Influence of Rotor Design on Flux Control of Hybrid Excited Synchronous Machine

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Abstract. The paper presents the comparative results of three different rotor design concepts of an Electrically Controlled Permanent Magnet Excited Synchronous Machine (ECPMSM) possessing a field control capability. The experimental results of a no-load back electromotive force (back-EMF) waveforms of these prototypes are presented in detail. Moreover, in order to compare the over-speed capability of the machine, all performances, e.g. range of speed, torque and the field weakening possibilities have been estimated.

1 Introduction

Permanent magnets excited machines with their excellent performance become more and more popular and suitable for electrical vehicles, mainly due to their high efficiency, as compared to other machine types [1], [2]. However, they suffer from uncontrollable magnetic flux, which limits their constant power operation, especially in high speed regions. Optimal motor drives for hybrid or electric vehicle applications should offer a field weakening capability of at least 1:4, which can be achieved with the proper machine geometry design and field weakening control strategies. This paper describes selected performances of a modified ECPMS-machine (Fig. 1) with surface-mounted PMs rotor (Fig. 1b) and a novel embedded PMs rotor designs (Fig. 1c), in comparison. In order to control the magnetic field of the machine, an additional coil (fed by a conventional DC-chopper) is fixed on the stator [3], [4].

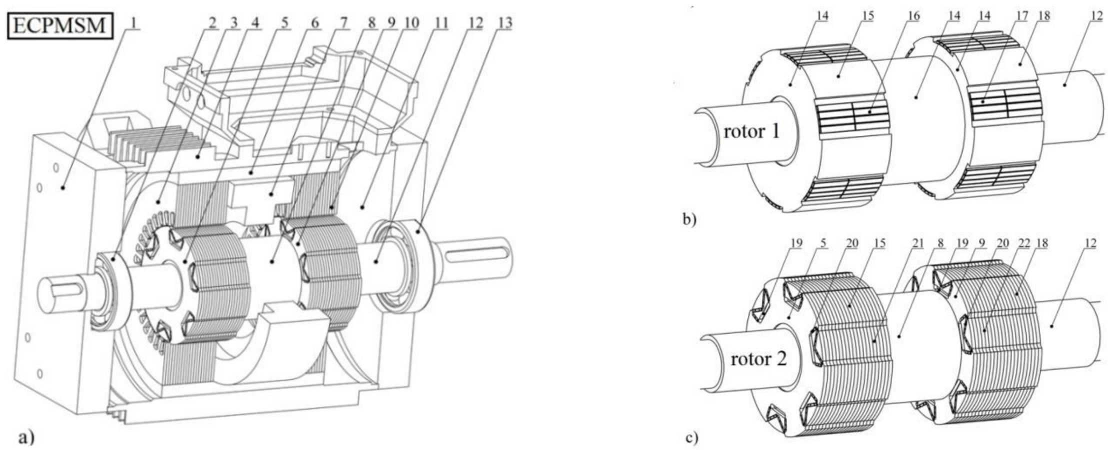

Fig. 1 Cross section of a prototype ECPMS-machine with 3-phase windings in laminated stator and a fixed DC excitation control coil – a); with two rotor designs: surface-mounted PMs rotor – b) and embedded PMs rotor – c)

For the rotor from Fig. 1b, the rotor's core and the iron poles of the machine are formed using the modified soft magnetic composites (MSMC) technology (Somaloy 500 + Kenolube 0,5% epoxy resin cured under pressure). For the rotor shown in Fig. 1c, the rotor's central core is formed using laminated toroidal steel and the other parts of the core are made of laminated steel.

2 New Rotor Design

Results obtained, especially for the rotor shown Fig. 1c, were very promising, thus different evolutions of this structure have been examined. This study has shown that the excellent magnetic field control possibility might be successfully achieved by another arrangement of PMs and flux barriers in the rotor construction. Fig. 2 shows exemplary two 3D-FE models of the machine with the initial (left) and final (right) rotor construction, together with magnetic field distributions, in comparison. Advanced numerical evaluations of both structures leaded to the conclusion that the new rotor has also better flux weakening properties (Fig. 3). According to FEA predictions, a wide constant-power speed range can be obtained with this configuration, without any negative effects of current injection. In this case control ratio over 10:1 can be effectively achieved in the short range of the current of the DC control coil.

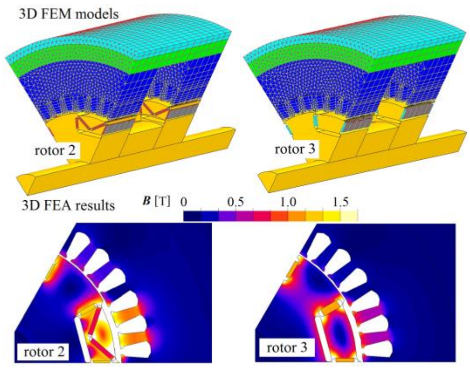

Fig. 2 Numerical evaluations of new rotor structures

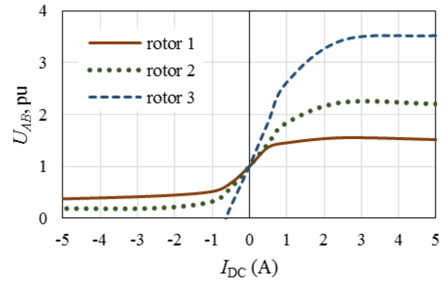

Fig. 3 Back-EMF characteristics of ECPMSM with different rotor concepts, in comparison

3 Conclusion

The main purpose of this paper is to present the effects of rotor construction on the field control capability of the ECPMS-machine with different rotor design concepts. The obtained results and laboratory measurements done for all built prototypes show a noticeable influence of the DC coil current on the field control range of the machine (achieved for the third rotor concept especially). Moreover, the results show that the starting torque and good field weakening performance of the ECPMS-machine with these rotor concepts, lead to a very effective machine with wide flux control range which can be used for electrical vehicles.

Acknowledgements

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References

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