Loss Minimizing Strategy of Permanent Magnet Synchronous Machines using Improved Direct Torque and Flux Control

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To my father Guangrong Xie and mother Junying Wang

Abstract

This thesis presents the loss minimization strategies utilizing improved torque and flux control for interior permanent magnet synchronous machines (IPMSMs). As a loss minimization method of the system based on the control strategy, the widely accepted direct torque control (DTC), field oriented control (FOC) and finite control set model predictive torque control (FCS-MPTC) are investigated and analyzed. Meanwhile, a nonlinear loss model control (LMC) is developed and integrated into the control strategies. Furthermore, a novel discrete-time machine model which is based on improved Euler method and an alternative deadbeat (DB)-MPTC with FCS are developed.

The first part of the thesis deals with the key point and the improvement of the conventional control strategies. For DTC, while the torque ripple reduction is still a challenge for researchers, the possible reasons of the torque ripple are investigated and analyzed based on stator flux, stator current and the stator flux observer. The principle and the implementation of the FOC and FCS-MPTC are carried out for novel prototypes of IPMSMs.

This thesis lays the foundation of a flux linkage-based machine loss model of IPMSMs. An improved nonlinear LMC is developed and verified by finite element method (FEM), which considers the nonlinear machine inductance, iron loss resistance and permanent magnet loss resistance. Then the improved LMC method is integrated into DTC, DTC with space vector modulator (SVM) and FCS-MPTC method as a stator flux reference to achieve the minimum copper loss, iron loss and permanent magnet (PM) loss of the system in every operating condition.

Until now, the calculation effort of the long horizon prediction controllers is still a challenge. Two proposed solutions are proposed in this thesis. An improved discrete-time machine model of IPMSMs for low switching frequency is developed based on trapezoidal Euler method. Another solution is that the proposed prediction model utilizes the deadbeat strategy to optimize the process of the switching selection of the inverter without modulator. To avoid the complete enumeration of all the voltage vectors, a branch and bound voltage sector (deadbeat sector) which consists the desired voltage vector is predicted.

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Wei Xie

Contents