Magnetic Anisotropy considered for Synchronous Claw-Pole Alternators with Axial Flux Component

S. Schulte, F. Henrotte, K. Hameyer

Institute of Electrical Machines, Chair of Electromagnetic Energy Conversion
RWTH Aachen University
Schinkelstr. 4, 52056 Aachen, Germany, Tel: (+49)-(0)241-8097667, Fax: (+49)-(0)241-8092270,
e-mail: stephan.schulte@iem.rwth-aachen.de

I. INTRODUCTION

Stators of rotating-field machines usually consist of stacks of laminated steel. Lamination aims at reducing eddy current losses (to occur due to time-variant flux), but increases the reluctance in the direction normal to the lamination and therefore reduces an axial flux component.

The focus of this paper is put on analyzing the influence of magnetic anisotropy in axial direction as a function of the stacking factor. FE methods are used for the computation of a 3D model of a synchronous claw-pole alternator with designated axial flux component as a matter of principle.

II. APPROACH

The magnetic permeability μ is independent of the direction for isotropic materials. On the other hand in case of axial anisotropy, the z-component μ_{zz} differs from those in x and y direction.

Thus, permeability μ must not be considered as a scalar, but as an approximation as a tensor for approaches regarding magnetic anisotropy [1].

$$\mu = \begin{bmatrix} \mu_{XX} & 0 & 0 \\ 0 & \mu_{YY} & 0 \\ 0 & 0 & \mu_{ZZ} \end{bmatrix}. \qquad (1)$$

Herein, μ_{xx} and μ_{yy} reflect the permeability $\mu_{r,Fe}$ of steel, μ_{zz} represents a series connection of steel (μ_{zrFe}) and insulation material ($\mu_{r,Ins}$) due to lamination. The ratio between $\mu_{z,Fe}$ and $\mu_{r,Ins}$ directly depends on the stacking factor k_{Fe}. The effective permeability in axial direction is given by

$$\mu_{r,Fe,eff} = \frac{\mu_{r,Fe}}{k_{Fe} + \mu_{r,Fe} \cdot (1 - k_{Fe})} = \mu_{ZZ}, \qquad (2)$$

which is the z component of the permeability tensor (1). This expression allows for modeling as solid component, instead of explicitly modeling a stack of single laminations. For detailed derivation, see full paper.

III. COMPUTATION

The described approach is implemented in the static 3D FE solver iMOOSE [2]. A simple test model is used to validate and verify the approach (details regarding model and simulation results to appear in the full paper).

The simplicity of the chosen test model facilitates analytical calculations used for validation. Both FE simulation results as well as analytical calculations match very well and therefore validate the approach used.

The described software package iMOOSE with implemented magnetic anisotropy is applied to a modified model of a regular claw-pole alternator. Design modifications of the machine are required to enforce a significant axial flux to occur.

Therefore, the rotor claws are shortened in order not to overlap in axial direction. Figure 1 shows a cut out of a claw-pole rotor with regular (l.) and shortened claws (r.).

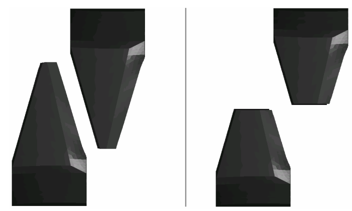

Fig. 1: Comparison of modelled rotor claws.

Flux linkage ψ of a stator coil vs. k_{Fe} is shown in Fig. 2.

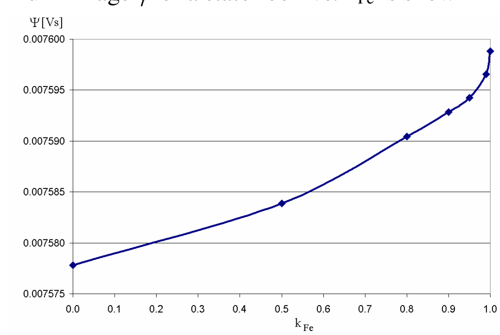

Fig. 2: Flux linkage in a coil vs. stacking factor.

IV. CONCLUSIONS

Within a reasonable range of the stacking factor (0.95→1.0) the flux linkage through a coil is decreased by 0.06% for the described model featuring shortened claws, based on magnetic anisotropy in axial direction.

The influence of anisotropy is less significant for the alternator with regular claw design according to design-based reduction of the axial flux component. Computation results for regular claw-pole alternators will appear in the full paper.

V. REFERENCES

[1] H. Vande Sande, *Modelling and Finite Element Simulation of Non-Linear and Anisotropic Quasi-Static Electromagnetic Systems, PhD, Leuven, 2003*

[2] D. van Riesen, C. Monzel, C. Kaehler, C. Schlensok, G. Henneberger, *iMOOSE - an open-source environment for finite-element calculations*. IEEE Transactions on Magnetics, Bd. 40, Nr. 2 S. 1390-1393, March 2004