9.4.13

1 a) $\underline{I}_a = 0 \qquad \underline{I}_b = \underline{I}^{a}_{k2p}$

$\underline{I}_b = -\underline{I}_c = 417A$

$\underline{I}_c = 417\, e^{j\pi} A$

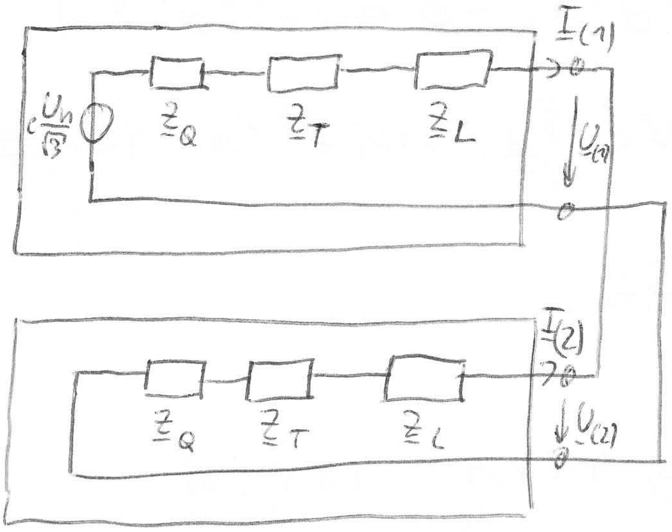
b) $\underline{I}_{(0)} = \frac{1}{3}\left(\underline{I}_a + \underline{I}_b + \underline{I}_c\right) = 0$

$\underline{I}_{(1)} = \frac{1}{3}\left(\underline{I}_a + \underline{a}\,\underline{I}_b + \underline{a}^2 \underline{I}_c\right) = \frac{1}{3} \overbrace{(\underline{a} - \underline{a}^2)}^{j\sqrt{3}} \cdot 417A = j\,240{,}8A$

$\underline{I}_{(2)} = \frac{1}{3}\left(\underline{I}_a + \underline{a}^2 \underline{I}_b + \underline{a}\,\underline{I}_c\right) = \frac{1}{3} \underbrace{(\underline{a}^2 - \underline{a})}_{-j\sqrt{3}} \cdot 417A = -j\,240{,}8A$

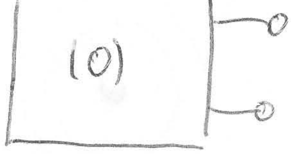
c)

(1)



(2)

$\underline{U}_{(1)} = \underline{U}_{(2)}$

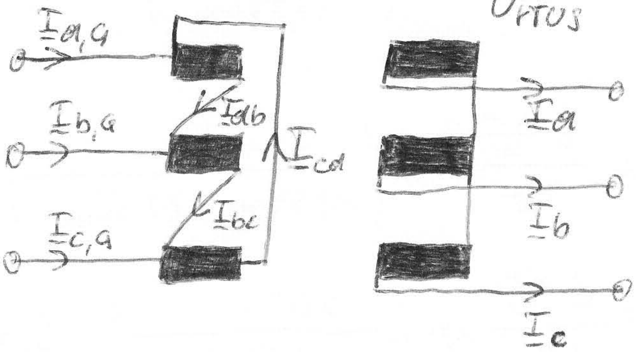


d) Primärseite ↓ YNd5

$\underline{ü} = \frac{U_{rTOS}}{U_{rTUS}} e^{j5\cdot 30°}$

Kein Minus, weil $\underline{I}_a$ raus fließt

$\frac{\underline{I}_{OS}}{\underline{I}_{US}} = \frac{1}{\underline{ü}^*}$ (S.118)



Sekundärseite Primärseite

$$\underline{U} = \frac{\frac{30kV}{\sqrt{3}}}{3kV} e^{j150°} = \frac{10}{\sqrt{3}} e^{j\frac{5}{6}\pi}$$

← Spannung an Spule

$$\underline{I}_{Us} = \underline{U}^* \underline{I}_{0s}$$

$$\underline{I}_{ab} = \underline{U}^* \underline{I}_a = \frac{10}{\sqrt{3}} e^{-j\frac{5\pi}{6}} \, 0A = 0$$

$$\underline{I}_{bc} = \underline{U}^* \underline{I}_b = \frac{10}{\sqrt{3}} e^{-j\frac{5\pi}{6}} \, 417A = 2408 \, e^{-j\frac{5\pi}{6}} A$$

$$\underline{I}_{ca} = \underline{U}^* \underline{I}_c = \frac{10}{\sqrt{3}} e^{-j\frac{5\pi}{6}} (-417)A = -2408 \, e^{-j\frac{5\pi}{6}} A$$

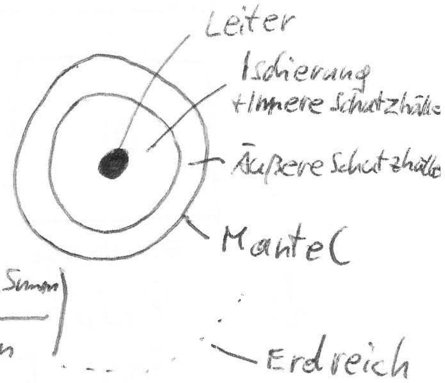
$$\underline{I}_{aG} = \underline{I}_{ab} - \underline{I}_{ca} = 0 - (-2408) e^{-j\frac{5\pi}{6}} A = 2408 e^{-j\frac{5\pi}{6}} A$$

$$\underline{I}_{bG} = \underline{I}_{bc} - \underline{I}_{ab} = 2408 e^{-j\frac{5\pi}{6}} A - 0 = 2408 e^{-j\frac{5\pi}{6}} A$$

$$\underline{I}_{cG} = \underline{I}_{ca} - \underline{I}_{bc} = -2408 e^{-j\frac{5\pi}{6}} A - 2408 e^{-j\frac{5\pi}{6}} A = 4816 \, e^{-j\frac{11\pi}{6}} A$$

e) $$\frac{I''_{k2p}}{I''_{k3p}} = \frac{\sqrt{3}}{2} \qquad (6-52)$$

$$I''_{k3p} = \frac{2}{\sqrt{3}} I''_{k2p} = \frac{2}{\sqrt{3}} 417A = 481{,}5A$$



2a) $$r_L = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{1200mm^2}{\pi}} = 19{,}54mm$$

Isolierung + Innere Schutzhülle

$$R'_{W1} = \frac{\varrho_{WVPE}}{2\pi} \ln\left(\frac{r_L + 21{,}5mm}{r_L}\right) = \frac{6\,K\frac{m}{W}}{2\pi} \ln\left(\frac{19{,}54mm + 21{,}5mm}{19{,}54mm}\right)$$

$$= 0{,}7086 \frac{Km}{W}$$

$$R'_{W2} = \frac{\varrho_{WVPE}}{2\pi} \ln\left(\frac{d_a/2}{r_L + 21{,}5mm}\right) = \frac{6\frac{Km}{W}}{2\pi} \ln\left(\frac{45mm}{19{,}54mm + 21{,}5mm}\right) = 87{,}96 \cdot 10^{-3} \frac{Km}{W}$$

$$R'_{W3} = \frac{\varrho_{WErde}}{2\pi} \ln\left(\frac{r_{Erde}}{d_a/2}\right) = \frac{2\frac{Km}{W}}{2\pi} \ln\left(\frac{500mm}{45mm}\right) = 0{,}7665 \frac{Km}{W}$$

$$R'_W = R'_{W1} + R'_{W2} + R'_{W3} = 0{,}7086 \frac{Km}{W} + 87{,}96 \cdot 10^{-3} \frac{Km}{W} + 0{,}7665 \frac{Km}{W} = 1{,}563 \frac{Km}{W}$$

2b) $P_V' = R' I^2$

$$R' = 1{,}25 \frac{\rho}{A} = 1{,}25 \frac{0{,}0178 \frac{\Omega\, mm^2}{m}}{1200\, mm^2} = 18{,}54 \cdot 10^{-6} \frac{\Omega}{m}$$

$$\Delta\vartheta = R_W' \cdot P_V' = R_W' \cdot R' \cdot I^2$$

$$I = \sqrt{\frac{\Delta\vartheta}{R_W' \cdot R'}} = \sqrt{\frac{70\, K}{1{,}563 \frac{Km}{W} \cdot 18{,}54 \cdot 10^{-6} \frac{\Omega}{m}}} = 1{,}554\, kA$$

c) Formel für Koaxialkabel:

$$C_B' = \frac{2\pi \varepsilon_0 \varepsilon_r}{\ln\left(\frac{r_a}{r_i}\right)} = \frac{2\pi \cdot 8{,}854 \frac{pF}{m} \cdot 2{,}4}{\ln\left(\frac{45\, mm}{19{,}54\, mm}\right)} = 160{,}1 \frac{pF}{m}$$

d) $S_{therm} = \sqrt{3}\, U_N \cdot I_{therm} = \sqrt{3}\; 380\, kV \cdot 1{,}554\, kA = 1{,}023\, GVA$

e) $Z' = \frac{1}{\omega C_B'}$

$$I_C' = \frac{U_N}{\sqrt{3}\, Z'} = \frac{U_N}{\sqrt{3}} \cdot \omega C_B' = \frac{380 kV}{\sqrt{3}} 2\pi\, 50 Hz \cdot 160{,}1 \frac{pF}{m} \quad (4-100)$$

$$I_C' = 11{,}03 \frac{mA}{m}$$

$$Q_C' = 3 \frac{U_N}{\sqrt{3}} I_C' = 3 \frac{380 kV}{\sqrt{3}}\, 11{,}03 \frac{mA}{m} = 7{,}260 \frac{kVA}{m} \quad (4-101)$$

f) $I_C' \cdot l = 11{,}03 \frac{mA}{m} \cdot 140 km = 1544\, A$

$Q_C' \cdot l = 7{,}260 \frac{kVA}{m} \cdot 140 km = 1{,}016\, GVA$

Das Kabel ist durch die Ladeströme nahezu vollständig ausgelastet, es kann keine sinnvolle Menge an Wirkleistung transportiert werden

3a) $S_{Nenn} = 3\, U_a\, I_a = 3\, U_a \frac{U_a}{Z}$

$$Z = 3 \frac{U^2}{S_{Nenn}} = 3 \frac{(40V)^2}{1{,}6kW} = 3\Omega$$

$\cos\varphi = 1 \Rightarrow \underline{Z} = 3\Omega$

b) symmetrisches System

$\Rightarrow \underline{Z}_{(0)} = \underline{Z}_L + \underline{Z}_{Last} + 3 \cdot \underline{Z}_N = 1\Omega + 3\Omega + 3 \cdot 0{,}333\Omega = 4{,}999\Omega$

$\underline{Z}_{(1)} = \underline{Z}_{(2)} = \underline{Z}_L + \underline{Z}_{Last} = 1\Omega + 3\Omega = 4\Omega$

c) $\underline{I}_{(0)} = \frac{1}{3}(\underline{I}_a + \underline{I}_b + \underline{I}_c) = \frac{1}{3}(8A + \underline{a}^2 10A + \underline{a}\, 10A) = -\frac{2}{3}A = -0{,}6667A$

$\underline{I}_{(1)} = \frac{1}{3}(\underline{I}_a + \underline{a}\,\underline{I}_b + \underline{a}^2\underline{I}_c) = \frac{1}{3}(8A + 10A + 10A) = \frac{28}{3}A = 9{,}333A$

$\underline{I}_{(2)} = \frac{1}{3}(\underline{I}_a + \underline{a}^2\underline{I}_b + \underline{a}\,\underline{I}_c) = \frac{1}{3}(8A + \underline{a}\,10A + \underline{a}^2 10A) = -\frac{2}{3}A = -0{,}6667A$

d) $\underline{U}_{(0)} = \underline{I}_{(0)} \cdot \underline{Z}_{(0)} = -0{,}6667A \cdot 4{,}999\Omega = -3{,}333V$

$\underline{U}_{(1)} = \underline{I}_{(1)} \cdot \underline{Z}_{(1)} = 9{,}333A \cdot 4\Omega = 37{,}33V$

$\underline{U}_{(2)} = \underline{I}_{(2)} \cdot \underline{Z}_{(2)} = -0{,}6667A \cdot 4\Omega = -2{,}669V$

e) $\underline{U}_a = \underline{U}_{(0)} + \underline{U}_{(1)} + \underline{U}_{(2)} = -3{,}333V + 37{,}33V - 2{,}669V = 31{,}33V$

$\underline{U}_b = \underline{U}_{(0)} + \underline{a}^2\underline{U}_{(1)} + \underline{a}\,\underline{U}_{(2)} = -3{,}333V + \underline{a}^2 37{,}33V - \underline{a}\, 2{,}669V$

$= (-20{,}66 - j34{,}64)V$

$\underline{U}_c = \underline{U}_{(0)} + \underline{a}\,\underline{U}_{(1)} + \underline{a}^2\underline{U}_{(2)} = -3{,}333V + \underline{a}\,37{,}33V - \underline{a}^2\, 2{,}669V$

$= (-20{,}66 + j34{,}64)V$

5 a) $k = \frac{\alpha a + c}{T_m} + \underbrace{b + d}_{0}$

$$\alpha = \frac{(q-1)\, q^n}{q^n - 1} = \frac{(1{,}06-1)\, 1{,}06^{20}}{1{,}06^{20}-1} = 0{,}08718 \tfrac{1}{a}$$

$$k = \frac{(\alpha + 0{,}01)\, a}{T_m}$$

$$a_{6,D} = \frac{k_D \cdot T_m}{\alpha + 0{,}01 \frac{1}{a}} = \frac{28{,}74 \frac{ct}{kWh} \cdot 950 \frac{h}{a}}{0{,}08718 \frac{1}{a} + 0{,}01 \frac{1}{a}} = 2810 \frac{€}{kW}$$

b) $\alpha = \frac{(q-1)\, q^n}{q^n - 1} = \frac{(1{,}06-1)\, 1{,}06^{13}}{1{,}06^{13}-1} = 0{,}1130 \frac{1}{a}$

$$a_{6,\ddot{O}} = \frac{k_{\ddot{O}} \cdot T_m}{\alpha + 0{,}01 \frac{1}{a}} = \frac{38 \frac{ct}{kWh} \cdot 950 \frac{h}{a}}{0{,}1130 \frac{1}{a} + 0{,}01 \frac{1}{a}} = 2935 \frac{€}{kW}$$

c) Anlage lohnt sich mehr in Österreich, da die spez. Investitions= kosten um rund 100 $\frac{€}{kW}$ höher sein dürfen

d) $\alpha_D = \frac{(q-1)\, q^n}{q^n - 1} = \frac{(1{,}03-1)\, 1{,}03^{20}}{1{,}03^{20}-1} = 67{,}22 \cdot 10^{-3} \frac{1}{a}$

$$\alpha_{\ddot{O}} = \frac{(q-1)\, q^n}{q^n - 1} = \frac{(1{,}03-1)\, 1{,}03^{13}}{1{,}03^{13}-1} = 94{,}03 \cdot 10^{-3} \frac{1}{a}$$

$$a_{3,D} = \frac{k_D T_m}{\alpha_D + 0{,}01 \frac{1}{a}} = \frac{28{,}74 \frac{ct}{kWh}\, 950 \frac{h}{a}}{67{,}22 \cdot 10^{-3} \frac{1}{a} + 0{,}01 \frac{1}{a}} = 3536 \frac{€}{kWh}$$

$$a_{3,\ddot{O}} = \frac{k_{\ddot{O}} T_m}{\alpha_{\ddot{O}} + 0{,}01 \frac{1}{a}} = \frac{38 \frac{ct}{kWh}\, 950 \frac{h}{a}}{94{,}03 \cdot 10^{-3} \frac{1}{a} + 0{,}01 \frac{1}{a}} = 3470 \frac{€}{kWh}$$

e) Durch die längere Rückzahlungsdauer kommt der Renditenrückgang für D. stärker zum tragen

D. ist rentabler