Exercice 5 :

Un moteur asynchrone $p = 3$ (6 pôles)

stator en λ

rotor bobiné couplé en λ

$U_{stator} = 380\,V$; $f = 50\,Hz$

$R_{1\,stat} = 20.10^{-3}\,\Omega$

$R_{2\,rot} = 30.10^{-3}\,\Omega$

$p_{fer} = 4800\,W$

$p_{meca} = 1300\,W$ à n_s nominal. $\approx C^{st}$ autour de n_s.

$I_0 = 74\,A$. (à vide)

Essai en court circuit : $U_{cc} = 72\,V$.

$I_{cc} = 220\,A$.

$P_{cc} = 7200\,W$.

1) En régime nominal

→ $P_{u_n} = 116\,kW$ → $g_n = 2,6\,\%$.

→ $S_N = 145\,kVA$.

n ?

$$\left[g_n = \frac{n_s - n}{n_s} \right]$$

$$\boxed{p = 3} \Rightarrow n_s = \frac{60 \times f}{p} = \frac{60 \times 50}{3} = \boxed{1000\,tr.min^{-1}}$$

$$g_n \cdot n_s = n_s - n$$

$$\boxed{n = n_s(1 - g)} \qquad n = 1000\left(1 - \frac{2,6}{100}\right)$$

$$\boxed{n = 974\,tr.min^{-1}}$$

Exc 5 (Suite)

1) Bilan de puissance :

P_{ab} $(\sqrt{3}\,UI\cos\varphi)$ $\Rightarrow$ $P_{J\,stat}$, P_{fer} $\Rightarrow$ P_{TR} $\left(3\frac{R_2}{g}I_2^2\right)$ $\Rightarrow$ $P_{J\,rot}$ $(3R_2I_2^2)$, perte meca $\Rightarrow$ P_U

au point de fonctionnement nominal, on a :

$$\boxed{I\ \text{ligne}} = \frac{S_N}{\sqrt{3}\,U} = \frac{145.10^3}{\sqrt{3}.380} = \boxed{220,3\ A}$$

$$\boxed{P_{J\,stat}} = 3R_1 I_{ligne}^2$$
$$= 3 \times 20.10^{-3}.(220,3)^2 = \boxed{2911,92\ W}$$

Pertes fer $= 4800\ W$

P_{TR} ?

$$P_{TR} = \frac{3R_2}{g} I_2^2 \quad \text{et} \quad P_{Jrot} = 3R_2 I_2^2 = P_{TR} \times g$$

Don peut écrire que :

$$P_{TR} = P_U + p\,meca + P_{Jrot}$$
$$= P_U + p\,meca + P_{TR}.g$$
$$P_{TR}(1-g) = P_U + p\,meca$$
$$P_{TR} = \frac{P_U + p\,meca}{(1-g)} = \frac{116.10^3 + 1300}{\left(1 - \frac{2,6}{100}\right)}$$

$$\boxed{P_{TR} = 120,431\ kW}$$

$P_{J\,stator} = 2911\ W \qquad P_f = 4800\ W$

et $P_{Tr} = 120\ 431$.

d'où $P_{abs} = P_{Tr} + P_{Jst} + P_{fer}$

$= 120\,431 + 2911 + 4800$

$$\boxed{P_{abs} = 128\ 142\ W}$$

$\cos\varphi = ?$

$$\cos\varphi = \frac{P_{abs}}{S_{abs}} = \frac{128{,}142}{145}$$

$$\boxed{\cos\varphi = 0{,}8837}$$

$\eta = ?$

$$\boxed{\eta} = \frac{P_u}{P_a} = \frac{116}{128{,}142} = \boxed{0{,}905}$$

T_{em} ?

$$T_{em} = \frac{P_{tr}}{\Omega_s} = \frac{120\,431}{\left(\frac{2\pi \times 1000}{60}\right)}$$

$$\boxed{T_{em}} = \frac{120\,431}{104{,}71} = \boxed{1150\ Nm}$$

T_u ?

$$T_u = \frac{P_u}{\Omega} = \frac{116 \cdot 10^3}{\left(\frac{2\pi \times 974}{60}\right)} = \frac{116 \cdot 10^3}{101{,}99}$$

$$\boxed{T_u = 1137{,}28\ Nm}$$

ex 5 (Suite)

2) Etablissement du modèle.

- Essai à vide R_f, X_f.

$$P_f = 4800\,W = 3 \cdot \frac{V^2}{R_f}$$

$$R_f = \frac{3 \times V^2}{4800} = \frac{3 \times 220^2}{4800}$$

$$\boxed{R_f = 30{,}25\,\Omega}$$

A vide, on absorbe $I_0 = 74\,A$.

Soit $S_0 = \sqrt{3} \times U I_0 = \sqrt{3} \times 380 \times 74$

$S_0 = 48\,705$ VAR

$$Q_0 = \sqrt{S_0^2 - P_0^2} = \sqrt{48{,}7^2 - 4{,}8^2}$$

$Q_0 = 48{,}46$ kVAR

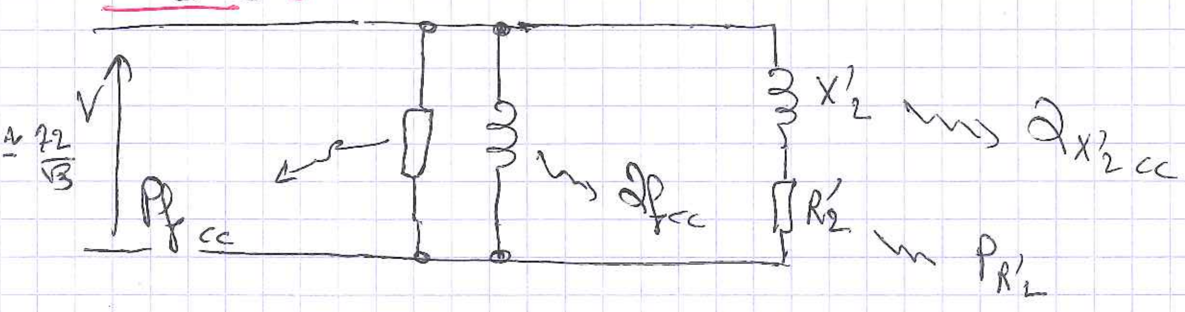
$$Q_0 = \frac{3V^2}{\cancel{R_f}} \qquad X_f = \frac{3V^2}{Q_0}$$

$$X_f = \frac{3 \times 220^2}{48{,}46 \cdot 10^3} = 2{,}99\,\Omega$$

$$\boxed{X_f = 2{,}99\,\Omega}$$

- Essai en court circuit

$P_{R'_2 cc}$?



$$P_{cc} = 7400\,W = P_{R_1 cc} + P_{f\,cc} + P_{R'_2 cc}$$

$I_{cc} = 220\,A$. , on considère que $P_{f\,cc} \simeq \frac{3V_{cc}^2}{R_f}$

d'où $$P_{cc} = 3R_1 I_{cc}^2 + \frac{3 \times V_{cc}^2}{R_f} + P_{R'_2 cc}$$

Soit $$P_{R'_2 cc} = P_{cc} - 3R_1 I_{cc}^2 - \frac{3V_{cc}^2}{R_f}$$

$$= 7400 - 3 \times 20 \cdot 10^{-3} \times 220^2 - \frac{3 \times 72^2}{30{,}25\,(\sqrt{3})^2}$$

$$P_{R'_2 cc} = 7400 - 2904 - 171{,}37$$

$$\boxed{P_{R'_2 cc} = 4324{,}6\ W}$$

$Q_{X'_2 cc}$?

$$S_{cc} = \sqrt{3} \times U_{cc} \times I_{cc}$$
$$= \sqrt{3} \times 72 \times \times 220$$

$$\boxed{S_{cc} = 27\,435{,}68\ VA}$$

$$Q_{cc} = \sqrt{S_{cc}^2 - P_{cc}^2} = \sqrt{27{,}435^2 - 7{,}400^2}$$

$$\boxed{Q_{cc} = 26{,}418\ kVAR}$$

$$Q_{X'_2} = Q_{cc} - Q_{f\,cc} = Q_{cc} - \frac{3V^2}{X_f}$$

$$\boxed{Q_{X'_2}} = 26.418 - \frac{3 \times 72^2}{\underset{2{,}99}{\underset{\shortparallel}{X_f}} \times (\sqrt{3})^2} = 26418 - 1733{,}7$$

$$= \boxed{24\,684{,}2\ VAR}$$

Ex5 (suite)

Etablissent des valeurs de R'_2 et X'_2

Avec $P_{R'_{2cc}}$ et $Q_{X'_{2cc}}$

On peut avoir

$$S_{Z'_{2cc}} = \sqrt{P_{R'_{2cc}}^2 + Q_{X'_{2cc}}^2}$$

$$= \sqrt{4324,6^2 + 24\,684,2^2}$$

$$S_{Z'_{2cc}} = 25\,060,18 \text{ VA.}$$

$$I_{1t} = \frac{S_{Z'_{2cc}}}{\sqrt{3}\,U_{1cc}} = \frac{25\,060,18}{\sqrt{3} \times 72}$$

$$\boxed{I_{1t} = 200,95 \text{ A}}$$

d'où

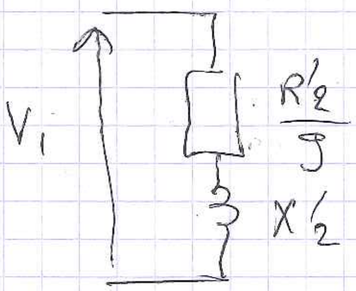
$$R'_2 = \frac{P_{R'_{2cc}}}{3 I_{1t}^2}$$

$$\boxed{R'_2} = \frac{4324,6}{3 \times 200,95^2} = \boxed{35,69 \text{ m}\Omega}$$

$$X'_2 = \frac{Q_{X'_{2cc}}}{3 I_{1t}^2} = \frac{24\,684,2}{3 \times 200,95^2}$$

$$\boxed{X'_2 = 0,2037\ \Omega}$$

→ Pour un glissement de $g = 2,6\,\%$.



Calcul de I_{1t} :

$$I_{1t} = \frac{V_1}{\sqrt{\left(\frac{R'_2}{g}\right)^2 + X'^2_2}} = \frac{220}{\sqrt{\left(\frac{35,69.10^{-3}}{0,026}\right)^2 + 0,203}}$$

$$I_{1t} = \frac{220}{1,38} = 158,54\text{ A}.$$

d'où $P_{TR} = 3\,\frac{R_2}{g}\,.I_{1t}^2 = 3 \times \frac{35,69.10^{-3}}{0,026} \times 158,54^2$

$$P_{TR} = 3 \times 1,372 \,.\, 158,54^2 = 103\,507\text{ W}$$

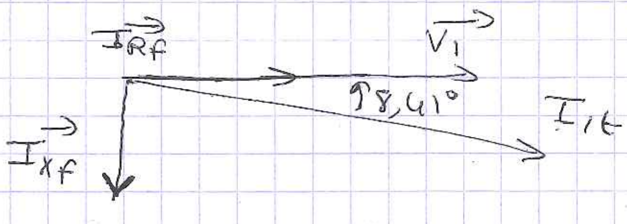
$$T_{em} = \frac{P_{TR}}{\left(\frac{2\pi n_s}{60}\right)} = \frac{103\,507}{\left(\frac{2\pi \times 1000}{60}\right)} = \frac{103\,507}{104,71}$$

$$\boxed{T_{em} = 988\text{ Nm}.}$$

$I_1 = ?$

$\varphi_{Z'_2}$? $= \text{Atan}\,\frac{X'_2}{\left(\frac{R'_2}{g}\right)}$

$= 8,41°$.



$I_{Rf} = \frac{V_1}{R_f} = \frac{220}{30,25} = 7,27\text{ A}$

$I_{Xf} = \frac{V_1}{X_f} = \frac{220}{2,99}$

$= 73,57\text{ A}$

$$I_1 = \sqrt{(I_{1t}\cos 8,41 + I_{Rf})^2 + (I_{Xf} + I_{1t}\sin 8,41)^2}$$

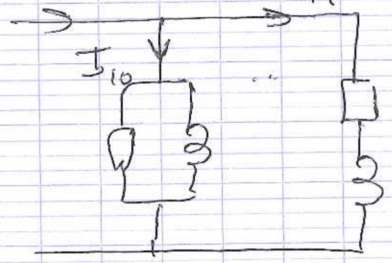
$$= \sqrt{(158,54\cos 8,41 + 7,27)^2 + (73,57 + 158,54\sin 8,41)^2}$$

$$= \sqrt{164,1^2 + 96,75^2} = 190,5\text{ A}.$$

$\boxed{\cos\varphi = ?}$ $\cos\varphi = \cos \text{Atan}\left(\frac{96,75}{164,1}\right) = \cos(30,52) = \boxed{0,86}.$

Ex 5 (Suite)

3) On place des resistances au rotor pour le démarrage.



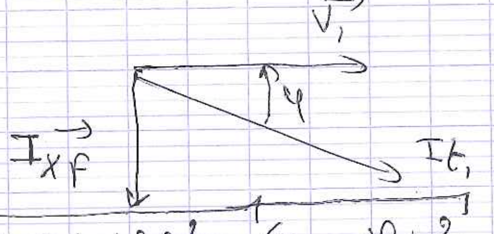
On prend $\boxed{I_N = 200\,A}$

Soit $\boxed{I_1} = 1,2 \times 200 = \boxed{240\,A}$

Détermination de I_{1t}.

(H) On néglige $\vec{I_{Rf}}$ devant $\vec{I_{Xf}}$

On obtient

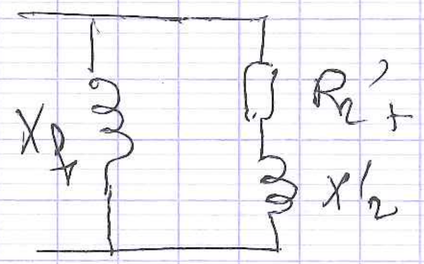


$$I_1 = \sqrt{(I_{Xf} + I_{t_1} \sin\varphi)^2 + (I_{t_1} \cos\varphi)^2}$$

$$I_1^2 = (I_{Xf} + I_{t_1} \sin\varphi)^2 + (I_{t_1} \cos\varphi)^2$$

On va calculer Z au démarrage en negligeant Rf devant Xf.

d'où l'approximation :



$\underline{Z}$?

$$\frac{1}{\underline{Z}} = \frac{1}{jX_f} + \frac{1}{R'_{2r} + jX'_2}$$

$$\underline{Z} = \frac{R'_{2r} + j(X'_2 + X_f)}{j(X_f)(R'_{2r} + jX'_2)}$$

$$\underline{Z} = \frac{R'_{2r} + j(X'_2 + X_f)}{-X_f X'_2 + j R'_{2r} \cdot X_f}$$

$$|\underline{Z}| = \sqrt{\frac{R'^2_{2r} + (X'_2 + X_f)^2}{(X_f X'_2)^2 + (R'_{2r} \cdot X_f)^2}}$$

On désire $|\underline{I_1}| = 1,2 I_N = \frac{|V_1|}{|\underline{Z}|}$

$$\underline{Z} = \frac{220}{240} = 0,916\ \Omega$$

On connait $X_f = 9,99\ \Omega$ $X'_2 = 0,203$

d'où $\boxed{|\underline{Z}|^2 = 0,916^2 = 0,840\ \Omega^2}$

ex 5 (Suite)

ex 3 :

$$z^2\left[(X_f X_2')^2 + (R_{2t}' X_f)^2\right] = R_{2t}'^2 + (X_2'+X_f)^2$$

$$z^2 \cdot (X_f X_2')^2 + z^2 R_{2t}'^2 \cdot X_f^2 = R_{2t}'^2 + (X_2'+X_f)^2$$

$$R_{2t}'^2 \left[1 - (z \cdot X_f)^2\right] = (z^2 \cdot X_f X_2')^2 - (X_2'+X_f)^2$$

$$R_{2t}'^2 = \frac{(z\, X_f X_2')^2 - (X_2'+X_f)^2}{1-(z X_f)^2}$$

$$R_{2t}' = \sqrt{}$$

$$R_{2t}' = \sqrt{\frac{(0,916 \times 2,99 \cdot 0,203)^2 - (0,203+2,99)^2}{1 - (0,916 \cdot 2,99)^2}}$$

$$R_{2t}' = \sqrt{\frac{0,555^2 - 10,195}{1 - 7,50}}$$

$$R_{2t}' = \sqrt{\frac{9,89}{6,50}} = \sqrt{1,52}$$

$$R_{2t}' = 1,233\ \Omega$$

Donc le rhéostat sera $R_h + R_2' = 1,233\ \Omega$

$R_h = 1,233 - 0,0356$

$R_h = 1,198\ \Omega$

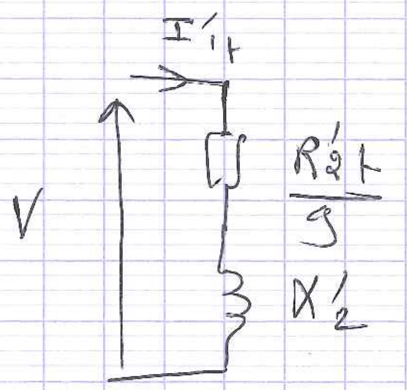
$\Rightarrow$ au démarrage : $P_{TR} = 3 R_2' \cdot I_{1t}^2 = 3 \times 1,233 \times \frac{V}{\sqrt{1,233^2 + 0,203^2}}$

$= 114\,580\ W$

$$\boxed{T_{démarrage} = \frac{P_{TR}}{\Omega_s} = \frac{114\,580}{104,71} \simeq 1100\ Nm}$$

Calcul de la puissance transmise à $g = 2,6\%$.

Soit :



$$I'_{1r} = \frac{V}{\sqrt{\left(\frac{R'_{2r}}{g}\right)^2 + \left(X'_2\right)^2}} = \frac{220}{\sqrt{\left(\frac{1,233}{0,026}\right)^2 + \left(0,23\right)^2}}$$

$$I'_{1r} = \frac{220}{47,42} = 4,63\ A.$$

$$P_{tr} = 3\,\frac{R'_{2r}}{g} \times I_{1r}^2 = 3 \times 47,42 \times 4,63^2$$

$$P_{tr} = 3049,81\ W$$

$$T_{dispo} = \frac{P_{tr}}{\left(\frac{2\pi\,1000}{60}\right)} = \frac{3049,81}{104,71}$$

$$T_{dispo} = 29,12\ N.$$

A cause des résistances au rotor, le couple dispo est très réduit, il faut les éliminer au fur et à mesure de manière à retrouver le fort couple possible délivré par cette machine.