Lösung zur Klausur „Elektrische Energiesysteme“ vom 23.07.2008

Aufgabe 1

a)

$$U_{N10} = \frac{U_N}{\sqrt{3}} = 11{,}55\ \text{kV}$$

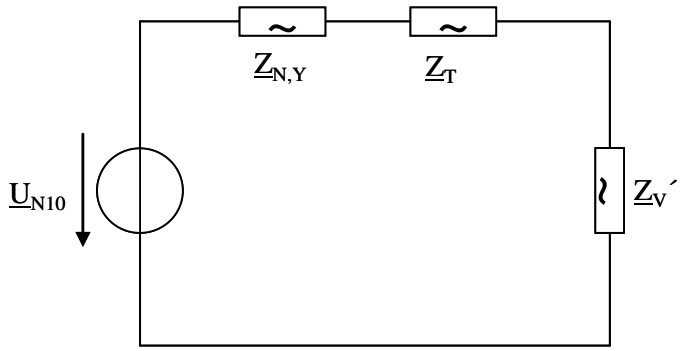
$$\ddot{u} = \frac{U_{N1}}{U_{N2}} = 50$$

$$\underline{Z}_{N,Y} = \frac{\underline{Z}_N}{3} = 3{,}33\ \Omega\, e^{j35°} = (2{,}73 + j1{,}91)\ \Omega$$

$$\underline{Z}_T = j\left(X_{1\sigma} + X_{2\sigma}' \cdot \ddot{u}^2\right) = j600\ \Omega$$

b)

$$\underline{Z}_V' = \underline{Z}_V \cdot \ddot{u}^2 = 12{,}5\ \text{k}\Omega\, e^{j35°} = (10{,}24 + j7{,}17)\ \text{k}\Omega$$



$$\underline{I}_V' = \frac{U_{N10}}{\underline{Z}_{N,Y} + \underline{Z}_T + \underline{Z}_V} = \frac{11{,}55\ \text{kV}}{(2{,}73 + j1{,}91 + j600 + 10.239 + j7140)\ \Omega} = 0{,}900\ \text{A}\, e^{-j37{,}1°}$$

$$\underline{U}_{V10}' = \underline{I}_V' \cdot \underline{Z}_V' = 0{,}907\ \text{A}\, e^{-j37{,}1°} \cdot 12{,}5\ \text{k}\Omega \cdot e^{j35°} = 11{,}24\ \text{kV} \cdot e^{-j2{,}1°}$$

$$\underline{U}_{V10} = \frac{\underline{U}_{V10}'}{\ddot{u}} = 224{,}8\ \text{V} \cdot e^{-j2{,}1°}$$

$$U_V = U_{V10} \cdot \sqrt{3} = 389{,}4\ \text{V}$$

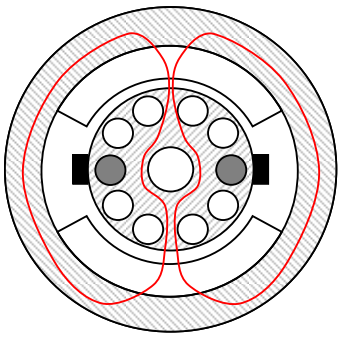
c)

$$\underline{I}_L' = \frac{U_{N10}}{\underline{Z}_{N,Y} + \underline{Z}_T} = \frac{11{,}55\ \text{kV}}{(2{,}73 + j1{,}91 + j600)\ \Omega} = 19{,}19\ \text{A}\, e^{-j89{,}7°}$$

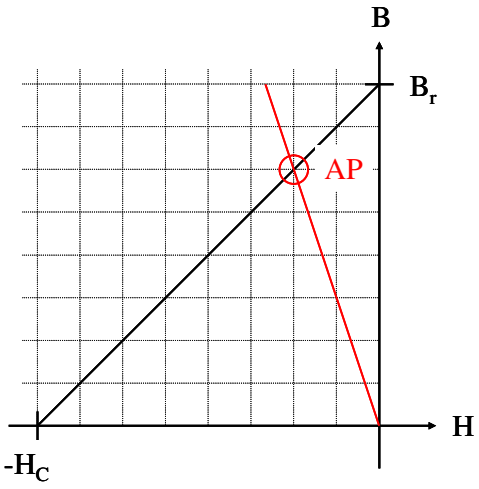
$$I_N = \frac{I_L'}{\sqrt{3}} = 11{,}1\ \text{A}$$

Aufgabe 2

a)



p = 1



Arbeitspunkt

c)

$$\Phi_P = B_r \cdot \frac{3}{4} \cdot A_P = 0{,}12 \text{ mV s}$$

$$U_a = U_0 = k \cdot \Phi_P \cdot n \Rightarrow k = \frac{U_a}{\Phi_P \cdot n_0} = \frac{12 \text{ V}}{0{,}12 \text{ mV s} \cdot 3000 \text{ min}^{-1}} = 2000$$

Aufgabe 3:

a)

$$s_{N,p=1} = \frac{3000-1470}{3000} = 0{,}51\,,\ s_{N,p=2} = \frac{1500-1470}{1500} = 0{,}02\,,\ s_{N,p=2} = \frac{1000-1480}{1000} = -0{,}47 \text{ usw.}$$

wegen $s_N \rightarrow \min$ gilt $p = 2$

$$M_N = \frac{P_{l,N}}{2\cdot\pi\cdot n_0} = p\cdot\frac{\sqrt{3}\cdot U_N\cdot I_N\cdot\cos\varphi_N}{2\cdot\pi\cdot f_N} = 2\cdot\frac{\sqrt{3}\cdot 690\text{ V}\cdot 136\text{ A}\cdot 0{,}86}{2\cdot\pi\cdot 50\text{ Hz}} = 890\text{ Nm}$$

$$\frac{M_{Kipp}}{M_N} = \frac{2}{\frac{s_{Kipp}}{s_N}+\frac{s_N}{s_{Kipp}}} = \frac{2}{\frac{0{,}07}{0{,}02}+\frac{0{,}02}{0{,}07}} = 0{,}528$$

$$M_{Kipp} = \frac{M_N}{0{,}528} = 1685\text{ Nm}$$

b)

$$I_{WN} = I_N\cdot\cos\varphi_N = 136\text{ A}\cdot 0{,}86 = 117\text{ A} \Leftrightarrow 2{,}92\text{ cm}$$

$$I_{WKipp} = I_{WN}\cdot\frac{M_{Kipp}}{M_N} = \frac{117\text{ A}}{0{,}528} = 222\text{ A} \Leftrightarrow 5{,}54\text{ cm}$$

$$I_K = 12\text{ cm}\cdot 40\frac{\text{A}}{\text{cm}} = 480\text{ A}\ \text{(abgelesen)}$$

rechnerische Lösung:

$$\underline{I}_{BN} = \underline{I}_0 - \frac{jI_{WN}}{\tan\varphi_N^*} = \underline{I}_0 - j\cdot I_{WN}\cdot\frac{s_N}{s_{Kipp}} = j\cdot I_N\cdot\sin\varphi_N$$

$$\Rightarrow I_0 = I_N\cdot\sin\varphi_N - I_{WN}\cdot s_N = 69{,}4\text{ A} - 33{,}4\text{ A} = 36\text{ A}$$

$$\frac{M_K}{M_{Kipp}} = \frac{2}{s_{Kipp}+\frac{1}{s_{Kipp}}} = \frac{2}{0{,}07+\frac{1}{0{,}07}} = 0{,}139$$

$$I_{WK} = I_{WKipp}\cdot\frac{M_K}{M_{Kipp}} = 319\text{ A}\cdot 0{,}139 = 31\text{ A}$$

$$\varphi_K^* = \arctan\frac{1}{s_{Kipp}} = 86°$$

$$I_{BK} = -I_0 - \frac{I_{Wk}}{s_{Kipp}} = -36\text{ A} - \frac{31\text{ A}}{0{,}07} = -479\text{ A}$$

$$I_K = \sqrt{I_{WK}^2 + I_{BK}^2} = 480\text{ A}$$

$$\varphi_K = \arctan\frac{I_{BK}}{I_{WK}} = \arctan\frac{-479\text{ A}}{31\text{ A}} = -86{,}3°$$

c)

ablesen: $M_{K,400\,V\Delta} = \frac{0{,}77\,\text{cm}}{5{,}54\,\text{cm}} \cdot 1685\,\text{Nm} = 234\,\text{Nm}$

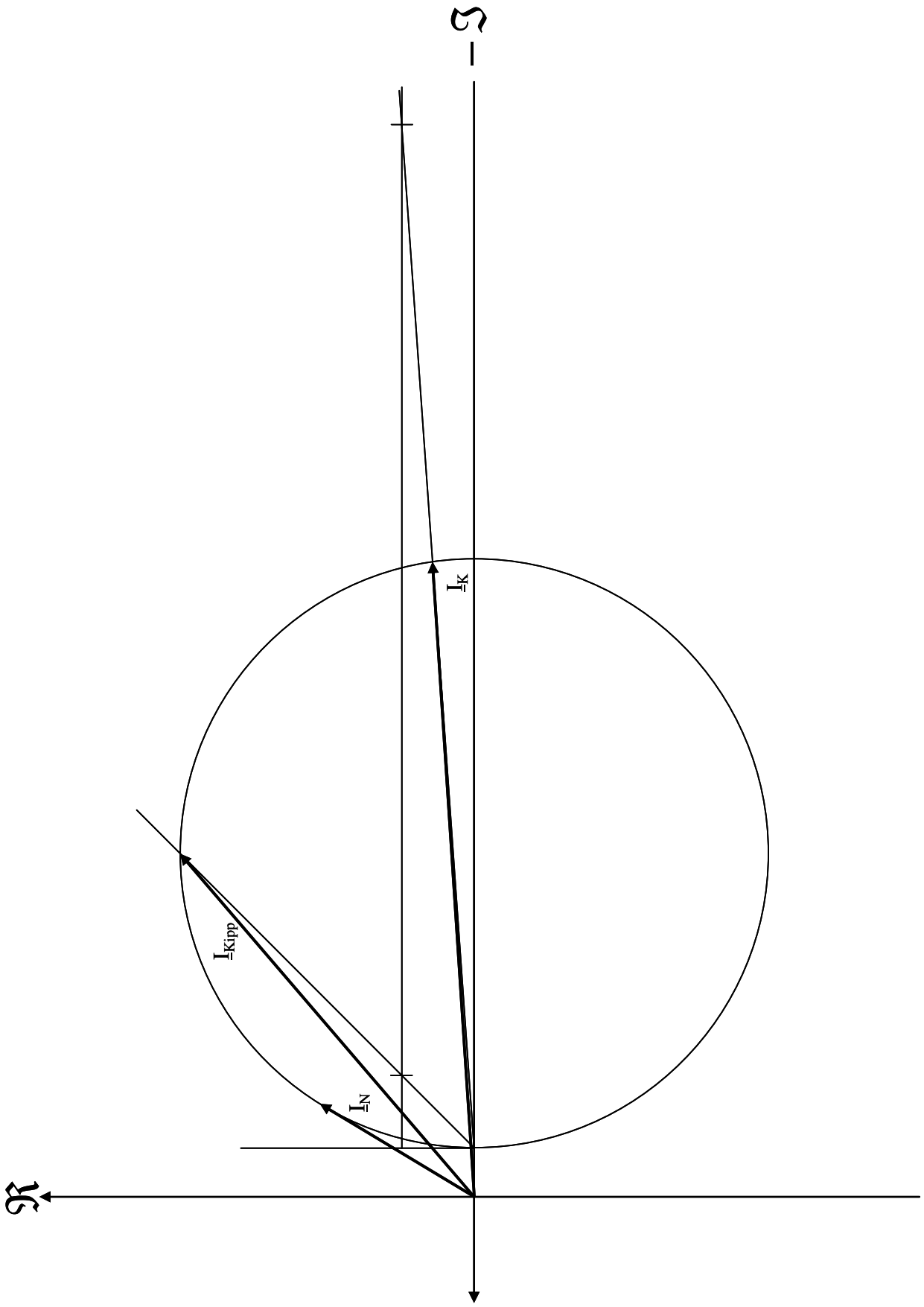
$$M_{K,400\,VY} = \frac{M_{K,400\,V\Delta}}{3} = 45\,\text{Nm}$$

rechnerische Lösung:

$$\frac{M_K}{M_{Kipp}} = \frac{2}{s_{Kipp} + \frac{1}{s_{Kipp}}} = \frac{2}{0{,}07 + \frac{1}{0{,}07}} = 0{,}139$$

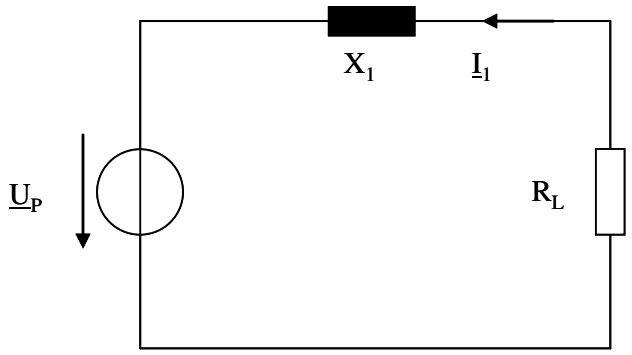
$$M_K = M_{K,400\,V\Delta} = 0{,}139 \cdot 973\,\text{Nm} = 234\,\text{Nm}$$

$$M_{K,400\,VY} = \frac{M_{K,400\,V\Delta}}{3} = 78\,\text{Nm}$$


$\underline{I}_K$
$\underline{I}_{Kipp}$
$\underline{I}_N$

Aufgabe 4:

a)



$$\underline{U}_N = \underline{U}_{PN} + jX_1 \cdot \underline{I}_{1N} = \underline{U}_{PN} + jX_1 \cdot \frac{\underline{U}_N}{R_L}$$

$$\Rightarrow X_{1N} = R_L \cdot \frac{\sqrt{U_{PN}^2 - U_N^2}}{U_N} = 99{,}2\ \Omega$$

b)

$$U_{Pb} = U_{PN} \cdot \frac{n_b}{n_N} = 50\ \text{V} \cdot \frac{1000\ \text{min}^{-1}}{6000\ \text{min}^{-1}} = 8{,}33\ \text{V}$$

$$X_{1b} = X_{1N} \cdot \frac{n_b}{n_N} = 99{,}2\ \Omega \cdot \frac{1000\ \text{min}^{-1}}{6000\ \text{min}^{-1}} = 16{,}5\ \Omega$$

$$U_b = U_{Pb} \cdot \frac{R_L}{\sqrt{R_L^2 + X_{1b}^2}} = 8{,}33\ \text{V} \cdot \frac{12\ \Omega}{\sqrt{12^2 + 16{,}5^2}\ \Omega} = 4{,}9\ \text{V}$$

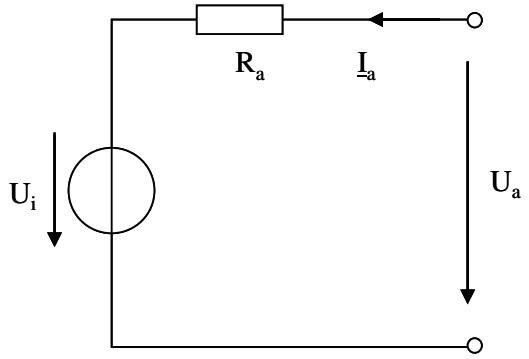
c)

$$n_c = \frac{U_c}{U_{PN}} \cdot n_N = \frac{25\ \text{V}}{50\ \text{V}} \cdot 6000\ \text{min}^{-1} = 3000\ \text{min}^{-1}$$

$$v_c = v_N \cdot \frac{U_{zul}}{U_{PN}} = \frac{25\ \text{V}}{50\ \text{V}} \cdot 30\ \frac{\text{km}}{\text{h}} = 15\ \frac{\text{km}}{\text{h}}$$

Aufgabe 5:

a)



$$U_{iN} = \frac{n_N}{n_0} \cdot U_N = \frac{3000}{4000} \cdot 12\ \text{V} = 9\ \text{V}$$

$$k\Phi = \frac{U_{iN}}{n_N} = \frac{9\ \text{V}}{3000\ \text{min}^{-1}} \cdot 60 \frac{\text{s}}{\text{min}} = 0{,}18\ \text{Vs}$$

$$I_N = \frac{P_N}{U_{iN}} = \frac{50\ \text{W}}{9\ \text{V}} = 5{,}56\ \text{A}$$

$$R_a = \frac{U_N - U_{iN}}{I_N} = 0{,}54\ \Omega$$

b)

$$M_N = \frac{P_N}{2\pi \cdot n_N} = \frac{50\ \text{V} \cdot 60 \frac{\text{s}}{\text{min}}}{2\pi \cdot 3000\ \text{min}^{-1}} = 0{,}159\ \text{Nm} \Rightarrow I_b = \frac{M_b}{M_N} \cdot I_N = 5{,}24\ \text{A}$$

$$\text{oder } I_b = \frac{M_b}{k\Phi} \cdot 2\pi = 5{,}24\ \text{A}$$

$$U_{ib} = U_N - R_a \cdot I_b = 9{,}17\ \text{V}$$

$$n_b = \frac{U_{ib}}{k\Phi} = \frac{9{,}17\ \text{V}}{0{,}18\ \text{Vs}} = 3057\ \text{min}^{-1}$$

c)

$$M_c = \frac{k\Phi}{2\pi} \cdot I_c = \frac{k\Phi}{2\pi} \cdot \frac{U_c}{R_a} = 0{,}53\ \text{Nm} > 0{,}45\ \text{Nm} \Rightarrow \text{ja}$$