Exercise 1: An IPMSM with following parameters is given.

$\Psi_{PM} = 0.3\ Vs$
$L_d = 1\ mH$
$L_q = 1.5\ mH$
$pole\ pair\ number = 4$
$V_{DC} = 400\ V$
$\hat{\imath}_S = 200\ A\ (peak\ value)$
$The\ stator\ resistance\ is\ ignored.$

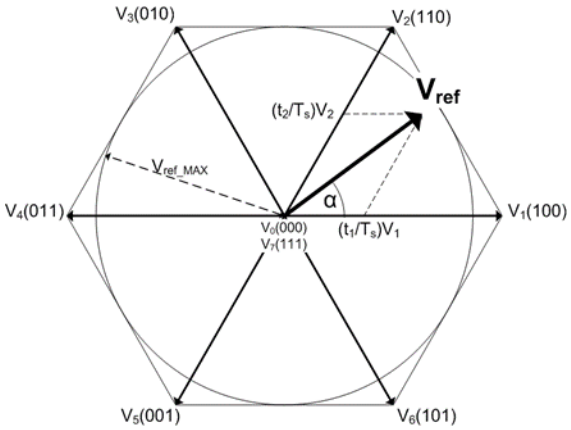
1. Draw the following characteristics on the i_d-i_q plane.
    a. Constant current (rated value)
    b. Constant torque of 350 Nm
    c. Constant stator flux $\Psi_s = 0.3\ Vs$
2. Calculate the torque numerically in excel as a function of current angle (0 deg at q axis) at rated current.
3. Determine the maximum torque at the rated current.
4. Calculate the base speed corresponding to the rated voltage and torque mentioned above. Assume star connected phase terminals and SV-PWM.
5. Draw the space vector diagram at maximum torque and base speed, calculate the power factor.
6. Why the maximum torque cannot be maintained beyond base speed?
7. Draw space vector diagram in the field weakening range.

Exercise 2: Losses in PMSM (Not covered during lectures)

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

Exercise 3: SV-PWM

A PMSM with 4 pole pairs are running at 1000 rpm. The phase voltages of this machine are regulated by applying Space Vector Pulse Width Modulation (SV-PWM) with a switching frequency equal to 10 kHz. At $t = t_0$, the reference voltage vector is in the first sector, it has an amplitude of $V_{DC}/(4\sqrt{3})$ and angle of α=30 deg as shown in Fig. 2.



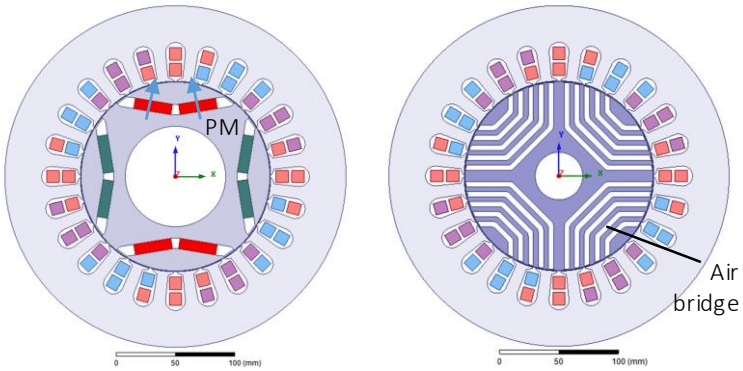
1. How many times the switching states are calculated in one electric period?
2. State the steps of determining the reference vectors and their duration.
3. State the active voltage vectors and draw the switching table at $t = t_0$.
4. State the active voltage vectors and draw the switching table at $t = t_0 + 0.02\ s$.
5. Show the derivation of the applicable maximum voltages with SV-PWM and Sine-PWM?
6. What is the main difference between SV-PWM and Sine-PWM?

Exercise 4: Control Block

1. Draw control diagram for the speed control of a SMPMSM machine with SV-PWM in the base speed range.
2. Write matrixes for the used transformations.
3. Which measurements are necessary?

Exercise 5: Rotating Field Theory

1. State the rules of creating a rotating field with 2-phases, draw basic stator winding distribution and give the phase currents.
2. State rules of creating a rotating field with 3 phases, draw basic stator winding distribution and give the phase currents.
3. What is the difference between $\alpha\beta$ and dq coordinates?
4. What is definition of d-axes?
5. Show the d-axes of the following rotor geometries.



6. What is the definition of i_d and i_q.
7. What is the definition of L_d and L_q.