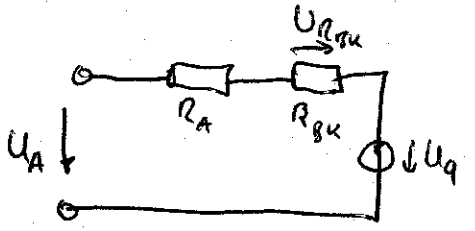
Gleichstrommaschinen

① $U_{AN} = 440\,V$; $I_{AN} = 50\,A$; $R_A = 0{,}6\,\Omega$; $U_{BK} = 3\,V$; $n_N = 800\,min^{-1}$

$R_E = 176\,\Omega$

$R_{BK} = \frac{3V}{50A} = 0{,}06\,\Omega$



a) $U_A = R_A \cdot I_A + U_q$

$\Rightarrow U_q = U_A - R_A I_A - U_{BK}$

$= 440V - (0{,}6\Omega \cdot 50A) - 3V$

$= 407\,V$

b) $M = c\phi \cdot I_A = \frac{U_q}{\omega} \cdot I_A = \frac{407V}{2 \cdot \pi \cdot \frac{800\,min^{-1}}{60\,s}} \cdot 50A = 242{,}9\,Nm$

c) $P_{auf} = U_{AN} \cdot I_{AN} = 440V \cdot 50A = 22\,kW$

$P_{rbg} = 500\,W$

$P_{Fe} = 600\,W$

$P_E = U_E I_E = \frac{U_A^2}{R_E} = \frac{(440V)^2}{176\Omega} = 1100\,W$

$P_{Cu} = I_A^2 R_A + P_E = (50A)^2\,0{,}6\Omega + 1100W = 2750\,W$

$P_{ab} = M\omega = P_{auf} - P_V$

$= P_A + P_E - P_{Cu} - P_{Fe} - P_{rbg}$

$= 22000\,W + 1100\,W - 2750W - 600W - 500W = 19250\,W$

$\eta = \frac{P}{P_A + P_E} = \frac{19250W}{23100\,W} = \frac{5}{6} = 0{,}833 \;\hat{=}\; 83{,}3\,\%$

d) $M = \frac{P}{\omega} = \frac{19250\,W}{2\pi \frac{800\,min^{-1}}{60\,s}} = 229{,}8\,Nm$

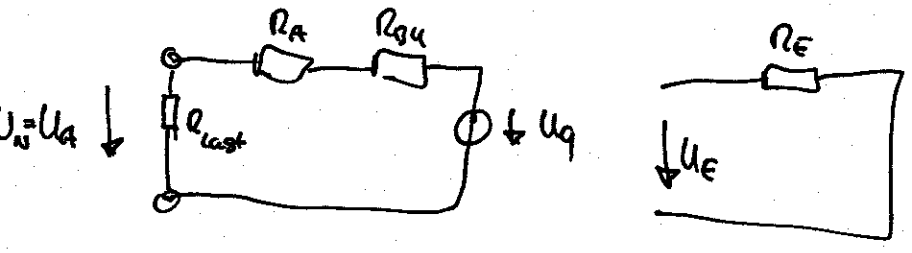
(4)

$U_E = 200\,V$ $\quad c = \frac{30}{\pi}$ $\quad R_E = 150\,\Omega$

$U_\Phi = 0{,}04\,Wb/A$ $\quad R_A = 1{,}5\,\Omega$ $\quad R_{ZU} = 0{,}5\,\Omega$

$R_{last} = 15\,\Omega$ $\quad U_N = 200\,V$

n ?



$$I_A = \frac{U_A}{R_{last}} = \frac{200\,V}{15\,\Omega} = 13\tfrac{1}{3}\,A$$

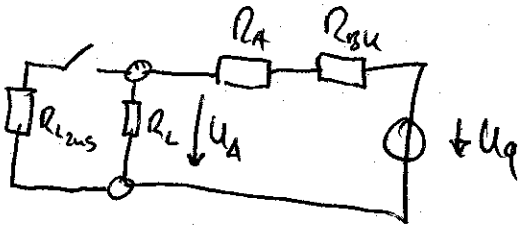
$$U_q = U_A - R_A \cdot I_A = 200\,V - (1{,}5\,\Omega + 0{,}5\,\Omega) \cdot 13\tfrac{1}{3}\,A = 173\tfrac{1}{3}\,V$$

$$\omega = \frac{U_q}{c\Phi} = \frac{173\frac{1}{3}\,V}{\frac{30}{\pi} \cdot 0{,}04\,Wb/A} = 453{,}78\,s^{-1}$$

$$n = \frac{\omega}{2\pi} = 72{,}2\,s^{-1} = 4333{,}3\,min^{-1}$$

⑤ $U_q = 400\,V$; $R_E = 600\,\Omega$; $R_A = 1{,}2\,\Omega$; $R_{Bu} = 0{,}3\,\Omega$

$R_L = 60\,\Omega$; $R_{Lzus} = 30\,\Omega$



a) $U_A = U_q \frac{R_L}{R_L + R_A + R_{Bu}} = 400\,V \frac{60\,\Omega}{61{,}5\,\Omega} = 390{,}2\,V$

$\frac{U_q}{\omega} = c\phi \qquad c\phi = \frac{U_q'}{\omega'} \Rightarrow \frac{U_q}{\omega} = \frac{U_q'}{\omega'} \Rightarrow \frac{\omega'}{\omega} = \frac{U_q'}{U_q}$

$U_A = U_q' \frac{R_L \,//\, R_{Lzus}}{(R_L \,//\, R_{Lzus}) + R_A + R_{Bu}} = U_q' \frac{20\,\Omega}{21{,}5\,\Omega}$

$U_q' = \frac{U_A \cdot 21{,}5\,\Omega}{20\,\Omega} = \frac{390{,}2\,V \cdot 21{,}5\,\Omega}{20\,\Omega} = 419{,}47\,V$

$\frac{419{,}47\,V}{400\,V} = 1{,}048 \Rightarrow \Delta\omega = 4{,}8\,\%$

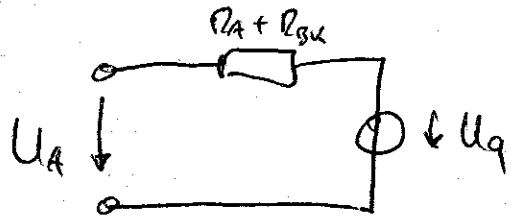
b) $U_{Last} = U_A = 390{,}2\,V$

c) $U_{RA} = U_q' \frac{R_A}{R_G} = 419{,}47\,V \frac{1{,}2\,\Omega}{21{,}5\,\Omega} = 23{,}4\,V$

$P_{VRA} = U_{RA}^2 / R_A = \frac{(23{,}4\,V)^2}{1{,}2\,\Omega} = 457\,W$

(7) $U_{AN} = 200\,V$; $R_A + R_{SK} = 2\,\Omega$; $I_{AN} = 20\,A$

$c\Phi = 0{,}9\, c\Phi_N$



$U_{qN} = U_{AN} - R_A \cdot I_{AN} = 200\,V - (2\,\Omega \cdot 20\,A)$
$= 160\,V$

$U_{qN} = c\Phi_N \cdot \omega_N$

$U_q' = 0{,}9\, c\Phi_N \cdot \omega_N$

$\frac{U_{qN}}{c\Phi_N} = \frac{U_q'}{0{,}9 \cdot c\Phi_N}$

$\Rightarrow U_q' = U_{qN} \cdot 0{,}9$
$= 160\,V \cdot 0{,}9 = 144\,V$

$I_{AN} = \frac{U_{AN} - U_q'}{R_A + R_{SK}} = \frac{200\,V - 144\,V}{2\,\Omega} = 28\,A$

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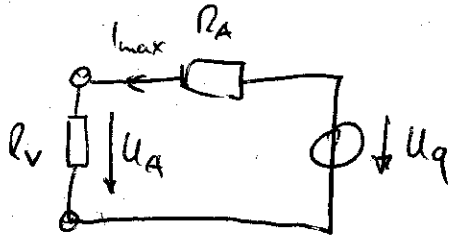
(9)



$I_{max} = 2 \cdot I_{AN} = 100\,A$

$R_A = 0{,}3\,\Omega$

$I_{AN} = 50\,A$

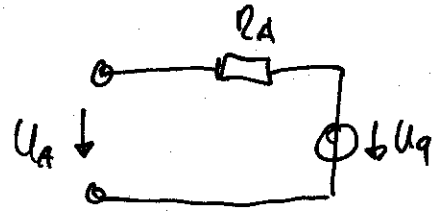
$U_A = 120\,V$

R_V ?

$R_{Ges} = \frac{U_A}{I_{max}} = \frac{120\,V}{100\,A} = 1{,}2\,\Omega$

$R_V = R_{Ges} - R_A = 1{,}2\,\Omega - 0{,}3\,\Omega = 0{,}9\,\Omega$

(8) $U_A = 220\,V$ $\quad M_1 = 8\,Nm$ $\quad I_{A1} = 16\,A$ $\quad n_1 = 3500\,min^{-1}$



a) R_A ?

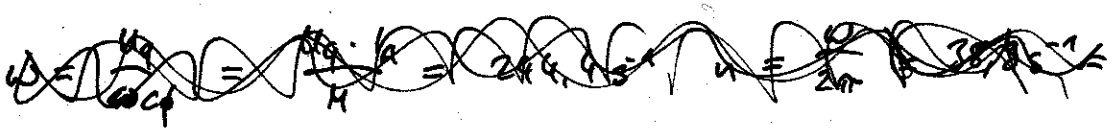
$$M = c\phi \cdot I_A \quad \Rightarrow \quad c\phi = \frac{M}{I_A}$$

$$U_q = c\phi \cdot \omega = \frac{M}{I_A}\,\omega = \frac{8\,Nm}{16\,A} \cdot 2\pi \cdot \frac{3500\,min^{-1}}{60\,s} = 183{,}8\,V$$

$$U_A = R_A\, I_A + U_q$$

$$R_A = \frac{U_A - U_q}{I_A} = \frac{220\,V - 183{,}8\,V}{16\,A} = 2{,}3\,\Omega$$

b) $M_2 = 12\,Nm$



$$\frac{M}{I_A} = c\phi \quad \Rightarrow \quad \frac{8\,Nm}{16\,A} = \frac{12\,Nm}{I_A'} \quad \Rightarrow I_A' = 12\,Nm \cdot 16\,A : 8\,Nm = 24\,A$$

$$U_q' = U_A - R_A \cdot I_A' = 220\,V - 2{,}3\,\Omega \cdot 24\,A = 164{,}8\,V$$

$$\omega' = \frac{U_q}{c\phi} = \frac{U_q' \cdot I_A'}{M} = \frac{164{,}8\,V \cdot 24\,A}{12\,Nm} = 329{,}6\,s^{-1}$$

$$n = \frac{\omega}{2\pi} = 52{,}46\,s^{-1} = 3147\,min^{-1}$$

(13)

$U_A = 220\,V$

$n = 3600\,min^{-1}$

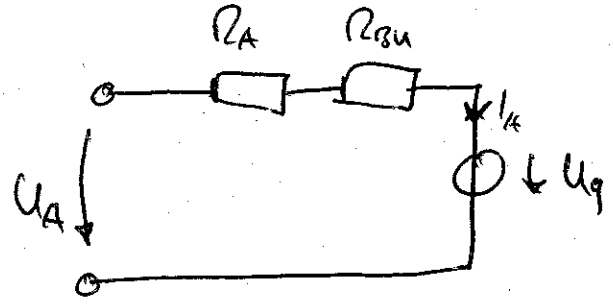
$M = 8\,Nm$

$I_A = 16\,A$

$P_{rbg} = 113\,W$

$U_{Bü} = 2\,V$

R_A ?



$$U_A = R_A \cdot I_A + U_q$$

$$R_{Bü} + R_A = \frac{U_A - U_q}{I_A}$$

$$M_G = M + \frac{P_{rbg}}{\omega} = 8\,Nm + \frac{113\,W}{2\pi \cdot 60\,s^{-1}} = 8{,}3\,Nm$$

$$M = c\phi\, I_A \qquad c\phi = \frac{M}{I_A}$$

$$U_q = \frac{M_G}{I_A} \cdot \omega = \frac{8{,}3\,Nm}{16\,A} \cdot 2\pi \frac{3600\,min^{-1}}{60\,s} = 195{,}6\,V$$

$$R_{Bü} + R_A = \frac{220\,V - 195{,}6\,V}{16\,A} = 1{,}53\,\Omega$$

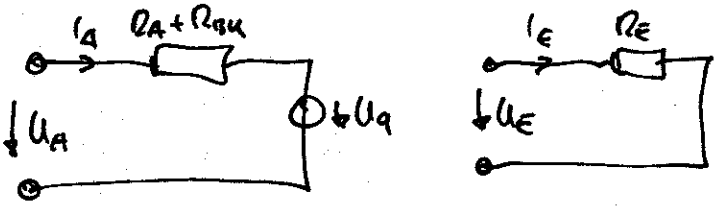
$$R_A = (R_A + R_{Bü}) - \frac{U_{Bü}}{I_A} = 1{,}53\,\Omega - \frac{2\,V}{16\,A} = 1{,}4\,\Omega$$

Zusatzaufgabe

$U_{AN} = 200\,V$, $I_{AN} = 20\,A$, $U_{EN} = 300\,V$, $I_{EN} = 0{,}9\,A$

$n_N = 3200\ min^{-1}$

$R_A + R_{Su} = 2\,\Omega$



a) $P_{auf} = P_A + P_E = U_A I_A + U_E I_E = 200V \cdot 20A + 300V \cdot 0{,}9A$

$= 4270\ W$

$P_V = P_{Cu} = I_A^2 (R_A + R_{Su}) + I_E^2 \frac{U_{EN}}{I_{EN}} = (20A)^2 \cdot 2\Omega + 0{,}9A \cdot 300V$

$= 1070\,W$

$P_{ab} = P_{auf} - P_V = 4270\,W - 1070\,W = 3200\ W$

$P_{ab} = M\omega \Rightarrow M = \frac{P_{ab}}{\omega} = \frac{3200\,W}{2\pi \frac{3200\,min^{-1}}{60s}} = 9{,}55\ Nm$

b) $c\phi^* = 0{,}5\, c\phi_N$ Durch Verringerung des Erregerstroms

$U_{AN} = U_A^*$ n? M?

$I_{AN} = I_A$

$U_q = U_A - R_A I_A = 200V - 2\Omega \cdot 20A = 160\ V$

$U_q = c\phi_N \cdot \omega_N$
$U_q = 0{,}5\, c\phi_N\, \omega$

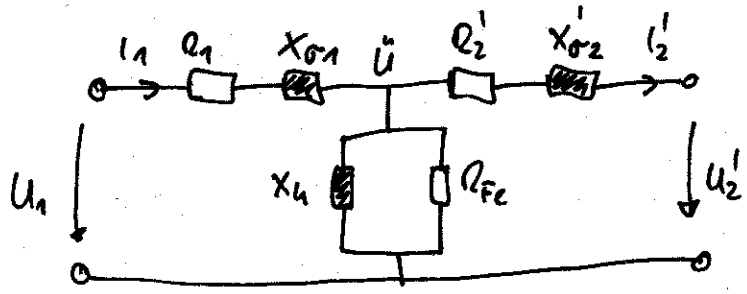
$c\phi_N \omega_N = 0{,}5\, c\phi_N\, \omega$

$2\omega_N = \omega \Rightarrow n = 2n_N = 6400\ min^{-1}$

$M_N = c\phi_N \cdot I_A$
$M = 0{,}5\, c\phi_N \cdot I_A$

$\frac{M_N}{c\phi_N} = \frac{M}{0{,}5 c\phi_N} \Rightarrow M = 0{,}5 \cdot M_N = 4{,}775\ Nm$

Trafos

① 

$R_1 = 1\Omega$ $\quad X_h = 100\Omega$
$X_{\sigma 1} = 2\Omega$ $\quad R_{Fe} = \infty$
$R_2' = 1\Omega$ $\quad U_1 = 220\,V$
$X_{\sigma 2}' = 2\Omega$

$\ddot{u} = \frac{N_1}{N_2} = 15{,}81$

a) U_{20}' ; U_2' bei $R_{Last} = 0{,}1\Omega$?

$$U_{20}' = U_1 \frac{X_h}{X_h + X_{\sigma 1}} = 220\,V \frac{100\Omega}{102\Omega} = 215{,}7\,V$$

$$R_{Last}' = \ddot{u}^2 \cdot R_{Last} = 15{,}81^2 \cdot 0{,}1\Omega = 25\Omega$$

(3) $U_{1N} = 380\,V$ $\quad \cos\varphi_{1N} = 0{,}9\,\text{ind}$ $\quad P_{1N} = 3000\,W$

$u_k = 4\,\%$ $\quad R_k = 0{,}5\,X_k$ $\quad P_{Fe} = 0{,}8 \cdot P_{CuN}$

η_N ? $\quad \eta = \frac{P_{ab}}{P_{2a}} = \frac{P_1 - P_V}{P_1} = 1 - \frac{P_{CuN}\left(\frac{I_1}{I_{1N}}\right)^2 + P_{Fe}}{P_1}$

$P_{1N} = U_{1N}\, I_{1N} \cos\varphi_{1N}$

$I_{1N} = \frac{P_{1N}}{U_{1N} \cdot \cos\varphi_{1N}} = \frac{3000\,W}{380\,V \cdot 0{,}9} = 8{,}77\,A$

~~$P_{CuN} = I_{1N}^2 R$~~

$U_{kN} = \frac{u_k \cdot U_{1N}}{100\,\%} = \frac{4\,\% \cdot 380\,V}{100\,\%} = 15{,}2\,V$

$Z_k = \frac{U_{kN}}{I_{1N}} = \frac{15{,}2\,V}{8{,}77\,A} = 1{,}733\,\Omega$

$Z_k = \sqrt{R_k^2 + X_k^2} = \sqrt{(0{,}5\,X_k)^2 + X_k^2} = \sqrt{1{,}25\,X_k^2} = 1{,}118\,X_k$

$\Rightarrow X_k = \frac{Z_k}{1{,}118} = 1{,}55\,\Omega$

$R_k = 0{,}5 \cdot 1{,}55\,\Omega = 0{,}775\,\Omega$

$P_{CuN} = R_k \cdot I_{1N}^2 = 0{,}775\,\Omega \cdot (8{,}77\,A)^2 = 59{,}6\,W$

$P_{Fe} = 0{,}8 \cdot P_{CuN} = 47{,}69\,W$

$\eta = 1 - \frac{59{,}6\,W + 47{,}69\,W}{3000\,W} = 0{,}964 \quad \hat{=}\ 96{,}4\,\%$

⑤ Dy $S_N = 150\,MVA$ $U_{1N} = 400\,kV$ $P_0 = 140\,kW$

$i_0 = 0{,}35\,\%$

a) I_0?

$$S_N = \sqrt{3}\, U_{1N}\, I_{1N} \Rightarrow I_{1N} = \frac{S_N}{\sqrt{3}\, U_{1N}} = \frac{150\,MVA}{\sqrt{3}\cdot 400\,kV} = 216{,}5\,A$$

a) $$I_0 = \frac{I_{1N}}{100\,\%} \cdot i_0 = \frac{216{,}5\,A}{100\,\%} \cdot 0{,}35\,\% = 757{,}75\,mA$$

b) $$\cos\varphi_0 = \frac{P_0}{\sqrt{3}\, U_0 I_0} = \frac{140\,kW}{\sqrt{3}\cdot 400\,kV \cdot 757{,}75\,mA} = 0{,}267$$

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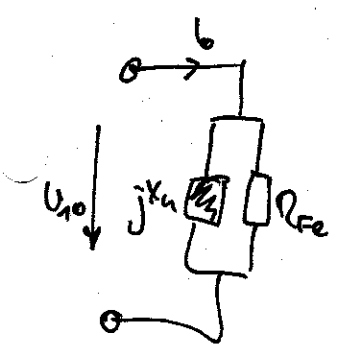
⑥ $S_N = 500\,MVA$ $U_{1N} = 245\,kV$ $I_0 = 4{,}12\,A$ $\varphi_0 = 78°$

Dy

a) P_0? $P_0 = \sqrt{3}\, U_{1N}\, I_0 \cdot \cos\varphi_0 = \sqrt{3}\cdot 245\,kV \cdot 4{,}12\,A \cdot \cos 78° = 363{,}5\,kW$

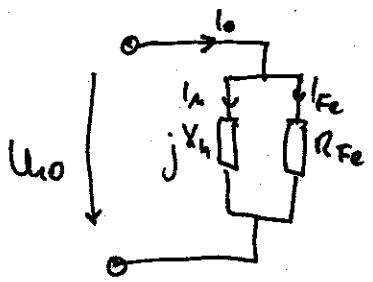


~~$P_0 = \frac{U_{1N}^2}{R_{Fe}} \Rightarrow R_{Fe} = \frac{U_{1N}^2}{P_0} = \frac{(245\,kV)^2}{363{,}5\,kW} = 165\,k\Omega$~~

(9) $S_N = 100\,kVA$ $U_{1N} = 400\,V$ $U_{2N} = U_{20} = 40\,V$

- Leerlauf $I_0 = 8A$; $P_0 = 500\,W$
- Kurzschluss $U_k = 48V$; $P_k = 8000\,W$

a) Leerlauf



$$\cos\varphi_0 = \frac{P_0}{U_{10} \cdot I_0} = \frac{500\,W}{400V \cdot 8A} = \frac{5}{32} = 0{,}156$$

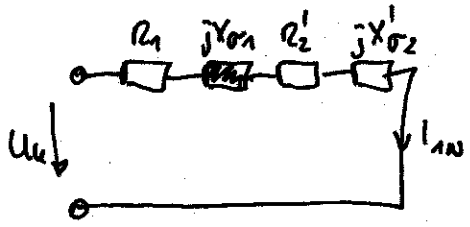
$$\varphi = 81°$$

$$I_{Fe} = I_0 \cdot \cos\varphi_0 = 8A \cdot \frac{5}{32} = 1{,}25A$$

$$I_\mu = I_0 \cdot \sin\varphi_0 = 8A \cdot \sin 81° = 7{,}9A$$

$$X_h = \frac{U_{1N}}{I_\mu} = \frac{400V}{7{,}9A} = 50{,}6\,\Omega$$

$$R_{Fe} = R_V = \frac{400V}{1{,}25A} = 320\,\Omega$$



$$S_N = U_{1N}\, I_{1N}$$

$$I_{1N} = \frac{S_N}{U_{1N}} = \frac{100\,kVA}{400V} = 250A$$

$$I_k = \frac{U_{1N}}{U_k} I_{1N} = \frac{400V}{48V} \cdot 250A = 2083{,}3\ A$$

$$U_k\,\% = \frac{U_k}{U_{1N}} 100\% = \frac{48V}{400V} \cdot 100\% = 12\,\%$$

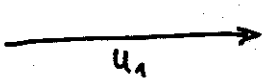
$$\cos\varphi_k = \frac{P_k}{U_k I_1} = \frac{8000W}{48V \cdot 250A} = \frac{2}{3} \Rightarrow \varphi_k = 48{,}2$$

$$Z_k = \frac{U_k}{I_{1N}} = \frac{48V}{250A} = 192\,m\Omega$$

$$R_1 + R_2' = Z_k \cdot \cos\varphi_k = 192m\Omega \cdot \frac{2}{3} = 128\,m\Omega$$

$$X_{\sigma 1} + X_{\sigma 2}' = \sqrt{Z_k^2 - (R_1 + R_2')^2} = \sqrt{192^2 - 128^2}\,m\Omega = 143{,}1\,\Omega$$

b)



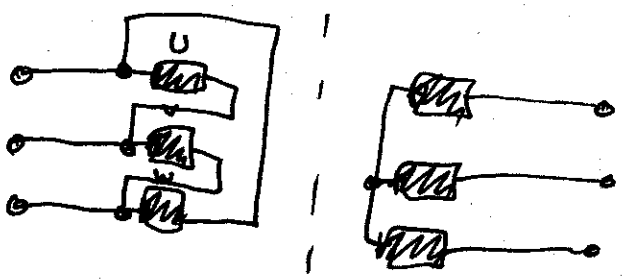
(10) Dy $S_N = 400\ kVA$ $U_{1N} = 6000\ V$

$P_0 = 2{,}5\ kW$ $P_k = 17{,}43\ kW$

Ges $I_{1Str.}$ bei η_{max} $\Rightarrow P_{Fe} = P_{Cu} = P_{CuN}\left(\frac{I_1}{I_{1N}}\right)^2$

$P_{CuN} = R_k I_{1N}^2$

$P_{CuN} = P_k$ $P_{Fe} \approx P_0$



$S = 3 U_{Str} I_{Str}$
$I_L = \sqrt{3}\, I_{Str}$; $U_L = U_{Str}$
$S = \sqrt{3}\, U_L I_L$

$S = 3 U_{Str} I_{Str}$
$I_L = I_{Str}$; $U_L = \sqrt{3}\, U_{Str}$
$S = \sqrt{3}\, U_L I_L$

$$P_{Fe} = P_{CuN}\left(\frac{I_1}{I_{1N}}\right)^2$$

$$P_{Fe} = P_{CuN}\,\frac{I_1^2}{I_{1N}^2}$$

$$I_1^2 = \frac{P_{Fe} \cdot I_{1N}^2}{P_{CuN}}$$

$$I_1 = \sqrt{\frac{2{,}5\,kW \cdot (22{,}22\,A)^2}{17{,}43\,kW}} = \underline{\underline{8{,}42\,A}}$$

$$I_{1N} = \frac{S}{3 \cdot U_{1N}} = \frac{400\ kVA}{3 \cdot 6000\ V} = 22{,}22\ A$$

Also

$$\left.\begin{aligned} P_{Fe} &= P_0 \\ P_{CuN} &= P_k \end{aligned}\right\} \quad P_0 = P_k\left(\frac{I_{Str}}{I_{1N}}\right)^2$$

$$\Rightarrow I_{Str} = \sqrt{\frac{P_0 \cdot I_{1N}^2}{P_k}} = \sqrt{\frac{P_0 \cdot \left(\frac{S_N}{3 \cdot U_{1N}}\right)^2}{P_k}}$$

(13) Yy $U = 800\,V$ $S_{1N} = 4000\,VA$ $X_k = 2R_k = 6\,\Omega$

u_k % ?

$$I_{1N} = \frac{S_{1N}}{U} = \frac{4000\,VA}{\sqrt{3}\cdot 800\,V} = 5\,A$$

$$Z_k = \sqrt{X_k^2 + R_k^2} = \sqrt{6^2 + 3^2}\,\Omega = 6{,}71\,\Omega$$

$$U_{kN} = Z_k \cdot I_{1N} = 6{,}71\,\Omega \cdot 5\,A = 33{,}55\,V$$

$$u_k\,\% = \frac{U_k}{U_{kN}} \cdot 100\,\% = \frac{33{,}55\,V}{800\,V} \cdot 100\,\% = 4{,}2\,\%$$

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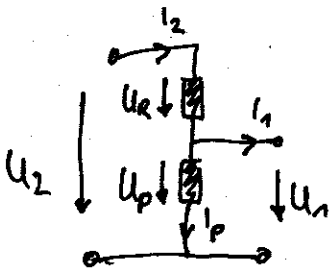
(18) $S = 100\,kVA$ $U_1 = 220\,V$ $U_2 = 380\,V$



a) $S_T = U_R I_2 = U_P I_P$

$$S_D = U_2 I_2$$

$$I_2 = \frac{S_D}{U_2} = \frac{100\,kVA}{380\,V} = 263{,}16\,A$$

$$I_1 = \frac{S_D}{U_1} = \frac{100\,kVA}{220\,V} = 454{,}55\,A$$

$$I_P = I_1 - I_2 = 454{,}55\,A - 263{,}16\,A = 191{,}39\,A$$

$$S_T = U_P \cdot I_P = U_1 \cdot I_P = 220\,V \cdot 191{,}39\,A = 42{,}1\,kVA$$

b) siehe a)

alternativ zu a)

$$S_T = S_D \left(1 - \frac{U_1}{U_2}\right) = 100\,kVA \left(1 - \frac{220\,V}{380\,V}\right) = 42{,}1\,kV$$

(19) $S_{N\,I} = 250\ \text{kVA}$ $\quad \ddot{u}_1 = \ddot{u}_2$ $\quad u_{k1} = 6\,\%$

$S_{N\,II} = 160\ \text{kVA}$ $\quad u_{k2} = 4\,\%$

a) $S = 350\ \text{kVA}$

$$\frac{S_1}{S_2} = \frac{S_{1N} \cdot u_{k2}\,\%}{S_{2N} \cdot u_{k1}\,\%} = \frac{250\ \text{kVA} \cdot 4\,\%}{160\ \text{kVA} \cdot 6\,\%} = \frac{25}{24}$$

$$S_1 = \frac{25}{24} \cdot S_2$$

$$S = S_1 + S_2 = \frac{25}{24} S_2 + S_2 = \frac{49}{24} S_2$$

$$S_2 = \frac{350\ \text{kVA} \cdot 24}{49} = 171{,}4\ \text{kVA}$$

$$S_1 = S - S_2 = 350\ \text{kVA} - 171{,}4\ \text{kVA} = 178{,}6\ \text{kVA}$$

b) ~~$S_{ges} = S_{N1} + S_{N2} = 250\ \text{kVA} + 160\ \text{kVA} = 410\ \text{kVA}$~~