## Report

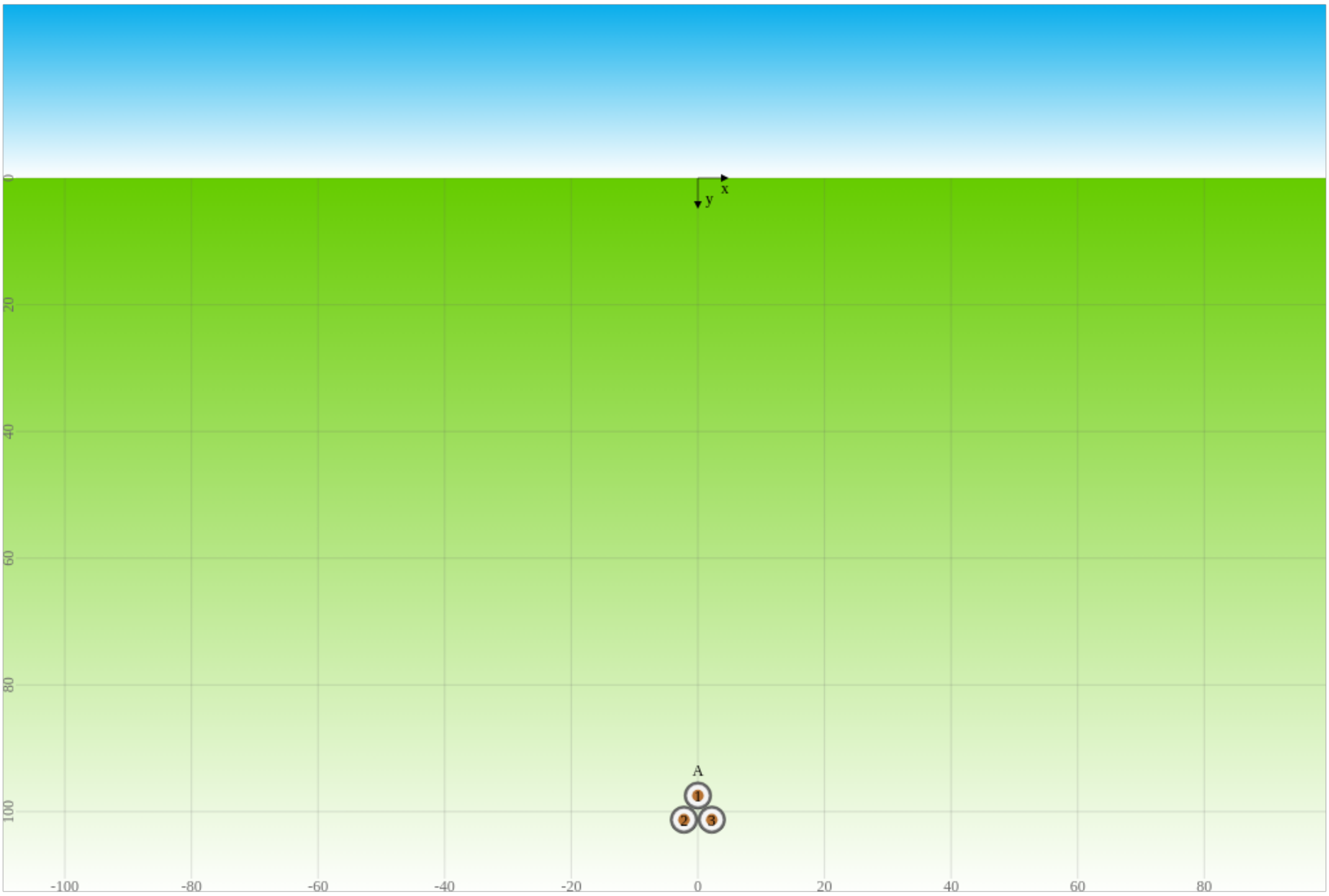
| | |
|---|---|
| **Title** | Case study 4: A 33kV land cable |
| **Project** | Verification CIGRE TB 880 |
| **Created** | Date: 2025-05-14 Time: 20:38 Software version: 3b07c (2025-05-14) |

## Arrangement

| | |
|---|---|
| Arrangement | **buried project** (#46688) |
| Options | None |
| CIGRE TB 880, guidance points | 02, 06, 26, 31 |
| CIGRE TB 880, test setting | 08 |
| Systems | A |

### Statistics

| | | |
|---|---|---|
| Number of iterations of the solver | $N_{calc}$ | 10 |
| Sum of currents from all systems | $I_{sum}$ | 537.46 A |
| Sum of average conductor temperatures from all systems | $\theta_{sum}$ | 90 °C |
| Number of overheated electrical systems | | 0 |
| Sum of losses from all systems | $W_{sum}$ | 88.612 W/m |



## Systems

**Following systems are active in the arrangement:**

| # | Object | Current [A] | Temp. [°C] | Losses [W/m] | Load |
|---|---|---|---|---|---|
| | | $I_c$ | $\theta_c$ \| $\theta_e$ | $W_{sys}$ | $LF$ |
| A | 16300 CIGRE TB 880 Case 4 33 kV land cable | 537.5 | 90.0 \| 74.7 | 88.6 | 1.00 |

## Objects

**Following objects are used:**

16300 CIGRE TB 880 Case 4 33 kV land cable

## Ambient

| | | |
|---|---|---|
| Calculation method | | IEC Standard (directly buried) |
| Ambient temperature | $\theta_a$ | 20 °C |
| Thermal resistivity soil | $\rho_4$ | 1 K.m/W |
| Thermal conductivity soil | $k_4$ | 1 W/(m.K) |
| Volumetric heat capacity soil material $10^{-4}\frac{{k_4}^{0.2}}{4.68}$ | $c_{p,soil}$ | 2136.8 J/(kg.K) |
| Thermal diffusivity soil | $\delta_{soil}$ | 5.00e-7 $m^2/s$ |
| Ratio thermal resistivity dry/moist soil $\frac{\rho_{4d}}{\rho_4}$ | $v_4$ | 1 |

### Constants

| | | |
|---|---|---|
| Standard acceleration of gravity | $g$ | 9.80665 $m/s^2$ |
| Archimedes' constant $\pi$ | $\pi$ | 3.141592653589793 |
| Absolute temperature | $\theta_{abs}$ | 273.15 K |
| Stefan Boltzmann constant | $\sigma$ | 5.67036713e-8 $W/m^2K^4$ |
| Vacuum permeability | $\mu_0$ | 1.2566370614359173e-6 H/m |
| Vacuum permittivity | $\epsilon_0$ | 8.854187817620389e-12 F/m |

# System A (Medium voltage cable)

## Ampacity

| | | |
|---|---|---|
| Cable | | CIGRE TB 880 Case 4 33 kV land cable |
| Rounded value, CIGRE TB 880 | $I_c$ | 530 A |
| Conductor current | $I_c$ | 537.46 A |

$$\sqrt{\frac{\theta_c - \theta_a + (v_4 - 1)\,\Delta\theta_x - v_4\Delta\theta_p - \Delta\theta_d}{R_c\left(T_1 + n_{ph}\left(1+\lambda_1\right)T_2 + \left(1+\lambda_1+\lambda_2+\lambda_3\right)\left(n_{ph}T_3 + n_{cc}\left(T_{4i} + T_{4ii} + T_{4\mu}v_4\right)\right) + n_{cc}\lambda_4\left(\frac{T_{4ii}}{2} + T_{4\mu}v_4\right)\right)}}$$

| | | |
|---|---|---|
| Operating voltage | $U_o$ | 33 kV |
| Angular frequency | $\omega$ | 314.2 rad/s |

$2\pi f$

| | | |
|---|---|---|
| Number of sources in system | $N_c$ | 3 |
| Number of conductors combined | $n_{cc}$ | 1 |

## Load

| | | |
|---|---|---|
| System frequency | $f$ | 50 Hz |
| Continuous load | $LF$ | 1 p.u. |

## Arrangement

| | | |
|---|---|---|
| Arrangement | | trefoil |
| Position cable 1 | $x_1 \vert y_1$ | 0.0 \| 974.6 mm |
| Position cable 2 | $x_2 \vert y_2$ | -22.0 \| 1012.7 mm |
| Position cable 3 | $x_3 \vert y_3$ | 22.0 \| 1012.7 mm |
| Separation of conductors in a system | $s_c$ | 44 mm |
| Mean distance between the phases | $a_m$ | 44 mm |
| Geometric mean distance between phases of the same system | $GMD$ | 0.044 m |

$S_m$

| | | |
|---|---|---|
| Depth of laying of sources | $L_c$ | 1000 mm |
| Depth of laying | $L_{cm}$ | 1 m |
| Outer diameter | $D_o$ | 0.044 m |
| Substitution coefficient u | $u$ | 45.4545 |

$$\frac{2L_{cm}}{D_o}$$

| | | |
|---|---|---|
| Geometric constant of circle buried | $g_u$ | 90.9091 |

$2u$

## Temperature

| | | |
|---|---|---|
| Temperature conductor | $\theta_c$ | 90 °C |

$\theta_a + \Delta\theta_c - (v_4 - 1)\,\Delta\theta_x + v_4\Delta\theta_p$

| | | |
|---|---|---|
| Temperature screen/sheath | $\theta_s$ | 78.39 °C |
| Temperature screen | $\theta_{sc}$ | 78.39 °C |

$$\theta_c - T_1\left(W_c + \frac{W_d}{2}\right)$$

| | | |
|---|---|---|
| External temperature object | $\theta_e$ | 74.72 °C |

$$\theta_c - T_1\left(W_c + \frac{W_d}{2}\right) - n_{ph}T_2\left(W_c\left(1+\lambda_1\right) + W_d\right) - n_{ph}T_3\left(W_I + W_d\right)$$

### Temperature rise

Temperature rise conductor | $\Delta\theta_c$ | 70 K

$$n_{ph}\left(W_c T_{int} + W_d T_d\right) + n_{cc}\left(W_d\left(T_{4i} + T_{4ii} + v_4 T_{4ss}\right) + \left(W_c + W_s + W_{ar} + W_{sp}\right)\left(T_{4i} + T_{4ii} + v_4 T_{4\mu}\right) + W_{duct}\left(\frac{T_{4ii}}{2} + v_4 T_{4\mu}\right)\right)$$

Temperature rise dielectric losses | $\Delta\theta_d$ | 0.2366 K

$$W_d\left(n_{ph} T_d + n_{cc}\left(T_{4i} + T_{4ii} + T_{4ss} v_4\right)\right)$$

Temperature rise by other buried objects | $\Delta\theta_p$ | 0 K

$$\sum_{k=1}^{q} \Delta\theta_{kp}$$

Critical soil temperature rise | $\Delta\theta_x$ | 0 K

### Losses

#### Ohmic

Conductor losses (phase) | $W_c$ | 28.202 W/m

$$I_c^2 R_c$$

Screen/sheath losses (phase) | $W_s$ | 1.227 W/m

$$\lambda_1 W_c$$

Duct losses | $W_{duct}$ | 0 W/m

Ohmic losses (phase) | $W_I$ | 29.429 W/m

$$W_c\left(1 + \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4\right)$$

#### Dielectric

Dielectric losses (phase) | $W_d$ | 0.108 W/m

$$\omega C_b\left(1000\frac{U_o}{\sqrt{3}}\right)^2 \tan\delta_i$$

#### Total

Total losses (phase) | $W_t$ | 29.537 W/m

$$W_I + W_d$$

Total losses (object) | $W_{tot}$ | 29.537 W/m

$$n_{ph} W_t$$

Total losses (system) | $W_{sys}$ | 88.612 W/m

### Thermal resistance

Thermal resistance ambient | $T_{4\mu}$ | 1.8525 K.m/W

$$= T_{4ss} = T_{4iii} = 3\frac{\rho_4}{2\pi}\left(\ln\left(g_u\right) - 0.63\right)$$

Thermal resistance conductor—sheath | $T_1$ | 0.411 K.m/W

$$1.07 T_1$$

Thermal resistance jacket | $T_3$ | 0.1242 K.m/W

$$1.6 T_3$$

#### Cable

Internal thermal resistance for current losses | $T_{int}$ | 0.5406 K.m/W

$$\frac{T_1}{n_{ph}} + \left(1 + \lambda_1\right) T_2 + \left(1 + \lambda_1 + \lambda_2 + \lambda_3\right) T_3$$

| | | |
|---|---|---|
| Internal thermal resistance for dielectric losses<br>$\frac{T_1}{2n_c} + T_2 + T_3$ | $T_d$ | 0.32971 K.m/W |

## Other characteristics

### Earthing

| | | |
|---|---|---|
| earthing screen/sheath | | both-side bonding |
| Variation of spacing | | No variation |

### Loss factor

| | | |
|---|---|---|
| Loss factor shield (screen/sheath)<br>$\lambda_{11} + \lambda_{12}$ | $\lambda_1$ | 0.0435 |
| Loss factor shield, circulating currents<br>$\frac{\frac{R_e}{R_c}}{1 + \left(\frac{R_e}{X_e}\right)^2}$ | $\lambda_{11}$ | 0.0435 |
| Loss factor shield, eddy currents | $\lambda_{12}$ | 0 |
| Electrical resistance shield/armour | $R_e$ | 6.6350e-1 Ω/km |
| Factor $F_e$ eddy-current losses | $F_e$ | 1 |
| Loss factor armour | $\lambda_2$ | 0 |

## Drying-out of soil

| | | |
|---|---|---|
| Characteristic diameter drying zone | $D_{dry}$ | 0.044 m |
| Depth characteristic diameter drying zone | $L_{dry}$ | 1 m |
| Geometric constant of circle drying zone | $g_{dry}$ | 1 p.u. |
| Substitution coefficient g | $g_a$ | 1 |

## Electrical parameters

### System

| | | |
|---|---|---|
| System length | $L_{sys}$ | 1000 m |
| Power factor | $\cos\varphi$ | 1 |

### Resistance

| | | |
|---|---|---|
| Electrical resistance conductor<br>$R_{cDC}\left(1 + y_s + y_p\right)$ | $R_c$ | 9.7629e-5 Ω/m → 0.0976 Ω |
| Electrical resistance DC conductor<br>$R_{c20}\left(1 + \alpha_c\left(\theta_c - 20\right)\right)$ | $R_{cDC}$ | 9.6143e-5 Ω/m → 0.0961 Ω |
| Skin effect factor conductor<br>$\frac{{x_s}^4}{192 + 0.8{x_s}^4}$ | $y_s$ | 0.00884 |
| Factor for skin effect on conductor<br>$\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_s}$ | $x_s$ | 1.14327 |
| Proximity effect factor conductor<br>$\frac{{x_p}^4}{192 + 0.8{x_p}^4}\left(\frac{d_c}{s_c}\right)^2\left(0.312\left(\frac{d_c}{s_c}\right)^2 + \frac{1.18}{\frac{{x_p}^4}{192+0.8{x_p}^4} + 0.27}\right)$ | $y_p$ | 0.00662 |
| Factor for proximity effect of conductors<br>$\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_p}$ | $x_p$ | 1.14327 |

| | | |
|---|---|---|
| Electrical resistance screen $R_{sc}\left(1+\alpha_{sc}\left(\theta_{sc}-20\right)\right)$ | $R_{sc}$ | 6.6350e-4 Ω/m → 0.6635 Ω |
| Electrical resistance shield | $R_s$ | 6.6350e-4 Ω/m → 0.6635 Ω |
| Reduction factor $\frac{R_s}{\sqrt{{R_s}^2+{X_s}^2}}$ | $RF$ | 0.6989 |

#### Electrical field strength, capacitive load current

| | | |
|---|---|---|
| Electrical field strength insulation inner/outer $\frac{U_e}{1000}\frac{1}{r_x\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$ | $E_i$ | 3.361 \| 1.874 kV/mm |
| Radius to point x in insulation | $r_x$ | 9.7 \| 17.4 mm |
| Line-to-ground voltage $\frac{1000U_o}{\sqrt{3}}$ | $U_e$ | 19052.56 V |
| Capacitance insulation $\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$ | $C_b$ | 2.377e-10 F/m → 0.2377 μF |
| Capacitive load current $U_e\omega C_b$ | $I_C$ | 1.423e-3 A/m → 1.4227 A |
| Charging capacity $n_{ph}{U_e}^2\omega C_b$ | $P_C$ | 27.1054 var/m → 27.1054 kvar |
| Capacitive earth short-circuit current $U_e\omega C_E$ | $I_{Ce}$ | 1.423e-3 A/m |

#### Reactance

| | | |
|---|---|---|
| Self reactance conductor $\omega\frac{\mu_0}{2\pi}\ln\left(\frac{D_E}{GMR_c}\right)$ | $X_a$ | 7.402e-4 Ω/m → 0.7402 Ω |
| Self reactance screen/sheath $\omega\frac{\mu_0}{2\pi}\ln\left(\frac{2s_c}{d_s}\right)$ | $X_e$ | 5.326e-5 Ω/m → 0.0533 Ω |

#### Induced current (approximate)

| | | |
|---|---|---|
| Induced circulating current shield $\max\left(I_c\sqrt{\frac{\lambda_{11,sb}R_c}{R_s}}\right)$ | $I_s$ | 43.005+0.000j A |
| Loss factor shield, circulating currents | $\lambda_{11,sb}$ | 0.0435+0.0000j |

#### Load, Voltage drop

| | | |
|---|---|---|
| Apparent power generator-side $\sqrt{3}U_oI_c$ | $S_G$ | 30.72 MVA |
| Voltage drop $\sqrt{3}\left(R_c\cos\varphi+\omega L_m\sin\varphi\right)$ | $V_{drop}$ | 0.17 V/(A.km) → 90.9 V = 0.28% |
| Inductance (mean) $\frac{\mu_0}{2\pi}\ln\left(\frac{GMD}{GMR_c}\right)$ | $L_m$ | 3.642e-7+0.000e0j H/m → 0.3642 mH |

### Telegrapher equation

| | | |
|---|---|---|
| Surge impedance<br>$\sqrt{\frac{Z_1}{Y_1}}$ | $Z_C$ | 42.1120-15.5236j Ω |
| Propagation constant<br>$\sqrt{Z_1 Y_1}$ | $\gamma_C$ | 1.159e-6+3.145e-6j |

#### Impedance valid up to 100 Hz without earth return

| | | |
|---|---|---|
| Positive sequence admittance<br>$G + j\omega C_b$ | $Y_1$ | 0.000e0+7.467e-8j S/m → 0.0000+0.0001j S |
| Positive sequence impedance<br>$R_1 + jX_1$ | $Z_1$ | 9.763e-5+1.144e-4j Ω/m → 0.0976+0.1144j Ω |
| Positive sequence reactance<br>$\omega \frac{\mu_0}{2\pi} \ln\left(\frac{GMD}{GMR_c}\right)$ | $X_1$ | 1.144e-4 Ω/m → 0.1144 Ω |

## Cable datasheet

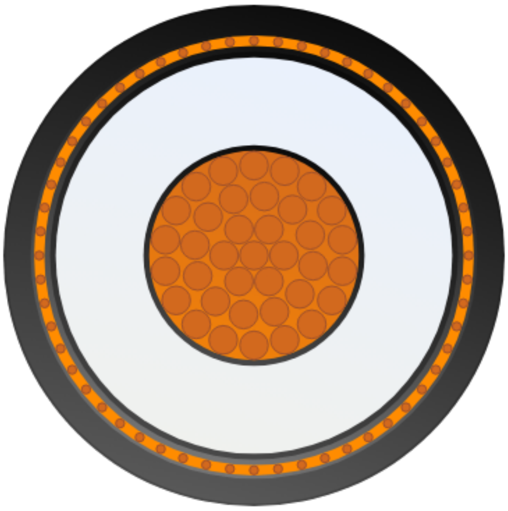
| | |
|---|---|
| **Title** | CIGRE TB 880 Case 4 33 kV land cable (#16300) |

Cable is used in following systems: A

CIGRE TB 880, guidance points 15, 20, 23, 25, 30, 32, 33, 34, 38, 39, 42, 44, 45

### General Data

| | | |
|---|---|---|
| Rated line-to-line voltage | $U_n$ | 33 kV |
| Base voltage for tests | $U_0$ | 19 kV |
| Highest voltage for equipment | $U_m$ | 36 kV |
| Nominal system frequency | $f$ | 50 Hz |
| Number of conductors cable | $n_c$ | 1 |
| Number of phases in a cable | $n_{ph}$ | 1 |




### Cable elements

#### Conductor

| | | |
|---|---|---|
| Cross-sectional area conductor | $A_c$ | 1 x 240 mm$^2$ |
| Conductor material | $M_c$ | Copper, round stranded |
| External diameter conductor | $d_c$ | 18.4 mm |
| Radius conductor | $r_c$ | 9.2 mm |

$\frac{d_c}{2}$

#### Insulation

| | | |
|---|---|---|
| Insulation material | $M_i$ | Crosslinked polyethylene (XLPE) |
| Thickness conductor shield | $t_{cs}$ | 0.5 mm |
| Thickness insulation | $t_{ins}$ | 7.7 mm |
| Thickness insulation screen | $t_{is}$ | 0.5 mm |
| Thickness insulation | $t_i$ | 8.7 mm |

$t_{ct} + t_{cs} + t_{ins} + t_{is}$

### Screen bedding

| | | |
|---|---|---|
| Screen bedding material | | Water-blocking tapes, semi-conducting |
| Thickness screen bedding | $t_{scb}$ | 0.5 mm |

### Screen

| | | |
|---|---|---|
| Type | | round wires |
| Screen material | $M_{sc}$ | Copper |
| diameter wires | $t_{sc}$ | 0.9 mm |
| Number of wires screen | $n_{scw}$ | 56 |
| Elongation screen | $\nu_{sc}$ | 0 % |

### Screen serving

| | | |
|---|---|---|
| Screen serving material | | Water-blocking tapes |
| Thickness screen serving | $t_{scs}$ | 0.3 mm |

### Jacket

| | | |
|---|---|---|
| Jacket material | $M_j$ | High density polyethylene (HDPE, ST7) |
| Thickness jacket | $t_j$ | 2.2 mm |
| Thickness of additional layer over jacket | $t_{jj}$ | 0.2 mm |

### Overall

| | | |
|---|---|---|
| External diameter object | $D_e$ | 44 mm |
| Absorption coefficient solar radiation | $\sigma_{sun}$ | 0.4 |
| Emissivity cable | $\epsilon_e$ | 0.9 |
| Reflectivity cable<br>$1 - \epsilon_e$ | $\eta_e$ | 0.1 |
| Mass cable<br>$m_{hollow} + m_{metal}$ | $m_{tot}$ | 3.475 kg/m |

## Electrical

### Conductor

| | | |
|---|---|---|
| Electrical resistance DC conductor 20°C | $R_{c20}$ | 7.5400e-5 Ω/m |
| Standard DC resistance of conductor | $R_{co}$ | 0.0754 Ω/km |
| Coating of wires | | plain |
| Skin effect coefficient | $k_s$ | 1 |
| Proximity effect coefficient | $k_p$ | 1 |
| Geometric mean radius conductor<br>$K_{GMR} r_{z1}$ | $GMR_c$ | 0.00712 m |
| Factor geometric mean radius | $K_{GMR}$ | 0.774 |
| Constant relating to conductor formation | $K_{BICC}$ | 0.0512 |
| Number of wires conductor | $n_{cw}$ | 91 |
| Diameter of wires conductor (average) | $d_{cw}$ | 2.87 mm |

### Insulation

| | | |
|---|---|---|
| Capacitance, with approximation (CIGRE TB 880)<br>$\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$ | $C_b$ | 2.377e-10 F/m |
| Capacitance (exact)<br>$\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$ | $C_b$ | 2.380e-10 F/m |

| | | |
|---|---|---|
| Capacitance to earth<br>$C_b$ | $C_E$ | 2.377e-10 F/m |
| Vacuum permittivity | $\epsilon_0$ | 8.854187817620389e-12 F/m |
| Radius above the inner semi-conducting layer<br>$\frac{d_c}{2} + t_{ct} + t_{cs}$ | $r_{isc}$ | 9.7 mm |
| Radius over capacitive insulation layers<br>$\frac{D_{ins}}{2}$ | $r_{osc}$ | 17.4 mm |
| Velocity of propagation<br>$\frac{1}{1000\sqrt{\mu_0 \epsilon_0 \epsilon_i}}$ | $v_{prop}$ | 189605.4 km/s |

### Screen + Sheath

| | | |
|---|---|---|
| Electrical resistance screen<br>$10^6 \frac{F_{lay,sc} \rho_{sc}}{A_{sc}}$ | $R_{sc}$ | 5.3967e-4 Ω/m |
| Effective length per unit lay length screen wires<br>$\sqrt{1 + \left(\frac{\pi d_{sc}}{L_{lay,sc}}\right)^2}$ | $F_{lay,sc}$ | 1.1151 |
| Length of lay screen wires | $L_{lay,sc}$ | 240 mm |
| Geometric mean radius screen<br>$\left(0.7788 \frac{t_{sc}}{2} n_{scw} \left(\frac{t_{sc}}{2}\right)^{n_{scw}-1}\right)^{\frac{1}{n_{scw}}} \frac{1}{1000}$ | $GMR_{sc}$ | 0.00048 m |
| Electrical resistance screen/sheath 20°C | $R_{so}$ | 5.397e-1 Ω/km |

### Radius

| | | |
|---|---|---|
| Radius conductor | $r_{z1}$ | 0.0092 m |
| Radius shield (inner) | $r_{z2}$ | 0.01795 m |
| Radius shield (outer) | $r_{z3}$ | 0.01975 m |
| Radius screen (inner) | $r_{z2,sc}$ | 0.01795 m |
| Radius screen (outer) | $r_{z3,sc}$ | 0.01975 m |
| Radius outersheath | $r_{z6}$ | 0.022 m |

## Material parameters

### Conductor

| | | |
|---|---|---|
| Electrical resistivity conductor material | $\rho_c$ | 1.724e-8 Ω.m |
| Temperature coefficient conductor material | $\alpha_c$ | 3.93e-3 1/K |
| Reciprocal of temperature coefficient conductor material | $\beta_c$ | 2.345e2 K |
| Volumetric heat capacity conductor material | $\sigma_c$ | 3.45e6 J/(K.m$^3$) |
| Thermal conductivity conductor material | $k_c$ | 384.62 W/(m.K) |
| Density conductor material | $\zeta_c$ | 8.94 g/cm$^3$ |

### Insulation

| | | |
|---|---|---|
| Relative permittivity insulation material | $\epsilon_i$ | 2.5 |
| Loss factor insulation material | $\tan\delta_i$ | 0.004 |
| Thermal resistivity insulation material | $\rho_i$ | 3.5 K.m/W |
| Volumetric heat capacity insulation material | $\sigma_i$ | 2.40e6 J/(K.m$^3$) |
| Density insulation material | $\zeta_i$ | 0.923 g/cm$^3$ |

| | | |
|---|---|---|
| Max. temperature conductor | $\theta_{cmax}$ | 90 °C |
| Max. temperature conductor, emergency overload | $\theta_{cmaxeo}$ | 105 °C |
| Max. temperature conductor, short-circuit | $\theta_{cmaxsc}$ | 250 °C |
| **Conductor shield** | | |
| Thermal resistivity conductor shield | $\rho_{cs}$ | 2.5 K.m/W |
| **Insulation screen** | | |
| Thermal resistivity insulation screen | $\rho_{is}$ | 2.5 K.m/W |

### Screen bedding

| | | |
|---|---|---|
| Thermal resistivity screen bedding | $\rho_{scb}$ | 6 K.m/W |
| Volumetric heat capacity screen bedding | $\sigma_{scb}$ | 2.00e6 J/(K.m$^3$) |
| Density tape material | $\zeta_{tape}$ | 0.34 g/cm$^3$ |

### Screen

| | | |
|---|---|---|
| Specific electrical resistivity screen material | $\rho_{sc}$ | 1.724e-8 Ω.m |
| Temperature coefficient screen material | $\alpha_{sc}$ | 3.93e-3 1/K |
| Reciprocal of temperature coefficient screen material | $\beta_{sc}$ | 2.345e2 K |
| Volumetric heat capacity screen material | $\sigma_{sc}$ | 3.45e6 J/(K.m$^3$) |
| Thermal conductivity screen material | $k_{sc}$ | 370.4 W/(m.K) |
| Density metallic screen material | $\zeta_{sc}$ | 8.94 g/cm$^3$ |

### Screen serving

| | | |
|---|---|---|
| Thermal resistivity screen serving | $\rho_{scs}$ | 6 K.m/W |
| Volumetric heat capacity screen serving | $\sigma_{scs}$ | 2.00e6 J/(K.m$^3$) |
| Density tape material | $\zeta_{tape}$ | 0.34 g/cm$^3$ |

### Jacket

| | | |
|---|---|---|
| Thermal resistivity jacket material | $\rho_j$ | 3.5 K.m/W |
| Thermal resistivity additional layer | $\rho_{jj}$ | 2.5 K.m/W |
| Volumetric heat capacity jacket material | $\sigma_j$ | 2.40e6 J/(K.m$^3$) |
| Electrical conductivity jacket material | $\kappa_j$ | 2.00e-15 S/m |
| Density jacket material | $\zeta_j$ | 0.941 g/cm$^3$ |

## Thermal resistance

### Internal thermal resistances for rating calculation

| | | |
|---|---|---|
| Thermal resistance conductor—sheath<br>$T_{ct} + T_{cs} + T_{ins} + T_{is} + T_{scb}$ | $T_1$ | 0.3841 K.m/W |
| Thermal resistance armour bedding | $T_2$ | 0 K.m/W |
| Thermal resistance jacket<br>$T_{scs} + T_{dsh} + T_{ab} + T_j + T_{jj}$ | $T_3$ | 0.0776 K.m/W |
| Thickness conductor—sheath<br>$t_i + t_{scb} + t_{scs} + \frac{H_{sh} + \Delta H}{2}$ | $t_1$ | 9.5 mm |
| Thickness sheath—armour<br>$\frac{H_{sh} + \Delta H}{2} + t_{ab}$ | $t_2$ | 0 mm |
| Thickness armour—surface<br>$t_j + t_{jj}$ | $t_3$ | 2.4 mm |

### Cable elements

Thermal resistance, transient | $T_{tot}$ | 0.4618 K.m/W
$T_1 + T_2 + T_3$

| | | |
|---|---|---|
| Thermal resistance, transient<br>$T_1 + T_2 + T_3$ | $T_{tot}$ | 0.4618 K.m/W |
| Thermal resistance insulation<br>$T_{ct} + T_{cs} + T_{ins} + T_{is}$ | $T_i$ | 0.35783 K.m/W |
| Thermal resistance conductor shield<br>$\frac{\rho_{cs}}{2\pi} \ln\left(\frac{D_{cs}}{D_{cs} - 2t_{cs}}\right)$ | $T_{cs}$ | 0.02106 K.m/W |
| Thermal resistance insulation<br>$\frac{\rho_i}{2\pi} \ln\left(\frac{D_{ins}}{D_{ins} - 2t_{ins}}\right)$ | $T_{ins}$ | 0.3255 K.m/W |
| Thermal resistance insulation screen<br>$\frac{\rho_{is}}{2\pi} \ln\left(\frac{D_{ins} + 2t_{is}}{D_{ins}}\right)$ | $T_{is}$ | 0.01127 K.m/W |
| Thermal resistance screen bedding<br>$\frac{\rho_{scb}}{2\pi} \ln\left(\frac{D_{scb}}{D_i}\right)$ | $T_{scb}$ | 0.02631 K.m/W |
| Thermal resistance screen serving<br>$\frac{\rho_{scs}}{2\pi} \ln\left(\frac{D_{scs}}{D_{sc}}\right)$ | $T_{scs}$ | 0.01473 K.m/W |
| Thermal resistance jacket<br>$\frac{\rho_j}{2\pi} \ln\left(\frac{D_j - 2t_{jj}}{D_j - 2\left(t_j + t_{jj}\right)}\right)$ | $T_j$ | 0.05926 K.m/W |
| Thermal resistance additional layer<br>$\frac{\rho_{jj}}{2\pi} \ln\left(\frac{D_j}{D_j - 2t_{jj}}\right)$ | $T_{jj}$ | 0.00363 K.m/W |

## Dimensions

### Diameter

| | | |
|---|---|---|
| External diameter conductor | $d_c$ | 18.4 mm |
| Diameter over conductor shield<br>$d_c + 2\left(t_{ct} + t_{cs}\right)$ | $D_{cs}$ | 19.4 mm |
| Diameter over insulation<br>$d_c + 2\left(t_{ct} + t_{cs} + t_{ins}\right)$ | $D_{ins}$ | 34.8 mm |
| Diameter over insulation incl. insulation screen<br>$d_c + 2\left(t_{ct} + t_{cs} + t_{ins} + t_{is}\right)$ | $D_i$ | 35.8 mm |
| Diameter over insulation screen<br>$d_c + 2t_i$ | $D_{is}$ | 35.8 mm |
| Diameter over screen bedding<br>$d_c + t_{i1} + 2t_{scb}$ | $D_{scb}$ | 36.8 mm |
| Mean diameter screen<br>$D_{scb} + t_{sc}$ | $d_{sc}$ | 37.7 mm |
| Diameter over screen<br>$D_{scb} + 2t_{sc}$ | $D_{sc}$ | 38.6 mm |
| Equivalent diameter of screen and sheath | $d_s$ | 37.7 mm |
| Diameter over screen serving<br>$D_{sc} + 2t_{scs}$ | $D_{scs}$ | 39.2 mm |

Diameter over jacket $D_j$ 44 mm
$D_{ar} + 2\left(t_j + t_{jj}\right)$

### Area

Cross-sectional area conductor $A_c$ 240 mm$^2$

Cross-sectional area insulation $A_i$ 740.7 mm$^2$
$\frac{\pi}{4}\left({D_{is}}^2 - {d_c}^2\right)$

Cross-sectional area screen bedding $A_{scb}$ 57 mm$^2$
$\pi t_{scb}\left(D_{scb} - t_{scb}\right)$

Cross-sectional area screen $A_{sc}$ 35.63 mm$^2$
$\left(\frac{t_{sc}}{2}\right)^2 \pi n_{scw}\left(1 + \frac{\nu_{sc}}{100}\right)$

Cross-sectional area screen serving $A_{scs}$ 36.7 mm$^2$
$\pi t_{scs}\left(D_{scs} - t_{scs}\right)$

Cross-sectional area jacket $A_j$ 313.7 mm$^2$
$\frac{\pi}{4}\left({D_j}^2 - \left(D_j - 2\left(t_j + t_{jj}\right)\right)^2\right)$