Middle East Technical University

Department of Electrical and Electronics Engineering

EE568 - Selected Topics on Electrical Machines

Spring 2019 – 2020

Project #4: Analysis of a Five-Phase Axial Flux PMSM

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**Introduction**

In this project,

**Analytical Calculation**

1. Magnetic Loading of the Machine

Calculation of the magnetic loading of the machine requires several design variables. These can be summarized as follows:

* Magnet thickness (lm): 12 mm
* Stator thickness (ls): 11 mm
* Airgap thickness (lg): 2.5 mm
* Magnet grade: N38H
* Br (at 80oC): 1.22 T
* Hc (at 80oC): 924.6 kA/m
* μr: 1.05

Considering the topology of the machine, magnetic equivalent circuit can be derived as in Fig. 1. Here, as the relative permeability of the electrical steel is too large, Rr can be ignored. Also, flux leakage paths between two magnets are long, therefore leakage reluctance can also be ignored. Using remaining circuit elements, we can obtain air-gap flux density as given below.

This value is the peak flux density over a pole area, assuming square-wave-shaped flux density distribution. To find the magnetic loading, the magnitude of the fundamental component of this square wave should be calculated.

1. Electric Loading of the Machine

In axial flux machines calculation of electric loading is different from radial flux machines. As the whole stator surface coincides with the air-gap, linear current density value can change as a function of radius. In [1], linear current density is calculated on the inner radius, which is the maximum linear current density in the motor. In the current topology, each corner of each “loop” on each layer can be considered as a turn in a slot. Therefore, resultant total turn number becomes 240. Following this approach, electric loading of the machine can be calculated as follows:

1. Verification of Torque Equation

Torque equation for an electric machine is:

where S is rotor surface area, and is rotor inner diameter. Parameters is the torque equation are:

* Â = 18483 A/m
* = 0.914 T

Using the values given, output torque of the motor is calculated as 30.7 Nm, as expected.

1. Back EMF Calculation and Verification of Power Equation

To verify the power of the machine using both mechanical and electrical parameters, the back EMF of the machine should be known. The power equality that should be satisfied is:

Phase back EMF can be calculated using previously obtained parameters.

As a result,

Power equality is satisfied. Therefore, verified machine specifications can be summarized as given below:

* Output torque: 30.7 Nm
* Shaft speed: 8.75 Hz
* Number of poles: 8
* Number of phases: 5
* Phase back EMF: 15.6 V
* Phase current: 21.2 A
* Axial length: 80 mm
* Inner radius: 62 mm
* Outer radius: 150 mm
* Air-gap length: 2.5 mm (each)
* Stator length: 11 mm
* Magnet thickness: 12 mm
* Number of loops: 60, (24 series turns per phase)

**References**

1. <http://web.mit.edu/kirtley/binlustuff/literature/electric%20machine/designOfAxialFluxPMM.pdf>