U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

Master in Mechanical Engineering | 1st year
M.EM010 |Electromechanical Systems| 2023-2024 – 2nd Semester

Exam

Duration: 2h00.

Notes:
*** Write your name on every exam sheet you submit**
*** Closed book exam**
*** The use of any calculator with graphic support is prohibited**

1. [2] Explain the working principle of a three-phase AC induction motor and how it differs from the three-phase synchronous reluctance motor. In a scenario where variable speed control is crucial, such as operating a large pump in a water cooling system, which motor would you choose? Please provide a justification for your selection.

2. [1.5] In the use of stepper motors, the choice between a unipolar or bipolar driver is naturally conditioned by the motor. Thus, for a two-phases, four-wire stepper motor, which type of driver would you choose? What are the other common two-phases stepper motors that could also be driven by the same type of driver?

3. [1] Regarding electric motors for battery operated vehicles (BEV), not all car manufacturers make use of the same type of motors, but the large majority make use of brushless motors. However, recently BMW introduced the use of brushed synchronous motors. In your opinion, what can justify this option?

4. [1.5] Sketch the characteristic current/time curve for two fuses characterized by the same nominal intensity, one being of the aM type (slow) and the other of the gL type (fast). Provide an example of application for each mentioned fuse.

5. [4] Consider the electrical circuit shown in Figure 1, which represents the 'power circuit' for controlling the direction of rotation of a DC motor.

   a) Identify the components referred by letters, A, B, C, D, E and their respective functions.

   b) Draw the ´control circuit´ for operating the motor. Consider that each direction of rotation starts by pressing a pushbutton (CW and CCW). Additionally, include a pushbutton (ST) to stop the motor.

   c) Regarding the component D, what ´utilization category´ would you expect to have? Justify.

   d) Consider that component E has a trip class 10. What does that mean? What "trip class" would you expect to have in component C? justify.

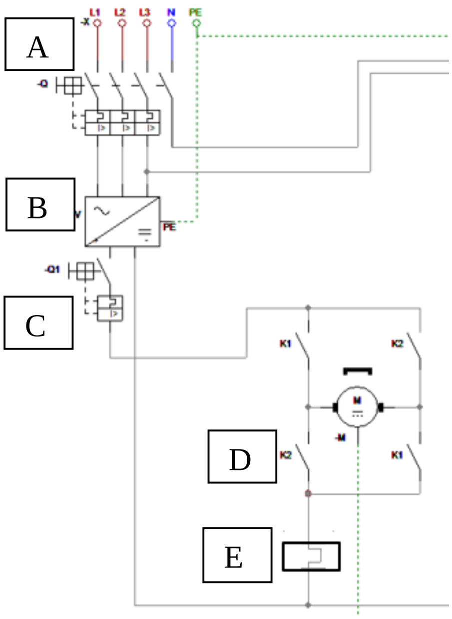

Figure 1

6. [1] Electrical extensions, 25 meters in length, like the one shown in the figure 2, usually incorporate an electrical protection device, and are recommended to be used with the cable fully extended.

   a) Identify and draw the symbol of the protection device that is used.

   b) What can justify the mentioned recommendation of use?

Figure 2

7. [1] When choosing a power meter for electrical installations with three-phase induction motors, identify four essential functions that you believe the power meter should have.

8. [5.5] Food dishes elevators are a type of elevators often used in restaurants which require transfer of these type of loads between two or more floor levels. Fig. 3 represents one of these type of elevators, as well as an example of specification requirements for this type of applications.

   a) Considering the data of Figure 3, which includes the weight of the moving platform (50 kg), the maximum load that can be carried by the elevator (75 kg) and a counterweight (75 kg), calculate the static power and the acceleration power corresponding to maximum load conditions.

   b) Verify whether the motor Z.E.80A4 (0,55 kW) from Table 1 below can drive the elevator with maximum load conditions using a VFD (Variable Frequency Drive) at a frequency of 70 Hz. Consider that a gearbox is used to convert the motor speed at 70Hz to the required elevator speed.

   c) Represent the characteristics curves (speed, torque) and (frequency, voltage) including the working point at 70Hz frequency.

   d) Please indicate three reasons to justify that using a VFD (Variable Frequency Drive) is a better solution than using a two speed motor for this application.

   e) What is the meaning of the Z_0 parameter in Table 1 and its application in the selection process of an induction motor?

- $m_{max.load} = 75\ kg$
- $m_{moving\ platform} = 50\ kg$
- $m_{counterweigth} = 75\ kg$
- $v_{max} = 0{,}4\ m/s$
- $a = 0{,}2\ m/s^2$
- $\eta_{global} = 85\ \%$

Figure 3

Table 1: The values correspond to a 50 Hz specification; ZBE corresponds to a motor with an incorporated electromechanical brake.

4-pole Z.E. motors 100% CDF (IE2)

Type	P_N [kW]	n_N [rpm]	M_N [Nm]	I_N 400 V [A]	$\cos\varphi_N$	IE - 2 $\eta_{1/2}$ %	$\eta_{3/4}$ %	4) $\eta_{4/4}$ %	I_A/I_N	M_A/M_N	M_K/M_N	J_{Mot} [$kgm^2 \times 10^{-3}$] ZNE	ZBE	Z_0 [1/h] 1)	2)	Brake Type	[Nm] M_{BStd}	Weight [kg] 3) ZNE	ZBE
Z.E 63 B4	0,18	1385	1,2	0,6	0,64	66,5	71,2	72,1	4,0	2,8	2,8	0,55	0,61	13000	13000	**B003**	2,5	7,8	10,5
Z.E 71 A4	0,25	1390	1,7	0,8	0,63	69,5	74,0	74,9	4,0	3,0	3,0	0,65	0,71	10000	12000	**B007**	3,4	8,5	11,2
Z.E 80 A4	0,55	1420	3,7	1,5	0,68	78,0	78,3	78,1	5,0	3,0	3,0	1,43	1,49	7800	11200	**B007**	7,6	12,2	15,6
Z.E 80 B4	0,75	1425	5	2	0,66	79,3	82,2	79,6	4,9	2,8	3,0	2,06	2,19	9400	13500	**B020**	10	15,1	19,5
Z.E 90 A4	1,1	1445	7,3	2,7	0,69	79,8	82,3	81,4	5,7	2,3	2,8	2,47	2,60	9400	13500	**B020**	16	16,0	20,4
Z.E 90 B4	1,5	1435	10	3,3	0,77	82,1	83,4	82,8	6,2	2,7	3,2	4,60	4,73	5000	7200	**B020**	20	20,7	26,3
Z.E 100 A4	2,2	1430	14,6	4,7	0,79	83,8	84,9	84,3	6,1	2,3	3,0	5,75	6,21	5400	7800	**B050**	33	24,5	33,6
Z.E 100 B4	3	1445	19,8	6,6	0,77	83,6	86,4	85,5	5,6	2,0	2,8	7,06	7,52	5300	7600	**B050**	39	23,2	32,3

(shaded) Only for operation with an inverter

1) Operation with brake rectifier without high-speed excitation
2) Operation with brake rectifier with high-speed excitation
3) Weight for B14 model
4) The nominal efficiencies as per efficiency class IE2 in accordance with IEC 60034-30 are specified

Duration: 2h00.

9. [2.5] Figure 4 below represents the torque/speed and torque/current curves of a permanent magnet (PM) servomotor (CMP80L). Included on the torque/speed graphs two points are marked with a star representing the effective and maximum working points of a given application.

   a) Indicate three of the most important characteristics of servomotors that make them a first choice, when selecting a drive solution for a moving axis of a CNC machine (ex. Milling machine).

   b) Based on the graphs of Figure 4 and the marked points estimate the values of the most relevant parameters when selecting a drive for this motor. Assume the stall torque (T_0) is 27,5 Nm and the stall current (I_0) is 27,8 A.

   c) Considering that the effective working point is too close to the limiting curve, what characteristic of the motor would allow increasing this limit?

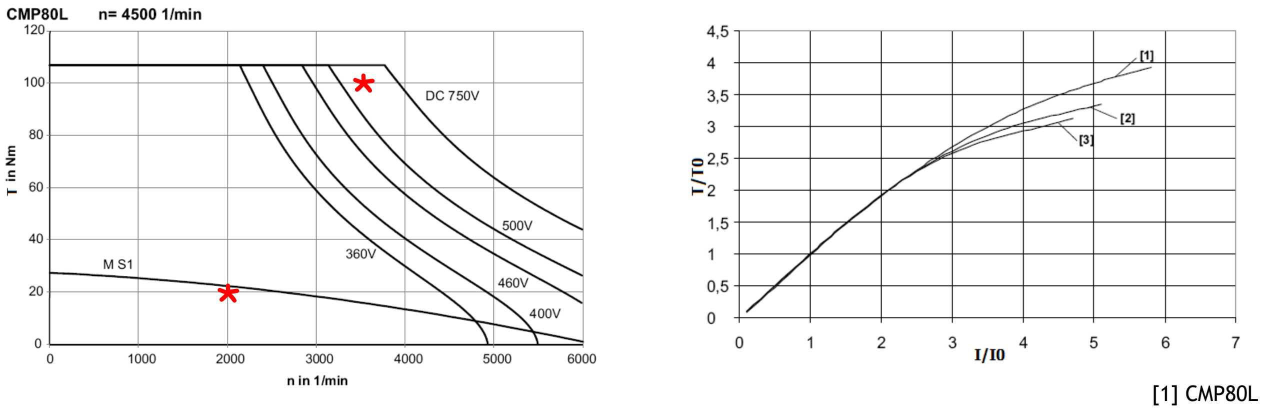

Figure 4

Notes:

$$J_{linear\ load}^{motor} = \frac{m}{\eta} \cdot \left(\frac{v}{\omega}\right)^2; \quad T_{max}^{f_2 > f_{base}} = T_{max}^{f_{base}} \cdot \left(\frac{f_{base}}{f_2}\right)^2; \quad \sum T_{ext} = J_{total} \cdot \alpha ;$$

$$T_{max\ load}^{f max} < 130\% \frac{P_N^{vfd}}{\omega_{max}}$$