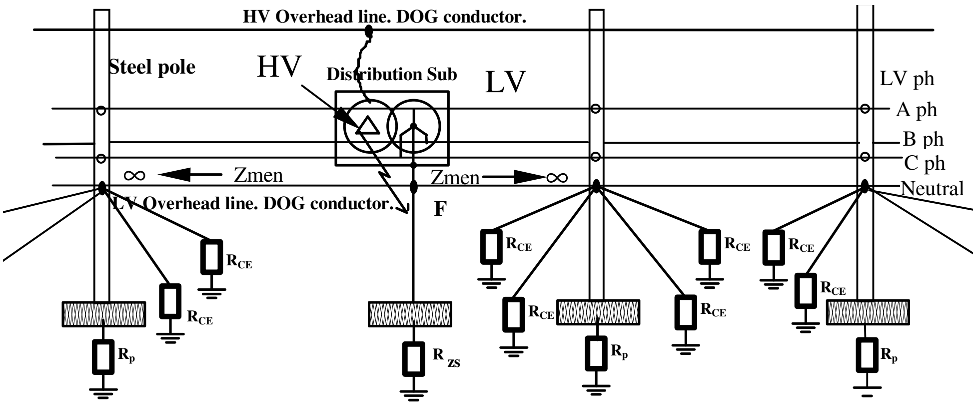
<u>HB 219 Worked Example 4.1.1</u> MEN Impedance of a Typical New Zealand Extensive Urban MEN System (without Pole Earthing)

Aerial HV and LV lines, no conductive poles bonded to the LV neutral, LV neutral bonded across at LV open points between adjacent distribution transformer service areas, but not bonded to the source zone substation earthing system.



<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) $L := 0.05$ (km)

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

$|Z_s| = 0.041$

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

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

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

The equivalent impedance of 4 customers (Ohms)

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

$Z_E = 1.38$

Equivalent impedance of the neutral or MEN circuit in one direction from the pole (Ohms) (See equation 5.11 in AS/NZS 3835.2)

$$Z_{eq} := \frac{Z_s}{2} + \sqrt{\frac{{Z_s}^2}{4} + Z_s \cdot Z_E}$$

$Z_{eq} = 0.207 + 0.151j$

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)

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

$Z_{MEN} = 0.103 + 0.076j$

Magnitude of the MEN impedance (Ohms) $|Z_{MEN}| = 0.128$

Angle of the MEN impedance (degrees) $\arg(Z_{MEN}) = 36.212\,\mathrm{deg}$

Calculation of the equivalent MEN impedance using the Ladder network equation

LV neutral span length (km) $L := 0.01, 0.02 .. 0.10$ (km)

The self impedance of the neutral conductor of span length L (Ohms) $Z_s(L) := Z_{sn} \cdot L$

Homogeneous Soil resistivity (Ohm-m) $\rho := 10, 20 .. 1000$

Customer earth electrode resistance (Ohms) (Earth electrode 1.8 m deep and 12 mm dia copper clad steel rod.) $R_{CE}(\rho) := 0.552 \cdot \rho$ $R_{CE}(100) = 55.2$

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

The equivalent impedance of 4 customers (Ohms) $Z_E(\rho) := \left(\frac{R_{CE}(\rho)}{n}\right)$ $Z_E(100) = 13.8$

Equivalent impedance of the neutral or MEN circuit in one direction from the pole (Ohms) (See equation 5.11 in AS/NZS 3835.2)

$$Z_{eq}(L,\rho) := \frac{Z_s(L)}{2} + \sqrt{\frac{Z_s(L)^2}{4} + Z_s(L) \cdot Z_E(\rho)}$$

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) $Z_{MEN}(L,\rho) := \frac{Z_{eq}(L,\rho)}{2}$

$Z_{MEN}(0.04, 100) = 0.284 + 0.194j$

Magnitude of the MEN impedance (Ohms) $|Z_{MEN}(0.04, 100)| = 0.344$

Angle of the MEN impedance (degrees) $\arg(Z_{MEN}(0.04, 100)) = 34.261 \text{ deg}$