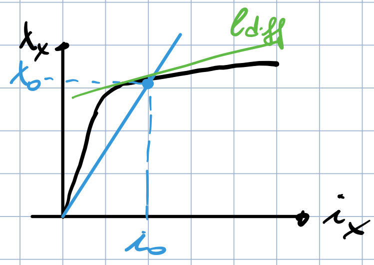
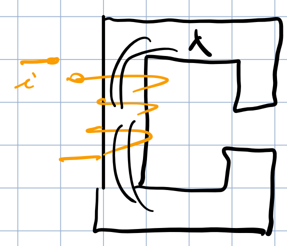
MODELLO DELLA MACCHINA SINCRONA CON SATURAZIONE

$$\begin{cases} v_d = R\, i_d + \dfrac{d\lambda_d}{dt} - \omega_{me}\,\lambda_q \\ v_q = R\, i_q + \dfrac{d\lambda_q}{dt} + \omega_{me}\,\lambda_d \end{cases}$$

$\lambda_d = \lambda_d(i_d)$

$\lambda_q = \lambda_q(i_q)$



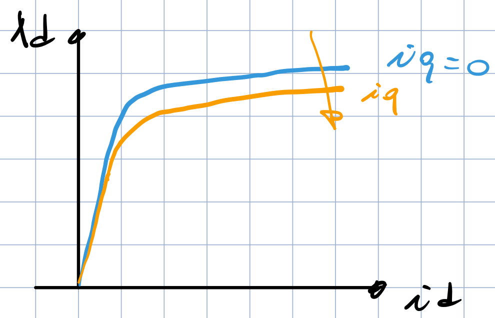


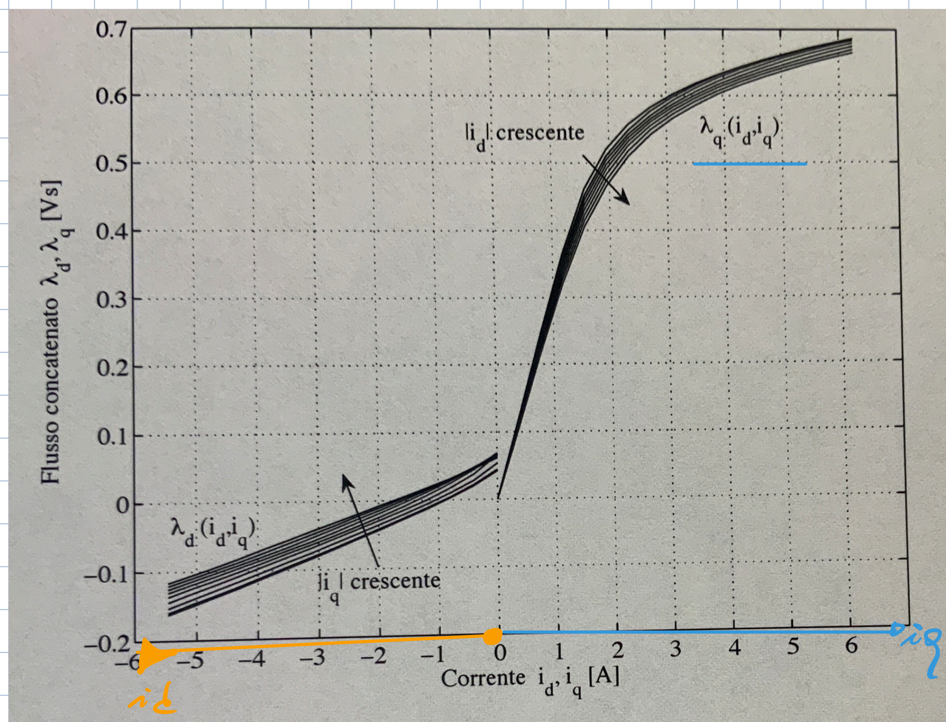
$L_{app} = \dfrac{\lambda_0}{i_0}$ $\qquad$ $l_{diff} = \left.\dfrac{d\lambda}{di}\right|_{i_0}$ $\qquad$ entrambe dipendono da i!

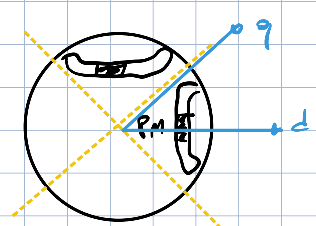
I f.c. dipendono da entrambe le correnti!

$\lambda_d(i_d, i_q)$

$\lambda_q(i_d, i_q)$

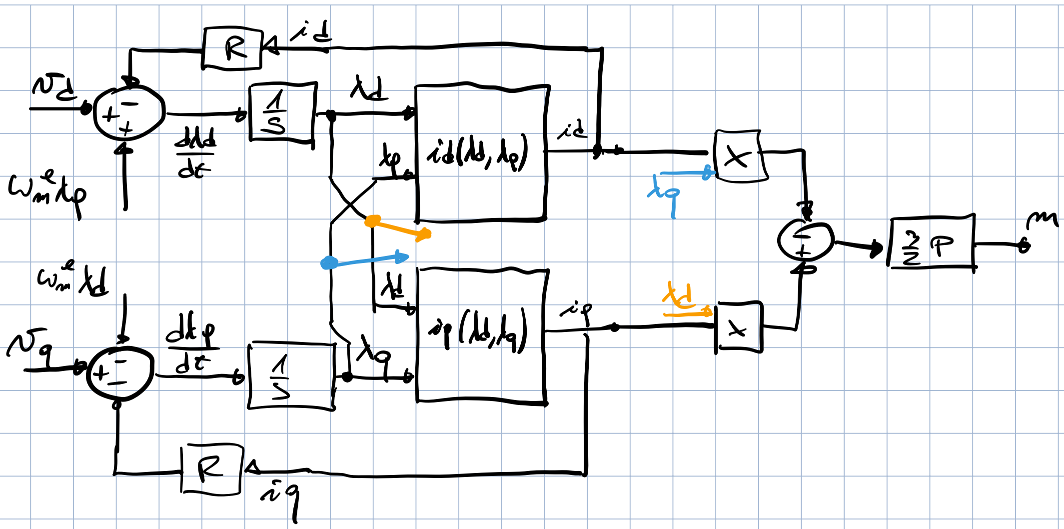






$$\begin{cases} v_d = R\, i_d + \dfrac{d\lambda_d}{dt} - \omega_{me}\,\lambda_q \\ v_q = R\, i_q + \dfrac{d\lambda_q}{dt} + \omega_{me}\,\lambda_d \end{cases}$$

$$m = \frac{3}{2}\, p\, (\lambda_d i_q - \lambda_q i_d)$$



$$\approx \lambda_m$$

$$\begin{cases} \lambda_d(i_d,i_q) = L_d(i_d,i_q)\, i_d + \lambda_d(0,i_q) \\ \lambda_q(i_d,i_q) = L_q(i_d,i_q)\, i_q + \lambda_q(i_d,0) = 0 \end{cases}$$

$$\begin{cases} L_d(i_d,i_q) = \dfrac{\lambda_d(i_d,i_q) - \lambda_d(0,i_q)}{i_d} \\ L_q(i_d,i_q) = \dfrac{\lambda_q(i_d,i_q) - \lambda_q(i_d,0)}{i_q} \end{cases}$$

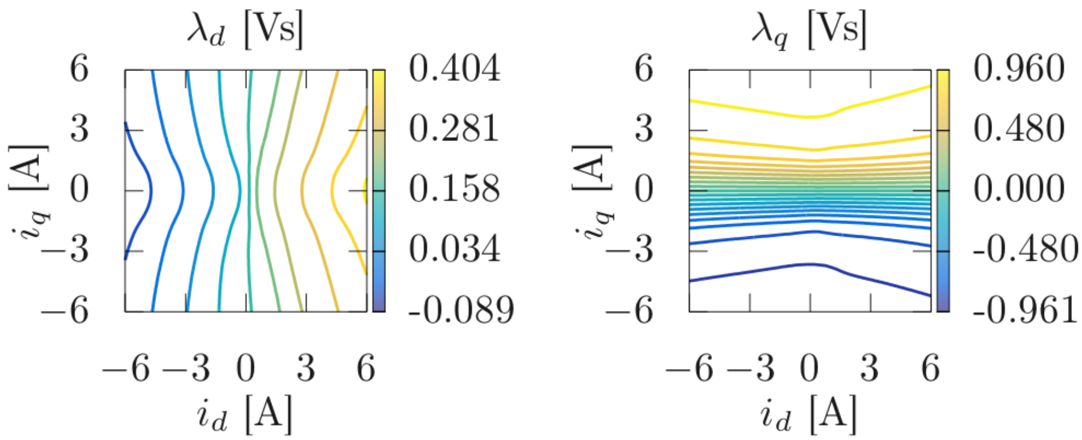
INDUTTANZE APPARENTI

$$\begin{cases} \dfrac{d\lambda_d}{dt} = \overset{l_{dd}}{\dfrac{\partial \lambda_d}{\partial i_d}} \dfrac{di_d}{dt} + \overset{l_{dq}}{\dfrac{\partial \lambda_d}{\partial i_q}} \dfrac{di_q}{dt} \\ \dfrac{d\lambda_q}{dt} = \underset{l_{qd}}{\dfrac{\partial \lambda_q}{\partial i_d}} \dfrac{di_d}{dt} + \underset{l_{qq}}{\dfrac{\partial \lambda_q}{\partial i_q}} \dfrac{di_q}{dt} \end{cases}$$

$l_{dq} = l_{qd}$ RECIPROCITA'

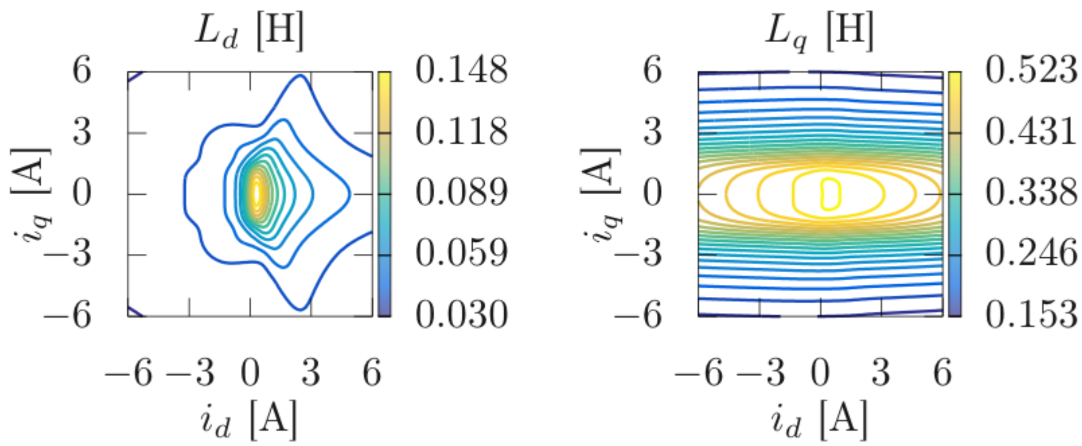
l_{xx} dipendono da (i_d e i_q)

$$\frac{d}{dt}\begin{bmatrix} \lambda_d \\ \lambda_q \end{bmatrix} = \begin{bmatrix} l_{dd} & l_{dq} \\ l_{dq} & l_{qq} \end{bmatrix} \frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix}$$



(a) (b)

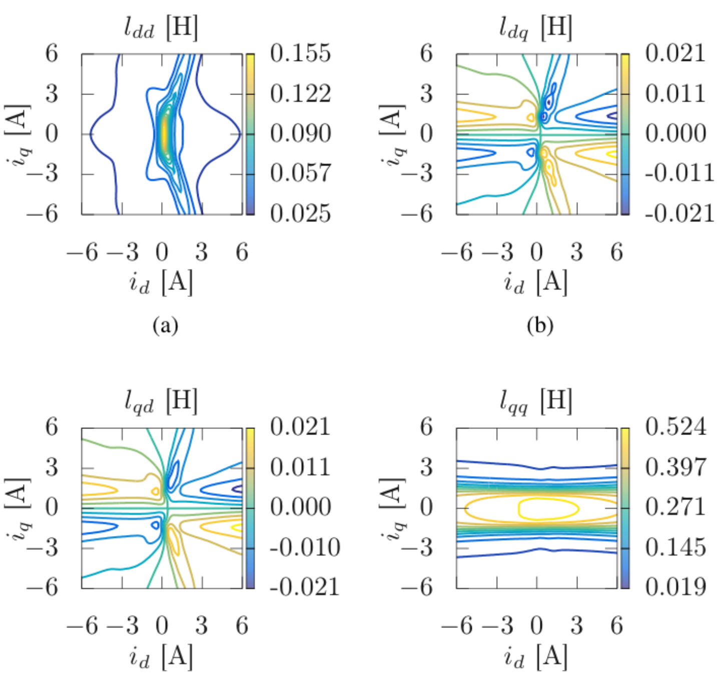
Fig. 4: PMA-SynRM flux-linkages maps (finite element analysis). (a) $\lambda_d(i_d, i_q)$ (b) $\lambda_q(i_d, i_q)$



(a) (b)

ces maps (finite ele-

$i_q)$



(a) (b) (c) (d)

Fig. 7: PMA-SynRM incremental inductances maps (finite element analysis). (a) $l_{dd}(i_d, i_q)$ (b) $l_{dq}(i_d, i_q)$ (c) $l_{qd}(i_d, i_q)$ (d) $l_{qq}(i_d, i_q)$

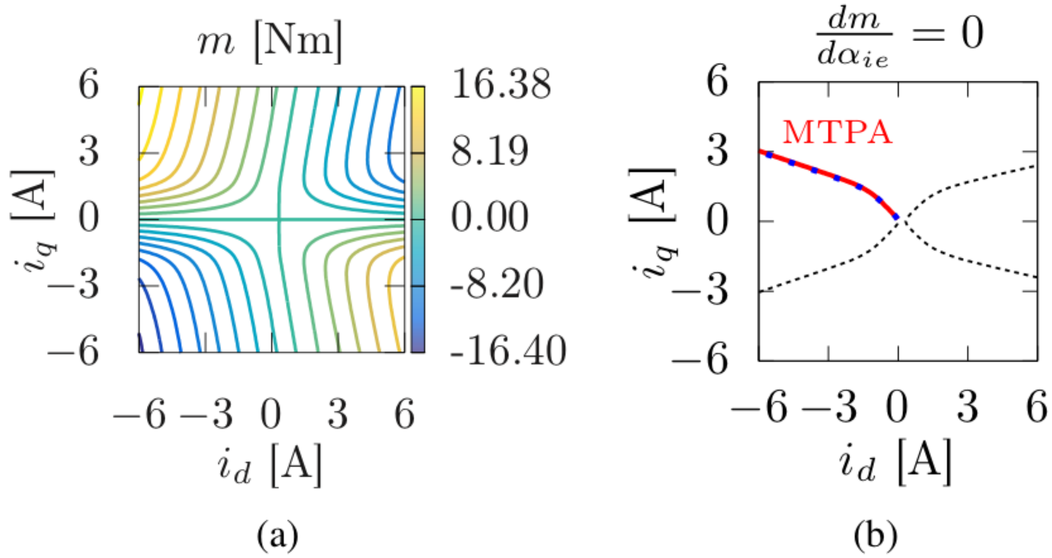


Fig. 8: PMA-SynRM torque map and MTPA trajectory (finite element analysis). (a) $m(i_d, i_q)$ (b) $\frac{\partial m(i_d,i_q)}{\partial \alpha_{ie}} = 0$. In red, MTPA trajectory computed with (8). In blue, MTPA trajectory computed with (10).

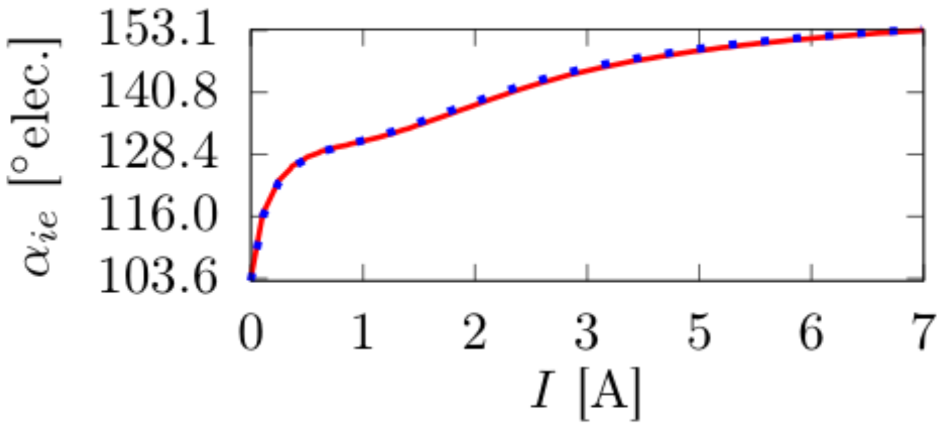


Fig. 9: PMA-SynRM MTPA trajectory in polar coordinates (finite element analysis). In red, MTPA trajectory computed with (8). In blue, MTPA trajectory computed with (10).

Per calcolare MTPA:

$$m = \frac{3}{2}p\left[\lambda_d i_q - \lambda_q i_d\right] \qquad \text{MTPA} \quad \frac{\partial m}{\partial \alpha_i} = 0 \qquad \begin{aligned} i_d &= i\cos\alpha_i \\ i_q &= i\sin\alpha_i \end{aligned}$$

$$\frac{\partial m}{\partial \alpha_i} = 0 = \frac{\partial \lambda_d}{\partial i_d}\frac{d i_d}{\partial \alpha_i} i_q + \frac{\partial \lambda_d}{\partial i_q}\frac{d i_q}{\partial \alpha_i} i_q + \lambda_d \frac{d i_q}{d\alpha_i} - \left[\frac{\partial \lambda_q}{\partial i_d}\frac{d i_d}{d\alpha_i} i_d + \frac{\partial \lambda_q}{\partial i_q}\frac{d i_q}{\partial \alpha_i} i_d + \lambda_q \frac{d i_d}{\partial \alpha_i}\right]$$

$$\frac{\partial \lambda_d}{\partial i_d} = l_{dd} \qquad \frac{\partial \lambda_d}{\partial i_q} = \frac{\partial \lambda_q}{\partial i_d} = l_{dq} = l_{qd} \qquad \frac{\partial \lambda_q}{\partial i_q} = l_{qq}$$

$$\frac{d i_d}{d\alpha_i} = -i\sin\alpha_i = -i_q \qquad \frac{d i_q}{d\alpha_i} = i\cos\alpha_i = i_d$$

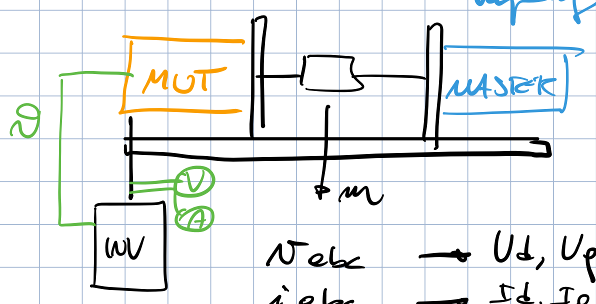
uso λ_d

$$\dots \quad 2\, l_{dq} i_d i_q - \left(l_{dd} i_q^2 + l_{qq} i_d^2\right) + \lambda_d i_d + \lambda_q i_q = 0$$

CARATTERIZZAZIONE CURVE $\lambda - i$ MACCHINA SINCRONA

$$\begin{cases} V_d = R I_d - \omega_m^e \lambda_q \\ V_q = R I_q + \omega_m^e \lambda_d \end{cases}$$

Ipotesi $\omega_m^e < \omega_B$



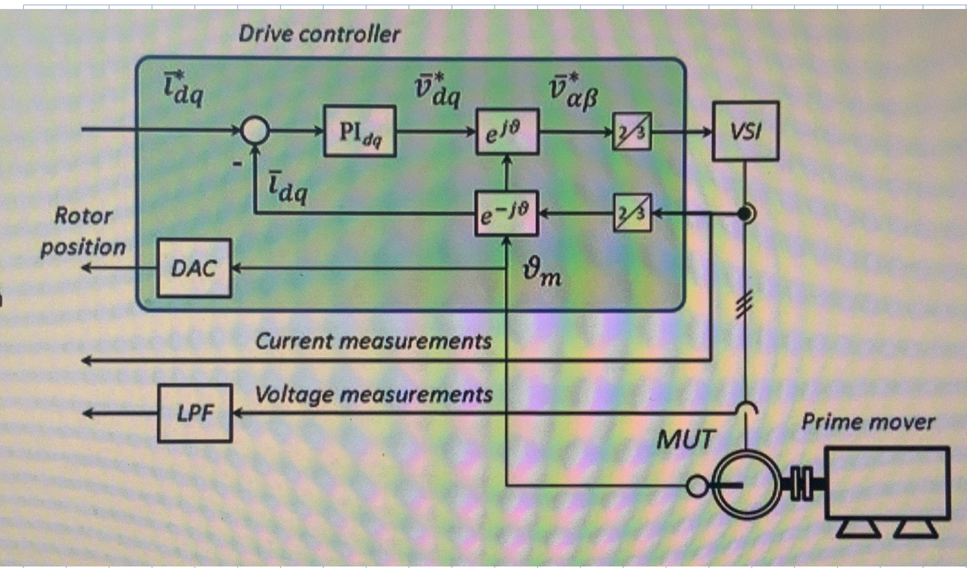
$N_{elc} \rightarrow U_d, U_q$

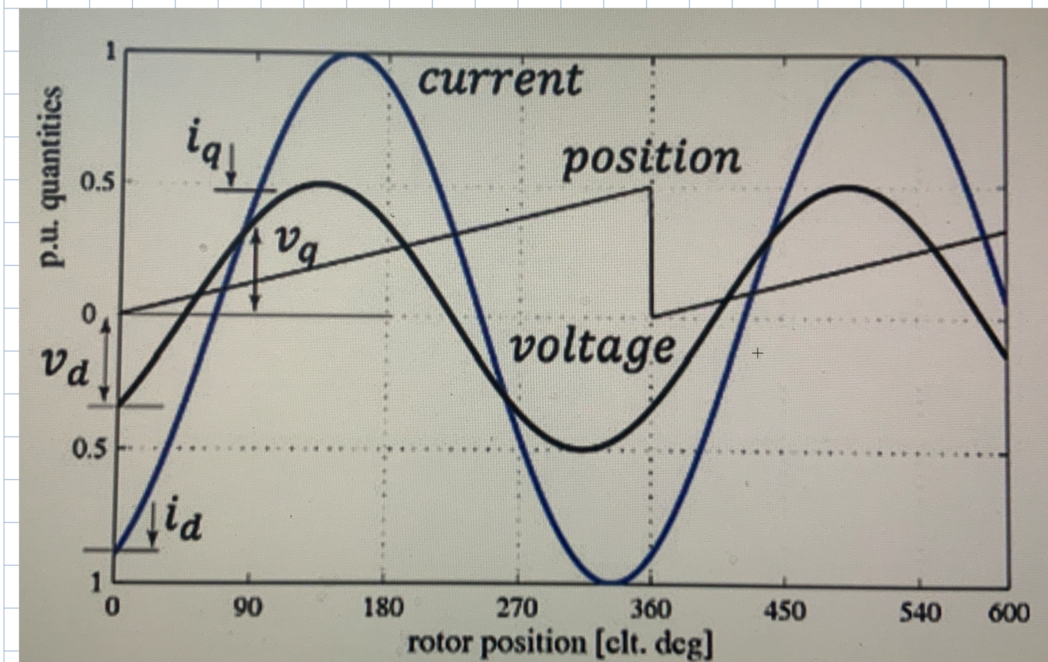
$i_{elc} \rightarrow I_d, I_q$

ϑ_m

$$\begin{cases} \lambda_q = \dfrac{-V_d + R I_d}{\omega_m^e} \\ \lambda_d = \dfrac{V_q - R I_q}{\omega_m^e} \end{cases}$$

? Come risolvo dipendenza da R?


Drive controller
VSI
DAC
Rotor position
Current measurements
Voltage measurements
LPF
MUT
Prime mover


current
position
voltage
p.u. quantities
rotor position [elt. deg]