

Report

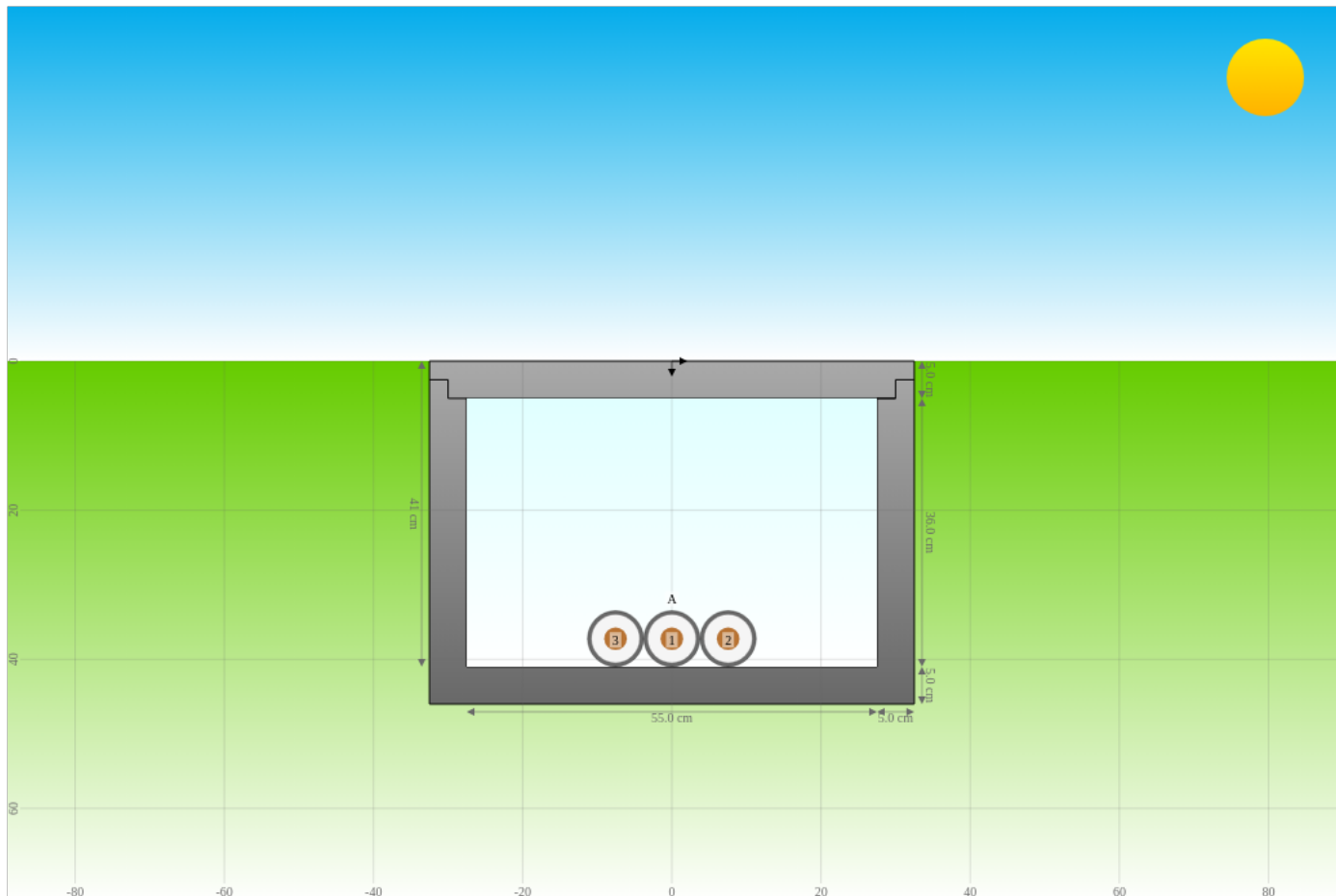
Title	Case study 0-5: Introductory (trough)
Project	Verification CIGRE TB 880
Created	Date: 2025-05-14 Time: 21:23 Software version: 51cac (2025-05-14)

Arrangement

Arrangement	trough project (#1861)
Options	None
CIGRE TB 880, guidance points	02, 06, 26, 31
Systems	A

Statistics

Number of iterations of the solver	N_{calc}	16
Sum of currents from all systems	I_{sum}	766.31 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}	106.374 W/m



Systems

Following systems are active in the arrangement:

#	Object	Current [A] I_c	Temp. [°C] $\theta_c \mid \theta_e$	Losses [W/m] W_{sys}	Load LF
A	16173 CIGRE TB 880 Case 0 XLPE insulated ca...	766.3	90.0 77.9	106.4	1.00

Objects

Following objects are used:

16173 CIGRE TB 880 Case 0 XLPE insulated cable 132 kV

Ambient

Ambient air temperature θ_{air} 25 °C

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

Trough

Calculation method		IEC 60287-2-1
Thermal resistance trough $\frac{1}{3p_{tr}}$	T_{tr}	0.2625 K.m/W
Effective perimeter trough $w_t + 2h_t$	p_{tr}	1.27 m

Dimension

Width (inner)	w_t	0.55 m
Height (inner)	h_t	0.36 m
Thickness wall	t_t	0.05 m
Depth of laying	L_{cm}	0.41 m

conditions inside

Air temperature with load $(1 - \lambda_t) \theta_{iter} + \lambda_t (\theta_{init} + \Delta\theta_{air})$	θ_{at}	52.92 °C
Temperature increase air $T_{tr} W_{sum}$	$\Delta\theta_{air}$	27.9196 K
Air temperature without load $\theta_{air} + \Delta\theta_{sun}$	θ_{init}	25 °C

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

Cable		CIGRE TB 880 Case 0 XLPE insulated cable 132 kV
Conductor current	I_c	766.31 A
$\sqrt{\frac{\theta_c - \theta_{at} - \Delta\theta_d}{R_c (T_1 + n_{ph} (1 + \lambda_1) T_2 + (1 + \lambda_1 + \lambda_2 + \lambda_3) (n_{ph} T_3 + n_{cc} (T_{4i} + T_{4ii} + T_{4iii})))}}$		
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	$x_1 y_1$	0.0 372.3 mm
Position cable 2	$x_2 y_2$	75.5 372.3 mm
Position cable 3	$x_3 y_3$	-75.5 372.3 mm
Separation of conductors in a system	s_c	75.5 mm
Mean distance between the phases	a_m	95.12 mm
Geometric mean distance between phases of the same system	GMD	0.09512 m
	$2^{\frac{1}{3}} S_m$	
Outer diameter	D_o	0.0755 m

Temperature

Temperature conductor $\theta_{at} + \Delta\theta_c$	θ_c	1: 81.36 2: 87.72 3: 90 °C
Temperature screen/sheath	θ_s	1: 71.76 2: 77.95 3: 80.17 °C
Temperature sheath $\theta_c - T_1 \left(W_c + \frac{W_d}{2} \right)$	θ_{sh}	1: 71.76 2: 77.95 3: 80.17 °C
External temperature object $\theta_c - T_1 \left(W_c + \frac{W_d}{2} \right) - n_{ph} T_2 (W_c (1 + \lambda_1) + W_d) - n_{ph} T_3 (W_I + W_d)$	θ_e	1: 70.32 2: 75.91 3: 77.9 °C

Temperature rise

Temperature rise conductor $n_{ph} (W_c T_{int} + W_d T_d) + n_{cc} \left((W_c + W_s + W_{ar} + W_{sp} + W_d) (T_{4i} + T_{4ii} + T_{4iii}) + W_{duct} \left(\frac{T_{4ii}}{2} + T_{4iii} \right) \right)$	$\Delta\theta_c$	1: 28.4449 2: 34.8029 3: 37.0816 K
Temperature rise dielectric losses $W_d (n_{ph} T_d + n_{cc} (T_{4i} + T_{4ii} + T_{4iii}))$	$\Delta\theta_d$	1: 0.3548 2: 0.3377 3: 0.3328 K
Temperature difference surface—ambient $\frac{\Delta\theta_c + \Delta\theta_d}{1 + K_A \Delta\theta_s^{0.25}}$	$\Delta\theta_s$	1: 17.6064 2: 23.2573 3: 25.2948 K

Losses**Ohmic**

Conductor losses (phase) $I_c^2 R_c$	W_c	1: 22.687 2: 23.071 3: 23.208 W/m
Screen/sheath losses (phase) $\lambda_1 W_c$	W_s	1: 3.505 2: 14.292 3: 18.456 W/m
Ohmic losses (phase) $W_c (1 + \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4)$	W_I	1: 26.192 2: 37.362 3: 41.664 W/m

Dielectric

Dielectric losses (phase) $\omega C_b \left(1000 \frac{U_o}{\sqrt{3}} \right)^2 \tan \delta_i$	W_d	0.385 W/m
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Total

Total losses (phase) $W_I + W_d$	W_t	1: 26.577 2: 37.747 3: 42.049 W/m
Total losses (object) $n_{ph} W_t$	W_{tot}	1: 26.577 2: 37.747 3: 42.049 W/m
Total losses (system)	W_{sys}	106.374 W/m

Thermal resistance

Thermal resistance ambient $\frac{1}{\pi D_o h_{bs} \Delta \theta_s^{\frac{1}{4}}}$	T_{4iii}	1: 0.657 2: 0.6128 3: 0.6001 K.m/W
Coefficient K in air $\frac{\pi D_o h_{bs}}{1 + \lambda_1 + \lambda_2 + \lambda_3} T_{int}$	K_A	1: 0.31 2: 0.233 3: 0.214
Heat dissipation coefficient for black surfaces in free air $\frac{Z_{bs}}{D_o^{g_{bs}}} + E_{bs}$	h_{bs}	3.133 W/m ² /K ^{5/4}
Installation constant E	E_{bs}	1.95
Installation constant g	g_{bs}	0.25
Installation constant Z	Z_{bs}	0.62

Cable

Internal thermal resistance for current losses $\frac{T_1}{n_{ph}} + (1 + \lambda_1) T_2 + (1 + \lambda_1 + \lambda_2 + \lambda_3) T_3$	T_{int}	1: 0.4824 2: 0.5076 3: 0.5172 K.m/W
Internal thermal resistance for dielectric losses $\frac{T_1}{2n_c} + T_2 + T_3$	T_d	0.26414 K.m/W

Other characteristics**Earthing**

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

Loss factor

Loss factor shield (screen/sheath) $\lambda_{11} + \lambda_{12}$	λ_1	1: 0.1545 2: 0.6195 3: 0.7952
Loss factor shield, circulating currents $\frac{R_e}{R_c} 4\xi_{X,2}$ $\frac{R_e}{R_c} (\xi_{X,3} + \xi_{X,2} - \xi_{X,1})$ $\frac{R_e}{R_c} (\xi_{X,3} + \xi_{X,2} + \xi_{X,1})$	λ_{11}	1: 0.1545 2: 0.6195 3: 0.7952
Parameter ξ calculation of loss factor $\frac{2R_e P_X Q_X X_m}{\sqrt{3} (R_e^2 + P_X^2) (R_e^2 + Q_X^2)}$ $\frac{0.25 Q_X^2}{R_e^2 + Q_X^2}$ $\frac{0.75 P_X^2}{R_e^2 + P_X^2}$	ξ_X	1: 0.0165 2: 0.0074 3: 0.1277
Loss factor shield, eddy currents	λ_{12}	0
Electrical resistance shield/armour	R_e	1: 2.0173e-1 2: 2.0590e-1 3: 2.0739e-1 Ω/km
Factor F_e eddy-current losses	F_e	1
Loss factor armour	λ_2	0

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: 3.8633e-5 2: 3.9287e-5 3: 3.9522e-5 Ω/m
Electrical resistance DC conductor $R_{c20} (1 + \alpha_c (\theta_c - 20))$	R_{cDC}	1: 3.5125e-5 2: 3.5832e-5 3: 3.6085e-5 Ω/m
Skin effect factor conductor $\frac{x_s^4}{192 + 0.8x_s^4}$	y_s	1: 0.06329 2: 0.06094 3: 0.06012
Factor for skin effect on conductor $\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_s}$	x_s	1: 1.89146 2: 1.87271 3: 1.86612
Proximity effect factor conductor $\frac{x_p^4}{192 + 0.8x_p^4} \left(\frac{d_c}{s_c} \right)^2 \left(0.312 \left(\frac{d_c}{s_c} \right)^2 + \frac{1.18}{\frac{x_p^4}{192 + 0.8x_p^4} + 0.27} \right)$	y_p	1: 0.0366 2: 0.03549 3: 0.0351
Factor for proximity effect of conductors $\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_p}$	x_p	1: 1.89146 2: 1.87271 3: 1.86612
Electrical resistance sheath $R_{sh} (1 + \alpha_{sh} (\theta_{sh} - 20))$	R_{sh}	1: 2.0173e-4 2: 2.0590e-4 3: 2.0739e-4 Ω/m
Electrical resistance shield	R_s	1: 2.0173e-4 2: 2.0590e-4 3: 2.0739e-4 Ω/m

Reduction factor	RF	1: 0.2997 2: 0.3053 3: 0.3073
$\frac{R_s}{\sqrt{R_s^2 + X_s^2}}$		

Electrical field strength, capacitive load current

Electrical field strength insulation inner/outer	E_i	6.956 3.603 kV/mm
$\frac{U_e}{1000} \frac{1}{r_x \ln \left(\frac{r_{osc}}{r_{isc}} \right)}$		

Radius to point x in insulation	r_x	16.65 32.15 mm
Line-to-ground voltage	U_e	76210.24 V
$\frac{1000U_o}{\sqrt{3}}$		

Capacitance insulation	C_b	2.111e-10 F/m → 0.2111 μF
$\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$		

Capacitive load current	I_C	5.054e-3 A/m → 5.0536 A
$U_e \omega C_b$		

Charging capacity	P_C	385.1382 var/m → 385.1382 kvar
$n_{ph} U_e^2 \omega C_b$		

Capacitive earth short-circuit current	I_{Ce}	5.054e-3 A/m
$U_e \omega C_E$		

Reactance

Self reactance conductor	X_a	7.088e-4 Ω/m → 0.7088 Ω
$\omega \frac{\mu_0}{2\pi} \ln \left(\frac{D_E}{GMR_c} \right)$		

Self reactance screen/sheath	X_e	5.040e-5 Ω/m → 0.0504 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	9.396e-5
$X_e + X_m$		

Substitution coefficient Q to calculate loss factor by circulating currents	Q_X	3.589e-5
$X_e - \frac{X_m}{3}$		

Induced current (approximate)

Induced circulating current shield	I_s	298.312+0.000j A
$\max \left(I_c \sqrt{\frac{\lambda_{11, sb} R_c}{R_s}} \right)$		

Loss factor shield, circulating currents	$\lambda_{11, sb}$	1: 0.1545+0.0000j 2: 0.6195+0.0000j 3: 0.7952+0.0000j
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Load, Voltage drop

Apparent power generator-side $\sqrt{3}U_o I_c$	S_G	175.202 MVA
Voltage drop $\sqrt{3}(R_c \cos \varphi + \omega L_m \sin \varphi)$	V_{drop}	0.067 V/(A.km) $\rightarrow$ 51.3 V = 0.04%
Inductance (mean) $\frac{\mu_0}{2\pi} \ln \left(\frac{GMD}{GMR_c} \right)$	L_m	4.187e-7+0.000e0j H/m $\rightarrow$ 0.4187 mH

Telegrapher equation

Surge impedance $\sqrt{\frac{Z_1}{Y_1}}$	Z_C	1: 45.0045-6.4727j 2: 45.0201-6.5799j 3: 45.0257-6.6184j Ω
Propagation constant $\sqrt{Z_1 Y_1}$	γ_C	1: 4.292e-7+2.984e-6j 2: 4.363e-7+2.985e-6j 3: 4.389e-7+2.986e-6j

Impedance valid up to 100 Hz without earth return

Positive sequence admittance $G + j\omega C_b$	Y_1	0.000e0+6.631e-8j S/m $\rightarrow$ 0.0000+0.0001j S
Positive sequence impedance $R_1 + jX_1$	Z_1	1: 3.863e-5+1.315e-4j 2: 3.929e-5+1.315e-4j 3: 3.952e-5+1.315e-4j Ω /m
Positive sequence reactance $\omega \frac{\mu_0}{2\pi} \ln \left(\frac{GMD}{GMR_c} \right)$	X_1	1.315e-4 Ω /m $\rightarrow$ 0.1315 Ω

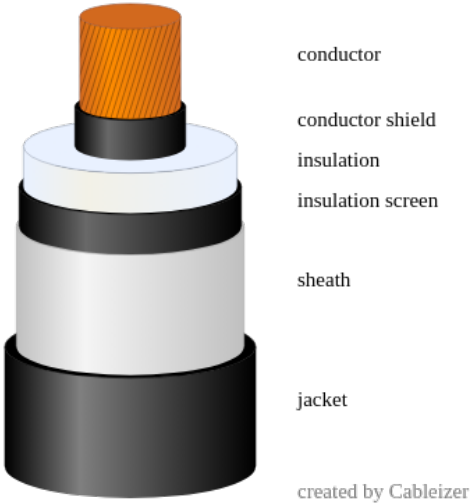
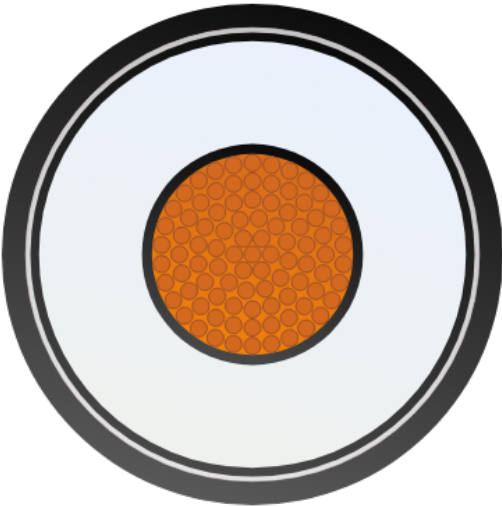
Cable datasheet

TitleCIGRE TB 880 Case 0 XLPE insulated cable 132 kV (#16173)

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 630 mm ²
Conductor material	M_c	Copper, round stranded
External diameter conductor	d_c	30.3 mm
Radius conductor	r_c	15.15 mm
$\frac{d_c}{2}$		

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_i	18.3 mm
$t_{ct} + t_{cs} + t_{ins} + t_{is}$		

Sheath

Sheath material	M_{sh}	Aluminium
Thickness sheath corrugated	t_{sh}	0.8 mm 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	σ_{sun}	0.4
Emissivity cable	ϵ_e	0.9
Reflectivity cable $1 - \epsilon_e$	η_e	0.1
Mass cable $m_{hollow} + m_{metal}$	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 $K_{GMR} r_{z1}$	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) $\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$	C_b	2.111e-10 F/m
Capacitance (exact) $\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$	C_b	2.114e-10 F/m
Capacitance to earth C_b	C_E	2.111e-10 F/m
Vacuum permittivity	ϵ_0	8.854187817620389e-12 F/m
Radius above the inner semi-conducting layer $\frac{d_c}{2} + t_{ct} + t_{cs}$	r_{isc}	16.65 mm
Radius over capacitive insulation layers $\frac{D_{ins}}{2}$	r_{osc}	32.15 mm

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

Screen + Sheath

Electrical resistance sheath	R_{sh}	1.6691e-4 Ω /m
$10^6 \frac{\rho_{sh}}{A_{sh}}$		
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	ρ_c	1.724e-8 Ω .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
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Insulation screen

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

Specific electrical resistivity sheath material	ρ_{sh}	2.840e-8 Ω .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 $T_{ct} + T_{cs} + T_{ins} + T_{is} + T_{scb} + T_{scs} + T_{dsh}$	T_1	0.4199 K.m/W
Thermal resistance armour bedding	T_2	0 K.m/W
Thermal resistance jacket $T_{ab} + T_j + T_{jj}$	T_3	0.0542 K.m/W
Thickness conductor—sheath $t_i + t_{scb} + t_{scs} + \frac{H_{sh} + \Delta H}{2}$	t_1	18.3 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	3.5 mm

Cable elements

Thermal resistance, transient $T_1 + T_2 + T_3$	T_{tot}	0.4741 K.m/W
Thermal resistance insulation $T_{ct} + T_{cs} + T_{ins} + T_{is}$	T_i	0.41987 K.m/W
Thermal resistance conductor shield $\frac{\rho_{cs}}{2\pi} \ln \left(\frac{D_{cs}}{D_{cs} - 2t_{cs}} \right)$	T_{cs}	0.03756 K.m/W
Thermal resistance insulation $\frac{\rho_i}{2\pi} \ln \left(\frac{D_{ins}}{D_{ins} - 2t_{ins}} \right)$	T_{ins}	0.36654 K.m/W
Thermal resistance insulation screen $\frac{\rho_{is}}{2\pi} \ln \left(\frac{D_{ins} + 2t_{is}}{D_{ins}} \right)$	T_{is}	0.01577 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	0.0542 K.m/W

Dimensions**Diameter**

External diameter conductor	d_c	30.3 mm
Diameter over conductor shield $d_c + 2(t_{ct} + t_{cs})$	D_{cs}	33.3 mm
Diameter over insulation $d_c + 2(t_{ct} + t_{cs} + t_{ins})$	D_{ins}	64.3 mm

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

Area

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