Project 3: Transient modeling of a PMSM
EJ2222 - Design of Electrical Machines

1 General instructions

In this assignment we will extract data from a FEM model in order to implement a transient PMSM model in Matlab/Simulink[1].

1.1 Report

A written report is to be handed in to Oskar Wallmark's post box. You may work together in groups of two when collaborating with the simulations but you must write and hand in the report individually. You will *not* get the corrected report in return so please keep an additional copy for your personal reference. Make sure to write down your e-mail address where the results of the examination of your report will be sent.

Remark 1: If you have problems solving the assignments, the computer lab is staffed by course teachers as outlined in the schedule. It is recommended that you primarily pose your questions related to the course tasks in that forum. Also, do not hesitate to pose questions to other fellow students. If you do not receive proper assistance after this, do not hesitate to contact Oskar Wallmark.

Remark 2: Include relevant pieces of your own Matlab code in the written report so that it is evident for the reader that you *have solved the assignments yourself and understand your solutions in all details.*

2 Assignment

Adapt the delivered FEMM model of a PMSM so that it has the same stator geometry and uses the same materials as in Project 1 and Project 2. Introduce a four-pole rotor with inset-mounted permanent magnets and size the permanent magnets so that the stator and rotor laminations are suitably magnetically loaded (i.e, without too excessive magnetic saturation).

a) As outlined in Chapter 5 in [1], extract suitable data from the FEMM model and implement a corresponding Matlab/Simulink model so that magnetic saturation "along" the d- and q-axis is considered. You may or may not choose to incorporate the effect of magnetic cross saturation but you need to take into consideration flux-linkage harmonics. The latter is sufficiently modeled if the open-circuit no-load voltage is reproduced properly.

b) Simulate a balanced short circuit of the three-phase converter by setting $v_d = v_q = 0$ V. Set the rotor speed to increase (linearly and slowly from zero and plot the resulting torque and current waveforms. Explain why the stator currents and torque arise and the shape of the torque. Compare the obtained results with a simpler machine model using constant machine parameters (obtained using the analytical formulas derived in [1]) and neglecting the impact of harmonics.

c) In [1], it is found that the developed torque T_e can be expressed as

$$T_e = \frac{3p}{4}\left(\psi_d i_q - \psi_q i_d\right). \qquad (1)$$

[1] Matlab and Simulink are registered trademarks of The MathWorks, Inc., Natick, MA.

However, if you follow the derivation of (1) in [1] carefully, you will see that it relies upon analytical models where magnetic saturation has not been considered. Use the implemented FEMM model and investigate the validity of (1) also in the presence of magnetic saturation.

Tip 1: Relevant material information about permanent magnets can be found at, e.g,. www.vacuumschmelze.com.

2.1 Non-compulsory optional assignment

*) If you have suitable knowledge in control of electric drives, implement a closed-loop current controller (preferably, implemented in the dq-axis reference frame) and compare the resulting torque and current waveforms to corresponding results from a constant-parameter machine model.

References

[1] O. Wallmark, *AC Machine Analysis – Fundamental Theory*. Stockholm, Sweden: KTH Royal Institute of Technology, 2016.