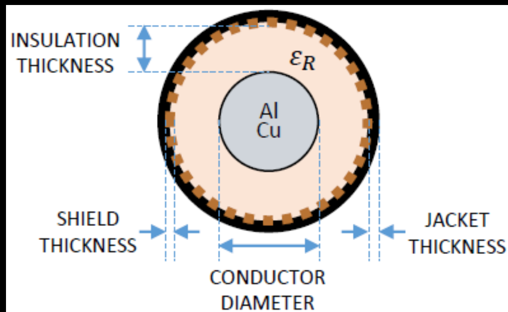
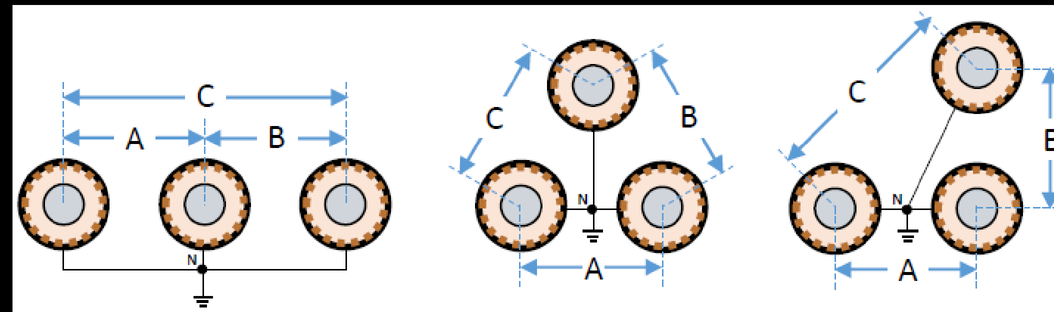
Shielded Cable Parameters Equations





			[3]Ampacity									
Conductor			@ 90°C		@ 105°C		[4]Insulation Thickness (in)					
kcmil	[1]mm²	[2]Diameter (in)	Cu	Al	Cu	Al	34.5 kV	69 KV	115 kV	138 kV	230 kV	345 kV
500	253.4	0.740	557	436	600	470	0.345	0.354	0.512	0.591	0.906	1.140
750	380.0	0.910	695	547	749	590	0.224	0.354	0.512	0.591	0.906	1.140
1000	506.7	1.060	807	641	870	691	0.224	0.354	0.512	0.591	0.906	1.140
1250	633.4	1.190	902	723	972	779	0.224	0.354	0.512	0.591	0.906	1.140
1500	760.1	1.320	981	795	1058	857	0.224	0.354	0.512	0.591	0.906	1.140
1750	886.7	1.430	1051	859	1133	926	0.224	0.354	0.512	0.591	0.906	1.140
2000	1013.4	1.500	1109	917	1196	989	0.224	0.354	0.512	0.591	0.906	1.140
2500	1266.8	1.730	1260	1043	1358	1124	0.224	0.354	0.512	0.591	0.906	1.140
3000	1520.1	1.890	1379	1150	1488	1240	0.224	0.354	0.512	0.591	0.906	1.140
3500	1773.5	2.070	1490	1249	1607	1347	0.224	0.354	0.512	0.591	0.906	1.140
4000	2026.8	2.170	1592	1342	1717	1447	0.224	0.354	0.512	0.591	0.906	1.140
5000	2533.5	2.480	1779	1513	1919	1632	0.224	0.354	0.512	0.591	0.906	1.140
6000	3040.2	2.670	1948	1669	2102	1799	0.224	0.354	0.512	0.591	0.906	1.140

(1) Cross-Sectional area calculated: 1.0 kcmil = 0.5067 mm²

(2) Conductor diameters from Southwire XLPE cable data

(3) Ampacities from Okonite Handbook (>= 2500 kcm exptrapolated)

(4) Insulation thickness from Southwire XLPE cable data (34.5 kV extrapolated)

Relative Insulation Permittivity

Type	ε_R
XLPE	2.3
EPR	3.0
PVC	5.0

$$\textit{Default shield thickness is estimated as } 0.081 \textit{ inches (diameter of } 12 \textit{ AWG)}$$

$$\textit{Default jacket thickness is estimated as } \frac{3}{16} = 0.18750 \textit{ inches}$$

Shielded Cable Parameters Equations (cont.)

all calculations use SI system

conductor diameter, insulation thickness and shield thickness must be converted to meters

$1\ meter = 39.3701\ inches$

$1\ meter = 3.28084\ feet$

Positive Sequence

Resistance at 20°C conductor temperature

DC resistance of conductor (per-meter)

$$R_{DC} = \frac{\rho}{A}$$

$$\rho_{Copper} = 0.017240\ \left(\frac{\Omega mm^2}{m}\right)$$

$$\rho_{Aluminum} = 0.028264\ \left(\frac{\Omega mm^2}{m}\right)$$

$$A = conductor\ area\ (mm^2)$$

AC resistance of conductor (per-meter)

$$R'_{AC} = R_{DC}[1 + \lambda_s + \lambda_p]$$

$$\lambda_s = skin\ effect\ factor$$

$$\lambda_p = proximity\ effect\ factor$$

$$\lambda_p \approx 0\ \ (insignificant\ compared\ to\ skin\ effect)$$

$$X_s = \sqrt{\frac{2f\mu_0}{R_{DC}}}\ \ (working\ variable)$$

$$f = system\ frequency\ (Hz)$$

$$\mu_0 = 4\pi * 10^{-7}\ \left(\frac{H}{m}\right)$$

$$\lambda_s = \frac{X_s^4}{192.0 + 0.8X_s^4}$$

$$R'_{AC} \approx R_{DC}[1 + \lambda_s]$$

Resistance at 90°C conductor temperature

$$R_{AC} = R'_{AC}[1 + \alpha(T - 20)]$$

$$T = 90\ \ (°C\ operating\ temperature)$$

$$\alpha = 0.00393\ (copper\ temperature\ coefficient\ @\ 20°C)$$

$$\alpha = 0.00403\ (aluminum\ temperature\ coefficient\ @\ 20°C)$$

$$R_{AC} = R'_{AC}[1 + 70\alpha]$$

Shielded Cable Parameters Equations (cont.)

Positive Sequence

Shunt Capacitance (per-meter)

$$C = \frac{2\pi\varepsilon_R\varepsilon_0}{\ln\left[\frac{r_s}{r_c}\right]} \left(\frac{F}{m}\right)$$

$$\varepsilon_R = relative\ permittivity\ of\ insulation$$

$$\varepsilon_0 = 8.854 * 10^{-12} \left(\frac{F}{m}\right)$$

$$r_s = shield\ radius = conductor\ radius + insulation\ thickness + \frac{shield\ thickness}{2}$$

$$r_c = conductor\ radius = \frac{conductor\ diameter}{2}$$

Shunt Susceptance (per-meter)

$$B = \omega C \left(\frac{mho}{m}\right)$$

$$\omega = 2\pi f \left(\frac{rad}{sec}\right)$$

Shunt Susceptance per-unit (per-meter)

$$B_{pu} = BZ_{Base}\ \ (no\ units)$$

$$Z_{Base} = \frac{kV^2}{100}\ \ (\Omega)$$

Shielded Cable Parameters Equations (cont.)

Positive Sequence

Impedance (per-meter)

$$Z = R_{AC} + j\frac{\omega\mu_0}{2\pi}\left[\frac{1}{4} + \ln\left[\frac{GMD}{r_c}\right]\right] + \frac{\left[\frac{\omega\mu_0}{2\pi}\ln\left[\frac{GMD}{r_{sh}}\right]\right]^2}{R_{sh} + j\frac{\omega\mu_0}{2\pi}\ln\left[\frac{GMD}{r_{sh}}\right]}$$

$$\omega = 2\pi f\left(\frac{rad}{sec}\right)$$

$$\mu_0 = 4\pi * 10^{-7}\left(\frac{H}{m}\right)$$

$$GMD = \sqrt[3]{ABC}\ \ (m)\ \ geometric\ mean\ distance\ between\ conductors$$

$$r_c = conductor\ radius\ \ (m)$$

$$r_{sh} = shield\ radius\ \ (m)$$

$$R_{sh} = resistance\ of\ shield\ \ (\Omega)\ \ default\ is\ 3R_{AC}\ or\ \frac{1}{3}\ neutral$$

Resistance (per-meter)

$$R = \mathcal{R}e(Z)$$

Reactance (per-meter)

$$X = im(Z)$$

Inductance (per-meter)

$$L = \frac{X}{\omega}$$

Shielded Cable Parameters Equations (cont.)

Zero Sequence

Shunt Capacitance, Susceptance (per-meter)

Zero Sequence = Positive Sequence

$$\boxed{\begin{aligned} C^0 &= C \\ B^0 &= B \\ B^0_{pu} &= B_{pu} \end{aligned}}$$

Impedance (per-meter)

$$\delta = \frac{1.851}{\sqrt{\omega\mu_0\rho_{earth}}}$$

$\rho_{earth} = resistivity\ of\ earth\ \ (\Omega m)\ \ default = 100$

$$Z^0 = R_{AC} + \frac{3\omega\mu_0}{8} + j\frac{\omega\mu_0}{2\pi}\left[\frac{1}{4} + 3\ln\left[\frac{\delta}{\sqrt[3]{r_c GMD^2}}\right]\right] - \frac{\left[\frac{3\omega\mu_0}{8} + j\frac{3\omega\mu_0}{2\pi}\ln\left[\frac{\delta}{\sqrt[3]{r_{sh} GMD^2}}\right]\right]^2}{R_{sh} + \frac{3\omega\mu_0}{8} + j\frac{3\omega\mu_0}{2\pi}\ln\left[\frac{\delta}{\sqrt[3]{r_{sh} GMD^2}}\right]}$$

$r_c = conductor\ radius\ \ (m)$

$r_{sh} = shield\ radius\ \ (m)$

$R_{sh} = resistance\ of\ shield\ \ (\Omega)\ \ default\ is\ 3R_{AC}\ or\ \frac{1}{3}\ neutral$

Resistance (per-meter)

$$R^0 = \mathcal{R}e(Z^0)$$

Reactance (per-meter)

$$X^0 = im(Z^0)$$

Inductance (per-meter)

$$L = \frac{X^0}{\omega}$$

Shielded Cable Parameters Equations (cont.)

convert to US units

$$R_{ft} = \frac{R}{3.28084} \left(\frac{\Omega}{ft}\right)$$

$$L_{ft} = \frac{L}{3.28084} \left(\frac{H}{ft}\right)$$

$$C_{ft} = \frac{C}{3.28084} \left(\frac{F}{ft}\right)$$

$$X_{ft} = \frac{X}{3.28084} \left(\frac{\Omega}{ft}\right)$$

$$B_{ft} = \frac{B}{3.28084} \left(\frac{mho}{ft}\right)$$

calculate total R,X,B

$$R = length * R_{ft} \ (\Omega)$$

$$X = length * X_{ft} \ (\Omega)$$

$$B = length * B_{ft} \ (mho)$$

convert to per-unit

$$R_{pu} = \frac{R}{Z_{Base}} \ (no\ units)$$

$$X_{pu} = \frac{X}{Z_{Base}} \ (no\ units)$$

$$B_{pu} = BZ_{Base} \ (no\ units)$$

thanks to myCableEngineering, NEPSI, for guidance

3ΦEE

Dedicated to Power Engineering

Questions or Comments …

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