Report

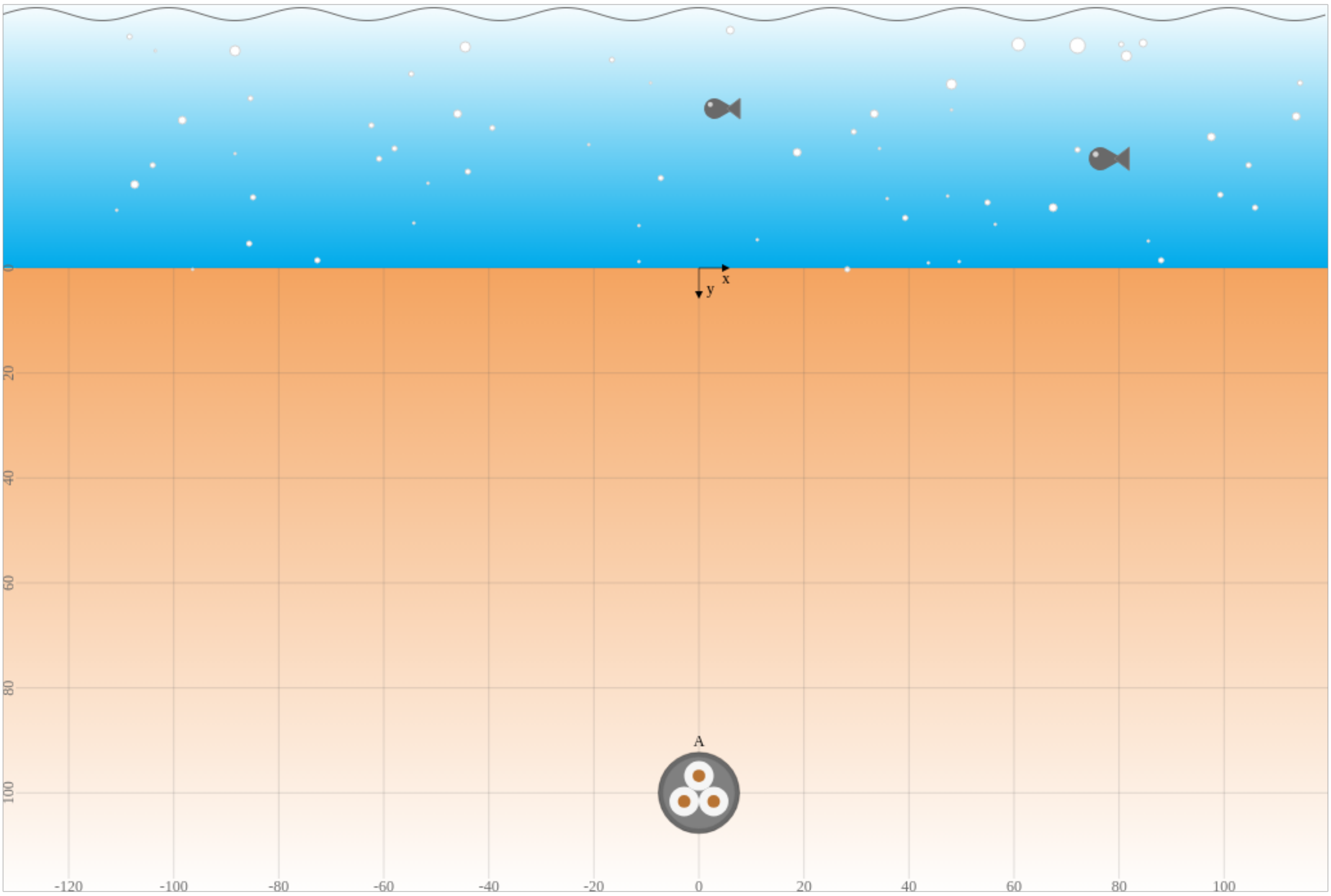
Title	Case study 2: A 30kV submarine array cable
Project	Verification CIGRE TB 880
Created	Date: 2025-05-14 Time: 20:24 Software version: 3b07c (2025-05-14)

Arrangement

Arrangement	**buried project** (#46684)
Options	None
CIGRE TB 880, guidance points	02, 06, 26, 31
Systems	A

Statistics

Number of iterations of the solver	N_{calc}	10
Sum of currents from all systems	I_{sum}	838.34 A
Sum of average conductor temperatures from all systems	θ_{sum}	90 °C
Number of overheated electrical systems		0
Sum of losses from all systems	W_{sum}	140.987 W/m



Systems

Following systems are active in the arrangement:

#	Object	Current [A]	Temp. [°C]	Losses [W/m]	Load
		I_c	θ_c | θ_e	W_{sys}	LF
A	16291 CIGRE TB 880 Case 2 30kV submarine ar...	838.3	90.0 | 66.0	141.0	1.00

Objects

Following objects are used:

16291 CIGRE TB 880 Case 2 30kV submarine array cable

Ambient

Calculation method		IEC Standard subsea (preview)
Ambient temperature	θ_a	15 °C
Thermal resistivity soil	ρ_4	0.7 K.m/W
Thermal conductivity soil	k_4	1.429 W/(m.K)
Volumetric heat capacity soil material $10^{-4}\frac{{k_4}^{0.2}}{4.68}$	$c_{p,soil}$	2294.7 J/(kg.K)
Thermal diffusivity soil	δ_{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 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 (Medium voltage cable)

Ampacity

Cable		CIGRE TB 880 Case 2 30kV submarine array cable
Rounded value, CIGRE TB 880	I_c	830 A
Conductor current	I_c	838.34 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	30 kV
Angular frequency	ω	314.2 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	50 Hz
Continuous load	LF	1 p.u.

Arrangement

Arrangement		individual
Position cable 1	$x_1 \| y_1$	0.0 | 1000.0 mm
Separation of conductors in a system	s_c	62.1 mm
Mean distance between the phases	a_m	62.1 mm
Geometric mean distance between phases of the same system	GMD	0.01406 m

GMR_{cc}

Depth of laying of sources	L_c	1000 mm
Depth of laying	L_{cm}	1 m
Outer diameter	D_o	0.1553 m
Substitution coefficient u	u	12.8783

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

Geometric constant of circle buried	g_u	25.7177

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

Temperature

Temperature conductor	θ_c	90 °C

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

Temperature screen/sheath	θ_s	79.39 °C
Temperature sheath	θ_{sh}	79.39 °C

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

Temperature armour	θ_{ar}	71.31 °C

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

External temperature object	θ_e	66 °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 $\Delta\theta_c$ 75 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 $\Delta\theta_d$ 0.2121 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 29.595 W/m

$$I_c{}^2 R_c$$

Screen/sheath losses (phase) W_s 4.819 W/m

$$\lambda_1 W_c$$

Armour losses (phase) W_{ar} 12.449 W/m

$$\lambda_2 W_c$$

Duct losses W_{duct} 0 W/m

Ohmic losses (phase) W_I 46.864 W/m

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

Dielectric

Dielectric losses (phase) W_d 0.132 W/m

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

Total

Total losses (phase) W_t 46.996 W/m

$$W_I + W_d$$

Total losses (object) W_{tot} 140.987 W/m

$$n_{ph} W_t$$

Total losses (system) W_{sys} 140.987 W/m

Thermal resistance

Thermal resistance ambient $T_{4\mu}$ 0.3618 K.m/W

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

Mutual heating coefficient F_{mh} 1

Cable

Internal thermal resistance for current losses T_{int} 0.2695 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 0.1752 K.m/W

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

Other characteristics

Earthing

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

Loss factor

Loss factor shield (screen/sheath) — λ_1 — 0.1628

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

Loss factor shield, circulating currents — λ_{11} — 0.1409

$$\frac{1.5\frac{R_e}{R_c}}{1+\left(\frac{R_e}{X_e}\right)^2}$$

Loss factor shield, eddy currents — λ_{12} — 0.0221

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

Electrical resistance shield/armour — R_e — 6.7339e-1 Ω/km

Substitution coefficient λ_0 for eddy-currents — λ_0 — 0.0013

$$3\frac{{m_0}^2}{1+{m_0}^2}\left(\frac{d_e}{2s_c}\right)^2$$

Substitution coefficient Δ_1 for eddy-currents — Δ_1 — 0.0821

$$\left(1.14{m_0}^{2.45}+0.33\right)\left(\frac{d_e}{2s_c}\right)^{0.92m_0+1.66}$$

Substitution coefficient Δ_2 for eddy-currents — Δ_2 — 0

Substitution coefficient m_0 for eddy-currents — m_0 — 0.0467 Hz.m/Ω

$$10^{-7}\frac{\omega}{R_{sh}}$$

Substitution coefficient β_1 for eddy-currents — β_1 — 38.6094

$$\sqrt{\frac{4\pi\omega}{10^7\rho_{sh}\left(1+\alpha_{sh}\left(\theta_{sh}-20\right)\right)}}$$

Substitution coefficient g_s for eddy-currents — g_s — 1.002261

$$1+\left(\frac{t_{sh}}{D_{sh}}\right)^{1.74}\left(10^{-3}\beta_1 D_{sh}-1.6\right)$$

Factor F_e eddy-current losses — F_e — 0.9941

$$\frac{4{M_e}^2{N_e}^2+\left(M_e+N_e\right)^2}{4\left({M_e}^2+1\right)\left({N_e}^2+1\right)}$$

Substitution coefficient M_e to calculate factor F_e — M_e — 13.0099

$$\frac{R_e}{X_e}$$

Substitution coefficient N_e to calculate factor F_e — N_e — 13.0099

$$\frac{R_e}{X_e}$$

Loss factor armour — λ_2 — 0.4207

$$\max\left(\left(1-\frac{R_c}{R_s}\lambda_{11}\right)\lambda_{21},0\right)$$

Loss factor armour, circulating currents — λ_{21} — 0.4244

$$1.23\frac{R_{ar}}{R_c}\left(\frac{2c_c}{d_{ar}}\right)^2\frac{1}{\left(\frac{2.77R_{ar}\cdot10^6}{\omega}\right)^2+1}$$

Drying-out of soil

Characteristic diameter drying zone	D_{dry}	0.155 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 $R_{cDC}\left(1+1.5\left(y_s+y_p\right)\right)$	R_c	4.2110e-5 Ω/m → 0.0421 Ω
Electrical resistance DC conductor $R_{c20}\left(1+\alpha_c\left(\theta_c-20\right)\right)$	R_{cDC}	3.6085e-5 Ω/m → 0.0361 Ω
Skin effect factor conductor $\frac{{x_s}^4}{192+0.8{x_s}^4}$	y_s	0.06012
Factor for skin effect on conductor $\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_s}$	x_s	1.86612
Proximity effect factor conductor $\frac{{x_p}^4}{192+0.8{x_p}^4}\left(\frac{d_c}{s_c}\right)^2\left(0.312\left(\frac{d_c}{s_c}\right)^2+\frac{1.18}{\frac{{x_p}^4}{192+0.8{x_p}^4}+0.27}\right)$	y_p	0.05118
Factor for proximity effect of conductors $\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_p}$	x_p	1.86612
Electrical resistance sheath $R_{sh}\left(1+\alpha_{sh}\left(\theta_{sh}-20\right)\right)$	R_{sh}	6.6883e-04 Ω/m
Electrical resistance sheath, CIGRE TB 880 $F_{lay,3c}R_{sh}$	R_{sh}	6.7339e-04 Ω/m
Electrical resistance shield	R_s	6.7339e-4 Ω/m → 0.6734 Ω
Reduction factor $\frac{R_s}{\sqrt{{R_s}^2+{X_s}^2}}$	RF	0.7166
Electrical resistance armour $R_{ar}\left(1+\alpha_{ar}\left(\theta_{ar}-20\right)\right)$	R_{ar}	1.2799e-4 Ω/m → 0.128 Ω

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	2.663 | 1.784 kV/mm
Radius to point x in insulation	r_x	16.25 | 24.25 mm
Line-to-ground voltage $\frac{1000U_o}{\sqrt{3}}$	U_e	17320.51 V

Capacitance insulation $\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$	C_b	3.493e-10 F/m → 0.3493 μF
Capacitive load current $U_e\omega C_b$	I_C	1.901e-3 A/m → 1.9007 A
Charging capacity $n_{ph}{U_e}^2\omega C_b$	P_C	98.7639 var/m → 98.7639 kvar
Capacitive earth short-circuit current $3U_e\omega C_E$	I_{Ce}	5.702e-3 A/m

Reactance

Self reactance conductor $\omega\frac{\mu_0}{2\pi}\ln\left(\frac{D_E}{GMR_c}\right)$	X_a	7.094e-4 Ω/m → 0.7094 Ω
Self reactance screen/sheath $\omega\frac{\mu_0}{2\pi}\ln\left(\frac{2a_m}{d_s}\right)$	X_e	5.141e-05 Ω/m
Self reactance screen/sheath, CIGRE TB 880 $F_{lay,3c}X_e$	X_e	5.176e-05 Ω/m

Induced current (approximate)

Induced circulating current shield $\max\left(I_c\sqrt{\frac{\lambda_{11,sb}R_c}{R_s}}\right)$	I_s	78.689+0.000j A
Loss factor shield, circulating currents	$\lambda_{11,sb}$	0.1409+0.0000j
Induced circulating current armour $\max\left(I_c\sqrt{\frac{\lambda_{21}R_c}{R_{ar}}}\right)$	I_{ar}	313.264 A

Load, Voltage drop

Apparent power generator-side $\sqrt{3}U_oI_c$	S_G	43.561 MVA
Voltage drop $\sqrt{3}\left(R_c\cos\varphi+\omega L_m\sin\varphi\right)$	V_{drop}	0.073 V/(A.km) → 61.1 V = 0.2%
Inductance (mean) $\frac{\mu_0}{2\pi}\ln\left(\frac{GMD}{GMR_c}\right)$	L_m	3.832e-8+0.000e0j H/m → 0.0383 mH

Telegrapher equation

Surge impedance $\sqrt{\frac{Z_1}{Y_1}}$	Z_C	17.1691-13.6046j Ω
Propagation constant $\sqrt{Z_1Y_1}$	γ_C	1.493e-6+1.884e-6j

Impedance valid up to 100 Hz without earth return

Positive sequence admittance $G + j\omega C_b$	Y_1	0.000e0+1.097e-7j S/m → 0.0000+0.0001j S
Positive sequence impedance $R_1 + jX_1$	Z_1	5.126e-5+1.204e-5j Ω/m → 0.0513+0.0120j Ω
Positive sequence reactance $\omega \frac{\mu_0}{2\pi} \ln\left(\frac{GMD}{GMR_c}\right)$	X_1	1.204e-5 Ω/m → 0.012 Ω

Cable datasheet

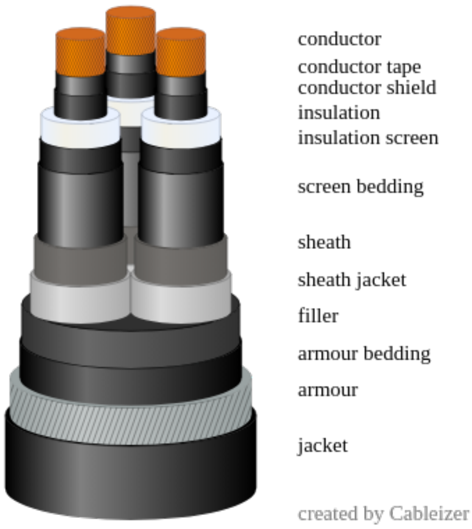
Title	CIGRE TB 880 Case 2 30kV submarine array cable (#16291)

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	30 kV
Base voltage for tests	U_0	18 kV
Highest voltage for equipment	U_m	36 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 630 mm^2
Conductor material	M_c	Copper, round stranded
External diameter conductor	d_c	30 mm
Radius conductor $\frac{d_c}{2}$	r_c	15 mm
Geometrical distance factor for multi-core cables $1+\frac{1}{sin\left(\frac{\pi}{3}\right)}$	F_x	2.1547
Distance conductor axis—cable axis $\frac{D_f - s_c}{2}$	c_c	36.4 mm
Separation of conductors in a system D_{shj}	s_c	62.1 mm

Insulation

Insulation material	M_i	Crosslinked polyethylene (XLPE)
Thickness conductor tape	t_{ct}	0.25 mm
Thickness conductor shield	t_{cs}	1 mm
Thickness insulation	t_{ins}	8 mm
Thickness insulation screen	t_{is}	0.9 mm
Thickness insulation $t_{ct} + t_{cs} + t_{ins} + t_{is}$	t_i	10.15 mm
Thickness of insulation between conductors $2t_i$	t_{i1}	20.3 mm
Thickness of insulation between conductor and metallic sheath $t_i + t_{scb} + t_{scs} + t_f$	t_{i2}	11.8 mm
Material of conductor tapes		Semiconducting tapes

Screen bedding

Screen bedding material		Water-blocking tapes, semi-conducting
Thickness screen bedding	t_{scb}	1.1 mm

Sheath

Sheath material	M_{sh}	Lead
Thickness sheath	t_{sh}	2.3 mm
corrugated		No

Jacket over each core

Sheath jacket material	M_{shj}	Polyethylene (LD/MDPE)
Thickness sheath jacket	t_{shj}	2.5 mm

Filler

Filler material	M_f	Shaped polyethylene (LDPE)
Thickness of filler/belt insulation	t_f	0.55 mm

Armour bedding

Armour bedding material	M_{ab}	Polypropylene (PP)
Thickness armour bedding	t_{ab}	1.2 mm

Armour

Construction of armour	a_{type}	Steel wires round
Thickness armour	t_{ar}	6 mm
Factor between AC and DC resistance armour $\frac{1.4 - 1.2}{5 - 2}(t_{ar} - 2) + 1.2$	f_{ar}	1.4667e0 Ω/m
Number of wires armour	n_{ar}	71

Jacket

Jacket material	M_j	Polypropylene (PP)
Thickness jacket	t_j	3 mm

Overall

External diameter object	D_e	155.3 mm
Absorption coefficient solar radiation	σ_{sun}	0.6
Emissivity cable	ϵ_e	0.9
Reflectivity cable $1 - \epsilon_e$	η_e	0.1
Mass cable $m_{hollow} + m_{metal}$	m_{tot}	43.767 kg/m

Electrical

Conductor

Electrical resistance DC conductor 20°C	R_{c20}	2.8300e-5 Ω/m
Effective length per unit lay length twisted conductors $\sqrt{1+\left(\frac{\pi D_{lay,3c}}{L_{lay,3c}}\right)^2}$	$F_{lay,3c}$	1.0068
Length of lay twisted conductors	$L_{lay,3c}$	2152 mm
Diameter of mechanical neutral line	$D_{lay,3c}$	80.11 mm
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 bundle $\left(GMR_c\left(\frac{s_c}{1000}\right)^{n_c}\right)^{\frac{1}{n_c}}$	GMR_{cc}	0.01406 mm
Geometric mean radius conductor $K_{GMR} r_{z1}$	GMR_c	0.01161 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	3.493e-10 F/m
Capacitance (exact) $F_{lay,3c} C_b$	C_b	3.498e-10 F/m
Capacitance insulation $\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$	C_b	3.474e-10 F/m
Capacitance to earth C_b	C_E	3.493e-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}	16.25 mm
Radius over capacitive insulation layers $\frac{D_{ins}}{2}$	r_{osc}	24.25 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}	5.4045e-4 Ω/m
$10^6\frac{\rho_{sh}}{A_{sh}}$		
Electrical resistance screen/sheath 20°C	R_{so}	5.404e-1 Ω/km
Electrical resistance screen/sheath, CIGRE TB 880	R_{so}	5.4413e-04 Ω/m

Armour

Electrical resistance armour	R_{ar}	1.0082e-04 Ω/m
$10^6\frac{f_{ar}\rho_{ar}}{A_{ar}}$		
Electrical resistance armour, CIGRE TB 880	R_{ar}	1.0398e-04 Ω/m
$F_{lay,ar}R_{ar}$		
Effective length per unit lay length armour	$F_{lay,ar}$	1.0313
$\text{Min}\left(2, \sqrt{1+\left(\frac{\pi d_{ar}}{L_{lay,ar}}\right)^2}\right)$		
Length of lay armour	$L_{lay,ar}$	1785 mm
Geometric mean radius armour	GMR_{ar}	0.00317 m
$\left(0.7788\frac{t_{ar}}{2}n_{ar}\left(\frac{t_{ar}}{2}\right)^{n_{ar}-1}\right)^{\frac{1}{n_{ar}}}\frac{1}{1000}$		

Radius

Radius conductor	r_{z1}	0.015 m
Radius shield (inner)	r_{z2}	0.0251 m
Radius shield (outer)	r_{z3}	0.0251 m
Radius sheath (inner)	$r_{z2,sh}$	0.0251 m
Radius sheath (outer)	$r_{z3,sh}$	0.0297 m
Radius armour (inner)	r_{z4}	0.06865 m
Radius armour (outer)	r_{z5}	0.07465 m
Radius outersheath	r_{z6}	0.07765 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	$\tan\delta_i$	0.004
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 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
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

Sheath

Specific electrical resistivity sheath material	ρ_{sh}	2.140e-7 Ω.m
Temperature coefficient sheath material	α_{sh}	4.00e-3 1/K
Reciprocal of temperature coefficient sheath material	β_{sh}	2.300e2 K
Volumetric heat capacity sheath material	σ_{sh}	1.45e6 J/(K.m^3)
Thermal conductivity sheath material	k_{sh}	33.4 W/(m.K)
Density sheath material	ζ_{sh}	11.34 g/cm^3

Jacket over each core

Thermal resistivity sheath jacket material	ρ_{shj}	2.5 K.m/W
Volumetric heat capacity sheath jacket material	σ_{shj}	2.40e6 J/(K.m^3)
Density metallic screen material	ζ_{sc}	0 g/cm^3

Filler

Thermal resistivity filler	ρ_f	6 K.m/W
Volumetric heat capacity filler	σ_f	2.40e6 J/(K.m^3)
Density filler material	ζ_f	0.93 g/cm^3

Armour bedding

Thermal resistivity armour bedding	ρ_{ab}	6 K.m/W
Volumetric heat capacity armour bedding	σ_{ab}	1.80e6 J/(K.m^3)
Density armour bedding material	ζ_{ab}	0.91 g/cm^3

Armour

Specific electrical resistivity armour material	ρ_{ar}	1.380e-7 Ω.m
Temperature coefficient armour material	α_{ar}	4.50e-3 1/K
Reciprocal of temperature coefficient armour material	β_{ar}	2.022e2 K
Volumetric heat capacity armour material	σ_{ar}	3.80e6 J/(K.m^3)
Thermal conductivity armour material	k_{ar}	36.1 W/(m.K)
Density armour material	ζ_{ar}	7.85 g/cm^3

Jacket

Thermal resistivity jacket material	ρ_j	6 K.m/W
Thermal resistivity additional layer	ρ_{jj}	2.5 K.m/W
Volumetric heat capacity jacket material	σ_j	1.80e6 J/(K.m^3)
Electrical conductivity jacket material	κ_j	1.00e-14 S/m
Density jacket material	ζ_j	0.91 g/cm^3

Thermal resistance

Internal thermal resistances for rating calculation

Thermal resistance conductor—sheath T_1 0.3603 K.m/W

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

Thermal resistance conductor—sheath, CIGRE TB 880 T_1 0.3579 K.m/W

$$\frac{1}{F_{lay,3c}} T_1$$

Thermal resistance armour bedding T_2 0.0779 K.m/W

$$\frac{1}{3} \frac{1}{F_{lay,3c}} \frac{\rho_{shj}}{2\pi} \ln\left(1 + \frac{2t_{shj}}{D_{sh} - (H_{sh} + \Delta H)}\right) + \frac{\rho_f}{6\pi} G_2$$

Thermal resistance jacket T_3 0.0376 K.m/W

$$T_j + T_{jj}$$

Thickness conductor—sheath t_1 11.25 mm

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

Thickness sheath—armour t_2 4.25 mm

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

Thickness armour—surface t_3 3 mm

$$t_j + t_{jj}$$

Geometric factor G_2 cables with separate sheaths G_2 0.2101

$$2\pi\left(0.00022619 + 2.11429 X_{G2} - 20.4762 {X_{G2}}^2\right)$$

Factor X_{G2} X_{G2} 0.0193

$$\frac{t_{sha}}{D_{shj}}$$

Total thickness between separate sheath and armour t_{sha} 1.2 mm

$$\frac{D_{ab} - D_f}{2}$$

Cable elements

Thermal resistance, transient T_{tot} 0.4734 K.m/W

$$T_1 + T_2 + T_3$$

Thermal resistance insulation T_i 0.27855 K.m/W

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

Thermal resistance conductor tape T_{ct} 0.01578 K.m/W

$$\frac{\rho_{ct}}{2\pi} \ln\left(\frac{d_c + 2t_{ct}}{d_c}\right)$$

Thermal resistance conductor shield T_{cs} 0.02527 K.m/W

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

Thermal resistance insulation T_{ins} 0.223 K.m/W

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

Thermal resistance insulation screen T_{is} 0.0145 K.m/W

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

Thermal resistance screen bedding T_{scb} 0.08176 K.m/W

$$\frac{\rho_{scb}}{2\pi}\ln\left(\frac{D_{scb}}{D_i}\right)$$

Thermal resistance sheath jacket T_{shj} 0.0334 K.m/W

$$\frac{\rho_{shj}}{2\pi}\ln\left(\frac{D_{shj}}{D_{sh}-(H_{sh}+\Delta H)}\right)$$

Thermal resistance sheath jacket, CIGRE TB 880 T_{shj} 0.0336 K.m/W

$$F_{lay,3c}T_{shj}$$

Thermal resistance armour bedding T_{ab} 0.02461 K.m/W

$$\frac{\rho_{ab}}{2\pi}\ln\left(\frac{D_{ab}}{F_x D_{shj}}\right)$$

Thermal resistance jacket T_j 0.03763 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 mm

Diameter over conductor shield D_{cs} 32.5 mm

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

Diameter over insulation D_{ins} 48.5 mm

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

Diameter over insulation incl. insulation screen D_i 50.3 mm

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

Diameter over insulation screen D_{is} 50.3 mm

$$d_c+2t_i$$

Diameter over screen bedding D_{scb} 52.5 mm

$$d_c+t_{i1}+2t_{scb}$$

Equivalent diameter of screen and sheath d_s 54.8 mm

Mean diameter sheath d_{sh} 54.8 mm

$$D_{shb}+t_{sh}+H_{sh}+\Delta H$$

Diameter over sheath D_{sh} 57.1 mm

$$D_{shb}+2\left(t_{sh}+H_{sh}+\Delta H\right)$$

Diameter over sheath jacket D_{shj} 62.1 mm

$$D_{sh}+2t_{shj}$$

Diameter over core cable D_{core} 62.1 mm

$$\frac{D_f-2t_f}{F_x}$$

Diameter over filler D_f 134.9 mm

$$F_x D_{shj}+2t_f$$

Diameter over armour bedding $F_x D_{shj} + 2\left(t_f + t_{ab}\right)$	D_{ab}	137.3 mm
Equivalent diameter of screen/sheath and armour	d_e	54.8 mm
Mean diameter armour $D_{ab} + t_{a,1} + t_{a,2}$	d_{ar}	143.3 mm
Diameter over armour $D_{ab} + 2\left(t_{a,1} + t_{a,2}\right)$	D_{ar}	149.3 mm
Diameter over jacket $D_{ar} + 2\left(t_j + t_{jj}\right)$	D_j	155.3 mm

Area

		values are per phase
Cross-sectional area conductor	A_c	630 mm^2
Cross-sectional area insulation $\frac{\pi}{4}\left({D_{is}}^2 - {d_c}^2\right)$	A_i	1280.3 mm^2
Cross-sectional area screen bedding $\pi t_{scb}\left(D_{scb} - t_{scb}\right)$	A_{scb}	177.6 mm^2
Cross-sectional area sheath $d_{sh} t_{sh} \pi$	A_{sh}	395.97 mm^2
Cross-sectional area sheath jacket $\frac{\pi}{4}\left({D_{shj}}^2 - \left(D_{sh} - \left(H_{sh} + \Delta H\right)\right)^2\right)$	A_{shj}	468.1 mm^2
Cross-sectional area filler $\pi\left(\frac{D_f}{2}\right)^2 - 3\pi {r_{core}}^2 + \frac{\sqrt{3}}{4}{D_{core}}^2 - 3\frac{{r_{core}}^2}{2}\left(\frac{\pi}{3} - sin\left(\frac{\pi}{3}\right)\right)$	A_f	6614.1 mm^2
Cross-sectional area armour bedding $\frac{\pi}{4}\left({D_{ab}}^2 - \left(D_{ab} - t_{ab}\right)^2\right)$	A_{ab}	257.7 mm^2
Cross-sectional area armour $n_{ar}\left(\frac{t_{ar}}{2}\right)^2 \pi$	A_{ar}	2007.48 mm^2
Cross-sectional area jacket $\frac{\pi}{4}\left({D_j}^2 - \left(D_j - 2\left(t_j + t_{jj}\right)\right)^2\right)$	A_j	1435.4 mm^2