Elektromehaničke i električne pretvorbe

EEP

Auditorne vježbe

2014/2015

21.10 2015

Posebna zahvala kolegi *šjor „luka123“* na auditornima broj 8, jer bez njih bi ovaj dokument bio nepotpun.

Zadaci koji su rješeni na auditornim vježbama neki su od zadataka za vježbu. Tamo imate potpuni tekst zadatka. Ovdje su pisani ulazni podaci, računska rješenja te dodatni komentari. Mada je ovdje sve napisano neke jako bitne stvari koje djeluju jednostavne nisu napisane, jer se smatra da teoriju već znate. Zbog toga je dobro da idete na predavanja i auditorne vježbe.

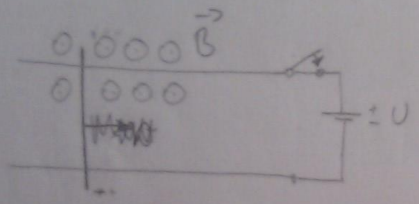
Ovo je temeljni predmet ukoliko namjeravate nastaviti na smjeru ESIT, stoga je dobro da razumjete problematiku i principe (Žarko će vas provjeriti na usmenom). Učite za znanje koje će vam itekako koristit u nastavku studija.

SRETNO

MATAN

Auditorne 1.

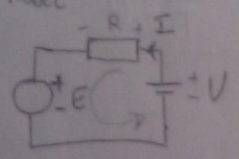
1.



$B = 0.8\,T$
$R = 1\,\Omega$
$U = 10\,V$
$l = 1\,m$

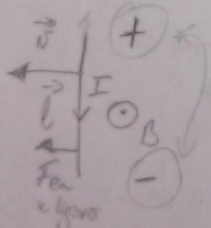
a) smjer $\vec{F}_{em}$, N, $\vec{E}_i$ u $t = 0^+$

MODEL



$\vec{F} = q(\vec{v} \times \vec{B})$

$\vec{F}_{em} = I(\vec{l} \times \vec{B})$



u $t = 0^+ \Rightarrow E = 0$ $\quad I = \frac{U}{R}$

$E = \vec{l} \cdot (\vec{v} \times \vec{B})$

je +

	E	F
PRAVO	D	L
PALAC	U	F
DLAN	B	O
PST 1	+E	I

$F = B \cdot I \cdot l = 0.8 \cdot 10 \cdot 1 = 8\,N$

) Brzina i struja u stacionarnom stanju
N i g

$F = B \cdot I \cdot l$

$E = B \cdot l \cdot N$

$N = \frac{E}{B \cdot l} = \frac{10}{0.8 \cdot 1}$

$F_{em} = m \cdot \frac{dv}{dt} = 0$ st. stanje

$W = F \cdot S$

$F_{em} = 0 = B \cdot I \cdot l$

$U - I \cdot R - E = 0$

$\boxed{U = E + I \cdot R}$ $\quad I = \frac{U - E}{R} \Rightarrow 0$ $\quad \boxed{U = E}$

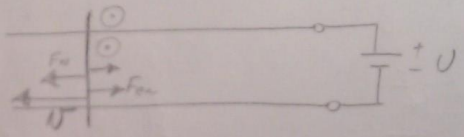
$W = F \cdot s = 0$

$E = P_{el} \cdot t = U \cdot I \cdot t = 0$

$\eta = \frac{0}{0} = ?$ UEMA ELM. PRETVORBE

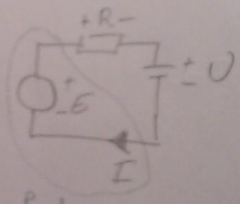
d) $F_v = 5N$ ulijevo

F, U, F_{em}, E u st. st



$F_{em} = 5N$ u desno $= B \cdot I \cdot l$

$I = \frac{5}{0.8 \cdot 1} = 6.25A$



Preh

$F =$

$v = \frac{E}{B \cdot l} = 20,3 \frac{m}{s}$

$0 + I \cdot R - E = 0$

$E = U + I \cdot R$

$E = 10 + 6,25 = 16,25$

$P_{reh} = F_v \cdot v = E \cdot I$

$5 \cdot 20,3 = 16,25 \cdot 6,25$

$101,5 = 101,5$

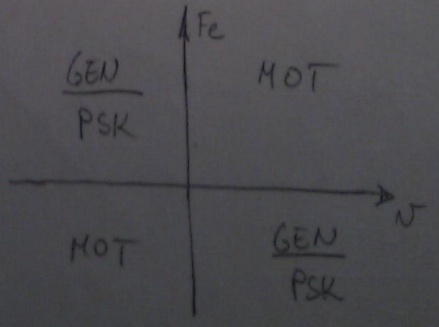
$P_{el} = U \cdot I = 62,5W$

$\eta = \frac{P_{iz}}{P_{ul}} = \frac{62,5W}{101,5W} = 0,615$ GeN - omjer između korisnog energija ide iz meh. dijela u ele.

E=U - nema pretvorbe

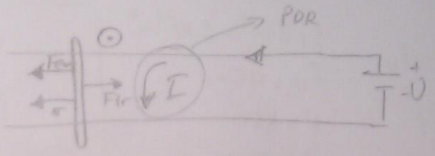
E<U - motorski

E>U - generatorski



d) $F_{tr} = 2N$

v, I, E



st. st

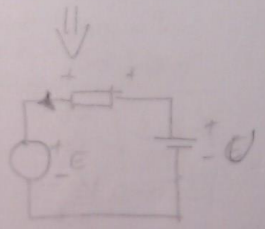
$F_{tr} = 2N$

$F_{en} = -F_{tr} = -2N$

$F_{en} = B \cdot I \cdot l$

$I = \frac{F}{B \cdot l} = \frac{2}{0,2 \cdot 1} = 2,5A$

$\vec{F} = I \cdot (\vec{l} \times \vec{B})$



$E + I \cdot R = U$

$E = U - I \cdot R$

$E = 7,5V$

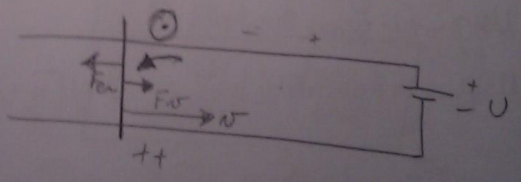
$E = Blv$

$v = \frac{E}{B \cdot l} = 9,38$

$\eta = \frac{P_{iz}}{P_{ul}} = \frac{F \cdot v}{U \cdot I} = \frac{2 \cdot 9,38}{10 \cdot 2,5} = 0.75$

e) $F_N = 10N$ udesno

I, v, F



$F_N = F_{em} = 10N$

$F = B \cdot I \cdot l$

$I = \frac{F_{em}}{B \cdot l} = 12,5A$

$\vec{F} = I(\vec{l} \times \vec{B})$

E

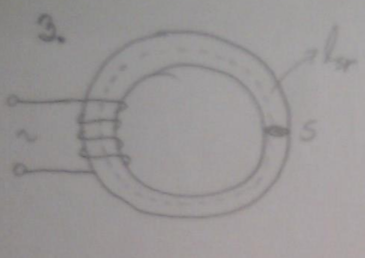
$U - I \cdot R + E = 0$

PSK → Protustrujno kočenje

oba izvora daju energiju

$E = IR - U = 2,5V$

3.



$S = 9\,cm^2 = 9 \cdot 10^{-4}\,m^2$

$l_{sr} = 0{,}6\,m$

$N = 850$

$U = 220\,V$

$f = 50\,Hz$

$\mu_r = 500$

$\mu = \mu_0 \cdot \mu_r$ ↓ $4\pi \cdot 10^{-7} \frac{Vs}{Am}$

$\phi = B \cdot S \; [Wb, Vs]$, $[T] \rightarrow \frac{Vs}{m^2}$

a) $\check{\phi}, \check{\psi}, \check{B}, L, R_m, \Lambda_m$ → mag. vodljivost

$\psi = N \cdot \phi$

$e = -\frac{d\psi}{dt}$

$\nabla \cdot \vec{B} = 0$ → ne postoji mag. monopol

$u(t) = U_{ef} \cdot \sqrt{2}\, \sin(2\pi f \cdot t)$

$u = -e = \frac{d\psi}{dt}$

$\phi = \phi_{max} \cdot \sin(2\pi f t)$

$\psi = N \cdot \phi = N \cdot \phi_{max} \sin(2\pi f t)$

$\frac{d\psi}{dt} = N \cdot \phi_{max}\, 2\pi f \cos(2\pi f t) = u = U\sqrt{2} \sin(2\pi f t)$

$U\sqrt{2} = N \cdot \phi_{max} \cdot 2\pi f$

$$U = \frac{N \cdot \phi_{max} \cdot 2\pi f}{\sqrt{2}} = 4{,}44 \cdot N \cdot \phi_{max} \cdot f \quad !$$

U → efektivno; ϕ_{max} → $B_{max} \cdot S$

→ ukoliko smo spojili zavojnicu N zavoja

$$B_{max} = \frac{U}{4{,}44 \cdot N \cdot f \cdot S} = 1{,}295\,T$$

$\Phi_{max} = B_{max} \cdot S = 1{,}17\,mVs$

$\Psi_m = N \cdot \Phi_m = 0{,}99\,Vs$

AMPEROV ZAKON PROTJEČANJA

$\oint_L \vec{H} \cdot d\vec{L} = \oint_S \sum I$

$B = \mu \cdot H$

$H \cdot l_{sr} = N \cdot I$

$\frac{B}{\mu} \cdot l_{sr} = N \cdot I$

$I_{max} = \frac{B_{max} \cdot l_{sr}}{\mu \cdot N} = \sqrt{2} \cdot 1{,}03A$

$\boxed{I_{ef} = 1{,}03A}$

$L = \frac{\Psi}{I} = \frac{N \cdot \Phi}{I} = \frac{N \cdot B \cdot S}{I} = \frac{N \cdot \mu \cdot H \cdot S}{I} = \frac{N \cdot \mu \cdot N \cdot \cancel{I} \cdot S}{\cancel{I} \cdot l_{sR}}$

$\boxed{L = \frac{N^2 \cdot \mu \cdot S}{l_{sR}}} = N^2 \cdot \Lambda_m \rightarrow$

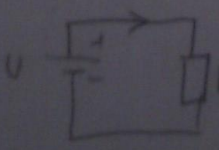
$\boxed{\Lambda_m = \frac{\mu \cdot S}{l_{sR}}}$

$\boxed{R_m = \frac{1}{\Lambda_m} = \frac{l_{sR}}{\mu \cdot S}}$

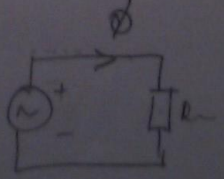
$L = 0{,}68H$

$\Lambda_m = 9{,}43 \cdot 10^{-7} \frac{Vs}{A}$

$R_m = 1{,}06 \cdot 10^{6} \frac{A}{Vs}$



$I = \frac{U}{R}$



$\Phi = \frac{N \cdot I}{R_m} = \frac{\Theta}{R_m}$

4. Transf => 100/10kV, 30MVA, 50Hz

$P_0 = 150kW$

110kV; 60Hz ?

$P_0 = ?$

$P_H/P_V = 1.5$

$P_H \sim B^{2,2}$

$P_0 = P_H + P_V = 2,5 P_V$

$\frac{P_H}{P_V} = 1,5$

$P_V = 60kW$

$P_H = 90kW$

$U_1 = 4,44 \cdot N \cdot S \cdot B_1 \cdot f_1$

$U_2 = 4,44 \cdot N \cdot S \cdot B_2 \cdot f_2$

$\frac{U_1}{U_2} = \frac{B_1}{B_2} \cdot \frac{f_1}{f_2} \Rightarrow \frac{B_2}{B_1} = 0.9167$

$P_H \sim f \cdot B^{2,2}$

$P_V \sim f^2 \cdot B^2$

$P_{H2} = P_{H1} \cdot \frac{f_2}{f_1} \cdot \left(\frac{B_2}{B_1}\right)^{2,2} = 89,2kW$

$P_{V2} = P_{V1} \cdot \left(\frac{f_2}{f_1}\right)\left(\frac{B_2}{B_1}\right)^{2,2} = 72,6kW$

$P_{02} = P_{H2} + P_{V2} = 161,8kW$

...uditorne 2

1. 1f T

5MVA

20/0,6kV

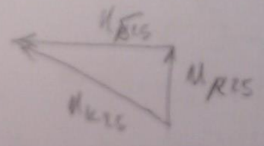
25°C ⟹ 75°C

$P_k = 68\,kW$ $u_k = 9\%$

$R_1 = 0{,}4\,\Omega$

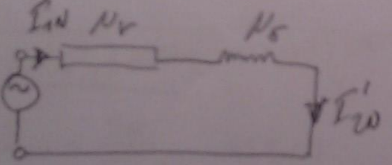
$R_2 = 0{,}5\,m\Omega$

$I_\mu = 10\, I_{0R} = 1\%\, I_N$



$I_{1N} = \frac{S_n}{U_{1n}} = 250\,A$

$I_{2N}' = \frac{S_n}{U_{2n}} = 8{,}33\,kA$



$u_{r25} = \frac{P_{k25}}{S_n} \cdot 100\% = 1{,}36\%$

$u_{X25} = \sqrt{u_{k25}^2 - u_{R25}^2} = 8{,}90\%$

($u_{k25} = 9\%$)

$b = \frac{235 + \theta_2}{235 + \theta_1} = \frac{235+75}{235+25} = 1{,}1923$

$P_k = P_{cu1} + P_{cu2} + P_{dod}$

$P_{cu1} + P_{cu2}$: raste s temp → $\cdot b$

P_{dod}: padajn s temp → $\frac{1}{b}$

$P_{cu25} = I_1^2 \cdot R_{1,25} + I_2^2 \cdot R_{2,25} = 59722\,W$

$P_{dod} = P_k - P_{cu25} = 68000 - 59722 = 8278\,W$

$P_{cu75} = P_{cu25} \cdot b = 59722 \cdot 1{,}1923 = 71207\,W$

$P_{dod75} = P_{dod25} \cdot \frac{1}{b} = 8278 \cdot \frac{1}{1{,}1923} = 6943\,W$

$P_{k75} = P_{cu75} + P_{dod75} = 78150\,W$

$$u_{rTS} = \frac{P_{kTS}}{S_n} \cdot 100\% = 1,56\%$$

$$u_{kTS} = \sqrt{u_{rTS}^2 + u_{\delta TS}^2} = 9,03\%$$

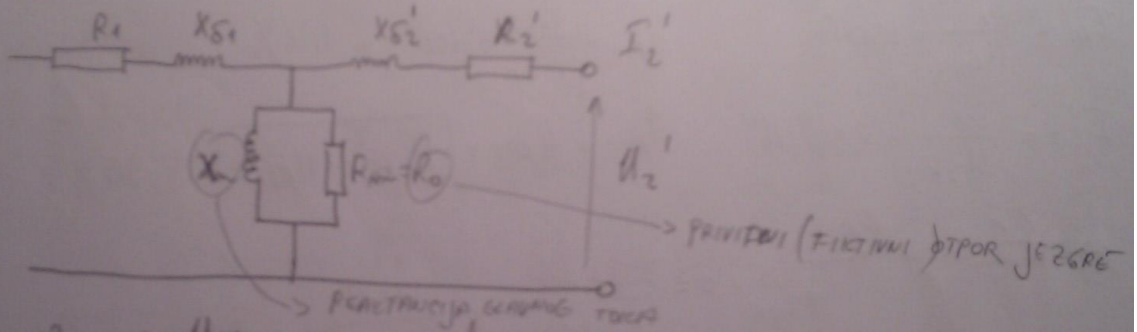
$u_k \sim Z_k = 9,03\%$

$u_r \sim R_k = 1,56\%$

$u_\delta \sim X_k = 8,90\%$

$$X_{1\delta} = X_{2\delta} = \frac{X_k}{2} = 4,45\%$$

$I_\mu = 1\% I_n = 0.01$



a^2, $A = \frac{U_{1n}}{U_{2n}}$ $R = \delta \cdot \frac{1}{S}$

$$R_{1\%TS} = \frac{R_{1n} \cdot b}{Z_b} \cdot 100\% = \frac{0.4 \cdot}{80} \cdot 100\% = 0,60\%$$

$$Z_b = \frac{U_n^2}{S_n} = 80\Omega$$

$$R'_{2\%TS} = R_{kTS} - R_1 = 0.96\%$$

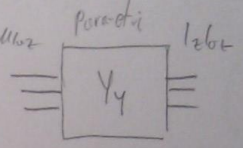
$$R'_{2m\%TS} = \frac{R_{2m} \cdot b \cdot a^2}{Z_b} \cdot 100\% = 0.83\%$$

$$X_\mu = \frac{U_n\%}{I_\mu\%} = \frac{1}{0.01} \cdot 100\% = 10000\%$$

$$R_0 = \frac{U_n\%}{I_{0R}} = \frac{1}{0,001} \cdot 100\% = 100\,000\%$$

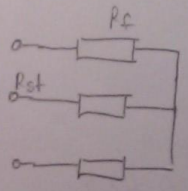
1. Svi trofazni transformatori bezobzira na stvarni spoj računaju se kao da su spojeni u spoj Yy

3fT
400kVA
10/0,4kV = Uvijek niskonaponski Y
Dyn5



75°C
$P_K = 3767\ W$
$P_0 = 441\ W$
$u_K = 3,88\%$
$I_0 = 0,13\%\ I_N$

22°C
$R_{st1} = 2,14\ \Omega$
$R_{st2} = 0,0023\ \Omega$



$U_f = \frac{U_L}{\sqrt{3}}$

$R_{st} = 2R_f$

$3 \cdot \frac{R_{st}}{2} \cdot I_f^2 \rightarrow P_{Cu}$
↓
faze

10/0.4kV

$I_{1N} = \frac{S_N}{\sqrt{3}\,U_{1N}} = 23,1A$

$b = \frac{235+75}{235+22} = 1,2062$

$I_{2N} = \ldots = 577,4A$

$P_{k75} = P_{Cu75} + P_{dod75}$
↓ ZADANO ↓ Prer

$P_{Cu75} = b \cdot P_{Cu25} = b \cdot \left(3 \cdot \frac{R_{st1}}{2} \cdot I_1^2 + 3 \cdot \frac{R_{st2}}{2} \cdot I_2^2\right)$

$P_{Cu75} = 2144,4 + 1387,4\ W = 3453$

$P_{dod75} = 265,2\ W$

$Z_b = \frac{U_{1N}^2}{S_n} = 250\Omega$

$$R_A = \frac{1}{2} R_{st_1} \cdot b \cdot \frac{1}{Zb} \cdot 100\% = 0{,}53\% \qquad R_2' = R_{2cu}' + R_{dod}$$

$$R_{2cu}' = \frac{1}{2} R_{st_2} \cdot b \cdot a^2 \cdot \frac{1}{Zb} \cdot 100\% = 0{,}867 \cdot \frac{1}{Zb} \cdot 100\%$$

$$a = \left(\frac{U_{1N}}{U_{2N}}\right)$$

$$R_{dod} = \frac{P_{dod}/3}{I_{1N}^2} = 0{,}166\,\Omega$$

$$R_K = R_1 + R_2'$$

$$R_2' = 1{,}033 \cdot \frac{1}{Zb} \cdot 100\% = 0{,}41\%$$

$$R_K = R_1 + R_2' = 0{,}53 + 0{,}41 = 0{,}94\%$$

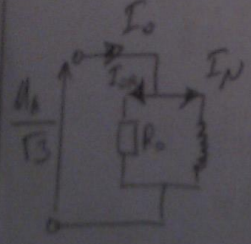
$$R_{K75\%} \sim U_{r\%} = 0{,}94\%$$

$$U_{K75} = 3{,}88\%$$

$$U_{\delta 75\%} = \sqrt{U_{K75}^2 - U_{r75\%}^2} = 3{,}76\%$$

$$\rightarrow X_K = 3{,}76\% = X_1 + X_{25}'$$

$$X_1 = X_{25}' = 1{,}88\%$$



$$P_{01} = \frac{\left(\frac{U_n}{\sqrt{3}}\right)^2}{R_0}$$

$$P_{0RL} = 3P_0 = \frac{U_n^2}{R_0} \qquad \Rightarrow R_0 = \frac{U_n^2}{P_0} = 2247{,}19\,\Omega$$

$$R_0 = 89888\%$$

$$I_{0R} = \frac{U_{0n}}{R_0} = \frac{\frac{U_n}{\sqrt{3}}}{R_0} = \ldots = 0{,}1125\%$$

$$I_\mu = \sqrt{I_0^2 - I_{0R}^2}$$

$$= \sqrt{0{,}13^2 - 0{,}11125^2}$$

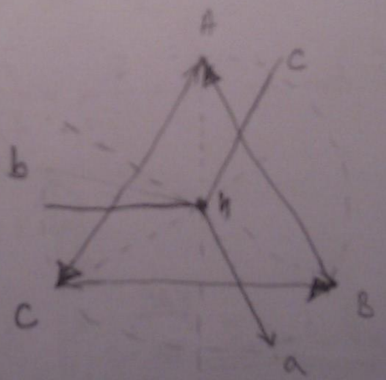
$$I_\mu = 0{,}06726\ \%$$

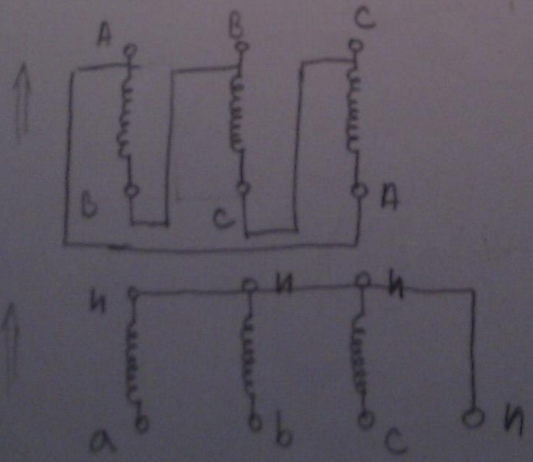
$$X_m = \frac{u_{1fN}}{I_\mu} = \ldots = 148685\%$$

grupa spoja

(3.) Yy0
↳ pomak između napona faze višenaponske i niženaponske strane

Dyn5





4.

$\frac{U_{1n}}{U_{2n}} = \frac{380}{220}$

$50 Hz$

$u_r = 2,5\%$, $u_k = 4,55\%$

ΔU i U_2' (u V i %) = ?

---

a) $\cos\varphi_2 = 0.8$ ind $I_2 = I_{2N}$

b) $\cos\varphi_2 = 0,6$ kap $I_2 = 0,5 I_{2N}$

$u_\delta = \sqrt{u_k^2 - u_r^2} = 3,8\%$

$\Delta u = \beta \cdot [u_r \cos\varphi_2 + u_\delta \sin\varphi_2]$

↳ faktor relativnog opt. tereta $\beta = \frac{S}{S_n} = \frac{I}{I_N}$

a) $\beta = 1$ b) $\beta = 0,5$

a) $\Delta u = 4,28\%$

b) $\cos\varphi = 0,6$ kap $\Rightarrow P \Rightarrow \sin\varphi = -0.8$ KAP

$\Delta u = -0.75\%$

↳ isto to znači!

Proširena formula za pad napona

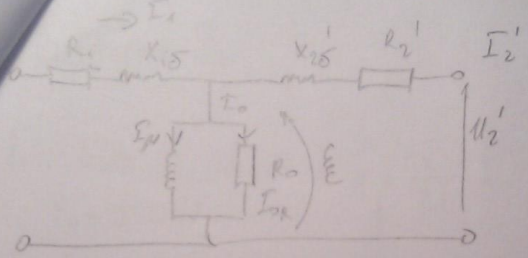
$\Delta u = \beta (u_r \cos\varphi_2 + u_\delta \sin\varphi_2 + 0,005 [u_\delta \cos\varphi_2 - u_r \sin\varphi_2])$

1. $\Delta U = \Delta u \cdot U_{1N} = -0,0075 \cdot 380 = -2.85 V$

$U_2' = U_{1N} + \Delta U = 377,15$

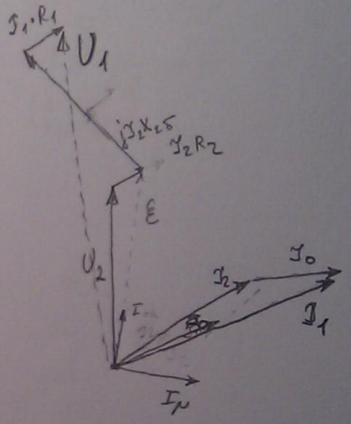
2. $\Delta U = \Delta u \cdot U_{2N} = -1,65 V$

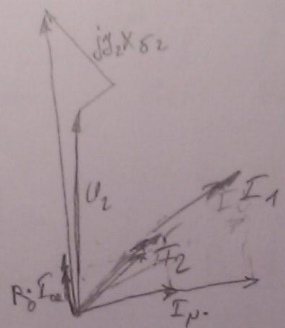
$U_2 = U_{2N} + \Delta U = 218,35 V$



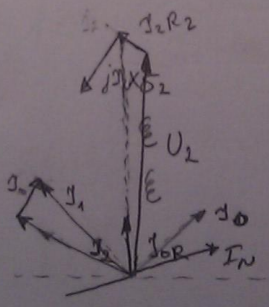
$$\underline{I}_1 = \underline{I}_0 + \underline{I}_2'$$

ind. opt.





kap. opt



Auditorne 3.

1. 3TR $S_N = 100\,kVA$

$P_0 = 350\,W$

$P_N = 1850\,W$

$\cos\varphi = 0{,}8$

$\eta = ?$

a) $\alpha = 0{,}6$ b) $\alpha = 1$

$$\eta = \frac{P_{iz}}{P_{ul}} = \frac{S_N \cdot \cos\varphi - P_g}{S_N \cdot \cos\varphi} = \frac{\alpha S_N \cos\varphi - P_g}{\alpha S_N \cdot \cos\varphi}$$

$$P_g = P_0 + P_t = P_0 + \alpha^2 P_{tN} = {}^{\alpha}$$

P_0 ↑ ff(I) — P_t ↑ f(I)

$S = S_N \cdot \cos\varphi$ (vrijedi za $U = U_N$)

$$\eta = 1 - \frac{P_g}{\alpha S_N \cdot \cos\varphi_2} = 1 - \frac{P_0 + \alpha^2 P_{tN}}{\alpha S_N \cdot \cos\varphi_2}$$

a) $\alpha = 0{,}6$ $\quad \eta = 1 - \frac{350 + 0{,}6^2 \cdot 1850}{0{,}6 \cdot 100\,kVA \cdot 0.8} = 97{,}81\%$

b) $\alpha = 1$ $\quad \eta = 97{,}13\%$

zbog čega je $\eta_1 \neq \eta_2$

$$\eta_{max} = \frac{d\eta}{d\alpha} = 0 \Rightarrow \alpha^2 P_{tN} = P_0$$

P_0 → gubitci PM u željezu

$$\alpha = \sqrt{\frac{P_0}{P_{tn}}} \Rightarrow \eta = \eta_{max}$$

P_{tn} → gubitci KS. u bakru

$$\alpha_{MAX} = \sqrt{\frac{350}{1950}} = 0{,}42366$$

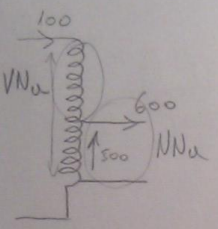
$\eta_{MAX} = 97{,}93\%$ pri $\cos\varphi_2 = 0.8$

Nazivna korisnost Transf. $\alpha = 1$ $\cos\varphi = 1$

$$\eta_n = 1 - \frac{P_{gn}}{S_N} = 1 - \frac{350 + 1850}{100k} = 97{,}70$$

① Autotransformator

$$I_{1k} = \frac{100\%}{u_k} \cdot I_N$$



3TR

8MVA = S_n

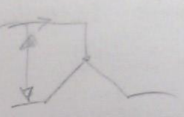
35/10,5kV

Yd5

$P_0 = 9,4kW$

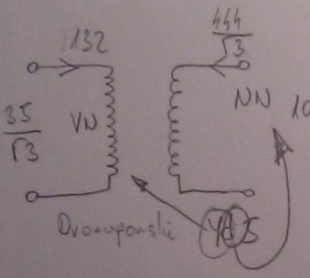
$P_t = 54kW$

$u_k = 7\%$



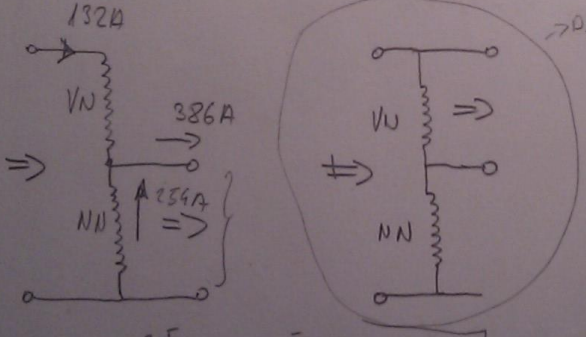
$u_{1N} =$

Ya O, S_a, u_{1a}/u_{2a}, η, u_{ka}



$$I_{1N} = \frac{S_N}{\sqrt{3}U_N} = 132A$$

$I_{2N} = 440A$



$$U_{1af} = \frac{35}{\sqrt{3}} + 10,5\ [kV]$$

$$= 30,71kV$$

$I_{1af} = 132A$

$I_{2af} = 386A$

} Linijski napon je u Y spoju

$U_{2af} = 10,5kV$

$$S_a \begin{cases} S_{1a} = \sqrt{3} I_{1a} \cdot U_{1a} = 12,2MVA \\ S_{2a} = \sqrt{3} I_{2a} \cdot U_{2a} = 12,2MVA \end{cases}$$

$$S_a = S_T \cdot \frac{u_{1a}}{u_{1a} - u_{2a}} = 12,2MVA$$

↓

Tipska snaga (SN)

$u_{1a} = \sqrt{3} u_{1af} = 53,2kV$ $\quad I_{1a} = 132A$

$u_{2a} = \sqrt{3} u_{2af} = 18,2kV$ $\quad I_{2a} = 386A$

$u_{ka} = u_k \frac{u_{ka} \cdot u_{ka}}{u_{ka}} = \dots = 4,61\%$

$\eta_a = 1 - \frac{P_{ga}}{S_a} = 1 - \frac{3,4\,kW + 5,46\,kW}{12,2\,M} = 99,48\%$

(P_{ga} → nepromijenjeno; S_a → nepromijenjeno)

prije → 99,21%

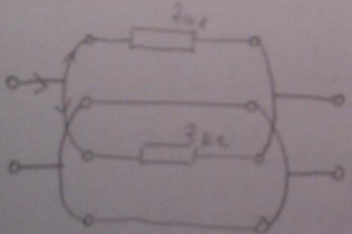
32,94 kW svaki h uštede → različito

32,94 MWh · 365 /· 50 €/MWh = 4427 €

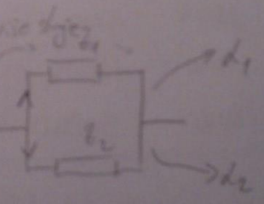
(3.) PARALELNI RAD

↳ bliske nazivne snage ~ „bliske" snage

odnos u_K



⇒ struji dobro



nisu isto opterećeni

$S_{1N} = S_{2N}$

$U_{1N} = U_{2N}$

$u_{K1\%} < u_{K2\%}$

$z_{K1\%} < z_{K2\%}$

$\alpha_1 > \alpha_2$

↓

$100\% > ? \; 80\%$

} Transf. sa manjim U_K će biti relativno više opterećen

$\vec{S} = \vec{S_1} + \vec{S_2} = S_1 + S_2$ (kod par. rad)

S_1 → 100 kVA, S_2 → 80 kVA

$100\,kVA + 0,8 \cdot 80\,kVA \neq 180\,kVA$

④ $S_d = U_{k\,max} \cdot \sum_i \frac{S_{ni}}{U_{ki}}$ – Stanojev

V

$S_V \Rightarrow$ snaga koja prenosi V-ti transformator

⑤ $S_V = S_{nV} \cdot \frac{S_{uk}}{U_{kV} \cdot \sum \frac{S_{ni}}{U_{ki}}}$

$\alpha = \frac{S_{uk}}{S_d}$ $\quad \alpha_i = \alpha \cdot \frac{U_{k\,max}}{U_{ki}}$

		U_k	P_0	P_f	
T_1	150 kVA	3,5%	450 W	1600 W	Yd7 10/0.4 kV
T_2	125 kVA	4%	350 W	1200 W	
T_3	100 kVA	4,5%	280 W	900 W	

a) 4 TR zna $\alpha = 90\%$, druga da preopterećena
$S = ?$ i koji su preopterećeni

T_1 i T_2 su $\alpha > 1$

$T_3 - \alpha_3 = 0.9$

$S_3 = S_{n3} \cdot \frac{S_{uk}}{U_{k3} \cdot \sum \frac{S_{ni}}{U_{ki}}}$ $\quad \sum = \frac{150}{3,5} + \frac{125}{4} + \frac{100}{4,5} = 96,3$ kVA

$0,95 S_{n3} = S_{n3} \cdot$ –11–

$0.9 = \frac{S_{uk}}{U_{k3} \cdot \sum}$

$S_{uk} = 0.9 \cdot 4,5 \cdot 96,3 = 330,14$ kVA

$\alpha_1 > \alpha_2 > \alpha_3$

$S_3 = 0.9 \cdot 100 = 90$ kVA

$S_1 = S_{n1} \cdot \frac{S_{uk}}{U_{k1} \cdot \sum} = 173,6$ kVA

$S_2 = S_{n2} \cdot \frac{S_{uk}}{U_{k2} \cdot \sum} = 126,6$ kVA

$S_d = M_{kMIN} \cdot \Sigma$

$= 3{,}5 \cdot \Sigma = 337{,}2\ kVA$

a ne 375!!!

c) η pri 80% dozvoljenog

$$\eta = 1 - \frac{P_{gub}}{S_{ulc} \cdot \cos\varphi}$$

$S_{ulc} = 0.8\, S_d$

$\cos\varphi = 0.85$ kap.

potrebno $\alpha_1, \alpha_2, \alpha_3$

$$\alpha = \frac{0.8\, S_d}{S_d} = 0.8 \qquad \alpha_i = \alpha \cdot \frac{M_{kMIN}}{M_{ki}}$$

$$\alpha_1 = 0.8 \cdot \frac{3{,}5}{3{,}5} = 0.8$$

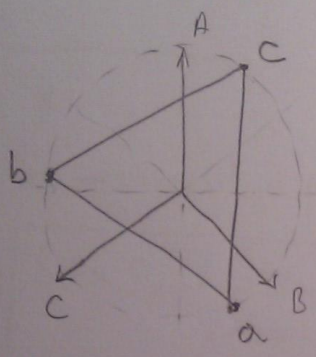
$$\alpha_2 = 0.8 \cdot \frac{3{,}5}{4} = 0.7$$

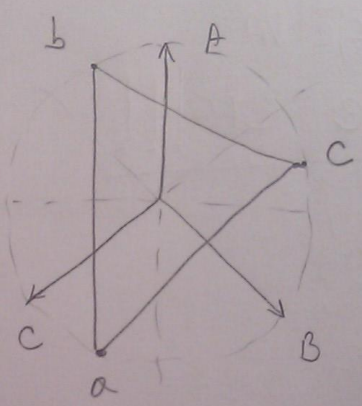
$$\alpha_2 = 0.8 \cdot \frac{3{,}5}{4{,}5} = 0{,}62$$

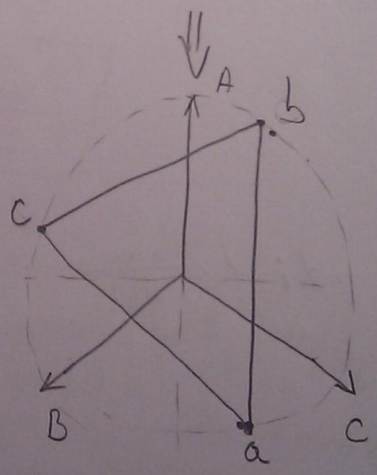
$$\eta = 1 - \frac{P_{01} + \alpha_1^2 P_{tN} + P_{02} + \alpha_2^2 \cdot P_{tN2} + P_{03} + \alpha_3^2 \cdot P_{tN3}}{0.8\, S_d \cdot \cos\varphi}$$

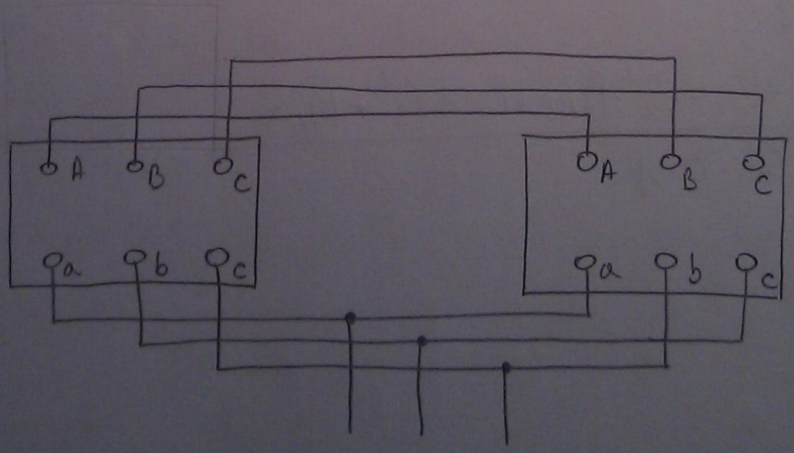
$\eta = 98{,}67\%$

5. yd5 i yd7 => treba ih spojit paralelno









Auditorne. 4.

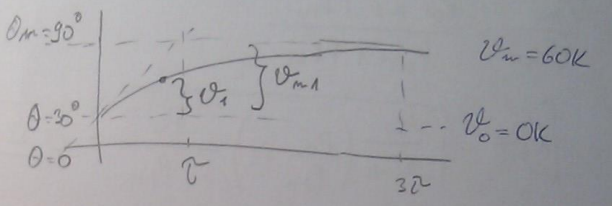
α_1 = konst.

$t_1 = 1{,}4\,h$ → $\vartheta_1 = 30°$

$\vartheta_{m1} = 60$

$P_0 = 2{,}6\,kW$

$P_{tn} = 9{,}1\,kW$

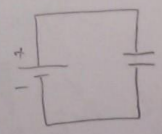


a) $T = ?\ \tau$

b) $1{,}8\,\alpha \rightarrow \vartheta_m$

$\theta - °C$ TEMPERATURA $\quad \vartheta - K$ NADTEMPERATURA ↳ TEMP. iz odnosa okoline

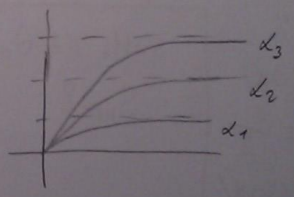
$\vartheta_m \sim P_g$ nadtemperatura proporcionalna snazi grijača



$$\vartheta = \vartheta_0 + (\vartheta_m - \vartheta_0)\left(1 - e^{-\frac{t}{T}}\right)$$

$\vartheta_0 = 0$

$$\vartheta = \vartheta_m\left(1 - e^{-\frac{t}{T}}\right)$$



$\alpha_1 \rightarrow P_{g1} \rightarrow t_1 \rightarrow \vartheta_1$

a) $\vartheta_1 = \vartheta_{m1}\left(1 - e^{-\frac{t_1}{T}}\right)$

$$T = -\frac{t_1}{\ln\left(1 - \frac{\vartheta_1}{\vartheta_{m1}}\right)} = 2.02\,h$$

b) Koliko će biti kvarova zagrijanje transf. kod 50% većeg opt

$\vartheta_{m2}, \alpha_2 = 1{,}5\alpha_1$

$\vartheta_{m1}, \alpha_1 = 60$

$\vartheta_{mn} = 80K$ uz P_{gn}

$P_{gn} = P_0 + P_{tn}$

$P_t = \alpha^2 \cdot P_{tn}$

$\vartheta_{m1} \sim P_{g1} = P_0 + \alpha_1^2 P_{tn}$

$\vartheta_{mn} \sim P_{gn} = P_0 + 1\,P_{tn}$

} izr α_1

$$\frac{\vartheta_{n1}}{\vartheta_{nn}} = \frac{P_{ot} + \alpha_1^2 P_{tn}}{P_o + 1\, P_{tn}}$$

$$\alpha_1 = \ldots \sqrt{\frac{\vartheta_{n1}}{\vartheta_{nn}}\left(\frac{P_o}{P_{tn}} + 1\right) + \frac{P_o}{P_{tn}}} = 0.824$$

$$\vartheta_{n2} = P_{ot} + \alpha_2^2 P_{tn} = P_{j2}$$

$$\frac{\vartheta_{n2}}{\vartheta_{nn}} = \frac{P_o + (1{,}5\,\alpha_1^2) P_{tn}}{P_o + (1^2)\, P_{tn}} \Rightarrow \vartheta_{n2} = 112{,}8\,K$$

U kojem trenutku t_2 će $\vartheta = \vartheta_{n2}$ uz opterećenje α_2!

(2.) 400 kW
10/0.4 kV
$u_k = 5\%$
$P_o = 2250\,W$
$P_h/P_v = \frac{2}{3}$
$P_t = 5750\,W$
60 Hz

$\vartheta_{nn} = 105\,K$
$\Theta_o = 40°C$

50 Hz uz $\Theta_{o1} = 20°C$
S_{nn} ?

$$P_h = k_h \cdot f \cdot B^2 = \frac{2}{5} P_o = 900\,W$$
$$P_v = k_v \cdot f^2 \cdot B^2 = \frac{2}{5} P_o = 1350\,W \quad \Big\} \text{ta}$$
$$P_o = P_h + P_v$$

60 Hz → 50 Hz

$U_{iw} = 4{,}44 f \Phi w \cdot 0{,}8 \sim f \cdot B \uparrow$

$$\frac{P_{t1}}{P_{tn}} = \frac{f_n}{f_1} = \frac{6}{5} = 1.2$$

$$\frac{P_{h1}}{P_{hn}} = \frac{f_1}{f_n}\left(\frac{B_1}{B_n}\right)^2 \Rightarrow P_{h1} = 1080\,W$$

$$P_{V1} = P_{Vn}\cdot\left(\frac{f_1}{f_n}\right)^2\left(\frac{B_1}{B_n}\right)^2 = \ldots 1350\,W = P_{V1}$$

$$P_{01} = P_{h1} + P_{V1} = 2430\,W$$

$$\vartheta_{mn} = 105^\circ C$$

$$\vartheta_{n1} = \vartheta_{mn} - \vartheta_{01} = 145 - 20 = \underline{125^\circ C}$$

$$P_g \sim \vartheta_m$$

$$P_g(\alpha_1) = ?$$

$B \sim f$

$$\vartheta_{m1} \sim P_{g1} = P_{01} + \alpha_1^2 \cdot P_{tn}$$

$$\vartheta_{mn} \sim P_{gn} = P_0 + 1^2 \cdot P_{tn}$$

$$\frac{\vartheta_{m1}}{\vartheta_{mn}} = \frac{P_{01} + \alpha^2 P_{tn}}{P_0 + P_{tn}} \Rightarrow \alpha_1 = 1,1111$$

$$\boxed{S_{n1} = 444\,kVA}$$

~~1.~~ 2.82/c

(3.) $\alpha_1 = 0.5 \rightarrow \vartheta_{n1} = 30°C$

$\alpha_2 = 1 \rightarrow \vartheta_{n2} = 65°C$

$T = 2\,h$

$\vartheta_2 = 40°C$

$t_2 = 3\,h$

Kod kojeg opt. u odnosu na nosioca $\alpha_2 = ?$

$\vartheta_{n2} \sim P_{g2} = P_o + P_{tn}$

$\vartheta_1 \sim P_{g1} = P_{o1} + \alpha_1^2 P_{tn}$

$\vartheta_2 \sim P_{g2} = P_{o2} + \alpha_2^2 P_{tn}$

$$\frac{\vartheta_{n2}}{\vartheta_{n1}} = \frac{P_o + P_{tn}}{P_o + P_{tn} \cdot \alpha_1^2} = \frac{\frac{P_o}{P_{tn}} + 1}{\frac{P_o}{P_{tn}} + 0.5^2}$$

$\rightarrow \alpha_{max} \rightarrow max\ \eta$!

$$\frac{P_o}{P_t} = 0{,}3528$$

$$\vartheta_2 = \vartheta_{2m}\left(1 - e^{\frac{t_2}{T}}\right)$$

$$\vartheta_{2m} = \frac{\vartheta_2}{1 - e^{\frac{t_2}{T}}} = 51{,}5K$$

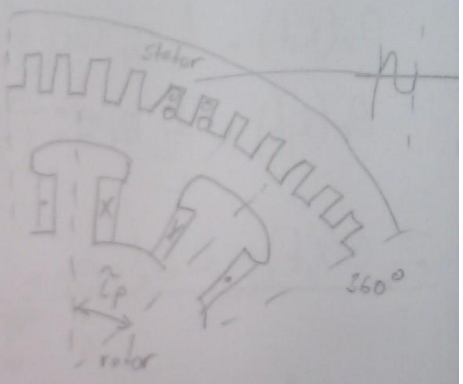
$$\frac{\vartheta_{2n}}{\vartheta_{2m}} = \frac{P_{o1} + 1P_{tn} \,/ : P_{tn}}{P_{o1} + \alpha_2^2 P_{tn}} = \frac{\frac{P_o}{P_{tn}} + 1}{\frac{P_{o1}}{P_{tn}} + \alpha_2^2}$$

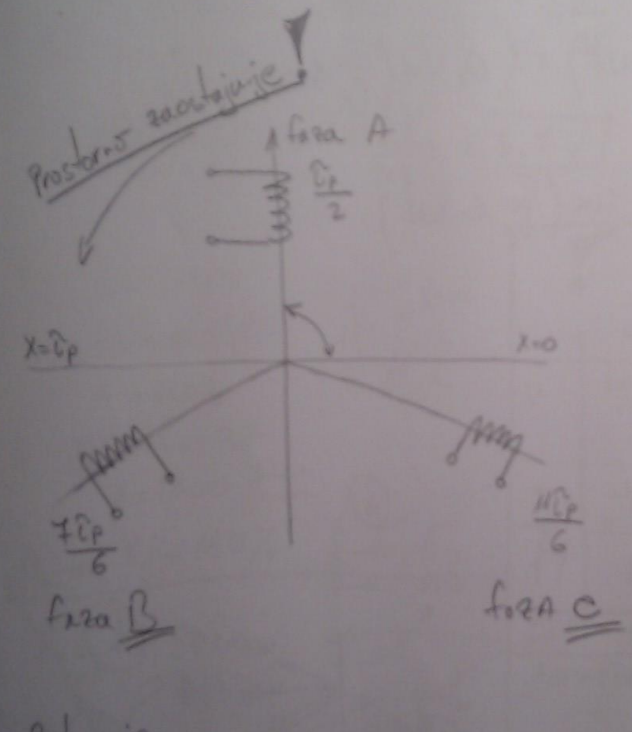
$$\boxed{\alpha_2 = 0.843}$$

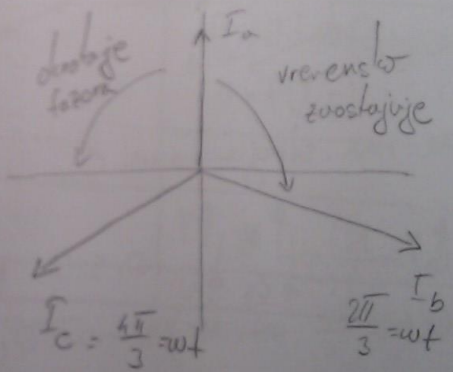
Auditorne 5.

Sinkroni strojevi

1. Za nacrtani raspored trofaznog namota i fazore struja treba nacrtati vektore komponenata direktnog i inverznog projekcija za trenutak kada je struja faze C maksimalna







Projekcije

$\Theta = k \cdot I$

$$\Theta(x,t) = \Theta_1 \cos(\omega t - \varphi_t) \cdot \cos\left(\frac{\pi x}{\tau_p} - \varphi_c\right)$$

$$\Theta_A(x,t) = \Theta_{1A} \cos\omega t \cdot \sin\left(\frac{\pi x}{\tau_p}\right)$$

$$\Theta_B(x,t) = \Theta_{1B} \cos\left(\omega t - \frac{2\pi}{3}\right) \sin\left(\frac{\pi}{\tau_p} x - \frac{2\pi}{3}\right)$$

$$\Theta_C(x,t) = \Theta_{1C} \cos\left(\omega t - \frac{4\pi}{3}\right) \sin\left(\frac{\pi}{\tau_p} x - \frac{4\pi}{3}\right)$$

$\Theta_{1a} = \Theta_{1b} = \Theta_{1c} = \Theta_1$

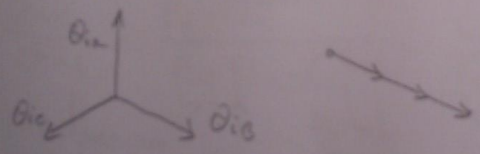
$$\Theta_a(x,t) = \frac{1}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x - \omega t\right) + \frac{1}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x + \omega t\right)$$

↳ pulsirajuće obrtno protjecanje može se rastaviti na dva obrtna protjecanja (DIREKTNO i INVERZNO)

$$\Theta_b(x,t) = \frac{1}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x - \omega t\right) + \frac{1}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x + \omega t - \frac{4\pi}{3}\right)$$

$$\Theta_c(x,t) = \frac{1}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x - \omega t\right) + \frac{1}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x + \omega t - \frac{2\pi}{3}\right)$$

$$\sum \Theta(x,t)_{nc} = \Theta_d + \underbrace{\Theta_i}_{0} = \frac{3}{2}\Theta_1 \sin\left(\frac{\pi}{\tau_p}x - \omega t\right)$$

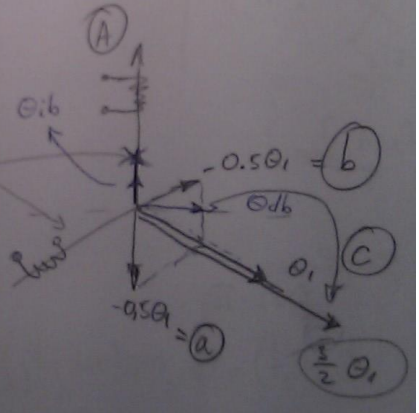


za max. struju faze C $\quad \omega t = \frac{4\pi}{3}$

$$\Theta_a\left(x = \frac{\tau_p}{2}, \omega t = \frac{4\pi}{3}\right) = -0.5\,\Theta_1$$

$$\Theta_b\left(x = \frac{7\tau_p}{6}, \omega t = \frac{4\pi}{3}\right) = -0.5\,\Theta_1$$

$$\Theta_c\left(x = \frac{11\tau_p}{6}, \omega t = \frac{4\pi}{3}\right) = \Theta_1$$



$D = 1m$

$L = 1m$

$B = 1T$

$n = 100 \frac{okr}{min} = \frac{100 \cdot 2\pi}{60} = \frac{10\pi}{3}$

$\boxed{v = \omega \cdot r = \omega \cdot \frac{D}{2}}$

$\omega = \frac{n\pi}{30} = \frac{10\pi}{3} \frac{rad}{s}$

1 okr -> 2π rad

$E = B \cdot l \cdot v$

$E = 1T \cdot 1m \cdot \frac{10\pi}{3} \cdot \frac{1}{2} = \frac{5\pi}{3} V = E_{max}$

$E_{ef} = \frac{E_{max}}{\sqrt{2}} = \frac{5.24V}{\sqrt{2}} = \boxed{3.7V}$

2. $S = 5MVA$

$U_n = 10{,}5kV$

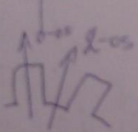
$f = 50Hz$

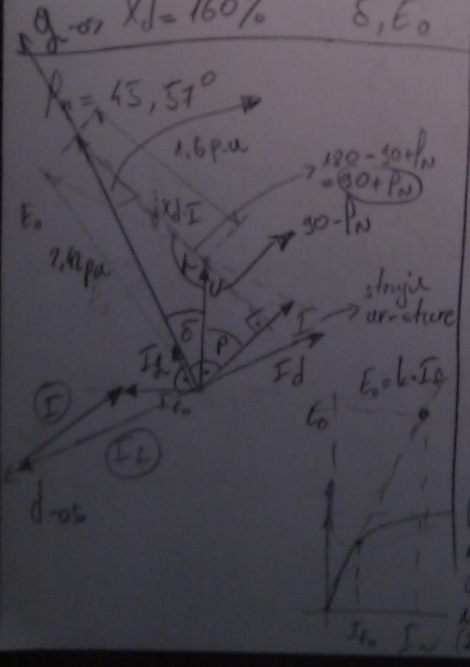
$\cos\varphi_n = 0{,}7$

$n = 1500 \frac{o}{min}$

$X_d = 160\%$

δ, E_0





U se mjenja na uštrb brzine i na uštrb (I_f)

	NA MREŽI	OTOČNO
U	ne mjenja se	(PH) $U = k \cdot N$ (mjenju se) $U = f(I_f)$
f	-"- n = konst	
n↑	P↑	P↑ n↑ (PH n↑)
I_f↑	Q↑	U↑ Q↑ (PH, U↑)

ARMATURNI NAMOT – NA STATORU

UZBUDNI NAMOT – TEČE ISTOSMJERNA STRUJA (STVARA MAG. POLJE koje rotira)

→ B_{max} i B_{min}

B_{max} ↓ veliki broj silnica

B_{min} ↓ maleni broj silnica

→ ARMATURNI NAMOT PRILIKOM ROTIRANJA MAG. polja (inducira stvarno projenjivi napon na armaturnom namotu

$$E_0^2 = U_N^2 + (X_d \cdot I)^2 - 2 U_N \cdot X_d \cdot I \cos\alpha$$

$$E_0 = \sqrt{1 + (1{,}6 \cdot 1)^2 - 2 \cdot 1 \cdot 1{,}6 \cos(90 + \varphi_N)}$$

$$E_0 = 2{,}42 \text{ p.u}$$

$$\frac{\sin\delta}{\sin(90+\varphi_N)} = \frac{I \cdot X_d}{E_0}$$

kod hidrogeneratora $L_d > L_q$

kod turbogeneratora $L_q = L_d$

3. Trofazni sinh. gen TURBOGEN

$S_n = 5\,MVA$
$U_N = 10{,}5\,kV$
$f = 50\,Hz$
$\cos\varphi_n = 0.7$
$n = 1500\ \frac{o}{min}$
$X_d = 160\%$
$I_f = I_n$
$\cos\varphi = 0.5 \sin\delta$

generator radi na krutoj mreži

$P = \sqrt{3}\, U_N \cdot I_n \cdot \cos\varphi$

$Q = \sqrt{3} \cdot U_N \cdot I_n \cdot \sin\varphi$

↳ izračunat $E_0 = 2{,}42$ p.u

$$E^2 = U_N^2 + (I \cdot X_d)^2 - 2 U_N I_n X_d \cdot \cos(90+\varphi_n)$$

$$(I \cdot X_d)^2 - 2 U_N I_n X_d \cos(90+\varphi_N) + U_N^2 - E_0^2 = 0$$

$S, P = ?$

$$I X_d = 1{,}5 \text{ p.u}$$

$$I = \frac{1{,}5 \text{ p.u}}{1{,}6 \text{ p.u}} = 0.9375 \text{ p.u}$$

$\frac{S}{S_n} = \frac{I}{I_n}$ → samo ako je napon konstantan za krutu mrežu!

$$S = S_n \cdot \frac{I}{I_n} = 4{,}69\,MVA$$

$$P = S \cdot \cos\varphi = 2{,}35\,MW$$

Auditorne Na sole 1 EDK

Sinkroni strojevi

Trobežni sinkroni gen

$S_n = 10\,MVA$

$U_n = 10\,kV$

$\cos\varphi_n = 0.8$

$n = 300\ \frac{okr}{min}$

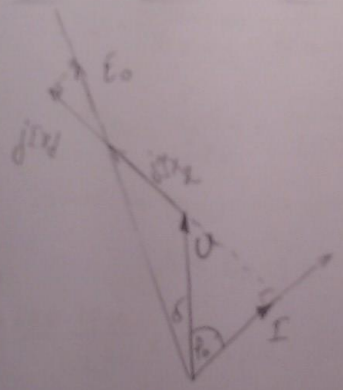
$X_d = 100\%$

$X_q = 60\%$

opterećen sa $S = 6\,MVA$

$\cos\varphi_0 = 0.6$ i $I_{fn} = 350\,A$

VFD = ? ✓ E_0, ✓ δ, I_F = ?



$\varphi_0 = 53,13°$ ako je $U = U_n$

$\underline{S} = \frac{S}{S_n} = 0.6\,p.u\ [\underline{I}_{pu}]$

$I \cdot X_q = 0.6 \cdot 0.5 = 0.3\,p.u$

$I \cdot X_d = 0.6 \cdot 1 = 0.6\,pu$

$\psi = \varphi_0 + \delta$

$tg\psi = \frac{I X_q + U_n \cdot \sin\varphi}{U_n \cdot \cos\varphi} = 1,833$

$\psi = 61,33°$ $\quad \delta = \psi - \varphi = 8,26°$

$E_0 = \sqrt{U_n^2 - (I X_q \cdot \cos\psi)^2} + I \cdot X_d \sin\psi$

$E_0 = \sqrt{1 - (0,3 \cdot \cos 61,33)^2} + 0,6 \cdot 0.878 = 1,52\,p.u$

$E_0 \sim I_f$

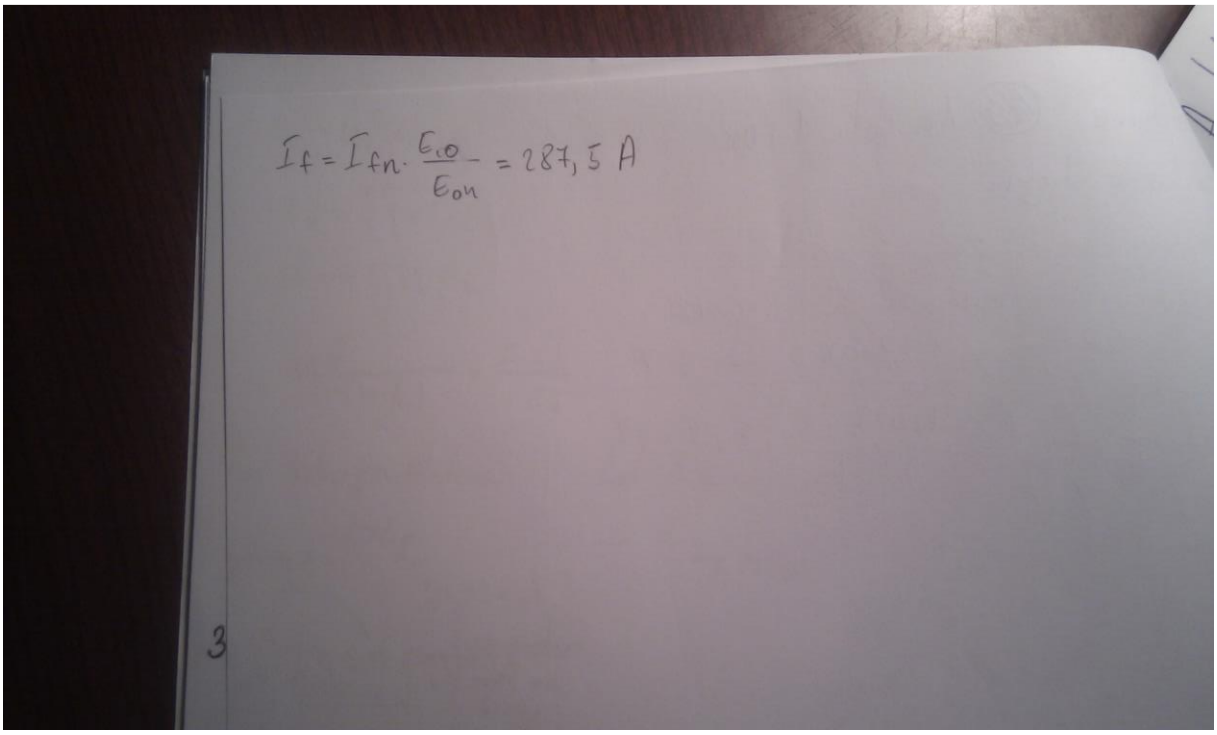
$\frac{E_{0n}}{I_{fn}} = \frac{E_0}{I_f}$ ✓

Treba nam E_{0n}

$E_{0n} = \sqrt{1 - (1,0,5 \cdot \cos\psi_n)} + 1,1 \sin\psi_n$

$E_{0n} = 1,85\,p.u$

$tg\psi_n = \frac{1,05 + 1,06}{1,0,8} = 1,375$ $\quad \psi_n = 54°$


$I_f = I_{fn} \cdot \frac{E_{10}}{E_{0n}} = 287,5\ A$
3

Auditorne 6.

1. 4 pola

$S = 50\,MVA$

$U_n = 10{,}5\,kV$

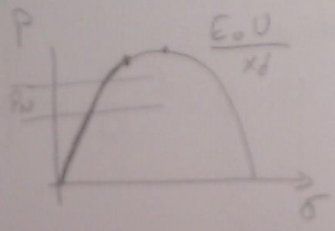
$f = 50\,Hz$

$\cos\varphi_n = 0{,}85$

$I_{f0} = 250\,A$

$I_{fk} = 550\,A$

$P = \frac{E_0 U}{X_d} \sin\delta$ → MAKSIMALNA SNAGA $\delta = 90°$



$X_d = \frac{U_{fazna}}{I_a = I_n}$ pa $\frac{I_{fk}}{I_{f0}}[p.u]$ $\quad I_{fk} = I_{f0}$

$X_{d\,p.u} = \frac{I_{fk}}{I_{f0}} = \frac{550\,A}{250\,A} = 2{,}2 = 220\%$

a) $\delta = 90°$ $\quad \sin\delta = 1$ $\quad$ ostavlja struja jednaku nazivnoj p.u

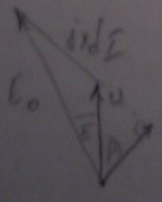
↳ $E_0 = ?$ $\quad I_{f0}[p.u] = 1{,}0\,p.u$

$E_0 \propto I_f[p.u] = 1\,p.u$

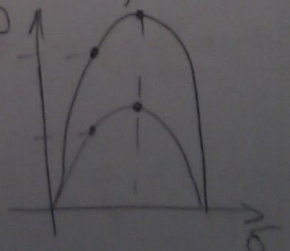
$P_{max\,p.u} = \frac{1\,p.u \cdot 1\,p.u}{2{,}2\,p.u} = 0{,}45\,p.u$

$P_{max} = P_{max\,p.u} \cdot S_B = 0{,}45 \cdot 50\,MVA = \underline{22{,}72\,MW}$

b)



$E_0 = \sqrt{(U_n \cdot \sin\varphi_n + I X_d)^2 + (U_N \cdot \cos\varphi_N)^2} = 2{,}856\,p.u$



$P_{max} = \frac{E_0 \cdot U}{X_d} = \frac{2{,}856 \cdot 1}{2{,}2} = 1{,}298\,p.u$

$P_{max} = 64{,}92\,MW$

$M = \frac{P}{\omega}$ $\quad n_s = \frac{60 \cdot f}{p}$ $\quad \omega_s = n \cdot \frac{\pi}{30} = \frac{60 \cdot f}{p} \cdot \frac{\pi}{30}$

$\omega_s = \frac{2\pi f}{p}$

2. $S_N = 10\,MVA$ HIDROGENERATOR

$U_N = 10\,kV$

$n = 375\ \frac{okr}{min}$

$f = 50\,Hz$

$\cos\varphi_N = 0{,}8$

$X_d = 100\%$

$X_q = 50\%$

→ $S = 8\,MVA$ ~~na motorni režim~~

$\cos\varphi = 0{,}6\ i\text{-}l$

$I_f = 0$

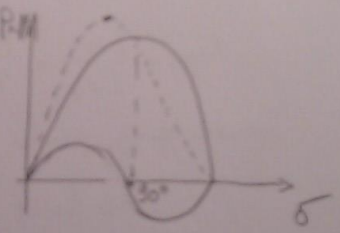
Dopušteno radi stoge kod sinkronog motora

$P = \frac{E_0 U}{X_d} \sin\delta + \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) \cdot \sin 2\delta$

1. ~~rezultirajući~~ ~~moment~~ moment

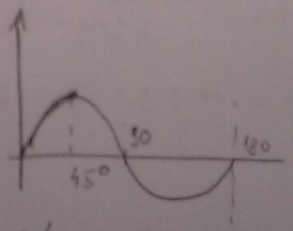
RELUKTANTNI

$E_0 \propto I_{f0}$



$P = S \cdot \cos\varphi = 4{,}8\,MW$

$P[r.j.] = \frac{4{,}8}{10} = 0{,}48\,p.u$



$P_{max} = \frac{U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) \cdot \underbrace{\sin(2 \cdot 45°)}_{1} = 0{,}5\left(\frac{1}{0{,}5} - 1\right) = 0{,}5\,p.u$

$P_{MAX} = 0{,}5\,p.u > P = 0{,}48\,p.u \Rightarrow$ Može se pretvoriti. Ostat će sinkroni generator u sinkronizmu

3. $S_N = 2\,MVA$

5. $S_N = 2MVA$

$U = 400V$

$f = 50Hz$

$X_d = 110\%$

$X_q = 75\%$

$\cos\varphi_N = 0{,}8$

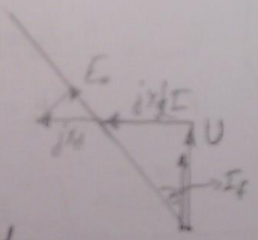
RT1 → $P = 1{,}2\,P_N$

$U = 0{,}9\,U_N$

RT2. → $P = P_N$ } I_f

$Q = 0$ } E_0

$U = U_N$ → $\cos\varphi_{RT2.} = 1$



RT1 $P = U \cdot I \cdot \cos\varphi$

$P = \sqrt{3} \cdot U \cdot I \cos\varphi$

$I_f = \frac{P}{\sqrt{3} U_N \cos\varphi}$

RT2. $I_{fuj} = \frac{S_N \cdot \cos\varphi_N}{U_N \cdot \cos\varphi_{RT2.}} = \frac{1 \cdot 0.8}{1 \cdot 1} = 0{,}8\,p.u$

$tg\delta = \frac{X_q \cdot I}{U_N} = \frac{0.8 \cdot 0{,}75}{1} \Rightarrow \delta = 30{,}96^\circ$

$E_0 = \sqrt{U^2 + (I \cdot X_q)^2} + I(X_d - X_q) \cdot \sin\delta = 1{,}6189\,p.u$

$P_{MAX} > P_{RT1}$

$P_{max} = \frac{1{,}6189 \cdot 0.8}{1{,}1} \cdot \sin\delta + \frac{0{,}8^2}{2}\left(\frac{1}{0{,}75} - \frac{1}{1{,}1}\right)\sin 2\delta = 1{,}3656\,p.u$

$\frac{\partial P_{max}}{\partial \delta} = 0 = 0{,}7636\cos^2\delta + 1{,}3245\cos\delta - 0{,}381818 = 0$

$\cos\delta_1 = -1{,}986$

$\cos\delta_2 = 0{,}25172 \quad \delta_2 = 75{,}42^\circ$

4. Pogonski dijagram (uvijek na ispitu)

$S_N = 247\,MVA$
$U_N = 13800\,V$
$\cos\varphi_N = 0{,}85$
$f = 50\,Hz$
$\eta = 98{,}6\%$
$I_{f0} = 822\,A$
$I_{fL} = 1750\,A$
$P_{MAX} = 80\,MW$
$P_{MIN} = 30\,MW$

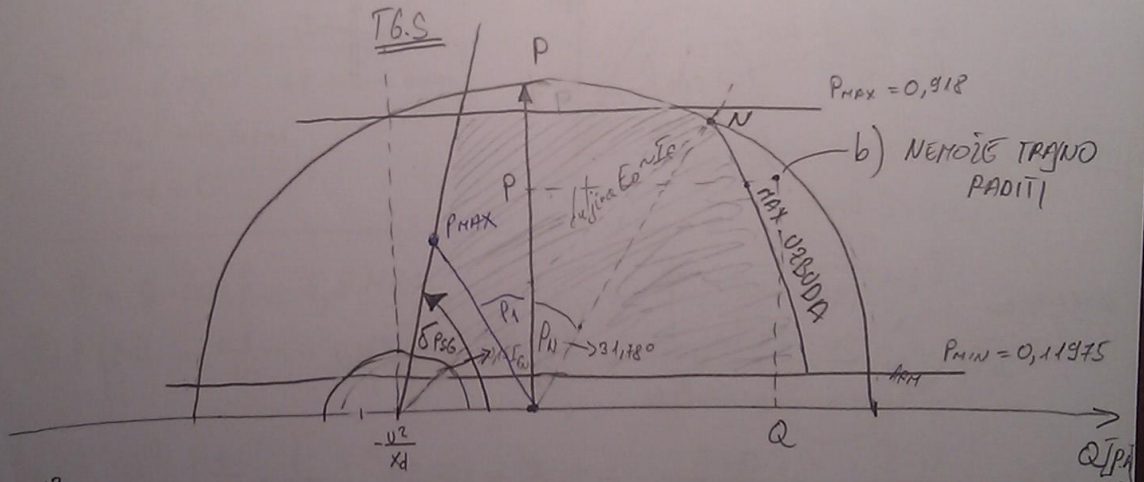
$\delta_{PGS} = 75°$
$I_{fMIN} = 0{,}15\,I_{fN}$

$$X_d = \frac{I_{fL}}{I_{f0}} = \frac{1750\,A}{822\,A} = 2{,}129$$

$$P_{MAX} = \frac{\eta \cdot P_{MAXPS}}{S_n} = 0{,}918\ p.u$$

$$P_{MIN} = \frac{\eta \cdot P_{MINPS}}{S_n} = 0{,}11975\ p.u$$

$\varphi_N = 31{,}78°$



$-\frac{U^2}{X_d} = 0{,}4697$

a) S kojom max P može raditi u kap. režimu za $\cos\varphi = 0{,}8$

$\varphi = 36{,}87° \Rightarrow$ UZMEMO kutomjer $\checkmark$ kap / ind

Ako ispadaju iz sinkronizma da oslobodimo povećajemo
↳ Moment ↗ I_f ↗

b) $P = 150\,MW \Rightarrow 0{,}607\ p.u$
$Q = 180\,MVAr \Rightarrow 0{,}7287\ p.u$

5. $S_N = 55\,MVA$

$U_N = 10{,}5\,kV$

$\cos\varphi_N = 0{,}9 \Rightarrow \varphi_N = 25{,}84°$

$f = 50\,Hz$

$n = 600\ \frac{obr}{min}$

$X_d = 126\%$

$X_q = 72\%$

$I_{fN} = 630 \qquad I_{f\,min} = 0{,}1\,I_0$

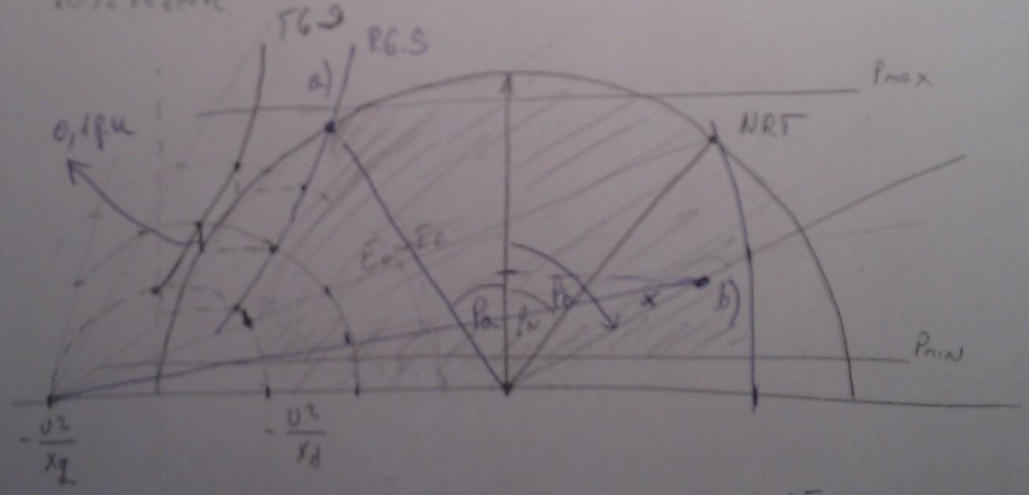
$P_{max\,PS} = 1{,}05\,P_{max} = 1{,}05 \cdot 1 \cdot 0{,}9 = 0{,}945\,pu$

$P_{min} = 0{,}1\,P_{max} = 0{,}09\,pu$

10% rezerve

$-\frac{U^2}{X_d} = -\frac{1}{1{,}26} =$

$-\frac{U^2}{X_q} = -\frac{1}{0{,}72} =$



a) KAR. I_{norm} na P.G.S.

b) $I_{nzb} = I_{fn}$

$\cos\varphi = 0{,}6$ ind $\Rightarrow P_b = 53{,}1°$

$P = 15\,MW = \frac{15}{35} = 0{,}4285\,pu$

$\frac{X[\Omega]}{E_0[\Omega]} = 0{,}94$

$I_{fb} = 0{,}94 \cdot I_{fN} = 592{,}2\,A$

Asinkroni strojevi — Auditorne vježbe 7 (poslje MI)

1. Trofazni AS. 2 pola

$f = 50\,Hz$

$n = 2900\ min^{-1}$

) Kolika je frekv. rot. struja

Koliko iznose:

a) Brzina vrtnje obr. protj. rotora u odnosu na rotor

b) - II - u odnosu na stator

c) Brzina vrtnje rotorskog protjecanja u odnosu na statorsko

$$s = \frac{n_s - n}{n_s} = \frac{100}{3000} = \frac{1}{30} = 3{,}333\,\%$$

$$n_s = \frac{60 \cdot f}{p} = 3000$$

$$\underline{fr} = f \cdot s = 0{,}0333 \cdot 50 = 1{,}67\,Hz$$

a) 

$$n_r = \frac{60 \cdot fr}{p} = 100\ min^{-1}$$

$$n_{rotor} = n + n_r = 2900 + 100 = 3000$$

$$n_{rotor} = n_{statora}$$

a) $100\ min^{-1}$

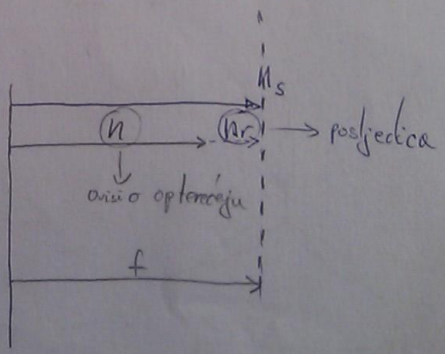
b) $3000\ min^{-1}$

c) $0\ min^{-1}$

$$n_s = n + n_r$$

$$n_s \cdot s = n_r$$

$$f_s \cdot s = fr$$



4. Na trobrojnom AM

Y D namoti se mogu spojiti

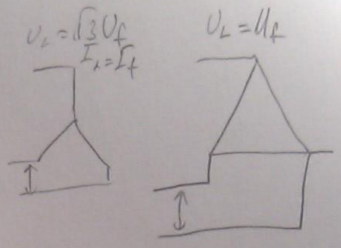
Na natpisnoj pločici motora stoji podatak

400/690V – linijski napon

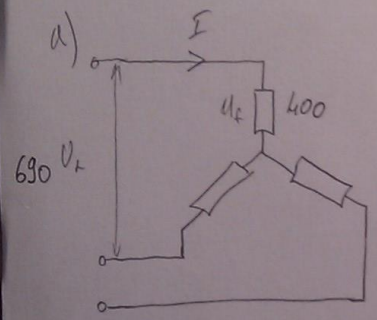
a) Kako treba spojiti namot za 690 V

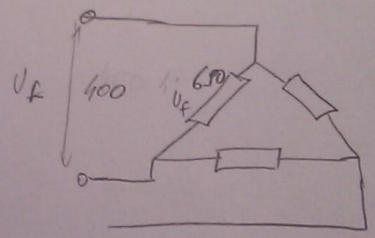
b) Ovisi li snaga o spoju

c) Skicirati spoj po IEC normi



a)

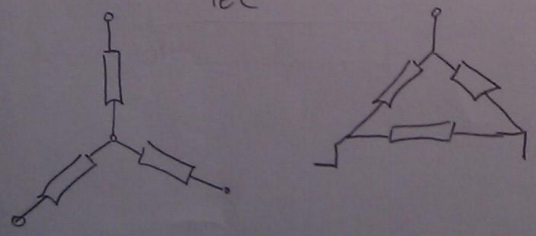


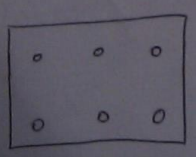


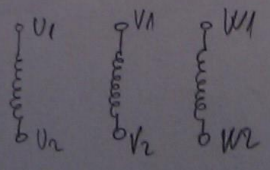
b) $P_Y = \sqrt{3} \cdot U_{LY} \cdot I_{LY} \cdot \cos\varphi = \sqrt{3} \cdot \sqrt{3} U_{fY} \cdot I_{fY} \cos\varphi = 3 U_{fY} \cdot I_{fY} \cdot \cos\varphi$

$P_\Delta = \sqrt{3} \cdot U_{L\Delta} \cdot I_{L\Delta} \cdot \cos\varphi = \sqrt{3} \cdot U_{f\Delta} \cdot \sqrt{3} I_{f\Delta} \cdot \cos\varphi = 3 U_{f\Delta} I_{f\Delta} \cdot \cos\varphi$

c) IEC







(b.) Pokusi PH i K.S.

Trofaznog asinh. kaveznog motora

400V, 50Hz, 30kW, Δ

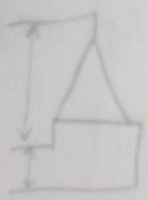
$R_S = 0,47\,\Omega$

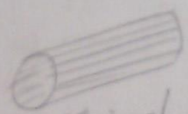
a) KS. → 100V (U_k), 70A (I_k), 6kW — ZAKOČEN ROTOR

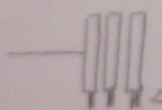
b) PH → 400V, 20,8A, 1,2kW — RASTEREĆEN ROTOR → Gubitci bez mehaničkih

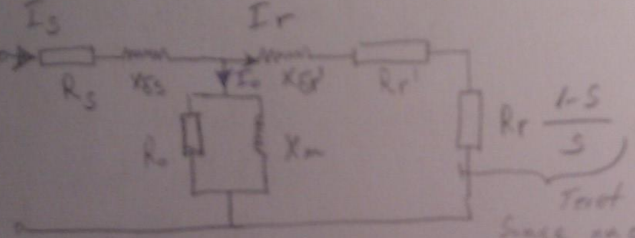
Odredite parametre nadomjesne sheme

$I_f = \frac{I_k}{\sqrt{3}} = \frac{70}{\sqrt{3}}$



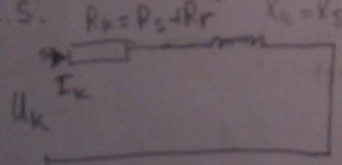






a) KS → $s = \frac{n_s - 0}{n_s} = 1$

K.S. $R_k = R_s + R_r'$ $X_k = X_{\sigma s} + X_{\sigma r}'$



$I_N = \frac{P_{el}}{\sqrt{3}\,U_N \cdot \cos\varphi}$

$P_{el} = \frac{P_{meh}}{\eta}$ **inf.**

$I_N \approx \frac{2 \cdot P_{meh}}{1000} = 60A$

a) $P_k = 6kW$

$P_k = 3 \cdot I_{fk}^2 \cdot R_k = 3\,I_{fk}^2 (R_s + R_r')$

$R_r' = \frac{P_k}{3 \cdot I_{fk}^2} - R_s = 0,753\,\Omega$

$X_k = \sqrt{Z_k^2 - R_k^2}$

$Z_k = \frac{U_k}{I_{kf}} = 2,474\,\Omega$

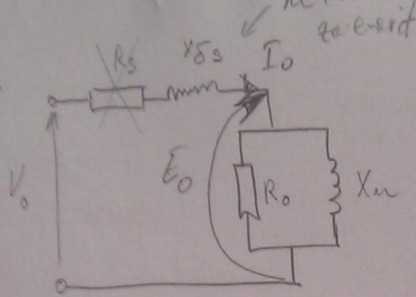
$R_k = 1,225\,\Omega$

$X_k = 2,15\,\Omega$

$X_{\sigma s} = X_{\sigma r}' = \frac{X_k}{2} = 1{,}08\,\Omega$

ne može se zanemarit ↙ Kod AS struja p.h. nije sasvim ...

PH



$I_0 = \frac{20{,}8}{\sqrt{3}}$

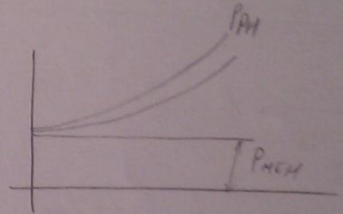
$Z_0 = R_0 \| jX_m$

$Z_0 = |X_{\sigma s} + R_0 \| jX_m|$

R_s: $P_0' = P_0 - 3 I_0^2 \cdot R_s = 1{,}2kW - 3 \cdot \left(\frac{20{,}8}{\sqrt{3}}\right)^2 \cdot 0{,}48\Omega = 996{,}7W = P_{Fe} \Rightarrow R_0$

$\dot{E}_0 = \dot{U}_0 - I_0 (R_s + jX_{\sigma s})$ (ispod: $\dot{U}_0$ = 400, $I_0 = \frac{20{,}8}{\sqrt{3}}$)   potrebno poznavati $\dot{U}_0, \dot{I}_0$ fazni pomak

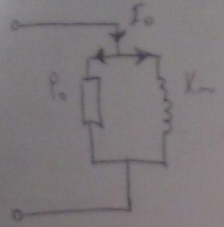
$P_{PH} = P_{Cu\,Rs} + \underbrace{P_{Fe} + P_{MEH}}_{\text{uži gubitci p.h.}}$



b) $S_0 = \sqrt{3} \cdot I_0 \cdot V_0 = 14411\,VA$
$P_0 = 1{,}2kW = 1200W$ $\Big\}$ $\cos\varphi_0 = \frac{P_0}{S_0} = 0{,}083$ $\varphi_0 = 85{,}22°$

$\dot{E}_0 = 400\angle 0° - \frac{20{,}8}{\sqrt{3}} \angle -85{,}22 \, (R_s + jX_{\sigma s})$

$E_0 = |E_0|$ uz zanemarenje R_s i $X_{\sigma s}$ $E_0 = U_0$



$$\frac{P_{Fe}}{3} = \frac{U_0^2}{R_0}$$

$$R_0 = \frac{3 \cdot U_0^2}{P_{Fe}} = 421{,}6$$

$$I_{0R} = \frac{U_0}{R_0} = 0{,}83\,A$$

$$I_\mu = \sqrt{I_0^2 - I_{0R}^2} = 11{,}9\,A$$

$$X_m = \frac{U_0}{I_\mu} = 33{,}3\,\Omega$$

14. 6 polni AM. (kolutni)

Y | Y

$R_{str} = 0{,}032\,\Omega$

$X_{\sigma r} = 0{,}265\,\Omega$

$$R_r = \frac{R_{str}}{2}$$

KS 400V 50Hz $E_{r0} = 217\,V$

$n = 950$ obr

$P_2 = 2{,}2\,kW$

$P_{tr,r} = 1{,}2\,kW$

a) $s = ?$ $\quad s = \frac{n_s - n}{n_s} = \frac{1000 - 950}{1000} = 5\,\%$

b) $f_r = ?$

$f_r = f \cdot s = 2{,}5\,Hz$

c) Lastna stevilo rotorja

$$I_r = \frac{E_{r0}}{\sqrt{3} \cdot \sqrt{\left(\frac{R_r}{s}\right)^2 + X_{\sigma r}^2}} = 301{,}5\,A$$

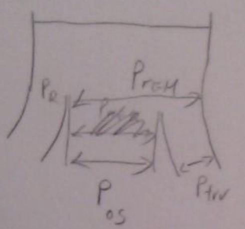
d) gubitci u vrotu rotora

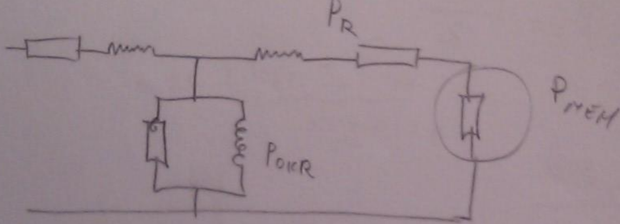
$P_R = 3 \cdot I_r^2 \cdot R_r = 3 \cdot 301,5^2 \cdot 0,016\Omega = 4363,3\ W$

e) kolika je snaga okr. mag. polja

$P_{okR} = \frac{P_R}{s} =$

$P_R = s \cdot P_{okR}$ $\qquad P_{meh} = (1-s)\, P_{okR}$





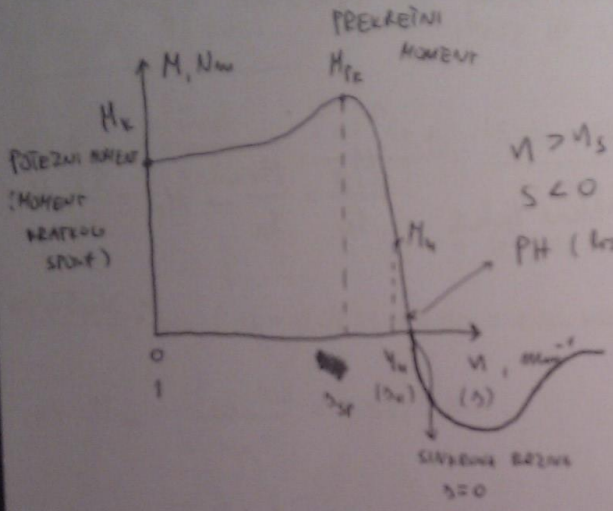
$\eta = 91,32\%$

$P_{al} = P_{ok} + P_s$

$2p = 8$

50 Hz

825 min^{-1}



$n > n_s$ (GENERATORSKI REŽIM)

$s < 0$

PH (brzina klizka rastuća)

AM ako se rotor rotira brzinom veće od sinkrone postaje generator.

a) $n_s = \frac{60f}{p} = \frac{60 \cdot 50}{4} = 750\ min^{-1}$

b) $s = \frac{n_s - n}{n_s} = \frac{750 - 825}{750}$

c) frekvencija rotorskih struja

$f_r = s f_s = -0{,}1 \cdot 50 = -5$ Hz

(2) 3f AM — kavezni

nmo: $P_{2n} = 22\ kW$ (na osovini)

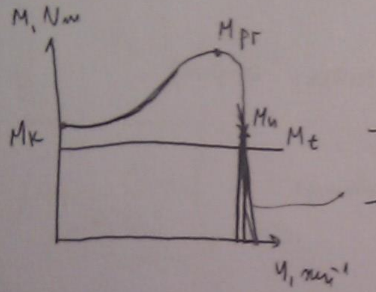
$U_n = 400\ V$ (sdružení)

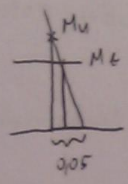
$f_n = 50\ Hz$

$n_n = 2970\ min^{-1}$

$n_1 = 2985\ min^{-1}$

optverčen momentu nezávislým v brzdné otáčky, při zvýšeném napětí.





podobnost trojuhelníků $\frac{M_n}{s_n} = \frac{M_1}{s_1} \rightarrow M_1 = \frac{s_1}{s_n} \cdot M$

$= 36,37\ N$

$M = \frac{P}{\omega}$

$M_{2n} = \frac{P_{2n} \cdot 30}{n_n \pi} = \frac{22000 \cdot 30}{2970 \pi} = 70,74\ Nm$

$s_1 = \frac{n_s - n_1}{n_s} = \frac{3000 - 2985}{3000} = 0,005$

$P_{2n} = 45\,kW,\ 400V,\ 50Hz$

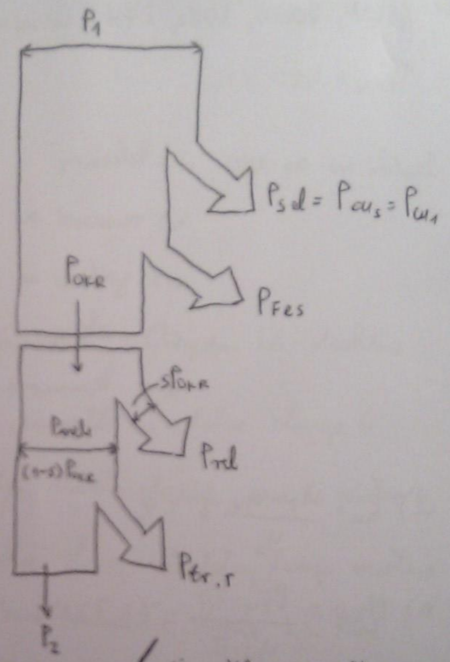
$I_n = 87A$

$n_n = 1465\ min^{-1}$

$\cos\varphi_n = 0{,}87$

$P_{tr,r} = 1{,}3\ kW$

$s_n = \frac{n_s - n_n}{n_s} = \frac{1500 - 1465}{1500} = 0{,}0233$ ili $2{,}33\%$



gubici željeza u rotoru se zanemaruju zbog male frekvencije

a) $P_{okr} = \frac{P_{meh}}{1 - s_n} = \frac{P_2 + P_{tr,r}}{1 - s_n} = \frac{45000 + 1300}{1 - 0{,}0233} = 47{,}406\ kW$

b) $P_{cu2} = s_n \cdot P_{okr} = 0{,}0233 \cdot 47{,}406 = 1{,}106\ kW$

c) $M_{2n} = \frac{P_{2n} \cdot 30}{n_n \pi} = 293{,}3\ Nm$

d) $P_{1n} = \sqrt{3}\, U_{1n} \cdot I_{1n} \cdot \cos\varphi_n = 52{,}44\ kW$

e) $\eta = \frac{P_{2n}}{P_{1n}} = \frac{45}{52{,}44} = 85{,}81\ \%$

5) 11kW, 400V, 50Hz, 27A, $\cos\varphi = 0{,}72$, 1425 min^{-1} → nazivni pogon AM

$P_{tr,v} = 480$

Izračunati za NRT: a) klizanje

b) moment na osovini

c) gubitke u rotorskom krugu

d) ukupne statorske gubitke

e) korisnost

a) $s_u = \frac{n_s - n_u}{n_s} = 5\%$

b) $M_{2u} = \frac{P_{2u} \cdot 30}{n_u \pi} = 73{,}72\,Nm$

c) $P_{rel} = s_u \cdot P_{okr} = s_u \cdot \frac{P_{meh}}{1-s_u} = \frac{s_u}{1-s_u}(P_{2u} + P_{tr,v}) = 604{,}21\,W$

d) $P_{gs} = P_{sel} + P_{Fes} = P_{1u} - P_{okr} = \sqrt{3} \cdot U_{1u} \cdot I_{1u} \cdot \cos\varphi_u - \frac{P_{rel}}{s_u} = 1384{,}2\,W$

e) $P_{1u} = \sqrt{3}\, U_{1u} \cdot I_{1u} \cdot \cos\varphi_u = 13468\,W$

$\eta = \frac{P_{2u}}{P_{1u}} = 81{,}66\%$

gubl... AM

$P_n = 200kW$

$U_n = 600kV$

$f = 50Hz$

Y

$n_n = 1480 \; min^{-1}$

PKS: $U_k = 1500V$

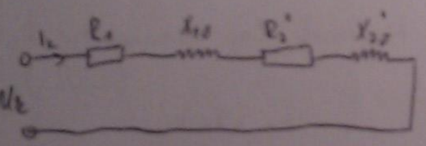
$I_k = 30A$

$P_k = 22kW$

$R_{st} = 3,225 \Omega$

$M_{tr} = 27,5 \; Nm$

Izvršen je PKS s smanjenim naponom jer nije bilo mogućnosti u vrijeme lab. dobiti impedanciju momenta i struje KS. Kod 1500V, 50Hz nametnuto na stator struja je iznosila 30A, a snaga uzeta iz mreže 22 kW, otpor namota statorske faze namota statora u toplom stanju iznosi je 3,225 Ω. Moment gubitaka zbog vlastitog trenja motora iznosi 27,5 Nm. Koliko bi iznosio početni potezni moment i struja KS kod nazivnog napona. Te koliki je odnos poteznog prema nazivnom momentu.



$P_k = P_{Cu1} + P_{el}$

$P_{Cu1} = 1,5 \, I_1^2 \cdot R_{st}$

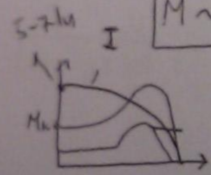
$P_{el} = P_k - P_{Cu1} = 22000 - 1,5 \cdot 30^2 \cdot 3,225 = 17646,3 W$

$M_k + M_{tr} = \frac{P_{el}}{\omega_s} = \frac{17646,3}{\frac{1500\pi}{30}} = 112,34 \; Nm \quad (U_k = 1500V)$

$M_k = 112,34 - 27,5 = 84,84 Nm$

$I_{kn} = I_k \cdot \frac{U_n}{U_k} = 30 \cdot \frac{6000}{1500} = 120 A$

$P_{kn} = P_k \left(\frac{U_n}{U_k} \right)^2 = 22000 \left(\frac{6000}{1500} \right)^2 = 352 kW$



$M \sim U^2$

$M_{2n} = \frac{P_{2n} \cdot 30}{n_n \pi} = \frac{200000 \cdot 30}{1480 \cdot \pi} = 1290,45 \; Nm$

$\frac{M_{kn}}{M_n} = \frac{1764,93}{1290,45} = 1,372$

$P_{el} = P_{kn} - 1,5 \, I_{kn}^2 \, R_{st} = 352000 - 1,5 \cdot 120^2 \cdot 3,225 = 282,34 W$

$M_{kn} + M_{tr} = \frac{P_{el\,n}}{\omega_s} = \frac{282340}{1500 \cdot \pi} \cdot 30 = \_\_\_\_ \quad , \quad M_{kn} = \_\_\_\_ - 27,5 = 1764,93 Nm$

⑥ 3X 4 polni AM, kratni, ima: 400V, 3,15 kW, 6,7A, 50Hz, ~~1384 min~~

Y

Parametri nadomestne sheme: $R_s = 1,7\,\Omega$, $R_r' = 2,6\,\Omega$, $X_{\delta s} = 2,8\,\Omega$, $X_{\delta s}' = 3,3\,\Omega$, $X_u = 96$...

a) $\cos\varphi = ?$

b) približni izmer I_{ks}

c) izgubi v rotoru

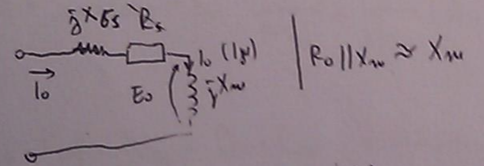
d) kvrino vrtni moment pri nazivni obremenitvi uz pretpostavku da su gubitci trenja ventilacije 1% nazivne snage.

e) I_{ku} pri nazivnom naponu

f) poterni moment pri nazivnom naponu.

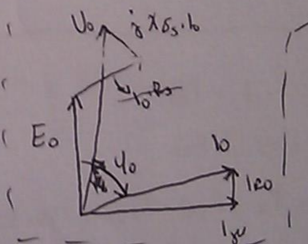
a) $\cos\varphi_u = \dfrac{P_{2u}}{\sqrt{3}\cdot U_{1u}\cdot I_{1u}\cdot \eta} = \dfrac{3150}{\sqrt{3}\cdot 400\cdot 6{,}7\cdot 0{,}84} = 0{,}808$

b)

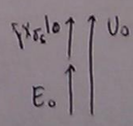


$R_0 \| X_m \approx X_m$

U_Z, izračunati bez zanemarenja R_0 i R_s (LOL)



$\overline{I_0} = -j\dfrac{U_0}{\sqrt{3}(X_{\delta s} + X_u)} = -j\dfrac{400}{\sqrt{3}(2{,}8+96)} = -j\,2{,}337\ A$



c) $\overline{I_s} = I_s\cos\varphi - jI_s\sin\varphi = 6{,}7\cdot 0{,}808 - j\,6{,}7\cdot 0{,}589 = 5{,}414 - j\,3{,}944 = 6{,}7\,\angle{-36{,}1^\circ}\ A$

$I_r = \overline{I_s} - \overline{I_0} = 5{,}414 - j\,3{,}949 - (-j\,2{,}337) = 5{,}414 - j\,1{,}612 = 5{,}648\,\angle{-16{,}6^\circ}\ A$

$P_{el} = 3\cdot I_r'^2\cdot R_r' = 3\cdot 5{,}648^2\cdot 2{,}6 = 248{,}8\ W$

$n_s = n_s(1-s_u) = 1391{,}2\ min^{-1}$

d) $P_{meh} = P_{2u} + P_{tr,v} = 1{,}01\,P_{2u} = 1{,}01\cdot 3{,}14 = 3{,}182\ kW$

⑫ $s_u = \dfrac{P_{el}}{P_{okr}} = \dfrac{P_{el}}{P_{meh} + P_{el}} = \dfrac{248}{3481 + 248{,}8} = 0{,}0729$

e) $Z_k = \sqrt{(R_s + R_r')^2 + (X_{\sigma s} + X_{\sigma r}')^2} = \sqrt{(1{,}7 + 2{,}16)^2 + (2{,}8 + 3{,}3)^2} = 7{,}46\ \Omega$

$$I_{sk} = I_{rk}' = \frac{U_s}{\sqrt{3} \cdot Z_k} = \frac{400}{\sqrt{3} \cdot 7{,}46} = 30{,}96\ A$$

f) $$M_k = \frac{P_{zel}}{\omega_s} = \frac{3 \cdot I_{rk}'^2 \cdot R_r'}{n_s \pi} \cdot 30 = \frac{330{,}96^2 \cdot 2{,}16}{1500\,\pi} \cdot 30 = 47{,}6\ Nm$$

Auditorne 9.

1. Trofazni kolutni AM poznati podaci

$P_{2n} = 1250\ kW$

$U_N = 6\ kV$

$f = 50\ Hz$

$n_n = 1480\ min^{-1}$

$\cos\varphi = 0.91$

$\eta = 0.96$

Napon među kolutima rotora otvorenog u zvijezdu iznosi

$E_{r0} = 865\ V$

Max. moment $= 2.7\ M_n$

Izračunaj:

a) P_{gub} rotora kod nazivnog opt?

b) Klizanje kod kojeg rotor razvija max moment

c) Struju rotora kod nazivnog opt.

d) Struju statora kod nazivnog opt.

e) Zanemari meh gubitke i pad napona na impedanciji statora $P_{trr} = 0$

$$S_n = \frac{n_s - n_n}{n_s} = \frac{1500-1480}{1500} = 0,01333$$

$$P_{rotel} = S_n \cdot P_{okr} =$$

$$P_{okr} = \frac{P_{meh}}{1-S_n} \approx \frac{P_{2n}}{1-S_n} = \frac{1250 \cdot 10^3}{1-0,0133} \quad (\to P_{trr} = 0)$$

$$P_{rotel} = 16,849\ kW$$

b) Klossova jedn.

$$\frac{M_n}{M_{max}} = \frac{2}{\frac{S_n}{S_{max}} + \frac{S_{max}}{S_n}} \Rightarrow \frac{S_n}{S_{max}} + \frac{S_{max}}{S_n} = \frac{2M_{max}}{M_n}$$

$$S_{max}^2 - 2\frac{M_{max}}{M_n} S_n S_{max} + S_n^2 = 0$$

$$S_{max1,2} \Rightarrow \boxed{S_{max1} = 0,06914} \quad S_{max2} = 0,00256$$

S_{max} mora biti veće od S_n

← za fazne vrijednosti

c) $I_{rn} = \frac{E_{ro}}{\sqrt{3}\sqrt{\left(\frac{R_r}{s_n}\right)^2 + X_{ro}^2}}$

$M_n = \frac{P_{2n}}{\omega_n} = \frac{P_{avr} - P_{el}}{\omega_n} = \frac{\left(\frac{1-s_n}{s_n}\right) P_{rel}}{\omega_n} = \frac{\left(\frac{1-s_n}{s_n}\right) \cdot 3 \cdot I_{rn}^2 \cdot R_r}{n_n \pi}$

$M_n = \frac{\left(\frac{1-s_n}{s_n}\right) \cdot E_{ro}^2}{3\left(\left(\frac{R_r}{s_n}\right)^2 + X_{ro}^2\right)} \cdot \frac{R_r}{n_n \cdot \pi} \cdot 30$

$M_n = \frac{(1-s_n) E_{ro}^2 \cdot s_n \cdot 30}{R_r \cdot n_n \cdot \pi} = \frac{E_{ro}^2 \cdot s_n \cdot 30}{R_r \cdot n_s \cdot \pi} \Rightarrow$

$R_r = \frac{E_{or}^2 \cdot s_n \cdot 30}{n_n \cdot \pi \cdot M_n} = \frac{E_{or}^2 \cdot s_n \cdot 30}{n_s \cdot \pi \cdot \frac{P_{2n}}{n_n \cdot \pi} \cdot 30} = \frac{n_n \cdot E_{or}^2 \cdot s_n}{n_s \cdot P_{2n}} = 7{,}855\,m\Omega$

$I_{rn} = \frac{E_{ro}}{\sqrt{3}\left(\sqrt{\left(\frac{R_r}{s_n}\right)^2 + X_{ro}^2}\right)} = \frac{E_{ro} \cdot s_n}{\sqrt{3} \cdot R_r} = 845{,}6\,A$

>>

d) $P_{1n} = \sqrt{3} \cdot U_n \cdot I_n \cdot \cos\varphi = \frac{P_{2n}}{\eta}$

$I_n = \frac{P_{2n}}{\sqrt{3} \cdot U_n \cdot \cos\varphi \cdot \eta} = 137{,}7\,A$

Trifazni AM.

$P_n = 55\,kW$

$n_n = 980\ \frac{okr}{min}$

$U = 400V$

$I\ 102\,A$

$f = 50$

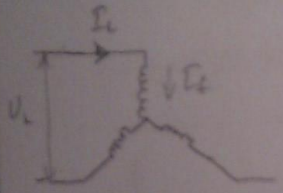
$\Delta \rightarrow Y$

Ukoliko kod pokretanja struju iz mreže $I_p = 6 I_n$ i razvija $M_p = 1{,}8 M_n$

Ako ga onda prespojimo u Y

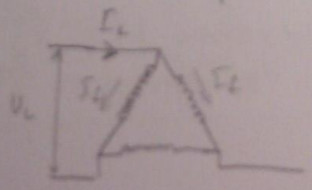
a) koliku struju će povući iz mreže

b) koliki potezni moment će razviti



$U_L = \sqrt{3}\, U_f$

$I_{LY} = I_f$



$U_L = U_f$

$I_L = \sqrt{3}\, I_f$

$U = I_{L\Delta} \left(R_f \parallel 2R_f \right)$

$U = I_{L\Delta} \cdot \frac{2}{3} R_f$

$U = I_{LY} \cdot 2R_f$

$I_{LY} \cdot 2R_f = I_{L\Delta} \cdot \frac{2}{3} R_f$

$$\boxed{I_{LY} = \frac{1}{3} I_{L\Delta}}$$

$$\boxed{I_{fY} = \frac{1}{3} \cdot \sqrt{3}\, I_{f\Delta} = \frac{1}{\sqrt{3}} I_{f\Delta}}$$

$$\frac{M_Y}{M_\Delta} = \left(\frac{U_{fY}}{U_{f\Delta}} \right)^2 = \frac{1}{3}$$

a) $I_{LY} = \frac{1}{3} \cdot 6 \cdot 102 = 204A$

b) $M_{nY} = \frac{M_{n\Delta}}{3} = \frac{1}{3} \cdot 1{,}8 \cdot \frac{55000}{980\pi} = 321{,}56\ Nm$

Trofazni klizno kolutni AM

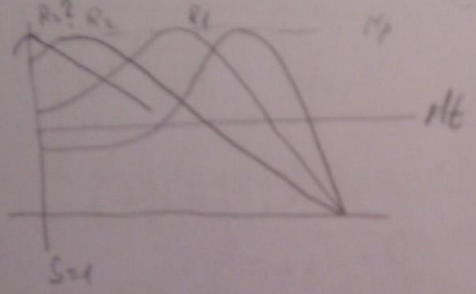
$M_p = 300 Nm$

$S = 15\%$

$R_{po\ fazi\ rotora} = 0{,}2\Omega$

a) Kolika otpor u fazi rotora treba dodati u otpornik kako se postige M_p pri pokretanju

b) Kolika je M_{max} motor postigao uz smanjeni napon od 5% uz nepromjenjenu frekvenciju



$\frac{R_r}{S_1} = \frac{R_r + R_{dod}}{S_2}$ $\quad S_2 = 1 \rightarrow$ miruje zaletna

$\boxed{R_{dod} = \frac{R_r \cdot S_2}{S_1} - R_r = 1{,}1332}$

b) $U_2 = 0.95\, U_1$

$M_{MAX2} = M_{MAX1}\left(\frac{U_2}{U_1}\right)^2 = 300\left(\frac{0.95\, U_1}{U_1}\right)^2 = 270{,}75 Nm$

(4)

$f = 50\,Hz$ spoj Δ

$U = 400\,V$

$P = 8\,kW$

$I = 18\,A$

$n = 1435\,min^{-1}$

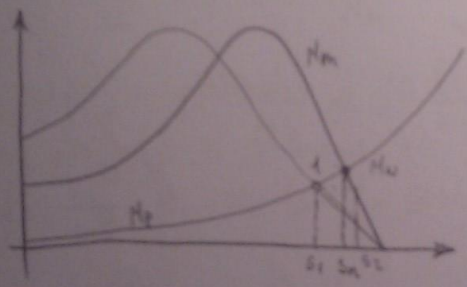
$R_r = 0{,}65\,\Omega$ u toplo stanju

$n_1 = 1200\,min^{-1}$

$M_p = 0{,}95\,M_n \cdot \left(\frac{n_1}{n_n}\right)^2 + 0{,}05\,M_n$

M_n i n_n jednaki su odgovarajućim veličinama motora

Radni otpor $= ?$ da bi se dobila brzina vrtnje n_1



$M_{p1} = 0{,}95\,M_n \cdot \left(\frac{n_1}{n_n}\right)^2 + 0{,}05\,M_n = 0{,}95\,M_n \cdot \left(\frac{1100}{1435}\right)^2 + 0{,}05\,M_n = 0{,}714\,M_n$

$S_1 = \frac{1500 - 1100}{1500} = 0{,}2$

$S_2 = \frac{1500 - 1435}{1500} = 0{,}0433$

$\frac{M_{n1}}{S_2} = \frac{M_n}{S_n} \Rightarrow S_2 = S_n \cdot \frac{M_{n1}}{M_n} = 0{,}0433 \cdot 0{,}714 = 0{,}0309$

$\frac{R_r + R_{dod}}{S_1} = \frac{R_r}{S_2} \rightarrow R_{dod} = \left(\frac{S_1}{S_2} - 1\right) R_r = \left(\frac{0{,}2}{0{,}0309} - 1\right) \cdot 0{,}65 = 3{,}56\,\Omega$

5. Trofazni kavezni

P = 1000 kW U = 6300 V

f = 50 Hz

$n_n = 2970\ min^{-1}$

Brzina vrtnje se regulira pretvaračem napona

Koristi se skalarna regulacija $\frac{U}{f} = konst$

Motor je opterećen momentom konst. iznosa

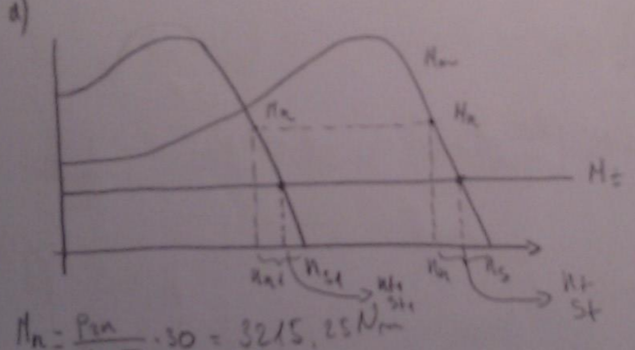
a) M_n i S_n

b) n_s okr. polja rotora 1920 okr min^{-1} koliki je U i f

c) n u f napon i frekv. prema b dijelu iznosi 1900 min^{-1} izračunati koliki je momentom opt. motor

d) P_g u mreži rotora pri M_t iz c) i $f_n = 50\ Hz$ a koliko pri istom momentu n = 1900 i f izračunate u b) dijelu zadatka

a)



$$M_n = \frac{P_{sn}}{n_n \cdot \pi} \cdot 30 = 3215,25\ Nm$$

$$S_n = \frac{n_s - n_n}{n_s} = \frac{3000 - 2970}{3000} = 0,01$$

b) $n_s = \frac{60 \cdot f}{p}$

$$f_1 = \frac{p \cdot n_{s1}}{60} = \frac{1 \cdot 1920}{60} = 32\ Hz$$

$$\frac{U_N}{f_N} = \frac{U_1}{f_1}$$

$$U_1 = \frac{f_1}{f_N} \cdot U_N$$

$$U_1 = \frac{32}{50} \cdot 6300 = 4032\ V$$

c) $S_{n1} = \frac{n_{s1} - n'_{n1}}{n_{s1}} = \frac{1920 - 1890}{1920} = 0{,}015625$ (1890)

$S_{t1} = \frac{n_{s1} - s_{t1}}{n_{s1}} = \frac{1920 - 1900}{1920} = 0{,}010416$

$\frac{M_n}{S_{n1}} = \frac{M_t}{S_{t1}} \Rightarrow M_t = \frac{S_{t1}}{S_{n1}} \cdot M_n = 2143{,}5\,N\,m$

d) $\frac{M_n}{S_n} = \frac{M_t}{S_t} \Rightarrow S_t = \frac{M_t}{M_n} \cdot S_n = 6{,}667 \cdot 10^{-3}$

$P_{rot} = S \cdot P_{ROTOR} = S \cdot \frac{P_{mech}}{1-S} \approx S \cdot \frac{P_2}{1-S} = M_2 \cdot \omega_2 \cdot \frac{S}{1-S}$

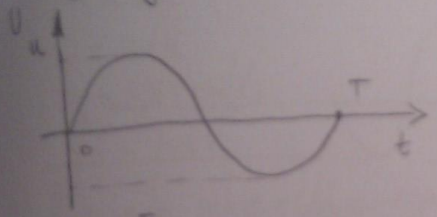
$P_{rotd} = \frac{S}{1-S} \cdot M_2 \cdot \omega_s \cdot (1-S) = S_t M_t \cdot \frac{n_s \pi}{30}$

$P_{rotel} = 4489\,W \longrightarrow 50\,Hz$

$P_{rotel_{32Hz}} = S_{t1} \cdot M_t \cdot \frac{n_{s1} \cdot \pi}{30} = 4489\,W$

Auditorne vježbe 10.

srednja vrijednost



$$U = \frac{1}{T}\int_0^T u(t)\,dt$$

induktivitet

$$u_L(t) = L\,\frac{di_L(t)}{dt} \;/\!/ \int$$

$$i_L(t) = \frac{1}{L}\int_0^T u(t)\,dt + i_L(0) \;/\cdot \frac{L}{T}$$

$$i_L(T) - i_L(0) = 0$$

$$u_L = \frac{1}{T}\int_0^T u(t)\,dt = 0$$

KAPACITET

$$i(t) = C\cdot\frac{du(t)}{dt}$$

$$I_C = \frac{1}{T}\int u(t)\,dt = 0$$

efektivne vrijednosti

$$P = \frac{U_{DC}^2}{R} \sim P = \frac{U_{DC}^2}{R}$$

$$P = \frac{1}{T}\int_0^T p(t)\,dt = \frac{1}{T}\int_0^T \frac{u^2(t)}{R}\,dt = \frac{1}{R}\underbrace{\left[\frac{1}{T}\int_0^T u^2(t)\,dt\right]}_{} = \underbrace{\frac{U_{ef}^2}{R}}$$

$$U_{ef} = \sqrt{\frac{1}{T}\int_0^T u^2(t)\,dt}$$

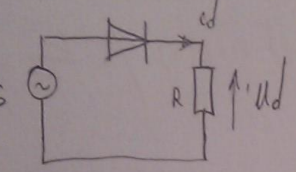
RMS
root mean square

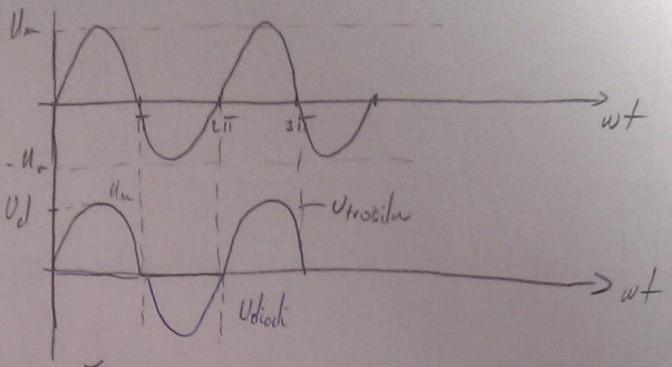
1. Poluvalni ispravljač na slici ima sljedeće podatke

$U_s = 170 \sin(377t)\ V$

$R = 15\Omega$

$I, I_{RMS}, P, \lambda = ?$





$$I_d = \frac{U_d}{R} = \frac{1}{R}\left[\frac{1}{2\pi}\int_0^{\pi} u(\omega t)\,d\omega t\right]$$

$$= \frac{1}{R}\left[\frac{1}{2\pi}\cdot U_m(-1)\cos(\omega t)\Big|_0^{\pi}\right]$$

$$= \frac{U_m}{R\cdot\pi} = \frac{170}{1{,}5\cdot\pi} = 3{,}6\,A$$

$$\int \sin^2(x) = \frac{x}{2} - \frac{\sin(2x)}{4}$$

$$I_{RMS} = \frac{U_{RMS}}{R} = \frac{1}{R}\sqrt{\frac{1}{T}\int_0^{T} u^2(t)\,dt}$$

$$= \frac{1}{R}\sqrt{\frac{1}{2\pi}\int_0^{\pi} U_m^2 \sin^2(\omega t)\,d(\omega t)} = \frac{U_m}{R}\sqrt{\frac{1}{2\pi}\left[\frac{\omega t}{2} - \frac{\sin(2\omega t)}{4}\right]_0^{\pi}}$$

$$= \frac{U_m}{R}\sqrt{\frac{1}{4\pi}\cdot\pi} = \frac{U_m}{2R} = 5{,}67\,A$$

$$P = I_{RMS}^2 \cdot R = 5{,}67^2 \cdot 15 = 481{,}67\,W$$

$$\lambda = \frac{P}{S} = \frac{P}{U_{s\,RMS}\cdot I_{RMS}} = \frac{481{,}67\,W}{\frac{170}{\sqrt{2}}\cdot 5{,}67} = 0{,}706$$

2. Poluvalni diodni ispravljač opterećen je R,L trošilom i ima sljedeće nazivne podatke

$R = 100\Omega$

$L = 0{,}1H$

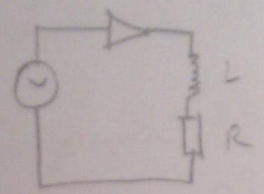
$\omega = 377$ rad/s

$U_m = 100V$

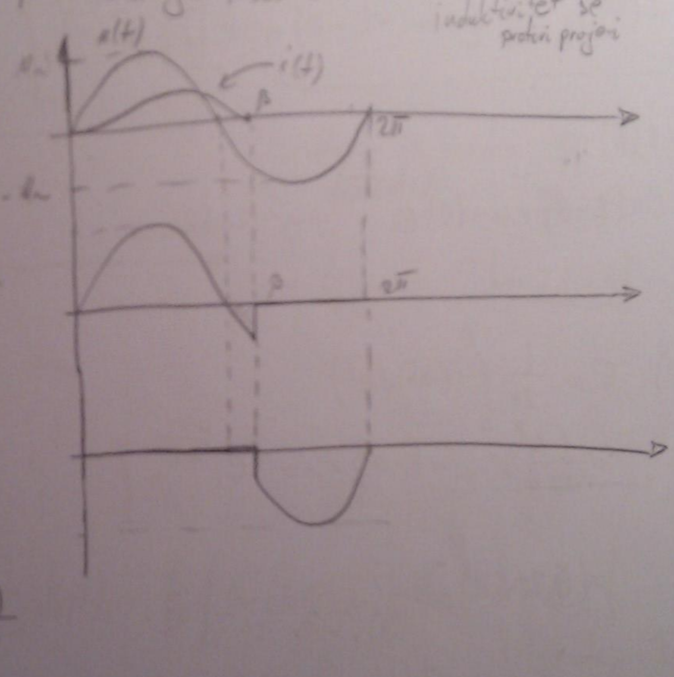
a) Nacrtajte valne oblike napona i struje trošila, napona na trošilu i diodi

b) srednju struju trošila

c) snagu predanu trošilu



induktivitet se protivi promjeni



$$U_m \sin(\omega t) = Ri(t) + L\frac{di_L(t)}{dt}$$

$$i(t) = i_f(t) + i_n(t)$$

(i_f – force, i_n – natural)

$$i_f(t) = \frac{U_m}{Z}\sin(\omega t - \Theta) \qquad \Theta = \mathrm{arctg}\left(\frac{\omega L}{R}\right)$$

$$Ri(t) + L\frac{di_L(t)}{dt} = 0 \Rightarrow i_n(t) = Ae^{-\frac{t}{\tau}} \qquad \tau = \frac{L}{R}$$

$$i(\omega t) = \frac{U_m}{Z}\sin(\omega t - \Theta) + Ae^{-\frac{\omega t}{\omega \tau}}$$

$i(0)=0$

$$\frac{U_m}{Z}\sin(\omega t-\theta)+Ae^{-\frac{\omega t}{\omega\tau}}=0$$

$$\frac{U_m}{Z}\sin(0-\theta)+Ae^{0}=0$$

$$A=\frac{U_m}{Z}\sin\theta$$

$$i(\omega t)=\frac{U_m}{Z}\left[\sin(\omega t-\theta)+\sin(\theta)\,e^{-\frac{\omega t}{\omega\tau}}\right] \qquad 0<\omega t<\beta$$

$i(\beta)=0$

$$\sin(\beta-\theta)+\sin(\theta)\,e^{-\frac{\beta}{\omega\tau}}=0 \longrightarrow \text{MATLAB}$$

$\beta = 3,5$ rad

b) $$I=\frac{1}{2\pi}\int_0^{\beta} i(\omega t)\,d\omega t$$

$$=\frac{1}{2\pi}\cdot\frac{U_m}{Z}\left[\sin(\omega t-\theta)+\sin\theta\,e^{-\frac{\omega t}{\omega\tau}}\right]_0^{\beta}$$

$$=0,308\,A$$

$Z=\sqrt{R^2+(\omega L)^2}=106,9\,\Omega$

$\theta=\tan^{-1}\left(\frac{\omega L}{R}\right)=0,361$

ef. vrijednost

$$I_{RMS}=\frac{1}{2\pi}\int_0^{\beta} i(\omega t)^2\,d\omega t=0,474\,A$$

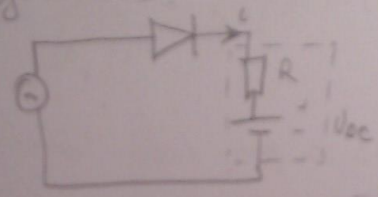
c) $P=I_{RMS}^2\cdot R=22,4\,W$

$$\lambda=\frac{P}{S}=\frac{22,4}{\frac{100}{12}\cdot 0,474}=0,67$$

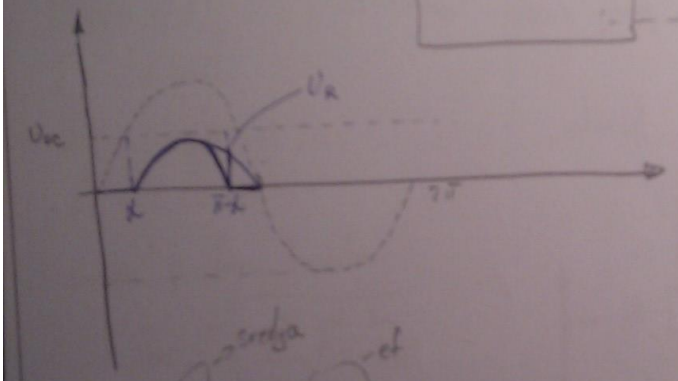
5. Polvalni diodni ispravljač opt polvalnim trošilo i EMS teret:

$U_{ef} = 230V$
$f = 50Hz$
$R = 20\Omega$
$U_{DC} = 150V$
$U_k = 1V$
$R_d = 2m\Omega$

izrač gubitke vodnja diode
$P_g = ?$
Pri proračunu izlaznog napona treba se zanemariti napon kolja diode



- Napon na trošilu α - određen sa U_{DC}



$P_g = I_d \cdot U_k + I_{ef}^2 \cdot R_d$

I_d - srednja, I_{ef} - ef

$$U_d = \frac{1}{2\pi}\int_{\alpha}^{\pi-\alpha}[U_m \sin(\omega t) - U_{DC}]\,d(\omega t) = \frac{1}{2\pi}\left[U_m(2\cos\alpha) - U_{DC}(\pi - 2\alpha)\right]$$

$U_m \sin\alpha = U_{DC}$ → dioda počne voditi

$$\alpha = \arcsin\left(\frac{U_{DC}}{U_m}\right) = 0{,}479$$

$$U_d = 39{,}75V \Rightarrow I_d = \frac{U_d}{R} = \frac{39{,}75}{20} = 1{,}99A$$

$$U_{rms} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi-\alpha}(U_m \sin(\omega t) - U_{DC})^2\,d(\omega t)} = \frac{1}{2\pi}\left[\int_{\alpha}^{\pi-\alpha}(U_m^2 \sin^2(\omega t) - 2U_m U_{DC}\sin\omega t + U_{DC}^2)\,d(\omega t)\right.$$

$$U_{RMS} = \sqrt{\frac{1}{2\pi}\left[U_m^2\left(\frac{\omega t}{2}\Big|_{\alpha}^{\pi-\alpha} - \frac{\sin(2\omega t)}{4}\Big|_{\alpha}^{\pi-\alpha}\right) + 2U_m U_d \cos(\omega t)\Big|_{\alpha}^{\pi-\alpha} + U_{DC}^2\Big|_{\alpha}^{\pi-\alpha}\right]}$$

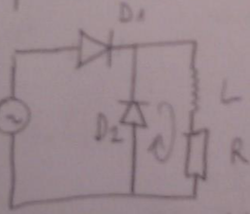
$$= 74{,}55\,V \Rightarrow I_{RMS} = 3{,}73\,A$$

$$P_g = 3{,}73^2 \cdot 2 \cdot 10^{-3} + 1{,}99 \cdot 1 = \boxed{2{,}02\,W}$$

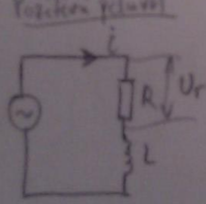
ZDK 4. Za poluvalni ispravljač sa povratnom diodom odrediti

Valni oblici napona i struje trošila

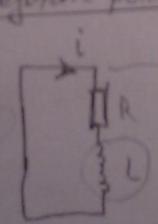
$R = 2\,\Omega$
$L = 25\,mH$
$U_m = 100\,V$
$f = 50\,Hz$

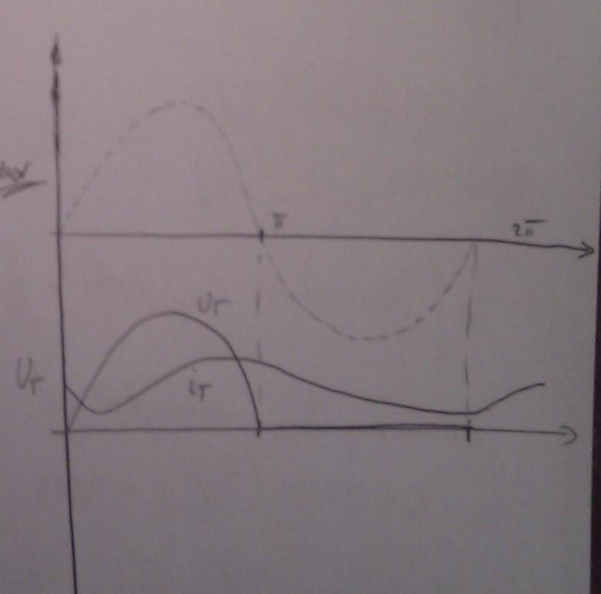


Pozitivni poluval



negativni poluval





$$u(t) = \frac{U_m}{\pi} + \frac{U_m}{2}\sin(\omega_0 t) - \sum_{n=2,4,\ldots}^{\infty} \frac{2U_m}{(n^2-1)\pi} \cdot \cos(n\omega_0 t)$$

sr. vr. — prvi harmonik — viši harmonici

$$U_d = \frac{U_m}{\pi} = \frac{100}{\pi} = 31{,}83\,V \qquad I_d = \frac{U_d}{R} = \frac{31{,}83}{2} = 15{,}9\,A$$

$I_n = \frac{U_m}{Z_n}$ $\quad Z_n = |R + jn\omega_0 L|$

$U_2 = \frac{2U_m}{(2^2-1)\pi} = 21{,}2\,V$ $\quad Z_1 = \sqrt{R^2 + j(1\omega_0 L)^2} = 8{,}15\,\Omega$

$U_4 = \frac{2U_m}{(4^2-1)\pi} = 4{,}24\,V$ $\quad Z_2 = 15{,}82\,\Omega$

$U_6 = \frac{2U_m}{(6^2-1)\pi} = 1{,}82\,V$ $\quad Z_4 = 31{,}46\,\Omega$

$Z_6 = 47{,}14\,\Omega$

$I_1 = 6{,}17\,A$

$I_2 = 1{,}34\,A$

$I_4 = 0{,}13\,A$

$I_6 = 0{,}039\,A$

Snaga predana trošilu

$I_{RMS} = \sqrt{\sum_{n=0}^{\infty} I_{RMSn}^2}$

$I_{RMS} = \sqrt{15{,}9^2 + \left(\frac{6{,}17}{\sqrt{2}}\right)^2 + \left(\frac{1{,}34}{\sqrt{2}}\right)^2 + \left(\frac{0{,}13}{\sqrt{2}}\right)^2 + \left(\frac{0{,}039}{\sqrt{2}}\right)^2}$

sr. vrijednost; sr. vrijednost = ef. vrijednost; ef. vrijednost

$I_{RMS} = 16{,}52\,A$

$P = I_{RMS}^2 \cdot R = 545{,}5\,W$

raste red $n \nearrow$ $Z \nearrow$ $U \searrow$

više harmonike rijetko zanemariti

$\frac{L}{R} = \tilde{c} \nearrow$ $Z \nearrow \Rightarrow I \searrow$

što je L veći valovitost veća

L veći valovitost manja

$\omega \nearrow$ $Z \nearrow$ - $I \searrow$

faktor snage el. m. struje izvora i trošila - izmjenične

$$\lambda = \frac{P}{S} = \frac{P}{U_{s0m} \cdot I_{s\,ef}} = \frac{565,3}{\frac{400}{\sqrt{2}} \cdot 11,24} = 0,686$$

$$I_{s\,ef} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} I_s^2 \, d\omega t} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} 15,9^2 \, d\omega t} = 11,24A$$

① Auditorne vježbe 11.

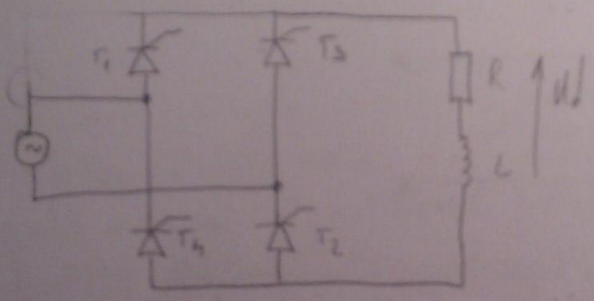
Istosmjerni stroj, nacrtajte upravljivi usmjerivač u mostnom spoju i za spoj na mreži napon U=230V odredite

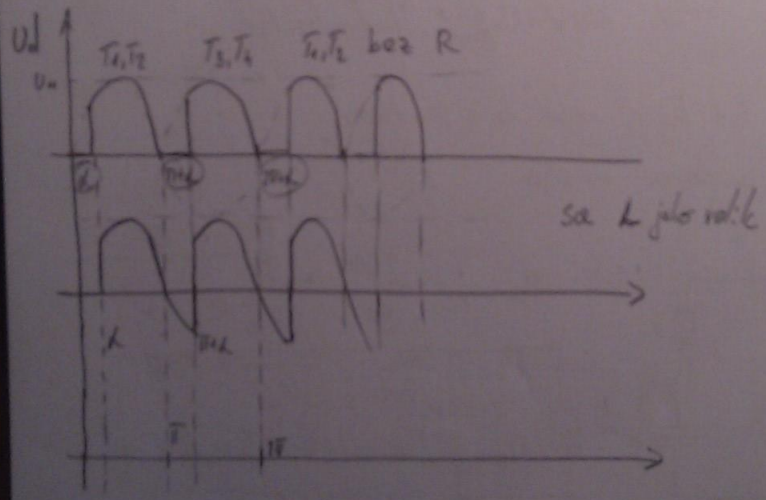
$U_{nzb} = 100V$

$I_{nzb} = 1A$

- original srednje vrijednosti napona trošila o kutu upravljanja
- kut upravljanja takav da se osigura uzbudna struja stroja
- valne oblike napona i struja

$\frac{L}{R} \Rightarrow \infty$





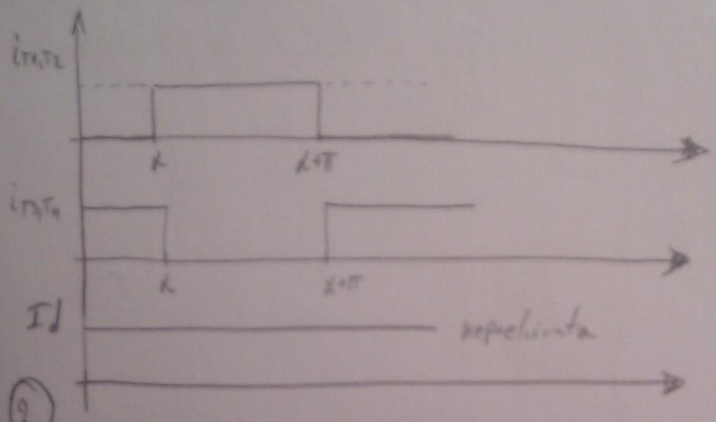
$$U_d = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} u_m \sin(\omega t)\,d\omega t = \frac{1}{\pi} u_m (-1)\cdot \cos\omega t \Big|_{\alpha}^{\pi+\alpha}$$

$$U_d = -\frac{230\sqrt{2}}{\pi}\left[\underbrace{\cos(\pi+\alpha)}_{-\cos\alpha} - \cos\alpha\right] = \frac{2\cdot 230\sqrt{2}}{\pi}\cos\alpha$$

$$\cos\alpha = \frac{U_d \cdot \pi}{2U_m} = \frac{100 \cdot \pi}{2 \cdot 230\sqrt{2}} = 0{,}483$$

$\alpha = 61{,}12°$

STRUJE KROZ TIRISTORE



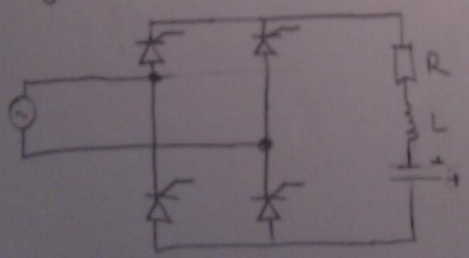
(2)

Fotonaponski modul ima nazivni napon 100V i $R_u = 0{,}5\Omega$ snaga modula P = 1kW a napon mreže 110V = U_{efm}. Induktivitet je dovoljno velik

a) Kut upravljanja α kod kojeg modul daje P = 1kW

b) Snagu koja prima napajanje mreža

c) gubitke na R_u =



$P_{DC} = U_{DC} \cdot I_{DC}$

$I_{DC} = \frac{P_{DC}}{U_{DC}} = \frac{1 \cdot 10^3}{100} = 10A$

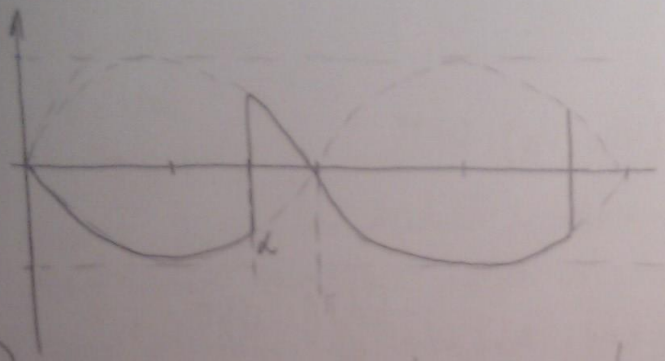
$U_R = I_d \cdot R = 10 \cdot 0{,}5 = 5V$

$\boxed{P_R = 10 \cdot 5 = 50W}$

$P_{AC} = P - P_R = 950W$

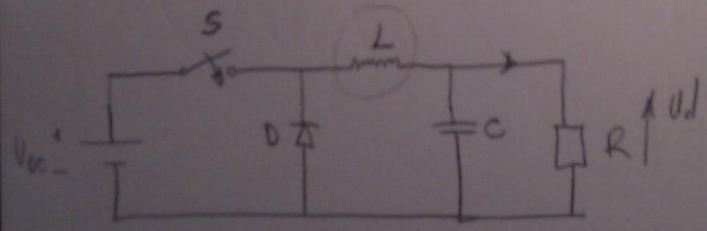
(2)

$$U_d = \frac{2U_m}{\pi}\cos\alpha \Rightarrow \alpha = \arccos\left(\frac{U_d\pi}{2U_m}\right) = 163{,}6^\circ = \left(\frac{-95\pi}{2\cdot 110\sqrt{2}}\right)$$

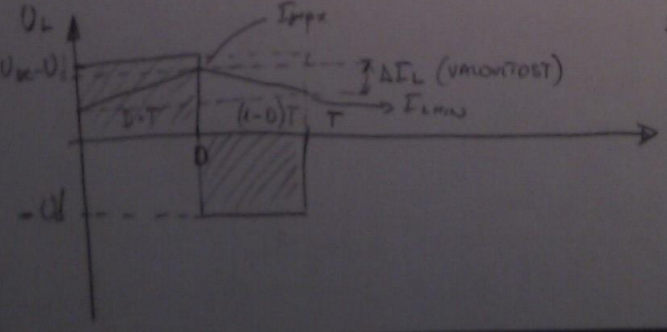


③ Nacrtajte silazni izlazni pretvarač bez galvanskog odvajanja. Nacrtajte valne oblike napona i struje induktiviteta za neprekidan režim rada. Izvedite naponsku i strujnu transf. jednadžbu. Izračunaj R pri kojem će pretvarač raditi na granici isprekidanog režima rada?

$U_{DC} = 100V$
$L = 20\,mH$
$f_0 = 10\,kHz$
$D = 0{,}6$



$U_L = U_{DC} - U_d$
Srednji napon na induktivitetu jednak nuli



ZATVORENA SKLOPKA

$$U_L = U_{DC} - U_d = L \frac{di_L}{dt}$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta T} = \frac{U_{DC} - U_D}{L}$$

$$\Delta I_{L\check{z}} = \frac{U_{DC} - U_D}{L} \cdot \Delta T = \frac{1}{L}(U_{DC} - U_D) \cdot D \cdot T$$

SKLOPKA OTVORENA

$$U_L = -U_d = L \frac{di_L}{dt} = L \frac{\Delta I_L}{\Delta T} \qquad \Delta I_{LO} = -\frac{U_d}{L}(1-D)T$$

$$\Delta I_{LO} + \Delta I_{L\check{z}} = 0$$

$$\frac{1}{L}(U_{DC} - U_d) \cdot D \cdot T = +\frac{U_d}{L}(1-D)T$$

$$U_{DC} D - U_d D = U_d - U_d D$$

$$\boxed{U_d = U_{DC} \cdot D}$$ transf. jednadžba

STRUJNA JEDNADŽBA

$$P_{DC} = P_d$$

$$I_S \cdot U_{DC} = I_d \cdot U_D$$

$$\boxed{I_d = I_S \cdot \frac{U_{DC}}{U_D} = \frac{I_S}{D}}$$

$$I_{MIN} = I_L - \left| \frac{\Delta I_L}{2} \right| = 0$$

$$\frac{U_d}{R} = \frac{1}{2} \cdot \frac{1}{L} U_d (1-D) T$$

$$R = \frac{2L}{(1-D)T} = \frac{2 \cdot 20 \cdot 10^{-3}}{(1-0{,}6)} \cdot 10 \cdot 10^{+3} = \boxed{1000\,\Omega}$$

4.

Istosmjerni uzlazni pretvarač ima slj. podatke

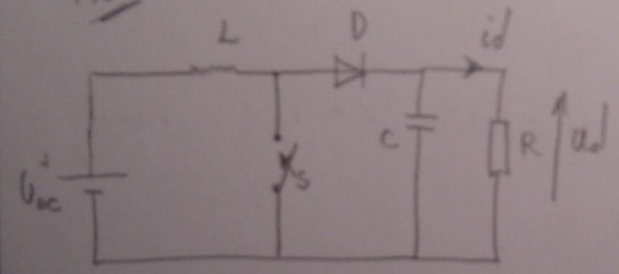
$U_{oc} = 5V$ ulazni

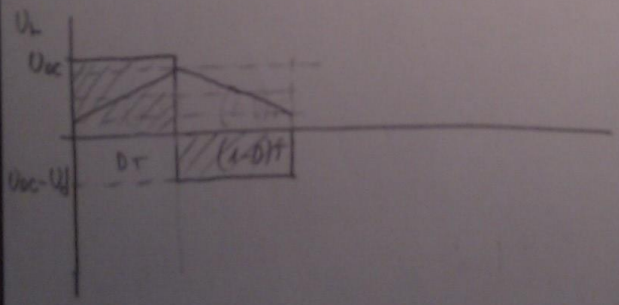
$U_d = 15V$ izlazni

$P_d = 25W$

$f_s = 300kHz$

Odredite D, minimalnu vrijednost L ako vam vrijednost struje kroz induktivitet nesmije biti manja od 50% nje e srednje vrijednosti kapacitet tolikv da valovitost izlaznog napona nebude veća od 1%





sklopka zatvorena

$U_L = U_{oc} = L \cdot \frac{di_L}{dt}$

$\Delta i_L = \frac{1}{L} \cdot U_{oc} \cdot \Delta T$

sklopka otvorena

$U_L = U_{oc} - U_d = L \cdot \frac{di_L}{dt}$

$\Delta i_L = \frac{1}{L} (U_{oc} - U_d) \Delta T$

$\Delta i_{L1} + \Delta i_{L2} = 0$

$\frac{1}{L} U_{oc} \cdot D \cdot T = \frac{-1}{L} (U_{oc} - U_d) \cdot (1-D) T$

$U_{DC} \cdot D = -U_{DC} + U_{DC} \cdot D + U_d + U_d D$

$U_d(1-D) = U_{DC}$

$$\boxed{U_d = \frac{U_{DC}}{1-D}}$$

$$D = \frac{U_d - U_{DC}}{U_d} = \frac{15-5}{15} = 0,67$$

$$P_d = \frac{U_d^2}{R} = U_d \cdot I_D = \qquad P_g = 0$$

$P_{DC} = U_{DC} \cdot I_L$

$P_d = P_{DC} \Rightarrow U_{DC} \cdot I_L = \frac{U_d^2}{R} = \frac{U_{DC}^2}{(1-D)^2 \cdot R}$

$$I_L = \frac{U_{DC}}{(1-D)^2 \cdot R}$$ -> sr. vrijednost struje induktiviteta

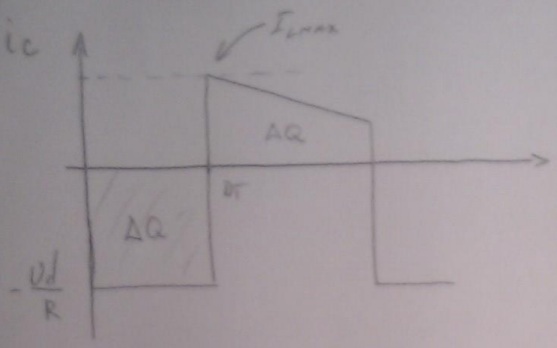
$$I_{MIN} = I_L - \left|\frac{\Delta I_L}{2}\right| > \frac{1}{2} I_L$$

$\frac{1}{2} I_L > \frac{1}{2} \Delta I_L$

$\frac{U_{DC}}{(1-D)^2 R} > \frac{U_{DC}}{L} \cdot D \cdot T$

$L > D(1-D)^2 \cdot \frac{R}{f}$ $\qquad \boxed{R = \frac{U_d^2}{P_d} = \frac{225}{25} = 9\Omega}$

$L_{MIN} > 0,67(1-0,67)^2 \cdot \frac{9}{300 \cdot 10^3} = 2,22 \mu H$



$Q = C \cdot Ud$

$\Delta Q = C \cdot \Delta Ud = \frac{Ud}{R} \cdot D \cdot T$

$$\frac{\Delta Ud}{Ud} = \frac{D}{R \cdot C \cdot f} \Rightarrow C > \frac{D}{\frac{\Delta Ud}{Ud} R \cdot f} \qquad C > \frac{0,67}{0,01 \cdot 3 \cdot 300 \cdot 10^3}$$

(5.) Izlazno silazni pretvarač ima sljedeće podatke

$U_{oc} = 24V$ $R = 5\Omega$ $C = 80\mu F$

$D = 0,4$ $L = 20\mu H$

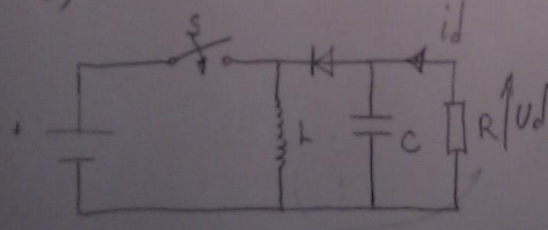
Odredite:

a) Izlazni napon na trošilu

b) Sklopni frekv. takvo da $\Delta I_L = 4,8A$

c) srednju vrijednost struje induktiviteta

d) valovitost izlaznog napona



sklopka zatvorena

$U_L = U_{oc} = L \frac{\Delta I_L}{\Delta T}$

$\Delta I_L = \frac{1}{L} U_{oc} \cdot D \cdot T$

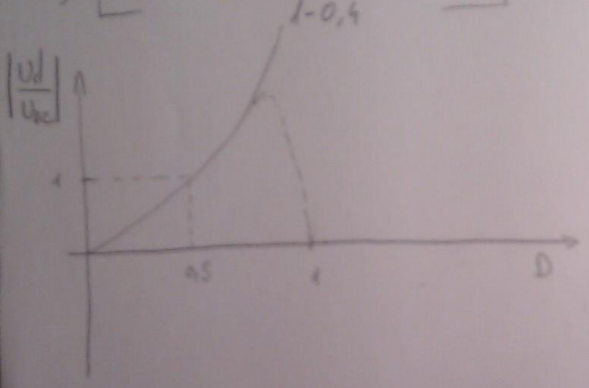
sklopka otvorena

$\Delta i_L = \frac{1}{L} Ud(1-D)T$

$$\frac{1}{K} U_{oc} \cdot D \cdot T = -\frac{1}{K} U_d (1-D) T$$

$$\boxed{U_d = -U_{oc} \cdot \frac{D}{1-D}}$$

a) $\boxed{U_d = -24 \cdot \frac{0,4}{1-0,4} = -16V}$



$$\Delta I_L = \frac{U_{oc}}{L} \cdot D \cdot T = 4,8A$$

$$f = \frac{U_{oc} \cdot D}{L \, \Delta I_L} = \frac{24 \cdot 0,4}{20 \cdot 10^{-6} \cdot 4,8} = 100kHz$$

$$I_S = I_L \cdot D \qquad U_{oc} \cdot I_S = \frac{U_d^2}{R}$$

$$I_L = \frac{U_d^2}{R} \cdot \frac{1}{D \cdot U_{oc}} = \frac{U_{oc} \cdot D}{R(1-D)^2} = \frac{24 \cdot 0,4}{5 \cdot 0,6^2} = 5,33A$$

$$I_{LMAX} = 7,33A \qquad I_{LMIN} = 2,93$$

$$\Delta Q = \Delta U_d \cdot C = \frac{U_d}{R} \cdot D \cdot T$$

$$\frac{\Delta U_d}{U_d} = \frac{D}{RCf} = 0,01 \Rightarrow 1\% .$$