Calculate initial sub-transient short-circuit current for three-phase, phase-to-phase and single-phase-to-ground short-circuit (Fig. 1.).

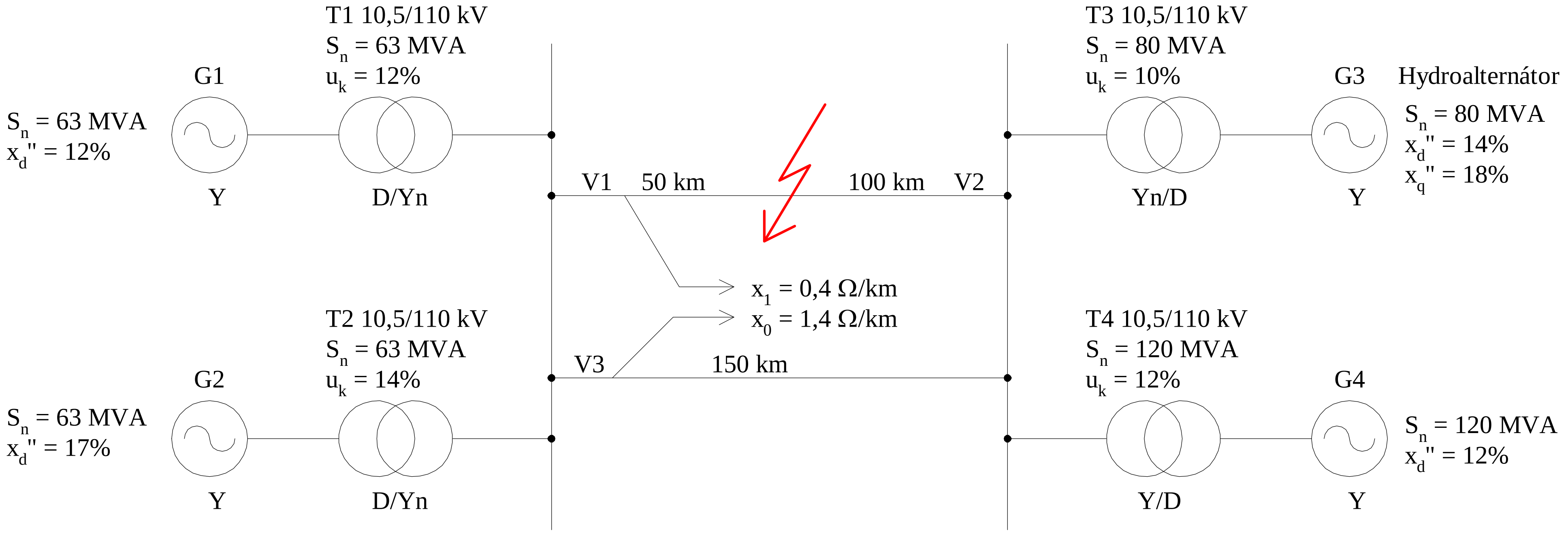


Fig. 1

We choose base power $S_v = 63$ MVA and base voltage $U_v = 110$ kV

hence base current $I_v = \dfrac{S_v}{\sqrt{3} \cdot U_v} = 330{,}7$ A .

Then we recalculate relative reactances of all elements for base power and voltage in the short-circuit place. For unbalanced short-circuits we must use symmetrical sequence components (positive (1), negative (2) and zero (0)). The recalculated reactances are therefore in three systems:

- generators

G1: $x_{1G1} = x_{2G1} = x_d'' \dfrac{S_v}{S_n} = 0{,}12 \cdot \dfrac{63}{63} = 0{,}12$

G2: $x_{1G2} = x_{2G2} = 0{,}17 \cdot \dfrac{63}{63} = 0{,}17$

G3: $x_{1G3} = 0{,}14 \cdot \dfrac{63}{80} = 0{,}11$

! negative reactance of hydroalternator !

$$x_{2G3} = \frac{x_d'' + x_q''}{2} \frac{S_v}{S_n} = \frac{0{,}14 + 0{,}18}{2} \cdot \frac{63}{80} = 0{,}126$$

G4: $x_{1G4} = x_{2G4} = 0{,}12 \cdot \dfrac{63}{120} = 0{,}063$

- transformers

T1: $x_{1T1} = x_{2T1} = x_{0T1} = u_k \dfrac{S_v}{S_n} = 0{,}12 \cdot \dfrac{63}{63} = 0{,}12$

T2: $x_{1T2} = x_{2T2} = x_{0T2} = 0{,}14 \cdot \dfrac{63}{63} = 0{,}14$

T3: $x_{1T3} = x_{2T3} = x_{0T3} = 0{,}1 \cdot \dfrac{63}{80} = 0{,}079$

T4: $x_{1T4} = x_{2T4} = 0{,}12 \cdot \dfrac{63}{120} = 0{,}063$

! zero reactance of transformer with not-ground Y winding !

$x_{0T4} = \infty$

- power lines

V1: $x_{1V1} = x_{2V1} = x_{1ved} \cdot l_1 \cdot \dfrac{S_v}{U_v^2} = 0{,}4 \cdot 50 \cdot \dfrac{63}{110^2} = 0{,}104$

$$x_{0V1} = x_{0ved} \cdot l_1 \cdot \frac{S_v}{U_v^2} = 1{,}4 \cdot 50 \cdot \frac{63}{110^2} = 0{,}364$$

V2: $x_{1V2} = x_{2V2} = 0{,}4 \cdot 100 \cdot \dfrac{63}{110^2} = 0{,}208$

$$x_{0V2} = 1{,}4 \cdot 100 \cdot \frac{63}{110^2} = 0{,}728$$

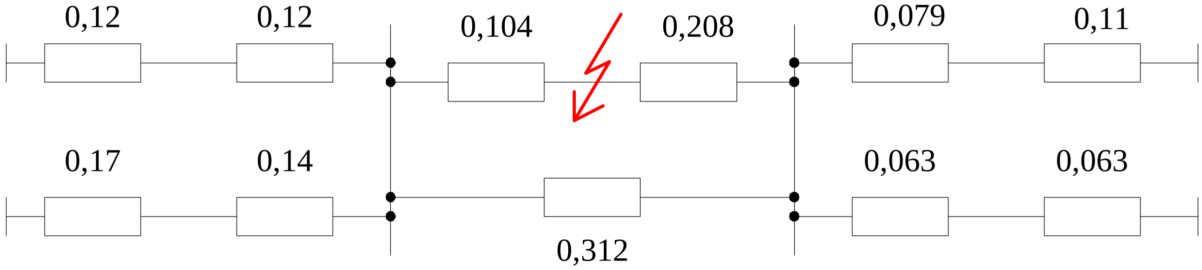
V3: $x_{1V3} = x_{2V3} = 0{,}4 \cdot 150 \cdot \dfrac{63}{110^2} = 0{,}312$

$$x_{0V3} = 1{,}4 \cdot 150 \cdot \frac{63}{110^2} = 1{,}093$$

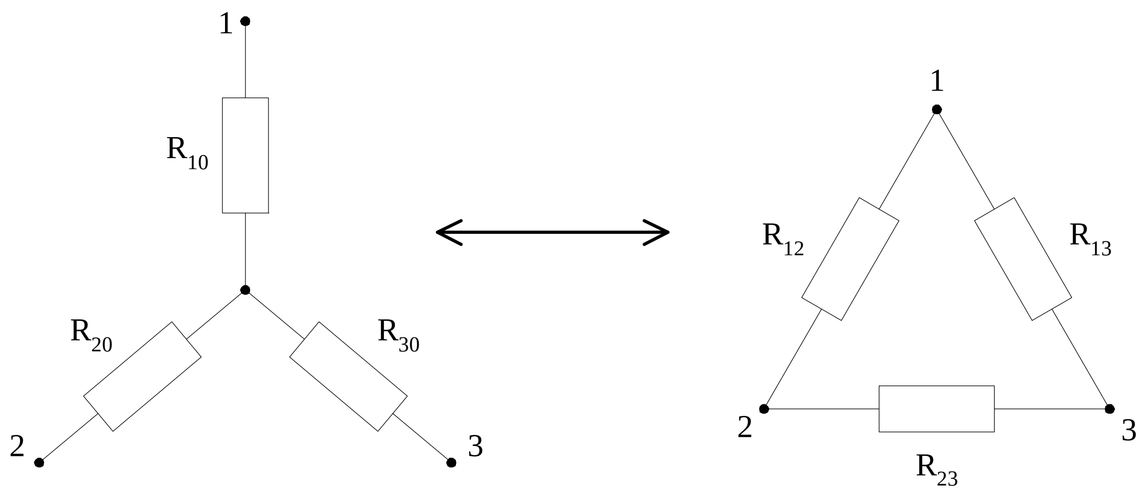
The substitution diagrams with recalculated reactances will be simplified further to obtain a total calculational reactance. The short-circuit place is considered as a source again. The substitution diagram must be considered for all three component systems.

The diagrams have the same topology in case of the positive and negative sequence. They differ only in the generator 3 reactance value.

Positive diagram:



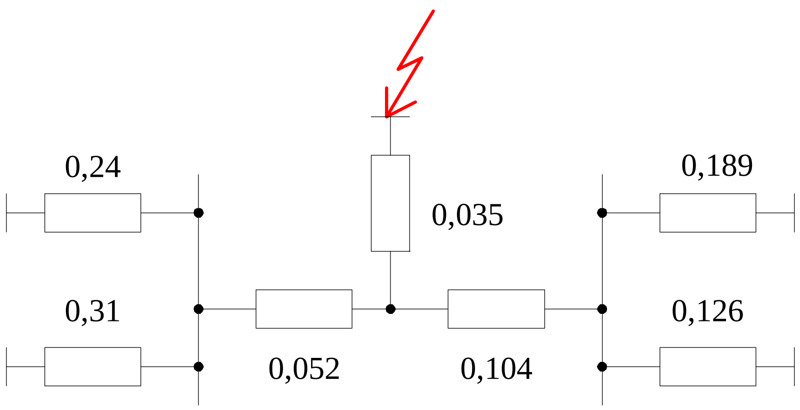
For other modification the internal triangle with the short-circuit must be converted to a star by means of the transfiguration relations:

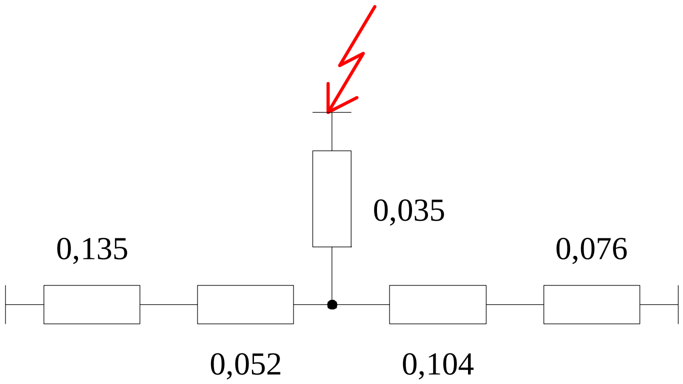


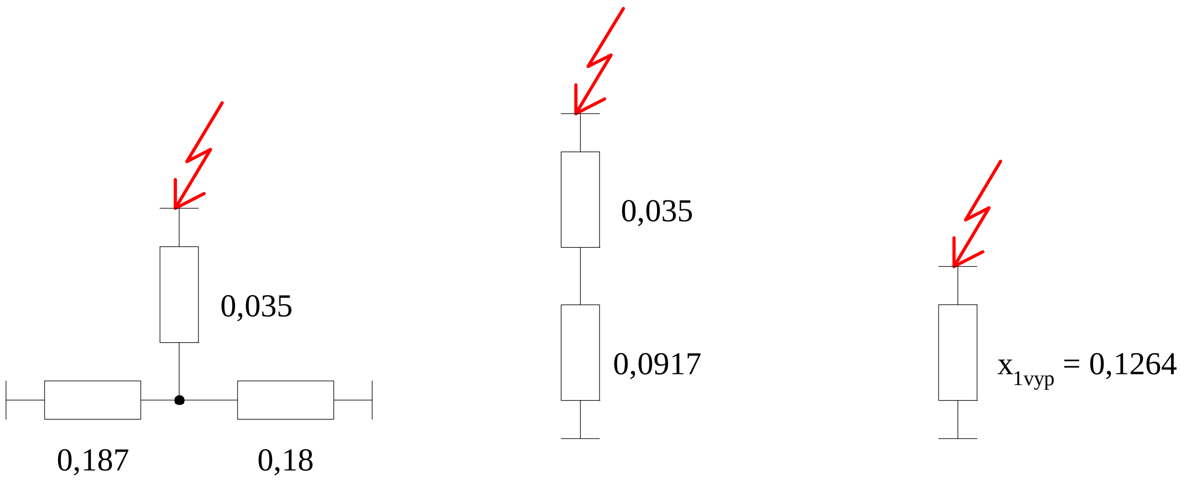
$$Y \rightarrow D: \quad R_{12} = R_{10} + R_{20} + \frac{R_{10} \cdot R_{20}}{R_{30}}$$

$$D \rightarrow Y: \quad R_{10} = \frac{R_{12} \cdot R_{13}}{R_{12} + R_{13} + R_{23}}$$

Further simplification:

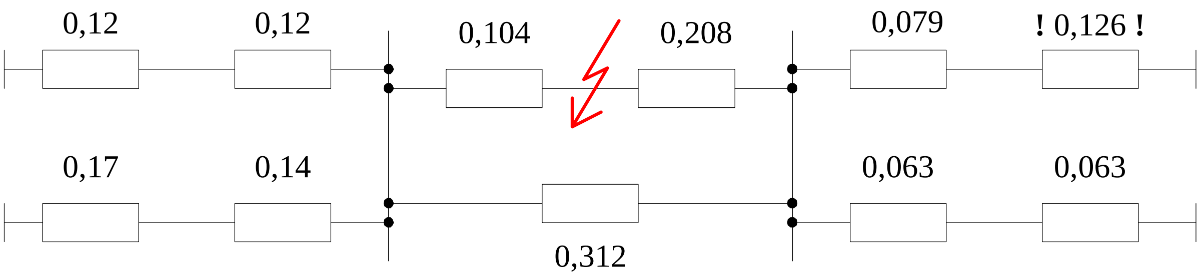


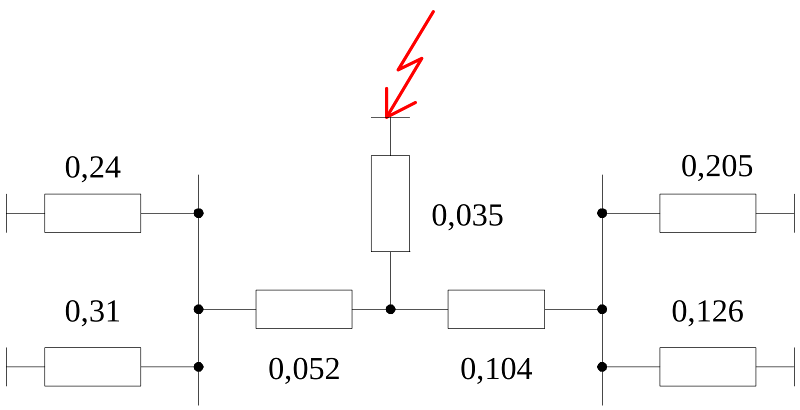


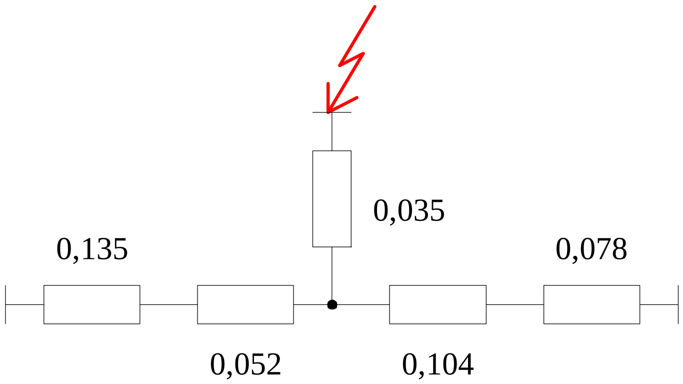


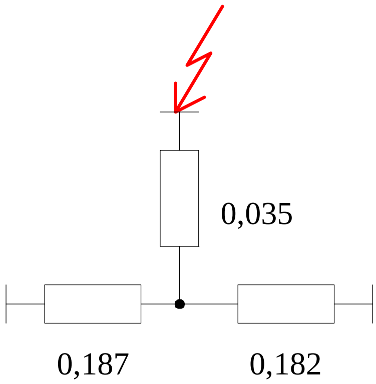
<u>Negative diagram:</u>

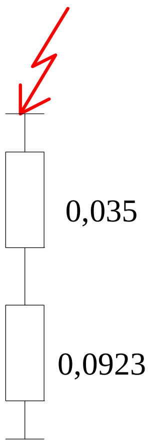
Modifications are the same like for the positive diagram.

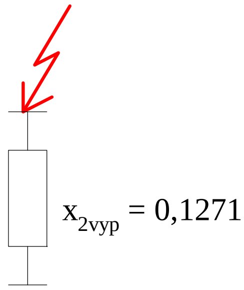






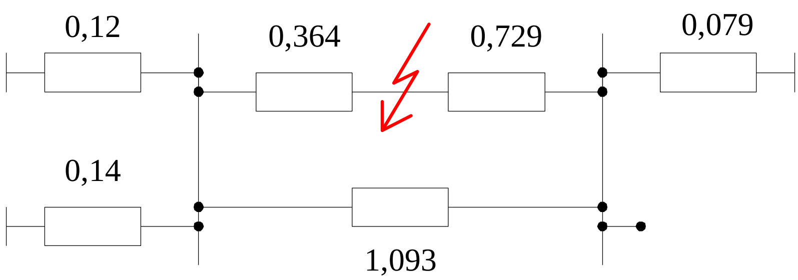


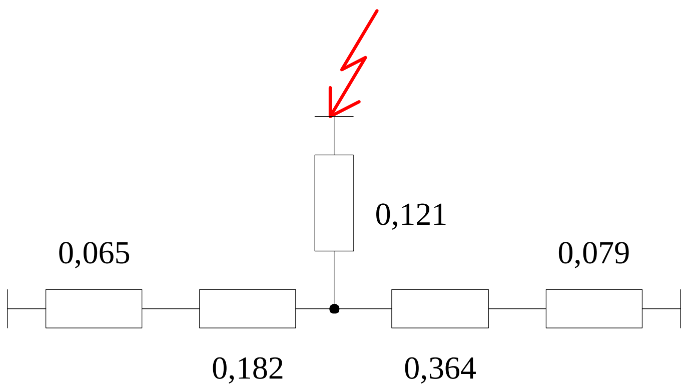


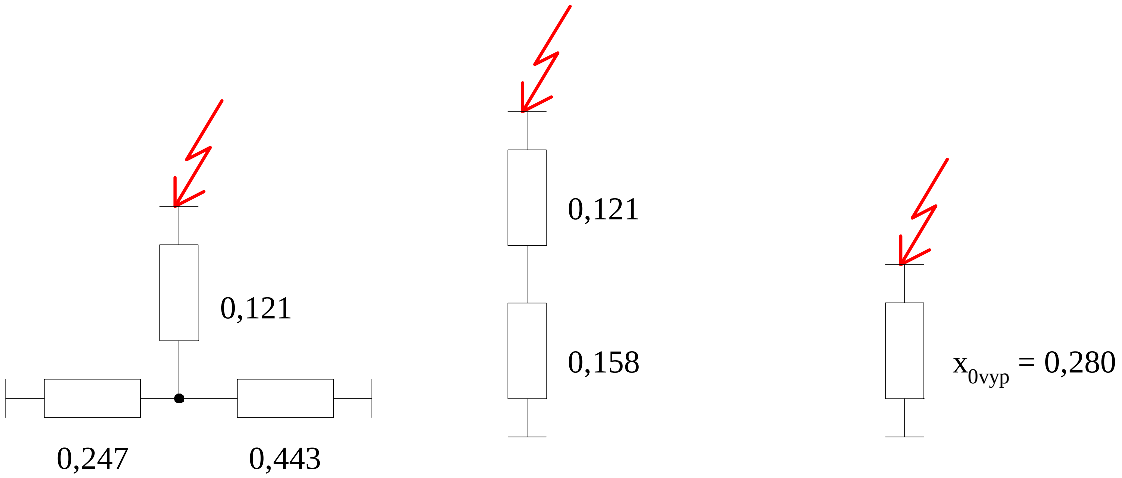


<u>Zero diagram:</u>

Zero sequence is formed by three phasors with the same phase. These are added algebraically in a node. If an element (generator, transformer) has an ungrounded Y winding, the zero sequence can't flow into the winding. Therefore its zero sequence impedance is infinite. Equivalent diagram and modifications are as follows:







We have all three sequence reactances now to calculate initial sub-transient short-circuit currents.

a) single-phase-to-ground short-circuit

$$I''^{(1)}_{k0} = \frac{3I_v}{x_{1vyp} + x_{2vyp} + x_{0vyp}} = \frac{3 \cdot 330{,}7}{0{,}1264 + 0{,}1271 + 0{,}28} = 1859\ \text{A}$$

b) phase-to-phase short-circuit

$$I''^{(2)}_{k0} = \frac{\sqrt{3} \cdot I_v}{x_{1vyp} + x_{2vyp}} = \frac{\sqrt{3} \cdot 330{,}7}{0{,}1264 + 0{,}1271} = 2259\ \text{A}$$

c) three-phase short-circuit

$$I''^{(3)}_{k0} = \frac{I_v}{x_{1vyp}} = \frac{330{,}7}{0{,}1264} = 2615\ \text{A}$$

(a,b,c relations result from transformation into sequences components.)