Ref. No. : Ex/PG/POW/PE/T/121B/2025

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

ANALYSIS OF ELECTRICAL MACHINES

Full Marks: 100

Group A (CO1) (Answer any one question):

1. What is the Kron's primitive machine? Explain along with a diagram.
Determine the voltage matrix equation for the various windings of Kron's primitive machine. What insights can be derived from the impedance matrix of Kron's primitive machine?
Illustrate the fundamental representation of a two-pole machine for (i) a DC compound motor, (ii) a synchronous machine having damper bars. 5+10+6+4

2. Define invariance of power for electrical machines.
Obtain identical transformations for currents from a rotating balanced 2-phase (α, β) winding to a pseudo-stationary 2-phase (d,q) winding.
Show that the power invariance is maintained under this transformation.
Determine the coil currents i_d and i_q of the pseudo-stationary 2-phase (d,q) winding and show that these are steady dc values for the steady state balanced operation with

$$i_\alpha = I_m \cos(\omega t + \varphi)$$
$$i_\beta = I_m \sin(\omega t + \varphi)$$

3+12+5+5

Group B (CO2) (Answer any two questions)

3. Find the expression for the armature self-inductance of the armature, for a salient pole synchronous machine by examining its fundamental parameters.
A 3-phase 50 Hz cylindrical synchronous machine possesses the following specifications:
Self-inductance for phase A = 3 mH and armature leakage inductance = 0.5 mH.
Determine the mutual inductances among the armature phase windings and its synchronous reactance. 10+5

4. (a) For a salient pole synchronous motor, P_1 and P_2 are the maximum values of electromagnetic power and reluctance power respectively. Show that the load angle delta δ at which the resultant power is maximum, can be obtained from the relation

$$cos\delta = \frac{-P_1 \pm \sqrt{P_1^2 + 32P_2^2}}{2P_2}$$

If the reluctance power is($^1/_4$) that of the electromagnetic power then calculate the load angle for steady state power limit.
(b) A two pole 3-phase 50 Hz star connected uniform air-gap synchronous machine has the synchronous inductance of 0.05H per phase. The armature winding resistance is negligible. The field winding has the self-inductance of 40 H and the resistance of 20 Ω. The mutual inductance between field winding and any one of armature winding is 0.5 H when their magnetic axes are aligned. This synchronous generator supplies power to a balanced load at 0.8 pf lagging and at rated speed. The field winding is energized

from 110 V dc supply. If the terminal voltage across the load terminals is 400 V per phase, compute the power output. 5+10

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

$$X_d = 1.25,\ X'_d = 0.2,\ T'_d = 1.2s, X''_d = 0.1, T''_d = 0.15s$$

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) Find the current in phase a as a function of time. Assume that the short has occurred when phase A is 100° away from field axis. Derive the formula used.

(ii) Write an equation for the envelope of short circuit current wave as a function of time.

(iii) Find the rms value of symmetrical short circuit current in phase A, just after the three phase short circuit. 15

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

8. Derive the space phasor equations for the stator currents, torque of induction machines and its inductance matrix. 10+5

9. Derive the torque expression for the Universal Field Oriented current controller in terms of air gap flux linkage. Draw the universal decoupling network. 15

10. Discuss the rotor field oriented voltage control.

Group D (CO4) (Answer any one question):

11. Develop the equivalent circuit for transients for the deep bar and double cage induction motor using space phasor parameters. Show the influence of skin effect on the rotor parameters. 15

10. Derive the stator short circuit current for the three-phase sudden short-circuit at the terminals of a large induction motor. 15