# Application of New Tools in the Thermal Behaviour Study of Electrical Machines

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**Abstract.** Economic, competitive or energy efficiency factors require designing smaller and more efficient machines that pose greater demands on its design. This, coupled with the need to reduce time and production costs requires the use of simulation software as basic design tool. One of these requirements is to know the thermal behaviour of the machine, subject on which this paper focuses. Based on the electromagnetic study of permanent magnet synchronous machine (PMSM), performed using finite elements, a special attention is given to the calculation of iron losses that are later used to simulate its thermal behaviour. The results are compared with those obtained in real tests of the machine on steady states allowing validate the method, to later on, analyse the transient behaviour of the machine.

## Key words

Thermal analysis, iron losses, permanent magnet, steady state, thermal model.

## 1. Introduction

The performance in industrial environments of any electrical machine is conditioned by a number of variables such as: electro-mechanical parameters, class of service, characteristics of isolation, type of construction, etc. One of these variables, and certainly not least important, is the thermal behaviour of the machine and which along with its electromagnetic behaviour –with which is closely related-, determines a good part of the industrial life of all electrical machine [1].

The thermal behaviour of the machine is specially important in the case of permanent magnet synchronous motors (PMSM) subjected in many of its applications to variable load conditions [2], and thus thermal stresses to which it is subjected represent a variation in the operating temperature of the magnets; this variation is an alteration in the magnets behaviour, that in the limit, can mean the loss of their magnetic properties [3].

Some time ago the classic design process for electrical machines was improved by the introduction in the process of calculation tools based on methods such as Finite Element; these tools allow a simulation of the behaviour of the machine previous to its construction. However, these help tools have focused mainly in their electromagnetic calculation, paying less attention to thermal design. This can be verified because the number of technical publications devoted to the electromagnetic study is considerably higher than those devoted to its thermal study [1]. This is largely due to the difficulty in defining the thermal circuit against the magnetic circuit, this happens because the heat transfer is performed by three different mechanisms: conduction, convection and radiation simultaneously.

In recent years there has been considerable progress in the development of increasingly compact Permanent Magnet Synchronous Motors (PMSM), which has allowed its introduction in applications impossible until that moment. This development is due to a combination of factors such as the improvement of permanent magnets or new manufacturing techniques [4], but also to the emergence of new tools for thermal design of them. Thus, in recent years has been an increase in technical publications devoted to study thermal machines [1-7] or a combination of thermal and magnetic studies [8, 9].

The main purpose of this paper is to present the process of analysis of a PMSM using electromagnetic and thermal design tools, relating the results of both and paying particular attention in the correct calculation of the magnetic losses in the machine stator which, given the nonsinusoidal flux evolution, the classic calculation shows lower value for the losses than the real ones.

## 2. Electromagnetic analysis

The machine analyzed in this study, designed for use in machine tool applications, is the kind of surface magnets having concentric stator winding and two parallel