Controlled Three-Phase Drives

Tutorial 7: PMSM Model and Current Control

Exercise 1: PMSM Model

1. Develop a MATLAB/SIMULINK Model for a permanent magnet synchronous machine (PMSM) in rotor-fixed coordinates. As model inputs, the three line voltages u_a, u_b, u_c and the load torque T_L shall be taken. The output variables are represented by the rotor angular speed ω_{me}, the rotor angle ε_{me} and the stator currents i_a, i_b and i_c.
2. For validating the machine model, a constant voltage shall be applied to the motor terminals. The motor position will be adjusted in a way that the d-axis has the same orientation as the applied voltage vector. In this case, no more torque is generated and the rotor angle does not change anymore. If a constant voltage component (stator-fixed) is applied in α-direction, the rotor will start turning from an unknown initial position until the d-axis and the α-axis exactly coincide. This method is often used in real life applications for the initialization of position sensors.

Hints:

- *All machine parameters should be adjustable through corresponding MATLAB variables. The variables should be initialized through the provided MATLAB script <init_pmsm.m>. Please do not modify the variables names in the script. In the upper part of the file the current exercise task needs to be entered.*
- *Executing the MATLAB script <init_pmsm.m> will open the SIMULINK-Model to be processed.*
- *The coordinate transformation from a,b,c to α,β-coordinates can be realized through the function <\Simulink\User-Defined-Functions\Fcn>.*

$$\begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} = \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} x_\alpha \\ x_\beta \\ x_0 \end{bmatrix} = \boldsymbol{T}^{-1} \begin{bmatrix} \dot{x}_\alpha \\ x_\beta \\ x_0 \end{bmatrix} \qquad \begin{bmatrix} x_\alpha \\ x_\beta \\ x_0 \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{3}} \\ \frac{\sqrt{2}}{3} & \frac{\sqrt{2}}{3} & \frac{\sqrt{2}}{3} \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} = \boldsymbol{T} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix}$$

$$\mathbf{Q}(\varepsilon) = \begin{bmatrix} \cos\varepsilon & \sin\varepsilon \\ -\sin\varepsilon & \cos\varepsilon \end{bmatrix}$$

$$\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} = \mathbf{Q}^{-1}(\varepsilon) \begin{bmatrix} x_d \\ x_q \end{bmatrix} = \mathbf{Q}(-\varepsilon) \begin{bmatrix} x_d \\ x_q \end{bmatrix}$$

Several transformation formulas

Exercise 2: Current Control according to Magnitude Optimum

By inserting an adequate element within the signal path of the reference variable it shall become possible to apply a torque setpoint. Extend the already processed simulation model by a controller as well as the transfer element for the reference variable.

Exercise 3: Current Control according to Symmetrical Optimum

The reference filter for the Symmetrical Optimum is to be realized by using discrete integration blocks. Extend your already processed simulation model by this reference filter.

Exercise 4: Investigating the Control Behavior

Conduct simulations by applying steps to the reference variables for both controllers and plot the respective step responses.

1. Analyze the voltages, which are applied to the inverter as well as the occurring currents in *dq*-coordinates. Do the voltages and currents lie within their valid ranges ? Compare the occurring quantities with their specified limits in the initialization file.
2. How can be guaranteed that the specified limit values are not exceeded ? Which problems can occur through these countermeasures and how can they be avoided ?