

Controllo di Motori

Monday, 22 May 2017 15:43

↳ Servomotori (es. azionamenti elettrici, bracci robotici)

↳ POSIZIONE E VELOCITÀ PRECISE

↳ TEMPI DI RISPOSTA RAPIDI

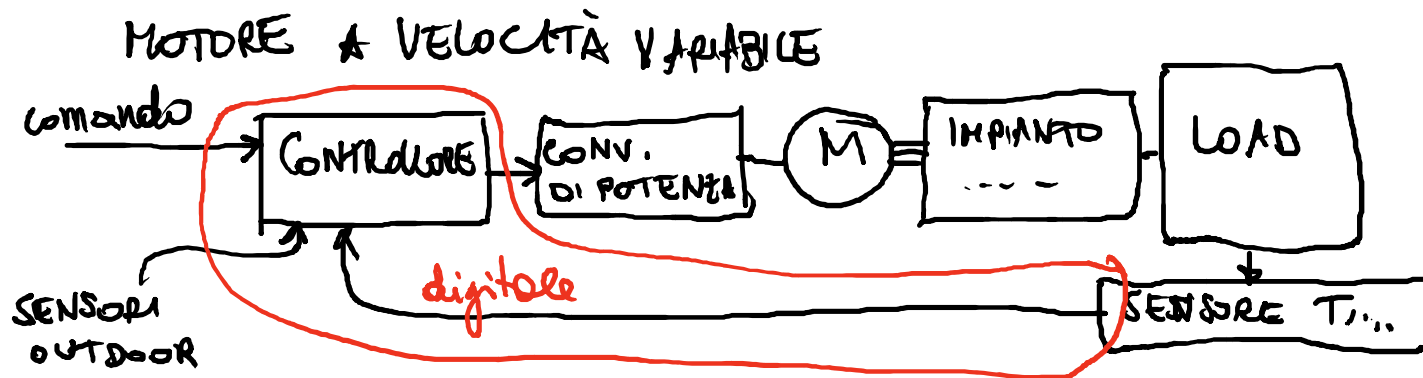
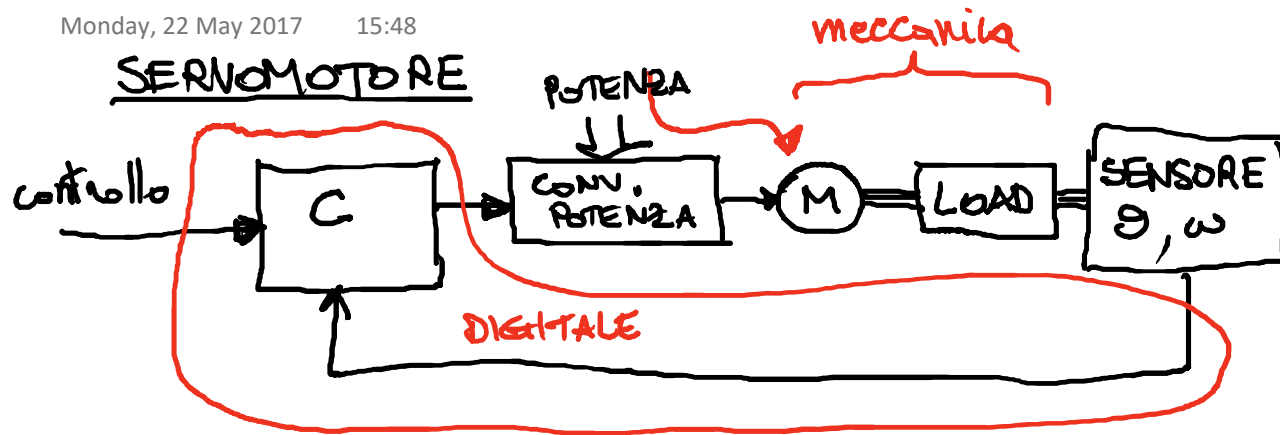
↳ Motori a velocità VARIABILE (es. impianto di condiz.)

↳ TEMPI DI RISPOSTA LENTI (il sistema controllato è lento)

↳ CONTROLLO DI VELOCITÀ

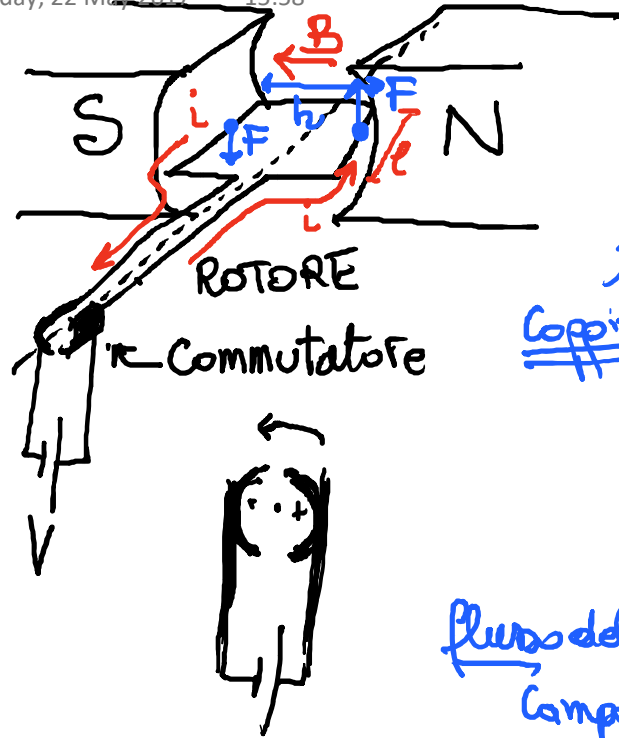
SISTEMA DI CONTROLLO

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MOTORE in CONTINUA

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$$\vec{F} = i \vec{L} \wedge \vec{B}$$

$$\tau = Fh = \underline{\underline{iBA}}$$

Coppia $lh = A$

se ha N spire

$$T = N i B A = i \phi_f$$

↑↑↑↑

flusso del $\phi_f = BAN$
 Campo magnetico concatenato con l'ewolgit
 del rotore

Monday, 22 May 2017

16:08



costante di coppia

avvolgimento del rotore

$$① T_{em} = K_t i_a \phi_f$$

↑
coppie elettromagnetiche

↑
corrente di armatura

(corrente nell'avvolgimento del rotore)



SE È PRESENTE

UN AVVOLGIMENTO DI

STATORE POSSO MODULARE ϕ_f

FORZA ELETTRICITRICE INDOTTA SULL'AVVOLGIMENTO DEL ROTORE

$$e_a \propto \phi_f \omega$$

$$① e_a = K_e \phi_f \omega$$

↑
COSTANTE DI TRAFERRO

CASO IDEALE (SENZA PERDITA)

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Potenza elettrica assorbita dal ROTORE

$$\underset{\uparrow}{e}_a \underset{\uparrow}{i}_a = \underset{\uparrow}{K_e} \underset{\uparrow}{\phi_f} \underset{\uparrow}{\omega} \underset{\uparrow}{i}_a$$

Potenza meccanica generata

$$T \omega = \underset{\uparrow}{K_T} \underset{\uparrow}{\phi_f} \underset{\uparrow}{i}_a \underset{\uparrow}{\omega}$$

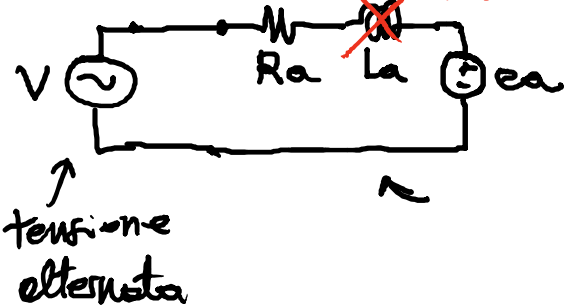
CASO IDEALE (senza perdite) : $\left[K_e = K_T \right]$
caso con perdita : $\left[K_e > K_T \right]$

Circuito eq. avvolgimento del rotore

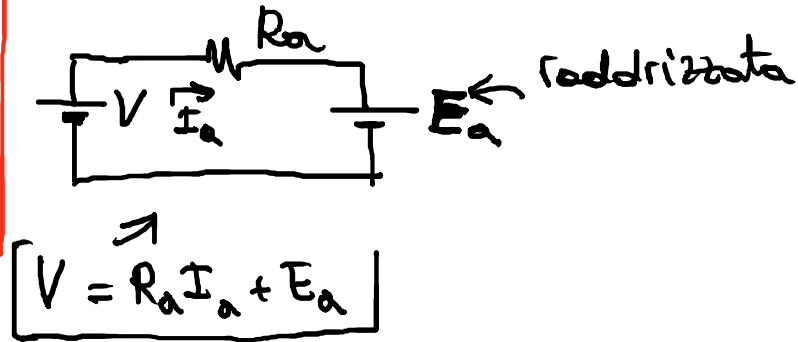
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a valle del commutatore

~~TRASCURARE~~



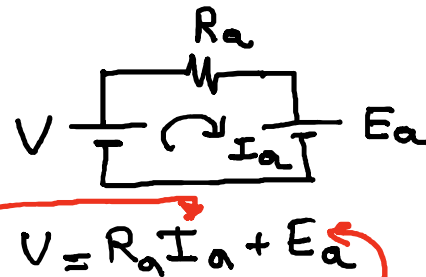
a monte del commutatore



Condizioni stazionarie

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$$\begin{cases} T_{em} = k_T \phi_f I_a \\ E_a = k_e \phi_f \omega \end{cases}$$



$$\overset{\downarrow}{V} = R_a \frac{\overset{\downarrow}{T_{em}}}{k_T \phi_f} + k_e \phi_f \omega \rightarrow \omega = \frac{1}{k_e \phi_f} \left[\overset{\uparrow}{V} - \frac{R_a T_{em}}{k_T \phi_f} \right]$$

poniamo $\boxed{\omega > 0} \rightarrow \boxed{E_a > 0}$

se $V > E_a \rightarrow I_a > 0$

se $V < E_a \rightarrow I_a < 0$

poniamo $\boxed{\omega < 0} \rightarrow E_a < 0$

se $V < E_a \rightarrow I_a < 0$

se $V > E_a \rightarrow I_a > 0$

$$P_a = E_a I_a > 0$$

$$P_a = E_a I_a < 0$$

MOTORE ($T_{em} > 0$)

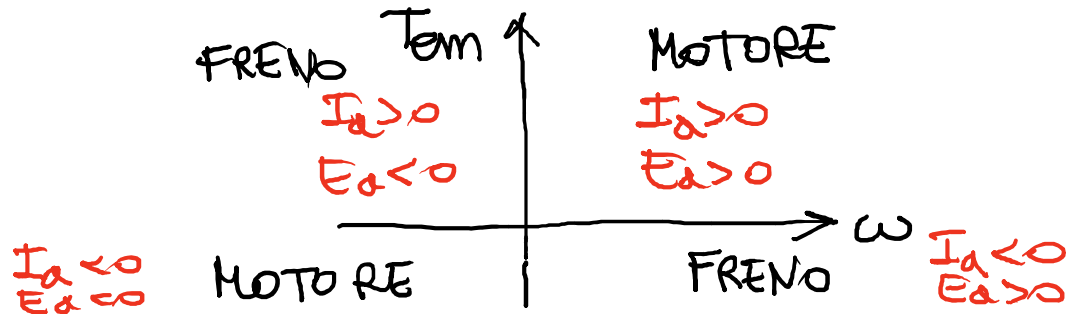
FRENO
(GENERATORE)

$$P_a = E_a I_a > 0$$

$$P_a = E_a I_a < 0$$

MOTORE ($T_{em} < 0$)

FRENO
(GENERATORE) ($T_{em} > 0$)



Motore in con magnete permanente

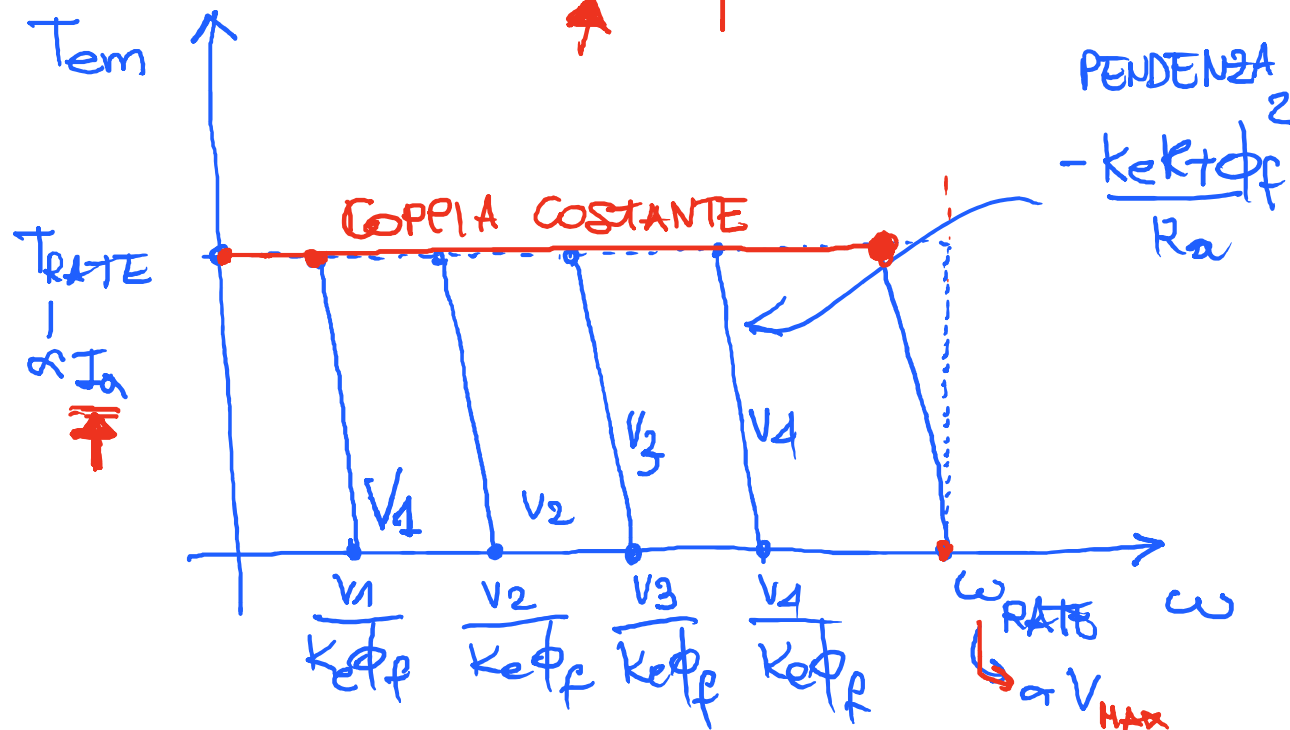
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$$\omega = \frac{1}{k_e \phi_f} \left[\underset{\uparrow}{V} - \frac{R_a T_{em}}{\underset{\uparrow}{k_T \phi_f}} \right]$$

$$[\phi_f = \text{cost}]$$

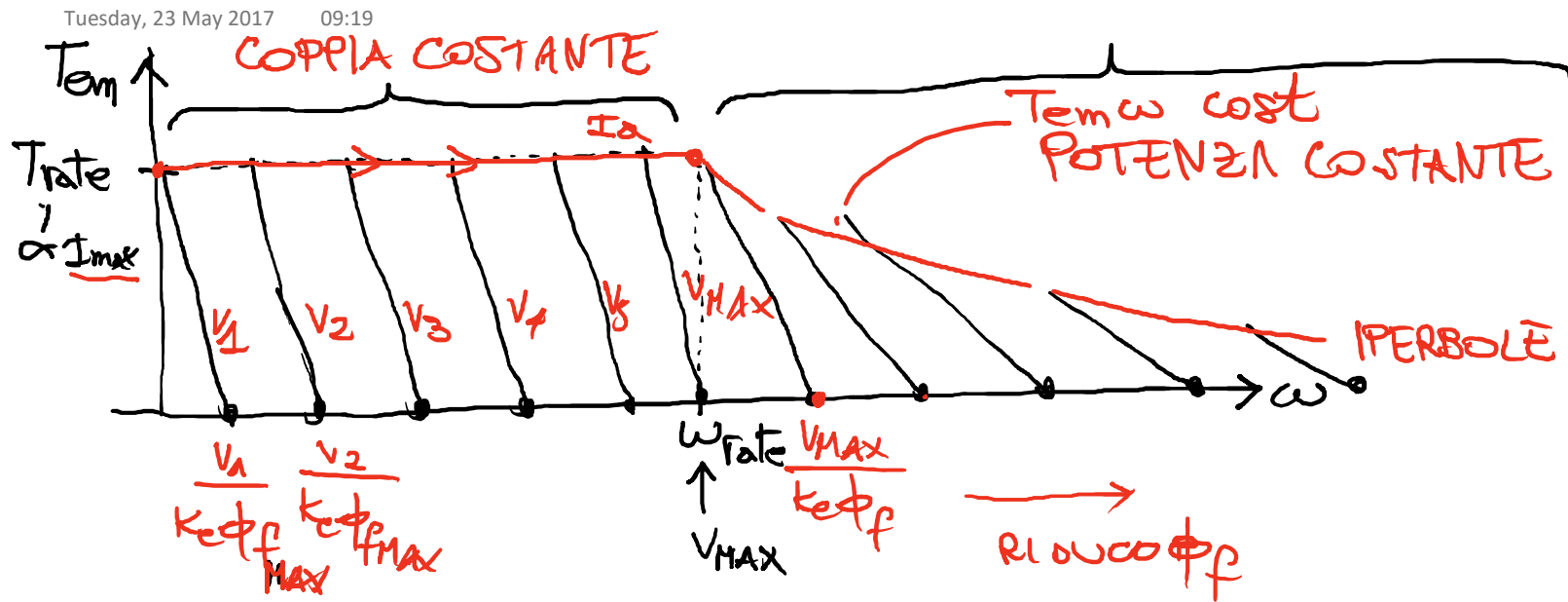
$$T_{em} = \frac{-k_e k_T \phi_f^2}{R_a} \omega + \frac{k_T \phi_f V}{R_a}$$

\uparrow
 pendenza
costante



- 1) $\omega_{MAX} \propto V$
- 2) $T \propto I_a$

Motore con eccitazione indipendente [avvolgimento di statore]

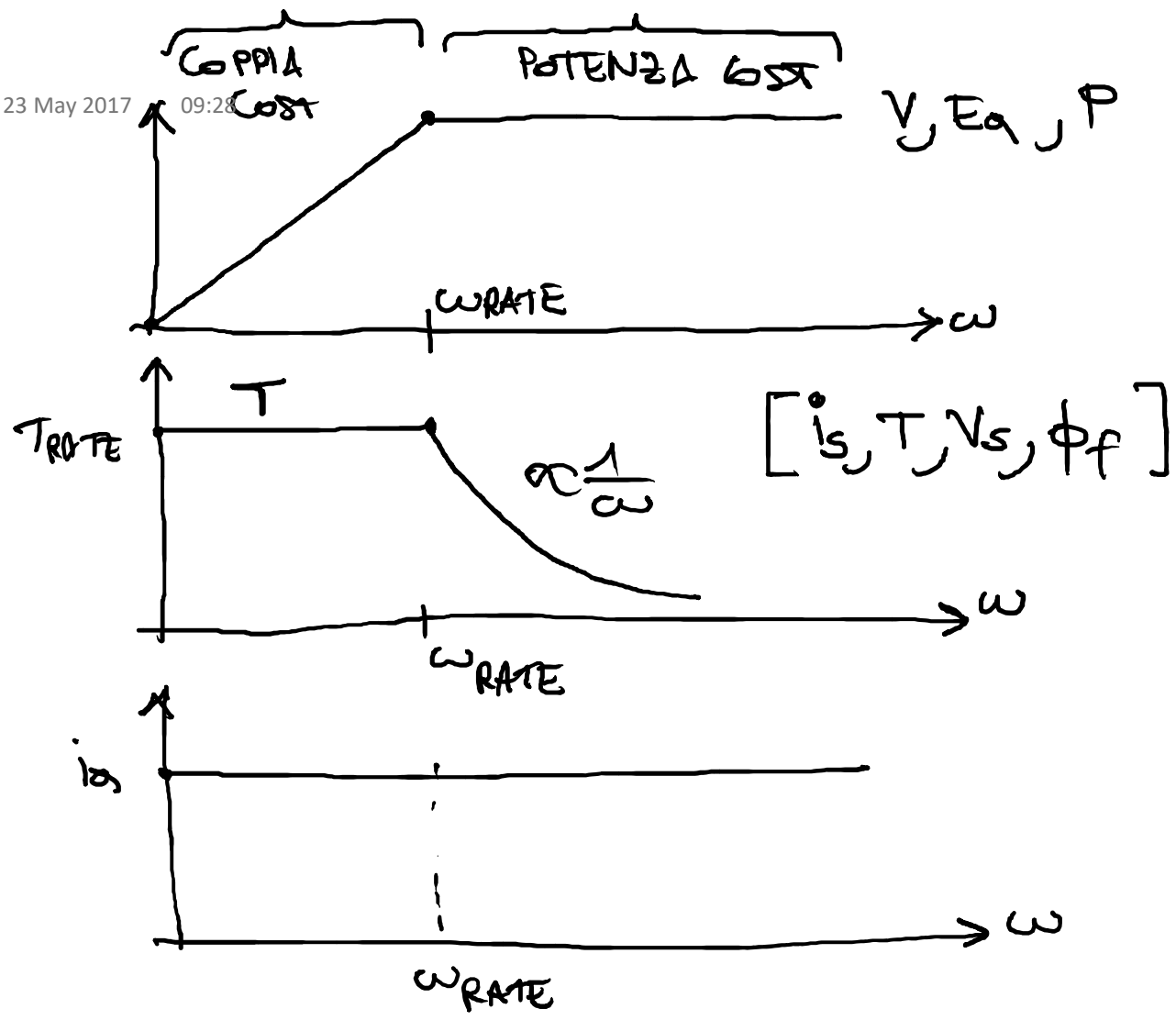


$$\phi_f \propto i_s$$

$$E_a I_a \geq T_m \omega$$

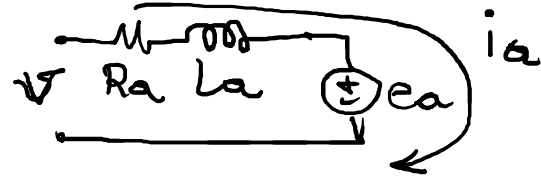
$\uparrow \uparrow$

$V_{MAX} I_{MAX}$



Modello di piccolo segnale

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$$V = (R_a + L_a s) i_a + e_a$$

\uparrow $k_e \phi_f \omega$

$$T_{em} = k_T \phi_f i_a$$

\uparrow

ASPETTI MECCANICI

nel dominio
del tempo

$$T_{em} = \underbrace{T_w}_{\text{COPPIA MECCANICA}} + \underbrace{B\omega}_{\text{ATTRITO}} + \underbrace{J\dot{\omega}}_{\text{Momento di inerzia}}$$

$$T_{em} = T_w + B\omega + Js\omega = k_T \phi_f i_a$$

$$V = \underbrace{(R_a + L_a s)}_{k_T \phi_f} [T_w + B\omega + Js\omega] + k_e \phi_f \omega \Rightarrow V - \frac{(R_a + L_a s) T_w}{k_T \phi_f} = \frac{(R_a + L_a s)(B + Js)}{k_T \phi_f} \omega + k_e \phi_f \omega$$

$$\omega = \left[V - \frac{(R_a + L_a s) T_w}{k_T \phi_f} \right] \frac{k_T \phi_f}{(R_a + L_a s)(B + Js) + k_e k_T \phi_f^2}$$

\uparrow
2 poli REALI NEGATIVI

Funzione di trasferimento $\frac{\omega}{V}$

$$\frac{\omega}{V} = \frac{k_t \phi_f}{(R_a + L_a s)(B + J s) + k_e k_t \phi_f^2}$$

← 2 poli REALI NEGATIVI

APPROX: B ≈ 0 (trascuriamo l'attrito meccanico)

$$\frac{\omega}{V} = \frac{k_t \phi_f}{R_a J s [1 + \tau_E s] + k_e k_t \phi_f^2} =$$

$$= \frac{\cancel{k_t \phi_f}}{k_e \cancel{k_t \phi_f^2} \left[\frac{R_a J}{k_e k_t \phi_f^2} s [1 + \tau_E s] + 1 \right]}$$

$$\tau_E = \frac{L_a}{R_a} \quad \leftarrow \begin{array}{l} \text{costante} \\ \text{di} \\ \text{tempo} \\ \text{induttore} \end{array}$$

τ_M costante di tempo meccanica
TIPICAMENTE $\tau_M \gg \tau_E$

$$\frac{\omega}{V} = \frac{\frac{1}{k_e \phi_f}}{5\tau_M(1 + \tau_{ES}) + 1} \sim \frac{\frac{1}{k_e \phi_f}}{(1 + \tau_{ES})(1 + \tau_{MS})}$$

δe
 $\tau_M \gg \tau_E$

$\tau_M \gg \tau_E$

2 poli MOLTO SEPARATI

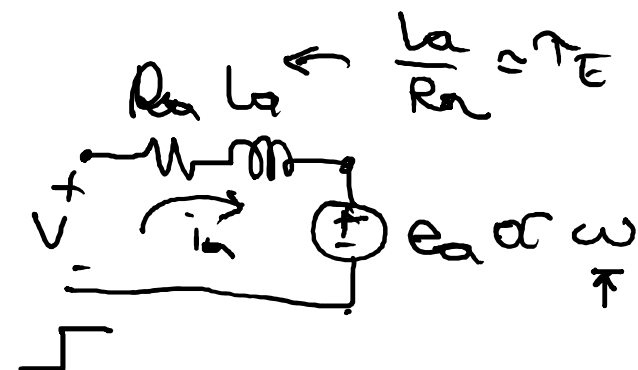
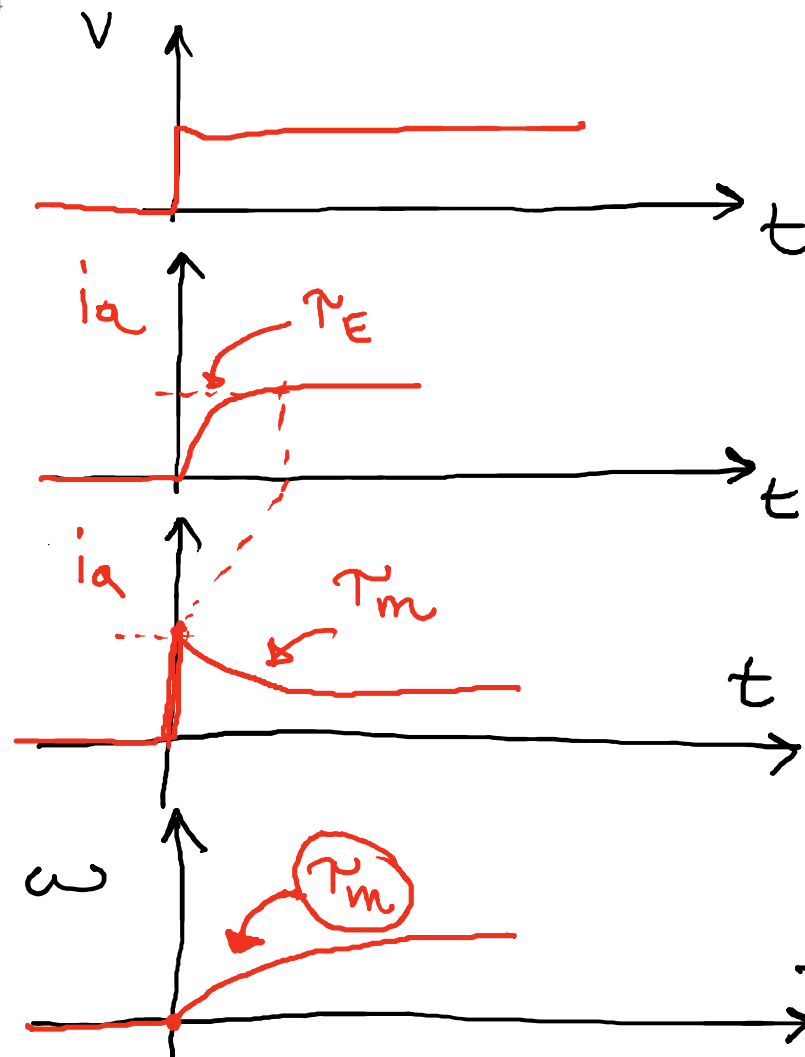
$-\frac{1}{\tau_M}, -\frac{1}{\tau_E}$

$-\frac{1}{\tau_E}, -\frac{1}{\tau_M}$

2 poli

$|\frac{1}{\tau_E}| \gg |\frac{1}{\tau_M}|$

RISPOSTA AL GRADINO

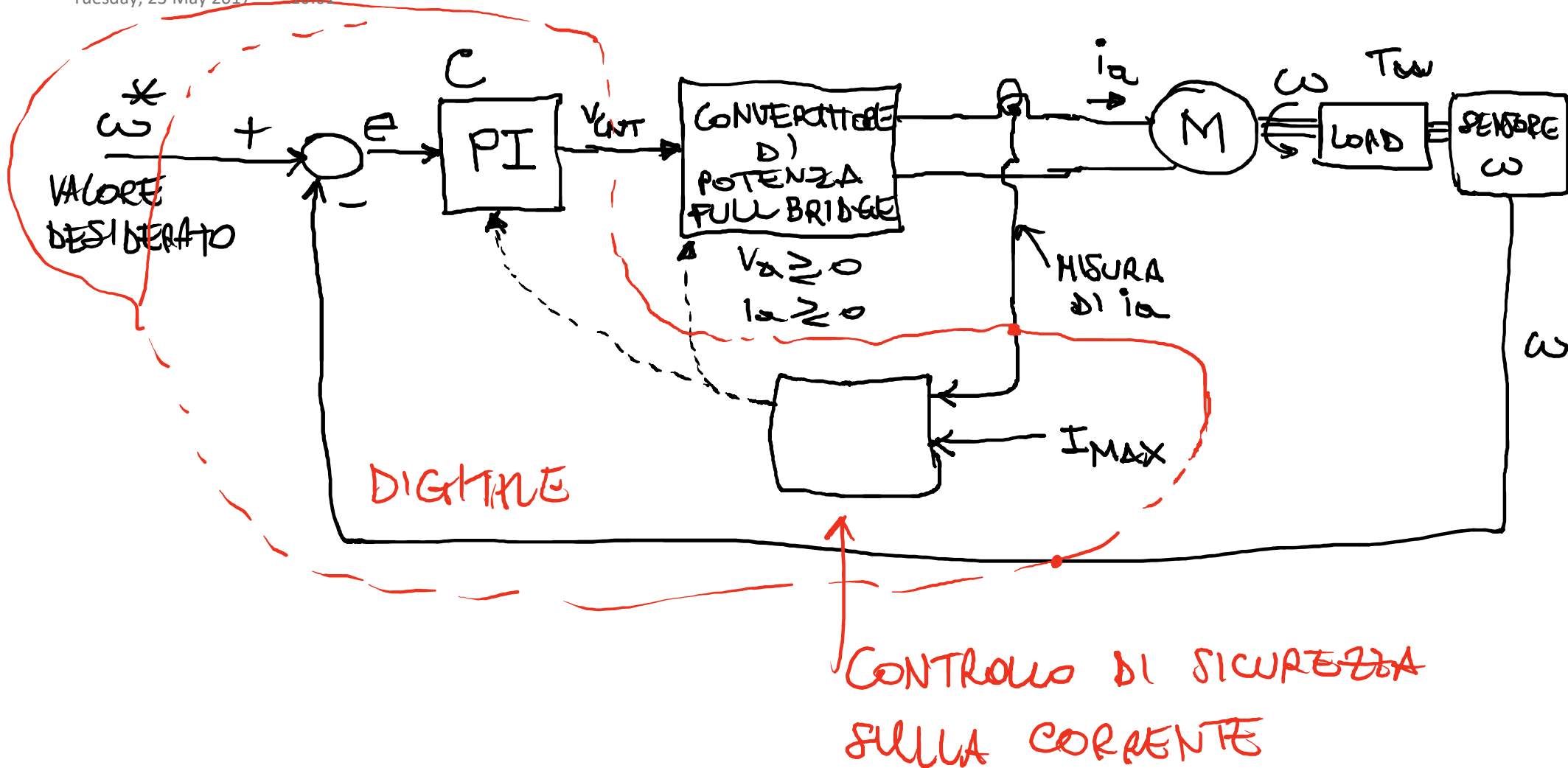


scala dei tempi BREVE

scala dei tempi LUNGA

SISTEMA DI CONTROLLO

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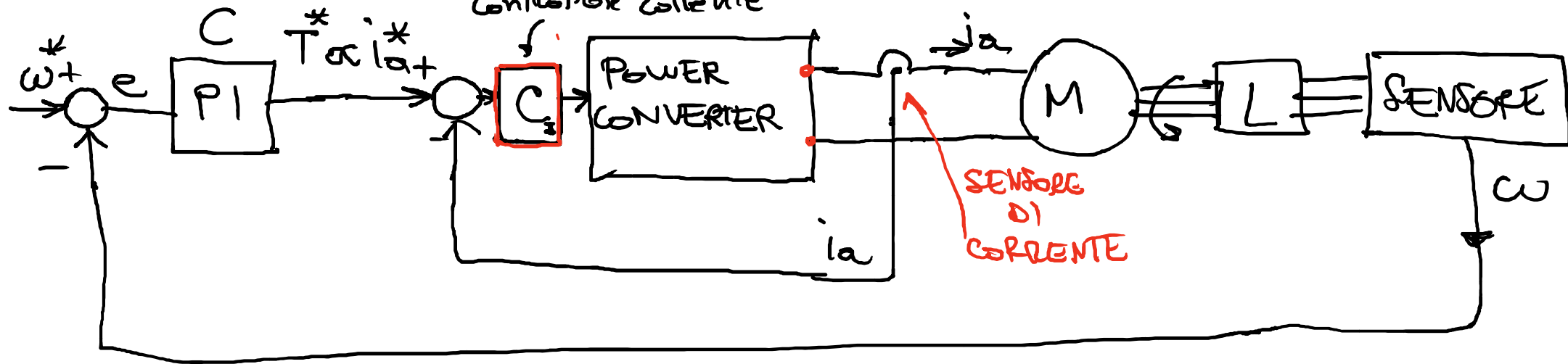


Controllo diretto della corrente

Tuesday, 23 May 2017

10:09

controllore corrente

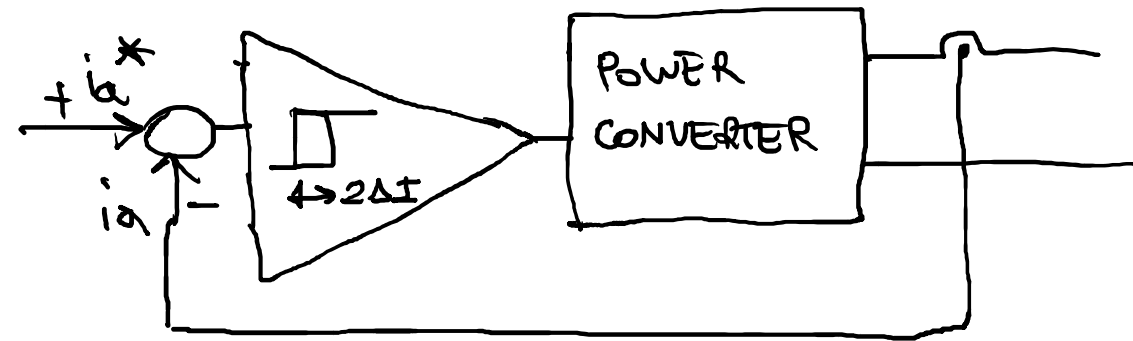
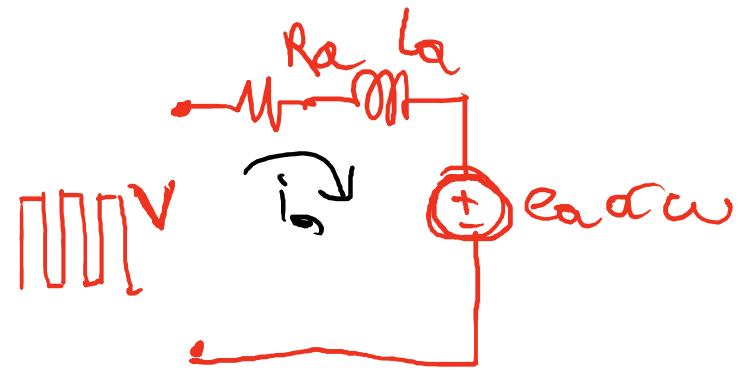
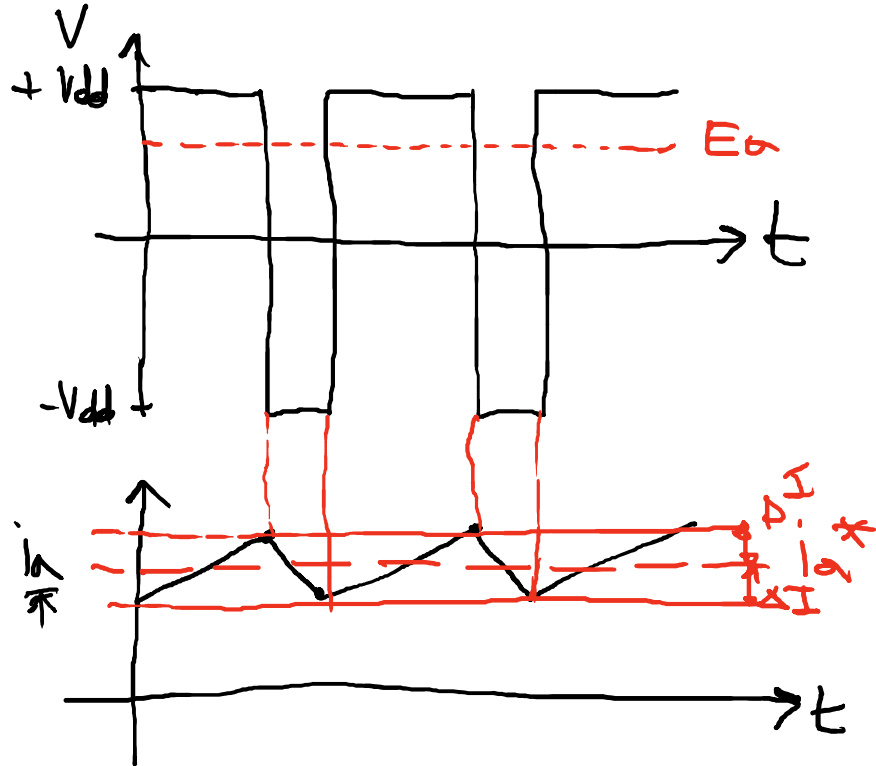


C_i
Controllo
della
corrente

BANDA DI TOLLERANZA
FREQUENZA FISSA

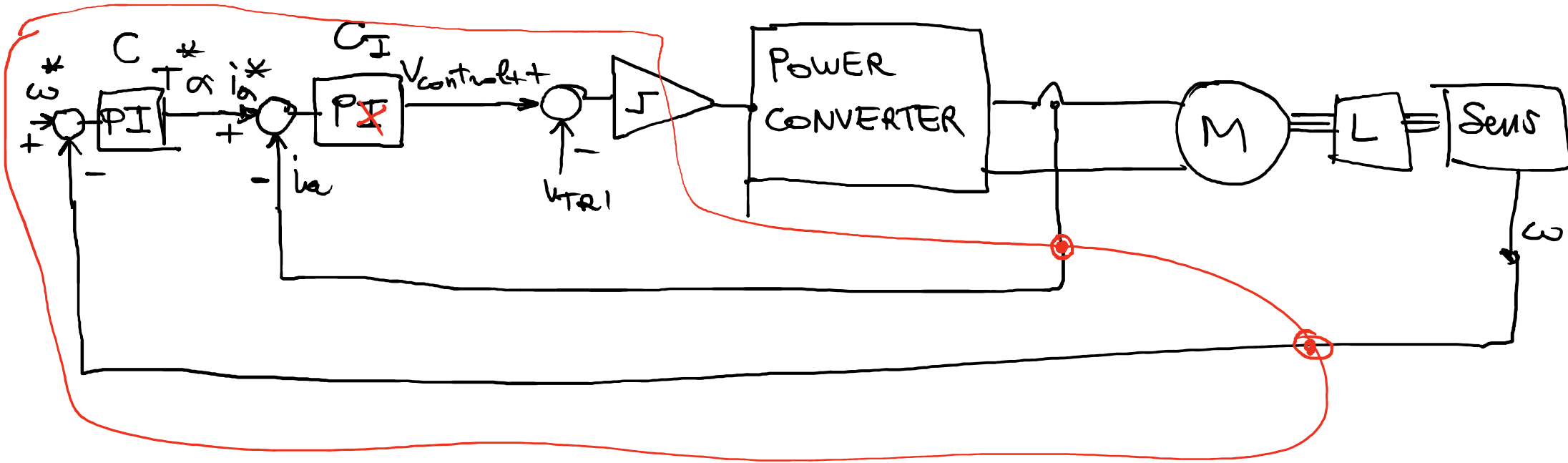
BANDA DI TOLLERANZA

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CONTROLLO A FREQUENZA FISSA

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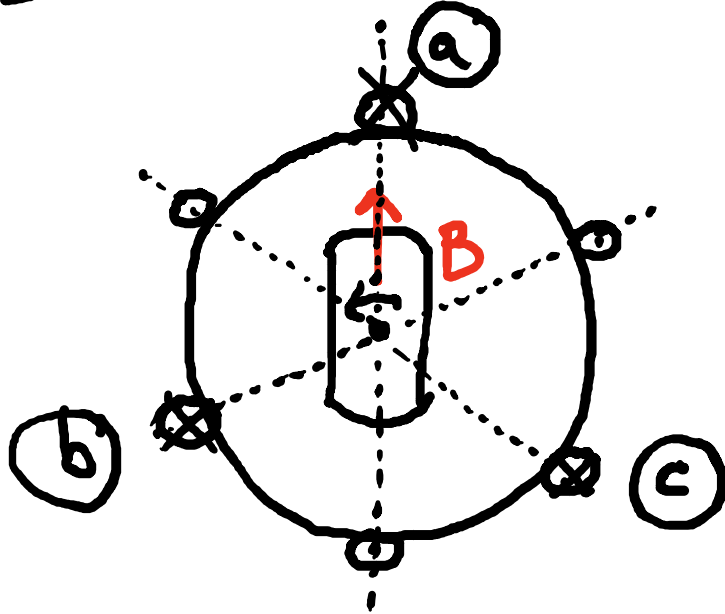


MOTORE SINCRONO

Wednesday, 24 May 2017 09:04

▷ SERVO

▷ MOTORI A VELOCITÀ



Rotore

▷ MAGNETE PERMANENTE

▷ AVVOLGIMENTO

Statore

▷ Avvolgimento che genera un campo magnetico rotante con velocità angolare ω

ES. un av. trifase a un polo.

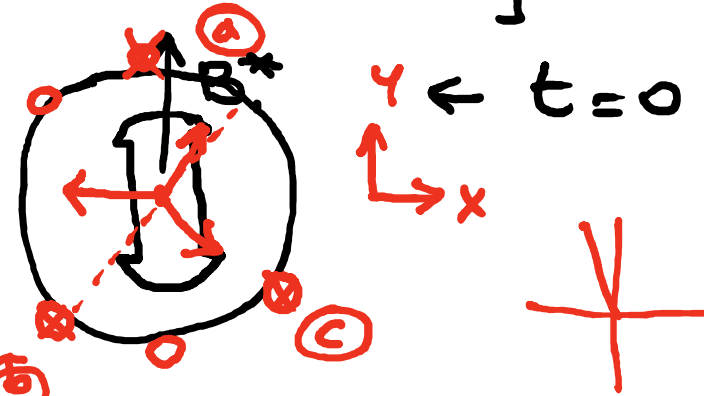
Avvolgimento di statore [avvolgimento di armatura]

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$$i_a = \sqrt{2} I_a \sin(\omega t + \delta)$$

$$i_b = \sqrt{2} I_a \sin(\omega t + \frac{2}{3}\pi + \delta)$$

$$i_c = \sqrt{2} I_a \sin(\omega t + \frac{4}{3}\pi + \delta)$$



Componente del B di statore in direzione

$$B_{Rx} = \underbrace{-B \sin(\omega t + \delta)}_{(a)} + \underbrace{\frac{B}{2} \sin(\omega t + \frac{2}{3}\pi + \delta)}_{(b)} + \underbrace{\frac{B}{2} \sin(\omega t + \frac{4}{3}\pi + \delta)}_{(c)}$$

$$= -B \sin(\omega t + \delta) + \frac{B}{2} \sin(\omega t + \delta) \overset{-\frac{1}{2}}{\cos(\frac{2}{3}\pi)} + \frac{B}{2} \cancel{\cos(\omega t + \delta)} \sin(\frac{2}{3}\pi) +$$

$$+ \frac{B}{2} \sin(\omega t + \delta) \overset{-\frac{1}{2}}{\cos(\frac{4}{3}\pi)} + \frac{B}{2} \cancel{\cos(\omega t + \delta)} \sin(\frac{4}{3}\pi) = -\frac{3}{2} B \sin(\omega t + \delta)$$

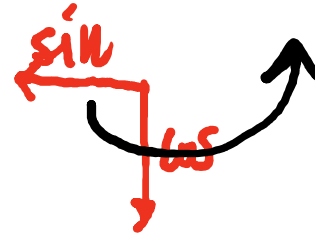
Componente B_{ry}

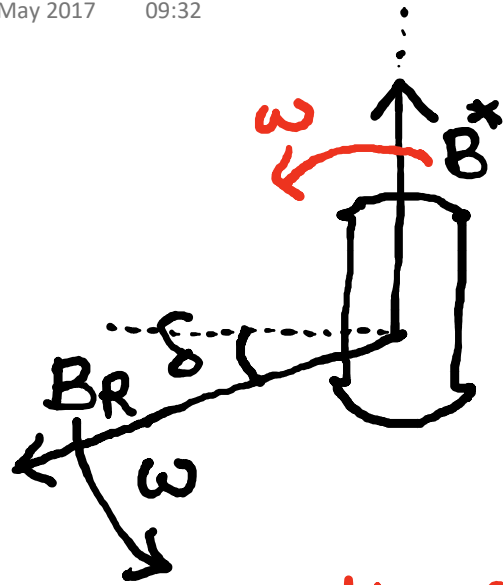
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$$B_{ry} = \underbrace{-\frac{\sqrt{3}}{2} B \sin(\omega t + \frac{2}{3}\pi + \delta)}_{(b)} + \underbrace{\frac{\sqrt{3}}{2} B \sin(\omega t + \frac{4}{3}\pi + \delta)}_{(c)}$$

$$= \cancel{\frac{-\sqrt{3}}{2} B \sin(\omega t + \delta) \overset{-\frac{1}{2}}{\cos(\frac{2}{3}\pi)}} - \frac{\sqrt{3}}{2} B \overset{\frac{\sqrt{3}}{2}}{\cos(\omega t + \delta) \sin(\frac{2}{3}\pi)} + \cancel{\frac{\sqrt{3}}{2} B \sin(\omega t + \delta) \overset{-\frac{1}{2}}{\cos(\frac{4}{3}\pi)}} + \frac{\sqrt{3}}{2} B \overset{-\frac{\sqrt{3}}{2}}{\cos(\omega t + \delta) \sin(\frac{4}{3}\pi)}$$

$$B_{ry} = -\frac{3}{2} B \cos(\omega t + \delta)$$





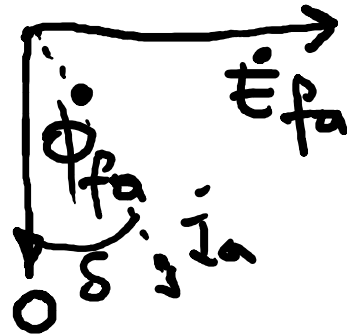
$t=0$

Hp la velocità angolare
del rotore è pari a ω

$$e_{fa} = N_s \frac{d\phi_{fa}(t)}{dt} = N_s \omega \phi_{fa} \cos \omega t$$

↑
numero di spire
avvolgimento (a)

ampiezza flusso del
campo magnetico
del Rotore (B^*)
concatenato con
l'avvolgimento (a)
dello statore
 $\phi_{fa}(t) = \phi_{fa} \cdot \sin(\omega t)$
 e_{fa} f.e.m. indotta
su (a) causata
dal B^*



Φ_{sa} flusso del campo magnetico ROTANTE generato dallo statore attraverso l'avvolgimento (a)

se L_a è l'autoinduttanza di (a)

$$N_s \Phi_{sa} = L_a i_a \rightarrow \Phi_{sa} = \frac{L_a i_a}{N_s}$$

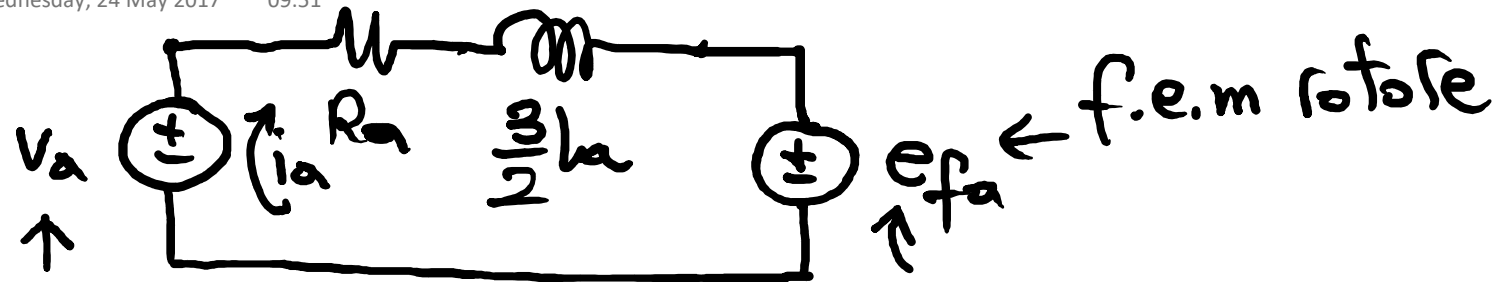
$$\Phi_{sa} = \frac{3}{2} \frac{L_a i_a}{N_s}$$

con solo
(a) acceso
con (a) (b) (c)
accesi

f.e.m. su (a) da $\Phi_{sa} \rightarrow \underline{\underline{E_{sa}}} = N_s \frac{d\Phi_{sa}}{dt} = \frac{3}{2} L_a \frac{di_a}{dt}$

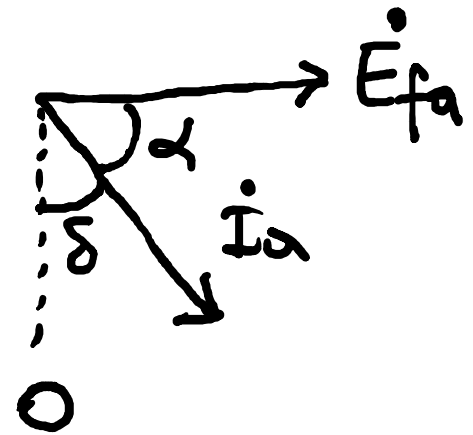
CIRCUITO EQUIVALENTE PER avvolgimento a

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$$P_{em}^{(a)} = \vec{I}_a \cdot \vec{E}_{fa} = I_a E_{fa} \cos \alpha = I_a E_{fa} \sin \delta$$

$$= I_a N_s \omega \Phi_{fa} \sin \delta$$

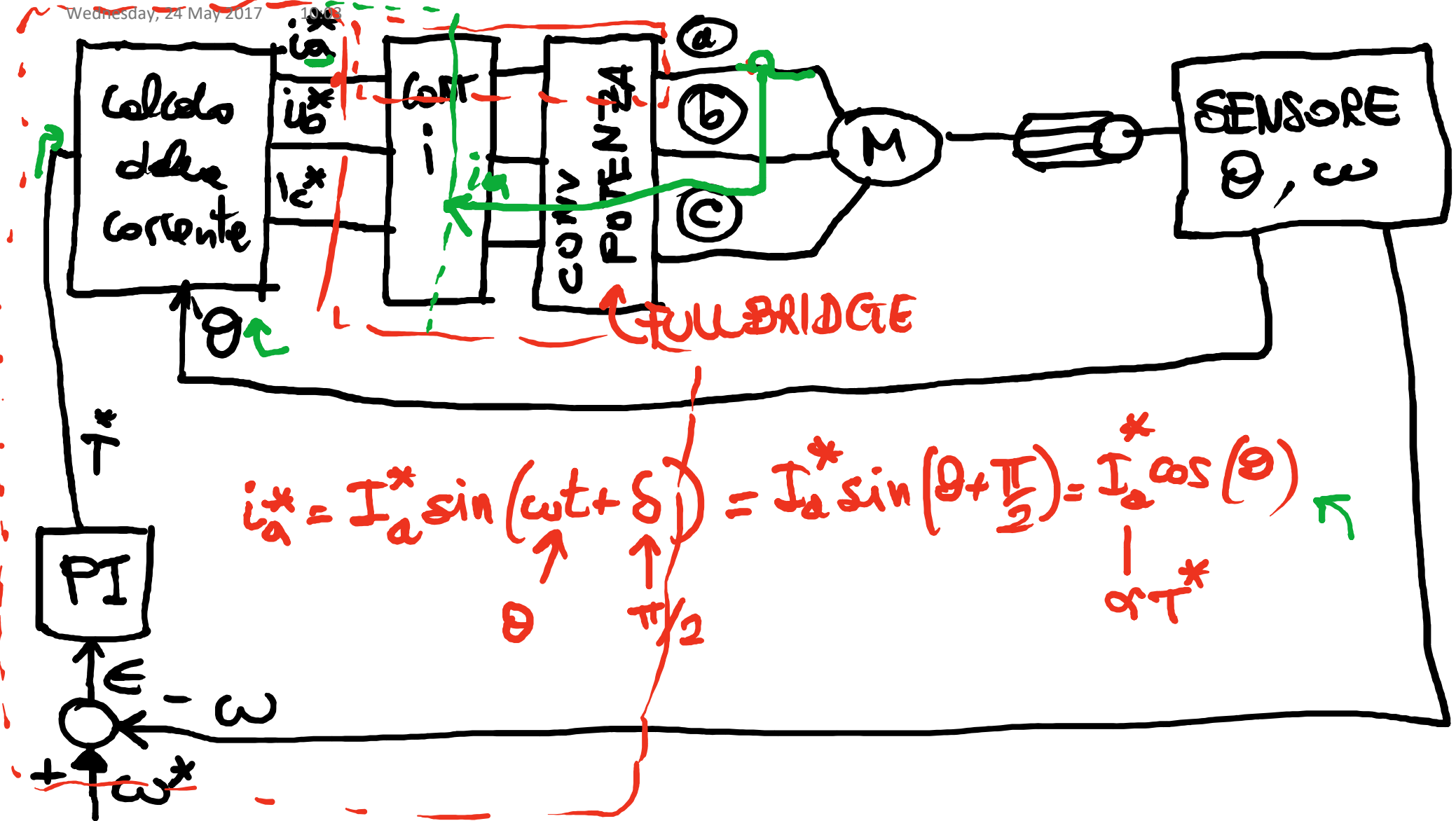


$$P_{em_{TOT}} = P_{em}^{(a)} + P_{em}^{(b)} + P_{em}^{(c)}$$

$$= \underbrace{3 I_a N_s \omega \Phi_{fa} \sin \delta}_{\omega T_{em}} = \omega T_{em} \Rightarrow T_{em} = 3 I_a N_s \Phi_{fa} \sin \delta$$

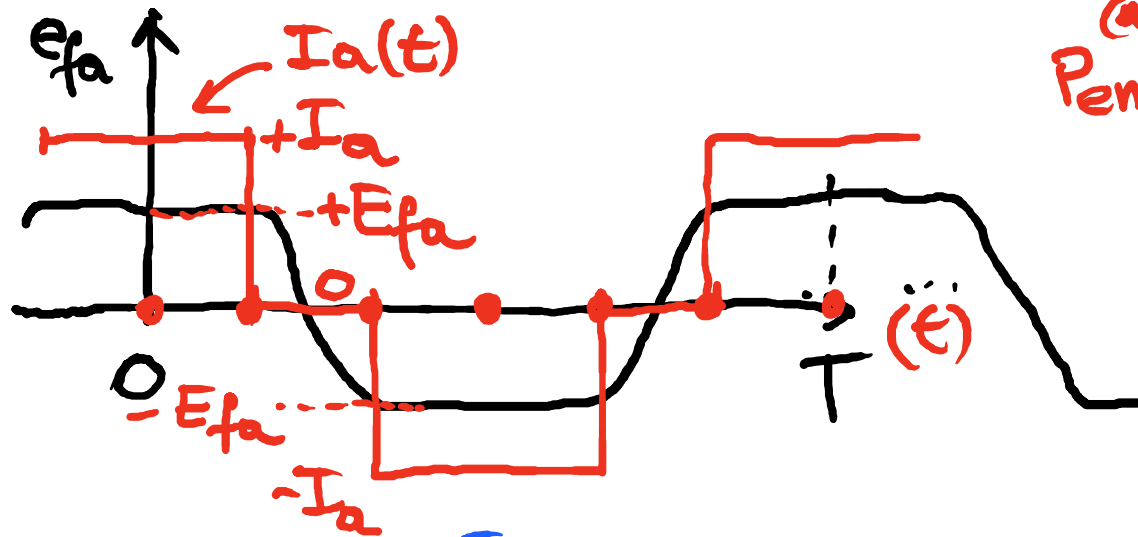
MAX se $\delta = \pi/2$

Controllo del motore sincrono



ECCITAZIONE TRAPEZOIDALE

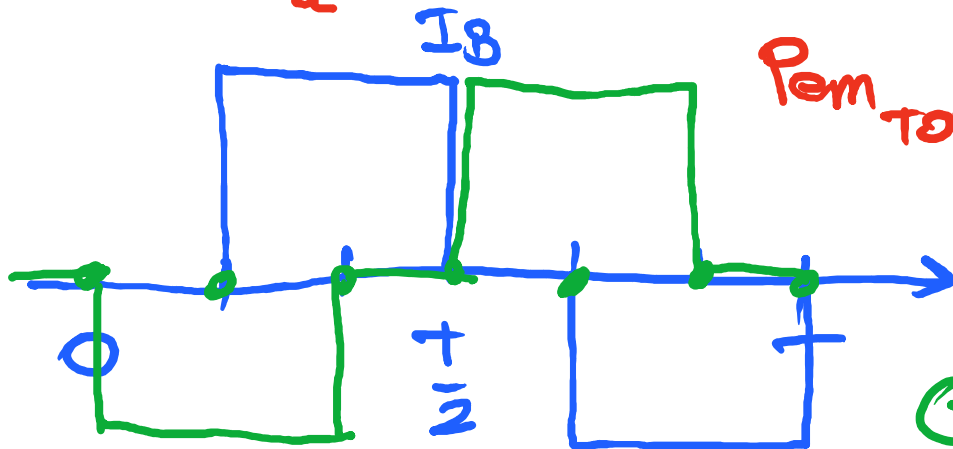
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$$P_{em}(t) = e_{fa}(t) i_a(t)$$

POTENZA
ELETTROMOTRICE
ISTANTANEA

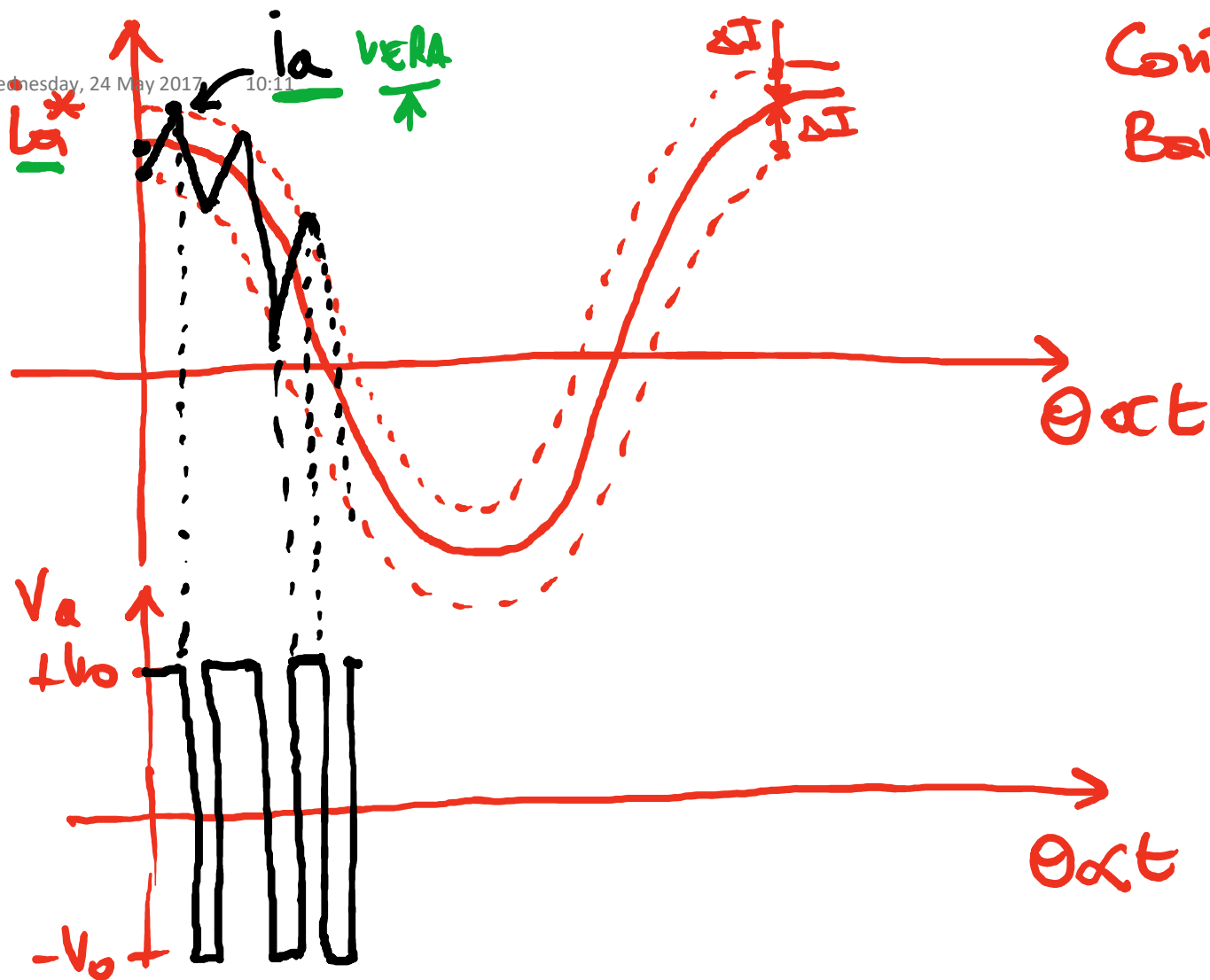
$$\left\{ \begin{array}{ll} E_{fa} I_a & \text{per } \frac{2}{3} T \\ 0 & \text{per } \frac{1}{3} T \end{array} \right.$$



$$P_{em_TOT}(t) = 2 E_{fa} I_a \quad \text{costante nel TEMPO}$$

- ⊕ $P_{em_TOT}(t)$ COSTANTE
[RIDOTTE VIBRAZIONE]
- ⊕ SENSORE DI θ SEMPLIFICATO.

Wednesday, 24 May 2017 10:11



Controllo con
Banda di TOLLERANZA