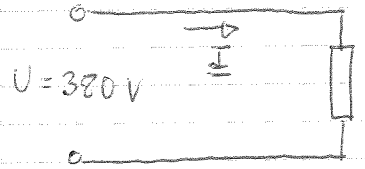
1.11* $U = 380$ V ; $\underline{Z} = 16 + j12$ Ω 1.11



$\underline{U} = 380 \angle 0°$ V

a) $\underline{I} = \dfrac{\underline{U}}{\underline{Z}} = \dfrac{380\angle 0°}{20\angle 36{,}9°} = 19\angle -36{,}9° = (15{,}2 - j\,11{,}4)$ A

$\underline{S} = \underline{U}\,\underline{I}^* = 380\angle 0° \cdot 19\angle 36{,}9° = 7220\angle 36{,}9° = (5774 + j\,4335)$ VA

$P + jQ$

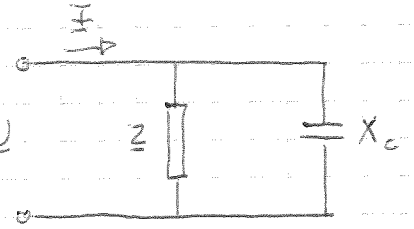
alt.

$P = UI\cos\varphi = 380 \cdot 19 \cos 36{,}9° = 5774$ W

$Q = UI\sin\varphi = 380 \cdot 19 \sin 36{,}9° = 4335$ VAr

alt. $S = \dfrac{U^2}{Z} = \dfrac{380^2}{20} = 7220$ VA → $P = S\cos\varphi$, $Q = S\sin\varphi$

b)



$\underline{I} = \underline{I}_{min}$

$S = \sqrt{P^2 + Q_g^2}$ → S_{min} om $Q = 0$

→ I_{min} ($S = UI$)

$\underline{Z} = R + jX_L$ → förbrukar Q_L

C → producerar, alstrar Q_C

$Q_L = Q_C$ → $I = I_{min}$

$X_L I^2 = \dfrac{U^2}{X_C} = Q \Rightarrow X_C = \dfrac{U^2}{Q} = \dfrac{380^2}{4335} = 33{,}3\ \Omega$

$S = UI = 380 \cdot 15{,}2 = 5776$ VA

$P = S = 5776$ W

$Q = 0$

alt $j\,11{,}4 = \dfrac{\underline{U}}{-jX_C}$ rita

$X_C = \dfrac{380}{11{,}4} = 33{,}3\ \Omega$

1.11

1.11

c)

X_c minskar med 25 %

$X_c' = 0{,}75 \cdot X_c = 0{,}75 \cdot 33{,}3 = 25\ \Omega$

$Q_c' = \frac{U^2}{X_c'} = \frac{380^2}{25} = 5776$ VAr

$Q = Q_L - Q_c = 4335 - 5776 = \underline{-1441}$ VAr

Q matas ut mot generator ; generator upptar 1441 VAr

$P = 5774$ W

$S = \sqrt{5774^2 + 1441^2} = 5941$ VA

alt:

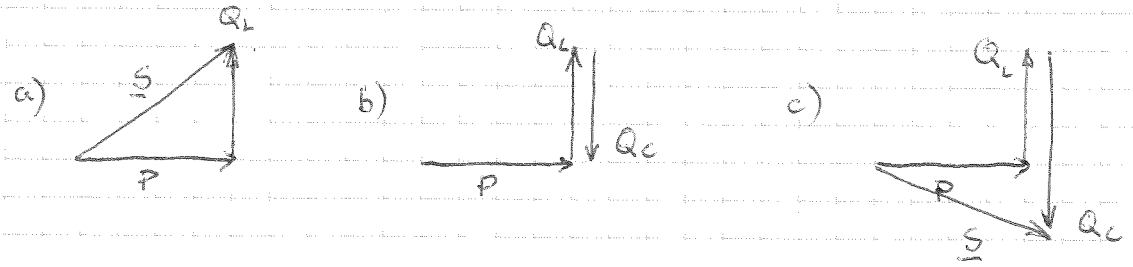
$\underline{Z}_{ekv} = \underline{Z} /\!/ X_c \Rightarrow \frac{(16 + j12)\cdot(-j25)}{16 + j12 - j25} = \frac{300 - j400}{16 - j13} =$

$= \frac{500\,\angle -53{,}1^\circ}{20{,}62\,\angle -39{,}1^\circ} = 24{,}25\,\angle -14^\circ\ \Omega$

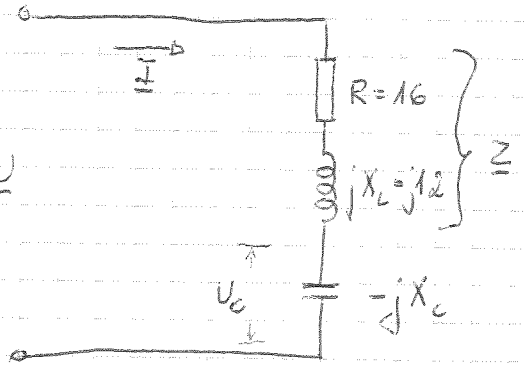
$\underline{I} = \frac{\underline{U}}{\underline{Z}_{ekv}} = \frac{380\,\angle 0^\circ}{24{,}25\,\angle -14^\circ} = 15{,}67\,\angle 14^\circ$ A kap

$\underline{S} = \underline{U}\,\underline{I}^* = 380\,\angle 0^\circ \cdot 15{,}67\,\angle -14^\circ = 5955\,\angle -14^\circ = (5778 - j1441)$ VA

(5778 = P, 1441 = Q)



d)

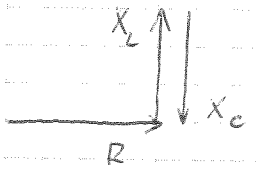


(P_{max} $U_c = ?$ vid)

$P = UI\cos\varphi \rightarrow$ om $\varphi = 0 \rightarrow P_{max}$

$Z_{ekv} = \sqrt{R^2 + (X_L - X_c)^2}$ $Z_{ekv} = Z_{min}$ om $X_L = X_c$ (då I_{max})

$\rightarrow X_c = -j12\ \Omega$ $\rightarrow Z = R = 16\ \Omega$



$I = \frac{U}{Z} = \frac{380}{16}$ A

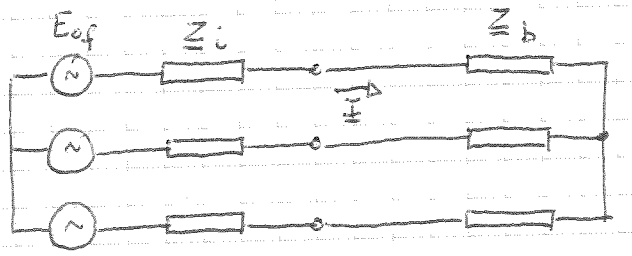
$U_c = \frac{380}{16} \cdot 12 = \underline{285\ V}$

2.2

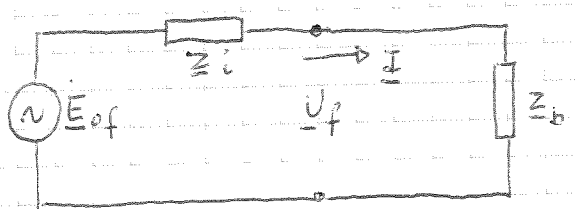
$E_0 = 500\ V$; $\underline{Z}_i = 0{,}5 + j3\ \Omega/fas$

Belastning: $\cos\varphi = 0{,}8$ ind ; $Z_b = 9\ \Omega/fas$

a) $\underline{I} = ?$



Ekv. Y-fas:



$$\underline{E}_{of} = \frac{E_0}{\sqrt{3}}\angle 0^\circ\ V \quad \text{referens}$$

$$\underline{Z}_i = 0{,}5 + j3 = 3{,}04\angle 80{,}54^\circ\ \Omega/fas$$

$$\cos\varphi = 0{,}8 \Rightarrow \varphi = 36{,}87^\circ \text{ ind}$$

$$\underline{Z}_b = 9\angle 36{,}87^\circ\ \Omega/fas = 7{,}2 + j5{,}4\ \Omega/fas$$

$$\underline{I} = \frac{\underline{E}_{of}}{\underline{Z}_i + \underline{Z}_b} = \frac{500/\sqrt{3}\angle 0^\circ}{0{,}5 + j3 + 7{,}2 + j5{,}4} = \frac{500\sqrt{3}\angle 0^\circ}{11{,}4\angle 47{,}5^\circ} = 25{,}3\angle -47{,}5^\circ\ A$$

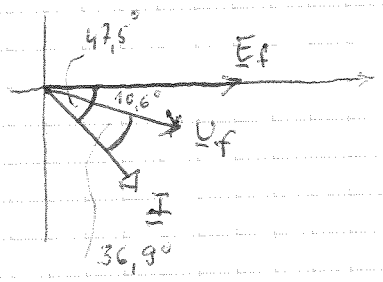
b) $$\underline{U}_f = \underline{Z}_b \underline{I} = 9\angle 36{,}87^\circ \cdot 25{,}3\angle -47{,}5^\circ = 227{,}7\angle -10{,}6^\circ\ V$$

$$U = \sqrt{3} \cdot 227{,}7 = 394{,}4\ V$$

c) $$\underline{S}_f = \underline{U}_f \underline{I}^* = 227{,}7\angle -10{,}6^\circ \cdot 25{,}3\angle 47{,}5^\circ = 5761\angle 36{,}9^\circ\ VA$$

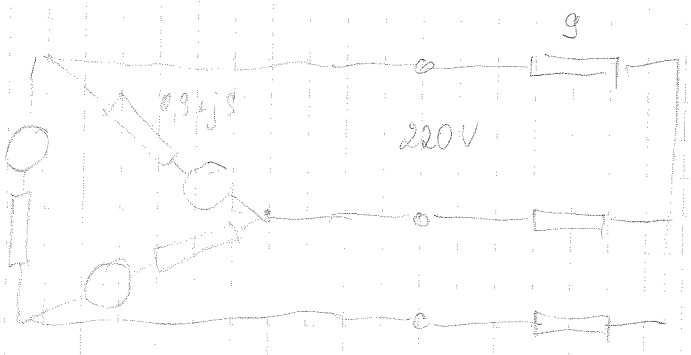
$$\underline{S} = 3\underline{S}_f = 17282\angle 36{,}9^\circ = (13826 + j10369)\ VA$$

P (W) $\quad Q$ (VAr)



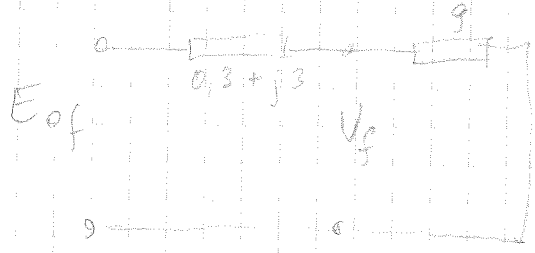
d) $$P_f = 3 R_i I^2 = 3 \cdot 0{,}5 \cdot (25{,}3)^2 = 960\ W$$

2.3



$$I = \frac{220}{\sqrt{3}\cdot 9} = 14,11A$$

$$I_\Delta = \frac{14,4}{\sqrt{3}} = 8,15A$$

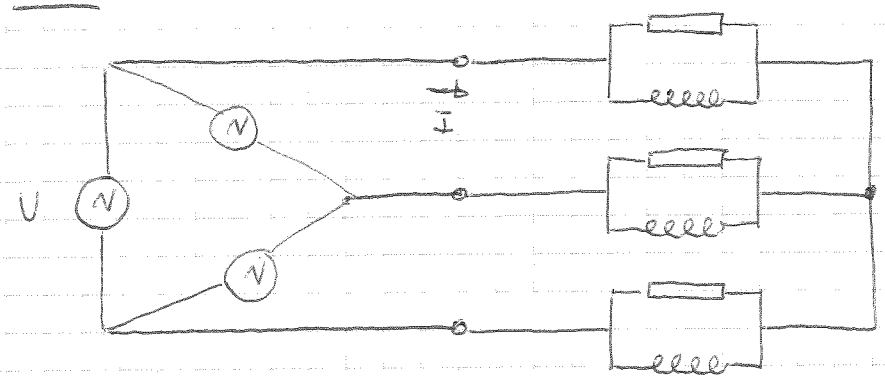


$$E_{of} = V_f + (0,3+j3)\cdot 14,11\angle 0$$
$$= 127 + 4,23 + j\,42,33$$
$$= 131,23 + j\,42,33 = 137,9\,V\angle 17,88°$$

$$E_o = 238,85V$$

2.9

2.9



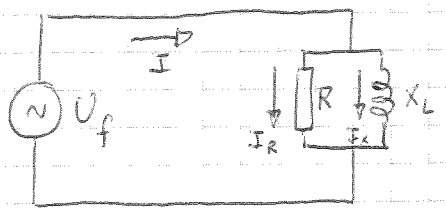
$U = 500\ V$

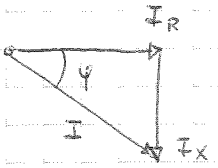
$I = 30\ A$

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

$\varphi = 36{,}87°$

Ekv. Y-fas:





$$P = 3 U_f I \cos\varphi = 3 \frac{500}{\sqrt{3}} \cdot 30 \cdot 0{,}8 = 20{,}79\ kW$$

$$I_R = I \cos\varphi = 30 \cdot 0{,}8 = 24\ A$$

$$I_x = I \sin\varphi = 30 \cdot 0{,}6 = 18\ A$$

$$P = 3 R I_R^2 \Rightarrow R = \frac{20786}{3 (24)^2} = \underline{\underline{12\ \Omega/fas}}$$

$$Q = 3 U_f I \sin\varphi = 3 \frac{500}{\sqrt{3}} \cdot 30 \cdot 0{,}6 = 15{,}59\ kVAr$$

$$Q = 3 X_L I_x^2 \Rightarrow X_L = \frac{Q}{3 (I_x)^2} = \underline{\underline{16\ \Omega/fas}}$$

alt

$$P = 3 \frac{U_f^2}{R}$$

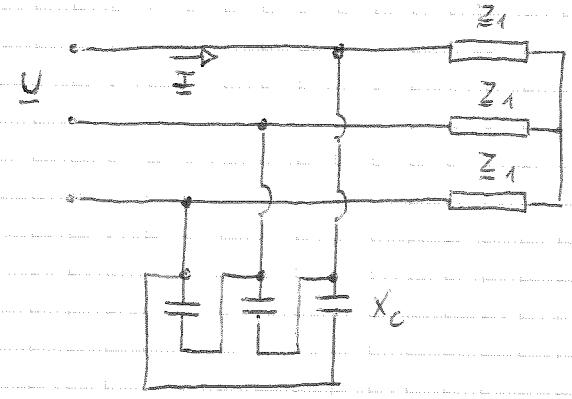
$$Q = 3 \frac{U_f^2}{X_L}$$

2.10

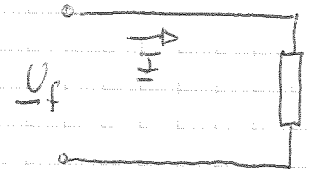
2.10

$\underline{Z}_1 = (15 + j\,9)\ \Omega/\text{fas} - Y$; $U = 380\,V$

$X_c = 100\ \Omega - \Delta$



a) Ekv. Y-fas:

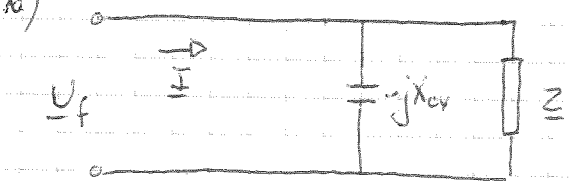


$\underline{Z} = 15 + j\,9 = 17{,}5\angle 30{,}96^\circ\ \Omega/\text{fas}$

$$\underline{I} = \frac{\underline{U}_f}{\underline{Z}} = \frac{380/\sqrt{3}\angle 0^\circ}{17{,}5\angle 30{,}96^\circ} = \underline{12{,}54\angle -30{,}96^\circ\ A}$$

$\cos 30{,}96^\circ = 0{,}86$ ind

b)



$X_c = 100\ \Omega$

$X_{cy} = \frac{1}{3}100 = 33{,}3\ \Omega/\text{fas}$

$$\underline{Z}_{tot} = \underline{Z} /\!/ -jX_{cy} = \frac{(15+j9)(-j\,33{,}3)}{15 + j\,3 - j\,33{,}3} = \frac{299{,}7 - j\,499{,}5}{15 - j\,24{,}3} =$$

$$= \frac{582{,}5\angle -59{,}0^\circ}{28{,}6\angle -58{,}40^\circ} = 20{,}4\angle \sim 0^\circ\ \Omega/\text{fas}$$

$$\underline{I} = \frac{\underline{U}_f}{\underline{Z}_{tot}} = \frac{220\angle 0^\circ}{20{,}4\angle 0^\circ} = \underline{10{,}78\angle 0^\circ\ A}$$

I ; fas med U_f

förklara fasvinkl

alt: $P = 3U_f I\cos\varphi$

$Q = 3U_f I \sin\varphi$

$Q_c = 3\frac{U^2}{X_c}$

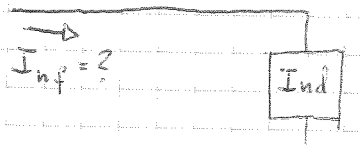
$Q_{res} = Q_L - Q_c \sim 0\ VA_r$

2.15 *

$U = 400\ V$; $f = 50\ Hz$

2.15

Före:



$P_i = 140\ kW$; $\cos\varphi_i = 0{,}707$

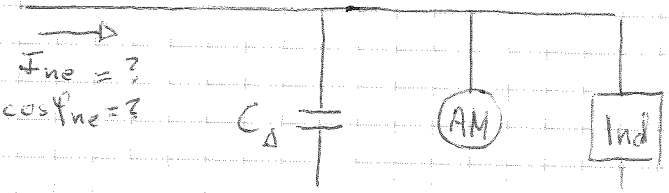
$\varphi_i = 45°$

$Q_i = P_i \tan\varphi_i = 140\ kVAr$

$S_i = \sqrt{2} \cdot 140\ kVA \Rightarrow I_{nf} = \dfrac{S_i}{\sqrt{3}U} = \dfrac{\sqrt{2} \cdot 140 \cdot 10^3}{\sqrt{3} \cdot 400} = 285{,}5\ A$

Efter:

$\underline{I}_{nf} = 285{,}5\angle -45°\ A$



$C_\Delta = 1\ mF$

$P_m = 15\ kW$; $P_i = 140\ kW$

$I_m = 28{,}5\ A$; $Q_i = 140\ kVAr$

AM

$$\begin{cases} S_m = \sqrt{3} \cdot 400 \cdot 28{,}5 = 19745\ VA \\ Q_m = \sqrt{S_m^2 - P_m^2} = \sqrt{19745^2 - 15000^2} = 12840\ VAr \end{cases}$$

Δ-kopplk. kond

$U_c = 400\ V$; $Q_c = 3\omega C_\Delta U_c^2 = 3 \cdot 100\pi \cdot 1 \cdot 10^{-3} \cdot 400^2 = 150{,}8\ kVAr$

$Q_{ne} = Q_i + Q_m - Q_c = 140 + 12{,}84 - 150{,}8 = 2{,}04\ kVAr$

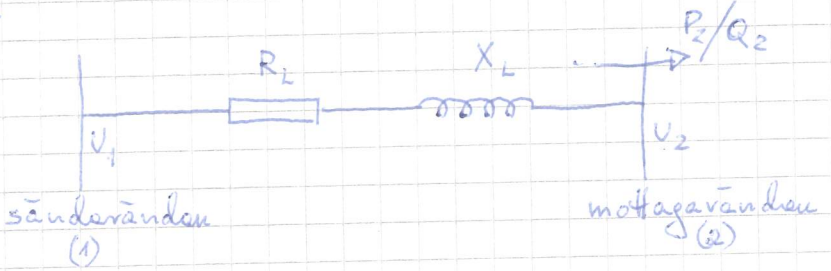
$P_{ne} = P_i + P_m = 140 + 15 = 155\ kW$

$\tan\varphi_{ne} = \dfrac{2{,}04}{155} \Rightarrow \cos\varphi_{ne} = 0{,}999$

$I_{ne} = \dfrac{P_{ne}}{\sqrt{3}U\cos\varphi_{ne}} = \dfrac{155 \cdot 10^3}{\sqrt{3} \cdot 400 \cdot 0{,}99} = 223{,}7\ A \angle -0{,}75°$

diskutera

* 3.1



$l = 40\,km$; $r = 0{,}25\ \Omega/km$, fas ; $x = 0{,}4\ \Omega/km$, fas

$P_2 = 4{,}15\ MW$; $\cos\varphi_2 = 0{,}8$; $U_2 = 30\,kV$

$U_{längsf} = a = R_L I \cos\varphi_2 + X_L I \sin\varphi_2$ $\quad / \cdot \sqrt{3}\,U_2$

$U_{tvärf} = b = X_L I \cos\varphi_2 - R_L I \sin\varphi_2$ $\quad / \sqrt{3}\,U_2$

$$U_{längs} = \frac{R_L P_2 + X_L Q_2}{U_2} \qquad \text{(som huvudsp)}$$

$$U_{tvär} = \frac{X_L P_2 - R_L Q_2}{U_2} \qquad \text{"}$$

a) med tvärspänningsfallet: $\quad X_L = 0{,}4 \cdot 40 = 16\ \Omega/fas$

$Q_2 = P_2 \tan\varphi_2 = 3{,}11\ MVAr$; $R_L = 0{,}25 \cdot 40 = 10\ \Omega/fas$

$$U_{längs} = \frac{10 \cdot 4{,}15 + 16 \cdot 3{,}11}{30} \approx 3{,}04\ kV$$

$$U_{tvär} = \frac{16 \cdot 4{,}15 - 10 \cdot 3{,}11}{30} \approx 1{,}18\ kV$$

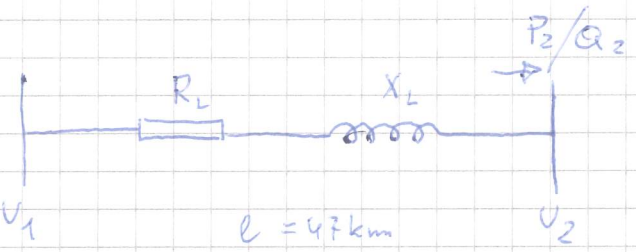
$$U_1 = \sqrt{(U_2 + U_{längs})^2 + U_{tvär}^2} = 33{,}06\ kV$$

vita visardiagr.

b) Utan tvärspänningsfallet:

$$U_1 = U_2 + U_{längs} = 33{,}04\ kV$$

3.2 *



3.2

$U_2 = ?$ om $U_1 = 51\,kV$

Linjen:

försumma tvärsp.f.

$$R_L = r \cdot \ell = 0{,}18 \cdot 47 = 8{,}46 \quad \Omega/\text{fas}$$

$$X_L = x \cdot \ell = 0{,}30 \cdot 47 = 14{,}10 \quad \Omega/\text{fas}$$

Belastningen:

P MW	cos φ	Q MVAr
2,2	0,9	1,07
1,7	0,8	1,28
0,6	0,6 kap	-0,8

$$P_2 = 4{,}5\,MW \qquad Q_2 = 1{,}55\,MVAr$$

$$U_1 = U_2 + \frac{R_L P_2 + X_L Q_2}{U_2} \;;\; U_2^2 - U_1 U_2 + R_L P_2 + X_L Q_2 = 0$$

$$R_L P_2 + X_L Q_2 = 8{,}46 \cdot 4{,}5 + 14{,}1 \cdot 1{,}55 = 59{,}9$$

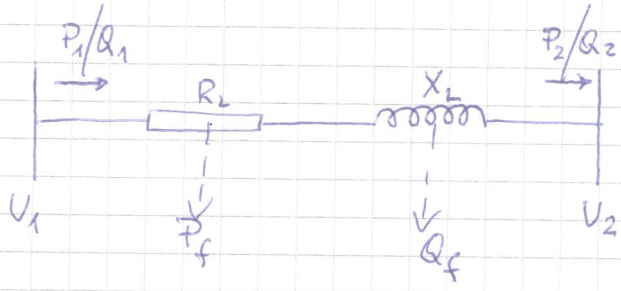
$$U_2^2 - 51 U_2 + 59{,}9 = 0$$

$$U_2 = 25{,}5 \pm \sqrt{25{,}5^2 - 59{,}9} = 25{,}5 \pm 24{,}3$$

$$U_2 = 49{,}8\,kV \qquad (\Delta U = 25{,}5 - 24{,}3 = 1{,}2\,kV)$$

3.3 *

3.3



$(1\,\Omega m = 10^6\,\Omega mm^2/m)$

$\rho = 17{,}5\ \Omega mm^2/km$

Linjen: $R_L = \rho \frac{l}{A} = 17{,}5 \cdot \frac{40}{120} = 5{,}8\ \Omega/fas$

$X_L = 0{,}4 \cdot 40 = 16\ \Omega/fas$

Lasten:

$P_2 = 12\,MW$; $\cos\varphi_2 = 0{,}8 \Rightarrow Q_2 = 9\,MVAr \Rightarrow S_2 = 15\,MVA$

$U_2 = 54\,kV$

a) Visardiagram:

Försumma tvärsp.fallet

$$U_{längs} = \frac{R_L P_2 + X_L Q_2}{U_2} = \frac{5{,}8 \cdot 12 + 16 \cdot 9}{54} = 3{,}96\ kV$$

$$U_1 = U_2 + U_{längs} \approx 58\,kV$$

$P_f = 3 R_L I^2$; $Q_f = 3 X_L I^2$

$$I = \frac{S_2}{\sqrt{3}\,U_2} = \frac{15}{\sqrt{3} \cdot 54} = 0{,}16\ kA$$

$P_f = 3 \cdot 5{,}8 \cdot 0{,}16^2 = 0{,}45\ MW$

$Q_f = 3 \cdot 16 \cdot 0{,}16^2 = 1{,}23\ MVAr$

b) Förlustsummeringsmetoden:

$P_1 = P_2 + P_f = 12 + 0{,}45 = 12{,}45\ MW$

$Q_2 = Q_2 + Q_f = 9 + 1{,}23 = 10{,}23\ MVAr$

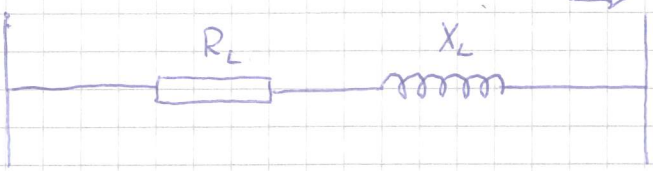
$S_1 = \sqrt{12{,}45^2 + 10{,}23^2} = 16{,}1\ MVA$; $S_1 = \sqrt{3}\,U_1 I$ där $I = 0{,}16\,kA$

$$U_1 = \frac{16{,}1}{\sqrt{3} \cdot 0{,}16} = 58{,}1\ kV$$

3.4

3.4

Före:



$U_1 = 21\,kV$ $\qquad$ $U_2 = ?$

$R_L = 5\,\Omega/fas$

$X_L = 8\,\Omega/fas$

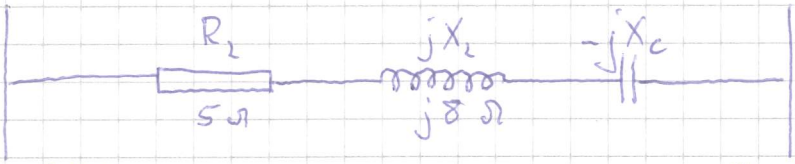
$S_2 = 5\,MVA$; $\cos\varphi_2 = 0{,}8 \Rightarrow$ $\quad P_2 = 0{,}8 \cdot 5 = 4\,MW$ $\quad Q_2 = 0{,}6 \cdot 5 = 3\,MVAr$

$$U_{längs} = \frac{R_L P_2 + X_L Q_2}{U_2} = \frac{5 \cdot 4 + 8 \cdot 3}{U_2} = \frac{44}{U_2}\ kV$$

$$U_1 \approx U_2 + U_{längs} \Rightarrow 21 = U_2 + \frac{44}{U_2} \Rightarrow U_2^2 - 21U_2 + 44 = 0$$

$$U_2 = 10{,}5 \pm 8{,}1 \Rightarrow U_2 = 18{,}6\,kV \qquad (U_{längs} = 2{,}4\,kV)$$

Efter:



$U_1 = 21\,kV$ $\qquad$ $U_2 = 1{,}1 \cdot 18{,}6 = 20{,}5\,kV$

$$U_{längs} = 21 - 20{,}5 = 0{,}5\,kV$$

$$0{,}5 = \frac{R_L P_2 + (X_L - X_C) Q_2}{U_2} \Rightarrow 10{,}25 = 20 + 24 - 3X_C$$

$$3X_C = 33{,}75 \Rightarrow \underline{\underline{X_C = 11{,}25\,\Omega/fas}}$$

4.1

$U_1 = 220\,V$ $\quad S = 75\,VA$ $\quad f = 50\,Hz$

$U_2 = 15\,V$

$A_{Fe} = (0,02 \cdot 0,03)\,m^2$ $\quad N_1;\ N_2 = ?$

$k_f = 0,9$

$\hat{B} = 1,2\,T$; $S_{Cu} = 2,5\,A/mm^2$; $\Delta U = 5\,\%$

a) Transf. formel

$$U_1 = 4,44\, f\, N_1\, A_{Fen} \cdot \hat{B} \qquad A_{Fenetto} = k_f\, A_{Fe}$$

$$N_1 = \frac{220}{4,44 \cdot 50 \cdot 0,02 \cdot 0,03 \cdot 0,9 \cdot 1,2} = \underline{1530 \text{ varv}}$$

Vid tomgång är $U_2 = 15 \cdot 1,05 = 15,75\,V$

$$\frac{U_1}{U_2} = \frac{N_1}{N_2} \Rightarrow N_2 = \frac{U_2}{U_1} N_1 = \frac{15,75}{220} \cdot 1530 = \underline{110 \text{ varv}}$$

$$I_2 = \frac{S}{U_2} = \frac{75}{15} = 5A \Rightarrow A_{2Cu} = \frac{I_2}{S_{Cu}} = \frac{5}{2,5} = \underline{2\,mm^2}$$

$$I_1 = I_2 \frac{N_2}{N_1} = 5\,\frac{110}{1530} = 0,359A \Rightarrow A_{1Cu} = \frac{0,359}{2,5} = \underline{0,144mm^2}$$

laminerad plåt $0,3 - 0,6\,mm$

ev. orienterad magnetiskt - goda magn. egenskaper i valsriktn.

legerad med 5-6 % kisel

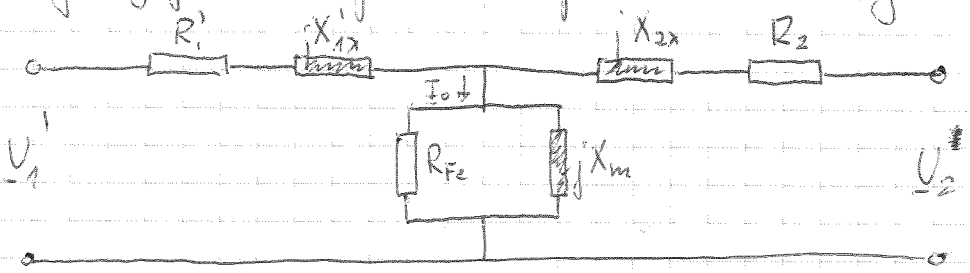
$E = 4,44\, f N A \hat{B}$

A: netto area

$V = \frac{1}{3} \cdot m^3 \cdot \frac{kg}{m^3}$

4.4 $S_n = 25\,kVA$; $400/230\,V$; en enfas trafo 4.4

Tomgångsprovet från nedsp.sida → börja med b)



$$U_2 = U_0 \Rightarrow P_0 = \frac{U_0^2}{R_{Fe}} \Rightarrow R_{Fe} = \frac{U_0^2}{P_0} = \frac{230^2}{275} = 192{,}4\ \Omega$$

$$S_0 = U_0 I_0 = 230 \cdot 7{,}8 = 1794\ VA$$

$$Q_0 = \sqrt{S_0^2 - P_0^2} = \sqrt{1794^2 - 275^2} = 1772{,}8\ VAr$$

$$X_m = \frac{U_0^2}{Q_0} = \frac{230^2}{1772{,}8} = 29{,}84\ \Omega$$

$$R_1' = \left(\frac{U_2}{U_1}\right)^2 \cdot R_1 = \left(\frac{230}{400}\right)^2 \cdot 0{,}031 = 0{,}010\ \Omega$$

$$X_{1\sigma}' = \left(\frac{U_2}{U_1}\right)^2 \cdot X_{1\sigma} = \left(\frac{230}{400}\right)^2 \cdot 0{,}15 = 0{,}05\ \Omega \qquad X_{\sigma 1}$$

$R_1' = 0{,}010\ \Omega$ $\quad R_2 = 0{,}011\ \Omega$ $\quad R_{Fe} = 192{,}4\ \Omega$

$X_{1\sigma}' = 0{,}05\ \Omega$ $\quad X_{2\sigma} = 0{,}05\ \Omega$ $\quad X_m = 29{,}84\ \Omega$

a) 400 V-sidan

$$R_2' = \left(\frac{U_1}{U_2}\right)^2 \cdot R_2 = \left(\frac{400}{230}\right)^2 \cdot 0{,}011 = 0{,}033\ \Omega$$

$$X_{2\sigma}' = \left(\quad\right)^2 \cdot X_{2\sigma} = \left(\quad\right)^2 \cdot 0{,}05 = 0{,}15\ \Omega$$

$$R_{Fe}' = \left(\quad\right)^2 \cdot R_{Fe} = \left(\quad\right)^2 \cdot 192{,}4 = 581{,}9\ \Omega$$

$$X_m' = \left(\quad\right)^2 \cdot X_m = \left(\quad\right)^2 \cdot 29{,}84 = 90{,}25\ \Omega$$

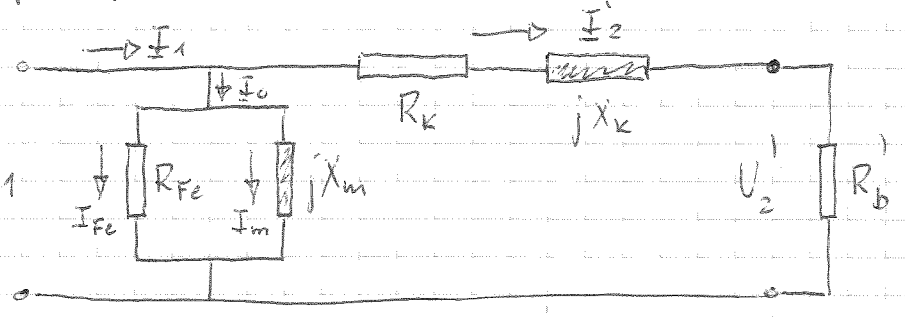
$R_1 = 0{,}031\ \Omega$
$X_{1\sigma} = 0{,}15\ \Omega$
$R_2' = 0{,}033\ \Omega$
$X_{2\sigma}' = 0{,}15\ \Omega$
$R_{Fe}' = 581{,}9\ \Omega$
$X_m' = 90{,}25\ \Omega$

4.5

$U_1 = 400\ V$; $R_b = 2{,}3\ \Omega$

Trafos förenklade ekv. schema:

a)



enl. 4:4 :

$R_{Fe} = 581{,}9\ \Omega$

$X_m = 90{,}25\ \Omega$

$R_K = R_1 + R_2' = 0{,}031 + 0{,}033 = 0{,}064\ \Omega$

$X_K = X_{1\sigma} + X_{2\sigma}' = 0{,}15 + 0{,}15 = 0{,}3\ \Omega$

$\underline{Z}_K = 0{,}064 + j\,0{,}3\ \Omega$

$\underline{Z}_b' = R_b' = R_b \left(\frac{400}{230}\right)^2 = 6{,}96\ \Omega$

$$\underline{I}_2' = \frac{\underline{U}_1}{\underline{Z}_K + \underline{Z}_b'} = \frac{400\angle 0^\circ}{0{,}064 + j\,0{,}3 + 6{,}96} = \frac{400\angle 0^\circ}{7{,}02 + j\,0{,}3} = \frac{400\angle 0^\circ}{7{,}03\angle 2{,}45^\circ} =$$

$$= 56{,}9\angle -2{,}45^\circ = (56{,}85 - j\,2{,}43)\ A$$

$$I_2 = I_2' \frac{U_1}{U_2} = 56{,}9 \frac{400}{230} = \underline{98{,}95\ A}$$

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

$$I_{Fe} = \frac{U_1}{R_{Fe}} = 0{,}69\ A \quad ; \quad I_m = \frac{U_1}{X_m} = 4{,}43\ A$$

$$\underline{I}_0 = (0{,}69 - j\,4{,}43)\ A \qquad 4{,}48 A$$

$$\underline{I}_1 = 56{,}85 - j\,2{,}43 + 0{,}69 - j\,4{,}43 = 57{,}54 - j\,6{,}86 = 57{,}95\angle -6{,}8^\circ\ A$$

$$\underline{I_1 = 57{,}95\ A}$$

liten I_0 -> försvinnas aftå

7,7 %

4.5

b) $U_2 = I_2 \cdot R_b = 98,95 \cdot 2,3 = \underline{227,6\ V}$

c) $P_2 = R_b I_2^2 = 2,3 \left(98,95\right)^2 = 22520\ W$

$P_0 = 275\ W$

$P_{cu} = R_k \left(I_2'\right)^2 = 0,064 \cdot \left(56,9\right)^2 = 207,2\ W$

$P_{forl} = 275 + 207,2 = 482,2\ W$

$$\eta = \frac{P_2}{P_1} = \frac{P_2}{P_2 + P_f} = \frac{22520}{22520 + 482,2} = 0,979$$

$$\underline{\eta = 97,9\ \%}$$

4.7 Enfastrafo

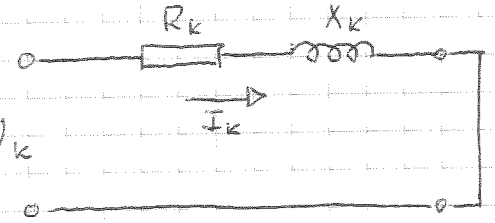
a) Ksl prov utförs med mävkström från högsp. sidan med nedsp. sidan kortsluten

$U_{1n} = 3300$ V ; $S_n = 50$ kVA

$$I_{1n} = \frac{S_n}{U_{1n}} = \frac{50 \cdot 10^3}{3{,}3 \cdot 10^3} = 15{,}15 \text{ A}$$

$I_k = I_{1n}$

Mha ksl. prov får vi fram R_k och X_k :



$U_k = 155$ V ; $P_k = 587$ W

$P_k = R_k I_k^2 \Rightarrow$

$$R_k = \frac{P_k}{I_k^2} = \frac{587}{15{,}15^2} = 2{,}56\ \Omega \quad ; \quad Z_k = \frac{U_k}{I_k} = \frac{155}{15{,}15} = 10{,}23\ \Omega$$

$$X_k = \sqrt{Z_k^2 - R_k^2} = 9{,}91\ \Omega \Rightarrow \underline{Z}_k = (2{,}56 + j\,9{,}91)\ \Omega$$

$$I_{2n} = \frac{S_n}{U_{2n}} = \frac{50 \cdot 10^3}{0{,}4 \cdot 10^3} = 125 \text{ A} \quad ; \quad I_2 = 0{,}8 \cdot I_{2n} = 100 \text{ A}$$

$$I_2' = I_2 \frac{U_{2n}}{U_{1n}} = 100\,\frac{400}{3300} = 12{,}12 \text{ A} \qquad \text{se *)} \rightarrow$$

$$\Delta U = I_2' \left(R_k \cos\varphi_2 + X_k \sin\varphi_2\right) = 12{,}12\left(2{,}56 \cdot 0{,}75 + 9{,}91 \cdot 0{,}66\right) =$$
$$= 102{,}7 \text{ V}$$

$$U_2' = U_1 - \Delta U = 3300 - 102{,}7 = 3197{,}3 \text{ V}$$

$$\underline{U_2 = U_2' \frac{U_{2n}}{U_{1n}} = 3197{,}3\,\frac{0{,}4}{3{,}3} = 387{,}5 \text{ V}}$$

$P_0 = 450\,W$

b) $P_1 = P_2 + P_{ztr}$

$P_{ztr} = P_0 + P_{cu} = P_0 + R_k (I_2')^2 = 450 + 2{,}56 (12{,}12)^2 =$

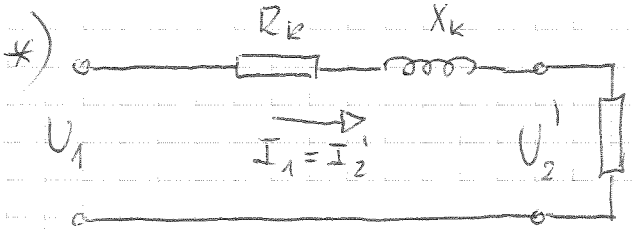
$= 450 + 376 = 826\,W$

$P_2 = U_2 I_2 \cos\varphi_2 = 387{,}5 \cdot 100 \cdot 0{,}75 = 29063\,W$

$P_1 = 29063 + 826 = 29889\,W \approx 29{,}9\,kW$

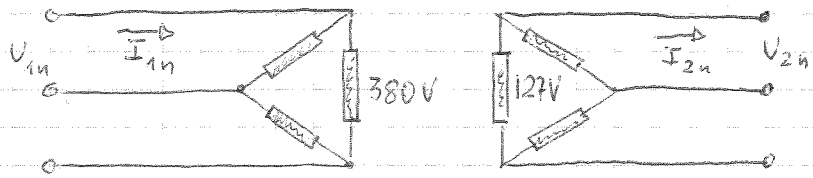
$\eta = \frac{P_2}{P_1} = \frac{29063}{29889} = 0{,}972 \Rightarrow \eta = 97{,}2\,\%$

*)



4.9 $S_n = 25\,kVA$

1. Δ/Δ



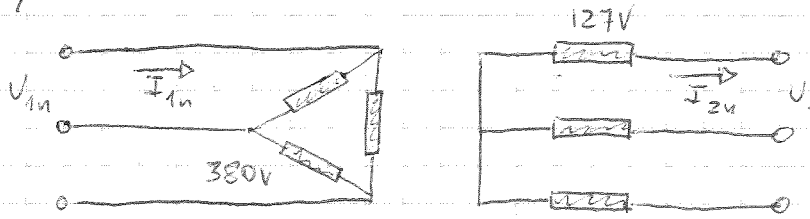
380/127 V

$S_n = \sqrt{3}\, U_{1n} I_{1n} \Rightarrow I_{1n} = \frac{25 \cdot 10^3}{\sqrt{3} \cdot 380} = 38\,A$

$I_{2n} = I_{1n} \frac{U_{1n}}{U_{2n}} = 38 \cdot \frac{380}{127} = 113{,}7\,A$

$\left(S_n = \sqrt{3}\, U_{2n} I_{2n} \Rightarrow I_{2n} = 113{,}7\,A \right)$

2. Δ/Y

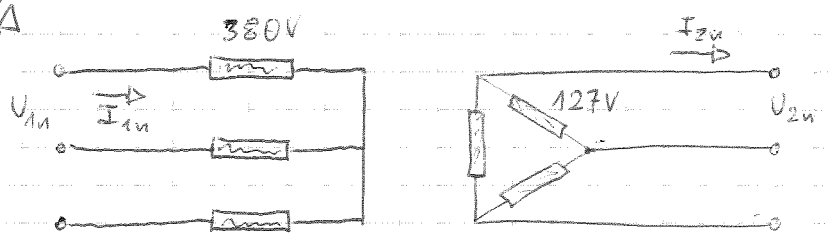


380/220 V

$I_{2n} = \frac{380}{220} \cdot 38 = \sqrt{3} \cdot 38 = 65{,}6\,A$

$I_{1n} = 38\,A$

3. Y/Δ

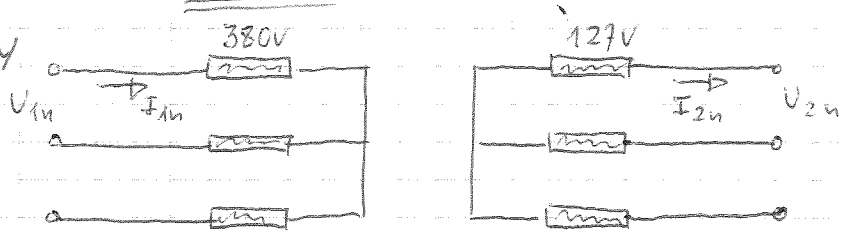


658/127 V

$U_{1n} = 380 \cdot \sqrt{3} = 658\,V$; $I_{1n} = \frac{S_n}{\sqrt{3}\, U_{1n}} = \frac{25 \cdot 10^3}{\sqrt{3}\, 658} = 21{,}9\,A$

$I_{2n} = 113{,}7\,A$ som i 1

4. Y/Y



658/220 V

$I_{1n} = 21{,}9\,A$ som 3 $\qquad I_{2n} = 65{,}6\,A$ som 2

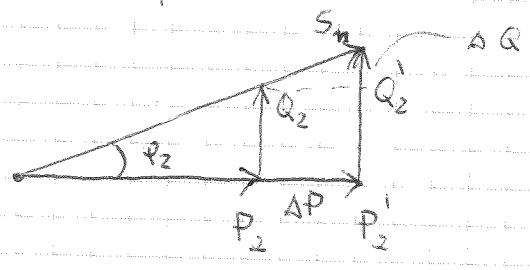
4.13

4.13

$S_n = 500\ kVA$; $6,0/0,4\ kV$

$P_2 = 300\ kW$; $\cos\varphi_2 = 0,8$ $\quad \Delta P = ?$

a) $\cos\varphi_2 = 0,8$ – konst

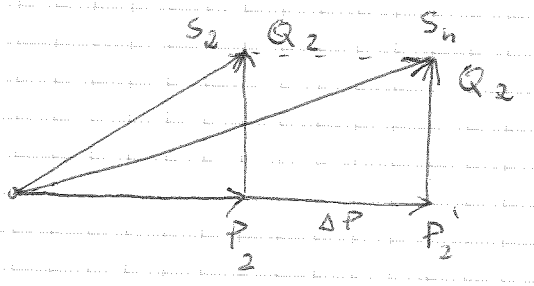


$P_2' = S_n \cos\varphi_2 = 500 \cdot 0,8 = 400\ kW$

$\underline{\Delta P = 400 - 300 = 100\ kW}$

b) $Q_2 = konst$

$Q_2 = P_2 \tan\varphi_2 = 300 \cdot 0,75 = 225\ kVAr$



$S_n^2 = (P_2 + \Delta P)^2 + Q_2^2$

$(300 + \Delta P)^2 = 500^2 - 225^2 = 199375$

$300 + \Delta P = 446,5$

$\underline{\Delta P = 146,5\ kW}$

$S_n = 125\,kVA$; $6,6/0,4\,kV$; Δ/Y

$z_k = 4,7\,\%$; $r_k = 1,1\,\%$

$$z_k = \frac{Z_k}{Z_{bas}} \quad ; \quad r_k = \frac{R_k}{Z_{bas}} \quad ; \quad X_k = \sqrt{Z_k^2 - R_k^2}$$

Räkna på 0,4 kV sidan:

$$Z_{bas} = \frac{U_{n2}^2}{S_n} = \frac{400^2}{125 \cdot 10^3} = 1,28\ \Omega/fas$$

$$Z_k = 0,047 \cdot 1,28 = 60,2 \cdot 10^{-3}\ \Omega/fas$$

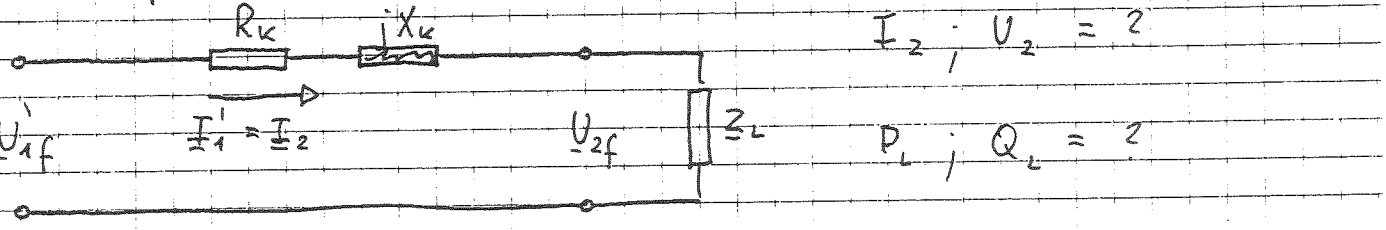
$$R_k = 0,011 \cdot 1,28 = 14,1 \cdot 10^{-3}\ \Omega/fas$$

$$X_k = 58,53 \cdot 10^{-3}\ \Omega/fas$$

a)

Y-kopplad last - $\underline{Z}_L = (0,6 + j\,1,0)\ \Omega/fas = 1,17 \angle 59,04^\circ\ \Omega/fas$

Ekv. Y-fas:



$$\underline{U}'_{1f} = \frac{400}{\sqrt{3}}\ V \quad ; \quad \underline{U}'_{1f} = \underline{Z}_{tot}\,\underline{I}_2$$

$$\underline{Z}_{tot} = \underline{Z}_k + \underline{Z}_L = 14,1 \cdot 10^{-3} + j\,58,53 \cdot 10^{-3} + 0,6 + j\,1,0 = 0,614 + j\,1,059 =$$

$$= 1,22 \angle 59,9^\circ\ \Omega/fas$$

$$\underline{I}_2 = \frac{400 \angle 0^\circ}{\sqrt{3} \cdot 1,22 \angle 59,9^\circ} = 189,3 \angle -59,9^\circ\ A \qquad \underline{I_2 = 189,3\ A}$$

$$\underline{U}_{2f} = \underline{Z}_L\,\underline{I}_2 = 189,3 \angle -59,9^\circ \cdot 1,17 \angle 59,04^\circ = 221,5 \angle -0,86^\circ\ V$$

$$U_2 = \sqrt{3}\,U_{2f} = \sqrt{3} \cdot 221,5 = 383,65\ V$$

$$P_L = \sqrt{3}\,U_2 I_2 \cos\varphi_L = \sqrt{3} \cdot 383,65 \cdot 189,3 \cdot \cos 59,04 = 64,7\ kW$$

$$Q_L = \sqrt{3}\,U_2 I_2 \sin\varphi_2 = \sqrt{3} \cdot 383,65 \cdot 189,3 \cdot \sin 59,04 = 107,9\ kVAr$$

b) ej då $I_2 > I_{n2}$ (180,4 A)
eller $S_2 > S_n$
transformatorn är överbelastad

c) $P_{Cu} = 3 R_k I_2^2 = 3 \cdot 14,1 \cdot 10^{-3} \cdot 189,3^2 = 1,52 \text{ kW}$

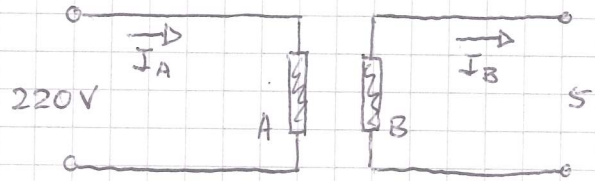
d) $I_1 = I_2 \frac{U_{n2}}{U_{n1}} = 189,3 \cdot \frac{0,4}{6,6} = 11,47 \text{ A}$

$I_\Delta = \frac{I_1}{\sqrt{3}} = 6,6 \text{ A}$

4.17

4.18

1. Fulltransformator (förlustfri; enfas)



$S = 200\ VA$

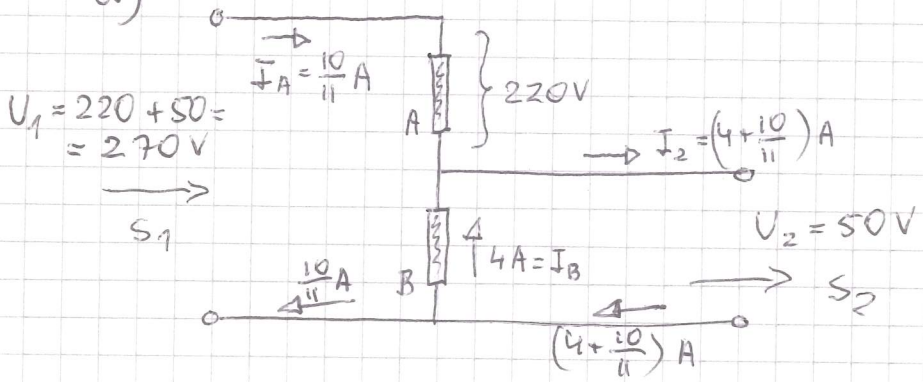
$\because\ S = U_1 I_A = U_2 I_B$

$I_A = \frac{200}{220} = \frac{10}{11}\ A$; Lindning A klarar $\frac{10}{11}\ A$

$I_B = \frac{200}{50} = 4\ A$; — " — B — " — 4 A

2. Spartransformator

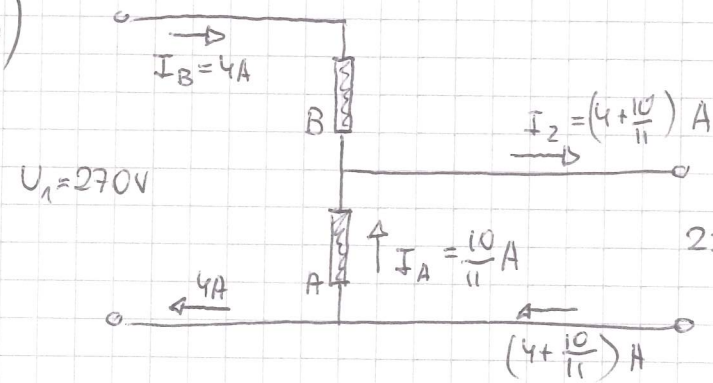
a)



270/50 V

$S_1 = 270 \cdot \frac{10}{11} = 245\ VA$ eller $S_2 = 50\left(4 + \frac{10}{11}\right) = 245\ VA$

b)



270/220 V

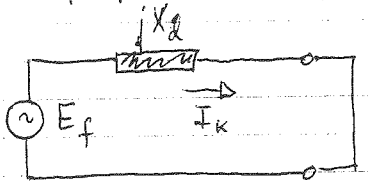
$S_1 = 270 \cdot 4 = 1080\ VA$ eller $S_2 = 220\left(4 + \frac{10}{11}\right) = 1080\ VA$

Jämför!

$S_n = 15\,kVA$; $U_n = 380\,V$

$I_k = I_a = 20\,A$ vid $E = 250\,V$

Med hjälp av ksl. prov kan X_d - beräknas:



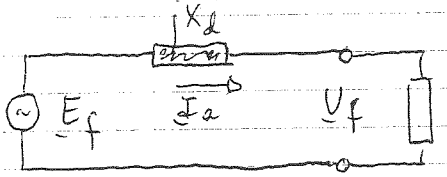
$$E_f = \frac{250}{\sqrt{3}}\ V$$

$$\underline{E}_f = jX_d \underline{I}_k$$

$$X_d = \frac{E_f}{I_k} = \frac{250}{\sqrt{3}\cdot 20} = 7{,}22\ \Omega/fas$$

a) Maskinens belastning: $R_\Delta = 27\,\Omega$

U - klämspänning - $U = 380\,V$; $E = ?$



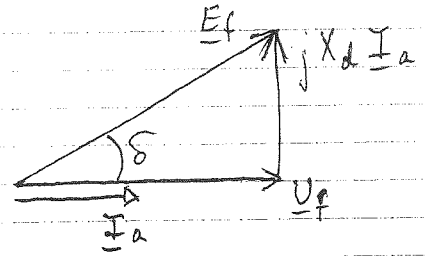
$$\underline{I}_a = \frac{\underline{U}_f}{R_Y} = \frac{380\angle 0^\circ}{\sqrt{3}\cdot 9} = 24{,}38\angle 0^\circ\ A$$

$$\underline{E}_f = \underline{U}_f + jX_d \underline{I}_a = \frac{380}{\sqrt{3}}\angle 0^\circ + j\,7{,}22\cdot 24{,}38\angle 0^\circ =$$

$$= 219{,}4 + j\,176{,}0 = 281{,}3\angle 38{,}74\ V$$

$$\underline{E} = \sqrt{3}\,E_f = 487\,V$$

b) lastvinkeln $\delta = ?$



$\delta = 38{,}74^\circ$ (se ovan)

c) Är maskinen överbelastad ?

$$I_n = \frac{S_n}{\sqrt{3}\, U_n} = \frac{15000}{\sqrt{3}\ 380} = 22{,}79\ A$$

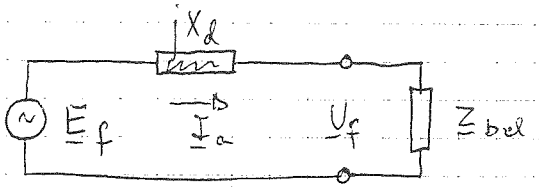
$I_a > I_n$ $\qquad 24{,}38 > 22{,}79$

Överbelastad

$U = 380\ V$; $E = 450\ V$; $X_d = 7{,}22\ \Omega/fas$

$\cos\varphi = 1$

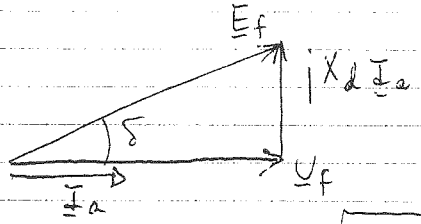
a) $I_a = ?$



$$\underline{E}_f = \frac{450}{\sqrt{3}}\ V$$

$$U_f = \frac{380}{\sqrt{3}}\ V$$

om $\cos\varphi = 1$ → I_a i fas med U_f



enl. visardiagr.:

$$E_f^2 = U_f^2 + (X_d I_a)^2$$

$$\underline{I_a} = \frac{\sqrt{E_f^2 - U_f^2}}{X_d} = \frac{\sqrt{\left(\frac{450}{\sqrt{3}}\right)^2 - \left(\frac{380}{\sqrt{3}}\right)^2}}{7{,}22} = \underline{19{,}27\ A}$$

b) $P = ?$

$$\underline{P = 3 U_f I_a \cos\varphi = 3 \cdot \frac{380}{\sqrt{3}} \cdot 19{,}27 \cdot 1 = 12{,}69\ kW}$$

c) $\delta = ?$

$$\cos\delta = \frac{U_f}{E_f} = \frac{380}{450} = 0{,}844$$

$$\underline{\delta = 32{,}38^\circ}$$

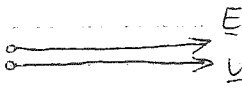
P kan även beräknas enl. följande:

$$\underline{P = \frac{E \cdot U}{X_d} \sin\delta = \frac{450 \cdot 380}{7{,}22} \cdot \sin 32{,}38 = 12{,}69\ kW}$$

7.3/1

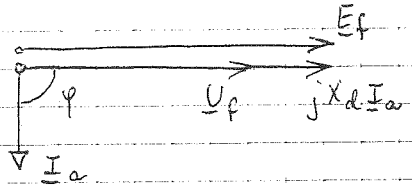
$U = 380\ V$; $X_d = 7{,}22\ \Omega/fas$

Infasning: $I_a = 0 \rightarrow \underline{E}_f = \underline{U}_f$



Ingen mekanisk effekt tillföres mask = ingen mek belastning =

= ingen aktiv effekt = endast reaktiv effekt → strömmen 90° efter U_f



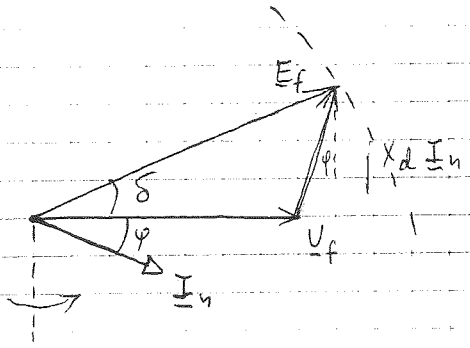
$$I_a = \frac{I_n}{2} = \frac{228}{2} = 11{,}4\ A$$

$$\underline{E}_f = \underline{U}_f + jX_d I_a = \frac{380}{\sqrt{3}} + 7{,}22 \cdot 11{,}4 = 301{,}7\ V$$

Oförändrad magnetisering → $E_f = 301{,}7\ V$; $U_f = \frac{380}{\sqrt{3}}\ V$

P ökas tills $I_a = I_n$

Visardiagram:



I_a får en aktiv komponent

cos satsen:

$$(X_d I_n)^2 = U_f^2 + E_f^2 - 2 U_f E_f \cos\delta$$

$$(7{,}22 \cdot 22{,}8)^2 = \left(\frac{380}{\sqrt{3}}\right)^2 + (301{,}7)^2 - 2\,\frac{380}{\sqrt{3}} \cdot 301{,}7 \cos\delta$$

$$\cos\delta = 0{,}846$$

$$\underline{\delta = 32{,}16^\circ}$$

7.3/2

$$P = \frac{E \cdot U}{X_d} \sin\delta = \frac{301{,}7 \cdot \sqrt{3} \cdot 380}{7{,}22} \sin 32{,}16^\circ = \underline{14{,}64\ \text{kW}}$$

$$P = S_n \cos\varphi \Rightarrow \cos\varphi = \frac{14640}{1500} = \underline{0{,}976}$$

övermagn. om maskinen avger reaktiv effekt $Q > 0$

$E_f > U_f$

alt.:

$$E_f^2 = U_f^2 + (X_d I_n)^2 - 2 U_f X_d I_n \cos(90+\varphi)$$

8.1

8.1*

3-fas AM; 6 poler ; $f = 50\,Hz$; $f_r = 1{,}5\,Hz$

$s = ?$; $n = ?$

$$f_r = s f \Rightarrow s = \frac{f_r}{f} = \frac{1{,}5}{50} = 0{,}03 \qquad \underline{s = 3\,\%}$$

$$n_s = 60\,\frac{f}{p} = 60 \cdot \frac{50}{3} = 1000\,rpm$$

$p = 3$

$$s = \frac{n_s - n}{n_s} \Rightarrow n = n_s(1-s) = 1000(1-0{,}03) = 970\,rpm$$

$$\underline{n = 970\,rpm}$$

8.2

8.2*

$P = 20\,kW$; $U_s = 380\,V$; $f = 50\,Hz$; $n_n = 1440\,rpm$

P_μ - försummas $\Rightarrow$ $P = P_m$ (brutto mek. effekt)

$P_{cur} = ?$

$$s = \frac{\omega_s - \omega}{\omega_s} \qquad s\omega_s - \omega_s = -\omega$$

$$\omega = (1-s)\,\omega_s$$

$P_{cur} = s P_\delta$ (1)

$$\frac{P_m}{\omega} = \frac{P_\delta}{\omega_s} \Rightarrow P_\delta = P_m \frac{\omega_s}{\omega} = \frac{P_m}{1-s} \quad (2)$$

(1) och (2) ger $P_{cur} = \frac{s}{1-s} P_m$

$n_s = 1500\,rpm$ (4 poler)

$$s = \frac{1500 - 1440}{1500} = 0{,}04 \Rightarrow s = 4\,\%$$

$$P_{cur} = \frac{0{,}04}{0{,}96} \cdot 20 = 0{,}833\,kW$$

$$\underline{P_{cur} = 833\,W}$$

8.5 3-fas AM

8.5*

$P_n = 0{,}35\,kW$; $U_s = 220\,V$; $f = 50\,Hz$;

[liten motor] → $\eta = 0{,}65$; $\cos\varphi = 0{,}76$; 2 poler

$R_s = 5{,}7\,\Omega/fas$; $P_{Fes} = 45\,W$; $P_\mu = 20\,W$

$n_n = ?$; $T_n = ?$

$$\eta = \frac{P_n}{P_s} \Rightarrow P_s = \frac{P_n}{\eta} = \frac{350}{0{,}65} = 538{,}5\,W$$

$$P_s = \sqrt{3}\,U_s\,I_s\cos\varphi \Rightarrow I_s = \frac{P_s}{\sqrt{3}\,U_s\cos\varphi} = \frac{538{,}5}{\sqrt{3}\cdot 220\cdot 0{,}76} =$$

$$= 1{,}86\,A$$

$$P_{cus} = 3\,R_s\,I_s^2 = 3\cdot 5{,}7\cdot 1{,}86^2 = 59{,}1\,W$$

$$P_\delta = P_s - P_{cus} - P_{Fes} = 538{,}5 - 59{,}1 - 45 = 434{,}4\,W$$

$$P_\delta = P_n + P_\mu + P_{cur}$$

$$P_{cur} = 434{,}4 - 350 - 20 = 64{,}4\,W$$

$$P_{cur} = s\,P_\delta \Rightarrow s = \frac{P_{cur}}{P_\delta} = 0{,}148\ (14{,}8\,\%)\ [\text{liten motor}]$$

$$n_s = 60\cdot\frac{50}{1} = 3000\,rpm$$

$$s = \frac{n_s - n_n}{n_s} \Rightarrow \underline{n_n = n_s(1-s) = 3000(1-0{,}148) = 2556\,rpm}$$

$$\underline{T_n = \frac{P_n}{\omega_n} = \frac{P_n\cdot 30}{\pi\,n_n} = \frac{350\cdot 30}{\pi\cdot 2556} = 1{,}31\,Nm}$$

8.6 8.6*

3-fas AM; $f = 50$ Hz; $P = 120$ kW

$U_{sn} = 3{,}3$ kV; $I_{sn} = 28{,}5$ A; $\cos\varphi = 0{,}82$; $n_n = 575$ rpm

P_μ - försummas; $R_s = 1{,}05\ \Omega$/fas

Start

$I_{start} = 160$ A; $P_{sstart} = 230$ kW

a) $T_{start} = ?$

Vid start gäller: $s = 1$; $P = 0$

P_μ - försummas $\rightarrow P_m = 0$

$P_m = P_\delta (1-s)$

$\Rightarrow P_s = P_\delta + P_{cus}$ även P_{Fes} kan försummas

$$T_{start} = \frac{P_\delta}{\omega_s}; \quad [P_\delta = P_{cus}]$$

$$P_{cus} = 3 R_s I_{start}^2 = 3 \cdot 1{,}05 \cdot 160^2 = 80{,}64 \text{ kW}$$

extra jämför med P_{cus} vid märkdrift: $P_{cus} = 3 \cdot 1{,}05 \cdot 28{,}5^2 = 2{,}56$ kW

$(I_{start}/I_{sn} = 5{,}6)$ 31,5 ggr!

$P_\delta = P_{sstart} - P_{cus} = 230 - 80{,}64 = 149{,}36$ kW

$n_s = 600$ rpm $p = ?$

$$T_{start} = \frac{149360}{\frac{2\pi \cdot 600}{60}} = 2377 \text{ Nm} \approx 2380 \text{ Nm}$$

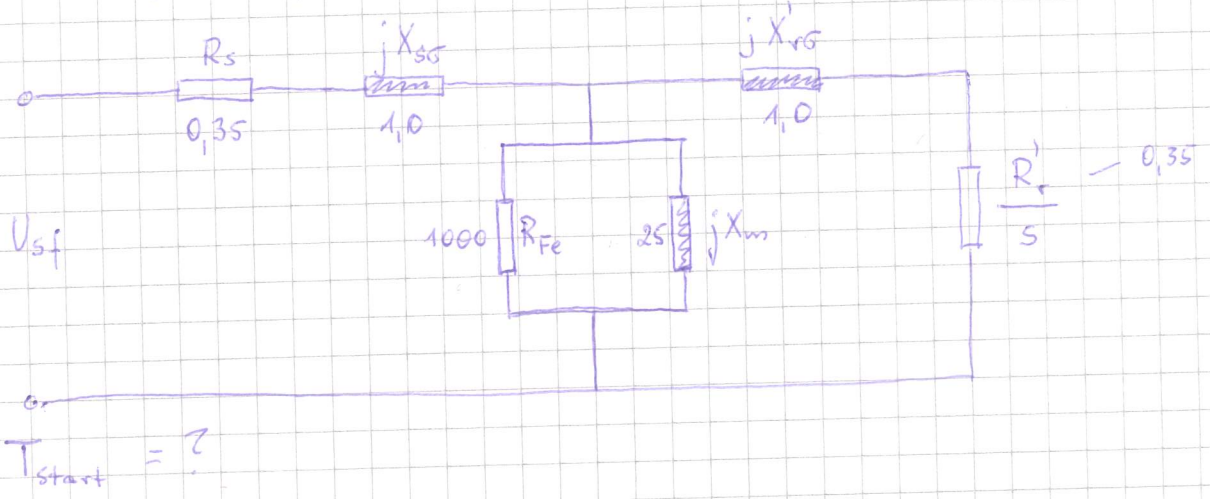
b) $P_n = \omega_n T_n \Rightarrow T_n = \frac{P_n}{\omega_n} = \frac{120 \cdot 10^3}{\frac{2\pi \cdot 575}{60}} = 1993$ Nm

$$\frac{T_{start}}{T_n} = \frac{2377}{1993} = 1{,}19$$

8.7

8.7*

3-fas AM; $f = 50$ Hz; 4 poler

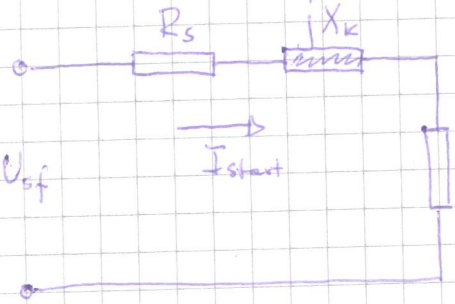


$T_{start} = ?$

Vid start $s = 1$; R_{Fe} och X_m kan försummas

då $Z_m \gg Z'_r$

Förenkla schema:



$X_k = X_{sσ} + X'_{rσ} = 2\ \Omega/\text{fas}$

$$|I_{start}| = \frac{U_{sf}}{\sqrt{(R_s + R'_r)^2 + X_k^2}} = \frac{380/\sqrt{3}}{\sqrt{0{,}7^2 + 2^2}} = 103{,}54\ \text{A}$$

Antag $P_\mu = 0 \Rightarrow T_m = T_n$ $\quad n_s = 1500$ rpm

$$T_{start} = \frac{1}{\omega_s} P_{\delta start} = \frac{1}{\omega_s} \frac{P_{cur}}{s} = \frac{1}{\omega_s} P_{cur} = \frac{1}{\omega_s} 3 R'_r I_{start}^2 =$$

$$= \frac{3 \cdot 0{,}35 \cdot 103{,}54^2}{\frac{2\pi \cdot 1500}{60}} = 71{,}66\ \text{Nm}$$

8.8

8.8*

3-fas AM; 6 poler; $P_n = 15\,kW$; $n_n = 970\,rpm$

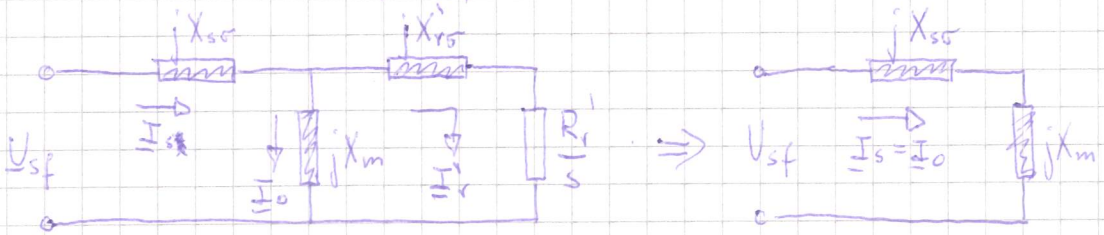
R_s och R_{Fe} - försummas

$X_{s\sigma} = 0{,}8\,\Omega/fas$; $X'_{r\sigma} = 0{,}65\,\Omega/fas$; $R'_r = \frac{0{,}19}{0{,}35}\,\Omega/fas$

$X_m = 13{,}4\,\Omega/fas$

a) $U_s = 400\,V$; $I_0 = ?$ - tomgång:

$s \approx 0 \Rightarrow \left|\frac{R'_r}{s}\right| \gg |X_m| \Rightarrow I'_r \approx 0 \Rightarrow I_s = I_0$



$$\underline{U}_{sf} = \underline{I}_0\, j\left(X_{s\sigma} + X_m\right)$$

$$\underline{I}_0 = \frac{400/\sqrt{3}\,\angle 0^\circ}{(13{,}4+0{,}8)\,\angle 90^\circ} = \underline{16{,}26\,\angle -90^\circ\ A}$$

b) $I_s = ?$ vid fullast $\qquad s = \frac{n_s - n_n}{n_s} = \frac{1000-970}{1000} = 0{,}03$

$$\frac{R'_r}{s} = \frac{0{,}19}{0{,}03} = 6{,}33\,\Omega/fas$$

$$\underline{Z} = j X_{s\sigma} + \frac{j X_m\left(\frac{R'_r}{s} + j X'_{r\sigma}\right)}{j X_m + j X'_{r\sigma} + \frac{R'_r}{s}} = j0{,}8 + \frac{j13{,}4\,(6{,}33 + j0{,}35)}{6{,}33 + j14{,}05} =$$

$$= j0{,}8 + \frac{13{,}4\,\angle 90^\circ \cdot 6{,}36\,\angle 5{,}86^\circ}{15{,}41\,\angle 65{,}75^\circ} = j0{,}8 + 5{,}53\,\angle 30{,}11^\circ =$$

$$= j0{,}8 + 4{,}78 + j2{,}77 = 4{,}78 + j3{,}57 = \underline{5{,}97\,\angle 36{,}75^\circ}\ \Omega/fas$$

$$\underline{I}_s = \frac{\underline{U}_{sf}}{\underline{Z}} = \frac{400/\sqrt{3}\,\angle 0^\circ}{5{,}97\,\angle 36{,}75^\circ} = \underline{38{,}68\,\angle -36{,}75^\circ\ A}$$

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

8.9 3-fas AM ; 4 poler ; $f = 50\,Hz$

8.9*

Fall a) $T_a = 70\,Nm$; $n_a = 1480\,rpm$

$$s_a = \frac{1500 - 1480}{1500} = \frac{20}{1500}$$

Fall b) $T_b = ?$; $n_b = 1455\,rpm$

$$s_b = \frac{1500 - 1455}{1500} = \frac{45}{1500}$$

$T = k \cdot s$

$$\frac{T_b}{T_a} = \frac{s_b}{s_a} \Rightarrow T_b = 70 \cdot \frac{45}{20} = 157{,}5\,Nm$$

$$P_b = \omega_b T_b = \frac{2\pi \cdot 1455}{60} \cdot 157{,}5 \approx 24000\,W$$

$$P_{cur} = s P_\delta = s \omega_s T$$

Fall a) $P_{cura} = s_a \omega_s T_a$

Fall b) $P_{curb} = s_b \omega_s T_b$

$$\therefore \frac{P_{cura}}{P_{curb}} = \frac{20 \cdot 70}{45 \cdot 157{,}5} \approx 0{,}2 \quad (0{,}1975)$$

5,06

$$\frac{s_b}{s_a} = 2{,}25$$

$$\frac{P_{curb}}{P_{cura}} = 2{,}25^2 = 5{,}06$$

8.11

3-fas AM ; 50 Hz

$s = 5\%$ $\quad n_{last} = 900 \div 1200$ rpm

a) Välj $n_s = 1000$ rpm $\rightarrow$ 6 poler

b) Vid märkdrift av AM gäller $s = 0{,}05 = \dfrac{1000 - n}{1000}$

$\Rightarrow n = 950$ rpm

Vid $n = 950$ rpm fås ur diagram

$T_{last} = 1 + 950 \cdot 0{,}02 = 20$ Nm

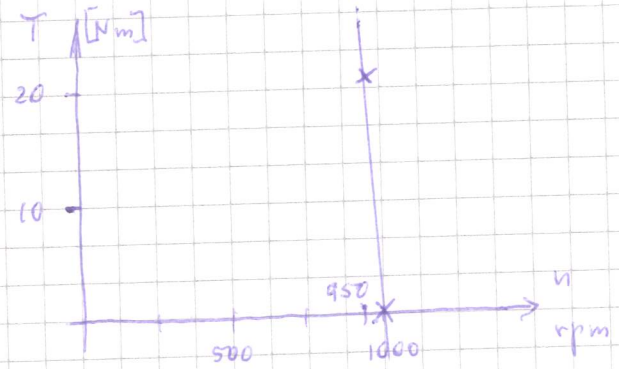
$P = \omega T \quad \Rightarrow \quad P = \dfrac{2\pi \cdot 950}{60} \cdot 20 \approx 1990$ W

$\Rightarrow$ välj $P_n = 2{,}2$ kW

c) $P_n = 2{,}2$ kW ; $n = 950$ rpm $\Rightarrow$

$\Rightarrow \quad T = \dfrac{2200}{\frac{2\pi \cdot 950}{60}} = 22{,}1$ Nm

Vid $n = n_s = 1000$ rpm är $T = 0$



$$\begin{cases} y - y_0 = k(x - x_0) \\ k = \dfrac{y_1 - y_0}{x_1 - x_0} \end{cases}$$

Momentlinjens ekv. mellan 950 och 1000 rpm

$$T - 0 = \frac{22{,}1 - 0}{950 - 1000}(n - 1000)$$

$$T = \frac{22{,}1}{50}(1000 - n)$$

8.11

d) Skärningspunkten:

$$\begin{cases} T = \frac{22,1}{50}(1000 - n) \\ T = 1 + n \cdot 0,02 \end{cases}$$

$$22,1(1000 - n) = 50(1 + 0,02n)$$

$$22100 - 22,1n = 50 + n$$

$$23,1n = 22050$$

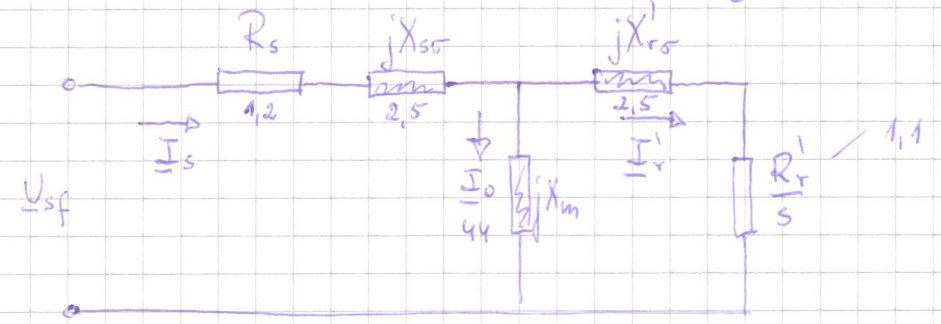
$$n = 954,55 \text{ rpm}$$

$$T = 1 + 954,55 \cdot 0,02 = 20,09$$

$$P = \omega T = \frac{2\pi \cdot 954,55}{60} \cdot 20,09 = 2008 \text{ W}$$

8.12 8.12*

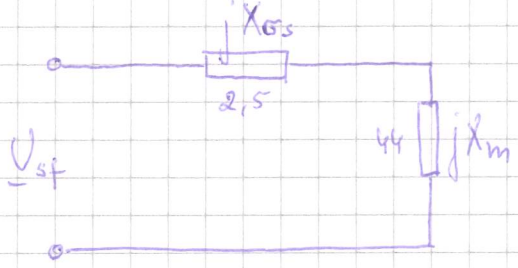
3-fas AM; $P_n = 4\,kW$; $U_{sn} = 400\,V$; $n_n = 1446\,rpm$;
$\cos\varphi = 0{,}76$; $I_{sn} = 8{,}6\,A$; $\eta = 91\%$



a) $\underline{Q = \sqrt{3}\, U_{sn}\, I_{sn} \sin\varphi = \sqrt{3} \cdot 400 \cdot 8{,}6 \cdot \sin 40{,}54^\circ = 3872\ VAr}$

b) Vid tomgång är s m. litet $\approx 0 \Rightarrow \frac{R'_r}{s}$ - stort

Ekv. schemat då:



$$Q = 3\,\frac{U_{sf}^2}{(X_{\sigma s} + X_m)} = 3\,\frac{\left(\frac{400}{\sqrt{3}}\right)^2}{46{,}5} = 3439\ VAr$$

Om man tar hänsyn till R_s får man $Q = 3435\ VAr$

Obs! Liten skillnad mellan driften vid märklast och tomgång — magnetiseringsström behövs

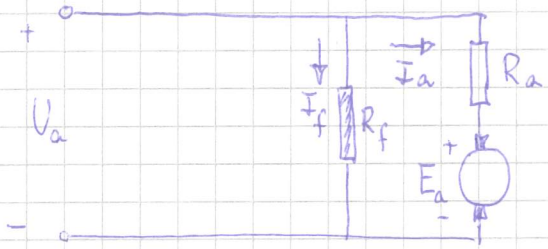
9.1 9.1*

LM - shuntmagn.

$U_a = 240\,V$ - konst. ; $R_a = 0{,}42\,\Omega$

Belastning: $I_a = 35\,A$; $n = 1475$ rpm

$n_0 = ?$; P_0 - försummas



U_a = konst → I_f = konst →

→ ϕ = konst

$E_a = k\,\omega\,\phi$

$E_a = U_a - R_a I_a = 240 - 0{,}42 \cdot 35 = 240 - 14{,}7 = 225{,}3\,V$

$225{,}3 = k\,\phi\,\omega$

$$k\,\phi = \frac{225{,}3 \cdot 60}{2\pi \cdot 1475} = 1{,}46$$

Vid tomgång gäller att $E_0 = U_0 = 240\,V$

$240 = k\,\phi\,\omega_0 \Rightarrow$

$$n_0 = \frac{60\,\omega_0}{2\pi} = \frac{60 \cdot 240}{2\pi \cdot 1{,}46} = 1571\ \text{rpm}$$

9.2 LM som i 9.1

9.2*

$$T = k \phi I_a$$

$$T_1 = k \phi \cdot 35$$

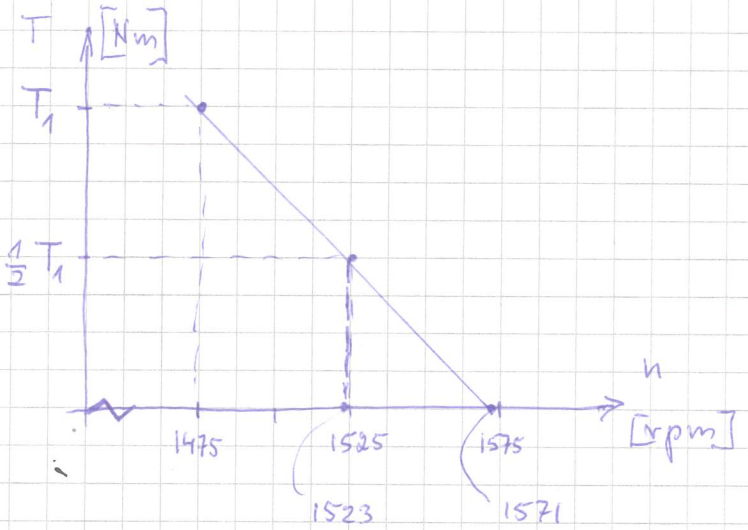
$$T_2 = \frac{1}{2} T_1 = k \phi I_{a2}$$

$$I_{a2} = \frac{1}{2} \cdot 35 = 17{,}5\ A \qquad n_2 = ?$$

$$E_{a2} = 240 - 0{,}42 \cdot 17{,}5 = 232{,}65\ V$$

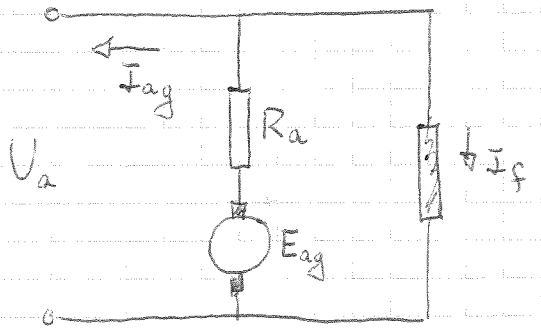
$$\left.\begin{aligned} E_{a2} &= k \phi \omega_2 \\ E_{a1} &= k \phi \omega_1 \end{aligned}\right\} \quad \omega_2 = \frac{E_{a2}}{E_{a1}} \omega_1 \Rightarrow$$

$$\Rightarrow n_2 = \frac{E_{a2}}{E_{a1}} n_1 = \frac{232{,}65}{225{,}3} \cdot 1475 = 1523\ rpm$$



9.4 9.4*

Generatordrift:



$U_a = 220\ V$

$I_{ag} = 120\ A$; $n_g = 950\ rpm$

I_f - försummas

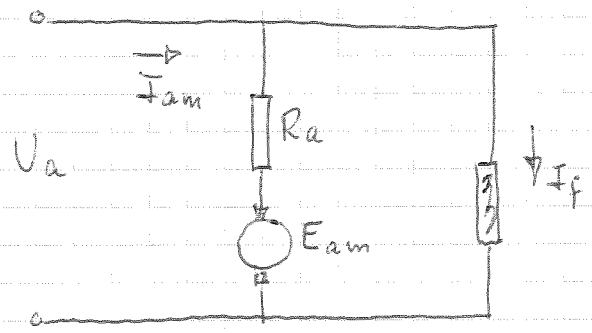
$$E_{ag} = U_a + R_a I_{ag} = 220 + 120 R_a$$

$$E_{ag} = k \phi_g \cdot \omega_g = k \phi_g \frac{\pi \cdot 950}{30}$$

momentet utv. av maskinen verkar bromsande →

→ riktat mot rotationen

Motordrift:



$U_a = 220\ V$

$I_{am} = 10\ A$; $n_m = 890\ rpm$

$$E_{am} = U_a - R_a I_{am} = 220 - 10 R_a$$

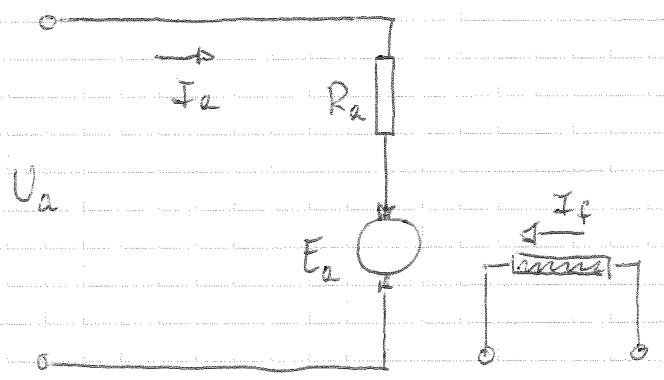
$$E_{am} = k \phi_m \cdot \frac{\pi \cdot 890}{30}$$

men U_a = konst → I_f = konst → ϕ = konst → $\phi_g = \phi_m$

$$\frac{220 + 120 R_a}{220 - 10 R_a} = \frac{k \phi_g \cdot 950}{k \phi_m \cdot 890}$$

$$R_a = \frac{132}{1163} = 0{,}1135\ \Omega$$

9.5 LM - sep. magn. 9.5*



$100 < U_a < 300$ V

$1{,}2 < I_f < 2{,}0$ A

Belastning:

$P \sim n^2$; $P = k_b n^2$

$U_a = 200$ V ; $n = 800$ rpm ; $I_a = 20$ A ; $I_f = 1{,}5$ A

Alla förluster försummas $\Rightarrow$ $R_a = 0$; $E_a = U_a$

a) $? \leq n \leq ?$

b) $? \leq I_a \leq ?$

$$P = E_a I_a = 200 \cdot 20 = 4000 \text{ W} \Rightarrow k_b = \frac{P}{n^2} = \frac{4000}{800^2} = \frac{1}{160}$$

$$E_a = k \omega \phi = k_\phi \omega I_f \; ; \; 200 = k_\phi \frac{2\pi \cdot 800}{60} 1{,}5$$

$$k_\phi = \frac{200}{\frac{2\pi \cdot 800}{60} \cdot 1{,}5} = \frac{1}{6} \frac{60}{2\pi}$$

$$n = \frac{E_a}{k_\phi \frac{2\pi}{60} \cdot I_f} = \frac{E_a}{\frac{1}{6} I_f} \quad [\text{rpm}]$$

$$n_{min} = \frac{U_{amin}}{\frac{1}{6} I_{fmax}} = \frac{100}{\frac{1}{6} \cdot 2} = 300 \text{ rpm}$$

$$\left.\begin{aligned} P_{min} &= U_{amin} \cdot I_{amin} \\ P_{min} &= k_b n_{min}^2 \end{aligned}\right\} \quad I_{amin} = \frac{k_b n_{min}^2}{U_{amin}} = \frac{\frac{1}{160} \cdot 300^2}{100} = 5{,}63 \text{ A}$$

$$n_{max} = \frac{U_{amax}}{\frac{1}{6} I_{fmin}} = \frac{300}{\frac{1}{6} \cdot 1{,}2} = 1500 \text{ rpm}$$

$$\left.\begin{aligned} P_{max} &= V_{amax} \cdot I_{amax} \\ P_{max} &= k_b \cdot n_{max}^2 \end{aligned}\right\} \quad I_{amax} = \frac{\frac{1}{160} \cdot 1500^2}{300} = 46{,}88\ A$$

$$300 \leq n \leq 1500 \quad rpm$$

$$5{,}63 \leq I_a \leq 46{,}88 \quad A$$

9.6

$I_{amax} = 40A$

9.6*

$I_{amax} = 40A$

$V_{amax} = 300V$

$P_{max} = V_{amax} \cdot I_{amax} = 40 \cdot 300 = 12000\,W$

$P = k_b n^2 \quad ; \quad k_b = \frac{1}{160}$

$12000 = \frac{1}{160} n^2$

$n = \sqrt{160 \cdot 12000} \approx 1386\ rpm$

$300 \leq n \leq 1386 \quad rpm$

$5{,}63 \leq I_a \leq 40 \quad A$

9.8 9.8*

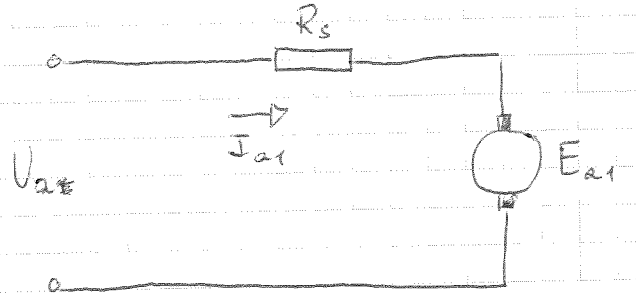
Seriemotor (LM)

$R_{s1} = 1\,\Omega = R_f + R_a$

$U_a = 200\ V$; $n_1 = 800\ rpm$; $I_{a1} = 15\ A$

$n_2 = ?$ da $R_{s2} = R_{s1} + 5 = 6\,\Omega$; $I_{a2} = I_{a1} = I_a$

1)



$I_f = I_a$

$E_{a1} = U_a - R_{s1} I_{a1} = 200 - 1 \cdot 15 = 185\ V$

$E_{a1} = k \cdot \omega_1 \cdot \phi_1 = k\phi\, \omega_1 I_{a1}$

$185 = k\phi \cdot \frac{2\pi \cdot 800}{60} \cdot 15 \Rightarrow k\phi = \frac{185 \cdot 60}{2\pi \cdot 800 \cdot 15} = \frac{15{,}42 \cdot 10^{-3}}{2\pi/60}$

2) $E_{a2} = 200 - 6 \cdot 15 = 110\ V$

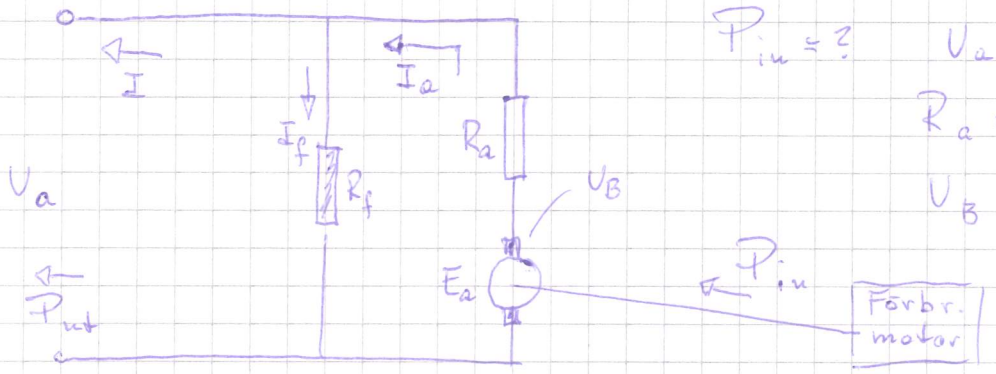
$E_{a2} = k\phi\, \omega_2 I_{a2} = k\phi \frac{2\pi n_2}{60} I_{a2} = 110$

$n_2 = \frac{110 \cdot 60}{15 \cdot 2\pi} \cdot \frac{2\pi}{60 \cdot 15{,}42 \cdot 10^{-3}} \approx 476\ rpm$

9.9 LM - shuntmagn.

9.9*

utbromsning – LM som generator



$P_{in} = ?$ $\quad U_a = 110\,V$; $I = 58\,A$

$R_a = 0{,}05\,\Omega$; $R_f = 55\,\Omega$

$U_B = 2\,V$

Förbränningsmotorns avgivna effekt = shuntgeneratorns tillförda effekt (P_μ-förlusterna försummas)

Sök P_{in} genom att summera alla effekter:

$$P_{in} = P_{ut} + P_f + P_{Cu} + P_B =$$

$$= U_a I + \frac{U_a^2}{R_f} + R_a I_a^2 + U_B I_a =$$

$$= U_a I + \frac{U_a^2}{R_f} + R_a \left(I + \frac{U_a}{R_f}\right)^2 + U_B \left(I + \frac{U_a}{R_f}\right) =$$

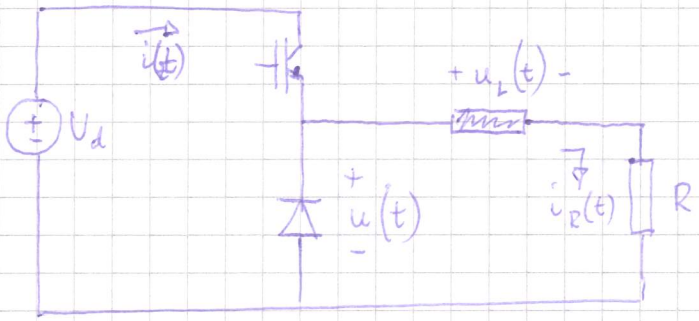
$$= 110 \cdot 58 + \frac{110^2}{55} + 0{,}05\left(58 + \frac{110}{55}\right)^2 + 2\left(58 + \frac{110}{55}\right) =$$

$$= 6380 + 220 + 180 + 120 = 6900\,W = \underline{6{,}9\,kW}$$

10.1 LS - omriktare 10.1

switchfrekv. $f = 4\,kHz$; $U_d = 72\,V$; $R = 4\,\Omega$

a) $I_R = 15\,A$; $t_p = ?$

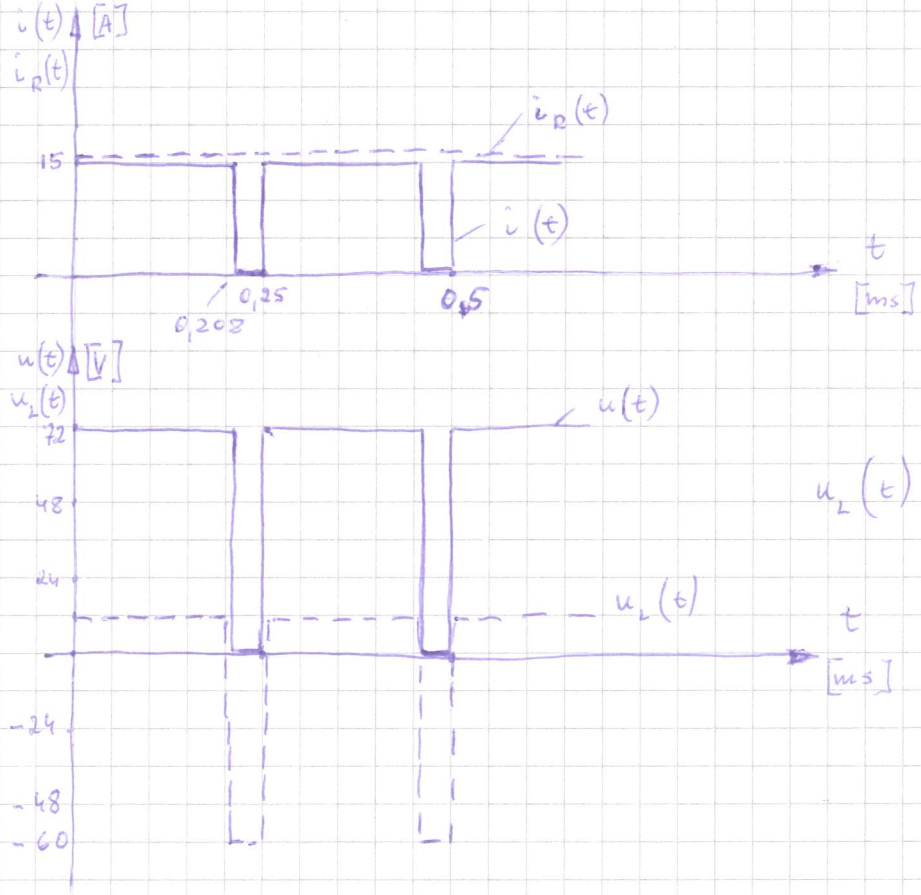


$U_R = \frac{t_p}{T} U_d$; $T = \frac{1}{f} = \frac{1}{4 \cdot 10^3} = 0{,}25\,ms$ - modulationsperiod

$U_R = I_R \cdot R = 15 \cdot 4 = 60\,V$

$t_p = T \frac{U_R}{U_d} = 0{,}25 \cdot \frac{60}{72} = \underline{0{,}208\,ms}$

b)

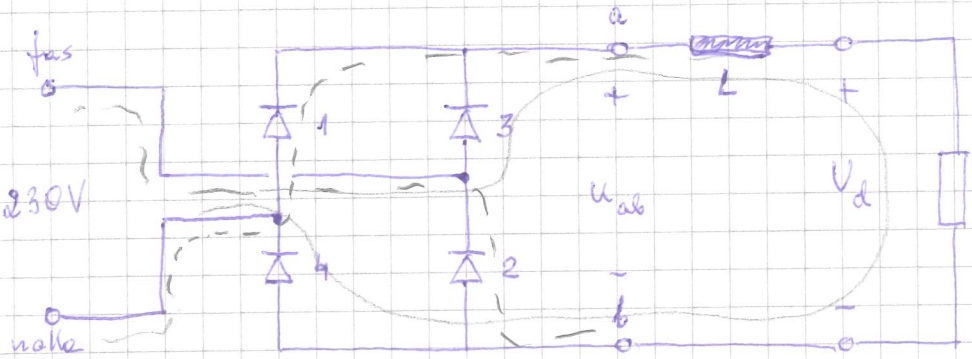


$u_L(t) = u(t) - u_R(t)$

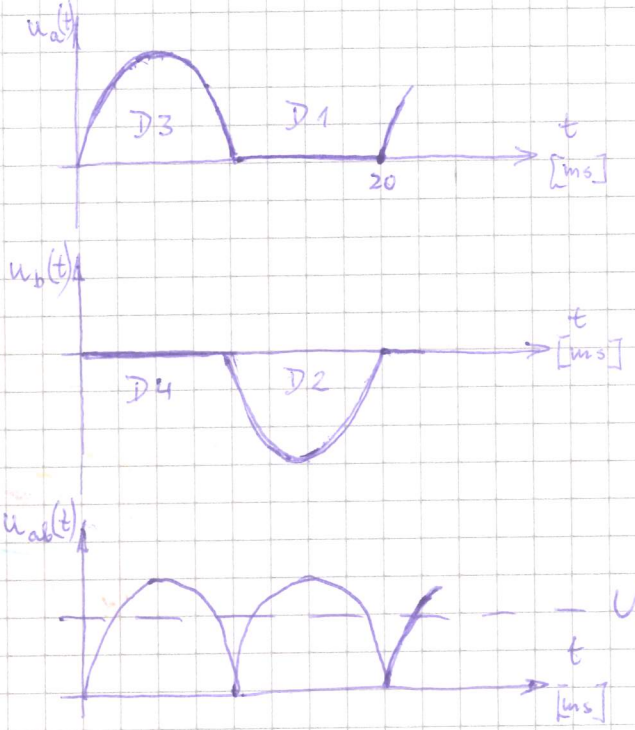
c) $\underline{I_{Rmax} = \frac{72}{4} = 18\,A}$; $\underline{\frac{t_p}{T} = 1}$

10.2

10.2



$U_d = ?$



U_d - medelvärdet av u_{ab}

$$U_d = \frac{1}{T}\int_0^T u_{ab}(\omega t)\, d(\omega t) =$$

$$= \frac{1}{\pi}\int_0^{\pi} \sqrt{2}\, U_f \sin(\omega t)\, d(\omega t) =$$

$$= \frac{1}{\pi}\sqrt{2}\, U_f \left(-\cos(\omega t)\right)\Big|_0^{\pi} =$$

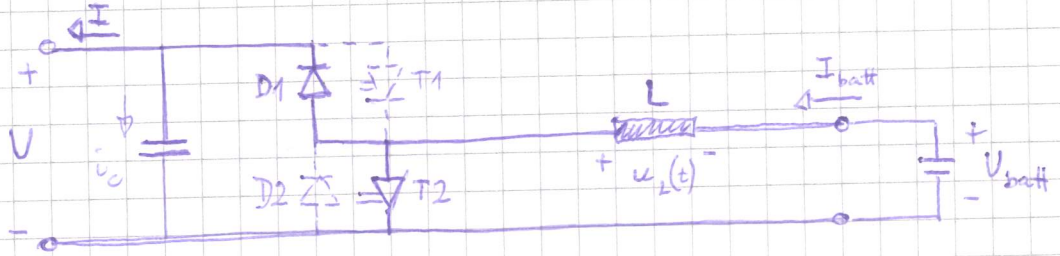
$$= \frac{1}{\pi}\sqrt{2}\, U_f \left(1+1\right) = \frac{2\sqrt{2}}{\pi} U_f = 0{,}9\, U_f$$

$U_f = 230\,V \Rightarrow U_d = 0{,}9 \cdot 230 = \underline{\underline{207\,V}}$

10.3

$U_{batt} = 96\,V$; $I = 10\,A$; $U = 300\,V$; $T = 0{,}1\,ms$

L o C - mycket stora

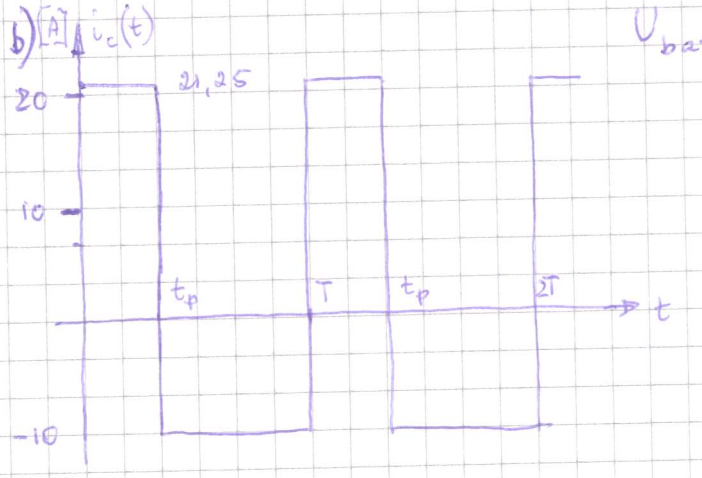


a) $\frac{t_p}{T} = ?$ $\qquad 0 \le t < t_p$ D1

$t_p < t < T$ T2

$U_{batt} = \frac{t_p}{T} U$ $\qquad \frac{t_p}{T} = \frac{96}{300} = 0{,}32$

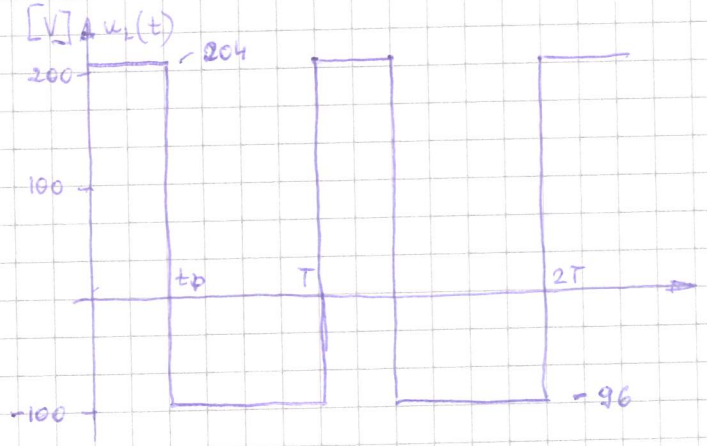
$t_p = 0{,}32 \cdot 0{,}1 = 0{,}032\,ms$

b) 

$U_{batt} \cdot I_{batt} = U I$

$I_{batt} = \frac{300}{96} \cdot 10 = 31{,}25\,A$

$i_C(t) = 31{,}25 - 10 = 21{,}25\,A$



$u_L = U - U_{batt} =$

$= 300 - 96 = 204\,V \rightarrow (t_p)$

$u_L = -96\,V \rightarrow (T - t_p)$

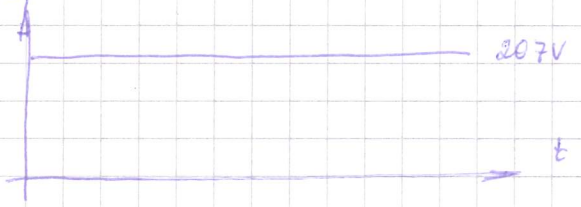
c) $I_{batt} = 31{,}25\,A$

10.7

10.7

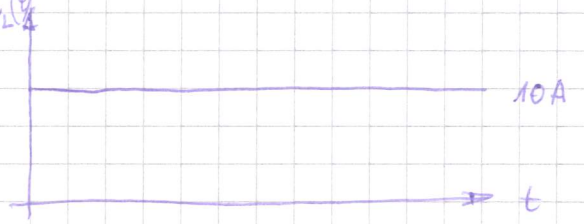
a) som 10.2 → 207 V

b) $u_c(t)$



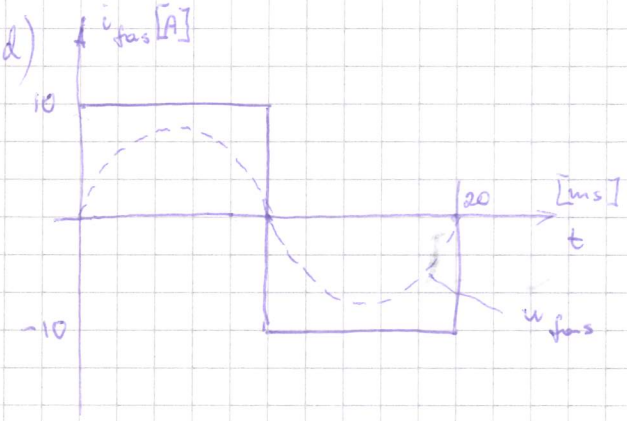
helt slået (m. stor kondensator)

c) $i_L(t)$



helt slået (m. stor induktans)

d)



10.8

10.8

3-f. diodhkv. riktare

$U = 380$ V

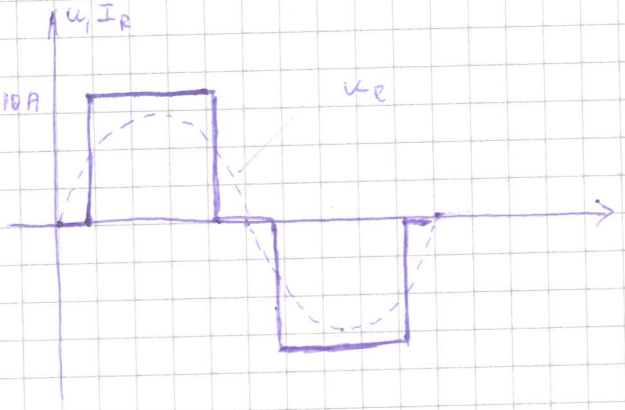
a) U_{ab} - se bilden 5.10 i komp

$$U_d = 1{,}35\,U = 513 \text{ V}$$

b) L - mycket stor

$I = 10$ A strömmen genom spolen helt slät

c)



30° - 1,67 ms

150° - 8,33 ms

210° - 11,67 ms

330° - 18,33 ms

$$U_d = \frac{3}{\pi}\int_{-\frac{\pi}{6}}^{\frac{\pi}{6}} \sqrt{2}\,U\cos\omega t\; d(\omega t) = \frac{3}{\pi}\sqrt{2}\,U \sin\omega t \Big|_{-\frac{\pi}{6}}^{\frac{\pi}{6}} =$$

$$= \frac{3}{\pi}\sqrt{2}\,U\left(0{,}5 + 0{,}5\right) = \frac{3\sqrt{2}}{\pi}\,U = 1{,}35\,U$$

F8 ~~F8~~

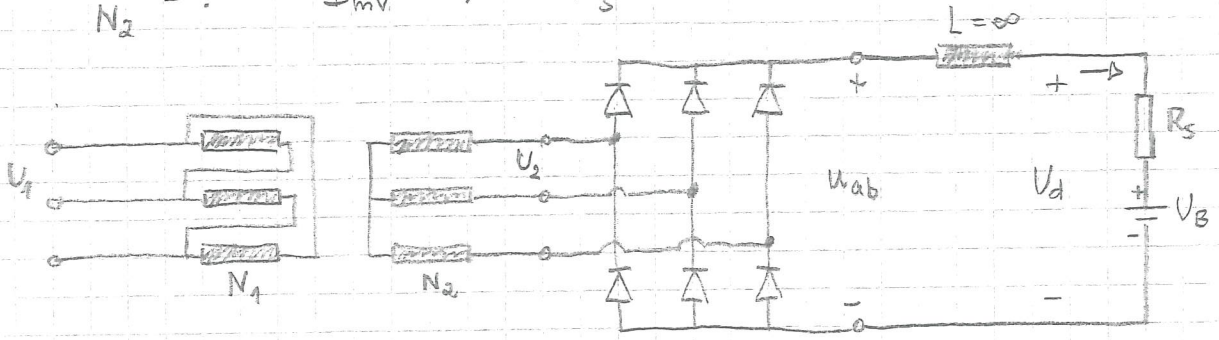
F8 Tvåvägs-sexpulskoppling – laddning av batterier

10.10

$108 \le U_B \le 125\ V$ $\quad I_{ladmax} = 60\ A$

$U_1 = 400\ V$ $\quad \Delta/Y$ - trafo $\quad \Delta U_v = 0{,}7\ V$

$\frac{N_1}{N_2} = ?$ $\quad I_{mv} = ?$ $\quad R_s = ?$



ÖH

$u_{ab}(t) = \sqrt{2}\, U_2 \cos\omega t$

$$U_d = \frac{1}{\frac{2\pi}{6}} \int_{-\pi/6}^{\pi/6} \sqrt{2}\, U_2 \cos\omega t \, d(\omega t) = \frac{3\sqrt{2}}{\pi} U_2 \left(\frac{1}{2} + \frac{1}{2}\right) \cong 1{,}35\, U_2$$

$U_d' = U_d + 2\Delta U_v = U_{Bmax} + 2\Delta U_v = 125 + 1{,}4 = 126{,}4\ V$

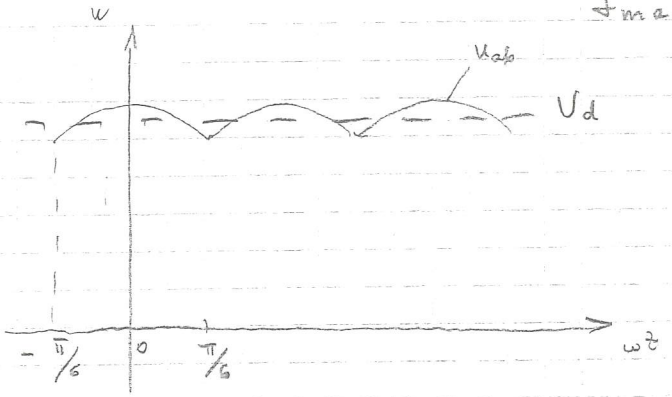
$U_2 = \frac{126{,}4}{1{,}35} = 93{,}6\ V \quad \Rightarrow U_{2f} = 54{,}04\ V$

$\frac{N_1}{N_2} = \frac{U_1}{U_{2f}} = \frac{400}{54{,}04} = \underline{\underline{7{,}4}}$ oms. mellan trafos lindningar

Varje ventil leder ström under 1/3 period

$I_{vmv} = \frac{I_{max}}{3} = \frac{60}{3} = \underline{\underline{20\ A}}$

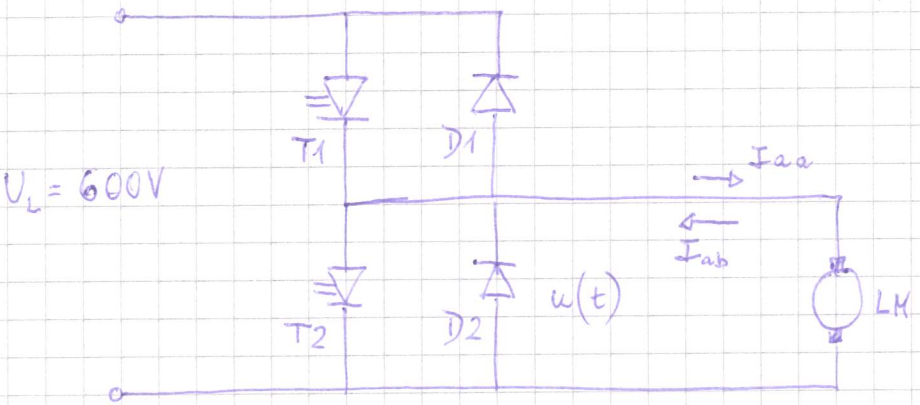
Serieresistansen $R_s = \frac{U_{Bmax} - U_{Bmin}}{I_{max}} = \frac{125 - 108}{60} = \underline{\underline{0{,}283\ \Omega}}$



10.9

10.9

$E_a = 200\,V$; $f = 1\,kHz$



a) $I_{aa} = 200\,A$ T1 ; D2

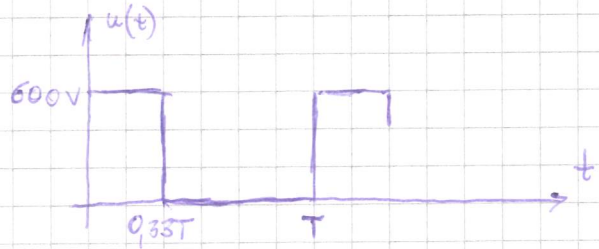
T1 leder → $u(t) = 600\,V$ $0 < t_p \leq t_p$

$$\frac{t_p}{T} = \frac{E_a}{U_L} \Rightarrow \frac{200}{600} = 0,33$$

nedsp.

$$T = \frac{1}{f} = \frac{1}{10^3} = 10^{-3}\,s \Rightarrow t_p = 0,33\,ms$$

D2 leder → $u(t) = 0$ $t_p < t < T$



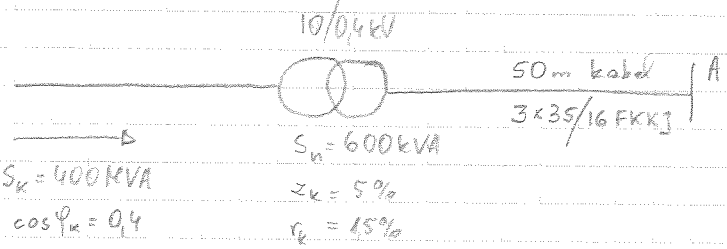
b) $I_{ab} = -200\,A$

D1 leder $u(t) = 600\,V$

T2 leder $u(t) = 0$

uppsp.

fig. som ovan



Impedansesummering: $U_e = 0,4\,kV$

Nätet:

$$S_k = \frac{U_e^2}{Z_k} \Rightarrow Z_k = \frac{U_e^2}{S_k} = \frac{0,4}{400} = 0,4\cdot10^{-3}\ \Omega/fas$$

$$R_k = Z_k \cdot \cos\varphi_k = 0,4\cdot10^{-3}\cdot 0,4 = 0,16\cdot10^{-3}\ \Omega/fas$$

$$X_k = Z_k \cdot \sin\varphi_k = 0,4\cdot10^{-3}\cdot 0,916 = 0,37\cdot10^{-3}\ \Omega/fas$$

Transformatorn:

$$R_k = r_k \cdot \frac{U_e^2}{S_n} = 0,015\ \frac{0,4^2}{0,6} = 4\cdot10^{-3}\ \Omega/fas$$

OBS!

$$X_k = x_k \cdot \frac{U_e^2}{S_n} = \sqrt{0,05^2 - 0,015^2}\cdot\frac{0,4^2}{0,6} = 12,7\cdot10^{-3}\ \Omega/fas$$

Kabel FKKJ (Cu - PE)

Enl. fig 6.5 s 32 $\Rightarrow$ R = 0,524 Ω/km ; X = 0,079 Ω/km /fas

$$R_k = 0,05\cdot 0,524 = 26,2\cdot10^{-3}\ \Omega/fas$$

$$X_k = 0,05\cdot 0,079 = 3,95\cdot10^{-3}\ \Omega/fas$$

$$\Sigma R_k = (0,16 + 4,0 + 26,2)\cdot10^{-3} = 30,36\cdot10^{-3}\ \Omega/fas$$

$$\Sigma X_k = (0,37 + 12,7 + 3,95)\cdot10^{-3} = 17,02\cdot10^{-3}\ \Omega/fas$$

$$Z_{kA} = \sqrt{30,36^2 + 17,02^2}\cdot10^{-3} = 34,8\cdot10^{-3}\ \Omega/fas$$

$$I_{kA} = \frac{U/\sqrt{3}}{Z_{kA}} = \frac{0,4}{\sqrt{3}\cdot 34,8\cdot10^{-3}} = 6,64\,kA$$

$$S_{kA} = \sqrt{3}\cdot U\cdot I_{kA} = \sqrt{3}\cdot 0,4\cdot 6,64 = 4,6\,MVA$$

Delkortslutningseffekter:

Nätet: $S_k = 400$ MVA

Trafo: $S_k = \frac{S_n}{z_k} = \frac{600 \cdot 10^3}{0,05} = 12$ MVA

Kabel:

Enl. tidigare: $R_k = 26,2 \cdot 10^{-3}$ Ω/fas

$X_k = 3,95 \cdot 10^{-3}$ Ω/fas

$$Z_k = \sqrt{26,2^2 + 3,95^2} \cdot 10^{-3} = 26,5 \cdot 10^{-3} \text{ Ω/fas}$$

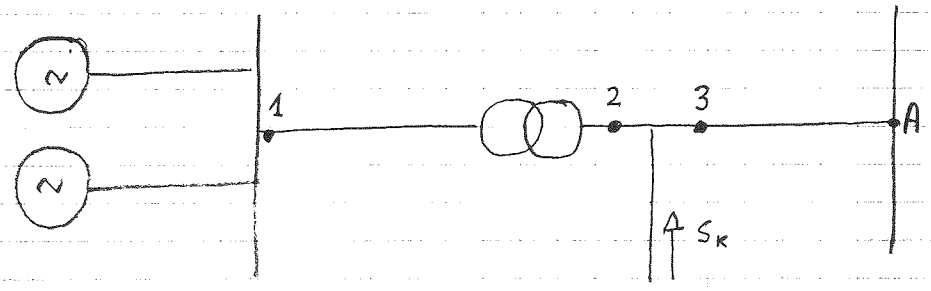
$$S_k = \frac{U^2}{z_k} = \frac{0,4^2}{26,5 \cdot 10^{-3}} = 6,04 \text{ MVA}$$

$$\frac{1}{S_{kA}} = \frac{1}{400} + \frac{1}{12} + \frac{1}{6,04}$$

$$\Rightarrow \underline{S_{kA} = 3,98 \text{ MVA}} \quad \Rightarrow I_{kA} = \frac{S_{kA}}{\sqrt{3}U} = \frac{3,98}{\sqrt{3} \cdot 0,4} = \underline{5,74 \text{ kA}}$$

Tänkför och diskutera

$S_{kA} = ?$; $I_{kA} = ?$ 11.3



1) Generatoren: $S_n = 50\ MVA$; $S_k = 6 \times S_n$

$$S_{k1} = 2 \cdot 6 \cdot S_n = 2 \cdot 6 \cdot 50 = 600\ MVA$$

2) Trafo $$S_{kT} = \frac{S_n}{z_k} = \frac{100}{0,1} = 1000\ MVA$$

$$S_{k2} = \frac{S_{k1} \cdot S_{kT}}{S_{k1} + S_{kT}} = \frac{600 \cdot 1000}{1600} = 375\ MVA$$

3)

$$S_{k3} = S_{k2} + S_k = 375 + 120 = 495\ MVA$$

Luftleitung: $$S_{kL} = \frac{U^2}{X} = \frac{130^2}{30} = 563,33\ MVA$$

A) $$\underline{S_{kA}} = \frac{S_{k3} \cdot S_{kL}}{S_{k3} + S_{kL}} = \frac{495 \cdot 563,33}{1058,33} = \underline{263,5\ MVA}$$

$$\underline{I_{kA}} = \frac{S_{kA}}{\sqrt{3} \cdot U} = \frac{263,5}{\sqrt{3} \cdot 130} = \underline{1,17\ kA}$$

$S_{KW2} = ?$; $\varphi_{KW2} = ?$; $I_{sQ1} = ?$; $I_{sQ2} = ?$

Räkna med impedanssummeringsmetoden då fasvinkeln skall anges.

1. Q1 - sidan

Nätet: $S_k = 800\ MVA$ (räkna på 70 kV - sidan)

$$Z_N = \frac{U^2}{S_k} = \frac{70^2}{800} = 6{,}125\ \Omega/fas$$

$$R_{KN} = Z_N \cos\varphi_k = 6{,}125 \cdot \cos 90^\circ = 0$$

$$X_{KN} = Z_N \sin\varphi_k = 6{,}125 \cdot \sin 90^\circ = 6{,}125\ \Omega/fas$$

Trafo T1

$$R_{KT1} = r_k \frac{U^2}{S_n} = 0{,}02 \frac{70^2}{50} = 1{,}96\ \Omega/fas$$

$$X_{KT1} = x_k \frac{U^2}{S_n} = \sqrt{0{,}1^2 - 0{,}02^2} \cdot \frac{70^2}{50} = 9{,}6\ \Omega/fas$$

$$\underline{Z}_{Q1} = 0 + 1{,}96 + j(6{,}125 + 9{,}6) = 1{,}96 + j\,15{,}725 = 15{,}85\angle 82{,}9^\circ\ \Omega/fas$$

$$I_{Q1} = \frac{U}{\sqrt{3}\, Z_{Q1}} = \frac{70 \cdot 10^3}{\sqrt{3} \cdot 15{,}85} = 2550\ A$$

$$\underline{I_{sQ1} = 2{,}5 \cdot 2550 = 6375\ A} \quad (ca\ 6400\ A)$$

2. Q2 - sidan

$$Z_{Q2} = \frac{U^2}{S_k} = \frac{70^2}{400} = 12{,}25\ \Omega/fas \qquad \cos\varphi_k = 0{,}342 \Rightarrow \varphi_k = 70^\circ$$

$$\underline{Z}_{Q2} = 12{,}25\angle 70^\circ = (4{,}19 + j\,11{,}51)\ \Omega/fas$$

$$I_{Q2} = \frac{U}{\sqrt{3}\, Z_{Q2}} = \frac{70 \cdot 10^3}{\sqrt{3} \cdot 12{,}25} = 3300\ A$$

$$\underline{I_{sQ2} = 2{,}5 \cdot 3300 = 8250\ A}$$

3. Q1-sidan // Q2-sidan

$$\underline{Z}_{W1} = \frac{\underline{Z}_{Q1} \cdot \underline{Z}_{Q2}}{\underline{Z}_{Q1} + \underline{Z}_{Q2}} = \frac{15,85\angle 82,9^\circ \cdot 12,25\angle 70^\circ}{1,96 + j\,15,725 + 4,19 + j\,11,51} =$$

$$= \frac{194,16\angle 152,9^\circ}{27,92\angle 77,28^\circ} = 6,95\angle 75,62^\circ\ \Omega/\text{fas} = (1,73 + j\,6,73)\ \Omega/\text{fas}$$

4. Trafo T2 (vid 70 kV)

$$R_{kT2} = r_k \frac{U^2}{S_n} = 0,02 \frac{70^2}{15} = 6,53\ \Omega/\text{fas}$$

$$X_{kT2} = x_k \frac{U^2}{S_n} = \sqrt{0,09^2 - 0,02^2}\ \frac{70^2}{15} = 28,66\ \Omega/\text{fas}$$

5.

$$\underline{Z}_{W2} = 6,53 + 1,73 + j(28,66 + 6,73) = 8,26 + j\,35,39 =$$

$$= 36,34\angle 76,86^\circ\ \Omega/\text{fas} \qquad \text{(vid 70 kV)}$$

$$\varphi_{kW2} = 76,86^\circ$$

$$S_{kW2} = \frac{U^2}{Z_{W2}} = \frac{70^2}{36,34} = 134,8\ \text{MVA}$$

$$\left(I_{kW2} = \frac{S_{kW2}}{\sqrt{3} \cdot U_{W2}} = \frac{134,8}{\sqrt{3} \cdot 20} = 3,89\ \text{kA} \right)$$