Identification of Synchronous Machine Magnetization Characteristics from Calorimetric Core-Loss Measurements

P. Rasilo[1,2], A. Abdallh[1], A. Belahcen[2], A. Arkkio[2], L. Dupré[1]

[1]Dept. of Electrical Energy, Systems and Automation, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium
[2]Dept. of Electrical Engineering, Aalto University School of Electrical Engineering, P.O. Box. 13000, FI-00076, Espoo, Finland
paavo.rasilo@alumni.aalto.fi

***Abstract*—The magnetic material characteristics of the core material of a wound-field synchronous machine (WFSM) are identified by solving an electromagnetic inverse problem. An effective hysteretic magnetization curve for the core is determined by minimizing the difference between global calorimetric loss measurements and finite-element (FE) calculations. In the FE model, the hysteresis loops are modeled with an inverse vector Preisach model combined to an analytical model for the Everett function. Models for the eddy-current and excess losses are also included in the model. Results with different rotor materials and both grid and inverter supplies are discussed.**

***Index Terms*—Electromagnetic inverse problems, loss measurements, magnetic hysteresis, synchronous machines.**

I. Introduction

The loss characteristics of the core laminations of electrical machines are typically deteriorated as a result of the manufacturing process, especially punching [1]. This is most likely the reason why our FE models underestimate the core losses of our 150-kVA WFSM [2]. In this study, we assume that mainly the magnetization characteristics of the WFSM have been affected by the punching. We attempt to estimate the hysteresis characteristics of the machine core material as a solution to a coupled experimental-numerical electromagnetic inverse problem by comparing simulated core losses to loss data obtained with calorimetric measurements [2]. The simulations are done with a 2-D time-stepping FE model including models for the hysteresis, eddy-current and excess losses in the core laminations. The magnetization curves of the core materials are analytically modeled with a vector hysteresis model based on a Lorentzian Preisach distribution function with five independent parameters $\boldsymbol{u} = (a, b, c, k_1, k_2)$ [3]. The inverse identification problem is formulated to find the unknown parameters $\boldsymbol{u}$ by iteratively minimizing the difference between sets of FE-modeled and measured core loss values $\boldsymbol{P}_{\text{core}}$ [4]:

$$\min_{\boldsymbol{u}} \left\| \boldsymbol{P}_{\text{core,FE}}(\boldsymbol{u}) - \boldsymbol{P}_{\text{core,meas}} \right\| .$$

II. Results and Discussion

Before solving the inverse problem, we have performed a sensitivity analysis in order to study up to what extend the core losses can be affected by the hysteresis characteristics. Fig. 1 shows the magnetization characteristics of a 0.5-mm Fe-Si core lamination measured from Epstein strips. It also compares the measured core losses to FE simulation results obtained with the measured characteristics and ones obtained by scaling the measured field strength by a factor two. It is seen that both the no-load core losses and the so-called stray-load losses are affected by the changes in the magnetization characteristics. Thus, as discussed in [4], it may indeed be possible to find an effective *B-H* loop for the machine core which yields a better correspondence with the measurements and simulations. In the full paper we will use the inverse approach to determine the magnetization properties for different rotor materials and compare the measured and simulated losses with both grid and inverter supplies. The effect of measurement uncertainties on the accuracy of the inverse problem solution will be also discussed.

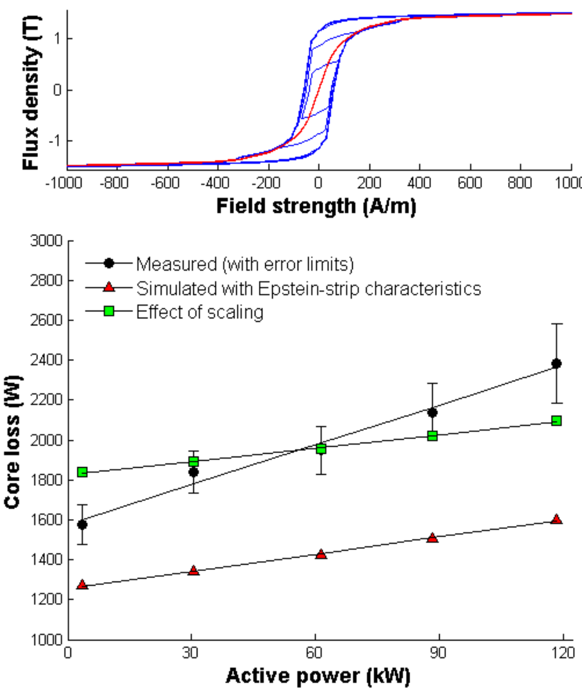

Fig. 1. Magnetization curves measured from Epstein strips and comparison of measured core losses to simulation results with the original material parameters and ones with scaled field strength.

References

[1] O. Nakazaki, Y. Kai, T. Todaka, M. Enokizono, "Iron loss properties of a practical rotating machine stator core at each manufacturing stage," *Int. J. Appl. Electrom.*, Vol. 33, No 1, pp. 79-86, January 2010.

[2] P. Rasilo, A. Belahcen, A. Arkkio, "Experimental determination and numerical evaluation of core losses in a 150-kVA wound-field synchronous machine," *IET Electr. Power Appl.*, Vol. 7, No. 2, pp. 97-105, February 2013.

[3] L. R. Dupré, G. Bán, M. Von Rauch, J. A. A. Melkebeek, "Relation between the microstructural properties of electrical steels and the Preisach modelling," *J. Magn. Magn. Mater.*, Vol. 195, No. 1, pp. 233-249, April 1999.

[4] A. Abdallh, L. Dupré, "Magnetic material characterization using an inverse problem approach," book chapter in Advanced Magnetic Materials, ISBN 978-953-51-0637-1, InTech, 2012.