DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

I SEMESTER M.TECH. (POWER ELECTRONICS & DRIVES)
END SEMESTER EXAMINATIONS, NOVEMBER-DECEMBER 2023

MODELLING OF ELECTRICAL MACHINES [ELE 5115]

REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 07 December 2023** **Max. Marks: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. Derive the magnetic energy stored as a function of plunger position 'x' for a relay shown in Fig Q(1A). N=1500, g=2 mm, d=0.15 m, l=0.1 m & i=5 A. Assume h>>g.

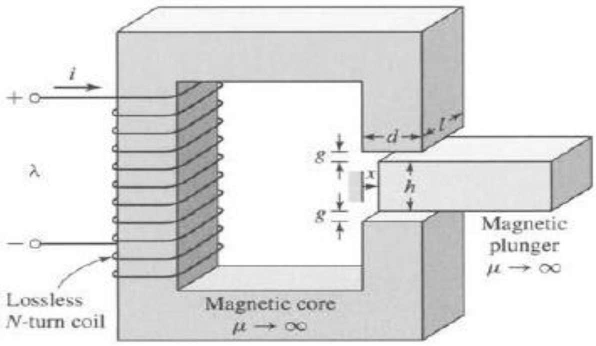

Fig. Q(1A) ***(03)***

1B. Consider a nonlinear magnetic system with cylindrical motion. Derive an expression for Torque using (i) Field-energy method and (ii) Co-energy method. ***(04)***

1C. The inductance of a solenoid as a function of displacement x is given by

$L(x)=0.15x^4-1.1x^3+2.86x^2-3.5x+2.8$

Calculate the force acting on the solenoid for an exciting current of 0.75A. ***(03)***

2A. With the help of neat diagrams, show that the rotor self-inductance of a constant airgap machine is independent of rotor position. ***(03)***

2B. With neat diagrams, derive an expression for self-inductance of a salient pole rotor. ***(03)***

2C. Obtain the transformation matrix to transform 3-phase variables to 2-phase variables using (i) power invariance and (ii) power variance approach. ***(04)***

3A. The following are the 3-phase ac voltages v_a=220sinωt, v_b=220sin(ωt-120°) & v_c =220 sin (ωt +120°). Transform these voltages to (i) stationary frame and (ii) rotating dq frame. ***(05)***

3B. Consider the dynamic model of a 3-phase induction motor in the stationary reference frame.

$V_{\alpha\beta}^{\alpha\beta} = RI_{\alpha\beta}^{\alpha\beta} + L\frac{d}{dt}I_{\alpha\beta}^{\alpha\beta} + GwI_{\alpha\beta}^{\alpha\beta}$ where

$$\boldsymbol{L} = \begin{bmatrix} l_{ls}+1.5L_{ms} & 0 & 1.5M_{sr}cos\theta & -1.5M_{sr}sin\theta \\ 0 & l_{ls}+1.5L_{ms} & 1.5M_{sr}sin\theta & 1.5M_{sr}cos\theta \\ 1.5M_{sr}cos\theta & 1.5M_{sr}sin\theta & l_{lr}+1.5L_{mr} & 0 \\ -1.5M_{sr}sin\theta & 1.5M_{sr}cos\theta & 0 & l_{lr}+1.5L_{mr} \end{bmatrix} \&$$

$$\boldsymbol{G} = \begin{bmatrix} 0 & 0 & -1.5M_{sr}sin\theta & -1.5M_{sr}cos\theta \\ 0 & 0 & 1.5M_{sr}sin\theta & -1.5M_{sr}sin\theta \\ -1.5M_{sr}sin\theta & 1.5M_{sr}cos\theta & 0 & 0 \\ -1.5M_{sr}cos\theta & -1.5M_{sr}sin\theta & 0 & 0 \end{bmatrix}$$

Derive the dynamic model of the machine in pseudo-stationary reference frame. ***(05)***

4A. Develop a small signal model of a separately excited dc motor with field voltage, armature voltage and load torque as inputs and field current, armature current and speed as the outputs. Also derive the transfer function $\Delta\omega_r(s)/\Delta V_a(s)$. ***(05)***

4B. Analyze the behaviour of q-axis equivalent circuit diagram of a salient pole synchronous machine with $S\psi_{qs}(s)$ as output & $I_{qs}(s)$ as the input. ***(05)***

5A. Consider the machine coils shown in Fig Q(5A). By observation, write the dynamic equations of a salient pole synchronous machine and hence develop the equivalent circuit diagrams of d-axis & q-axis in synchronous reference frame.

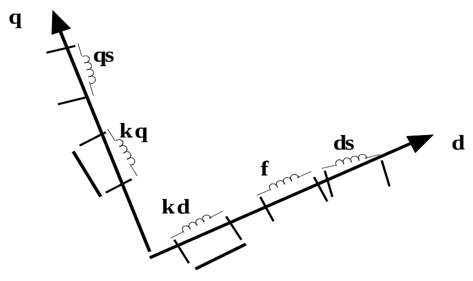

Fig. Q(5A) ***(04)***

5B. With the help of phasor diagram of an under-excited salient pole synchronous machine, show that the active power

$$P = \frac{EV_a sin\delta}{x_{ds}} - \frac{EV_a sin2\delta}{2}(\frac{1}{x_{qs}} - \frac{1}{x_{ds}})$$ ***(03)***

5C. Compare the working principle of permanent magnet synchronous machine and synchronous reluctance machine. ***(03)***