VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Yuanfeng Lan**

The public defense will take place on **Thursday 23rd March 2023 at 4:30pm** in room **D.2.01** (Building **D**, VUB Main Campus)

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Meeting ID: 312 067 332 763
Passcode: 825S8M

OPTIMAL DESIGN AND CONTROL OF A SWITCHED RELUCTANCE MACHINE FOR ELECTRIC VEHICLES APPLICATIONS

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Abstract of the PhD research

Switched reluctance machine (SRM) has been a promising candidate for electrical vehicle (EV) applications according to the increasing research on it in recent years. The SRMs are well known for their rugged structure for high-speed performance and the simple rotor structure for less expensive manufacturing. The electric machines for electric vehicle (EV) applications require high power density, high torque density, high start torque, low torque ripple, low volume size, high-speed performance, high efficiency, low acoustic noises, and reasonable manufacturing cost. Compared to SRMs, the permanent magnet synchronous machines (PMSM) have high power density and high start torque. Still, the maximum speed is limited by the rotor structure and permanent magnet in the rotor. The induction machines (IM) offer lower costs, but the start torque is limited for EV applications. The synchronous reluctance machines (SynRM) obtain limited maximum speed and power density due to the rotor structure. The main challenge that SRMs have encountered is the high torque ripple.

In this regard, this Ph.D. research is concerned with finding a solution to minimize the torque ripple with magnetic structure design and new SiC converter design. Besides, an improved control approach is proposed. A new two-stack structure segmental SRM with a 90 electrical degrees shift was introduced to mitigate the issue of torque ripples. The two-stack structure is designed to 2D to simplify the stator yoke and rotor. Based on the proposed new two-stack structure, the maximum torque point of the present phase is aligned to the zero-torque point of the next phase, which ensures the sum torque produces less torque ripple. At first, the electromagnetic model is developed with finite element method (FEM). And the MATLAB-based optimization algorithms called golden section search and parabolic interpolation, were applied to create the magnetic design. Secondly, a new four-level SiC converter with a buck-boost circuit and bidirectional regenerating capability has been proposed to reduce the torque ripple and to extend the speed range of the motor. This new SiC converter has increased the power density of the motor by boosting the voltage. The number of the switches and diodes for the new four-level SiC converter is equal to the conventional asymmetric H-bridge. This new SiC converter has increased the power density but kept the cost of power electronics relatively low. Thirdly, a new control method has been proposed to deal with the double salient structure of the SRM and convert the SRM to an equivalent synchronous reluctance machine (SynRM). Furthermore, the equivalent SynRM was controlled with a vector control method. The model of SRM systems is developed in the MATLAB/Simulink® environment, which can be used to generate C-code for controller automatically.

A segmental SRM is prototyped to validate the optimization design method. Besides, an experimental testbench is prepared for testing a three-phase conventional SRM (CSRM) benchmark and the proposed SRM. The experimental results show that the proposed segmental SRM obtains higher average torque and a low torque ripple compared to results of a CSRM. Compared to a CSRM, the average torque of the developed SRM can be improved by 29.3% and the torque ripple can be reduced by 6.5%.