EE 462 – Utilization of Electric Energy

2018-2019 Spring Semester

Homework 3

Deadline: May 15th Wednesday 23:59

Part A: Design

Design a surface mount permanent magnet synchronous machine (SM-PMSM) that is: determine its flux linkage and dq-inductances, so that it can be used in the application with the following specifications. Assume Space Vector PWM (SVPWM) is applied, so determine maximum phase voltage accordingly. Ignore all losses and phase inductances in Part A.

Pole pair number $p = 6$
$P_{nominal} = 60\ kW$
$T_{nominal} = 250\ Nm$
$n_{max} = 12000\ rpm$
$V_{dc} = 400\ V$
$I_{nominal}$ = 250 A (amplitude)

1. Calculate base speed of the SM-PMSM.
2. Draw torque speed characteristics and show the limiting factors (current, voltage, losses) in the boundaries of the torque speed characteristics.
3. In dq-frame, why i_d current is called flux producing current component and when do we apply i_d current to phases. Will there be a net torque is only i_d current is applied?
4. Calculate flux linkage (λ_{PM}) of the machine so that system can deliver the desired nominal torque at nominal current.
5. Determine the maximum $L_d = L_q$ value so that phase voltage stays below applicable phase voltage at base speed and nominal torque.
6. Determine minimum inductance $L_d = L_q$ so that machine can operate at nominal power at maximum speed. Please note that this inductance value is different than part 4.
7. Select a phase inductance value so that your machine can meet the specifications. There is no one correct answer.
8. Comment on how you would adjust the flux linkage and phase inductances.

Part B: Losses in PMSM

1. What are the losses in PMSM machines?
2. How do the copper losses change with temperature?
3. Write the formula for the core losses and explain briefly the core loss components.
4. Which losses do exist in permanent magnet material? Briefly explain.
5. Why loss estimation is important?
6. Which losses do exist in PMSM if the machine is rotating without producing any torque (idle)?

You can refer to: G. Bertotti, "General properties of power losses in soft ferromagnetic materials," in *IEEE Transactions on Magnetics*, vol. 24, no. 1, pp. 621-630, Jan. 1988.

Part C: Electric Machines used in Electric Vehicles

Read “Z. Q. Zhu, W. Q. Chu and Y. Guan, "Quantitative comparison of electromagnetic performance of electrical machines for HEVs/EVs," in *CES Transactions on Electrical Machines and Systems*, vol. 1, no. 1, pp. 37-47, March 2017.” and answer the following questions.

1. Why switched reluctance machine drives are not used in electric vehicle applications?
2. Why car manufacturers prefer IPMSM over IM drives?
3. Why IM with copper rotor bars are preferred in electric vehicles?
4. What is the difference between PMSM and PM-assisted Synchronous Machine? Why the latter is promising?