Homework 1 – Introduction to AC Machies

This homework is to be solved using computational tools (such as MATLAB). You should show your work (how the resultant plot is obtained analytically, and required explanations).
The provided template must be used and the homework should be submitted by converting the .m file solution to pdf by using ***publish*** *command. Required explanations and several tips are given in the template.*

Q.1. (50 pts) Consider the stator side (double layer) of a 50 Hz AC machine shown in Fig. 1. Each coil side has 8 turns.

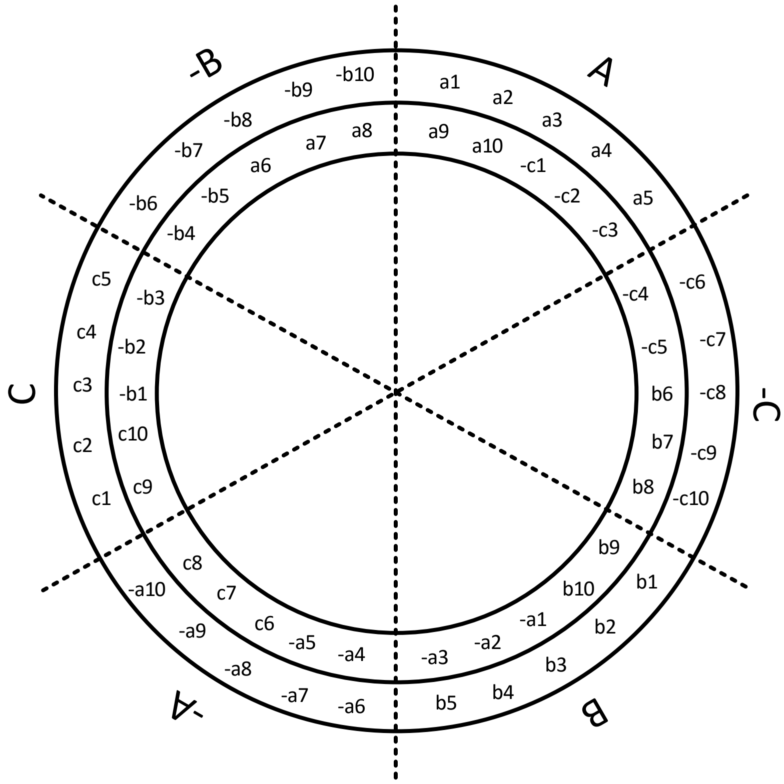

Figure 1: Stator Side of the AC Machine

Part A: (24 pts) Answer the following by also briefly explaining how you determined them:

a. What is the pole number?
b. What is the slot number?
c. What is the slot angle in degrees?
d. What is the phase belt angle in degrees?
e. What is the number of slots per phase per pole?
f. What is the coil span (pitch) in electrical radians?
g. What is total number of series turns per phase?

h. What is the distribution factor for the fundamental component?
i. What is the chording factor (pitch factor) for the fundamental component?
j. What is the winding factor for the fundamental component?
k. What is the mechanical speed of the rotating MMF (in rpm) if the stator windings are excited with balanced 3-phase currents at 50 Hz?

Part B: (26 pts) The stator of the machine given in Part A is excited by balanced three phase currents with peak value of 2A ($\hat{I}$) and frequency of 50 Hz (f) where the phase sequence is A-B-C and phase-a current can be considered as following:

$$i_a(t) = \hat{I}\cos(2\pi f t)$$

a. At t = 0, obtain the MMF waveforms due to phase-a (MMF_A), phase-b (MMF_B), phase-c (MMF_C) currents (against position or slot number) separately and obtain the resultant MMF (MMF_TOTAL).
b. Repeat Part (a) at t = 6.67 msec.
c. Repeat Part (a) at t = 10 msec.
d. Repeat Part (a) at t = 13.33 msec.
e. Sketch MMF_A at these four different instants on the same axis using **subplot** function. Comment on the result.
f. Sketch MMF_A, MMF_B and MMF_C at t = 0, on the same axis using **subplot** function. Comment on the result.
g. Sketch MMF_A, MMF_B and MMF_C at t = 6.67 msec, on the same axis using **subplot** function. Comment on the result.
h. Sketch MMF_A, MMF_B and MMF_C at t = 13.33 msec, on the same axis using **subplot** function. Comment on the result.
i. Sketch MMF_A, MMF_B, MMF_C and MMF_TOTAL at t = 0 msec, on the same axis using **subplot** function. Comment on the result.
j. Sketch MMF_TOTAL at these four different instants on the same axis using **subplot** function. Comment on the result.
k. What should be the phase sequence of the applied currents so that the total MMF rotation is reversed?

Q.2. (30 pts) Consider the AC machine given in Figure 1. Suppose that the air gap flux density is given as:

$$B = \sin(\Theta) + 0.3\sin(3\Theta) + 0.18\ \sin(5\Theta) + 0.11\sin(7\Theta) + 0.09\sin(9\Theta)$$

The machine dimensions are: core radius (r) = 0.3 m, core length (l) = 0.5 m.

For the following components, fundamental, 3^{rd}, 5^{th}, 7^{th} and 9^{th} harmonic;

a. Find the flux/pole and plot against harmonic order (up to 10th)..
b. Find the distributon factor, pitch factor and winding factor and plot against harmonic order (up to 10th), on the same axis using **subplot**. Comment on the results.
c. Find the voltage (in rms) induced on a coil wound on the rotor and plot against harmonic order (up to 10th). Comment on the results.
d. Obtain the overall flux/pole by combining the given harmonic components and plot against position along with its fundamental component.
e. Obtain the induced voltage by combining the calculated harmonic components and plot against time along with its fundamental component. Note that the calculated voltages are in RMS.
f. Obtain the line-to-line voltage by combining the phase-a and phase-b voltages and plot against time.
g. Comment on the results in parts (d), (e) and (f).

Q.3. (20 pts) Suppose that the stator windings of a 4 pole AC machine are supplied by balanced ***three phase AC currents*** as given below:

$$i_a(t) = \hat{I}\cos(2\pi f t)$$

$$i_b(t) = \hat{I}\cos(2\pi f t - {}^{2\pi}/_{3})$$

$$i_c(t) = \hat{I}\cos(2\pi f \mathrm{t} - {}^{4\pi}/_{3})$$

and the rotor (on which a single coil is wound) is rotated at N_r in the ***same direction with the MMF*** produced by the stator. Find the frequency of the voltage seen on the rotor coil for the following cases:

a. f = 50 Hz & N_r = 1400 rpm

b. f = 50 Hz & N_r = 1100 rpm

If now the rotor rotation is reversed; what will be the frequency of the voltage seen on the rotor coil for the following cases:

c. f = 50 Hz & N_r = 1400 rpm

d. f = 50 Hz & N_r = 1100 rpm

Explain all your steps in detail!