Ref. No. : Ex/PG/PE/T/111B/2025

M.E. POWER ENGINEERING FIRST YEAR FIRST SEMESTER EXAMINATION-2025

ANALYSIS OF ELECTRICAL MACHINES

Time : Three hours Full Marks: 100

Group A (CO1) (Answer any two questions):

1. Discuss the salient features of Kron's primitive machine?
   Obtain an expression for electrical torque of Kron's primitive machine. Show that no torque is produced by interaction of flux and current on the same axis.
   Draw basic two pole machine representation of (i) DC compound motor,
   (ii) synchronous machine with damper bars. 5+7+4+4
2. Define linear transformation for electrical machines.
   Obtain identical transformations for currents from a rotating balanced 3-phase (a,b,c) winding to a pseudo-stationary 2-phase (d,q) winding. Show that the power invariance is maintained under this transformation.
   For steady state balanced operation with
   $$i_\alpha = I_m \cos(\omega t + \varphi)$$
   $$i_\beta = I_m \sin(\omega t + \varphi)$$
   Determine the primitive coil currents i_d and i_q and show that these are steady dc values. 3+10+3+4
3. a) What is connection matrix? Find the new voltage matrix and the transformed impedance matrix in case the currents are instantaneous when the current connection matrix C is given. 10
   b) A 5hp, 400 V, 3 phase star connected, 4 pole, 50 Hz Induction motor has the following data:
   $r_s = 0.025\ ohm, r_r = 0.15\ ohm, R_c = 500\ ohm, X_m = 75\ ohm, x_{ls} = x_{lr} = 0.5\ ohm$
   Find the torque and the expression three phase currents for synchronously rotating reference frame when its speed is 1450 rpm. 10

Group B (CO2) (Answer any three questions)

4. Derive the expressions for the armature mutual inductances for a salient pole synchronous machine from consideration of its basic parameters. 10

5. A two pole 3-phase 50 Hz star connected uniform air-gap synchronous machine has the following data:
   Armature winding - synchronous inductance = 0.05H per phase, Resistance is negligible; Field winding – self-inductance = 50 H, resistance = 25 Ω; Mutual inductance between field winding and any one of armature winding, when their magnetic axes are aligned = 0.5 H.
   This synchronous generator delivers power to a balanced load at 0.8 pf lagging and at rated speed. Field winding is energized from 100 V dc source. If the terminal voltage across the load terminals is 400 V per phase, compute the power output. 10

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6. Develop the expression of the transient field current when a sudden three phase short circuit occurs at the terminals of a three phase synchronous generator with negligible resistances in the field and armature windings. State the assumptions. 10

7. A 3-phase 11 kV, 100 MVA, star connected turbo alternator has the following pu constants.

$$X_d = 1.0,\ X'_d = 0.2,\ T'_d = 1s, X''_d = 0.1, T''_d = 0.2s$$

This alternator is operating at no-load with its rated terminal voltage. Now a sudden short-circuit occurs across its terminals; armature transformer voltages are neglected.

(i) Derive the expression of the current in phase A as a function of time and find its value. Assume that the short has occurred when phase A is 90° away from field axis.

(ii) If the transformer voltages are considered, then find maximum possible magnitude of dc component just after the short circuit. 10

Group C (CO3) (Answer any three questions):

8. Develop the induction machine model in arbitrary reference frame. Also derive the expression of the corresponding torque. 10
9. Discuss the rotor field oriented voltage control. 10
10. Derive the stator short circuit current for the three-phase sudden short-circuit at the terminals of a large induction motor. 10
11. Find the torque expression for the induction motor using universal field oriented control. Also draw the universal decoupling network. 10