



VEBKO ONLINE HELP

Grounding Factor in Distance

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1 Imported Content

Numeric distance protection relays use various algorithms, based on measured current and voltage, to calculate fault impedance. The calculated impedances differ under certain conditions, such as single-phase-to-ground faults. Generally, three methods are commonly used for calculating impedance in phase-to-ground faults: Type A, Type B, and Type C. Here, a single-phase-to-ground fault (Phase E1-L) has been applied to three relays with different algorithms. The voltage and current measured by each relay are displayed as shown.

$$V_{L1E} = 20 \text{ V} \cdot e^{j0}$$

$$I_{L1} = I_E = 2 \text{ A} \cdot e^{-j30}$$

Figure 1

The line impedances calculated by the distance relays are shown as displayed. The different measured impedance values are due to the varying grounding factors used in the distance relays. Below, these three methods are introduced. As you may know, the distance relay determines the fault location by calculating impedance. The shown diagram represents the equivalent circuit of a double-fed line where a single-phase-to-ground fault has occurred in Phase L1.

$$\text{Type A} : X = 4.4 \Omega; R = 7.0 \Omega$$

$$\text{Type B} : X = 4.2 \Omega; R = 6.2 \Omega$$

$$\text{Type C} : X = 4.2 \Omega; R = 8.2 \Omega$$

Figure 2

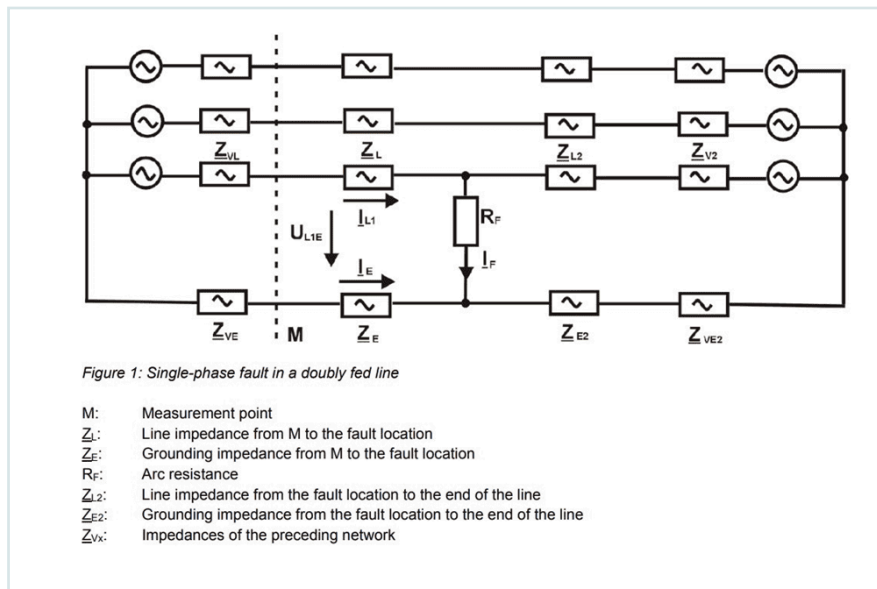


Figure 3

In this circuit, the relay at point M measures voltage and current and calculates impedance based on Kirchhoff's law. In the written equation, the term R_F is considered as zero undefined due to the arc caused by the short circuit. Therefore, by making certain assumptions to simplify this equation, the relay calculates the voltage at point M. In the equations, R_F is assumed to be zero, and $I_E \cdot Z_E$ are determined using the grounding factor.

$$V_{LE1} = I_{LE} \cdot Z_{L1} - I_E Z_E + R_F I_F.$$

Figure 4

The grounding factor (K) is used in phase-to-ground faults and relates to line parameters, defined as the ratio of ground impedance to line impedance. The diagram shows the equivalent circuit for a phase-to-ground fault, assuming $R_F = 0$, where the total impedance Z_S is divided into line impedance Z_L and ground impedance Z_E . With these assumptions, we have the equations as shown.

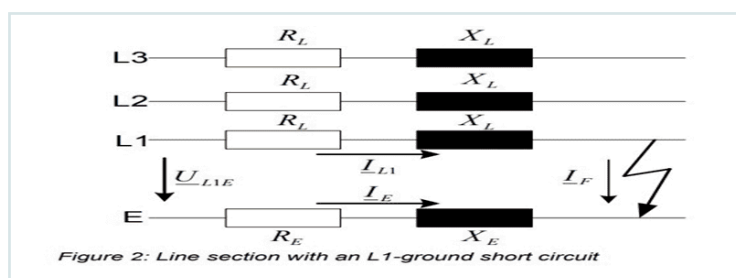


Figure 5

$$\begin{aligned} Z_S &= Z_L + Z_E \\ Z_L &= R_L + jX_L \\ Z_E &= R_E + jX_E \\ Z_{SE} &= \frac{Z_{0S} - Z_{1S}}{3} \end{aligned}$$

Figure 6

In the displayed equations, Z_{0S} and Z_{1S} represent the positive sequence and zero sequence impedances of the source, respectively. In general, there are three methods for expressing the grounding factor (K), which are convertible to one another. The first method is the ratio of ground impedance to line impedance, which is a complex number. The second method is the division of zero-sequence impedance by positive-sequence impedance.

$$\begin{aligned} K_L &= \frac{Z_E}{Z_L} \\ K_0 &= \frac{Z_0}{Z_1} \end{aligned}$$

Figure 7

The third method represents the grounding factor as a pair of real numbers. Depending on what information about the grounding factor is available, it can be independently entered in the Object Test

window, Distance Block, Factor Grounding section of the Vebko software. The Factor Grounding section in the Parameters Protection Distance window allows for inputting the grounding factor and selecting the relay's algorithm. Using the Mode dropdown menu, the method of entering the factor (RL/RE or KL K, K0) can be chosen without affecting the relay's algorithm.

$$K_r = \frac{R_E}{R_L}$$

$$K_x = \frac{X_E}{X_L}$$

Figure 8

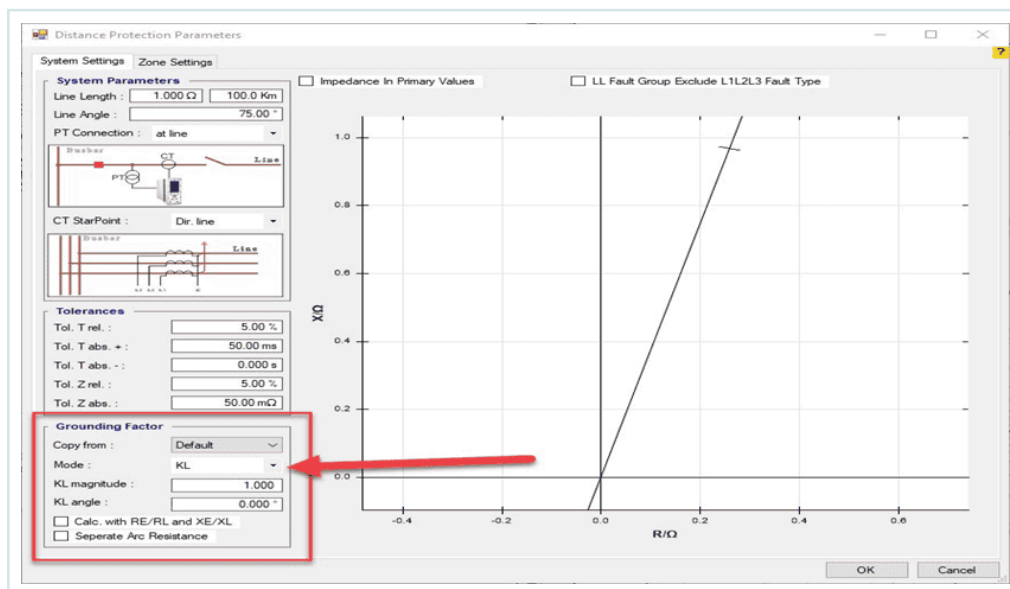


Figure 9

As mentioned, there are equations for converting different types of grounding factors into each other. The relationship between the KL factor and other grounding-related factors is shown. **Distance Protection Relay Algorithm Type A, 'KL Complex'**: The distance relay with Type A algorithm uses the KL factor, as shown, for calculating impedance in a phase-to-ground fault.

$$K_L = \frac{K_0 - 1}{3}$$

$$K_L = \frac{K_r}{1 + j \frac{R_L}{X_L}} + \frac{K_x}{1 - j \frac{X_L}{R_L}}$$

Figure 10

$$V_{L1E} = I_{L1E} \cdot Z_{L1} - I_E \cdot Z_E$$

$$Z_E = K_L \cdot Z_L$$

$$\Rightarrow V_{L1E} = I_{L1E} \cdot Z_{L1} - K_L \cdot Z_L$$

Figure 11

In the shown equation, assuming that the first-phase current, ground current, and fault current are equal ($I_{L1} = I_E = I_F$), and with V as the voltage measured by the relay during the fault, the impedance measured by the relay is calculated as shown. **Distance Protection Relay Algorithm Type B, 'XL/XE, RL/RE'**: The distance relay with Type B algorithm calculates impedance for a phase-to-ground fault using the complex grounding factors K_r and K_x , as displayed.

$$Z_{TypeA} = R_{TypeA} + jX_{TypeA} = \frac{\frac{V}{I}}{1 + K_L}$$

Figure 12

$$V_{L1E} = I_{L1E} \cdot (R_L + jX_L) - I_E \cdot (R_E + jX_E)$$

$$R_E = K_r \cdot R_L$$

$$X_E = K_x \cdot X_L$$

$$V_{L1E} = I_{L1E} \cdot (R_L + jX_L) - I_E \cdot (K_r \cdot R_L + jK_x \cdot X_L)$$

Figure 13

In the given equation, it is assumed that the first-phase current, ground current, and fault current are equal (i.e., $I_{L1} = I_F = I_{E1} = I_F = I_E$). Additionally, V represents the voltage measured by the relay during the fault. Based on this, the impedance measured by the relay is calculated as shown.

$$X_{TypeB} = \frac{\text{Im} \left\{ \frac{V}{I} \right\}}{1 + K_x}$$

$$R_{TypeB} = \frac{\text{Re} \left\{ \frac{V}{I} \right\}}{1 + K_r}$$

$$|Z| = \sqrt{R^2 + X^2} \quad \varphi = \tan\left(\frac{X}{R}\right)$$

Figure 14

Distance Protection Relay Algorithm Type C, 'Separated Arc': Type C distance relays use an algorithm similar to Type B for calculating the imaginary part of the fault impedance X . However, they calculate the real part of the fault impedance R differently. This algorithm considers the arc resistance (RF arc) by assuming that the fault current I_F is equal to the line current. The main concept in this algorithm is

to combine arc resistance with line resistance. In other words, the real part of the ground impedance is subtracted from the real part of the phase-to-ground fault impedance (ground-fault loop). The ground resistance value can then be determined from the calculated XL as a function of the factor Kr and the line angle.

$$X_{TypeC} = \frac{\text{Im} \left\{ \frac{V}{I} \right\}}{1 + K_x}$$

$$R_{TypeC} = \text{Re} \left\{ \frac{V}{I} \right\} - X_{TypeC} \cdot \arctan(\varphi_L) \cdot K_r$$

Figure 15

	$X_{\text{meas}} =$	$R_{\text{meas}} =$
Type A	$\text{Im} \left\{ \frac{\underline{U}/\underline{I}}{1 + \underline{K}_L} \right\}$	$\text{Re} \left\{ \frac{\underline{U}/\underline{I}}{1 + \underline{K}_L} \right\}$
Type B	$\frac{\text{Im} \{ \underline{U}/\underline{I} \}}{1 + K_x}$	$\frac{\text{Re} \{ \underline{U}/\underline{I} \}}{1 + K_r}$
Type C	$\frac{\text{Im} \{ \underline{U}/\underline{I} \}}{1 + K_x}$	$\text{Re} \{ \underline{U}/\underline{I} \} - X_{TypeC} \cdot \arctan(\varphi_L) \cdot K_r$

Figure 16

Interpretation of Results for Different Algorithms: Simplifying (IE=-IF=IL1IE =-IF =IL1) allows for comparing the obtained results. The displayed table shows the line impedance calculated by different distance protection algorithms.

The displayed table shows a key result of the analysis. The measured impedance ($Z_{\text{meas}} = R_{\text{meas}} + j$

xmeas) by the distance relay includes the line impedance (Z_L) along with a portion of the arc resistance. The amount of added RF arc resistance to the line impedance depends on the distance protection algorithm used.

	$X_{meas} =$	$R_{meas} =$
Type A	$X_L + \text{Im}\{R_F / (1 + \underline{K}_L)\}$	$R_L + \text{Re}\{R_F / (1 + \underline{K}_L)\}$
Type B	X_L	$R_L + R_F / (1 + K_r)$
Type C	X_L	$R_L + R_F$

Figure 17

"As shown in the table, in Type A relays, the grounding factor or KL impacts both the real and imaginary parts of the impedance as a complex value. In this case, the arc effect from a short circuit is considered an inductive and resistive phenomenon, represented as a complex impedance. In Type B algorithms, the relays reduce the arc resistance (R_F) by a factor of $1 / (1 + K_r)$ in the real part. In Type C algorithms, relays measure impedance without any compensation factor for arc resistance (R_F). Distance relays of Types A, B, and C define measured impedance differently. Consequently:

▯ Scaling on the impedance plane changes and will no longer depend solely on (X) and (R). The relevant axes scaling is illustrated in the accompanying diagrams.

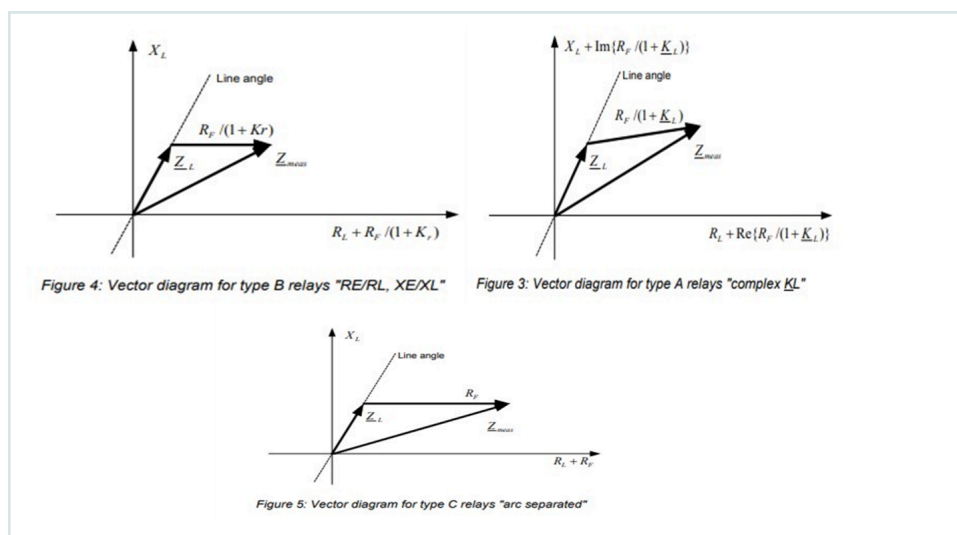


Figure 18

- ▮ Measured impedances from different relay types are not directly comparable on the same impedance plane.
- ▮ All distance protection algorithms produce the same (R_L) and (X_L) results at the line angle or when $RF = 0$.
- ▮ Outside the line angle, depending on the fault's location on the impedance plane, the arc resistance is added to the line impedance."
- ▮ All distance protection algorithms function correctly; however, grounding factors must be considered when setting zones and testing relays.

Considering Grounding Factors During Testing The Vebko software, including the Test and Stable versions, implements all mentioned distance protection algorithms.

As discussed, depending on the available grounding factor data, it can be entered independently according to the equations in the Vebko software's Object Test window, within the Distance Block under the Factor Grounding section. You can also select any of the mentioned algorithms to calculate current and voltage. It's crucial that both the testing software and the relay use the same algorithm during testing; otherwise, this may result in inaccurate test outcomes.

The choice of distance protection algorithm is selected by checking boxes, as shown in the figure.

Type	Setting
Type A "complex $\underline{K}_L$ "	☐ Calc. with RE/RL and XE/XL ☐ Separate arc resistance
Type B " RE/RL , XE/XL "	☒ Calc. with RE/RL and XE/XL ☐ Separate arc resistance
Type C "arc separated"	☐ Calc. with RE/RL and XE/XL ☒ Separate arc resistance

Figure 19

For the algorithms used by distance protection relays, refer to the relevant manuals and documentation. Since algorithms are not always publicly available, some common examples are listed

in the displayed table.

Type	Relay
Type A "complex <u>K</u> L"	REL 316, Relay with MHO characteristic
Type B "RE/RL, XE/XL"	7SA5**, 7SA6**
Type C "arc separated"	SEL321, SEL421, REL4**, Rel5**, LFZR, EPAC, MICOM (Valid for polygonal zones only! For MHO characteristics applies type A!)

Figure 20

[jg1]Grounding Factor in Distance