UPRAVLJANJE ELEKTROMOTORNIM POGONIMA
Ponovljeni 1. međuispit 2009.

1. Zadani podaci su:
$P_n = 33$ kW
$U_{an} = 440$ V
$I_{an} = 83$ A
$n_n = 1040$ r/min
$R_a = 0{,}24\ \Omega$
$M_{tr,red} = 15$ Nm
$M_t = 150$ Nm
$M_{tr,v} =$ konst.
- četverokvadrantni čoper; bipolarna modulacija

Konstante motora su:

$$c_e = \frac{U_{an} - I_{an}R_a}{n_n} = \frac{440 - 83 \cdot 0{,}24}{1040} = 0{,}4039\ {}^{\mathrm{Vmin}}/_{\mathrm{r}}$$

$$c_m = \frac{30c_e}{\pi} = 3{,}8572\ {}^{\mathrm{Nm}}/_{\mathrm{A}}$$

Nazivni moment motora je:

$$M_n = \frac{30P_n}{n_n\pi} = \frac{30 \cdot 33000}{1040 \cdot \pi} = 303{,}0065\ \mathrm{Nm}$$

Nazivni elektromagnetski moment motora je:

$$M_{emn} = I_{an}c_m = 83 \cdot 3{,}8572 = 320{,}1460\ \mathrm{Nm}$$

Moment trenja i ventilacije je:

$$M_{tr,v} = M_{emn} - M_n = 320{,}1460 - 303{,}0065 = 17{,}1395\ \mathrm{Nm}$$

(a) Radi se o drugom kvadrantu. Izraz za momente je jednak:

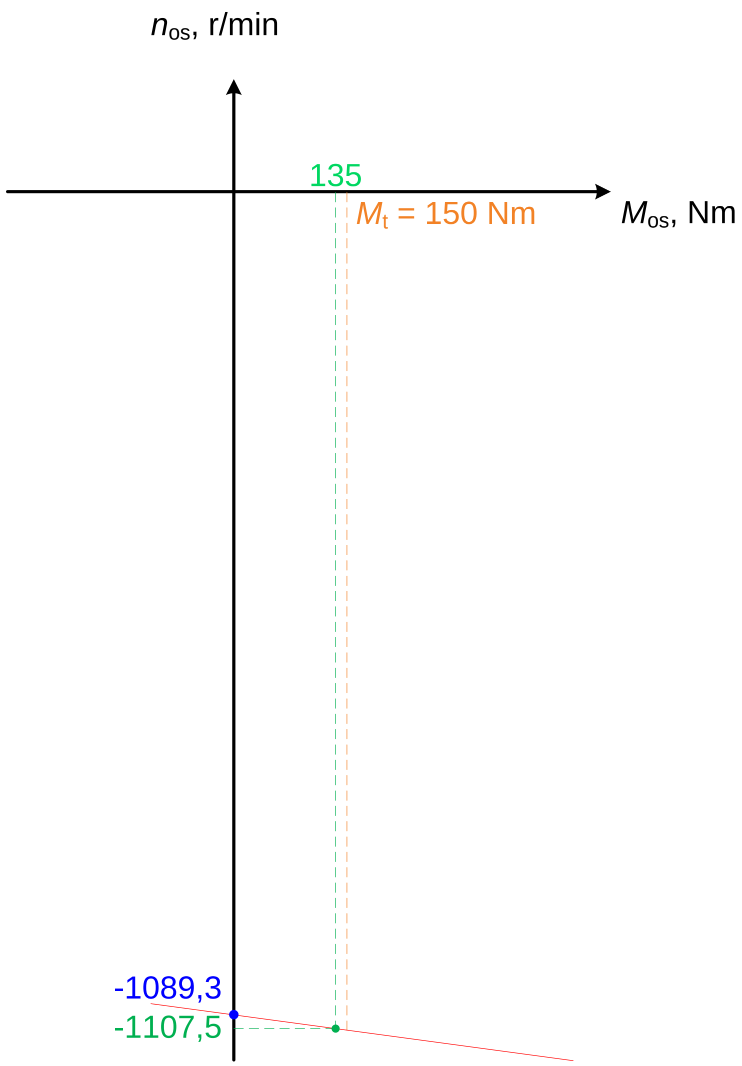
$$M_{em} = M_t - M_{tr,v} - M_{tr,red} = 150 - 17{,}1395 - 15 = 117{,}8605\ \mathrm{Nm}$$

Struja armature tada iznosi:

$$I_a = \frac{M_{em}}{c_m} = \frac{117{,}8605}{3{,}8572} = 30{,}5561\ A$$

Brzina motora iznosi:

$$n = \frac{U_a - I_aR_a}{c_e} = \frac{-440 - 30{,}5561 \cdot 0{,}24}{0{,}4039} = -1107{,}5\ {}^{\mathrm{r}}/_{\mathrm{min}}$$



$$n_0 = \frac{U_{an}}{c_e} = 1089{,}3\ {}^{\mathrm{r}}/_{\mathrm{min}}$$

$$M_{os} = M_t - M_{red} = 135\ \mathrm{Nm}$$

(b) Radi se o dizanju tereta pa je jednadžba za momente jednaka:

$$M_{em} = M_t + M_{tr,v} + M_{tr,red} = 150 + 17{,}1395 + 15 = 182{,}1395\ \mathrm{Nm}$$

Struja armature tada iznosi:

$$I_a = \frac{M_{em}}{c_m} = \frac{182{,}1395}{3{,}8572} = 47{,}2209\ A$$

Vrijedi:

$$I_a\left(R_a + R_p\right) = 47{,}2209 \cdot (0{,}24 + 3) = 152{,}9957\ \mathrm{V} < U_{an} = 440\ \mathrm{V}$$

Radi se o motorskom načinu rada.

Brzina vrtnje je jednaka:

$$n = \frac{U_a - I_a R_a}{c_e} = \frac{440 - 47{,}2209 \cdot 3{,}24}{0{,}4039} = 710{,}542\ {}^{\mathrm{r}}/_{\mathrm{min}}$$

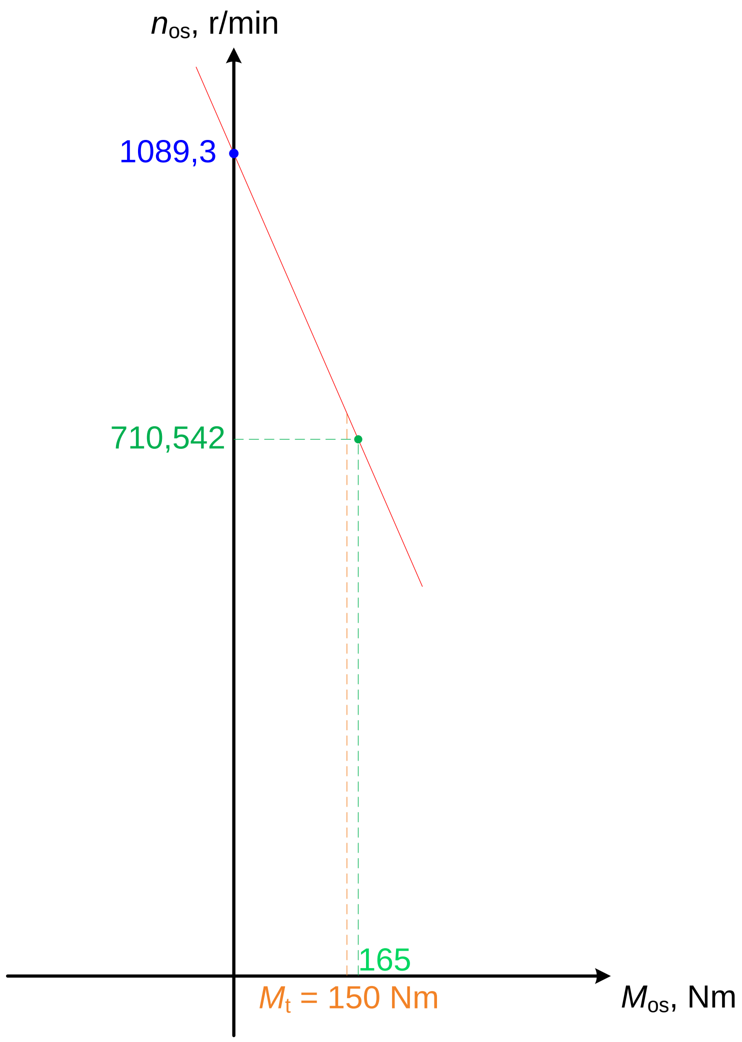
Za korisnost je potrebno naći snagu uzetu iz mreže i snagu na osovini:

$$P_m = U_{an} I_a = 440 \cdot 47{,}2209 = 20777\ \mathrm{W}$$

$$M_{os} = M_t + M_{red} = 150 + 15 = 165\ \mathrm{Nm}$$

$$P_{os} = M_{os} \frac{n\pi}{30} = 165 \cdot \frac{710{,}542 \cdot \pi}{30} = 12277\ \mathrm{W}$$

$$\eta = \frac{P_{os}}{P_m} \cdot 100\% = \frac{12277}{20777} \cdot 100\% = 59{,}09\%$$



(c)

$$U_a = nc_e + I_a R_a = 710 \cdot 0{,}4039 + 47{,}2209 \cdot 0{,}24 = 298{,}1184\ \mathrm{V}$$

Radi se o bipolarnoj modulaciji pa je:

$$U_a = (2D - 1)U_{DC} \rightarrow D = \frac{1}{2}\left(\frac{U_a}{U_{DC}} + 1\right)$$

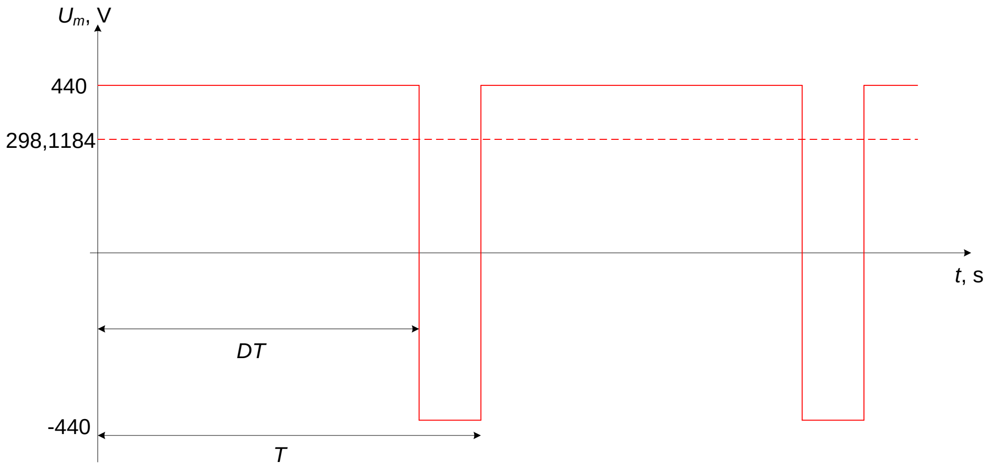
$$D = \frac{1}{2}\left(\frac{298{,}1184}{440} + 1\right) = 0{,}8388$$

Za korisnost je potrebno naći snagu uzetu iz mreže i snagu na osovini:

$$P_m = U_a I_a = 298{,}1184 \cdot 47{,}2209 = 14077\ \mathrm{W}$$

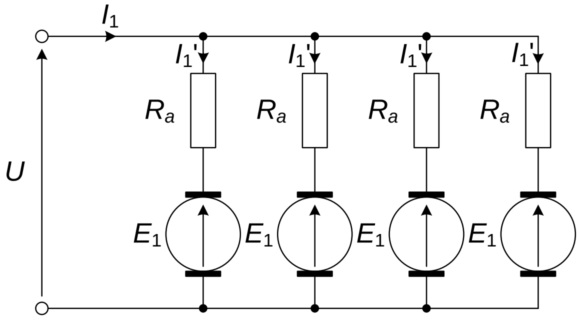
$$P_{os} = 12277\ \mathrm{W}$$

$$\eta = \frac{P_{os}}{P_m} \cdot 100\% = \frac{12277}{14077} \cdot 100\% = 87{,}21\%$$



2. Zadani podaci su:
$U = 550\ \text{V}$
$I_1 = 100\ \text{A}$
$R_a = 0{,}3\ \Omega$
$v_1 = 45\ \text{km/h}$
$M_2 = 4M_1$

Shema za prvi slučaj je:

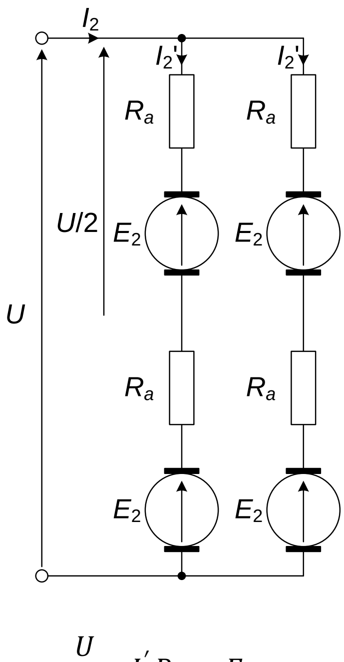


$$U - I_1' R_a = E_1$$

$$4I_1' = I_1 \rightarrow I_1' = \frac{1}{4} I_1 = 25\ \text{A}$$

$$\boldsymbol{E_1} = 550 - 25 \cdot 0{,}3 = \mathbf{542{,}5\ V}$$

Za drugi slučaj shema je:



$$\frac{U}{2} - I_2' R_a = E_2$$

$$2I_2' = I_2 \rightarrow I_2' = \frac{1}{2} I_2$$

$$M_1 = 4M_1' = 4I_1'c_m = 100c_m$$

$$M_2 = 2M_2'' = 2 \cdot 2M_2' = 2 \cdot 2I_2'c_m = 4I_2'c_m$$

$$M_2 = 4M_1 \rightarrow 4I_2'c_m = 400c_m \rightarrow I_2' = 100\ \mathrm{A}$$

$$\boldsymbol{E_2} = \frac{550}{2} - 100 \cdot 0{,}3 = \mathbf{245\ V}$$

Vrijedi:

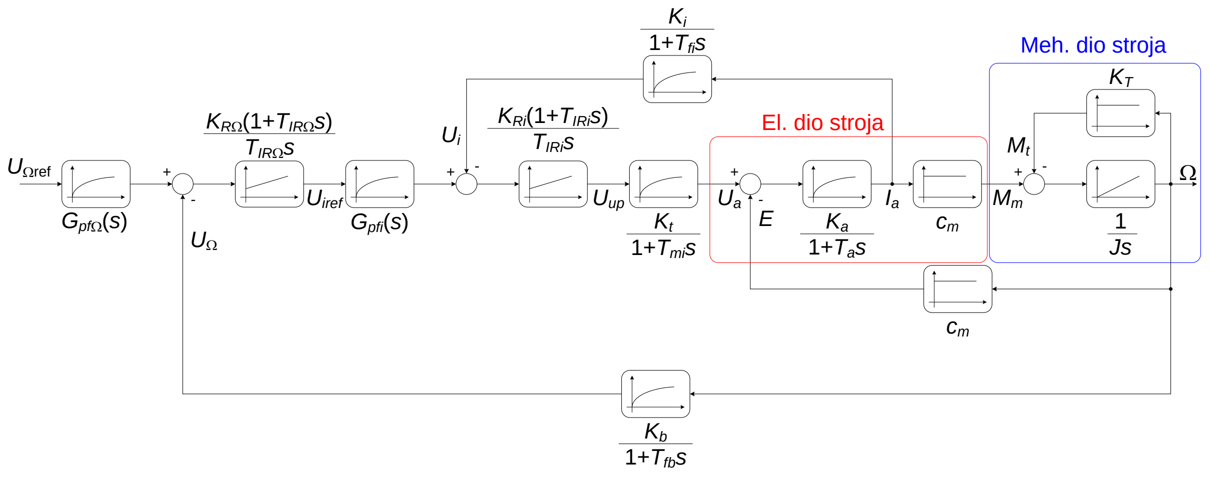
$$\frac{E_2}{E_1} = \frac{c_e n_2}{c_e n_1} = \frac{n_2}{n_1} = \frac{v_2}{v_1} \rightarrow v_2 = v_1 \frac{E_2}{E_1}$$

$$v_2 = 45 \cdot \frac{245}{542{,}5} = 20{,}3226\ {}^{\mathrm{km}}/_{\mathrm{h}}$$

3. Zadani podaci su:

$P_n = 13{,}5 \text{ kW}$
$U_{an} = 420 \text{ V}$
$I_{an} = 40{,}6 \text{ A}$
$U_{un} = 242 \text{ V}$
$I_{un} = 2{,}3 \text{ A}$
$n_n = 1480 \text{ r/min}$
$P_g = 11 \text{ kW}$
$U_g = 220 \text{ V}$
$I_g = 45 \text{ A}$
$R_a = 0{,}2\ \Omega$
$L_a = 4 \text{ mH}$
$K = c_e = c_m = 2{,}66 \text{ Vs/rad}$
$J = 0{,}478 \text{ kgm}^2$
$K_t = 44$
$T_{mi} = 1{,}67 \text{ ms}$
$K_i = 0{,}1 \text{ V/A}$
$T_{fi} = 2 \text{ ms}$
$K_b = 0{,}031 \text{ Vs}$
$T_{fb} = 15 \text{ ms}$
$M_t = K_T \omega$

(a) Strukturni blokovski prikaz regulacijskog sustava kaskadne regulacije brzine vrtnje istosmjernog motora s nezavisnom i konstantnom uzbudom dan je na slici ispod. Pri tome su $G_{pfi}(s)$ i $G_{pf\Omega}(s)$ prefiltri za struju armature, odnosno brzinu vrtnje motora, koji se dodaju po potrebi.



(b)

$$P_g = M_t \omega_n = K_T \omega_n^2 \rightarrow K_T = \frac{P_g}{\omega_n^2}$$

$$K_T = \frac{11000}{154{,}98^2} = 0{,}4579\ {}^{\text{Nms}}/_{\text{rad}}$$

Sinteza regulatora struje armature

Vrijede sljedeći izrazi (u ovoj fazi izvoda se ne koristi prefiltar $G_{pfi}(s)$):

$$I_a(s) = [U_a(s) - E(s)]\frac{K_a}{1+T_a s}$$

$$U_i(s) = \frac{K_i}{1+T_{fi}s}I_a(s)$$

$$U_a(s) = \left[U_{iref}(s) - U_i(s)\right]K_{Ri}\frac{1+T_{IRi}s}{T_{IRi}s}\frac{K_t}{1+T_{mi}s}$$

Kada se drugi izraz ubaci u treći izraz, a potom to sve u prvi izraz, dobije se:

$$I_a(s) = \left\{\left[U_{iref}(s) - \frac{K_i}{1+T_{fi}s}I_a(s)\right]K_{Ri}\frac{1+T_{IRi}s}{T_{IRi}s}\frac{K_t}{1+T_{mi}s} - E(s)\right\}\frac{K_a}{1+T_a s}$$

Traži se prijenosna funkcija $\frac{I_a(s)}{U_{iref}(s)}$ pa će se uzeti $E = 0$:

$$I_a(s) = \left\{\left[U_{iref}(s) - \frac{K_i}{1+T_{fi}s}I_a(s)\right]K_{Ri}\frac{1+T_{IRi}s}{T_{IRi}s}\frac{K_t}{1+T_{mi}s}\right\}\frac{K_a}{1+T_a s}$$

$$I_a(s) = U_{iref}(s)K_{Ri}\frac{1+T_{IRi}s}{T_{IRi}s}\frac{K_t}{1+T_{mi}s}\frac{K_a}{1+T_a s} - \frac{K_i}{1+T_{fi}s}I_a(s)K_{Ri}\frac{1+T_{IRi}s}{T_{IRi}s}\frac{K_t}{1+T_{mi}s}\frac{K_a}{1+T_a s}$$

$$I_a(s)\left[1 + \frac{K_{Ri}K_iK_tK_a}{T_{IRi}s}\frac{1+T_{IRi}s}{(1+T_{fi}s)(1+T_{mi}s)(1+T_a s)}\right] = U_{iref}(s)\frac{K_{Ri}K_tK_a}{T_{IRi}s}\frac{1+T_{IRi}s}{(1+T_{mi}s)(1+T_a s)}$$

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{\frac{K_{Ri}K_tK_a}{T_{IRi}s}\frac{1+T_{IRi}s}{(1+T_{mi}s)(1+T_a s)}}{1 + \frac{K_{Ri}K_iK_tK_a}{T_{IRi}s}\frac{1+T_{IRi}s}{(1+T_{fi}s)(1+T_{mi}s)(1+T_a s)}}$$

Vrijedi $T_a = \frac{L_a}{R_a} = \frac{4\cdot 10^{-3}}{0{,}2} = 20$ ms, $T_{mi} = 1{,}67$ ms i $T_{fi} = 2$ ms. Iz toga slijedi da je T_a dominantna vremenska konstanta. **Regulacijski krug struje armature** pogodan je za projektiranje regulatora po **tehničkom optimumu.** Kompenzira se dominantna vremenska konstanta pa je:

$$T_{IRi} = T_a = 5{,}852 \text{ ms}$$

Vrijedi $T_\Sigma = T_{mi} + T_{fi} = 3{,}67$ ms. Strukturnim pojednostavljenjem, uz uvrštavanje $T_{IRi} = T_a$, se dobije:

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{\frac{K_{Ri}K_tK_a}{T_a s(1+T_{mi}s)}}{1 + \frac{K_{Ri}K_iK_tK_a}{T_a s(1+T_{fi}s)(1+T_{mi}s)}} = \frac{\frac{K_{Ri}K_tK_a}{T_a s(1+T_{mi}s)}}{\frac{T_a s(1+T_{fi}s)(1+T_{mi}s) + K_{Ri}K_iK_tK_a}{T_a s(1+T_{fi}s)(1+T_{mi}s)}}$$

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{K_{Ri}K_tK_a\left(1+T_{fi}s\right)}{T_as\left(1+T_{fi}s\right)\left(1+T_{mi}s\right)+K_{Ri}K_iK_tK_a} = \frac{K_{Ri}K_tK_a\left(1+T_{fi}s\right)}{T_as(1+T_\Sigma s)+K_{Ri}K_iK_tK_a}$$

$$\frac{I_a(s)}{U_{iref}(s)} = \left(1+T_{fi}s\right)\frac{K_{Ri}K_tK_a}{T_aT_\Sigma s^2+T_as+K_{Ri}K_iK_tK_a}$$

$$\frac{I_a(s)}{U_{iref}(s)} = \left(1+T_{fi}s\right)\frac{1}{K_{Ri}K_iK_tK_a}\frac{K_{Ri}K_tK_a}{\frac{T_aT_\Sigma}{K_{Ri}K_iK_tK_a}s^2+\frac{T_a}{K_{Ri}K_iK_tK_a}s+1}$$

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{1+T_{fi}s}{K_i}\frac{1}{\frac{T_aT_\Sigma}{K_{Ri}K_iK_tK_a}s^2+\frac{T_a}{K_{Ri}K_iK_tK_a}s+1}$$

Promatramo dio $\frac{1}{\frac{T_aT_\Sigma}{K_{Ri}K_iK_tK_a}s^2+\frac{T_a}{K_{Ri}K_iK_tK_a}s+1}$ koji je oblika $\frac{1}{1+\frac{2\zeta}{\omega_n}s+\frac{s^2}{\omega_n^2}}$, pa slijedi:

$$\frac{1}{\omega_n^2} = \frac{T_aT_\Sigma}{K_{Ri}K_iK_tK_a}$$

$$\frac{2\zeta}{\omega_n} = \frac{T_a}{K_{Ri}K_iK_tK_a}$$

Izbor $\zeta = \frac{\sqrt{2}}{2}$ predstavlja tehnički najprihvatljiviji izbor za većinu primjena:

$$\frac{2\zeta}{\omega_n} = \frac{T_a}{K_{Ri}K_iK_tK_a} \rightarrow \frac{1}{\omega_n} = \frac{1}{2\zeta}\frac{T_a}{K_{Ri}K_iK_tK_a} = \frac{1}{\sqrt{2}}\frac{T_a}{K_{Ri}K_iK_tK_a}$$

Kada se gornji izraz kvadrira, slijedi:

$$\frac{1}{\omega_n^2} = \frac{1}{2}\frac{T_a^2}{(K_{Ri}K_iK_tK_a)^2}$$

Izjednačavanjem izraza $\frac{1}{\omega_n^2} = \frac{T_aT_\Sigma}{K_{Ri}K_iK_tK_a}$ i $\frac{1}{\omega_n^2} = \frac{1}{2}\frac{T_a^2}{(K_{Ri}K_iK_tK_a)^2}$ slijedi:

$$\frac{T_aT_\Sigma}{K_{Ri}K_iK_tK_a} = \frac{1}{2}\frac{T_a^2}{(K_{Ri}K_iK_tK_a)^2}$$

$$T_\Sigma = \frac{1}{2}\frac{T_a}{K_{Ri}K_iK_tK_a} \rightarrow K_{Ri} = \frac{T_a}{2T_\Sigma K_iK_tK_a} = \frac{\frac{L_a}{R_a}}{2\left(T_{mi}+T_{fi}\right)K_iK_t\frac{1}{R_a}} = \frac{L_a}{2\left(T_{mi}+T_{fi}\right)K_iK_t}$$

$$K_{Ri} = \frac{4}{2\cdot 3{,}67\cdot 0{,}1\cdot 44} = 0{,}124$$

Prijenosna funkcija $\frac{I_a(s)}{U_{iref}(s)}$ sada postaje (uvrštavanjem $K_{Ri} = \frac{T_a}{2T_\Sigma K_i K_t K_a}$):

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{1 + T_{fi}s}{K_i} \frac{1}{\frac{T_a T_\Sigma}{\frac{T_a}{2T_\Sigma K_i K_t K_a} K_i K_t K_a} s^2 + \frac{T_a}{\frac{T_a}{2T_\Sigma K_i K_t K_a} K_i K_t K_a} s + 1}$$

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{1 + T_{fi}s}{K_i} \frac{1}{1 + 2T_\Sigma s + 2T_\Sigma^2 s^2}$$

S obzirom na to da se u prijenosnoj funkciji $\frac{I_a(s)}{U_{iref}(s)}$ pojavljuje nula zbog mjernog člana struje armature, koristi se prefiltar:

$$G_{pfi}(s) = \frac{1}{1 + T_{fi}s}$$

pa se dobije:

$$\frac{I_a(s)}{U_{iref}(s)} = \frac{1}{K_i} \frac{1}{1 + 2T_\Sigma s + 2T_\Sigma^2 s^2}$$

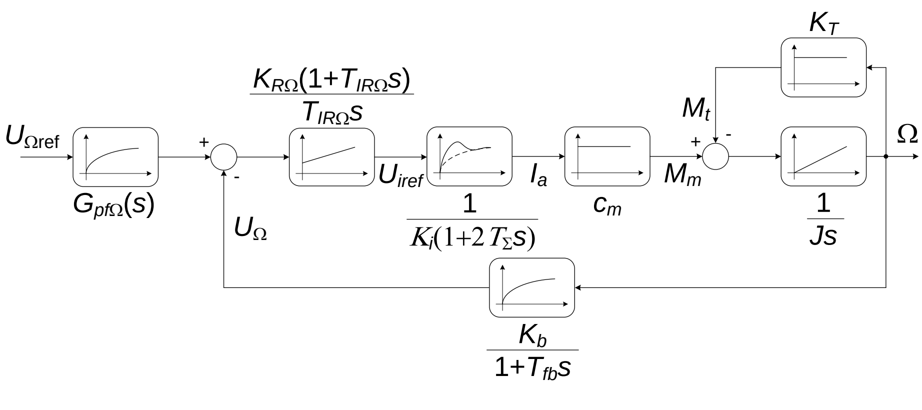
S obzirom na to da je regulacijski krug struje armature podređen regulacijskom krugu brzine vrtnje, vrlo je praktično, sa stajališta sinteze regulatora brzine vrtnje, strukturno pojednostaviti prijenosnu funkciju, tj. nadomjestiti je prijenosnom funkcijom:

$$\frac{I_a(s)}{U_{iref}(s)} \approx \frac{1}{K_i} \frac{1}{1 + T_s s}$$

gdje je $T_s = 2T_\Sigma = 7{,}34$ ms nadomjesna vremenska konstanta.

<u>**Sinteza regulatora brzine vrtnje**</u>

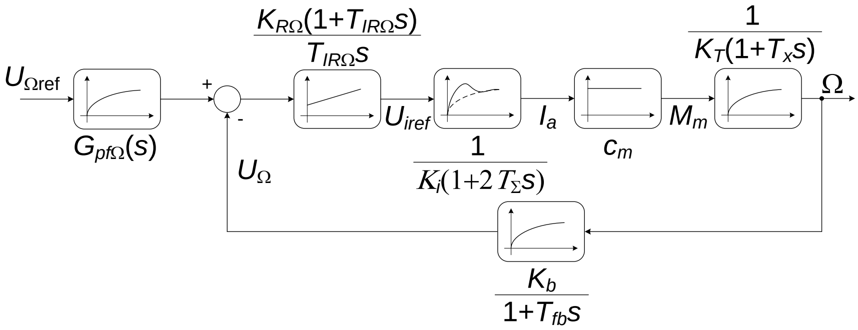
Uz prethodno uzeta pojednostavljena, strukturna shema postaje:



Prijenosna funkcija $\frac{\Omega(s)}{M_m(s)}$ glasi:

$$\frac{\Omega(s)}{M_m(s)} = \frac{1}{Js + K_T}$$

Shema se mijenja u:



pri čemu je $T_x = \frac{J}{K_T}$. U zadatku se traži i da se sinteza **regulatora brzine vrtnje** obavi prema **tehničkom optimumu**. Vrijede sljedeći izrazi (u ovoj fazi izvoda se ne koristi prefiltar $G_{pf\Omega}(s)$):

$$\Omega(s) = \frac{1}{K_T(1+T_x s)} M_m(s)$$

$$U_\Omega(s) = \frac{K_b}{1+T_{fb}s}\Omega(s)$$

$$M_m(s) = [U_{\Omega ref}(s) - U_\Omega(s)]K_{R\Omega}\frac{1+T_{IR\Omega}s}{T_{IR\Omega}s}\frac{1}{K_i}\frac{1}{1+2T_\Sigma s}c_m$$

Kada se drugi izraz ubaci u treći izraz, a potom to sve u prvi izraz, dobije se:

$$\Omega(s) = \frac{1}{K_T(1+T_x s)}\left[U_{\Omega ref}(s) - \frac{K_b}{1+T_{fb}s}\Omega(s)\right]K_{R\Omega}\frac{1+T_{IR\Omega}s}{T_{IR\Omega}s}\frac{1}{K_i}\frac{1}{1+2T_\Sigma s}c_m$$

$$\Omega(s)\left[1+\frac{K_{R\Omega}K_b c_m(1+T_{IR\Omega}s)}{K_T K_i T_{IR\Omega}s(1+T_x s)(1+2T_\Sigma s)\left(1+T_{fb}s\right)}\right] = U_{\Omega ref}(s)\frac{K_{R\Omega}c_m(1+T_{IR\Omega}s)}{K_T K_i T_{IR\Omega}s(1+T_x s)(1+2T_\Sigma s)}$$

$$\frac{\Omega(s)}{U_{\Omega ref}(s)} = \frac{\dfrac{K_{R\Omega}c_m(1+T_{IR\Omega}s)}{K_T K_i T_{IR\Omega}s(1+T_x s)(1+2T_\Sigma s)}}{1+\dfrac{K_{R\Omega}K_b c_m(1+T_{IR\Omega}s)}{K_T K_i T_{IR\Omega}s(1+T_x s)(1+2T_\Sigma s)\left(1+T_{fb}s\right)}}$$

Vrijedi: $T_s = 2T_\Sigma = 0{,}00734$ ms, $T_{fb} = 0{,}015$ ms i $T_x = \frac{J}{K_T} = \frac{0{,}478}{0{,}4579} = 1{,}0438$ ms. Kompenzira se dominantna vremenska konstanta pa je:

$$T_{IR\Omega} = T_x = 1{,}0438 \text{ ms}$$

Strukturnim pojednostavljenjem, uz uvrštavanje $T_{IR\Omega} = T_x$ i $T_\Sigma^* = T_s + T_{fb}$, se dobije:

$$\frac{\Omega(s)}{U_{\Omega ref}(s)} = \frac{\dfrac{K_{R\Omega}c_m}{K_T K_i T_{IR\Omega}s(1+2T_\Sigma s)}}{1+\dfrac{K_{R\Omega}K_b c_m}{K_T K_i T_{IR\Omega}s(1+2T_\Sigma s)\left(1+T_{fb}s\right)}}$$

$$\frac{\Omega(s)}{U_{\Omega ref}(s)}=\frac{\dfrac{K_{R\Omega}c_m}{K_TK_iT_{IR\Omega}s(1+2T_\Sigma s)}}{\dfrac{K_TK_iT_{IR\Omega}s(1+2T_\Sigma s)\left(1+T_{fb}s\right)+K_{R\Omega}K_bc_m}{K_TK_iT_{IR\Omega}s(1+2T_\Sigma s)\left(1+T_{fb}s\right)}}$$

$$\frac{\Omega(s)}{U_{\Omega ref}(s)}=\frac{K_{R\Omega}c_m\left(1+T_{fb}s\right)}{K_TK_iT_{IR\Omega}s(1+2T_\Sigma s)\left(1+T_{fb}s\right)+K_{R\Omega}K_bc_m}=\frac{K_{R\Omega}c_m\left(1+T_{fb}s\right)}{K_TK_iT_{IR\Omega}s(1+T_\Sigma^* s)+K_{R\Omega}K_bc_m}$$

$$\frac{\Omega(s)}{U_{\Omega ref}(s)}=\left(1+T_{fb}s\right)\frac{1}{K_{R\Omega}K_bc_m}\frac{K_{R\Omega}c_m}{\dfrac{K_TK_iT_{IR\Omega}T_\Sigma^*}{K_{R\Omega}K_bc_m}s^2+\dfrac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}s+1}$$

$$\frac{\Omega(s)}{U_{\Omega ref}(s)}=\left(1+T_{fb}s\right)\frac{1}{K_b}\frac{1}{\dfrac{K_TK_iT_{IR\Omega}T_\Sigma^*}{K_{R\Omega}K_bc_m}s^2+\dfrac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}s+1}$$

Promatramo dio $\frac{1}{\frac{K_TK_iT_{IR\Omega}T_\Sigma^*}{K_{R\Omega}K_bc_m}s^2+\frac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}s+1}$ koji je oblika $\frac{1}{1+\frac{2\zeta}{\omega_n}s+\frac{s^2}{\omega_n^2}}$, pa slijedi:

$$\frac{1}{\omega_n^2}=\frac{K_TK_iT_{IR\Omega}T_\Sigma^*}{K_{R\Omega}K_bc_m}$$

$$\frac{2\zeta}{\omega_n}=\frac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}$$

Izbor $\zeta=\frac{\sqrt{2}}{2}$ predstavlja tehnički najprihvatljiviji izbor za većinu primjena:

$$\frac{2\zeta}{\omega_n}=\frac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}\rightarrow\frac{1}{\omega_n}=\frac{1}{2\zeta}\frac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}=\frac{1}{\sqrt{2}}\frac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}$$

Kada se gornji izraz kvadrira, slijedi:

$$\frac{1}{\omega_n^2}=\frac{1}{2}\frac{K_T^2K_i^2T_{IR\Omega}^2}{K_{R\Omega}^2K_b^2c_m^2}$$

Izjednačavanjem izraza $\frac{1}{\omega_n^2}=\frac{K_TK_iT_{IR\Omega}T_\Sigma^*}{K_{R\Omega}K_bc_m}$ i $\frac{1}{\omega_n^2}=\frac{1}{2}\frac{K_T^2K_i^2T_{IR\Omega}^2}{K_{R\Omega}^2K_b^2c_m^2}$ slijedi:

$$\frac{K_TK_iT_{IR\Omega}T_\Sigma^*}{K_{R\Omega}K_bc_m}=\frac{1}{2}\frac{K_T^2K_i^2T_{IR\Omega}^2}{K_{R\Omega}^2K_b^2c_m^2}$$

$$T_\Sigma^*=\frac{1}{2}\frac{K_TK_iT_{IR\Omega}}{K_{R\Omega}K_bc_m}\rightarrow K_{R\Omega}=\frac{K_TK_iT_{IR\Omega}}{2T_\Sigma^*K_bc_m}=\frac{0{,}4579\cdot 0{,}1\cdot 1{,}0438}{2\cdot 0{,}02234\cdot 0{,}031\cdot 2{,}66}=12{,}9778$$

Prijenosna funkcija $\frac{I_a(s)}{U_{iref}(s)}$ sada postaje (uvrštavanjem $K_{R\Omega}=\frac{K_T K_i T_{IR\Omega}}{2T_\Sigma^* K_b c_m}$):

$$\frac{\Omega(s)}{U_{\Omega\mathrm{r}ef}(s)}=\left(1+T_{fb}s\right)\frac{1}{K_b}\frac{1}{\frac{K_T K_i T_{IR\Omega}T_\Sigma^*}{\frac{K_T K_i T_{IR\Omega}}{2T_\Sigma^* K_b c_m}K_b c_m}s^2+\frac{K_T K_i T_{IR\Omega}}{\frac{K_T K_i T_{IR\Omega}}{2T_\Sigma^* K_b c_m}K_b c_m}s+1}$$

$$\frac{\Omega(s)}{U_{\Omega\mathrm{r}ef}(s)}=\frac{1+T_{fb}s}{K_b}\frac{1}{1+2T_\Sigma^* s+2{T_\Sigma^*}^2 s^2}$$

S obzirom na to da se u prijenosnoj funkciji $\frac{\Omega(s)}{U_{\Omega ref}(s)}$ pojavljuje nula zbog mjernog člana brzine vrtnje, koristi se prefiltar:

$$G_{pf\Omega}(s)=\frac{1}{1+T_{fb}s}$$