Design and System Analyses of Canned Switched Reluctance Drives for Hydraulic Pump Applications

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To my family

Abstract

In the last years the switched reluctance machines (SRM) reach an increasing attention and popularity in the family of electrical machines because of the fast power electronic development. Furthermore, the cross-section design and the working principle of a switched reluctance machine are very simple while the rotor has no exciting sources like windings or permanent magnets for operation purposes. Consequently, this geometrical simplicity results in lower manufacturing costs, lower maintenance efforts, more reliability and robustness. Due to these facts switched reluctance machines are perfectly suited to drive hydraulic pumps under extreme environment conditions; either as a dry-running version or as a canned version for seal-less applications.

To alleviate the understanding and the design process of a switched reluctance machine the basic working and mathematical principles are described. Moreover, based on the fundamentals of electrical machine design an approach of the design process for switched reluctance drives with respect to the converter and control method is given in general.

The design process of a switched reluctance machine is different from traditional design methods for DC and AC electric machines. This is caused by the extreme localized saturation and hence the non-linearity at high performance operation. In addition to that an unfamiliar power-electronic converter is required to synchronize the excitation with the rotor position. All these facts make it complex and difficult to compute an accurate prototype and optimize the used materials and the required control strategy. Therefore, a stand-alone simulation tool for switched reluctance drives either as dry-running or canned versions is developed, which permits rapidly different steady-state and dynamic design analyses of the motor, of the power electronic as well as of the controller. This simulation allows the easy change of the machine specifications and requirements, like geometry, control parameters and materials. Additionally, it is possible to change the calculation methods for different electromagnetic, mechanical, thermal as well as vibration and noise investigations.

After defining the specifications and requirements of the hydraulic pump drive the analytical design is started by a trial and error process of assigning parameters and then calculating the performance by repeating this process until the objectives are achieved. Several machine configurations are received from steady-state electromagnetic and mechanical investigations and their dynamic behavior is analysed under consideration of the supply source, the converter and the controller.

Furthermore, the electrical and mechanical characteristics are also analysed and optimized in a more detailed way with finite-element simulations. Besides copper and iron losses, very high losses are produced additionally in the stator and rotor can shields of the seal-less version. These can losses usually count more than 60% of the total losses and have a big impact on the thermal behavior and stability of the switched reluctance drive. Aside from the conventional used winding topology different winding topologies for switched reluctance machines are analysed for the dry-running and canned version because the winding topology shows also a big impact on the drive performance, especially on the can losses, as well as on the acoustic noise emission.

Finally, a prototype of the 12/8 dry-running version of the switched reluctance drive for hydraulic pump applications as well as the test bench is build-up and presented. The measured

performance characteristics are analysed and compared with the results of the analytical and finite-element investigations.

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Table of content