ESERCIZIO

$$\begin{cases} U_e = 200V \\ P = 4\ kW \\ I_e = 23\ A \\ n = 6000\ rpm \\ R_a = 0{,}6\ \Omega \end{cases}$$

PM

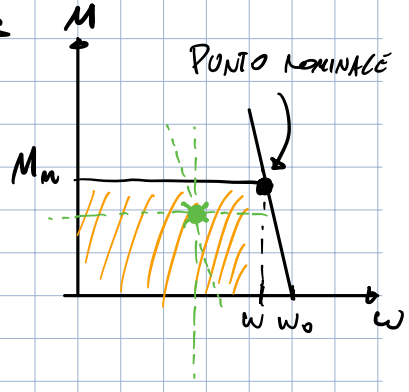
$P_{fe} + P_{mech} \propto n^2$

? Che tensione si deve applicare al motore per trainare un carico $M_L = 5\ Nm$ a 4000 rpm $\left(418\ \frac{rad}{s}\right)$

$$U_e = k\phi\omega + R_a I_a$$

$$\omega = \frac{2\pi n}{60} = \frac{2\pi \cdot 6000}{60} = 628{,}3\ \frac{rad}{s}$$

$$k\phi = \frac{U_e - R_a I_a}{\omega} = \frac{200 - 0{,}6 \cdot 23}{628{,}3} = 0{,}2964 \quad Vs$$



$$M_N = \frac{P}{\omega} = \frac{4000}{628{,}3} = 6{,}37\ Nm$$

$$\omega_0 = \frac{U_e}{k\phi} = \frac{200}{0{,}2964} = 674{,}76\ \frac{rad}{s}$$

Devo sviluppare $5\ Nm$ @ $418\ \frac{rad}{s}$

Perdite nel punto di funzionamento nominale:

$$P_{fe} + P_{mech} = U_e I_e - P - R_a I_e^2 = 200 \cdot 23 - 4000 - 0{,}6 \cdot 23^2$$

$$= 282{,}6\ W$$

$$= B \cdot \omega^2$$

$$B = \frac{P_{fe} + P_{mech}}{\omega^2} = \frac{282{,}6}{628{,}3^2} = 7{,}15 \cdot 10^{-4}\ Nms$$

@ $4000\ rpm = 418{,}9\ \frac{rad}{s}$

$$M_{4000} = M_L + B \cdot \omega_{4000} = 5 + 7{,}15 \cdot 10^{-4} \cdot 418{,}9 = 5{,}3\ Nm$$

$$I_e = \frac{M_{4000}}{k\phi} = \frac{5{,}3}{0{,}2964} = 17{,}88\ A$$

$$U_e = k\phi\omega + R_e I_e = 0{,}2965 \cdot 518{,}9 + 0{,}6 \cdot 17{,}88$$
$$= 134{,}9\ V$$

$$I_{sp} = \frac{U_e}{R_e} = \frac{200}{0{,}6} = 333{,}3\ A = 14{,}5\ I_e\ !$$

$$M_{sp} = k\phi I_{sp} = 98{,}8\ Nm \qquad (6{,}37\ Nm)$$

ESERCIZIO 2

MOTORE DC CON PM

$U_e = 450\ V$
$I_e = 11{,}5\ A$
$n = 5000$ rpm
$n_0 = 5350$ rpm

$P_{fe} + P_{mech} \approx 0$

Carico inerziale

e) Calcolare velocità di rotazione e corrente assorbita a regime

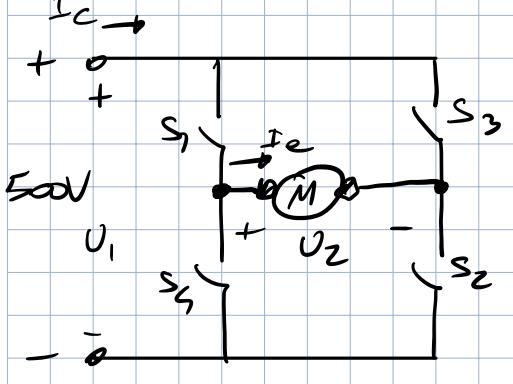
$$\omega_0 = \frac{2\pi n}{60} = \frac{2\pi \cdot 5350}{60} = 559{,}9\ \frac{rad}{s} \qquad \omega = \frac{2\pi \cdot 5000}{60} = 523{,}3\ \frac{rad}{s}$$

$$k\phi = \frac{U_e}{\omega_0} = \frac{450}{559{,}9} = 0{,}8\ Vs$$

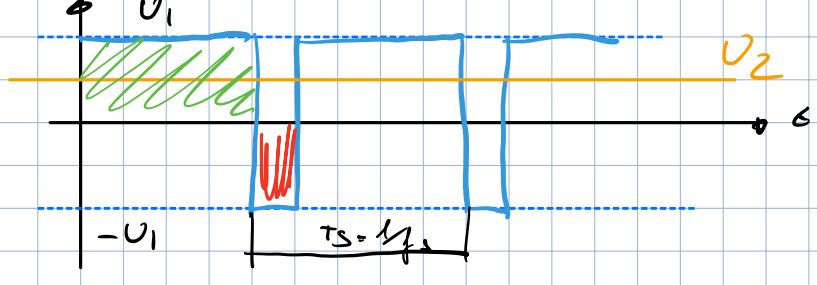
$$U_e = k\phi\omega + R_e I_e \qquad R_e = \frac{U_e - k\phi\omega}{I_e} = \frac{450 - 0{,}8 \cdot 523{,}3}{11{,}5} = 2{,}72\ \Omega$$

A regime con carico inerziale $\omega = \omega_0$
$I_e = 0$

b) Per portare $n = 5000$ si usa un ponte "H" alimentato a 500V con $f_s = 10$ kHz



? δ, t_{ON}, t_{OFF}, t_{off}, t_{on}, I_e, I_C



$n = 5000\ rpm = \frac{2\pi 5000}{60} = 518{,}67\ \frac{rad}{s} = \frac{U_2}{k\phi}$

$U_2 = k\phi\,\omega_{5000} = 0{,}8 \cdot 518{,}67 = 335{,}93\ V$

$U_2 = \left[U_1 t_{ON} - U_1 t_{OFF}\right]\frac{1}{T_S} = U_1\left[\frac{t_{ON}}{T_S} - \frac{t_{OFF}}{T_S}\right] = U_1\left[\delta - (1-\delta)\right]$

$= U_1\left[2\delta - 1\right]$

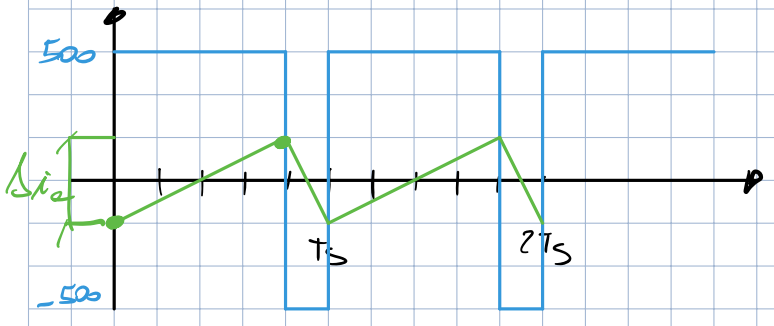
$2\delta - 1 = \frac{U_2}{U_1} \qquad \delta = \left[\frac{U_2}{U_1} + 1\right]\frac{1}{2} = 0{,}83$

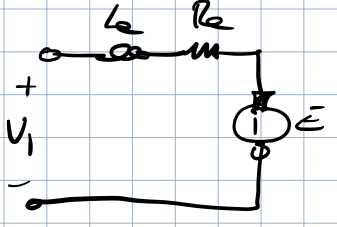
$t_{ON} = \delta T_S = 83\ \mu s$

$t_{off} = \frac{1-\delta}{f_s} = 17\ \mu s$

$U_1 I_C = U_2 I_e \qquad I_e = 0 \Rightarrow I_C = 0$

c) Assm $L_e = 50\ mH$ calcular ondulação corrente I_e





$\tau_e = \frac{L_e}{R_e} = \frac{50 \cdot 10^{-3}}{2{,}72} = 18{,}3\ ms$

$\frac{T_S}{\tau_e} \quad \frac{1}{10 \cdot 10^3} \quad 18{,}3 = \frac{0{,}1}{18{,}3}$

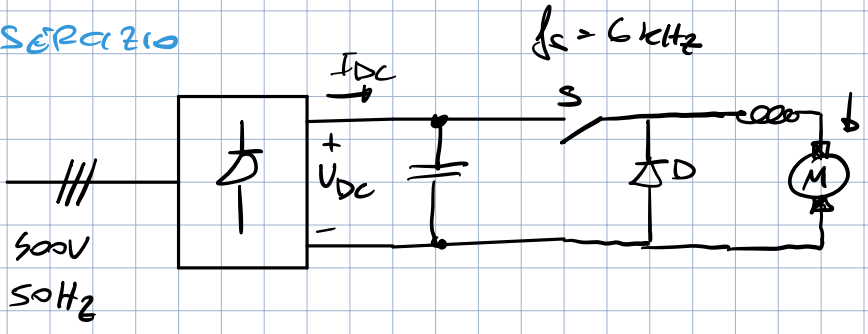
$\Delta i_e = \frac{V_L}{L}\Delta t$

$\Delta i_e = \frac{U_1 - U_2}{L}\frac{\delta}{f_s} = \dots = \frac{2U_1}{Lf_s}(1-\delta)\delta = \frac{2 \cdot 500}{50 \cdot 10^{-3}\ 10 \cdot 10^3}(1-0{,}83)0{,}83$

$= 282\ mA$

$\Delta m = k\phi\,\Delta i_e = 0{,}8 \cdot 0{,}28 = 0{,}22\ Nm$

ESERCIZIO



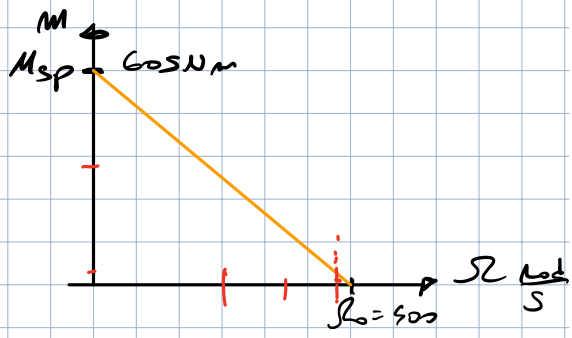
PM
$U_e = 550V$
$I = 25\,A$
$P = 10\,kW$
$\Omega_0 = 600\,rad/s$
$R = 0{,}8\,\Omega$
$L = 10\,mH$

$P_{fe} + P_{mech} \propto \omega^2$

e) Calcolare M_{sp} e tracciare caratt. meccanica

$$k\phi = \frac{U_e}{\omega_0} = \frac{550}{500} = 1{,}1\ V_s$$

$$M_{sp} = k\phi \frac{U_e}{R} = 1{,}1 \cdot \frac{550}{0{,}8} = 605\ Nm$$



b) Calcolare perdite e rendimento del motore in condizioni nominali

$$P_{in} = U_e I_a = 550 \cdot 25 = 11.000\ W$$

$$P_{out} = P = 10.000\ W$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{10}{11} = 0{,}91 \quad 91\%$$

$$P_J = R_a I^2 = 0{,}8 \cdot 25^2 = 500\ W$$

$$P_{fe} + P_{mech} = P_{in} - P_{out} - P_J = 500\ W$$

= soluzione corso!

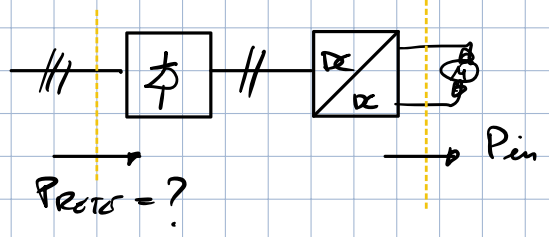
c) Calcolare coppia e velocità nominali del motore

$$U_e = k\phi\omega + R_a I_a \qquad \omega = \frac{U_e - R_a I_a}{k\phi} = \frac{550 - 0{,}8 \cdot 25}{1{,}1} = 381{,}8\ \frac{rad}{s}$$

$$= 3658\ rpm$$

$$M = \frac{P}{\omega} = \frac{10 \cdot 10^3}{381{,}8} = 26{,}2\ Nm$$

d) Calcolare la potenza attiva assorbita dalla rete quando il motore funziona in condizioni nominali



DC/DC: $\Delta t \cong 1{,}5\ V$ sia per S che D
trascuro le commutazioni, sovrastima di conduzione
S e D conducono alternativamente

$$P_{DC/DC} = 1{,}5 \cdot 25 = 37{,}5\ W$$

RADD: $\Delta t \cong 1{,}5\ V$ sui diodi
corrente costante I_{DC}

$$I_{DC} = \frac{P + P_{DC/DC}}{U_{DC}} = \frac{11.000 + 37{,}5}{560} = 29{,}5\ A$$

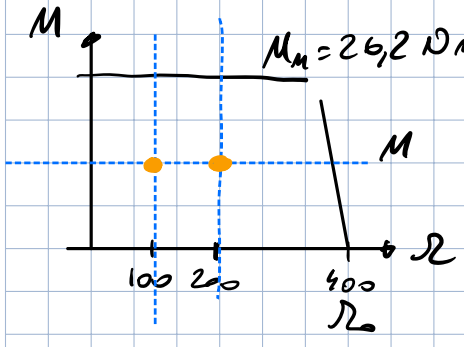
$$U_{DC} = \frac{3}{\pi}\sqrt{2}\,500 = 1{,}35 \cdot 500 = 560\ V$$

$$P_{RADD} = 2 \cdot 1{,}5 \cdot I_{DC} = 61{,}32\ W$$

$$P_{RETE} = P_{in} + P_{DC/DC} + P_{RADD} = 11000 + 37{,}5 + 61{,}32 = 11098\ W$$

ΔP convertore $98\ W$ $0{,}9\%$

e) Calcolare δ del carico per far lavorare il motore a $\frac{1}{2}$ coppia nominale alle velocità di 100 e 200 $\frac{rad}{s}$



$$M = \frac{26{,}2}{2} = 13{,}1\ Nm$$

$\omega_1 = 100\ \frac{rad}{s}$

$\omega_2 = 200\ \frac{rad}{s}$

Potenze in gioco

$$\begin{cases} P_{100} = M \cdot \omega_1 = 13{,}1 \cdot 100 = 1310\ W \\ P_{200} = M \cdot \omega_2 = 13{,}1 \cdot 200 = 2620\ W \end{cases}$$

Perdite fenomeni

$$\begin{cases} \Delta P_{100} = P_{mech} + P_{fe}\left(\frac{\omega_1}{\omega}\right)^2 = 500\left(\frac{100}{\pi 30}\right)^2 = 34{,}3\ W \\ \Delta P_{200} = P_{mech} + P_{fe}\left(\frac{\omega_2}{\omega}\right)^2 = 500\left(\frac{200}{\pi 30}\right)^2 = 137{,}2\ W \end{cases}$$

Le coppie erogate

$$\begin{cases} \frac{P_{100} + \Delta P_{100}}{\omega_1} = M_{100} = 13{,}44\ Nm \\ \frac{P_{200} + \Delta P_{200}}{\omega_2} = M_{200} = 13{,}78\ Nm \end{cases}$$

La corrente dal motore

$$\begin{cases} I_{100} = \frac{M_{100}}{k\phi} = 12{,}22\ A \\ I_{200} = \frac{M_{200}}{k\phi} = 12{,}53\ A \end{cases}$$

Le tensioni di alimentazione

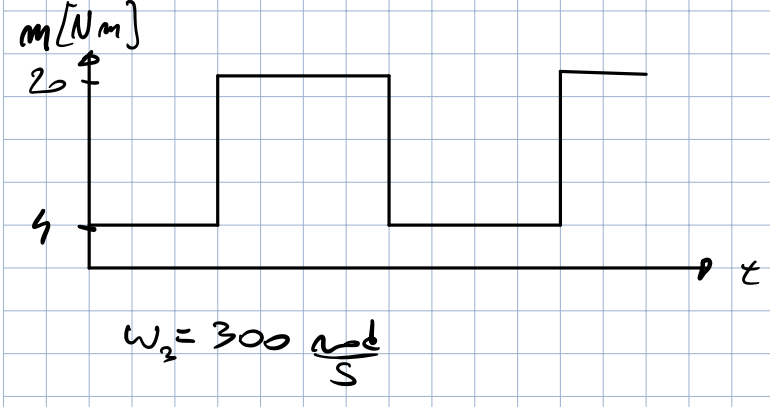
$$\begin{cases} U_{100} = k\phi\,\omega_{100} + R_a I_{100} = 118{,}8\ V \\ U_{200} = k\phi\,\omega_{200} + R_a I_{200} = 230{,}02\ V \end{cases}$$

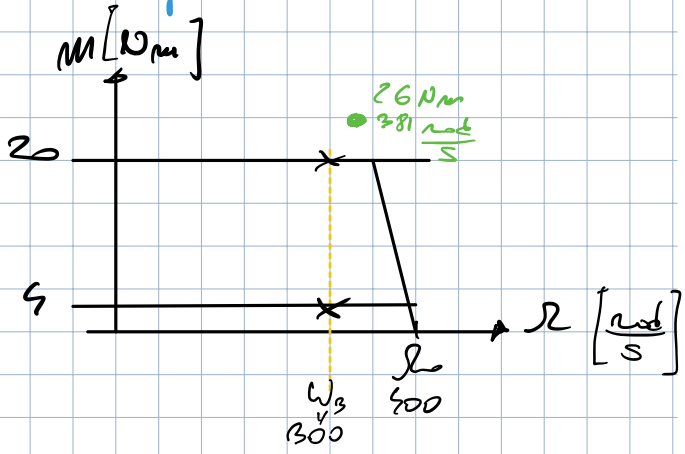
Calcolo δ per far lavorare il convertitore con queste tensioni di uscita

Hp: CCM

$$\begin{cases} \delta_{100} = \frac{U_{100}}{U_{dc}} = \frac{118{,}8}{540} = 0{,}22 \\ \delta_{200} = \frac{U_{200}}{U_{dc}} = \frac{230}{540} = 0{,}42 \end{cases}$$

f) Calcolare δ per poter lavorare con il seguente carico:





$$\Delta P_{300} = P_{mech} + P_{fe}\left(\frac{\omega_3}{\omega}\right)^2 = 500\left(\frac{300}{381}\right)^2 = 308{,}7\ W$$

$$M_{\Delta P_{300}} = \frac{\Delta P_{300}}{\omega_3} = \frac{308{,}7}{300} = 1{,}03\ Nm$$

Coppie che deve produrre il motore

$$\begin{cases} m_{20} = 20 + 1{,}03 = 21{,}03\ Nm \\ m_4 = 4 + 1{,}03 = 5{,}03\ Nm \end{cases}$$

Le corrente assorbite:

$$\begin{cases} I_{20} = \frac{m_{20}}{k\phi} = \frac{21{,}03}{1{,}1} = 19{,}1\ A \\ I_4 = \frac{m_4}{k\phi} = \frac{5{,}03}{1{,}1} = 4{,}57\ A \end{cases}$$

La tensione di alimentazione del motore

$$\begin{cases} U_{20} = k\phi\,\omega_3 + R_e I_{20} = 1{,}1 \cdot 300 + 0{,}8 \cdot 19{,}1 = 355{,}3\ V \\ U_4 = k\phi\,\omega_3 + R_e I_4 = 1{,}1 \cdot 300 + 0{,}8 \cdot 4{,}57 = 333{,}7\ V \end{cases}$$

Determino: δ del DC/DC

Hp CCM

$$\begin{cases} \delta_{20} = \frac{U_{20}}{U_{DC}} = \frac{355{,}3}{550} = 0{,}64 \\ \delta_4 = \frac{U_4}{U_{DC}} = \frac{333{,}7}{550} = 0{,}617 \end{cases}$$

$$\Delta i = \frac{U_{DC}\,\delta(1-\delta)}{L_a\,f_s} = \frac{550 \cdot 0{,}617(1-0{,}617)}{10 \cdot 10^{-3} \quad 6 \cdot 10^3} = 2{,}12\ A$$

0,64 1-0,64 2,07