Department of Energy Science and Engineering
Indian Institute of Technology Bombay

EN 213 Electrical Networks and Machines: Assignment 1

Make suitable assumptions wherever necessary and state them explicilty

Maximum Marks: 30 **Submission date: 06/11/2024**

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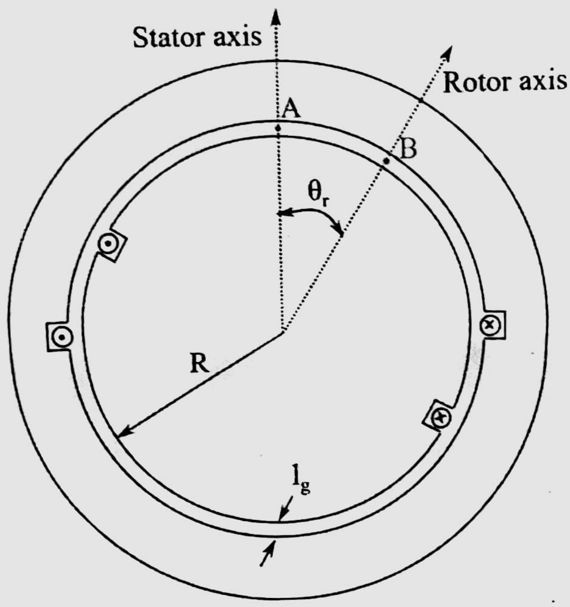
1. The cross-sectional view of AC machine shown below consists of cylindrical rotor with 2 slots and N_r turns. The rotor has radius R and carries current I_r. The stator also contains 2 slots and N_s turns, while it carries current I_s. The airgap is of uniform length l_g (<< R). Both the stator and rotor are made up of highly permeable magnetic material. Length of machine is L. The rotor angle θ_r is the angle between stator- and rotor- magnetic axes. Rotor rotates at a constant speed of $\omega_r = \frac{d\theta_r}{dt}$. 'A' and 'B' are the points on the airgap, that lie on the stator- and rotor-magnetic axes respectively.



   (a) Sketch the waveforms for magnetic field intensity (H) and magnetic field density (B), at points A and B (on the airgap), due to I_s alone, as a function of the rotor angle θ_r. [1]

   (b) Sketch the waveforms for magnetic field intensity (H) and magnetic field density (B), at points A and B (on the airgap), due to I_r alone, as a function of the rotor angle θ_r. [1]

   (c) Derive the expression for self inductance of stator (L_{ss}). Does the value of L_{ss} depend on rotor position? If so, compute the minimum and maximum values of L_{ss}. [2]

   (d) Derive the expression for self inductance of rotor (L_{rr}). Does the value of L_{rr} depend on rotor position? If so, compute the minimum and maximum values of L_{rr}. [2]

   (e) Derive the expression for mutual inductance between stator and rotor (L_{sr}). Does this value depend on rotor position? If so, compute the minimum and maximum values of L_{sr}. [2]

   (f) List all possible assumptions made by you, while deriving the expressions in (b)-(d). [2]

2. The following tests are conducted on a 3-phase, star-connected round-rotor synchronous generator, rated at 1.5MVA and 2kV.

   Test 1: The machine is rotated at rated speed under no load and the input mechanical power is measured to be 40 kW. The field circuit is energized during this test.

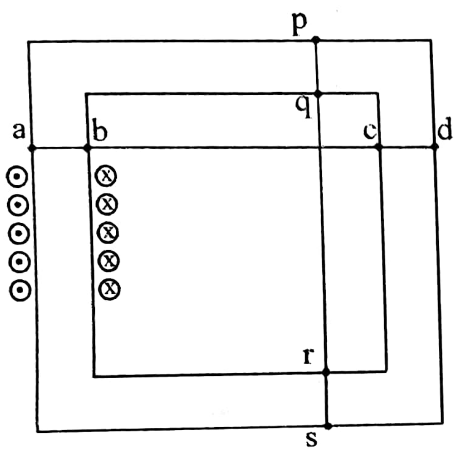
Test 2: A DC voltage of 300V is applied between two of the stator phase terminals of the machine at stand-still and the current is measured to be 750A.

(a) Using the data obtained from the above tests, determine the peak efficiency of machine, if the load is operating at a lagging power factor of 0.8. Also, determine stator copper losses in the machine under this condition. Assume that the stray-load losses are negligible. [2]

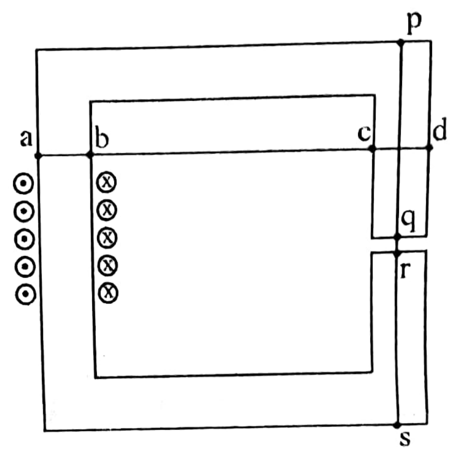
(b) Plot the variation of efficiency verses load current (from no-load till rated load). [2]

(c) Repeat part (b), if the power factor of the load is unity. [2]

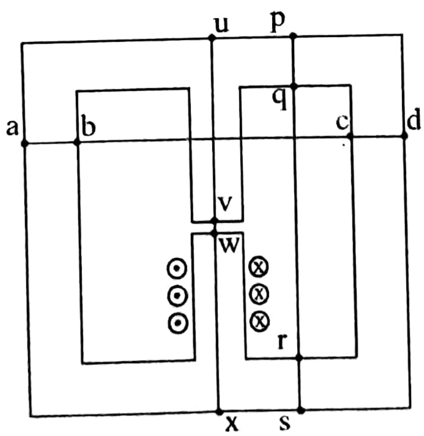
3. Consider the following magnetic circuits shown in the figure below. For all the three magnetic circuits, the cross-sectional area is the same throughout the core. The coil has 200 turns and carries a current of 2 A. The relative permeability of the core is 4000, and the air gap length is 1 mm (located at the centre of the right limb and centre limb in circuits (ii) and (iii) respectively). Assume that the magnetic circuit is linear. The area of outer and inner squares are 2500 and 1936 sq.cm respectively.



(i)



(ii)



(iii)

(a) For the circuit in Fig.(i), derive the analytical expressions for variation in magnetic field intensity (H) and magnetic flux density (B), along the straight lines 'abcd' and 'pqrs'. Plot the same and verify your results obtained using FEM software. [3]

(b) Repeat part (a), for the magnetic circuit shown in Fig. (ii). [3]

(c) For the circuit in Fig.(iii), derive the analytical expressions for variation in magnetic field intensity (H) and magnetic flux density (H), along the straight lines 'abcd', 'pqrs' and 'uvwx'. Plot the same and verify your results obtained using FEM software. [5]

(d) Determine the inductance of the coil for the magnetic circuits (i)-(iii). [3]