

Report

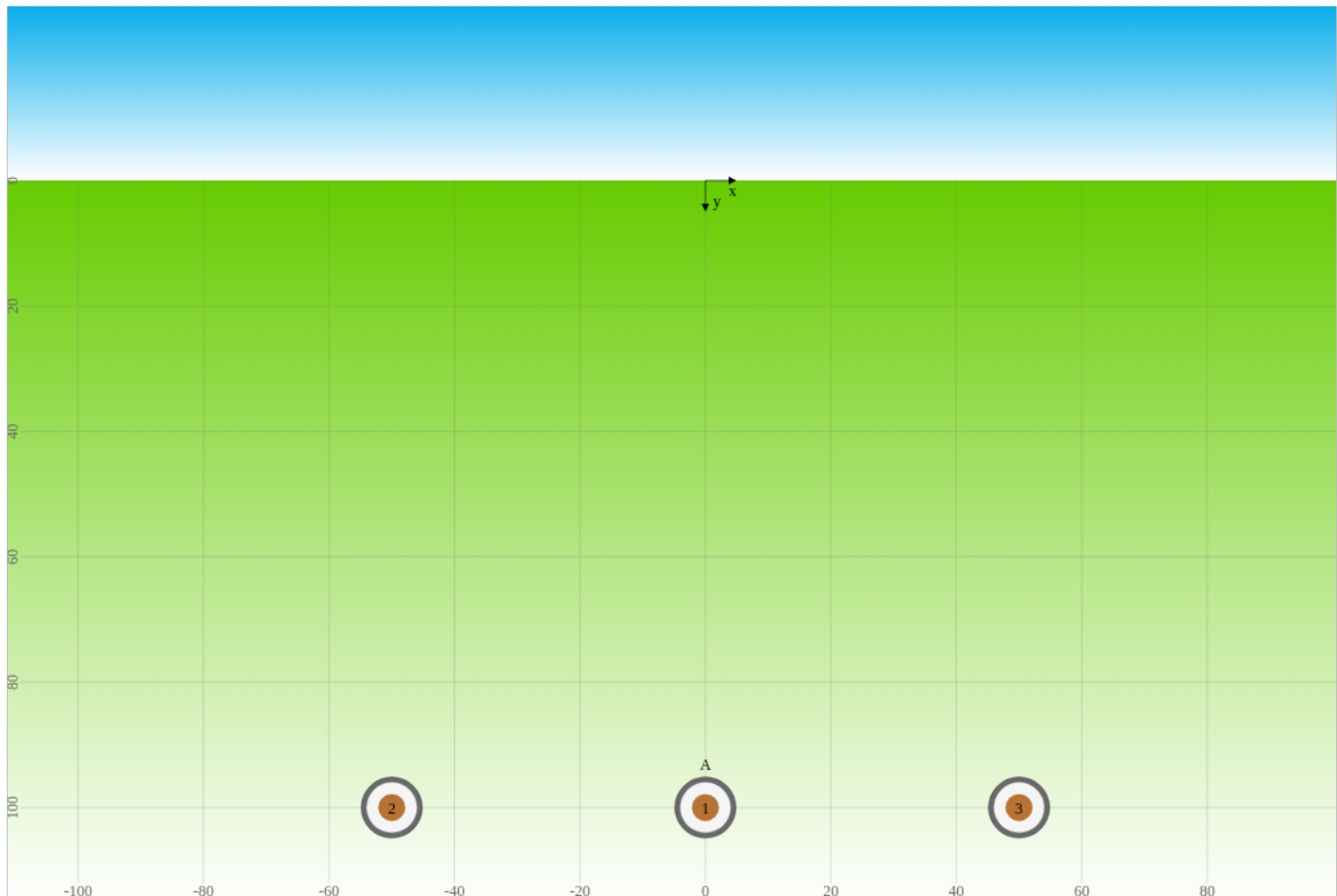
Title	Case study 1-2: Direct buried 132kV cables (flat, cb)
Project	Verification CIGRE TB 880
Created	Date: 2025-05-26 Time: 09:24 Software version: f8c9 (2025-05-24)

Arrangement

Arrangement	buried project (#46692)
Options	None
CIGRE TB 880, guidance points	02, 06, 09, 26, 31
Systems	A

Statistics

Number of iterations of the solver	N_{calc}	10
Sum of currents from all systems	I_{sum}	1457.74 A
Sum of average conductor temperatures from all systems	θ_{sum}	86.36 °C
Number of overheated electrical systems		0
Sum of losses from all systems	W_{sum}	140.897 W/m



Systems

Following systems are active in the arrangement:

#	Object	Current [A]	Temp. [°C]	Losses [W/m]	Load
		I_c	$\theta_c \mid \theta_e$	W_{sys}	LF
A	16301 CIGRE TB 880 Case 1 132kV cable	1457.7	90.0 69.3	140.9	1.00

Objects

Following objects are used:

16301 CIGRE TB 880 Case 1 132kV cable

Ambient

Calculation method		IEC Standard (directly buried)
Ambient temperature	θ_a	20 °C
Thermal resistivity soil	ρ_4	1 K.m/W
Thermal conductivity soil	k_4	1 W/(m.K)
Volumetric heat capacity soil material	$c_{p,soil}$	2136.8 J/(kg.K)
$10^{-4} \frac{k_4^{0.2}}{4.68}$		
Thermal diffusivity soil	δ_{soil}	5.00e-7 m ² /s
Ratio thermal resistivity dry/moist soil	v_4	1
$\frac{\rho_{4d}}{\rho_4}$		

Constants

Standard acceleration of gravity	g	9.80665 m/s ²
Archimedes' constant π	π	3.141592653589793
Absolute temperature	θ_{abs}	273.15 K
Stefan Boltzmann constant	σ	5.67036713e-8 W/m ² K ⁴
Vacuum permeability	μ_0	1.2566370614359173e-6 H/m
Vacuum permittivity	ϵ_0	8.854187817620389e-12 F/m

System A (High voltage cable)**Ampacity**

Cable		CIGRE TB 880 Case 1 132kV cable
Rounded value, CIGRE TB 880	I_c	1450 A
Conductor current	I_c	1457.74 A

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

Operating voltage	U_o	132 kV
Angular frequency $2\pi f$	ω	314.2 rad/s
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		flat
Position cable 1	$x_1 y_1$	0.0 1000.0 mm
Position cable 2	$x_2 y_2$	-500.0 1000.0 mm
Position cable 3	$x_3 y_3$	500.0 1000.0 mm
Separation of conductors in a system	s_c	500 mm
Mean distance between the phases	a_m	629.96 mm
Geometric mean distance between phases of the same system $2^{\frac{1}{3}} S_m$	GMD	0.62996 m
Depth of laying of sources	L_c	1000 mm
Depth of laying	L_{cm}	1 m
Outer diameter	D_o	0.098 m
Substitution coefficient u $\frac{2L_{cm}}{D_o}$	u	20.4082
Geometric constant of circle buried $u + \sqrt{u^2 - 1}$	g_u	40.7918

Temperature

Temperature conductor $\theta_a + \Delta\theta_c - (v_4 - 1) \Delta\theta_x + v_4 \Delta\theta_p$	θ_c	1: 90 2: 84.65 3: 84.43 °C
Temperature screen/sheath $\frac{\theta_{sc} + \theta_{sh}}{2}$	θ_s	1: 71.43 2: 66.04 3: 66.06 °C
Temperature screen $\theta_c - T_1 \left(W_c + \frac{W_d}{2} \right)$	θ_{sc}	1: 72.42 2: 67.3 3: 67.09 °C
Temperature sheath $\theta_{sc} - T_{scs} \left(W_c (1 + \lambda_{11,sc}) + \frac{W_d}{2} \right)$	θ_{sh}	1: 70.44 2: 64.79 3: 65.03 °C

External temperature object θ_e 1: 69.32 | 2: 64.23 | 3: 64.03 °C

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

Temperature rise

Temperature rise conductor $\Delta\theta_c$ 1: 70 | 2: 64.6515 | 3: 64.4277 K

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

Temperature rise dielectric losses $\Delta\theta_d$ 1: 0.6032 | 2: 0.5579 | 3: 0.5579 K

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

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 1: 46.167 | 2: 45.563 | 3: 45.537 W/m

$$I_c^2 R_c$$

Screen/sheath losses (phase) W_s 1: 0.738 | 2: 0.841 | 3: 0.654 W/m

$$\lambda_1 W_c$$

Duct losses W_{duct} 0 W/m

Ohmic losses (phase) W_I 1: 46.905 | 2: 46.404 | 3: 46.191 W/m

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

Dielectric

Dielectric losses (phase) W_d 0.465 W/m

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

Total

Total losses (phase) W_t 1: 47.371 | 2: 46.869 | 3: 46.657 W/m

$$W_I + W_d$$

Total losses (object) W_{tot} 1: 47.371 | 2: 46.869 | 3: 46.657 W/m

$$n_{ph} W_t$$

Total losses (system) W_{sys} 140.897 W/m

Thermal resistance

Thermal resistance ambient $T_{4\mu}$ 1: 1.0411 | 2: 0.9438 | 3: 0.9438 K.m/W

$$= T_{4ss} = T_{4iii} = \frac{\rho_4}{2\pi} (\ln(g_u) + \ln(F_{mh}))$$

Mutual heating coefficient F_{mh} 1: 17 | 2: 9.22 | 3: 9.22

$$\prod_{k=1}^q \frac{d_{pk1}}{d_{pk2}}$$

Cable

Internal thermal resistance for current losses T_{int} 1: 0.4454 | 2: 0.4455 | 3: 0.4453 K.m/W

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

Internal thermal resistance for dielectric losses T_d 0.25487 K.m/W

$$\frac{T_1}{2n_c} + T_2 + T_3$$
Other characteristics**Earthing**

earthing screen/sheath Cross-bonding

Length of sections a_S 1.0 | 1.0 | 1.2 p.u.

Minor ratio of section lengths p_{cb} 1

$$\frac{a_{S2}}{a_{S1}}$$

Major ratio of section lengths q_{cb} 1.2

$$\frac{a_{S3}}{a_{S1}}$$

Factor for cross-bonded earthing f_{cb} 0.004

$$\frac{p_{cb}^2 + q_{cb}^2 + 1 - p_{cb} - p_{cb}q_{cb} - q_{cb}}{(p_{cb} + q_{cb} + 1)^2}$$
Loss factor

Loss factor shield (screen/sheath) λ_1 1: 0.016 | 2: 0.0185 | 3: 0.0144

$$\lambda_{11} + \lambda_{12}$$

Loss factor shield, circulating currents λ_{11} 1: 0.0126 | 2: 0.0176 | 3: 0.0135

$$f_{cb} \frac{R_e}{R_c} 4\xi_{X,2}$$

$$f_{cb} \frac{R_e}{R_c} (\xi_{X,3} + \xi_{X,2} + \xi_{X,1})$$

$$f_{cb} \frac{R_e}{R_c} (\xi_{X,3} + \xi_{X,2} - \xi_{X,1})$$

Parameter ξ calculation of loss factor ξ_X 1: 0.0879 | 2: 0.1331 | 3: 0.5222

$$\frac{2R_e P_X Q_X X_m}{\sqrt{3} (R_e^2 + P_X^2) (R_e^2 + Q_X^2)}$$

$$\frac{0.25 Q_X^2}{R_e^2 + Q_X^2}$$

$$\frac{0.75 P_X^2}{R_e^2 + P_X^2}$$

Loss factor shield, eddy currents λ_{12} 1: 0.0034 | 2: 0.0009 | 3: 0.0009

$$\frac{R_{sh}}{R_c} \left(g_s \lambda_0 (1 + \Delta_1 + \Delta_2) + \frac{(\beta_1 t_{sh})^4}{12 \cdot 10^{12}} \right)$$

Electrical resistance shield/armour R_e 1: 1.3224e-1 | 2: 1.2997e-1 | 3: 1.2992e-1 Ω/km

Substitution coefficient λ_0 for eddy-currents λ_0 1: 0.0001 | 2: 0 | 3: 0

$$6 \frac{m_0^2}{1 + m_0^2} \left(\frac{d_e}{2s_c} \right)^2$$

$$1.5 \frac{m_0^2}{1 + m_0^2} \left(\frac{d_e}{2s_c} \right)^2$$

$1.5 \frac{m_0^2}{1+m_0^2} \left(\frac{d_e}{2s_c} \right)^2$		
Substitution coefficient Δ_1 for eddy-currents	Δ_1	1: 0 2: -0.0129 3: 0.0044
$0.86m_0^{3.08} \left(\frac{d_e}{2s_c} \right)^{1.4m_0+0.7}$		
$\frac{-0.74(m_0+2)\sqrt{m_0}}{2+(m_0-0.3)^2} \left(\frac{d_e}{2s_c} \right)^{m_0+1}$		
$4.7m_0^{0.7} \left(\frac{d_e}{2s_c} \right)^{0.16m_0+2}$		
Substitution coefficient Δ_2 for eddy-currents	Δ_2	1: 0 2: 0 3: 0
0		
$0.92m_0^{3.7} \left(\frac{d_e}{2s_c} \right)^{m_0+2}$		
$21m_0^{3.3} \left(\frac{d_e}{2s_c} \right)^{1.47m_0+5.06}$		
Substitution coefficient m_0 for eddy-currents	m_0	1: 0.0512 2: 0.0522 3: 0.0521 Hz.m/ Ω
$10^{-7} \frac{\omega}{R_{sh}}$		
Substitution coefficient β_1 for eddy-currents	β_1	1: 107.4833 2: 108.5144 3: 108.4695
$\sqrt{\frac{4\pi\omega}{10^7\rho_{sh}(1+\alpha_{sh}(\theta_{sh}-20))}}$		
Substitution coefficient g_s for eddy-currents	g_s	1: 1.000197 2: 1.000199 3: 1.000199
$1 + \left(\frac{t_{sh}}{D_{sh}} \right)^{1.74} (10^{-3}\beta_1 D_{sh} - 1.6)$		
Factor F_e eddy-current losses	F_e	1
Loss factor armour	λ_2	0

Drying-out of soil

Characteristic diameter drying zone	D_{dry}	0.098 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 $R_{cDC}(1+y_s+y_p)$	R_c	1: 2.1726e-5 2: 2.1441e-5 3: 2.1429e-5 Ω /m
Electrical resistance DC conductor $R_{c20}(1+\alpha_c(\theta_c-20))$	R_{cDC}	1: 1.9254e-5 2: 1.8937e-5 3: 1.8923e-5 Ω /m
Skin effect factor conductor $\frac{x_s^4}{192+0.8x_s^4}$	y_s	1: 0.12751 2: 0.13136 3: 0.13153

Factor for skin effect on conductor	x_s	1: 2.28502 2: 2.30409 3: 2.30489
$\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_s}$		
Proximity effect factor conductor	y_p	1: 0.00087 2: 0.00089 3: 0.00089
$\frac{x_p^4}{192 + 0.8x_p^4} \left(\frac{d_c}{s_c}\right)^2 \left(0.312 \left(\frac{d_c}{s_c}\right)^2 + \frac{1.18}{\frac{x_p^4}{192 + 0.8x_p^4} + 0.27}\right)$		
Factor for proximity effect of conductors	x_p	1: 1.55398 2: 1.56695 3: 1.5675
$\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_p}$		
Electrical resistance screen	R_{sc}	1: 1.6854e-4 2: 1.6573e-4 3: 1.6561e-4 Ω/m
$R_{sc} (1 + \alpha_{sc} (\theta_{sc} - 20))$		
Electrical resistance sheath	R_{sh}	1: 6.1385e-4 2: 6.0224e-4 3: 6.0274e-4 Ω/m
$R_{sh} (1 + \alpha_{sh} (\theta_{sh} - 20))$		
Electrical resistance shield	R_s	1: 1.3224e-4 2: 1.2997e-4 3: 1.2992e-4 Ω/m
$\frac{R_{sh} R_{sc}}{R_{sh} + R_{sc}}$		
Reduction factor	RF	1: 0.2066 2: 0.2032 3: 0.2031
$\frac{R_s}{\sqrt{R_s^2 + X_s^2}}$		

Electrical field strength, capacitive load current

Electrical field strength insulation inner/outer	E_i	5.994 3.477 kV/mm
$\frac{U_e}{1000} \frac{1}{r_x \ln\left(\frac{r_{ose}}{r_{isc}}\right)}$		
Radius to point x in insulation	r_x	23.35 40.25 mm
Line-to-ground voltage	U_e	76210.24 V
$\frac{1000U_o}{\sqrt{3}}$		
Capacitance insulation	C_b	2.551e-10 F/m $\rightarrow$ 0.2551 μF
$\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$		
Capacitive load current	I_C	6.107e-3 A/m $\rightarrow$ 6.1069 A
$U_e \omega C_b$		
Charging capacity	P_C	465.41 var/m $\rightarrow$ 465.41 kvar
$n_{ph} U_e^2 \omega C_b$		
Capacitive earth short-circuit current	I_{Ce}	6.107e-3 A/m
$U_e \omega C_E$		

Reactance

Self reactance conductor	X_a	6.865e-4 $\Omega/\text{m} \rightarrow$ 0.6865 Ω
$\omega \frac{\mu_0}{2\pi} \ln\left(\frac{D_E}{GMR_c}\right)$		
Self reactance screen/sheath	X_e	1.532e-4 $\Omega/\text{m} \rightarrow$ 0.1532 Ω
$\omega \frac{\mu_0}{2\pi} \ln\left(\frac{2s_c}{d_s}\right)$		

Mutual reactance between conductors flat formation without transposition X_m 4.355e-5 Ω/m

$$\omega \frac{\mu_0}{2\pi} \ln 2$$

Substitution coefficient P to calculate loss factor by circulating currents P_X 1.967e-4

$$X_e + X_m$$

Substitution coefficient Q to calculate loss factor by circulating currents Q_X 1.387e-4

$$X_e - \frac{X_m}{3}$$

Induced current (approximate)

Induced circulating current shield I_s 1: -39.277+68.030j | 2: 78.555+0.000j | 3: -39.277-68.030j A

$$\max \left(I_c \sqrt{\frac{\lambda_{11, sb} R_c}{R_s}} \right) I_k$$

Loss factor shield, circulating currents $\lambda_{11, sb}$ 1: 0.0126+0.0000j | 2: 0.0176+0.0000j | 3: 0.0135+0.0000j

Load, Voltage drop

Apparent power generator-side S_G 333.284 MVA

$$\sqrt{3} U_o I_c$$

Voltage drop V_{drop} 0.038 V/(A.km) $\rightarrow$ 54.9 V = 0.04%

$$\sqrt{3} (R_c \cos \varphi + \omega L_m \sin \varphi)$$

Inductance (mean) L_m 7.258e-7+0.000e0j H/m $\rightarrow$ 0.7258 mH

$$\frac{\mu_0}{2\pi} \ln \left(\frac{GMD}{GMR_c} \right)$$

Telegrapher equation

Surge impedance Z_C 1: 53.4027-2.5385j | 2: 53.4011-2.5053j | 3: 53.4011-2.5039j Ω

$$\sqrt{\frac{Z_1}{Y_1}}$$

Propagation constant γ_C 1: 2.034e-7+4.279e-6j | 2: 2.008e-7+4.279e-6j | 3: 2.006e-7+4.279e-6j

$$\sqrt{Z_1 Y_1}$$

Impedance valid up to 100 Hz without earth return

Positive sequence admittance Y_1 0.000e0+8.013e-8j S/m $\rightarrow$ 0.0000+0.0001j S

$$G + j\omega C_b$$

Positive sequence impedance Z_1 1: 2.173e-5+2.280e-4j | 2: 2.144e-5+2.280e-4j | 3: 2.143e-5+2.280e-4j Ω/m

$$R_1 + jX_1$$

Positive sequence reactance X_1 2.280e-4 $\Omega/\text{m} \rightarrow$ 0.228 Ω

$$\omega \frac{\mu_0}{2\pi} \ln \left(\frac{GMD}{GMR_c} \right)$$

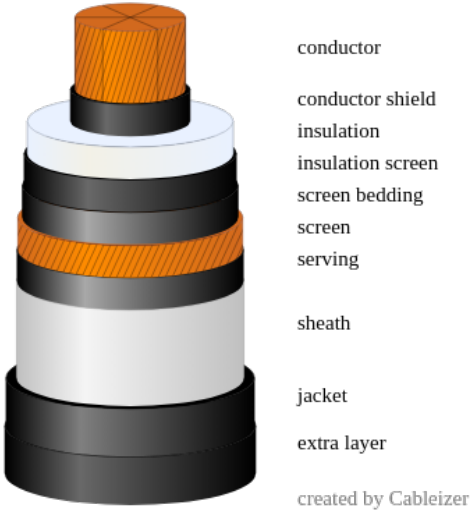
Cable datasheet

TitleCIGRE TB 880 Case 1 132kV cable (#16301)

Cable is used in following systems: [A](#)
CIGRE TB 880, guidance points15, 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 1200 mm ²
Conductor material	M_c	Copper, round Milliken
External diameter conductor	d_c	43.1 mm
Radius conductor	r_c	21.55 mm
$\frac{d_c}{2}$		

Insulation

Insulation material	M_i	Crosslinked polyethylene (XLPE)
Thickness conductor shield	t_{cs}	1.8 mm
Thickness insulation	t_{ins}	16.9 mm
Thickness insulation screen	t_{is}	1.2 mm
Thickness insulation	t_i	19.9 mm
$t_{ct} + t_{cs} + t_{ins} + t_{is}$		

Screen bedding

Screen bedding material		Water-blocking tapes, semi-conducting
Thickness screen bedding	t_{scb}	0.7 mm

Screen

Type		round wires
Screen material	M_{sc}	Copper
diameter wires	t_{sc}	1.77 mm
Number of wires screen	n_{scw}	57
Elongation screen	ν_{sc}	0 %

Screen serving

Screen serving material		Water-blocking tapes
Thickness screen serving	t_{scs}	0.28 mm

Sheath

Sheath material	M_{sh}	Aluminium
Thickness sheath	t_{sh}	0.2 mm
corrugated		No

Jacket

Jacket material	M_j	High density polyethylene (HDPE, ST7)
Thickness jacket	t_j	4.1 mm
Thickness of additional layer over jacket	t_{jj}	0.5 mm

Overall

External diameter object	D_e	98 mm
Absorption coefficient solar radiation	σ_{sun}	0.4
Emissivity cable	ϵ_e	0.9
Reflectivity cable	η_e	0.1
$1 - \epsilon_e$		
Mass cable	m_{tot}	17.127 kg/m
$m_{hollow} + m_{metal}$		

Electrical**Conductor**

Electrical resistance DC conductor 20°C	R_{c20}	1.5100e-5 Ω /m
Standard DC resistance of conductor	R_{co}	0.0151 Ω /km
Coating of wires		plain
Insulation of wires		bare bi-directional wires
Skin effect coefficient	k_s	0.8
Proximity effect coefficient	k_p	0.37
Geometric mean radius conductor	GMR_c	0.01672 m
$K_{GMR} r_{z1}$		
Factor geometric mean radius	K_{GMR}	0.776
Constant relating to conductor formation	K_{BICC}	0.051
Number of wires conductor	n_{cw}	127
Diameter of wires conductor (average)	d_{cw}	3.469 mm

Insulation

Capacitance, with approximation (CIGRE TB 880)	C_b	2.551e-10 F/m
$\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$		
Capacitance (exact)	C_b	2.554e-10 F/m
$\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$		
Capacitance to earth	C_E	2.551e-10 F/m
C_b		
Vacuum permittivity	ϵ_0	8.854187817620389e-12 F/m
Radius above the inner semi-conducting layer	r_{isc}	23.35 mm
$\frac{d_c}{2} + t_{ct} + t_{cs}$		
Radius over capacitive insulation layers	r_{osc}	40.25 mm
$\frac{D_{ins}}{2}$		
Velocity of propagation	v_{prop}	189605.4 km/s
$\frac{1}{1000\sqrt{\mu_0\epsilon_0\epsilon_i}}$		

Screen + Sheath

Electrical resistance screen	R_{sc}	1.3975e-4 Ω /m
$10^6 \frac{F_{lay,sc}\rho_{sc}}{A_{sc}}$		
Effective length per unit lay length screen wires	$F_{lay,sc}$	1.1369
$\sqrt{1 + \left(\frac{\pi d_{sc}}{L_{lay,sc}}\right)^2}$		
Length of lay screen wires	$L_{lay,sc}$	500 mm
Geometric mean radius screen	GMR_{sc}	0.00095 m
$\left(0.7788 \frac{t_{sc}}{2} n_{scw} \left(\frac{t_{sc}}{2}\right)^{n_{scw}-1}\right)^{\frac{1}{n_{scw}}} \frac{1}{1000}$		
Electrical resistance sheath	R_{sh}	5.1016e-4 Ω /m
$10^6 \frac{\rho_{sh}}{A_{sh}}$		
Electrical resistance screen/sheath 20°C	R_{so}	1.097e-1 Ω /km
$\frac{R_{sc}R_{sh}}{R_{sc} + R_{sh}}$		

Radius

Radius conductor	r_{z1}	0.02155 m
Radius shield (inner)	r_{z2}	0.04127 m
Radius shield (outer)	r_{z3}	0.0441 m
Radius screen (inner)	$r_{z2,sc}$	0.04127 m
Radius screen (outer)	$r_{z3,sc}$	0.04481 m
Radius sheath (inner)	$r_{z2,sh}$	0.0441 m
Radius sheath (outer)	$r_{z3,sh}$	0.0445 m
Radius outersheath	r_{z6}	0.049 m

Material parameters

Conductor

Electrical resistivity conductor material	ρ_c	1.724e-8 $\Omega\cdot\text{m}$
Temperature coefficient conductor material	α_c	3.93e-3 1/K
Reciprocal of temperature coefficient conductor material	β_c	2.345e2 K
Volumetric heat capacity conductor material	σ_c	3.45e6 J/(K.m ³)
Thermal conductivity conductor material	k_c	384.62 W/(m.K)
Density conductor material	ζ_c	8.94 g/cm ³

Insulation

Relative permittivity insulation material	ϵ_i	2.5
Loss factor insulation material	$\tan\delta_i$	0.001
Thermal resistivity insulation material	ρ_i	3.5 K.m/W
Volumetric heat capacity insulation material	σ_i	2.40e6 J/(K.m ³)
Density insulation material	ζ_i	0.923 g/cm ³
Max. temperature conductor	θ_{cmax}	90 °C
Max. temperature conductor, emergency overload	θ_{cmaxeo}	105 °C
Max. temperature conductor, short-circuit	θ_{cmaxsc}	250 °C

Conductor shield

Thermal resistivity conductor shield	ρ_{cs}	2.5 K.m/W
--------------------------------------	-------------	-----------

Insulation screen

Thermal resistivity insulation screen	ρ_{is}	2.5 K.m/W
---------------------------------------	-------------	-----------

Screen bedding

Thermal resistivity screen bedding	ρ_{scb}	12 K.m/W
Volumetric heat capacity screen bedding	σ_{scb}	2.00e6 J/(K.m ³)
Density tape material	ζ_{tape}	0.34 g/cm ³

Screen

Specific electrical resistivity screen material	ρ_{sc}	1.724e-8 $\Omega\cdot\text{m}$
Temperature coefficient screen material	α_{sc}	3.93e-3 1/K
Reciprocal of temperature coefficient screen material	β_{sc}	2.345e2 K
Volumetric heat capacity screen material	σ_{sc}	3.45e6 J/(K.m ³)
Thermal conductivity screen material	k_{sc}	370.4 W/(m.K)
Density metallic screen material	ζ_{sc}	8.94 g/cm ³

Screen serving

Thermal resistivity screen serving	ρ_{scs}	12 K.m/W
Volumetric heat capacity screen serving	σ_{scs}	2.00e6 J/(K.m ³)
Density tape material	ζ_{tape}	0.34 g/cm ³

Sheath

Specific electrical resistivity sheath material	ρ_{sh}	2.840e-8 $\Omega\cdot\text{m}$
Temperature coefficient sheath material	α_{sh}	4.03e-3 1/K
Reciprocal of temperature coefficient sheath material	β_{sh}	2.281e2 K
Volumetric heat capacity sheath material	σ_{sh}	2.50e6 J/(K.m ³)
Thermal conductivity sheath material	k_{sh}	208.3 W/(m.K)
Density sheath material	ζ_{sh}	2.712 g/cm ³

Jacket

Thermal resistivity jacket material	ρ_j	3.5 K.m/W
Thermal resistivity additional layer	ρ_{jj}	2.5 K.m/W
Volumetric heat capacity jacket material	σ_j	2.40e6 J/(K.m ³)
Electrical conductivity jacket material	κ_j	2.00e-15 S/m
Density jacket material	ζ_j	0.941 g/cm ³

Thermal resistance**Internal thermal resistances for rating calculation**

Thermal resistance conductor—sheath $T_{ct} + T_{cs} + T_{ins} + T_{is} + T_{scb}$	T_1	0.3789 K.m/W
Thermal resistance armour bedding $T_{scs} + T_{dsh}$	T_2	0.0121 K.m/W
Thermal resistance jacket $T_{ab} + T_j + T_{jj}$	T_3	0.0533 K.m/W
Thickness conductor—sheath $t_i + t_{scb} + t_{scs} + \frac{H_{sh} + \Delta H}{2}$	t_1	20.88 mm
Thickness sheath—armour $\frac{H_{sh} + \Delta H}{2} + t_{ab}$	t_2	0 mm
Thickness armour—surface $t_j + t_{jj}$	t_3	4.6 mm

Cable elements

Thermal resistance, transient $T_1 + T_2 + T_3$	T_{tot}	0.4443 K.m/W
Thermal resistance insulation $T_{ct} + T_{cs} + T_{ins} + T_{is}$	T_i	0.34692 K.m/W
Thermal resistance conductor shield $\frac{\rho_{cs}}{2\pi} \ln \left(\frac{D_{cs}}{D_{cs} - 2t_{cs}} \right)$	T_{cs}	0.03192 K.m/W
Thermal resistance insulation $\frac{\rho_i}{2\pi} \ln \left(\frac{D_{ins}}{D_{ins} - 2t_{ins}} \right)$	T_{ins}	0.30332 K.m/W
Thermal resistance insulation screen $\frac{\rho_{is}}{2\pi} \ln \left(\frac{D_{ins} + 2t_{is}}{D_{ins}} \right)$	T_{is}	0.01169 K.m/W
Thermal resistance screen bedding $\frac{\rho_{scb}}{2\pi} \ln \left(\frac{D_{scb}}{D_i} \right)$	T_{scb}	0.03198 K.m/W
Thermal resistance screen serving $\frac{\rho_{scs}}{2\pi} \ln \left(\frac{D_{scs}}{D_{sc}} \right)$	T_{scs}	0.01214 K.m/W
Thermal resistance jacket $\frac{\rho_j}{2\pi} \ln \left(\frac{D_j - 2t_{jj}}{D_j - 2(t_j + t_{jj})} \right)$	T_j	0.0492 K.m/W

Thermal resistance additional layer	T_{jj}	0.00408 K.m/W
$\frac{\rho_{jj}}{2\pi} \ln \left(\frac{D_j}{D_j - 2t_{jj}} \right)$		

Dimensions

Diameter

External diameter conductor	d_c	43.1 mm
Diameter over conductor shield	D_{cs}	46.7 mm
$d_c + 2(t_{ct} + t_{cs})$		
Diameter over insulation	D_{ins}	80.5 mm
$d_c + 2(t_{ct} + t_{cs} + t_{ins})$		
Diameter over insulation incl. insulation screen	D_i	82.9 mm
$d_c + 2(t_{ct} + t_{cs} + t_{ins} + t_{is})$		
Diameter over insulation screen	D_{is}	82.9 mm
$d_c + 2t_i$		
Diameter over screen bedding	D_{scb}	84.3 mm
$d_c + t_{i1} + 2t_{scb}$		
Mean diameter screen	d_{sc}	86.07 mm
$D_{scb} + t_{sc}$		
Diameter over screen	D_{sc}	87.84 mm
$D_{scb} + 2t_{sc}$		
Equivalent diameter of screen and sheath	d_s	87.344 mm
$\sqrt{\frac{d_{sc}^2 + d_{sh}^2}{2}}$		
Diameter over screen serving	D_{scs}	88.4 mm
$D_{sc} + 2t_{scs}$		
Mean diameter sheath	d_{sh}	88.6 mm
$D_{shb} + t_{sh} + H_{sh} + \Delta H$		
Diameter over sheath	D_{sh}	88.8 mm
$D_{shb} + 2(t_{sh} + H_{sh} + \Delta H)$		
Diameter over sheath jacket	D_{shj}	88.8 mm
Diameter over jacket	D_j	98 mm
$D_{ar} + 2(t_j + t_{jj})$		

Area

Cross-sectional area conductor	A_c	1200 mm ²
Cross-sectional area insulation	A_i	3938.6 mm ²
$\frac{\pi}{4} (D_{is}^2 - d_c^2)$		
Cross-sectional area screen bedding	A_{scb}	183.8 mm ²
$\pi t_{scb} (D_{scb} - t_{scb})$		
Cross-sectional area screen	A_{sc}	140.25 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}	77.5 mm ²
$\pi t_{scs} (D_{scs} - t_{scs})$		

Cross-sectional area sheath $d_{sh}t_{sh}\pi$	A_{sh}	55.67 mm ²
Cross-sectional area jacket $\frac{\pi}{4} \left(D_j^2 - (D_j - 2(t_j + t_{jj}))^2 \right)$	A_j	1349.8 mm ²