Maschinenfabrik Reinhausen GmbH
Testcenter
Falkensteinstraße 8
93059 Regensburg

Type test report

No. VI 6E 008e

Type test for types:	On-load tap-changers VACUTAP® VI with - three phase design - star-point (Y) application - number of contacts: 10, 12 or 14 - highest voltage for equipment: 123 kV - maximum rated through-current: 400 A - maximum rated step voltage: 1500 V - reversing, coarse or without change-over selector
Test standards:	IEC 60214-1:2014, sub-clause 5.2.8: “Dielectric tests” IEEE C57.131-2024, sub-clause 5.2.8 “Dielectric tests”
Classification:	Class I in compliance with IEC 60214-1:2014, sub clause 5.2.8.3 Cat. 1 in compliance with IEEE C57.131-2024, sub-clause 5.2.8.3
Test samples:	1: VACUTAP® VI III 400 Y – 123 – 14 27 1W/G 2: VACUTAP® VI III 400 D – 76 – 14 27 1W/G
Manufacturer:	Maschinenfabrik Reinhausen GmbH
Date of test:	February 2025 to March 2025
Tests performed:	
Full wave lightning impulse (LI) tests:	Impulse 1.2 / 50 µs. Three applications with positive and negative polarity each.
Chopped wave lightning impulse (LIC) tests:	Impulse 1.2 / 50 / 3 µs. Three applications with positive and negative polarity each.
Switching impulse (SI) test:	Impulse 250 / 2500 µs. Three applications with positive and negative polarity each.
Applied voltage test:	Single phase alternating voltage 50 Hz / 60 s.
Test results:	The requirements of IEC 60214-1:2014 sub-clause 5.2.8 “Dielectric tests” and IEEE C57.131-2024, sub-clause 5.2.8 “Dielectric tests” were met.

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i. V. Dr. Thomas Strof
[valid without signature]

Maschinenfabrik Reinhausen GmbH
- TAP-CHANGER TESTING -

Table of contents

1. General 3

2. Data of test samples 3

3. Test specification 3

4. Specification of insulation distances 3

5. Scope of application 6

6. Test setup 6

7. Tests performed 8

8. Test results 40

9. Appendix 41

10. List of amendments 42

1. General

Applicant:

Name of applicant:	Maschinenfabrik Reinhausen GmbH
Street:	Falkensteinstraße 8
Post-code – Location:	93059 – Regensburg, Germany

Place of test:

Name of laboratory:	Maschinenfabrik Reinhausen GmbH, Testcenter
Street:	Falkensteinstraße 8
Post-code – Location:	93059 – Regensburg, Germany

2. Data of test samples

Test sample 1

Type designation:	VACUTAP® VI III 400 Y – 123 – 14 27 1W/G
Type characteristics:	On-load tap-changer
Serial numbers:	2773200
IBASE:	1016777019
Year of manufacture:	2024
Manufacturer:	Maschinenfabrik Reinhausen GmbH

Test sample 2

Type designation:	VACUTAP® VI III 400 D – 40 – 14 27 1W/G
Type characteristics:	On-load tap-changer
Serial numbers:	2773198
IBASE:	1016777019
Year of manufacture:	2024
Manufacturer:	Maschinenfabrik Reinhausen GmbH

3. Test specification

Test standards: IEC 60214-1:2014, sub-clause 5.2.8: “Dielectric tests”
IEEE C57.131-2024, sub-clause 5.2.8 “Dielectric tests

4. Specification of insulation distances

Specification of the insulating distances of the tap selector and change-over selector and the corresponding voltage stress of the transformer windings:

Symbol	Definition of the insulation distances of the transformer windings
a1	Between fine tap selector contacts of the winding of one tap position (connected or not).
a	Between beginning and end of a tap winding and, for a coarse winding model, also between beginning and end of a coarse winding. Note for coarse tap selector connection in (-) position of the change-over selector: When stressed with impulse voltage, the permissible withstand voltage "a" between the end of a coarse winding connected with the K tap selector contact and the tap selector contact at the end of the tap winding of the same phase must be adhered to.
b	Between the tap selector contacts of different phases and between change-over selector contacts of different phases, which are connected with the beginning/end of a tapped winding or with a tap selector contact. The permissible voltages between the contacts for tap-changers for delta connections depend on the positions of the change-over selector and tap selector.

f	Between tap selector contacts and (+) change-over selector contacts to ground. Different values apply for the delta connection version: f1 = between take-off lead and ground and in (+) position of change-over selector between (+) change-over selector contacts and ground. f2 = between non-selected tap selector contacts and in (-) position of change-over selector between (+) contacts and ground.

Additionally, for coarse tap selector connection in (+) position of the change-over selector:

c1	From one (-) change-over selector contact to take-off lead of the same phase.
c2	Between (-) change-over selector contacts of different phases and from one (-) change-over selector contact to one (+) change-over selector contact of another phase.

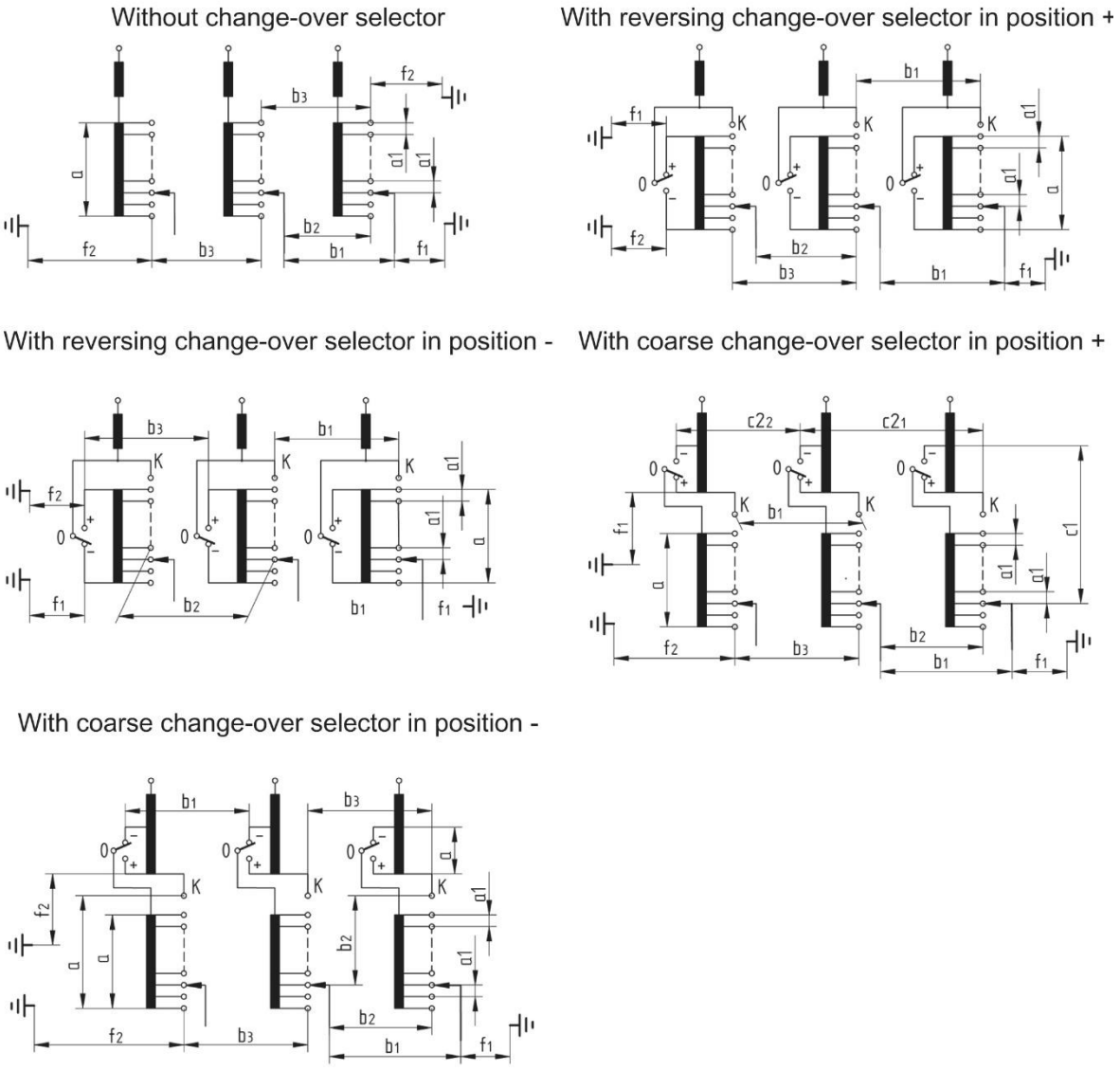


Figure 1: Insulating distances of the transformer windings.

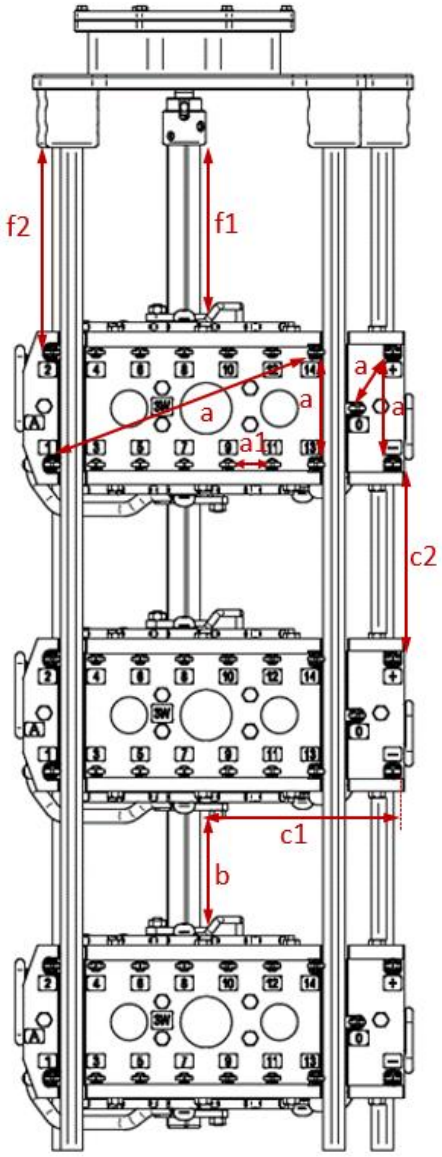


Figure 2: Insulating distances on the on-load tap changer.

Note: In case of several insulating distances of the same design all distances were tested, figure 2 shows only examples of these distances.

5. Scope of application

On-load tap-changers type VACUTAP® VI with star-point (Y) application and highest voltage for equipment Um = 123 kV are available with reversing change-over selector, coarse change-over selector or without change-over selector.

On-load tap-changers type VACUTAP® VI are designed with 14 tap selector contacts. Optionally, customers can reduce the number of tap selector contacts to 12 or 10 by using bridges. The bridges required for this are supplied by the manufacturer (Maschinenfabrik Reinhausen GmbH).
Without built-in bridges the dielectric stress of the insulating distances between neighboring fine tap selector contacts (insulation distance “a1”) is twice as high as with built-in bridges. Thus, the basic configuration with 14 contacts (without bridges) is considered as worst case and configurations with 10 or 12 tap selector contacts (with built-in bridges) are covered by the performed tests. Other insulation distances are not affected by mounted bridges between the tap selector contacts.

The design of insulating distances “a”, “a1” and “c1” does not depend on the highest voltage for equipment and the application of on-load tap-changer type VACUTAP® VI. Hence, these tests were exemplary carried out on type VACUTAP® VI III 400 D – 40 – 14 27 1W/G (test sample 2).
The design of insulating distances “f1”, “f2”, “b” and “c2” depends on the highest voltage for equipment resp. on the application of the on-load tap-changer. Hence, these insulating distances were tested on type VACUTAP® VI III 400 Y – 123 – 14 27 1W/G (sample 1).
Thus, all on-load tap-changers of type VACUTAP® VI with star-point (Y) application and Um = 123 kV are covered by the performed tests.

To cover VACUTAP® VI variants with reversing change-over selector and coarse change-over selector, the dielectric test was performed in two test sequences.
First, the test samples were configured and tested with reversing change-over selector. Thereafter, the change-over selectors of the test samples were configured as coarse change-over selector for further tests. The VACUTAP® VI variant without change-over selector was not tested explicit, because this variant is less critical and covered by the performed tests.

Therefore, this type test report is valid for on-load tap-changers of type VACUTAP® VI with following characteristics:

- Number of phases: 3
- Application: star-point (Y)
- Number of contacts: 10, 12 or 14
- Highest voltage for equipment: 123 kV
- Maximum rated through-current: 400 A
- Maximum rated step voltage: 1500 V
- Change-over selector: without change-over selector, coarse change-over selector or reversing change-over selector

6. Test setup

6.1 General

Test arrangements:	The dielectric tests were performed on permanently installed measuring chains for applied voltage tests and impulse voltage tests (see chapters 6.2 and 6.3).
Treatment of the test sample before testing:	Vacuum drying procedure.
Test tank oil filling:	Clean transformer oil according to IEC 60296 was filled in a Plexiglas test tank (volume 29,000 liters).
Breakdown strength of transformer oil:	69.8 – 83.4 kV / 2.5mm.

6.2 Test circuit for applied voltage test

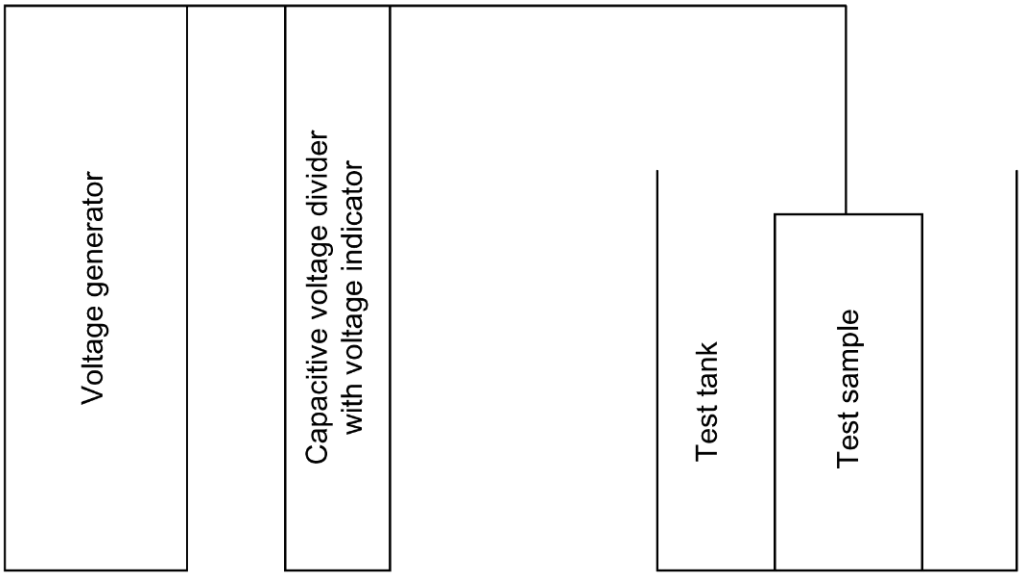


Figure 3: Test circuit for applied voltage test.

6.3 Test circuit for lightning impulse voltage tests (full / chopped wave) and switching impulse test

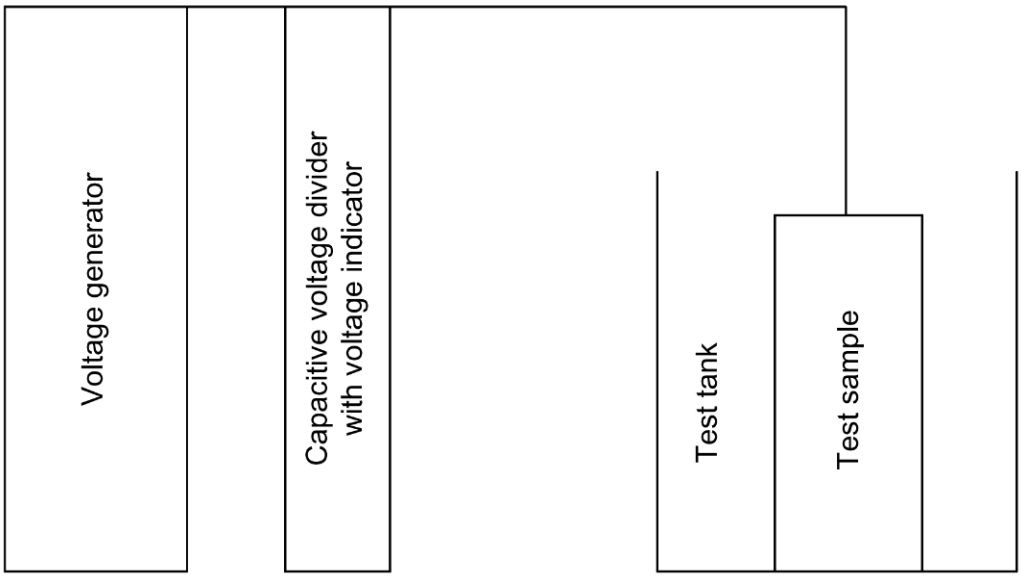


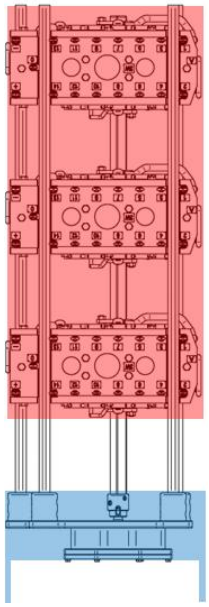
Figure 4: Test circuit for lightning impulse voltage tests (full / chopped wave) and switching impulse test.

7. Tests performed

7.1 Full wave lightning impulse test (LI)

Test standards:	IEC 60214-1:2014, sub-clause 5.2.8.5 IEEE C57.131-2024, sub-clause 5.2.8.5
Impulse voltage generator:	See chapter 6.3 (max. charging: 1800 kV)
Voltage waveform (T_1/T_2):	1.2 / 50 µs
Number of applications:	Three applications with positive and three with negative polarity

7.1.1 Insulating distance “f1”

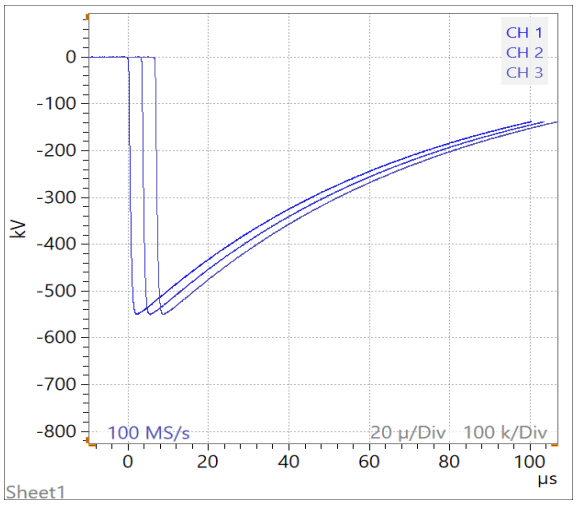


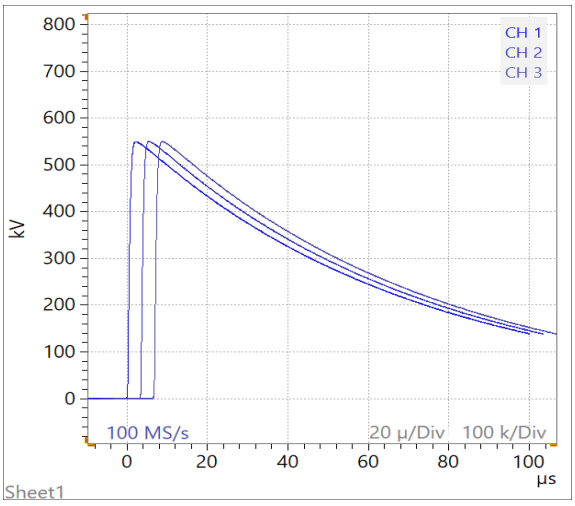
BLUE: Grounded
RED: 100% test voltage

Figure 5: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-550	-549.9	1.2	1.255	50	51.66	≤ 5	< 1
2		-550.1		1.254		51.65		< 1
3		-550.1		1.255		51.69		< 1
4	550	549.8		1.268		51.76		< 1
5		550.1		1.264		51.78		< 1
6		550.2		1.266		51.77		< 1

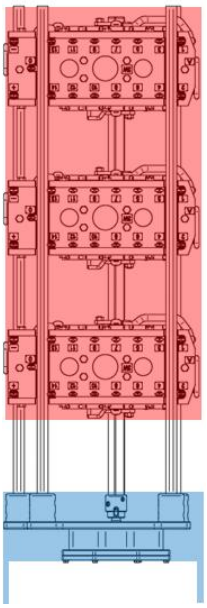
Table 1: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “f1”.





Figures 6a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “f1”.

7.1.2 Insulating distance “f2”

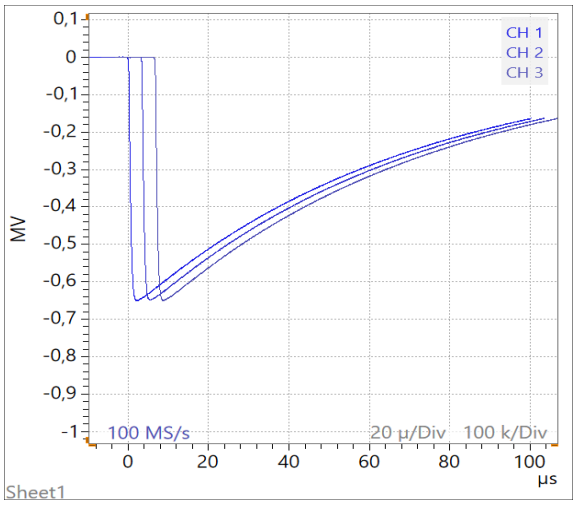


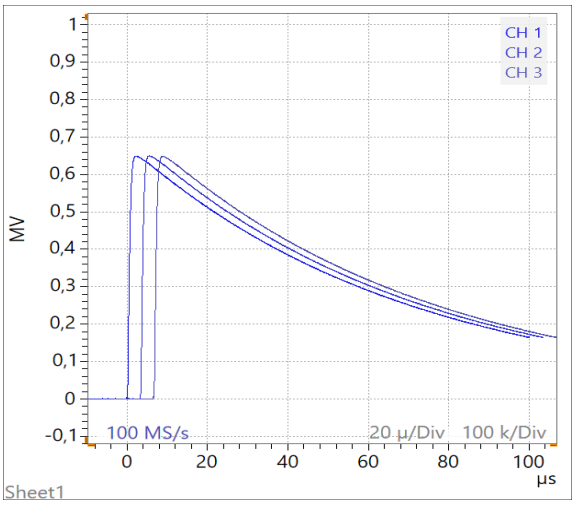
BLUE: Grounded
RED: 100% test voltage

Figure 7: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-650	-650.9	1.2	1.260	50	51.81	≤ 5	< 1
2		-649.0		1.259		51.83		< 1
3		-650.5		1.260		51.81		< 1
4	650	649.3		1.277		51.95		< 1
5		649.6		1.274		51.96		< 1
6		648.5		1.274		51.95		< 1

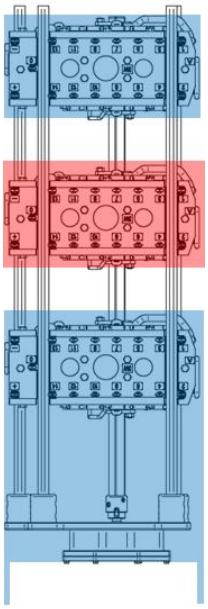
Table 2: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “f2”.





Figures 8a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “f2”.

7.1.3 Insulating distance “b”

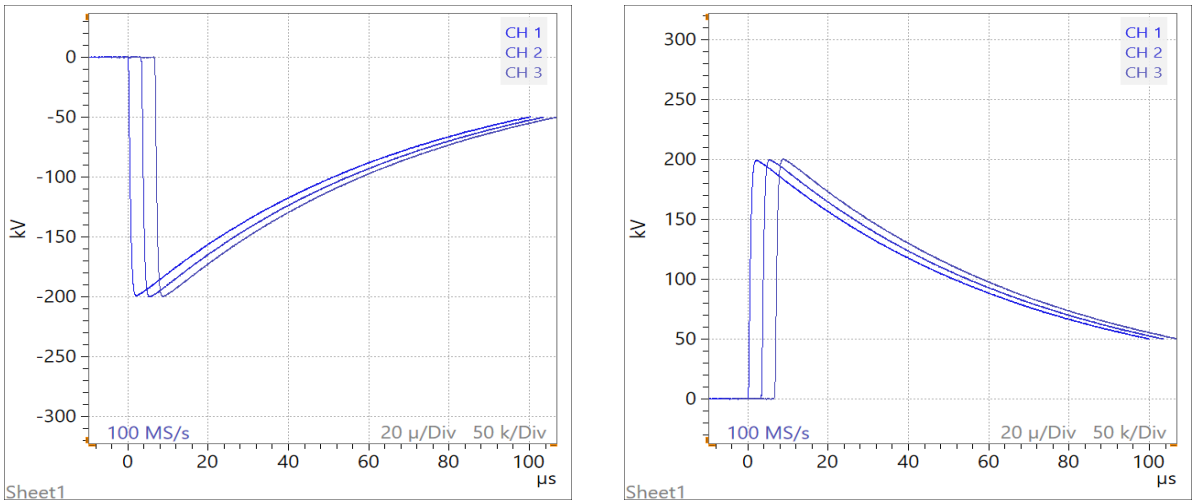


BLUE: Grounded
RED: 100% test voltage

Figure 9: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-200	-199.1	1.2	1.260	50	51.52	≤ 5	< 1
2		-200.1		1.260		51.58		< 1
3		-200.0		1.256		51.55		< 1
4	200	199.2		1.266		51.54		< 1
5		199.6		1.262		51.57		< 1
6		200.3		1.266		51.62		< 1

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



Figures 10a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “b”.

7.1.4 Insulating distance “a” (circuit 1)

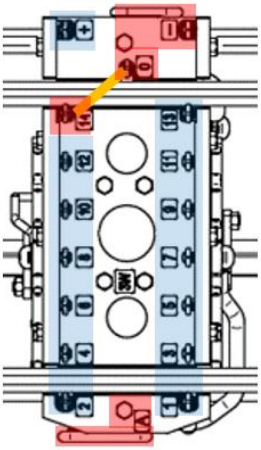
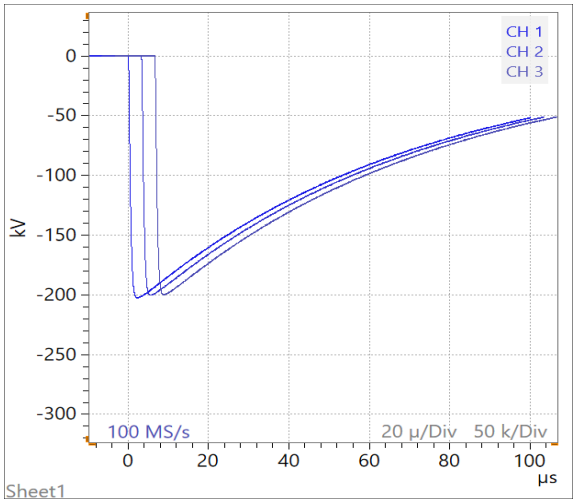
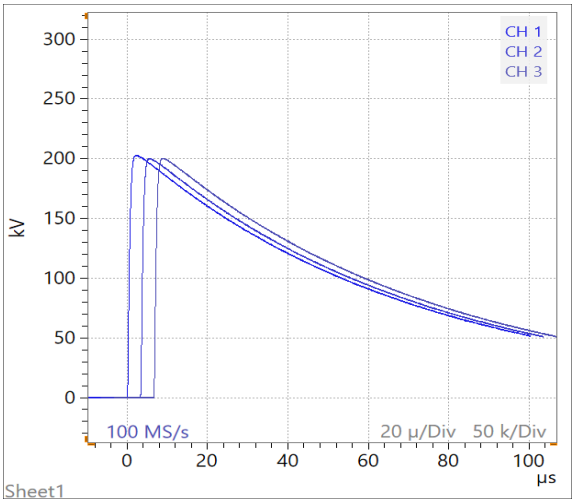


Figure 11: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-200	-202.6	1.2	1.286	50	52.32	≤ 5	< 1
2		-200.3		1.286		52.37		< 1
3		-199.9		1.284		52.33		< 1
4	200	202.8		1.290		52.29		< 1
5		200.2		1.287		52.31		< 1
6		200.3		1.290		52.32		< 1

Table 4: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “a”.





Figures 12a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “a”.

7.1.5 Insulating distance “a” (circuit 2)

BLUE: Grounded
RED: 100% test voltage

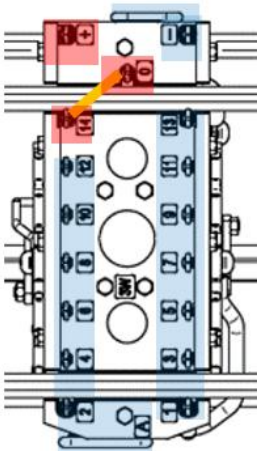
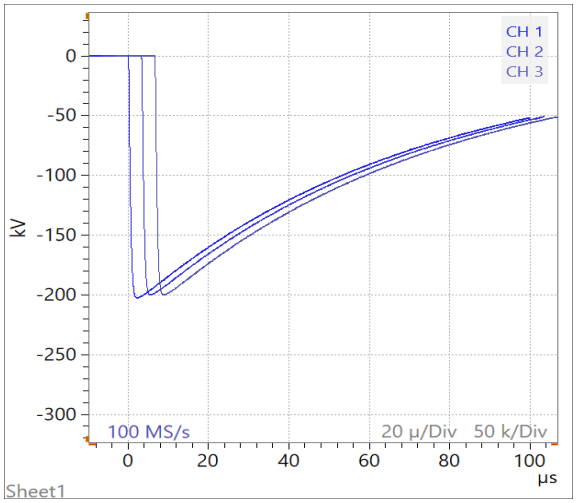
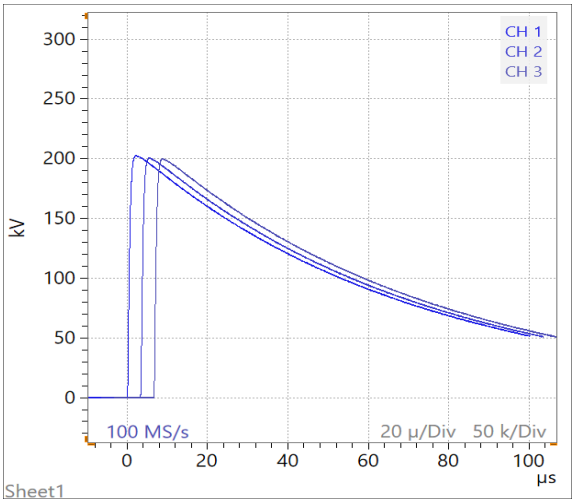


Figure 13: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß' in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-200	-202.6	1.2	1.271	50	52.29	≤ 5	< 1
2		-200.1		1.271		52.24		< 1
3		-200.2		1.270		52.30		< 1
4	200	202.5		1.273		52.25		< 1
5		200.5		1.272		52.23		< 1
6		199.9		1.273		52.25		< 1

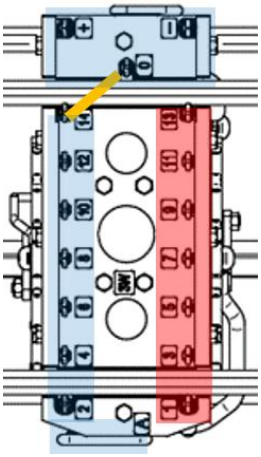
Table 5: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “a”.





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

7.1.6 Insulating distance “a1”

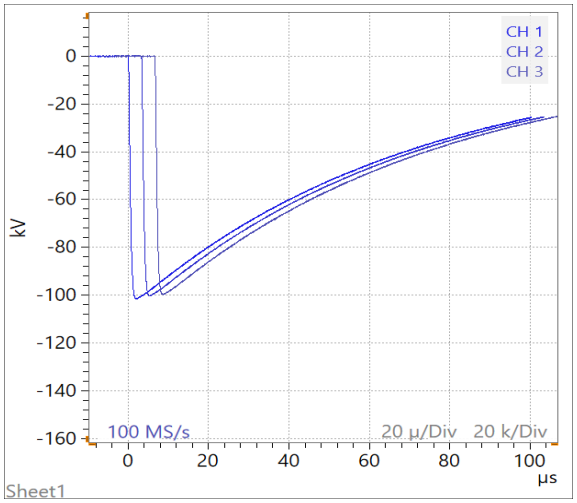


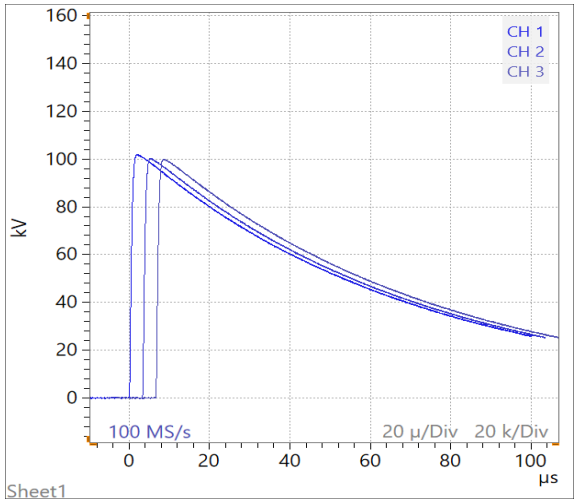
BLUE: Grounded
RED: 100% test voltage

Figure 15: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-100	-101.6	1.2	1.212	50	51.86	≤ 5	< 1
2		-100.3		1.214		51.82		< 1
3		-99.73		1.212		51.83		< 1
4	100	101.9		1.212		51.83		< 1
5		100.1		1.212		51.88		< 1
6		99.90		1.211		51.84		< 1

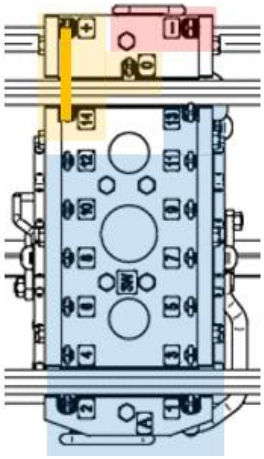
Table 6: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “a1”.





Figures 16a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “a1”.

7.1.7 Insulating distance “c1”

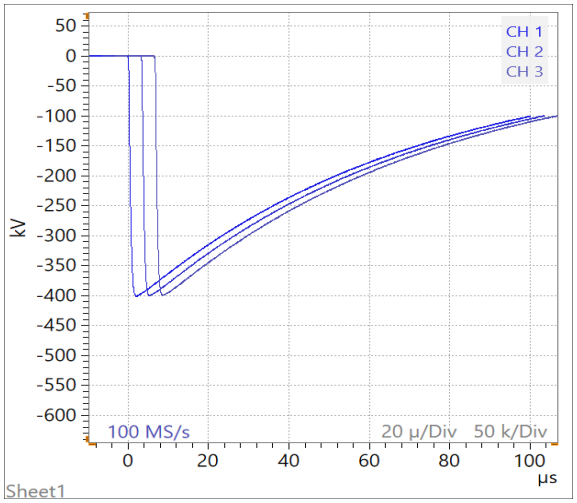


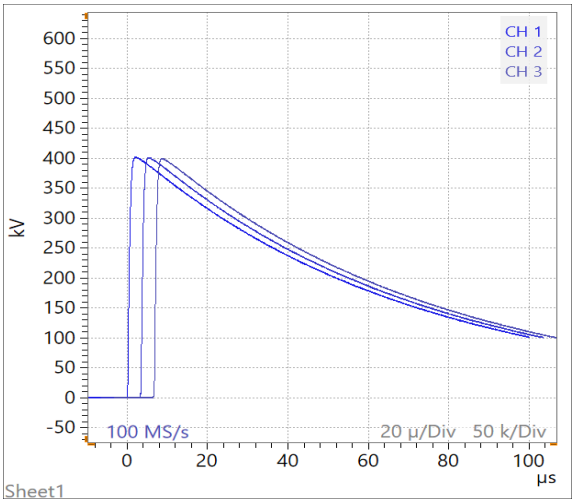
BLUE: Grounded
RED: 100% test voltage
YELLOW: 50% test voltage

Figure 17: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-400	-401.3	1.2	1.217	50	51.52	≤ 5	< 1
2		-400.3		1.218		51.49		< 1
3		-399.9		1.220		51.50		< 1
4	400	402.0		1.231		51.59		< 1
5		400.8		1.228		51.59		< 1
6		399.7		1.229		51.54		< 1

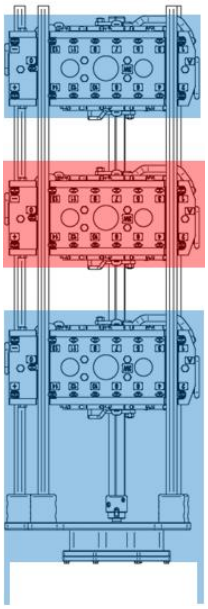
Table 7: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “c1”.





Figures 18a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “c1”.

7.1.8 Insulating distance “c2”

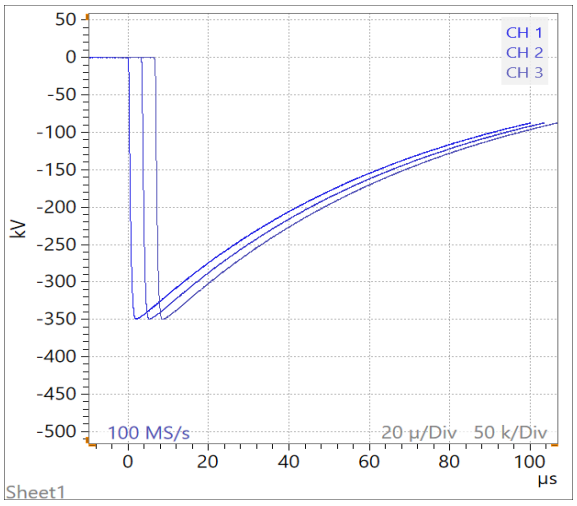


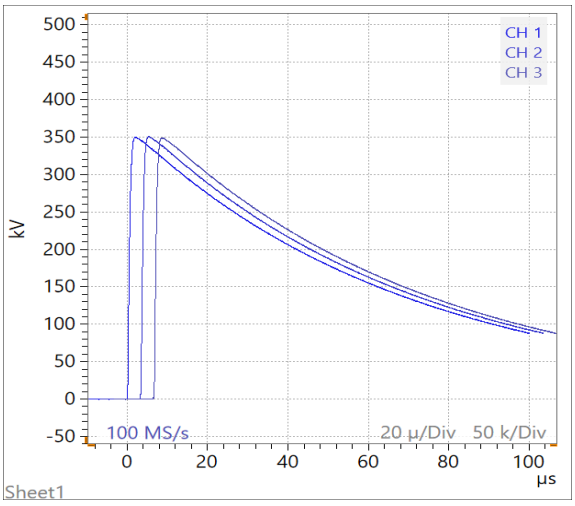
BLUE: Grounded
RED: 100% test voltage

Figure 19: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to half-value T_2 in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-350	-349.8	1.2	1.221	50	51.45	≤ 5	< 1
2		-349.9		1.221		51.46		< 1
3		-350.2		1.219		51.45		< 1
4	350	349.8		1.233		51.55		< 1
5		350.6		1.232		51.51		< 1
6		349.2		1.235		51.54		< 1

Table 8: Test results of full wave lightning impulse test (1.2/50 µs) on insulating distance “c2”.





Figures 20a-b: Oscillograms of full wave lightning impulse test (1.2/50 µs) on insulating distance “c2”.

7.2 Chopped wave lightning impulse test (LIC)

Test standards:	IEC 60214-1:2014, sub-clause 5.2.8.6 IEEE C37-151-2024, sub-clause 5.2.8.6
Impulse voltage generator:	See chapter 6.3 (max. charging: 1800 kV)
Voltage waveform ($T_1/T_2/T_c$):	1.2 / 50 / 3 µs
Number of applications:	Three applications with positive and three with negative polarity

7.2.1 Insulating distance “f1”

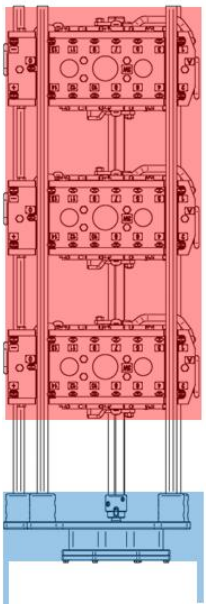
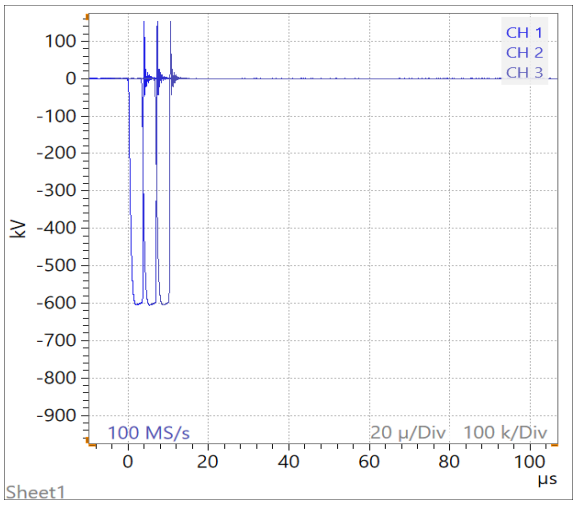
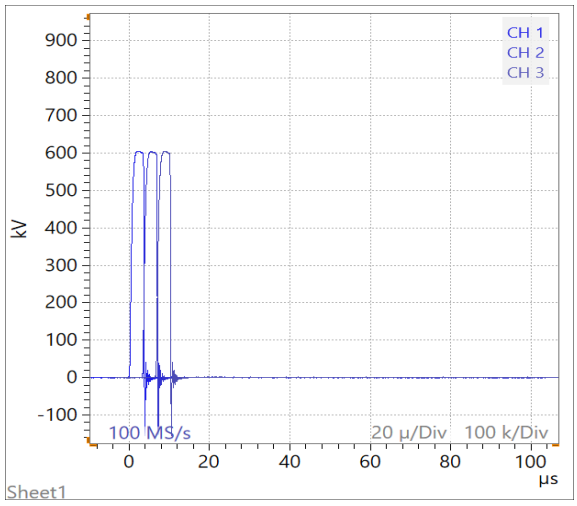


Figure 21: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-605	-605.1	1.2	1.262	3	3.700	≤ 5	< 1
2		-605.3		1.266		3.679		< 1
3		-605.2		1.263		3.692		< 1
4	605	604.7		1.282		3.665		< 1
5		603.8		1.279		3.638		< 1
6		604.9		1.283		3.656		< 1

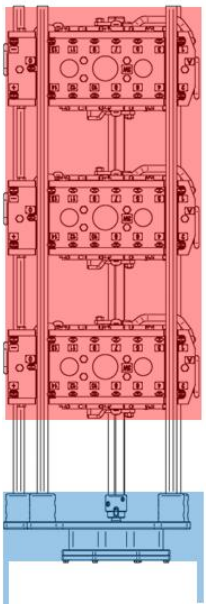
Table 9: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “f1”.





Figures 22a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “f1”.

7.2.2 Insulating distance “f2”

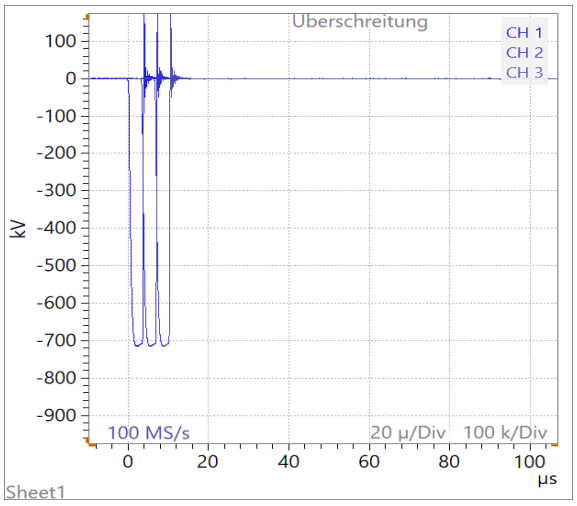


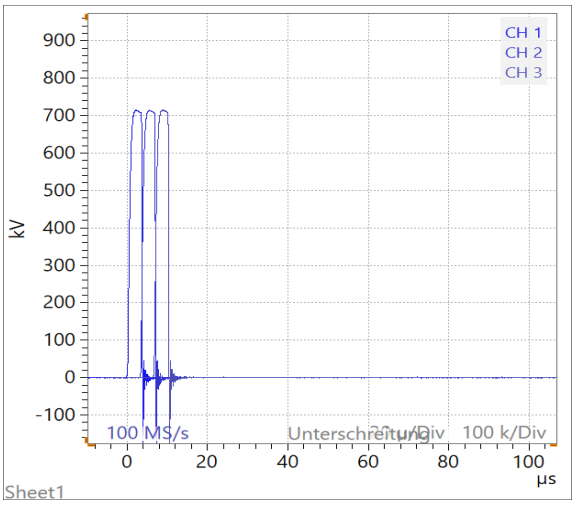
BLUE: Grounded
RED: 100% test voltage

Figure 23: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-715	-715.4	1.2	1.264	3	3.703	≤ 5	< 1
2		-714.9		1.268		3.715		< 1
3		-715.2		1.263		3.708		< 1
4	715	714.2		1.286		3.682		< 1
5		714.2		1.280		3.675		< 1
6		714.8		1.279		3.695		< 1

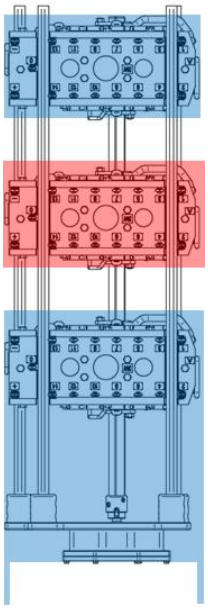
Table 10: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “f2”.





Figures 24a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “f2”.

7.2.3 Insulating distance “b”

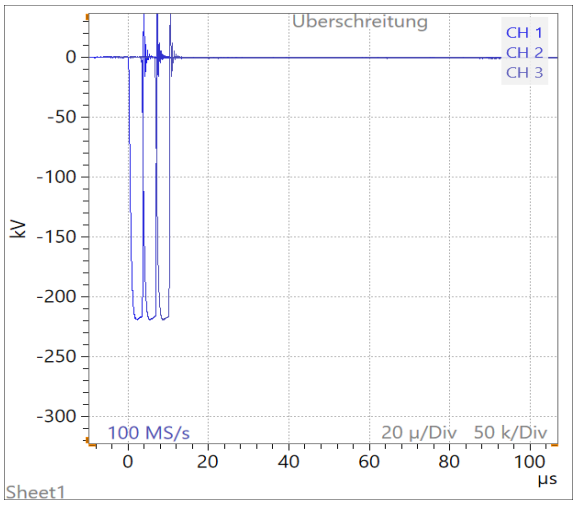


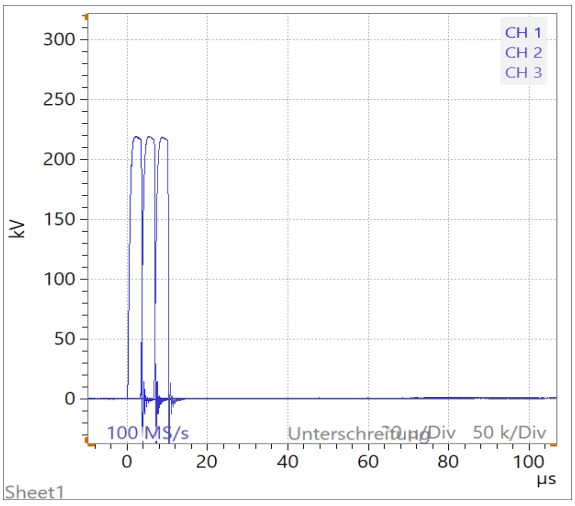
BLUE: Grounded
RED: 100% test voltage

Figure 25: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-220	-219.0	1.2	1.266	3	3.643	≤ 5	< 1
2		-219.0		1.260		3.644		< 1
3		-219.0		1.263		3.647		< 1
4	220	219.1		1.262		3.619		< 1
5		219.1		1.257		3.597		< 1
6		218.4		1.265		3.599		< 1

Table 11: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “b”.





Figures 26a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “b”.

7.2.4 Insulating distance “a” (circuit 1)

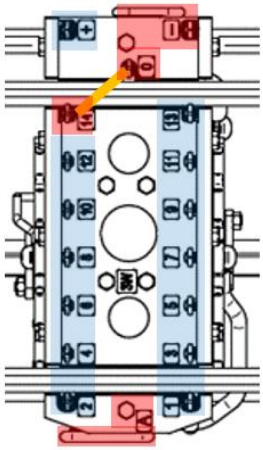
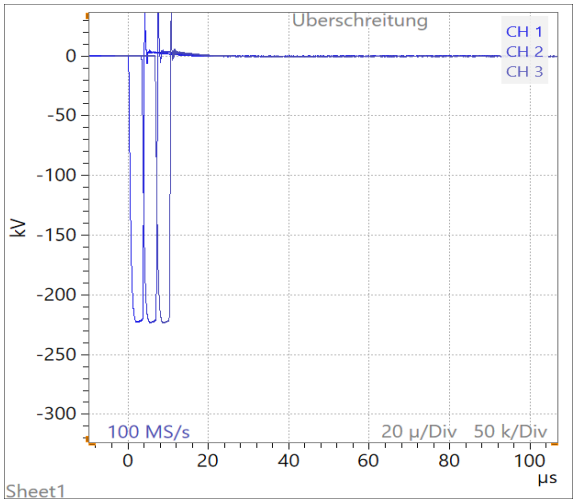
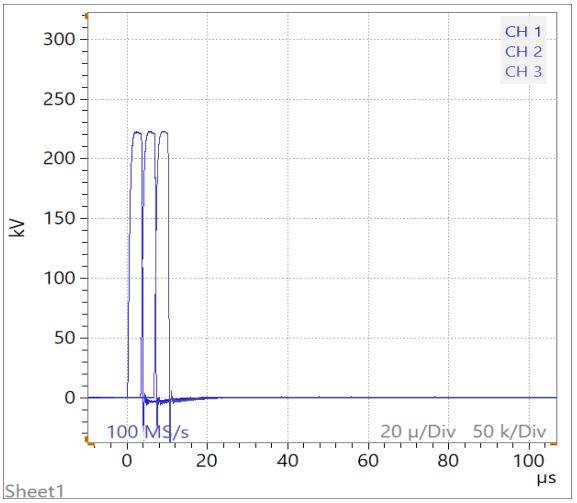


Figure 27: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-220	-222.9	1.2	1.294	3	3.769	≤ 5	< 1
2		-223.3		1.296		3.802		< 1
3		-223.4		1.289		3.782		< 1
4	220	222.5		1.293		3.751		< 1
5		222.8		1.286		3.752		< 1
6		223.0		1.289		3.717		< 1

Table 12: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a”.





Figures 28a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a”.

7.2.5 Insulating distance “a” (circuit 2)

BLUE: Grounded
RED: 100% test voltage

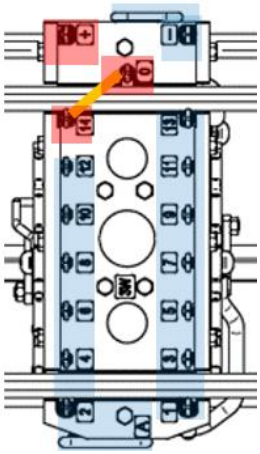
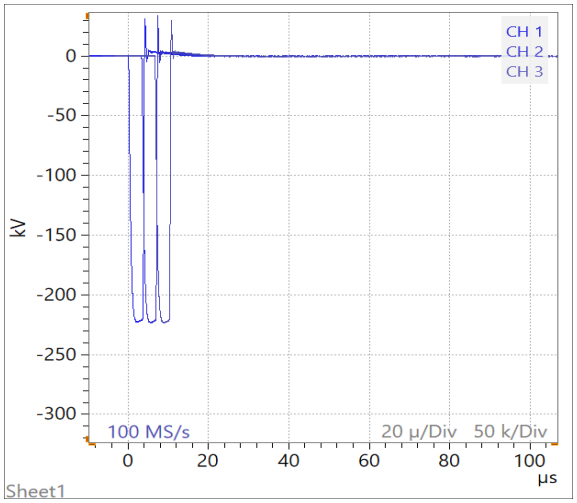
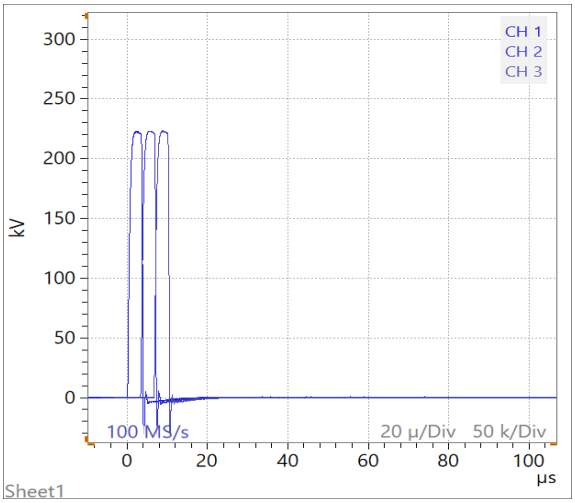


Figure 29: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-220	-222.8	1.2	1.278	3	3.799	≤ 5	< 1
2		-223.3		1.277		3.780		< 1
3		-223.4		1.276		3.787		< 1
4	220	222.6		1.276		3.720		< 1
5		223.1		1.273		3.718		< 1
6		223.1		1.277		3.748		< 1

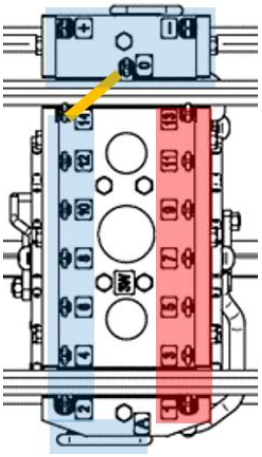
Table 13: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a”.





Figures 30a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a”.

7.2.6 Insulating distance “a1”

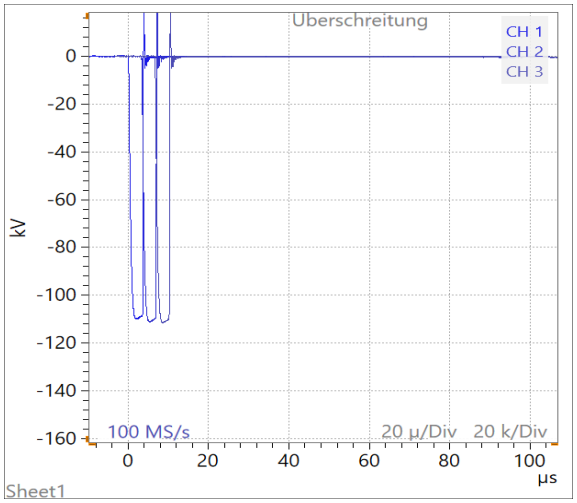


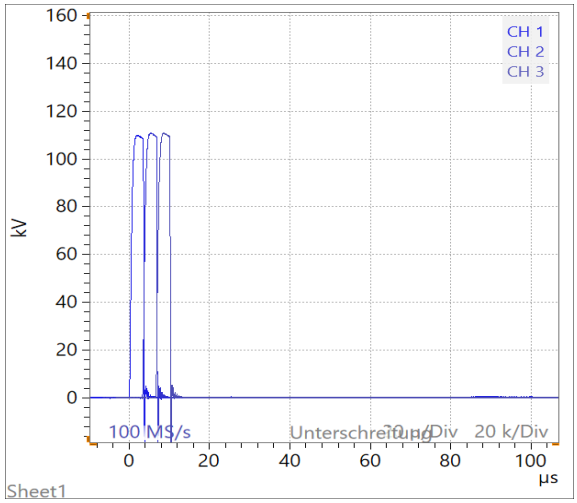
BLUE: Grounded
RED: 100% test voltage

Figure 31: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-110	-110.0	1.2	1.219	3	3.664	≤ 5	< 1
2		-111.1		1.219		3.653		< 1
3		-111.5		1.222		3.654		< 1
4	110	109.9		1.213		3.594		< 1
5		110.8		1.220		3.594		< 1
6		110.7		1.219		3.578		< 1

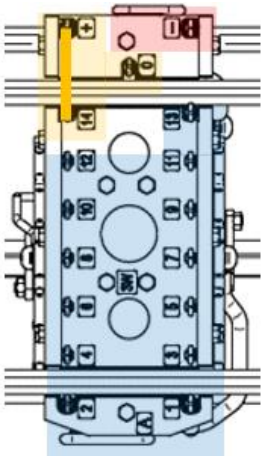
Table 14: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a1”.





Figures 32a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “a1”.

7.2.7 Insulating distance “c1”

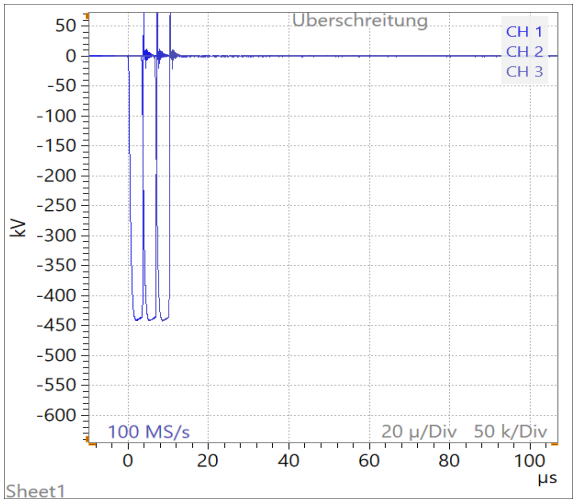


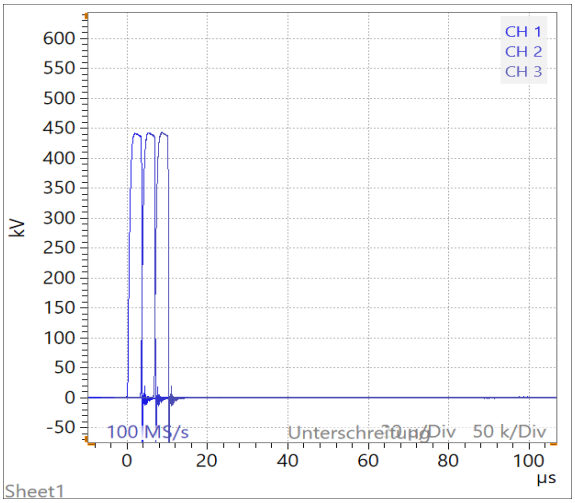
BLUE: Grounded
RED: 100% test voltage
YELLOW: 50% test voltage

Figure 33: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-440	-441.5	1.2	1.229	3	3.665	≤ 5	< 1
2		-442.0		1.229		3.653		< 1
3		-442.2		1.226		3.666		< 1
4	440	441.4		1.232		3.626		< 1
5		442.4		1.235		3.620		< 1
6		442.5		1.231		3.639		< 1

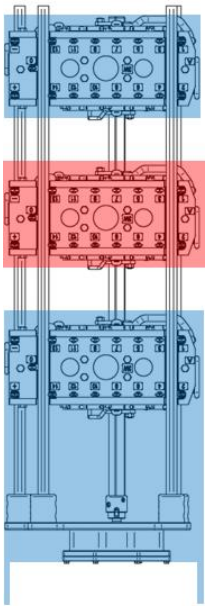
Table 15: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “c1”.





Figures 34a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “c1”.

7.2.8 Insulating distance “c2”

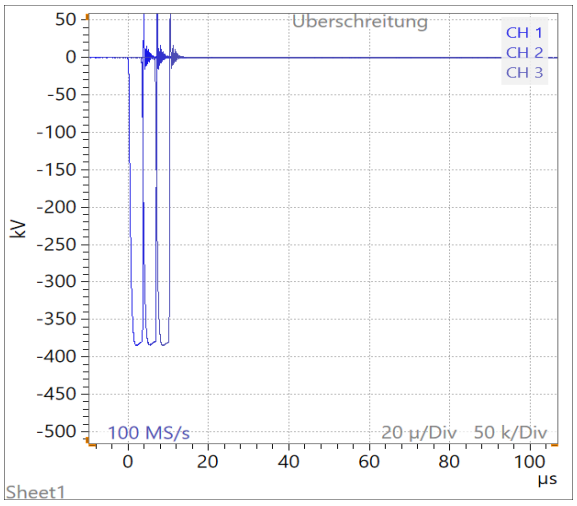


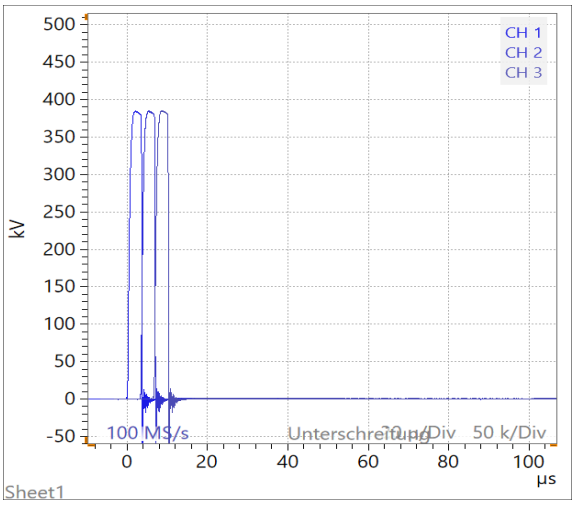
BLUE: Grounded
RED: 100% test voltage

Figure 35: Wirings and connections on the test sample.

Test no.	Peak amplitude U_p in kV		Front time T_1 in µs		Time to chopping T_C in µs		Overshoot ß’ in %	
	Nominal	Tested	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-385	-384.6	1.2	3.659	3	3.659	≤ 5	< 1
2		-384.3		3.659		3.659		< 1
3		-385.1		3.658		3.658		< 1
4	385	384.6		3.612		3.612		< 1
5		384.7		3.608		3.608		< 1
6		385.2		3.603		3.603		< 1

Table 16: Test results of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “c2”.



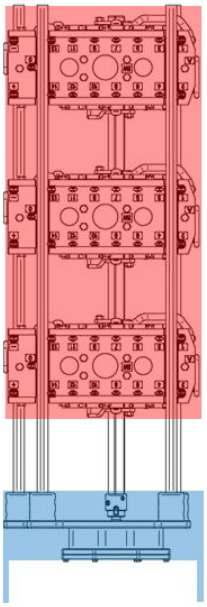


Figures 36a-b: Oscillograms of chopped wave lightning impulse test (1.2/50/3 µs) on insulating distance “c2”.

7.3 Switching impulse test (SI)

Test standard:	IEC 60214-1:2014, sub-clause 5.2.8.7 IEEE C37-151-2024, sub-clause 5.2.8.7
Impulse voltage generator:	See chapter 6.3 (max. charging: 1800 kV)
Voltage waveform (T_P/T_2):	250 / 2500 µs
Number of applications:	Three applications with positive and three with negative polarity

7.3.1 Insulating distance “f1”

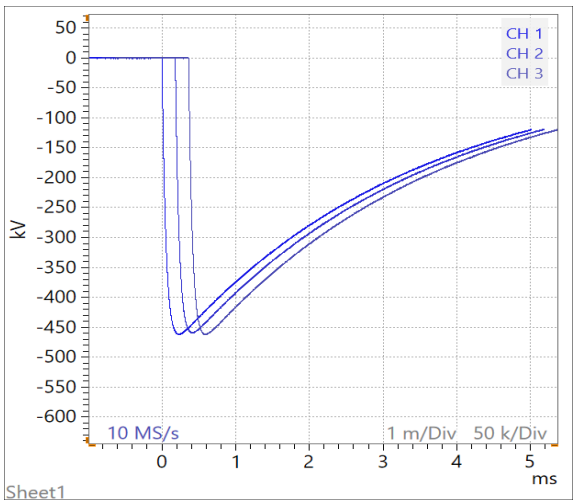


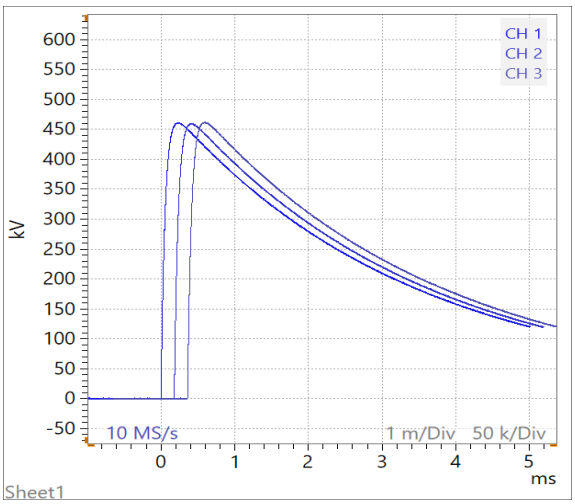
BLUE: Grounded
RED: 100% test voltage

Figure 37: Wirings and connections on the test sample.

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
1	-460	-461.4	250	226.6	2500	2669
2		-458.9		226.6		2669
3		-461.6		226.7		2669
4	460	460.4		228.6		2670
5		459.0		228.4		2669
6		461.3		228.6		2670

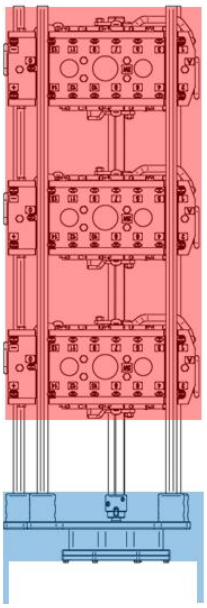
Table 17: Test results of switching impulse test (250/2500 µs) on insulating distance “f1”.





Figures 38a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “f1”.

7.3.2 Insulating distance “f2”

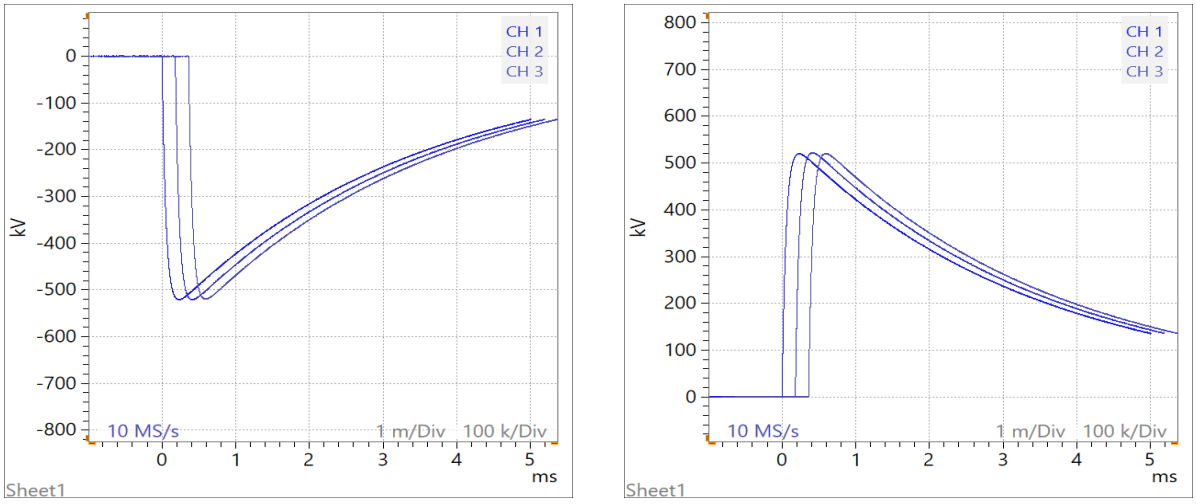


BLUE: Grounded
RED: 100% test voltage

Figure 39: Wirings and connections on the test sample.

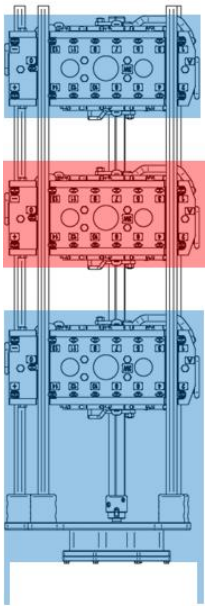
Test no.	Peak amplitude U_p in kV		Time to peak T_P in µs		Time to half-value T_2 in µs	
	Nominal	Tested	Nominal	Tested	Nominal	Tested
1	-520	-520.6	250	226.6	2500	2670
2		-520.6		226.6		2672
3		-519.3		226.5		2672
4	520	519.4		228.9		2674
5		521.5		229.0		2674
6		519.8		228.9		2675

Table 18: Test results of switching impulse test (250/2500 µs) on insulating distance “f2”.



Figures 40a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “f2”.

7.3.3 Insulating distance “b”

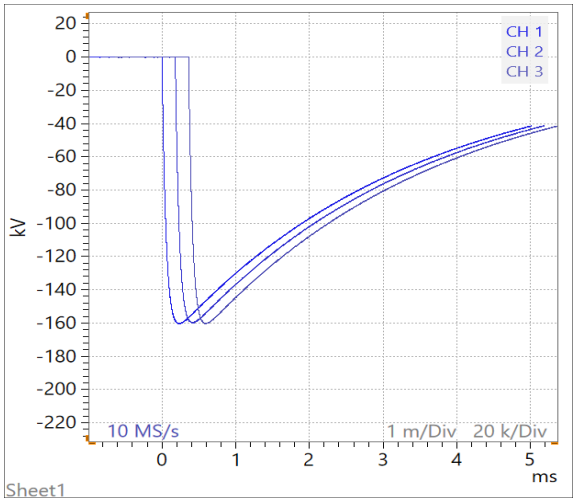


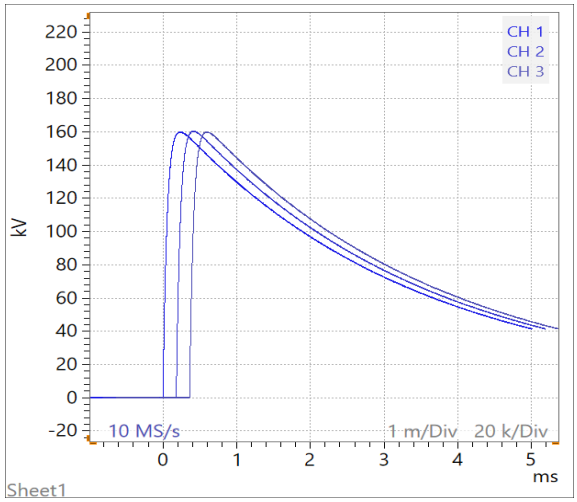
BLUE: Grounded
RED: 100% test voltage

Figure 41: Wirings and connections on the test sample.

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
1	-160	-160.2	250	230.5	2500	2667
2		-159.7		230.7		2663
3		-160.2		230.6		2664
4	160	159.8		230.6		2665
5		160.2		230.6		2666
6		159.8		230.8		2664

Table 19: Test results of switching impulse test (250/2500 µs) on insulating distance “b”.





Figures 42a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “b”.

7.3.4 Insulating distance “a” (circuit 1)

BLUE: Connected contacts
RED: 100% test voltage

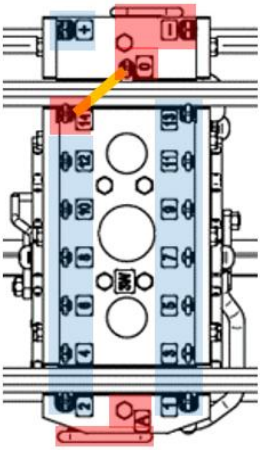
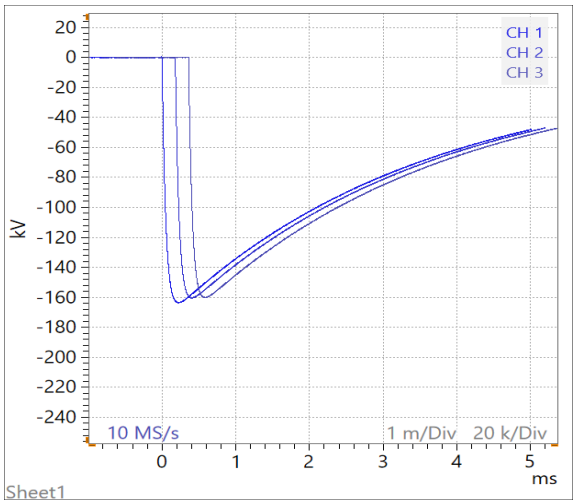
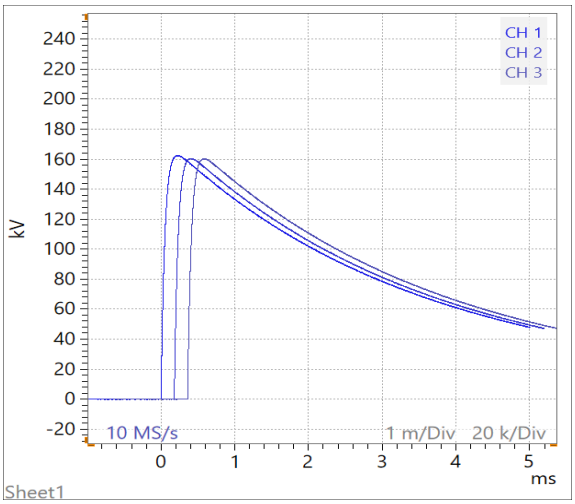


Figure 43: Wirings and connections on the test sample.

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
1	-160	-163.4	250	220.8	2500	2873
2		-160.3		221.0		2874
3		-160.1		221.1		2873
4	160	162.1		221.2		2873
5		160.2		221.0		2872
6		160.1		221.2		2871

Table 20: Test results of switching impulse test (250/2500 µs) on insulating distance “a”.





Figures 44a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “a”.

7.3.5 Insulating distance “a” (circuit 2)

BLUE: Grounded
RED: 100% test voltage

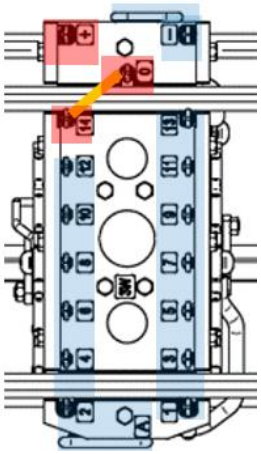
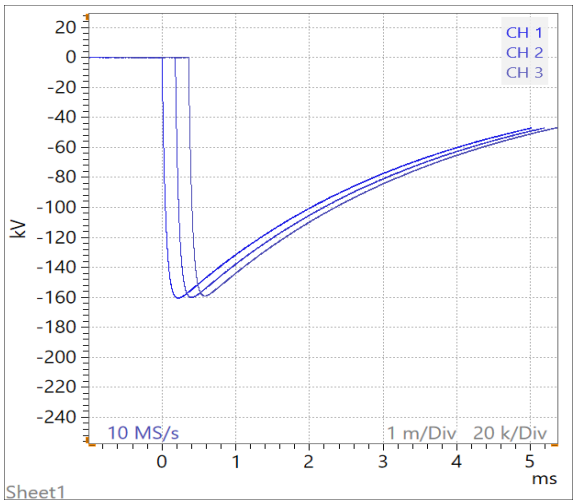
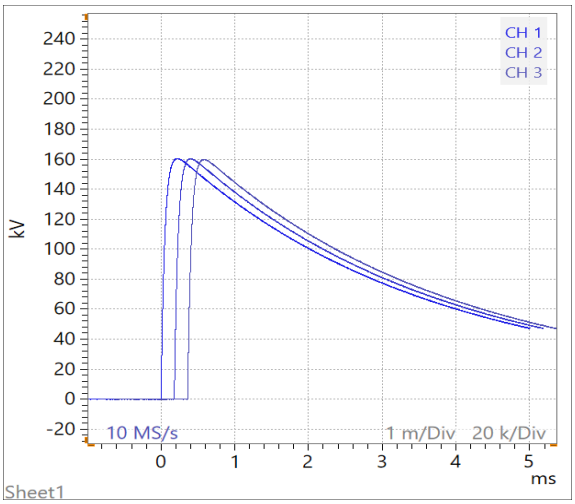


Figure 45: Wirings and connections on the test sample.

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
1	-160	-160.4	250	217.0	2500	2867
2		-160.0		217.3		2866
3		-159.1		217.0		2867
4	160	160.2		217.1		2866
5		160.1		217.3		2865
6		159.6		217.2		2866

Table 21: Test results of switching impulse test (250/2500 µs) on insulating distance “a”.





Figures 46a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “a”.

7.3.6 Insulating distance “a1”

BLUE: Connected contacts
RED: 100% test voltage

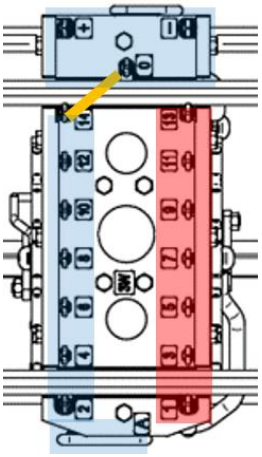
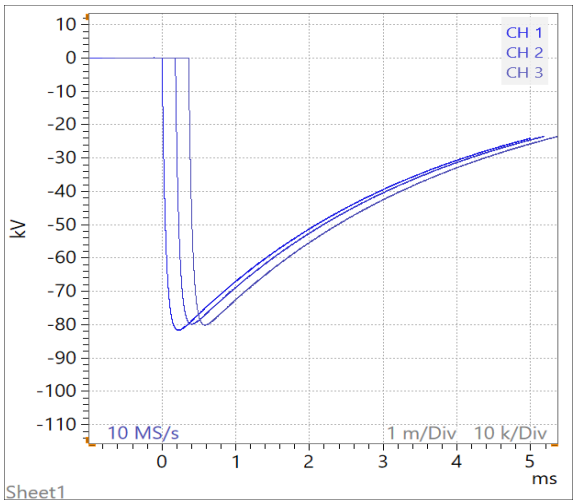
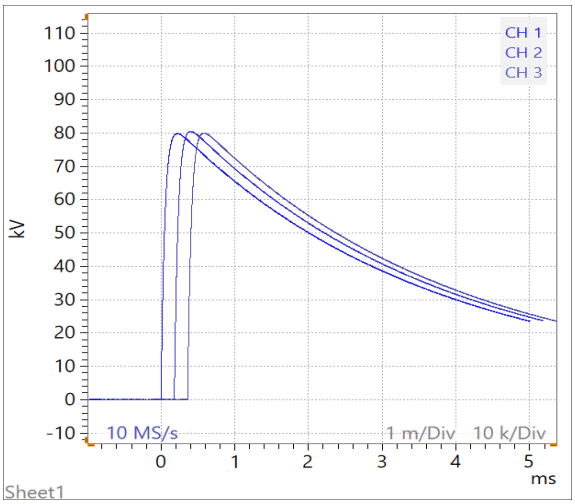


Figure 47: Wirings and connections on the test sample.

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
1	-80	-81.62	250	218.8	2500	2870
2		-79.77		218.8		2871
3		-80.07		218.6		2872
4	80	79.77		218.6		2873
5		80.41		219.4		2871
6		79.96		219.6		2870

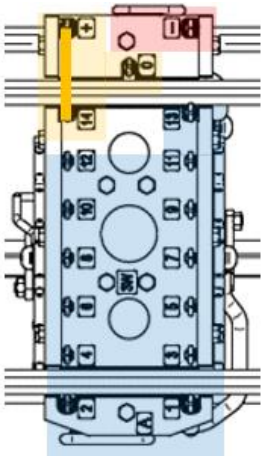
Table 22: Test results of switching impulse test (250/2500 µs) on insulating distance “a1”.





Figures 48a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “a1”.

7.3.7 Insulating distance “c1”

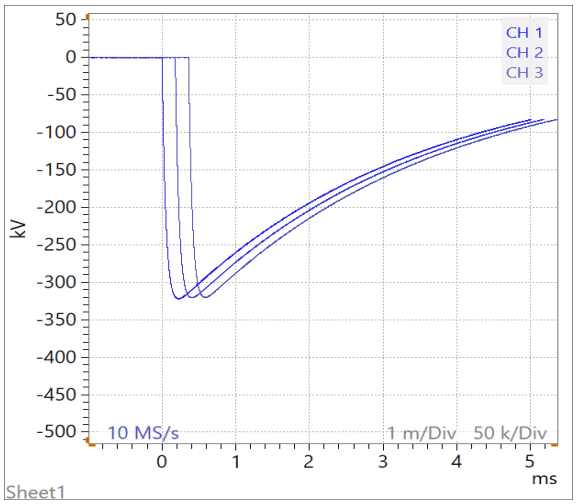


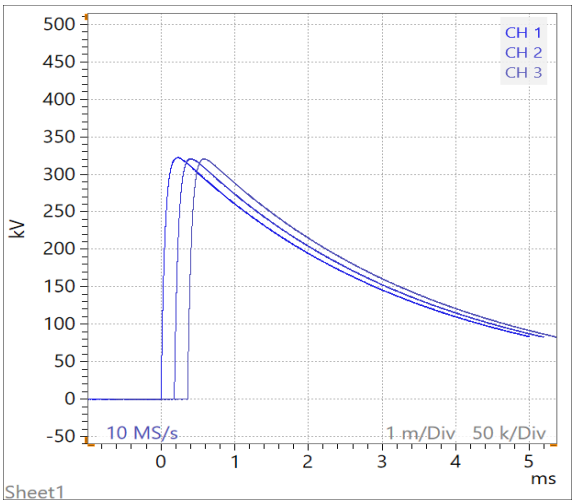
BLUE: Grounded
RED: 100% test voltage
YELLOW: 50% test voltage

Figure 49: Wirings and connections on the test sample.

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
1	-320	-321.8	250	220.0	2500	2652
2		-320.4		220.0		2652
3		-320.1		219.8		2652
4	320	321.9		221.1		2652
5		320.4		220.8		2653
6		320.2		221.3		2652

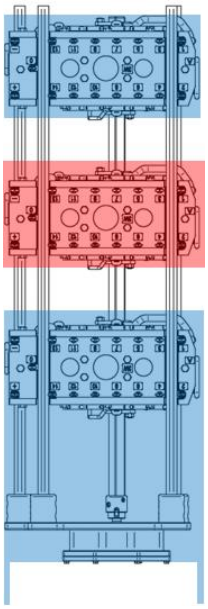
Table 23: Test results of switching impulse test (250/2500 µs) on insulating distance “c1”.





Figures 50a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “c1”.

7.3.8 Insulating distance “c2”

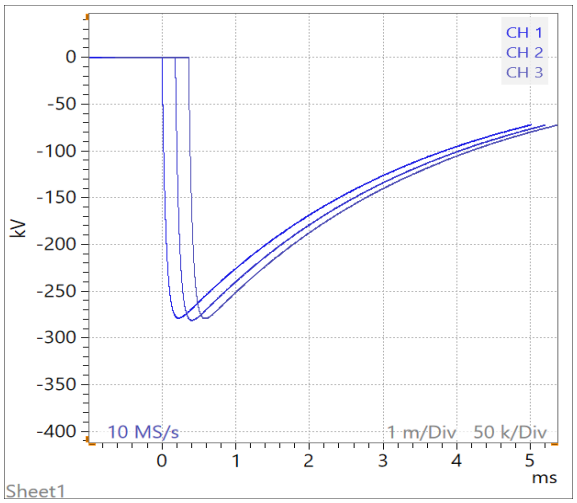


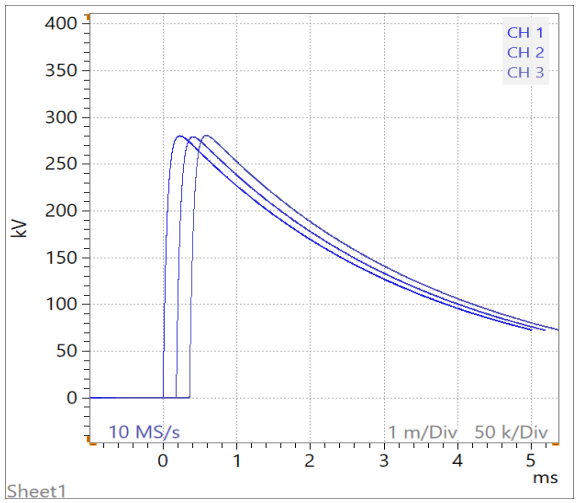
BLUE: Grounded
RED: 100% test voltage

Figure 51: Wirings and connections on the test sample.

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
1	-280	-278.9	250	222.5	2500	2658
2		-281.0		222.3		2660
3		-279.3		222.6		2658
4	280	280.1		223.2		2660
5		279.2		223.0		2659
6		280.6		223.5		2658

Table 24: Test results of switching impulse test (250/2500 µs) on insulating distance “c2”.



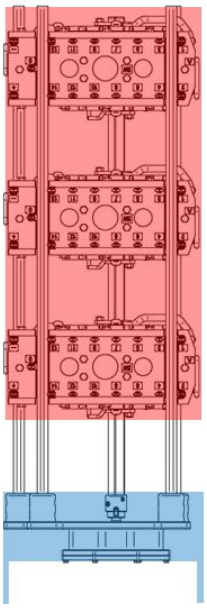


Figures 52a-b: Oscillograms of switching impulse test (250/2500 µs) on insulating distance “c2”.

7.4 Applied voltage test (AV)

Test standards:	IEC 60214-1:2014, sub-clause 5.2.8.8 IEEE C57.131-2024, sub-clause 5.2.8.8
Voltage generator:	See chapter 6.2 (max. voltage: 700 kV)
Voltage waveform:	Sine-shaped (frequency: 50 Hz).
Test duration (t_D):	60 s

7.4.1 Insulating distance “f1”



BLUE: Connected contacts
RED: 100% test voltage

Figure 53: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
230	230.0	> 60	71.0

Table 25: Test results of applied voltage test (50 Hz) on insulating distance “f1”.

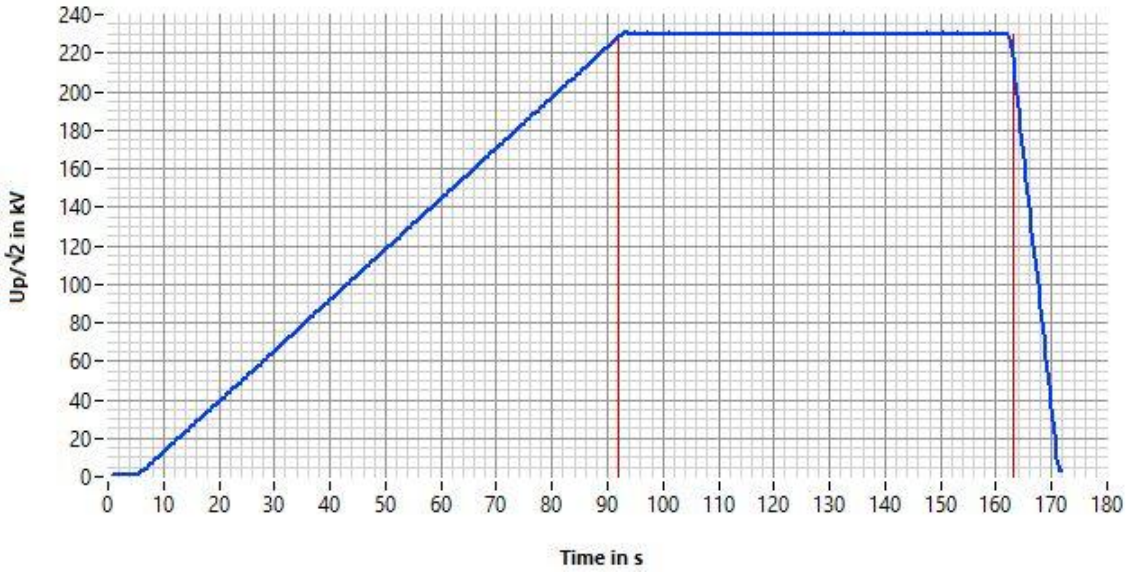
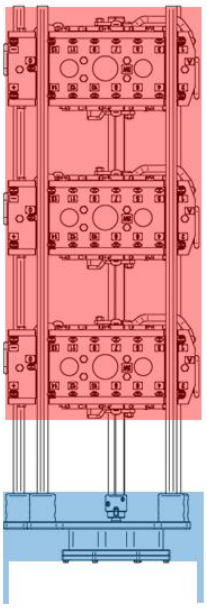


Figure 54: Oscillogram of applied voltage test (50 Hz) on insulating distance “f1”.

7.4.2 Insulating distance “f2”



BLUE: Grounded
RED: 100% test voltage

Figure 55: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
275	274.9	> 60	70.5

Table 26: Test results of applied voltage test (50 Hz) on insulating distance “f2”.

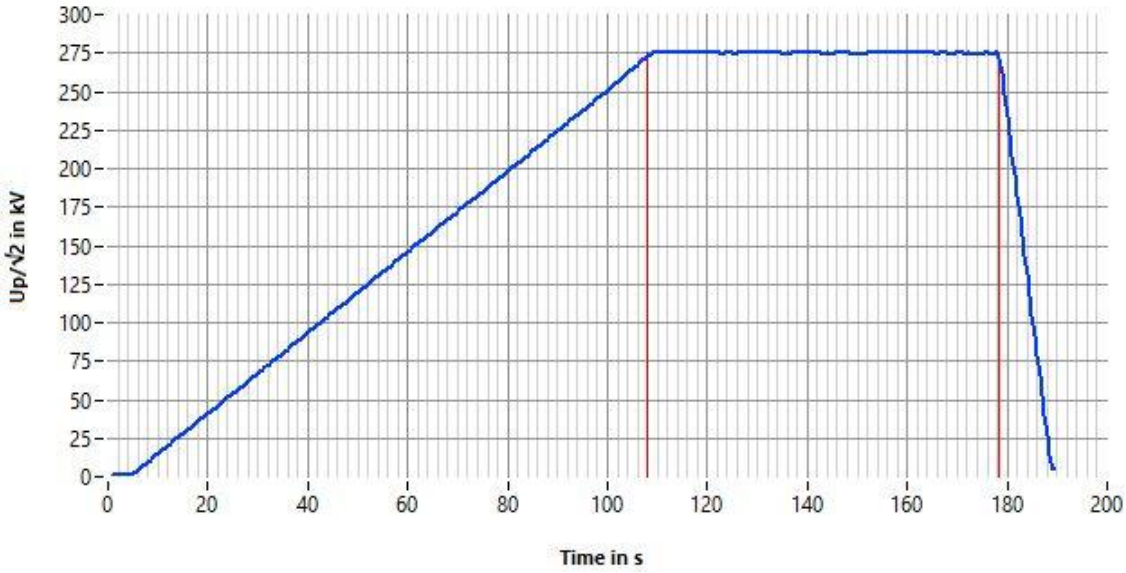
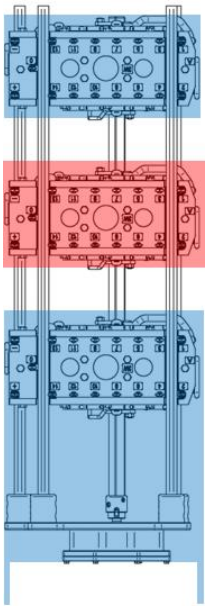


Figure 56: Oscillogram of applied voltage test (50 Hz) on insulating distance “f2”.

7.4.3 Insulating distance “b”



BLUE: Grounded
RED: 100% test voltage

Figure 57: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
85	85.4	> 60	70.0

Table 27: Test results of applied voltage test (50 Hz) on insulating distance “b”.

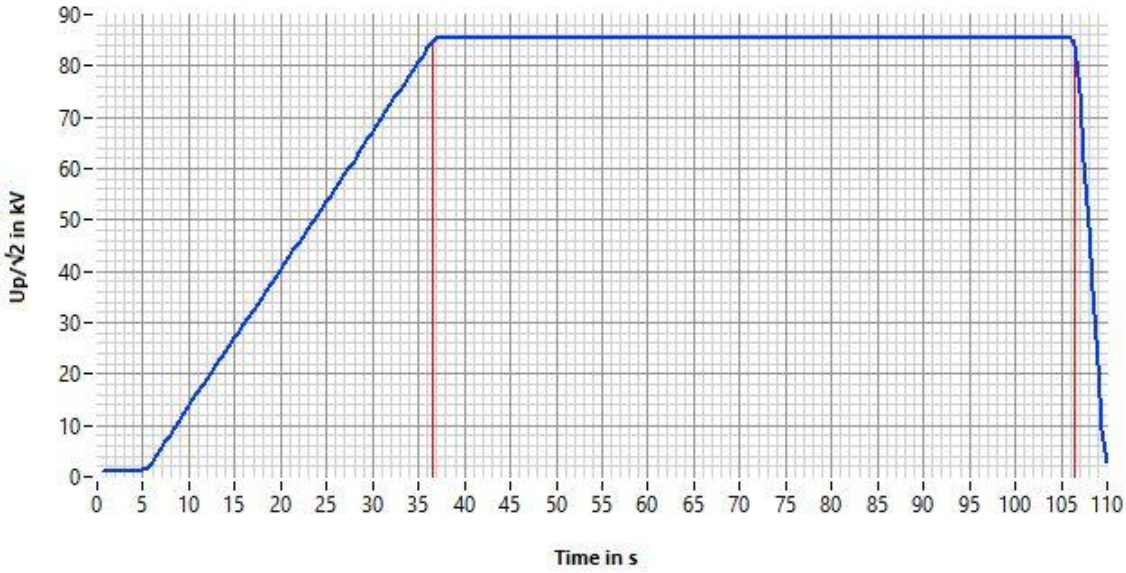


Figure 58: Oscillogram of applied voltage test (50 Hz) on insulating distance “b”.

7.4.4 Insulating distance “a” (circuit 1)

BLUE: Grounded
RED: 100% test voltage

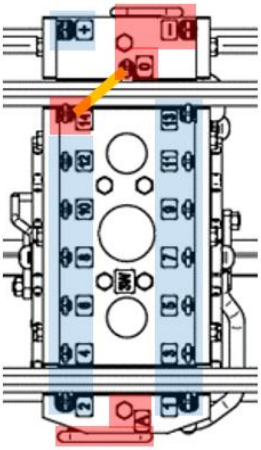


Figure 59: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
50	50.2	> 60	70.5

Table 28: Test results of applied voltage test (50 Hz) on insulating distance “a”.

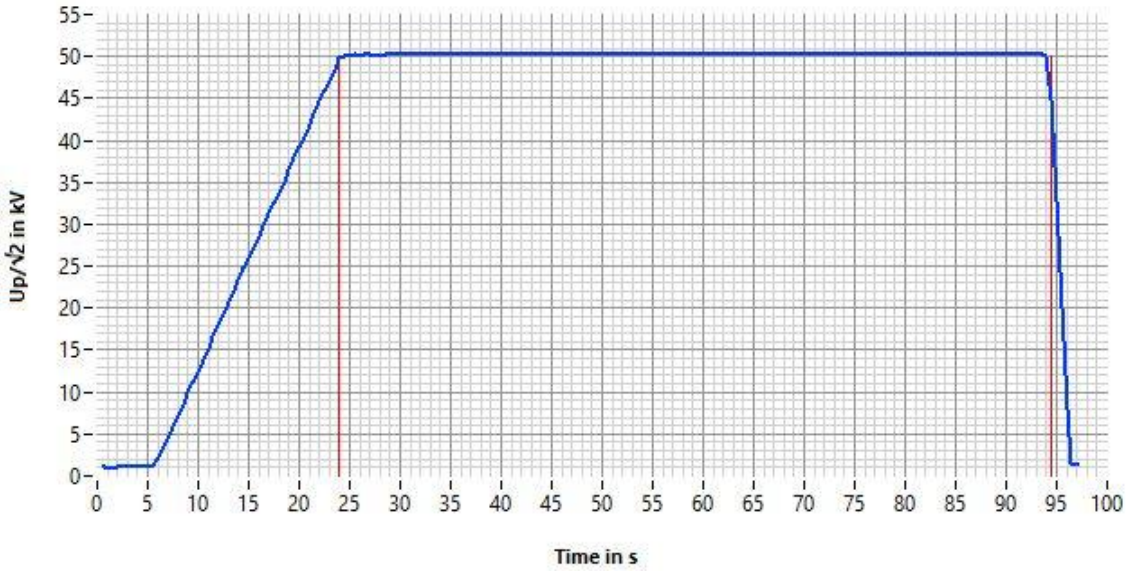


Figure 60: Oscillogram of applied voltage test (50 Hz) on insulating distance “a”.

7.4.5 Insulating distance “a” (circuit 2)

BLUE: Grounded
RED: 100% test voltage

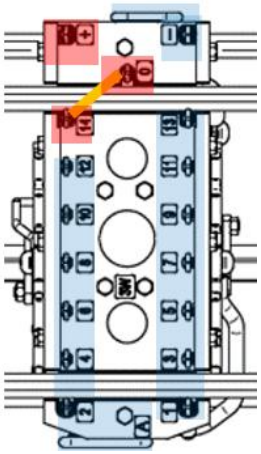


Figure 61: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
50	50.0	> 60	69.0

Table 29 Test results of applied voltage test (50 Hz) on insulating distance “a”.

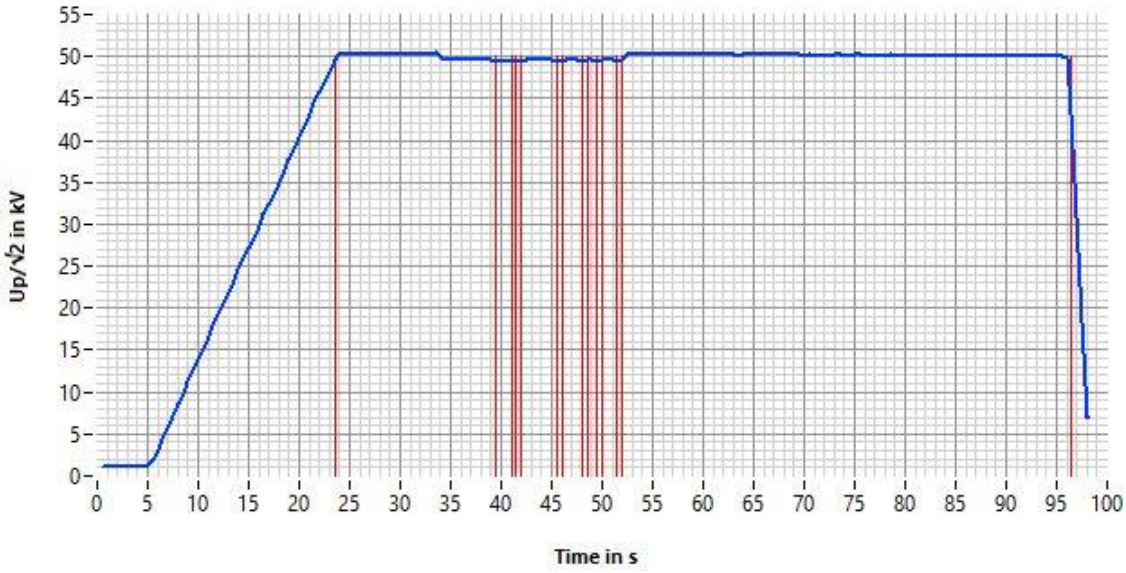


Figure 62: Oscillogram of applied voltage test (50 Hz) on insulating distance “a”.

7.4.6 Insulating distance “a1”

BLUE: Connected contacts
RED: 100% test voltage

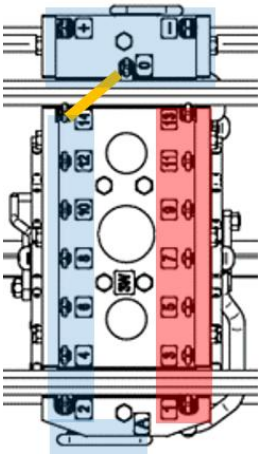


Figure 63: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
20	19.9	> 60	61.2

Table 30: Test results of applied voltage test (50 Hz) on insulating distance “a1”.

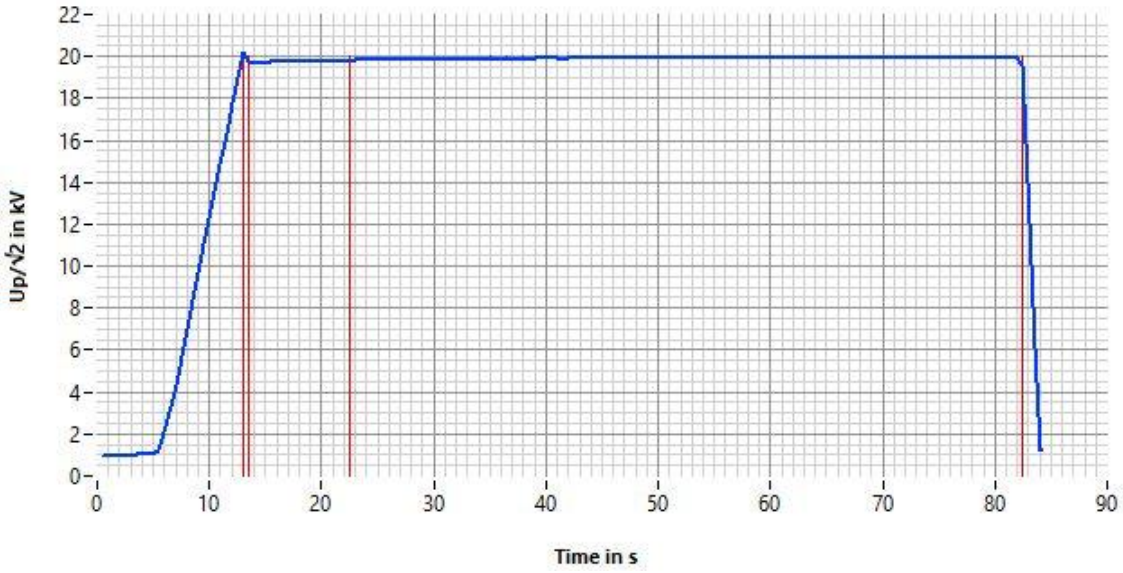
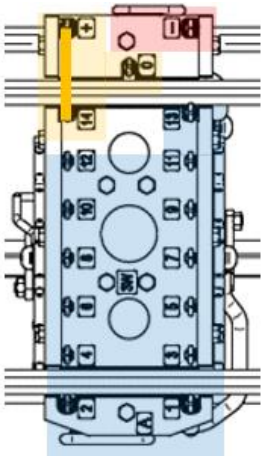


Figure 64: Oscillogram of applied voltage test (50 Hz) on insulating distance “a1”.

7.4.7 Insulating distance “c1”



BLUE: Connected contacts
RED: 100% test voltage
YELLOW: 50% test voltage

Figure 65: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
100	100.2	> 60	70.5

Table 31: Test results of applied voltage test (50 Hz) on insulating distance “c1”.

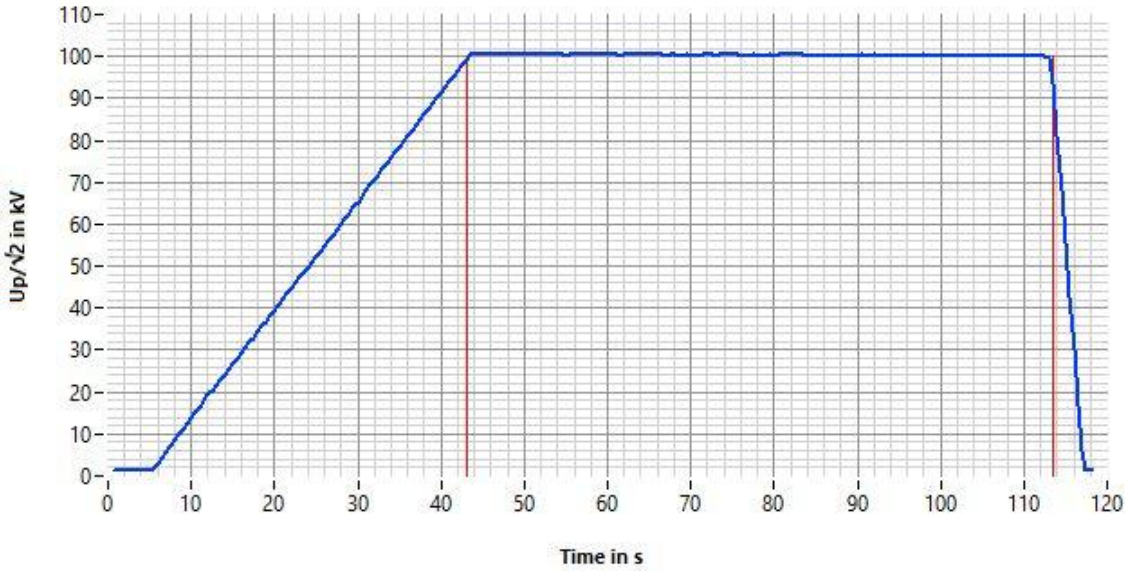
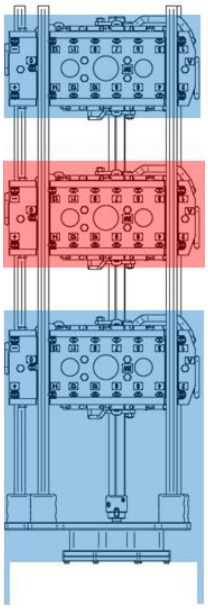


Figure 66: Oscillogram of applied voltage test (50 Hz) on insulating distance “c1”.

7.4.8 Insulating distance “c2”



BLUE: Grounded
RED: 100% test voltage

Figure 67: Wirings and connections on the test sample.

Applied voltage (50 Hz) (U_P / √2) in kV		Test duration in s	
Nominal	Tested	Nominal	Tested
140	140.4	> 60	70.5

Table 32: Test results of applied voltage test (50 Hz) on insulating distance “c2”.

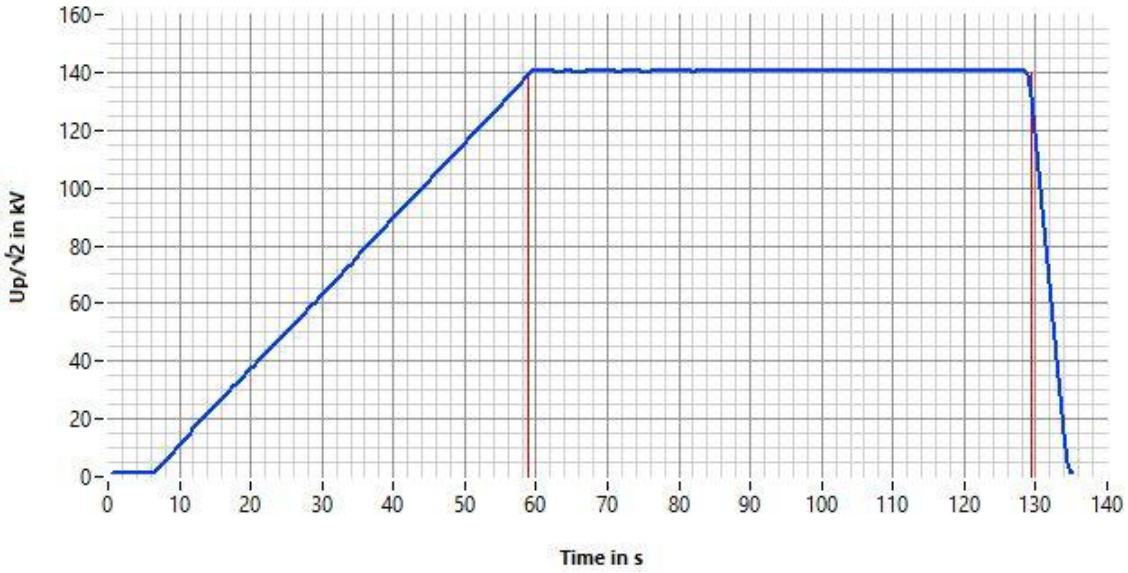


Figure 68: Oscillogram of applied voltage test (50 Hz) on insulating distance “c2”.

8. Test results

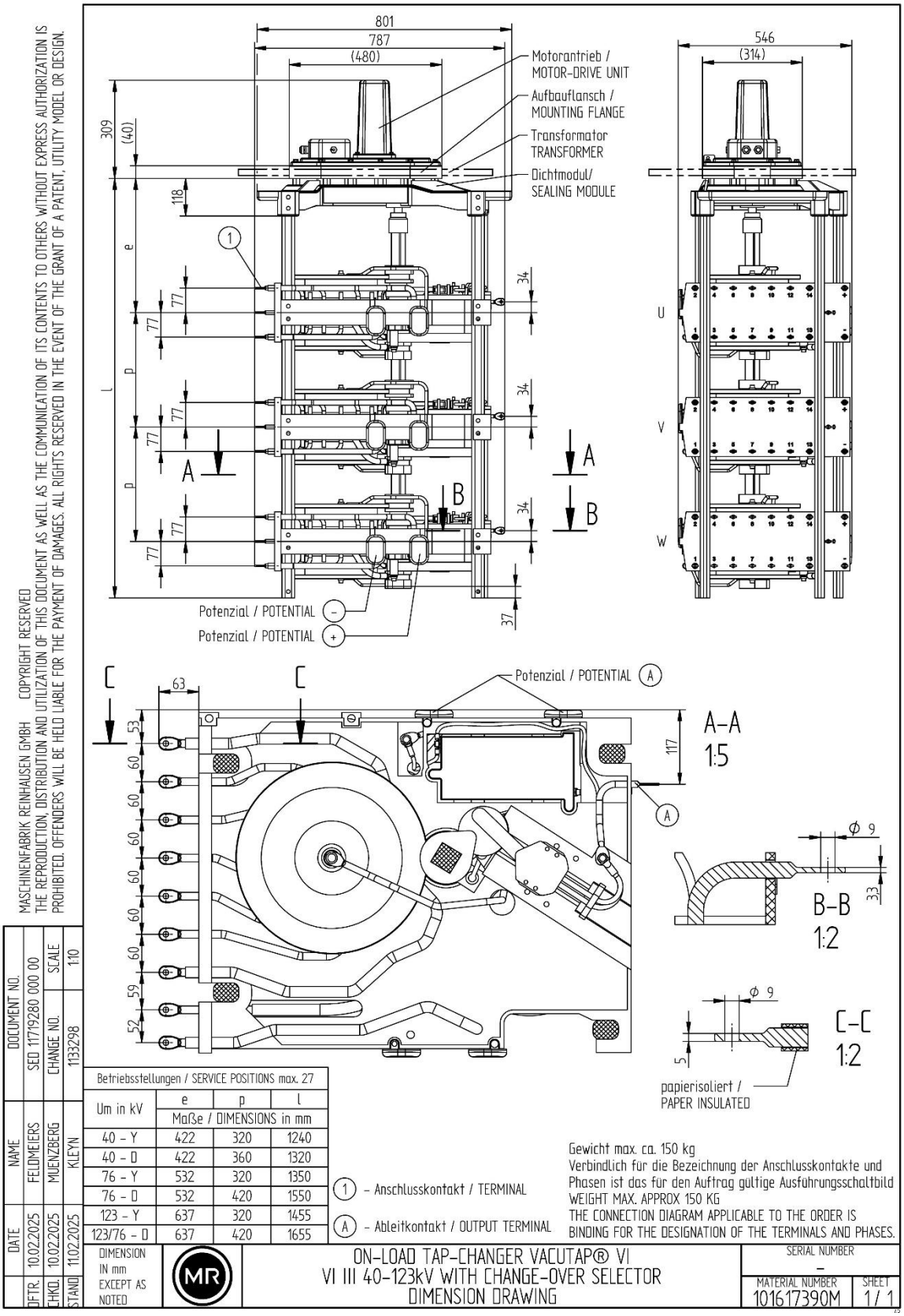
The requirements of IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, sub-clause 5.2.8 “Dielectric tests” and IEEE C57.131-2024, sub-clause 5.2.8 “Dielectric tests” were met.

The full wave lightning impulse voltage 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 disruptive discharge. The confirmed values are shown in table 33.

Tested insulating distance (Symbol see figs. 1 - 3)	Full wave lightning impulse test (LI) 1.2/50 µs in kV peak	Chopped wave lightning impulse test (LIC) 1.2/50/3 µs in kV peak	Switching impulse test (SI) 250/2500 µs in kV peak	Power-frequency voltage tests 50 Hz / 60 s in kV r.m.s.
f1	550	605	460	230
f2	650	715	520	275
b	200	220	160	85
a1	100	110	80	20
a	200	220	160	50
c1	400	440	320	100
c2	350	385	280	140

Table 33: Confirmed withstand voltages of defined insulation distances.

9. Appendix



Betriebsstellungen / SERVICE POSITIONS max. 27			
Um in kV	e	p	l
	Maße / DIMENSIONS in mm		
40 - Y	422	320	1240
40 - D	422	360	1320
76 - Y	532	320	1350
76 - D	532	420	1550
123 - Y	637	320	1455
123/76 - D	637	420	1655

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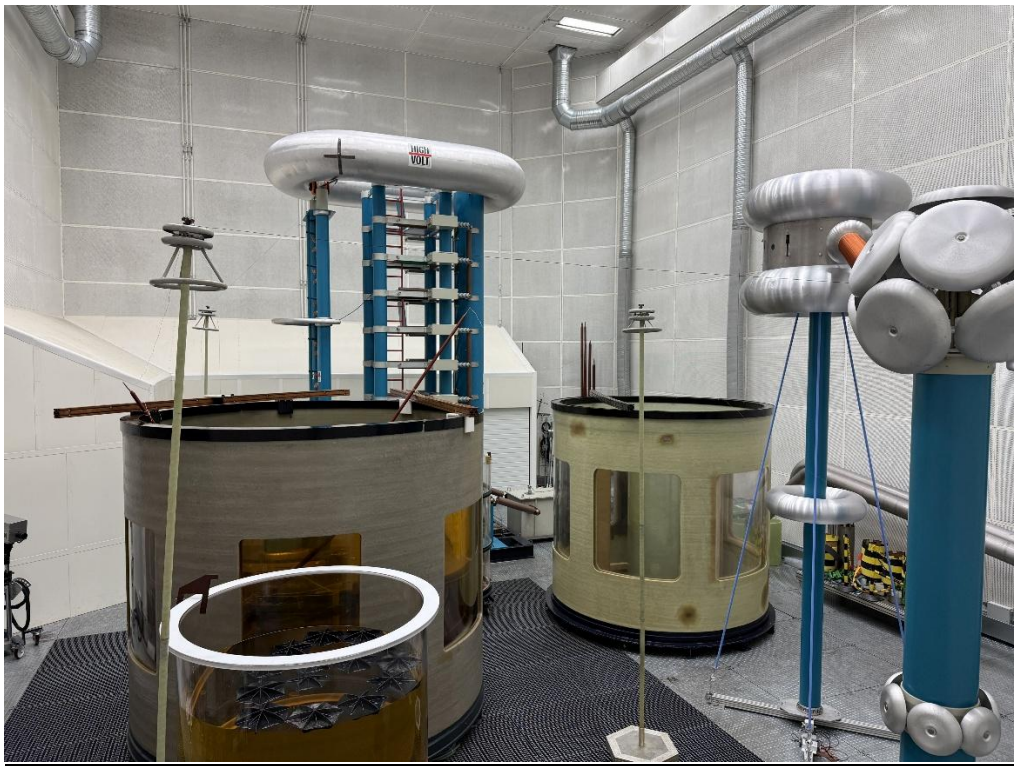
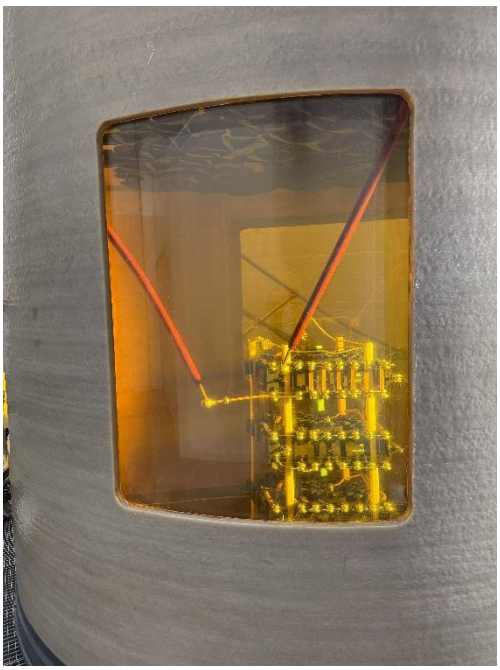
Figure 69: Dimension drawing of the test samples.



Pictures 1: Test setup.



Pictures 2: Test sample prepared for the dielectric tests (example).

10. List of amendments

Version	Date	Author	Amendment
01	17.07.2025	R. Wagner	---

End of document.