HB 219 Worked Example 3.2.2 Rural Distribution Transformer Supplied by HV Overhead Line

Rural network, distribution transformer supplying single customer, 10 km aerial HV feed to pole-mounted distribution transformer, no OHEW, common HV/LV earth, LV neutral not bonded to HV source substation.

22 kV source, no NER.

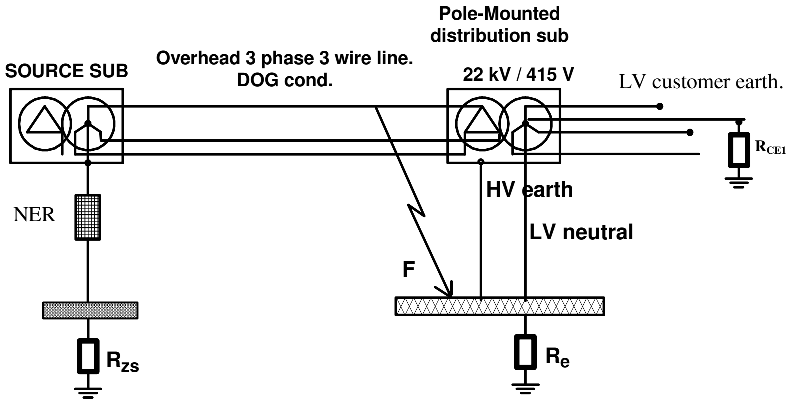


Fig. 3.2.2.1. Rural distribution transformer supplied by HV overhead line

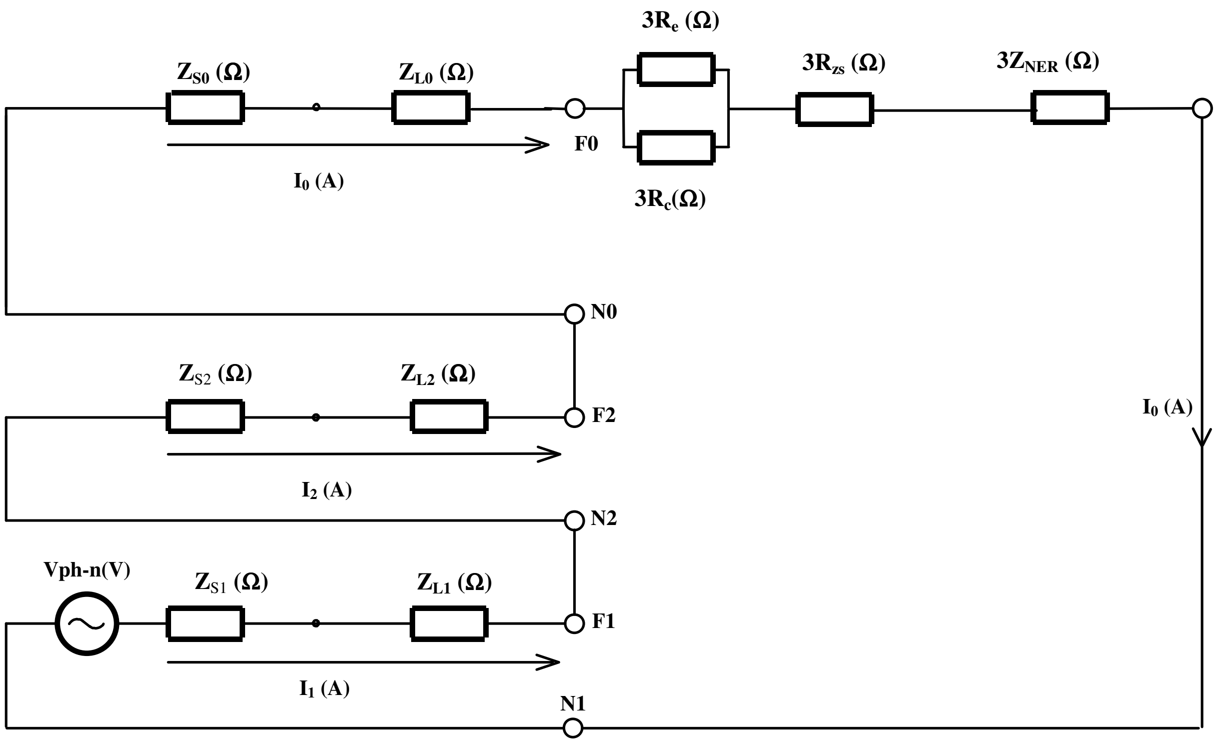


Fig 3.2.2.2. Symmetrical components network for a HV single phase to earth fault at the distribution transformer

22kV SYSTEM DATA

SOURCE VOLTAGE (volts) & IMPEDANCE (ohms)

Single phase source voltage V_{ph-n} (Volts) $\quad Vs_1 := 12702$

Single Phase Fault Level S (MVA) $\quad S := 400$

Source impedance calculated from the fault level. Assume source impedance is purely reactive and positive sequence = negative sequence = zero sequence impedance.

Positive sequence source impedance (Ohms) $\quad Z_{S1} := \frac{22^2}{S} \cdot j \qquad Z_{S1} = 1.210j$

Negative sequence source impedance (Ohms) $\quad Z_{S2} := Z_{S1}$

Zero sequence source impedance (Ohms) $\quad Z_{S0} := Z_{S1}$

22kV Overhead line impedance

Conductor size: DOG (6/4.72mm aluminium with 7/1.57mm steel)

Length (km) $\quad L := 10.0$

Line sequence impedances (Ohms/km)

Positive sequence line impedance (Ohms/km) $\quad Z_{L1} := 0.2722 + 0.3407j$

Negative sequence line impedance (Ohms/km) $\quad Z_{L2} := Z_{L1}$

Zero sequence line impedance (Ohms/km) $\quad Z_{L0} := 0.4204 + 1.6545j$

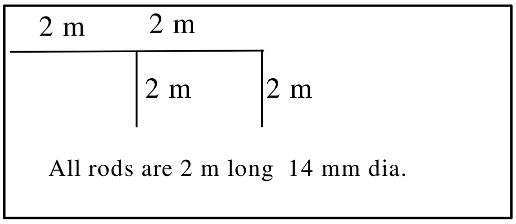
22kV NER AND EARTHING IMPEDANCE (Ohms)

Neutral Earthing Resistor (Ohms) $\quad Z_{NER} := 0$

Zone substation earthing system resistance (Ohms) $\quad R_{zs} := 0.01$

Surface soil resistivity (Ohm-m) $\quad \rho := 10$ Ohm-m

Distribution transformer earthing system



Transformer earthing system resistance (Ohms) $\quad R_e := 0.19 \cdot \rho \qquad R_e = 1.900$

The equivalent hemispherical radius (m) $\quad r_E := \frac{\rho}{2 \cdot \pi \cdot R_e} \qquad r_E = 0.838$

Customer electrode resistance: The customer has one 1.2 m deep copper clad 12 mm diameter steel electrode (typical of Australia). Neglecting the impedance of the distribution line neutral conductor, the MEN resistance will be equal to the resistance of the electrode.

Resistance of one customer electrode (Ohms) $\quad R_c := 0.75 \cdot \rho \qquad R_c = 7.50$

The equivalent hemispherical radius of the customer electrode(m) $\quad r_E := \frac{\rho}{2 \cdot \pi \cdot R_c}$

$r_E = 0.212$

Equivalent MEN plus Re resistance (Ohms) $R_{eq} := \left(\frac{1}{R_c} + \frac{1}{R_e}\right)^{-1}$

$R_{eq} = 1.516$

CALCULATIONS

One Phase to Earth fault on the 22kV feeder at the distribution transformer

Sequence network impedance (Ohms)

$Z_{pos} := Z_{S1} + Z_{L1} \cdot L$ $Z_{neg} := Z_{S2} + Z_{L2} \cdot L$ $Z_{zero} := Z_{S0} + Z_{L0} \cdot L + 3 \cdot R_{eq} + 3 \cdot R_{zs}$

$Z_{pos} = 2.722 + 4.617j$ $Z_{neg} = 2.722 + 4.617j$ $Z_{zero} = 8.782 + 17.755j$

Zero sequence fault current (Amps)

$$I_0 := \frac{Vs_1}{Z_{pos} + Z_{neg} + Z_{zero} + 3 \cdot Z_{NER}}$$

Fault current (Amps)

$I_f := 3 \cdot I_0$ $I_f = 582.4 - 1104.9j$ $|I_f| = 1249.0$

EPR at the distribution transformer (Volts)

$EPR_{dt} := I_f \cdot R_{eq}$ $|EPR_{dt}| = 1893$