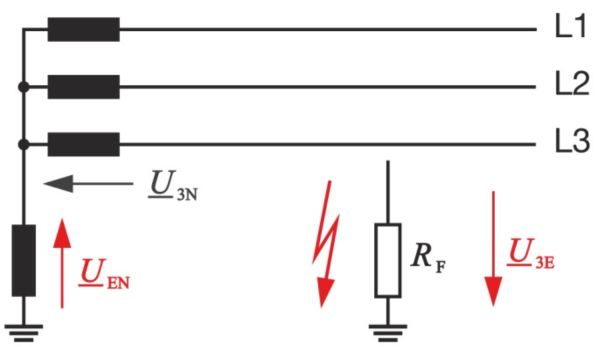
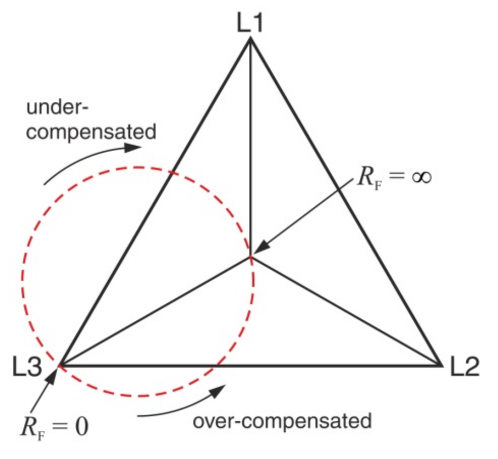
Info Letter No. 21

The influence of the contact resistance at the earth-fault location on the zero sequence voltage U_{EN} in compensated networks

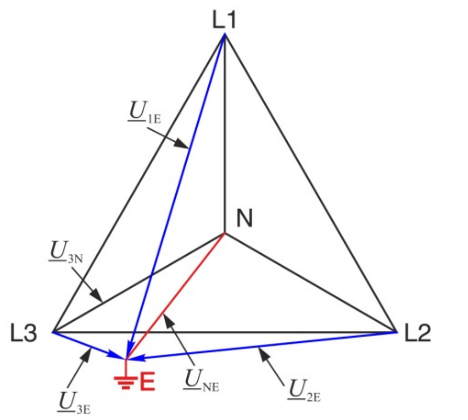
The earth fault in compensated networks is usually presented without a contact resistance at the fault location *(R_F = 0)*. In the vector diagram in the case of an earth fault the earth point then changes into a vertex of the voltage triangle.



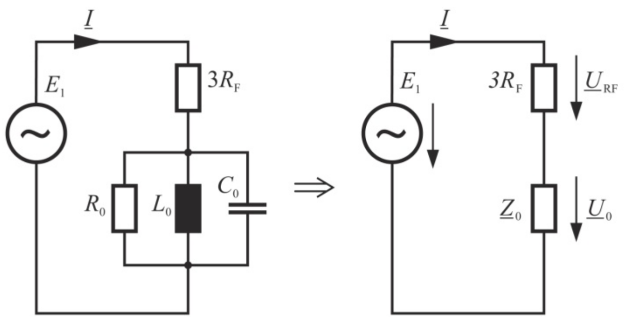
However, usually an arc occurs at the fault location with a finite resistance ($R_F \neq 0$). As a function of the detuning v, the damping d and the resistance R_F at the fault location, the earth point E at the fault location changes into a circular arc, in overcompensation counterclockwise and with undercompensation clockwise towards the centre of the voltage triangle. The location of the centre of the circle is determined by the detuning and damping.



The vector diagram of the voltages then changes and thus also the voltages at the phase-earth capacitances and the earth fault coils according to the magnitude and phase angle.



The new voltages can be calculated with the aid of the symmetrical components. The zero sequence is represented by a parallel resonant circuit consisting of the phase-earth capacitance, earth fault coil and discharge resistors.



The current *I* in the zero sequence is

$$\underline{I} = \frac{\underline{E}_1}{3 \cdot R_F + \underline{Z}_0}$$

(for the names of the components, see the example calculation on page 3)

For the voltages:

$$\underline{E}_1 = \underline{U}_{R_F} + \underline{U}_0$$

$$\underline{U}_{R_F} = \underline{I} \cdot 3 \cdot R_F$$

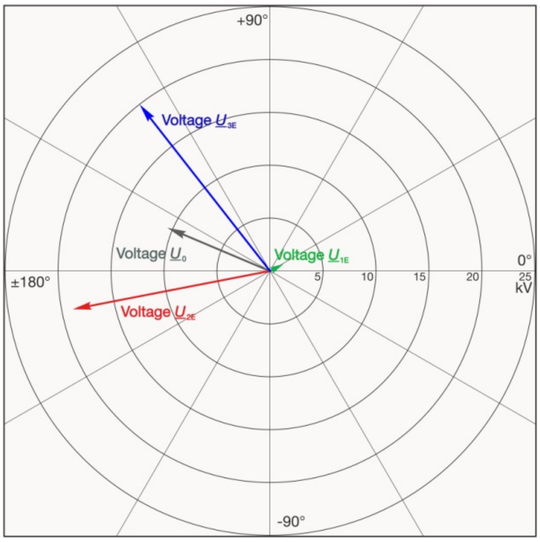
$$\underline{U}_0 = \underline{I} \cdot \underline{Z}_0$$

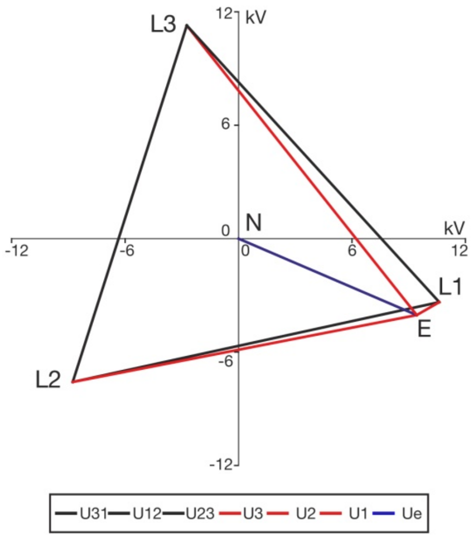
During the conversion in the 012 system of the symmetric components, observe that the current about the fault location is three times as large as the current in the equivalent circuit diagram. Therefore the fault resistance R_F, the Inductance L_D of the E-coil and the discharge resistance *R* must be used with the triple values.

Example:

The recording of an earth fault by a digital protection relay gave the following values and the associated voltage triangle.

$\underline{U}_0$	10 517.7 V	157°
$\underline{U}_{1E}$	1 404.7 V	27°
$\underline{U}_{2E}$	18 955.5 V	191°
$\underline{U}_{3E}$	19 966.9 V	128°





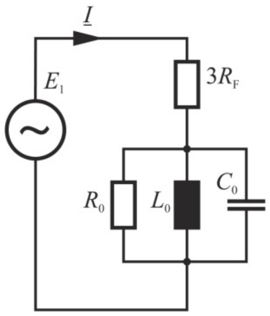
For a clearer view of the relationships, the series impedances ($R_F >> Z_L$) and the harmonics were **not** considered.

Example:

A 20 kV network has a capacitive earth fault current of 100 A, the e-coil is set to an inductive current of 105 A, the sum of all discharge resistances is 4 kΩ and the contact resistance at the fault location would be 200 ohms.

Wanted:

All values for the equivalent circuit.



The phase-earth capacitance *Ce*

$$C_e = \frac{I_E}{\sqrt{3} \cdot U \cdot \omega}$$

$$C_e = \frac{100\ \text{A}}{\sqrt{3} \cdot 20\ \text{kV} \cdot 314\ \text{s}^{-1}}$$

$$C_e = 9{,}2\ \mu\text{F}$$

$$C_0 = C_e = 9{,}2\ \mu\text{F}$$

The inductance of the e-coil

$$L_D = \frac{U}{\sqrt{3} \cdot I_L \cdot \omega}$$

$$L_D = \frac{20\ \text{kV}}{\sqrt{3} \cdot 105\ \text{A} \cdot 314\ \text{s}^{-1}}$$

$$L_D = 0{,}35\ \text{H}$$

$$L_0 = 3 \cdot L_D = 1{,}05\ \text{H}$$

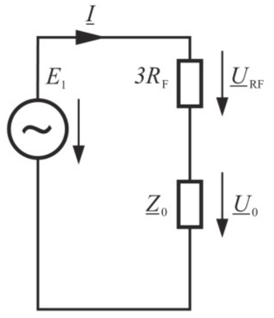
The discharge resistance

$$R_0 = 3 \cdot 4\ \text{k}\Omega$$

$$R_0 = 12\ \text{k}\Omega$$

Literature:

[1] Poll, J.: **Sternpunktverlagerungen in gelöschten 110-kV-Netzen**
Elektrizitätswirtschaft 80 (1981) 22, P 810-813



$$\underline{Z}_0 = \frac{1}{\frac{1}{R_0} + j\left(\omega \cdot C_0 - \frac{1}{\omega \cdot L_0}\right)}$$

$$\underline{Z}_0 = \frac{1}{0{,}083\ \text{mS} + j\,(2{,}89\ \text{mS} - 3{,}02\ \text{mS})}$$

$$\underline{Z}_0 = \frac{1}{1{,}606 \cdot e^{\text{j}-58{,}7°}\,\text{mS}}$$

$$\underline{Z}_0 = 6\,225 \cdot e^{\text{j}58{,}7°}\,\Omega$$

The loop resistance

$$\underline{Z}_\text{S} = \underline{Z}_0 + R_\text{F}$$

$$\underline{Z}_\text{S} = 6\,225 \cdot e^{\text{j}58{,}7°}\,\Omega\ + 600\ \Omega$$

$$\underline{Z}_\text{S} = 6\,557 \cdot e^{\text{j}54°}\,\Omega$$

The current

$$\underline{I} = \frac{E_1}{3 \cdot R_\text{F} + \underline{Z}_0}$$

$$\underline{I} = \frac{11\,560 \cdot e^{\text{j}0°}\ \text{V}}{6\,557 \cdot e^{\text{j}54{,}3°}\ \Omega}$$

$$\underline{I} = 1{,}76 \cdot e^{\text{j}-54°}\,\text{A}$$

The voltage at the fault location

$$\underline{U}_\text{RF} = \underline{I} \cdot R_\text{F}$$

$$\underline{U}_\text{RF} = 1{,}76 \cdot e^{\text{j}-54°}\,\text{A} \cdot 600\ \Omega$$

$$\underline{U}_\text{RF} = 1\,058 \cdot e^{\text{j}-54°}\,\text{V}$$

The voltage at the e-coil

$$\underline{U}_0 = \underline{I} \cdot \underline{Z}_0$$

$$\underline{U}_0 = 1{,}76 \cdot e^{\text{j}-54°}\,\text{A} \cdot 6\,557 \cdot e^{\text{j}58{,}7°}\,\Omega$$

$$\underline{U}_0 = 10\,976 \cdot e^{\text{j}4{,}5°}\,\text{V}$$

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The series will be continued.
We will gladly supply missing Info Letters at any time!

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