Homework 2

This homework can be solved by hand (pencil and paper). You should submit your solution to the "homework box" in front of the Machinery Lab. Late submissions will not be accepted!

Q.1. (60 pts) Consider a 2-pole, 50 Hz AC machine. The machine properties are as follows:

Stator: 2-pole, 3-phase, double layer, fractional-pitched, 18 slots, 30 series conductors per coil side.

Rotor: 2-pole, 1-phase, single layer, full-pitched, 12 slots, 10 series conductors per coil side.

Rotor radius is **10 cm**. Air gap distance is **2 mm**. Rotor core axial length is **30 cm**.

a. Draw the rotor winding diagram.
b. Calculate the rotor winding factor.
c. Calculate the peak value of the rotor MMF if the rotor winding is excited by 10 Amps DC.
d. Calculate the flux per pole created by the rotor MMF. *HINT: First calculate the flux density.*
e. Suppose that the rotor is rotating at 3000 rpm. Under these conditions, the fundamental component of the induced EMF on one of the stator phases is measured as 350 Vrms. Find the possible pitch factors for the stator winding.
f. Draw the corresponding stator winding diagrams for the possible cases found in part (e).
g. Which harmonic order can be eliminated from the induced voltage of the stator phases for each pitch factor? Which pitch factor you found in part (e) is more advantageous?
h. Assume now that, the rotor is not excited and not rotated, and the stator is excited by balanced, 50 Hz, three-phase currents with peak value of 5 Amps. Calculate the peak value of the stator MMF. Calculate also the flux density, flux per pole and the induced voltage on the rotor terminals.

Q.2. (40 pts) A series of tests are made on a 3-phase, 700kW, 690V, 4-pole, 50 Hz, Y connected, wound rotor induction machine and the following results are obtained for one phase of the motor:

Locked rotor test: P_1 = 4 kW, V_1 = 34 V, I_1 = 250 A *(all variables are per phase)*

No load test: P_1 = 4.5 kW, V_1 = 400 V, I_1 = 8.5 A *(all variables are per phase)*

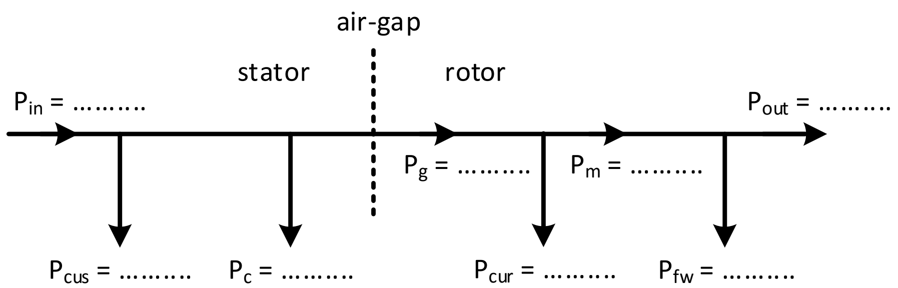
The total rotational loss of the machine at no load test is 4.5 kW.

The DC resistance measured between two phases is: R_{dc} = 0.06 Ω

Assumptions:

- The rotational loss is constant at all operating conditions.
- Throughout the question, the shunt branch is moved to the stator terminals.
- In the equivalent circuit: $X_1 = X_2'$

a. Find all the equivalent circuit parameters of this machine. Draw its equivalent circuit (referred to the stator) and show those parameters.
b. Calculate the synchronous speed.
c. Calculate the slip at maximum torque.
d. Calculate the maximum torque when rated terminal voltage is applied to the machine.
e. Calculate the starting torque when rated terminal voltage is applied to the machine.
f. Draw the torque speed characteristics (all three regions) of this machine and show those points.
g. ***Increase**, **decrease** or **no change.***
    - What happens to the maximum torque when the terminal voltage is increased?
    - What happens to the maximum torque when external resistances are connected to the rotor windings?
    - What happens to the starting torque when the terminal voltage is increased?
    - What happens to the starting torque when external resistances are connected to the rotor windings?
h. Suppose that a constant torque load is connected to the shaft of this machine when the applied voltage is rated and the machine slip is observed as 0.05. What is the load torque? What is the rotor speed?
i. At the operating condition in (h), find the efficiency of the machine. Fill the power flow diagram given below. Note that all power components should be calculated as total power (not per phase).



P_{cus}: Stator copper loss, P_c: Core loss, P_g: Air gap power, P_{cur}: Rotor copper loss

P_m: Gross mechanical output power, P_{out}: Net mechanical output power

P_{fw}: Rotational loss (friction and windage)