PLECS

DEMO MODEL

Permanent-Magnet Synchronous Machine
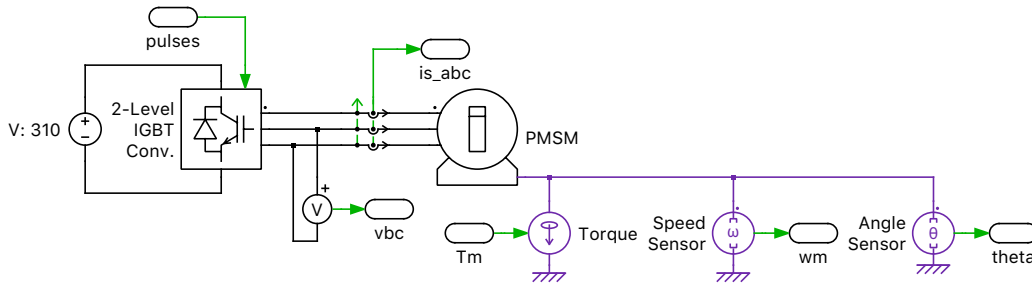
Last updated in PLECS 4.3.1

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1   Overview

This example shows an inverter-fed, 8-pole, surface-mount permanent-magnet synchronous machine (PMSM) with an outer speed regulator and an inner hysteresis-type current controller.

Figure 1: Permanent-magnet synchronous machine

2   Model

2.1   Electrical and machine model

The inverter circuit is modeled as an ideal three-legged bridge with a stiff $310\,\mathrm{VDC}$ supply. The phase currents are being measured for closed-loop current control. A hysteresis controller is implemented to control the switching of the three legs of the inverter. This AC motor is a synchronous machine with surface-mounted magnets ($L_\mathrm{d} = L_\mathrm{q}$). The machine is modeled to have a sinusoidal back electromotive force (EMF). It is assumed that the magnetic strength of the rotor magnets is unchanged during the operation. The load torque on the PMSM is modeled using a Controlled Torque Source. A more detailed description about the PMSM can be found in the component description of the Permanent Magnet Synchronous Machine in the PLECS component library.

2.2   Control

The speed of the PMSM is regulated by an outer speed loop using a PI controller with an anti-windup mechanism. The output of the PI controller is the torque-producing quadrature current set point (i_q^*) for the electric machine. It is translated into an equivalent phase current set point (i_abc^*). The measured phase currents are compared to the corresponding reference currents. The error signal created as the difference between the two is then fed into a hysteresis current controller to generate the switching signal for each inverter leg.

3   Simulation

Run the simulation with the model as provided to view the behavior at start-up followed by a change in the load torque. The machine is accelerated from standstill to the desired speed in the first $12.7\,\mathrm{ms}$. During the acceleration, the PI controller output is saturated and the maximum machine torque is applied. At steady state, the average torque generated by the machine is equal to the load torque.

The PMSM initially experiences a constant load torque of $3\,\mathrm{Nm}$. At $40\,\mathrm{ms}$, the load torque is stepped down to $1\,\mathrm{Nm}$. In order to maintain the desired speed, the outer speed regulator reduces the current set point resulting in lower amplitude of the fundamental of the phase currents. The three-phase stator currents are depicted in Fig. 2. The magnitude of the torque ripple remains unchanged due to the unchanged hysteresis band of the current controller.
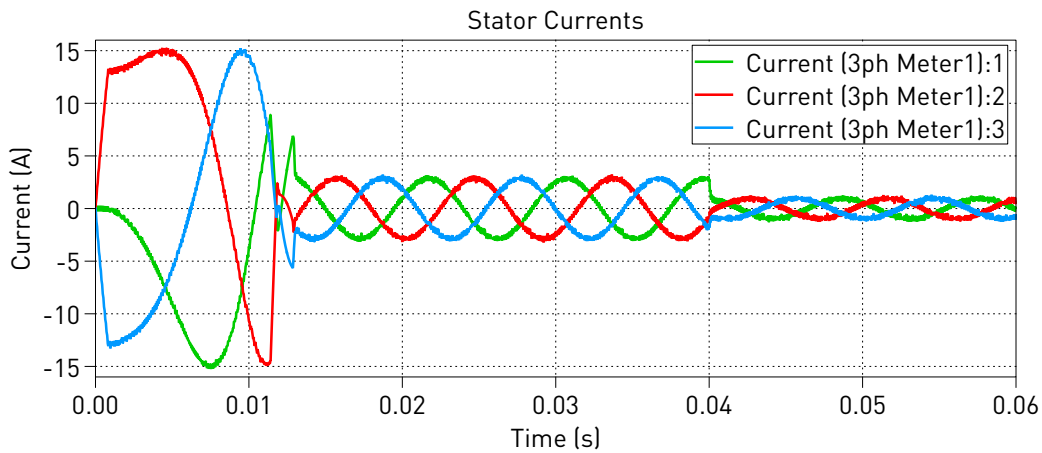
Figure 2: Simulation result of the PMSM with outer speed loop and inner current loop, under load torque step at $40\,\mathrm{ms}$

Save the trace of the stator currents in the scope labelled "is_abc" under the name "Speed=700". Next, change the speed set point (ω_{ref}) to 350. Rerun the simulation. Notice that the fundamental frequency of the stator currents are halved when the machine speed is halved.

Revision History:

PLECS 4.3.1   First release

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