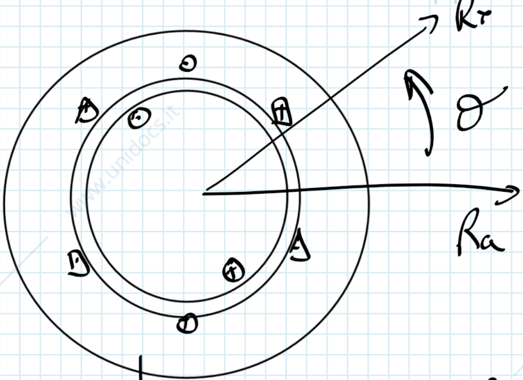


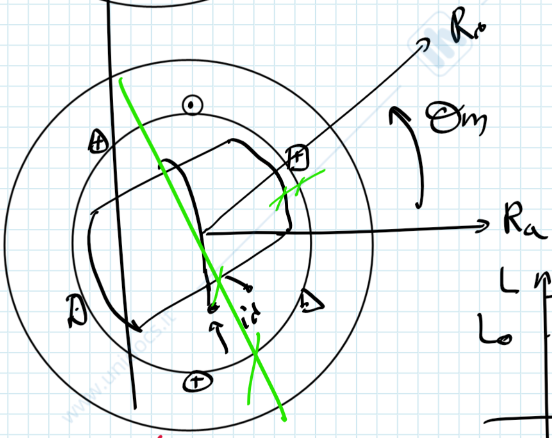
$$\bar{v}_s = R_s \bar{i}_s + j X_s \bar{i}_s + \bar{e}$$

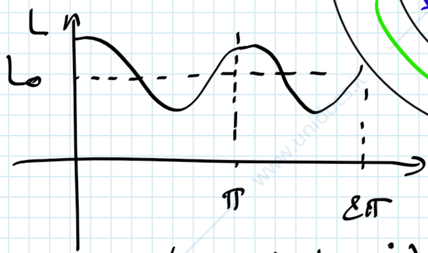
$$j\omega \frac{3}{2} L \bar{i}_s \qquad j\omega L_f \bar{i}_r$$

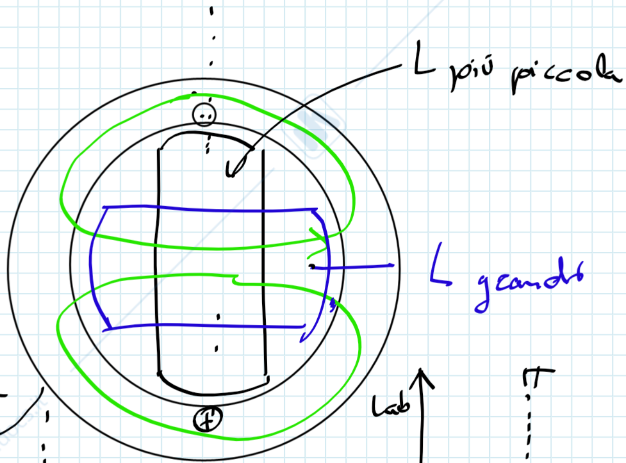
$$\bar{i}_s = \sqrt{\frac{3}{2}}\, I_M e^{j\omega t}$$

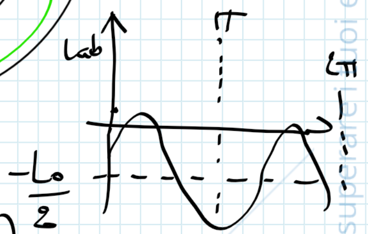
$$\theta_m = \omega t + \theta$$

$$\bar{i}_r = \sqrt{\frac{3}{2}}\, I_r e^{j\theta_m}$$









$$L_{aa} = L_0 + L_m \cos(2\theta_m)$$

$$L_{bb} = L_0 + L_m \cos 2\left(\theta_m - \frac{2}{3}\pi\right)$$

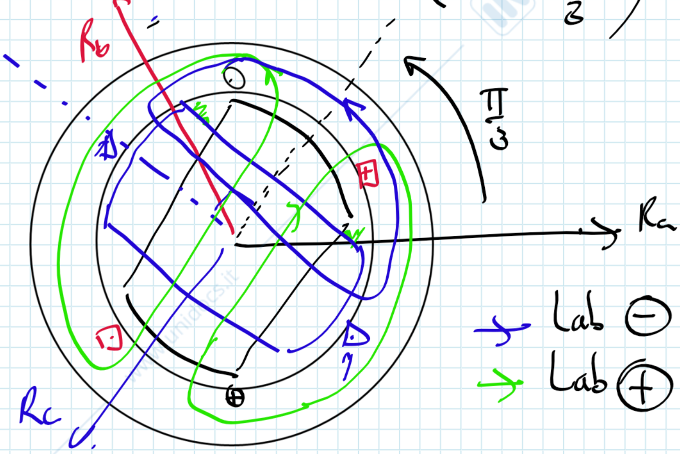
$$L_{cc} = L_0 + L_m \cos 2\left(\theta_m + \frac{2}{3}\pi\right)$$

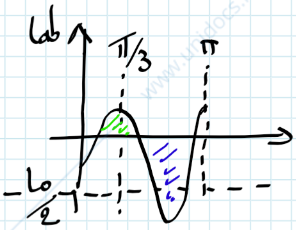
$$L_{ba} = L_{ab} = -\frac{L_0}{2} + L_m \cos(\;)$$

$$L_{ab} = -\frac{L_0}{2} + L_m \cos 2\left(\theta_m - \frac{\pi}{3}\right)$$

$$\rightarrow L_{bc} = -\frac{L_0}{2} + L_m \cos 2\left(\underbrace{\theta_m - \frac{\pi}{3} - \frac{2}{3}\pi}_{-\pi}\right)$$

$$L_{ca} = -\frac{L_0}{2} + L_m \cos 2\left(\theta_m \underbrace{- \frac{\pi}{3} + \frac{2}{3}\pi}_{\frac{\pi}{3}}\right)$$





$$L_{ab} = -\frac{L_0}{2} + L_m \cos 2\left(\theta_m - \frac{\pi}{3}\right) \qquad L_{bc} = -\frac{L_0}{2} + L_m \cos 2(\theta_m - \pi)$$

$$L_{ca} = -\frac{L_0}{2}\; L_m \cos 2\left(\theta_m + \frac{\pi}{3}\right)$$

$$v_a = \cancel{R_s i_a} + \frac{d\psi_a}{dt} \qquad v_b = \frac{d\psi_b}{dt} \qquad v_c = \frac{d\psi_c}{dt}$$

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{d}{dt}\left(\begin{bmatrix} L_{aa} & L_{ab} & L_{ca} \\ L_{ab} & L_{bb} & L_{bc} \\ L_{ca} & L_{bc} & L_{cc} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_f \cos\theta_m \\ L_f \cos\left(\theta_m - \frac{2}{3}\pi\right) \\ L_f \cos\left(\theta_m + \frac{2}{3}\pi\right) \end{bmatrix} I_r \right) \begin{pmatrix} 1 \\ + \\ \alpha \\ + \\ \alpha^2 \end{pmatrix} \cdot \sqrt{\frac{2}{3}}$$

$$\underbrace{\sqrt{\tfrac{2}{3}}\begin{bmatrix}1 & \alpha & \alpha^2\end{bmatrix}\begin{bmatrix}v_a\\ v_b\\ v_c\end{bmatrix}}_{\bar v_s} = \frac{d}{dt}\sqrt{\tfrac{2}{3}}\left(\underbrace{\begin{bmatrix}1 & \alpha & \alpha^2\end{bmatrix}\begin{bmatrix}L_{aa} & L_{ab} & L_{ac}\\ L_{ba} & L_{bb} & L_{bc}\\ L_{ca} & L_{bc} & L_{cc}\end{bmatrix}\begin{bmatrix}i_a\\ i_b\\ i_c\end{bmatrix}}_{i_a+i_b+i_c=0} + \underbrace{\begin{bmatrix}1 & \alpha & \alpha^2\end{bmatrix}\begin{bmatrix}L_f\cos\theta_m\\ L_f\cos(\theta_m-\frac{2}{3}\pi)\\ L_f\cos(\theta_m+\frac{2}{3}\pi)\end{bmatrix} I_f}_{L_f\,\bar i_f = \sqrt{\frac{3}{2}} I_f e^{j\theta_m}}\right)$$

$$\psi_a = \overbrace{\left(L_0 + L_m\cos 2\theta_m\right)}^{L_{aa}} i_a + \overbrace{\left(-\frac{L_0}{2} + L_m\cos 2\left(\theta_m-\frac{\pi}{3}\right)\right)}^{L_{ba}} i_b + \overbrace{\left(-\frac{L_0}{2} + L_m\cos 2\left(\theta_m+\frac{\pi}{3}\right)\right)}^{L_{ca}} i_c$$

$$= \underbrace{L_0 i_a - \frac{L_0}{2} i_b - \frac{L_0}{2} i_c}_{\frac{3}{2}L_0 i_a} + L_m i_a\cos 2\theta_m + i_b L_m\cos 2\left(\theta_m-\frac{\pi}{3}\right) + i_c L_m\cos 2\left(\theta_m+\frac{\pi}{3}\right)$$

$$\left(2\theta_m - \frac{2}{3}\pi\right) \qquad \left(2\theta_m + \frac{2}{3}\pi\right)$$

$$\psi_b = \overbrace{\left(-\frac{L_0}{2} + L_m\cos 2\left(\theta_m-\frac{\pi}{3}\right)\right)}^{L_{ba}} i_a + \left(L_0 + L_m\cos 2\left(\theta_m-\frac{2}{3}\pi\right)\right) i_b + \left(-\frac{L_0}{2} + L_m\cos 2\left(\theta_m-\pi\right)\right) i_c$$

$$2\theta_m - \frac{4}{3}\pi \qquad 2\theta_m - \cancel{2\pi}$$

$$= \frac{3}{2}L_0 i_b + L_m\cos\left(2\theta_m - \frac{2}{3}\pi\right) i_a + L_m\cos\left(2\theta_m + \frac{2}{3}\pi\right) i_b + L_m\cos 2\theta_m\, i_c$$

$$\psi_c = \frac{3}{2}L_0 i_c + L_m\cos\left(2\theta_m + \frac{2}{3}\pi\right) i_a + L_m\cos 2\theta_m\, i_b + L_m\cos\left(2\theta_m - \frac{2}{3}\pi\right) i_c$$

$$\cos\varphi = \frac{e^{j\varphi}+e^{-j\varphi}}{2}$$

$\sqrt{\frac{2}{3}}$

$$1\quad \psi_a = \frac{3}{2}L_0 i_a + L_m\cos 2\theta_m\, i_a + L_m\cos\left(2\theta_m - \frac{2}{3}\pi\right) i_b + L_m\cos\left(2\theta_m+\frac{2}{3}\pi\right) i_c$$

$+$

$$e^{j\frac{2}{3}\pi}\quad \psi_b = \frac{3}{2}L_0 i_b + L_m\cos\left(2\theta_m - \frac{2}{3}\pi\right) i_a + L_m\cos\left(2\theta_m+\frac{2}{3}\pi\right) i_b + L_m\cos 2\theta_m\, i_c$$

$+$

$$e^{-j\frac{2}{3}\pi}\quad \psi_c = \frac{3}{2}L_0 i_c + L_m\cos\left(2\theta_m+\frac{2}{3}\pi\right) i_a + L_m\cos\left(2\theta_m\right) i_b + L_m\cos\left(2\theta_m-\frac{2}{3}\pi\right) i_c$$

1, α, α^2

$$\bar\psi_s = L_s\,\bar i_s$$

$$b\underbrace{(1+\alpha+\alpha^2)}_{0}$$

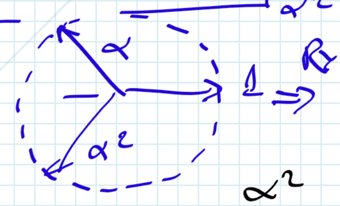
$$\left[\underbrace{e^{-j2\theta_m}}_{1} + e^{-j2\theta_m}\underbrace{e^{-j\frac{2}{3}\pi}}_{\alpha} + e^{-j2\theta_m}\underbrace{e^{+j\frac{2}{3}\pi}}_{\alpha}\right]$$

$e^{-j\frac{2}{3}\pi}$, $e^{j\frac{2}{3}\pi}$

$$\sqrt{\frac{2}{3}}\frac{L_m}{2}\left(e^{j2\theta_m} + \cancel{e^{-j2\theta_m}} + e^{j2\theta_m}\cancel{e^{-j\frac{2}{3}\pi}}\,\cancel{e^{j\frac{2}{3}\pi}} + \cancel{e^{-j2\theta_m}e^{+j\frac{2}{3}\pi}e^{j\frac{2}{3}\pi}} + e^{j2\theta_m}\cancel{e^{j\frac{2}{3}\pi}}\,\cancel{e^{-j\frac{2}{3}\pi}} + \cancel{e^{-j2\theta_m}e^{-j\frac{2}{3}\pi}e^{-j\frac{2}{3}\pi}}\right) i_a$$

α, α^2

$$\sqrt{\frac{2}{3}}\frac{L_m}{2}\left(3e^{j2\theta_m}\right) i_a \qquad \bar\psi_s = 1^a \text{ colonna} = \sqrt{\frac{2}{3}}\,\frac{3}{2}L_m\, e^{j2\theta_m}\, i_a$$



$$\sqrt{\frac{2}{3}}\frac{L_m}{2}\left(e^{j2\theta_m}\overbrace{e^{-j\frac{2}{3}\pi}}^{\alpha^2} + \cancel{e^{-j2\theta_m}e^{+j\frac{2}{3}\pi}}^{\alpha} + e^{j2\theta_m}\overbrace{e^{j\frac{2}{3}\pi}e^{j\frac{2}{3}\pi}}^{e^{-j\frac{2}{3}\pi}} + \cancel{e^{-j2\theta_m}e^{-j\frac{2}{3}\pi}e^{+j\frac{2}{3}\pi}}^{1} + e^{j2\theta_m}\overbrace{e^{-j\frac{2}{3}\pi}}^{\alpha^2} + e^{-j2\theta_m}e^{-j\frac{2}{3}\pi} = \alpha^2\right)$$

$$\sqrt{\frac{2}{3}}\frac{L_m}{2}\left(e^{j2\theta_m}e^{-j\frac{2}{3}\pi} + 0\right)$$

$$\boxed{\sqrt{\frac{2}{3}}\,\frac{3}{2}L_m e^{j2\vartheta_m}\, i_a} \qquad \boxed{\sqrt{\frac{2}{3}}\,\frac{3}{2}L_m e^{j2\vartheta_m}\, i_c\,\alpha} \qquad 1+\alpha+\alpha^2=0$$

$$\boxed{\sqrt{\frac{2}{3}}\,\frac{3}{2}L_m e^{j2\vartheta_m}\, i_b\,\alpha^2}$$

$$\bar{i}_s = \underline{\left(i_a+\alpha i_b+\alpha^2 i_c\right)} = \left(i_a + e^{j\frac{2}{3}\pi} i_b + e^{-j\frac{2}{3}\pi} i_c\right)$$

$$\bar{\psi}_s = \frac{3}{2}L_o\,\bar{i}_s + \frac{3}{2}L_m e^{j2\vartheta_m}\sqrt{\frac{2}{3}}\left(i_a + i_b\alpha^2 + i_c\alpha\right) + L_f\,\bar{i}_e$$

$$\underline{i_s} = \left(\underline{i_a + i_b e^{-j\frac{2}{3}\pi} + i_c e^{j\frac{2}{3}\pi}}\right)$$

$$\bar{\psi}_s = \widetilde{\frac{3}{2}L_o\bar{i}_s} + \frac{3}{2}L_m e^{j2\vartheta_m}\,\underline{i_s} + \underbrace{L_f\,\bar{i}_e} \qquad I_s = |\bar{i}_s| \qquad \overbrace{\sqrt{\frac{3}{2}}I_n e^{j\omega t}}^{I_s} \qquad \overbrace{\sqrt{\frac{3}{2}}I_e e^{j\vartheta_m}}^{I_e^*}$$

$$\bar{v}_s = R_s\,\bar{i}_s + \frac{d}{dt}\bar{\psi}_s = R\bar{i}_s + \frac{d}{dt}\left(\frac{3}{2}L_o\bar{i}_s + \frac{3}{2}L_m e^{j2\vartheta_m}\,\underline{i_s} + L_f\,\bar{i}_e\right)$$

$$\bar{v} = R\bar{i}_s + j\overbrace{\omega\frac{3}{2}L_o}^{X_s}\bar{i}_s + \overbrace{j\omega L_f\bar{i}_e}^{\bar{e}} + \frac{d}{dt}\left(\frac{3}{2}L_m e^{j2\vartheta_m}\sqrt{\frac{3}{2}}I_n e^{-j\omega t}\right) \qquad \underline{\vartheta_m = \omega t + \vartheta}$$

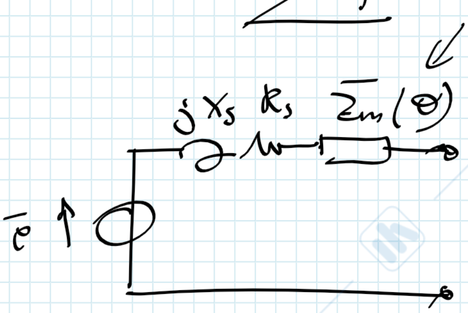
$$= R\bar{i}_s + jX_s\bar{i}_s + \bar{e} + \frac{d}{dt}\left(\frac{3}{2}L_m e^{j2\omega t + 2\vartheta}\cdot I_s e^{-j\omega t}\right) =$$

$$= R\bar{i}_s + jX_s\bar{i}_s + \bar{e} + \frac{d}{dt}\left(\frac{3}{2}L_m e^{j2\vartheta}\cdot \underbrace{I_s e^{j\omega t}}_{\bar{i}_s}\right) =$$

ϑ

angolo c.R. e il rotore

$$\bar{v} = R\bar{i}_s + jX_s\bar{i}_s + \bar{e} + \underbrace{j\omega\frac{3}{2}L_m e^{j2\vartheta}}_{\bar{Z}_m}\cdot\bar{i}_s$$



$$T = \frac{P}{\omega} = \frac{R_e\left(\bar{v}_s\,\underline{i_s}\right)}{\omega}$$

$R_s i_s^2$ // p. joule

$jX_s i_s^2$ // energ. acc.

$$p = R_e\left(\overbrace{R_s\bar{i}_s\,\underline{i_s}} + \overbrace{jX_s\bar{i}_s\,\underline{i_s}} + \underbrace{j\omega L_f\,\bar{i}_e\,\underline{i_s}}_{\text{coppia isotropa}} + j\omega\frac{3}{2}L_m e^{j2\vartheta}\,\bar{i}_s\,\underline{i_s}\right) =$$

$R_s i_s^2$ $\quad jX_s i_s$ $\quad$ Un pò viene acc $\quad I_s^2$

$$p = \mathbb{R}e\Big(\underbrace{R_s \bar{i}_s i_s}_{\text{perdita calore}} + \underbrace{j X_s \bar{i}_s i_s}_{p=p} + \underbrace{j\omega L_f \bar{i}_f i_s + j\omega \tfrac{3}{2} L_m e^{j2\theta} \bar{i}_s i_s}_{\text{coppia isotropo}} \Big) =$$

$$p = \mathbb{R}e\Big(j\omega L_f \bar{i}_f i_s + j\omega \tfrac{3}{2} L_m e^{j2\theta} I_s^2 \Big) = -\mathbb{I}m\Big(\quad \Big)$$

$$= -\mathbb{I}m\Big(\omega L_f I_f^{*} \cancel{e^{j\omega t}}{}^{+\theta} \cdot I_s \cancel{e^{-j\omega t}} + \omega \tfrac{3}{2} L_m e^{j2\theta} I_s^2 \Big) \leftarrow \mathbb{R}e(jx) = -\mathbb{I}m(x)$$

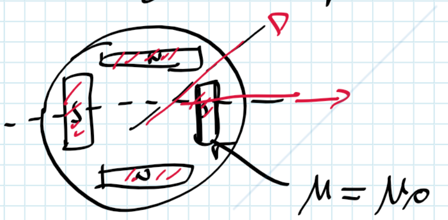
parte Im

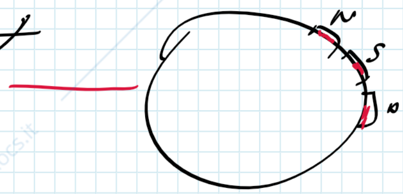
$$p = \underbrace{-\omega L_f I_f^{*} I_s \sin\theta}_{} \; \underbrace{- \omega \tfrac{3}{2} L_m I_s^2 \sin 2\theta}_{}$$

$\frac{p}{\omega}$ = coppia isotropo $\qquad$ p/ω = coppia di anisotropia.

$\boxed{\text{SINCRONI A MP}} \rightarrow \boxed{\text{BRUSHLESS}} \qquad \boxed{L_f I_f^{*} = \psi_{MP}}$

dist. trap. $\leftarrow$ $\boxed{\text{DC}}$ $\qquad$ $\boxed{\text{AC}}$ dist. sinus. al traferro





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