Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038 X, No.9, 12th May 2011, Reference Paper: 552

European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)	International Conference on Renewable Energies and Power Quality (ICREPQ'11) Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2010

Rotating Electric Machine Thermal Study

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Abstract. This paper presents a mathematical model and numerical simulation results for heat transfer analysis that takes place at the frame level of a rotating electric machines provided with longitudinal cooling fins. For this purpose a relatively complex three-dimensional model is used, numerical treatable with affordable hardware and software resources. The frame-environment convective heat transfer process is considered. The frame is cooled by forced convection in two cases: the thermal radiation heat transfer is taken into account and without considering it. Numerical simulation results reveal the heat transfer pathways from the frame to the environment, and allow assessment of important parameters in designing the machine's cooling.

Key words

Heat transfer coefficient, electric machine, computation, finite element.

1. Introduction

Rotating electrical machines used in electric drive systems can operate in different duty cycles under normal or overload conditions. The main malfunctions that arise during operation of these machines are of electromagnetic, thermal or mechanical nature. From mechanical and thermal point of views, the electromagnetic stresses inside the machine's iron core and windings are chosen such that the machine to withstand. The degree of loading is utmost related to the thermal state of the machine, i.e. the heat. However, in accordance with the considered duty cycle and environment conditions the machine must operate under load for a long period of time, such that the temperature of any part is not greater than the insulation class threshold. For this reason the thermal regimes during machine's operation are studies of great importance.

Inside a machine the heat transfer occurs due to the thermal imbalance between two media. This transfer is by conduction, convection or radiation. Heat transfer always occurs in one direction, from warmer medium towards the coldest one, and it will end when the two temperatures become equal. The study is based on heat transfer principles of thermodynamics, conduction physics, heat conversion and thermal radiation. Analysis of thermal phenomena involves description by mathematical expressions between the phenomena specific quantities and auxiliary quantities directly related to the specific quantities.

The electric machines specific thermal issues are macroscopic. Their thermal regimes are characterized by heat sources together with other specific quantities such as thermal time constants, thermal coefficients of materials and of the environment geometry in which heat transfer takes place.

Thermal stresses of an electrical machine conclude the effective output that normally can be provided. Determination of heat distribution inside the machine is a difficult task that requires a large amount of calculation. Addressing this problem can be done by finite difference numerical methods [1], [2], finite element numerical methods [3], [4], [5] or by using equivalent thermal schemes (global analysis of machine) [6], [7]. All previously mentioned approaches require knowledge of thermal parameters of the machine components.

The thermal study of the machine is performed here by using the finite element method because it has the advantage of better modelling the geometries of various parts of the machine. Similar studies based on finite element method can be found in [8-11].

In the field of electrical drives, knowing the loading limits of a machine for various operating modes is an important issue because the output power must be such as to lead to its normal operation, knowing that both under-sizing and over-sizing of the machine are not acceptable solutions from economical point of view.

In most variable speed electric drive systems the electric motor is induction type. Usually, these machines have an IP44 ingress protection at least and are totally enclosed fan cooled type. The induction machines have a small air-gap, such that the internal cooling is insufficient. For this reason, the machine is cooled using an external fan mounted on the machine's shaft. In order to increase the cooling efficiency the machine housing has longitudinal fins that increase the heat transfer rate towards the environment by increasing the housing's outer surface.