HB 219 Worked Example 3.5.1 Isolated Urban MEN System (New Subdivision) Supplied by HV Overhead Line

Urban network, new subdivision, isolated MEN with 48 customers, 500 m underground cable feed fro
2 km aerial HV line to a pad-mounted distribution transformer, no OHEW, common HV/LV earth, LV
neutral not bonded to HV source zone substation.

11 kV source, no NER.

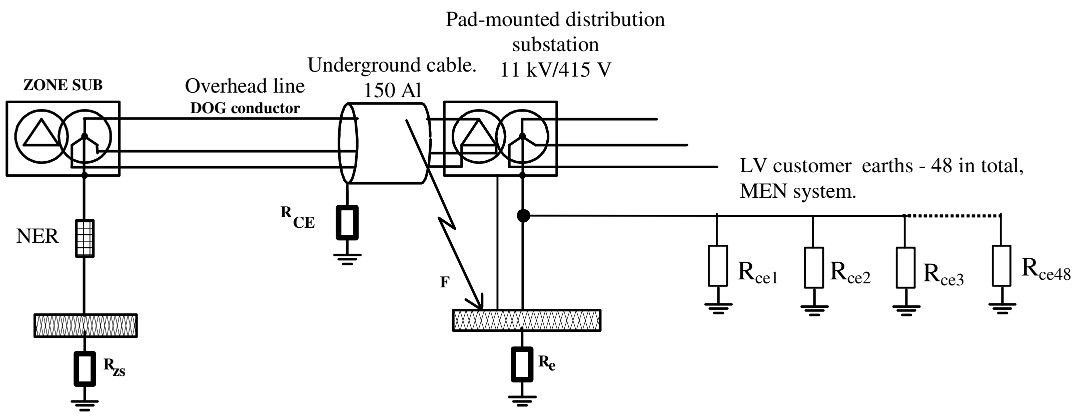


Fig. 3.5.1.1 Supply to underground subdivision. Single phase to earth fault at the pad mounted distribution transformer.

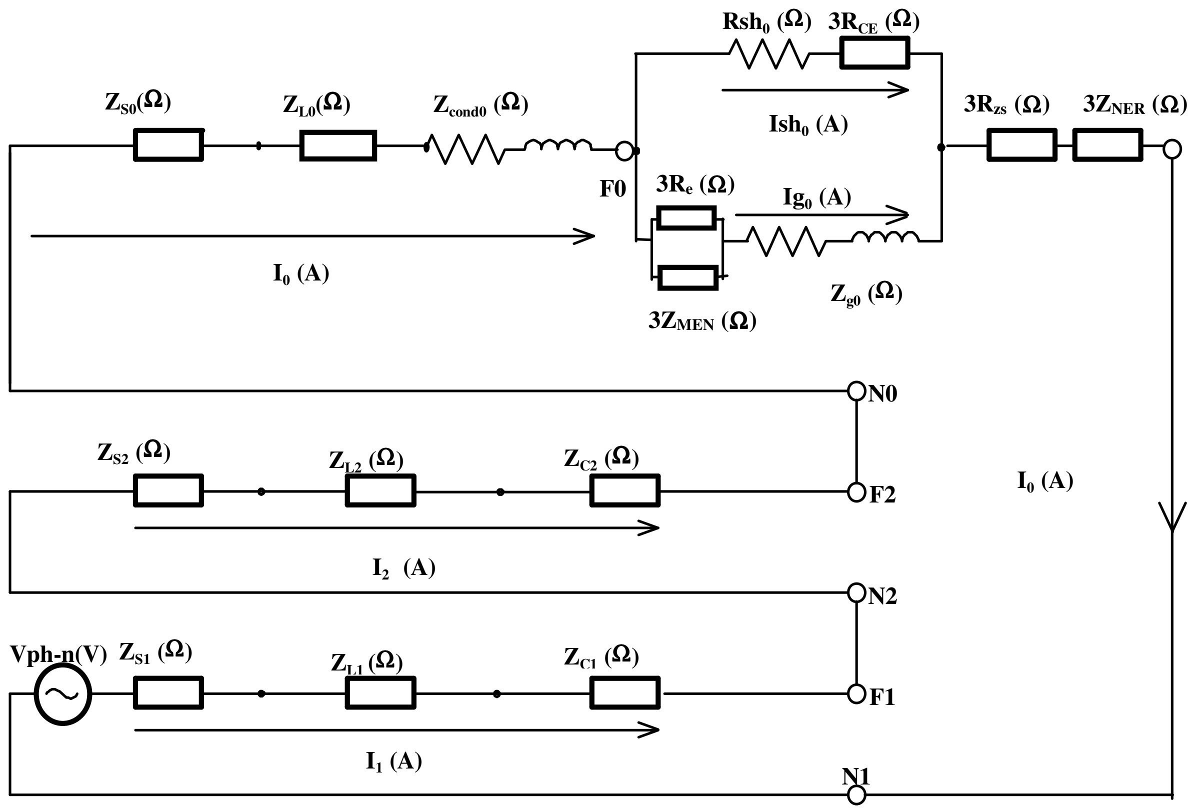


Fig. 3.5.1.2 Symmetrical components sequence network for a single phase to earth fault at the pad-mounted distribution transformer.

11kV SYSTEM DATA

SOURCE VOLTAGE (Volts) & IMPEDANCE (Ohms)

Single phase source voltage (Volts) $Vs_1 := 6350$

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 impedance.

Positive sequence source impedance (Ohms) $Z_{S1} := \frac{11^2}{S} \cdot j$ $Z_{S1} = 0.61j$

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(Ohm/km) $Z_{L1} := 0.2722 + 0.3407j$

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

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

11kV Distribution cable impedance

Cable size and Type: 150 sqmm Al Belted PILCPS Length (km) $C := 0.5$

Cable sequence impedances (Ohms/km)

Positive sequence cable impedance (Ohms/km) $Z_{C1} := 0.2078 + 0.0773j$

Negative sequence cable impedance (Ohms/km) $Z_{C2} := Z_{C1}$

Zero sequence cable impedance (Ohms/km)

$Z_{cond0} := 0.2062 + 0.1142j$ $R_{sh0} := 2.6612$ $Z_{g0} := 0.1480 + 2.0779j$

11kV NER AND EARTHING IMPEDANCE (Ohms)

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

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

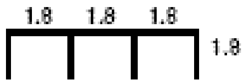
Surface soil resistivity (Ohm-m) $\rho := 10$

MEN impedance associated with 48 customer electrodes

Each customer has one 1.8 m deep copper clad 12 mm diameter electrode. 4 customers are supplied from each pole, and the LV span length between poles is 50m. The deep layer soil resistivity is assumed to be 100 Ohm-m. The LV neutral is a DOG conductor with a self impedance of 0.322 + 0.757j ohms/km.

MEN impedance of 48 customer LV distribution network (see HB 219 Worked Example 4.2.1 for the derivation of this value) (Ohms) $Z_{MEN} := 0.133 + 0.036j$

Distribution transformer earthing system



Transformer earthing system resistance (Ohms) $R_e := 0.1346 \cdot \rho$ $R_e = 1.35$

The equivalent hemispherical radius (m) $r_E := \dfrac{\rho}{2 \cdot \pi \cdot R_e}$ $r_E = 1.18$

Equivalent MEN plus Re impedance (Ohms) $Z_{eq} := \left(\dfrac{1}{Z_{MEN}} + \dfrac{1}{R_e}\right)^{-1}$ $Z_{eq} = 0.12 + 0.03j$

Cable sheath earthing resistance at termination pole (Ohms) $R_{CE} := 0.43 \cdot \rho$ $R_{CE} = 4.30$

CALCULATIONS

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

Sequence network impedances (Ohms)

$Z_{pos} := Z_{S1} + Z_{L1} \cdot L + Z_{C1} \cdot C$ $Z_{pos} = 0.65 + 1.33j$

$Z_{neg} := Z_{S2} + Z_{L2} \cdot L + Z_{C2} \cdot C$ $Z_{neg} = 0.65 + 1.33j$

$$Z_{zero} := Z_{S0} + Z_{L0} \cdot L + Z_{cond0} \cdot C + 3 \cdot R_{zs} + \left(\frac{1}{3 \cdot R_{CE} + R_{sh0} \cdot C} + \frac{1}{Z_{g0} \cdot C + 3 \cdot Z_{eq}}\right)^{-1}$$

$Z_{zero} = 1.48 + 5.03j$

Zero sequence fault current (Amps)

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

Zero sequence fault current returning via earth (Amps)

$$I_{g0} := I_0 \cdot \frac{3 \cdot R_{CE} + R_{sh0} \cdot C}{3 \cdot R_{CE} + R_{sh0} \cdot C + \left(Z_{g0} \cdot C + 3 \cdot Z_{eq}\right)}$$

$I_{g0} = 200.97 - 724.96j$ $\left|I_{g0}\right| = 752.30$

Fault current returning via earth (Amps)

$I_g := 3 \cdot I_{g0}$ $\left|I_g\right| = 2256.91$

EPR at the distribution transformer (Volts)

$EPR_{dt} := I_g \cdot Z_{eq}$ $\left|EPR_{dt}\right| = 283$