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A novel rotor design for hybrid excited machine with multi-flux barriers

Abstract*. The paper presents a novel rotor concept for a hybrid excited synchronous machine with multi-flux barriers in the rotor structure. Based on 3D finite element analysis (3D-FEA) the influence of multi-flux barriers on the field-control (FC) capabilities, electromagnetic torque, no-load magnetic flux linkage and back electromotive force (back-EMF) have been reported. Additionally, FC characteristics versus DC control coil current (I_{DC}) of the machine are presented.*

Keywords: electrical machine, permanent magnet, hybrid excitation, flux-weakening, flux-strengthening, field-control, 3D-FEA.

Introduction

At present, permanent magnet (PM) machines are commonly used in vehicle drives applications. Typical PM machines suffer from restricted flux-weakening (FW) capability at constant power operating region. Therefore, nowadays much attention is devoted to develop unconventional machines with variable-flux (VF) capabilities e.g. with hybrid excitation (HE). The purpose of this paper is to present novel rotor structure of an Electric Controlled Permanent Magnet Synchronous machine (ECPMS-machine).

A novel rotor concept for the ECPMS-machine

A magnetic FC of the ECPMS-machine (Fig. 1a) is carried out by a DC field-excitation coil (DC coil) fixed on the stator. The magnetic field excited by the DC coil current (I_{DC}) allows to change the stator flux linkage Ψ_S in the required range, e.g. in the range of 3:1 for electric vehicle drives. In order to improve the torque density of the ECPMS-machine a new rotor design concept with iron pole (IP), PM pole (PMP) and multi-flux barriers (M-FB's), presented in Fig. 1b, has been developed. The 36-stator slot, double-stator with 12-rotor pole topology was consciously selected to further comparative study with the results obtained in the previous research stages, presented in [1-4] e.g.

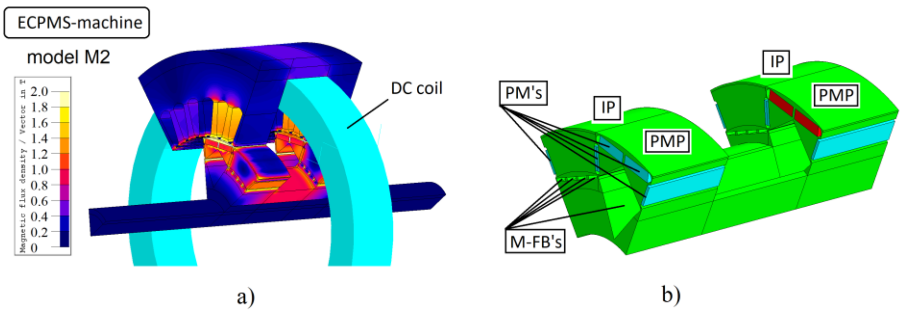

Fig.1. 3D-FE-model M2 (a) with a new rotor design concept (b) for the FCAFPM machine.

The main objective of the M-FB's is to improve magnetic flux distribution in the air-gap of the machine while preserving good performance in terms of FC ability. Additionally, the another target of the study was to demonstrate the influence of the M-FB's in the rotor structure on FW and FS characteristics. For this purposes two finite element (FE) models of the ECPMS-machine have been developed by using Flux3D software package: model M1 with M-FB's and model M2 without M-FB's. In order to reduce the calculation cost, a 3D-FE models of the machine was limited to one-sixth of the entire machine.

3D-FEA results

Figure 2a shows simulation results of no-load back electromotive force (back-EMF) waveforms achieved at three (FW, FC and no-load) different DC field excitation levels for the model M1. In the Fig. 2b shown real impact M-FB's in the rotor structure on magnetic flux distribution in the air-gap of the machine. The presented results of predictions of back-EMF waveforms show that using M-FB's in the rotor structure improved the air-gap magnetic flux density distribution approx. 15,2% but, unfortunately at the expense of a slight decrease in FC range.

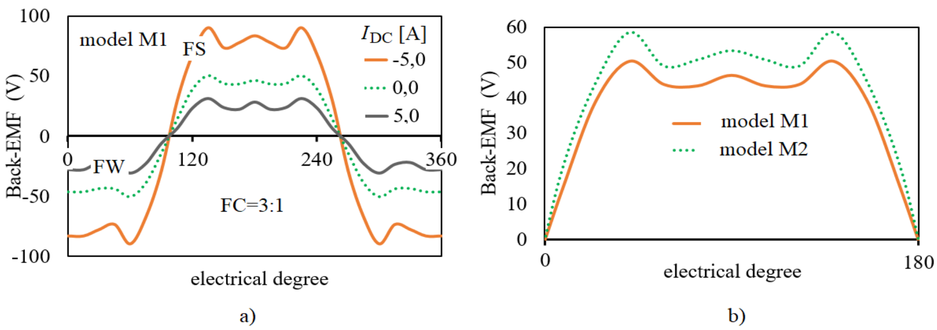

Fig.2. Simulation results of back-EMF waveforms for the model M1 (a) and FEA predictions of no-load back-EMF waveforms for the model M1 and model M2, with comparison.

Conclusion

Presented simulation results show that the FC ratio up to 3:1 and improved power density of the ECPMS-machine design can be effectively achieved and showing its good application potential in the development of variable speed drive applications.

Acknowledgments: This work has been supported with the grant of the National Science Centre, Poland 2015/17/B/ST8/03251.

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