Postprint: Temperature Field Analysis of Permanent Magnet Synchronous Motor Based on Lumped-Parameter Thermal Network Method

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Date: 2019-03-05T00:00:00+00:00

Abstract

Permanent magnet synchronous motors exhibit particularly outstanding performance metrics compared to other motor types and are widely applied across various fields. With the development of motor manufacturing technology, the single-unit capacity of motors has increased, resulting in excessively high internal temperature rise that affects motor performance and reliable operation. This paper employs the lumped parameter thermal network method (LPTN) to analyze the temperature field of permanent magnet synchronous motors, considering the influence of permanent magnet eddy current losses in high-speed motors on the temperature distribution. A 38-node thermal network model is established to accurately reflect the temperature rise of each motor component. Finally, the correctness of this thermal network calculation model is verified through comparison with finite element method (FEM) analysis results and motor temperature rise test results.

Full Text

Preamble

Thermal Analysis of PMSM Based on Lumped Parameter Thermal Network Method

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Abstract

Permanent magnet synchronous motors (PMSMs) exhibit outstanding performance characteristics compared to other motor types and are widely utilized across various fields. With the development of motor manufacturing technology, the single-unit capacity of motors has increased, leading to excessive internal temperature rise that affects motor performance and reliable operation. This paper analyzes the temperature field of a PMSM using the lumped parameter thermal network (LPTN) method, considering the influence of permanent magnet eddy current losses in high-speed motors on the motor temperature field. A 38-node thermal network model is established to accurately reflect the temperature rise of each motor component. Finally, the validity of the thermal network calculation model is verified through comparison with finite element method (FEM) analysis results and motor temperature rise test results.

Keywords: Permanent magnet synchronous motor, temperature field, lumped parameter thermal network, finite element method

Funding: National Natural Science Foundation Youth Project (51507148) and Hunan Provincial Strategic Emerging Industry Technology Research Project (2012GK4080).

1 Introduction

In recent years, permanent magnet synchronous motors have been widely applied in various fields due to their advantages of compact size, large capacity, and high efficiency. As motor power density increases and motor materials are fully utilized, motors frequently operate at the limits of electrical and magnetic loading, resulting in increased losses and excessive temperature rise. For permanent magnet motors, excessively high temperatures can easily cause irreversible demagnetization of permanent magnets, affecting motor performance and reliable operation [1]. Therefore, analysis of motor temperature fields is particularly important.

Currently, common methods for motor temperature rise calculation include the finite element method (FEM), lumped parameter thermal network method (LPTN), and computational fluid dynamics (CFD). Both FEM and CFD are numerical calculation methods that can obtain overall temperature distribution cloud maps of motors through computer analysis [2-3]. However, even with current computer equipment, calculations using these two methods are timeconsuming. The LPTN method, by contrast, divides similar motor parts into several sections in the form of nodes, employs circuit concepts, and obtains temperatures at various internal nodes through thermal resistance and temperature calculation formulas. Since the calculation methods for thermal resistance are similar, LPTN can be simplified and extended accordingly for different motor models. Compared with FEM and CFD, this method saves considerable time and offers significant advantages in calculation time.

LPTN has been applied in temperature field analysis and optimization of induction motors and synchronous motors. Literature [4] used LPTN for motor temperature field analysis. Building upon this foundation, this paper adds six end cover nodes, two bearing nodes, and three shaft nodes to make the motor' s grid structure more regular and better aligned with actual motor heat transfer conditions. Temperature field analysis and calculation of the motor are performed using LPTN based on consideration of permanent magnet eddy current losses. Finally, the effectiveness of the method is verified through comparison with FEM analysis results and motor temperature rise test results.

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2 Lumped Parameter Thermal Network Method (LPTN)

LPTN divides the main components of a motor into multiple temperature units according to their respective structures and heat generation/dissipation conditions, and connects each unit through thermal conductance. This discretizes the motor' s internal temperature field into an equivalent thermal network. A Matlab calculation program is developed to solve for the temperature of each motor part and obtain the average temperature rise distribution.

2.1 Analysis Process

When using LPTN for motor temperature field analysis and calculation, reasonable assumptions must be made for the motor calculation model as follows:

1. The motor' s temperature distribution is circumferentially symmetrical, and the cooling conditions in the circumferential direction are considered identical.
2. In the internal cavities on both sides of the motor, the air temperature at each point is the same and can be calculated using a single point.
3. The skin effect in stator slot windings is neglected.
4. The mutual conductance between two nodes is equal and independent of temperature rise.
5. The motor' s radiation heat transfer process is neglected.

The LPTN temperature

Note: Figure translations are in progress. See original paper for figures.

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