## Report

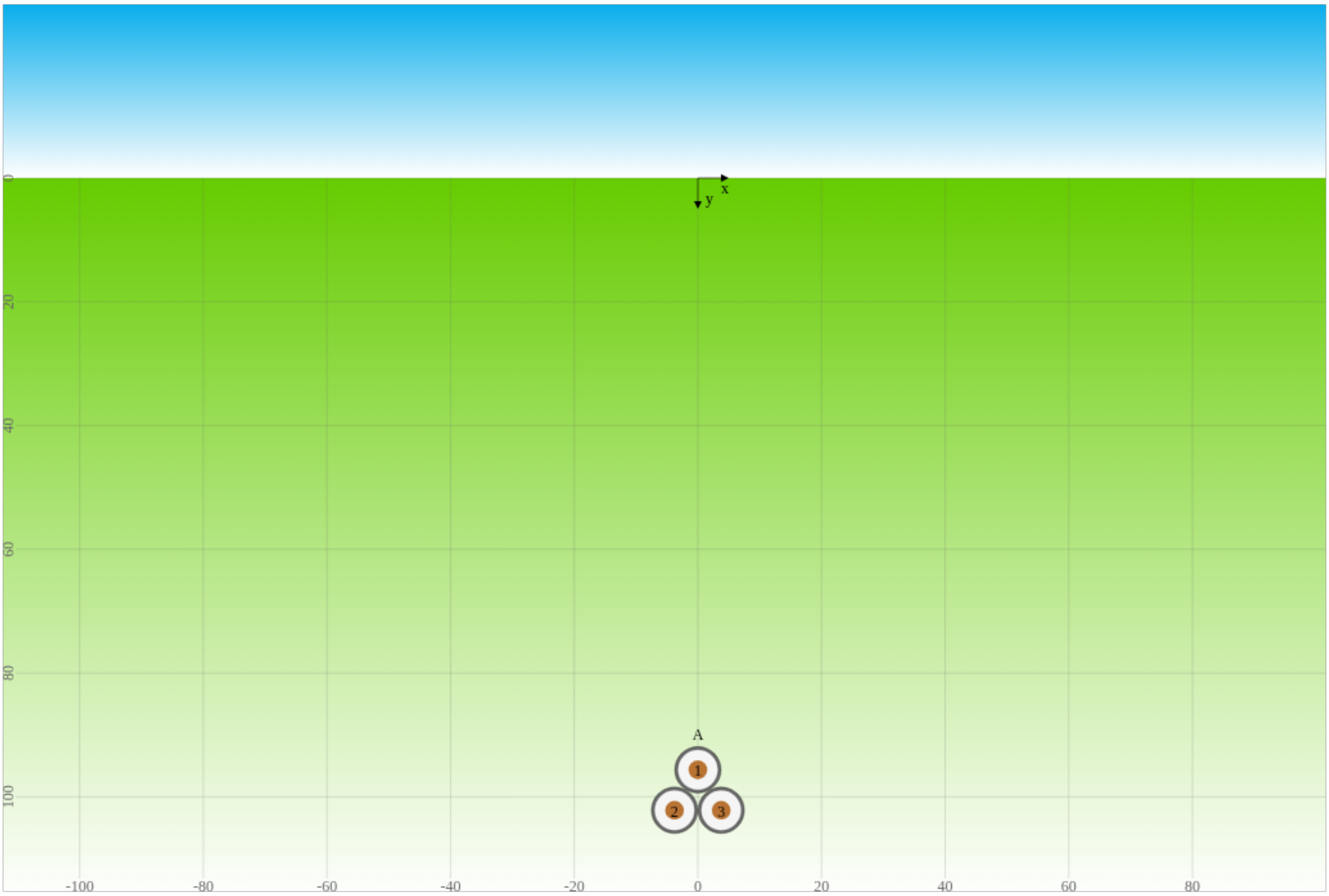
| | |
|---|---|
| **Title** | Case study 0-1: Introductory (touching trefoil) |
| **Project** | Verification CIGRE TB 880 |
| **Created** | Date: 2025-05-19 Time: 10:57 Software version: 8482 (2025-05-16) |

## Arrangement

| | |
|---|---|
| Arrangement | **buried project** (#46635) |
| Options | None |
| CIGRE TB 880, guidance points | 02, 06, 26, 31 |
| CIGRE TB 880, test setting | 08, 47 |
| Systems | A |

### Statistics

| | | |
|---|---|---|
| Number of iterations of the solver | $N_{calc}$ | 10 |
| Sum of currents from all systems | $I_{sum}$ | 803.16 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 | $W_{sum}$ | 105.652 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 | 16173 CIGRE TB 880 Case 0 XLPE insulated ca... | 803.2 | 90.0 \| 76.2 | 105.7 | 1.00 |

## Objects

**Following objects are used:**

16173 CIGRE TB 880 Case 0 XLPE insulated cable 132 kV

## 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 $\frac{\rho_{4d}}{\rho_4}$ | $\upsilon_4$ | 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 (High voltage cable)

## Ampacity

| | | |
|---|---|---|
| Cable | | CIGRE TB 880 Case 0 XLPE insulated cable 132 kV |
| Rounded value, CIGRE TB 880 | $I_c$ | 800 A |
| Conductor current | $I_c$ | 803.16 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 | $U_o$ | 132 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 \| 956.4 mm |
| Position cable 2 | $x_2 \vert y_2$ | -37.8 \| 1021.8 mm |
| Position cable 3 | $x_3 \vert y_3$ | 37.8 \| 1021.8 mm |
| Separation of conductors in a system | $s_c$ | 75.5 mm |
| Mean distance between the phases | $a_m$ | 75.5 mm |
| Geometric mean distance between phases of the same system | $GMD$ | 0.0755 m |

$S_m$

| | | |
|---|---|---|
| Depth of laying of sources | $L_c$ | 1000 mm |
| Depth of laying | $L_{cm}$ | 1 m |
| Outer diameter | $D_o$ | 0.0755 m |
| Substitution coefficient u | $u$ | 26.4901 |

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

| | | |
|---|---|---|
| Geometric constant of circle buried | $g_u$ | 52.9801 |

$2u$

## 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 | $\theta_s$ | 79.21 °C |
| Temperature sheath | $\theta_{sh}$ | 79.21 °C |

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

| | | |
|---|---|---|
| External temperature object | $\theta_e$ | 76.16 °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

$$n_{ph}\left(W_cT_{int}+W_dT_d\right)+n_{cc}\left(W_d\left(T_{4i}+T_{4ii}+v_4T_{4ss}\right)+\left(W_c+W_s+W_{ar}+W_{sp}\right)\left(T_{4i}+T_{4ii}+v_4T_{4\mu}\right)+W_{duct}\left(\frac{T_{4ii}}{2}+v_4T_{4\mu}\right)\right)$$

Temperature rise dielectric losses $\Delta\theta_d$ 0.7284 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) $W_c$ 25.494 W/m

$${I_c}^2R_c$$

Screen/sheath losses (phase) $W_s$ 9.338 W/m

$$\lambda_1W_c$$

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

Ohmic losses (phase) $W_I$ 34.832 W/m

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

#### Dielectric

Dielectric losses (phase) $W_d$ 0.385 W/m

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

#### Total

Total losses (phase) $W_t$ 35.217 W/m

$$W_I+W_d$$

Total losses (object) $W_{tot}$ 35.217 W/m

$$n_{ph}W_t$$

Total losses (system) $W_{sys}$ 105.652 W/m

### Thermal resistance

Thermal resistance ambient $T_{4\mu}$ 1.5947 K.m/W

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

Thermal resistance jacket $T_3$ 0.0867 K.m/W

$$1.6T_3$$

#### Cable

Internal thermal resistance for current losses $T_{int}$ 0.5384 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 $T_d$ 0.29666 K.m/W

$$\frac{T_1}{2n_c}+T_2+T_3$$

## Other characteristics

### Earthing

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

### Loss factor

| | | |
|---|---|---|
| Loss factor shield (screen/sheath) $\lambda_{11} + F_e\lambda_{12}$ | $\lambda_1$ | 0.3663 |
| Loss factor shield, circulating currents $\frac{\frac{R_e}{R_c}}{1+\left(\frac{R_e}{X_e}\right)^2}$ | $\lambda_{11}$ | 0.2935 |
| Loss factor shield, eddy currents $\frac{R_{sh}}{R_c}\left(g_s\lambda_0\left(1+\Delta_1+\Delta_2\right)+\frac{\left(\beta_1 t_{sh}\right)^4}{12{\cdot}10^{12}}\right)$ | $\lambda_{12}$ | 0.0771 |
| Electrical resistance shield/armour | $R_e$ | 2.0674e-1 Ω/km |
| Substitution coefficient $\lambda_0$ for eddy-currents $3\frac{{m_0}^2}{1+{m_0}^2}\left(\frac{d_e}{2s_c}\right)^2$ | $\lambda_0$ | 0.0136 |
| Substitution coefficient $\Delta_1$ for eddy-currents $\left(1.14{m_0}^{2.45}+0.33\right)\left(\frac{d_e}{2s_c}\right)^{0.92m_0+1.66}$ | $\Delta_1$ | 0.0806 |
| Substitution coefficient $\Delta_2$ for eddy-currents | $\Delta_2$ | 0 |
| Substitution coefficient $m_0$ for eddy-currents $10^{-7}\frac{\omega}{R_{sh}}$ | $m_0$ | 0.152 Hz.m/Ω |
| Substitution coefficient $\beta_1$ for eddy-currents $\sqrt{\frac{4\pi\omega}{10^7\rho_{sh}\left(1+\alpha_{sh}\left(\theta_{sh}-20\right)\right)}}$ | $\beta_1$ | 105.9373 |
| Substitution coefficient $g_s$ for eddy-currents $1+\left(\frac{t_{sh}}{D_{sh}}\right)^{1.74}\left(10^{-3}\beta_1 D_{sh}-1.6\right)$ | $g_s$ | 1.002454 |
| Factor $F_e$ eddy-current losses $\frac{4{M_e}^2{N_e}^2+\left(M_e+N_e\right)^2}{4\left({M_e}^2+1\right)\left({N_e}^2+1\right)}$ | $F_e$ | 0.9439 |
| Substitution coefficient $M_e$ to calculate factor $F_e$ $\frac{R_e}{X_e}$ | $M_e$ | 4.1018 |
| Substitution coefficient $N_e$ to calculate factor $F_e$ $\frac{R_e}{X_e}$ | $N_e$ | 4.1018 |
| Loss factor armour | $\lambda_2$ | 0 |

## Drying-out of soil

| | | |
|---|---|---|
| Characteristic diameter drying zone | $D_{dry}$ | 0.075 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>$R_{cDC}\left(1+y_s+y_p\right)$ | $R_c$ | 3.9522e-5 Ω/m → 0.0395 Ω |
| Electrical resistance DC conductor<br>$R_{c20}\left(1+\alpha_c\left(\theta_c-20\right)\right)$ | $R_{cDC}$ | 3.6085e-5 Ω/m → 0.0361 Ω |
| Skin effect factor conductor<br>$\frac{{x_s}^4}{192+0.8{x_s}^4}$ | $y_s$ | 0.06012 |
| Factor for skin effect on conductor<br>$\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_s}$ | $x_s$ | 1.86612 |
| Proximity effect factor conductor<br>$\frac{{x_p}^4}{192+0.8{x_p}^4}\left(\frac{d_c}{s_c}\right)^2\left(0.312\left(\frac{d_c}{s_c}\right)^2+\frac{1.18}{\frac{{x_p}^4}{192+0.8{x_p}^4}+0.27}\right)$ | $y_p$ | 0.0351 |
| Factor for proximity effect of conductors<br>$\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_p}$ | $x_p$ | 1.86612 |
| Electrical resistance sheath<br>$R_{sh}\left(1+\alpha_{sh}\left(\theta_{sh}-20\right)\right)$ | $R_{sh}$ | 2.0674e-4 Ω/m → 0.2067 Ω |
| Electrical resistance shield | $R_s$ | 2.0674e-4 Ω/m → 0.2067 Ω |
| Reduction factor<br>$\frac{R_s}{\sqrt{{R_s}^2+{X_s}^2}}$ | $RF$ | 0.3064 |

### Electrical field strength, capacitive load current

| | | |
|---|---|---|
| Electrical field strength insulation inner/outer<br>$\frac{U_e}{1000}\frac{1}{r_x\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$ | $E_i$ | 6.956 \| 3.603 kV/mm |
| Radius to point x in insulation | $r_x$ | 16.65 \| 32.15 mm |
| Line-to-ground voltage<br>$\frac{1000U_o}{\sqrt{3}}$ | $U_e$ | 76210.24 V |
| Capacitance insulation<br>$\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$ | $C_b$ | 2.111e-10 F/m → 0.2111 $\mu$F |
| Capacitive load current<br>$U_e\omega C_b$ | $I_C$ | 5.054e-3 A/m → 5.0536 A |
| Charging capacity<br>$n_{ph}{U_e}^2\omega C_b$ | $P_C$ | 385.1382 var/m → 385.1382 kvar |
| Capacitive earth short-circuit current<br>$U_e\omega C_E$ | $I_{Ce}$ | 5.054e-3 A/m |

### Reactance

| | | |
|---|---|---|
| Self reactance conductor<br>$\omega\frac{\mu_0}{2\pi}\ln\left(\frac{D_E}{GMR_c}\right)$ | $X_a$ | 7.088e-4 Ω/m → 0.7088 Ω |
| Self reactance screen/sheath<br>$\omega\frac{\mu_0}{2\pi}\ln\left(\frac{2s_c}{d_s}\right)$ | $X_e$ | 5.040e-5 Ω/m → 0.0504 Ω |

### Induced current (approximate)

| | | |
|---|---|---|
| Induced circulating current shield<br>$\max\left(I_c\sqrt{\frac{\lambda_{11,sb}R_c}{R_s}}\right)$ | $I_s$ | 190.235+0.000j A |
| Loss factor shield, circulating currents | $\lambda_{11,sb}$ | 0.2935+0.0000j |

### Load, Voltage drop

| | | |
|---|---|---|
| Apparent power generator-side<br>$\sqrt{3}U_oI_c$ | $S_G$ | 183.627 MVA |
| Voltage drop<br>$\sqrt{3}\left(R_c\cos\varphi+\omega L_m\sin\varphi\right)$ | $V_{drop}$ | 0.068 V/(A.km) → 55 V = 0.04% |
| Inductance (mean)<br>$\frac{\mu_0}{2\pi}\ln\left(\frac{GMD}{GMR_c}\right)$ | $L_m$ | 3.725e-7+0.000e0j H/m → 0.3725 mH |

## Telegrapher equation

| | | |
|---|---|---|
| Surge impedance<br>$\sqrt{\frac{Z_1}{Y_1}}$ | $Z_C$ | 42.5858-6.9976j Ω |
| Propagation constant<br>$\sqrt{Z_1Y_1}$ | $\gamma_C$ | 4.640e-7+2.824e-6j |

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

| | | |
|---|---|---|
| Positive sequence admittance<br>$G+j\omega C_b$ | $Y_1$ | 0.000e0+6.631e-8j S/m → 0.0000+0.0001j S |
| Positive sequence impedance<br>$R_1+jX_1$ | $Z_1$ | 3.952e-5+1.170e-4j Ω/m → 0.0395+0.1170j Ω |
| Positive sequence reactance<br>$\omega\frac{\mu_0}{2\pi}\ln\left(\frac{GMD}{GMR_c}\right)$ | $X_1$ | 1.170e-4 Ω/m → 0.117 Ω |

## Cable datasheet

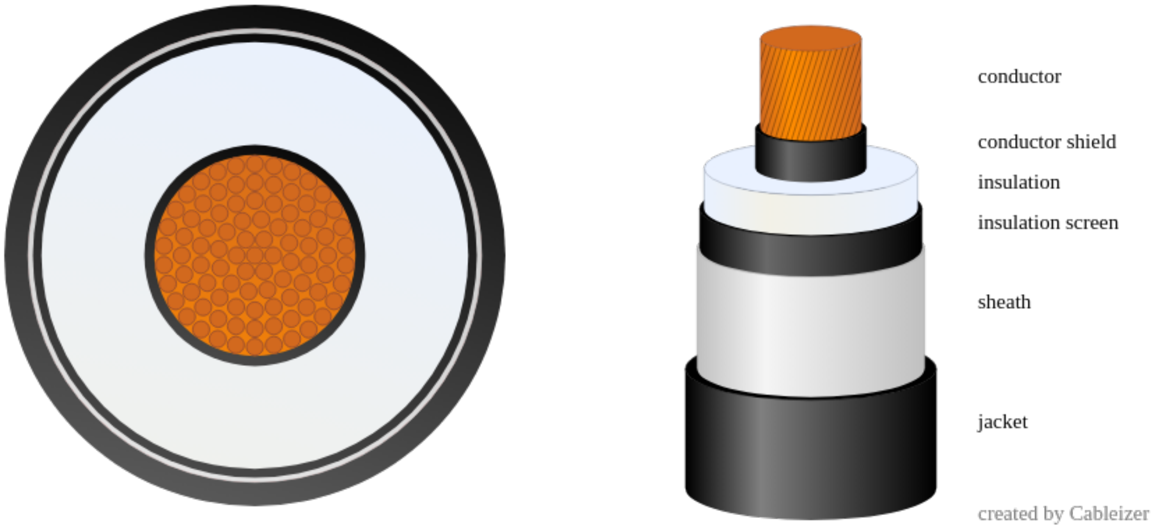
| | |
|---|---|
| **Title** | CIGRE TB 880 Case 0 XLPE insulated cable 132 kV (#16173) |

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 | $U_n$ | 132 kV |
| Base voltage for tests | $U_0$ | 76 kV |
| Highest voltage for equipment | $U_m$ | 145 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 630 mm$^2$ |
| Conductor material | $M_c$ | Copper, round stranded |
| External diameter conductor | $d_c$ | 30.3 mm |
| Radius conductor $\frac{d_c}{2}$ | $r_c$ | 15.15 mm |

#### Insulation

| | | |
|---|---|---|
| Insulation material | $M_i$ | Crosslinked polyethylene (XLPE) |
| Thickness conductor shield | $t_{cs}$ | 1.5 mm |
| Thickness insulation | $t_{ins}$ | 15.5 mm |
| Thickness insulation screen | $t_{is}$ | 1.3 mm |
| Thickness insulation $t_{ct} + t_{cs} + t_{ins} + t_{is}$ | $t_i$ | 18.3 mm |

### Sheath

| | | |
|---|---|---|
| Sheath material | $M_{sh}$ | Aluminium |
| Thickness sheath | $t_{sh}$ | 0.8 mm |
| corrugated | | No |

### Jacket

| | | |
|---|---|---|
| Jacket material | $M_j$ | High density polyethylene (HDPE, ST7) |
| Thickness jacket | $t_j$ | 3.5 mm |

### Overall

| | | |
|---|---|---|
| External diameter object | $D_e$ | 75.5 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>$m_{hollow} + m_{metal}$ | $m_{tot}$ | 9.418 kg/m |

## Electrical

### Conductor

| | | |
|---|---|---|
| Electrical resistance DC conductor 20°C | $R_{c20}$ | 2.8300e-5 Ω/m |
| Standard DC resistance of conductor | $R_{co}$ | 0.0283 Ω/km |
| Coating of wires | | plain |
| Skin effect coefficient | $k_s$ | 1 |
| Proximity effect coefficient | $k_p$ | 1 |
| Geometric mean radius conductor<br>$K_{GMR} r_{z1}$ | $GMR_c$ | 0.01173 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) | $d_{cw}$ | 2.97 mm |

### Insulation

| | | |
|---|---|---|
| Capacitance, with approximation (CIGRE TB 880)<br>$\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$ | $C_b$ | 2.111e-10 F/m |
| Capacitance (exact)<br>$\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$ | $C_b$ | 2.114e-10 F/m |
| Capacitance to earth<br>$C_b$ | $C_E$ | 2.111e-10 F/m |
| Vacuum permittivity | $\epsilon_0$ | 8.854187817620389e-12 F/m |
| Radius above the inner semi-conducting layer<br>$\frac{d_c}{2} + t_{ct} + t_{cs}$ | $r_{isc}$ | 16.65 mm |
| Radius over capacitive insulation layers<br>$\frac{D_{ins}}{2}$ | $r_{osc}$ | 32.15 mm |

| | | |
|---|---|---|
| Velocity of propagation $\frac{1}{1000\sqrt{\mu_0\epsilon_0\epsilon_i}}$ | $v_{prop}$ | 189605.4 km/s |

### Screen + Sheath

| | | |
|---|---|---|
| Electrical resistance sheath $10^6\,\frac{\rho_{sh}}{A_{sh}}$ | $R_{sh}$ | 1.6691e-4 Ω/m |
| Electrical resistance screen/sheath 20°C | $R_{so}$ | 1.669e-1 Ω/km |

### Radius

| | | |
|---|---|---|
| Radius conductor | $r_{z1}$ | 0.01515 m |
| Radius shield (inner) | $r_{z2}$ | 0.03305 m |
| Radius shield (outer) | $r_{z3}$ | 0.03305 m |
| Radius sheath (inner) | $r_{z2,sh}$ | 0.03305 m |
| Radius sheath (outer) | $r_{z3,sh}$ | 0.03465 m |
| Radius outersheath | $r_{z6}$ | 0.03775 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 | $\tan\delta_i$ | 0.001 |
| 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 |

### Sheath

| | | |
|---|---|---|
| Specific electrical resistivity sheath material | $\rho_{sh}$ | 2.840e-8 Ω.m |
| Temperature coefficient sheath material | $\alpha_{sh}$ | 4.03e-3 1/K |
| Reciprocal of temperature coefficient sheath material | $\beta_{sh}$ | 2.281e2 K |
| Volumetric heat capacity sheath material | $\sigma_{sh}$ | 2.50e6 J/(K.m$^3$) |
| Thermal conductivity sheath material | $k_{sh}$ | 208.3 W/(m.K) |
| Density sheath material | $\zeta_{sh}$ | 2.712 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 $T_1$ 0.4199 K.m/W

$$T_{ct} + T_{cs} + T_{ins} + T_{is} + T_{scb} + T_{scs} + T_{dsh}$$

Thermal resistance armour bedding $T_2$ 0 K.m/W

Thermal resistance jacket $T_3$ 0.0542 K.m/W

$$T_{ab} + T_j + T_{jj}$$

Thickness conductor—sheath $t_1$ 18.3 mm

$$t_i + t_{scb} + t_{scs} + \frac{H_{sh} + \Delta H}{2}$$

Thickness sheath—armour $t_2$ 0 mm

$$\frac{H_{sh} + \Delta H}{2} + t_{ab}$$

Thickness armour—surface $t_3$ 3.5 mm

$$t_j + t_{jj}$$

### Cable elements

Thermal resistance, transient $T_{tot}$ 0.4741 K.m/W

$$T_1 + T_2 + T_3$$

Thermal resistance insulation $T_i$ 0.41987 K.m/W

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

Thermal resistance conductor shield $T_{cs}$ 0.03756 K.m/W

$$\frac{\rho_{cs}}{2\pi} \ln\left(\frac{D_{cs}}{D_{cs} - 2t_{cs}}\right)$$

Thermal resistance insulation $T_{ins}$ 0.36654 K.m/W

$$\frac{\rho_i}{2\pi} \ln\left(\frac{D_{ins}}{D_{ins} - 2t_{ins}}\right)$$

Thermal resistance insulation screen $T_{is}$ 0.01577 K.m/W

$$\frac{\rho_{is}}{2\pi} \ln\left(\frac{D_{ins} + 2t_{is}}{D_{ins}}\right)$$

Thermal resistance jacket $T_j$ 0.0542 K.m/W

$$\frac{\rho_j}{2\pi} \ln\left(\frac{D_j - 2t_{jj}}{D_j - 2\left(t_j + t_{jj}\right)}\right)$$

## Dimensions

### Diameter

External diameter conductor $d_c$ 30.3 mm

Diameter over conductor shield $D_{cs}$ 33.3 mm

$$d_c + 2\left(t_{ct} + t_{cs}\right)$$

Diameter over insulation $D_{ins}$ 64.3 mm

$$d_c + 2\left(t_{ct} + t_{cs} + t_{ins}\right)$$

| | | |
|---|---|---|
| Diameter over insulation incl. insulation screen<br>$d_c + 2\left(t_{ct} + t_{cs} + t_{ins} + t_{is}\right)$ | $D_i$ | 66.9 mm |
| Diameter over insulation screen<br>$d_c + 2t_i$ | $D_{is}$ | 66.9 mm |
| Equivalent diameter of screen and sheath | $d_s$ | 67.7 mm |
| Mean diameter sheath<br>$D_{shb} + t_{sh} + H_{sh} + \Delta H$ | $d_{sh}$ | 67.7 mm |
| Diameter over sheath<br>$D_{shb} + 2\left(t_{sh} + H_{sh} + \Delta H\right)$ | $D_{sh}$ | 68.5 mm |
| Diameter over sheath jacket | $D_{shj}$ | 68.5 mm |
| Diameter over jacket<br>$D_{ar} + 2\left(t_j + t_{jj}\right)$ | $D_j$ | 75.5 mm |

### Area

| | | |
|---|---|---|
| Cross-sectional area conductor | $A_c$ | 630 mm$^2$ |
| Cross-sectional area insulation<br>$\frac{\pi}{4}\left({D_{is}}^2 - {d_c}^2\right)$ | $A_i$ | 2794.1 mm$^2$ |
| Cross-sectional area sheath<br>$d_{sh} t_{sh} \pi$ | $A_{sh}$ | 170.15 mm$^2$ |
| Cross-sectional area jacket<br>$\frac{\pi}{4}\left({D_j}^2 - \left(D_j - 2\left(t_j + t_{jj}\right)\right)^2\right)$ | $A_j$ | 791.7 mm$^2$ |