Optimal design and control of a switched reluctance machine for electric vehicle applications

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Abstract

This thesis explores the design and driving capabilities of switched reluctance machines (SRMs) for electric vehicle (EV) applications. Transportation contributes to 14% of global greenhouse gas (GHG) emissions. Among the transportation sections, passenger road vehicles and freight road vehicles accounted for 74% of the emissions. Thus, the development of EVs is an appropriate solution for improving the energy consumption efficiency of vehicles and reducing GHG emissions. Battery electric vehicles (BEVs) propel with electric machines (EMs). Hybrid electric vehicles (HEVs) operate both EMs and internal combustion engines (ICEs). Various types of EMs have been used in EV applications. Permanent-magnet synchronous machines (PMSMs) are the most commonly used EMs for EVs. However, the increasing price of permanent magnets has resulted in demands for the development of alternative EM. The SRM is a promising EM candidate. Compared to PMSM, SRMs are eliminated using permanent magnets. Moreover, in contrast to induc machines (IMs), SRMs do not have windings on the rotor. Further, compared with synchronous relu machines (SynRMs), SRMs provide simpler rotor structures and more reliable converters. The primary drawbacks of SRM include torque ripple, noise, and vibration. This study attempted to address the drawback of torque ripple in SRMs. Three approaches were investigated to achieve this goal: the design of an SRM with a segmental rotor, a phase voltage boosted converter topology for an SRM drive system, and an analytical SRM control method. Further, a conventional SRM with the same power parameters was selected as the reference or SRM drive systems.machine for validating the segmental SRM. Moreover, the final designs were validated through simulations and experiments. The primary contribution of this dissertation is the proposal of an SRM with a segmental rotor and the validation of its prototype. The segmental rotor was composed of four segments with steel lamination and an aluminum shaft. A boost converter for SRM was proposed and tested experimentally. The boost circuit comprised a diode and a capacitor. In addition, an analytical method for designing and controlling the boost converter was developed in this study. The simulation and experimental results show that the segmental SRM produces an 8.3% lower torque ripple than a conventional SRM. Compared with the conventional asymmetric halfbridge (AHB) converter, the research results illustrated that the SRM generated an 8.6% lower torque ripple and 7% higher power with the designed boost converter. The proposed analytical control method was validated using simulation and experimental results. In addition, dual closed-loop control systems with speed and current loops were developed

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