Maschinenfabrik Reinhausen GmbH
Testcenter
Falkensteinstraße 8
93059 Regensburg

Type test report

No. VI 4E 002e

Type test for types:	On-load tap-changers VACUTAP® VI with - three phase design - star-point (Y) or delta (D) application - number of contacts: 10, 12 or 14 - highest voltage for equipment: 40 kV, 76 kV or 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 5.2.5 “Transition impedance test” IEEE C57.131-2024, sub-clause 5.2.5 “Transition impedance test”
Test samples:	1: Transition resistor variant VI-05 (2.79 Ω) 2: Transition resistor variant VI-12 (2.30 Ω) Test samples 1 and 2 mounted in on-load tap-changer VACUTAP® VI III 400 D – 123/76 – 14 27 1W.
Manufacturer:	Maschinenfabrik Reinhausen GmbH
Date of test:	July 2024
Tests performed:	The tests were performed according to IEC 60214-1:2014, Annex C.
Test sequence 1:	27 current pulses, equivalent to one-half of an operation cycle of on-load tap-changer type VACUTAP® VI with 14 contacts and change-over selector, were applied on the test samples in regular intervals of 5.4 s. The tests were performed with loadings equivalent to 1.5 times the maximum rated through-current and the relevant rated step voltage of the transition resistor application range.
Test sequence 2:	One current pulse, equivalent to loading with twice the maximum rated through-current and the relevant rated step voltage of the transition resistor application range, was applied on the test samples.
Test results:	The requirements of IEC 60214-1:2014, sub-clause 5.2.5 “Transition impedance test” and IEEE C57.131-2024, sub-clause 5.2.5 “Transition impedance test” were met.

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

Maschinenfabrik Reinhausen GmbH
- TAP-CHANGER TESTING -

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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 / variant:	VI-05
	Resistor value:	2.79 Ω
Test sample 2:	Type / variant:	VI-12
	Resistor value:	2.30 Ω

The test samples were mounted in on-load tap-changer VACUTAP® VI III 400 D – 123/76 – 14 27 1W:

Serial number:	2655735
IBASE:	981172461
Year of manufacture:	2023
Manufacturer:	Maschinenfabrik Reinhausen GmbH

3. Test specification

Test standards:	IEC 60214-1:2014, sub-clause 5.2.5 “Transition impedance test” IEEE C57.131-2024, sub-clause 5.2.5 “Transition impedance test”

4. Scope of application

On-load tap-changers type VACUTAP® VI with maximum rated through-current 400 A are available with 10, 12 or 14 contacts and with or without change-over selector. Depending on the custom-designed operation point of the on-load tap-changer, various transition resistors are used in service.

The basic design of the transition resistors is alike, i.e. equivalent materials, fixations, resistor connecting leads and same position in the on-load tap-changer. The only differences are the diameters of the resistor wires, number of frames, number of parallel wires and the wire length of one resistance path.

To cover all transition resistor variants, according to the step capacity diagram of VACUTAP® VI, the maximum thermal stress per operation was determined for the different transition resistor variants under consideration of relevant thermal characteristics like highest calculated heating and energy input of the transition resistors.

Based on this theoretical consideration, the test was performed on following two test samples, in accordance with the requirements of IEC 60214-1:2014 resp. IEEE C57.131-2024, sub-clause 5.2.5 and Annex C, with 27 current pulses, equivalent to one-half of an operation cycle of an on-load tap-changer type VACUTAP® VI with 14 contacts and change-over selector:
Test sample 1 (VI-05, 2.79 Ω): Transition resistor at the operation point with maximum rated through-current and relevant rated step voltage according to the step capacity diagram of VACUTAP® VI.
Test sample 2 (VI-12, 2.30 Ω): Transition resistor with the highest determined thermal stress per operation among all transition resistors according to the step capacity diagram of VACUTAP® VI.

Thus, testing the chosen test samples covers the complete application range of all transition resistors according to the step capacity diagram of VACUTAP® VI.

Other characteristics of the on-load tap-changer are not relevant for the transition impedance test.

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) or delta (D)
- Number of contacts: 10, 12 or 14
- Highest voltage for equipment: 40 kV, 76 kV or 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

5. Test setup

Test method and test conditions:	The tests were performed according to IEC 60214-1:2014, resp. IEEE C57.131-2024, Annex C. The transition resistors were mounted in thermally situation like in service. The on-load tap-changer was mounted in horizontal position.
Condition of transition resistors:	New, as manufactured.
Oil compartment content:	Clean mineral oil mixture (e.g. Nynas Nytro Taurus, Shell Diala D).
Test circuit:	See figure 1.
Switching sequence:	See figures 2a-b.
Measurement and evaluation:	The temperature of the transition resistors was recorded and evaluated.

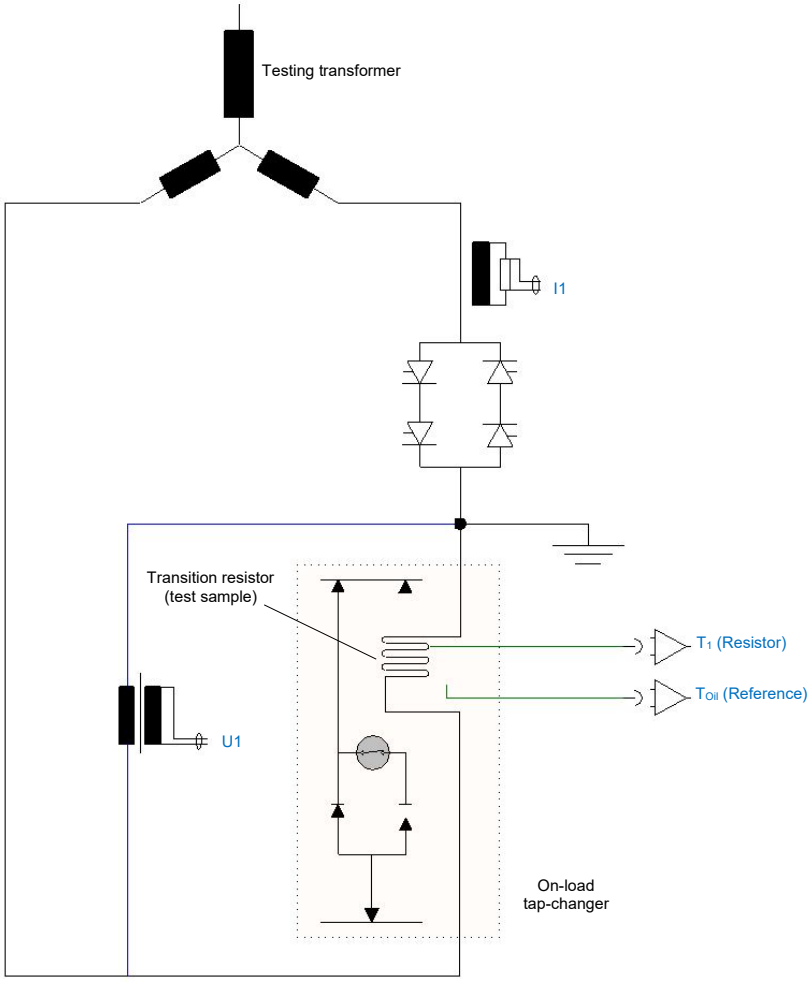


Figure 1: Test circuit (schematic sketch).

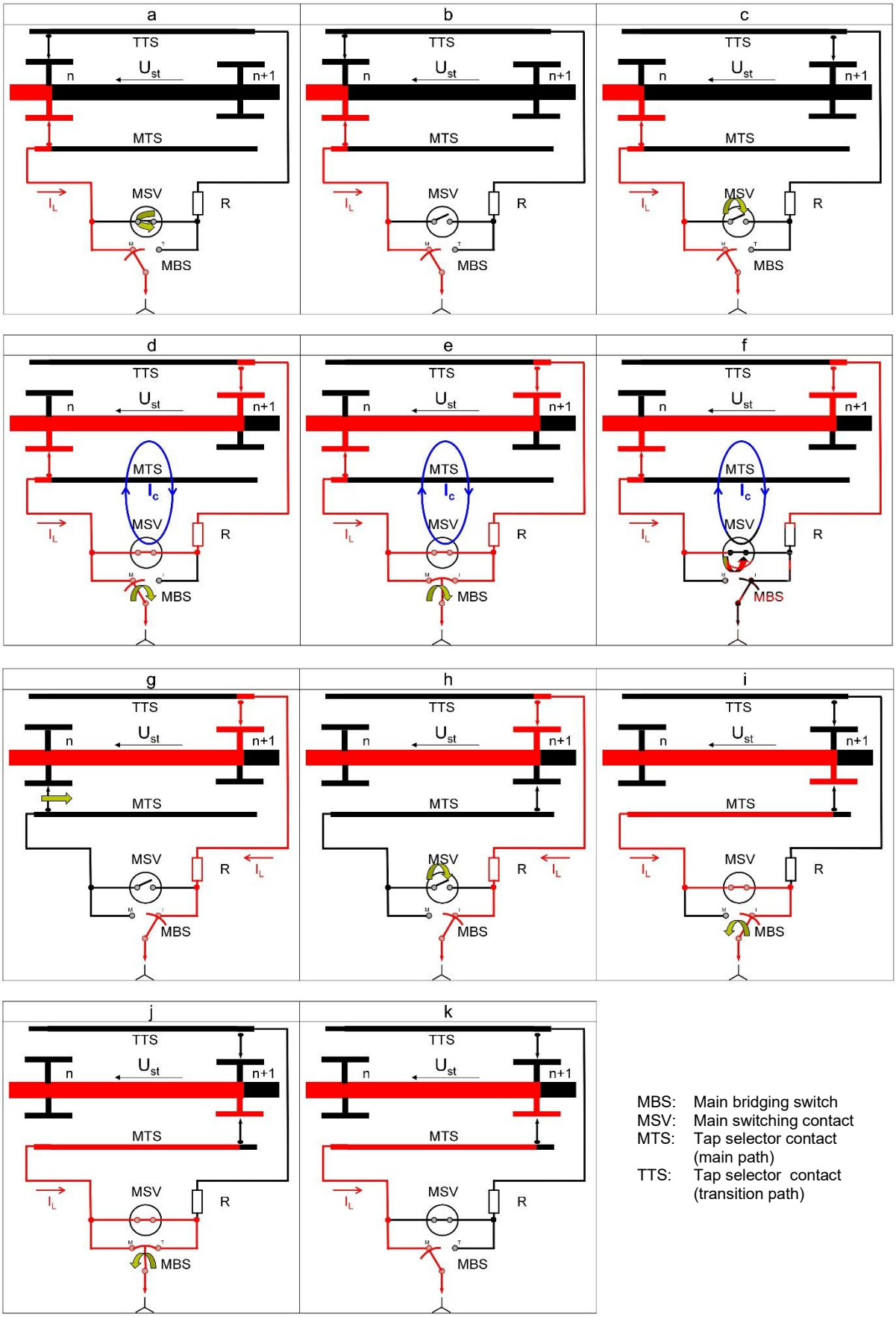
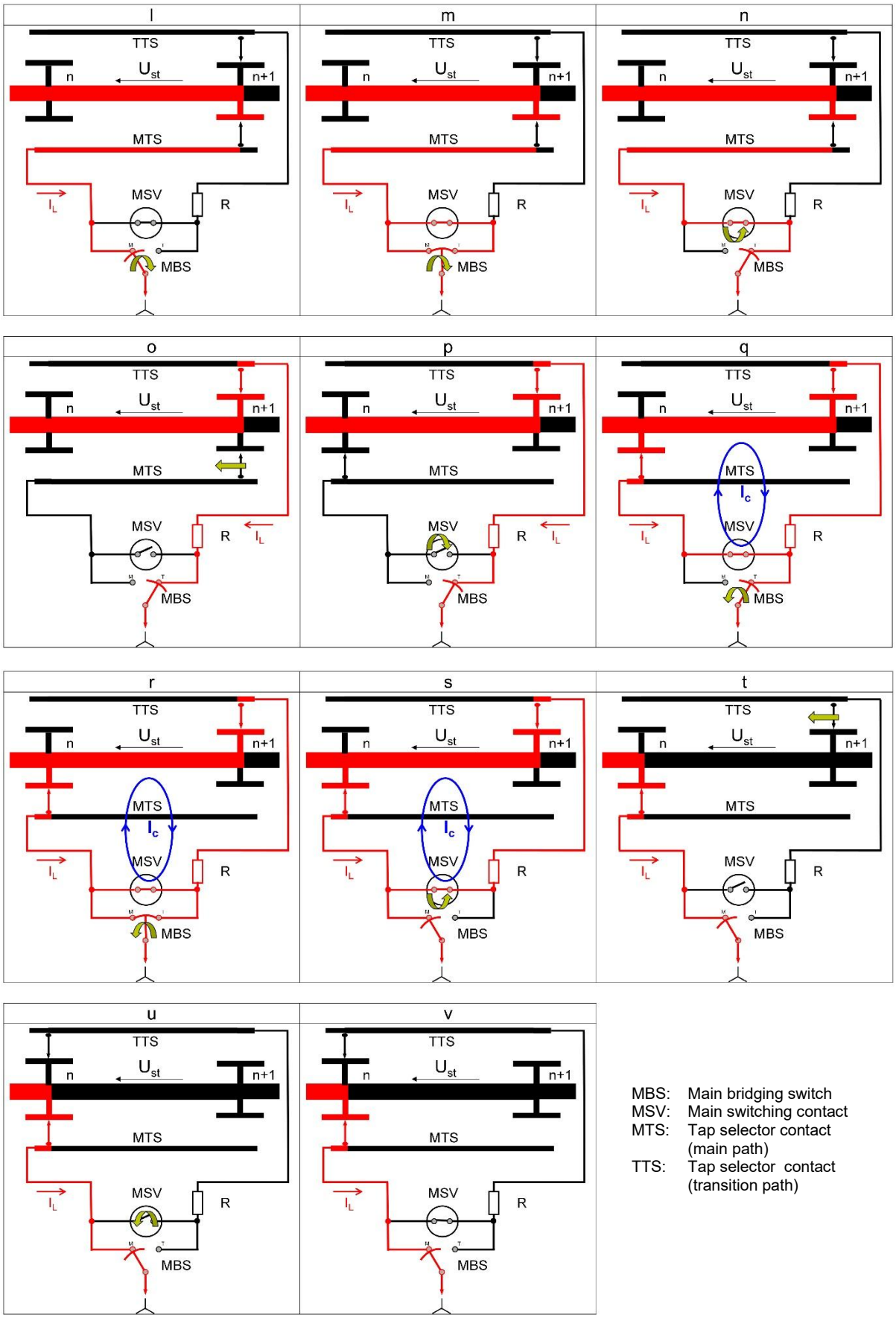
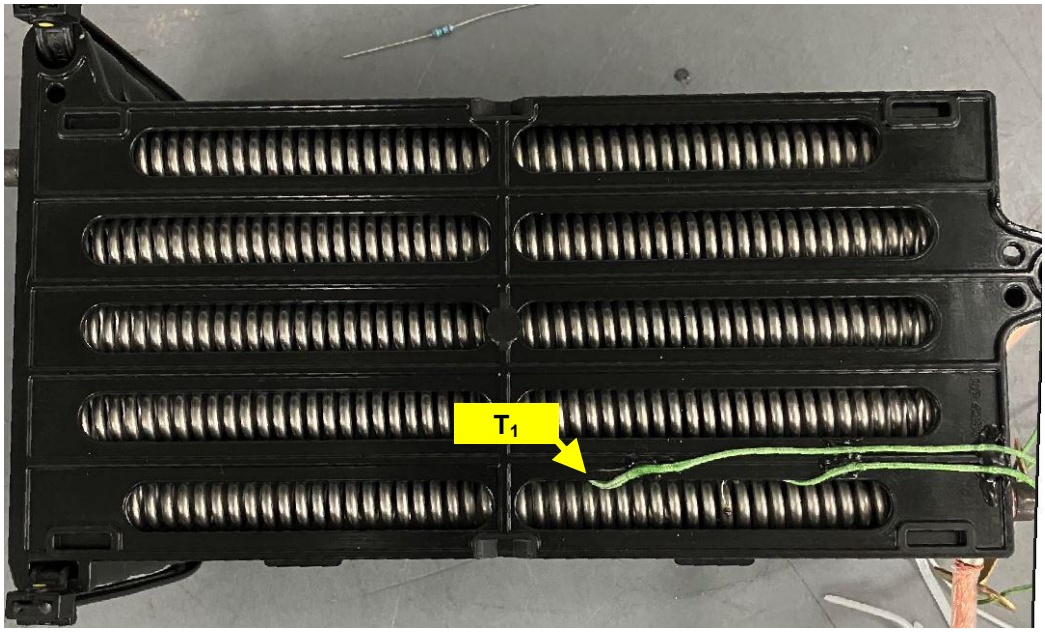


Figure 2a: Switching sequence of on-load tap-changer type VACUTAP® VI (direction n ⟶ n+1)

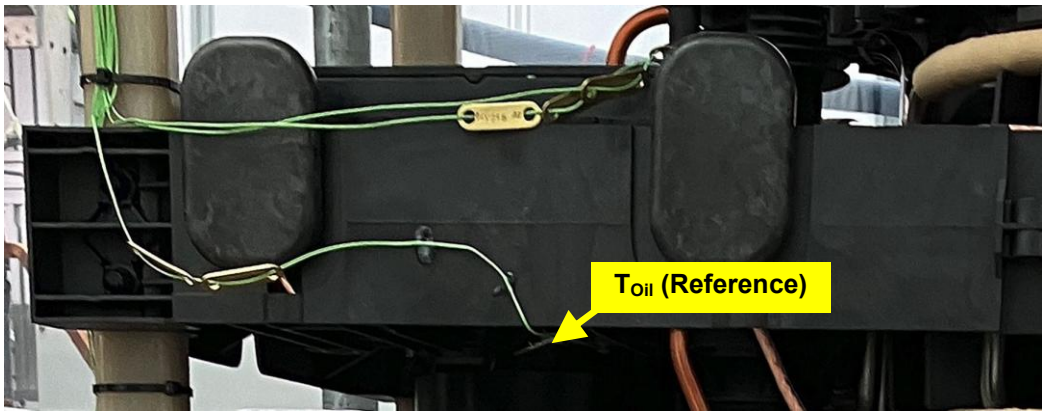


MBS: Main bridging switch
MSV: Main switching contact
MTS: Tap selector contact (main path)
TTS: Tap selector contact (transition path)

Figure 2b: Switching sequence of on-load tap-changer type VACUTAP® VI (direction n+1 ⟶ n)



Picture 1: Temperature measurement point of transition resistor wire (exemplary for test sample 1).



Picture 2: Temperature measurement point of oil reference (exemplary for test sample 1).

6. Test performed

The tests were performed in two test sequences:

Test sequence 1: Resistor load equivalent to the loading during switching operations with 1.5 times the maximum rated through-current and relevant rated step voltage of the transition resistor application range.

Test sequence 2: Resistor load equivalent to the loading during a switching operation with 2.0 times the maximum rated through-current and relevant rated step voltage of the transition resistor application range.

6.1 Required calculated values as Integral ($I_1^2 \times t_1$)

During one tap-change operation the transition resistor is loaded with through-current and circulating current (see switching sequence, figures 2a-b).

Table 1 shows the required calculated values as integral ($I_1^2 \times t_1$) per operation when loaded with 1.5 times the rated through-current at relevant rated step voltage (test sequence 1). Table 2 shows the required calculated values as integral ($I_1^2 \times t_1$) per operation when loaded with 2.0 times the rated through-current at relevant rated step voltage (test sequence 2).

Integral $I_1^2 \times t_1$ in A²s	
Test sample 1 (VI-05, 2.79 Ω)	**Test sample 2** (VI-12, 2.30 Ω)
59,476	29,732

Table 1: Test sequence 1 – Required calculated values.

Integral $I_1^2 \times t_1$ in A²s	
Test sample 1 (VI-05, 2.79 Ω)	**Test sample 2** (VI-12, 2.30 Ω)
85,516	40,315

Table 2: Test sequence 2 – Required calculated values.

6.2 Test sequence 1

The transition resistors were loaded with 27 current pulses, corresponding to one-half of one cycle of operations of on-load tap-changer type VACUTAP® VI with 14 contacts and change-over selector. The applied current pulses (I_1) and the duration of current flow (t_1) of each current pulse as well as the corresponding integral ($I_1^2 \times t_1$) are documented in table 3.

Current pulse no.	**Test sample 1** (VI-05, 2.79 Ω)			**Test sample 2** (VI-12, 2.30 Ω)		
	I_1 (r.m.s) in A	t_1 in ms	$I_1^2 \times t_1$ in A²s	I_1 (r.m.s) in A	t_1 in ms	$I_1^2 \times t_1$ in A²s
1	625	168	65,907	408	208	34,691
2	608	168	62,351	400	208	33,264
3	606	168	61,936	400	208	33,286
4	607	168	62,038	400	208	33,269
5	606	168	61,854	400	208	33,262
6	606	168	61,944	400	208	33,250
7	607	168	61,971	400	208	33,313
8	607	168	61,984	400	208	33,320
9	607	168	61,998	400	208	33,225
10	607	168	62,100	400	208	33,257
11	607	168	62,078	400	208	33,311
12	607	168	62,089	400	208	33,274
13	606	168	61,937	400	208	33,243
14	606	168	61,926	400	208	33,249
15	607	168	61,998	400	208	33,304
16	607	168	62,033	400	208	33,284
17	607	168	62,090	400	208	33,270
18	607	168	62,051	400	208	33,267
19	607	168	62,127	400	208	33,257
20	608	168	62,154	400	208	33,253
21	607	168	62,128	400	208	33,267
22	607	168	62,056	400	208	33,281
23	608	168	62,256	400	208	33,232
24	608	168	62,248	400	208	33,250
25	608	168	62,222	400	208	33,285
26	608	168	62,184	400	208	33,312
27	608	168	62,292	400	208	33,316
Mean value	**608**	**168**	**62,220**	**400**	**208**	**33,326**

Table 3: Test sequence 1 – Applied current pulses and mean values.

Table 3 shows that the mean values of integral ($I_1^2 \times t_1$) of the performed current pulses were above the required calculated values (see table 1) for each tested transition resistor.

Figures 3a-b show the oscillograms of the performed tests with current pulses and the progression of temperature rise. Figures 4a-b show the last current pulse (incl. measurement of temperature rise) more detailed.

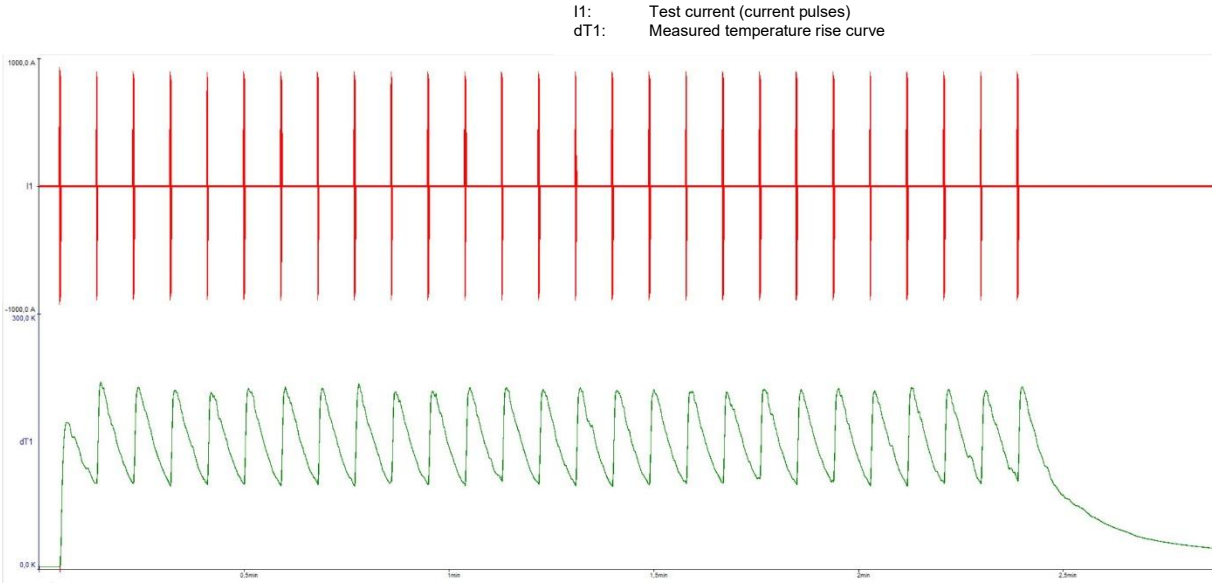


Figure 3a: Current pulses and temperature rise of test sample 1 (VI-05, 2.79 Ω).

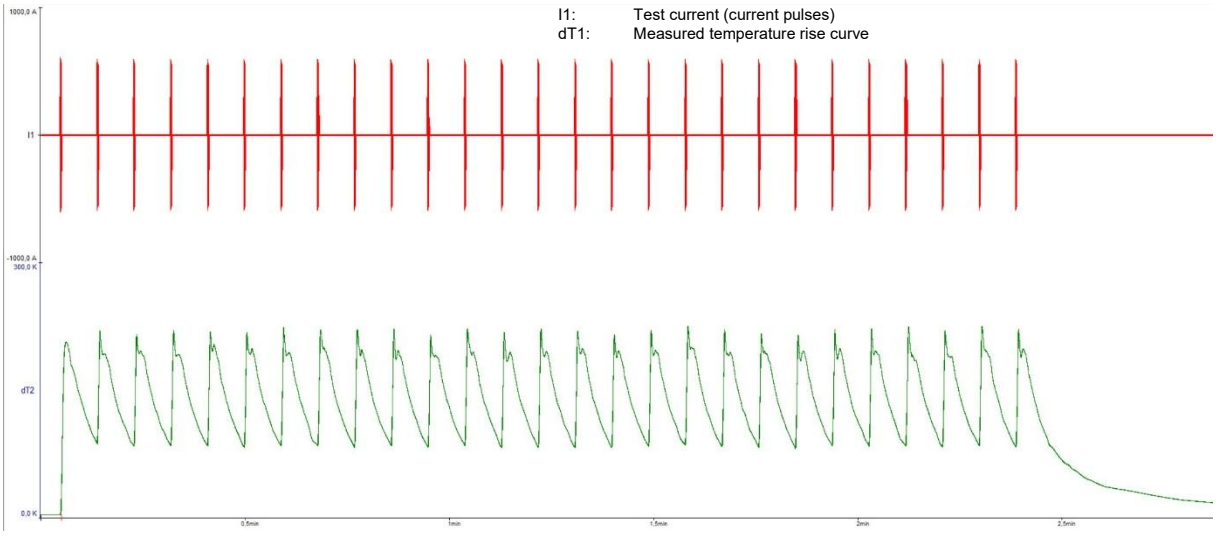


Figure 3b: Current pulses and temperature rise of test sample 2 (VI-12, 2.30 Ω).

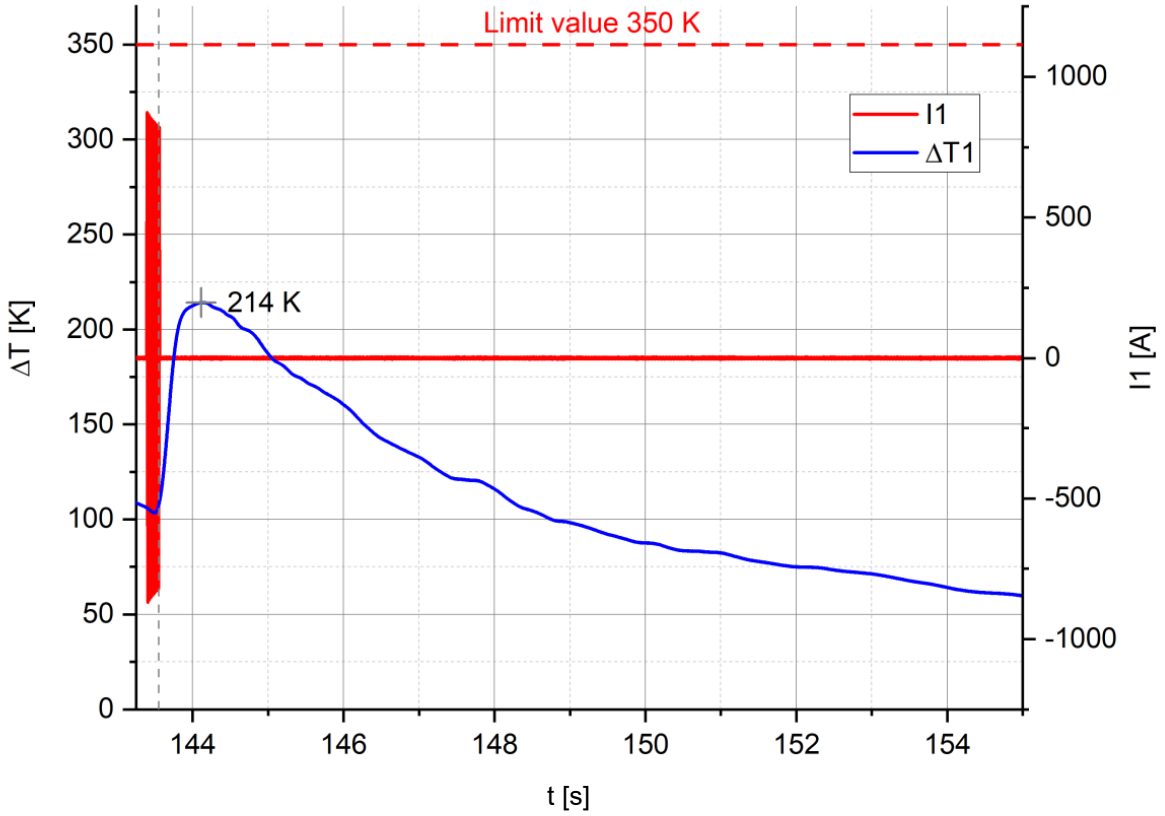


Figure 4a: Last current pulse performed on test sample 1 (VI-05, 2.79 Ω).

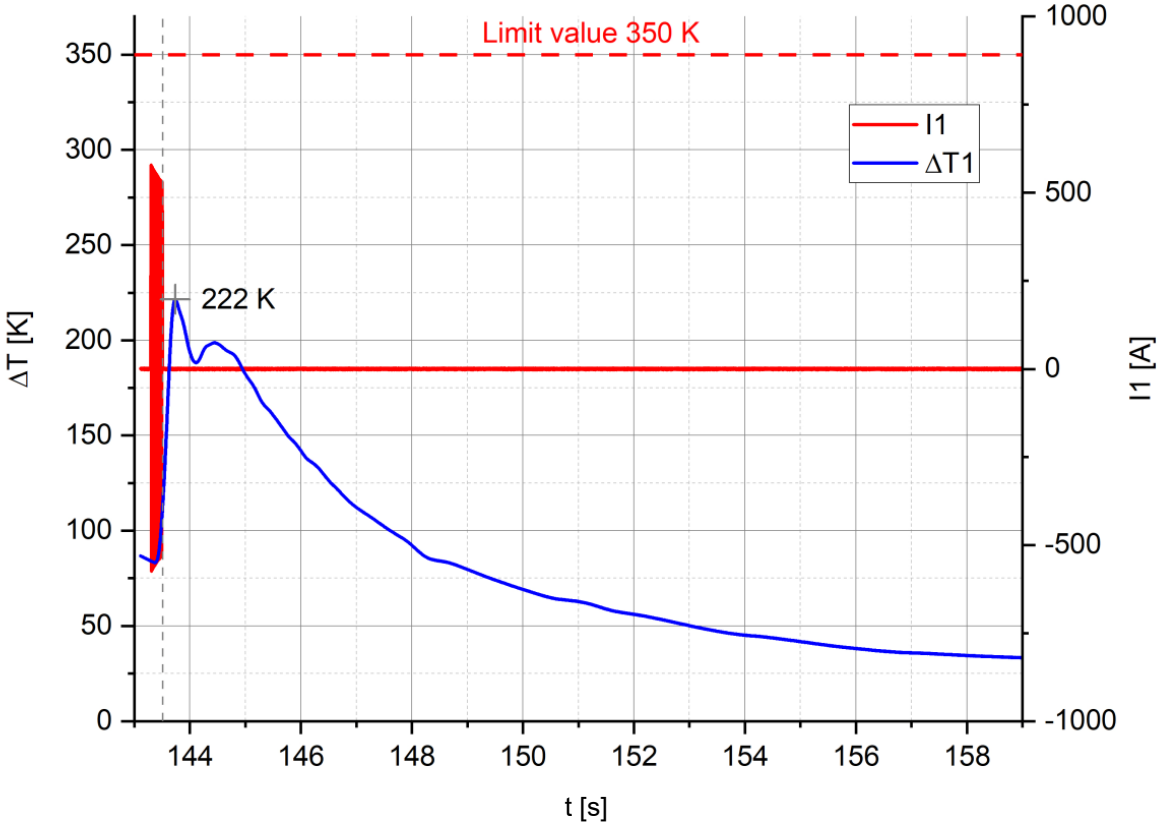


Figure 4b: Last current pulse performed on test sample 2 (VI-12, 2.30 Ω).

Table 4 shows the results of the measured maximum temperature rises after the last current pulse (see figures 4a-b).

Timing of measurement	**Maximum temperature rise** in K	
	Test sample 1 (VI-05, 2.79 Ω)	**Test sample 2** (VI-12, 2.30 Ω)
After current pulse no. 27	214	222

Table 4: Temperature rises of tested transition resistors at end of test sequence 1.

6.3 Test sequence 2

The transition resistors were loaded with one current pulse equivalent to 2.0 times the rated through-current and relevant rated step voltage. The resistor current (I_1) and the duration of current flow (t_1) of the current pulse as well as the corresponding integral ($I_1^2 \times t_1$) are documented in table 5.

Current pulse no.	**Test sample 1** (VI-05, 2.79 Ω)			**Test sample 2** (VI-12, 2.30 Ω)		
	I_1 (r.m.s) in A	t_1 in ms	$I_1^2 \times t_1$ in A^2s	I_1 (r.m.s) in A	t_1 in ms	$I_1^2 \times t_1$ in A^2s
1	810	138	90,834	541	158	46,245

Table 5: Test sequence 2 – Applied current pulses.

Table 5 shows that the value of integral ($I_1^2 \times t_1$) of each tested transition resistor was above the required calculated value (see table 2).

The tests proved that the transition resistors withstood the stresses at 2.0 times the rated through-current and relevant rated step voltage without any wear on the mechanical parts or deterioration of the insulation material. Table 6 shows the measured resistance values before and after the tests.

Timing of measurement	**Resistance** in Ω	
	Test sample 1 (VI-05, 2.79 Ω)	**Test sample 2** (VI-12, 2.30 Ω)
Before the tests	2.73	2.34
After the tests	2.75	2.36

Table 6: Results of transition resistor measurement.

7. Test results

The requirements of IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, 5.2.5: “Transition impedance test” and IEEE C57.131-2024, sub-clause 5.2.5 “Transition impedance test” were met.

The temperature rise of the transition resistors was below the maximum permissible value of 350 K for liquid environment on-load tap-changers. Parts adjacent to the transition resistors were not affected.

The test samples withstood the stresses at twice the maximum rated through-current and the relevant rated step voltage without any wear on the mechanical parts or deterioration of the insulation material. The measured resistance values before and after the tests were within the permissible tolerance of ± 10 %.

8. List of amendments

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

End of document.