Type test report no. VR 2E 001e

Switching tests of diverter switch

Product Approval
CTTP/Wag
10.02.2017

Type test for types: Diverter switches VACUTAP® VRS / VRM / VRL / VRH / VRX with
- single phase, two phase or three phase design,
- maximum rated through-current up to 1300 A / 2600 A[1],
- maximum rated step voltage up to 6000 V / 12000 V[2].

Test specification: IEC 60214-1:2014, 5.2.3: “Switching tests”.

Test sample: Diverter switch
VACUTAP® VRH III 1300 Y – 72.5, S/N: 1734901

Manufacturer: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.

Date of test: September 2016 to January 2017.

Places of test: 1: Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.
2: High Power Laboratories “FGH”, Mannheim, Germany.

Tests performed:

Service duty test: 360,000 switching operations performed at maximum rated through-current (1300 A) and relevant rated step voltage (4615 V).

Breaking capacity test: 40 switching operations performed at twice the max. rated through-current (2 x 1300 A = 2600 A) and relevant rated step voltage (4615 V).

40 switching operations performed at max. rated step voltage (6000 V) and twice the relevant rated through-current (2 x 1000 A = 2000 A).

Test results: The requirements of IEC 60214-1:2014 were fulfilled, i.e.:

- The service duty test was passed successfully. Comparison of 100 oscillograms taken at regular intervals during the test did not show a significant alteration in the characteristics of the diverter switch in such a way as to endanger the operation of the apparatus.
- The breaking capacity test was passed successfully. Oscillograms taken for each operation indicated that in no case the arcing time was such as to endanger the operation of the apparatus.
- The inspection of the diverter switch after the tests did not leave any doubts as to the suitability of the diverter switch for service.

[1] Single phase design with two sectors (current paths) of identical design (2 x 1300 A) for applications with enforced current splitting.
[2] Single phase design with two sectors for applications with variable shunt reactors with maximum rated step voltage 2 x 6000 V (VACUTAP® VRX).

This report contains 100 pages.

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

1. Test specification

The type test was performed in accordance with IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, 5.2.3: “Switching tests”.

2. Data of test sample

Type designation:	VACUTAP® VRH III 1300 Y – 72.5
Type characteristics:	Diverter switch
Serial number:	1734901
IBASE:	543304037, 554137145
Year of manufacture:	2016
Manufacturer:	Maschinenfabrik Reinhausen GmbH, Regensburg, Germany.

3. 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 switching element of a single current path (sector) has the same design for all diverter switches type VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL, VACUTAP® VRH and VACUTAP® VRX with maximum rated through-current up to 1300 A / 2600 A[1]. The switching element of a single current path (sector) is designed with 4 vacuum interrupters. Each two vacuum interrupters operate as switching contacts and as transition contacts. All vacuum interrupters are of the same type.

Diverter switches type VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL or VACUTAP® VRH with maximum rated through-current 2600 A are designed with two identical current paths (2 x 1300 A). These diverter switches are for applications with enforced current splitting, e.g. by two parallel transformer windings. The load current of each current path is half of the total load (1300 A).
The tests were performed on a single current path (sector) of VACUTAP® VRH with maximum rated through-current 1300 A. Thus, diverter switches type VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL or VACUTAP® VRH with maximum rated through-current 2600 A are covered by the performed tests.

Diverter switches type VACUTAP® VRX with maximum rated step voltage 12000 V are designed with two identical sectors (2 x 6000 V) for two transformer windings in series, e.g. for applications with variable shunt reactors.
The tests were performed on a single sector of VACUTAP® VRH (maximum rated step voltage 6000 V). Thus, diverter switches type VACUTAP® VRX with maximum rated step voltage 12000 V (2 x 6000 V) are also covered by the performed tests.

The design of the transition resistors depends on the custom-designed operation point of the diverter switch. In order to cover the whole application range according to the step capacity diagram of diverter switches type VACUTAP® VRS, VACUTAP® VRM, VACUTAP® VRL, VACUTAP® VRH and VACUTAP® VRX, the tests were carried out with suitable modified transition resistor variants.

The switching capacity does not depend on the highest voltage for equipment and on the type of tap selector the diverter switch is combined with.

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 current paths (per phase): 1 or 2[1,2]
- Maximum rated through-current: up to 1300 A / 2600 A[1]
- Maximum rated step voltage: up to 6000 V / 12000 V[2]

[1] Single phase design with two sectors (current paths) of identical design (2 x 1300 A) for applications with enforced current splitting.

[2] Single phase design with two sectors for applications with variable shunt reactors with maximum rated step voltage 2 x 6000 V (VACUTAP® VRX).

4. Test setup / test arrangement

Mounting and mechanism:	The test sample was mounted in a test frame and operated with a motor-drive unit attached outside. The test was performed on sector S1 of the test sample.
Transition resistors:	See tables 1 to 3.
Oil cooling:	The heat produced by the transition resistors was drained by a cooling system to enable switching intervals ≤ 5.4 s during the service duty test.
Mounted safety devices:	Protective relay RS 2001 and pressure relief device MPrec.
Filling of diverter switch oil compartment:	Transformer oil according to specification IEC 60296.
Servicing during the test:	No servicing during the tests.
Condition of test sample:	New as manufactured.
Test circuits:	Service duty test: A resonance circuit with an additional auxiliary diverter switch was used as test circuit in order to minimize the effects of the tests on the power supply system, see figure 1a. Breaking capacity test: The test was performed at the high power laboratories “FGH”, Mannheim, Germany. Test circuit see figure 1b.
Switching sequence:	See figure 2.
Recording and evaluation:	By transient recorder.
Evaluations:	Service duty test: 20 oscillograms were taken at the beginning of the test and 20 after every 90,000 operations, making a total of 100 oscillograms (see figures 3.1 … 3.100). Breaking capacity test: 40 oscillograms were taken at each breaking capacity test, making a total of 80 oscillograms (see figures 4.1 … 4.40 and 5.1 … 5.40).

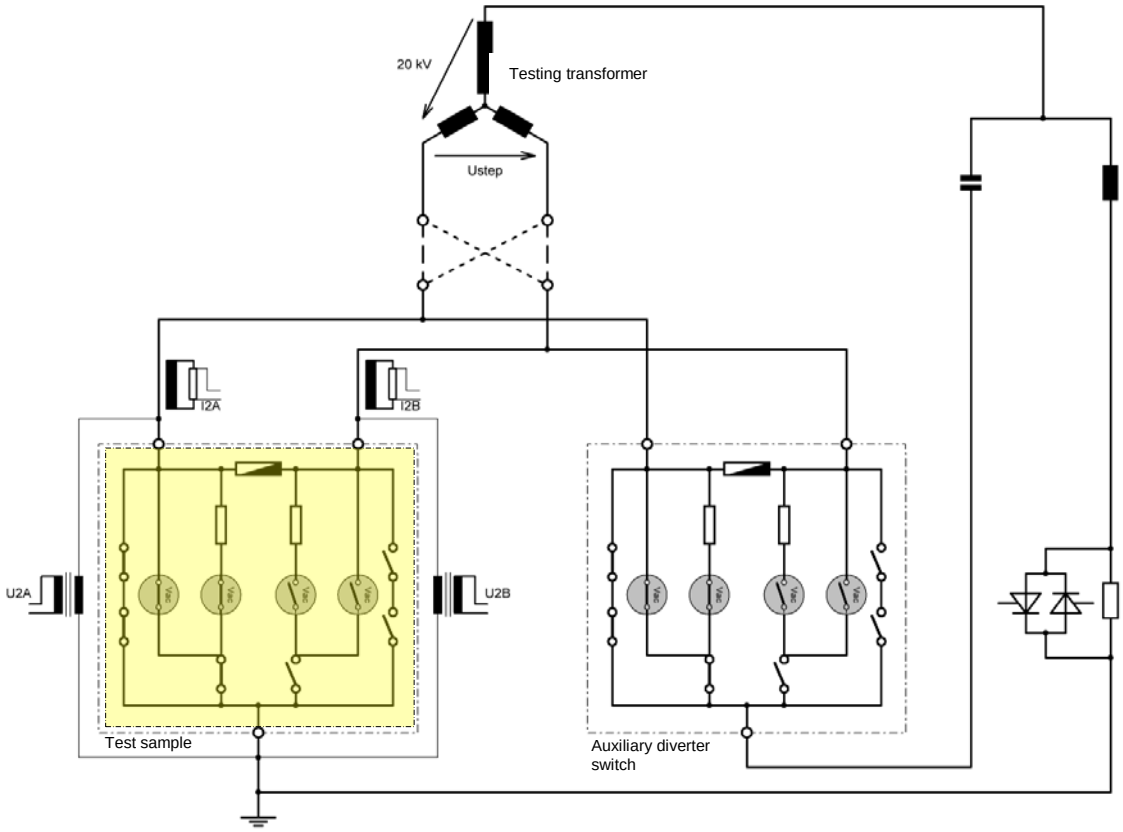


Figure 1a: Test circuit for the service duty test.

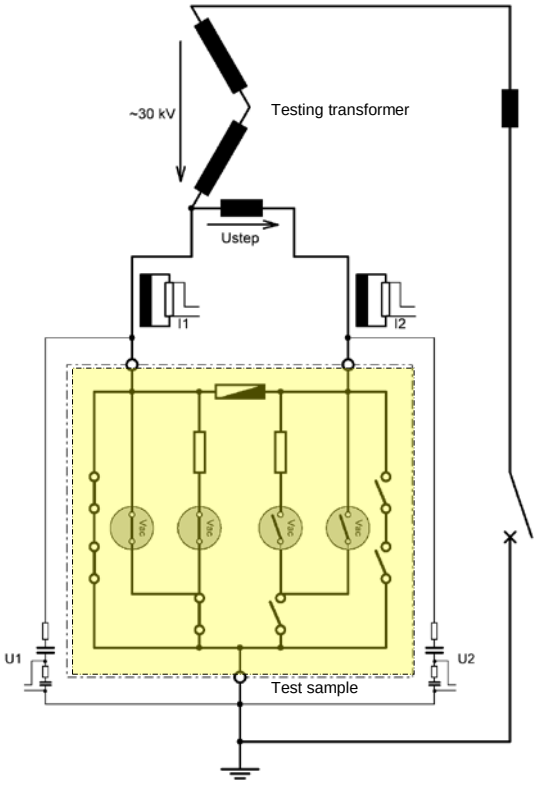
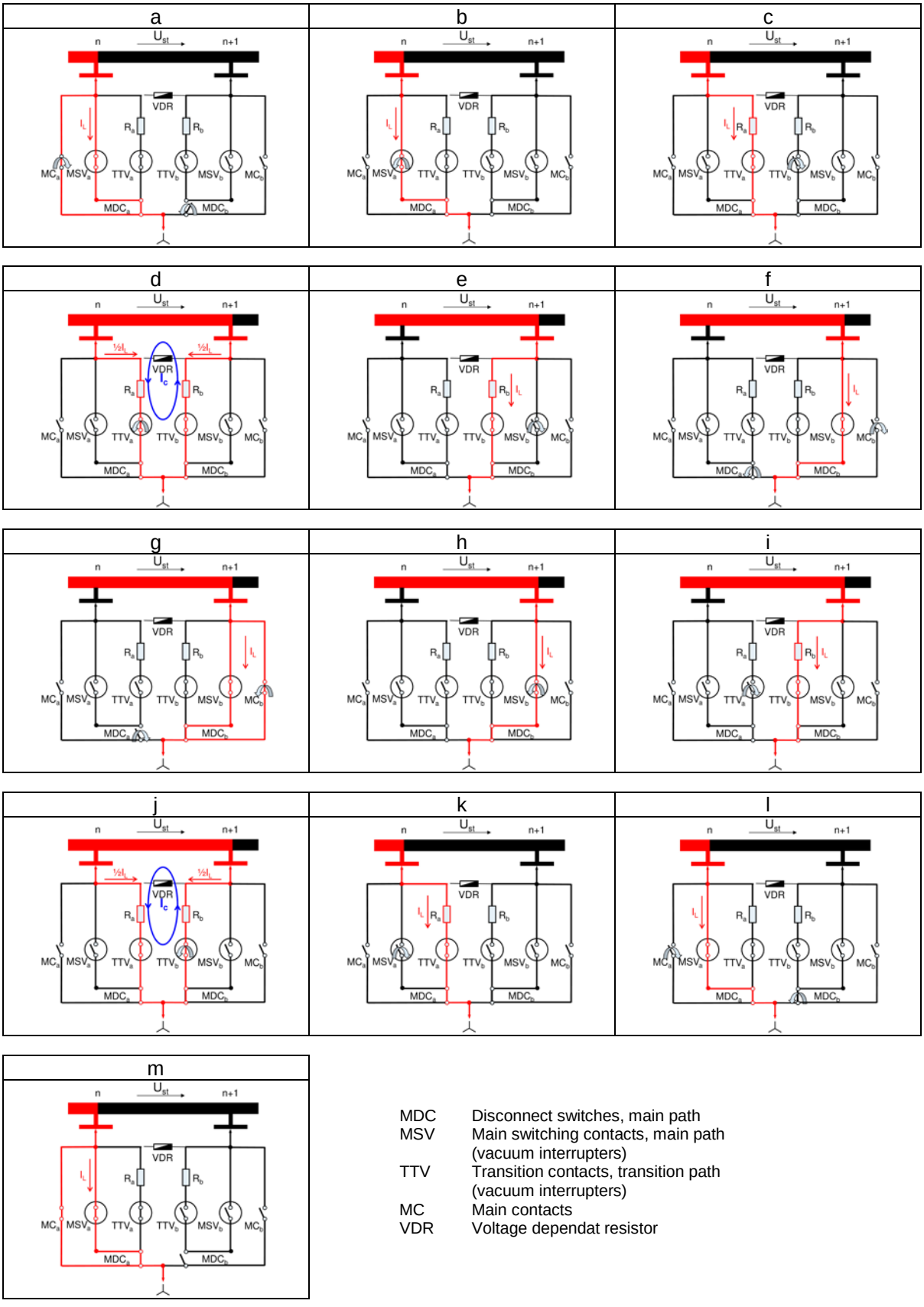


Figure 1b: Test circuit for the breaking capacity test.



MDC	Disconnect switches, main path
MSV	Main switching contacts, main path (vacuum interrupters)
TTV	Transition contacts, transition path (vacuum interrupters)
MC	Main contacts
VDR	Voltage dependat resistor

Figure 2: Switching sequence of diverter switch type VACUTAP® VRS / VRM / VRL / VRH / VRX.

5. Tests performed

According to IEC 60214-1:2014 the number of operations carried out during the service duty test shall be equal to 1.2 times the number of tap-change operations between maintenance according to the manufacturer's handbook but shall not be less than 50,000 operations.
The maintenance interval of diverter switches type VACUTAP® VR is stated to 300,000 operations. Therefore the number of operations at the service duty test shall be 360,000 operations (1.2 x 300,000 operations).
Furthermore, the IEC 60214-1:2014 requires breaking capacity tests determined by the limiting loading points of the application range of the tested type. According to IEC 60214-1:2014 the rated values of these loading points are:

Loading point 1: Maximum rated through-current: 1300 A / Relevant rated step voltage: 4615 V.
Loading point 2: Maximum rated step voltage: 6000 V / Relevant rated through-current: 1000 A.

Therefore the type test was performed in following test sequences:

Test sequence 1: Service duty test
360,000 operations performed at maximum rated through-current (1300 A) and relevant rated step voltage (4615 V).

Test sequence 2: Breaking capacity test
40 switching operations performed at twice maximum rated through-current (2 x 1300 A) and relevant rated step voltage (4615 V).

Test sequence 3: Breaking capacity test
40 switching operations performed at maximum rated step voltage (6000 V) and twice the relevant rated through-current (2 x 1000 A).

Tables 1, 2 and 3 show the tested values of currents and voltages compared with the required values according to IEC 60214-1:2014. The tested values of "step voltage" and "through-current" were higher than the required values in order to cover the breaking currents and recovery voltages of the main switching contacts and the transition contacts for the complete application range and for all transition resistor variants.

The breaking currents and the recovery voltages of the transition contacts are determined by vector addition of through-current and circulating current resp. of step voltage and voltage drop at the transition resistor by through-current. Therefore values depend on the switching direction (i.e. addition = "heavy" or subtraction = "light" operation). Under service conditions 50% of the operations have to be switched with "heavy" and 50% with "light" conditions. In the performed tests only "heavy" operations were evaluated.

	Nominal test values IEC 60214-1:2014	Tested values
Step voltage[4]	4615 V	6364 V
Through-current[4]	1300 A	1366 A
Number of operations	360,000	360,000
Main switching contacts - breaking current[4] - recovery voltage[4] - maximum arcing time[3]	 1300 A 2765 V	 1368 A 3098 V ≤ 10 ms
Transition contacts - breaking current (heavy)[4] - recovery voltage (heavy)[4] - breaking current (light)[4] - recovery voltage (light)[4] - maximum arcing time[3]	 1735 A 7380 V 435 A 1850 V	 2002 A 9397 V 715 A 3291 V ≤ 11 ms
Transition resistor - value - cross section	 2.13 Ω 13.2 mm²	 2.35 Ω 12.0 mm²
Example of oscillogram		See figs. 3.1 … 3.100

Table 1: Test sequence 1 - Tested values compared with required test values according to IEC 60214-1:2014.

	Nominal test values IEC 60214-1:2014	Tested values
Step voltage[4]	4615 V	5450 V
Through-current[4]	2600 A	3028 A
Number of operations	40	40
Main switching contacts - breaking current[4] - recovery voltage[4] - maximum arcing time[3]	 2600 A 5530 V	 3020 A 5678 V ≤ 11 ms
Transition contacts - breaking current (heavy)[4] - recovery voltage (heavy)[4] - breaking current (light)[4] - recovery voltage (light)[4] - maximum arcing time[3]	 2385 A 10146 V 215 A 915 V	 2586 A 10866 V 472 A 2402 V ≤ 11 ms
Transition resistor - value - cross section	 2.13 Ω 13.2 mm²	 2.29 Ω 12.0 mm²
Example of oscillogram		See figs. 4.1 … 4.40

Table 2: Test sequence 2 - Tested values compared with required test values according to IEC 60214-1:2014.

	Nominal test values IEC 60214-1:2014	Tested values
Step voltage[4]	6000 V	6311 V
Through-current[4]	2000 A	2300 A
Number of operations	40	40
Main switching contacts - breaking current[4] - recovery voltage[4] - maximum arcing time[3]	 2000 A 4690 V	 2294 A 4835 V ≤ 11 ms
Transition contacts - breaking current (heavy)[4] - recovery voltage (heavy)[4] - breaking current (light)[4] - recovery voltage (light)[4] - maximum arcing time[3]	 2279 A 10690 V 279 A 1310 V	 2370 A 10857 V 274 A 1721 V < 12 ms
Transition resistor - value - cross section	 2.35 Ω 12.0 mm²	 2.47 Ω 10.8 mm²
Example of oscillogram		See figs. 5.1 … 5.40

Table 3: Test sequence 3 - Tested values compared with required test values according to IEC 60214-1:2014.

[3] Arcing times automatically evaluated by transient recorder, example see fig. 3.1.

[4] Mean values.

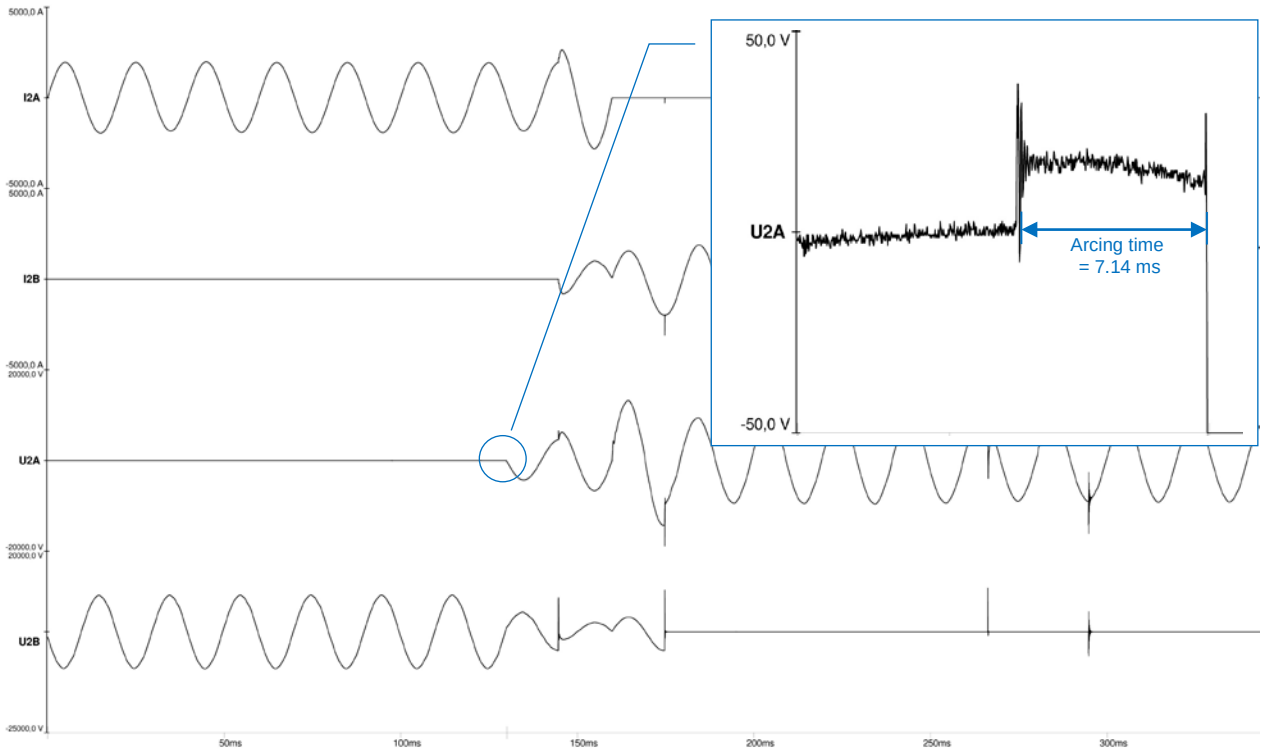


Fig. 3.1: Service duty test (test sequence 1 – switching operation no. 514).

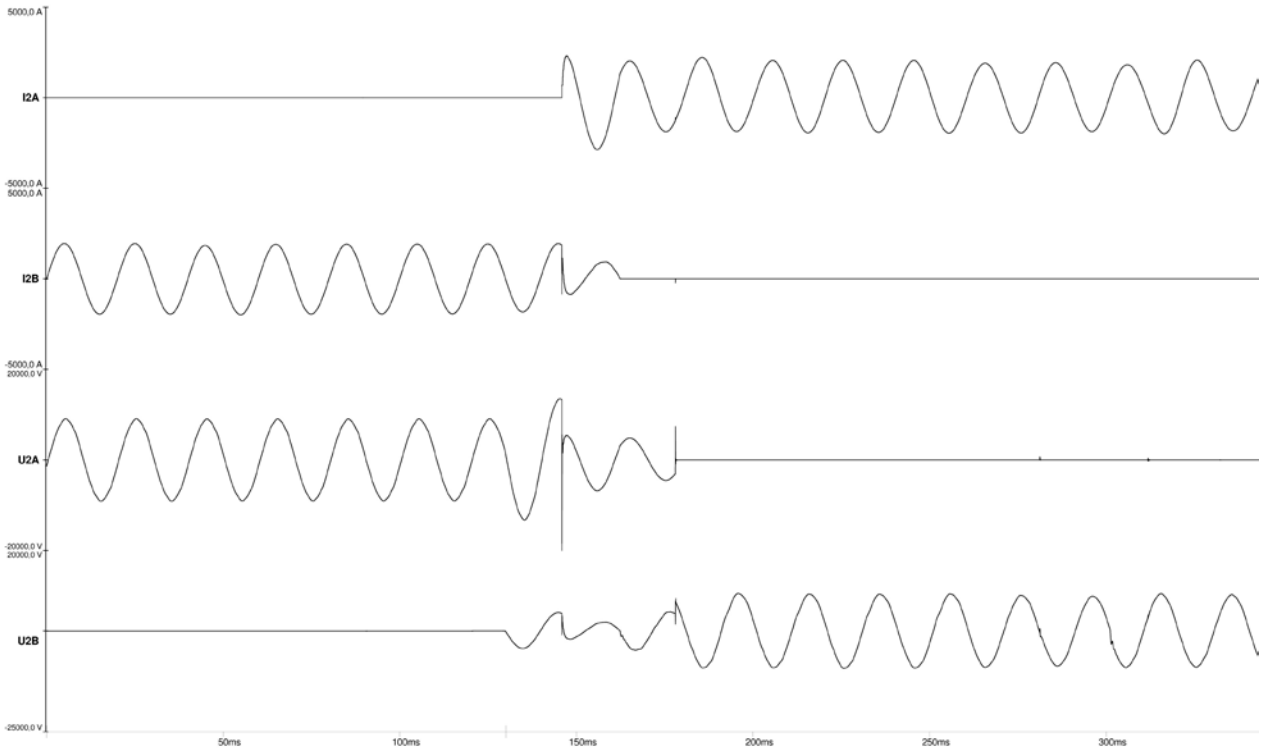


Fig. 3.2: Service duty test (test sequence 1 – switching operation no. 515).

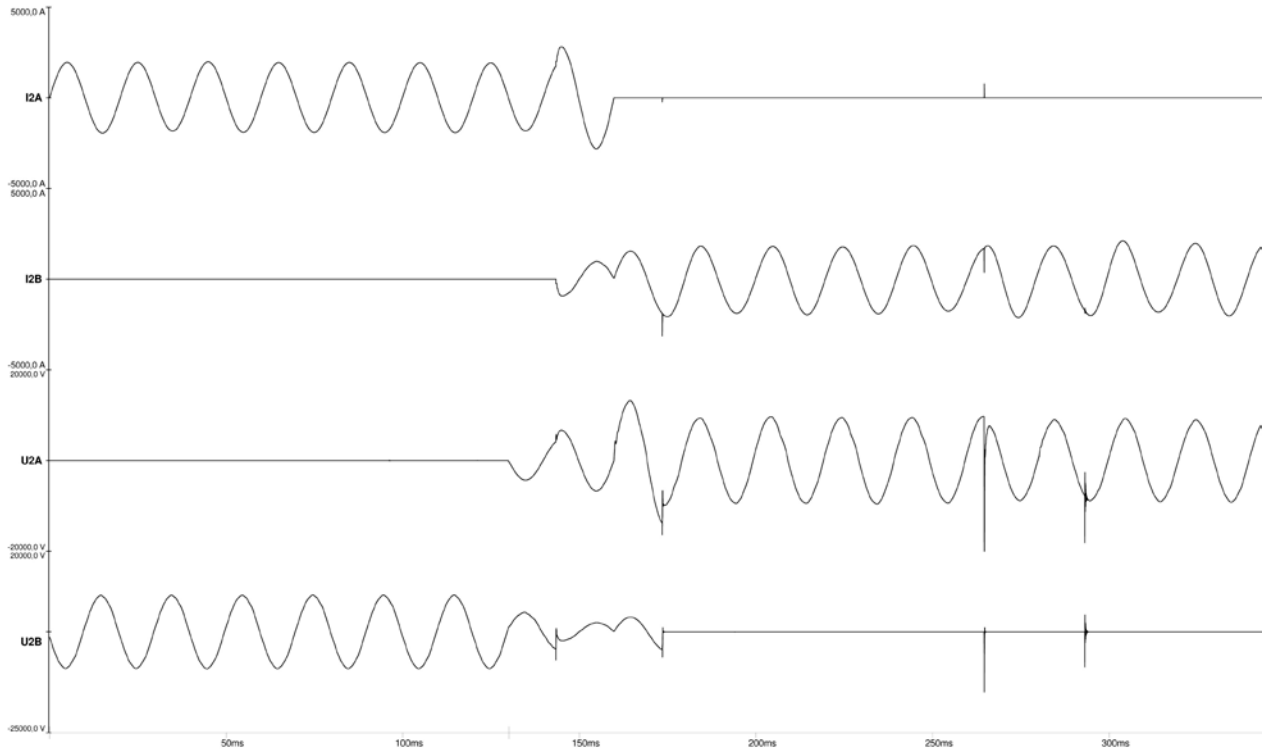


Fig. 3.3: Service duty test (test sequence 1 – switching operation no. 516).

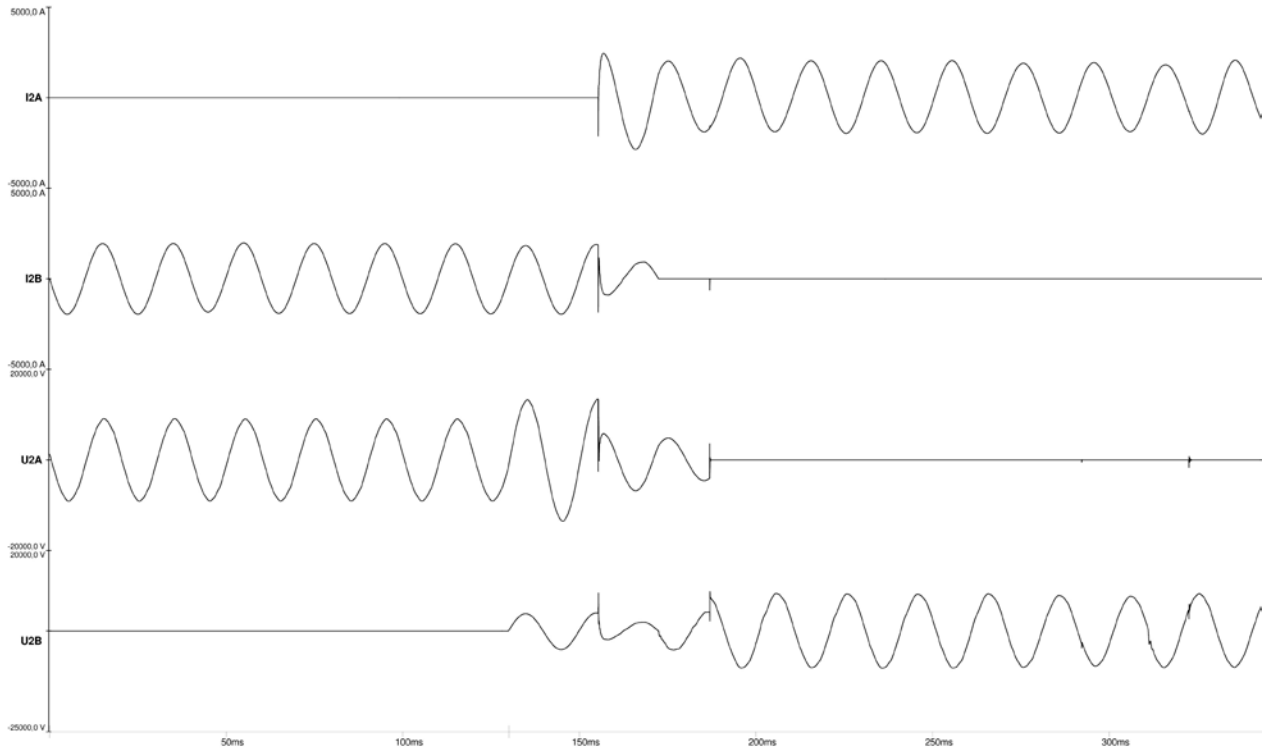


Fig. 3.4: Service duty test (test sequence 1 – switching operation no. 517).

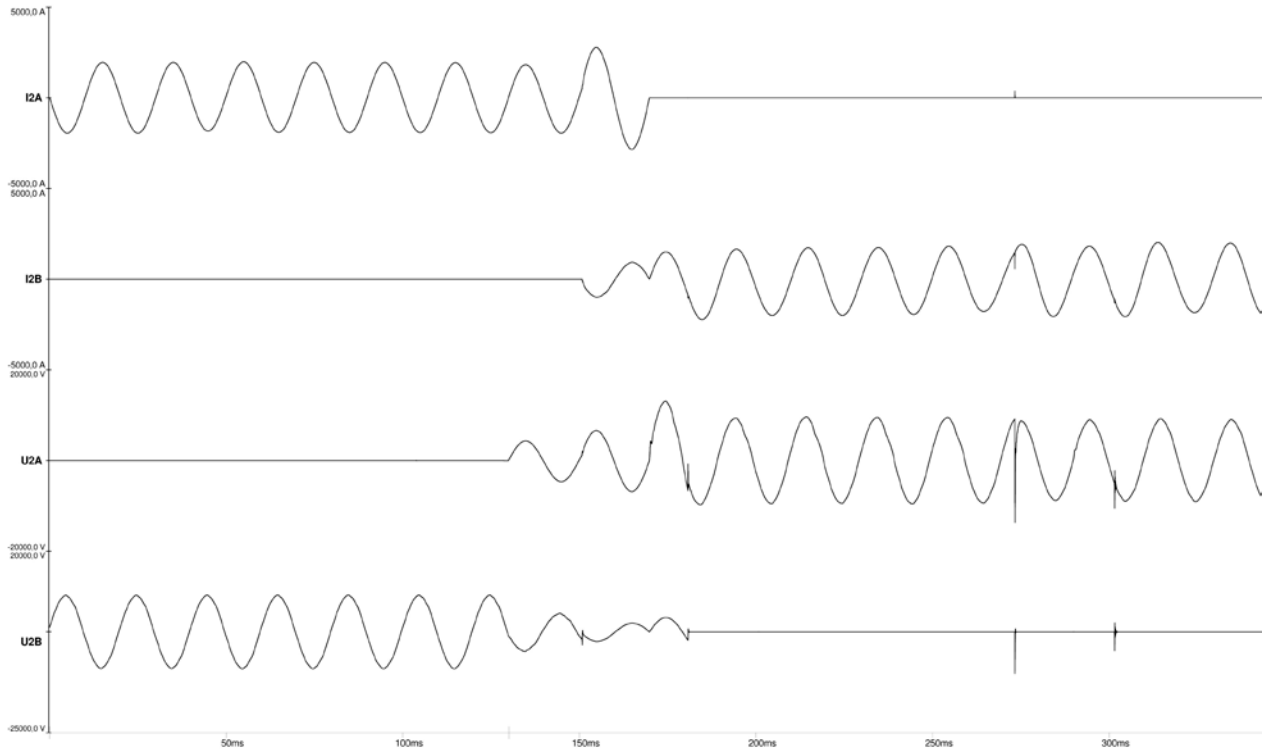


Fig. 3.5: Service duty test (test sequence 1 – switching operation no. 518).

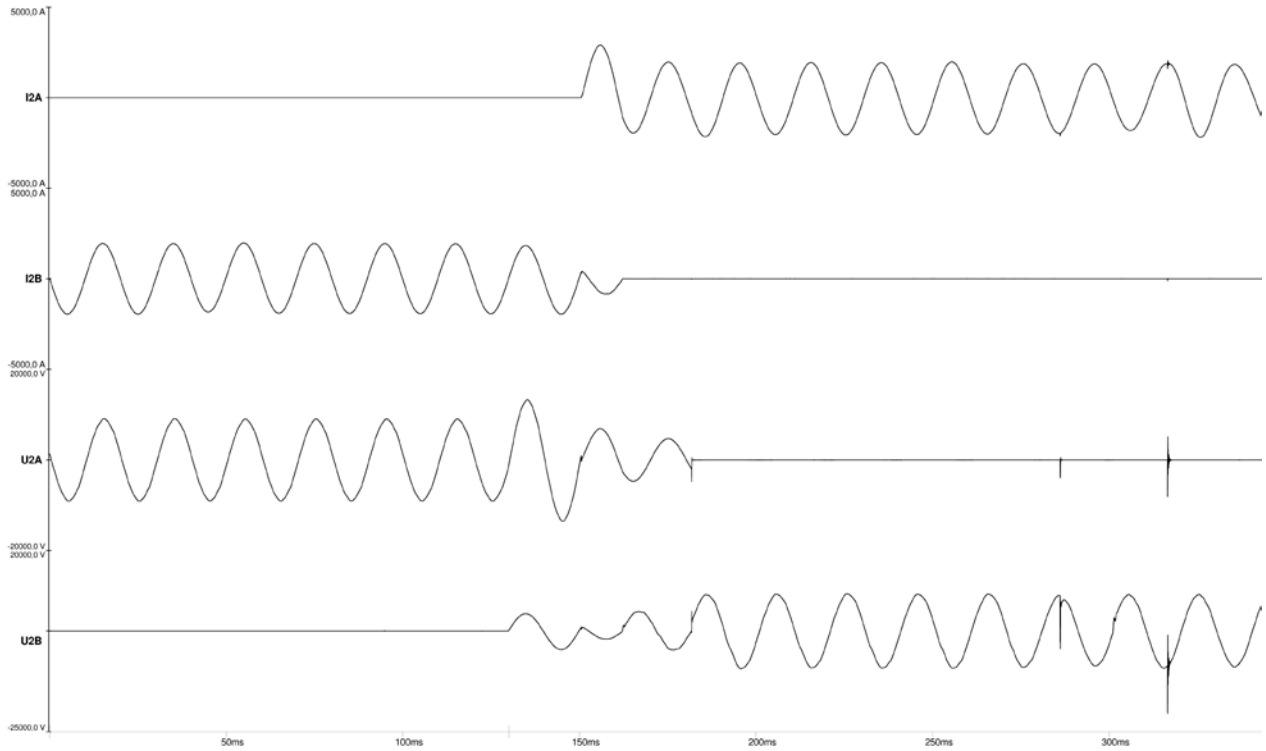


Fig. 3.6: Service duty test (test sequence 1 – switching operation no. 519).

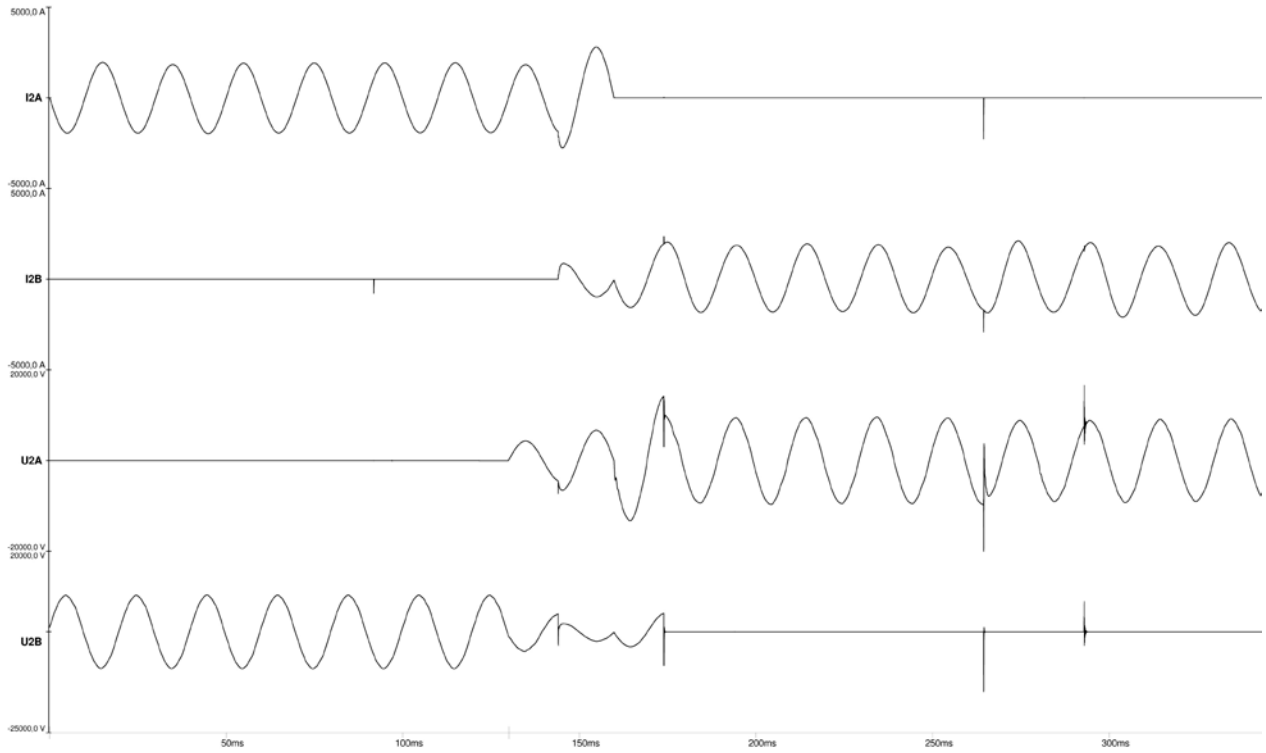


Fig. 3.7: Service duty test (test sequence 1 – switching operation no. 520).

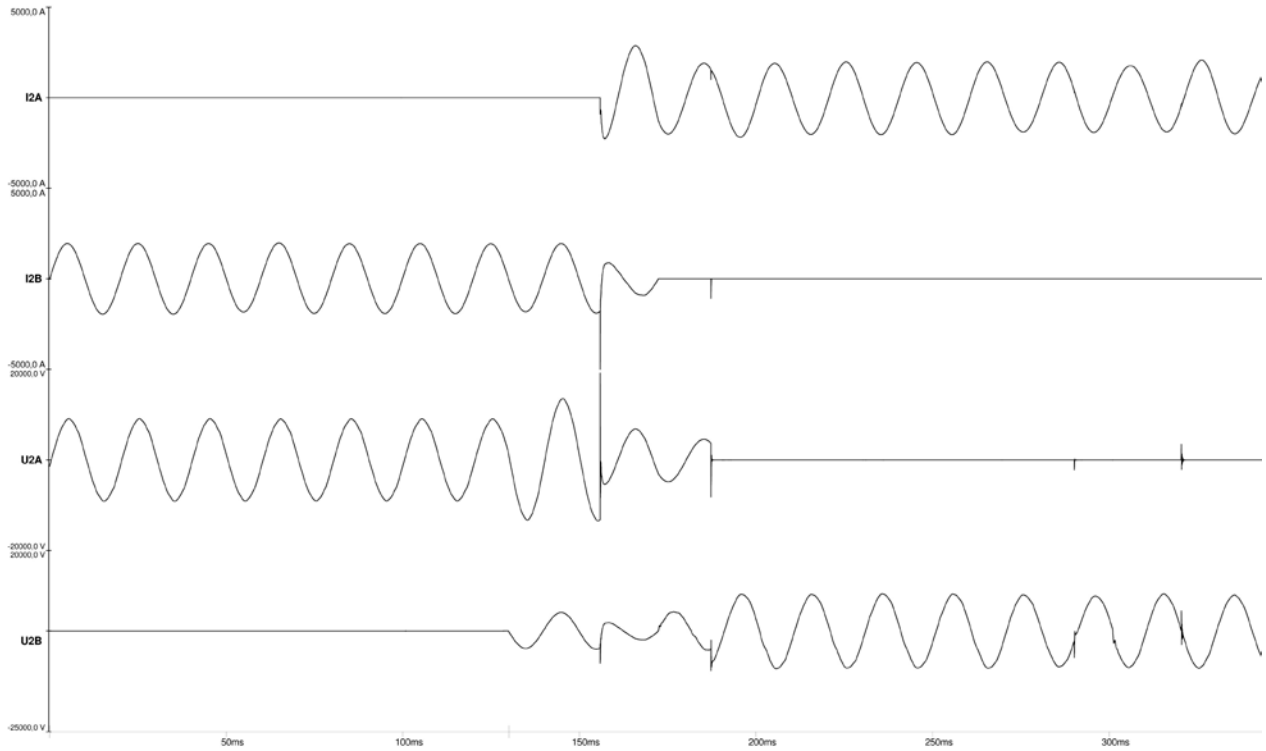


Fig. 3.8: Service duty test (test sequence 1 – switching operation no. 521).

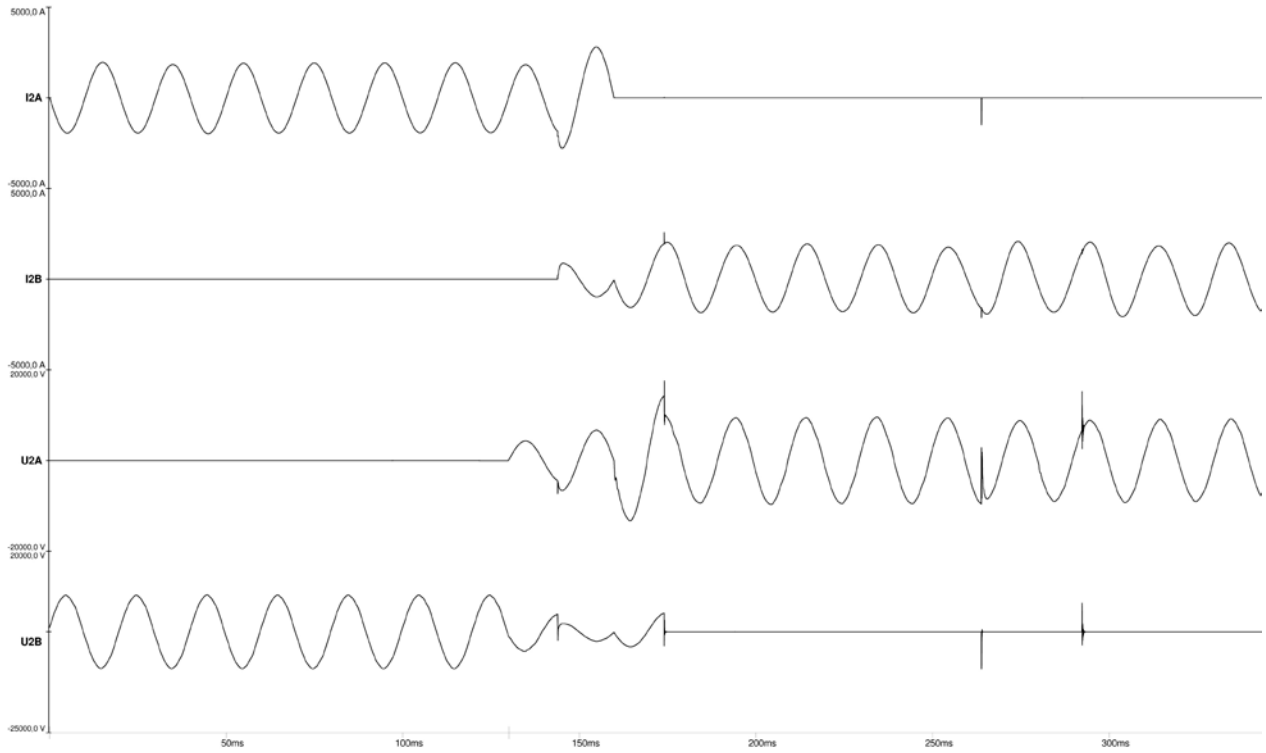


Fig. 3.9: Service duty test (test sequence 1 – switching operation no. 522).

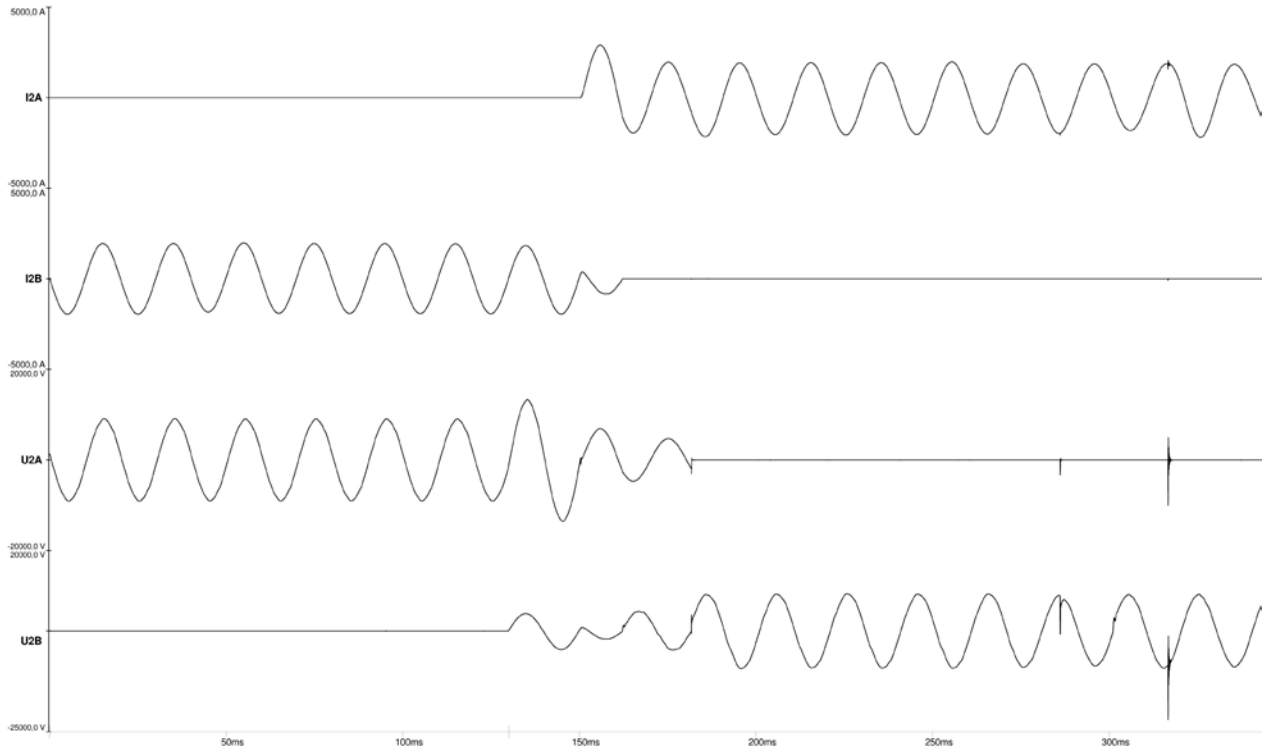


Fig. 3.10: Service duty test (test sequence 1 – switching operation no. 523).

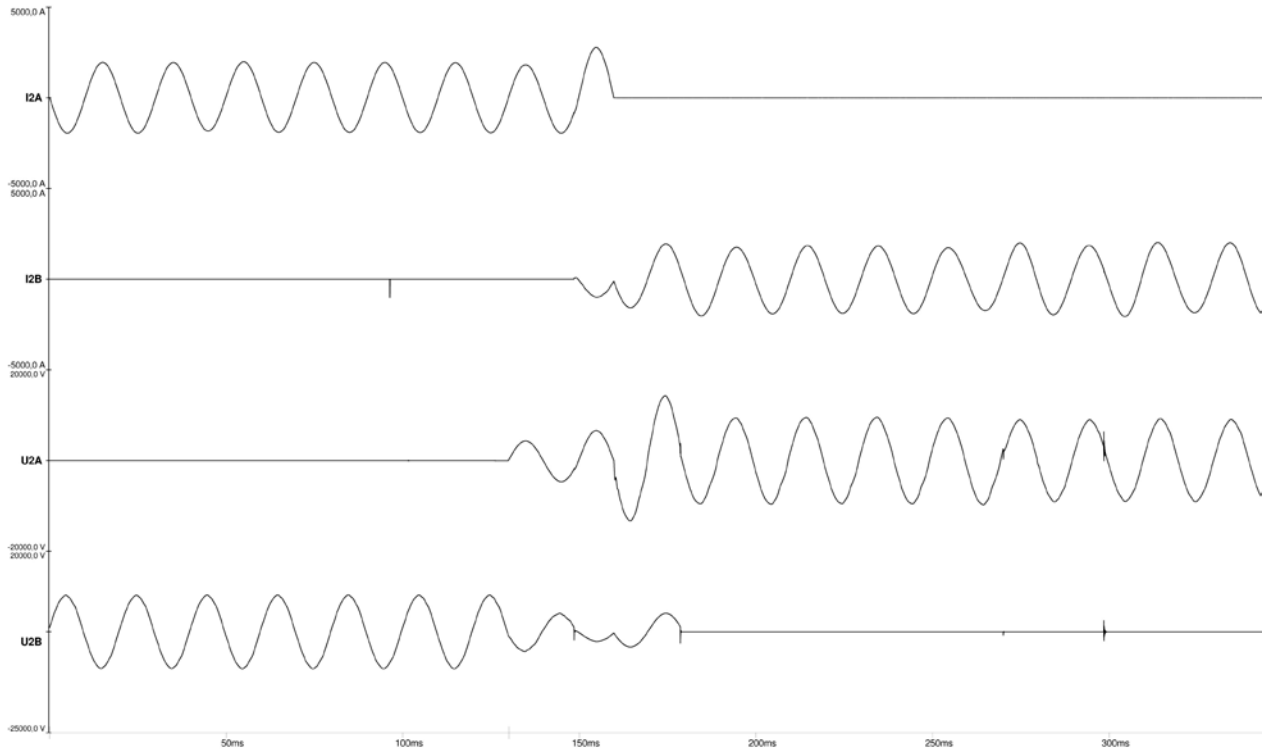


Fig. 3.11: Service duty test (test sequence 1 – switching operation no. 524).

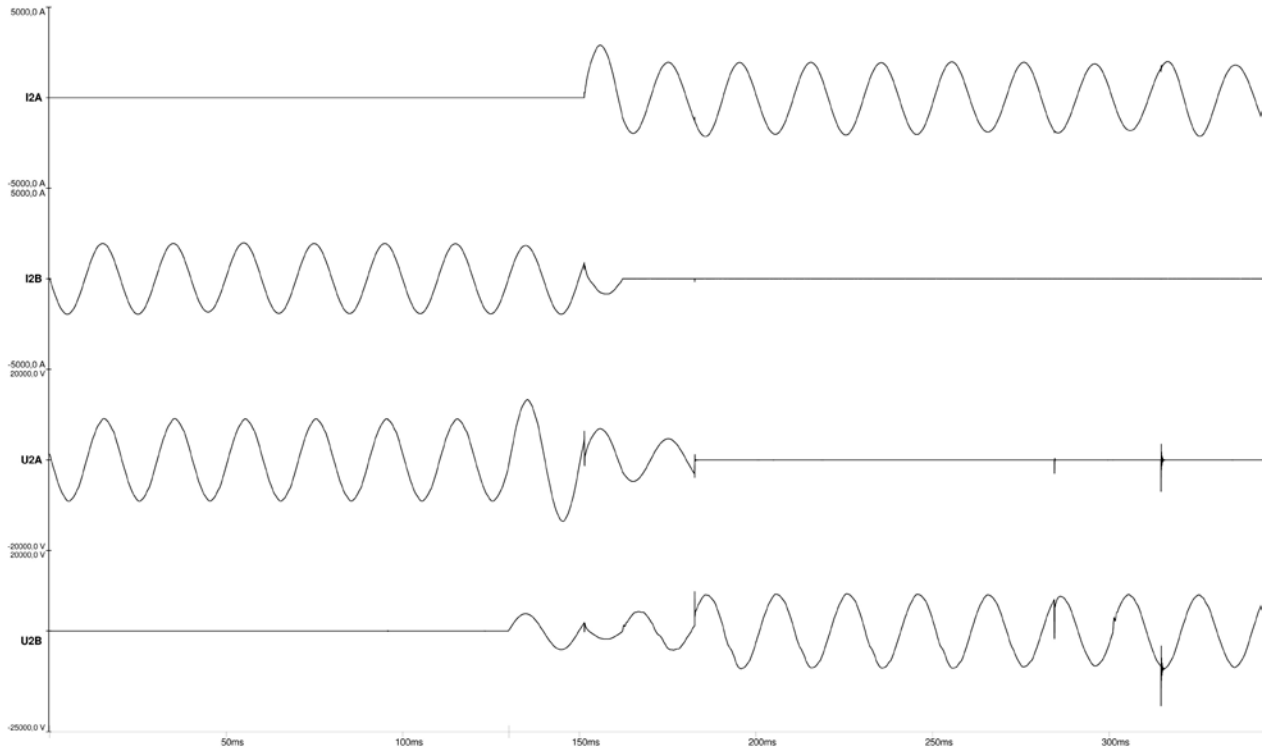


Fig. 3.12: Service duty test (test sequence 1 – switching operation no. 525).

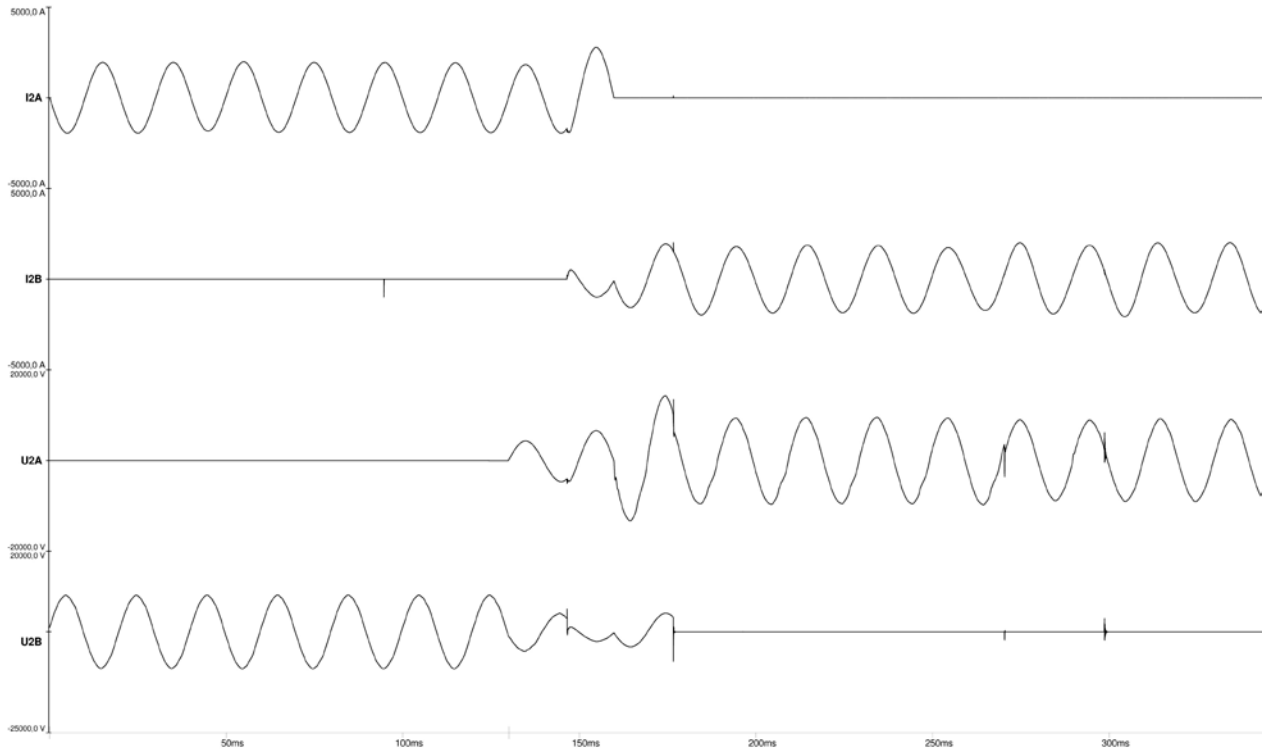


Fig. 3.13: Service duty test (test sequence 1 – switching operation no. 526).

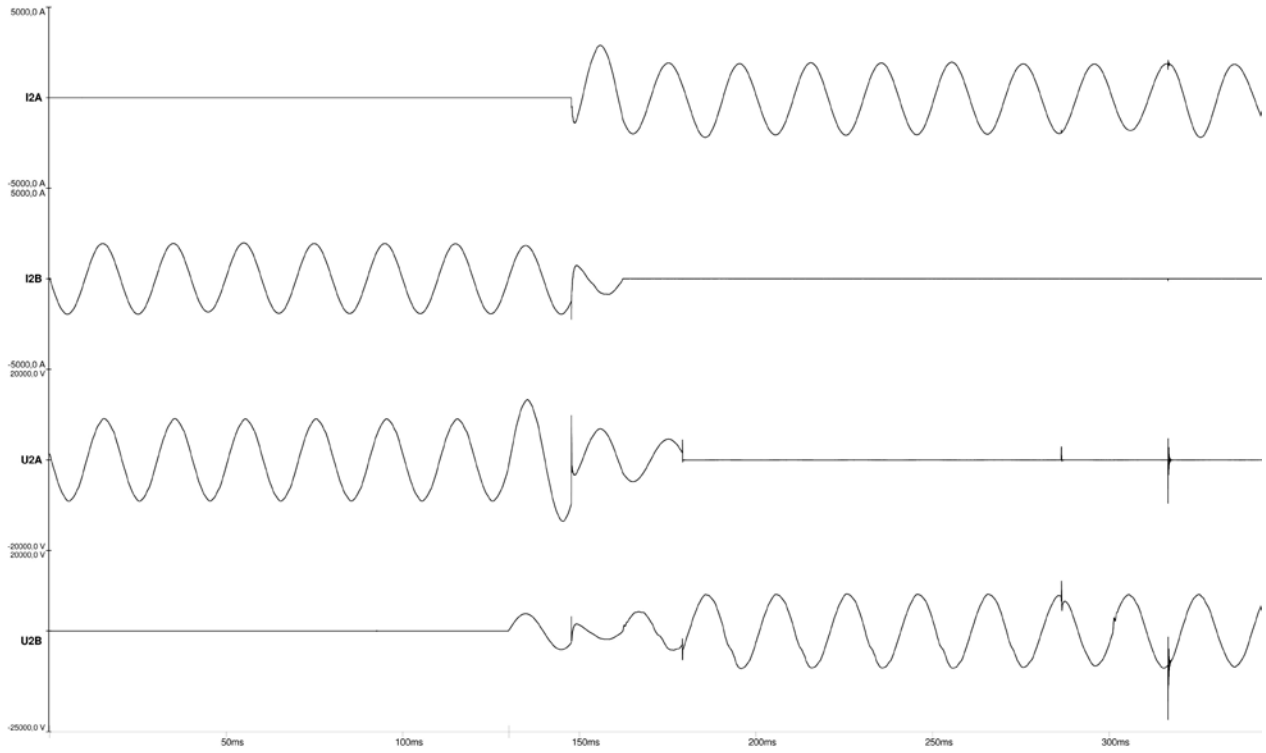


Fig. 3.14: Service duty test (test sequence 1 – switching operation no. 527).

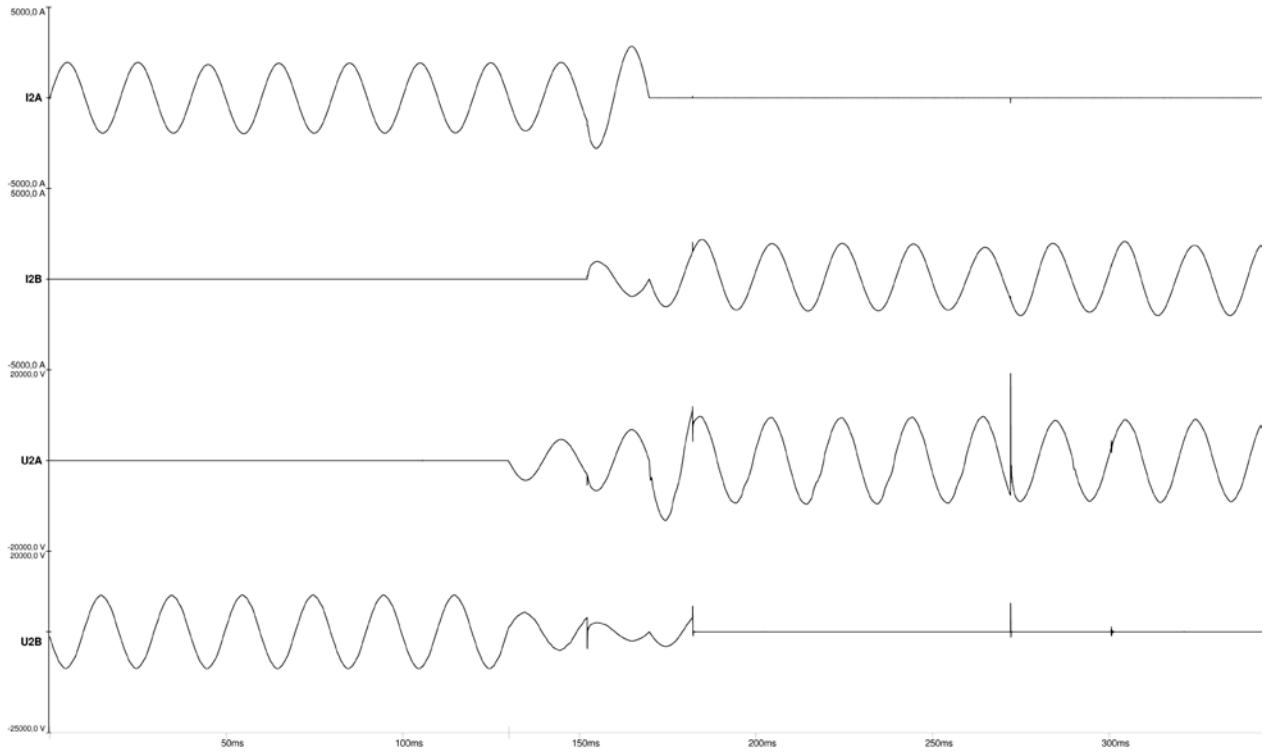


Fig. 3.15: Service duty test (test sequence 1 – switching operation no. 528).

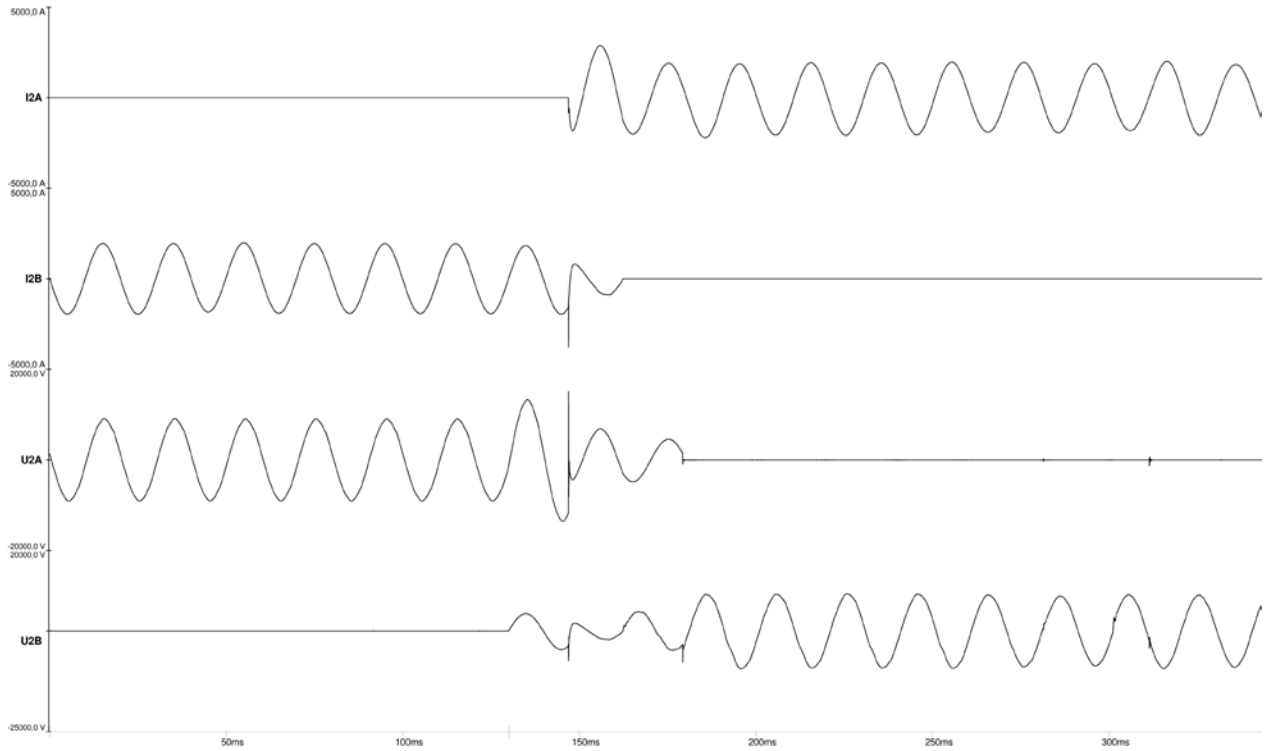


Fig. 3.16: Service duty test (test sequence 1 – switching operation no. 529).

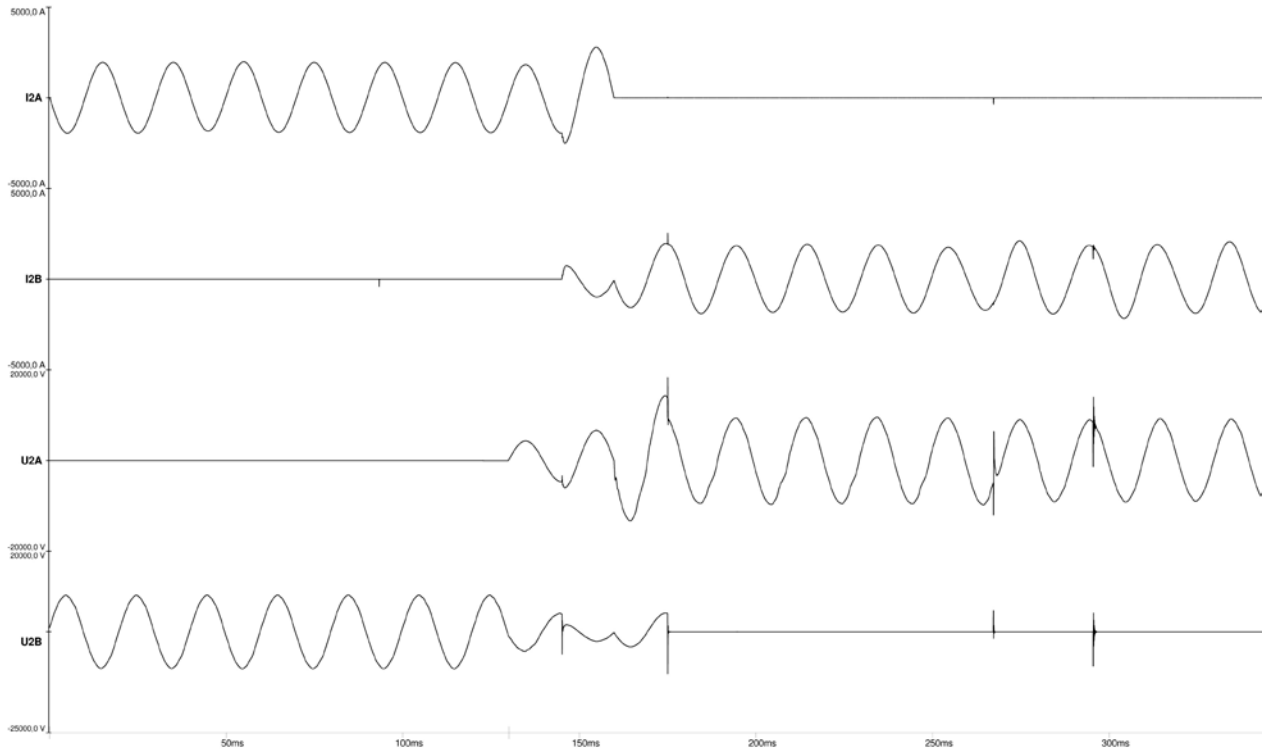


Fig. 3.17: Service duty test (test sequence 1 – switching operation no. 530).

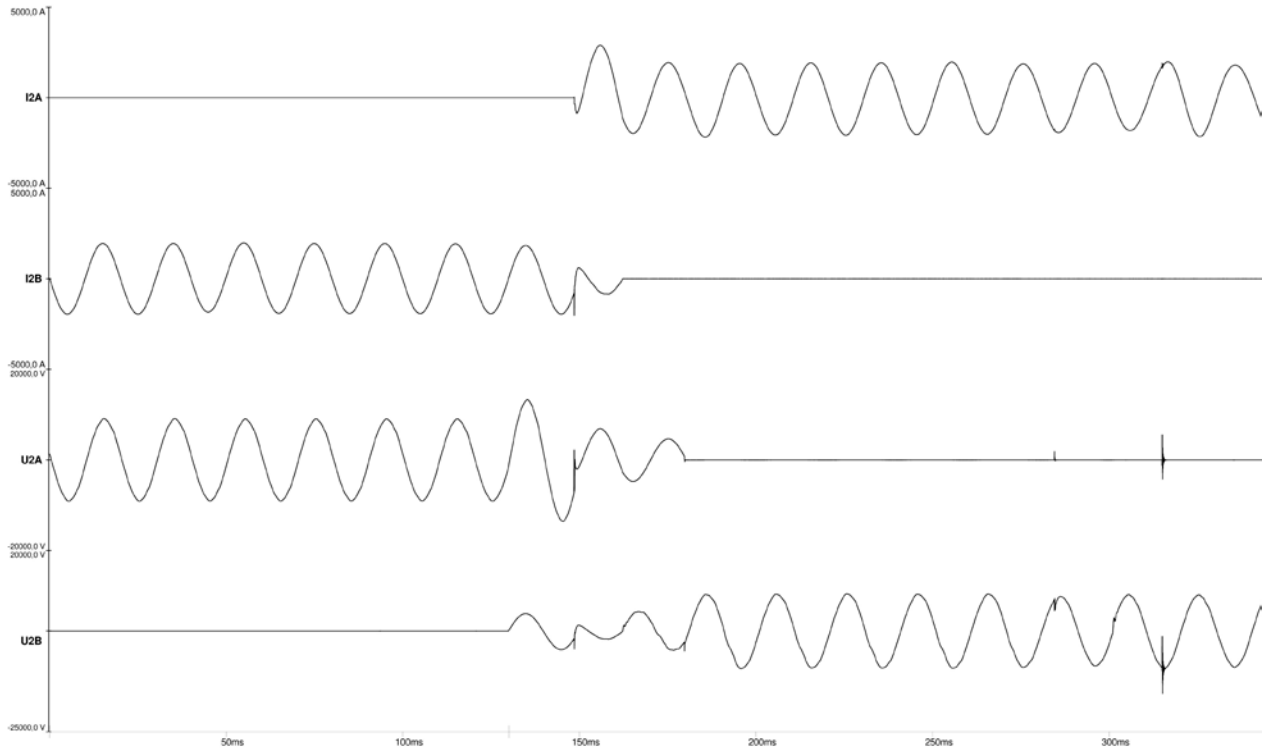


Fig. 3.18: Service duty test (test sequence 1 – switching operation no. 531).

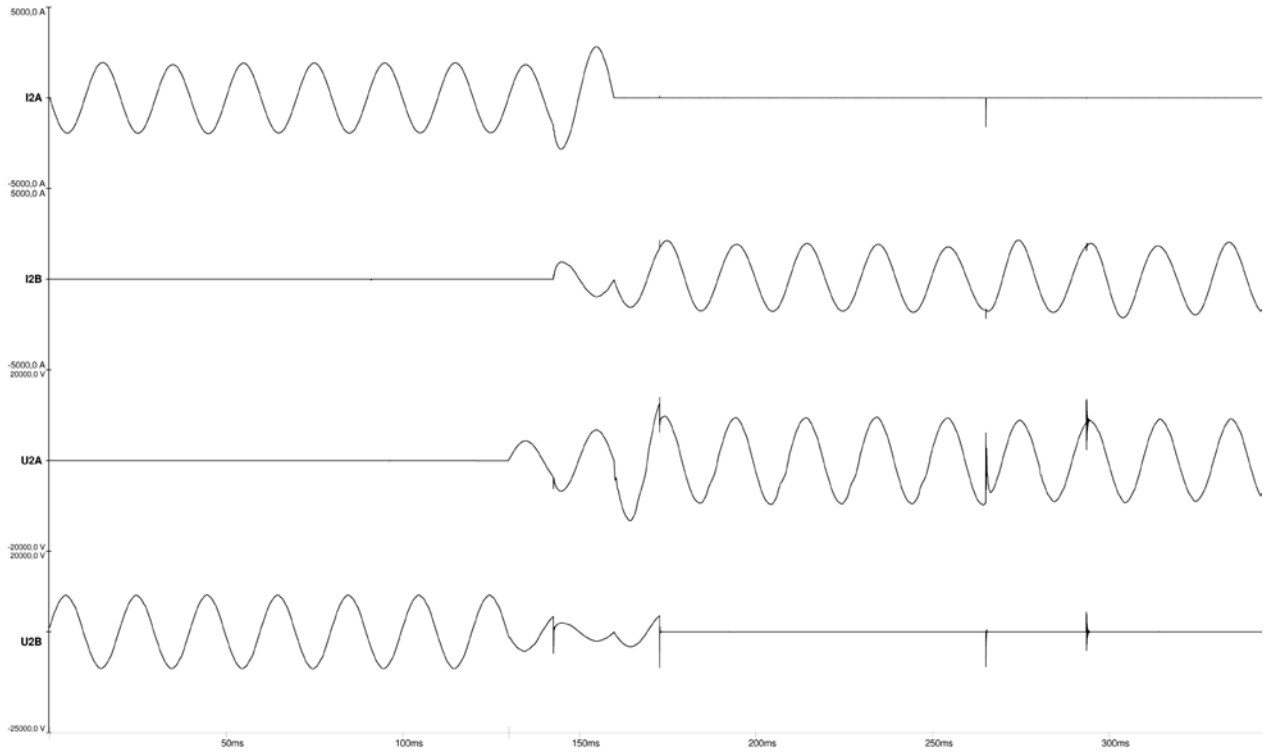


Fig. 3.19: Service duty test (test sequence 1 – switching operation no. 532).

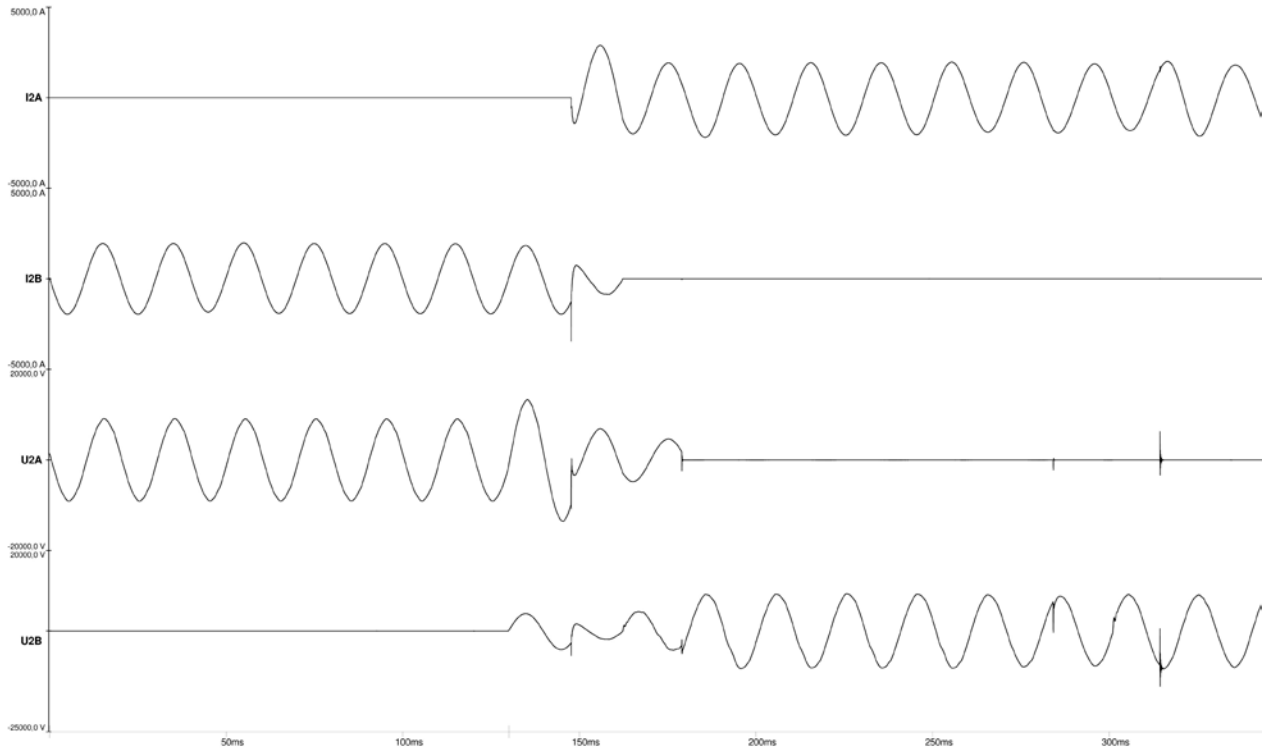


Fig. 3.20: Service duty test (test sequence 1 – switching operation no. 533).

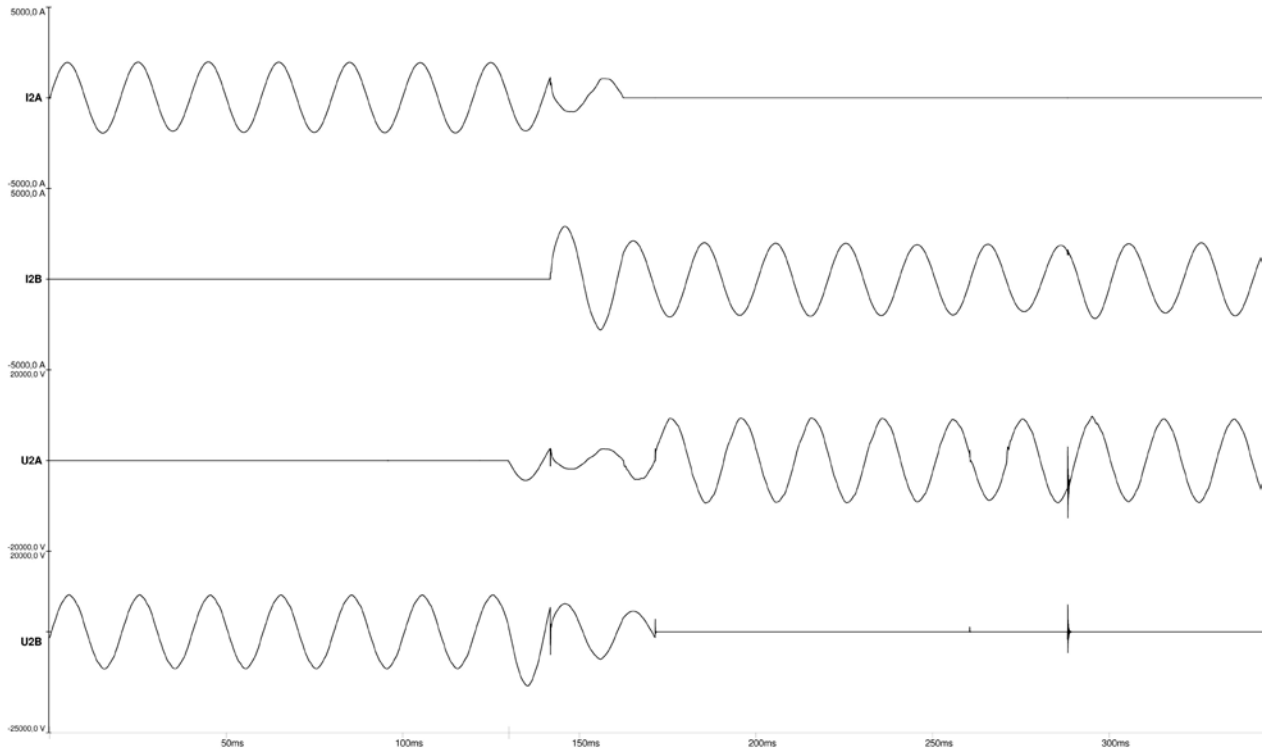


Fig. 3.21: Service duty test (test sequence 1 – switching operation no. 90574).

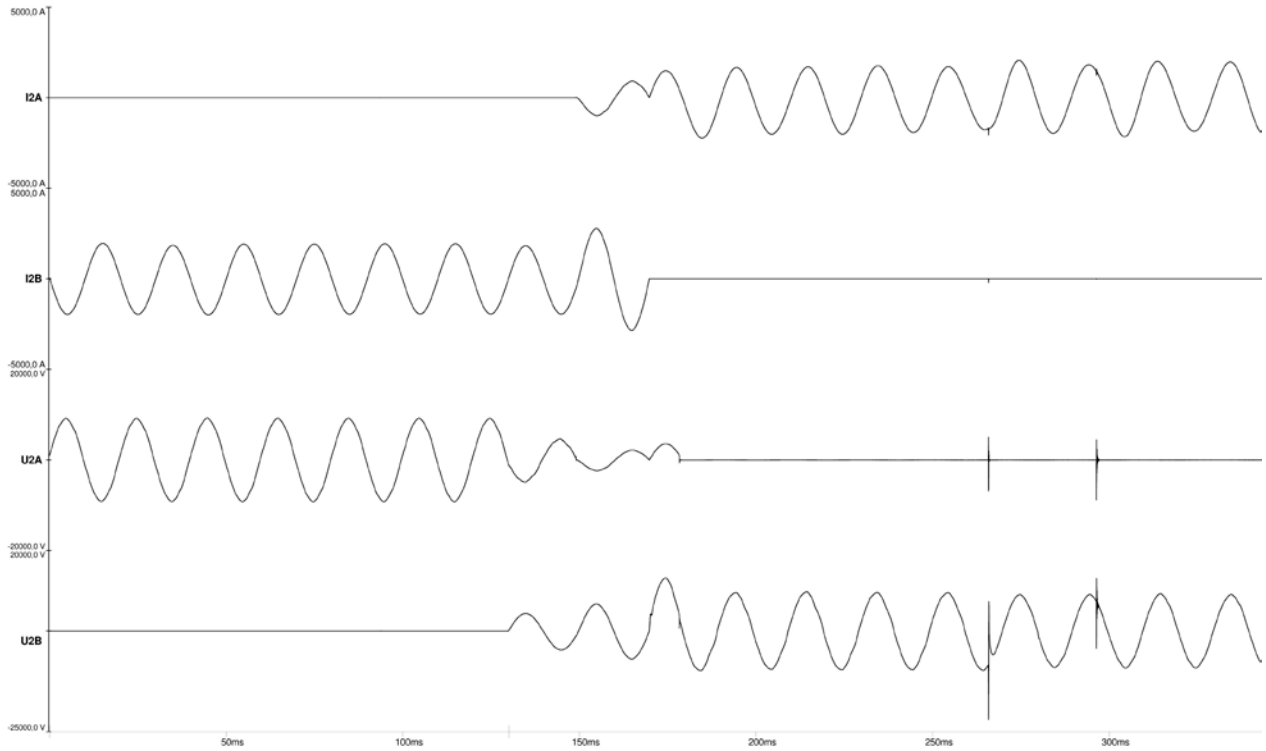


Fig. 3.22: Service duty test (test sequence 1 – switching operation no. 90575).

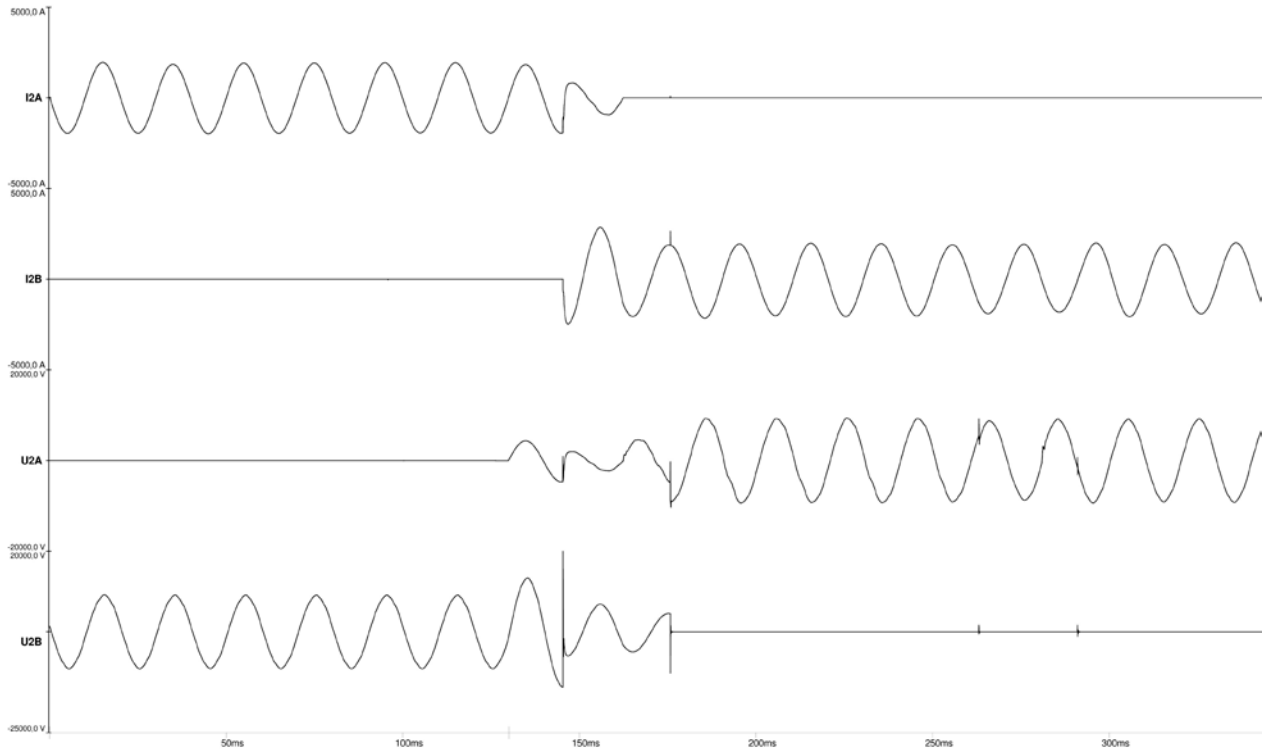


Fig. 3.23: Service duty test (test sequence 1 – switching operation no. 90576).

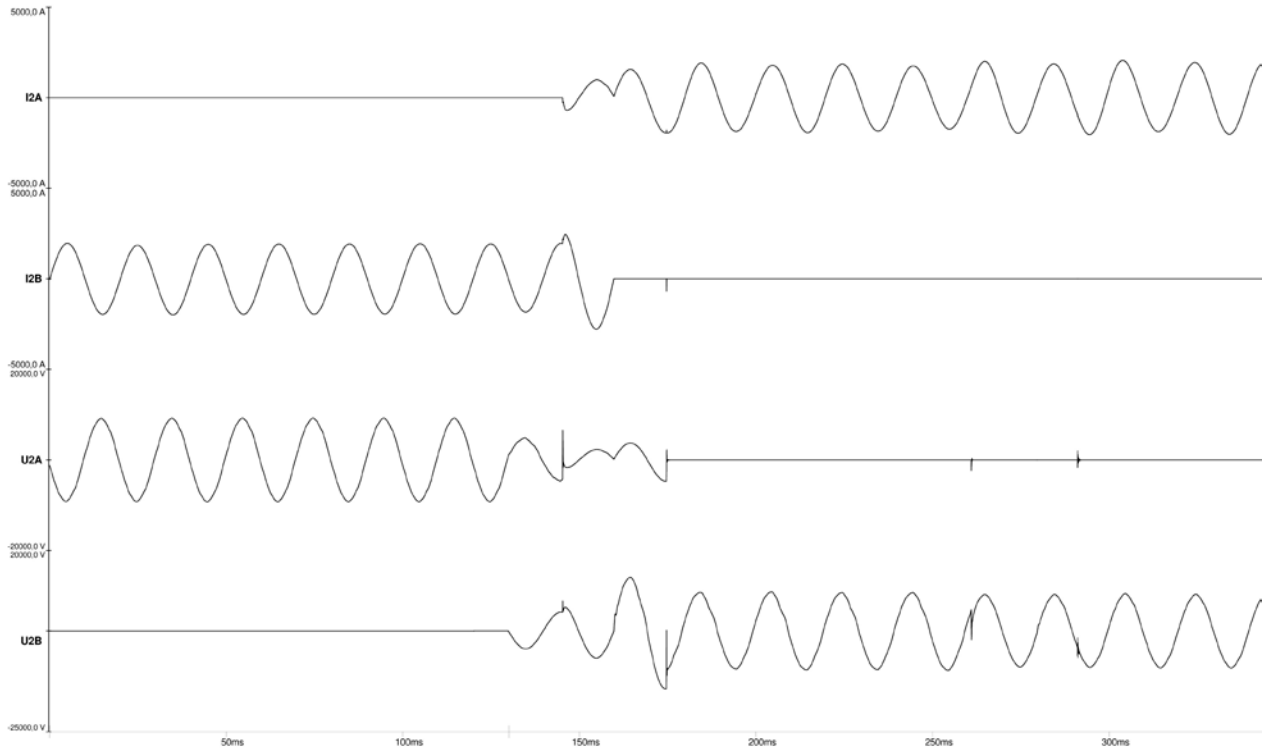


Fig. 3.24: Service duty test (test sequence 1 – switching operation no. 90577).

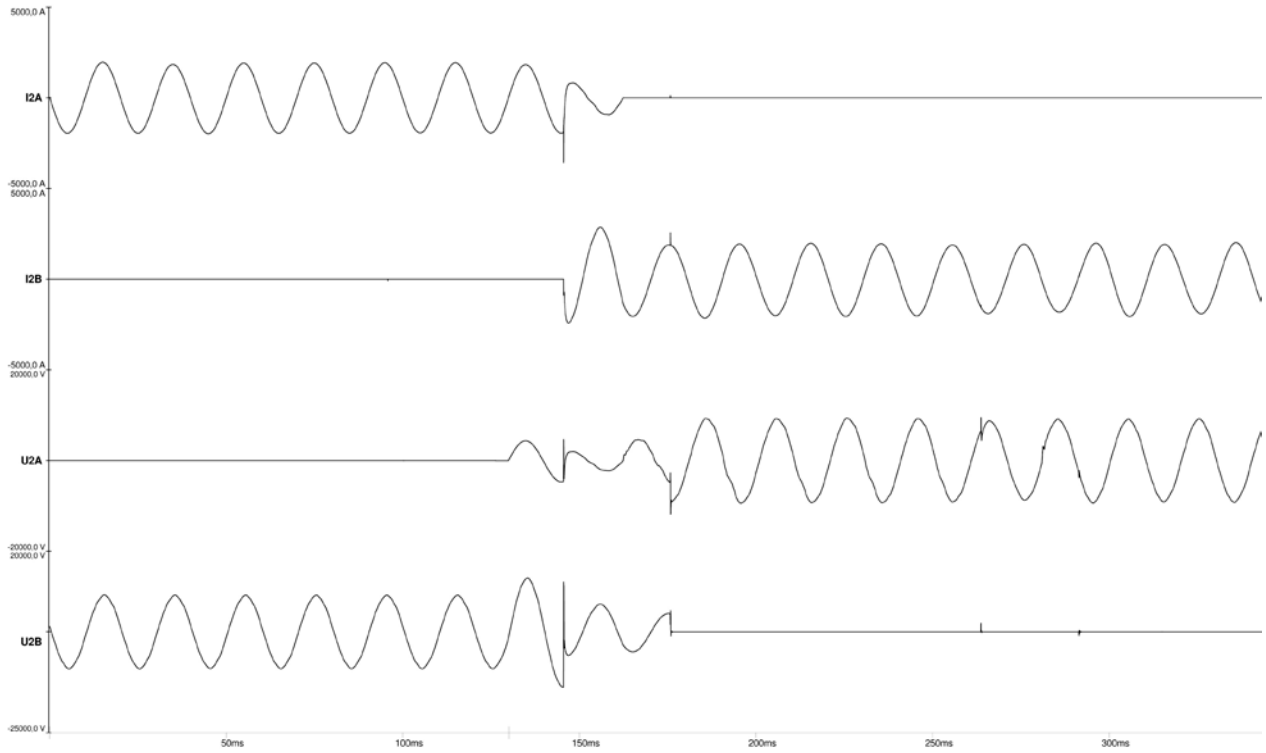


Fig. 3.25: Service duty test (test sequence 1 – switching operation no. 90578).

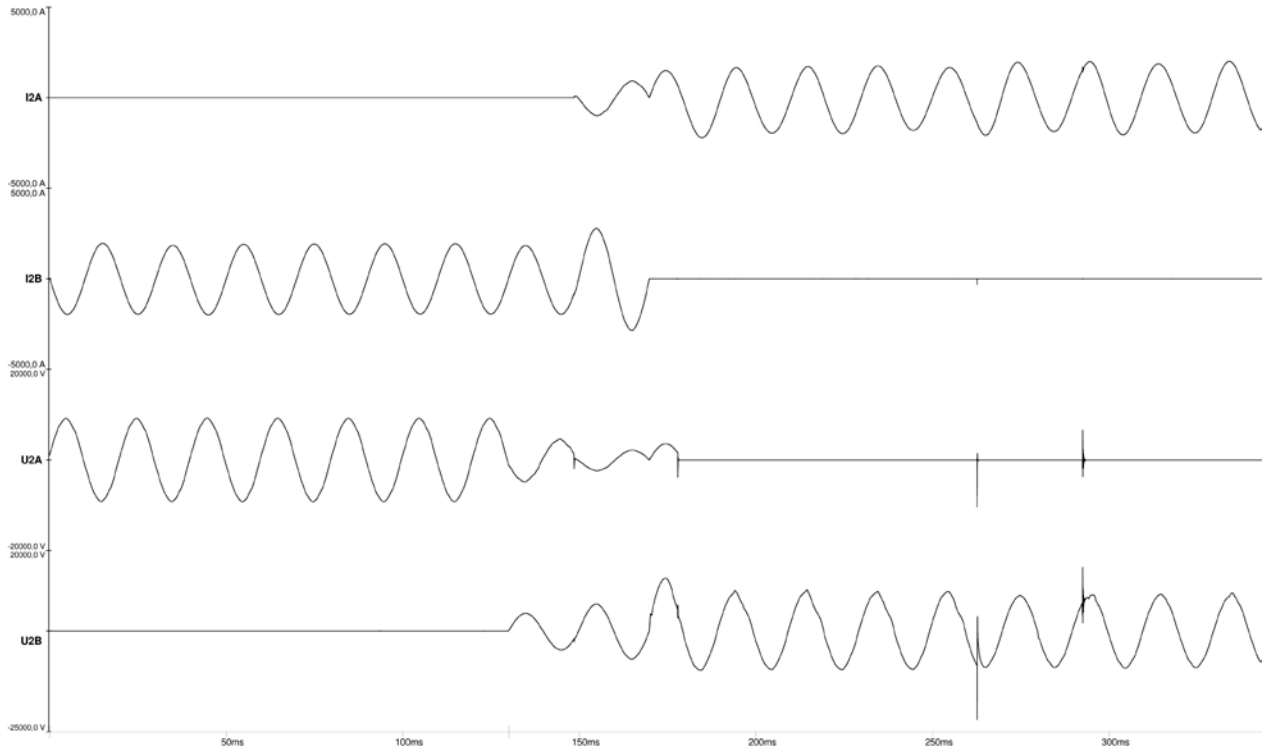


Fig. 3.26: Service duty test (test sequence 1 – switching operation no. 90579).

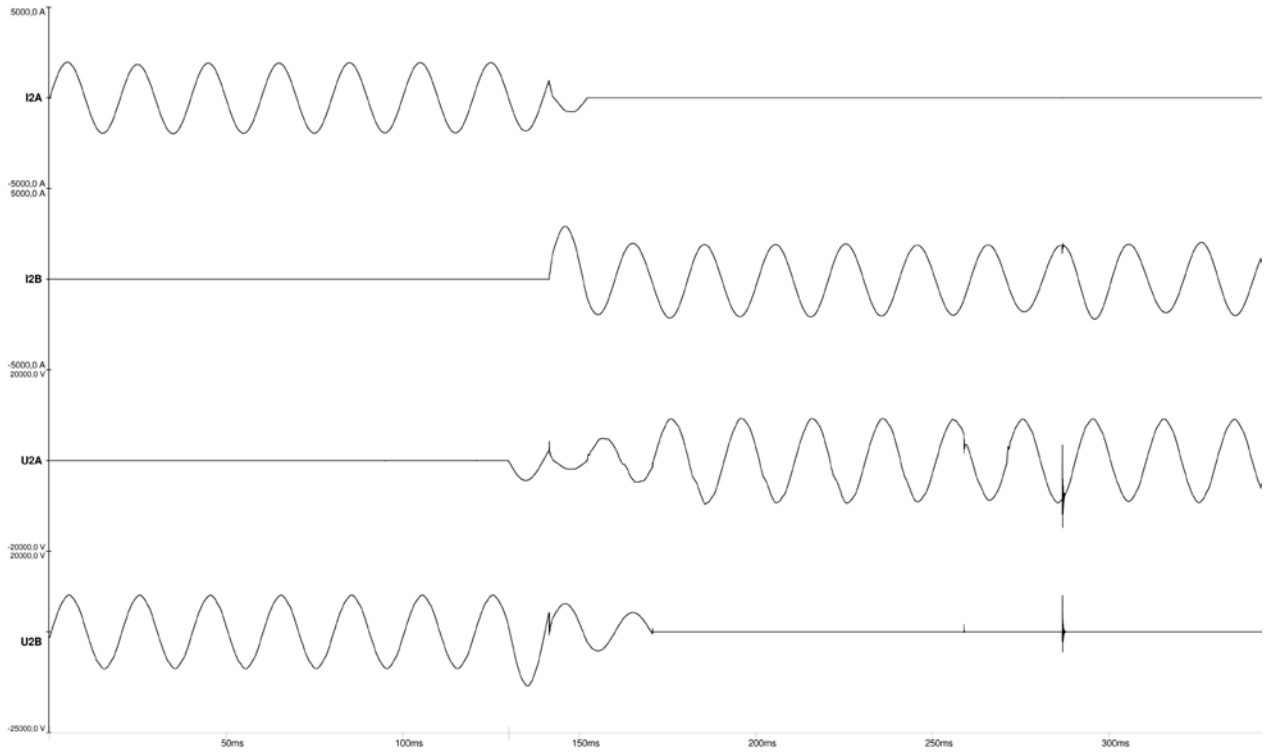


Fig. 3.27: Service duty test (test sequence 1 – switching operation no. 90580).

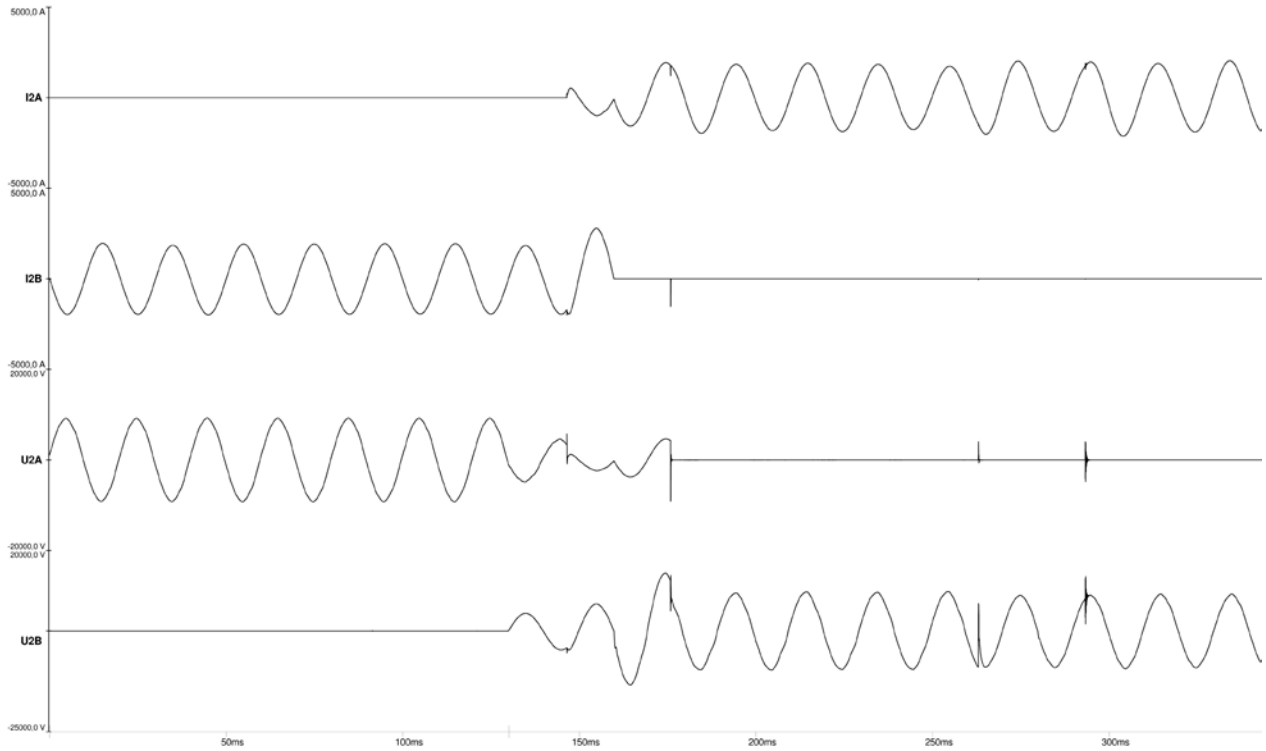


Fig. 3.28: Service duty test (test sequence 1 – switching operation no. 90581).

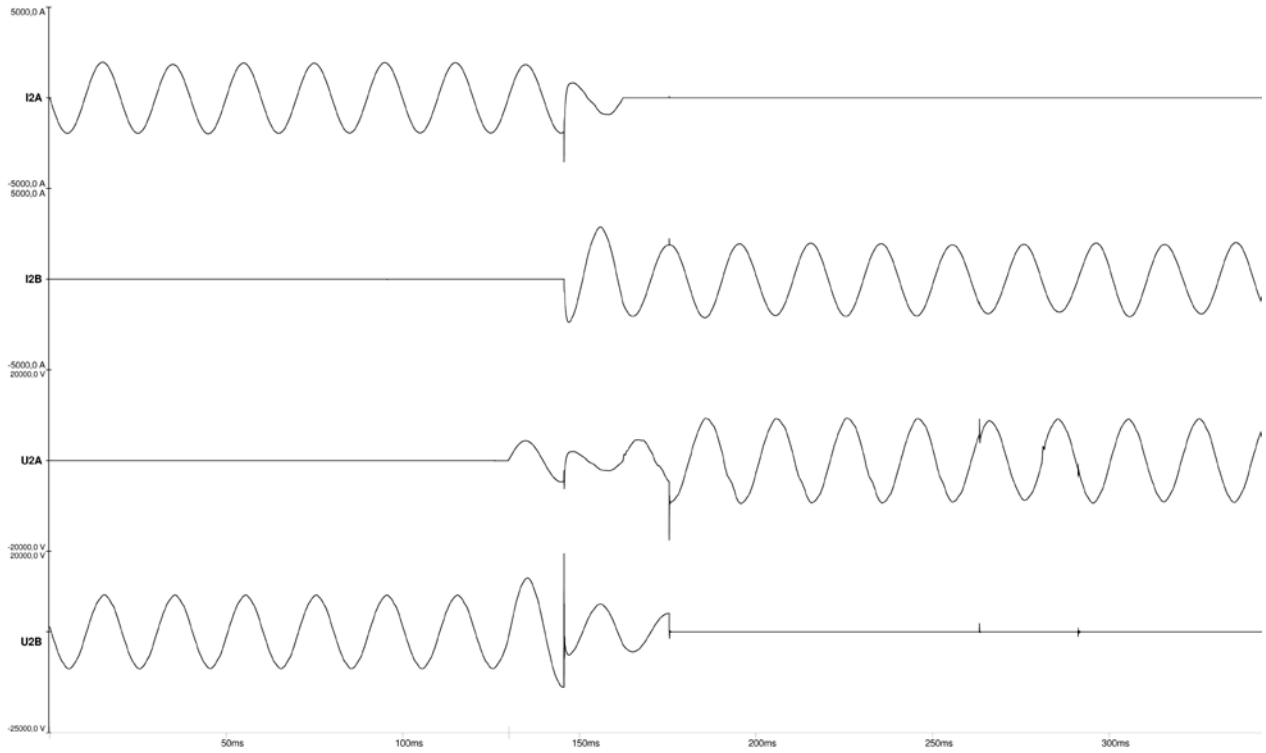


Fig. 3.29: Service duty test (test sequence 1 – switching operation no. 90582).

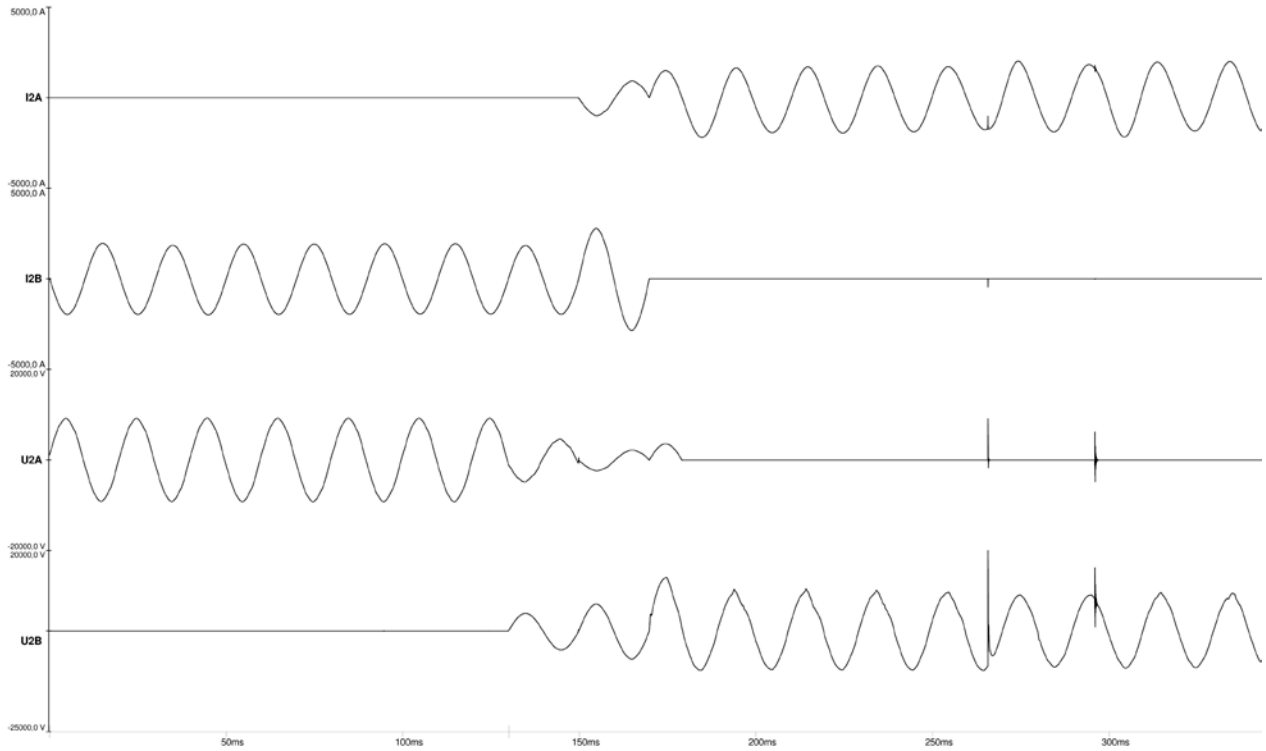


Fig. 3.30: Service duty test (test sequence 1 – switching operation no. 90583).

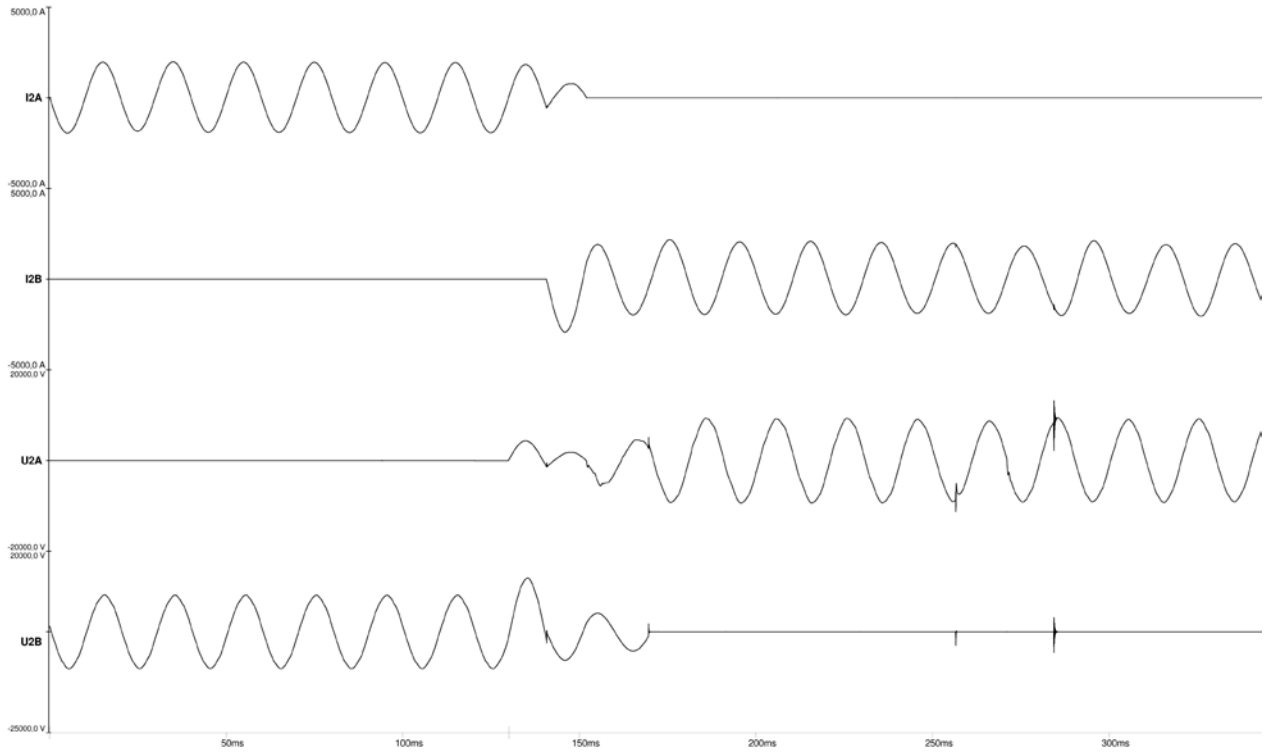


Fig. 3.31: Service duty test (test sequence 1 – switching operation no. 90584).

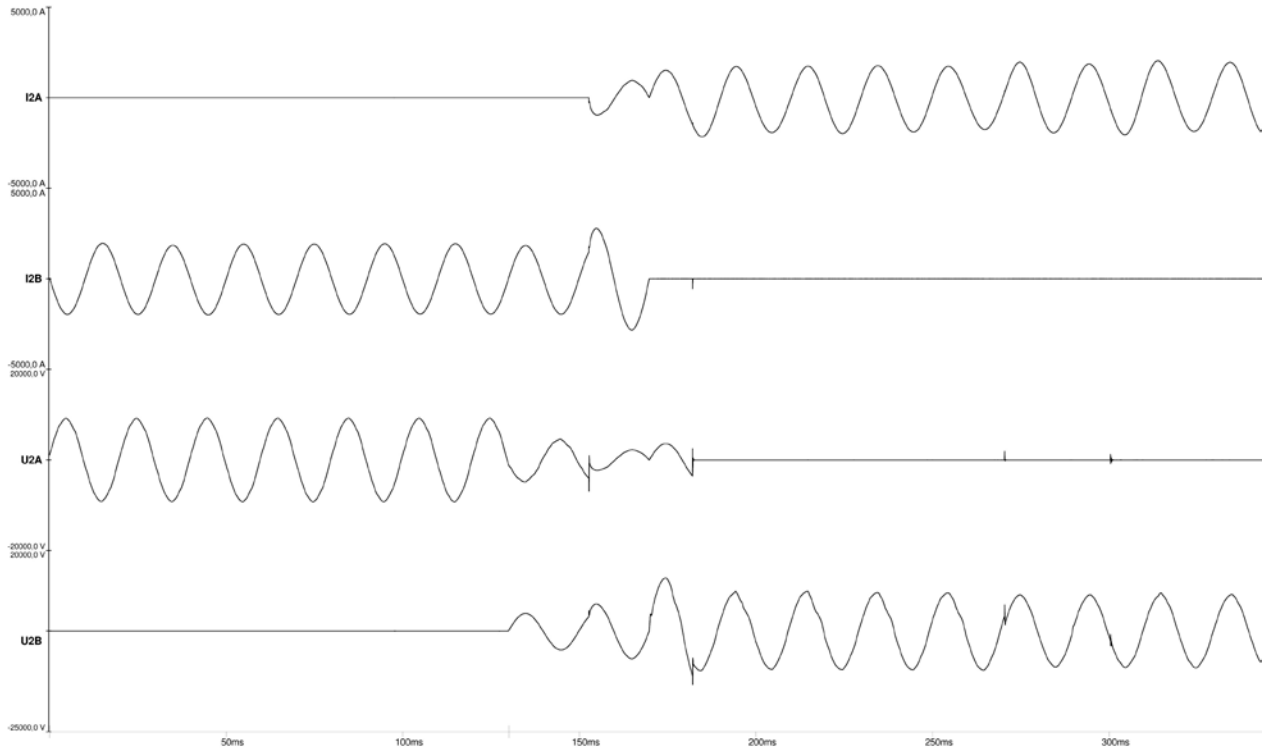


Fig. 3.32: Service duty test (test sequence 1 – switching operation no. 90585).

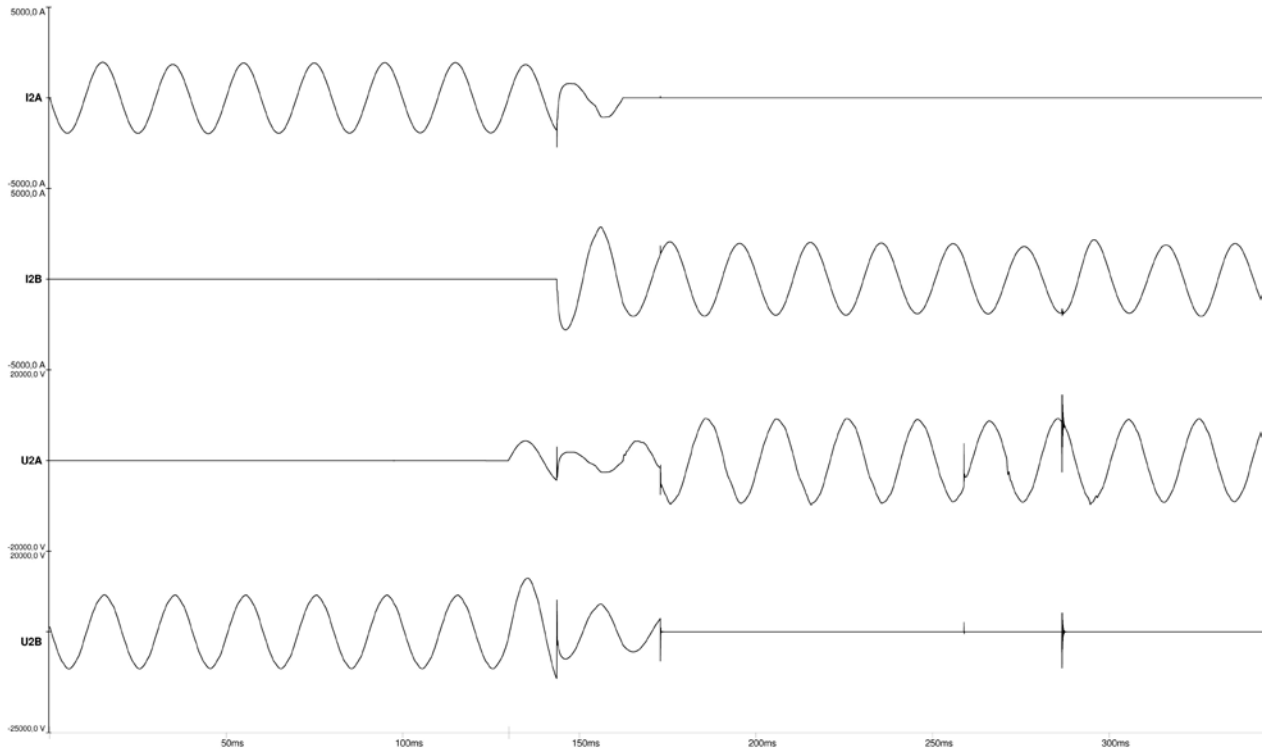


Fig. 3.33: Service duty test (test sequence 1 – switching operation no. 90586).

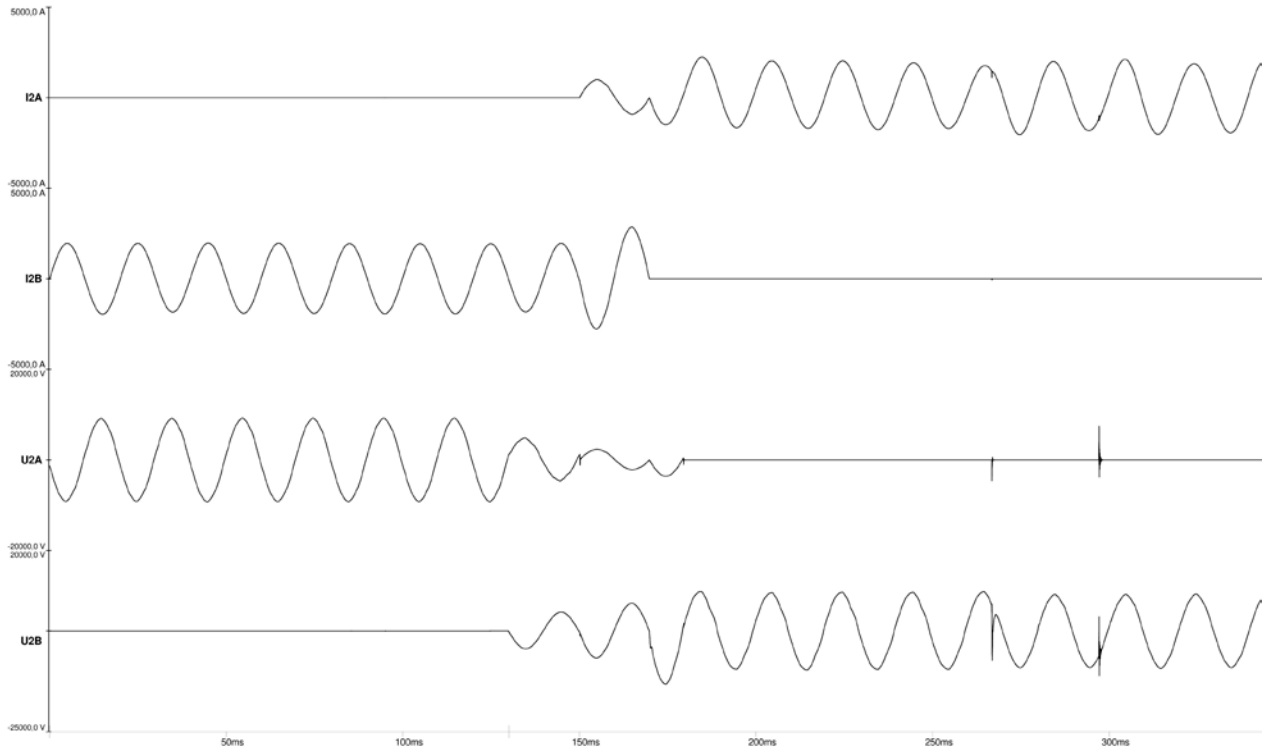


Fig. 3.34: Service duty test (test sequence 1 – switching operation no. 90587).

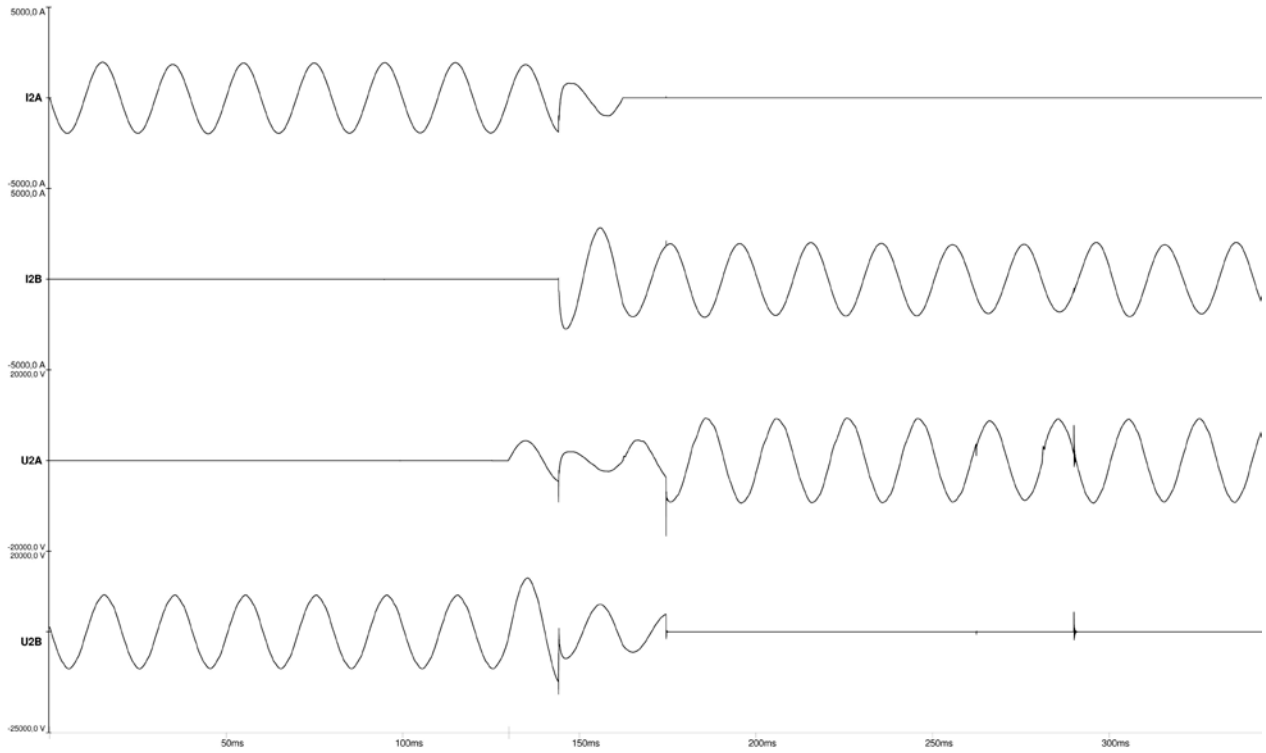


Fig. 3.35: Service duty test (test sequence 1 – switching operation no. 90588).

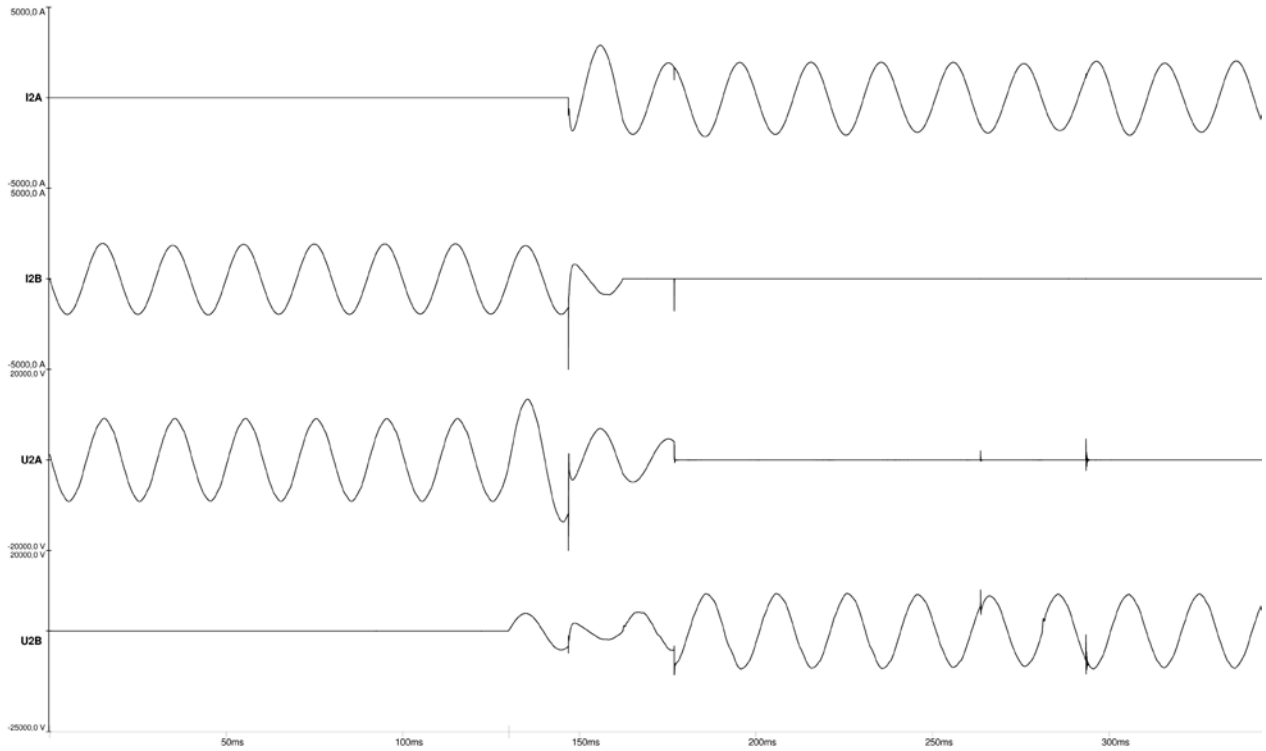


Fig. 3.36: Service duty test (test sequence 1 – switching operation no. 90589).

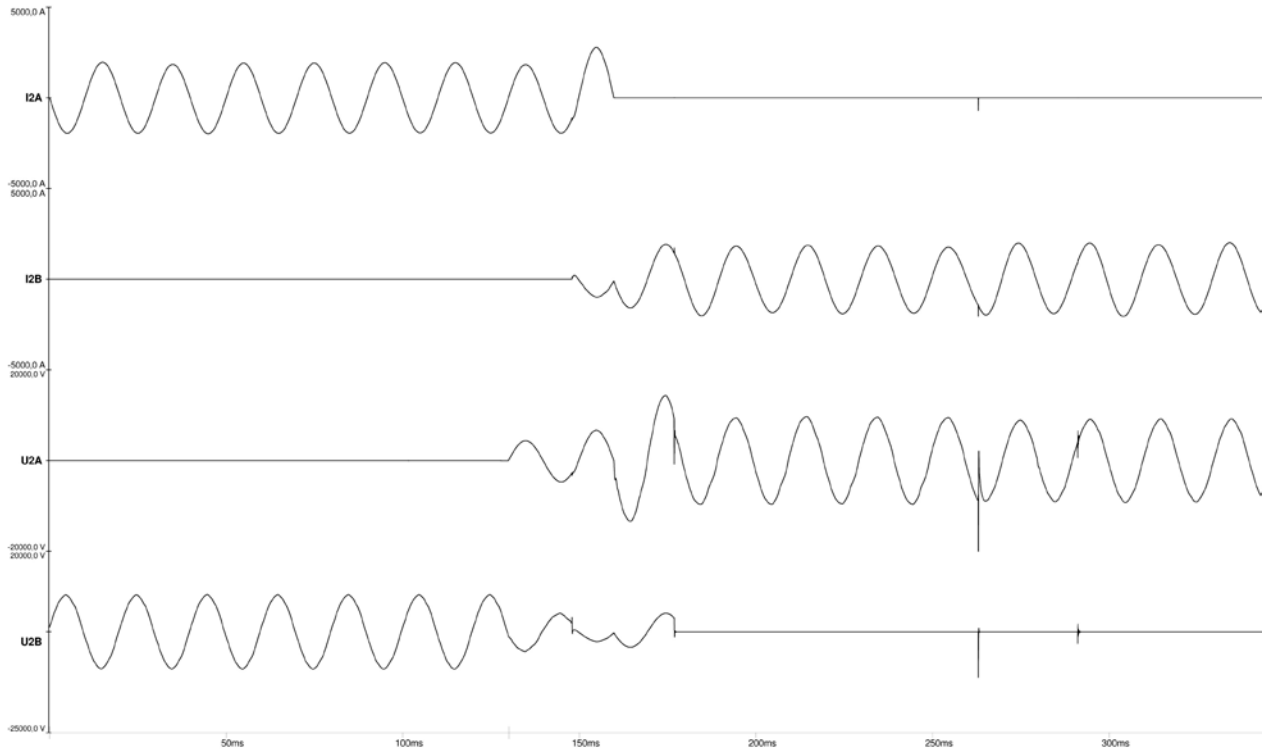


Fig. 3.37: Service duty test (test sequence 1 – switching operation no. 90590).

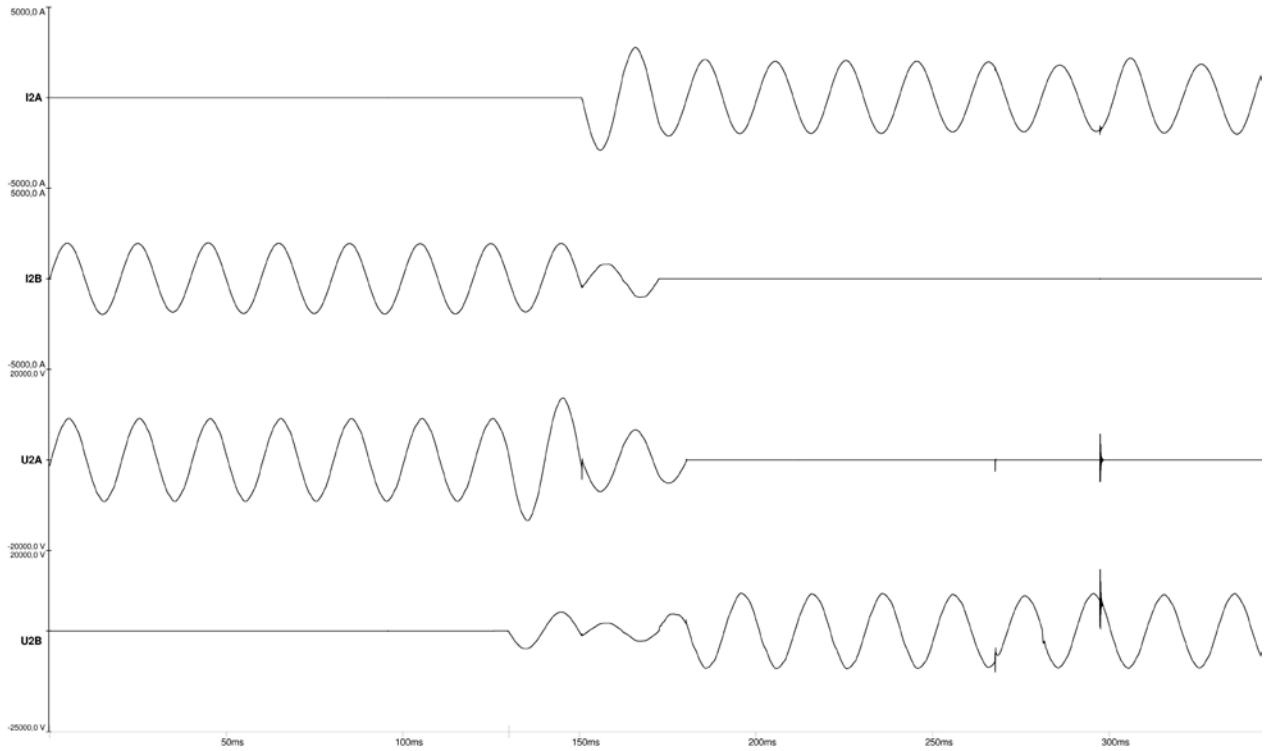


Fig. 3.38: Service duty test (test sequence 1 – switching operation no. 90591).

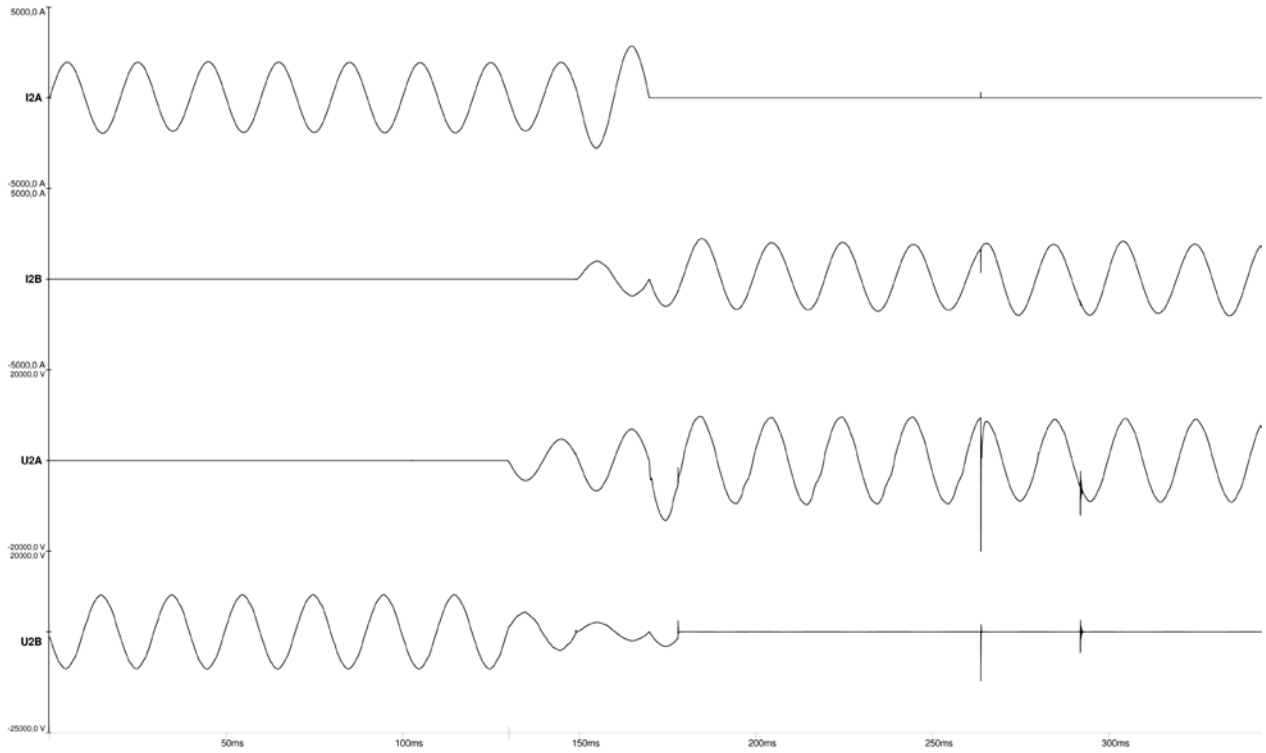


Fig. 3.39: Service duty test (test sequence 1 – switching operation no. 90592).

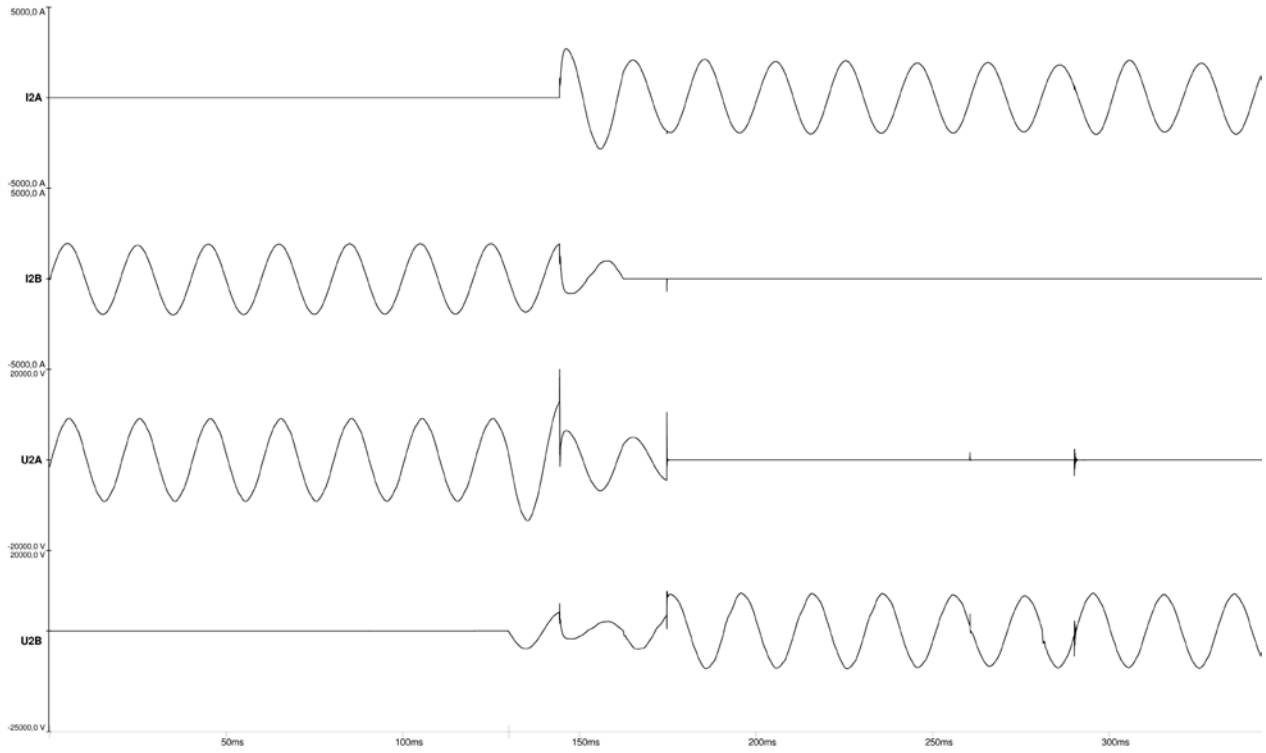


Fig. 3.40: Service duty test (test sequence 1 – switching operation no. 90593).

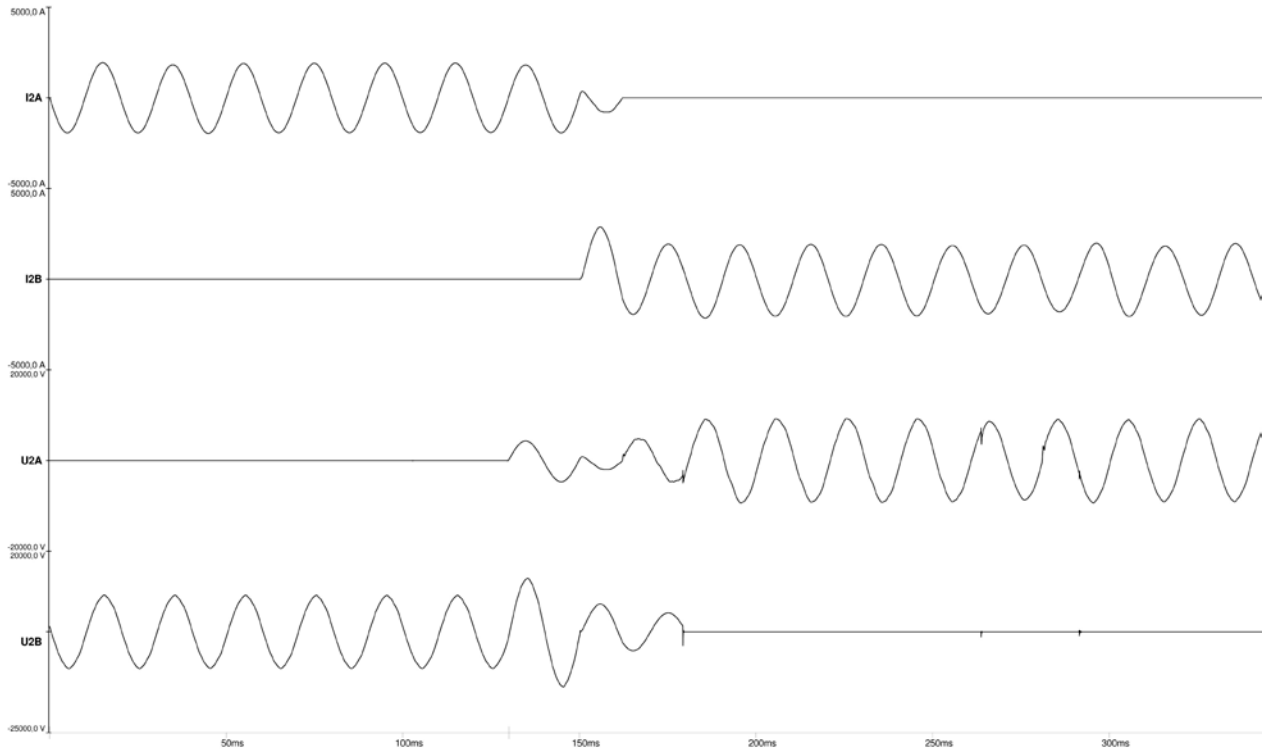


Fig. 3.41: Service duty test (test sequence 1 – switching operation no. 180582).

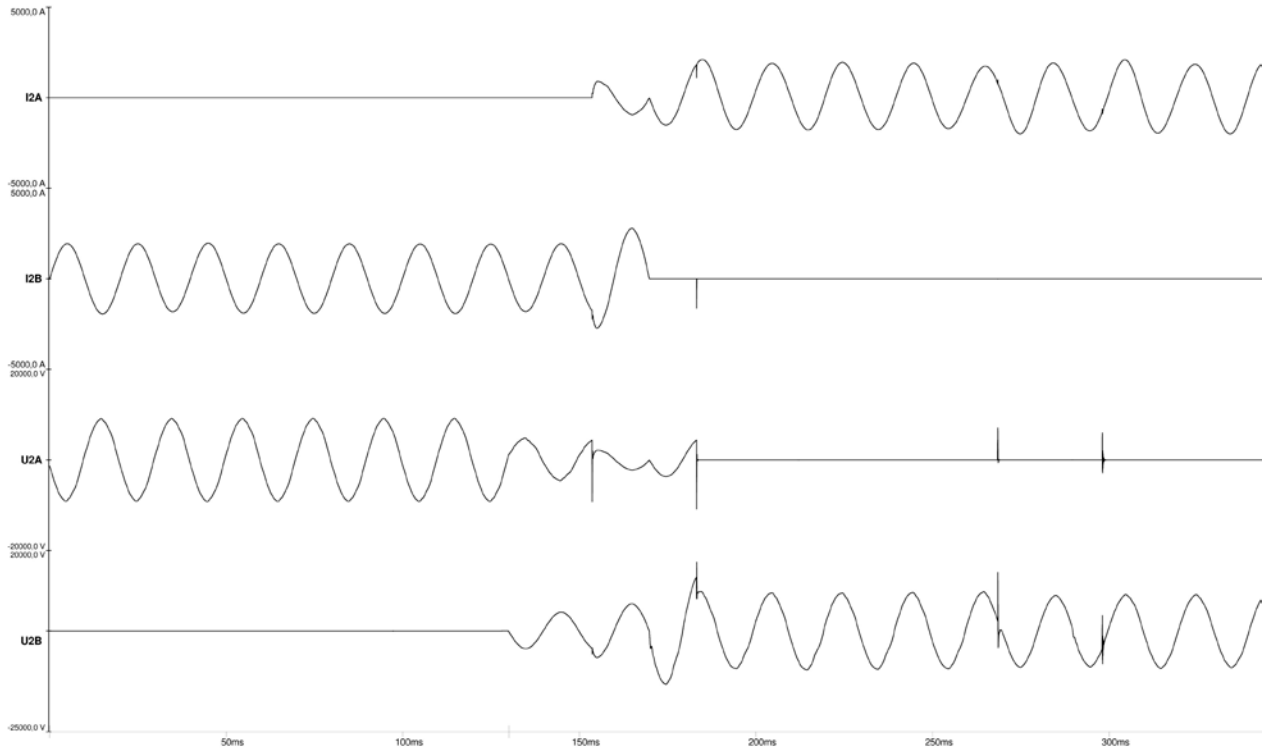


Fig. 3.42: Service duty test (test sequence 1 – switching operation no. 180583).

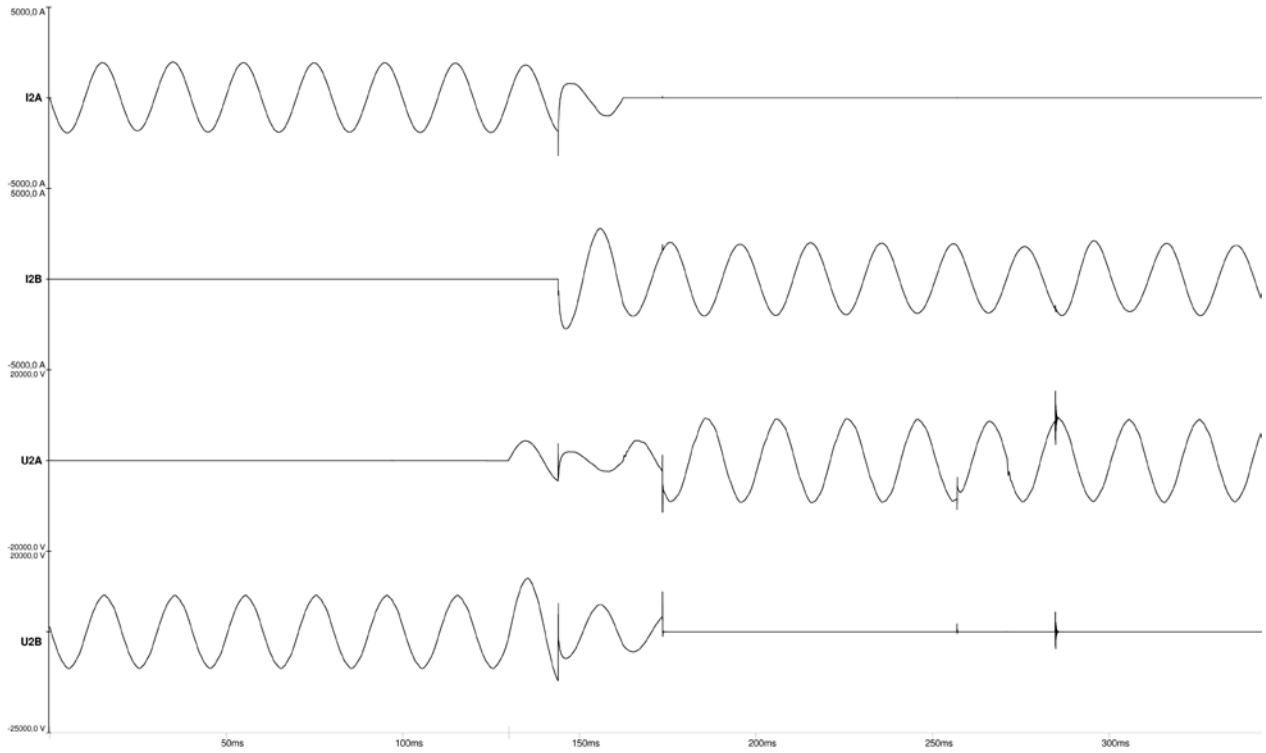


Fig. 3.43: Service duty test (test sequence 1 – switching operation no. 180584).

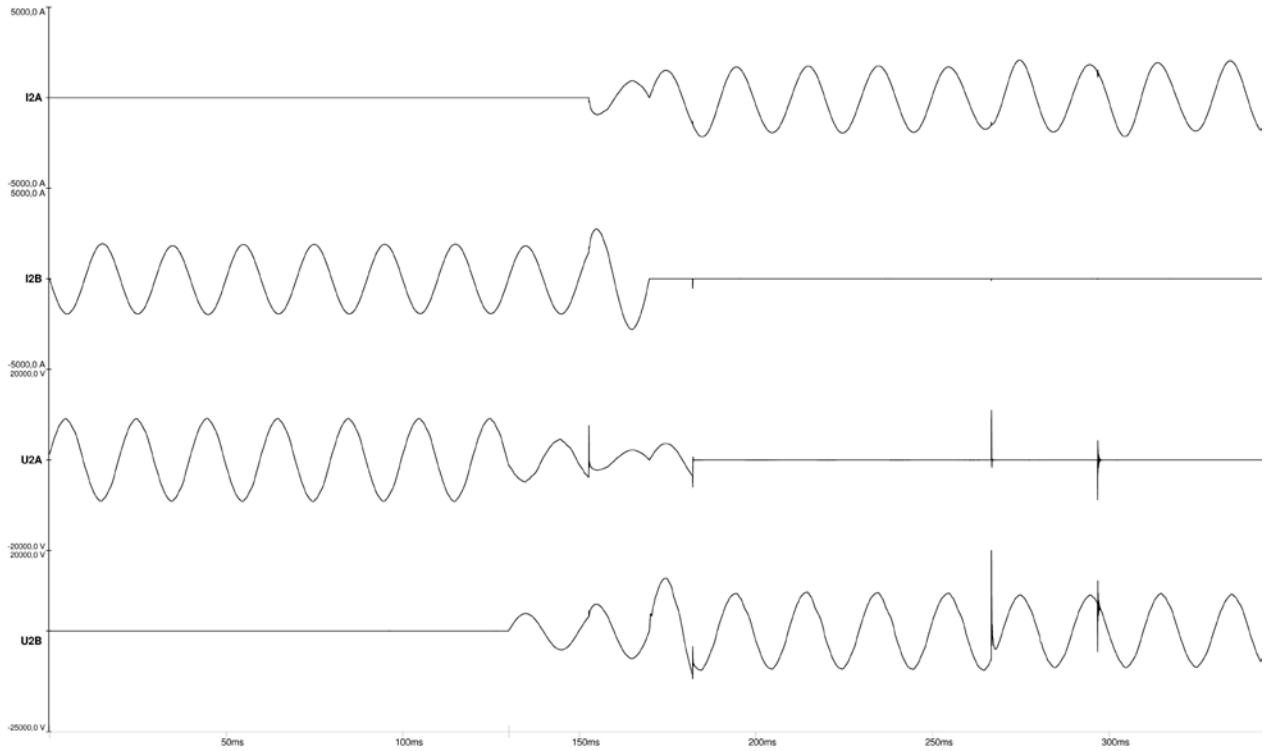


Fig. 3.44: Service duty test (test sequence 1 – switching operation no. 180585).

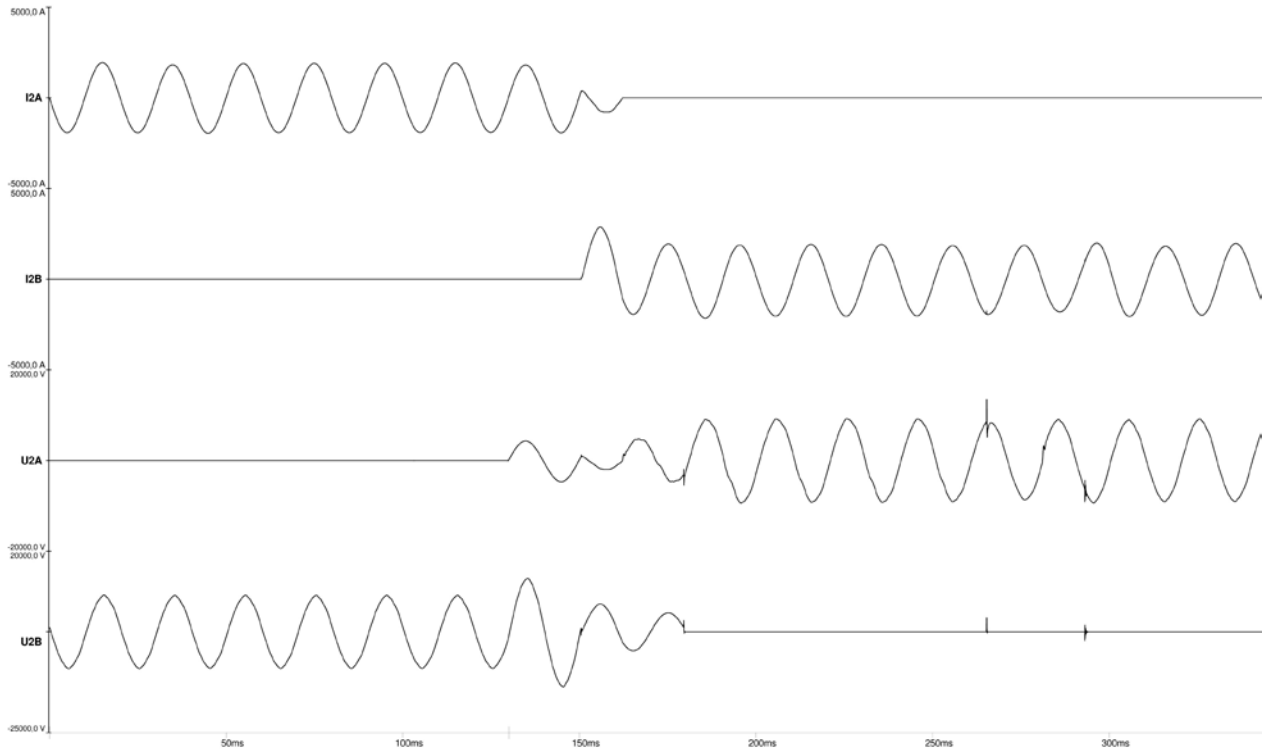


Fig. 3.45: Service duty test (test sequence 1 – switching operation no. 180586).

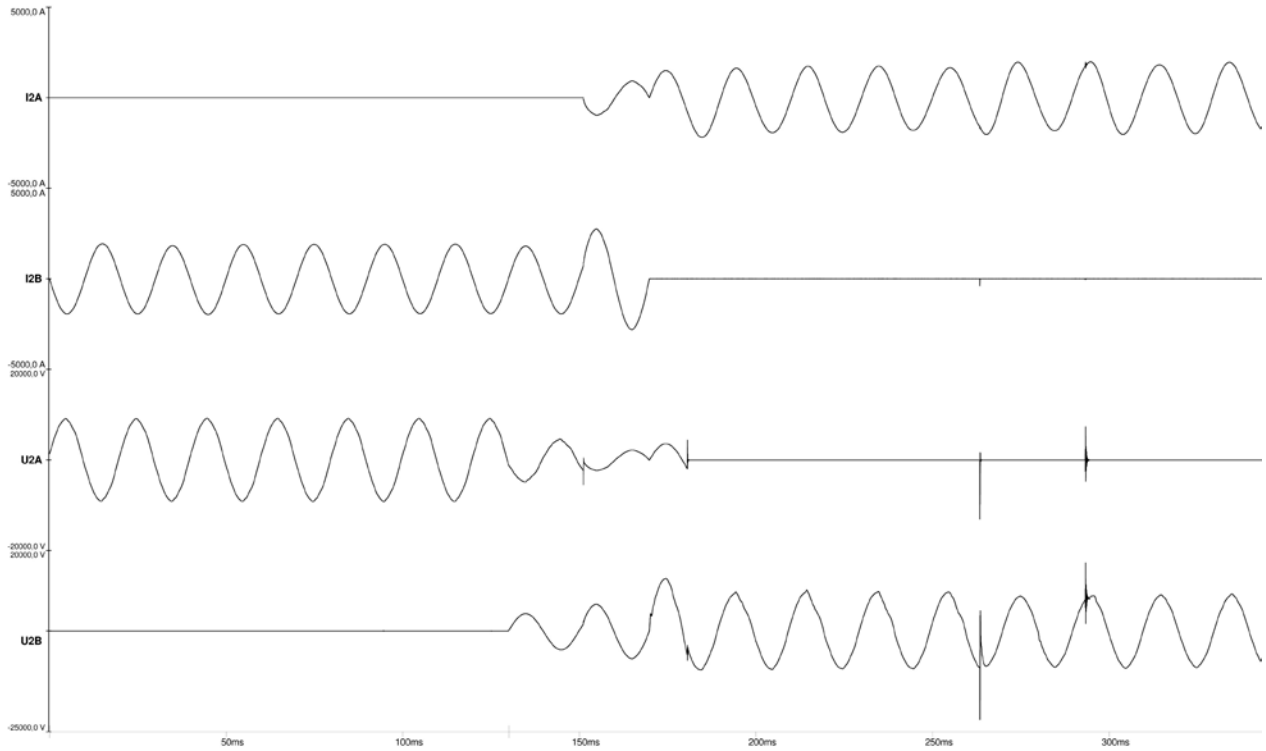


Fig. 3.46: Service duty test (test sequence 1 – switching operation no. 180587).

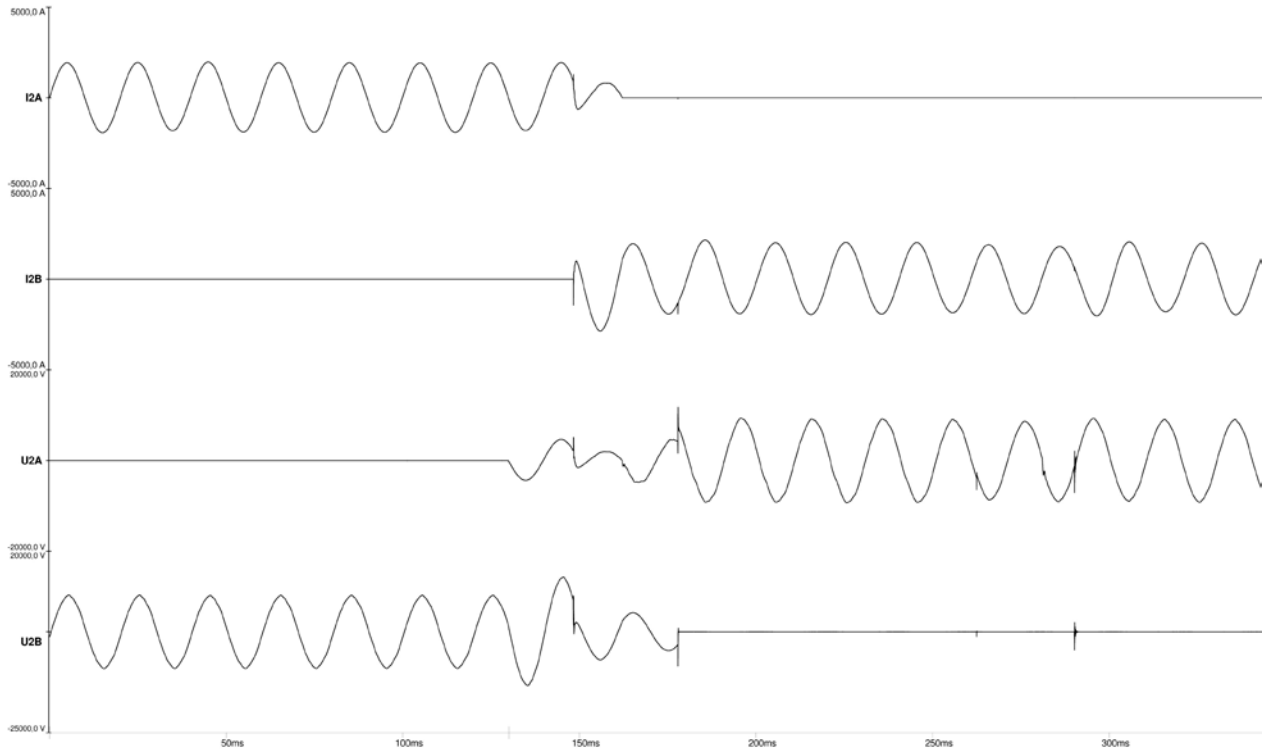


Fig. 3.47: Service duty test (test sequence 1 – switching operation no. 180588).

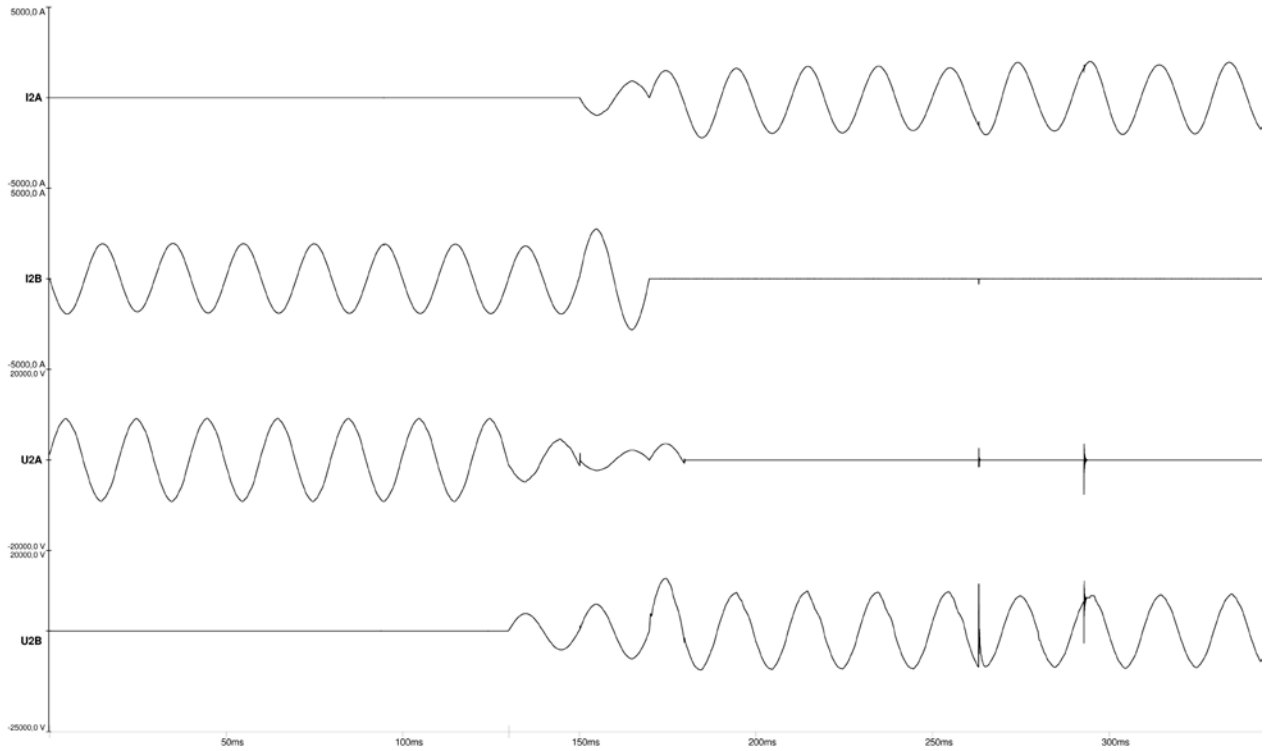


Fig. 3.48: Service duty test (test sequence 1 – switching operation no. 180589).

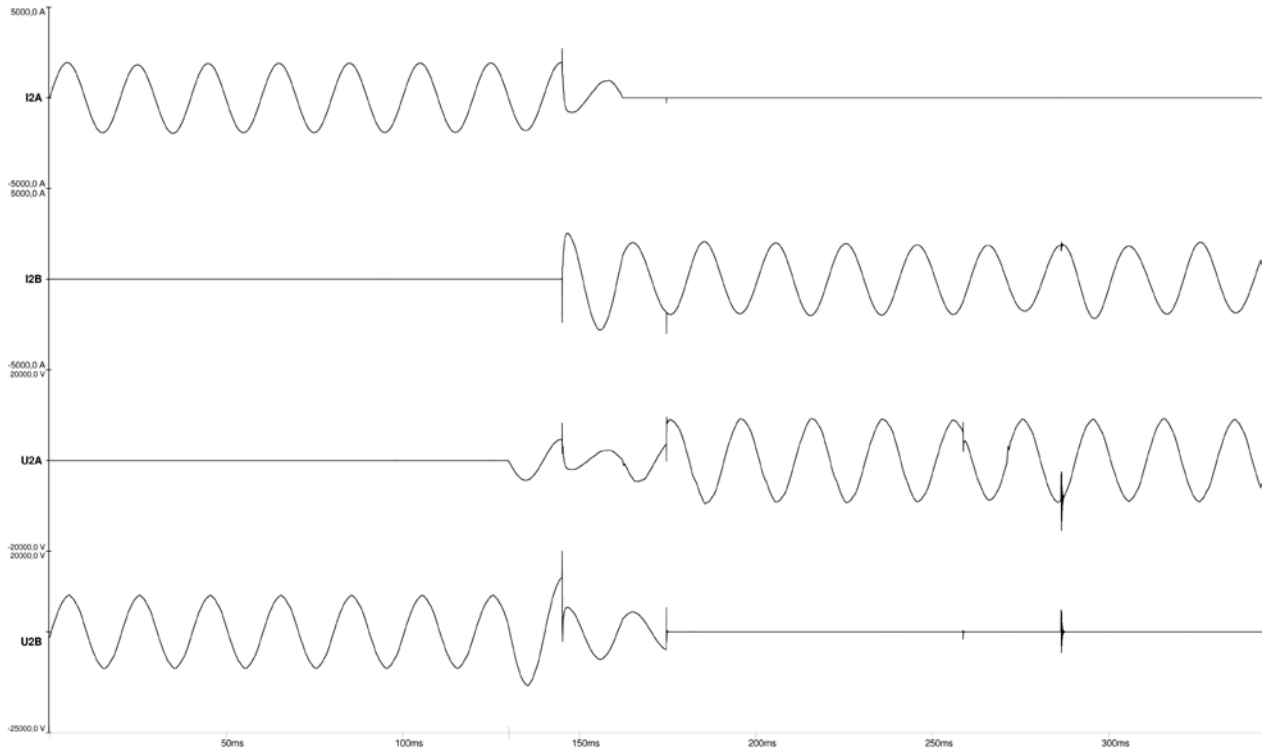


Fig. 3.49: Service duty test (test sequence 1 – switching operation no. 180590).

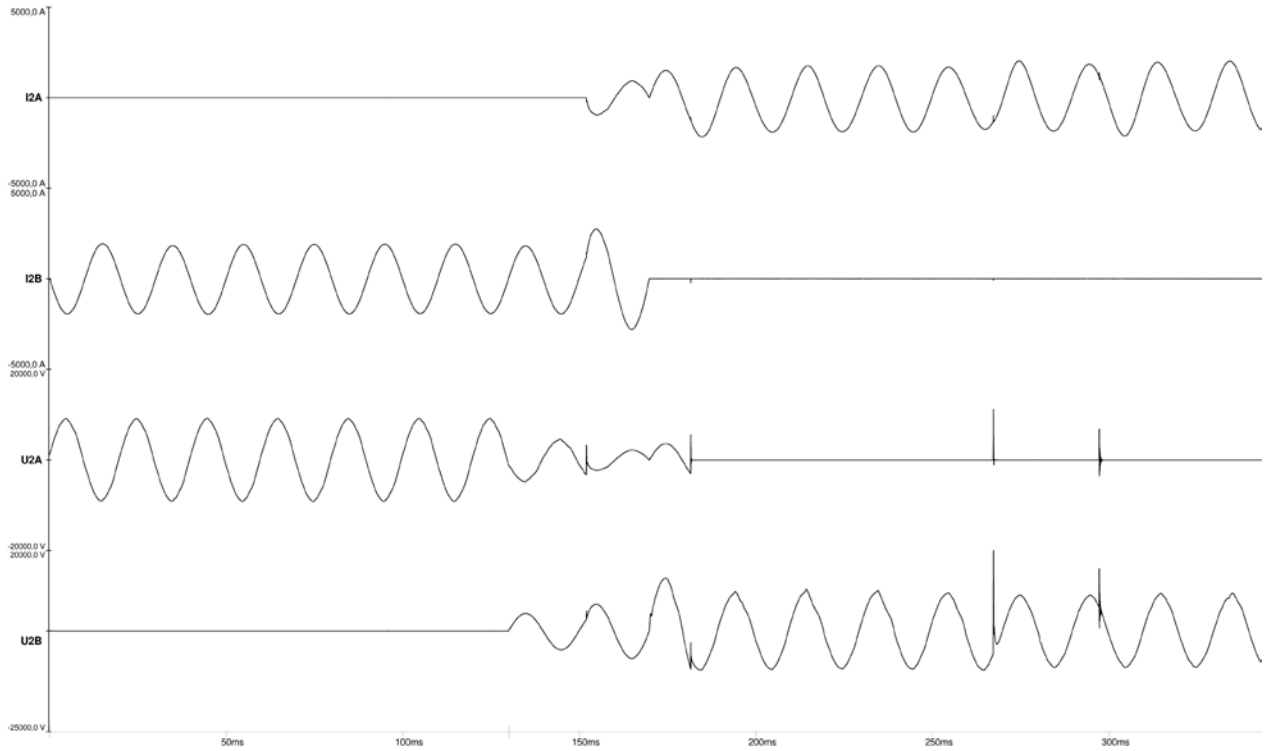


Fig. 3.50: Service duty test (test sequence 1 – switching operation no. 180591).

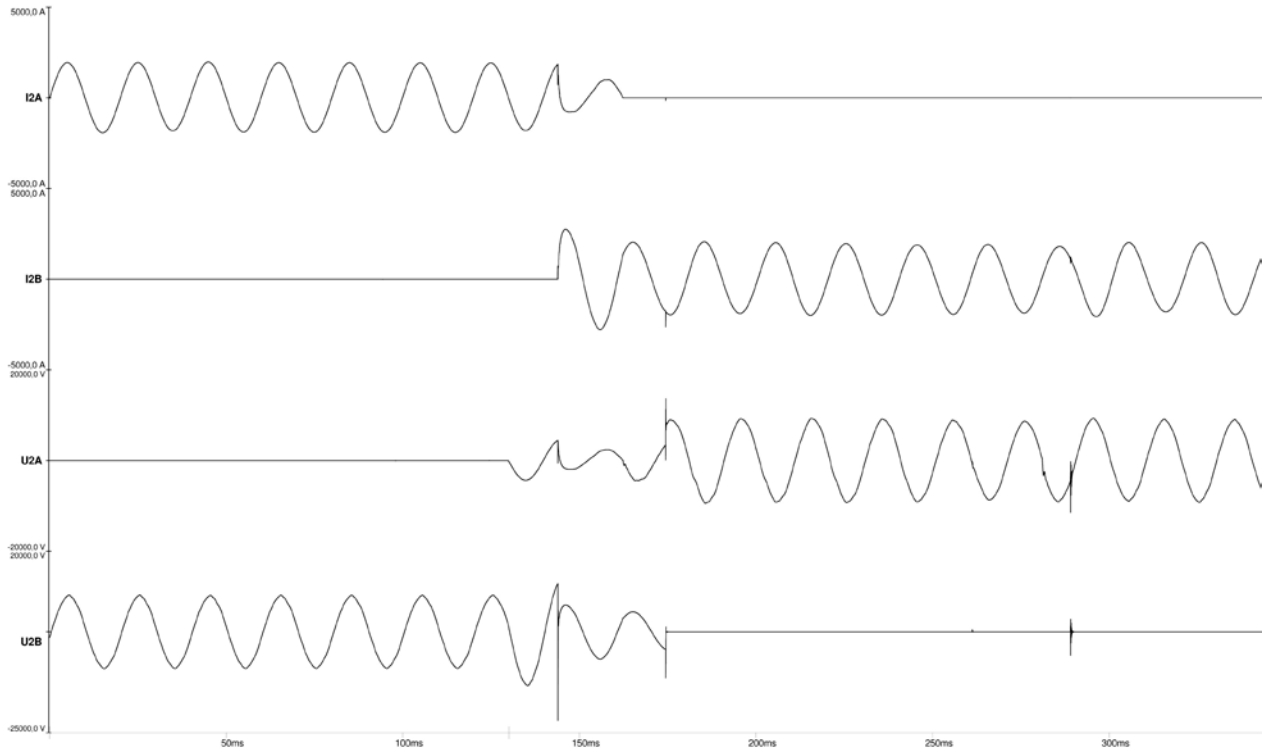


Fig. 3.51: Service duty test (test sequence 1 – switching operation no. 180592).

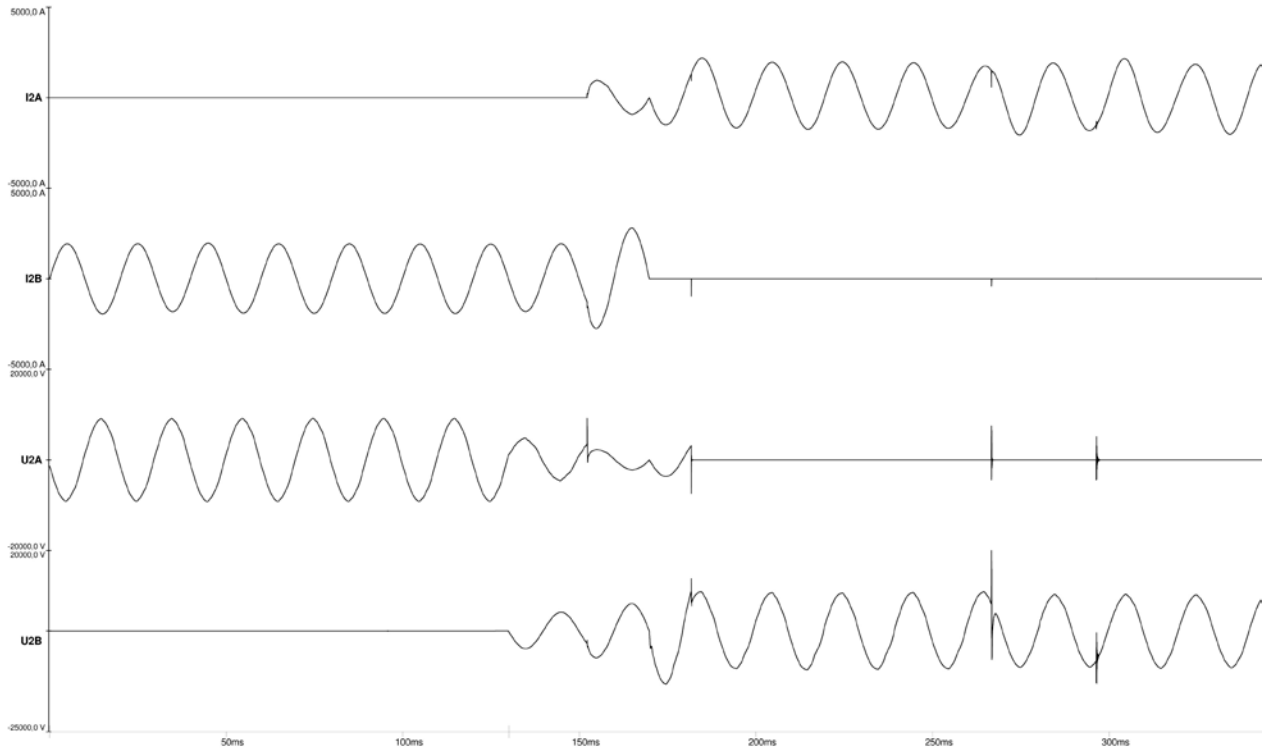


Fig. 3.52: Service duty test (test sequence 1 – switching operation no. 180593).

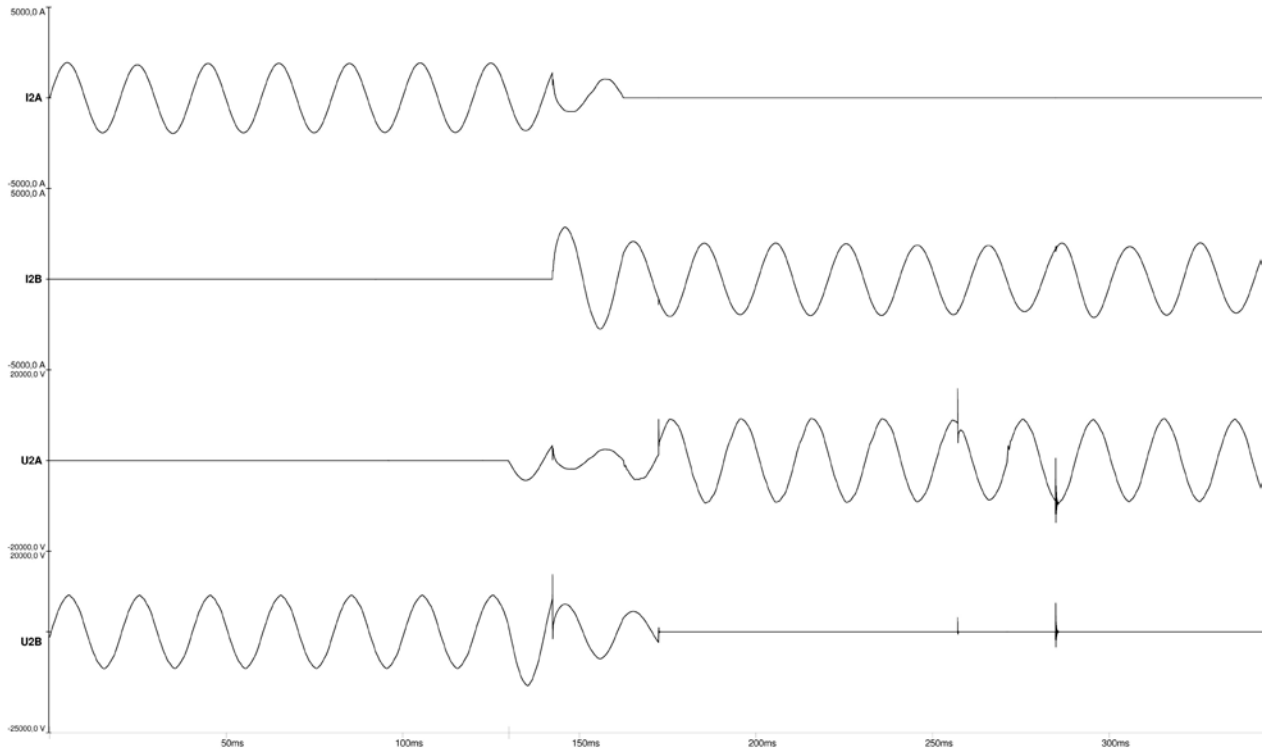


Fig. 3.53: Service duty test (test sequence 1 – switching operation no. 180594).

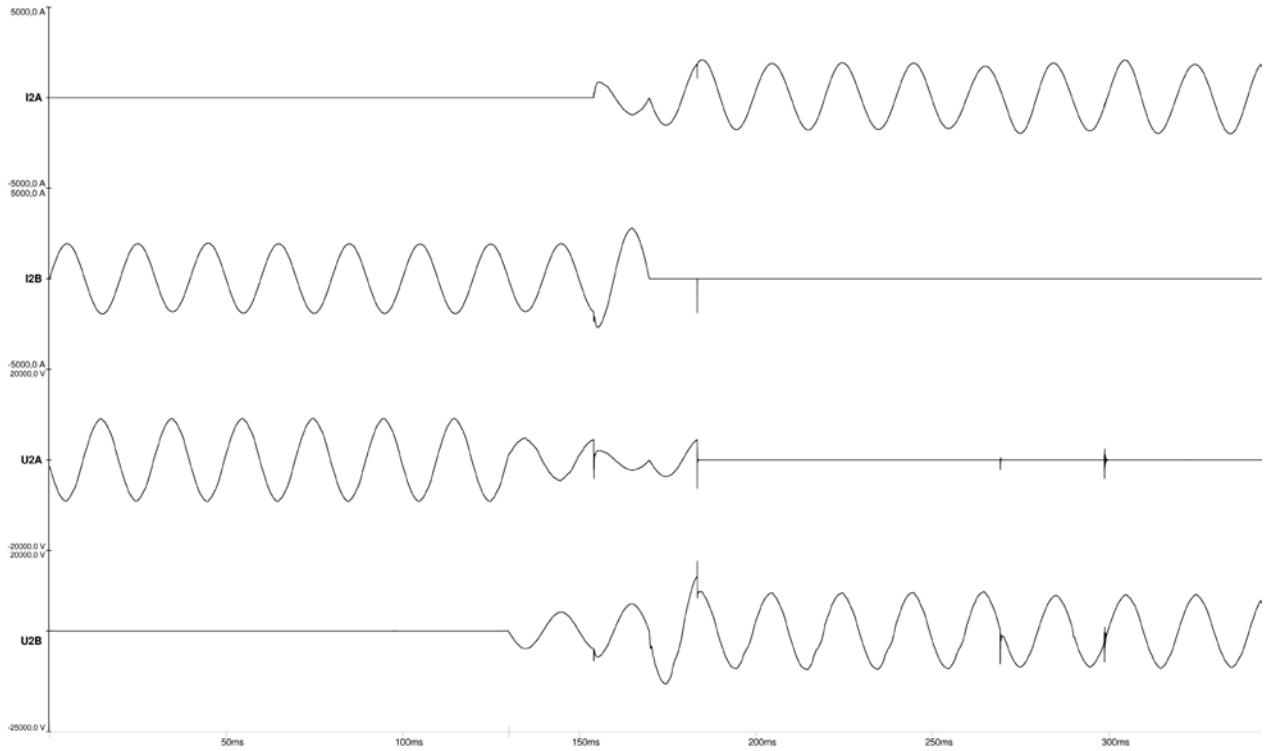


Fig. 3.54: Service duty test (test sequence 1 – switching operation no. 180595).

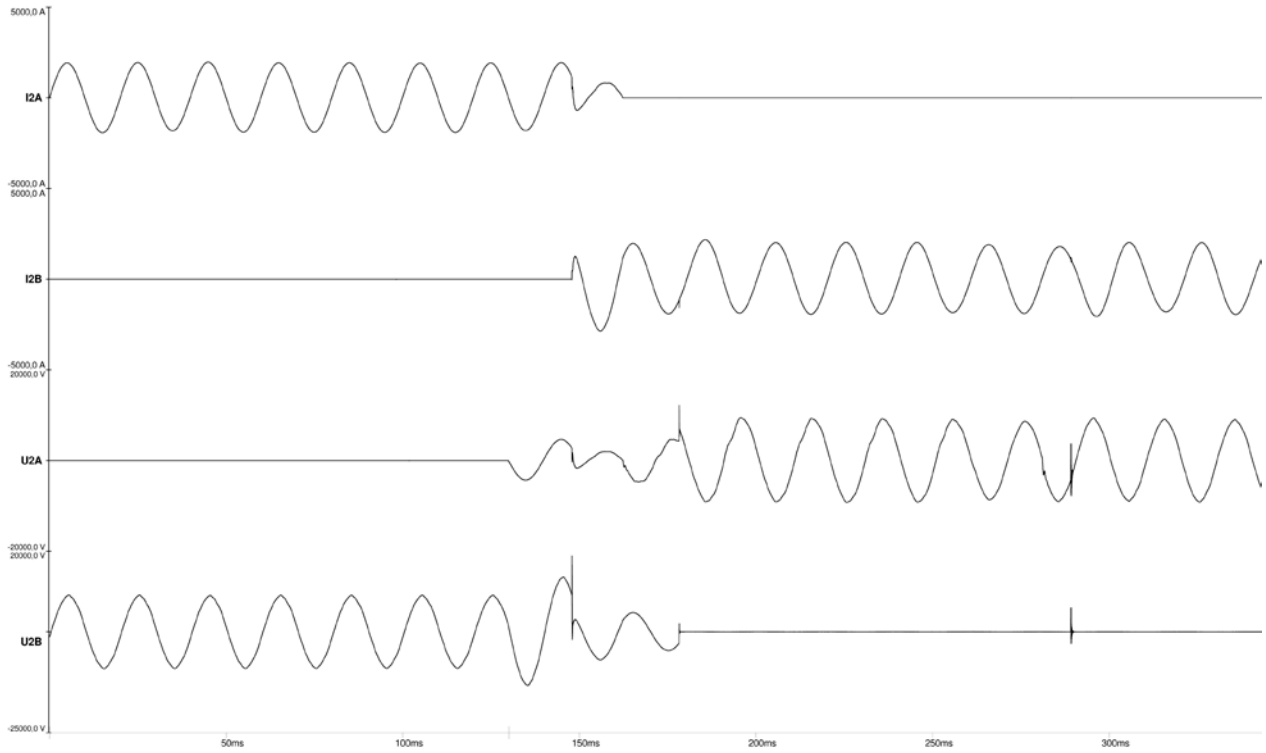


Fig. 3.55: Service duty test (test sequence 1 – switching operation no. 180596).

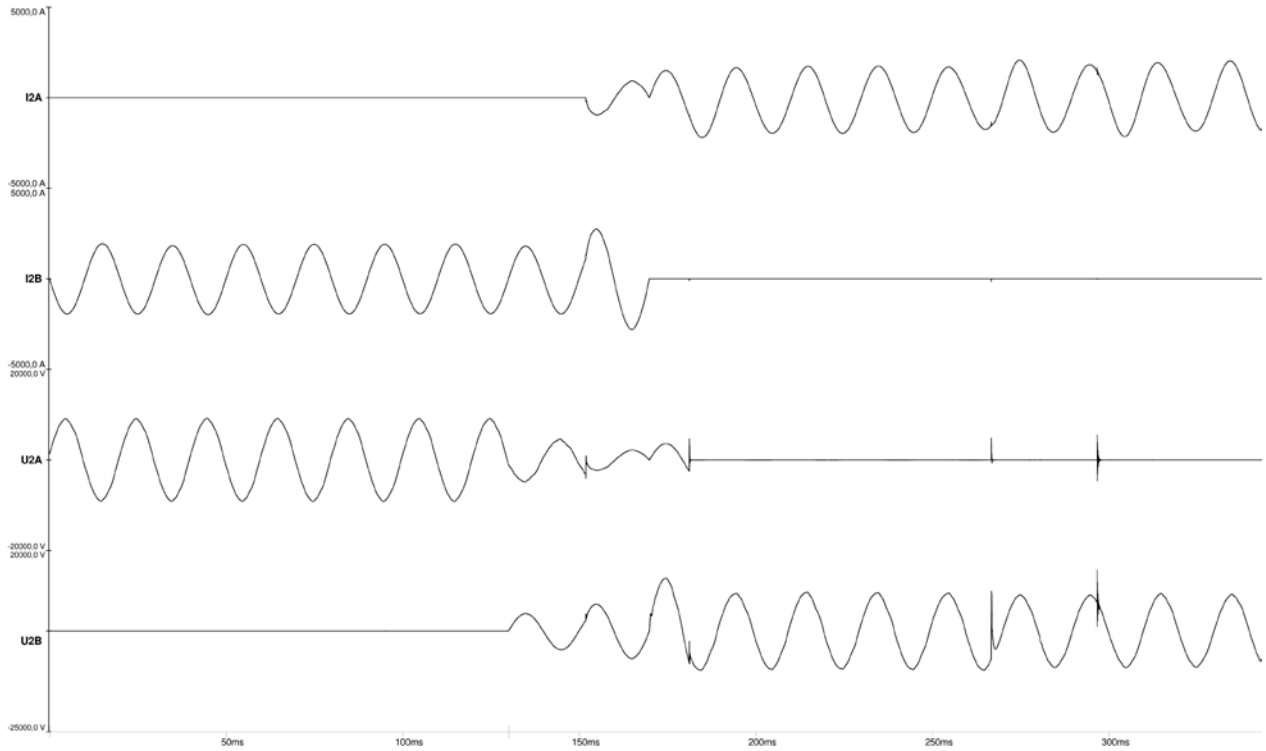


Fig. 3.56: Service duty test (test sequence 1 – switching operation no. 180597).

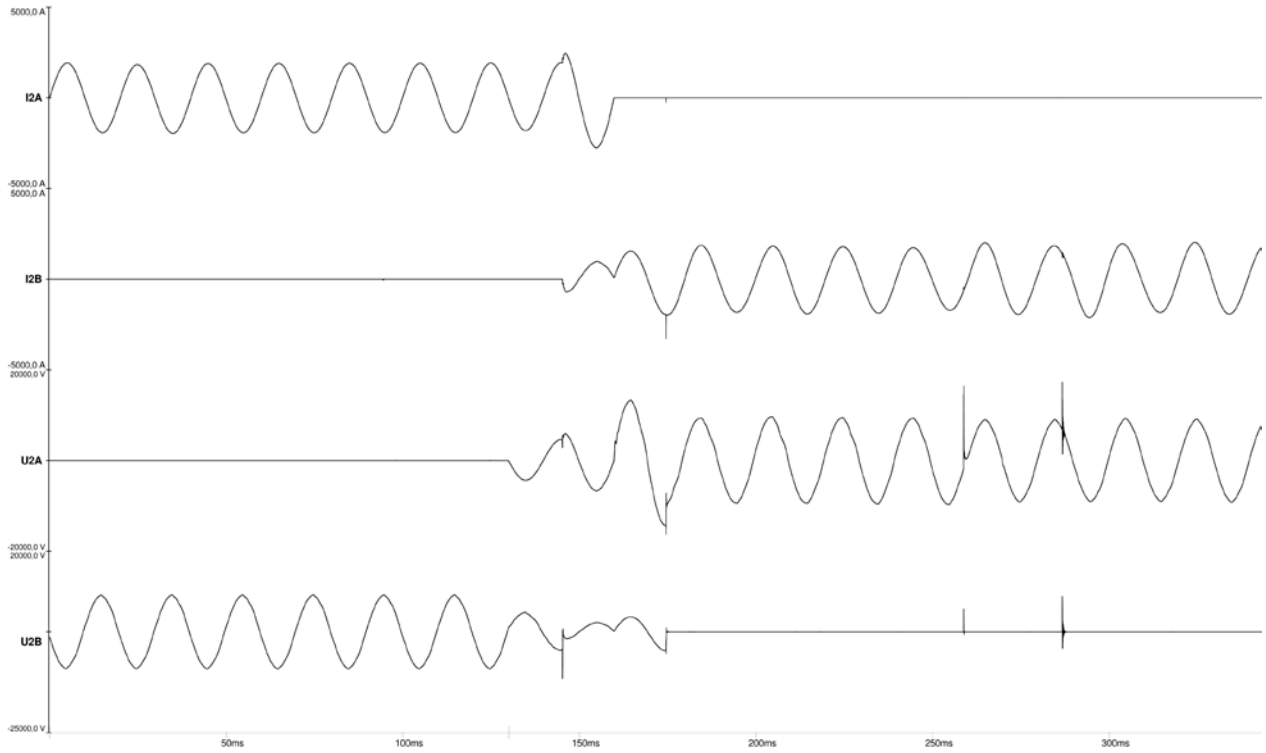


Fig. 3.57: Service duty test (test sequence 1 – switching operation no. 180598).

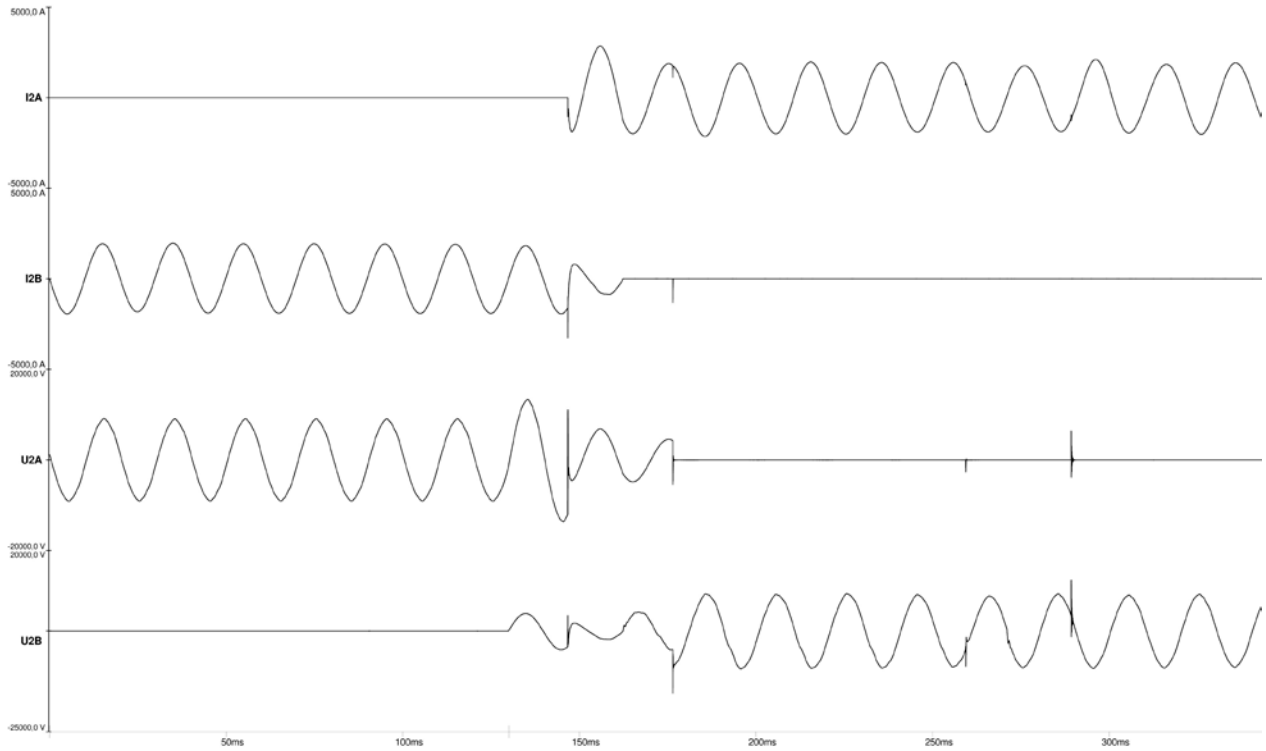


Fig. 3.58: Service duty test (test sequence 1 – switching operation no. 180599).

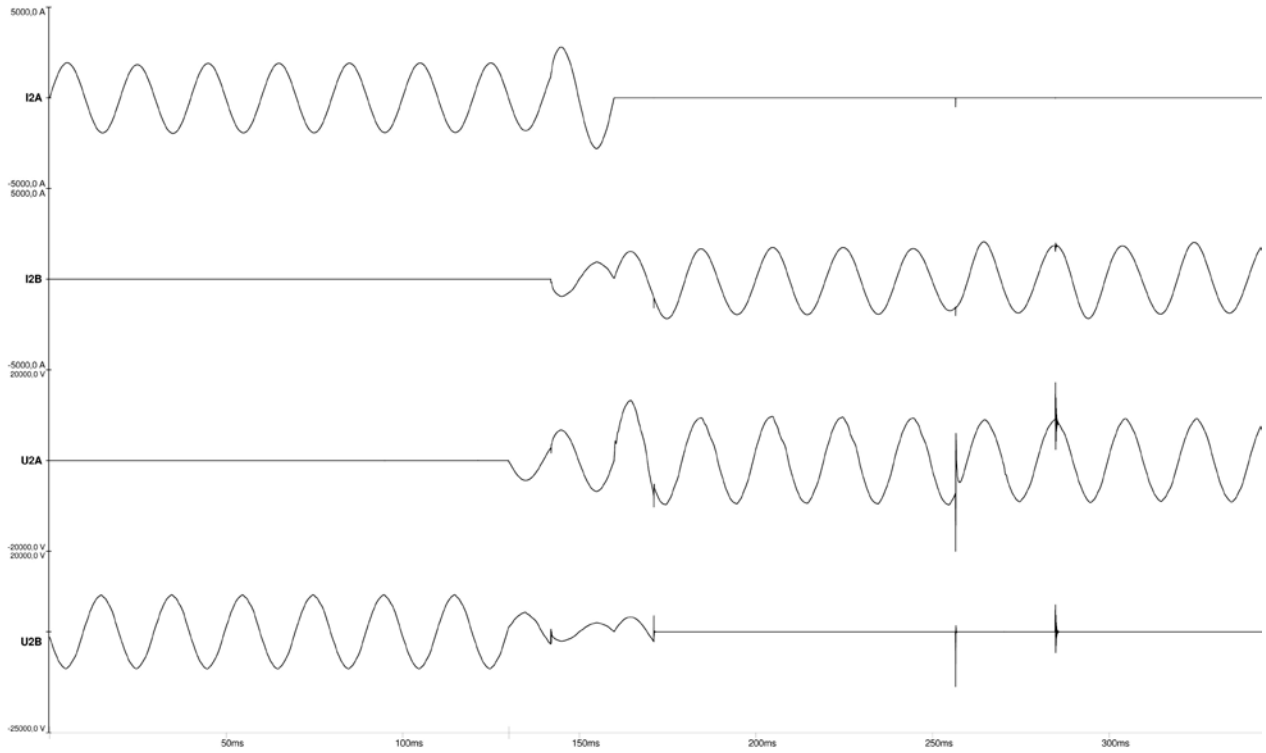


Fig. 3.59: Service duty test (test sequence 1 – switching operation no. 180600).

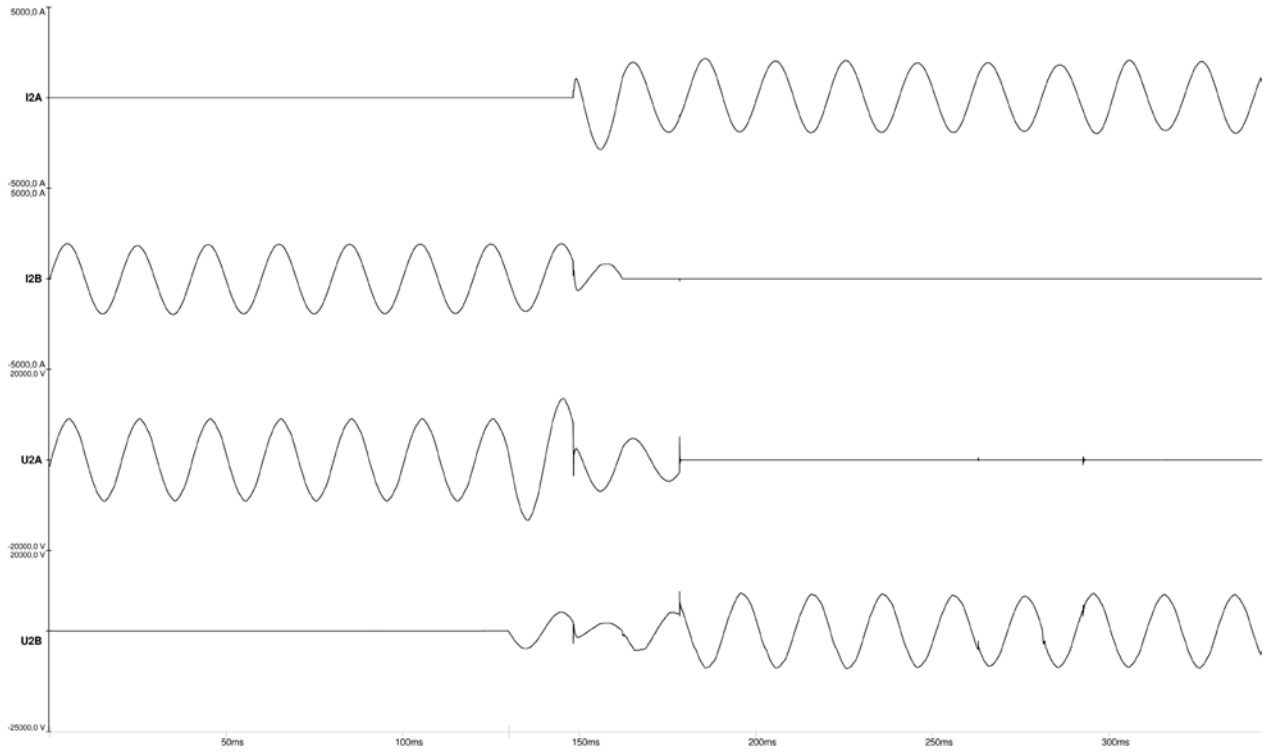


Fig. 3.60: Service duty test (test sequence 1 – switching operation no. 180601).

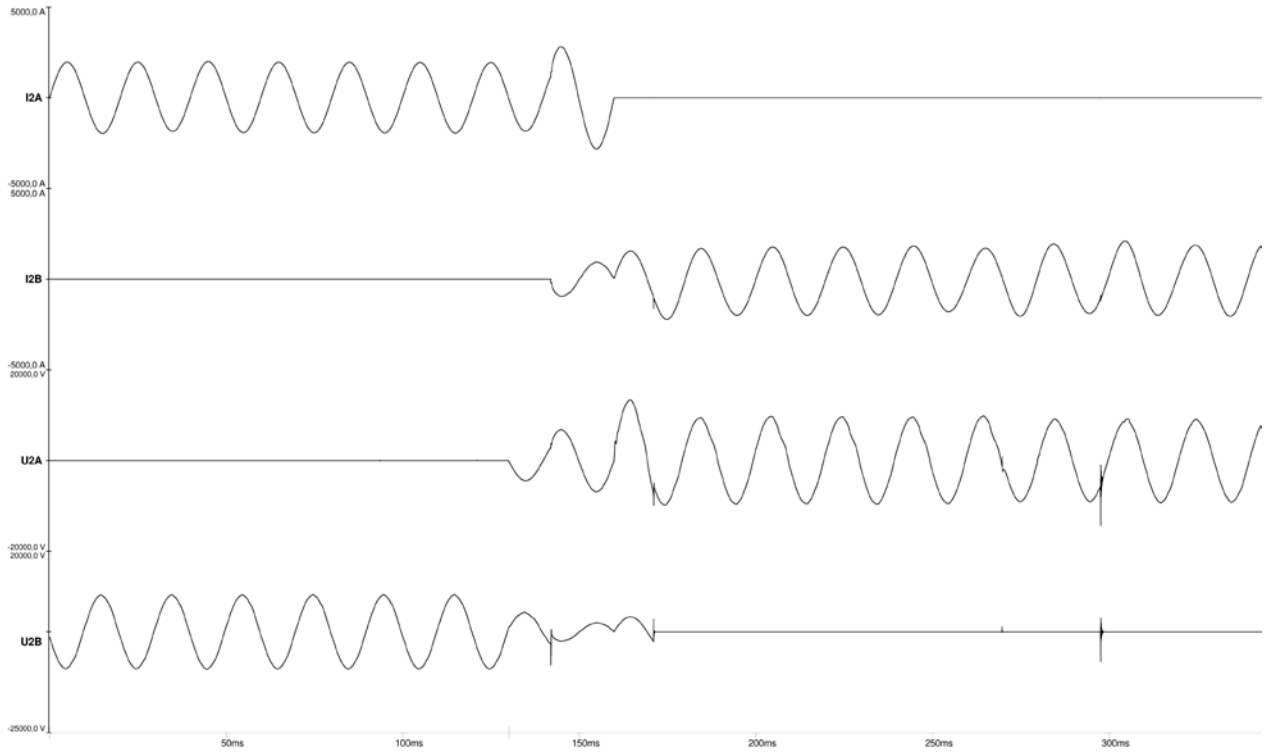


Fig. 3.61: Service duty test (test sequence 1 – switching operation no. 270683).

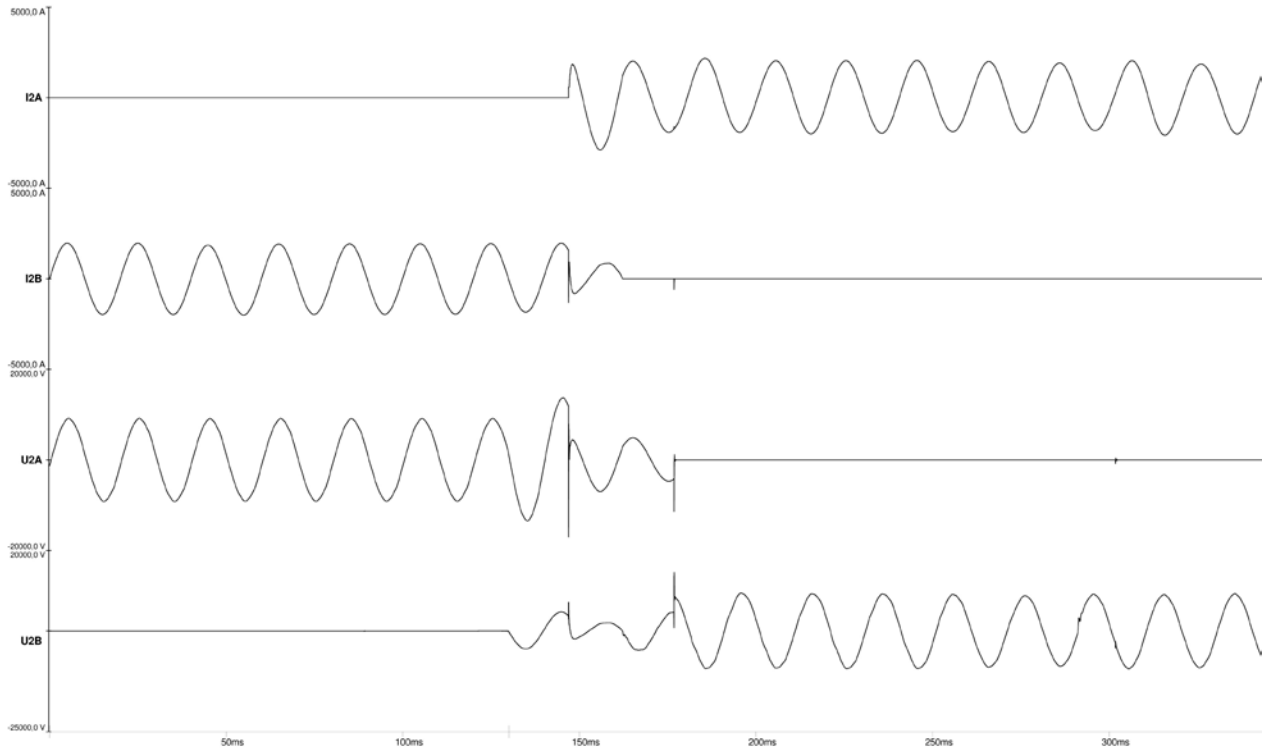


Fig. 3.62: Service duty test (test sequence 1 – switching operation no. 270684).

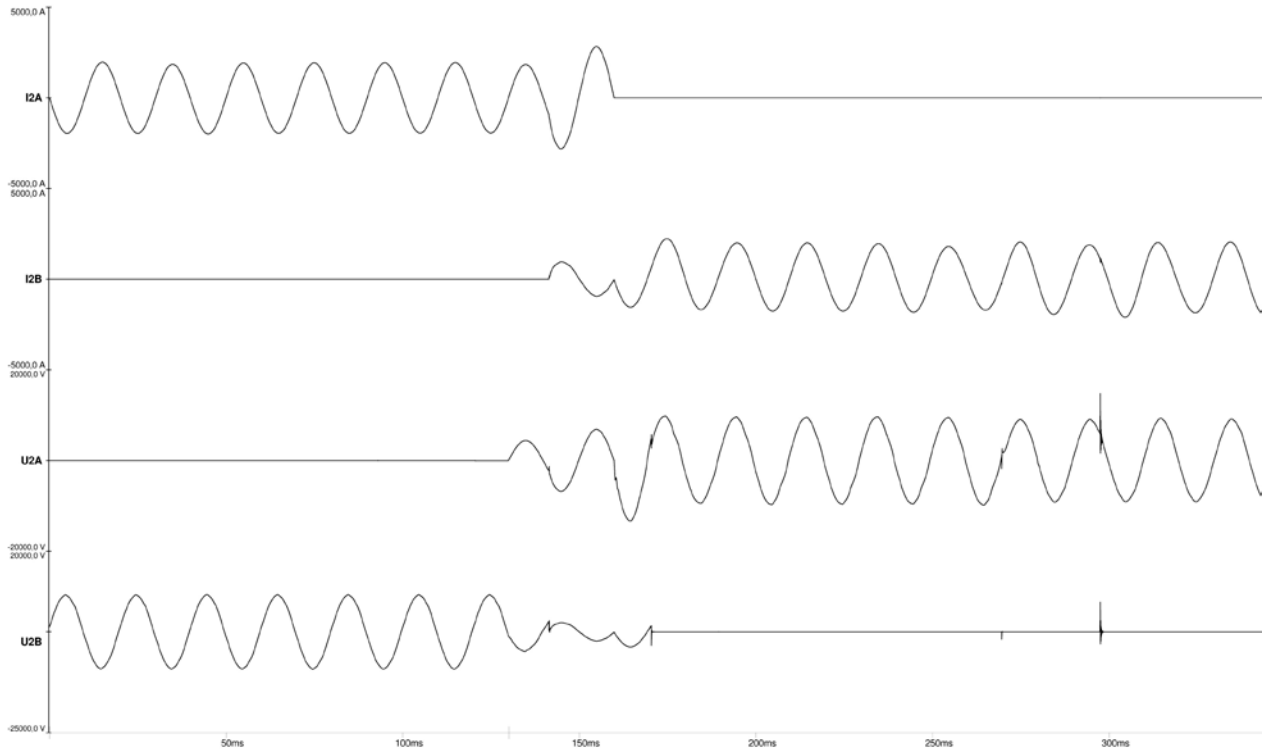


Fig. 3.63: Service duty test (test sequence 1 – switching operation no. 270685).

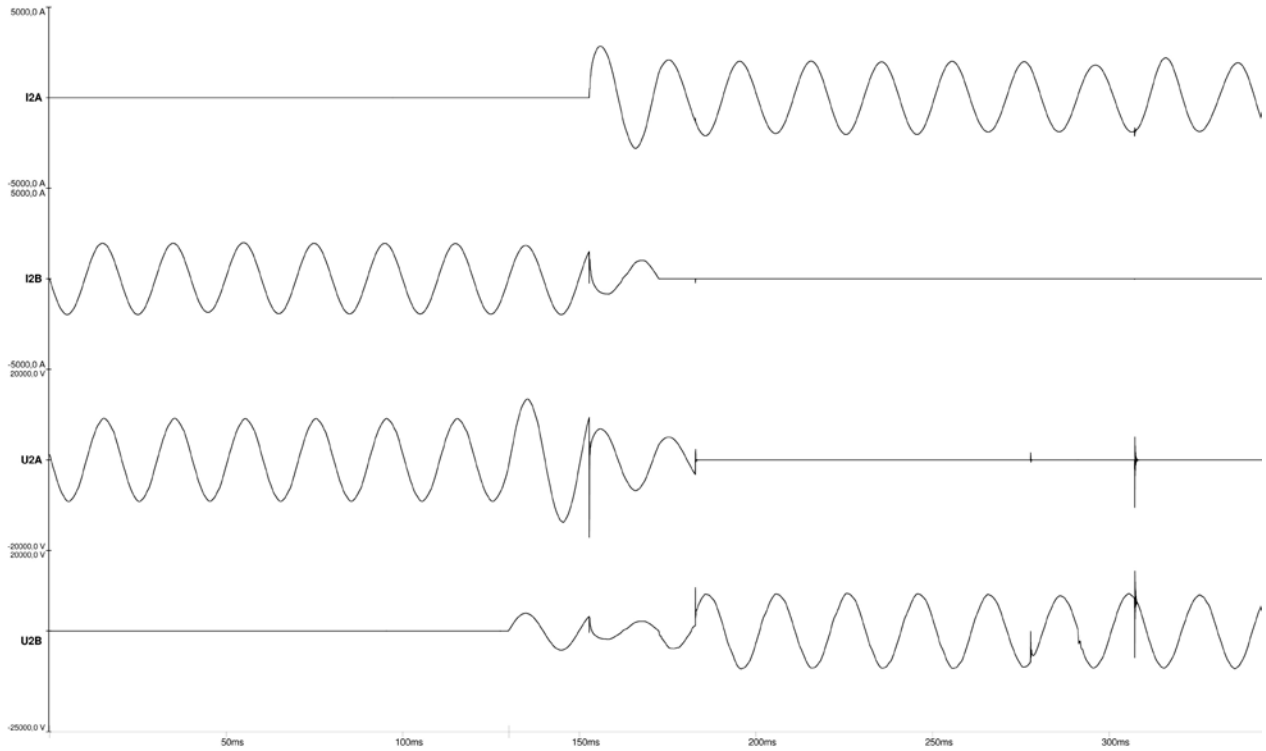


Fig. 3.64: Service duty test (test sequence 1 – switching operation no. 270686).

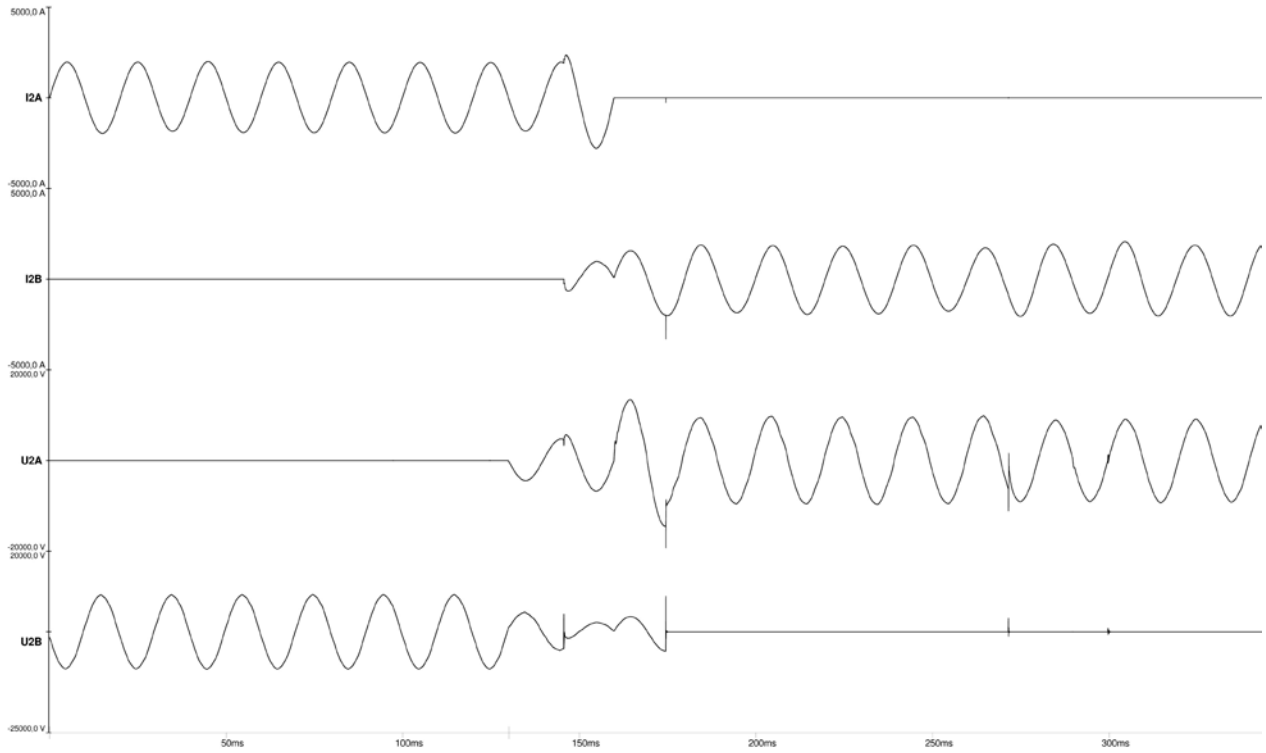


Fig. 3.65: Service duty test (test sequence 1 – switching operation no. 270687).

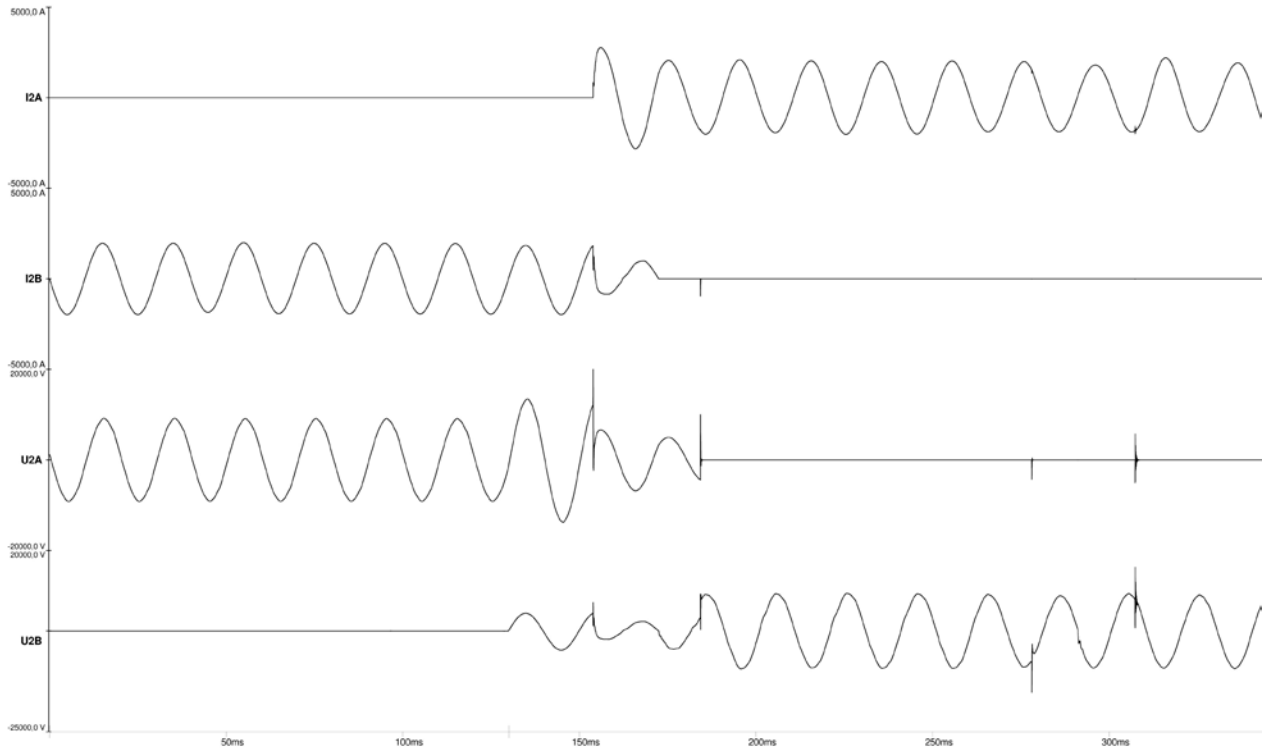


Fig. 3.66: Service duty test (test sequence 1 – switching operation no. 270688).

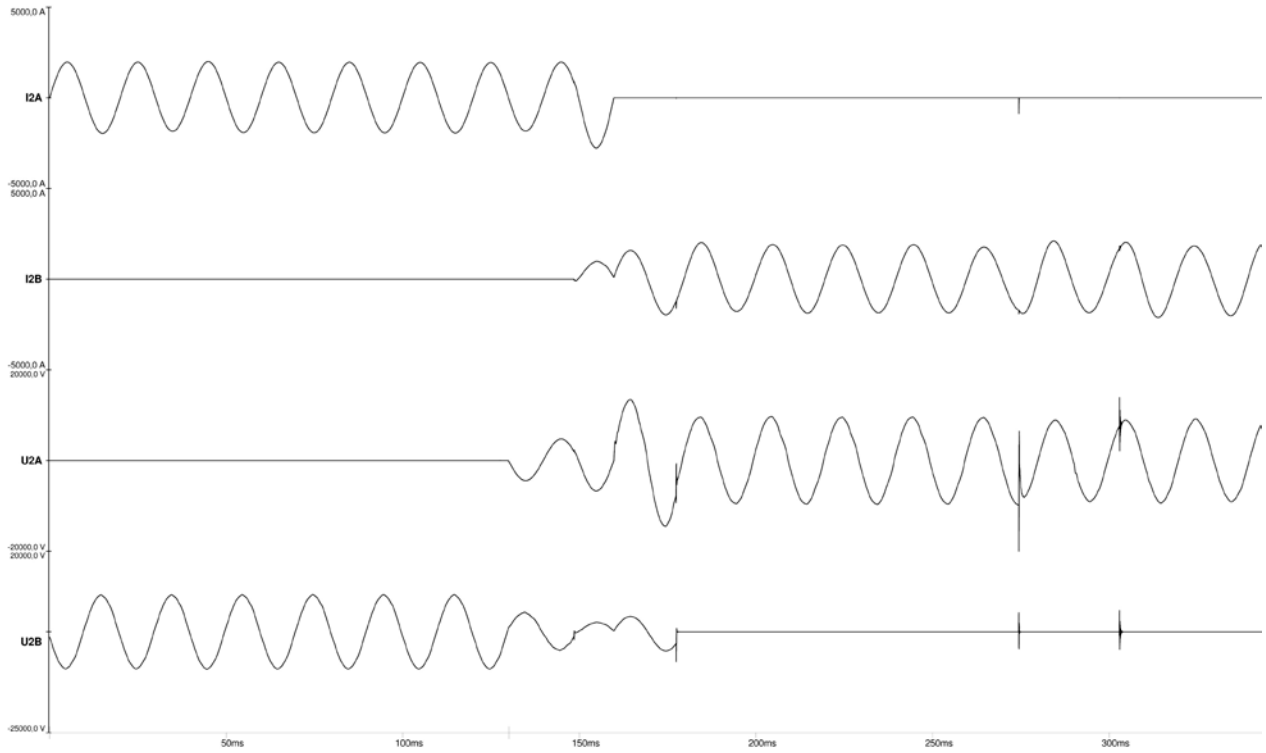


Fig. 3.67: Service duty test (test sequence 1 – switching operation no. 270689).

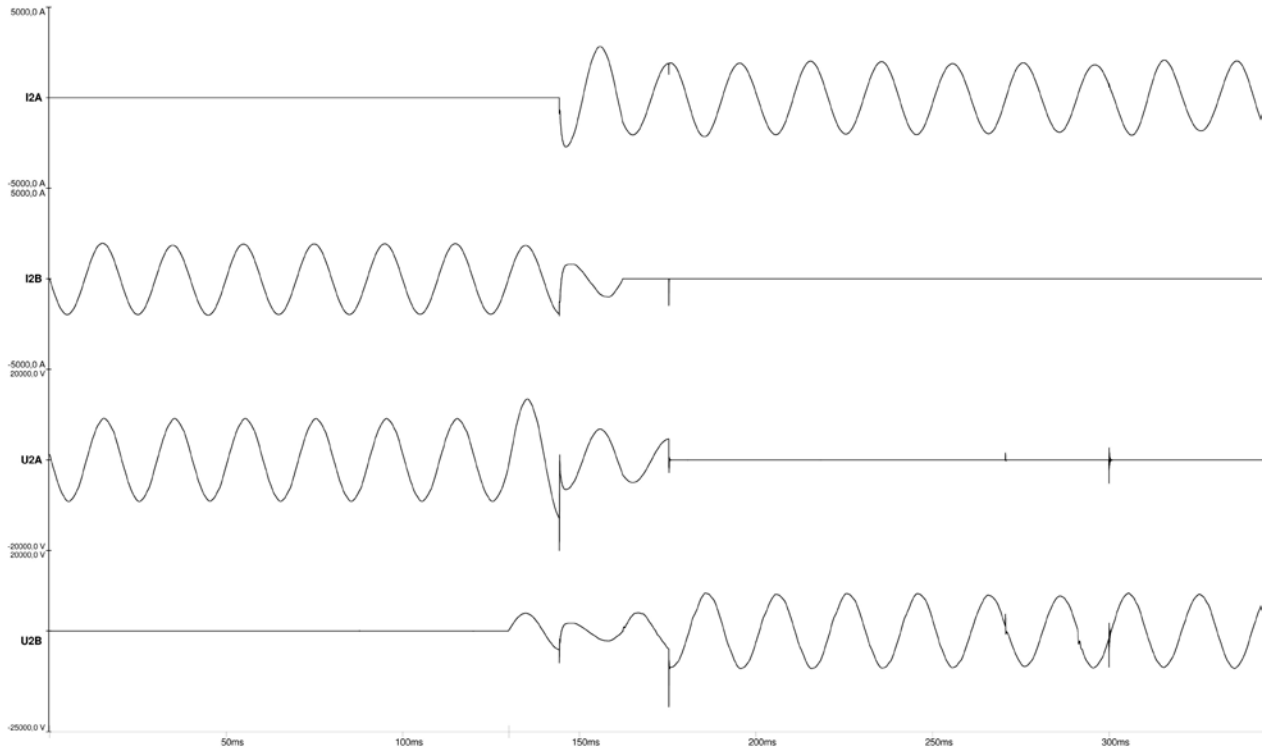


Fig. 3.68: Service duty test (test sequence 1 – switching operation no. 270690).

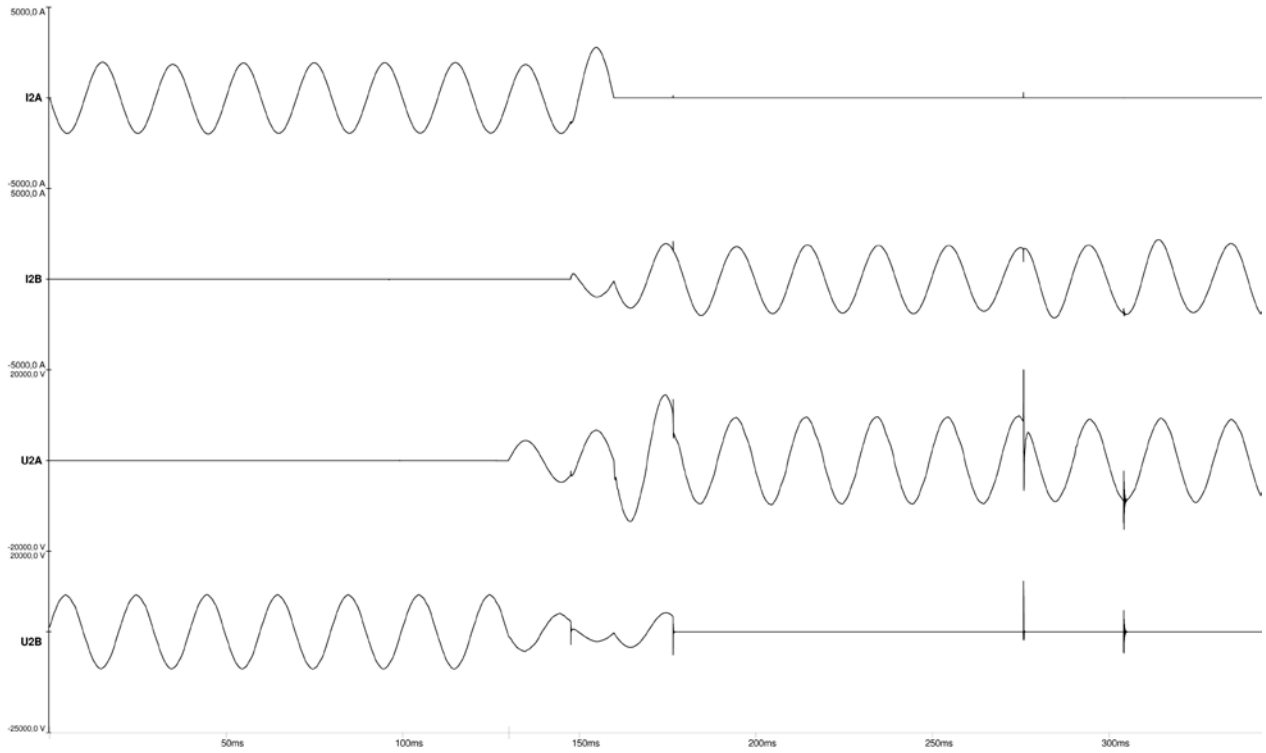


Fig. 3.69: Service duty test (test sequence 1 – switching operation no. 270691).

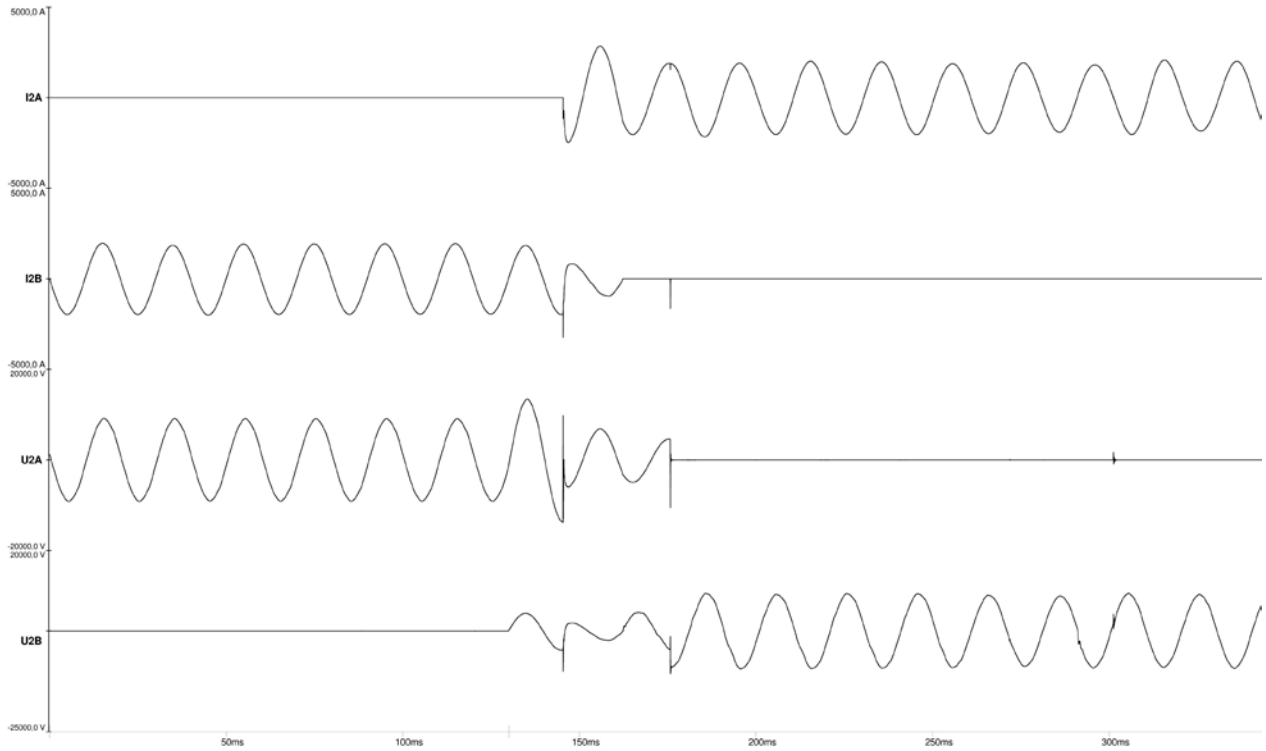


Fig. 3.70: Service duty test (test sequence 1 – switching operation no. 270692).

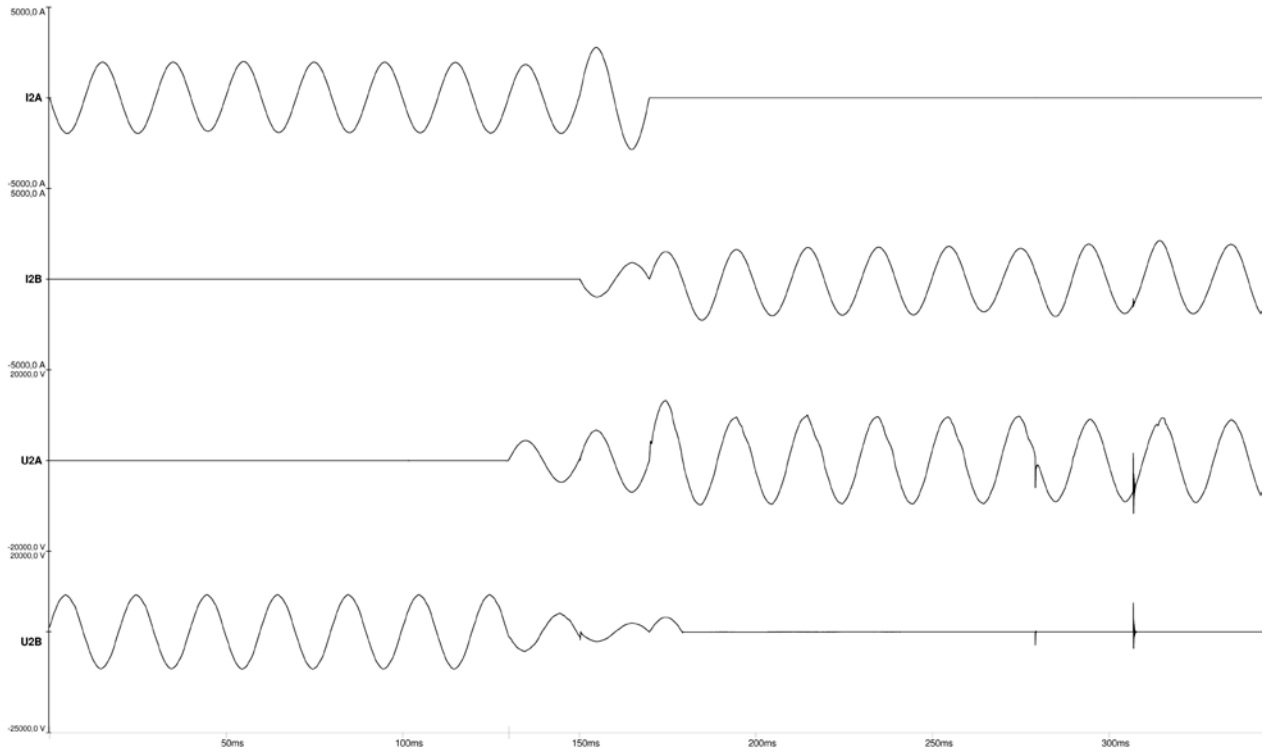
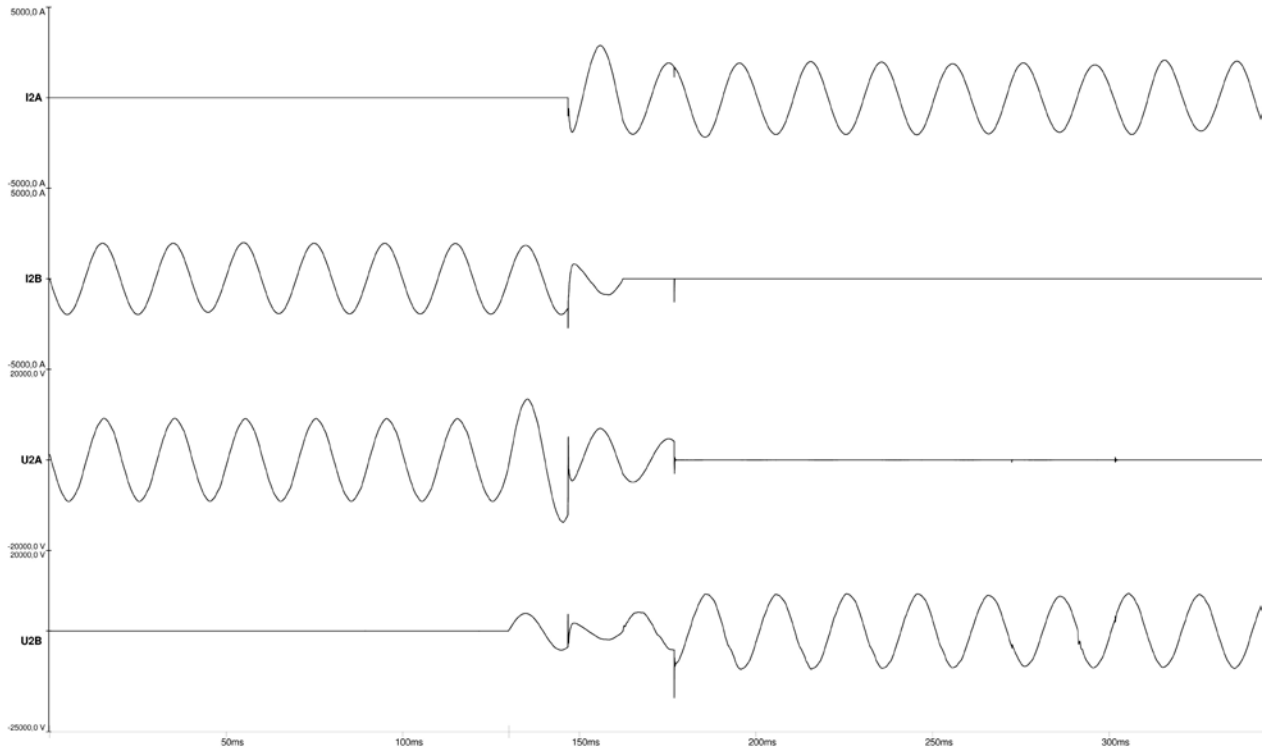


Fig. 3.71: Service duty test (test sequence 1 – switching operation no. 270693).



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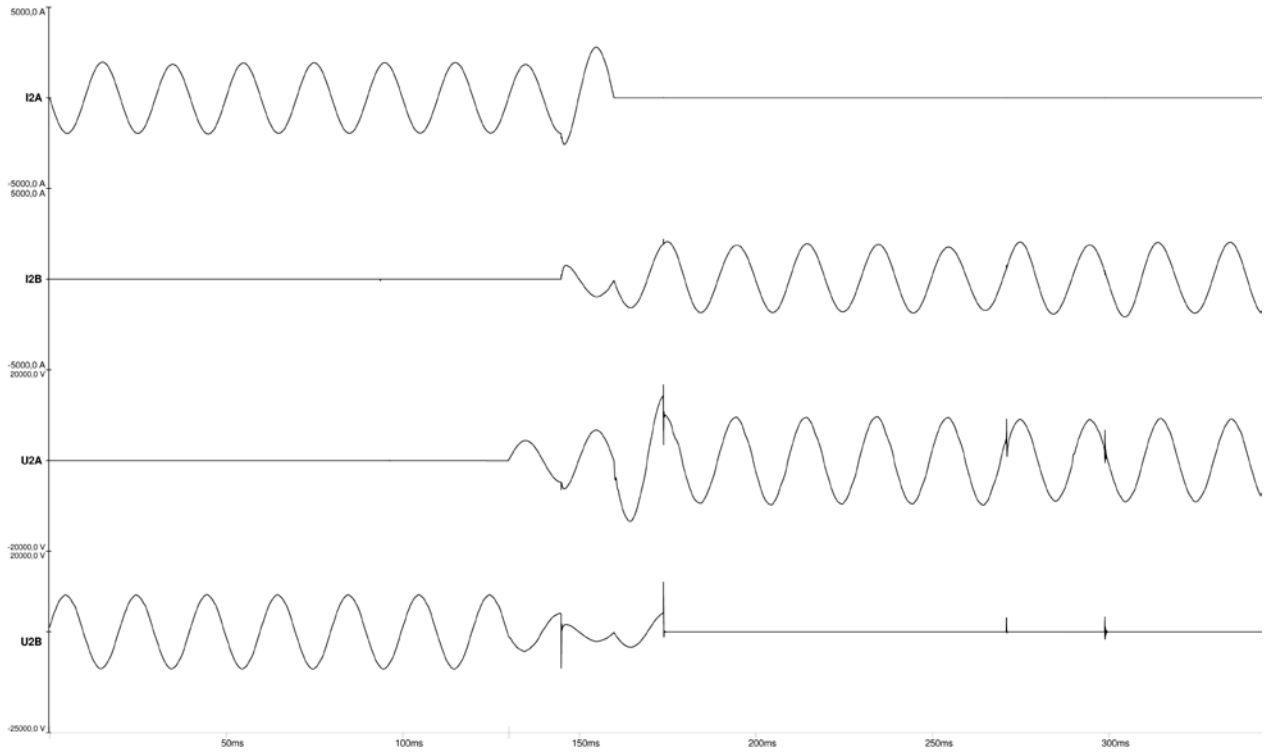

Fig. 3.73: Service duty test (test sequence 1 – switching operation no. 270695).

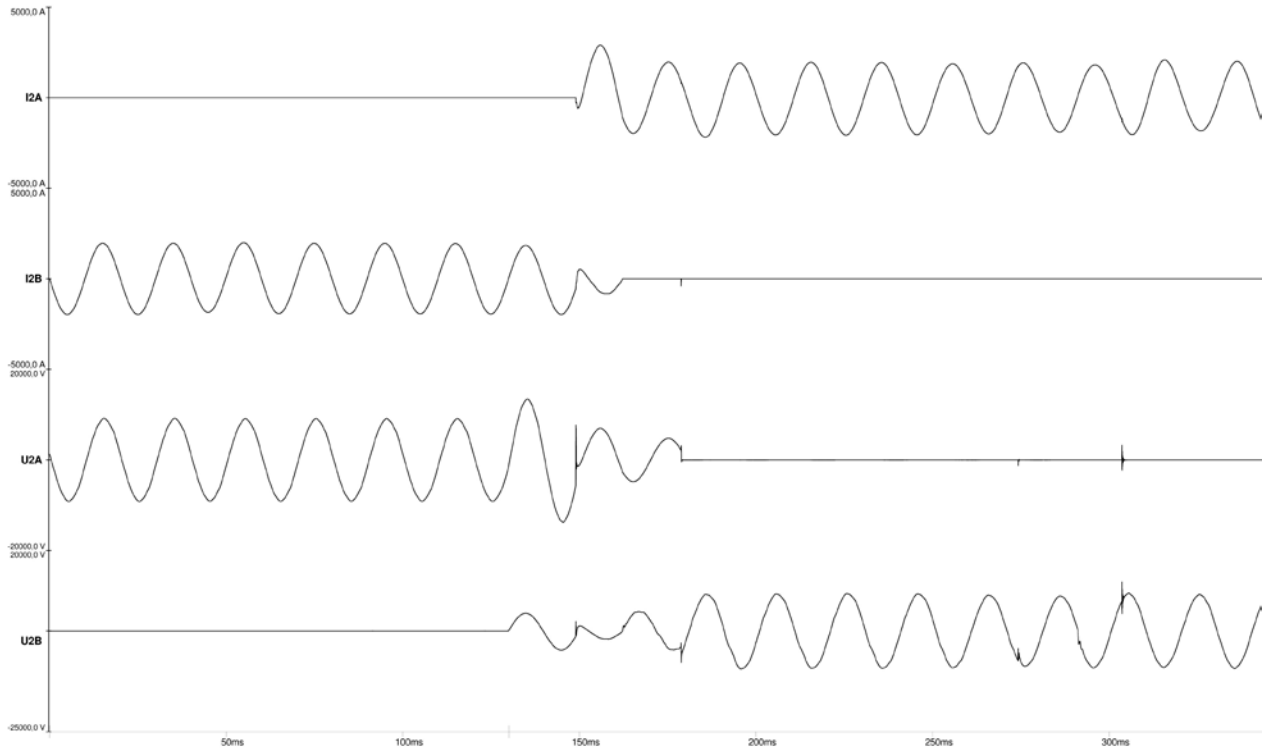

Fig. 3.74: Service duty test (test sequence 1 – switching operation no. 270696).

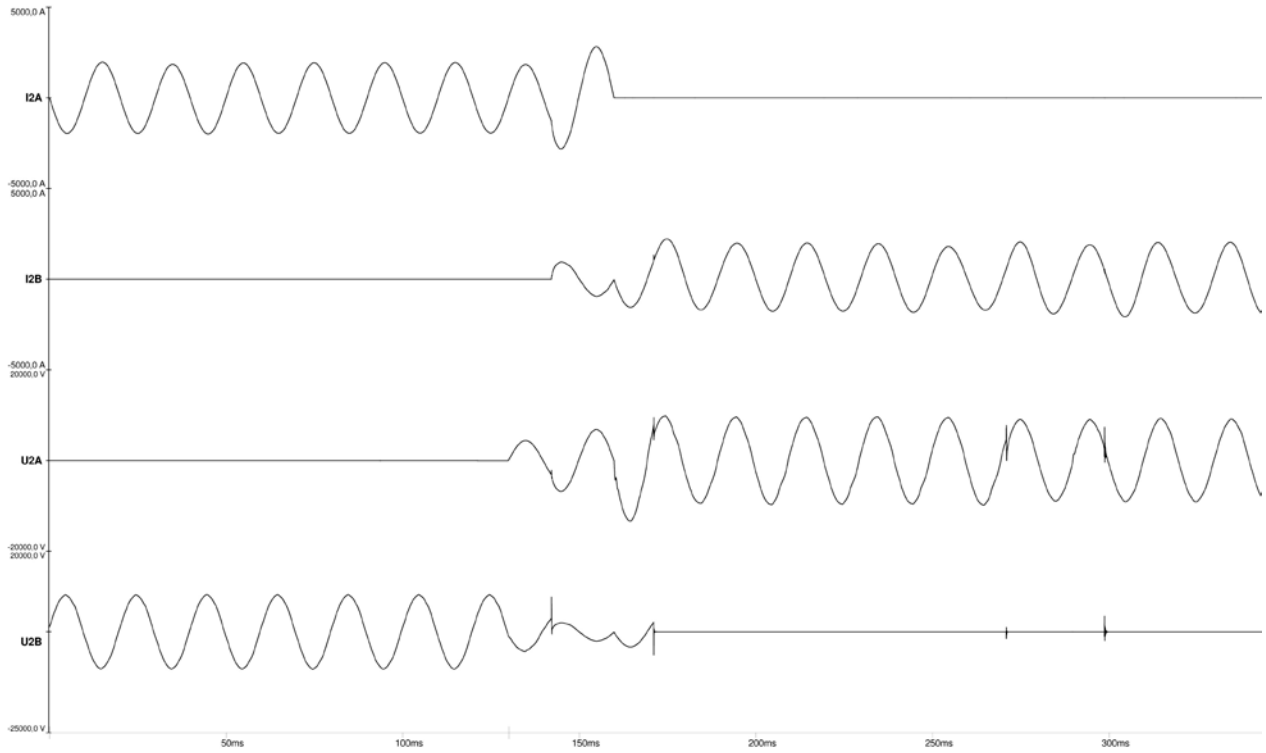

Fig. 3.75: Service duty test (test sequence 1 – switching operation no. 270697).

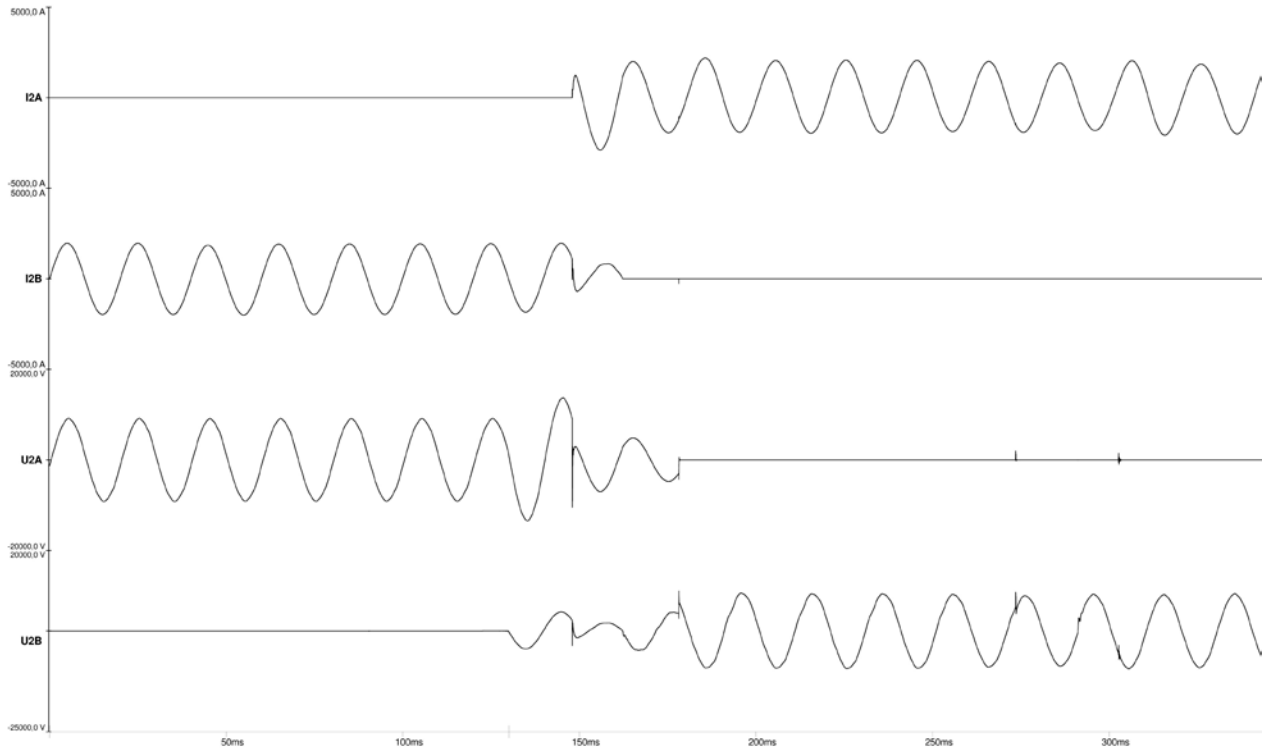

Fig. 3.76: Service duty test (test sequence 1 – switching operation no. 270698).

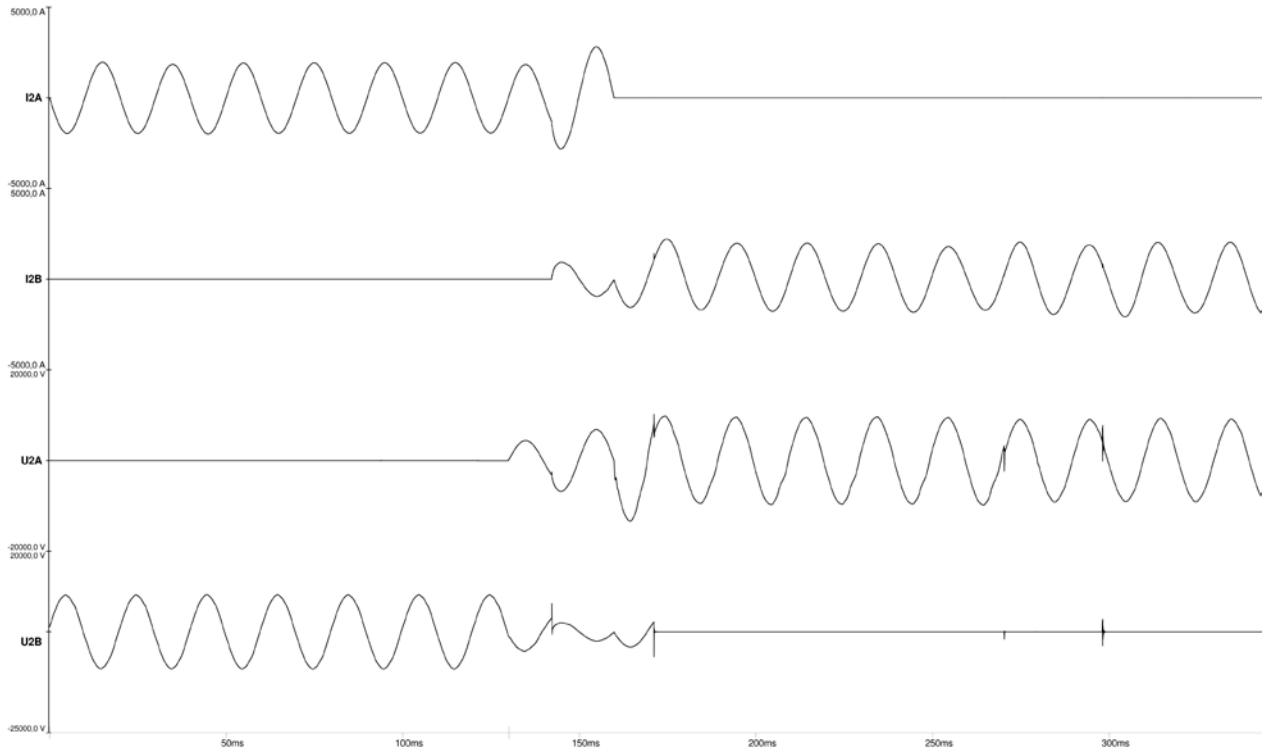

Fig. 3.77: Service duty test (test sequence 1 – switching operation no. 270699).

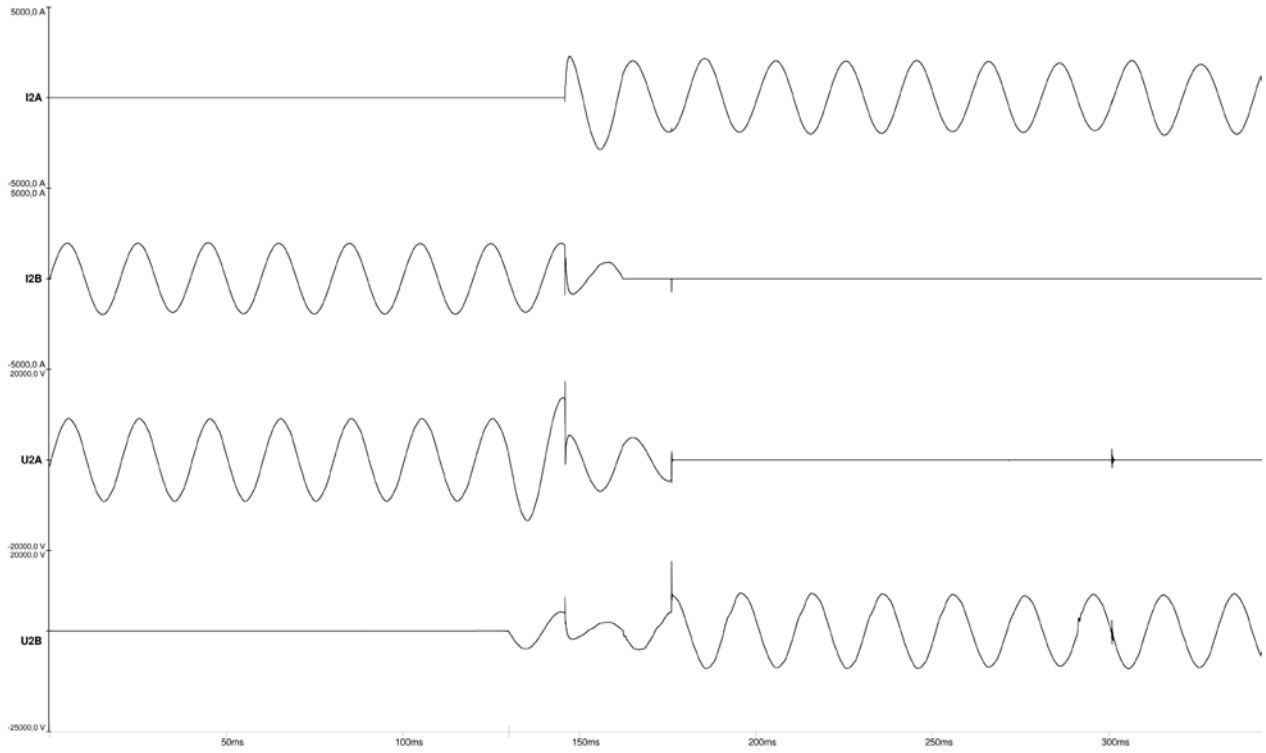

Fig. 3.78: Service duty test (test sequence 1 – switching operation no. 270700).

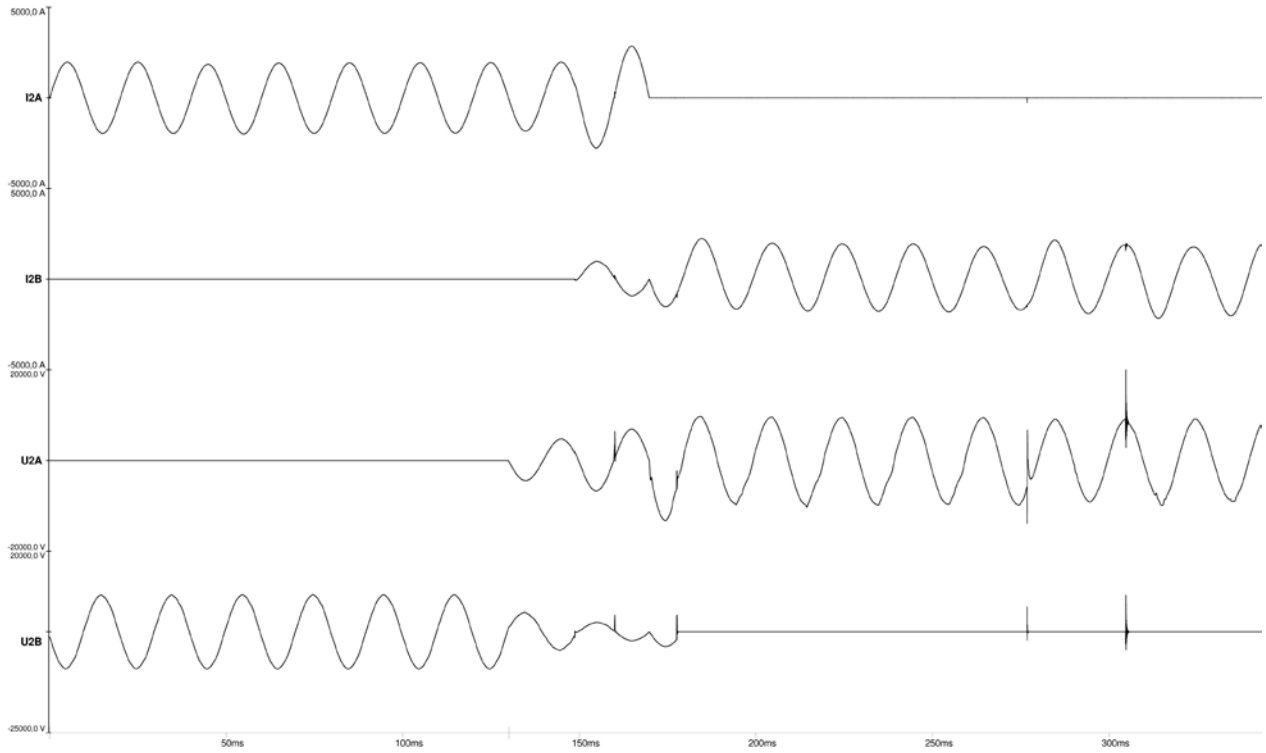

Fig. 3.79: Service duty test (test sequence 1 – switching operation no. 270701).

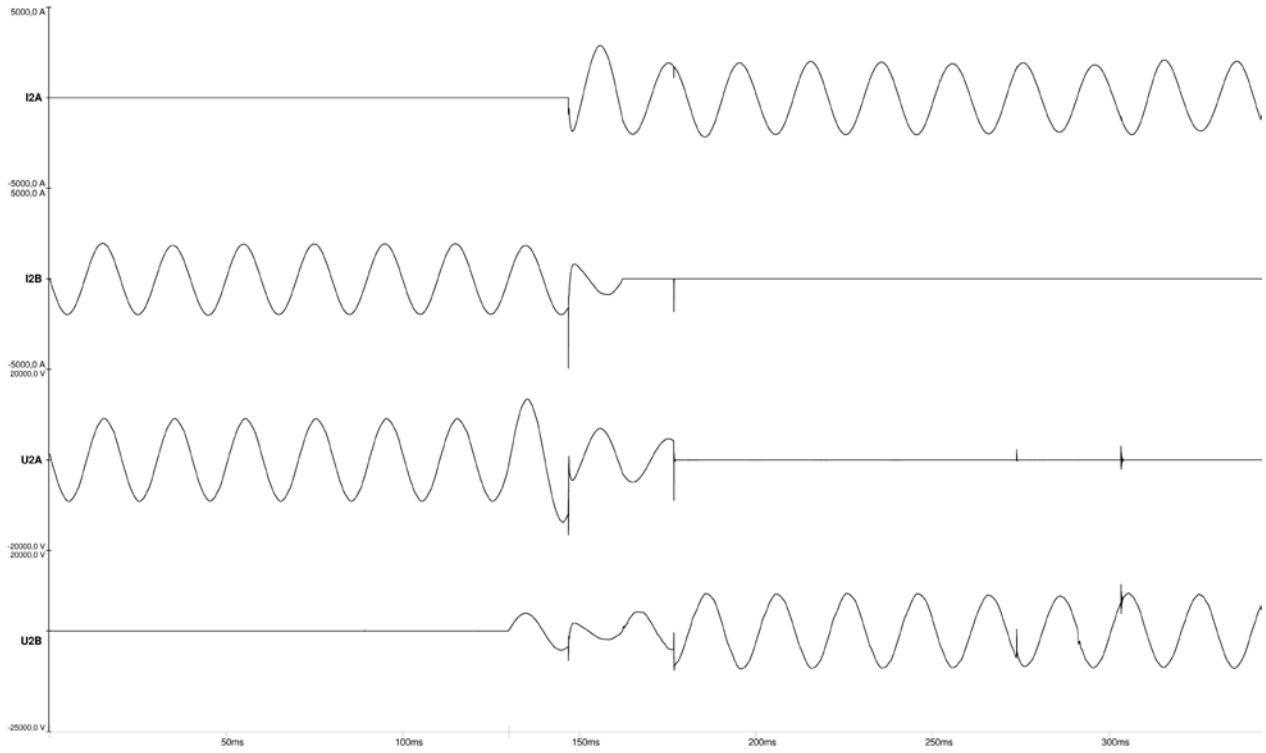

Fig. 3.80: Service duty test (test sequence 1 – switching operation no. 270702).

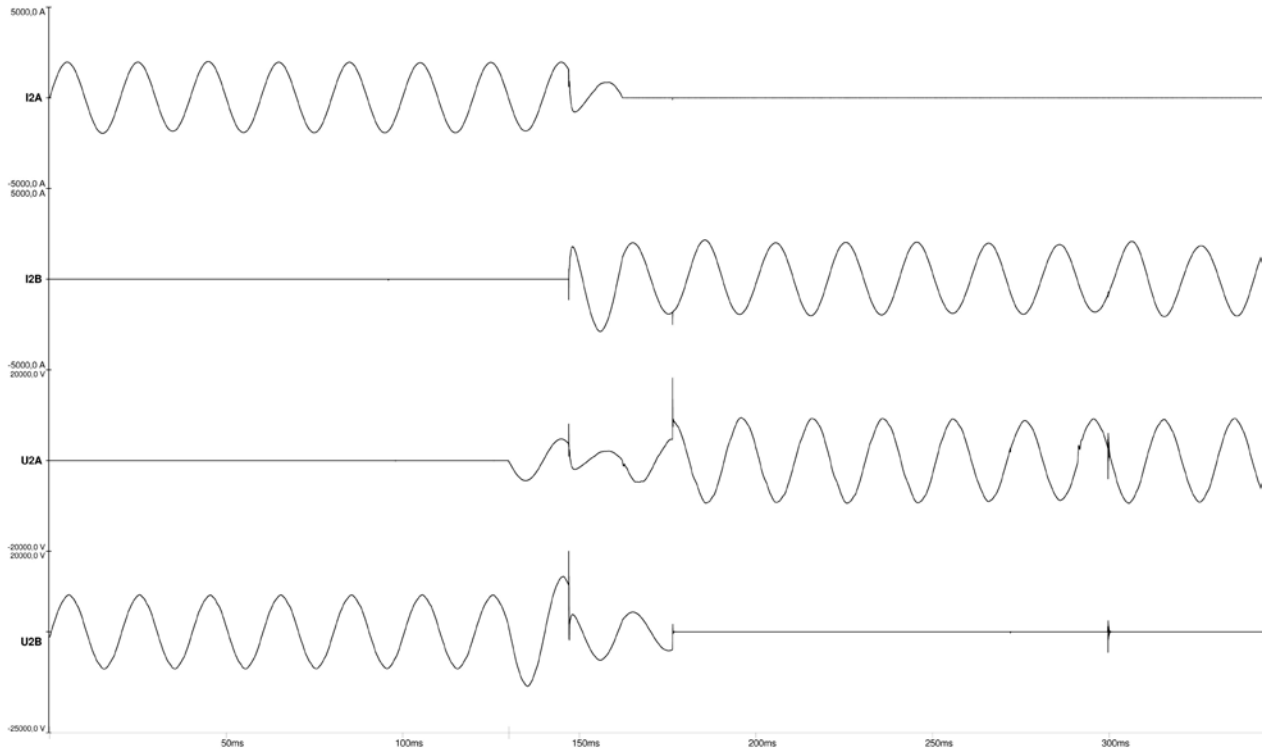

Fig. 3.81: Service duty test (test sequence 1 – switching operation no. 360592).

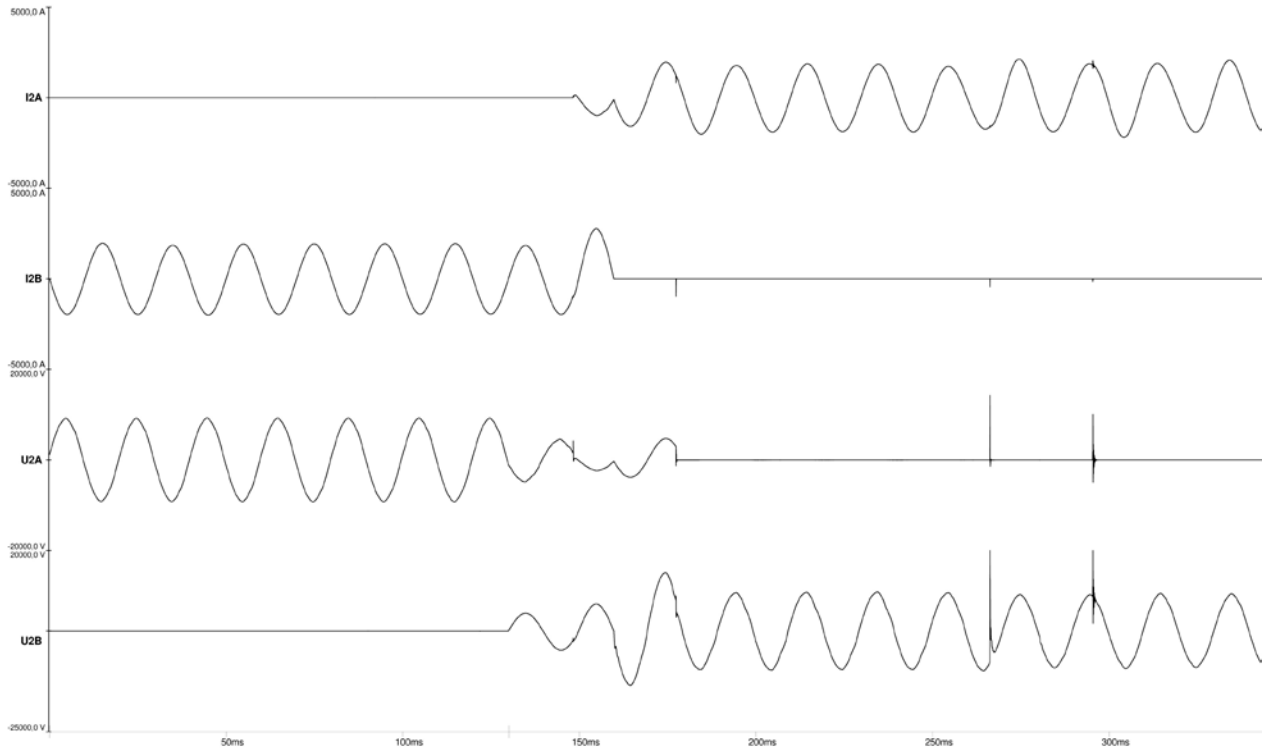

Fig. 3.82: Service duty test (test sequence 1 – switching operation no. 360593).

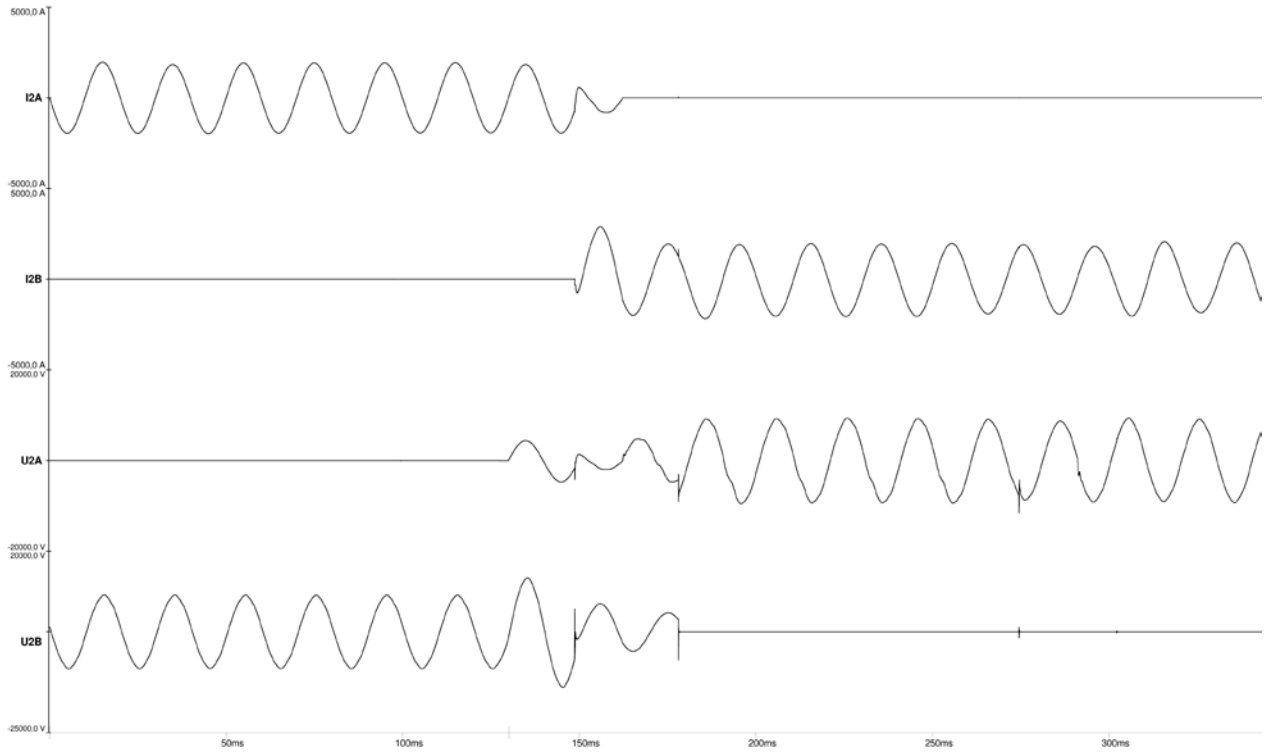

Fig. 3.83: Service duty test (test sequence 1 – switching operation no. 360594).

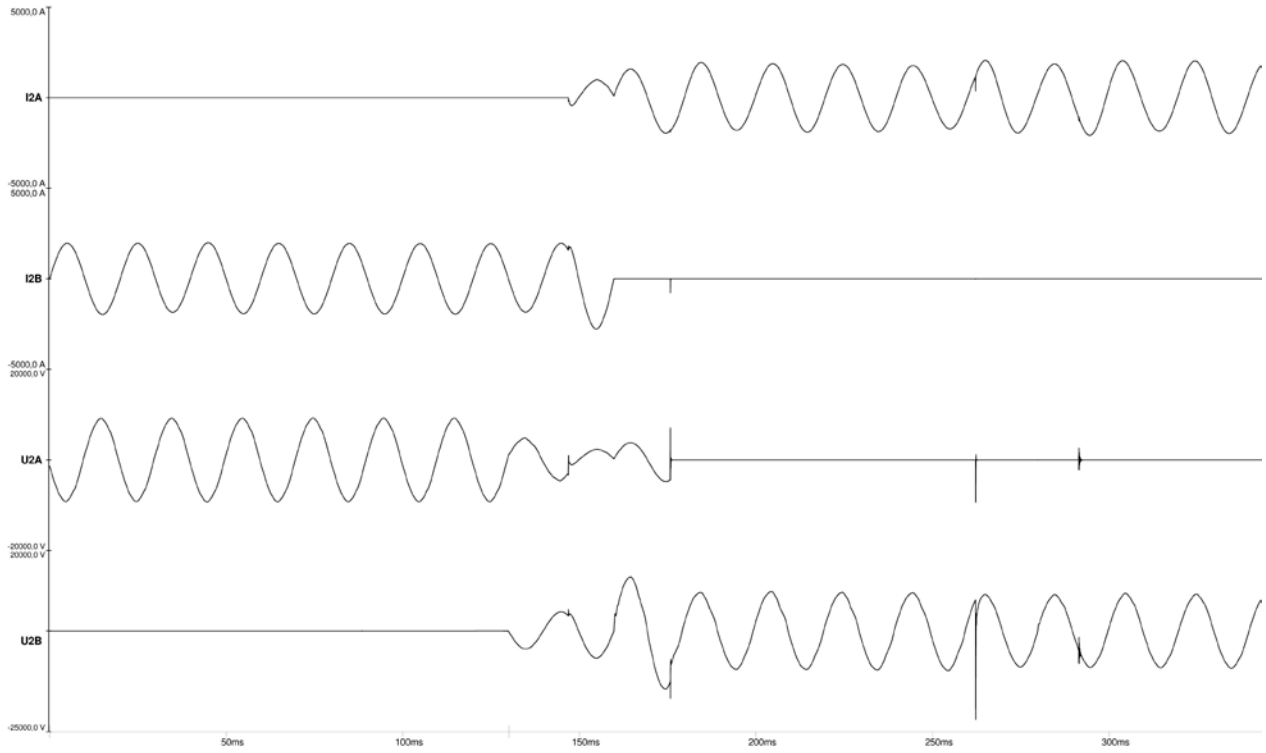

Fig. 3.84: Service duty test (test sequence 1 – switching operation no. 360595).

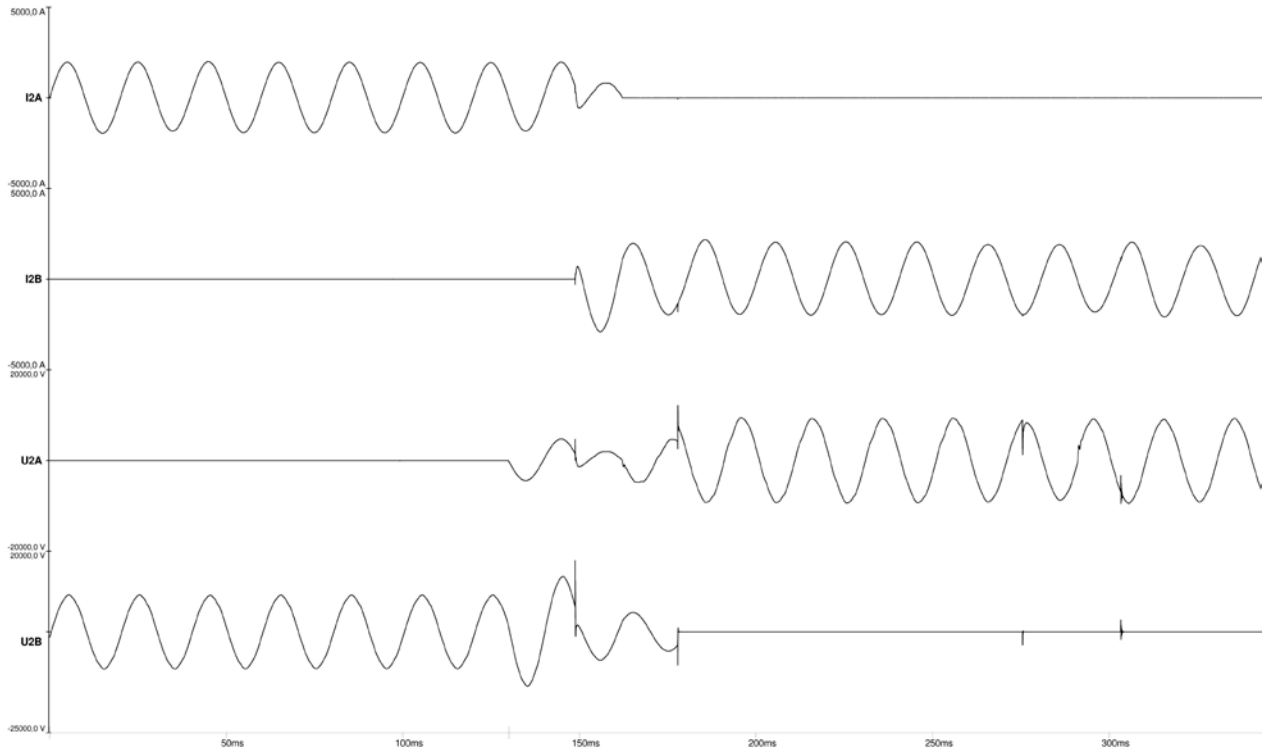

Fig. 3.85: Service duty test (test sequence 1 – switching operation no. 360596).

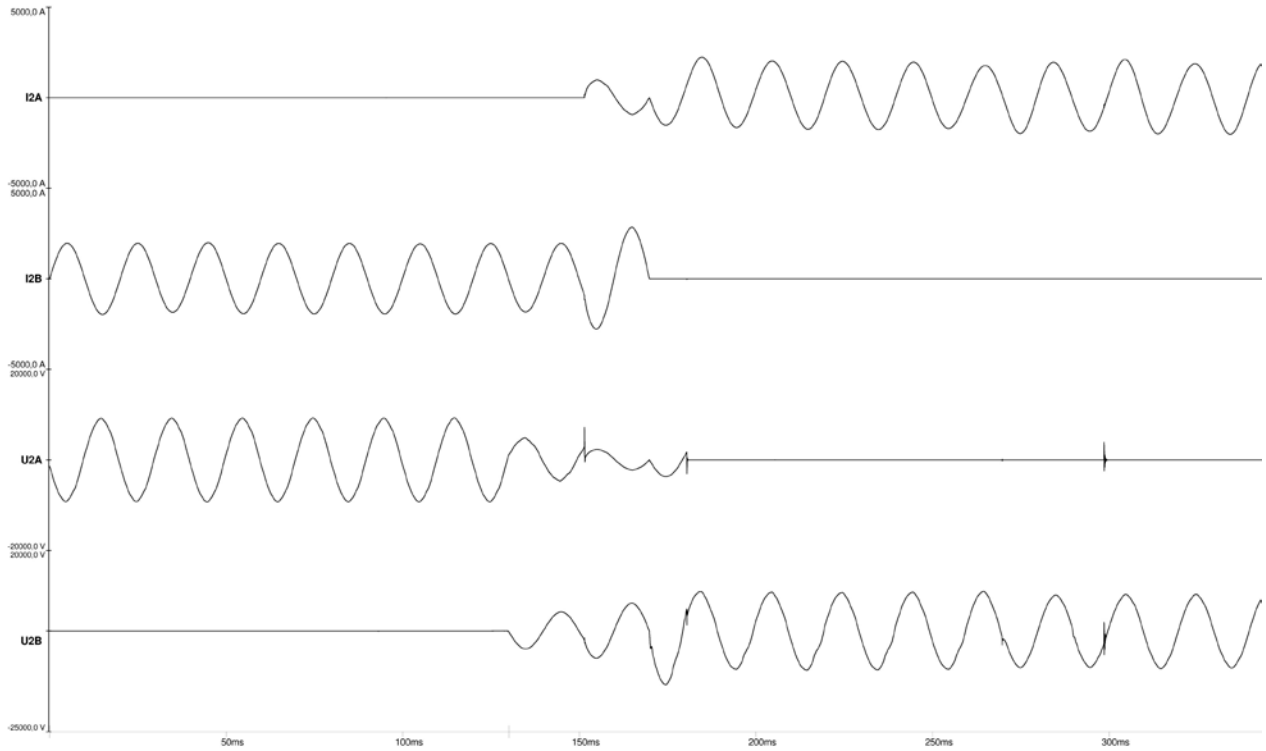

Fig. 3.86: Service duty test (test sequence 1 – switching operation no. 360597).

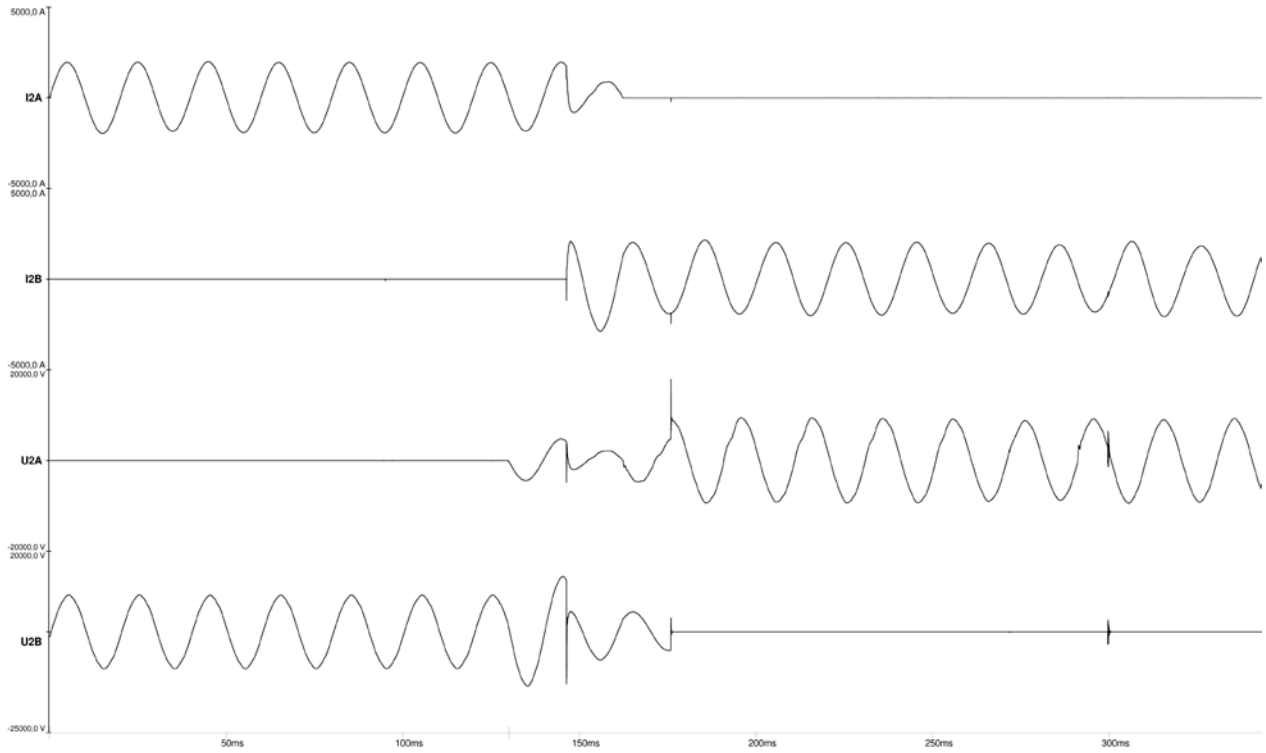

Fig. 3.87: Service duty test (test sequence 1 – switching operation no. 360598).

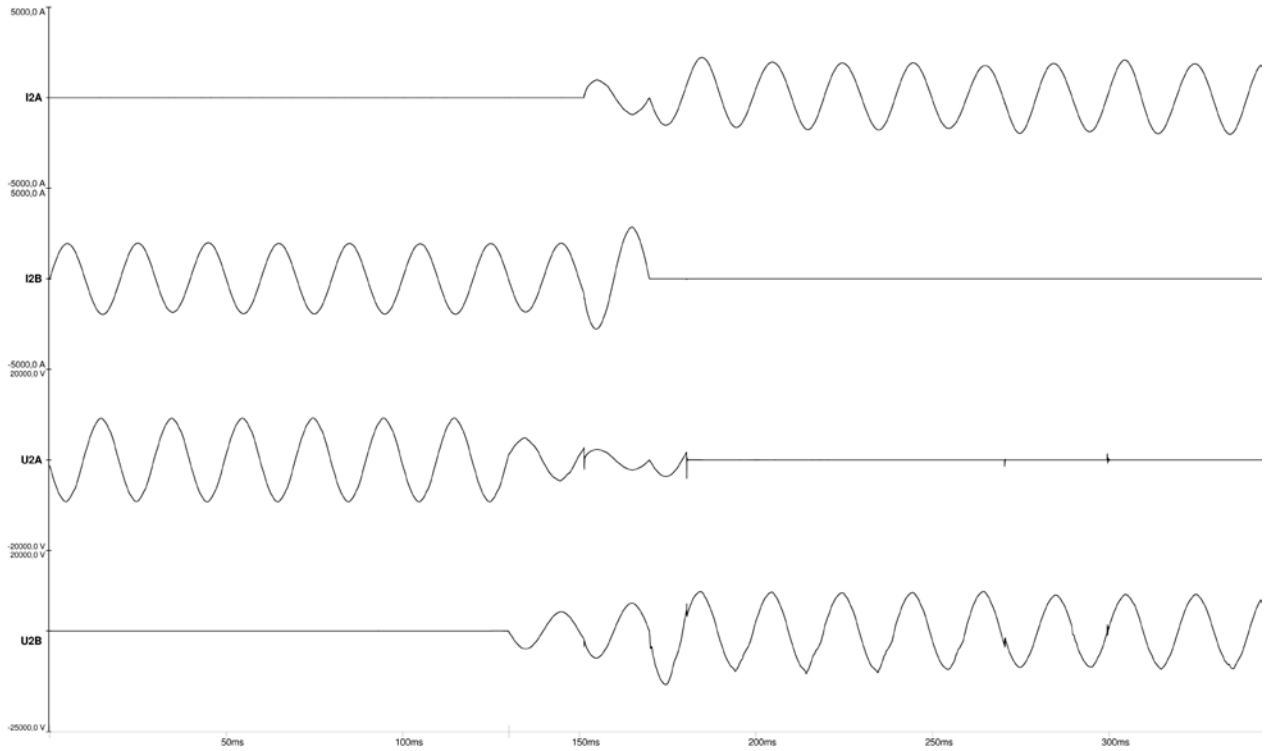

Fig. 3.88: Service duty test (test sequence 1 – switching operation no. 360599).

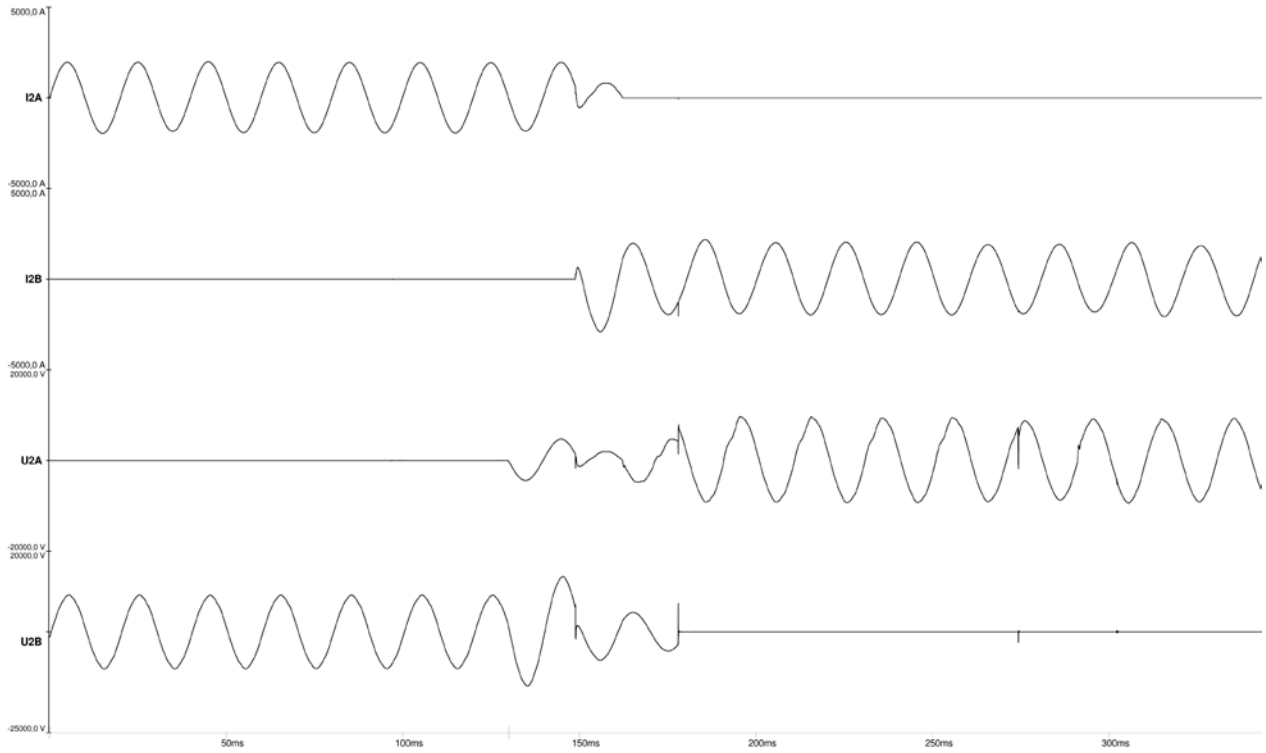

Fig. 3.89: Service duty test (test sequence 1 – switching operation no. 360600).

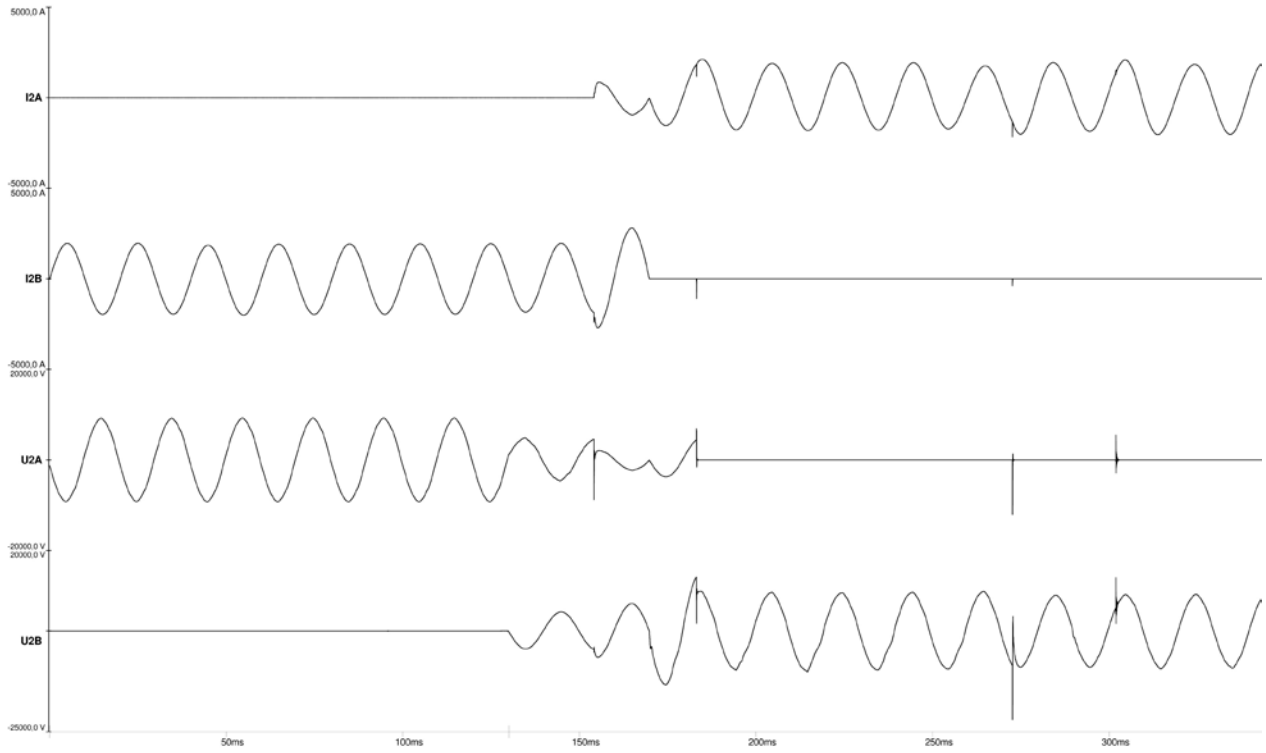

Fig. 3.90: Service duty test (test sequence 1 – switching operation no. 360601).

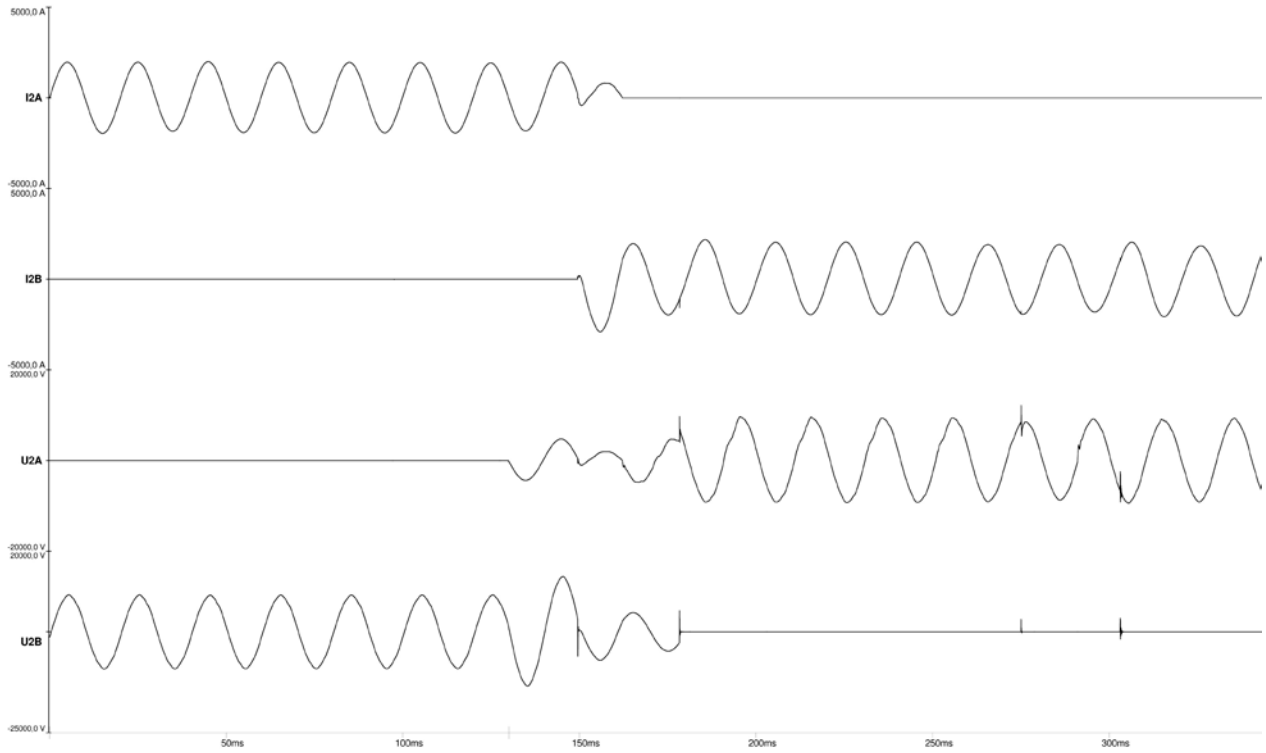

Fig. 3.91: Service duty test (test sequence 1 – switching operation no. 360602).

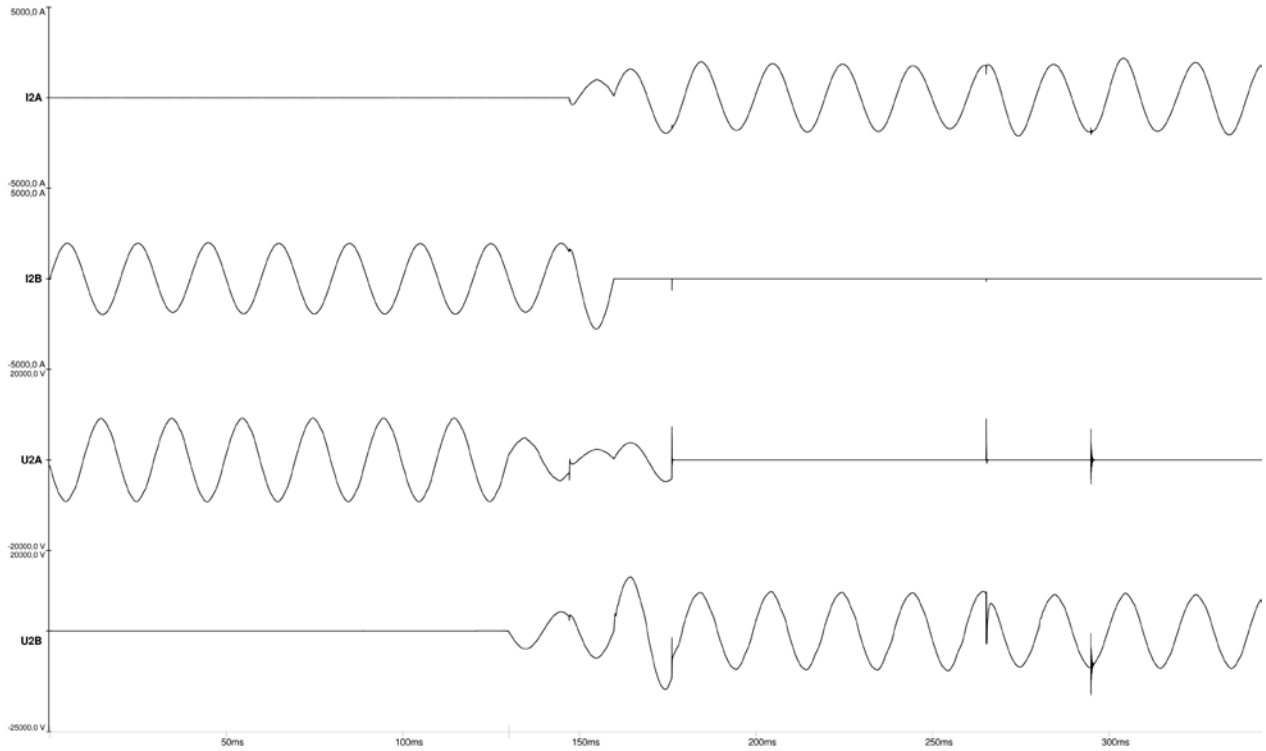

Fig. 3.92: Service duty test (test sequence 1 – switching operation no. 360603).

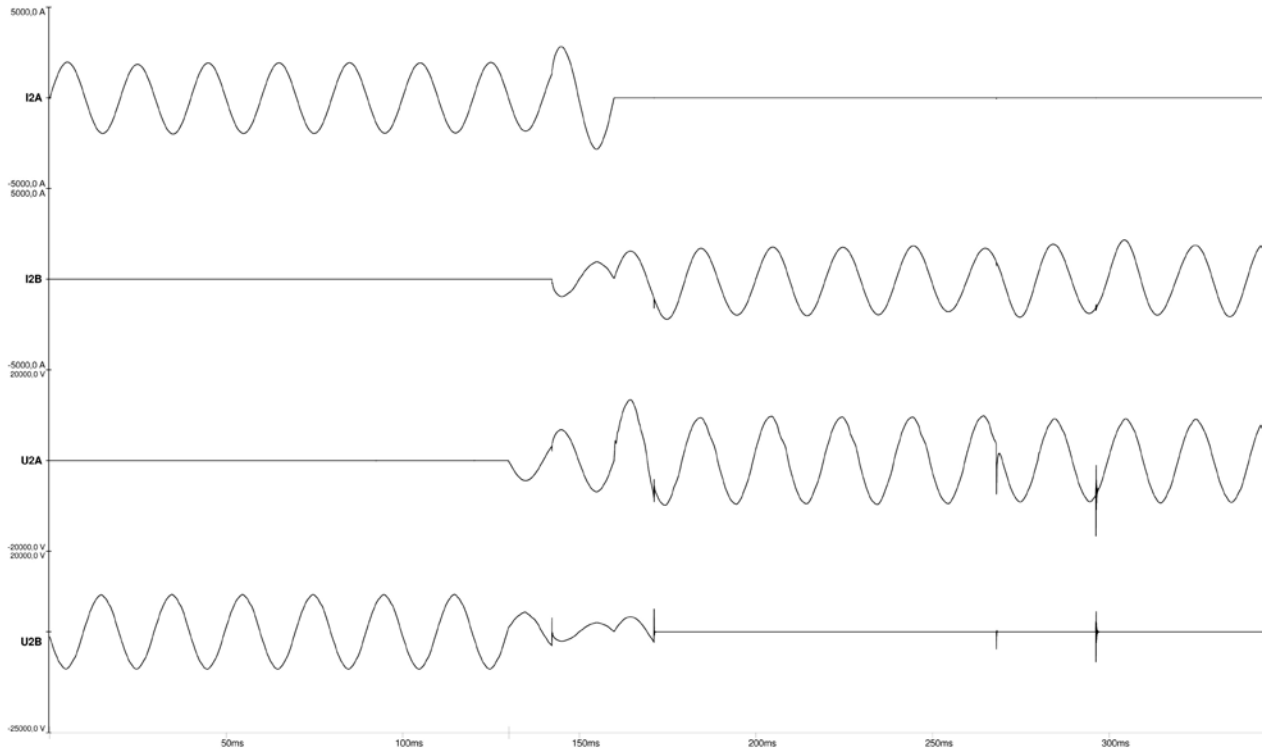

Fig. 3.93: Service duty test (test sequence 1 – switching operation no. 360604).

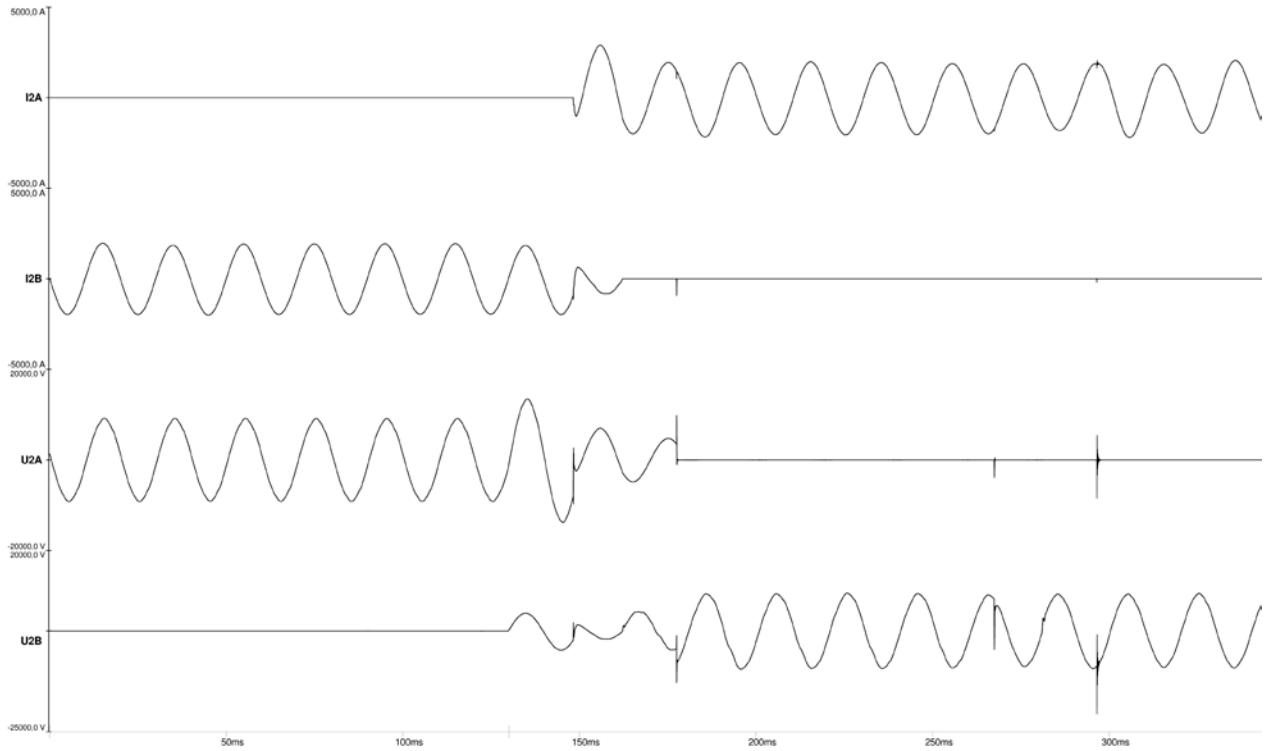

Fig. 3.94: Service duty test (test sequence 1 – switching operation no. 360605).

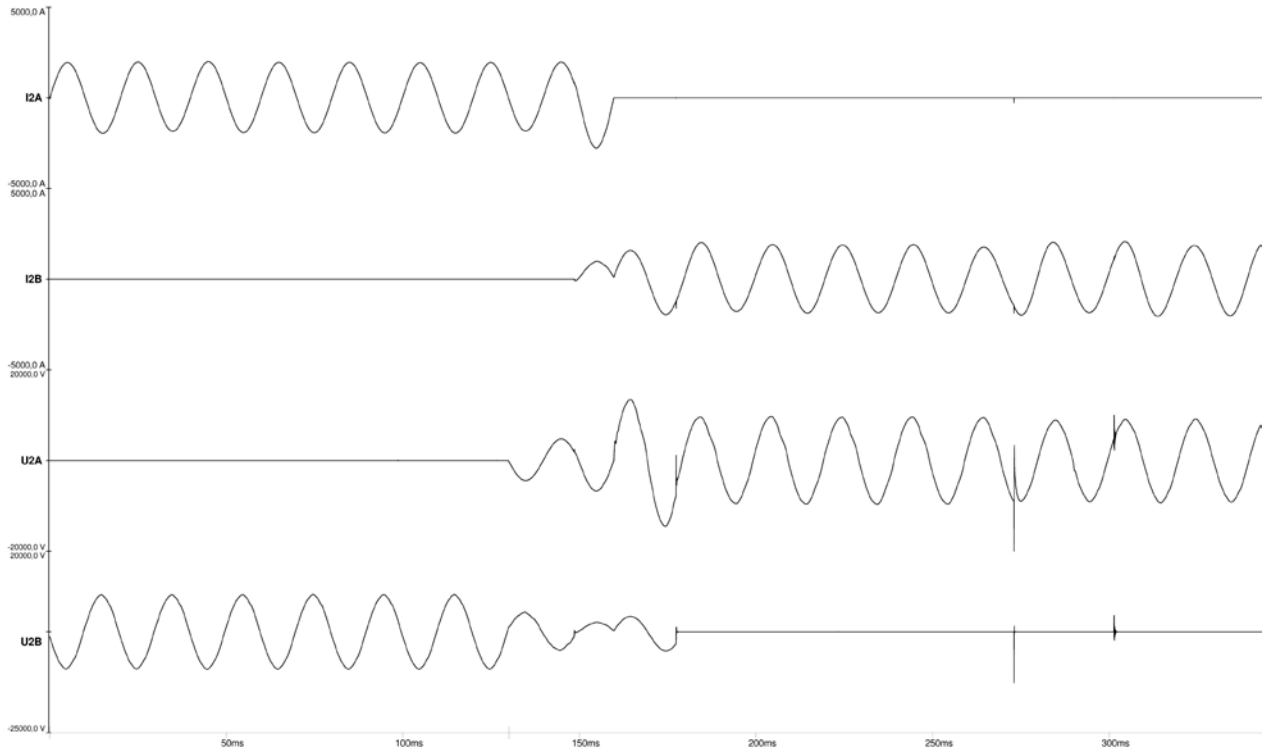

Fig. 3.95: Service duty test (test sequence 1 – switching operation no. 360606).

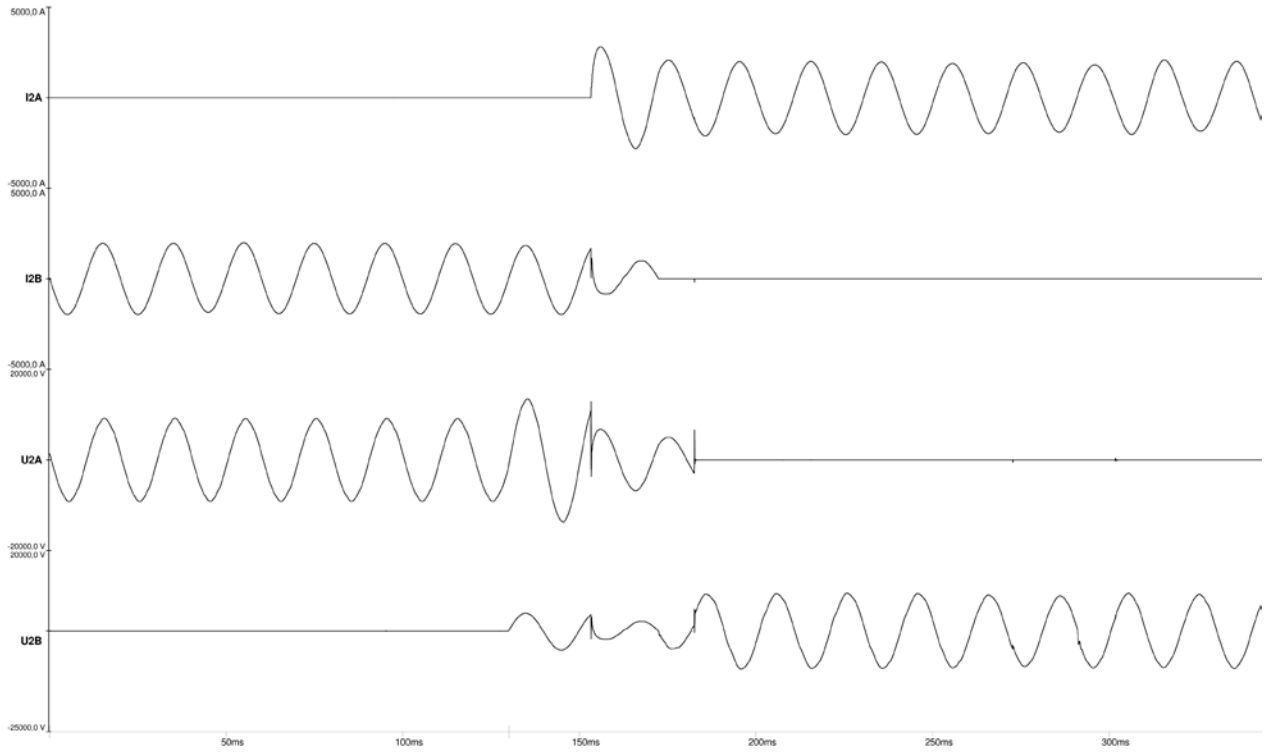

Fig. 3.96: Service duty test (test sequence 1 – switching operation no. 360607).

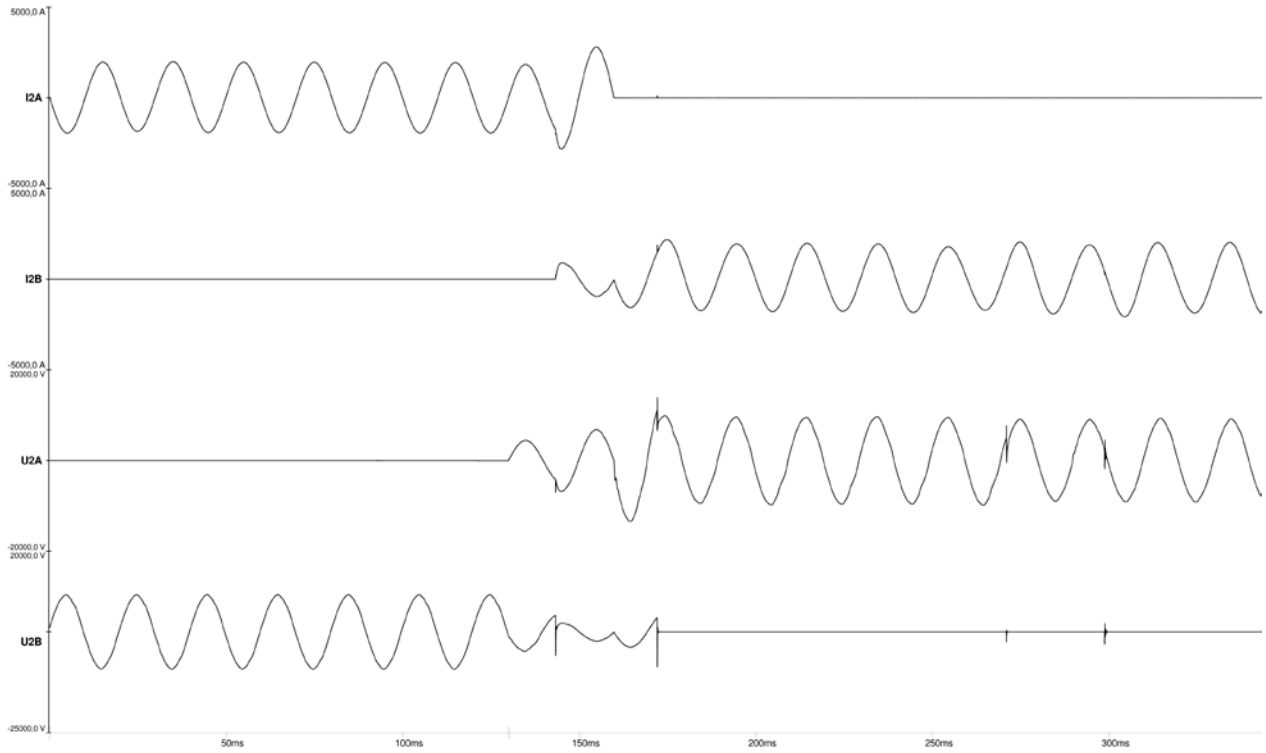

Fig. 3.97: Service duty test (test sequence 1 – switching operation no. 360608).

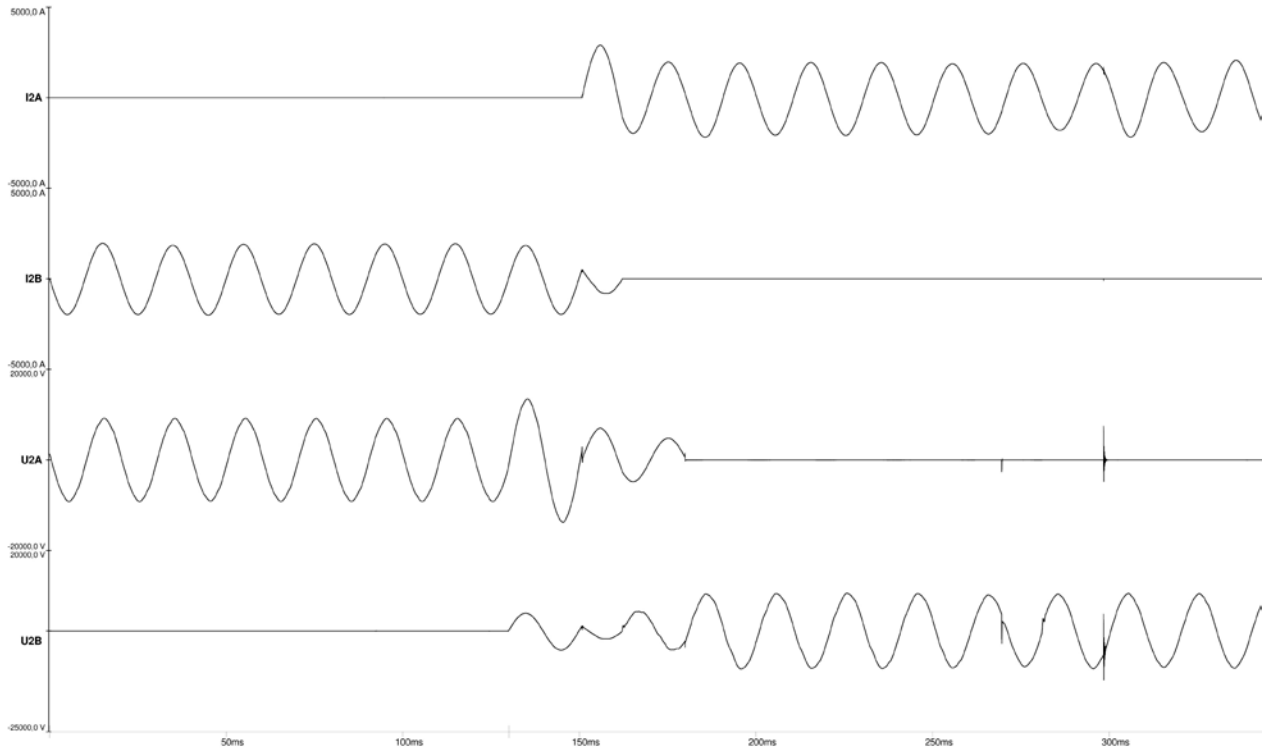

Fig. 3.98: Service duty test (test sequence 1 – switching operation no. 360609).

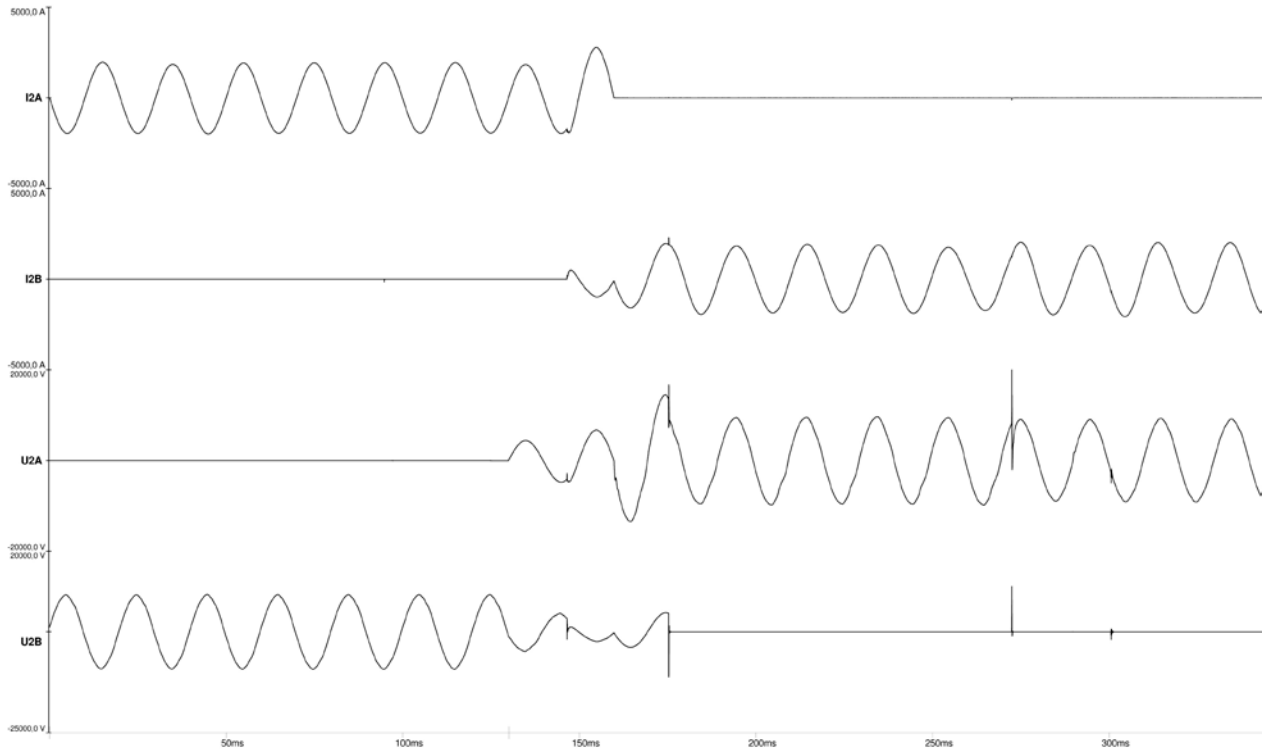

Fig. 3.99: Service duty test (test sequence 1 – switching operation no. 360610).

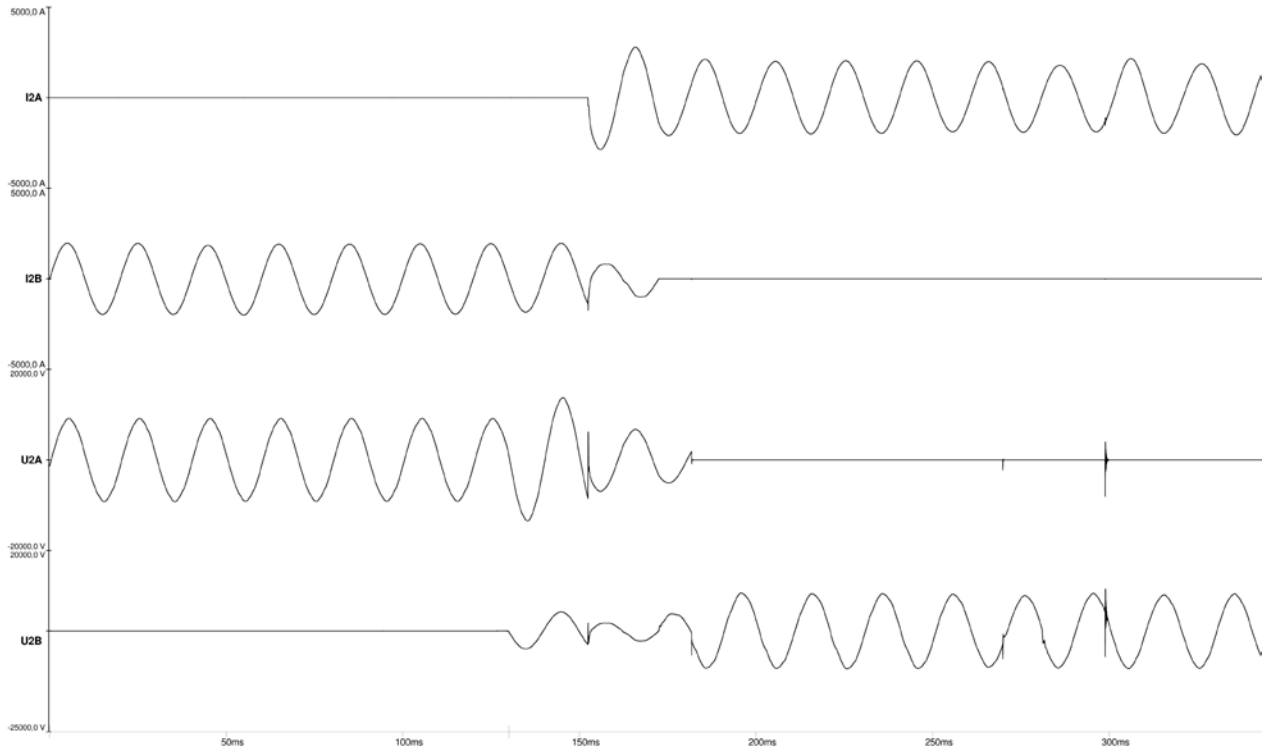

Fig. 3.100: Service duty test (test sequence 1 – switching operation no. 360611).

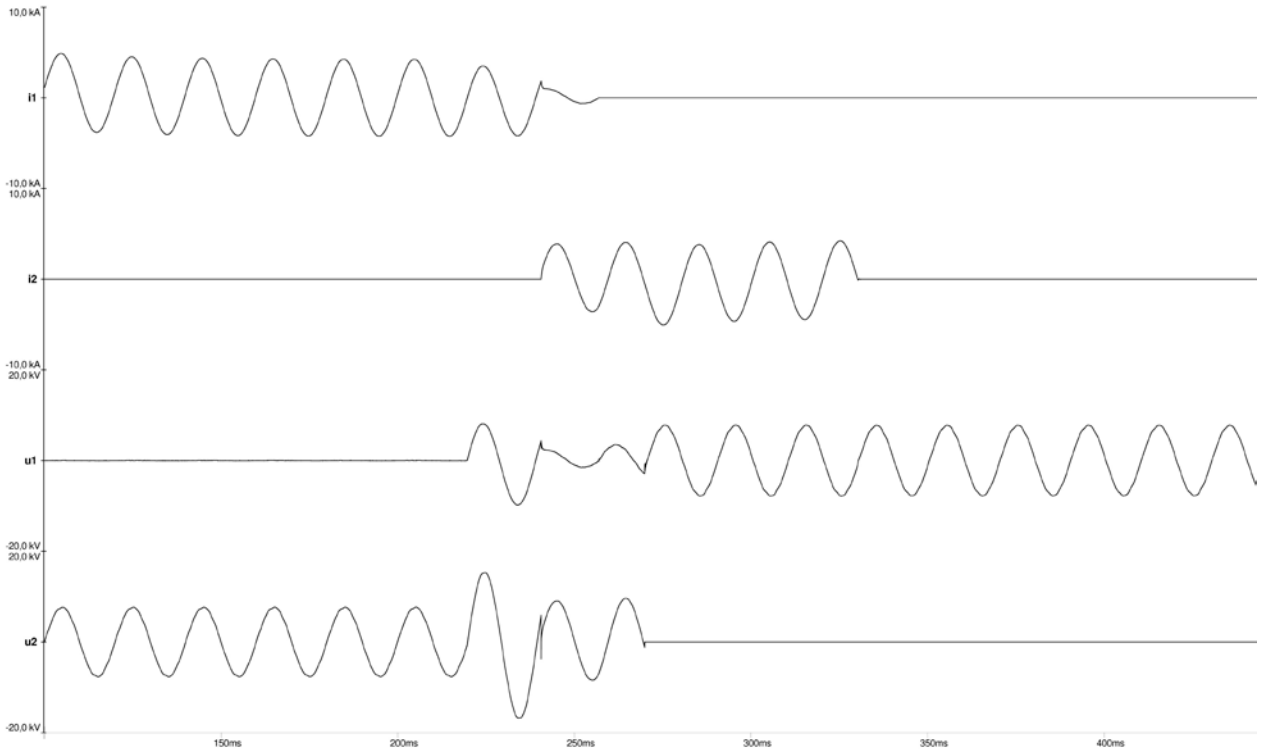

Fig. 4.1: Breaking capacity test (test sequence 2 – switching operation no. 1).

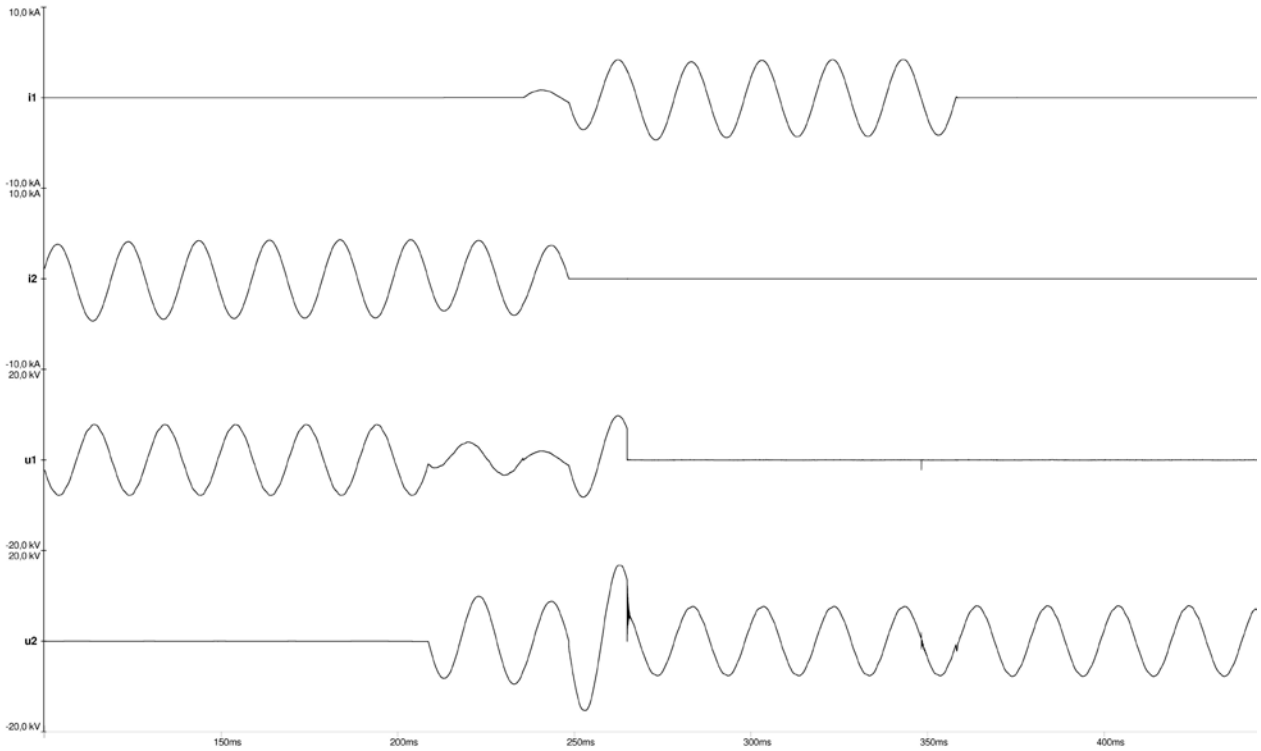

Fig. 4.2: Breaking capacity test (test sequence 2 – switching operation no. 2).

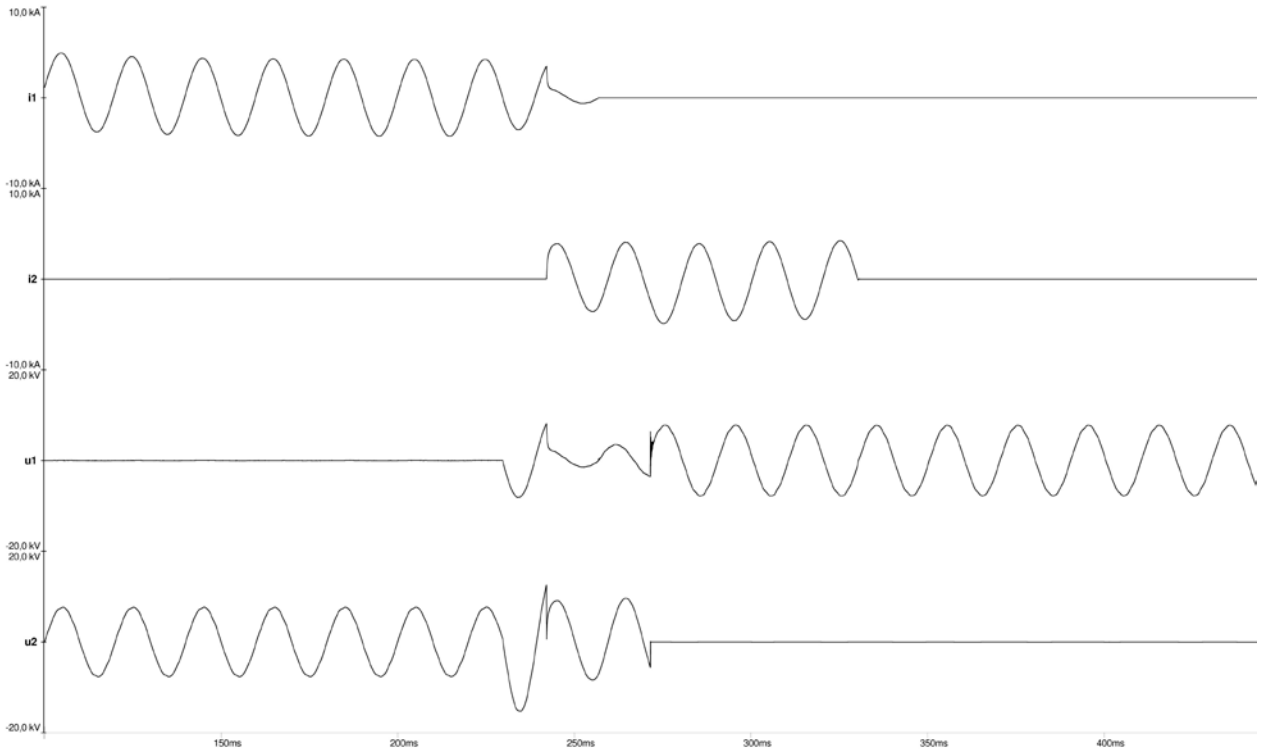

Fig. 4.3: Breaking capacity test (test sequence 2 – switching operation no. 3).

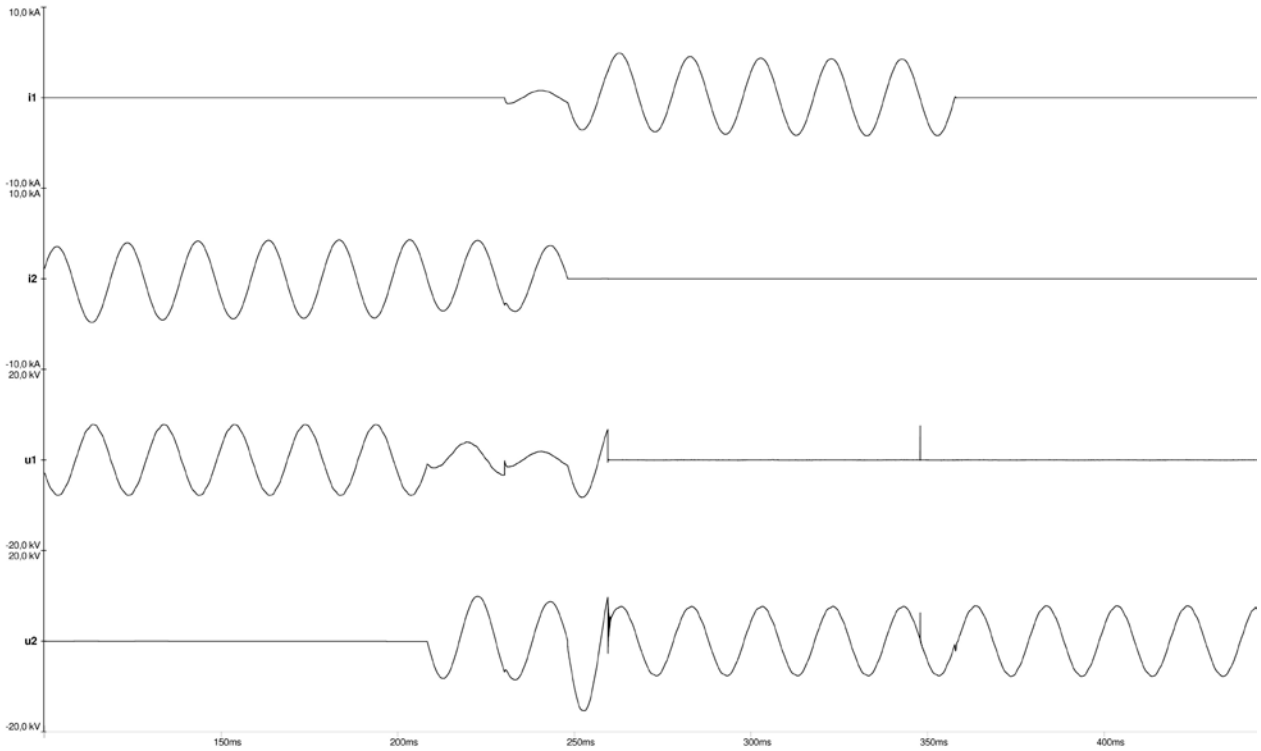

Fig. 4.4: Breaking capacity test (test sequence 2 – switching operation no. 4).

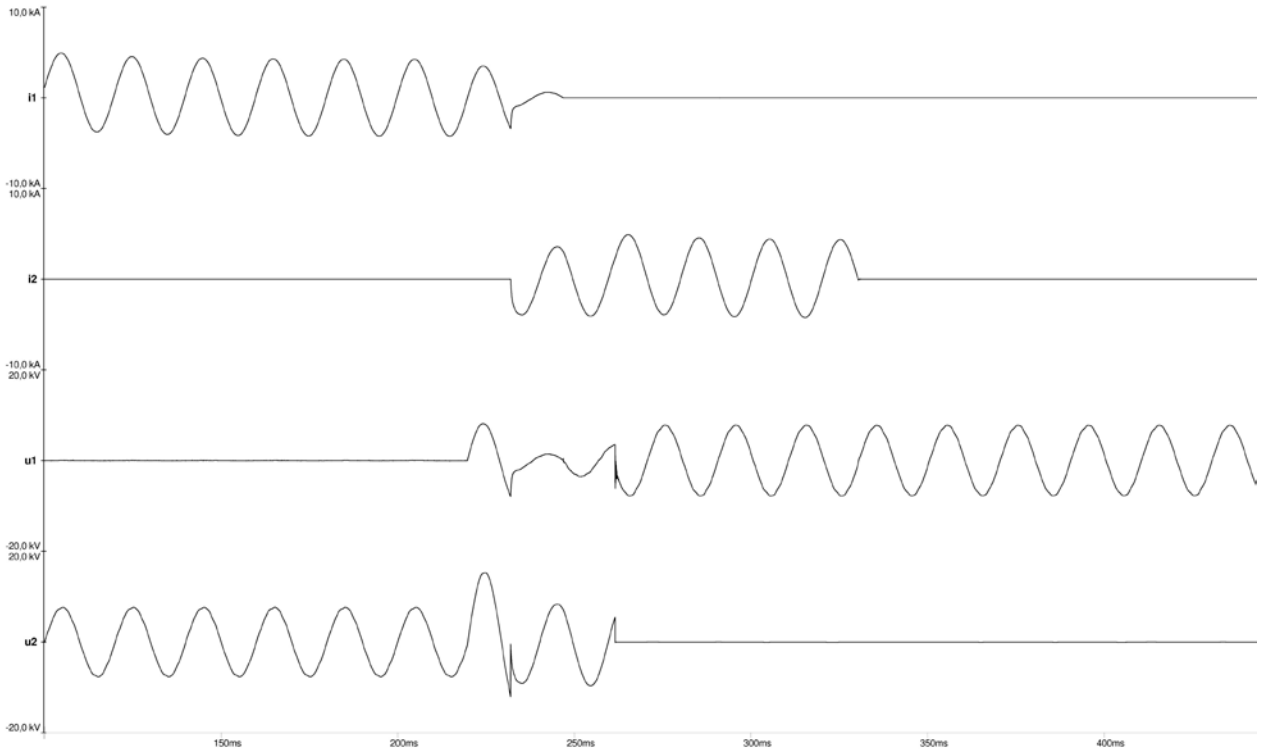

Fig. 4.5: Breaking capacity test (test sequence 2 – switching operation no. 5).

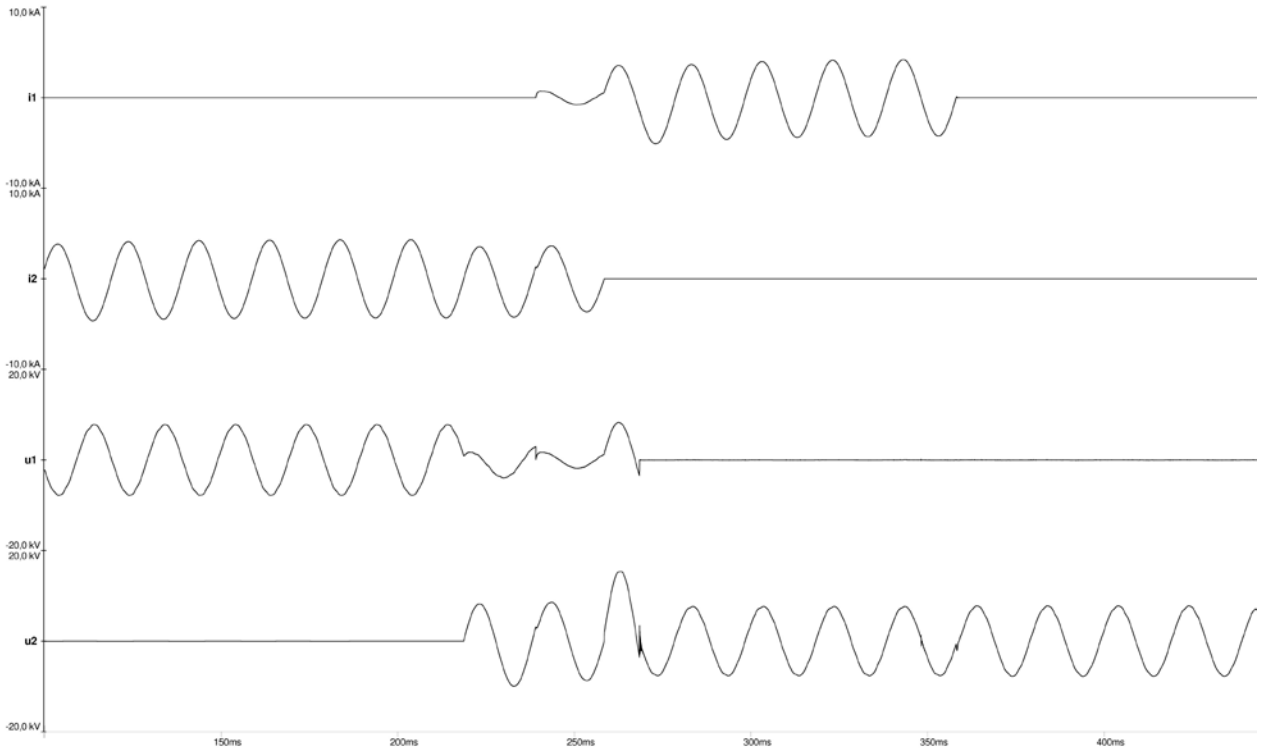

Fig. 4.6: Breaking capacity test (test sequence 2 – switching operation no. 6).

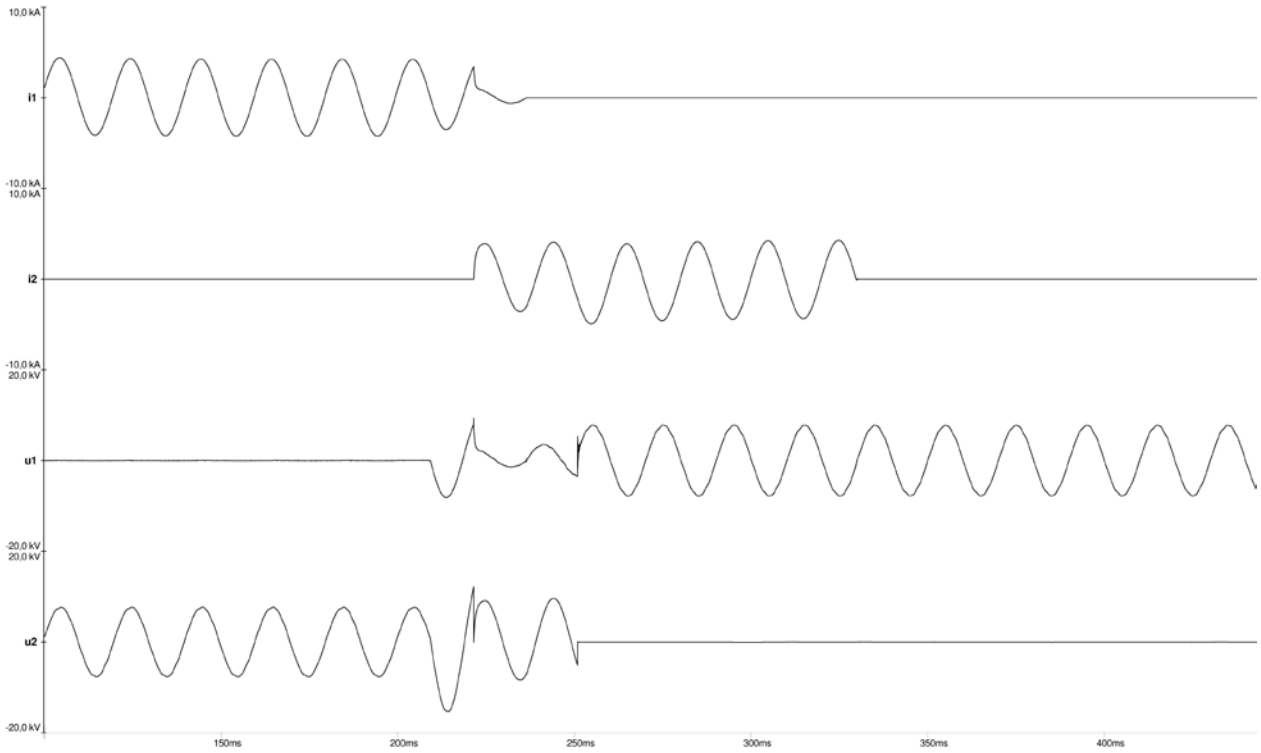

Fig. 4.7: Breaking capacity test (test sequence 2 – switching operation no. 7).

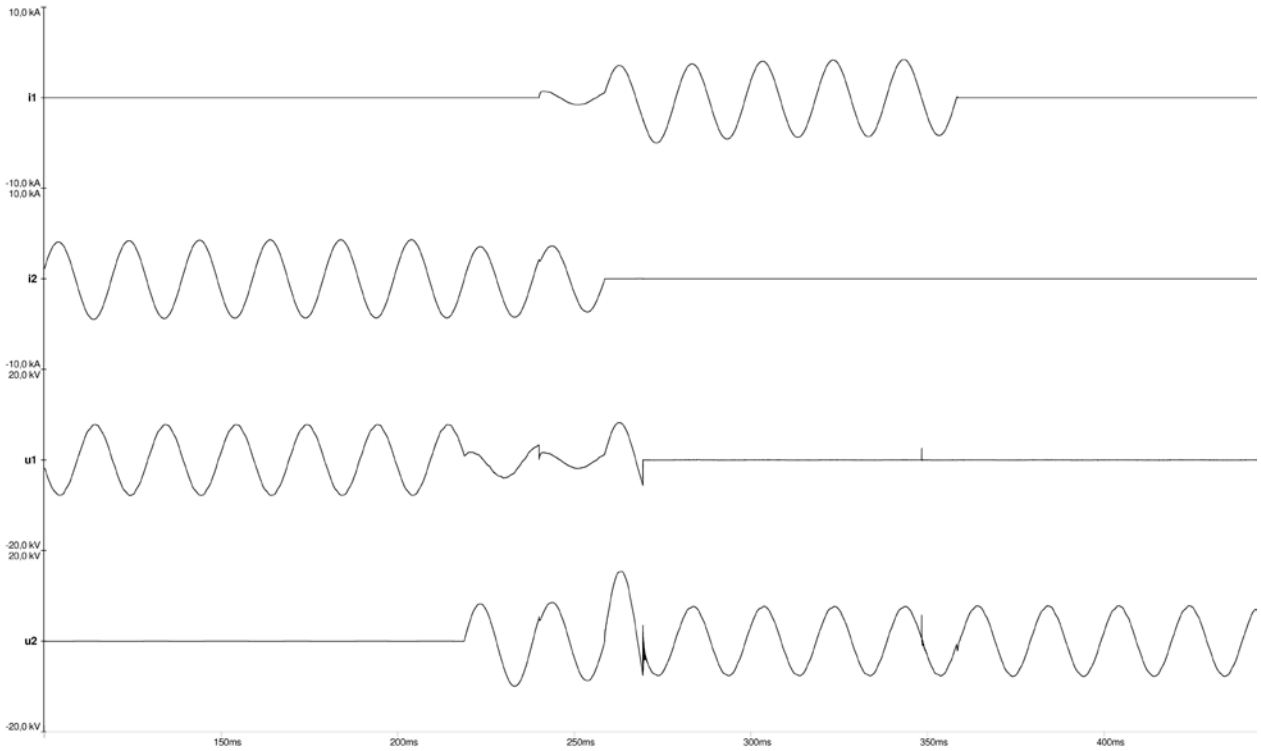

Fig. 4.8: Breaking capacity test (test sequence 2 – switching operation no. 8).

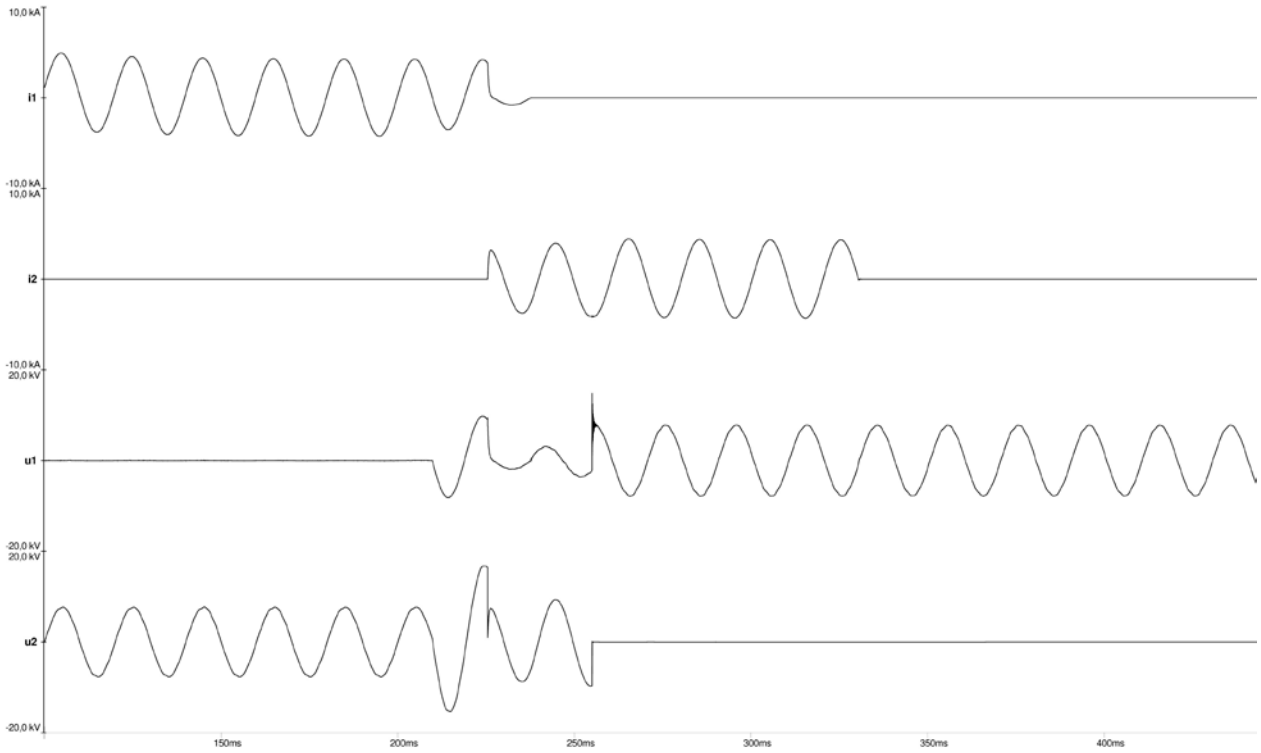

Fig. 4.9: Breaking capacity test (test sequence 2 – switching operation no. 9).

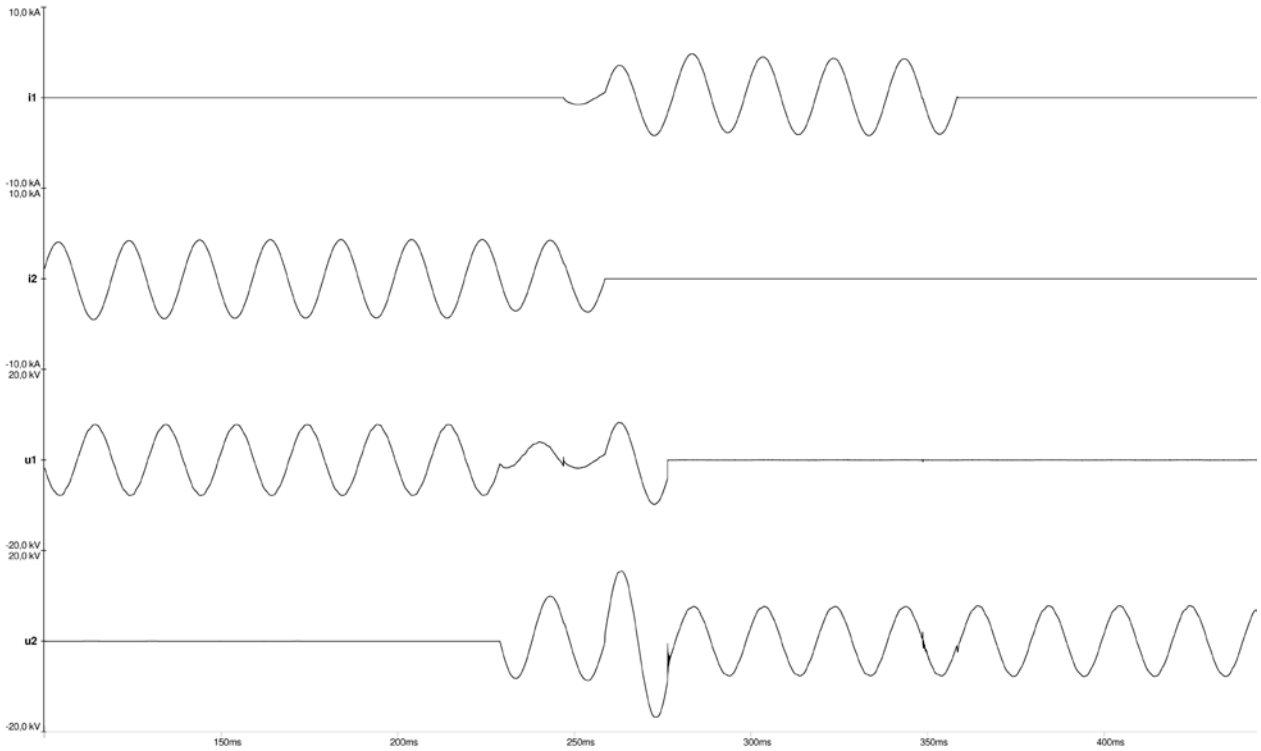

Fig. 4.10: Breaking capacity test (test sequence 2 – switching operation no. 10).

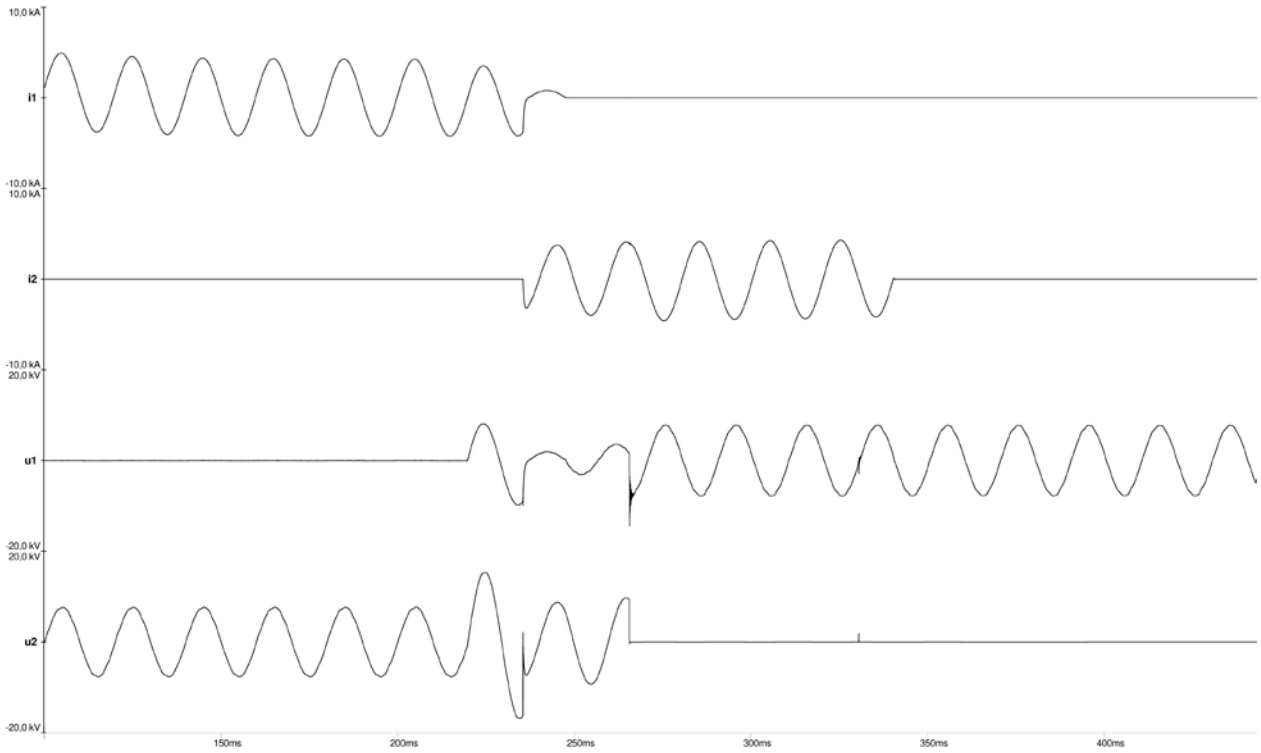

Fig. 4.11: Breaking capacity test (test sequence 2 – switching operation no. 11).

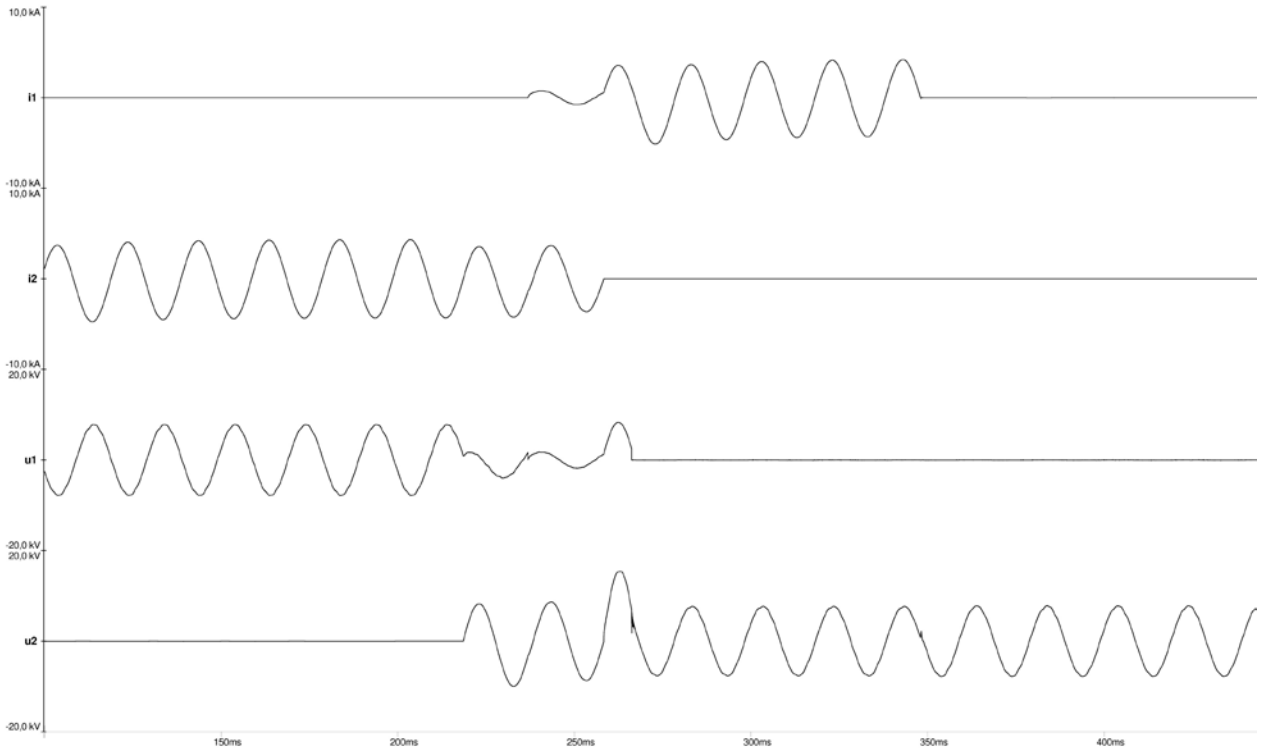

Fig. 4.12: Breaking capacity test (test sequence 2 – switching operation no. 12).

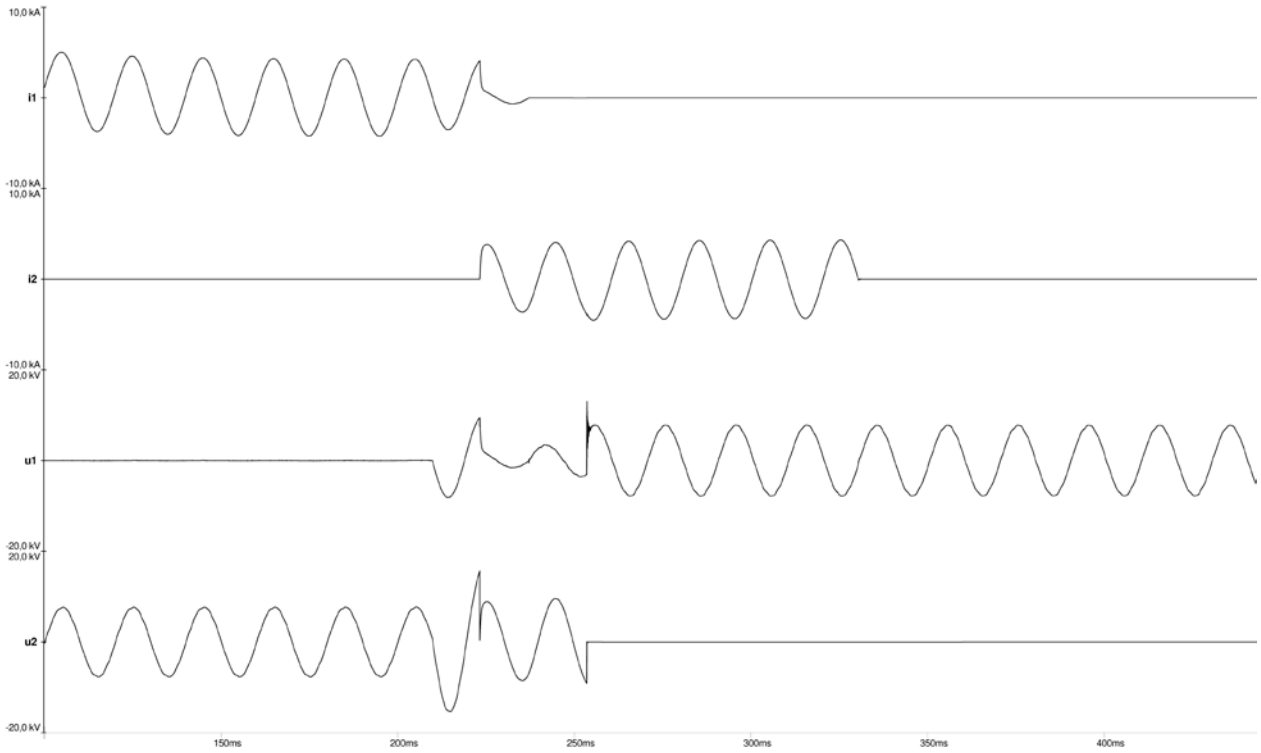

Fig. 4.13: Breaking capacity test (test sequence 2 – switching operation no. 13).

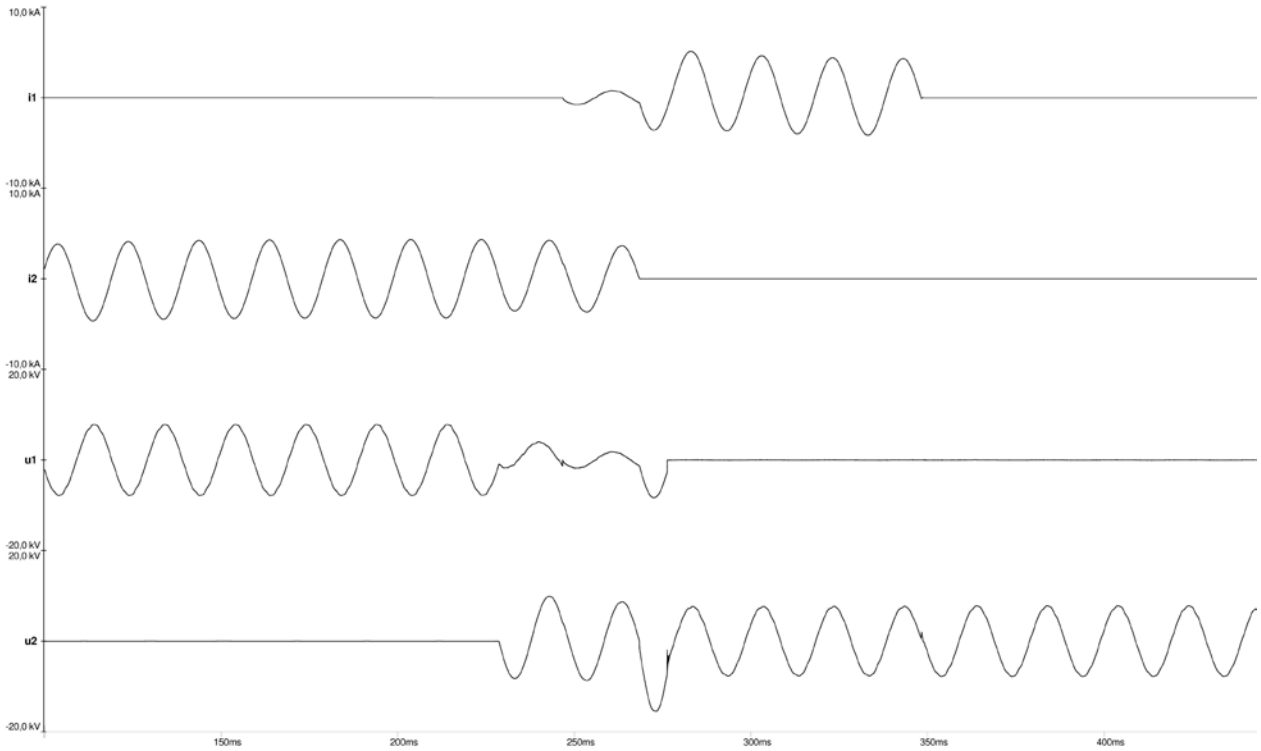

Fig. 4.14: Breaking capacity test (test sequence 2 – switching operation no. 14).

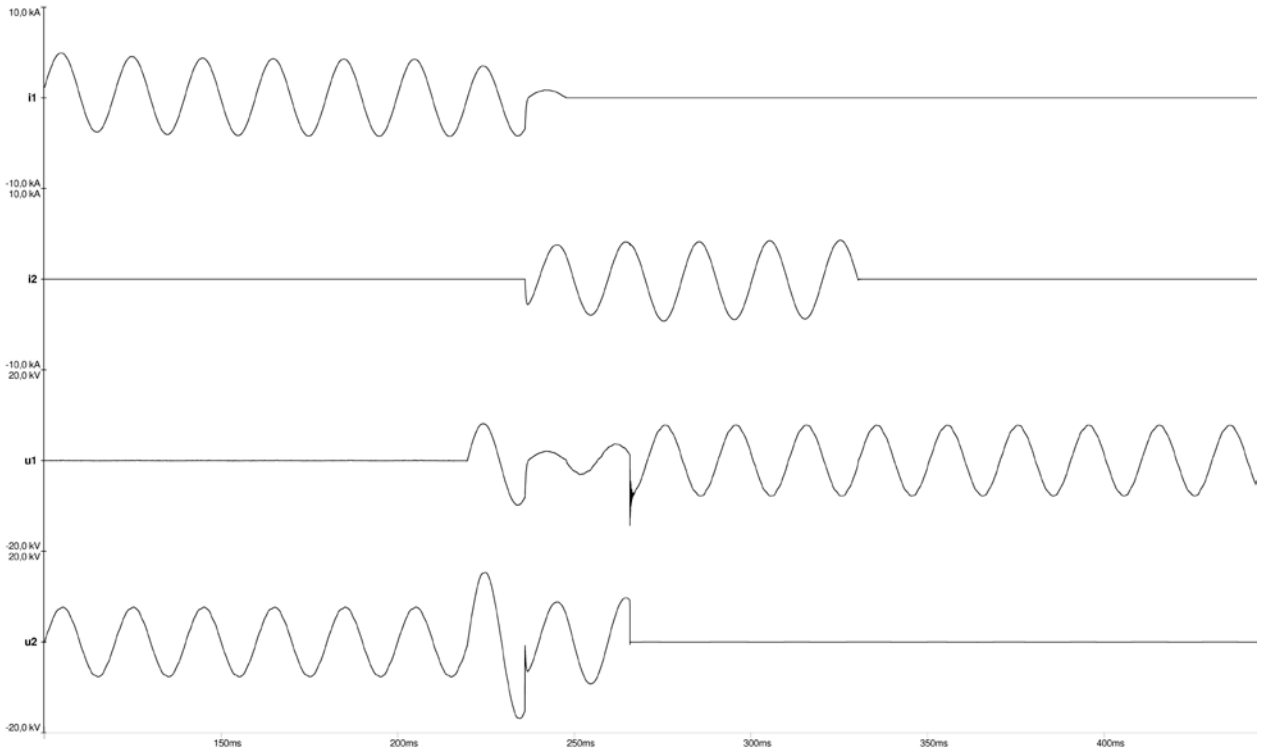

Fig. 4.15: Breaking capacity test (test sequence 2 – switching operation no. 15).

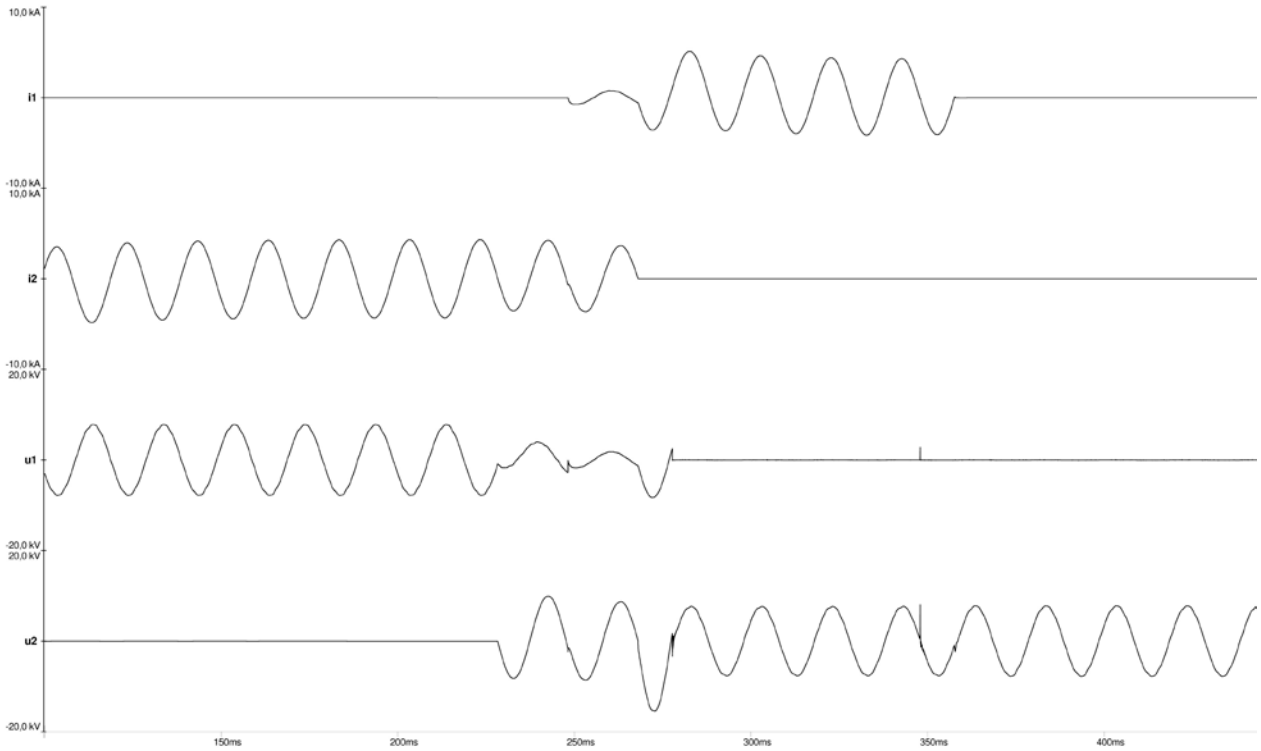

Fig. 4.16: Breaking capacity test (test sequence 2 – switching operation no. 16).

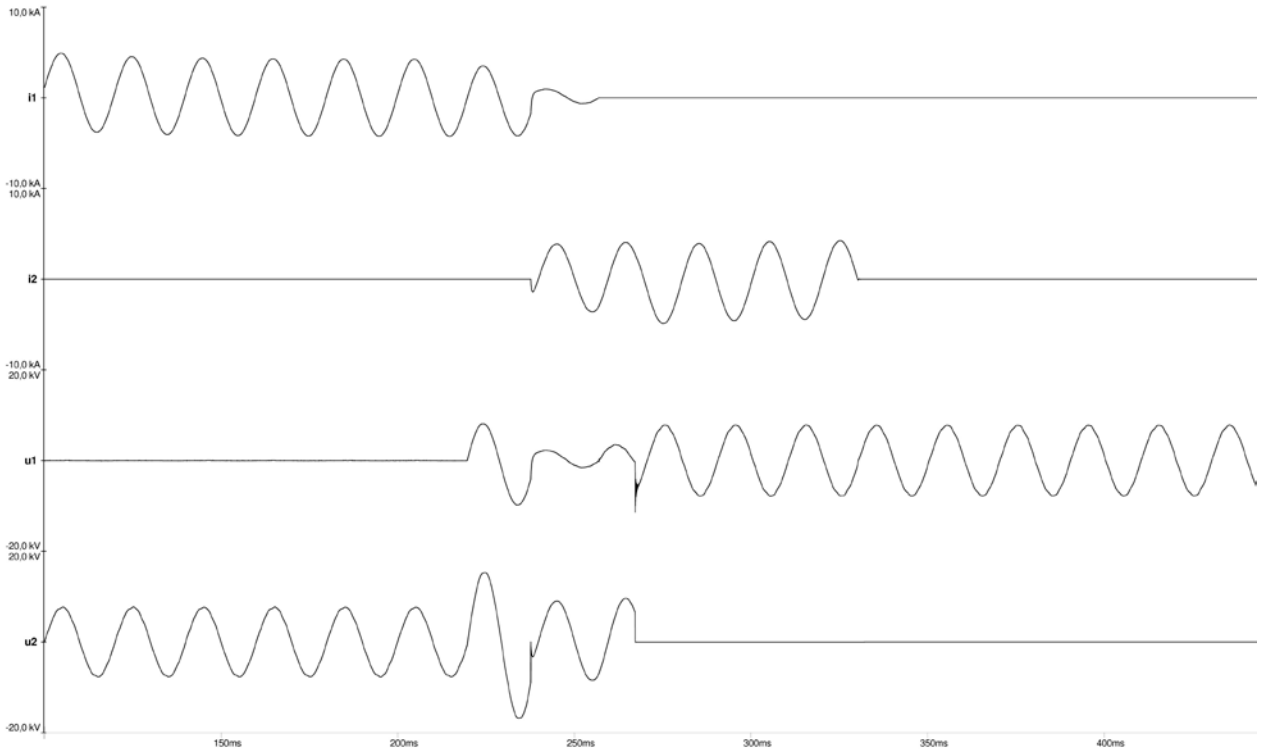

Fig. 4.17: Breaking capacity test (test sequence 2 – switching operation no. 17).

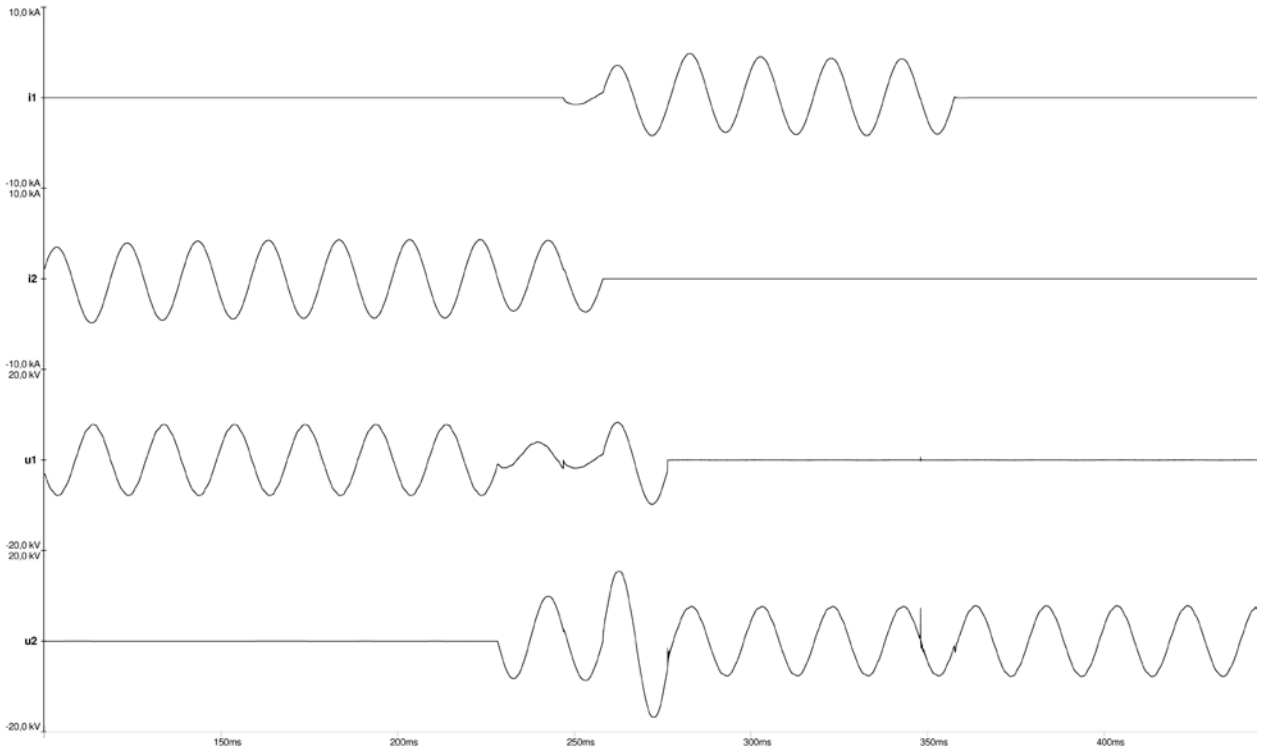

Fig. 4.18: Breaking capacity test (test sequence 2 – switching operation no. 18).

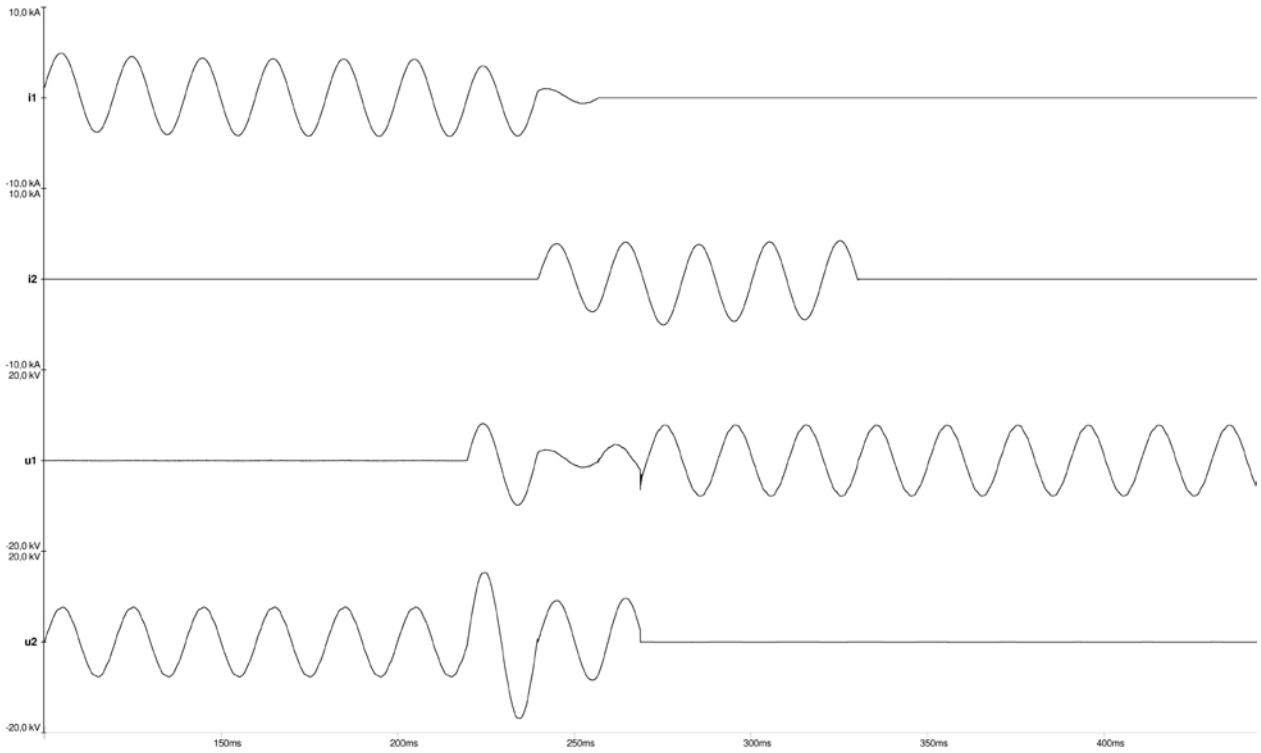

Fig. 4.19: Breaking capacity test (test sequence 2 – switching operation no. 19).

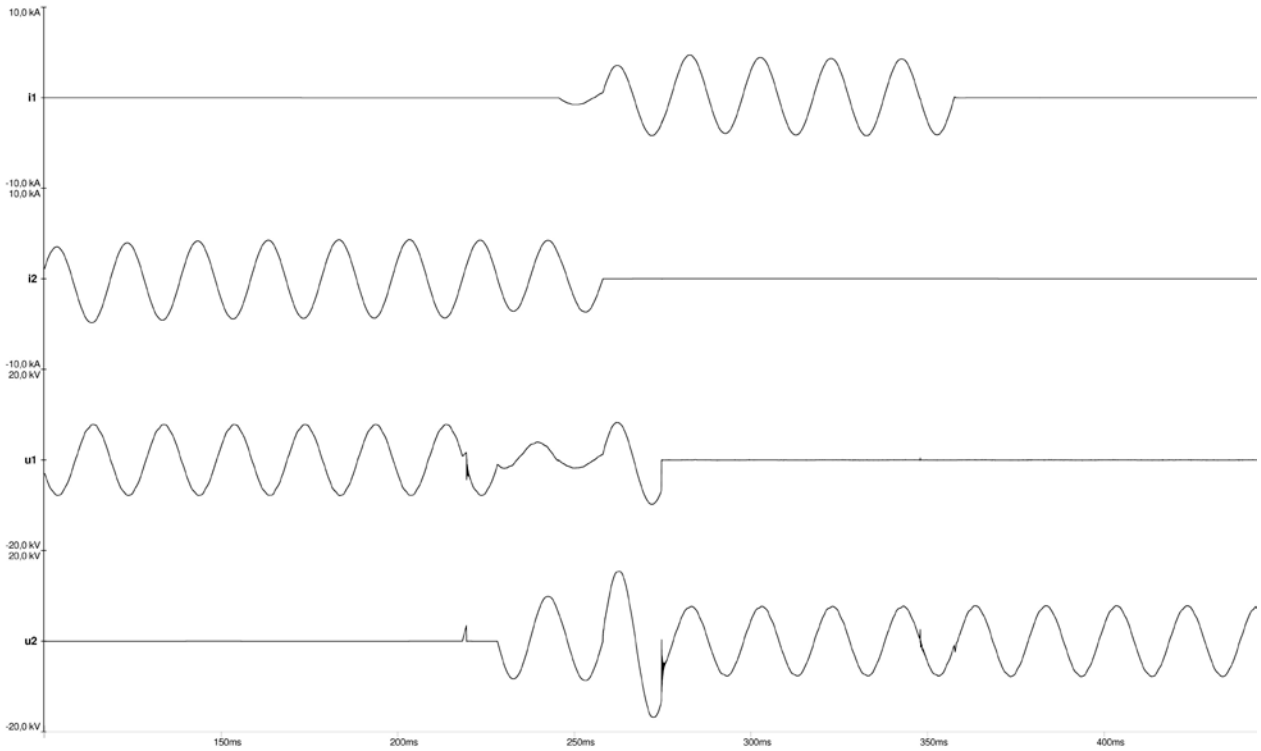

Fig. 4.20: Breaking capacity test (test sequence 2 – switching operation no. 20).

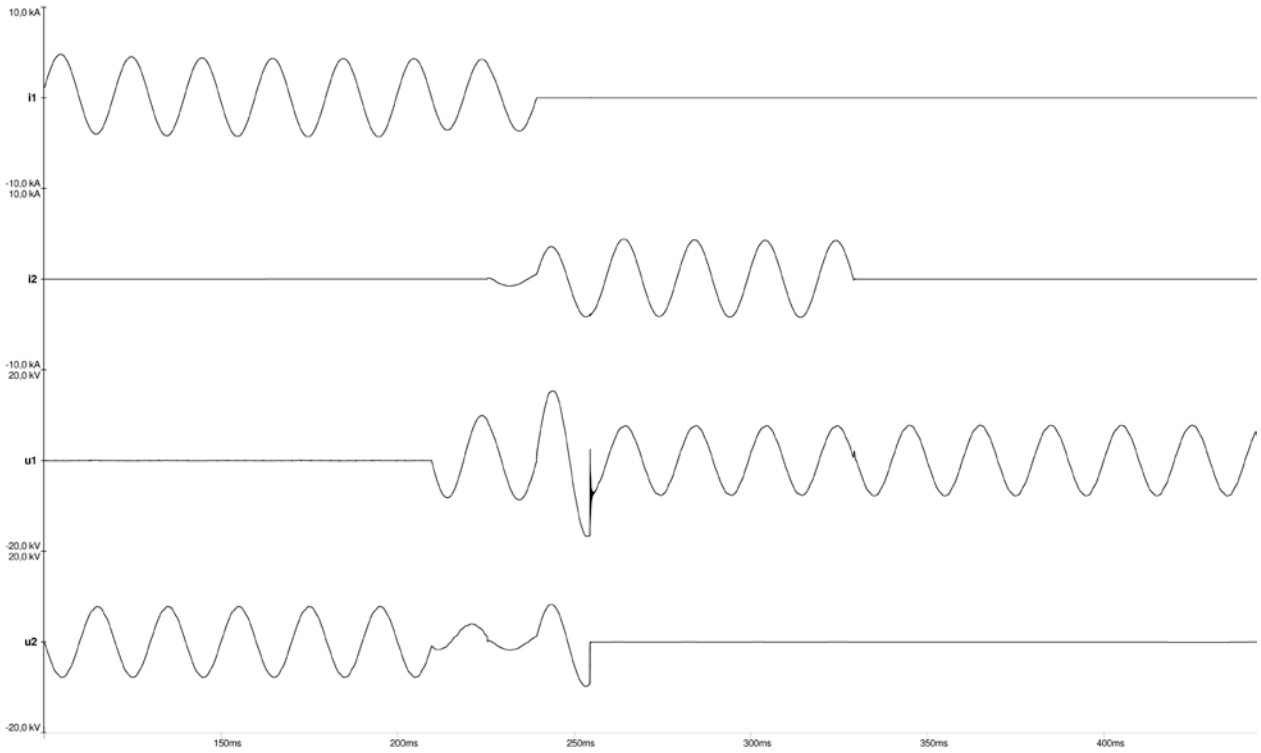

Fig. 4.21: Breaking capacity test (test sequence 2 – switching operation no. 21).

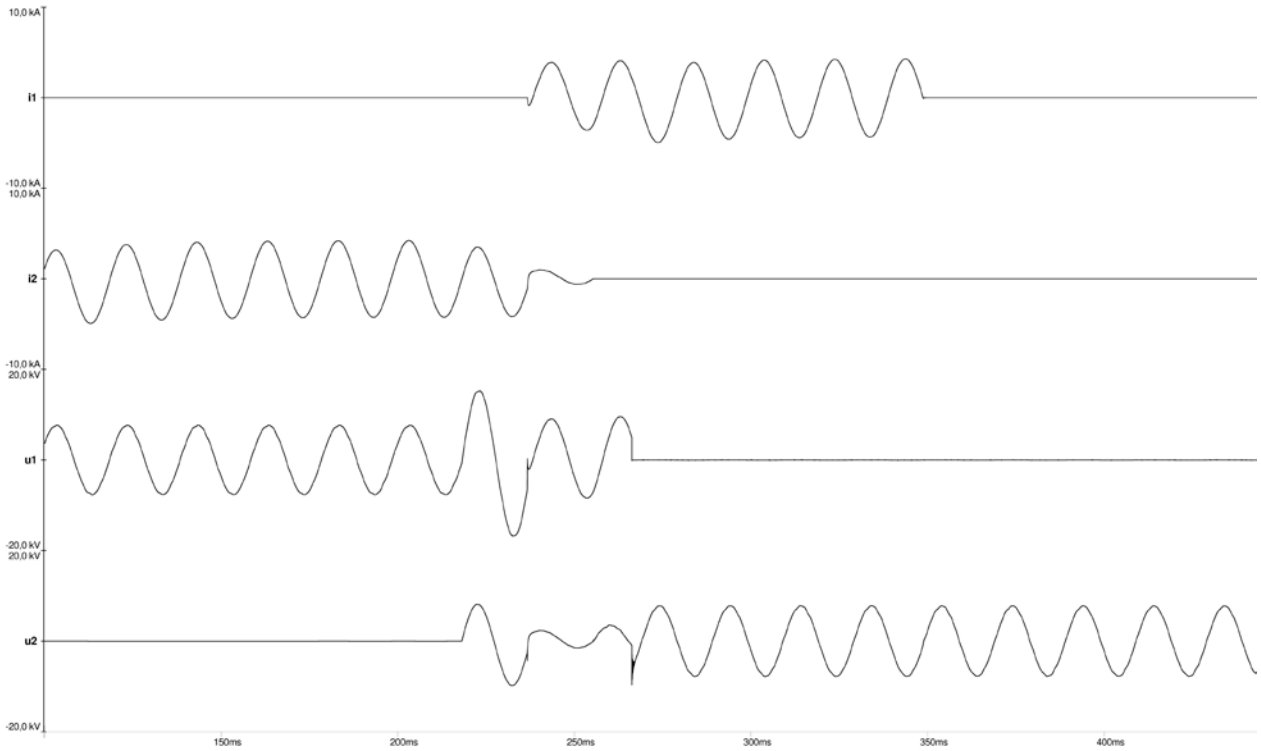

Fig. 4.22: Breaking capacity test (test sequence 2 – switching operation no. 22).

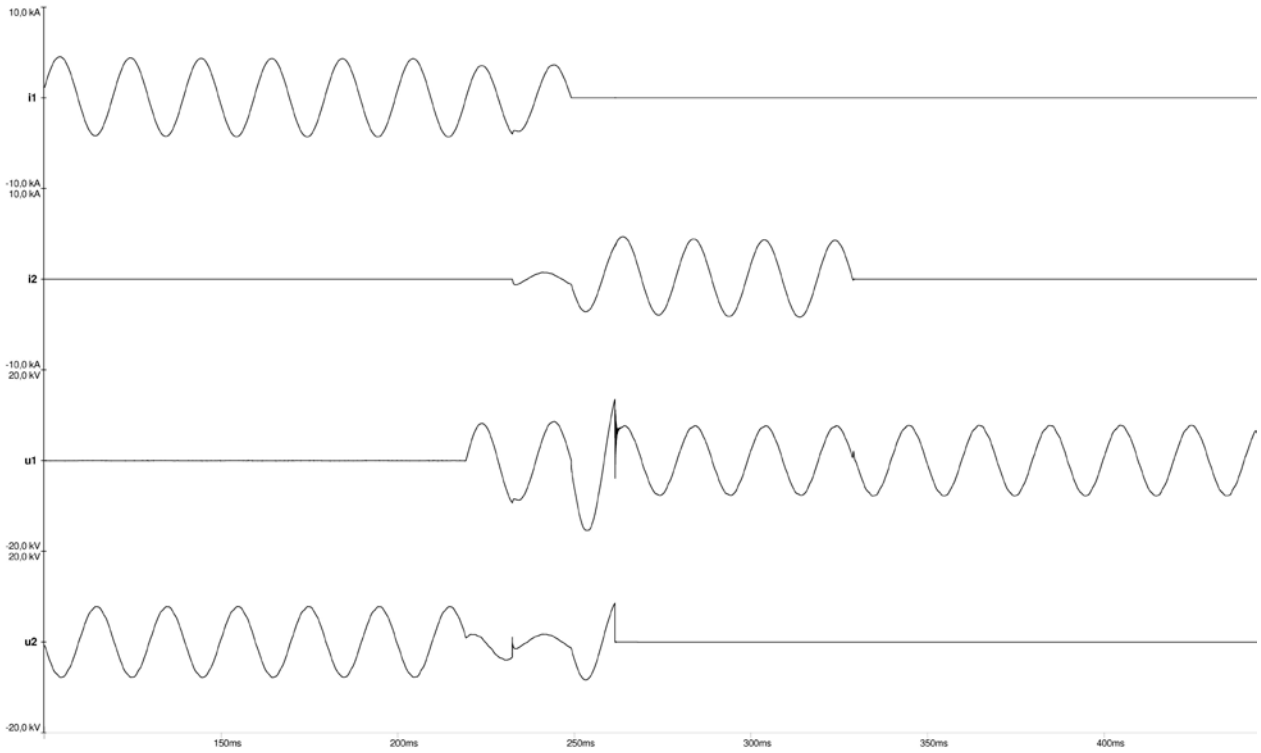

Fig. 4.23: Breaking capacity test (test sequence 2 – switching operation no. 23).

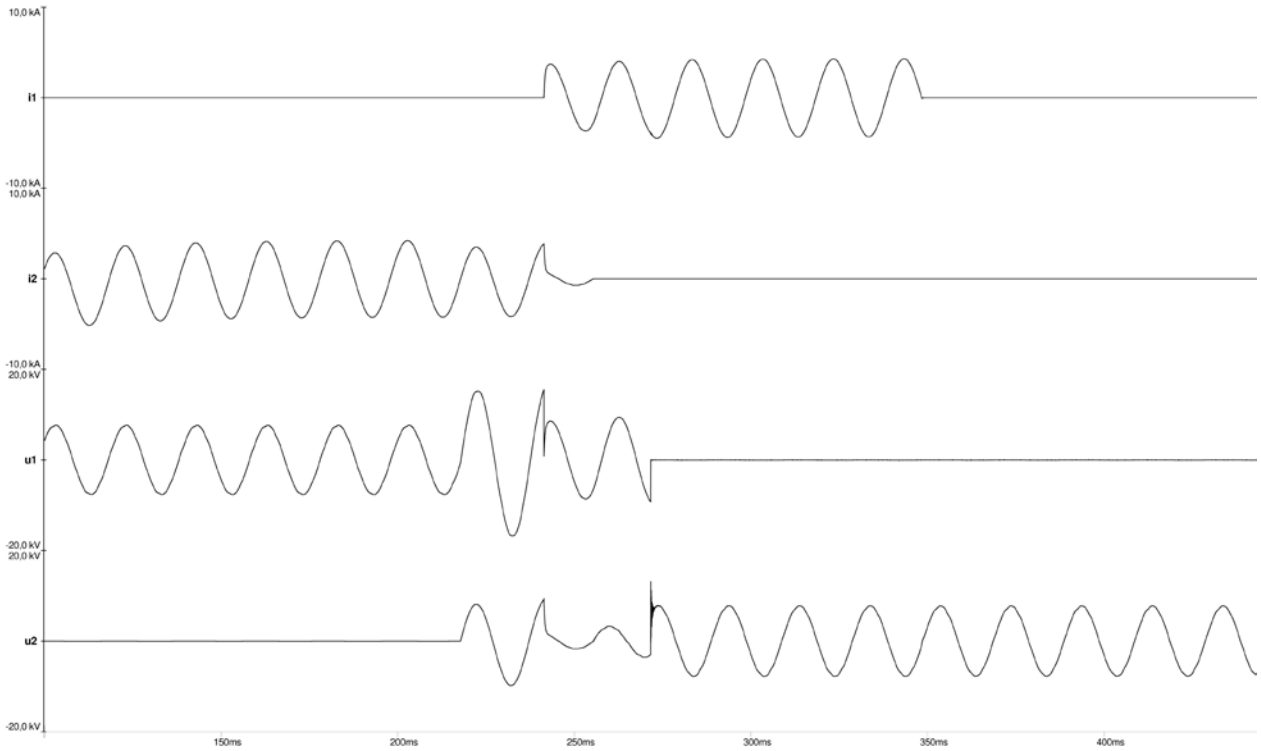

Fig. 4.24: Breaking capacity test (test sequence 2 – switching operation no. 24).

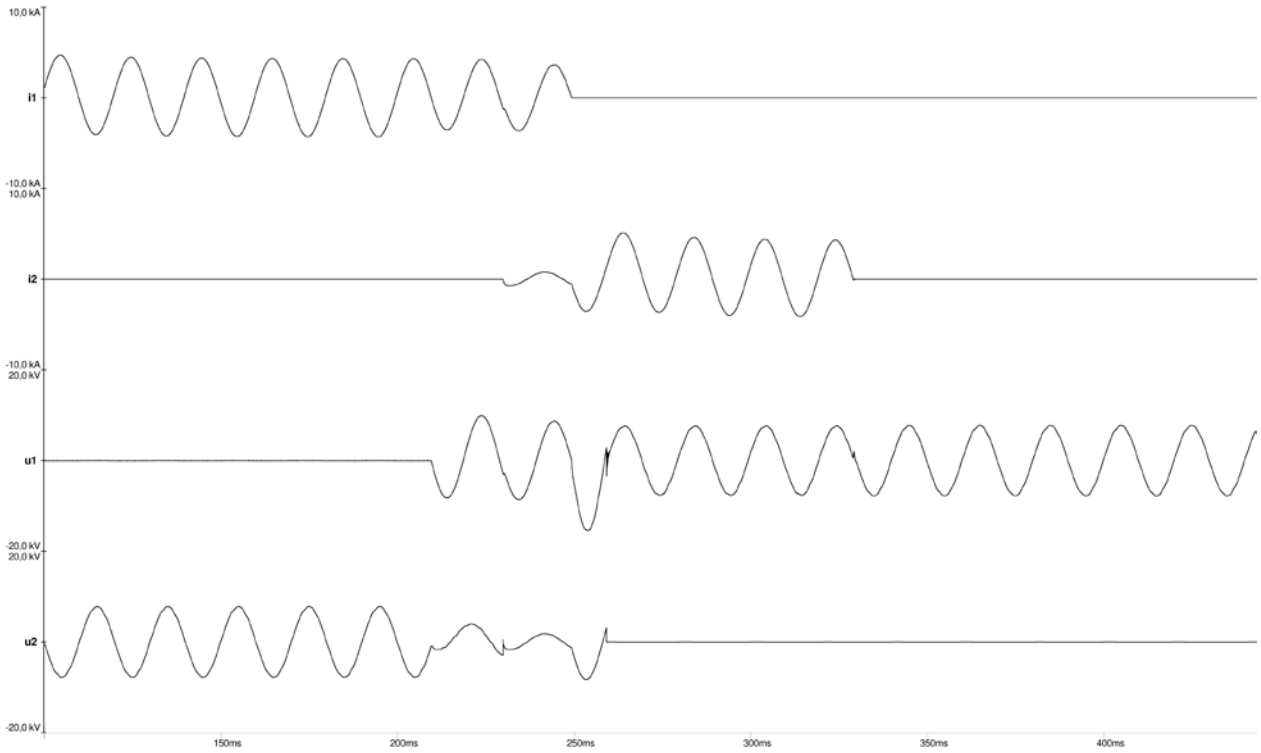

Fig. 4.25: Breaking capacity test (test sequence 2 – switching operation no. 25).

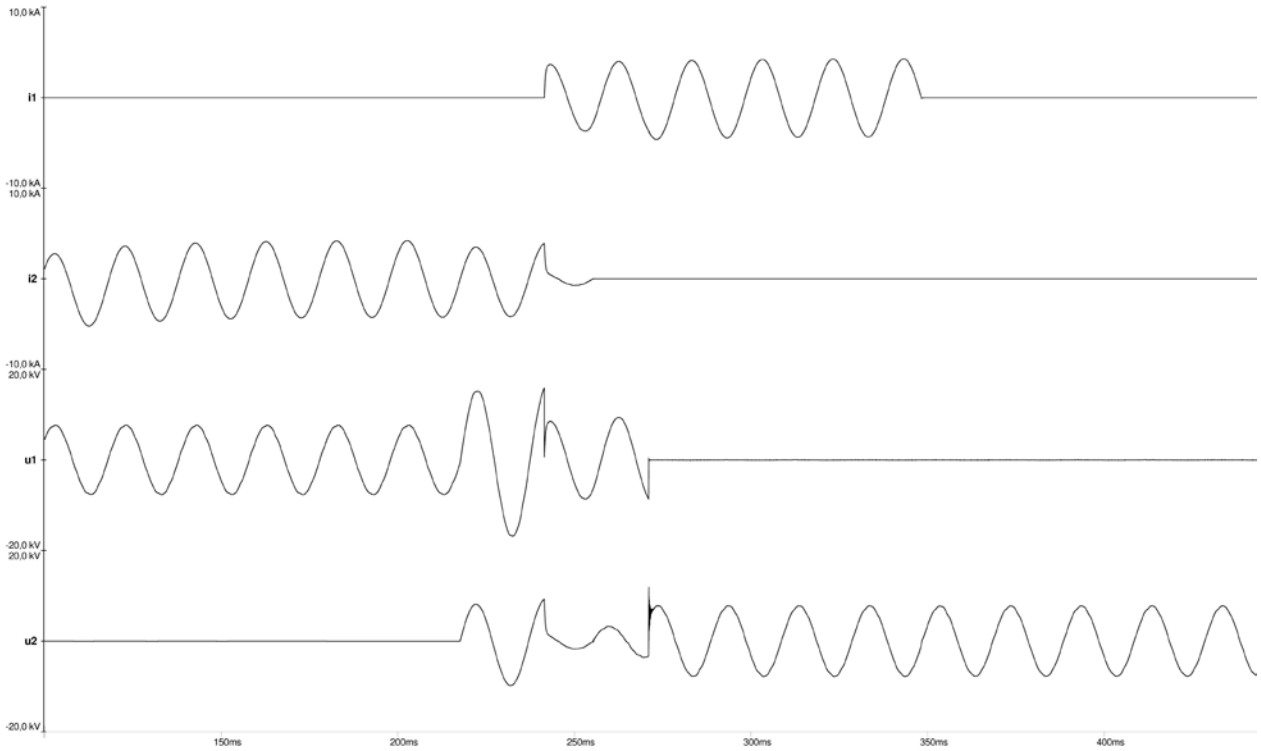

Fig. 4.26: Breaking capacity test (test sequence 2 – switching operation no. 26).

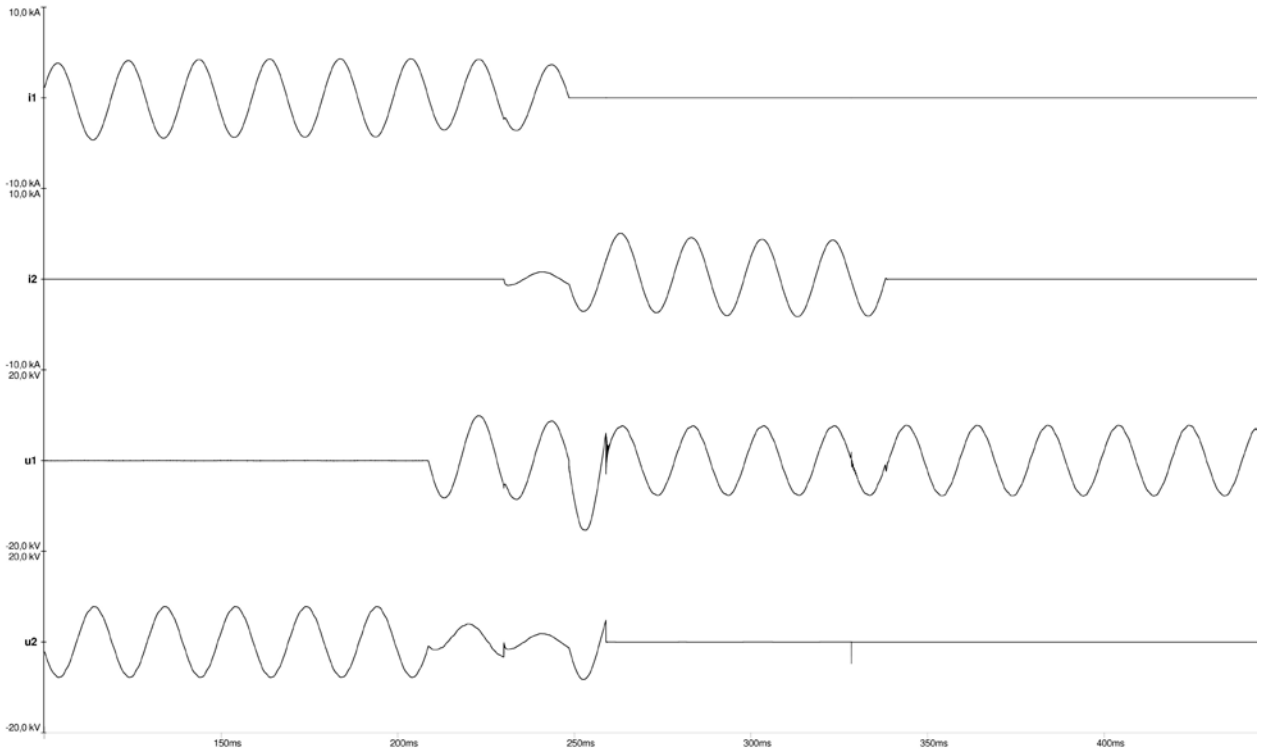

Fig. 4.27: Breaking capacity test (test sequence 2 – switching operation no. 27).

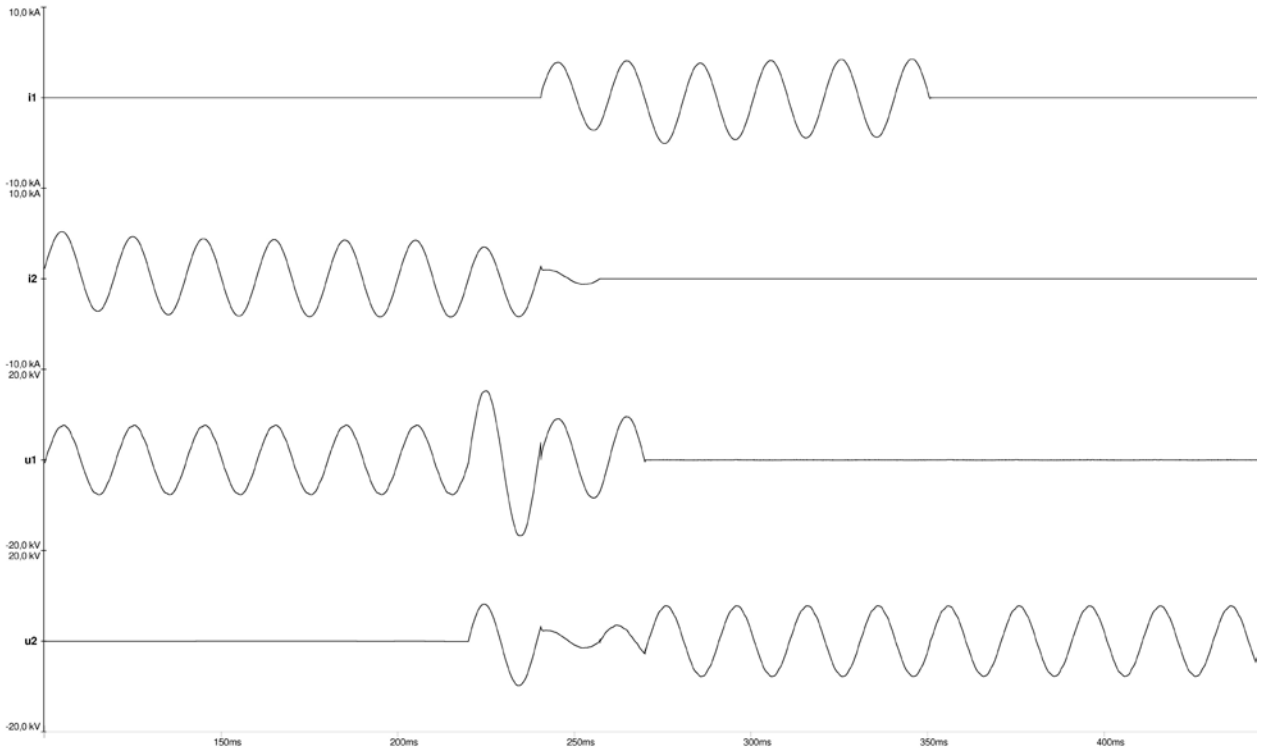

Fig. 4.28: Breaking capacity test (test sequence 2 – switching operation no. 28).

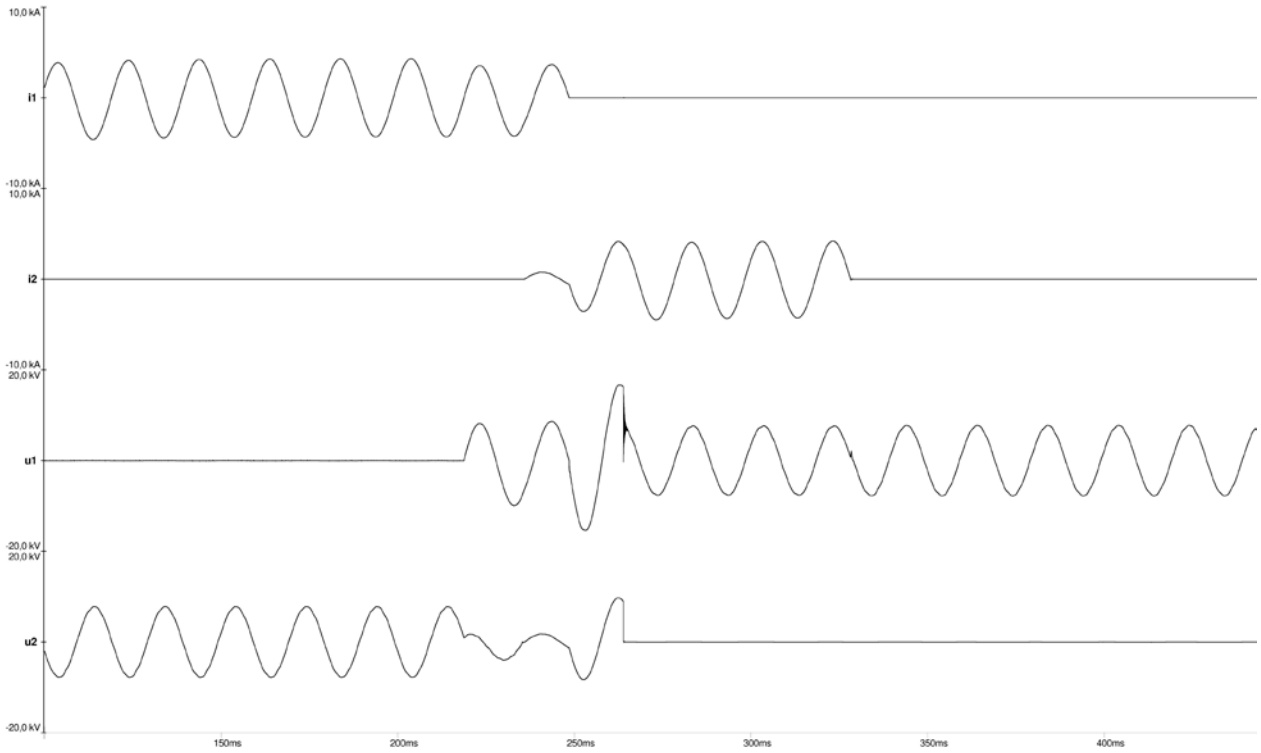

Fig. 4.29: Breaking capacity test (test sequence 2 – switching operation no. 29).

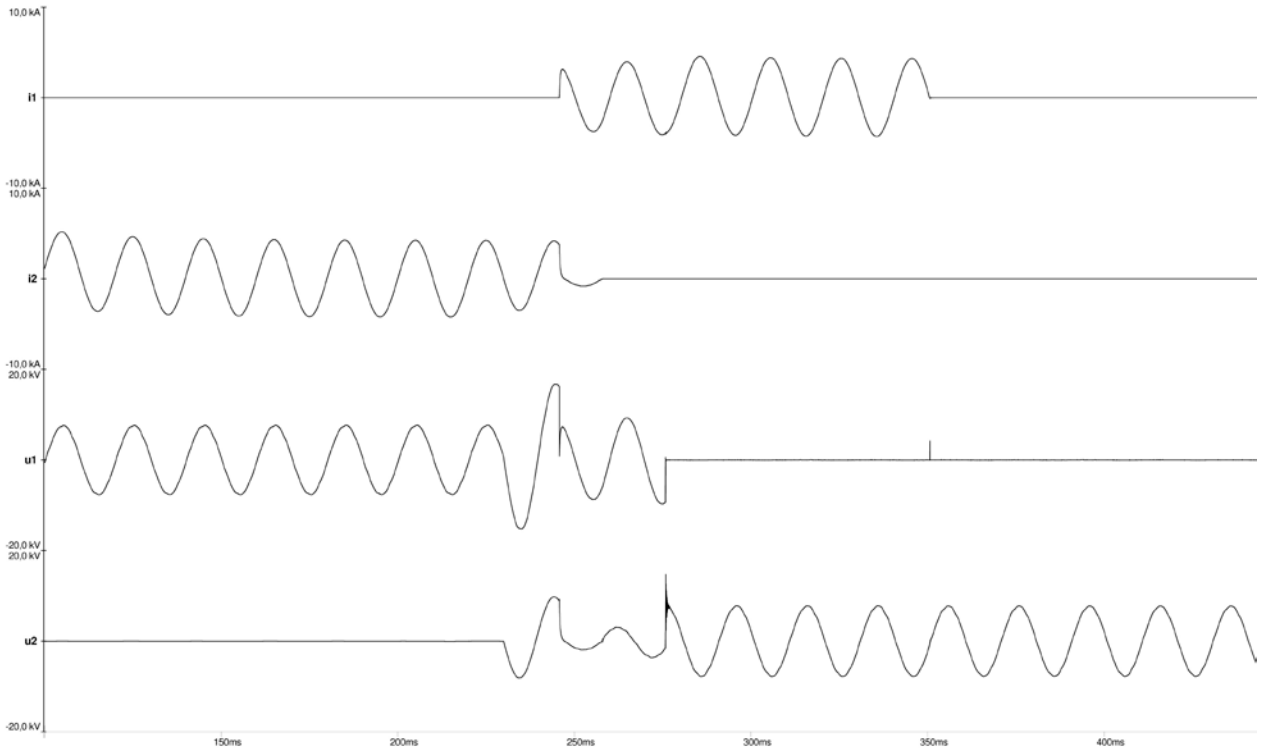

Fig. 4.30: Breaking capacity test (test sequence 2 – switching operation no. 30).

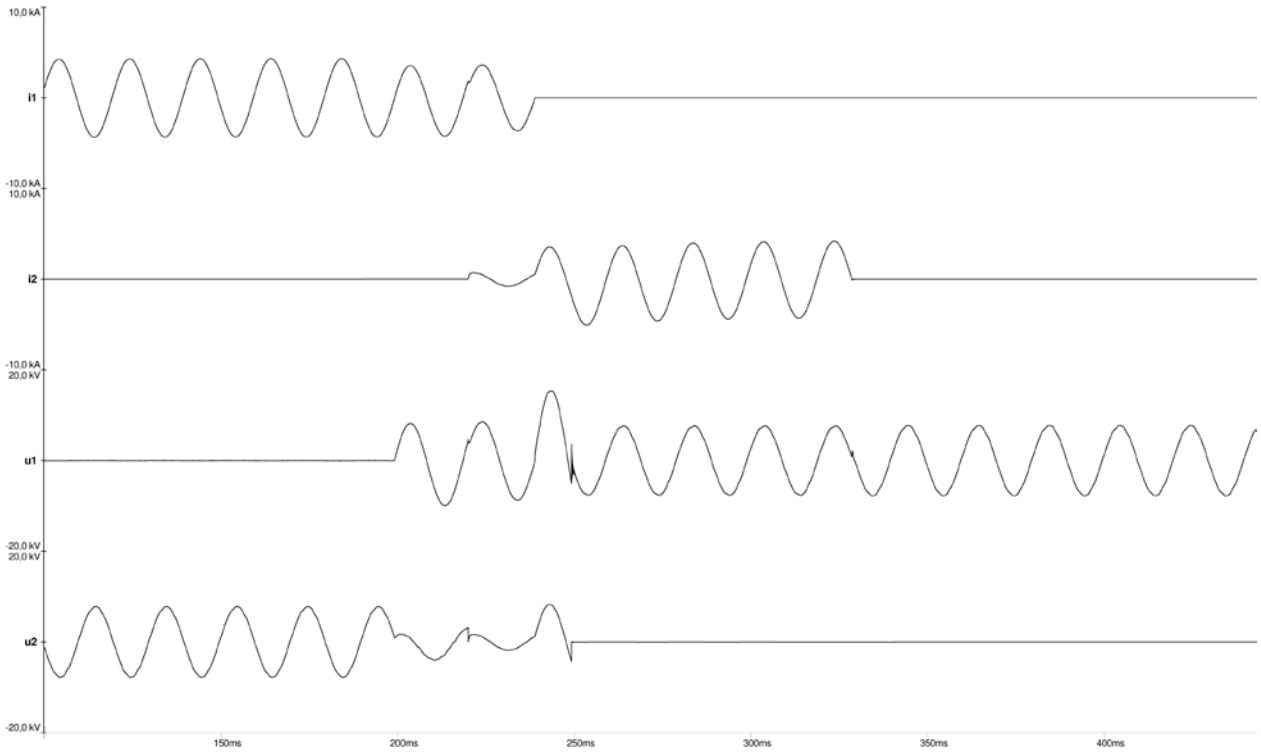

Fig. 4.31: Breaking capacity test (test sequence 2 – switching operation no. 31).

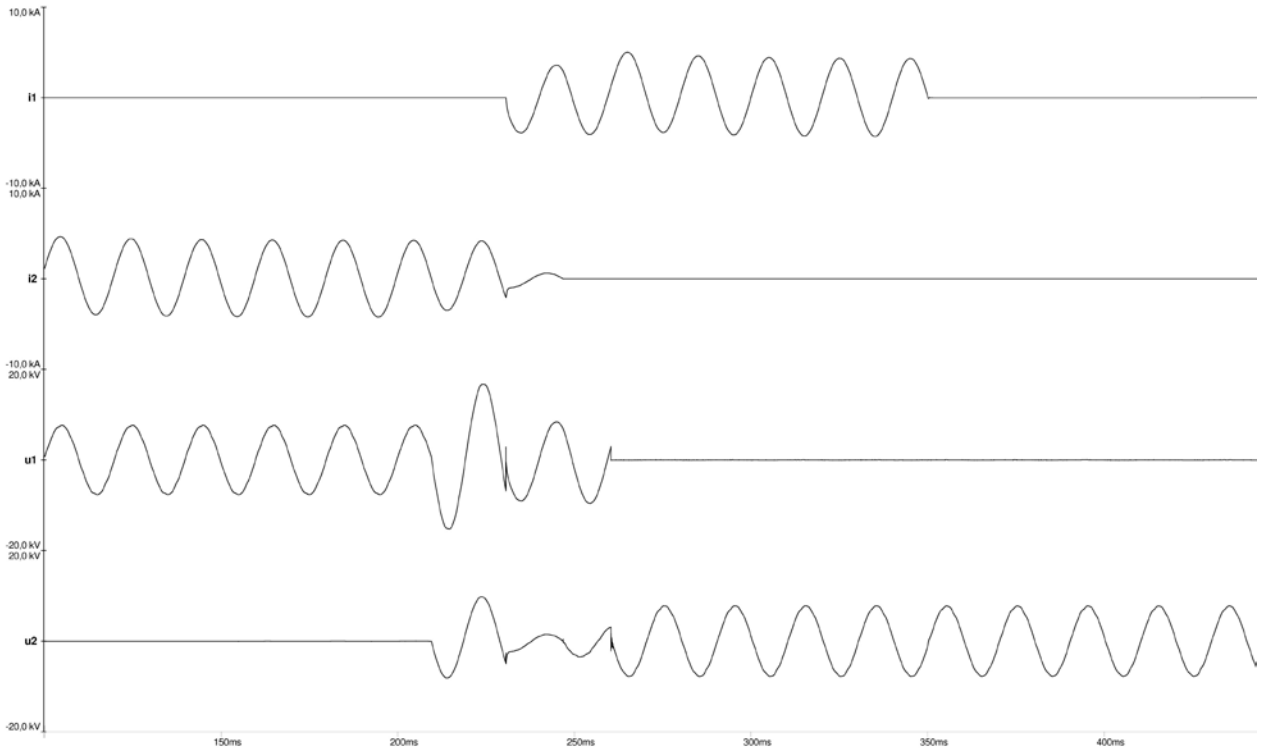

Fig. 4.32: Breaking capacity test (test sequence 2 – switching operation no. 32).

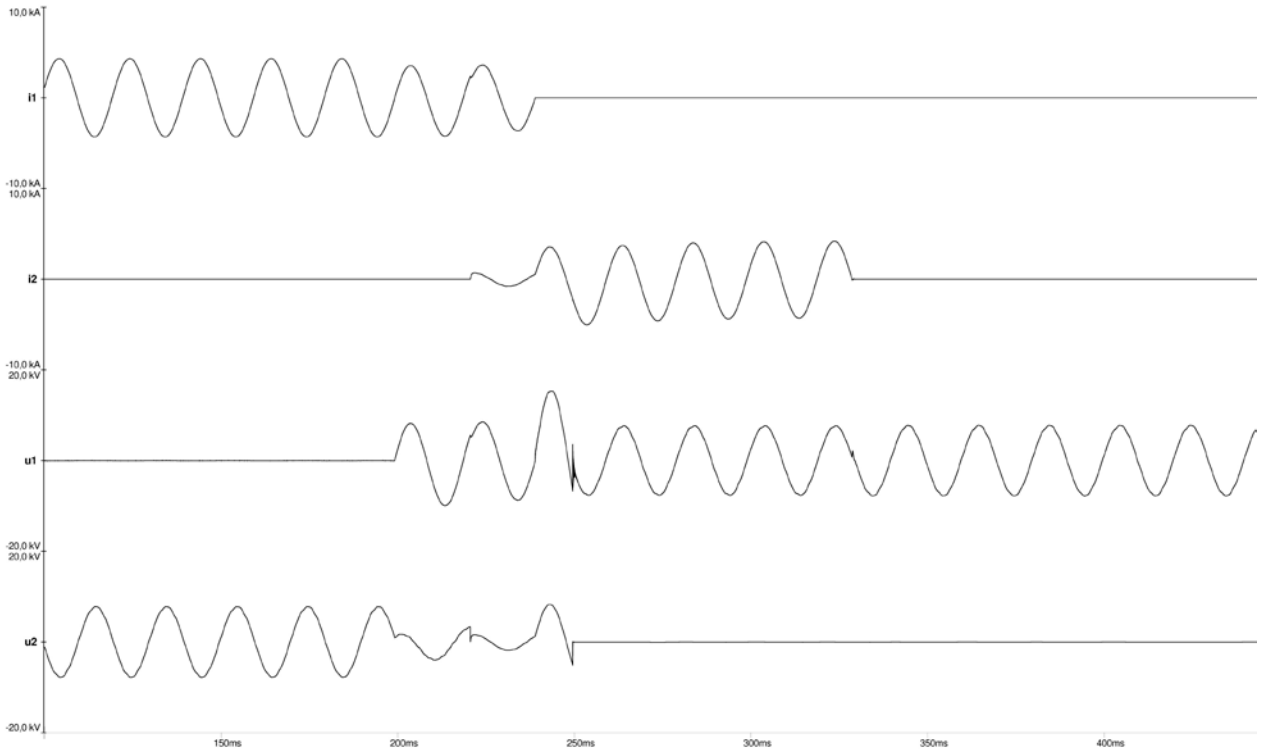

Fig. 4.33: Breaking capacity test (test sequence 2 – switching operation no. 33).

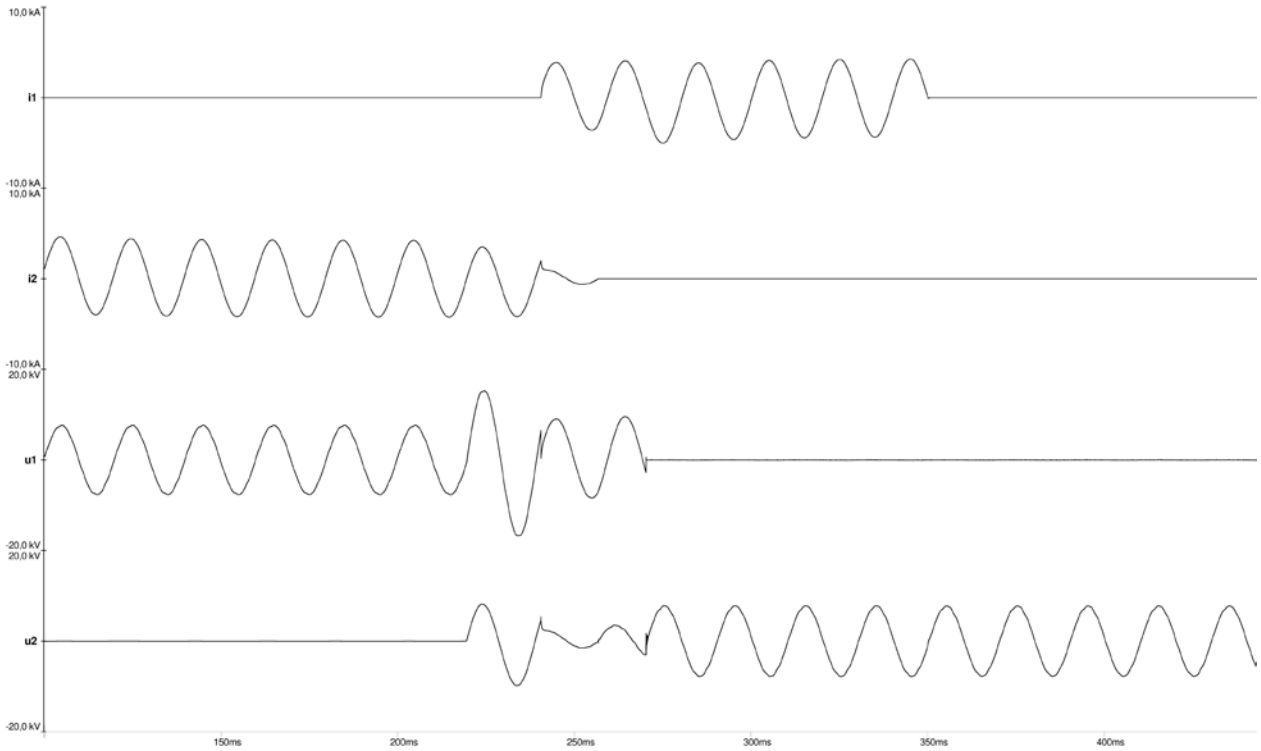

Fig. 4.34: Breaking capacity test (test sequence 2 – switching operation no. 34).

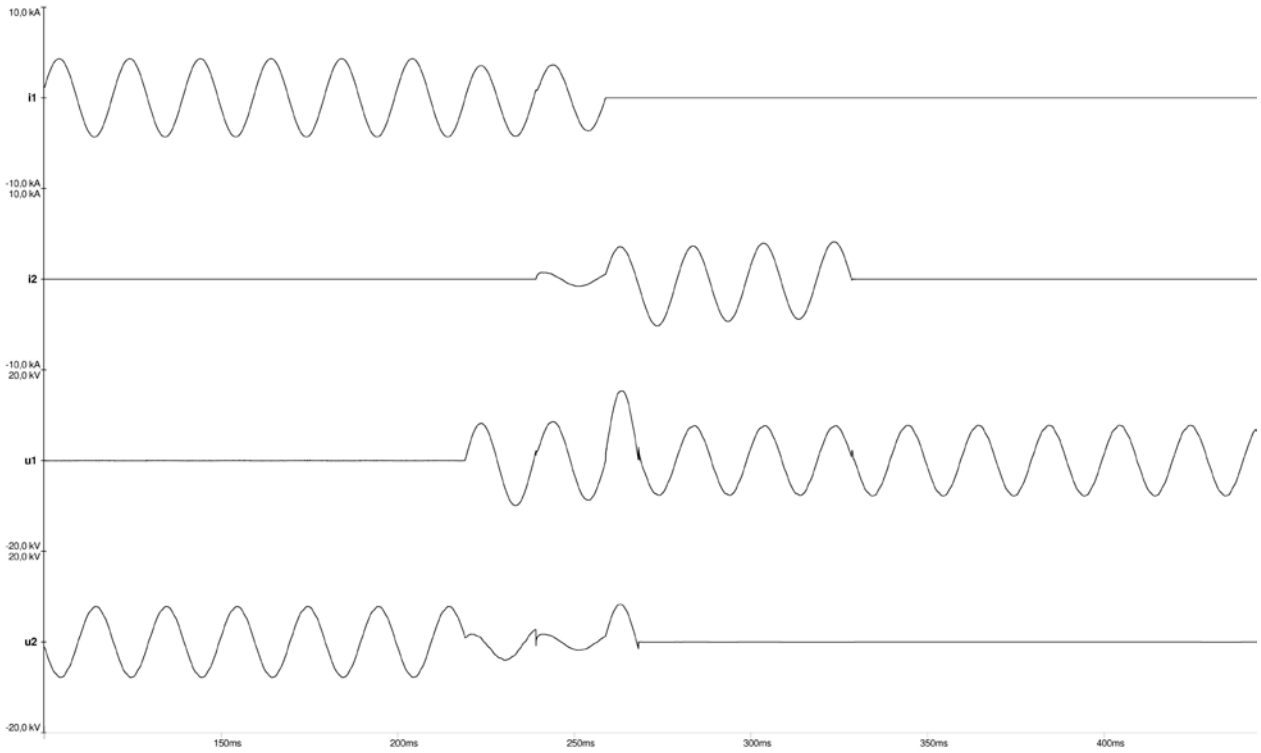

Fig. 4.35: Breaking capacity test (test sequence 2 – switching operation no. 35).

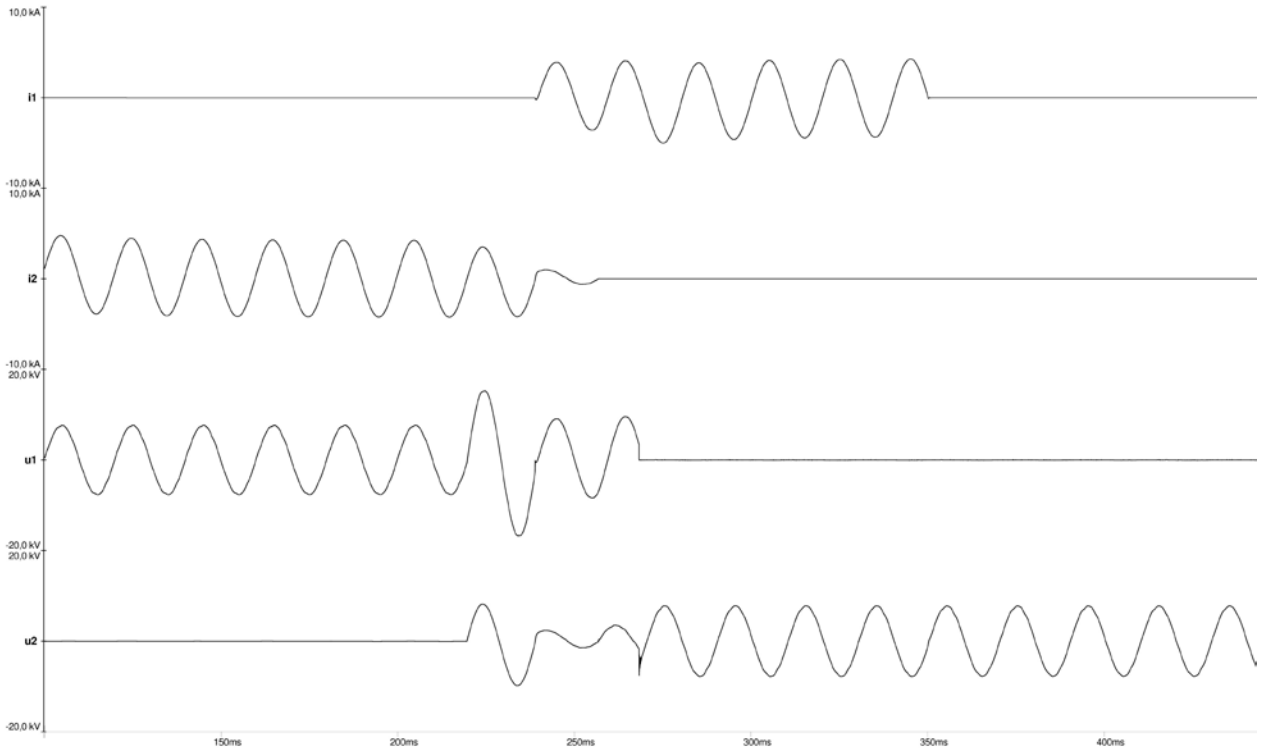

Fig. 4.36: Breaking capacity test (test sequence 2 – switching operation no. 36).

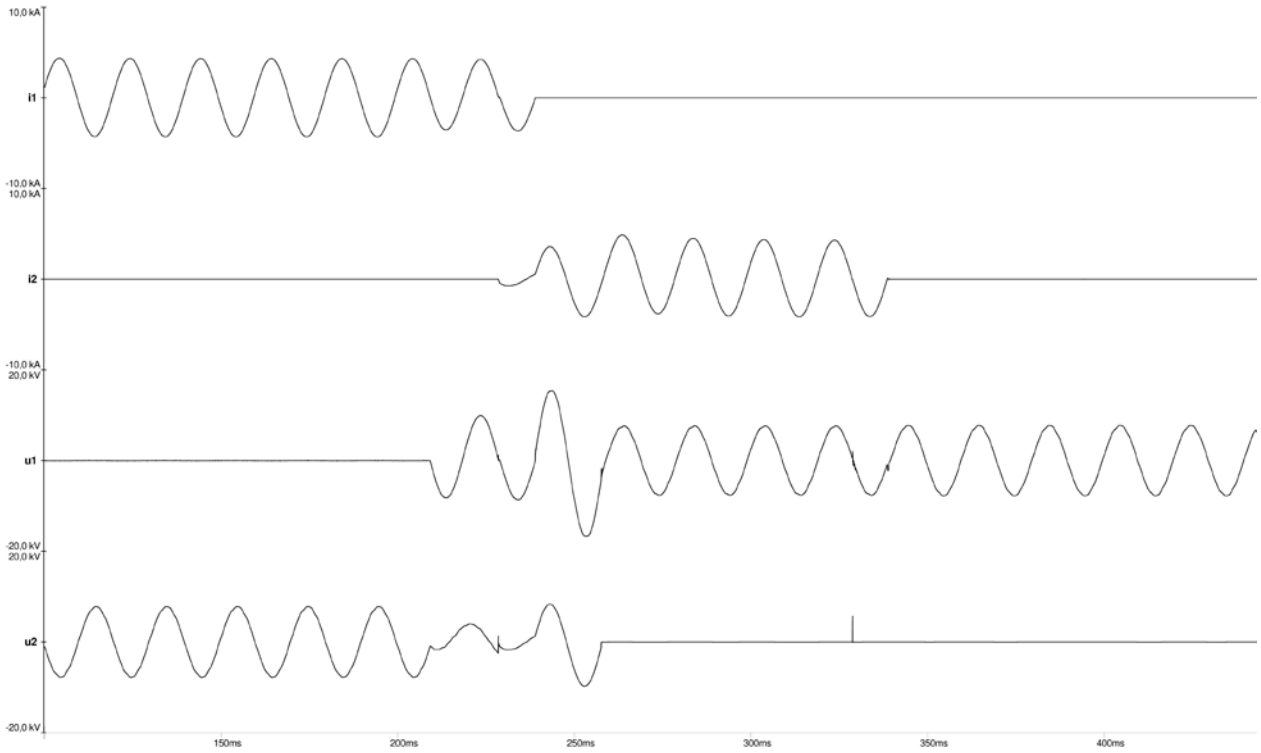

Fig. 4.37: Breaking capacity test (test sequence 2 – switching operation no. 37).

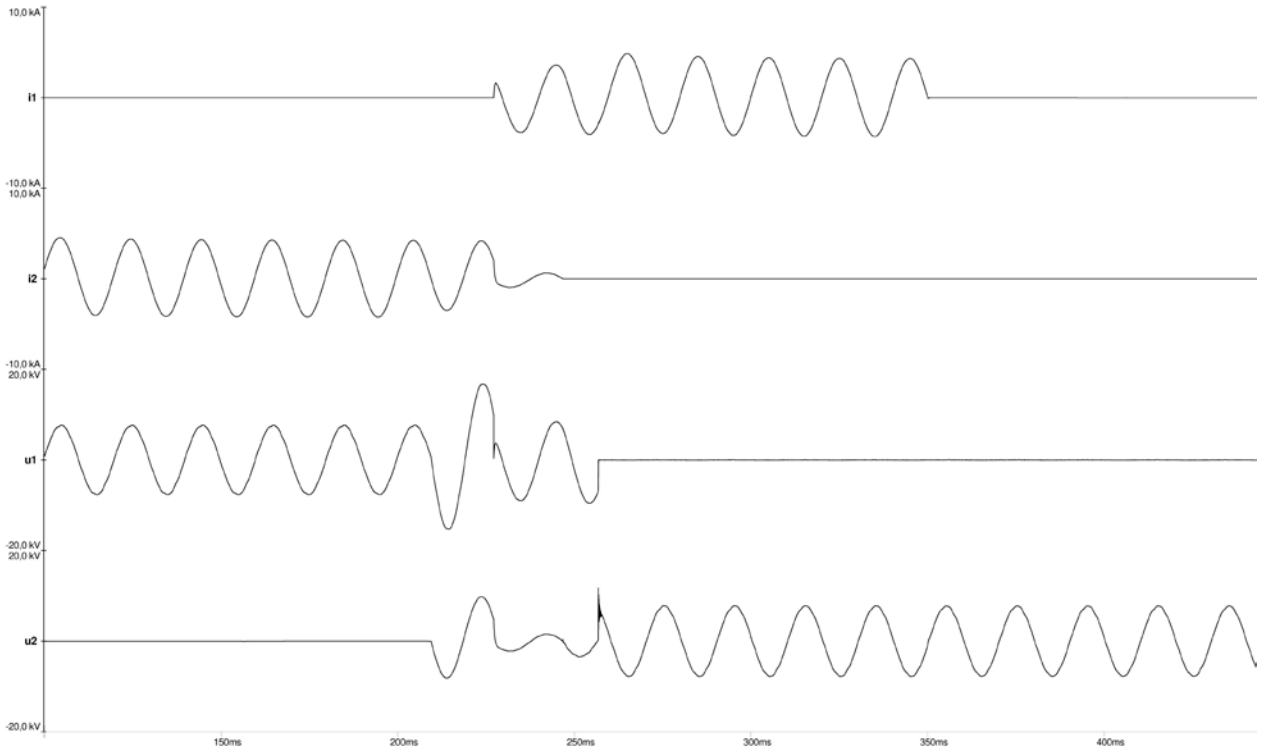

Fig. 4.38: Breaking capacity test (test sequence 2 – switching operation no. 38).

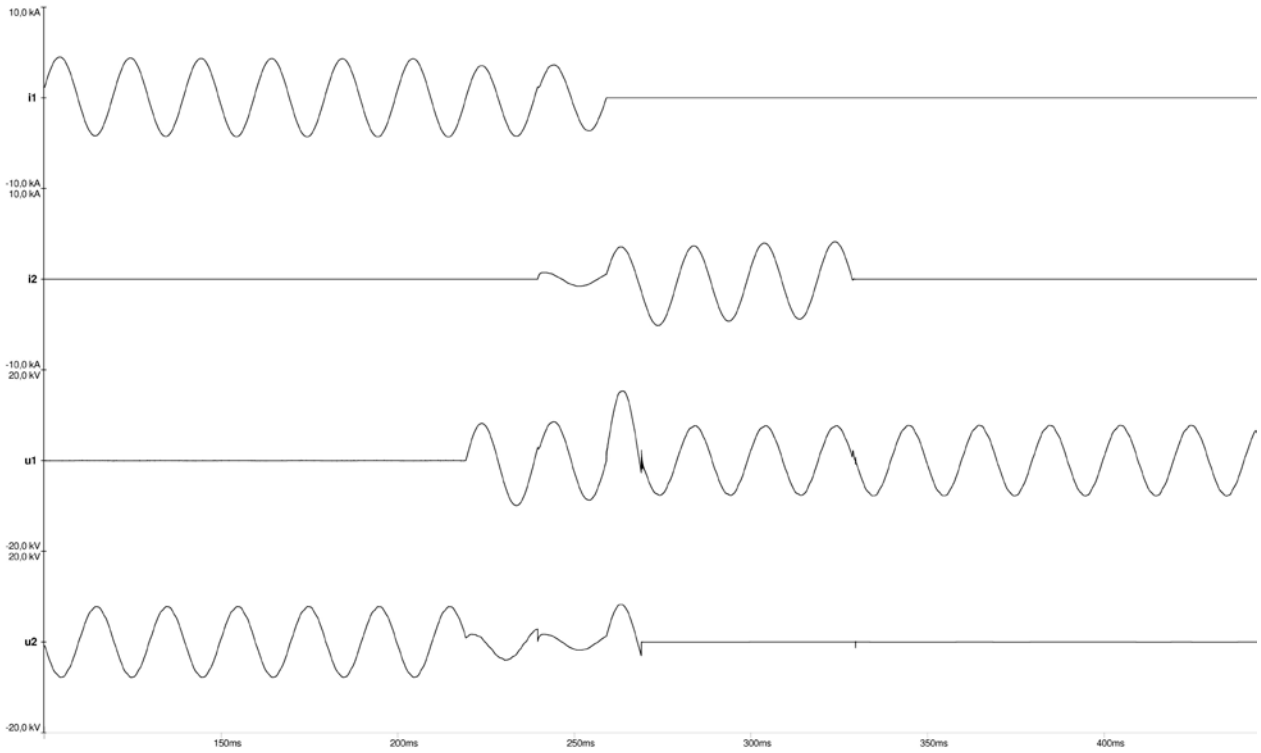

Fig. 4.39: Breaking capacity test (test sequence 2 – switching operation no. 39).

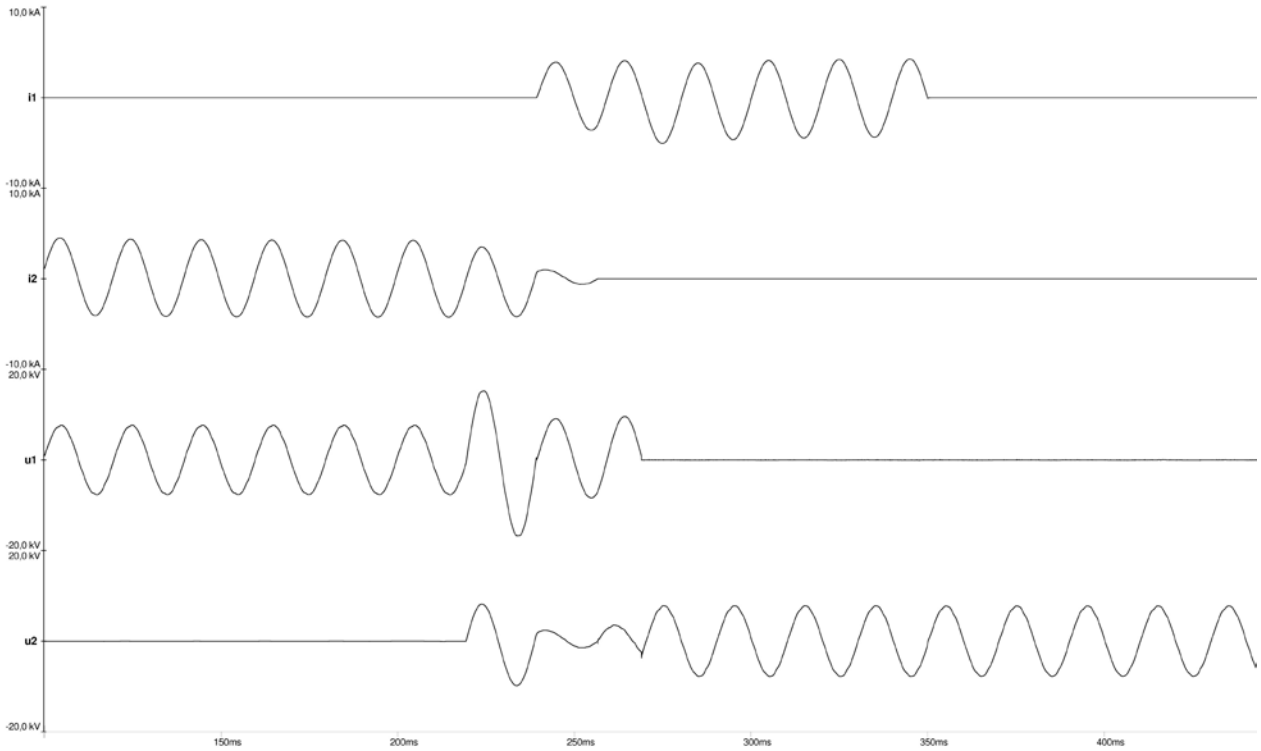

Fig. 4.40: Breaking capacity test (test sequence 2 – switching operation no. 40).

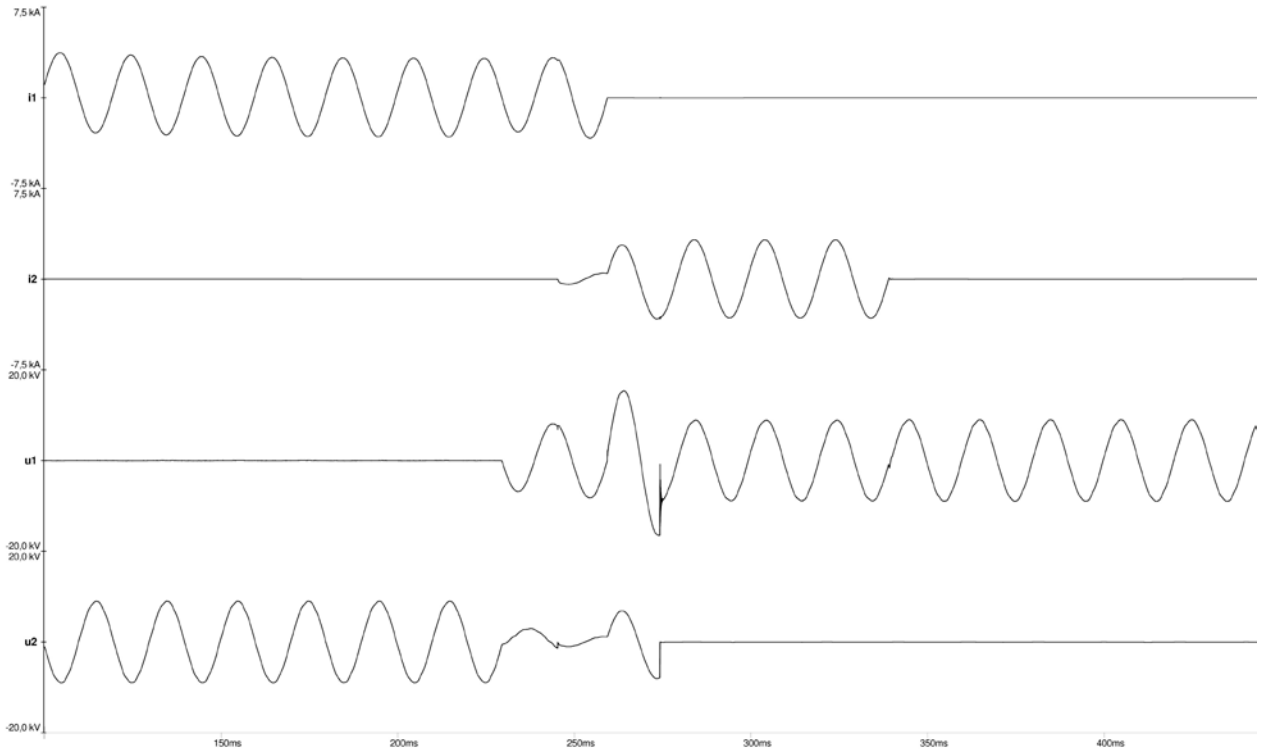

Fig. 5.1: Breaking capacity test (test sequence 3 – switching operation no. 1).

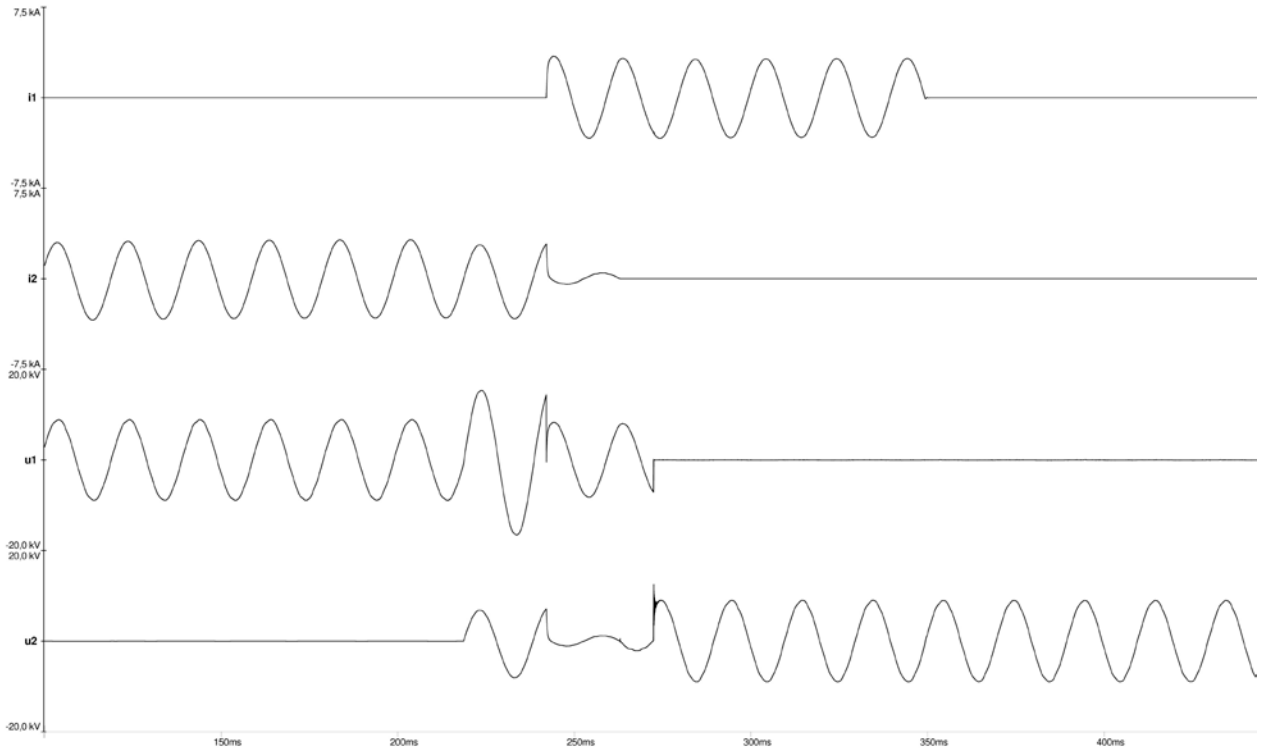

Fig. 5.2: Breaking capacity test (test sequence 3 – switching operation no. 2).

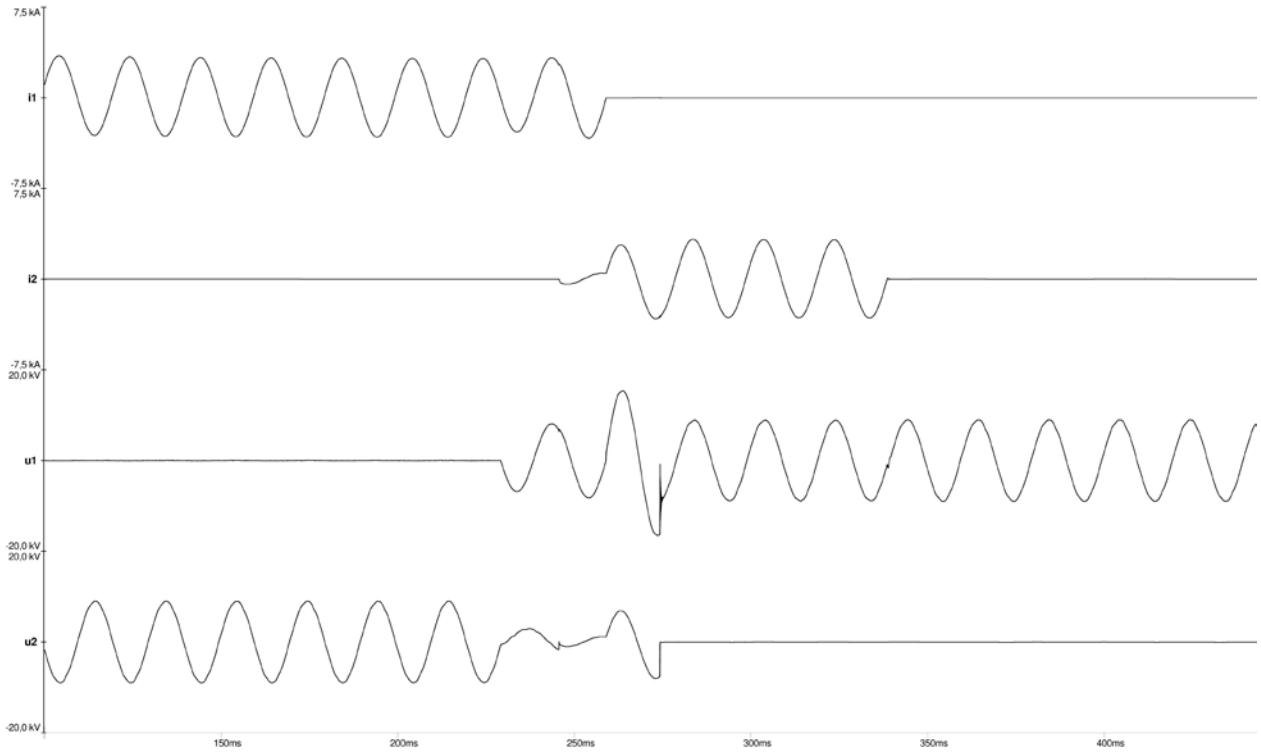

Fig. 5.3: Breaking capacity test (test sequence 3 – switching operation no. 3).

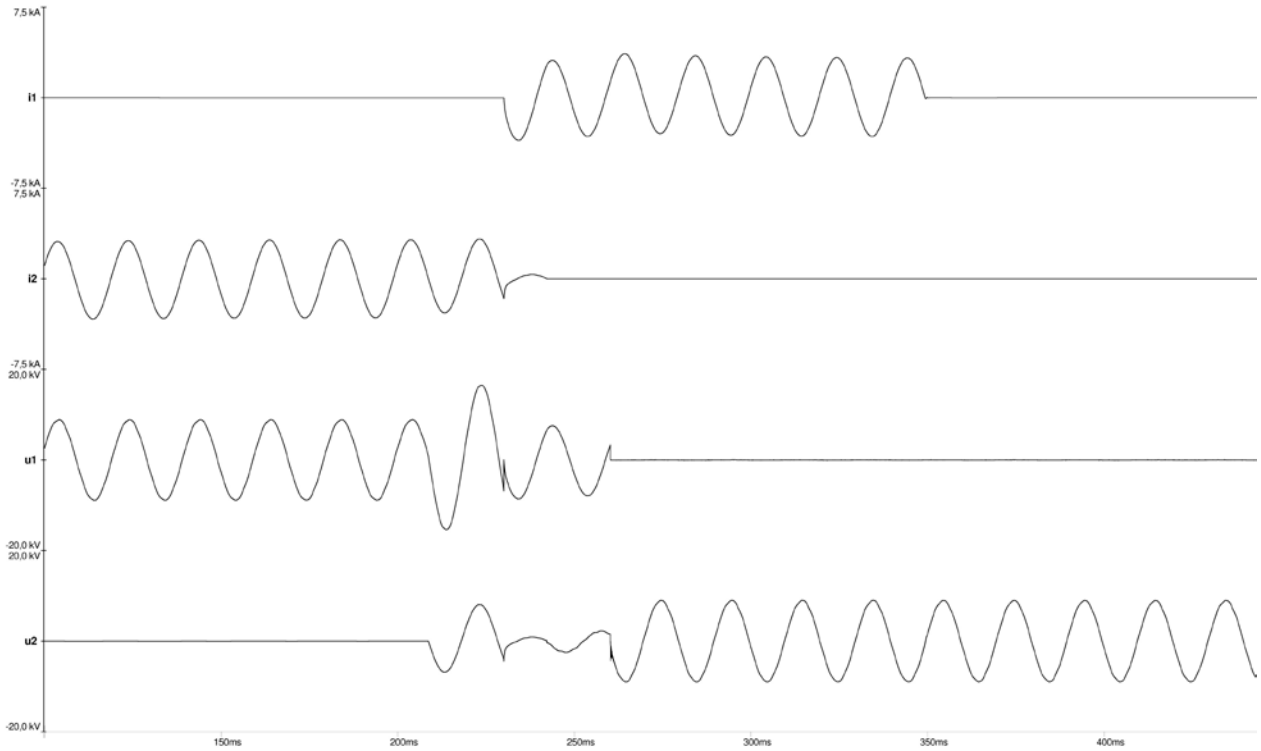

Fig. 5.4: Breaking capacity test (test sequence 3 – switching operation no. 4).

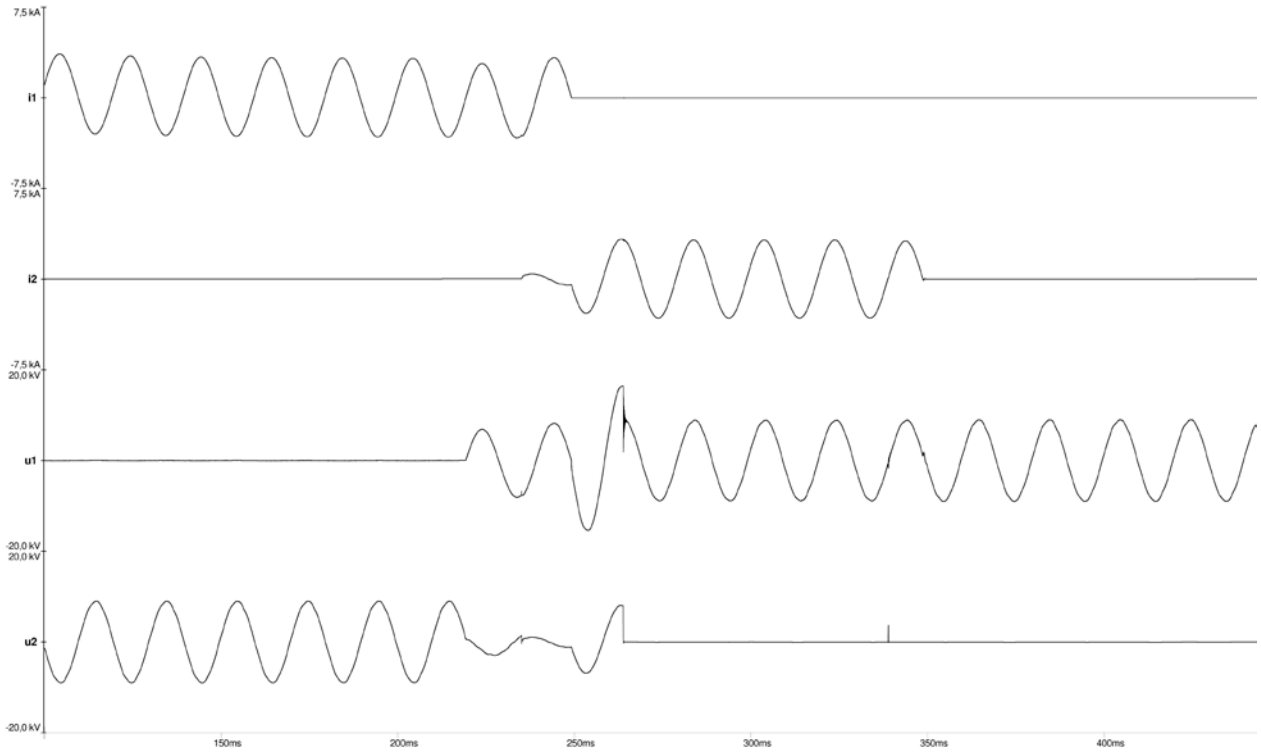

Fig. 5.5: Breaking capacity test (test sequence 3 – switching operation no. 5).

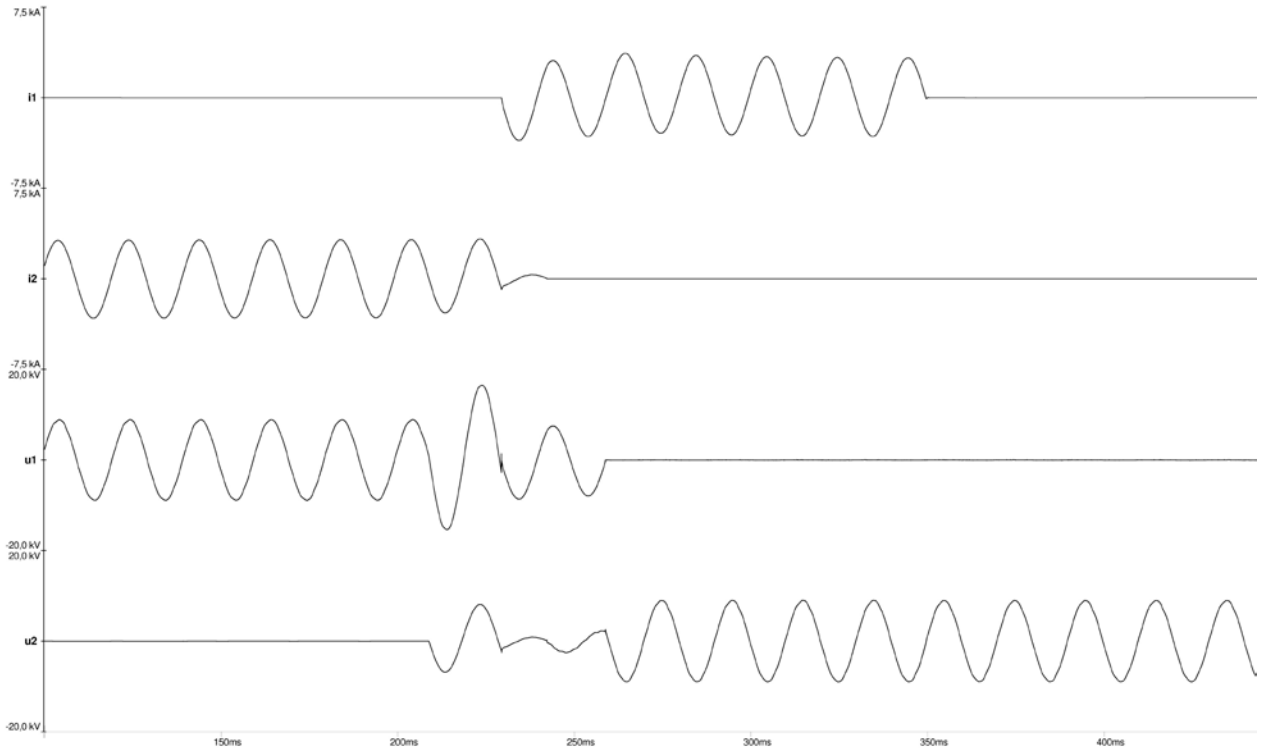

Fig. 5.6: Breaking capacity test (test sequence 3 – switching operation no. 6).

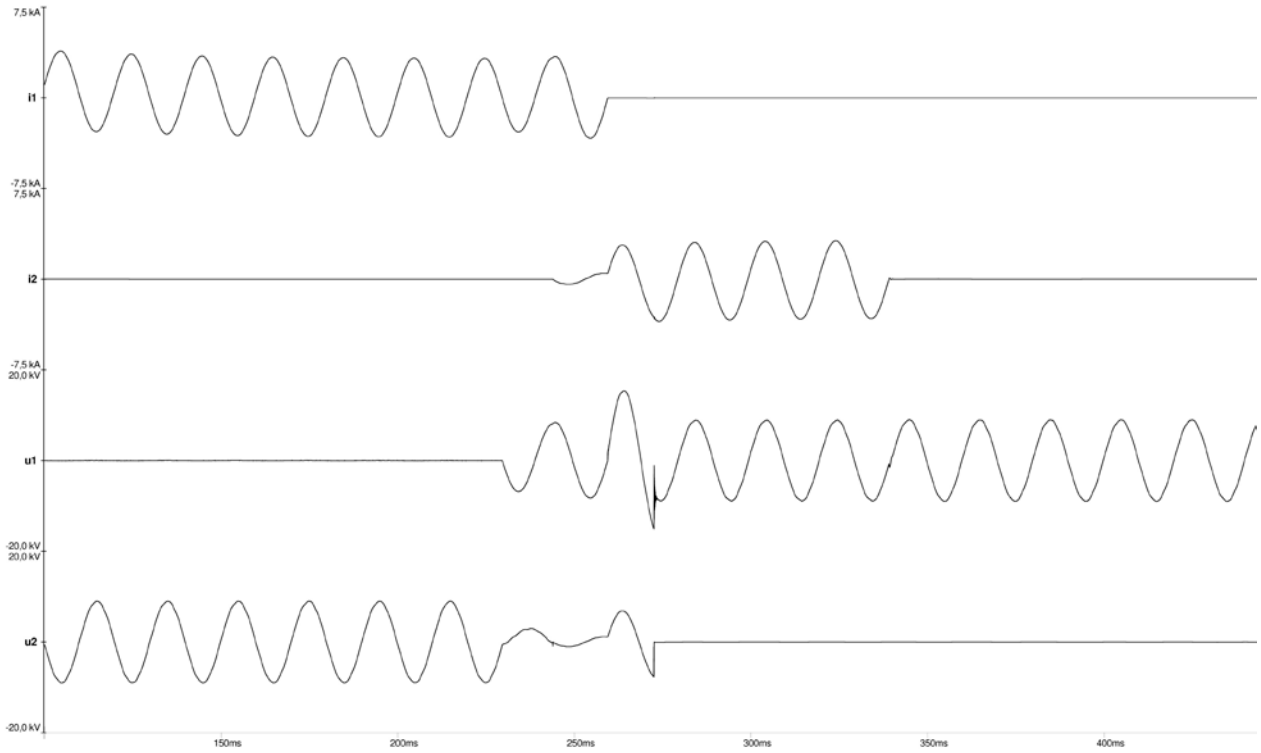

Fig. 5.7: Breaking capacity test (test sequence 3 – switching operation no. 7).

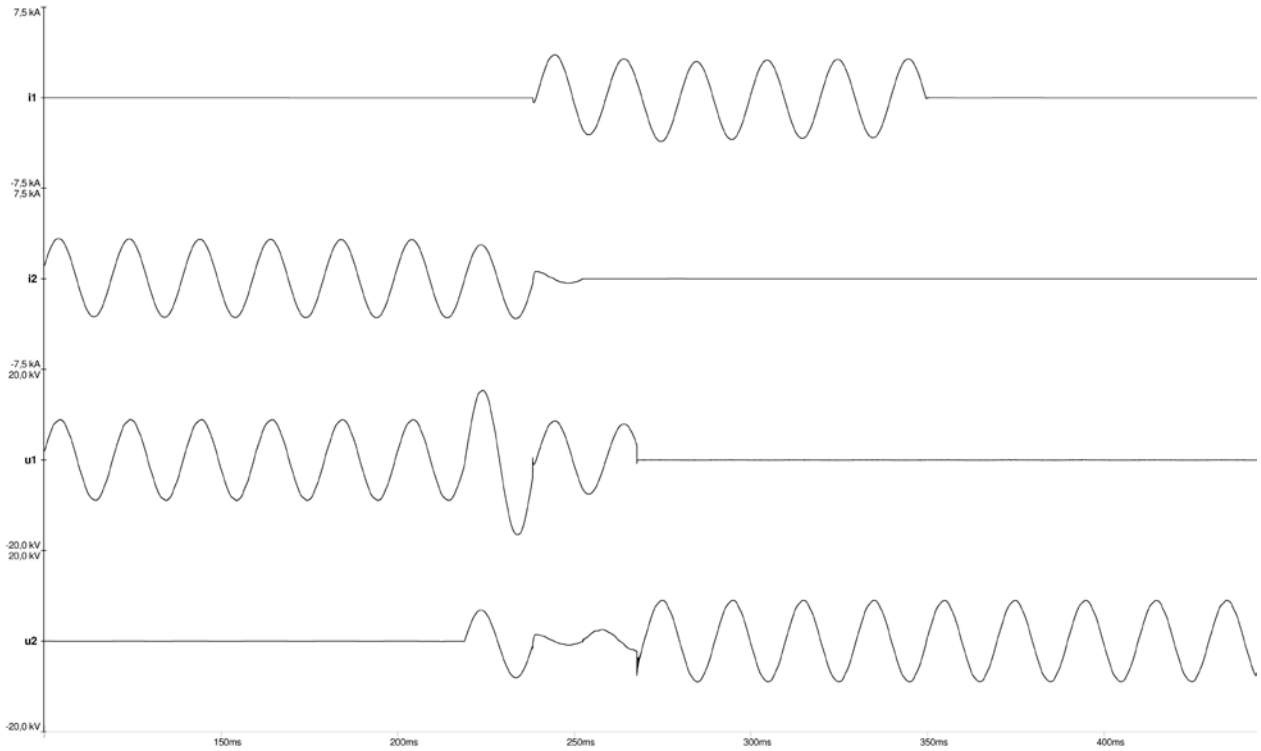

Fig. 5.8: Breaking capacity test (test sequence 3 – switching operation no. 8).

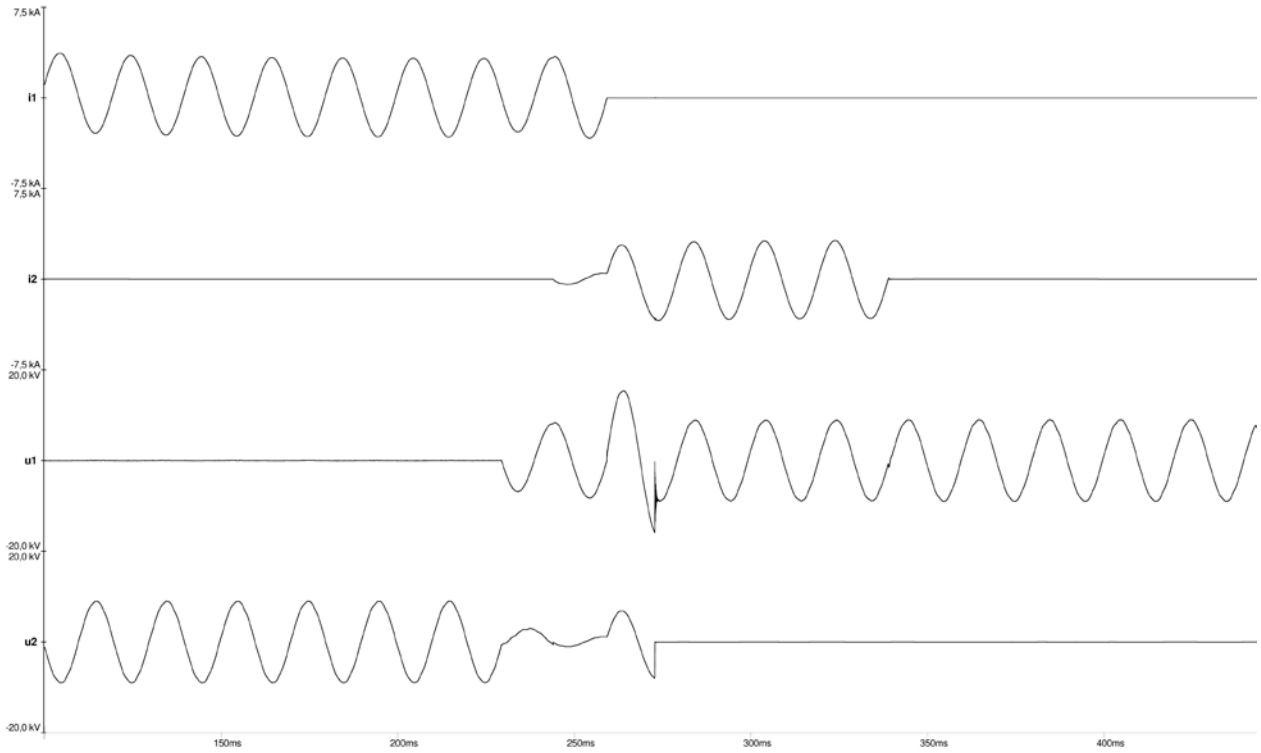

Fig. 5.9: Breaking capacity test (test sequence 3 – switching operation no. 9).

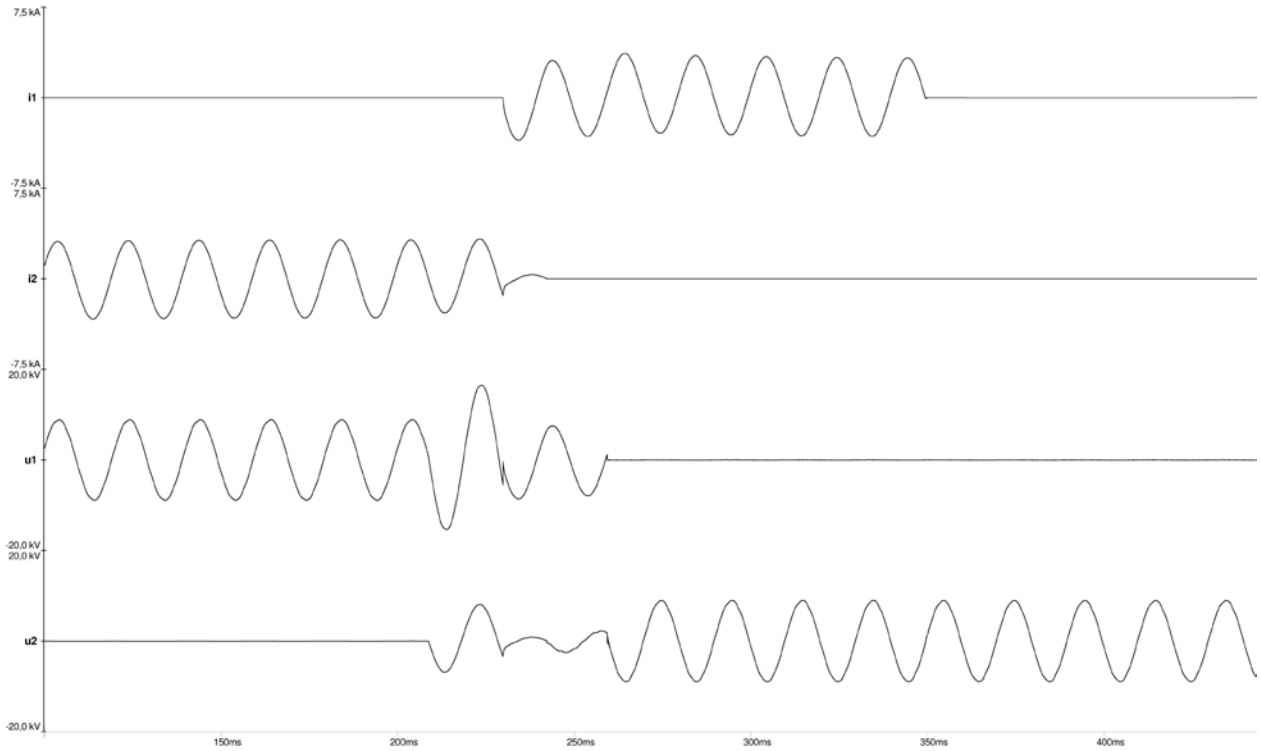

Fig. 5.10: Breaking capacity test (test sequence 3 – switching operation no. 10).

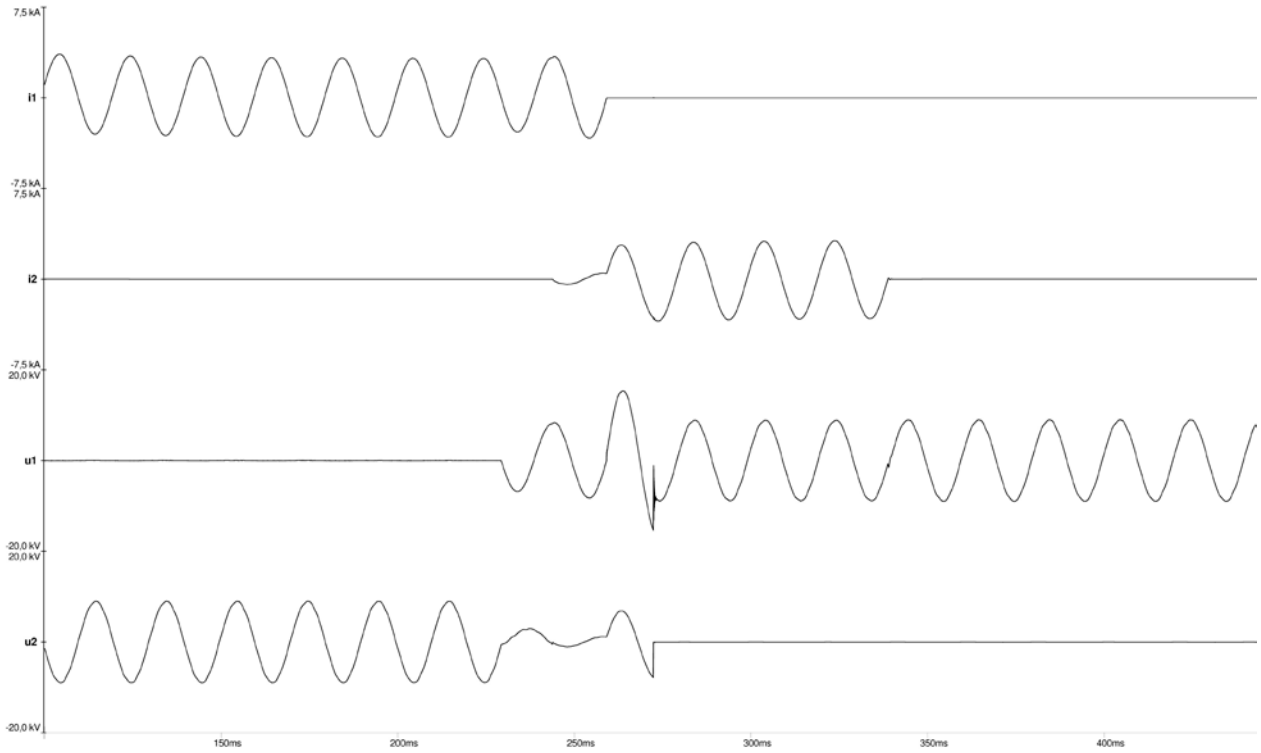

Fig. 5.11: Breaking capacity test (test sequence 3 – switching operation no. 11).

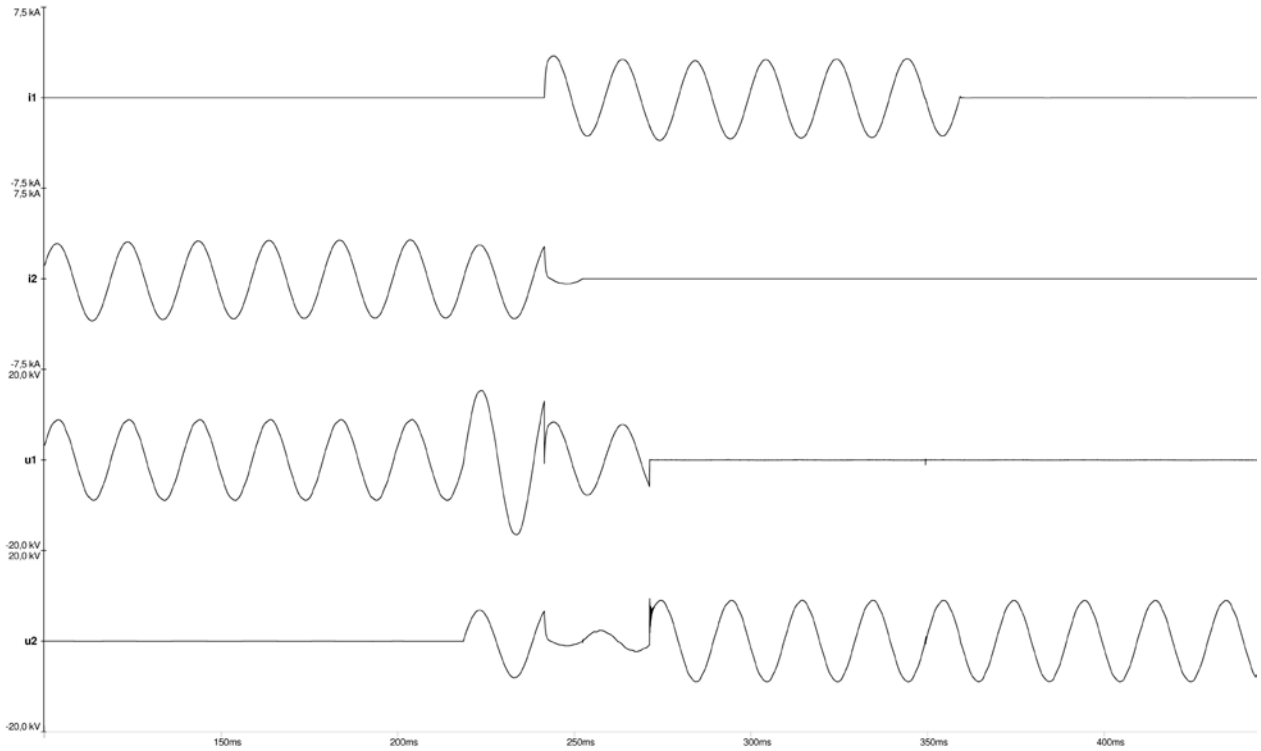

Fig. 5.12: Breaking capacity test (test sequence 3 – switching operation no. 12).

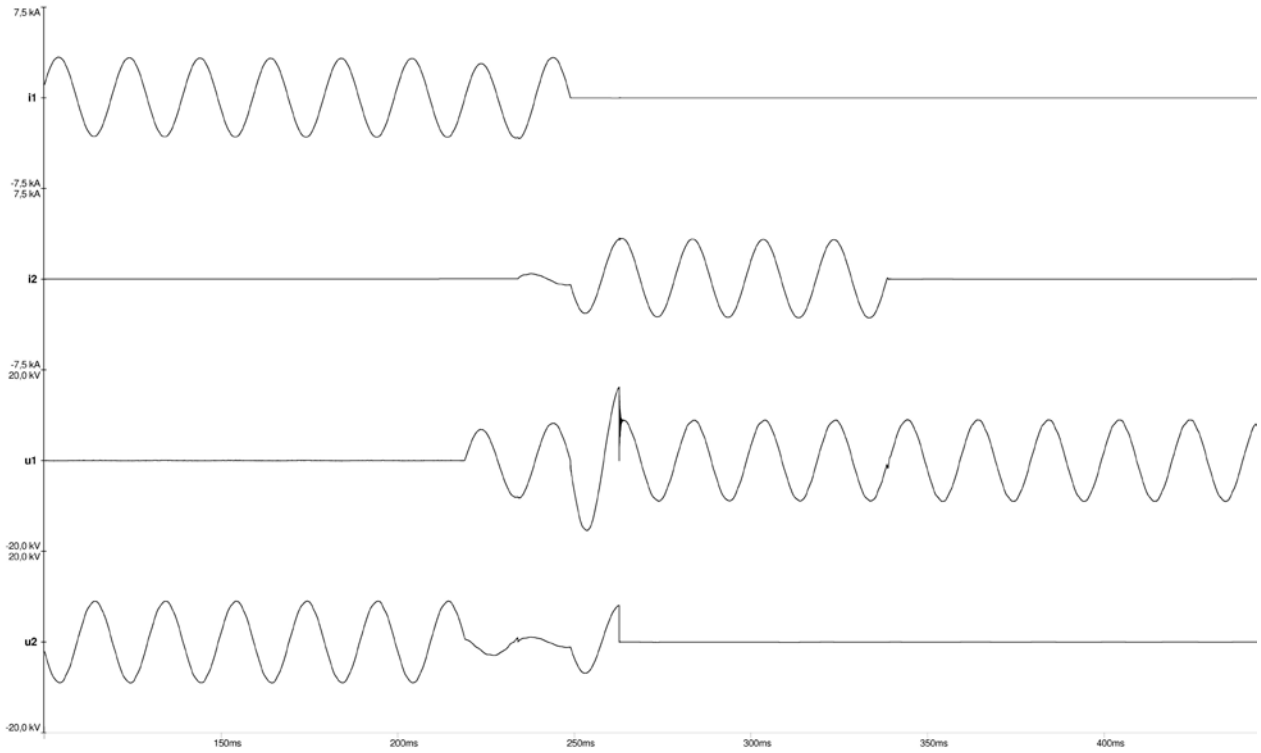

Fig. 5.13: Breaking capacity test (test sequence 3 – switching operation no. 13).

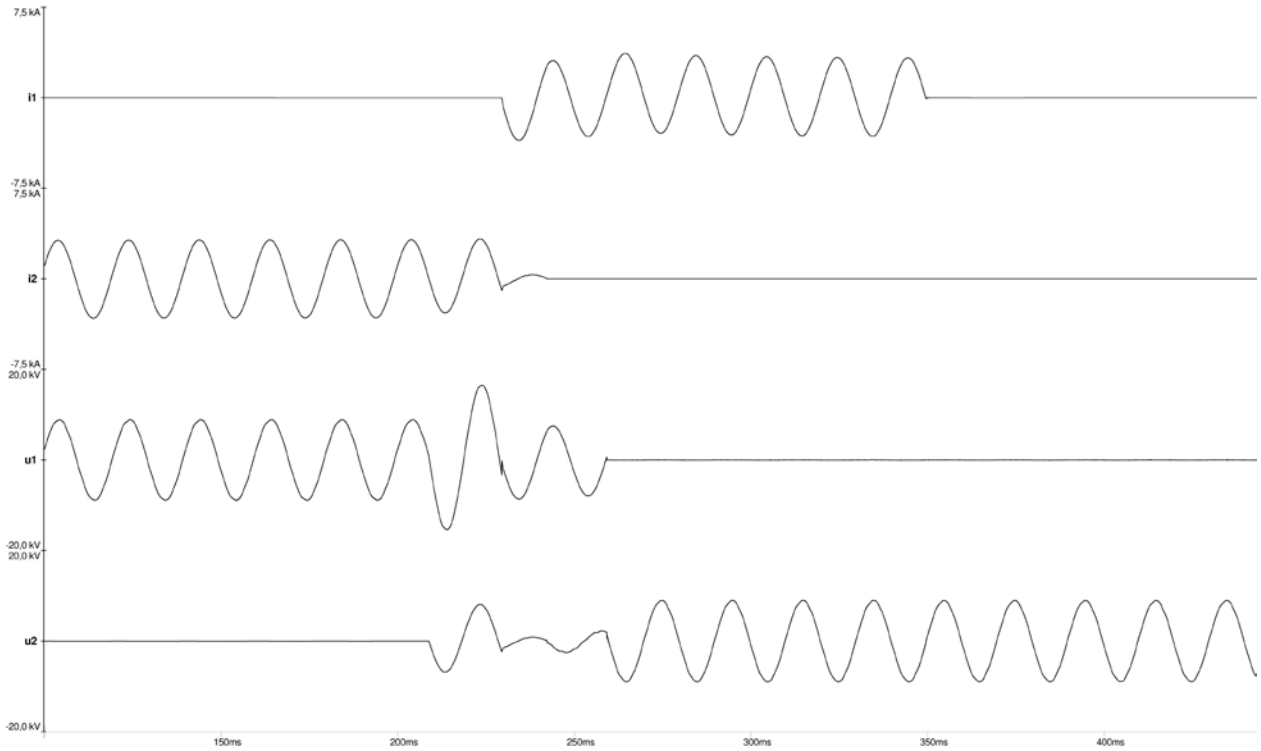

Fig. 5.14: Breaking capacity test (test sequence 3 – switching operation no. 14).

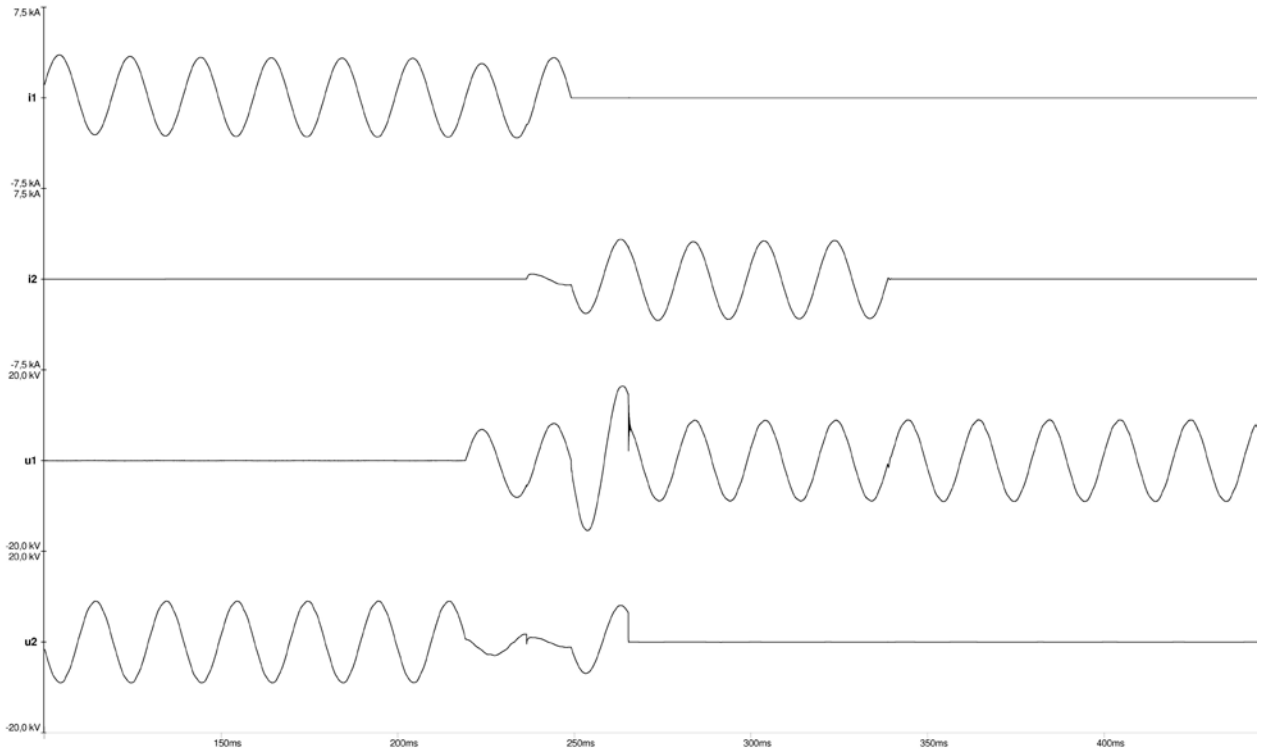

Fig. 5.15: Breaking capacity test (test sequence 3 – switching operation no. 15).

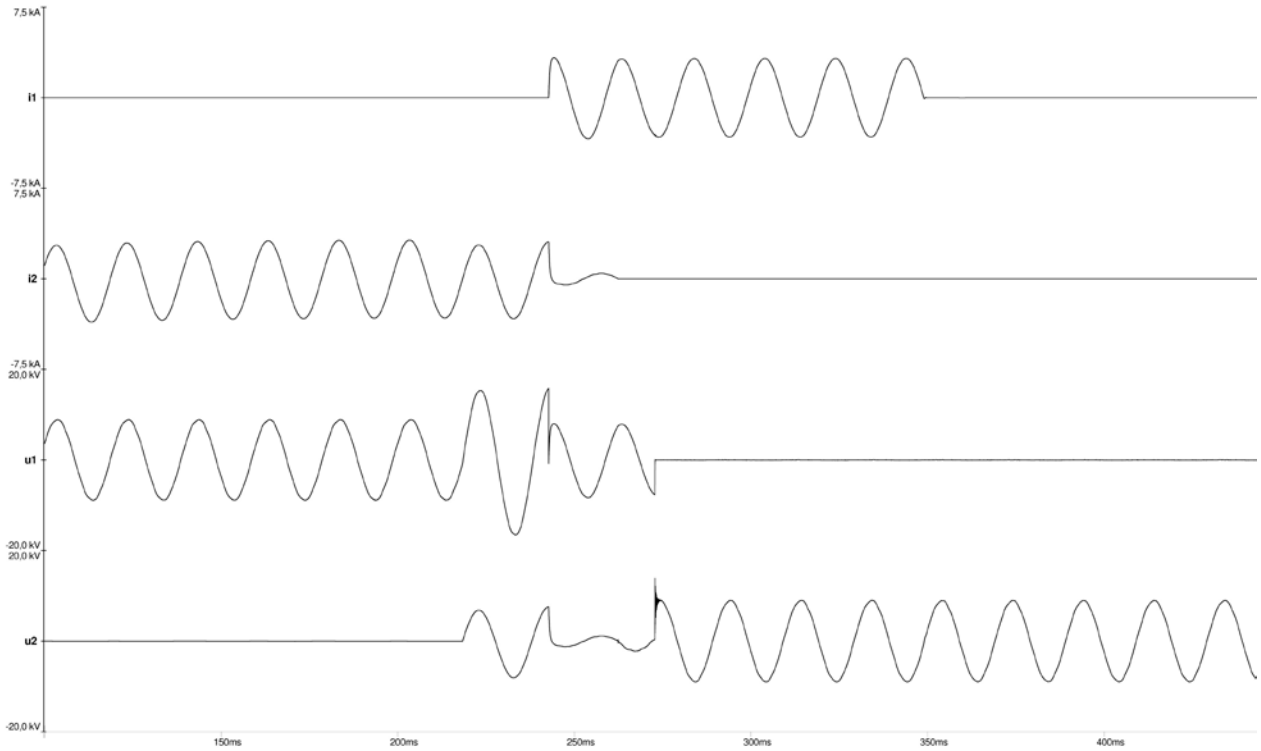

Fig. 5.16: Breaking capacity test (test sequence 3 – switching operation no. 16).

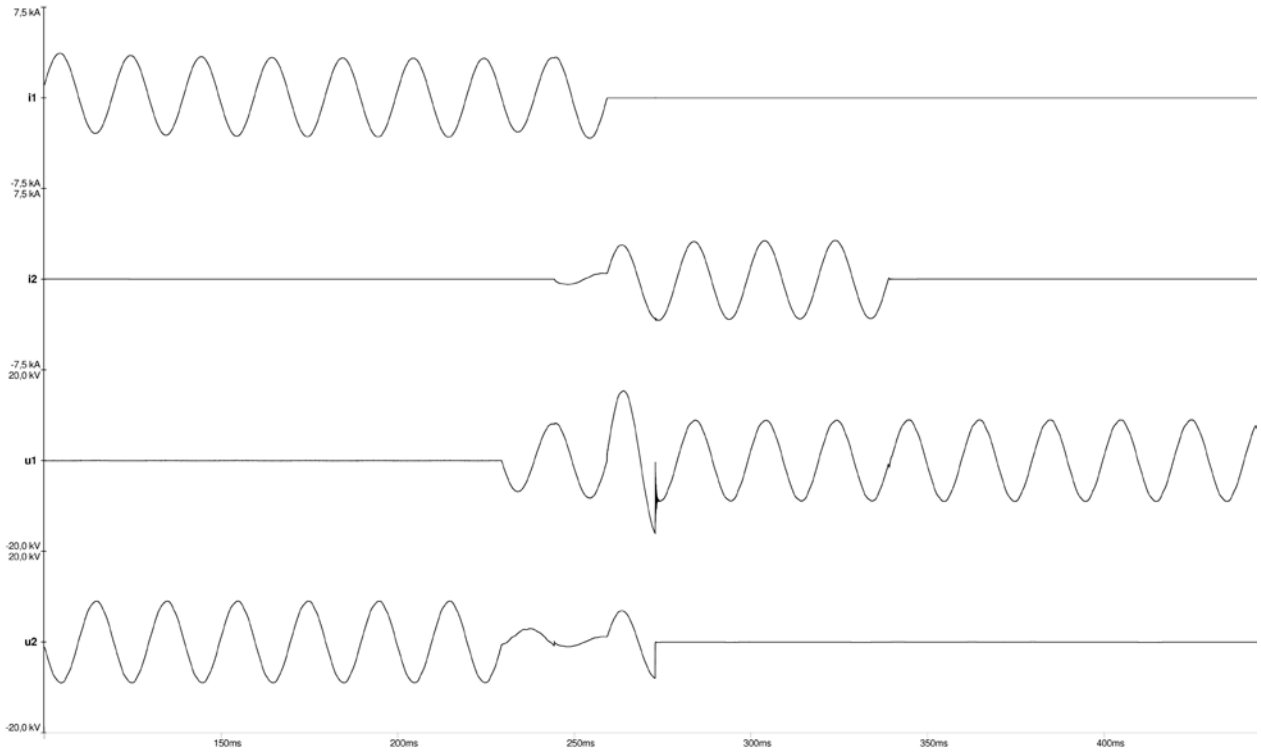

Fig. 5.17: Breaking capacity test (test sequence 3 – switching operation no. 17).

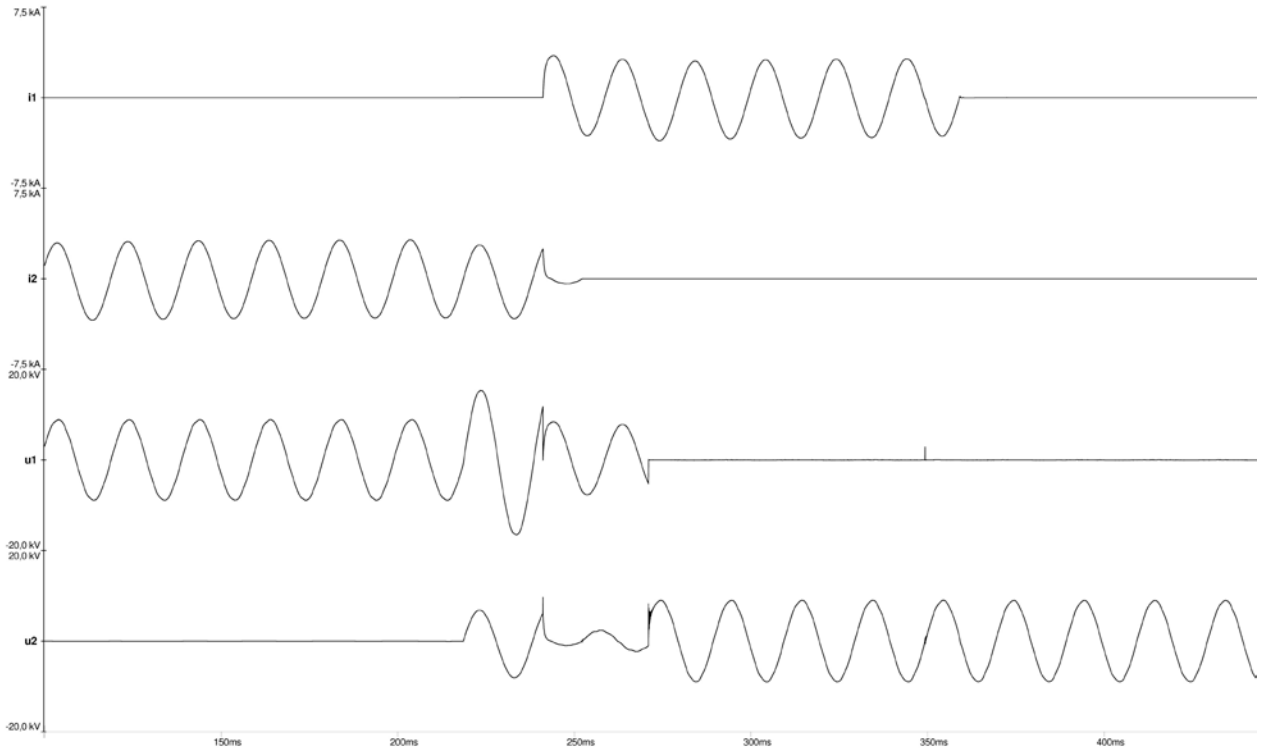

Fig. 5.18: Breaking capacity test (test sequence 3 – switching operation no. 18).

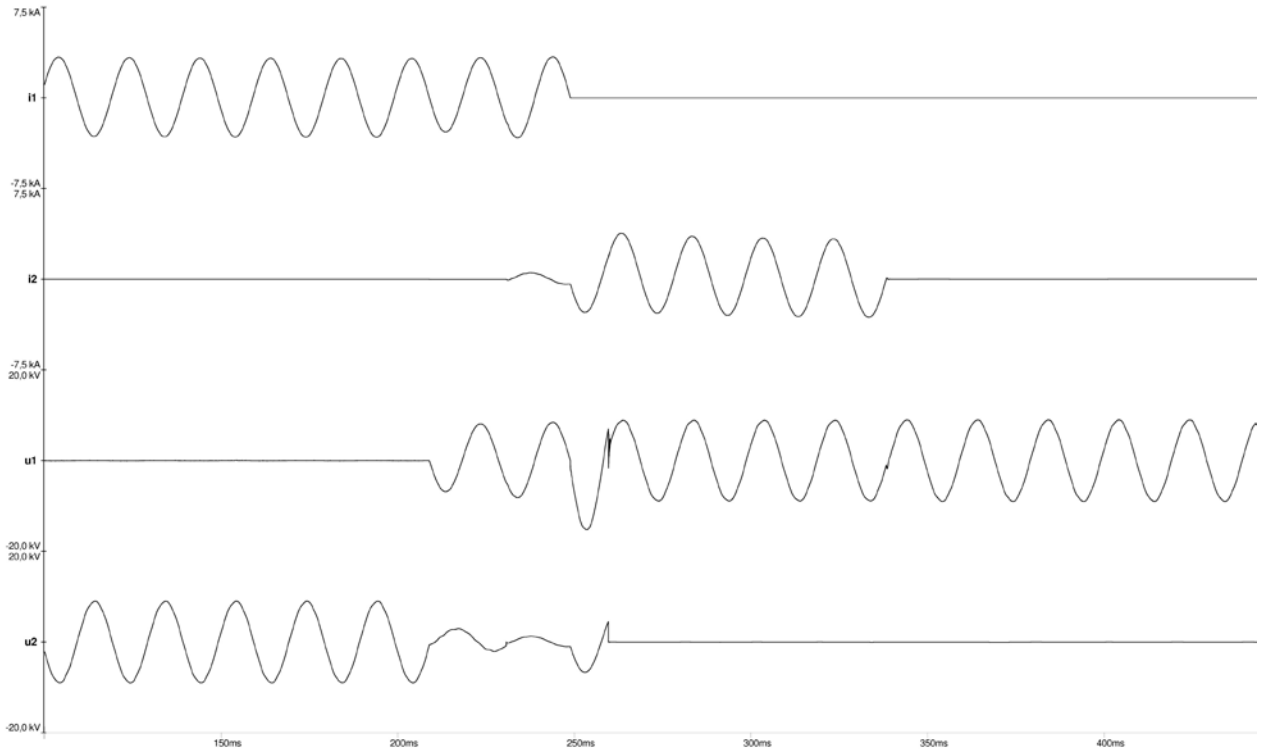

Fig. 5.19: Breaking capacity test (test sequence 3 – switching operation no. 19).

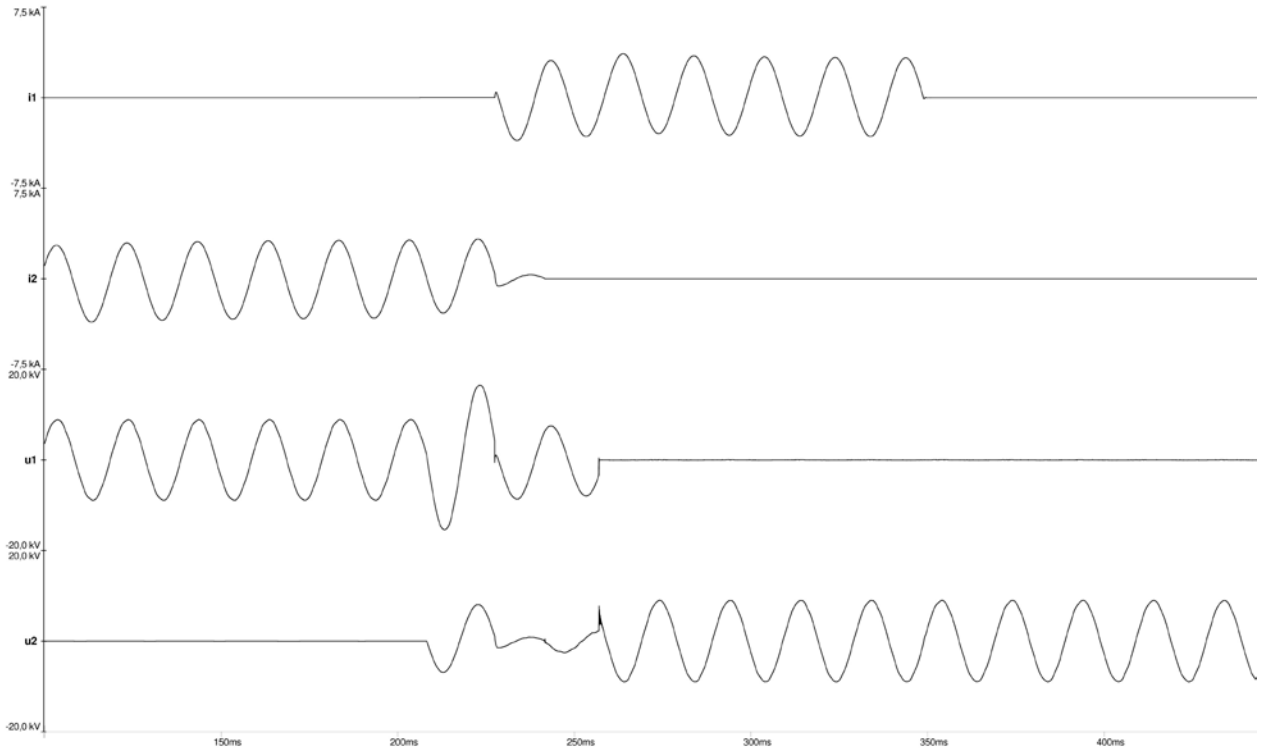

Fig. 5.20: Breaking capacity test (test sequence 3 – switching operation no. 20).

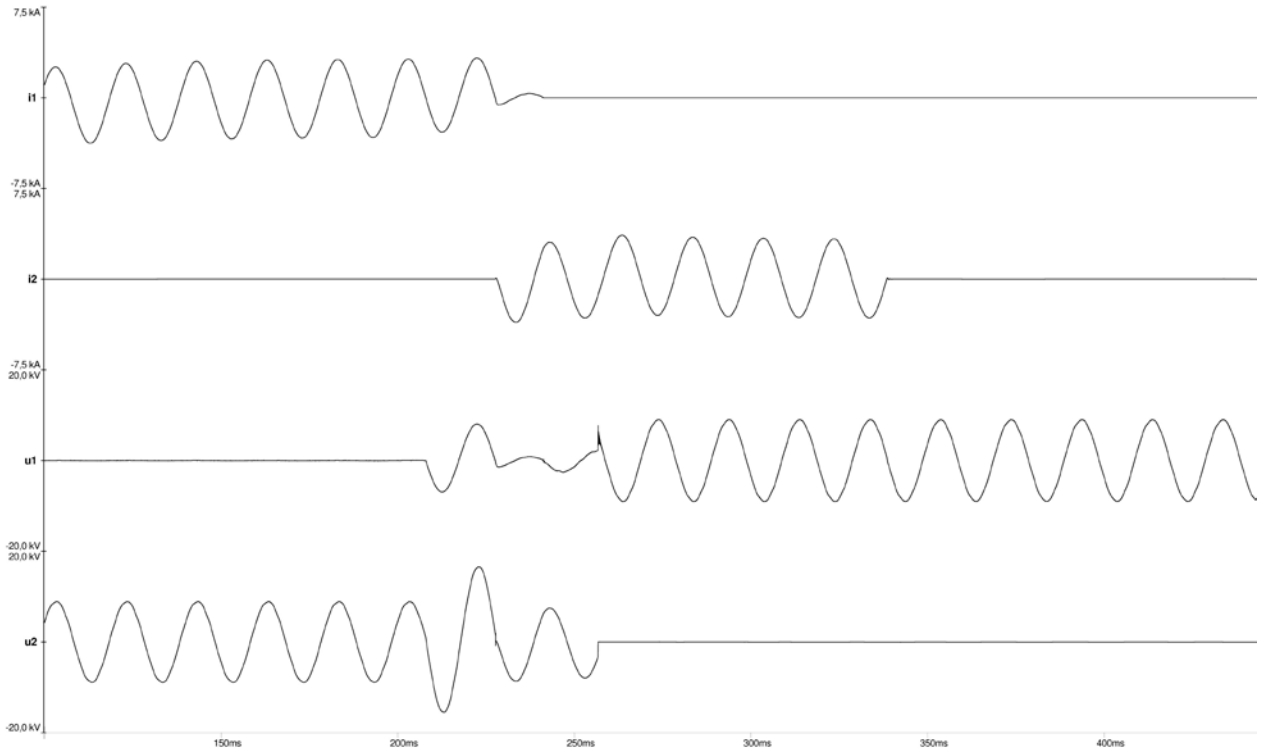

Fig. 5.21: Breaking capacity test (test sequence 3 – switching operation no. 21).

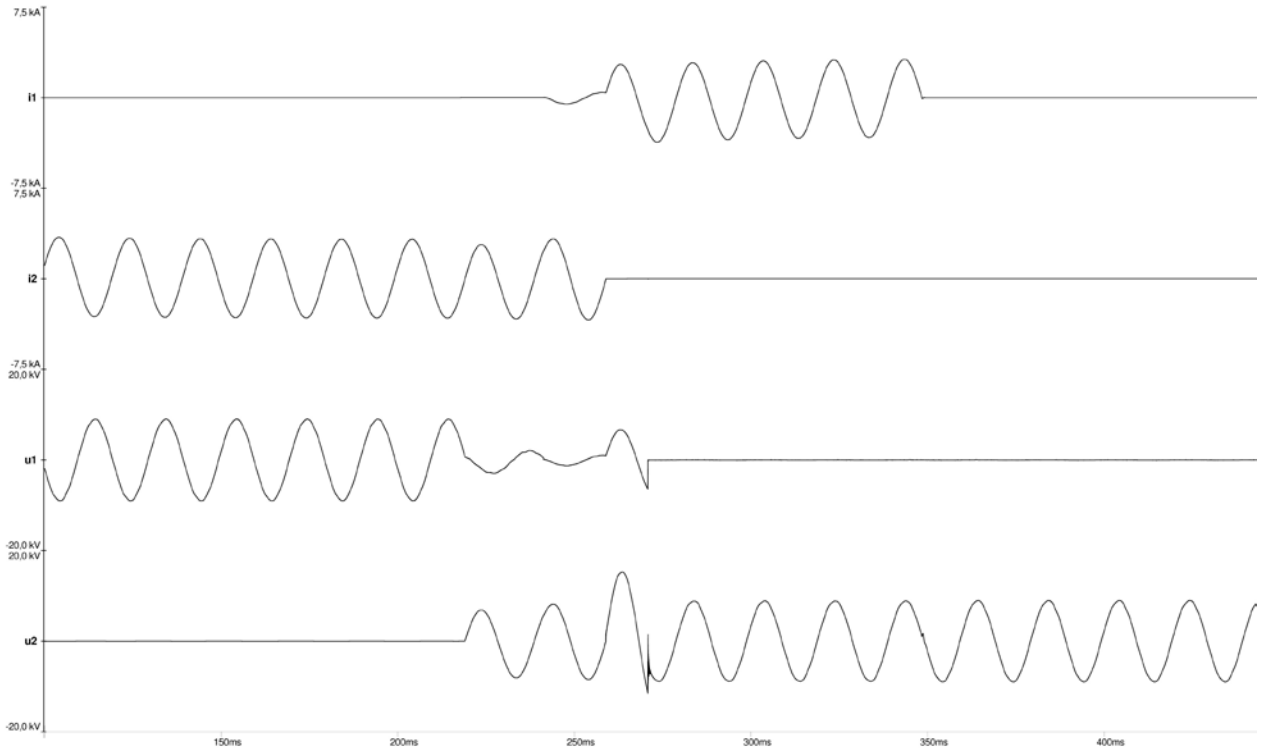

Fig. 5.22: Breaking capacity test (test sequence 3 – switching operation no. 22).

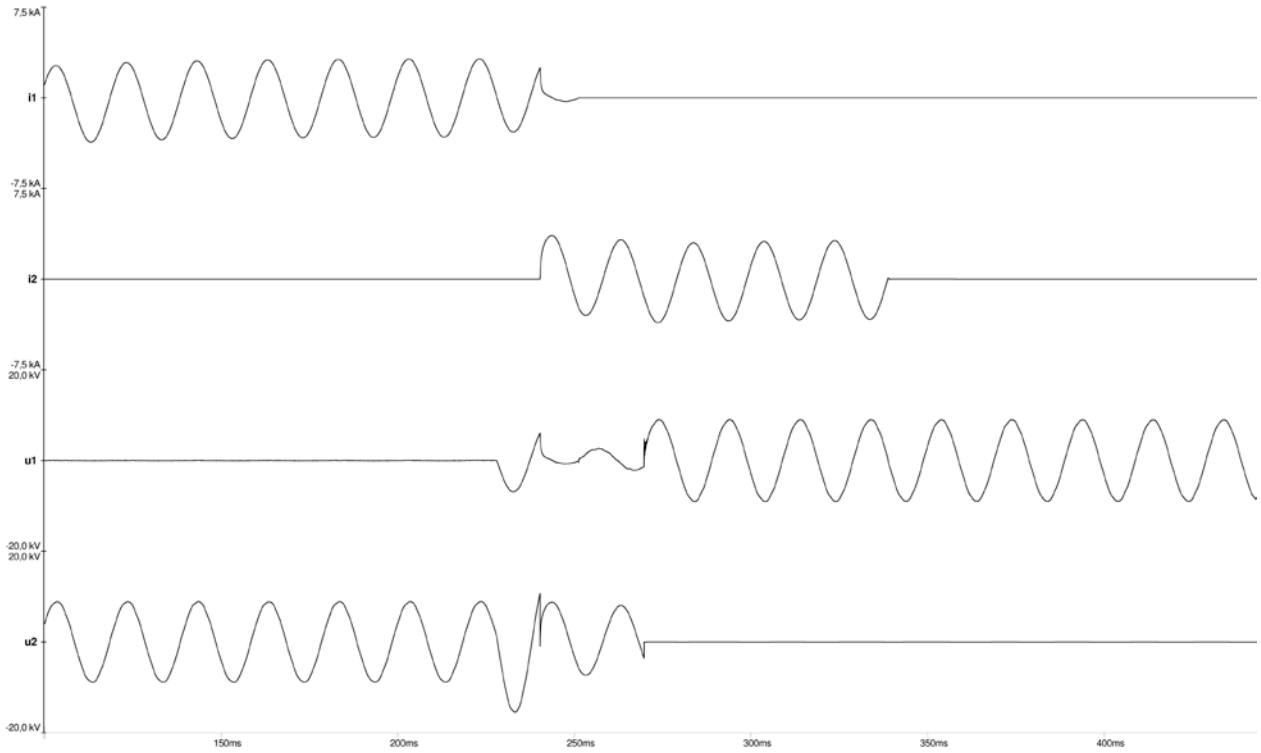

Fig. 5.23: Breaking capacity test (test sequence 3 – switching operation no. 23).

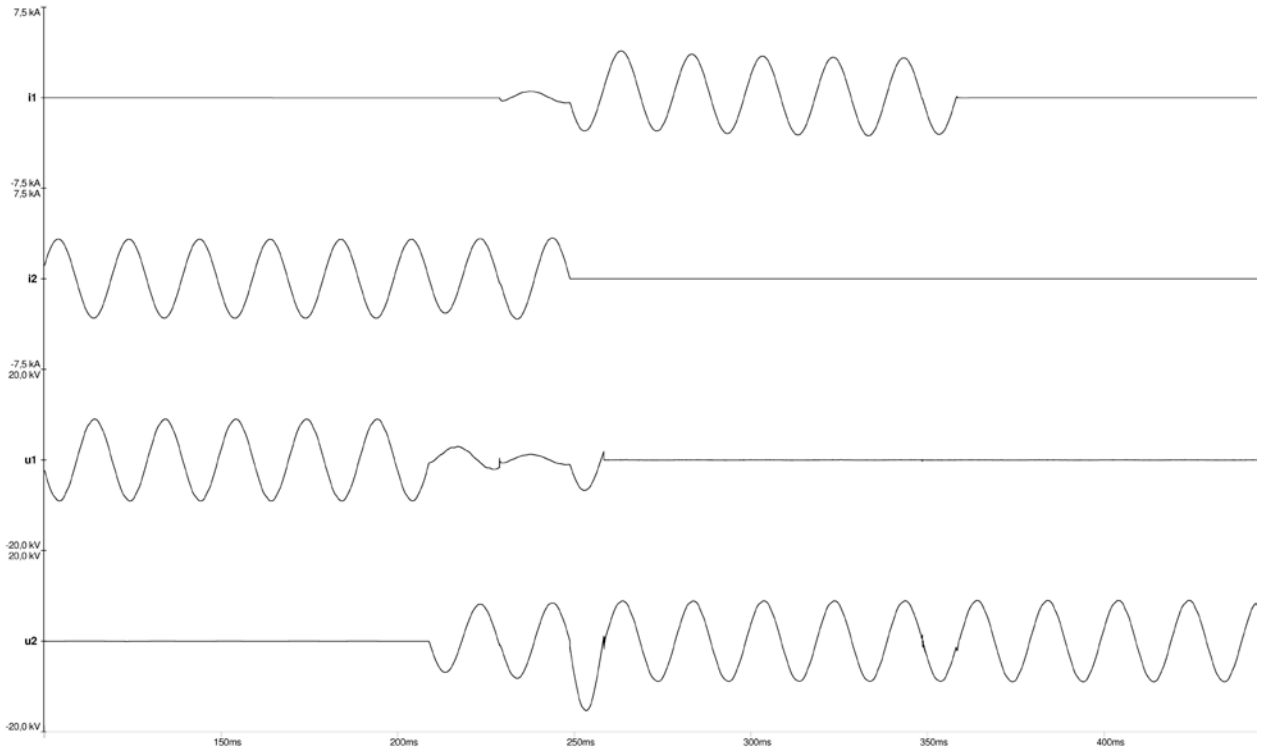

Fig. 5.24: Breaking capacity test (test sequence 3 – switching operation no. 24).

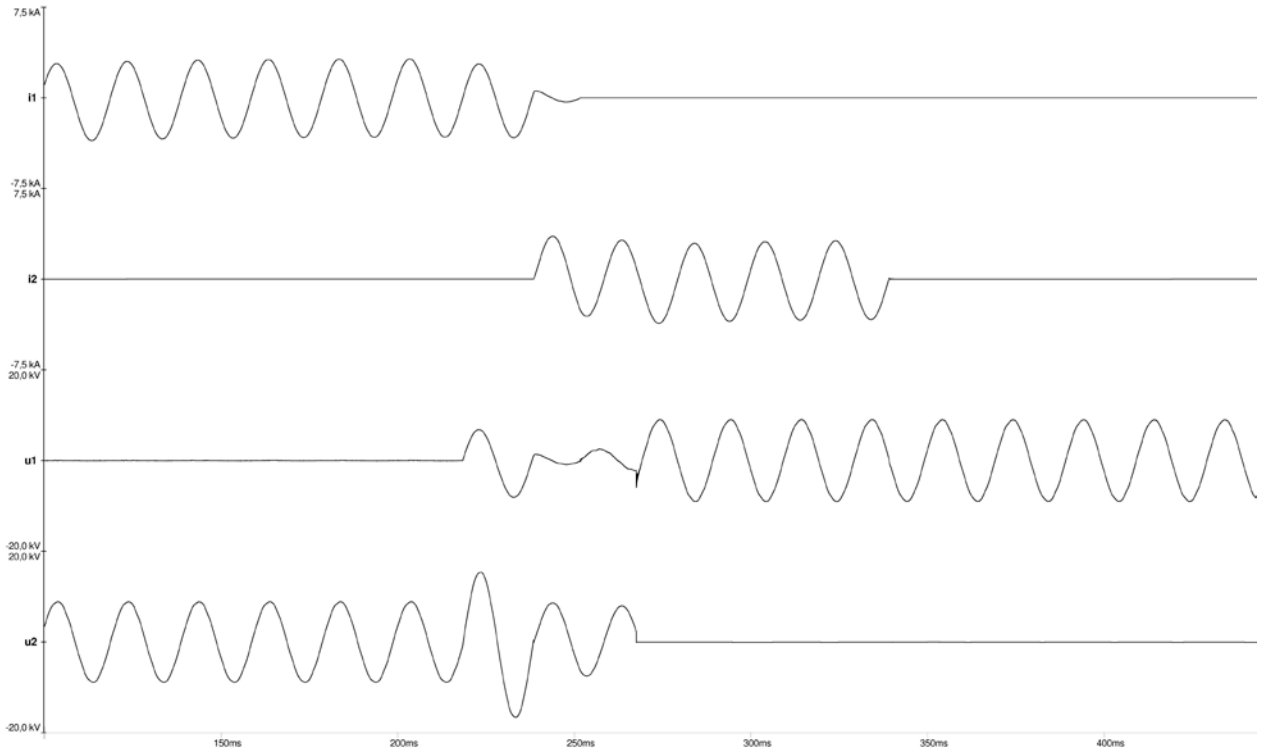

Fig. 5.25: Breaking capacity test (test sequence 3 – switching operation no. 25).

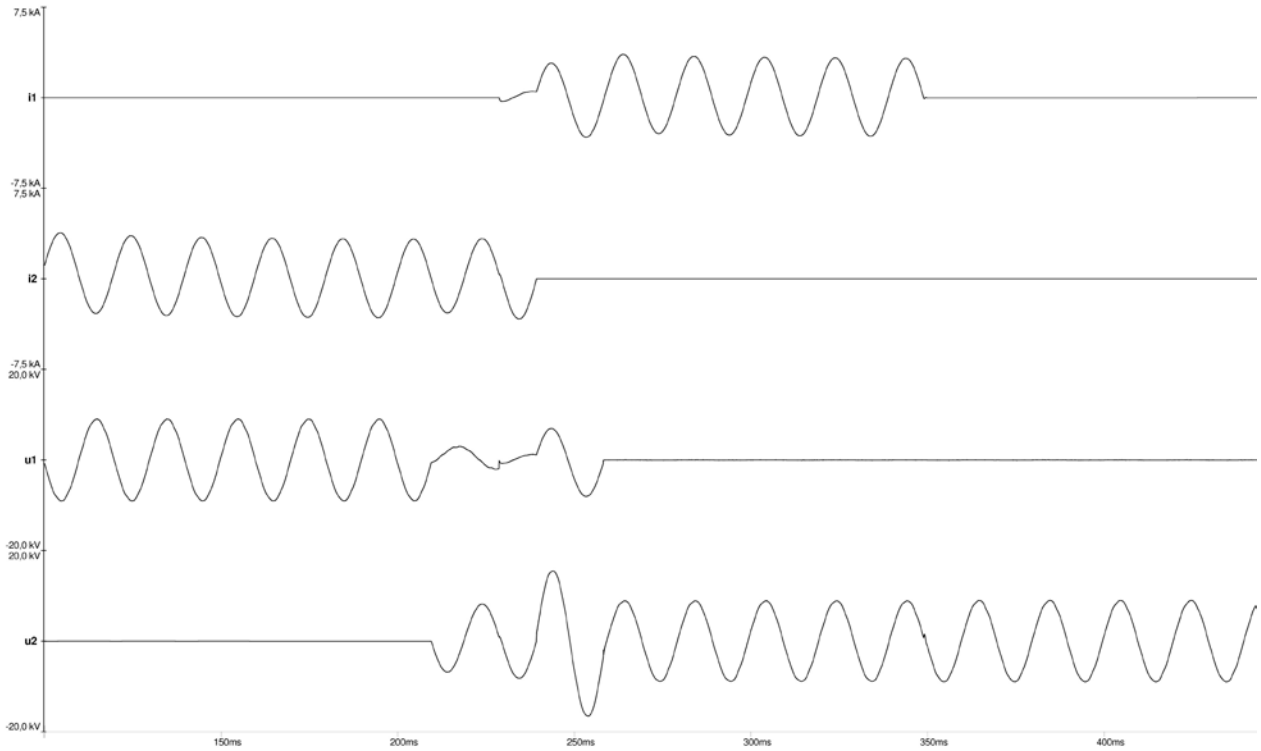

Fig. 5.26: Breaking capacity test (test sequence 3 – switching operation no. 26).

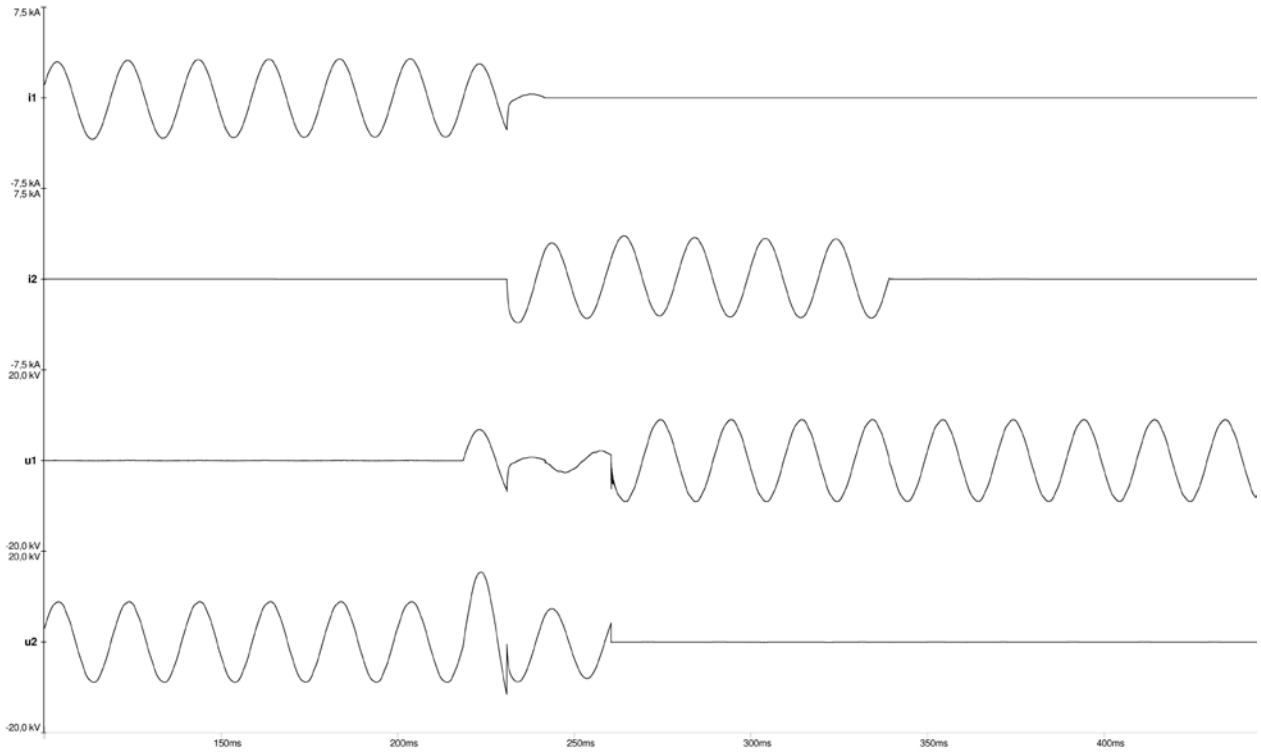

Fig. 5.27: Breaking capacity test (test sequence 3 – switching operation no. 27).

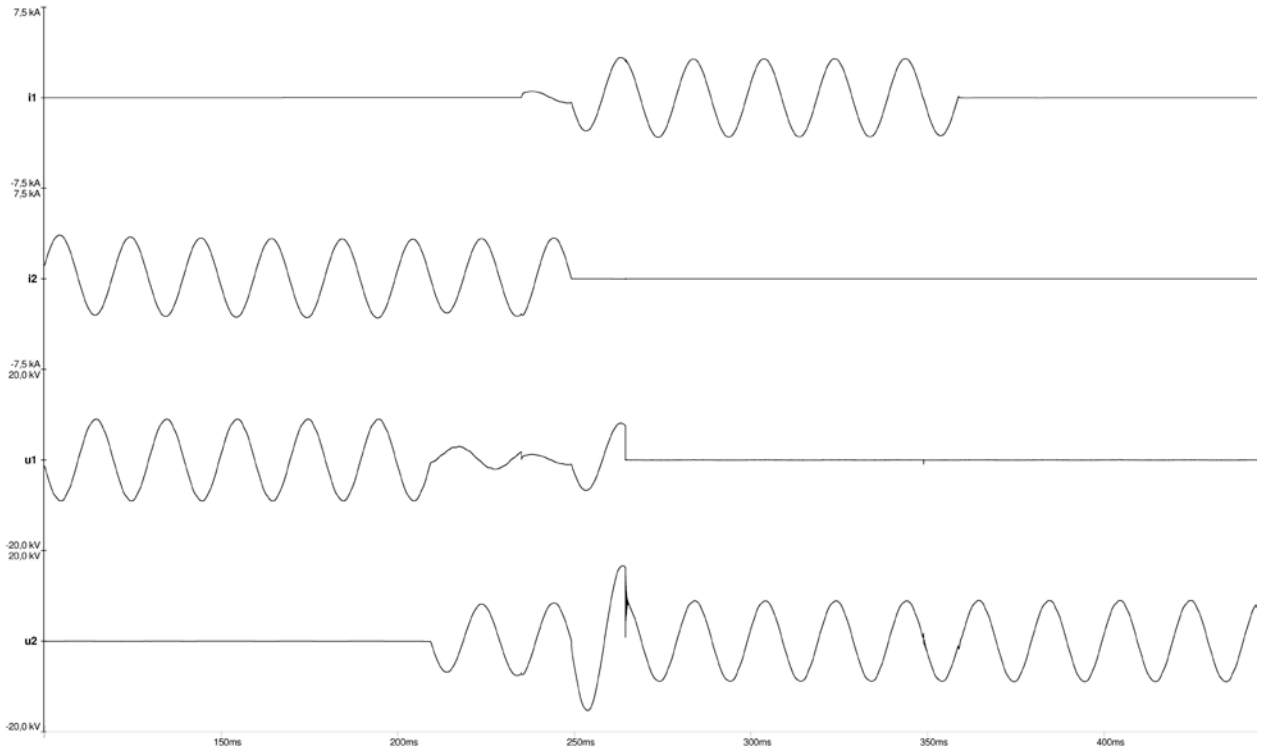

Fig. 5.28: Breaking capacity test (test sequence 3 – switching operation no. 28).

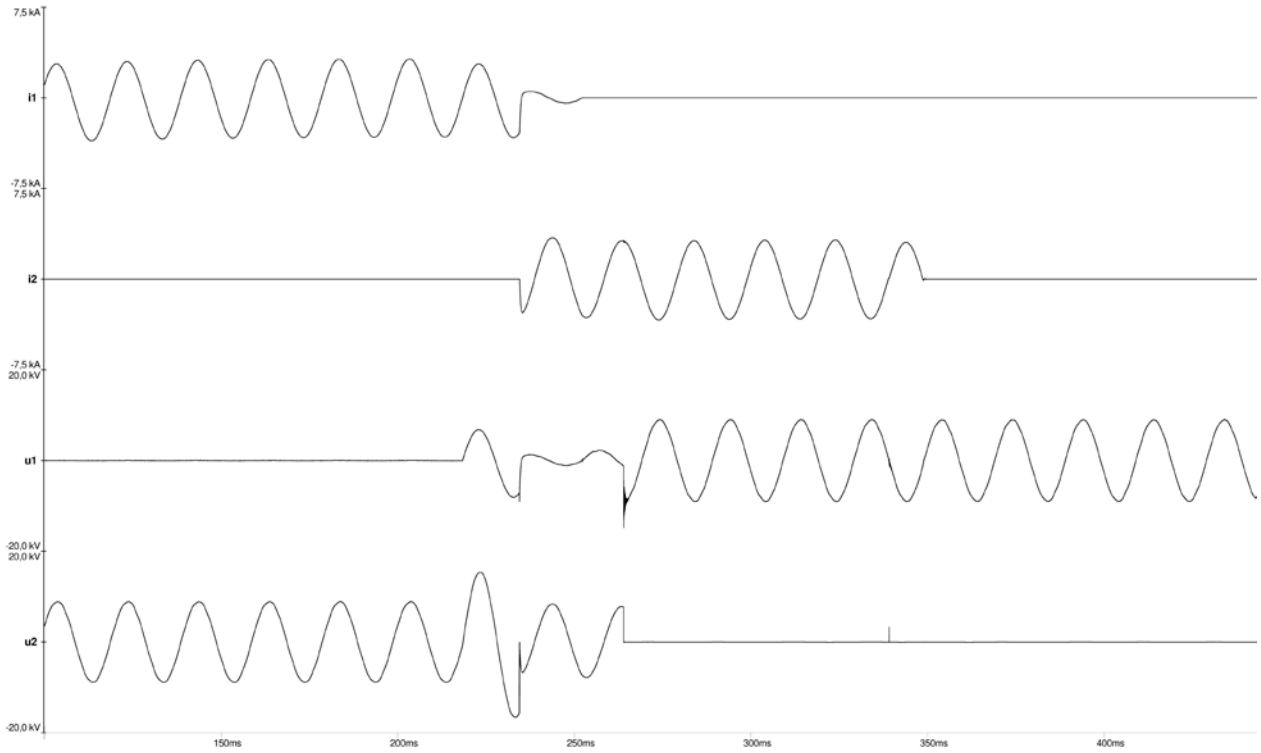

Fig. 5.29: Breaking capacity test (test sequence 3 – switching operation no. 29).

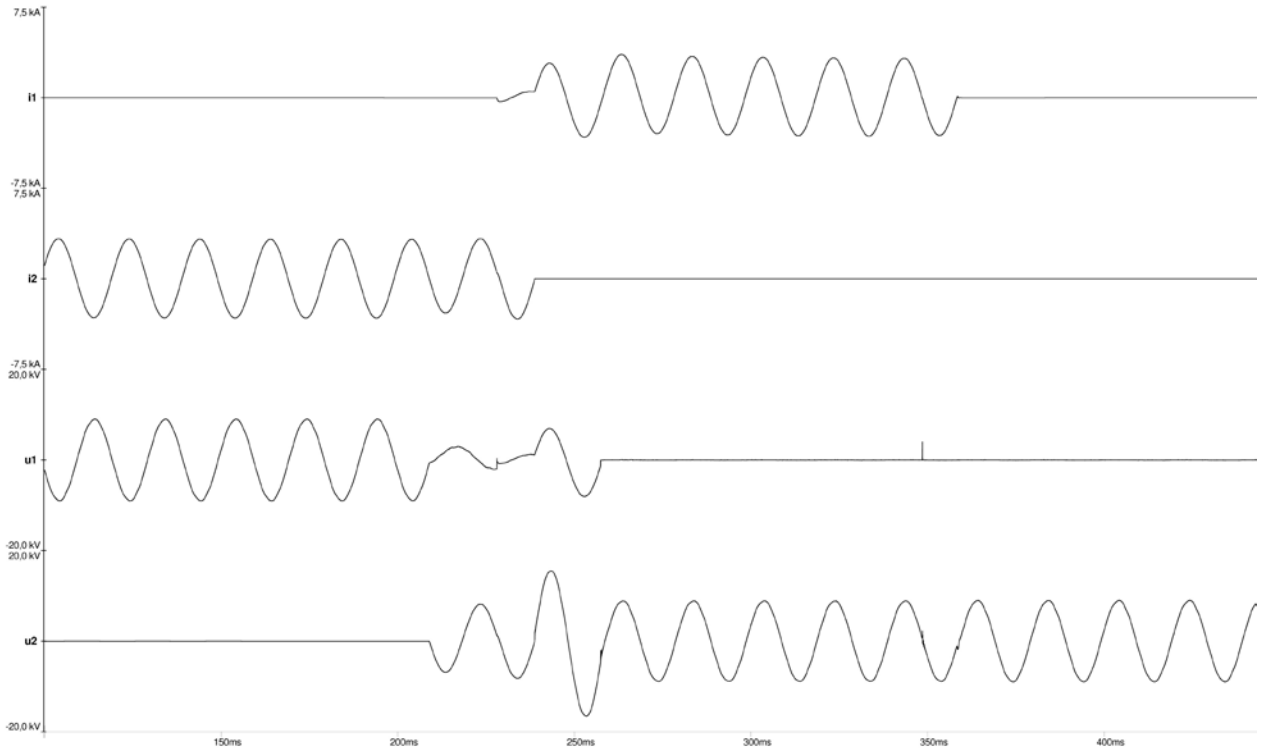

Fig. 5.30: Breaking capacity test (test sequence 3 – switching operation no. 30).

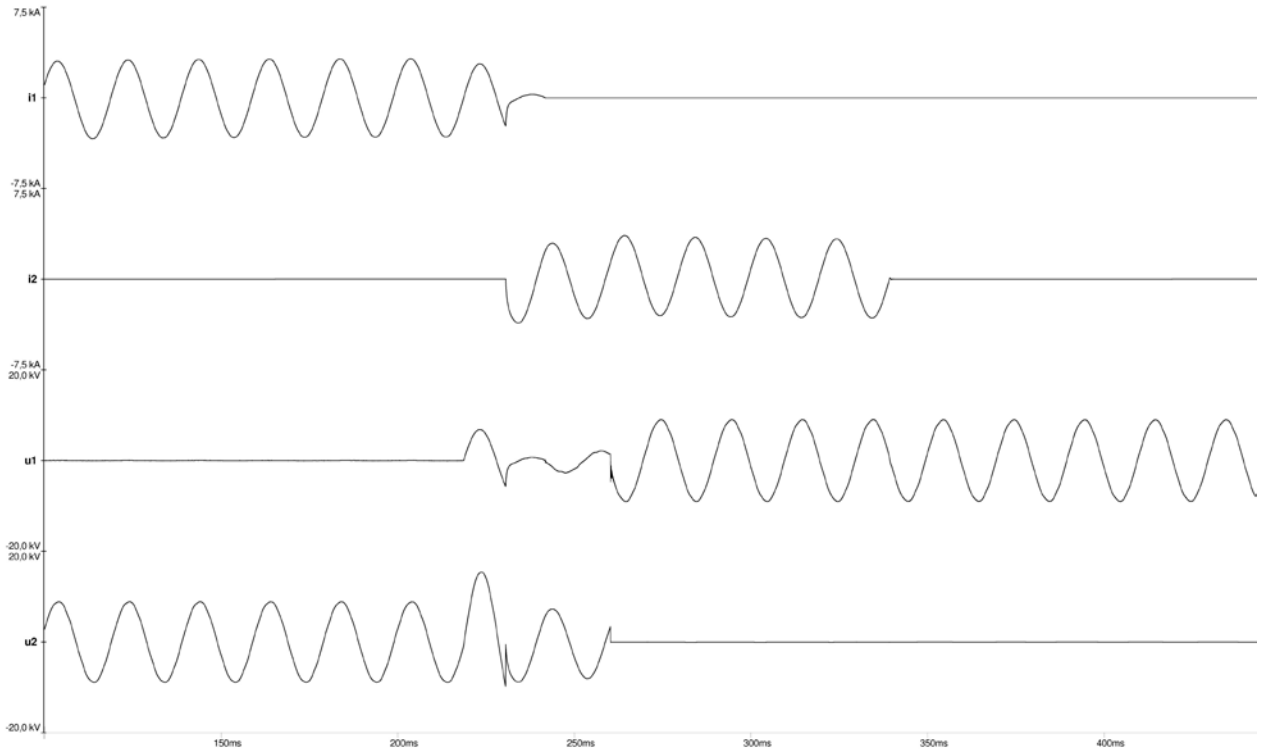

Fig. 5.31: Breaking capacity test (test sequence 3 – switching operation no. 31).

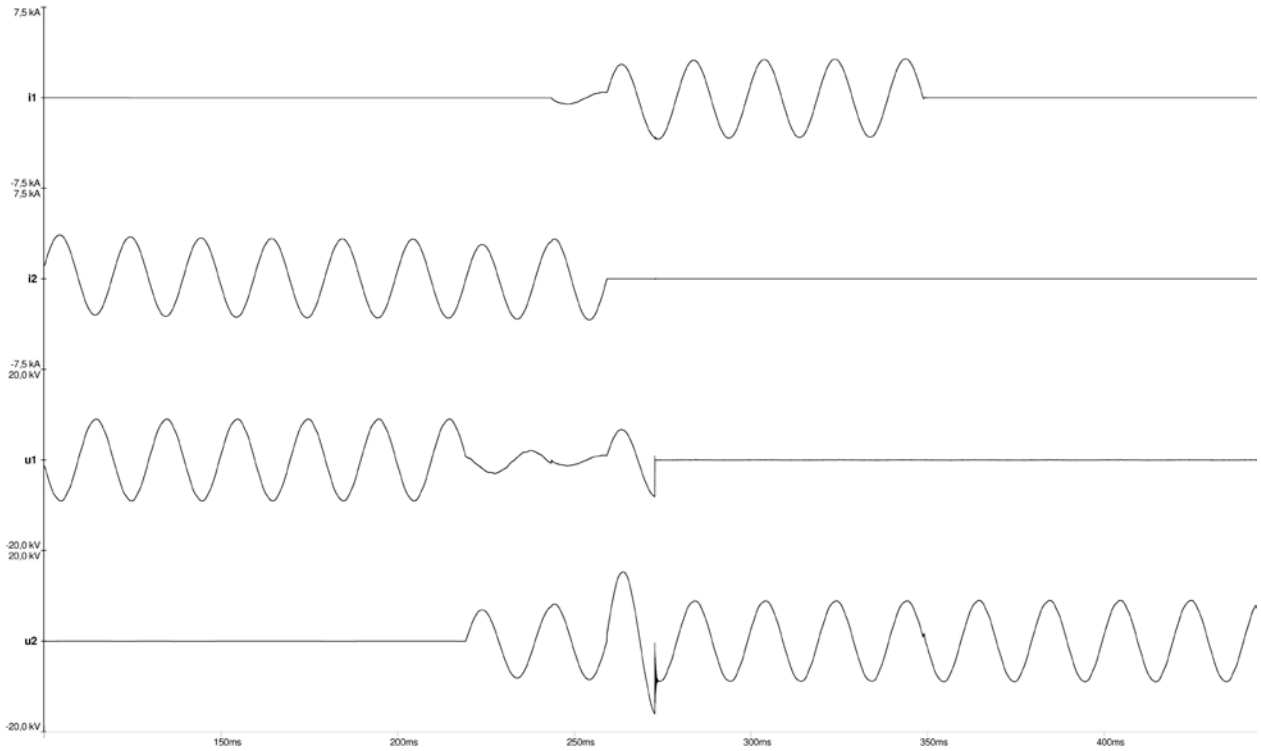

Fig. 5.32: Breaking capacity test (test sequence 3 – switching operation no. 32).

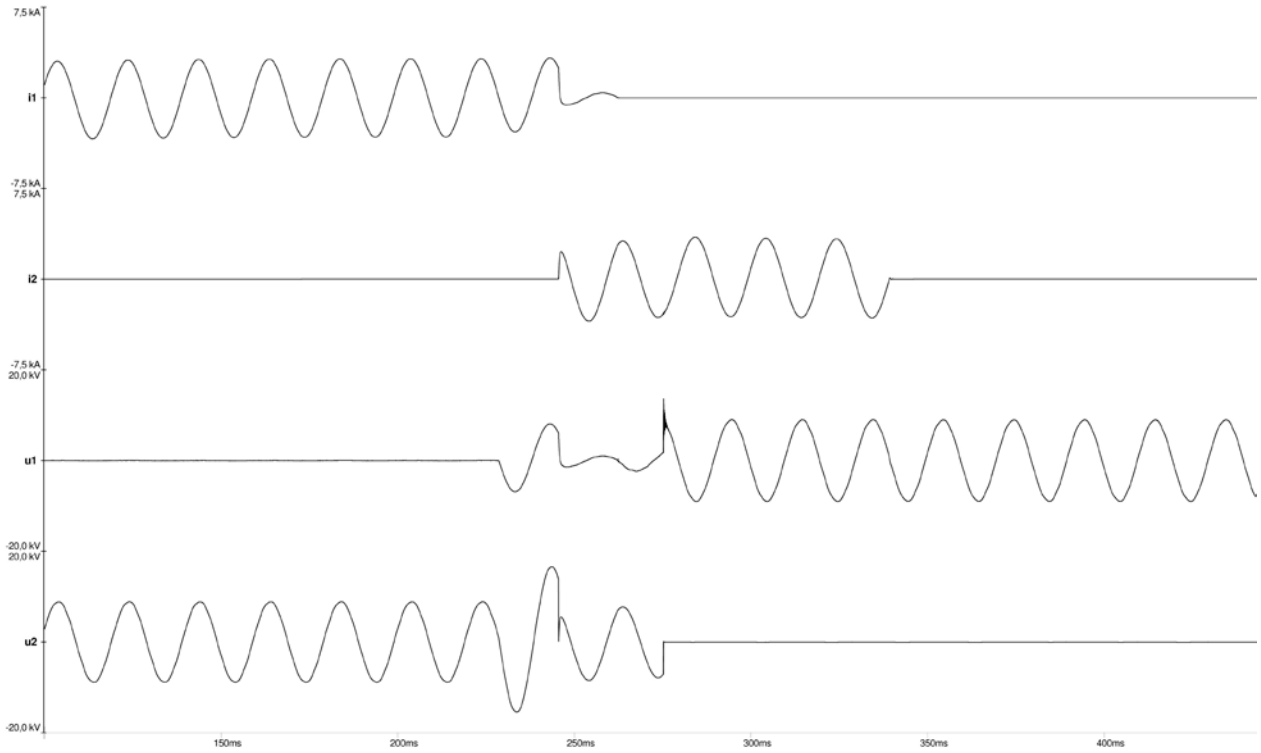

Fig. 5.33: Breaking capacity test (test sequence 3 – switching operation no. 33).

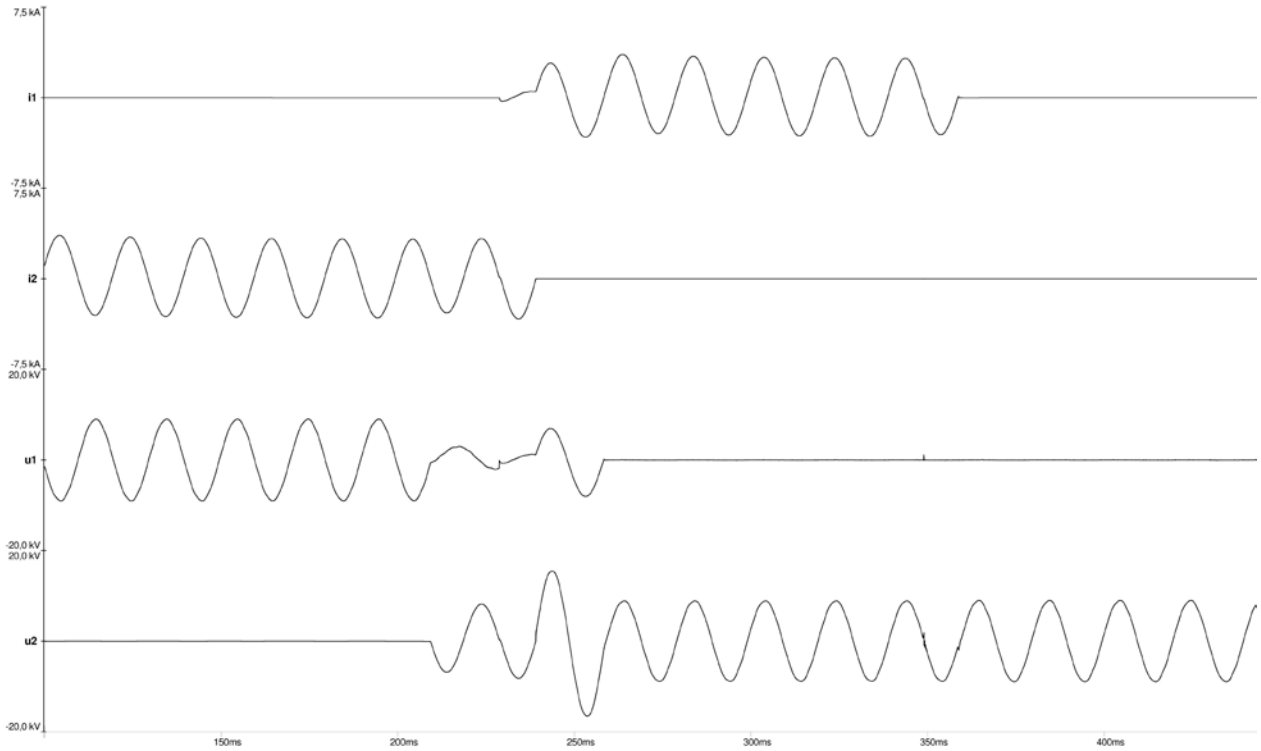

Fig. 5.34: Breaking capacity test (test sequence 3 – switching operation no. 34).

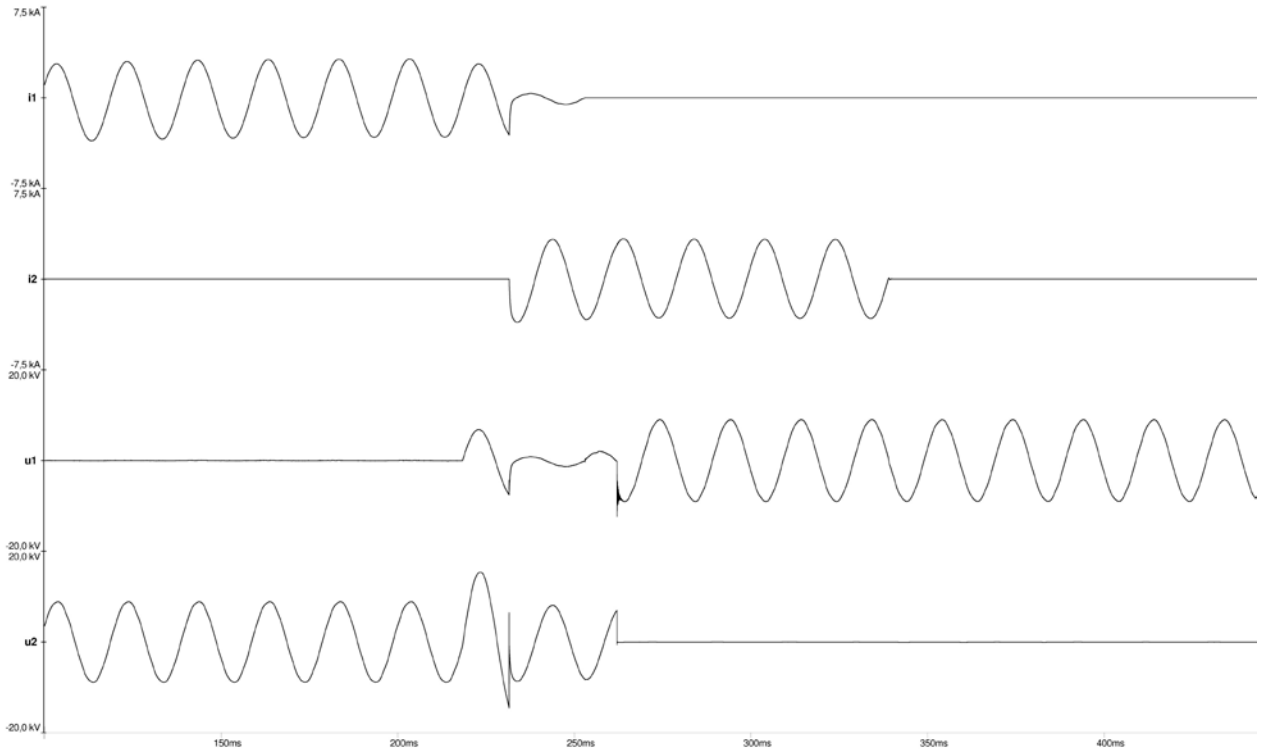

Fig. 5.35: Breaking capacity test (test sequence 3 – switching operation no. 35).

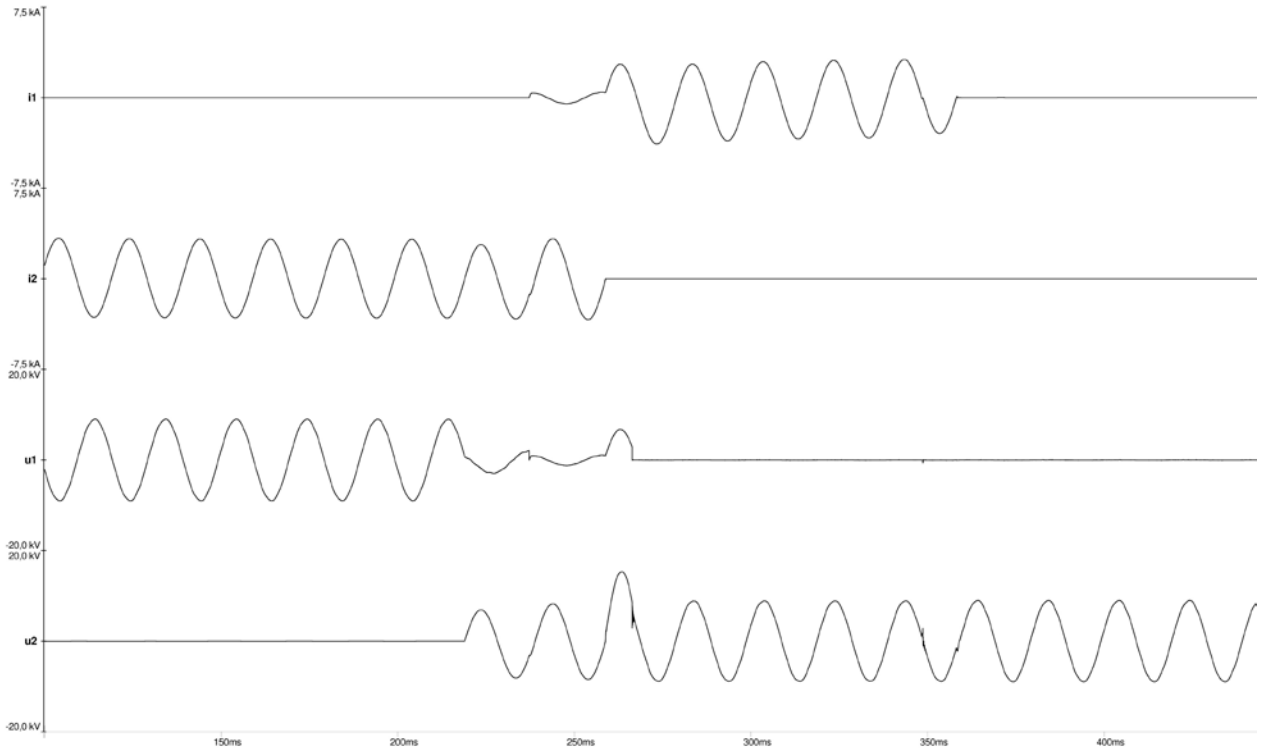

Fig. 5.36: Breaking capacity test (test sequence 3 – switching operation no. 36).

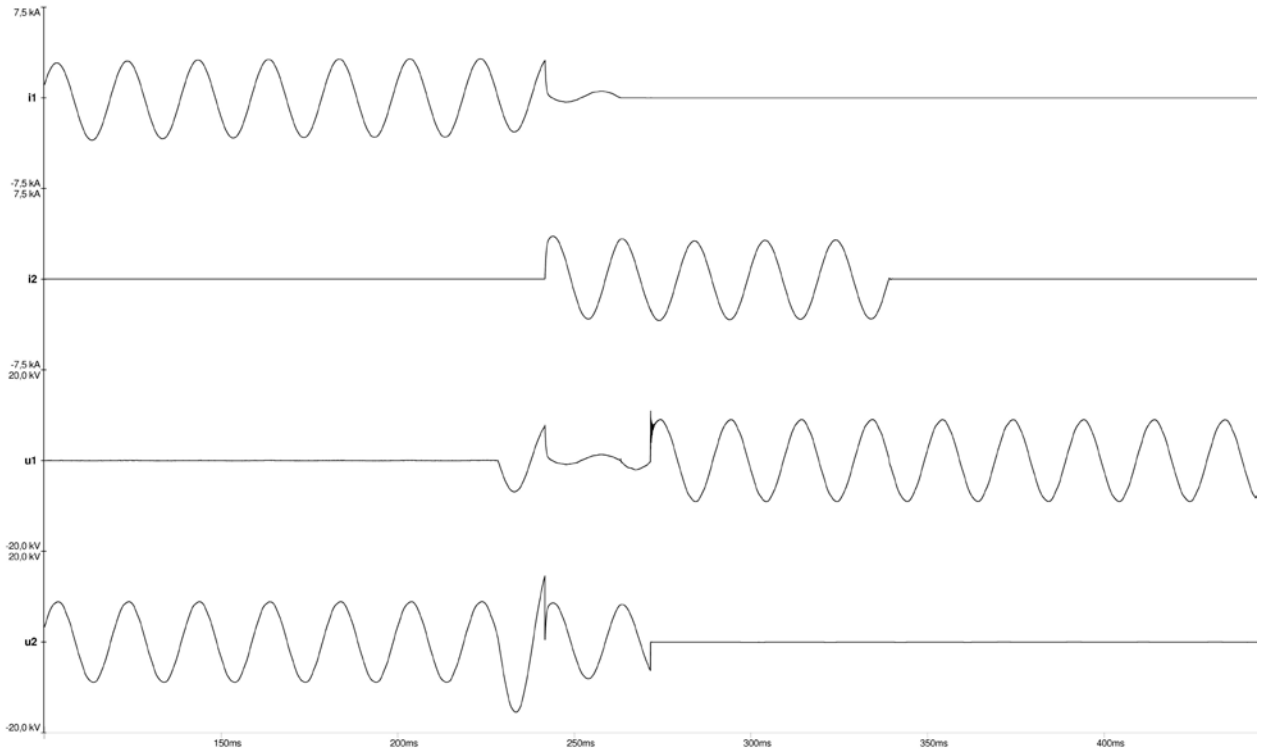

Fig. 5.37: Breaking capacity test (test sequence 3 – switching operation no. 37).

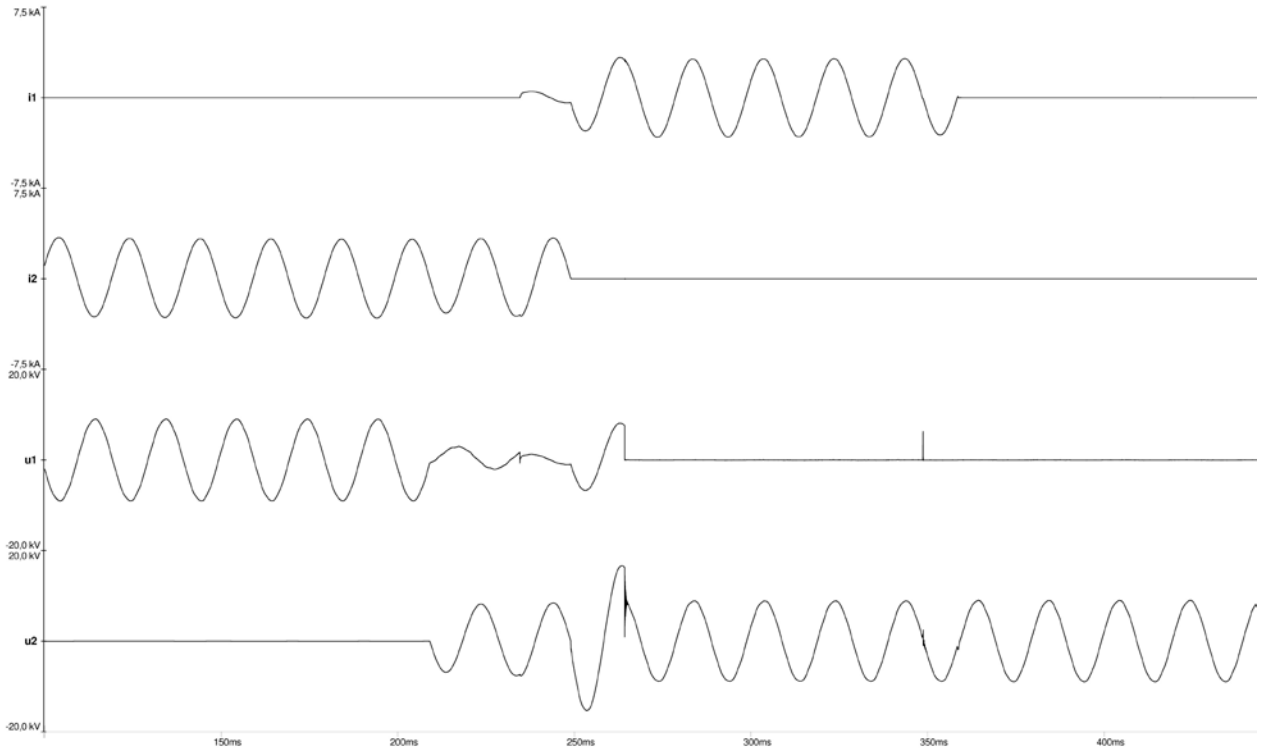

Fig. 5.38: Breaking capacity test (test sequence 3 – switching operation no. 38).

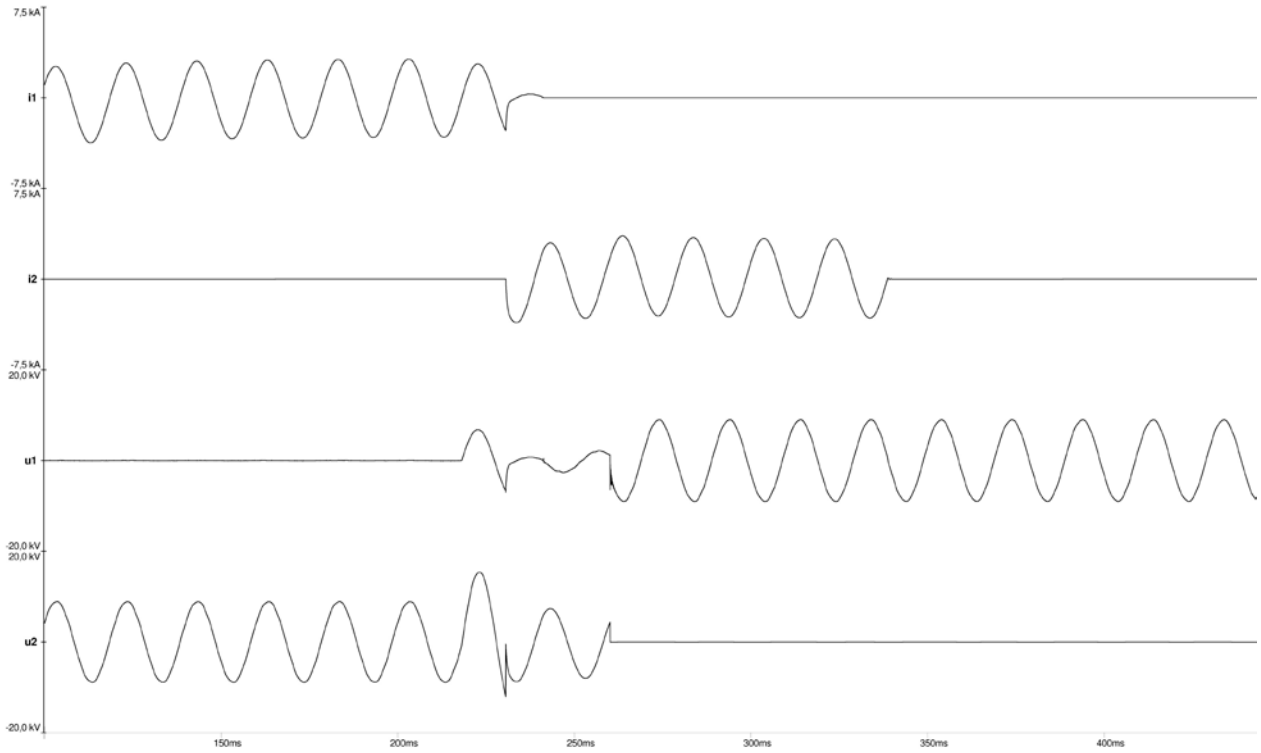

Fig. 5.39: Breaking capacity test (test sequence 3 – switching operation no. 39).

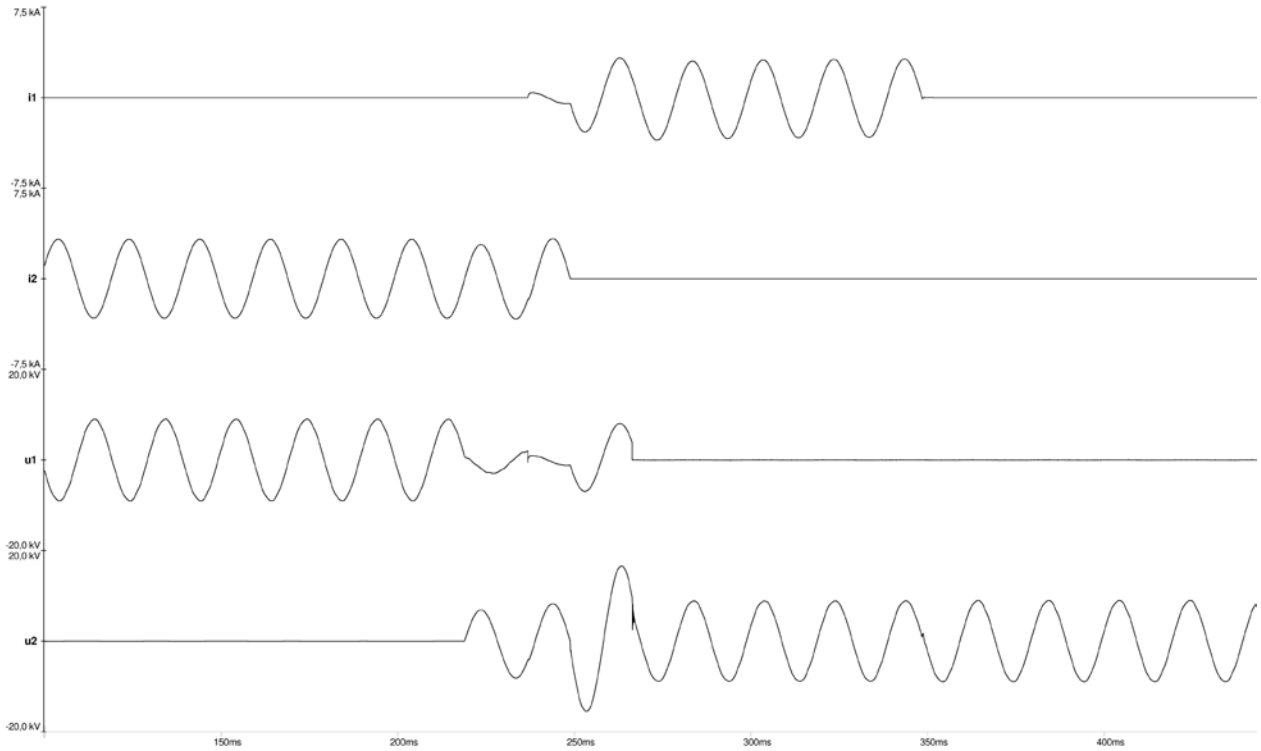

Fig. 5.40: Breaking capacity test (test sequence 3 – switching operation no. 40).

Picture 1a: Movable main switching contact (MSVa).

Picture 1b: Fixed main switching contact (MSVa).

Picture 2a: Movable main switching contact (MSVb).

Picture 2b: Fixed main switching contact (MSVb).

Picture 3a: Movable transition contact (TTVa).

Picture 3b: Fixed transition contact (TTVa).

Picture 4a: Movable transition contact (TTVb).

Picture 4b: Fixed transition contact (TTVb).

6. Test results

The requirements of IEC 60214-1:2014 “Tap-changers - Part 1: Performance requirements and test methods”, sub-clause 5.2.3: “Switching tests” were met, i.e.:

- The service duty test was passed successfully. The switched currents and voltages were not less than 95% of the required calculated values according to IEC 60214-1:2014 (see table 1). In total 360,000 operations were performed. Comparison of 100 oscillograms taken at regular intervals during the test did not show a significant alteration in the characteristics of the diverter switch in such a way as to endanger the operation of the apparatus (see figs. 3.1 … 3.100). All arcing times were less than 12 ms.
- The breaking capacity tests were passed successfully. The switched currents and voltages were not less than 95% of the required calculated values according to IEC 60214-1:2014 (see tables 2 and 3). The oscillograms taken for each operation indicated that in no case the arcing time was such as to endanger the operation of the apparatus (see tables 2 and 3 resp. figs. 4.1 … 4.40 and 5.1 … 5.40). All arcing times were less than 12 ms.
- The inspection of the diverter switch after the tests did not leave any doubts as to the suitability of the diverter switch for service. Photographs of the opened vacuum interrupter bottles, taken after 360,000 operations, showed suitability for service (see pictures 1a/b, 2a/b, 3a/b and 4a/b).