System Simulation of a PMSM Servo Drive using the Field-Circuit Coupling

Thomas Herold, Enno Lange and Kay Hameyer
Institute of Electrical Machines (IEM)
www.iem.rwth-aachen.de
RWTH Aachen University
Schinkelstraße 4, 52062 Aachen, Germany
Email: thomas.herold@iem.rwth-aachen.de

***Abstract*—In the development process of electrical drive trains, consisting of the motor, the power electronics and the control scheme, it is difficult to predict the exact machine and control behavior in combination with the converter. Therefore, system simulations with analytical machine models embedded in a circuit simulation environment are performed. To increase accuracy by paying attention to alternating machine parameters, such as saturation, a finite element model can be used instead of the analytical machine model. In this paper such a field-circuit coupling is applied to the simulation of a PMSM servo drive and the results are shown and discussed.**

I. Introduction

Within the design process of electrical drive trains the system simulation represents an important step. Because servo drives do not only consist of the electrical machine but also of the power electronics and the control, it is necessary to consider all corresponding parts to achieve a proper operation in all working points. Especially for complex control strategies like self-sensing where saturation and inverter influences have to be taken into account this becomes very important [1], [2]. With circuit simulation software it is possible to combine the converter and the control with an analytical representation of the machine. Since the machine is typically designed with the help of Finite Element (FE) simulations it is reasonable to take the FE model into consideration, which can substitute the analytical model for a more precise simulation. In this paper a system simulation of a PMSM servo drive is presented. The used circuit simulator is PLECS™associated with the ODE (ordinary differential equation) solver Matlab/Simulink™. For the FE simulation an IEM in-house software (iMOOSE) is applied. After an introduction to the simulated components and the appropriate simulation methods at hand, the system simulation is performed and the results are shown.

II. Lumped parameter based field-circuit coupling

The field-circuit coupling is based on a linearized lumped parameter representation of the electrical machine whose values are systematically extracted from the FE model. The lumped inductances L as well as the induced voltages V are defined on energy-based considerations [3]. These lumped parameters are embedded into the circuit simulation (Fig. 1). The circuit simulator continues with the circuit simulation until a new set of lumped parameters needs to be extracted. This is done on a regular basis or a more elaborated approach.

III. The overall simulation model

The overall model consists of three sections. The basic part is the FE model of the PMSM. It is connected to the circuit simulation tool on the one hand, exchanging inductance, voltage and current signals. On the other hand it communicates

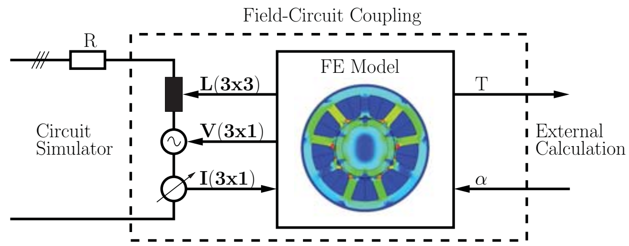

Fig. 1. Embedded lumped parameter model of the field-circuit coupled device.

with an ODE simulation environment where the mechanical equations are solved and a closed-loop speed control is designed. The applied control scheme is a PI-cascade with an inner current- and an outer speed-loop. The required feedback speed signal is directly provided by the mechanical equations while the currents, measured in the circuit simulation, are transformed to dq-coordinates by Park transformation. The actuating voltage of the control is transferred to the converter in the circuit simulation via a space-vector-modulation [4], controlling the duty-cycles of the semiconductor valves.

IV. Conclusion

This paper presents the simulation of an electrical drive train by a field-circuit coupling method and explains the basic principles. In the performed simulation an FE model of a PMSM is combined with a circuit simulation tool. This approach considers nonlinearities, saturation effects, mutual magnetization influences of the d- and q-axis, etc., that are hardly to include in an analytical model. Several operating areas and load scenarios of the drive are analyzed and discussed. The results are shown in the full paper.

References

[1] Reigosa, D.D.; Garcia, P.; Raca, D.; Briz, F.; Lorenz, R.D., "Measurement and Adaptive Decoupling of Cross-Saturation Effects and Secondary Saliencies in Sensorless Controlled IPM Synchronous Machines," Industry Applications, IEEE Transactions on , vol.44, no.6, pp.1758-1767, Nov.-dec. 2
[2] Li, Y.; Zhu, Z.Q.; Howe, D.; Bingham, C.M., "Modeling of Cross-Coupling Magnetic Saturation in Signal-Injection-Based Sensorless Control of Permanent-Magnet Brushless AC Motors," Magnetics, IEEE Transactions on , vol.43, no.6, pp.2552-2554, June 2007
[3] Lange, E.; Henrotte, F.; Hameyer, K., "An Efficient Field-Circuit Coupling Based on a Temporary Linearization of FE Electrical Machine Models," Magnetics, IEEE Transactions on , vol.45, no.3, pp.1258-1261, March 2009
[4] van der Broeck, H.W.; Skudelny, H.-C.; Stanke, G.V., "Analysis and realization of a pulsewidth modulator based on voltage space vectors," Industry Applications, IEEE Transactions on , vol.24, no.1, pp.142-150, Jan/Feb 1988

978-1-4244-7061-7/10/$26.00 ©2010 IEEE