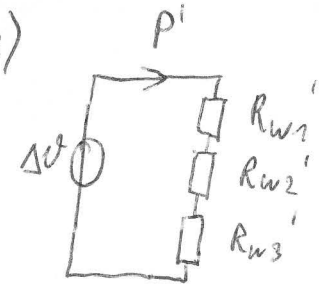
5.11.13

1 a)



$$R_{w1}' = \frac{\rho_{W,PE}}{2\pi} \ln\left(\frac{r_2}{\sqrt{\frac{A}{\pi}}}\right) = \frac{3{,}5\,\frac{\Omega mm^2}{m}}{2\pi} \ln\left(\frac{20mm + \sqrt{\frac{1000mm^2}{\pi}}}{\sqrt{\frac{1000mm^2}{\pi}}}\right) = 418{,}8 \cdot 10^{-3}\,\frac{\Omega}{km}$$

$$R_{w2}' = \frac{\rho_{W,PE}}{2\pi} \ln\left(\frac{r_3}{r_2}\right) = \frac{3{,}5\,\frac{\Omega mm^2}{m}}{2\pi} \ln\left(\frac{\frac{92mm}{2}}{20mm + \sqrt{\frac{1000mm^2}{\pi}}}\right) = 108{,}8 \cdot 10^{-3}\,\frac{\Omega}{km}$$

$$R_{w3}' = \frac{\rho_{W,Eindraht}}{2\pi} \ln\left(\frac{r_4}{r_3}\right) = \frac{2{,}0\,\frac{\Omega mm^2}{m}}{2\pi} \ln\left(\frac{500mm}{\frac{92mm}{2}}\right) = 759{,}5 \cdot 10^{-3}\,\frac{\Omega}{km}$$

$$R_w' = R_{w1}' + R_{w2}' + R_{w3}' = 418{,}8 \cdot 10^{-3}\,\frac{\Omega}{km} + 108{,}8 \cdot 10^{-3}\,\frac{\Omega}{km} + 759{,}5 \cdot 10^{-3}\,\frac{\Omega}{km}$$

$$= 1{,}287\,\frac{\Omega}{km}$$

b) $$R' = 1{,}25 \cdot \frac{\rho_{Cu}}{A} = 1{,}25 \cdot \frac{0{,}0178\,\frac{\Omega mm^2}{m}}{1000mm^2} = 22{,}25\,\frac{\mu\Omega}{m}$$

$$P' = R' I^2 = \frac{\Delta\vartheta}{R_w'}$$

$$I = \sqrt{\frac{\Delta\vartheta}{R' \cdot R_w'}} = \sqrt{\frac{70K}{22{,}25\frac{\mu\Omega}{m} \cdot 1{,}287\frac{\Omega}{km}}} = 1{,}563kA$$

c) $$C_B' = \frac{2\pi\varepsilon_0\varepsilon_r}{\ln\left(\frac{r_2}{\sqrt{\frac{A}{\pi}}}\right)} = \frac{2\pi \cdot 8{,}854 \cdot 10^{-12}\,\frac{F}{m} \cdot 2{,}4}{\ln\left(\frac{20mm + \sqrt{\frac{1000mm^2}{\pi}}}{\sqrt{\frac{1000mm^2}{\pi}}}\right)} = 177{,}6\,\frac{pF}{m}$$

d) $$S_{therm} = 3 U_{ph} I_{ph} = \sqrt{3}\, U_{Nenn} \cdot I = \sqrt{3}\, 220kV \cdot 1{,}563kA = 595{,}6MVA$$

e) $$I_{Lade}' = \frac{U_{Nenn}}{\sqrt{3}} \cdot \omega C_B' = \frac{220kV}{\sqrt{3}}\, 2\pi\, 50Hz \cdot 177{,}6\,\frac{pF}{m} = 7{,}087 \cdot 10^{-3}\,\frac{A}{m}$$

$$Q_{Lade}' = \sqrt{3}\, U_{Nenn} \cdot I_{Lade}' = \sqrt{3}\, 220kV \cdot 7{,}087 \cdot 10^{-3}\,\frac{A}{m} = 2{,}701\,\frac{kVA}{m}$$

f) $$l = \frac{S_{therm}}{Q_{Lade}'} = \frac{595{,}6MVA}{2{,}701\,\frac{kVA}{m}} = 220{,}5km$$

2a) $\underline{I}_a = 0$

$\underline{I}_b = -\underline{I}_c = 450A$

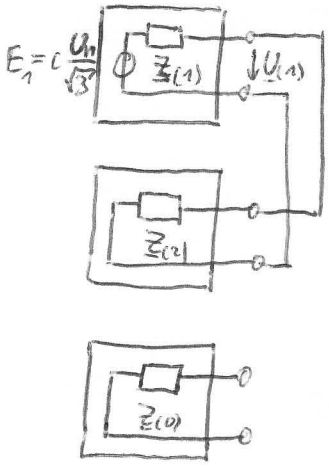
$\underline{I}_c = 450\, e^{j\pi}\, A$

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

$\underline{I}_{(1)} = \frac{1}{3}(\underline{I}_a + \underline{a}\,\underline{I}_b + \underline{a}^2\underline{I}_c) = \frac{1}{3}\underbrace{(\underline{a} - \underline{a}^2)}_{j\sqrt{3}}\, 450A = j259{,}8\,A$

$\underline{I}_{(2)} = \frac{1}{3}(\underline{I}_a + \underline{a}^2\underline{I}_b + \underline{a}\,\underline{I}_c) = \frac{1}{3}\underbrace{(\underline{a}^2 - \underline{a})}_{-j\sqrt{3}}\, 450A = -j259{,}8\,A$

c) $\underline{I}_{(1)} = -\underline{I}_{(2)}$ $\quad U_{b,F} = U_{c,F} \Rightarrow \underline{U}_{(1)} = \underline{U}_{(2)}$



Da das System symmetrisch ist, ist $\underline{Z}_{(1)} = \underline{Z}_{(2)}$

d) $\underline{U}_{(0)} = \underline{Z}_{(0)} \cdot \underbrace{\underline{I}_{(0)}}_{0} = 0V$

Annahme $c = 1{,}1$

$\underline{U}_{(1)} = \underline{U}_{(2)} = \frac{\underline{Z}_{(1)}}{\underline{Z}_{(1)} + \underline{Z}_{(2)}}\, c\, \frac{U_n}{\sqrt{3}} = \frac{1}{2} \cdot 1{,}1 \cdot \frac{30kV}{\sqrt{3}} = 9{,}526kV$

e) $\frac{I''_{k2p}}{I''_{k3p}} = \frac{\sqrt{3}}{2}$

$I''_{k3p} = \frac{2}{\sqrt{3}}\, I''_{k2p} = \frac{2}{\sqrt{3}}\, 450A = 519{,}6\,A$

3a) $z_k = u_k \frac{U_2^2}{S_N} = 0{,}11 \cdot \frac{(20\,kV)^2}{64\,MVA} = 0{,}6875\,\Omega$

b) $R_k = P_k \frac{U_2^2}{S_N^2} = 1620\,kW \frac{(20\,kV)^2}{(64\,MVA)^2} = 0{,}1582\,\Omega$

c) $X_k = \sqrt{z_k^2 - R_k^2} = \sqrt{(0{,}6875\,\Omega)^2 - (0{,}1582\,\Omega)^2} = 0{,}6691\,\Omega$

d) $P_L = G_L U_L^2$

$G_L = \frac{P_L}{U_L^2} = \frac{22\,kW}{(20\,kV)^2} = 55\,\mu S$

e) $I_k = \frac{U_2}{z_k} = \frac{20\,kV}{0{,}6875\,\Omega} = 29{,}09\,kA$

f) z_k, R_k, X_k halbieren sich; G_L verdoppelt sich

$z_k' = \frac{z_k}{2} = \frac{0{,}6875\,\Omega}{2} = 0{,}3438\,\Omega$

$R_k' = \frac{R_k}{2} = \frac{0{,}1582\,\Omega}{2} = 0{,}0791\,\Omega$

$X_k' = \frac{X_k}{2} = \frac{0{,}6691\,\Omega}{2} = 0{,}3346\,\Omega$

$G_L' = 2 \cdot G_L = 2 \cdot 55\,\mu S = 110\,\mu S$

5a) $Z = c \cdot P + (b+d) \cdot E$

$= 55 \frac{€}{kW_{el}a} \cdot 225 MW_{el} + \left(\frac{0{,}208 \frac{€}{m} \cdot 3{,}6 \frac{MJ}{kWh}}{0{,}58 \cdot 30 \frac{MJ}{m^3}} + 0{,}001 \frac{€}{kWh_{el}} \right) \cdot 1125 \frac{GWh}{a}$

$= 61{,}91 \cdot 10^6 \frac{€}{a}$

b) $Z = c \cdot P = 65 \frac{€}{kW_{el}a} \cdot 225 MW_{el} = 14{,}63 \cdot 10^6 \frac{€}{a}$

c) $\beta_+ = \frac{(q^m - 1) \cdot q}{q - 1} = \frac{(1{,}06^{13} - 1) \cdot 1{,}06}{1{,}06 - 1} = 20{,}02\,a$

d) $\beta_{-,12} = \frac{q^n - 1}{(q-1) q^n} = \frac{1{,}06^{12} - 1}{(1{,}06 - 1) 1{,}06^{12}} = 8{,}384\,a$

$\beta_{-,27} = \frac{q^n - 1}{(q-1) q^n} = \frac{1{,}06^{27} - 1}{(1{,}06 - 1) 1{,}06^{27}} = 13{,}21\,a$

e) $A_0 = a \cdot P = 590 \frac{€}{kW_a} \cdot 225 MW_{el} = 132{,}8 \cdot 10^6 €$

$B = A_0 q^m + \beta_+ Z + Z + \beta_{-,12} Z$

$= 132{,}8 \cdot 10^6 € \cdot 1{,}06^{13} + 61{,}91 \cdot 10^6 \frac{€}{a} (20{,}02\,a + 1\,a + 8{,}384\,a)$

$= 2{,}104 \cdot 10^9 €$

f) $A_0 = a \cdot P = 3500 \frac{€}{kW_a} \cdot 225 MW_{el} = 787{,}5 \cdot 10^6 €$

$B = A_0 q^m + \beta_+ Z + Z + \beta_{-,27} Z$

$= 787{,}5 \cdot 10^6 € \cdot 1{,}06^{13} + 14{,}63 \cdot 10^6 \frac{€}{a} (20{,}02\,a + 1\,a + 13{,}21\,a)$

$= 2{,}180 \cdot 10^9 €$

g) $B = A_0 q^m + \beta_+ Z + Z + \beta_{-,27} Z + A_1 q^{-n}$

$= 132{,}8 \cdot 10^6 € \cdot 1{,}06^{13} + 61{,}91 \cdot 10^6 \frac{€}{a} (20{,}02\,a + 1\,a + 13{,}21\,a) + 30 \cdot 10^6 € 1{,}06^{-12}$

$= 2{,}409 \cdot 10^9 €$

h) Laufwasserkraftwerk, da der Barwert niedriger ist.