Type test report no. VR 6E 003e

Dielectric tests of diverter switch

Product Approval
TETP/LLD
02.03.2020

Type test for types:	Diverter switches VACUTAP® VRS / VRM / VRL / VRH / VRX with - single phase, two phase or three phase design, - highest voltage for equipment U_m 72.5 kV up to 300 kV.
Test specification:	IEC 60214-1:2014, sub-clause 5.2.8: “Dielectric tests”.
Classification:	Class II in compliance with IEC 60214-1:2014, sub clause 5.2.8.3.
Test samples:	Diverter switches VACUTAP® VRM I 1301 – 72.5, S/N: 1734905a VACUTAP® VRM I 1301 – 123, S/N: 1734905b VACUTAP® VRM I 1301 – 300, S/N: 1734905c VACUTAP® VRM II 1002 – 72.5, S/N: 2095365 VACUTAP® VRL III 1300 Y – 170, S/N: 1734906a VACUTAP® VRL III 1300 Y – 245, S/N: 1734906b VACUTAP® VRL III 1300 Y – 72.5, S/N: 2125888 VACUTAP® VRS I 1301 – 72.5, S/N: 2122390
Manufacturer:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.
Date of tests:	August 2016 to December 2016 & September 2019 to October 2019.
Place of tests:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.
Tests performed:	
Full wave lightning impulse tests (LI):	Impulse 1.2/50 µs: Each 3 applications performed with positive and negative polarity.
Chopped wave lightning impulse tests (LIC):	Impulse 1.2/50/3 µs: Each 3 applications performed with positive and negative polarity.
Switching impulse tests (SI):	Impulse 250/2500 µs: Each 3 applications performed with positive and negative polarity.
Applied voltage tests (AV):	Performed with single-phase alternating voltage (50 Hz / 60 s).
Measurement of partial discharges:	In compliance with IEC 60214-1:2014, sub-clause 5.2.8.9.
Tested insulation distances:	- to earth, - between diverter switch contacts in their final open position.
Test results:	The requirements of IEC 60214-1:2014 were met. - All test voltages were withstood without discharge. - The levels of partial discharge did not exceed the corresponding permissible limits.

This report contains 37 pages.

i. V. Dr. Thomas Strof
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Maschinenfabrik Reinhausen GmbH
- PRODUCT APPROVAL -

1. Test specification

The type tests were performed in accordance with IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, sub-clause 5.2.8: “Dielectric tests”.

2. Specification of the insulating distances of the diverter switch

2.1 Insulating distance “f” of the diverter switch

The insulating distance “f” specifies the insulation to earth. It is the distance between the live parts of the diverter switch, including the spring accumulator and the head of the diverter switch and ground. Types with highest voltage for equipment U_m equal to or higher than 170 kV are equipped with grading rings on this distance.

Three-phase diverter switches type VACUTAP® VRS / VRM / VRL / VRH are available from U_m = 72.5 kV up to 245 kV.

Two-phase diverter switches type VACUTAP® VRS / VRM / VRL / VRH and single-phase diverter switches type VACUTAP® VRS / VRM / VRL / VRH with two current paths for applications with enforced current splitting are available from U_m = 72.5 kV up to 362 kV.

Single-phase diverter switches type VACUTAP® VRS / VRM / VRL / VRH are available from U_m = 72.5 kV up to 420 kV. Single-phase diverter switches type VACUTAP® VRX for applications with variable shunt reactors are available from U_m = 72.5 kV up to 362 kV.

Diverter switches with three-phase design are classified to class I for use at the neutral point of windings. Diverter switches of single-phase and two-phase design are classified to class II for use at a position other than the neutral point of windings.

Figure 38a/b shows the dimensions of the insulating distances “f” of the diverter switches in function of U_m exemplary for VACUTAP® VRS / VRM / VRL / VRH. These distances are identical for all diverter switches type VACUTAP® VRS / VRM / VRL / VRH / VRX with the same U_m.

The type tests were performed according to the requirements for class II in compliance with IEC 60214-1:2014, sub clause 5.2.8.3. The requirements for class I are covered.

2.2 Insulating distance “a0” of the diverter switch

The insulating distance “a0” specifies the distance between diverter switch contacts in their final open position.

To protect this insulating distance from transient over-voltages, ZnO surge arresters are incorporated in the diverter switches.

3. Data of test samples

Test sample 1	
Type designation:	VACUTAP® VRM I 1301 – 72.5
Type characteristics:	Diverter switch
Serial number / IBASE:	1734905a / 546541064 and 547813653
Year of manufacture:	2016
Manufacturer:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed:	Insulating distance „f“ / Partial discharges on “f”

Test sample 2	
Type designation:	VACUTAP® VRM I 1301 – 123
Type characteristics:	Diverter switch
Serial number / IBASE:	1734905b / 547813653
Year of manufacture:	2016
Manufacturer:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed:	Insulating distance „f“ / Partial discharges on “f”

Test sample 3
Type designation: VACUTAP® VRM I 1301 – 300
Type characteristics: Diverter switch
Serial number / IBASE: 1734905c / 547813653
Year of manufacture: 2016
Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed: Insulating distance „f“ / Partial discharges on “f”

Test sample 4
Type designation: VACUTAP® VRM II 1002 – 72.5
Type characteristics: Diverter switch
Serial number / IBASE: 2095365 / 708835167
Year of manufacture: 2019
Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed: Insulating distance „a0“

Test sample 5
Type designation: VACUTAP® VRL III 1300 Y – 170
Type characteristics: Diverter switch
Serial number / IBASE: 1734906a / 546541165
Year of manufacture: 2016
Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed: Insulating distance „f“ / Partial discharges on “f”

Test sample 6
Type designation: VACUTAP® VRL III 1300 Y – 245
Type characteristics: Diverter switch
Serial number / IBASE: 1734906b / 547813653
Year of manufacture: 2016
Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed: Insulating distance „f“ / Partial discharges on “f”

Test sample 7
Type designation: VACUTAP® VRL III 1300 Y – 72.5
Type characteristics: Diverter switch
Serial number / IBASE: 2125888 / 714818662
Year of manufacture: 2019
Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed: Insulating distance „a0“

Test sample 8
Type designation: VACUTAP® VRS I 1301 – 72.5
Type characteristics: Diverter switch
Serial number / IBASE: 2122390 / 714818591
Year of manufacture: 2019
Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany
Tests performed: Insulating distance „a0“

4. Scope of application

Diverter switches type VACUTAP® VR are available in the basic design variants VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL, VACUTAP® VRH and VACUTAP® VRX.

The design of insulating distance “f” depends on the highest voltage for equipment U_m of the diverter switch and it does not depend on the basic design variant (VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL, VACUTAP® VRH or VACUTAP® VRX), the number of phases and the number of sectors of the diverter switch.
Therefore, the rated withstand voltages and the partial discharges on insulating distance “f” were tested on various test samples with U_m = 72.5kV up to 300 kV (test samples 1, 2, 3, 5 and 6).

The design of insulating distance “a0” does not depend on the highest voltage for equipment U_m and the basic design variant (VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL, VACUTAP® VRH or VACUTAP® VRX), but it depends on the number of sectors of the diverter switch.
Therefore the rated withstand voltages and the protection levels between diverter switch contacts at their final open position were tested on various test samples with single sector design, two sector design and three sector design (test samples 4, 7 and 8).

The dielectric withstand capability does not depend on the maximum rated through-current.

Therefore this type test report is valid for diverter switches type VACUTAP® VR with following characteristics:

- Design variants: VRS, VRM, VRL, VRH or VRX
- Number of phases: 1, 2 or 3
- Number of sectors: 1, 2 or 3
- Highest voltage for equipment U_m: 72.5 kV up to 300 kV

5. Test conditions / Test arrangement

Place of tests:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.
Treatment before testing:	The test samples were vacuum dried in accordance with the instructions of the manufacturer.
Test tanks oil filling:	Plexiglas tanks (22,000 liters and 3,500 liters) filled with transformer mineral oil according to specification IEC 60296 (Nynas Nytro Taurus & Nynas Nytro 4000X) at room temperature (see appendix 2, pictures 3 and 4). The breakdown strength of the transformer oil during the tests was between 55 kV / 2.5 mm and 82 kV / 2.5 mm.
Test setup:	The tests were performed with permanently installed measuring chains for alternating voltage tests and impulse voltage tests (see appendix 2, figures 39 & 40). The test samples were placed in the Plexiglas test tanks and connected to test voltages (example see appendix 2, picture 4).
Wirings and connections:	See appendix 3, figures 41 to 46.

6. Tests performed

6.1 Full wave lightning impulse test (LI)

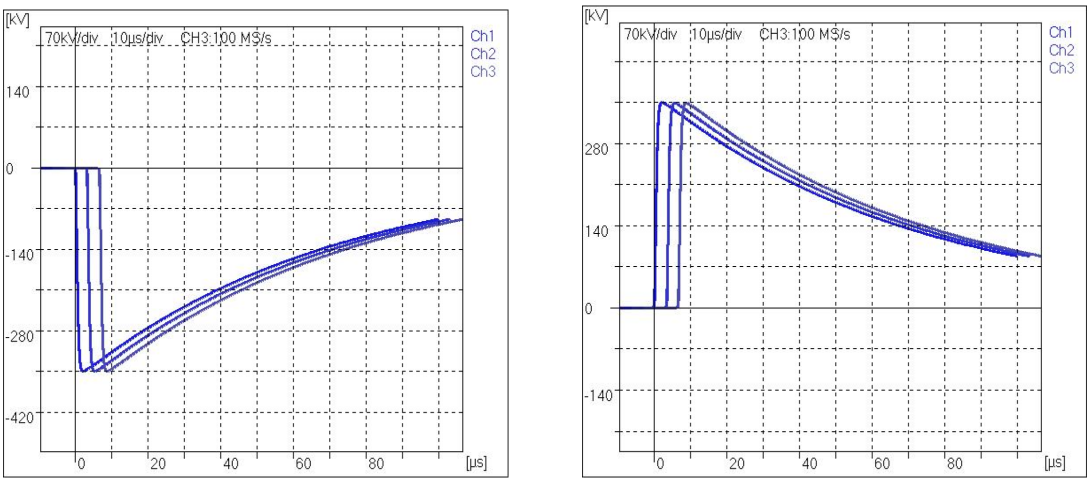
Test standard:	IEC 60214-1:2014, sub-clause 5.2.8.5.
Impulse voltage generator:	Impulse generator (max. charging: 1800 kV), see appendix 2, picture 2.
Voltage waveform (T_1/T_2):	1.2 / 50 µs.
Wirings and connections:	See appendix 3, figures 41...46.
Test voltages (U_p):	See tables 1...8.
Oscillograms:	See figures 1a/b...8a/b.
Number of applications:	Three applications with positive and three with negative polarity.

Note:
To protect the insulating distance “a0” from transient over-voltages, a ZnO surge arrester is incorporated in the diverter switch. As a result of the ZnO-wiring the voltage waveforms of lightning impulses (full wave / chopped wave) and the waveform of the switching impulse deviate from nominal waveforms. The waveforms shown in the oscillograms are typical for diverter switches equipped with ZnO surge arrester (see figures 6a/b…8a/b).

6.1.1 Insulating distance “f” (U_m = 72.5 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-350	-350.2	1.2	1.229	50	51.96
	2		-350.2		1.231		51.94
	3		-350.1		1.230		51.98
	4	350	350.7		1.238		51.99
	5		349.8		1.236		52.00
	6		350.0		1.235		51.97

Table 1: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “f” (U_m = 72.5 kV).

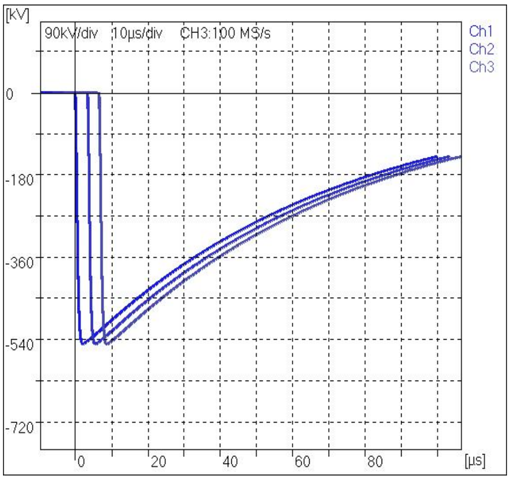


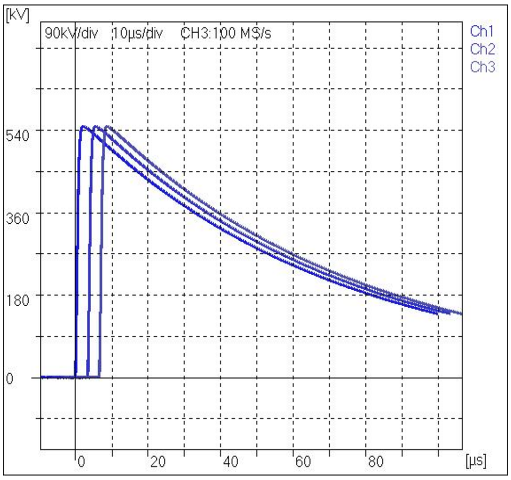
Figures 1a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “f” (U_m = 72.5 kV).

6.1.2 Insulating distance "f" (U_m = 123 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-550	-550.0	1.2	1.230	50	51.98
	2		-550.0		1.227		52.00
	3		-550.1		1.229		52.03
	4	550	550.0		1.242		52.02
	5		550.3		1.242		52.03
	6		549.4		1.241		52.01

Table 2: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance "f" (U_m = 123 kV).



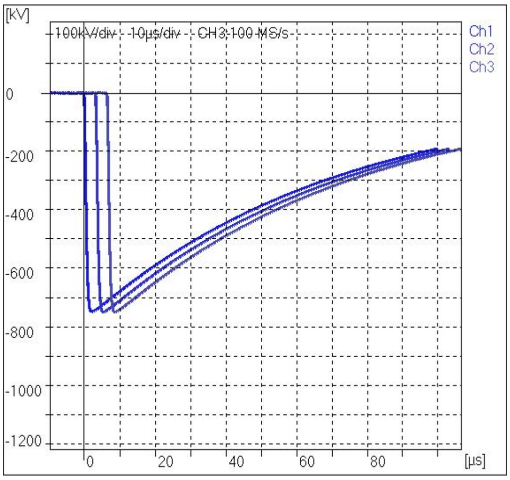


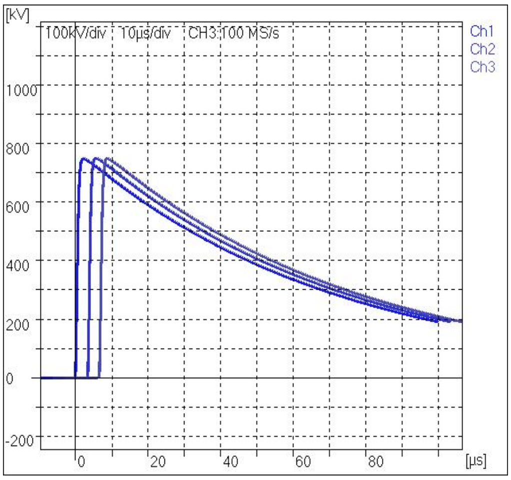
Figures 2a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance "f" (U_m = 123 kV).

6.1.3 Insulating distance "f" (U_m = 170 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-750	-748.9	1.2	1.233	50	52.25
	2		-749.6		1.232		52.30
	3		-750.6		1.234		52.27
	4	750	749.1		1.243		52.36
	5		750.9		1.245		52.33
	6		749.6		1.246		52.34

Table 3: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance "f" (U_m = 170 kV).



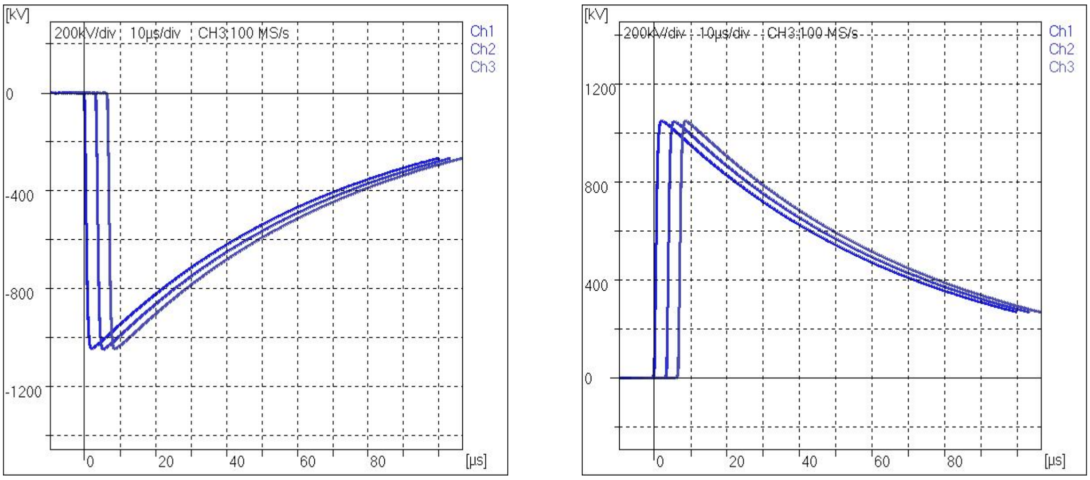


Figures 3a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance "f" (U_m = 170 kV).

6.1.4 Insulating distance “f” (U_m = 245 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-1050	-1048	1.2	1.223	50	52.22
	2		-1050		1.222		52.18
	3		-1050		1.222		52.20
	4	1050	1052		1.228		52.30
	5		1050		1.227		52.23
	6		1050		1.228		52.25

Table 4: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “f” (U_m = 245 kV).

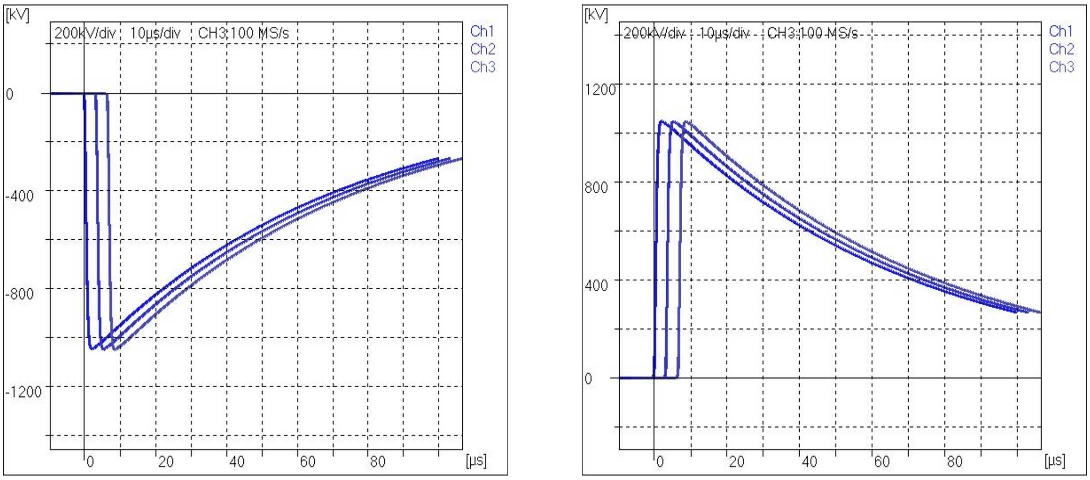


Figures 4a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “f” (U_m = 245 kV).

6.1.5 Insulating distance “f” (U_m = 300 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-1050	-1049	1.2	1.222	50	52.25
	2		-1049		1.222		52.29
	3		-1050		1.221		52.31
	4	1050	1051		1.228		52.33
	5		1050		1.227		52.33
	6		1050		1.225		52.32

Table 5: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “f” (U_m = 300 kV).

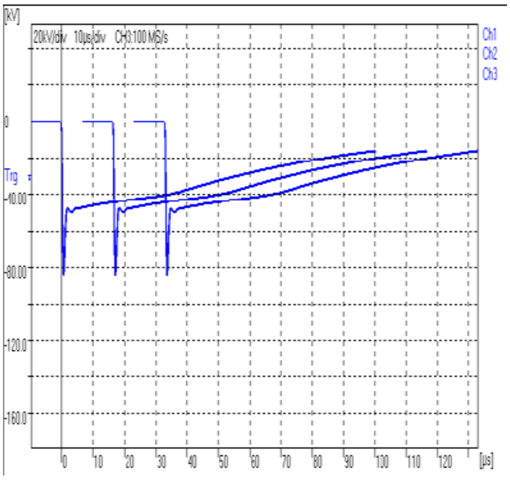


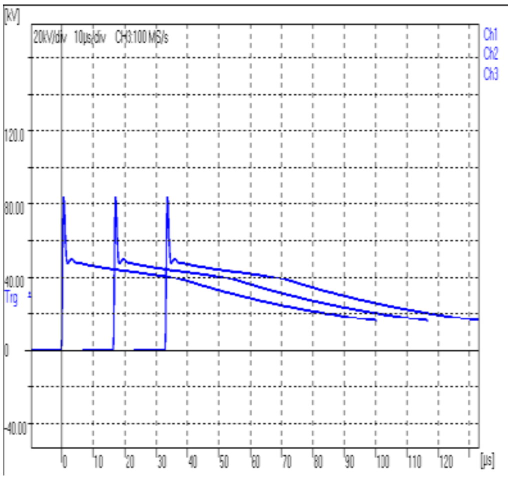
Figures 5a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “f” (U_m = 300 kV).

6.1.6 Insulating distance “a0” (single sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Front time (T_1) in *µs*	Time to half-value (T_2) in *µs*
a0	1	-150	1.2	50
	2			
	3			
	4	150		
	5			
	6			

Table 6: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “a0”.



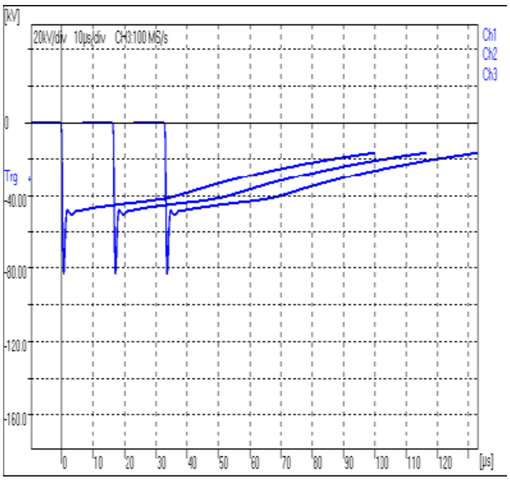


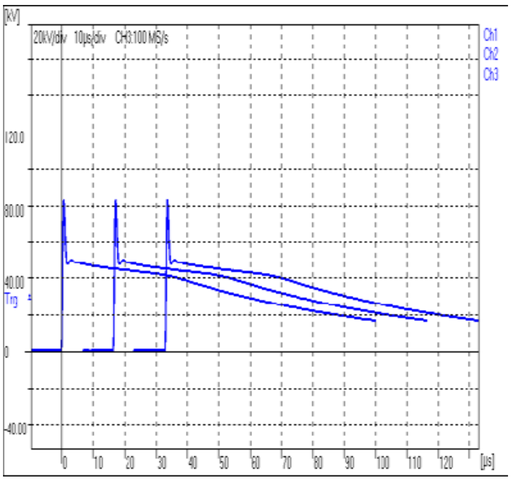
Figures 6a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “a0”.

6.1.7 Insulating distance “a0” (two sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Front time (T_1) in *µs*	Time to half-value (T_2) in *µs*
a0	1	-150	1.2	50
	2			
	3			
	4	150		
	5			
	6			

Table 7: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “a0”.



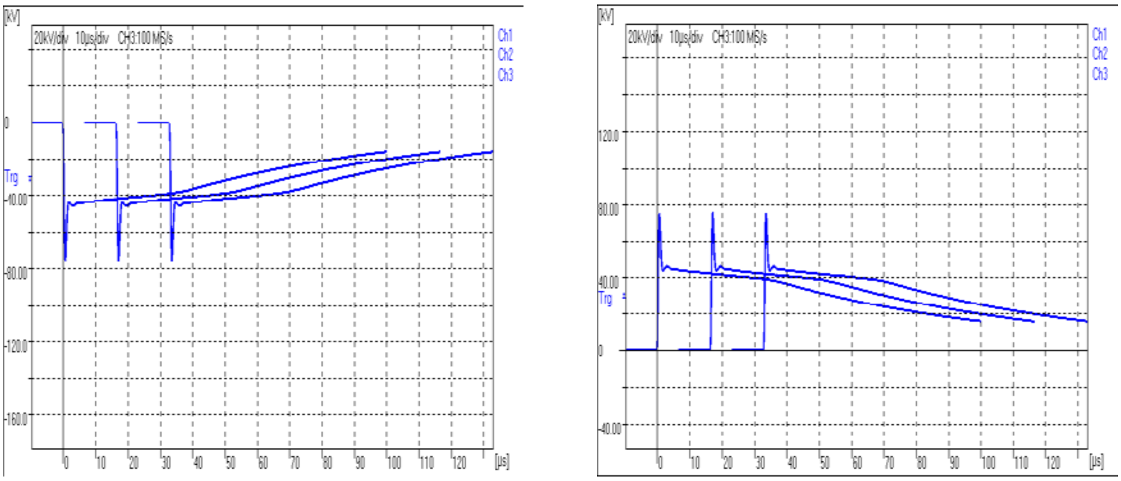


Figures 7a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “a0”.

6.1.8 Insulating distance “a0” (three sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Front time (T_1) in *µs*	Time to half-value (T_2) in *µs*
a0	1	-150	1.2	50
	2			
	3			
	4	150		
	5			
	6			

Table 8: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “a0”.



Figures 8a/b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “a0”.

6.2 Chopped wave lightning impulse test (LIC)

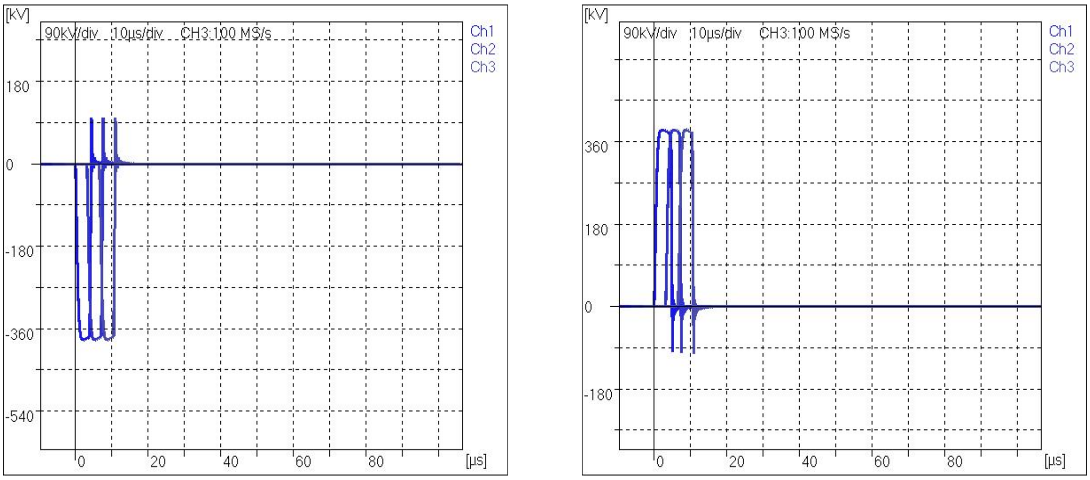
Test standard:	IEC 60214-1:2014, sub-clause 5.2.8.6.
Impulse voltage generator:	Impulse generator (max. charging: 1800 kV), see appendix 2, picture 2.
Voltage waveform ($T_1/T_2/T_c$):	1.2 / 50 / 3 µs.
Wirings and connections:	See appendix 3, figures 41...46.
Test voltages (U_p):	See tables 9...16.
Oscillograms:	See figures 9a/b...16a/b.
Number of applications:	Three applications with positive and three with negative polarity.

Note:
To protect the insulating distance “a0” from transient over-voltages, a ZnO surge arrester is incorporated in the diverter switch. As a result of the ZnO-wiring the voltage waveforms of lightning impulses (full wave / chopped wave) and the waveform of the switching impulse deviate from nominal waveforms. The waveforms shown in the oscillograms are typical for diverter switches equipped with ZnO surge arrester (see figures 14a/b…16a/b).

6.2.1 Insulating distance “f” (U_m = 72.5 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to chopping (T_C) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-385	-385.1	1.2	1.231	4	4.062
	2		-385.0		1.231		4.069
	3		-385.0		1.230		4.058
	4	385	387.0		1.241		4.694
	5		386.9		1.237		3.969
	6		386.9		1.240		3.940

Table 9: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “f” (U_m = 72.5 kV).

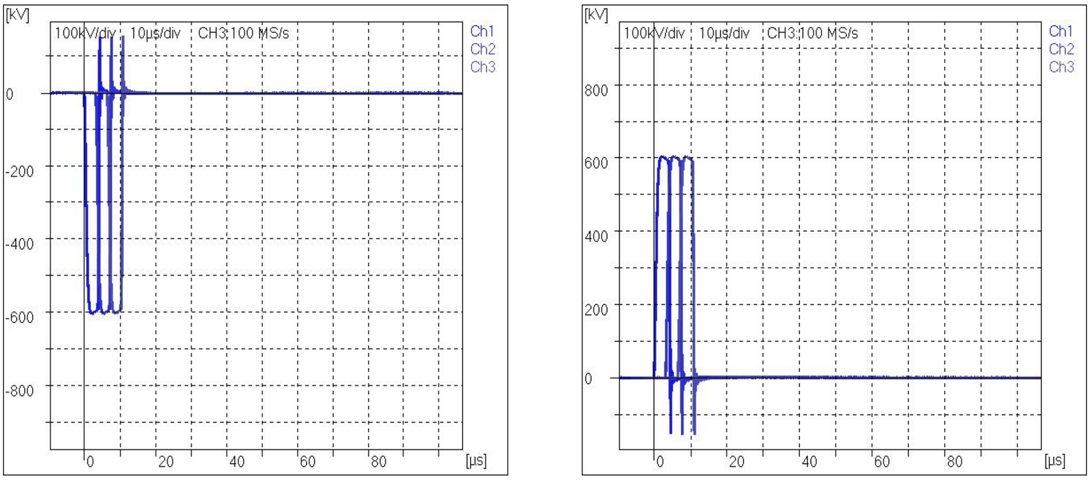


Figures 9a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “f” (U_m = 72.5 kV).

6.2.2 Insulating distance "f" (U_m = 123 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to chopping (T_C) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-605	-603.7	1.2	1.230	4	3.966
	2		-603.8		1.232		3.972
	3		-603.9		1.232		3.962
	4	605	604.4		1.244		4.144
	5		604.7		1.245		4.125
	6		604.8		1.247		4.067

Table 10: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 123 kV).

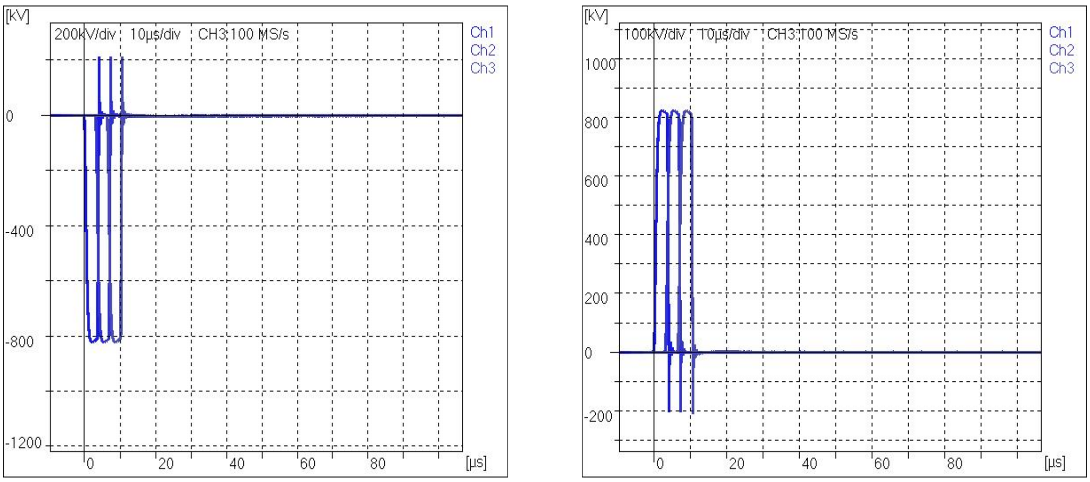


Figures 10a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 123 kV).

6.2.3 Insulating distance "f" (U_m = 170 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to chopping (T_C) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-825	-823.0	1.2	1.237	4	3.835
	2		-823.2		1.239		3.845
	3		-823.3		1.240		3.835
	4	825	823.5		1.249		3.775
	5		823.7		1.251		3.762
	6		823.5		1.248		3.772

Table 11: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 170 kV).

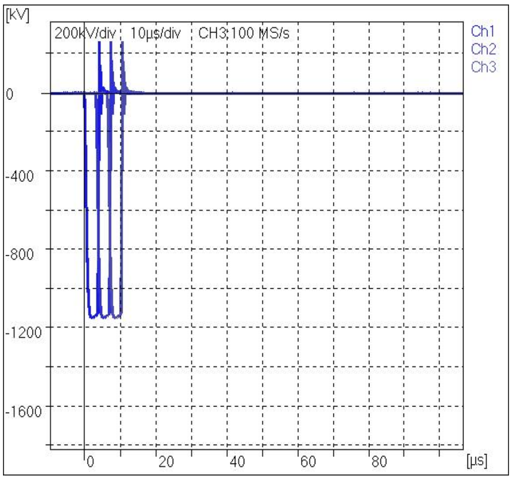


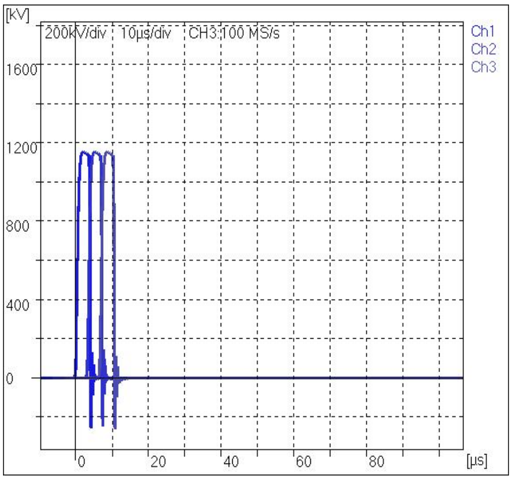
Figures 11a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 170 kV).

6.2.4 Insulating distance "f" (U_m = 245 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to chopping (T_C) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-1155	-1152	1.2	1.227	4	3.835
	2		-1152		1.228		3.856
	3		-1152		1.227		3.853
	4	1155	1155		1.231		3.892
	5		1155		1.231		3.920
	6		1155		1.232		3.869

Table 12: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 245 kV).



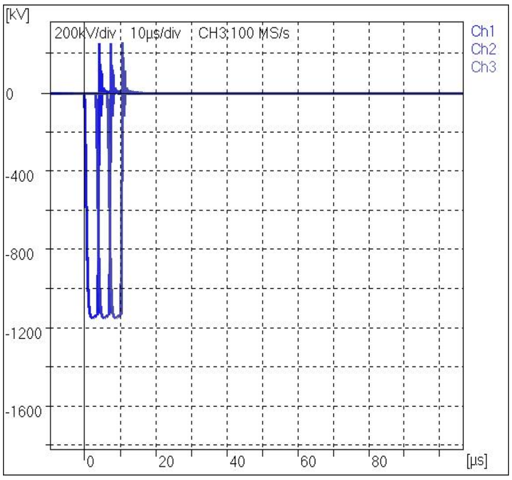


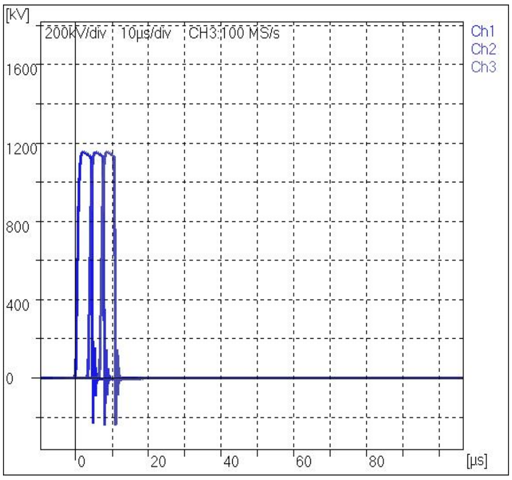
Figures 12a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 245 kV).

6.2.5 Insulating distance "f" (U_m = 300 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Front time (T_1) in *µs*		Time to chopping (T_C) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-1155	-1151	1.2	1.226	4	3.845
	2		-1151		1.225		3.845
	3		-1152		1.225		3.873
	4	1155	1155		1.232		4.460
	5		1155		1.231		4.277
	6		1155		1.232		4.121

Table 13: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 300 kV).



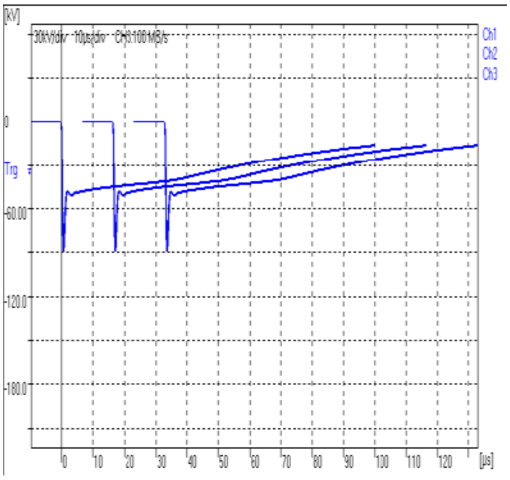


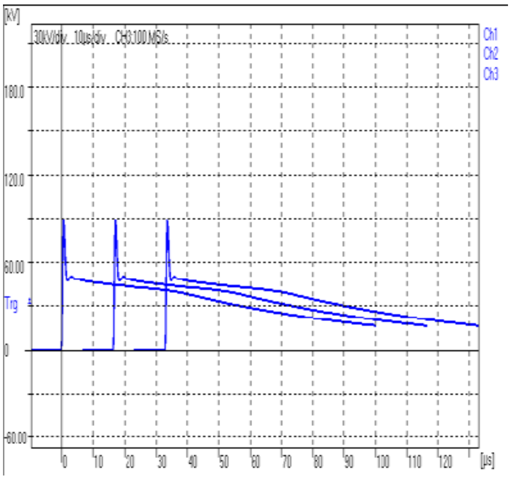
Figures 13a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance "f" (U_m = 300 kV).

6.2.6 Insulating distance “a0” (single sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Front time (T_1) in *µs*	Time to chopping (T_C) in *µs*
a0	1	-165	1.2	4
	2			
	3			
	4	165		
	5			
	6			

Table 14: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a0”.



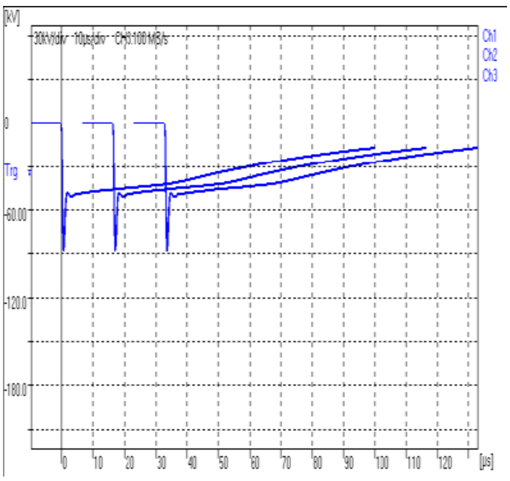


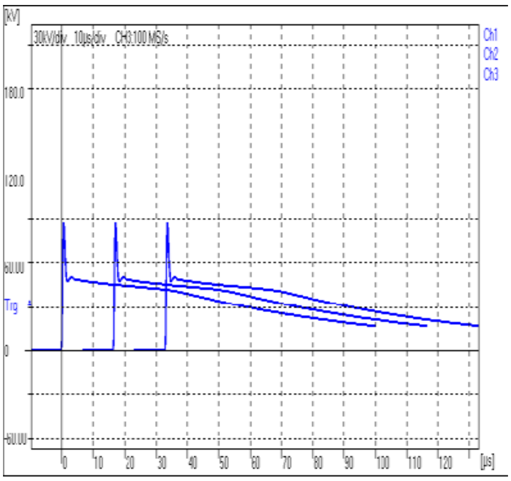
Figures 14a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a0”.

6.2.7 Insulating distance “a0” (two sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Front time (T_1) in *µs*	Time to chopping (T_C) in *µs*
a0	1	-165	1.2	4
	2			
	3			
	4	165		
	5			
	6			

Table 15: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a0”.



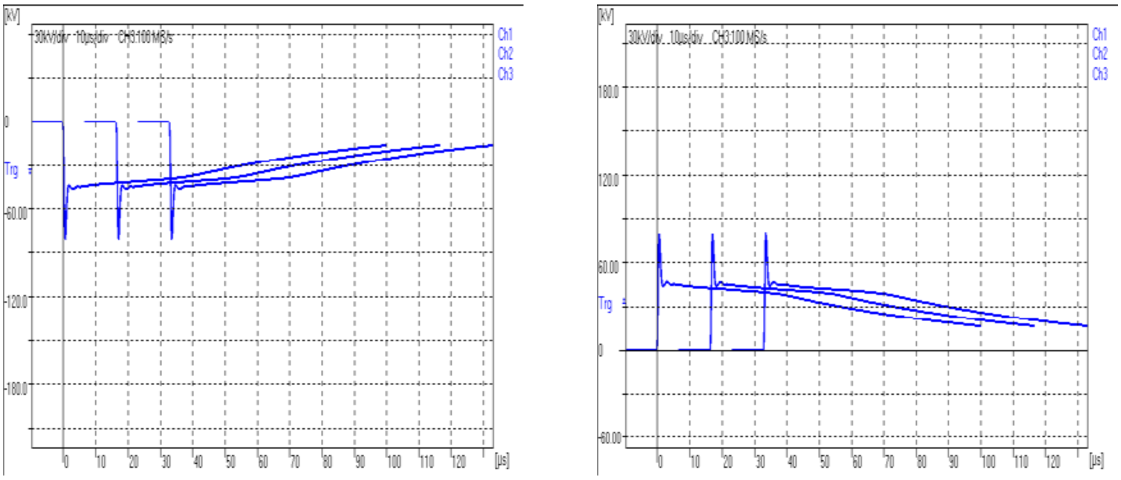


Figures 15a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a0”.

6.2.8 Insulating distance “a0” (three sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Front time (T_1) in *µs*	Time to chopping (T_C) in *µs*
a0	1	-165	1.2	4
	2			
	3			
	4	165		
	5			
	6			

Table 16: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a0”.



Figures 16a/b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a0”.

6.3 Switching impulse test (SI)

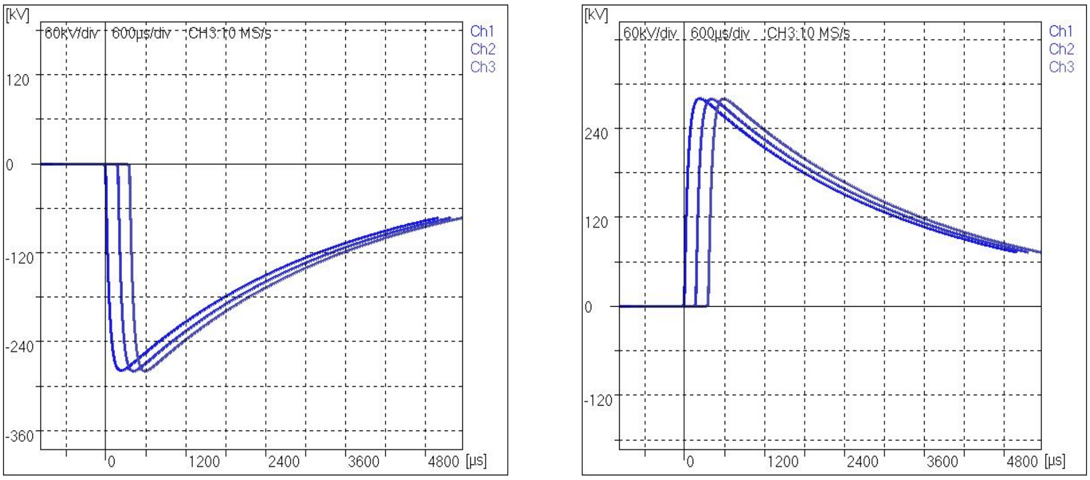
Test standard:	IEC 60214-1:2014, sub-clause 5.2.8.7.
Impulse voltage generator:	Impulse generator (max. charging: 1800 kV), see appendix 2, picture 2.
Voltage waveform (T_P/T_2):	250 / 2500 µs.
Wirings and connections:	See appendix 3, figures 41...46.
Test voltages (U_p):	See tables 17...24.
Oscillograms:	See figures 17a/b...24a/b.
Number of applications:	Three applications with positive and three with negative polarity.

Note:
To protect the insulating distance “a0” from transient over-voltages, a ZnO surge arrester is incorporated in the diverter switch. As a result of the ZnO-wiring the voltage waveforms of lightning impulses (full wave / chopped wave) and the waveform of the switching impulse deviate from nominal waveforms. The waveforms shown in the oscillograms are typical for diverter switches equipped with ZnO surge arrester (see figures 22a/b…24a/b).

6.3.1 Insulating distance “f” (U_m = 72.5 kV)[1]

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Time to peak (T_P) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-280	-279.4	250	228.1	2500	2667
	2		-280.0		228.2		2667
	3		-280.0		228.3		2666
	4	280	280.7		228.3		2666
	5		280.1		228.4		2667
	6		280.2		228.4		2667

Table 17: Test results of switching impulse test (250/2500 µs) on insulating distance “f” (U_m = 72.5 kV).



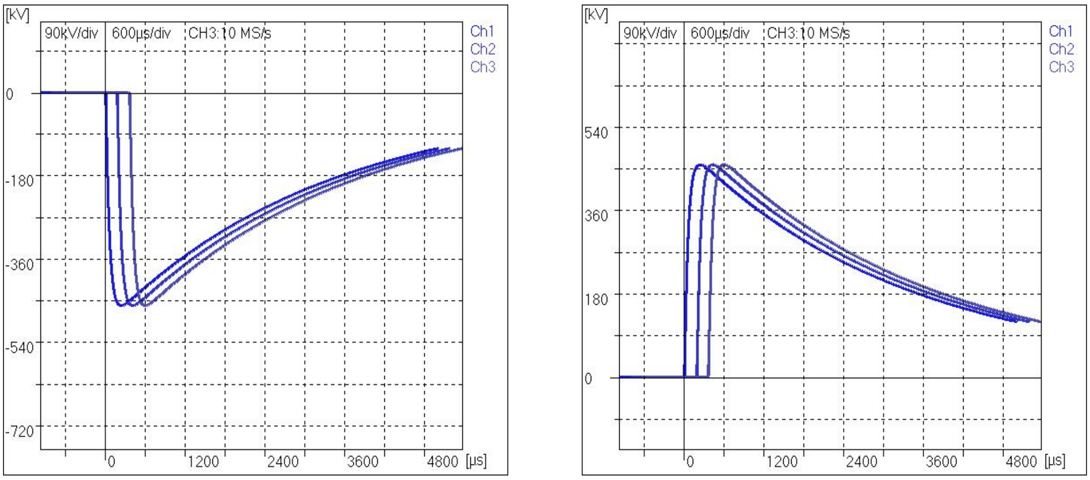
Figures 17a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “f” (U_m = 72.5 kV).

[1] Not required by IEC 60214-1:2014.

6.3.2 Insulating distance "f" (U_m = 123 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Time to peak (T_P) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-460	-459.9	250	228.3	2500	2677
	2		-460.0		226.5		2677
	3		-460.1		226.8		2678
	4	460	459.8		229.0		2679
	5		460.1		230.2		2679
	6		460.1		228.2		2680

Table 18: Test results of switching impulse test (250/2500 µs) on insulating distance "f" (U_m = 123 kV).

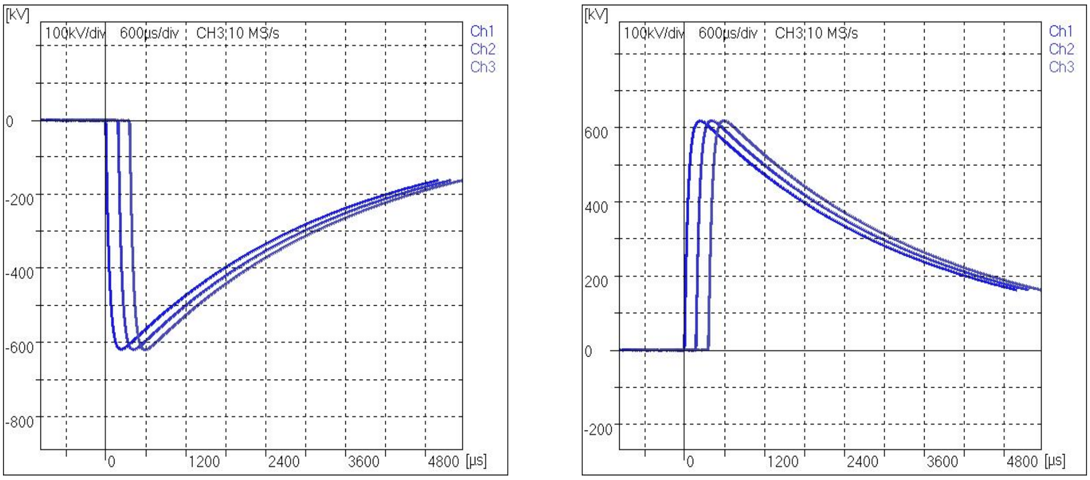


Figures 18a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance "f" (U_m = 123 kV).

6.3.3 Insulating distance "f" (U_m = 170 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Time to peak (T_P) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-620	-618.9	250	225.8	2500	2677
	2		-619.5		225.8		2678
	3		-620.3		225.9		2677
	4	620	619.1		226.6		2681
	5		620.4		226.8		2680
	6		619.7		226.7		2683

Table 19: Test results of switching impulse test (250/2500 µs) on insulating distance "f" (U_m = 170 kV).

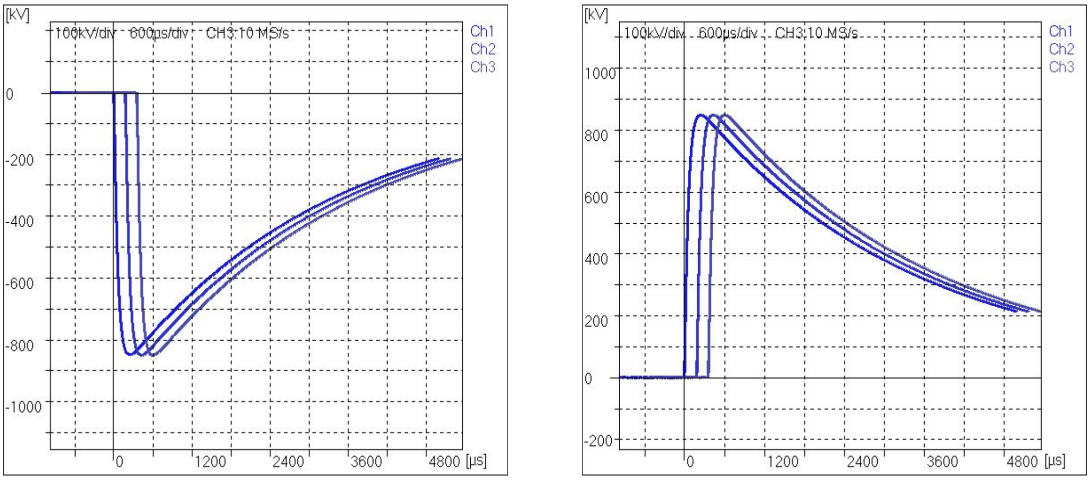


Figures 19a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance "f" (U_m = 170 kV).

6.3.4 Insulating distance “f” (U_m = 245 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Time to peak (T_P) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-850	-848.9	250	238.2	2500	2624
	2		-849.8		238.1		2627
	3		-849.9		238.2		2635
	4	850	850.2		238.0		2628
	5		850.6		238.3		2627
	6		849.7		238.1		2628

Table 20: Test results of switching impulse test (250/2500 µs) on insulating distance “f” (U_m = 245 kV).

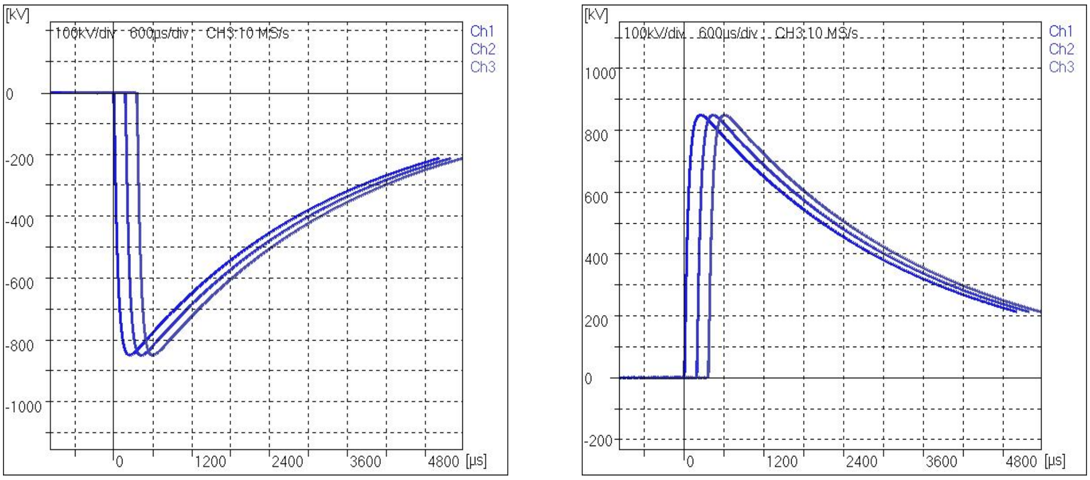


Figures 20a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “f” (U_m = 245 kV).

6.3.5 Insulating distance “f” (U_m = 300 kV)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*		Time to peak (T_P) in *µs*		Time to half-value (T_2) in *µs*	
		Nominal	Tested	Nominal	Tested	Nominal	Tested
f	1	-850	-849.2	250	237.8	2500	2625
	2		-850.2		236.6		2626
	3		-850.0		235.2		2627
	4	850	850.9		241.8		2627
	5		850.2		236.7		2627
	6		850.2		236.7		2627

Table 21: Test results of switching impulse test (250/2500 µs) on insulating distance “f” (U_m = 300 kV).

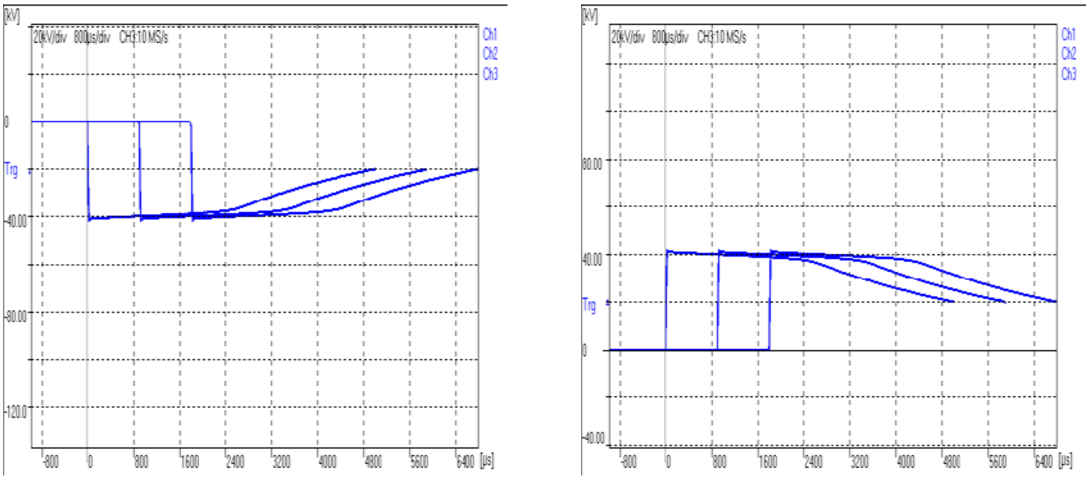


Figures 21a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “f” (U_m = 300 kV).

6.3.6 Insulating distance “a0” (single sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Time to peak (T_P) in *µs*	Time to half-value (T_2) in *µs*
a0	1	-100	250	2500
	2			
	3			
	4	100		
	5			
	6			

Table 22: Test results of switching impulse test (250/2500 µs) on insulating distance “a0”.

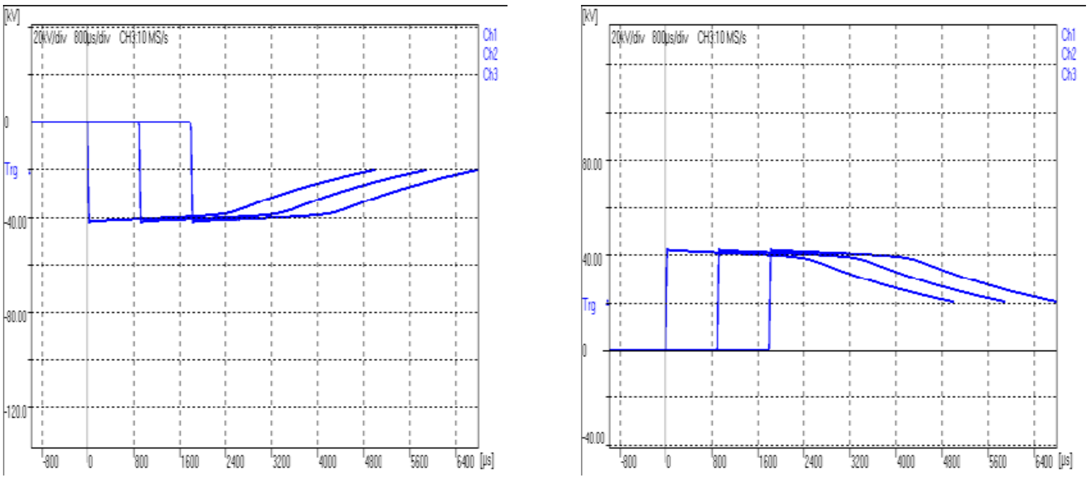


Figures 22a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “a0”.

6.3.7 Insulating distance “a0” (two sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Time to peak (T_P) in *µs*	Time to half-value (T_2) in *µs*
a0	1	-100	250	2500
	2			
	3			
	4	100		
	5			
	6			

Table 23: Test results of switching impulse test (250/2500 µs) on insulating distance “a0”.

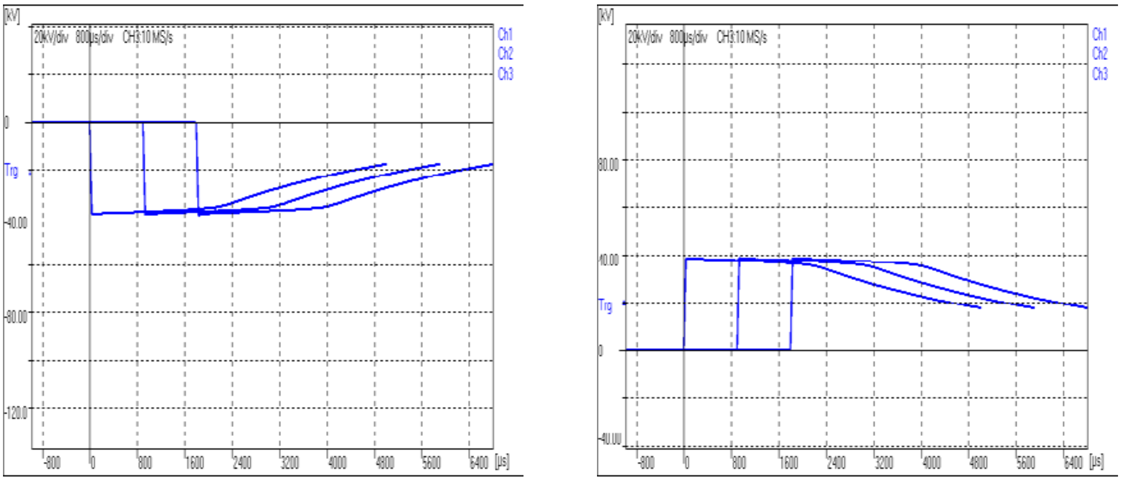


Figures 23a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “a0”.

6.3.8 Insulating distance “a0” (three sector design)

Tested insulating distance	Test no.	Peak amplitude (U_p) in *kV*	Time to peak (T_P) in *µs*	Time to half-value (T_2) in *µs*
a0	1	-100	250	2500
	2			
	3			
	4	100		
	5			
	6			

Table 24: Test results of switching impulse impulse test (250/2500 µs) on insulating distance “a0”.



Figures 24a/b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “a0”.

6.4 Applied voltage test (AV)

Test standard:	IEC 60214-1:2014, sub-clause 5.2.8.8.
Voltage generator:	Applied voltage generator (max. voltage 700 kV), see appendix 2, picture 1.
Voltage waveform:	Sine-shaped (frequency: 50 Hz).
Wirings and connections:	See appendix 3, figures 41...46.
Test voltages ($U_{r.m.s.}$):	See tables 25...32.
Oscillograms:	See figures 25...32.
Test duration (t_D):	60 s.

6.4.1 Insulating distance “f” (U_m = 72.5 kV)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
f	140	140	60	62

Table 25: Test results of applied voltage test (50 Hz) on insulating distance “f” (U_m = 72.5 kV).

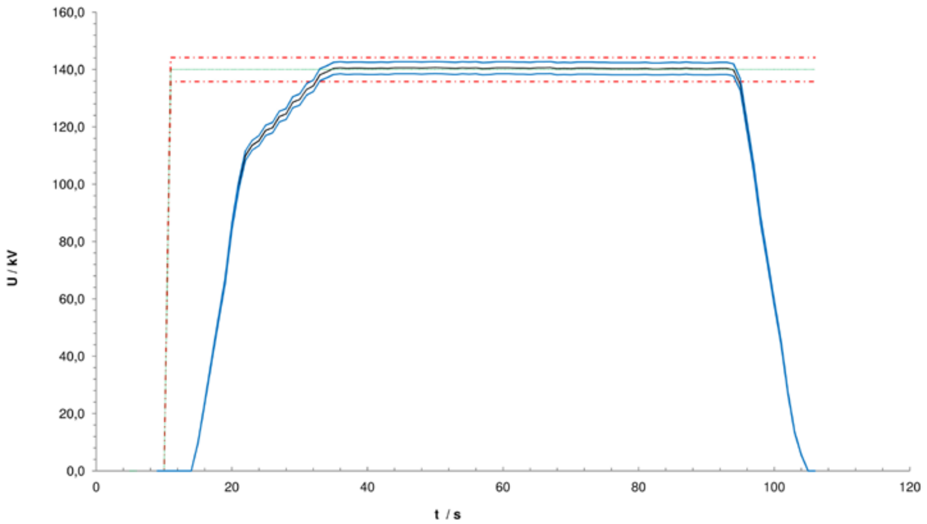


Figure 25: Oscillogram of applied voltage test (50 Hz) on insulating distance “f” (U_m = 72.5 kV).

6.4.2 Insulating distance “f” (U_m = 123 kV)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
f	230	230	60	61

Table 26: Test results of applied voltage test (50 Hz) on insulating distance “f” (U_m = 123 kV).

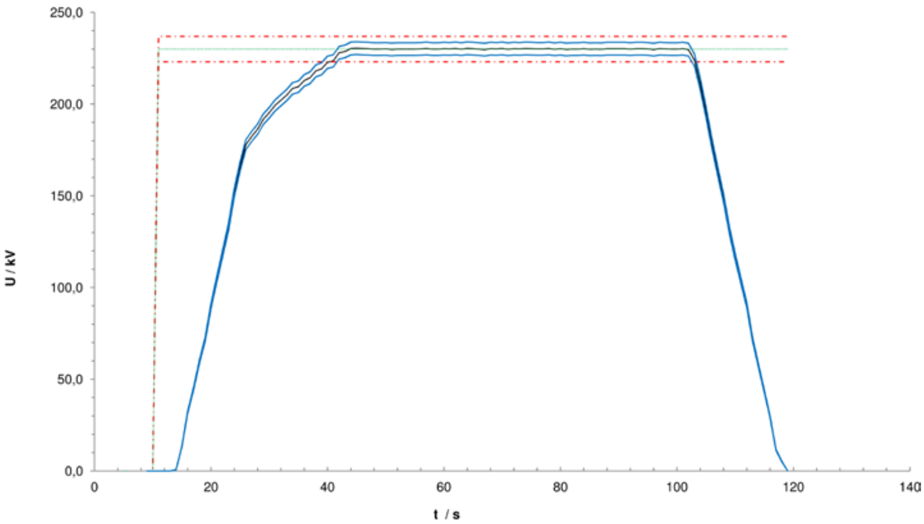


Figure 26: Oscillogram of applied voltage test (50 Hz) on insulating distance “f” (U_m = 123 kV).

6.4.3 Insulating distance “f” (U_m = 170 kV)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
f	325	325	60	62

Table 27: Test results of applied voltage test (50 Hz) on insulating distance “f” (U_m = 170 kV).

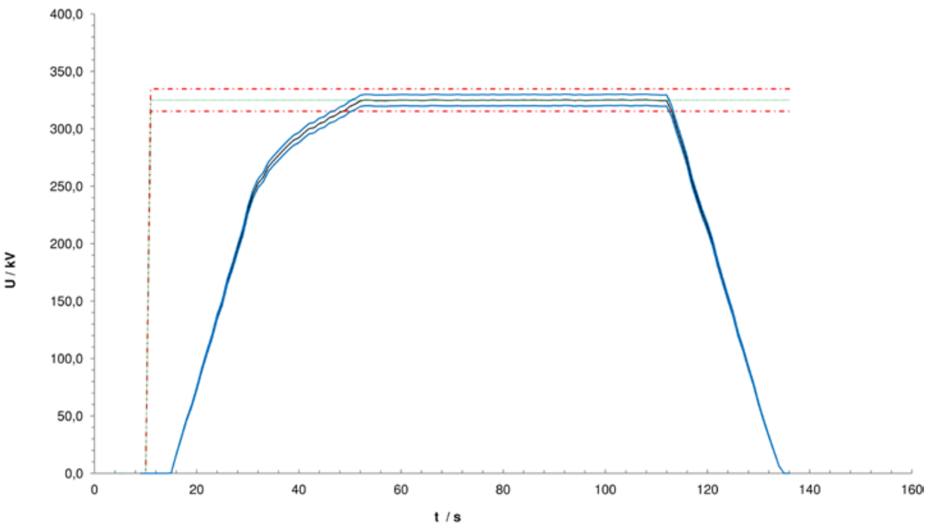


Figure 27: Oscillogram of applied voltage test (50 Hz) on insulating distance “f” (U_m = 170 kV).

6.4.4 Insulating distance “f” (U_m = 245 kV)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
f	460	460	60	67

Table 28: Test results of applied voltage test (50 Hz) on insulating distance “f” (U_m = 245 kV).

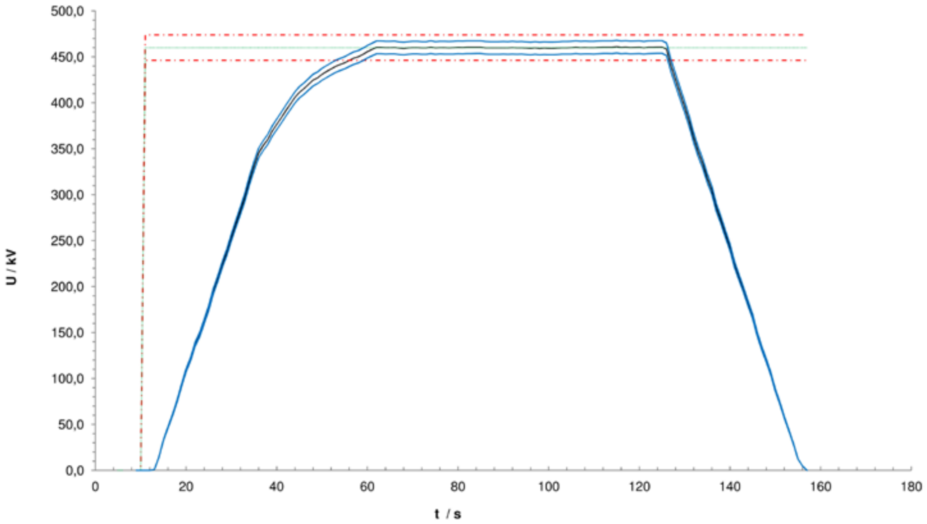


Figure 28: Oscillogram of applied voltage test (50 Hz) on insulating distance “f” (U_m = 245 kV).

6.4.5 Insulating distance “f” (U_m = 300 kV)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
f	460	460	60	60

Table 29: Test results of applied voltage test (50 Hz) on insulating distance “f” (U_m = 300 kV).

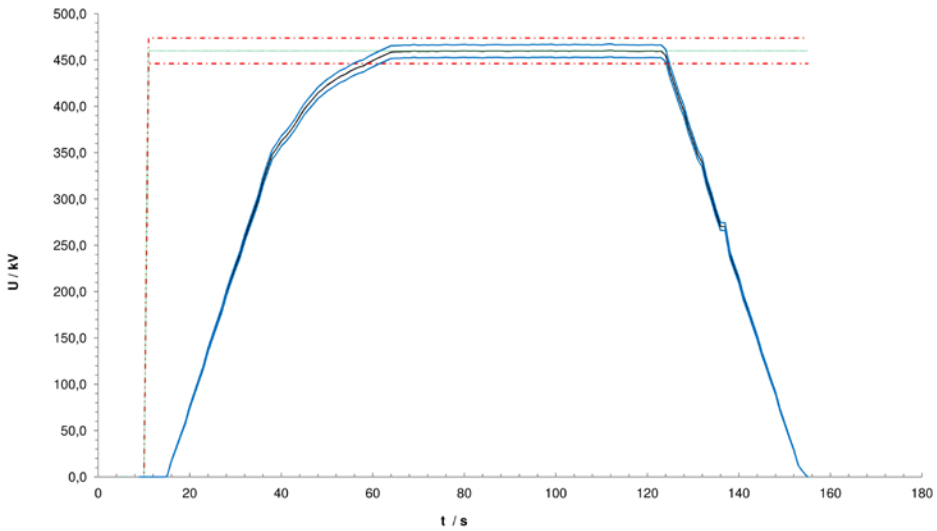


Figure 29: Oscillogram of applied voltage test (50 Hz) on insulating distance “f” (U_m = 300 kV).

6.4.6 Insulating distance “a0” (single sector design)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
a0	20	20	60	62

Table 30: Test results of applied voltage test (50 Hz) on insulating distance “a0”.

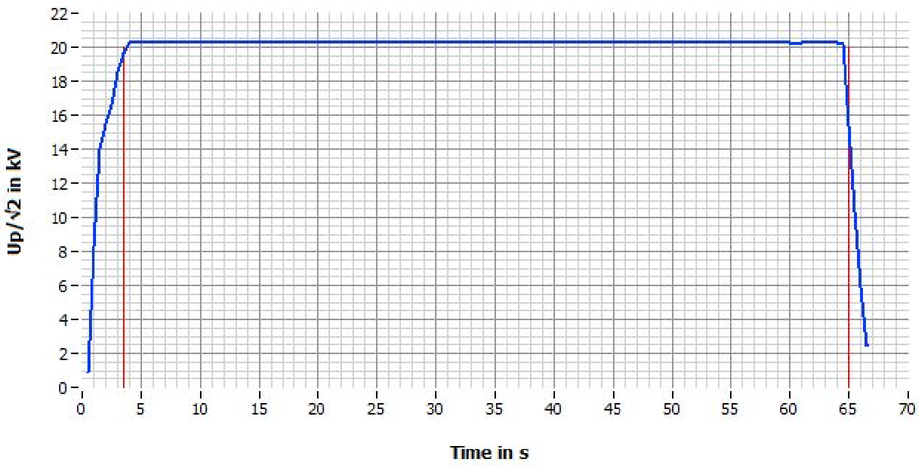


Figure 30: Oscillogram of applied voltage test (50 Hz) on insulating distance “a0”.

6.4.7 Insulating distance “a0” (two sector design)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
a0	20	20	60	61

Table 31: Test results of applied voltage test (50 Hz) on insulating distance “a0”.

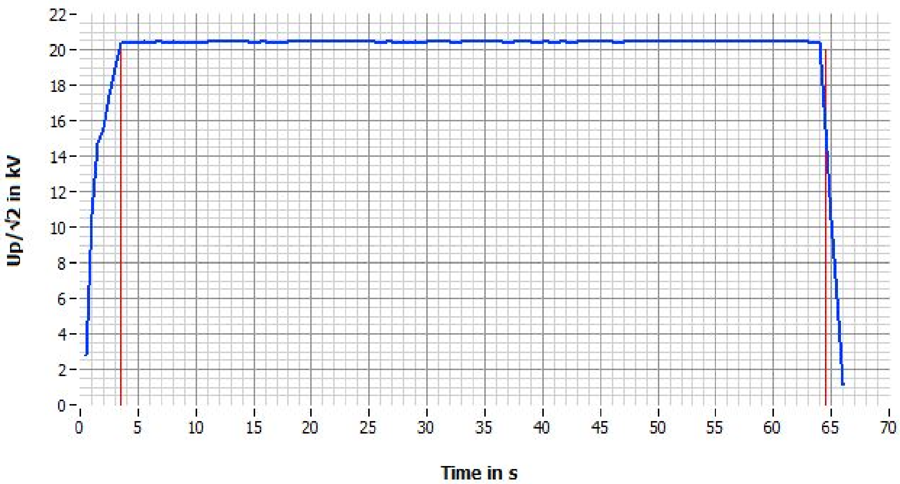


Figure 31: Oscillogram of applied voltage test (50 Hz) on insulating distance “a0”.

6.4.8 Insulating distance “a0” (three sector design)

Tested insulating distance	Applied voltage (50 Hz) in *kV*		Test duration in *s*	
	Nominal	Tested	Nominal	Tested
a0	20	20	60	69

Table 32: Test results of applied voltage test (50 Hz) on insulating distance “a0”.

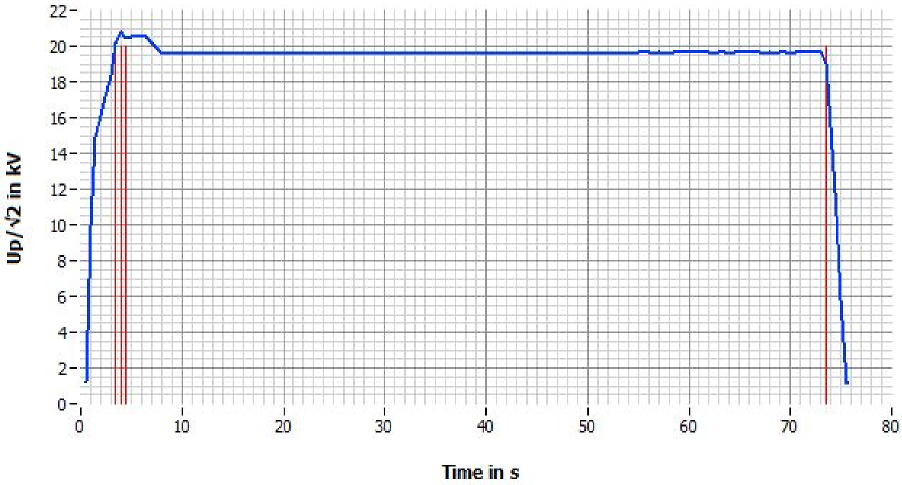


Figure 32: Oscillogram of applied voltage test (50 Hz) on insulating distance “a0”.

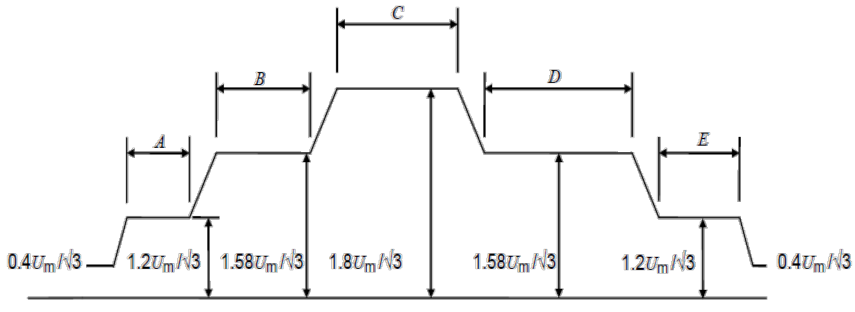
6.5 Measurement of partial discharges

Test standard:	IEC 60214-1:2014, sub-clause 5.2.8.9.
Voltage generator:	Applied voltage generator (max. voltage 700 kV), see appendix 2, picture 1.
Voltage waveform:	Sine-shaped (frequency: 50 Hz).
Wirings and connections:	See appendix 3, figures 44...46.
Test voltages / durations :	See tables 33a...37a.
Oscillograms:	See figures 33...37.

Test procedure:

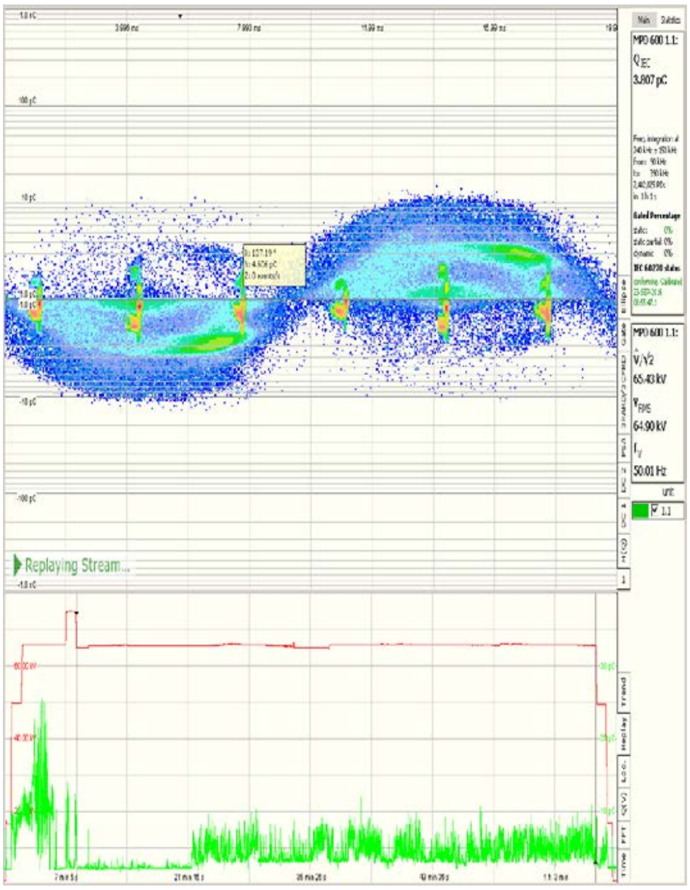
- the voltage was switched on at a level not higher than 0.4 Um / √3;
- the background PD level was measured and recorded;
- the voltage was raised to 1.2 Um / √3 and held there for a minimum duration of 1 min;
- the PD level was measured and recorded;
- the voltage was raised to 1.58 Um / √3 and held there for a minimum duration of 5 min;
- the PD level was measured and recorded;
- the voltage was raised to the enhanced voltage 1.8 Um / √3 and held there for a duration of 60 s.
- immediately after the test time, the voltage was reduced without interruption to 1.58 Um / √3;
- the PD level was measured and recorded;
- the voltage was held at 1.58 Um / √3 for a duration of at least 60 min;
- the PD level was measured and recorded every 5 min during the 60 min period;
- after the last PD measurement in the 60 min period, the voltage was reduced to 1.2 / √3 and held there for a minimum duration of 1 min;
- the PD level was measured and recorded;
- the voltage was reduced to 0.4 Um / √3;
- the background PD level was measured and recorded;
- the voltage was reduced to a level below 0.4 Um / √3;
- the voltage was switched off.

The partial discharge was continuously observed on at least one measuring channel for the entire duration test.



Permissible tolerances according to IEC 60214-1:2014:	*PD during test step D: < 50 pC* *PD during test step E: < 30 pC* *PD background level: < 10 pC*

6.5.1 Insulation distance “f” (U_m = 72.5 kV)



Test steps according to test procedure as described in chapter 6.5				
Test step	Duration in *min*		Test voltage in *kV*	
	Nominal	Tested	Nominal	Tested
(U_{start})	-	-	17	17
A	1	1	50	50
B	5	5	66	66
C	1	1	75	75
D	60	60	66	66
E	1	1	50	50
(U_{stop})	-	-	17	17

Table 33a: Nominal and tested voltages and durations for insulation distance “f” (U_m = 72.5 kV).

Figure 33: Measurement of partial discharges at insulation distance “f” (U_m = 72.5 kV).

Tested insulation distance	PD background level in *pC*			PD at 1.58 Um / √3 during 60 min in *pC*		PD at 1.2 Um / √3 during 1 min in *pC*	
	Nominal	Maximum tested at begin of PD measurement	Maximum tested at end of PD measurement	Nominal	Maximum tested	Nominal	Maximum tested
f	< 10	< 2	< 2	< 50	< 14	< 30	< 6

Table 33b: Partial discharge test at insulation distance “f” (U_m = 72.5 kV).

6.5.2 Insulation distance "f" (U_m = 123 kV)

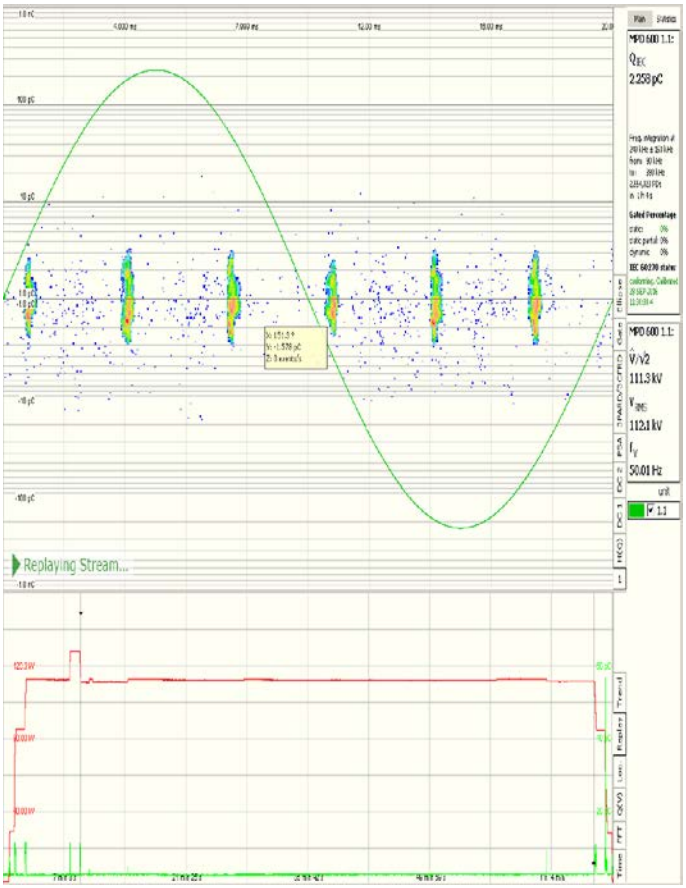


Figure 34: Measurement of partial discharges at insulation distance "f" (U_m = 123 kV).

Test steps according to test procedure as described in chapter 6.5				
Test step	Duration in *min*		Test voltage in *kV*	
	Nominal	Tested	Nominal	Tested
(U_{start})	-	-	28	28
A	1	1	85	85
B	5	5	112	112
C	1	1	128	128
D	60	60	112	112
E	1	1	85	85
(U_{stop})	-	-	28	28

Table 34a: Nominal and tested voltages and durations for insulation distance "f" (U_m = 123 kV).

Tested insulation distance	PD background level in *pC*			PD at 1.58 Um / √3 during 60 min in *pC*		PD at 1.2 Um / √3 during 1 min in *pC*	
	Nominal	Maximum tested at begin of PD measurement	Maximum tested at end of PD measurement	Nominal	Maximum tested	Nominal	Maximum tested
f	< 10	< 2	< 2	< 50	< 2	< 30	< 2

Table 34b: Partial discharge test at insulation distance "f" (U_m = 123 kV).

6.5.3 Insulation distance “f” (U_m = 170 kV)

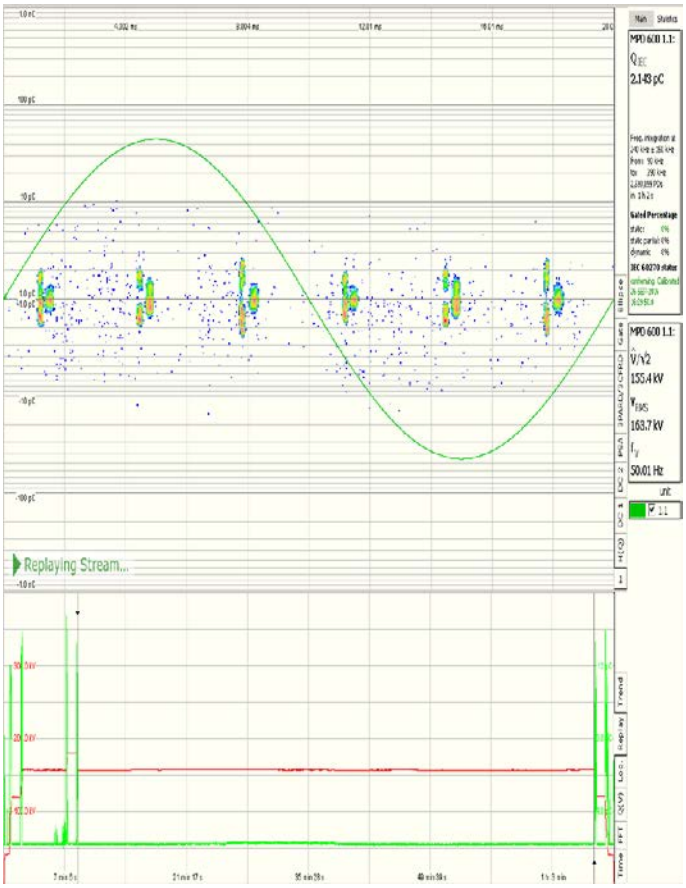


Figure 35: Measurement of partial discharges at insulation distance “f” (U_m = 170 kV).

Test steps according to test procedure as described in chapter 6.5				
Test step	Duration in *min*		Test voltage in *kV*	
	Nominal	Tested	Nominal	Tested
(U_{start})	-	-	39	39
A	1	1	118	118
B	5	5	155	155
C	1	1	177	177
D	60	60	155	155
E	1	1	118	118
(U_{stop})	-	-	39	39

Table 35a: Nominal and tested voltages and durations for insulation distance “f” (U_m = 170 kV).

Tested insulation distance	PD background level in *pC*			PD at 1.58 Um / √3 during 60 min in *pC*		PD at 1.2 Um / √3 during 1 min in *pC*	
	Nominal	Maximum tested at begin of PD measurement	Maximum tested at end of PD measurement	Nominal	Maximum tested	Nominal	Maximum tested
f	< 10	< 2	< 3	< 50	< 3	< 30	< 3

Table 35b: Partial discharge test at insulation distance “f” (U_m = 170 kV).

6.5.4 Insulation distance “f” (U_m = 245 kV)

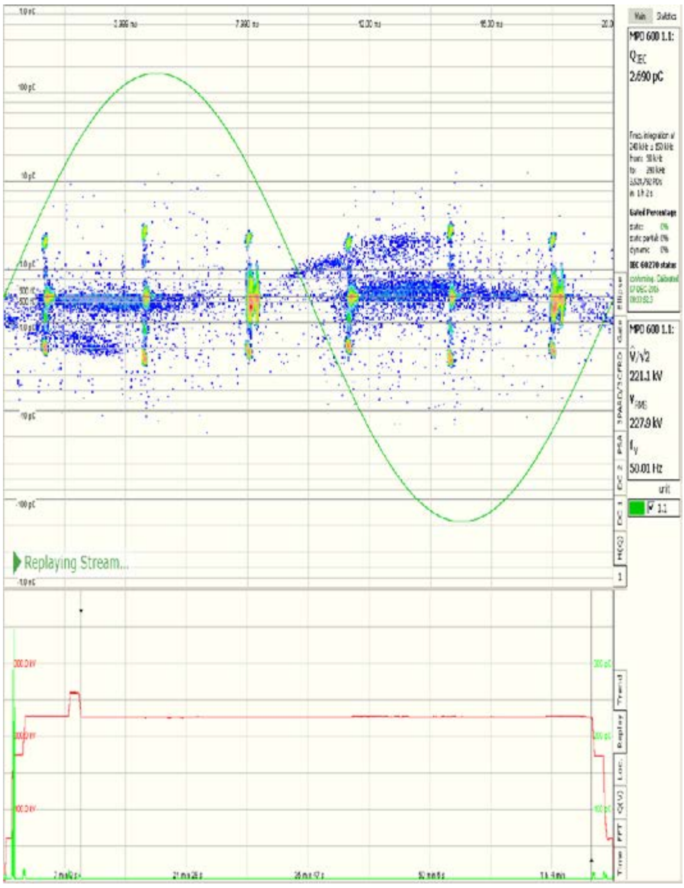


Figure 36: Measurement of partial discharges at insulation distance “f” (U_m = 245 kV).

Test steps according to test procedure as described in chapter 6.5				
Test step	Duration in *min*		Test voltage in *kV*	
	Nominal	Tested	Nominal	Tested
(U_{start})	-	-	57	57
A	1	1	170	170
B	5	5	223	223
C	1	1	255	255
D	60	60	223	223
E	1	1	170	170
(U_{stop})	-	-	57	57

Table 36a: Nominal and tested voltages and durations for insulation distance “f” (U_m = 245 kV).

Tested insulation distance	PD background level in *pC*			PD at 1.58 Um / √3 during 60 min in *pC*		PD at 1.2 Um / √3 during 1 min in *pC*	
	Nominal	Maximum tested at begin of PD measurement	Maximum tested at end of PD measurement	Nominal	Maximum tested	Nominal	Maximum tested
f	< 10	< 2	< 2	< 50	< 2	< 30	< 2

Table 36b: Partial discharge test at insulation distance “f” (U_m = 245 kV).

6.5.5 Insulation distance “f” (U_m = 300 kV)

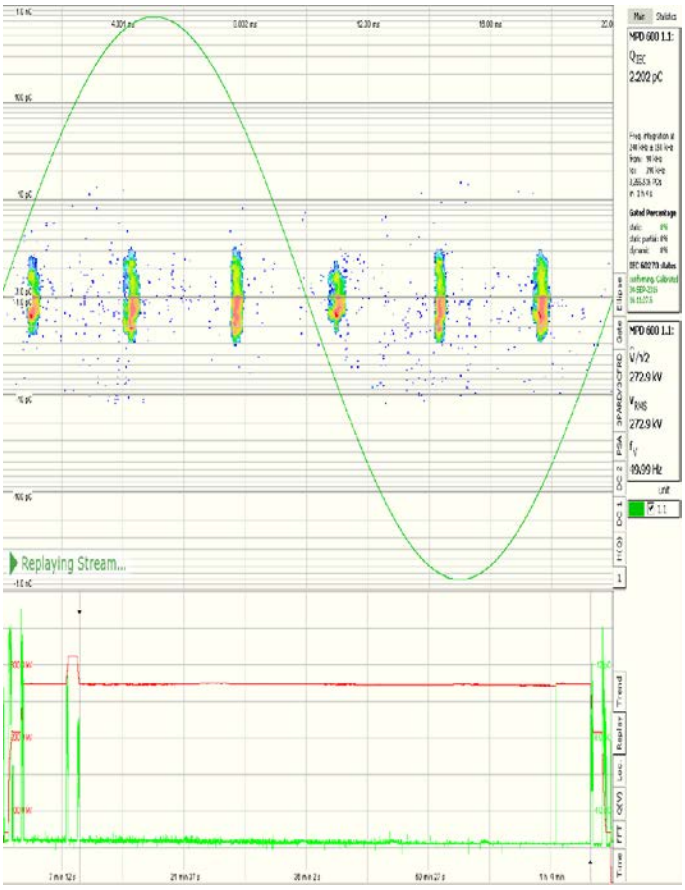


Figure 37: Measurement of partial discharges at insulation distance “f” (U_m = 300 kV).

Test steps according to test procedure as described in chapter 6.5				
Test step	Duration in *min*		Test voltage in *kV*	
	Nominal	Tested	Nominal	Tested
(U_{start})	-	-	69	69
A	1	1	208	208
B	5	5	274	274
C	1	1	312	312
D	60	60	274	274
E	1	1	208	208
(U_{stop})	-	-	69	69

Table 37a: Nominal and tested voltages and durations for insulation distance “f” (U_m = 300 kV).

Tested insulation distance	PD background level in *pC*			PD at 1.58 Um / √3 during 60 min in *pC*		PD at 1.2 Um / √3 during 1 min in *pC*	
	Nominal	Maximum tested at begin of PD measurement	Maximum tested at end of PD measurement	Nominal	Maximum tested	Nominal	Maximum tested
f	< 10	< 2	< 2	< 50	< 2	< 30	< 2

Table 37b: Partial discharge test at insulation distance “f” (U_m = 300 kV).

7. Test results

The requirements according to IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, sub-clause 5.2.8: “Dielectric tests” were met.

The full wave lightning impulse tests (LI), the chopped wave lightning impulse tests (LIC), the switching impulse tests (SI) as well as the applied voltage tests (AV) were withstood without any discharge.

The confirmed withstand voltages for the insulating distance to earth (insulating distance “f”) and for the insulating distance between diverter switch contacts in their final open position (insulating distance “a0”) are shown in tables 38 and 39.

Highest voltage for equipment U_m in *kV* (r.m.s.)	Full wave lightning impulse withstand voltage (LI) 1.2 / 50 µs in *kV* (peak)	Chopped wave lightning impulse withstand voltage (LIC) 1.2 / 50 / 3 µs in *kV* (peak)	Switching impulse withstand voltage (SI) 250 / 2500 µs in *kV* (peak)	Applied voltage (AV) 50 Hz / 60 s in *kV* (r.m.s.)
72.5	350	385	280[1]	140
123	550	605	460	230
170	750	825	620	325
245	1050	1155	850	460
300	1050	1155	850	460

Table 38: Confirmed withstand voltages for the insulating distance to earth (insulating distance “f”).

Highest voltage for equipment U_m in *kV* (r.m.s.)	Full wave lightning impulse withstand voltage (LI) 1.2 / 50 µs in *kV* (peak)	Chopped wave lightning impulse withstand voltage (LIC) 1.2 / 50 / 3 µs in *kV* (peak)	Switching impulse withstand voltage (SI) 250 / 2500 µs in *kV* (peak)	Applied voltage (AV) 50 Hz / 60 s in *kV* (r.m.s.)
72.5 … 300	150	165	100	20

Table 39: Confirmed withstand voltages for the insulating distance between diverter switch contacts in their final open position (insulating distance “a0”).

During the partial discharge (PD) measurements, no collapse of the test voltage and no continuously rising tendency occurred. The levels of partial discharges did not exceed the corresponding permissible limits. Details see table 40.

Highest voltage for equipment U_m in *kV* (r.m.s.)	PD background level in *pC*	PD at 1.58 $U_m / \sqrt{3}$ during 60 min in *pC*	PD at 1.2 $U_m / \sqrt{3}$ during 1 min in pC
72.5 … 300	< 3	< 50	< 30

Table 40: Confirmed results of partial discharge measurements at insulation distance to earth (insulating distance “f”).

[1] Not required by IEC 60214-1:2014.

Appendix 1: Dimension drawing

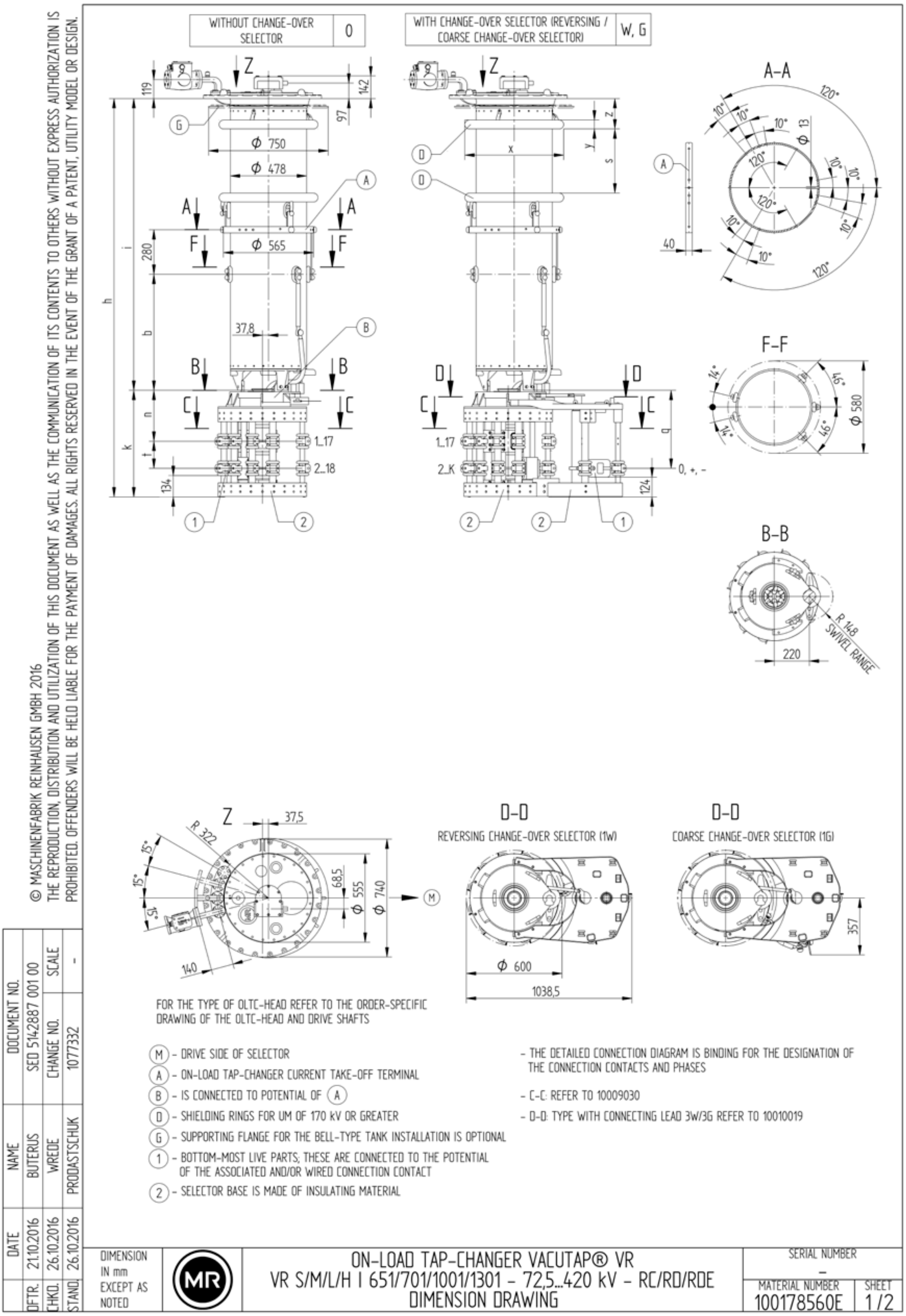


Figure 38a: Example of dimension drawing of on-load tap-changers type VACUTAP® VRS / VRM / VRL / VRH with single phase design , combined with tap selectors type RC / RD / RDE (page 1/2).

VACUTAP® VRS

SELECTOR SIZE		RC							RD							RDE						
Um [kV]		72,5	123	170	245	300	362	420	72,5	123	170	245	300	362	420	72,5	123	170	245	300	362	420
DIMENSIONS [mm]	h	1838	1968	2098	2198	2350	2453	2572	1918	2048	2178	2278	2430	2533	2652	1958	2088	2218	2318	2470	2573	2692
	i	1168	1298	1428	1528	1680	1783	1902	1168	1298	1428	1528	1680	1783	1902	1168	1298	1428	1528	1680	1783	1902
	b	425							425							425						
	s	-	-	302	402	554	573	692	-	-	302	402	554	573	692	-	-	302	402	554	573	692
	z	-	-	191	191	191	228	228	-	-	191	191	191	228	228	-	-	191	191	191	228	228
	x	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695
	y	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100
	k	670							750							790						
	n	319							359							379						
	t	170							210							230						
	q	489							569							609						
OIL CONTENT [dm³]		160	180	200	220	240	260	280	160	180	200	220	240	260	280	160	180	200	220	240	260	280
DISPLACEMENT [dm³]		249	269	299	319	349	389	409	250	270	300	320	350	390	410	251	271	301	321	351	391	411
MAX. WEIGHT [kg]		358	364	377	380	386	393	398	363	369	382	385	391	398	403	365	371	384	387	393	400	405

VACUTAP® VRM / VRH 651

SELECTOR SIZE		RC							RD							RDE						
Um [kV]		72,5	123	170	245	300	362	420	72,5	123	170	245	300	362	420	72,5	123	170	245	300	362	420
DIMENSIONS [mm]	h	1990	2120	2250	2350	2502	2605	2724	2070	2200	2330	2430	2582	2685	2804	2110	2240	2370	2470	2622	2725	2844
	i	1320	1450	1580	1680	1832	1935	2054	1320	1450	1580	1680	1832	1935	2054	1320	1450	1580	1680	1832	1935	2054
	b	576							576							576						
	s	-	-	302	402	554	573	692	-	-	302	402	554	573	692	-	-	302	402	554	573	692
	z	-	-	191	191	191	228	228	-	-	191	191	191	228	228	-	-	191	191	191	228	228
	x	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695
	y	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100
	k	670							750							790						
	n	319							359							379						
	t	170							210							230						
	q	489							569							609						
OIL CONTENT [dm³]		180	200	230	245	270	285	305	180	200	230	245	270	285	305	180	200	230	245	270	285	305
DISPLACEMENT [dm³]		269	299	329	349	379	419	439	270	300	330	350	380	420	440	271	301	331	351	381	421	441
MAX. WEIGHT [kg]		367	373	386	390	395	402	407	372	378	391	395	400	407	412	374	380	393	397	402	409	414

VACUTAP® VRL / VRH 1301

SELECTOR SIZE		RC							RD							RDE						
Um [kV]		72,5	123	170	245	300	362	420	72,5	123	170	245	300	362	420	72,5	123	170	245	300	362	420
DIMENSIONS [mm]	h	2141	2271	2401	2501	2653	2756	2875	2221	2351	2481	2581	2733	2836	2955	2261	2391	2521	2621	2773	2876	2995
	i	1471	1601	1731	1831	1983	2086	2205	1471	1601	1731	1831	1983	2086	2205	1471	1601	1731	1831	1983	2086	2205
	b	728							728							728						
	s	-	-	302	402	554	573	692	-	-	302	402	554	573	692	-	-	302	402	554	573	692
	z	-	-	191	191	191	228	228	-	-	191	191	191	228	228	-	-	191	191	191	228	228
	x	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695	-	-	Ø 620	Ø 620	Ø 620	Ø 695	Ø 695
	y	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100	-	-	Ø 56	Ø 56	Ø 56	Ø 100	Ø 100
	k	670							750							790						
	n	319							359							379						
	t	170							210							230						
	q	489							569							609						
OIL CONTENT [dm³]		210	230	250	270	290	310	330	210	230	250	270	290	310	330	210	230	250	270	290	310	330
DISPLACEMENT [dm³]		299	329	359	379	409	449	469	300	330	360	380	410	450	470	301	331	361	381	411	451	471
MAX. WEIGHT [kg]		377	383	395	399	405	412	416	382	388	400	404	410	417	421	384	390	402	406	412	419	423

	DATE	NAME	DOCUMENT NO.	
DFTR.	21.10.2016	BUTERUS	SED 5142887 001 00	
CHKD.	26.10.2016	WREDE	CHANGE NO.	SCALE
STAND.	26.10.2016	PRODASTSCHUK	1077332	-

DIMENSION IN mm EXCEPT AS NOTED	MR	ON-LOAD TAP-CHANGER VACUTAP® VR VR S/M/L/H I 651/701/1001/1301 - 72,5...420 kV - RC/RD/RDE DIMENSION DRAWING	SERIAL NUMBER: - MATERIAL NUMBER: 100178560E SHEET: 2/2

Figure 38b: Example of dimension drawing of on-load tap-changers type VACUTAP® VRS / VRM / VRL / VRH with single phase design , combined with tap selectors type RC / RD / RDE (page 2/2).

Appendix 2: Schematic test circuits and test equipment

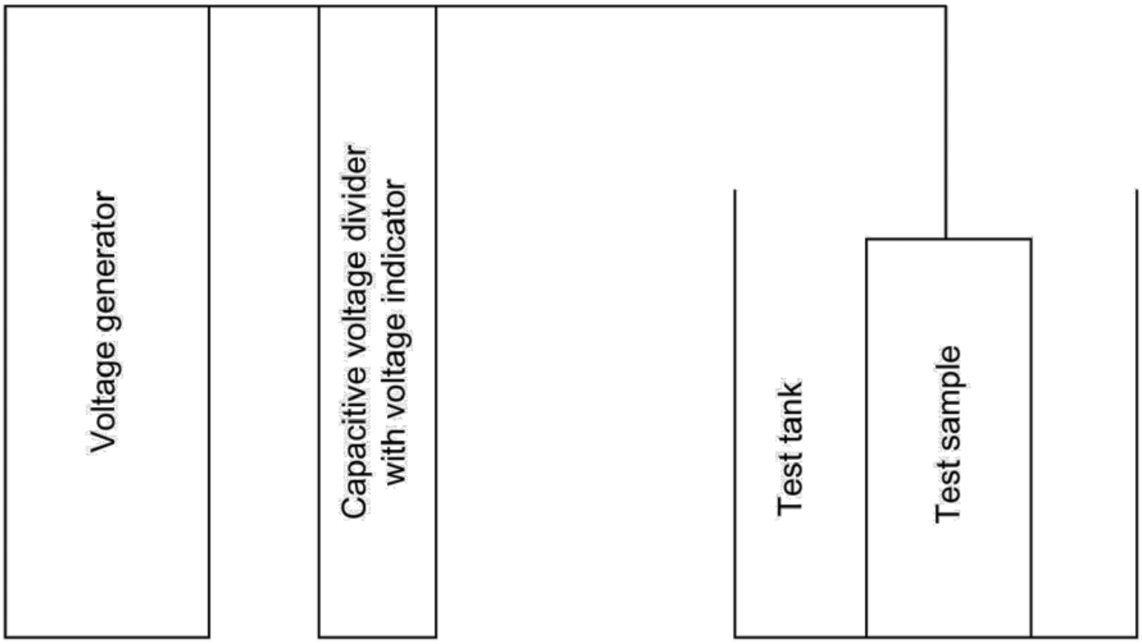


Figure 39: Schematic test circuit for lightning impulse tests (full / chopped wave), switching impulse test and applied voltage test.

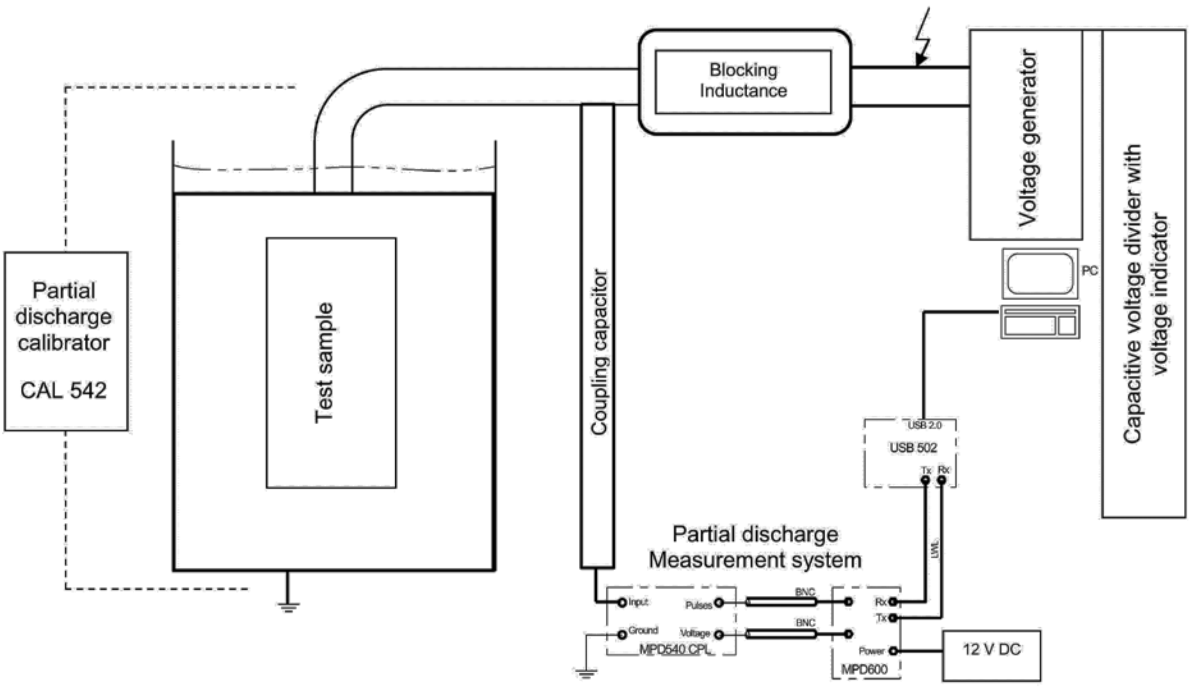
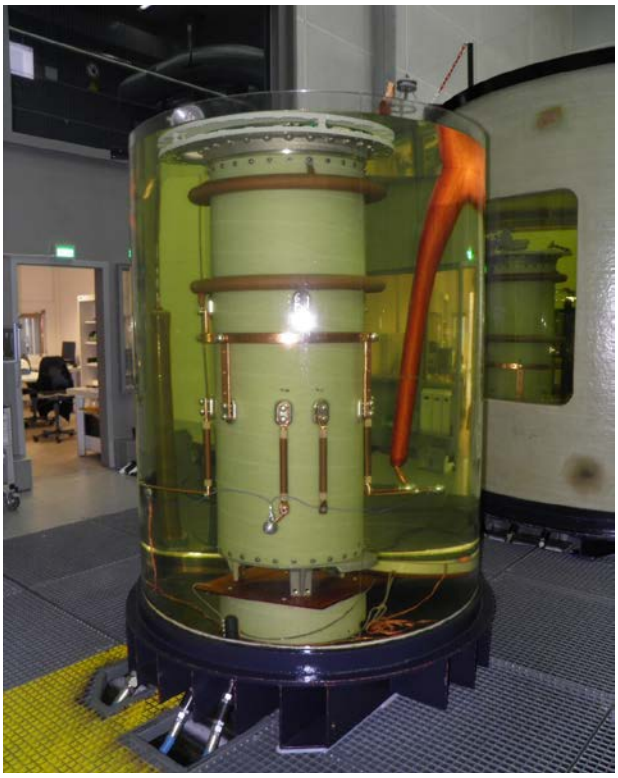


Figure 40: Schematic test circuit for partial discharge measurement.

Picture 1: Test equipment for applied voltage test.

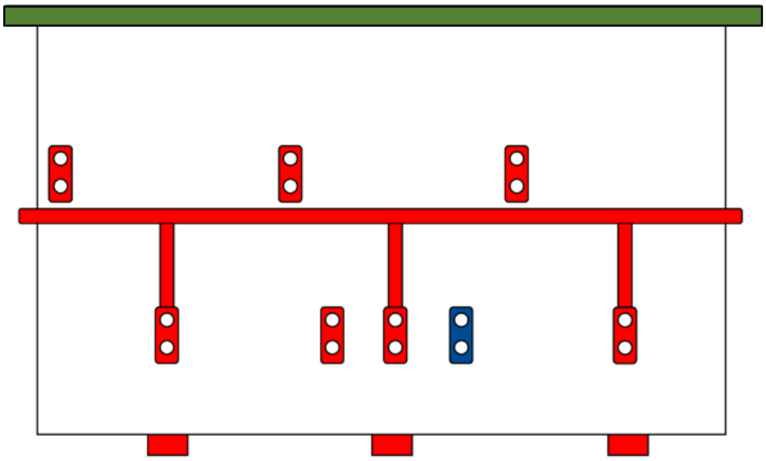
Picture 2: Test equipment for impulse voltage tests.

Picture 3: Test setup for insulation distance “f”.



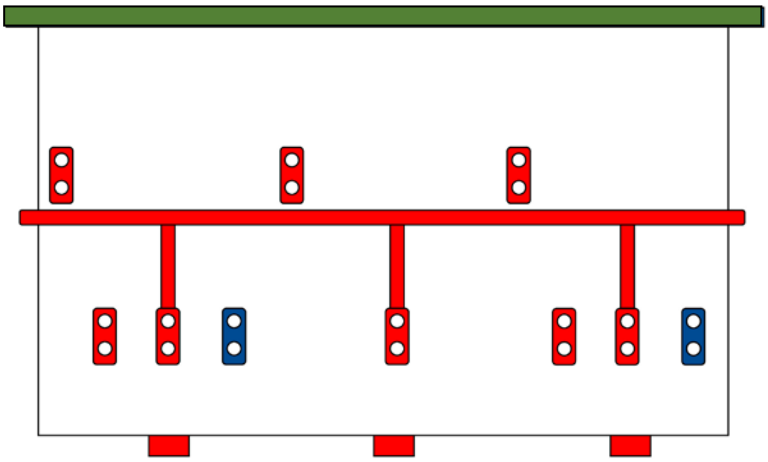
Picture 4: Test setup for insulation distance “a0”.

Appendix 3: Wirings and connections



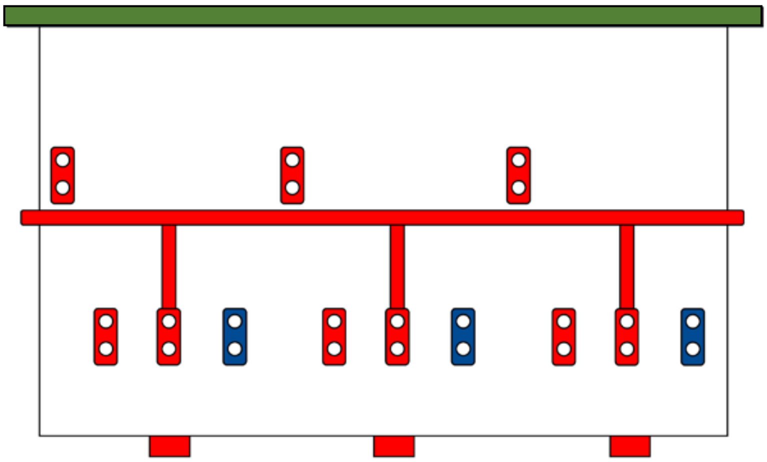
BLUE: Connection to ground
RED: Connected to test voltage
GREEN: No connection (floating)

Figure 41: Schematic sketch of connections for testing insulating distances “a0“ (single sector design).



BLUE: Connection to ground
RED: Connected to test voltage
GREEN: No connection (floating)

Figure 42: Schematic sketch of connections for testing insulating distances “a0“ (two sector design).



BLUE: Connection to ground
RED: Connected to test voltage
GREEN: No connection (floating)

Figure 43: Schematic sketch of connections for testing insulating distances “a0“ (three sector design).

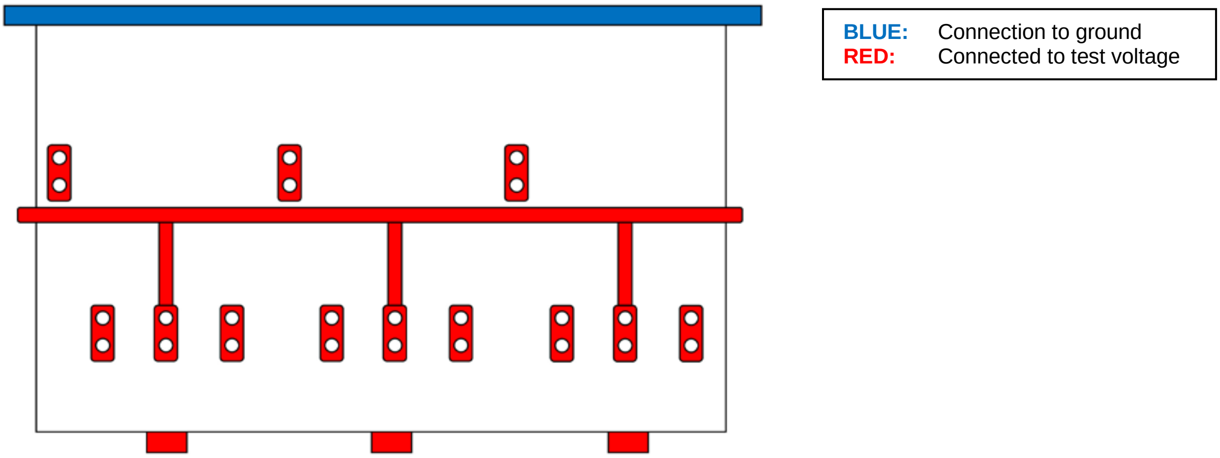


Figure 44: Schematic sketch of connections for testing insulating distances “f“ (U_m = 72.5 kV).

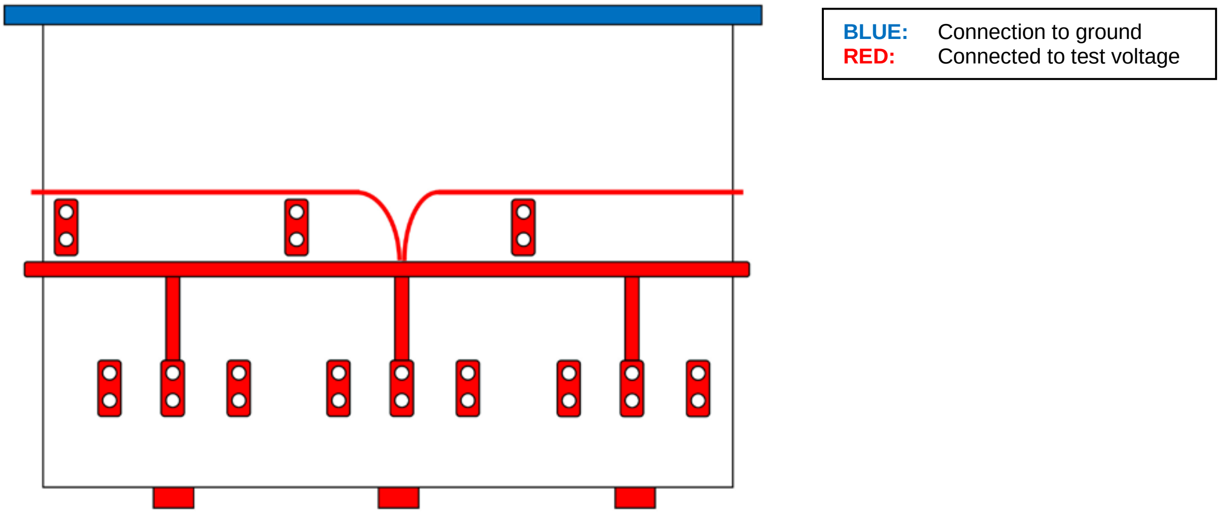


Figure 45: Schematic sketch of connections for testing insulating distances “f“ (U_m = 123 kV).

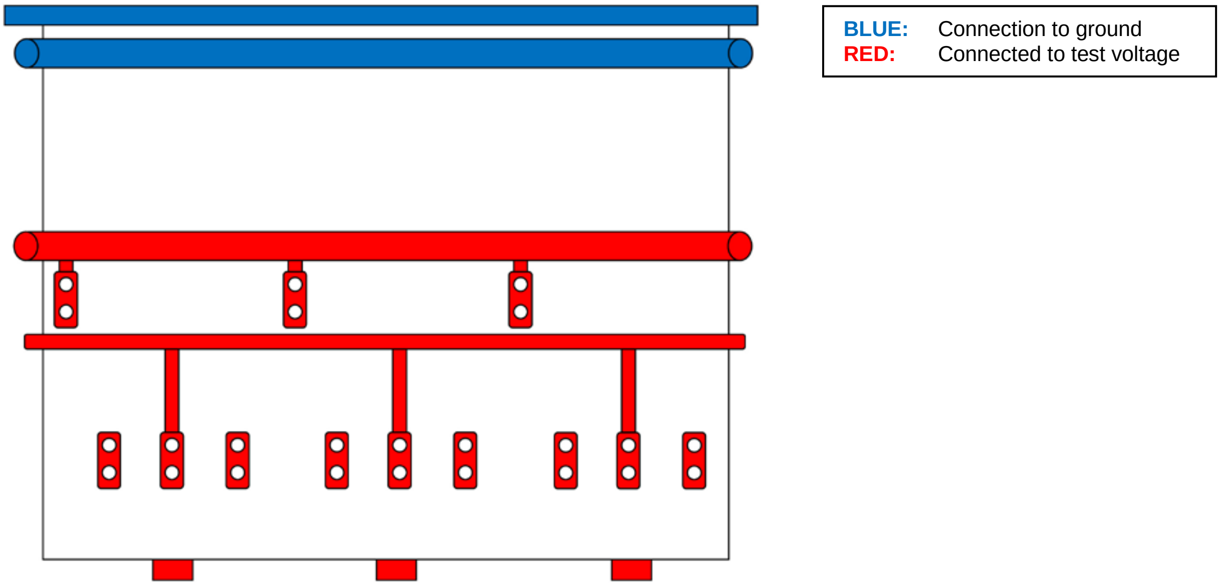


Figure 46: Schematic sketch of connections for testing insulating distances “f“ (U_m = 170…300 kV).