



Test Report No. 2022-56

Type Test of a 123 kV- Cable System consisting of XLPE-cable, two Outdoor Terminations, one Sectionalizing Joint and one Straight Through Joint

Customer: Südkabel GmbH
Rhenaniastr. 12-30
68199 Mannheim

Reporter:

This report includes 47 numbered pages and is only valid with the original signature. Copying of extracts is subject to the written authorization of the test laboratory. The test results concern exclusively the tested objects.

1 Purpose of Test

A 123 kV- Cable System consisting of XLPE-cable, two Outdoor Terminations, one Sectionalizing Joint and one Straight Through Joint was subjected to a type test according to IEC 60840:2020, subclause 12.4.2 "Type tests on cable systems" and DIN VDE 0276-632:2017.

2 Miscellaneous Data

Test objects: **123 kV cable system**

- Outdoor termination, type EHFVC DMR
Drawing No. O.36.72.16a, dated 05.04.2022, Fig. 2.1
- Outdoor termination, type EHFST 123/145
Drawing No. O.36.75, dated 22.09.2022, Fig. 2.2
- Straight through joint, type SEHDV DMR
Drawing No. O.3600.35.16A dated 10.06.2022, Fig 2.3
- Sectionalizing joint, type SEHDVCB DMR
Drawing No. O.3600.36.16A dated 28.03.2022, Fig 2.4
- Single-core cable with Cu2500 conductor, XLPE insulation, type 2XS(FL)2Y 1x2500 RMS/188 DMR >c-0-u-w< Fig. 2.5.

Manufacturer: Südkabel GmbH
Rhenaniastr. 12-30
68199 Mannheim

Place of test: Institut für Elektroenergiesysteme und
Hochspannungstechnik (IEH)
Karlsruher Institut für Technologie (KIT)
Engesserstr. 11 – 76128 Karlsruhe
Testing laboratory accredited by DAkkS according to DIN EN
ISO/IEC 17025:2018.
The accreditation is valid only for the standards listed in the annex
of the accreditation certificate No. D-PL-11068-09-00.
The bending test was performed at Südkabel GmbH.

Testing dates: Bending test: 14.09.2022
Delivery: 20.09.2022
Mounting: 20.09. – 14.10.2022
Test date: 06.10.2022 – 20.04.2023

Atmospheric conditions: Temperature: 18°C - 25°C
Air pressure: 980 - 1020 mbar
rel. humidity: 35% - 70%

Representatives

Customer's representatives:

Dipl.-Ing. D. Pfisterer, Südkabel GmbH

Representatives responsible for the tests

Dr.-Ing. R. Badent

Dr.-Ing. B. Hoferer

Mr. O. Müller

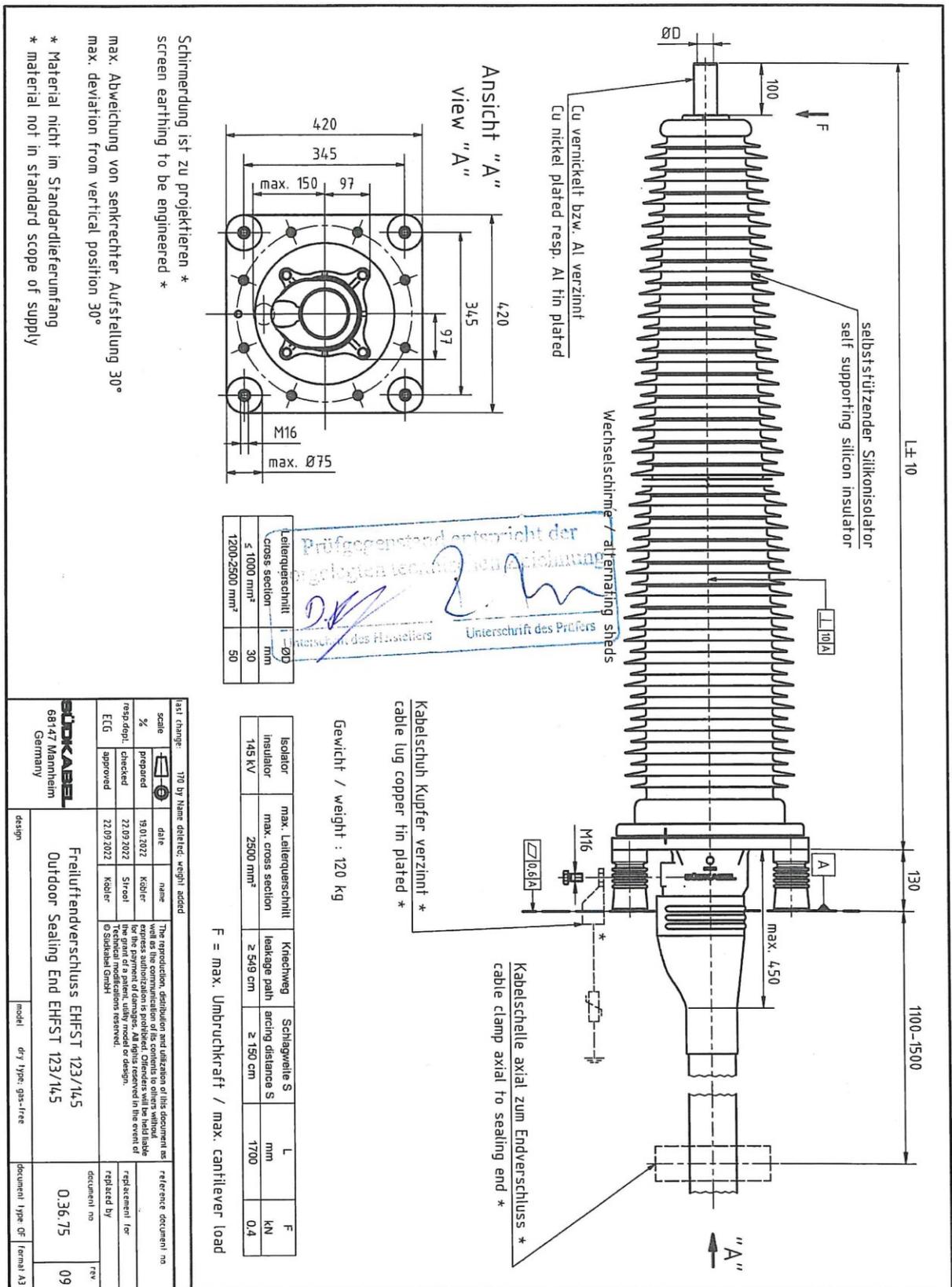


Fig 2.2: Outdoor Termination

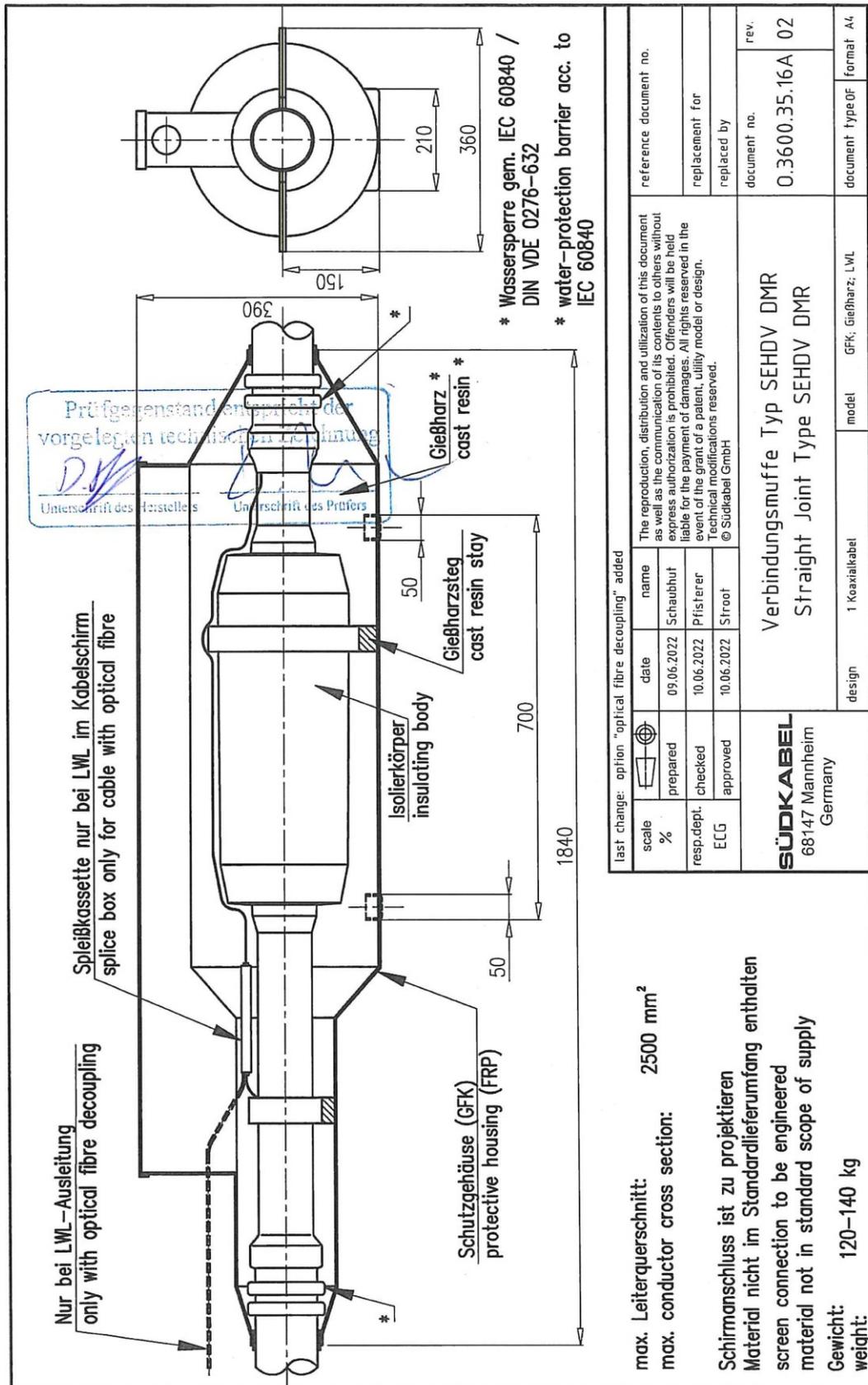


Fig 2.3: Straight through Joint

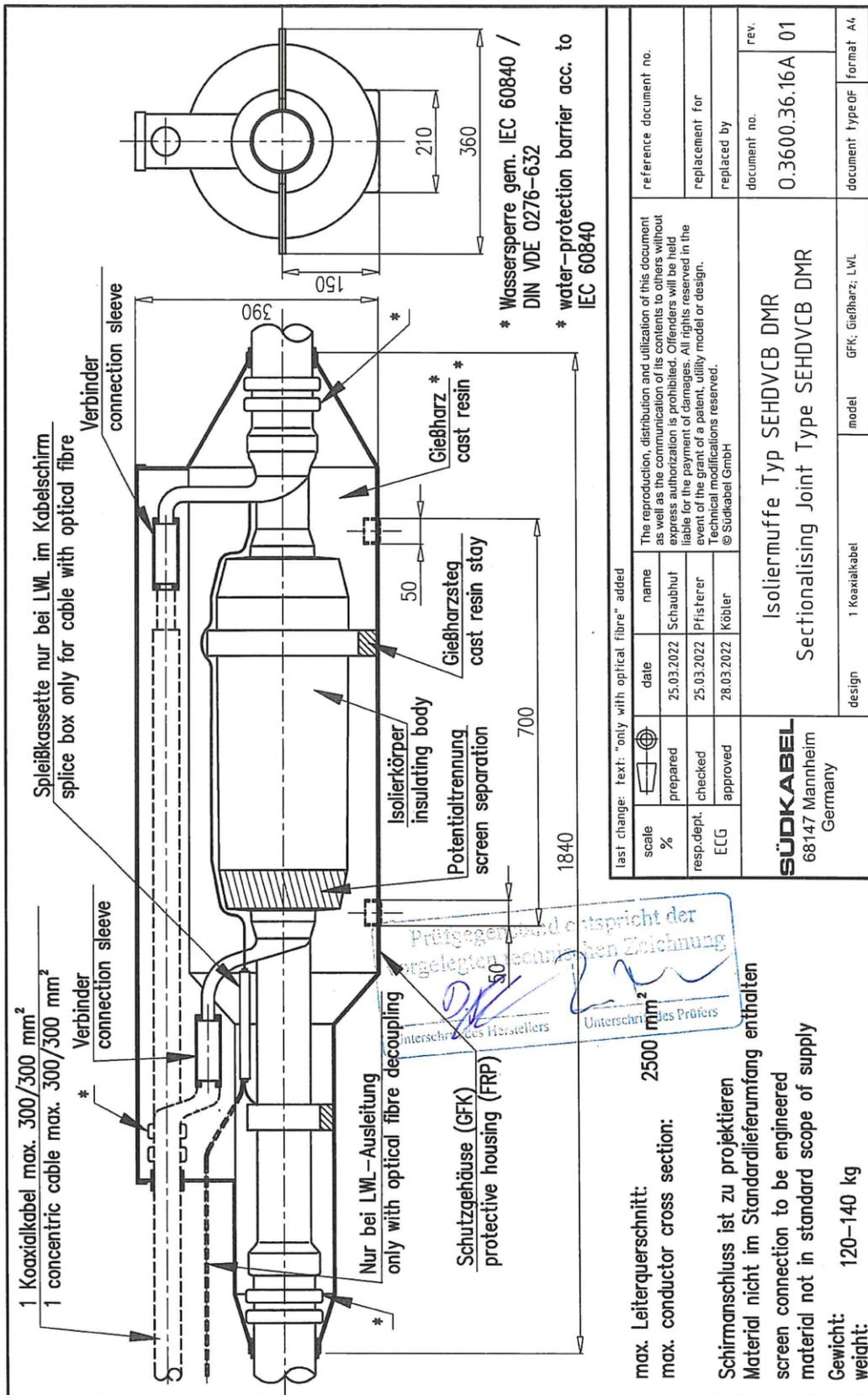


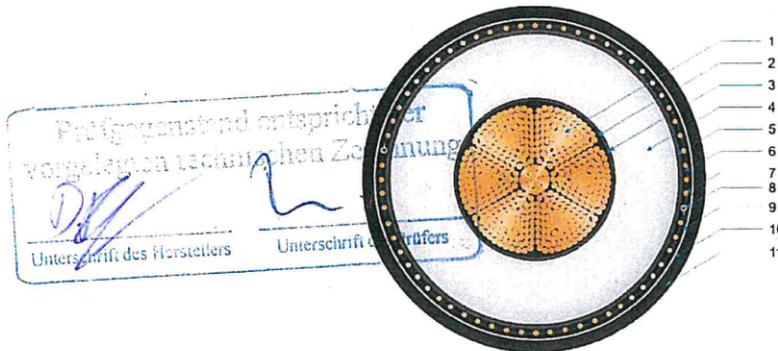
Fig 2.4: Sectionalizing Joint

Technical Document no. KSH-2019-136-K-02 rev06

SÜDKABEL

Customer: Amprion
Project: Korridor A-Nord
Subject: Cable Data Sheet DMR – 2500 mm²

TS 4906004



(not to scale)
 (subject to change)

Cable Type Designation

2XS(FL)2Y 1x2500 RMS/188 DMR >C-O-U-W<

Construction

1	conductor	copper, 6 segments, uni-directional stranding; swelling tapes wrapped around each segmental and between each copper wire layer	2500 mm ²	diameter nominal	61.4 mm (59.7-63.5)
2	bedding	fabric tape, semi-conducting		nominal thickness	0.4 mm*
3	conductor screen	conductive XLPE-compound		nominal thickness	1.5 mm
4	insulation	XLPE		nominal thickness	12.8 mm
				diameter approx.	91 mm
5	insulation screen	conductive XLPE-compound		nominal thickness	1.5 mm
6	bedding	swelling tape, semi-conducting		nominal thickness	0.4 mm*
7	wire screen	copper wires	188 mm ²	nominal thickness	1.80 mm
8	optical fibres	in steel tubes (multi-mode, single-mode) [Remark 1]		no. of tubes x fibres	2 x 2, 2 pcs.
9	bedding	swelling tape, semi-conducting		nominal thickness	0.4 mm*
10	metallic sheath	copolymer-laminated aluminium; overlapping 20 mm		nominal thickness	0.2 mm
11	outer sheath	HDPE (black), conductive outer layer (black), halogen-free, UV-resistant		nominal thickness	5 mm
	cable weight	nominal 31.5 kg/m		cable diameter approx.	111 mm

[Remark 1] Withstand temperature: 180 °C for 10 s

Mechanical Data

dynamic bending radius during laying	minimum	2.8 m
professional single bend radius when installed	minimum	1.7 m
pulling force at conductor during laying	maximum	125 kN
side wall pressure during laying	maximum	10 kN/m
laying temperature of cable during installation	minimum	-5 °C

Electrical Data

operating voltage U ₀ / U (U _m)		64 / 110 (123) kV
DC-resistance of conductor at 20 °C	maximum	0.0072 Ω/km
capacitance	nominal	0.403 μF/km
electrical stress at conductor screen	nominal	5.9 kV/mm
electrical stress at insulation screen	nominal	4.3 kV/mm

*: Tolerances of thickness +/- 40% due to variant in tension
 Design aspects and used material are subject of PQ-Test qualification.

Date: 21/11/2022

Issued: KSE / Peters

Reference no.: TS 4906004

page 1/3

Fig 2.5: XLPE-cable, Cu2500

Tests: Test volume, chronological order and requirements correspond to IEC 60840:2020 subclause 12.4.2 "Type tests on cable systems", incl. Annex E and ANNEX H and DIN VDE 0276-632:2017. All tests were performed according IEC 60060-1:2010.

For conformity assessment, the decision rules according IEC Guide 115:2021, subclause 4.4.2 procedure 1, resp. ILAC G8:2019, subclause 4.2.1 were applied.

- Pos. 1 Bending Test
- Pos. 2 Check of insulation thickness
- Pos. 3 Partial Discharge Test
U = 3 U₀ = 192 kV; 10 s, thereafter;
U = 2,5 U₀ = 160 kV
sensitivity better than 2 pC
no detectable discharge exceeding declared sensitivity
- Pos. 4 AC-voltage withstand test
U = 230 kV, t = 60 s
- Pos. 5 Partial Discharge Test
U = 3 U₀ = 192 kV; 10 s, thereafter;
U = 2,5 U₀ = 160 kV
sensitivity better than 2 pC
no detectable discharge exceeding declared sensitivity
- Pos. 6 Tan δ-Measurement at elevated temperature
8 h loading up to 95°C - 100°C conductor temperature
with at least 2 h at 95°C - 100°C
Test voltage: U = 96 kV
max tan δ: 10·10⁻⁴
- Pos. 7 Heating cycle voltage test
Load cycle: 24 h
8h loading up to 95°C - 100 °C conductor temperature with at least
2h at 95°C-100°C, 16h cooling
Test voltage: U = 2,5 U₀ = 160 kV
Number of cycles: 20
- Pos. 8 Partial Discharge Test at ambient and elevated temperature
U = 3 U₀ = 192 kV; 10 s, thereafter;

- $U = 2,5 U_0 = 160 \text{ kV}$
sensitivity better than 2 pC
no detectable discharge exceeding declared sensitivity
- Pos. 9 Lightning impulse voltage test at elevated temperature
 $T = 95^\circ\text{C}-100^\circ\text{C}$, at least 2h, $U = 550 \text{ kV}$,
10 impulses each polarity
- Pos. 10 Switching impulse voltage test at elevated temperature
 $T = 95^\circ\text{C}-100^\circ\text{C}$, at least 2h, $U = 350 \text{ kV}$,
10 impulses each polarity
- Pos. 11 AC-voltage withstand test
 $U = 230 \text{ kV}$, $t = 60 \text{ s}$
- Pos. 12 AC-voltage withstand test
 $U = 160 \text{ kV}$, $t = 4 \text{ h}$
- Pos. 13 Partial Discharge Test at ambient and elevated temperature
 $U = 3 U_0 = 192 \text{ kV}$; 10 s, thereafter;
 $U = 2,5 U_0 = 160 \text{ kV}$
sensitivity better than 2 pC
no detectable discharge exceeding declared sensitivity
- Pos. 14 Electrical test of the sheath with conductive coating
Lightning impulse voltage test
 $U = 65 \text{ kV}$, 10 impulses each polarity
- Pos. 15 Electrical test of the joint with conductive coating
Lightning impulse voltage test
 $U = 85 \text{ kV}$, 10 impulses each polarity
- Pos. 16 Examination
- Pos. 17 Water Penetration test according Annex E
- Pos. 18 Measurement of resistivity of semi-conducting screens
Ageing treatment at 100°C ; 168 h.
Measurement of resistivity

Additional tests for accessories, ANNEX H

Test object: Sectionalizing Joint

- Pos. 19.1 Heating cycle test without Voltage
Load cycle: 24 h
8h loading up to 95°C - 100 °C conductor temperature with at least
2h at 95°C-100°C, 16h cooling
Number of cycles: 20
- Pos. 19.2 Water immersion and heat cycling
Raising the water temperature up to 70-75°C with at least 5h at 70-
75°C, thereafter cooling to within 10°C above ambient temperature.
Number of cycles: 20
- Pos. 19.3 DC voltage test in water
- Pos.19.3.1 DC-voltage test in water of the sectionalizing joint insulation section
(cross bonding joint) U = - 25 kV, 1min
- Pos.19.3.2 DC-voltage test in water of the outer protection, both screens
connected – water (cross bonding joint); U = - 25 kV, 1min
- Pos. 19.4 Lightning impulse voltage test of the sectionalizing joint insulation
section (cross bonding joint)
U = 60 kV, 10 impulses each polarity
Lightning impulse voltage test of the outer protection, both screens
connected - earthed exterior (cross bonding joint)
U = 37.5 kV, 10 impulses each polarity
- Pos. 19.5 Joint examination

3 Mounting

The cable preparation, assembling and mounting of the cable system was accomplished by technicians of Südkabel GmbH. Fig. 3.1 shows the complete test setup.

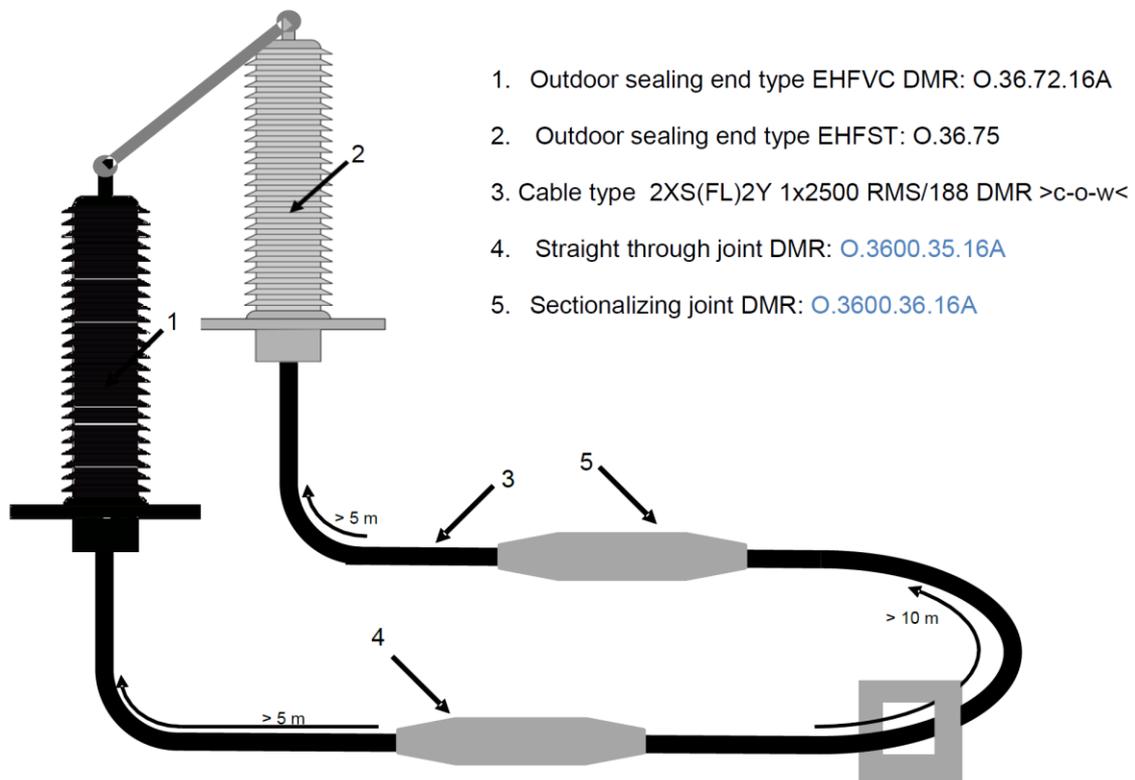


Fig 3.1: Test setup

4 Test Setup

4.1 Bending Test

The sample was bent around a test cylinder, diameter 3253 mm. According IEC 60840:2020, resp. DIN VDE 0276-632:2017 the bending diameter must be $20(d+D)+5\%$, D = nominal external diameter of the cable, d = nominal diameter of the conductor.

Values of the test sample: $D = 111$ mm and $d = 61,4$ mm.

This results in a maximum diameter of the test cylinder: $d_B = 3620,4$ mm.

The test sample was bent around the test cylinder at room temperature. Then the sample was unwound and the process repeated except that the bending of the sample was done in the reverse direction. This cycle of operations was carried out three times in total, Figure 4.1.

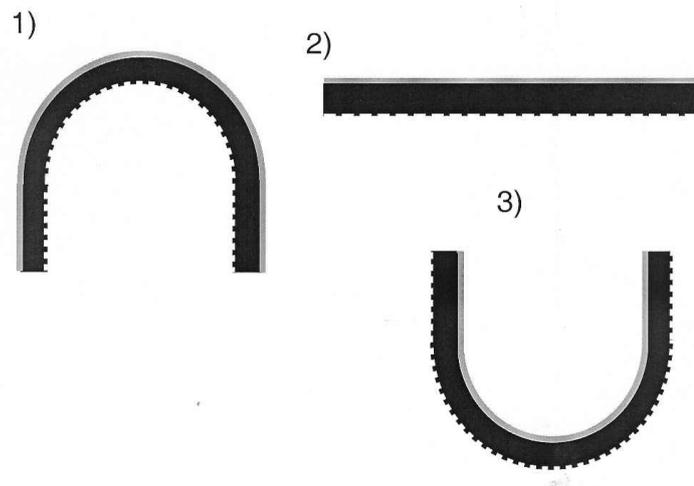


Figure 4.1: Bending test.

The bending test was evaluated by visual inspection according IEC 60840:2020, ANNEX G.1

4.2 Check of Insulation Thickness

The insulation thickness was measured as described in IEC 60811-1-1, subclause 8.1. For measuring the insulation thickness a profile projector with a magnification of 10 was used which allowed a reading of 0,01 mm.

4.3 AC Voltage Withstand Test

The test voltage was generated by an 1000-kVA transformer. The voltage measurement was carried out with a capacitive divider ($C_H = 200 \text{ pF}$; ratio = 2.000) and a digital peak voltmeter

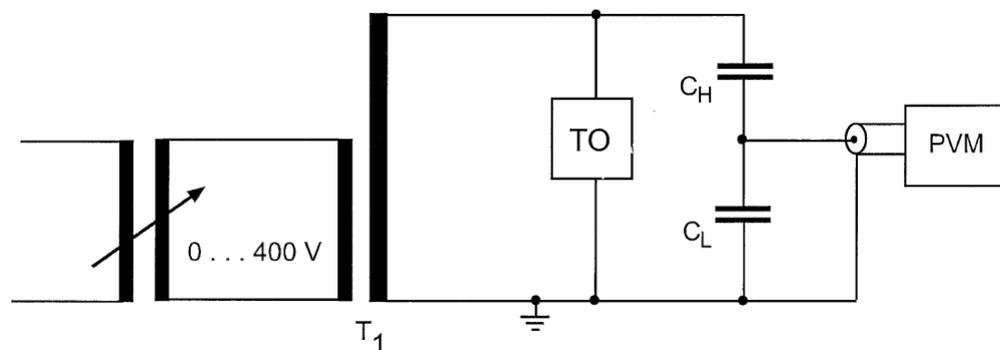


Figure 4.3: Test-setup for AC-voltage withstand test and PD measurement

AC-transformer:	400V/400kV; $S_N = 1000 \text{ kVA}$
Voltage measurement:	$C_H = 200 \text{ pF}$; ratio 2000:1 uncertainty 3 %
TO:	Test object

4.4 Partial-Discharge Test

The PD-measurement was performed with an analogue bridge according to *Kreuger*, Figure 4.4. External PDs producing common mode signals at the detector are rejected by the differential amplifier. Internal PDs represent differential mode signals and are amplified. The background noise level at 160 kV_{rms} was max. 1,0 pC.

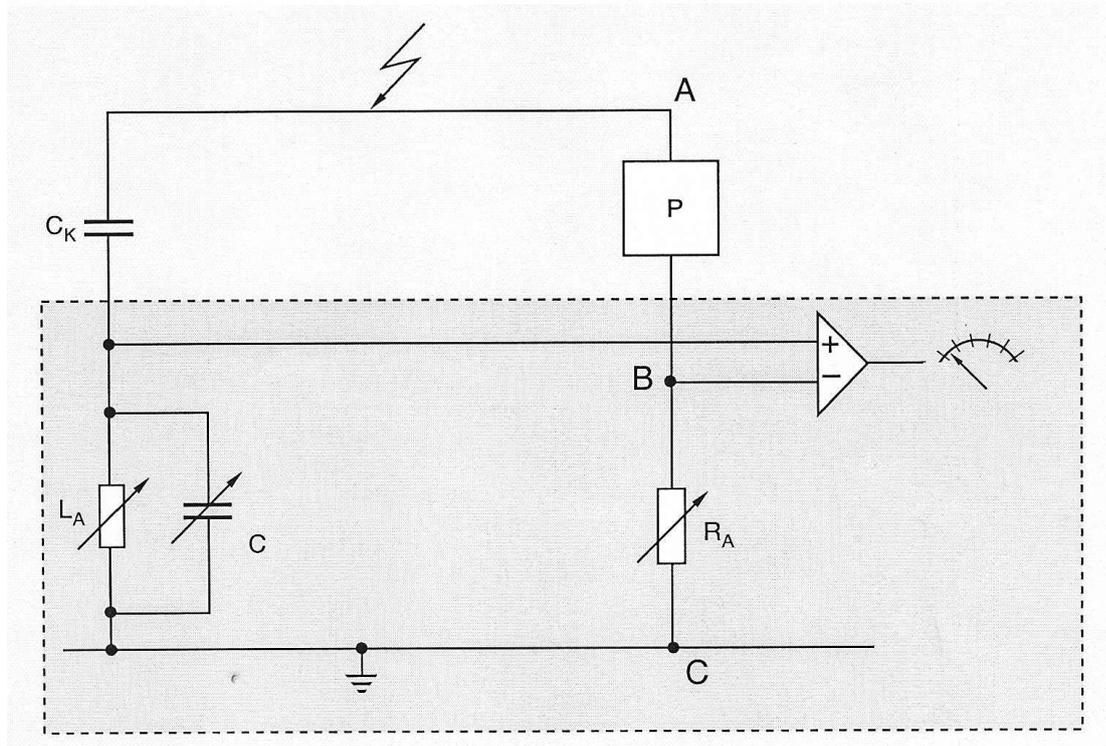


Figure 4.4: Scheme of PD test circuit
P: Test object
 C_K : Coupling Capacitor

For balancing the bridge a calibrating impulse with $q_A = 100 \text{ pC}$ is applied between the terminals A (high-voltage) and C (ground) and the amplifier output is minimized. A pulse between the terminals A and C corresponds to an external PD. For the calibration a PD pulse, $q_A = 2 \text{ pC}$, is applied between A and B. Subsequently, the amplifier output of the PD measuring unit is adapted to the applied pulse.

4.5 Tan δ -Measurement

For the measurement of the dissipation factor $\tan\delta$ an Universal current measuring system (MI600 OMICRON) was used, allowing measurements in the range from $10^{-5} < \tan \delta < 1$ with an uncertainty of 10^{-4} . The capacity of the compressed gas type capacitor, used as reference capacitor, was 103,9 pF, $\tan \delta < 10^{-5}$.

4.6 Cyclic Current Loading

According to IEC the test objects must be heated by a current which provides the permitted service temperature of the tested cable plus 5 K - 10 K, that means 95°C - 100°C, for XLPE-cables. The required heating current I was determined via a dummy cable. A 6 m sample of the cable used for the test, was provided with thermo couples NiCr-Ni at the conductor. One thermo couple in the middle of the dummy cable, two other thermo couples were installed each 1,0 m away from the middle. The difference between the three readings was less than 2 K. Further-more two additional thermo couples NiCr-Ni were placed on the outer sheath of the cable, one on the dummy and one on the test loop. Figure 4.6 illustrates the temperature rise at the conductor with a maximum heating current of $I = 3700$ A, 8h. The steady state current at thermal stabilisation was app $I = 3200$ A. Current inception was accomplished by four transformers which used the cable as secondary winding. The current was regulated by a control unit and measured by a current transformer, 5000/1, and a digital multimeter. The measurement uncertainty was 3%.

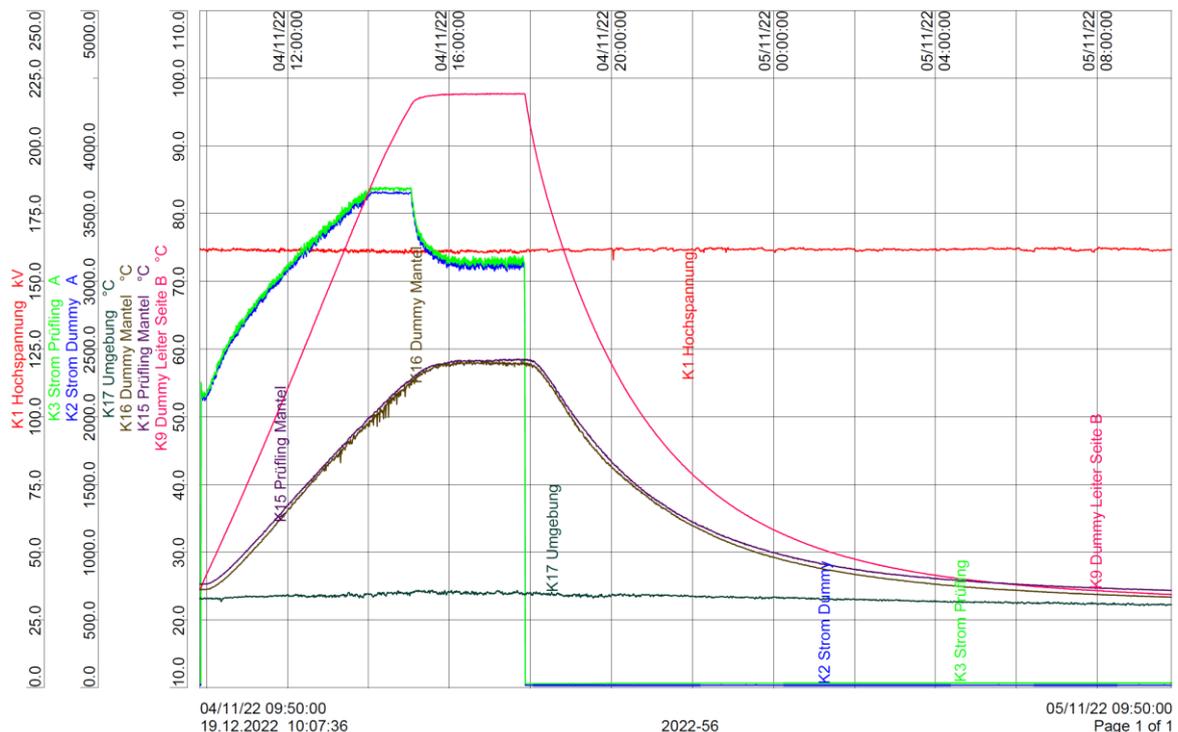


Figure 4.6: Heat cycle, Cu2500 cable, $I = 3200 \dots 3700$ A regulated, 8h; cooling 16 h

K8:	Dummy Conductor	K16:	Dummy sheath
K15:	Test object sheath	K17:	Ambient
K3:	Current test object	K2:	Current dummy
K1:	High Voltage		

4.7 Lightning Impulse Voltage Test

For lightning impulse voltage testing 8 stages of a Marx generator (Haefely) with a maximum cumulative charging voltage of $U = 1600 \text{ kV}$ and a maximum impulse energy of $E_{\text{max}} = 80 \text{ kW}_s$ were used. The crest value of the impulse voltage was measured by a damped capacitive divider and a subsequent impulse peak voltmeter. The front time and the time to half value were evaluated from the oscillographs.

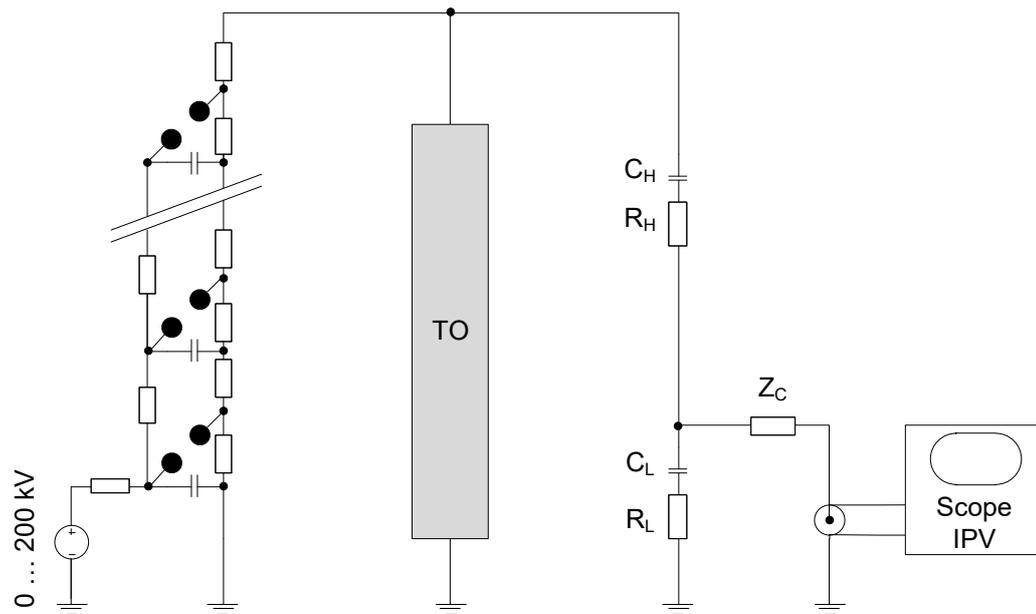


Figure 4.7.1: Schematics of lightning impulse voltage withstand test circuit

C_H : 1200 pF; $R_H = 70 \Omega$; Ratio: 30850:1; $Z_C = 50 \Omega$

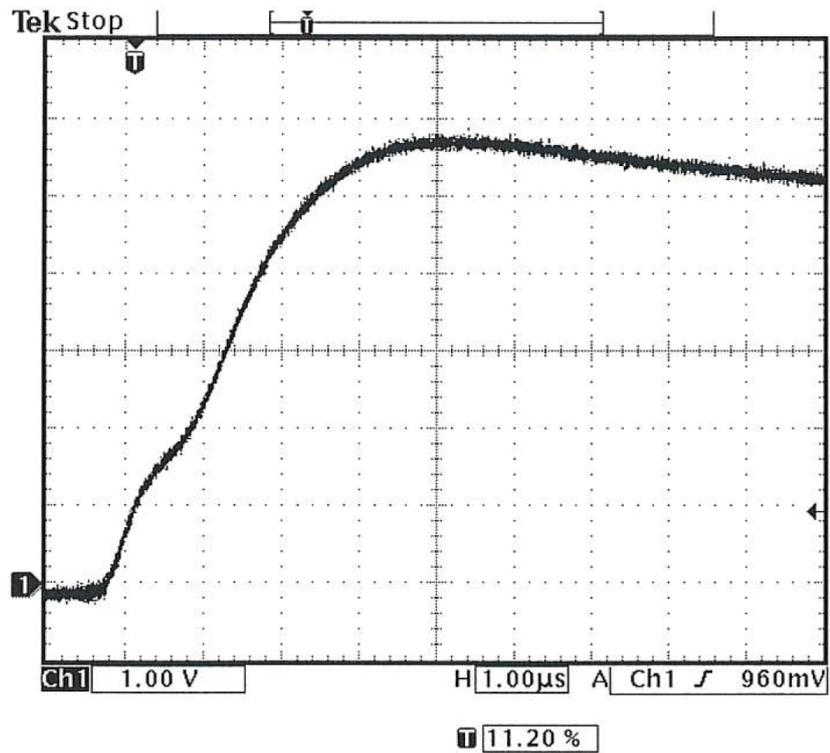
IPV: impulse-peak-voltmeter – measurement uncertainty 3%

Oscilloscope: Tektronix TDS 3044B – measurement uncertainty 2%

The waveform parameters were determined at reduced charging voltage. Figure 4.7.2 – 4.7.5 show the waveforms at the impulse test. Figure 4.7.2 shows the front time, Figure 4.7.3 the time to half value for positive polarity each. Figure 4.7.4 shows the front time, Figure 4.7.5 the time to half value for negative polarity each.

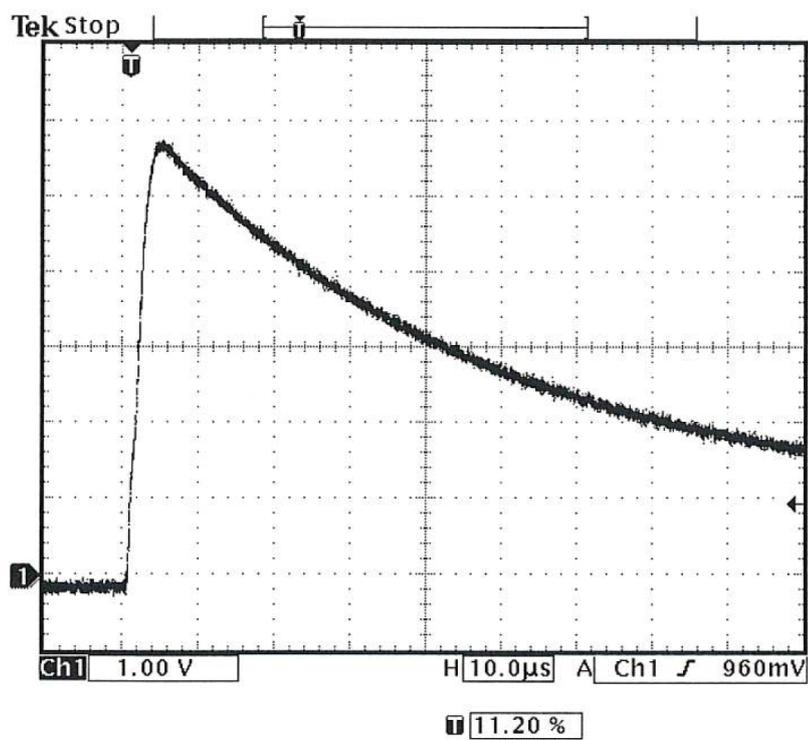
Positive impulse: : $T_1 = 3,41 \mu\text{s}$ $T_2 = 48,0 \mu\text{s}$

Negative impulse: $T_1 = 3,42 \mu\text{s}$ $T_2 = 47,7 \mu\text{s}$



28 Nov 2022
12:49:10

Figure 4.7.2: Front time, positive polarity
horiz.: 1 μ s/Div; vert.: 1 V/Div; ratio 30850:1



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Figure 4.7.3: Time to half value, positive polarity
horiz.: 10 μ s/Div; vert.: 1 V/Div; ratio 30850:1

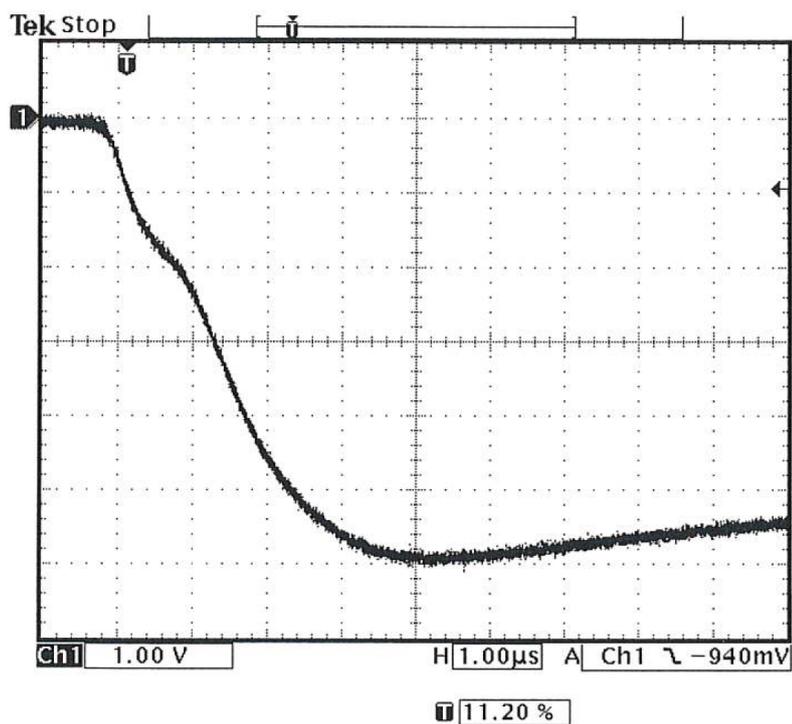


Figure 4.7.4: Front time, negative polarity
horiz.: 1 μs/Div; vert.: 1 V/Div; ratio 30850:1

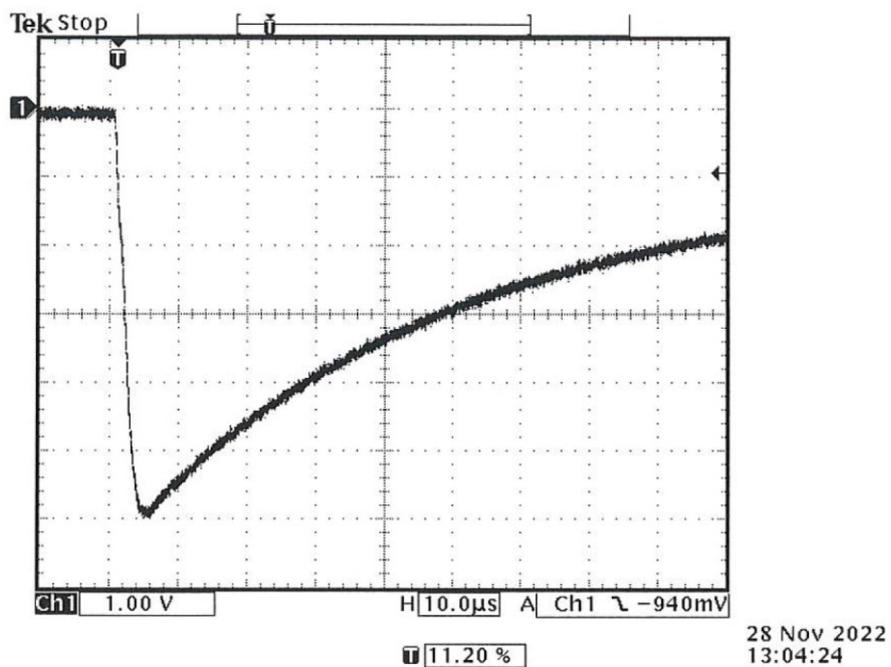


Figure 4.7.5: Time to half value, negative polarity
horiz.: 10 μs/Div; vert.: 1 V/Div; ratio 30850:1

4.8 Switching Impulse Voltage Test

For switching impulse testing, the same generator as already described in subclause 4.2 with modified resistors was used.

The waveform parameters were determined at reduced charging voltage. Figure 4.8.1 shows the time to peak while Figure 4.8.2 the time to half value for positive polarity. Figure 4.8.3 shows the time to peak while Figure 4.8.4 the time to half value for negative polarity respectively

Positive impulse: $T_1 = 255 \mu\text{s}$ $T_2 = 2591 \mu\text{s}$

Negative impulse: $T_1 = 259 \mu\text{s}$ $T_2 = 2571 \mu\text{s}$

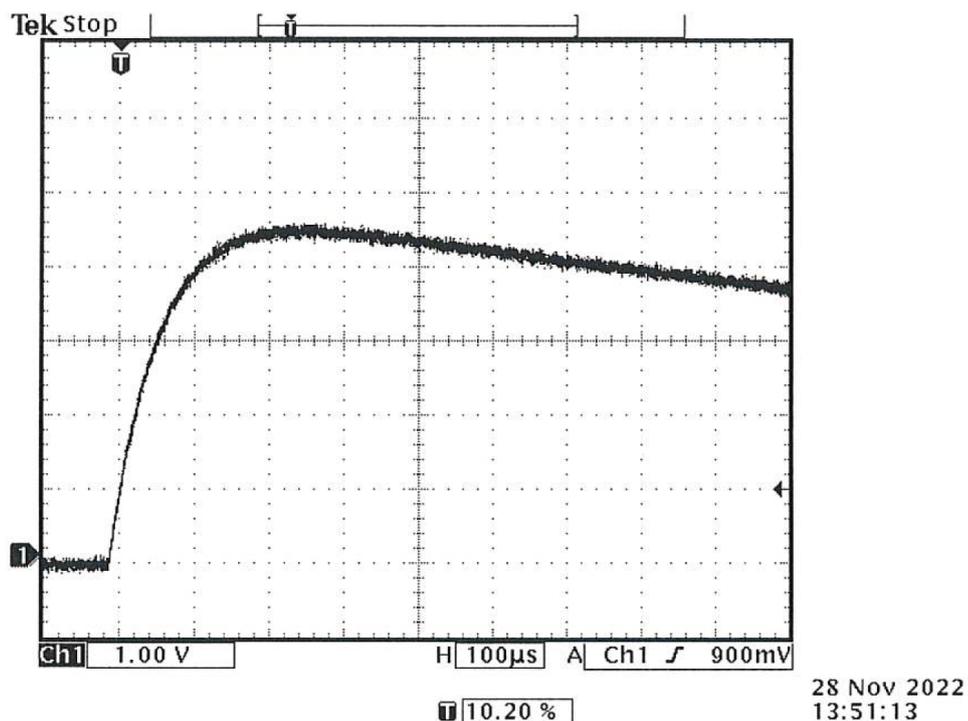


Fig. 4.8.1: Time to peak, positive polarity
horiz.: 100 μs/Div; vert.: 1 V/Div; ratio = 30450:1

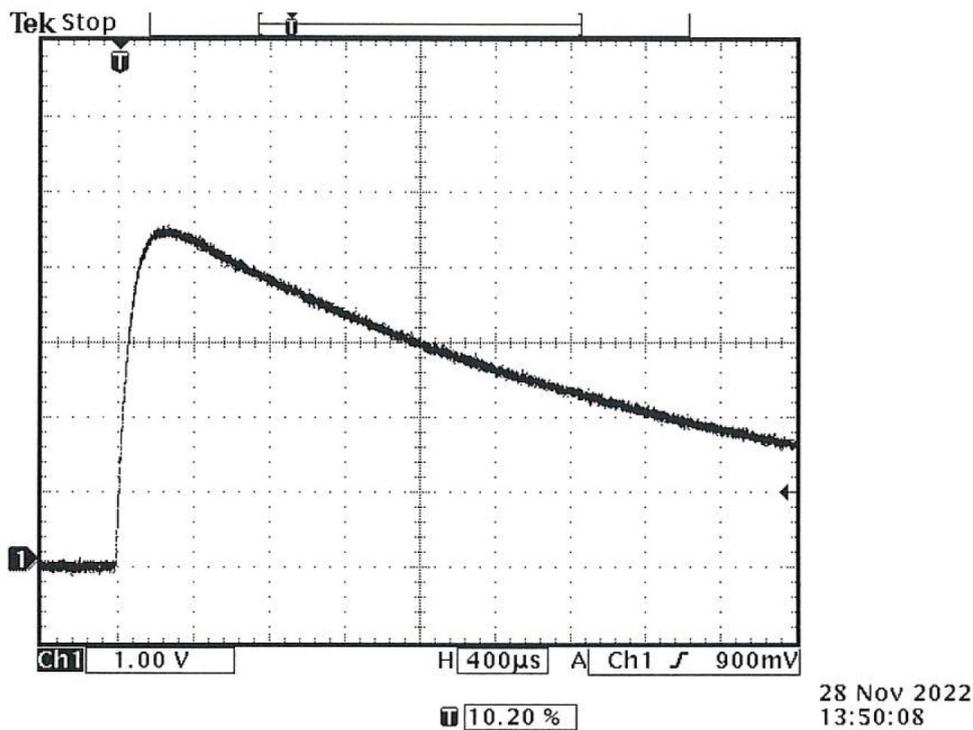


Fig. 4.8.2: Time to half value, positive polarity
horiz.: 400 μs/Div; vert.: 1 V/Div; ratio = 30450:1

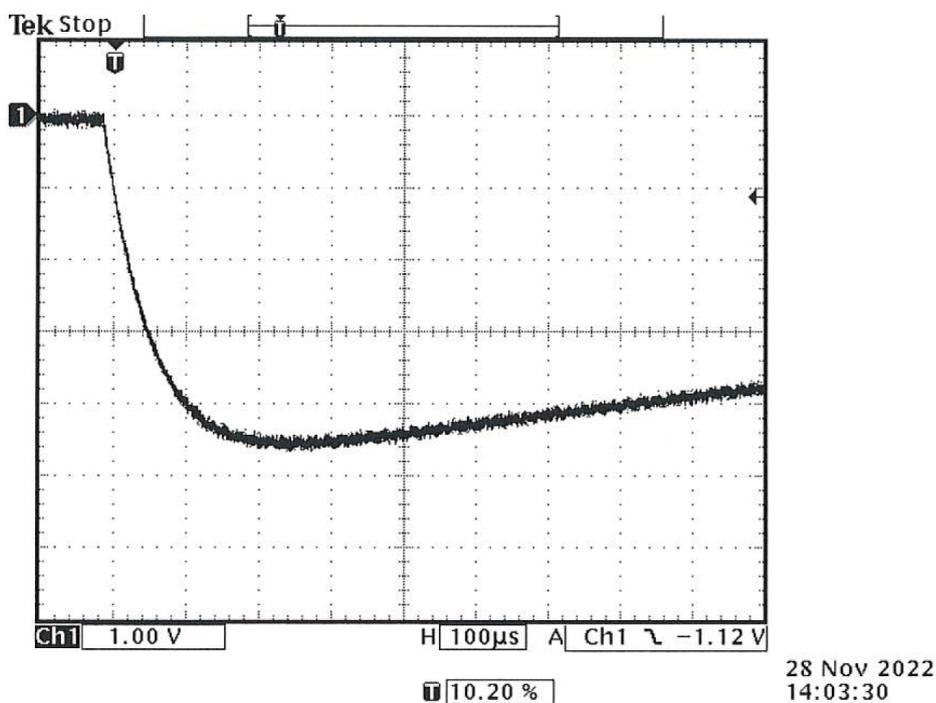


Fig. 4.8.3: Time to peak, negative polarity
horiz.: 100 μs/Div; vert.: 1 V/Div; ratio = 30450:1

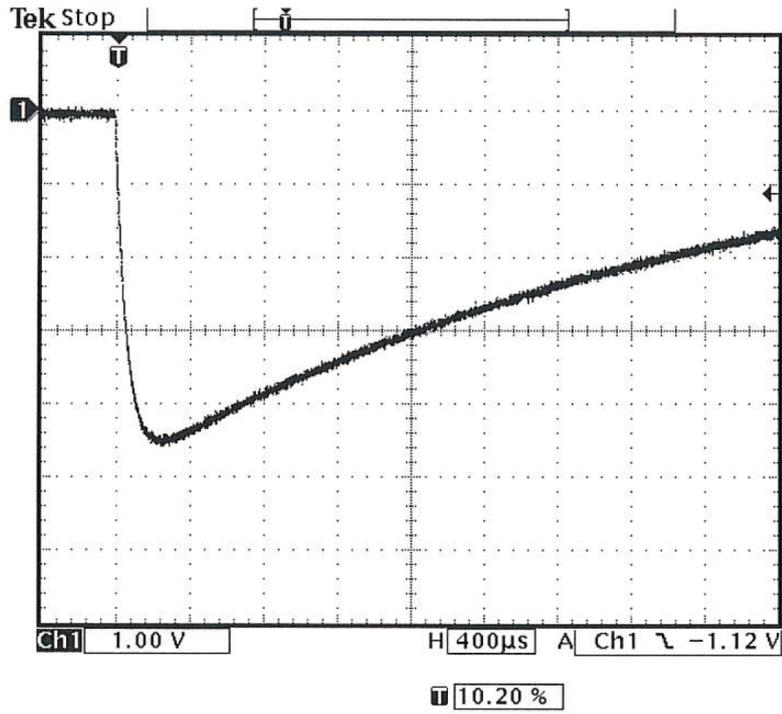


Fig. 4.8.4: Time to half value, negative polarity
horiz.: 400 μs/Div; vert.: 1 V/Div; ratio = 30450:1

4.9 Water Penetration Test

A sample of cable, which has been subjected to the bending test, was cut to a length of app 6400 mm. At both ends, all layers external the conductor were removed at a length of app 200 mm and cable lugs were installed. The length of the complete cable with all layers was then 6000 mm. A ring, 50mm wide, was removed from the centre of the length. This ring comprised all layers external to the conductor.

Afterwards, a PVC pipe with a T-junction was installed over the ring. The pipe was tightened with a rubber seal and a hose clamp. The inner diameter of the vertical tube was 100 mm, the length of the tube was app 1200 mm.

The tube was filled with water ($T = 23^{\circ}\text{C}$) within 5 minutes. The height of water in the tube was 1000 mm above the cable centre.

For heat cycling, the sample was connected in series with the dummy. 10 cycles with 8h heating and 16h natural cooling were performed.

4.10 Measurement of the Resistivity of semi-conducting screens

Two test pieces were prepared from two samples of the complete cable, one for conductor screen measurement and one for insulation screen measurement.

The conductor screen test piece was prepared by cutting a sample of core in half longitudinally and removing the conductor. The insulation screen test piece was prepared by removing all the coverings from a sample of core.

Four silver-painted electrodes according IEC 60840:2020, Fig. D1.a and D1.b were applied to the semi-conducting surfaces.

The assembly was placed in an oven, preheated to $90^{\circ}\text{C} \pm 2\text{K}$ and after at least 30 min., the resistance between the electrodes was measured.

The two samples were then stored in an oven at $100^{\circ}\text{C} \pm 2\text{K}$ for 168 h.

The assembly was then again placed in an oven, preheated to $90^{\circ}\text{C} \pm 2\text{K}$ and after at least 30 min., the resistance between the electrodes was measured.

4.11 Additional tests for accessories, ANNEX H.3

4.11.1 Water Immersion and Heat Cycling

For additional testing of the sectionalizing joint according ANNEX H, the joint was immersed in water. The water height was more than 1,0m over the highest point of the joint. For this, a big water basin (4,5 m long, 1,2 m wide and 1,6 m high) was used. A total of 20 heating cycles were applied by rising the water temperature to within 15 – 20K below the maximum temperature of the cable in normal operation, that means a temperature between 70 and 75°C. In each cycle the temperature was raised to the specified value, kept constant for at least 5h and was then cooled down to 10K above ambient temperature or 30°C absolute. The cycle time was 24 h. The temperature of the water was measured with thermo couples NiCr-Ni placed just some cm above the test object. Figure 4.11.1 shows one heat cycle.

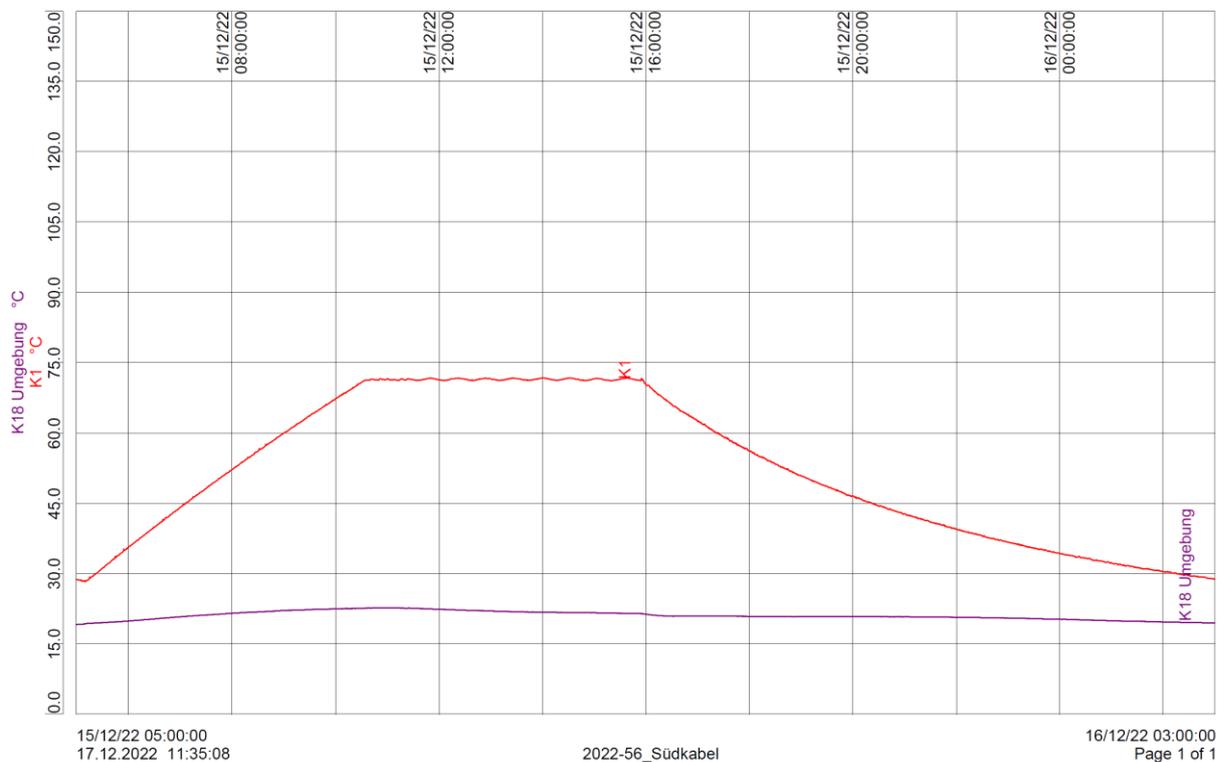


Figure 4.11.1: K18: Ambient temperature
K1: Water temperature above the joint

4.11.2 DC Voltage Withstand Test

The DC-voltage was generated by a power supply unit. The voltage measurement was carried out with an ohmic divider, ratio 2000:1. The measurement uncertainty was 1%. During the test the test object was placed in a tank filled with water. The height of the water was 1000 mm above the test object. The conductivity of the water at 20°C was 63 mS/m.

4.11.3 Lightning Impulse Voltage Test – Metal Screens to Earth

For lightning impulse testing of the metal screens to earth, the joint was wrapped with a conductive coating (aluminium foil) over the entire exterior. A 1 stage impulse generator as already described in 4.7 was used. The impulse voltage was measured by a damped capacitive divider and a subsequent impulse peak voltmeter (Haefely). The front time and the time to half value were evaluated from the oscillographs.

4.11.4 Lightning Impulse Voltage Test – Metal Screen to Metal Screen

For lightning impulse testing between the metal screens the same 1 stage impulse generator as already described in 4.7 was used. The impulse voltage was measured by a damped capacitive divider and a subsequent impulse peak voltmeter (Haefely). The front time and the time to half value were evaluated from the oscillographs.

5 Results

5.1 Bending Test

The test was carried out as described in 4.

Test date:	14.09.2022
Required value of the test cylinder:	$d_B \leq 3620,4 \text{ mm}$
Value of the test cylinder:	$d_B = 3253 \text{ mm}$
Number of cycles:	3 left, 3 right

The bending test was evaluated according IEC 60840:2020, ANNEX G1

Test date:	04.10.2022
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The examination of the samples with normal vision without magnification showed no delamination, folding, cracking or tearing of the metal tape or foil, or buckling or crossing of the screen wires.

The test was passed successfully.

5.2 Check of Insulation Thickness

The test was carried out as described in 4.

Test date:	06.10.2022
Nominal value:	12,8 mm
Measured Values:	12,78 mm
	12,82 mm
	13,71 mm
	13,80 mm
	13,63 mm
	13,40 mm
Average Value:	13,35 mm
Result:	The average value exceeds the nominal value by 4,3 %, so no correction was necessary

5.3 PD-Test

The test was carried out as described in 4.

Test date:	18.10.2022
Calibration pulse:	$q_{cal} = 2 \text{ pC}$
Background noise level:	1,0 pC
Test voltage:	U = 192 kV; t = 10 s, thereafter U = 160 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.4 AC Voltage Withstand Test

The test was carried out as described in 4.

Test date:	18.10.2022
Test voltage:	U = 230 kV; t = 60 s

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.5 PD-Test

The test was carried out as described in 4.

Test date:	25.10.2022
Calibration pulse:	$q_{cal} = 2 \text{ pC}$
Background noise level:	1,0 pC
Test voltage:	U = 192 kV; t = 10 s, thereafter U = 160 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.6 Tan δ - Measurement at elevated Temperature

The test was carried out as described in 4.

Test date:	28.10.2022
Heating current:	I = 3200 – 3700 A, regulated, 8h
Temperature:	T = 97,8 °C
Test Voltage:	U = 96 kV
tan δ :	tan $\delta = 0,48 * 10^{-4}$

The test was passed successfully

5.7 Heating cycle voltage test

The test was carried out as described in 4.

Test date:	02.11. – 24.11.2022
Test voltage:	U = 160 kV
Heating current:	I = 3200 - 3700 A regulated, 8h
Cycle:	8 h heating; 16 h cooling
Number of cycles:	20

Neither breakdown nor flashover occurred.

The test was passed successfully

5.8 PD Test

5.8.1 PD-Test at ambient Temperature

The test was carried out as described in 4.

Test date:	24.11.2022
Calibration pulse:	$q_{cal} = 2 \text{ pC}$
Background noise level:	1,0 pC
Test voltage:	U = 192 kV; t = 10 s, thereafter U = 160 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.8.2 PD-Test at elevated Temperature

The test was carried out as described in 4.

Test date:	25.11.2022
Calibration pulse:	$q_{cal} = 2 \text{ pC}$
Heating current:	I = 3200 – 3700 A, regulated, 8h
Temperature:	T = 96,1 °C
Background noise level:	1,0 pC
Test voltage:	U = 192 kV; t = 10 s, thereafter U = 160 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.9 Lightning Impulse Voltage Withstand Test

This test was carried out as described in chapter 4.

Test date:	28.11.2022
Test voltage:	U = 550 kV
Heating current:	I = 3200 - 3700 A regulated, 8h
Temperature:	T = 96,4 °C
Impulse:	1-5 / 40-60 μ s, both polarities
Number of tests:	10 positive polarity, 10 negative polarity

Neither flashover nor breakdown occurred at the test objects during all lightning impulse voltage withstand tests.

The test was passed successfully

Table 5.9.1 shows the test results with positive polarity, table 5.9.2 with negative polarity.

No.	Charging voltage / kV	U / kV	Figure	Remark
1	30,0	180	4.7.2	front time,
2	30,0	180	4.7.3	time to half value
3	45,8	278		50%
4	58,9	360		65%
5	72,0	439		80%
6	90,2	551	5.9.1	1. 100%
7	90,2	550	5.9.1	2. 100%
8	90,2	549	5.9.1	3. 100%
9	90,2	548	5.9.1	4. 100%
10	90,2	548	5.9.1	5. 100%
11	90,2	551	5.9.2	6. 100%
12	90,2	551	5.9.2	7. 100%
13	90,2	551	5.9.2	8. 100%
14	90,2	550	5.9.2	9. 100%
15	90,2	548	5.9.2	10. 100%

Table 5.9.1: Lightning impulse voltage withstand test, positive polarity

No.	Charging voltage / kV	\hat{u} / kV	Figure	Remark
1	-30,0	-180	4.7.4	front time,
2	-30,0	-180	4.7.5	time to half value
3	-45,8	-277		50%
4	-58,9	-359		65%
5	-72,0	-437		80%
6	-90,5	-551	5.9.3	1. 100%
7	-90,5	-552	5.9.3	2. 100%
8	-90,5	-552	5.9.3	3. 100%
9	-90,5	-550	5.9.3	4. 100%
10	-90,5	-552	5.9.3	5. 100%
11	-90,5	-550	5.9.4	6. 100%
12	-90,5	-551	5.9.4	7. 100%
13	-90,5	-551	5.9.4	8. 100%
14	-90,5	-552	5.9.4	9. 100%
15	-90,5	-550	5.9.4	10. 100%

Table 5.9.2: Lightning impulse voltage withstand test, negative polarity

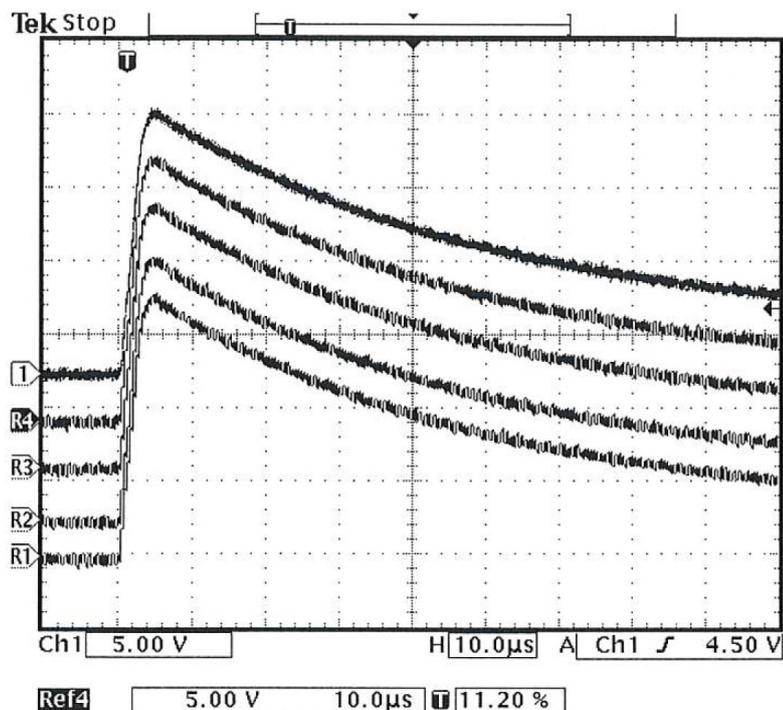


Figure 5.9.1: 1st – 5th 100%-stress, positive polarity
Hor.: 10 μs/Div; Vert.: 5 V/Div; ratio: 30850:1

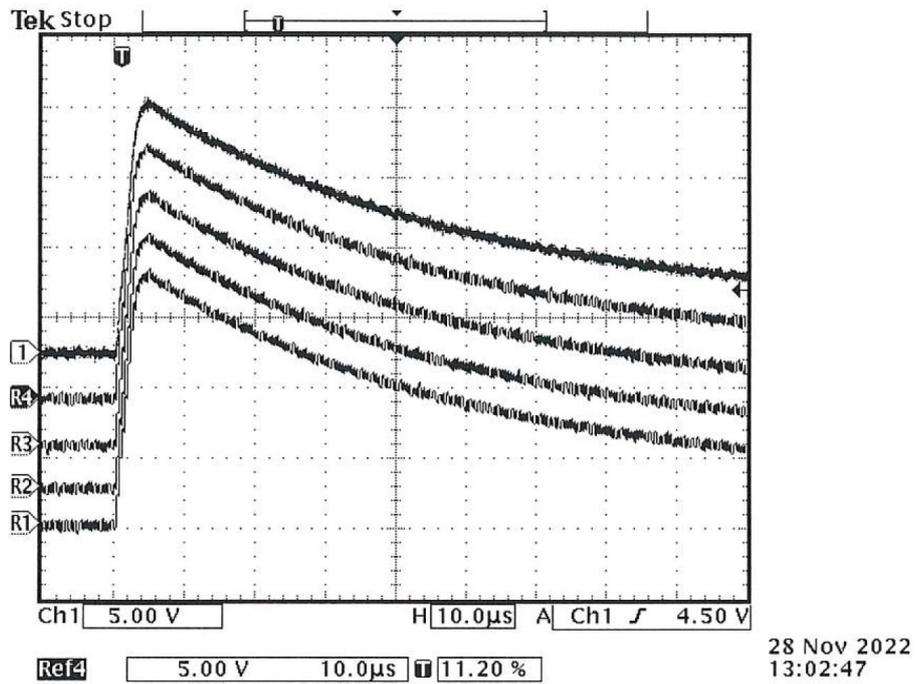


Figure 5.9.2: 6th – 10th 100%-stress, positive polarity
Hor.: 10 μs/Div; Vert.: 5 V/Div; ratio: 30850:1

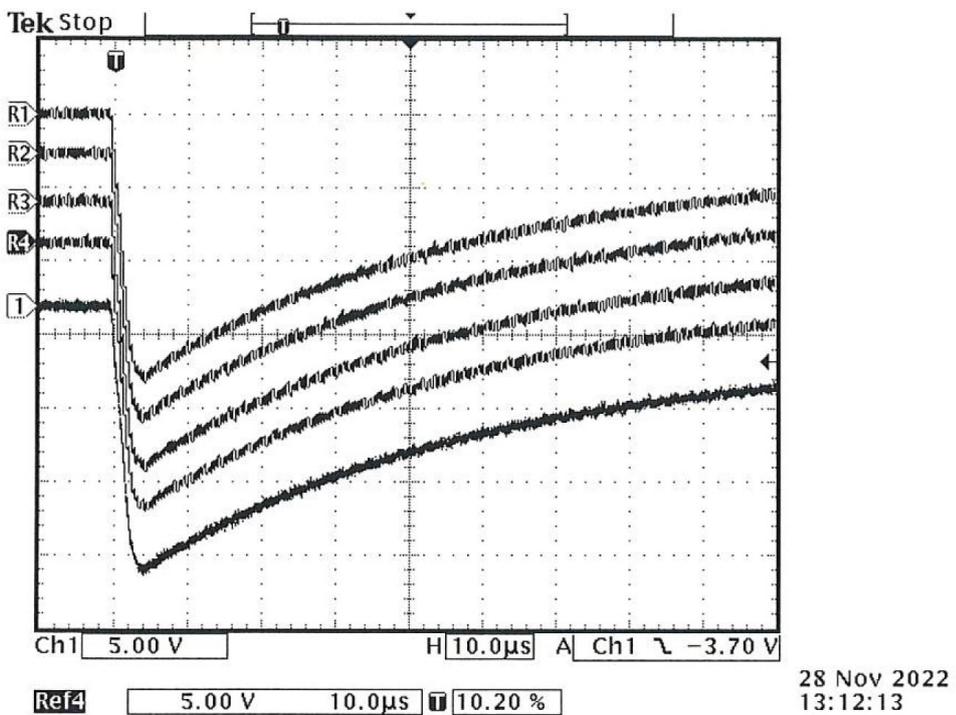


Figure 5.9.3: 1st – 5th 100%-stress, negative polarity
Hor.: 10 μs/Div; Vert.: 5 V/Div; ratio: 30850:1

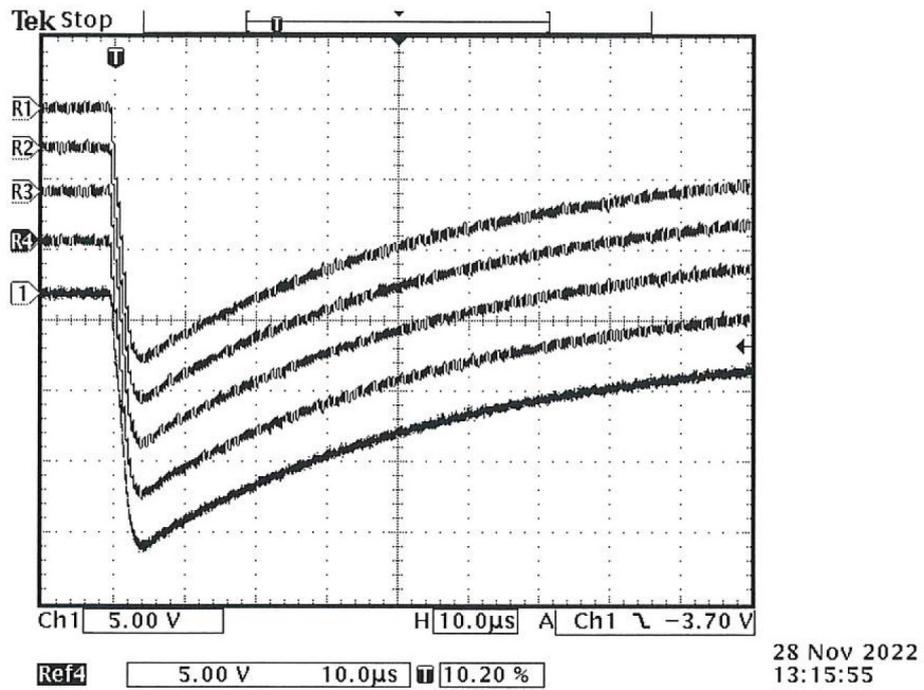


Figure 5.9.4 6th – 10th 100%-stress, negative polarity
Hor.: 10 µs/Div; Vert.: 5 V/Div; ratio: 30850:1

5.10 Switching Impulse Voltage Withstand Test

This test was carried out as described in chapter 4.

Test date:	28.11.2022
Test voltage:	U = 350 kV
Heating current:	I = 3200 - 3700 A regulated, 8h
Temperature:	T = 96,4 °C
Impulse:	1-5 / 40-60 μ s, both polarities
Number of tests:	10 positive polarity, 10 negative polarity

Neither flashover nor breakdown occurred at the test objects during all switching impulse voltage withstand tests.

The test was passed successfully

Table 5.10.1 shows the test results with positive polarity, table 5.10.2 with negative polarity.

No.	Charging voltage / kV	U / kV	Figure	Remark
1	30,0	136	4.7.2	front time,
2	30,0	136	4.7.3	time to half value
3	38,6	176		50%
4	49,9	229		65%
5	61,0	280		80%
6	76,3	351	5.10.1	1. 100%
7	76,3	350	5.10.1	2. 100%
8	76,3	350	5.10.1	3. 100%
9	76,3	349	5.10.1	4. 100%
10	76,3	352	5.10.1	5. 100%
11	76,3	352	5.10.2	6. 100%
12	76,3	350	5.10.2	7. 100%
13	76,3	349	5.10.2	8. 100%
14	76,3	350	5.10.2	9. 100%
15	76,3	351	5.10.2	10. 100%

Table 5.10.1: Switching impulse voltage withstand test, positive polarity

No.	Charging voltage / kV	\hat{u} / kV	Figure	Remark
1	-30,0	-136	4.7.4	front time,
2	-30,0	-136	4.7.5	time to half value
3	-38,6	-176		50%
4	-49,9	-228		65%
5	-61,0	-279		80%
6	-76,3	-349	5.10.3	1. 100%
7	-76,3	-352	5.10.3	2. 100%
8	-76,3	-349	5.10.3	3. 100%
9	-76,3	-350	5.10.3	4. 100%
10	-76,3	-350	5.10.3	5. 100%
11	-76,3	-348	5.10.4	6. 100%
12	-76,3	-352	5.10.4	7. 100%
13	-76,3	-350	5.10.4	8. 100%
14	-76,3	-351	5.10.4	9. 100%
15	-76,3	-351	5.10.4	10. 100%

Table 5.10.2: Switching impulse voltage withstand test, negative polarity

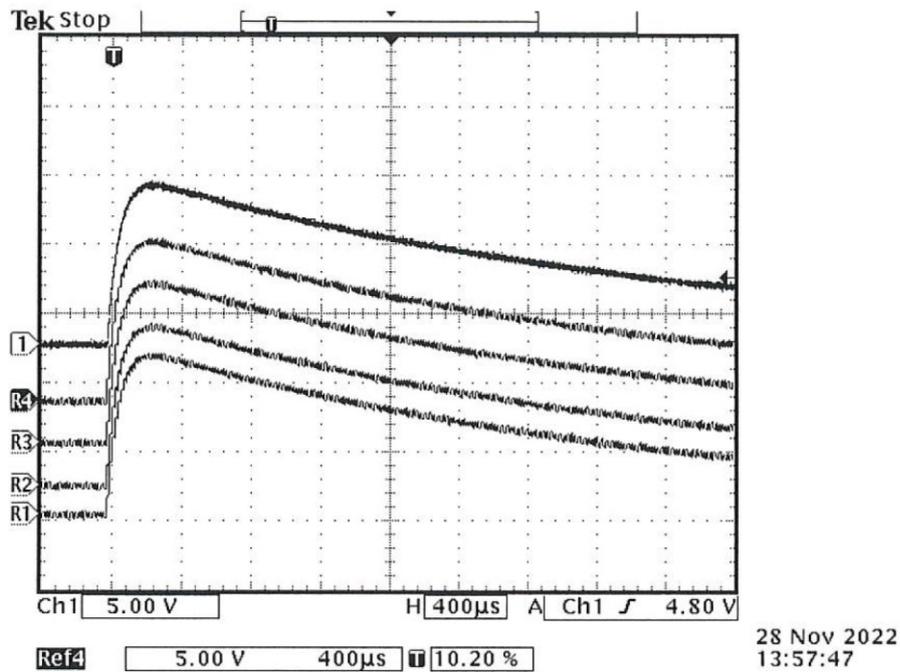
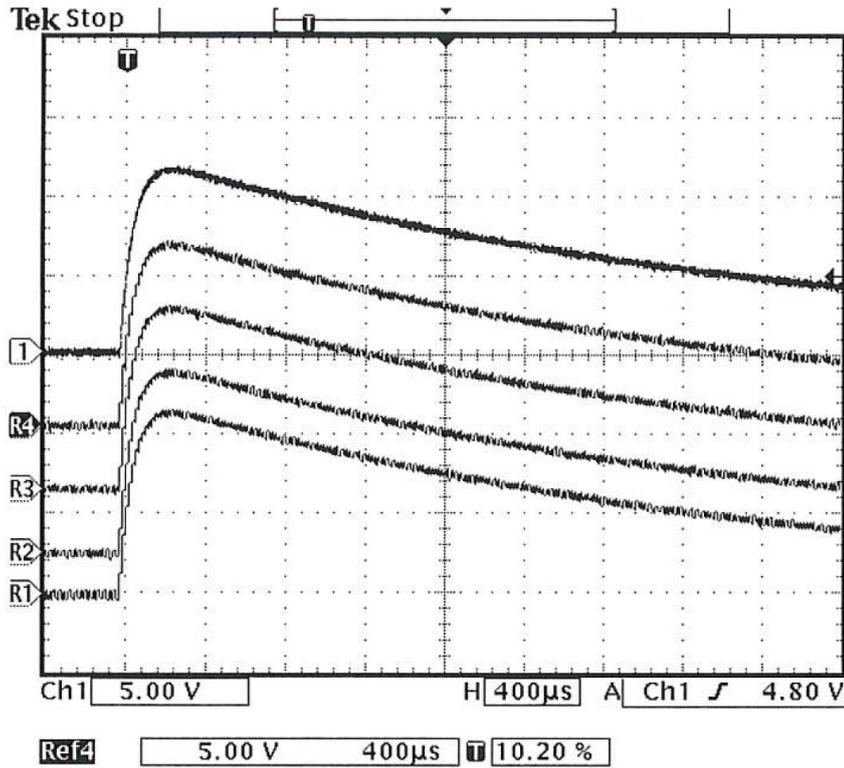
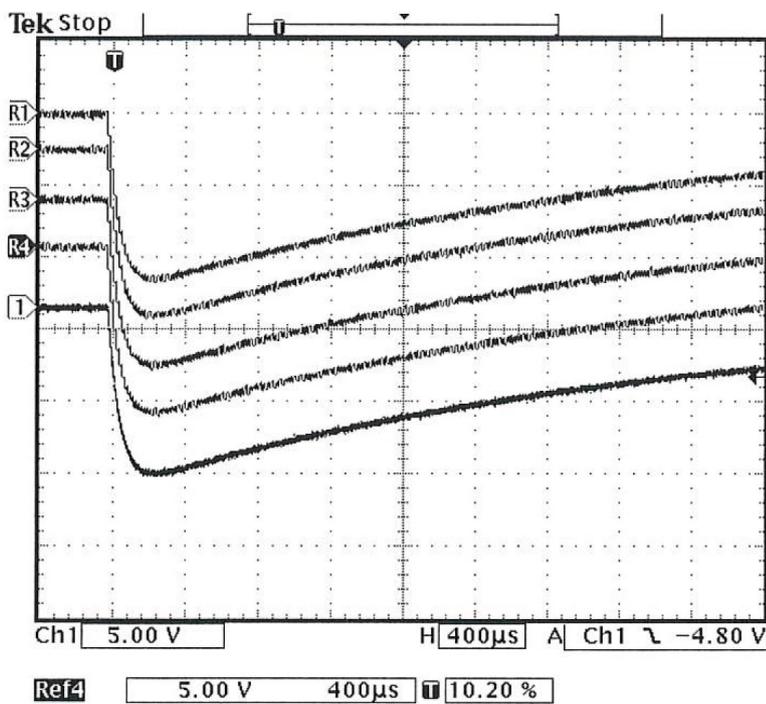


Figure 5.10.1: 1st – 5th 100%-stress, positive polarity
 Hor.: 400 µs/Div; Vert.: 5 V/Div; ratio: 30450:1



28 Nov 2022
14:00:46

Figure 5.10.2: 6th – 10th 100%-stress, positive polarity
Hor.: 400 µs/Div; Vert.: 5 V/Div; ratio: 30450:1



28 Nov 2022
14:09:39

Figure 5.10.3: 1st – 5th 100%-stress, negative polarity
Hor.: 400 µs/Div; Vert.: 5 V/Div; ratio: 30450:1

5.12 AC Voltage Withstand Test

The test was carried out as described in 4.

Test date: 29.11.2022
Test voltage: U = 160 kV; t = 4 h

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.13.1 PD Test at elevated Temperature

The test was carried out as described in 4.

Test date: 30.11.2022
Calibration pulse: $q_{cal} = 2 \text{ pC}$
Heating current: I = 3200 - 3700 A, regulated, 8h
Temperature: T = 95,3 °C
Background noise level: 1,0 pC
Test voltage: U = 192 kV; t = 10 s, thereafter
U = 160 kV; with pd reading
PD: no detectable discharges

The test was passed successfully

5.13.2 PD-Test at ambient Temperature

The test was carried out as described in 4.

Test date: 30.11.2022
Calibration pulse: $q_{cal} = 2 \text{ pC}$
Background noise level: 1,0 pC
Test voltage: U = 192 kV; t = 10 s, thereafter
U = 160 kV; with pd reading
PD: no detectable discharges

The test was passed successfully

5.14 Electrical test of the sheath with conductive coating

The voltage was applied between screen and the conductive coating of the sheath.

Test date: 01.12.2022
Voltage: Lightning impulse voltage
3,36 μ s / 52,9 μ s positive polarity
2,15 μ s / 51,9 μ s negative polarity
U = 65 kV, 10 impulses each polarity

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.15 Electrical test of the joint with conductive wrapping

The voltage was applied between screen and the conductive wrapping of the joint.

Test date: 02.12.2022
Voltage: Lightning impulse voltage
1,20 μ s / 50,0 μ s positive polarity
1,19 μ s / 50,2 μ s negative polarity
U = 85 kV, 10 impulses each polarity

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.16 Examination

Test date: 05.12. – 06.12.2022

On completion of the electrical tests, the XLPE insulation of the cable and the accessories were examined. There was no sign of deterioration (e.g. electrical degradation, leakage, corrosion or harmful shrinkage).

Test date: 11.01.2023

The longitudinally metal foil bonded to the oversheath was also examined. The visual examination showed no delamination, folding, cracking or tearing of the metal tape or foil, or buckling or crossing of the screen wires. The adhesion strength of the metal foil was tested according ANNEX G, procedure G.2.2. The peel strength of the overlapped metal foil was tested according ANNEX G, procedure G.2.3. The relative force of all samples was $> 1,0$ N/mm.

The test was passed successfully.

5.17 Water Penetration Test

The test was carried out as described in 4.

Test date:	01.-11. – 12.11.2022
Number of cycles:	10
Max. temperature:	T = 98 °C
Height of water:	1000 mm

During the whole period of testing, no water emerged from the end of the test piece

The test was passed successfully.

5.18 Resistivity of semi-conducting Screens

The test was carried out as described in 4.

Test date:	19.12. – 29.12.2022
Resistivity before ageing:	$\rho_c = 0,928 \Omega m$ $\rho_i = 1,066 \Omega m$
Ageing:	T = 100°C; 168 h
Resistivity after ageing:	$\rho_c = 1,374 \Omega m$ $\rho_i = 2,528 \Omega m$
Requirement:	$\rho_c \leq 1000 \Omega m$ $\rho_i \leq 500 \Omega m$

The test was passed successfully.

5.19 Additional tests for accessories, ANNEX H.3 Sectionalizing Joint

5.19.1 Heating Cycle Test without Voltage

The test was carried out as described in 4.

Test date:	02.11. – 24.11.2022
Heating current:	I = 3200 - 3700 A regulated, 8h
Cycle:	8 h heating; 16 h cooling
Number of cycles:	20

Neither breakdown nor flashover occurred.

The test was passed successfully

5.19.2 Water Immersion and Heat Cycling

The test was carried out as described in 4.

Test date:	09.12. – 26.12.2022
Temperature:	70-75°C, t = 5h
Number of cycles:	20

The test was passed successfully.

5.19.3 DC Voltage Test in Water

The test was carried out as described in 4.

Test date: 04.01.2023
Test: Both screens connected with HV Source, Water grounded
Test voltage: U = -25 kV; t = 1 min

Neither breakdown nor flashover occurred at both test objects during DC voltage test.

Test: One Screen connected with HV Source,
the other screen grounded
Test voltage: U = -25 kV; t = 1 min

Neither breakdown nor flashover occurred at both test objects during DC voltage test.

The test was passed successfully.

5.19.4 Lightning Impulse Voltage Test

The test was carried out as described in 4.

Test date:	09.01.2023
Test:	Both Screens connected with HV Source, conductive coating of the entire exterior surface was grounded
Impulse:	1,87 / 48,3 μ s pos. polarity 1,22 / 48,2 μ s neg. polarity
Test voltage:	U = 37,5 kV; 10 impulses each polarity

Neither breakdown nor flashover occurred at the test object during lightning impulse voltage test.

The test was passed successfully.

Test:	One Screen connected with HV Source, the other screen grounded
Impulse:	1,22 / 50,3 μ s pos. polarity
Test voltage:	U = 75 kV; 10 impulses each polarity

At the fourth impulse, positive polarity, a breakdown occurred at the test object

The test was failed

According customer's instruction, the test was repeated with lower voltage level.

Test:	One Screen connected with HV Source, the other screen grounded
Impulse:	1,17 / 49,7 μ s pos. polarity 1,19 / 49,7 μ s neg. polarity
Test voltage:	U = 60 kV; 10 impulses each polarity

Neither breakdown nor flashover occurred at the test object during lightning impulse voltage test.

The test was passed successfully.

5.19.5 Examination of the Joint

Test date: 20.04.2023

After testing the joint according ANNEX H, there was no evidence of water ingress or internal corrosion. There was no water after the water protection barriers inside the joint.

The test was passed successfully.

6 Conclusion

The 123 kV- Cable System consisting of XLPE-cable, two Outdoor Terminations, one Sectionalizing Joint and one Straight Through Joint, manufactured by Südkabel GmbH, passed all tests described in Chapter 2 successfully. The test object fulfilled the requirements according to IEC 60840:2020, subclause 12.4.2 "Type tests on cable systems" and DIN VDE 0276-632:2017.

Karlsruhe, 20.04.2023
