, thermal, mechanical and acoustic problems. GetDP does not have its own graphical interface; instead the complete problem, is transcribed into text data files. Gmsh is a 3D mesh generator with built-in pre- and post-processing facilities. Its design goal is to provide a fast, light and user-friendly meshing tool with parametric input and advanced visualization capabilities. The specification of any input to these modules is done either interactively using the graphical user interface or in text data files using Gmsh own scripting language.

In the tutorial the capabilities of Gmsh and GetDP regarding electromagnetic analysis of synchronous machines modelling will be presented, with a focus on 2D magnetics and standard features.

"Koil - a tool to design the winding of rotating electric machinery" *Luigi Alberti*

Koil is an open source software to design the windings of rotating electrical machinery. It is written in C++ using cross-platform technology. *Koil* manages both the synthesis (design) and the analysis of the windings. Standard symmetrical windings are automatically generated starting from the number of phases, poles and slots. Custom windings (including non-symmetrical ones) can be introduced using a scripting environment. *Koil* represents the winding using a practical diagram of the coils and many results computed in the software can be exported as picture/graph or text files. Among the implemented features there are: computation of the winding factors, computation of magnetomotive force harmonics amplitude, comparison of windings with different number of slots and poles, single and double layer feasibility check, consideration of higher number of phases (more than three). During the talk, a comprehensive demonstration of these capabilities in conjunction with the theory behind the software will be illustrated.

Instructors

Luigi Alberti received the Laurea degree and the PhD in Electrical Engineering from the University of Padova in 2005 and 2009, respectively. From 2009 to 2012 he was Research Associate at the University of Padova. In 2012 he moved to the Faculty of Science and Technology at the Free University of Bozen-Bolzano, Italy, to start research and educational activities in the field of electrical engineering and electrical machines. Since 2016 he is with the Department of Industrial Engineering, University of Padova, Italy, where he is Associate Professor working on design, analysis and control of electric machines and drives, with particular interest in renewable energies and more electric vehicles.

Omar Bottesi received the master degree in Electrical Engineering from the University of Padova in October 2012 and the PhD in Sustainable Energy and Technologies from the Free University of Bozen-Bolzano in 2017. Since 2017, he is Research Assistant at the Free University of Bolzano, Faculty of Science and Technology where he hold the course of Electrotechnics and Electrical Machines at the bachelor in industrial and mechanical engineering. He is currently working on design, analysis and control of electric machines and drives, as well as on development of models of battery for electric vehicle.

Cristian Babetto received the B.S. and M.S. degrees in electrical engineering from the University of Padova, Padova, Italy, in 2013 and 2015, respectively. He is currently working toward the Ph.D. degree in the Electric Drives Laboratory, Department of Industrial Engineering, University of Padova. His research activities are concentrated on the design and analysis of synchronous reluctance machines and permanent magnet assisted synchronous reluctance machines for high-speed, fault-tolerant and electric mobility applications.