23.7.12

1) a) $D_{AB} = \sqrt{(2{,}5m)^2 + (5m)^2} = 5{,}590\,m$

$D_{BC} = \sqrt{(1m)^2 + (5m)^2} = 5{,}099\,m$

$D_{AC} = \sqrt{(2{,}5m - 1m)^2 + (5m + 5m)^2} = 10{,}11\,m$

$D = \sqrt[3]{D_{AB} \cdot D_{BC} \cdot D_{AC}} = \sqrt[3]{5{,}590m \cdot 5{,}099m \cdot 10{,}11m} = 6{,}605\,m$

$r_B = \sqrt[n]{n \cdot r \cdot r_T^{\,n-1}} = \sqrt{2 \cdot \sqrt{\frac{338mm^2}{\pi}} \cdot \frac{400mm}{2 \cdot \sin(\frac{\pi}{2})}} = 64{,}41\,mm$

$L_B' = \frac{\mu_0}{2\pi}\left(\ln\left(\frac{D}{r_B}\right) + \frac{1}{4 \cdot n}\right) = \frac{4 \cdot \pi \cdot 10^{-7}\frac{H}{m}}{2\pi}\left(\ln\left(\frac{6{,}605m}{0{,}06441m}\right) + \frac{1}{4 \cdot 2}\right)$

$= 951{,}1\,\frac{nH}{m} = 951{,}1\,\frac{\mu H}{km}$

b) $\alpha \approx \frac{R'}{2}\sqrt{\frac{C'}{L'}} + 0 = \frac{0{,}0945\frac{\Omega}{km}}{2 \cdot 2}\sqrt{\frac{12\frac{nF}{km}}{951{,}1\frac{\mu H}{km}}} = 83{,}92 \cdot 10^{-6}\,\frac{1}{km}$

$\beta \approx \omega\sqrt{L'C'} = 2\pi\, 50Hz \sqrt{951{,}1\frac{\mu H}{km} \cdot 12\frac{nF}{km}} = 1{,}061 \cdot 10^{-3}\,\frac{1}{km}$

$\underline{\gamma} = \alpha + j\beta = (83{,}92 \cdot 10^{-6} + j\,1{,}061 \cdot 10^{-3})\frac{1}{km}$

c) $\underline{U}_1 = \underline{U}_2 \cosh(\underline{\gamma} l) + \underset{\underset{\underline{Z}_2}{\shortparallel}}{\underline{Z}_W} \underline{I}_2 \sinh(\underline{\gamma} l) = \underline{U}_2\left(\cosh(\underline{\gamma} l) + \sinh(\underline{\gamma} l)\right)$

$\underline{U}_2 = \frac{\underline{U}_1}{\cosh(\underline{\gamma} l) + \sinh(\underline{\gamma} l)} = \frac{\underline{U}_1}{\frac{1}{2}\left(e^{\underline{\gamma} l} + e^{-\underline{\gamma} l} + e^{\underline{\gamma} l} - e^{-\underline{\gamma} l}\right)} = \frac{\underline{U}_1}{e^{\underline{\gamma} l}}$

$|\underline{U}_2| = \frac{U_1}{|e^{\alpha l} \cdot e^{j\beta l}|} = \frac{U_1}{|e^{\alpha l}|} = \frac{220kV}{e^{2 \cdot 10^{-4}\frac{1}{km} \cdot 127km}} = 214{,}5\,kV$

d) $\underline{U}_1 = \underline{U}_2 \cosh(\underline{\gamma} l) + 0 \Rightarrow \underline{U}_2 = \frac{\underline{U}_1}{\cosh(\underline{\gamma} l)}$

e) $Z_W = \sqrt{\frac{L'}{C'}} = \sqrt{\frac{951{,}1\frac{\mu H}{km}}{12\frac{nF}{km}}} = 281{,}5\,\Omega$

$P_{nat} = \frac{U_n^2}{Z_w} = \frac{(220\,kV)^2}{281{,}5\,\Omega} = 171{,}9\,MW$

2a) $\alpha = \frac{1}{\beta_-} = \frac{(q-1)\cdot q^n}{q^n-1} = \frac{(1{,}07-1)\cdot 1{,}07^{20}}{1{,}07^{20}-1} = 0{,}09439\,\frac{1}{a}$

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

$T_m = \frac{\alpha a}{k} = \frac{0{,}09439\frac{1}{a}\cdot 800\frac{€}{kW}}{0{,}092\frac{€}{kWh}} = 820{,}8\,\frac{h}{a}$

c) $\beta_{-,5} = \frac{q^n-1}{(q-1)\cdot q^n} = \frac{1{,}07^5-1}{(1{,}07-1)\cdot 1{,}07^5} = 4{,}100\,a$

d) $\beta_{-,15} = \frac{q^n-1}{(q-1)\cdot q^n} = \frac{1{,}07^{15}-1}{(1{,}07-1)\cdot 1{,}07^{15}} = 9{,}108\,a$

e) $\text{Ertrag} = \text{Tarif} \cdot P_n \cdot T_m$

$\frac{\text{Ertrag}}{P_n \cdot T_m} = k_5 = 9{,}2\,ct/kWh$

f) $\frac{\text{Ertrag}}{P_n \cdot T_m} = k_{15} = 5{,}02\,ct/kWh$

$z\sum_{i=5}^{20} q^{-i} = z\sum_{i=0}^{15} q^{-i}\cdot q^{-5} = z\,\beta_{-,15}\cdot q^{-5}$

g) $B_0 = \frac{B}{P_n \cdot T_m} = k_5 \cdot \beta_{-,5} + k_{15}\cdot \beta_{-,15}\cdot q^{-5} = 9{,}2\,\frac{ct}{kWh}\cdot 4{,}100\,a + 5{,}02\,\frac{ct}{kWh}\cdot 9{,}108\,a \cdot 1{,}07^{-5}$

$= 0{,}7032\,\frac{€\,a}{kWh}$

h) $T_m = \frac{\alpha \cdot d}{\frac{B_0}{\beta_{-,20}}} = \frac{0{,}09439\frac{1}{a}\cdot 800\frac{€}{kW}}{0{,}7032\frac{€\,a}{kWh}\cdot \frac{(1{,}07-1)\cdot 1{,}07^{20}}{1{,}07^{20}-1}\frac{1}{a}} = 1138\,\frac{h}{a}$

4a) $S = \sqrt{3}\, U_{12} I_1 = 3\, U_1 I_1 = 3 \frac{U_1^2}{Z_{Last}}$

$$Z_{Last} = 3 \frac{U_N^2}{S_N} = 3 \cdot \frac{(230V)^2}{10{,}25kVA} = 15{,}48\Omega$$

$$R_{Last} = Z_{Last} \cdot \cos\varphi = 15{,}48\Omega \cdot 0{,}85 = 13{,}16\Omega$$

$$X_{Last} = \sqrt{Z_{Last}^2 - R_{Last}^2} = \sqrt{(15{,}48\Omega)^2 - (13{,}16\Omega)^2} = 8{,}151\Omega$$

b) $$\underline{Z}_{(0)} = \frac{\underline{U}_{(0)}}{\underline{I}_{(0)}} = \frac{\frac{1}{3}(\underline{U}_a + \underline{U}_b + \underline{U}_c)}{\frac{1}{3}(\underline{I}_a + \underline{I}_b + \underline{I}_c)} = \frac{3\,\underline{U}_a}{3\,\underline{I}_a} = \frac{(\underline{Z}_L + \underline{Z}_{Last})\underline{I}_a + 3 \cdot \underline{I}_a \underline{Z}_N}{\underline{I}_a}$$

$$= \underline{Z}_L + \underline{Z}_{Last} + 3\,\underline{Z}_N$$

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

Symmetrisches Netz $\Rightarrow$ $\underline{Z}_{(0)} = \underline{Z}_L + \underline{Z}_{Last} + 3\,\underline{Z}_N$

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

$$Z_{(0)} = (1 + j2)\Omega + (25 + j20)\Omega + 3 \cdot 1\Omega = (29 + j22)\Omega$$

$$Z_{(1)} = (1 + j2)\Omega + (25 + j20)\Omega = (26 + j22)\Omega$$

c) $$\underline{U}_{(0)} = \frac{1}{3}(\underline{U}_{aN} + \underline{U}_{bN} + \underline{U}_{cN}) = \frac{1}{3}(\underline{U}_{aN} + 0{,}7\,\underline{a}^2\underline{U}_{aN} + 0{,}7\,\underline{a}\,\underline{U}_{aN}) =$$

$$= \frac{1}{3}(\underline{U}_{aN} - 0{,}7\,\underline{U}_{aN}) = \frac{1}{10}\underline{U}_{aN} = \frac{1}{10}\frac{346V}{\sqrt{3}} = 19{,}98V$$

$$\underline{U}_{(1)} = \frac{1}{3}(\underline{U}_{aN} + \underline{a}\,\underline{U}_{bN} + \underline{a}^2\underline{U}_{cN}) = \frac{1}{3}(\underline{U}_{aN} + 0{,}7\,\underline{U}_{aN} + 0{,}7\,\underline{U}_{aN}) = \frac{8}{10}\underline{U}_{aN} =$$

$$= \frac{8}{10}\frac{346V}{\sqrt{3}} = 159{,}8V$$

$$\underline{U}_{(2)} = \frac{1}{3}(\underline{U}_{aN} + \underline{a}^2\underline{U}_{bN} + \underline{a}\,\underline{U}_{cN}) = \frac{1}{3}(\underline{U}_{aN} + \underline{a}\,0{,}7\,\underline{U}_{aN} + \underline{a}^2\,0{,}7\,\underline{U}_{aN})$$

$$= \frac{1}{10}\underline{U}_{aN} = \frac{1}{10}\frac{346V}{\sqrt{3}} = 19{,}98V$$

d) $|\underline{I}_{(0)}| = \frac{|\underline{U}_{(0)}|}{|\underline{Z}_{(0)}|} = \frac{19{,}98\,V}{36\,\Omega} = 0{,}5550\,A$

$|\underline{I}_{(1)}| = \frac{|\underline{U}_{(1)}|}{|\underline{Z}_{(1)}|} = \frac{159{,}8\,V}{34\,\Omega} = 4{,}700\,A$

$|\underline{I}_{(2)}| = \frac{|\underline{U}_{(2)}|}{|\underline{Z}_{(2)}|} = \frac{19{,}98\,V}{34\,\Omega} = 0{,}5876\,A$

e) symmetrische Spannung $\Rightarrow$ $I_{(0)} = I_{(2)} = 0$, $\underline{U}_{(1)} = \underline{U}_{aN}$

$|\underline{I}_{(1)}| = \frac{|\underline{U}_{(1)}|}{|\underline{Z}_{1}|} = \frac{346\,V}{\sqrt{3}\cdot 34\,\Omega} = 5{,}875\,A$

$|\underline{I}_{a}| = |\underline{I}_{(1)}| = 5{,}875\,A$

$|\underline{I}_{b}| = |\underline{a}^2 \underline{I}_{(1)}| = 5{,}875\,A$

$|\underline{I}_{c}| = |\underline{a}\, \underline{I}_{(1)}| = 5{,}875\,A$

5a) $Z_Q = c \cdot \frac{U_{nQ}^2}{S''_{kQ}} = 1{,}1 \cdot \frac{(30\,kV)^2}{100\,MVA} = 9{,}9\,\Omega$

$R_Q = 0{,}4 \cdot Z_Q = 0{,}4 \cdot 9{,}9\,\Omega = 3{,}96\,\Omega$

$X_Q = \sqrt{Z_Q^2 - R_Q^2} = 9{,}073\,\Omega$

$\underline{Z}_Q = (3{,}96 + j\,9{,}073)\,\Omega$

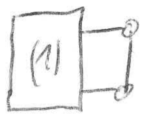
b) $R_L = R' \cdot l = 0{,}20\,\frac{\Omega}{km} \cdot 40\,km = 8\,\Omega$

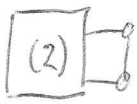
$X_L = \omega L' \cdot l = 2\pi \cdot 50\,Hz \cdot 0{,}75\,\frac{mH}{km} \cdot 40\,km = 9{,}425\,\Omega$

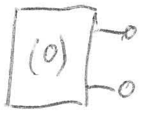
$\underline{Z}_L = (8 + j\,9{,}425)\,\Omega$

5c) $\underline{U}_a = \underline{U}_b = \underline{U}_c \quad \Rightarrow \quad \underline{U}_{(1)} = \underline{U}_{(2)} = 0$

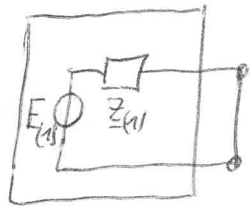
$\underline{I}_a + \underline{I}_b + \underline{I}_c = 0 \qquad \underline{I}_{(0)} = 0$





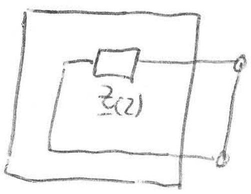


$\underline{E}_{(1)} = c \cdot \frac{U_n}{\sqrt{3}}$



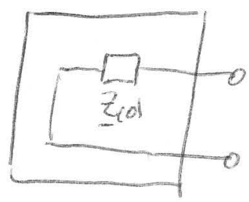
d) $|\underline{I}_1| = c \cdot \frac{U_n}{\sqrt{3}\,|\underline{Z}_1|} = 1{,}1 \cdot \frac{30\,kV}{\sqrt{3}\,|10\,\Omega + j15\,\Omega|} = 1{,}057\,kA$

e)



$\Rightarrow |\underline{I}_2| = 0$

f)



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

g) $|\underline{I}_a| = |\underline{I}_{(1)}| = |\underline{I}_b| = |\underline{a}^2 \underline{I}_1| = |\underline{I}_c| = |\underline{a}\,\underline{I}_1| = 1{,}057\,kA$