Ref. No. : Ex/PG/PE/T/111B/2024

M.E. POWER ENGINEERING FIRST YEAR FIRST SEMESTER - 2024

**ANALYSIS OF ELECTRICAL MACHINES**

Full Marks: 100

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

1. What is Kron's primitive machine?
   Write the voltage equations of the 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 shunt motor with interpoles, (ii) synchronous machine with damper bars and (iii) induction motor.
   3+3+8+3+3

2. What is meant by "invariance of power" as applied to the electrical machines? What is its role in linear transformation?
   Obtain the identical transformations for currents from a rotating balanced 3-phase (a,b,c) winding to a rotating balanced 2-phase (α, β, 0) 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 $i_q$.
   3+2+4+4+7

3. a) Define the connection matrix? Find the new voltage matrix and the transformed impedance matrix in case the currents are (i) instantaneous, (ii) expressed in complex notation when the current connection matrix C is known. 10

   b) A 3 phase 8 pole, 50 Hz squirrel cage induction motor develops a torque of 250 Nm at a rated phase voltage of 400 V. The three phase stator winding is replaced by a 2 phase stator winding for which the number of poles, effective number of turns per phase and the conductor size are not changed. If the induction motor is able to operate, then find the rated phase voltage of two phase induction motor. If the two phase induction motor is energized at that rated phase voltage from 2 phase supply, then find (i) the rated phase voltage of the two phase induction motor and (ii) the torque. Ignore the losses. 10

**Group B** (CO2) (Answer any three questions)

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

5. a) A 3-phase 50 Hz cylindrical synchronous machine has the following parameters:
   Self-inductance for phase A = 2.5mH and Armature leakage inductance = 0.5 mH
   Calculate the mutual inductances between the armature phase windings and its synchronous reactance. 5

b) 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 $\delta$ 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. 5

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, 100MVA, star connected turbo alternator has the following pu constants.

$$X_d = 1,\ X'_d = 0.25,\ T'_d = 1s, X''_d = 0.15, T''_d = 0.25s$$

A sudden short-circuit has occured at its terminals. This alternator was operating at no-load with its rated terminal voltage initially. Neglect the armature transformer voltages.

(i) Find the current in phase A as a function of time. Assume that the short circuit has occurred when phase A is 120° away from the field axis.

(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. 10

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

8. Write the space phasor equations of induction machines and derive its inductance matrix. 10
9. Develop the induction machine torque equation in the stator reference frame and the synchronously rotating reference frame. 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. Develop the equations related to the universal field oriented control of induction motor and draw the corresponding decoupling network. Why this control is called the indirect flux oriented control? 10