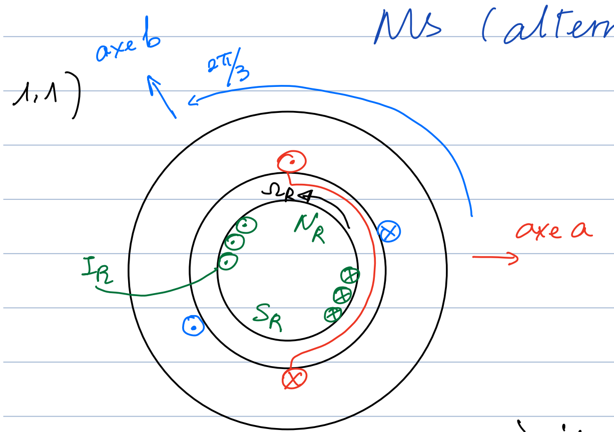
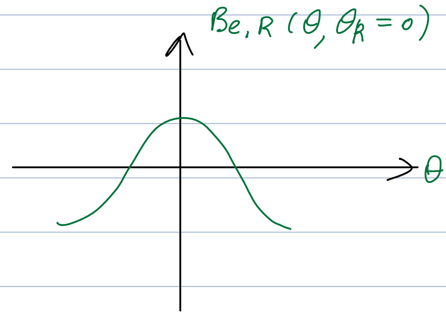
MS (alternateur autonome)

1.1)





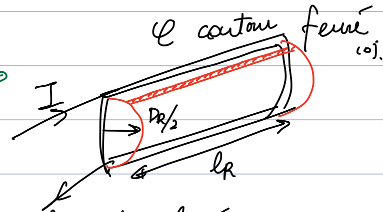
à vide : pas de courant.

$$v_a = -\frac{d\Phi_a}{dt} \leftarrow R, \cancel{X} \leftarrow i_{abc} = 0$$

$\mathcal{C}$ contour fermé (c).

$$\Phi_{a,R} = n_s \cdot \iint_{S_\mathcal{C}} \vec{B}_{e,R}(\theta,\theta_R)\, d\vec{s}$$

mais intégrer par rapport à θ



Surface qui s'appuie sur le contour fermé

$$\Phi_{a,R}(\theta_R(t)) = n_s \int_{\theta=-\frac{\pi}{2}}^{\theta=+\frac{\pi}{2}} \alpha_R I_R \cos(\theta-\theta_R)\cdot\left(\frac{D_R}{2}\cdot l_R\, d\theta\right)$$

$$= n_s \alpha_R I_R \frac{D_R l_R}{\cancel{2}} \Big[\underbrace{\sin\left(\tfrac{\pi}{2}-\theta_R\right) - \sin\left(-\tfrac{\pi}{2}-\theta_R\right)}_{\cancel{2}\cos(\theta_R)}\Big]$$

$$= n_s \alpha_R I_R D_R l_R \cos(\theta_R(t))$$

dérivée composée. $\frac{d\theta_R}{dt}$.

$$i_{abc} = 0 \Rightarrow v_a = -\frac{d\Phi_{aR}}{dt} = +n_s \alpha_R I_R D_R l_R \Omega_R(t) \cdot \sin(\theta_R(t))$$

seule inconnue

$\alpha_R = 0,22\ T/A$

$\alpha_S = 0,8\ mT/A$

$$n_s = \frac{230\cdot\sqrt{2}}{0,22\cdot 3,5\cdot 0,3\cdot 0,5\cdot \frac{2\pi\cdot 3000}{60}} \simeq 9 \text{ spires.}$$

1.2) Si N_R passe à 1500 tr/min

E 2 fois plus faible, $E_{eff} = 230/2 = 115\ V$

E : tension à vide

1,3) Sator

$L_s(\theta_R)$ si pôle saillant

c)
$$\begin{bmatrix} \Phi_{a,s} \\ \Phi_{b,s} \\ \Phi_{c,s} \end{bmatrix} = \begin{bmatrix} L_s & M_s & M_s \\ M_s & L_s & M_s \\ M_s & M_s & L_s \end{bmatrix} \cdot \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

réciprocité

a)
$$\Phi_{a,a} = n_s \cdot \int_{\theta=-\frac{\pi}{2}}^{\theta=\frac{\pi}{2}} \alpha_s \cdot i_a \cos(\theta) \cdot \left(\frac{D_R l_R}{2} d\theta\right) = \underbrace{n_s D_R l_R \alpha_s}_{L_s = n_s^2 \cdot \mathcal{P}} i_a$$

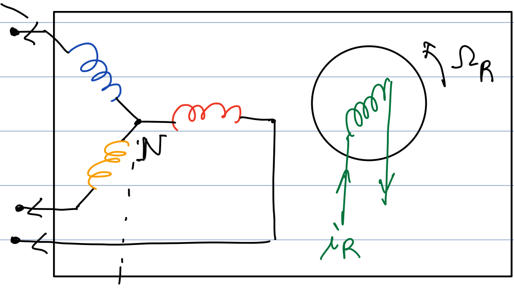
$\mathcal{P}$ ← cachée dans α_s

$= 1.08\,mH$

b)
$$\Phi_{a,b} = n_s \cdot \int_{\theta=-\frac{\pi}{2}}^{\theta=\frac{\pi}{2}} \alpha_s \cdot i_a \cdot \underbrace{\cos\left(\theta - \frac{2\pi}{3}\right)}_{\text{retardé}} \frac{D_R l_R}{2} d\theta = \underbrace{(n_s D_R l_R \alpha_s)}_{M_s = -\frac{L_s}{2} = -0{,}54\,mH} \cdot \left(-\frac{1}{2}\right) i_b$$

d)

convention générateur



contrainte

$i_N = i_a + i_b + i_c = 0$

$i_b + i_c = -i_a$

$\Phi_{as} = L_s i_a + M_s i_b + M_s i_c$

$= (L_s - M_s)\, i_a$

$\boxed{L_{cs} = \frac{3}{2} L_s = 1.6\,mH}$

Flux dépend des autres termes mais cachés dans un seul terme : inductance cyclique. l'inductance qui caractérise la machine

$$\mathcal{L}_s = \begin{bmatrix} L_{cs} & 0 & 0 \\ 0 & L_{cs} & 0 \\ 0 & 0 & L_{cs} \end{bmatrix}$$

$\boxed{\text{inductance cyclique statorique}}$

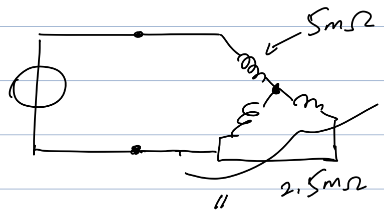
1.4) pertes Joules.

la machine ne tourne plus. On injecte un courant continu.

↓ plus de V.

(courant constant i_s)

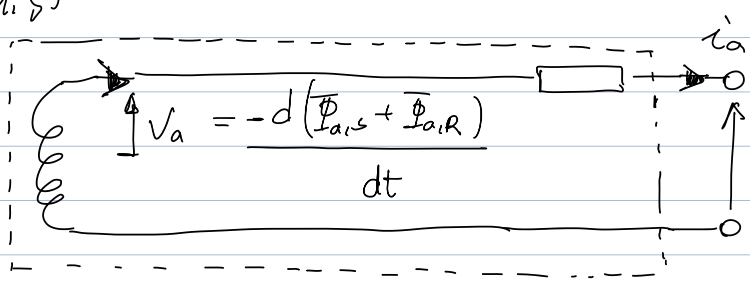
—ooo— fil ⇒ —www—



$$I_{DC} = \frac{V_{DC}}{1.5 \cdot R_s} = 133\,A$$

1.5)

$$e = -\frac{d\Phi}{dt} = -\frac{d\Phi}{d\theta} \cdot \underbrace{\frac{d\theta}{dt}}_{\Omega_R}$$



$$V_a = -\frac{d(\Phi_{a,s} + \Phi_{a,R})}{dt}$$

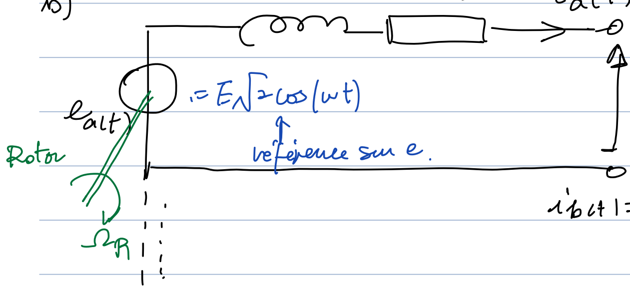
a)

$$v_a(t) = -R_s i_a(t) - L_{cs} \frac{di_a(t)}{dt} \underbrace{- \Omega_R \frac{d\Phi_{aR}}{d\theta_R}}_{e_a(t)}$$

tension à vide (pas de courant) F.E.M.

⇓

b)



c) $i_a(t) = I\sqrt{2}\cos(\omega_e t - \beta)$

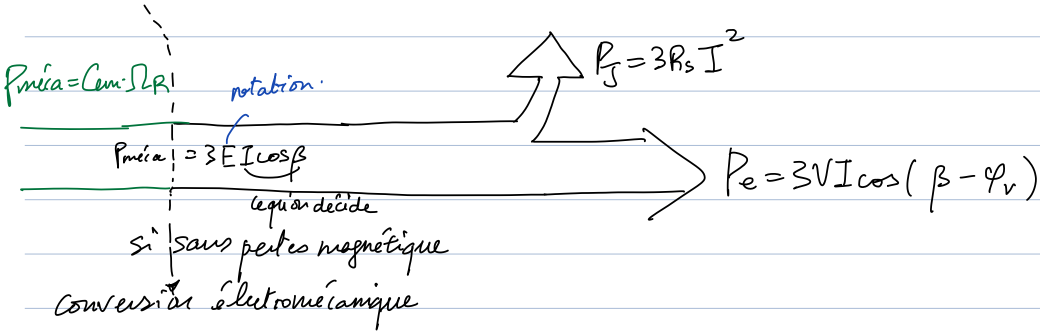
$e_a(t) = E\sqrt{2}\cos(\omega t)$

référence sur e.

$v_a(t) = V\sqrt{2}\cos(\omega_e t - \varphi_v)$

$i_b(t) = I\sqrt{2}\cos(\omega_e t - \beta - \frac{2\pi}{3})$

$e_b(t) = E\sqrt{2}\cos(\omega t - \frac{2\pi}{3})$ on tourne sur le cont plus tard.



d) $C_{em} = \dfrac{3 E I \cos\beta}{\Omega_R}$

$e_a = E\sqrt{2}\cos(\omega t)$

$e_b = E\sqrt{2}\cos(\omega t - \frac{2\pi}{3})$ $\rightarrow$ i décalé de β $\begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} = I\sqrt{2}\begin{pmatrix} \cos(\omega t-\beta) \\ \cos(\omega t - \frac{2\pi}{3}-\beta) \\ \cos(\omega t+\frac{2\pi}{3}-\beta) \end{pmatrix}$

$e_c = E\sqrt{2}\cos(\omega t + \frac{2\pi}{3})$

$p = e_{abc}^{t} \cdot i_{abc} = E \cdot I \cdot \frac{\cancel{2}}{\cancel{2}} \left\{ \underbrace{\begin{matrix} \cos(2\omega t-\beta) \\ \cos(2\omega t-\beta-\frac{4\pi}{3}) \\ \cos(2\omega t-\beta+\frac{4\pi}{3}) \end{matrix}}_{=0} + 3\cos(\beta) \right\}$

P instantanée = constante.

$= 3 E I \cos\beta$

$e_a(t) = -\Omega_R \dfrac{d\Phi_{a,R}}{d\theta_R}$

$= -\dfrac{d\Phi_{aR}}{d\theta_R} \times \dfrac{d\theta_R}{dt}$

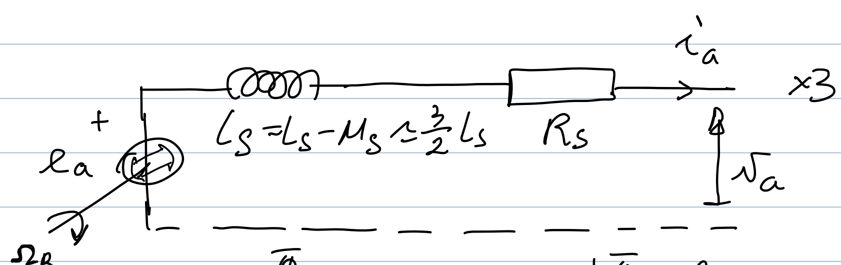
$\Phi_{a,R}(\theta_R) = \left(\Phi_{SR}\sqrt{2}\right)\cdot\cos(\theta_R - \psi)$

on décide quand on tourne

$\dfrac{d\Phi_{aR}}{d\theta_R} = \Phi_{SR}\sqrt{2}\cos(\theta_R - \psi + \frac{\pi}{2})$

$e_a(t) = E\sqrt{2}\cos(\omega t)$ $t=0 \Rightarrow e_{max}$. $\theta_R - \psi + \frac{\pi}{2} = 0$

$C_{em} = \dfrac{3EI\cos\beta}{\Omega_R} = 3\,\Phi_{SR}\, I\cos\beta$



$e_a(t) = -\dfrac{d\Phi_{aR}(t)}{dt} = -\Omega_R \cdot \dfrac{d\Phi_{aR}(\theta_R)}{d\theta_R}$

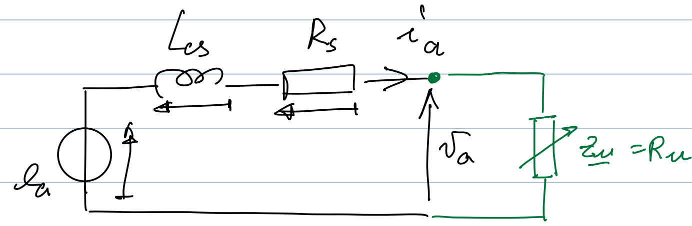
$C_{em} = \dfrac{\sum e_k i_k}{\Omega_R} = 3\underbrace{\left(\dfrac{\overset{max}{\hat{E}}}{\Omega_R}\right)}_{\Phi_{SR\,eff}} \hat{I}\cos(\underbrace{\widehat{I,E}}_{\beta})$

$\Phi_{aR} = \Phi_{SR\,eff}\sqrt{2}\cos(\theta_R)$

$\dfrac{d\Phi}{d\theta_R} = \Phi_{SR\,eff}\sqrt{2}\cos(\theta_R + \frac{\pi}{2})$

2) Fonctionnement en alternateur autonome

2,1).



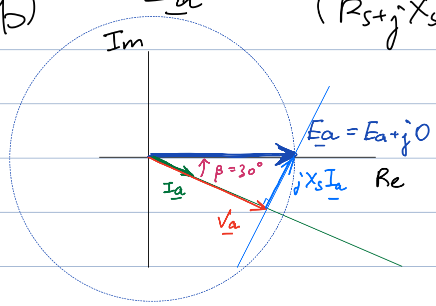
$N_R = 3000$ tr/min

$$e_a(t) = L_{cs}\frac{di_a}{dt} + R_s i_a + ?$$

a) $$\underline{E_a} = jL_{cs}\Omega_R \underline{I_a} + R_s\underline{I_a} + Z_u \underline{I_a}$$

$\underset{méca}{\Omega_R} = \underset{élec}{\omega}$ (1 paire de pôle)

b) $$\underline{I_a} = \frac{\underline{E_a}}{(R_s + jX_s) + \underline{Z_u}} \simeq \frac{\underline{E_a}}{R_u + jX_s} = \frac{\underline{E_a}}{R_u^2 + X_s^2}(R_u - jX_s)$$



$$\left\{\begin{array}{l} |\underline{I_a}| = \dfrac{|\underline{E_a}|}{\sqrt{R_u^2 + X_s^2}} = \dfrac{230}{\sqrt{1^2 + 0{,}5^2}} = 206\,A \\ \beta = \arctan\left(\dfrac{X_s}{Z_u}\right) = 8 \quad \text{car } |\underline{V_a}| = R_u \cdot |\underline{I_a}| \\ \qquad \simeq 30° \end{array}\right.$$

$|\underline{V_a}| = 206$

$$\underline{V_a} = \underline{Z_u}\cdot\underline{I_a} = \underline{E_a}\cdot\frac{\underline{Z_u}}{(R_s + jX_s) + \underline{Z_u}}$$

$R_s = 5\,m\Omega \ll X_s$ et $|\underline{Z_u}|$

$X_s = L_{cs}\Omega_R \qquad \Omega_R = N_R \cdot \frac{2\pi}{60} = 314{,}2$ rad/s

$= 1.6m \cdot 314{,}2$

$= 502\,m\Omega$

c) $$|\underline{V_a}| = \underline{E_a}\cdot\frac{R_u}{\sqrt{R_u^2 + X_s^2}} = \underline{E_a}\cdot\frac{1}{\sqrt{1 + \left(\frac{X_s}{R_u}\right)^2}} \xrightarrow[\text{à vide}]{R_u \to \infty} E_a$$

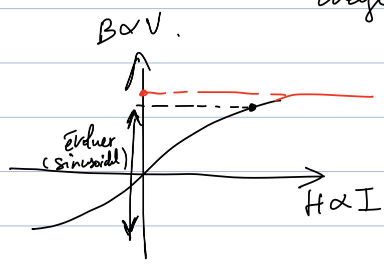
d) $|\underline{E_a}| \searrow 0 \qquad R_u \overset{+\infty}{\downarrow} 0$

$|V_a| \downarrow$. quand $R_u \downarrow$ (plus d'appareils)

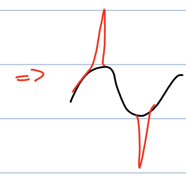
augmente Ω_R mais $L_{cs}\Omega_R \;\Delta \rightarrow \omega$ bouge aussi $\Rightarrow$ donc rotor bobiné.

$\Rightarrow$ agir sur V_a sans bouger la fréquence

→ charge le flux → saturé !

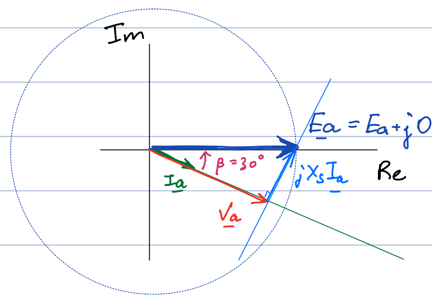


=>

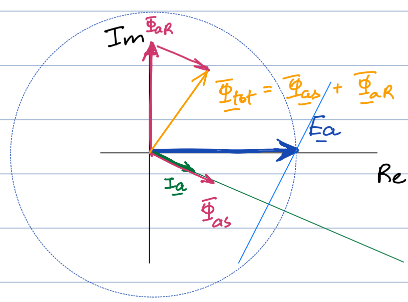


=> il faut maîtriser la fréquence
↓
horloge du réseau

2,2)



2,3)
F2



$e_a(t) = -\frac{d}{dt}(\Phi_{aR}(t))$

$\underline{\Phi}_{aR} = +j\frac{\underline{E}_a}{\Omega_R} \Leftarrow \underline{E}_a = -j\Omega_R\,\underline{\Phi}_{aR}$

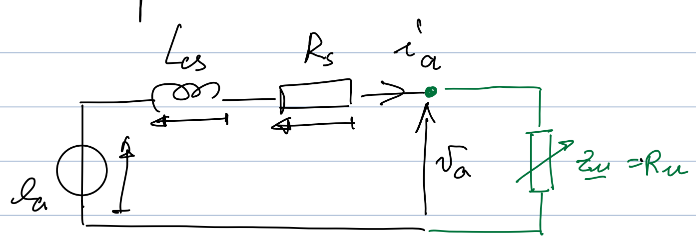
$\Rightarrow |\underline{\Phi}_{aR}| = \frac{230}{314,2} = 730\,mWb$

$\underline{\Phi}_{as} = L_{cs}\cdot\underline{I}_a \Rightarrow |\underline{\Phi}_{as}| = 1,6\cdot10^{-3}\cdot 206 = 329,6\,mWb$

le stator est en train d'être retiré par le rotor

2,3) Bilan de puissance

a)



$P_u = 3R_uI_a^2 = 127\,kW$

$\Omega_R = 314\,rad/s$

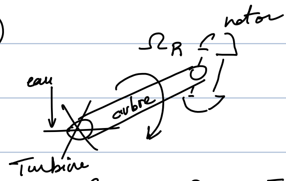
$C_{em} = \frac{P_E}{\Omega_R} = 404\,N\cdot m$

$P_\alpha = 0W$

$P_J = 3R_sI_a^2 = 0,6\,kW$

$P_E = 3E_aI_a\cos\beta$

c)



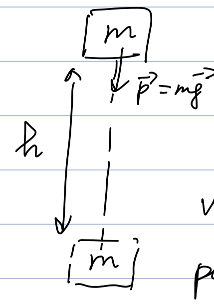
à réguler (maintenir le + constant possible)

$$C_{Tub} - C_{em} = J_\Delta \frac{d\Omega_R}{dt}$$

C_{Tub} : Contrôlé par le débit

C_{em} : perturbation subie (R_u varie)

e) $H = 100\,m$



$$P = \frac{W}{\Delta t} = \frac{m}{\Delta t} \cdot g h$$

$\frac{m}{\Delta t}$: débit massique

$W_m = mgh$ (J)

puissance : $W = J/s$

$$= \rho \cdot Q_v \cdot g h$$

Q_v : débit volumique.

on veut que $C_{Tub} = C_{em} \Rightarrow \rho Q_v g h = P_{élec}$ ∵ $P_J \simeq 0$

$$Q_v = \frac{P_{élec}}{\rho g h} = \frac{P_{élec}}{10^6} = \frac{127k}{10^6} = 0{,}127\,m^3 \cdot s^{-1}$$
$$= 127\,l \cdot s^{-1}$$

Ω constante

si $R_u = 2\Omega$

$$\underline{I_a} \simeq \frac{\underline{E_a}}{R_u + jX_s} \qquad I_a = \frac{E_a}{\sqrt{R_u^2 + X_s^2}}$$

NON linéaire !

$Q_v' \neq 2Q_v$!

$R_u = 1\Omega \rightarrow 206A$

$R_u = 2\Omega \rightarrow 112A$

$P_u = 75\,kW$

$\Rightarrow Q_{vol} = 75\,l \cdot s^{-1}$

$$C^* - C_{en} = I_s \left(\frac{dx}{dt}\right)$$

$$\| \\ 0$$