Guest Editorial

WITH RESPECT to electromagnetic analysis, thermal analysis of electric machines has been in the background for quite some time. This inequality is evidenced by a search of the technical literature on thermal analysis topics where a limited number of papers can be found in the last decade. In particular, the low interest in thermal analysis involved small and medium machines, because the cost in time of these studies was often noneconomic with respect to the value of the product. On the contrary, the designers of large and high-power motors and generators used a completely different approach, including sophisticated thermal studies in the machine development.

The global market has changed these methodologies in a short time. In fact, the requests for higher energy efficiency, cost reduction, material exploitation, and new electrical machines' structures required accurate thermal analysis in parallel with the electromagnetic design. It is important to underline the fact that similar considerations can be made speaking about the power converters where the incredible increase of their power density was made possible thanks to accurate and sophisticated thermal verifications. For these reasons, this Special Section of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS has been devoted to the main aspects of thermal problems in electrical machines and drives.

Independent of the application fields, the thermal analysis can be split into two approaches based on analytical lumped circuit and numerical methods. The main advantage of the lumped-parameter thermal network has a very fast computation time, but on the other hand, the definition of a thermal network that accurately models the main heat transfer paths requires a major effort by the developer.

The main advantage of the numerical analysis is the possibility of modeling any device geometry. However, the development of the model is very time consuming in terms of model setup and computation. Two types of numerical analysis based on the finite-element analysis (FEA) and the computational fluid dynamics (CFD) approaches are available. FEA allows the analysis of heat transfer in solid components only, and it requires the same analytical/empirical algorithms used in the thermal network when convection heat transfers are involved. CFD is the typical approach to predict heat flow in complex regions where the other methods do not ensure acceptable accuracy. On the other hand, CFD requires complex and expensive software and very high computational time with respect to the other methods.

This "Special Section on Thermal Issues in Electrical Machines and Drives" includes 14 papers which cover all the newest techniques on this topic, with several interesting applications.

Three papers present interesting theoretical approaches for heat transfer determination in complex cooling systems.

The paper by Valenzuela and Tapia presents the evaluation of the heat transfer capability of a finned frame for different velocities of the cooling fan, and different fin numbers and dimensions. The paper by Staton and Cavagnino deals with the formulations used to predict convection cooling and flow in electric machines. Empirical dimensionless analysis formulations are proposed to calculate the convection heat transfer. The paper by Pickering *et al.* investigates the cooling of the end region of a two-pole strip-wound totally enclosed fan cooled induction motor. The theoretical approaches and the proposed formulations reported in these three papers can be considered of general application and interest.

Four papers deal with innovative and useful model of several types of electrical machines. The paper by Gao *et al.* presents a reduced thermal model useful for induction motor thermal protection. On the same topic is the paper by Lagonotte *et al.* The paper by Nerg *et al.* deals with a lumped-parameter-based thermal model applicable to radial-flux electrical machines while the paper by Kral *et al.* presents a thermal model of a totally enclosed water-cooled induction machine.

Five papers report the use of electrothermal models for the design of different electrical machine topologies. The paper by Dorrell reports on methods for the analysis of electrical machines by combined electromagnetic and thermal models. On the same line is the paper by Alberti and Bianchi which proposes a coupled thermal-magnetic analysis of an induction motor to get a rapid and accurate prediction of its performance. The paper by Buccella *et al.* presents a combined electrical-thermal model for the design of planar transformers used in switching mode power supplies. The thermal behavior of axial flux synchronous phase modulation machines through a 3-D thermal-magnetic FEA is presented by Marignetti *et al.*, while Di Gerlando *et al.* present electromagnetic and thermal aspects of special permanent-magnet machines, employed in damping seismic oscillations in structural systems.

Two papers are more devoted to electrical drives. The paper by Zhang *et al.* proposes a remote and sensorless stator winding resistance estimation method for thermal protection of soft-starter-connected induction motors. The paper by Tenconi *et al.* presents the temperature analysis of a liquid-cooled totally integrated motor-drive unit for propulsion applications.

On the basis of the papers included in this Special Section, the Guest Editor hopes that research activities on the thermal analysis of electrical machine and drives will have an impact on new contributions to this stimulating and attractive topic. In fact, new technologies and more and more powerful computation systems are opening new front lines on thermal analysis which is gaining researcher interest year after year.

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