Report

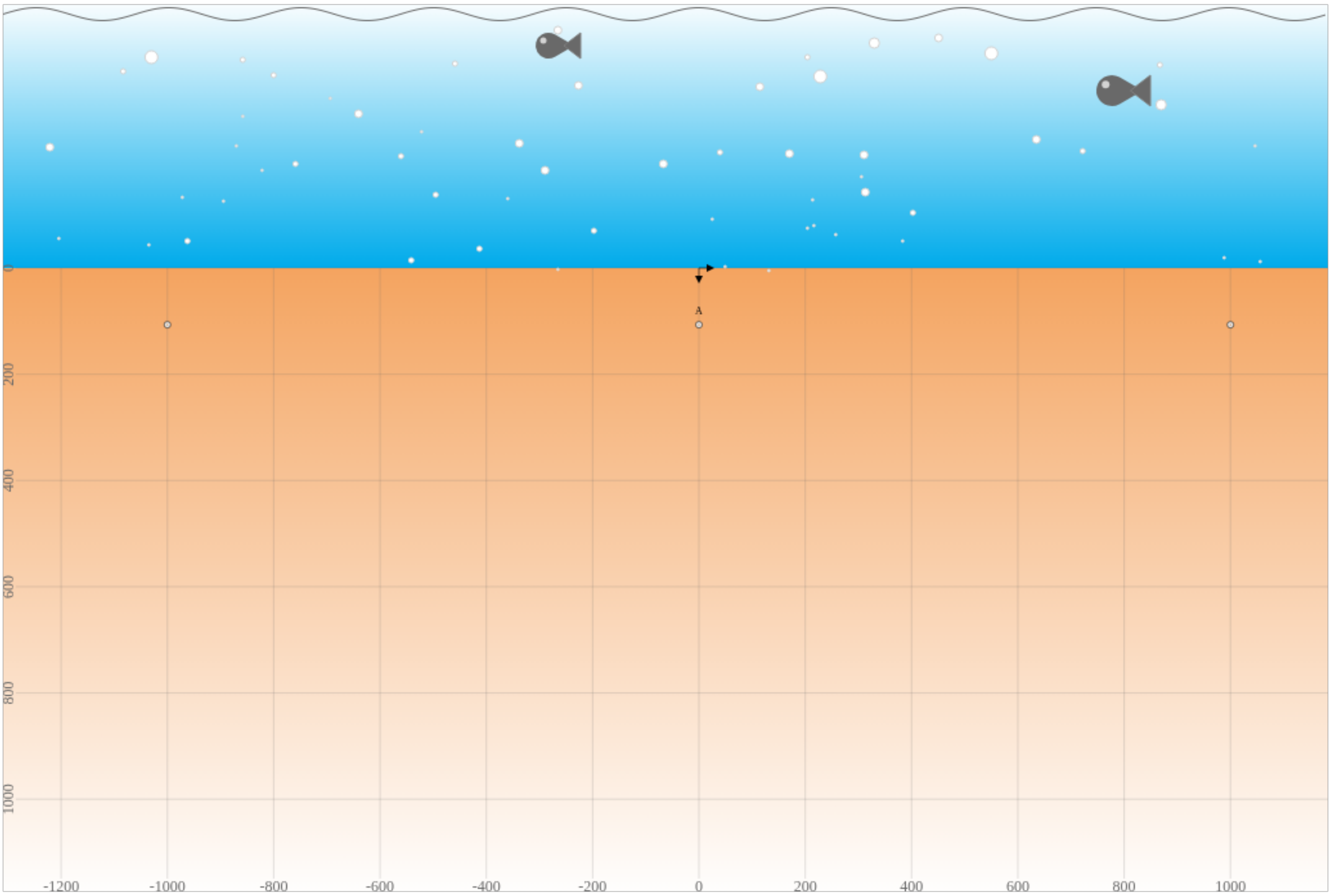
Title	Case study 6: A 400kV single core AC submarine cable
Project	Verification CIGRE TB 880
Created	Date: 2025-05-26 Time: 09:22 Software version: f8c9 (2025-05-24)

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}	28
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}	337.461 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	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 $10^{-4} \frac{{k_4}^{0.2}}{4.68}$	$c_{p,soil}$	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^2K^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

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

Operating voltage	U_o	400 kV
Angular frequency	ω	314.2 rad/s

$2\pi f$

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	GMD	12.59921 m

$2^{\frac{1}{3}}S_m$

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	u	15.892

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

Geometric constant of circle buried	g_u	31.7526

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

Temperature

Temperature conductor	θ_c	1: 90 | 2: 89.74 | 3: 89.74 °C

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

Temperature screen/sheath	θ_s	1: 66.86 | 2: 66.61 | 3: 66.61 °C

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

Temperature screen	θ_{sc}	1: 67.69 | 2: 67.44 | 3: 67.44 °C

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

Temperature sheath	θ_{sh}	1: 66.03 | 2: 65.79 | 3: 65.79 °C

$$\theta_{sc} - T_{scs}\left(W_c\,(1+\lambda_{11,sc}) + \frac{W_d}{2}\right)$$

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

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

External temperature object θ_e 1: 58.91 | 2: 58.67 | 3: 58.67 °C

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

Temperature rise

Temperature rise conductor $\Delta\theta_c$ 1: 74.4418 | 2: 74.3911 | 3: 74.3911 K

$$n_{ph}\left(W_cT_{int} + W_dT_d\right) + n_{cc}\left(W_d\left(T_{4i} + T_{4ii} + v_4T_{4ss}\right) + \left(W_c + W_s + W_{ar} + W_{sp}\right)\left(T_{4i} + T_{4ii} + v_4T_{4\mu}\right) + W_{duct}\left(\frac{T_{4ii}}{2} + v_4T_{4\mu}\right)\right)$$

Temperature rise dielectric losses $\Delta\theta_d$ 1.9822 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 $\Delta\theta_p$ 1: 0.5583 | 2: 0.3501 | 3: 0.3501 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: 34.801 | 2: 34.779 | 3: 34.779 W/m

$$I_c{}^2R_c$$

Screen/sheath losses (phase) W_s 1: 37.616 | 2: 37.586 | 3: 37.586 W/m

$$\lambda_1W_c$$

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

$$\lambda_2W_c$$

Duct losses W_{duct} 0 W/m

Ohmic losses (phase) W_I 1: 110.031 | 2: 109.95 | 3: 109.95 W/m

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

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: 112.46 | 3: 112.46 W/m

$$W_I + W_d$$

Total losses (object) W_{tot} 1: 112.541 | 2: 112.46 | 3: 112.46 W/m

$$n_{ph}W_t$$

Total losses (system) W_{sys} 337.461 W/m

Thermal resistance

Thermal resistance ambient $T_{4\mu}$ 0.3852 K.m/W

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

Mutual heating coefficient $\prod_{k=1}^{q} \frac{d_{pk1}}{d_{pk2}}$	F_{mh}	1: 1.046 | 2: 1.028 | 3: 1.028

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: 0.8641 | 2: 0.864 | 3: 0.864 K.m/W
Internal thermal resistance for dielectric losses $\frac{T_1}{2n_c} + T_2 + T_3$	T_d	0.4046 K.m/W

Other characteristics

Earthing

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

Loss factor

Loss factor shield (screen/sheath) $\lambda_{11,sc} + \lambda_{11,sh} + F_e\lambda_{12}$	λ_1	1: 1.0809 | 2: 1.0807 | 3: 1.0807
Loss factor shield, circulating currents $\frac{W_{sar}}{2W_c}$	λ_{11}	1: 1.0809 | 2: 1.0807 | 3: 1.0807
Loss factor shield, eddy currents $\frac{R_{sh}}{R_c}\left(g_s\lambda_0\,(1+\Delta_1+\Delta_2) + \frac{(\beta_1 t_{sh})^4}{12{\cdot}10^{12}}\right)$	λ_{12}	1: 0.0002 | 2: 0.0002 | 3: 0.0002
Electrical resistance shield/armour $\frac{R_s R_{ar}}{R_s + R_{ar}}$	R_e	1: 7.2712e-2 | 2: 7.2650e-2 | 3: 7.2650e-2 Ω/km
Substitution coefficient λ_0 for eddy-currents $6\frac{{m_0}^2}{1+{m_0}^2}\left(\frac{d_e}{2s_c}\right)^2$ $1.5\frac{{m_0}^2}{1+{m_0}^2}\left(\frac{d_e}{2s_c}\right)^2$ $1.5\frac{{m_0}^2}{1+{m_0}^2}\left(\frac{d_e}{2s_c}\right)^2$	λ_0	1: 0 | 2: 0 | 3: 0
Substitution coefficient Δ_1 for eddy-currents $0.86{m_0}^{3.08}\left(\frac{d_e}{2s_c}\right)^{1.4m_0+0.7}$ $\frac{-0.74\,(m_0+2)\sqrt{m_0}}{2+(m_0-0.3)^2}\left(\frac{d_e}{2s_c}\right)^{m_0+1}$ $4.7{m_0}^{0.7}\left(\frac{d_e}{2s_c}\right)^{0.16m_0+2}$	Δ_1	1: 0 | 2: -0.0008 | 3: 0
Substitution coefficient Δ_2 for eddy-currents 0 $0.92{m_0}^{3.7}\left(\frac{d_e}{2s_c}\right)^{m_0+2}$	Δ_2	1: 0 | 2: 0 | 3: 0

$$21{m_0}^{3.3}\left(\frac{d_e}{2s_c}\right)^{1.47m_0+5.06}$$

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 $\sqrt{\frac{4\pi\omega}{10^7\rho_{sh}\left(1+\alpha_{sh}\left(\theta_{sh}-20\right)\right)}}$	β_1	1: 39.4705 | 2: 39.4868 | 3: 39.4868
Substitution coefficient g_s for eddy-currents $1+\left(\frac{t_{sh}}{D_{sh}}\right)^{1.74}\left(10^{-3}\beta_1 D_{sh}-1.6\right)$	g_s	1: 1.007065 | 2: 1.00707 | 3: 1.00707
Factor F_e eddy-current losses $\frac{4{M_e}^2{N_e}^2+\left(M_e+N_e\right)^2}{4\left({M_e}^2+1\right)\left({N_e}^2+1\right)}$	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) ${I_c}^2R_e\frac{{B_2}^2+{B_1}^2+R_eB_2}{\left(R_e+B_2\right)^2+{B_1}^2}$	W_{sar}	1: 75.231 | 2: 75.171 | 3: 75.171 W/m
Loss coefficient B_1 armour $\omega\left(H_s+H_1+H_3\right)$	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 $R_{cDC}\left(1+1.5\left(y_s+y_p\right)\right)$	R_c	1: 3.2223e-5 | 2: 3.2203e-5 | 3: 3.2203e-5 Ω/m

Electrical resistance DC conductor | R_{cDC} | 1: 2.8180e-5 | 2: 2.8157e-5 | 3: 2.8157e-5 Ω/m

$R_{c20}\left(1+\alpha_c\left(\theta_c-20\right)\right)$

Skin effect factor conductor | y_s | 1: 0.09565 | 2: 0.09579 | 3: 0.09579

$$\frac{{x_s}^4}{192+0.8{x_s}^4}$$

Factor for skin effect on conductor | x_s | 1: 2.11172 | 2: 2.11256 | 3: 2.11256

$$\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_s}$$

Proximity effect factor conductor | y_p | 1: 0 | 2: 0 | 3: 0

$$\frac{{x_p}^4}{192+0.8{x_p}^4}\left(\frac{d_c}{s_c}\right)^2\left(0.312\left(\frac{d_c}{s_c}\right)^2+\frac{1.18}{\frac{{x_p}^4}{192+0.8{x_p}^4}+0.27}\right)$$

Factor for proximity effect of conductors | x_p | 1: 2.11172 | 2: 2.11256 | 3: 2.11256

$$\sqrt{10^{-7}\frac{8\pi f}{R_{cDC}}k_p}$$

Electrical resistance screen | R_{sc} | 1: 2.6091e-4 | 2: 2.6070e-4 | 3: 2.6070e-4 Ω/m

$R_{sc}\left(1+\alpha_{sc}\left(\theta_{sc}-20\right)\right)$

Electrical resistance sheath | R_{sh} | 1: 1.9776e-4 | 2: 1.9759e-4 | 3: 1.9759e-4 Ω/m

$R_{sh}\left(1+\alpha_{sh}\left(\theta_{sh}-20\right)\right)$

Electrical resistance shield | R_s | 1: 1.1249e-4 | 2: 1.1240e-4 | 3: 1.1240e-4 Ω/m

$$\frac{R_{sh}R_{sc}}{R_{sh}+R_{sc}}$$

Reduction factor | RF | 1: 0.1808 | 2: 0.1807 | 3: 0.1807

$$\frac{R_s}{\sqrt{{R_s}^2+{X_s}^2}}$$

Electrical resistance armour | R_{ar} | 1: 2.0561e-4 | 2: 2.0542e-4 | 3: 2.0542e-4 Ω/m

$R_{ar}\left(1+\alpha_{ar}\left(\theta_{ar}-20\right)\right)$

Electrical field strength, capacitive load current

Electrical field strength insulation inner/outer | E_i | 12.515 | 4.951 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 | 19.9 | 50.3 mm

Line-to-ground voltage | U_e | 230940.11 V

$$\frac{1000U_o}{\sqrt{3}}$$

Capacitance insulation | C_b | 1.498e-10 F/m → 0.1498 μF

$$\frac{1}{2\pi\epsilon_0}\frac{10^{-9}}{18}C_b$$

Capacitive load current | I_C | 1.087e-2 A/m → 10.8668 A

$U_e\omega C_b$

Charging capacity | P_C | 2509.5896 var/m → 2509.5896 kvar

$n_{ph}{U_e}^2\omega C_b$

Capacitive earth short-circuit current | I_{Ce} | 1.087e-2 A/m

$U_e\omega C_E$

Reactance

Self reactance conductor $\omega \frac{\mu_0}{2\pi} \ln\left(\frac{D_E}{GMR_c}\right)$	X_a	6.999e-4 Ω/m → 0.6999 Ω
Self reactance screen/sheath $\omega \frac{\mu_0}{2\pi} \ln\left(\frac{2s_c}{d_s}\right)$	X_e	3.270e-4 Ω/m → 0.327 Ω
Mutual reactance between conductors flat formation without transposition $\omega \frac{\mu_0}{2\pi} \ln 2$	X_m	4.355e-5 Ω/m
Substitution coefficient P to calculate loss factor by circulating currents $X_e + X_m$	P_X	3.705e-4
Substitution coefficient Q to calculate loss factor by circulating currents $X_e - \frac{X_m}{3}$	Q_X	3.125e-4

Induced current (approximate)

Induced circulating current shield $\max\left(I_c \sqrt{\frac{\lambda_{11,sb} R_c}{R_s}}\right)$	I_s	578.260+0.000j A
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 $\sqrt{3} U_o I_c$	S_G	719.999 MVA
Voltage drop $\sqrt{3}\,(R_c \cos\varphi + \omega L_m \sin\varphi)$	V_{drop}	0.056 V/(A.km) → 58 V = 0.01%
Inductance (mean) $\frac{\mu_0}{2\pi} \ln\left(\frac{GMD}{GMR_c}\right)$	L_m	1.368e-6+0.000e0j H/m → 1.3676 mH

Telegrapher equation

Surge impedance $\sqrt{\frac{Z_1}{Y_1}}$	Z_C	1: 95.6205-3.5808j | 2: 95.6204-3.5786j | 3: 95.6204-3.5786j Ω
Propagation constant $\sqrt{Z_1 Y_1}$	γ_C	1: 1.685e-7+4.499e-6j | 2: 1.684e-7+4.499e-6j | 3: 1.684e-7+4.499e-6j

Impedance valid up to 100 Hz without earth return

Positive sequence admittance $G + j\omega C_b$	Y_1	0.000e0+4.705e-8j S/m → 0.0000+0.0000j S

Positive sequence impedance $R_1 + jX_1$	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
Positive sequence reactance $\omega \frac{\mu_0}{2\pi} \ln\left(\frac{GMD}{GMR_c}\right)$	X_1	4.296e-4 Ω/m → 0.4296 Ω

Cable datasheet

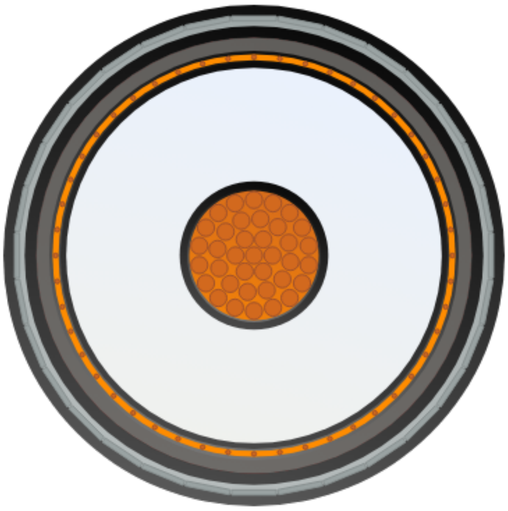
Title CIGRE TB 880 Case 6 400kV single core AC submarine (#16318)

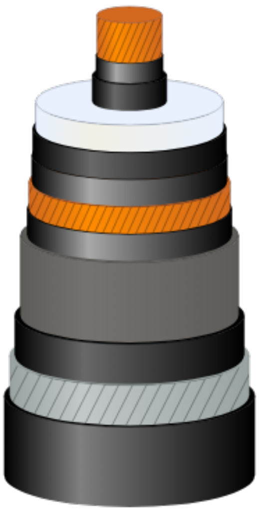
Cable is used in following systems: A

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 $\frac{d_c}{2}$	r_c	17.35 mm

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 $t_{ct} + t_{cs} + t_{ins} + t_{is}$	t_i	34.5 mm
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 $\frac{1.4-1.2}{5-2}(t_{ar}-2)+1.2$	f_{ar}	1.2467e0 Ω/m
Number of wires armour	n_{ar}	32
Diameter armour wire $\sqrt{\frac{4t_{ar}w_{ar}}{\pi}}$	d_f	6.423 mm
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 $1-\epsilon_e$	η_e	0.1
Mass cable $m_{hollow}+m_{metal}$	m_{tot}	39.467 kg/m

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 $\frac{R_{sc}R_{sh}}{R_{sc}+R_{sh}}$	R_{so}	9.489e-2 Ω/km

Armour

Electrical resistance armour $10^6\frac{f_{ar}\rho_{ar}}{A_{ar}}$	R_{ar}	1.6593e-04 Ω/m
Electrical resistance armour, CIGRE TB 880 $F_{lay,ar}R_{ar}$	R_{ar}	1.7174e-04 Ω/m
Effective length per unit lay length armour $\text{Min}\left(2,\sqrt{1+\left(\frac{\pi d_{ar}}{L_{lay,ar}}\right)^2}\right)$	$F_{lay,ar}$	1.035
Length of lay armour	$L_{lay,ar}$	1478.51 mm
Inductance H_1 armour $10^{-7}\pi\mu_e\frac{n_{ar}{d_f}^2}{L_{lay,ar}d_{ar}}sin\left(\phi_{ar}\right)cos\left(\gamma_{ar}\right)$	H_1	1.6288e-7 H/m
Inductance H_2 armour $10^{-7}\pi\mu_e\frac{n_{ar}{d_f}^2}{L_{lay,ar}d_{ar}}sin\left(\phi_{ar}\right)sin\left(\gamma_{ar}\right)$	H_2	1.6288e-7 H/m
Inductance H_3 armour $0.4\left(\mu_t cos\left(\phi_{ar}\right)^2-1\right)\frac{d_f}{d_{ar}}\cdot 10^{-6}$	H_3	1.7049e-7 H/m
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 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 — 0.6189 K.m/W

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

Thermal resistance armour bedding — T_2 — 0.0515 K.m/W

$$T_{scs} + T_{dsh} + T_{ab}$$

Thermal resistance jacket — T_3 — 0.0436 K.m/W

$$T_j + T_{jj}$$

Thickness conductor—sheath — t_1 — 35.9 mm

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

Thickness sheath—armour — t_2 — 3 mm

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

Thickness armour—surface — t_3 — 3 mm

$$t_j + t_{jj}$$

Cable elements

Thermal resistance, transient — T_{tot} — 0.714 K.m/W

$$T_1 + T_2 + T_3$$

Thermal resistance insulation — T_i — 0.60056 K.m/W

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

Thermal resistance conductor tape — T_{ct} — 0.0298 K.m/W

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

Thermal resistance conductor shield — T_{cs} — 0.04214 K.m/W

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

Thermal resistance insulation — T_{ins} — 0.51654 K.m/W

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

Thermal resistance insulation screen — T_{is} — 0.01208 K.m/W

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

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

Dimensions

Diameter

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

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

Area

Cross-sectional area conductor	A_c	800 mm^2
Cross-sectional area insulation $\frac{\pi}{4}\left({D_{is}}^2 - {d_c}^2\right)$	A_i	7500.2 mm^2
Cross-sectional area screen bedding $\pi t_{scb}\left(D_{scb} - t_{scb}\right)$	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 $\pi t_{scs}\left(D_{scs} - t_{scs}\right)$	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 $\frac{\pi}{4}\left({D_{ab}}^2 - \left(D_{ab} - t_{ab}\right)^2\right)$	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 $\frac{\pi}{4}\left({D_j}^2 - \left(D_j - 2\left(t_j + t_{jj}\right)\right)^2\right)$	A_j	1237.5 mm^2