РАЧУНСКЕ ВЕЖБЕ ОГЭСМ 2012/2013.

I термин 18.02. 2013.

① $n_{ee} = 78$ об/мин

а) $n = \frac{60 f}{p} \Rightarrow \frac{60 \cdot 50}{p} = 78$ об/мин

$\Downarrow$

$p = 38.46 \Rightarrow 2p \approx 76$ бопова (но, јбними баран број)

$n_{ЗН} = \frac{60 \cdot 50}{38} = 78.95$ об/мин

б) $n = \frac{60 \cdot 25}{p} = 78$ об/мин $\Rightarrow p = 19.23 \Rightarrow$ $2p \approx 38$ бопова

$n_{ЗН} = \frac{60 \cdot 25}{19} = 78.95$ об/мин

в) $n = \frac{60 \cdot 60}{p} = 78$ об/мин $\Rightarrow p = 46.15 \Rightarrow 2p \approx 92$ бопа

$n_{ЗН} = \frac{60 \cdot 60}{46} = 78.26$ об/мин

② $n_{сихр}^{ХГ} << n_{сихр}^{РТ} \rightarrow$ веће, веће бр. бопова $\frac{B}{p}$

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② $U \approx E \sim \omega \Phi \sim 2\pi f \cdot B_m \frac{2}{\pi} \cdot \tau L \sim f B_m$

$$\frac{U^{50Hz}}{50} = \frac{U^{60Hz}}{60}$$

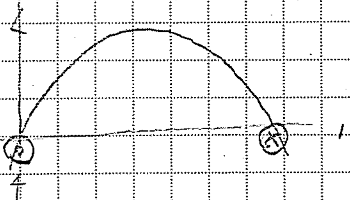
$\Downarrow$

$$U^{50Hz} = \frac{5}{6} \cdot 440 \cong 367\ V$$

③ флукс во возду = флукс низ пресек, не флукс намотката!

$$\Psi_f = N_{нав} \cdot \Phi_{пол}$$

флукс ф. намотката — флукс во возду



$$f = \frac{pn}{60} = 60Hz$$

$$E_{фазно}^{ef} = \underbrace{4.44}_{2\pi/\sqrt{2}} \times \underbrace{N_{нав} p \cdot \Phi}_{\Psi_{намотката}} \cdot f = 266.4V$$

б) $e_a = E_f^{ef}\sqrt{2}\sin\omega t = 377\sin(377t)\,V$

$e_b = E_f^{ef}\sqrt{2}\sin(\omega t - 2\pi/3) = 377\sin(377t - 120^\circ)\,V$

$e_c = 377\sin(377t + 120^\circ)\,V$

в) $e_{ab} = e_a - e_b \cong 653\sin(377t + 30^\circ)\,V$

$e_{bc} = e_b - e_c \cong 653\sin(377t - 30^\circ)\,V$

$e_{ca} = e_c - e_a \cong 653\sin(377t + 150^\circ)\,V$

(4) $N_{\varphi} = 60$ σπείρες/φάση $2p = 2$

$k = 0.92$

$n = 3000$ στρ/min $= n_{σύγχρ}$ $\Rightarrow$ $f = 50Hz$

$\Phi = 3.26 \cdot 10^{-2}$ Wb/pole

$E_{\varphi} = 2.22 \cdot N_{φασ} \cdot k \cdot \Phi \cdot f = 230.38V$ ΕΟ φάση

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(5) $Z = 144$ $2p = 16$ $q = 3$ $\Rightarrow$ $\tau = \frac{144}{16} = 9$, $m = 3$

$N_{\alpha} = 10$

$k_\tau = 1$

$\Phi = 3 \cdot 10^{-2}$ Wb/p

$\omega_{\mu\eta\chi} = 39.3$ rad/s $\Rightarrow$ $f = p \cdot \frac{\omega_{\mu\eta\chi}}{2\pi} \cong 50Hz$

$$k_p = \frac{\sin\frac{m\pi}{2\tau}}{m \sin\frac{\pi}{2\tau}} = 0.96$$

$E_{\varphi} = 2.22 \cdot \frac{N_{φασ}}{2} \cdot k_p \cdot k_\tau \cdot \Phi \cdot f \cdot N_{\alpha} = 1534.46V$

$E_{\pi\varepsilon\delta} = E_{\varphi}\sqrt{3} = 2657.76V$

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(6) $B = \sin\theta + 0.3\sin 3\theta + 0.2 \sin 5\theta$ $m = 5$

$$k_{p\nu} = \frac{\sin\left(\frac{m\pi\nu}{2\tau}\right)}{m\sin\left(\frac{\nu\pi}{2\tau}\right)} \qquad k_{\tau\nu} = \sin\left(\frac{y}{\tau}\cdot\frac{\pi}{2}\cdot\nu\right) \qquad \tau = 15$$

	1	3	5
k_p	0.9767	0.6472	0.2
k_τ	0.951	-0.588	0
k	0.9288	0.381	0

a) $E_{por}^{\nu} = B_{\nu} l v \Rightarrow \frac{E_{por}^{\nu}}{E_{por}^{1}} = \frac{B_{\nu}}{B_1} \Rightarrow E_{por}^{1} = 100\%$

$E_{por}^{3} = 30\%$

$E_{por}^{5} = 20\%$

$\frac{E_{por}}{E_1} = 1.063$

б) $E_{fav}^{\nu} = \Phi_{\nu} \cdot \omega_{\nu} \sim f_{\nu} \cdot \Phi_{\nu} \cdot k_{T\nu}$

$\Phi_{\nu} = \int_0^{\pi} B_{\nu} \cdot \sin(\nu\theta) \cdot d\theta \cdot r l =$

$= \frac{B_{\nu}}{\nu} \cdot 2 \cdot r l = \frac{2}{\pi} \cdot \frac{B_{\nu}}{\nu} \cdot \tau l \sim \frac{B_{\nu}}{\nu}$

$E_{fav}^{\nu} / E_{fav}^{1} = \frac{f_{\nu}}{f_1} \cdot \frac{B_{\nu}}{\nu B_1} \cdot \frac{k_{\nu}}{k_1} \Rightarrow E_{fav}^{1} = 100\%;\ E_{fav}^{3} = 18.5\%;\ E_{fav}^{5} = \phi$

$\frac{E_{fav}}{E_{fav}^{1}} = 1.017$

в) $E_f^{\nu} \sim f_{\nu} \cdot \Phi_{\nu} \cdot k_{\nu}$ $E_f^{1} = 100\%$

$\frac{E_f^{\nu}}{E_f^{1}} = \frac{B_{\nu}}{B_1} \cdot \frac{k_{\nu}}{k_1} \Rightarrow E_f^{3} = 12.56\%$ $E_f^{5} = \phi$; $\frac{E_f}{E_{f1}} = 1.0078$

g) $E_{Lf}^{3} = \phi$ $E_{Lf}^{5} = \phi \Rightarrow E_{Lf}/E_{Lf1} = 1$

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(7) $B = B_m(\sin\theta + 0.36\sin 3\theta - 0.4\sin 5\theta)$

a) израз. зоб: $\frac{\Phi_{\nu}}{\Phi_1} = \frac{B_{\nu}}{\nu B_1} \Rightarrow \frac{\Phi_3}{\Phi_1} = 0.12$; $\frac{\Phi_5}{\Phi_1} = -0.08$

$\Phi_{rez} = \Phi_1 + \Phi_3 + \Phi_5 = 1.04\,\Phi_1 \Rightarrow \Phi_1/\Phi_{rez} = 0.9615$

$\Phi_3/\Phi_{rez} = 0.1154$

$\Phi_5/\Phi_{rez} = -0.0769$

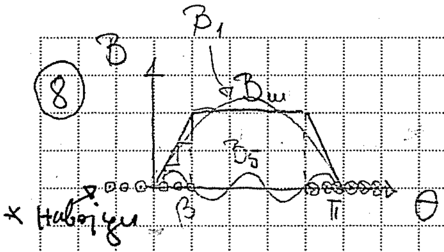
б) $E_f^{ef} = 1$; останува ова у фазата за след ?

$E_{f3}^{ef} = \frac{k_3}{k_1} \cdot \frac{B_3}{B_1} = 0.151$; $E_{5f} = \phi$

$E_f = 1.011$; $E_{Lin} = \sqrt{3}\,E_{1f} = 1.73$

II термин 25.02.2013.

(8) Трапезни облик приближнији синусном него правоугаони?



ν-ти хармоник ЕМ индукције:

$$B_\nu = \frac{1}{\pi}\int_{-\pi}^{\pi} B(\theta)\sin(\nu\theta)\,d\theta = \frac{4}{\pi}\int_{0}^{\pi/2} B(\theta)\sin\nu\theta\,d\theta =$$

* непарна ф-ја у односу на 0; парна у одн. на π/2

конкр. случај

$$\frac{4}{\pi}\left[\frac{B_m}{\beta}\int_{0}^{\beta}\theta\sin\nu\theta\,d\theta + B_m\int_{\beta}^{\pi/2}\sin\nu\theta\,d\theta\right] = \dots$$

($u = \theta$, dv)

парц. инт.:

$$\left[-\frac{\theta}{\nu}\cos\nu\theta\Big|_0^\beta + \frac{1}{\nu^2}\sin\nu\theta\Big|_0^\beta = -\frac{\beta}{\nu}\cos\nu\beta + \frac{\sin\nu\beta}{\nu^2}\right]$$

$$\dots = \frac{4}{\pi}\left[-\frac{B_m}{\nu}\cos\nu\beta + \frac{B_m\sin\nu\beta}{\nu^2\beta} + \frac{B_m}{\nu}\cos\nu\beta\right] =$$

*** ν је НЕПАРНО!

зато је $\cos\frac{\nu\pi}{2} = 0$

$$= \boxed{\frac{4\sin(\nu\beta)}{\pi\beta\cdot\nu^2}}\,B_m$$

↳ општи израз за АМПЛИТУДУ ν-тог хармоника

$$B_5 = \frac{4\sin(5\beta)}{\pi\beta\cdot 25} = 0 \Rightarrow \sin 5\beta = 0 \Rightarrow 5\beta = (2k+1)\pi$$

$k = 0, 1, 2 \dots$

$k = 0 \rightarrow 5\beta = \pi \rightarrow \beta = 36^\circ$

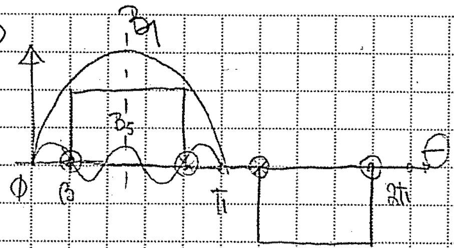
$k = 1 \rightarrow 5\beta = 2\pi \rightarrow \beta = 72^\circ$

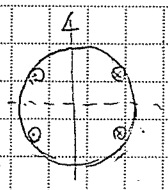
$\beta = 36^\circ \rightarrow B_1 = \frac{4\sin 36^\circ}{\pi\cdot\frac{\pi}{5}} = 1.19\,B_m$

$\beta = 72^\circ \rightarrow B_1 = \frac{4\sin 72^\circ}{\pi\cdot\frac{2\pi}{5}} = 0.96\,B_m$

Повољније решење је β=72°, јер је тада расподела боље приближнија sin ф-ји (амплитуда осн. хармоника приближна је B_m)

(9)





* општа формула за ν-ти хармоник

ν-ти хармоник: $B_\nu = \frac{4}{\pi}\int_0^{\pi/2} B(\theta)\sin\nu\theta\, d\theta = \frac{4}{\pi}\int_\beta^{\pi/2} B_m \sin(\nu\theta)\, d\theta = \frac{4B_m}{\nu\pi}\cos(\nu\beta)$

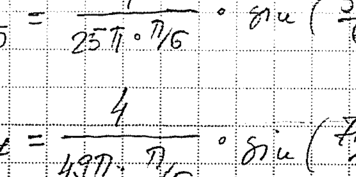
$B_5 = \frac{4}{5\pi} B_m \cos(5\beta) = 0 \Rightarrow \beta = \frac{(2k+1)\pi}{5\cdot 2}$; $\beta = \frac{\pi}{10} = \underline{18^\circ}$

$B_7 = \frac{4}{7\pi} B_m \cos(7\beta) = 0 \Rightarrow \beta = \frac{\pi}{2\cdot 7} = 12.86^\circ \approx \underline{13^\circ}$

* Могу се усвојити још и вредности $\underline{54^\circ}$ и $\underline{39^\circ}$. Вредност од 39° даје расподелу јако блиску синусној. (проверити) Веће вредности од ових нису повољне, јер тада расподела значајно одступа од синусне !

* Предност трапезне → апроксимативна хармоника опада са ν^2 !

(10)



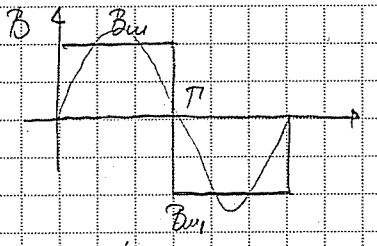
Веће имамо: $B_\nu = \frac{4}{\nu^2\pi\beta}\cdot\sin\nu\beta\cdot B_m$ *

$B_3 = \frac{4}{9\pi\cdot\frac{\pi}{6}}\cdot\sin\left(3\frac{\pi}{6}\right)\cdot B_m = \underline{0.27\cdot B_m}$

$B_5 = \frac{4}{25\pi\cdot\pi/6}\cdot\sin\left(\frac{5\pi}{6}\right) = \underline{0.049\cdot B_m}$

$B_7 = \frac{4}{49\pi\cdot\pi/6}\cdot\sin\left(\frac{7\pi}{6}\right) = \underline{-0.025\, B_m}$

* Изрази за BX појединих расподела морају се изводити на испиту !

(11) 

$B_{mv} = \lim_{\beta \to 0} \frac{4}{\nu^2 \pi \beta} \sin \nu\beta \cdot B_m = \frac{4}{\nu^2 \pi} \cdot \lim_{\beta \to 0} \left(\nu \cdot \frac{\sin \nu\beta}{\nu\beta} \right) \cdot B_m =$

$= \boxed{\frac{4}{\nu\pi}} \cdot B_m$ ← общий израз за ПРАВОУГАОНУ расподелу

Реш: $B_1 = \frac{4}{\pi} B_m$

$B_3 = \frac{4}{3\pi} B_m$

$B_5 = \frac{4}{5\pi} B_m$

$B_7 = \frac{4}{7\pi} B_m$

* Ради се о АМПЛИТУДАЧА карактеристика; односно их треба сабрати.

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(12) $\beta = 90° \Rightarrow B_v = \lim_{\beta \to \pi/2} \frac{4}{\nu^2 \pi \beta} \cdot \sin \nu\beta \cdot B_m = \frac{8}{\nu^2 \pi^2} \sin\left(\nu \frac{\pi}{2}\right) B_m$

$B_1 = \frac{8}{\pi^2} B_m$

$B_3 = -\frac{8}{9\pi^2} B_m$

$B_5 = \frac{8}{25\pi^2} B_m$

$B_7 = -\frac{8}{49\pi^2} B_m$

* општи израз за троугаону расподелу

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(13) $f = 60\,Hz$; $Z = 24$; $y/\tau = 5/6$; 4 nav / nav. delu $\quad q = 3$, $2p = 8$

$B_\theta = B_m (\sin\theta + 0.35 \sin 3\theta - 0.40 \sin 5\theta)$

$n = n_{sinh}$; $\Phi_{uk} = 4.80 \cdot 10^{-2}$ Wb / pola.

* двослојни намотај

$m = Z/3 = 8$

Увучено једнослојно: $Z = \frac{Z}{2} \cdot 2p = \underline{192}$ жлеба

$\frac{\Phi_v}{\Phi_1} = \frac{1}{\nu} \cdot \frac{B_{mv}}{B_{m1}} \Rightarrow \Phi_3 = \frac{1}{3} \cdot \frac{0.35}{1} \cdot \Phi_1 = 0.117\,\Phi_1$

$$\Phi_5 = \frac{1}{5} \cdot \frac{-0.4}{1} \Phi_1 = -0.08\,\Phi_1$$

$$\Phi_{uk} = \Phi_1 + \Phi_3 + \Phi_5 = (1 + 0.117 - 0.08)\,\Phi_1 = 1.037\,\Phi_1$$

$\Phi_1 = 46.3$ mWb

$\Phi_3 = 5.41$ mWb

$\Phi_5 = -3.7$ mWb

Навојни сачиниоци: $k_{pv} = \frac{\sin(v\frac{\alpha\pi}{2z})}{q\sin(v\frac{\pi}{2z})}$; $k_{Tv} = \sin\left(v \cdot \frac{y}{\tau} \cdot \frac{\pi}{2}\right)$

$f_{1v} = v \cdot 60$ Hz

v	1	3	5
k_{pv}	0.956	0.641	0.195
k_{Tv}	0.966	0.707	0.259
k_v	0.923	0.453	0.05

$E_v = 2.22 \cdot k_v \cdot N_{prov} \cdot \Phi_v \cdot f_v$

N_{prov} – број проводника у једној фази

$* N_{prov} = \frac{z}{2} \cdot N_{prv/žlebu} = \frac{192}{3} \cdot 8 = 512$

z – укупан број проводника у једној фази

$N_{prv/žlebu}$ – број проводника у једном жлебу

$E_1 = 2.22 \cdot 0.923 \cdot 512 \cdot 60 \cdot 46.3 \cdot 10^{-3} = 2914.45$ V

$E_3 = 2.22 \cdot 0.453 \cdot 512 \cdot 3 \cdot 60 \cdot 5.41 \cdot 10^{-3} = 501.40$ V

$E_5 = 2.22 \cdot 0.05 \cdot 512 \cdot 5 \cdot 60 \cdot 3.7 \cdot 10^{-3} = 63.08$ V

(двослојна) ↓

1 жлеб 5+ 8 пров.

Ефективни фазни напон:

$$E_f = \sqrt{E_1^2 + E_3^2 + E_5^2} \approx 2958\ V$$

Линијски: $E_{ei} = \sqrt{3} \cdot \sqrt{E_1^2 + E_5^2} = 5049.16$ V

III термин 11. 03. 2013.

МПС: $\underline{\underline{F_\nu}} = \frac{q}{2}\cdot\frac{4}{\pi}\cdot\frac{k_\nu \cdot N_{nav/fazi}}{2p\nu}\cdot I\sqrt{2}$ (нав) мпс се дели на 2 пола (2× међугвожђе)

4

* АМПЛИТУДА МПС ν-тог хармоника ПО ПОЛУ (простопер. струја)

(14) $q = 3$; (TG) → КОНСТ. МЕЂУГВОЖЂЕ ; битно, наслоси

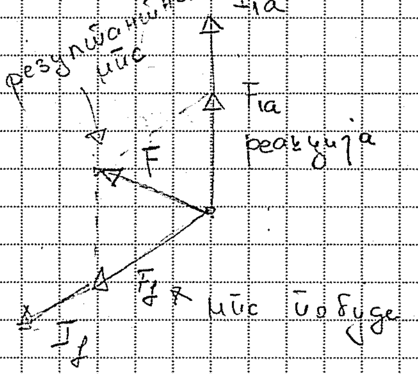
2MVA, 1000 V, 50 Hz, $p = 2$

$Z_1 = 60$; $N_1 = 100$ нав/фази ← СТАТОР

РОТОР: $w_2 / Z_2 = 2/3$; * $q_2 = 1$ * $N_2 = 500$ нав (пров/фази)

$S = 700$ MVA ; $\cos\varphi = 0$

$y = \tau$



* $F_{1a} = \frac{q}{2}\cdot\frac{4}{\pi}\cdot\frac{k_1\cdot(q\cdot N_1)\cdot I_{1a}\sqrt{2}}{2p}$

$k_1 = ?$

$Z_1 = 60/2p = 15$; $w_1 = 15/3 = 5$

$k_1 = \frac{\sin\left(\frac{w_1}{z_1}\frac{\pi}{2}\right)}{w_1 \sin(\pi/2z_1)} = \underline{0.9567}$

$F_{1a} = \frac{3}{2}\cdot\frac{4}{\pi}\cdot\frac{0.9567\cdot 100\cdot\sqrt{2}}{2p}\cdot I_{1a} = \underline{129.2\, I_{1a}}$

МПС ротора: $F_f = \frac{4}{\pi}\cdot\frac{k_2\cdot(2N_2)\cdot I_f}{2p}$

* нема $\sqrt{2}$ (DC струја); нема ни $q/2$

($F_f = const$, није обртно поље)

$k_2 = ?$

$Z_2 = \frac{56\cdot 3/2}{2p} = \underline{21}$; $w_2 = \frac{2}{3} z_2 = \underline{14}$ ⇒ $k_2 = \frac{\sin\left(\frac{w_2}{z_2}\frac{\pi}{2}\right)}{w_2 \sin\left(\frac{\pi}{2z_2}\right)} = \underline{0.8278}$

*исти бр. полова рот. и статора

$$F_{f1} = \frac{4}{\pi} \cdot \frac{0.8278 \cdot 1000 \cdot I_f}{4} = 263.5\, I_f$$

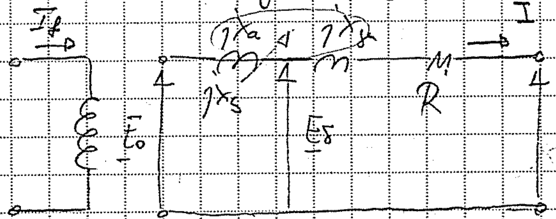
$$S = 0.7\, S_n \Rightarrow I_{1a} = 0.7\, I_{1n} = 0.7 \cdot \frac{2 \cdot 10^6}{\sqrt{3} \cdot 10^3} = 808.29\,A$$

$$\Phi_{1a} = \Phi_{1f} \Leftrightarrow F_{1a} = F_{1f} \Rightarrow 129.2\, I_{1a} = 263.5\, I_f$$

* ово вами када је $\cos\varphi = 0$ и const незасићење

$$I_f = 396.7\,A$$

(15)



$\underline{U} = U\angle 0°$

E_0 - инд. емс

E_δ - емс у неутр.

X_a - реактанса реакције инд.

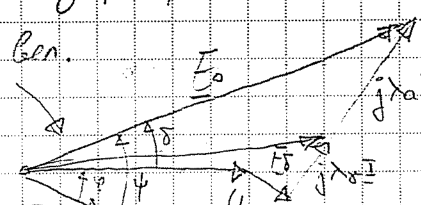
X_γ - реакт. рас.

X_s - синхр. реакт.

R - акт. отп. инд.

Векторски дијаграм ТГ:

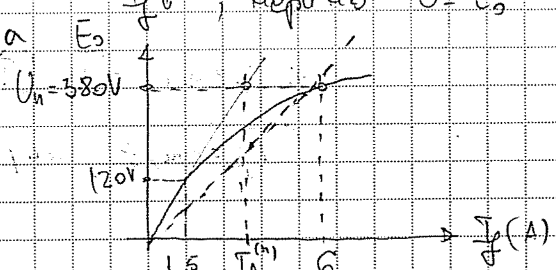
* фазне вел.



Одређивање X_s:

1° ПХ

$I_f \uparrow$, нерично $U = E_0$



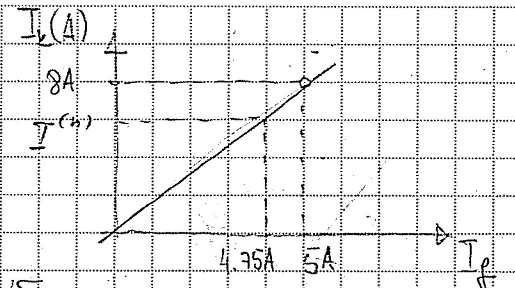
* фазне стр. лин. напони

$$I_f^{(n)} = \frac{380}{120} \cdot 1.5 = 4.75A$$

* за ПХ. 1. к-ка U_{nom} у незас.

* Фазне / линијске ?

2° КС



$I^{(n)} = \frac{8}{5} \cdot 4.75 = 7.6A$

$*\ n \approx n_s$

$X_s = \frac{U_n/\sqrt{3}}{I_k}$

$I_f^{(z)} = 6A$ (380V у пх, засићена)

$X_s^{(n)} = \frac{380/\sqrt{3}}{7.6} = 28.867\,\Omega$ ← незас.

$X_s^{(z)} = \frac{380/\sqrt{3}}{\frac{8}{5} \cdot 6} = 22.854\,\Omega$ ← зас.

(6 ↑ $I_f^{(z)}$)

} одступање

Релативне: $x_s = \frac{X_s}{Z_B}$; $Z_B = \frac{U_B}{I_B} = \frac{U_n/\sqrt{3}}{I_n} = 27.424\,\Omega$

$x_s^{(n)} = 1.0526$ р.ј. (105.26 %)

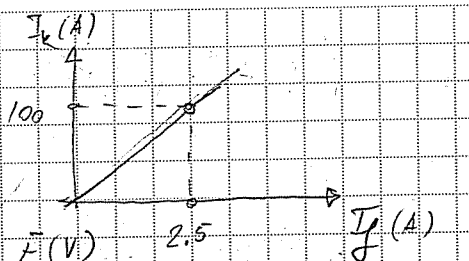
$x_s^{(z)} = 0.8333$ р.ј. (83.33 %)

$\boxed{OKS} = \frac{1}{x_s^{(z)}} = \frac{I_f^{(z)}}{I_f|_{I_{kn}}} = \frac{6}{5} = 1.2$ (однос КС; коеф. засићења) ← није исто

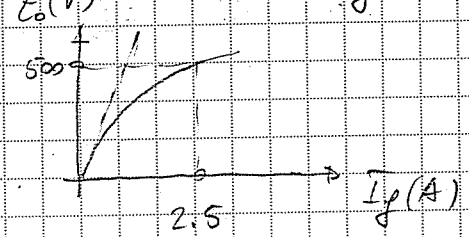
→ У пракси се своди на незас. уколико се не нагласи otherwise.

(16) 1f SG

ХС:



ПХ:



E_0 - ?
ΔU - ?
$I = 100A$, $U = 2000V$

а) $\cos\varphi = 1$ б) $\cos\varphi = 0.8$ (ind) в) $\cos\varphi = 0.707$ (cap)

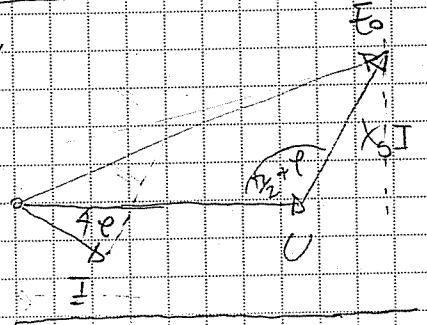
$\underline{U} = U\angle 0°$

$$\underline{E_0} = \underline{U} + jX_s\underline{I} = U + jX_s(I\cos\varphi - jI\sin\varphi) =$$

$$= \underbrace{U + X_s I\sin\varphi}_{R_e} + j\underbrace{X_s I\cos\varphi}_{I_m}$$

* ind: $\varphi > 0$
cap: $\varphi < 0$

* Ипи (cos) шеорема:



$$E_0 = \sqrt{U^2 + (X_s I)^2 + 2UIX_s\sin\varphi}$$

$$X_s = \frac{U_n}{I_k} = \frac{500}{100} = 5\Omega$$ на 1 ф

$R = 0$

* 1f машина → $\sqrt{3}$ без

(*) Фазорске дијаграме ми Надрешај за сваки решени

$U = 2000V$ и $I = 100A$

а) $E_0 = \sqrt{U^2 + (X_s I)^2} = 2062V$ ⇒ $\Delta U = \frac{E_0 - U}{U} \cdot 100 = 3.08\%$

б) $E_0 = 2335V$ ⇒ $\Delta u = \frac{E_0 - U}{U} \cdot 100 = 16.73\%$

$\sin\varphi = 0.6$

ф) $\sin\varphi = -0.707 \Rightarrow E_0 = \underline{1684\,V}$; $\eta = \underline{-15.8\,\%}$

(17) (2) ; 6.3 kV

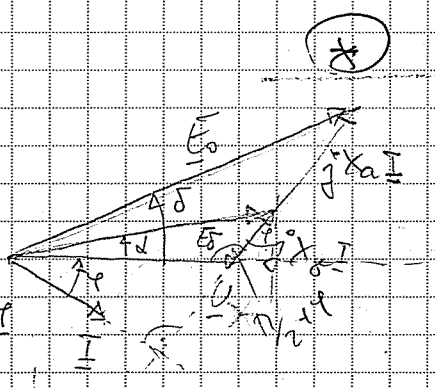
$I = 250\,A$, $\cos\varphi = 0.85$ (ind)

$E_\delta = 7\,kV$

a) $\measuredangle(\underline{E}_\delta, \underline{U}) = ?$ $X_s = ?$

б) $E_\delta = ?$ → I исчо , $\cos\varphi = 1$

(1) Фазорни диаграми:



* $\underline{E}_\delta = E_\delta \angle\alpha$; $\underline{U} = U\angle 0°$; $\underline{I} = I\angle -\varphi$

→ $\underline{E}_\delta = \underline{U} + jX_\delta \underline{I}$

$E_\delta \cos\alpha = U + X_\delta I \sin\varphi$ | · cosφ

$E_\delta \sin\alpha = X_\delta I \cos\varphi$ | · (−sinφ)

$E_\delta(\cos\alpha\cos\varphi - \sin\alpha\sin\varphi) = U\cos\varphi$

$E_\delta \cos(\alpha+\varphi) = U\cos\varphi \rightarrow \alpha = \arccos\frac{U\cos\varphi}{E_\delta} - \varphi$

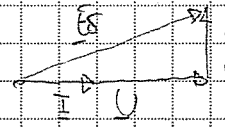
$\measuredangle 7000/\sqrt{3} \rightarrow$ ФАЗНО

$\boxed{\alpha = 8.3°}$

$X_\delta = ?$ → $X_\delta = \frac{E_\delta \sin\alpha}{I\cos\varphi} = \underline{2.745\,\Omega}$ (ФАЗНО)

→ Cos теорема (II начин)

б) $\cos\varphi = 1$ → $\underline{E}_\delta = \underline{U} + jX_\delta \underline{I} = \frac{6300}{\sqrt{3}} + j\,2.745 \cdot 250$ (ФАЗНО)



$E_\delta = \sqrt{U^2 + (X_\delta I)^2} = 3701.5\,V$

$E_{\delta лин} = E_\delta\sqrt{3} = \underline{6411.2\,V}$

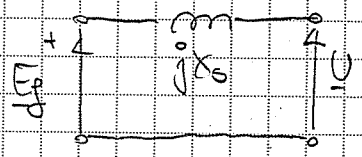
(18) TG, 2500 kVA, 6600 V, $X_s = 10.4\,\Omega$ (4)

$S = S_n$, $\cos\varphi = 0.8$ (ind) ∧ $\cos\varphi = 0.8$ (cap)

a) FR = ?

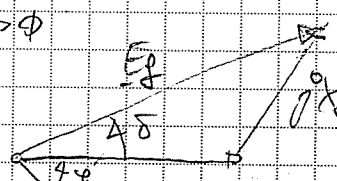
$$U_{nf} = \frac{U_n}{\sqrt{3}} = 3810.51\ V$$

$$I_{nf} = I_n = \frac{S_n}{\sqrt{3}U_n} = 218.69\ A$$



$\cos\varphi = 0.8$ (ind)

* $\varphi > \Phi$



* $R \simeq 0$

$\underline{U} = U\angle 0^\circ = U_{nf}$

ΦΑΘΟ

$$\underline{E_f} = \underline{U} + jX_s\underline{I} = U + jX_s I(\cos\varphi - j\sin\varphi)$$

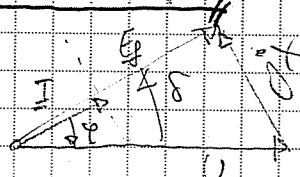
$$\underline{E_f} = 5175.14 + j\,1819.5 = 5485.68\angle 19.37^\circ\ V$$

$$\delta = 19.37^\circ$$

$$FR = \frac{E_f - U}{U} = 0.44$$ ← φακτωρ ρεγκαγιέ

$\cos\varphi = 0.8$ (cap)

* $\varphi < \Phi$ (cap)



$$\underline{E_f} = U + jX_s(I\cos\varphi - jI\sin\varphi) =$$

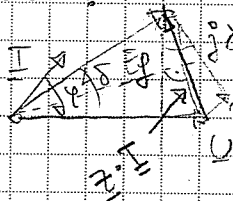
$$= 2445.89 + j\,1819.5 = 3048.4\angle 36.6^\circ\ V$$

$$FR = \frac{E_f - U}{U} = -0.2$$

δ) $FR = 0$; $S = S_n \Rightarrow I = I_n$; $|\underline{E_f}| = |\underline{U}| = 6600/\sqrt{3}\ V$

$\cos\varphi = ?$

* $R = 0.071\,\Omega$



$$|\underline{Z}|\cdot I/2 = U\sin(\delta/2) \Rightarrow \delta = 34.73^\circ$$

$|\underline{Z}| = \sqrt{10.4^2 + 0.071^2}$; $\underline{Z}\cdot\underline{I} = |Z|\cdot I\ \angle\arg(\underline{Z}) - \varphi$

$$\underline{E_f} = E_f\cos\delta + jE_f\sin\delta = U + (R + jX_s)(I\cos\varphi - jI\sin\varphi)$$

$\arg(\underline{Z}) = \operatorname{arctg}\frac{X_s}{R} = \underline{89.6^\circ}$

$\underline{E_f}\cos\delta + j\underline{E_f}\sin\delta = U + \underline{Z}\underline{I}\left(\cos(89.6-\varphi) + j\sin(89.6-\varphi)\right)$

$3151.65 = 3810.5 + 2274.38\cos(89.6^\circ - \varphi)$

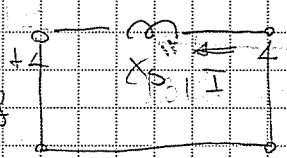
$\Downarrow$

$\underline{\varphi = -17.47^\circ} \Rightarrow \underline{\cos\varphi = 0.9523 \text{ (cap)}}$

(19) 1500kW, $\cos\varphi = 1$, 2300V, 60Hz, (Y) $2p = 30$

$X_s = 1.95\ \Omega/\text{faza}$ * MOTOR

a) $\mu_{max} = ?$ 2300V, 60Hz, $I_f = ct$, $\cos\varphi = 1$



Rețea $\cos\varphi = 1$, $P = S$ (altfel $P/\cos\varphi$)

$\underline{I} = P/\sqrt{3}U_n = \underline{376.53A}$

$U = U_{fn} = 2300/\sqrt{3} = \underline{1327.9V}$

$\underline{E_f} = U - j\underline{X_s}\,\underline{I} = 1327.9 - j\,734.23 = \underline{1517.37\ \angle -28.94^\circ}$ V

$\delta = \underline{-28.94^\circ}$

* Fără grijă față de rețea

$P_{motor} = \frac{3 \cdot E_f \cdot U}{X_s}\sin\delta \rightarrow P_{max} = P(\delta = 90^\circ)$ *

$P_{max} = \frac{3E_f U}{X_s} = \underline{3099.87\ kW}$

$\mu_{max} = \frac{P_{max}}{\Omega_s} = \frac{P_{max}}{2\pi f/p} = \underline{123.34\ kNm}$

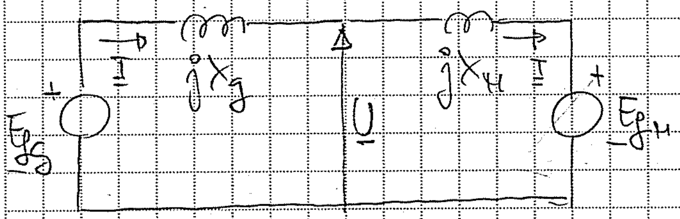
b) $2 = 3$ $2p = 2$ 2300V 1250kVA 3600 o/min (60Hz)

$X_s = 2.65\ \Omega$; $n = n_s$; $\cos\varphi_n = 1$, $P = P_{max}$, $U = U_{max}$

$\underline{T_{fn}}$, $\underline{T_{fG}} \rightarrow \underline{\text{CONST}}$ MT; $M_{max} = ?$

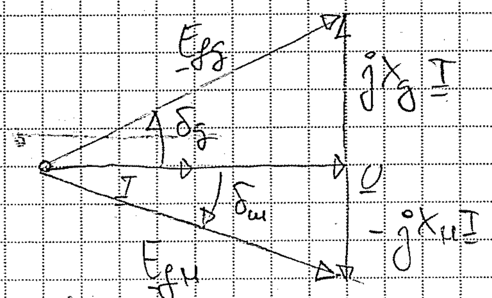
$U_M(M_{max}) = ?$

Генератор = мрежа за напајање !



$P_M = S_M = 1500\ kW$

$I = I_n = 376.53\ A$



* $\cos\varphi$ → у односу на $\underline{U}$?

$U = U_{fn} = 1327.9\ V$

$\underline{E}_{fg} = 1327.9 + j2.65 \cdot 376.53 = 1661\angle 36.92^\circ\ V$

$\underline{E}_{fM} = 1327.9 - j1.95 \cdot 376.53 = 1517.37\angle -28.94^\circ\ V$ (прошли пример)

* $E_{fg} = const$ * $E_{fM} = const$ * $U \neq const$ (мотор се више не напаја из круте мреже !)

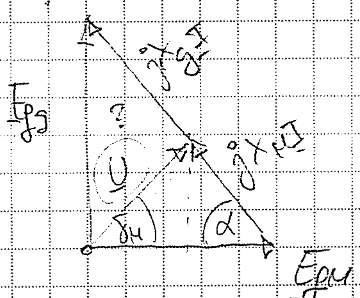
усв. → φ

$$P = 3\frac{E_{fg}E_{fM}}{X_g + X_M}\sin(\delta_g + \delta_M)$$

$$P_{max} = P\Big|_{\delta_M + \delta_g = 90^\circ} = \frac{3E_{fg}E_{fM}}{X_g + X_M} = 1643.71\ kW$$

$$M_{max\ мот} = \frac{P_{max}}{\Omega_M} = 65.4\ kNm$$

$2p = 39$?



$$(X_g + X_M)I = \sqrt{E_{fg}^2 + E_{fM}^2} = 2249.74\ V$$

$$X_M I = X_M/(X_M + X_g) \cdot 2249.74 = 953.69\ V$$

$$U^2 = E_{fM}^2 + (X_M I)^2 - 2(X_M I)E_{fM}\cos\alpha; \quad \cos\alpha = \frac{E_{fM}}{(X_M + X_g)I}$$

$$U^2 = E_{fM}^2 + (X_M I)^2 - 2\frac{X_M}{X_M + X_g}E_{fM}^2 \Rightarrow U = 1122.5\ V\ (фазни)$$

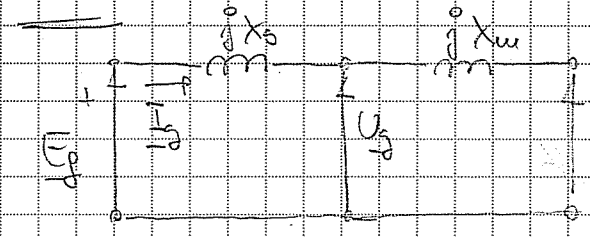
IV термин 18.03.2013.

(20) 600 MVA, 24 kV, 60 Hz, $X_s = 1.67\,\Omega$

систем 24 kV, $X_w = 0.24\,\Omega$; $U_g = \text{const} = 24\,kV$

а) $S = 300\,MVA$; фаз. дијаграм, $I_g = ?$, $\gamma_g = ?$, $E_g = ?$

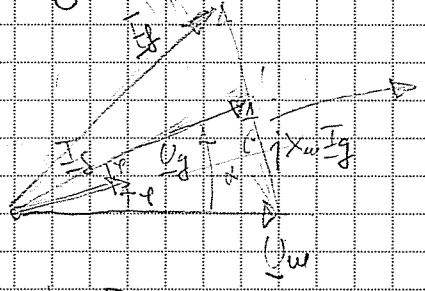
б) $S = 600\,MVA$ — " — " — " — " —

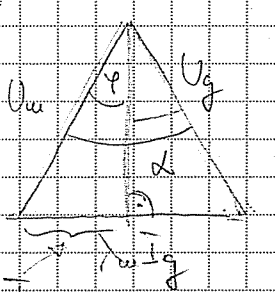


$$\underline{U}_g = \underline{U}_w + j X_w \underline{I}_g$$

$$\underline{E}_g = \underline{U}_w + j(X_w + X_s)\underline{I}_g$$

* услов задатка: $|\underline{U}_w| = |\underline{U}_g| = 24\,kV$





$\varphi = \alpha/2$

$$\varphi = \arcsin \frac{X_w I_g}{2U_w} \rightarrow \frac{24\cdot 10^3}{\sqrt{3}} *$$

$$\underline{I_g} = \frac{S}{\sqrt{3}U} = \frac{300\cdot 10^6}{\sqrt{3}\cdot 24\cdot 10^3} = \underline{7216.88\,A} \Rightarrow \underline{\varphi = -3.58^\circ} \rightarrow \underline{I_g} = \dots$$

$\cos\varphi = 0.998$ (ind)

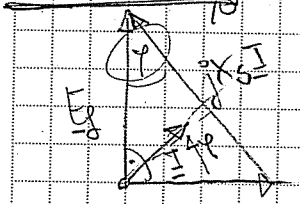
$$\underline{E}_g = \underline{U}_w + j(X_w + X_s)\underline{I}_g = \frac{24\cdot 10^3}{\sqrt{3}} + j\,1.91 \times 7216.88\,\underline{/-3.58^\circ} =$$

$$= (12995. + j\,13257)\,V = \underline{(18924.91\,\underline{/46.63^\circ})\,V}$$

б) задатак: $\varphi = -7.18^\circ \rightarrow \cos\varphi = 0.992$ (ind)

$$\underline{E}_g = (29262.4\,\underline{/69.16^\circ})\,V$$

Задача 21



$$\dot{E}_f = \dot{U} + jX_s\dot{I}$$

$$j361.15 = 220 + j22.92\,\dot{I}$$

$$\dot{I} = \frac{j361.15 - 220}{j22.92} = (15.76 + j9.6)\ A$$

$$\boxed{\dot{I} = 18.45\,\angle 31.35^\circ\ A}$$

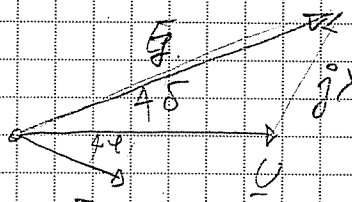
$$\cos\varphi = \frac{E_f}{\dot{I}} = 0.85\ (cap) \quad (\cos 31.35^\circ)$$

(21) ПХ: $U = U_n = 220V \rightarrow I_f = 6A$

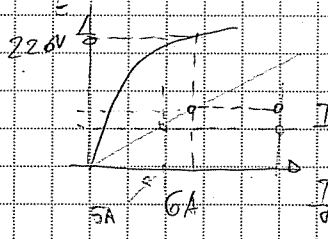
КС: $I = I_n = 8A \rightarrow I_f = 5A$

$U = U_n$ (све величине су ФАЗНЕ, јер је машина 1Φ)

а) $\cos\varphi = 0.8$ (ind)



$E_f > U \rightarrow$ НАДОБУЂЕНА машина (инд. режим, $Q > \Phi$)



← ПОДСЕТИ ПХ

обавезно овако УВЕК

$$X_s = \frac{U_n}{I_k} = \frac{U_n}{\frac{6}{5} I_n} = \frac{U_n}{I_k(I_{fn})} = 22.92\,\Omega$$

$$\underline{E_f} = \underline{U_n} + j X_s \underline{I_n} = 220\angle 0^\circ + j 22.92 \cdot 8 (\underbrace{\cos\varphi}_{0.8} - j \underbrace{\sin\varphi}_{0.6}) =$$

$$= 361.15\angle 24^\circ \; V$$

Машина се врећира као НЕЗАСИЋЕНА → линеарна к-ка ПХ

↳ наћласа да ово није сасвим прецизно!

$$\frac{E_f}{I_{fx}} = \frac{U_n}{I_{fn}} \Rightarrow \frac{E_f}{I_{fx}} = \frac{220}{6} \Rightarrow I_{fx} = \frac{E_f \cdot 6}{220} = \frac{361.15 \cdot 6}{220} = 9.85A$$

б) Извести израз за једначину к-ку ($S = 3 \cdot U \cdot I^*$) ТГ...

$$P = \frac{3 E_f U}{X_s} \cdot \sin\delta \leftarrow \text{ТГ}$$

$$P_{max} = P(\delta = 90^\circ) = \frac{220 \cdot 361.15}{22.92} = 3.47\,kW$$

↓ 1Φ → (X1)

→ наставак

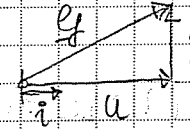
(22) $S_n = 60\,MVA$; $U_n = 13.2\,kV$; $x_s = 1.2$ r. j.

$P_T = 50\,MW$; $\cos\varphi = 1$ $\quad \varphi_{sub} \approx 0$

$p = \frac{P}{S_n} = \frac{50}{60} = 0.833$ r. j.

$U = 1$ r. j. $\quad$ ** реп. јединице → НЕМА ТРОУГЛЕ

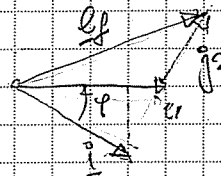
$p = U i \cos\varphi \Rightarrow i = \frac{p}{U} = 0.833$ r. j.



$\underline{e_g} = U + j x_s \underline{i} = 1 + j\,1.2 \cdot 0.833 = \underline{1.41\,\angle 45^\circ}$

a) $|\underline{i}| = 1$ $\quad p = 0.833 = const \Rightarrow U \cdot i \cos\varphi_{ind} = 1 \cdot 1 \cdot \cos\varphi_{ind} = 0.833$

$\varphi_{ind} = 33.59^\circ \Rightarrow \underline{i} = 1\,\angle -33.59^\circ = (0.833 - j\,0.553)$ r. j.

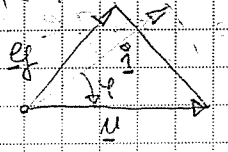


$\underline{e_g}^{ind} = U + j x_s \underline{i} = 1.664 + j\,0.9996 =$

$= \underline{1.94\,\angle 31^\circ}$ r. j.

б) $|\underline{i}| = 1$ $\quad \cos\varphi_{cap} = 0.833 \rightarrow \varphi_{cap} = -33.59^\circ$

$\underline{i} = (0.833 + j\,0.553)$ r. j.



$\underline{e_g}^{cap} = U + j x_s \underline{i} = 0.3364 + j\,0.9996 = \underline{1.055\,\angle 71.4^\circ}$ r. j.

$L_{ind} = \frac{e_g^{ind}}{e_g^{\circ}} = \underline{1.376\,H} \left(= \frac{i_f^{ind}}{i_f^{\circ}} \right)$; $L_{cap} = \frac{e_g^{cap}}{e_g^{\circ}} = \underline{0.748\,H} \left(= \frac{i_f^{cap}}{i_f^{\circ}} \right)$

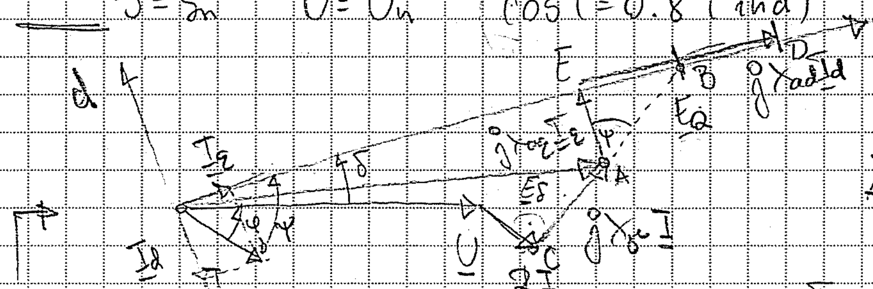
(*) Претпоставка: машина незасићена, ems ~ струји

(23) $x_d = 1$ r.j. $\quad x_q = 0.6$ r.j. $\quad R_a \approx 0$

$e_f = ?$

$S = S_n \quad U = U_n \quad \cos\varphi = 0.8$ (ind)

* изведи ако стигнем



$$\overline{AB} = \frac{X_{aq} \underline{I}_q}{\cos\varphi}, \quad \underline{I}_q = \underline{I}\cos\varphi \quad \Big\} \quad \overline{AB} = X_{aq} \underline{I}$$

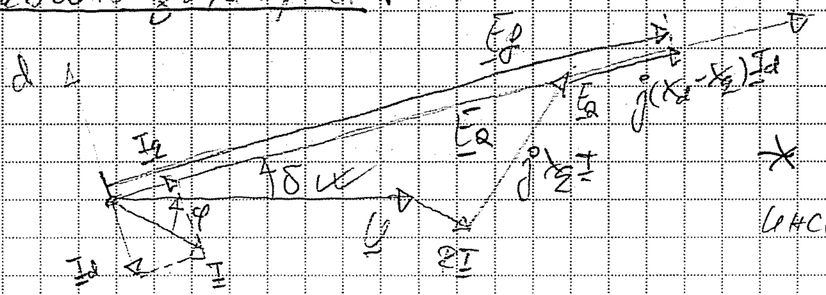
* мод. Блонделов дијаграм?

$$\overline{CA} = X_\gamma \underline{I}$$

$$CA + AB = CB = X_\gamma \underline{I} + X_{aq} \underline{I} = X_q \underline{I}$$

$$\overline{BE} = X_{aq} \underline{I} \cdot \operatorname{tg}\varphi = X_{aq} \underline{I}_d, \quad \overline{DE} = X_{ad} \underline{I}_d \quad \Rightarrow \quad \overline{BD} = (X_{ad} - X_{aq}) \underline{I}_d = (X_d - X_q) \underline{I}_d$$

Модификовани дијаграм:



* фора → инсистант кб?

$$\underline{E}_f = \underline{U} + R\underline{I} + \underline{j} X_\gamma \underline{I} + \underline{j} X_{aq} \underline{I}_q + \underline{j} X_{ad} \underline{I}_d$$

$$\underline{E}_Q = \underline{U} + R\underline{I} \,(\to 0) + \underline{j} X_q \underline{I} \rightarrow e_Q = 1 + j0.6 \cdot (0.8 - j0.6) = 1.442\angle 19.4^\circ$$

* $|\underline{i}| = \frac{s}{u} = 1; \quad \underline{i} = i\cos\varphi - j i \sin\varphi = 0.8 - j0.6 \qquad \delta = 19.4^\circ$

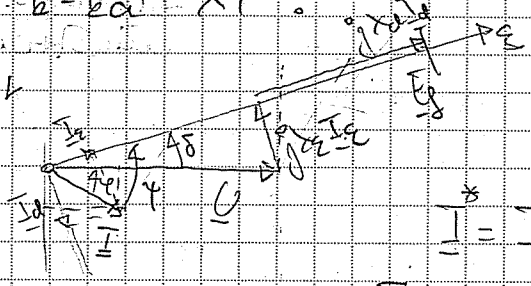
$i\sin(\delta+\varphi)$ — овај угао

$$\underline{e}_f = \underline{e}_Q + \underline{j}(x_d - x_q) i_d \Rightarrow |e_f| = e_Q + (x_d - x_q) i_d = 1.77 \text{ r.j.}$$

Теоријски део →

(24) 3 MVA, 2300 V, (Y), 60 Hz, 2p = 24, $R_s \approx 0$, $X_d = 1.8\,\Omega$, $X_\ell = 1\,\Omega$

* Уласна к-ка: ХГ:



$$\underline{S} = 3\underline{U}\cdot\underline{I}^*, \quad \underline{U} = U\angle 0°$$

$$\underline{I}^* = I\cos\varphi + j\,I\sin\varphi$$

$$I\cos\varphi = I_q\cos\delta + I_d\sin\delta$$

$$I\sin\varphi = I_d\cos\delta - I_q\sin\delta$$

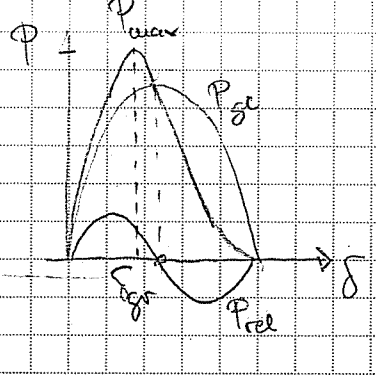
(+) ако је на (−) делу d-осе

$$E_{q0} = U\cos\delta + X_d I_d \rightarrow I_d = \frac{E_{q0} - U\cos\delta}{X_d}$$

$$\Phi = U\sin\delta - X_\ell I_\ell \rightarrow I_q = \frac{U\sin\delta}{X_q}$$

$$P = 3UI\cos\varphi = 3\cdot U\cdot\left[I_q\cos\delta + I_d\sin\delta\right] = 3\cdot U\cdot\left[\frac{E_{q0} - U\cos\delta}{X_d}\sin\delta + \frac{U\sin\delta}{X_q}\cos\delta\right] =$$

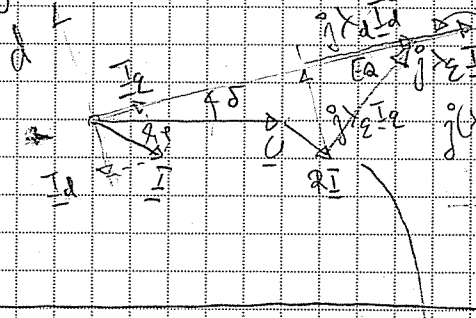
$$= \underbrace{\frac{3E_{q0}U}{X_d}\sin\delta}_{\text{главни члан}} + \underbrace{\frac{3}{2}U^2\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta}_{\text{реактивна снага; постоји и у необухваћеном режиму; последица анизотропности ротора}}$$



* Инд. оптерећење: $E > U$; машина надбуђена; реакција индукта делује супротно од тока ротора, тј. да демагнетише машину → потребна већа побуда како би се компензовала реакција индукта.

* Кап. оптерећење: све супротно.

* Упрошћени Блондељов дијаграм:



$$\underline{E}_p = \underline{U} + R\underline{I} + jX_d(\underline{I}_d + \underline{I}_q) + jX_{aq}\underline{I}_q + jX_{ad}\underline{I}_d =$$

$$= \underline{U} + R\underline{I} + jX_q\underline{I}_q + jX_d\underline{I}_d$$

---

(24) (Наставак)

a) $\cos\varphi = 0.8$ (ind)

$S = S_n \Rightarrow \underline{I}_n = \frac{S_n}{\sqrt{3}U_n} = \underline{753.06\,A}$; $U_f = \frac{U_n}{\sqrt{3}} = \underline{1327.91\,V}$

$\delta = ?^\circ \rightarrow \underline{E}_Q = \underline{U} + jX_q\underline{I}(\cos\varphi - j\sin\varphi) = 1941.52\,\angle 19.96^\circ\ V$

$+0.6$

$\varphi = +36.87^\circ$ (ind, $> \Phi$)

$\boxed{\delta = 19.96^\circ}$

$\underline{E}_p = ?$

$|\underline{E}_p| = |\underline{E}_Q| + (X_d - X_q)I_d = \boxed{2382.77\,V}$

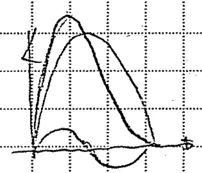
$I_d = I\sin(\delta + \varphi) = \underline{630.35\,A}$; $I_q = I\cos(\delta + \varphi) = \underline{412.02\,A}$

уск. $> \Phi$ јер је на $\ominus$ осу d-осе

б) * ако ниси извео, изведи сад ! (ЈЕ) * $E_g = const$!

$$P = \frac{3E_gU}{X_d}\sin\delta + \frac{3U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\cdot\sin 2\delta$$ ← маш. са ист. половима

P_{max} - ?



$$\frac{dP}{d\delta} = 0 \Rightarrow \underbrace{\frac{3E_gU}{X_d}}_{5273506.85}\cos\delta + \underbrace{3U^2\left(\frac{1}{X_q} - \frac{1}{X_d}\right)}_{1870214.36}\underbrace{\cos 2\delta}_{2\cos^2\delta - 1} = 0$$

$$3740428.72\cos^2\delta + 5273506.85\cos\delta - 1870214.36 = 0$$

⇓

$\cos\delta = 0.2935$ ∨ ~~$\cos\delta = -1.703$~~

⇓

$\delta_{max} = 72.932°$

⇓

$$P_{max} = P(\delta_{max}) = \frac{3E_gU}{X_d}\sin\delta_{max} + \frac{3U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta_{max}$$

$$P_{max} \cong 5566\ kW$$

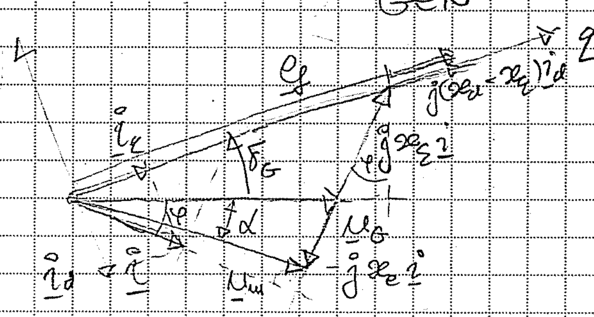
$$M_{max} = \frac{P_{max}}{\Omega} = \frac{P_{max}}{2\pi f / p}$$

$$M_{max} \cong 175\ kNm$$

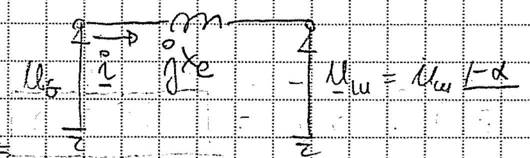
(25) $q = 3$, $X_d = 180\%$, $X_q = 165\%$

$U = U_n$, $X_e = 12\%$, $S = \frac{S_n}{4}$, $\cos\varphi = 0.95$ (ind) ← GEN!

a)



б) $|\underline{u}_M| = 1$



[ово може да и није неопходно]

* угаона к-ка: $p = u_G \, i \cos\varphi = 0.95$ ← услов зад!

$p = \frac{u_G u_M}{x_e} \sin\alpha$ ← нема 3! (р.ч.)

$\underline{u}_M = u_G - j x_e \, i (\cos\varphi - j \sin\varphi)$

$i = \frac{S}{u_G} = \frac{1}{u_G}$ * $\sin\varphi = 0.3122$

$|\underline{u}_M|^2 = \left(u_G - \frac{1}{u_G} x_e \sin\varphi\right)^2 + \left(\frac{1}{u_G} \cdot x_e \cos\varphi\right)^2$

$1 = u_G^2 - 2 x_e \sin\varphi + x_e^2 \cdot \frac{1}{u_G^2}$

$u_G^4 - (1 + 2 x_e \sin\varphi) u_G^2 + x_e^2 = 0$

$u_G^4 - 1.075 \, u_G^2 + 0.0144 = 0 \Rightarrow u_G^2 = 1.0614$

$\boxed{u_G = 1.03 \text{ r.j.}}$

$\Downarrow$

$i = \frac{1}{u_G} = \underline{0.97 \text{ r.j.}}$

$\underline{e}' = u_G + j x_q \underline{i} = 1.03 + j1.65 \cdot 0.97 (0.95 - j0.3122)$

$\underline{e}' = 2.16 \angle 44.83^\circ \Rightarrow \boxed{\delta_G = 44.83^\circ}$

* Из угаоне к-ке: $p = 0.95 = \frac{U_G U_M}{x_e} \sin\alpha \Rightarrow \alpha = 6.35°$

нема губ. P

угао изм. нап. (G) и (M)

* Угао изм. емс и напона мреже: $\delta_M = \delta_G + \alpha = 51.18°$

g) $U_G = 1.03$ r.j.

$e_q = e' + (x_d - x_q) i_d$

$i_d = i \sin(\delta_G + \varphi) = 0.864$

$\delta_G = 44.83°$, $\varphi = 18.195°$

$e_q = 2.16 + (1.8 - 1.65)\cdot 0.864 = 2.29$ r.j.

* За базни напон усвојен је напон мреже

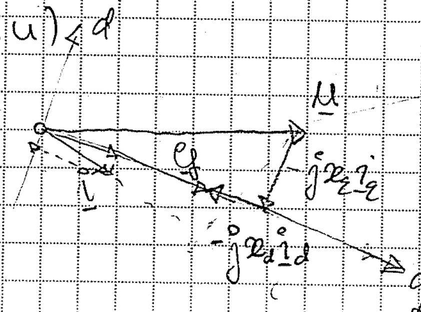
V

(26) $P_{max} = ?$ (p.u) (M) $U = U_n \Rightarrow U = 1$ r.j.; $x_d = 0.85$; $x_q = 0.6$

08.04.'13. $i = ?$ (p.u)

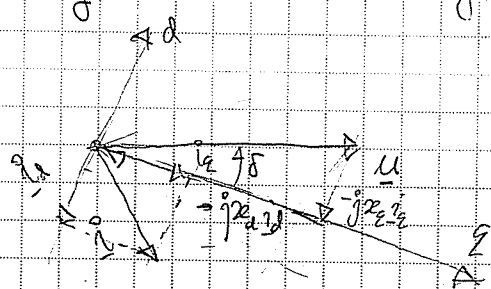
$r \approx 0$

мотор:



$e_q = U - jx_q i_q - jx_d i_d \; (-ri)$, $ri \approx 0$

Непобуђен → $e_q = 0$: $U = jx_q i_q + jx_d i_d$



$P = \frac{e_q U}{x_d}\sin\delta + \frac{U^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right)\sin 2\delta$

трење без

$P_{max} = P(\delta = 45°) = \frac{U^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right)$

$P_{max} = 0.245$ r.j.

$\mathring{i} = ?$

$u\cos\delta = x_d \mathring{i}_d \Rightarrow \mathring{i}_d = \frac{u\cos\delta}{x_d} = 0.832$ р.ј.

$u\sin\delta = x_q \mathring{i}_q \Rightarrow \mathring{i}_q = \frac{u\sin\delta}{x_q} = 1.18$ р.ј.

$\mathring{i} = \sqrt{\mathring{i}_d^2 + \mathring{i}_q^2} = 1.443$ р.ј.

---

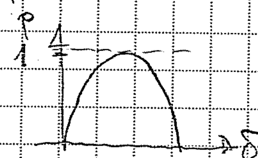
(27) $X_s = 85\%$ $e_{gmin} = ? \rightarrow p = p_{nom}$

* МОТОР: ном. опт. <=> ном. АКТ. СНАГА

$p = 1 \Rightarrow \frac{e_g u}{x_s} \sin\delta = 1$

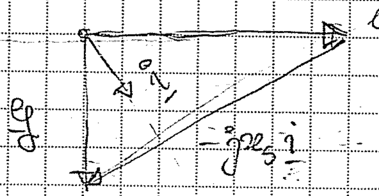
$e_{gmin} \rightarrow$ добија се ако је $p = p_{max} \Rightarrow \delta = 90°$

$p = p_{max} = 1 = \frac{e_g u}{x_s} \cdot \sin 90 \rightarrow 1$



$e_{gmin} = \frac{p \cdot x_s}{u} = 0.85$ р.ј. $\Rightarrow$ $\mathring{i}_g = 0.85$ р.ј.

Дијаграм:



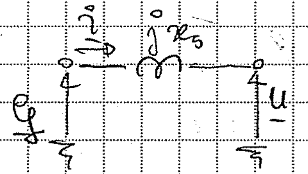
(јер је при $I_g = I_{gnom}$ $E_p = U_{nom}$, ит. 1 р.и)

*обл. шта је ном. поб. стр, овако није добро

(28) $x_s = 2$ r.j. * $u = 1$ r.j.

δ, $\cos\varphi$, p, q = ?

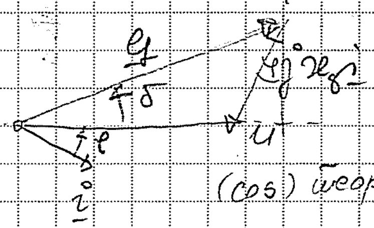
a) (G) $e_g = 2.5$ $i = 0.9$



$u + j x_s i = e_g$

$u + x_s i \sin\varphi + j x_s i \cos\varphi = e_g$

$|e_g|^2 = (u + x_s i \sin\varphi)^2 + (x_s i \cos\varphi)^2$



(cos) теорема: $2.5^2 = u^2 + (x_s i)^2 + 2 u x_s i \sin\varphi$

$2.5^2 = 1^2 + (2\cdot 0.9)^2 + 2\cdot 2\cdot 0.9 \sin\varphi$

⇓

$\sin\varphi = 0.558 \Rightarrow \varphi = 33.94^\circ$

⇓

$\cos\varphi = 0.83$ //

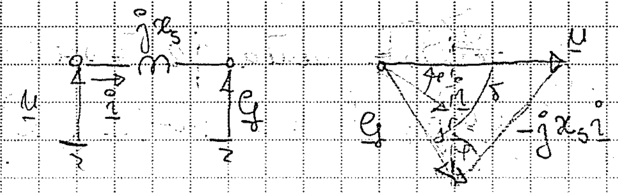
$x_s i \cos\varphi = e_g \sin\delta$

⇓

$\delta = 36.69^\circ$ //

$p = ui\cos\varphi = 0.747$ r.j. //

$q = ui\sin\varphi = 0.502$ r.j. //

б) 

* (cos) теорема:

$(x_s i)^2 = e_g^2 + u^2 - 2e_g u \cos\delta$

$\delta = 64.59^\circ$ // (-64.59°)

$e_g \sin\delta = x_s i \cos\varphi \Rightarrow \cos\varphi = 0.988$ //

$\varphi = 8.91^\circ$

$p = ui\cos\varphi = 0.792$ r.j. //

$q = ui\sin\varphi = 0.124$ r.j. //

* знаци у одн. на „моторне" смерове → (+) ако је смер из мреже ка машини

в) (G) - производи q

(M) - троши q

г) (G) јесте } (M) није } уради за $\varphi = 0^\circ$

(29) $2p = 6$ (Y) $U_n = 380\ V$, $f = 50\ Hz$, $X_s = 0.8\ \Omega$

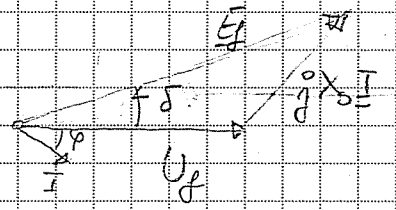
$S = 80\ kVA$; $M_T = 392\ Nm$.

а) E_f, δ, M_{max} - ?

$M_T = 392\ Nm \Rightarrow P_T = M_T \cdot \Omega_s = M_T \cdot \frac{2\pi f}{p} = 41.05\ kW \Rightarrow P = 41.05\ kW$

$\cos\varphi = \frac{P}{S} = 0.5131$ (ind) $\Rightarrow \varphi = +59.13°$

$I = \frac{S}{\sqrt{3}U_n} = 121.55\ A$



$380/\sqrt{3}$

ФАЗНА!

$\underline{E_f} = \underline{U_f} + j\underline{X_s}\underline{I} = \frac{380}{\sqrt{3}} + j0.8 \cdot 121.55 \cdot (0.5131 - j0.8583) = 306.94\angle 9.355°\ V$

$\delta = 9.355°$

$M_{max} = \frac{P_{max}}{\Omega} = \frac{P|_{\delta=90°}}{\Omega} = \frac{\frac{3E_f U}{X_s}}{\Omega} \approx 2412.5\ Nm$

б) $\cos\varphi_d = 0.8943$; $P_d = 135.8\ kW$

$\cos\varphi$; δ, M_T - ?

$U = const$; $E_f(I_f) = const$ * $P_{загуб} \approx \phi$

$P' = P + P_d = 176.85\ kW$
4

захійва крепна? (Const)

$Q_d = P_d \cdot tg\varphi_d = +67.94\ kVAr$ ← ПРЕТПОСТАВЯБЕНО ИНД. ОПТЕРЕТЯБЕ
4
$+26.58°$

$Q^1 = Q + Q_d = 68.67 + 67.94 = 136.61\ kVAr$

4 const P

$\underline{I} = \frac{P' - jQ'}{\sqrt{3}U_n} = (268.7 - j207.54)\ A$

$\underline{E_g}' = U + jX_s \underline{I}' = 441.32 \angle 29.15°\ V \Rightarrow E_g' \neq E_g \Rightarrow$ ОПТ. НЕ ИНДУКТИВНО

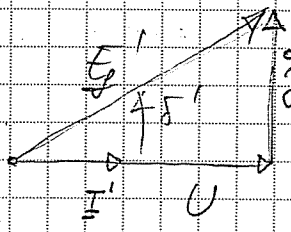
↓

АНАЛИТИЧНО ОПТЕРЕТЕНЕ:

$Q_d < \Phi \Rightarrow Q' = Q + Q_d = 68.67 + (-67.94) = 0.73\ kVAr$

$P' = 176.85\ kW$

$\underline{I}' = \frac{P' - jQ'}{\sqrt{3}U_n} = 268.7 + j1.11 \approx 268.7 \angle \varphi°\ A \Rightarrow \cos\varphi' \approx 1$



$\underline{E_g}' = U + jX_s \underline{I}' = \frac{380}{\sqrt{3}} + j0.8 \cdot 268.7 = 307.15 \angle 44.42°\ V$

* $E_g' \approx E_g$ ИЛИ

$\delta' = 44.42°$

$M_T' = \frac{P' \left(= P_T\right)}{\Omega} = \frac{176.85 \cdot 10^3}{2\pi \cdot 50/3} = 1688.8\ Nm$ ($= M_{max} \sin\delta \ldots$)

(30) HG ; $S_n = 90$ MVA

$N_f = 14$; $R_f = 0.002\ \Omega$

* $L_f(I_f) - ?$ $\quad \tau_f(I_f) - ?$

$F = N_f I_f \Rightarrow I_f = F/N_f$ ✓

$L_f = \frac{\Psi_f}{I_f} \cdot 10^3$; Ψ_f - флукс НАМОТАЈА (кроз све навојке)

$\Psi_f = N_f \cdot \Phi$

* L_f - сопствена инд. (мера флукса који спреже САМО сопствено намотаја кроз сопствене навојке)

$\tau_f = L_f / R_f$ [s] $\quad L_f = \frac{N_f^2 \Phi}{F} \cdot 10^3$ [mH]

I_f [A]	542.86	1064.3	1757.14	2414.3
L_f [mH]	6.96	6.31	4.70	3.71
τ_f [s]	3.48	3.16	2.35	1.86

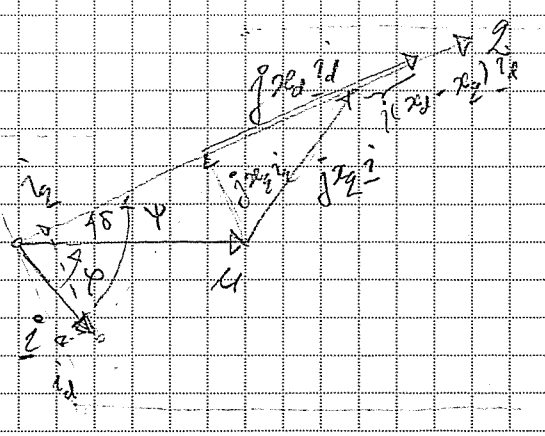
(31) $q = 3$ $\quad S_n = 10$ MVA $\quad U_n = 10.3$ kV $\quad 50$ Hz $\quad p = 10$

$\cos\varphi_n = 0.8$; $X_d = 100\%$; $X_q = 50\%$; $S = 7$ MVA ; $\varphi = 56.4°$

a) $E_0, \delta - ?$

$U = U_n \Rightarrow u = 1$ p.u.

$i = S/S_n = I/I_n = 0.7$ p.u.



$\dot{I}_q = \dot{I}\cos\gamma = 0.387$ р.е. $> \varphi$ * $\cos\varphi = \cos\varphi_н = 0.8$ (ind)

$\dot{I}_d = \dot{I}\sin\gamma = 0.583$ р.е. $> \varphi$

$U\sin\delta = x_q \dot{I}_q \Rightarrow \sin\delta = 0.1935 \Rightarrow \underline{\delta = 11.16^\circ}$

$e_0 = U\cos\delta + x_d \dot{I}_d = \underline{1.564 \text{ р.е.}} \Rightarrow E_0 = 1.564 \cdot \frac{10^3}{\sqrt{3}} = \underline{9.30 \text{ kV}}$

б) $k_{sн} - ?$ $\quad U_б = \frac{S_б}{\Omega_б} = \frac{S_н}{\Omega_н} = \frac{10 \cdot 10^6}{2\pi \cdot \frac{50}{10}} = 318.31 \text{ kNm}$

$k_{sн} = \frac{dM}{d\delta} = U_б \cdot \left[\frac{e_{qн}}{x_d} \cos\delta + U^2 \left(\frac{1}{x_q} - \frac{1}{x_d} \right) \cos 2\delta \right] = \underline{782.88 \text{ kNm/rad}}$

---

(32) $q = 3$ $\quad S_н = 150 \text{ kVA}$

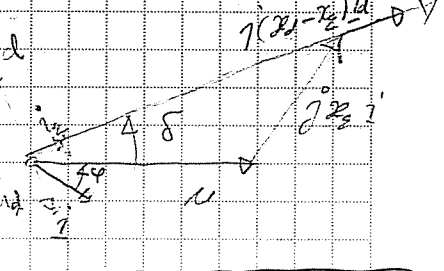
$x_d = 1.25$ р.е. $\quad x_q = 0.9$ р.е. $\quad p = 20$

$U = U_н$; $\cos\varphi_н = 0.8$ (ind) ; $S = S_н$

а) $k_{sp} = ?$ $\quad * k_{sp} = \frac{dP}{d\delta} = S_н \cdot \frac{dp}{d\delta} = S_н \left(\frac{e_{qн}}{x_d} \cos\delta + U^2 \left(\frac{1}{x_q} - \frac{1}{x_d} \right) \cos 2\delta \right)$

$\underline{e'} = U + j x_q \underline{\dot{I}} = 1 + j\,0.9 \cdot 1^\circ (0.8 - j\,0.6) = 1.54 + j\,0.72 =$

$= \underline{1.7 \angle 25.06^\circ \text{ р.е.}} \Rightarrow \underline{\delta = 25.06^\circ}$



36.87°

$e_p = e' + (x_d - x_q)\dot{I}_d = e' + (x_d - x_q)\dot{I}\sin(\delta + \varphi)$

$\underline{e_p = 2.0088 \text{ р.е.}}$

$k_{sp} = 150 \cdot 10^6 \cdot \underbrace{\frac{dp}{d\delta}}_{1.655} = \underline{248.29 \text{ MW/rad}}$

б) $k_{sн} = U_{нач} \cdot \frac{dM}{d\delta} = U_{нач} \cdot \frac{dP}{d\delta} = \frac{k_{sp}}{\Omega}$

$\underline{k_{sн} = 15.81 \text{ MNm/rad}}$

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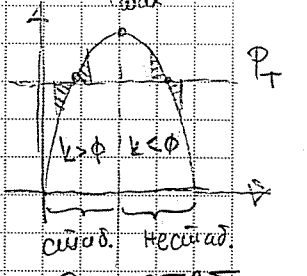
* $\Delta P = k_{sp} \cdot \Delta\delta$

$\Downarrow$

$f(\delta)$

$\Delta U = k_{sн} \Delta\delta$



* знак k_{sp} → крит. СТАТ. СТАБИЛЬНОСТИ

(33) (ТМ) 380V, 50Hz, $2p = 4$, (Y), $X_s = 1\Omega$ ___ МОТОР !

потпобуђен (ind; $Q > 0$), $M = 287$ Nm, $S = 82$ kVA

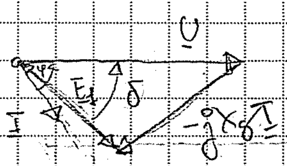
* $P_{gub} \approx 0$ УЗИМА Q из мреже; (+) смер снаге за (M) → из мреже!

a) $\cos\varphi$, Q - ?

P_{el} (el. snaga) $= P_{meh} \Rightarrow P = M \cdot \Omega = 287 \cdot \frac{2\pi \cdot 50}{2} = 45.08$ kW

$\cos\varphi = \frac{P}{S} = 0.5497$ (ind) (>0 => из мреже)

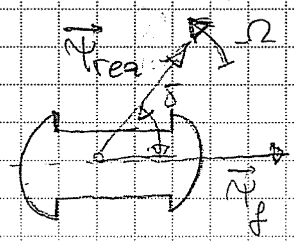
$\varphi = 56.65°$ (струја касни) $\Rightarrow Q = S \sin\varphi = 68.5$ kVAr



б) $\underline{I} = \frac{P - jQ}{\sqrt{3}U} = (68.49 - j104.07)$ A

$\underline{E}_f = \underline{U} - jX_s\underline{I} = \frac{380}{\sqrt{3}} - j1 \cdot (68.49 - j104.07) = 134.12\angle -30.71°$ V

$\delta_{el} = -30.71° \Rightarrow \delta_{meh} = \frac{\delta_{el}}{p} = -15.35°$



в) $M_{max} = \frac{P_{max}}{\Omega} = \frac{3 \cdot \frac{E_f U}{X_s}}{\Omega} \cdot \sin 90° \approx 562$ Nm у односу на дато оптерећење

$\nu \overset{def}{=} \frac{M_{max}}{M_{opt}} = \frac{562}{287} = 1.96$ (у датом режиму)

г) * Не мешати УГАО СНАГЕ (δ) и ФАКТОР СНАГЕ ($\cos\varphi$)!

$M'_{opt} = 145\ Nm$ // $\cos\varphi,\ \delta - ?$

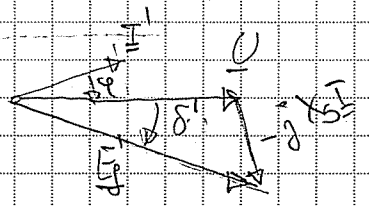
$E'_f = 2E_f = 268.24\ V$ ⇒ НАДПОБУЂЕН; очекујемо КАПАЦИТИВНУ СТРУЈУ!

$P' = M'_{opt} \cdot \Omega = 22.78\ kW$ // (зове Q пречи)

$P' = -\frac{3E'_f U}{X_s} \sin\delta' \Rightarrow \delta' = -7.41°$ // (МОТОР! $\delta < \Phi$)

$\underbrace{\quad}_{176.55\ kW}$

$\underline{I}' = \frac{-\underline{E}'_f + \underline{U}}{jX_s} = \frac{-E'_f(\cos\delta' + j\sin\delta') + U}{jX_s} =$



$= 58.04\angle 53.41°$ ⇒ $\varphi = 53.41°$ ($>\Phi$, кап)

⇓

$\cos\varphi = 0.596$ (cap) //

(34) 6600V, 400kVA, $X_s = 100\ \%$ (SK) → $\cos\varphi_k = \Phi$

$P_p = 400\ kW$, $\cos\varphi_p = 0.8$ (ind)

Z_a, $R_{arm} \approx \Phi$

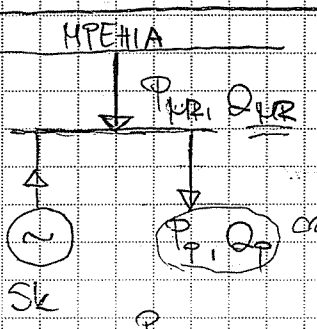
$Q_k = ?$

а) $\cos\varphi_p = 1$

б) $\cos\varphi_p = 0.95$ (ind)

в) $\cos\varphi_p = 0.95$ (cap)

Реш:



$\cos\varphi_p = \frac{P_{MR}}{S_{MR}} = \frac{P_p}{\sqrt{P_p^2 + (Q_p - Q_k)^2}}$ ← $P_{MR} = P_p$

← $Q_k = Q_p - P_p \cdot tg\varphi_p = Q_p - P_p \cdot \frac{\sin\varphi_p}{\cos\varphi_p}$ //

← $Q_p = P_p \cdot \frac{0.6}{0.8} = 300\ kVAr$

* зависи на КАРАКТЕР

а) $Q_k = Q_p = 300\ kVAr$ //

б) $Q_k = 168.52\ kVAr$ //

в) $Q_k = 431.5\ kVAr$ //

(35) $P_{max}^{k} = ?$ $\quad S \le S_n$

$Q_k = +300\ kVAr$ * Натоварени за реф. сигурност

$P_{max}^2 + Q_k^2 = S_n^2 \Rightarrow P_{max}^k = \underline{264.58\ kW}$

$\underline{S}_k = P_k - jQ_k = (264.58 + j300)\ kVA$

$\underline{I} = \frac{\underline{S}_k^*}{\sqrt{3}U_n} = (23.145 + j26.243)\ A$ * КАП. ОЩЕ ДАЛЕЧ Q ?

$\underline{E}_g = \underset{6600/\sqrt{3}}{U} - jX_s\underline{I} = \underline{7128.82\ /-20.7^\circ\ V}$ * ФАЗНА ВРЕДНОСТ ?

* $X_s = x_{s\,p.u.} \cdot \frac{U_{nf}}{I_{nf}} = x_{s\,p.u.} \cdot \frac{3U_{nf}^2}{3U_{nf}I_{nf}} = x_{s\,p.u.} \cdot \frac{U_n^2}{S_n} = \underline{108.9\ \Omega}$

---

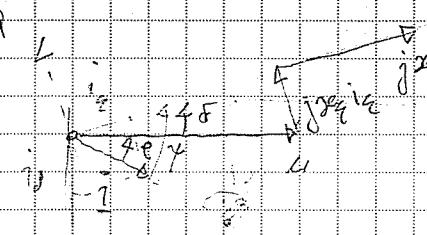
(36) $71.5\ MVA$, $13.8\ kV$, $\cos\varphi_n = 0.8$, $x_d = 1.2$, $x_q = 0.5$

Намерете

* Ном. раз: $S = S_n \Rightarrow S = U \cdot i = 1 \Rightarrow i = 1\ r.u.$

$\cos\varphi = \cos\varphi_n = 0.8$; $\sin\varphi = 0.6$

$\underline{i} = i(\cos\varphi - j\sin\varphi) = 0.8 - j0.6$



$i\cos\varphi = i_d\sin\delta + i_q\cos\delta$

$i\sin\varphi = i_d\cos\delta - i_q\sin\delta$

$\underline{S} = \underline{U}\underline{I}^* = \underbrace{(Ui_d\sin\delta + Ui_q\cos\delta)}_{P} + j\underbrace{(Ui_d\cos\delta - Ui_q\sin\delta)}_{Q}$

$e_g = U\cos\delta + x_d i_d \rightarrow i_d = \frac{e_g - U\cos\delta}{x_d}$

$i_q = \frac{U\sin\delta}{x_q}$

$$P = \frac{e_q U}{x_d}\sin\delta + \frac{U^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right)\sin 2\delta$$

$$Q = \frac{e_q U}{x_d}\cos\delta + \frac{U^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right)\cos 2\delta - \frac{U^2}{2}\left(\frac{1}{x_2} + \frac{1}{x_d}\right)$$

Ном: $e_q = U\cos\delta + x_d \dot{i}_d = U\cos\delta + x_d I \sin(\delta+\varphi)$

$U\cos\varphi \cdot tg\,\psi = U\sin\varphi + x_2 \dot{i} \Rightarrow tg\,\psi = \frac{U\sin\varphi + x_2 i}{U\cos\varphi} = 1.375$

$\psi = 53.97^\circ \Rightarrow \delta = \psi - \varphi = 17.1^\circ \Rightarrow e_q = 1.926$ р.е.

$\delta_{gr} - ?$

$\frac{dP}{d\delta} = 0 \Rightarrow \ldots \quad \delta_{gr} = 63.75^\circ$

$P_{max} = P(\delta_{gr}) = 1.9$ р.е.

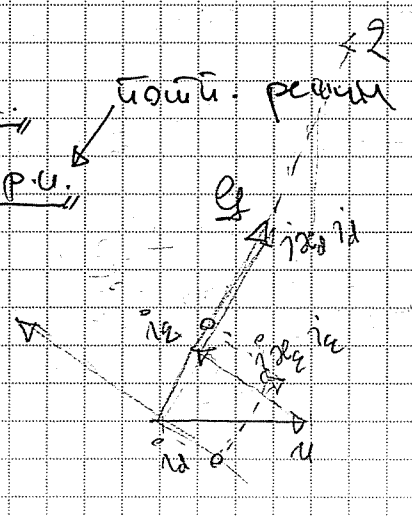
$Q_{max} = Q(\delta_{gr}) = -1.062$ р.е.

Ном. реж

$P_{max} = P_{max} \cdot S_n = 135.85$ МВт

$Q_{max} = Q_{max} \cdot S_n = -75.93$ МВАр

КАП. реж



додати

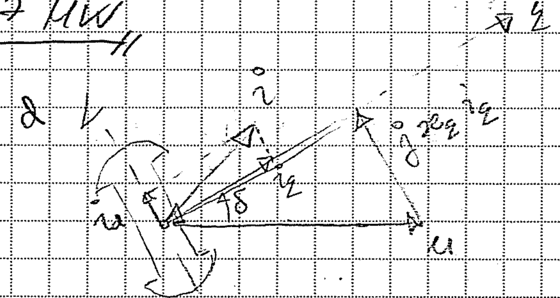
(37) $S_n = 10$ MVA, $x_d = 1.2$, $x_q = 0.6$

$S = 6$ MVA (0.6 p.u), U_n, f_{nom}, $\cos\varphi = 0.65$ (ind)

a) $e_f = 0 \Rightarrow p = \frac{u^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right)\sin 2\delta$

$$p_{max} = p(\delta = 45°) = \frac{u^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right) = \underline{0.417 \text{ p.u.}}$$

$P_{max} = p_{max} \cdot S_n = \underline{4.167 \text{ MW}}$



б) δ, $i(\%)$ - ?

$p = s \cdot \cos\varphi = 0.39$

$e_f = 0$

$$p = \frac{u^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right) \cdot \sin 2\delta \Rightarrow \underline{\delta = 34.7°}$$

$x_q i_q = u\sin\delta \Rightarrow i_q = \underline{0.949 \text{ p.u.}}$

$x_d i_d = u\cos\delta \Rightarrow i_d = \underline{0.685 \text{ p.u.}}$

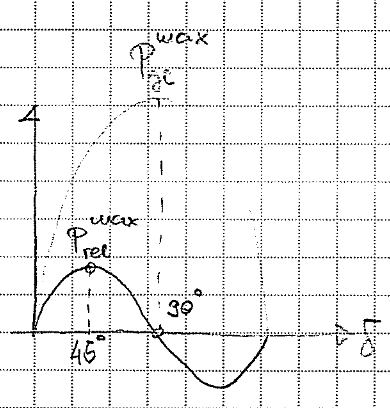
$I(\%) = \sqrt{i_d^2 + i_q^2} \cdot 100\% = \underline{117\%}$

в) $I > I_n$ за 17% → не сме стално радити под овакви условима !

(38) $M_{rel} = 0.3 M_{el} \Rightarrow P_{rel}^{max} = 0.3 P_{el}^{max}$

$u = 0.6 e_f$

$$p_{el}^{max} = \frac{e_f u}{x_d}\sin 90° = \frac{\frac{1}{0.6}u^2}{x_d}$$



$$p_{rel}^{max} = \frac{u^2}{2}\left(\frac{1}{x_q} - \frac{1}{x_d}\right) = 0.5u^2\left(\frac{1}{x_q} - \frac{1}{x_d}\right)$$

$$0.5 u^2\left(\frac{1}{x_q} - \frac{1}{x_d}\right) = 0.3 \cdot \frac{1}{0.6} u^2 \cdot \frac{1}{x_d} \Rightarrow \frac{0.5}{x_q} = \frac{1}{x_d} \Rightarrow$$

$$\frac{x_d}{x_2} = 2$$

б) $\frac{P_{max}}{P_{gr}} = ?$; $\delta_{gr} = ?$

$$P_{max} = \frac{E_g U}{x_d} \sin\delta_{gr} + \left(\frac{U^2}{2}\left(\frac{1}{x_2} - \frac{1}{x_d}\right)\right) \sin 2\delta_{gr}$$

P_{red}

$$P_{gr} = \frac{E_g U}{x_d}$$

$$\frac{P_{max}}{P_{gr}} = \sin\delta_{gr} + \frac{P_{red}}{P_{gr}} \sin 2\delta_{gr} = \sin\delta_{gr} + 0.3 \sin 2\delta_{gr}$$

P_{gr} const

$$\frac{P(\delta)}{P_{gr}} = \sin\delta + 0.3 \sin 2\delta$$

P_{gr} const

$$\frac{dP}{d\delta} = 0 \Leftrightarrow \frac{d\left(P/P_{gr}\right)}{d\delta} = 0$$

$$\cos\delta + 0.6 \cos 2\delta = 0$$

$$\cos\delta + 1.2\cos^2\delta - 0.6 = 0$$

$$\cos\delta_{gr} = \frac{-1 + \sqrt{1 + 2.88}}{2.4} \Rightarrow \delta_{gr} = 66.17^\circ$$

$\sin\delta_{gr} + 0.3 \sin\delta_{gr}$

$$\frac{P_{max}}{P_{gr}} = \frac{P_{max}}{P_{gr}} = 1.136$$

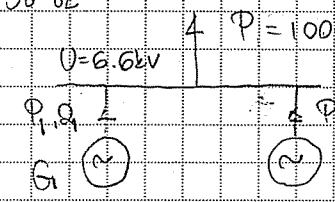
Числи се на P_g^{max} ⇒

(39.) TG 6.6kV 1000kW $\cos\varphi = 0.8$ (ind) $\Rightarrow \sin\varphi = 0.6$

$P_1 = 3P_2$

$X_{s1} = 24\,\Omega$ $\cos\varphi_1 = 0.75$ (ind) $\left.\right\}$ $R_{a1}, R_{a2} \approx 0$

$X_{s2} = 38\,\Omega$



$P = P_1 + P_2 = 3P_2 + P_2 = 1000\text{kW} \Rightarrow \underline{P_2 = 250\text{kW}}$; $\underline{P_1 = 750\text{kW}}$

$Q = P \cdot \operatorname{tg}\varphi = P \cdot 0.75 = 750\text{kVAr}$

$Q_1 = P_1 \cdot \operatorname{tg}\varphi_1 = 661.44\text{kVAr}$ $\Rightarrow Q_2 = Q - Q_1 = 88.56\text{kVAr}$

* ода су НАПОНСКЕ !!

a) $\underline{I}_1 = \frac{\underline{S}_1^*}{\sqrt{3}U} = \frac{P_1 - jQ_1}{\sqrt{3}U} = \underline{87.48\text{ A} \angle -41.4^\circ}$

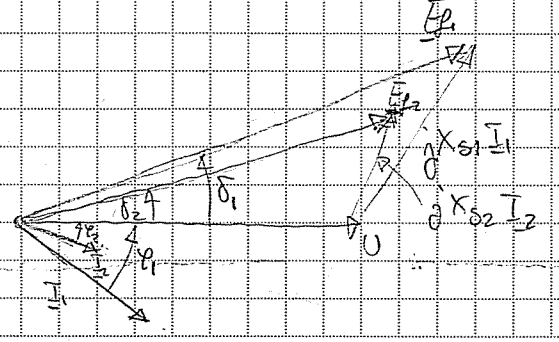
$\underline{I}_2 = \frac{P_2 - jQ_2}{\sqrt{3}U} = \underline{93.2 \angle -19.5^\circ\text{ A}}$

б) $\underline{\cos\varphi_1 = 0.75\text{ (ind)}}$, $\cos\varphi_2 = \cos 19.5^\circ = \underline{0.943\text{ (ind)}}$

г), д): $\underline{E}_{f1} = \frac{U}{\sqrt{3}} + jX_{s1}\underline{I}_1 = \underline{5432.25 \angle 16.85^\circ\text{ V}} \Rightarrow \underline{\delta_1 = 16.85^\circ}$

$\underline{E}_{f2} = \frac{U}{\sqrt{3}} + jX_{s2}\underline{I}_2 = \underline{4188.07 \angle 11.44^\circ\text{ V}} \Rightarrow \underline{\delta_2 = 11.44^\circ}$

е)



(40) $\underline{Z}_G = (1 + j20)\,\Omega \rightarrow$ (G) (λ)

$\underline{Z}_{SH} = (2 + j30)\,\Omega \rightarrow$ (M)

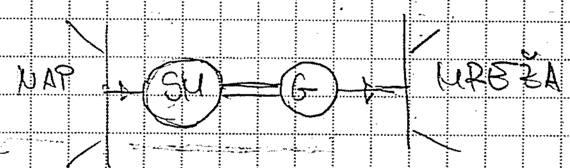
$U_G = 2000\,V$ (f-f) $\quad I_G = 15\,A$ (f) $\quad \cos\varphi_G = 0.8$ (ind)

E_G, E_M, δ_{GM} - ? $\quad$ у одн. на $\underline{U_G}$?

$2p_M = 2p_G = 8$

* ВЕЗАНИ НА ИСТУ МРЕЖУ ⇒ гр. слика ?

Реш:

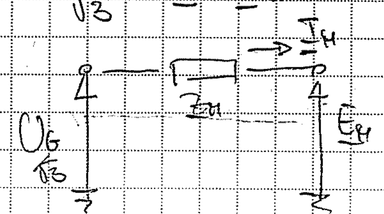


(SG): $\quad \underline{E}_G = \frac{U_G}{\sqrt{3}} + \underline{Z}_G \underline{I}_G = \frac{2000}{\sqrt{3}} + (1+j20)\cdot 15\,(0.8 - j0.6) =$

$= \underline{1366.37 \angle 9.73^\circ\,V} \Rightarrow \underline{\delta_G = 9.73^\circ\,(\text{ел})}$ у одн. на U_G ?

(SM): $\quad P_M = P_{G\,meh} \Rightarrow P_M = \underbrace{\sqrt{3}U_G I_G \cos\varphi_G + 3R_G I_G^2}_{P_{G\,meh} = P_{Gel} + P_{gub}} = 42244.2\,W$

$\underline{E}_M = \frac{U_G}{\sqrt{3}} - \underline{Z}_M \underline{I}_M$



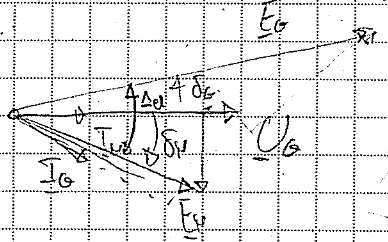
* Оўш. радна тачка → минимална струја? ⇒ фактор не узима Q из мреже ⇒ $\cos\varphi_M = 1$ (у одн. на U_G) ?

$\underline{E}_M \underline{I}_M^* = \frac{U_G}{\sqrt{3}} \underline{I}_M^* - \underline{Z}_M I_M^2$

$\Rightarrow Re\{\underline{E}_M \underline{I}_M^*\} = \frac{U_G}{\sqrt{3}} I_M \cancel{\cos\varphi_M} - R_M I_M^2 = \frac{P_M}{3}$ $\quad$ * метода здравог разума

$I_M^2 - 577.35\,I_M + 7040.7 = 0 \Rightarrow I_M = \underline{12.46\,A}$

$\underline{E}_M = \frac{U_G}{\sqrt{3}} - (2+j30)\,I_M = \underline{1190 \angle -18.31^\circ\,V} \Rightarrow \underline{\delta_M = -18.31^\circ\,(\text{ел})}$ у одн. на U_G ?



* Угаона растојање:

$$\delta_{weh} = \frac{\delta_G - \delta_M}{p} \approx 7^\circ$$ ← мех. бонерал !

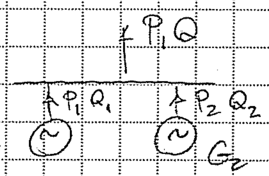
(41) $P(n) \to$ k-ka ТУРБИНЕ !

$I_{f1} = I_{f2}$

$I_1 = 100\,A$; $\cos\varphi_1 = 0.9\,(ind) \to \varphi_1 = 25.84^\circ$

$I_2 = 75\,A$; $\cos\varphi_2 = 0.7\,(ind) \to \varphi_2 = 45.57^\circ$

* $U_1 = U_2 = U_\ell$



a) $P_1 = \sqrt{3}\,U_\ell I_1 \cos\varphi_1 = 155.88\,U_\ell$

$P_2 = \sqrt{3}\,U_\ell I_2 \cos\varphi_2 = 90.93\,U_\ell$

$P = P_1 + P_2 = 246.8\,U_\ell$

$P_1(\%) = \frac{P_1}{P} \cdot 100 = 63.16\,\%$

$P_2(\%) = \frac{P_2}{P} \cdot 100 = 36.84\,\%$

б) $Q_1 = \sqrt{3}\,U_\ell I_1 \sin\varphi_1 = 75.49\,U_\ell$

$Q_2 = \sqrt{3}\,U_\ell I_2 \sin\varphi_2 = 92.76\,U_\ell$ $\Rightarrow Q = Q_1 + Q_2 = 168.26\,U_\ell$

$tg\varphi_{opt} = \frac{Q}{P} = 0.682 \Rightarrow \cos\varphi_{opt} = 0.826\,(ind)$

в) Мења се САМО побуда $\Rightarrow P_1 = const$; $P_2 = const$!

$Q = Q_1' + Q_2' = const$

$\varphi_1' = \varphi_2' = \varphi$ $\quad P_1' = P_1 \Rightarrow P_1 = \sqrt{3}\,U_\ell I_1' \cos\varphi$

$P_2' = P_2 \Rightarrow P_2 = \sqrt{3}\,U_\ell I_2' \cos\varphi$ $\Rightarrow$

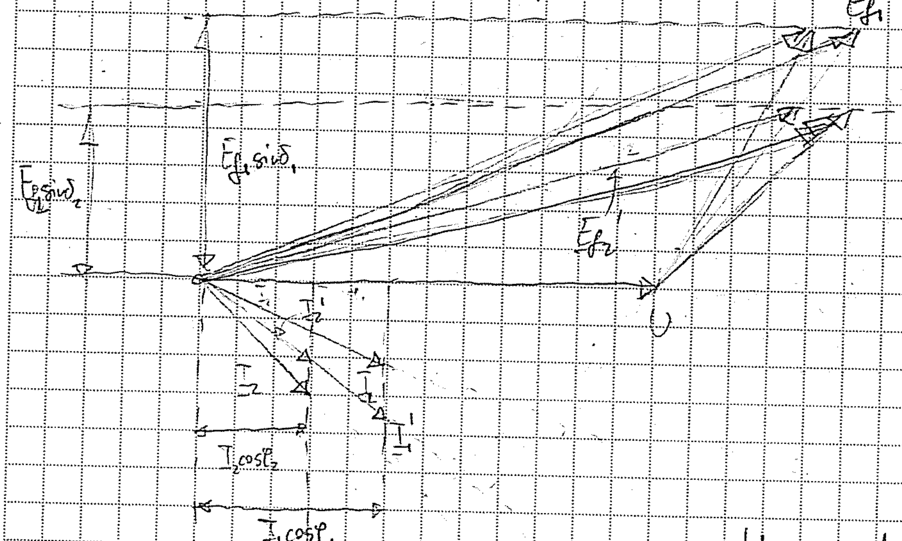
$I_1' = I_1 \frac{\cos\varphi_1}{\cos\varphi} = 108.9\,A$

$I_2' = I_2 \frac{\cos\varphi_2}{\cos\varphi} = 63.56\,A$

$Q = 168.26\,U_\ell = Q_1' + Q_2' = P_1' tg\varphi + P_2' tg\varphi = P \cdot tg\varphi \Rightarrow \varphi = \varphi_1' = \varphi_2' = Q/P = 34.28^\circ$

Илустрација (вект. дијаграм):

$P = cte$; $U = cte$
$\Downarrow$
$I\cos\varphi = cte$
$E_f \sin\delta = cte$

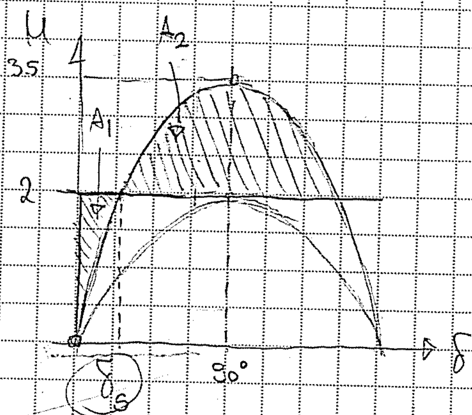


(42) $X = 100\%$ (1 p.u)

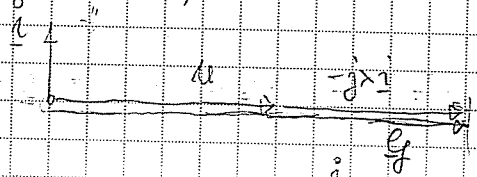
$X' = 40\%$ (0.4 p.u)

$I = I_{nom}$; $P = \Phi$, $U = \Phi$

$\Delta U = 200\%$



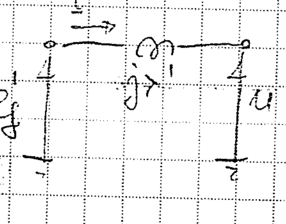
$i^\circ = 1$ p.u ; $\cos\varphi = 0$



$E_f = U + Xi = 2$ p.u.

$U(\delta) = \frac{E_f U}{X}\sin\delta = 2\cdot\sin\delta$

Транзијенти:



$E_f' = U + jX'i = U + X'i = 1.4$ p.u

$U'(\delta) = \frac{E_f' U}{X'}\sin\delta = 3.5\sin\delta$

* δ се не може тренутно повећати → const непосредно након оптерећења!

Услов стабилности: $A_2 > A_1$

$\delta_0 = \arcsin\left(\frac{2}{3.5}\right) = 34.85^\circ$ (0.608 rad)

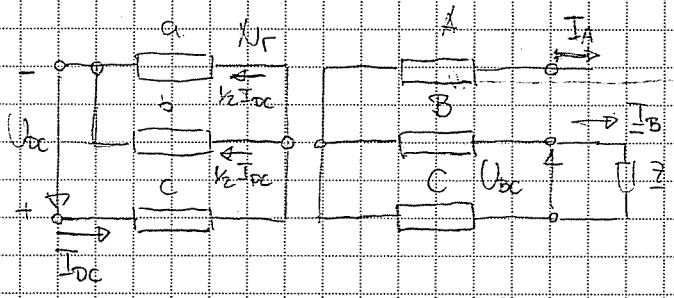
[rad]

$$A_1 = 2\cdot\delta_0 - \int_{\pi-\delta_0}^{\delta_0} 3.5\sin\delta\,d\delta = 2\delta_0 - 3.5 + 3.5\cos\delta_0 = \underline{0.588}$$

$$A_2 = \int_{\delta_0}^{\pi-\delta_0} 3.5\sin\delta\,d\delta - 2\cdot(\pi - 2\delta_0) = \underline{1.893}$$

$A_2 > A_1 \Rightarrow$ СИСТЕМ ЈЕ СТАБИЛАН

(43)



1ϕ SG

230V, 50Hz, Y

$\frac{N_1}{N_2} = 1$

$X_{SG} = X_{SEP} = 2\,\Omega/\text{faza}$

$X_{TR} = 15\,\Omega/\text{faza}$

а) Доказати да је ef. вр. нап. U_{3c} дата са:

$$U_{3c} = \frac{|\underline{Z}|}{|\underline{Z}_d + \underline{Z}_i + \underline{Z}|}\,\dot{U}_{3c}^{\circ}, \text{ где су:}$$

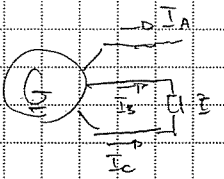
$\dot{U}_{3c}^{\circ}$ → ef. вредност напона фре прикљ. оптерећења

$\underline{Z}_d$ → екв. импеданса (G) за дир. редослед

$\underline{Z}_i$ ↔ — " — — " — инв. — " —

б) Одр. вредност добуџне снаге потребне за напајање трофазног потрошача снаге 5.29kW при 230V.

а)



Фре прикључења: $\dot{U}_A^{\circ} = \dot{U}_d^{\circ}$

$\dot{U}_B^{\circ} = a^2\dot{U}_d^{\circ}$

$\dot{U}_C^{\circ} = a\dot{U}_d^{\circ}$

Прикљ. $\underline{Z}$: $\underline{I}_A = 0 \Rightarrow \underline{I}_d + \underline{I}_i + \underline{I}_0 = 0$

$\underline{I}_B = -\underline{I}_C \Rightarrow a^2\underline{I}_d + a\underline{I}_i + \underline{I}_0 = -(a\underline{I}_d + a^2\underline{I}_i + \underline{I}_0)$

$\underline{I}_A + \underline{I}_B + \underline{I}_C = 0 \Rightarrow \underline{I}_0 = 0$ ← *

$\underline{I}_A = \underline{I}_d + \underline{I}_i = 0 \Rightarrow \underline{I}_d = -\underline{I}_i$ //

$\underline{U}_B = \underline{U}_C + \underline{Z}\underline{I}_B \Rightarrow \underline{U}_B - \underline{U}_C = a^2\underline{U}_d + a\underline{U}_i + \underline{U}_0 - (a\underline{U}_d + a^2\underline{U}_i + \underline{U}_0) = \underline{Z}(a^2\underline{I}_d + a\underline{I}_i)$

$(a^2-a)(\underline{U}_d - \underline{U}_i) = \underline{Z}(a^2-a)\underline{I}_d$

$\underline{U}_d = \underline{U}_i + \underline{Z}\underline{I}_d$ //

$\underline{U}_d = \underline{U}_d^0 - \underline{Z}_d\underline{I}_d = \underline{U}_A^0 - \underline{Z}_d\underline{I}_d$

$\underline{U}_i = \underline{U}_i^0 - \underline{Z}_i\underline{I}_i = -\underline{Z}_i\underline{I}_i = +\underline{Z}_i\underline{I}_d$

$\underline{U}_i = \underline{Z}_i\underline{I}_d = \underline{U}_d - \underline{Z}\underline{I}_d = \underline{U}_A^0 - \underline{Z}_d\underline{I}_d - \underline{Z}\underline{I}_d$

$\underline{I}_d = \dfrac{\underline{U}_A^0}{\underline{Z}_d + \underline{Z}_i + \underline{Z}}$

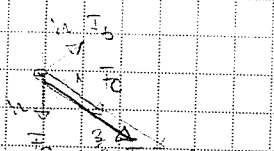
$\underline{U}_{BC} = \underline{Z}\underline{I}_B = \underline{Z}(a^2\underline{I}_d + a\underline{I}_i) = \underline{Z}(a^2-a)\underline{I}_d = \dfrac{\underline{Z}}{\underline{Z}_d + \underline{Z}_i + \underline{Z}} \cdot \underbrace{(a^2-a)\underline{U}_A^0}_{\underline{U}_{BC}}$

$\underline{U}_{BC} = \dfrac{|\underline{Z}|}{|\underline{Z}_d + \underline{Z}_i + \underline{Z}|} \cdot \underline{U}_{BC}^0$ //

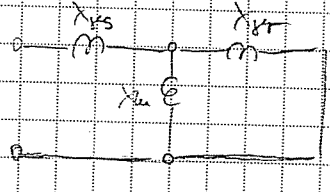
δ) $\underline{I}_{DC} = ?$ $\quad P = 5.29\,kW,\ 230V \Rightarrow \underline{I}_B = \dfrac{P}{U} = 23A$

$U_{BC} = 230V$

$\underline{I}_{DC} = \dfrac{3}{2} N_2 \underline{I}_{DC} = \dfrac{3}{2} N_S \underline{I}_{DC}$



$\underline{Z}_d = j(X_M + X_{\sigma S}) = j17\Omega$ //



$R_2 \approx 0 \Rightarrow \underline{Z}_i = j(X_{\sigma S} + X_{\sigma T} \| X_M) = j3.76\,\Omega$ //

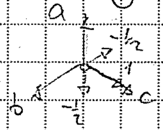
$\underline{Z} = \dfrac{230^2}{5290} = 10\Omega$ //

$$U_{BC}^{0} = \frac{|Z_d + Z_i + Z|}{|Z|} \cdot U_{BC} \approx 530V$$

у напонату статора

$U_{BC_{max}}^{0} = \omega \Psi_f$; Ψ_f – обд. флукс, потиче од струје I_{DC}

$F_{DC} = \frac{3}{2} N_R I_{DC}$ → МПС ротора



$\Psi_f = L_m' \cdot \frac{3}{2} \frac{N_R}{N_S} I_{DC}$ (онај део флукса ротора који се затвара кроз статор) * $L_m' = \frac{N_S N_R}{R_\mu} = \frac{N_S^2}{R_\mu}$

$$\frac{U_{BC}^{0}}{\sqrt{3}} = \frac{1}{\sqrt{2}} \cdot X_m' \cdot \frac{3}{2} I_{DC} \Rightarrow I_{DC} = 28.85A$$

$X_m' = \frac{2}{3} X_m = 10\Omega$

амплитуда напона/ЕМС

индукована напон по фази

реактанса „трофазног магнећења"

међусобна реактанса фазних намотаја S и R

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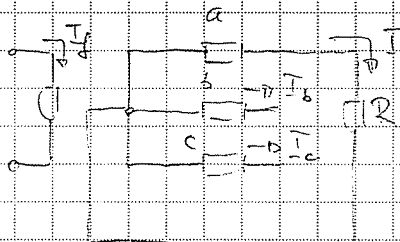
(44) 7.5kVA, 380V

$R = 10\Omega$

$X_S = X_d = 0.6$ p.u.; $x_i = 0.25$ p.u.; $x_0 = 0.05$ p.u.

a)



$I_a = I_d + I_i + I_0$

$I_b = 0 \Rightarrow a^2 I_d + a I_i + I_0 = 0$

$I_c = 0 \Rightarrow a I_d + a^2 I_i + I_0 = 0$

$\Rightarrow I_d = I_i = I_0$

$U_a = R I_a \Rightarrow U_d + U_i + U_0 = R(I_d + I_i + I_0) = 3R I_d$

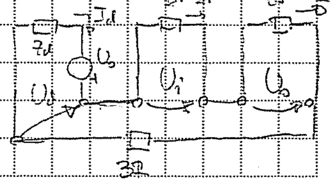
$U_d = U^0 - Z_d I_d$

$U_i = -Z_i I_i$

$U_0 = -Z_0 I_0$

$U_d + U_i + U_0 = 3R I_d = U^0 - (Z_d + Z_i + Z_0) I_d$

$$I_d = \frac{U^0}{(Z_d + Z_i + Z_0) + 3R}$$



$$\underline{I}_A = 3\underline{I}_d = \frac{\underline{U}^\circ}{\frac{\underline{Z}_d + \underline{Z}_i + \underline{Z}_o}{3} + R} \Rightarrow \underline{Z}_{ech} = \frac{\underline{Z}_d + \underline{Z}_i + \underline{Z}_o}{3}$$

a) $U^\circ = 380V/\sqrt{3}$

$$Z_B = \frac{U_n^2}{S_n} = 19.25\Omega \Rightarrow X_d = 11.55\Omega$$

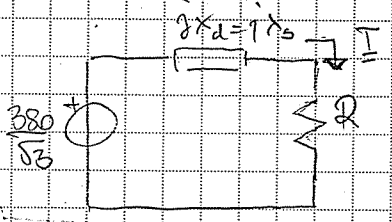
$$\lambda_i = 4.81\Omega$$

$$X_o = 0.95\Omega$$

$$U_R = R I_A = 10 \cdot \frac{380/\sqrt{3}}{\left| j\frac{11.55+4.81+0.95}{3} + 10 \right|} = 190\,V$$

b) 10Ω/faza ; 3f

Zaciecka ciecia:



$$\underline{I}_B = a^2\underline{I}_A \quad \underline{I}_A = \underline{I}_d$$

$$\underline{I}_C = a\underline{I}_A \quad \underline{I}_i = \underline{I}_o = 0$$

$$U_R^{3f} = \frac{380}{\sqrt{3}} \cdot \frac{R}{\sqrt{R^2 + X_o^2}} = 148.6\,V < U_R^{1f}$$

c) $\underline{U}_d = \underline{U}^\circ - \underline{Z}_d\underline{I}_d = \underline{U}^\circ - \frac{\underline{Z}_d\underline{U}^\circ}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_o + 3R} = \frac{(\underline{Z}_i + \underline{Z}_o + 3R)\underline{U}^\circ}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_o + 3R}$

$$\underline{U}_i = -\underline{Z}_i\underline{I}_i = \frac{-\underline{Z}_i\underline{U}^\circ}{\underbrace{\underline{Z}_d + \underline{Z}_i + \underline{Z}_o}_{\underline{Z}_{ez}} + 3R} \; ; \; \underline{U}_o = \frac{-\underline{Z}_o\underline{U}^\circ}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_o + 3R}$$

$$\underline{Z}_{ez} = j(X_d + \lambda_i + X_o) = j17.32\Omega$$

$$\underline{U}_d = 193.48\angle -13.1^\circ\,V \; ; \; \underline{U}_i = 30.46\angle -120^\circ\,V \; ; \; \underline{U}_o = 6.08\angle -120^\circ\,V$$

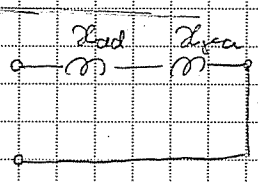
$$\underline{U}_B = a^2\underline{U}_d + a\underline{U}_i + \underline{U}_o = 177.58\angle -132^\circ\,V \Rightarrow |\underline{U}_B| = 177.58V$$

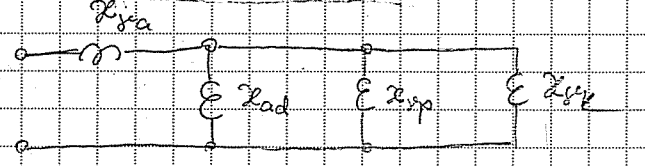
$$\underline{U}_C = a\underline{U}_d + a^2\underline{U}_i + \underline{U}_o = 218.11\angle 104.52^\circ\,V \Rightarrow |\underline{U}_C| = 218.11V$$

(45) $S_n = 50\,MVA$, $U_n = 10.5\,kV$, $f = 50\,Hz$, $\cos\varphi_n = 0.85$, (Y)

$x_{ad} = 0.8$ p.u.; $x_{yca} = 0.2$ p.u.; $x_{yp} = 0.3$ p.u.; $x_{yk} = 0.1$ p.u.

$U^\circ = 1$ p.u.

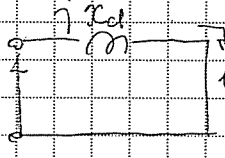
d: 

i: 

$j x_d = j\,1$ p.u. //

$j x_i = j(x_{yca} + x_{ad} \| x_{yp} \| x_{yk}) = 0.268$ p.u. //

a) 3fks: $U_A = U_B = U_C = \phi$ // $\Rightarrow U_d = U_i = U_0 = \phi$

Zam. shema: 

$\underline{i}_d = \frac{U^\circ}{j x_d} = -j\,1$ p.u.

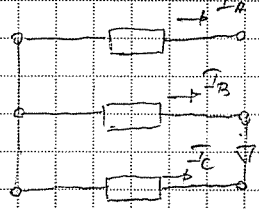
$\underline{i}_i = \underline{i}_0 = \phi$

$\underline{i}_a = \underline{i}_d = -1\,\angle -90^\circ$ p.u. // $\Rightarrow \underline{I}_a = 1\,\angle -90^\circ \cdot \frac{S_n}{\sqrt{3} U_n} = 1\,\angle -90^\circ \cdot 2749.3\,A = 2749.3\,\angle -90^\circ\,A$ //

$I_p = I_u$

$\underline{i}_b = a^2 \underline{i}_d = 1\,\angle 150^\circ$ p.u. // $\Rightarrow \underline{I}_b = 2749.3\,\angle 150^\circ\,A$ //

$\underline{i}_c = a\,\underline{i}_d = 1\,\angle 30^\circ$ p.u. // $\Rightarrow \underline{I}_c = 2749.3\,\angle 30^\circ\,A$ //

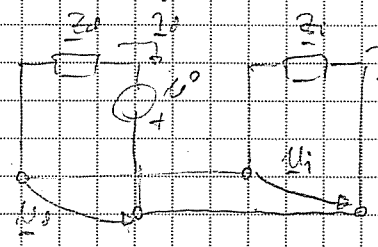
b) 2fks: 

$\underline{I}_B = -\underline{I}_C$; $\underline{I}_A = \phi$

// $\underline{I}_0 = \phi$

$\underline{I}_d = -\underline{I}_i$

$\Rightarrow U_B = U_C \Rightarrow U_d = U_i$

Shema: 

$\underline{U}_d = U^\circ - \underline{Z}_d \underline{I}_d$

$\underline{U}_i = -\underline{Z}_i \underline{I}_i = \underline{Z}_i \underline{I}_d = \underline{U}_d$ $\Rightarrow \underline{I}_d = \frac{U^\circ}{Z_d + Z_i}$

$\underline{I}_b = -\underline{I}_i = 0.789\,\angle -90^\circ$ p.u.

$\dot{I}_a = 0 \Rightarrow \underline{I}_a = 0$

$\dot{I}_b = a^2 \dot{I}_d + a \dot{I}_i = (a^2 - a)\dot{I}_d = -j\sqrt{3} \cdot (-j0.289) = \underline{1.366 \angle 180^\circ}$ p.u. $= -\dot{I}_c$

$\underline{I}_b = -\underline{I}_c = \underline{3456.4 \angle 180^\circ}$ A

$\underline{U}_0 = U^\circ - \underline{Z}_d \dot{I}_d = \dfrac{\underline{Z}_i}{\underline{Z}_d + \underline{Z}_i} U^\circ = 0.211$ p.u. $= \underline{U}_i$

$\underline{U}_0 = 0$

ΦΑΒΗΔ

$\underline{U}_a = \underline{U}_d + \underline{U}_i + \underline{U}_0 = 0.422$ p.u. $\Rightarrow \underline{U}_a = U_a \cdot U_b = U_a \left(\dfrac{U_n}{\sqrt{3}}\right) = \underline{2.56 kV}$

$\underline{U}_b = \underline{U}_c = (a^2 + a)\underline{U}_d = -\underline{U}_0 = \underline{0.211 \angle 180^\circ}$ p.u. $\Rightarrow \underline{U}_b = \underline{U}_c = \underline{1.28 \angle 180^\circ kV}$

$* \quad \underline{I}_{k2} > \underline{I}_{k3}$

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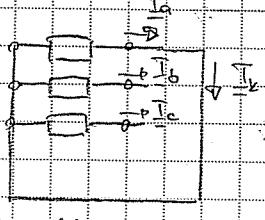
(46) $S_n = 100$ MVA, $U_n = 10.5 kV$, $f = 50 Hz$, $x_d = 0.9$ p.u., $x_i = 0.38$ p.u., $x_0 = 0.08$ p.u.

(ד) , $U^\circ = 1$ p.u.



$\underline{I}_b = \underline{I}_c = 0 \Rightarrow \underline{I}_d = \underline{I}_i = \underline{I}_0$

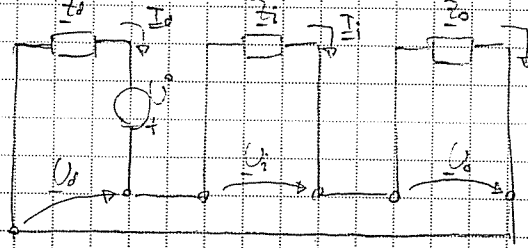
$\underline{I}_a = \underline{I}_d + \underline{I}_i + \underline{I}_0$

$\underline{U}_a = 0 \Rightarrow \underline{U}_d + \underline{U}_i + \underline{U}_0 = 0$

$U^\circ = \dfrac{U_n}{\sqrt{3}} = \underline{U}_d + \underline{Z}_d \underline{I}_d$

$0 = \underline{U}_i + \underline{Z}_i \underline{I}_i$

$0 = \underline{U}_0 + \underline{Z}_0 \underline{I}_0$



$\underline{I}_d = \underline{I}_i = \underline{I}_0 = \dfrac{U^\circ}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_0} = \underline{0.727 \angle -90^\circ}$ p.u.

$\underline{U}_d = U^\circ - \underline{Z}_d \underline{I}_d = 0.346$ p.u.; $\underline{U}_i = -\underline{Z}_i \underline{I}_i = -0.284$ p.u.; $\underline{U}_0 = -0.0625$ p.u.

$\underline{I}_a = \underline{I}_d + \underline{I}_i + \underline{I}_0 = \frac{3\underline{U}^0}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_0} = 2.18 \angle -90°$

$\underline{I}_b = \underline{I}_c = 0$

$\underline{U}_a = 0$

$\underline{U}_b = a^2\underline{U}_d + a\underline{U}_i + \underline{U}_0 = \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)\cdot 0.316 + \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)\cdot(-0.284) - 0.0625 =$

$= 0.553 \angle -100°$ p.u.

$\underline{U}_c = a\underline{U}_d + a^2\underline{U}_i + \underline{U}_0 = 0.553 \angle +100°$ p.u.

$\left.\begin{aligned} \underline{I}_B &= \frac{S_n}{\sqrt{3}U_n} = 5.4986\,kA \\ U_{fb} &= U_n/\sqrt{3} = 6.06\,kV \end{aligned}\right\} \Rightarrow \quad \underline{I}_a = -j11.99\,kA$

$\underline{U}_b = 3.351 \angle -100°\,kV$

$\underline{U}_c = 3.351 \angle +100°\,kV$

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(47) 10MVA, 10.5kV

2fcs: $I_b = 980A$, $U_{ac} = 5695V$

$Z_0 = 0.1$ p.u.

$U^0 = 1$ p.u.

$\underline{I}_b = I_b \cdot \frac{\sqrt{3}U_n}{S_n} = 1.691$ p.u. $(= \underline{I}_{b2})$

$U_{ac} = \frac{U_{ac}}{U_n\sqrt{3}} = 0.939$ p.u.

2fcs: $\underline{I}_d = -\underline{I}_i \Rightarrow \underline{I}_0 = (a^2 - a)\underline{I}_d \Rightarrow |\underline{I}_b| = \sqrt{3}\,I_d \Rightarrow I_d = 0.976$ p.u.

$\underline{U}_d = \underline{U}_i \Rightarrow U_{ac} = U_d + U_i - aU_d - a^2U_i = (2 - a - a^2)U_d = 3U_d$

$U_0 = a$

$U_d = 0.313$ p.u.

$\underline{I}_d = \frac{U^0}{|\underline{Z}_d + \underline{Z}_i|}$; $|\underline{U}_0| = |\underline{U}_d| = \frac{|\underline{Z}_i|}{|\underline{Z}_d + \underline{Z}_i|}U^0$

$|\underline{Z}_i| = \frac{|\underline{U}_d|}{|\underline{I}_d|} = 0.32$ p.u. $\Rightarrow \underline{Z}_i = j0.32$ p.u.

$\dot{I}_a = 0 \Rightarrow \underline{I}_a = 0$

$\dot{I}_b = a^2 \dot{I}_d + a \dot{I}_i = (a^2 - a)\dot{I}_d = -j\sqrt{3} \cdot (-j0.289) = \underline{1.366 \angle 180^\circ}$ p.u. $= -\dot{I}_c$

$\underline{I}_b = -\underline{I}_c = \underline{3456.4 \angle 180^\circ}$ A

$\dot{U}_d = \dot{U}^\circ - \underline{Z}_d \dot{I}_d = \dfrac{\underline{Z}_i}{\underline{Z}_d + \underline{Z}_i} \dot{U}^\circ = 0.211$ p.u. $= \underline{U}_i$

$\underline{U}_a = 0$

ФАЗНЫЙ

$\underline{U}_a = \underline{U}_d + \underline{U}_i + \underline{U}_0 = 0.422$ p.u. $\Rightarrow U_a = U_{\text{ном}} \cdot U_b = U_a \cdot \left(\dfrac{U_n}{\sqrt{3}}\right) = \underline{2.56\,kV}$

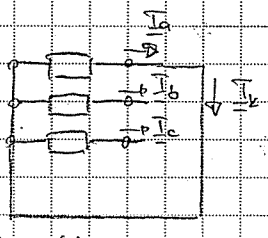
$\underline{U}_b = \underline{U}_c = (a^2 + a)\underline{U}_d = -\underline{U}_d = 0.211 \angle 180^\circ$ p.u. $\Rightarrow \underline{U}_b = \underline{U}_c = \underline{1.28 \angle 180^\circ\,kV}$

$* \quad \underline{I}_{k2} > \underline{I}_{k3}$

---

(46) $S_n = 100$ MVA, $U_n = 10.5$ kV, $f = 50$ Hz, $x_d = 0.8$ p.u, $x_i = 0.38$ p.u, $x_0 = 0.08$ p.u.

(4), $U^\circ = 1$ p.u.



$\underline{I}_b = \underline{I}_c = 0 \Rightarrow \underline{I}_d = \underline{I}_i = \underline{I}_0$

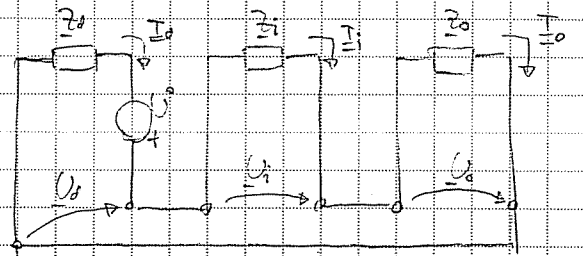
$\underline{I}_a = \underline{I}_d + \underline{I}_i + \underline{I}_0$

$\underline{U}_a = 0 \Rightarrow \underline{U}_d + \underline{U}_i + \underline{U}_0 = 0$

$\dot{U}^\circ = \dfrac{\underline{U}_n}{\sqrt{3}} = \underline{U}_d + \underline{Z}_d \underline{I}_d$

$0 = \underline{U}_i + \underline{Z}_i \underline{I}_i$

$0 = \underline{U}_0 + \underline{Z}_0 \underline{I}_0$



$\underline{I}_d = \underline{I}_i = \underline{I}_0 = \dfrac{\dot{U}^\circ}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_0} = 0.727 \angle -90^\circ$ p.u.

$\underline{U}_d = \dot{U}^\circ - \underline{Z}_d \dot{I}_d = 0.346$ p.u; $\underline{U}_i = -\underline{Z}_i \dot{I}_i = +0.284$ p.u; $\underline{U}_0 = -0.0625$ p.u.

$\dot{I}_a = \dot{I}_d + \dot{I}_i + \dot{I}_0 = \frac{3\dot{U}^0}{\underline{Z}_d + \underline{Z}_i + \underline{Z}_0} = 2.18 \angle -90°$

$\dot{I}_b = \dot{I}_c = 0$

$\underline{U}_0 = 0$

$\underline{U}_b = a^2 \underline{U}_d + a \underline{U}_i + \underline{U}_0 = \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) \cdot 0.346 + \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) \cdot (-0.284) - 0.0625 =$

$= 0.553 \angle -100° \text{ p.u.}$

$\underline{U}_c = a \underline{U}_d + a^2 \underline{U}_i + \underline{U}_0 = 0.553 \angle +100° \text{ p.u.}$

$\underline{I}_B = \frac{S_n}{\sqrt{3} U_n} = 5.4986 \text{ kA}$

$U_b = U_n \sqrt{3} = 6.06 \text{ kV}$

$\Rightarrow$

$\underline{I}_a = -j\,11.991 \text{ kA}$

$\underline{U}_b = 3.351 \angle -100° \text{ kV}$

$\underline{U}_c = 3.351 \angle +100° \text{ kV}$

---

(47) 10 MVA, 10.5 kV

2fus: $I_b = 980 A$, $U_{ac} = 5695 V$

$Z_0 = 0.1$ p.u.

$U^0 = 1$ p.u.

$\dot{I}_b = I_b \cdot \frac{\sqrt{3} U_n}{S_n} = 1.691 \text{ p.u.} \quad (= \dot{I}_{k2})$

$U_{ac} = \frac{U_{ac}}{U_n \sqrt{3}} = 0.939 \text{ p.u.}$

2fus: $\dot{I}_d = -\dot{I}_i \Rightarrow \dot{I}_0 = (a^2 - a)\dot{I}_d \Rightarrow |\dot{I}_0| = \sqrt{3}\,\dot{I}_d \Rightarrow \dot{I}_d = 0.976 \text{ p.u.}$

$U_d = U_i \Rightarrow U_{ac} = U_d + U_i - a U_d - a^2 U_i = (2 - a - a^2) U_d = 3 U_d$

$U_0 = 0$

$U_d = 0.313 \text{ p.u.}$

$\dot{I}_d = \frac{U^0}{|\underline{Z}_d + \underline{Z}_i|}$, $|\underline{U}_0| = |\underline{U}_i| = \frac{|\underline{Z}_i|}{|\underline{Z}_d + \underline{Z}_i|} U^0$

$|\underline{Z}_i| = \frac{|\underline{U}_0|}{|\underline{I}_d|} = 0.32 \text{ p.u.} \Rightarrow \underline{Z}_i = j\,0.32 \text{ p.u.}$

$$X_i = x_i \cdot \frac{U_n^2}{S_n} = 3.53\,\Omega$$

$$x_d = \frac{U_c^0}{i_d^0} - x_i = 0.704\ \text{p.u.} \Rightarrow X_d = 7.76\,\Omega$$

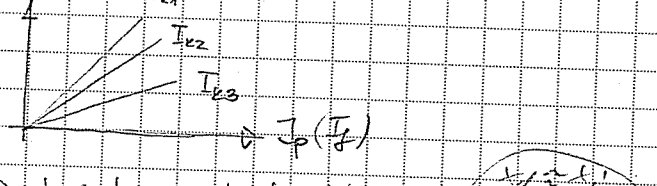
3f k.s.: $i_d^0 = \frac{U^0}{x_d} = 1.42\ \text{p.u.}$

$i_{k3}^0 = i_d^0 = 1.42\ \text{p.u.} \Rightarrow I_{k3} = 1.42 \cdot \frac{S_n}{\sqrt{3}U_n} = 781\,A$

1f k.s.:

$$i_{k1}^0 = \frac{3U^0}{x_d + x_i + x_0} = 2.67\ \text{p.u.} \Rightarrow I_{k1} = 1468\,A$$

* $I_{k1} > I_{k2} > I_{k3}$



U praksi suprotno,

kritičan 3f k.s. → (B) → $x_0 \ll x_d$, $i_1 \ll i_d$, i praksa: $x_d \approx x_1$, $x_0 \approx 3x_d$

13.05.2013.

(48) $2p = 6$, 220V, 60 Hz, $X_d = 15\,\Omega$, $X_q = 3\,\Omega$, $P_{gub} \approx 0$

a) $M_{max} = ?$

b) $(\cos\varphi)_{max} = ?$ $\quad P_{mek} = ?$

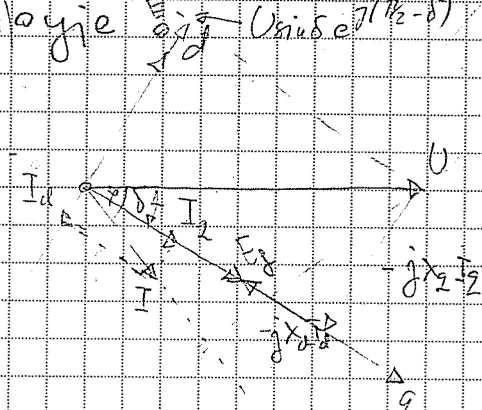
a) $E_f = \phi$ (per)

$$M_{el} = \frac{3U_f^2}{2} \cdot \frac{1}{\Omega_s} \cdot \left(\frac{1}{X_q} - \frac{1}{X_d}\right) \cdot \sin 2\delta$$

$$M_{el\,max} = M_{el}(\delta = 45^\circ) = \frac{3}{2} \cdot \frac{(220/\sqrt{3})^2}{2\pi \cdot 60/3} \left(\frac{1}{X_q} - \frac{1}{X_d}\right) = 51.35\ Nm$$

б) Промена оптерећења → мења се стр. I и угао δ → врх вектора струје описује круг → КРУЖНИ ДИЈАГРАМ

струје $\underline{E}_g$ ... $U\sin\delta\, e^{j(\pi/2-\delta)}$



Општи случај (побуђен мотор): машина

(1) $$I_d = \frac{E_f - U\cos\delta}{X_d}$$

(2) $$I_q = \frac{U\sin\delta}{X_q}$$

* $\delta > \phi$ (услов за мотор)

(3) $$\underline{I} = \underline{I}_d + \underline{I}_q = I_d \cdot e^{j(\pi/2-\delta)} + I_q e^{-j\delta}$$

* $$\underline{I}_d = \frac{E_f e^{-j\delta} - U\cos\delta\, e^{-j\delta}}{-jX_d} = \frac{E_f - U\cos\delta}{X_d} e^{j(\frac{\pi}{2}-\delta)}$$

* $$\underline{I}_q = \frac{U\sin\delta \cdot e^{j(\frac{\pi}{2}-\delta)}}{jX_q} = \frac{U\sin\delta}{X_q} e^{-j\delta}$$

само начини

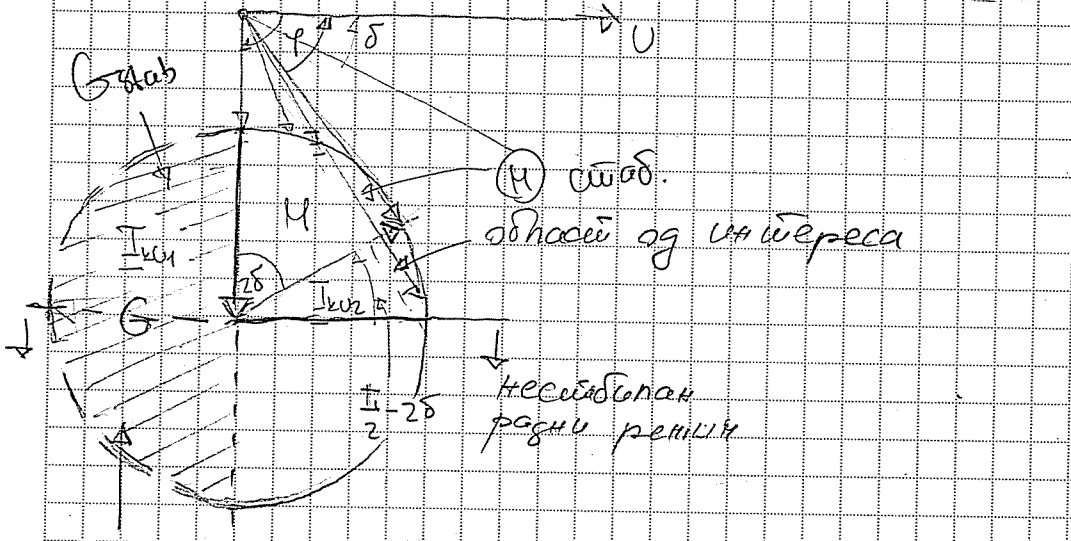
$$\sin\delta = \frac{e^{j\delta} - e^{-j\delta}}{2j} \; ; \; \cos\delta = \frac{e^{j\delta} + e^{-j\delta}}{2}$$

ф. оса → НАПОН U

$$\underline{I} = \underline{I}_d + \underline{I}_q = \frac{E_f}{X_d} e^{j(\frac{\pi}{2}-\delta)} - \frac{U}{X_d}\frac{e^{j\delta}+e^{-j\delta}}{2} \cdot e^{j(\frac{\pi}{2}-\delta)} + \frac{U}{X_q}\cdot\frac{e^{j\delta}-e^{-j\delta}}{2j}\cdot e^{-j\delta} =$$

$$= \underbrace{\frac{E_f}{X_d} e^{j(\frac{\pi}{2}-\delta)}}_{\underline{I}_E \parallel \phi} + \underbrace{\frac{U}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right) e^{+j(\frac{\pi}{2}-2\delta)}}_{\underline{I}_{ko2}} + \underbrace{\frac{U}{2}\left(\frac{1}{X_d} + \frac{1}{X_q}\right) e^{-j\pi/2}}_{\underline{I}_{ko1}}$$

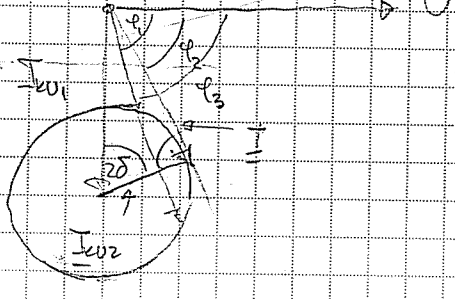
Кружни дијаграм фен. МОТОРА ($E_\delta = \Phi \Rightarrow I_E = \Phi$):



област

Тех. раса ($2\delta > 180°$)

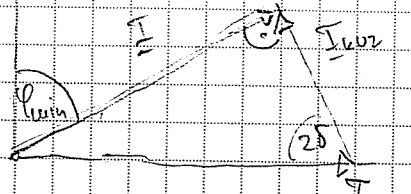
а) $(\cos\varphi)_{max} \Rightarrow \varphi_{min}$:



$\varphi_2 < \varphi_1$

$\varphi_2 < \varphi_3$

φ_{min} → раса је вектор струје $\underline{I}$ ТАНГЕНТА НА КРУГ !



$\cos\varphi_{min} = \left|\frac{I_{kv2}}{I_{kv1}}\right|$ $(\varphi_{min} = 2\delta)$

$I_{kv1} = \frac{U}{2}\left(\frac{1}{X_d} + \frac{1}{X_\Sigma}\right) = 25.4\,A$

$I_{kv2} = 16.94\,A$

$(\cos\varphi)_{max} = 0.667$

$I = \sqrt{I_{ku1}^2 - I_{ku2}^2} = 18.93A$

$P_{max} = ?$ → $\cos 2\delta = (\cos\varphi)_{max} = 0.667 \Rightarrow 2\delta = 48.16^\circ = \varphi_{min}$

$P_{max} = \frac{3U^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta = 4.81\,kW$

---

(49) $X_s = X_d = 90\%$ $X_d' = 35\%$ (M)

а) $E_f = const = U_{nom}$ → синхр. небит. → ЛАБ → бандем (sync)

$m_{max} = ?$

$u = 1$ r.j. $\Rightarrow e = 1$ r.j. $= const$; δ је ПРОМ!

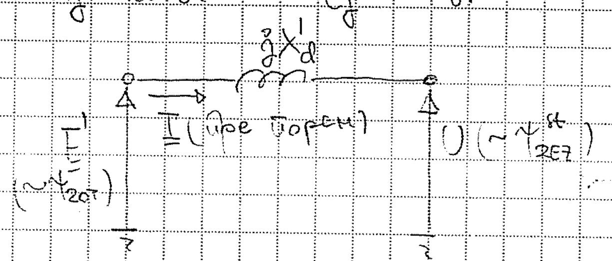
$m = \frac{eu}{x_s}\sin\delta \Rightarrow m_{max} = m(\delta = 90^\circ) = \frac{eu}{x_s} = \frac{1\cdot 1}{0.9} = 1.11$

* Најосновни разлику изм. постепеног и наглог опт.!

б) НАГЛО Δm → јако брзо оптерећивање!

$\Psi_f \approx const \Rightarrow E_f \approx const$

Пробај да објасниш колико схватнеш...

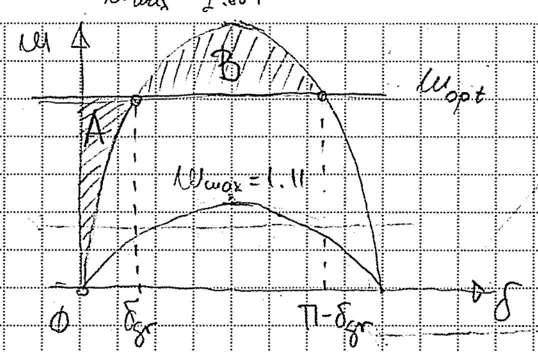


$\underline{E}' = \underline{U} + jX_d' \cdot \underline{I}$

$\underline{I} = 0 \Rightarrow E' = U = 1$ r.j.

$m'(\delta) = \frac{e'u}{x_d'}\sin\delta = 2.857\sin\delta$ (крива момента у транз. периоду)

$M'_{max} = 2.857$



Метода једнаких површина
↓
Гранични услов стабилности: $\boxed{A = B}$

(површине ~ енергији)

$$\int_0^{\delta_{gr}} (M_{opt} - M'_{max} \sin\delta) d\delta = \int_{\delta_{gr}}^{\pi-\delta_{gr}} (M'_{max} \sin\delta - M_{opt}) d\delta$$

$$M_{opt} \cdot \underset{*}{\delta_{gr}} + M'_{max} (\cos\delta_{gr} - 1) = 2M'_{max} \cos\delta_{gr} - M_{opt} \cdot (\pi - 2\delta_{gr})$$

* [rad]

$$M_{opt} = M'_{max} \sin\delta_{gr}$$

$$M'_{max} (\sin\delta_{gr}) \cdot \delta_{gr} + M'_{max} (\cos\delta_{gr} - 1) = 2M'_{max} \cos\delta_{gr} - M'_{max} \sin\delta_{gr} (\pi - 2\delta_{gr})$$

$$(\pi - \delta_{gr}) \cdot \sin\delta_{gr} = 1 + \cos\delta_{gr}$$

Графички или итеративном методом
↓
Погодно применити: $\sin\delta_{gr} = \sin(\pi - \delta_{gr})$

$\cos\delta_{gr} = -\cos(\pi - \delta_{gr})$

$x = \pi - \delta_{gr}$ . . .

$$\underset{*}{\delta_{gr} = 49.46^\circ}$$

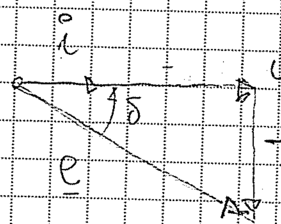
Водити рачуна о смислености решења !

$$M_{opt} = \frac{EU}{X'_d} \cdot \sin\delta_{gr} = 2.17 \quad (217\%)$$

g) $m_{opt} = 1$ r.j.

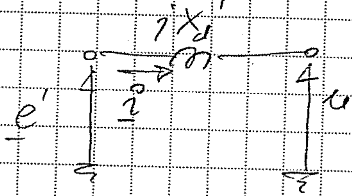
$i = i_{min} \Rightarrow \cos\varphi = 1$ — Мордејеве криве!

$p = m = u \cdot i \cos\varphi \Rightarrow i = 1$ p.u.



$e^0 = \sqrt{u^2 + (x_d i)^2} = 1.345$

$e' = \sqrt{u^2 + (x_d' i)^2} = 1.06$

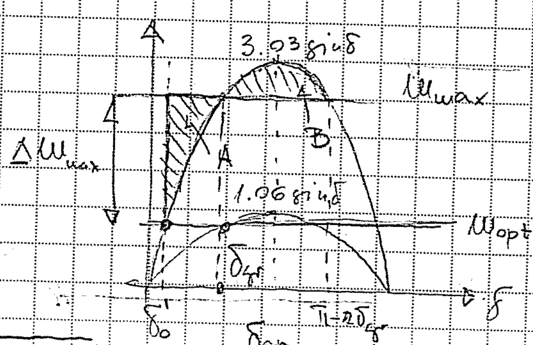


$\delta_0 = \arcsin\left(\frac{m_{opt}}{e^0 u} \cdot x_d\right) \approx 42^\circ$

$(m' = m_{opt})$

$m' = \frac{e' u}{x_d'} \sin\delta = 3.03 \sin\delta$

$\delta_0' = \arcsin\left(\frac{m_{opt}}{e' u} \cdot x_d'\right) = 19.27^\circ$



- δ се не може тренутно променити!
- $m_{max} = 3.03 \sin\delta_{gr}$

A = B

$$\int_{\delta_0'}^{\delta_{gr}} (m_{max} - m')\, d\delta = \int_{\delta_{gr}}^{\pi - \delta_{gr}} (m' - m_{max})\, d\delta$$

$$3.03 \sin\delta_{gr} (\delta_{gr} - \delta_0') + 3.03 (\cos\delta_{gr} - \cos\delta_0') = 6.06 \cos\delta_{gr} - 3.03 \sin\delta_{gr} (\pi - 2\delta_{gr})$$

$$\sin\delta_{gr} (\pi - \delta_{gr} - \delta_0') = \cos\delta_{gr} + \cos\delta_0'$$

$$\pi - \delta_{gr} - \delta_0' = \frac{\cos\delta_{gr} + \cos\delta_0'}{\sin\delta_{gr}} \quad (\cos\delta_0' = 0.944)$$

→ трансцедентна, нум. решавање...

Получи се: $\delta_{gr} \approx 55°$

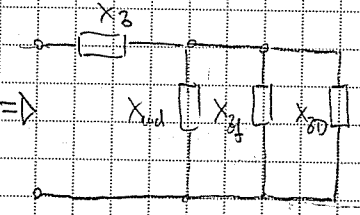
$$\Delta P_{max} = 3.03 \cdot \sin\delta_{gr} - P_{заг} = \underline{1.482} \text{ (148.2 \%)}$$

* max създ. прен. преобразувателя

(50) $X_T = 0.125$, $X_{3\phi} = 0.239$, $X_{3D} = 0.172$, $X_{ud} = 0.57$

X_d'', X_d', X_d = ?

Екв. кола за обр. X_d'':

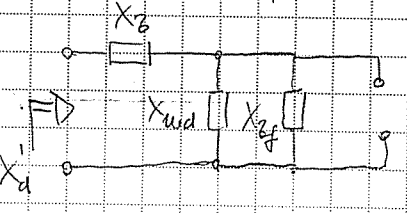


$$X_d'' = X_T + X_{ud} \parallel X_{3\phi} \parallel X_{3D} =$$

$$= 0.125 + \left(\frac{1}{0.57} + \frac{1}{0.239} + \frac{1}{0.172}\right)^{-1} =$$

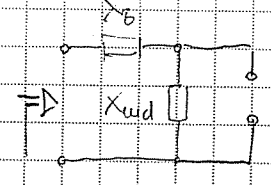
$$= \underline{0.21 \text{ (21 \%)}}$$

Екв. кола за обр. X_d':



$$X_d' = X_T + X_{ud} \parallel X_{3\phi} = \underline{0.293 \text{ (29.3 \\%)}}$$

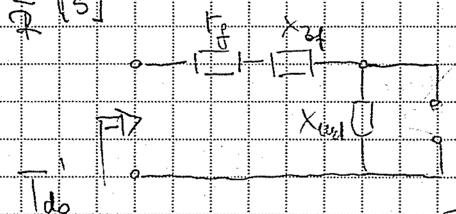
Екв. кола за обр. X_d:



$$X_d = X_T + X_{ud} = \underline{0.695 \text{ (69.5 \%)}}$$

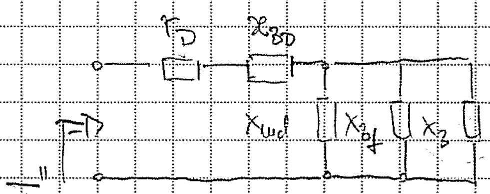
(51) $r_D = 0.0154$, $r_f = 0.00058$, 50 Hz

$T = \frac{1}{R}$ [s]



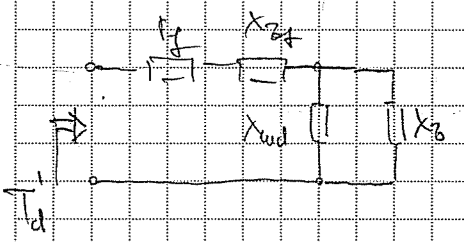
$$T'_{d0} = \frac{X_{md} + X_{\gamma f}}{r_f \cdot \omega} = \frac{0.809}{314 \cdot 0.00058} = \underline{4.44\,s}$$

(Врем. к-та поб. нам. при отв. статору)



$$T''_d = \frac{x_{\gamma D} + \left(\frac{1}{X_{md}} + \frac{1}{x_{\gamma f}} + \frac{1}{x_s}\right)^{-1}}{\omega r_D} = \underline{0.0504\,s}$$

(вр. к-та приг. при к.с. статору)



$$T'_d = \frac{x_{\gamma f} + x_{md} \| x_s}{\omega\, r_f} = \underline{1.875\,s}$$

---

(52) $r_s = 0.006$

$$T_a = \frac{X''_d}{\omega r_s} = \frac{0.21}{314 \cdot 0.006} = \underline{0.111\,s}$$ – Временска константа статора → временска к-та са којом опада DC компонента у статору → стварно да се не мења ...

DC комп. "види" све намотаје (поб. и пригушни) →

Временски облик стр. к.с:

$$i(t) = -\sqrt{2}\,U^{(0)} \cdot \left[\frac{1}{X_d} + \left(\frac{1}{X'_d} - \frac{1}{X_d}\right) e^{-t/T'_d} + \left(\frac{1}{X''_d} - \frac{1}{X'_d}\right) \cdot e^{-t/T''_d}\right] \cos(\omega t + \theta_0)$$

(услед приг. намотаја)

$$+ \sqrt{2}\,U^{(0)} \cdot \frac{1}{X''_d} \cdot e^{-t/T_a} \cos\theta_0$$

(DC компонента)

Најнеповољнији тренутак настанка квара → $\theta_0 = \phi$ → тада се има max струја (у посматраној фази) → то је тренутак када се оса поб. намотаја поклапа са осом посм. стат. намотаја! Максимална струја јавља се у тренутку $t \approx 0.01s$ (сматрамо да у том интервалу DC комп. не опада значајно)

$U^0 = 1$ p.u.

$\theta_0 = \phi$ *

$\omega t = \pi$

$$I_{max} = i(t=0.01;\ \theta_0=\phi) = -\sqrt{2}\cdot 1 \cdot \left[\frac{1}{0.695} + \left(\frac{1}{0.293} - \frac{1}{0.695}\right)\cdot e^{-0.01/1.875} + \left(\frac{1}{0.21} - \frac{1}{0.293}\right)e^{-0.01/0.0504}\right]\cdot \cos(\pi) + \sqrt{2}\cdot 1 \cdot \frac{1}{0.21}\cdot e^{-0.01/0.111}\cdot 1$$

$$I_{max} = 12.84 \text{ p.u.}$$

Након неколико секунди, због малих вредности врем. константи, струја квара опада на устаљену вредност:

$$I_{ks} = \frac{U^0}{X_d} = \frac{1}{0.695} = 1.439 \text{ p.u.}$$