6.3.13

1a) $Z_k = u_k \dfrac{U_2^2}{S_N} = 0{,}12 \cdot \dfrac{(10\,kV)^2}{32\,MVA} = 0{,}375\,\Omega$

b) $R_k = P_k \dfrac{U_2^2}{S_N^2} = 840\,kW \dfrac{(10\,kV)^2}{(32\,MVA)^2} = 0{,}08203\,\Omega$

c) $P_L = G_L U_L^2 \qquad U_L = U_2 \qquad$ Gl. (22.50) aus VO ET2

$G_L = \dfrac{P_L}{U_2^2} = \dfrac{12\,kW}{(10\,kV)^2} = 120\,\mu S$

d) $Q_L = -B_L U_L^2 \qquad$ Gl. (22.50) — " —

$S_L = U_L I_L = \underbrace{U_2\, I_2}_{S_N} \cdot 0{,}3\,\%$

$Q_L = \sqrt{S_L^2 - P_L^2} = \sqrt{(32\,MVA \cdot 0{,}003)^2 - (12\,kW)^2}$

$= 95{,}25\,kVAr$

$B_L = -\dfrac{Q_L}{U_L^2} = -\dfrac{95{,}25\,kVAr}{(10\,kV)^2} = -952{,}5\,\mu S$

e) $I_k = \dfrac{U_2}{Z_k} = \dfrac{10\,kV}{0{,}375\,\Omega} = 26{,}67\,kA$

f) $Z_{kp} = \ddot{u}^2 Z_k = \left(\dfrac{110\,kV}{10\,kV}\right)^2 0{,}375\,\Omega = 45{,}38\,\Omega$

2a) $Z_{Last} = \frac{U_{aN}}{I_a} = \frac{660V}{\sqrt{3} \cdot 5{,}3A} = 71{,}90\Omega$

$R_{Last} = \cos\varphi \cdot Z_{Last} = 0{,}8 \cdot 71{,}90\Omega = 57{,}52\Omega$

$X_{Last} = \sqrt{Z_{Last}^2 - R_{Last}^2} = \sqrt{(71{,}90\Omega)^2 - (57{,}52\Omega)^2}$

$= 43{,}14\Omega$

$\underline{Z}_{Last} = 57{,}52\Omega + j43{,}14\Omega$

b) symmetrisches System

$\Rightarrow \underline{Z}_{(0)} = \underline{Z}_L + \underline{Z}_{Last} + 3 \cdot \underline{Z}_N = (1+j2)\Omega + (60+j70)\Omega + 3 \cdot 1\Omega$

$= (64 + j72)\Omega$

$\underline{Z}_{(1)} = \underline{Z}_L + \underline{Z}_{Last} = (1+j2)\Omega + (60+j70)\Omega$

$= (61 + j72)\Omega$

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

c) $\underline{U}_{(0)} = \frac{1}{3}(\underline{U}_a + \underline{U}_b + \underline{U}_c) = \frac{1}{3}(360V + \underline{a}^2 300V + \underline{a}\,300V)$

$= 20V$

$\underline{U}_{(1)} = \frac{1}{3}(\underline{U}_a + \underline{a}\,\underline{U}_b + \underline{a}^2\underline{U}_c) = \frac{1}{3}(360V + 300V + 300V)$

$= 320V$

$\underline{U}_{(2)} = \frac{1}{3}(\underline{U}_a + \underline{a}^2\underline{U}_b + \underline{a}\,\underline{U}_c) = \frac{1}{3}(360V + \underline{a}\,300V + \underline{a}^2 300V)$

$= 20V$

2 d) $\underline{I}_{(0)} = \frac{\underline{U}_{(0)}}{\underline{Z}_{(0)}} = \frac{20V}{(64+j72)\Omega} = (0{,}1379 - j0{,}1552)A$

$\underline{I}_{(1)} = \frac{\underline{U}_{(1)}}{\underline{Z}_{(1)}} = \frac{320V}{(61+j72)\Omega} = (2{,}192 - j2{,}587)A$

$\underline{I}_{(2)} = \frac{\underline{U}_{(2)}}{\underline{Z}_{(2)}} = \frac{20V}{(61+j72)\Omega} = (0{,}1370 - j0{,}1617)A$

3a) $j\omega 3L_p + \frac{1}{j\omega\, C_E'\cdot l} = 0$ siehe S. 275 im Skriptum

$L_p = \frac{1}{\omega^2 3 C_E' l} = \frac{1}{(2\pi 50Hz)^2 3 \cdot 9\frac{nF}{km} \cdot 20km} = 18{,}76 H$

b) Annahme: rein induktiv

$\underline{X}_d'' = j x_d'' \cdot \frac{U_N^2}{S_N} |\ddot{\underline{u}}|^2 = j0{,}12 \cdot \frac{(4kV)^2}{7MVA}\left(\frac{20kV}{4kV}\right)^2 = j6{,}857\Omega$ ⊛

$\underline{Z}_T = j u_k \frac{U_N^2}{S_N} = j0{,}15 \cdot \frac{(20kV)^2}{7MVA} = j8{,}571\Omega$

$P_k = 0$

$\underline{Z}_L = j X_1' l = j0{,}35\frac{\Omega}{km} \cdot 20km = j7\Omega$

Mitsystemimpedanz

⊛ $\underline{I}_{os} = \frac{1}{\ddot{\underline{u}}^*}\underline{I}_{us}$

$\underline{U}_{os} = \ddot{\underline{u}}\, \underline{U}_{us}$

$\underline{Z}_{os} = \frac{\underline{U}_{os}}{\underline{I}_{os}} = \frac{\underline{U}_{us}}{\underline{I}_{us}} |\ddot{\underline{u}}|^2$, $\frac{\underline{U}_{us}}{\underline{I}_{us}} = \underline{Z}_{us}$

Symmetrisches System: $X_0 = 0$

c) $\underline{Z}_{(0)} = \underset{\substack{\| \\ 0}}{\underline{X}_{d(0)}} + \underline{Z}_{T(0)} + X_0' \cdot l + \underbrace{\frac{j\omega 3L_p \cdot \frac{1}{j\omega C_E' l}}{j\omega 3L_p + \frac{1}{j\omega C_E' l}}}_{=\infty} = \infty$

siehe Abb 4-42

siehe auch S. 275 im Skriptum

$\underline{Z}_{(1)} = \underline{Z}_{(2)} = \underline{X}_d'' + \underline{Z}_T + \underline{Z}_L = j6{,}857\Omega + j8{,}571\Omega + j7\Omega$

$= j22{,}43\Omega$

d) $\underline{U}_{bN,F} = \underline{U}_{cN,F} = 0$

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

$\underline{U}_{(0)} = \frac{1}{3}\left(\underline{U}_{aN,F} + \underline{U}_{bN,F} + \underline{U}_{cN,F}\right) = \frac{1}{3}\underline{U}_{aN,F}$

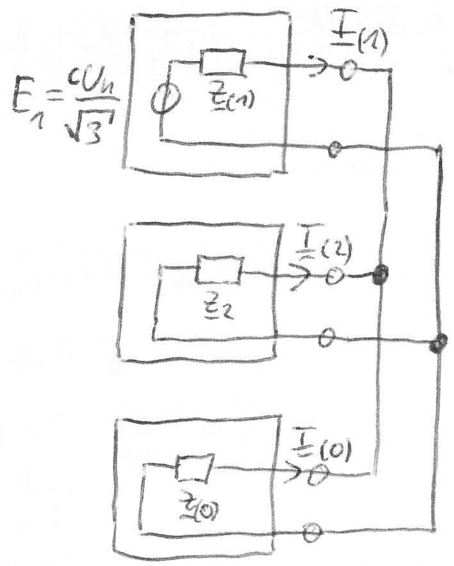
$\underline{U}_{(1)} = \frac{1}{3}\left(\underline{U}_{aN,F} + \underline{a}\,\underline{U}_{bN,F} + \underline{a}^2\underline{U}_{cN,F}\right) = \frac{1}{3}\underline{U}_{aN,F} \quad \Rightarrow \underline{U}_{(0)} = \underline{U}_{(1)} = \underline{U}_{(2)}$

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

$\underline{I}_{(0)} = \frac{1}{3}\left(\underline{I}_{b,F} + \underline{I}_{c,F}\right)$

$\underline{I}_{(1)} = \frac{1}{3}\left(\underline{a}\,\underline{I}_{b,F} + \underline{a}^2\underline{I}_{c,F}\right) \quad \Rightarrow \underline{I}_{(0)} + \underline{I}_{(1)} + \underline{I}_{(2)} = 0$

$\underline{I}_{(2)} = \frac{1}{3}\left(\underline{a}^2\underline{I}_{b,F} + \underline{a}\,\underline{I}_{c,F}\right)$



e) $\underline{I}_{(1)} = -\underline{I}_{(2)} = \dfrac{E_1}{\underline{Z}_1 + \underline{Z}_2} = \dfrac{\overset{\text{Annahme, da nicht angegeben}}{1{,}1 \cdot 20000\,V}}{\sqrt{3} \cdot 2 \cdot j\, 22{,}43\,\Omega}$

$= -j\,283{,}1\,A$

$\underline{I}_{(0)} = 0$ da exakt kompensiert $(\underline{Z}_{(0)} = \infty)$

f) $\underline{I}_a = \underline{I}_{(0)} + \underline{I}_{(1)} + \underline{I}_{(2)} = 0A$

$\underline{I}_b = \underline{I}_{(0)} + \underline{a}^2 \underline{I}_{(1)} + \underline{a}\, \underline{I}_{(2)} = \overbrace{(\underline{a}^2 - \underline{a})}^{-j\sqrt{3}}(-j\,283{,}1)\,A$

$= -490{,}3\,A$

$\underline{I}_c = \underline{I}_{(0)} + \underline{a}\, \underline{I}_{(1)} + \underline{a}^2 \underline{I}_{(2)} = \overbrace{(\underline{a} - \underline{a}^2)}^{j\sqrt{3}}(-j\,283{,}1)\,A$

$= 490{,}3\,A$

5) a) $T_m = \frac{360\,GWh/a}{200\,MW_{el}} = 1800\frac{h}{a}$

$A_0 = 3100\frac{€}{kW_{el}} \cdot 200\,MW_{el} = 620 \cdot 10^6 €$

$k = \frac{\alpha \cdot a + c}{T_m} + b + d$

bereits elektrisch
daher muss man η
nicht berücksichtigen

$Z = K \overset{\circ}{=} kE = \left(\frac{\alpha \cdot a + c}{T_m} + b + d\right)E = \left(\frac{30\frac{€}{kW_{el}a}}{1800\frac{h}{a}} + 0{,}09\frac{€}{kWel\,h} + 0{,}0015\frac{€}{kWh_{el}}\right)$

$\cdot 360\,GWh$

$Z = 38{,}94 \cdot 10^6 €$

$\beta_- = \frac{q^n - 1}{(q-1)\cdot q^n} = \frac{1{,}06^{50} - 1}{(1{,}06-1)\cdot 1{,}06^{50}} = 15{,}76$

$B_0 = A_0 + \beta_- Z = 620 \cdot 10^6 € + 15{,}76 \cdot 38{,}94 \cdot 10^6 €$

$= 1{,}234 \cdot 10^9 €$

b) $A_0 = 1300\frac{€}{kW_{el}} \cdot 200\,MW_{el} = 260 \cdot 10^6 €$

$Z = \left(\frac{c}{T_m} + b + d\right)E = \left(\frac{25\frac{€}{kW_{el}a}}{1800\frac{h}{a}} + \frac{0{,}07\frac{€}{kWh\,thermisch}}{0{,}38} + 0{,}003\frac{€}{kWh_{el}}\right) \cdot$

$\cdot 360\,GWh$

$= 72{,}40 \cdot 10^6 €$

$\beta_- = \frac{q^n - 1}{(q-1)\,q^n} = \frac{1{,}06^{35} - 1}{(1{,}06-1)\cdot 1{,}06^{35}} = 14{,}50$

$B_0 = A_0 + \beta_- Z = 260 \cdot 10^6 € + 14{,}50 \cdot 72{,}40 \cdot 10^6 €$

$= 1{,}310 \cdot 10^9 €$

c) $\beta_- = \frac{q^n - 1}{(q-1)\, q^n} = \frac{1{,}06^{50} - 1}{(1{,}06-1) \cdot 1{,}06^{50}} = 15{,}76$

$B = A_0 + A_1\, q^{-n} + \beta_-\, z = 260 \cdot 10^6 € + 25 \cdot 10^6 € \cdot 1{,}06^{-35} + 15{,}76 \cdot 72{,}40 \cdot 10^6 €$

$= 1{,}404 \cdot 10^9 €$

d) Das Pumpspeicherkraftwerk, da es niedrigere Stromgestehungs=kosten besitzt