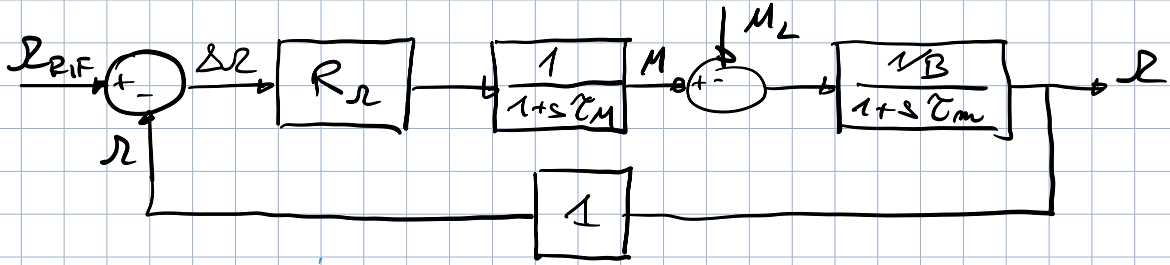
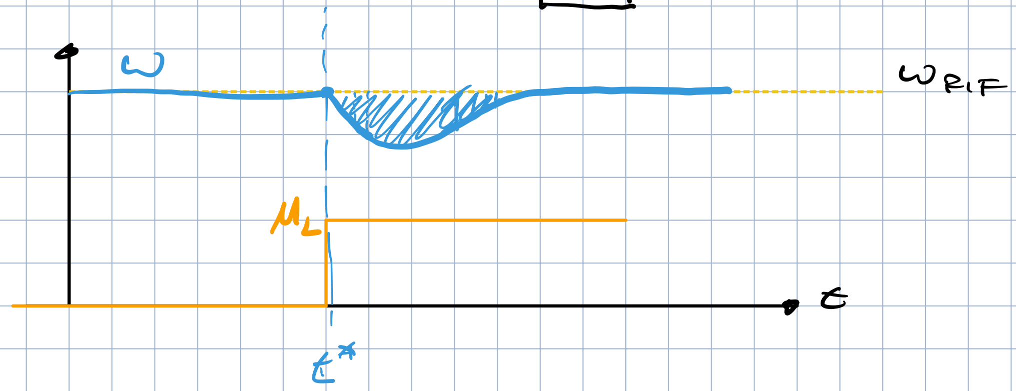
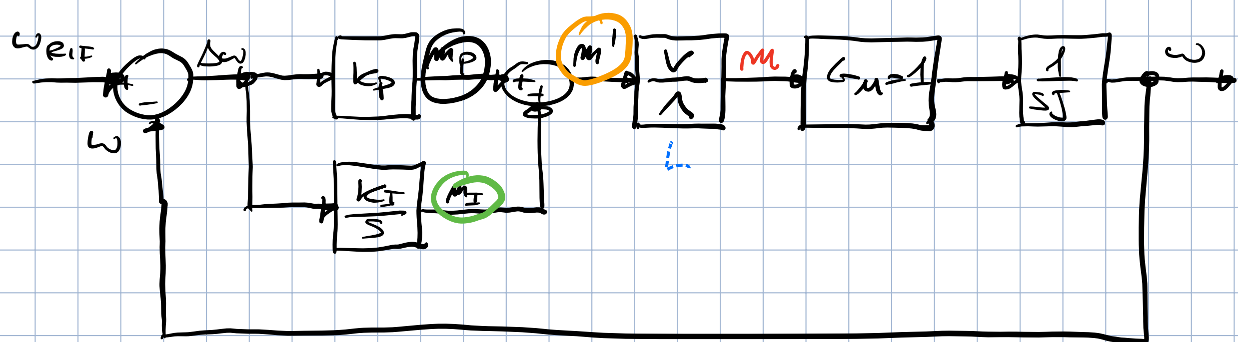




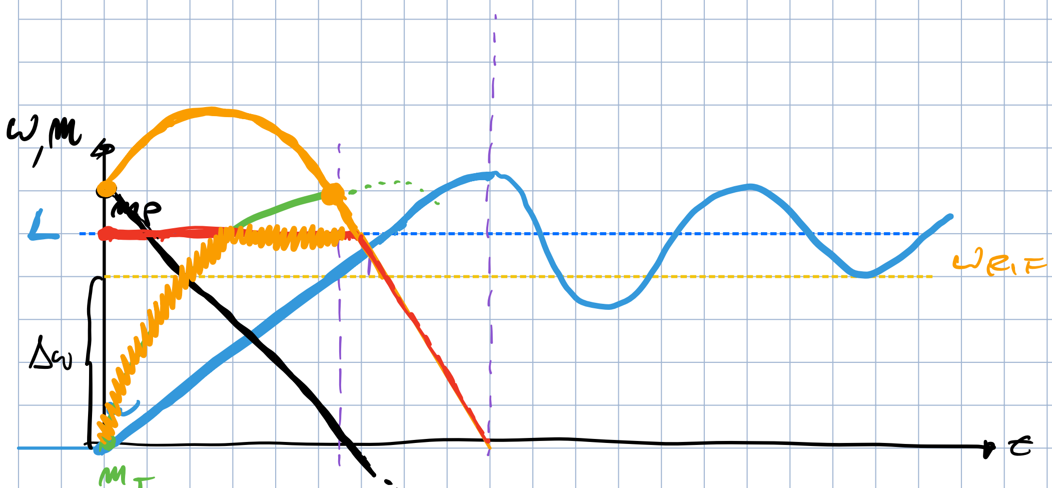
$$M(\infty) = M_L = \underbrace{k_p \Delta\Omega(\infty)}_{=0} + \int_0^{+\infty} k_I \Delta\omega \, dt$$

$$K_I = \frac{M_L}{\int_0^{+\infty} \Delta\omega \, dt} \qquad \int_0^{+\infty} \Delta\omega \, dt = \frac{M_L}{K_I}$$

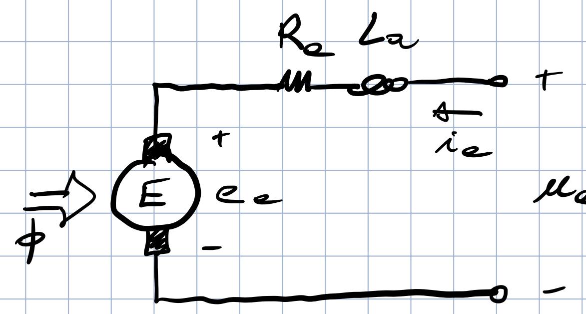
PROGETTO DEL REGOLATORE (PI) CON LIMITATORE E ANTI-WINDUP



$$m_p = k_p \Delta\omega \qquad m_I = \int_0^t K_I \Delta\omega \, dt$$



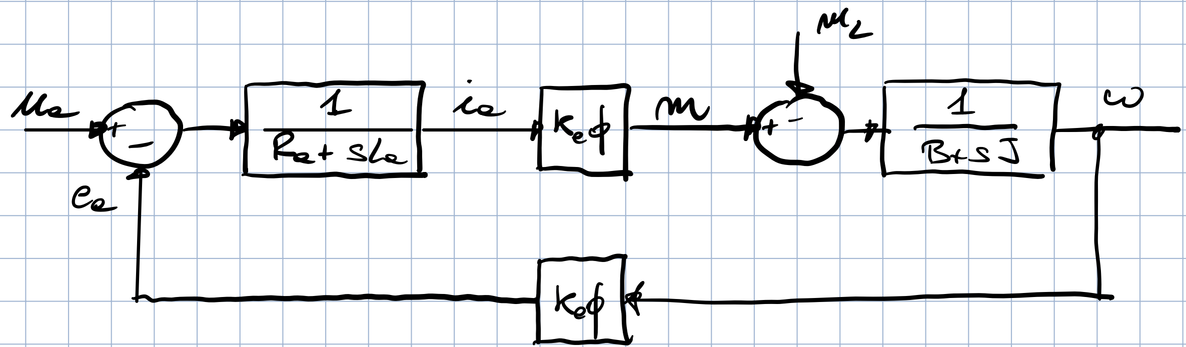
MOTORE DC



$$u_a = R_a i_a + L_a \frac{di_a}{dt} + e_a$$

$$e_a = K_e \phi \omega$$

$$m = K_e \phi i_a = m_L + J\frac{d\omega}{dt} + B\omega$$



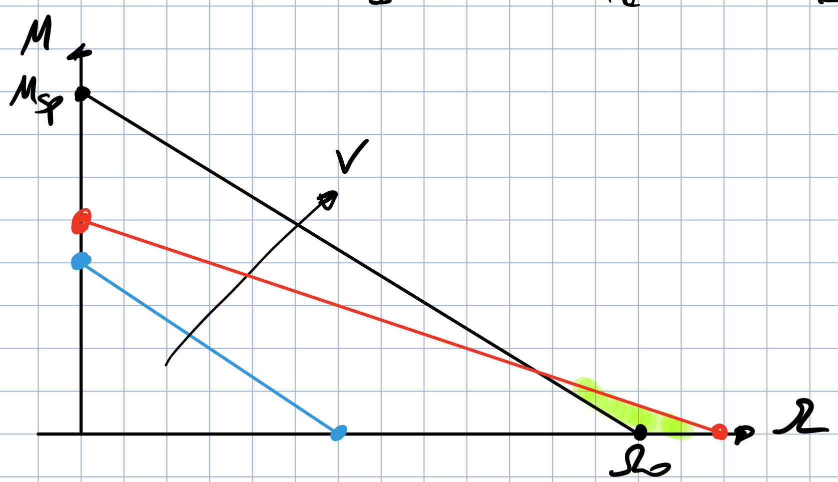
2 IN U_a ; M_L $\qquad \frac{\Omega(s)}{U_a(s)} \qquad \frac{I_a(s)}{U_a(s)}$

2 OUT Ω ; I_a $\qquad \frac{\Omega(s)}{M_L(s)} \qquad \frac{I_a(s)}{M_L(s)}$

A REGIME $\frac{d}{dt} = 0 \qquad \omega = \Omega = \text{cost}$

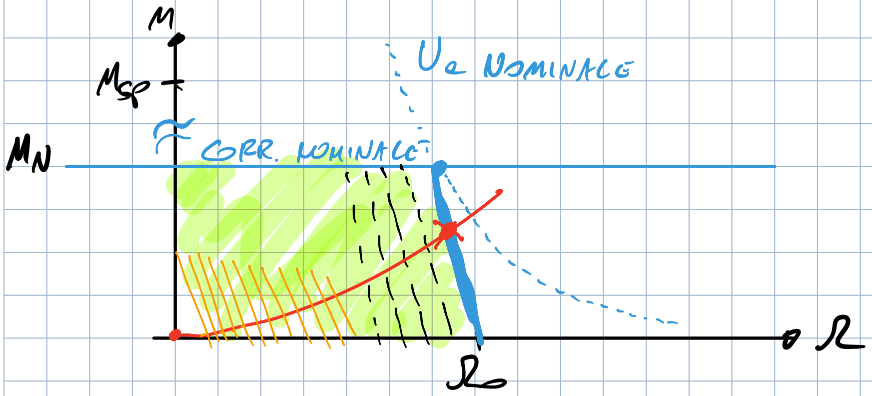
$$E_a = K_e \phi \Omega \qquad U_a = E_a + R_a I_a \qquad M = K_e \phi I_a$$

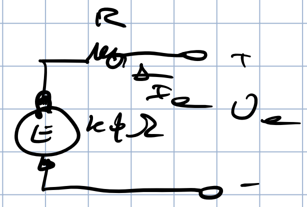
$$M = K_e\phi I_a = K_e\phi \frac{U_a - E_a}{R_a} = K_e\phi \frac{U_a}{R_a} - \frac{(K_e\phi)^2 \Omega}{R_a}$$



$$M_{sp} = k\phi \frac{U_a}{R_a} = k\phi I_{sp}$$

$$\Omega_0 = \frac{U_a}{k\phi}$$





CONSIDERO LA DINAMICA

$$\frac{\Omega(s)}{U_e(s)} = \frac{\frac{1}{R+sL}\, k_e\phi\, \frac{1}{B+sJ}}{1+\frac{(k_e\phi)^2}{(R+sL)(B+sJ)}} = \frac{k_e\phi}{(R+sL)(B+sJ)+(k_e\phi)^2}$$

$B \approx 0$

$$\frac{\Omega}{U_e} = \frac{k_e\phi}{s^2LJ+sRJ+(k_e\phi)^2} = \frac{\frac{1}{k_e\phi}}{s^2\frac{LJ}{(k\phi)^2}+s\frac{RJ}{(k\phi)^2}+1}$$

$$= \frac{\frac{1}{k_e\phi}}{s^2\tau_e\tau_{m1}+s\tau_{m1}+1}$$

$\tau_e = \frac{L_e}{R_e}$ cost. tempo elettrica

$\tau_{m1} = \frac{R_e J}{(k\phi)^2}$ cost. tempo elettromeccanica

$\tau_m = \frac{J}{B} \cong \infty$ $(B=0)$

$\frac{1}{\tau_m} \cong 0$

$$\lim_{t\to\infty} \omega(t) = \lim_{s\to 0} s\,\Omega(s)\cdot\frac{U_e}{s} = \frac{U_e}{k_e\phi} = \Omega_0$$

$$D(s) = s^2\tau_e\tau_{m1} + s\tau_{m1} + 1$$

$$p_{1,2} = \frac{1}{2\tau_e}\left[-1 \pm \sqrt{1 - \frac{4\tau_e}{\tau_{m1}}}\right]$$

- $4\tau_e = \tau_{m1}$ $\qquad 4\frac{L_e}{R_e} = \frac{R_e J}{(K\phi)^2}$

$$p_{1,2} = -\frac{1}{2\tau_e}$$ CRITICAMENTE SMORZATA

- $\tau_{m1} > 4\tau_e$ $\qquad J \nearrow \qquad K\phi \searrow$

$\tau_{m1} \gg 4\tau_e$

$$p_{1,2} = -\frac{1}{2\tau_e} \pm \left(\frac{1}{2\tau_e} - \frac{1}{\tau_{m1}}\right) \cong \begin{cases} -\frac{1}{\tau_{m1}} \\ -\frac{1}{\tau_e} \end{cases}$$ SISTEMA SMORZATO

- $\tau_{m1} < 4\tau_e$ $\qquad J \searrow \qquad K\phi \nearrow$

2 RADICI COMPLESSE CONIUGATE — OSCILLAZIONI SMORZATE

ESEMPIO: $V_e = 100\,V$ $\qquad K\phi = 0,5\ Vs$
$R_e = 1\,\Omega$ $\qquad J = 1/64\ kg\,m^2$
$L_e = 10\,mH$

$$\Omega_0 = \frac{V_e}{K\phi} = \frac{100}{0,5} = 200\ \frac{rad}{s}$$ Come ci arrivo?

$$\tau_e = \frac{L_e}{R_e} = \frac{10 \cdot 10^{-3}}{1} = 10\ ms$$

$$\tau_{m1} = \frac{R_e J}{(K\phi)^2} = \frac{1 \cdot 1/64}{0,25} = \frac{1}{64 \cdot 0,25} = 62,5\ ms$$

$4\tau_e < \tau_{m1}$ $\qquad$ 2 poli reali e distinti

$$-\frac{1}{\tau_e} = -\frac{1}{10} \cdot 10^3 = -100 \qquad -\frac{1}{\tau_{m1}} = -\frac{1000}{62,5} = -16$$

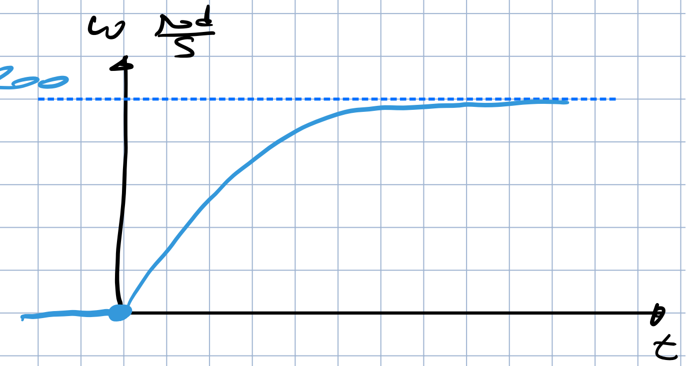
$$\Omega(s) = \frac{\frac{k\phi}{sL}}{\left(s+\frac{1}{\tau_e}\right)\left(s+\frac{1}{\tau_{m1}}\right)} \cdot \frac{U_e}{s}$$

GRADINO DI TENSIONE

$$= \frac{A}{s} + \frac{B}{s+\frac{1}{\tau_e}} + \frac{C}{s+\frac{1}{\tau_m}}$$

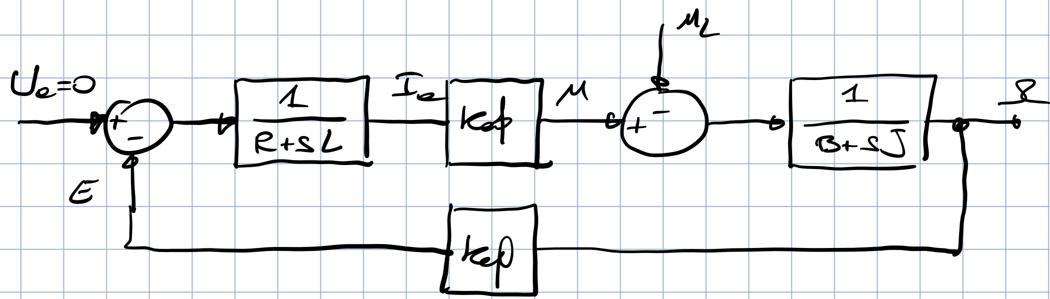
$$\Omega(s) = \frac{200}{s} + \frac{66}{s+100} - \frac{266}{s+16}$$

$$\omega(t) = 200 + 66\, e^{-t/\tau_e} - 266\, e^{-t/\tau_{m1}}$$



CONSIDERO ORA M_L COME INGRESSO

$$\frac{\Omega}{M_L}$$

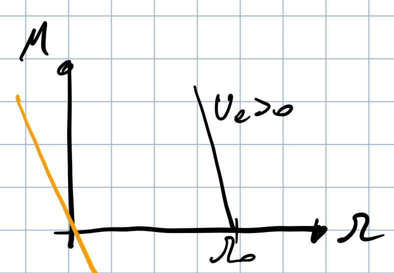


$$\frac{\Omega}{M_L} = \frac{-\frac{1}{B+sJ}}{1+\frac{1}{B+sJ}\frac{1}{R+sL}(k\phi)^2}$$

$$B=0 \quad \simeq \frac{-(R+sL)}{s^2LJ + sRJ + (k\phi)^2}$$

Ho lo stesso denominatore di prima

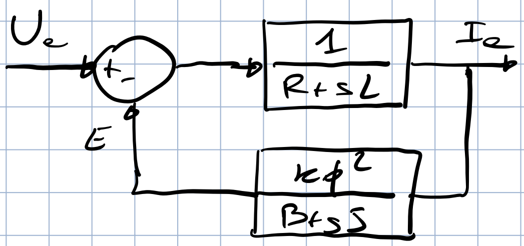
$$\omega(\infty) = \lim_{s\to 0} \cancel{s} \cdot \frac{\Omega}{M_L} \cdot \frac{M^*}{\cancel{s}} = M^* \frac{-R}{(k\phi)^2}$$



$$m = \cancel{k\phi \frac{U_e}{R}} - \frac{(k\phi)^2}{R}\omega$$

$$M^* \frac{R}{(k\phi)^2} = -\Omega$$

CONSIDERO ORA $\frac{I_e}{V_e}$ $\quad (M_L = 0)$

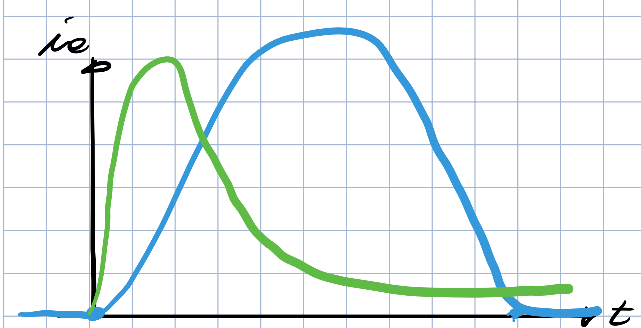


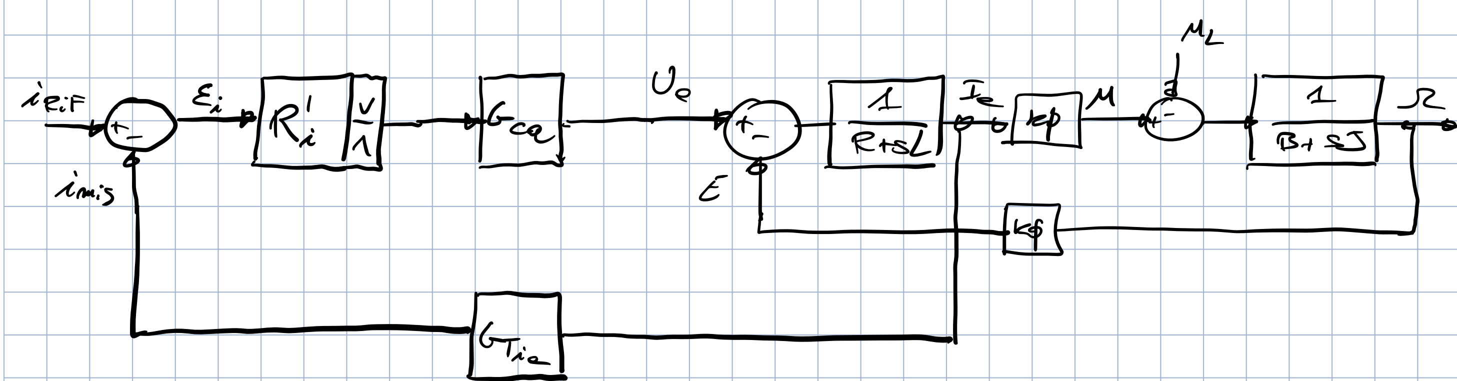
$$\frac{I_e}{V_e} = \frac{\frac{1}{R+sL}}{1+\frac{1}{R+sL}\,\frac{k\phi^2}{B+sJ}} = \frac{B+sJ}{(R+sL)(B+sJ)+k\phi^2}$$

$$B=0 \quad \simeq \frac{s\frac{J}{(k\phi)^2}}{s^2\tau_e\tau_{m1}+s\tau_{m1}+1} = \frac{1}{R}\,\frac{s\frac{RJ}{(k\phi)^2}}{s^2\tau_e\tau_{m1}+s\tau_{m1}+1}$$

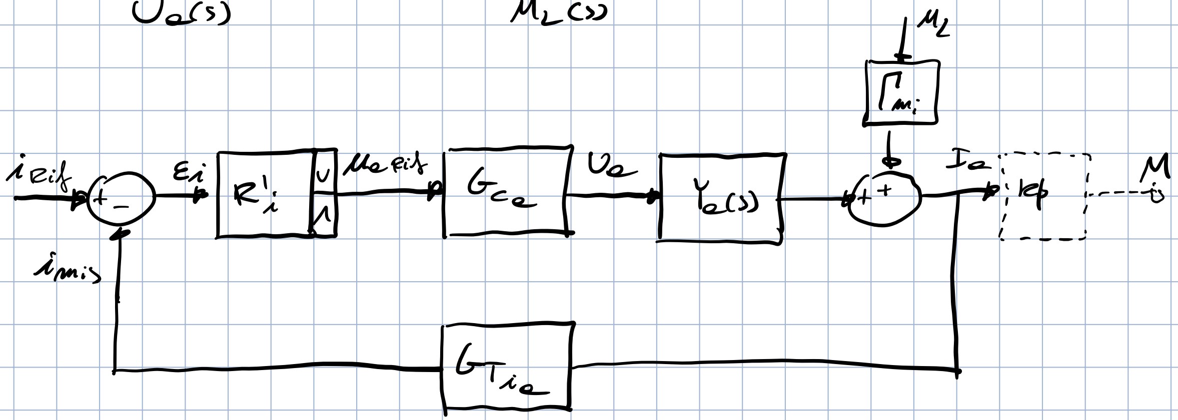
$$\simeq \boxed{\frac{1}{R}\,\frac{s\tau_{m1}}{(1+s\tau_{m1})(1+s\tau_e)}} \qquad \tau_e \ll \tau_{m1}$$

$$(1+s\tau_{m1})(1+s\tau_e) = s^2\tau_e\tau_{m1}+s(\tau_e+\tau_{m1})+1$$





$$Y_e = \frac{I_e(s)}{U_e(s)} \qquad \Gamma_{mi} = \frac{I_e(s)}{M_L(s)}$$

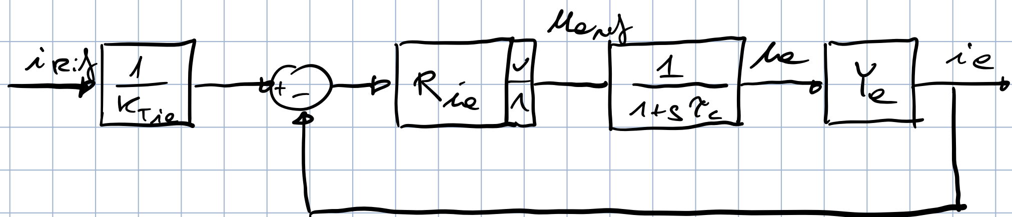


Se Porgo $M_L = 0$

$$G_{ce} = \frac{K_{ce}}{1 + s\tau_c}$$

SISTEMA DEL PRIMO ORDINE CON UN CERTO RITARDO

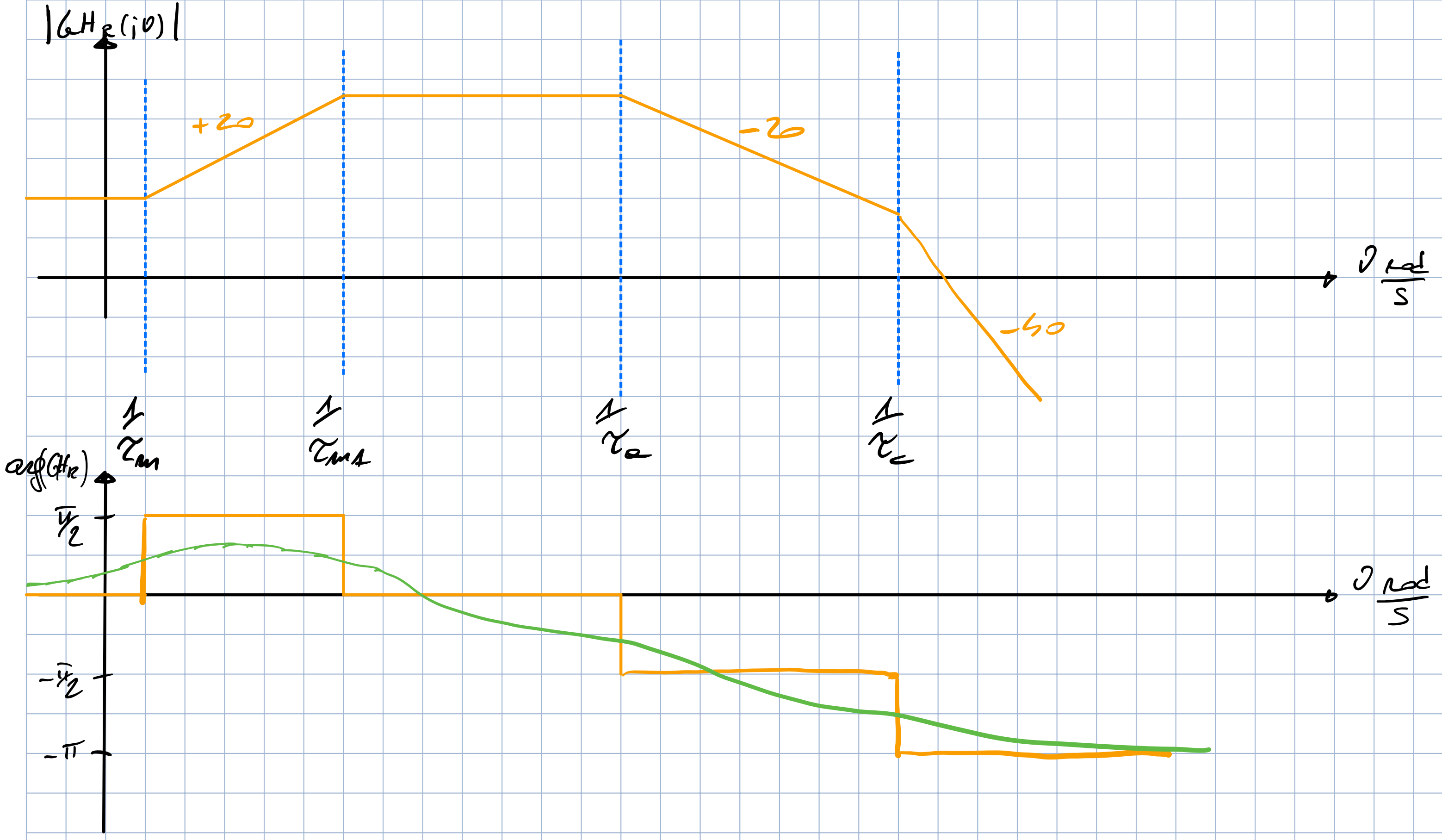
$$G_{Tie} = \frac{K_{Tie}}{1 + s\tau_{Tie}}$$



$$R_{ie} = K_{Tie} K_{ce} R'_{ie}$$

$$GH_R = \frac{1}{1 + s\tau_c} Y_e(s) = \frac{1}{1 + s\tau_c} \frac{\frac{B + sJ}{(k\phi)^2}}{s^2 \tau_e \tau_{m1} + s\tau_{m1} + 1}$$

$$= \frac{B}{(k\phi)^2} \frac{1}{1 + s\tau_c} \frac{1 + s\tau_m}{(1 + s\tau_e)(1 + s\tau_{m1})} \qquad \tau_m = \frac{J}{B}$$



BANDA PASSANTE MAX $\omega_{ci} \le \frac{1}{\tau_c}$

CON CONTROLLO PROPORZIONALE HO ERRORE A REGIME

$$\frac{\Delta I}{I_{rif}} = \frac{1}{1+GH(0)} = \frac{1}{1+k_p GH_R(0)} = \frac{1}{1+\frac{k_p B}{k\phi^2}}$$

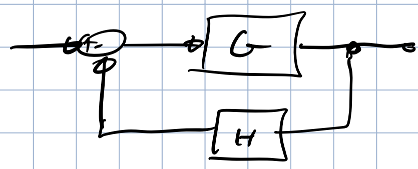
Nota: $B=0$ Ho errore a regime nullo

SE VOGLIO ELIMINARE ERRORE A REGIME USO UN CONTROLLORE PI

$$R = k_p + \frac{k_I}{s} = k_I \frac{1+s\tau_R}{s} \qquad \tau_R = \frac{k_p}{k_I}$$

- CANCELLAZIONE ZERO POLO
- OTTIMO SIMMETRICO
- IMPONGO $M\varphi$ dell'attraversamento

$$W = \frac{G}{1+GH}$$



Se $H = 1$ $\qquad W = \dfrac{G}{1+G} = \dfrac{1}{1+s\frac{1}{\nu_{ei}}}$