
TEST REPORT

2013 07 3D 0406

OBJECT	Combined Transformer
MANUFACTURER	Electrotécnica Artech Hermanos S.L.
MODEL	KA-123
APPLICANT	Electrotécnica Artech Hermanos S.L. C/ Derio Bidea, 28 – 48100 Munguía (Vizcaya)
TESTED BY	L.C.O.E. – High Voltage Department C/ Eric Kandel, 1 – 28906 Getafe (Madrid – Spain)
TEST DATES	From 27 th September to 28 th November 2013
DATE OF ISSUE	4 th December 2013
RESULTS	Tests successfully according to IEC 60044-1, IEC 60044-2 and IEC 60044-3 standards

This report consists of 45 pages and 5 annexes

Authorized signatory/s

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- The results of the tests refer exclusively to the sample which was tested.
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1 IDENTIFICATION OF THE TEST OBJECT

1.1 Description of the test object

Description:	Combined Transformer
Manufacturer:	Arteche
Type:	KA-123
Serial number:	13002263/3 (Test object 1) 13002263/2 (Test object 2)
According to Standard:	IEC 60044-3
Year of manufacture:	2013

1.2 Rated characteristics assigned by the manufacturer

Highest Voltage for equipment, U_m :	123 kV
Rated power-frequency withstand test voltage:	230 kV
Rated lightning impulse withstand test voltage:	550 kV
Rated chopped lightning impulse withstand test voltage:	630 kV
Rated frequency:	50 Hz
Rated ambient temperature category:	From - 25 °C to + 40 °C
Total weight:	550 kg
Oil weight:	160 kg
Installation:	Outdoor

1.2.1 Current transformer

Rated primary current, I_n :	600 – 1200 A
Rated continuous thermal current:	200 %
Short-time current, I_{th} :	40 kA 1s
Short-time dynamic current, I_{dyn} :	100 kA
Rated ratio and terminal markings:	
Primary K-L, I_{pn}	600 – 1200 A
Secondary 1k-1I, I_{sn}	1 A 10 VA Class 0.2S
Secondary 2k-2I, I_{sn}	1 A 10 VA Class 0.2S
Secondary 3k-3I, I_{sn}	1 A 10 VA Class 0.5
Secondary 4k-4I, I_{sn}	1 A 15 VA Class 5PR
Secondary 5k-5I, I_{sn}	1 A 15 VA Class 5PR
Secondary 6k-6I, I_{sn}	1 A 15 VA Class 5PR
Security factor 1k-1I, 2k-2I and 3k-3I secondary:	10
Accuracy limit factor 4k-4I, 5k-5I and 6k-6I secondary:	35

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1.2.2 Voltage transformer

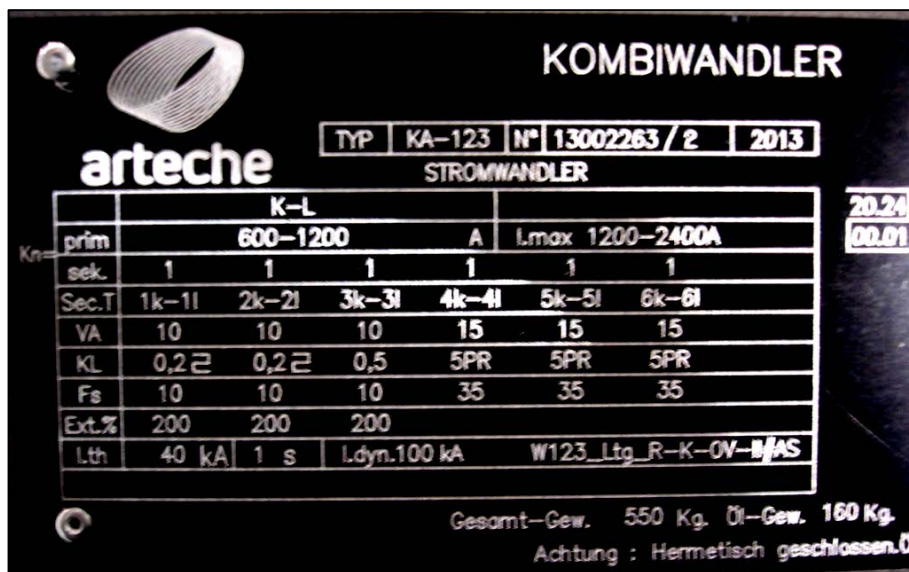
Rated primary voltage, U_{pn} : 110 000 / $\sqrt{3}$ V

Voltage factor: 1.9 U_n 8 h

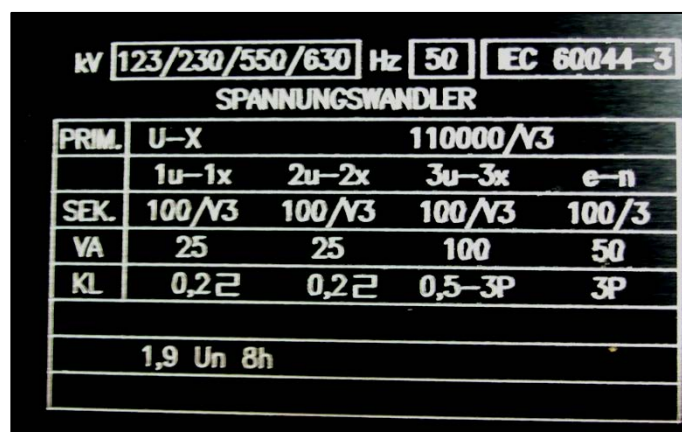
Rated ratio and terminal markings:

Primary U-X, U_{pn}	110 000 / $\sqrt{3}$ V
Secondary 1u-1x, u_{sn}	100 / $\sqrt{3}$ V 25 VA Class 0.2S
Secondary 2u-2x, u_{sn}	100 / $\sqrt{3}$ V 25 VA Class 0.2S
Secondary 3u-3x, u_{sn}	100 / $\sqrt{3}$ V 100 VA Class 0.5-3P
Secondary e-n, u_{sn}	100 / 3 V 50 VA Class 3P

1.3 Rating Plate



Picture 1.1 – Rating plate of current transformer.



Picture 1.2 – Rating plate of voltage transformer.

2 GENERAL INFORMATION

2.1 Tests carried out by

Tests have been performed in L.C.O.E. High Voltage laboratory place at Tecnogetafe, Eric Kandel street, number 1 – 28906 Getafe (Madrid), except short-circuit test of current transformer, which has been performed in HPL (Boroa).

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2.2 Measurement uncertainty

The uncertainty of the test is calculated and at the disposal of the applicant.

2.3 Standards and technical specifications applied

Tests have been performed according to the following standards:

- UNE-EN 60044-1/A1:2001 Spanish official version of IEC 60044-1 “*Instrument transformers. Part 1: Current transformers*”. International Standard Edition 1.2 2003-02.
- UNE-EN 60044-2:1999, “*Transformadores de medida. Parte 2: Transformadores de tensión inductivos*”, Spanish official version of the European Standard EN 60044-2 March 1999, which adopts the modified International Standard IEC 60044-2:1997.
- UNE-EN 60044-3:2004, “*Transformadores de medida. Parte 3: Transformadores combinados*”, Spanish official version of the European Standard EN 60044-3 January 2003, which adopts the modified International Standard IEC 60044-3:2002.
- UNE-EN 60044-6:2000 Spanish official version of IEC 60044-6 “*Instrument transformers Part 6: Requirements for protective current transformers for transient performance*” International Standard Edition 1.0 1992-03.
- UNE-EN 60060-1:2012. Spanish official version of IEC 60060-1:2010, “*High Voltage Test Techniques. Part 1: General definitions and test requirements*”. International Standard Edition 3 2010.

2.4. Additional information

In this report, voltage values corresponding to power frequency are expressed in crest divided by root of 2 and test voltage levels corresponding to lightning and switching impulses are expressed in crest value.

3 PERFORMED TESTS

3.1 Test for accuracy of combined transformer

3.1.1 Test for accuracy of current transformer

- Test date: 27th and 28th September 2013
- Procedure: IEC 60044-1 sections 11.4 and 12.4
- Test object: Serial number 13002263/3

Ratio and phase displacement errors were measured in accordance with sections 11.4 and 12.4 of the standard IEC 60044-1.

- Results of accuracy. Secondary winding 1k-1l.

Ratio	Current (% In)	Burden	Errors		
			Ratio (%)	Phase (min)	
1200 / 1 A	1	25 % (2.5 VA)	+0.055	+2.4	
	5		+0.049	+2.2	
	20		+0.048	+1.2	
	100		+0.063	+0.3	
	120		+0.069	+0.3	
	200		+0.080	+0.8	
	1	100 % (10 VA)	+0.074	+6.8	
	5		+0.047	+5.4	
	20		+0.031	+2.3	
	100		+0.054	+1.4	
	120		+0.061	+2.7	
	200		+0.079	+1.7	
	600 / 1 A	1	25 % (2.5 VA)	+0.068	+2.6
		5		+0.057	+2.4
20		+0.045		+1.5	
100		+0.060		+0.7	
120		+0.065		+0.7	
200		+0.074		+2.4	
1		100 % (10 VA)	+0.045	+6.4	
5			+0.021	+4.8	
20			+0.017	+2.6	
100			+0.042	+1.4	
120			+0.046	+1.9	
200			+0.066	+2.4	

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 0.2S).

- Results of accuracy. Secondary winding 2k-2l.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	1	25 % (2.5 VA)	+0.050	+2.3
	5		+0.048	+2.2
	20		+0.050	+1.7
	100		+0.060	+0.6
	120		+0.064	+2.0
	200		+0.079	+0.5
	1	100 % (10 VA)	+0.069	+6.4
	5		+0.048	+5.0
	20		+0.034	+2.3
	100		+0.053	+1.4
	120		+0.059	+1.2
	200		+0.076	+0.7
600 / 1 A	1	25 % (2.5 VA)	+0.049	+2.1
	5		+0.050	+2.1
	20		+0.045	+1.3
	100		+0.056	+0.5
	120		+0.058	+0.6
	200		+0.076	+1.0
	1	100 % (10 VA)	+0.046	+6.1
	5		+0.033	+4.8
	20		+0.025	+2.5
	100		+0.046	+1.4
	120		+0.050	+1.5
	200		+0.071	+4.8

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 0.2S).

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- Results of accuracy. Secondary winding 3k-3I.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	5	25 % (2.5 VA)	-0.033	+8.0
	20		+0.119	+4.0
	100		+0.182	+2.0
	120		+0.190	+1.9
	200		+0.185	+1.9
	5	100 % (10 VA)	-0.165	+20.7
	20		-0.029	+12.7
	100		+0.027	+8.0
	120		+0.038	+7.2
	200		+0.060	+5.4
600 / 1 A	5	25 % (2.5 VA)	+0.007	+11.1
	20		+0.138	+5.6
	100		+0.188	+3.3
	120		+0.193	+3.1
	200		+0.214	+2.6
	5	100 % (10 VA)	-0.181	+20.2
	20		-0.046	+12.6
	100		+0.016	+7.7
	120		+0.024	+7.1
	200		+0.057	+5.4

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 0.5).

- Results of accuracy. Secondary winding 4k-4I.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	100	100 % (15 VA)	-0.034	+53.8
600 / 1 A	100	100 % (15 VA)	-0.054	+54.1

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 5PR).

- Results of accuracy. Secondary winding 5k-5I.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	100	100 % (15 VA)	-0.116	+53.7
600 / 1 A	100	100 % (15 VA)	-0.150	+53.9

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 5PR).

- Results of accuracy. Secondary winding 6k-6l.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	100	100 % (15 VA)	-0.096	+55.1
600 / 1 A	100	100 % (15 VA)	-0.131	+55.3

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 5PR).

- Conclusion: **Test passed**

3.1.2 Test for accuracy of voltage transformer

- Test date: 29th October 2013
- Procedure: IEC 60044-2 section 12.3
- Test object: Serial number 13002263/3

Ratio and phase displacement errors of voltage transformer were measured in accordance with section 12.3 of IEC 60044-2.

- Results of accuracy. Secondary winding 1u-1x.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	120	25 VA	+0.059	-0.4
	100		+0.072	-0.5
	80		+0.074	-0.5
	120	6.25 VA	+0.089	-0.4
	100		+0.103	-0.5
	80		+0.105	-0.5

Windings 2u-2x, 3u-3x and e-n without burden.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	120	25 VA	-0.045	-3.1
	100		-0.032	-3.1
	80		-0.030	-3.2
	120	6.25 VA	-0.015	-3.1
	100		-0.001	-3.2
	80		+0.001	-3.2

Windings 2u-2x and 3u-3x loaded with rated burdens and winding e-n without burden.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 0.2).

- Results of accuracy. Secondary winding 2u-2x.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	120	25 VA	+0.060	-0.5
	100		+0.072	-0.5
	80		+0.074	-0.6
	120	6.25 VA	+0.090	-0.4
	100		+0.103	-0.5
	80		+0.105	-0.5

Windings 1u-1x, 3u-3x and e-n without burden.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	120	25 VA	-0.048	-3.4
	100		-0.037	-3.5
	80		-0.034	-3.5
	120	6.25 VA	-0.018	-3.3
	100		-0.005	-3.5
	80		-0.004	-3.4

Windings 1u-1x and 3u-3x loaded with rated burdens and winding e-n without burden.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 0.2).

- Results of accuracy. Secondary winding 3u-3x.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	190	100 VA	-0.355	+2.2
	120		-0.064	-1.3
	100		-0.051	-1.3
	80		-0.048	-1.4
	5		-0.081	-1.8
	2		-0.093	-1.9
	190	15 VA	-0.221	+2.9
	120		+0.072	-0.6
	100		+0.087	-0.7
	80		+0.089	-0.7
	5		+0.057	-1.1
	2		+0.046	-1.2

Windings 1u-1x, 2u-2x and e-n without burden.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	190	100 VA	-0.437	-0.5
	120		-0.110	-2.3
	100		-0.097	-2.3
	80		-0.093	-2.4
	5		-0.129	-2.8
	2		-0.144	-3.0
	190	15 VA	-0.300	+0.1
	120		+0.029	-1.7
	100		+0.043	-1.7
	80		+0.046	-1.8
	5		+0.011	-2.1
	2		-0.004	-2.3

Windings 1u-1x and 2u-2x loaded with rated burdens and winding e-n loaded with rated burden at 190 % of rated voltage of the transformer.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 0.5 and class 3P).

- Results of accuracy. Secondary winding e-n.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	190	50 VA	-0.876	+3.9
	100		-0.376	+0.7
	5		-0.417	+0.2
	2		-0.437	+0.1
	190	12.5 VA	-0.730	+2.8
	100		-0.228	-0.5
	5		-0.268	-0.9
	2		-0.288	-1.1

Windings 1u-1x, 2u-2x and 3u-3x without burden.

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Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/3 V	190	50 VA	-0.956	-1.4
	100		-0.457	-4.5
	5		-0.499	-5.1
	2		-0.516	-5.2
	190	12.5 VA	-0.848	-1.6
	100		-0.345	-4.7
	5		-0.386	-5.3
	2		-0.403	-5.4

Windings 1u-1x, 2u-2x and 3u-3x loaded with rated burdens.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 3P).

- Conclusion: **Test passed**

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3.2 Lightning and chopped impulse test

- Test date: 11th October 2013
- Procedure: IEC 60044-1 sections 7.3 and 9.1
IEC 60044-2 sections 8.3 and 10.1
- Test object: Serial number 13002263/2

Lightning Impulse test on combined transformer was performed according to section 7.3 of standard IEC 60044-3. The test wave polarity of the impulses was both negative and positive, and chopping time of chopped impulse was between 2 μ s and 5 μ s.

Peak value of full impulses was equal to 550 kV and test voltage of chopped impulse was 630 kV (around 115 % of 550 kV). Sequence of the impulse test:

- 1 Reduced positive impulse (less than 80 % of test voltage)
- 15 Full positive impulses (100 % of test voltage)

- 1 Reduced negative impulse (less than 80 % of test voltage)
- 1 Full negative impulse (100 % of test voltage)
- 2 Chopped negative impulses (115 % of test voltage)
- 14 Full negative impulses (100 % of test voltage)

- Lightning impulse test with positive polarity. Results:

<i>Test Parameters</i>	
Peak Value of Full Impulses	550 kV
Ambient temperature	19.5 °C
Relative Humidity	35 %
Atmospheric Pressure	944 hPa

<i>Number</i>	<i>Impulse</i>	<i>Peak Value (kV)</i>	<i>Wave shape (μs)</i>	<i>Result</i>
1	Reduced	324.4	1.49 / 52.5	OK
2	Full	548.9	1.49 / 52.7	OK
3	Full	549.0	1.50 / 52.6	OK
4	Full	549.1	1.50 / 52.5	OK
5	Full	552.9	1.48 / 52.7	OK
6	Full	552.9	1.50 / 52.6	OK
7	Full	552.9	1.49 / 52.6	OK
8	Full	548.7	1.50 / 52.6	OK
9	Full	552.7	1.49 / 52.7	OK
10	Full	572.3	1.49 / 52.6	OK
11	Full	548.9	1.50 / 52.5	OK
12	Full	552.6	1.50 / 52.7	OK
13	Full	548.9	1.49 / 52.7	OK
14	Full	552.8	1.49 / 52.6	OK
15	Full	548.9	1.50 / 52.7	OK
16	Full	552.9	1.49 / 52.6	OK

No flashover or insulation damage was detected during the test.

- Lightning impulse test with negative polarity. Results:

<i>Test Parameters</i>	
Peak Value of Full Impulses	550 kV
Peak Value of Chopped Impulses	630 kV
Ambient temperature	19.5 °C
Relative Humidity	35 %
Atmospheric Pressure	944 hPa

<i>Number</i>	<i>Impulse</i>	<i>Peak Value (kV)</i>	<i>Wave shape (μs)</i>	<i>Result</i>
1	Reduced	335	1.50 / 52.8	OK
2	Full	548	1.49 / 53.0	OK
3	Chopped	627	1.50 / 3.76 (*)	OK
4	Chopped	623	1.49 / 3.32 (*)	OK
5	Full	544	1.50 / 53.4	OK
6	Full	547	1.50 / 53.2	OK
7	Full	543	1.49 / 53.2	OK
8	Full	548	1.50 / 53.0	OK
9	Full	548	1.49 / 53.1	OK
10	Full	548	1.50 / 53.2	OK
11	Full	543	1.49 / 53.2	OK
12	Full	543	1.49 / 53.1	OK
13	Full	543	1.49 / 53.3	OK
14	Full	548	1.49 / 53.1	OK
15	Full	544	1.49 / 53.2	OK
16	Full	548	1.49 / 53.1	OK
17	Full	548	1.50 / 53.2	OK
18	Full	548	1.50 / 53.0	OK

No flashover or insulation damage was detected during the test.

- Conclusion: **Test passed**

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3.3 Wet test for outdoor type transformers

- Test date: 14th October 2013
- Procedure: IEC 60044-1 section 7.4
IEC 60044-2 section 8.4
- Test object: Serial number 13002263/2

Wet test for outdoor type transformers was performed in accordance with section 7.4 of IEC 60044-1 standard and section 8.4 of IEC 60044-2.

Test voltage of 230 kV (Peak/ $\sqrt{2}$), 120 Hz and corrected by local atmospheric conditions was applied for 50 seconds on combined transformer between primary winding (U-X) and ground under wet conditions according to standard IEC 60060-1.

- Test Parameters:

<i>Test Parameters</i>	
Test voltage (normal conditions)	230 kV
Test voltage (local conditions)	224.9 kV
Test frequency	120 Hz
Test duration	50 s
<i>Rain Parameters</i>	
Horizontal flow rate	1.4 mm / min
Vertical flow rate	1.4 mm / min
Water conductivity	101 μ S / cm
Water temperature	15 °C
<i>Ambient Conditions</i>	
Ambient temperature	19 °C
Relative Humidity	46 %
Atmospheric Pressure	951 hPa

- Results:
No flashover or insulation damage was detected during the test.
- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.4 Radio interference voltage test

- Test date: 10th October 2013
- Procedure: IEC 60044-1 section 7.5
IEC 60044-2 section 8.5
- Test object: Serial number 13002263/2

Radio interference voltage was measurement on combined transformer in accordance with section 7.5 of IEC 60044-1 standard and section 8.5 of IEC 60044-2 standard.

Test voltage of 106 kV ($1.5 U_m/\sqrt{3}$), 50 Hz was applied for 30 seconds on combined transformer between primary U terminal and ground terminal. Then test voltage of 78.1 kV ($1.1 U_m/\sqrt{3}$) was applied for 30 seconds and RIV was measured for each level.

- Results of test:

<i>Test Parameters</i>	
Test voltage Level 1	106.0 kV
Test voltage Level 2	78.1 kV
Test frequency	50 Hz
Test duration	30 s (each level)
Ambient temperature	23.5 °C
Relative Humidity	39 %
Atmospheric Pressure	945 hPa

<i>Test Voltage (kV)</i>	<i>RIV (µV)</i>	<i>RIV Limits (µV)</i>	<i>Result</i>
106.0 kV	638 µV	-	OK
78.1 kV	631 µV	2500 (IEC)	OK

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.5 Induced voltage withstand test on primary winding

- Test date: 15th October 2013
- Procedure: IEC 60044-1 section 8.2.1
IEC 60044-2 section 9.2
- Test object: Serial number 13002263/2

Power frequency withstand test on primary winding was performed on combined transformer in accordance with section 8.2.1 of IEC 60044-1 standard and section 9.2 of IEC 60044-2 standard.

- Induced voltage withstand test.

Test voltage of 230 kV, 120 Hz was applied for 50 seconds between primary winding terminals of voltage transformer. Frame, case, primary winding terminal X of voltage transformer and one terminal of each secondary winding were connected to earth.

<i>Test Parameters</i>	
Test voltage	230 kV
Test frequency	120 Hz
Test duration	50 s
<i>Ambient Conditions</i>	
Ambient temperature	19.5 °C
Relative Humidity	56 %
Atmospheric Pressure	950 hPa

No flashover or insulation damage was detected during the test.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.6 Partial discharges measurement

- Test date: 15th October 2013
- Procedure: IEC 60044-1 section 8.2.2
IEC 60044-2 section 9.2.4
- Test object: Serial number 13002263/2

Partial discharges measurement was performed on combined transformer in accordance with section 8.2.2 of IEC 60044-1 and section 9.2.4 of IEC 60044-2 standard.

Test voltage of 230 kV, 120 Hz was applied for 50 s between primary winding U terminal of voltage transformer and ground. Frame, case, primary winding terminal X of voltage transformer and one terminal of each secondary winding were connected to earth.

Partial discharges were measured at voltage level of 147.6 kV ($1.2 U_m$) and at voltage level of 85.2 kV ($1.2 U_m/\sqrt{3}$).

- Test Parameters:

<i>Excitation Voltage</i>		230 kV
<i>Test Frequency</i>		120 Hz
<i>Test Duration</i>		50 s
<i>Level 1</i>	<i>Test Voltage</i>	147.6 kV
	<i>Partial Discharges Level</i>	< 4 pC
	<i>Partial Discharges Limit</i>	10 pC
<i>Level 2</i>	<i>Test Voltage</i>	85.2 kV
	<i>Partial Discharges Level</i>	< 4 pC
	<i>Partial Discharges Limit</i>	5 pC

- Results:

Partial discharges levels were lower than limits specified by IEC 60044-1 and IEC 60044-2 standards.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.7 Separate source withstand voltage test on primary winding

- Test date: 6th November 2013
- Procedure: IEC 60044-1 section 8.2.1
IEC 60044-2 section 9.2
- Test object: Serial number 13002263/2

Power frequency withstand test on terminal X of voltage transformer was performed on combined transformer in accordance with section 8.2.1 of IEC 60044-1 standard and section 9.2 of IEC 60044-2.

Test voltage of 3 kV, 50 Hz was applied for 60 s between primary winding terminal X of voltage transformer and earth. Frame, case and one terminal of each secondary winding were connected to earth.

<i>Separate source withstand voltage test. Terminal X.</i>	
Test Voltage	3 kV
Test Frequency	50 Hz
Test duration	60 s
<i>Ambient Conditions</i>	
Ambient Temperature	19 °C
Relative Humidity	44 %
Atmospheric Pressure	945 hPa

No flashover or insulation damage was detected during the test.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.8 Power frequency withstand test on secondary windings

- Test date: 6th November 2013
- Procedure: IEC 60044-1 section 8.3
IEC 60044-2 section 9.3
- Test object: Serial number 13002263/2

Power frequency withstand test on secondary windings was performed on combined transformer according to section 8.3 of IEC 60044-1 standard and section 9.3 of IEC 60044-2 standard.

Test voltage of 3 kV, 50 Hz was applied for 60 seconds between short-circuited terminals of each secondary winding and earth with frame, case and other windings of the transformer connected to ground.

- Test Parameters:

<i>Power frequency withstand test. Secondary windings of current transformer and secondary windings of voltage transformer.</i>	
Test voltage	3 kV
Test frequency	50 Hz
Test duration	60 s
<i>Ambient Conditions</i>	
Ambient temperature	19 °C
Relative Humidity	44 %
Atmospheric Pressure	945 hPa

- Results:

No flashover or insulation damage was detected during the test.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.9 Inter-turn overvoltage test

- Test date: 14th November 2013
- Procedure: IEC 60044-1 section 8.4
- Test object: Serial number 13002263/3

Inter-turn overvoltage test was performed on current transformer in accordance with section 8.4 of IEC 60044-1 standard.

With each secondary winding open-circuited, a primary current equal to rated extended primary current was applied for 60 seconds or a limited current if peak voltage of secondary winding equal to 4.5 kV was obtained during the test.

- Test Parameters:

<i>Inter-turn overvoltage test</i>		
Test frequency		50 Hz
Test duration		60 s
Secondary 1k-1I	Test Current	738 A
	Maximum peak voltage	4.59 kV _{PEAK}
Secondary 2k-2I	Test Current	715 A
	Maximum peak voltage	4.57 kV _{PEAK}
Secondary 3k-3I	Test Current	2400 A
	Maximum peak voltage	3.49 kV _{PEAK}
Secondary 4k-4I	Test Current	2400 A
	Maximum peak voltage	3.47 kV _{PEAK}
Secondary 5k-5I	Test Current	2400 A
	Maximum peak voltage	3.54 kV _{PEAK}
Secondary 6k-6I	Test Current	2400 A
	Maximum peak voltage	3.46 kV _{PEAK}
<i>Ambient Conditions</i>		
Ambient temperature		19.5 °C
Relative Humidity		36.8 %
Atmospheric Pressure		956.7 hPa

- Results:
No flashover or insulation damage was detected during the test.
- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.10 Short-time current test

- Test date: 22th October 2013
- Procedure: IEC 60044-1 section 7.1
- Test object: Serial number 13002263/3

Short-time current test was performed on current transformer in accordance with section 7.1 of IEC 60044-1 standard.

For the purpose of this test, secondary winding of the transformer was circuit-opened and a primary current equal to 43.4 kA (rms) was applied during 923 ms (thermal test). The peak value of the first crest of applied current was equal to 104.2 kA (dynamic test).

- Results of test:

<i>Test Parameters</i>	
Short-time current I_{th}	43.4 kA
Short-time dynamic current I_{dyn}	104.2 kA
Test duration	923 ms
Thermal equivalent	40 kA / 1.08 s
<i>Ambient Conditions</i>	
Ambient temperature	21.0 °C

- Requirements after short-circuit test:

3.10.1 Visual inspection of test object.

- Test date: 22th October 2013
- Results of test:

After short-circuit test current transformer is not visibly damaged and the insulation next to the surface of both the primary and the secondary windings does not show significant deterioration.

- Conclusion: **Test passed**

3.10.2 Test for accuracy of current transformer after short-circuit test

See section 3.11.2 of this test report.

3.10.3 Power frequency withstand test on primary winding after short-circuit test.

See section 3.11.3 of this test report.

3.10.4 Partial discharges measurement after short-circuit test

See section 3.11.4 of this test report.

3.10.5 Power frequency withstand test on secondary windings after short-circuit test

See section 3.11.5 of this test report.

3.10.6 Inter-turn overvoltage test after short-circuit test

See section 3.9 of this test report.

3.11 Short-circuit withstand capability test of voltage transformer

- Test date: 29th October 2013
- Procedure: IEC 60044-2 section 8.2
- Test object: Serial number 13002263/3

Short-circuit withstand capability test was performed according to section 8.2 of IEC 60044-2 standard.

The voltage transformer was energized from the primary winding with each secondary winding short-circuited. Rated voltage was applied to voltage transformer for 1 s.

- Short-circuit test results. Secondary winding 1u-1x.

<i>Short-circuit test. Winding 1u-1x</i>	
Test voltage	65.0 kV
Test frequency	50 Hz
Test duration	992 ms
Secondary winding current	1036 A
Ambient temperature	21 °C

- Short-circuit test results. Secondary winding 2u-2x.

<i>Short-circuit test. Winding 2u-2x</i>	
Test voltage	67.8 kV
Test frequency	50 Hz
Test duration	1.01 s
Secondary winding current	1049 A
Ambient temperature	21 °C

- Short-circuit test results. Secondary winding 3u-3x.

<i>Short-circuit test. Winding 3u-3x</i>	
Test voltage	69.2 kV
Test frequency	50 Hz
Test duration	997 ms
Secondary winding current	1047 A
Ambient temperature	21 °C

- Short-circuit test results. Secondary winding e-n.

<i>Short-circuit test. Winding e-n</i>	
Test voltage	64.2 kV
Test frequency	50 Hz
Test duration	997 ms
Secondary winding current	1014 A
Ambient temperature	21 °C

- Requirements after short-circuit test:

3.11.1 Visual inspection of test object

- Test date: 29th October 2013
- Results of test:

After short-circuit test, the voltage transformer is not visibly damage and the insulation next to the conductor surface does not show significant deterioration (carbonization).

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.11.2 Test for accuracy after short-circuit tests

3.11.2.1 Test for accuracy of current transformer after short-circuit test

- Test date: 7th November 2013
- Procedure: IEC 60044-1 sections 11.4 and 12.4
- Test object: Serial number 13002263/3

Ratio and phase displacement errors were measured in accordance with sections 11.4 and 12.4 of the standard IEC 60044-1.

- Results of accuracy. Secondary winding 1k-1l.

Ratio	Current (% I _n)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	1	25 % (2.5 VA)	+0.367	-15.9
	5		+0.120	-1.6
	20		+0.070	-0.0
	100		+0.069	-0.1
	120		+0.070	-0.1
	200		+0.072	-0.1
	1	100 % (10 VA)	+0.231	-3.5
	5		+0.107	+1.0
	20		+0.052	+0.9
	100		+0.058	+0.3
	120		+0.059	+0.2
	200		+0.063	+0.2
600 / 1 A	1	25 % (2.5 VA)	+0.360	-18.1
	5		+0.118	-1.8
	20		+0.071	-0.0
	100		+0.071	-0.1
	120		+0.072	-0.1
	200		+0.074	-0.1
	1	100 % (10 VA)	+0.377	-13.0
	5		+0.107	+0.8
	20		+0.050	+0.7
	100		+0.059	+0.2
	120		+0.061	+0.2
	200		+0.064	+0.2

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 0.2S).

- Results of accuracy. Secondary winding 2k-2l.

Ratio	Current (% In)	Burden	Errors		
			Ratio (%)	Phase (min)	
1200 / 1 A	1	25 % (2.5 VA)	+0.396	-19.0	
	5		+0.121	-1.9	
	20		+0.073	-0.1	
	100		+0.071	-0.0	
	120		+0.071	-0.0	
	200		+0.073	-0.1	
	1	100 % (10 VA)	+0.368	-12.2	
	5		+0.112	+0.7	
	20		+0.056	+0.9	
	100		+0.060	+0.3	
	120		+0.061	+0.2	
	200		+0.064	+0.3	
	600 / 1 A	1	25 % (2.5 VA)	+0.354	-16.5
		5		+0.123	-2.1
20		+0.073		-0.0	
100		+0.071		-0.1	
120		+0.072		-0.1	
200		+0.074		-0.1	
1		100 % (10 VA)	+0.363	-13.0	
5			+0.116	+0.4	
20			+0.054	+0.7	
100			+0.061	+0.2	
120			+0.062	+0.2	
200			+0.065	+0.2	

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 0.2S).

NO TEXT BELOW THE LINE

- Results of accuracy. Secondary winding 3k-3I.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	5	25 % (2.5 VA)	-0.100	+9.4
	20		+0.007	+7.0
	100		+0.071	+4.4
	120		+0.078	+4.1
	200		+0.093	+3.2
	5	100 % (10 VA)	-0.159	+18.5
	20		-0.077	+13.6
	100		-0.024	+8.5
	120		-0.016	+7.8
	200		+0.007	+6.0
600 / 1 A	5	25 % (2.5 VA)	+0.017	+4.9
	20		+0.112	+3.4
	100		+0.163	+2.2
	120		+0.168	+2.1
	200		+0.179	+1.6
	5	100 % (10 VA)	-0.165	+18.9
	20		-0.076	+13.6
	100		-0.024	+8.6
	120		-0.016	+7.9
	200		+0.006	+6.1

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 0.5).

- Results of accuracy. Secondary winding 4k-4I.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	100	100 % (15 VA)	-0.034	+56.0
600 / 1 A	100	100 % (15 VA)	-0.037	+56.2

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 5PR).

- Results of accuracy. Secondary winding 5k-5I.

Ratio	Current (% In)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	100	100 % (15 VA)	-0.117	+55.6
600 / 1 A	100	100 % (15 VA)	-0.120	+55.8

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 5PR).

- Results of accuracy. Secondary winding 6k-6l.

Ratio	Current (% I _n)	Burden	Errors	
			Ratio (%)	Phase (min)
1200 / 1 A	100	100 % (15 VA)	-0.089	+57.0
600 / 1 A	100	100 % (15 VA)	-0.088	+57.2

Current and phase displacement errors are between the limits specified for the accuracy class of the current transformer (class 5PR).

- Conclusion: **Test passed**

3.11.2.2 Test for accuracy of voltage transformer after short-circuit test

- Test date: 5th November 2013
- Procedure: IEC 60044-2 section 12.3
- Test object: Serial number 13002263/3

Ratio and phase displacement errors of voltage transformer were measured in accordance with section 12.3 of IEC 60044-2.

- Results of accuracy. Secondary winding 1u-1x.

Ratio	Voltage (% U _n)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/√3 / 100/√3 V	120	25 VA	+0.062	-0.4
	100		+0.074	-0.4
	80		+0.076	-0.5
	120	6.25 VA	+0.091	-0.3
	100		+0.105	-0.5
	80		+0.106	-0.4

Windings 2u-2x, 3u-3x and e-n without burden.

Ratio	Voltage (% U _n)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/√3 / 100/√3 V	120	25 VA	-0.043	-3.0
	100		-0.030	-3.1
	80		-0.028	-3.1
	120	6.25 VA	-0.013	-3.0
	100		-0.001	-3.0
	80		+0.002	-3.1

Windings 2u-2x and 3u-3x loaded with rated burdens and winding e-n without burden.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 0.2).

- Results of accuracy. Secondary winding 2u-2x.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	120	25 VA	+0.062	-0.4
	100		+0.074	-0.5
	80		+0.077	-0.6
	120	6.25 VA	+0.092	-0.3
	100		+0.105	-0.5
	80		+0.106	-0.5

Windings 1u-1x, 3u-3x and e-n without burden.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	120	25 VA	-0.047	-3.3
	100		-0.036	-3.3
	80		-0.033	-3.4
	120	6.25 VA	-0.017	-3.2
	100		-0.005	-3.3
	80		-0.003	-3.3

Windings 1u-1x and 3u-3x loaded with rated burdens and winding e-n without burden.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 0.2).

- Results of accuracy. Secondary winding 3u-3x.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	190	100 VA	-0.351	+2.2
	120		-0.064	-1.2
	100		-0.050	-1.4
	80		-0.047	-1.3
	5		-0.081	-1.8
	2		-0.097	-2.0
	190	15 VA	-0.218	+2.9
	120		+0.073	-0.5
	100		+0.087	-0.6
	80		+0.090	-0.6
	5		+0.056	-1.1
	2		+0.044	-1.2

Windings 1u-1x, 2u-2x and e-n without burden.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	190	100 VA	-0.427	-0.6
	120		-0.106	-2.4
	100		-0.092	-2.4
	80		-0.089	-2.4
	5		-0.126	-2.8
	2		-0.143	-3.1
	190	15 VA	-0.311	+0.1
	120		+0.031	-1.6
	100		+0.045	-1.8
	80		+0.047	-1.7
	5		+0.012	-2.1
	2		-0.004	-2.3

Windings 1u-1x and 2u-2x loaded with rated burdens and winding e-n loaded with rated burden at 190 % of rated voltage of the transformer.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 0.5 and class 3P).

- Results of accuracy. Secondary winding e-n.

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/ $\sqrt{3}$ / 100/ $\sqrt{3}$ V	190	50 VA	-0.868	+2.5
	100		-0.326	-0.8
	5		-0.367	-1.3
	2		-0.386	-1.6
	190	12.5 VA	-0.760	+2.4
	100		-0.216	-0.9
	5		-0.256	-1.4
	2		-0.276	-1.6

Windings 1u-1x, 2u-2x and 3u-3x without burden.

NO TEXT BELOW THE LINE

Ratio	Voltage (% Un)	Burden	Errors	
			Ratio (%)	Phase (min)
110 000/√3 / 100/3 V	190	50 VA	-1.047	-0.2
	100		-0.510	-3.3
	5		-0.553	-3.9
	2		-0.574	-4.2
	190	12.5 VA	-0.898	-1.3
	100		-0.358	-4.5
	5		-0.398	-5.1
	2		-0.416	-5.4

Windings 1u-1x, 2u-2x and 3u-3x loaded with rated burdens.

Voltage and phase displacement errors are between the limits specified for the accuracy class of the voltage transformer (class 3P).

3.11.3 Power frequency withstand test on primary winding after short-circuit tests

- Test date: 5th November 2013
- Procedure: IEC 60044-1 section 8.2.1
IEC 60044-2 section 9.2
- Test object: Serial number 13002263/3

Power frequency withstand test on primary winding was performed on combined transformer after short-circuit tests in accordance with section 8.2.1 of IEC 60044-1 standard and section 9.2 of IEC 60044-2 standard.

- Induced voltage withstand test.

Test voltage of 207 kV (90% of rated power frequency withstand test voltage), 120 Hz was applied for 50 seconds between primary winding terminals of voltage transformer. Frame, case, primary winding terminal X and one terminal of each secondary winding were connected to earth.

<i>Test Parameters</i>	
Test voltage	207 kV
Test frequency	120 Hz
Test duration	50 s
<i>Ambient Conditions</i>	
Ambient temperature	17.5 °C
Relative Humidity	63 %
Atmospheric Pressure	949 hPa

No flashover or insulation damage was detected during the test.

- Conclusion: **Test passed**

3.11.4 Partial discharges measurement after short-circuit tests

- Test date: 5th November 2013
- Procedure: IEC 60044-1 section 8.2.2
IEC 60044-2 section 9.2.4
- Test object: Serial number 13002263/3

Partial discharges measurement was performed on combined transformer after short-circuit tests in accordance with section 8.2.2 of IEC 60044-1 and section 9.2.4 of IEC 60044-2 standard.

Test voltage of 207 kV (90% of rated power frequency withstand test voltage), 120 Hz was applied for 50 s between primary winding U terminal of voltage transformer and ground. Frame, case, primary winding terminal X of voltage transformer and one terminal of each secondary winding were connected to earth.

Partial discharges were measured at voltage level of 147.6 kV ($1.2 U_m$) and at voltage level of 85.2 kV ($1.2 U_m/\sqrt{3}$).

- Test Parameters:

<i>Excitation Voltage</i>		207 kV
<i>Test Frequency</i>		120 Hz
<i>Test Duration</i>		50 s
<i>Level 1</i>	<i>Test Voltage</i>	147.6 kV
	<i>Partial Discharges Level</i>	5 – 6 pC
	<i>Partial Discharges Limit</i>	10 pC
<i>Level 2</i>	<i>Test Voltage</i>	85.2 kV
	<i>Partial Discharges Level</i>	< 3 pC
	<i>Partial Discharges Limit</i>	5 pC

- Results:

Partial discharges levels were lower than limits specified by IEC 60044-1 and IEC 60044-2 standards.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.11.5 Power frequency withstand test on secondary windings after short-circuit tests

- Test date: 6th November 2013
- Procedure: IEC 60044-1 section 8.3
IEC 60044-2 section 9.3
- Test object: Serial number 13002263/3

Power frequency withstand test on secondary windings was performed on combined transformer after short-circuit tests according to section 8.3 of IEC 60044-1 standard and section 9.3 of IEC 60044-2 standard.

Test voltage of 2.7 kV, 50 Hz was applied for 60 seconds between short-circuited terminals of each secondary winding and earth with frame, case and other windings of the transformer connected to ground.

- Test Parameters:

<i>Power frequency withstand test. Secondary windings of current transformer and secondary windings of voltage transformer.</i>	
Test voltage	2.7 kV
Test frequency	50 Hz
Test duration	60 s
<i>Ambient Conditions</i>	
Ambient temperature	19 °C
Relative Humidity	44 %
Atmospheric Pressure	945 hPa

- Results:
No flashover or insulation damage was detected during the test.
- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.11.6 Separate source withstand voltage test on primary winding after short-circuit tests

- Test date: 6th November 2013
- Procedure: IEC 60044-1 section 8.2.1
IEC 60044-2 section 9.2
- Test object: Serial number 13002263/3

Power frequency withstand test on terminal X of voltage transformer was performed on combined transformer after short-circuit tests in accordance with section 8.2.1 of IEC 60044-1 standard and section 9.2 of IEC 60044-2.

Test voltage of 2.7 kV, 50 Hz was applied for 60 s between primary winding terminal X of voltage transformer and earth. Frame, case and one terminal of each secondary winding were connected to earth.

<i>Separate source withstand voltage test. Terminal X.</i>	
Test Voltage	2.7 kV
Test Frequency	50 Hz
Test duration	60 s
<i>Ambient Conditions</i>	
Ambient Temperature	19 °C
Relative Humidity	44 %
Atmospheric Pressure	945 hPa

No flashover or insulation damage was detected during the test.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.12 Instrument security factor of measuring current transformer

- Test date: 19th November 2013
- Procedure: IEC 60044-1 section 11.6
- Test object: Serial number 13002263/3

Security factor of measuring current transformer was measured in accordance with section 11.6 of IEC 60044-1 standard.

- Results:

<i>Security factor of secondary winding 1k-1l</i>	
Security factor measured	5.2
Instrument security factor	10
Ambient Temperature	18.3 °C
<i>Security factor of secondary winding 2k-2l</i>	
Security factor measured	5.1
Instrument security factor	10
Ambient Temperature	18.3 °C
<i>Security factor of secondary winding 3k-3l</i>	
Security factor measured	6.6
Instrument security factor	10
Ambient Temperature	18.3 °C

Security factor of secondary winding measured is lower than rated instrument security factor assigned by the manufacturer.

- Conclusion: **Test passed**

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3.13 Test for composite error of protective current transformer

- Test date: 14^h November 2013
- Procedure: IEC 60044-1 section 12.5
- Test object: Serial number 13002263/3

Composite error of protective current transformer was measured in accordance with section 12.5 of IEC 60044-1 standard.

Test voltage equal to secondary limiting e.m.f. was applied to secondary winding with primary circuit open and the excitation current was measured.

- Results:

<i>Composite error of secondary winding 4k-4l</i>	
Composite error measured	1.51 %
Instrument composite error	5.0 %
Accuracy Limit Factor	35
Ambient Temperature (°C)	18.3 °C
<i>Composite error of secondary winding 5k-5l</i>	
Composite error measured	1.51 %
Instrument composite error	5.0 %
Accuracy Limit Factor	35
Ambient Temperature (°C)	18.3 °C
<i>Composite error of secondary winding 6k-6l</i>	
Composite error measured	1.53 %
Instrument composite error	5.0 %
Accuracy Limit Factor	35
Ambient Temperature (°C)	18.3 °C

Composite errors measured are lower than rated composite errors assigned by the manufacturer.

- Conclusion: **Test passed**

NO TEXT BELOW THE LINE

3.14 Measurement of core magnetization characteristic

- Test date: 14th and 18^h November 2013
- Procedure: IEC 60044-6 annex B
- Test object: Serial number 13002263/3

Core magnetization characteristic of the current transformer was obtained in accordance with Annex B of IEC 60044-6.

With the primary winding open, a test voltage of 50 Hz was applied to each secondary winding and peak value of the current was measured up to the saturation point of the core.

Magnetizing Inductance L_m and Secondary loop constant T_s of protective current transformer class PR Core have been calculated according to Annex B of IEC 60044-6 standard. Determination of remanence factor K_R of secondary windings was performed by using DC method.

- Core magnetization characteristic. Results of secondary winding 4k-4l.

I_{RMS} (mA)	I_{PEAK} (mA)	U_{RMS} (V)	Flux (Wb)
85.6	128.7	109.2	0.492
157.2	227.9	204.1	0.919
231.4	335.5	301.5	1.357
307.9	443.8	401.5	1.807
388.3	558.9	504.3	2.270
469.9	674.6	603.8	2.718
566.7	831.1	707.2	3.184
663.6	996.2	782.3	3.522
761.0	1168.0	836.6	3.766
887.3	1371.0	892.9	4.020
968.1	1523.0	922.7	4.154
1024.9	1619.0	945.1	4.254
1141.9	1784.0	983.8	4.429
1245.9	1943.0	1020.0	4.592
1511.6	2336.0	1103.5	4.967
1675.3	2559.0	1153.4	5.192
1823.3	2782.0	1200.2	5.403
1996.5	3026.0	1251.7	5.635

NO TEXT BELOW THE LINE

Resistance Measurement. Winding 4k-4l	
Winding Resistance	Temperature
3.87 Ω	18.3 $^{\circ}\text{C}$
4.74 Ω	75 $^{\circ}\text{C}$
Core magnetization characteristic. Winding 4k-4l	
Magnetizing Inductance L_m	3.0 H
Secondary Loop constant T_s	0.18
Secondary Loop resistance R_s (75 $^{\circ}\text{C}$)	16.74 Ω
Remanence Factor K_R	2.61 %

- Core magnetization characteristic. Results of secondary winding 5k-5l.

I_{RMS} (mA)	I_{PEAK} (mA)	U_{RMS} (V)	Flux (Wb)
67.3	169.3	94.2	0.424
146.2	271.2	195.8	0.882
229.5	369.7	305.9	1.377
301.4	489.3	397.4	1.789
381.2	593.8	502.5	2.262
462.9	722.2	599.0	2.696
567.0	885.3	708.3	3.189
645.0	1018.0	768.1	3.458
711.9	1142.0	808.1	3.638
792.8	1270.0	848.2	3.818
920.6	1472.0	902.0	4.061
1036.5	1652.0	944.9	4.254
1158.5	1825.0	986.9	4.443
1244.8	1978.0	1015.3	4.570
1409.0	2222.0	1067.7	4.806
1561.4	2434.0	1115.3	5.021
1696.7	2621.0	1155.9	5.203
1850.0	2818.0	1202.9	5.415
2005.3	3047.0	1245.9	5.609

Resistance Measurement. Winding 5k-5l	
Winding Resistance	Temperature
3.97 Ω	18.3 $^{\circ}\text{C}$
4.86 Ω	75 $^{\circ}\text{C}$
Core magnetization characteristic. Winding 5k-5l	
Magnetizing Inductance L_m	3.0 H
Secondary Loop constant T_s	0.18
Secondary Loop resistance R_s (75 $^{\circ}\text{C}$)	16.86 Ω
Remanence Factor K_R	2.60 %

- Core magnetization characteristic. Results of secondary winding 6k-6l.

I_{RMS} (mA)	I_{PEAK} (mA)	U_{RMS} (V)	Flux (Wb)
74.7	162.5	101.5	0.457
157.6	282.8	206.7	0.931
235.6	399.3	307.6	1.385
314.9	522.4	414.3	1.865
388.0	608.0	500.8	2.254
470.8	739.3	602.0	2.710
568.2	890.8	699.0	3.147
621.5	995.8	746.9	3.362
710.9	1148.0	803.6	3.618
798.2	1288.0	848.3	3.818
936.6	1507.0	906.1	4.079
1067.1	1705.0	954.6	4.297
1153.2	1811.0	983.3	4.426
1242.9	1966.0	1013.1	4.561
1397.1	2185.0	1062.6	4.783
1551.0	2395.0	1110.2	4.998
1706.1	2614.0	1158.6	5.216
1865.9	2842.0	1208.8	5.442
2059.2	3110.0	1263.4	5.687

Resistance Measurement. Winding 6k-6l	
Winding Resistance	Temperature
3.88 Ω	18.3 $^{\circ}C$
4.75 Ω	75 $^{\circ}C$
Core magnetization characteristic. Winding 6k-6l	
Magnetizing Inductance L_m	3.1 H
Secondary Loop constant T_s	0.19
Secondary Loop resistance R_s (75 $^{\circ}C$)	16.75 Ω
Remanence Factor K_R	2.46 %

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3.15 Mutual influence test

3.15.1 Influence of the voltage transformer on the current transformer

- Test date: 6th November 2013
- Procedure: IEC 60044-3 section 11.3.3
- Test object: Serial number 13002263/3

Influence of the voltage transformer on the current transformer was measured according to section 11.3.3 of IEC 60044-3 standard.

A resistor of 100 Ω was connected to each secondary winding of the current transformer with the other secondary windings short-circuited and with secondary windings of voltage transformer open-circuited. Test voltages of 1.2 U_n and 1.9 U_n were applied to primary winding of voltage transformer and the voltage of the secondary winding was measured.

- Test results:

<i>Influence of Voltage Transformer</i>						
<i>Test Voltage</i>	<i>1.2 U_n (76.2 kV)</i>			<i>1.9 U_n (120.7 kV)</i>		
<i>Error variation at 5 % I_n</i>						
<i>Secondary winding</i>	U_i	$\pm\Delta\varepsilon_i$	$\pm\Delta\delta_i$	U_i	$\pm\Delta\varepsilon_i$	$\pm\Delta\delta_i$
1k-1l	4.7 mV	$\pm 0.09 \%$	± 3.2 min	5.6 mV	$\pm 0.11 \%$	± 3.9 min
2k-2l	4.2 mV	$\pm 0.08 \%$	± 2.9 min	5.2 mV	$\pm 0.10 \%$	± 3.6 min
3k-3l	3.3 mV	$\pm 0.07 \%$	± 2.3 min	3.4 mV	$\pm 0.07 \%$	± 2.3 min
4k-4l	4.4 mV	$\pm 0.09 \%$	± 3.0 min	4.8 mV	$\pm 0.10 \%$	± 3.3 min
5k-5l	4.8 mV	$\pm 0.10 \%$	± 3.3 min	5.4 mV	$\pm 0.11 \%$	± 3.7 min
6k-6l	4.5 mV	$\pm 0.09 \%$	± 3.1 min	5.3 mV	$\pm 0.11 \%$	± 3.6 min

<i>Influence of Voltage Transformer</i>						
<i>Test Voltage</i>	<i>1.2 U_n (76.2 kV)</i>			<i>1.9 U_n (120.7 kV)</i>		
<i>Error variation at 120 % I_n</i>						
<i>Secondary winding</i>	U_i	$\pm\Delta\varepsilon_i$	$\pm\Delta\delta_i$	U_i	$\pm\Delta\varepsilon_i$	$\pm\Delta\delta_i$
1k-1l	4.7 mV	$\pm 0.004 \%$	± 0.1 min	5.6 mV	$\pm 0.005 \%$	± 0.2 min
2k-2l	4.2 mV	$\pm 0.004 \%$	± 0.1 min	5.2 mV	$\pm 0.004 \%$	± 0.1 min
3k-3l	3.3 mV	$\pm 0.003 \%$	± 0.1 min	3.4 mV	$\pm 0.003 \%$	± 0.1 min
4k-4l	4.4 mV	$\pm 0.004 \%$	± 0.1 min	4.8 mV	$\pm 0.004 \%$	± 0.1 min
5k-5l	4.8 mV	$\pm 0.004 \%$	± 0.1 min	5.4 mV	$\pm 0.005 \%$	± 0.2 min
6k-6l	4.5 mV	$\pm 0.004 \%$	± 0.1 min	5.3 mV	$\pm 0.004 \%$	± 0.2 min

Current and phase displacement errors of current transformer including error variations (ratio and phase displacement) of current transformer due to influence of voltage transformer are between the limits specified for the accuracy class.

3.15.2 Influence of the current transformer on the voltage transformer

- Test date: 19th November 2013
- Procedure: IEC 60044-3 section 11.3.2
- Test object: Serial number 13002263/3

Influence of the current transformer on the voltage transformer was measured according to section 11.3.2 of IEC 60044-3 standard.

Test currents equal to rated current and rated continuous thermal current were applied to primary winding of current transformer with secondary windings of current transformer short-circuited.

Primary winding of voltage transformer was short-circuited during the test and induced voltage due to primary current was measured on voltage secondary winding with rated burden connected to it.

- Test results:

<i>Influence of Current Transformer</i>						
<i>Test Current</i>	<i>I_n (1200 A)</i>			<i>2 I_n (2400 A)</i>		
<i>Error variation at 80 % U_n</i>						
<i>Secondary winding</i>	<i>U_v</i>	<i>±Δε_i</i>	<i>±Δδ_i</i>	<i>U_v</i>	<i>±Δε_i</i>	<i>±Δδ_i</i>
1u-1x Burden 25 VA	4.35 mV	±0.009 %	±0.3 min	8.98 mV	±0.019 %	±0.7 min
2u-2x Burden 25 VA	4.33 mV	±0.009 %	±0.3 min	8.93 mV	±0.019 %	±0.7 min
3u-3x Burden 100 VA	4.33 mV	±0.009 %	±0.3 min	8.92 mV	±0.019 %	±0.7 min
e-n burden 50 VA	4.38 mV	±0.016 %	±0.6 min	8.98 mV	±0.034 %	±1.2 min

<i>Influence of Current Transformer</i>						
<i>Test Current</i>	<i>I_n (1200 A)</i>			<i>2 I_n (2400 A)</i>		
<i>Error variation at 2 % U_n</i>						
<i>Secondary winding</i>	<i>U_v</i>	<i>±Δε_i</i>	<i>±Δδ_i</i>	<i>U_v</i>	<i>±Δε_i</i>	<i>±Δδ_i</i>
3u-3x Burden 100 VA	4.33 mV	±0.38 %	±13 min	8.92 mV	±0.77 %	±27 min
e-n burden 50 VA	4.38 mV	±0.66 %	±23 min	8.98 mV	±1.35 %	±46 min

Voltage and phase displacement errors of voltage transformer including error variations (ratio and phase displacement) of voltage transformer due to influence of current transformer are between the limits specified for the accuracy class.

- Conclusion: **Test passed**

3.16 Temperature-rise test

- Test date: 26th, 27th and 28th November 2013
- Procedure: Section 7.2 of IEC 60044-1
Section 8.1 of IEC 60044-2
Section 7.2 of IEC 60044-3
- Test object: Serial number 13002263/3

Temperature-rise test was performed on combined transformer according to section 7.2 of IEC 60044-3 standard.

Temperature rises of both voltage windings and current secondary windings were measured by the increase-in-resistance method and five thermocouples were placed over the surface of the transformer low part. Three thermocouples were placed near the test object to control the ambient temperature.

The combined transformer was subjected to rated continuous thermal current (2400 A) and test voltage equal to $1.2 U_n$ (76.2 kV) during the temperature rise test.

Rated burdens (cos phi 1) were connected to secondary windings 1u-1x, 2u-2x and 3u-3x of voltage transformer and rated burdens were connected to current secondary windings during the test. After approximately ten hours from the application of the current and voltage, thermal stability was achieved in the test object and winding resistances were measured.

Then, rated burden of secondary winding e-n was connected, test voltage was increased to $1.9 U_n$ (120.7 kV) and eight hours later the winding resistances were measured again.

- Temperature-rise of the windings. Test voltage $1.2 U_n$ and test current $2 I_n$.

<i>Windings of voltage transformer</i>					
	<i>U-X</i>	<i>1u-1x</i>	<i>2u-2x</i>	<i>3u-3x</i>	<i>e-n</i>
R_o (Ohm)	10 900 Ω	0.0292 Ω	0.0283 Ω	0.0275 Ω	0.0186 Ω
θ_o ($^{\circ}$ C)	15.8 $^{\circ}$ C				
R_t (Ohm)	11 200 Ω	0.0301 Ω	0.0290 Ω	0.0283 Ω	0.0190 Ω
θ_f ($^{\circ}$ C)	11.1 $^{\circ}$ C				
$\Delta\theta$ (K)	11.6 K \pm 3K	12.4 K \pm 3K	10.9 K \pm 3K	12.0 K \pm 3K	10.0 K \pm 3K

<i>Windings of current transformer</i>						
	<i>1k-1l</i>	<i>2k-2l</i>	<i>3k-3l</i>	<i>4k-4l</i>	<i>5k-5l</i>	<i>6k-6l</i>
R_o (Ohm)	2.65 Ω	2.76 Ω	2.02 Ω	3.81 Ω	3.91 Ω	3.82 Ω
θ_o ($^{\circ}$ C)	15.8 $^{\circ}$ C					
R_t (Ohm)	3.12 Ω	3.24 Ω	2.38 Ω	4.52 Ω	4.67 Ω	4.55 Ω
θ_f ($^{\circ}$ C)	11.1 $^{\circ}$ C					
$\Delta\theta$ (K)	49.6 K \pm 3K	48.7 K \pm 3K	48.7 K \pm 3K	51.1 K \pm 3K	53.2 K \pm 3K	52.2 K \pm 3K

- Temperature-rise of the windings. Test voltage $1.9 U_n$ for 8 hours and test current $2 I_n$.

<i>Windings of voltage transformer</i>					
	<i>U-X</i>	<i>1u-1x</i>	<i>2u-2x</i>	<i>3u-3x</i>	<i>e-n</i>
R_o (Ohm)	10 900 Ω	0.0292 Ω	0.0283 Ω	0.0275 Ω	0.0186 Ω
θ_o ($^{\circ}$ C)	15.8 $^{\circ}$ C				
R_t (Ohm)	11 650 Ω	0.0314 Ω	0.0304 Ω	0.0296 Ω	0.0198 Ω
θ_f ($^{\circ}$ C)	14.7 $^{\circ}$ C				
$\Delta\theta$ (K)	18.3 K \pm 3K	20.0 K \pm 3K	19.7 K \pm 3K	20.2 K \pm 3K	17.3 K \pm 3K

<i>Windings of current transformer</i>						
	<i>1k-1l</i>	<i>2k-2l</i>	<i>3k-3l</i>	<i>4k-4l</i>	<i>5k-5l</i>	<i>6k-6l</i>
R_o (Ohm)	2.65 Ω	2.76 Ω	2.02 Ω	3.81 Ω	3.91 Ω	3.82 Ω
θ_o ($^{\circ}$ C)	15.8 $^{\circ}$ C					
R_t (Ohm)	3.20 Ω	3.33 Ω	2.45 Ω	4.65 Ω	4.79 Ω	4.65 Ω
θ_f ($^{\circ}$ C)	14.7 $^{\circ}$ C					
$\Delta\theta$ (K)	53.5 K \pm 3K	53.4 K \pm 3K	53.2 K \pm 3K	55.8 K \pm 3K	57.0 K \pm 3K	55.3 K \pm 3K

Temperature rises of primary winding and secondary windings were lower than limit specified of 60 K (thermal insulation class A) specified by IEC 60044-1 and IEC 60044-2 standards.

- Temperature-rise measurement of external parts. Results:

Ambient Temperature before the test	16.3 $^{\circ}$ C
Ambient Temperature after 1.9 U_n 8 hours – 2 I_n test	15.2 $^{\circ}$ C
Continuous test voltage (1.2 U_n)	76.2 kV
Test voltage applied for 8 hours (1.9 U_n)	120.7 kV
Continuous test current (2 I_n)	2400 A
Burden connected to secondary windings 1u-1x, 2u-2x	25 VA
Burden connected to secondary winding 3u-3x	100 VA
Burden connected to secondary winding e-n for 1.9 U_n test	50 VA
Burden connected to secondary windings 1k-1l, 2k-2l, 3k-3l	10 VA
Burden connected to secondary windings 4k-4l, 5k-5l, 6k-6l	15 VA
Max temperature-rise of tank – lateral side	9.1 K
Max temperature-rise of tank – superior part	9.3 K
Max temperature-rise of tank – inferior part	5.5 K
Max temperature-rise of terminal box – zone 1	3.8 K
Max temperature-rise of terminal box – zone 2	4.8 K

Temperature rise of metallic parts of the transformer was lower than limit specified of 60 K (thermal insulation class A) specified by IEC 60044-1 and IEC 60044-2 standards.

- Conclusion: **Test passed**

4 SUMMARY AND CONCLUSIONS

The following tests according to IEC 60044-1, IEC 60044-2 and IEC 60044-3 standards have been performed on combined transformer type KA-123, identification 13002263/3 and manufactured by Artech.

- Test for accuracy of combined transformer.
- Inter-turn overvoltage test.
- Instrument security factor of measuring current transformer.
- Test for composite error of protective current transformer.
- Short-time current test of current transformer.
- Short-circuit withstand capability test of voltage transformer.
- Core magnetization characteristic.
- Mutual Influence test.
- Temperature-rise test.

The following tests according to IEC 60044-1, IEC 60044-2 and IEC 60044-3 standards have been performed on combined transformer type KA-123, identification 13002263/2 and manufactured by Artech.

- Lightning and chopped impulse test.
- Wet test for outdoor type transformers.
- Radio Interference Voltage Measurement.
- Induced voltage withstand test on primary winding.
- Partial discharges measurement.
- Separate source withstand voltage test on primary winding.
- Power frequency withstand test on secondary windings.

All tests performed on combined transformers have been successful.

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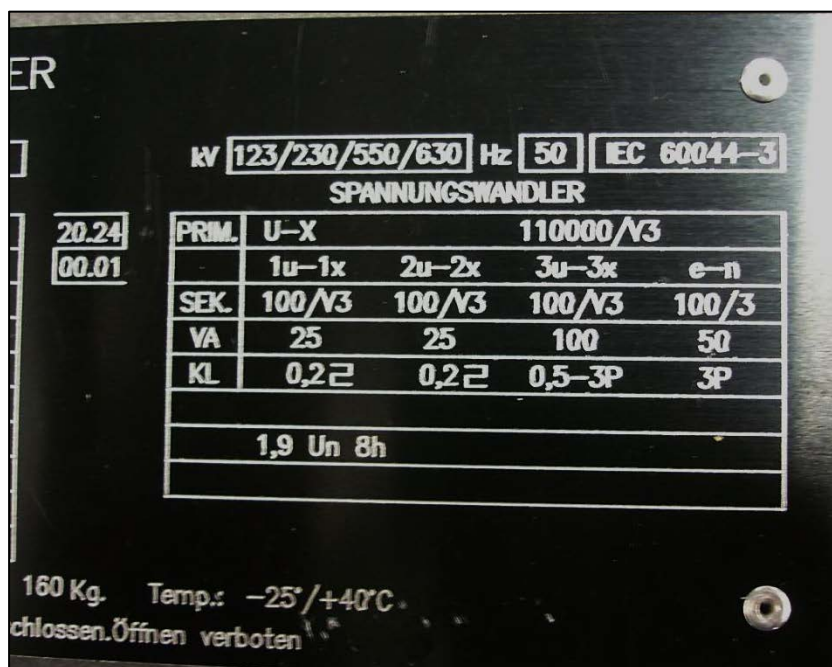
Annex 1

Rating Plate and Scheme

➤ Figure 1 – Arteche KA-123 Rating plate of current transformer.



➤ Figure 2 – Arteche KA-123 Rating plate of voltage transformer.



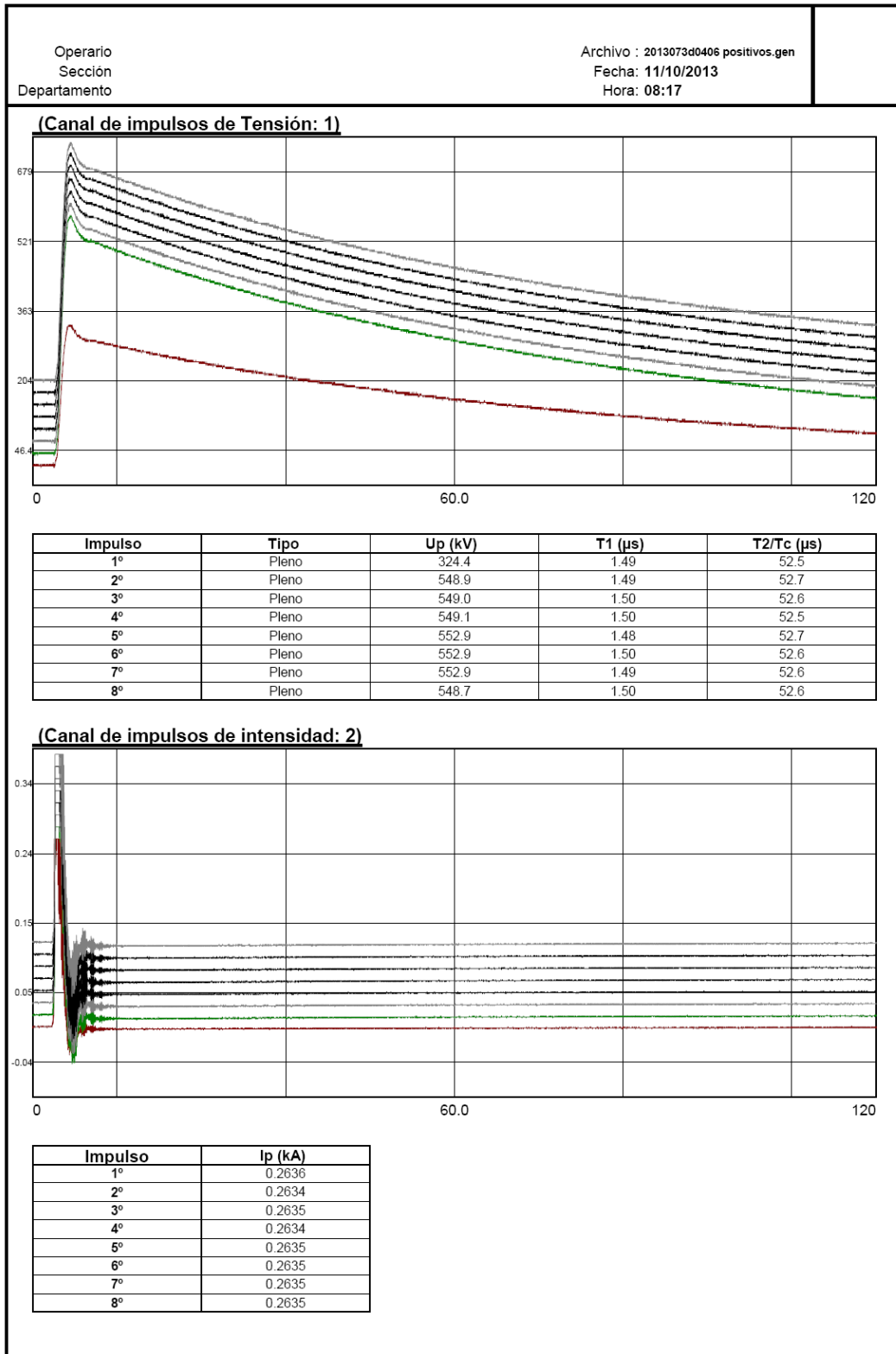
➤ *Figure 3 – Picture of combined transformer. RIV Measurement.*



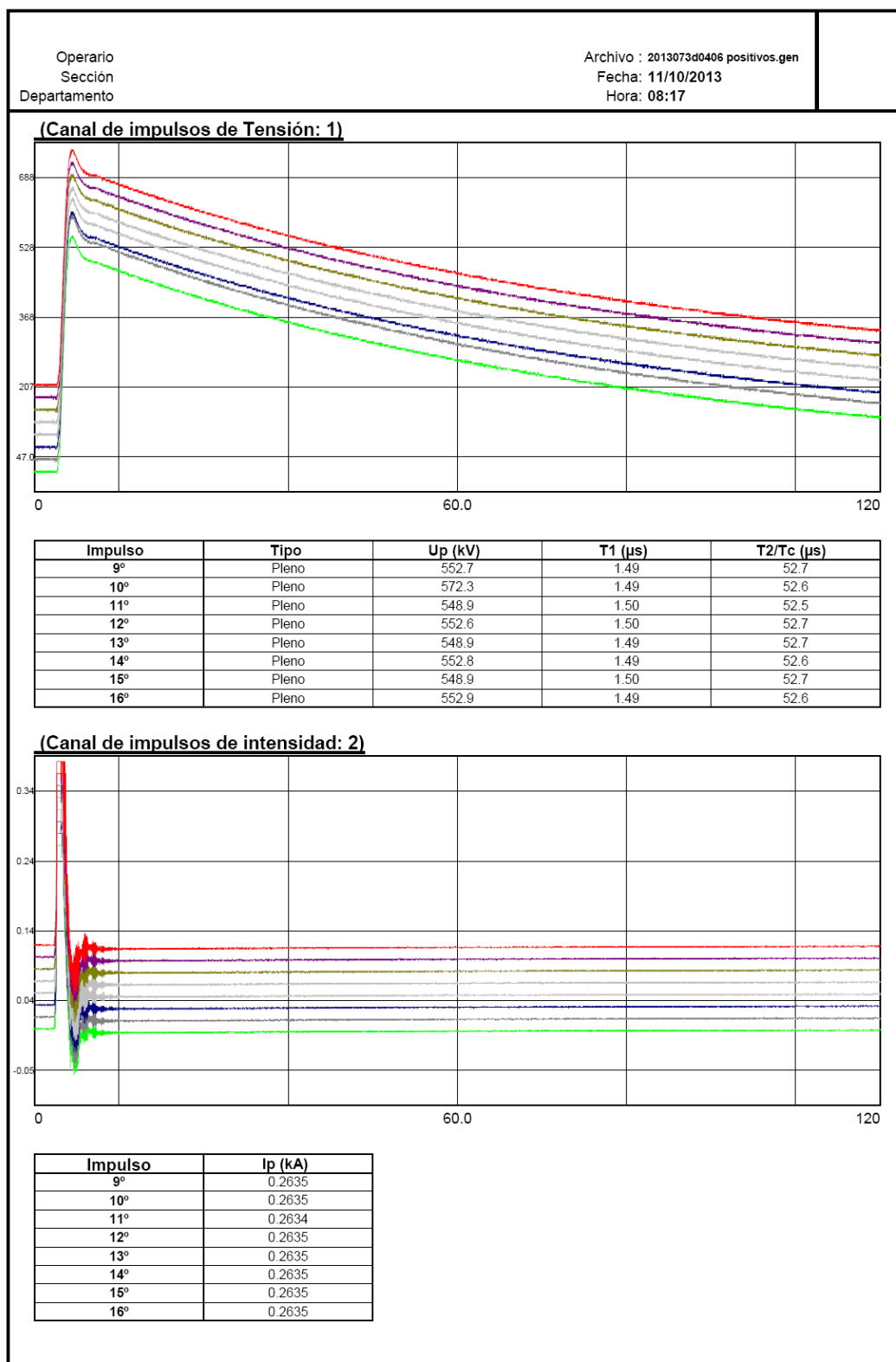
Annex 2

Lightning and chopped impulse test

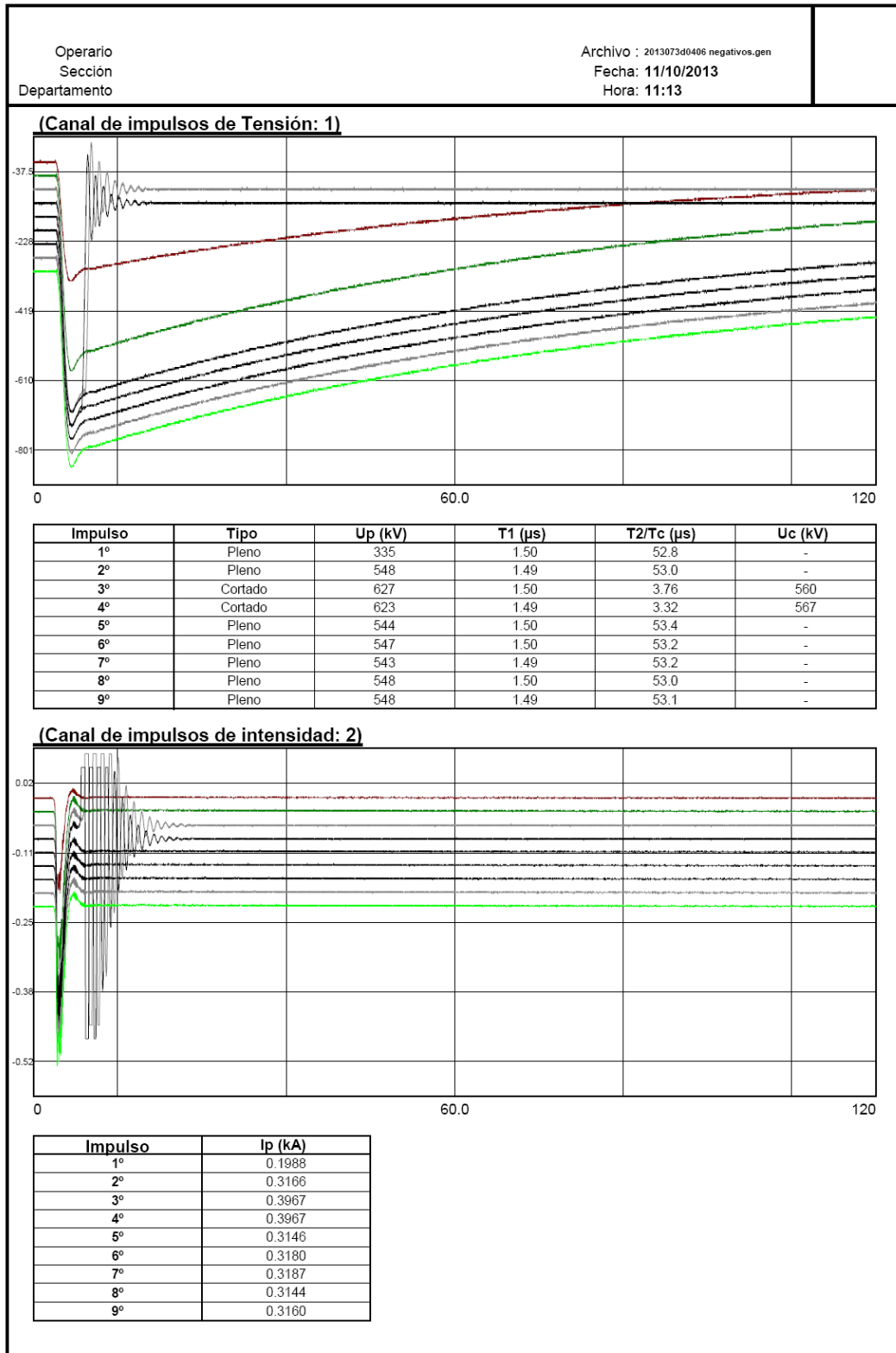
➤ *Figure 1 – Lightning impulses of positive polarity (Impulses N° 1 to N° 8)*



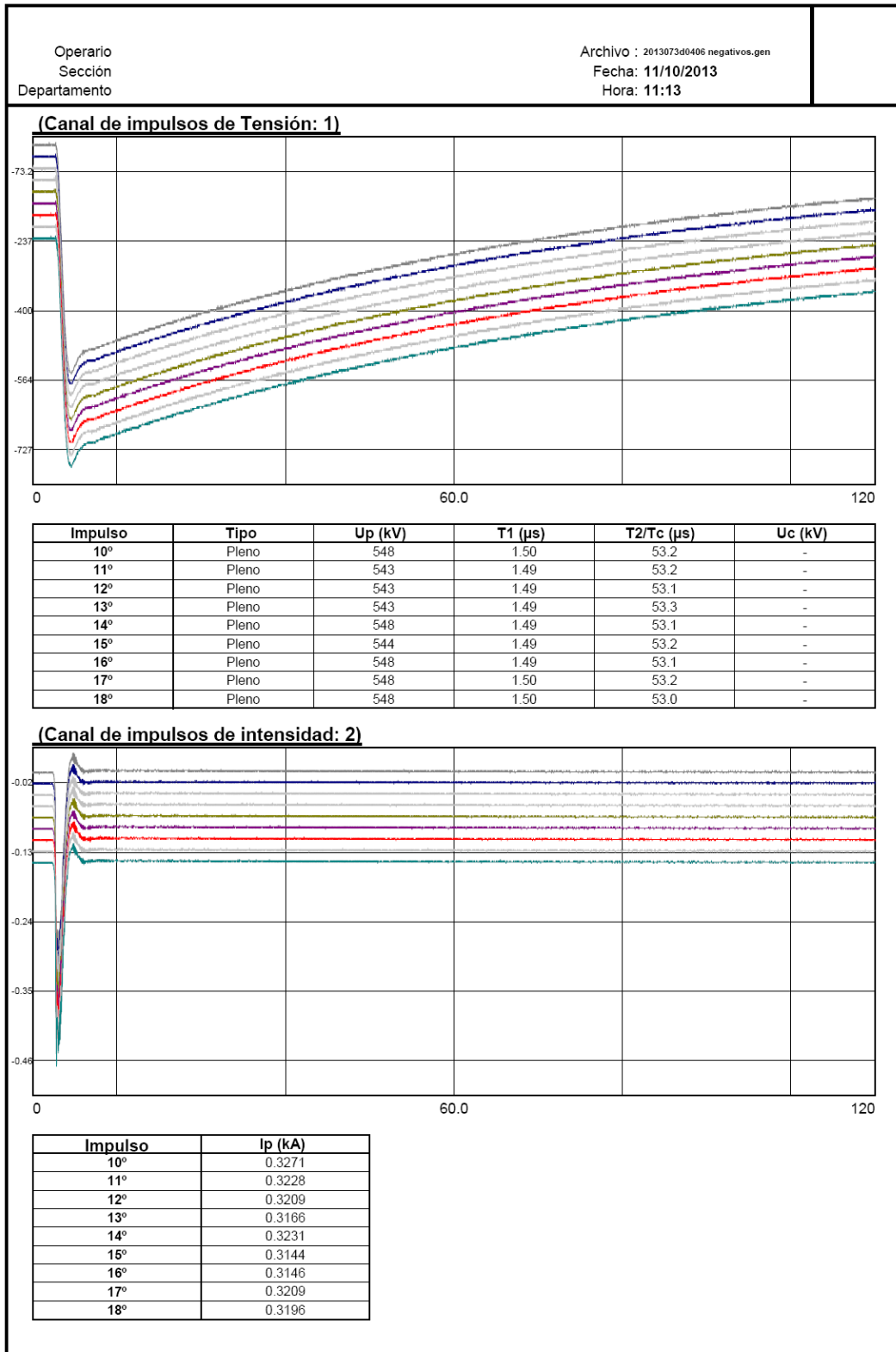
➤ *Figure 2 – Lightning impulses of positive polarity (Impulses N° 9 to N° 16)*



➤ *Figure 3 – Lightning impulses of negative polarity (Impulses Nº 1 to Nº 9)*



➤ *Figure 4 – Lightning impulses of negative polarity (Impulses N° 10 to N° 18)*

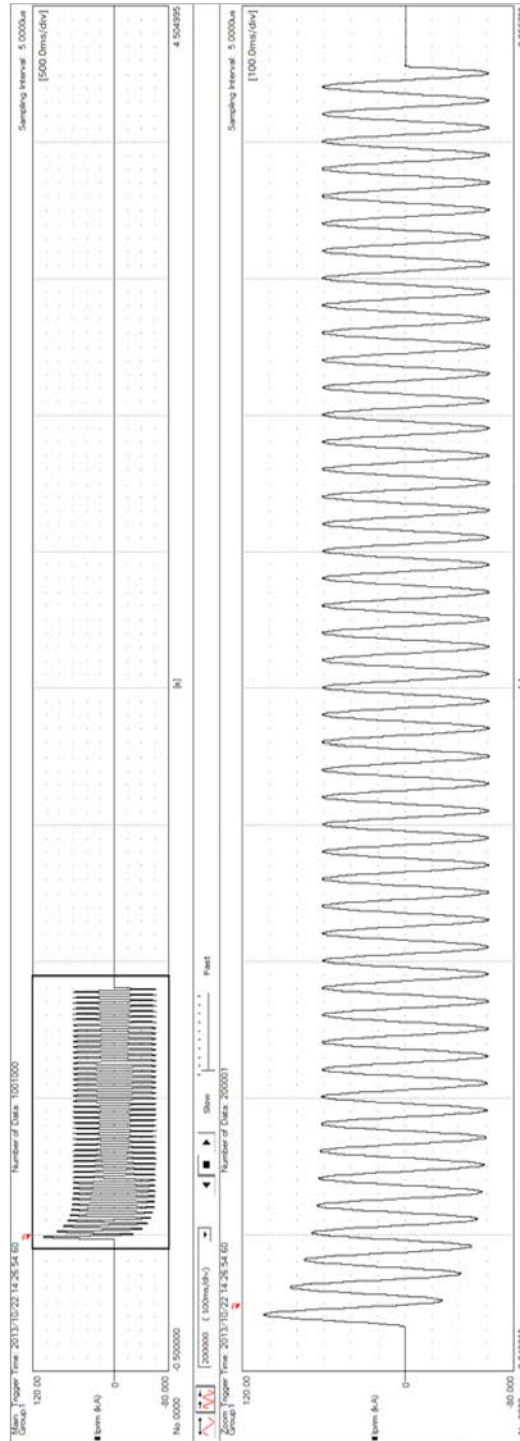


Annex 3

Short-time current test of current transformer

➤ *Figure 1 – Short-circuit test.*

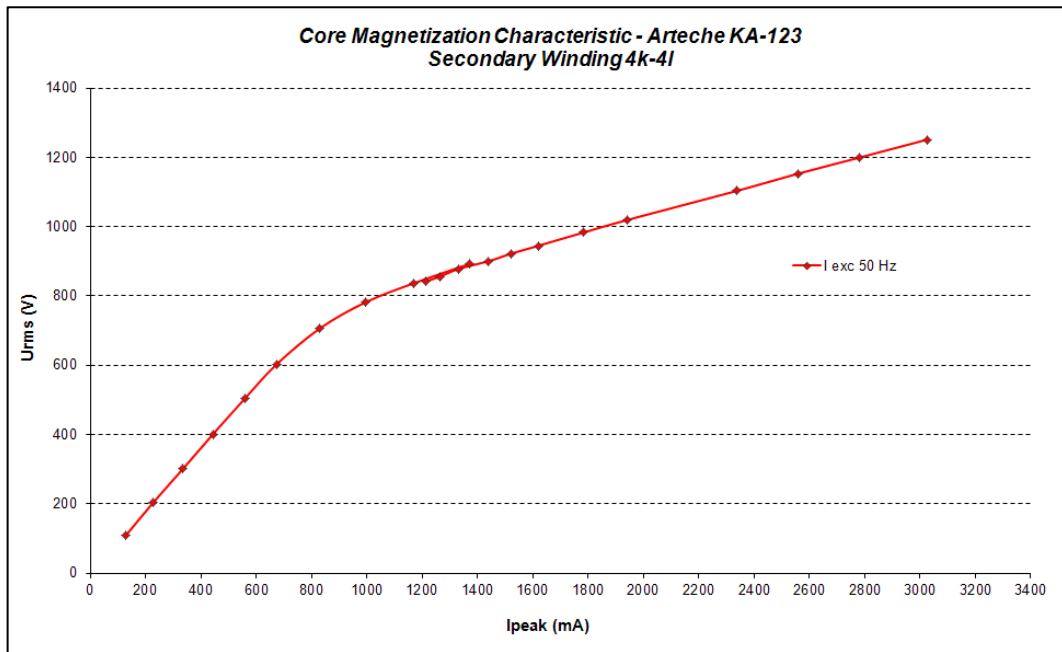
Short-time current ⇒ 43.4 kA
Short-time dynamic current ⇒ 104.2 kA
Test duration ⇒ 923 ms



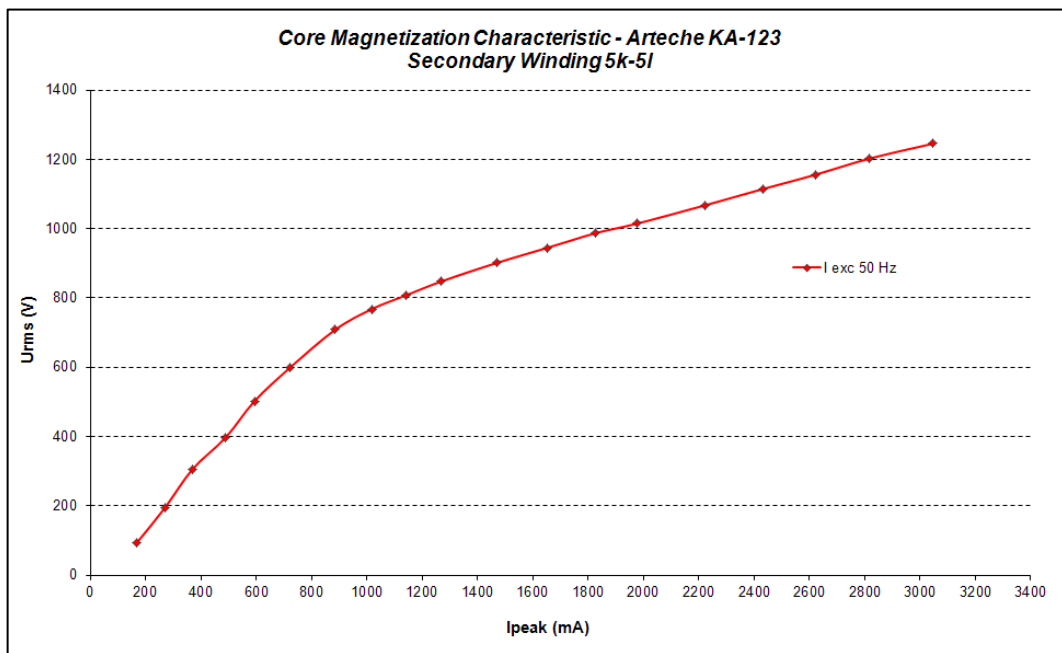
Annex 4

Measurement of core magnetization characteristic

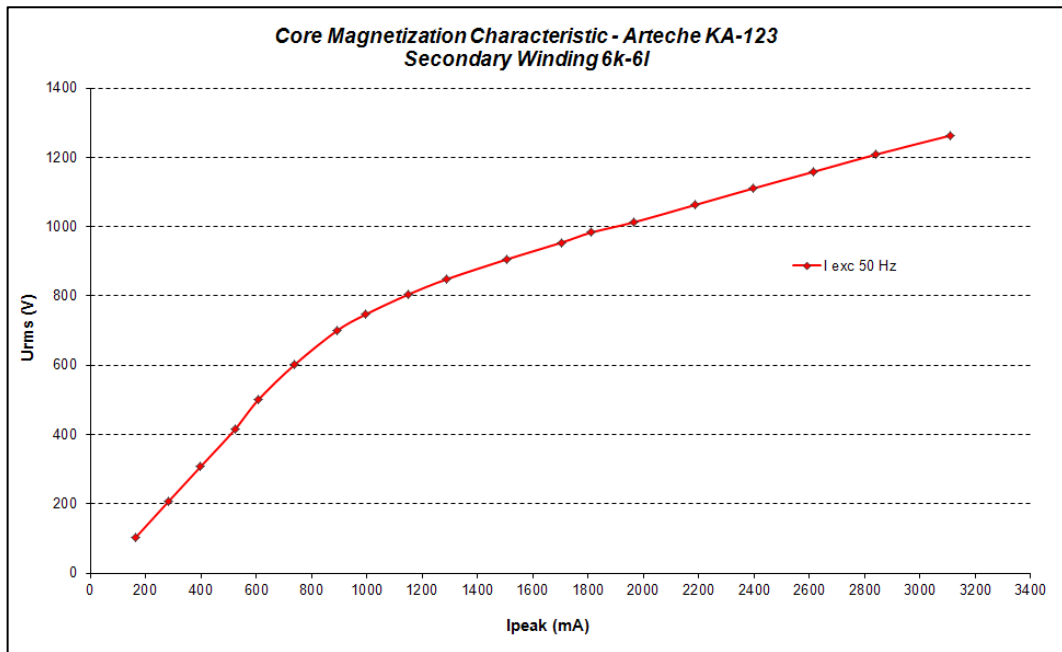
➤ *Figure 1 – Core magnetization characteristic. Secondary winding 4k-4l*



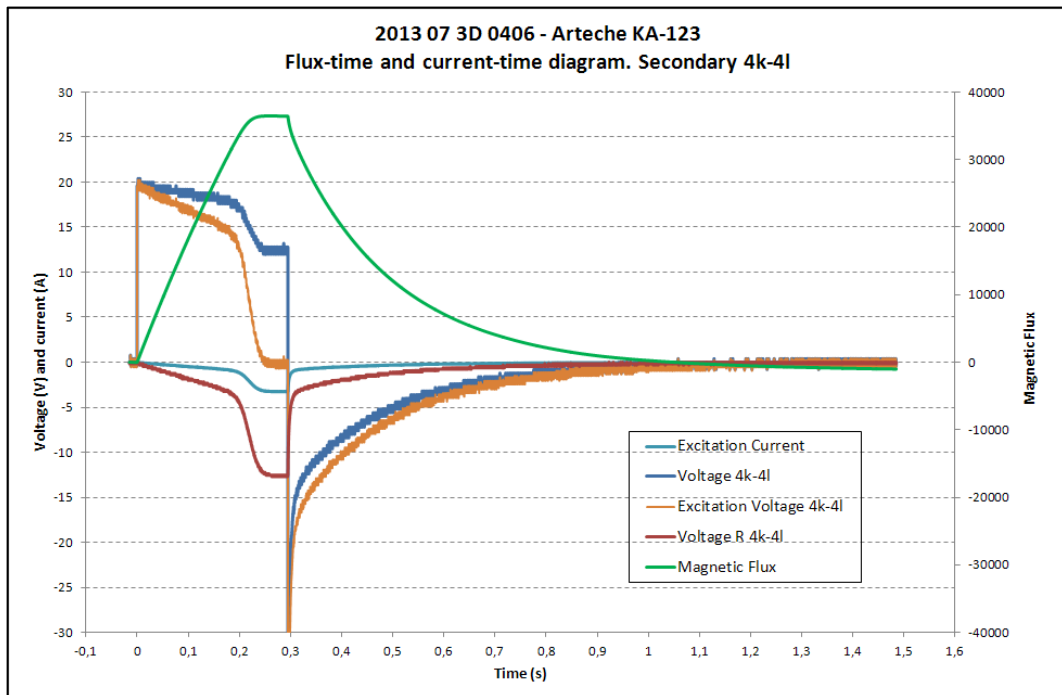
➤ *Figure 2 – Core magnetization characteristic. Secondary winding 5k-5l*



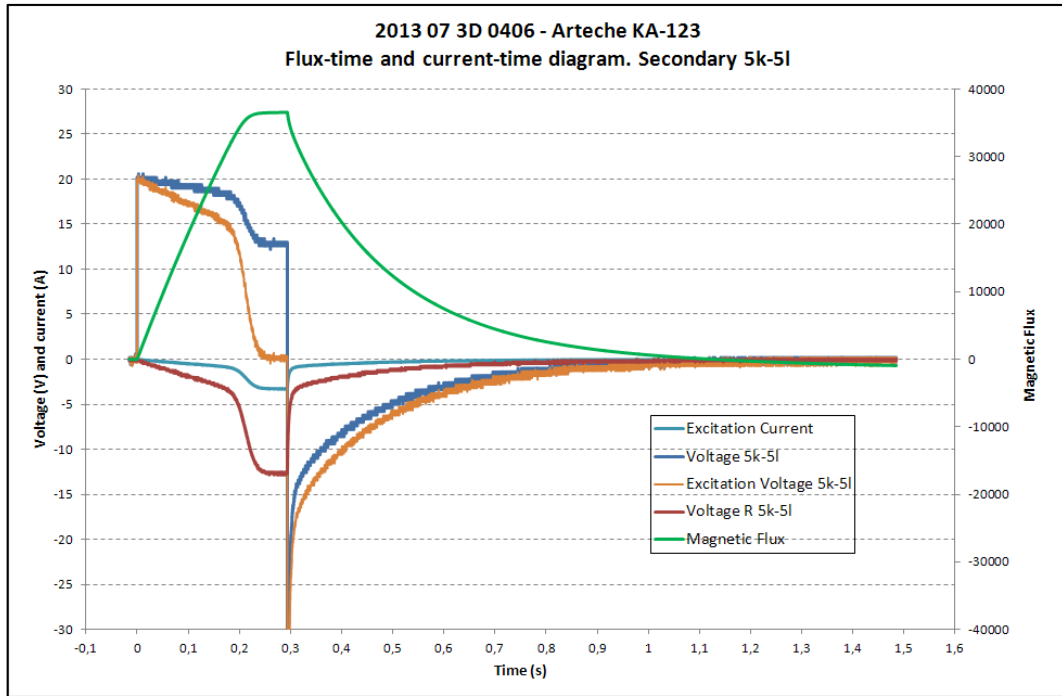
➤ *Figure 3 – Core magnetization characteristic. Secondary winding 6k-6I*



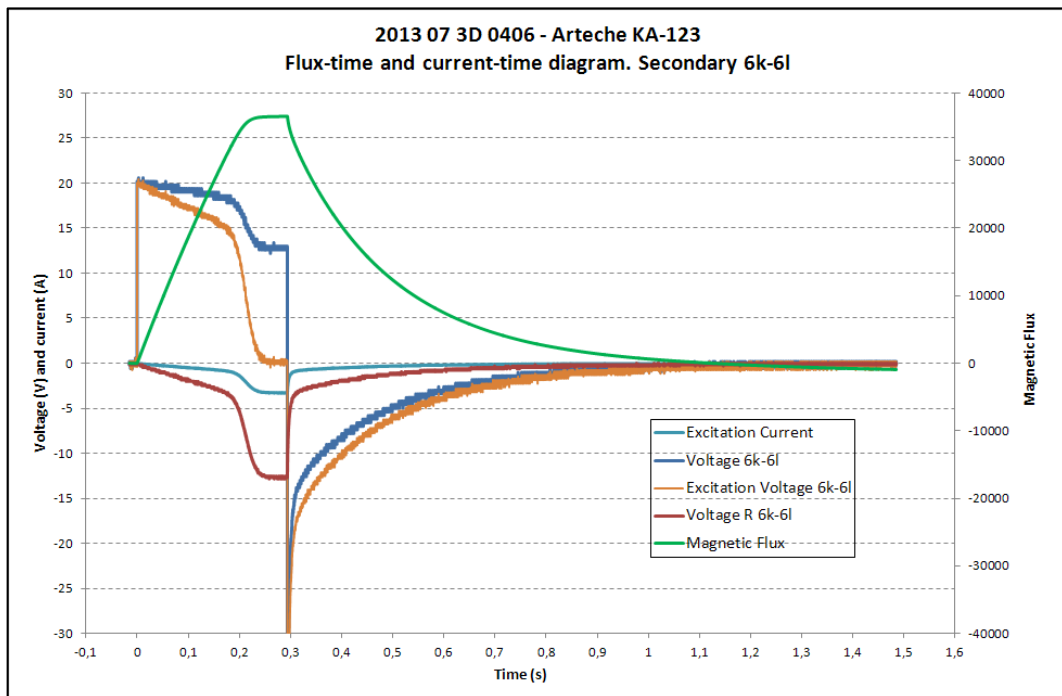
➤ *Figure 4 – Determination of Remanence factor. Flux and current diagrams. Secondary winding 4k-4I.*



➤ *Figure 5 – Determination of Remanence factor. Flux and current diagrams. Secondary winding 5k-5l.*



➤ *Figure 6 – Determination of Remanence factor. Flux and current diagrams. Secondary winding 6k-6l.*



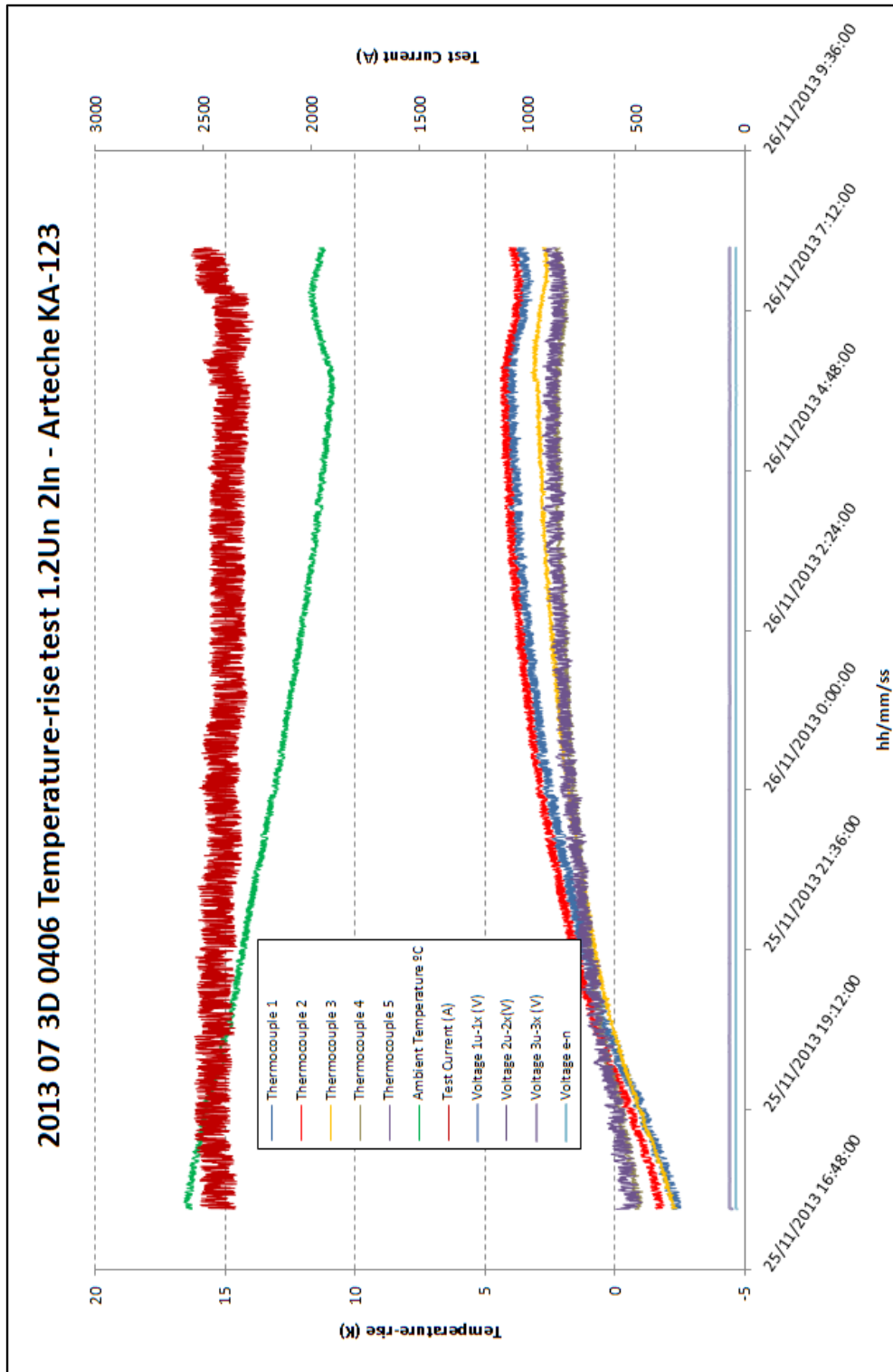
Annex 5

Temperature-rise test

➤ *Figure 1 – Temperature-rise test.*

Test Voltage ⇒ 76.2 kV (1.2 U_n)

Test Current ⇒ 2400 A (2 I_n)



- *Figure 2 – Temperature-rise test.*
 Test Voltage ⇒ 120.7 kV (1.9 U_n) 8 hours.
 Test Current ⇒ 2400 A (2 I_n)

