

Report

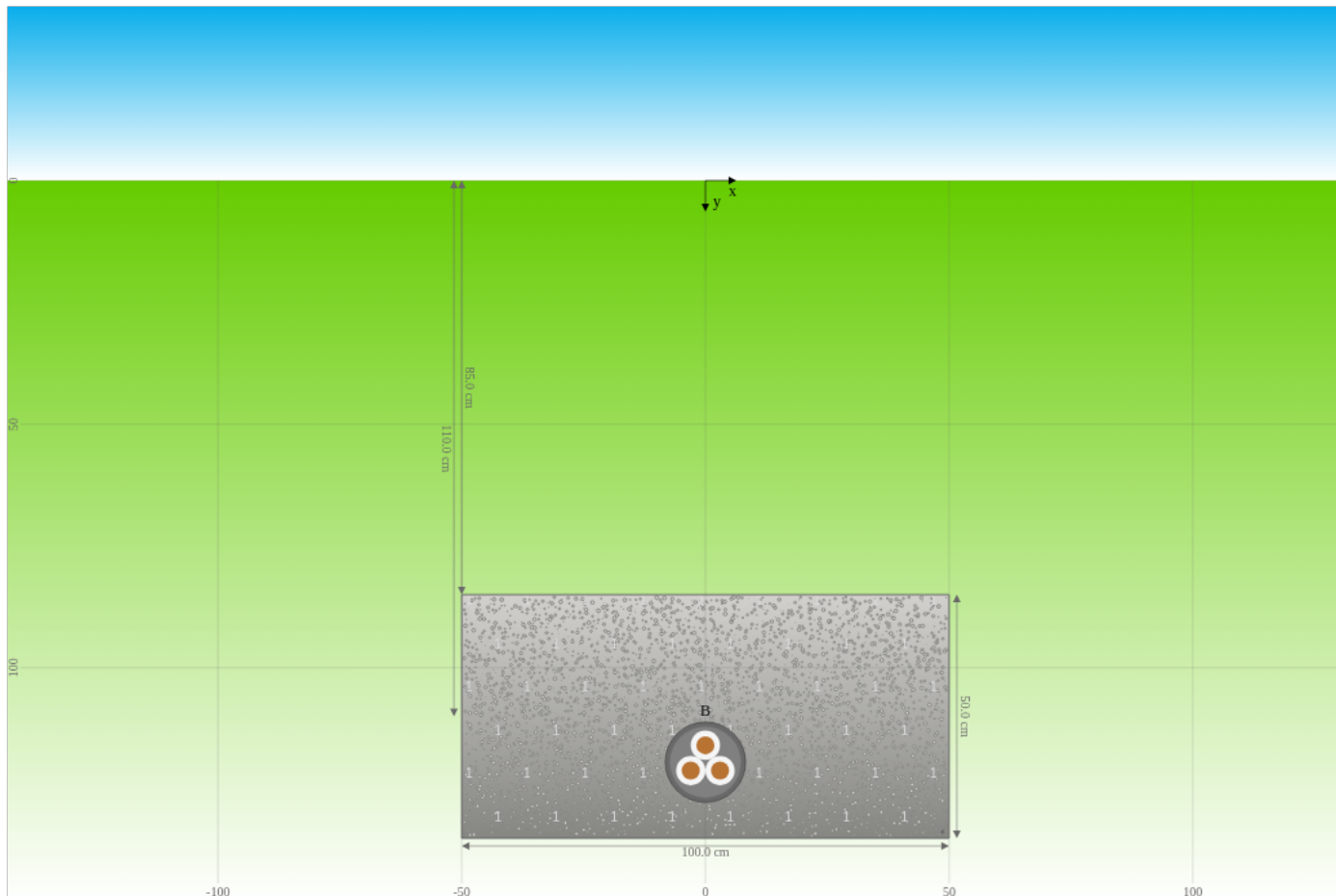
Title	Case study 3: A 230kV HPFF cable
Project	Verification CIGRE TB 880
Created	Date: 2025-05-20 Time: 13:26 Software version: 03eef9 (2025-05-19)

Arrangement

Arrangement	buried project (#46694)
Options	None
CIGRE TB 880, guidance points	02, 06, 26, 31
Systems	B

Statistics

Number of iterations of the solver	N_{calc}	10
Sum of currents from all systems	I_{sum}	1184.32 A
Sum of average conductor temperatures from all systems	θ_{sum}	85 °C
Number of overheated electrical systems		0
Sum of losses from all systems	W_{sum}	135.184 W/m



Systems

Following systems are active in the arrangement:

#	Object	Current [A]	Temp. [°C]	Losses [W/m]	Load
		I_c I_{cLF}	θ_c θ_e	W_{sys} μW_{sys}	LF μ
B	16304 CIGRE TB 880 Case 3 230kV HPFF cable SI	1184.3 1059.3	85.0 63.4	135.2 93.0	0.80 0.69

Objects

Following objects are used:

16304 CIGRE TB 880 Case 3 230kV HPFF cable SI

Ambient

Calculation method		IEC Standard (with backfill)
Ambient temperature	θ_a	25 °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}	4.68e-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

Zones

Backfill 1

Calculation method		IEC 60287-2-1 ed2.0 (2015)
Thermal resistivity backfill	ρ_b	0.55 K.m/W
Horizontal center backfill	x_b	0 mm
Vertical center backfill	L_b	1100 mm
Height backfill	h_b	500 mm
Width backfill	w_b	1000 mm
Geometric factor backfill	G_b	1.8387
$\ln(u_b + \sqrt{u_b^2 - 1})$		
Substitution coefficient u	u_b	3.224
$\frac{L_b}{r_b}$		
Equivalent radius backfill	r_b	341.2 mm
$e^{\frac{\text{Min}(w_b, h_b)}{2 \text{Max}(w_b, h_b)} \left(\frac{4}{\pi} - \frac{\text{Min}(w_b, h_b)}{\text{Max}(w_b, h_b)} \right) \ln \left(1 + \left(\frac{\text{Max}(w_b, h_b)}{\text{Min}(w_b, h_b)} \right)^2 \right) + \ln \left(\frac{\text{Min}(w_b, h_b)}{2} \right)}$		

System B (High voltage cable)

Warning! The conductor temperature exceeds the maximum allowable temperature of 80.0 °C under emergency overload operation.

Ampacity

Cable CIGRE TB 880 Case 3 230kV HPFF cable SI

Rounded value, CIGRE TB 880

I_c 1180 A

Conductor current

I_c 1184.32 A

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

Conductor root mean square current

$I_{c,LF}$ 1059.29 A

$$\sqrt{LF} I_c$$

Operating voltage

U_o 230 kV

Angular frequency

ω 377 rad/s

$$2\pi f$$

Number of sources in system

N_c 1

Number of conductors combined

n_{cc} 3

$$N_c n_{ph}$$

Load

System frequency

f 60 Hz

Cyclic load with Load factor

LF 0.8 p.u.

Loss factor daily load variation

μ 0.688 p.u.

$$k_{LF} LF + (1 - k_{LF}) LF^2$$

Characteristic diameter daily load

D_x 205.1 mm

$$60000 K_x \sqrt{\frac{\tau}{3600} \delta_{soil}}$$

Factor for fictitious diameter by Neher

K_x 1.02

Transient load period

τ 24 hours

Load loss coefficient

k_{LF} 0.3 p.u.

Arrangement

Arrangement

individual

Position cable 1

$x_1 | y_1$ 0.0 | 1193.8 mm

Separation of conductors in a system

s_c 79.96 mm

Mean distance between the phases

a_m 79.959 mm

Geometric mean distance between phases of the same system

GMD 0.02095 m

$$GMR_{cc}$$

Depth of laying of sources

L_c 1193.8 mm

Depth of laying

L_{cm} 1.194 m

Outer diameter

D_o 0.2231 m

Substitution coefficient u

u 10.7001

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

Geometric constant of circle buried

g_u 21.3533

$$u + \sqrt{u^2 - 1}$$

Geometric constant of circle characteristic diameter g_x 23.2338 p.u.

$$\frac{2L_c}{D_x} + \sqrt{\left(\frac{2L_c}{D_x}\right)^2 - 1}$$

Temperature

Temperature conductor θ_c 85 °C

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

Temperature screen/sheath θ_s 71.63 °C

Temperature screen θ_{sc} 71.63 °C

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

Mean temperature medium in the steel pipe θ_{spf} 68.23 °C

$$\frac{\theta_{sc}}{2} + \frac{\theta_{sp}}{2}$$

Temperature steel pipe θ_{sp} 64.83 °C

$$\theta_c - T_1 \left(W_c + \frac{W_d}{2} \right) - n_{ph} T_2 (W_c (1 + \lambda_1 + \lambda_2) + W_d)$$

External temperature object θ_e 63.45 °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 $\Delta\theta_c$ 60 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 $\Delta\theta_d$ 5.6122 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 30.104 W/m

$$I_c^2 R_c$$

Screen/sheath losses (phase) W_s 0.085 W/m

$$\lambda_1 W_c$$

Steel pipe losses (phase) W_{sp} 11.454 W/m

$$\lambda_3 W_c$$

Duct losses W_{duct} 0 W/m

Ohmic losses (phase) W_I 41.643 W/m

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

Dielectric

Dielectric losses (phase)	W_d	3.418 W/m
$\omega C_b \left(1000 \frac{U_o}{\sqrt{3}} \right)^2 \tan \delta_i$		

Total

Total losses (phase)	W_t	45.061 W/m
$W_I + W_d$		
Total losses (object)	W_{tot}	135.184 W/m
$n_{ph} W_t$		
Total losses (system)	W_{sys}	135.184 W/m

Thermal resistance

Thermal resistance ambient	$T_{4\mu}$	0.275 K.m/W
$T_{4ss} \left(\mu + \frac{(1-\mu) T_{4d}}{T_{4ss}} \right)$		
Thermal resistance steady-state	T_{4ss}	0.3996 K.m/W
$T_{4iii} + T_{4db}$		
Thermal resistance daily load cycle	T_{4d}	0 K.m/W
$\frac{\rho_b}{2\pi} \ln \left(\frac{\text{Max}(D_x, D_{od})}{D_{od}} \right)$		
Mutual heating coefficient	F_{mh}	1

Backfill

Thermal resistance backfill correction	T_{4db}	0.1317 K.m/W
$\frac{N_b (\rho_4 - \rho_b)}{2\pi} G_b$		
Number of loaded objects in backfill	N_b	1
Thermal resistance ambient	T_{4iii}	0.268 K.m/W
$\frac{\rho_4}{2\pi} (\ln(g_u) + \ln(F_{mh}))$		
Thermal resistance steel pipe filling @ 68.2 °C	T_2	0.0674 K.m/W
$\frac{U_{spf}}{1 + 0.1 (V_{spf} + Y_{spf} \theta_{spf}) D_{eq}}$		

Cable

Internal thermal resistance for current losses	T_{int}	0.2219 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	0.14771 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)	λ_1	0.0028
$\lambda_{11} + \lambda_{12}$		
Loss factor shield, circulating currents	λ_{11}	0.0028
$\frac{1.5 \frac{R_e}{R_c}}{1 + \left(\frac{R_e}{X_e}\right)^2}$		
Loss factor shield, eddy currents	λ_{12}	0
Electrical resistance shield/armour	R_e	1.1038e2 Ω /km
Loss factor armour	λ_2	0
Loss factor steel pipe pipe-type cable	λ_3	0.3805
$10^{-5} \frac{0.00438s_c + 0.00226Di_{sp}}{R_c} \left(\frac{f}{60}\right)^2 \sqrt{\frac{60}{f}}$		

Drying-out of soil

Characteristic diameter drying zone	D_{dry}	0.223 m
Depth characteristic diameter drying zone	L_{dry}	1.194 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_c	2.1463e-5 Ω /m $\rightarrow$ 0.0215 Ω
$R_{cDC} (1 + 1.5 (y_s + y_p))$		
Electrical resistance DC conductor	R_{cDC}	1.8035e-5 Ω /m $\rightarrow$ 0.018 Ω
$R_{c20} (1 + \alpha_c (\theta_c - 20))$		
Skin effect factor conductor	y_s	0.0653
$\frac{x_s^4}{192 + 0.8x_s^4}$		
Factor for skin effect on conductor	x_s	1.90713
$\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_s}$		
Proximity effect factor conductor	y_p	0.06142
$\frac{x_p^4}{192 + 0.8x_p^4} \left(\frac{d_c}{s_c}\right)^2 \left(0.312 \left(\frac{d_c}{s_c}\right)^2 + \frac{1.18}{\frac{x_p^4}{192 + 0.8x_p^4} + 0.27}\right)$		
Factor for proximity effect of conductors	x_p	1.75889
$\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_p}$		
Electrical resistance screen	R_{sc}	1.5285e0 Ω /m $\rightarrow$ 1528.4707 Ω
$R_{sc} (1 + \alpha_{sc} (\theta_{sc} - 20))$		
Electrical resistance skid wires	R_{sw}	1.1898e-1 Ω /m $\rightarrow$ 118.9759 Ω
Electrical resistance shield	R_s	1.1038e-1 Ω /m $\rightarrow$ 110.3837 Ω
$\frac{1}{\frac{1}{R_{sc}} + \frac{1}{R_{sw}}}$		

Reduction factor	RF	1
$\frac{R_s}{\sqrt{R_s^2 + X_s^2}}$		
Electrical resistance steel pipe	R_{sp}	3.9080e-5 Ω /m $\rightarrow$ 0.0391 Ω
$R_{sp}(1 + \alpha_{sp}(\theta_{sp} - 20))$		

Electrical field strength, capacitive load current

Electrical field strength insulation inner/outer	E_i	13.019 8.524 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	24.079 36.779 mm
Line-to-ground voltage	U_e	132790.56 V
$\frac{1000U_o}{\sqrt{3}}$		
Capacitance insulation	C_b	3.672e-10 F/m $\rightarrow$ 0.3672 μ F
$\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$		
Capacitive load current	I_C	1.838e-2 A/m $\rightarrow$ 18.3842 A
$U_e \omega C_b$		
Charging capacity	P_C	7323.7363 var/m $\rightarrow$ 7323.7363 kvar
$n_{ph} U_e^2 \omega C_b$		
Capacitive earth short-circuit current	I_{Ce}	5.515e-2 A/m
$3U_e \omega C_E$		

Reactance

Self reactance conductor	X_a	8.184e-4 Ω /m $\rightarrow$ 0.8184 Ω
$\omega \frac{\mu_0}{2\pi} \ln\left(\frac{D_E}{GMR_c}\right)$		
Self reactance screen/sheath	X_e	6.679e-5 Ω /m $\rightarrow$ 0.0668 Ω
$\omega \frac{\mu_0}{2\pi} \ln\left(\frac{2.3s_c}{d_s}\right)$		

Induced current (approximate)

Induced circulating current shield	I_s	0.878+0.000j A
$\max\left(I_c \sqrt{\frac{\lambda_{11, sb} R_c}{R_s}}\right)$		
Loss factor shield, circulating currents	$\lambda_{11, sb}$	0.0028+0.0000j
Induced circulating current pipe	I_{sp}	541.385 A
$I_c \sqrt{\frac{\lambda_3 R_c}{R_{sp}}}$		

Load, Voltage drop

Apparent power generator-side	S_G	471.799 MVA
$\sqrt{3}U_o I_c$		
Voltage drop	V_{drop}	0.037 V/(A.km) $\rightarrow$ 44 V = 0.02%
$\sqrt{3}(R_c \cos\varphi + \omega L_m \sin\varphi)$		

Inductance (mean)

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

L_m

$3.058\text{e-}8 + 0.000\text{e}0\text{j H/m} \rightarrow 0.0306 \text{ mH}$

Telegrapher equation

Surge impedance

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

Z_C

$48.3068 - 2.0360\text{j } \Omega$

Propagation constant

$$\sqrt{Z_1 Y_1}$$

γ_C

$2.819\text{e-}7 + 6.688\text{e-}6\text{j}$

Impedance valid up to 100 Hz without earth return

Positive sequence admittance

$$G + j\omega C_b$$

Y_1

$0.000\text{e}0 + 1.384\text{e-}7\text{j S/m} \rightarrow 0.0000 + 0.0001\text{j S}$

Positive sequence impedance

$$R_1 + jX_1$$

Z_1

$2.723\text{e-}5 + 3.225\text{e-}4\text{j } \Omega/\text{m} \rightarrow 0.0272 + 0.3225\text{j } \Omega$

Positive sequence reactance

$$1.15\omega \frac{\mu_0}{2\pi} \ln \left(\frac{S_{sp}}{GMR_{sp}} \right)$$

X_1

$3.225\text{e-}4 \text{ } \Omega/\text{m} \rightarrow 0.3225 \text{ } \Omega$

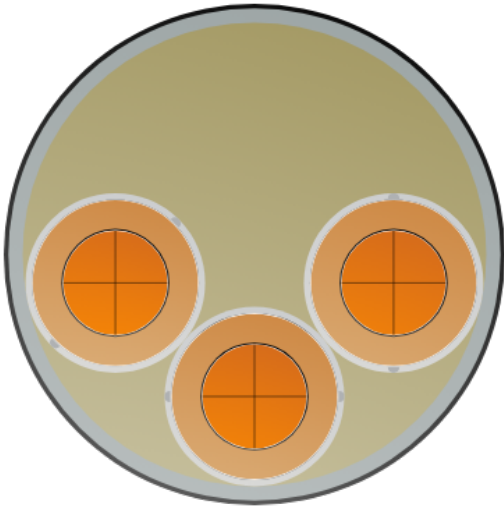
Cable datasheet

Title	CIGRE TB 880 Case 3 230kV HPFF cable SI (#16304)
Description	SI units

Info! Electric stress is higher than recommended in Cigre ELT-151 ($U_n \geq 220$ kV).
Info! PPLP was developed for EHV cables $U_n > 330$ kV.
Cable is used in following systems: [B](#)
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	220 kV
Base voltage for tests	U_0	127 kV
Highest voltage for equipment	U_m	245 kV
Nominal system frequency	f	50 Hz
Number of conductors cable	n_c	3
Number of phases in a cable	n_{ph}	3



Cable elements

Conductor

Cross-sectional area conductor	A_c	3 x 2500 kcmil (1270 mm ²)
Conductor material	M_c	Copper, round Milliken
External diameter conductor	d_c	46.33 mm
Radius conductor	r_c	23.165 mm
$\frac{d_c}{2}$		
Geometrical distance factor for multi-core cables	F_x	2.1547
$1 + \frac{1}{\sin\left(\frac{\pi}{3}\right)}$		
Distance conductor axis—cable axis	c_c	41.238 mm
$\frac{D_f - s_c}{2}$		
Separation of conductors in a system	s_c	79.96 mm
D_{sw}		

Insulation

Insulation material	M_i	Polypropylene laminated paper (PPLP)
Thickness conductor tape	t_{ct}	0.25 mm
Thickness conductor shield	t_{cs}	0.66 mm
Thickness insulation	t_{ins}	12.7 mm
Thickness insulation screen	t_{is}	0.36 mm
Thickness insulation	t_i	13.97 mm
$t_{ct} + t_{cs} + t_{ins} + t_{is}$		
Thickness of insulation between conductors	t_{i1}	27.94 mm
$2t_i$		
Thickness of insulation between conductor and metallic sheath	t_{i2}	14.57 mm
$t_i + t_{scb} + t_{scs} + t_f$		
Material of conductor tapes		Semiconducting tapes

Screen bedding

Screen bedding material		Water-blocking tapes, semi-conducting
Thickness screen bedding	t_{scb}	0.05 mm

Screen

Type		Tapes
Screen material	M_{sc}	Stainless steel
Diameter over screen	t_{sc}	0.127 mm
Thickness skid wires	t_{sw}	2.54 mm
Number of wires skid wires	n_{sw}	2

Steel pipe

Steel pipe filling medium	M_{spf}	Dielectric oil
Thickness steel pipe	t_{sp}	6.35 mm

Jacket

Jacket material	M_j	High density polyethylene (HDPE, ST7)
Thickness jacket	t_j	2.03 mm

Overall

External diameter object	D_e	223.139 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}	76.972 kg/m
$m_{hollow} + m_{metal}$		

Electrical**Conductor**

Electrical resistance DC conductor 20°C	R_{c20}	1.4365e-5 Ω/m
Standard DC resistance of conductor	R_{co}	0.0144 Ω/km
Coating of wires		plain
Insulation of wires		bare bi-directional wires
Skin effect coefficient	k_s	0.435

Proximity effect coefficient	k_p	0.37
Geometric mean radius conductor bundle $\left(GMR_c \left(\frac{s_c}{1000}\right)^{n_c}\right)^{\frac{1}{n_c}}$	GMR_{cc}	0.02095 mm
Geometric mean radius conductor $K_{GMR} r_{z1}$	GMR_c	0.01798 m
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}	3.568 mm

Insulation

Capacitance, with approximation (CIGRE TB 880) $\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$	C_b	3.672e-10 F/m
Capacitance (exact) $\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$	C_b	3.677e-10 F/m
Capacitance to earth C_b	C_E	3.672e-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}	24.079 mm
Radius over capacitive insulation layers $\frac{D_{ins}}{2}$	r_{osc}	36.779 mm
Velocity of propagation $\frac{1}{1000\sqrt{\mu_0\epsilon_0\epsilon_i}}$	v_{prop}	179160.3 km/s

Screen + Sheath

Electrical resistance screen $10^6 \frac{F_{lay,sc}\rho_{sc}}{A_{sc}}$	R_{sc}	1.5285e0 Ω /m
Electrical resistance skid wires $10^6 \frac{\rho_{sw}}{A_{sw}}$	R_{sw}	3.4537e-02 Ω /m
Electrical resistance skid wires, CIGRE TB 880 $F_{lay,sw} R_{sw}$	R_{sw}	1.1898e-01 Ω /m
Electrical resistance of screen and skid wires $\frac{1}{\frac{1}{R_{sc}} + \frac{1}{R_{sw}}}$	R_s	1.1038e-1 Ω /m
Effective length per unit lay length screen wires $\sqrt{1 + \left(\frac{\pi d_{sc}}{L_{lay,sc}}\right)^2}$	$F_{lay,sc}$	12.3264
Length of lay screen wires	$L_{lay,sc}$	19.05 mm

Effective length per unit lay length skid wires	$F_{lay,sw}$	3.4449
$\sqrt{1 + \left(\frac{\pi D_{sw}}{L_{lay,sw}}\right)^2}$		
Length of lay skid wires	$L_{lay,sw}$	76.2 mm
Electrical resistance screen/sheath 20°C	R_{so}	1.528e3 Ω/km

Steel pipe

Electrical resistance steel pipe	R_{sp}	3.2519e-5 Ω/m
$10^6 \frac{\rho_{sp}}{A_{sp}}$		
Geometric mean radius steel pipe	GMR_{sp}	0.02862 m
$e^{-(\frac{1}{4})} \sqrt{\frac{A_{sp}}{\pi}} \frac{1}{1000}$		

Radius

Radius conductor	r_{z1}	0.02316 m
Radius shield (inner)	r_{z2}	0.03712 m
Radius shield (outer)	r_{z3}	0.03738 m
Radius screen (inner)	$r_{z2,sc}$	0.03712 m
Radius screen (outer)	$r_{z3,sc}$	0.03738 m
Radius outersheath	r_{z6}	0.11157 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	2.8
Loss factor insulation material	$\tan\delta_i$	0.0014
Thermal resistivity insulation material	ρ_i	5.5 K.m/W
Volumetric heat capacity insulation material	σ_i	2.00e6 J/(K.m ³)
Density insulation material	ζ_i	0.9 g/cm ³
Max. temperature conductor	θ_{cmax}	70 °C
Max. temperature conductor, emergency overload	θ_{cmaxeo}	80 °C
Max. temperature conductor, short-circuit	θ_{cmaxsc}	130 °C

Conductor tape

Thermal resistivity conductor tape	ρ_{ct}	6 K.m/W
Density tape material	ζ_{tape}	0.34 g/cm ³

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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Screen bedding

Thermal resistivity screen bedding	ρ_{scb}	6 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}	7.000e-7 Ω .m
Temperature coefficient screen material	α_{sc}	1.00e-3 1/K
Reciprocal of temperature coefficient screen material	β_{sc}	9.800e2 K
Volumetric heat capacity screen material	σ_{sc}	3.80e6 J/(K.m ³)
Thermal conductivity screen material	k_{sc}	14.4 W/(m.K)
Density metallic screen material	ζ_{sc}	7.48 g/cm ³

Skid wires

Specific electrical resistivity skid wire material	ρ_{sw}	7.000e-7 Ω .m
Temperature coefficient skid wire material	α_{sw}	1.00e-3 1/K
Reciprocal of temperature coefficient skid wire material	β_{sw}	9.800e2 K
Volumetric heat capacity skid wires	σ_{sw}	3.80e6 J/(K.m ³)
Thermal conductivity skid wires	k_{sw}	14.4
Density skid wire material	ζ_{sw}	7.48 g/cm ³

Steel pipe

Specific electrical resistivity steel pipe material	ρ_{sp}	1.380e-7 Ω .m
Temperature coefficient steel pipe material	α_{sp}	4.50e-3 1/K
Reciprocal of temperature coefficient steel pipe material	β_{sp}	2.022e2 K
Volumetric heat capacity steel pipe material	σ_{sp}	3.80e6 J/(K.m ³)
Thermal conductivity steel pipe material	k_{sp}	36.1 W/(m.K)
Density steel pipe material	ζ_{sp}	7.85 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 $\frac{\rho_i}{2\pi} \ln \left(1 + \frac{2t_1}{d_c} \right)$	T_1	0.4203 K.m/W
Thermal resistance between sheath and pipe $T_{spf} + T_{ab}$	T_2	0.0841 K.m/W
Thermal resistance jacket $\frac{\rho_j}{2\pi} \ln \left(\frac{D_j}{D_j - 2t_3} \right)$	T_3	0.0102 K.m/W
Thickness conductor—sheath $\frac{D_{sc}}{2} - \frac{d_c}{2} + t_{scs}$	t_1	14.27 mm

Thickness sheath—armour $t_{shj} + t_{ab} + t_f$	t_2	0.55 mm
Thickness armour—surface $t_j + t_{jj}$	t_3	2.03 mm

Cable elements

Thermal resistance, transient $T_1 + T_2 + T_3$	T_{tot}	0.5146 K.m/W
Thermal resistance insulation $T_{ct} + T_{cs} + T_{ins} + T_{is}$	T_i	0.39609 K.m/W
Thermal resistance conductor tape $\frac{\rho_{ct}}{2\pi} \ln \left(\frac{d_c + 2t_{ct}}{d_c} \right)$	T_{ct}	0.01041 K.m/W
Thermal resistance conductor shield $\frac{\rho_{cs}}{2\pi} \ln \left(\frac{D_{cs}}{D_{cs} - 2t_{cs}} \right)$	T_{cs}	0.01106 K.m/W
Thermal resistance insulation $\frac{\rho_i}{2\pi} \ln \left(\frac{D_{ins}}{D_{ins} - 2t_{ins}} \right)$	T_{ins}	0.37079 K.m/W
Thermal resistance insulation screen $\frac{\rho_{is}}{2\pi} \ln \left(\frac{D_{ins} + 2t_{is}}{D_{ins}} \right)$	T_{is}	0.00383 K.m/W
Thermal resistance screen bedding $\frac{\rho_{scb}}{2\pi} \ln \left(\frac{D_{scb}}{D_i} \right)$	T_{scb}	0.00131 K.m/W
Thermal resistance steel pipe filling @ 50.0 °C $\frac{U_{spf}}{1 + 0.1 (V_{spf} + Y_{spf} \theta_{spf}) D_{eq}}$	T_{spf}	0.0841 K.m/W
Constant U pipe-type cable	U_{spf}	0.26
Constant V pipe-type cables	V_{spf}	0
Constant Y pipe-type cables	Y_{spf}	0.0026
Equivalent diameter of a group of round objects $2.15D_{sc}$	D_{eq}	160.99 mm
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	0.01024 K.m/W

Dimensions

Diameter

External diameter conductor	d_c	46.33 mm
Diameter over conductor shield $d_c + 2(t_{ct} + t_{cs})$	D_{cs}	48.158 mm
Diameter over insulation $d_c + 2(t_{ct} + t_{cs} + t_{ins})$	D_{ins}	73.558 mm
Diameter over insulation incl. insulation screen $d_c + 2(t_{ct} + t_{cs} + t_{ins} + t_{is})$	D_i	74.27 mm
Diameter over insulation screen $d_c + 2t_i$	D_{is}	74.27 mm

Diameter over screen bedding $d_c + t_{i1} + 2t_{scb}$	D_{scb}	74.371 mm
Mean diameter screen $D_{scb} + t_{sc}$	d_{sc}	74.498 mm
Diameter over screen $D_{scb} + 2n_{scw}t_{sc}$	D_{sc}	74.879 mm
Equivalent diameter of screen and sheath $\sqrt{\frac{\left(\frac{D_{ins}+D_{sc}}{2}\right)^2 + \left(\frac{D_{sc}+D_{sw}}{2}\right)^2}{2}}$	d_s	75.836 mm
Diameter over skid wires $D_{sc} + 2t_{sw}$	D_{sw}	79.959 mm
Diameter over core cable	D_{core}	74.879 mm
Diameter over filler $F_x D_{sh} + 2t_f$	D_f	162.435 mm
Inner diameter steel pipe	Di_{sp}	206.375 mm
Outer diameter steel pipe $Di_{sp} + 2t_{sp}$	Do_{sp}	219.075 mm
Diameter over jacket $Do_{sp} + 2t_j$	D_j	223.139 mm

Area

values are per phase

Cross-sectional area conductor	A_c	1270 mm ²
Cross-sectional area insulation $\frac{\pi}{4} (D_{is}^2 - d_c^2)$	A_i	2646.4 mm ²
Cross-sectional area screen bedding $\pi t_{scb} (D_{scb} - t_{scb})$	A_{scb}	11.9 mm ²
Cross-sectional area screen $n_{scw} t_{sc} w_{sc}$	A_{sc}	5.65 mm ²
Cross-sectional area skid wires $n_{sw} \frac{\pi}{2} t_{sw}^2$	A_{sw}	20.3 mm ²
Cross-sectional area jacket $\frac{\pi}{4} (D_j^2 - (D_j - 2(t_j + t_{jj}))^2)$	A_j	1411.5 mm ²