

Report

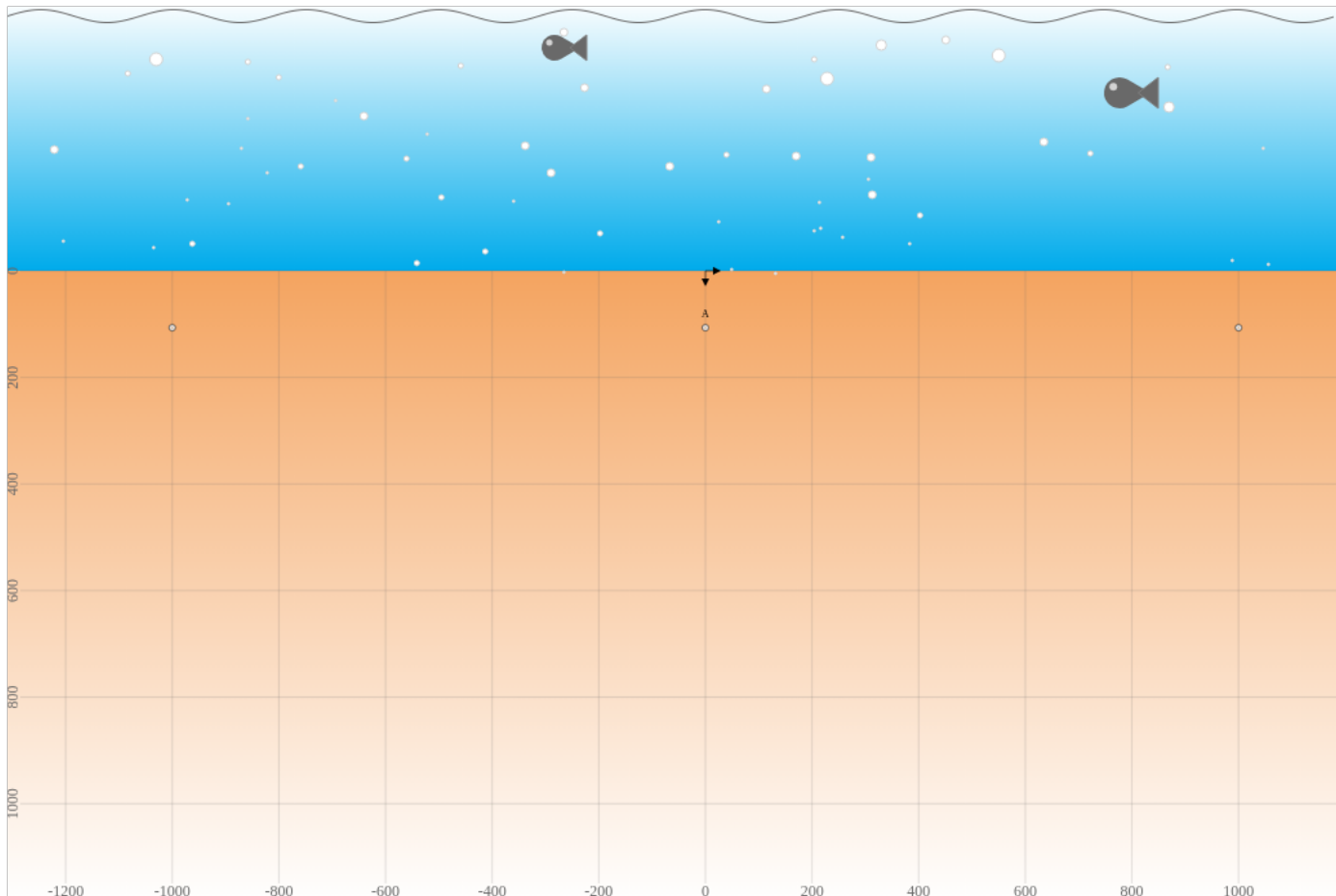
Title	Case study 6: A 400kV single core AC submarine cable
Project	Verification CIGRE TB 880
Created	Date: 2025-05-26 Time: 09:08 Software version: f8c9 (2025-05-24)

Arrangement

Arrangement	buried project (#46700)
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}	1039.23 A
Sum of average conductor temperatures from all systems	θ_{sum}	89.83 °C
Number of overheated electrical systems		0
Sum of losses from all systems	W_{sum}	337.459 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	16318 CIGRE TB 880 Case 6 400kV single core...	1039.2	90.0 58.9	337.5	1.00

Objects

Following objects are used:

16318 CIGRE TB 880 Case 6 400kV single core AC submarine

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	$c_{p,soil}$	2294.7 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 (Extra high voltage cable)**Ampacity**

Cable		CIGRE TB 880 Case 6 400kV single core AC submarine
Rounded value, CIGRE TB 880	I_c	1030 A
Conductor current	I_c	1039.23 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	400 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 1067.2 mm
Position cable 2	$x_2 y_2$	-10000.0 1067.2 mm
Position cable 3	$x_3 y_3$	10000.0 1067.2 mm
Separation of conductors in a system	s_c	10000 mm
Mean distance between the phases	a_m	12599.21 mm
Geometric mean distance between phases of the same system $2^{\frac{1}{3}} S_m$	GMD	12.59921 m
Depth of laying of sources	L_c	1067.2 mm
Depth of laying	L_{cm}	1.067 m
Outer diameter	D_o	0.1343 m
Substitution coefficient u $\frac{2L_{cm}}{D_o}$	u	15.892
Geometric constant of circle buried $u + \sqrt{u^2 - 1}$	g_u	31.7526

Temperature

Temperature conductor $\theta_a + \Delta\theta_c - (v_4 - 1) \Delta\theta_x + v_4 \Delta\theta_p$	θ_c	1: 90 2: 89.74 3: 89.74 °C
Temperature screen/sheath $\frac{\theta_{sc} + \theta_{sh}}{2}$	θ_s	1: 66.86 2: 66.61 3: 66.61 °C
Temperature screen $\theta_c - T_1 \left(W_c + \frac{W_d}{2} \right)$	θ_{sc}	1: 67.69 2: 67.44 3: 67.44 °C
Temperature sheath $\theta_{sc} - T_{scs} \left(W_c (1 + \lambda_{11,sc}) + \frac{W_d}{2} \right)$	θ_{sh}	1: 66.03 2: 65.79 3: 65.79 °C

Temperature armour θ_{ar} 1: 63.83 | 2: 63.58 | 3: 63.58 °C

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

External temperature object θ_e 1: 58.91 | 2: 58.67 | 3: 58.67 °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: 75 | 2: 74.7407 | 3: 74.7407 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: 1.9947 | 2: 1.99 | 3: 1.99 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: 34.8 | 2: 34.779 | 3: 34.779 W/m

$$I_c^2 R_c$$

Screen/sheath losses (phase) W_s 1: 37.615 | 2: 37.585 | 3: 37.585 W/m

$$\lambda_1 W_c$$

Armour losses (phase) W_{ar} 1: 37.615 | 2: 37.585 | 3: 37.585 W/m

$$\lambda_2 W_c$$

Duct losses W_{duct} 0 W/m

Ohmic losses (phase) W_I 1: 110.031 | 2: 109.949 | 3: 109.949 W/m

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

Dielectric

Dielectric losses (phase) W_d 2.51 W/m

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

Total

Total losses (phase) W_t 1: 112.541 | 2: 112.459 | 3: 112.459 W/m

$$W_I + W_d$$

Total losses (object) W_{tot} 1: 112.541 | 2: 112.459 | 3: 112.459 W/m

$$n_{ph} W_t$$

Total losses (system) W_{sys} 337.459 W/m

Thermal resistance

Thermal resistance ambient $T_{4\mu}$ 1: 0.3902 | 2: 0.3884 | 3: 0.3884 K.m/W

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

Mutual heating coefficient

 F_{mh}

1: 1.046 | 2: 1.028 | 3: 1.028

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

Cable

Internal thermal resistance for current losses

 T_{int}

1: 0.8641 | 2: 0.864 | 3: 0.864 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

0.4046 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

1: 1.0809 | 2: 1.0807 | 3: 1.0807

$$\lambda_{11,sc} + \lambda_{11,sh} + F_e \lambda_{12}$$

Loss factor shield, circulating currents

 λ_{11}

1: 1.0809 | 2: 1.0807 | 3: 1.0807

$$\frac{W_{sar}}{2W_c}$$

Loss factor shield, eddy currents

 λ_{12}

1: 0.0002 | 2: 0.0002 | 3: 0.0002

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

Electrical resistance shield/armour

 R_e 1: 7.2712e-2 | 2: 7.2650e-2 | 3: 7.2650e-2 Ω/km

$$\frac{R_s R_{ar}}{R_s + R_{ar}}$$

Substitution coefficient λ_0 for eddy-currents λ_0

1: 0 | 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: -0.0008 | 3: 0

$$0.86 m_0^{3.08} \left(\frac{d_e}{2s_c} \right)^{1.4 m_0 + 0.7}$$

$$\frac{-0.74 (m_0 + 2) \sqrt{m_0}}{2 + (m_0 - 0.3)^2} \left(\frac{d_e}{2s_c} \right)^{m_0 + 1}$$

$$4.7 m_0^{0.7} \left(\frac{d_e}{2s_c} \right)^{0.16 m_0 + 2}$$

Substitution coefficient Δ_2 for eddy-currents Δ_2

1: 0 | 2: 0 | 3: 0

$$0$$

$$0.92 m_0^{3.7} \left(\frac{d_e}{2s_c} \right)^{m_0 + 2}$$

$21m_0^{3.3} \left(\frac{d_e}{2s_c} \right)^{1.47m_0+5.06}$		
Substitution coefficient m_0 for eddy-currents $10^{-7} \frac{\omega}{R_{sh}}$	m_0	1: 0.1589 2: 0.159 3: 0.159 Hz.m/ Ω
Substitution coefficient β_1 for eddy-currents $\sqrt{\frac{4\pi\omega}{10^7\rho_{sh}(1+\alpha_{sh}(\theta_{sh}-20))}}$	β_1	1: 39.4704 2: 39.4868 3: 39.4868
Substitution coefficient g_s for eddy-currents $1 + \left(\frac{t_{sh}}{D_{sh}} \right)^{1.74} (10^{-3}\beta_1 D_{sh} - 1.6)$	g_s	1: 1.007065 2: 1.00707 3: 1.00707
Factor F_e eddy-current losses $\frac{4M_e^2 N_e^2 + (M_e + N_e)^2}{4(M_e^2 + 1)(N_e^2 + 1)}$	F_e	1: 0.0439 2: 0.0438 3: 0.0438
Substitution coefficient M_e to calculate factor F_e $\frac{R_e}{X_e + X_m}$	M_e	1: 0.1962 2: 0.1961 3: 0.1961
Substitution coefficient N_e to calculate factor F_e $\frac{R_e}{X_e - \frac{X_m}{3}}$	N_e	1: 0.2327 2: 0.2325 3: 0.2325
Loss factor armour $\frac{W_{sar}}{2W_c}$	λ_2	1: 1.0809 2: 1.0807 3: 1.0807
Total loss in shield and magnetic armour (phase) $I_c^2 R_e \frac{B_2^2 + B_1^2 + R_e B_2}{(R_e + B_2)^2 + B_1^2}$	W_{sar}	1: 75.23 2: 75.17 3: 75.17 W/m
Loss coefficient B_1 armour $\omega(H_s + H_1 + H_3)$	B_1	4.4625e-4 Ω /m
Loss coefficient B_2 armour ωH_2	B_2	5.1170e-5 Ω /m
Conductance sheath $2 \cdot 10^{-7} \ln \left(\frac{2a_m}{d_s} \right)$	H_s	1.0871e-6 H/m

Drying-out of soil

Characteristic diameter drying zone	D_{dry}	0.134 m
Depth characteristic diameter drying zone	L_{dry}	1.067 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 $R_{cDC} (1 + 1.5(y_s + y_p))$	R_c	1: 3.2223e-5 2: 3.2203e-5 3: 3.2203e-5 Ω /m
---	-------	--

Electrical resistance DC conductor $R_{c20} (1 + \alpha_c (\theta_c - 20))$	R_{cDC}	1: 2.8180e-5 2: 2.8157e-5 3: 2.8157e-5 Ω/m
Skin effect factor conductor $\frac{x_s^4}{192 + 0.8x_s^4}$	y_s	1: 0.09565 2: 0.09579 3: 0.09579
Factor for skin effect on conductor $\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_s}$	x_s	1: 2.11172 2: 2.11257 3: 2.11257
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 2: 0 3: 0
Factor for proximity effect of conductors $\sqrt{10^{-7} \frac{8\pi f}{R_{cDC}} k_p}$	x_p	1: 2.11172 2: 2.11257 3: 2.11257
Electrical resistance screen $R_{sc} (1 + \alpha_{sc} (\theta_{sc} - 20))$	R_{sc}	1: 2.6091e-4 2: 2.6070e-4 3: 2.6070e-4 Ω/m
Electrical resistance sheath $R_{sh} (1 + \alpha_{sh} (\theta_{sh} - 20))$	R_{sh}	1: 1.9776e-4 2: 1.9759e-4 3: 1.9759e-4 Ω/m
Electrical resistance shield $\frac{R_{sh} R_{sc}}{R_{sh} + R_{sc}}$	R_s	1: 1.1249e-4 2: 1.1240e-4 3: 1.1240e-4 Ω/m
Reduction factor $\frac{R_s}{\sqrt{R_s^2 + X_s^2}}$	RF	1: 0.1808 2: 0.1807 3: 0.1807
Electrical resistance armour $R_{ar} (1 + \alpha_{ar} (\theta_{ar} - 20))$	R_{ar}	1: 2.0561e-4 2: 2.0542e-4 3: 2.0542e-4 Ω/m

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	12.515 4.951 kV/mm
Radius to point x in insulation	r_x	19.9 50.3 mm
Line-to-ground voltage $\frac{1000U_o}{\sqrt{3}}$	U_e	230940.11 V
Capacitance insulation $\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$	C_b	1.498e-10 F/m $\rightarrow$ 0.1498 μF
Capacitive load current $U_e \omega C_b$	I_C	1.087e-2 A/m $\rightarrow$ 10.8668 A
Charging capacity $n_{ph} U_e^2 \omega C_b$	P_C	2509.5896 var/m $\rightarrow$ 2509.5896 kvar
Capacitive earth short-circuit current $U_e \omega C_E$	I_{Ce}	1.087e-2 A/m

Reactance

Self reactance conductor X_a 6.999e-4 Ω /m $\rightarrow$ 0.6999 Ω

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

Self reactance screen/sheath X_e 3.270e-4 Ω /m $\rightarrow$ 0.327 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 3.705e-4

$$X_e + X_m$$

Substitution coefficient Q to calculate loss factor by circulating currents Q_X 3.125e-4

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

Induced current (approximate)

Induced circulating current shield I_s 578.259+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: 1.0809+0.0000j | 2: 1.0807+0.0000j | 3: 1.0807+0.0000j

Induced circulating current armour I_{ar} undefined A

Load, Voltage drop

Apparent power generator-side S_G 719.997 MVA

$$\sqrt{3} U_o I_c$$

Voltage drop V_{drop} 0.056 V/(A.km) $\rightarrow$ 58 V = 0.01%

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

Inductance (mean) L_m 1.368e-6+0.000e0j H/m $\rightarrow$ 1.3676 mH

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

Telegrapher equation

Surge impedance Z_C 1: 95.6205-3.5808j | 2: 95.6204-3.5786j | 3: 95.6204-3.5786j Ω

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

Propagation constant γ_C 1: 1.685e-7+4.499e-6j | 2: 1.684e-7+4.499e-6j | 3: 1.684e-7+4.499e-6j

$$\sqrt{Z_1 Y_1}$$

Impedance valid up to 100 Hz without earth return

Positive sequence admittance Y_1 0.000e0+4.705e-8j S/m $\rightarrow$ 0.0000+0.0000j S

$$G + j\omega C_b$$

Positive sequence impedance	Z_1	1: 3.222e-5+4.296e-4j 2: 3.220e-5+4.296e-4j 3: 3.220e-5+4.296e-4j Ω/m
$R_1 + jX_1$		
Positive sequence reactance	X_1	4.296e-4 $\Omega/\text{m} \rightarrow 0.4296 \Omega$
$\omega \frac{\mu_0}{2\pi} \ln \left(\frac{GMD}{GMR_c} \right)$		

Cable datasheet

Title

CIGRE TB 880 Case 6 400kV single core AC submarine (#16318)

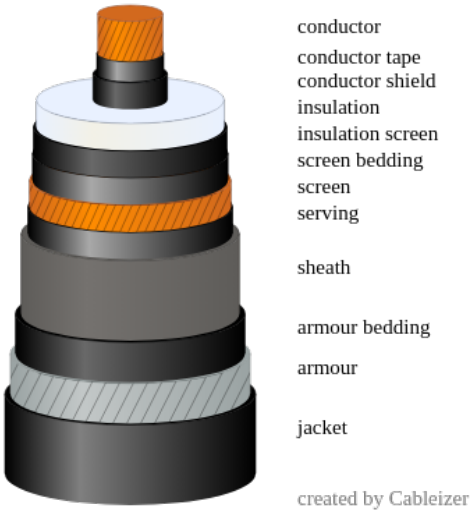
Cable is used in following systems: [A](#)

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	400 kV
Base voltage for tests	U_0	230 kV
Highest voltage for equipment	U_m	420 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 800 mm ²
Conductor material	M_c	Copper, round stranded, compacted
External diameter conductor	d_c	34.7 mm
Radius conductor	r_c	17.35 mm
$\frac{d_c}{2}$		

Insulation

Insulation material	M_i	Crosslinked polyethylene (XLPE)
Thickness conductor tape	t_{ct}	0.55 mm
Thickness conductor shield	t_{cs}	2 mm
Thickness insulation	t_{ins}	30.4 mm
Thickness insulation screen	t_{is}	1.55 mm
Thickness insulation	t_i	34.5 mm
$t_{ct} + t_{cs} + t_{ins} + t_{is}$		
Material of conductor tapes		Semiconducting tapes

Screen bedding

Screen bedding material		Water-blocking tapes, semi-conducting
Thickness screen bedding	t_{scb}	0.5 mm

Screen

Type		round wires
Screen material	M_{sc}	Copper
diameter wires	t_{sc}	1.6 mm
Number of wires screen	n_{scw}	48
Elongation screen	ν_{sc}	0 %

Screen serving

Screen serving material		Water-blocking tapes
Thickness screen serving	t_{scs}	0.9 mm

Sheath

Sheath material	M_{sh}	Lead
Thickness sheath	t_{sh}	3.6 mm
corrugated		No

Armour bedding

Armour bedding material	M_{ab}	Polyethylene (LDPE)
Thickness armour bedding	t_{ab}	3 mm

Armour

Construction of armour	a_{type}	Steel wires flat
Thickness armour	t_{ar}	2.7 mm
Factor between AC and DC resistance armour	f_{ar}	1.2467e0 Ω/m
$\frac{1.4 - 1.2}{5 - 2} (t_{ar} - 2) + 1.2$		
Number of wires armour	n_{ar}	32
Diameter armour wire	d_f	6.423 mm
$\sqrt{\frac{4t_{ar}w_{ar}}{\pi}}$		
Width armour	w_{ar}	12 mm

Jacket

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

Overall

External diameter object	D_e	134.3 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}	39.467 kg/m
$m_{hollow} + m_{metal}$		

Electrical

Conductor

Electrical resistance DC conductor 20°C	R_{c20}	2.2100e-5 Ω/m
Standard DC resistance of conductor	R_{co}	0.0221 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	0.01351 m
Factor geometric mean radius	K_{GMR}	0.779
Constant relating to conductor formation	K_{BICC}	0.0528
Number of wires conductor	n_{cw}	37
Diameter of wires conductor (average)	d_{cw}	4.384 mm

Insulation

Capacitance, with approximation (CIGRE TB 880) $\frac{1}{2\pi\epsilon_0} \frac{10^{-9}}{18} C_b$	C_b	1.498e-10 F/m
Capacitance (exact) $\frac{2\pi\epsilon_0\epsilon_i}{\ln\left(\frac{r_{osc}}{r_{isc}}\right)}$	C_b	1.500e-10 F/m
Capacitance to earth C_b	C_E	1.498e-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}	19.9 mm
Radius over capacitive insulation layers $\frac{D_{ins}}{2}$	r_{osc}	50.3 mm
Velocity of propagation $\frac{1}{1000\sqrt{\mu_0\epsilon_0\epsilon_i}}$	v_{prop}	189605.4 km/s

Screen + Sheath

Electrical resistance screen $10^6 \frac{F_{lay,sc}\rho_{sc}}{A_{sc}}$	R_{sc}	2.1973e-4 Ω/m
Effective length per unit lay length screen wires $\sqrt{1 + \left(\frac{\pi d_{sc}}{L_{lay,sc}}\right)^2}$	$F_{lay,sc}$	1.23
Length of lay screen wires	$L_{lay,sc}$	466.3 mm
Geometric mean radius screen $\left(0.7788 \frac{t_{sc}}{2} n_{scw} \left(\frac{t_{sc}}{2}\right)^{n_{scw}-1}\right)^{\frac{1}{n_{scw}}} \frac{1}{1000}$	GMR_{sc}	0.00086 m
Electrical resistance sheath $10^6 \frac{\rho_{sh}}{A_{sh}}$	R_{sh}	1.6701e-4 Ω/m

Electrical resistance screen/sheath 20°C	R_{so}	9.489e-2 Ω/km
$\frac{R_{sc}R_{sh}}{R_{sc} + R_{sh}}$		

Armour

Electrical resistance armour	R_{ar}	1.6593e-04 Ω/m
$10^6 \frac{f_{ar}\rho_{ar}}{A_{ar}}$		
Electrical resistance armour, CIGRE TB 880	R_{ar}	1.7174e-04 Ω/m
$F_{lay,ar}R_{ar}$		
Effective length per unit lay length armour	$F_{lay,ar}$	1.035
$\text{Min} \left(2, \sqrt{1 + \left(\frac{\pi d_{ar}}{L_{lay,ar}} \right)^2} \right)$		
Length of lay armour	$L_{lay,ar}$	1478.51 mm
Inductance H_1 armour	H_1	1.6288e-7 H/m
$10^{-7} \pi \mu_e \frac{n_{ar} d_f^2}{L_{lay,ar} d_{ar}} \sin(\phi_{ar}) \cos(\gamma_{ar})$		
Inductance H_2 armour	H_2	1.6288e-7 H/m
$10^{-7} \pi \mu_e \frac{n_{ar} d_f^2}{L_{lay,ar} d_{ar}} \sin(\phi_{ar}) \sin(\gamma_{ar})$		
Inductance H_3 armour	H_3	1.7049e-7 H/m
$0.4 (\mu_t \cos(\phi_{ar})^2 - 1) \frac{d_f}{d_{ar}} \cdot 10^{-6}$		
Longitudinal relative permeability steel wires	μ_e	400
Transverse relative permeability steel wires	μ_t	10
Relative permeability steel wires	μ_s	300
Angle between armour and cable axis	ϕ_{ar}	0.261 rad
Angular time delay	γ_{ar}	0.785 rad

Radius

Radius conductor	r_{z1}	0.01735 m
Radius shield (inner)	r_{z2}	0.05155 m
Radius shield (outer)	r_{z3}	0.05305 m
Radius screen (inner)	$r_{z2,sc}$	0.05155 m
Radius screen (outer)	$r_{z3,sc}$	0.05475 m
Radius sheath (inner)	$r_{z2,sh}$	0.05305 m
Radius sheath (outer)	$r_{z3,sh}$	0.06025 m
Radius armour (inner)	r_{z4}	0.06145 m
Radius armour (outer)	r_{z5}	0.06415 m
Radius outersheath	r_{z6}	0.06715 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 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

Screen

Specific electrical resistivity screen material	ρ_{sc}	1.724e-8 Ω .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}	2.140e-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

Armour bedding

Thermal resistivity armour bedding	ρ_{ab}	2.5 K.m/W
Volumetric heat capacity armour bedding	σ_{ab}	2.40e6 J/(K.m ³)
Density armour bedding material	ζ_{ab}	0.93 g/cm ³

Armour

Specific electrical resistivity armour material	ρ_{ar}	1.380e-7 $\Omega.m$
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 $T_{ct} + T_{cs} + T_{ins} + T_{is} + T_{scb}$	T_1	0.6189 K.m/W
Thermal resistance armour bedding $T_{scs} + T_{dsh} + T_{ab}$	T_2	0.0515 K.m/W
Thermal resistance jacket $T_j + T_{jj}$	T_3	0.0436 K.m/W
Thickness conductor—sheath $t_i + t_{scb} + t_{scs} + \frac{H_{sh} + \Delta H}{2}$	t_1	35.9 mm
Thickness sheath—armour $\frac{H_{sh} + \Delta H}{2} + t_{ab}$	t_2	3 mm
Thickness armour—surface $t_j + t_{jj}$	t_3	3 mm

Cable elements

Thermal resistance, transient $T_1 + T_2 + T_3$	T_{tot}	0.714 K.m/W
Thermal resistance insulation $T_{ct} + T_{cs} + T_{ins} + T_{is}$	T_i	0.60056 K.m/W
Thermal resistance conductor tape $\frac{\rho_{ct}}{2\pi} \ln \left(\frac{d_c + 2t_{ct}}{d_c} \right)$	T_{ct}	0.0298 K.m/W
Thermal resistance conductor shield $\frac{\rho_{cs}}{2\pi} \ln \left(\frac{D_{cs}}{D_{cs} - 2t_{cs}} \right)$	T_{cs}	0.04214 K.m/W
Thermal resistance insulation $\frac{\rho_i}{2\pi} \ln \left(\frac{D_{ins}}{D_{ins} - 2t_{ins}} \right)$	T_{ins}	0.51654 K.m/W
Thermal resistance insulation screen $\frac{\rho_{is}}{2\pi} \ln \left(\frac{D_{ins} + 2t_{is}}{D_{ins}} \right)$	T_{is}	0.01208 K.m/W

Thermal resistance screen bedding $\frac{\rho_{scb}}{2\pi} \ln \left(\frac{D_{scb}}{D_i} \right)$	T_{scb}	0.01833 K.m/W
Thermal resistance screen serving $\frac{\rho_{scs}}{2\pi} \ln \left(\frac{D_{scs}}{D_{sc}} \right)$	T_{scs}	0.0316 K.m/W
Thermal resistance armour bedding $\frac{\rho_{ab}}{2\pi} \ln \left(\frac{D_{ab}}{D_{shj} - (H_{sh} + \Delta H)} \right)$	T_{ab}	0.01992 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	0.04364 K.m/W

Dimensions

Diameter

External diameter conductor	d_c	34.7 mm
Diameter over conductor shield $d_c + 2(t_{ct} + t_{cs})$	D_{cs}	39.8 mm
Diameter over insulation $d_c + 2(t_{ct} + t_{cs} + t_{ins})$	D_{ins}	100.6 mm
Diameter over insulation incl. insulation screen $d_c + 2(t_{ct} + t_{cs} + t_{ins} + t_{is})$	D_i	103.7 mm
Diameter over insulation screen $d_c + 2t_i$	D_{is}	103.7 mm
Diameter over screen bedding $d_c + t_{i1} + 2t_{scb}$	D_{scb}	104.7 mm
Mean diameter screen $D_{scb} + t_{sc}$	d_{sc}	106.3 mm
Diameter over screen $D_{scb} + 2t_{sc}$	D_{sc}	107.9 mm
Equivalent diameter of screen and sheath $\sqrt{\frac{d_{sc}^2 + d_{sh}^2}{2}}$	d_s	109.856 mm
Diameter over screen serving $D_{sc} + 2t_{scs}$	D_{scs}	109.7 mm
Mean diameter sheath $D_{shb} + t_{sh} + H_{sh} + \Delta H$	d_{sh}	113.3 mm
Diameter over sheath $D_{shb} + 2(t_{sh} + H_{sh} + \Delta H)$	D_{sh}	116.9 mm
Diameter over sheath jacket	D_{shj}	116.9 mm
Diameter over armour bedding $D_{sh} + 2t_{ab}$	D_{ab}	122.9 mm
Equivalent diameter of screen/sheath and armour $\sqrt{\frac{d_s^2 + d_{ar}^2}{2}}$	d_e	117.991 mm
Mean diameter armour $D_{ab} + t_{a,1} + t_{a,2}$	d_{ar}	125.6 mm

Diameter over armour $D_{ab} + 2(t_{a,1} + t_{a,2})$	D_{ar}	128.3 mm
Diameter over jacket $D_{ar} + 2(t_j + t_{jj})$	D_j	134.3 mm

Area

Cross-sectional area conductor A_c	A_c	800 mm ²
Cross-sectional area insulation $\frac{\pi}{4} (D_{is}^2 - d_c^2)$	A_i	7500.2 mm ²
Cross-sectional area screen bedding $\pi t_{scb} (D_{scb} - t_{scb})$	A_{scb}	163.7 mm ²
Cross-sectional area screen $\left(\frac{t_{sc}}{2}\right)^2 \pi n_{scw} \left(1 + \frac{\nu_{sc}}{100}\right)$	A_{sc}	96.51 mm ²
Cross-sectional area screen serving $\pi t_{scs} (D_{scs} - t_{scs})$	A_{scs}	307.6 mm ²
Cross-sectional area sheath $d_{sh} t_{sh} \pi$	A_{sh}	1281.39 mm ²
Cross-sectional area armour bedding $\frac{\pi}{4} (D_{ab}^2 - (D_{ab} - t_{ab})^2)$	A_{ab}	572.1 mm ²
Cross-sectional area armour $n_{ar} t_{ar} w_{ar}$	A_{ar}	1036.8 mm ²
Cross-sectional area jacket $\frac{\pi}{4} (D_j^2 - (D_j - 2(t_j + t_{jj}))^2)$	A_j	1237.5 mm ²