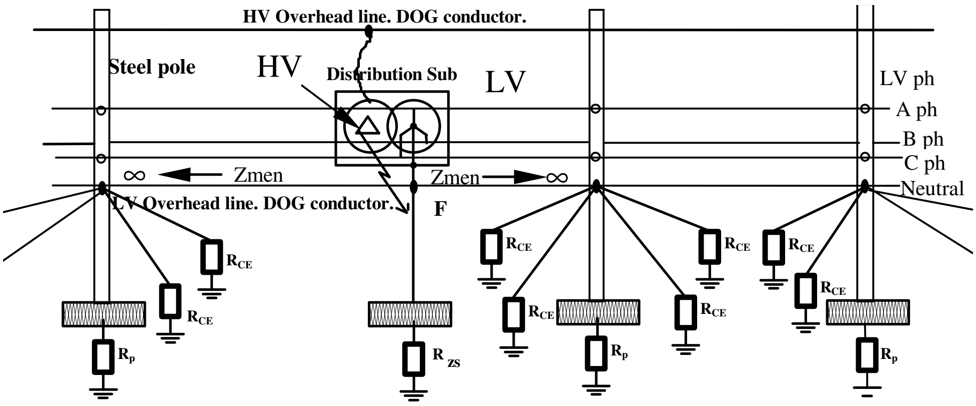
<u>HB 219 Worked Example 4.2.1</u> MEN Impedance of a Typical New Zealand Isolated Urban 48 Customer MEN System (without Pole Earthing)

Aerial HV and LV lines, 48 LV customers supplied from the distribution transformer, poles not connected to the LV neutral, no bonding of the LV neutral to any adjacent distribution transformer service areas (i.e. isolated MEN system).



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<u>Calculation of the self impedance of the neutral conductor</u>

Conductor Type and size:	DOG (6/4.72mm aluminium with 7/1.57mm steel)
Resistance of the neutral conductor (Ohms/km)	$R_n := 0.2722$
Frequency (Hz)	$f := 50$
Deep Layer Soil resistivity (Ohm-m)	$\rho_d := 100$
Diameter of the conductor (mm)	$d := 14.2$
GMR of the neutral conductor (mm)	$GMR_n := 0.768 \cdot \left(\frac{d}{2}\right)$

Self impedance of the conductor (Ohms/km)

$$Z_{sn} := R_n + 988.2 \cdot 10^{-6} \cdot f + j \cdot \left(2.893 \cdot 10^{-3} \cdot f \cdot \log\left(\frac{658368 \cdot \sqrt{\frac{\rho_d}{f}}}{GMR_n}\right)\right)$$

$$Z_{sn} = 0.322 + 0.757j$$

Calculation of the equivalent MEN impedance using the Ladder network equation

LV neutral span length (km) $L := 0.05$

The self impedance of the neutral conductor of span length L (Ohm) $Z_s := Z_{sn} \cdot L$ $\quad Z_s = 0.016 + 0.038j$ $\quad |Z_s| = 0.041$

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

Customer earth electrode resistance (Ohm) (Earth electrode 1.8 m deep 12 mm dia Copper clad steel rod.) $R_{CE} := 0.552 \cdot \rho$ $\quad R_{CE} = 5.52$

Number of customers at each pole $n := 4$

The equivalent impedance of 4 customers

$$Z_E := \left(\frac{R_{CE}}{n}\right)$$

$$Z_E = 1.38$$

Earth impedance of MEN, looking away from the distribution transformer, at the first pole (from the far end) (Ohms) $Z_1 := Z_E$

At the second pole from the far end

$$Z_2 := \frac{Z_E \cdot (Z_s + Z_1)}{Z_E + (Z_s + Z_1)}$$

$$Z_2 = 0.694 + 9.35j \times 10^{-3}$$

At third pole from the far end

$$Z_3 := \frac{Z_E \cdot (Z_s + Z_2)}{Z_E + (Z_s + Z_2)}$$

$$Z_3 = 0.469 + 0.021j$$

At fourth pole from the far end

$$Z_4 := \frac{Z_E \cdot (Z_s + Z_3)}{Z_E + (Z_s + Z_3)}$$

$$Z_4 = 0.36 + 0.032j$$

At fifth pole from the far end

$$Z_5 := \frac{Z_E \cdot (Z_s + Z_4)}{Z_E + (Z_s + Z_4)}$$

$$Z_5 = 0.297 + 0.043j$$

At sixth pole from the far end

$$Z_6 := \frac{Z_E \cdot (Z_s + Z_5)}{Z_E + (Z_s + Z_5)}$$

$$Z_6 = 0.258 + 0.054j$$

If the distribution transformer is located midway in the 50m pole span, the earth impedance of the MEN circuit looking in one direction from the distribution transformer (Ohms)

$$Z_N := 0.5 \cdot Z_s + Z_6$$

$$Z_N = 0.266 + 0.072j$$

This is the impedance looking in one direction only. At a distribution transformer with overhead distribution this MEN network normally extends in both directions (on one side of the street only).

Therefore the total MEN impedance is half of the above value.

Total MEN impedance (Ohms)

$$Z_{MEN} := \frac{Z_N}{2}$$

$$Z_{MEN} = 0.133 + 0.036j$$

Magnitude of the Total MEN impedance (Ohms) $\quad \left|Z_{MEN}\right| = 0.138$

Angle of the Total MEN impedance (degrees) $\quad \arg\left(Z_{MEN}\right) = 15.246\,\text{deg}$