MIDDLE EAST TECHNICAL UNIVERSITY

ELECTRICAL AND ELECTRONICS ENGINEERING DEPARTMENT

EE 462 Utilization of Electrical Energy

Midterm I Examination

6 April 2018

Duration: 100 minutes

Attempt all questions Solutions

Show all your calculations for full credit.

Write your name on all papers, and please mention it clearly if you continue your solutions on a different page.

Student Name: Muammer ERMİŞ

Student ID: ____________________

Q1		35pts
Q2		35pts
Q3		40 pts
Total		110

Q1) (35 pts) An illustrative diagram for a conveyor band system is as shown in Fig. 1.

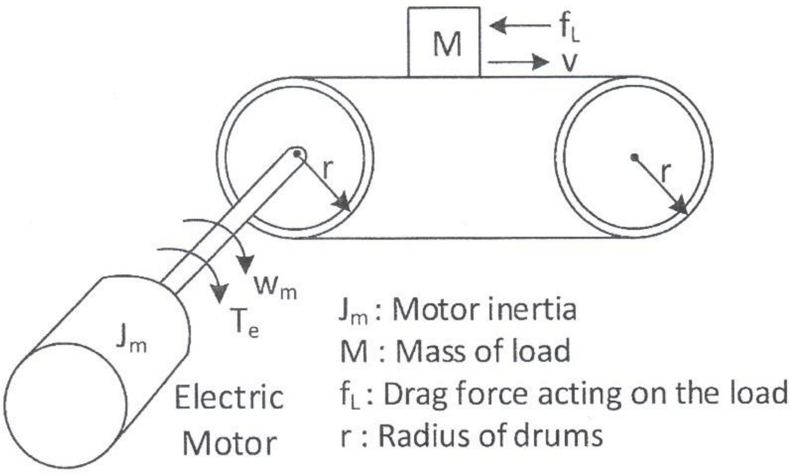

Figure 1. Conveyor band

a) Obtain the torque balance equation on the rotational side by referring force balance equation of the linear motion side to rotational side.

Assume that the motor shaft is rigid and inertia of drums is negligibly small.

b) Calculate motor speed in rpm by assuming that v = 5 m/s and r = 0.2 m. Is it a normal, expected value? Discuss.

c) How can we match the linear speed of v = 5 m/s, if the driving motor is a 3-phase, 4-pole, 50 Hz induction motor? Recommend a method and quantify it.

a) $f = M\frac{dv}{dt} + f_L$

$V = r \cdot \omega_m$

$T = f \cdot r = r^2 M \frac{d\omega_m}{dt} + r \cdot f_L$

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$T_{em} = J_m \frac{d\omega_m}{dt} + T$

$T_{em} = J_m \frac{d\omega_m}{dt} + r^2 M \frac{d\omega_m}{dt} + r \cdot f_L$ //

b) $\omega_m = V/r = 5/0.2 = 25$ mech rad/s

$$n_m = \omega_m \times \frac{60}{2\pi} = 238.7 \text{ rpm} \ //$$

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It is unusually low for standart low or medium power motors.

c) $n_s = \frac{120 \cdot f}{p} = 1500$ rpm

Assume $s = 3\%$

$n_r = (1-s)\, n_s = 1455$ rpm

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Therefore, a speed reduction type gear box may be used.

Gear-ratio $= N_m/N_L \cong 240/1455 \cong 1/6$ //

Alternative soln: Belt drive.

Q2) (35 pts) A fully-static electric motor drive drives a constant torque load of 637 Nm, initially at 1500 rpm as shown in Fig. 2.a and 2.b. The combined inertia of the motor and its load is $J = 10$ kg.m^2.

The problem is to bring the motor-load combination to a stop.

a) What is the time spent in bringing the operating point from initial steady-state operating point to point 1 in Fig. 2.a according to our main assumption?

Time constants, $T_e \ll T_m$

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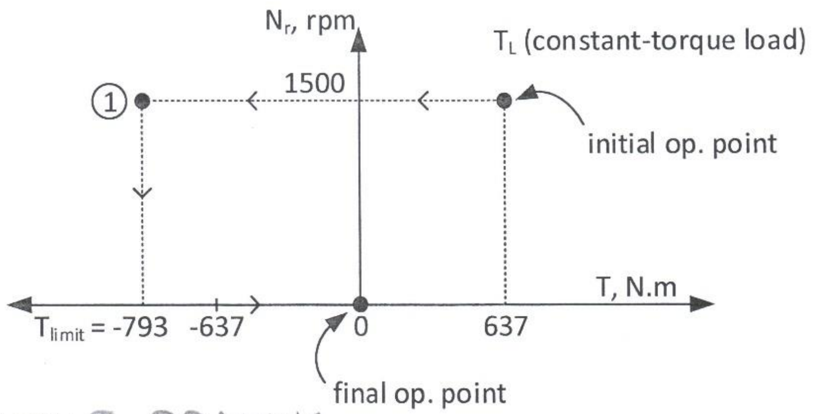
In an actual system it is of the order of a few ms.

One may assume that it is zero.

b) What may be the braking technique illustrated in Fig. 2.a ? Describe it. Calculate the braking time in seconds. Determine the shaft speed variation against time during braking. Sketch it.



REGENERATIVE BRAKING.

Figure 2.a.

$$J\frac{dw}{dt} = T_e - T_L \rightarrow 10\frac{dw}{dt} = -793 - 637$$

$$\frac{dw}{dt} = -\frac{793+637}{10} = -143 \quad \text{and} \quad W_0 = 1500 \times \frac{2\pi}{60}$$

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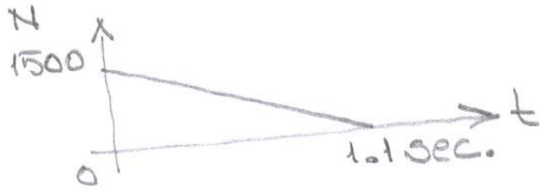
$$= 157.08 \text{ mech rad/s}$$

Since the right hand side of diff. eqn. is constant,

$$\frac{\Delta W}{\Delta t} = -143 \quad \text{and} \quad \Delta W = 0 - 157.08 = -157.08$$



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$\therefore\ \Delta t = 1.1$ s //

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c) Repeat part b for the speed/torque locus given in Fig. 2.b.

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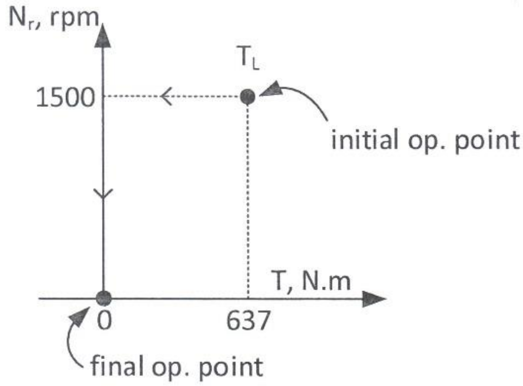
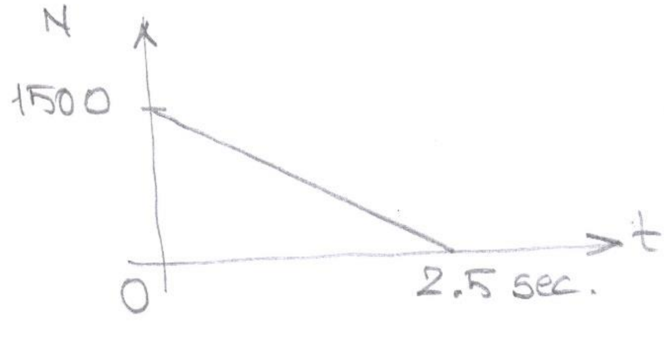


Figure 2.b.

$$\frac{\Delta\omega}{\Delta t} = (0 - 637)/10 = -63.7$$

Therefore, $\Delta t \cong 2.5$ s //



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Coasts down under the drag force of load and friction and windage.

d) Comment on the results.

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Q3) (40 pts) The 250 kW separately-excited DC machine in Fig. 3.a will be used as the driving machine in a 4-quadrant dc motor drive. The resulting drive characteristics are as given in Fig. 3.b.

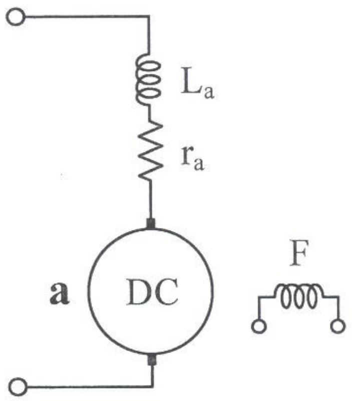

Figure 3. a.

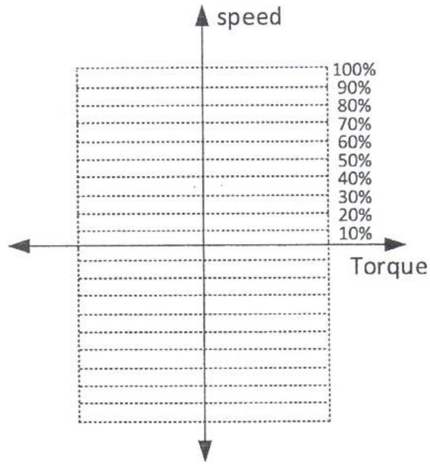

Figure 3. b.

Available drive components that can be used in the construction of the resulting 4-Q drive are as given in Fig. 3. c.

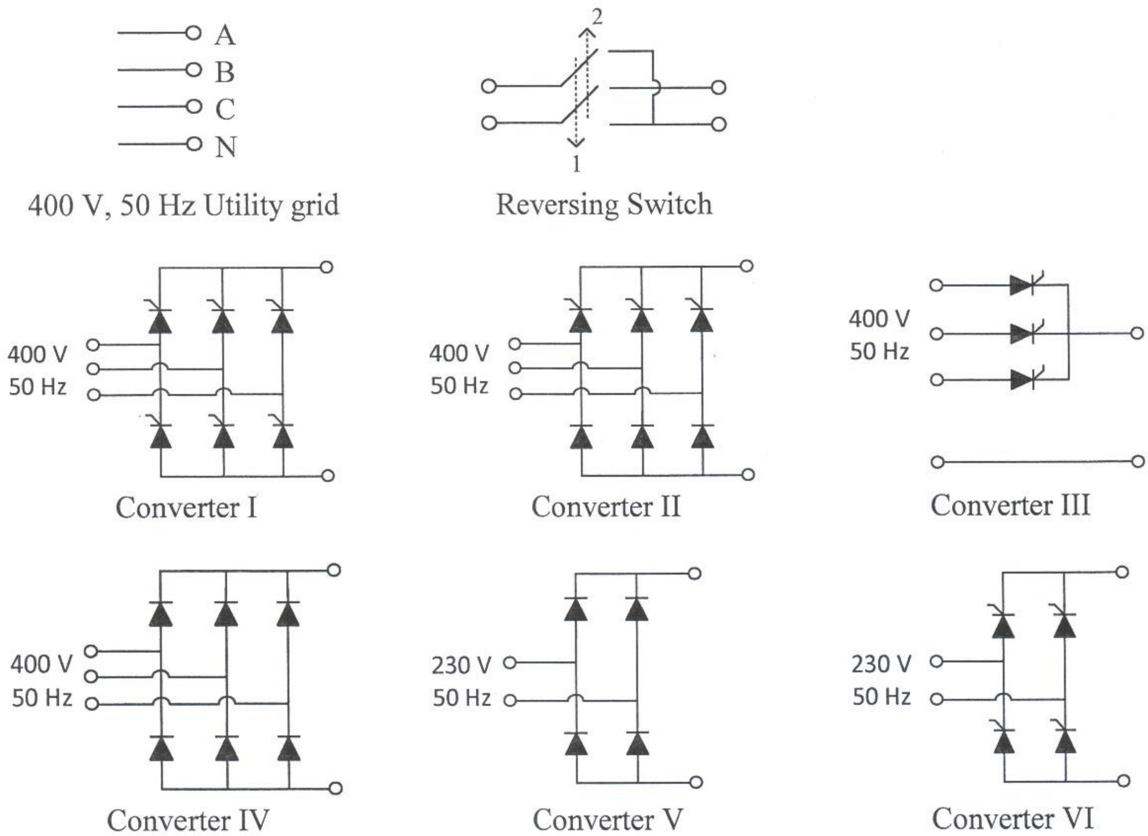

Figure 3. c.

PART I. Design the 4-Q DC motor drive by using **some** of the drive components shown in Fig 3.c. **More than one** component of the same type **may be used** in your circuitry. Draw the circuit diagram of the overall system excluding control circuitry. State whether the resulting drive is a fully-static system or not.

List its advantages and disadvantages. Give the reasoning behind your choice.

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PART II. Define **positive conventions** for applied motor voltage (V_m), armature current (Ia), induced armature emf (E_a), speed (w), torque (T_e), power flow in the armature circuit (P) and field current (I_f) on the same schematic diagram of the DC machine.

Draw now the speed-torque plane and mark the operating quadrants from Q1 to Q4. On these four quadrants, **mark** the polarities of V_m and E_a and directions of I_a, T_e, w and P. Which converter/s and the reversing switch (if used) **are to be operated** in each quadrant. Each converter can be represented by a block. **Compare** magnitudes of V_m and E_a in all quadrants. Mark on these four quadrants the **operation modes** of the DC machine, converter and the resulting drive.

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