University Dr. Moulay Tahar of SAIDA
Faculty of Sciences and Technology
Department of Electrotechnics and Automatics

Year: 2025-2026
In-depth electrical machines

Final exam (01H30)

Question (02 points):

1. Give the main starting methods of induction motors.

Exercise 01 (08 points):

The nameplate of a separately excited DC motor shows the following information:

$$U = 240\ V,\ I = 35\ A,\ P_u = 7\ kW,\ n = 800\ rpm$$

A. Calculate (at rated load):

1- The motor efficiency, given that the inductor copper losses are *150 W*.

2- The armature copper losses, given that the armature resistance is *0.5 Ω*.

3- The electromagnetic power and the collective losses.

4- The electromagnetic torque, the useful torque, and the torque due to constant losses.

B. The motor operates at constant torque. The armature still absorbs $I = 35\ A$. To control the speed, we modify the voltage U.

1- Name an electronic device that allows the speed control.

2- The new voltage U takes the value $U' = 110\ V$. Calculate the new e.m.f. (E') and the corresponding rotation speed (n').

Exercise 02 (10 points):

The characteristics of a three-phase alternator are as follows:

- Star-connected stator windings at the frequency of *50 Hz*.
- No-load characteristic: $E = 152.\ I_e$
- Resistance between two phases of the armature $R = 1\ \Omega$.
- Synchronous reactance $X_S = 1.75\ \Omega$.

1. Find the synchronous impedance of the machine Z_S.

2. The alternator supplies a balanced three-phase inductive load with a power factor of *0.8*. The RMS line voltage at the armature terminals $U = 5.5\ kV$. The RMS line current $I = 577\ A$.

2.1 What is the intensity of the excitation current I_e?

2.2 Calculate the copper losses in the armature p_{js}.

2.3 A no-load test gave the total no-load losses equal to *80 kW*. What is the efficiency of the alternator?

Good luck.

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Question : (2)

* Main starting methods of induction machines :

- Soft starter - star - delta - dimmer - Rheostat - reduced load -

Exercise 01 : (08)

$U = 240\,V$ $\quad I = 35\,A$ $\quad P_u = 7\,kW$

$n = 800\,rpm$

A.1 Motor efficiency : $\eta = \frac{P_u}{P_A}$

$P_A = UI + U_e I_e$ $\quad P_{je} = r_e I_e^2$

$= (240 \cdot 35) + 150$ $\quad = (\varepsilon \cdot I_a) I_e$

$= 8400 + 150$ $\quad = U_e I_e$

$= 150\,W$

$P_A = 8550\,W$

$\eta = \frac{7.000}{8.550} = \boxed{81,87\ \%}$ (1)

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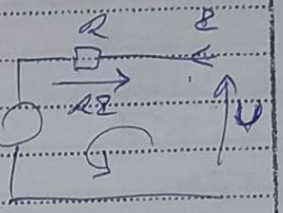
A.2. Armature copper losses:

$P_{JR} = R I^2 = 0,5 \cdot 35^2 = \boxed{612,5 \text{ W}}$ (1)

A.3. Electromagnetic power

$P_{EM} = E I$



$E = U - RI$

$= 240 - (0,5 \cdot 35) = 222,5 \text{ V}$ $U = E + RI$

$P_{EM} = 222,5 \cdot 35 \Rightarrow P_{EM} = \boxed{7\,787,5 \text{ W}}$ (0,5)

- Collective losses:

$P_c = P_u + P_p = P_{EM} - P_u = 7.787,5 - 7.000$

$\boxed{P_c = 787,5 \text{ W}}$ (0,5)

A.4. Electromagnetic torque:

$T_{em} = \frac{P_{EM}}{\Omega} = \frac{7.787,5}{800 \cdot \frac{2\pi}{60}} = \boxed{92,95 \text{ N.m}}$ (1)

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- Useful torque :

$T_u = \frac{P_u}{\Omega} = \frac{7000}{800 \cdot \frac{2\pi}{60}} = 83,55 \ N.m$ (1)

- Torque due to constant losses :

$T_p = \frac{P_c}{\Omega} = \frac{787,5}{800 \cdot \frac{2\pi}{60}} = 9,40 \ N.m$ (1)

$= T_{em} - T_u$

B 1. In order to reduce the voltage we use a buck chopper. (1)

B 2. $U' = 110 \ V$ $\quad I = 35 \ A$

$E' = U' - RI = 110 - (0,5 \cdot 35)$

$E' = 92,5 \ V$ $\quad E' = k n'$ (0,5)

$k = \frac{E}{n} = \frac{E'}{n'}$ $\Rightarrow$ $n' = \frac{E'}{E} n$

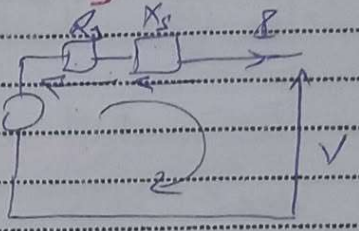
$n' = \frac{92,5}{222,5} \cdot 800 \Rightarrow n' = 333 \ rpm$ (0,5)

Exercise 01 : $E = 152\ \Omega$ (10)

$R = 1\ \Omega \Rightarrow R_1 = 0,5\ \Omega$

$X_s = 1,75\ \Omega$

1. Synchronous impedance Z_s :



$Z_s = \sqrt{R_1^2 + X_s^2}$

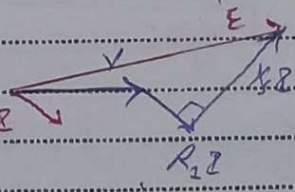
$= \sqrt{0,5^2 + 1,75^2}$

$Z_s = \boxed{1,82\ \Omega}$ (2)

2. $U = 5,5\ kV$ $\quad I = 577\ A$ $\quad \cos\varphi = 0,8$

$\varphi = 36,86°$

$\underline{E} = \underline{V} + R_1\underline{I} + X_s\underline{I}$



(1)

$= \frac{5500}{\sqrt{3}} + 0,5 \cdot 577 \cos(-36,86°)\, I$

$+ j\, 0,5 \cdot 577 \sin(-36,86°) + 1,75 \cos(90° - 36,86°) \cdot 577$ (1.)

$+ j\, 1,75 \cdot 577 \sin(90° - 36,86°)$

$\underline{E} = 3175,426 + 230,829 - j\,173,060 + 605,710 + j\,807,804$ (2)

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$\underline{E} = 4011,965 + j\,634,844$

$\underline{E} = 4061,88 \angle 8,99°$ V (1)

$I_a = \frac{E}{152} \Rightarrow I_a = 26,722$ A (1)

2. Copper losses in the armature :

$P_{js} = 3 R_1 I^2 = 3 \times 0,5 \times 577^2$

$P_{js} = 499\,393,5$ W (1)

3. Efficiency : $P_u = 80\,000$ W

$P_{ue} = \sqrt{3}\, U I \cos\varphi = 4\,397\,330,890$ W

$\eta = \frac{P_u}{P_{ue} + \Sigma p} = 88,35$ % (1)

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