1 Leitungsgleichungen

a)

$$\underline{\gamma} = \sqrt{(R' + \mathrm{j}\omega L')\,(G' + \mathrm{j}\omega C')} \tag{1}$$

$$\underline{Z}_W = \sqrt{\frac{R' + \mathrm{j}\omega L'}{G' + \mathrm{j}\omega C'}} \tag{2}$$

$$P_{nat} = \frac{U_n^2}{Z_W} \tag{3}$$

b)

$$R_L = \frac{U_n^2}{P_L} \tag{4}$$

c)

$$\underline{S}_1 = \underline{U}_1 \underline{I}_1^* = \underline{U}_1 \frac{\underline{U}_1^*}{\underline{Z}_W^*} = \frac{U_n^2}{\underline{Z}_W^*} \tag{5}$$

d)

$$\underline{U}_1 = \cosh\left(\underline{\gamma} l\right) \underline{U}_2 + \sinh\left(\underline{\gamma} l\right) \underline{Z}_W \underline{I}_2 \tag{6}$$

$$= \cosh\left(\underline{\gamma} l\right) \underline{U}_2 + \sinh\left(\underline{\gamma} l\right) \underline{Z}_W \frac{\underline{U}_2}{R_L} \tag{7}$$

$$\underline{U}_2 = \frac{\underline{U}_1}{\cosh\left(\underline{\gamma} l\right) + \sinh\left(\underline{\gamma} l\right) \frac{\underline{Z}_W}{R_L}} \tag{8}$$

e)

$$\underline{U}_1 = \cosh\left(\underline{\gamma} l\right) \underline{U}_2 + \sinh\left(\underline{\gamma} l\right) \underline{Z}_W \underline{I}_2 \tag{9}$$

$$= \cosh\left(\underline{\gamma} l\right) 0{,}9\,\underline{\mathrm{U}}_1 + \sinh\left(\underline{\gamma} l\right) \underline{Z}_W \frac{0{,}9\,\underline{\mathrm{U}}_1}{\underline{Z}_2} \tag{10}$$

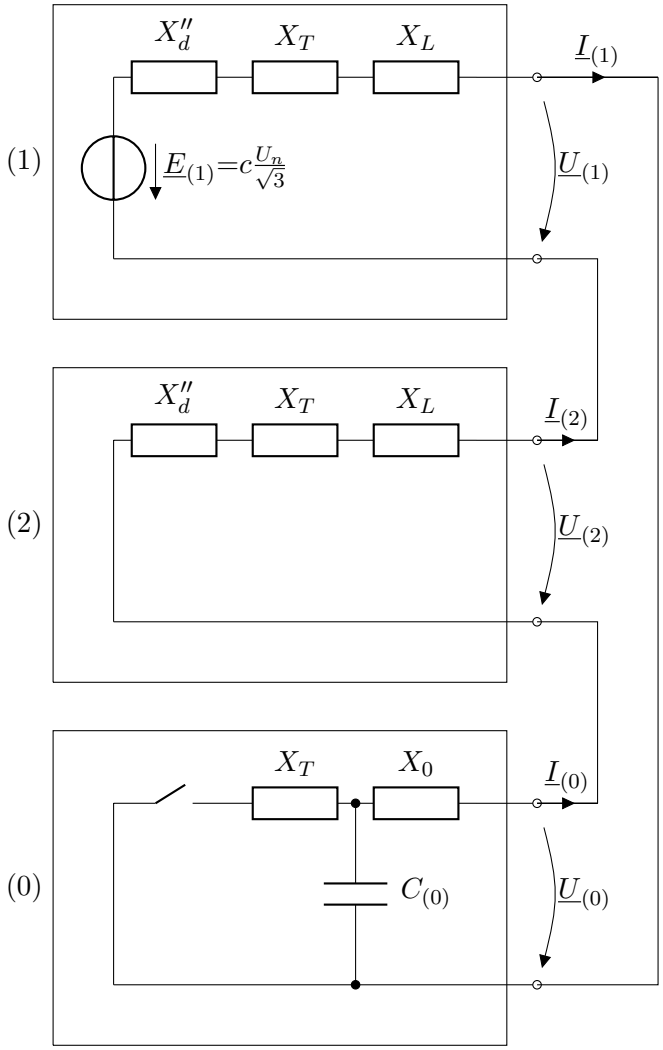
$$\sinh\left(\underline{\gamma} l\right) \underline{Z}_W \frac{0{,}9\,\underline{\mathrm{U}}_1}{\underline{Z}_2} = \underline{U}_1 - \cosh\left(\underline{\gamma} l\right) 0{,}9\,\underline{\mathrm{U}}_1 \tag{11}$$

$$\underline{Z}_2 = \frac{\sinh\left(\underline{\gamma} l\right) \underline{Z}_W 0{,}9\,\underline{\mathrm{U}}_1}{\underline{U}_1 - \cosh\left(\underline{\gamma} l\right) 0{,}9\,\underline{\mathrm{U}}_1} \tag{12}$$

f)

2 Ein- und zweipoliger Kurzschluss

a)



b)

$$X''_d = x''_d \frac{U_2^2}{S_N} \tag{13}$$

$$X_T = u_k \frac{U_2^2}{S_N} \tag{14}$$

$$X_L = \omega L'_B l \tag{15}$$

$$C_{(0)} = C'_E l \tag{16}$$

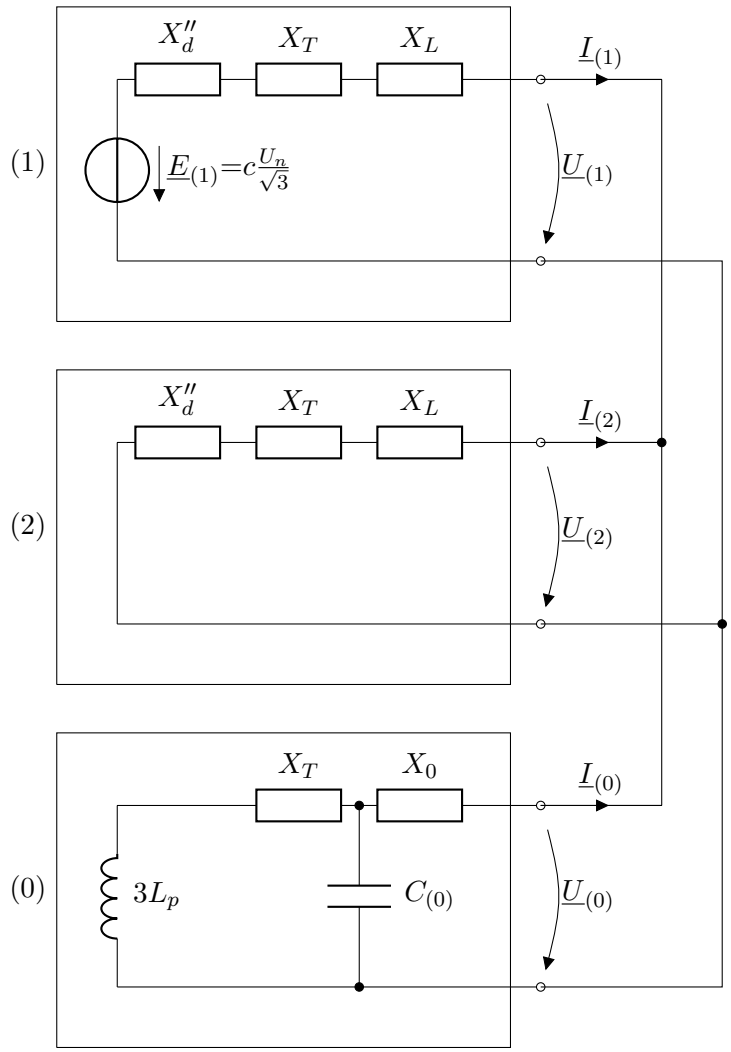
$$\underline{I}_{(1)} = \frac{c\frac{U_n}{\sqrt{3}}}{2\mathrm{j}\left(X''_d + X_T + X_L\right) + \mathrm{j}X_0 + \frac{1}{\mathrm{j}\omega C_{(0)}}} \tag{17}$$

$$\underline{I}''_{k1p} = \underline{I}_a = \underline{I}_{(0)} + \underline{I}_{(1)} + \underline{I}_{(2)} = 3\underline{I}_{(1)} \tag{18}$$

c)

$$\mathrm{j}\omega 3L_p + \mathrm{j}X_T + \frac{1}{\mathrm{j}\omega C_{(0)}} = 0 \tag{19}$$

$$L_p = \frac{1}{3\omega^2 C_{(0)}} - \frac{X_T}{3\omega} \tag{20}$$



d)

e)

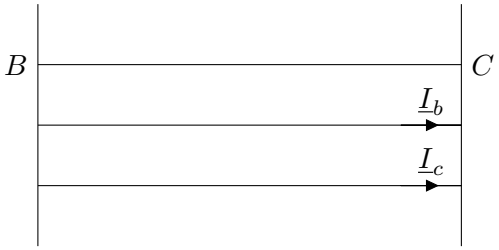
$$\underline{I}_{(0)} = 0\,\mathrm{A} \tag{21}$$

$$\underline{I}_{(1)} = -\underline{I}_{(2)} = \frac{c\frac{U_n}{\sqrt{3}}}{2\mathrm{j}\left(X''_d + X_T + X_L\right)} \tag{22}$$

$$\underline{I}_b = \underline{I}_{(0)} + \underline{a}^2\underline{I}_{(1)} + \underline{a}\underline{I}_{(2)} = \left(\underline{a}^2 - \underline{a}\right)\underline{I}_{(1)} = -\mathrm{j}\sqrt{3}\underline{I}_{(1)} \tag{23}$$

$$\underline{I}_c = \underline{I}_{(0)} + \underline{a}\underline{I}_{(1)} + \underline{a}^2\underline{I}_{(2)} = \left(\underline{a} - \underline{a}^2\right)\underline{I}_{(1)} = \mathrm{j}\sqrt{3}\underline{I}_{(1)} \tag{24}$$

f) In der Skizze sind die wahren Flussrichtungen und nicht die Orientierungen eingezeichnet.



3 A Transformator

a)

$$R_k = P_k \frac{U_2^2}{S_N^2} \tag{25}$$

b)

$$P_L = G_L U_L^2 \tag{26}$$

$$G_L = \frac{P_L}{U_L^2} = \frac{P_L}{U_2^2} \tag{27}$$

c)

$$Q_L = -B_L U_L^2 \tag{28}$$

$$S_L = U_L I_L = U_N I_N \cdot 0{,}25\,\% = S_N \cdot 0{,}25\,\% \tag{29}$$

$$Q_L = \sqrt{S_L^2 - P_L^2} \tag{30}$$

$$B_L = -\frac{Q_L}{U_L^2} \tag{31}$$

d)

$$Z_k = u_k \frac{U_2^2}{S_N} \tag{32}$$

3 B Parallelschaltung von zwei Transformatoren

a)

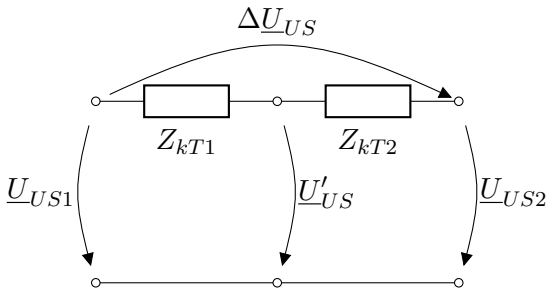
$$\Delta \underline{U}_{US} = \underline{U}_{US1} - \underline{U}_{US2} = \underline{U}_{OS} \left(\frac{1}{\underline{\ddot{u}}_1} - \frac{1}{\underline{\ddot{u}}_2} \right) \tag{33}$$

$$\underline{U}'_{US} = \underline{U}_{US1} - \frac{Z_{kT1}}{Z_{kT1} + Z_{kT2}} \Delta \underline{U}_{US} \tag{34}$$

b)

$$\underline{I}_k = \frac{\Delta \underline{U}_{US}}{Z_{kT1} + Z_{kT2}} \tag{35}$$

c)



4 Fünf Sicherheitsregeln

Siehe Skriptum S.IX

5 Wirtschaftlichkeitsrechnung

a)

$$\alpha = \frac{(q-1)\,q^n}{q^n-1} = \frac{(1{,}05-1)\,1{,}05^{25}}{1{,}05^{25}-1} = 0{,}070\,95\,\frac{1}{\mathrm{a}} \tag{36}$$

$$T_m = \frac{E}{P} = \frac{2100\,\frac{\mathrm{GW\,h}}{\mathrm{a}}}{300\,\mathrm{MW_{el}}} = 7000\,\frac{\mathrm{h}}{\mathrm{a}} \tag{37}$$

$$k = \frac{\alpha a + c}{T_m} + b + d \tag{38}$$

$$= \frac{0{,}070\,95\,\frac{1}{\mathrm{a}} \cdot 590\,\frac{€}{\mathrm{kW_{el}}} + 87\,\frac{€}{\mathrm{kW_{el}\,a}}}{7000\,\frac{\mathrm{h}}{\mathrm{a}}} + \frac{0{,}37\,\frac{€}{\mathrm{m^3}} \cdot 3{,}6\,\frac{\mathrm{MJ}}{\mathrm{kW\,h}}}{0{,}59 \cdot 30\,\frac{\mathrm{MJ}}{\mathrm{m^3}}} + 0{,}001\,\frac{€}{\mathrm{kW\,h_{el}}} \tag{39}$$

$$= 0{,}094\,66\,\frac{€}{\mathrm{kW\,h_{el}}} \tag{40}$$

b)

$$\alpha = \frac{(q-1)\,q^n}{q^n-1} = \frac{(1{,}04-1)\,1{,}04^{40}}{1{,}04^{40}-1} = 0{,}050\,52\,\frac{1}{\mathrm{a}} \tag{41}$$

$$T_m = \frac{E}{P} = \frac{1560\,\frac{\mathrm{GW\,h}}{\mathrm{a}}}{300\,\mathrm{MW_{el}}} = 5200\,\frac{\mathrm{h}}{\mathrm{a}} \tag{42}$$

$$k = \frac{\alpha a + c}{T_m} + b + d \tag{43}$$

$$= \frac{0{,}050\,52\,\frac{1}{\mathrm{a}} \cdot 3100\,\frac{€}{\mathrm{kW_{el}}} + 78\,\frac{€}{\mathrm{kW_{el}\,a}}}{5200\,\frac{\mathrm{h}}{\mathrm{a}}} \tag{44}$$

$$= 0{,}045\,12\,\frac{€}{\mathrm{kW\,h_{el}}} \tag{45}$$

c)

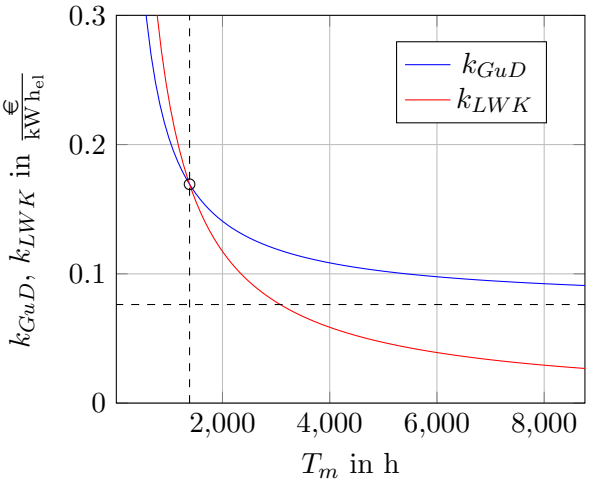
$$k_{GuD} = \frac{\alpha_{LWK} a_{LWK} + c_{LWK}}{T_{m,LWK}} \tag{46}$$

$$T_{m,LWK} = \frac{\alpha_{LWK} a_{LWK} + c_{LWK}}{k_{GuD}} = \frac{0{,}050\,52\,\frac{1}{\mathrm{a}} \cdot 3100\,\frac{€}{\mathrm{kW_{el}}} + 78\,\frac{€}{\mathrm{kW_{el}\,a}}}{0{,}094\,66\,\frac{€}{\mathrm{kW\,h_{el}}}} = 2478\,\frac{\mathrm{h}}{\mathrm{a}} \tag{47}$$

d)

$$k_{GuD} = \frac{128{,}9\,\frac{€}{\mathrm{kW_{el}\,a}}}{T_m} + 0{,}076\,25\,\frac{€}{\mathrm{kW\,h_{el}}} \tag{48}$$

$$k_{LWK} = \frac{234{,}6\,\frac{€}{\mathrm{kW_{el}\,a}}}{T_m} \tag{49}$$



e)