

Correction : TD série 1 Machine Synchrone

Exercice 1

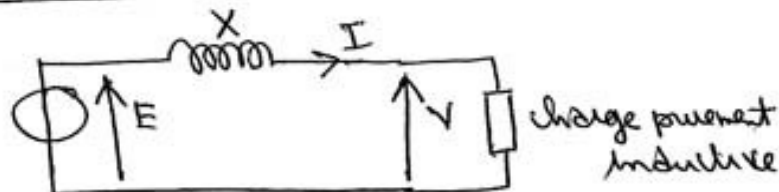
1 fonctionnement en alternateur :

1.1 machine 380V/660V } $U_{nom} = 380V = V_{réseau}$
 réseau: 380V/660V } \Rightarrow il faut coupler le stator
 de la machine en étoile.

$f = 50\text{Hz}$ $p = 3 \Rightarrow n = \frac{f}{p} = \frac{50}{3} = 16,67\text{tr/s}$

$n = 1000\text{tr/min}$

1.2



$V = \frac{U}{\sqrt{3}} = \frac{540}{\sqrt{3}} \approx 312\text{V}$

$E = jX I + V$

$E = jX I + jV$

$E = j10X + j312$

$E = j(10X + 312)$

$420 = (10X + 312)^2 \Rightarrow 420 = 10X + 312$

$\Rightarrow 10X = 420 - 312 = 108 \Rightarrow X = 10,8\Omega$

$X = L\omega \Rightarrow L = \frac{X}{\omega} = \frac{10,8}{314} \approx 0,0344\text{H}$

$X = 2\pi f L = 2\pi \times 0,0344 \times 50$

$X = 0,216 \Omega$

2°/ $T_r = 120 \text{ N.m} = U_t$

$\Sigma \text{ pertes} = 0$

2.1

$P_g = U I \sqrt{3} \cos \varphi = T \times \Omega$ (car $\Sigma \text{ pertes} = 0$)

$P_g = T \times \Omega = 120 \times \frac{1000 \times 2\pi}{60} = 12565 \text{ W}$

$(\Omega = \frac{2\pi n}{60})$

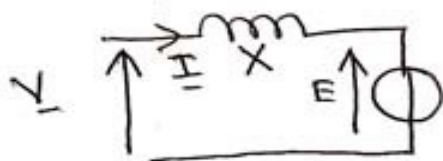
La puissance reste constante car le moteur entraîne une charge dont le couple résistant est constant.

2.2

$\cos \varphi = 1$

$I = \frac{P}{U \sqrt{3} \cos \varphi} = \frac{12565}{660 \sqrt{3} \times 1} = 11 \text{ A}$

$\varphi = (\vec{I}, \vec{V}) = 0$



$\underline{V} = j X \underline{I} + E$

$\underline{E} = \underline{V} - j X \underline{I}$

$\underline{V} = [380; 0] = 380$

$X = 0.216 \Omega = 0.216 \times 50$

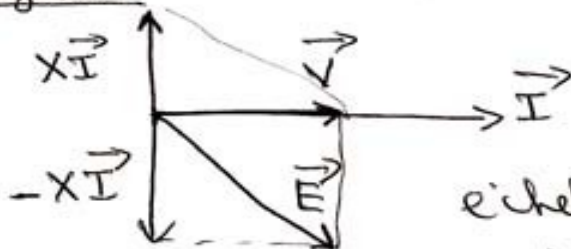
$X = 10.8 \Omega$

$\underline{E} = 380 - j 10.8 \times 11 = 380 - j 118.7$

$E = \sqrt{380^2 + (118.7)^2} = 398 \text{ V}$

$I_{ex} = \frac{E}{3 \Omega} = \frac{398}{3 \times 50} = 2.65 \text{ A}$

Diagramme:



$\vec{E} = \vec{V} - X\vec{I}$
 $\vec{E} = \vec{V} + (-X\vec{I})$

échelle conseillée: 1 cm \rightarrow 50V

$V = 380 \text{ V} \rightarrow 7.6 \text{ cm}$

$XI = 118.7 \text{ V} \rightarrow \approx 2.4 \text{ cm}$

on trouve $E \approx 8 \text{ cm} \times 50 \text{ V/cm} \approx \underline{400 \text{ V}}$

Exercice 2

$$1^{\circ}) \quad n = \frac{f}{p} = \frac{50}{13} = 3,846 \text{ tr/s} = 230,8 \text{ tr/min}$$

$$2^{\circ}) \quad Z_s = \frac{E_{PN}}{I_{cc}} \frac{10,17 I_{ex} / \sqrt{3}}{I_{cc}} = \frac{6,177 I_{ex}}{I_{cc}}$$

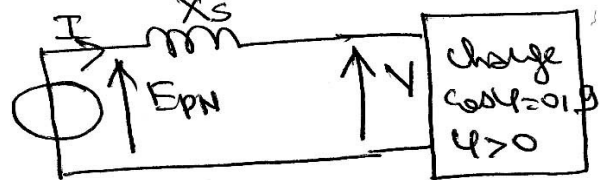
$$\text{Power } I_{ex} = 434 \text{ A on a } I_{cc} = 2000 \text{ A}$$

$$\text{donc } Z_s = \frac{6,177 \times 434}{2000} = 1,34 \Omega$$

$$X_s = \sqrt{Z_s^2 - R_s^2} = \sqrt{1,34^2 - 0,0054^2} \approx 1,34 \Omega$$

$$3^{\circ}) \quad I_{ex} = \frac{E_N}{10,17} = \frac{E_{PN}}{\sqrt{3} \times 10,17} = \frac{E_{PN}}{6,177}$$

Calcul de E_{PN}



$$E_{PN} = j X_s I + \underline{V}$$

$$\underline{V} = \left[\frac{V}{\sqrt{3}} ; +25,84^\circ \right]$$

$$I = 3330 \text{ A}$$

$$\varphi = (\vec{I}, \vec{V}) = +\cos^{-1}(0,9)$$

$$\varphi = 25,84^\circ$$

$$\underline{V} = \left[\frac{5650}{\sqrt{3}} ; 25,84^\circ \right] = [3262 ; 25,84^\circ]$$

$$\underline{V} = 3262 \cos 25,84^\circ + j 3262 \cdot \sin 25,84^\circ$$

$$\underline{V} = 2935,9 + j 1421,8$$

$$X_s I = 1,34 \times 3330 = 4462,2$$

$$\text{donc } \underline{E}_{PN} = j X_s I + \underline{V} = j 4462,2 + 2935,9 + j 1421,8$$

$$\underline{E}_{PN} = 2935,9 + j 5884 \quad E_{PN} = \sqrt{2935,9^2 + 5884^2}$$

$$E_{PN} = 6575,8 \text{ V} \Rightarrow I_{ex} = \frac{6575,8}{6,177} \approx 1065 \text{ A}$$

40/

$$R_e = 0,136 \Omega$$

$$p_c = 420 \text{ kW}$$

$$\eta = \frac{P_2}{P_1}$$

$$P_2 = U_e I \sqrt{3} \cos \varphi$$

$$P_2 = 5650 \times 3330 \sqrt{3} \times 0,9 = 29,133 \text{ MW}$$

$$P_1 = P_2 + p_c + p_{ex} + p_{js}$$

$$p_c = 0,42 \text{ MW}$$

$$p_{ex} = R_e \times I_{ex}^2 = 0,136 \times 1065^2 = 0,154 \text{ MW}$$

$$p_{js} = 3 R_s I^2 = 514 \times 10^3 \times 3330^2 = 0,106 \text{ MW}$$

$$P_1 = 29,133 + 0,42 + 0,154 + 0,106 = 29,964 \text{ MW}$$

$$\eta = \frac{29,133}{29,964} = 97,188 \%$$

Correction Exercice 3 :

1°)

a) $\omega = 2 \cdot \pi \cdot f = 2 \times \pi \times 400 = 2512 \text{ rad/s}$.

b) $p = f/n = 400/(12000/60) = 400/200 = 2$, il y a 2 paires de pôles.

c) $I_n = S_n / (3 \cdot V_n) = 90\,000 / (3 \times 115) = 260 \text{ A}$.

2°)

a) $Z_s = E_v / I_{cc} = 4,4 I_e / (3,07 I_e) = 4,4/3,07 = 1,433 \Omega$.

b) $X_s = (Z_s^2 - R_s^2)^{1/2} = (1,433^2 - 0,01^2)^{1/2} = 1,432 \Omega$.

3°)

a) L'alternateur est couplé en étoile, donc la valeur de la F.é.m à vide sera égale à la tension simple V : $E_v = 115 \text{ V}$.

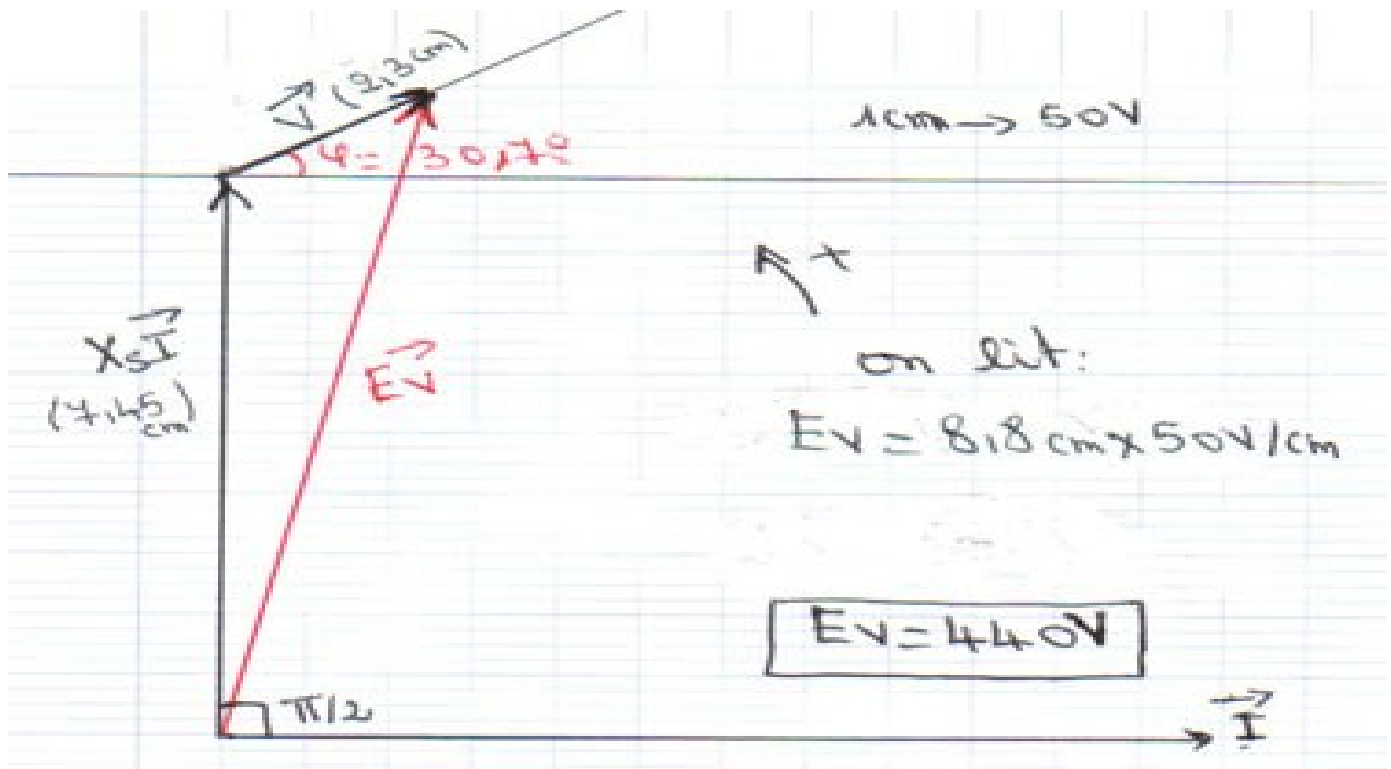
$$I_{e0} = E_v / 4,4 = 115 / 4,4 = 26,14 \text{ A}$$

b) $I_n = 260 \text{ A}$, $\cos \varphi = 0,86$ ($\varphi = 30,7^\circ$)

En appliquant la loi des mailles (en notation complexe): $\underline{V} + \underline{X}_s \cdot \underline{I} = \underline{E}_v$, on prend une échelle de 1 cm pour 50 V.

$$X_s \cdot I = 1,432 \times 260 = 372,6 \text{ V (7,45 cm)}$$

$$V = 115 \text{ V (2,3 cm)}$$



Méthode analytique

on a $\underline{V} + \underline{X}_s \cdot \underline{I} = \underline{E}_v$

$\underline{X}_s \cdot \underline{I} = jX_s \cdot I = 372,6j$ et $\underline{V} = 115 e^{j\phi} = 115(\cos 30,7 + j \sin 30,7) = 98,9 + 58,54j$

$\underline{E}_v = 98,9 + 58,54j + 372,6j = 98,9 + 431,14j = 442,3 \cdot e^{j77}$

La valeur de la F.é.m : $\underline{E}_v = 442,3 \text{ V}$

c) Pour $V = 115 \text{ V}$ avec un $\cos \phi = 0,86$ on a $I_e = E_v / 4,4 = 440 / 4,4 = 100 \text{ A}$