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	2GKP013K1486144 / 13	Voltage factor	1,9Un/8h	Ue	0,2 mV/kA

CURRENT PART

K_n: 300-600 / 5-1-5-1 A/A

I_{th}/1s: 40-40 kA I_{dyn}: 100-100 kA

I_{cth}: 450-900 A

	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2	5S1-5S2	6S1-6S2
A	5	1	5	1		
VA	40	30	60	120		
Kl.	0,2	0,5	5P	10P		
FS/ALF	5	10	20	15		
Ext.%	150	150				

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	0->10	25	25	40	100
Kl.	0,1	0,1	0,1/3P	1/3P	1,0
VA_{sth}	1000	1000	1000	1000	450

Transportation: Vertical / Horizontal

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	600 / 180 kg	Temp. range	-40°C → +40°C
S/N	86143 / 13	Voltage factor	1,9Un/8h	Ue	0,2 mV/kA

CURRENT PART

K_n: 150-300-600/5-5 A/A

I_{th}/1s: 40-40-40 kA I_{dyn}: 100-100-100 kA

I_{cth}: 180-360-720 A

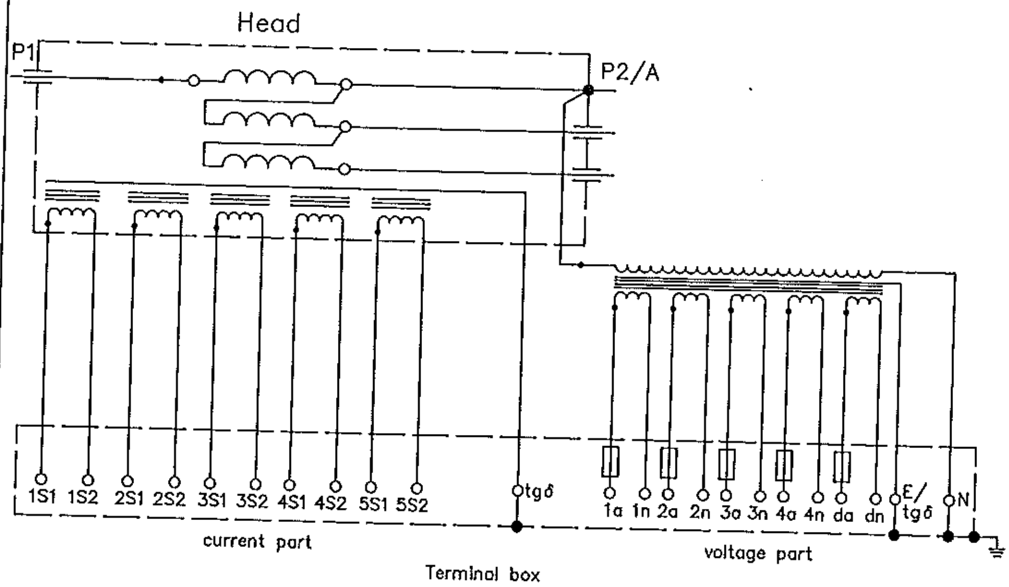
	1S1-1S2	2S1-2S2	3S1-3S2	4S1-4S2	5S1-5S2	6S1-6S2
A	5	5				
VA	30	30				
Class	5P	5P				
FS/ALF	20	20				
Ext.%						

VOLTAGE PART

A-N: 132:√3 kV

	1a-1n	2a-2n	3a-3n	4a-4n	da-dn
V	110:√3	110:√3			
VA	25	25			
Class	0,5	0,5/3P			
VA_{sth}	1000	1000			

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

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 / 13	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} 225-450 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.%	150					

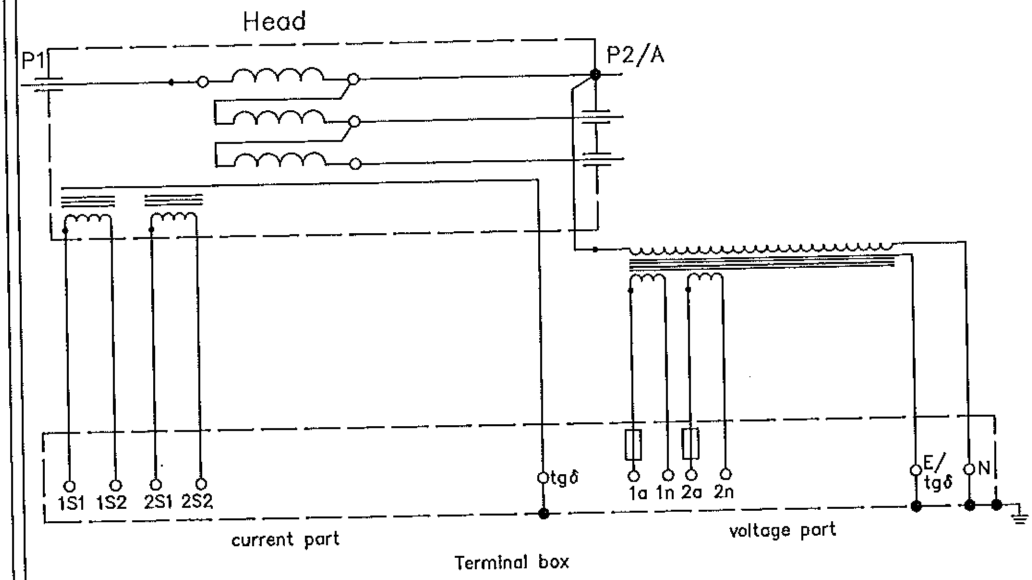
VOLTAGE PART

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_{sth}	1000	1000	1000	1000	450

Transportation: Vertical / Horizontal

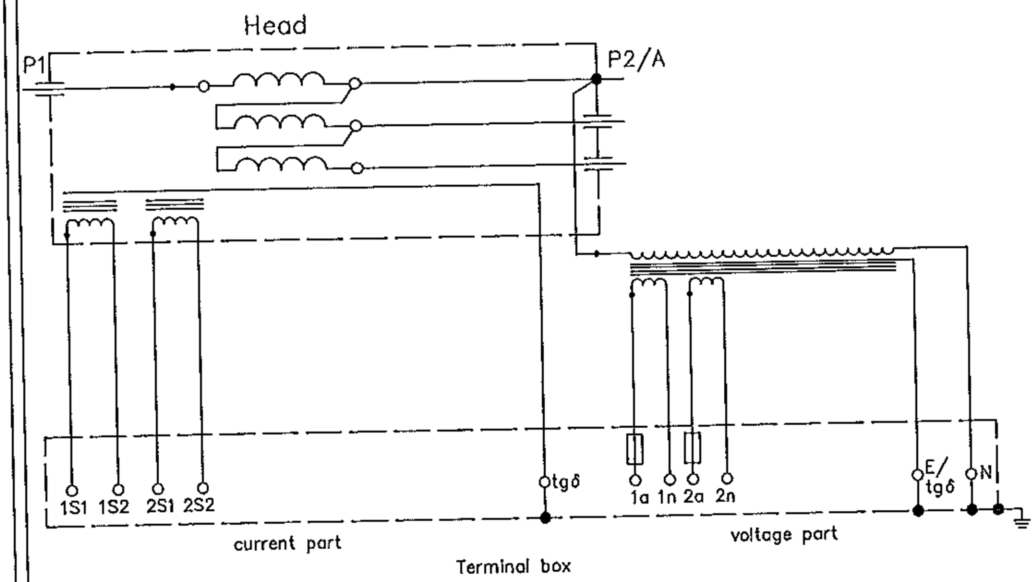
250



Instrument transformer electrical diagram

ATTENTION!

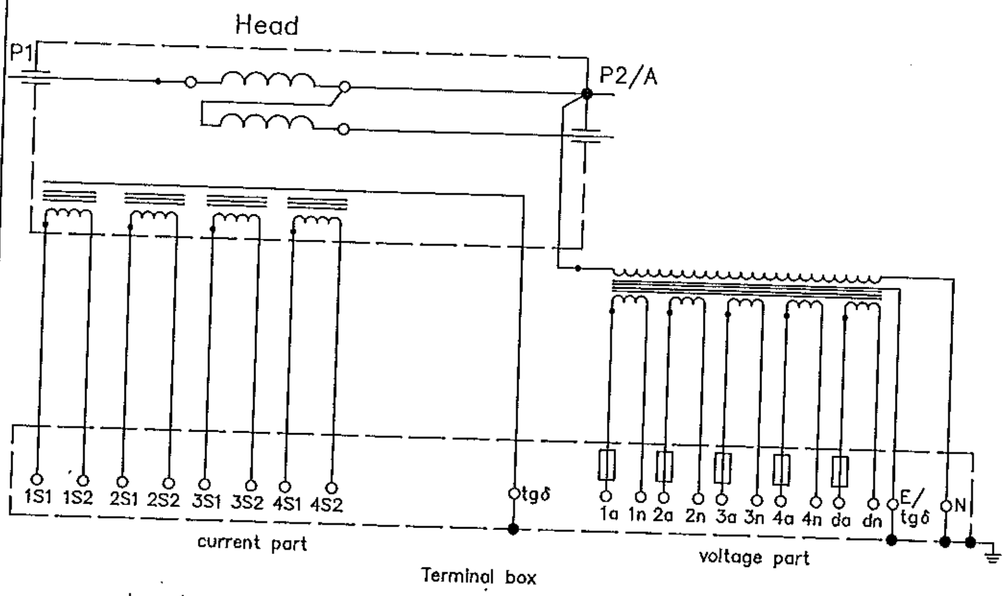
1. HIGH VOLTAGE AT OPEN CURRENT SECONDARY TERMINALS XS1 – XS2
2. DURING INSTRUMENT TRANSFORMER OPERATION TERMINALS: N, E/tgδ, tgδ MUST BE EARTHED



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



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
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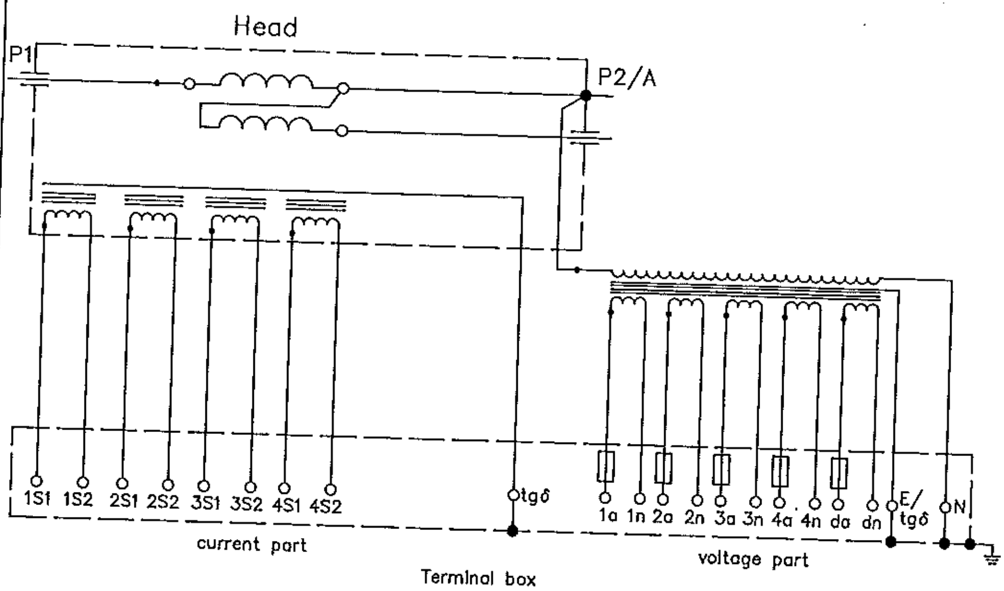

Instrument transformer electrical diagram

ATTENTION!

1. HIGH VOLTAGE AT OPEN CURRENT SECONDARY TERMINALS XS1 – XS2
2. DURING INSTRUMENT TRANSFORMER OPERATION TERMINALS: N, E/tgδ, tgδ MUST BE EARTHED
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ANNEX 2 for test report EWN/145/E/13

Reports of routine test and determination of errors of combined transformers type PVA123a and PVA145a performed in Factory Laboratory of ABB sp. z o.o.

- Tests before type test and special test (Measurements before type test and special tests)
  - Report No. 2GKP013K1486138 – 12.11.2013,
- Tests before type test and special test (Measurements before type test and special tests)
  - Report No. 2GKP013K1486144 – 18.11.2013,
- Tests before type test and special test (Measurements before type test and special tests)
  - Report No. 2GKP013K1486145 – 04.12.2013,
- Tests after lightning impulse test
  - Report No. 2GKP013K1486138 – 09.12.2013,
- Tests after lightning impulse test
  - Report No. 2GKP013K1486144 – 20.12.2013.

ABB Sp. z o.o. 06 – 300 Przasnysz ul. Leszno 59		Routine tests report of combined instrument transformer			TYP: PVA123a Nr fabr. 2GKP013K1486138	
A – N 110: $\sqrt{3}$ kV	Insulation level: 126/230/550 kV	Voltage factor: 1,9 /8h	Ith 1 s [kA] 40-63-63	Idyn [kA] 100-158-158	Icth [A]: 180-360-720	IEC 61869-4 50 Hz

VOLTAGE PART	Winding	Usn [kV]	Sn [VA]	class	Sth [VA]
	1a-1n	0,1:√3	25	0,1	1000
		0,1:√3	25	3,0	1000
	2a-2n	0,1:√3	25	0,1	1000
		0,1:√3	25	3,0	1000
	3a-3n	0,1:√3	25	0,1/3P	1000
		0,1:√3	500	3/3P	1000
	4a-4n	0,1:√3	25	0,1/3P	1000
		0,1:√3	25	3/3P	1000
	da-dn	0,1: 3	100	1	450
		0,1: 3	300	3P	450

CURRENT PART	Winding	Isn [A]	Sn [VA]	class	Przekładnia [A/A]
	1S1-1S2	5	1->5	0,5FS5	50-10-200/5
	2S1-2S2	1	1->2.5	0,5FS10	50-10-200/1
	3S1-3S2	5	10	5P 10	50-10-200/5
	4S1-4S2	1	2.5	5P80	50-10-200/1
		1		PX Ek=190V Ie<=0,1A/95 V Rct<=0,3Ω Rb=3,5 Ω Kx=50 4-2-1/200	50-10-200/1
		1		TPX Kssc= 13 Ktd= 14,6 cykl = 0,1s Tp= 0,05 Rct<=0,3Ω Rb=1 Ω Ratio error <=0.5%	50-10-200/1
	5S1-5S2	1	5	5P10	50-10-200/1

List of performer tests

1. Oil dielectric parameters check before filling (oil after tgδ wg 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=230 kV / 60 s,f =97 Hz; N; Up = 3 kV/ 60s, f=50 Hz ☑
5. Partial discharge ☑
6. Power-frequency withstand test on secondary – Up = 3 kV/60 s ☑
7. Inter-turn overvoltage test for current transformers– lower value
   (U szczyt. = 4,5 kV lub U szczyt. Przy Icth) / 60s ☑
8. Determination of errors ☑
9. Determination of the over current factors: FS, ALF ☑
10. Measurement of capacitance and dielectric dissipation factor (tgδ) ☑
11. Determination of core magnetization characteristics ☑
12. Measurement of windings' resistance ☑

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Oil dielectric parameters check before filling (oil after treatment)

- Measurement of oil tgδ according to IEC 60247
  Tgδ = 0,06%; electrical stress = 1 kV/mm, f=50 Hz, Oil temp. = 90°C±1°C

- Measurement of breakdown voltage according to IEC 60156
  Mean breakdown voltage =77,42 kV, Relative standard deviation = 5,64%; f=50 Hz,
  oil temp. = 26 °C, measurement with the stirrer, type of electrodes used: partially spherical.

Sample	Breakdown voltage [kV]
1	83.2
2	80.1
3	70.8
4	79.2
5	76.4
6	74.8

Partial discharge measurement

- Measurement according to procedure A (PD test voltages were reached while decreasing the voltage after the power-frequency withstand test on primary winding)
  Stress voltage 230 kV / 60 s
  Frequency 97 Hz

Test voltage	1,2 Um = 151 kV	1,2 Um / √3 = 87.5 kV
Level of partial discharge	2 pC	1,5 pC

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

Inter-turn overvoltage test for current transformers

	Peak voltage on secondary winding [kVpeak]	Current in primary winding [A]
1S1-1S2	0.086	400
2S1-2S2	0.307	400
3S1-3S2	0.205	400
4S1-4S2	1.41	400
5S1-5S2	0.736	400

Determination of voltage part errors (ε U %), (Δφ U min), cosφ = 0,8

Uzwojenie	Usn [kV]	Sn [VA]	klasa	Sth [VA]
1a-1n	0,1:√3	25	0,1	1000
2a-2n	0,1:√3	25	0,1	1000
3a-3n	0,1:√3	25	0,1/3P	1000
4a-4n	0,1:√3	25	3/3P	1000
da-dn	0,1: 3	100	3P	450

1a – 1n 25 VA; 2a-2n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA. cos fi = 0,8 ind. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.037	-0.035	-0.035	
Δφ U	2.2	2.2	2.3	

1a – 1n 6,25 VA; 2a-2n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	0.004	0.005	0.005	
Δφ U	2.1	2.1	2.2	

2a – 2n 25 VA; 1a-1n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA. cos fi = 0,8 ind. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.027	-0.025	-0.025	
Δφ U	2.3	2.3	2.4	

2a – 2n 6,25 VA; 1a-1n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	0.013	0.014	0.015	
Δφ U	2.1	2.2	2.2	

3a – 3n 25 VA; 1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind. cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.171	-0.109	-0.020	-0.018	-0.017	-0.117
Δφ U	-3.0	0.2	2.4	2.5	2.5	1.1

3a – 3n 6,25 VA; 1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind. cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.126	-0.066	0.019	0.021	0.021	-0.078
Δφ U	-3.2	-0.0	2.2	2.2	2.3	0.9

4a – 4n 25 VA; 1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 25 VA cos fi = 0,8 ind. cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.170	-0.109	-0.024	-0.023	-0.023	-0.122
Δφ U	-2.7	0.5	2.8	2.8	2.8	1.4

4a – 4n 6,25 VA; 1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 25 VA cos fi = 0,8 ind. cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.125	-0.065	0.021	0.023	0.023	-0.077
Δφ U	-3.0	0.1	2.4	2.4	2.4	1.0

da – dn 100 VA; cos fi = 0,8 ind. 1a-1n 25VA; 2a-2n 25VA; 3a-3n 500VA; 4a-4n 25VA , cos fi = 0.8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	
ε U	-0.741	-0.739	-0.738	
Δφ U	8.9	8.9	9.0	

1a – 1n 25 VA; 2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA. cos fi = 0,8 ind.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.035	0.037	0.037
Δφ U	3.6	3.6	3.6

1a – 1n 6,25 VA; 2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA cos fi = 0,8 ind.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.075	0.077	0.077
Δφ U	3.4	3.5	3.5

2a – 2n 25 VA; 2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA. cos fi = 0,8 ind.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.044	0.046	0.047
Δφ U	3.7	3.7	3.8

2a – 2n 6,25 VA; 1a-1n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA cos fi = 0,8 ind.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.084	0.086	0.086
Δφ U	3.5	3.5	3.6

3a – 3n 25 VA; 1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA cos fi = 0,8 ind.

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.094	-0.037	0.050	0.052	0.053	-0.046
Δφ U	-1.4	1.7	3.7	3.8	3.8	2.5

3a – 3n 6,25 VA; 1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA cos fi = 0,8 ind.

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.054	0.003	0.090	0.062	0.092	-0.007
Δφ U	-1.6	1.4	3.6	3.6	3.6	2.3

4a – 4n 25 VA; 1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA cos fi = 0,8 ind.

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.101	-0.041	0.045	0.047	0.047	-0.052
Δφ U	-1.2	1.9	4.0	4.0	4.1	2.7

4a – 4n 6,25 VA; 1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA cos fi = 0,8 ind.

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.054	0.002	0.090	0.092	0.092	-0.007
Δφ U	-1.4	1.5	3.6	3.6	3.7	2.4

da – dn 25 VA; 1a-1n 0VA; 2a-2n 0VA; 3a-3n 0VA; 4a-4n 0VA , cos fi = 0,8 ind.

	0,8 U_n	1,0 U_n	1,2 U_n	
ε U	-0.304	-0.302	-0.302	
Δφ U	5.2	5.2	5.3	

*) at 1,9 Un winding da-dn is loaded with Sn, cos fi = 0,8 ind.

Determination of voltage part errors (ε U %), (Δφ U min), cosφ = 0,8

Uzwojenie	Usn [kV]	Sn [VA]	klasa	Sth [VA]
1a-1n	0,1:√3	25	3,0	1000
2a-2n	0,1:√3	25	3,0	1000
3a-3n	0,1:√3	500	3/3P	1000
4a-4n	0,1:√3	25	3/3P	1000
da-dn	0,1: 3	300	3P	450

1a – 1n 25 VA; cos fi = 0,8 ind.
2a-2n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.517	-0.515	-0.516	
Δφ U	-7.1	-7.1	-7.0	

1a – 1n 25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.035	0.037	0.037
Δφ U	3.6	3.6	3.6

1a – 1n 6,25 VA; cos fi = 0,8 ind.
2a-2n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.478	-0.476	-0.475	
Δφ U	-7.2	-7.2	-7.1	

1a – 1n 6,25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.075	0.077	0.077
Δφ U	3.5	3.5	3.5

2a – 2n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.511	-0.509	-0.509	
Δφ U	-7.1	-7.1	-7.0	

2a – 2n 25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.045	0.046	0.047
Δφ U	3.7	3.7	3.8

2a – 2n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.470	-0.470	-0.469	
Δφ U	-7.3	-7.3	-7.2	

2a – 2n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.084	0.086	0.086
Δφ U	3.5	3.5	3.6

3a – 3n 500 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-1.151	-1.089	-0.996	-0.995	-0.993	-1.245
Δφ U	1.9	4.9	7.2	7.3	7.3	2.7

3a – 3n 500 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-1.080	-1.019	-0.926	-0.924	-0.924	-1.175
Δφ U	3.3	6.3	8.5	8.5	8.7	4.1

3a – 3n 125 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.383	-0.318	-0.230	-0.228	-0.227	-0.478
Δφ U	-1.9	1.2	3.5	3.5	3.6	-1.1

3a – 3n 125 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.305	-0.247	-0.158	-0.156	-0.155	-0.407
Δφ U	-0.5	2.7	4.8	4.8	4.9	0.3

4a – 4n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 500 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.595	-0.537	-0.446	-0.445	-0.443	-0.699
Δφ U	-10.7	-7.5	-5.1	-5.1	-5.1	-9.7

4a – 4n 25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.097	-0.040	0.047	0.049	-0.049	-0.205
Δφ U	-1.2	1.9	4.0	4.0	4.1	-0.6

4a – 4n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 500 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.265	-0.203	-0.113	-0.112	-0.11	-0.367
Δφ U	-4.5	-1.2	1.1	1.1	1.1	-3.6

4a – 4n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.053	0.007	0.091	0.093	0.094	-0.161
Δφ U	-1.5	1.5	3.6	3.7	3.7	-0.9

da – dn 300 VA; cos fi = 0,8 ind.
1a-1n 25VA; 2a-2n 25VA; 3a-3n 500VA; 4a-4n 25VA, cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	1,0 U_n	1,9 U_n
ε U	-1.229	-1.172	-1.072	-1.089
Δφ U	-5.8	-2.4	0.7	0.9

da – dn 75 VA; cos fi = 0,8 ind.
1a-1n 0VA; 2a-2n 0VA; 3a-3n 0VA; 4a-4n 0VA ,

	0,02 U_n	0,05 U_n	1,0 U_n	1,9 U_n
ε U	-0.731	-0.668	-0.572	-0.584
Δφ U	4.5	7.7	9.8	10.2

*) at 1,9 Un winding da-dn is loaded with Sn, cos fi = 0,8 ind.

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

Ipn (A): 50

	1S1-1S2 5 VA; cosφ = 0,8				1S1-1S2 1 VA; cosφ = 0,8			
	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-0.432	-0.235	-0.018	0.127	0.264	0.299	0.314	0.328
Δφ I	19.5	7.5	-1.0	-3.1	15.8	8.9	4.9	3.4
	2S1-2S2 2.5 VA; cosφ = 1				2S1-2S2 1 VA; cosφ = 1			
	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.024	-0.011	0.132	0.194	0.252	0.251	0.283	0.316
Δφ I	33.2	23.1	7.4	4.3	19.3	11.6	5.5	4.6

3S1-3S2	
	1,0 In
ε I	0.896
Δφ I	8.3

4S1-4S2	
	1,0 In
ε I	-0.394
Δφ I	14.4

5S1-5S2	
	1,0 In
ε I	0.709
Δφ I	16.4

Ipn (A): 100

	1S1-1S2 5 VA; cosφ = 0,8				1S1-1S2 1 VA; cosφ = 0,8			
	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-0.393	-0.277	0.007	0.132	0.294	0.303	0.314	0.329
Δφ I	17.7	9.3	-0.4	-3.3	13.3	8.9	4.9	3.3
	2S1-2S2 2.5 VA; cosφ = 1				2S1-2S2 1 VA; cosφ = 1			
	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.025	0.013	0.136	0.194	0.249	0.244	0.277	0.315
Δφ I	33.1	20.6	6.4	5.2	19.0	12.4	5.7	4.1

3S1-3S2	
	1,0 In
ε I	0.880
Δφ I	8.4

4S1-4S2	
	1,0 In
ε I	-0.402
Δφ I	14.7

5S1-5S2	
	1,0 In
ε I	0.711
Δφ I	15.1

Ipn (A): 200

	1S1-1S2 5 VA; cosφ = 0,8				1S1-1S2 1 VA; cosφ = 0,8			
	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-0.581	-0.280	0.010	0.013	0.084	0.282	0.305	0.270
Δφ I	27.7	9.6	-0.7	0.2	25.8	11.2	5.2	7.5
	2S1-2S2 2.5 VA; cosφ = 1				2S1-2S2 1 VA; cosφ = 1			
	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.002	-0.002	0.132	0.192	0.237	0.257	0.281	0.313
Δφ I	36.4	22.8	6.8	4.8	20.7	11.8	5.6	4.6

3S1-3S2	
	1,0 In
ε I	0.880
Δφ I	8.9

4S1-4S2	
	1,0 In
ε I	-0.393
Δφ I	14.4

5S1-5S2	
	1,0 In
ε I	0.705
Δφ I	15.4

255

256

Current part: Measurements uncertainty: **ε I = ±0,045 %, Δφ I = ±2,3 min**
Voltage part: Measurements uncertainty: **ε U = ±0,044 %, Δφ U = ±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	4.32	6.22	U < E_{FS}	☑
2S1-2S2	1	9.63	31.35	U < E_{FS}	☑

- granicznego dokładności (ALF) – próba błędu złożonego ε_c rdzeni zabezpieczeniowych

Winding	E_{ALF} [V]	Ie [A]	ε_c [%]	Condition	Assessment
3S1-3S2	21.18	1.176	2.35	ε_c < 5%	☑
4S1-4S2	220.64	0.124	0.16	ε_c < 5%	☑
5S1-5S2	53.08	0.129	1.29	ε_c < 5%	☑

Determination of parameters of class PX core 4S1-4S2:

Ipn (A)	50	100	200
Factor Kx	53.85	54.87	54.87
Turns ratio error [%]	-0.009	-0.003	0.002

Determination of parameters of class TPX core 4S1-4S2:

Ipn (A)	50	100	200
Factor Kssc	13.41	13.87	13.86
Factor Ktd	14.45	14.46	14.46
Current ratio error [%]	-0.232	-0.230	-0.235
Ts [s]	5.319	5.511	5.500
ε-peak [%]	2.36	1.57	1.55

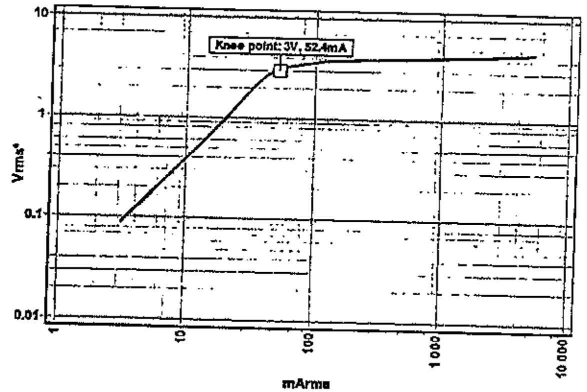
Measurement of capacitance and dielectric dissipation factor (tg δ)
Temperature: 22,3 °C, Frequency: 50 Hz

Primary voltage	Instrument transformer			Current part			Voltage part		
	Capacity	Capacity	Leak current	Tg δ	Capacity	Leak current	Tg δ	Capacity	Leak current
	[%]	[pF]	[mA]	[%]	[pF]	[mA]	[%]	[pF]	[mA]
10 kV	0.24	1383	4.38	0.25	1116	3.532	0.23	266	0.836
63 kV	0.24	1383	27.54	0.24	1116	22.21	0.22	266	5.297
71 kV	0.24	1383	30.9	0.24	1117	24.98	0.22	266	5.963

Core magnetization characteristics:

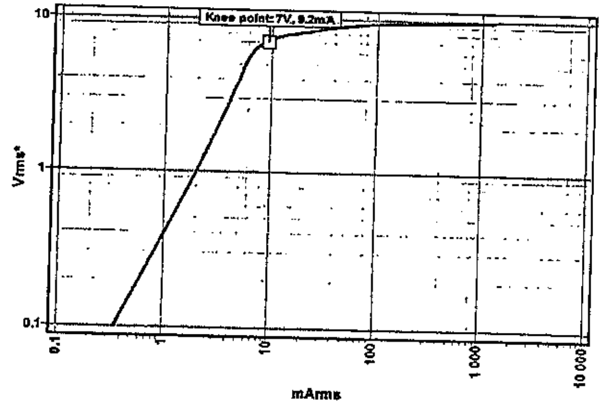
Winding 1S1-1S2

[V]	[mA]
4.5	5292
4.3	2108.3
3.8	135.6
3.2	55.41
2.7	42.37
2.2	35
1.6	28.78
1	20.73
0.5	12.12
0.1	3.25



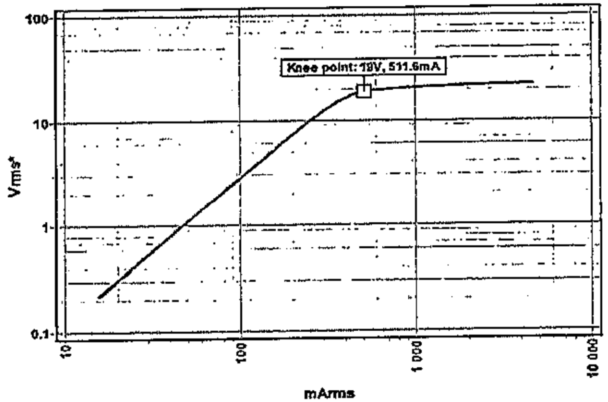
Winding 2S1-2S2

[V]	[mA]
9.7	1224.3
9.5	413.6
8.9	53.1
8.4	26.71
7.8	14.58
7.2	9.49
6.7	7.87
6.1	6.93
5.5	6.19
5	5.66
3.8	4.75
2.8	3.93
1.7	2.85
0.5	1.23
0.1	0.32



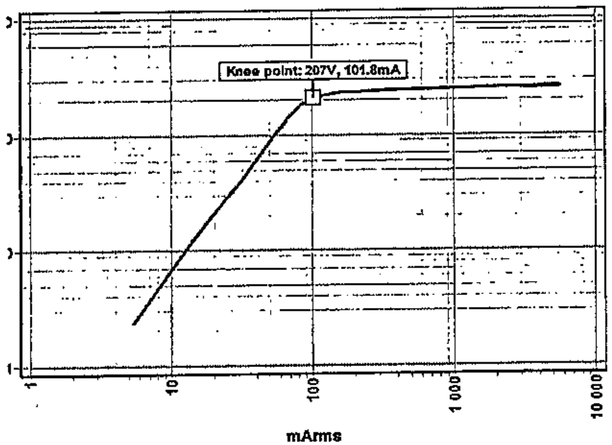
Winding 3S1-3S2

[V]	[mA]
22	2714.7
21.4	1328.1
20.6	814.6
19.2	555.1
17.8	444.8
16.5	398.7
15	358.4
13.8	329.9
12.3	297
10.9	268.9
9.6	243.4
6.7	186.1
4.1	130.9
1.2	51.58
0.2	13.46



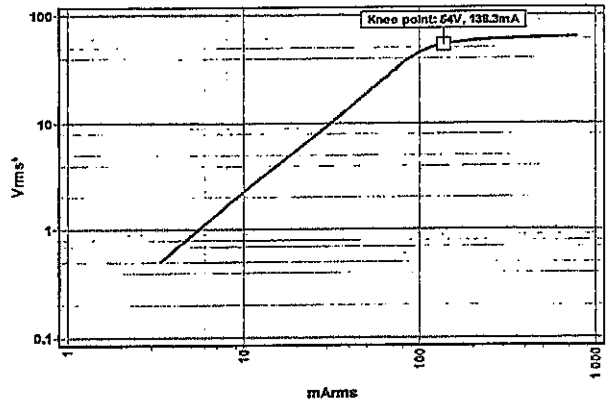
Winding 4S1-4S2

[V]	[mA]
258.5	5777
251.1	1957.8
248.2	1141.9
241.4	449.8
234	217
229.3	168.1
220.6	123.9
207.3	100.74
194.2	90.53
178.1	81.76
152.6	72.53
109.8	58.59
67.7	43.23
25.2	23
1.8	4.79



Winding 5S1-5S2

[V]	[mA]
64.5	1117.4
62.8	569.9
60.2	267.2
58.6	204.4
57.1	169.8
56.1	156
52.9	127.3
50.3	114.1
47.6	105.77
39	87.24
30.5	71.18
22	56.3
13.7	40.21
5.1	19.51
0.5	3.51



Measurement of windings' resistance

Windings' resistance of current part:

	R (23°C)	R ct (75°C)
P1-P2 range 50 A	266.0 μΩ	320.4 μΩ
P1-P2 range 100 A	100.0 μΩ	120.4 μΩ
P1-P2 range 200 A	47.0 μΩ	56.6 μΩ
1S1-1S2	0.048 Ω	0.058 Ω
2S1-2S2	0.527 Ω	0.635 Ω
3S1-3S2	0.024 Ω	0.029 Ω
4S1-4S2	0.214 Ω	0.257 Ω
5S1-5S2	0.315 Ω	0.380 Ω

Windings' resistance of voltage part:

	R (24,9°C)	R ct (75°C)
A-N	17.30 kΩ	20.835 kΩ
1a-1n	44.120 mΩ	53.136 mΩ
2a-2n	45.150 mΩ	54.377 mΩ
3a-3n	46.680 mΩ	56.220 mΩ
4a-4n	48.050 mΩ	57.869 mΩ
da-dn	31.900 mΩ	38.419 mΩ

Checked by: OG-4 KJ-06

Przasnysz. 12.11.2013 r.

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ABB Sp. z o.o. 06-300 Przasnysz ul. Leszno 59		**Routine tests report of combined instrument transformer**			**TYPE: PVA145a** **Serial no: 2GKP013K1486144**	
A-N 132:√3 kV	Insulation level: 145/275/650 kV	Voltage factor: 1.9/8h	Ith 1s [kA]: 40-40	Idyn [kA]: 100-100	Icth [A]: 450-900	IEC 61869-4 50 Hz

VOLTAGE PART	**Winding**	**Usn [kV]**	**Sn [VA]**	**class**	**Sth [VA]**
	1a - 1n	0,11:√3	0->10	0,1	1000
	2a - 2n	0,11:√3	25	0,1	1000
	3a - 3n	0,11:√3	25	0,1/3P	1000
	4a - 4n	0,11:√3	40	1/3P	1000
	da - dn	0,11	100	1,0	450

CURRENT PART	**Winding**	**Isn [A]**	**Sn [VA]**	**class**	**Ratio [A/A]**
	1S1-1S2	5	40	0,2FS 5	300-600/5
	2S1-2S2	1	30	0,5FS 10	300-600/1
	3S1-3S2	5	60	5P 20	300-600/5
	4S1-4S2	1	120	10P 15	300-600/1

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 = 275kV / 60s, f = 97 Hz; 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) / ☑
8. Determination of ☑
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 = 0.07 %; electrical stress = 1kV/mm, f = 50Hz, oil temp. = 90C

- Measurement of breakdown voltage according to IEC 60156
  Mean breakdown voltage = 75.92 kV, Relative standard deviation = 7.19
  f = 50Hz, oil temp. = 26 °C, measurement with the stirrer, type of electrodes used: partially

Sample	Breakdown voltage [kV]
1	81
2	68.2
3	77.5
4	75.3
5	82.2
6	71.3

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 kV
Level of partial discharge	1.8 pC	1.25 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	1.31	900
2S1-2S2	4.5	620
3S1-3S2	2.05	900
4S1-4S2	4.5	86

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

1a-1n: 10 VA p.f. = 1
2a-2n: 25VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.025	-0.025	-0.027
Δφ U	0.5	0.5	0.6

1a-1n: 0 VA
2a-2n: 25VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.009	-0.009	-0.011
Δφ U	0.9	0.9	0.9

2a-2n: 25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.043	-0.042	-0.044
Δφ U	1.3	1.3	1.4

2a-2n: 6.25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.006	-0.005	-0.006
Δφ U	1.2	1.3	1.3

3a-3n: 25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 4a-4n: 40VA 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	-0.106	-0.117	-0.035	-0.035	-0.036	-0.131
Δφ U	0.1	1.1	1.4	1.4	1.5	0.3

3a-3n: 6.25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 4a-4n: 40VA 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	-0.070	-0.079	0.003	0.003	0.001	-0.094
Δφ U	-0.0	1.0	1.3	1.3	1.4	0.3

4a-4n: 40 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 3a-3n: 25VA 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	-0.120	-0.134	-0.048	-0.047	-0.048	-0.142
Δφ U	0.9	1.9	2.1	2.1	2.2	1.1

1a-1n: 10 VA p.f. = 1
2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	0.061	0.061	0.059
Δφ U	2.4	2.4	2.5

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	0.078	0.077	0.076
Δφ U	2.8	2.9	2.9

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	0.030	0.030	0.029
Δφ U	2.9	3.0	3.0

2a-2n: 6.25 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	0.067	0.068	0.067
Δφ U	2.9	2.9	3.0

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	-0.043	-0.053	0.036	0.036	0.035	-0.060
Δφ U	1.9	2.8	3.0	3.0	3.1	2.0

3a-3n: 6.25 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	-0.008	-0.015	0.073	0.073	0.072	-0.023
Δφ U	1.8	2.7	2.9	3.0	3.0	2.0

4a-4n: 40 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	-0.067	-0.078	0.008	0.008	0.008	-0.086
Δφ U	2.3	3.2	3.3	3.3	3.4	2.3

4a-4n: 10 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 3a-3n: 25VA 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	-0.055	-0.069	0.016	0.016	0.015	-0.078
Δφ U	0.6	1.6	1.8	1.8	1.9	0.8

da-dn: 100 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.751	-0.751	-0.751
Δφ U	1.8	1.8	1.9

4a-4n: 10 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	-0.004	-0.012	0.071	0.072	0.071	-0.022
Δφ U	2.1	3.0	3.1	3.1	3.1	2.1

da-dn: 25 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	-0.519	-0.517	-0.518
Δφ U	3.1	3.0	3.2

* at 1,9 Un winding da-dn is loaded with 100 VA, p.f. = 0,8

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

Ipn (A): 300

1S1-1S2: 40 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.061	-0.047	-0.033	-0.034
Δφ I	0.6	0.1	-0.3	-0.3

2S1-2S2: 30 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.086	-0.063	-0.017	-0.029
Δφ I	2.9	1.3	-0.4	0.5

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

	1,0 In
ε I	-0.109
Δφ I	0.7

1S1-1S2: 10 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.015	-0.014	-0.016	-0.016
Δφ I	0.1	0.1	0.0	0.0

2S1-2S2: 7.50 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	0.007	0.010	0.014	0.016
Δφ I	1.3	0.8	0.2	0.2

4S1-4S2: 120 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.128
Δφ I	0.9

Ipn (A): 600

1S1-1S2: 40 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.053	-0.047	-0.032	-0.032
Δφ I	0.9	0.4	-0.2	-0.2

2S1-2S2: 30 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.080	-0.065	-0.019	-0.040
Δφ I	2.8	1.5	-0.2	1.2

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

	1,0 In
ε I	-0.108
Δφ I	0.7

1S1-1S2: 10 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.008	-0.013	-0.014	-0.014
Δφ I	0.1	0.3	0.1	0.0

2S1-2S2: 7.50 VA p.f. = 0,8 lag.

	0,05 In	0,2 In	1,0 In	1,5 In
ε I	0.013	0.010	0.017	0.019
Δφ I	1.0	0.7	0.1	0.1

4S1-4S2: 120 VA p.f. = 0,8 lag.

	1,0 In
ε I	-0.125
Δφ I	0.9

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	31.18	50.21	U < E_{FS}	☑
2S1-2S2	1	96.9	360.75	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

259

260.

3S1-3S2	283.75	0.153	0.15	$\varepsilon_c \leq 5\%$	☑
4S1-4S2	1932.84	0.014	0.09	$\varepsilon_c \leq 10\%$	☑

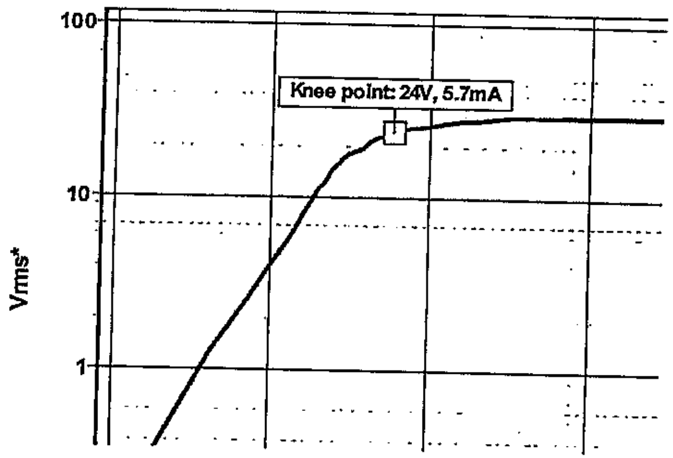
Measurement of capacitance and dielectric dissipation factor - δ
Temperature: 22.3 °C, Frequency: 50

Primary voltage	Instrument transformer			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	0.24	1409	4.44	0.26	1131	3.571	0.22	277	0.873
63 kV	0.25	1409	28.18	0.25	1131	22.5	0.22	277	5.522
71 kV	0.25	1409	31.6	0.25	1132	25.3	0.22	277	6.214

Core magnetization characteristics:

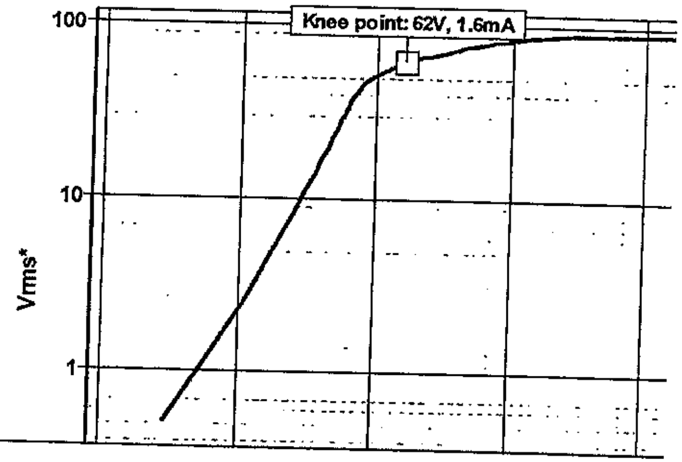
Winding 1S1-1S2

[V]	[mA]
31.5	3069.1
30	46.38
28	15.21
25.8	7.59
25.3	6.76
24.4	5.8
23.7	5.53
22.3	4.6
21	4.17
19.6	3.75
15.4	2.54
11.1	1.95
6.9	1.42
2.6	0.71
0.3	0.16



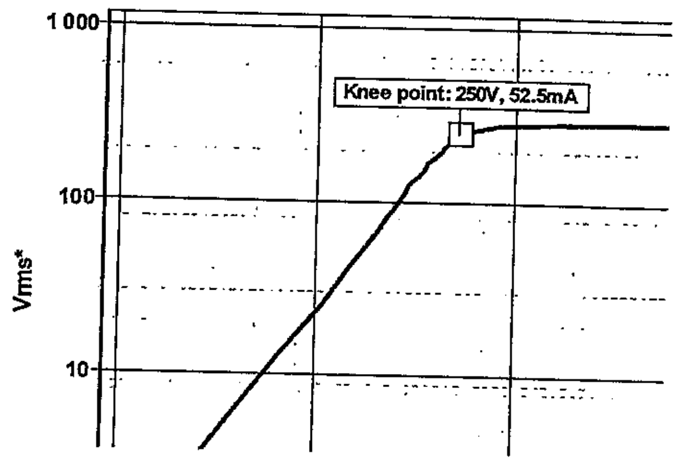
Winding 2S1-2S2

[V]	[mA]
97.9	1134.1
85.5	11.43
79.7	6.6
73.8	3.99
67.9	2.52
65.2	2.08
62.2	1.69
59.3	1.43
56.6	1.24
53.3	1.07
42.1	0.74
30.9	0.58
19.7	0.44
8.3	0.25
0.5	0.03



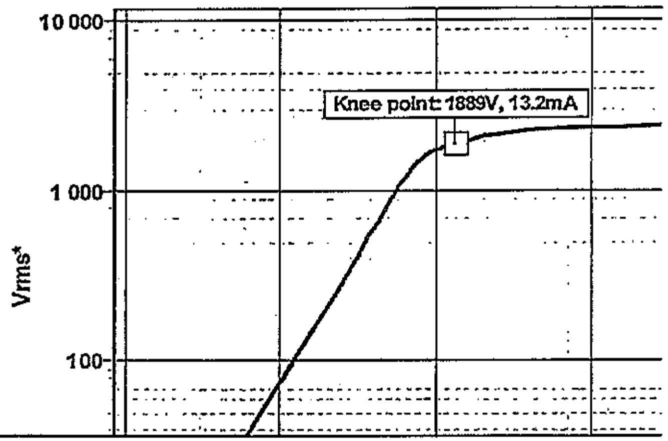
Winding 3S1-3S2

[V]	[mA]
307.	7274
304.	2660.1
290.	314
267.	62.38
261.	57.88
253.	53.51
240.	49.93
226.	47.34
210	44.59
197.	42.95
154.	35.26
111.	27.48
68.8	20.51
25.6	10.79
2.4	2.14



Winding 4S1-4S2

[V]	[mA]
2478.7	1023.3
2459.6	589.2
2411.4	252.8
2379.1	141.4
2206	30.87
2162.3	26.38
2077.5	20.58
1945.8	14.77
1813.8	11.2
1664.8	9.07
1527.4	7.89
1104.1	5.79
674.	4.24
249.	2.27
22	0.43



*) Average rectifier effective value.

Measurement of windings' resistance

Windings' resistance of current part:

	R (24 °C)	Rct (75 °C)
P1-P2 range 300A	602.0 μΩ	722.7 μΩ
P1-P2 range 600A	326.0 μΩ	391.3 μΩ
1S1-1S2	0.403 Ω	0.483 Ω
2S1-2S2	6.050 Ω	7.263 Ω
3S1-3S2	0.437 Ω	0.525 Ω
4S1-4S2	9.050 Ω	10.884 Ω

Windings' resistance of voltage part:

	R (24 °C)	Rct (75 °C)
A-N	21.70 kΩ	26.049 kΩ
1a-1n	47.150 mΩ	56.600 mΩ
2a-2n	48.550 mΩ	58.281 mΩ
3a-3n	50.200 mΩ	60.262 mΩ
4a-4n	51.800 mΩ	62.182 mΩ
da-dn	114.900 mΩ	137.929 mΩ

Checked by: .... OG-4 KJ-06 Przasnysz, dn 2013-11-18

ABB Sp. z o.o. 06-300 Przasnysz ul. Leszno 59		Routine tests report of combined instrument transformer			TYPE: PVA145a Serial no: 2GKP013K1486145	
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: 0,8 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

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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 — 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	-0.164	-0.162	-0.162
Δφ U	-1.3	-1.3	-1.3

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	-0.017	-0.016	-0.016
Δφ U	-1.3	-1.3	-1.3

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	-0.163	-0.162	-0.162
Δφ U	-1.1	-1.1	-1.1

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	-0.017	-0.015	-0.015
Δφ U	-1.3	-1.3	-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	-0.254	-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 — 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	-0.004	-0.003	-0.003	-0.170
Δφ U	-2.5	-1.5	-1.1	-1.1	-1.1	-4.6

4a-4n: 100 VA — 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	-0.261	-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 — 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	0.116	0.117	0.118
Δφ U	5.1	5.2	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	0.263	0.265	0.265
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	0.118	0.119	0.119
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	0.267
Δφ U	5.2	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	0.022	0.027	0.127	0.129	0.129	-0.038
Δφ U	4.8	5.5	5.6	5.6	5.6	2.5

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	0.172	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 — 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	0.007	0.008	0.107	0.108	0.109	-0.060
Δφ U	5.6	6.4	6.4	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

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

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	4.6	5.4	5.5	5.5	5.5	2.3

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 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	-0.165	-0.113	-0.044	-0.060
Δφ I	4.3	1.7	-0.4	0.9

2S1-2S2: 40 VA — p.f. = 0,8 lag.

	1,0 In
ε I	-0.141
Δφ I	0.9

4S1-4S2: 60 VA — p.f. = 0,8 lag.

	1,0 In
ε I	-0.146
Δφ I	1.3

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

3S1-3S2: 60 VA — p.f. = 0,8 lag.

	1,0 In
ε I	-0.153
Δφ I	1.7

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

2S1-2S2: 40 VA — p.f. = 0,8 lag.

	1,0 In
ε I	-0.140
Δφ I	0.8

4S1-4S2: 60 VA — p.f. = 0,8 lag.

	1,0 In
ε I	-0.145
Δφ I	1.2

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

3S1-3S2: 60 VA — p.f. = 0,8 lag.

	1,0 In
ε I	-0.148
Δφ I	1.7

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	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	εc ≤5%	☑
4S1-4S2	1388.83	0.015	0.08	εc ≤5%	☑

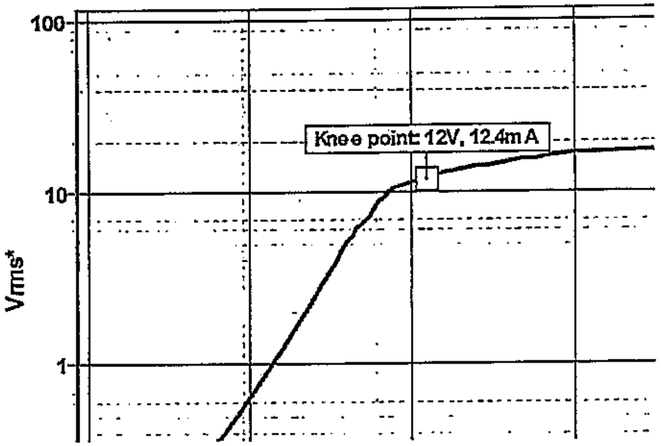
Measurement of capacitance and dielectric dissipation factor - δ
Temperature: 24.2 °C, Frequency: 50

Primary voltage	Instrument transformer			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:

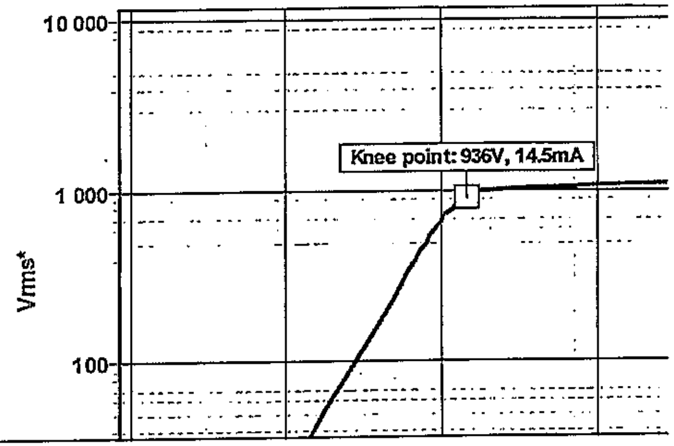
Winding 1S1-1S2

[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



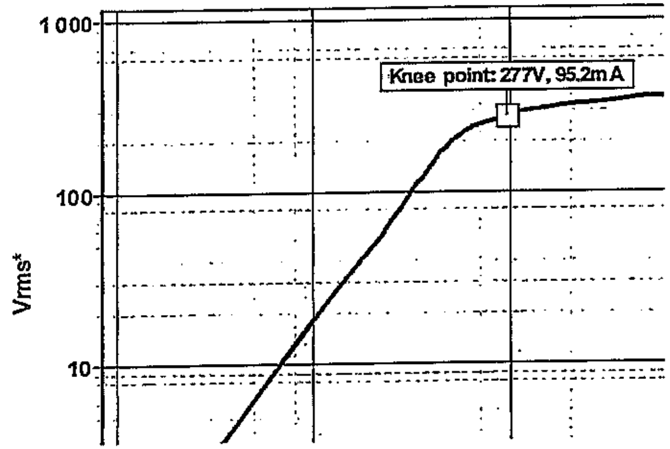
Winding 2S1-2S2

[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



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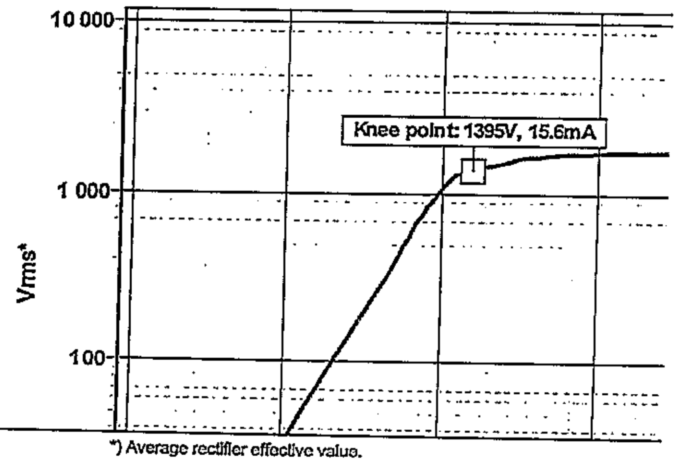
Winding 4S1-4S2

[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	0.389 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-06 .... Przasnysz, 2013-12-04

ABB Sp. z o.o. 06 – 300 Przasnysz ul. Leszno 59		Routine tests report of combined instrument transformer after lightning impulse			TYP: PVA123a Nr fabr. 2GKP013K1486138	
A – N 110:√3 kV	Insulation level: 126/230/550 kV	Voltage factor: 1,9 /8h	Ith 1 s [kA] 40-63-63	Idyn [kA] 100-158-158	Icth [A]: 100-200-400	IEC 61869-4 50 Hz

CZŁON NAPIĘCIOWY	Uzwojenie	Usn [kV]	Sn [VA]	klasa	Sth [VA]
	1a-1n	0,1:√3	25	0,1	1000
		0,1:√3	25	3,0	1000
	2a-2n	0,1:√3	25	0,1	1000
		0,1:√3	25	3,0	1000
	3a-3n	0,1:√3	25	0,1/3P	1000
		0,1:√3	500	3/3P	1000
	4a-4n	0,1:√3	25	0,1/3P	1000
		0,1:√3	25	3/3P	1000
	da-dn	0,1: 3	100	1	450
		0,1: 3	300	3P	450

CZŁON PRĄDOWY	Uzwojenie	Isn [A]	Sn [VA]	klasa	Przekładnia [A/A]
	1S1-1S2	5	1->5	0,5FS5	50-10-200/5
	2S1-2S2	1	1->2,5	0,5FS10	50-10-200/1
	3S1-3S2	5	10	5P 10	50-10-200/5
	4S1-4S2	1	2.5	5P80	50-10-200/1
		1		PX Ek = 190V Io <= 0,1A/95 V Rct <= 0,3 Ω Rb = 3,5 Ω Kx = 50 4-2-1/200	50-10-200/1
		1		TPX Kssc = 13 Ktd = 14,6 cykl = 0,1s Tp = 0,05 Rct <= 0,3Ω Rb = 1 Ω Ratio error <= 0.5%	50-10-200/1
	5S1-5S2	1	5	5P10	50-10-200/1

List of performer tests

1. Oil dielectric parameters check before filling (oil after tgδ wg 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=184 kV / 60 s,f =97 Hz; N; Up = 3 kV/ 60s, f=50 Hz
5. Partial discharge ☑
6. Power-frequency withstand test on secondary – Up = 3 kV/60 s ☑
7. Inter-turn overvoltage test for current transformers– lower value (U szczyt. = 4,5 kV lub U szczyt. Przy Icth) / 60s ☑
8. Determination of errors ☑
9. Determination of the over current factors: FS, ALF ☑
10. Measurement of capacitance and dielectric dissipation factor (tgδ) ☑
11. Determination of core magnetization characteristics ☑
12. Measurement of windings' resistance ☑

Oil dielectric parameters check before filling (oil after treatment)

- Measurement of oil tgδ according to IEC 60247
  Tgδ = 0,06%; electrical stress = 1 kV/mm, f=50 Hz, Oil temp. = 90°C±1°C

- Measurement of breakdown voltage according to IEC 60156
  Mean breakdown voltage =77,42 kV, Relative standard deviation = 5,64%; f=50 Hz, oil temp. = 26 °C, measurement with the stirrer, type of electrodes used: partially spherical.

Próbka	Napięcie przebicia [kV]
1	83.2
2	80.1
3	70.8
4	79.2
5	76.4
6	74.8

Partial discharge measurement

- Measurement according to procedure B
  Stress voltage 184 kV / 60 s
  Frequency 97 Hz

Test voltage	1,2 Um = 151 kV	1,2 Um / √3 = 87.5 kV
Level of partial discharge	1.2 pC	1,2 pC

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

Inter-turn overvoltage test for current transformers

Winding	Peak voltage on secondary winding [kVpeak]	Current in primary winding [A]
1S1-1S2	0.086	400
2S1-2S2	0.307	400
3S1-3S2	0.205	400
4S1-4S2	1.41	400
5S1-5S2	0.736	400

Determination of voltage part errors (ε U %), (Δφ U min), cosφ = 0,8

Uzwojenie	Usn [kV]	Sn [VA]	klasa	Sth [VA]
1a-1n	0,1:√3	25	0,1	1000
2a-2n	0,1:√3	25	0,1	1000
3a-3n	0,1:√3	25	0,1/3P	1000
4a-4n	0,1:√3	25	3/3P	1000
da-dn	0,1: 3	100	3P	450

1a – 1n 25 VA; cos fi = 0,8 ind.
2a-2n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.036	-0.034	-0.034	
Δφ U	2.1	2.1	2.2	

1a – 1n 6,25 VA; cos fi = 0,8 ind.
2a-2n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	0.004	0.006	0.006	
Δφ U	2.0	2.0	2.1	

2a – 2n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.026	-0.024	-0.024	
Δφ U	2.2	2.3	2.3	

2a – 2n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 3a-3n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	0.013	0.015	0.015	
Δφ U	2.1	2.2	2.2	

3a – 3n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.171	-0.109	-0.019	-0.017	-0.017	-0.116
Δφ U	-3.0	0.2	2.4	2.4	2.5	1.0

3a – 3n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.126	-0.066	0.020	0.022	0.022	-0.077
Δφ U	-3.2	-0.0	2.2	2.2	2.2	0.8

4a – 4n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.169	-0.111	-0.023	-0.021	-0.021	-0.120
Δφ U	-2.7	0.5	2.7	2.7	2.8	1.3

4a – 4n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_t U_n
ε U	-0.123	-0.063	0.022	0.024	0.024	-0.075
Δφ U	-3.1	0.1	2.3	2.3	2.4	0.9

da – dn 100 VA; cos fi = 0,8 ind.
1a-1n 25VA; 2a-2n 25VA; 3a-3n 500VA; 4a-4n 25VA , cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	-0.741	-0.739	-0.738
Δφ U	8.9	8.9	9.0

1a – 1n 25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.035	0.037	0.037
Δφ U	3.5	3.5	3.6

1a – 1n 6,25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.076	0.078	0.078
Δφ U	3.4	3.3	3.4

2a – 2n 25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.045	0.047	0.048
Δφ U	3.6	3.6	3.7

2a – 2n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.085	0.087	0.087
Δφ U	3.5	3.5	3.6

3a – 3n 25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.097	-0.035	0.053	0.054	0.055	-0.044
Δφ U	-1.6	1.5	3.7	3.7	3.8	2.5

3a – 3n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.054	0.003	0.090	0.062	0.092	-0.007
Δφ U	-1.6	1.4	3.6	3.6	3.6	2.3

4a – 4n 25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.100	-0.041	0.046	0.048	0.048	-0.050
Δφ U	-1.3	1.8	4.0	4.0	4.0	2.7

4a – 4n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.057	0.002	0.092	0.093	0.094	-0.005
Δφ U	-1.8	1.4	3.6	3.6	3.6	2.3

da – dn 25 VA; cos fi = 0,8 ind.
1a-1n 0VA; 2a-2n 0VA; 3a-3n 0VA; 4a-4n 0VA ,

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	-0.304	-0.302	-0.302
Δφ U	5.2	5.2	5.3

*) at 1,9 Un winding da-dn is loaded with Sn, cos fi = 0,8 ind.

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Determination of voltage part errors (ε U %), (Δφ U min), cosφ = 0,8

Uzwojenie	Usn [kV]	Sn [VA]	klasa	Sth [VA]
1a-1n	0,1:√3	25	3,0	1000
2a-2n	0,1:√3	25	3,0	1000
3a-3n	0,1:√3	500	3/3P	1000
4a-4n	0,1:√3	25	3/3P	1000
da-dn	0,1: 3	300	3P	450

1a – 1n 25 VA; cos fi = 0,8 ind.
2a-2n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_f U_n
ε U	-0.463	-0.461	-0.461	
Δφ U	-6.6	-7.1	-6.6	

1a – 1n 25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.037	0.039	0.039
Δφ U	3.4	3.4	3.4

1a – 1n 6,25 VA; cos fi = 0,8 ind.
2a-2n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_f U_n
ε U	-0.424	-0.422	-0.422	
Δφ U	-6.7	-6.7	-6.6	

1a – 1n 6,25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.076	0.078	0.078
Δφ U	3.3	3.3	3.4

2a – 2n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA. cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_f U_n
ε U	-0.465	-0.463	-0.463	
Δφ U	-6.6	-6.6	-6.5	

2a – 2n 25 VA; cos fi = 0,8 ind.
2a-2n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA.

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.047	0.049	0.049
Δφ U	3.5	3.5	3.6

2a – 2n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 3a-3n 500 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,8 U_n	1,0 U_n	1,2 U_n	k_f U_n
ε U	-0.425	-0.424	-0.423	
Δφ U	-6.8	-6.7	-6.7	

2a – 2n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 3a-3n 0 VA; 4a-4n 0 VA

	0,8 U_n	1,0 U_n	1,2 U_n
ε U	0.086	0.088	0.088
Δφ U	3.4	3.4	3.5

3a – 3n 500 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-1.125	-1.062	-0.970	-0.969	-0.970	-1.219
Δφ U	0.4	3.8	6.2	6.2	6.3	1.7

3a – 3n 500 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-1.061	-0.997	-0.902	-0.900	-0.901	-1.149
Δφ U	2.1	5.3	7.6	7.7	7.8	3.2

3a – 3n 125 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 4a-4n 25 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.369	-0.309	-0.222	-0.220	-0.220	-0.470
Δφ U	-2.3	0.9	3.2	3.2	3.3	-1.5

3a – 3n 125 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 4a-4n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.299	-0.239	-0.152	-0.150	-0.150	-0.399
Δφ U	-0.8	2.3	4.5	4.5	4.6	-0.0

4a – 4n 25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 500 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_f U_n
ε U	-0.587	-0.528	-0.437	-0.436	-0.436	-0.673
Δφ U	-11.1	-7.8	-5.5	-5.4	-5.4	-9.8

4a – 4n 25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.100	-0.037	0.049	0.050	-0.050	-0.202
Δφ U	-1.5	1.7	3.8	3.9	3.9	-0.8

4a – 4n 6,25 VA; cos fi = 0,8 ind.
1a-1n 25 VA; 2a-2n 25 VA; 3a-3n 500 VA cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	k_f U_n
ε U	-0.539	-0.483	-0.394	-0.392	-0.392	-0.628
Δφ U	-11.4	-8.2	-5.9	-5.9	-5.8	-10.2

4a – 4n 6,25 VA; cos fi = 0,8 ind.
1a-1n 0 VA; 2a-2n 0 VA; 3a-3n 0 VA

	0,02 U_n	0,05 U_n	0,8 U_n	1,0 U_n	1,2 U_n	1,9 U_n*
ε U	-0.052	0.007	0.093	0.095	0.095	-0.158
Δφ U	-1.9	1.3	3.5	3.5	3.5	-1.2

da – dn 300 VA; cos fi = 0,8 ind.
1a-1n 25VA; 2a-2n 25VA; 3a-3n 500VA; 4a-4n 25VA , cos fi = 0,8 ind

	0,02 U_n	0,05 U_n	1,0 U_n	1,9 U_n
ε U	-2.382	-2.274	-2.237	-2.039
Δφ U	12.9	15.2	20.1	14.7

da – dn 75 VA; cos fi = 0,8 ind.
1a-1n 0VA; 2a-2n 0VA; 3a-3n 0VA; 4a-4n 0VA ,

	0,02 U_n	0,05 U_n	1,0 U_n	1,9 U_n
ε U	-0.725	-0.660	-0.564	-0.580
Δφ U	4.1	7.2	9.5	9.9

*) at 1,9 Un winding da-dn is loaded with Sn, cos fi = 0,8 ind.

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

Ipn (A): 50

1S1-1S2 5 VA; cosφ = 0,8	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-0.383	-0.232	-0.025	0.132
Δφ I	17.3	7.5	-1.1	-3.3

1S1-1S2 1 VA; cosφ = 0,8	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.295	0.300	0.315	0.333
Δφ I	13.2	8.8	4.9	3.1

2S1-2S2 2.5 VA; cosφ = 1	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.035	0.008	0.138	0.193
Δφ I	32.6	22.0	7.0	3.9

2S1-2S2 1 VA; cosφ = 1	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.254	0.241	0.276	0.321
Δφ I	18.7	12.7	5.8	3.1

3S1-3S2	1,0 In
ε I	0.935
Δφ I	7.4

4S1-4S2	1,0 In
ε I	-0.391
Δφ I	14.6

5S1-5S2	1,0 In
ε I	0.701
Δφ I	15.5

Ipn (A): 100

1S1-1S2 5 VA; cosφ = 0,8	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-0.743	-0.243	0.021	0.132
Δφ I	37.0	8.3	-0.8	-3.3

1S1-1S2 1 VA; cosφ = 0,8	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.129	0.305	0.317	0.334
Δφ I	29.3	8.9	4.9	3.1

2S1-2S2 2.5 VA; cosφ = 1	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.027	0.009	0.137	0.191
Δφ I	32.6	22.5	7.1	4.0

2S1-2S2 1 VA; cosφ = 1	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.251	0.237	0.272	0.319
Δφ I	19.0	13.6	6.1	3.0

3S1-3S2	1,0 In
ε I	0.912
Δφ I	7.7

4S1-4S2	1,0 In
ε I	-0.391
Δφ I	14.5

5S1-5S2	1,0 In
ε I	0.707
Δφ I	15.5

Ipn (A): 200

1S1-1S2 5 VA; cosφ = 0,8	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-1.099	-0.369	0.144	0.007
Δφ I	53.4	13.3	4.5	0.3

1S1-1S2 1 VA; cosφ = 0,8	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	-0.438	0.236	0.238	0.271
Δφ I	52.4	15.1	10.2	7.2

2S1-2S2 2.5 VA; cosφ = 1	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.027	0.005	0.143	0.194
Δφ I	33.4	22.6	6.4	4.0

2S1-2S2 1 VA; cosφ = 1	0,05I_n	0,2 I_n	1,0 I_n	2,0 I_n
ε I	0.250	0.250	0.278	0.314
Δφ I	19.4	12.5	5.7	4.5

3S1-3S2	1,0 In
ε I	0.933
Δφ I	7.1

4S1-4S2	1,0 In
ε I	-0.392
Δφ I	14.5

5S1-5S2	1,0 In
ε I	0.711
Δφ I	15.2

Current part: Measurements uncertainty: ε I = ±0,045 %, Δφ I = ±2,3 min
Voltage part: Measurements uncertainty: ε U = ±0,044 %, Δφ U = ±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	4.36	6.16	U < E_{FS}	☑
2S1-2S2	1	9.71	31.07	U < E_{FS}	☑

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

Winding	E_{ALF} [V]	Ie [A]	ε_c [%]	Warunek	Assessment
3S1-3S2	21.14	1.154	2.31	ε_c < 5%	☑
4S1-4S2	219.68	0.123	0.15	ε_c < 5%	☑
5S1-5S2	52.95	0.129	1.29	ε_c < 5%	☑

Determination of parameters of class PX core 4S1-4S2:

Ipn (A)	50	100	200
Factor Kx	54.93	54.94	54.94
Turns ratio error [%]	-0.007	-0.003	0.002

Determination of parameters of class TPX core 4S1-4S2:

Ipn (A)	50	100	200
Factor Kssc	13.91	13.91	13.92
Factor Ktd	14.46	14.46	14.46
Current ratio error [%]	-0.225	-0.230	-0.235
Ts [s]	5.498	5.517	5.500
ε-peak [%]	1.530	1.529	1.530

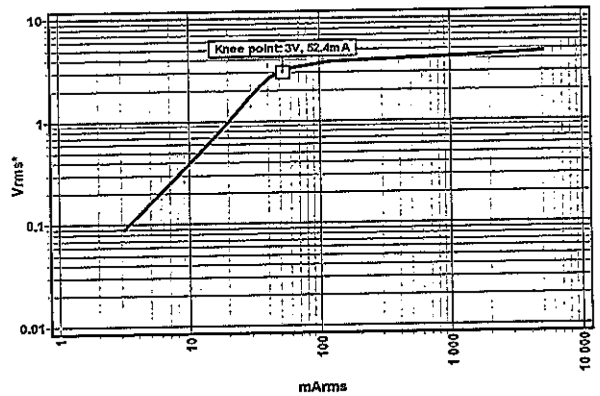
Measurement of capacitance and dielectric dissipation factor (tg δ)
Temperature: 22,3 °C, Frequency: 50 Hz

Primary voltage	Instrument transformer			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	0.25	1379	4.338	0.26	1113	3.493	0.22	266	0.837
63 kV	0.24	1379	27.09	0.25	1113	21.92	0.22	266	5.236
71 kV	0.24	1379	30.62	0.25	1113	24.78	0.22	266	5.909

Core magnetization characteristics:

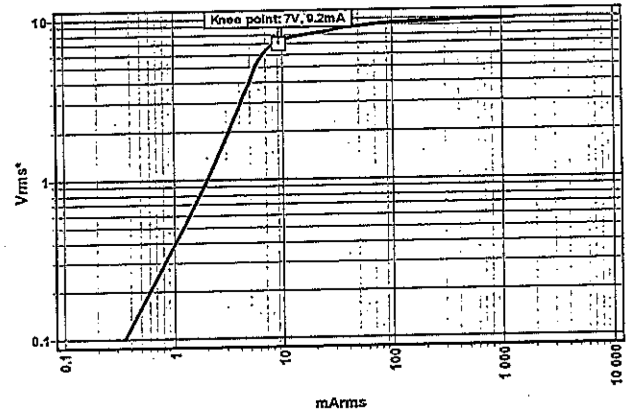
Winding 1S1-1S2

[V]	[mA]
4.6	5057.8
4.3	1790.6
3.8	124.7
3.2	55.39
2.7	42.69
2.2	35.42
1.7	29.05
1	20.79
0.5	12.46
0.1	3.17



Winding 2S1-2S2

[V]	[mA]
9.8	1309.8
9.6	439.0
9.0	57.87
8.4	25.12
7.8	13.93
7.3	9.77
6.7	7.71
6.1	6.84
5.6	6.22
5	5.64
3.9	4.82
2.7	3.90
1.7	2.85
0.5	1.23
0.1	0.35



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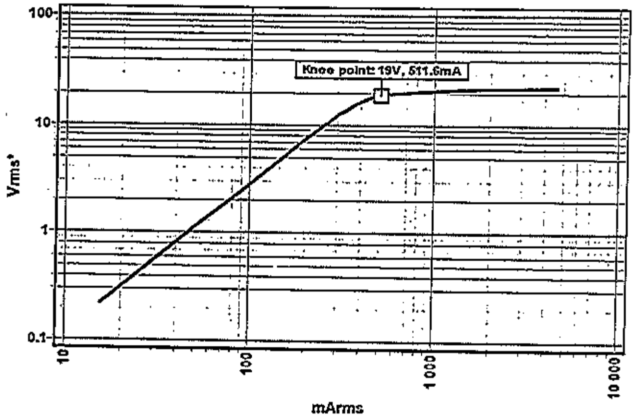
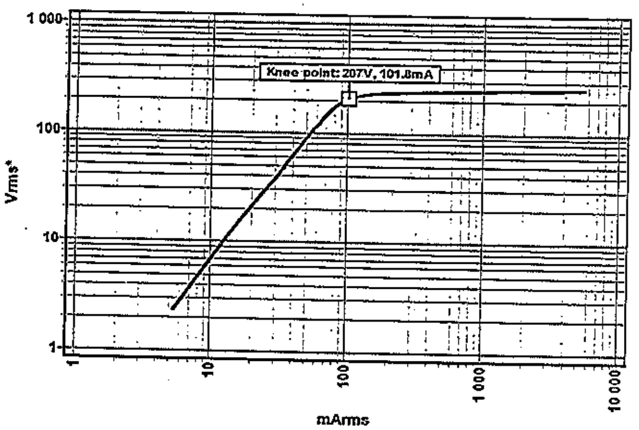
Winding 3S1-3S2

[V]	[mA]
22.5	4634.9
22.0	2540.5
21.5	1365.1
20.6	816.5
19.3	552.6
18.0	458.0
16.4	398.9
15.1	363.5
13.9	333.9
12.5	304.2
9.7	246.6
6.7	188.0
4.1	132.0
1.2	52.98
0.2	15.74



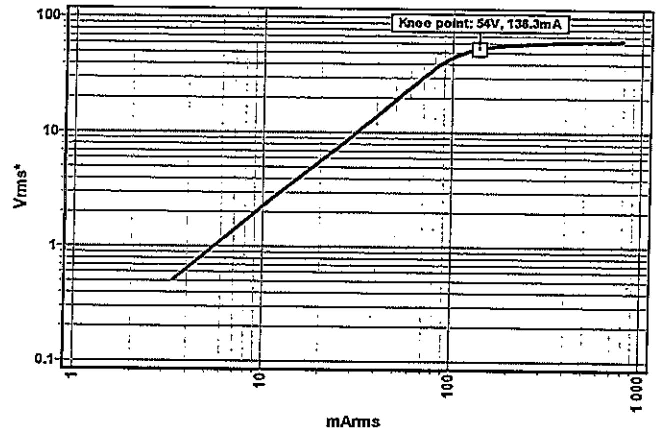
Winding 4S1-4S2

[V]	[mA]
256.8	5461.1
251.7	1865.2
247.3	945.4
240.7	380.0
228.1	158.8
220.4	123.8
207.6	101.98
194.3	91.74
181.6	84.24
165.7	76.94
152.1	72.53
110.0	57.96
67.6	42.38
25.9	23.12
2.3	5.49



Winding 5S1-5S2

[V]	[mA]
63.7	772.4
62.2	428.8
59.6	234.6
57.9	186.5
56.9	166.4
55.2	146.8
52.6	125.8
49.4	112.0
46.8	104.48
38.4	85.51
30.0	69.8
22.1	55.71
13.6	39.17
5.1	18.76
0.5	3.43



Measurement of windings' resistance

Windings' resistance of current part:

	R (23°C)	R ct (75°C)
P1-P2 range 50 A	257.0 μΩ	309.5 μΩ
P1-P2 range 100 A	99.0 μΩ	119.2 μΩ
P1-P2 range 200 A	53.0 μΩ	63.8 μΩ
1S1-1S2	0.046 Ω	0.056 Ω
2S1-2S2	0.504 Ω	0.607 Ω
3S1-3S2	0.023 Ω	0.028 Ω
4S1-4S2	0.204 Ω	0.245 Ω
5S1-5S2	0.301 Ω	0.362 Ω

Windings' resistance of voltage part:

	R (23,°C)	R ct (75°C)
A-N	16.70 kΩ	20.113 kΩ
1a-1n	42.780 mΩ	51.523 mΩ
2a-2n	43.770 mΩ	52.715 mΩ
3a-3n	45.160 mΩ	54.389 mΩ
4a-4n	46.430 mΩ	55.918 mΩ
da-dn	30.970 mΩ	37.299 mΩ

Checked by: ....

Przasnysz, 09.12.2013 r.

ABB Sp. z o.o. 06-300 Przasnysz ul. Leszno 59		Routine tests report of combined instrument transformer after lightning impulse			TYPE: PVA145a Serial no: 2GKP013K1486144	
A-N 132:√3 kV	Insulation level: 145/275/650 kV	Voltage factor: 1,9/8h	Ith 1s [kA]: 40-40	Idyn [kA]: 100-100	Icth [A]: 450-900	IEC 61869-4 50 Hz

VOLTAGE PART	Winding	Usn [kV]	Sn [VA]	class	Sth [VA]
	1a - 1n	0,11:√3	0->10	0,1	1000
	2a - 2n	0,11:√3	25	0,1	1000
	3a - 3n	0,11:√3	25	0,1/3P	1000
	4a - 4n	0,11:√3	40	1/3P	1000
	da - dn	0,11	100	1,0	450

CURRENT PART	Winding	Isn [A]	Sn [VA]	class	Ratio [A/A]
	1S1-1S2	5	40	0,2FS 5	300-600/5
	2S1-2S2	1	30	0,5FS 10	300-600/1
	3S1-3S2	5	60	5P 20	300-600/5
	4S1-4S2	1	120	10P 15	300-600/1

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 = 220kV / 60s, f = 97 Hz; 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 = 0.07 %; electrical stress = 1kV/mm, f = 50Hz, oil temp. = 90C

- Measurement of breakdown voltage according to IEC 60156
  Mean breakdown voltage = 75.92 kV, Relative standard deviation = 7.19
  f = 50Hz, oil temp. = 26 °C, measurement with the stirrer, type of electrodes used: partially

Sample	Breakdown voltage [kV]
1	81
2	68.2
3	77.5
4	75.3
5	82.2
6	71.3

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: 220 kV / 60 s
  Frequency: 97 Hz

Test voltage	1,2 Um = 174 kV	1,2 Um / √3 = 100.5 kV
Level of partial discharge	1.8 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	1.41	900
2S1-2S2	4.5	580
3S1-3S2	2.18	900
4S1-4S2	4.5	86

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

1a-1n: 10 VA p.f. = 1
2a-2n: 25VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.025	-0.025	-0.026
Δφ U	0.5	0.5	0.6

1a-1n: 0 VA
2a-2n: 25VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.009	-0.009	-0.010
Δφ U	0.9	0.9	1.0

2a-2n: 25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.043	-0.042	-0.044
Δφ U	1.3	1.3	1.4

2a-2n: 6.25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 3a-3n: 25VA; 4a-4n: 40VA p.f. = 0,8 lag.

	0,8 Un	1,0 Un	1,2 Un
ε U	-0.006	-0.005	-0.007
Δφ U	1.3	1.3	1.3

3a-3n: 25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 4a-4n: 40VA 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	-0.117	-0.126	-0.035	-0.035	-0.036	-0.131
Δφ U	0.1	1.1	1.4	1.4	1.5	0.3

3a-3n: 6.25 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 4a-4n: 40VA 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	-0.078	-0.087	0.002	0.002	0.001	-0.093
Δφ U	-0.0	1.0	1.3	1.3	1.4	0.3

4a-4n: 40 VA p.f. = 0,8 lag.
1a-1n: 10VA; 2a-2n: 25VA; 3a-3n: 25VA 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	-0.126	-0.137	-0.049	-0.049	-0.051	-0.143
Δφ U	0.9	1.9	2.1	2.1	2.2	1.1

1a-1n: 10 VA p.f. = 1
2a-2n: 0 VA; 3a-3n: 0 VA; 4a-4n: 0 VA

	0,8 Un	1,0 Un	1,2 Un
ε U	0.061	0.061	0.060
Δφ U	2.4	2.4	2.5

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	0.077	0.077	0.076
Δφ U	2.8	2.9	2.9

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	0.029	0.029	0.028
Δφ U	2.9	2.9	3.0

2a-2n: 6.25 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	0.066	0.066	0.065
Δφ U	2.9	2.9	3.0

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	-0.043	-0.053	0.036	0.036	0.035	-0.059
Δφ U	1.9	2.8	3.0	3.0	3.1	2.1

3a-3n: 6.25 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	-0.008	-0.015	0.073	0.073	0.072	-0.022
Δφ U	1.8	2.7	2.9	3.0	3.0	2.0

4a-4n: 40 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	-0.068	-0.080	0.007	0.007	0.006	-0.086
Δφ U	2.3	3.2	3.3	3.3	3.4	2.4

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4a-4n: 10 VA 1a-1n: 10VA; 2a-2n: 25VA; 3a-3n: 25VA	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	-0.059	-0.072	0.015	0.015	0.014	-0.079
Δφ U	0.6	1.6	1.8	1.8	1.9	0.8

4a-4n: 10 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	-0.003	-0.013	0.072	0.072	0.070	-0.022
Δφ U	2.0	2.9	3.0	3.0	3.1	2.1

da-dn: 100 VA 1a-1n: 10VA; 2a-2n: 25VA; 3a-3n: 25VA; 4a-4n: 40VA	p.f. = 0,8 lag. p.f. = 0,8 lag.			
	0,8 Un	1,0 Un	1,2 Un	
ε U	-0.757	-0.752	-0.754	-0.761
Δφ U	1.8	1.8	1.8	2.7

da-dn: 25 VA 1a-1n: 0 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	-0.523	-0.522	-0.522
Δφ U	3.1	3.1	3.2

* at 1,9 Un winding da-dn is loaded with 100 VA, p.f. = 0,8

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

Ipn (A): 300

1S1-1S2: 40 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.058	-0.047	-0.031	-0.028
Δφ I	0.6	0.1	-0.3	-0.3
2S1-2S2: 30 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.087	-0.065	-0.017	-0.028
Δφ I	2.9	1.3	-0.4	0.5
3S1-3S2: 60 VA	p.f. = 0,8 lag.			
	1,0 In			
ε I	-0.109			
Δφ I	0.7			

1S1-1S2: 10 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.014	-0.015	-0.014	-0.013
Δφ I	0.1	0.1	0.0	0.0
2S1-2S2: 7,50 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	0.006	0.009	0.014	0.016
Δφ I	1.3	0.8	0.2	0.2
4S1-4S2: 120 VA	p.f. = 0,8 lag.			
	1,0 In			
ε I	-0.128			
Δφ I	0.9			

Ipn (A): 600

1S1-1S2: 40 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.060	-0.054	-0.034	-0.031
Δφ I	0.9	0.4	-0.2	-0.2
2S1-2S2: 30 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.083	-0.067	-0.020	-0.040
Δφ I	2.8	1.5	-0.2	1.2
3S1-3S2: 60 VA	p.f. = 0,8 lag.			
	1,0 In			
ε I	-0.108			
Δφ I	0.7			

1S1-1S2: 10 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	-0.010	-0.017	-0.016	-0.014
Δφ I	0.1	0.3	0.1	0.0
2S1-2S2: 7,50 VA	p.f. = 0,8 lag.			
	0,05 In	0,2 In	1,0 In	1,5 In
ε I	0.013	0.010	0.017	0.019
Δφ I	1.0	0.7	0.1	0.1
4S1-4S2: 120 VA	p.f. = 0,8 lag.			
	1,0 In			
ε I	-0.126			
Δφ I	0.9			

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	Io [A]	U [V]	EFS [V]	Condition	Assessment
1S1-1S2	2.5	31.35	49.99	U < EFS	☑
2S1-2S2	1	97.33	360.33	U < EFS	☑

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

Winding	EALF [V]	Io [A]	εc [%]	Condition	Assessment

3S1-3S2	282.89	0.135	0.14	εc ≤ 5%	☑
4S1-4S2	1928.96	0.014	0.09	εc ≤ 10%	☑

Measurement of capacitance and dielectric dissipation factor - δ

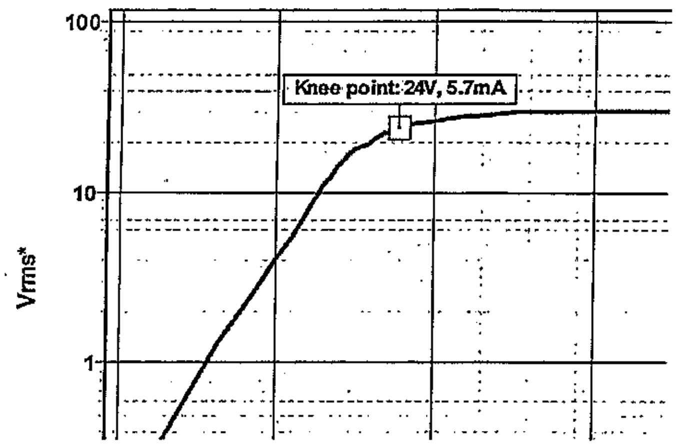
Temperature: 22.3 °C, Frequency: 50

Primary voltage	Instrument transformer			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	0.24	1407	4.423	0.26	1130	3.518	0.22	277	0.87
63 kV	0.25	1407	27.95	0.25	1130	22.41	0.22	277	5.494
71 kV	0.25	1407	31.13	0.25	1130	24.96	0.22	277	6.128

Core magnetization characteristics:

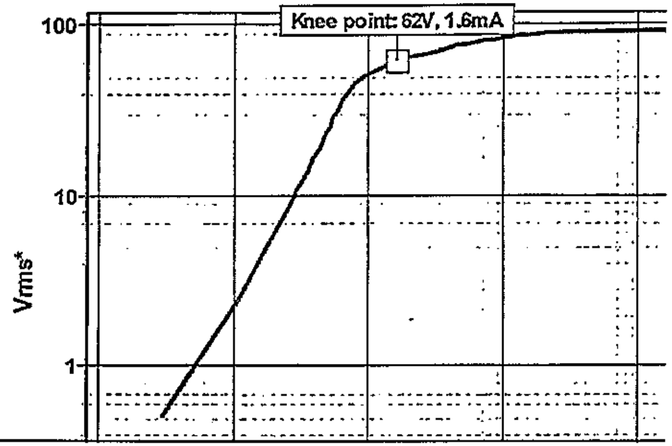
Winding 1S1-1S2

[V]	[mA]
31.5	3069.1
30	46.38
28	15.21
25.8	7.59
25.3	6.76
24.4	5.8
23.7	5.53
22.3	4.6
21	4.17
19.6	3.75
15.4	2.54
11.1	1.95
6.9	1.42
2.6	0.71
0.3	0.16



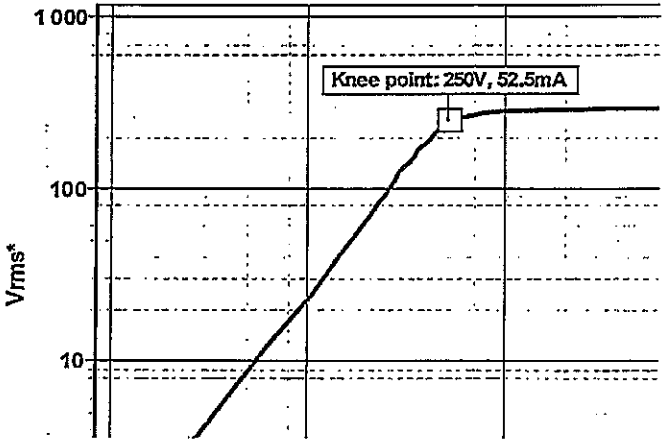
Winding 2S1-2S2

[V]	[mA]
97.9	1134.1
85.5	11.43
79.7	6.6
73.8	3.99
67.9	2.52
65.2	2.08
62.2	1.69
59.3	1.43
56.6	1.24
53.3	1.07
42.1	0.74
30.9	0.58
19.7	0.44
8.3	0.25
0.5	0.03



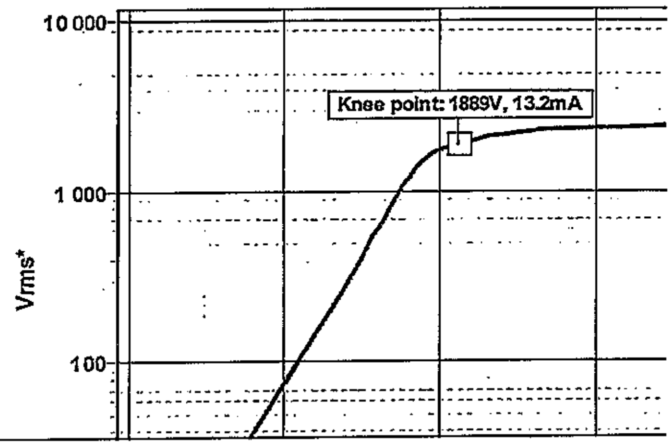
Winding 3S1-3S2

[V]	[mA]
307.	7274
304.	2660.1
290.	314
267.	62.38
261.	57.88
253.	53.51
240.	49.93
226.	47.34
210	44.59
197.	42.95
154.	35.26
111.	27.48
68.8	20.51
25.6	10.79
2.4	2.14



Winding 4S1-4S2

[V]	[mA]
2478.7	1023.3
2459.6	589.2
2411.4	252.8
2379.1	141.4
2206	30.87
2162.3	26.38
2077.5	20.58
1945.8	14.77
1813.8	11.2
1664.8	9.07
1527.4	7.89
1104.1	5.79
674.	4.24
249.	2.27
22	0.43



*) Average rectifier effective value.

Measurement of windings' resistance

Windings' resistance of current part:

	R (24 °C)	Rct (75 °C)
P1-P2 range 300A	602.0 μΩ	722.7 μΩ
P1-P2 range 600A	323.0 μΩ	387.7 μΩ
1S1-1S2	0.395 Ω	0.474 Ω
2S1-2S2	6.010 Ω	7.215 Ω
3S1-3S2	0.429 Ω	0.515 Ω
4S1-4S2	8.790 Ω	10.552 Ω

Windings' resistance of voltage part:

	R (24 °C)	Rct (75 °C)
A-N	21.60 kΩ	25.929 kΩ
1a-1n	47.010 mΩ	56.432 mΩ
2a-2n	48.290 mΩ	57.969 mΩ
3a-3n	50.100 mΩ	60.142 mΩ
4a-4n	51.600 mΩ	61.942 mΩ
da-dn	114.100 mΩ	136.969 mΩ

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

Przasnysz, dn 2013-12-20

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ANNEX 3 for test report EWN/145/E/13

Lightning impulse test. Impulse 1,2/50 μs, full and chopped:

- Oscillograms of test voltages and detection currents.

- Report No. EWN/145/E/13-1a – 20.11.2013.
- Report No. EWN/145/E/13-1b – 09.11.2013.

HIGH VOLTAGE LABORATORY

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Próba udarem piorunowym 1.2/50us
project : ewn145e13-1a   test date 20-11-2013   page 1

Test - object - data

WNR	EWN/145/E/13-1a		TR-No. 2GKP013K1486144 O.-No. 4500513518		
test object	PVA 145a		vector group	-	
output	-	kVA	BIL	650	
voltage	132	kV	frequency	50	Hz
customer	ABB Sp. z o. o. Żegańska 1, 04-713 Warszawa				

LI lightning-impulse

no.	Up [kV]	T1[μs]	T2[μs]	Tc[μs]	remark
1	-324.7	1.31	47.8		LI: 1A-1N - RW(50.0%)
2	-647.5	1.31	48.1		LI: 1A-1N - FW(100.0%)
3	-373.6	1.32		3.83	LI: 1A-1N - CRW(57.5%)
4	-742	1.34		3.82	LI: 1A-1N - CFW(115.0%)
5	-749.1	1.32		3.78	LI: 1A-1N - CFW(115.0%)
6	-649.9	1.32	48.1		LI: 1A-1N - FW(100.0%)
7	-649.3	1.32	48.1		LI: 1A-1N - FW(100.0%)
8	-649.7	1.32	48.1		LI: 1A-1N - FW(100.0%)
9	-649.2	1.32	48.2		LI: 1A-1N - FW(100.0%)
10	-649.6	1.32	48.2		LI: 1A-1N - FW(100.0%)
11	-649.4	1.31	48.2		LI: 1A-1N - FW(100.0%)
12	-649.3	1.31	48.2		LI: 1A-1N - FW(100.0%)
13	-649.9	1.32	48.2		LI: 1A-1N - FW(100.0%)
14	-649.6	1.32	48.2		LI: 1A-1N - FW(100.0%)
15	-650.9	1.32	48.2		LI: 1A-1N - FW(100.0%)
16	-650.9	1.32	48.2		LI: 1A-1N - FW(100.0%)
17	-650.9	1.32	48.2		LI: 1A-1N - FW(100.0%)
18	-651.2	1.32	48.3		LI: 1A-1N - FW(100.0%)
19	-651.1	1.32	48.2		LI: 1A-1N - FW(100.0%)
20	324.7	1.32	48		LI: 1A-1N - RW(50.0%)
21	648.4	1.32	48.3		LI: 1A-1N - FW(100.0%)
22	650	1.32	48.3		LI: 1A-1N - FW(100.0%)
23	650.2	1.32	48.3		LI: 1A-1N - FW(100.0%)
24	649.7	1.32	48.3		LI: 1A-1N - FW(100.0%)
25	649.4	1.32	48.3		LI: 1A-1N - FW(100.0%)
26	649.2	1.32	48.4		LI: 1A-1N - FW(100.0%)
27	649.3	1.32	48.4		LI: 1A-1N - FW(100.0%)
28	649	1.32	48.4		LI: 1A-1N - FW(100.0%)
29	649.8	1.32	48.4		LI: 1A-1N - FW(100.0%)

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Próba udarem piorunowym 1.2/50us

project : ewn145e13-1a

30	649.1	1.32	48.4		LI: 1A-1N - FW(100.0%)
31	648.9	1.32	48.4		LI: 1A-1N - FW(100.0%)
32	649	1.32	48.4		LI: 1A-1N - FW(100.0%)
33	648.7	1.31	48.4		LI: 1A-1N - FW(100.0%)
34	648.3	1.32	48.4		LI: 1A-1N - FW(100.0%)
35	648.5	1.31	48.4		LI: 1A-1N - FW(100.0%)

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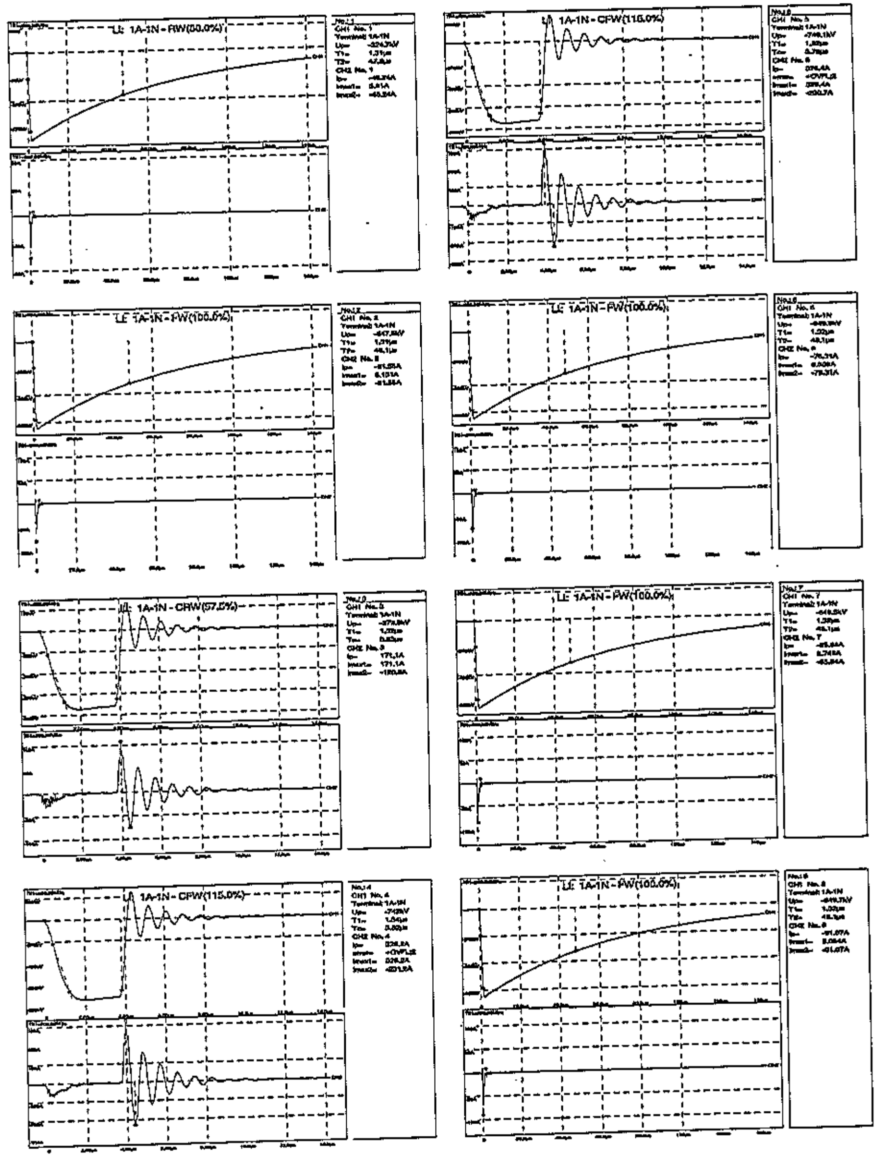
Próba udarem piorunowym 1.2/50us

project : ewn145e13-1a



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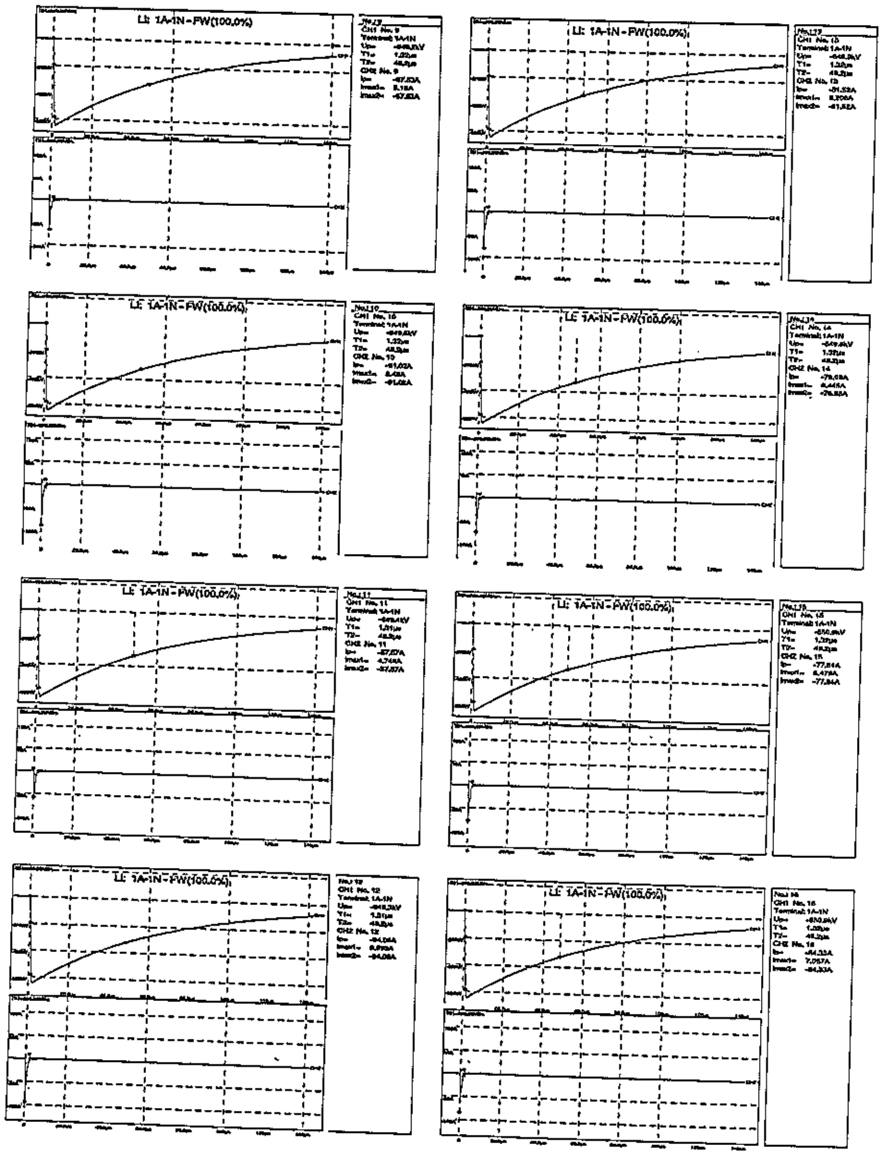
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

Próba udarem piorunowym 1.2/50us

project : ewn145e13-1a



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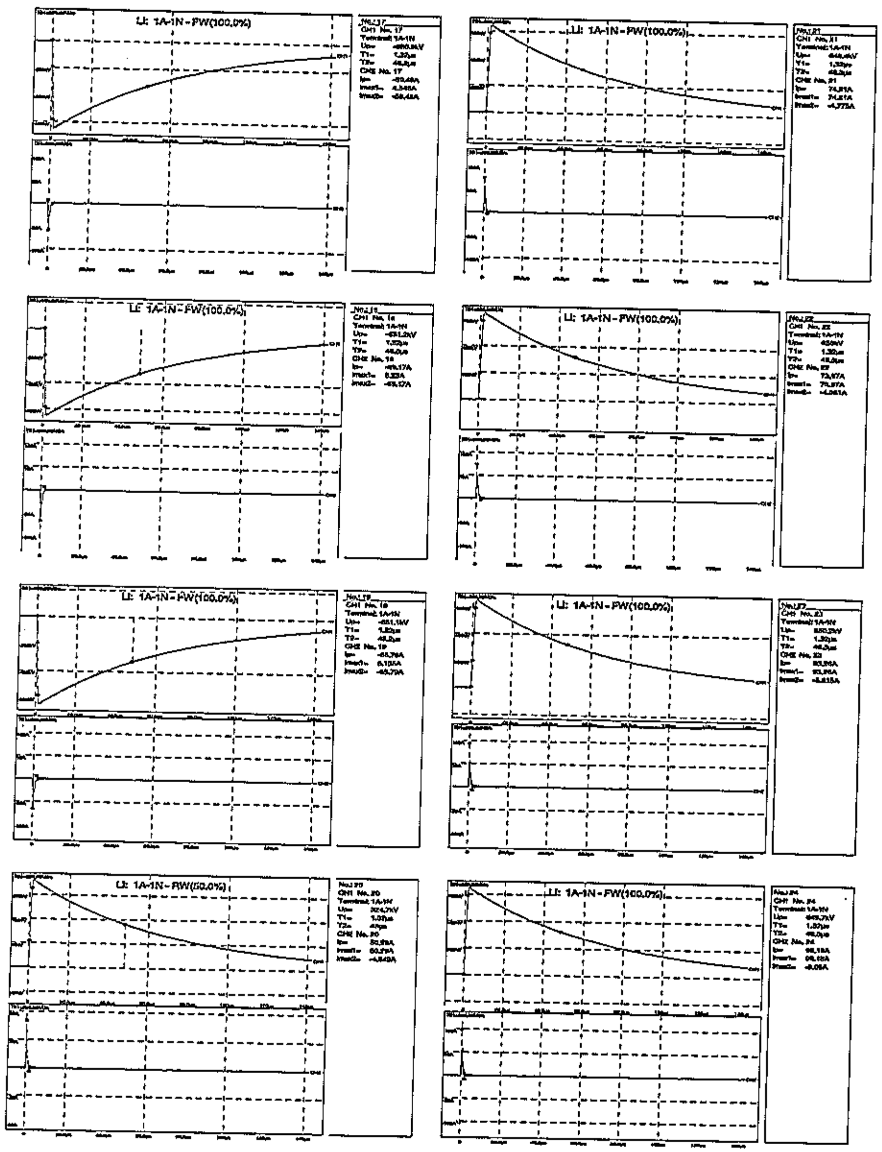
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

Próba udarem piorunowym 1.2/50us

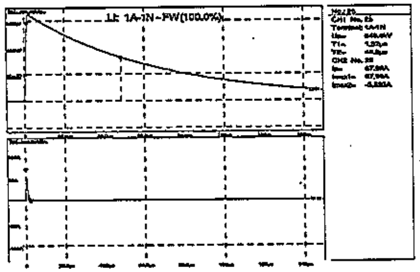
project : ewn145e13-1a

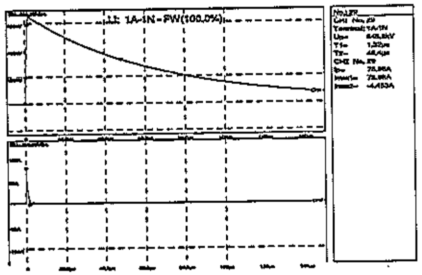


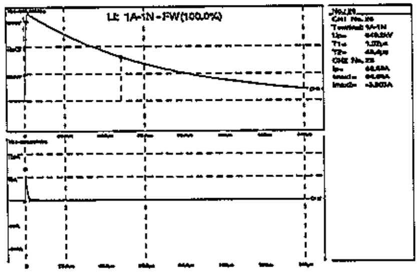
POLAND 01-330 WARSZAWA, ul. Mory 8
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

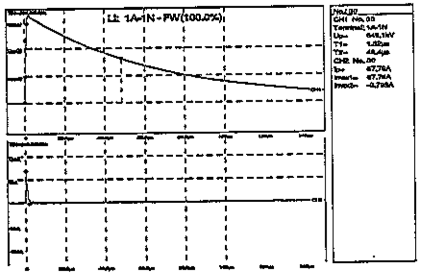
Próba udarem piorunowym 1.2/50us

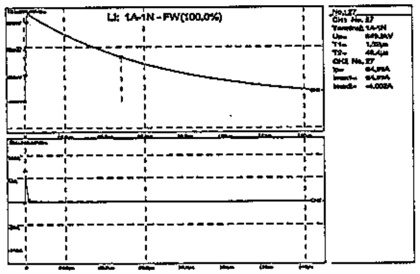
project : ewn145e13-1a

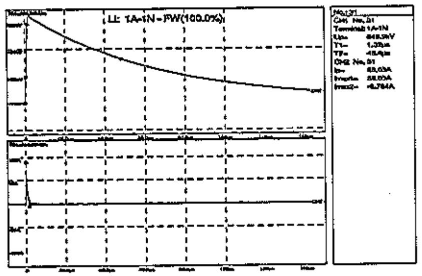


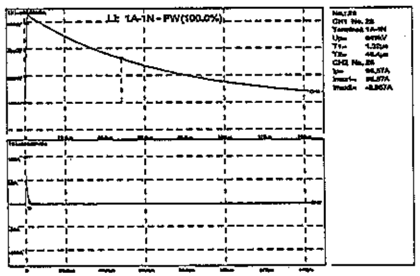


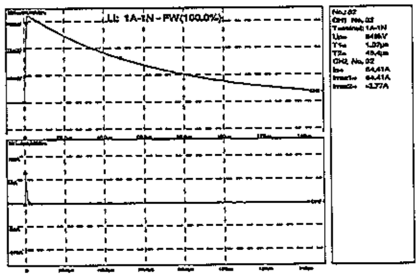












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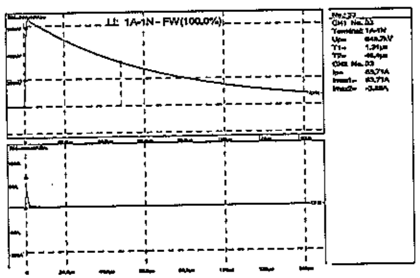
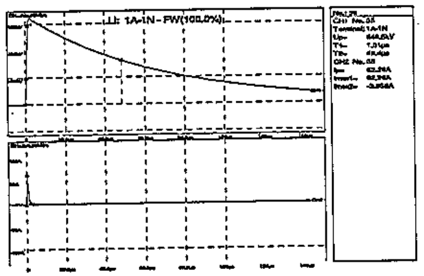
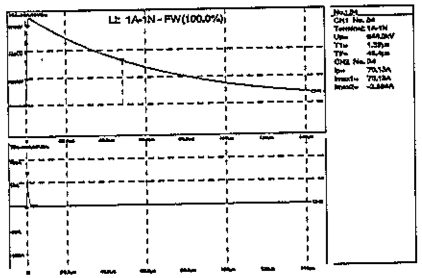
Próba udarem piorunowym 1.2/50us

project : ewn145e13-1a







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Próba udarem piorunowym 1.2/50us

project : ewn145e13-1b   test date 09-11-2013

Test - object - data

WNR EWN/145/E/13-1b TR-No. 2GKP013K1486138 O.-No. 4500513518

test object	PVA 123a		vector group	-	
output	-	kVA	BIL	550	
voltage	110	kV	frequency	50	Hz

customer ABB Sp. z o. o.
Żegańska 1, 04-713 Warszawa

LI lightning-impulse

no.	Up [kV]	T1[µs]	T2[µs]	Tc[µs]	remark
1	-276.3	1.36	50.6		LI: 1A-1N - RW(50.0%)
2	-549.5	1.34	50.5		LI: 1A-1N - FW(100.0%)
3	-317	1.36		3.96	LI: 1A-1N - CRW(57.5%)
4	-633.6	1.35		3.99	LI: 1A-1N - CFW(115.0%)
5	-627.6	1.35		3.97	LI: 1A-1N - CFW(115.0%)
6	-549.8	1.35	50.5		LI: 1A-1N - FW(100.0%)
7	-549.5	1.34	50.5		LI: 1A-1N - FW(100.0%)
8	-549.6	1.34	50.5		LI: 1A-1N - FW(100.0%)
9	-549.5	1.35	50.5		LI: 1A-1N - FW(100.0%)
10	-549.6	1.35	50.5		LI: 1A-1N - FW(100.0%)
11	-549.7	1.35	50.5		LI: 1A-1N - FW(100.0%)
12	-549.5	1.35	50.6		LI: 1A-1N - FW(100.0%)
13	-549.5	1.35	50.5		LI: 1A-1N - FW(100.0%)
14	-549.5	1.35	50.5		LI: 1A-1N - FW(100.0%)
15	-549.5	1.35	50.6		LI: 1A-1N - FW(100.0%)
16	-549.6	1.35	50.6		LI: 1A-1N - FW(100.0%)
17	-549.5	1.35	50.6		LI: 1A-1N - FW(100.0%)
18	-549.3	1.35	50.6		LI: 1A-1N - FW(100.0%)
19	-549.5	1.35	50.6		LI: 1A-1N - FW(100.0%)
20	275.8	1.35	51		LI: 1A-1N - RW(50.0%)
21	552.3	1.35	50.6		LI: 1A-1N - FW(100.0%)
22	552	1.35	50.6		LI: 1A-1N - FW(100.0%)
23	552.6	1.35	50.6		LI: 1A-1N - FW(100.0%)
24	552.3	1.35	50.6		LI: 1A-1N - FW(100.0%)
25	553.5	1.35	50.6		LI: 1A-1N - FW(100.0%)
26	554	1.35	50.6		LI: 1A-1N - FW(100.0%)
27	554.4	1.35	50.7		LI: 1A-1N - FW(100.0%)
28	554.8	1.35	50.6		LI: 1A-1N - FW(100.0%)
29	554.7	1.35	50.7		LI: 1A-1N - FW(100.0%)

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Próba udarem piorunowym 1.2/50us

project : ewn145e13-1b

30	554.9	1.35	50.6		LI: 1A-1N - FW(100.0%)
31	554.6	1.34	50.6		LI: 1A-1N - FW(100.0%)
32	554.7	1.35	50.7		LI: 1A-1N - FW(100.0%)
33	554.6	1.35	50.7		LI: 1A-1N - FW(100.0%)
34	554.5	1.35	50.7		LI: 1A-1N - FW(100.0%)
35	554.2	1.35	50.7		LI: 1A-1N - FW(100.0%)

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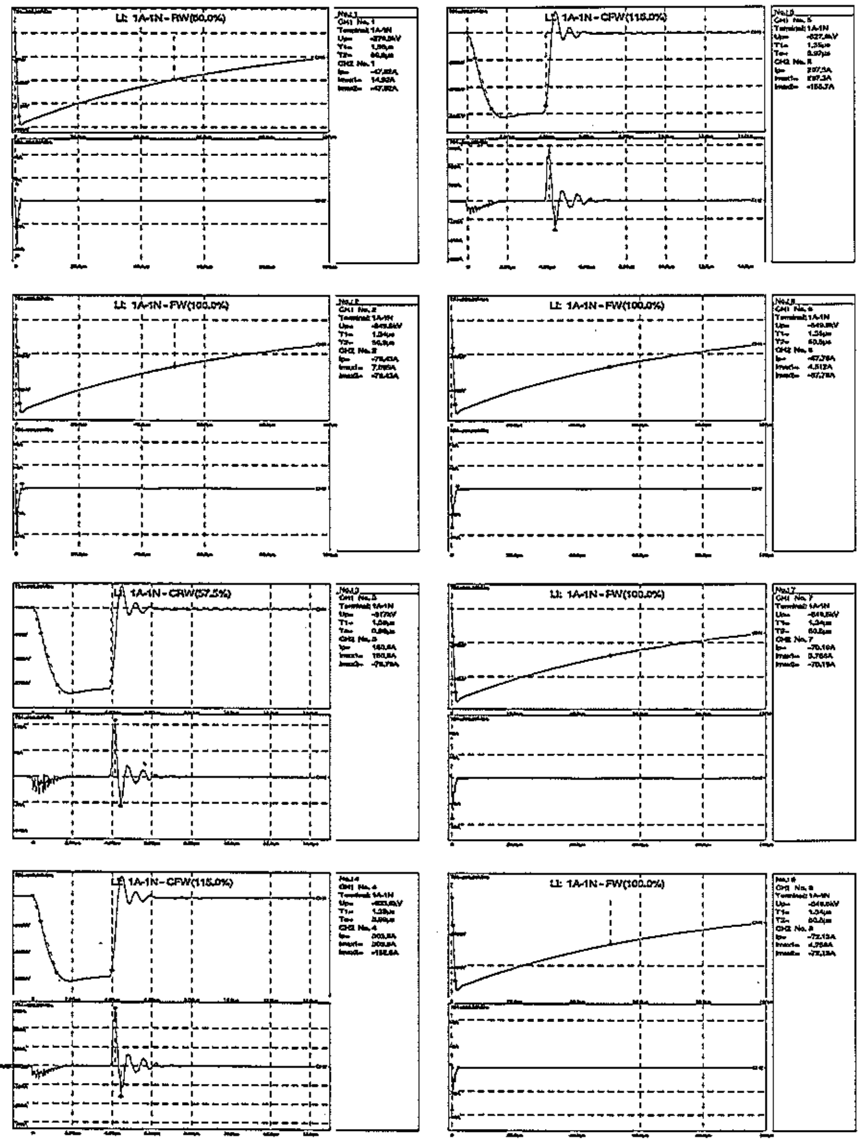
Próba udarem piorunowym 1.2/50us

project : ewn145e13-1b



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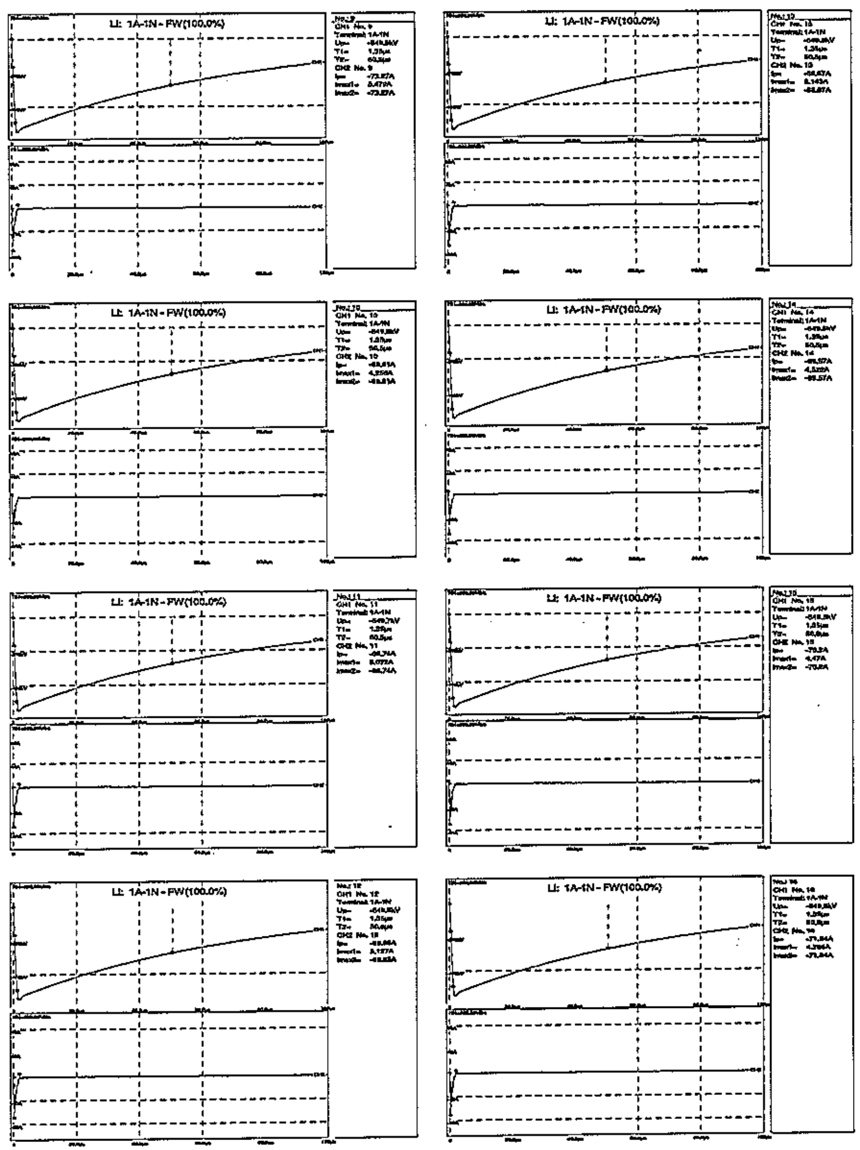
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

Próba udarem piorunowym 1.2/50us

project : ewn145e13-1b



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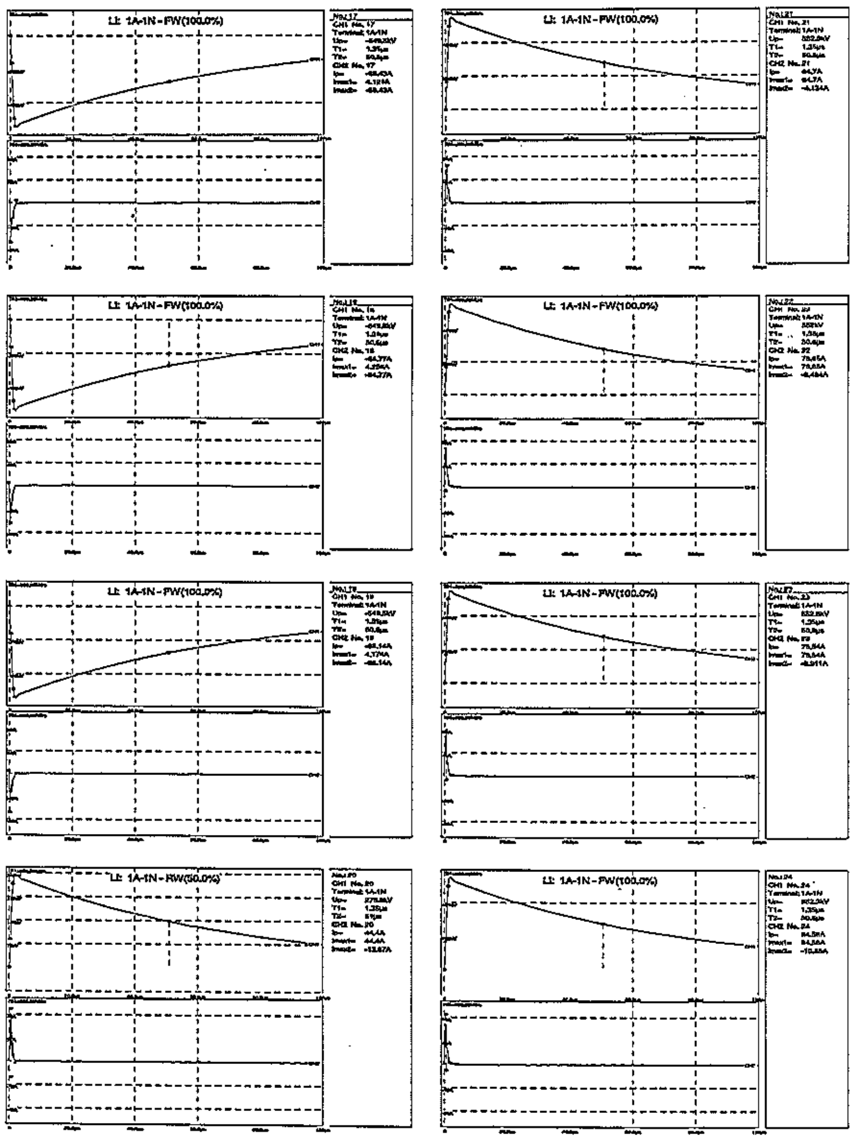
Próba udarem piorunowym 1.2/50us

project : ewn145e13-1b



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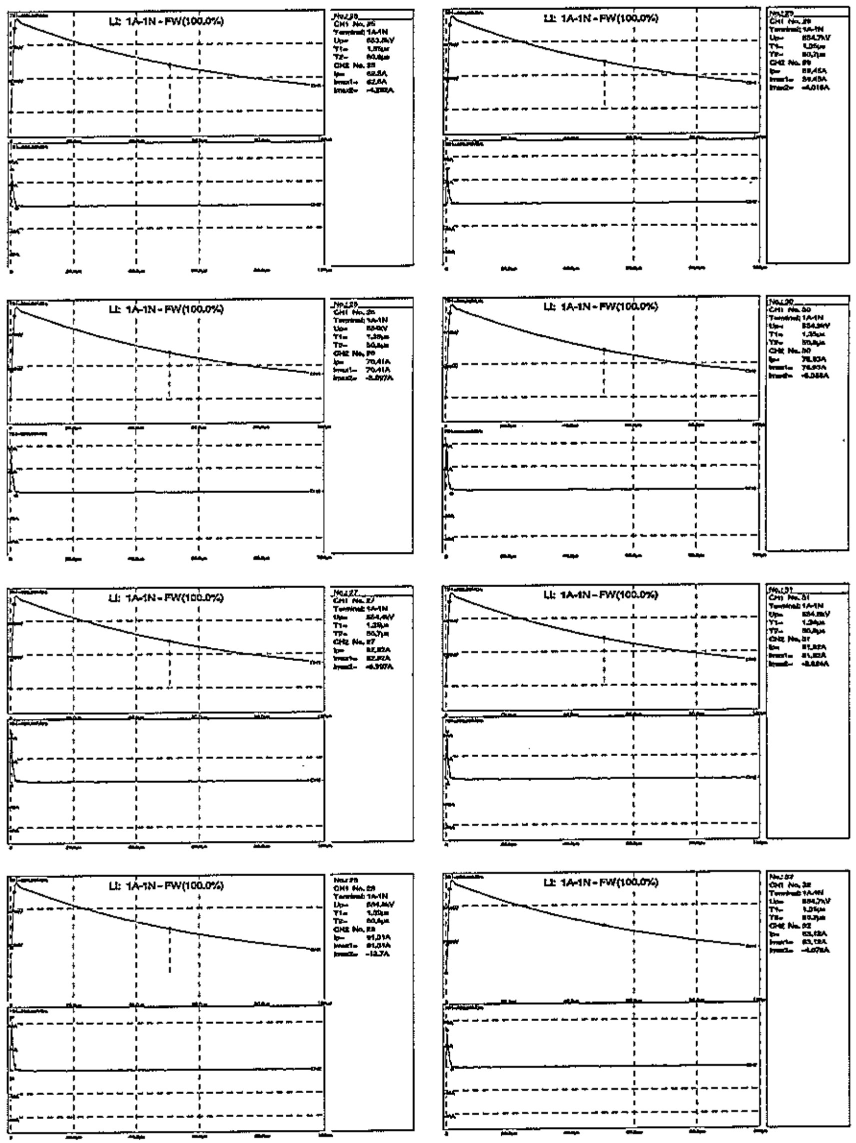
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

Próba udarem piorunowym 1.2/50us

project : ewn145e13-1b



HIGH VOLTAGE LABORATORY

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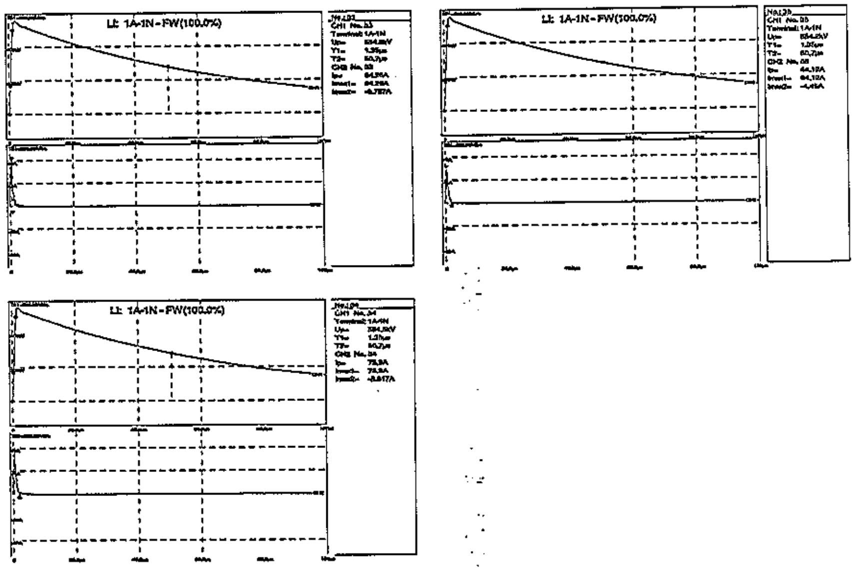
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

Próba udarem piorunowym 1.2/50us
project: ewn145e13-1b



LABORATORIUM WYSOKICH NAPIĘĆ INSTYTUTU ENERGETYKI 01-330 WARSZAWA, ul. Mory 8, tel. (+48 22) 3451242 tel. fax. (+48 22) 836-80-48, e-mail: ewn@ien.com.pl	EWN/145/E/13 ANNEX 4

ANNEX 4 for test report EWN/145/E/13

Transmitted overvoltage measurement:

- Oscillograms of measured overvoltages transmitted to the secondary windings.

- Report No. EWN/145/E/13-2a – 21.11.2013.
- Report No. EWN/145/E/13-2b – 13.11.2013.

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Pomiar przepięć przenoszonych
project: ewn145e13-2a   test date 21-11-2013   page 1

Test - object - data

WNR	EWN/145/E/13-2a	TR-No. 2GKP013K1486144 O.-No. 4500513518		
test object	PVA 145a		vector group	-
output	-	kVA	BIL	(19 kV)
voltage	132	kV	frequency	50 Hz
customer	ABB Sp. z o. o. Żegańska 1, 04-713 Warszawa			

LI lightning-impulse

no.	Up [kV]	T1[µs]	T2[µs]	Tc[µs]	remark
1	19.24	0.5	58.1		1a-1n
2	19.24	0.5	58.1		1a-1n zoom
3	19.2	0.5	58.2		2a-2n
4	19.2	0.5	58.2		2a-2n zoom
5	19.21	0.5	58.2		3a-3n
6	19.21	0.5	58.2		3a-3n zoom
7	19.23	0.5	58.2		4a-4n
8	19.23	0.5	58.2		4a-4n zoom
9	19.23	0.51	58.1		da-dn
10	19.23	0.51	58.1		da-dn zoom
11	19.23	0.5	58.1		1S1-1S2
12	19.23	0.5	58.1		1S1-1S2 zoom
13	19.23	0.51	58.1		2S1-2S2
14	19.23	0.51	58.1		2S1-2S2 zoom
15	19.25	0.5	58.1		3S1-3S2
16	19.25	0.5	58.1		3S1-3S2 zoom
17	19.19	0.5	58.3		4S1-4S2
18	19.19	0.5	58.3		4S1-4S2 zoom

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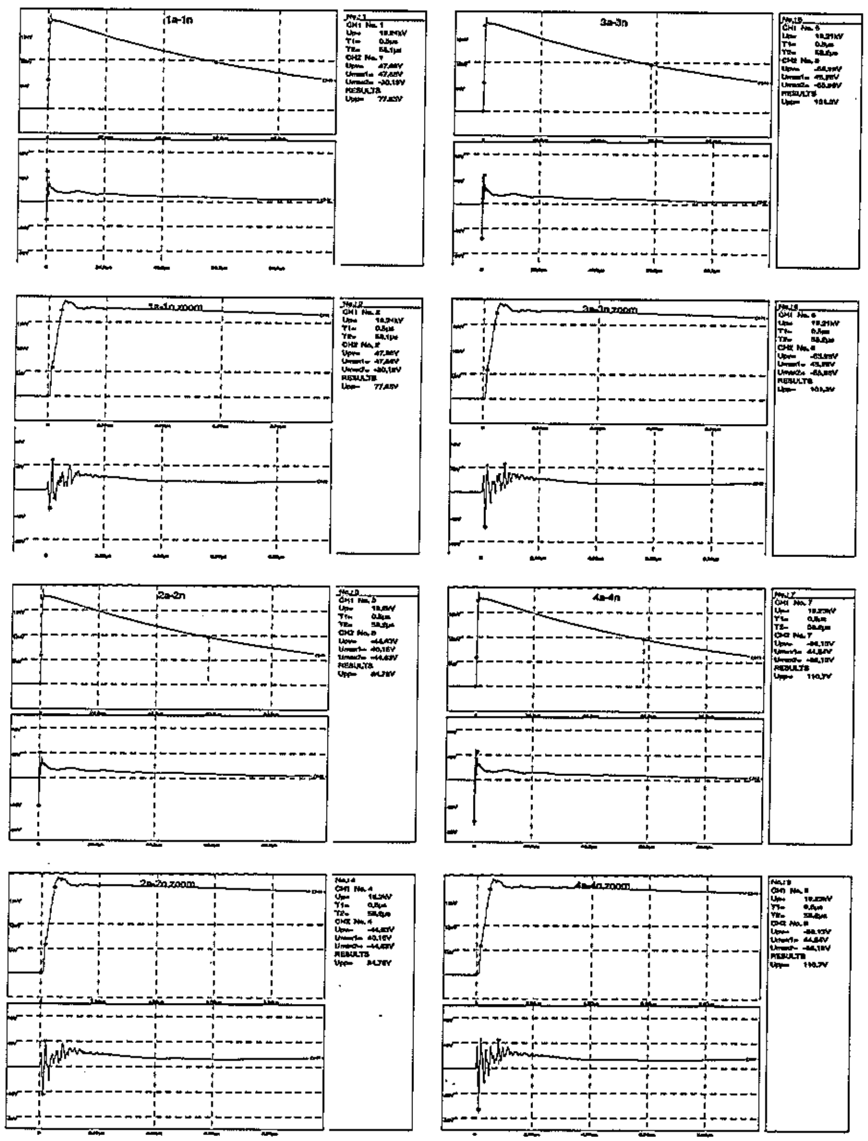
Pomiar przepięć przenoszonych
project: ewn145e13-2a   page 2



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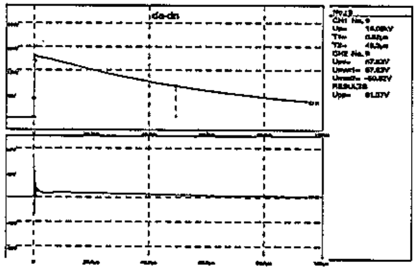
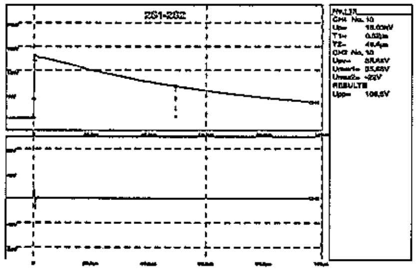
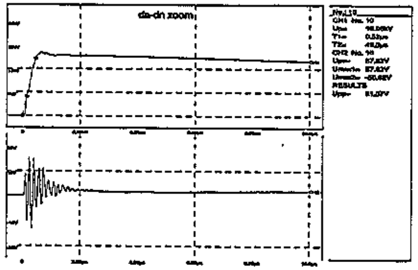
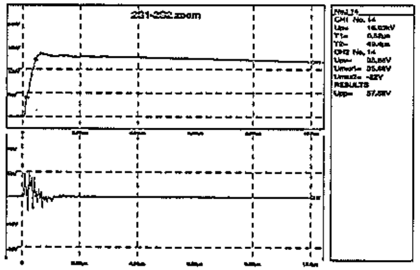
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

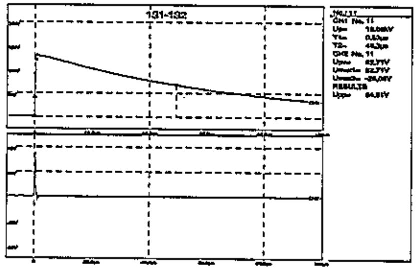
Pomiar przepięć przenoszonych
project : ewn145e13-2b

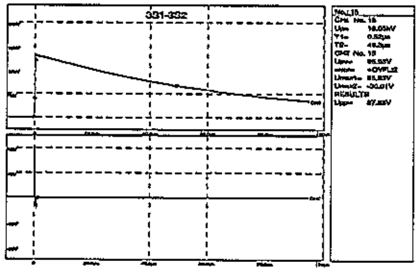


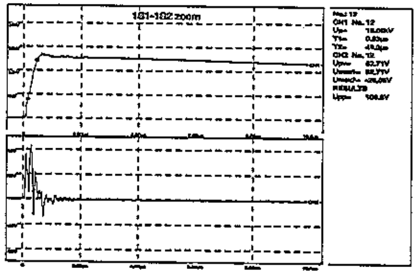


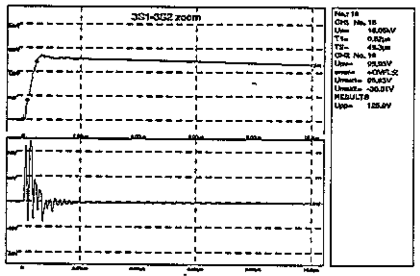






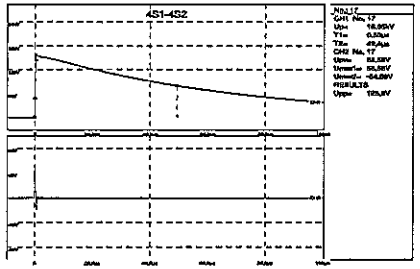


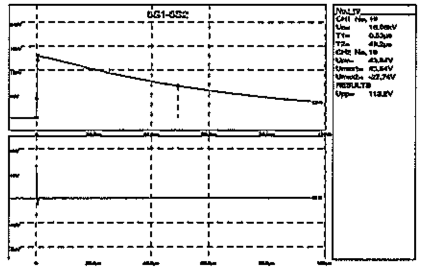


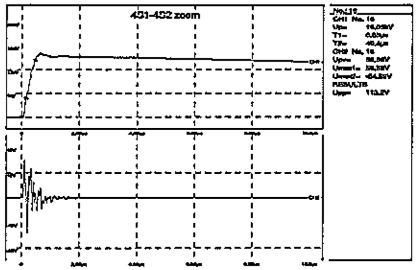


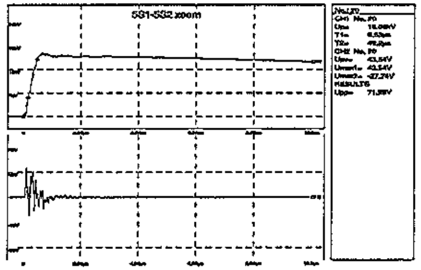
HIGH VOLTAGE LABORATORY POLAND 01-330 WARSZAWA, ul. Mory 8
fax: (+4822) 836-80-48, mail: ewn@ien.com.pl

Pomiar przepięć przenoszonych
project : ewn145e13-2b









LABORATORIUM WYSOKICH NAPIĘĆ

INSTYTUTU ENERGETYKI

LABORATORY ACCREDITED
BY THE POLISH CENTRE FOR ACCREDITATION
Accreditation Certificate of Testing Laboratory
No AB 272

AB 272

TEST REPORT

No. EWN/11/E/12-1

Type test and special tests
of voltage instrument transformer type PV 123
manufactured by ABB sp. z o.o.

Warsaw, March 2012

POLAND 01-330 WARSZAWA, ul. Mory 8, tel. (+48 22) 836-80-48, fax (+48 22) 836-80-48 e-mail: ewn@ien.com.pl

TESTS REPORTS No EWN/11/E/12-1

TEST OBJECT:	Voltage instrument transformer type PV 123 Serial No: 2GKP011V1084703 (84703/11)
TEST ORDERED BY:	ABB Sp. z o.o. 04-713 Warszawa, ul. Żegańska 1
ORDER NO:	4500380553/1 – 20.01.2012
SCOPE OF TEST:	Type test
PROCEDURA OF TESTS:	in accordance with standards: PN-EN 60044-2:2001 (EN 60044-2:1999)
RECEIVING OBJECT DATE:	January 2012
DATE OF TESTS:	January 2012 – March 2012
TESTS RESULTS:	are presented in following parts of report <u>Test results are concern to tested object only.</u>

Tests was performed in witness of representatives of ABB sp. z o.o. :

Marcin TARNOWSKI M.Sc.E.E.
Paweł DĘBSKI M.Sc.E.E.
Jarosław DUZDOWSKI M.Sc.E.E.
Zbigniew WESOŁOWSKI M.Sc.E.E.

TEST PERFORMER:	Jan SZOKALSKI M.Sc.E.E.	SIGNATURE
TEST OVERSEERER:	Jerzy MIKOŁAJCZYK M.Sc.E.E.	SIGNATURE
HEAD OF HIGH VOLTAGE DEPARTMENT:	January L. MIKULSKI, Ass. Prof., Dr. hab. E. E.	SIGNATURE

Warsaw, March 2012

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CONTENTS

The Report contain:
19 numbered pages
In Report are presented:
5 drawing
1 numbered table
6 appendixes
and non numbered diagrams and tables

1. COMPETENCE OF THE LABORATORY

The High Voltage Laboratory of Institute of Power Engineering (IEn) in Warsaw is in possession of accreditation issued by the Polish Centre for Accreditation (Accreditation Certificate of Testing Laboratory No AB 272) concerning following tests:

Insulators and insulator strings	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Distribution substations	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Circuit breakers, disconnectors	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Insulators	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Current and voltage transformers	–	**lightning and switching impulse tests**
	–	**power-frequency voltage 50 Hz tests**
Power transformers	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
Lightning arresters and limiters	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
Cables and cable fittings	–	lightning and switching impulse tests

Note! Tests described in sub-clauses 4.10, hereby Report are not comply the scope of Laboratory accreditation.

Hereby Report concerning test results obtained in other competent laboratories - (see Appendixes 2,3,4) :

- Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw having Accreditation Certificate PCA Nr AB 324
- High Current Laboratory of Institute of Power Engineering in Warsaw having Accreditation Certificate PCA Nr AB 323
- Factory Laboratory of ABB sp. z o.o. in Przasnysz - Regional Verification Office in Warsaw - determination of errors and test in range of type tests at supervision of representative of High Voltage Laboratory of Institute of Power Engineering in Warsaw.

2. DESCRIPTION OF TEST OBJECT

The tested object was voltage instrument transformer type PV 123 manufactured by ABB sp. z o.o. 04-713 Warszawa, ul. Żegańska 1; had following parameters:

Serial number 2GKP011V1084703 (84703/11)

- Rated primary voltage — $110/\sqrt{3}$ kV
- Rated frequency — 50 Hz
- Rated insulation level — LI 550kV/ AC 230kV
- Minimum creepage distance — 3640 mm (porceline insolator)

View of rated nameplates of tested transformers show figure 1.

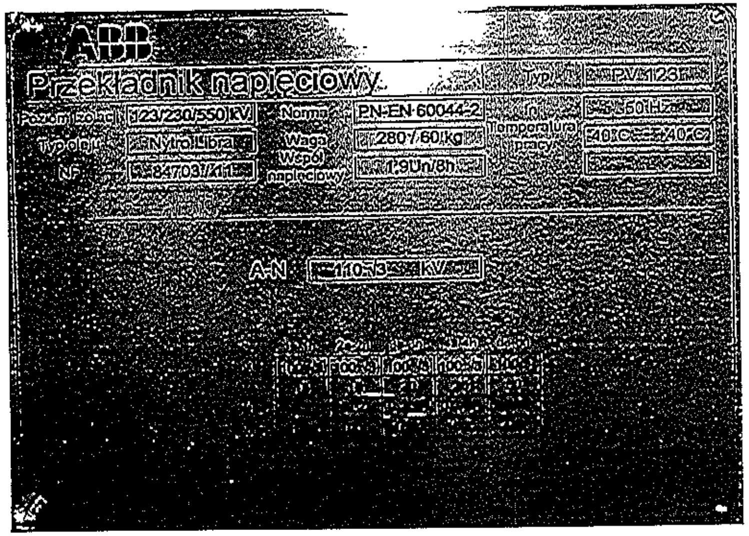

Fig. 1 Rated nameplate of tested transformer

Identification of tested object was done at following documents attached to hereby Report (Appendix 1):

- Manufacturer Conformity Declaration,
- Dimension drawing No. 2GKV614114/ (19.01.2012),
- Electric diagram of Voltage instrument transformer,
- Drawing of rated nameplate.

3. AGREED SCOPE OF TESTS

According to ordered the type test and selected special test were done comply following standard:

- PN-EN 60044-2:2001 + A1:2003 +A2:2004 „Przekładniki. Część 2: Przekładniki napięciowe indukcyjne" (EN-60044-2:1999 + A1:2000 + A2:2003 „Instrument transformers. Part 2: Inductiv voltage transformers").

On request of ordering party the additional special test were performed. The performed test results are contained in Table 1.

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Table 1. List of performed tests

Item	Performed tests	Requirement
TYPE TESTS		
1	Temperature-rise test	PN EN 60044-2, p.8.1
2	Short-circuit withstand capability test of secondary windings	PN EN 60044-2, p.8.2,
3	Lighting impulse test	PN EN 60044-2, p.8.3
4	Wet test for outdoor transformers	PN EN 60044-2, p.8.4
5	Determination of errors	PN EN 60044-2, p. 12.3, 13.6.2,
6	Measurement of the radio interference voltage (RIV)	PN EN 60044-2/A1, p. 8.5
SPECIAL TESTS		
7	Chopped impulse test on the primary winding	PN EN 60044-2, p. 10.1
8	Measurement of capacitance and dielectric dissipation factor	PN EN 60044-2, p. 10.2
9	Mechanical test	PN EN 60044-2, p. 10.3
10	Transmitted overvoltage measurement	PN EN 60044-2/A2, p. 10.3

During mentioned above tests at Factory Laboratory of ABB sp. z o.o. in Przasnysz Leszno 59 Street, were performed determination of errors of transformer to prove positive results of consecutive tests. The complete tests were performed according to mentioned above standards. The tests were supervised by representatives of High Voltage Laboratory of Institute of Power Engineering in Warsaw in purpose to prove results of tests. The tests stands are under authority of Regional Verification Office in Warsaw (No. stand S08/OUM1-5/01 XVI i S08/OUM1-5/01 XVII).

4. PERFORMED TESTS

4.0 Routine test and determination of errors before tests in IEn and after tests finishing.

Before delivery the transformer to IEn Laboratory and after type test and special test completed in ABB Factory Laboratory in Przasnysz were performed determination of errors measurement under supervision of representative of IEn. During test were checked:

- verification of terminals marking,
- power-frequency withstand test on the primary winding 50 Hz, $U_{test} = 230$ kV, t = 60 s,
- partial discharge measurement for voltage transformers q<10pC (U_m) q < 5pC ($1{,}2 \cdot U_m/\sqrt{3}$),
- power-frequency withstand test on secondary windings 50 Hz, $U_{test} = 3$ kV, t = 60 s,
- power-frequency withstand test between sections 50 Hz, $U_{test} = 4{,}5$ kV, t = 60 s,
- determination of errors.

The test results are presented in reports attached to hereby Report (Appendix 2):

- Tests before type test and special test (Measurements before type test and special tests) - Report No. 2GKP011V1084703 – 19.01.2012,
- Tests after type test and special tests completed (Measurements after type test and special test completed) - 2GKP011V1084703 – 26.03.2012.

It were proved that all tests required in routine test gave positive results. It were proved that all metrological properties of transformer are comply accurate classes for all winding.

These tests results are base for later determination of errors for purpose of verification result of tests described below.

4.1 Temperature-rise test

This test was performed in High Current Laboratory of Institute of Power Engineering in Warsaw.

Stage 1

The voltage value 1,2 Un = 76,2 kV was applied to the A terminal.

The secondary voltage windings were loaded as follows: 1a-1n – 15 VA, cosφ = 1, at the voltage 100/√3 V; 2a-2n – 15 VA, cosφ = 1, at the voltage 100/√3 V; 3a-3n – 20 VA, cosφ = 1, at the voltage 100/√3 V; 4a-4n – 25 VA, cosφ = 1, at the voltage 100/√3 V.

The winding of residual voltage remained open.

The test was performed till reached steady state of the measured temperatures.

Stage 2

The voltage value 1,9 Un = 119,7 kV was applied to the A terminal.

The secondary voltage windings were loaded as follows: 1a-1n – 15 VA, cosφ = 1, at the voltage 100/√3 V; 2a-2n – 15 VA, cosφ = 1, at the voltage 100/√3 V; 3a-3n – 20 VA at the voltage 100/√3 V; 4a-4n – 25 VA, cosφ = 1, at the voltage 100/√3 V.

The residual winding da-dn was loaded by – 450 VA, cosφ = 1, at the voltage 100/3 V.

The duration of the test was 8 h.

Stage 3

The voltage value Un = 63 kV was applied to the 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 test was performed till reaching the steady state of the measured temperatures.

Rise of temperature in steady state not exceeding permissible value of 65 K + 10 K = 75 K (according to 5.4 of PN-EN 60044-2 and 4.2 of PN-EN 60044-3).

Test result - positive.

Detailed information about test arrangement and performed tests, tests results are present in separate Reports No. EWP/07/E/2012-3e of 27.02.2012. – (Appendix 4)

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4.2 Short-circuit withstand capability of secondary circuit

The test of short-circuit withstand capability of secondary circuit of voltage transformer was performed for combined transformers type PVA 123, serial No. 84500, manufactured by ABB. (Test Report EWN/70/E/11-1 – High Voltage Laboratory IEn) Voltage part of this combined transformer PVA 123 was identical construction to the voltage transformer PV 123. The test was performed in Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw.

To the voltage transformer was applied rated voltage $110/\sqrt{3}$ kV during 1 second at short-circuited secondary winding. The test was performed twice – one with short-circuited secondary winding for measurement and second with short-circuited residual voltage winding.

$U_{test} = 63{,}5$ kV, $t = 1$ s

During test transformer behaviour was correct. After test not stated any failures or oil leakage.

Test result - positive.

After the test of short-circuit withstand capability of secondary circuit of transformer in Factory Laboratory of ABB sp. z o.o. in Przasnysz 59 Leszno 59 Street, under supervision of representative of IEn was performed determination of errors.

The test result of these measurement are present in Report No. 2GKP011V1084703 – 26.03.2012 – (Appendix No. 3 of hereby Report).

It was found that metrological properties of transformer are comply to assigned accurate classes of transformer windings and measured values are practically identically to measured values before short-time test. This prove positive result of short-time test.

4.3 Lightning impulse test

Test was done in test arrangement of surge generator type Haefely 5 MV, 375 kJ. Equivalent circuit diagram is shows on Figure 2. The test was performed on standardized lightning impulse 1,2/50μs. The purpose of test was checking internal insulation of transformer. The influence of atmospheric condition on test voltage value was not taken into consideration.

The Lightning impulse test was performed jointly with chopped impulse test on the primary winding (clause 3.8 of hereby Report).

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Test condition:

- Full impulse test voltage U = 550 kV,
- Chocked impulse test voltage 1,15 · 550 kV = 632,5 kV,
- Sequence of impulses:
  positive polarity – 15 full impulses,
  negative polarity – 1 full impulse, 2 chocked impulses, 14 full impulses,
- During test was recorded test voltage and current flowed through along of voltage transformer.

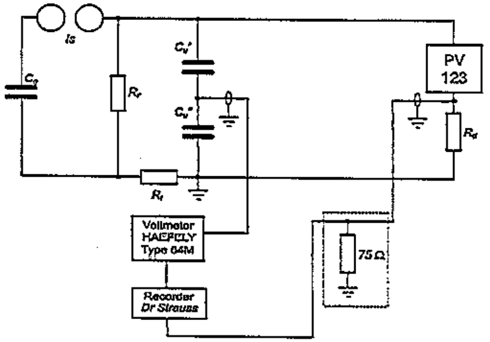

Fig. 2 Equivalent circuit diagram of test arrangement for lightning impulses:
C_g = 0,125 µF, C_u = 1,2 nF, R_t = 175 Ω, R_r = 600 Ω, R_d = 8,95 Ω.
Measurement uncertainty - 1,5 %

The oscillograms not shows failures of transformer insulation.
Result of test - positive.

Recorded oscillograms of all applied impulses are shown in Appendix No. 5 of hereby Report.

4.4 Wet test for outdoor transformers

The test was performed in arrangement of test transformer type TuR 700kV, 0,5A. Equivalent circuit diagram is presented on Figure 3.

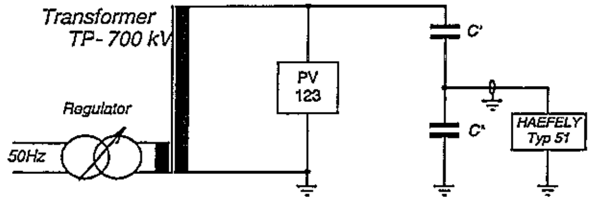

Fig. 3 Equivalent circuit diagram for power frequency voltage 50 Hz:
C = 200 pF (C' in series with C'')
Measurement uncertainty - 1,5 %

The test was performed on transformers model with disassembled winding (Figure 4). All external elements of transformers, which can influenced on test results were identical to the complete transformer.

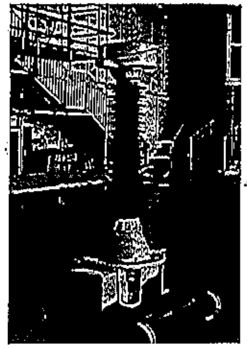

Fig. 4 Wet test of voltage transformers type PV 123 at power frequency voltage 50 Hz.

Because electric strength of inner insulation is not depend from atmospheric conditions and this property was tested during routine test at ABB's Factory Laboratory (Raports No. 2GKP011V1084703 – 19.01.2012 and No. No. 2GKP011V1084703 – 26.03.2012 of Factory Laboratory ABB sp. z o.o. Przasnysz Division).

In each cases the test voltage was U=230 kV was applied during 1 minute.

During wet test for outdoor transformers the transformer was wetting by artificial rain at parameters:

- vertical component of precipitation H_v = 1,6 mm/min
- horizontal component of precipitation H_h = 1,5 mm/min
- water electrical resistivity ρ= 99 Ωm

The test voltage was corrected according to density of air.

During test were not observed any flashover or failure of insulation.

Test result - positive.

4.5 Determination of errors

Measurements of errors for voltage transformers was performed in Factory Laboratory of ABB sp. z o.o. in Przasnysz 59 Leszno 59 Street, under supervision of representative of IEn.

The measurement was done two times:

- Tests before type test and special test (Measurements before type test and special tests) - Report No. 2GKP011V1084703 – 19.01.2012,
- Tests after type test and special tests completed (Measurements after type test and special test completed) - Report No. 2GKP011V1084703 – 26.03.2012.

Detailed information about tests results consists Appendix No. 2 of hereby Report.

Analyzing test results of measurements of errors for voltage transformer was found that:

- **For measurement windings 1a-1n and 2a-2n class 0,2:**
  - for voltages $0,8U_n$, $1U_n$ i $1,2U_n$ voltage error ΔU(%) < 0,2% and phase displacement δ_u(min) < 10 min.
- **For winding for protection 3a-3n class 0,2% and 3P:**
  - for voltages $0,8U_n$, $1U_n$ i $1,2U_n$ voltage error ΔU(%)< 0,2% and phase displacement δ_u(min) < 10 min.

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- for voltages $0,02U_n$, $0,05U_n$ i $1,9U_n$ voltage error ΔU(%)< 3% and phase displacement δ_u(min) < 120 min.

- **For winding for protection 4a-4n class 0,2% and 3P:**
  - for voltages $0,8U_n$, $1U_n$ i $1,2U_n$ voltage error ΔU(%)< 0,2% and phase displacement δ_u(min) < 10 min.
  - for voltages $0,02U_n$, $0,05U_n$ i $1,9U_n$ voltage error ΔU(%)< 3% and phase displacement δ_u(min) < 120 min.
- **For residual voltage winding da-dn class 3P:**
  - for voltages $0,02U_n$, $0,05U_n$ $1,0U_n$ i $1,9U_n$ voltage error ΔU(%)< 3% and phase displacement δ_u(min) < 120 min.

For each of voltage windings values of error are contain in range compatible to appropriate class of accuracy.

4.6 Radio interference voltage measurement

Following to requirement of IEC/CISPR 18-2 the measurements was performed in testing arrangement as is show on Figure 5. The interference voltage was measured on resistance 300Ω at frequency 0,5 MHz. To determinate coefficient of correction +24 dB before measurement the instrument was calibrated by stabile signal generator . To measurement of interference voltage the instrument LMZ-5 was used. The level of background was checked for range of test voltages 0 - 150 kV. Interference voltages originated form testing arrangement, radio broadcasts etc., were below 5μV (14 dB).

According to PN EN 60044-1/A1 interference voltage at voltage $Up=1.1 \cdot U_m/\sqrt{3}$=78 kV has not to exceed the value RIV_{dop} = 2500μV.

The instrument had logarithmic scale: RIV_{dop} = 2500μV → 68 dB (0 dB = 1 μV).

Before the test, the instrument transformer was supplied with voltage $1,5 \cdot U_m/\sqrt{3}$, held for 30 sec. Next, within about 10 sec the voltage was decreased to value $1,1 \cdot U_m/\sqrt{3}$, held for 30 sec.

The measurements were done at test voltages in range $0,3 \div 1,1 \cdot U_m/\sqrt{3}$.Test voltage was decreased step by step with value 0,1xUp since $Up=1,1 \cdot U_m/\sqrt{3}$ up to value $Up=0,3 \cdot U_m/\sqrt{3}$. Next, voltage was increased by this same values and finally deceased again.. For each of test voltage the measurement of radio interference voltage were performed and registered level in last series of decreasing voltage was drawn in function of test voltage Utest.

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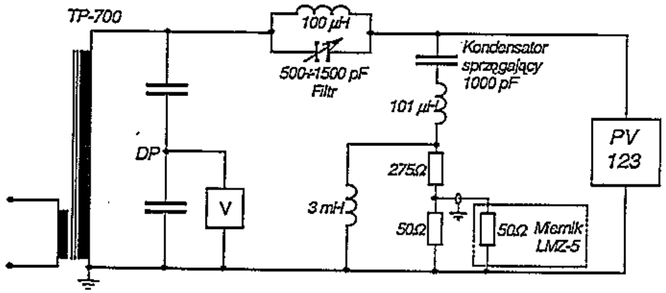
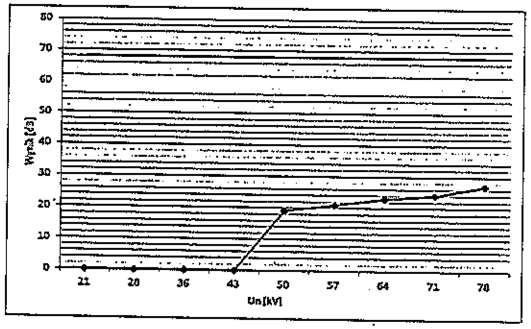


Fig. 5 Test arrangement for Radio interference voltage measurement

The results of measurements are present in Table and diagram below.

Up [kV]		78	71	64	57	50	43	36	28	21
xUn/√3		1,1	1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3
[dB]	→	3	1	-1	-3	-5	-	-	-	-
	←	3	0	-1	-3	-5	-	-	-	-
	→	3	0	-1	-3	-5	-	-	-	-
Wynik	[dB]	27	24	23	21	19	-	-	-	-
	[µV]	22	16	13	11	9	-	-	-	-



Measured Radio Interference Voltage RIV = 22 µV (27dB) is much less than permissible level RIV_{perm} = 2500 µV (68dB).
Test result - positive.

4.7 Chopped impulse test on the primary winding

Chopped Impulse Test was supplemented to Lightning Impulse test 1,2/50µs and was described in clause 4.3 of hereby Report.

Recorded oscillograms not show of failure of insulation of voltage transformers. Test result - positive.

Oscillograms of all applied impulses are present in Appendix No. 4 of hereby Report.

4.8 Measurement of capacitance and dielectric dissipation factor

The measurement was performed st at ABB's Factory Laboratory (Raports No. 2GKP011V1084703 – 19.01.2012 and No. No. 2GKP011V1084703 – 26.03.2012 of Factory Laboratory ABB sp. z o.o. Przasnysz Division).
Condition of measurements:

Up = 10 kV; $110/\sqrt{3}$ kV = 63,5 kV; $123/\sqrt{3}$ kV = 71 kV

Ambient temperature during measurement was 20,7°C and (22,8°C).

Test results are present in table below:

Up [kV]	C_x [pF]	tgδ [%]
10	264 (265)	0,2 (0,19)
63,5	265 (266)	0,2 (0,2)
71	265 (266)	0,2 (0,21)

The standard specifications for capacitance and dissipation factor for instrument transformers not provide criterion for these parameters. The Standard PN-EN 60044-2:2001 (EN 60044-2:1999) only contain note that value of dissipation factor is usually less than 0,5%.

4.9 Mechanical tests

The mechanical tests were performed in Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw. The test consist in applying to the transformer mechanical load – static and dynamic, in three direction in turn. Static load was 20% higher than standard requirement for II class of load. The test conditions were as follow:

$F_R = 3600$ N, $t = 60$ s

It was assumed that dynamic load is 1,4 times higher than static load.

During the tests behaving of voltage transformer was correct. After test not stated any damages or oil leakage.

Test result - positive.

Detailed information about test arrangement, performed tests and tests results are present in Report No. EUR/12/E/12-3E – 30.03.2012 – (Appendix 3)

4.10 Transmitted overvoltage measurement

During the test to the HV terminal of transformer were applied impulse voltage.

It were recorded maximal value of overvoltages which came in each secondary windings - both current and voltage. According to requirement of Standard for impulse 0,5/50 µs and value $U_{test}=1{,}6 \times \sqrt{2} \times U_m/\sqrt{3} \cong 160$ kV the values of transmitted overvoltages can not exceed 1,6 kV.

During all measurements to the transformer were applied lightning impulses at value ten times less, that is $U_I= 16$ kV. Concerning linear of phenomenon, registered overvoltages should have values less than 160 V (peak-to- peak value).

Registration was don by digital oscilloscope of "Dr Strauss" with input impedance 50 Ω and transmission band 200 MHz.

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Results of test are present in table below.

Winding	Overvoltage value $U_{pp}/2 \times 10$ [V]
1a-1n	503
2a-2n	772
3a-3n	910
4a-4n	928
da-dn	732

It was found that for each of secondary winding of transformer transmitted overvoltages not exceed value of 1600 V.

Test result - positive.

The oscillograms of all applied and registered impulses are present in Appendix No. 6 of hereby Report.

5. SUMMARY

- The voltage instruments transformer type PV 123 manufactured by ABB sp. z o.o. 04-713 Warszawa, ul. Żegańska 1, with parameters described in clause 2 of hereby Report and identified on base provided documents (as presented in Appendix No. 1) was performed.
- The voltage instruments transformer type PV 123 **passed positively** type test according to requirement of standard:
  - PN-EN 60044-2:2001 + A1:2003 +A2:2004 „Przekładniki. Część 2: Przekładniki napięciowe indukcyjne" (EN-60044-2:1999 + A1:2000 + A2:2003 „Instrument transformers. Part 2: Inductiv voltage transformers"),

  and program described in Table 1, clause 3 of hereby Report.
- The voltage instruments transformer type PV 123 **passed positively** special tests according requirement mentioned above standards and program described in Table 1, clause 3 of hereby Report.

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6. LIST OF APPENDIXES

Appendix No. 1

Documents provided by ABB Sp. z o.o. used as base of identification of test object:

- Manufacturer Conformity Declaration
- Dimension drawing No. 2GKV614114/ (19.01.2012)
- Electric diagram of Voltage instrument transformer
- Drawing of rated nameplate

Appendix No. 2

Reports of routine test and determination of errors of voltage transformer type PV 123 performed in Factory Laboratory of ABB sp. z o.o.

- Tests before type test and special test (Measurements before type test and special tests) - Report No. 2GKP011V1084703 – 19.01.2012,
- Tests after type test and special tests completed (Measurements after type test and special test completed) - 2GKP011V1084703 – 26.03.2012.

Appendix No. 3

Report of performed tests in Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw.

- Test Report No. EUR/12/E/12-3E (Mechanical tests.)

Appendix No. 4

Report of performed tests in High Current Laboratory of Institute of Power Engineering in Warsaw.

- EWP/07/E/2012-3e of 27.02.2012 (Temperature-rise tests)

Appendix No. 5

Lightning impulse test. Impulse 1,2/50 μs, full and chopped:

- Oscillograms of test voltages and detection currents.

Appendix No. 6

Transmitted overvoltage measurement:

- Oscillograms of measured transmitted to secondary windings overvoltages.

INSTYTUT ENERGETYKI
INSTITUTE OF POWER ENGINEERING
LABORATORIUM WIELKOPRĄDOWE
HIGH CURRENT LABORATORY

01-330 Warszawa
ul. Mory 8
tel. 22 34-51-386
tel./fax 22 836-80-16
e-mail: ewp@ien.com.pl
www.ien.com.pl/ewp

TEST REPORT No. EWP/35/E/2013-3e

TEST OBJECT:	Combined instrument transformer type PVA 145a
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/145/E/13 dated 17.12.2013
TYPE OF TESTS:	**Mechanical impact test**
TEST PROCEDURE:	IEC 61869-1:2007, EN 62262: 2002, IEC 60068-2-75: 1998, PN-EN 61869-1:2009E, PN-EN 62262: 2003E, PN-EN 60068-2-75: 2000P
TEST OBJECT DELIVERED:	28.11.2013
DATE OF TESTS:	21.12.2013
TESTS RESULTS:	Positive for IK7
THE TESTS WERE WITNESSED BY:	-
TEST ENGINEER:	Lidia Gruza M.Sc. Eng.
HEAD OF LABORATORY:	Lidia Gruza M.Sc. Eng.

Warsaw, 3.02.2014

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1. Description of the test object

Test object	Combined instrument transformer
Type	PVA 145a
Serial number	2GKP013K1486144
Manufacturer	ABB Sp. z o.o. Power Products 59 Leszno Str. 06–300 Przasnysz, Poland
Year of production	2013
Insulator	Composite Insulator
Number of windings	CT part – 5, CT part –4
Oil type	Nytro Libra
Minimum creepage distance	4495 mm
Insulating oil weight	150 kg
Total weight	540 kg
Dimensions	According to drawing no. 2GKK614123

The laboratory proceeded the identification of test objects on the base of above mentioned documentation (see sub-cl. 3).
The test object is shown in the photograph 1.
The test object was ready for testing by the Customer.

2. Technical data declared by the Manufacturer

Maximum operating voltage	145 kV
Rated frequency	50 Hz
Voltage factor and time	$1{,}9U_n/8h$
Rated continuous thermal current, I_{cth}	450-900 A
Rated short-time thermal current, I_{th}/ 1s	40-40 kA
Rated dynamic current, I_{dyn}	100-100 kA

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4. Scope of the tests

Test programme agreed with Orderer comprised of tests:

No.	Kind of test	Tests according the Standard	Location of the test
1.	Mechanical impact test	IEC 61869-1:2007 p. 6.10.6 i p. 7.2.7.2, EN 62262: 2002	EWP

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

5. Tests and their results

Combined instrument transformer was installed at the test stand, as it was during normal operation.
The test was performed after the temperature-rise test of the tested object. The test procedure was used as defined in IEC 61869-1 sub.-cl. 7.2.7.2. Impact level IK7 was approved for tested combined instrument transformer, according to the requirements given in IEC 61869-1 sub.-cl. 6.10.6 Standard. Test procedure was used according to the IEC 61869-1 sub.-cl. 7.2.7.2 Standard.
The base of tested instrument transformer was protected against moving.
The pendulum – operated impact test apparatus as defined in IEC 60068-2-75 sub.-cl. 4 (Eha test) – was used to carried–out the mechanical test.
Because of the enclosure shape of the parts of the instrument transformer, the pendulum hammer has been used in the form of the steel ball, but the arm was of rope fixed to the unit in according to the Fig. No. D.1 of the EN 6008-2-75: 1997 Standard.
The striking element (the ball) having the mass of 0,5 kg has been dropped to the enclosure from the height of 400 mm ±1%. Simultaneously the tested surface has been protected against secondary strikes (rebounds).
During the test three blows with the energy of 2 J are applied to each point of the enclosure (the weakest points): to the upper tank, lower tank and insulator.
The test was carried-out at the ambient temperature of 15 °C.

5.1. Measuring instruments

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[1].

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

6. Summary

The tested combined instrument transformer type PVA 145a met requirements of the IEC 61869-1:2007 standard for protection of equipment against mechanical impact under normal service conditions for impact level IK7.

7. Opinions and interpretations

None

8. Photographic documentation

Photograph No. 1. View of tested combined instrument transformer on the test stand during preparation for the mechanical impact test.

APPENDIX No. 2.

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

DECLARATION OF CONFORMITY No. 091/2013 (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: **2GKP013K1486144;**

Place and date of issue of declaration

Przasnysz 13.01.2014

ABB
ABB Sp. z o.o.
ul. Zegańska 1, 04-713 Warszawa
NIP: 526-030-44-04; PL 5260304404
Regon 010017105
ODDZIAŁ W PRZASNYSZU
ul. Leszno 59, 06-300 Przasnysz
tel. (22) 223 6921, fax (22) 223 6958
(9)

Referent ds. Realizacji Zamówień
ABB Sp. z o.o.
Oddział w Przasnyszu
Małgorzata Gożdziewska

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

(Name) (Signature)

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HIGH VOLTAGE LABORATORY

INSTYTUT ENERGETYKI

LABORATORY ACCREDITED
BY THE POLISH CENTRE FOR ACCREDITATION
Accreditation Certificate of Testing Laboratory
No AB 272

PCA
AB 272
ilac-MRA

TEST REPORT

No. EWN/39/E/15

Wet power-frequency voltage test
of current transformers type PA145a
manufactured by ABB sp. z o.o.

Warsaw, April 2015

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TEST REPORT No EWN/39/E/15

TEST OBJECT:	Two current transformers type: PA145a 300-600A No. 87181/14 PA145a 150-300A No. 87182/14
TEST CUSTOMER:	ABB Sp. z o.o. 04-713 Warszawa, ul. Żegańska 1
ORDER NO:	4500629153 – 10.03.2015
SCOPE OF TEST:	Wet power-frequency voltage test
TEST PROCEDURE:	In accordance with: PN-EN 61869-1:2009 (IEC 61869-1:2007) PN-EN 60060-1:2011 (IEC 60060-1:2010)
TEST DATE:	24.03.2015 r.
TEST RESULT:	POSITIVE

<u>Test results are concern to tested object only.</u>

TEST PERFORMER:	Adam WIELONEK	SIGNATURE
AUTHORISATION:	Jerzy MIKOŁAJCZYK M.Sc.E.E.	SIGNATURE
HEAD OF HIGH VOLTAGE DEPARTMENT:	January L. MIKULSKI, Ass. Prof., Dr. hab. E. E.	SIGNATURE

Warsaw, April 2015

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CONTENTS

The Report contain:
10 numbered pages

In Report are presented:
5 drawing
2 photographs

1. COMPETENCE OF THE LABORATORY

The High Voltage Laboratory of Institute of Power Engineering (IEn) in Warsaw is in possession of accreditation issued by the Polish Centre for Accreditation (Accreditation Certificate of Testing Laboratory No AB 272) concerning following tests:

Insulators and insulator strings	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Distribution substations	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Circuit breakers, switches	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Disconnectors	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Current and voltage transformers	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Power transformers	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
Lightning arresters and limiters	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
Cables and cable fittings	–	lightning and switching impulse tests

The detailed scope of accreditation of the laboratory is available on the http://www.pca.gov.pl

2. TEST OBJECT DESCRIPTION

The tested objects were two current transformers type **PA145a** manufactured by ABB Sp. z o.o. Division in Przasnysz, 06-300 Przasnysz, ul. Leszno 59, different construction:

1. **PA145a 300-600A nr ser. 87181/14** of creepage distance of insulator **1005 mm** ,
2. **PA145a 150-300A nr ser. 87182/14** of creepage distance of insulator **1119 mm.**

Identification of tested objects was performed on the basis of dimensional drawing and pictures of nameplates attached to hereby Report.

3. SCOPE OF TESTS AGREED UPON

According to the order tests were carried out according to the following requirements:

- PN-EN 61869-1:2009 „Przekładniki – Część 1: Wymagania ogólne"
  (idt. IEC 61869-1:2007 „Instrument transformers" – Part 1: General requirements")
  – p. 7.2.4
- PN-EN 60060-1:2011 „Wysokonapięciowa technika probiercza – Część 1: Ogólne definicje i wymagania probiercze"
  (idt. IEC 60060-1:2010 „High-voltage test techniques – Part 1: General definitions and test requirements")
  – p. 4.4

In accordance with the requirements of the Customer wet power-frequency voltage test was carried out with the following voltage values:

Current transformer PA145a 300-600A nr ser. 87181/14 - test voltage Up = 230 kV

Current transformer PA145a 150-300A nr ser. 87182/14 - test voltage Up = 275 kV

4. PERFORMED TESTS AND RESULTS

Wet power-frequency voltage test was performed in TuR 700kV transformer test system, 0,5A. The respective circuit scheme is shown on figure 1.

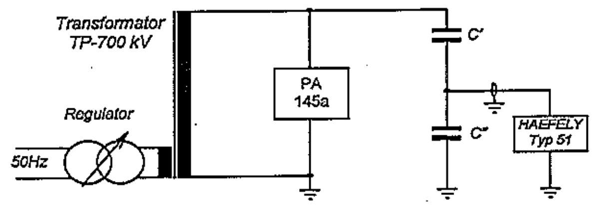


Fig. 1 Simplified diagram of the power-frequency measurement system
C = 200 pF (C' in series with C")

Measurement uncertainty - 1,5 % of the measured value for the confidence interval 95% and k=2.

During wet test the transformers were wetting by artificial rain with parameters:
- vertical component of precipitation H_v = 1,7 mm/min
- horizontal component of precipitation H_h = 1,6 mm/min
- water electrical conductivity σ= 108 μS/cm

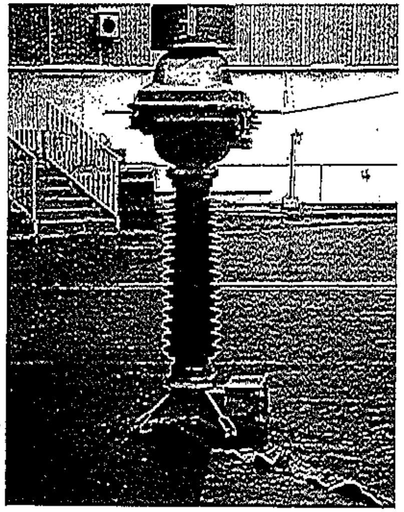
The test voltage was corrected according to air density (T=12°C, p=999hPa).

Test voltage was applied during 1 minute.

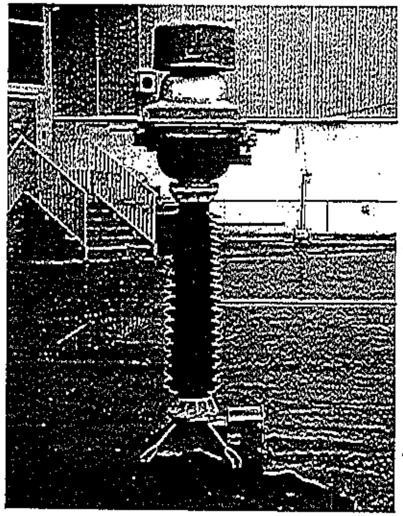
TEST RESULTS

- **Current transformer PA145a 300-600A No. 87181/14, Up=230kV**
  During test were not observed any flashover or failure of insulation.
  Test result - POSITIVE.
- **Current transformer PA145a 150-300A nr ser. 87182/14, Up=275kV**
  During test were not observed any flashover or failure of insulation.
  Test result - POSITIVE.

Tested transformers are shown in the photographs 1 and 2



Phot. 1 Current transformer PA145a 300-600A No. 87181/14 in wet test.



Phot. 2 Current transformer PA145a 150-300A nr ser. 87182/14 in wet test.

5. APPENDIXES: DOCUMENTS PROVIDET BY CUSTOMER

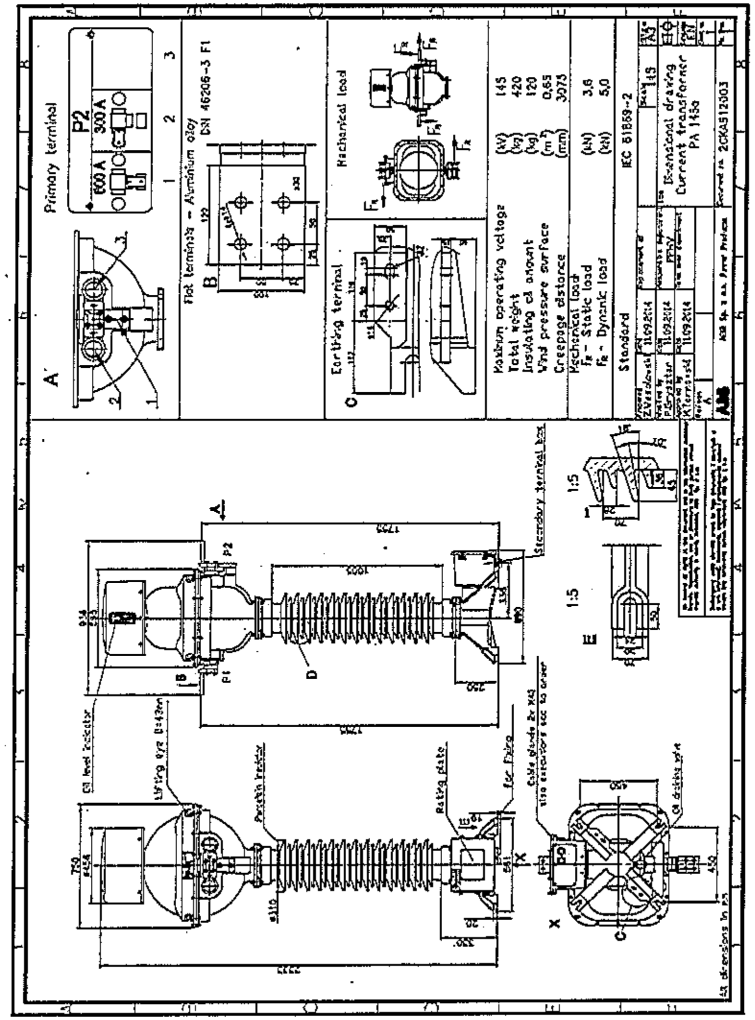


Fig. 2 Dimensional drawing of transformer PA145a 300-600A No. 87181/14

POLAND 01-330 WARSZAWA, ul. Mory 8, tel. +48223451242
fax. +48228368048, e-mail: ewn@ien.com.pl

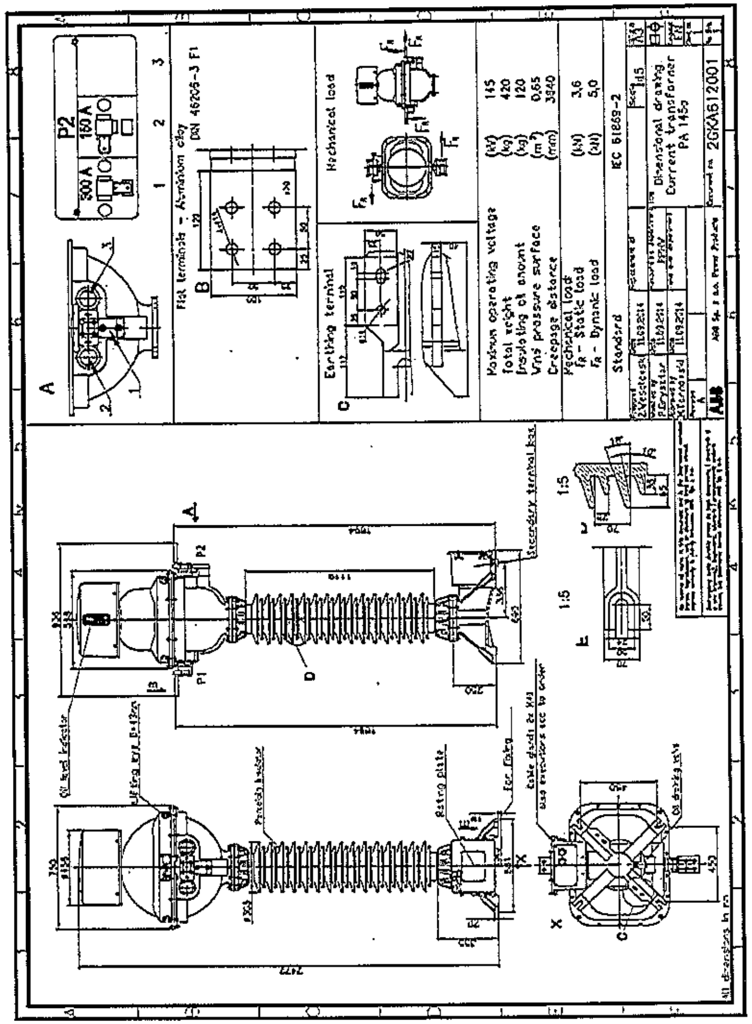


Fig. 3 Dimensional drawing of transformer PA145a 150-300A nr ser. 87182/14

HIGH VOLTAGE LABORATORY
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fax. +48228368048, e-mail: ewn@ien.com.pl
EWN/39/E/15

ABB

Current Transformer — Type: PA 145a

Insulation level: 145/275/650 kV | Standard: IEC 61869-2 | fn: 50 Hz
Oil type: Nytro Libra | Weight / Oil weight: 420 / 120 kg | Temp. range: -40°C — +40°C
S/N: 2GKP014A1287181

K_n: 300-600/5-5-1 A/A
$I_{th}/1s$: 40-40 kA | I_{dyn}: 100-100 kA
I_{cth}: 450-900 A

	A	VA	Class	FS/ALF	Ext.%
1S1-1S2	5	40	0,2	5	150
2S1-2S2	5	60	5P	20	
3S1-3S2	1	120	10P	15	
4S1-4S2					
5S1-5S2					
6S1-6S2					

Transportation: Vertical / Horizontal

Fig. 4 Rated nameplate of transformer PA145a 300-600A No. 87181/14

ABB

Current Transformer — Type: PA 145a

Insulation level: 145/275/650 kV | Standard: PN-EN 61869-2 | fn: 50 Hz
Oil type: Nytro Libra | Weight / Oil weight: 420 / 120 kg | Temp. range: -40°C — +40°C
S/N: 2GKP014A1287182

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

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

Transportation: Vertical / Horizontal

Fig. 5 Rated nameplate of transformer PA145a 150-300A No. 87182/14

LABORATORIUM WYSOKICH NAPIĘĆ

INSTYTUTU ENERGETYKI

LABORATORY ACCREDITED
BY THE POLISH CENTRE FOR ACCREDITATION
Accreditation Certificate of Testing Laboratory
No AB 272

PCA
AB 272

TEST REPORT

No. EWN/11/E/12-2

Tests of current instrument transformer type PA 123 (PA 145) for insulation level LI 650kV/AC 275kV, manufactured by ABB sp. z o.o.

Warsaw, March 2012

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TESTS REPORTS No EWN/11/E/12-2

TEST OBJECT:	Current instrument transformer type PA 123 (PA145) Serial No: 2GKP011A1084700 (84700/11)
TEST ORDERED BY:	ABB Sp. z o.o. 04-713 Warszawa, ul. Żegańska 1
ORDER NO:	4500380553/2 – 20.01.2012
SCOPE OF TEST:	Selected type tests and special tests
PROCEDURA OF TESTS:	in accordance with standards: PN-EN 60044-1:2000 (EN 60044-1:1999)
RECEIVING OBJECT DATE:	January 2012
DATE OF TESTS:	January 2012 – March 2012
TESTS RESULTS:	are presented in following parts of report Test results are concern to tested object only.

Tests was performed in witness of representatives of ABB sp. z o.o. :

Marcin TARNOWSKI M.Sc.E.E.
Paweł DĘBSKI M.Sc.E.E.
Jarosław DUZDOWSKI M.Sc.E.E.
Zbigniew WESOŁOWSKI M.Sc.E.E.

TEST PERFORMER:	Jan SZOKALSKI M.Sc.E.E.	SIGNATURE
TEST OVERSEERER:	Jerzy MIKOŁAJCZYK M.Sc.E.E.	SIGNATURE
HEAD OF HIGH VOLTAGE DEPARTMENT:	January L. MIKULSKI, Ass. Prof., Dr. hab. E. E.	SIGNATURE

Warsaw, March 2012

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CONTENTS

The Report contain:
18 numbered pages
In Report are presented:
5 drawing
1 numbered table
6 appendixes
and non numbered diagrams and tables

1. COMPETENCE OF THE LABORATORY

The High Voltage Laboratory of Institute of Power Engineering (IEn) in Warsaw is in possession of accreditation issued by the Polish Centre for Accreditation (Accreditation Certificate of Testing Laboratory No AB 272) concerning following tests:

Insulators and insulator strings	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Distribution substations	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Circuit breakers, disconnectors	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Insulators	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
	–	radio interference measurements
Current and voltage transformers	–	**lightning and switching impulse tests**
	–	**power-frequency voltage 50 Hz tests**
Power transformers	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
Lightning arresters and limiters	–	lightning and switching impulse tests
	–	power-frequency voltage 50 Hz tests
Cables and cable fittings	–	lightning and switching impulse tests

Note! Tests described in sub-clauses 4.8, hereby Report are not comply the scope of Laboratory accreditation.
Hereby Report concerning test results obtained in other competent laboratories - (see Appendixes 2,3) :

- Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw having Accreditation Certificate PCA Nr AB 324
- High Current Laboratory of Institute of Power Engineering in Warsaw having Accreditation Certificate PCA Nr AB 323
- Factory Laboratory of ABB sp. z o.o. in Przasnysz - Regional Verification Office in Warsaw - determination of errors and test in range of type tests at supervision of representative of High Voltage Laboratory of Institute of Power Engineering in Warsaw.

2. DESCRIPTION OF TEST OBJECT

The tested object was current instrument transformer type PA 123 (Pa 145) manufactured by ABB sp. z o.o. 04-713 Warszawa, ul. Żegańska 1, had following parameters:

Serial number 2GKP011A1084700 (84703/11)

- Rated primary current — 50 – 100 – 200 A
- Rated short-time current I_{th}/1s — 40 – 50 – 50 kA
- Rated dynamic current I dyn — 100 – 125 – 125 kA
- Rated frequency — 50 Hz
- Rated insulation level — LI 550kV/ AC 230kV*)
- Minimum creepage distance — 3800 mm (composite insulator)

*) **Attention ! All voltarge test was performed for insulation level LI 650kV/AC 275kV (for current transformer type PA 145).**

View of rated nameplates of tested transformers show figure 1.

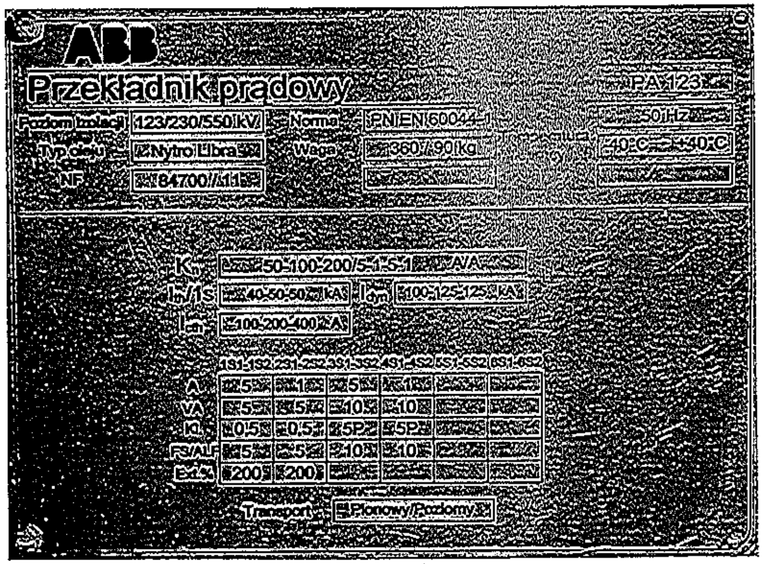

Fig. 1 Rated nameplate of tested transformer

Identification of tested object was done at following documents attached to hereby Report (Appendix 1):

- Manufacturer Conformity Declaration,
- Dimension drawing No. 2GKA614117 (19.01.2012),
- Electric diagram of Current instrument transformer,
- Drawing of rated nameplate.

3. AGREED SCOPE OF TESTS

According to ordered selected tests were done comply following standards:

- PN-EN 60044-1:2000 + A1:2003 +A2:2004 „Przekładniki. Część 1: Przekładniki prądowe" (EN-60044-1:1999 + A1:2000 + A2:2003 „Instrument transformers. Part 1: Current transformers").

On request of ordering party the additional special test were performed. The performed test results are contained in Table 1.

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Table 1. List of performed tests

Item	Performed tests	Requirement
TYPE TESTS		
1	Lighting impulse test	PN EN 60044-1, p.7.3
2	Wet test for outdoor transformers	PN EN 60044-1, p.7.4
3	Determination of errors	PN EN 60044-1, p. 11.4, 11.6, 12.4
4	Measurement of the radio interference voltage (RIV)	PN EN 60044-1/A1, p. 7.5
SPECIAL TESTS		
5	Chopped impulse test on the primary winding	PN EN 60044-1, p. 9.1
6	Measurement of capacitance and dielectric dissipation factor	PN EN 60044-1, p. 9.2
7	Mechanical test	PN EN 60044-1, p. 9.3
8	Transmitted overvoltage measurement	PN EN 60044-1/A2, p. 9.3

During mentioned above tests at Factory Laboratory of ABB sp. z o.o. in Przasnysz Leszno 59 Street, were performed determination of errors of transformer to prove positive results of consecutive tests. The complete tests were performed according to mentioned above standards. The tests were supervised by representatives of High Voltage Laboratory of Institute of Power Engineering in Warsaw in purpose to prove results of tests. The tests stands are under authority of Regional Verification Office in Warsaw (No. stand S08/OUM1-5/01 XVI i S08/OUM1-5/01 XVII).

4. PERFORMED TESTS

4.0 Routine test and determination of errors before tests in IEn and after tests finishing.

Before delivery the transformer to IEn Laboratory and after type test and special test completed in ABB Factory Laboratory in Przasnysz were performed determination of errors measurement under supervision of representative of IEn. During test were checked:

- verification of terminals marking,
- power-frequency withstand test on the primary winding 50 Hz, $U_{test} = 275$ kV, $t = 60$ s,
- partial discharge measurement for current transformers $q<10pC$ (U_m) $q < 5pC$ ($1{,}2 \cdot U_m/\sqrt{3}$),
- power-frequency withstand test on secondary windings 50 Hz, $U_{test} = 3$ kV, $t = 60$ s,
- power-frequency withstand test between sections 50 Hz, $U_{test} = 4{,}5$ kV, $t = 60$ s,
- determination of errors.

The test results are presented in reports attached to hereby Report (Appendix 2):

- Tests before type test and special test (Measurements before type test and special tests) - Report No. 2GKP011A1084700 – 19.01.2012,
- Tests after type test and special tests completed (Measurements after type test and special test completed) - 2GKP011A1084700 – 26.03.2012.

It were proved that all tests required in routine test gave positive results. It were proved that all metrological properties of transformer are comply accurate classes for all winding.

These tests results are base for later determination of errors for purpose of verification result of tests described below.

4.1 Lightning impulse test

Test was done in test arrangement of surge generator type Haefely 5 MV, 375 kJ. Equivalent circuit diagram is shows on Figure 2. The test was performed on standardized lightning impulse 1,2/50μs. The purpose of test was checking internal insulation of transformer. The influence of atmospheric condition on test voltage value was not taken into consideration.

The Lightning impulse test was performed jointly with chopped impulse test on the primary winding (clause 3.8 of hereby Report).

Test condition:

- Full impulse test voltage U = 650 kV,
- Chocked impulse test voltage 1,15 · 650 kV = 747,5 kV,
- Sequence of impulses:
  positive polarity – 15 full impulses,
  negative polarity – 1 full impulse, 2 chocked impulses, 14 full impulses,
- During test was recorded test voltage and current flowed through along of current transformer.

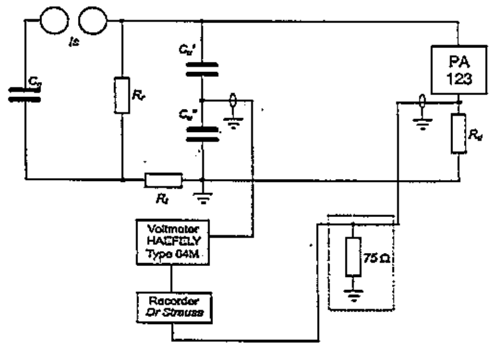

Fig. 2 Equivalent circuit diagram of test arrangement for lightning impulses:
C_g = 0,125 μF, C_u = 1,2 nF, R_t = 175 Ω, R_r = 600 Ω, R_d = 8,95 Ω.
Measurement uncertainty - 1,5 %

The oscillograms not shows failures of transformer insulation.
Result of test - positive.

Recorded oscillograms of all applied impulses are shown in Appendix No. 5 of hereby Report.

4.2 Wet test for outdoor transformers

The test was performed in arrangement of test transformer type TuR 700kV, 0,5A. according to standard PN-EN 60060-1:2011 (EN 60060-1:2010). Equivalent circuit diagram is presented on Figure 3.

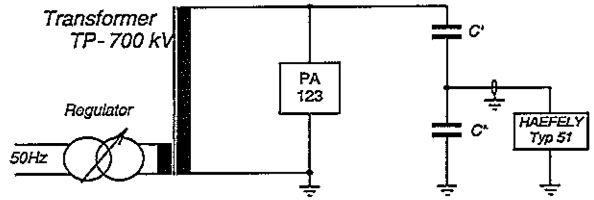

Fig. 3 Equivalent circuit diagram for power frequency voltage 50 Hz:
C = 200 pF (C' in series with C")
Measurement uncertainty - 1,5 %

During wet test for outdoor transformers the transformer was wetting by artificial rain at parameters:

- vertical component of precipitation H_v = 1,6 mm/min
- horizontal component of precipitation H_h = 1,7 mm/min
- water electrical resistivity ρ= 98 Ωm

The test voltage U=275 kV (corrected according to density of air) was applied during 1 minute.

During test were not observed any flashover or failure of insulation.
Test result - positive.

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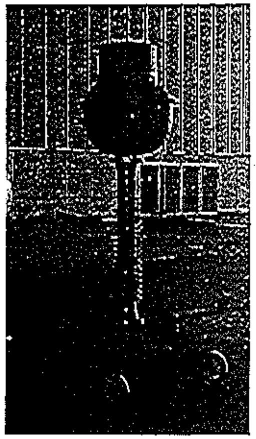


Fig. 4 Wet test of current transformers type PA 123 (PA 145) at power frequency voltage 50 Hz.

4.3 Determination of errors

4.3.1 Determination of errors

Measurements of errors for current transformers was performed in Factory Laboratory of ABB sp. z o.o. in Przasnysz 59 Leszno 59 Street, under supervision of representative of IEn.
The measurement was done two times:

- Tests before type test and special test (Measurements before type test and special tests) - Report No. 2GKP011A1084700 – 19.01.2012,
- Tests after type test and special tests completed (Measurements after type test and special test completed) - Report No. 2GKP011A1084700 – 26.03.2012.

Detailed information about tests results consists Appendix No. 2 of hereby Report.

Analyzing test results for current transformer was found that:

- **For measurement windings 1S1-1S2(5A) class 0,5S FS5 and 2S1-2S2(1A) class 0,5FS5:**
  - for currents 0,05 I_n current error $\Delta I(\%) < 1{,}5\%$
  and phase displacement δ_u(min) < 90 min.
  - for currents 0,20 I_n current error $\Delta I(\%) < 0{,}75\%$
  and phase displacement δ_u(min) < 45 min.
  - for currents 1,0 I_n i 1,2 I_n current error $\Delta I(\%) < 0{,}5\%$
  and phase displacement δ_u(min) < 30 min.
- **For protective windings 3S1-3S2(5A) class 5P10 and 4S1-2S2(1A) class 5P10:**
  - for currents 1,0 I_n current error $\Delta I(\%) < 1\%$
  and phase displacement δ_u(min) < 60 min.

For each of current windings values of error are contain in range compatible to appropriate class of accuracy.

4.3.2 Verification of instrument security factor FS of current part measurement windings of instrument transformer

The tested current transformer has two measurement windings:

1S1-1S2 → I_n= 5 A, S_n=5VA, class 0,5S FS5;

2S1-2S2 → I_n= 1 A, S_n=5VA, class 0,5 FS5.

The results of determination of core magnetization characteristics and veryfication of limiting e.m.f (check of instrument security factor (FS)) are present in Report No. 2GKP011A1084700 – 19.01.2012– (Appendix No. 2 of hereby Report).

It was found that instrument security factor FS is equal to 5 for measurement windings of current transformer is determined properly.

Test result - positive.

4.3.3 Verification of Limits of error ALF for protective winding of current part of instrument transformer

The tested combined transformer has two windings for protection purposes:

3S1-3S2 → I_n= 5 A, S_n=10VA, class 5P10;

4S1-4S2 → I_n= 1 A, S_n=10VA, class 5P10.

The results of determination of core magnetization characteristics and veryfication of limiting e.m.f (check of accuracy limit factor (ALF)) are present in No. 2GKP011A1084700 – 19.01.2012– (Appendix No. 2 of hereby Report).

It was found that limit of error ALF equal 10 for windings for protection of current transformer is determined properly.

Test result - positive.

4.4 Radio interference voltage measurement

Following to requirement of IEC/CISPR 18-2 the measurements was performed in testing arrangement as is show on Figure 5. The interference voltage was measured on resistance 300Ω at frequency 0,5 MHz. To determinate coefficient of correction +24 dB before measurement the instrument was calibrated by stabile signal generator . To measurement of interference voltage the instrument LMZ-5 was used. The level of background was checked for range of test voltages 0 - 150 kV. Interference voltages originated form testing arrangement, radio broadcasts etc., were below 5µV (14 dB).

According to PN EN 60044-1/A1 interference voltage at voltage $Up=1.1 \cdot U_m/\sqrt{3}=92$ kV has not to exceed the value $RIV_{dop}=2500\mu V$.

The instrument had logarithmic scale:

$RIV_{dop}=2500\mu V \rightarrow 68$ dB (0 dB = 1 µV).

Before the test, the instrument transformer was supplied with voltage $1{,}5 \cdot U_m/\sqrt{3}$, held for 30 sec. Next, within about 10 sec the voltage was decreased to value $1{,}1 \cdot U_m/\sqrt{3}$, held for 30 sec.

The measurements were done at test voltages in range $0{,}3 \div 1{,}1 \cdot U_m/\sqrt{3}$ .Test voltage was decreased step by step with value 0,1xUp since $Up=1{,}1 \cdot U_m/\sqrt{3}$ up to value $Up=0{,}3 \cdot U_m/\sqrt{3}$. Next, voltage was increased by this same values and finally deceased again.. For each of test voltage the measurement of radio interference voltage were performed and registered level in last series of decreasing voltage was drawn in function of test voltage Utest.

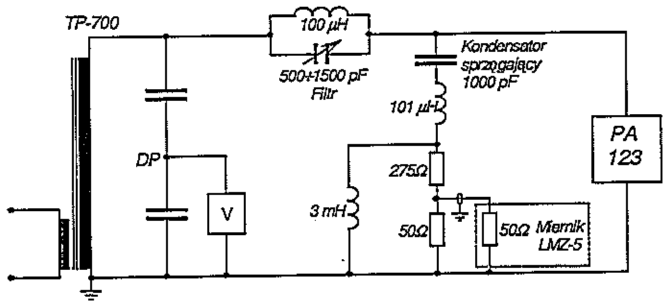
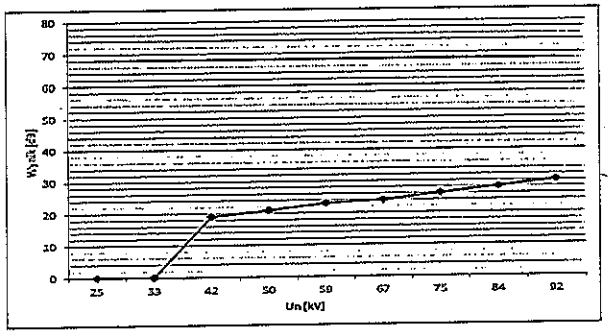


Fig. 5 Test arrangement for Radio interference voltage measurement

The results of measurements are present in Table and diagram below.

Up [kV]		92	84	75	67	59	50	42	33	25
xUn/√3		1,1	1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3
[dB]	→	6	5	2	0	-1	-2	-5	-	-
	←	6	3	2	0	-1	-3	-5	-	-
	→	6	3	2	0	-1	-3	-5	-	-
Wynik	[dB]	30	28	26	24	23	21	19	-	-
	[µV]	32	25	20	16	14	11	9	-	-



Measured Radio Interference Voltage RIV = 32 µV (30dB) is much less than permissible level RIV_{perm} = 2500 µV (68dB).

Test result - positive.

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4.5 Chopped impulse test on the primary winding

Chopped Impulse Test was supplemented to Lightning Impulse test 1,2/50µs and was described in clause 4.3 of hereby Report.

Recorded oscillograms not show of failure of insulation of current transformers. Test result - positive.

Oscillograms of all applied impulses are present in Appendix No. 4 of hereby Report.

4.6 Measurement of capacitance and dielectric dissipation factor

The measurement was performed st at ABB's Factory Laboratory (Raports No. 2GKP011A1084700 – 19.01.2012 and No. No. 2GKP011A1084700 – 26.03.2012 of Factory Laboratory ABB sp. z o.o. Przasnysz Division).

Condition of measurements:

$U_P = 10$ kV; $110/\sqrt{3}$ kV = 63,5 kV; $123/\sqrt{3}$ kV = 71 kV

Ambient temperature during measurement was 22,2°C and (22,3°C).

Test results are present in table below:

Up [kV]	C_x [pF]	tgδ [%]
10	973 (973)	0,22 (0,22)
63,5	973 (973)	0,22 (0,22)
71	973 (973)	0,22 (0,22)

The standard specifications for capacitance and dissipation factor for instrument transformers not provide criterion for these parameters. The Standard **PN-EN 60044-1:2000 (EN 60044-1:1999) only contain note that value of dissipation factor is usually less than 0,5%.**

4.7 Mechanical tests

The mechanical tests were performed in Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw. The test consist in applying to the transformer mechanical load – static and dynamic, in three direction in turn. Static load was 20% higher than standard requirement for II class of load. The test conditions were as follow:

$F_R = 3600$ N, $t = 60$ s

It was assumed that dynamic load is 1,4 times higher than static load.

During the tests behaving of current transformer was correct. After test not stated any damages or oil leakage.

Test result - positive.

Detailed information about test arrangement, performed tests and tests results are present in Report No. EUR/12/E/12-1E – 28.03.2012 – (Appendix 3)

4.10 Transmitted overvoltage measurement

During the test to the HV terminal of transformer were applied impulse voltage.

It were recorded maximal value of overvoltages which came in each secondary windings - both current and voltage. According to requirement of Standard for impulse 0,5/50 µs and value U_{test}=1,6 x $\sqrt{2}$ x $U_m/\sqrt{3}$ ≅ 189 kV the values of transmitted overvoltages can not exceed 1,6 kV.

During all measurements to the transformer were applied lightning impulses at value ten times less, that is U_I= 16 kV. Concerning linear of phenomenon, registered overvoltages should have values less than 160 V (peak-to- peak value).

Registration was don by digital oscilloscope of "Dr Strauss" with input impedance 50 Ω and transmission band 200 MHz.

Results of test are present in table below.

Winding	Overvoltage value $U_{pp}/2 \times 10$ [V]
1S1-1S2	346
2S1-2S2	314
3S1-3S2	420
4S1-4S2	398

It was found that for each of secondary winding of transformer transmitted overvoltages not exceed value of 1600 V.

Test result - positive.

The oscillograms of all applied and registered impulses are present in Appendix No. 6 of hereby Report.

5. SUMMARY

- The current instruments transformer type PA 123 (PA 145) manufactured by ABB sp. z o.o. 04-713 Warszawa, ul. Żegańska 1, with parameters described in clause 2 of hereby Report and identified on base provided documents (as presented in Appendix No. 1) was performed.
- The current instruments transformer type PA 123 (PA 145) for insulation level LI 650kV/ /AC 275kV **passed positively** selected type test according to requirement of standard:

- PN-EN 60044-1:2000 + A1:2003 +A2:2004 „Przekładniki. Część 1: Przekładniki prądowe" (EN-60044-1:1999 + A1:2000 + A2:2003 „Instrument transformers. Part 1: Current transformers").

and according program described in Table 1, clause 3 of hereby Report.

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6. LIST OF APPENDIXES

Appendix No. 1

Documents provided by ABB Sp. z o.o. used as base of identification of test object:

- Manufacturer Conformity Declaration
- Dimension drawing No. 2GKA614117 (19.01.2012)
- Electric diagram of Current instrument transformer
- Drawing of rated nameplate

Appendix No. 2

Reports of routine test and determination of errors of current transformer type PA 123 performed in Factory Laboratory of ABB sp. z o.o.

- Tests before type test and special test (Measurements before type test and special tests) - Report No. 2GKP011A1084700 – 19.01.2012,
- Tests after type test and special tests completed (Measurements after type test and special test completed) - 2GKP011A1084700 – 26.03.2012.

Appendix No. 3

Report of performed tests in Distribution Equipment Laboratory of Institute of Power Engineering in Warsaw.

- Test Report No. EUR/12/E/12-1E (Mechanical tests.)

Appendix No. 4

Lightning impulse test. Impulse 1,2/50 µs, full and chopped:

- Oscillograms of test currents and detection currents.

Appendix No. 5

Transmitted overvoltage measurement:

- Oscillograms of measured transmitted to secondary windings overvoltages.

M. Pożaryskiego 28; 04-703 WARSZAWA, Poland, tel. (+48 22) 812 23 38 fax. (+48 22) 812 04 07

TEST REPORT No. 8281/NZL/NBR/2012

Object of tests:	**Secondary terminal box of HV combined transformer**
Manufacturer:	**ABB Sp. z o.o., ul. Żegańska 1, 04-713 Warszawa Oddział w Przasnyszu, 06-300 Przasnysz/Poland, ul. Leszno 59**
Test performed:	Verification of the degree of protection IP55
Normative document:	PN-EN 60529:2003, EN 60529:1991 + A1:2000, IDT
Ordered by:	**ABB Sp. z o.o., ul. Żegańska 1, 04-713 Warszawa Oddział w Przasnyszu, 06-300 Przasnysz/Poland, ul. Leszno 59**

Contract/Order No.: BSK/579/NZL/2012 on 12.07.2012	Reference number: 504-023826/038
Objects delivered for tests: 09.07.2012	Date of tests completion: 10.07.2012

The test results presented in this report relate only to the samples tested.

ilac-MRA PCA POLSKIE CENTRUM AKREDYTACJI BADANIA AB 074

The Switchgear and Controlgear Testing Laboratory of the Electrotechnical Institute is accredited by Polish Centre of Accreditation in accordance with PN-EN ISO/IEC 17025:2005 in the scope of:
testing of low and high voltage alternating and direct current switchgear and controlgear
ACCREDITATION CERTYFICATE No. AB 074

Tested by: Janusz Domański, M.Sc. Eng.

Head of the Team of Laboratories IEl: Robert Franaszek, M.Sc. Eng.

WARSAW, 2012-07-13

This Test Report contains of 7 pages and 1 Annex.

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CONTENTS

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1. Location and time of tests

The tests were performed at Switchgear and Controlgear Testing Laboratory of the Electrotechnical Institute in Warsaw.

Date of tests: 09 and 10 July 2012.

2. Test object

The Manufacturer – **ABB Sp. z o.o., ul. Żegańska 1, 04-713 Warszawa Oddział w Przasnyszu/ Poland** has provided to tests the Secondary terminal box of HV combined transformer.

The technical documentation of the Secondary terminal box of HV combined transformer is given on Annex 1. The name plate of the combined transformer is given on Photo 1.

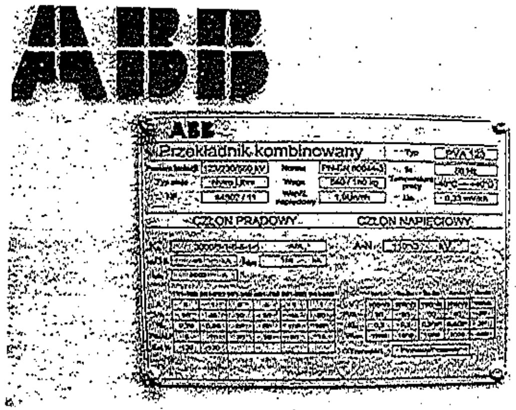

Photo 1 – The nameplate of HV combined transformer

3. Scope of tests

Verification of the degree of protection IP55 according to:

PN-EN 60529:2003 — Stopnie ochrony zapewnianej przez obudowy (Kod IP)
EN 60529:1991 + A1:2000, IDT — Degrees of protection provided by enclosures (IP Code)

The test results are given in Table bellow

Item	Test	Requirements acc. to	Testing acc. to	Test result
1	Visual inspection	PN-EN 60529:2003 Clause 11	PN-EN 60529:2003 Clause 11	Positive
2	Verification of the degree of protection IP5X	PN-EN 60529:2003 Clauses 5 and 11	PN-EN 60529:2003 Clauses 13.4 and 13.6	Positive
3	Verification of the degree of protection IPX5	PN-EN 60529:2003 Clauses 6 and 11	PN-EN 60529:2003 Clauses 14 and 14.2.5	Positive

4. Description and the test results

4.1. Visual inspection

Inspection was made according to PN-EN 60529:2003, Clause 11.

During inspection were checked:

- overall quality,
- compliance of the implementation with the design documentation and with the identification documents.

Test result of inspection is **positive.**

4.2. Verification of the degree of protection IP55

4.2.1. Verification of the degree of protection against solid foreign objects (IP5X)

Verification of the protection against solid foreign objects, indicated by the first characteristic numeral 5, was performed according to the PN-EN 60529:2003, Clauses 13.4 and 13.5.

The test was performed in the dust chamber type ST 2500 U. Secondary terminal box of HV combined transformer before test in the dust chamber is given on Photo 2, and after test – on Photo 3.

Test conditions during test:

- ambient air temperature – 25 °C
- relative humidity – 60 %
- atmospheric pressure – 1000 hPa
- working volume of dust chamber – 2,5 m^3
- duration of test – 8 h

After test no deposit of talcum powder was observed inside the box.

Test result of IP5X verification is **positive.**

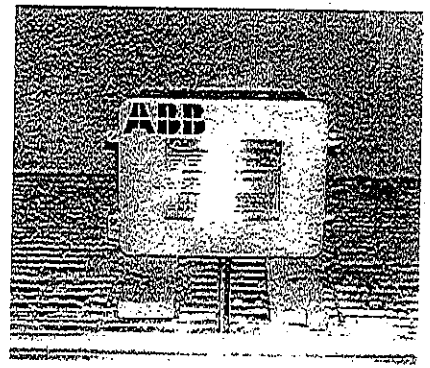

Photo 2 – Secondary terminal box in a dust chamber before IP5X test

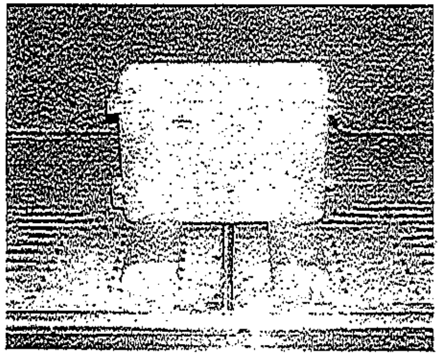

Photo 3 – Secondary terminal box in a dust chamber after IP5X test

4.2.2. Verification of the degree of protection against ingress of water (IPX5)

Verification of the protection against ingress of water, indicated by the first characteristic numeral 5, was performed according to the PN-EN 60529:2003, Clause 14.2.5.

The object under test, mounted as in normal use, was spread from all practicable directions with a stream of water from a standard test nozzle.

Test conditions:

- internal diameter of the nozzle – 6,3 mm
- rate of water flow – 12,5 l/min ± 5%
- distance from nozzle to box enclosure – (2,5 – 3,0) m
- test duration – 3 min

Secondary terminal box of HV combined transformer during IPX5 test is given on Photos 4 and 5.

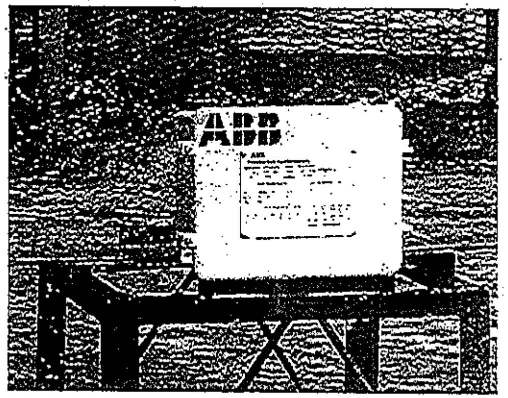

Photo 4 – Secondary terminal box of combined transformer during IPX5 test

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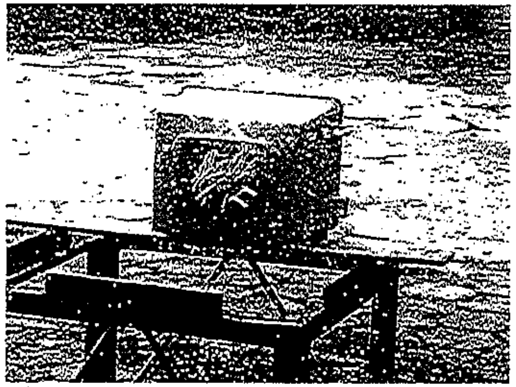

Photo 5 – Secondary terminal box of combined transformer during IPX5 test

After the IPX5 test inside the box was observed only a small amount of water. The water has entered through a vent – see Photo 6. The amount of water and its location does not indicate deterioration in working conditions of combined transformer or impair safety.

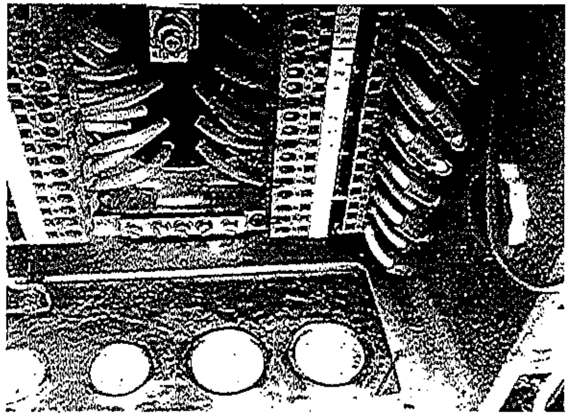

Photo 6 – Secondary terminal box of combined transformer after IPX5 test

The result of IPX5 verification is **positive.**

The verification results of the degree of protection IP55 provided by enclosure of the secondary terminal box of HV combined transformer is **positive.**

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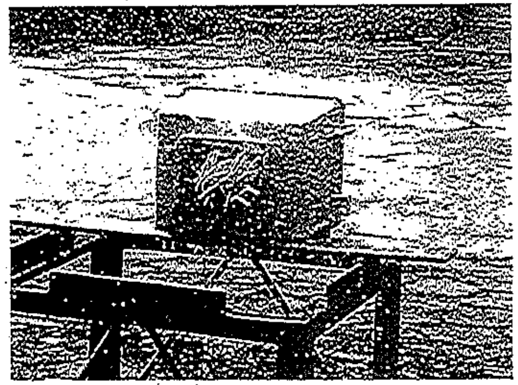


Photo 5 – Secondary terminal box of combined transformer during IPX5 test

After the IPX5 test inside the box was observed only a small amount of water. The water has entered through a vent – see Photo 6. The amount of water and its location does not indicate deterioration in working conditions of combined transformer or impair safety.

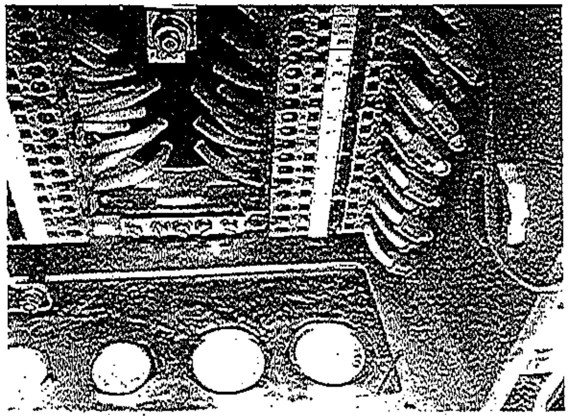


Photo 6 – Secondary terminal box of combined transformer after IPX5 test

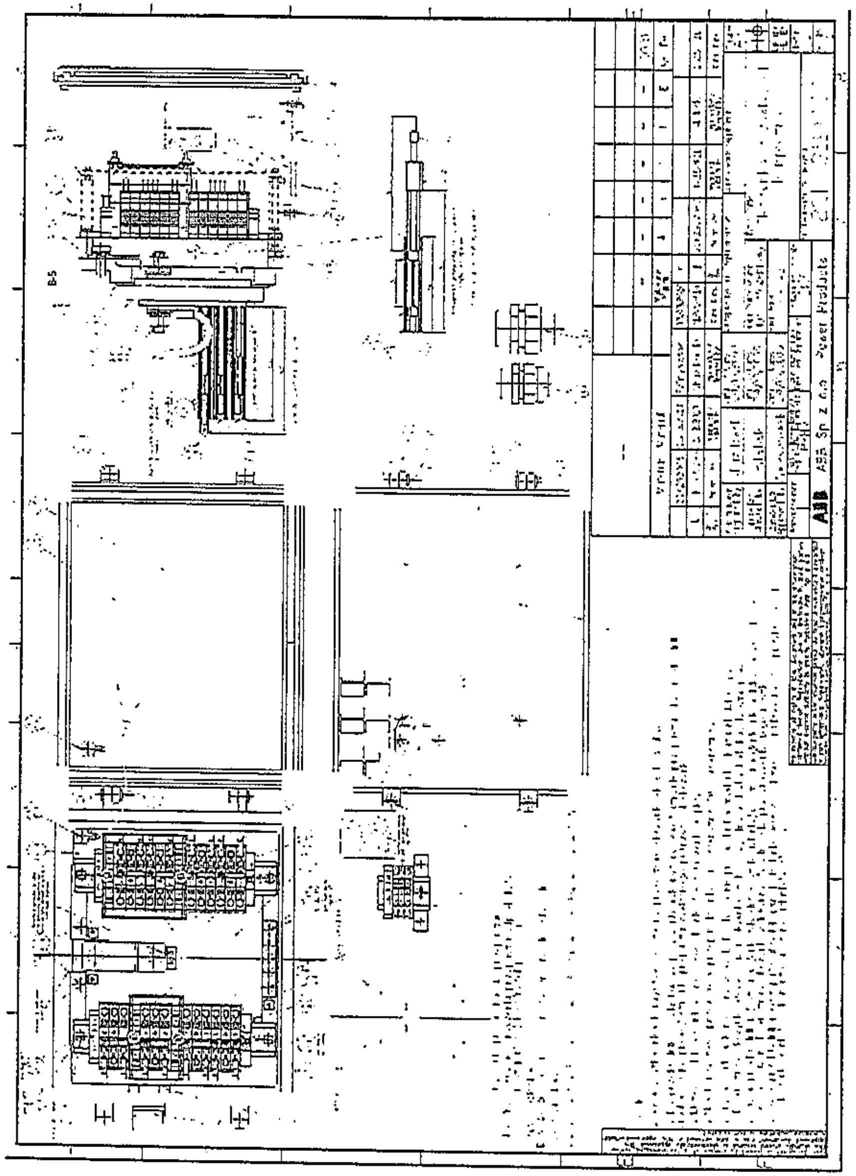
The result of IPX5 verification is **positive.**

The verification results of the degree of protection IP55 provided by enclosure of the secondary terminal box of HV combined transformer is **positive.**

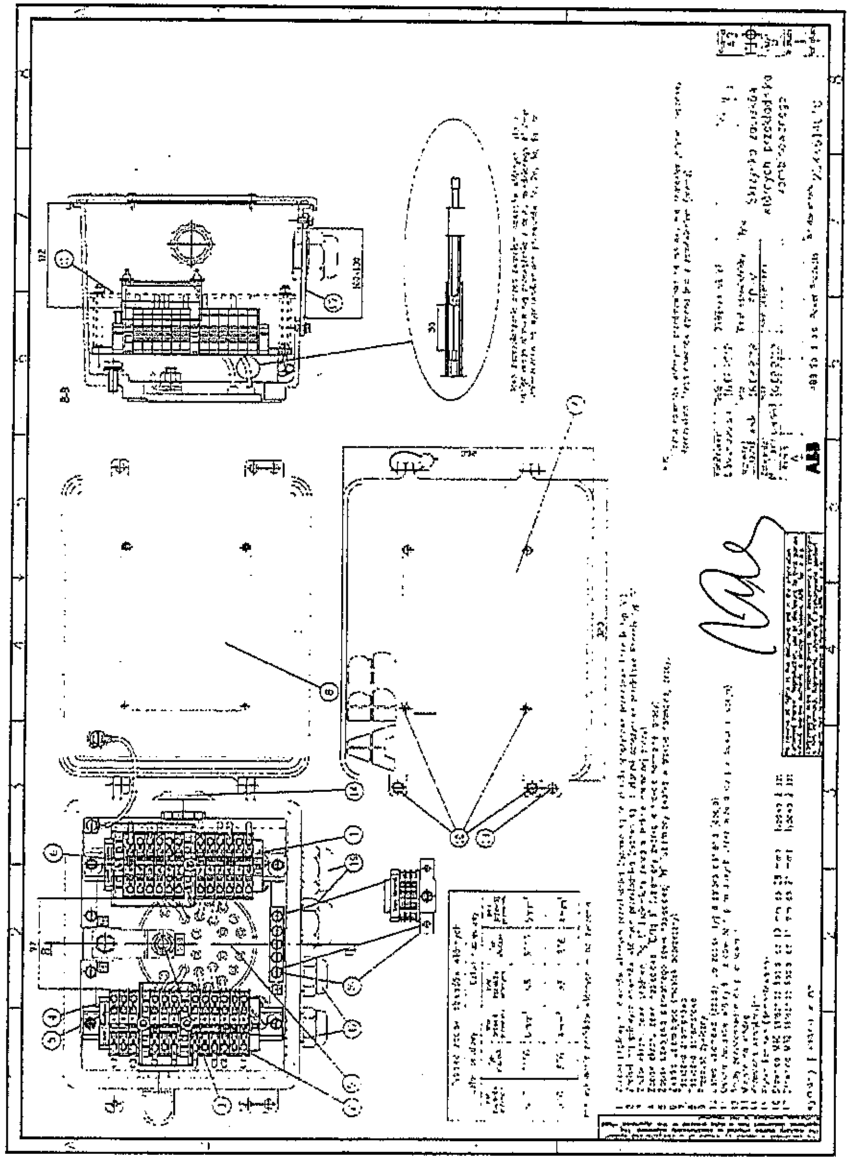
5. Conclusion

The secondary terminal box of HV combined transformer, designed according to the drawings No. 2GKK311093R and No. 2GKK614010 complies with the requirements of PN-EN 60529:2003 and EN 60529:1991 +A1:2000, stated for the degree of protection IP55.

IEL	LABORATRORIES OF THE ELECTROTECHNICAL INSTIUTE SWITCHGEAR AND CONTROLGEAR TESTING LABORATORY	Annex 1 to TEST REPORT No. 8281/NZL/NBR/2012 Page: 1 / 2



IEL	LABORATRORIES OF THE ELECTROTECHNICAL INSTIUTE SWITCHGEAR AND CONTROLGEAR TESTING LABORATORY	Annex 1 to TEST REPORT No. 8281/NZL/NBR/2012 Page: 2 / 7



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Issued by department	Last edit date	Lang.	Revision	Page
ZCCO/Poland/SST	2015-05-25	English	1.0	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 Nasierowski/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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TABLE OF CONTENTS

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.

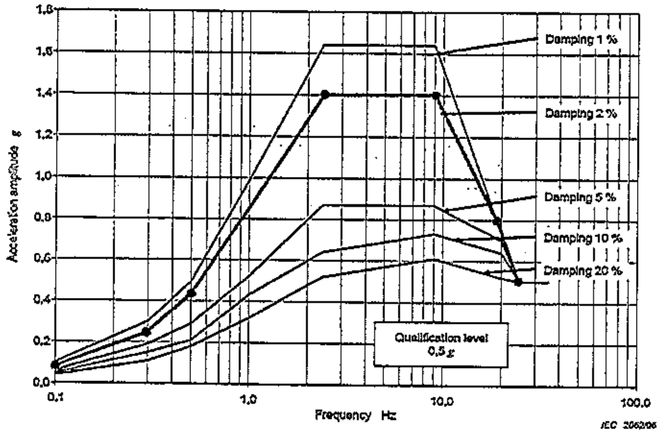

Figure 1. *Design response spectrum – 2% damping (red curve)*

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.

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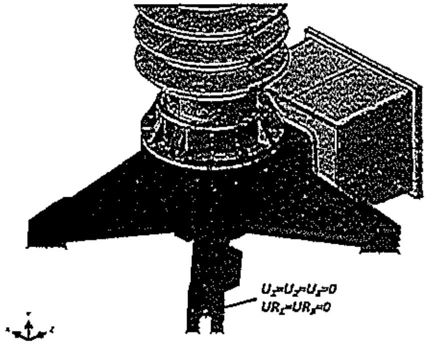

Figure 2. *Boundary conditions – general view*

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.

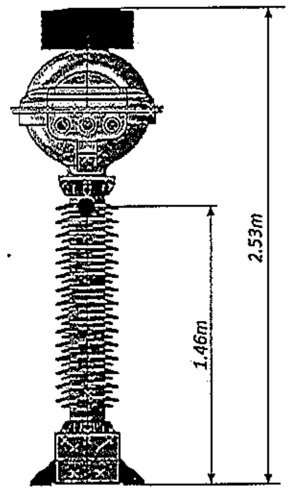

Figure 3. *Simplified representation of the PA 123a/PA 145a transformer*

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.

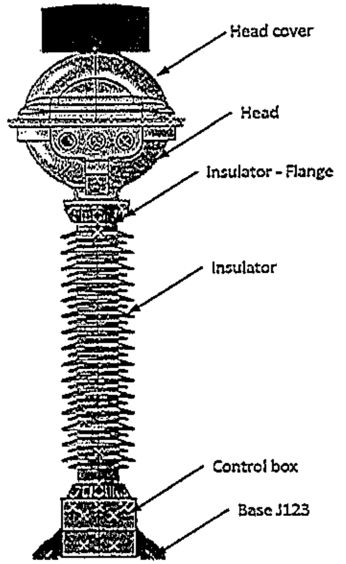

Figure 4. *Assembly – component naming*

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.

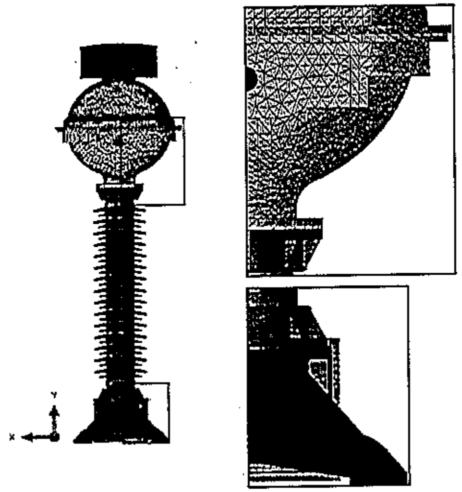

Figure 5. *FE model – general view*

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.

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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.

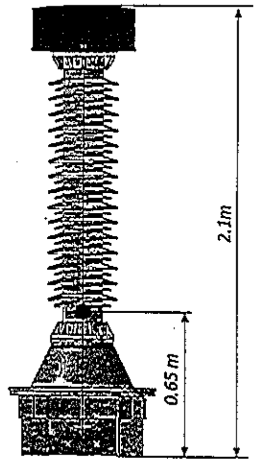

Figure 6. *Simplified representation of the PV 123 transformer*

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.

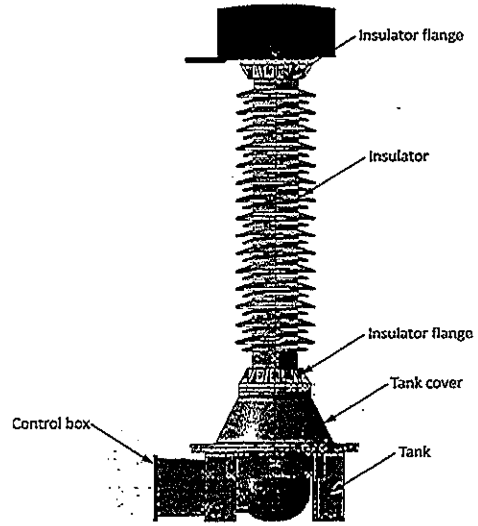

Figure 7. *Assembly – component naming*

Material and mass information is listed in Table 2.

Table 2. *Mass and material data*

Drawing number	Component name	Material name	Mass [kg]	Youngs 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.

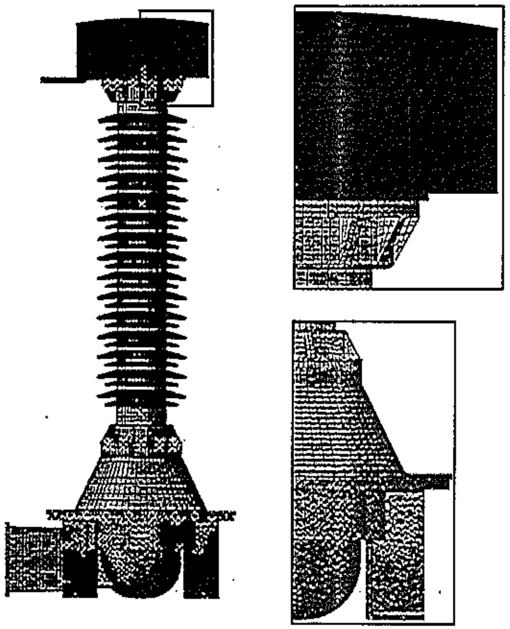

Figure 8. *FE model – general view*

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.

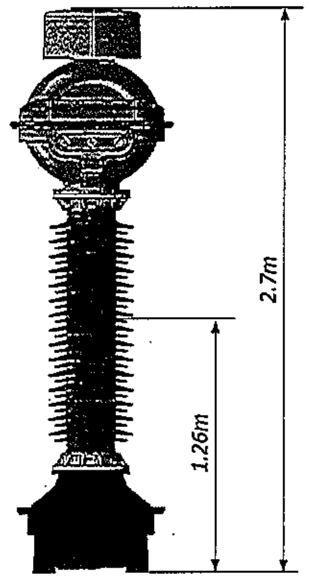

Figure 9. *Simplified representation of the PVA123a /PVA145a transformer*

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.

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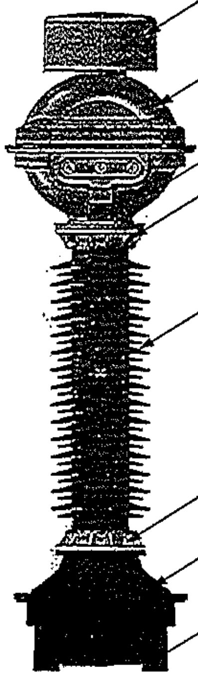

Figure 10. *Assembly – component naming*

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.

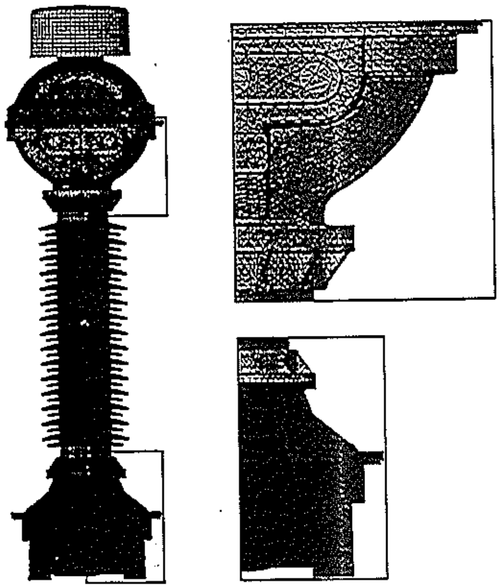

Figure 11. *FE model – general view*

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.

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.

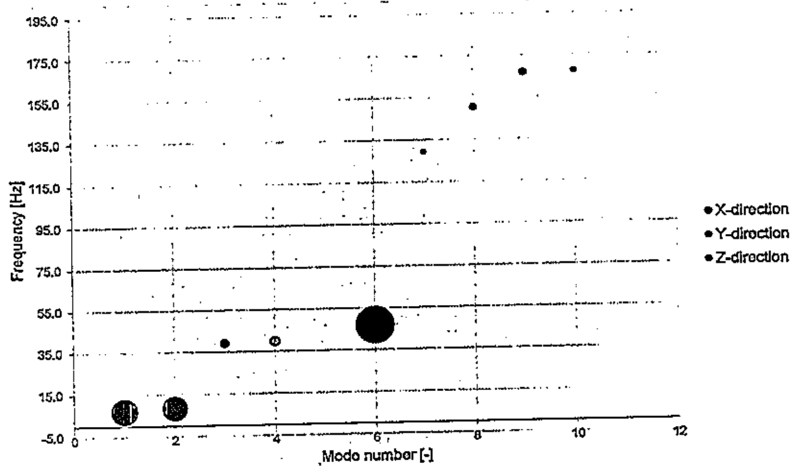

Figure 12. *Natural frequency extraction – effective modal mass*

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

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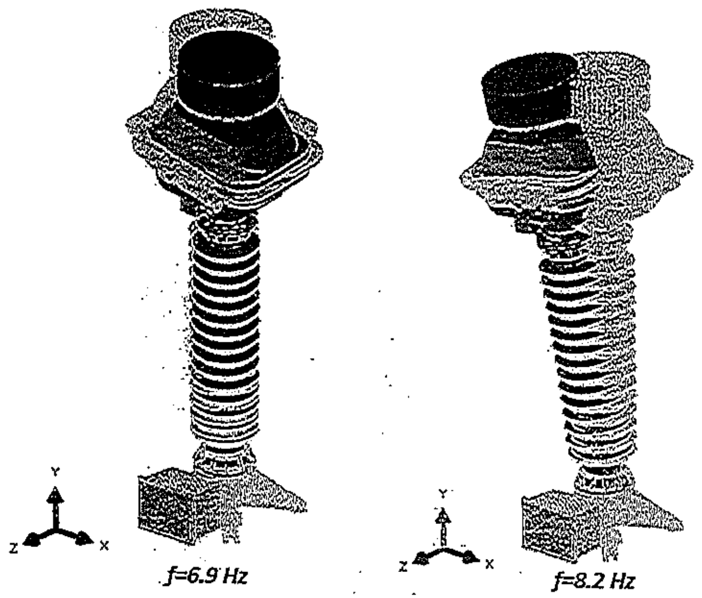

Figure 13. *Natural frequency extraction – mode shapes*

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.

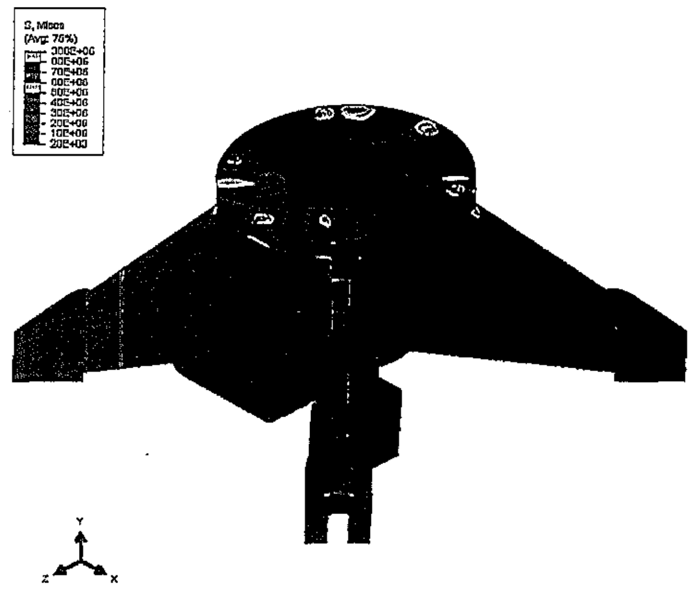

Figure 14. *Von-Mises stress [Pa] distribution – tank (view 01)*

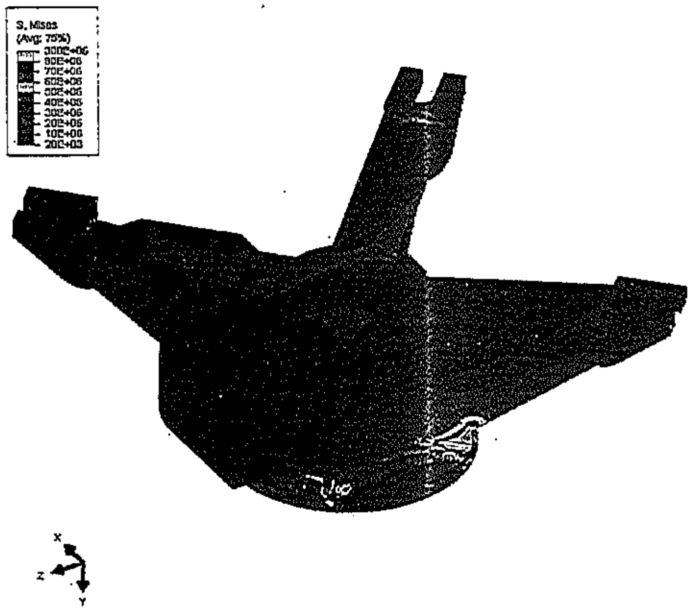

Figure 15. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 16.

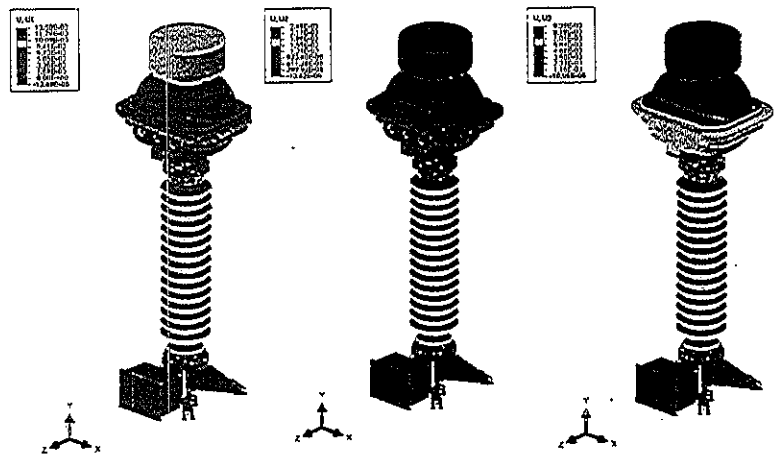

Figure 16.*Displacement [m] field - distribution*

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.

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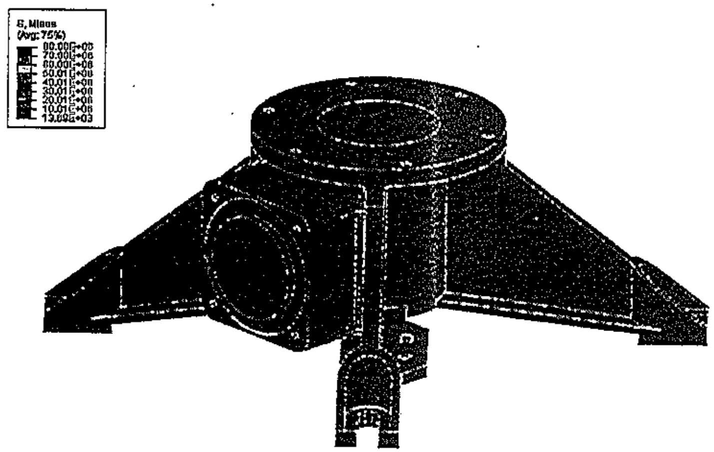

Figure 17. *Von-Mises stress [Pa] distribution (AF3) – tank (view 01)*

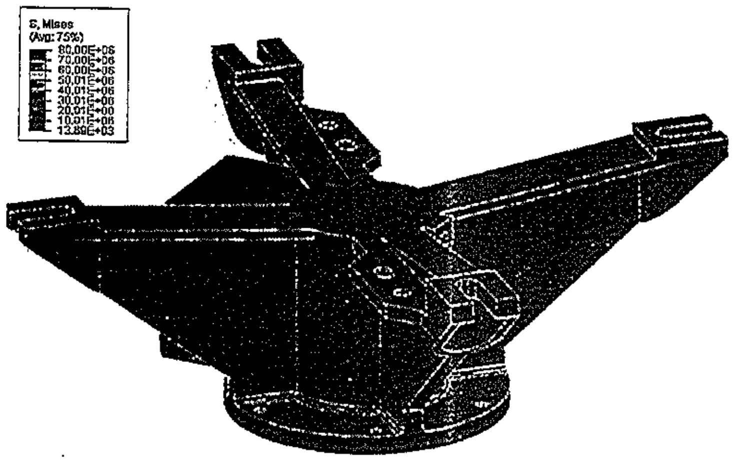

Figure 18. *Von-Mises stress [Pa] distribution (AF3) – tank (view 02)*

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.

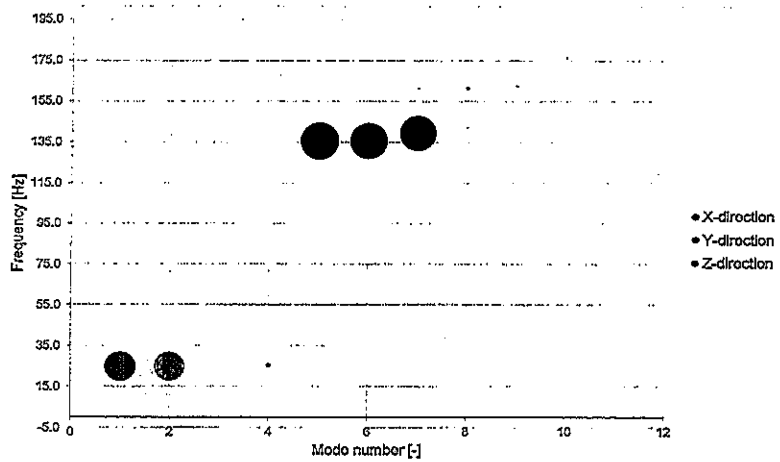

Figure 19. *Natural frequency extraction – effective modal mass*

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

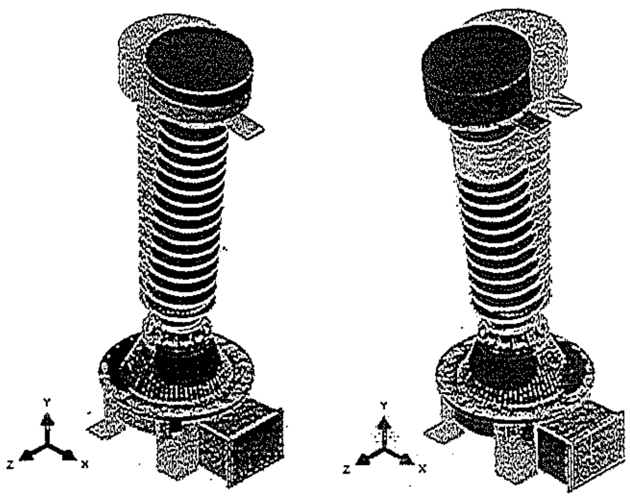

Figure 20. *Natural frequency extraction – mode shapes*

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%

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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.

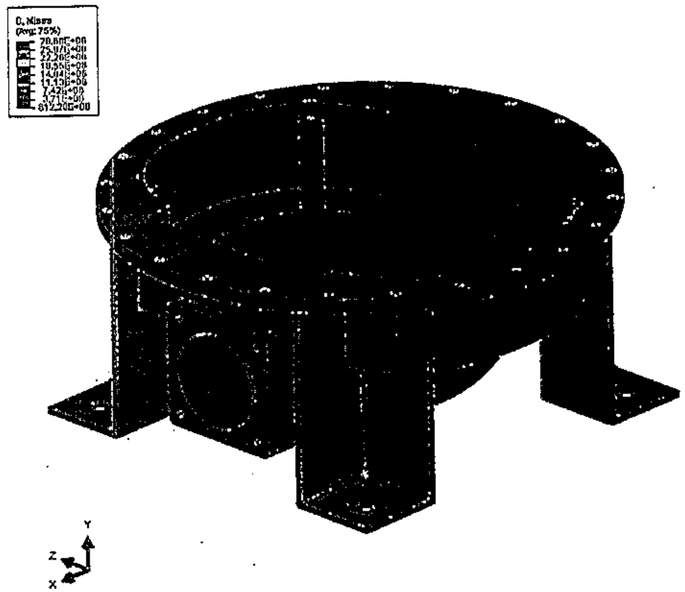

Figure 21. *Von-Mises stress [Pa] distribution – tank (view 01)*

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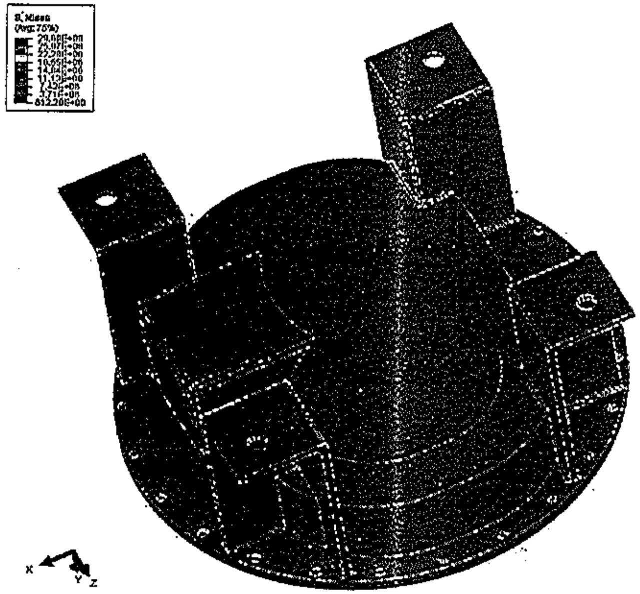

Figure 22. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 23.

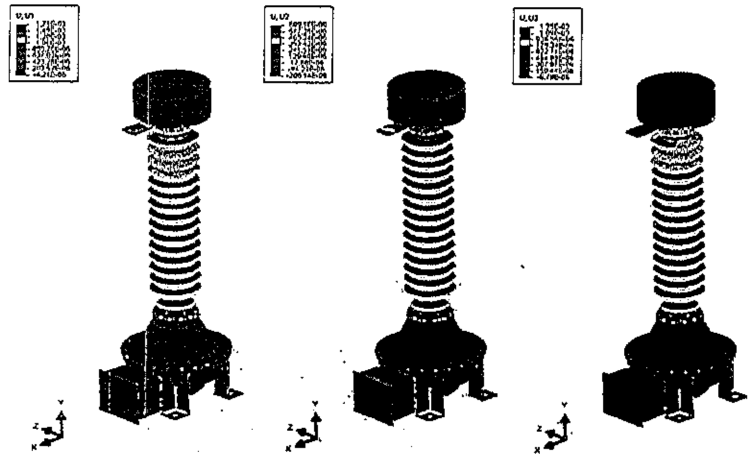

Figure 23.*Displacement [m] field - distribution*

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.

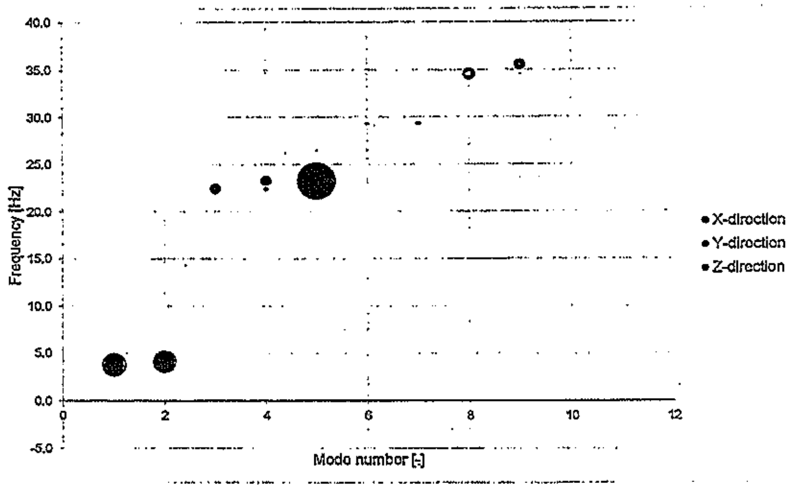

Figure 24. *Natural frequency extraction – effective modal mass*

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

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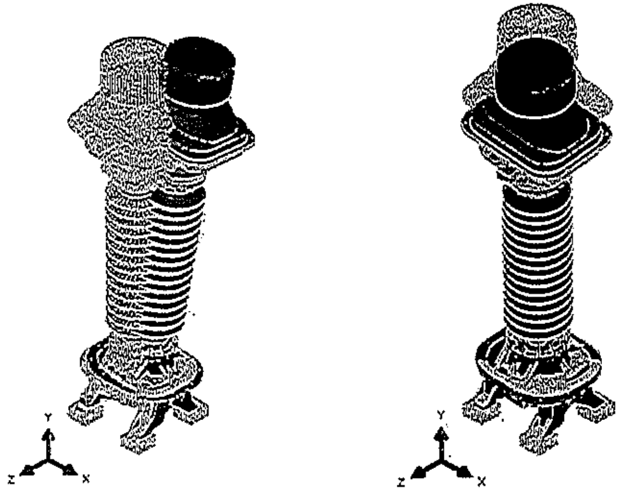

f=3.8 Hz *f=4.1 Hz*

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.

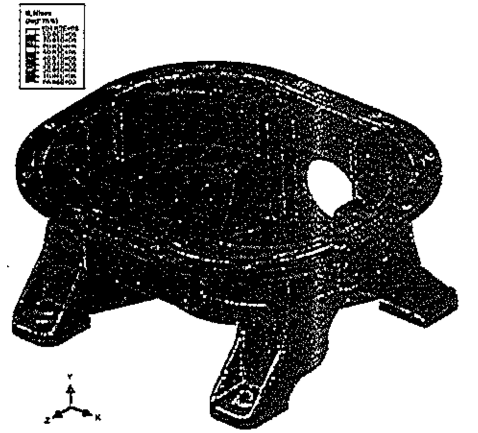

Figure 26. *Von-Mises stress [Pa] distribution – tank (view 01)*

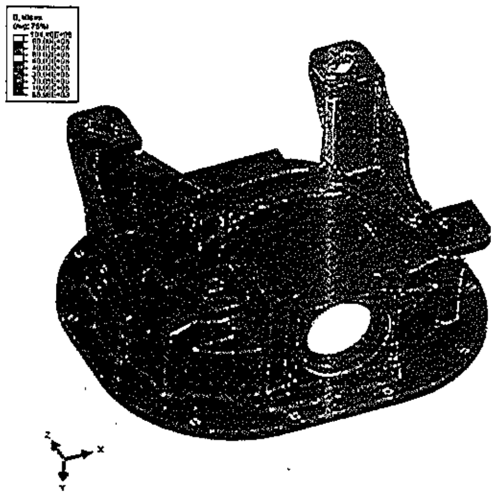

Figure 27. *Von-Mises stress [Pa] distribution – tank (view 02)*

Displacement field is presented in Figure 23.

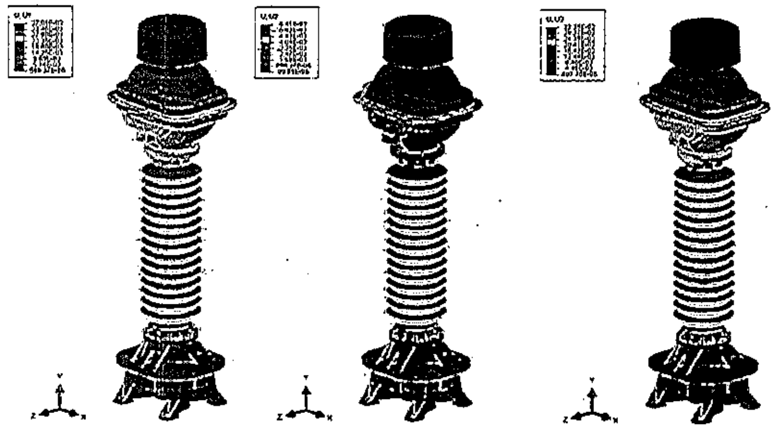

Figure 28.*Displacement [m] field - distribution*

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

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[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	Juszkiewicz Grzegorz	original document

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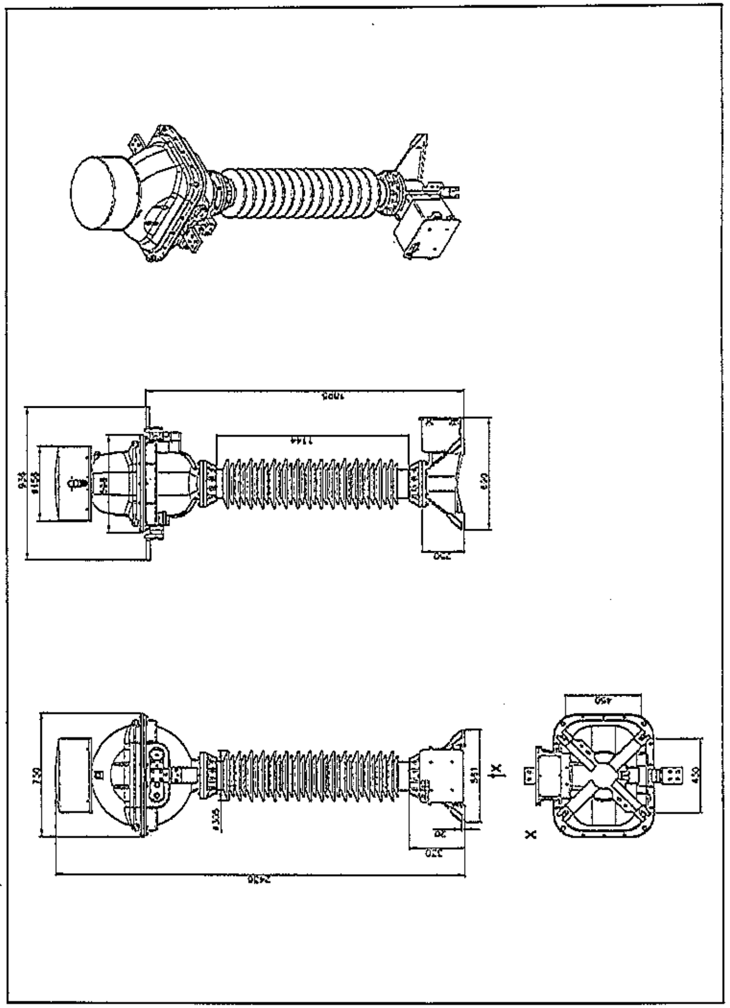
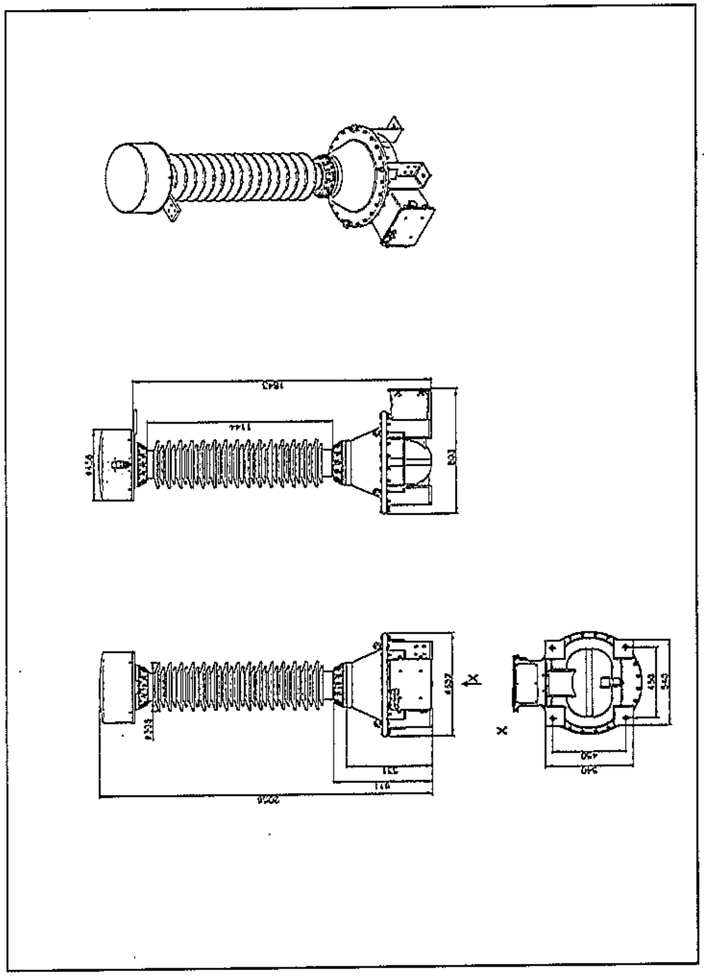
8 APPENDICES

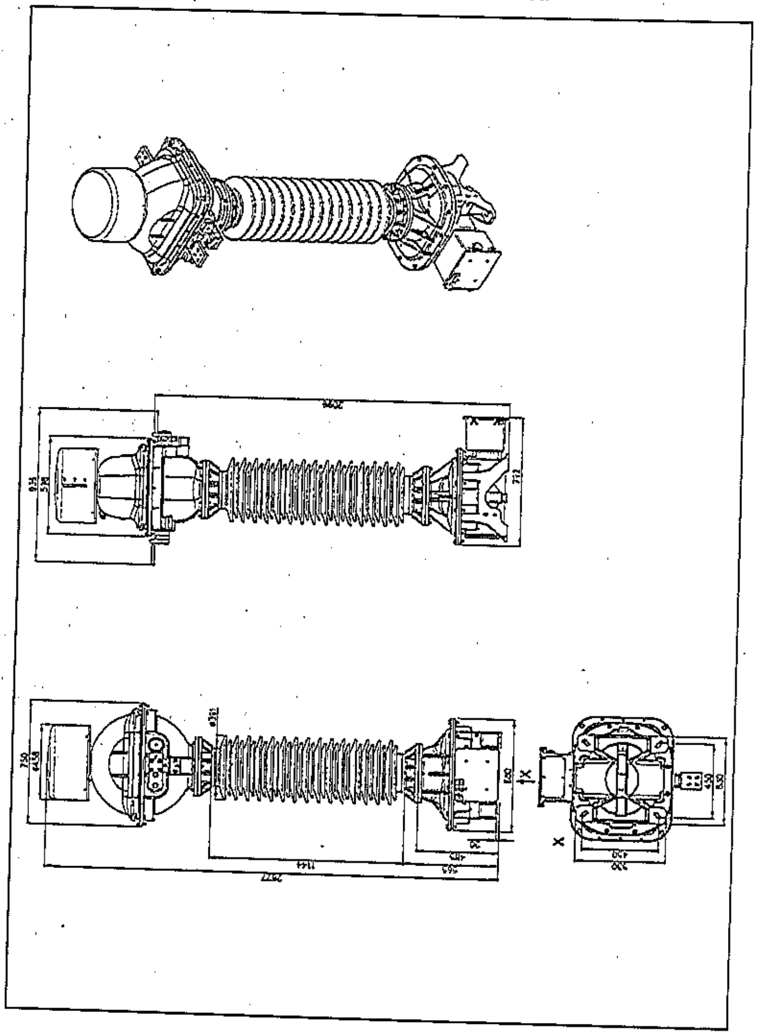
8.1 Current Instrument transformer PA123a/PA145a



8.2 Voltage Instrument transformer PV123



8.3 Combined Instrument transformer PVA123a /PVA145a



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