6.11.12

1a) $D_{AB} = \sqrt{(4m)^2 + (4m+8m)^2} = 12{,}65m$

$D_{BC} = \sqrt{(8m-6{,}5m)^2 + (6{,}5m)^2} = 6{,}671m$

$D_{AC} = \sqrt{(4m+6m)^2 + (6{,}5m-4m)^2} = 10{,}31m$

$D = \sqrt[3]{D_{AB} \cdot D_{BC} \cdot D_{AC}} = \sqrt[3]{12{,}65m \cdot 6{,}671m \cdot 10{,}31m} = 9{,}547m$

$r_B = \sqrt[n]{n \cdot \sqrt{\frac{A}{\pi}} \cdot \left(\frac{a}{\sqrt{2}}\right)^{n-1}} = \sqrt[4]{4 \cdot \sqrt{\frac{242{,}5mm^2}{\pi}} \left(\frac{400mm}{\sqrt{2}}\right)^3} = 167{,}9mm$

$L_B' = \frac{\mu_0}{2\pi}\left(\ln\left(\frac{D}{r_B}\right) + \frac{1}{4n}\right) = \frac{4\pi \cdot 10^{-7}\frac{H}{m}}{2\pi}\left(\ln\left(\frac{9{,}547m}{0{,}1679m}\right) + \frac{1}{4 \cdot 4}\right)$

$= 820{,}6\frac{nH}{m} = 820{,}6\frac{\mu H}{km}$

b) $C_B' \approx \frac{2\pi\varepsilon_0\varepsilon_r}{\ln\left(\frac{D}{r_B}\right)} = \frac{2\pi \cdot 8{,}854\frac{pF}{m}}{\ln\left(\frac{9{,}547m}{0{,}1679m}\right)} = 13{,}77\frac{pF}{m} = 13{,}77\frac{nF}{km}$

c) $\alpha \approx \frac{R'}{2}\sqrt{\frac{C'}{L'}} + 0 = \frac{0{,}2\frac{\Omega}{km}}{4 \cdot 2}\sqrt{\frac{13{,}77\frac{nF}{km}}{820{,}6\frac{\mu H}{km}}} = 102{,}4 \cdot 10^{-6}\frac{1}{km}$

Leiter im Bündel

$\beta \approx \omega\sqrt{L'C'} = 2\pi \cdot 50Hz \cdot \sqrt{820{,}6\frac{\mu H}{km} \cdot 13{,}77\frac{nF}{km}} = 1{,}056 \cdot 10^{-3}\frac{1}{km}$

$\gamma = \alpha + j\beta = (102{,}4 \cdot 10^{-6} + j\,1{,}056 \cdot 10^{-3})\frac{1}{km}$

d) $\underline{Z}_W = Z_W \quad \gamma = j\beta$

$\cosh(j\beta l) = \cos(\beta l) \quad , \quad \sinh(j\beta l) = j\sin(\beta l)$

$\underline{U}_1 = \cosh(\gamma l)\,\underline{U}_2 = \cos(\beta l)\,\underline{U}_2$

$\underline{I}_1 = \sinh(\gamma l)\frac{\underline{U}_2}{\underline{Z}_W} = j\sin(\beta l)\frac{\underline{U}_2}{\underline{Z}_W}$

$$\underline{Z}_1 = \frac{\underline{U}_1}{\underline{I}_1} = \frac{\cos(\beta l)\,\underline{U}_2}{j\sin(\beta l)\,\underline{U}_2} \cdot Z_W = -j\,Z_W \frac{\cos(\beta l)}{\sin(\beta l)}$$

$$\underline{S}_1 = \frac{\underline{U}_1^2}{\underline{Z}_1^*} = \frac{\underline{U}_1^2 \cdot \tan(\beta l)}{j\,Z_W}$$

e) $\beta l < \frac{\pi}{2} \Rightarrow \mathrm{Im}(\underline{S}_1) < 0 \Rightarrow$ Blindleistungserzeuger

$\frac{\pi}{2} < \beta l < \pi \Rightarrow \mathrm{Im}(\underline{S}_1) > 0 \Rightarrow$ Blindleistungsverbraucher

$\pi < \beta l < \frac{3\pi}{2} \Rightarrow \mathrm{Im}(\underline{S}_1) < 0 \Rightarrow$ Blindleistungserzeuger

usw.

f) $S_{therm} = \sqrt{3}\,U_{12}\,I_1 = \sqrt{3}\,U_{Nenn}\,4 \cdot I_{max} = \sqrt{3}\;380\,kV \cdot 4 \cdot 400\,A$

$= 1{,}053\;GVA$

g) Die Leitung muss mit dem Wellenwiderstand $\underline{Z}_W$ abgeschlossen sein.

2a) $Z_Q = c\,\frac{U_{nQ}^2}{S_{kQ}''} = 1{,}1\,\frac{(20\,kV)^2}{80\,MVA} = 5{,}5\,\Omega$

$R_Q = 0{,}4 \cdot Z_Q = 0{,}4 \cdot 5{,}5\,\Omega = 2{,}2\,\Omega$

$X_Q = \sqrt{Z_Q^2 - R_Q^2} = \sqrt{(5{,}5\,\Omega)^2 - (2{,}2\,\Omega)^2} = 5{,}041\,\Omega$

$\underline{Z}_Q = 2{,}2\,\Omega + 5{,}041\,\Omega$

2b) $R_L = R' \cdot l = 0{,}1 \frac{\Omega}{km} \cdot 60\,km = 6\,\Omega$

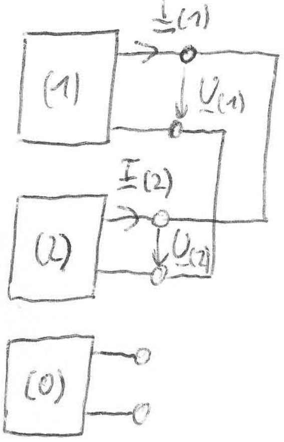
$X_L = \omega \cdot L' \cdot l = 2\pi \cdot 50\,Hz \cdot 0{,}5 \frac{mH}{km} \cdot 60\,km = 9{,}425\,\Omega$

$\underline{Z}_L = 6\,\Omega + j\,9{,}425\,\Omega$

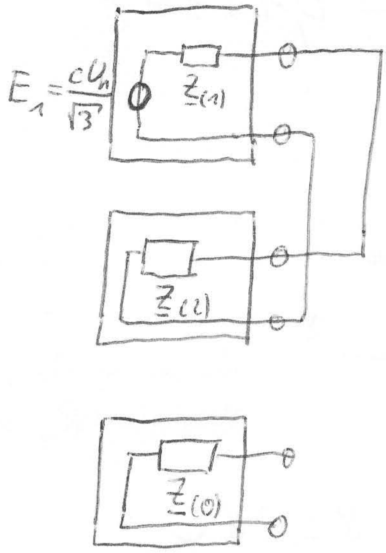
c) $\underline{U}_{bN,F} = \underline{U}_{cN,F}$ $\Rightarrow$ $\underline{U}_{(1)} = \underline{U}_{(2)}$

$\underline{I}_{b,F} + \underline{I}_{c,F} = 0$ $\quad$ $\underline{I}_{(1)} = -\underline{I}_{(2)}$

$\underline{I}_{a,F} = 0$ $\quad$ $\underline{I}_{(0)} = 0$



d)



$$|\underline{I}_{(1)}| = \frac{E_1}{|\underline{Z}_{(1)} + \underline{Z}_2|} = \frac{1{,}1 \cdot 20\,kV}{\sqrt{3} \cdot 2 \cdot |6\,\Omega + j\,12\,\Omega|}$$

$$= 473{,}4\,A$$

e) $|\underline{I}_{(2)}| = |\underline{I}_{(1)}|$

f) $|\underline{I}_{(0)}| = 0$

$$g)\ |\underline{I}_a| = |(\underbrace{\underline{I}_{(0)}}_{=0} + \underbrace{\underline{I}_{(1)} + \underline{I}_{(2)}}_{0})| = 0$$

$$|\underline{I}_b| = |(\underline{I}_{(0)} + \underline{a}^2 \underline{I}_{(1)} + \underline{a}\,\underline{I}_{(2)})| = |(\underline{a}^2 - \underline{a})\,\underline{I}_{(1)}| = |-j\sqrt{3}| \cdot |\underline{I}_{(1)}|$$

$$= \sqrt{3} \cdot 473{,}4\,A = 820{,}0\,A$$

$$|\underline{I}_c| = |(\underline{I}_{(0)} + \underline{a}\,\underline{I}_{(1)} + \underline{a}^2 \underline{I}_{(2)})| = |(\underline{a} - \underline{a}^2)\,\underline{I}_{(1)}| = |j\sqrt{3}| \cdot |\underline{I}_{(1)}| =$$

$$= \sqrt{3} \cdot 473{,}4\,A = 820{,}0\,A$$

$$3a)\ k = \frac{\alpha a + c}{T_m} = \frac{\alpha a + 0{,}01 a}{T_m}$$

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

$$\alpha = \frac{(q-1)\,q^n}{q^n - 1} = \frac{(1{,}07-1)\cdot 1{,}07^{13}}{1{,}07^{13} - 1} = 0{,}1197\,\tfrac{1}{a}$$

$$a = \frac{38\,\frac{ct}{kWh} \cdot 950\,\frac{h}{a}}{0{,}1197\,\frac{1}{a} + 0{,}01\,\frac{1}{a}} = 2{,}783 \cdot 10^3\,\frac{€}{kW}$$

$$b)\ B_- = \frac{q^n - 1}{(q-1)\cdot q^n} = \frac{1{,}07^4 - 1}{(1{,}07-1)\cdot 1{,}07^4} = 3{,}387$$

Anzahlung $A_{R,-9} = 0$
Restwert $R_+ = 0$

$$Z = (\alpha \cdot a + c)\,P = (0{,}1197\,\tfrac{1}{a} + 0{,}01\,\tfrac{1}{a})\,2{,}783 \cdot 10^3\,\tfrac{€}{kW} \cdot 100\,kW = 36{,}10 \cdot 10^3\,€$$

$$B_+ = \frac{(q^m - 1)\cdot q}{q - 1} = \frac{(1{,}07^9 - 1)\cdot 1{,}07}{1{,}07 - 1} = 12{,}82$$

$$B_0 = Z B_+ + Z + Z B_- = 36{,}10 \cdot 10^3\,€\,(3{,}387 + 1 + 12{,}82)$$

$$= 621{,}2 \quad 10^3\,€$$

3c) $\alpha = \frac{(q-1)\,q^n}{q^n - 1} = \frac{(1{,}07-1)\cdot 1{,}07^{25}}{1{,}07^{25}-1} = 85{,}81\cdot 10^{-3}\,\frac{1}{a}$

$$k = \frac{\alpha\left(a - 250\,\frac{€}{kW}\right) + 0{,}01\,\frac{1}{a}\cdot a}{T_m}$$

$$k\cdot T_m + \alpha\cdot 250\,\frac{€}{kW} = \left(\alpha + 0{,}01\,\frac{1}{a}\right) a$$

$$a = \frac{k\cdot T_m + \alpha\cdot 250\,\frac{€}{kW}}{\alpha + 0{,}01\,\frac{1}{a}} = \frac{24\,\frac{ct}{kWh}\cdot 950\,\frac{h}{a} + 85{,}81\cdot 10^{-3}\,\frac{1}{a}\cdot 250\,\frac{€}{kW}}{85{,}81\cdot 10^{-3}\,\frac{1}{a} + 0{,}01\,\frac{1}{a}}$$

$$a = 2{,}604\cdot 10^{3}\,\frac{€}{kW}$$

d) Anlage rentiert sich nach neuem Ökostromgesetz weniger, da die spez. Investitionskosten niedriger sind.

5a) $S = 3\,U_1\,I_1 = 3\,U_1\,\frac{U_1}{Z_{Last}}$

$$Z_{Last} = 3\,\frac{U_{Nenn}^2}{S_{Nenn}} = 3\cdot\frac{(100\,V)^2}{3{,}33\,kW} = 9{,}009\,\Omega$$

$$\cos\varphi = 1 \Rightarrow \underline{Z}_{Last} = 9{,}009\,\Omega$$

b) symmetrisches System $\Rightarrow$

$$\underline{Z}_{(0)} = \underline{Z}_L + \underline{Z}_{Last} + 3\,\underline{Z}_N = 2\,\Omega + 9{,}009\,\Omega + 3\cdot 0{,}333\,\Omega$$

$$= 12{,}01\,\Omega$$

$$\underline{Z}_{(1)} = \underline{Z}_{(2)} = \underline{Z}_L + \underline{Z}_{Last} = 2\,\Omega + 9{,}009\,\Omega = 11{,}01\,\Omega$$

5c) $\underline{U}_{(0)} = \frac{1}{3}(\underline{U}_a + \underline{U}_b + \underline{U}_c) = \frac{1}{3}(90V + \underline{a}^2\, 90V + \underline{a}\, 100V)$

$= 3{,}333\, \underline{a}\, V$

$\underline{U}_{(1)} = \frac{1}{3}(\underline{U}_a + \underline{a}\, \underline{U}_b + \underline{a}^2 \underline{U}_c) = \frac{1}{3}(90V + 90V + 100V)$

$= 93{,}33\, V$

$\underline{U}_{(2)} = \frac{1}{3}(\underline{U}_a + \underline{a}^2 \underline{U}_b + \underline{a}\, \underline{U}_c) = \frac{1}{3}(90V + \underline{a}\, 90V + \underline{a}^2 100V)$

$= 3{,}333\, \underline{a}^2\, V$

d) $\underline{I}_{(0)} = \frac{\underline{U}_{(0)}}{\underline{Z}_{(0)}} = \frac{3{,}333\, \underline{a}\, V}{12{,}01\Omega} = 0{,}2775\, \underline{a}\, A$

$\underline{I}_{(1)} = \frac{\underline{U}_{(1)}}{\underline{Z}_{(1)}} = \frac{93{,}33\, V}{11{,}01\Omega} = 8{,}477\, A$

$\underline{I}_{(2)} = \frac{\underline{U}_{(2)}}{\underline{Z}_{(2)}} = \frac{3{,}333\, \underline{a}^2 V}{11{,}01\Omega} = 0{,}3027\, \underline{a}^2 A$

e) $\underline{I}_a = \underline{I}_{(0)} + \underline{I}_{(1)} + \underline{I}_{(2)} = 0{,}2775\, \underline{a}\, A + 8{,}477\, A + 0{,}3027\, \underline{a}^2 A$

$= (8{,}187 - j0{,}02182)\, A$

$\underline{I}_b = \underline{I}_{(0)} + \underline{a}^2 \underline{I}_{(1)} + \underline{a}\, \underline{I}_{(2)} = 0{,}2775\, \underline{a}\, A + 8{,}477\, \underline{a}^2 A + 0{,}3027\, A$

$= (-4{,}075 - j7{,}101)\, A$

$\underline{I}_c = \underline{I}_{(0)} + \underline{a}\, \underline{I}_{(1)} + \underline{a}^2 \underline{I}_{(2)} = 0{,}2775\, \underline{a}\, A + 8{,}477\, \underline{a}\, A + 0{,}3027\, \underline{a}\, A$

$= (-4{,}529 + j7{,}844)\, A$