Optimization of the Rotor Geometry of a Permanent Magnet Synchronous Machine

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Introduction

Converting an induction machine (IM) to a permanent magnet synchronous motor (PMSM) can be a solution to increase the efficiency.

We want to know what the optimal rotor geometry is in order to obtain a PMSM with sufficient power, high efficiency, low cogging torque and low magnet volume.

The methodology to assess if the conversion for a given IM is useful, was done by:

- A numerical optimization of the rotor geometry by using finite element software
- The loss model parameters were estimated
- A financial analysis to assess if the payback time of the conversion is reasonable

Optimization shows that one can choose a machine with low magnet volume, high average efficiency, low cogging torque, and sufficient mechanical power.

Methodology

Numerical model

The numerical model is a transient 2D Finite Element Model (FEM) that uses the moving mesh technique.

The rotor geometry depends on the optimization parameters: \( t_1 \), \( N_p \) and \( \alpha_1 \).

A domain scan is done for 4 magnet thicknesses, 3 different numbers of magnet segments per pole and 6 magnet pole angles.

The loss parameters were determined by a function based on five material specific coefficients \( a, b, c, d, \) that gives the loss in Wh/kg over a time period of the magnetic induction.

\[
L = \frac{1}{T} \int_0^T \left( \frac{dB(t)}{dt} \right)^2 \, dt = \frac{1}{T} \int_0^T \left( \frac{B(t)}{\mu_0 n_1} \right)^2 \, dt
\]

The losses in the copper stator windings are computed from the enforced stator current and the measured resistance at the steady state temperature of 50°C.

Experimental Validation

For experimental validation a converted 2-pole and 6-pole IM to 2-pole and 6-pole PMSM was built.

The measured efficiency at 73.5% and 87.7% for the 2-pole IM and converted PMSM was measured.

Conclusions

- The gain in efficiency is much higher for the 6-pole machine than for the 2-pole machine. Nevertheless, the payback time is comparable for both machines because the 6-pole machine has more magnet volume and less annual energy consumption.
- Optimization shows that one can choose a machine with low magnet volume, high average efficiency, low cogging torque, and sufficient mechanical power.