Brushless DC Motor Drive (Read Chap. 4 and 14)
In this assignment you will implement a model of BLDC motor drive system. The system parameters are:

- $V_{dc} = 45V$
- $r_s = 0.25\, \Omega$
- $L_{ss} = 0.375\, \text{mH}$
- $\lambda'_m = 21.5\, \text{mV} \cdot \text{s}$
- $J_{rot} = 0.22e^-3\, \text{kg} \cdot \text{m}^2$
- The friction torque is $T_{fric} = 0.12\, \text{N} \cdot \text{m}$.

Initially assume that $\varphi_v = 0$, but this angle will be changed.

Part 1: The motor is assumed to operate from a three phase 180-degree VSI using Hall sensors.
Implement the following studies:
(a) Start the drive system with zero initial conditions. At $t = 1.0\, \text{s}$, apply a mechanical load torque $T_m = 1.5\, \text{Nm}$, and continue running the model till $t = 2.5\, \text{s}$. Plot variables $v_{as}$, $i_{as}$, $i_{dc}$, $T_e$, $\omega_{rm}$.
(b) Implement Average-Value Model (see Chap. 14) and repeat the study in (a). Compare and comment on your results.
(c) Extract and plot the transfer functions $H_1(s) = \frac{T_e}{V_{dc}}$ and $H_2(s) = \frac{\omega_{rm}}{V_{dc}}$ corresponding to two operating points: i) no load, and ii) loaded $T_m = 1.5\, \text{Nm}$ (four transfer functions in total). Is loading the motor changes transfer functions? If so, explain why.
(d) Use $\varphi_v = -30^\circ$, $\varphi_v = 0$ and $\varphi_v = +30^\circ$, and plot the steady state torque-speed characteristics of this motor (all on the same plot, see Chap. 4) first using the corresponding steady state equations. Describe what is the effect of changing this angle?
(e) Then verify that your detailed and average models predict the same torque-speed characteristics (plot several points from your dynamic models on top of the analytical curves). Describe what is matching and what is not?

Part 2: The motor is assumed to operate from a three phase 120-degree VSI using Hall sensors.
(a) Describe how would you go about implementing the detailed and average models of the 120-degree inverter with this BLDC motor?
(b) Neglect commutation, and implement the Average-Value Model (see Sudhoff’s paper [1]) and repeat the study in Part 1 (a). Compare the results and explain the difference between the 180 and 120 degree operation?
(c) Use $\varphi_v = -30^\circ$, $\varphi_v = 0$ and $\varphi_v = +30^\circ$, and plot the steady state torque-speed characteristics of this motor (all on the same plot) first using the corresponding steady state equations. Explain/describe what is the effect of changing this angle for this case? How is it different from the Part 1(d)?
(d) Verify that your average model predicts the same characteristics.

Based on your conducted studies and results, write a short summary of what you have learned about BLDC Motors and their modeling.

Thank you for taking this course, and I hope that you have enjoyed it!

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