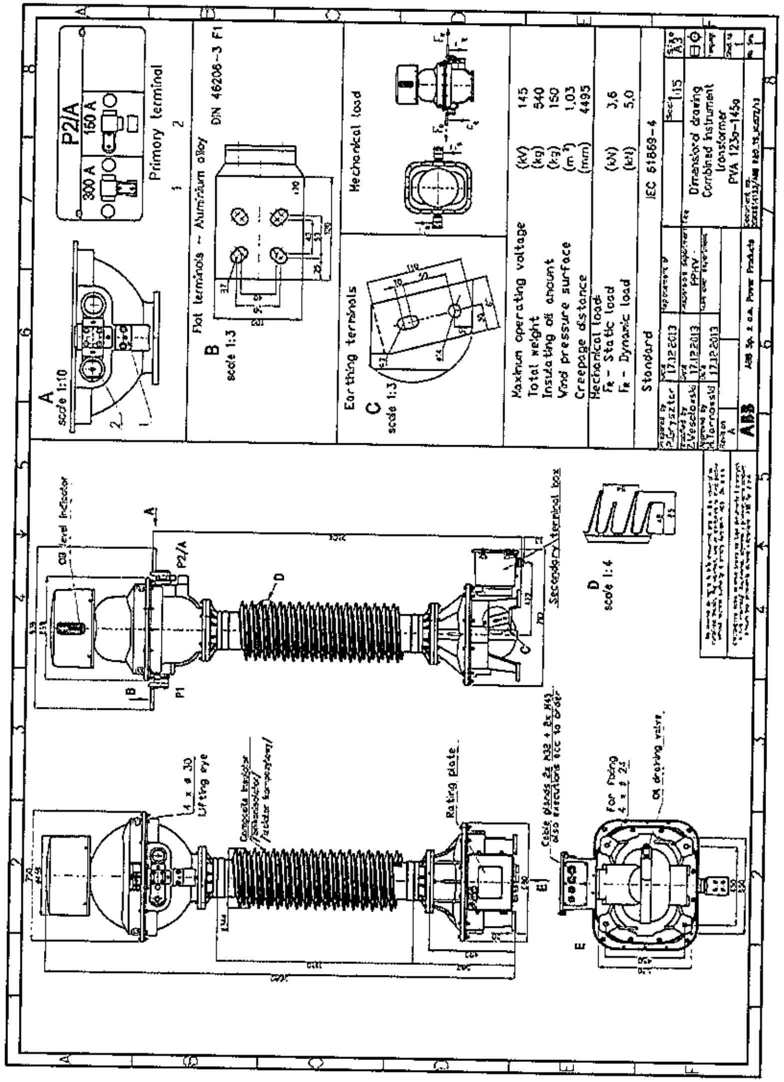


ABB

Combined Instrument Transformer

Insulation level	145/275/650 kV	Standard	IEC 61869-4	Type	PVA 145a
Oil type	Nytro Libra	Weight / Oil weight	540 / 150 kg	fn	50 Hz
S/N	2GKP013K1486145	Voltage factor	1,9Un/8h	Temp. range	-50°C → +40°C
				Ue	0,2 mV/kA

CURRENT PART

K_n 150-300 / 5-1-5-1 A/A

$I_{th}/1s$ 20-20 kA I_{dyn} 50-50 kA

I_{cth} 180-360 A

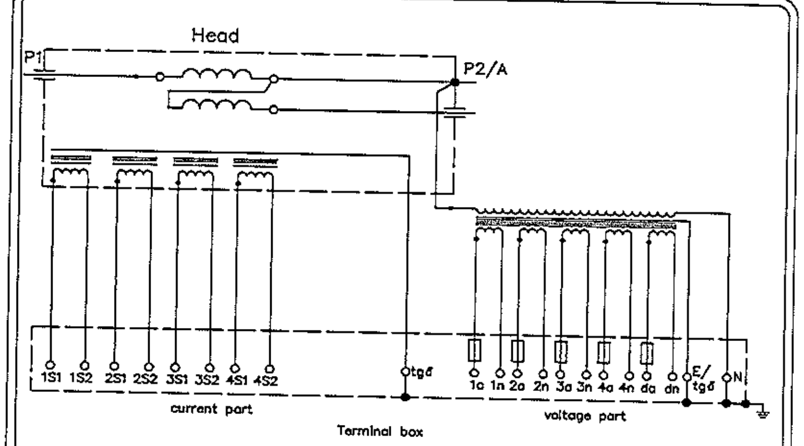
	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2	5S1-5S2	6S1-6S2
A	5	1	5	1		
VA	30	40	60	60		
Kl.	0,2	5P	5P	5P		
FS/ALF	5	20	20	20		
Ext.%	120					

VOLTAGE PART

A-N 132:√3 kV

	1a-1n	2a-2n	3a-3n	4a-4n	da-dn
V	110:√3	110:√3	110:√3	110:√3	110:3
VA	100	100	100	100	200
Kl.	1,0	1,0	1/3P	3/3P	3,0
VA_{th}	1000	1000	1000	1000	450

Transportation Vertical / Horizontal



Instrument transformer electrical diagram

ATTENTION!

1. HIGH VOLTAGE AT OPEN CURRENT SECONDARY TERMINALS XS1 – XS2
2. DURING INSTRUMENT TRANSFORMER OPERATION TERMINALS: N, E/tgδ, tgδ MUST BE EARTHED
3. AFTER THREE WINDINGS da - dn ARE CONNECTED IN BROKEN DELTA THE CIRCUIT SHOULD BE EARTHED IN ONE POINT ONLY

AC 117

INSTITUTE OF POWER ENGINEERING
Certification Department

PRODUCT EVALUATION REPORT

No DZC/36c/E/2013/2014

Product name and symbol: **HV combined instrument transformer, single-phase, outdoor, type: PVA 123a and PVA 145a**

Supplier: **ABB Sp. z o.o., Oddział w Przasnyszu, ul. Leszno 59, 06-300 Przasnysz**

Warsaw, February 2014

Author: mgr inż. Grażyna Wieczorek

Contents:

Non-conformities observed:

None found

General evaluation result:

Positive
Based on the analysis made, herewith I conclude for granting of compliance certificates to the HV combined instrument transformers, types: PVA 123a and PVA145a, with composite or ceramic insulator, manufactured by ABB Sp. z o.o., Oddział w Przasnyszu

Grażyna Wieczorek		5 February 2014
Full name	signature	date

1. Introduction

Report from evaluation of HV overhead, single-phase, current transformer series, types: PVA 123a and PVA 145a, manufactured by ABB Sp. z o.o., Oddział w Przasnyszu, developed during the certification process carried out by Zespół ds. Certyfikacji (Certification Team) upon manufacturer's application (contract No DZC/36c/E/2013 of the 23 October 2013)

This document concerns the new series of combined instrument transformers featuring design modifications and marked: PVA ...a.

The PVA 123a and PVA 145a combined instrument transformers are used for feeding measurement and protection systems in electric power grids with the highest system voltage of 126 kV or 145 kV and frequency of 50 Hz. Combined transformers consist of a current element and a voltage element located inside a common enclosure with a composite insulator (cover configuration: straight and spiral) or with a ceramic insulator filled with transformer oil.

The PVA transformer tests were carried out on selected representatives at the laboratories of Instytut Energetyki (Institute of Power Engineering) in Warszawa and Instytut Elektrotechniki Oddział w Gdańsku (Electrotechnical Institute, Gdańsk Branch) as well as (for product tests and deviation measurements) at the manufacturer's laboratory. The selection procedure included the most severe conditions resulting from the combined transformer design and occurring during the temperature-rise tests, short-circuit withstand, voltage and mechanical tests such as: values of continuous and short-circuit currents, winding wire size, different main circuits, winding power for measurement and protection, housing types, accuracy classes, etc. Tests were carried out on seven selected combined transformer prototypes. The results are valid for the entire transformer series acc. to the list as suggested for certification. Test results confirming the combined transformers features are listed in the reports in cl. 2 of this document. The test results were compared against requirements in the following standards:

- PN-EN 61869-1:2009
  Instrument transformers – Part 1: General requirements
- PN-EN 61869-2:2013-06
  Instrument transformers – Part 2: Detailed requirements for current transformers
- PN-EN 61869-3:2011
  Instrument transformers – Part 3: Detailed requirements for voltage transformers
- IEC 61869-4 Ed. 1.0
  Instrument transformers - Part 4: Additional requirements for combined transformers
- PN-EN 60529:2003
  Protection class provided by the housing (IP)

- PN-EN 62262:2003
  Degrees of protection against external mechanical impacts as provided by electric device enclosures (IK coding)

Customer/manufacturer: ABB Sp. z o.o., Przasnysz holds the complex certificate for the following standards: ISO 9001:2008, ISO 14001:2004 and PN-N-18001:2004 – certificate No 0198 150 01525 issued by TÜV Rheinland Polska Sp. z o.o.

2. List of applied documents

The combined transformers design and the test results were evaluated and analysed based on the following documents delivered by the Manufacturer and included in the reports:

D1. Report No EWP/10/E/2014-1e. Temperature-rise test High Current Laboratory. Warsaw, January 2014.

D2. Report No EWP/10/E/2014-2e. IEn. Temperature-rise test High Current Laboratory Warsaw, February 2014.

D3. Report No EWP/35/E/2013-1e. IEn. Temperature-rise tests. High Current Laboratory Warsaw, February 2014.

D4. Report EUR/66/E/13-2 E). Mechanical tests Distribution Equipment Laboratory Warsaw, December 2013.

D5. Report No EUR/66/E/13-1 E (Mechanical tests). IEn. Distribution Equipment Laboratory Warsaw, December 2013.

D6. Report No EUR/71/E/13-3 E (Short-time current test, combined error measurement, test of strength against short-circuit in the secondary circuit). IEn. Distribution Equipment Laboratory Warsaw, January 2014.

D7. Report No EUR/74/E/13 E Short-time current test. Test for composite error). IEn Distribution Equipment Laboratory Warsaw December 2013.

D8. Report No EUR/71/E/13-1 E Short-time current test. IEn Distribution Equipment Laboratory Warsaw, January 2014.

D9. Report No EUR/71/E/13-4 E Short-time current test, Test for composite error). IEn. Distribution Equipment Laboratory). Warsaw, January 2014.

D10. Test report No EWN/145/E/13. Type tests, special tests and additional tests of combined transformers type PVA123a and PVA145a manufactured by ABB sp. z o.o.). IEn. High Voltage Laboratory Warsaw, January 2014.

D11. Report No 8281/NZL/NBR/12. IP tests for terminal box IEl. Distribution Equipment Test Laboratory Warsaw, July 2012.

D12. Report No EWP/35/E/2013-3e Mechanical impact test. IEn High Current Laboratory), Warsaw, February 2014

D13. Dimensional drawings:
Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614122/ABB R&D_TS_KU568/13 (17.12.2013).
Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614123/ABB R&D_TS_KU570/13 (17.12.2013).

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614121/ABB R&D_TS_KU570/13 (17.12.2013).

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614123/ABB R&D_TS_KU571/13 (17.12.2013).

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614123/ABB R&D_TS_KU572/13 (17.12.2013).

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614120/ABB R&D_TS_KU569/13/A (17.12.2013).

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614121/ABB R&D_TS_KU569/13 (17.12.2013).

D13. Product test reports and accuracy check reports – see reports from D1÷10 tests

D14. Rating plates – see reports from D1÷10 tests

D15. Electrical diagrams – see reports from D1÷10 tests

3. Testing laboratory competences

Type tests, product tests and special tests for PVA...a combined transformers were carried out at the following laboratories:

- Laboratorium Wysokich Napięć (High Voltage Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA No AB 272.
- - Laboratorium Urządzeń Rozdzielczych (Distribution Equipment Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA No AB 324.
- - Laboratorium Wielkoprądowe (High Current Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA Nr AB 323.
- Laboratorium Fabryczne ABB Sp. z o.o. (ABB Manufacturing Plant Laboratory) in Przasnysz – Punkt Legalizacyjny OUM Warszawa (OUM Warsaw Verification Unit) – deviation measurement, and product tests under supervision of Instytut Energetyki (Institute of Power Engineering), Laboratorium Wysokich Napięć (High Voltage Laboratory).
- Laboratorium Badawcze Aparatury Rozdzielczej (Distribution Equipment Test Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA No AB 074.

4. Test result list

4.1. Type tests, additional tests

The tests were made on selected PVA ...a combined transformer models (various rated currents for the PVA...a current elements, various main circuit designs, various design of PVA...a transformers secondary circuits, different accuracy classes and various insulation covers, etc.) The tests results are valid for the entire combined transformer series acc. to the list as suggested for

certification. Table 1 shows manufacturer's solutions for the PVA...a current circuits. Representatives for short-circuit tests and heating tests were selected from that list.

PVA...a combined transformers were selected to temperature-rise test based on the most heat-exposed design solutions.

Voltage tests were made for two combined transformers: PVA 123a, and 145a.

The short-circuit withstand tests were made for PVA...a combined transformers. Representatives were selected based on their exposition to dynamic and thermal effects to the main circuits.

Table 2 shows carried out tests. Their scope meets requirements included in respective standards for: type tests, special tests, routine tests, and some additional requirements. Respective item numbers in PN-EN 61869 and IEC 61869 as well as report numbers with detailed test results are listed.

Results of all tests were positive.

4.2. Routine tests

Routine tests and accuracy class tests were carried out at the manufacturer's laboratory for all the combined transformers tested under the IEn supervision.

The tests included:

- oil measurements before filling the instrument transformer,
- verification of markings,
- power-frequency voltage withstand tests on primary terminals,
- power-frequency voltage withstand tests on secondary terminals,
- non-complete discharge intensity,
- inter-winding insulation test,
- test for accuracy,
- over-current coefficient determination,
- magnetisation characteristics determination,
- measurement of capacitance and dielectric dissipation factor,
- winding resistance measurement.

Test results were listed in protocols, their numbers being the same as that of the combined transformer tested. After the voltage tests and short circuit tests, additional routine tests and accuracy class tests were carried out.

Test result: positive

Table 1. Main circuit list:

Circuit design description	Current circuit assembly drawing number	Drawing title:	Ith/Idyn level assumed	Remarks	Tests carried out with Ith/Idyn current
Rod ϕ40 Cu	2GKK314130A0001	Main circuit, rod ϕ40 Cu	63/158 kA	Prototype 2	P2 positive test
Rod ϕ40 Al	2GKK314131A0001	Main circuit, rod ϕ40 Al	63/158 kA	Prototype 8	P8 positive test
Rod ϕ40 Al + pipe ϕ60x4 Al	2GKK314132A0001	Main circuit, rod ϕ40 Al + pipe ϕ60x4 Al	63-63/ 158-158 kA	Prototype 8	P8 positive test
Rod ϕ40 Al + pipe ϕ60x4 Al + 2 turns of 240 mm2 cable	2GKK314133A0001	Main circuit, rod ϕ40 Al + pipe ϕ60x4Al + 2 turns of 240 mm2 cable	63-63-40/ 158-158-100 kA	Prototype 1	P1 positive test.
1 turn of 240 mm2 cable	2GKK314134A0001	Main circuit, 1 turn of 240 mm2 cable	40/100 kA	Prototype 1	P1 positive test.
2 turns of 240 mm2 cable	2GKK314134A0002	Main circuit, 2 turns of 240 mm2 cable	40/100 kA	Prototype 1	P1 positive test.
3 turns of 120 mm2 cable	2GKK314137A0001	Main circuit, 3 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
6 turns of 120 mm2 cable	2GKK314137A0002	Main circuit, 6 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
9 turns of 120 mm2 cable	2GKK314137A0003	Main circuit, 9 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
12 turns of 120 mm2 cable	2GKK314137A0004	Main circuit, 12 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
3 + 3 turns of 120 mm2 cable	2GKK314138A0001	Main circuit, 3 + 3 turns of 120 mm2 cable	20-20 / 50-50 kA	Prototype 7	P7 positive test
6 + 6 turns of 120 mm2 cable	2GKK314138A0002	Main circuit, 6 + 6 turns of 120 mm2 cable	20-20 / 50-50 kA	Prototype 7	P7 positive test
3 + 3 + 6 turns of 120 mm2 cable	2GKK314139A0001	Main circuit, 3 + 3 + 6 turns of 120 mm2 cable	20-20-20/ 50-50-50 kA	Prototype 7	P7 positive test

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Table 2. List of tests made for PVA...a combined instrument transformer

Item	Test type	Requirements	Report numbers
	TYPE TESTS		
1	Short-time current test	IEC 61869-4, cl. 7.2.201 PN EN 61869-2, cl.7.2.201	EUR/71//E/13-1 EUR/71//E/13-3 EUR/71//E/13-4 EUR/74//E/13
2	Temperature-rise test	IEC 61869-4, cl.7.2.2 PN EN 61869-2 cl.7.2.2 PN EN 61869-2, cl. 7.2.2.204 PN EN 61869-3, cl.7.2.2	EWP/10/E/2014-1 EWP/10/E/2014-2 EWP/35/E/2013-1 EWP/07/E/2012-4
3	Impulse voltage withstand test	IEC 61869-4, cl. 7.2.3 PN-EN 61869-1, cl. 7.2.3 PN EN 61869-3, item 7.2.3	EWN/145/E/13
4	Wet test	IEC 61869-4, cl. 7.2.4 PN-EN 61869-1, cl. 7.2.4 PN-EN 61869-3, cl. 7.2.4	EWN/145/E/13
5	Short-circuit withstand capability test	IEC 61869-4, cl. 7.2.301 PN EN 61869-3, item 7.2.301	EUR/33/E/11-2
6	Tests for accuracy and mutual influence test	IEC 61869-4, cl. 7.2.6.401, 7.2.6.402 and 7.3.5 PN EN 61869-2, cl. 7.2.6 PN EN 61869-3, cl. 7.2.6	EWN/145/E/13 and protocols from manufacturer's laboratory
7	RIV test	PN EN 61869-1, cl. 7.2.5.1	EWN/145/E/13
8	Test for composite error	PN EN 61869-2, cl. 7.2.6.203	EUR/71//E/13-3 EUR/71//E/13-4
9	Terminal box verification of the IP coding	PN EN 61869-1, cl. 7.2.7.1 PN-EN 60529, cl.13.14	8281/NZL/NBR/12
10	Mechanical impact test (IK)	PN EN 61869-1, cl. 7.2.7.1 PN-EN 62272	EWP/35/E/2013-3
	SPECIAL TESTS		
11	Chopped impulse voltage withstand test on primary terminals.	IEC 61869-4, cl. 7.4.1 PN-EN 61869-1, cl. 7.4.1 PN EN 61869-3, cl. 7.4.1	EWN/145/E/13
12	Mechanical tests	IEC 61869-4, cl. 7.4.5 PN-EN 61869-1, cl. 7.4.5	EUR/66/E/13-1 EUR/66/E/13-2
13	Transmitted overvoltage test	IEC 61869-4, cl. 7.4.4 PN-EN 61869-1, cl. 7.4.4 PN EN 61869-3, cl. 7.4.4	EWN/145/E/13
14	Measurement of capacitance and dielectric dissipation factor	IEC 61869-4, cl. 7.4.3 PN-EN 61869-1, cl. 7.4.3 PN EN 61869-2, cl. 7.4.3 PN EN 61869-3, cl. 7.4.3	and protocols from manufacturer's laboratory
	ADDITIONAL TESTS		
15	Capacitor discharge test	C = 6µF. $U = 1.1 \cdot \sqrt{2} \cdot 110/\sqrt{3}$ kV No damage, no temperature increase above 65 K.	EWN/145/E/13

5. SUMMARY

Based on the test results for selected representatives of PVA 123a and PVA 145a instrument transformer series as selected and based on analysis of the standards, it was determined that:

- All tests from the type test range, special tests and additional tests which were carried out were sufficient for a complete evaluation of the apparatuses.
- Instrument transformer errors tests and instrument transformer secondary circuit designs were analysed, and their metrological properties were confirmed.
- PVA 123a and PVA 145a instrument transformer main circuit designs were analysed. It was determined that the short-circuit tests and heating tests as carried out are binding for all design solutions.
- Tests were made according to requirements of the 61869 series standard (PN and IEC)
- Taken the test results under consideration, the technical data listed in Tables 3 and 4 may be referenced to the PVA 123a and PVA 145a instrument transformer series.
- This document may be a basis for issuing compliance certificates for PVA 123a and PVA 145a instrument transformer series manufactured by ABB Sp. z o.o. Oddział w Przasnyszu. The certificate validity date is suggested to be February 2017.

Table 3. List of technical data assigned to PVA 123a

Combined transformer type PVA 123a	
Rated primary voltage [U_{pr}]	110/√3 kV
Highest voltage of combined transformer [U_m]	≤ 126 kV
Rated frequency [f_R]	50 Hz
Rated insulation level	AC 230 kV / LI 550 kV
Burden class'	F_R = 3.600 N
External insulation – creepage distance of insulator'	3.640–4.495 mm[1]
Degree of protection of secondary terminal enclosure	IP55
Degree of protection to mechanical impact of enclosure [2]	IK7
Current element	
Rated primary current [I_{pr}]	50 A + 3.000 A
Extended current rating	up to 200%
Rated continuous thermal current [I_{cth}]	≤ 3.000 A
Rated short-time thermal current [I_{th}] during 1 sec	20 kA or 40 kA or 63k A
Rated short-time thermal current [I_{th}] during 3 sec	20 kA or 40kA
Rated dynamic current [I_{dyn}]	50 kA or 100 kA or 158 kA
Rated secondary current [I_{sr}]	1 A or 5 A
Core power to measurements and to protection (S_r)	1VA – 200 VA
Measure core accuracy class (cl.)	0.1: 0.2: 0.2S: 0.5: 0.5S: 1: 3: 5
Protective core accuracy class (cl.)	5P; 10P; 5PR; 10PR; PX; PXR; TPX; TPY; TPZ
Voltage element	
Rated voltage factor [F_V] / time	1.5/30 sec; 1.9/30 sec or 1.9/8 h
Rated secondary voltage [U_{sr}]	100/√3 V; 110/√3 V;
Windings class to measurements and to protection (cl.)	0.1: 0.2; 0.5; 1: 3; 3P; 6P
Windings power to measurements and to protection (S_r)	≤ 1.000 VA
Rated voltage of residual voltage winding [$U_{sr\,da-dn}$]	100/3 V; 110/3 V; 100 V; 110 V
Residual voltage winding class (cl.)	0.5; 1; 3; 3P; 6P
Residual voltage winding power (S_r)	≤ 450 VA
Total thermal limiting output [S_{th}]	4.000 VA

REMARKS:

[1] Applies to composite and ceramic insulators.

[2] Do not apply to ceramic insulators.

Table 3. List of technical data assigned to PVA 145a

Combined transformer type PVA 145a	
Rated primary voltage [U_{pr}]	132/√3 kV
Highest voltage of combined transformer [U_m]	≤ 145 kV
Rated frequency [f_R]	50 Hz
Rated insulation level	AC 275 kV / LI 650 kV
Burden class	F_R = 3,600 N
External insulation – creepage distance of insulator	3,640–4,495 mm[1]
Degree of protection of secondary terminal enclosure	IP55
Degree of protection to mechanical impact of enclosure [2]	IK7
Current element	
Rated primary current [I_{pr}]	50 A ÷ 3,000 A
Extended current rating	up to 200%
Rated continuous thermal current [I_{cth}]	≤ 3,000 A
Rated short-time thermal current [I_{th}] during 1 sec	20 kA or 40 kA or 63k A
Rated short-time thermal current [I_{th}] during 3 sec	20 kA or 40kA
Rated dynamic current [I_{dyn}]	50 kA or 100 kA or 158 kA
Rated secondary current [I_{sr}]	1 A or 5 A
Core power to measurements and to protection (S_c)	1VA – 200 VA
Measure core accuracy class (cl.)	0.1; 0.2; 0.2S; 0.5; 0.5S; 1; 3; 5
Protective core accuracy class (cl.)	5P; 10P; 5PR; 10PR; PX; PXR; TPX; TPY; TPZ
Voltage element	
Rated voltage factor [F_V] / time	1.5/30 sec; 1.9/30 sec or 1.9/8 h
Rated secondary voltage [U_{sr}]	100/√3 V; 110/√3 V;
Windings class to measurements and to protection (cl.)	0.1; 0.2; 0.5; 1; 3; 3P; 6P
Windings power to measurements and to protection (S_r)	≤ 1,000 VA
Rated voltage of residual voltage winding [$U_{sr(da-dn)}$]	100/3 V; 110/3 V; 100 V; 110 V
Residual voltage winding class (cl.)	0.5; 1; 3; 3P; 6P
Residual voltage winding power (S_r)	≤ 450 VA
Total thermal limiting output [S_{Vth}]	4,000 VA

REMARKS:

[1] Applies to composite and ceramic insulators.
[2] Do not apply to ceramic insulators.

APPENDIX

Type test reports, special test reports (pages not numbered)

D1. Report No EWP/10/E/2014-1e. Temperature-rise test High Current Laboratory. Warsaw. January 2014.

D2. Report No EWP/10/E/2014-2e. IEn. Temperature-rise test High Current LaboratoryWarsaw. February 2014.

D3. Report No EWP/35/E/2013-1e. IEn. Temperature-rise tests. High Current Laboratory Warsaw. February 2014.

D4. Report EUR/66/E/13-2 E). Mechanical tests Distribution Equipment Laboratory Warsaw. December 2013.

D5. Report No EUR/66/E/13-1 E (Mechanical tests). IEn. Distribution Equipment Laboratory Warsaw. December 2013.

D6. Report No EUR/71/E/13-3 E (Short-time current test. combined error measurement. test of strength against short-circuit in the secondary circuit). IEn. Distribution Equipment Laboratory Warsaw. January 2014.

D7. Report No EUR/74/E/13 E Short-time current test. Test for composite error). IEn Distribution Equipment Laboratory Warsaw December 2013.

D8. Report No EUR/71/E/13-1 E Short-time current test. IEn Distribution Equipment Laboratory Warsaw. January 2014.

D9. Report No EUR/71/E/13-4 E Short-time current test. Test for composite error). IEn. Distribution Equipment Laboratory). Warsaw. January 2014.

D10. Test report No EWN/145/E/13. Type tests. special tests and additional tests of combined transformers type PVA123a and PVA145a manufactured by ABB sp. z o.o.). IEn. High Voltage Laboratory Warsaw. January 2014.

D11. Report No 8281/NZL/NBR/12. IP tests for terminal box. IEl. Distribution Equipment Test Laboratory Warsaw. July 2012.

D12. Report No EWP/35/E/2013-3e Mechanical impact test. IEn High Current Laboratory). Warsaw. February 2014

INSTITUTE OF POWER ENGINEERING
DISTRIBUTION EQUIPMENT LABORATORY

01-330 Warsaw, ul Mory 8
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tel. +48 22 345-13-86

TEST REPORT No. EUR/04/E/14 E

TEST OBJECT:	Combined instrument transformer type PVA 145a with composite insulator Serial No. 2GKP013K1486145
MANUFACTURER:	ABB Sp. z o.o. Division in Przasnysz, ul. Leszno 59, 06-300 Przasnysz
TESTS ORDERED BY:	ABB Sp. z o.o., ul. Żegańska 1, 04-713 Warszawa order No. 4500531639 dated 20.01.2014
TYPE OF TESTS:	Short-circuit withstand capability test
TESTS PROCEDURE:	According to IEC 61869-3:2011
DATE OF TESTS:	21/22.01.2014
TESTS RESULT:	Positive for 76,2 kV at short-circuit in secondary circuits of VT

Tests result refers only to the test object

THE TESTS WERE WITNESSED BY:	-

Test engineer

Tomasz Kaczmarczyk

HEAD OF LABORATORY

Lidia Gruza

Warsaw, 03.02.2014

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1. TEST OBJECT

1.1 Description

Combined instrument transformer type PVA 145a is used for supplying of measuring and protection circuits in the network of maximum operating voltage 145 kV and frequency 50 Hz. The transformer consists of current and voltage transformers mounted in common housing with composite insulator immersed with transformer oil.

1.2 Technical data

The Manufacturer attributed the following construction data to the test object.

Maximum operating voltage	145 kV	
Rated frequency	50 Hz	
Terminal		
Rated continuous thermal current	150 A	300 A
Rated short-time current for 1 s	180 A	360 A
Rated dynamic current	20 kA	
	50 kA	

1.3 Technical documentation

For the purpose of tests the orderer delivered the following technical documentation:
- dimensional drawing combined transformer PVA 123a-145a, No. 2GKK614123 (17.12.2013),
- routine tests report of combined instrument transformer (04.12.2013),
- routine tests report of combined instrument transformer after short-time current test (27.01.2013),
- rating plate,
- instrument transformer electrical diagram prepared by ABB Sp. z o.o (Annex 3 and 4).

The laboratory proceeded the identification of test object on the base of above documentation and the rating plate. Conformity of manufacturing with constructional documentation is stated in manufacturer's declaration, copy of which presents Annex 4.

1.4 Preparation for tests

The test object was prepared for tests in the factory by the manufacturer.

2. SCOPE OF TESTS

Test program, agreed with orderer, comprised the following tests according to requirements of IEC 61869-3:2011:

- short-circuit withstand capability test acc. to item 7.2.301 of above standard at parameters:
  $U_p \geq 76{,}2$ kV, $t_p = 1$ s.

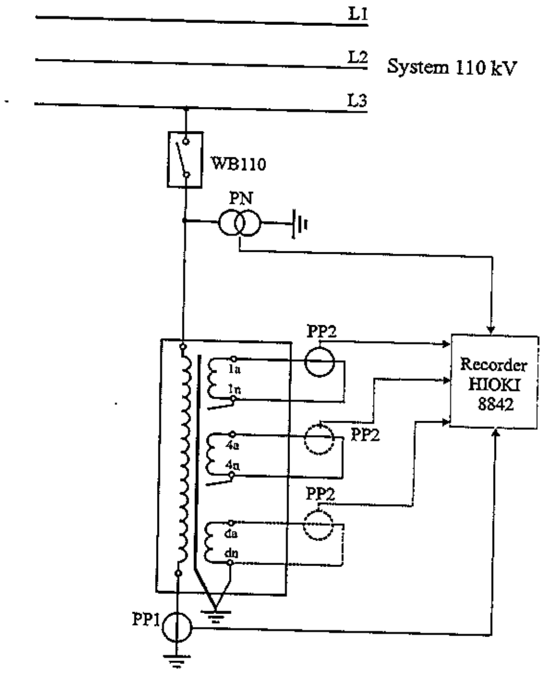
- routine test before and after short-time current test made in factory.

---

3. TEST AND MEASURING CIRCUITS

For the tests the transformer was fixed to the rigid construction of the test stand. Short-circuit withstand capability test were made in one phase circuit presented on fig. 1.
The following quantities were recorded during short-circuit withstand capability tests using digital recorder type HIOKI 8842:

- primary voltage and current, secondary current in short-circuited windings: 1a-1n (next 4a-4n and da-dn) during short-circuit withstand capability tests of voltage transformer using:
  - inductive voltage transformer type U110a class 0,5 with a ratio 110/√3/0,1/√3 kV/kV for primary voltage measurement,
  - laboratory current transformer type GE 4461 class 0,2 with a ratio 5/5 A/A for primary current measurement (uncertainty of measurement ±0,013% for k = 2),
  - laboratory current transformer type IL 20a class 0,5 with a ratio 2.000/5 A/A for secondary currents measurements (uncertainty of measurement ±0,012% for k = 2).



WB110 - back-up circuit-breaker
PN - voltage transformer
PP1, PP2 - current transformers

Fig. 1. Test and measuring circuits during short-circuit withstand capability tests

4. TESTS AND THEIRS DETAILED RESULTS

Tests results presents tables 1.

During the tests the following records were made:

- Nos. 33225, 33226, 33227 – short-circuit withstand capability test,
  (Annex 1 presents the copies of short-circuit test records - all records are stored in laboratory's archives),
- phot. 1 – current transformer on the tests stand
  (Annex 2 presents the photograph).

Table 1. Results of short-circuit withstand capability tests

Test No.	Terminals	U_z	I_{PS}	I_{SS}	t_z	Observations
-	-	kV	A	A	s	-
33225	1a – 1n	76,5[1)]	0,62	1062	1,04	Behaviour of transformer during the tests was correct. After tests no damage nor oil leak was stated.
33226	4a – 4n	76,5[1)]	0,61	1054	1,02	Behaviour of transformer during the tests was correct. After tests no damage nor oil leak was stated.
33227	da - dn	76,5[1)]	0,34	1019	1,02	Behaviour of transformer during the tests was correct. After tests no damage nor oil leak was stated.

Legend:

U_z - test voltage

I_{PS} - r.m.s. value of primary side test current

I_{SS} - r.m.s. value of secondary side test current

t_z - test duration

[1)] - required $U_z \geq 76,2$ kV

5. TESTS RESULTS EVALUATION

According to criteria given in IEC 61869-3:2011 the results of tests is positive for:

- 76,2 kV at short-circuit in secondary circuits of voltage transformer.

ANNEX 1

Test records

As not numbered pages the following copies of records are given:

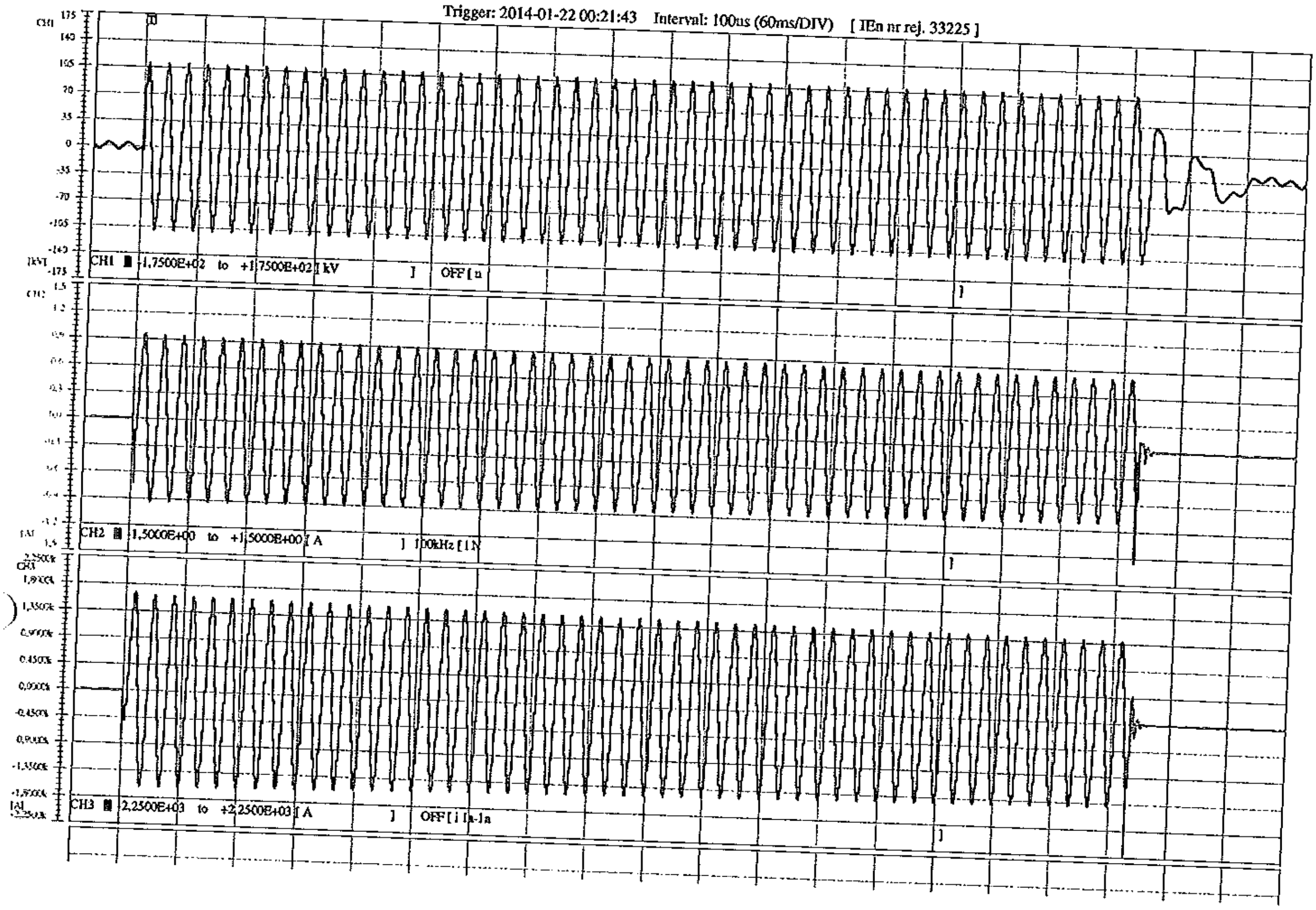
33225, 33226, 33227 – short circuit withstand capability test.

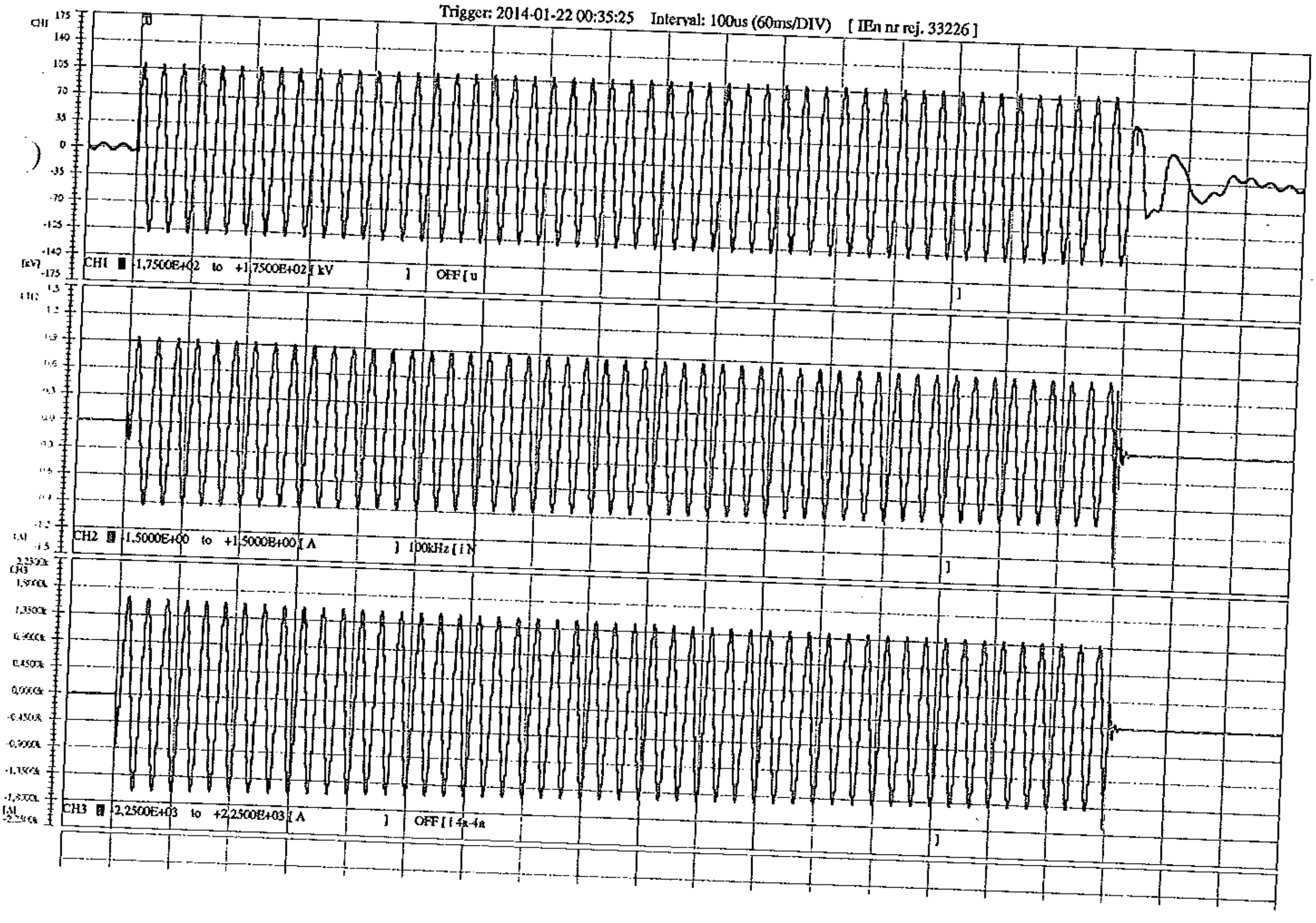
Denotations:

u_z –*test voltage during voltage transformer tests,*

i_N – *test current on primary side of VT,*

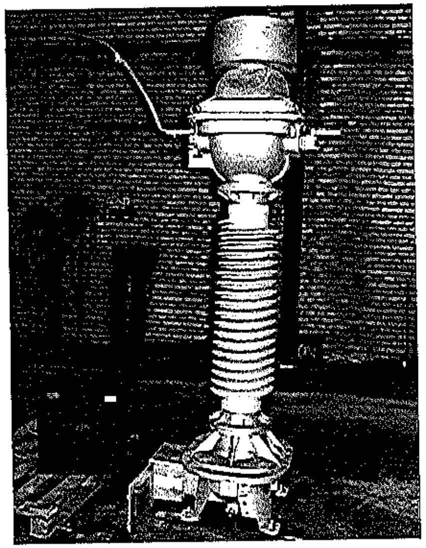
$i_{1a\text{-}1n}$, $i_{4a\text{-}4n,}$ $i_{da\text{-}dn}$– *test current on secondary side of VT.*


Trigger: 2014-01-22 00:21:43 Interval: 100us (60ms/DIV) [IEn nr rej. 33225]

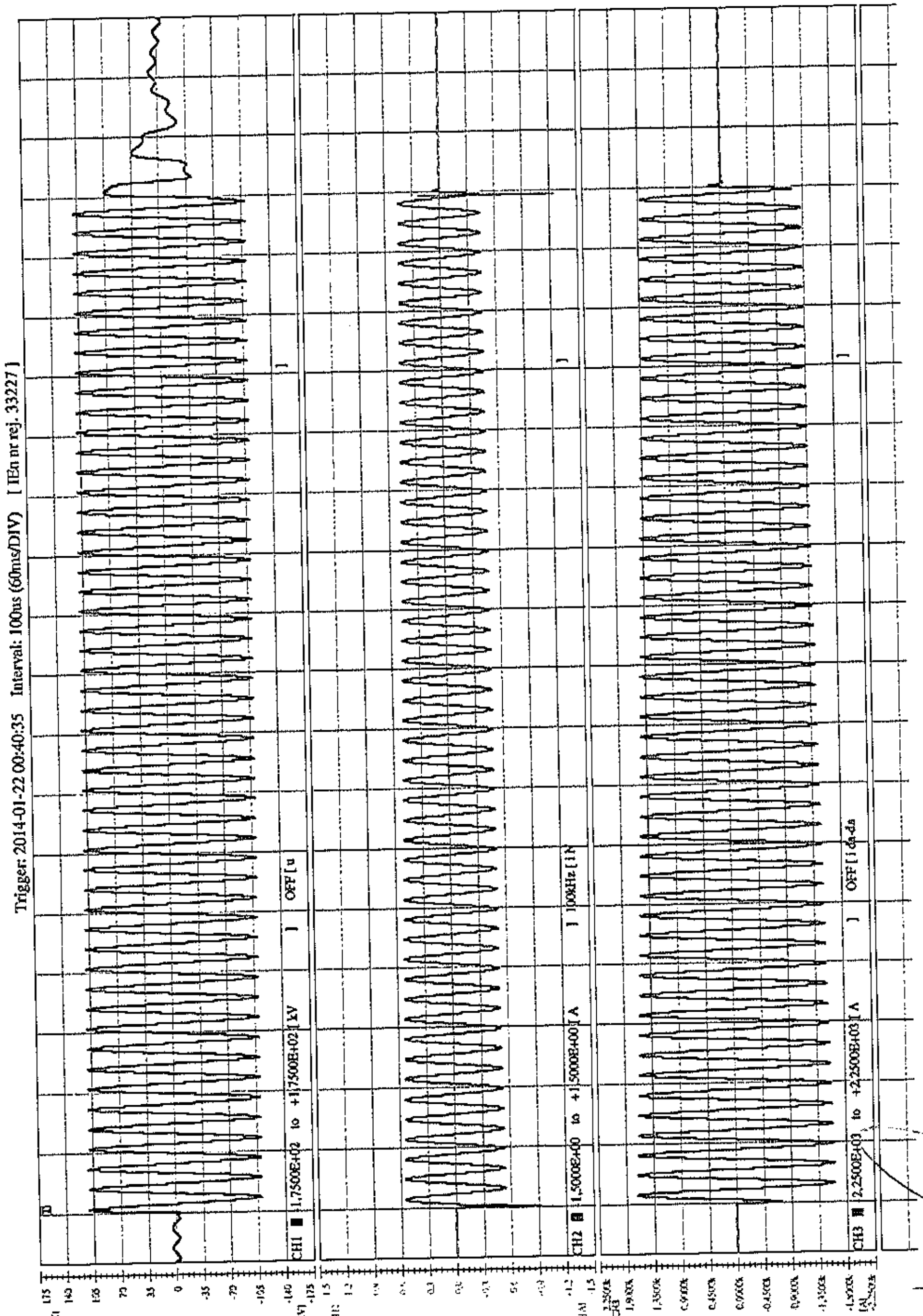

Trigger: 2014-01-22 00:35:25 Interval: 100us (60ms/DIV) [IEn nr rej. 33226]

ANNEX 2

Photographs taken during the tests



Phot. 1. PVA 123a after short circuit withstand capability test.



ANNEX 3 Routine test report before and after tests

ABB Sp. z o.o. 06-300 Przasnysz ul. Leszno 59		Routine tests report of combined instrument transformer			TYPE: PVA145a Serial no: 2GKP013K1488145	
A-N 132:√3 kV	Insulation level: 145/275/650 kV	Voltage factor: 1.9/8h	Ith 1s [kA]: 20-20	Idyn [kA]: 50-50	Icth [A]: 225-450	IEC 61869-4 50 Hz

VOLTAGE PART	Winding	Usn [kV]	Sn [VA]	class	Sth [VA]
	1a - 1n	0,11:√3	100	1,0	1000
	2a - 2n	0,11:√3	100	1,0	1000
	3a - 3n	0,11:√3	100	1/3P	1000
	4a - 4n	0,11:√3	100	3/3P	1000
	da - dn	0,11:3	200	3,0	450

CURRENT PART	Winding	Isn [A]	Sn [VA]	class	Ratio [A/A]
	1S1-1S2	5	30	0,2FS 5	150-300/5
	2S1-2S2	1	40	5P 20	150-300/1
	3S1-3S2	5	60	5P 20	150-300/5
	4S1-4S2	1	60	5P 20	150-300/1

List of performed tests:

1. Oil dielectric parameters check before filling (oil after treatment):
   tg δ acc. IEC 60247, breakdown voltage acc. IEC 60156 ☑
2. Verification of terminal ☑
3. Pressure and tightness test; oil overpressure: 0,6 bar / 24h – no traces of oil ☑
4. Power-frequency withstand on primary windings - P1+P2/A: Up = 275kV / 60s, f = 97Hz; N: Up = 3kV / 60s, f = 50Hz ☑
5. Partial discharge ☑
6. Power-frequency withstand test on secondary - Up = 3 kV/60s ☑
7. Inter-turn overvoltage test for current transformers - lower value (U peak=4,5kV or U peak for Icth) / 60s ☑
8. Determination of errors ☑
9. Determination of the over current factors: FS, ☑
10. Measurement of capacitance and dielectric dissipation factor - tg δ ☑
11. Determination of core magnetization characteristics ☑
12. Measurement of windings' resistance ☑

Oil dielectric parameters check before filling (oil after treatment)

- Measurement of oil tg δ according to IEC
  Tg δ = 0.06 %; electrical stress = 1kV/mm, f = 50Hz, oil temp. = 90C

- Measurement of breakdown voltage according to IEC 60156
  Mean breakdown voltage = 78.15 kV, Relative standard deviation = 5.99
  f = 50Hz, oil temp. = 25 °C, measurement with the stirrer, type of electrodes used: partially

Sample	Breakdown voltage [kV]
1	73.7
2	84.3
3	82.8
4	78.4
5	76.9
6	72.8

Partial discharge measurement

- Measurement according to procedure A (PD test voltages were reached while decreasing the after the power-frequency withstand test on primary
  Stress voltage: 275 kV / 60 s
  Frequency: 97 Hz

Test voltage	1,2 Um = 174 kV	1,2 Um / √3 = 100,5
Level of partial discharge	2 pC	1.2 pC

Remarks: background noise level: 1 (measured after voltage switch off), measuring circuit was calibrated with 5 pC (calibrating

Inter-turn overvoltage test for current transformers

Winding	Peak voltage on secondary winding [kVpeak]	Current in primary winding [A]
1S1-1S2	0.368	450
2S1-2S2	4.29	450
3S1-3S2	1.09	450
4S1-4S2	4.5	310

Determination of voltage part errors (ε U%), Δφ U min)

1a-1n: 100 VA
2a-2n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.164	-0.162	-0.162
Δφ U	-1.3	-1.3	-1.3

1a-1n: 25 VA
2a-2n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0,017	-0,016	-0,016
Δφ U	-1.3	-1.3	-1.3

2a-2n: 100 VA
1a-1n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.163	-0.162	-0.162
Δφ U	-1.1	-1.1	-1.1

2a-2n: 25 VA
1a-1n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.017	-0.015	-0.015
Δφ U	-1.3	-1.3	-1.3

3a-3n: 100 VA
1a-1n: 100VA; 2a-2n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.254	-0,251	-0.150	-0.148	-0,149	-0.314
Δφ U	-2.1	-1.2	-0.8	-0.8	-0.8	-4.2

3a-3n: 25 VA
1a-1n: 100VA; 2a-2n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.103	-0,102	-0,004	-0,003	-0,003	-0,170
Δφ U	-2.5	-1.5	-1.1	-1.1	-1.1	-4.6

4a-4n: 100 VA
1a-1n: 100VA; 2a-2n: 100VA; 3a-3n: 100VA p.f. = 0,8 lag. p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.261	-0.261	-0,163	-0.162	-0.162	-0.329
Δφ U	-1.0	-0.0	0.4	0.4	0.4	-3.1

1a-1n: 100 VA
2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	0.116	0.117	0.118
Δφ U	5.1	5.2	5.2

1a-1n: 25 VA
2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	0.263	0.265	0.265
Δφ U	5.1	5.1	5.2

2a-2n: 100 VA
1a-1n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	0.118	0.119	0.119
Δφ U	5.3	5.3	5.4

2a-2n: 25 VA
1a-1n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	0.268	0.267	0.267
Δφ U	5.2	5.2	5.2

3a-3n: 100 VA
1a-1n: 0 VA; 2a-2n: 0 VA; 4a-4n: 0 VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.022	0,027	0.127	0.129	0,129	-0.038
Δφ U	4.8	6.5	5.6	5.6	5.6	2.5

3a-3n: 25 VA
1a-1n: 0 VA; 2a-2n: 0 VA; 4a-4n: 0 VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.172	0.172	0.275	0.276	0.277	0.111
Δφ U	4.4	5.2	5.3	5.3	5.3	2.1

4a-4n: 100 VA
1a-1n: 0 VA; 2a-2n: 0 VA; 3a-3n: 0 VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.007	0.008	0.107	0.108	0.109	-0.060
Δφ U	5.6	6.4	0.4	6.4	6.5	3.3

4a-4n: 25 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 3a-3n: 100VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.098	-0.096	0.001	0.002	0.002	-0.165
Δφ U	-1.9	-1.0	-0.6	-0.6	-0.6	-4.1

4a-4n: 25 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 3a-3n: 0 VA

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.179	0.176	0.273	0.274	0.275	0.107
Δφ U	4.8	5.4	5.5	5.5	5.5	2.3

da-dn: 200 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA
p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.177	-0.159	-0.125
Δφ U	16.6	16.1	15.3

da-dn: 50 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	1,053	1.053	1.053
Δφ U	9.7	9.7	9.8

* at 1,9 Un winding da-dn is loaded with 200 VA, p.f. = 0,8

Determination of current part errors (ε 1%), Δφ 1 min)

Ipn (A): 150

1S1-1S2: 30 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.165	-0.113	-0.044	-0.060
Δφ I	4,3	1,7	-0,4	0,9

1S1-1S2: 7,50 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.020	-0.017	0.003	0.007
Δφ I	2,4	1,6	0,4	0,2

2S1-2S2: 40 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.141
Δφ I	0,9

3S1-3S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.153
Δφ I	1,7

4S1-4S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.146
Δφ I	1.3

Ipn (A): 300

1S1-1S2: 30 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0,441	-0,110	-0,042	-0,057
Δφ I	17.7	1.6	-0.4	0.7

1S1-1S2: 7,50 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0,043	-0,018	0.003	0,004
Δφ I	3,1	2.1	0.5	0.6

2S1-2S2: 40 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.140
Δφ I	0.8

3S1-3S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.148
Δφ I	1.7

4S1-4S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.145
Δφ I	1,2

Current part: Measurements $\varepsilon_I = \pm 0{,}046\ \%$, $\Delta\varphi_I = \pm 2{,}3$ min
Voltage part: Measurements uncertainty: $\varepsilon_U = \pm 0{,}044\ \%$, $\Delta\varphi_U = \pm 2{,}2$ min

Determination of the over current factors:

- Instrument security factor (FS) of measuring cores

Winding	Ie [A]	U [V]	E_{FS} [V]	Condition	Assessment
1S1-1S2	2.5	17.84	36.02	U < E_{FS}	☑

- accuracy limit factor (ALF) – test for composite error ε_c of protective cores

Winding	E_{ALF} [V]	Ie [A]	ε_c [%]	Condition	Assessment
2S1-2S2	960.93	0.015	0.08	$\varepsilon_c \leq 5\%$	☑

3S1-3S2	278.86	0.097	0.1	$\varepsilon_c \leq 5\%$	☑
4S1-4S2	1388.83	0.015	0.08	$\varepsilon_c \leq 5\%$	☑

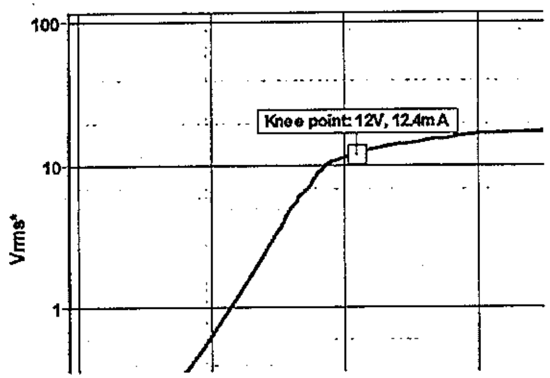
Measurement of capacitance and dielectric dissipation factor - δ
Temperature: 24.2 °C, Frequency: 50

Primary voltage	Instrument transformor			Current part			Voltage part		
	Tg δ	Capacity	Leak.current	Tg δ	Capacity	Leak.current	Tg δ	Capacity	Leak.current
	[%]	[pF]	[mA]	[%]	[pF]	[mA]	[%]	[pF]	[mA]
10 kV	0.23	1404	4.399	0.24	1128	3.572	0.23	275	0.862
63 kV	0.23	1404	27.83	0.24	1129	22.34	0.22	276	5.46
71 KV	0.23	1404	31.36	0.24	1129	25.21	0.22	276	6.156

Core magnetization characteristics:

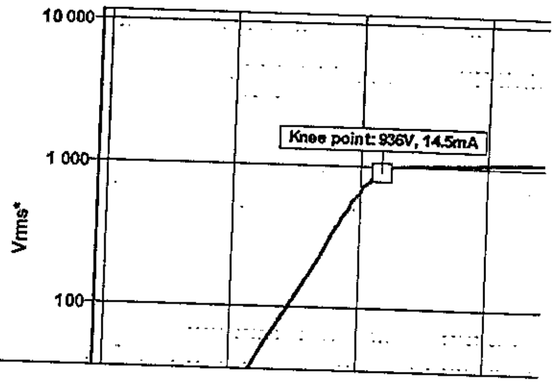
Winding 1S1-1S2

[V]	[mA]
18	3659
16.7	103.41
15.5	48.71
14.4	27.86
13.5	19.59
13	15.84
12.4	12.69
11.8	10.63
11.3	9.23
10.6	7.96
8.4	5.89
6.1	4.59
4	3.37
1.7	1.96
0.1	0.25



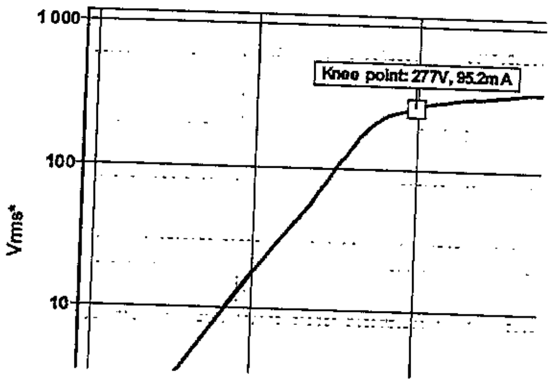
Winding 2S1-2S2

[V]	[mA]
1132.4	1427.9
1127.1	877.7
1104.4	263.7
1029.5	26.54
1000.1	17.54
978.	16.07
948.	14.66
894.	13.85
832	12.48
782.	11.95
612	9.3
442.	7.32
274.	5.42
103.	2.88
10.2	0.66



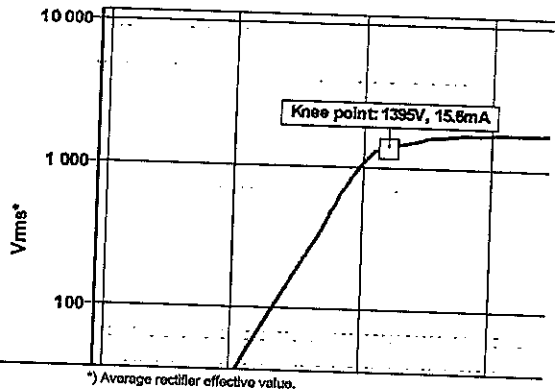
Winding 3S1-3S2

[V]	[mA]
375.	7431
331.	241.6
310.	162
304.	146.6
297.	128
282.	101.48
266.	83.09
253.	72.52
239.	65.23
197.	51.48
153.	41.82
111	33.85
68.8	25.06
26.5	13.39
2.4	2.72



Winding 4S1-4S2

[V]	[mA]
1872.8	2020.9
1734.7	80.36
1627.6	35.01
1534.8	23.91
1509.5	21.62
1451	17.85
1393.2	15.51
1339.3	13.82
1280.7	12.48
1052.2	9.76
832.	8.05
608.	6.47
389.	4.93
168.	2.92
10.3	0.52



*) Average rectifier effective value.

Measurement of windings' resistance

Windings' resistance of current part:

	R (23 °C)	Rct (75 °C)
P1-P2 range 150A	1883.0 μΩ	2267.8 μΩ
P1-P2 range 300A	970.0 μΩ	1168.2 μΩ
1S1-1S2	0.239 Ω	0.287 Ω
2S1-2S2	7.990 Ω	9.623 Ω
3S1-3S2	0.388 Ω	0.468 Ω
4S1-4S2	9.450 Ω	11.381 Ω

Windings' resistance of voltage part:

	R (23 °C)	Rct (75 °C)
A-N	21.30 kΩ	25.653 kΩ
1a-1n	47.010 mΩ	56.617 mΩ
2a-2n	48.480 mΩ	58.387 mΩ
3a-3n	50.000 mΩ	60.218 mΩ
4a-4n	51.700 mΩ	62.265 mΩ
da-dn	34.080 mΩ	41.045 mΩ

Checked by: .... OG-4 KJ-08 ...

Przasnysz, 2013-12-04

ABB Sp. z o.o. 06-300 Przasnysz ul. Leszno 59		Routine tests report of combined instrument transformer After short circuit voltage part			TYPE: PVA145a Serial no: 2GKP013K1486145	
A-N 132:√3 kV	Insulation level:	Voltage factor: 1.9/8h	Ith 1s [kA]: 20-20	Idyn [kA]: 50-50	Icth [A]: 225-450	IEC 61869-4 50 Hz

VOLTAGE PART	Winding	Usn [kV]	Sn [VA]	class	Sth [VA]
	1a - 1n	0,11:√3	100	1,0	1000
	2a - 2n	0,11:√3	100	1,0	1000
	3a - 3n	0,11:√3	100	1/3P	1000
	4a - 4n	0,11:√3	100	3/3P	1000
	da - dn	0,11:3	200	3,0	450

CURRENT PART	Winding	Isn [A]	Sn [VA]	class	Ratio [A/A]
	1S1-1S2	5	30	0,2FS 5	150-300/5
	2S1-2S2	1	40	5P 20	150-300/1
	3S1-3S2	5	60	5P 20	150-300/5
	4S1-4S2	1	60	5P 20	150-300/1

List of performed tests:

1. Oil dielectric parameters check before filling (oil after treatment):
   tg δ acc. IEC 60247, breakdown voltage acc. IEC 60156 ☑
2. Verification of terminal ☑
3. Pressure and tightness test: oil overpressure: 0,8 bar / 24h – no traces of oil ☑
4. Power-frequency withstand
   on primary windings - P1+P2/A: Up = 247,5 kV / 60s, f = 105Hz; N: Up = 3kV / 60s, f = 50Hz ☑
5. Partial discharge ☑
6. Power-frequency withstand test on secondary - Up = 3 kV/60s ☑
7. Inter-turn overvoltage test for current - lower value (U peak=4,5kV or U peak for Icth) / 60s ☑
8. Determination of ☑
9. Determination of the over current factors: FS, ALF ☑
10. Measurement of capacitance and dielectric dissipation factor - δ ☑
11. Determination of core magnetization characteristics ☑
12. Measurement of windings' resistance ☑

Oil dielectric parameters check before filling (oil after

- Measurement of oil tg δ according to IEC
  Tg δ = 0,06 %; electrical stress = 1kV/mm, f = 50Hz, oil temp. = 90C

- Measurement of breakdown voltage according to IEC 60156
  Mean breakdown voltage = 78.15 kV, Relative standard deviation = 5.99
  f = 50Hz, oil temp. = 25 °C, measurement with the stirrer, type of electrodes used: partially

Sample	Breakdown voltage [kV]
1	73.7
2	84.3
3	82.8
4	78.4
5	76.9
6	72.8

Partial discharge measurement

- Measurement according to procedure B voltage

Stress voltage: 247,5 kV / 60 s
Frequency: 97 Hz

Test voltage	1,2 Um = 174kV	1,2 Um / √3 = 100.5
Level of partial discharge	2.5 pC	1.2 pC

Remarks: background noise level: 1 (measured after voltage switch off), measuring circuit was calibrated with 5 pC (calibrating

Inter-turn overvoltage test for current transformers

Winding	Peak voltage on secondary winding [kVpeak]	Current in primary winding [A]
1S1-1S2	0.384	450
2S1-2S2	4.5	430
3S1-3S2	1.07	450
4S1-4S2	4.5	280

Determination of voltage part errors (ε U%), Δφ U min)

1a-1n: 100 VA p.f. = 0,8 lag.
2a-2n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.161	-0.159	-0.159
Δφ U	-1.4	-1.4	-1.4

1a-1n: 25 VA p.f. = 0,8 lag.
2a-2n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.015	-0.013	-0.013
Δφ U	-1.4	-1.4	-1.4

2a-2n: 100 VA p.f. = 0,8 lag.
1a-1n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.161	-0.160	-0.160
Δφ U	-1.2	-1.2	-1.2

2a-2n: 25 VA p.f. = 0,8 lag.
1a-1n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.014	-0.013	-0.013
Δφ U	-1.3	-1.4	-1.3

3a-3n: 100 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.250	-0.251	-0.149	-0.147	-0.147	-0.314
Δφ U	-2.3	-1.3	-0.8	-0.9	-0.8	-4.2

3a-3n: 25 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.103	-0.102	-0.003	-0.002	-0.002	-0.170
Δφ U	-2.6	-1.6	-1.2	-1.2	-1.1	-4.6

4a-4n: 100 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 3a-3n: 100VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.257	-0.258	-0.161	-0.160	-0.160	-0.329
Δφ U	-1.1	-0.2	0.2	0.2	0.3	-3.1

1a-1n: 100 VA p.f. = 0,8 lag.
2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	0.118	0.120	0.120
Δφ U	5.1	5.1	5.2

1a-1n: 25 VA p.f. = 0,8 lag.
2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	0.265	0.267	0.267
Δφ U	5.1	5.1	5.2

2a-2n: 100 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	0.119	0.121	0.121
Δφ U	5.3	5.3	5.4

2a-2n: 25 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	0.266	0.267	0.268
Δφ U	5.1	5.2	5.2

3a-3n: 100 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 4a-4n: 0 VA

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.028	0.028	0.128	0.130	0.130	-0.038
Δφ U	4.7	5.4	5.5	5.5	5.6	2.6

3a-3n: 25 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 4a-4n: 0 VA

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.174	0.175	0.275	0.276	0.276	0.111
Δφ U	4.4	5.2	5.2	5.2	5.3	2.1

4a-4n: 100 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 3a-3n: 0 VA

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0,011	0.011	0,110	0,112	0,111	-0.060
Δφ U	5.8	6.3	6.3	6.3	6.4	3.3

4a-4n: 25 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 3a-3n: 100VA p.f. = 0,8 lag.

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	-0.093	-0.096	0.003	0.004	0.004	-0.165
Δφ U	-2.0	-1,0	-0.8	-0.7	-0.6	-4.1

4a-4n: 25 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 3a-3n: 0 VA

	0,02 Un	0,05 Un	0,8 Un	1,0 Un	1,2 Un	1,9 Un*
ε U	0.179	0.177	0.274	0.275	0.276	0.107
Δφ U	4.7	5.4	5.4	5.4	5.5	2.3

da-dn: 200 VA p.f. = 0,8 lag.
1a-1n: 100VA; 2a-2n: 100VA; 3a-3n: 100VA; 4a-4n: 100VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.177	-0.159	-0.125
Δφ U	16.6	16.1	15.3

da-dn: 50 VA p.f. = 0,8 lag.
1a-1n: 0 VA; 2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	1.081	1.081	1.081
Δφ U	9.0	8.9	9.0

* at 1,9 Un winding da-dn is loaded with 200 VA, p.f. = 0,8

Determination of current part errors (ε I%), Δφ I min)

Ipn (A): 150

1S1-1S2: 30 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.175	-0.105	-0.042	-0.050
Δφ I	4.8	1.5	-0.4	0.5

2S1-2S2: 40 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.139
Δφ I	0.9

4S1-4S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.146
Δφ I	1.0

1S1-1S2: 7.50 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.023	-0.014	0.002	0.007
Δφ I	2.8	1.5	0.5	0.4

3S1-3S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.160
Δφ I	1.2

Ipn (A): 300

1S1-1S2: 30 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.166	-0.101	-0.041	-0.056
Δφ I	4.7	1.4	-0.4	0.7

2S1-2S2: 40 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.139
Δφ I	0.8

4S1-4S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.144
Δφ I	1.0

1S1-1S2: 7.50 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.014	-0.008	0.004	0.007
Δφ I	2.5	1.4	0.5	0.5

3S1-3S2: 60 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.157
Δφ I	1.3

Current part: Measurements $\varepsilon_I = \pm 0,045$ %, $\Delta\varphi_I = \pm 2,3$ min
Voltage part: Measurements uncertainty: $\varepsilon_U = \pm 0,044$ %, $\Delta\varphi_U = \pm 2,2$ min

Determination of the over current factors:

- instrument security factor (FS) of measuring cores

Winding	Ie [A]	U [V]	E_{FS} [V]	Condition	Assessment
1S1-1S2	2.5	17.84	35.93	U < E_{FS}	☑

- accuracy limit factor (ALF) – test for composite error ε_c of protective cores

Winding	E_{ALF} [V]	Ie [A]	εc [%]	Condition	Assessment
2S1-2S2	980.1	0.015	0.08	εc ≤5%	☑

3S1-3S2	278.51	0.1	0.1	εc ≤5%	☑
4S1-4S2	1385.12	0.015	0.08	εc ≤5%	☑

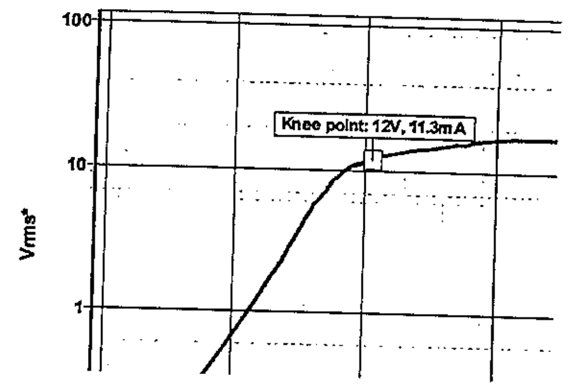
Measurement of capacitance and dielectric dissipation factor - δ
Temperature: 23.2 °C, Frequency: 50

Primary voltage	Instrument transformer			Current part			Voltage part		
	Tg δ [%]	Capacity [pF]	Leak.current [mA]	Tg δ [%]	Capacity [pF]	Leak.current [mA]	Tg δ [%]	Capacity [pF]	Leak.current [mA]
10 kV	0.23	1391	4.392	0.24	1115	3.53	0.23	276	0.871
63 kV	0.23	1391	27.54	0.23	1115	22.08	0.23	276	5.453
71 kV	0.23	1391	30.01	0.23	1115	24.70	0.23	275	6.122

Core magnetization characteristics:

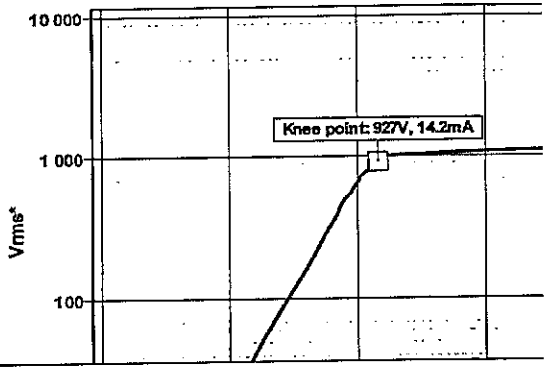
Winding 1S1-1S2

[V]	[mA]
18	3519.8
17	136.6
15.8	57.25
14.7	31.73
13.2	17.13
12.6	13.6
12.1	11.35
11.5	9.58
10.8	8.2
10.3	7.37
8.8	5.62
6.3	4.34
4	3.25
1.7	1.89
0.1	0.24



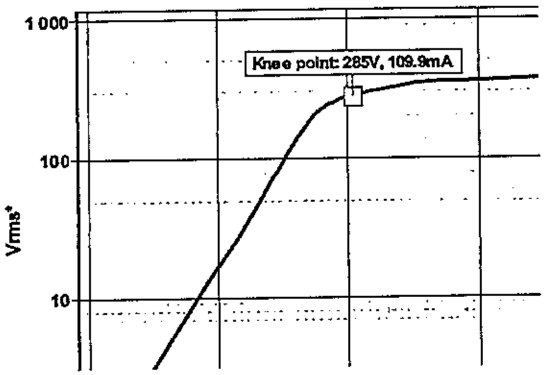
Winding 2S1-2S2

[V]	[mA]
1134.6	1823
1130.8	1194.6
1113.7	432.2
1047	40.79
1019.9	21.84
990.	16.73
967.	15.44
901.	13.44
847.	12.71
794.	12.29
621.	9.61
449.	7.46
277.	5.5
105.	2.95
10.7	0.7



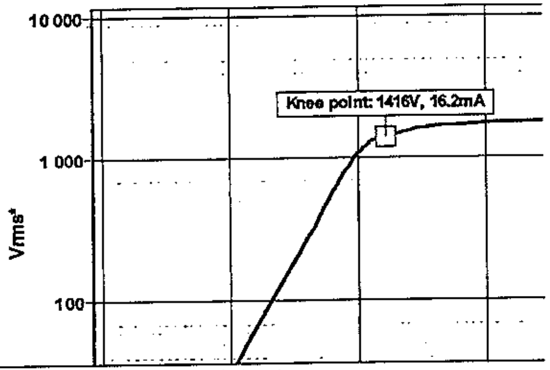
Winding 3S1-3S2

[V]	[mA]
377.	10440
335.	258.5
314	170.6
305.	148.6
300.	138.7
283.	106.74
270.	89.86
257	77.84
242.	68.66
200.	53.43
156.	43.17
113.	34.76
70.1	25.63
26.4	13.48
2.6	2.82



Winding 4S1-4S2

[V]	[mA]
1869	1774.6
1728.5	76.4
1610.1	31.58
1524.3	22.36
1499.9	20.66
1470.4	18.88
1413.6	16.1
1350.3	14.04
1298.1	12.73
1071.7	9.9
848.	8.23
611.	6.51
385.	4.9
159.	2.81
10.8	0.53



*) Average rectifier effective value.

Measurement of windings' resistance

Windings' resistance of current part:

	R (23 °C)	Rct (75 °C)
P1-P2 range 150A	1706.0 μΩ	2054.6 μΩ
P1-P2 range 300A	881.0 μΩ	1061.0 μΩ
1S1-1S2	0.236 Ω	0.284 Ω
2S1-2S2	7.950 Ω	9.575 Ω
3S1-3S2	0.385 Ω	0.464 Ω
4S1-4S2	9.270 Ω	11.164 Ω

Windings' resistance of voltage part:

	R (23 °C)	Rct (75 °C)
A-N	20.90 kΩ	25.171 kΩ
1a-1n	46.820 mΩ	56.388 mΩ
2a-2n	48.340 mΩ	58.219 mΩ
3a-3n	49.840 mΩ	60.025 mΩ
4a-4n	51.400 mΩ	61.904 mΩ
da-dn	34.010 mΩ	40.960 mΩ

Checked by: .... OG-4 KJ-06 ....

Przasnysz, 2014-01-27

ANNEX 4 **Documentations delivered by orderer**

ABB ABB Sp. z o.o.	Declaration of conformity	ABB Sp. z o.o. Dept. In Przasnysz POLAND

DECLARATION OF CONFORMITY No. 092/2013 (EN)
(acc. to ISO/IEC 17050-1)

Manufacturer: ABB Sp. z o.o. Dept. in Przasnysz

Address: Str. Leszno 59
06-300 Przasnysz / POLAND

Product: Combined Instrument Transformer PVA 145a

Above mentioned product comforms with the following standard :

Standard	Title	Edition/Date
IEC 61869 - 4	Combined Instrument Transformers	2013

Additional information:
Serial numbers: **2GKP013K1486145;**

Place and date of issue of declaration

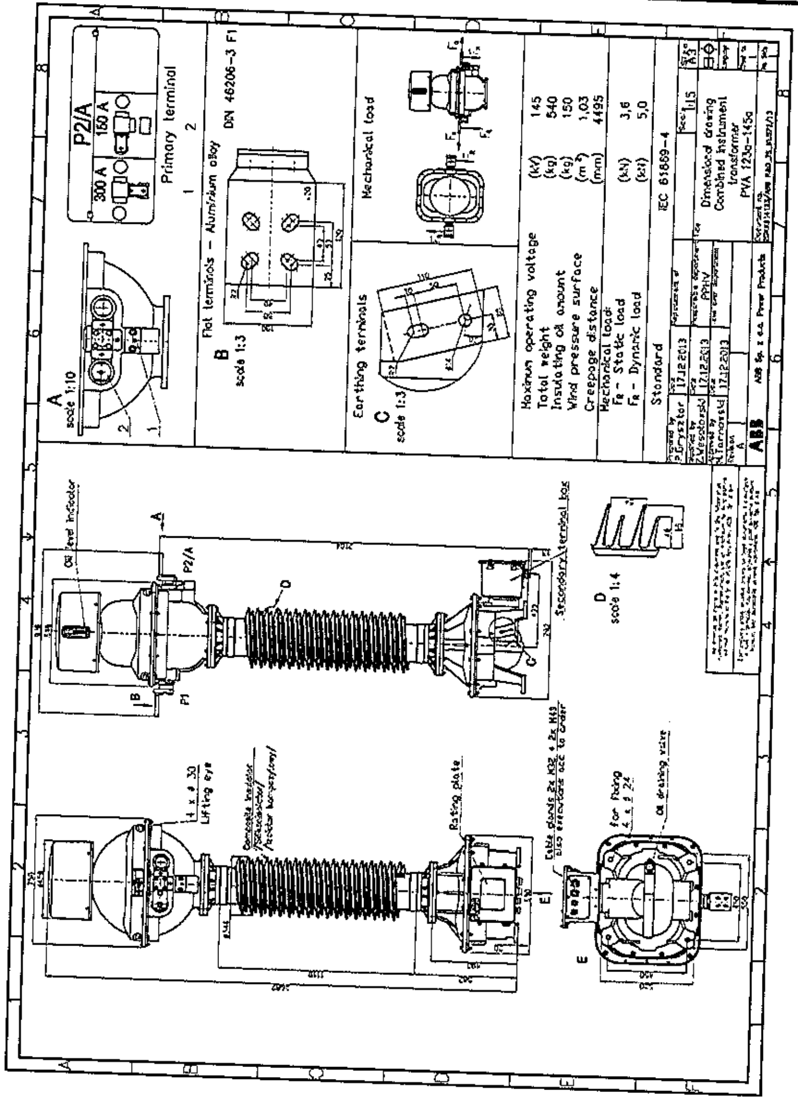
Przasnysz 13.01.2014

ABB
ABB Sp. z o.o.
ul. Żegańska 1, 04-713 Warszawa
NIP: 526-030-44-84; PL 5260304484
Regon 010017165
ODDZIAŁ W PRZASNYSZU
ul. Leszno 59, 06-300 Przasnysz
tel. (22) 223 8921, fax (22) 223 8958
(9)

Kierownik ds. Realizacji Zamówień
ABB Sp. z o.o.
Oddział w Przasnyszu
Małgorzata Zdziewska

Kierownik ds. Zapewnienia Jakości
ABB Sp. z o.o.
Oddział w Przasnyszu
Krzysztof Łabecki

(Name) (Signature)



ABB

Combined Instrument Transformer

Type PVA 145a

Insulation level 145/275/650 kV
Standard IEC 61869-4
fn 50 Hz
Oil type Nytro Libra
Weight / Oil weight 540 / 150 kg
Temp. range -50°C → +40°C
S/N 2GKP013K1486145
Voltage factor 1,9Un/8h
Ue 0,2 mV/kA

CURRENT PART

K_n 150-300 / 5-1-5-1 A/A
$I_{th}/1s$ 20-20 kA
I_{dyn} 50-50 kA
I_{cth} 180-360 A

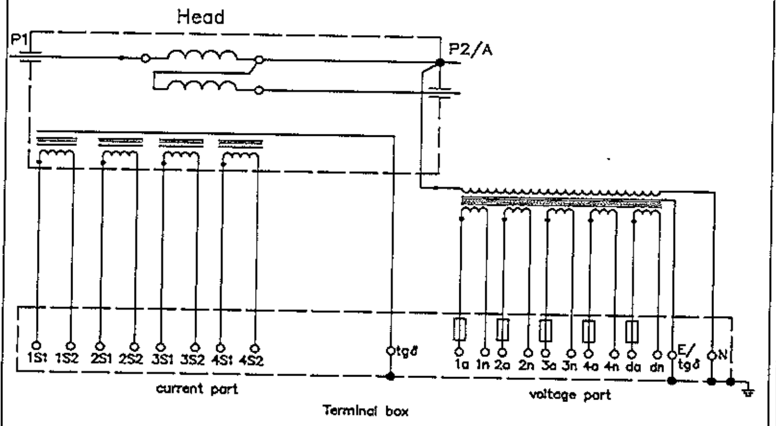
	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2	5S1-5S2	6S1-6S2
A	5	1	5	1		
VA	30	40	60	60		
Kl.	0,2	5P	5P	5P		
FS/ALF	5	20	20	20		
Ext.%	120					

VOLTAGE PART

A-N 132:√3 kV

	1a-1n	2a-2n	3a-3n	4a-4n	da-dn
V	110:√3	110:√3	110:√3	110:√3	110:3
VA	100	100	100	100	200
Kl.	1,0	1,0	1/3P	3/3P	3,0
VA_{th}	1000	1000	1000	1000	450

Transportation Vertical / Horizontal



Instrument transformer electrical diagram

ATTENTION!

1. HIGH VOLTAGE AT OPEN CURRENT SECONDARY TERMINALS XS1 – XS2
2. DURING INSTRUMENT TRANSFORMER OPERATION TERMINALS: N, E/tgδ, tgδ MUST BE EARTHED
3. AFTER THREE WINDINGS da - dn ARE CONNECTED IN BROKEN DELTA THE CIRCUIT SHOULD BE EARTHED IN ONE POINT ONLY

INSTYTUT ENERGETYKI
INSTITUTE OF POWER ENGINEERING
LABORATORIUM WIELKOPRĄDOWE
HIGH CURRENT LABORATORY

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01-330 Warszawa; Poland
phone/fax +48 22 836 80 16
e-mail: ewp@ien.com.pl
www.ien.com.pl/ewp

TEST REPORT NO.
EWP/03/E/2016

TEST OBJECT: Combined instrument transformer type PVA 145a

MANUFACTURER:
ABB Sp. z o.o.
ul. Leszno 59
06-300 Przasnysz, Poland

TESTS ORDERED BY:
ABB Sp. z o.o.
ul. Żegańska 1
04-713 Warszawa, Poland
Order No. 4500709453 dated 19.01.2016

TYPE OF TESTS: Temperature-rise test

TESTS PROCEDURE: IEC 61869-1:2007, IEC 61869-2:2012, IEC 61869-3:2011, IEC 61869-4:2013, IEC 62271-1:2007/A1:2011

OBJECT DELIVERED: 18.12.2015

DATE OF TESTS: 01.02-02.02.2016

TESTS RESULTS: Positive for current $I_{eth} = 3600A$

THE TESTS WERE WITNESSED BY: -

Authorised by
TEST ENGINEER:
Grzegorz ZABOKLICKI M.Sc. Eng.

Approved by
HEAD OF LABORATORY:
Maciej OWSIŃSKI M.Sc. Eng.

Warsaw, 15.02.2015

Contents

Report contains 16 numbered pages with:	
4	Figures
2	Appendices

1. Description of the test object

Test object	Combined instrument transformer
Type	PVA 145a
Serial number	2GKP015K1689425
Manufacturer	ABB Sp. z o.o.
Year of production	2015
Insulator	Porcelain insulator
Number of windings	VT part 5, CT part 4
Oil type	Nytro 10XN
Temperature range	-40°C - +40°C
Total weight / oil weight	620 / 150 kg
Dimensions	According to appendix No.1 2GKK614815A1277

The laboratory made the identification of test objects basing on documentation given in sub-cl. 3. The test object is shown in the figure 4. The object was prepared for tests by the Manufacturer.

2. Technical data declared by the Manufacturer

Rated voltage [kV]	132:√3
Maximum operating voltage [kV]	145
Rated frequency [Hz]	50
Voltage factor and time	1,9U_n/8h
Rated continuous thermal current, I_{cth}	3600 A
Rated short-time thermal current, I_{th}/ 1s	63 kA
Rated dynamic current, I_{dyn}	158 kA

Winding	1a-1n	2a-2n	3a-3n	3a-3n	da-dn
Rated secondary voltage [V]	110:√3	110:√3	110:√3	110:√3	110
Rated output [VA]	25	25	25	25	150
Accuracy class	0,2	0,2	0,2/3P	0,2/3P	3P
Thermal limiting output [VA]	1000	1000	1000	1000	450

Winding	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2
Rated secondary current [A]	5	1	5	1
Rated output [VA]	200	100	20	Rb=5Ω, class TPY 10x13, Rct<= 8Ω, Ts=500 ms, cykl 100 ms, Tp=50 ms
Accuracy class	0,2	0,1	5P	
FS/ALF	10	5	60	

3. Technical documentation of the test object

1. Drawing No. 2GKK614815A1277 – Dimensional drawing combined instrument transformer PVA123a-PVA145a; ABB Sp. z o.o. , approved 04.02.2016 – Appendix No. 1

4. Scope of the tests

Test program agreed with Orderer comprised of following tests:

No.	Kind of test	Tests according the Standard	Location of the test
1.	Temperature-rise tests	IEC 61869-1:2007 p. 6.4 i 7.2.2, IEC 61869-2:2012 p.6.4.1 i 7.2.2.204 IEC 61869-3:2011 p. 6.4.1 i p.7.2.2 IEC 61869-4:2013 p. 6.4.1 i 7.2.2 IEC 62271-1:2007/A1:2011, table no. 3	EWP

EWP The test was performed in Institute of Power Engineering, by High - Current Laboratory.

5. Tests and their results

Combined transformer was installed at the test stand, as it was during normal operation.
The rated voltage with a required value was applied to the primary voltage winding.
The secondary voltage windings and the residual voltage winding were loaded with the suitable power, according to the test programme given below, which was agreed with the Orderer.
Primary current terminals P1 and P2/A was bridged at the range of 3000 A. According to Manufacturer's request current in primary current winding was equal to **I_{cth} = 3600A.**
The arrangement of the thermocouples is given in Figure 3. The temperature-rises of windings were measured by the resistance rise method.
During the test, the measurements of loaded windings were made every 1-hour. The abstract of the protocol of temperature-rise test is given in Table 1. The summary of test results is given in Table 2.

The temperature-rise of windings were calculated from the follow formula:

$$\Delta t = \frac{R_k}{R_0}(235 + t_0) - 234{,}5 - t_a$$

R_o – resistance of winding in cold state
R_k – resistance of winding in warm state
t_0 – temperature of winding in cold state
t_a – ambient temperature

Tests were performed according to the IEC 61869-1 sub-cl. 6.4 and 7.2.2; IEC 61869-2 sub-cl. 6.4.1 and 7.2.2.204; IEC 61869-3 sub-cl. 6.4.1 and 7.2.2; IEC 61869-4 sub-cl. 6.4.1 and 7.2.2.

Stage No. 1: Test at the rated load

The voltage value 1,2 U_n = 91,5 kV was applied to the P2/A terminal.
The secondary voltage windings were loaded as follows:1a-1n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V; 2a-2n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V; 3a-3n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V; 4a-4n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V. The winding of residual voltage remained open.
The secondary current windings were loaded as follows:1S1-1S2 ⇒ 200 VA, cos φ = 1; 2S1-2S2 ⇒ 100 VA, cos φ = 1; 3S1-3S2 ⇒ 20VA, cos φ=1; 4S1-4S2 ⇒ 5Ω;
The test was performed till reached steady state of the measured temperatures.

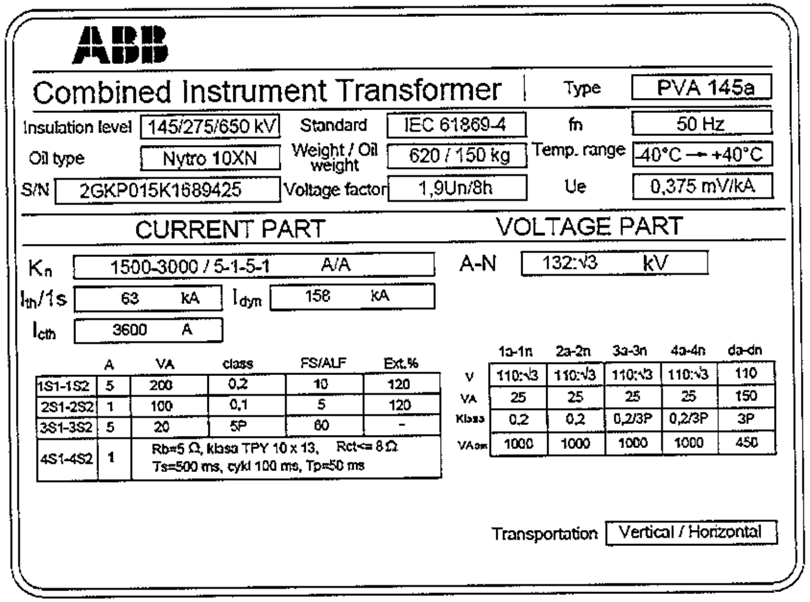
Stage No. 2: Test of 8 h

The voltage value 1,9 U_n = 144,8 kV was applied to the P2/A terminal.
The secondary voltage windings were loaded as follows:1a-1n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V; 2a-2n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V; 3a-3n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V; 4a-4n ⇒ 25 VA, cos φ = 1, at the voltage 110/√3 V.
The residual winding da-dn was loaded by ⇒ 450 VA, cos φ = 1, at the voltage 110 V.
The secondary current windings were loaded as follows: 1S1-1S2 ⇒ 200 VA, cos φ = 1; 2S1-2S2 ⇒ 100 VA, cos φ = 1; 3S1-3S2 ⇒ 20VA, cos φ=1; 4S1-4S2 ⇒ 5Ω;
The duration of the test was 8 h.

Stage No. 3: Test with thermal limiting output

The voltage value U_n = 76,2 kV was applied to the P2/A terminal.
According to Manufacturers request secondary voltage windings (i.e. 1a-1n, 2a-2n, 3a-3n and 4a -4n) were loaded by limit power 1000 VA at cos φ = 1. The residual winding remained open.
The secondary current windings were loaded as follows: 1S1-1S2 ⇒ 200 VA, cos φ = 1; 2S1-2S2 ⇒ 100 VA, cos φ = 1; 3S1-3S2 ⇒ 20VA, cos φ=1; 4S1-4S2 ⇒ 5Ω;
The test was performed till reaching the steady state of the measured temperatures.

Measuring equipment
The temperatures were measured by means of type K thermocouples (NiCr – NiAl) with accuracy ±0,6°C[1]. The ambient temperature was measured using four thermocouples type K immersed into tank filled with oil. These thermocouples were placed in the distance of 1 meter from the tested transformer at the height of 1 meter above floor - the accuracy of measurement ±0,6°C[1].The resistance was measured by means of meter type 2291 manufactured by TETTEX Instruments with accuracy ± 0,1 mΩ[1]



ABB

Combined Instrument Transformer

Type	PVA 145a				
Insulation level	145/275/650 kV	Standard	IEC 61869-4	fn	50 Hz
Oil type	Nytro 10XN	Weight / Oil weight	620 / 150 kg	Temp. range	-40°C → +40°C
S/N	2GKP015K1689425	Voltage factor	1,9Un/8h	Ue	0,375 mV/kA

CURRENT PART

K_n 1500-3000 / 5-1-5-1 A/A
I_{th}/1s 63 kA I_{dyn} 158 kA
I_{cth} 3600 A

	A	VA	class	FS/ALF	Ext.%
1S1-1S2	5	200	0,2	10	120
2S1-2S2	1	100	0,1	5	120
3S1-3S2	5	20	5P	60	-
4S1-4S2	1	Rb=5 Ω, klasa TPY 10 x 13, Rct<= 8 Ω Ts=500 ms, cykl 100 ms, Tp=50 ms			

VOLTAGE PART

A-N 132:√3 kV

	1a-1n	2a-2n	3a-3n	4a-4n	da-dn
V	110:√3	110:√3	110:√3	110:√3	110
VA	25	25	25	25	150
Klasa	0,2	0,2	0,2/3P	0,2/3P	3P
VA$_{om}$	1000	1000	1000	1000	450

Transportation Vertical / Horizontal

Fig. 1. Nameplate of tested combined instrument transformer

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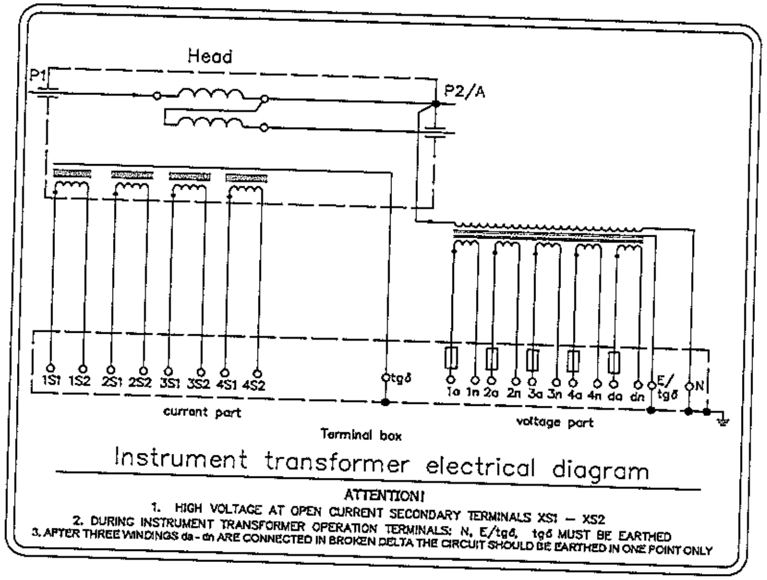
[1] The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor k = 2.



Instrument transformer electrical diagram

ATTENTION!

1. HIGH VOLTAGE AT OPEN CURRENT SECONDARY TERMINALS XS1 – XS2
2. DURING INSTRUMENT TRANSFORMER OPERATION TERMINALS: N, E/tgδ, tgδ MUST BE EARTHED
3. AFTER THREE WINDINGS da - dn ARE CONNECTED IN BROKEN DELTA THE CIRCUIT SHOULD BE EARTHED IN ONE POINT ONLY

Fig. 2. Electrical diagram of terminal box of tested combined instrument transformer

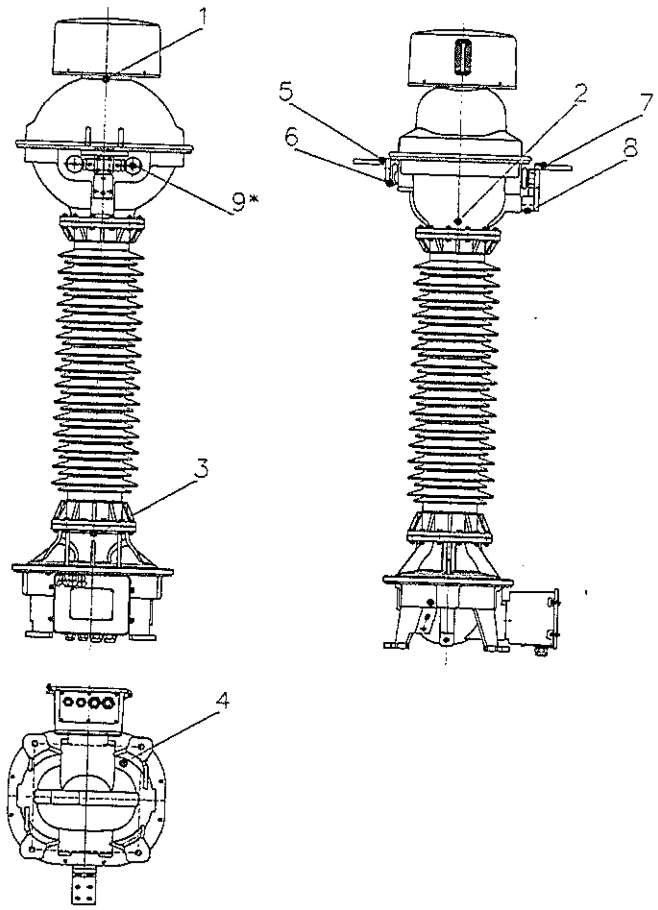


Fig. 3. Arrangement of thermocouples during temperature-rise test:
1 – oil (over current coil), 2 – head (contraction of the flange connecting the head the the insulator), 3 – under the flange of tank lid, 4 – lower tank (placed inside over earthing terminal), 5 – terminal P1, 6 – terminal P1, 7 – terminal P2/A (3000A), 8 – terminal P2/A (3000A), 9 - current path inside the combined instrument transformer.

Table 1. Temperature-rise test results of combined instrument transformer PVA 145a, serial no. 2GKP015K1689425

	Heating time [h]																								
	Stage 1																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
U, kV	91,5																								
$I_{1S1-1S2}$, A	0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0
$I_{P1-P2/A}$, A	0	3615	3602	3616	3610	3612	3604	3601	3610	3613	3615	3615	3603	3617	3619	3607	3619	3620	3616	3620	3603	3602	3618	3611	3606
ΔT 1, K	0	2,34	8,05	13,64	17.63	20,45	22,73	24,53	26,11	26,88	27,93	28,56	29,41	29,97	30,62	30,76	31,43	31,82	32,24	32,65	33,10	33,59	33,95	34,27	34,51
ΔT 2, K	0	6,80	11,65	15,31	17,88	19,65	21,14	22,39	23,37	24,27	24,85	25,61	26,30	26,84	26,84	27,23	27,38	27,55	27,85	28,26	28,87	29,13	29,43	29,56	29,80
ΔT 3, K	0	0,20	0,60	0.76	1,25	1,55	1,71	1,95	2,16	2,16	2,36	2,46	2,75	2,72	2,79	2,84	2,77	2,82	2,77	2,82	2,88	2,87	2,98	2,91	2,89
ΔT 4, K	0	0,04	0,46	0.82	1,13	0,97	1,01	1,23	1,21	1,34	1,48	1,83	1,98	2,05	2,00	1,95	1.93	1,90	1,93	1,96	1,98	2,02	2.11	2,06	2,01
ΔT 5, K	0	33,00	42,53	46,22	48,58	49,82	49,70	50,56	50,59	49,78	50,10	51,07	51,28	50,48	50,62	50,25	50,40	50,40	50,80	51,42	52,12	52,18	52,53	52,70	52,89
ΔT 6, K	0	32,92	42,31	46,00	48,63	50,45	50,49	52,44	52,29	52,10	51,97	52,12	52,53	51,34	51,52	51,79	51,67	51,77	52,17	52,46	53,37	53,79	54,31	54,56	55,32
ΔT 7, K	0	28,07	35,17	38,10	40,15	41,65	41,70	43,53	43,41	42,91	43,02	44,69	45,02	43,98	44,17	43,85	44,03	44,26	45,02	45,56	46,21	45,89	46,77	46,77	46,84
ΔT 8, K	0	20,99	28,17	31,47	33,95	36,70	36,85	39,40	39,45	39,47	39,68	41,00	41,22	40,36	41,45	41,27	41,33	41,95	42,68	43,34	44,32	44,57	45,48	45,48	45,51
ΔT 9, K	0	17,88	24,88	29,08	32,15	34,92	35,97	38,17	38,46	38,64	39.73	40,95	41,94	41,62	42,14	41,74	42,00	42,53	43,24	44,18	45,12	45,45	45,99	46,22	46,46
ΔT_{1a-1n}, K	0	1,78	2,75	3,32	3,89	4,26	4,55	4,94	4,92	5,01	5,15	5,36	5,54	5,57	5,65	5,71	5,75	5,80	5,92	5,97	5,98	6,02	6,04	6,02	6,14
ΔT_{2a-2n}, K	0	1,63	2,63	3,24	3,80	4,16	4,44	4,98	5,12	5,26	5,29	5,55	5,73	5,75	5,83	5,89	5,98	5,98	6,09	6,15	6,21	6,20	6,26	6,19	6,30
ΔT_{3a-3n}, K	0	1,53	2,24	2.83	3,73	3,76	4.08	4,67	4,81	5,10	5,33	5,48	5,55	5.52	5,50	5,50	5,58	5,63	5,70	5,80	5,80	5,84	5,85	5,84	5,94
ΔT_{4a-4n}, K	0	1,44	2,33	3,00	3,63	3,96	4,32	4,90	4,93	5,01	5,13	5,33	5,66	5,73	5,65	5,65	5,68	5,73	5,89	5,94	5,94	6,04	6,10	6,08	6,13
ΔT da-dn	0	1,28	2,25	3,02	3,67	3,90	4.31	4,93	5,09	5,30	5,50	5,77	6,02	6.22	6,14	6,09	6.30	6,30	6,31	6.31	6,48	6,47	6.43	6,59	6,54
$\Delta T_{P2/A-N}$, K	0	1,35	2,13	2,59	3,15	3,76	4,31	5,20	5,60	5,82	6,03	6,32	6,46	6,55	6,71	6,89	6,87	6,99	7,12	7,36	7,55	7,78	7,86	7,91	8,21
$\Delta T_{1S1-1S2}$, K	0	3,79	6,40	9,56	13,11	16,46	19,95	23,47	26,42	29,35	32,17	34,38	36,56	38,57	40,37	41,97	42,57	43,14	44,23	45,14	46,29	47,36	48,23	49,18	50,10
$\Delta T_{2S1-2S2}$, K	0	3,25	5,85	9,14	12.67	16,15	19,73	23,32	26,54	29,43	32.21	34,70	37,02	39,06	40,90	42,54	43,88	45,20	46,33	47,60	48,58	49,60	50,55	51,42	52,31
$\Delta T_{3S1-3S2}$, K	0	3,72	6,52	9,66	13,21	16,56	20,02	23,64	26,67	29,66	32,47	35,10	37,30	39,46	41,12	42,78	43,98	45,38	46,52	47,75	48,83	49,74	50,62	51,55	52,42
$\Delta T_{4S1-4S2}$, K	0	2,09	4,45	7,60	11,14	14,62	18,19	21,84	25,11	28,03	30,80	33,33	35,65	37,75	39,61	41,28	42,70	43,97	45,10	46,32	47,76	47,98	48,89	49,72	50,53
$\Delta T_{P1-P2/A}$, K	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R_{1a-1n} mΩ	46,01	46,35	46,56	46,69	46,80	46,91	46,97	47,01	47,02	47,04	47,07	47,10	47,13	47,14	47,17	47,19	47,20	47,21	47,23	47,24	47,25	47,26	47,27	47,28	47,31
R_{2a-2n} mΩ	47,03	47,35	47,57	47,71	47,82	47,93	47,99	48.06	48,10	48,13	48,14	48,18	48,21	48.22	48,25	48,27	48.29	48,29	48,31	48,32	48,34	48,34	48,36	48,36	48,39
R_{3a-3n} mΩ	48,39	48,70	48,87	49,01	49,19	49,24	49,31	49,39	49,43	49,49	49,54	49,56	49,57	49,57	49,58	49,59	49,61	49,62	49,63	49,65	49,66	49,67	49,68	49,69	49,72
R_{4a-4n} mΩ	49,60	49,90	50,11	50,27	50,40	50,51	50,59	50,67	50,69	50,71	50,74	50,77	50,83	50,85	50,85	50,86	50,87	50,88	50,91	50.92	50,93	50,95	50,97	50,98	51,00
Rda-dn mΩ	110,5	111,1	111,6	112,0	112,3	112,5	112,7	112,9	113,0	113,1	113,2	113,3	113.4	113,5	113,5	113,5	113,6	113,6	113.6	113,6	113,7	113.7	113,7	113,8	113,8
$R_{1S1-1S2}$ mΩ	441,7	448,5	453,4	459,2	465,5	471,8	478,0	483,9	489,2	494,4	499,4	503,2	507,0	510,6	513,9	516,8	517,9	518,9	520,8	522,4	524,5	526,4	528,0	529,8	531,8
$R_{2S1-2S2}$ Ω	5,351	5,422	5,481	5,554	5,630	5,709	5,786	5,859	5,929	5,991	6,051	6,103	6.152	6,196	6,237	6,273	6,302	6,330	6,354	6,381	6,403	6,425	6,446	6,466	6.486
$R_{3S1-3S2}$ mΩ	574,9	583,6	590,4	597,9	606,1	614,3	622,3	630,2	637,3	644,2	650,7	656,6	661,6	666,6	670,6	674,5	677,3	680,5	683,1	685,9	688,5	690,6	692,7	695,0	697,1
$R_{4S1-4S2}$ Ω	5,560	5,608	5,664	5,737	5,816	5,898	5,978	6,055	6,129	6,194	6,256	6,311	6,362	6,409	6,452	6,490	6,522	6,550	6,575	6,602	6,635	6,640	6,661	6,681	6,700
$R_{P1-P2/A}$ µΩ	30,7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t_o, °C	16,6	16,7	16,9	17,0	17,1	17,3	17,3	17,2	17,2	17,2	17,2	17,3	17,2	17,2	17,3	17,4	17,4	17,4	17,4	17,4	17,4	17,4	17,5	17,5	17,6
Oil level indicator,mm	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57

ΔT 1 - ΔT 9 – temperature-rise of the thermocouple

Table 1. Cont.

	Heating time [h]														
	Stage 2								Stage 3						
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
U, kV	144,8								76,2						
$I_{1S1-1S2}$, A	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0
$I_{P1-P2/A}$, A	3616	3610	3617	3609	3612	3614	3601	3617	3610	3618	3615	3601	3616	3618	3614
ΔT 1, K	34,92	35,16	35,50	35,75	36,02	36,07	36,09	36,18	36,26	36,51	36,91	37,03	37,26	37,45	37,65
ΔT 2, K	29,82	29,99	30,21	30,37	30.66	30,76	30,76	30,90	32.01	32,19	32.89	32,80	32,79	33,09	33,19
ΔT 3, K	3,45	3,80	4,21	4,64	4,77	4,87	4,99	5,09	5,07	5,08	4,87	5,05	5,04	5,20	5,55
ΔT 4, K	2,31	2,61	2,98	3,17	3,39	3,52	3,49	3,78	3,77	3,78	3,57	3,47	3,73	3,91	4,66
ΔT 5, K	53,65	53,94	54,14	54,15	54,25	54,27	53,79	53,78	54.78	55,46	55,74	55,86	55,85	55,79	55,82
ΔT 6, K	55,65	56,11	56,43	56,46	56,56	56,57	56,52	56,46	57,26	57,79	58,32	58,23	58,22	58,16	58,22
ΔT 7, K	47,80	48,16	48,64	48,68	48,80	48,83	48,85	48,85	49,43	50,14	50,51	50,49	50,45	50,37	50,60
ΔT 8, K	46,43	47,36	48,21	48,25	48,37	48,40	48,42	48,41	49,31	50,07	50,85	50,73	50,67	50,13	50,86
ΔT 9, K	47,31	47,89	48,43	48,46	48,56	48,57	48,69	48,49	49,55	50,17	50,82	50,71	50,64	50,25	50,88
ΔT_{1a-1n}, K	7,63	8,61	9,38	10,04	10,41	10,79	11,06	11,20	17,98	19,24	20,18	21,09	21,81	21,85	22.52
ΔT_{2a-2n}, K	7,87	8,89	9,74	10,39	10,76	11,18	11,50	11,58	18,74	20,68	21,69	22,69	23,50	23,55	24,20
ΔT_{3a-3n}, K	7,52	8,56	9,44	10,12	10,48	10,90	11,26	11,33	19,39	21,58	22,72	23,74	24,63	24,72	25,41
ΔT_{4a-4n}, K	7,87	8,83	9,74	10,41	10,76	11,22	11,52	11,75	20,31	22,65	23,86	24,90	25,98	26,02	26,69
ΔT da-dn	8,38	9,51	10,42	11,12	11,44	11,95	12,40	12,60	21,93	24,66	26,04	27,34	28,48	28,70	29,39
$\Delta T_{P2/A-N}$, K	8,47	8,83	9,42	10,15	10,73	11,61	12,44	13,13	19.57	28,64	32,71	35,50	37,30	38,60	39,56
$\Delta T_{1S1-1S2}$, K	50,91	51,71	52,56	53,31	53,75	54,48	55,00	55,42	55,83	56,24	56,42	56,52	57,05	57,09	57,61
$\Delta T_{2S1-2S2}$, K	53,22	53,97	54,86	55,67	56,29	56,90	57,37	57,90	58,29	58,63	58,88	59,00	59,39	59,71	60,04
$\Delta T_{3S1-3S2}$, K	53,40	54,14	54,97	55,86	56,26	57,01	57,54	58,03	58,39	58,79	58,98	59,12	59.53	59,60	60,14
$\Delta T_{4S1-4S2}$, K	51,41	52,72	53,58	54,40	55,09	55,68	56,18	56,64	57,06	57,39	57,63	57,87	58,20	58,51	58,83
$\Delta T_{P1-P2/A}$, K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48,84
R_{1a-1n} mΩ	47,58	47,76	47,90	48,02	48,07	48,13	48,18	48,21	49,45	49,68	49,89	50,07	50,20	50,21	50,33
R_{2a-2n} mΩ	48,68	48,87	49.03	49,15	49,20	49,27	49,33	49,35	50,69	51,05	51,28	51,48	51,63	51,64	51,76
R_{3a-3n} mΩ	50.02	50,22	50,39	50,52	50.57	50,64	50,71	50,73	52.28	52,70	52,96	53,17	53,34	53,36	53,49
R_{4a-4n} mΩ	51,34	51,53	51,71	51,84	51,89	51,97	52,03	52,08	53,77	54,23	54,51	54,73	54,94	54,94	55,08
Rda-dn mΩ	114,6	115,1	115,5	115,8	115,9	116,1	116,3	116,4	120,5	121,7	122,4	123,0	123,5	123,6	123,9
$R_{1S1-1S2}$ mΩ	532,9	534,3	535,8	537,1	537,7	538.9	539,8	540,6	541,3	542.0	542,7	543.0	543,9	544,0	544,9
$R_{2S1-2S2}$ Ω	6,505	6,521	6,540	6,557	6,568	6,58	6,59	6,60	6,61	6,62	6,63	6,63	6,64	6,65	6,65
$R_{3S1-3S2}$ mΩ	699,3	701,0	702,9	704,9	705,6	707.2	708,4	709,6	710,4	711.3	712,2	712,7	713,6	713,8	715,0
$R_{4S1-4S2}$ Ω	6,719	6,748	6,767	6,785	6,798	6,81	6,82	6,83	6,84	6,85	6,86	6,87	6,87	6,88	6,89
$R_{P2/A-N}$ KΩ	21,87	21,90	21,95	22,01	22,05	22,12	22,25	22,25	22,79	23,55	23,91	24,15	24,30	24,41	24,49
$R_{P1-P2/A}$ µΩ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36.8-
t_o, °C	17,6	17,6	17,6	17,6	17,5	17,4	17,4	17,4	17,4	17,4	17,6	17,7	17,7	17,7	17,7
Oil level indicator, mm	-	-	-	-	-	-	-	68	-	-	-	-	-	-	74

ΔT 1 - ΔT 9 – temperature-rise of the thermocouple

Table 2. Temperature-rises given during the tests

			Temperature rise ΔT [K]	Limit [K]
Stage No. 1	Windings	1S1-1S2	50,1	65 1,2,3,4)
		2S1-2S2	52,3	
		3S1-3S2	52,4	
		4S1-4S2	50,5	
		P1-P2/A	*Not measured*	
		1a- 1n	6,1	
		2a-2n	6,3	
		3a-3n	5,9	
		4a-4n	6,1	
		da-dn	6,5	
		A-N	8,2	
	Thermocouple No. 1	Oil	34,5	55 1,2,3,4)
	Thermocouple No. 2	Head	29,8	40 5)
	Thermocouple No. 3	Under the flange of tank lid	2,9	
	Thermocouple No. 4	Lower tank	2,0	
	Thermocouple No. 5	Terminal P1	52,9	65 5)
	Thermocouple No. 6	Terminal P1	55,3	
	Thermocouple No. 7	Terminal P2/A	46,8	
	Thermocouple No. 8	Terminal P2/A	45,5	
	Thermocouple No. 9	Current path inside the combined instrument transformer	46,5	65 1,2,3,4)
Stage No. 2	Windings	1S1-1S2	55,4	65+10 1,2,3,4)
		2S1-2S2	57,9	
		3S1-3S2	58,0	
		4S1-4S2	56,6	
		P1-P2/A	*Not measured*	
		1a- 1n	11,2	
		2a-2n	11,6	
		3a-3n	11,3	
		4a-4n	11,8	
		da-dn	12,6	
		A-N	13,1	
	Thermocouple No. 1	Oil	36,2	55+10 1)
	Thermocouple No. 2	Head	30,9	40 5)
	Thermocouple No. 3	Under the flange of tank lid	5,1	
	Thermocouple No. 4	Lower tank	3,8	
	Thermocouple No. 5	Terminal P1	53,8	65 5)
	Thermocouple No. 6	Terminal P1	56,5	
	Thermocouple No. 7	Terminal P2/A	48,9	
	Thermocouple No. 8	Terminal P2/A	48,4	
	Thermocouple No. 9	Current path inside the combined instrument transformer	48,5	65+10 1,2,3,4)

Table 2. Cont.

			Temperature rise ΔT [K]	Limit [K]
Stage No. 3	Windings	1S1-1S2	57,6	65 1,2,3,4)
		2S1-2S2	60,0	
		3S1-3S2	60,1	
		4S1-4S2	58,8	
		P1-P2/A	48,8	
		1a- 1n	22,5	
		2a-2n	24,2	
		3a-3n	25,4	
		4a-4n	26,7	
		da-dn	29,4	
		A-N	39,6	
	Thermocouple No. 1	Oil	37,7	55 1,2,3,4)
	Thermocouple No. 2	Head	33,2	40 2)
	Thermocouple No. 3	Under the flange of tank lid	5,6	
	Thermocouple No. 4	Lower tank	4,7	
	Thermocouple No. 5	Terminal P1	55,8	65 5)
	Thermocouple No. 6	Terminal P1	58,2	
	Thermocouple No. 7	Terminal P2/A	50,6	
	Thermocouple No. 8	Terminal P2/A	50,9	
	Thermocouple No. 9	Current path inside the combined instrument transformer	50,9	65+10 1,2,3,4

[1] acc. to IEC 61869-1, [2] wg IEC 61869-2, [3] acc. to IEC 61869-3, [4] acc. to IEC 61869-4, [5] acc. to IEC 62271-1,

6. Summary

Results of the temperature-rise test for combined transformer type PVA145a with primary continous thermal current I_{cth} = 3600A are as follows:

- in steady state, at the rated load of secondary voltage and current windings (without residual winding), and supply voltage 1,2U_n (Stage No. 1), permitted temperature-rise limits were not exceeded.

- results of test 8 h at supply voltage 1,9U_n and rated load of voltage and current windings and load of residual winding with thermal limiting output (Stage No. 2), shows that permitted temperature-rise limits were not exceeded.

- in steady state, results of test with thermal limiting output for voltage windings (without residual windings), rated load of current windings and supply voltage U_n (Stage No. 3), permitted temperature-rise limits were not exceeded.

The tested combined transformer met requirements of IEC 61869-1:2007, IEC 61869-2:2012, IEC 61869-3:2011, IEC 61869-4:2013 and IEC 62271-1:2007/A1:2011 standards.

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6. Photographic documentation

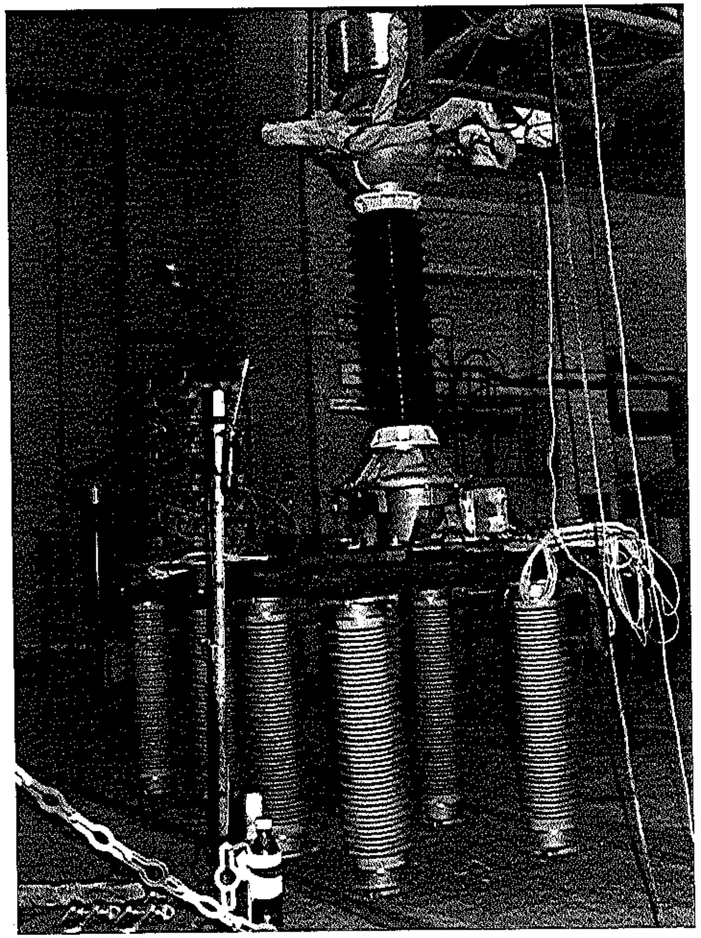

Fig. 4. Combined transformer on the test stand during temperature-rise test

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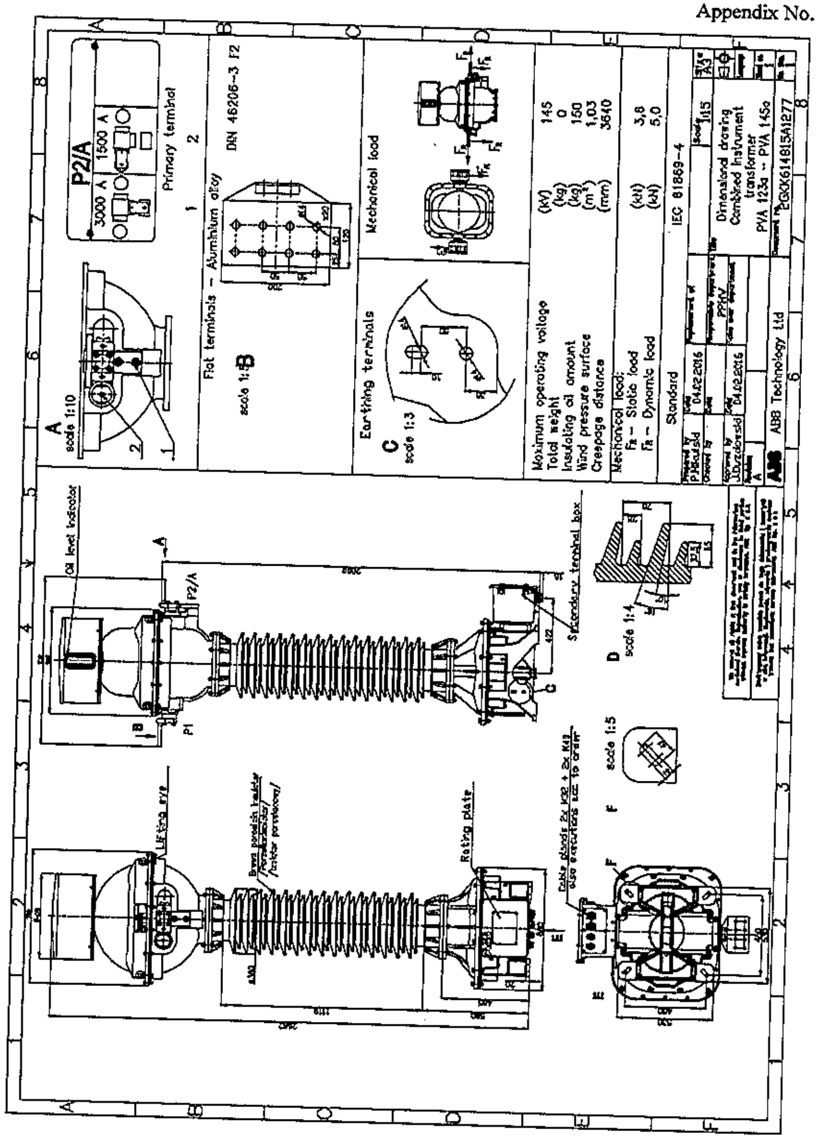
Appendix No. 1



Appendix No. 2

ABB Declaration of conformity

DECLARATION OF CONFORMITY No. 111/2016 (EN)
(acc. to ISO/IEC 17050-1)

Manufacturer: ABB

Product: Combined Instrument Transformer PVA145a

Above mentioned product conforms with the following standard:

Standard	Title	Edition/Date
IEC 61869-4:	Instrument Transformers – Part 4: Additional requirements for combined transformers	2013

Additional information:
Serial numbers: **2GKP015K1689425;**

Place and date of issue of declaration

Przasnysz 09.02.2016

Kierownik Operacyjny PPHV
ABB Sp. z o.o.
Oddział w Przasnyszu
(Name) Rafał Dębski

Kierownik ds. Zapewnienia Jakości
ABB Sp. z o.o.
Oddział w Przasnyszu
Krzysztof Lubecki
(Signature)

INSTYTUT ENERGETYKI
INSTITUTE OF POWER ENGINEERING
LABORATORIUM WIELKOPRĄDOWE
HIGH CURRENT LABORATORY

01-330 Warszawa
ul. Mory 8
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e-mail: ewp@ien.com.pl
http://ien.com.pl/en/lwp_n.php

TEST REPORT No. EWP/07/E/2012-4e

TEST OBJECT:	Combined instrument transformer type PVA 123
MANUFACTURER:	ABB Sp. z o.o. Power Products 59 Leszno Str. 06–300 Przasnysz, Poland
TESTS ORDERED BY:	Institute of Power Engineering High Voltage Department Internal order No. EWN/11/E/12 dated 16.02.2012
TYPE OF TESTS:	Temperature-rise test
TEST PROCEDURE:	IEC 60044-3:2002, IEC 60044-1:1996, IEC 60044-2: 1997. IEC 60044-2 1997 /A2:2002
TEST OBJECT DELIVERED:	10.02.2012
DATE OF TESTS:	16.02.2012 – 17.02.2012
TESTS RESULTS:	Positive

Tests result refers only to the test object.
The Test Report consist tests from and beyond the scope of accreditation (details in sub-cl. 4)
Publishing or reproducing of this report in other version then exact and complete without written permission of laboratory is forbidden

TEST ENGINEER:	Jacek Tymochowicz M.Sc. Eng.
HEAD OF LABORATORY:	Lidia Gruza M.Sc. Eng.

Warsaw, 20.02.2012

Contents

Report contains 17 numbered pages with:

2	Drawings
3	Photographs
0	Oscillogramms
1	Appendix

1. Description of the test object

Test object	Combined instrument transformer
Type	PVA 123
Serial number	2GKP011K1484707
Manufacturer	ABB Sp. z o.o. Power Products 59 Leszno Str. 06–300 Przasnysz, Poland
Year of production	2011
Insulator	Porcelain insulator
Number of windings *)	VT part - 5, CT part– 4
Oil type	Nytro Libra
Minimum creepage distance	3640 mm
Insulating oil weight	150 kg
Total weight	640 kg
Dimensions	According to drawing no. 2GKK614213

The laboratory made the identification of test objects on the base of the documentation given in par. 3 – see Appendix.

The test object is shown in the photographs No. 1, 2 and 3. The object was prepared for testing by the Manufacturer.

2. Technical data declared by the Manufacturer

Maximum operating voltage	123 kV
Rated frequency	50 Hz
Voltage factor and time	$1{,}9U_n/8h$
Rated continuous thermal current, I_{cth}	1125-2250 A
Rated short-time thermal current, I_{th}/ 1s	50-50 kA
Rated dynamic current, I_{dyn}	125-125 kA

VT part					
Type of secondary winding	1a-1n	2a-2n	3a-3n	4a-4n	da-dn
Rated secondary voltage	100:√3 V	100:√3 V	100:√3 V	100:√3 V	100:3 V
Rated output	30 VA	30 VA	30 VA	60 VA	50 VA
Accuracy class	0,2	0,2	0,2/3P	0,5/3P	3P
Thermal limiting output	1000 VA	1000 VA	1000 VA	1000 VA	450 VA
CT part					
Type of secondary winding	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2	
Rated secondary current	5 A	5 A	5 A	1 A	
Rated output	15 VA	10 VA	50 VA	60 VA	
Accuracy class	0,2	5P	5P	5P	
FS/ALF	5	20	30	30	
Rated transformation ratio	750-1500/5 A/A	750-1500/5 A/A	750-1500/5 A/A	750-1500/1 A/A	
Ext.	150 %				

3. Technical documentation of the test object

1. Drawing no. 2GKK614213 – Dimensional drawing. Combined instrument transformer PVA 123, ABB Sp. z o.o. Power Products, approved 19.01.2012
2. Combined transformer verification protocol type PVA 123, Series No.: 2GKP011K1484707. ABB Sp. z o.o., Przasnysz, 19.01.2012
3. Construction of combined instrument transformer PVA 123, Serial No. 2GKP011K148707, ABB Sp. z o.o., Przasnysz, dated 22.01.2012.
4. Kind of current paths of HV instrument transformer type PVA 123, PA 123 (PA 145), ABB Sp. z o.o., Przasnysz, dated 22.01.2012.

4. Scope of the tests

Test programme agreed with Orderer comprised of tests:

Kind of test	Tests according the Standard	Location of the test
Temperature-rise tests	IEC 60044-3:2002 sub-cl. 4.2, 7.2b, IEC 60044-1:1996 sub-cl. 4.6, 7.2, IEC 60044-2:1997 sub-cl. 5.4, 8.1, 13.6.1 IEC 62271-1:2007, Table No. 3, sub-cl. 4	EWP

EWP	The test was performed in Institute of Power Engineering, by High - Current Laboratory.

5. Tests and their results

Combined transformer was installed at the test stand, as it was during normal operation.
Electric diagram of terminal box of tested combined transformer is given in Fig. 1.
The rated voltage with a required value was applied to the primary voltage winding.
The secondary voltage windings and the residual voltage winding were loaded with the suitable power, according to the test programme given below, which was agreed with the Orderer.
Primary current terminals P1 and P2/A was bridged at the range of 1500 A.
According to Manufacturer's request current in primary current winding was equal to **I_{cth} = 2250 A.**
The arrangement of the thermocouples is given in Figure No. 2.
The temperature-rises of windings were measured by the resistance rise method.
During the test, the measurements of loaded windings were made every 1 hour and registered the deflection of oil level indicator.
The resistances of all windings were measured before the tests and after of each stage of tests.
The abstract of the protocol of temperature-rise test is given in Table No. 1.
The summary of test results is given in Table 2.

The temperature-rise of windings were calculated from the formula:

$$\Delta T = \frac{R}{R_0 \alpha} = \frac{R_1 - R_0}{R_0 \cdot 0{,}004}$$

Stage No. 1: Test at the rated load

Test was performed according to the IEC 60044-1 sub-cl. 4.6, 7.2, IEC 60044-2 sub-cl. 5.4 a), 8.1 and 13.6.1, IEC 60044-3 sub-cl. 4,2, 7.2b). The voltage value 1,2 U_n = 76,2 kV was applied to the P2/A terminal.
The secondary voltage windings were loaded as follows:1a-1n ⇒ 30 VA, cos φ = 1, at the voltage 100/√3 V; 2a-2n ⇒ 30 VA, cos φ = 1, at the voltage 100/√3 V; 3a-3n ⇒ 30 VA, cos φ = 1, at the voltage 100/√3 V; 4a-4n ⇒ 60 VA, cos φ = 1, at the voltage 100/√3 V.
The winding of residual voltage remained open.
The secondary current windings of the CT were loaded as follows:1S1-1S2 ⇒ 15 VA, cos φ = 1; 2S1-2S2 ⇒ 10 VA, cos φ = 1; 4S1-4S2 ⇒ 60 VA, cos φ = 1.
Supply (current control) was applied to the secondary current winding 3S1-3S2.
Terminals P1 and P2/A were short-circuited at the range 1500 A.
The test was performed till reached steady state of the measured temperatures.

Stage No. 2: Test of 8 h

Test was done immediately after the Stage No. 1 according to the IEC 60044-1 sub-cl. 4.6, 7.2, IEC 60044-2 sub-cl. 5.4 c), 8.1, and 13.6.1, IEC 60044-3 sub-cl. 4,2, 7.2b). The voltage value 1,9 U_n = 119,7 kV was applied to the P2/A terminal.
The secondary voltage windings were loaded as follows: 1a-1n ⇒ 30 VA, cos φ = 1, at the voltage 100/√3 V; 2a-2n ⇒ 30 VA, cos φ = 1, at the voltage 100/√3 V; 3a-3n ⇒ 30 VA at the voltage 100/√3 V; 4a-4n ⇒ 60 VA, cos φ = 1, at the voltage 100/√3 V.

The residual winding da-dn was loaded by ⇒ 450 VA, cos φ = 1, at the voltage 100/3 V.
The secondary windings of the CT part were loaded by powers: 1S1-1S2 ⇒ 15 VA cos φ = 1; 2S1-2S2 ⇒ 10 VA cos φ = 1; 4S1-4S2 ⇒ 60 VA, cos φ = 1.
Supply (current control) was applied to the secondary current winding 3S1-3S2.
Terminals P1 and P2/A were short-circuited at the range 1500 A.
The duration of the test was 8 h.

Stage No. 3: Test with thermal limit power

Test was done immediately after Stage No. 2 according to the IEC 60044-1 sub-cl. 4.6, 7.2, IEC 60044-2 sub-cl. 5.4 a), 8.1, and 13.6.1, IEC 60044-3 sub-cl. 4,2, 7.2b). The voltage value U_n = 63 kV was applied to the P2/A terminal.
According to Manufacturers request secondary voltage windings (i.e. 1a-1n, 2a-2n, 3a-3n and 4a - 4n) were loaded by limit power 1000 VA at cos φ = 1.
The residual winding remained open.

The secondary current winding of the CT part were loaded as follows: 1S1-1S2 ⇒ 15 VA, cos φ = 1; 2S1-2S2 ⇒ 10 VA; 4S1-4S2 ⇒ 60 VA, cos φ = 1.
Supply (current control) was applied to secondary current winding 3S1-3S2.
Terminals P1 and P2/A were short-circuited at the range 1500 A.
The test was performed till reaching the steady state of the measured temperatures.

Measuring instruments

The temperatures were measured by means of type K thermocouples (NiCr – NiAl) with accuracy ± 0,6°C[1].
The ambient temperature was measured using four mercurial thermometers immersed into tank filled with oil. These thermometers were placed in the distance of 1 meter from the tested transformer at the height of 1 meter above floor- the accuracy of measurement ± 0,03°C[2].
The resistance was measured by means of meter type 2291 manufactured by TETTEX Instruments with accuracy ± 0,01 mΩ[3]

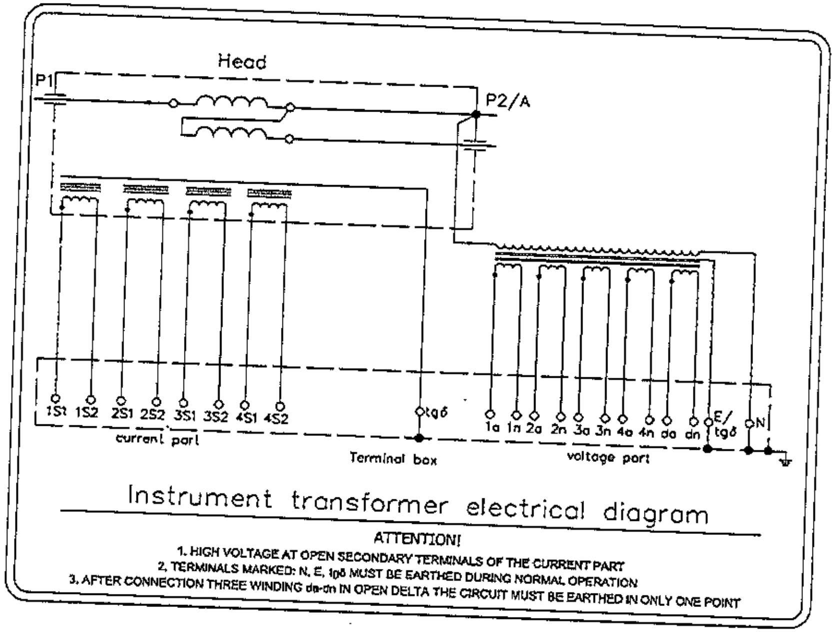

Fig. 1. Electrical diagram of terminal box of tested combined instrument transformer

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[1] The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor k = 2.

[2] The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor k = 2.

[3] The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor k = 2.

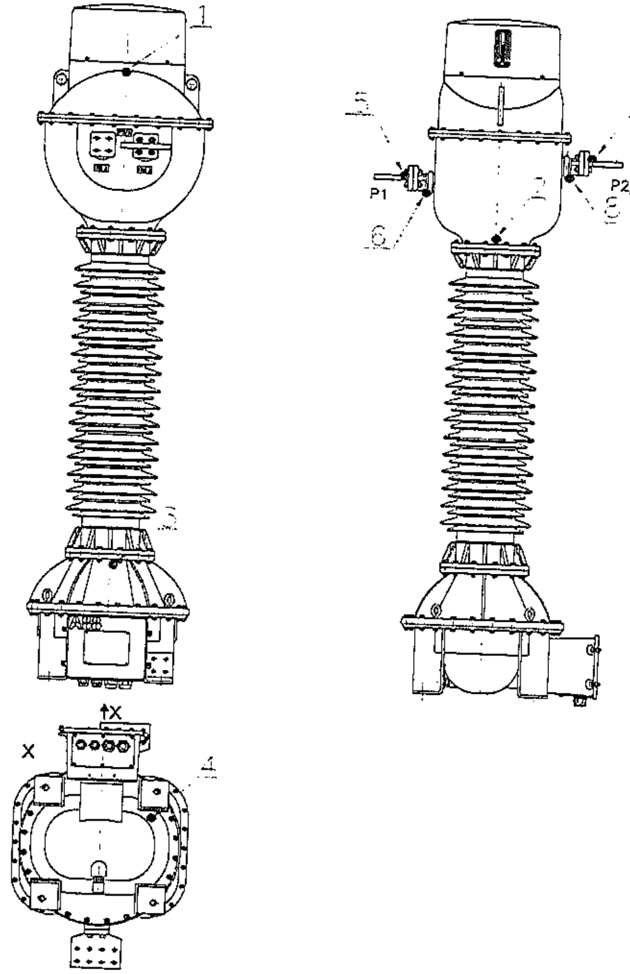

Fig. 2. Arrangement of thermocouples during temperature-rise test:

1 – oil (over current coil), 2 – head (contraction of the flange connecting the head the the insulator), 3 – under the flange of tank lid, 4 – lower tank (placed inside over earthing terminal), 5 – terminal P1, 6 – terminal P1, 7 – terminal P2/A (1500A), 8 – terminal P2/A (1500A).

Table 1. Temperature-rise test results of combined instrument transformer PVA 123, nr fabr. 2GKP011K1484707*)

No. of thermocouple	Heating time [h]																					
	Stage No. 1																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	10,07	12,32	13,32	15,07	16,57	17,80	19,05	19,30	19,80	20,80	21,77	22,77	23,75	25,00	25,98	27,20	27,95	28,43	28,68	28,93	29,43	29,93
2	10,07	11,32	12,07	13,57	14,82	16,32	17,55	18,30	18,55	18,80	19,80	20,80	21,27	22,27	23,25	24,25	25,00	25,48	25,48	25,48	25,73	25,23
3	8,57	10,57	10,57	10,82	11,07	11,32	11,57	11,82	11,82	11,82	12,07	12,07	12,32	12,82	13,32	14,07	14,32	14,82	15,07	15,07	14,82	14,57
4	8,07	10,57	10,82	11,07	11,32	11,32	11,57	11,57	11,82	12,07	12,32	12,57	12,82	13,32	13,82	14,32	14,57	14,82	14,82	14,82	14,32	13,82
5	10,07	23,50	26,48	28,43	30,40	31,38	31,88	32,35	32,60	32,85	33,60	34,33	35,06	36,03	36,53	37,25	38,00	38,23	38,48	38,48	38,73	38,98
6	10,07	24,25	27,70	29,43	31,13	31,38	32,10	32,35	32,60	33,10	33,35	33,85	34,33	35,30	35,80	36,78	37,01	37,25	37,50	37,50	38,00	37,75
7	10,32	21,77	24,25	26,23	26,98	27,45	28,18	28,43	28,68	28,93	29,43	30,15	30,65	31,13	31,38	32,10	32,35	32,85	33,10	33,35	33,60	33,85
8	10,07	21,02	23,75	25,48	27,20	27,70	28,43	28,93	29,18	30,15	30,90	31,13	31,63	32,35	33,10	34,33	34,33	34,58	34,83	35,06	35,55	35,55
$T_{ot.\,en}$, °C	10,18	10,15	10,38	10,53	10,63	10,65	10,65	10,63	10,63	10,68	10,78	10,88	10,90	10,90	10,85	10,88	10,88	10,90	10,90	10,98	10,95	10,95
U_{zas}, kV	76,2																					
$I_{zas\ 3S1\text{-}3S2}$, A	7,63	7,64	7,64	7,66	7,66	7,65	7,66	7,67	7,66	7,67	7,66	7,65	7,64	7,66	7,65	7,66	7,66	7,65	7,65	7,66	7,66	7,65
$I_{1S1\text{-}1S1}$, A	7,61	7,58	7,58	7,59	7,58	7,59	7,58	7,6	7,58	7,61	7,58	7,59	7,59	7,6	7,59	7,6	7,6	7,59	7,59	7,6	7,6	7,6
I_k, A	2219,2	2222,1	2222,1	2227,9	2227,9	2225	2227,9	2230,8	2227,9	2230,8	2227,9	2225	2222,1	2227,9	2225	2227,9	2227,9	2225	2225	2227,9	2227,9	2225
$I_{P2\text{-}A,N}$, mA	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$R_{1S1\text{-}1S2}$, mΩ	157,52	161,48	163,26	164,92	166,70	168,33	169,95	171,28	172,75	174,07	175,30	176,35	177,32	178,38	179,49	180,14	180,95	181,62	182,31	182,96	183,57	184,27
$R_{2S1\text{-}2S2}$, mΩ	248,46	255,27	258,49	261,20	264,15	266,91	269,41	271,73	274,13	276,28	278,32	280,10	281,68	283,34	284,92	286,34	287,70	288,80	289,84	290,92	291,92	292,79
$R_{3S1\text{-}3S2}$, mΩ	579,07	594,96	603,49	610,26	617,42	624,02	630,33	635,99	641,88	647,09	652,10	656,42	660,26	664,42	668,32	671,74	675,07	677,86	680,31	682,96	685,36	687,51
$R_{4S1\text{-}4S2}$, Ω	8,0147	8,1187	8,213	8,2983	8,3828	8,4618	8,5372	8,6094	8,6953	8,7382	8,8186	8,854	8,8981	8,9422	8,9897	9,0333	9,0704	9,1014	9,1311	9,1624	9,1919	9,2193
$R_{P1\text{-}P2/A}$, mΩ	0,0256	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$\Delta T_{1S1\text{-}1S2}$	-	6,28	9,11	11,7	14,6	17,2	19,7	21,8	24,17	26,3	28,2	29,9	31,4	33,1	34,9	35,9	37,2	38,2	39,3	40,4	41,3	42,45
$\Delta T_{2S1\text{-}2S2}$	-	6,85	10,1	12,8	15,8	18,6	21,1	23,4	25,83	28	30	31,8	33,4	35,1	36,7	38,1	39,5	40,6	41,6	42,7	43,7	44,6
$\Delta T_{3S1\text{-}3S2}$	-	6,86	10,5	13,5	16,6	19,4	22,1	24,6	27,12	29,4	31,5	33,4	35,1	36,8	38,5	40	41,4	42,7	43,7	44,9	45,9	46,82
$\Delta T_{4S1\text{-}4S2}$	-	3,24	6,19	8,85	11,5	13,9	16,3	18,6	21,23	22,6	25,1	26,2	27,6	28,9	30,4	31,8	32,9	33,9	34,8	35,8	36,7	37,57
$\Delta T_{P1\text{-}P2/A}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table No. 1, cont.

	Stage No. 1, cont.																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
$R_{1a\text{-}1n}$, mΩ	44,132	44,451	44,652	44,786	44,899	44,973	45,031	45,084	45,116	45,146	45,172	45,199	45,217	45,237	45,240	45,261	45,273	45,276	45,295	45,314	45,319	45,327
$R_{2a\text{-}2n}$, mΩ	45,928	46,252	46,470	46,604	46,714	46,799	46,858	46,914	46,952	46,987	47,013	47,043	47,065	47,086	47,096	47,125	47,130	47,130	47,148	47,154	47,164	47,174
$R_{3a\text{-}3n}$, mΩ	47,616	47,922	48,145	48,288	48,345	48,499	48,565	48,611	48,662	48,695	48,738	48,762	48,778	48,804	48,825	48,842	48,854	48,851	48,864	48,885	48,892	48,899
$R_{4a\text{-}4n}$, mΩ	49,372	49,676	49,908	50,066	50,142	50,279	50,357	50,407	50,462	50,492	50,541	50,564	50,588	50,606	50,635	50,647	50,663	50,654	50,671	50,695	50,701	50,710
$R_{da\text{-}dn}$, mΩ	32,255	32,436	32,583	32,673	32,754	32,821	32,863	32,897	32,930	32,954	32,984	33,006	33,017	33,030	33,053	33,060	33,073	33,081	33,087	33,089	33,102	33,114
$R_{P2/A\text{-}N}$, kΩ	19,23	-	19,29	-	19,35	-	19,44	-	19.52	-	19,6	-	19,7	-	19,75	-	19,8	-	19,8	-	19,85	-
$\Delta T_{1a\text{-}1n}$	-	1,81	2,95	3,70	4,34	4,76	5,09	5,39	5,57	5,74	5,89	6,04	6,15	6,26	6,28	6,40	6,46	6,48	6,59	6,70	6,72	6,77
$\Delta T_{2a\text{-}2n}$	-	1,76	2,95	3,68	4,28	4,74	5,06	5,37	5,57	5,76	5,91	6,07	6,19	6,30	6,36	6,52	6,54	6,54	6,64	6,67	6,73	6,78
$\Delta T_{3a\text{-}3n}$	-	1,61	2,78	3,53	3,83	4,64	4,98	5,22	5,49	5,67	5,89	6,02	6,10	6,24	6,35	6,44	6,50	6,48	6,55	6,66	6,70	6,74
$\Delta T_{4a\text{-}4n}$	-	1,54	2,71	3,51	3,90	4,59	4,99	5,24	5,52	5,67	5,92	6,04	6,16	6,25	6,40	6,46	6,54	6,49	6,58	6,70	6,73	6,78
$\Delta T_{da\text{-}dn}$	-	1,40	2,54	3,24	3,87	4,39	4,71	4,98	5,23	5,42	5,65	5,82	5,91	6,01	6,19	6,24	6,34	6,40	6,45	6,46	6,56	6,66
$\Delta T_{P2/A\text{-}N}$	-	-	0,78		1,56		2,73		3,77		4,81		6,11		6,76		7,41		7,41		8,06	
Deflection of the oil level indicator mm.	0	0,6	0,7	0,8	1,3	1,4	1,7	1,9	2,1	2,3	2,3	2,4	2,5	2,7	2,8	2,9	3	3,2	3,3	3,3	3,4	3,5

Table No. 1. cont.

No. of thermocouple	Heating time [h]															
	Stage No. 1, cont.			Stage No. 2								Stage No. 3				
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
1	29,68	28,93	28,43	28,68	28,43	27,95	27,45	27,95	27,95	27,95	28,18	28,43	28,68	28,93	29,18	29,43
2	24,50	24,00	24,50	24,00	24,00	24,00	23,75	24,25	24,25	24,50	24,75	25,00	25,48	25,48	25,48	25,48
3	13,82	13,07	12,82	13,57	14,82	14,82	15,32	15,82	16,57	16,57	16,82	16,82	16,82	17,30	17,55	17,55
4	13,32	12,82	12,82	13,57	14,32	15,32	15,07	15,82	16,07	16,57	16,57	16,07	16,32	16,57	16,82	16,82
5	38,23	37,50	37,01	35,80	36,03	36,03	35,55	35,55	35,55	35,80	35,80	35,30	36,78	37,01	37,50	36,78
6	37,01	36,28	36,03	35,30	34,83	34,83	34,33	34,58	34,58	34,83	34,83	34,33	35,80	35,80	36,28	35,55
7	33,60	33,10	32,35	31,38	30,90	31,38	30,65	30,90	30,65	30,65	30,40	29,93	31,38	32,10	31,88	31,38
8	35,30	34,58	34,58	33,85	33,35	33,35	32,85	32,85	33,10	33,10	33,10	32,60	34,08	33,85	34,08	33,60
$T_{ot\,śr}$, °C	10,98	11,10	11,20	11,40	11,68	11,80	11,98	11,98	12,20	12,43	12,53	12,60	12,65	12,68	12,70	12,75
U_{zas}, kV	76,2			119,7								63				
$I_{zas\,3S1-3S2}$, A	7,65	7,66	7,68	7,66	7,66	7,67	7,68	7,65	7,65	7,65	7,65	7,65	7,65	7,65	7,65	7,65
$I_{1S1-1S1}$, A	7,6	7,58	7,61	7,6	7,6	7,61	7,62	7,6	7,61	7,58	7,59	7,59	7,58	7,59	7,59	7,58
I_z, A	2225	2227,9	2233,7	2227,9	2227,9	2230,8	2233,7	2225	2225	2225	2225	2225	2225	2225	2225	2225
$J_{P2'A-N}$, mA	-	-	-	42	-	-	-	-	-	-	-	60	-	-	-	-
$R_{1S1-1S2}$, mΩ	184,72	185,16	185,69	186,01	186,39	186,90	187,10	187,39	187,57	187,78	187,99	187,92	188,04	188,13	188,33	188,50
$R_{2S1-2S2}$, mΩ	293,79	294,63	295,32	295,92	296,52	297,22	297,61	298,10	298,38	298,72	299,06	298,94	299,23	299,36	299,64	299,87
$R_{3S1-3S2}$, mΩ	690,06	692,16	693,63	695,27	696,74	698,24	699,33	700,52	701,10	701,94	702,77	702,15	702,84	703,46	704,03	704,46
$R_{4S1-4S2}$, Ω	9,2478	9,2709	9,2866	9,3070	9,3225	9,3389	9,3566	9,3634	9,3753	9,3848	9,3943	9,3890	9,3957	9,4020	9,4076	9,4123
$R_{P1-P2'A}$, mΩ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0284
$\Delta T_{1S1-1S2}$	43,2	43,9	44,7	45,2	45,8	46,6	46,9	47,4	47,7	48	48,4	48,2	48,4	48,6	48,9	49,2
$\Delta T_{2S1-2S2}$	45,6	46,5	47,2	47,8	48,4	49,1	49,5	49,9	50,2	50,6	50,9	50,8	51,1	51,2	51,5	51,7
$\Delta T_{3S1-3S2}$	47,9	48,8	49,5	50,2	50,8	51,4	51,9	52,4	52,7	53	53,4	53,1	53,4	53,7	53,9	54,1
$\Delta T_{4S1-4S2}$	38,5	39,2	39,7	40,3	40,8	41,3	41,9	42,1	42,4	42,7	43	42,9	43,1	43,3	43,4	43,6
$\Delta T_{P1-P2'A}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27,3

Table No. 1. cont.

	Stage No. 1, cont.			Stage No. 2, cont.								Stage No. 3, cont.				
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
R_{1a-1a_1}, mΩ	45,330	45,340	45,352	46,269	46,571	46,734	46,886	46,967	47,036	47,116	47,161	47,984	48,168	48,272	48,372	48,468
R_{2a-2a_1}, mΩ	47,170	47,191	47,198	48,215	48,532	48,720	48,878	48,966	49,029	49,114	49,168	50,112	50,330	50,449	50,564	50,669
R_{3a-3a_1}, mΩ	48,900	48,918	48,925	50,043	50,389	50,579	50,745	50,829	50,894	50,985	51,039	51,970	52,245	52,353	52,499	52,603
R_{4a-4a_1}, mΩ	50,713	50,718	50,738	51,933	52,292	52,497	52,670	52,758	52,827	52,918	52,985	53,867	54,182	54,340	54,481	54,605
R_{da-da_1}, mΩ	33,106	33,108	33,129	34,088	34,337	34,484	34,604	34,656	34,702	34,767	34,802	35,362	35,636	35,770	35,874	35,963
$R_{P2'A-N_1}$, kΩ	19,86	-	19,87	-	20,14	-	20,42	-	20,54	-	20,53	-	21,95	-	22,5	22,75
ΔT_{1a-1a_1}	6,79	6,84	6,91	12,11	13,82	14,74	15,60	16,06	16,45	16,90	17,16	21,82	22,86	23,45	24,02	24,56
ΔT_{2a-2a_1}	6,76	6,87	6,91	12,45	14,17	15,20	16,06	16,54	16,88	17,34	17,64	22,77	23,96	24,61	25,24	25,81
ΔT_{3a-3a_1}	6,74	6,84	6,87	12,74	14,56	15,56	16,43	16,87	17,21	17,69	17,97	22,86	24,30	25,03	25,64	26,18
ΔT_{4a-4a_1}	6,79	6,82	6,92	12,97	14,79	15,82	16,70	17,15	17,49	17,96	18,29	22,76	24,36	25,16	25,87	26,50
ΔT_{da-da_1}	6,60	6,61	6,77	14,21	16,14	17,28	18,21	18,61	18,97	19,47	19,74	24,08	26,21	27,24	28,05	28,74
$\Delta T_{P2'A-N_1}$	8,19	-	8,32	-	11,83	-	15,47	-	17,03	-	16,90	-	35,36	-	42,51	45,76
Deflection of the oil level indicator cm.	3,5	3,5	3,5	3,6	3,8	3,9	3,9	4	4,1	4,2	4,2	4,3	4,3	4,4	4,5	4,6

*) Marked with „-„ are value not measured (agreed with Orderer)
I_z – test primary current

Table No. 2. Temperature-rises [K] given during the tests combined instrument transformer PVA 123 serial no. 2GKP011K1484707 (primary current 2250 A)

Winding	Δϑ after Stage No. 1	Δϑ after Stage No. 2	Δϑ after Stage No. 3	$\Delta\vartheta_{dop}$
1S1-1S2	44,7	48,4	49,20	75 $^{1);3)}$
2S1-2S2	47,2	50,9	51,70	
3S1-3S2	49,5	53,4	54,10	
4S1-4S2	39,7	43	43,60	
P1-P2/A	*Not measured*	*Not measured*	27,30	
1a-1n	6,91	17,16	24,56	75 $^{2);3)}$
2a-2n	6,91	17,64	25,81	
3a-3n	6,87	17,97	26,18	
4a-4n	6,92	18,29	26,50	
da-dn	6,77	19,74	28,74	
P2/A-N	8,32	16,90	45,76	

Thermocouple		Δϑ after Stage No. 1	Δϑ after Stage No. 2	Δϑ after Stage No. 3	$\Delta\vartheta_{dop}$
No.	Location				
1	Oil	17,23	15,65	16,68	55 $^{1), 2), 3)}$
2	Head – top part next to terminal	13,30	12,23	12,73	40 $^{4)}$
3	Under the tank lid from side of terminal box	1,62	4,30	4,80	
4	Enclosure of lower tank	1,62	4,05	4,07	
5	Terminal P1	25,81	23,28	24,03	65 $^{4)}$
6	Terminal P1	24,83	22,30	22,80	
7	Terminal P2/A	21,15	17,88	18,63	
8	Terminal P2/A	23,38	20,58	20,85	

$^{1)}$ acc. to IEC 60044-1:1996, $^{2)}$ acc. to IEC 60044-2:1997,
$^{3)}$ acc. to IEC 60044-3:2002, $^{4)}$ acc. to IEC 62271-1:2007,
Δϑ - temperature-rise; $\Delta\vartheta_{dop}$ – permitted value in steady state

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6. Summary

In tested combined instrument transformer type PVA 123, with porcelain insulator, as results of temperature rise test with current I_{cth}= 2250 A:

- in steady state, at the rated load of secondary current and voltage windings (without residual winding), at cos φ = 1 and supply voltage 1,2U$_n$ (Stage No. 1), permitted temperature-rise limits were not exceeded.

The tested combined transformer met requirements of IEC 60044-3:2002, IEC 60044-1:1996, IEC 60044-2:1997, IEC 60044-2:1997/A2:2002 and IEC 62271-1:2007 standards.

- results of test 8 h at supply voltage 1,9U$_n$ and rated load of current and voltage windings at cos φ = 1 and load of residual winding with thermal limit power (Stage No. 2), shows that permitted temperature-rise limits were not exceeded.

The tested combined transformer met requirements of IEC 60044-3:2002, IEC 60044-1:1996, IEC 60044-2: 1997, IEC 60044-2:1997/A2:2002 and IEC 62271-1: 2007 standards.

- results of test with thermal limit power (Stage No. 3) at rated load of current windings at cos φ = 1 and supply voltage U$_n$, and at the same time loading of all voltage windings (without residual windings) with thermal limit power, shows that permitted temperature-rise limits were not exceeded.

The tested combined transformer met requirements of IEC 60044-3:2002, IEC 60044-1:1996, IEC 60044-2:1997, IEC 60044-2:1997/A2:2002 and IEC 62271-1:2007 standards.

7. Opinions and interpretations

None

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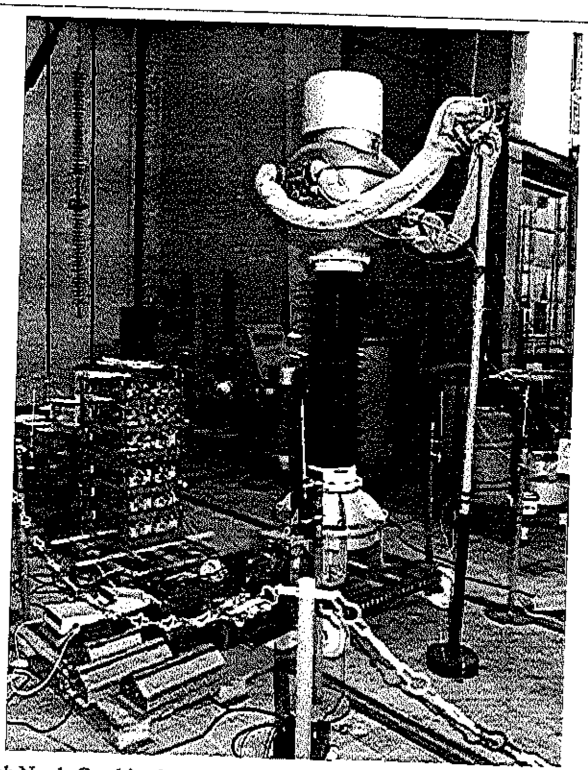
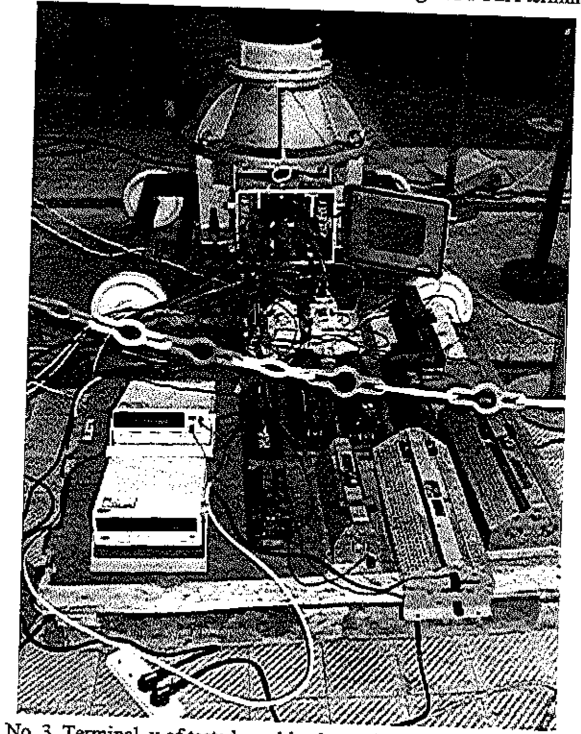
8. Photographic documentation



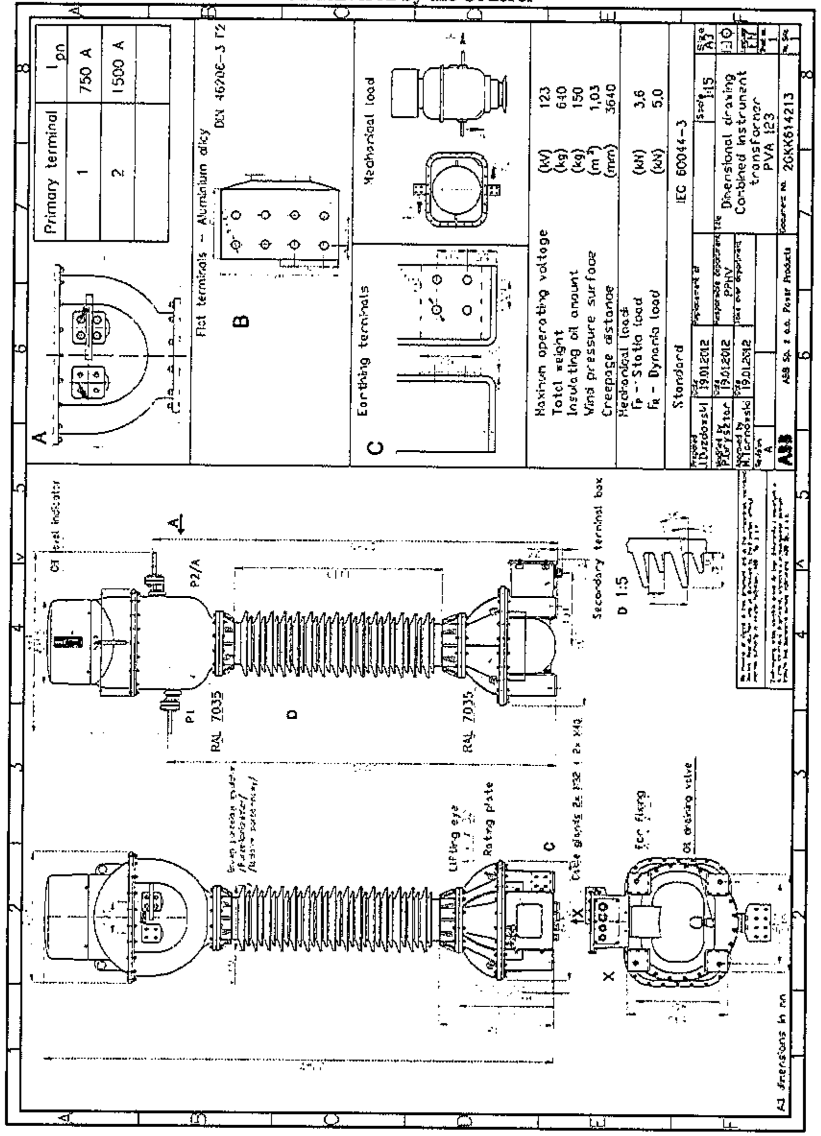
Photograph No. 1. Combined transformer on the test stand during temperature-rise test.

Photograph No. 2. The conductors short-circuiting of P1-P2A terminals.



Photograph No. 3. Terminal x of tested combined transformer during temperature-rise test.

APPENDIX Documentation delivered by the Orderer



INSTYTUT ENERGETYKI
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TEST REPORT NO.
EWP/65/E/2015

TEST OBJECT:	Combined instrument transformer type PVA 145a
MANUFACTURER:	ABB Sp. z o.o. ul. Leszno 59 06–300 Przasnysz, Poland
TESTS ORDERED BY:	ABB Sp. z o.o. ul. Żegańska 1 04-713 Warszawa, Poland Order No. 4500699879 dated 03.12.2015
TYPE OF TESTS:	Temperature-rise test
TESTS PROCEDURE:	IEC 61869-1:2007, IEC 61869-2:2012, IEC 61869-3:2011, IEC 61869-4:2013, IEC 62271-1 :2007/A1 :2011
OBJECT DELIVERED:	18.12.2015
DATE OF TESTS:	12.01.2016
TESTS RESULTS:	Positive for current I_{cth}=3200A
THE TESTS WERE WITNESSED BY:	-

Authorised by
TEST ENGINEER:
Mariusz SUL M.Sc. Eng.

Mariusz Sul

Approved by
HEAD OF LABORATORY:
Maciej OWSIŃSKI M.Sc. Eng.

Warsaw, 12.02.2016

Contents

Report contains 16 numbered pages with:	
4	Figures
2	Appendices

1. Description of the test object

Test object	Combined instrument transformer
Type	PVA 145a
Serial number	2GKP015K1689425
Manufacturer	ABB Sp. z o.o.
Year of production	2015
Insulator	Porcelain insulator
Number of windings	VT part 5, CT part 4
Oil type	Nytro 10XN
Temperature range	-40°C - +40°C
Total weight / oil weight	620 / 150 kg
Dimensions	According to appendix No.1 2GKK614815A1277

The laboratory made the identification of test objects basing on documentation given in sub-cl. 3. The test object is shown in the Figure 4. The object was prepared for tests by the Manufacturer.

2. Technical data declared by the Manufacturer

Rated voltage [kV]	$132:\sqrt{3}$
Maximum operating voltage [kV]	145
Rated frequency [Hz]	50
Voltage factor and time	$1,9U_n/8h$
Rated continuous thermal current, I_{cth}	3200 A
Rated short-time thermal current, I_{th}/ 1s	63 kA
Rated dynamic current, I_{dyn}	158 kA

Winding	1a-1n	2a-2n	3a-3n	3a-3n	da-dn
Rated secondary voltage [V]	$110:\sqrt{3}$	$110:\sqrt{3}$	$110:\sqrt{3}$	$110:\sqrt{3}$	110
Rated output [VA]	25	25	25	25	150
Accuracy class	0,2	0,2	0,2/3P	0,2/3P	3P
Thermal limiting output [VA]	1000	1000	1000	1000	450

Winding	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2
Rated secondary current [A]	5	1	5	1
Rated output [VA]	200	100	20	Rb=5Ω, class TPY 10x13, Rct<= 8Ω, Ts=500 ms, cykl 100 ms, Tp=50 ms
Accuracy class	0,2	0,1	5P	
FS/ALF	10	5	60	

3. Technical documentation of the test object

1.	Drawing No. 2GKK614815A1277 – Dimensional drawing combined instrument transformer PVA123a-PVA145a; ABB Sp. z o.o. , approved 04.02.2016 – Appendix No. 1

4. Scope of the tests

Test program agreed with Orderer comprised of following tests:

No.	Kind of test	Tests according the Standard	Location of the test
1.	Temperature-rise tests	IEC 61869-1:2007 p. 6.4 i 7.2.2, IEC 61869-2:2012 p.6.4.1 i 7.2.2.204 IEC 61869-3:2011 p. 6.4.1 i p.7.2.2 IEC 61869-4:2013 p. 6.4.1 i 7.2.2 IEC 62271-1 :2007/A1:2011, table no. 3	EWP

EWP	The test was performed in Institute of Power Engineering, by High - Current Laboratory.

5. Tests and their results

Combined transformer was installed at the test stand, as it was during normal operation.
The rated voltage with a required value was applied to the primary voltage winding.
The secondary voltage windings and the residual voltage winding were loaded with the suitable power, according to the test programme given below, which was agreed with the Orderer.
Primary current terminals P1 and P2/A was bridged at the range of 3000 A. According to Manufacturer's request current in primary current winding was equal to **I_{cth} = 3200A.**
The arrangement of the thermocouples is given in Figure 3. The temperature-rises of windings were measured by the resistance rise method.
During the test, the measurements of loaded windings were made every 1-hour. The abstract of the protocol of temperature-rise test is given in Table 1. The summary of test results is given in Table 2.

The temperature-rise of windings were calculated from the follow formula:

$$\Delta t=\frac{R_k}{R_0}(234{,}5+t_0)-234{,}5-t_a$$

R_o – resistance of winding in cold state
R_k – resistance of winding in warm state
t_0 – temperature of winding in cold state
t_a – ambient temperature

Tests were performed according to the IEC 61869-1 sub-cl. 6.4 and 7.2.2; IEC 61869-2 sub-cl. 6.4.1 and 7.2.2.204; IEC 61869-3 sub-cl. 6.4.1 and 7.2.2; IEC 61869-4 sub-cl. 6.4.1 and 7.2.2.

Stage No. 1: Test at the rated load

The voltage value 1,2 U_n = 91,5 kV was applied to the P2/A terminal.
The secondary voltage windings were loaded as follows:1a-1n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V; 2a-2n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V; 3a-3n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V; 4a-4n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V. The winding of residual voltage remained open.
The secondary current windings were loaded as follows:1S1-1S2 ⇒ 200 VA, cosφ = 1; 2S1-2S2 ⇒ 100 VA, cosφ = 1; 3S1-3S2 ⇒ 20VA, cosφ=1; 4S1-4S2 ⇒ 5Ω;
The test was performed till reached steady state of the measured temperatures.

Stage No. 2: Test of 8 h

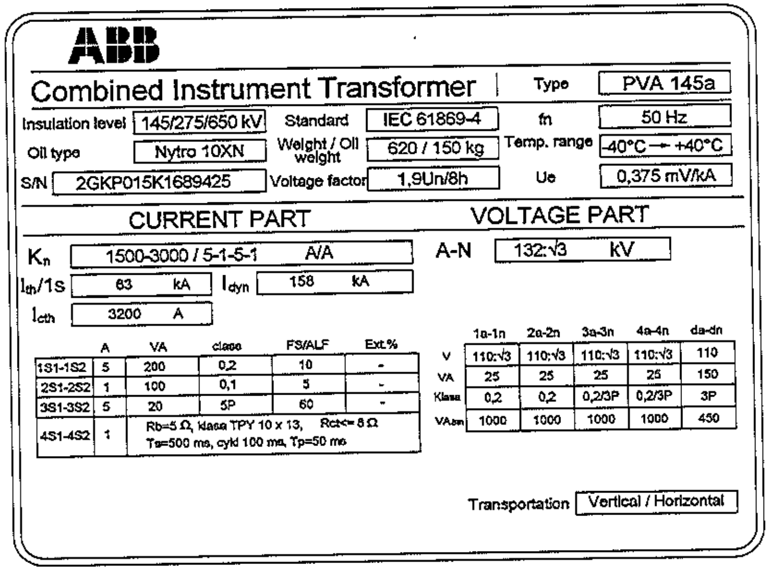
The voltage value 1,9 U_n = 144,8 kV was applied to the P2/A terminal.
The secondary voltage windings were loaded as follows:1a-1n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V; 2a-2n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V; 3a-3n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V; 4a-4n ⇒ 25 VA, cosφ = 1, at the voltage 110/√3 V.
The residual winding da-dn was loaded by ⇒ 450 VA, cosφ = 1, at the voltage 110 V.
The secondary current windings were loaded as follows: 1S1-1S2 ⇒ 200 VA, cosφ = 1; 2S1-2S2 ⇒ 100 VA, cosφ = 1; 3S1-3S2 ⇒ 20VA, cosφ=1; 4S1-4S2 ⇒ 5Ω;
The duration of the test was 8 h.

Stage No. 3: Test with thermal limiting output

The voltage value U_n = 76,2 kV was applied to the P2/A terminal.
According to Manufacturers request secondary voltage windings (i.e. 1a-1n, 2a-2n, 3a-3n and 4a-4n) were loaded by limit power 1000 VA at cosφ = 1. The residual winding remained open.
The secondary current windings were loaded as follows: 1S1-1S2 ⇒ 200 VA, cosφ = 1; 2S1-2S2 ⇒ 100 VA, cosφ = 1; 3S1-3S2 ⇒ 20VA, cosφ=1; 4S1-4S2 ⇒ 5Ω;
The test was performed till reaching the steady state of the measured temperatures.

Measuring equipment

The temperatures were measured by means of type K thermocouples (NiCr – NiAl) with accuracy ±0,6°C[1]. The ambient temperature was measured using four thermocouples type K immersed into tank filled with oil. These thermocouples were placed in the distance of 1 meter from the tested transformer at the height of 1 meter above floor - the accuracy of measurement ±0,6°C[1]. The resistance was measured by means of meter type 2291 manufactured by TETTEX Instruments with accuracy ± 0,1 mΩ[1]



ABB

Combined Instrument Transformer

Type	PVA 145a				
Insulation level	145/275/650 kV	Standard	IEC 61869-4	fn	50 Hz
Oil type	Nytro 10XN	Weight / Oil weight	620 / 150 kg	Temp. range	-40°C → +40°C
S/N	2GKP015K1689425	Voltage factor	1,9Un/8h	Ue	0,375 mV/kA

CURRENT PART

K_n 1500-3000 / 5-1-5-1 A/A
I_{th}/1s 63 kA I_{dyn} 158 kA
I_{cth} 3200 A

	A	VA	class	FS/ALF	Ext.%
1S1-1S2	5	200	0,2	10	-
2S1-2S2	1	100	0,1	5	-
3S1-3S2	5	20	5P	60	-
4S1-4S2	1	Rb=5 Ω, klasa TPY 10 x 13, Rct<= 8 Ω Ts=500 ms, cykl 100 ms, Tp=50 ms			

VOLTAGE PART

A-N 132:√3 kV

	1a-1n	2a-2n	3a-3n	4a-4n	da-dn
V	110:√3	110:√3	110:√3	110:√3	110
VA	25	25	25	25	150
Klasa	0,2	0,2	0,2/3P	0,2/3P	3P
VAsn	1000	1000	1000	1000	450

Transportation Vertical / Horizontal

Fig. 1. Nameplate of tested combined instrument transformer

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[1] The expanded uncertainty assigned corresponds to a coverage probability of 95 % and the coverage factor k = 2.

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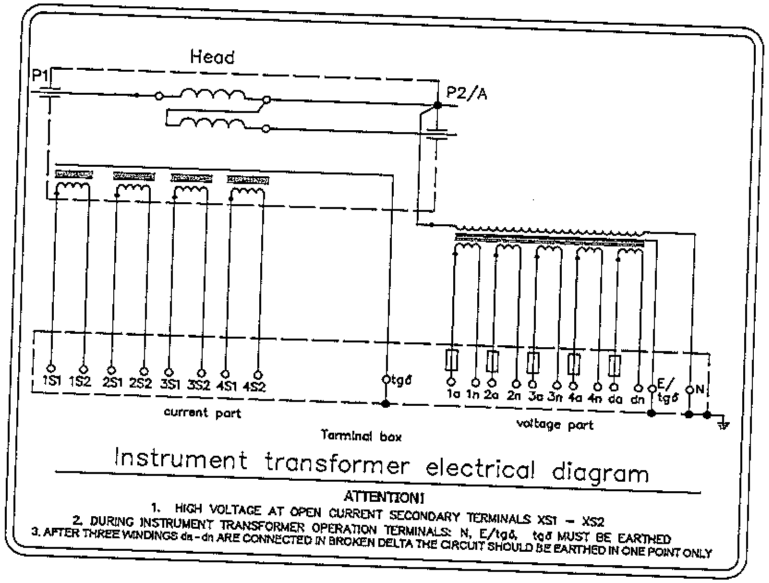

ATTENTION!
1. HIGH VOLTAGE AT OPEN CURRENT SECONDARY TERMINALS XS1 – XS2
2. DURING INSTRUMENT TRANSFORMER OPERATION TERMINALS: N, E/tgδ, tgδ MUST BE EARTHED
3. AFTER THREE WINDINGS da - dn ARE CONNECTED IN BROKEN DELTA THE CIRCUIT SHOULD BE EARTHED IN ONE POINT ONLY

Fig. 2. Electrical diagram of terminal box of tested combined instrument transformer

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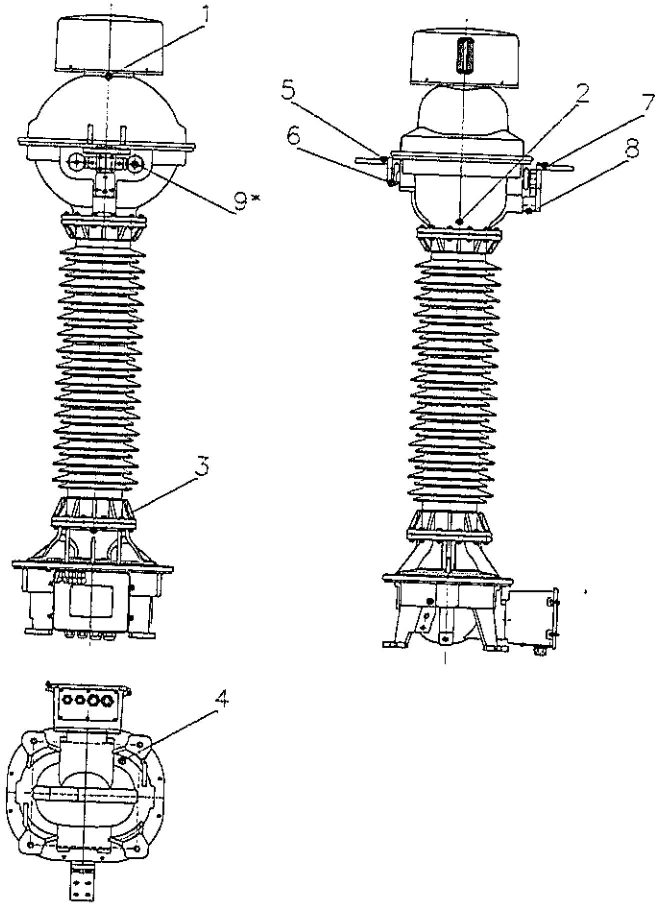

Fig. 3. Arrangement of thermocouples during temperature-rise test:
1 – oil (over current coil), 2 – head (contraction of the flange connecting the head the the insulator), 3 – under the flange of tank lid, 4 – lower tank (placed inside over earthing terminal), 5 – terminal P1, 6 – terminal P1, 7 – terminal P2/A (3000A), 8 – terminal P2/A (3000A), 9 - current path inside the combined instrument transformer.

Table 1. Temperature-rise test results of combined instrument transformer PVA 145a

	Heating time [h]																					
		Stage 1																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
U, kV	0	91,5																				
$I_{1S1-1S1}$, A	0	5,40	5,35	5,35	5,35	5,35	5,35	5,35	5,40	5,35	5,35	5,35	5,35	5,40	5,40	5,40	5,40	5,40	5,40	5,40	5,40	5,40
$I_{P1-P2/A}$, A	0	3216	3224	3214	3225	3216	3214	3213	3214	3214	3201	3221	3225	3226	3201	3227	3220	3223	3224	3217	3209	3224
ΔT 1, K	0	1,07	5,45	9,70	13,20	15,82	17,95	19,33	20,27	21,24	22,00	22,53	22,99	23,37	23,94	24,50	24,85	25,36	25,56	25,97	26,31	26,70
ΔT 2, K	0	0,74	0,87	0,83	0,60	0,78	0,75	0,89	0,78	0,69	0,95	0,95	0,79	0,68	0,77	0,86	0,77	0,92	0,78	0,85	0,76	0,76
ΔT 3, K	0	-0,04	0,52	1,23	1,55	1,76	2,08	2,50	2,39	2,38	1,95	2,68	2,57	2,66	2,82	3,04	3,08	3,02	3,28	3,20	3,18	3,13
ΔT 4, K	0	-0,64	0,12	0,58	0,45	0,76	1,48	1,74	1,65	1,74	1,95	2,05	1,91	2,03	2,04	2,21	2,12	2,28	2,27	2,19	2,17	2,22
ΔT 5, K	0	27,96	35,76	39,50	40,69	42,33	41,15	41,30	41,26	40,24	41,05	41,76	41,08	41,10	40,73	41,58	42,43	43,40	43,80	44,44	44,27	44,27
ΔT 6, K	0	28,20	35,30	39,28	40,35	42,43	40,57	40,92	41,29	39,58	39,17	42,05	41,06	41,55	41,23	42,06	42,90	43,87	44,35	45,29	45,12	44,87
ΔT 7, K	0	23,29	29,31	32,42	33,30	34,82	34,03	34,23	34,56	33,53	33,44	35,29	34,89	35,12	35,85	36,72	37,65	38,06	37,99	38,53	38,27	38,56
ΔT 8, K	0	17,87	22,87	26,64	28,03	30,38	29,40	29,99	30,95	29,72	30,25	32,37	31,77	32,66	33,53	34,52	35,39	35,72	35,44	36,43	36,26	36,17
ΔT 9, K	0	14,84	20,18	24,01	26,18	28,49	28,61	29,50	30,42	29,97	30,69	32,29	32,55	32,76	33,51	34,35	35,04	35,65	35,75	36,48	36,46	36,61
ΔT_{1a-1n}, K	0	1,52	2,61	3,39	3,82	4,28	4,72	5,05	5,15	5,25	5,57	5,68	5,75	5,82	5,98	6,05	6,07	6,20	6,21	6,28	6,32	6,27
ΔT_{2a-2n}, K	0	1,42	2,23	2,99	3,46	3,96	4,34	4,76	5,01	5,11	5,43	5,48	5,59	5,72	5,76	5,84	5,90	6,02	6,04	6,06	6,14	6,09
ΔT_{3a-3n}, K	0	1,33	2,51	3,15	3,85	4,18	4,61	4,87	5,16	5,30	5,66	5,66	5,72	5,84	5,93	6,05	6,06	6,18	6,25	6,27	6,25	6,35
ΔT_{4a-4n}, K	0	1,24	2,35	3,01	3,70	4,07	4,53	4,83	5,06	5,30	5,61	5,60	5,71	5,78	5,92	6,03	6,04	6,16	6,22	6,24	6,26	6,31
ΔT_{da-dn}, K	0	1,29	2,29	3,06	3,58	4,01	4,65	4,84	5,18	5,39	5,67	5,85	5,81	6,00	6,17	6,31	6,22	6,46	6,42	6,39	6,55	6,55
$\Delta T_{P2/A-N}$, K	0	1,03	1,51	1,98	2,31	3,24	3,33	4,01	4,26	4,84	5,02	5,69	5,89	6,57	7,11	7,38	7,65	8,15	8,82	9,15	9,44	9,92
$\Delta T_{1S1-1S2}$, K	0	3,29	5,44	7,98	10,61	13,42	16,06	18,11	20,33	22,47	24,46	26,28	27,88	29,38	30,85	32,19	33,29	34,56	35,59	36,70	37,59	38,50
$\Delta T_{2S1-2S2}$, K	0	2,58	4,76	7,27	10,13	13,06	15,99	18,67	21,00	23,29	25,37	27,34	29,04	30,60	32,09	33,42	34,64	35,98	37,06	38,11	39,03	39,97
$\Delta T_{3S1-3S2}$, K	0	3,21	5,48	7,89	10,57	13,56	16,23	18,98	21,27	23,52	25,72	27,46	29,03	30,57	32,08	33,44	34,48	35,89	36,99	37,78	38,50	39,37
$\Delta T_{4S1-4S2}$, K	0	1,48	3,39	5,94	8,72	11,64	14,63	17,30	19,72	22,15	24,33	26,18	27,90	29,49	30,92	32,29	33,55	34,84	35,97	37,03	38,00	38,90
$\Delta T_{P1-P2/A}$, K	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R_{1a-1n} mΩ	47,04	47,38	47,61	47,78	47,89	47,98	48,07	48,14	48,18	48,20	48,25	48,28	48,30	48,32	48,36	48,39	48,41	48,43	48,44	48,46	48,48	48,47
R_{2a-2n} mΩ	48,16	48,49	48,67	48,84	48,96	49,06	49,14	49,23	49,30	49,32	49,37	49,39	49,42	49,45	49,47	49,50	49,53	49,55	49,56	49,57	49,60	49,59
R_{3a-3n} mΩ	49,48	49,80	50,06	50,21	50,38	50,45	50,54	50,60	50,68	50,71	50,77	50,78	50,80	50,83	50,86	50,90	50,92	50,94	50,96	50,97	50,98	51,00
R_{4a-4n} mΩ	50,68	50,99	51,24	51,40	51,57	51,65	51,75	51,82	51,89	51,94	51,99	52,00	52,03	52,05	52,09	52,13	52,15	52,17	52,19	52,20	52,22	52,23
R_{da-dn} mΩ	111,0	111,7	112,2	112,6	112,9	113,1	113,4	113,5	113,7	113,8	113,9	114,0	114,0	114,1	114,2	114,3	114,3	114,4	114,4	114,4	114,5	114,5
R_{A-N}, kΩ	20,85	20,96	21,01	21,06	21,10	21,18	21,19	21,25	21,28	21,33	21,34	21,40	21,42	21,48	21,53	21,56	21,59	21,63	21,69	21,72	21,75	21,79
$R_{1S1-1S2}$, mΩ	438,6	444,9	448,9	453,6	458,5	463,5	468,2	471,9	476,0	479,8	483,2	486,5	489,4	492,1	494,8	497,3	499,4	501,6	503,5	505,5	507,2	508,8
$R_{2S1-2S2}$, Ω	5,296	5,357	5,406	5,462	5,526	5,589	5,652	5,710	5,762	5,811	5,854	5,897	5,934	5,968	6,001	6,031	6,059	6,087	6,111	6,134	6,155	6,175
$R_{3S1-3S2}$, mΩ	570,4	578,4	583,9	589,7	596,2	603,1	609,3	615,7	621,2	626,4	631,3	635,4	639,1	642,7	646,3	649,6	652,2	655,4	658,0	659,9	661,7	663,7
$R_{4S1-4S2}$, Ω	5,505	5,544	5,589	5,648	5,713	5,778	5,845	5,905	5,961	6,015	6,062	6,104	6,143	6,179	6,212	6,244	6,274	6,302	6,328	6,352	6,375	6,395
$R_{P1-P2/A}$, μΩ	27,3	-	-	-	-	-	—	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t_a, °C	14,08	14,36	14,48	14,60	14,75	14,77	14,80	14,84	14,95	14,96	14,90	14,95	14,99	15,02	15,08	15,16	15,25	15,23	15,27	15,30	15,37	15,37

ΔT 1 - ΔT 9 – temperature-rise of the thermocouple

Table 1. Cont.

	Heating time [h]														
		Stage 2								Stage 3					
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
U, kV		144,8								76,2					
$I_{1S1-1S1}$, A	5,4	5,4	5,4	5,4	5,35	5,3	5,35	5,35	5,4	5,35	5,35	5,35	5,35	5,35	5,4
$I_{P1-P2/A}$, A	3224	3218	3216	3221	3214	3203	3212	3216	3219	3215	3205	3209	3214	3204	3217
ΔT 1, K	27,07	27,55	27,80	27,99	28,28	28,44	28,62	28,73	28,81	28,89	29,06	29,13	29,32	29,38	29,44
ΔT 2, K	0,93	1,16	1,17	1,06	0,98	0,93	1,01	0,97	1,11	0,87	0,42	0,86	0,90	0,94	1,23
ΔT 3, K	3,14	3,76	4,50	4,76	5,08	5,42	5,42	5,88	5,89	5,50	5,50	5,82	5,37	6,17	6,51
ΔT 4, K	1,85	2,76	2,65	3,36	3,56	4,05	4,11	4,28	4,29	3,95	4,10	4,14	4,28	4,50	4,96
ΔT 5, K	44,78	45,81	45,20	45,40	45,56	45,48	45,98	45,61	45,96	45,82	45,01	45,58	45,81	45,53	45,64
ΔT 6, K	45,73	46,87	48,25	46,14	46,20	46,05	46,91	46,27	46,84	46,75	46,41	46,52	46,61	46,24	46,40
ΔT 7, K	38,81	39,50	38,88	39,11	39,11	39,07	39,45	39,17	39,59	39,67	39,14	39,62	39,78	39,48	39,62
ΔT 8, K	36,93	37,93	37,27	37,45	37,51	37,57	38,25	37,97	38,35	38,43	37,94	38,43	38,54	38,14	38,40
ΔT 9, K	37,17	37,91	37,61	37,90	38,01	37,98	38,50	38,34	38,69	38,72	38,45	38,91	38,98	38,84	39,03
ΔT_{1a-1n}, K	6,30	8,23	9,18	9,72	9,73	10,08	10,41	10,61	10,82	17,14	18,62	19,43	20,37	20,83	21,25
ΔT_{2a-2n}, K	7,05	8,11	9,08	9,66	10,13	10,47	10,79	10,99	11,24	18,24	19,94	20,84	21,96	22,37	22,46
ΔT_{3a-3n}, K	6,68	8,26	9,25	9,86	10,37	10,64	11,00	11,24	11,38	18,55	20,41	21,28	22,38	22,97	23,21
ΔT_{4a-4n}, K	6,34	8,22	9,24	9,89	10,38	10,69	11,04	11,32	11,45	18,84	20,85	21,86	22,97	23,60	23,84
ΔT_{da-dn}, K	6,53	8,64	9,65	10,45	10,80	11,07	11,48	11,81	12,10	20,47	22,76	24,12	25,46	26,12	26,33
$\Delta T_{P2/A-N}$, K	10,37	10,24	9,06	10,28	11,14	11,08	11,39	11,88	12,20	22,77	26,75	31,18	34,51	37,48	38,31
$\Delta T_{1S1-1S2}$, K	39,16	40,05	40,56	41,09	41,73	42,12	42,64	43,10	43,39	43,81	44,20	44,39	44,67	44,88	45,04
$\Delta T_{2S1-2S2}$, K	40,70	41,55	42,29	42,81	43,41	43,75	44,27	44,77	45,08	45,49	45,87	46,08	46,40	46,57	46,75
$\Delta T_{3S1-3S2}$, K	39,44	41,40	42,12	42,59	43,23	43,58	44,10	44,56	44,92	45,26	45,66	45,81	46,15	46,36	46,57
$\Delta T_{4S1-4S2}$, K	39,69	40,55	41,17	41,75	42,33	42,83	43,33	43,72	44,10	44,50	44,86	45,15	45,37	45,45	45,75
$\Delta T_{P1-P2/A}$, K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35,22
R_{1a-1n} mΩ	48,48	48,87	49,07	49,19	49,21	49,31	49,38	49,44	49,51	50,69	50,96	51,11	51,29	51,38	51,46
R_{2a-2n} mΩ	49,78	50,01	50,22	50,35	50,46	50,56	50,63	50,69	50,77	52,11	52,43	52,60	52,82	52,90	52,92
R_{3a-3n} mΩ	51,07	51,41	51,63	51,77	51,89	51,98	52,06	52,13	52,19	53,60	53,96	54,13	54,35	54,47	54,52
R_{4a-4n} mΩ	52,24	52,65	52,88	53,03	53,15	53,25	53,33	53,41	53,47	54,96	55,36	55,56	55,79	55,92	55,97
R_{da-dn} mΩ	114,5	115,5	116,0	116,4	116,6	116,8	117,0	117,2	117,4	121,1	122,1	122,7	123,3	123,6	123,7
R_{A-N}, kΩ	21,83	21,83	21,74	21,85	21,93	21,94	21,97	22,02	22,06	22,94	23,27	23,64	23,92	24,17	24,24
$R_{1S1-1S2}$, mΩ	510,0	511,8	512,9	514,0	515,3	516,3	517,3	518,3	519,1	519,7	520,3	520,6	521,1	521,5	521,8
$R_{2S1-2S2}$, Ω	6,191	6,212	6,230	6,243	6,258	6,269	6,281	6,294	6,30	6,31	6,32	6,32	6,33	6,33	6,34
$R_{3S1-3S2}$, mΩ	663,9	668,7	670,6	671,9	673,6	674,8	676,1	677,4	678,6	679,2	680,0	680,3	681,1	681,6	682,1
$R_{4S1-4S2}$, Ω	6,413	6,435	6,451	6,466	6,481	6,496	6,508	6,519	6,53	6,54	6,55	6,55	6,56	6,56	6,57
$R_{P1-P2/A}$, μΩ	-	-	-	-	-	-	—	-	-	-	-	-	-	-	31,4
t_a °C	15,39	15,52	15,63	15,72	15,82	16,00	16,04	16,15	16,31	16,23	16,18	16,16	16,17	16,18	16,19

ΔT 1 - ΔT 9 – temperature-rise of the thermocouple

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Table 2. Temperature-rises given during the tests

			Temperature rise ΔT [K]	Limit [K]
Stage No. 1	Windings	1S1-1S2	39,2	65 1,2,3,4)
		2S1-2S2	40,7	
		3S1-3S2	39,4	
		4S1-4S2	39,7	
		P1-P2/A	*Not measured*	
		1a- 1n	6,3	
		2a-2n	7,1	
		3a-3n	6,7	
		4a-4n	6,3	
		da-dn	6,5	
		P2/A-N	10,4	
	Thermocouple No. 1	Oil	27,1	55 1,2,3,4)
	Thermocouple No. 2	Head	0,9	40 5)
	Thermocouple No. 3	Under the flange of tank lid	3,1	
	Thermocouple No. 4	Lower tank	1,9	
	Thermocouple No. 5	Terminal P1	44,8	65 5)
	Thermocouple No. 6	Terminal P1	45,7	
	Thermocouple No. 7	Terminal P2/A	38,8	
	Thermocouple No. 8	Terminal P2/A	36,9	
	Thermocouple No. 9	Current path inside the combined instrument transformer	37,2	65 1,2,3,4)
Stage No. 2	Windings	1S1-1S2	43,4	65+10 1,2,3,4)
		2S1-2S2	45,1	
		3S1-3S2	44,9	
		4S1-4S2	44,1	
		P1-P2/A	*Not measured*	
		1a- 1n	10,8	
		2a-2n	11,2	
		3a-3n	11,4	
		4a-4n	11,5	
		da-dn	12,1	
		P2/A-N	12,2	
	Thermocouple No. 1	Oil	28,8	55+10 1,2,3,4)
	Thermocouple No. 2	Head	1,1	40 5)
	Thermocouple No. 3	Under the flange of tank lid	5,9	
	Thermocouple No. 4	Lower tank	4,3	
	Thermocouple No. 5	Terminal P1	46,0	65 5)
	Thermocouple No. 6	Terminal P1	46,8	
	Thermocouple No. 7	Terminal P2/A	39,6	
	Thermocouple No. 8	Terminal P2/A	38,4	
	Thermocouple No. 9	Current path inside the combined instrument transformer	38,7	65+10 1,2,3,4)

Table 2. Cont.

			Temperature rise ΔT [K]	Limit [K]
Stage No. 3	Windings	1S1-1S2	45,0	65 1,2,3,4)
		2S1-2S2	46,8	
		3S1-3S2	46,6	
		4S1-4S2	45,8	
		P1-P2/A	35,2	
		1a- 1n	21,3	
		2a-2n	22,5	
		3a-3n	23,2	
		4a-4n	23,8	
		da-dn	26,3	
		P2/A-N	38,3	
	Thermocouple No. 1	Oil	29,4	55 1,2,3,4)
	Thermocouple No. 2	Head	1,2	40 5)
	Thermocouple No. 3	Under the flange of tank lid	6,5	
	Thermocouple No. 4	Lower tank	5,0	
	Thermocouple No. 5	Terminal P1	45,6	65 5)
	Thermocouple No. 6	Terminal P1	46,4	
	Thermocouple No. 7	Terminal P2/A	39,6	
	Thermocouple No. 8	Terminal P2/A	38,4	
	Thermocouple No. 9	Current path inside the combined instrument transformer	39,0	65 1,2,3,4)

1) acc. to IEC 61869-1, 2) wg IEC 61869-2, 3) acc. to IEC 61869-3, 4) acc. to IEC 61869-4,
5) acc. to IEC 62271-1,

6. Summary

Results of the temperature-rise test for combined transformer type PVA145a with primary continuous thermal current I_{cth}=3200A are as follows:

- in steady state, at the rated load of secondary voltage and current windings (without residual winding), and supply voltage 1,2U_n (Stage No. 1), permitted temperature-rise limits were not exceeded.

- results of test 8 h at supply voltage 1,9U_n and rated load of voltage and current windings and load of residual winding with thermal limiting output (Stage No. 2), shows that permitted temperature-rise limits were not exceeded.

- in steady state, results of test with thermal limiting output for voltage windings (without residual windings), rated load of current windings and supply voltage U_n (Stage No. 3), permitted temperature-rise limits were not exceeded.

The tested combined transformer met requirements of IEC 61869-1:2007, IEC 61869-2:2012, IEC 61869-3:2011, IEC 61869-4:2013 and IEC 62271-1:20007/A1:2011 standards.

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6. Photographic documentation

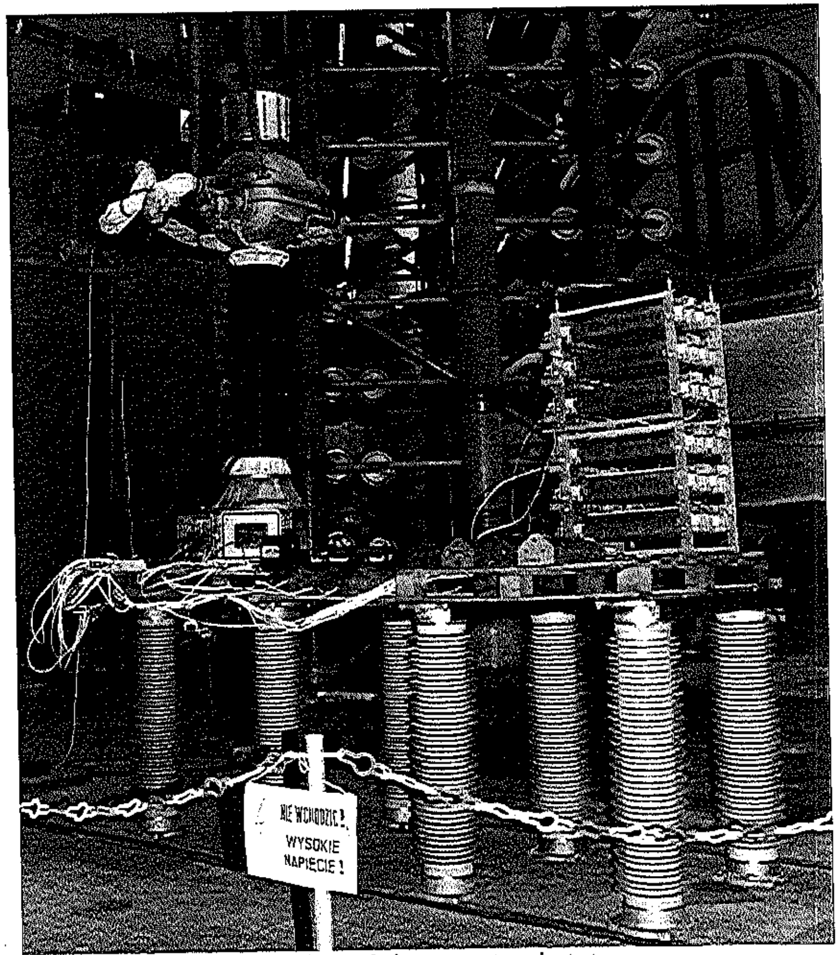
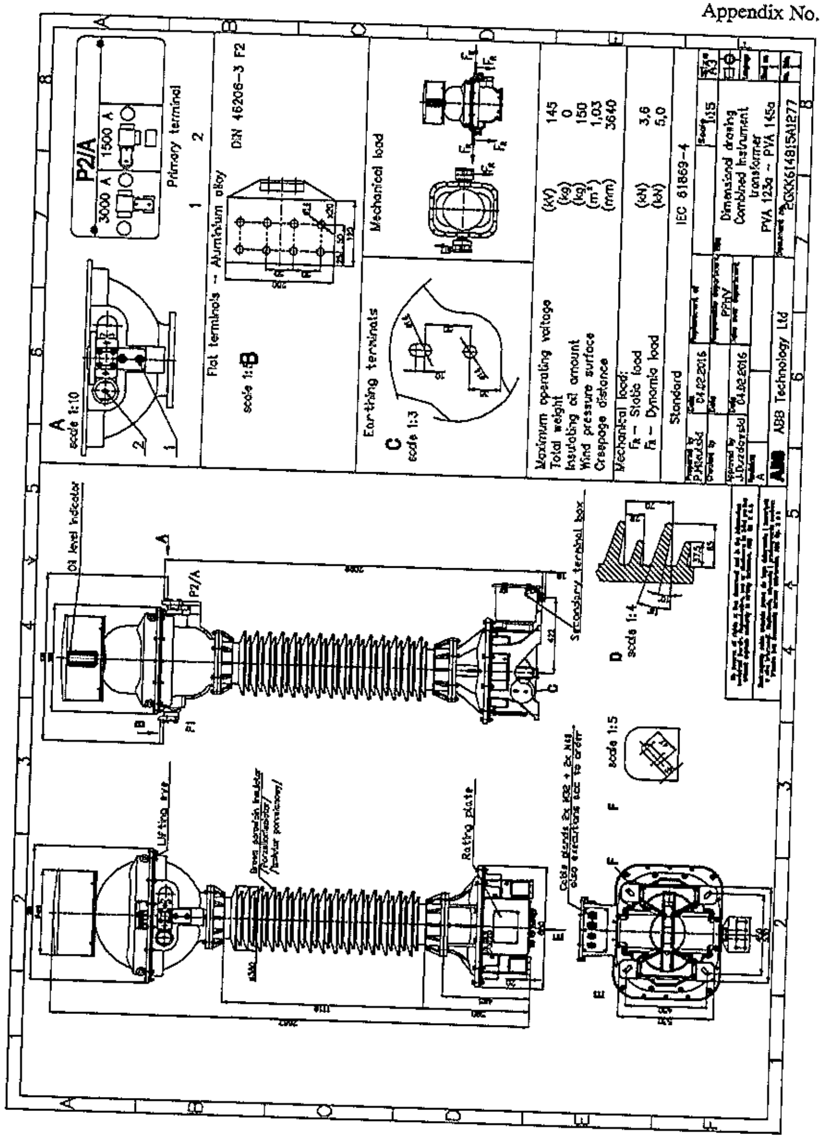


Fig.4. Combined instrument transformer during temperature-rise test

Appendix No. 1



Appendix No. 2

ABB | Declaration of conformity

DECLARATION OF CONFORMITY No. 111/2016 (EN)
(acc. to ISO/IEC 17050-1)

Manufacturer: ABB

Product: Combined Instrument Transformer PVA145a

Above mentioned product conforms with the following standard:

Standard	Title	Edition/Date
IEC 61869-4:	Instrument Transformers – Part 4: Additional requirements for combined transformers	2013

Additional information:
Serial numbers: 2GKP015K1689425;

Place and date of Issue of declaration

Przasnysz 09.02.2016

Kierownik Operacyjny PPHV
ABB Sp. z o.o.
Oddział w Przasnyszu
(Name) Paweł Dębski

Kierownik ds. Zapewnienia Jakości
ABB Sp. z o.o.
Oddział w Przasnyszu
Krzysztof Lubecki
(Signature)

INSTITUTE OF POWER ENGINEERING
Certification Department

PRODUCT EVALUATION REPORT

No DZC/36c/E/2013/2014
Revision 2. 24.03.2015

Product name and symbol: **HV combined instrument transformer, single-phase, outdoor, type: PVA 123a and PVA 145a**

Supplier: **ABB Sp. z o.o., Oddział w Przasnyszu, ul. Leszno 59, 06-300 Przasnysz**

Warsaw, March 2015

Author: mgr inż. Grażyna Wieczorek

Contents:

APPENDIX – Type test reports and special test reports (pages not numbered)

Non-conformities observed:

None found

General evaluation result:

Positive
Based on the analysis made, herewith I conclude for granting of compliance certificates to the HV combined instrument transformers, types: PVA 123a and PVA145a, with composite or ceramic insulator, manufactured by ABB Sp. z o.o., Oddział w Przasnyszu

Grażyna Wieczorek		24 March 2015
Full name	signature	date

1. Introduction

Report from evaluation of HV overhead, single-phase, current transformer series, types: PVA 123a and PVA 145a, manufactured by ABB Sp. z o.o., Oddział w Przasnyszu, developed during the certification process carried out by Zespół ds. Certyfikacji (Certification Team) upon manufacturer's application (contract No DZC/36c/E/2013 of the 23 October 2013)

This document concerns the new series of combined instrument transformers featuring design modifications and marked: PVA ...a.

The PVA 123a and PVA 145a combined instrument transformers are used for feeding measurement and protection systems in electric power grids with the highest system voltage of 126 kV or 145 kV and frequency of 50 Hz. Combined transformers consist of a current element and a voltage element located inside a common enclosure with a composite insulator (cover configuration: straight and spiral) or with a ceramic insulator filled with transformer oil.

The PVA transformer tests were carried out on selected representatives at the laboratories of Instytut Energetyki (Institute of Power Engineering) in Warszawa and Instytut Elektrotechniki Oddział w Gdańsku (Electrotechnical Institute, Gdańsk Branch) as well as (for product tests and deviation measurements) at the manufacturer's laboratory. The selection procedure included the most severe conditions resulting from the combined transformer design and occurring during the temperature-rise tests, short-circuit withstand, voltage and mechanical tests such as: values of continuous and short-circuit currents, winding wire size, different main circuits, winding power for measurement and protection, housing types, accuracy classes, etc. Tests were carried out on seven selected combined transformer prototypes. The results are valid for the entire transformer series acc. to the list as suggested for certification. Test results confirming the combined transformers features are listed in the reports in cl. 2 of this document. The test results were compared against requirements in the following standards:

- PN-EN 61869-1:2009
  Instrument transformers – Part 1: General requirements
- PN-EN 61869-2:2013-06
  Instrument transformers – Part 2: Detailed requirements for current transformers
- PN-EN 61869-3:2011
  Instrument transformers – Part 3: Detailed requirements for voltage transformers
- IEC 61869-4 Ed. 1.0
  Instrument transformers - Part 4: Additional requirements for combined transformers
- PN-EN 60529:2003
  Protection class provided by the housing (IP)

- PN-EN 62262:2003
  Degrees of protection against external mechanical impacts as provided by electric device enclosures (IK coding)

Customer/manufacturer: ABB Sp. z o.o., Przasnysz holds the complex certificate for the following standards: ISO 9001:2008, ISO 14001:2004 and PN-N-18001:2004 – certificate No 0198 150 01525 issued by TÜV Rheinland Polska Sp. z o.o.

2. List of applied documents

The combined transformers design and the test results were evaluated and analysed based on the following documents delivered by the Manufacturer and included in the reports:

D1. Report No EWP/10/E/2014-1e, Temperature-rise test High Current Laboratory, Warsaw, January 2014.

D2. Report No EWP/10/E/2014-2e, IEn, Temperature-rise test High Current Laboratory Warsaw, February 2014.

D3. Report No EWP/35/E/2013-1e, IEn, Temperature-rise tests, High Current Laboratory Warsaw, February 2014.

D4. Report EUR/66/E/13-2 E), Mechanical tests Distribution Equipment Laboratory Warsaw, December 2013.

D5. Report No EUR/66/E/13-1 E (Mechanical tests), IEn, Distribution Equipment Laboratory Warsaw, December 2013.

D6. Report No EUR/71/E/13-3 E (Short-time current test, combined error measurement, test of strength against short-circuit in the secondary circuit), IEn, Distribution Equipment Laboratory Warsaw, January 2014.

D7. Report No EUR/74/E/13 E Short-time current test, Test for composite error), IEn Distribution Equipment Laboratory Warsaw December 2013.

D8. Report No EUR/71/E/13-1 E Short-time current test, IEn Distribution Equipment Laboratory Warsaw, January 2014.

D9. Report No EUR/71/E/13-4 E Short-time current test, Test for composite error), IEn, Distribution Equipment Laboratory), Warsaw, January 2014.

D10. Test report No EWN/145/E/13, Type tests, special tests and additional tests of combined transformers type PVA123a and PVA145a manufactured by ABB sp. z o.o.), IEn, High Voltage Laboratory Warsaw, January 2014.

D11. Report No 8281/NZL/NBR/12, IP tests for terminal box IEl, Distribution Equipment Test Laboratory Warsaw, July 2012.

D12. Report No EWP/35/E/2013-3e Mechanical impact test, IEn High Current Laboratory), Warsaw, February 2014.

D13. Report No EUR/23/E/2014 E, Short-time current tests, IEn, Distribution Equipment Laboratory), Warsaw, May 2014.

D13. Dimensional drawings:

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614122/ABB R&D_TS_KU568/13 (17.12.2013),

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614123/ABB R&D_TS_KU570/13 (17.12.2013),

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614121/ABB R&D_TS_KU570/13 (17.12.2013),

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614123/ABB R&D_TS_KU571/13 (17.12.2013),

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614123/ABB R&D_TS_KU572/13 (17.12.2013),

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614120/ABB R&D_TS_KU569/13/A (17.12.2013),

Dimensional drawing Combined instrument transformer PVA 123a-145a 2GKK614121/ABB R&D_TS_KU569/13 (17.12.2013).

D13. Product test reports and accuracy check reports – see reports from D1÷10 tests

D14. Rating plates – see reports from D1÷10 tests

D15. Electrical diagrams – see reports from D1÷10 tests

3. Testing laboratory competences

Type tests, product tests and special tests for PVA...a combined transformers were carried out at the following laboratories:

- Laboratorium Wysokich Napięć (High Voltage Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA No AB 272.
- - Laboratorium Urządzeń Rozdzielczych (Distribution Equipment Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA No AB 324.
- - Laboratorium Wielkoprądowe (High Current Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA Nr AB 323.
- Laboratorium Fabryczne ABB Sp. z o.o. (ABB Manufacturing Plant Laboratory) in Przasnysz – Punkt Legalizacyjny OUM Warszawa (OUM Warsaw Verification Unit) – deviation measurement, and product tests under supervision of Instytut Energetyki (Institute of Power Engineering), Laboratorium Wysokich Napięć (High Voltage Laboratory).
- Laboratorium Badawcze Aparatury Rozdzielczej (Distribution Equipment Test Laboratory), a unit of Instytut Energetyki (Institute of Power Engineering) in Warsaw, holding the PCA Accreditation Certificate of the Research Laboratory PCA No AB 074.

4. Test result list

4.1. Type tests, additional tests

The tests were made on selected PVA ...a combined transformer models (various rated currents for the PVA...a current elements, various main circuit designs, various design of PVA...a transformers secondary circuits, different accuracy classes and various insulation covers, etc.) The tests results are valid for the entire combined transformer series acc. to the list as suggested for certification. Table 1 shows manufacturer's solutions for the PVA...a current circuits. Representatives for short-circuit tests and heating tests were selected from that list.

PVA...a combined transformers were selected to temperature-rise test based on the most heat-exposed design solutions.

Voltage tests were made for two combined transformers: PVA 123a, and 145a.

The short-circuit withstand tests were made for PVA...a combined transformers. Representatives were selected based on their exposition to dynamic and thermal effects to the main circuits.

Table 2 shows carried out tests. Their scope meets requirements included in respective standards for: type tests, special tests, routine tests, and some additional requirements. Respective item numbers in PN-EN 61869 and IEC 61869 as well as report numbers with detailed test results are listed.

Results of all tests were positive.

4.2. Routine tests

Routine tests and accuracy class tests were carried out at the manufacturer's laboratory for all the combined transformers tested under the IEn supervision.

The tests included:

- oil measurements before filling the instrument transformer,
- verification of markings,
- power-frequency voltage withstand tests on primary terminals,
- power-frequency voltage withstand tests on secondary terminals,
- non-complete discharge intensity,
- inter-winding insulation test,
- test for accuracy,
- over-current coefficient determination,
- magnetisation characteristics determination,
- measurement of capacitance and dielectric dissipation factor,
- winding resistance measurement.

Test results were listed in protocols. their numbers being the same as that of the combined transformer tested. After the voltage tests and short circuit tests. additional routine tests and accuracy class tests were carried out.

Test result: positive

Table 1. Main circuit list:

Circuit design description	Current circuit assembly drawing number	Drawing title:	Ith/Idyn level assumed	Remarks	Tests carried out with Ith/Idyn current
Rod ϕ40 Cu	2GKK314130A0001	Main circuit, rod ϕ40 Cu	63/158 kA	Prototype 2	P2 positive test
Rod ϕ40 Al	2GKK314131A0001	Main circuit, rod ϕ40 Al	63/158 kA	Prototype 8	P8 positive test
Rod ϕ40 Al + pipe ϕ60x4 Al	2GKK314132A0001	Main circuit, rod ϕ40 Al + pipe ϕ60x4 Al	63-63/ 158-158 kA	Prototype 8	P8 positive test
Rod ϕ40 Al + pipe ϕ60x4 Al + 2 turns of 240 mm2 cable	2GKK314133A0001	Main circuit, rod ϕ40 Al + pipe ϕ60x4Al + 2 turns of 240 mm2 cable	63-63–40/ 158-158–100 kA	Prototype 1	P1 positive test.
1 turn of 240 mm2 cable	2GKK314134A0001	Main circuit, 1 turn of 240 mm2 cable	40/100 kA	Prototype 1	P1 positive test.
2 turns of 240 mm2 cable	2GKK314134A0002	Main circuit, 2 turns of 240 mm2 cable	40/100 kA	Prototype 1	P1 positive test.
3 turns of 240 mm2 cable	2GKK314134A0003	Main circuit, 3 turns of 240 mm2 cable	40/100 kA	Prototype 6	P6 positive test
4 turns of 240 mm2 cable	2GKK314134A0004	Main circuit, 4 turns of 240 mm2 cable	40/100 kA	Prototype 6	P6 positive test
5 turns of 240 mm2 cable	2GKK314134A0005	Main circuit, 5 turns of 240 mm2 cable	40/100 kA	Prototype 6	P6 positive test
6 turns of 240 mm2 cable	2GKK314134A0006	Main circuit, 6 turns of 240 mm2 cable	40/100 kA	Prototype 6	P6 positive test
7 turns of 240 mm2 cable	2GKK314134A0007	Main circuit, 7 turns of 240 mm2 cable	40/100 kA	Prototype 6	P6 positive test
8 turns of 240 mm2 cable	2GKK314134A0008	Main circuit, 8 turns of 240 mm2 cable	40/100 kA	Prototype 6	P6 positive test
2+2 turns of 240 mm2 cable	2GKK314135A0001	Main circuit, 2+2 turns of 240 mm2 cable	40–40/ 100-100 kA	Prototype 6	P6 positive test
3+3 turns of 240 mm2 cable	2GKK314135A0002	Main circuit, 3+3 turns of 240 mm2 cable	40–40/ 100-100 kA	Prototype 6	P6 positive test
4+4 turns of 240 mm2 cable	2GKK314135A0003	Main circuit, 4+4 turns of 240 mm2 cable	40–40/ 100-100 kA	Prototype 6	P6 positive test
2+2+4 turns of 240 mm2 cable	2GKK314136A0001	Main circuit, 2+2+4 turns of 240 mm2 cable	40–40–40/ 100-100-100 kA	Prototype 6	P6 positive test
3 turns of 120 mm2 cable	2GKK314137A0001	Main circuit, 3 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
6 turns of 120 mm2 cable	2GKK314137A0002	Main circuit, 6 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
9 turns of 120 mm2 cable	2GKK314137A0003	Main circuit, 9 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
12 turns of 120 mm2 cable	2GKK314137A0004	Main circuit, 12 turns of 120 mm2 cable	20/50 kA	Prototype 7	P7 positive test
3 + 3 turns of 120 mm2 cable	2GKK314138A0001	Main circuit, 3 + 3 turns of 120 mm2 cable	20-20 / 50-50 kA	Prototype 7	P7 positive test
6 + 6 turns of 120 mm2 cable	2GKK314138A0002	Main circuit, 6 + 6 turns of 120 mm2 cable	20-20 / 50-50 kA	Prototype 7	P7 positive test
3 + 3 + 6 turns of 120 mm2 cable	2GKK314139A0001	Main circuit, 3 + 3 + 6 turns of 120 mm2 cable	20-20-20/ 50-50-50 kA	Prototype 7	P7 positive test

Table 2. List of tests made for PVA...a combined instrument transformer

Item	Test type	Requirements	Report numbers
	TYPE TESTS		
1	Short-time current test	IEC 61869-4, cl. 7.2.201 PN EN 61869-2, cl.7.2.201	EUR/71//E/13-1 EUR/71//E/13-3 EUR/71//E/13-4 EUR/74//E/13 EUR/23/E/14
2	Temperature-rise test	IEC 61869-4, cl.7.2.2 PN EN 61869-2 cl.7.2.2 PN EN 61869-2, cl. 7.2.2.204 PN EN 61869-3, cl.7.2.2	EWP/10/E/2014-1 EWP/10/E/2014-2 EWP/35/E/2013-1 EWP/07/E/2012-4
3	Impulse voltage withstand test	IEC 61869-4, cl. 7.2.3 PN-EN 61869-1, cl. 7.2.3 PN EN 61869-3, item 7.2.3	EWN/145/E/13
4	Wet test	IEC 61869-4, cl. 7.2.4 PN-EN 61869-1, cl. 7.2.4 PN-EN 61869-3, cl. 7.2.4	EWN/145/E/13
5	Short-circuit withstand capability test	IEC 61869-4, cl. 7.2.301 PN EN 61869-3, item 7.2.301	EUR/71/E/13-3
6	Tests for accuracy and mutual influence test	IEC 61869-4, cl. 7.2.6.401, 7.2.6.402 and 7.3.5 PN EN 61869-2, cl. 7.2.6 PN EN 61869-3, cl. 7.2.6	EWN/145/E/13 and protocols from manufacturer's laboratory
7	RIV test	PN EN 61869-1, cl. 7.2.5.1	EWN/145/E/13
8	Test for composite error	PN EN 61869-2, cl. 7.2.6.203	EUR/71//E/13-3 EUR/71//E/13-4 EUR/23/E/14
9	Terminal box verification of the IP coding	PN EN 61869-1, cl. 7.2.7.1 PN-EN 60529, cl.13.14	8281/NZL/NBR/12
10	Mechanical impact test (IK)	PN EN 61869-1, cl. 7.2.7.1 PN-EN 62272	EWP/35/E/2013-3
	SPECIAL TESTS		
11	Chopped impulse voltage withstand test on primary terminals.	IEC 61869-4, cl. 7.4.1 PN-EN 61869-1, cl. 7.4.1 PN EN 61869-3, cl. 7.4.1	EWN/145/E/13
12	Mechanical tests	IEC 61869-4, cl. 7.4.5 PN-EN 61869-1, cl. 7.4.5	EUR/66/E/13-1 EUR/66/E/13-2
13	Transmitted overvoltage test	IEC 61869-4, cl. 7.4.4	

		PN-EN 61869-1, cl. 7.4.4 PN EN 61869-3, cl. 7.4.4	EWN/145/E/13
14	Measurement of capacitance and dielectric dissipation factor	IEC 61869-4, cl. 7.4.3 PN-EN 61869-1, cl. 7.4.3 PN EN 61869-2, cl. 7.4.3 PN EN 61869-3, cl. 7.4.3	and protocols from manufacturer's laboratory
ADDITIONAL TESTS			
15	Capacitor discharge test	C = 6μF, $U = 1.1 \cdot \sqrt{2} \cdot 110/\sqrt{3}$ kV No damage, no temperature increase above 65 K.	EWN/145/E/13

5. SUMMARY

Based on the test results for selected representatives of PVA 123a and PVA 145a instrument transformer series as selected and based on analysis of the standards, it was determined that:

- All tests from the type test range, special tests and additional tests which were carried out were sufficient for a complete evaluation of the apparatuses.
- Instrument transformer errors tests and instrument transformer secondary circuit designs were analysed, and their metrological properties were confirmed.
- PVA 123a and PVA 145a instrument transformer main circuit designs were analysed. It was determined that the short-circuit tests and heating tests as carried out are binding for all design solutions.
- Tests were made according to requirements of the 61869 series standard (PN and IEC)
- Taken the test results under consideration, the technical data listed in Tables 3 and 4 may be referenced to the PVA 123a and PVA 145a instrument transformer series.
- This document may be a basis for issuing compliance certificates for PVA 123a and PVA 145a instrument transformer series manufactured by ABB Sp. z o.o. Oddział w Przasnyszu. The certificate validity date is suggested to be February 2017.

Table 3. List of technical data assigned to PVA 123a

Combined transformer type PVA 123a	
Rated primary voltage [U_{pr}]	110/√3 kV
Highest voltage of combined transformer [U_m]	≤ 126 kV
Rated frequency [f_R]	50 Hz
Rated insulation level	AC 230 kV / LI 550 kV
Burden class	F_R = 3.600 N
External insulation – creepage distance of insulator'	3.640–4.495 mm[1]
Degree of protection of secondary terminal enclosure	IP55
Degree of protection to mechanical impact of enclosure [2]	IK7
Current element	
Rated primary current [I_{pr}]	50 A ÷ 3.000 A
Extended current rating	up to 200%
Rated continuous thermal current [I_{cth}]	≤ 3.000 A
Rated short-time thermal current [I_{th}] during 1 sec	20 kA or 40 kA or 63k A
Rated short-time thermal current [I_{th}] during 3 sec	20 kA or 40kA

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Rated dynamic current [I_{dyn}]	50 kA or 100 kA or 158 kA
Rated secondary current [I_{sr}]	1 A or 5 A
Core power to measurements and to protection (S_r)	1VA – 200 VA
Measure core accuracy class (cl.)	0.1; 0.2; 0.2S; 0.5; 0.5S; 1; 3; 5
Protective core accuracy class (cl.)	5P; 10P; 5PR; 10PR; PX; PXR; TPX; TPY; TPZ
Voltage element	
Rated voltage factor [F_V] / time	1.5/30 sec; 1.9/30 sec or 1.9/8 h
Rated secondary voltage [U_{sr}]	100/√3 V; 110/√3 V;
Windings class to measurements and to protection (cl.)	0.1; 0.2; 0.5; 1; 3; 3P; 6P
Windings power to measurements and to protection (S_r)	≤ 1.000 VA
Rated voltage of residual voltage winding [$U_{sr(dn-dn)}$]	100/3 V; 110/3 V; 100 V; 110 V
Residual voltage winding class (cl.)	0.5; 1; 3; 3P; 6P
Residual voltage winding power (S_r)	≤ 450 VA
Total thermal limiting output [S_{Vth}]	4.000 VA

REMARKS:

[1] Applies to composite and ceramic insulators.

[2] Do not apply to ceramic insulators.

Table 3. List of technical data assigned to PVA 145a

Combined transformer type PVA 145a	
Rated primary voltage [U_{pr}]	132/√3 kV
Highest voltage of combined transformer [U_m]	≤ 145 kV
Rated frequency [f_R]	50 Hz
Rated insulation level	AC 275 kV / LI 650 kV
Burden class	F_R = 3.600 N
External insulation – creepage distance of insulator	3.640–4.495 mm[1]
Degree of protection of secondary terminal enclosure	IP55
Degree of protection to mechanical impact of enclosure [2]	IK7
Current element	
Rated primary current [I_{pr}]	50 A ÷ 3.000 A
Extended current rating	up to 200%
Rated continuous thermal current [I_{cth}]	≤ 3.000 A
Rated short-time thermal current [I_{th}] during 1 sec	20 kA or 40 kA or 63k A
Rated short-time thermal current [I_{th}] during 3 sec	20 kA or 40kA
Rated dynamic current [I_{dyn}]	50 kA or 100 kA or 158 kA
Rated secondary current [I_{sr}]	1 A or 5 A
Core power to measurements and to protection (S_r)	1VA – 200 VA
Measure core accuracy class (cl.)	0.1; 0.2; 0.2S; 0.5; 0.5S; 1; 3; 5
Protective core accuracy class (cl.)	5P; 10P; 5PR; 10PR; PX; PXR; TPX; TPY; TPZ
Voltage element	
Rated voltage factor [F_V] / time	1.5/30 sec; 1.9/30 sec or 1.9/8 h
Rated secondary voltage [U_{sr}]	100/√3 V; 110/√3 V;
Windings class to measurements and to protection (cl.)	0.1; 0.2; 0.5; 1; 3; 3P; 6P
Windings power to measurements and to protection (S_r)	≤ 1.000 VA
Rated voltage of residual voltage winding [$U_{sr(dn-dn)}$]	100/3 V; 110/3 V; 100 V; 110 V
Residual voltage winding class (cl.)	0.5; 1; 3; 3P; 6P

Residual voltage winding power (S_r)		≤ 450 VA
Total thermal limiting output [S_{th}]		4,000 VA

REMARKS:

[1] Applies to composite and ceramic insulators.
[2] Do not apply to ceramic insulators.

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APPENDIX

Type test reports, special test reports (pages not numbered)

D1. Report No EWP/10/E/2014-1e. Temperature-rise test High Current Laboratory. Warsaw. January 2014.

D2. Report No EWP/10/E/2014-2e. IEn. Temperature-rise test High Current LaboratoryWarsaw. February 2014.

D3. Report No EWP/35/E/2013-1e. IEn. Temperature-rise tests. High Current Laboratory Warsaw. February 2014.

D4. Report EUR/66/E/13-2 E). Mechanical tests Distribution Equipment Laboratory Warsaw. December 2013.

D5. Report No EUR/66/E/13-1 E (Mechanical tests). IEn. Distribution Equipment Laboratory Warsaw. December 2013.

D6. Report No EUR/71/E/13-3 E (Short-time current test. combined error measurement. test of strength against short-circuit in the secondary circuit). IEn. Distribution Equipment Laboratory Warsaw. January 2014.

D7. Report No EUR/74/E/13 E Short-time current test. Test for composite error). IEn Distribution Equipment Laboratory Warsaw December 2013.

D8. Report No EUR/71/E/13-1 E Short-time current test. IEn Distribution Equipment Laboratory Warsaw. January 2014.

D9. Report No EUR/71/E/13-4 E Short-time current test. Test for composite error). IEn. Distribution Equipment Laboratory). Warsaw. January 2014.

D10. Test report No EWN/145/E/13. Type tests. special tests and additional tests of combined transformers type PVA123a and PVA145a manufactured by ABB sp. z o.o.). IEn, High Voltage Laboratory Warsaw. January 2014.

D11. Report No 8281/NZL/NBR/12. IP tests for terminal box. IEl. Distribution Equipment Test Laboratory Warsaw. July 2012.

D12. Report No EWP/35/E/2013-3e Mechanical impact test. IEn High Current Laboratory). Warsaw. February 2014.

D13. Report No EUR/23/E/2014 E. Short-time current tests. IEn. Distribution Equipment Laboratory). Warsaw. May 2014.

ABB	ZCCO Corporate Research			9ADB008898
Issued by department ZCCO/Poland/SST	Last edit date 2015-05-25	Lang. English	Revision 1.0	Page 1/37
Customer	ABB PLABB	Classification:		Confidential
Doc. title	Seismic analyses of HV Instrument Transformers. IEC 62271-300 - AF5 seismic level.	Status of document		Released
Project name/ID	SST activities - BU9953 - CHTET / 50005877	CR Program:		CHTET
Main Author:	Grzegorz Juszkiewicz/PLCRC/SST	Case ID:		15101
Additional Author(s):				
Distribution	Marcin Tarnowski/PPHV, Pawel Grysztar/PLHV, Jaroslaw Duzdowski/PPHV, Dariusz Siperek/PPHV, Piotr Mikulski/PPHV, Przemyslaw Naslerowski/PPHV Piotr Saj/PLCRC, Marek Florkowski/PLCRC			
Keywords	simulation, FE method, seismic analysis, frequency modes, response spectrum			
Approved by:	Marek Florkowski/PLCRC	Final Approval Date:		2015-05-21

Technical_Note.dot Rev 1.00

Electronic document

Technical report

Simulation Support Team

Case submitted by	Marcin Tarnowski
Business Unit	PPHV
Type of analysis (used tool)	ABAQUS (seismic analysis)
Description of analysis	Seismic analysis different variants of current, voltage and combined transformers (PA123a / PA145a, PV123, PVA123a / PVA145a) according to guidelines described in IEC standard. Consideration of seismic, wind, and dead loads.

Executive summary

This report covers investigation related to seismic analysis of HV Instrument transformers (PV123, PA123a /PA145a, PVA123a /PVA145a) subjected to various load scenarios. Simulation covered the following load conditions: dead load, wind load, terminal force load, seismic load (AF5 - 0.5 g). Analysis showed that all designs are satisfying required safety criteria.

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1 INTRODUCTION

The goal of the analysis was to evaluate seismic performance of PA123a /PA145a (see 8.1), PV123 (see 8.2), PVA145a/PVA123a (8.3) type transformers. Simulation was done using guidelines of IEC TR 62271-300 standard. For more information please see [1].

Computations concerned evaluation of stress field distribution and maximum bending moment between flange and insulator. Present report describes used simulation technique, analysis steps, loads and boundary conditions variations and summarizes obtained results.

2 SIMULATION SOFTWARE

All simulations were performed using Abaqus/CAE package. Abaqus includes FEM (finite element method) solver, pre- and post processor and enables performing many types of multiphysics simulations: mechanical, thermal, acoustic, piezoelectric, seismic, and others.

Parts and assemblies can be created in Abaqus, or they can be imported from CAD systems using native file formats. Abaqus functionality enables to define materials, interactions, loads, boundary conditions, mesh. User is also available to set up simulation parameters such as pre-processing memory. It is always possible to change all simulation settings and properties, because they're all parameterized.

Simulation results can be visualized in Abaqus postprocessor or in external software, which is able to import simulation results in Abaqus format. In postprocessor user can view all predefined field outputs, show or hide part instances, create cross-sections, make animations, automatically generate reports, diagnose model (warnings, errors). For more information about ABAQUS please see [2].

3 SIMULATION SETUP

Analysis has been made using Finite Element Method.

3.1 Simulation procedure

According to [1] analysis included three main simulation steps:

- Static load:
  - Wind load.
  - Terminal load.
  - Gravitational load.
- Natural frequency extraction.
- Dynamic analysis.

3.2 Simulation steps

Simulation consisted of three main simulation steps.

3.2.1 Natural frequency extraction

In the first simulation step natural frequency extraction was performed. The frequency extraction procedure performs eigenvalue extraction to calculate the natural frequencies and the corresponding mode shapes of a system.

The eigenvalue problem for the natural frequencies of an undamped finite element model can be described by equation (3-1):

$$(-\omega^2 M^{MN} + K^{MN})\phi^N = 0 \qquad (3\text{-}1)$$

where: M^{MN} – mass matrix (kg); K^{MN} – stiffness matrix (Pa), which includes initial stiffness effects if the base state (gravitational load); ϕ – eigenvector (the mode of vibration); M, N – degrees of freedom (-). Based on specification [1] one can assume that most critical frequency modes are in range of 0-35 Hz.

3.2.2 Response spectrum analysis

The response spectrum method is a convenient way of describing shock motion in terms of the maximum response of a single degree of freedom (1-DOF) oscillator of arbitrary natural period and damping ratio. Each data point of the response spectrum curve represents the peak response from a time history analysis of the earthquake applied to 1-DOF oscillator system. The ordinate defines the natural period at which the oscillator is tuned. Repeating the procedure for a great many frequencies defines a continuous curve for an assumed level of damping.

A spectral response analysis estimates the maximum displacement of the structure during a 'design' shock load without recourse of direct integration. Finite element implementation of the response spectrum calculate the response of each mode independent, and then combine the scaled response one of a number of established combination rules, to give an estimate of peak response. Spectrum plot used in simulation is presented in Figure 1.

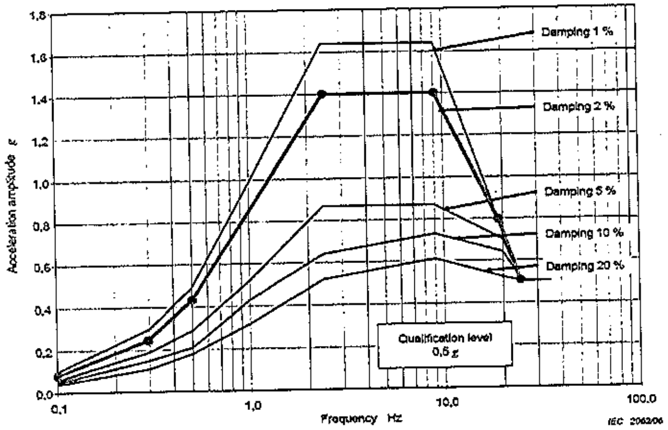

Figure 1. *Design response spectrum – 2% damping (red curve)*

3.3 Loads and boundary conditions

3.3.1 Loads

The following static load scenarios have been considered

1. Gravitational load, g=9.81 m/s^2.
2. Terminal operating load, acc. to [3]. According to Table 14, page 90 terminal force are adequate to rated voltage and current level. Applied force values were the following:
    a. **PA123a /PA145a:** Longitudinal force-1250 N, Transversal force – 1000 N, Vertical force – 1250 N.
    b. **PV123:** Longitudinal force-1750 N, Transversal force – 1250 N, Vertical force – 1500 N.
    c. **PVA123a/PVA145a:** Longitudinal force-1750 N, Transversal force – 1250 N, Vertical force – 1500 N.
3. Wind load, 10m/s load. Wind load has been represented as directional pressure evaluated according to drag force equation:

$$F_D = \frac{1}{2}\rho u^2 C_D A \qquad (3\text{-}1)$$

where: F_D – drag force [N], ρ – mass density of the fluid [kg/m^3], u – flow velocity [m/s], A – reference area [m^3], C_D – drag coefficient [-].

Evaluated pressure level for all designs was ca. p=71 Pa.

Seismic load have been predefined according design response spectrum described in the standard [1] – ground acceleration reference AF5. Main input parameters were the following:

- XZ base motion with vertical load equal to 50% of horizontal direction.
- YZ base motion with vertical load equal to 50% of horizontal direction.
- Damping ratio – 2% ([1], page 23, chapter 7.3.2 point b).

As the final outcome from the analysis static loads were combined with the most conservative seismic load.

3.3.2 Boundary conditions

Simulation assumes that the apparatus will be mounted on ground. An example of boundary conditions is presented in

During analysis model has been fixed at the bottom face of used test frame. General view of static loads and boundary conditions is presented in Figure 2. Area highlighted by red has been constrained (Y-rotation released). Base of the bottom tank has been supported in Y direction (as it is placed on the ground). Described boundary conditions have been used for all analyzed models.

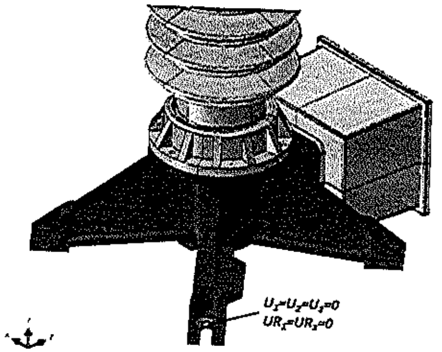

Figure 2. *Boundary conditions – general view*

3.4 Acceptance criteria

According to [1] the following acceptance criteria shall be met:

- Stresses observed at metallic parts should not exceed yield point of material.
- The maximum bending moment of the insulator should not exceed ultimate value. For more information please refer to [4] (Table 1, page 23).

3.5 Current transformer - PA 123a/PA 145a

This chapter gathers details related to FE model of current transformer **PA 123a/PA 145a**.

3.5.1 Model simplifications

For simulation requirements some areas of the model were simplified. Small geometrical features like casting rounding, chamfers were removed in order to improve mesh generation process. Details of the geometry and center of mass can be found in Figure 3. Red point indicates center of mass of the transformer.

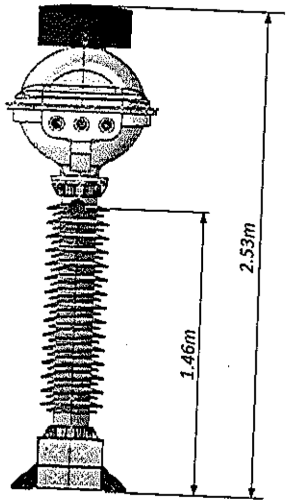

Figure 3. *Simplified representation of the PA 123a/PA 145a transformer*

Concrete between flange and ceramic insulator has been introduced using connector element with predefined rotational stiffness.

Because of the simulation method (dynamics based on modal analysis) components were connected together using bonded connection or conformal mesh.

3.6 Material and mass information

Component naming is presented in Figure 4.

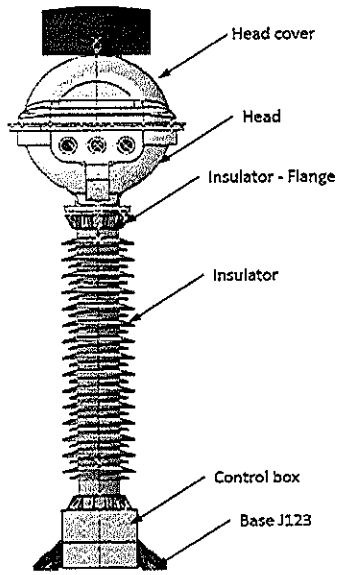

Figure 4. *Assembly – component naming*

Material and mass information is listed in Table 1

Table 1. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Young's modulus [MPa]	Yield strength [MPa]	Ultimate strength [MPa]
2GKA310015	Base J123	EN-AC 43200 (grade F)	16.5	69000	80	160
2GKA310404	Insulator	Porcelain	71	100000	140	
	Insulator - Flange	EN-AC 43200 (grade T6)	3.5	69000	180	220
2GKA414718	Head	EN-AC 43200 (grade F)	22.5	69000	80	160
2GKK314089	Head cover	EN-AC 43200 (grade F)	20	69000	80	160
	Coil	-	150			
2GKK311093R	Control box	EN-AC 43200 (grade F)	5.5	69000	80	160
	Oil		120			

The maximum allowable bending moment for ceramic insulator is equal to M_B=13.3 kNm.

3.7 Finite element (FE) model

General view of FE model is presented in Figure 5.

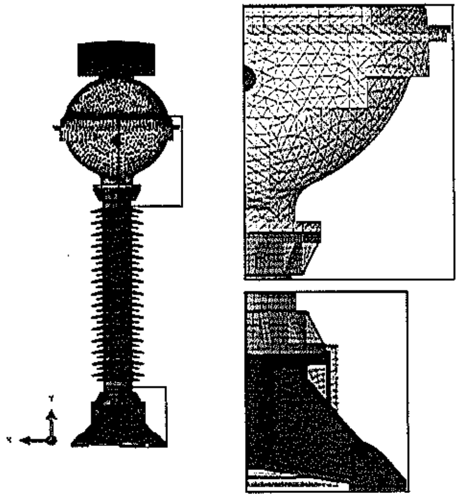

Figure 5. *FE model – general view*

Mesh statistics were the following:

- Total number of nodes: 533430
- Total number of elements: 242866
  - 210555 quadratic tetrahedral elements of type C3D10
  - 31050 quadratic hexahedral elements of type C3D20R
  - 1243 quadratic quadrilateral elements of type S8R
  - 18 quadratic triangular elements of type STRI65

Description of the coordinate system.

- X – 1st horizontal axis.
- Z – 2nd horizontal axis.
- Y – vertical axis.

360

3.8 Voltage transformer - PV 123

This chapter gathers details related to FE model of voltage transformer PV 123.

3.8.1 Model simplifications

For simulation requirements some areas of the model were simplified. Small geometrical features like casting rounding, chamfers were removed in order to improve mesh generation process. Details of the geometry and center of mass can be found in Figure 6. Red point indicates center of mass of the transformer.

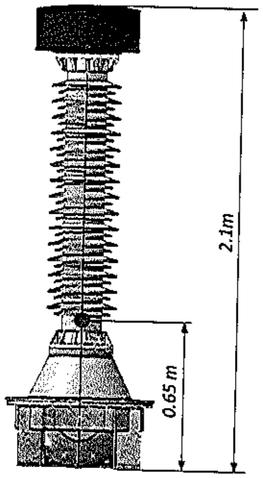

Figure 6. *Simplified representation of the PV 123 transformer*

Concrete between flange and ceramic insulator has been introduced using connector element with predefined rotational stiffness.

Because of the simulation method (dynamics based on modal analysis) components were connected together using bonded connection or conformal mesh.

3.9 Material and mass information

Component naming is presented in Figure 7.

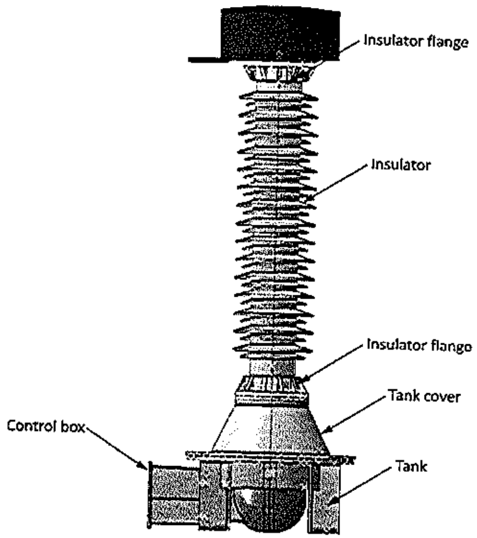

Figure 7. *Assembly – component naming*

Material and mass information is listed in Table 2.

Table 2. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Young's modulus [MPa]	Yield strenght [MPa]	Ultimate strenght [MPa]
2GKK310150P	Bottom tank	EN-AC 43200 (grade F)	25	69000	80	160
2GKK310147P	Core	Steel	22.5	206000	300	370
2GKV314005	Tank cover	EN-AC 43200 (grade F)	15.5	69000	80	160
2GKA310404	Insulator	Porcelain	71	100000	140	
	Insulator flange	EN-AC 43200 (grade T6)	3.5	69000	180	220
	Coil	-	30			
2GKK311093R	Control box	EN-AC 43200 (grade F)	5.5	69000	80	160
	Oil		60			

The maximum allowable bending moment for ceramic insulator is equal to **M_B=13.3 kNm.**

3.10 Finite element (FE) model

General view of FE model is presented in Figure 8.

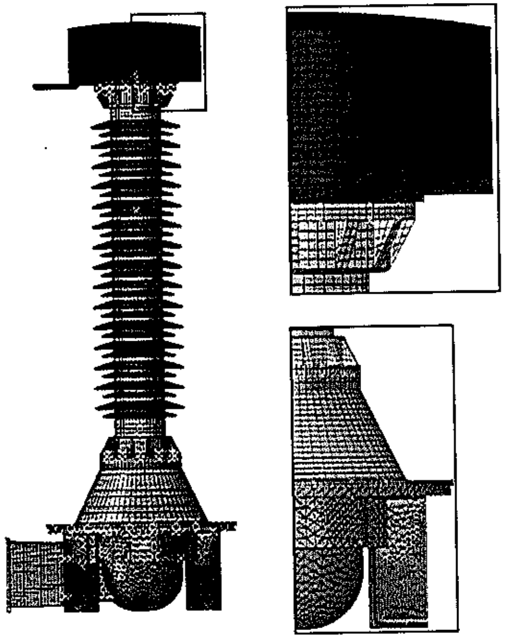

Figure 8. *FE model – general view*

Mesh statistics were the following:

- Total number of nodes: 608507
- Total number of elements: 236033
  - 4606 quadratic quadrilateral elements of type S8R
  - 58 quadratic triangular elements of type STRI65
  - 58965 quadratic hexahedral elements of type C3D20R
  - 8577 linear hexahedral elements of type C3D8R
  - 163827 quadratic tetrahedral elements of type C3D10

Description of the coordinate system.

- X – 1st horizontal axis.
- Z – 2nd horizontal axis.
- Y – vertical axis.

3.11 Combined transformer – PVA123a /PVA145a

This chapter gathers details related to FE model of combined transformer **PVA123a /PVA145a.**

3.11.1 Model simplifications

For simulation requirements some areas of the model were simplified. Small geometrical features like casting rounding, chamfers were removed in order to improve mesh generation process. Details of the geometry and center of mass can be found in Figure 9. Red point indicates center of mass of the transformer.

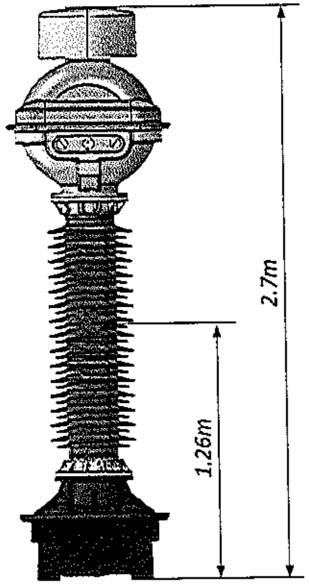

Figure 9. *Simplified representation of the PVA123a /PVA145a transformer*

Concrete between flange and ceramic insulator has been introduced using connector element with predefined rotational stiffness.

Because of the simulation method (dynamics based on modal analysis) components were connected together using bonded connection or conformal mesh.

3.12 Material and mass information

Component naming is presented in Figure 7.

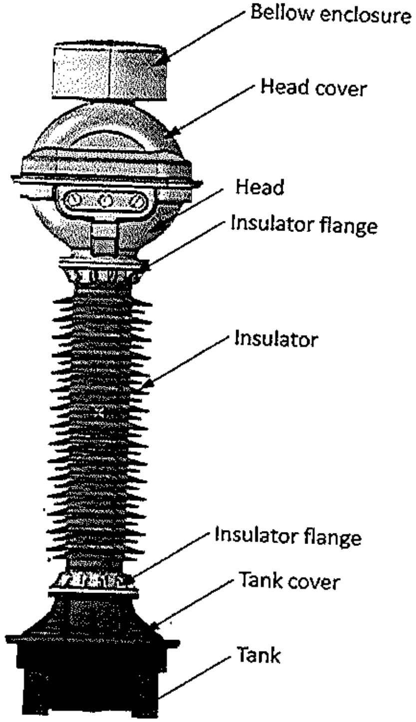

Figure 10. *Assembly – component naming*

Material and mass information is listed in Table 3.

Table 3. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Young's modulus [MPa]	Yield strength [MPa]	Ultimate strength [MPa]
2GKK314076	Tank	EN-AC 43200 (grade F)	25	69000	80	160
2GKK314084	Core	Steel	33.8	206000	300	370
2GKK314075	Tank cover	EN-AC 43200 (grade F)	18	69000	80	160
2GKK314070	Insulator	Porcelain	131	100000	140	
	Insulator flange	EN-AC 43200 (grade T6)	5	69000	180	220
2GKK314080	Head	EN-AC 43200 (grade F)	23.5	69000	80	160
2GKK314089	Head cover PVA-PA123a /PA145a-145	EN-AC 43200 (grade F)	23	69000	80	160
2GKK310902	Bellow	Stainless steel	5	190000	200	500
2GKK310014P	Below enclosure	EN-AC 43200 (grade F)	7	69000	80	160
-	Voltage coil	-	30	-	-	-
-	Current coil	-	150	-	-	-
2GKK310802	Epoxy insulator	-	2.5	-	-	-
2GKK311093R	Control box	EN-AC 43200 (grade F)	5.5	69000	80	160
-	Oil		150	-	-	-

The maximum allowable bending moment for ceramic insulator is equal to **M_B=13.3 kNm**.

3.13 Finite element (FE) model

General view of FE model is presented in Figure 11.

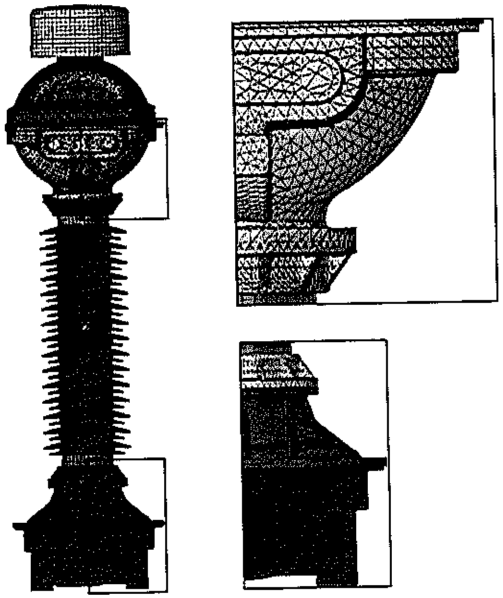

Figure 11. *FE model – general view*

Mesh statistics were the following:

- Total number of nodes: 1009580
- Total number of elements: 463007
  - 58507 quadratic hexahedral elements of type C3D20R
  - 300489 quadratic tetrahedral elements of type C3D10
  - 2519 linear quadrilateral elements of type S4R
  - 97 linear triangular elements of type S3
  - 9900 linear hexahedral elements of type C3D8R
  - 528 quadratic wedge elements of type C3D15
  - 90967 quadratic tetrahedral elements of type C3D10M

Description of the coordinate system.

- X – 1st horizontal axis.
- Z – 2nd horizontal axis.
- Y – vertical axis.

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4 SIMULATION RESULTS

This chapter gathers simulation results evaluated in the analysis. Obtained outcome incudes static and the most conservative (design) seismic load.

4.1 PA123a /PA145a

4.1.1 Natural frequency extraction

Effective modal mass plot is presented Figure 12. Bubble size indicated amount of mass which participates in motion at specific frequency range. Based no presented plot one can see that the most critical modes were located between 6.9 – 8.2 Hz.

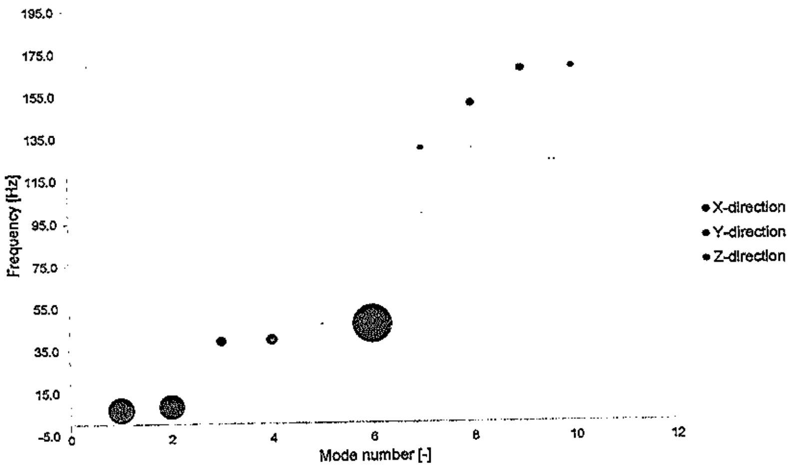
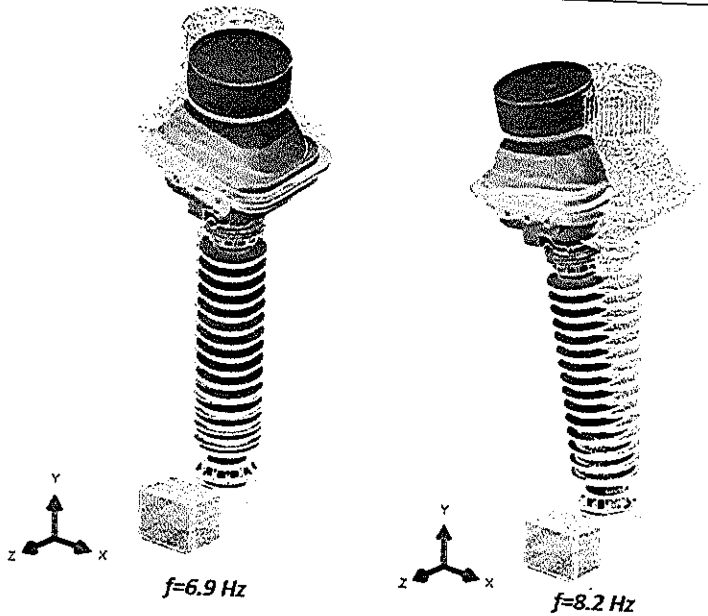


Figure 12. *Natural frequency extraction – effective modal mass*

Effective modes and associated with the shapes are presented in Figure 13.



f=6.9 Hz *f=8.2 Hz*

Figure 13. *Natural frequency extraction – mode shapes*

Summary of modal mass participation is listed in Table 4.

Table 4. *Modal mass participation – summary*

Mode no	Frequency [Hz]	X-direction	Y-direction	Z-direction
1	6.9	40%	0%	35%
2	8.2	34%	0%	40%
3	38.9	2%	0%	6%
4	39.7	6%	0%	2%
5	46.9	0%	0%	0%
6	98.7	0%	89%	0%
7	129.2	0%	0%	2%
8	150.3	4%	0%	0%
9	166.6	0%	0%	4%
10	167.4	2%	0%	0%

4.1.2 Dynamic analysis

Stress distribution for tank component is presented in Figure 14 and Figure 15. Stress scale has been limited to 80 MPa as the maximum allowable stress level.

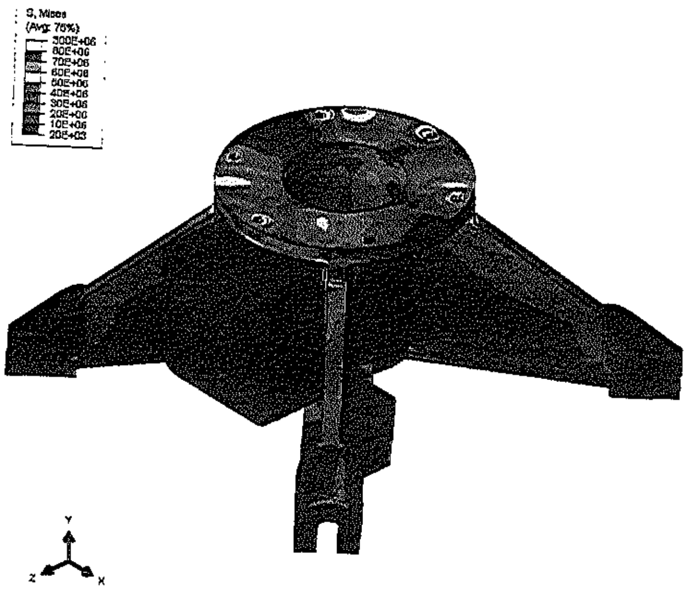


Figure 14. *Von-Mises stress [Pa] distribution – tank (view 01)*

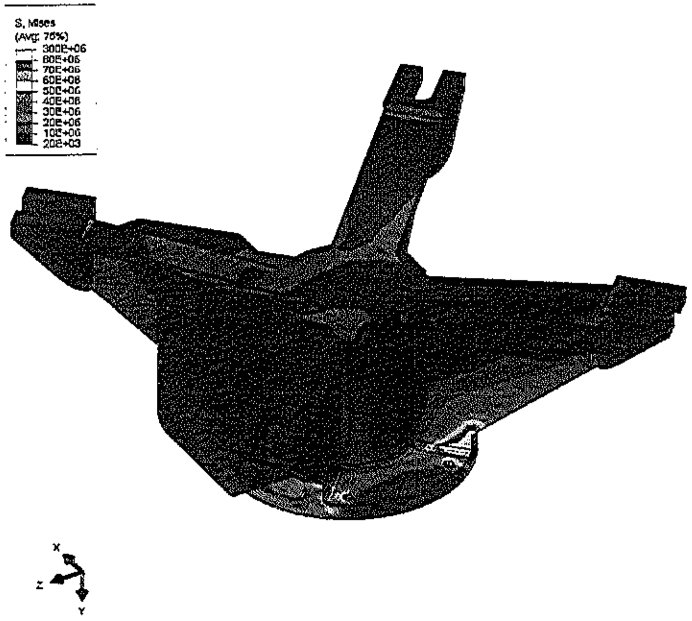


Figure 15. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 16.

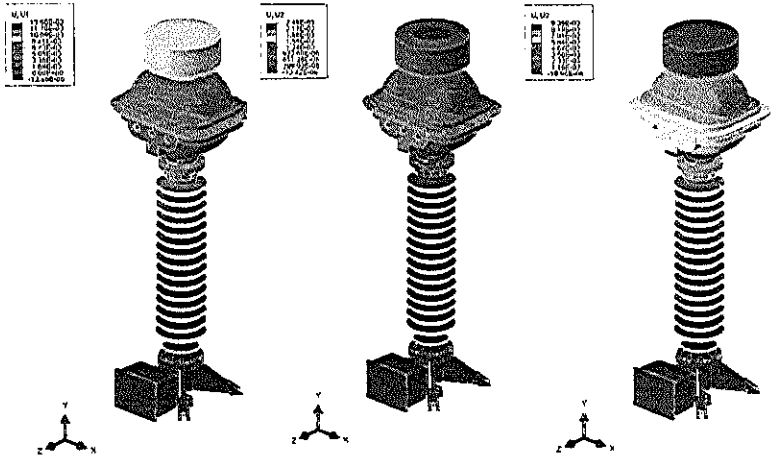


Figure 16.*Displacement [m] field - distribution*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=4848 Nm.
- M_z=7476 Nm.

Insulator has satisfied the maximum bending moment condition. One can observer that stresses evaluated at the base are slightly above yield point of material. Therefore small yielding may occur. One must have in mind that analysis did not cover possible casting imperfections. Design has been also verified according to AF3 seismic level (0.3 g Zero Period Acceleration). Stress distribution for such load scenario is presented from Figure 17 to Figure 18. Obtained stress level was significantly below yield point of material.

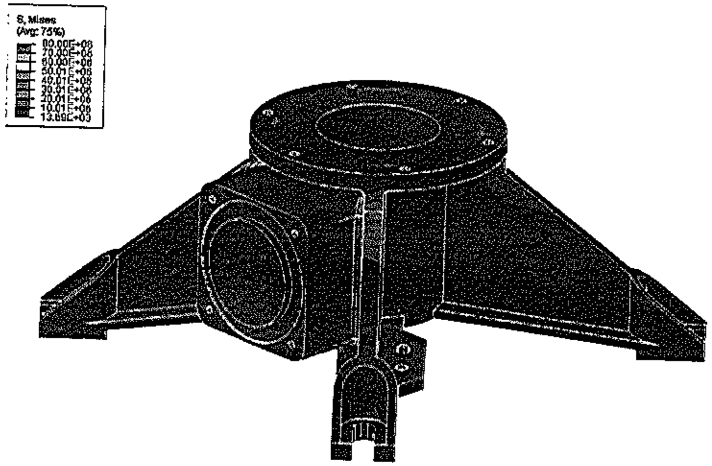


Figure 17. *Von-Mises stress [Pa] distribution (AF3) – tank (view 01)*

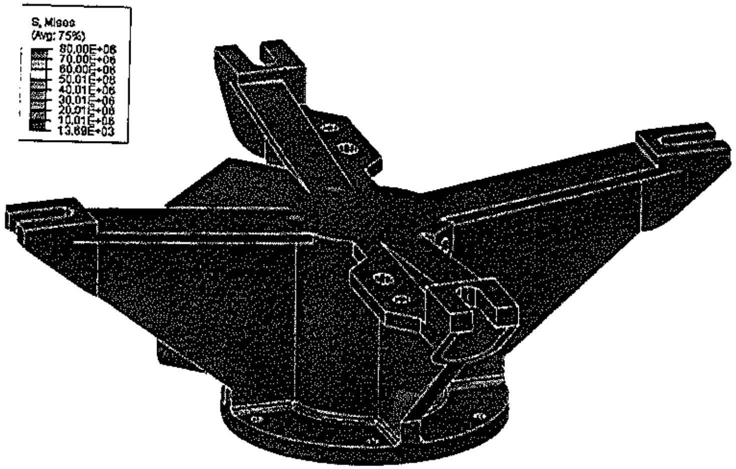


Figure 18. *Von-Mises stress [Pa] distribution (AF3) – tank (view 02)*

4.2 PV 123

4.2.1 Natural frequency extraction

Effective modal mass plot is presented Figure 19. Bubble size indicated amount of mass which participates in motion at specific frequency range. Based no presented plot one can see that the most critical modes were located between 24.7– 25.3 Hz.

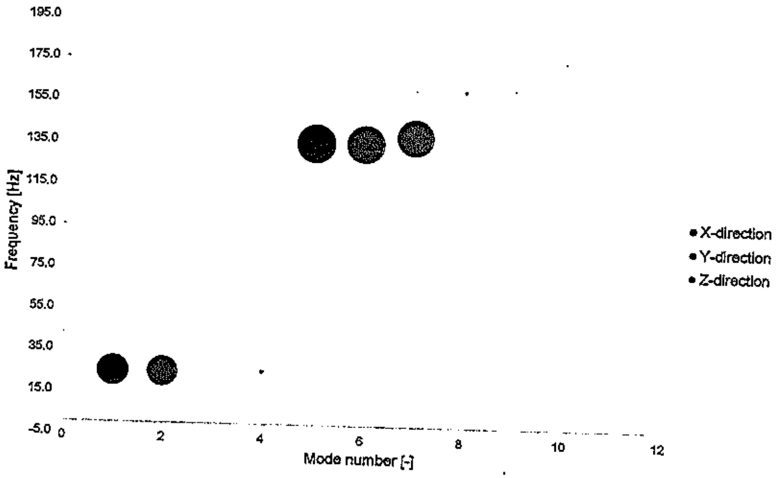
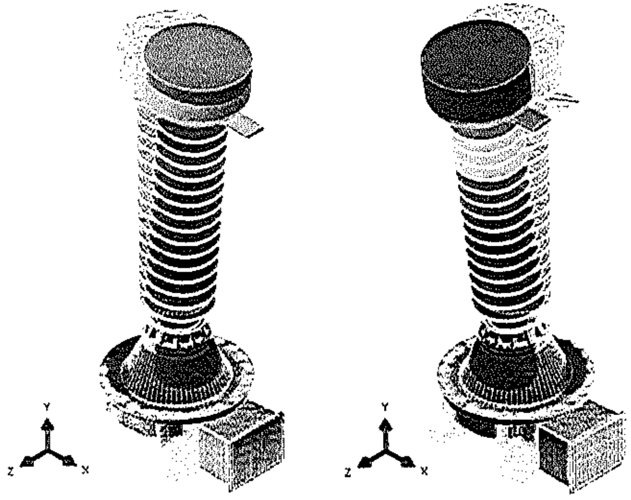


Figure 19. *Natural frequency extraction – effective modal mass*

Effective modes and associated with the shapes are presented in Figure 20.



f=24.7 Hz *f=25.3 Hz*

Figure 20. *Natural frequency extraction – mode shapes*

Summary of modal mass participation is listed in Table 5.

Table 5. *Modal mass participation – summary*

Mode no.	Frequency [Hz]	X-direction	Y-direction	Z-direction
1	24.7	24%	0%	0%
2	25.2	0%	0%	24%
3	25.4	0%	0%	0%
4	26.5	0%	0%	0%
5	135.5	37%	0%	0%
6	139.3	0%	0%	36%
7	161.3	0%	34%	0%
8	162.4	0%	0%	0%
9	175.8	0%	0%	0%
10	176.2	0%	0%	0%

4.2.2 Dynamic analysis

Stress distribution for tank component is presented in Figure 21 and Figure 22. As described in chapter 3.8.1 location of center of mass is close to the ground level, therefore expected bending moment and so the stress was low. One can see that the maximum stress level reached ca. 30 MPa and it was located at vicinity of coupling constraint. Stress level satisfies required safety condition.

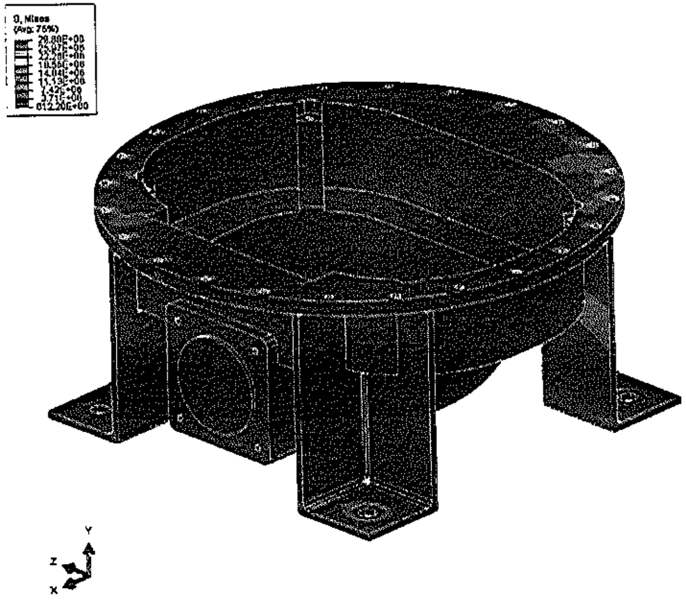


Figure 21. *Von-Mises stress [Pa] distribution – tank (view 01)*

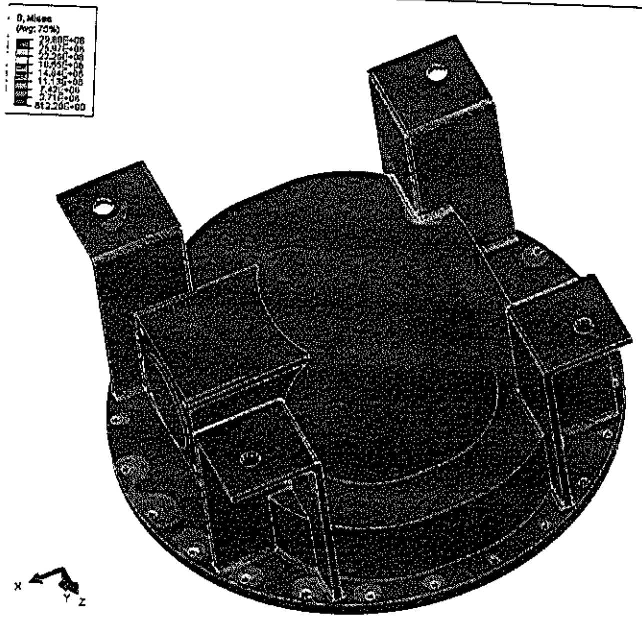


Figure 22. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 23.

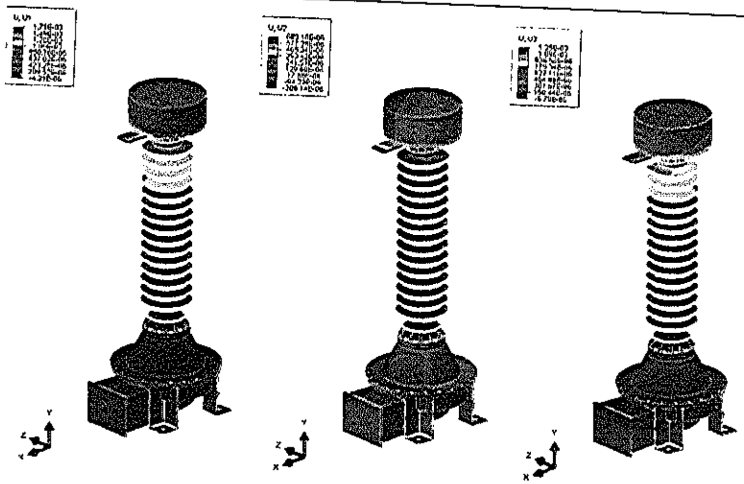


Figure 23.*Displacement [m] field - distribution*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=2079 Nm.
- M_z=2263 Nm.

Insulator has satisfied the maximum bending moment condition.

4.3 PVA123a /PVA145a

4.3.1 Natural frequency extraction

Effective modal mass plot is presented Figure 24. Bubble size indicated amount of mass which participates in motion at specific frequency range. Based no presented plot one can see that the most critical modes were located between 3.8– 4.1 Hz.

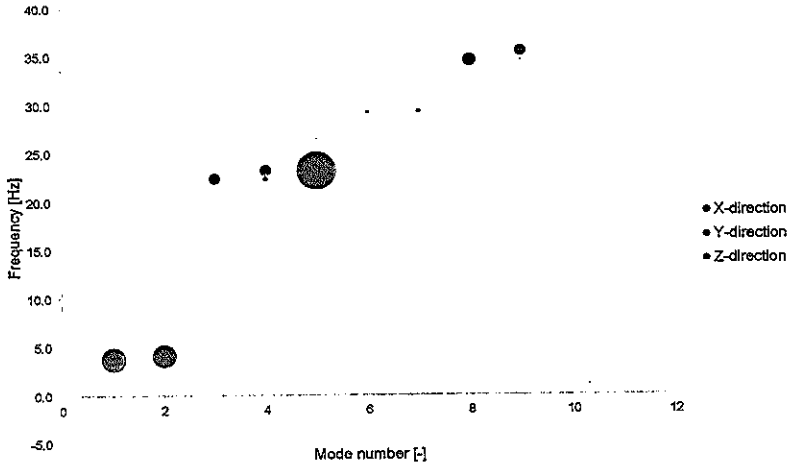
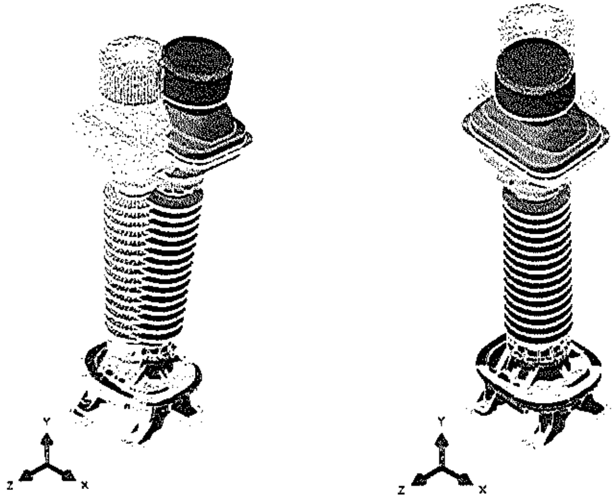


Figure 24. *Natural frequency extraction – effective modal mass*

Effective modes and associated with the shapes are presented in Figure 25.



f=3.8 Hz *f=4.1 Hz*

Figure 25. *Natural frequency extraction – mode shapes*

Summary of modal mass participation is listed in Table 6.

Table 6. *Modal mass participation – summary*

Mode no.	Frequency [Hz]	X-direction	Y-direction	Z-direction
1	3.8	35%	0%	32%
2	4.1	32%	0%	35%
3	22.4	7%	0%	0%
4	23.2	0%	2%	8%
5	26.5	0%	95%	0%
6	29.2	0%	0%	1%
7	29.3	1%	0%	0%
8	34.6	10%	0%	0%
9	35.5	0%	0%	8%
10	36.2	0%	0%	3%

4.3.2 Dynamic analysis

Stress distribution for tank component is presented in Figure 26 and Figure 27. One can see that the maximum stress level reached ca. 70 MPa. Stress level satisfies required safety condition.

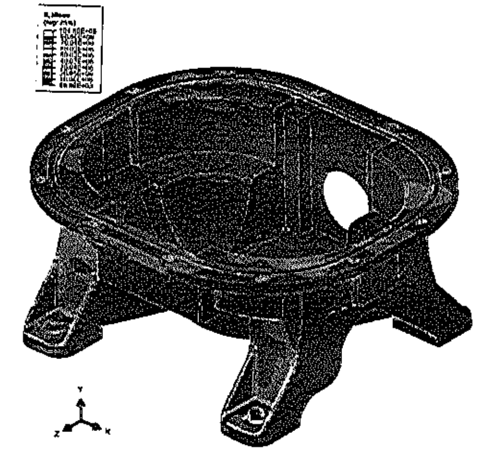


Figure 26. *Von-Mises stress [Pa] distribution – tank (view 01)*

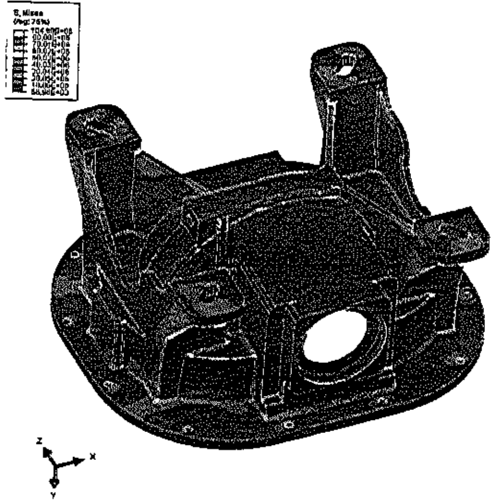


Figure 27. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 23.

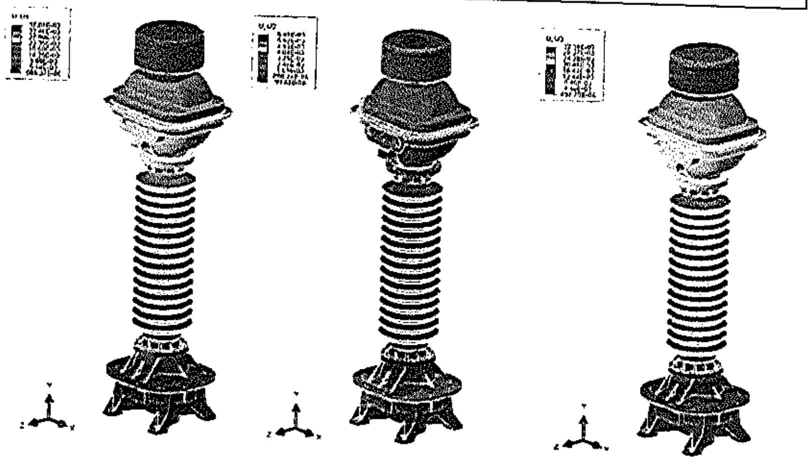


Figure 28.*Displacement [m] field - distribution*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=6864 Nm.
- M_z=7752 Nm.

Insulator has satisfied the maximum bending moment condition.

5 CONCLUSIONS

The goal of the analysis was to investigate family of HV Instrument Transformers using guidelines described in IEC 62271-300. Based on performed analysis main conclusions are the following:

- Current transformer PA 123a/PA 145a. This design has been investigated for two seismic levels: AF5 (0.5 g) and AF3 (0.3 g). For AF5 level stresses were above yield strength of material. These concentrations can be caused by sharp edges which are usually eliminated in real casting process. On the other hand one must have in mind that possible material imperfection were not considered in the simulation. For AF3 load scenario stresses were below yield strength of material. Bushing has satisfied required safety factor for both load scenarios.
- Voltage transformer - PV 123. Seismic level – AF5. Center of mass for this particular design is very close to the ground level. Therefore obtained level of stress and so bending moment was relatively low. Design satisfies required safety factors for AF5 seismic level.
- Combined transformer PVA 123a/PVA 145a. Seismic level – AF5. Obtained stress level was below yield strength of material. Bending moment was also below ultimate value. Whole design should be considered as safe.
- Damping factor used in the analysis was equal to 2%.
- Transformer oil has been modeled as uniformly distributed additional mass.

Disclaimer

The analysis documented herein has been prepared in accordance with reasonable standards of scientific endeavor and the best knowledge of the author(s).

The simulation results may depend on a variety of factors, including quality of input data, applied model simplifications and chosen numerical methods.

6 BIBLIOGRAPHY

[1] **TR 62271-300** – *High voltage switchgear and controlgear – Part 300: Seismic qualification and alternating current circuit breakers*, Technical report. First edition:2006-11

[2] ABAQUS, *ABAQUS 6.13 Documentation*, DS Simulia, USA, www.simulia.com

[3] *IEC* **62271-100** – *High voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*, Technical report. Edition 2.0: 2008-04

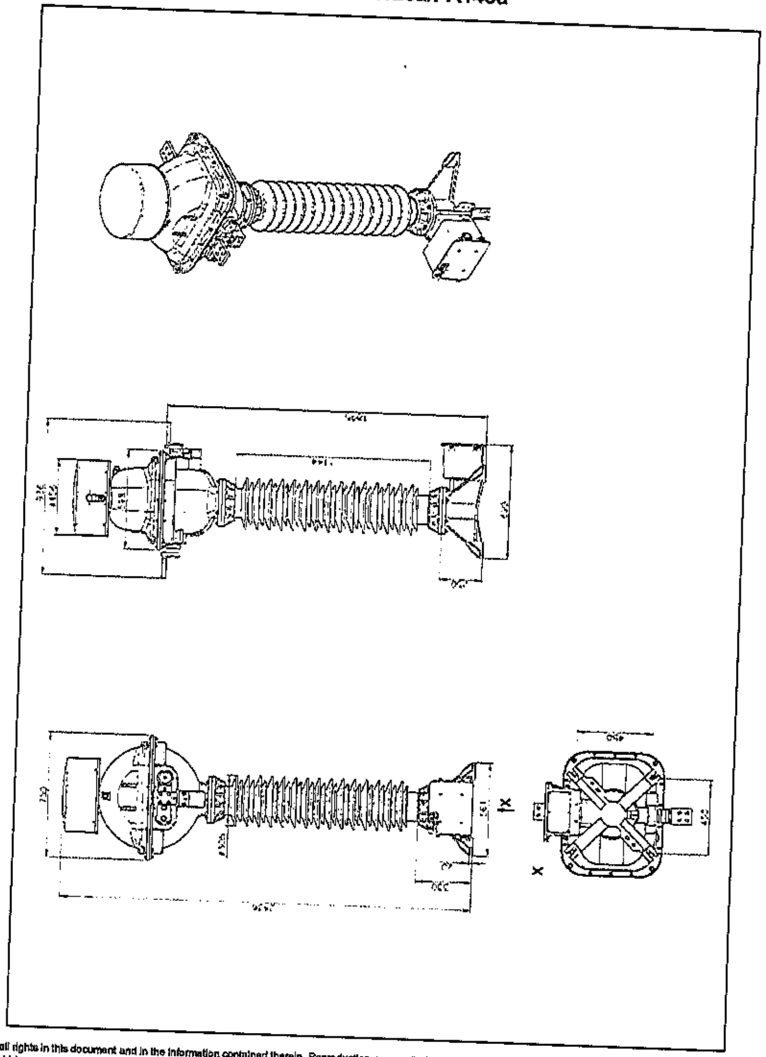
[4] *IEC* **62155-100** – *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*, International standard. First edition: 2003-05

7 CHANGE HISTORY

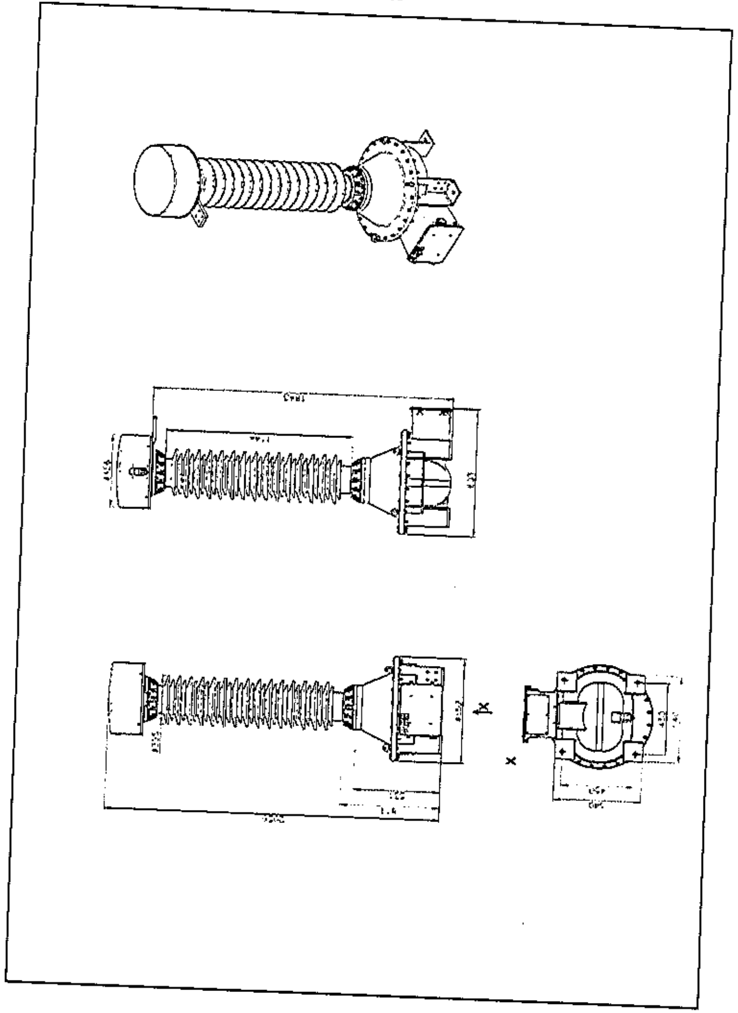
Date	Revision	Author(s)	Change
2015-05-22	Rev. 1	Juszklewicz Grzegorz	original document

8 APPENDICES

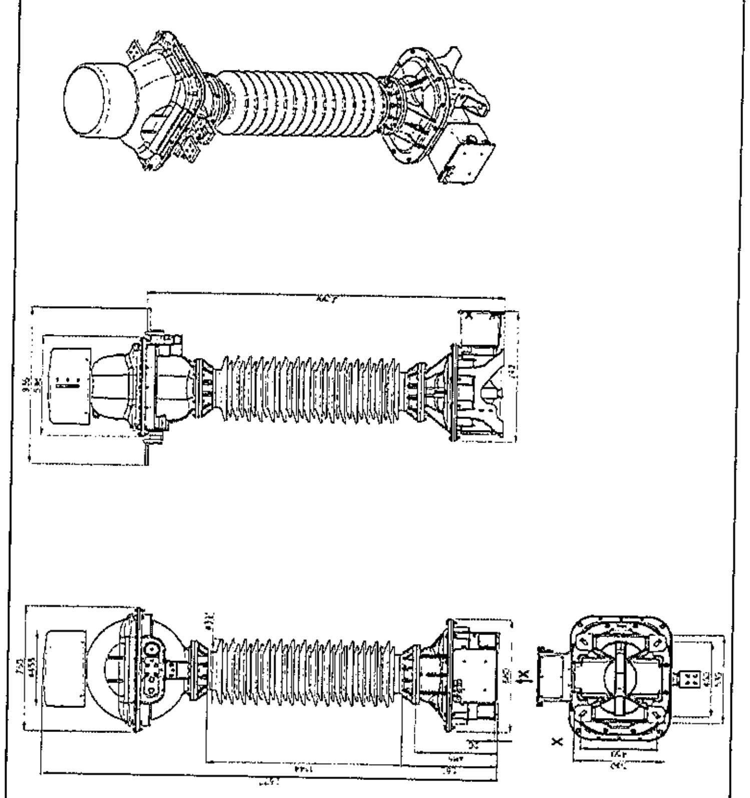
8.1 Current Instrument transformer PA123a/PA145a



8.2 Voltage Instrument transformer PV123



8.3 Combined Instrument transformer PVA123a /PVA145a



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Customer	ABB PLABB	Classification:	Confidential	
Doc. title	**Seismic analyses of HV Instrument Transformers. IEEE 693- high (0.5g)/moderate(0.25g) seismic level**	Status of document	Released	
Project name/ID	Simserv_PPHV_Przasnysz_15172/50005903	CR Program:	CHTET	
Main Author:	Grzegorz Juszkiewicz/PLCRC/SST	Case ID:	15172	
Additional Author(s):				
Distribution	Marcin Tarnowski/PPHV, Pawel Grysztar/PPHV, Jaroslaw Duzdowsk/PPHV, Dariusz Siperek/PPHV, Piotr Mikulski/PPHV, Przemyslaw Naslerowski/PPHV Piotr Saj/PLCRC, Marek Florkowski/PLCRC			
Keywords	simulation, FE method, seismic analysis, frequency modes, response spectrum			
Approved by:		Final Approval Date:	2015-08-17	

Technical_Note.dot Rev 1.00

Electronic document

Technical report

Simulation Support Team

Case submitted by	Marcin Tarnowski
Business Unit	PPHV
Type of analysis (used tool)	ABAQUS (seismic analysis)
Description of analysis	Seismic analysis different variants of current, voltage and combined transformers (PA123a/PA145a, PV123, PVA123a/PVA 145a) according to guidelines described in IEEE 693 standard. Consideration of seismic and dead loads.

Executive summary

This report covers investigation related to seismic analysis of HV Instrument transformers (PV123, PA123a /PA145a, PVA123a /PVA145a) subjected to various load scenarios. Simulation covered the following load conditions: dead load, terminal force load, seismic load (Moderate - 0.25g; High – 0.5g). Analysis showed that designs: **PA123a/PA145a** and **PVA123a /PVA145a** can withstand moderate seismic level, while **PV123** can withstand high seismic load scenario.

TABLE OF CONTENTS

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1 INTRODUCTION

The goal of the analysis was to evaluate seismic performance of PA123a/PA145a (see 8.1), PV123 (see 8.2), PVA145a/PVA123a (see 8.3) type transformers. Simulation was done using guidelines of IEEE 693 standard. For more information please see [1].

Computations concerned evaluation of stress field distribution and maximum bending moment between flange and insulator. Present report describes used simulation technique, analysis steps, loads and boundary conditions variations and summarizes obtained results.

2 SIMULATION SOFTWARE

All simulations were performed using Abaqus/CAE package. Abaqus includes FEM (finite element method) solver, pre- and post processor and enables performing many types of multiphysics simulations: mechanical, thermal, acoustic, piezoelectric, seismic, and others.

Parts and assemblies can be created in Abaqus, or they can be imported from CAD systems using native file formats. Abaqus functionality enables to define materials, interactions, loads, boundary conditions, mesh. User is also available to set up simulation parameters such as pre-processing memory. It is always possible to change all simulation settings and properties, because they're all parameterized.

Simulation results can be visualized in Abaqus postprocessor or in external software, which is able to import simulation results in Abaqus format. In postprocessor user can view all predefined field outputs, show or hide part instances, create cross-sections, make animations, automatically generate reports, diagnose model (warnings, errors). For more information about ABAQUS please see [2].

3 SIMULATION SETUP

Analysis has been made using Finite Element Method.

3.1 Simulation procedure

According to [1] analysis included three main simulation steps:

- Static load:
    - Terminal load.
    - Gravitational load.
- Natural frequency extraction.
- Dynamic analysis.

3.2 Simulation steps

Simulation consisted of three main simulation steps.

3.2.1 Natural frequency extraction

In the first simulation step natural frequency extraction was performed. The frequency extraction procedure performs eigenvalue extraction to calculate the natural frequencies and the corresponding mode shapes of a system.

The eigenvalue problem for the natural frequencies of an undamped finite element model can be described by equation (3-1):

$$(-\omega^2 M^{MN} + K^{MN})\phi^N = 0 \qquad (3\text{-}1)$$

where: M^{MN} – mass matrix (kg); K^{MN} – stiffness matrix (Pa), which includes initial stiffness effects if the base state (gravitational load); ϕ – eigenvector (the mode of vibration); *M, N* – degrees of freedom (-). Based on specification [1] one can assume that most critical frequency modes are in range of 0-35 Hz.

3.2.2 Response spectrum analysis

The response spectrum method is a convenient way of describing shock motion in terms of the maximum response of a single degree of freedom (1-DOF) oscillator of arbitrary natural period and damping ratio. Each data point of the response spectrum curve represents the peak response from a time history analysis of the earthquake applied to 1-DOF oscillator system. The ordinate defines the natural period at which the oscillator is tuned. Repeating the procedure for a great many frequencies defines a continuous curve for an assumed level of damping.

A spectral response analysis estimates the maximum displacement of the structure during a 'design' shock load without recourse of direct integration. Finite element implementation of the response spectrum calculate the response of each mode independent, and then combine the scaled response one of a number of established combination rules, to give an estimate of peak response. Spectrum plot used in simulation is presented in Figure 1.

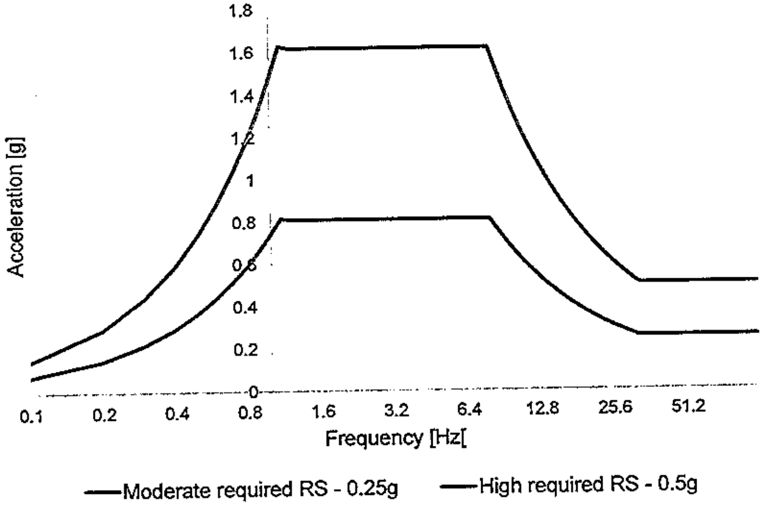

Figure 1. *Design response spectrum (RS) – 2% damping*

3.3 Loads and boundary conditions

3.3.1 Loads

The following static load scenarios have been considered

1. Gravitational load, g=9.81 m/s^2.
2. Terminal operating load. These load conditions were specified according to [3] (*Table 7 – Static withstand test loads*). For considered voltage-current range static withstand force (Load class II) should be equal to 3000 N. With respect to '*NOTE 1 The sum of the loads acting in routinely operating conditions should not exceed 50% of the specified withstand test load*', maximum operating force is equal to **1500 N**.

Seismic load have been predefined according design response spectrum described in the standard [1] – ground acceleration reference – Moderate/High Required Response Spectrum. Main input parameters were the following:

- XYZ base motion with vertical load (Y) equal to 80% of horizontal direction.
- Damping ratio – 2%.

As the final outcome from the analysis static loads were combined with the seismic load.

3.3.2 Boundary conditions

Simulation assumes that the apparatus will be mounted on ground. During analysis model has been fixed at the bottom face of used test frame. General view of static loads and boundary conditions is presented in Figure 2. Area highlighted by red has been constrained (Y-rotation released). Base of the bottom tank has been supported in Y direction (as it is placed on the ground). Described boundary conditions have been used for all analyzed models.

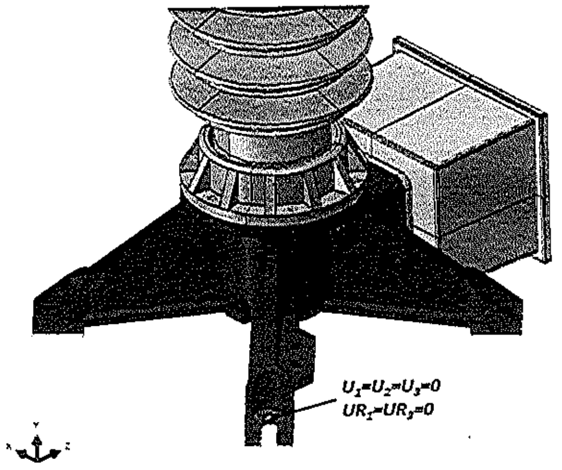

Figure 2. *Boundary conditions – general view*

3.4 Acceptance criteria

With respect to the standard [1] the following acceptance criteria were used

- Seismic load should be combined with dead load and possible normal operating loads.
- The maximum allowable bending moment shall not exceed **6.65 kNm** (50% of ultimate load/stress)
- Aluminum components shall not exceed **73 MPa** (minimum ultimate tensile strength divided by 2.2 safety factor).

3.5 Current transformer - PA 123a/PA 145a

This chapter gathers details related to FE model of current transformer **PA 123a/PA 145a**.

3.5.1 Model simplifications

For simulation requirements some areas of the model were simplified. Small geometrical features like casting rounding, chamfers were removed in order to improve mesh generation process. Details of the geometry and center of mass can be found in Figure 3. Red point indicates center of mass of the transformer.

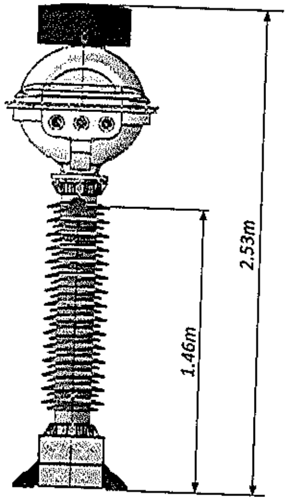

Figure 3. *Simplified representation of the PA 123a/PA 145a transformer*

Concrete between flange and ceramic insulator has been introduced using connector element with predefined rotational stiffness.

Because of the simulation method (dynamics based on modal analysis) components were connected together using bonded connection or conformal mesh.

3.6 Material and mass information

Component naming is presented in Figure 4.

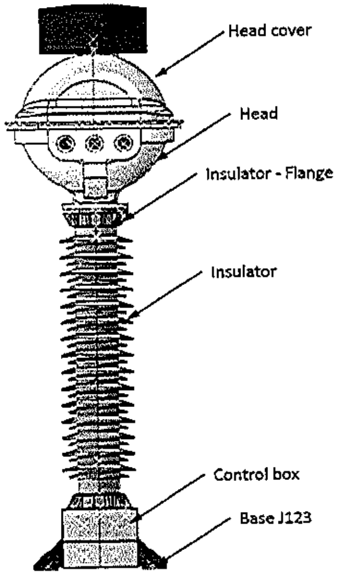

Figure 4. *Assembly – component naming*

Material and mass information is listed in Table 1

Table 1. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Young's modulus [MPa]	Yield strength [MPa]	Ultimate strength [MPa]
2GKA310015	Base J123	EN-AC 43200 (grade F)	16.5	69000	80	160
2GKA310404	Insulator	Porcelain	71	100000	140	
	Insulator - Flange	EN-AC 43200 (grade T6)	3.5	69000	180	220
2GKA414718	Head	EN-AC 43200 (grade F)	22.5	69000	80	160
2GKK314089	Head cover	EN-AC 43200 (grade F)	20	69000	80	160
	Coil	-	150			
2GKK311093R	Control box	EN-AC 43200 (grade F)	5.5	69000	80	160
	Oil		120			

The ultimate bending moment for ceramic insulator is equal to **M_B=13.3 kNm.**

3.7 Finite element (FE) model

General view of FE model is presented in Figure 5.

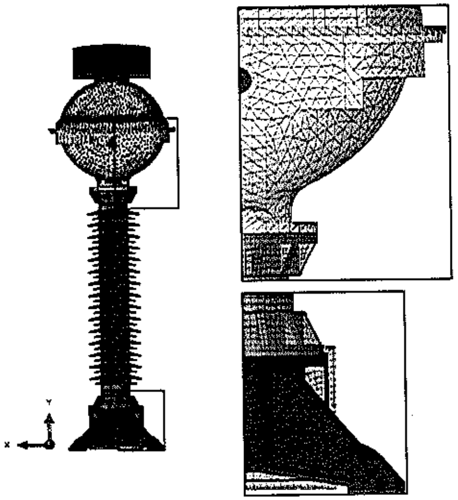

Figure 5. *FE model – general view*

Mesh statistics were the following:

- Total number of nodes: 533430
- Total number of elements: 242866
    - 210555 quadratic tetrahedral elements of type C3D10
    - 31050 quadratic hexahedral elements of type C3D20R
    - 1243 quadratic quadrilateral elements of type S8R
    - 18 quadratic triangular elements of type STRI65

Description of the coordinate system.

- X – 1st horizontal axis.
- Z – 2nd horizontal axis.
- Y – vertical axis.

3.8 Voltage transformer - PV 123

This chapter gathers details related to FE model of voltage transformer **PV 123**.

3.8.1 Model simplifications

For simulation requirements some areas of the model were simplified. Small geometrical features like casting rounding, chamfers were removed in order to improve mesh generation process. Details of the geometry and center of mass can be found in Figure 6. Red point indicates center of mass of the transformer.

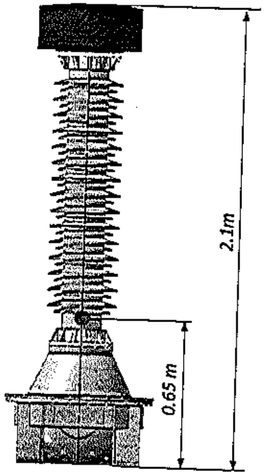

Figure 6. *Simplified representation of the PV 123 transformer*

Concrete between flange and ceramic insulator has been introduced using connector element with predefined rotational stiffness.

Because of the simulation method (dynamics based on modal analysis) components were connected together using bonded connection or conformal mesh.

3.9 Material and mass information

Component naming is presented in Figure 7.

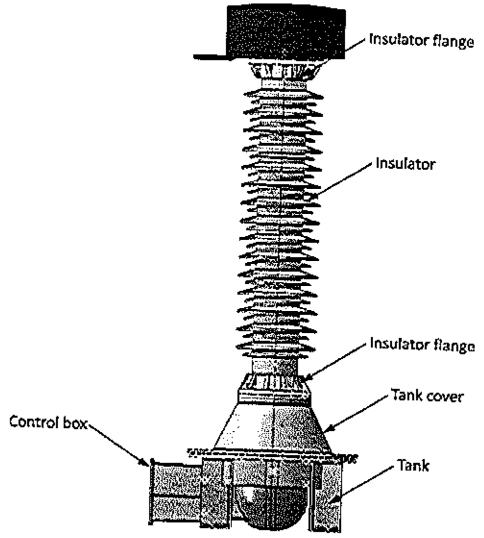

Figure 7. *Assembly – component naming*

Material and mass information is listed in Table 2.

Table 2. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Young's modulus [MPa]	Yield strenght [MPa]	Ultimate strenght [MPa]
2GKK310150P	Bottom tank	EN-AC 43200 (grade F)	25	69000	80	160
2GKK310147P	Core	Steel	22.5	206000	300	370
2GKV314005	Tank cover	EN-AC 43200 (grade F)	15.5	69000	80	160
2GKA310404	Insulator	Porcelain	71	100000	140	
	Insulator flange	EN-AC 43200 (grade T6)	3.5	69000	180	220
	Coil	-	30			
2GKK311093R	Control box	EN-AC 43200 (grade F)	5.5	69000	80	160
	Oil		60			

The ultimate bending moment for ceramic insulator is equal to $\mathbf{M_B=13.3\ kNm}$.

3.10 Finite element (FE) model

General view of FE model is presented in Figure 8.

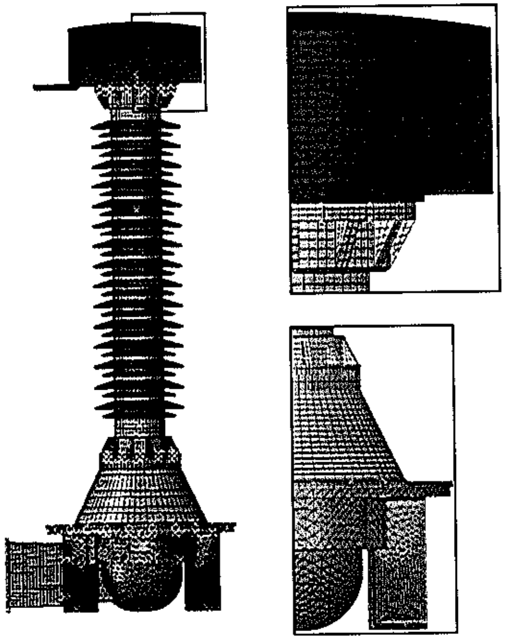

Figure 8. *FE model – general view*

Mesh statistics were the following:

- Total number of nodes: 608507
- Total number of elements: 236033
    - 4606 quadratic quadrilateral elements of type S8R
    - 58 quadratic triangular elements of type STRI65
    - 58965 quadratic hexahedral elements of type C3D20R
    - 8577 linear hexahedral elements of type C3D8R
    - 163827 quadratic tetrahedral elements of type C3D10

Description of the coordinate system.

- X – 1st horizontal axis.
- Z – 2nd horizontal axis.
- Y – vertical axis.

3.11 Combined transformer – PVA123a /PVA145a

This chapter gathers details related to FE model of combined transformer PVA123a /PVA145a.

3.11.1 Model simplifications

For simulation requirements some areas of the model were simplified. Small geometrical features like casting rounding, chamfers were removed in order to improve mesh generation process. Details of the geometry and center of mass can be found in Figure 9. Red point indicates center of mass of the transformer.

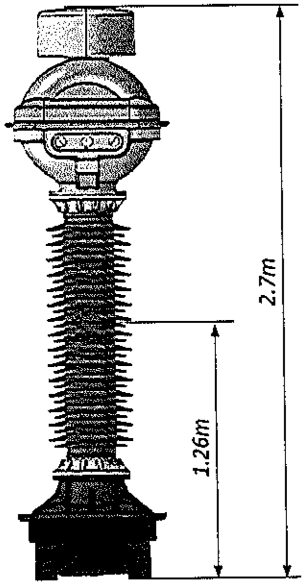

Figure 9. *Simplified representation of the PVA123a /PVA145a transformer*

Concrete between flange and ceramic insulator has been introduced using connector element with predefined rotational stiffness.

Because of the simulation method (dynamics based on modal analysis) components were connected together using bonded connection or conformal mesh.

3.12 Material and mass information

Component naming is presented in Figure 10

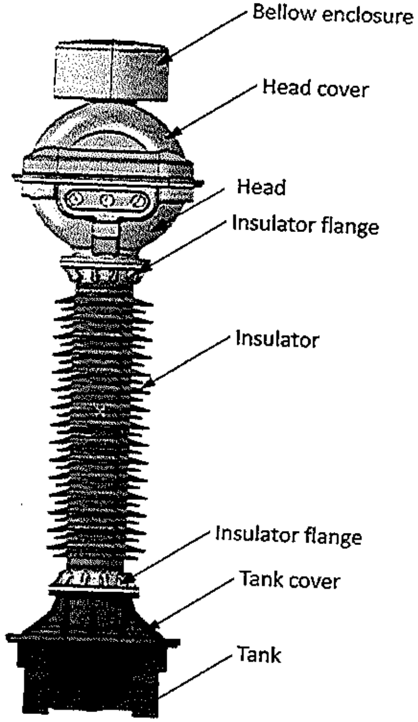

Figure 10. *Assembly – component naming*

Material and mass information is listed in Table 3.

Table 3. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Young's modulus [MPa]	Yield strength [MPa]	Ultimate strength [MPa]
2GKK314076	Tank	EN-AC 43200 (grade F)	25	69000	80	160
2GKK314084	Core	Steel	33.8	206000	300	370
2GKK314075	Tank cover	EN-AC 43200 (grade F)	18	69000	80	160
2GKK314070	Insulator	Porcelain	131	100000	140	
	Insulator flange	EN-AC 43200 (grade T6)	5	69000	180	220
2GKK314080	Head	EN-AC 43200 (grade F)	23.5	69000	80	160
2GKK314089	Head cover PVA-PA123A /PA145A-145	EN-AC 43200 (grade F)	23	69000	80	160
2GKK310902	Bellow	Stainless steel	5	190000	200	500
2GKK310014P	Below enclosure	EN-AC 43200 (grade F)	7	69000	80	160
-	Voltage coil	-	30	-	-	-
-	Current coil	-	150	-	-	-
2GKK310802	Epoxy Insulator	-	2.5	-	-	-
2GKK311093R	Control box	EN-AC 43200 (grade F)	5.5	69000	80	160
-	Oil		150	-	-	-

The ultimate bending moment for ceramic insulator is equal to M_B=13.3 kNm.

3.13 Finite element (FE) model

General view of FE model is presented in Figure 11.

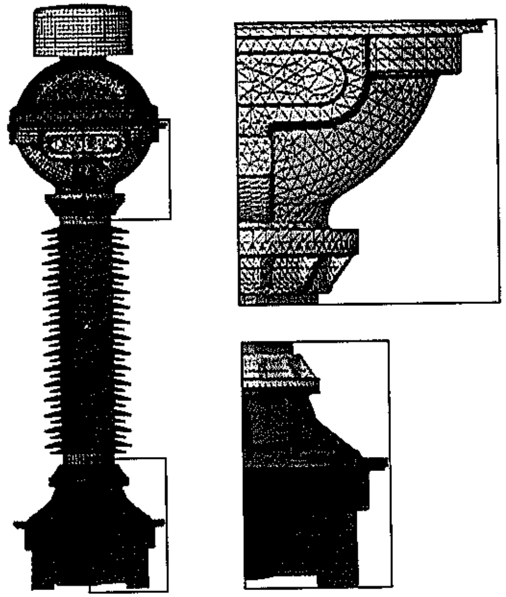

Figure 11. *FE model – general view*

Mesh statistics were the following:

- Total number of nodes: 1009580
- Total number of elements: 463007
  - 58507 quadratic hexahedral elements of type C3D20R
  - 300489 quadratic tetrahedral elements of type C3D10
  - 2519 linear quadrilateral elements of type S4R
  - 97 linear triangular elements of type S3
  - 9900 linear hexahedral elements of type C3D8R
  - 528 quadratic wedge elements of type C3D15
  - 90967 quadratic tetrahedral elements of type C3D10M

Description of the coordinate system.

- X – 1st horizontal axis.
- Z – 2nd horizontal axis.
- Y – vertical axis.

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4 SIMULATION RESULTS

This chapter gathers simulation results evaluated in the analysis. Obtained outcome incudes static and the seismic load.

4.1 PA123a /PA145a

4.1.1 Natural frequency extraction

Effective modal mass plot is presented Figure 12. Bubble size indicated amount of mass which participates in motion at specific frequency range. Based no presented plot one can see that the most critical modes were located between 6.9 – 8.2 Hz.

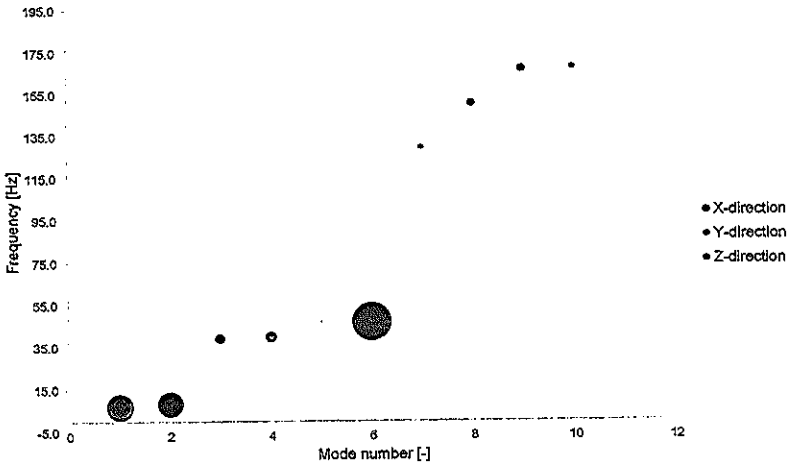
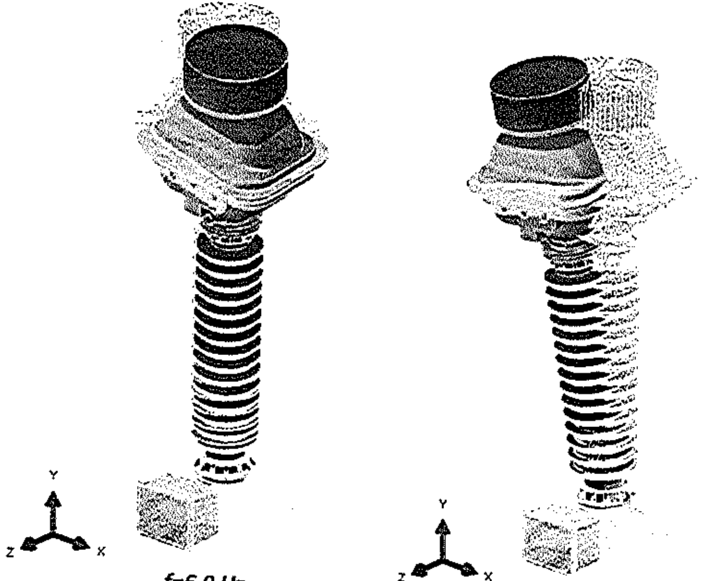


Figure 12. *Natural frequency extraction – effective modal mass*

Effective modes and associated with the shapes are presented in Figure 13.



f=6.9 Hz *f=8.2 Hz*

Figure 13. *Natural frequency extraction – mode shapes*

Summary of modal mass participation is listed in Table 4.

Table 4. *Modal mass participation – summary*

Mode no	Frequency [Hz]	X-direction	Y-direction	Z-direction
1	6.9	40%	0%	35%
2	8.2	34%	0%	40%
3	38.9	2%	0%	6%
4	39.7	6%	0%	2%
5	46.9	0%	0%	0%
6	98.7	0%	89%	0%
7	129.2	0%	0%	2%
8	150.3	4%	0%	0%
9	166.6	0%	0%	4%
10	167.4	2%	0%	0%

4.1.2 Dynamic analysis

Stress distribution for tank component is presented in Figure 14 and Figure 15. Stress scale has been limited to 73 MPa as the maximum allowable stress level.

Figure 14. *Von-Mises stress [Pa] distribution – tank (view 01)*

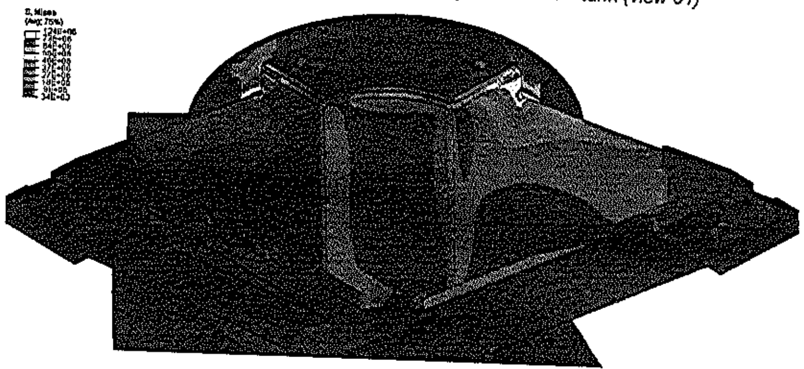


Figure 15. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 16.

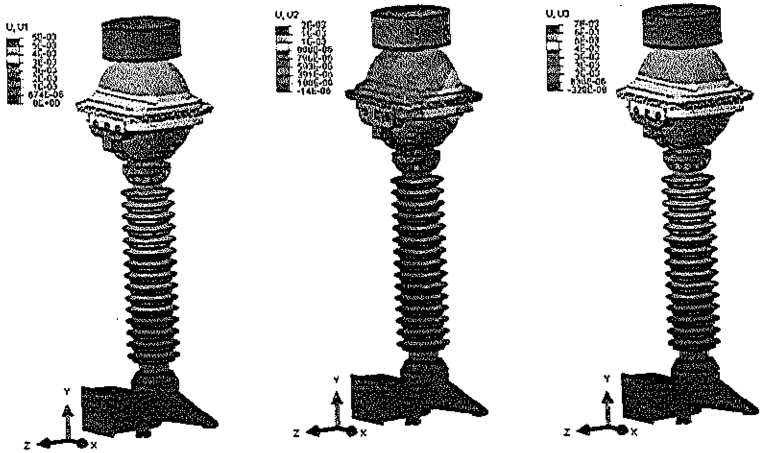


Figure 16.*Displacement [m] field - distribution*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=7961 Nm.
- M_z=7992 Nm.

Insulator **has not** satisfied the maximum bending moment condition. One can observe that stresses evaluated at the base are slightly above allowable value. Therefore small yielding may occur. One must have in mind that analysis did not cover possible casting imperfections.

Design has been verified according to Moderate seismic level (0.25 g Zero Period Acceleration). Stress distribution for such load scenario is presented from Figure 17 to Figure 18. Obtained stress level was below allowable level.

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=4816 Nm.
- M_z=4821 Nm.

Insulator **has satisfied** allowable bending moment condition.

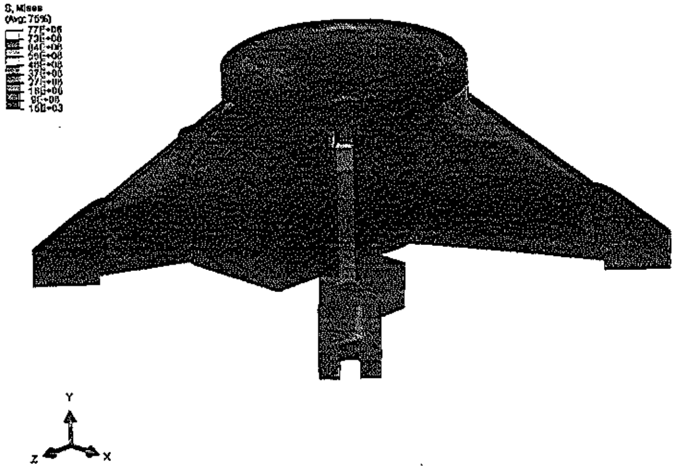


Figure 17. *Von-Mises stress [Pa] distribution (AF3) – tank (view 01)*

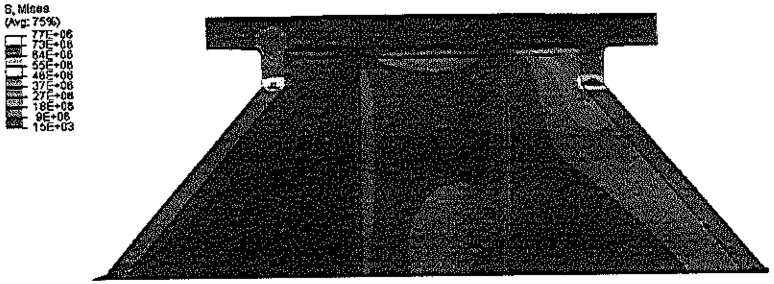


Figure 18. *Von-Mises stress [Pa] distribution (AF3) – tank (view 02)*

4.2 PV 123

4.2.1 Natural frequency extraction

Effective modal mass plot is presented Figure 19. Bubble size indicated amount of mass which participates in motion at specific frequency range. Based no presented plot one can see that the most critical modes were located between 24.7– 25.3 Hz.

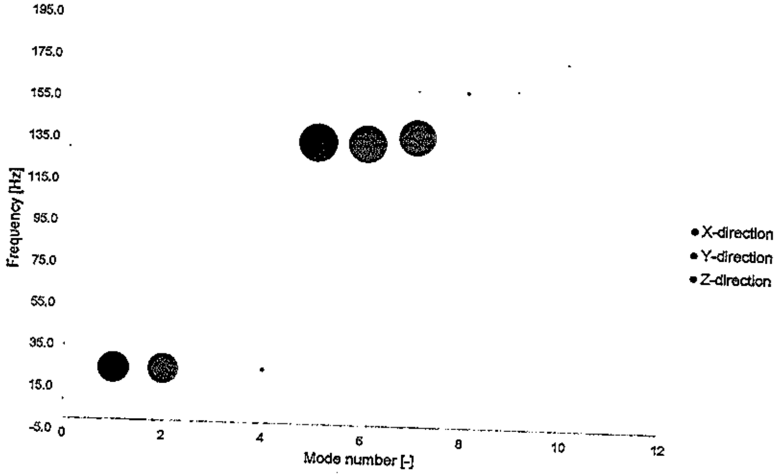
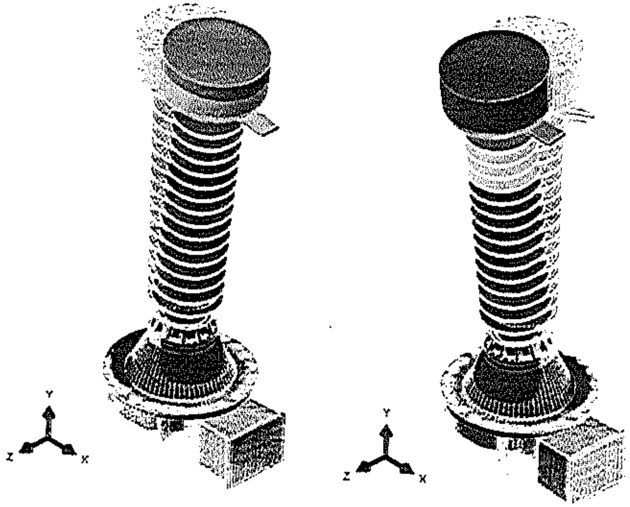


Figure 19. *Natural frequency extraction – effective modal mass*

Effective modes and associated with the shapes are presented in Figure 20.



f=24.7 Hz

f=25.3 Hz

Figure 20. *Natural frequency extraction – mode shapes*

Summary of modal mass participation is listed in Table 5.

Table 5. *Modal mass participation – summary*

Mode no.	Frequency [Hz]	X-direction	Y-direction	Z-direction
1	24.7	24%	0%	0%
2	25.2	0%	0%	24%
3	25.4	0%	0%	0%
4	26.5	0%	0%	0%
5	135.5	37%	0%	0%
6	139.3	0%	0%	36%
7	161.3	0%	34%	0%
8	162.4	0%	0%	0%
9	175.8	0%	0%	0%
10	176.2	0%	0%	0%

4.2.2 Dynamic analysis

Stress distribution for tank component is presented in Figure 21 and Figure 22. As described in chapter 3.8.1 location of center of mass is close to the ground level, therefore expected bending moment and so the stress was low. One can see that the maximum stress level reached ca. 24 MPa and it was located at vicinity of coupling constraint. Stress level satisfies required safety condition.

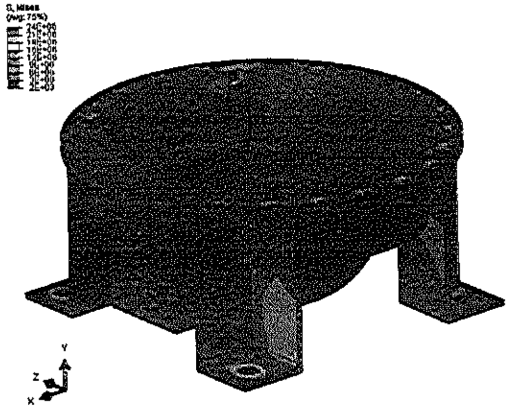


Figure 21. *Von-Mises stress [Pa] distribution – tank (view 01)*

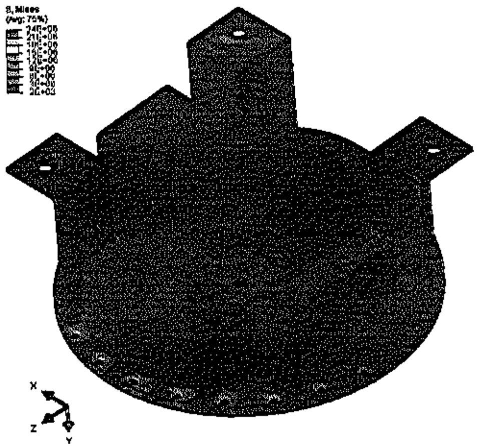


Figure 22. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 23.

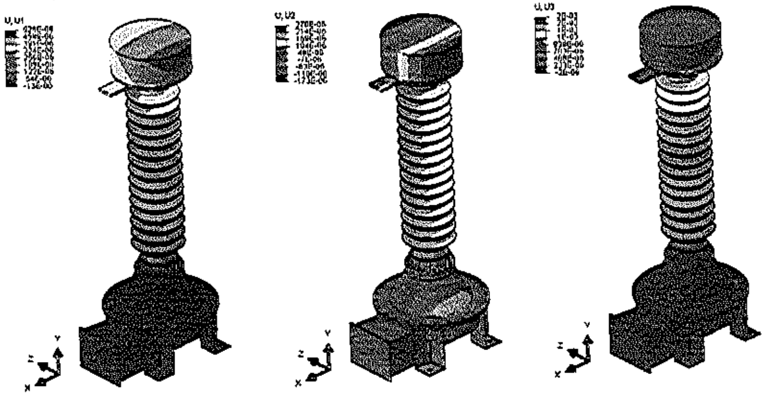


Figure 23.*Displacement [m] field - distribution*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=2224 Nm.
- M_z=2228 Nm.

Insulator **has satisfied** the maximum bending moment condition.

4.3 PVA123a /PVA145a

4.3.1 Natural frequency extraction

Effective modal mass plot is presented Figure 24. Bubble size indicated amount of mass which participates in motion at specific frequency range. Based no presented plot one can see that the most critical modes were located between 3.8– 4.1 Hz.

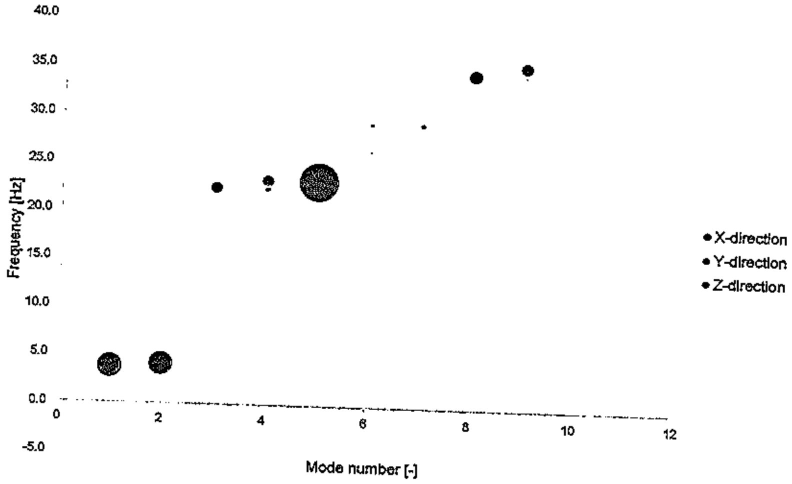
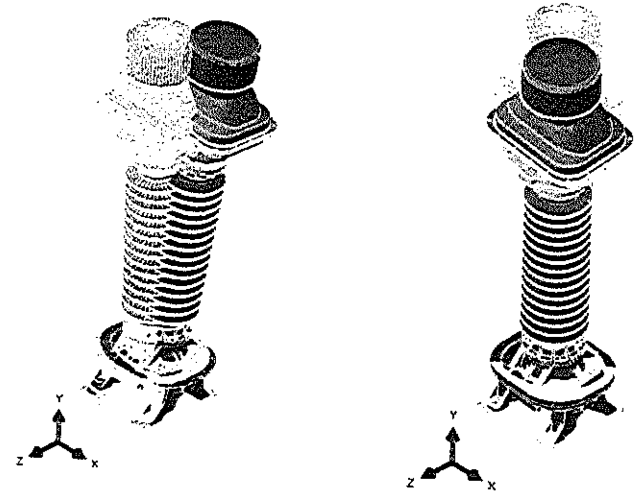


Figure 24. *Natural frequency extraction – effective modal mass*

Effective modes and associated with the shapes are presented in Figure 25.



f=3.8 Hz *f=4.1 Hz*

Figure 25. *Natural frequency extraction – mode shapes*

Summary of modal mass participation is listed in Table 6.

Table 6. *Modal mass participation – summary*

Mode no.	Frequency [Hz]	X-direction	Y-direction	Z-direction
1	3.8	35%	0%	32%
2	4.1	32%	0%	35%
3	22.4	7%	0%	0%
4	23.2	0%	2%	8%
5	26.5	0%	95%	0%
6	29.2	0%	0%	1%
7	29.3	1%	0%	0%
8	34.6	10%	0%	0%
9	35.5	0%	0%	8%
10	36.2	0%	0%	3%

4.3.2 Dynamic analysis

Stress distribution for tank component is presented in Figure 26 and Figure 27. One can see that the maximum stress was above 73 MPa allowable limit.

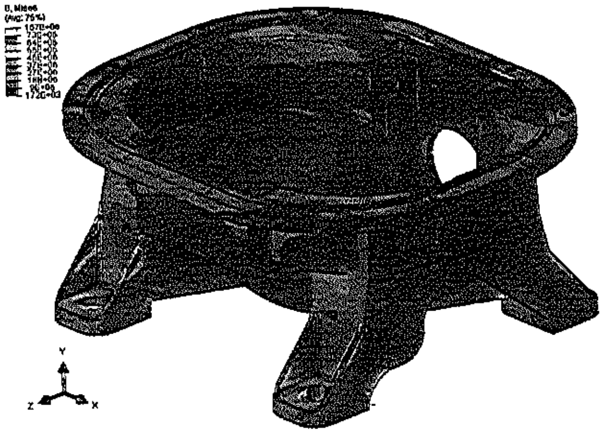


Figure 26. *Von-Mises stress [Pa] distribution – tank (view 01)*

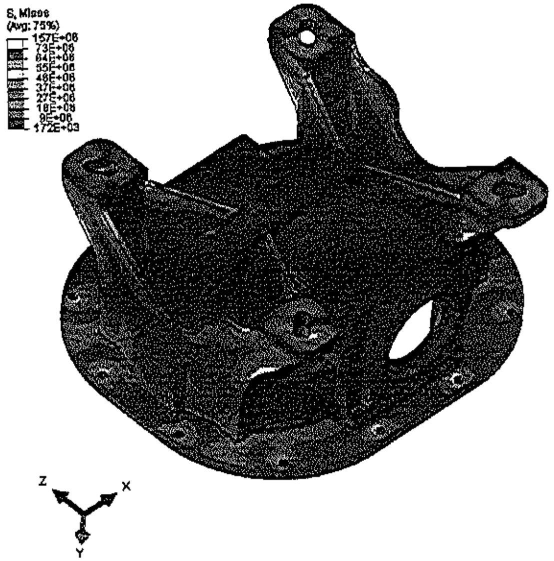


Figure 27. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 28.

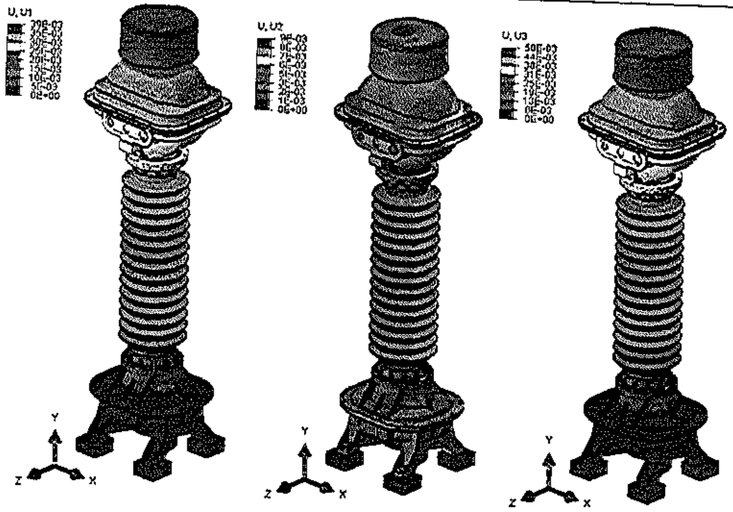


Figure 28.*Displacement [m] field - distribution*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=10451 Nm.
- M_z=8515 Nm.

Insulator **has not** satisfied the maximum bending moment condition. Stress distribution for moderate seismic level is presented in Figure 29 and Figure 30.

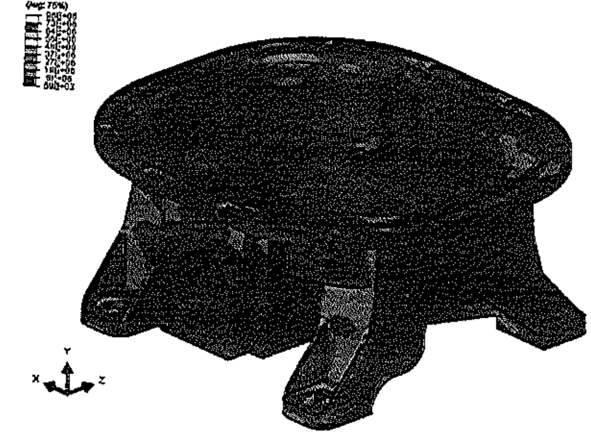


Figure 29. *Von-Mises stress [Pa] distribution – tank (view 01)*

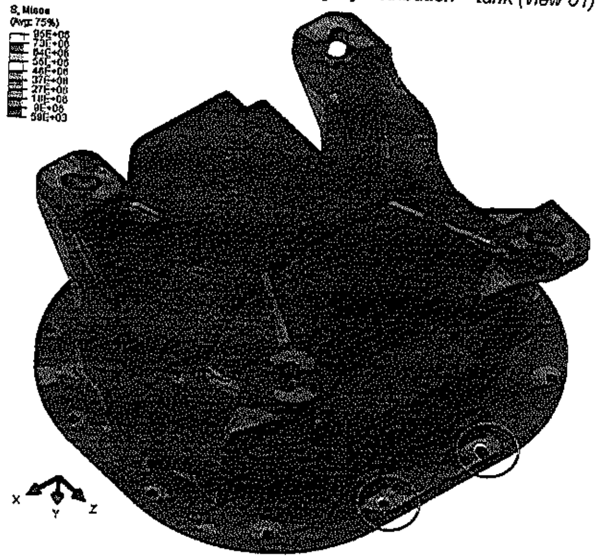


Figure 30. *Von-Mises stress [Pa] distribution – tank (view 02)*

The maximum bending moment evaluated at the interface between flange and insulator was equal to:

- M_x=6335 Nm.
- M_z=4080 Nm.

The maximum bending moment satisfies allowable value.

---

5 CONCLUSIONS

The goal of the analysis was to investigate family of HV Instrument Transformers using guidelines described in IEEE 693 standard. Summary of satisfied criteria is presented in Table 7. Column 'IEEE 693' lists allowable seismic level for selected design. Columns (2, 3) list seismic level where obtained stresses/bending moment were below yield strength/ultimate bending moment.

Table 7. *Summary of acceptance criteria*

Design name	(1) IEEE 693	(2) Yield strength	(3) Ultimate bending load
PA123a /PA145a	MODERATE	HIGH	HIGH
PV 123	HIGH	HIGH	HIGH
PVA123a /PVA145a	MODERATE	HIGH	HIGH

With respect to **IEEE 693 criteria** main conclusions are the following:

- PA123a/PA145a withstands Moderate seismic qualification level.
- PV 123 withstands High seismic qualification level.
- PVA123a/PVA145a withstand Moderate seismic qualification level.

Disclaimer

The analysis documented herein has been prepared in accordance with reasonable standards of scientific endeavor and the best knowledge of the author(s).

The simulation results may depend on a variety of factors, including quality of input data, applied model simplifications and chosen numerical methods.

6 BIBLIOGRAPHY

[1] IEEE 693 – *IEEE Recommended Practice for Seismic Design and Substations*, The Institute of Electrical and Electronics Engineers, Inc, NY 10016-5997, USA

[2] ABAQUS, *ABAQUS 6.13 Documentation*, DS Simulia, USA, www.simulia.com

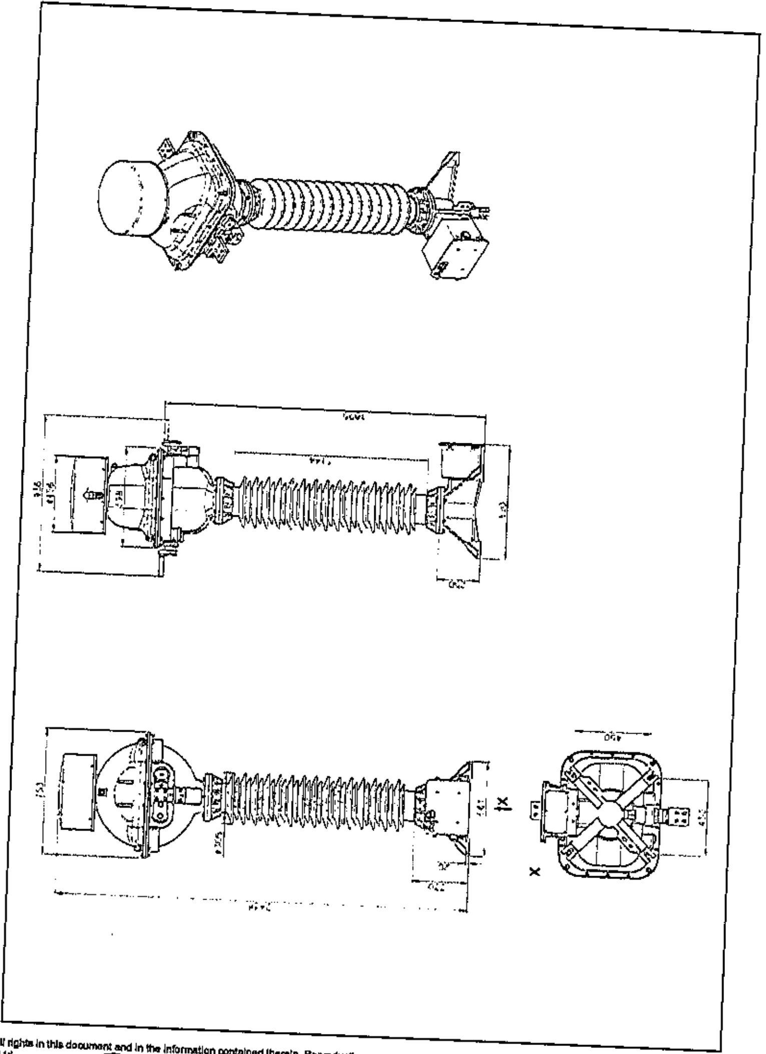
[3] *IEC* 61869-1 – *Instrument transformers – Part 1: General requirements*, International standard, Edition 1.0 2007-10

7 CHANGE HISTORY

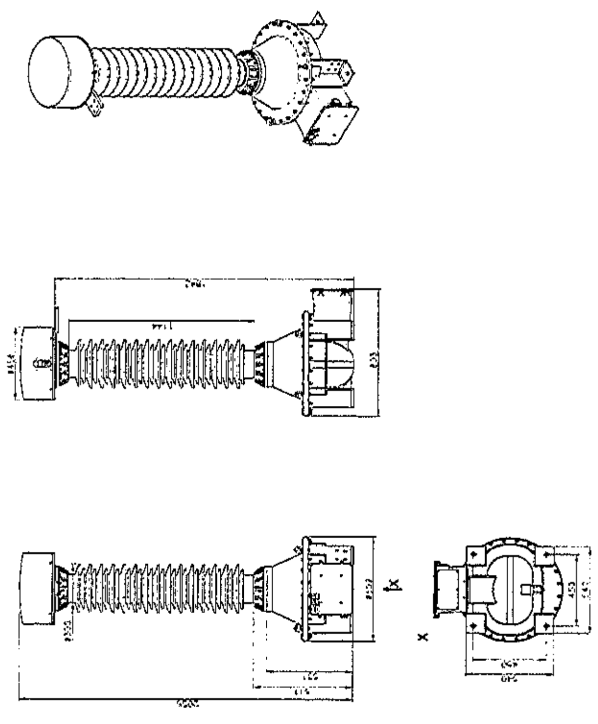
Date	Revision	Author(s)	Change
2015-08-31	Rev. 1	Juszklewicz Grzegorz	original document

8 APPENDICES

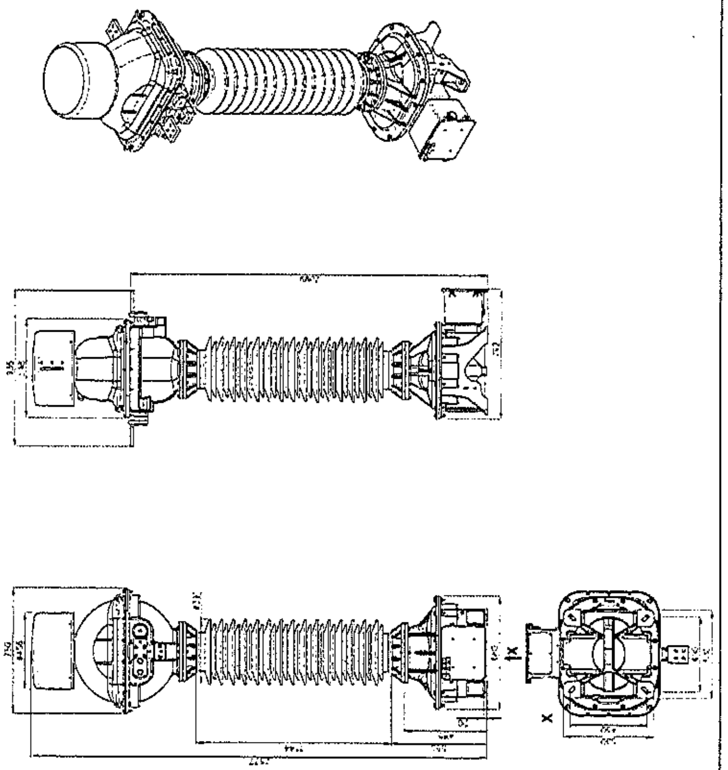
8.1 Current transformer PA123a /PA145a



8.2 Voltage transformer PV123



8.3 Combined transformer PVA123a /PVA145a



„Доставка на електрически апарати 110кV“, реф. № PPD 17-064.

Обособена позиция 4 – Доставка на комбинирани измервателни трансформатори 110kV за монтаж на открито – 15 бр.

ПРИЛОЖЕНИЕ 5

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[illegible] 168
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tel. (22) 223 8349, fax (22) 223 8958
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Варшава, 27 Януари 2017 г.

ч.ел

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„Доставка на електрически апарати 110кV“, реф. № PPD 17-064.

Обособена позиция 4 – Доставка на комбинирани измервателни трансформатори 110кV за монтаж на открито – 15 бр.

ПРИЛОЖЕНИЕ 6

ABB

ROUTINE TEST PLAN for Combined Instrument Transformers

План за рутинни изпитания на Комбиниран Измервателен Трансформатор

Number / *Номер*
2GKK614153

Page / Страница 1
Pages / Общо 4

Type/ Тип

-- units of Combined Instrument Transformers (--брой Комб. Изм. Трансформатори)

Valid for order ………. / KU ….
Валидно за поръчка ………… / KU ….

Sl. **№**	**Test** ***Изпитание***	**Test according to:** ***Изпитание съгл.:***	**Requirement according to:** ***Изисквания***	**Place of test** ***Място на***	**Remarks** ***Забележки***	***Date*** ***Дата***	**Acceptance** ***Приемане***	**Signature** ***Подпис***
1	Enclosure tightness test at ambient temperature *Изпитване за херметичност при температура на околната среда*	IEC 61869-1	Cl. 7.3.7.2	Quality control - ABB Przasnysz *Контрол на качеството*				
2	Verification of terminal markings and technical parameters *Проверка на маркировката на клемите и техническите*	IEC 61869-1 IEC 61869-2 IEC 61869-3 IEC 61869-4	Cl. 6.13; 7.3.6 Cl. 6.13 Cl. 6.13 Cl. 6.13	Quality control - ABB Przasnysz *Контрол на качеството*				
3	Power-frequency voltage withstand tests on primary windings and partial discharge measurement *Обявено издържано напрежение с промишлена честота за изолацията на първичната намотка и измерване на частичните разряди.*	IEC 61869-1 IEC 61869-2 IEC 61869-3 IEC 61869-4 IEC 60720	Cl. 7.3.1; 7.3.2 Cl. 7.3.1 Cl. 7.3.1; 7.3.2 Cl. 7.3.1;	Quality control - ABB Przasnysz *Контрол на качеството*				
4	Determination of the secondary and primary windings resistance *Определяне на съпротивлението на първичната и вторичните намотки*	IEC 61869-2 -- --	Cl. 7.3.201 Order (if special requirements) *Поръчка (при специални изисквания)*	Quality control - ABB Przasnysz *Контрол на качеството*				

Prepared by Подготвено от	Date *Дата*	Checked by *Проверено от*	Date *Дато*	Approved by *Одобрено от*	Date *Дата*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

ABB

ROUTINE TEST PLAN for Combined Instrument Transformers
План за рутинни изпитания на Комбиниран Измервателен Трансформатор

Number / *Номер*
2GKK614153

Page / Страница 1
Pages / Общо 4

Type/ Тип

-- units of Combined Instrument Transformers (--брой Комб. Изм. Трансформатори)

Valid for order ………../ KU ….
Валидно за поръчка …………/ KU ….

Sl. №	Test *Изпитание*	Test according to: *Изпитание съгл.:*	Requirement according to: *Изисквания*	Place of test *Място на*	Remarks *Забележки*	*Date* *Дата*	Acceptance *Приемане*	Signature *Подпис*
5	Power-frequency voltage withstand tests on secondary terminals and between sections (if applicable) *Обявено издържано напрежение с промишлена честота за изолацията на вторичните клеми и между секциите (ако е приложимо)*	IEC 61869-1	Cl. 7.3.3; 7.3.4	Quality control - ABB Przasnysz *Контрол на качеството*				
6	Measurement of factors: FS/ALF/Ts/Ek/Ie/Kr and magnetizing characteristic of the Current Transformer *Измерване на фактори: FS/ALF/Ts/Ek/Ie/Kr и намагнитващите характеристики на ТТ.*	IEC 61869-2 --	Cl. 7.2.6.202; 7.3.5.203; 7.3.5.205; 7.3.202; 7.3.203; 7.2.6.206 Order *Поръчка*	Quality control - ABB Przasnysz *Контрол на качеството*				
7	Inter-turn overvoltage test of the Current Transformer *Изпитание на пренапрежение на вътрешните навивки на ТТ*	IEC 61869-2	Cl. 7.3.204	Quality control - ABB Przasnysz *Контрол на качеството*				

Prepared by Подготвено от	Date *Дата*	Checked by *Проверено от*	Date *Дато*	Approved by *Одобрено от*	Date *Дата*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

ABB	ROUTINE TEST PLAN for Combined Instrument Transformers *План за рутинни изпитания на Комбиниран Измервателен Трансформатор*	Number / *Номер* **2GKK614153**	Page / Страница 1 Pages / Общо 4
		Type/ Тип	
	-- units of Combined Instrument Transformers (--брой Комб. Изм. Трансформатори)	Valid for order ………. / KU …. *Валидно за поръчка ………… / KU ….*	

Sl. №	Test *Изпитание*	Test according to: *Изпитание съгл.:*	Requirement according to: *Изисквания съгласно:*	Place of test *Място на изпитанието*	Remarks *Забележки*	*Date* *Дата*	Acceptance *Приемане*	Signature *Подпис*
8	Test for accuracy of the current transformer: - Tests for ratio error and phase displacement of measuring CT; - Tests for ratio error and phase displacement of class P; PR; TPX; TPY and TPZ protective CT - Test for turns ratio error for class PX and PXR protective CT *Изпитание на точността на ТТ:* *Изпитание на грешката и фазовото отместване на ТТ за мерене ;* - *Изпитание на грешката и фазовото отместване на клас P; PR; TPX; TPY; TPZ на ТТ за защита* - *Проверка за грешка в съотношението на навивките за клас PX и PXR на ТТ за защита*	IEC 61869-2 IEC 61869-4	Cl. 7.3.5.201, 7.3.5.202, 7.3.5.204, 7.3.5.206 Cl. 7.3.5.401	Quality control - ABB Przasnysz *Контрол на качеството*				
9	Test for accuracy of the voltage transformer: - Tests for ratio error and phase displacement of measuring VT; - Tests for ratio error and phase displacement of protective VT Изпитание на точността на НТ: - Изпитвания за грешка в съотношението и фазовото изместване на НТ за мерене; - Изпитвания за грешка в съотношението и фазовото изместване на НТ за защита	IEC 61869-3 IEC 61869-4	Cl. 7.3.5.301; 7.3.5.302 Cl. 7.3.5.401	Quality control - ABB Przasnysz *Контрол на качеството*				

Prepared by Подготвено от	Date *Дата*	Checked by *Проверено от*	Date *Дато*	Approved by *Одобрено от*	Date *Дата*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

ABB

ROUTINE TEST PLAN for Combined Instrument Transformers
План за рутинни изпитания на Комбиниран Измервателен Трансформатор

Number / *Номер*
2GKK614153

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Type/ Тип

-- units of Combined Instrument Transformers (--брой Комб. Изм. Трансформатори)

Valid for order ………. / KU ….
Валидно за поръчка ………… / KU ….

10	Capacitance and dielectric dissipation factor measurement *Измерване на капацитет и фактор на диелектрично разсейване*	IEC 61869-1 IEC 61869-2 IEC 61869-3	Cl. 7.4.3 Cl. 7.4.3 Cl. 7.4.3	Quality control - ABB Przasnysz *Контрол на качеството*				
11	Inspection : visual check & verification of parameters according to order Инспекция: Визуална проверка и проверка на параметрите по поръчка	-- --	Order *Поръчка*	Quality control - ABB Przasnysz *Контрол на качеството*				

Prepared by Подготвено от	Date *Дата*	Checked by *Проверено от*	Date *Дато*	Approved by *Одобрено от*	Date *Дата*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

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ROUTINE TEST PLAN for Combined Instrument Transformers

Plan próby wyrobu dla Przekładników Kombinowanych

Number / *Numer*
2GKK614153

Page / *Strona* 1
Pages / *Stron* 4

Type/ Typ

-- units of Combined Instrument Transformers (-- szt. Przekładników Kombinowanych)

Valid for order ..../ KU ....
Obowiązuje do zam. dla ..../ KU ....

Sl. No	Test *Badanie*	Test according to: *Badanie według:*	Requirement according to: *Wymaganie według:*	Place of test *Miejsce badania*	Remarks *Uwagi*	***Date*** ***Data***	Acceptance *Akceptacja*	Signature *Podpis*
1	Enclosure tightness test at ambient temperature *Sprawdzenie szczelności obudowy w temperaturze otoczenia*	IEC 61869-1	Cl. 7.3.7.2	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
2	Verification of terminal markings and technical parameters *Sprawdzenie oznakowania zacisków i parametrów technicznych*	IEC 61869-1 IEC 61869-2 IEC 61869-3 IEC 61869-4	Cl. 6.13; 7.3.6 Cl. 6.13 Cl. 6.13 Cl. 6.13	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
3	Power-frequency voltage withstand tests on primary terminals and partial discharge measurement *Próba izolacji uzwojeń pierwotnych napięciem o częstotliwości sieciowej oraz pomiar wyładowań niezupełnych.*	IEC 61869-1 IEC 61869-2 IEC 61869-3 IEC 61869-4 IEC 60720	Cl. 7.3.1; 7.3.2 Cl. 7.3.1 Cl. 7.3.1; 7.3.2 Cl. 7.3.1;	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
4	Determination of the secondary and primary windings resistance *Wyznaczenie rezystancji uzwojeń wtórnych i pierwotnych*	IEC 61869-2 -- --	Cl. 7.3.201 Order (if special requirements) *Zamówienie (jeśli specjalne wym.)*	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	

Prepared by *Opracował*	Date *Data*	Checked by *Sprawdził*	Date *Data*	Approved by *Zatwierdził*	Date *Data*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

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ROUTINE TEST PLAN for Combined Instrument Transformers

Plan próby wyrobu dla Przekładników Kombinowanych

Number / *Numer*
2GKK614153

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Type/ Typ

-- units of Combined Instrument Transformers (-- szt. Przekładników Kombinowanych)

Valid for order ………. / KU ….
Obowiązuje do zam. dla ………… / KU ….

Sl. No	Test *Badanie*	Test according to: *Badanie według:*	Requirement according to: *Wymaganie według:*	Place of test *Miejsce badania*	Remarks *Uwagi*	*Date* *Data*	Acceptance *Akceptacja*	Signature *Podpis*
5	Power-frequency voltage withstand tests on secondary terminals and between sections (if applicable) *Próba izolacji uzwojeń wtórnych oraz między sekcjami uzwojeń (jeśli ma zastosowanie) napięciem o częstotliwości sieciowej*	IEC 61869-1	Cl. 7.3.3; 7.3.4	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
6	Measurement of factors: FS/ALF/Ts/Ek/Ie/Kr and magnetizing characteristic of the Current Transformer *Pomiar współczynników: FS/ALF/Ts/Ek/Ie/Kr i charakterystyki magnesowania przekładnika prądowego.*	IEC 61869-2 --	Cl. 7.2.6.202; 7.3.5.203; 7.3.5.205; 7.3.202; 7.3.203; 7.2.6.206 Order *Zamówienie*	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
7	Inter-turn overvoltage test of the Current Transformer *Próba izolacji międzyzwojowej przekładnika prądowego*	IEC 61869-2	Cl. 7.3.204	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	

Prepared by *Opracował*	Date *Data*	Checked by *Sprawdził*	Date *Data*	Approved by *Zatwierdził*	Date *Data*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

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ROUTINE TEST PLAN for Combined Instrument Transformers

Plan próby wyrobu dla Przekładników Kombinowanych

-- units of Combined Instrument Transformers (-- szt. Przekładników Kombinowanych)

Number / *Numer*
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Pages / *Stron* 4

Type/ Typ

Valid for order .... / KU ....
Obowiązuje do zam. dla .... / KU ....

Sl. No	Test *Badanie*	Test according to: *Badanie według:*	Requirement according to: *Wymaganie według:*	Place of test *Miejsce badania*	Remarks *Uwagi*	*Date* *Data*	Acceptance *Akceptacja*	Signature *Podpis*
8	Test for accuracy of the current transformer: • Tests for ratio error and phase displacement of measuring CT; • Tests for ratio error and phase displacement of class P; PR; TPX; TPY and TPZ protective CT • Test for turns ratio error for class PX and PXR protective CT *Próby dokładności przekładnika prądowego:* • *Próby błędu przekładni i przesunięcia kątowego przekładnika pomiarowego;* • *Próby błędu przekładni i przesunięcia kątowego przekładnika zabezpieczeniowego o klasach P; PR; TPX; TPY; TPZ* • *Próba błędu przekładni zwojowej dla klas PX i PXR przekładnika zabezpieczeniowego*	IEC 61869-2 IEC 61869-4	Cl. 7.3.5.201, 7.3.5.202, 7.3.5.204, 7.3.5.206 Cl. 7.3.5.401	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
9	Test for accuracy of the voltage transformer: • Tests for ratio error and phase displacement of measuring VT; • Tests for ratio error and phase displacement of protective VT *Próby dokładności przekładnika napięciowego:* • *Próby błędu przekładni i przesunięcia kątowego przekładnika pomiarowego;* • *Próby błędu przekładni i przesunięcia kątowego przekładnika zabezpieczeniowego*	IEC 61869-3 IEC 61869-4	Cl. 7.3.5.301; 7.3.5.302 Cl. 7.3.5.401	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	

Prepared by *Opracował*	Date *Data*	Checked by *Sprawdził*	Date *Data*	Approved by *Zatwierdził*	Date *Data*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

ABB	**ROUTINE TEST PLAN for Combined Instrument Transformers** ***Plan próby wyrobu dla Przekładników Kombinowanych***	Number / *Numer* **2GKK614153**
		Page / *Strona* 4 Pages / *Stron* 4
		Type/ Typ
	-- units of Combined Instrument Transformers (-- szt. Przekładników Kombinowanych)	Valid for order ..../ KU .... *Obowiązuje do zam. dla .... / KU ....*

10	Capacitance and dielectric dissipation factor measurement *Pomiar pojemności i współczynnika strat dielektrycznych*	IEC 61869-1 IEC 61869-2 IEC 61869-3	Cl. 7.4.3 Cl. 7.4.3 Cl. 7.4.3	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	
11	Inspection : visual check & verification of parameters according to order *Oględziny – sprawdzenie zgodności parametrów z zamówieniem*	-- --	Order *Zamówienie*	Quality control - ABB Przasnysz *Kontrola Jakości*			☐	

Prepared by *Opracował*	Date *Data*	Checked by *Sprawdził*	Date *Data*	Approved by *Zatwierdził*	Date *Data*
Ł. Lubieniecki	27.07.2015	J. Duzdowski	27.07.2015	P. Dębski	27.07.2015

ДЕКЛАРАЦИЯ

за приемане на условията в проекта на договор

Долуподписаните Екехарт Нойрайтер и Стефан Минчев в качеството ни на представляващи АББ България ЕООД участник в обществена поръчка с предмет: **„Доставка на електрически апарати 110кV“**, реф. № PPD 17-064 **Обособена позиция 4 -** Доставка на комбинирани измервателни трансформатори 110 kV за монтаж на открито – 15 бр.

ДЕКЛАРИРАМЕ, ЧЕ:

Приемаме условията в проекта на договор, приложен в документацията за участие.

Дата: 11.07.2017

Декларатор: ....

Екехарт Нойрайтер
Управител
АББ България ЕООД

....

Стефан Минчев
Управител
АББ България ЕООД

ДЕКЛАРАЦИЯ

за срока на валидност на офертата

Долуподписаните,

Екехарт Бернхард Нойрайтер, притежаващ лична карта ID N: L8XH0JRMR издадена на 11.03.2013 – Германия, адрес гр. София, бул. Христофор Колумб № 9, ет.3,

в качеството ми на Управител на АББ България ЕООД

и

Стефан Василев Минчев, притежаващ лична карта №641790843, издадена на 11.01.2011 от МВР – гр. София, адрес: гр. София, бул. Христофор Колумб № 9, ет.3,

в качеството ми на Управител на АББ България ЕООД,

участник в процедура за възлагане на обществена поръчка с предмет: **„Доставка на електрически апарати 110kV"**, реф. № PPD 17-064, **Обособена позиция 4 -** Доставка на комбинирани измервателни трансформатори 110 kV за монтаж на открито – 15 бр.

ДЕКЛАРИРАМЕ, ЧЕ:

С подаване на настоящата оферта, направените от нас предложения и поети ангажименти са валидни за срока, посочен в обявлението, считано от крайния срок за подаване на офертите.

Дата: 11.07.2017

Декларатор:

Екехарт Нойрайтер
Управител
АББ България ЕООД

Стефан Минчев
Управител
АББ България ЕООД