HB 219 Worked Example 3.2.1 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.

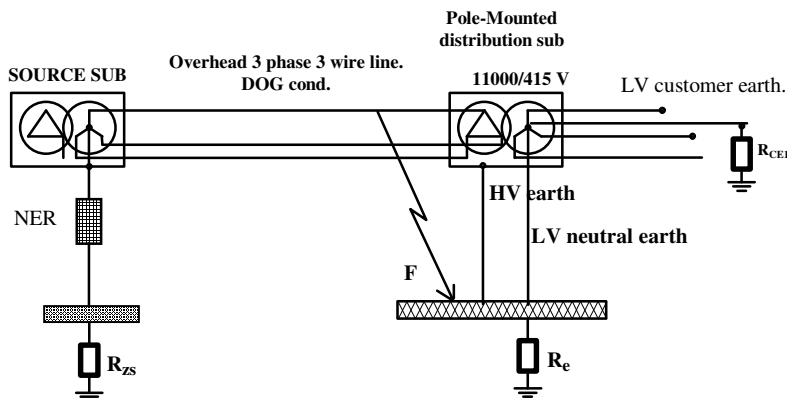## 11 kV source, no NER.

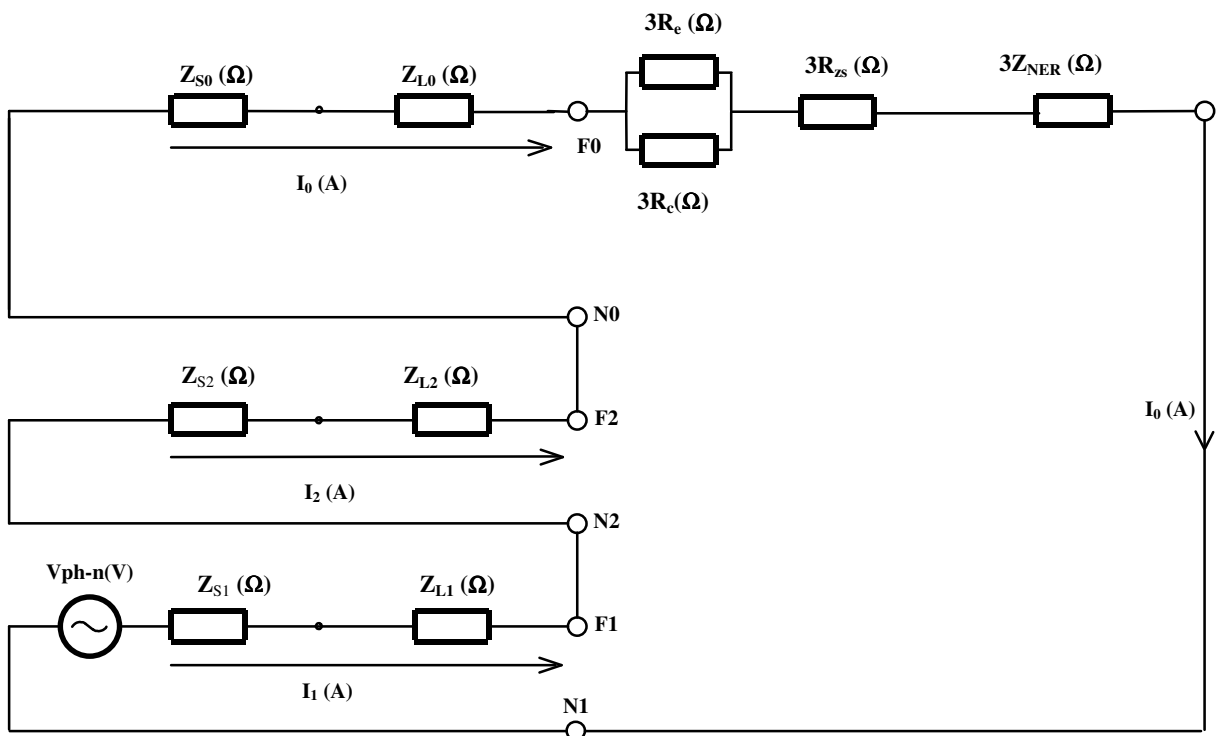Fig. 3.2.1.1   Rural distribution transformer supplied by HV overhead line

Fig. 3.2.1.2   Symmetrical components network for a HV single phase to earth fault at the distribution transformer.

11kV SYSTEM DATA

SOURCE VOLTAGE (volts) & IMPEDANCE (Ohms)

Single phase source voltage V_{ph-n} (Volts)　　　　　　$Vs_1 := 6350$

Single Phase Fault Level S (MVA)　　　　　　　　　　$S := 100$

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)　　$Z_{S1} := \dfrac{11^2}{S} \cdot j$　　$Z_{S1} = 1.210j$

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

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

11kV Overhead line impedance

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

Length (km)　　　　　　　　　　　　　　　　$L := 10.0$

Line sequence impedances (Ohms/km)

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

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

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

11kV NER AND EARTHING IMPEDANCE (Ohms)

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

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

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

Distribution transformer earthing system

Transformer earthing system resistance (Ohms)　　$R_e := 0.1346 \cdot \rho$　　$R_e = 1.346$

The equivalent hemispherical radius (m)　　　$r_E := \dfrac{\rho}{2 \cdot \pi \cdot R_e}$　　$r_E = 1.182$

Customer electrode resistance: The customer has one 1.8 m deep copper clad, 12 mm diameter electrode. 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)　$R_c := 0.552 \cdot \rho$　　$R_c = 5.52$

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

$$r_E = 0.288$$

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

$$R_{eq} = 1.082$$

CALCULATIONS

One Phase to Earth fault on the 11kV feeder at the distribution transformer

Sequence network impedance (Ohms)

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

$$Z_{pos} = 2.722 + 4.617j \qquad Z_{neg} = 2.722 + 4.617j \qquad Z_{zero} = 7.480 + 17.755j$$

Zero sequence fault current (Amps)

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

Fault current (Amps)

$$I_f := 3 \cdot I_0 \qquad I_f = 275.0 - 574.2j \qquad \left| I_f \right| = 636.6$$

EPR at the distribution transformer (Volts)

$$EPR_{dt} := I_f \cdot R_{eq} \qquad \left| EPR_{dt} \right| = 689$$