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实验室名称：苏州电器科学研究院股份有限公司
国家电器产品质量检验检测中心

Lab Name: Suzhou Electrical Apparatus Science Research Institute Co., Ltd.
China National Center for Quality Inspection and Test of Electrical Apparatus Products

№ 23M1237-S

型式试验报告
Type Test Report

委 托 单 位: 四川众信通用电力有限公司
Client: Sichuan Zhongxin General Electric Power Co.,Ltd.

产 品 名 称: 油浸式电力变压器
Name of Product: Oil Immersed Transformer

产 品 型 号:
Product Type: SZ22-63000/110-NX1

检 验 类 别: 型式试验
Test Category: Type test

DQJC

Suzhou Electrical Apparatus Science Research Institute Co., Ltd.

Test Report

№: 23M1237-S

Client	Sichuan Zhongxin General Electric Power Co.,Ltd.	Test category	Type test
Manufacturer	Sichuan Zhongxin General Electric Power Co.,Ltd.	Date of sample receiving	Sep. 01, 2023
Name of sample	Oil Immersed Transformer	Type of sample	SZ22-63000/110-NX1
Address of manufacturer	(Industrial Zone) No.998, Xinghua 5 Road, Xinjin District, Chengdu City	Original number or date of production	202308961
Date of test	From Sep. 03, 2023 to Sep. 12, 2023	Number of sample	1 set
Test items	Routine test Type test (including calculation of the winding hot-spot temperature-rise) Measurement of bushing capacitances and dielectric dissipation factor (tanδ) Measurement of frequency response Short-circuit withstand test Measurement of no-load excitation characteristics Long-duration no-load test Measurement of zero-sequence impedances on three-phase transformers Measurement of the harmonics of the no-load current Vacuum deflection test on liquid-immersed transformers Pressure deflection test on liquid-immersed transformers	Test standards	GB/T 1094.1—2013 GB/T 1094.2—2013 GB/T 1094.3—2017 GB/T 1094.5—2008 GB/T 1094.10—2022 GB/T 6451—2015 GB/T 7595—2017 JB/T 10088—2016 GB 20052—2020 Commission requirements
Test conclusion	The test results of routine test, type test (including calculation of the winding hot-spot temperature-rise), measurement of bushing capacitances and dielectric dissipation factor (tanδ), measurement of frequency response, short-circuit withstand test, measurement of no-load excitation characteristics, long-duration no-load test, measurement of zero-sequence impedances on three-phase transformers, measurement of the harmonics of the no-load current, vacuum deflection test on liquid-immersed transformers and pressure deflection test on liquid-immersed transformers of the oil immersed transformer (type: SZ22-63000/110-NX1) are in accordance with test standards and commission requirements. The sample has passed the above tests. Measured parameters of no-load loss and load loss of the sample meet the requirements of energy efficiency grade 1 of GB 20052—2020. Signing and issuing date: 2023-09-25 Note: the conclusion is valid only for the inspected and tested sample.		
Remarks	/		

Compiled by: 杨小伟 Proofread by: 陈红亚 Checked by: 袁小勇 Approved by: 宋仲华

1. Sample parameters

Rated power: 63000kVA

Rated voltage: 110/10.5kV

Rated current: 330.7/3464.2A

Rated frequency:50Hz

Number of phases: 3

Tapping ranges: ±8×1.25%

Connection symbol: YNd11

Cooling method: ONAN

Thermal class of insulation: A

Insulation level:	HV	Um/LI/LIC/AC	126/480/530/200kV
	HVN	Um/LI/AC	72.5/325/140kV
	LV	Um/LI/LIC/AC	12/75/85/35kV

2. Test standards

GB/T 1094.1—2013 *Power transformers—Part 1: General*

GB/T 1094.2—2013 *Power transformers—Part 2: Temperature rise for liquid-immersed transformers*

GB/T 1094.3—2017 *Power transformers—Part 3: Insulation levels, dielectric tests and external clearances in air*

GB/T 1094.5—2008 *Power transformers—Part 5: Ability to withstand short circuit*

GB/T 1094.10—2022 *Power transformers—Part 10: Determination of sound levels*

GB/T 6451—2015 *Specification and technical requirements for oil-immersed power transformers*

GB/T 7595—2017 *Quality of transformer oils in service*

JB/T 10088—2016 *Sound level for 6kV~1000kV power transformers*

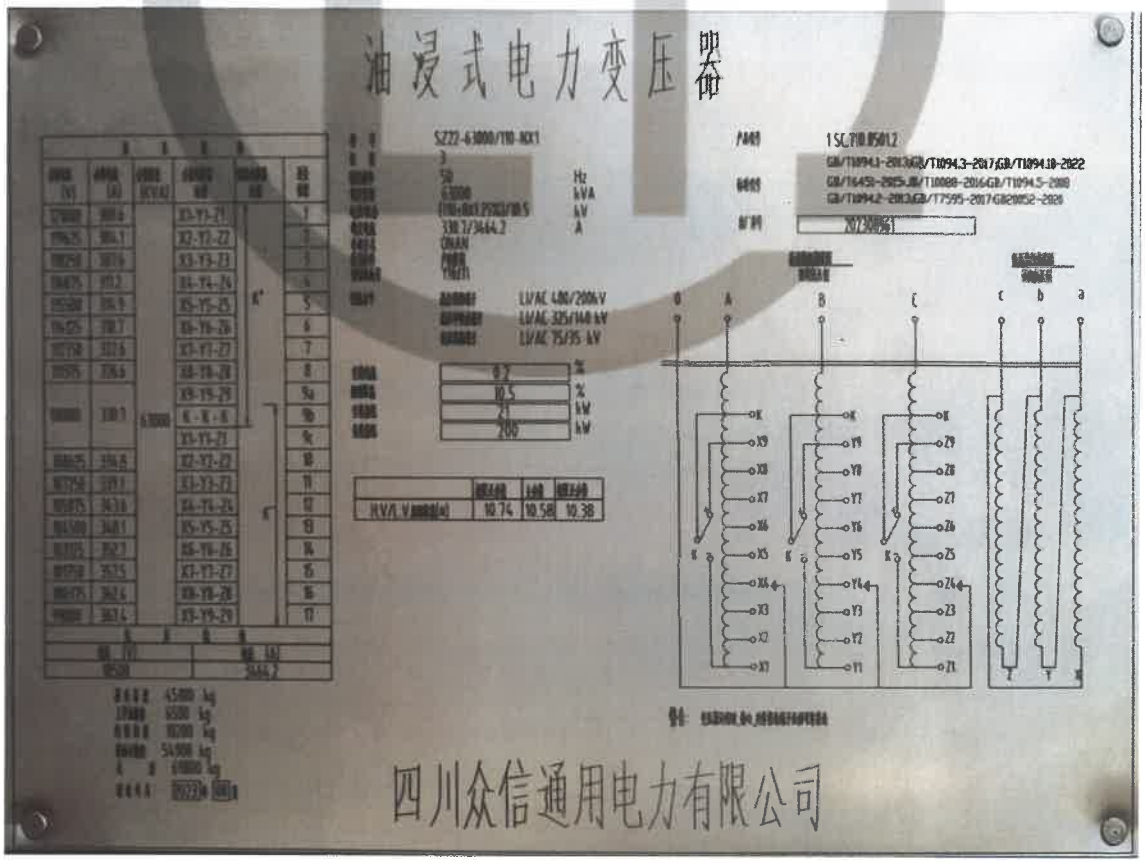
GB 20052—2020 *Minimum allowable values of energy efficiency and the energy efficiency grades for power transformers*

Commission requirements

3. Sample description

The oil immersed transformer is for outdoor use. The structure of the coil is circular concentric type and external photos of the sample have been attached.

Photos of the sample



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Summary of test results

No	Test items	Specified value	Measured value		Concl-usion
		Standards (commission requirements)	Before short-circuit test	After short-circuit test	
1	Measurement of d.c. insulation resistance between each winding to earth and between windings (routine test)	Providing value of insulation resistance Providing absorption ratio Providing polarity index	See 4.1	See 4.19.4.1	/
2	Check of core and frame insulation for liquid-immersed transformers with core or frame insulation (routine test)	Providing value of insulation resistance at 20℃(GΩ): ≥0.5	See 4.2	See 4.19.4.2	PASS
3	Measurement of dissipation factor (tanδ) of the insulation system capacitances (routine test)	Dielectric dissipation factor tanδ (20℃): measured	See 4.3	See 4.19.4.3	/
4	Determination of capacitances windings-to-earth and between windings (routine test)	Providing value of capacitance	See 4.4	See 4.19.4.4	/
5	Measurement of bushing capacitances and dielectric dissipation factor (tanδ) (commission test)	Providing value of capacitance Providing dielectric dissipation factor tanδ	See 4.5	See 4.19.4.5	/
7	Auxiliary wiring insulation test (AuxW) (routine test)	Wiring for auxiliary power and control circuit: 2kV 60s	2kV 60s	2kV 60s	PASS
8	Measurement of voltage ratio and check of phase displacement (routine test)	Voltage ratio tolerance of principal tapping: obtaining the lower of the following values between ±0.5% of declared ratio and ±1/10 of the actual percentage impedance Connection symbol: YNd11	See 4.7	See 4.19.4.7	PASS
8	Measurement of winding resistance (routine test)	Maximum resistance unbalance rate Phase resistance: ≤2% Line resistance: ≤1%	HV (phase): 0.51% LV (line):0.91%	HV (phase):0.44% LV (line): 0.93%	PASS

No	Test items	Specified value Standards (commission requirements)	Measured value Before short-circuit test	 After short-circuit test	Concl-usion
9	Measurement of no-load loss and current (routine test)	I_0 (%): 0.42 +30% P_0 (kW): 25.000 +0%	0.12 22.2504	0.12 22.4023	PASS
10	Measurement of no-load loss and current at 90% and 110% of rated voltage (type test)	I_0 (%): measured P_0 (kW): measured	90% 110% 0.10 0.24 19.0375 34.4140	90% 110% 0.10 0.25 19.0517 34.9875	/
11	Measurement of short-circuit impedance and load loss (routine test)	t: 75℃ Z (%): 10.5 ±7.5% P_k (kW):209.000 +0% P_{total} (kW): 234.000 +0%	10.26 200.6415 222.8919	10.28 201.0593 223.4616	PASS
12	Tests on on-load tap-changers (routine test)	According to clause 11.7 of GB/T1094.1-2013	Meet the requirements	Meet the requirements	PASS
13	Lightning impulse test (LI, LIC, LIN) (routine test, type test)	HV: Full wave (kV): 480 ±3% Chopped wave (kV): 530 ±3% Neutral point (kV): 325 ±3%	/	479.29~483.65 530.75~536.27 325.10~328.20	PASS
		LV: Full wave (kV):75 ±3% Chopped wave (kV): 85 ±3%	/	75.28~77.06 85.72~86.29	
14	Applied voltage test (AV) (routine test)	HV and neutral point: 140kV 60s LV: 35kV 60s	140kV 60s 35kV 60s	140kV 60s 35kV 60s	PASS
15	Line terminal AC withstand test (LTAC) (routine test)	Phase-to-earth test			PASS
		Applied voltage (kV): 21	ac: 21 ab: 21 bc: 21	ac: 21 ab: 21 bc: 21	
		Induced voltage (kV): 200	A: 200 B: 200 C: 200	A: 200 B: 200 C: 200	
		Duration (s): 120 (f_n/f) Frequency (Hz): >50	30 200	30 200	

No	Test items	Specified value Standards (commission requirements)	Measured value Before short-circuit test	Measured value After short-circuit test	Concl-usion
16	Induced voltage withstand test and induced voltage test with partial discharge measurement (IVW, IVPD) (routine test)	Phase-to-earth voltage			PASS
		$0.4U_r/\sqrt{3}$ (kV) Discharge magnitude ≤50pC	25.4 A: <15; B: <15; C: <10	25.4 A: <15; B: <20; C: <15	
		$1.2U_r/\sqrt{3}$ (kV) Duration (min): 1 Discharge magnitude ≤100pC	76.2 1 A: <35; B: <30; C: <30	76.2 1 A: <30; B: <30; C: <35	
		$1.58U_r/\sqrt{3}$ (kV) Duration (min): 5 Discharge magnitude ≤100pC	100.3 5 A: <70; B: <80; C: <75	100.3 5 A: <80; B: <80; C: <75	
		$2.0U_r/\sqrt{3}$ (kV) Duration (min): 0.5	127.0 0.5	127.0 0.5	
		$1.58Ur/\sqrt{3}$ (kV) Duration (min): 60 Discharge magnitude ≤100pC	100.3 60 A: <70; B: <80; C: <95	100.3 60 A: <80; B: <90; C: <95	
		$1.2Ur/\sqrt{3}$ (kV) Duration (min): 1 Discharge magnitude ≤100pC	76.2 1 A: <30; B: <35; C: <50	76.2 1 A: <35; B: <35; C: <45	
		$0.4Ur/\sqrt{3}$ (kV) Discharge magnitude ≤50pC	25.4 A: <15; B: <20; C: <20	25.4 A: <15; B: <25; C: <20	
		Frequency (Hz): >50	200		

No	Test items	Specified value Standards (commission requirements)	Measured value Before short-circuit test	Measured value After short-circuit test	Concl-usion
17	Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment (routine test, type test)	Breakdown voltage (kV): ≥45 tanδ (90℃): ≤0.5% Water content (mg/L): ≤20	65.7 0.12% 10.3	63.1 0.12% 10.5	PASS
		Providing gas chromatograph analysis: Hydrogen: <30μL/L Acetylene: 0 Total hydrocarbon: <20μL/L	See 4.17	See 4.19.4.17	
18	Measurement of frequency response (special test)	Providing frequency response characteristics curve	See 4.18	See 4.19.4.18	PASS
19	Short-circuit withstand test (special test)	Test times of each phase: 3 times Duration (s): 0.25±10% The test oscillogram shall be normal. The reactance variation in phase before and after the test is not more than 2%. The outside and out-of-tank inspection does not reveal any obvious defects. Routine retests shall be passed after short-circuit test.	3 times 0.256~0.259 Without abnormity The maximum reactance variation in phase is 0.26% Without obvious defects Routine retests are passed.		PASS
20	Measurement of no-load excitation characteristics (commission test)	Providing no-load excitation characteristic curve	See 4.20		/
21	Long-duration no-load test (commission test)	Applied voltage (kV): 1.1Un Duration (h): 12 Without acetylene in oil	1.1Un 12 For gas chromatograph analysis, see 4.19.4.17		PASS
22	Measurement of zero-sequence impedances on three-phase transformers (special test)	Providing zero-sequence impedance value (Ω)	See 4.22		/
23	Measurement of the harmonics of the no-load current (commission test)	Providing harmonics of the no-load current of each phase	Harmonics of the no-load current of I_1-I_{19}		/

No	Test items	Specified value Standards (commission requirements)	Measured value	Concl-usion
24	Temperature-rise test (including calculation of the winding hot-spot temperature-rise) (type test)	Top oil temperature-rise limit (K):53 Winding temperature-rise limit (K):60 Winding hot-spot temperature-rise limit (K):78 Tank surface and metallic structural parts temperature-rise (K): 75	Top oil temperature-rise:50.7 HV winding temperature-rise:55.0 LV winding temperature-rise: 56.2 HV winding hot-spot temperature-rise:69.2 LV winding hot-spot temperature-rise:70.8 Tank surface and metallic structural parts temperature-rise: 57.9	PASS
25	Leak testing with pressure for liquid-immersed transformers (routine test)	Main transformer: Applied pressure (kPa): 30 Duration (h): 24 No oil leakage or damage	 30 24 No oil leakage or damage	PASS
		On-load tap-changer tank: Applied pressure (kPa):30 Duration (h): 24 No oil leakage or damage	 30 24 No oil leakage or damage	
26	Determination of sound levels (type test)	At no-load condition: Sound pressure level $\overline{L_{PA}}$ dB (A): Sound power level L_{WA}dB (A): ≤80	 54 74	PASS
		At load condition: Sound pressure level $\overline{L_{PA}}$ dB (A): Sound power level L_{WA}dB (A): ≤80	 50 70	
		The sum of no-load sound power level and load sound power level: Sound power level L_{SUM} dB (A): ≤80	 75	
27	Vacuum deflection test on liquid-immersed transformers (special test)	Applied vacuum degree (kPa):0.133 Elastic deflection of tank wall (mm): ≤40 Elastic deflection of tank cover (mm): ≤18 Permanent deflection of tank wall (mm): ≤1 Permanent deflection of tank cover (mm): ≤1 No damage	See 4.27	PASS
28	Pressure deflection test on liquid-immersed transformers (special test)	Applied positive pressure (kPa):100 Elastic deflection of tank wall (mm): ≤40 Elastic deflection of tank cover (mm): ≤18 Permanent deflection of tank wall (mm): ≤1 Permanent deflection of tank cover (mm): ≤1 No damage	See 4.28	PASS

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4. Test items and results

4.1 Measurement of d.c. insulation resistance between each winding to earth and between windings (routine test)

Test date: Sep. 05, 2023
Relative humidity: 72%; Oil temperature: 24.7℃

Measured part	R_{15} (GΩ)	R_{60} (GΩ)	R_{600} (GΩ)	Absorption ratio (R_{60}/R_{15})	Polarity index (R_{600}/R_{60})
HV—LV and earth	44.1	61.7	81.4	1.40	1.32
LV—HV and earth	22.6	31.5	45.8	1.39	1.45
HV, LV—earth	30.5	43.2	59.7	1.42	1.38

4.2 Check of core and frame insulation for liquid-immersed transformers with core or frame insulation (routine test)

Test date: Sep. 05, 2023
Relative humidity: 72%; Oil temperature: 24.7℃

Measured part	Measured insulation resistance (GΩ)	Insulation resistance corrected to 20℃ (GΩ)
Core—earth	5.86	7.09
Frame—earth	4.34	5.25
Core—frame	6.07	7.34

4.3 Measurement of dissipation factor (tanδ) of the insulation system capacitances (routine test)

Test date: Sep. 05, 2023
Relative humidity: 72%; Oil temperature: 24.7℃

Measured part	Dielectric dissipation factor tanδ (%)	Dielectric dissipation factor tanδ corrected to 20℃ (%)	Capacitance (pF)
HV—LV and earth	0.39	0.34	11583
LV—HV and earth	0.42	0.37	13824
HV, LV—earth	0.45	0.40	10635

4.4 Determination of capacitances windings-to-earth and between windings (routine test)

Test date: Sep. 05, 2023

See 4.3.

4.5 Measurement of bushing capacitances and dielectric dissipation factor (tanδ) (commission test)

Test date: Sep. 05, 2023

Relative humidity: 72%; Oil temperature: 24.7℃

Measured content	Applied voltage	No			
		A	B	C	O
		202307101	202307102	202307103	202307104
tanδ（%）	10kV	0.29	0.32	0.29	0.37
Nominal capacitance (pF)		173	174	175	294
Measured capacitance (pF)		177	179	173	291

4.6 Auxiliary wiring insulation test (AuxW) (routine test)

Test date: Sep. 05, 2023

Relative humidity:72%; Ambient temperature: 24.9℃; Air pressure: 100.8kPa

Part of applied voltage	Test voltage (kV)	Test duration (s)	Result
Wiring for auxiliary power and control circuits	2	60	PASS

4.7 Measurement of voltage ratio and check of phase displacement (routine test) Test date: Sep. 05, 2023

HV winding		LV winding		Transformation ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AB/ab	BC/bc	CA/ca	
1	121.000			11.524	0.09	0.06	0.13	
2	119.625			11.393	0.11	0.08	0.17	
3	118.250			11.262	0.08	0.05	0.13	
4	116.875			11.131	0.09	0.06	0.13	
5	115.500			11.000	0.11	0.08	0.19	
6	114.125			10.869	0.07	0.03	0.12	
7	112.750			10.738	0.07	0.04	0.14	
8	111.375			10.607	0.09	0.07	0.16	
9b	110.000	/	10.5	10.476	0.08	0.07	0.21	YNd11
10	108.625			10.345	0.08	0.08	0.18	
11	107.250			10.214	0.08	0.04	0.20	
12	105.875			10.083	0.10	0.06	0.16	
13	104.500			9.952	0.09	0.07	0.17	
14	103.125			9.821	0.11	0.08	0.17	
15	101.750			9.690	0.12	0.09	0.17	
16	100.375			9.560	0.07	0.08	0.13	
17	99.000			9.429	0.08	0.07	0.18	

4.8 Measurement of winding resistance (routine test)

Test date: Sep. 05, 2023
Oil temperature: 24.6℃

Winding	Tapping position	Measured value (Ω)			Resistance unbalance rate (%)
		A~O a~b	B~O b~c	C~O c~a	
HV	1	0.2271	0.2276	0.2269	0.31
	2	0.2242	0.2247	0.2241	0.27
	3	0.2212	0.2215	0.2209	0.27
	4	0.2180	0.2185	0.2179	0.28
	5	0.2147	0.2149	0.2144	0.23
	6	0.2112	0.2116	0.2109	0.33
	7	0.2085	0.2089	0.2083	0.29
	8	0.2048	0.2052	0.2045	0.34
	9b	0.2009	0.2016	0.2015	0.35
	10	0.2045	0.2048	0.2039	0.44
	11	0.2078	0.2081	0.2074	0.34
	12	0.2111	0.2116	0.2108	0.38
	13	0.2140	0.2145	0.2137	0.37
	14	0.2172	0.2176	0.2165	0.51
	15	0.2199	0.2204	0.2197	0.32
	16	0.2234	0.2239	0.2228	0.49
	17	0.2267	0.2276	0.2265	0.48
LV	/	4.086×10^{-3}	4.049×10^{-3}	4.068×10^{-3}	0.91

4.9 Measurement of no-load loss and current (routine test) Test date: Sep. 05, 2023

Voltage multiple	Applied voltage (kV)		No-load current		No-load loss (kW)	
	Average value	r.m.s. value	(A)	(%)	Measured value	Corrected value
90%Ur	9.453	9.463	3.52	0.10	19.059	19.0375
100%Ur	10.527	10.543	4.27	0.12	22.285	22.2504
110%Ur	11.548	11.715	8.29	0.24	34.919	34.4140

Remarks: at 100%Ur, the difference between r.m.s. voltage and average voltage is within 3%.

4.10 Measurement of no-load loss and current at 90% and 110% of rated voltage (type test)

See 4.9.

4.11 Measurement of short-circuit impedance and load loss (routine test) Test date: Sep. 05, 2023

Oil temperature: 24.6℃

Winding	Tapping position	Applied current I		Measured voltage (kV)	Measured load loss (kW)	Short-circuit impedance (for each phase)		Load loss (kW)	Total loss (kW)
		(A)	I/Ir (%)			HV impedance (Ω)	(%)	Corrected value	Corrected value
						t=75℃ I=Ir	t=75℃ I=Ir	t=75℃ I=Ir	t=75℃ I=Ir
HV | LV	1	159.45	53.04	6.795	49.215	24.61	10.59	194.5790	216.8294
	9b	179.58	54.31	6.128	53.168	19.70	10.26	200.6415	222.8919
	17	196.06	53.36	5.321	58.695	15.67	10.07	231.5167	253.7671

4.12 Tests on on-load tap-changers (routine test)

Test date: Sep. 05, 2023

Operation tests:

a. with the transformer de-energized, eight complete cycles of operation (a cycle of operation goes from one end of the tapping range to the other, and back again);

b. with the transformer de-energized, and with the auxiliary voltage reduced to 85% of its rated value, one complete cycle of operation;

c. with the transformer energized at rated voltage and frequency at no load, one complete cycle of operation;

d. with one winding short-circuited and rated current in the tapped winding, 10 cycles of tap-change operations across the range of two steps on each side from the middle tapping (the tapchanger will pass 20 times through the changeover position).

Test result: PASS

4.13 Lightning impulse test (LI, LIC, LIN) (routine test, type test)

This test is not applicable before short-circuit withstand test.

4.14 Applied voltage test (AV) (routine test) Test date: Sep. 05, 2023

Relative humidity: 72%; Ambient temperature: 24.9℃; Oil temperature: 24.9℃; Air pressure: 100.8kPa

Part of applied voltage	Test voltage (kV)	Test duration (s)	Result
HV and neutral point—LV and earth	140	60	PASS
LV—HV, neutral point and earth	35	60	

4.15 Line terminal AC withstand test (LTAC) (routine test) Test date: Sep. 05, 2023

Relative humidity: 72%; Ambient temperature: 24.9℃; Oil temperature: 24.9℃; Air pressure: 100.8kPa

Phase-to-earth test

Part of applied voltage	Tapping position	Applied voltage (kV)	Induced voltage (kV)		Frequency (Hz)	Test duration (s)	Result
		LV	HV				
ab	5	21	A	200	200	30	PASS
bc		21	B	200			
ca		21	C	200			

4.16 Induced voltage withstand test and induced voltage test with partial discharge measurement (IVW, IVPD) (routine test)

Test date: Sep. 05, 2023

Relative humidity: 72%; Ambient temperature: 24.9°C; Oil temperature: 24.7°C; Air pressure: 100.8kPa

HV tapping position is 9b. Frequency is 200Hz.

Applied voltage		Duration (min)	Partial discharge magnitude (pC)		
Multiple	Phase-to-earth voltage (kV)		A	B	C
$0.4Ur/\sqrt{3}$	25.4	/	<15	<15	<10
$1.2Ur/\sqrt{3}$	76.2	1	<35	<30	<30
$1.58Ur/\sqrt{3}$	100.3	5	<70	<80	<75
$2.0Ur/\sqrt{3}$	127.0	0.5	/	/	/
$1.58Ur/\sqrt{3}$	100.3	5	<70	<75	<70
		10	<65	<70	<95
		15	<70	<80	<95
		20	<70	<75	<90
		25	<65	<70	<90
		30	<60	<70	<90
		35	<60	<75	<90
		40	<65	<75	<90
		45	<65	<75	<90
		50	<65	<75	<90
		55	<65	<75	<90
		60	<65	<75	<90
$1.2Ur/\sqrt{3}$	76.2	1	<30	<35	<50
$0.4Ur/\sqrt{3}$	25.4	/	<15	<20	<20

Remarks: Ur=110kV.

4.17 Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment (routine test, type test)

Test date: Sep. 05, 2023

Relative humidity: 67%; Ambient temperature:24.4℃

Dielectric dissipation factor (90℃)	Breakdown voltage (kV)	Water content (mg/L)
0.12%	65.7	10.3

Gas chromatograph analysis (before all tests) Test date: Sep. 05, 2023

μL/L

H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	Total hydrocarbon
0.83	7.54	143.89	1.04	0	0.32	0	1.36

Gas chromatograph analysis (after dielectric test, before temperature-rise test) Test date: Sep. 05, 2023

μL/L

H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	Total hydrocarbon
1.02	9.48	150.13	1.06	0	0.33	0	1.39

Gas chromatograph analysis (after temperature-rise test, before short-circuit test) Test date: Sep. 06, 2023

μL/L

H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	Total hydrocarbon
1.14	11.05	158.42	1.08	0	0.33	0	1.41

4.18 Measurement of frequency response (special test) Test date: Sep. 07, 2023

HV windings frequency response curve before short circuit test

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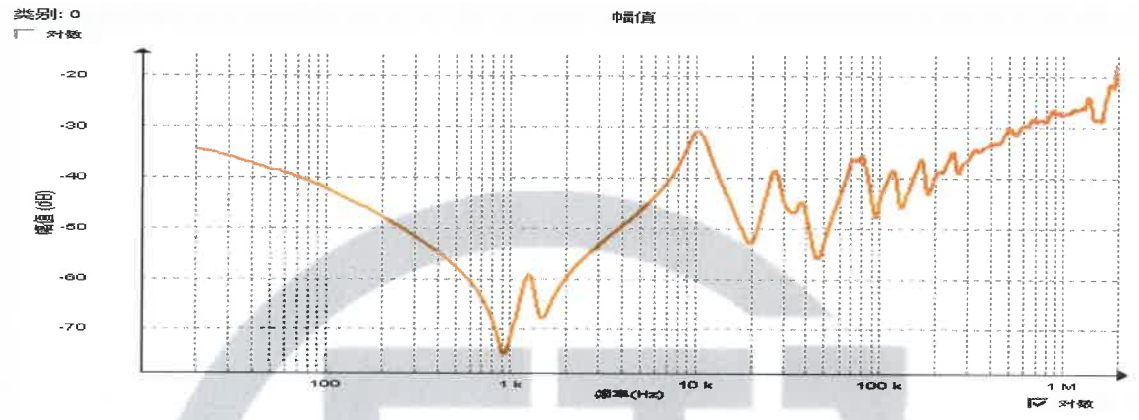

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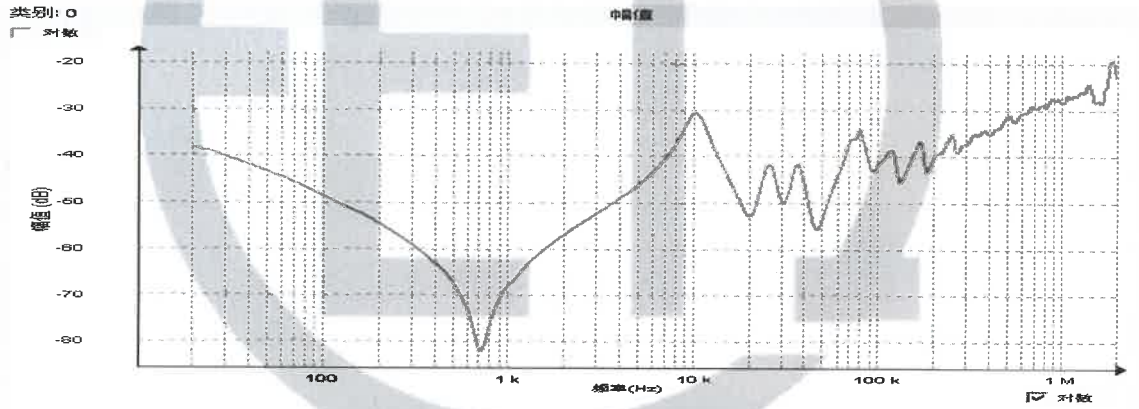
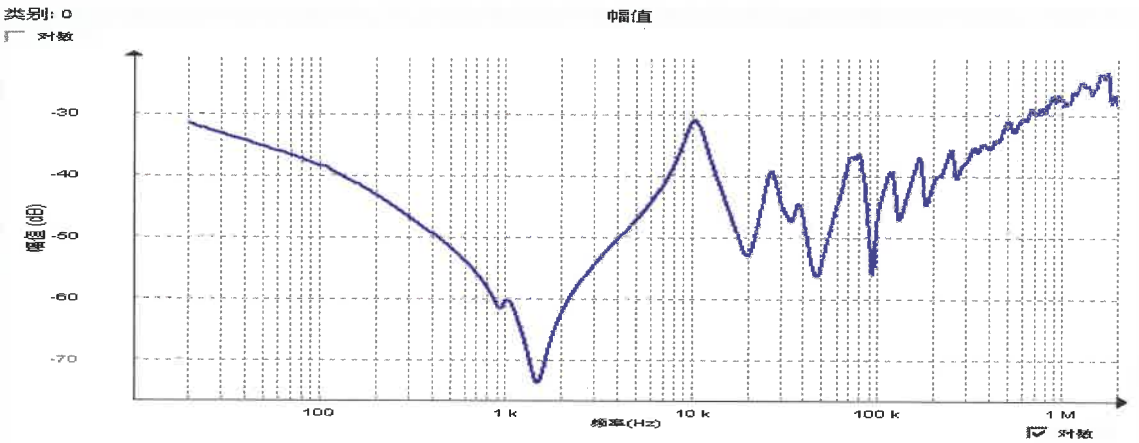
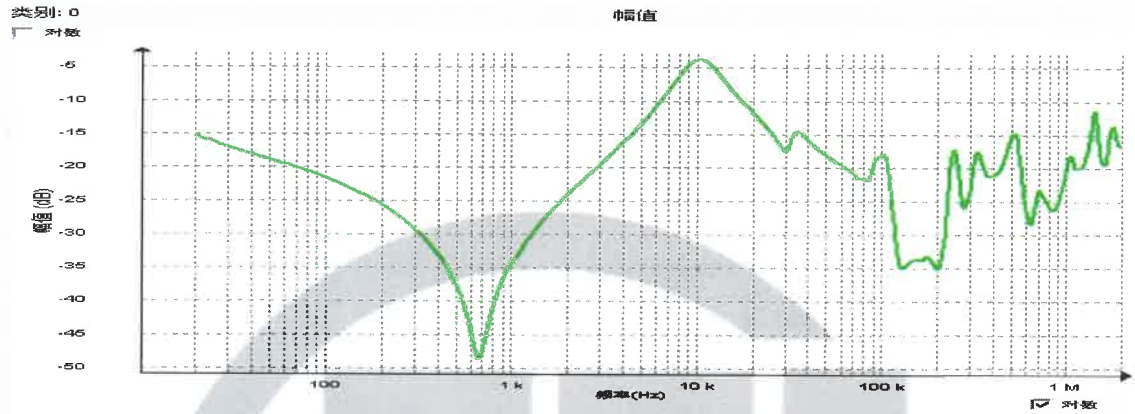


CO

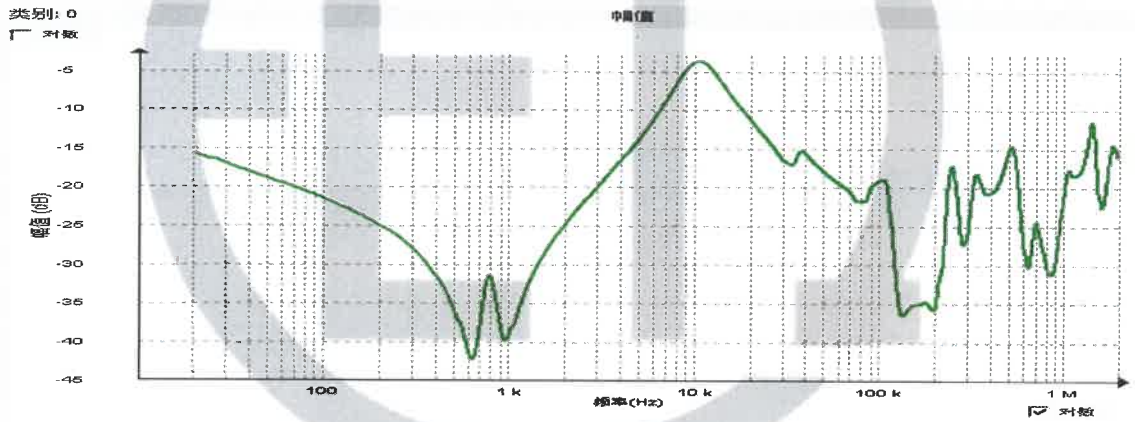


LV windings frequency response curve before short circuit test

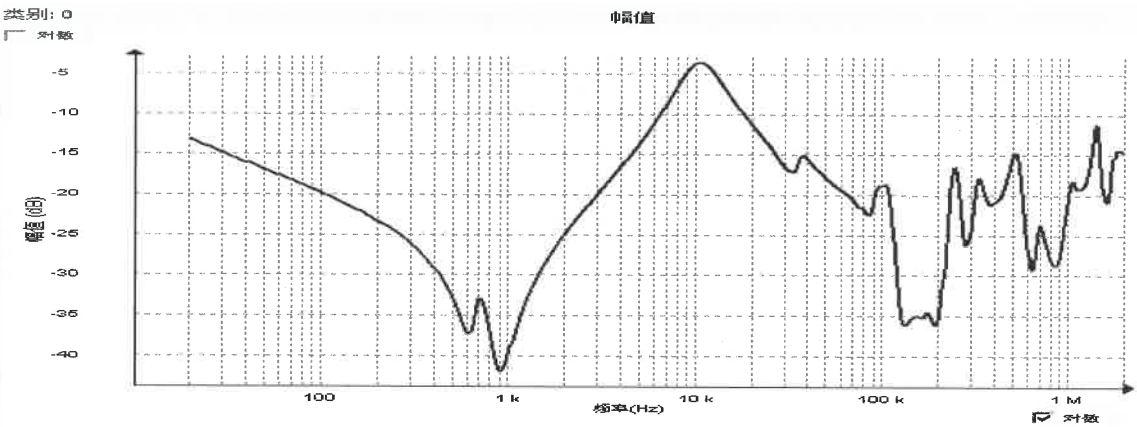
ab



bc



ca



4.19 Short-circuit withstand test (special test) Test date: Sep. 08, 2023

Single-phase supply should be used and test voltage shall be supplied between one HV line terminal and the other two line terminals connected together. HV neutral point is earthed. LV side is connected by short-circuit and earthed. The test oscillogram shall be normal. For the test oscillogram, see $P_{23\sim31}$. The percentages of peak current and symmetrical current are the ratio of applied current value to calculated current value.

4.19.1 Current calculation of short-circuit test (reference temperature 75°C)

Tapping position	Symmetrical value of phase current (A)	Peak value of phase current (A)	Coefficient ($K\sqrt{2}$)
1	2692	6865	2.55
9b	3017	7693	2.55
17	3360	8568	2.55

4.19.2 Current injection of short-circuit test

Tapping position / phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical value of phase current		Peak value of phase current		Duration (s)	Oscillogram No
			Measured value (A)	(%)	Measured value (A)	(%)		
1/A	A-BC	The first time	2628	97.62	6863	99.97	0.258	23M1237-S-T001
		The second time	2654	98.59	6867	100.03	0.256	23M1237-S-T002
		The third time	2620	97.33	6772	98.65	0.257	23M1237-S-T003

Times	Measurement of reactance					
	Reactance values of phase (Ω)			Variation in phase reactance (%)		
	A	B	C	A	B	C
Before tests	24.046	24.391	24.074	/	/	/
The first time	24.074	24.608	24.410	0.12	0.09	0.08
The second time	24.092	24.610	24.412	0.19	0.10	0.09
The third time	24.101	24.610	24.412	0.23	0.10	0.09

The maximum reactance variation in phase is 0.23%.

Tapping position / phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical value of phase current		Peak value of phase current		Duration (s)	Oscillogram No
			Measured value (A)	(%)	Measured value (A)	(%)		
9b/B	B-CA	The first time	2979	98.74	7720	100.35	0.258	23M1237-S-T004
		The second time	2924	96.92	7546	98.09	0.256	23M1237-S-T005
		The third time	2898	96.06	7480	97.23	0.258	23M1237-S-T006

Times	Measurement of reactance					
	Reactance values of phase (Ω)			Variation in phase reactance (%)		
	A	B	C	A	B	C
Before tests	19.296	19.573	19.343	/	/	/
The first time	19.343	19.673	19.592	0.24	0.14	0.10
The second time	19.343	19.679	19.591	0.24	0.17	0.09
The third time	19.343	19.685	19.594	0.24	0.20	0.11

The maximum reactance variation in phase is 0.24%.

Tapping position / phase category	Applied voltage terminal	Times	Measurement of current					
			Symmetrical value of phase current		Peak value of phase current		Duration (s)	Oscillogram No
			Measured value (A)	(%)	Measured value (A)	(%)		
17/C	C-AB	The first time	3209	95.51	8327	97.19	0.259	23M1237-S-T007
		The second time	3264	97.14	8472	98.88	0.257	23M1237-S-T008
		The third time	3285	97.77	8490	99.09	0.257	23M1237-S-T009

Times	Measurement of reactance					
	Reactance values of phase (Ω)			Variation in phase reactance (%)		
	A	B	C	A	B	C
Before tests	15.298	15.540	15.336	/	/	/
The first time	15.336	15.701	15.565	0.25	0.22	0.16
The second time	15.336	15.702	15.570	0.25	0.22	0.19
The third time	15.337	15.702	15.579	0.26	0.22	0.25

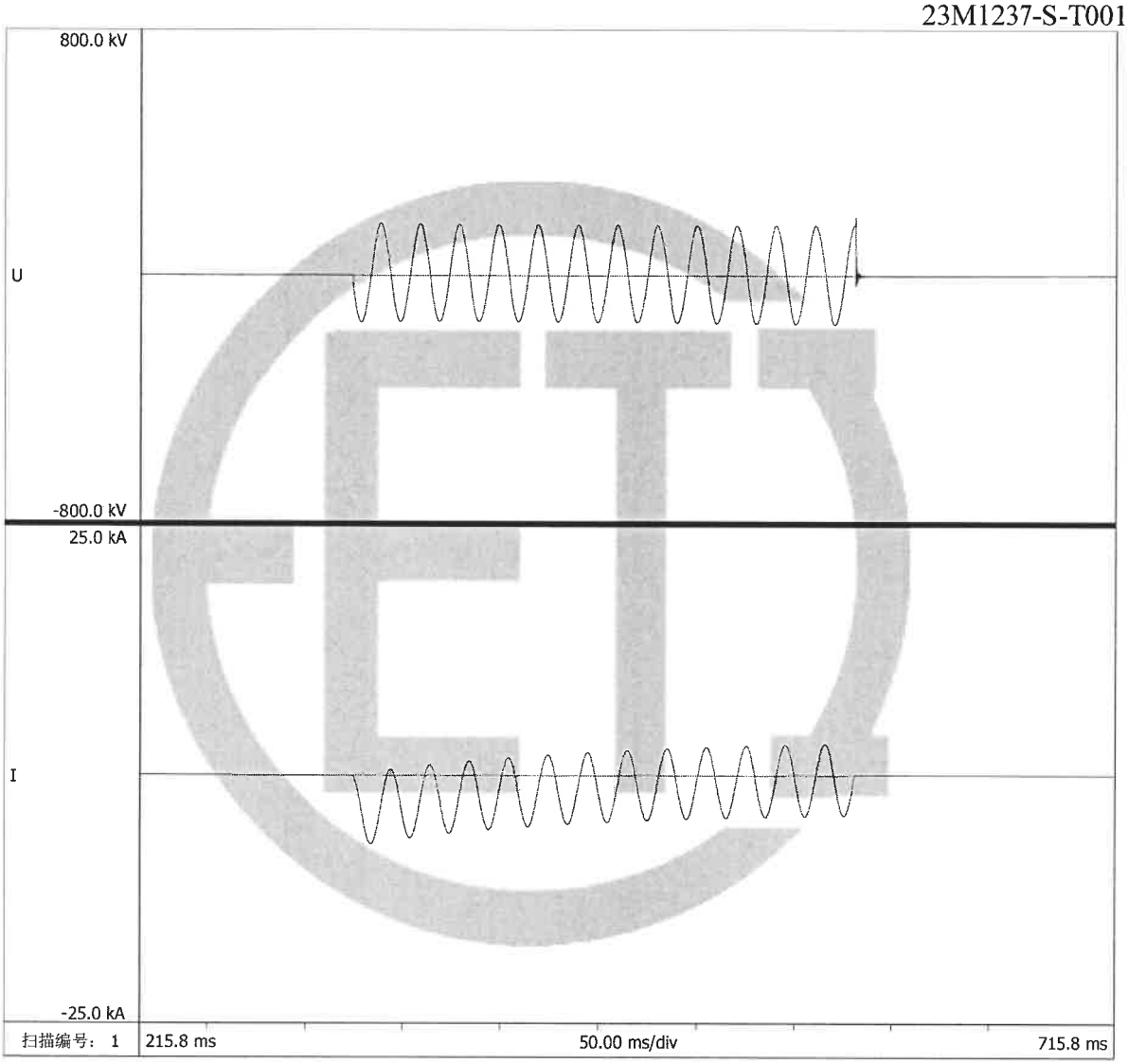
The maximum reactance variation in phase is 0.26%.

4.19.3 Outside and out-of-tank inspection

The outside inspection indicates no anomalies. The out-of-tank inspection does not reveal any obvious distortion and displacement of coil, lead and supporting structures after the short-circuit test and no traces of discharge are found. For the pictures before and after the short-circuit test, see $P_{69\sim70}$.

Oscillogram

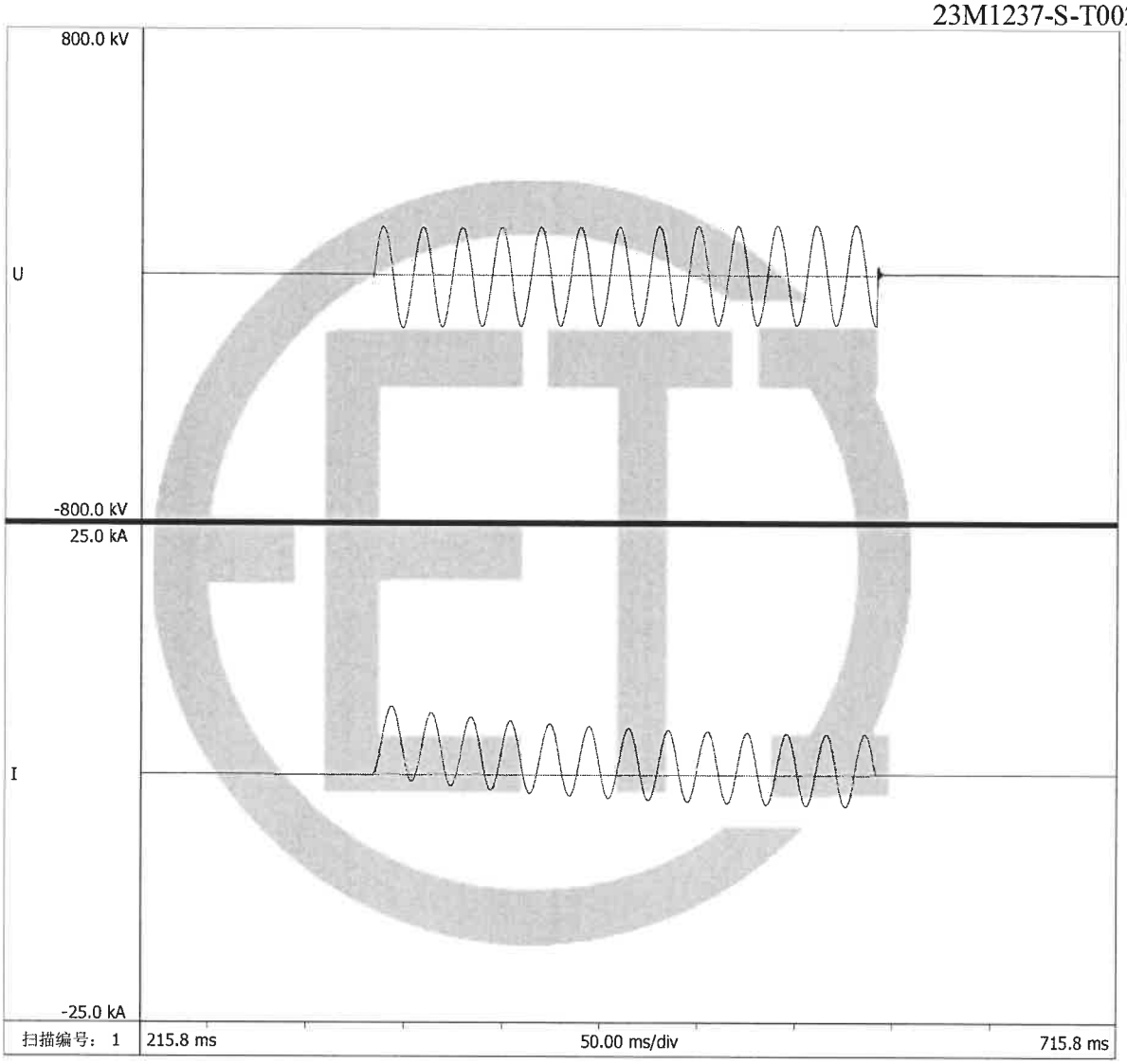
23M1237-S-T001



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
1/A	A-BC	6863	99.97	2628	97.62	0.258

Oscillogram

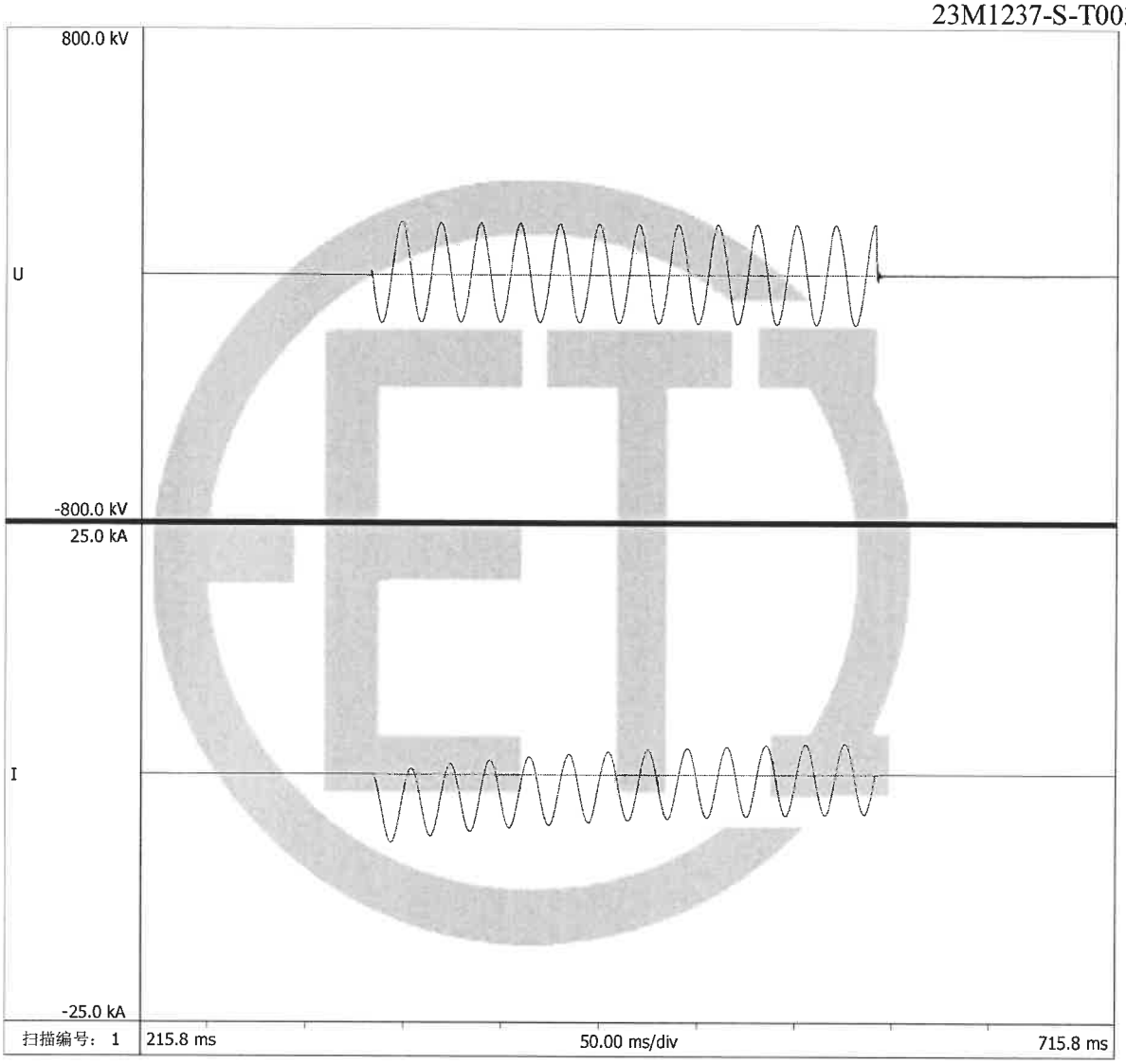
23M1237-S-T002



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
1/A	A-BC	6867	100.03	2654	98.59	0.256

Oscillogram

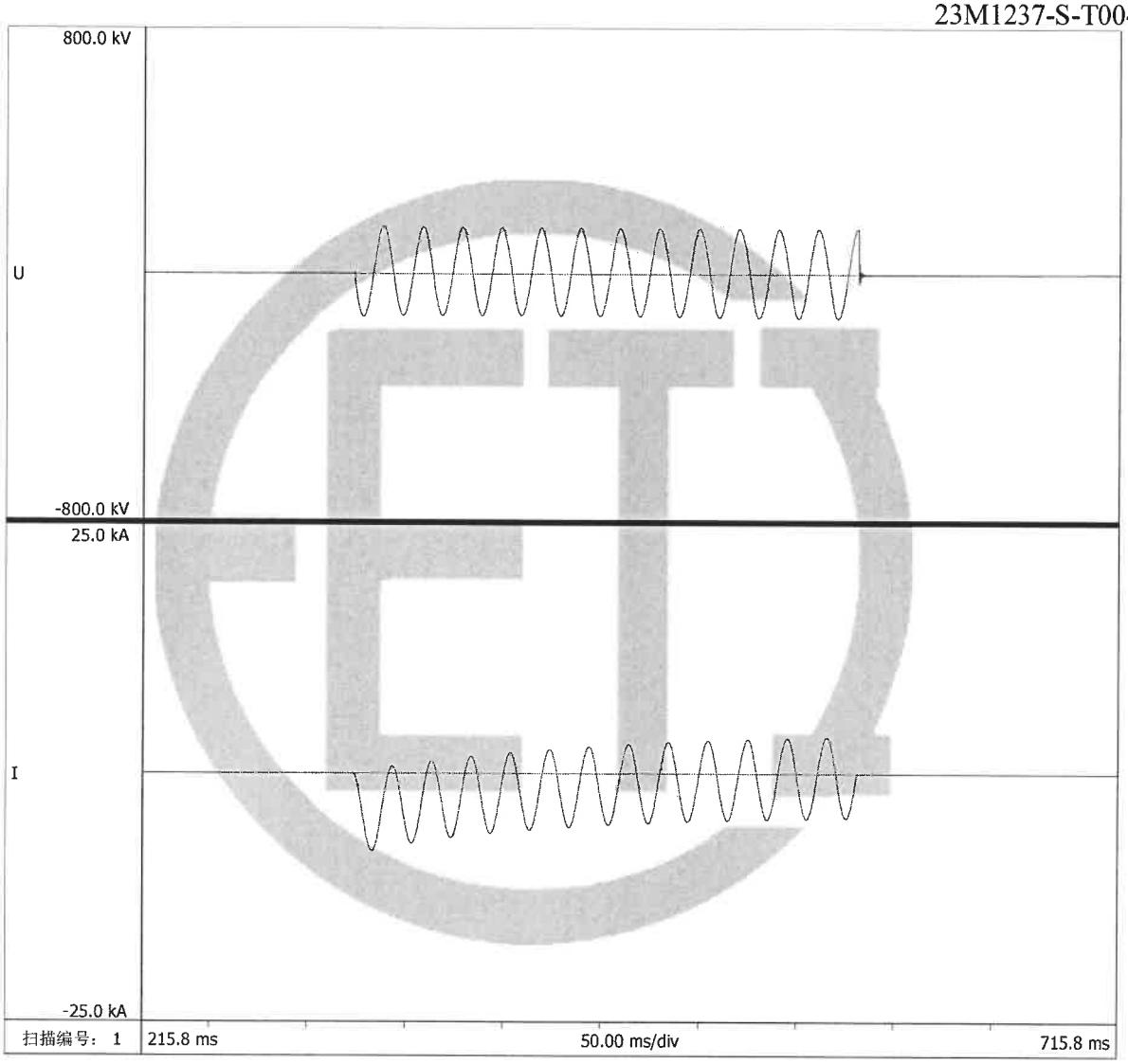
23M1237-S-T003



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
1/A	A-BC	6772	98.65	2620	97.33	0.257

Oscillogram

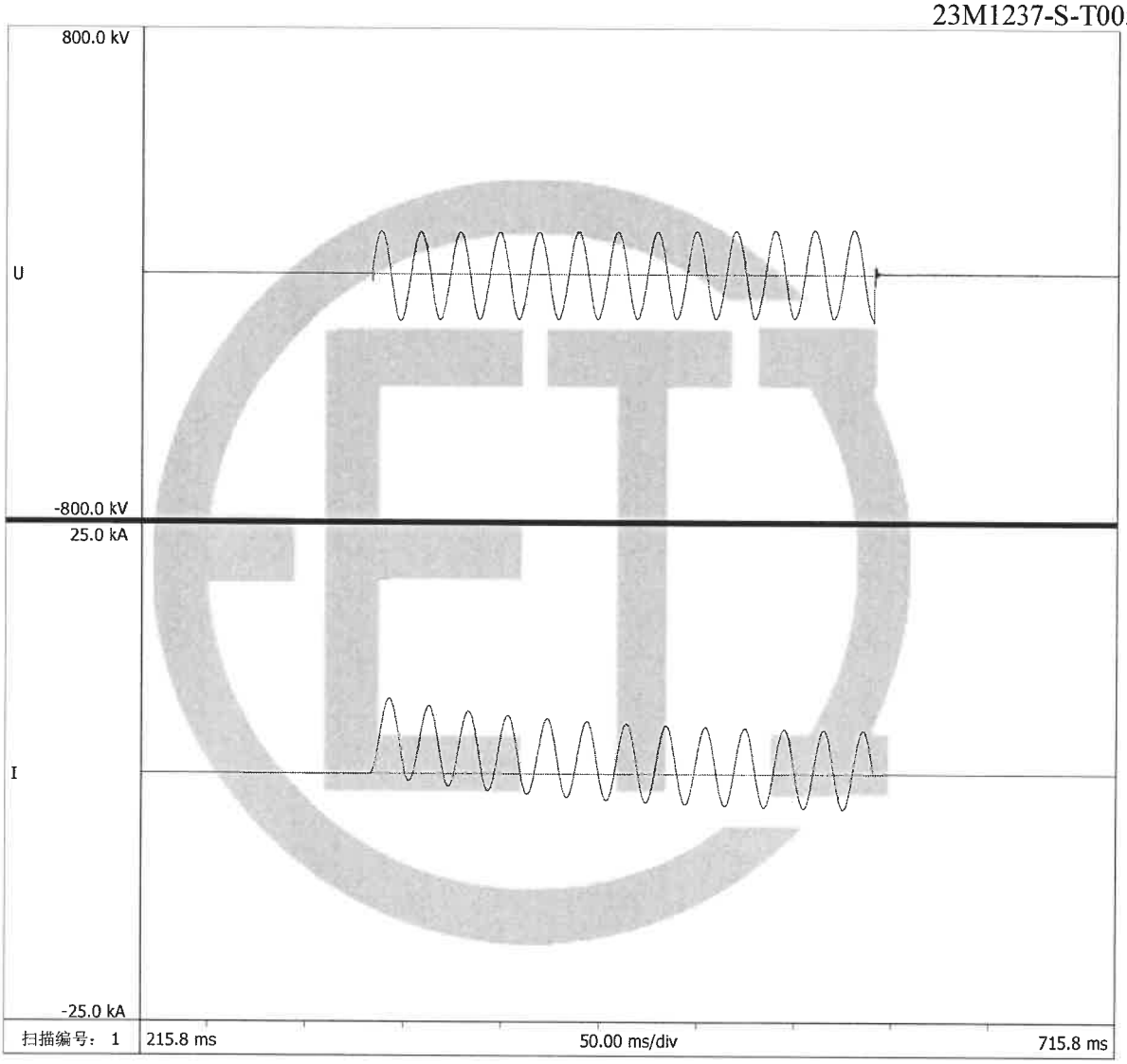
23M1237-S-T004



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
9b/B	B-CA	7720	100.35	2979	98.74	0.258

Oscillogram

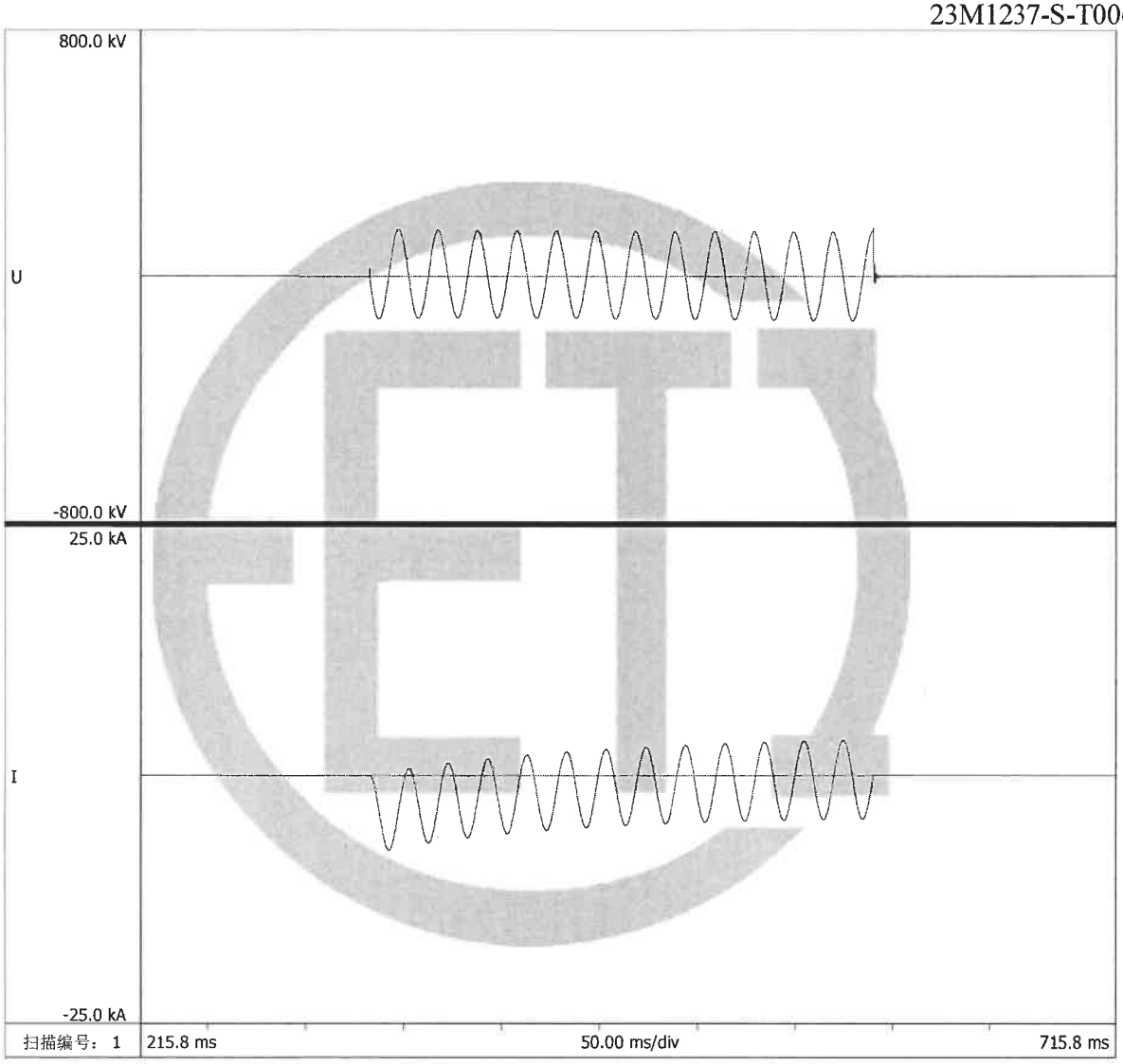
23M1237-S-T005



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
9b/B	B-CA	7546	98.09	2924	96.92	0.256

Oscillogram

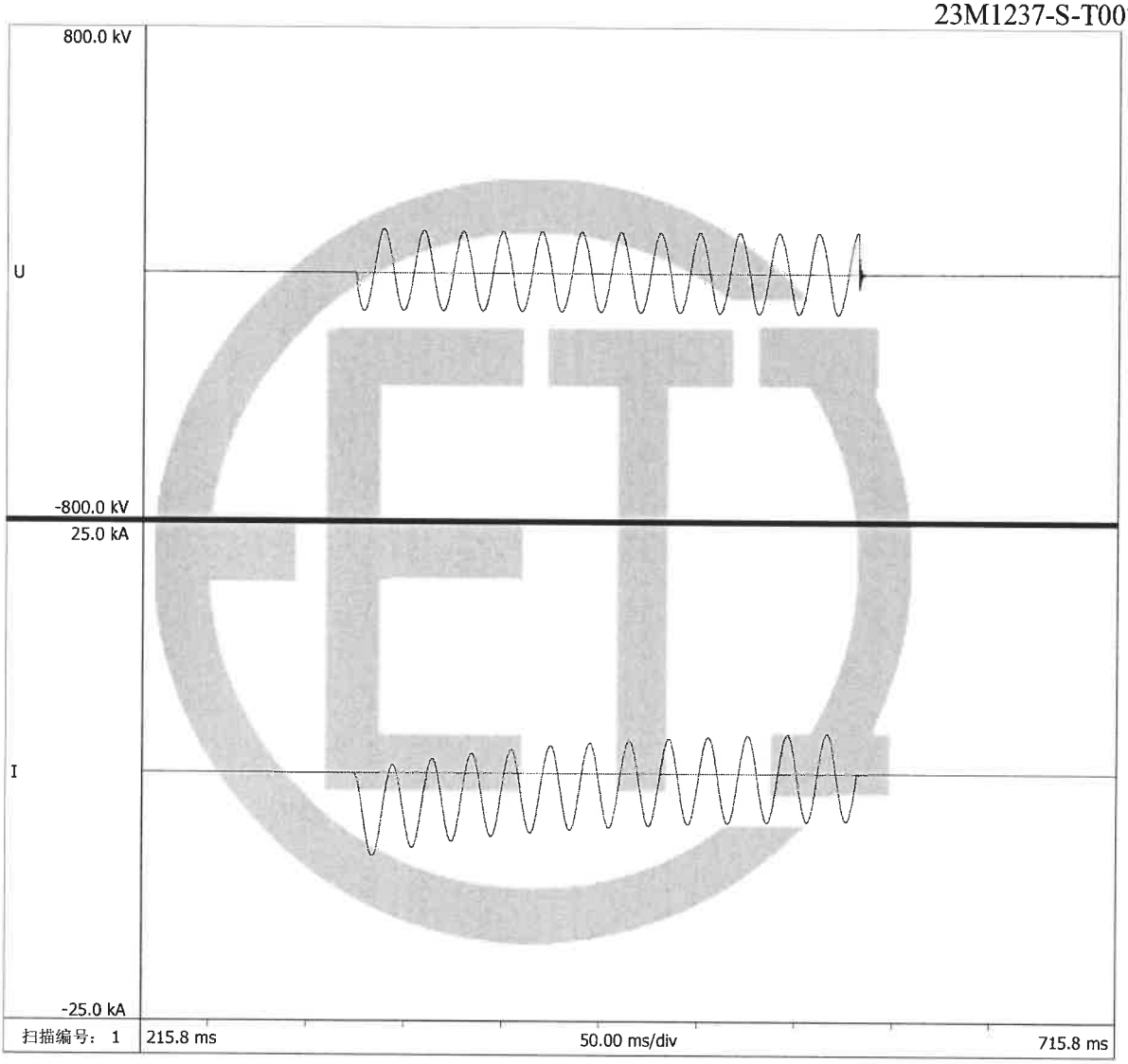
23M1237-S-T006



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
9b/B	B-CA	7480	97.23	2898	96.06	0.258

Oscillogram

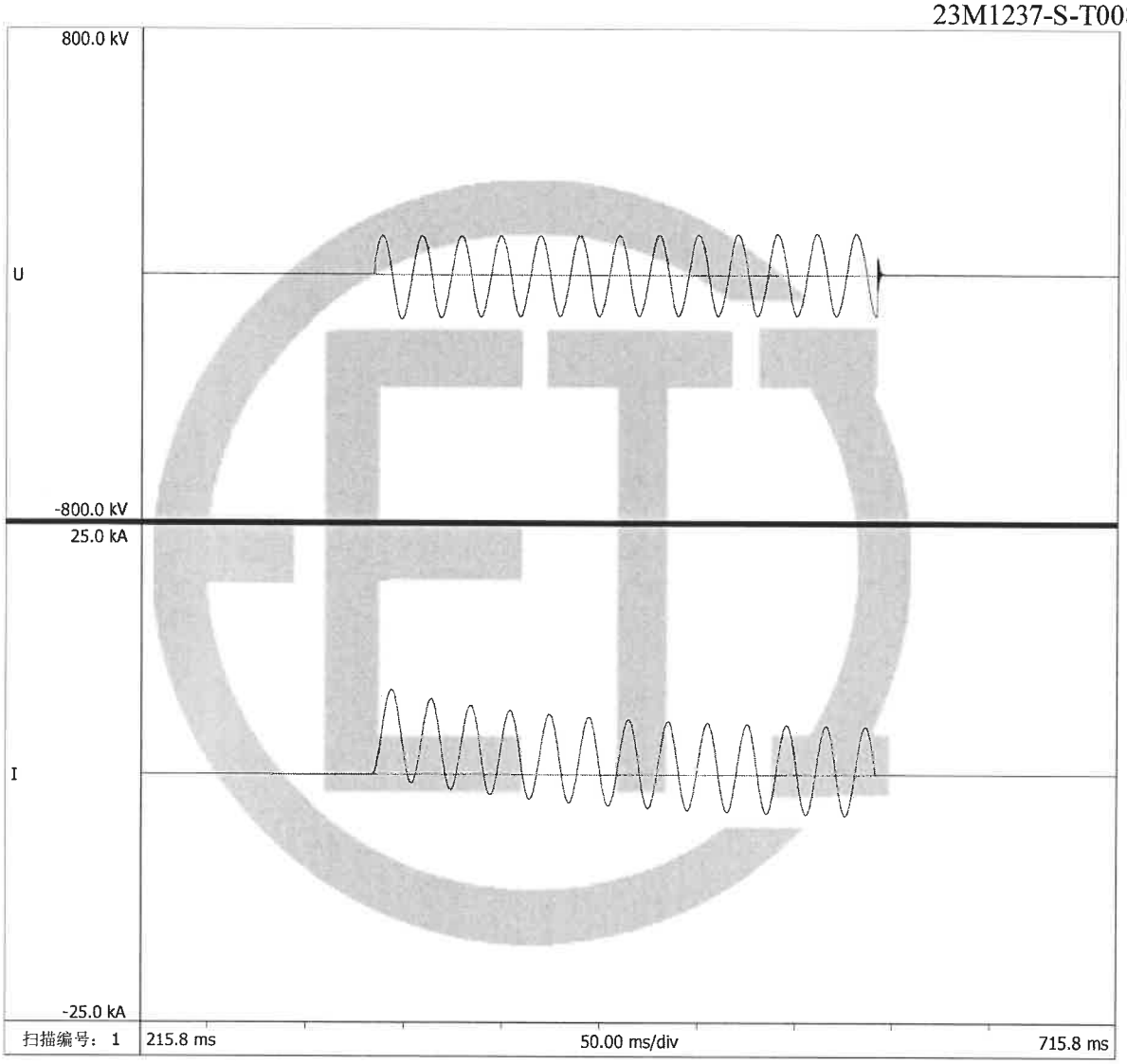
23M1237-S-T007



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
17/C	C-AB	8327	97.19	3209	95.51	0.259

Oscillogram

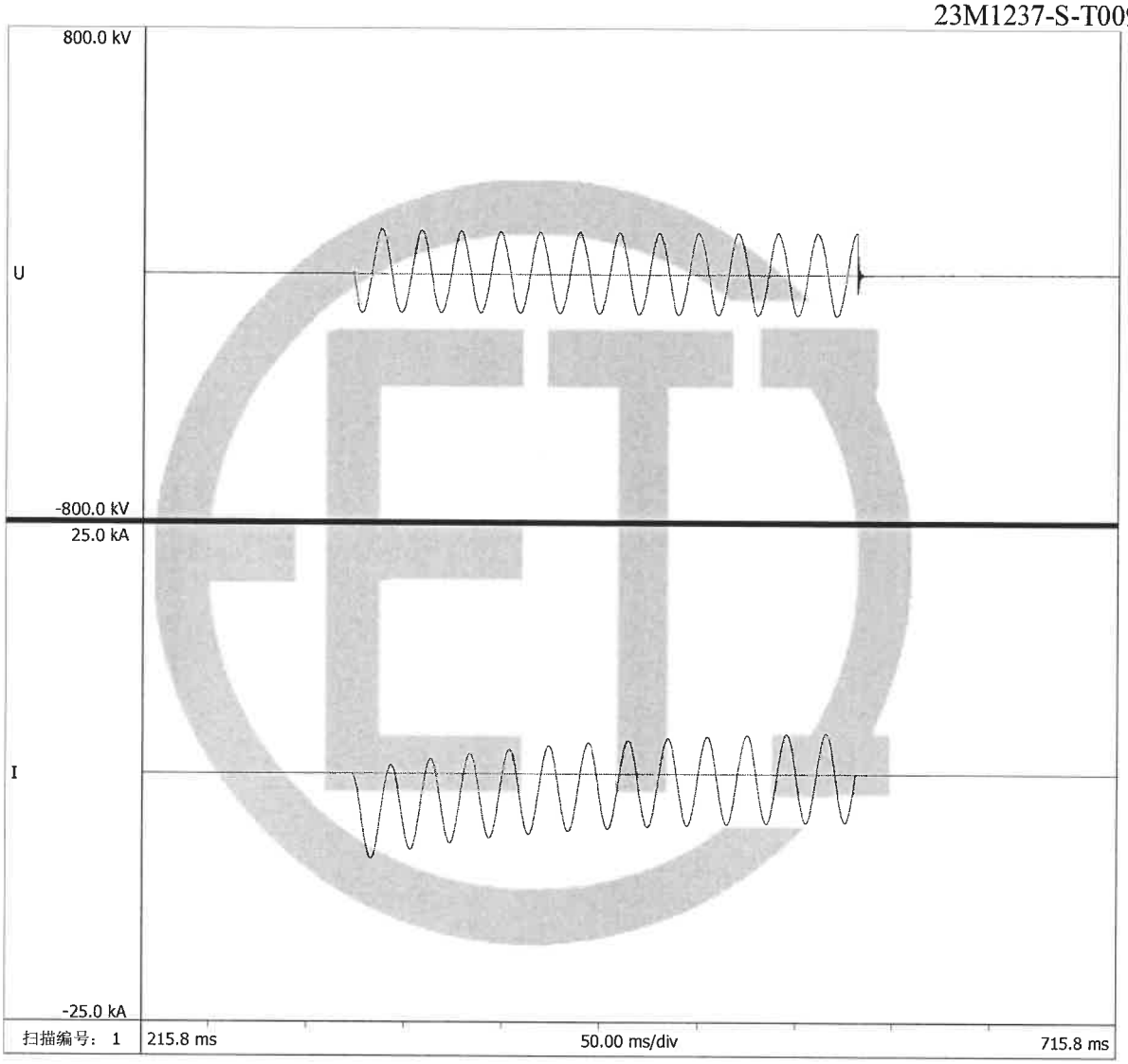
23M1237-S-T008



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
17/C	C-AB	8472	98.88	3264	97.14	0.257

Oscillogram

23M1237-S-T009



Tapping position / phase category	Applied voltage terminal	Peak value of phase current (A)		Symmetrical value of phase current (A)		Duration (s)
		Measured value (A)	Measured /calculated (%)	Measured value (A)	Measured /calculated (%)	
17/C	C-AB	8490	99.09	3285	97.77	0.257

4.19.4 Routine retests

4.19.4.1 Measurement of d.c. insulation resistance between each winding to earth and between windings (routine test)

Test date: Sep. 11, 2023

Relative humidity: 63%; Oil temperature: 26.2℃

Measured part	R_{15} (GΩ)	R_{60} (GΩ)	R_{600} (GΩ)	Absorption ratio (R_{60}/R_{15})	Polarity index (R_{600}/R_{60})
HV—LV and earth	36.8	54.2	74.7	1.47	1.38
LV—HV and earth	19.7	27.2	39.9	1.38	1.47
HV, LV—earth	25.4	37.1	52.6	1.46	1.42

4.19.4.2 Check of core and frame insulation for liquid-immersed transformers with core or frame insulation (routine test)

Test date: Sep. 11, 2023

Relative humidity: 63%; Oil temperature: 26.2℃

Measured part	Measured insulation resistance (GΩ)	Insulation resistance corrected to 20℃ (GΩ)
Core—earth	5.42	6.97
Frame—earth	3.95	5.08
Core—frame	5.36	6.89

4.19.4.3 Measurement of dissipation factor (tanδ) of the insulation system capacitances (routine test)

Test date: Sep. 11, 2023

Relative humidity: 63%; Oil temperature: 26.2℃

Measured part	Dielectric dissipation factor tanδ (%)	Dielectric dissipation factor tanδ corrected to 20℃ (%)	Capacitance (pF)
HV—LV and earth	0.40	0.34	11726
LV—HV and earth	0.44	0.37	13974
HV, LV—earth	0.46	0.39	10596

4.19.4.4 Determination of capacitances windings-to-earth and between windings (routine test)

Test date: Sep. 11, 2023

See 4.19.4.3.

4.19.4.5 Measurement of bushing capacitances and dielectric dissipation factor (tanδ) (commission test)

Test date: Sep. 11, 2023

Relative humidity: 63%; Oil temperature: 26.2℃

Measured content	Applied voltage	No			
		A	B	C	O
		202307101	202307102	202307103	202307104
tanδ（%）	10kV	0.28	0.30	0.27	0.36
Nominal capacitance (pF)		173	174	175	294
Measured capacitance (pF)		179	181	172	297

4.19.4.6 Auxiliary wiring insulation test (AuxW) (routine test)

Test date: Sep. 11, 2023

Relative humidity:56%; Ambient temperature: 26.1℃; Air pressure: 101.0kPa

Part of applied voltage	Test voltage (kV)	Test duration (s)	Result
Wiring for auxiliary power and control circuits	2	60	PASS

4.19.4.7 Measurement of voltage ratio and check of phase displacement (routine test)

Test date: Sep. 11, 2023

HV winding		LV winding		Transformation ratio by calculation	Measured voltage ratio tolerance (%)			Connection symbol
Tapping position	Voltage (kV)	Tapping position	Voltage (kV)		AB/ab	BC/bc	CA/ca	
1	121.000	/	10.5	11.524	0.10	0.08	0.12	YNd11
2	119.625			11.393	0.11	0.10	0.14	
3	118.250			11.262	0.10	0.06	0.15	
4	116.875			11.131	0.13	0.09	0.15	
5	115.500			11.000	0.13	0.10	0.17	
6	114.125			10.869	0.08	0.05	0.14	
7	112.750			10.738	0.08	0.06	0.16	
8	111.375			10.607	0.08	0.05	0.13	
9b	110.000			10.476	0.06	0.08	0.19	
10	108.625			10.345	0.07	0.06	0.16	
11	107.250			10.214	0.07	0.05	0.18	
12	105.875			10.083	0.08	0.05	0.15	
13	104.500			9.952	0.11	0.07	0.19	
14	103.125			9.821	0.13	0.10	0.16	
15	101.750			9.690	0.11	0.08	0.15	
16	100.375			9.560	0.08	0.06	0.14	
17	99.000			9.429	0.11	0.10	0.20	

4.19.4.8 Measurement of winding resistance (routine test)

Test date: Sep. 11, 2023
Oil temperature: 26.1℃

Winding	Tapping position	Measured value (Ω)			Resistance unbalance rate (%)
		A~O a~b	B~O b~c	C~O c~a	
HV	1	0.2282	0.2287	0.2279	0.35
	2	0.2251	0.2256	0.2249	0.31
	3	0.2221	0.2224	0.2218	0.27
	4	0.2192	0.2198	0.2191	0.32
	5	0.2156	0.2161	0.2153	0.37
	6	0.2288	0.2292	0.2286	0.26
	7	0.2096	0.2101	0.2093	0.38
	8	0.2058	0.2061	0.2055	0.29
	9b	0.2019	0.2024	0.2018	0.30
	10	0.2057	0.2062	0.2055	0.34
	11	0.2095	0.2100	0.2091	0.43
	12	0.2331	0.2337	0.2328	0.39
	13	0.2151	0.2154	0.2147	0.33
	14	0.2189	0.2194	0.2185	0.41
	15	0.2221	0.2226	0.2218	0.36
	16	0.2251	0.2256	0.2248	0.36
	17	0.2281	0.2289	0.2279	0.44
LV	/	4.107×10^{-3}	4.069×10^{-3}	4.082×10^{-3}	0.93

4.19.4.9 Measurement of no-load loss and current (routine test) Test date: Sep. 11, 2023

Voltage multiple	Applied voltage (kV)		No-load current		No-load loss (kW)	
	Average value	r.m.s. value	(A)	(%)	Measured value	Corrected value
90%Ur	9.456	9.471	3.58	0.10	19.082	19.0517
100%Ur	10.533	10.548	4.32	0.12	22.435	22.4023
110%Ur	11.592	11.760	8.55	0.25	35.502	34.9875

Remarks: at 100%Ur, the difference between r.m.s. voltage and average voltage is within 3%.

4.19.4.10 Measurement of no-load loss and current at 90% and 110% of rated voltage (type test)

See 4.19.4.9.

4.19.4.11 Measurement of short-circuit impedance and load loss (routine test) Test date: Sep. 11, 2023

Oil temperature: 26.1℃

Winding	Tapping position	Applied current I		Measured voltage (kV)	Measured load loss (kW)	Short-circuit impedance (for each phase)		Load loss (kW)	Total loss (kW)
		(A)	I/Ir (%)			HV impedance (Ω)	(%)	Corrected value	Corrected value
						t=75℃ I=Ir	t=75℃ I=Ir	t=75℃ I=Ir	t=75℃ I=Ir
HV | LV	1	161.76	53.81	6.898	50.952	24.62	10.60	194.9401	217.3424
	9b	176.15	53.27	6.025	51.486	19.75	10.28	201.0593	223.4616
	17	200.17	54.48	5.436	61.584	15.68	10.08	232.0265	254.4288

4.19.4.12 Tests on on-load tap-changers (routine test) Test date: Sep. 11, 2023

Operation tests:

a. with the transformer de-energized, eight complete cycles of operation (a cycle of operation goes from one end of the tapping range to the other, and back again);

b. with the transformer de-energized, and with the auxiliary voltage reduced to 85% of its rated value, one complete cycle of operation;

c. with the transformer energized at rated voltage and frequency at no load, one complete cycle of operation;

d. with one winding short-circuited and rated current in the tapped winding, 10 cycles of tap-change operations across the range of two steps on each side from the middle tapping (the tapchanger will pass 20 times through the changeover position).

Test result: PASS

4.19.4.13 Lightning impulse test (LI, LIC, LIN) (routine test, type test) Test date: Sep. 11, 2023

Atmospheric conditions of test:
Relative humidity: 54%; Ambient temperature: 25.8°C; Oil temperature: 25.7°C; Air pressure:101.0kPa.

Test items and voltage

Withstand terminal	Rated withstand voltage (kV)		Tapping position
	Lightning full wave	Lightning chopped wave	
A, B, C	480	530	A:1; B:9b; C:17
O	325	/	1
a, b, c	75	85	/

Test sequence:

Line terminal:

One negative reduced level full wave impulse;

One negative full level full wave impulse;

One negative reduced level chopped wave impulse;

Two negative full level chopped wave impulses;

Two negative full level full wave impulses.

Neutral point:

One negative reduced level full wave impulse;

Three negative full level full wave impulses.

Test records:

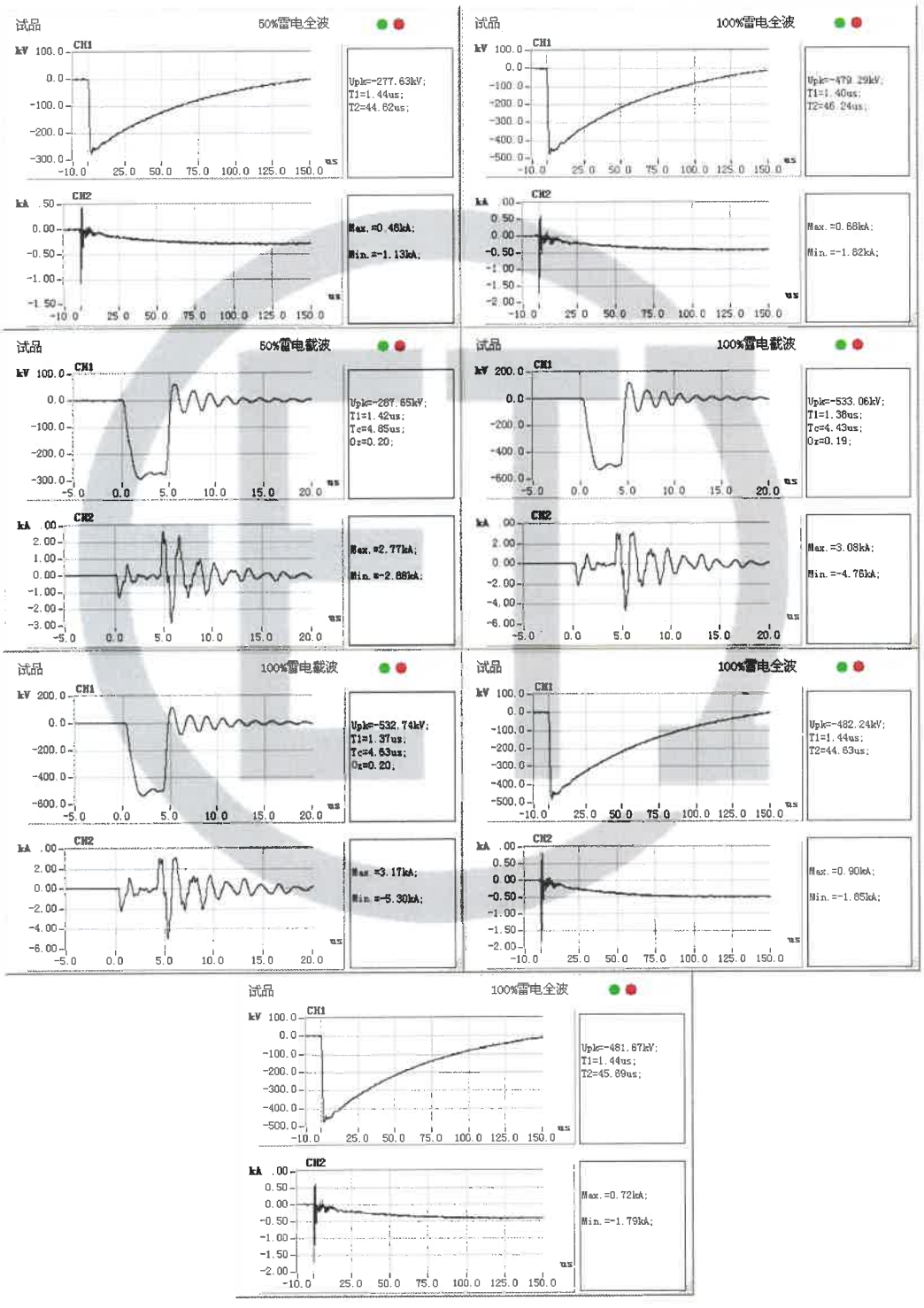
T1: wave front time; T2: time to half-value; Tc: time to chopping; Upk: peak voltage.

For waveform diagram, see P_{39-45}.

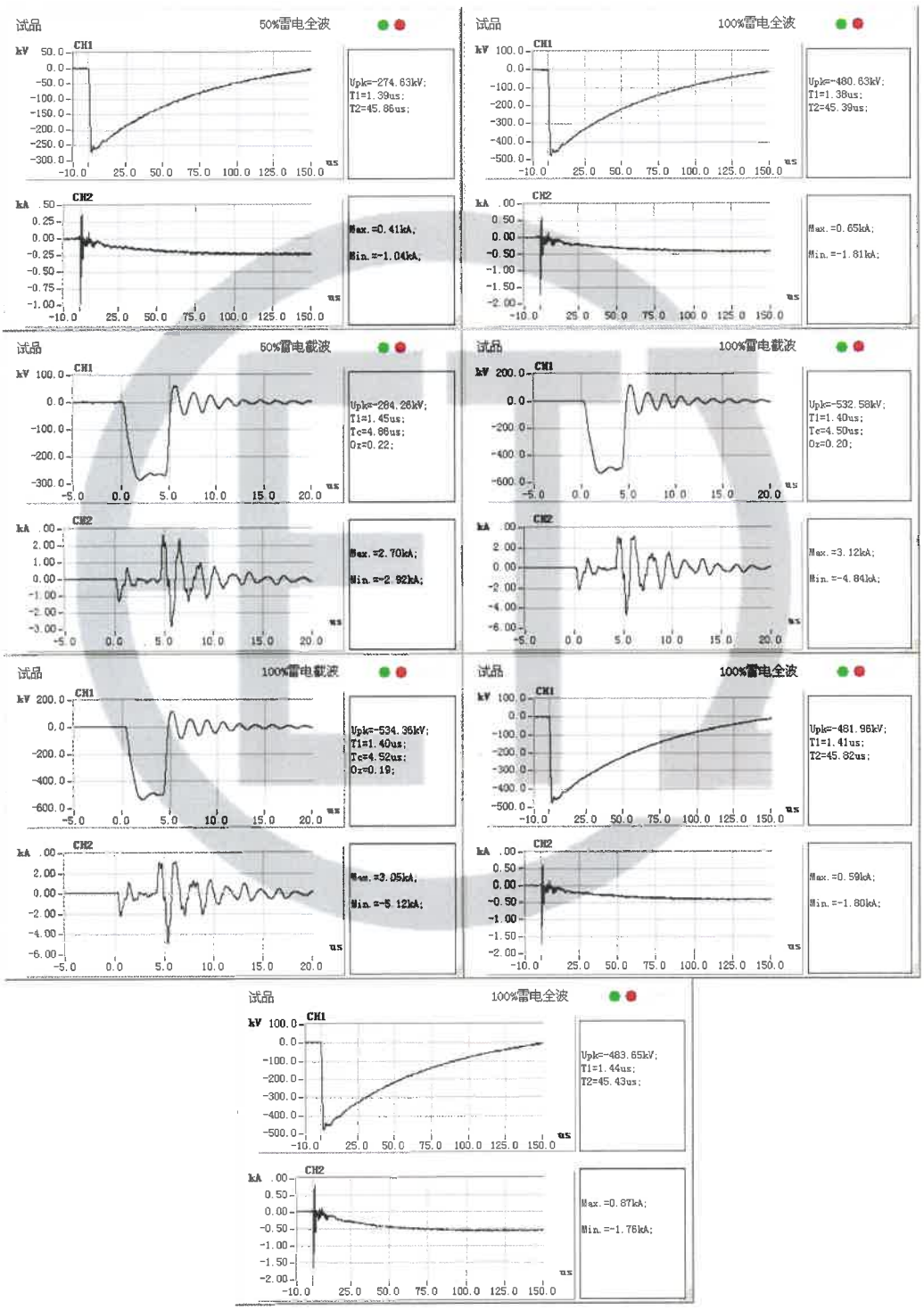
Voltage ranges of oscillograms are as below:

Withstand terminal	Full wave (kV)	Chopped wave (kV)
A, B, C	479.29~483.65	530.75~536.27
O	325.10~328.20	/
a, b, c	75.28~77.06	85.72~86.29

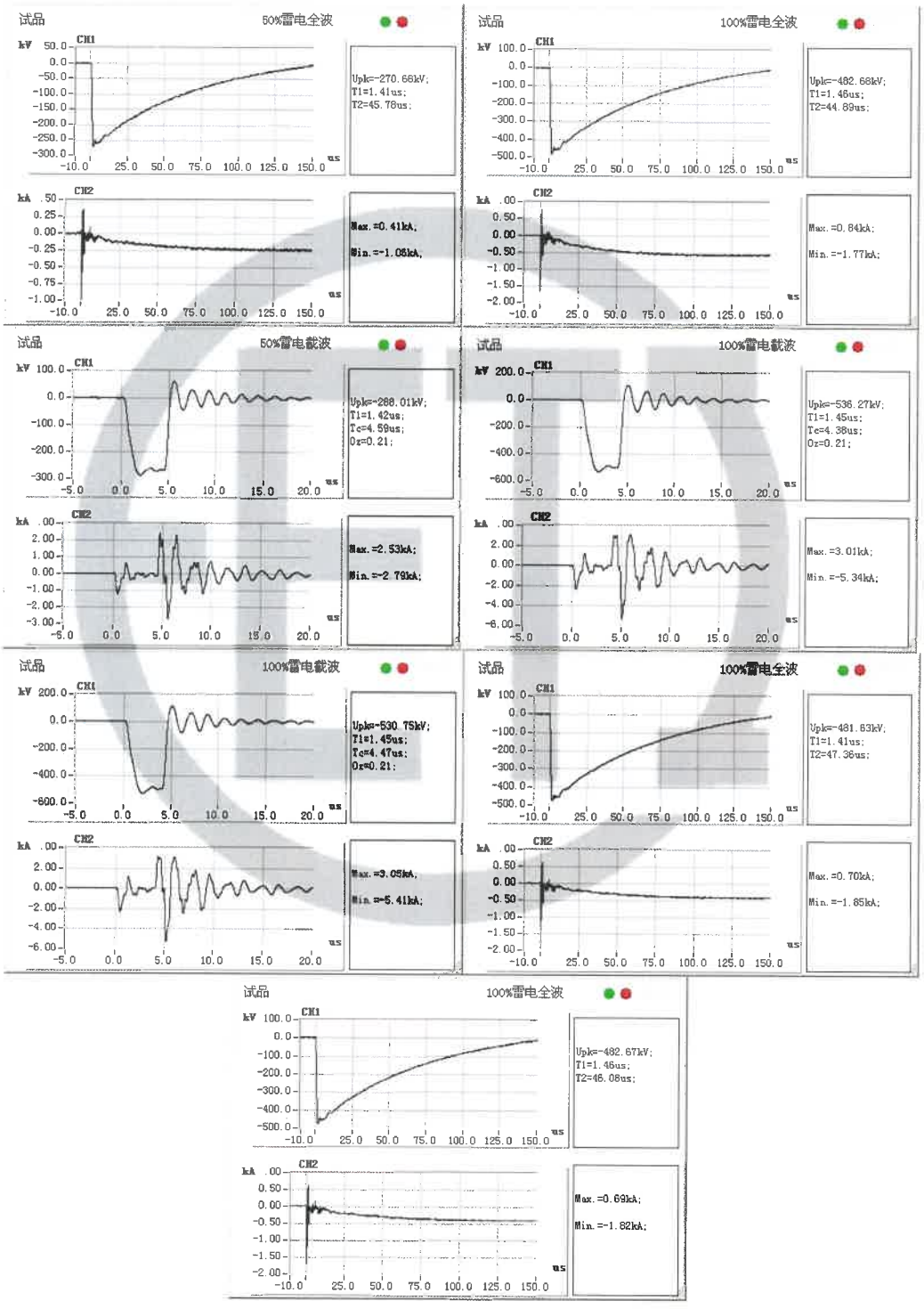
Tested terminal: A Test polarity: negative Channel 1: voltage wave Channel 2: current wave



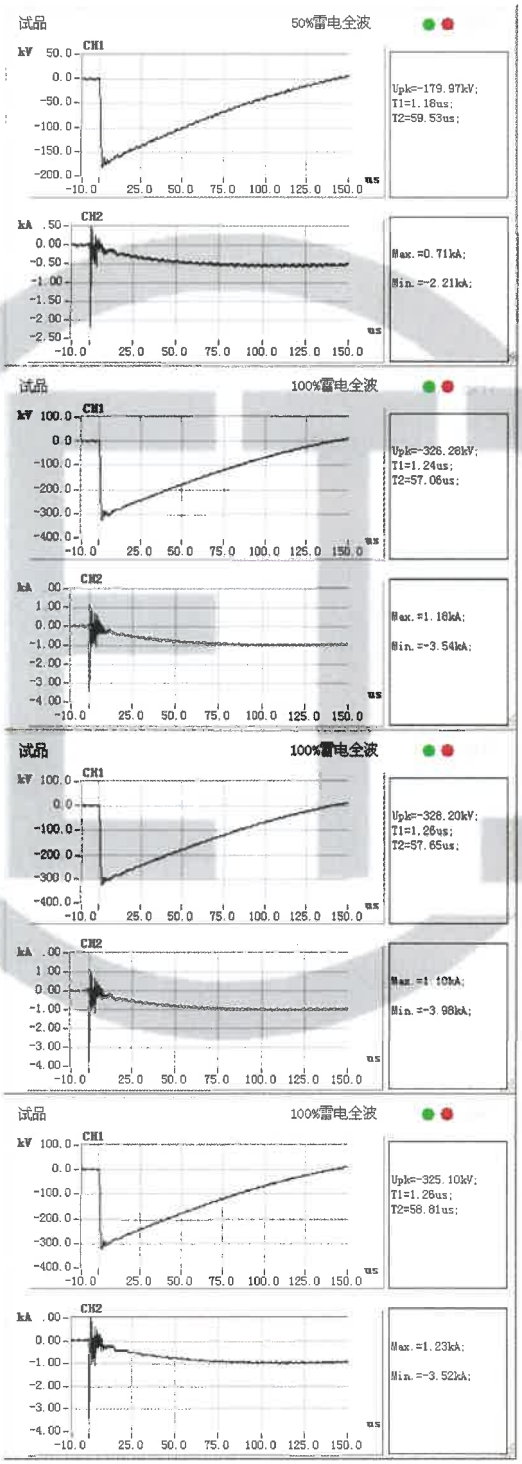
Tested terminal: B Test polarity: negative Channel 1: voltage wave Channel 2: current wave



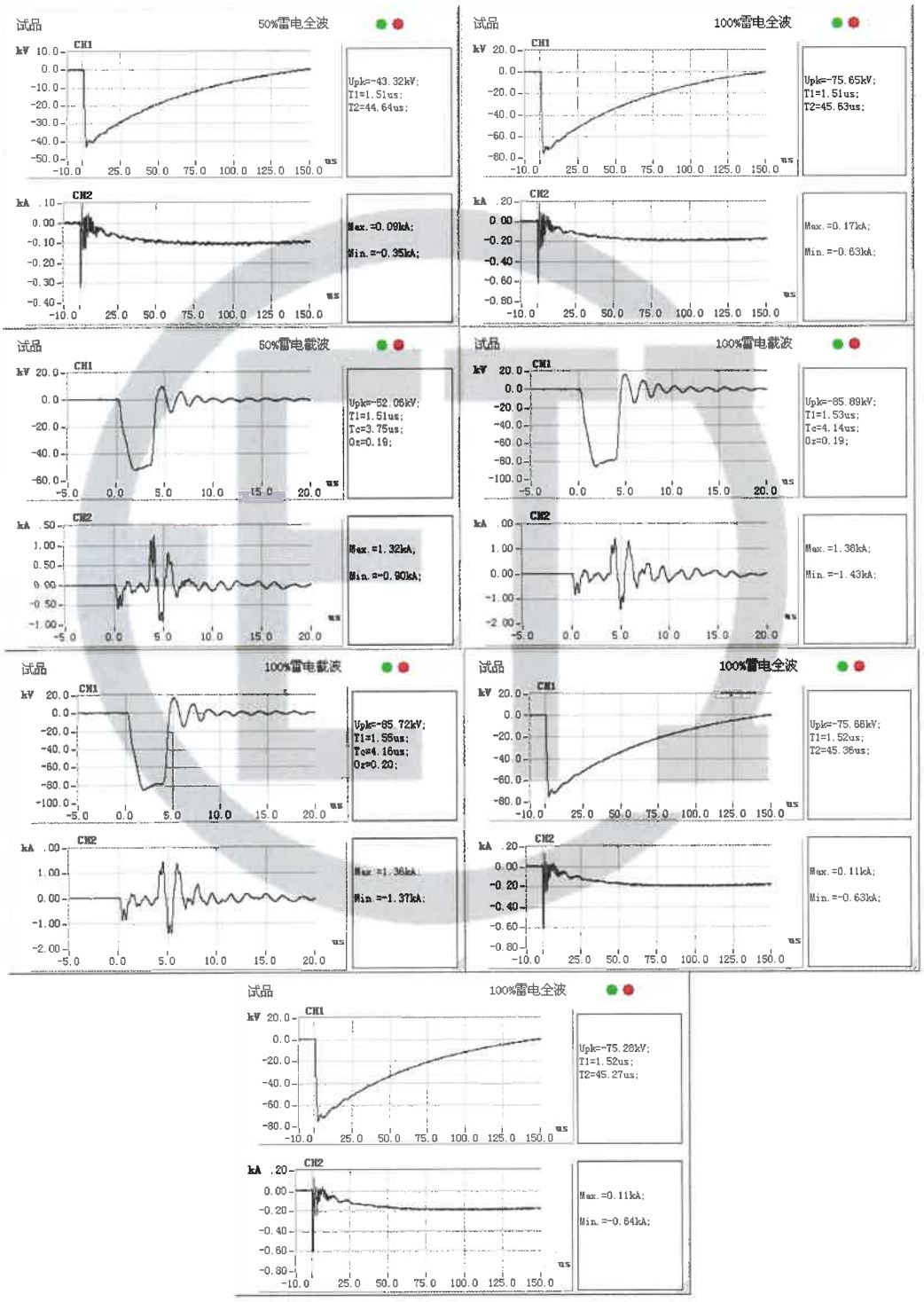
Tested terminal: C Test polarity: negative Channel 1: voltage wave Channel 2: current wave



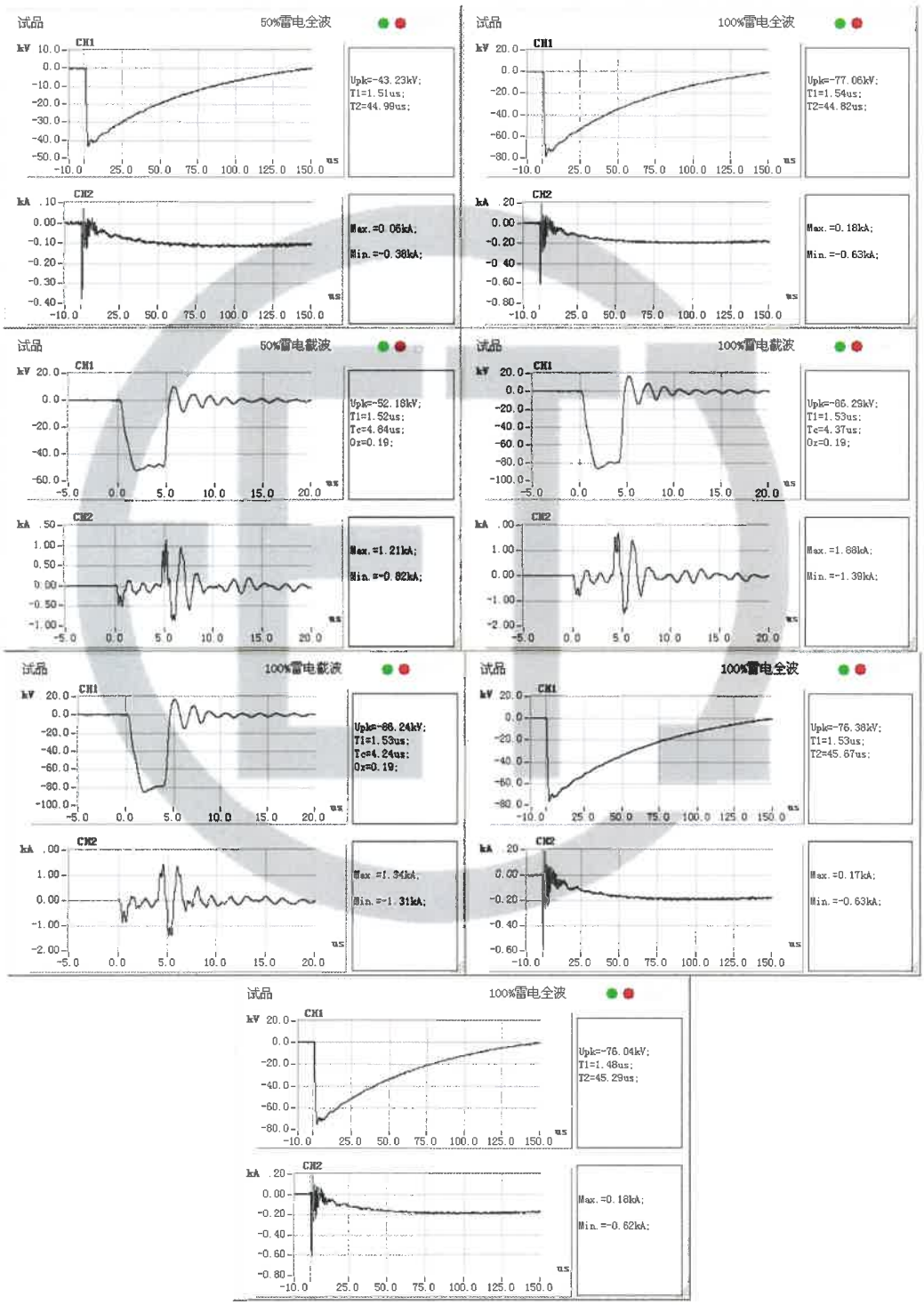
Tested terminal: O Test polarity: negative Channel 1: voltage wave Channel 2: current wave



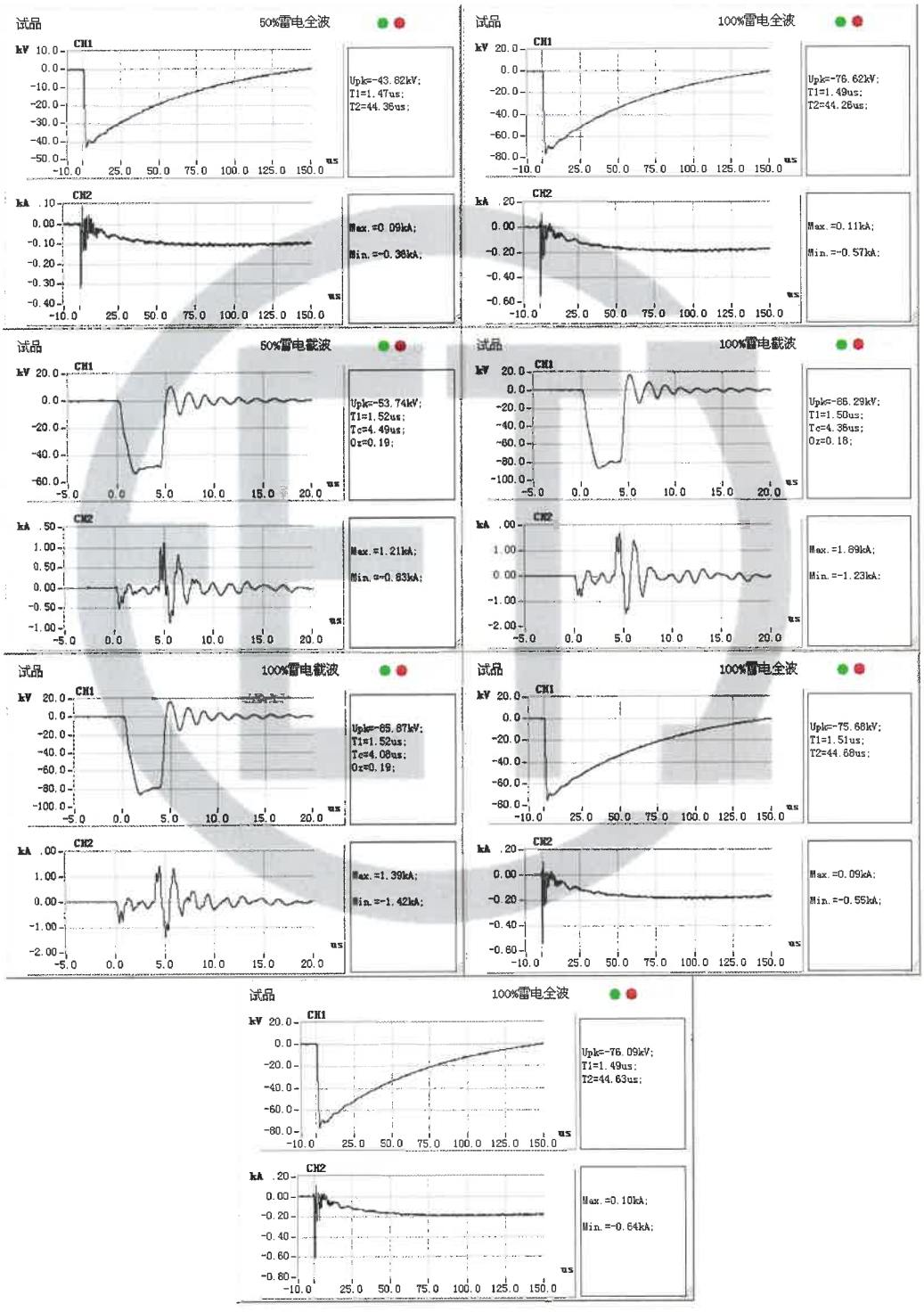
Tested terminal: a Test polarity: negative Channel 1: voltage wave Channel 2: current wave



Tested terminal: b Test polarity: negative Channel 1: voltage wave Channel 2: current wave



Tested terminal: c Test polarity: negative Channel 1: voltage wave Channel 2: current wave



4.19.4.14 Applied voltage test (AV) (routine test) Test date: Sep. 11, 2023

Relative humidity: 56%; Ambient temperature: 26.1℃; Oil temperature: 25.6℃; Air pressure: 101.0kPa

Part of applied voltage	Test voltage (kV)	Test duration (s)	Result
HV and neutral point—LV and earth	140	60	PASS
LV—HV, neutral point and earth	35	60	

4.19.4.15 Line terminal AC withstand test (LTAC) (routine test) Test date: Sep. 11, 2023

Relative humidity: 56%; Ambient temperature: 26.1℃; Oil temperature: 25.6℃; Air pressure: 101.0kPa

Phase-to-earth test

Part of applied voltage	Tapping position	Applied voltage (kV)	Induced voltage (kV)		Frequency (Hz)	Test duration (s)	Result
		LV	HV				
ab	5	21	A	200	200	30	PASS
bc		21	B	200			
ca		21	C	200			

4.19.4.16 Induced voltage withstand test and induced voltage test with partial discharge measurement (IVW, IVPD) (routine test)

Test date: Sep. 11, 2023

Relative humidity: 56%; Ambient temperature: 26.1℃; Oil temperature: 26.1℃; Air pressure: 101.0kPa

HV tapping position is 9b. Frequency is 200Hz.

Applied voltage		Duration (min)	Partial discharge magnitude (pC)		
Multiple	Phase to earth voltage (kV)		A	B	C
0.4Ur/$\sqrt{3}$	25.4	/	<15	<20	<15
1.2Ur/$\sqrt{3}$	76.2	1	<30	<30	<35
1.58Ur/$\sqrt{3}$	100.3	5	<80	<80	<75
2.0Ur/$\sqrt{3}$	127.0	0.5	/	/	/
1.58Ur/$\sqrt{3}$	100.3	5	<75	<80	<70
		10	<70	<75	<90
		15	<70	<75	<95
		20	<75	<75	<90
		25	<75	<80	<90
		30	<80	<80	<90
		35	<80	<90	<90
		40	<80	<90	<90
		45	<75	<85	<90
		50	<75	<85	<90
		55	<75	<80	<90
		60	<75	<80	<90
1.2Ur/$\sqrt{3}$	76.2	1	<35	<35	<45
0.4Ur/$\sqrt{3}$	25.4	/	<15	<25	<20

Remarks: Ur=110kV.

4.19.4.17 Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment (routine test, type test)

Test date: Sep. 08, 2023
Relative humidity: 61%; Ambient temperature:22.9℃

Dielectric dissipation factor (90℃)	Breakdown voltage (kV)	Water content (mg/L)
0.12%	63.1	10.5

Gas chromatograph analysis (after short-circuit test, before dielectric retests) Test date: Sep. 08, 2023

μL/L

H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	Total hydrocarbon
1.43	15.91	180.42	1.14	0	0.36	0	1.50

Gas chromatograph analysis (after dielectric retests, before long-duration no-load test)

Test date: Sep. 11, 2023

μL/L

H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	Total hydrocarbon
1.49	18.01	187.64	1.16	0	0.37	0	1.53

Gas chromatograph analysis (after long-duration no-load test, after all tests) Test date: Sep. 12, 2023

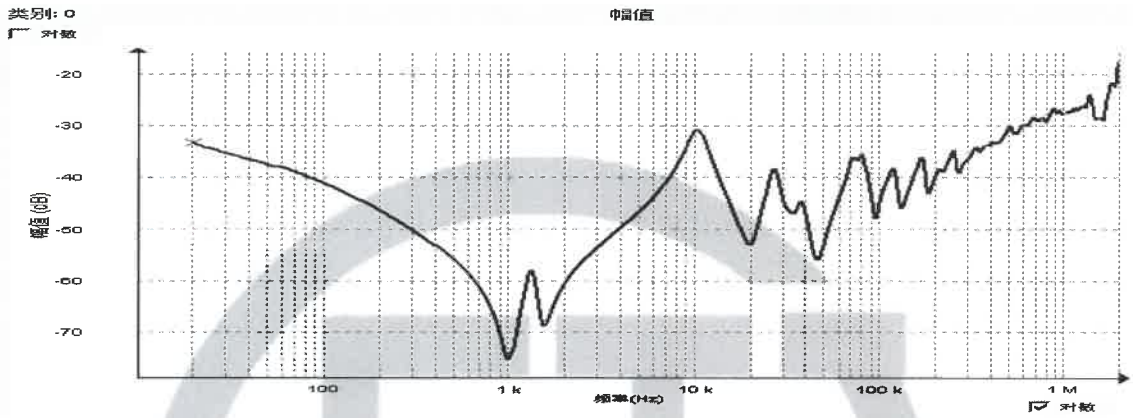
μL/L

H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	Total hydrocarbon
1.26	13.58	169.21	1.11	0	0.34	0	1.45

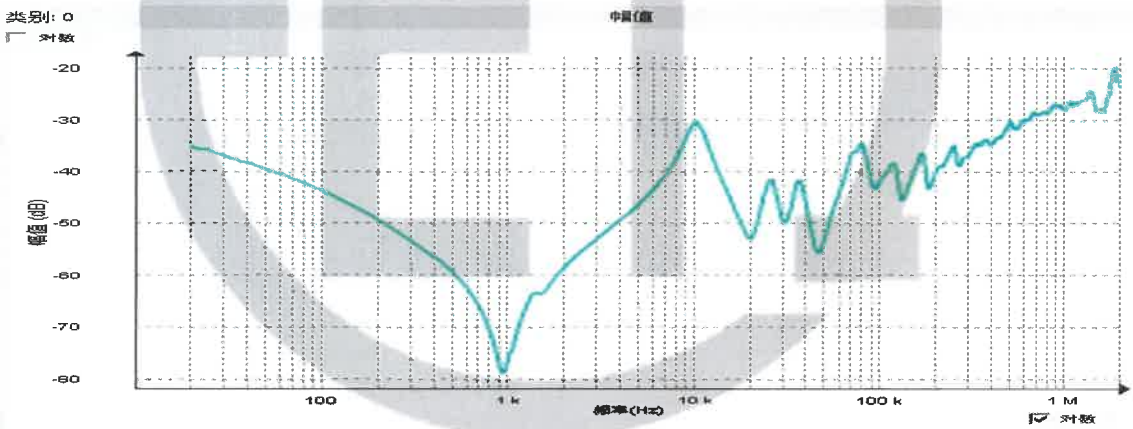
4.19.4.18 Measurement of frequency response (special test) Test date: Sep. 08, 2023

HV windings frequency response curve after short circuit test

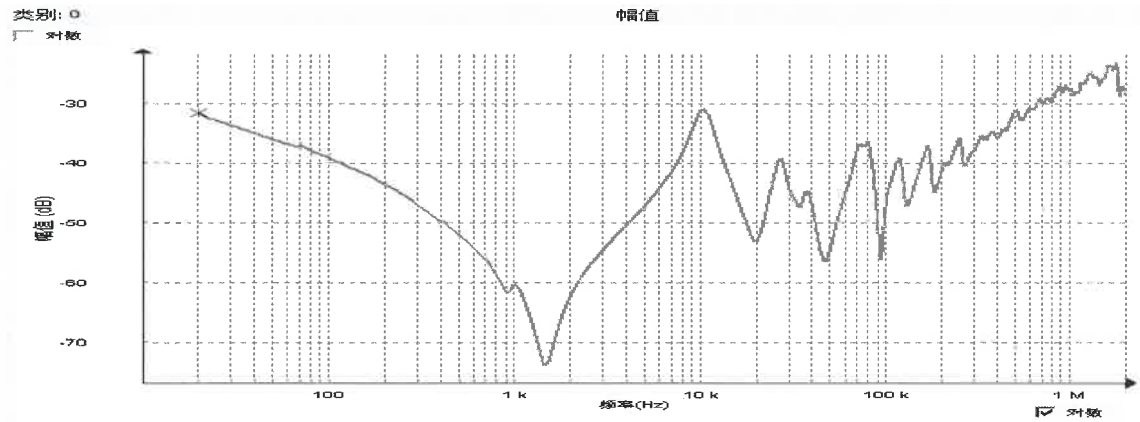
AO



BO

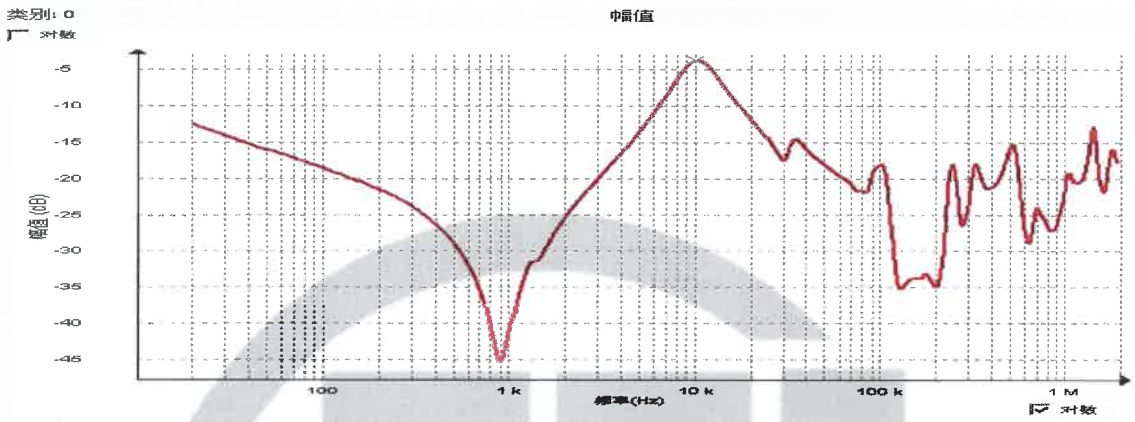


CO

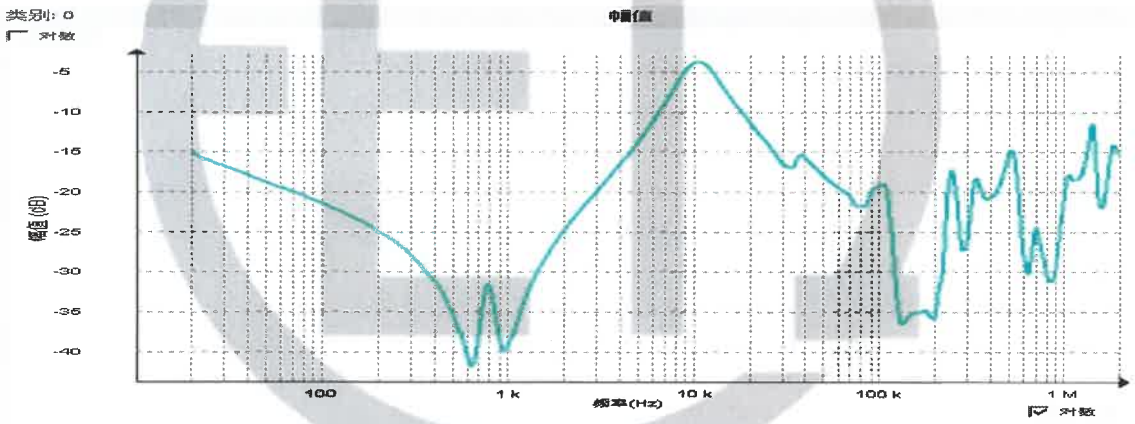


LV windings frequency response curve after short circuit test

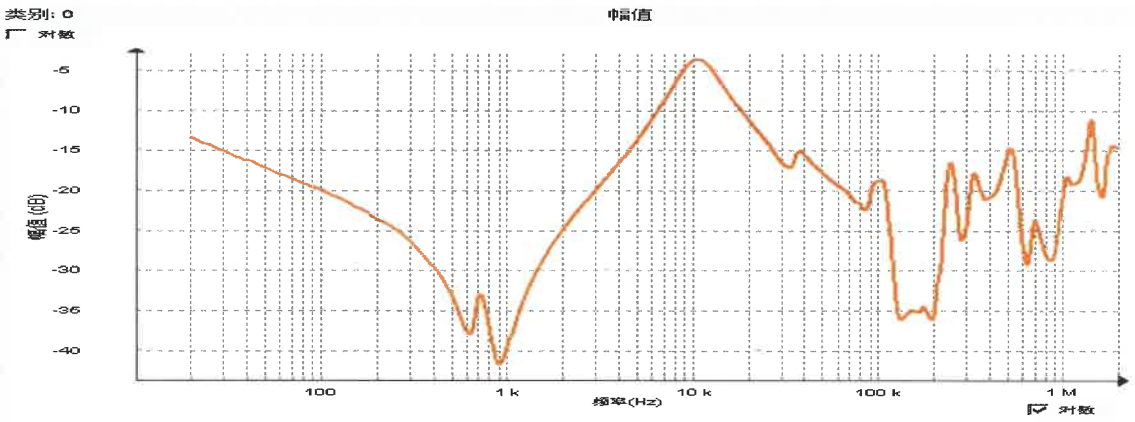
ab



bc



ca

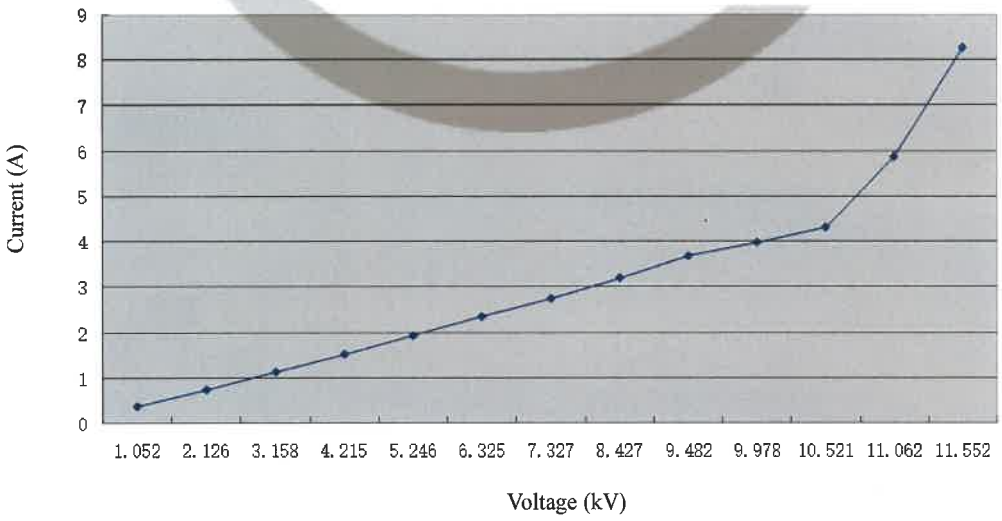


4.20 Measurement of no-load excitation characteristics (commission test) Test date: Sep. 11, 2023

Voltage	Measured voltage (kV)	Measured current (A)
0.1Un	1.052	0.3615
0.2Un	2.126	0.7315
0.3Un	3.158	1.125
0.4Un	4.215	1.517
0.5Un	5.246	1.924
0.6Un	6.325	2.345
0.7Un	7.327	2.742
0.8Un	8.427	3.201
0.9Un	9.482	3.685
0.95Un	9.978	3.985
1.0Un	10.521	4.315
1.05Un	11.062	5.876
1.1Un	11.552	8.292

Remarks: Un =10.5kV.

No-load excitation characteristic curve



4.21 Long-duration no-load test (commission test) Test date: Sep. 12, 2023

1.1 times rated voltage is applied on LV side for 12h. No C_2H_2 is found in oil and the content of total hydrocarbon has no obvious variation before and after the test. For the gas in oil chromatograph analysis data, see 4.19.4.17.

Duration (h)	Voltage (kV)	Current (A)	No-load loss (kW)
1	11.593	8.39	35.388
2	11.551	8.38	35.655
3	11.585	8.36	35.497
4	11.427	8.42	35.695
5	11.569	8.46	35.392
6	11.667	8.36	35.598
7	11.762	8.42	35.727
8	11.472	8.41	35.375
9	11.564	8.34	35.579
10	11.749	8.39	35.606
11	11.560	8.46	35.685
12	11.600	8.46	35.478

4.22 Measurement of zero-sequence impedances on three-phase transformers (special test)

Test date: Sep. 05, 2023

Connection symbol	Power supply terminal	Open-circuit terminal	Short-circuit terminal	Applied current (A)	Measured voltage (V)	Impedance (Ω)
YNd11	ABC—O	abc	/	124.265	706.654	17.06

4.23 Measurement of the harmonics of the no-load current (commission test) Test date: Sep. 05, 2023

No	CH-A THD(%) =20.79		CH-B THD(%) =21.92		CH-C THD(%) =23.42	
	In (A)	In/I1 (%)	In (A)	In/I2 (%)	In (A)	In/I3 (%)
01	4.87	100.00	3.80	100.00	4.17	100.00
02	0.08	1.68	0.05	1.29	0.06	1.38
03	0.45	9.26	0.33	8.63	0.32	7.63
04	0.02	0.48	0.02	0.55	0.03	0.82
05	0.86	17.65	0.71	18.63	0.88	21.06
06	0.01	0.24	0.01	0.32	0.02	0.46
07	0.26	5.26	0.28	7.26	0.26	6.24
08	0.02	0.31	0.01	0.36	0.01	0.25
09	0.05	1.06	0.05	1.29	0.06	1.46
10	0.00	0.09	0.00	0.08	0.01	0.12
11	0.06	1.23	0.04	1.15	0.05	1.26
12	0.00	0.00	0.00	0.04	0.00	0.06
13	0.02	0.48	0.03	0.68	0.02	0.58
14	0.00	0.00	0.00	0.00	0.00	0.00
15	0.05	1.06	0.03	0.76	0.04	0.91
16	0.00	0.00	0.00	0.00	0.00	0.00
17	0.02	0.32	0.01	0.19	0.01	0.35
18	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00

4.24 Temperature-rise test (including calculation of the winding hot-spot temperature-rise) (type test)

Test date: from Sep. 05, 2023 to Sep. 06, 2023

Measurement of top oil temperature rise:

Short-circuit method is adopted in the test. Tapping position is 17. LV side is short-circuited. Test duration is 13h of which the stabilization time is 3h. It is required to apply 253.7671kW of total loss and 252.5260kW is actually applied during testing.

Measurement of HV, LV winding temperature-rise:

367.40A current is required and 366.86A is actually applied during testing.

Measured data

Measurement of top oil temperature-rise and average oil temperature-rise			Measurement of average temperature-rise of windings-to-oil							Ambient temperature (°C)	
Top oil temperature (°C)	Average oil temperature (°C)	Total loss injection/ specified total loss (%)	Current injection/ rated current (%)	Cold resistance (Ω)		Average oil temperature (°C)		Average winding temperature (°C)		Total loss	Measurement of cold resistance
76.8	66.9	99.51	99.85	HV	0.4532	At the instant of shut down	67.0	HV	81.2	26.3	24.6
				LV	4.086 $\times 10^{-3}$	At the end of cooling curve	65.7	LV	82.4		

Calculations of temperature-rise

Top oil temperature-rise (K)		50.7
Winding temperature-rise (K)	HV	55.0
	LV	56.2
Winding hot-spot temperature-rise (K)	HV	69.2
	LV	70.8
Temperature-rise of tank surface and metallic structural parts (K)	/	57.9

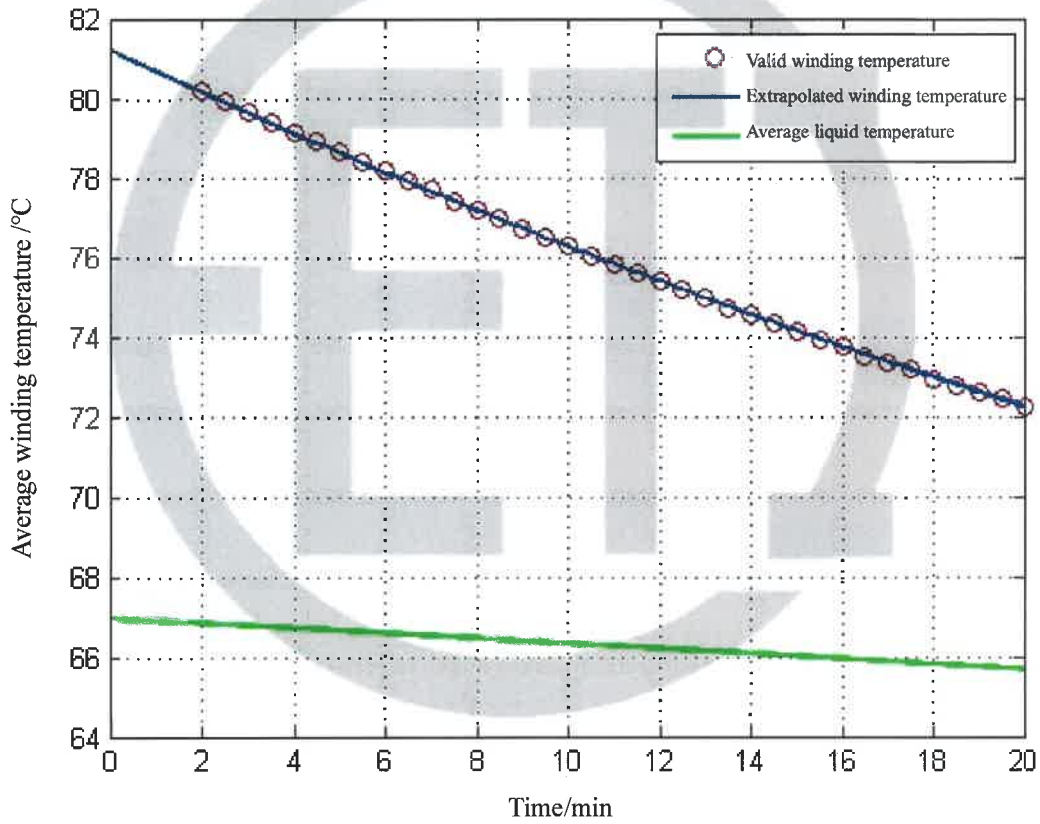
Remarks: the calculated results of temperature-rise are the corrected value under specified total loss and rated current. Both HV and LV winding hot-spot factors are 1.3.

Winding temperature curve

Average winding temperature data

Average HV winding temperature	81.2℃

Average temperature of HV winding at the instant of shutdown is 81.2℃

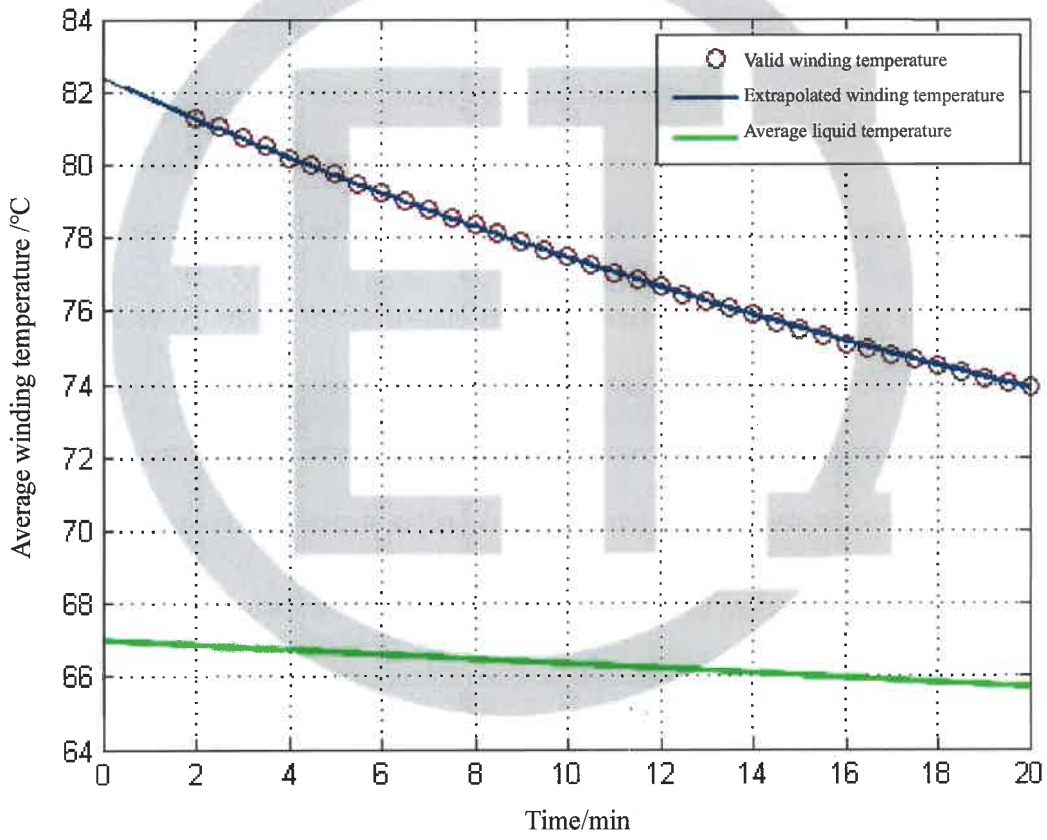


Winding temperature curve

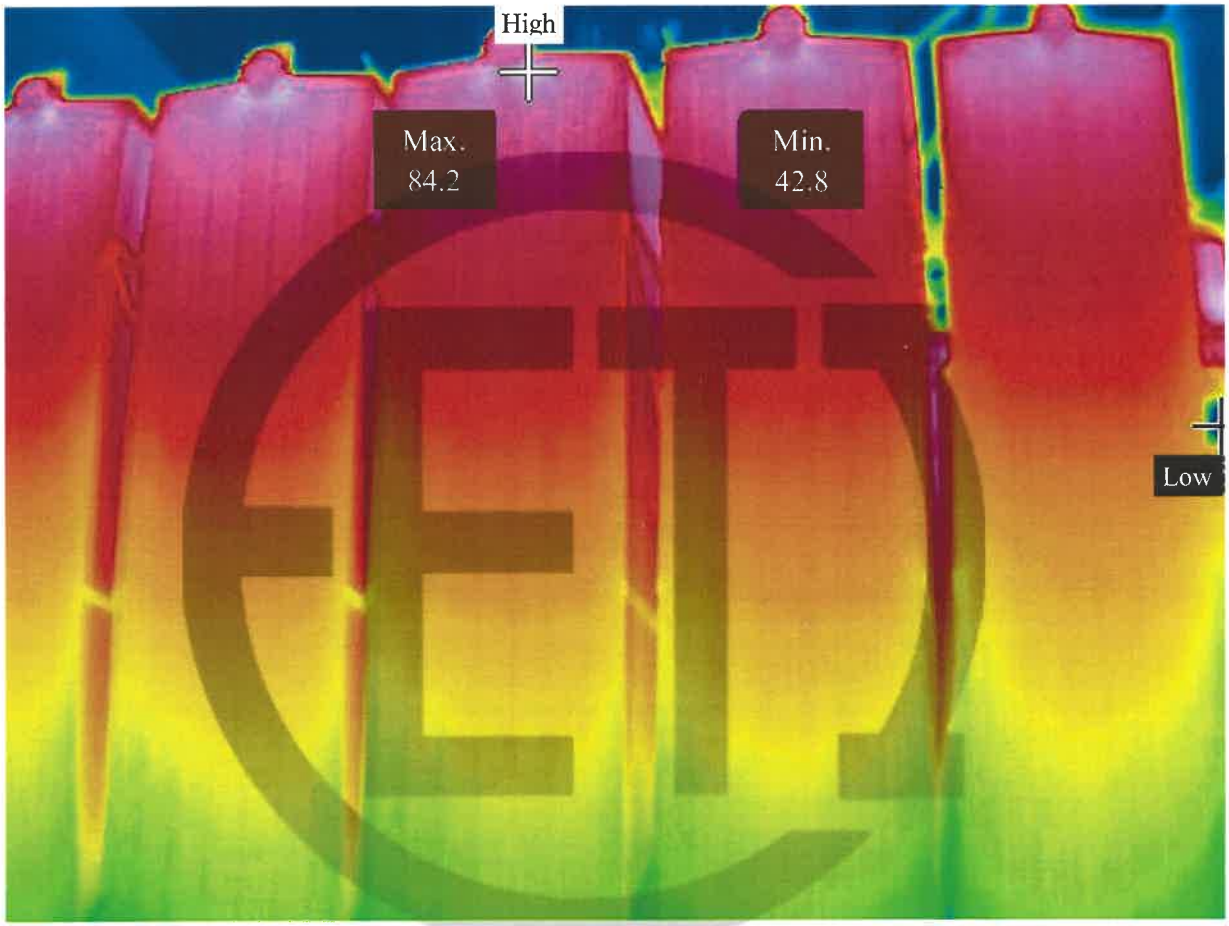
Average winding temperature data

Average LV winding temperature	82.4℃

Average temperature of LV winding at the instant of shutdown is 82.4℃



Temperature-rise thermogram of tank surface and metallic structural parts



4.25 Leak testing with pressure for liquid-immersed transformers (routine test)

Test date: from Sep. 03, 2023 to Sep. 05, 2023

Test method	Applied part	Applied pressure (kPa)	Duration (h)	Result
Static pressure method	Main part of transformer	30	24	No oil leakage or damage
	On-load tap-changer tank	30	24	No oil leakage or damage

Remarks: the tank of product is of general structure. No oil leakage or damage is found before leak testing.

4.26 Determination of sound levels (type test) Test date: Sep. 05, 2023

4.26.1 Rough estimation of the load current sound power level

Equation:

$$L_{WA,\,IN} \approx 39 + 18\lg\frac{Sr}{Sp} = 71.4\text{dB (A)}$$

where: Sr—the rated power is 63MVA;

Sp—the reference power is 1MVA.

Because $L_{WA,\,IN}$ is less 8.6dB (A) than limit value 80.0dB (A) of assured sound power level, according to standard requirement, it need to measure load current sound power level.

4.26.2 At no-load condition

4.26.2.1 Measurement of sound pressure level and calculation of sound power level

The transformer is excited at rated conditions. The prescribed contour shall be spaced 1.0m away from the principal radiating surface. Walk-around measurement is adopted in the test with 1/3 octave band. The height 1 of the measured point is 1.0m. The height 2 of the measured point is 2.0m.

Test environment

The total area of the surface of the test room Sv (m^2)	The average acoustic absorption coefficient α	The amount of acoustic absorption A (m^2)	Distance from the principal radiating surface (m)	The area of the measurement surface S (m^2)	Environmetal correction K (dB)
3293.2	0.2	658.6	1.0	102.7	2.1

Measured values (dB)

Status of cooling device	Average of background noise		Average noise value of transformer $\overline{L_{PA0}}$	A weighted sound pressure level $\overline{L_{PA}} = 10\lg(10^{0.1\overline{L_{PA0}}} - 10^{0.1\overline{L_{bgA}}}) - K$	A weighted sound power level $L_{WA} = \overline{L_{PA}} + 10\lg(S/S_0)$
	Before the test	After the test			
/	32.4	32.3	56.4	54	74

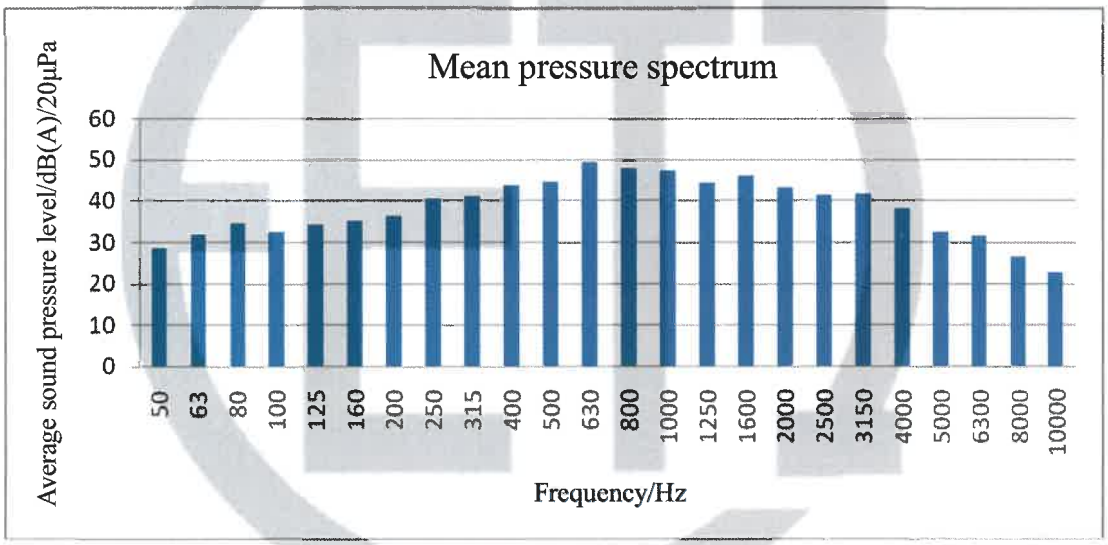
Remarks: $\overline{L_{PA0}}$: the uncorrected average A-weighted sound pressure level; $\overline{L_{PA0}} = 10\lg\left(\frac{1}{N}\sum_{i=1}^{N}10^{0.1L_{PAi}}\right)$

$\overline{L_{bgA}}$: the lower of the two calculated average A weighted background noise pressure level.

4.26.2.2 Values of frequency spectrum during the test

Octave band (Hz)	Initial $\overline{L_{bgA}}$ (dB)	Final $\overline{L_{bgA}}$ (dB)	$\overline{L_{PA0}}$ (dB)
50	11.5	12.1	28.6
63	12.8	12.5	31.9
80	12.4	12.8	34.5
100	20.5	20.7	32.6
125	18.6	19.2	34.2
160	20.7	21.1	35.1
200	18.9	19.2	36.5
250	20.5	20.2	40.6
315	21.6	21.1	41.2
400	19.2	19.5	43.9
500	21.5	21.1	44.8
630	20.9	20.8	49.5
800	22.1	21.8	48.2
1000	23.6	23.1	47.6
1250	17.6	18.2	44.6
1600	16.8	17.2	46.2
2000	16.2	16.5	43.2
2500	17.5	17.2	41.6
3150	14.9	14.2	41.9
4000	13.2	13.5	38.2
5000	13.5	13.9	32.6
6300	10.3	10.8	31.5
8000	9.1	9.9	26.5
10000	8.6	9.2	22.6

Remarks: for frequency spectra of sound pressure see P_{62}.


Mean pressure spectrum
Average sound pressure level/dB(A)/20μPa
60
50
40
30
20
10
0
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
Frequency/Hz

4.26.3 At load condition

4.26.3.1 Measurement of sound pressure level and calculation of sound power level

The transformer is excited at rated conditions. The prescribed contour shall be spaced 1.0m away from the principal radiating surface. Walk-around measurement is adopted in the test with 1/3 octave band. The height 1 of the measured point is 1.0m. The height 2 of the measured point is 2.0m.

Test environment

The total area of the surface of the test room Sv (m^2)	The average acoustic absorption coefficient α	The amount of acoustic absorption A (m^2)	Distance from the principal radiating surface (m)	The area of the measurement surface S (m^2)	Environmetal correction K (dB)
3293.2	0.2	658.6	1.0	102.7	2.1

Measured values (dB)

Status of cooling device	Average of background noise		Average noise value of transformer $\overline{L_{PA0}}$	A weighted sound pressure level $\overline{L_{PA}} = 10\lg(10^{0.1\overline{L_{PA0}}} - 10^{0.1\overline{L_{bgA}}}) - K$	A weighted sound power level $L_{WA} = \overline{L_{PA}} + 10\lg(S/S0)$
	Before the test	After the test			
/	32.4	32.3	52.5	50	70

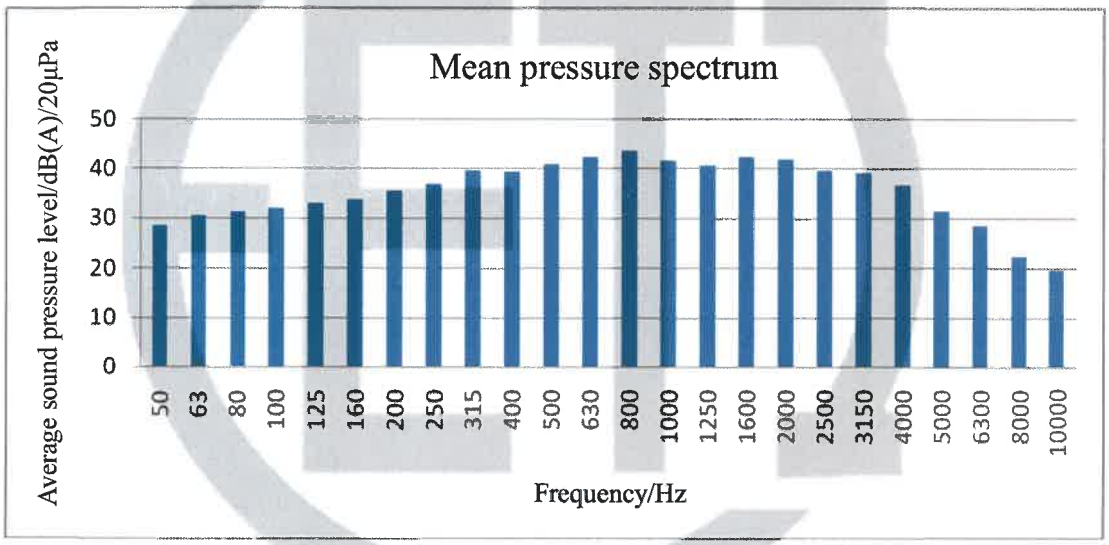
Remarks: $\overline{L_{PA0}}$: the uncorrected average A-weighted sound pressure level; $\overline{L_{PA0}} = 10\lg\left(\frac{1}{N}\sum_{i=1}^{N} 10^{0.1L_{PAi}}\right)$

$\overline{L_{bgA}}$: the lower of the two calculated average A weighted background noise pressure level.

4.26.3.2 Values of frequency spectrum during the test

Octave band (Hz)	Initial $\overline{L_{bgA}}$ (dB)	Final $\overline{L_{bgA}}$ (dB)	$\overline{L_{PA0}}$ (dB)
50	11.5	12.1	28.5
63	12.8	12.5	30.5
80	12.4	12.8	31.4
100	20.5	20.7	32.1
125	18.6	19.2	33.2
160	20.7	21.1	33.8
200	18.9	19.2	35.6
250	20.5	20.2	37.0
315	21.6	21.1	39.8
400	19.2	19.5	39.5
500	21.5	21.1	41.1
630	20.9	20.8	42.5
800	22.1	21.8	43.8
1000	23.6	23.1	41.9
1250	17.6	18.2	40.8
1600	16.8	17.2	42.5
2000	16.2	16.5	42.1
2500	17.5	17.2	39.8
3150	14.9	14.2	39.2
4000	13.2	13.5	36.8
5000	13.5	13.9	31.5
6300	10.3	10.8	28.7
8000	9.1	9.9	22.5
10000	8.6	9.2	19.6

Remarks: for frequency spectra of sound pressure see P_{65}.


Mean pressure spectrum
Average sound pressure level/dB(A)/20μPa
50
40
30
20
10
0
50
63
80
100
125
160
200
250
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
6300
8000
10000
Frequency/Hz

4.26.4 The sum of no-load sound power level and load sound power level

(dB)

Cooling method	A weighted sound power level (no-load sound level) L_{WA_UN}	A weighted sound power level (load sound level) L_{WA_IN}	A weighted sound power level $L_{WA,SN}=10\lg(10^{0.1L_{WA,UN}}+10^{0.1L_{WA,IN}})$
ONAN	74	70	75

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4.27 Vacuum deflection test on liquid-immersed transformers (special test) Test date: Sep. 03, 2023

Test method	Applied pressure (kPa)	Duration (min)
Vacuum degree	0.133	5

Measured items		Measured point										
		Tank wall								Tank cover		
		HV side			LV side			Left side	Right side	Middle of length		
		Left	Middle	Right	Left	Middle	Right	Middle	Middle	Left	Middle	Right
Vacuum degree	Initial distance (mm)	165	167	168	171	175	176	165	170	156	155	153
	Distance after pressure injection (mm)	168	171	172	174	180	180	170	173	160	159	156
	Distance without pressure (mm)	165	168	169	171	175	177	166	170	156	156	157
	Elastic deflection (mm)	3	4	4	3	5	4	5	3	4	4	3
	Permanent deflection (mm)	0	1	1	0	0	1	1	0	0	1	1
Remarks		No damage										

Remarks: 1. the tank of product is of general structure.
2. the described left and right sides of test point are viewed from HV side.
3. The test points are obtained from the 1/2 height of the tank in vertical direction, 1/4, 1/2 and 3/4 position respectively in horizontal direction.

4.28 Pressure deflection test on liquid-immersed transformers (special test) Test date: Sep. 03, 2023

Test method	Applied pressure (kPa)	Duration (min)
Positive pressure	100	5

Measured items		Measured point										
		Tank wall								Tank cover		
		HV side			LV side			Left side	Right side	Middle of length		
		Left	Middle	Right	Left	Middle	Right	Middle	Middle	Left	Middle	Right
Positive pressure	Initial distance (mm)	165	168	169	171	175	177	166	170	156	156	157
	Distance after pressure injection (mm)	160	162	164	167	170	172	159	165	152	152	155
	Distance without pressure (mm)	165	167	168	171	175	176	165	169	156	155	156
	Elastic deflection (mm)	5	6	5	4	5	5	7	5	4	4	2
	Permanent deflection (mm)	0	1	1	0	0	1	1	1	0	1	1
Remarks		No damage										

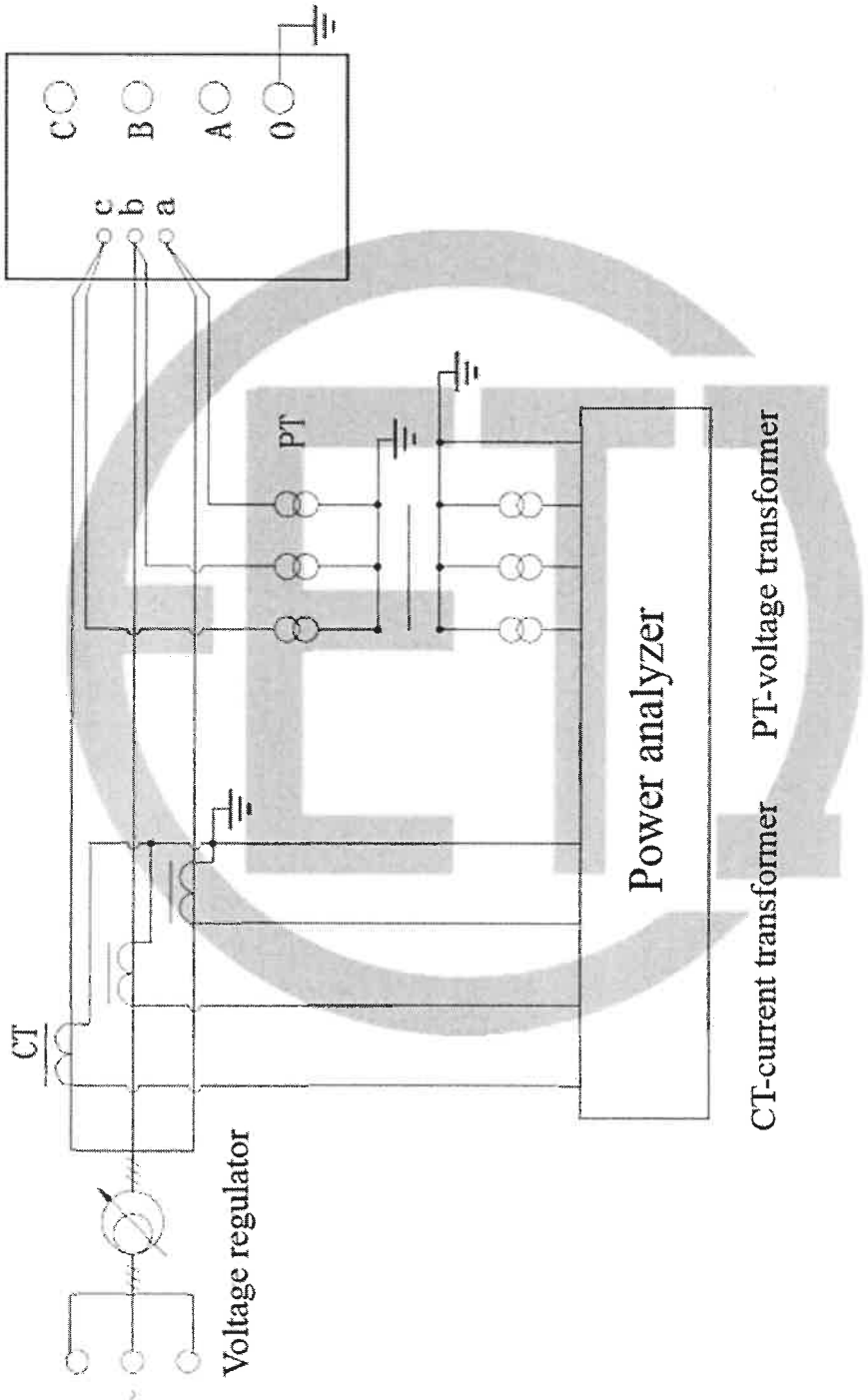
Remarks: 1. the tank of product is of general structure.
2. the described left and right sides of test point are viewed from HV side.
3. The test points are obtained from the 1/2 height of the tank in vertical direction, 1/4, 1/2 and 3/4 position respectively in horizontal direction.

HV side before short-circuit:

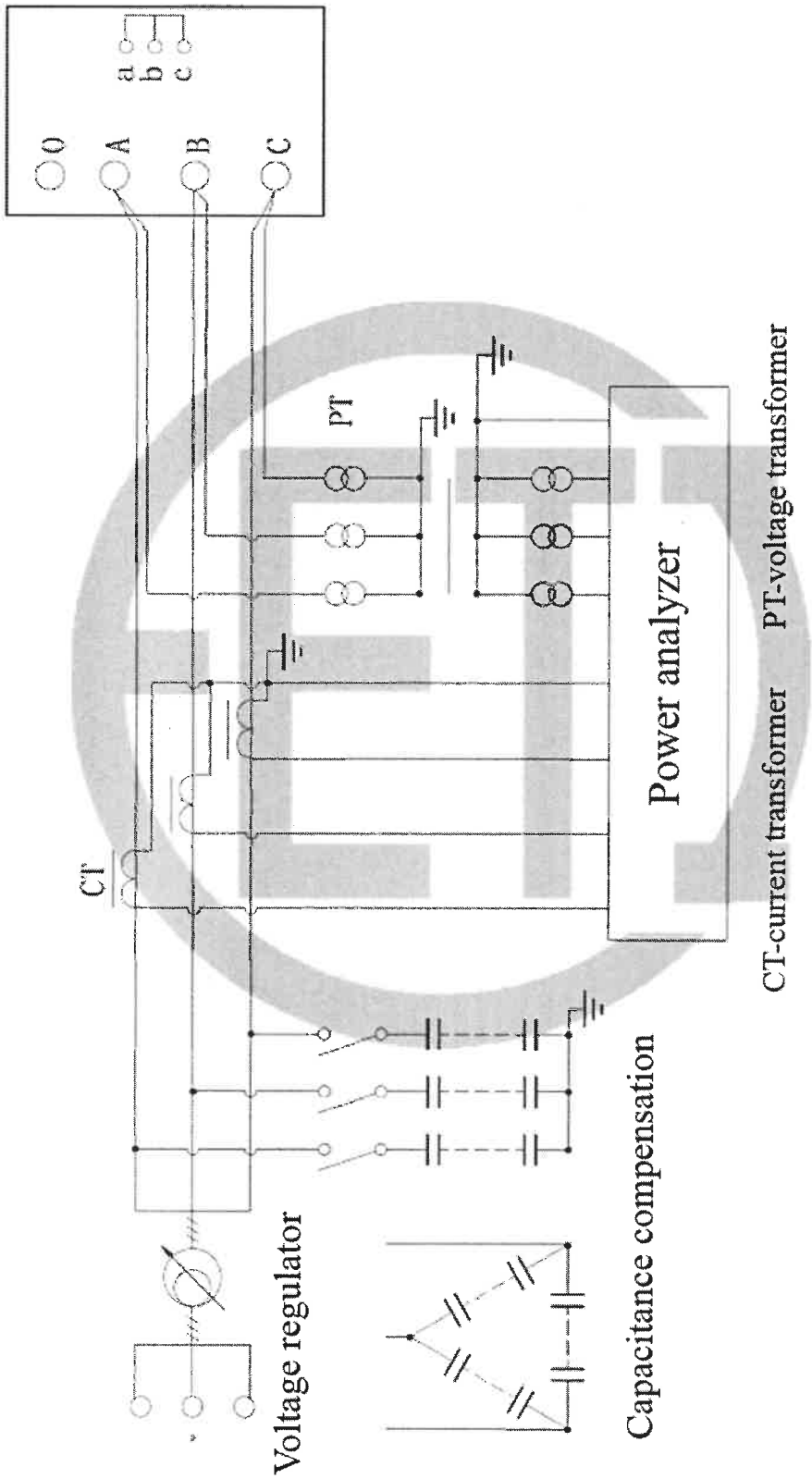
LV side before short-circuit:

HV side after short-circuit:

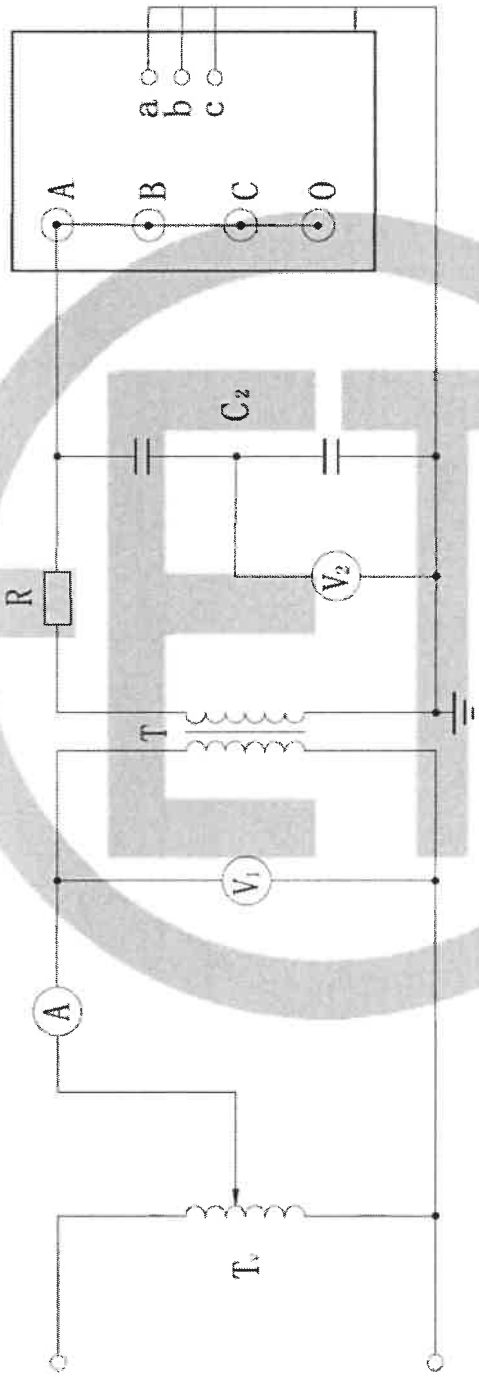
LV side after short-circuit:



Schematic diagram of measurement of no-load loss and current

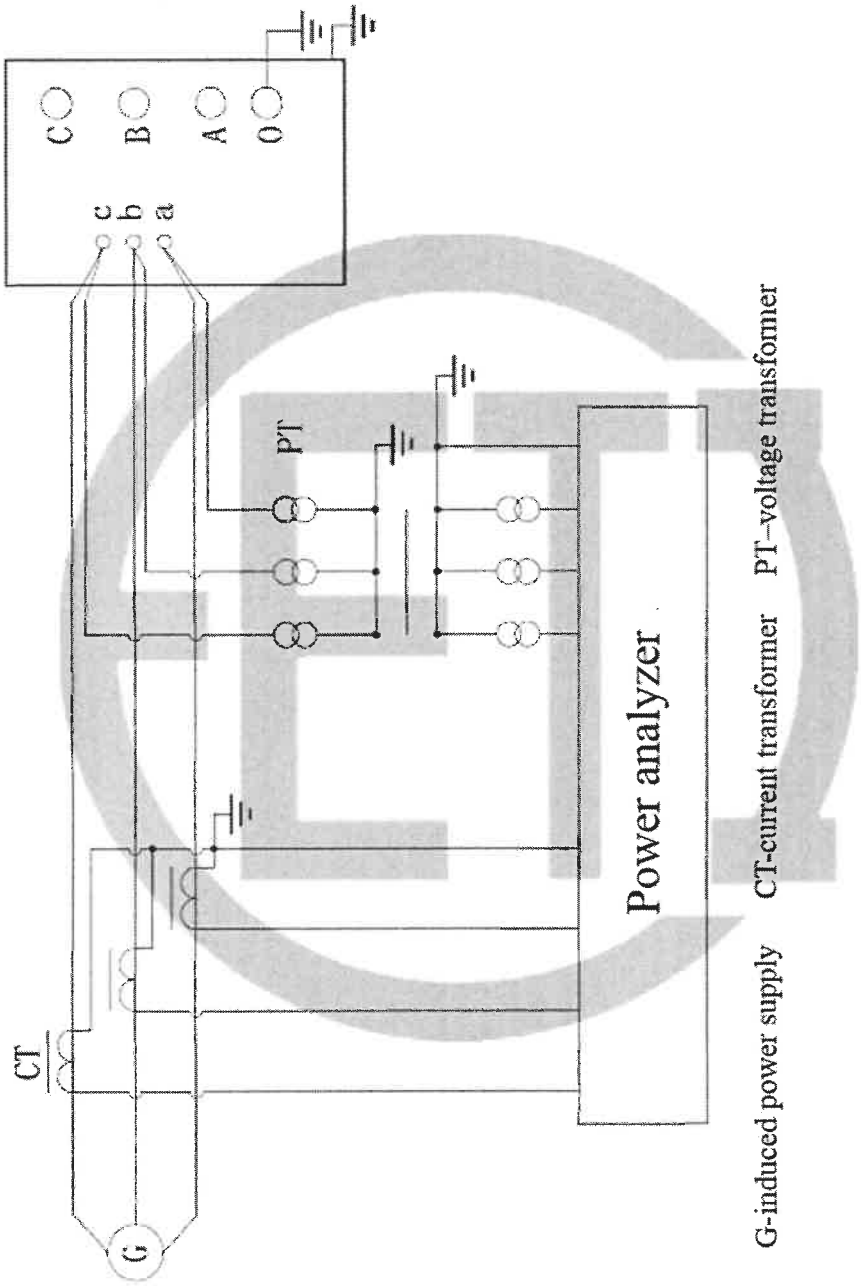


Schematic diagram of measurement of short-circuit impedance and load loss

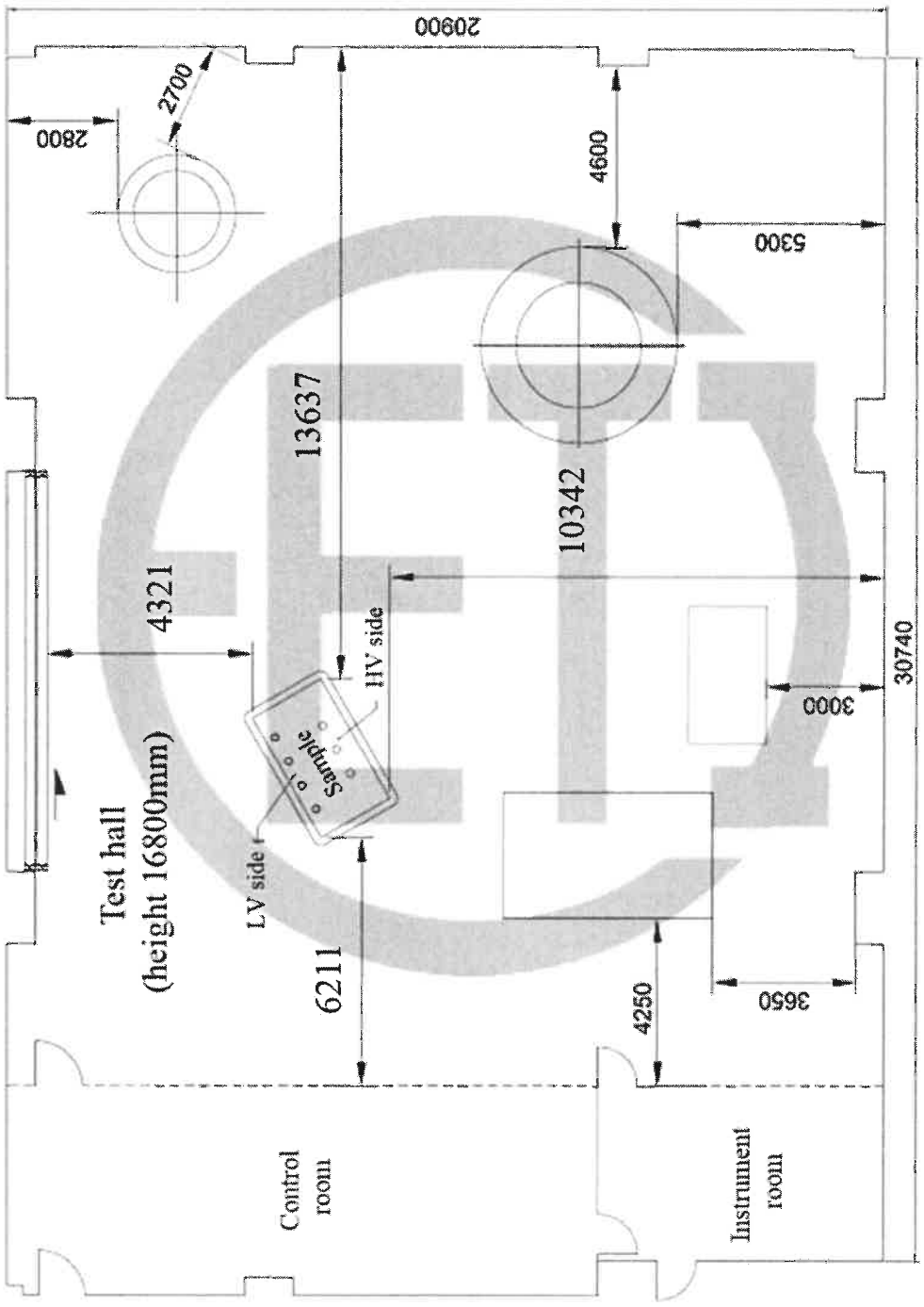


T_v-power supply
V_1-volmeter
T-testing transformer
R-resistance
A-amperemeter
C_2-capacitive divider
V_2-peak value voltmeter

Schematic diagram of applied voltage test



Schematic diagram of induced voltage withstand test



Sound levels arrangement diagram

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Instruments used in the tests

No	Test items	Name & type of instrument	Number & validity	Accuracy class
1	Measurement of d.c. insulation resistance between each winding to earth and between windings	Digital mega-ohm meter F1550C	ER17-017 2024-04-26	200k~5/10/20/50/ 100GΩ class 5, others class 20
2	Check of core and frame insulation for liquid-immersed transformers with core or frame insulation			
3	Measurement of dissipation factor (tanδ) of the insulation system capacitances	Movable insulation diagnostic and analysis system MIDAS2880	ER19-002 2024-02-09	Capacity: ±0.3%rdg±0.3pF Inductance: ±0.5%rdg±0.5mH
4	Measurement of bushing capacitances and dielectric dissipation factor (tanδ)			
5	Determination of capacitances windings-to-earth and between windings			
6	Measurement of winding resistance	DC resistance tester JYR (50C)	ER16-025 2024-03-03	0.2%±0.2μΩ
7	Measurement of voltage ratio and check of phase displacement	Transformer ratio tester JYT (A)	RI15-045 2024-05-25	AC10V: ≤150±0.1% 150~500±0.3%; AC160V: < 2000±0.1% 2000~10000±0.3%; Automatic DC supply <1000 ±0.1% 1000~5000 ±0.3%
8	Measurement of short-circuit impedance and load loss	Transformer power loss test system TMS580-200-4000	749-1237 2024-07-02	Voltage range: 100V~200kV, accuracy; 0.12% Current range: 1A~4000A, accuracy; 0.15%
9	Measurement of no-load loss and current			
10	Measurement of no-load loss and current at 90% and 110% of rated voltage			
11	Tests on on-load tap-changers			
12	Insulating liquid test, measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment	High precision full-automatic capacitance, inductance and dielectric loss measuring bridge 2840-Combi	ER18-003 2024-06-19	±0.2%rdg±0.01pF; ±0.5%rdg±1×10^{-5}
		Automatic dielectric strength tester NRNY-1004A	ER18-007 2024-05-15	±2%
		Moisture analyzer CA-200	CA02-002 2024-02-09	±3μg (water for 10μg to 1mg or above) RSD 0.3% or under (water for 1mg or above)
		Gas chromatogram analyzer 7890B	749-1732 2024-10-20	/

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Instruments used in the tests

No	Test items	Name & type of instrument	Number & validity	Accuracy class
13	Applied voltage test	Assemblies equipment of power-frequency partial discharge-free test YDTW-300/300	745-051 2024-04-26	/
		Capacitor voltage divider TAWF-400/300	745-051-1 2024-04-26	/
14	Auxiliary wiring insulation test	Power-frequency withstand voltage tester PFT6-5	745-083 2023-10-12	/
15	Line terminal AC withstand test	Transformer power loss test system TMS580-200-4000	749-1237 2024-07-02	Voltage range: 100V~200kV, accuracy; 0.12% Current range: 1A~4000A, accuracy; 0.15%
16	Induced voltage withstand test and induced voltage test with partial discharge measurement	Transformer power loss test system TMS580-200-4000	749-1237 2024-07-02	Voltage range: 100V~200kV, accuracy; 0.12% Current range: 1A~4000A, accuracy; 0.15%
		Multi-channel partial discharge tester DDX9121	745-058 2024-06-28	Resolution of partial discharge meter: 10 bits, partial discharge capture: 8 bits (7+), phase resolution 0.1', linear error <1%, ratio factor indeterminacy <1%, linear (10-100% FS) <1%, resolution 11 bits, measuring model Peak / √2 true RMS, synchronism: local voltage, HV source (automatic), rewrite HV synchronism by manual, synchronism lock range: 20Hz to 400Hz
17	Temperature-rise test	Transformer power loss test system TMS580-200-4000	749-1237 2024-07-02	Voltage range: 100V~200kV, accuracy; 0.12% Current range: 1A~4000A, accuracy; 0.15%
		Thermocouple type T	TT33-129/130/131/132/133/134 2024-01-11	/
		Data acquisition/switch unit 34970A	TT11-065 2024-01-11	V±5.25%, A±1.5%, T±1℃, Ω±0.81%
		Infrared thermal camera Ti480 RPO	TT14-033 2024-05-28	±2℃ or ±2% of reading, take larger one
		DC resistance tester JYR (50C)	ER16-079 2024-05-19	0.2%±0.2μΩ
		DC resistance tester JYR (50C)	ER16-056 2024-08-14	0.2%±0.2μΩ
		Electronic stopwatch PC396	HT15-010 2024-02-17	/

Instruments used in the tests

No	Test items	Name & type of instrument	Number & validity	Accuracy class
18	Measurement of no-load excitation characteristics	Transformer power loss test system TMS580-200-4000	749-1237 2024-07-02	Voltage range: 100V~200kV, accuracy; 0.12% Current range: 1A~4000A, accuracy; 0.15%
19	Long-duration no-load test			
20	Measurement of zero-sequence impedances on three-phase transformers			
21	Measurement of the harmonics of the no-load current			
22	Determination of sound levels	Transformer power loss test system TMS580-200-4000	749-1237 2024-07-02	Voltage range: 100V~200kV, accuracy; 0.12% Current range: 1A~4000A, accuracy; 0.15%
		Sound level meter 2270	SP01-013 2024-05-25	Class 1
		Sound level calibrator 4231	SP01-020 2024-05-25	Class 1
		Steel tapeline 5m	LS05-032 2024-03-06	/
23	Short-circuit withstand test	Data collector 1-GEN16T-2	EI56-019 2023-11-23	Class 1.5
		LCR automatic tester UC2860XD	ER16-091 2024-06-05	±0.05%
		Voltage transformer TEMP-1000HU	EH112-001 2023-10-22	Class 0.2
		Voltage transformer VEOS525	EH111-001 2024-09-16	Class 0.2, class 3P
		Voltage transformer VEOS525	EH111-002 2024-09-16	Class 0.2, class 3P
		Voltage transformer VEOS525	EH111-003 2024-09-16	Class 0.2, class 3P
		Current diverter FLT1-30/2.5	EI30-016 2023-10-17	Class 0.2
		Current diverter FLT1-30/2.5	EI30-017 2023-10-17	Class 0.2
		Current diverter FLT1-30/2.5	EI30-018 2023-10-17	Class 0.2
		Low sensitivity current diverter FLP1	EI31-081 2025-02-08	Class 0.2
		Low sensitivity current diverter FLP1	EI31-082 2025-02-08	Class 0.2
		Resistance and capacitance general mixed voltage divider TBF252kV-400pF/500MΩ	EV39-004 2024-04-10	/

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Instruments used in the tests

No	Test items	Name & type of instrument	Number & validity	Accuracy class
24	Lightning impulse test	Assemblies testing equipment of impulse voltage generator CJDY-2400kV/360kJ	750-008 2025-07-04	/
		Weakly damped capacitor voltage divider DDF-2400/400	750-008-1 2025-07-04	/
25	Measurement of frequency response	Transformer winding deformation tester FRAX99	ER16-021 2024-02-09	/
26	Leak testing with pressure for liquid-immersed transformers	Pressure gauge Y-100	FP81-428 2024-01-17	Class 1.6
27	Vacuum deflection test on liquid-immersed transformers	Vacuum gauge	FP81-515 2024-02-04	Class 2.5
		Steel tapeline 5m	LS05-032 2024-03-06	/
28	Pressure deflection test on liquid-immersed transformers	Pressure gauge Y-100	FP81-428 2024-01-17	Class 1.6
		Steel tapeline 5m	LS05-032 2024-03-06	/

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