

HB 219 Worked Example 3.6.2 Extensive Urban MEN System Supplied by a HV Overhead Line

2 km aerial HV feed to a pole-mounted distribution transformer, no OHEW, common HV/LV earth, extensive MEN (Australian type), LV neutral not bonded to HV source substation.

11 kV source, 20 ohm NER.

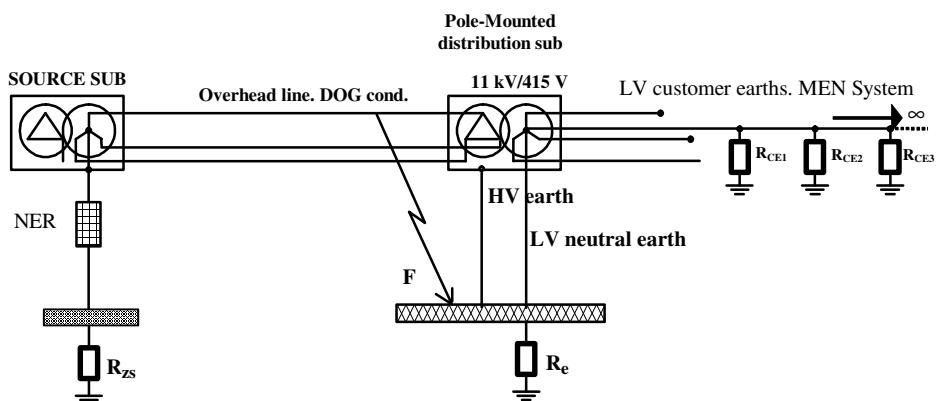


Fig. 3.6.2.1 Extensive urban MEN network supplied by a HV overhead line

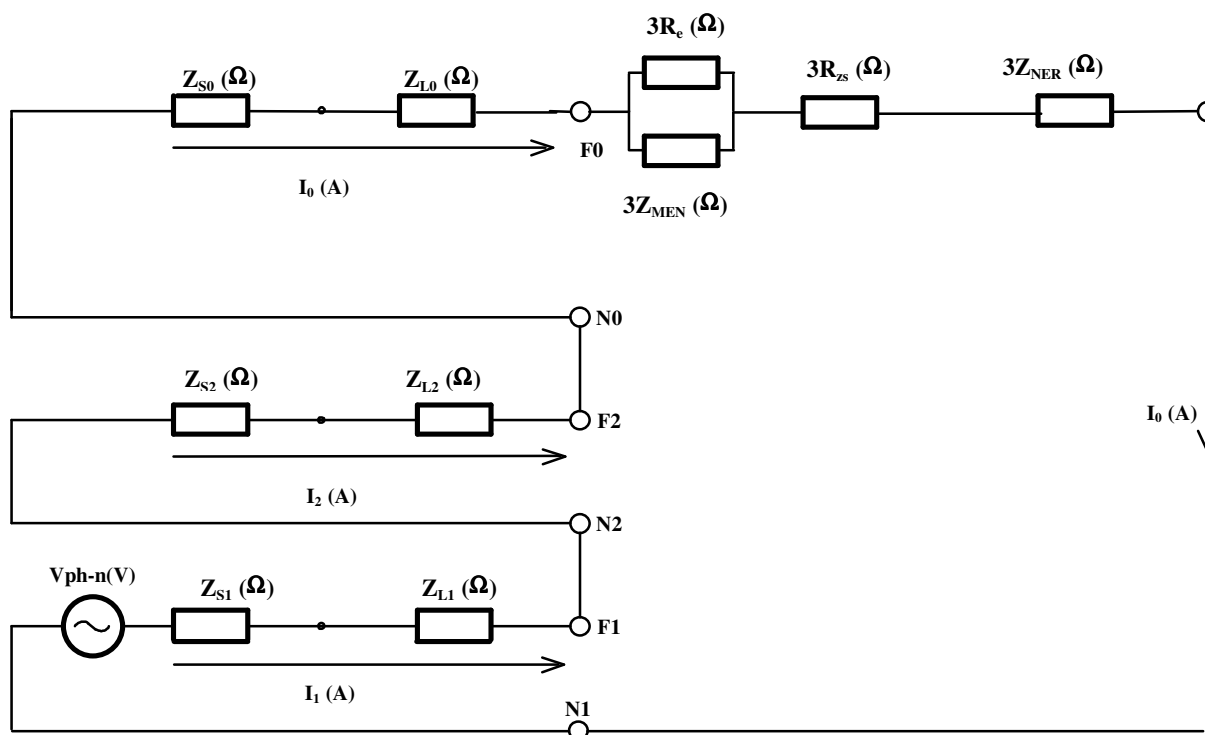


Fig. 3.6.2.2 Symmetrical components network for a HV single phase to earth fault at the distribution transformer

11kV SYSTEM DATA

SOURCE VOLTAGE (volts) & IMPEDANCE (Ohms)

Single phase source voltage V_{ph-n} (Volts)

$$V_{S1} := 6350$$

Single Phase Fault Level S (MVA)

$$S := 200$$

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

Positive sequence source impedance (Ohms)

$$Z_{S1} := \frac{11^2}{S} \cdot j \quad Z_{S1} = 0.6j$$

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)

$$L := 2.0$$

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)

$$Z_{NER} := 20$$

Zone substation earthing system resistance (Ohms)

$$R_{ZS} := 0.01$$

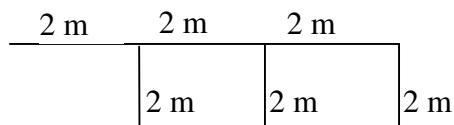
Surface soil resistivity (Ohm-m)

$$\rho := 10 \quad \text{Ohm-m}$$

MEN impedance of typical urban extensive MEN system (see HB 219 Worked Example 4.1.2 for the derivation of this value) (Ohms)

$$Z_{MEN} := 0.084 + 0.063j$$

Distribution transformer earthing system



All rods 2 m long and 14 mm dia.

Transformer earthing system resistance (Ohms)

$$R_e := 0.14 \cdot \rho \quad R_e = 1.4$$

The equivalent hemispherical radius (m)

$$r_E := \frac{\rho}{2 \cdot \pi \cdot R_e} \quad r_E = 1.1$$

Equivalent MEN plus R_e impedance (Ohms)

$$Z_{eq} := \left(\frac{1}{Z_{MEN}} + \frac{1}{R_e} \right)^{-1}$$

$$Z_{eq} = 0.1 + 0.1j$$

CALCULATIONS

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

Sequence network impedances (Ohms)

$$\begin{aligned} Z_{\text{pos}} &:= Z_{S1} + Z_{L1} \cdot L & Z_{\text{neg}} &:= Z_{S2} + Z_{L2} \cdot L & Z_{\text{zero}} &:= Z_{S0} + Z_{L0} \cdot L + 3 \cdot Z_{\text{eq}} + 3 \cdot R_{ZS} \\ Z_{\text{pos}} &= 0.5 + 1.3j & Z_{\text{neg}} &= 0.5 + 1.3j & Z_{\text{zero}} &= 1.1 + 4.1j \end{aligned}$$

Zero sequence fault current (Amps)

$$I_0 := \frac{V_{S1}}{Z_{\text{pos}} + Z_{\text{neg}} + Z_{\text{zero}} + 3 \cdot Z_{\text{NER}}}$$

Fault current (Amps)

$$I_f := 3 \cdot I_0$$

$$I_f = 302.8 - 32.4j$$

$$|I_f| = 304.5$$

EPR at the distribution transformer (Volts)

$$EPR_{\text{dt}} := I_f \cdot Z_{\text{eq}} \quad |EPR_{\text{dt}}| = 30$$