Bereich Hochspannungsprüftechnik
Institut für Elektroenergiesysteme und Hochspannungstechnik

Universität Fridericiana (TH) Karlsruhe
76128 Karlsruhe – Kaiserstraße 12
Tel.: +4972160842520 Fax: +49721695224

Test Report No 2013-36/1

Type Test
of a 145 kV- Outdoor Termination
for XLPE-Cables

Client: 3M Deutschland GmbH
Carl-Schurz Str.1
41453 Neuss

Reporter: Dr.-Ing. R. Badent
Dr.-Ing. B. Hoferer

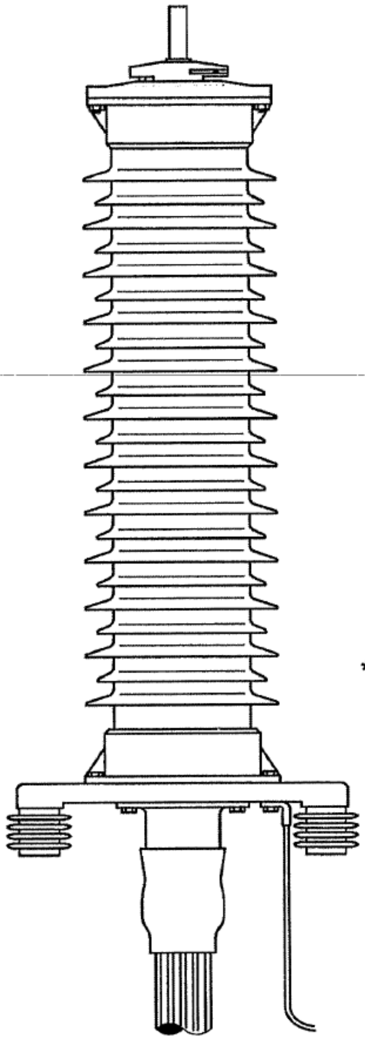
1 Purpose of Test

A 145 kV – Outdoor Termination for XLPE-cables, manufacturer 3M, was subjected to a type test according to IEC 60840 11-2011, subclause 15.4.2 "Type tests on accessories".

2 Miscellaneous Data

Test object:	*145 kV –Outdoor Termination* – 3M Cold Shrink Wet Termination TS 145-II, type 98-ED 810-2 Drawing No XE-0091-3763-1, dated 20.03.2013, Figure 2.1 – 132-kV-XLPE-cable, type AXALJ-CL 132kV 1x1600/135, manufacturer Ericsson Network Technologies AB, Figure 2.2
Manufacturer:	3M Deutschland GmbH Carl-Schurz Str.1 41453 Neuss
Place of test:	*Institute of Electric Energy Systems and High Voltage Technology* – University of Karlsruhe Kaiserstraße 12 – 76128 Karlsruhe Accreditation No.: DAT-PL-039/94-03
Testing dates:	Delivery: 01.04.2013 Mounting: 02.04 – 10.04.2013 Test date: 11.04 – 05.06.2013
Atmospheric conditions:	Temperature: 18°C - 25°C Air pressure: 980 - 1020 mbar rel. humidity: 30% - 70%
Representatives	*Client´s representatives* Dipl.-Ing. S. Hoffmann, 3M Mr. D. Miter, 3M *Representatives responsible for the tests* Dr.-Ing. R. Badent Dr.-Ing. B. Hoferer Mr. O. Müller

3M Wet Termination



Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

Unterschrift des Herstellers — Unterschrift des Prüfers

Kit No.	98-ED 810-2/3
Conductor Cross Section (mm^2)	1000 - 1600
Diameter over Primary Insulation* D (mm)	71 - 81

* Different cable constructions may change the actual application range.
Diameter over primary insulation is the final determining factor.

3M Deutschland GmbH		Issue: 1	Issue date: 20.03.2013

Please note: This product may only be assembled by trained specialized personnel according to these assembly instructions. The preceding specifications are the result of in-depth research. They correspond to the state of our experience. A test by you will convince you of the excellent properties of the 3M products. Verify yourself whether these products are suitable for your purposes. All questions regarding a warranty liability are governed by our terms of sale, unless legal provisions provide differently.

AABBDD07665		1. Issue date: 20.03.13
Language:	English	1. Change date:
Drawn:	M. Hubrich	2. Change date:
Checked:	S. Hoffmann	3. Change date:
		4. Change date:

3M Cold Shrink
Wet Termination TS 145-II

98-ED 810-2

for single core polymeric cable with copper wire sheath acc. IEC 60840 64/110 (126 kV and 76/132 (145) kV

3M Electrical Products — **XE-0091-3848-0**

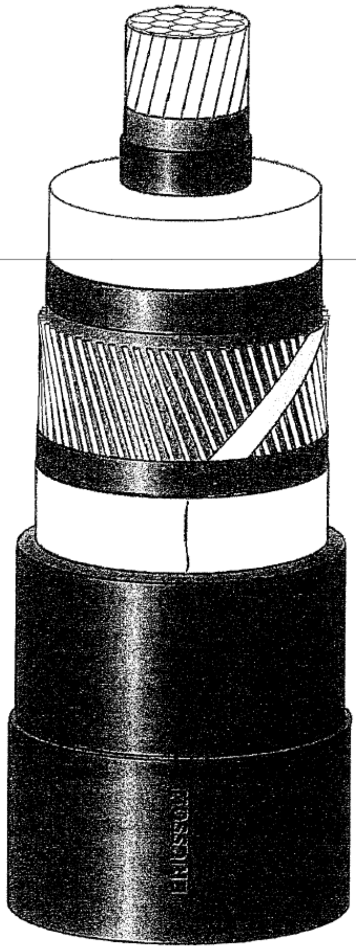
Figure 2.1: 3M Outdoor Termination TS 145-II

Technical Description – Phk06064

Prüfgegenstand entspricht der vorgelegten technischen Zeichnung

Unterschrift des Herstellers | Unterschrift des Prüfers

AXALJ-CL 132kV 1x1600/135



Conductor of aluminum, circular, stranded, compacted.
Longitudinally water tight by means of swelling material.
Nominal cross-section: 1600 mm².
Diameter, nominal: 46,7 mm.

Semi conducting tape.

Conductor screen, extruded.

Insulation of XLPE, dry cured.
Nominal thickness: 17,0 mm.
Diameter over approx. 83,6 mm.

Insulation screen, extruded, firmly bonded to the insulation.

Screen of helically applied copper wires.
Longitudinally water tight by means of swell able material.
Nominal cross-section 135 mm².

Semi conducting tape.

Longitudinally applied Al-PE tape for radial water tightness.

Sheath of HD-PE laminated with the AL-PE tape.
Nominal thickness: 3,9 mm.

Conductive Layer.
Nominal thickness: 0,3 mm.

Complete cable:
Outer diameter approx. 99 mm.
Weight approx. 10,5 kg/m.

Ericsson Network Technologies AB
Falun, SWEDEN
Phone +46 23 684 00
www.ericsson.com/networktechnologies

Phk06064 – rev A

ERICSSON

Figure 2.2: XLPE-Cable, Type AXALJ-CL 132kV 1x1600/135

Tests: Test volume, chronological order and requirements conform to IEC 60840 11-2011, subclause 15.4.2 “Type tests on accessories”.

Pos. 1 Check of insulation thickness

Pos. 2 Partial Discharge Test
$\hat{u}/\sqrt{2}$ = 1,75 U_0 = 133 kV 10 s thereafter ;
$\hat{u}/\sqrt{2}$ = 1,5 U_0 = 114 kV
no detectable discharge

Pos. 3 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: $\hat{u}/\sqrt{2}$ = 2,0 U_0 = 152 kV
Number of cycles: 20

Pos. 4 Partial discharge test at ambient and elevated temperature
$\hat{u}/\sqrt{2}$ = 1,75 U_0 = 133 kV 10 s thereafter ;
$\hat{u}/\sqrt{2}$ = 1,5 U_0 = 114 kV
no detectable discharge
8h loading up to 95°C - 100 °C conductor temperature with at least 2h at 95°C-100°C
$\hat{u}/\sqrt{2}$ = 1,75 U_0 = 133 kV 10 s thereafter ;
$\hat{u}/\sqrt{2}$ = 1,5 U_0 = 114 kV
no detectable discharge

Pos. 5 Lightning impulse voltage test at elevated temperature
T = 95°C-100°C, at least 2h, û = 650 kV,
10 impulses each polarity

Pos. 6 AC-voltage withstand test during cooling period
$\hat{u}/\sqrt{2}$ = 190 kV, t = 15 min

Pos. 7 Accessory examination

3 Mounting

The cable preparation, assembling and mounting of the termination was accomplished by technicians of 3M. The cable length between accessories was at least 5 m.

4 Test Setup

4.1 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.

4.2 AC Voltage Withstand Test

The test voltage was generated by a 200-kVA transformer. The voltage was measured with a capacitive divider (C_H = 351 pF; ratio = 10.000:1) and a peak voltmeter reading $\hat{u} / \sqrt{2}$. The primary side of the AC-transformer was connected to a motor-generator set consisting of a variable frequency DC motor and a synchronous generator with variable excitation. The generator delivers voltages from 0 ... 500 V with currents up to 1000 A.

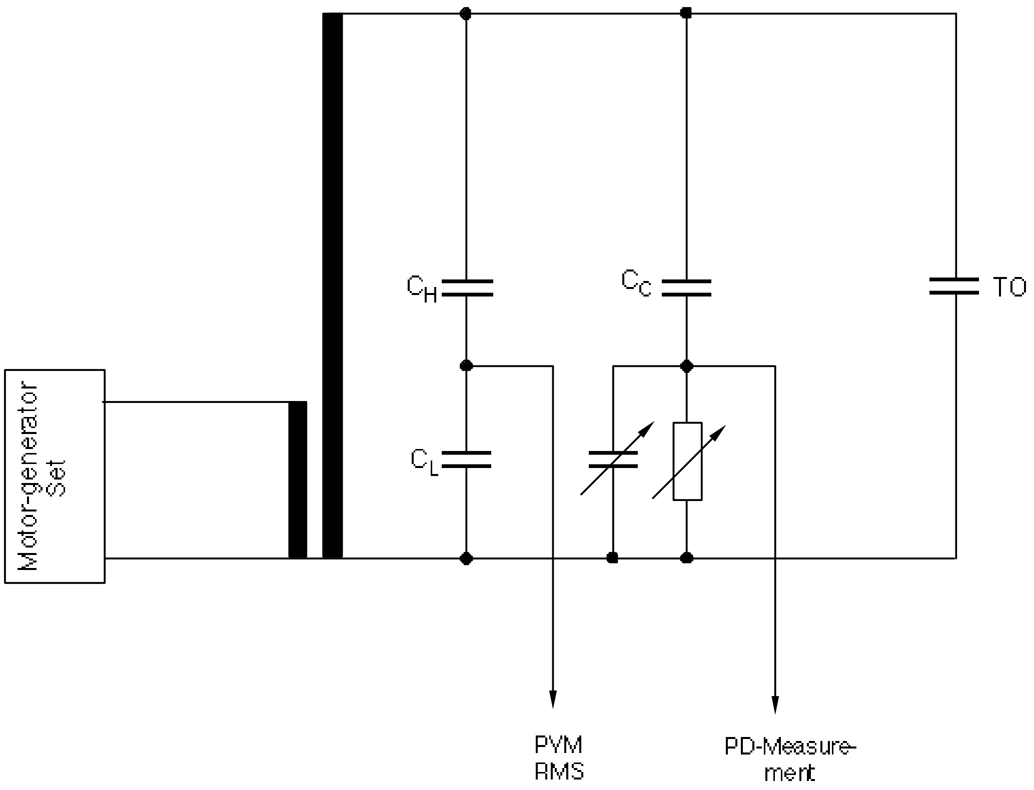


Figure 4.2: Test-setup for AC-voltage withstand test and PD measurement

AC-transformer:	400V/200kV; S_N = 200 kVA
Voltage measurement:	C_H = 351 pF; ratio 10.000:1 uncertainty 3 %
PD measurement:	C_C = 1000 pF; U_N = 800 kV_{rms} uncertainty 5 %

4.3 Partial-Discharge Test

The PD-measurement was performed with an analog bridge according to *Kreuger*, Figure 4.3. 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 114 kV_{rms} was 2,0 pC.

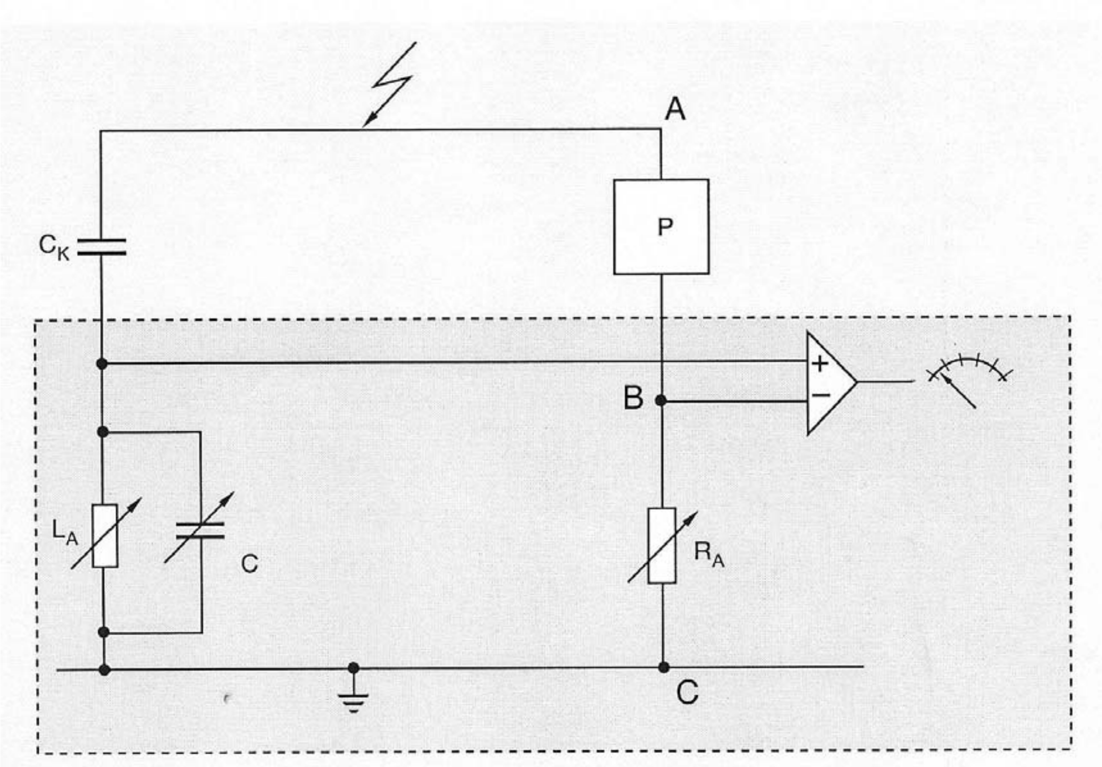


Figure 4.3: Scheme of PD test circuit
P: Test object
C_K: Coupling Capacitor

For balancing the bridge a calibrating impulse with q_A = 1000 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 = 5 pC, is applied between A and B. Subsequently, the amplifier output of the PD measuring unit is adapted to the applied pulse.

4.4 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-cable. The required heating current I was determined via a dummy cable. A 8 m sample of the cable used for the test, was provided with a 1 mm diameter drilling hole down to the centre conductor. The temperature was measured with a thermocouple NiCr-Ni. Two other thermocouples were installed on the conductor each 1,0 m away from the middle. The difference between the three readings was less than 2 K. Furthermore two additional thermocouples NiCr-Ni were placed on the outer sheath of the cable, one on the dummy and one on the test loop. Figure 4.4 illustrates the temperature rise at the conductor with a maximum heating current of I = 2300 A, 8h. Current inception was accomplished by three transformers (U_1 = 400 V; U_2 = 10 V) which used the cable as secondary winding. The current was regulated by a control unit and measured by a current transformer, 3000/1, and a digital multimeter. The measurement uncertainty was 1%.

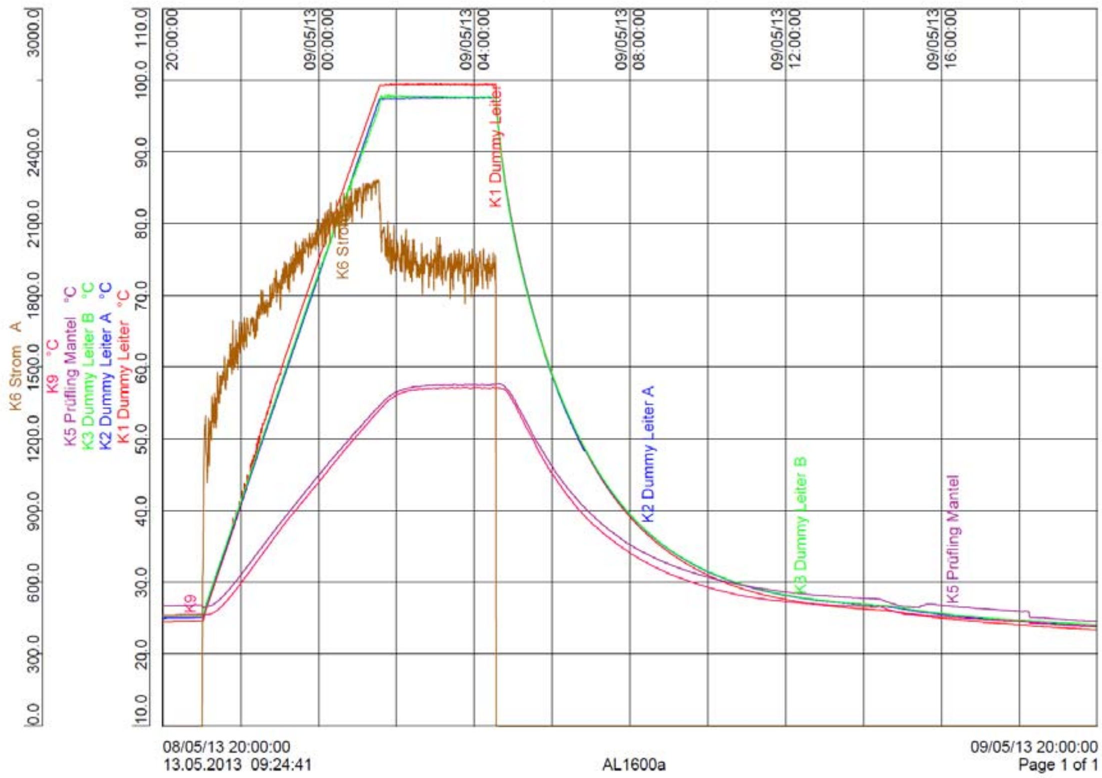


Figure 4.4: Heat cycle I = 1900 .. 2300 A regulated, 8h; I = 0A, 16 h

K1,K2,K3:	Conductor temperature dummy
K5:	Jacket temperature tested cable
K9:	Jacket temperature dummy
K6:	Current

4.5 Lightning Impulse Voltage Withstand Test

For the lightning impulse voltage withstand test, a Marx-Generator (Haefely) with a maximum cumulative charging voltage of U = 3.6 MV and impulse energy of E_{max} = 180 kWs was used. This test was run with 7 stages, the capacity of the energy storage capacitor was C_S = 71,4 nF. The test voltage value was measured by a damped capacitive divider connected to an impulse peak voltmeter (Haefely). The front time and the time to half value were evaluated from the oscillograph curves.

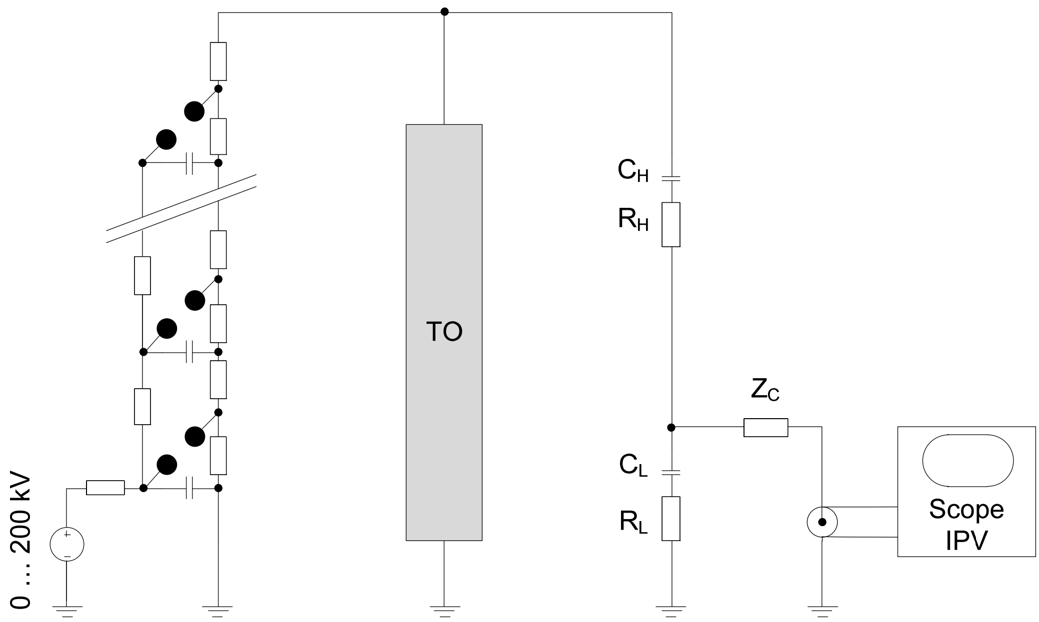


Figure 4.5.1: Schematics of lightning impulse voltage withstand test circuit
C_H: 1200 pF; R_H = 70 Ω; Ratio: 3215:1; Z_C = 50 Ω
IPV: impulse-peak-voltmeter (Haefely) – measurement uncertainty 3%
Oscilloscope: Tektronix TDS 3044B – measurement uncertainty 2%

The waveform parameters were determined at reduced charging voltage. Figure 4.5.2 shows the front time, Figure 4.5.3 the time to half value for positive polarity each. Figure 4.5.4 shows the front time, Figure 4.5.5 the time to half value for negative polarity each.

Positive impulse:	T_1 = 2,97 µs	T_2 = 53,2 µs
Negative impulse:	T_1 = 3,14 µs	T_2 = 54,2 µs

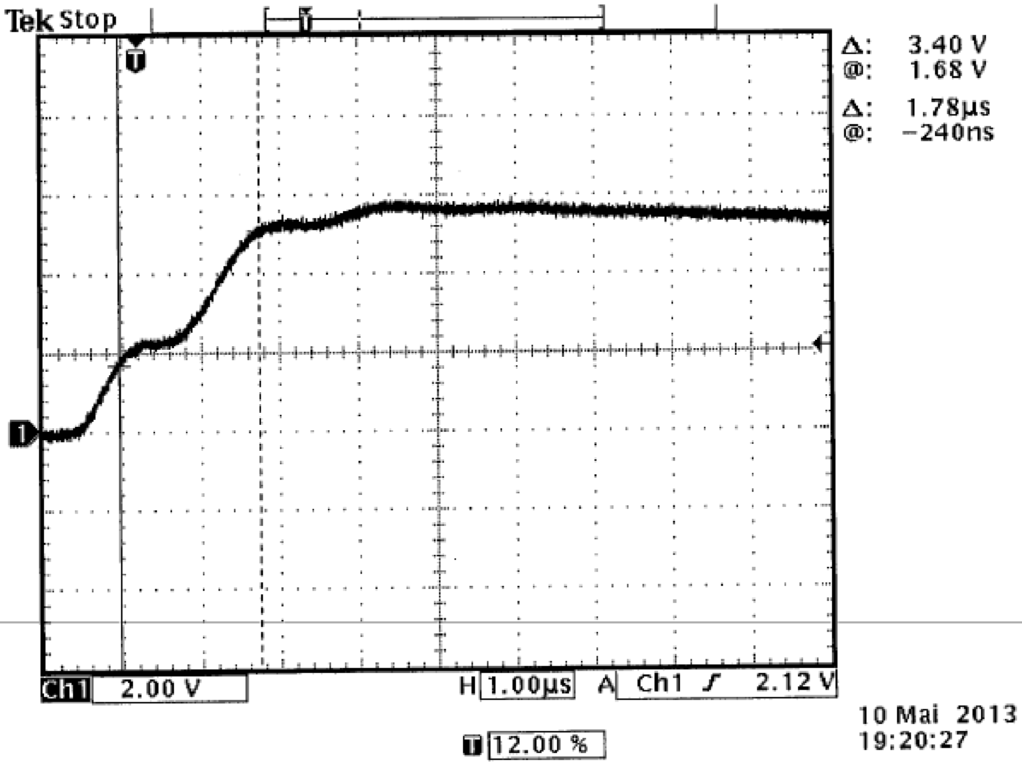


Figure 4.5.2: Front time, positive polarity
Hor.: 1 µs/Div; Vert.: 2 V/Div; probe 10:1; ratio 3215:1

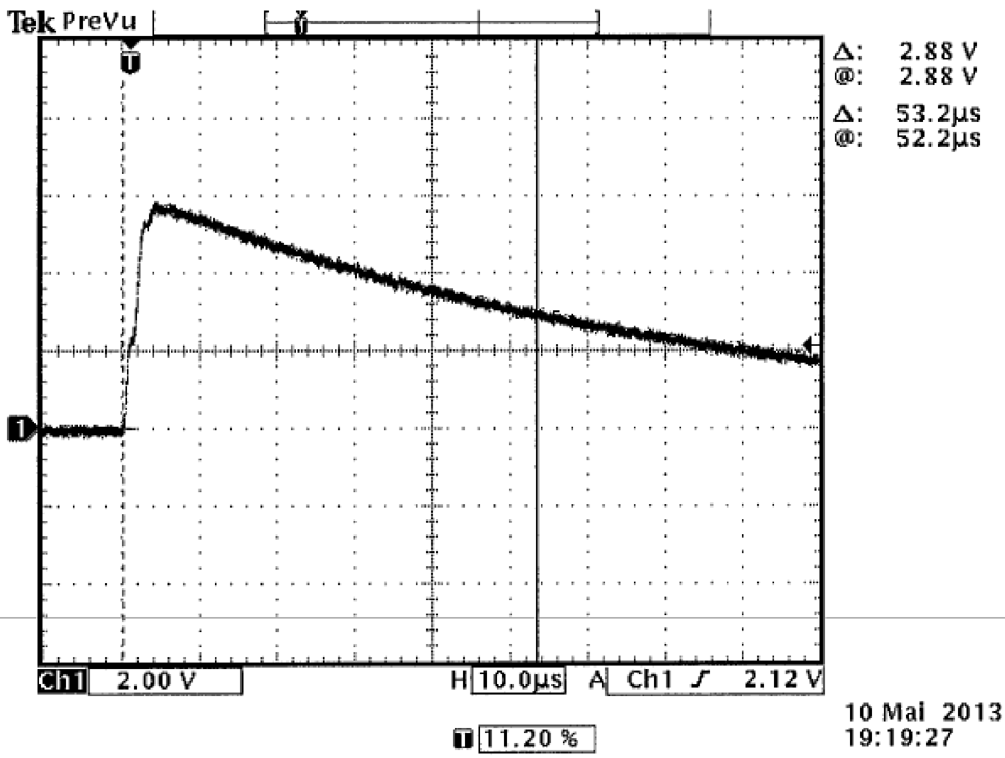


Figure 4.5.3: Time to half value, positive polarity
Hor.: 10 µs/Div; Vert.: 2 V/Div; probe 10:1; ratio 3215:1

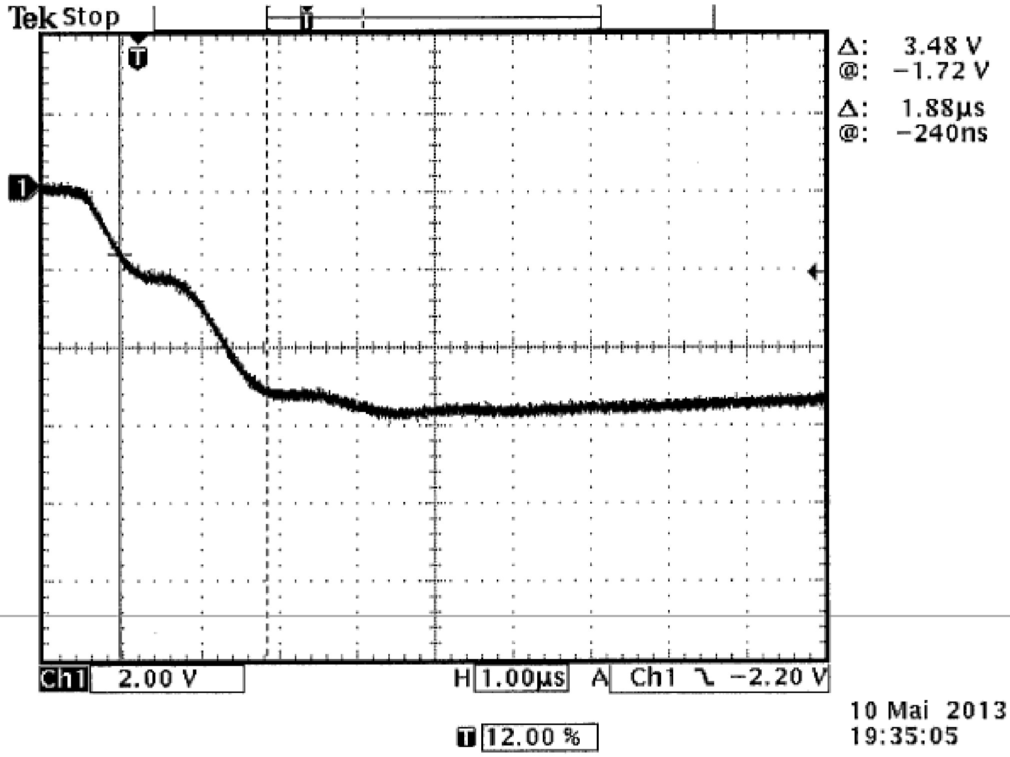


Figure 4.5.4: Front time, negative polarity
Hor.: 1 µs/Div; Vert.: 2 V/Div; probe 10:1; ratio 3215:1

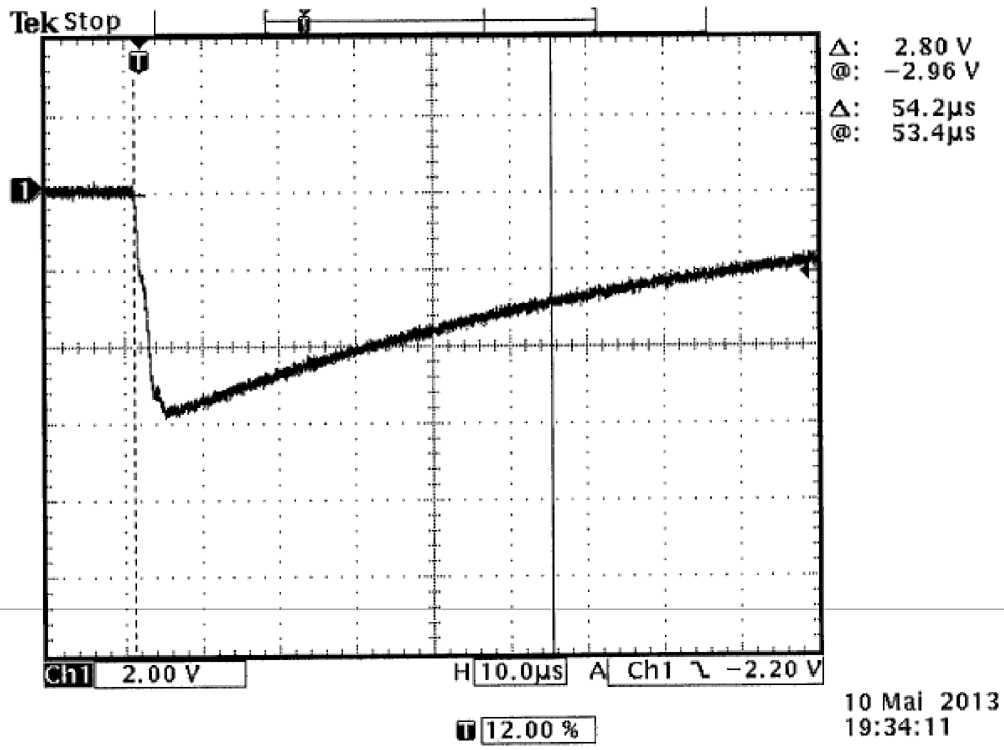


Figure 4.5.5: Time to half value, negative polarity
Hor.: 10 µs/Div; Vert.: 2 V/Div; probe 10:1; ratio 3215:1

5 Results

5.1 Check of Insulation Thickness

The test was carried out as described in 4.

Test date:	03.04.2013
Nominal value:	17,0 mm
Measured values:	17,82 mm
	18,15 mm
	17,23 mm
	16,77 mm
	17,66 mm
	17,74 mm
Average Value:	17,56 mm
Result:	The average value exceeds the nominal value only by 3,3%, so no correction was necessary.

5.2 PD-Test

The test was carried out as described in 4.

Test date:	11.04.2013
Calibration pulse:	q_{cal} = 5 pC
Background noise level:	0,8 pC
Test voltage:	$\hat{u} / \sqrt{2}$ = 133 kV; t = 10 s, thereafter
	$\hat{u} / \sqrt{2}$ = 114 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.3 Heating cycle voltage test

The test was carried out as described in 4.

Test date:	19.04. – 09.05.2013
Test voltage:	$\hat{u} / \sqrt{2}$ = 152 kV
Heating current:	I = 1900 –2300 A regulated, 8h
	I = 0A, 16 h
Cycle:	8 h heating; 16 h cooling
Number of cycles:	20

Neither breakdown nor flashover occurred.

The test was passed successfully

5.4 PD Test

5.4.1 PD-Test at ambient Temperature

The test was carried out as described in 4.

Test date:	10.05.2013
Calibration pulse:	q_{cal} = 5 pC
Background noise level:	2,0 pC
Test voltage:	$\hat{u} / \sqrt{2}$ = 133 kV; t = 10 s, thereafter
	$\hat{u} / \sqrt{2}$ = 114 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.4.2 PD-Test at elevated Temperature

The test was carried out as described in 4.

Test date:	10.05.2013
Calibration pulse:	q_{cal} = 5 pC
Heating current:	I = 1900 – 2300 A
Temperature:	T = 97,1 °C
Background noise level:	2,0 pC
Test voltage:	$\hat{u}/\sqrt{2}$ = 133 kV; t = 10 s, thereafter
	$\hat{u}/\sqrt{2}$ = 114 kV; with pd reading
PD:	no detectable discharges

The test was passed successfully

5.5 Lightning Impulse Voltage Withstand Test

This test was carried out as described in chapter 4.

Test date:	10.05.2013
Test voltage:	û = 650 kV
Heating current:	I = 1900 –2300 A regulated, 8h
Temperature:	T = 96,8 °C
Impulse:	1-5 µs / 40-60 µs
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 5.5.1 shows the test results with positive polarity, table 5.5.2 with negative polarity.

No.	Charging voltage / kV	û / kV	Figure	Remark
1	30,0	180,8	4.5.2	front time,
2	30,0	182,4	4.5.3	time to half value
3	53,9	324		50%
4	75,4	453		70%
5	97,4	584		90%
6	108,4	650	5.5.1	1. 100%
7	108,4	650	5.5.1	2. 100%
8	108,4	650	5.5.1	3. 100%
9	108,4	650	5.5.1	4. 100%
10	108,4	650	5.5.1	5. 100%
11	108,4	650	5.5.2	6. 100%
12	108,4	651	5.5.2	7. 100%
13	108,4	650	5.5.2	8. 100%
14	108,4	650	5.5.2	9. 100%
15	108,4	651	5.5.2	10. 100%

Table 5.5.1: Lightning impulse voltage withstand test, positive polarity

No.	Charging voltage / kV	û / kV	Figure	Remark
1	-30,0	-182,1	4.5.4	front time,
2	-30,0	-182,1	4.5.5	time to half value
3	-53,9	-325		50%
4	-75,4	-454		70%
5	-97,4	-586		90%
6	-108,4	-650	5.5.3	1. 100%
7	-108,4	-650	5.5.3	2. 100%
8	-108,4	-651	5.5.3	3. 100%
9	-108,4	-651	5.5.3	4. 100%
10	-108,4	-651	5.5.3	5. 100%
11	-108,4	-650	5.5.4	6. 100%
12	-108,4	-650	5.5.4	7. 100%
13	-108,4	-650	5.5.4	8. 100%
14	-108,4	-651	5.5.4	9. 100%
15	-108,4	-652	5.5.4	10. 100%

Table 5.5.2: Lightning impulse voltage withstand test, negative polarity

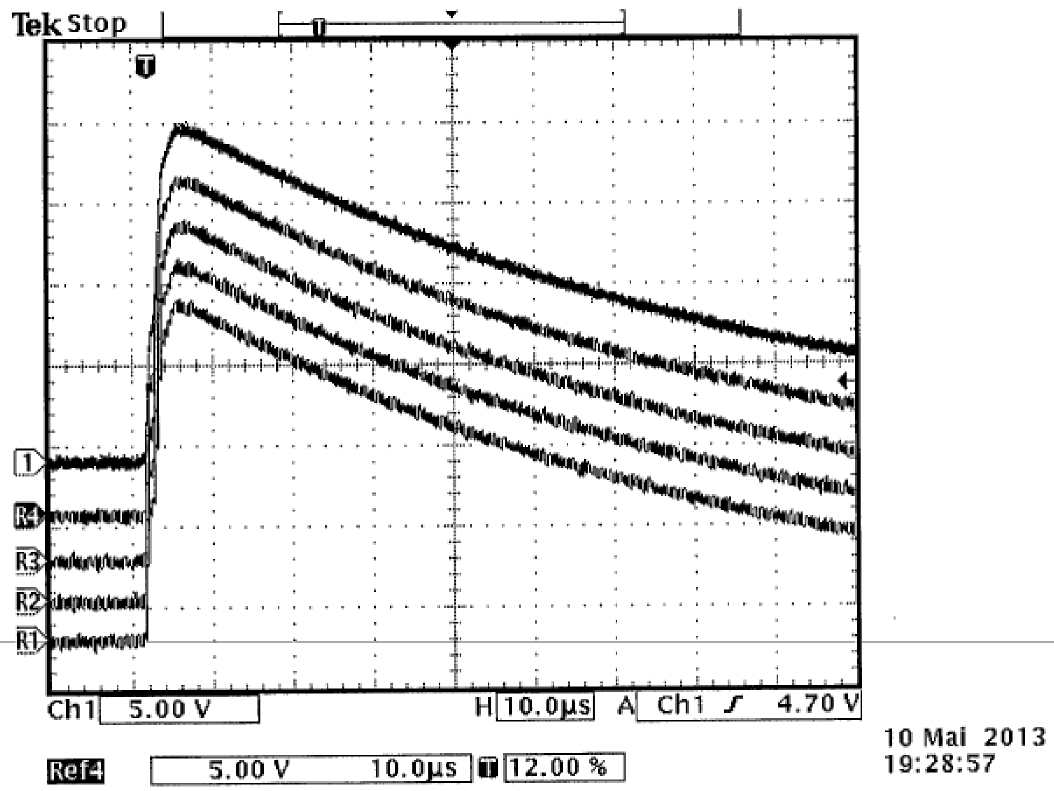


Figure 5.5.1: 1st – 5th 100%-stress, positive polarity
Hor.: 10 µs/Div; Vert.: 5 V/Div; probe 10:1; ratio 3215:1

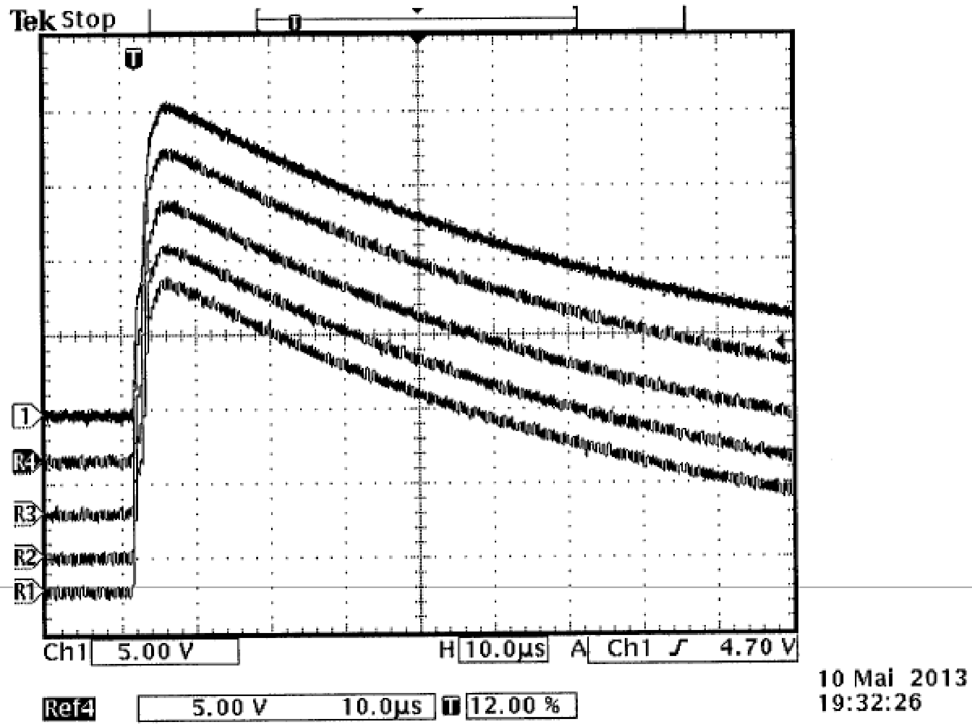


Figure 5.5.2: 6^{th} – 10^{th} 100%-stress, positive polarity
Hor.: 10 µs/Div; Vert.: 5 V/Div; probe 10:1; ratio 3215:1

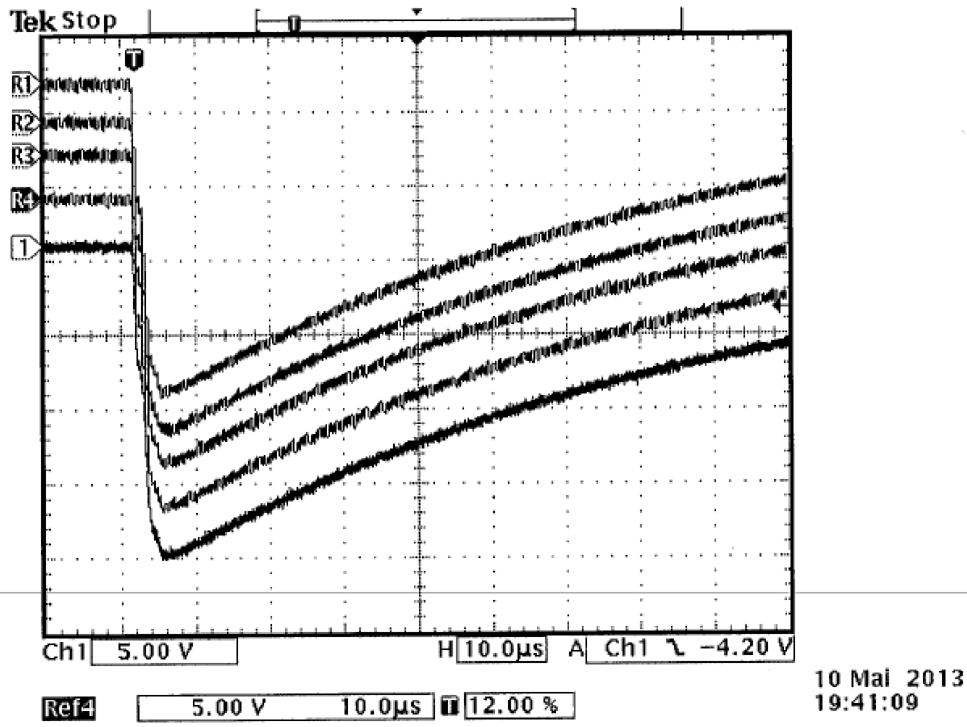


Figure 5.5.3: 1^{st} – 5^{th} 100%-stress, negative polarity
Hor.: 10µs/Div; Vert.: 5 V/Div; probe 10:1; ratio 3215:1

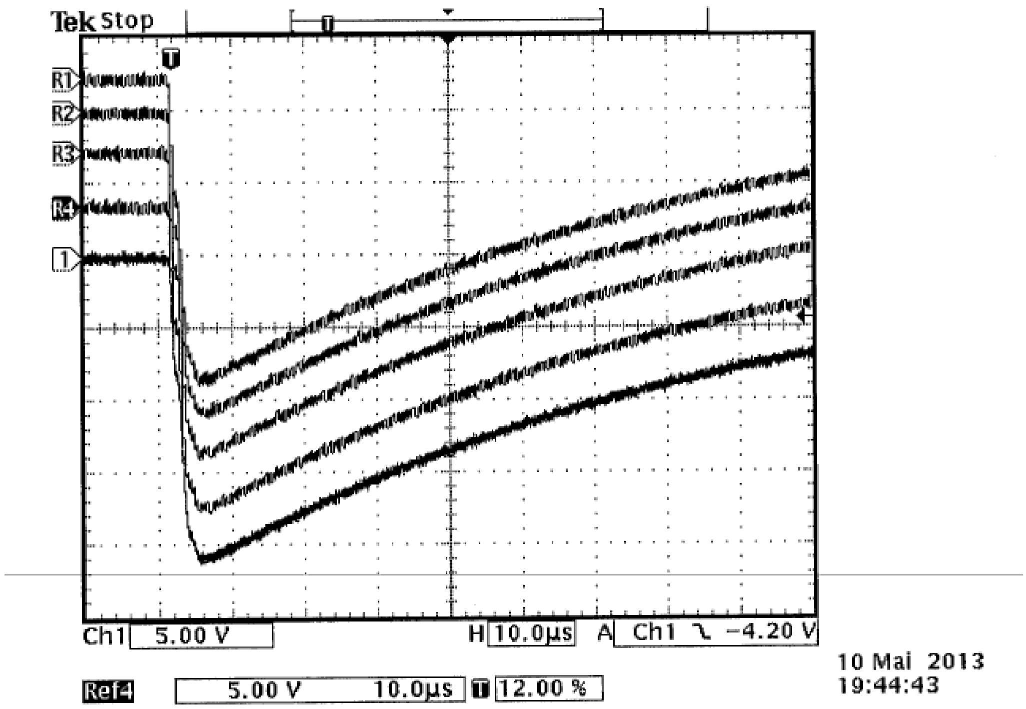


Figure 5.5.4 6th – 10th 100%-stress, negative polarity
Hor.: 10µs/Div; Vert.: 5 V/Div; probe 10:1; ratio 3215:1

5.6 AC Voltage Withstand Test

The test was carried out as described in 4.

Test date: 11.05.2013
Test voltage: $\hat{u}/\sqrt{2}$ = 190 kV; t = 15 min

Neither breakdown nor flashover occurred.

The test was passed successfully.

5.7 Accessory Examination

Test date: 05.06.2013

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

The test was passed successfully.

6 Conclusion

The 145 kV-Outdoor Termination TS 145-II, type 98-ED 810-2, manufacturer 3M, passed all tests described in Chapter 2 successfully. The test object fulfilled the requirements according IEC 60840 11-2011, subclause 15.4.2 “Type tests on accessories”.

Karlsruhe, 24.07.2013

Dr.-Ing. R. Badent
Head of Department
„High Voltage Dielectric Testing“

Dr.-Ing. B. Hoferer
Vice-Head of Department
„High Voltage Dielectric Testing“