

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

Christian Laudensack

Vollständiger Abdruck der von der Fakultät für Elektro- und Informationstechnik der Universität der Bundeswehr München zur Erlangung des akademischen Grades eines

Doktor-Ingenieur (Dr.-Ing.)

genehmigte Dissertation.

Gutachter:

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Die Dissertation wurde am 17.04.2015 bei der Universität der Bundeswehr München eingereicht und durch die Fakultät für Elektro- und Informationstechnik am 03.09.2015 angenommen. Die mündliche Prüfung fand am 24.03.2016 statt.

Forschungsberichte Elektrische Antriebstechnik und Aktorik

Band 20

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

Shaker Verlag
Aachen 2016

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Zugl.: München, Univ. der Bundeswehr, Diss., 2016

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Printed in Germany.

ISBN 978-3-8440-4679-3

ISSN 1863-0707

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen

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Internet: www.shaker.de • e-mail: info@shaker.de

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.

Acknowledgements

There are numerous people I must thank for the memorable time and for the support through my research work at the Institute of Electrical Drives and Actuators (EAA) at the Universität der Bundeswehr München.

At first, I would like to express my deep gratitude to my academic and research advisor Prof. Dr.-Ing. Dieter Gerling for giving me the opportunity to be part of the EAA-Team. I am deeply indebted to him for offering me so many academic and personal opportunities, which have been of enormous significance to me. Without this great source of inspiration the research work would not have come to fruition in this way.

I would like to express my sincere thanks to the examination committee of my thesis, Prof. Dr.-Ing. Klaus Landes and Prof. Dr.-Ing. Wolfgang Amrhein, for their support and valuable comments on this work.

I would also like to thank Dr.-Ing. Hans-Joachim Köbler and Dr.-Ing. Harald Hofmann for their generous help during my working. A special thanks goes to Dr.-Ing. Benno Lange and the laboratory team as well as to M.Sc. Yevgen Polonskiy for their support and assistance in the experimental work.

Furthermore, I would like to acknowledge Dr.-Ing. Gurakuq Dajaku for giving me valuable suggestions during various stages of my thesis and M.Sc. Oleg Moros for his careful review of this work.

In addition, I would like to thank Dr.-Ing. Sven Urschel, Dipl.-Ing. Michael Könen and Mr. Ernst Graf from the KSB AG for their close co-operation and for the high degree of freedom they gave me in my research activities. The financial support of the KSB AG is gratefully acknowledged.

I am deeply indebted to my family for giving me all best for a good life basis and encouraged me during my work. I would like to especially acknowledge my mother for encouraging me to pursue my interests and for both accepting and supporting my decisions.

Most importantly, I would like to express heartfelt gratitude to my girlfriend and to my son for all support and encouragement. I greatly appreciate their patience and understanding. I wouldn't have been in this position, if I hadn't had the support and best wishes from them.

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