Report

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TIC 3155-14

Factory Acceptance Test on a three-phase power transformer 60 MVA / 220 kV

Manufacturer
Siemens Transformer (Wuhan) Co., Ltd.
Wuhan, China

Arnhem, 23 January 2015

INSPECTION REPORT

Report number	TIC 3155-14
Client	Siemens Transformer (Wuhan) Co., Ltd. No.1 Jinyang Avenue Yangluo Economic Development Zone Wuhan City, Hubei Province China, 430415
Reference	72130865
Concerning	Factory Acceptance Test
Date	13 to 16 December 2014
Place	Wuhan, China
Object	Three-phase Power Transformer 60 MVA / 220 kV
Manufacturer	Siemens Transformer (Wuhan) Co., Ltd. No.1 Jinyang Avenue Yangluo Economic Development Zone Wuhan City, Hubei Province China, 430415

REQUIREMENTS

The tests were carried out in accordance with IEC 60076-1 2011, IEC 60076-2 2011, IEC 60076-3 2013 and IEC 60076-10 2001.

TEST PROGRAMME

For the programme, specified by the client, a reference is made on pages 3 and 4.
The tests were carried out in accordance with IEC 60076-1 2011, IEC 60076-2 2011, IEC 60076-3 2013 and IEC 60076-10 2001.

SUMMARY AND CONCLUSION

The results obtained relate only to the work ordered and to the material tested.
The difference between mean voltage and R.M.S voltage was larger than 3% at 110% of the rated voltage. Client didn't specify the guaranteed value for no-load loss and current at 110% of the rated voltage.
For the remaining points, this transformer passed all the tests successfully.

KEMA Nederland B.V.

S.A.M. Verhoeven
Director Testing, Inspections & Certification The Netherlands

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Arnhem, 23 January 2015

This report consists of:
75 pages incl. 15 annexes (57 pages)

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MATERIAL DATA

Type		Three-phase 60 MVA / 220 kV power transformer TSSN7854
Manufacturer		Siemens Transformer (Wuhan) Co., Ltd.
Serial Number		V100643
Year of Manufacture		2014
Insulation		Paper / oil
Rated voltages	[kV]	220 / 110 / 13,8
Tapping range	[kV]	220 +10/-10 x 1,25%
Rated frequency	[Hz]	50
Highest voltages	[kV]	245 / 123 / 17,5
Rated current	[A]	157,5 / 314,9 / 334,7

		Switching impulse	Lightning impulse/CW	Separate source
High voltage winding (HV)	[kV]	850	1050/1155	460
Middle voltage winding (MV)	[kV]	-	550/605	230
Low voltage winding (LV)	[kV]	-	125/138	38
HV neutral point (HVN)	[kV]	-	130	50
MV neutral point (MVN)	[kV]	-	130	50

Rated power ONAN	[MVA]	60 / 60 / 8
Vector Group		YNyn0d1
Cooling type		ONAN
Terminals		HV: 1U, 1V, 1W MV: 2U, 2V, 2W LV: 3U, 3V, 3W HVN: 1N MVN: 2N
Standards		IEC 60076

The transformer was tested with radiators and conservator.
Photos of the transformer under test are presented in annex O.

Drawings and documents

Nameplate drawing No.	V04 11 361, annex N, page 1.
General outline drawing No.	V04 11 357, annex N, page 2.

TEST PROGRAMME

		Kind of test [1)]	Standard/ Specification	Clause
0	INSPECTION OF THE TEST-SETUP			
1	DIELECTRIC EXAMINATIONS			
1.	Dielectric tests			
1.	Applied voltage test	R	IEC 60076-3	10
1.1.2	Induced voltage test with partial discharge measurement (IVPD)	R	IEC 60076-3	11.3
1.1.3	Lightning impulse test, including chopped wave	R & S	IEC 60076-3	13
1.1.4	Switching impulse test	R	IEC 60076-3	14
1.1.5	Auxiliary wiring insulation test	R	IEC 60076-3	9
2.	Dielectric measurement			
1.	Measurement of dissipation factor and system capacitances	R	IEC 60076-1	11.1.2.2.c
1.2.2	Measurement of insulation resistances	R	IEC 60076-1	11.1.2.2.b
1.2.3	Check of core and frame insulation	R	IEC 60076-1	11.12
2	BEHAVIOUR UNDER NORMAL CONDITIONS			
1.	Measurement of winding resistances	R	IEC 60076-1	11.2
2.2	Measurement of voltage ratios and check of phase displacement	R	IEC 60076-1	11.3
2.3	Measurement of load loss and short-circuit impedance	R	IEC 60076-1	11.4
2.4	Measurement of no-load loss and current	R	IEC 60076-1	11.5
5.	Measurement of the harmonics of the no-load current	-	Client requirement	
6.	Measurement of zero-sequence impedance	S	IEC 60076-1	11.6
2.7	Determination of acoustic sound pressure levels	T	IEC 60076-10	
2.8	Temperature-rise test	T	IEC 60076-2	
2.9	Dissolved gas analysis	R	IEC 60076-1	11.2.2.d
2.10	Tightness test	R	IEC 60076-1	11.8
2.11	Frequency response analysis test	S	IEC 60076-1	11.1.4.l
3	FUNCTIONAL TESTS OF COMPONENTS AND AUXILARY INSTRUMENTS			
3.1	Tests on on-load tap changer	R	IEC 60076-1	11.7
2.	Tests on current transformers	R	IEC 60076-1	11.1.2.1.i
3.	Rating plate	-	Client requirement	

[1)] R = Routine test T = Type test S = Special test

PERSONS ATTENDING THE INSPECTION

Mr. Cai Zehong Siemens Transformer (Wuhan) Co., Ltd.

THE INSPECTION WAS CARRIED OUT BY

Mr. Gu Bin KEMA Nederland B.V.

PURPOSE OF THE INSPECTION

Purpose of the inspection was to verify whether the material complies with the requirements.

DESCRIPTION AND RESULTS OF THE INSPECTION

0 INSPECTION OF THE TEST SET-UP

The tests were carried out in the laboratory of the manufacturer, who is therefore jointly responsible for the correctness of the results obtained. The measuring devices and the test set-up were checked by KEMA and where necessary calibrated.

Results

The results do not give rise to remarks.

1 DIELECTRIC EXAMINATIONS

1.1 Dielectric tests

1.1.1 Applied voltage test

This test was carried out in accordance with IEC 60076-3, clauses 10.
The tests were performed according the following table:

Voltage supplied to	Earthed	Voltage [kV]	Frequency [Hz]	Duration [s]
HV winding and neutral	remaining winding and frame	50	50	60
MV winding and neutral	remaining winding and frame	50	50	60
LV winding	remaining winding and frame	38	50	60

Results

The results do not give rise to remarks.

2. Induced voltage test with partial discharge measurement (IVPD)

This test was carried out in accordance with IEC 60076-3, clause 11.3.
The induced voltage withstand test was carried out by applying a three-phase AC voltage of 200 Hz across three terminals of the low voltage winding. In this way voltage is induced on the HV and MV terminal in accordance with the voltage levels and for the duration as per the requirements of the standard. These levels were:

- 0,4 U_r
- 1,2 U_r during 1 minute
- 1,58 U_r during 5 minutes
- test voltage 1,8 U_r during 30 seconds
- 1,58 U_r during 60 minutes
- 1,2 U_r during 1 minute
- 0,4 U_r.

U_r is 220 kV and 110 kV respectively. Test voltage for the HV terminal and MV terminal was 396 kV and 198 kV, which corresponds with 1,8 U_r.
During the test the tapping selector for HV winding was in position 11.
The test voltage was measured at the low voltage terminals. The calculated ratio between the voltage on the terminal under test and the low voltage had been verified before the test in the actual test circuit by measurement at reduced voltage.
The neutral terminals for HV and MV winding were connected to ground.
Throughout the tests neither flashover nor breakdown occurred.
The partial discharges were measured during this test.
The circuit was calibrated with a pulse generator. The tests were carried out subsequently with the required voltage levels and duration.
The results are presented in annex B.

Results

The measured values do not give rise to remarks.

1.1.3 Lightning impulse test including chopped wave

This test was carried out in accordance with IEC 60076-3, clause 13.
The lightning impulse tests were carried out on all terminals, including the neutral terminals. Every terminal except the neutral was subjected to a chopped wave.
The specified test voltage for the HV terminal was 1050 kV for full wave and 1155 kV for chopped wave. The tests were carried out in tapping position 21, 11 and 1 for phase 1U, 1V and 1W separately. The current was measured over a 0,11 Ω shunt, connected between the HV terminal and earth.
The specified test voltage for the MV terminal was 550 kV for full wave and 605 kV for chopped wave. The current was measured over a 0,11 Ω shunt, connected between the MV terminal and earth.
The HV neutral terminal the specified test voltage was 130 kV for full wave and was tested in tapping position 1.
The MV neutral terminal the specified test voltage was 130 kV for full wave.
For the LV terminal the specified test voltage was 125 kV full wave and 138 kV for chopped wave. The current was measured over a 0,11 Ω shunt, connected between the other LV terminals and earth.
The test sequence consisted of one reduced full wave, one full wave, two chopped waves and two full waves all with negative polarity.
The wave shape was within the requirements of the standard.
The front and tail times (first full wave) are given in annex A. The test results are presented in annex M, page 18 up to page 26.

Results

The impulse waves, recorded before and after the 100% full waves, have been compared and they are identical in shape.
Neither flashover, nor breakdown occurred.

1.1.4 Switching impulse test

This test was carried out in accordance with IEC 60076-3, clause 14.
For the HV terminal the test voltage specified was 850 kV. The tests were carried out in tapping position 1. The non-tested HV terminals were connected together to earth via a 9 kΩ resistance. The MV terminals were floated and the LV terminals were earthed to one point. The neural point for HV winding was connected via a 0,11 Ω shunt to earth to measure the current.
The neutral point for MV winding was connected to ground.
The time to peak, time above-90% and time-to-zero (first full wave) are given in annex A.
The test results are presented in annex M, page 16 up to page 17.

Results

The impulse waves, recorded before and after the 100% full waves, have been compared and they are identical in shape.
Neither flashover, nor breakdown occurred.

1.1.5 Auxiliary wiring insulation test

This test was carried out in accordance with IEC 60076-3, clause 9.
An AC test voltage of 2 kV was applied between auxiliary power, control circuitry and ground for 1 minute.
An AC test voltage of 2,5 kV was applied between current transformer secondary windings and ground for 1 minute.

Results

The results do not give rise to remarks.

1.2 Dielectric measurements

1.2.1 Measurement of dissipation factor and system capacitances

This test was carried out in accordance with IEC 60076-1, clause 11.1.2.2.c.
Measured were the dissipation factor (tan δ) and the capacitances of the mutual insulation between the windings and ground.
Also these tests were performed on the HV and MV bushings.
The results are presented in annex D.

Results

The measured values do not give rise to remarks.

1.2.2 Measurement of insulation resistances

This test was carried out in accordance with IEC 60076-1, clause 11.1.2.2.b.
Measured, before the dielectric tests, were the insulation resistances between the combinations mutual windings and ground, between core and clamp, between core and earth, and between clamp and earth.
The measured values are presented in annex C.

Results

The measured values do not give rise to remarks.

1.2.3 **Check of core and frame insulation**

This test was carried out in accordance with IEC 60076-1, clause 11.12.

voltage applied at	earthed	test voltage (DC) kV	duration s
Core	remaining windings and frame	2,5	60
Frame	remaining windings and core	2,5	60

Results

The results do not give rise to remarks.

2 BEHAVIOUR UNDER NORMAL CONDITIONS

2.1 Measurement of winding resistances

This test was carried out in accordance with IEC 60076-1, clause 11.2.
The winding resistances were measured for all windings and in all positions of the tapping changer.
The results are presented in annex E.

Results

The measured values do not give rise to remarks.

2.2 Measurement of voltage ratios and check of phase displacement

This test was carried out in accordance with IEC 60076-1, clause 11.3.
The measurement was done with a ratio bridge for all tapping positions HV/MV, HV/LV and MV/LV. The measured values, compared with the theoretical ones, are given in annex F.
The connection symbol was checked together with the determination of the voltage ratio. Balance of the bridge can be attained only if the voltages connected to the bridge from the primary and secondary side have the same phase and sense.
The results of the tests are presented in annex F.

Results

The measured values, compared with the theoretical values, are within the standard tolerances. The connection symbol matched the specification.

3. Measurement of load loss and short-circuit impedance

This test was carried out in accordance with IEC 60076-1, clause 11.4.
The short-circuit impedance and load losses of the transformer were measured as follows:

- The combination HV to MV at the HV rated, middle and extreme tapping positions with the MV short circuited and currents based for 60 MVA.
- The combination HV to LV at the HV rated, middle and extreme tapping positions with the LV short circuited and currents based for 8 MVA.
- The combination MV to LV with the LV short circuited and currents based for 8 MVA.

The measuring results were recalculated for 75 °C winding temperature.
The results of the tests are presented in annex G.

Results

The measured values were within the specified tolerance and within the guaranteed value.

2.4 Measurement of no-load loss and current

This test was carried out in accordance with IEC 60076-1, clause 11.5.
The no-load loss and no-load current were measured before the dielectric tests mentioned under 1.1.1 to 1.1.5, at 90%, 95% 100%, 105% and 110% of the rated voltage at tapping position 11, supplied to the low voltage winding terminals.
The results are presented in annex H.

Results

The difference between mean voltage and R.M.S voltage was larger than 3% at 110% of the rated voltage. Client didn't specify the guaranteed no-load loss and current at 110% of the rated voltage.
The measured no-load loss and current at 100% of the rated voltage were within the specified tolerance and within the guaranteed value.

2.5 Measurement of the harmonics of the no-load current

This test was carried out in accordance with client requirement.
Before the dielectric tests mentioned under 1.1.1 to 1.1.5, the fundamental, and the 2nd up to the 19th harmonics on the no-load current were measured 100% of the rated voltage at tapping position 11, supplied to the low voltage winding terminals.
The result is presented in annex M, page 10.

Results

The measured values do not give rise to remarks.

6. Measurement of zero-sequence impedance

This test was carried out in accordance with IEC 60076-1, clause 11.6.
The following tests were carried out at tapping position 11:

- Voltage was applied between the short-circuited HV terminals 1U1V1W and neutral 1N, MV terminals 2U2V2W and neutral 2N were short-circuited.
- Voltage was applied between the short-circuited MV terminals 2U2V2W and neutral 2N, HV terminals 1U1V1W and neutral 1N were left open.
- Voltage was applied between the short-circuited MV terminals 2U2V2W and neutral 2N Om, HV terminals 1U1V1W and neutral 1N were short-circuited.

The results are presented in annex I.

Results

The results do not give rise to remarks.

2.7 Determination of acoustic sound pressure levels

This test was carried out in accordance with IEC 60076-10.
The acoustic sound level was measured at the selected locations, around the transformer, at two different heights (one third and two-thirds of the height) at no-load condition.
The test was performed in the ONAN situation with rated voltage and the tap changer in position 11. The measuring points were measured at 0,3 meter from the tank. The measured value is calculated to the sound pressure level.

The results are presented in annex J and the measurements are presented in annex M, page 13 up to page 14.

Results

The measured values do not give rise to remarks.

2.8 Temperature-rise test

This test was carried out in accordance with IEC 60076-2.
Temperature-rise test for ONAN condition was carried out.
Ten temperature sensors were placed on various spots. Two were placed on inlet and outlet of the radiators on each side of the transformer, two were placed in top-oil pockets and four were placed for ambient temperature.
The tapping changer was set to tapping 21.
A total loss of 321,4 kW was injected to the HV winding first, the MV winding was short-circuited and LV winding was open-circuited. When the temperature stabilized after about three hours, the top oil temperature could be measured. The test current was reduced to rated current of 180,0 A and maintained for 1 hour. Then, the transformer was switched off and the resistances for the cool down curve calculation for HV 1V-1N and MV 2V-2N were measured during 20 minutes. By extrapolating both winding temperatures at switch off time were calculated, using the measured cold temperature resistances.
For determining the temperature rise for the LV winding, the LV winding was short-circuited and the rated current of 23,9 A was supplied to the HV winding for one hour with the MV terminal open-circuited. Then, the transformer was switched off and the resistances for the cool down curves for LV 3V-3W were measured during 20 minutes. By extrapolating the winding temperature at switch off time was calculated, using the measured cold temperature resistances.
The calculated results are presented in annex K and the measurements and cool-down curve calculations are presented in annex M, page 29 up to page 31.

Results

The transformer met the requirements for the temperature-rise test.

2.9 Dissolved gas analysis

This test was carried out in accordance with IEC 60076-1, clause 11.2.2.d.
Oil samples were taken before all the tests, before dielectric tests, after lightning impulse voltage test, after dielectric tests, after temperature-rise test, and after all the tests. The samples of the oil were taken for dissolved gas analysis (DGA).
The results are presented in annex L.

Results

No excessive CO and/or CO_2 contents have been detected in the DGA's, proving the cooling of the transformer windings is sufficient. Also no excessive carbon hydro gasses content have been detected, proving the dielectric design is sufficient.

2.10 Tightness test

This test was carried out in accordance with IEC 60076-1, clause 11.8.
The transformer including its radiators and conservator were given a top oil pressure of 40 kPa during 24 hours.

Results

No leakage was detected.

2.11 Frequency response analysis test

This test was carried out in accordance with IEC 60076-1, clause 11.1.4.l
For future site tests the FRA test was performed for all windings.

For all phases the following combinations were measured:

- A signal with frequency 1 Hz-2 MHz was supplied to HV neutral 1N, the signal was received and measured separately from HV terminal 1U, 1V and 1W at tapping position 1.
- A signal with frequency 1 Hz-2 MHz was supplied to MV neutral 2N, the signal was received and measured separately from MV terminal 2U, 2V and 2W.
- A signal with frequency 1 Hz-2 MHz was supplied to LV terminal 3V, the signal was received and measured from LV terminal 3U. A signal with frequency 1 Hz-2 MHz was supplied to LV terminal 3W, the signal was received and measured from LV terminal 3V. A signal with frequency 1 Hz-2 MHz was supplied to LV terminal 3W, the signal was received and measured from LV terminal 3U.

The FRA waveshapes are presented in annex M, page 34 up to page 36.

Results

The measured values do not give rise to remarks.

3 FUNCTIONAL TESTS OF COMPONENTS AND AUXILARY INSTRUMENTS

1. Test on on-load tap changer

This test was carried out in accordance with IEC 60076-1, clause 11.7.
The tap changer is from the series VMIII-300Y-72,5/B-12233WR from Maschinenfabrik Reinhausen GmbH. The serial number is 1541682.
The following tests were carried out:

- With the transformer un-energized, eight complete cycles of operation.
- With the transformer un-energized, and with the auxiliary voltage reduced to 85% of its rated value, one complete cycle of operation.
- With the transformer energized at rated voltage and frequency at no load, one complete cycle of operation.
- With one winding short-circuited and, as far as practicable, rated current in the tapped winding, 10 cycles of tap-change operations across the range of two steps on each side from reversing changeover selector at tapping position 11.

Results

The results don’t give rise to remarks.

3.2 Current transformers

This test was performed in accordance with IEC 60076-1, clause 11.1.2.1.i.
The current transformers were checked for the polarity and the ratio.
The polarity was controlled by applying a DC current to the bushing while measuring the secondary currents polarity. The ratio was checked by comparing the ratio to the applied primary current.
The results are presented in annex M, page 32.

Results

The results don’t give rise to remarks.

3.3 Rating plate

The rating plate was mounted on the transformer.
The nameplate drawing is presented in annex N, page 1.
Further the general outline drawing is presented in annex N, page 2.

Results

The check does not give rise to remarks.

ANNEX A LIGHTNING IMPULSE TEST

Transformer serial no. V100643

Performed on winding	Terminal	BIL (Full / Chopped) [kV]	Tapping position	Wave shape (front / tail / time to chop) [µs]	Polarity
HV	1U	1062 / 1154	21	1,37 / 52,2 / 3,7	-
	1V	1071 / 1152	11	1,38 / 53,9 / 4,0	-
	1W	1042 / 1161	1	1,40 / 55,3 / 4,2	-
MV	2U	547 / 604	-	1,22 / 55,3 / 3,2	-
	2V	547 / 601	-	1,06 / 55,3 / 3,6	-
	2W	541 / 606	-	1,04 / 54,6 / 3,4	-
HV neutral	1N	131	1	6,58 / 50,7	-
MV neutral	2N	131	-	3,45 / 54,3	-
LV	3U	126 / 140	-	1,25 / 51,0 / 3,5	-
	3V	125 / 137	-	1,26 / 52,1 / 3,9	-
	3W	126 / 139	-	1,28 / 52,2 / 3,6	-

SWITCHING IMPULSE TEST

Winding	Terminal	BIL [kV]	Tapping position	Wave shape [µs] T to peak / T > 90% / T to 0	Polarity
HV	1U	838	1	147 / 371 / > 1000	-
	1V	848	1	148 / 380 / > 1000	-
	1W	854	1	148 / 381 / > 1000	-

ANNEX B PARTIAL DISCHARGE MEASUREMENT IVPD

Transformer serial no. V100643

Power supply three phase, 200 Hz to LV terminals, tapping position 11								
U / Ur*	U	Duration	After calibration with 500 pC for all phases					
phase to	phase to		Phase 1U	Phase 2U	Phase 1V	Phase 2V	Phase 1W	Phase 2W
phase	phase		HV	MV	HV	MV	HV	MV
%	kV		pC	pC	pC	pC	pC	pC
40	88	0 min.	37	20	48	20	24	16
120	264	0 min.	39	20	44	20	22	16
120	264	1 min.	40	20	45	20	23	16
158	348	0 min.	40	20	44	20	22	16
158	348	5 min.	41	21	55	21	25	17
Utest	396	30 sec.	-	-	-	-	-	-
158	348	0 min.	38	24	53	21	24	17
158	348	5 min.	38	25	56	21	25	17
158	348	10 min.	39	25	57	21	25	17
158	348	15 min.	39	26	57	21	26	17
158	348	20 min.	39	26	57	21	26	17
158	348	25 min.	40	26	59	21	26	17
158	348	30 min	39	24	57	21	24	17
158	348	35 min.	39	24	57	21	24	17
158	348	40 min.	39	24	57	21	24	17
158	348	45 min.	39	24	57	21	24	17
158	348	50 min.	39	24	57	20	24	17
158	348	55 min.	39	24	57	21	24	17
158	348	60 min.	39	24	57	20	24	16
120	264	0 min.	37	24	48	20	24	16
120	264	1 min.	37	24	48	20	24	15
40	88	0 min.	35	24	48	19	24	15

* Ur = 220 kV

Annex C

ANNEX C MEASUREMENT OF INSULATION RESISTANCE IN MΩ AT 25,6 °C

Transformer serial no. V100643

Measurement of insulation resistance in MΩ at 25,6 °C			
Measurement between at kV	15 sec.	60 sec.	600 sec.
HV / (MV+LV+E)-5	4230	5980	13600
MV / (HV+LV+E)-5	5693	7800	51800
LV / (HV+MV+E)-5	2180	9460	20700
(HV+MV) / (LV+E)-5	4220	7640	15800
(MV+LV) / (HV+E)-5	2450	7590	12850
(HV+MV+LV) / E-5	1630	8260	13470
Core / clamp+E-2,5	-	2570	-
Clamp / core+E-2,5	-	3210	-
Core / Clamp -2,5	-	4620	-

ANNEX D MEASUREMENT OF DISSIPATION FACTOR AND CAPACITANCES AT 25,6 °C

Transformer serial no. V100643

Dissipation factor and capacitances at 25,6 °C			
Measurement between:	kV	Capacitance [pF]	Tan delta [%]
HV / (MV+LV+E)	10	13270	0,23
MV / (HV+LV+E)	10	13850	0,25
LV / (HV+MV+E)	10	5829	0,20
(HV+MV) / (LV+E)	10	17480	0,27
(MV+LV) / (HV+E)	10	19530	0,24
(HV+MV+LV) / E	10	14000	0,27

Requirement: Tan delta ≤ 0,5%.

Bushing dissipation factor and capacitances at 25,6 °C			
Bushing	kV	Capacitance [pF]	Tan delta [%]
1U	10	436,7	0,24
1V	10	434,3	0,24
1W	10	434,1	0,24
2U	10	254,5	0,23
2V	10	253,6	0,23
2W	10	254,3	0,24

Requirement: Tan delta ≤ 0,5%.

ANNEX E WINDING RESISTANCES

Transformer serial no. V100643

Winding	Tapping position	Resistance in mOhms at 25,6 °C		
		1U – 1N	1V – 1N	1W – 1N
	1	1417	1417	1409
	2	1408	1407	1398
	3	1397	1396	1388
	4	1387	1386	1378
	5	1377	1375	1367
	6	1366	1365	1357
	7	1356	1355	1347
	8	1345	1344	1336
	9	1335	1334	1326
	10	1325	1324	1316
HV	11	1313	1311	1302
	12	1324	1323	1316
	13	1335	1333	1326
	14	1345	1344	1336
	15	1356	1354	1346
	16	1366	1364	1357
	17	1377	1375	1367
	18	1387	1385	1378
	19	1397	1396	1388
	20	1407	1406	1398
	21	1418	1417	1409
		Resistance in mOhms at 25,6 °C		
MV		2U – 2N	2V – 2N	2W – 2N
	-	278,0	277,2	277,6
		Resistance in mOhms at 25,6 °C		
LV		3U – 3V	3V – 3W	3U – 3W
	-	91,77	91,26	91,27

ANNEX F MEASUREMENT OF VOLTAGE RATIO

Transformer serial no. V100643

Measurement of voltage ratio					
HV tapping position	HV / MV [kV / kV]	Calculated ratio	Measured difference (%)		
			1U1V // 2U2V	1V1W // 2V2W	1U1W // 2U2W
1	247,500 / 110,000	2,250	0,14	0,09	0,11
2	244,750 / 110,000	2,225	0,13	0,09	0,11
3	242,000 / 110,000	2,200	0,14	0,09	0,11
4	239,250 / 110,000	2,175	0,14	0,09	0,12
5	236,500 / 110,000	2,150	0,13	0,10	0,10
6	233,750 / 110,000	2,125	0,14	0,10	0,10
7	231,000 / 110,000	2,100	0,13	0,11	0,10
8	228,250 / 110,000	2,075	0,14	0,10	0,13
9	225,500 / 110,000	2,050	0,14	0,11	0,12
10	222,750 / 110,000	2,025	0,14	0,10	0,12
11	220,000 / 110,000	2,000	0,14	0,12	0,11
12	217,250 / 110,000	1,975	0,12	0,08	0,11
13	214,500 / 110,000	1,950	0,12	0,10	0,09
14	211,750 / 110,000	1,925	0,13	0,09	0,11
15	209,000 / 110,000	1,900	0,13	0,09	0,09
16	206,250 / 110,000	1,875	0,13	0,10	0,11
17	203,500 / 110,000	1,850	0,14	0,10	0,12
18	200,750 / 110,000	1,825	0,13	0,10	0,12
19	198,000 / 110,000	1,800	0,14	0,12	0,10
20	195,250 / 110,000	1,775	0,14	0,11	0,12
21	192,500 / 110,000	1,750	0,15	0,11	0,13

Transformer serial no. V100643

Measurement of voltage ratio					
HV tapping position	HV / LV [kV / kV]	Calculated ratio	Measured difference (%)		
			1U1V // 3U3V	1V1W // 3V3W	1U1W // 3U3W
1	247,500 / 13,800	17,935	- 0,22	- 0,26	- 0,21
2	244,750 / 13,800	17,736	- 0,25	- 0,25	- 0,23
3	242,000 / 13,800	17,536	- 0,20	- 0,25	- 0,21
4	239,250 / 13,800	17,337	- 0,20	- 0,25	- 0,20
5	236,500 / 13,800	17,138	- 0,20	- 0,25	- 0,20
6	233,750 / 13,800	16,938	- 0,19	- 0,21	- 0,20
7	231,000 / 13,800	16,739	- 0,20	- 0,21	- 0,21
8	228,250 / 13,800	16,540	- 0,17	- 0,22	- 0,19
9	225,500 / 13,800	16,341	- 0,18	- 0,21	- 0,19
10	222,750 / 13,800	16,141	- 0,17	- 0,19	- 0,18
11	220,000 / 13,800	15,942	- 0,17	- 0,19	- 0,18
12	217,250 / 13,800	15,743	- 0,16	- 0,19	- 0,16
13	214,500 / 13,800	15,543	- 0,14	- 0,19	- 0,15
14	211,750 / 13,800	15,344	- 0,16	- 0,20	- 0,14
15	209,000 / 13,800	15,145	- 0,14	- 0,18	- 0,15
16	206,250 / 13,800	14,946	- 0,14	- 0,19	- 0,12
17	203,500 / 13,800	14,746	- 0,13	- 0,19	- 0,12
18	200,750 / 13,800	14,547	- 0,12	- 0,17	- 0,11
19	198,000 / 13,800	14,348	- 0,11	- 0,14	- 0,10
20	195,250 / 13,800	14,149	- 0,10	- 0,15	- 0,10
21	192,500 / 13,800	13,949	- 0,09	- 0,14	- 0,09
MV tapping position	MV / LV [kV / kV]	Calculated ratio	Measured difference (%)		
			2U2V // 3U3V	2V2W // 3V3W	2U2W // 3U3W
-	110,000 / 13,800	7,971	- 0,10	- 0,16	- 0,10

ANNEX G LOAD LOSS AND IMPEDANCE MEASUREMENT BASED ON 60 MVA

Transformer serial no. V100643

Load loss and impedance measurement based on 60 MVA				
HV tapping position		1	11	21
Ratio	kV	247,5	220,0	192,5
	kV	110,0	110,0	110,0
Rated currents at 60 MVA	A	140,0	157,5	180,0
	A	314,9	314,9	314,9
Resistance at 25,6 °C				
Average HV (phase to phase)	mOhm	2828,7	2617,3	2829,3
Average MV (phase to phase)	mOhm	555,2	555,2	555,2
Joules loss at 60 MVA				
A at Tm [25,1/25,1/25,1] °C	kW	165,4	179,6	219,6
B at 75 °C	kW	197,1	214,0	261,7
Load loss at 69 MVA				
C measured value at Tm °C	kW	184,0	195,9	232,8
D stray losses at Tm °C				
= C – A	kW	18,6	16,3	13,2
E stray losses at 75 °C				
=D.(235 + Tm) / (235 + 75)	kW	15,6	13,7	11,1
F load loss				
at 75 °C = B + E	kW	212,7	227,7	272,8
guaranteed load-loss	kW	-	**235,0**	-
Tolerance	%	-	**0**	-
Impedance voltage				
Measured at 60 MVA	$\%U_n$	10,47	10,00	9,90
Guaranteed value at 60 MVA	$\%U_n$	-	**10,00**	-
Tolerance	%	-	**± 7,5**	-

LOAD LOSS AND IMPEDANCE MEASUREMENT BASED ON 8 MVA

Transformer serial no. V100643

Load loss and impedance measurement based on 60 MVA					
HV tapping position		1	11	21	-
Ratio	kV	247,5	220,0	192,5	110,0
	kV	13,8	13,8	13,8	13,8
Rated currents at 8 MVA	A	18,7	21,0	24,0	42,0
	A	334,7	334,7	334,7	334,7
Resistance at 25,6 °C					
Average HV (phase to phase)	mOhm	2828,7	2617,3	2829,3	-
Average MV (phase to phase)	mOhm	-	-	-	555,2
Average LV (phase to phase)	mOhm	91,4	91,4	91,4	91,4
Joules loss at 8 MVA					
A at Tm [25,1/25,1/25,1] °C	kW	16,8	17,1	17,8	16,8
B at 75 °C	kW	20,0	20,3	21,2	20,0
Load loss at 8 MVA					
C measured value at Tm °C	kW	19,6	20,3	21,1	20,5
D stray losses at Tm °C					
= C – A	kW	2,8	3,2	3,3	3,7
E stray losses at 75 °C					
=D.(235 + Tm) / (235 + 75)	kW	2,4	2,8	2,7	3,1
F load loss					
at 75 °C = B + E	kW	22,4	23,1	23,9	23,1
guaranteed load-loss	kW	-	-	-	
Tolerance	%	-	-	-	
Impedance voltage					
Measured at 8 MVA	$\%U_n$	4,42	4,84	5,45	6,55
Guaranteed value at 8 MVA	$\%U_n$	-	-	-	-
Tolerance	%	-	-	-	-

ANNEX H NO-LOAD LOSS AND NO-LOAD CURRENT BEFORE DIELECTRIC TESTS

Transformer serial no. V100643

No-load loss and no-load current before dielectric tests						
U/ Ur (%)	RMS voltage [kV]	Average voltage [kV]	Average current [A]	Average current [%]	Measured loss [kW]	Corrected loss [kW]
90	12,454	12,420	1,775	0,07	36,15	36,05
95	13,164	13,111	1,971	0,07	41,44	41,27
100	13,907	13,799	2,533	0,10	48,97	48,59
105	14,770	14,490	4,894	0,19	61,04	59,86
110	15,909	15,177	15,614	0,62	81,14	77,22

Guaranteed maximum no-load loss at 100% voltage: 51,0 kW.

Guaranteed maximum no-load current at 100 % voltage: 1,0 %.

ANNEX I ZERO SEQUENCE IMPEDANCE MEASUREMENT

Transformer serial no. V100643

Tapping position	Supply between	Open terminal	Shorted terminal	Applied current [A]	Measured voltage [V]	Zero sequence impedance [Ω/phase]
11	1U1V1W-1N	2U2V2W-2N	-	81,76	5771,0	211,75
11	1U1V1W-1N	-	2U2V2W-2N	84,98	1615,8	57,04
11	2U2V2W-2N	1U1V1W-1N	-	160,68	3941,8	73,60
11	2U2V2W-2N	-	1U1V1W-1N	159,38	1059,6	19,94

ANNEX J ACOUSTIC SOUND LEVEL

Transformer serial no. V100643

Acoustic sound level		
Location		Indoor
Rated voltage	[% Ur]	100
Rated current	[% In]	-
Cooling method		ONAN
Measured points		
1/3 of height		30
2/3 of height		30
Distance	[m]	0,3
Exponential average of:		
Measured sound pressure	[dB(A)]	64,3
Background sound pressure before / after	[dB(A)]	45,6 / 46,0
Correction	[dB(A)]	2,6
Corrected result	[dB(A)]	61,7
Guaranteed sound pressure	[dB(A)]	-
Tolerance	[dB(A)]	-

Annex K

ANNEX K TEMPERATURE RISE TEST

Transformer serial no. V100643

General			
Temperature-rise test for a rating of:	[MVA]	60	8
Cooling method		ONAN	ONAN
Tapping position		11	11
Losses supplied at 50 Hz	[kW]	321,4	-
Measured current at HV side	[A]	194,8	23,9
Results of temperature-rise test			
Temperature-rise of:			
Top oil (≤ 60 K)	[K]	57,0	-
HV winding after correction (≤ 65 K)	[K]	55,8	-
MV winding after correction (≤ 65 K)	[K]	59,2	-
LV winding after correction (≤ 65 K)	[K]	-	48,9
Measured temperatures			
Ambient temperature total losses	[°C]	26,8	26,8
Ambient temperature rated current for HV and MV winding	[°C]	27,5	-
Ambient temperature rated current for LV winding	[°C]	-	28,0
Average temperature rise			
Oil (steady state)	[K]	44,8	44,8
Oil (rated current) for HV and MV winding	[K]	43,4	-
Oil (rated current) for LV winding	[K]	-	33,5
1V-1N from cool down curve	[°C]	82,1	-
2V-2N from cool down curve	[°C]	85,5	-
3V-3W from cool down curve	[°C]	-	65,8
Gradient copper-oil			
HV winding	[K]	11,2	-
MV winding	[K]	14,6	-
LV winding	[K]	-	4,3

ANNEX L DISSOLVED GAS ANALYSIS

Transformer serial no. V100643

Gas components (µL/L)	Dissolved gas analysis							
	H_2	CO	CO_2	CH_4	C_2H_4	C_2H_6	C_2H_2	Overall hydrocarbon content
Before all the tests	0,00	2,50	109,70	0,20	0,00	0,00	0,00	0,20
Before dielectric tests	0,00	2,50	109,70	0,20	0,00	0,00	0,00	0,20
After lightning impulse test	0,60	3,70	147,80	0,20	0,00	0,00	0,00	0,20
After dielectric tests	1,50	4,20	164,50	0,20	0,00	0,00	0,00	0,20
After temperature rise test	2,70	5,40	189,60	0,30	0,00	0,00	0,00	0,30
After temperature rise test	2,70	5,40	189,60	0,30	0,00	0,00	0,00	0,30

ANNEX M TEST REPORT

SIEMENS

NO.: V100643

Test Report

Product	Power Transformer
Type	TSSN7854
Product No.:	V100643
Project	LAP SE RIO TOLTÉN Station

Issued by: ÉÜ Date: 2014.12.16

Checked by: 杨碧勋 Date: 2014.12.16

Approved by: 蔡祥红 Date: 2014.12.16

Siemens Transformer (Wuhan) Co., Ltd., P.R. of China

KEMA
Gu Bin
Date: 2014.12.16
Part:

Content

Appendix:

A. Transformer sweep frequency response analysis report

S test report Serial No.:V100643

1. Rating and Specification

Rated Power:	60 MVA /60 MVA /8 MVA	
Rated Voltage:	220 ± 10 × 1.25%kV / 110kV / 13.8kV	
Rated Current:	157.5 / 314.9/ 334.7A	
Rated Frequency:	50Hz	
Connection Symbol:	YNyn0d1	
Cooling Type :	ONAN	
Insulation Level:	HV	Um 245 / SI 850 / LI 1050 / LIC 1155 / AC 460
	HVN	Um 24 / LI 130 / AC 50
	MV	Um 123 / LI 550/LIC 605 / AC 230
	MVN	Um 24 / LI 130 / AC 50
	LV	Um 17.5 / LI 125/LIC 138/AC 38

2. Test standard

IEC 60076-1-2011	Power Transformers-Part 1: General
IEC 60076-2-2011	Power Transformers-Part 2: Temperature rise for liquid immersed transformers
IEC 60076-3-2013	Power Transformers-Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-4-2002	Power Transformers-Part 4: Guide to the lightning impulse and switching impulse testing-Power trans formers and reactors
IEC 60076-10-2001	Power Transformers-Part 10: Determination of sound levels
IEC 60076-18-2012	Measurement of frequency response
IEC 60296-2012	Fluids for electro technical applications – Unused Mineral insulating oils for transformers and switchgear
IEC 61181-2012	Mineral oil-filled electrical equipment-Application of dissolved gas analysis (DGA) to factory tests on electrical equipment
IEC 60422-2013	Mineral insulating oil electrical equipment - Supervision and maintenance guidance

3. Leak testing with pressure for liquid-immersed transformers

Test method	Position	Supplied pressure (kPa)	Leakage test time (h)	Test result
Supplied dry compressed air	Top oil pressure	40	24	No leakage and damage

4. Test of transformer oil

Before all tests:

Breakdown voltage (kV)	tan δ at 90°C (%)	Water content (ppm)
69.4	0.12	6.0

Chromatography Analysis (ppm)	H_2	CO	CO_2	CH_4	C_2H_4	C_2H_6	C_2H_2	C_1+C_2 (note 1)
Before all tests	0	2.5	109.7	0.2	0	0	0	0.2
After lightning impulse test	0.6	3.7	147.8	0.2	0	0	0	0.2
After dielectric tests	1.5	4.2	164.5	0.2	0	0	0	0.2
After temperature rise test	2.7	5.4	189.6	0.3	0	0	0	0.3

Note 1: C_1+C_2 are organic gas , C1 is CH4 gas , C 2 are C2H4, C2H6, C2H2 mixed gas

5. Measurement of voltage ratio and check of phase displacement

1. HV-MV voltage ratio

(H.V.)		(M.V.)	Calculated voltage ratio	Measured error (%)		
Tap	Voltage (V)	Voltage (V)		1U1V / 2U2V	1V1W / 2V2W	1U1W / 2U2W
1	247500	110000	2.2500	0.14	0.09	0.11
2	244750		2.2250	0.13	0.09	0.11
3	242000		2.2000	0.14	0.09	0.11
4	239250		2.1750	0.14	0.09	0.12
5	236500		2.1500	0.13	0.10	0.10
6	233750		2.1250	0.14	0.10	0.10
7	231000		2.1000	0.13	0.11	0.10
8	228250		2.0750	0.14	0.10	0.13
9	225500		2.0500	0.14	0.11	0.12
10	222750		2.0250	0.14	0.10	0.12
11	220000		2.0000	0.14	0.12	0.11
12	217250		1.9750	0.12	0.08	0.11
13	214500		1.9500	0.12	0.10	0.09
14	211750		1.9250	0.13	0.09	0.11
15	209000		1.9000	0.13	0.09	0.09
16	206250		1.8750	0.13	0..10	0.11
17	203500		1.8500	0.14	0.10	0.12
18	200750		1.8250	0.13	0.10	0.12
19	198000		1.8000	0.14	0.12	0.10
20	195250		1.7750	0.14	0.11	0.12
21	192500		1.7500	0.15	0.11	0.13

Connection symbol: YNyn0

5.2 HV-LV voltage ratio

(H.V.)		(L.V.)	Calculated voltage ratio	Measured error (%)		
Tap	Voltage (V)	Voltage (V)		1U1V / 3U3V	1V1W / 3V3W	1U1W / 3U3W
1	247500	13800	17.935	-0.22	-0.26	-0.21
2	244750		17.736	-0.25	-0.25	-0.23
3	242000		17.536	-0.20	-0.25	-0.21
4	239250		17.337	-0.20	-0.25	-0.20
5	236500		17.138	-0.20	-0.25	-0.20
6	233750		16.938	-0.19	-0.21	-0.20
7	231000		16.739	-0.20	-0.21	-0.21
8	228250		16.540	-0.17	-0.22	-0.19
9	225500		16.341	-0.18	-0.21	-0.19
10	222750		16.141	-0.17	-0.19	-0.18
11	220000		15.942	-0.17	-0.19	-0.18
12	217250		15.743	-0.16	-0.19	-0.16
13	214500		15.543	-0.14	-0.19	-0.15
14	211750		15.344	-0.16	-0.20	-0.14
15	209000		15.145	-0.14	-0.18	-0.15
16	206250		14.946	-0.14	-0.19	-0.12
17	203500		14.746	-0.13	-0.19	-0.12
18	200750		14.547	-0.12	-0.17	-0.11
19	198000		14.348	-0.11	-0.14	-0.10
20	195250		14.149	-0.10	-0.15	-0.10
21	192500		13.949	-0.09	-0.14	-0.09

Connection symbol: YNd1

5.3 MV-LV voltage ratio

(H.V.)		(L.V.)	Calculated voltage ratio	Measured error (%)		
Tap	Voltage (V)	Voltage (V)		2U2V / 3U3V	2V2W / 3V3W	2U2W / 3U3W
-	110000	13800	7.9710	-0.10	-0.16	-0.10

Connection symbol: ynd1

Final connection symbol: YNyn0d1

6. Measurement of winding DC resistance

Temperature of oil: 25.6 °C

Winding	Tap	Measured value (Ω)			Max Unbalance rate (%)
		1U-1N	1V-1N	1W-1N	
H.V.	1	1.417	1.417	1.409	0.84
	2	1.408	1.407	1.398	
	3	1.397	1.396	1.388	
	4	1.387	1.386	1.378	
	5	1.377	1.375	1.367	
	6	1.366	1.365	1.357	
	7	1.356	1.355	1.347	
	8	1.345	1.344	1.336	
	9	1.335	1.334	1.326	
	10	1.325	1.324	1.316	
	11	1.313	1.311	1.302	
	12	1.324	1.323	1.316	
	13	1.335	1.333	1.326	
	14	1.345	1.344	1.336	
	15	1.356	1.354	1.346	
	16	1.366	1.364	1.357	
	17	1.377	1.375	1.367	
	18	1.387	1.385	1.378	
	19	1.397	1.396	1.388	
	20	1.407	1.406	1.398	
	21	1.418	1.417	1.409	
M.V.		2U-2N	2V-2N	2W-2N	0.29
	-	0.2780	0.2772	0.2776	
L.V.		3U-3V	3V-3W	3U-3W	0.47
	-	0.09177	0.09126	0.09127	

7. Capacitive bushing test

Temperature of oil: 25.6 °C

Series No.	Type	Tanδ (%)	Capacitance (pF)
140214	PNO2521050800K200	0.24	434.1
140213	PNO2521050800K200	0.24	434.3
140212	PNO2521050800K200	0.24	436.7
140218	PNO126550800K200	0.24	254.3
140217	PNO126550800K200	0.23	253.6
140216	PNO126550800K200	0.23	254.5

8. Measurement of d. c. insulation resistance between each winding to earth

Temperature of oil: 25.6 °C

Measurement part	Insulation resistance (MΩ)			Absorption ratio	Polarization index
	R_{15S}	R_{60S}	R_{600S}	R_{60S} / R_{15S}	R_{600S} / R_{60S}
LV – HV & MV & G	2180	9460	20700	4.34	2.19
MV – HV & LV & G	5693	7800	51800	1.37	6.64
HV – MV & LV & G	4230	5980	13600	1.41	2.27
HV & MV – LV & G	4220	7640	15800	1.81	2.07
MV & LV – HV & G	2450	7590	12850	3.10	1.69
HV & MV & LV – G	1630	8260	13470	5.07	1.63
Core - G	2570 MΩ				
Clamp - G	3210 MΩ				
Core - Clamp	4620 MΩ				

9. Measurement of dissipation factor (tanδ) of the insulation system capacitances, and determination of capacitances windings-to-earth

Temperature of oil: 25.6 °C

Measurement part	tanδ (%)	Capacitance (pF)
LV – HV & MV & G	0.20	5829
MV – HV & LV & G	0.25	13850
HV – MV & LV & G	0.23	13270
HV & MV – LV & G	0.27	17480
MV & LV – HV & G	0.24	19530
HV & MV & LV – G	0.27	14000

10. Measurement of no-load loss and current at 90%, 95%, 100%, 105%, 110% of rated voltage

%	Mean value (kV)	R.M.S value (kV)	No load current			No load loss(kW)		
			Measure value		Guaranteed value	Measure value	Corrected value	Guaranteed value
			(A)	(%)	(%)			
90	12.42	12.45	1.78	0.07	-	36.2	36.1	-
95	13.11	13.16	1.97	0.07	-	41.4	41.3	-
100	13.80	13.91	2.53	0.10	≤ 1	49.0	48.6	≤ 51
105	14.49	14.77	4.89	0.19	-	61.0	59.9	-
110	15.18	15.91	15.6	0.62	-	81.1	77.2	-

11. Measurement of harmonics content of magnetizing current

Excited voltage at tap 11	100%Ur (I_N/I_1%)		
Order	3U Phase	3V Phase	3W Phase
1	100.000	100.000	100.000
2	2.342	2.327	1.465
3	33.273	32.190	10.544
4	1.980	1.721	1.335
5	39.123	36.792	35.560
6	0.049	0.310	0.160
7	28.895	27.341	24.308
8	1.062	1.292	0.557
9	7.454	8.406	0.649
10	0.471	0.605	0.234
11	3.937	4.600	3.418
12	0.026	0.013	0.010
13	0.700	0.858	0.523
14	0.030	0.010	0.009
15	0.069	0.174	0.127
16	0.028	0.022	0.007
17	0.175	0.200	0.250
18	0.003	0.034	0.018
19	0.163	0.442	0.193
Note : I_1 : fundamental I_N/I_1 : nth harmonic/ fundamental f = 50 Hz			

12. Measurement of zero-sequence impedance on three-phase transformer

Tap	Current (A)	Voltage (V)	Zero-sequence Impedance Ω/phase	Supplied terminals	Status of other terminals
11	81.76	5771.0	211.8	1U1V1W-1N	2U2V2W-2N Opened
	84.98	1615.8	57.04	1U1V1W-1N	2U2V2W-2N Shorted
	160.68	3941.8	73.60	2U2V2W-2N	1U1V1W-1N Opened
	159.38	1059.6	19.94	2U2V2W-2N	1U1V1W-1N Shorted

13. Measurement of short-circuit impedance and load loss

1. Base on 60MVA

Measurement part	Tap	Supplied current (A)	Measured voltage (kV)	Measured power (kW)	Impedance at 75°C (%)	Guaranteed impedance at 75°C (%)	Load loss at 75°C (kW) Measured value	Guaranteed load loss at 75°C (kW)
HV- MV	1	72.19	13.36	48.94	10.47	-	212.7	-
	11	80.62	11.26	51.36	10.00	10 ± 7.5	227.7	≤ 235
	21	90.82	9.615	59.29	9.90	-	272.8	-

13.2 Base on 8MVA

Measurement part	Tap	Supplied current (A)	Measured voltage (kV)	Measured power (kW)	Impedance at 75°C (%)	Guaranteed impedance at 75°C (%)	Load loss at 75°C (kW) Measured value	Guaranteed load loss at 75°C (kW)
HV- LV	1	9.70	5.69	5.31	4.42	-	22.4	-
	11	10.96	5.56	5.54	4.84	-	23.1	-
	21	12.62	5.52	5.82	5.45	-	23.9	-

13.3 Base on 8MVA

Meas-urement part	Tap	Supplied current (A)	Measured voltage (kV)	Measured power (kW)	Impedance at 75°C (%)	Guaran-teed im-pedance at 75°C (%)	Load loss at 75°C (kW) Measured value	Guaran-teed load loss at 75°C (kW)
MV- LV	-	22.65	3.88	5.96	6.55	-	23.1	-

14. Measurement of sound level

Background noise before test

Measured point	Background noise (dB)	Measured point	Background noise (dB)
1	46.4	6	46.6
2	42.9	7	43.3
3	46.9	8	46.3
4	45.1	9	45.6
5	42.4	10	47.6

0.3m away from the principal radiating surface for no load test at ONAN

Measured point	A — weighted sound pressure level (dB)		Measured point	A — weighted sound pressure level (dB)	
	1/3H	2/3H		1/3H	2/3H
1	60.1	59.8	16	67.0	65.1
2	64.5	61.0	17	67.6	63.3
3	60.0	60.1	18	62.1	64.1
4	61.5	61.0	19	67.3	64.5
5	62.5	61.8	20	63.8	67.1
6	61.3	64.1	21	63.8	66.6
7	64.6	65.0	22	60.5	61.5
8	65.5	61.5	23	60.2	61.3
9	63.8	62.1	24	63.0	61.8
10	61.6	58.9	25	65.1	66.1
11	69.8	65.1	26	63.6	65.3
12	67.8	65.5	27	68.1	63.3
13	67.1	65.1	28	63.1	64.8
14	62.3	63.0	29	62.1	63.8
15	66.6	63.3	30	62.4	60.1

Background noise after test

Measured point	Background noise (dB)	Measured point	Background noise (dB)
1	44.6	6	43.1
2	46.9	7	44.8
3	46.4	8	43.8
4	47.3	9	48.4
5	42.4	10	47.8

Test condition

Total surface area of testing room S_V (m^2)	Average Absorption factor a	Absorption amount A (m^2)	Length of prescribed contour (m)	Height of tank (m)	Area of measuring surface S (m^2)	Environmental correction K (dB)
2388	0.25	597	28.3	3.4	120.3	2.6

State of cooling equipment	$(\overline{LPA'})$ Uncorrected average A-weighted sound pressure (dB)	Average A-weighted background noise (dB)	
		Before the tests	After the tests
ONAN/0.3m (no-load)	64.3	45.6	46.0

State of cooling equipment	Corrected average A-weighted sound pressure level (dB)	Sound pressure guaranteed value (dB)
	$\overline{LPA}=\overline{LPA'}-K$	
ONAN/0.3m (no-load)	61.7	-

15. Operation test on on-load tap-changer

Manufacturer: MR

Type: VMIII 300Y-72.5/B -12233WR

Serial NO.: 1541682

Operation test:

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

(2) With the transformer de-energized, and with the auxiliary voltage reduced to 85% of its rated value, one complete cycle of operation.

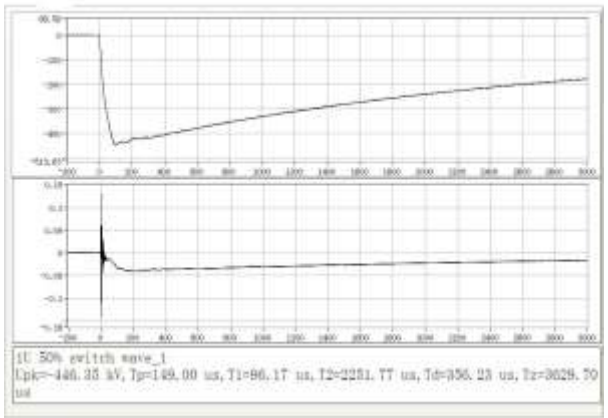
(3) With the transformer energized at rated voltage and frequency at no load, one complete cycle of operation.

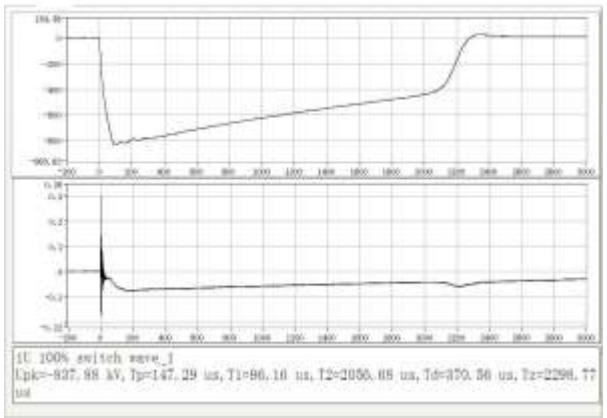
(4) With one winding short-circuited and, as far as practicable, rated current in the tapped winding, 10 cycles of tap-change operations across the range of two steps on each side from where a coarse or reversing changeover selector operates, or otherwise from the middle tapping(the tap-changer will pass 20 times through the changeover position).

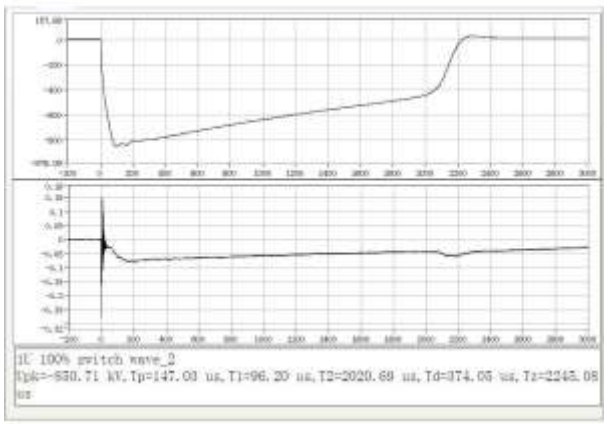
Above service test all normal.

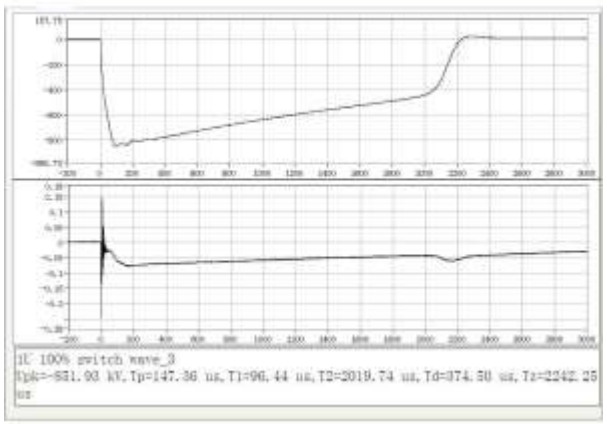
16. Switching impulse test

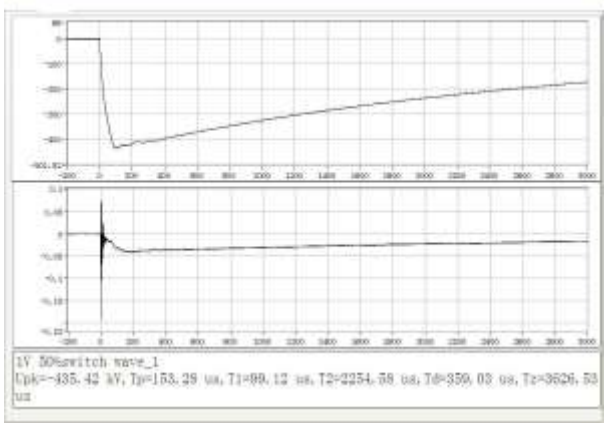
Tested terminal	Tap	Switching wave		Conclusion
		Voltage (kV)	(Tp/Td/Tz) (μs)	
1U	1	838	147.0/374.0/2245.1	Passed
1V	1	848	148.1/382.3/1896.8	
1W	1	854	148.1/384.3/2226.8	

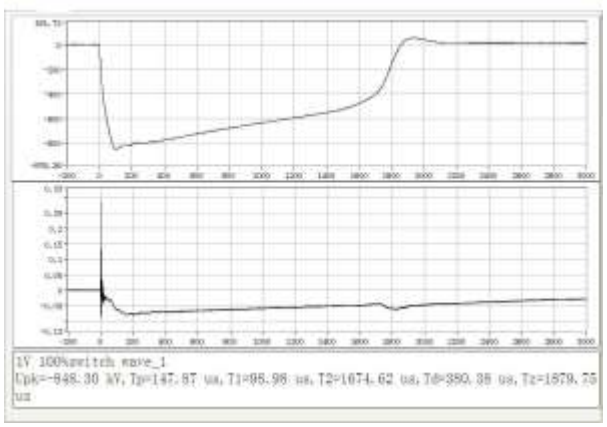


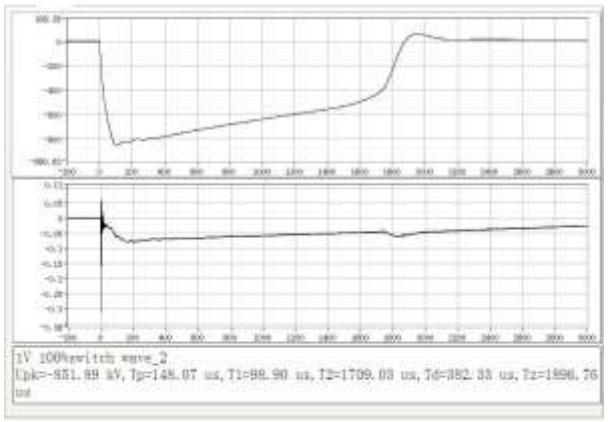


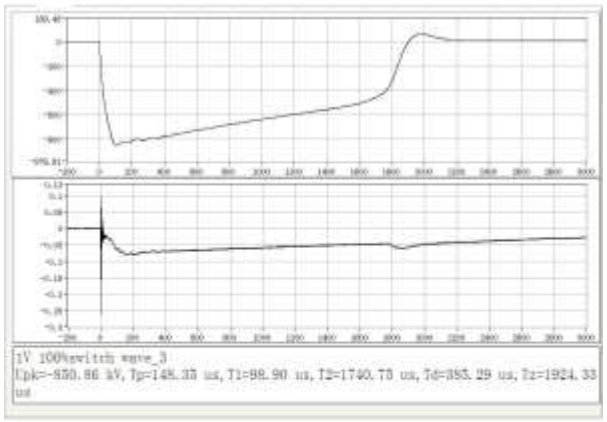


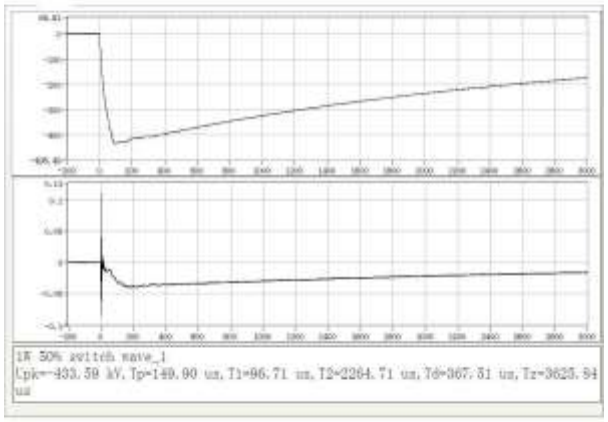


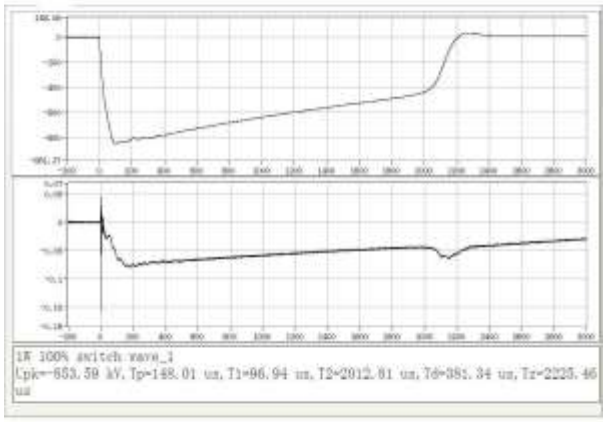


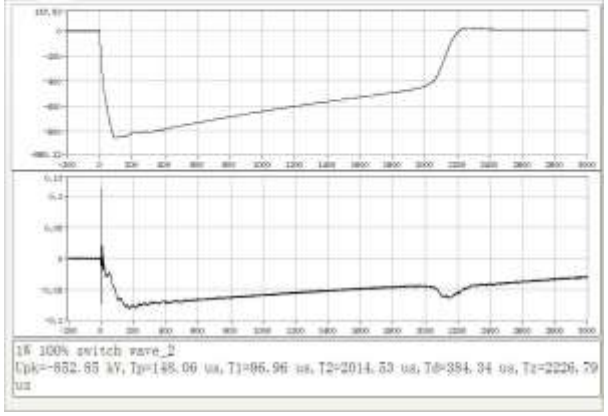


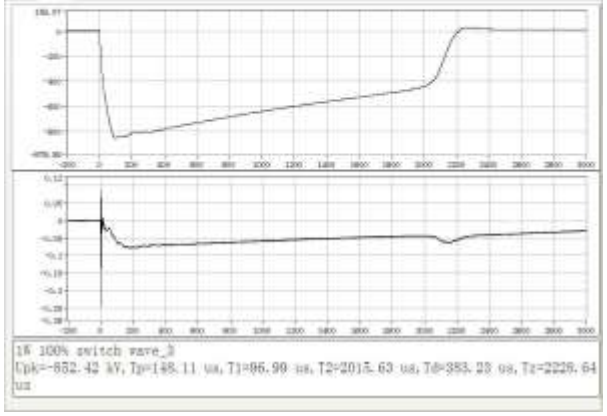

1V 100%switch wave_2
Upk=-851.89 kV, Tp=148.07 us, T1=98.90 us, T2=1709.03 us, Td=382.33 us, Tz=1896.76 us


1V 100%switch wave_3
Upk=-850.86 kV, Tp=148.33 us, T1=98.90 us, T2=1740.73 us, Td=385.29 us, Tz=1924.33 us


1R 50% switch wave_1
Upk=-833.59 kV, Tp=149.90 us, T1=96.71 us, T2=2264.71 us, Td=367.31 us, Tz=3625.94 us


1R 100% switch wave_1
Upk=-853.59 kV, Tp=148.01 us, T1=96.94 us, T2=2012.81 us, Td=381.34 us, Tz=2225.46 us

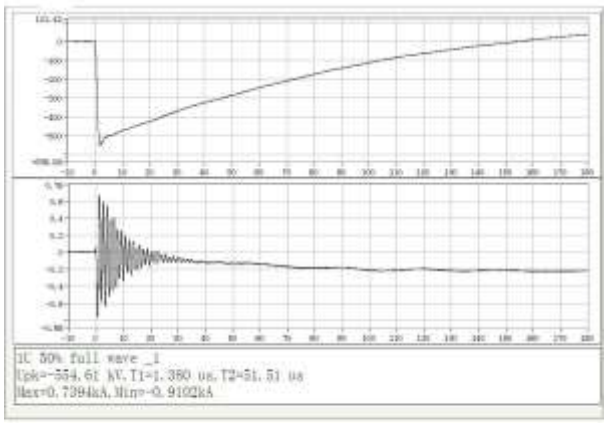

1R 100% switch wave_2
Upk=-852.83 kV, Tp=148.06 us, T1=96.96 us, T2=2014.53 us, Td=384.34 us, Tz=2226.79 us

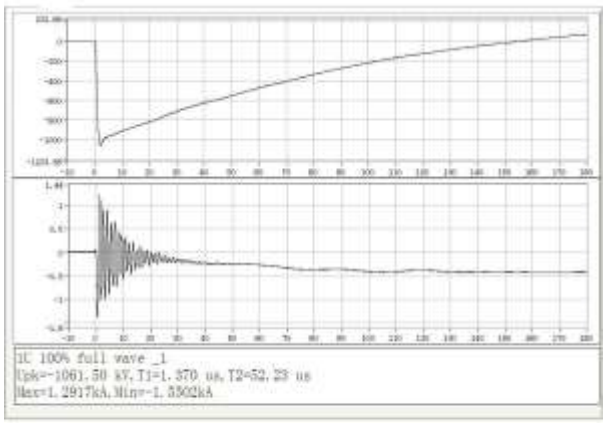

1R 100% switch wave_3
Upk=-852.42 kV, Tp=148.11 us, T1=96.90 us, T2=2015.63 us, Td=383.23 us, Tz=2226.64 us

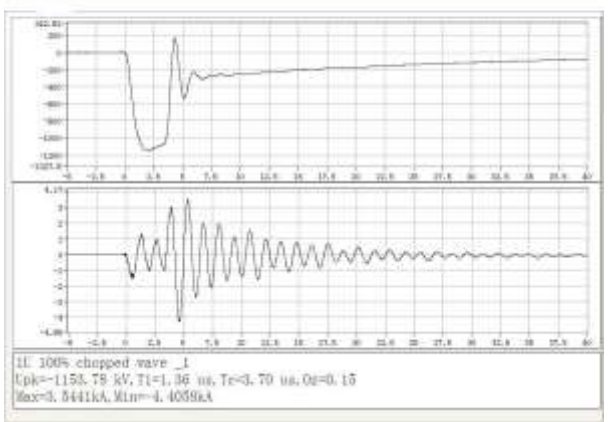
17. Lightning impulse test

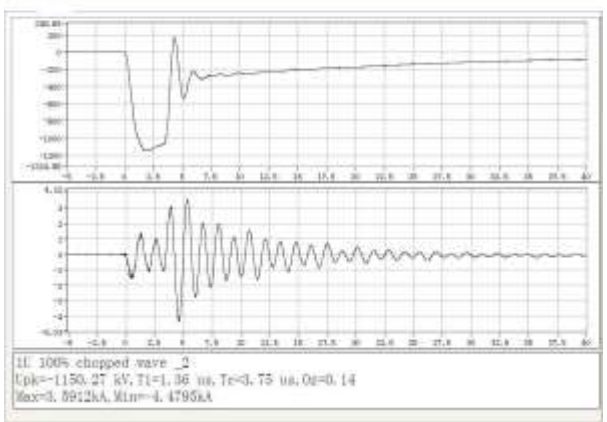
Tested terminal	Tap	Full wave		Chopped wave		Conclusion
		Voltage (kV)	(T1/T2) (μs)	Voltage (kV)	(T1/Tc) (μs)	
1U	21	1062	1.37/52.2	1154	1.36/3.70	Passed
1V	11	1071	1.38/53.9	1152	1.37/3.95	
1W	1	1042	1.40/55.3	1161	1.41/4.15	
1N	1	131	6.58/50.7	/	/	
2U	/	547	1.21/55.3	604	1.22/3.17	
2V	/	547	1.06/55.3	601	1.04/3.58	
2W	/	541	1.04/54.6	606	0.99/3.38	
2N	/	131	3.45/54.3	/	/	
3U	/	126	1.25/51.0	140	1.29/3.46	
3V	/	125	1.26/52.1	137	1.29/3.88	
3W	/	126	1.28/52.2	139	1.31/3.56	

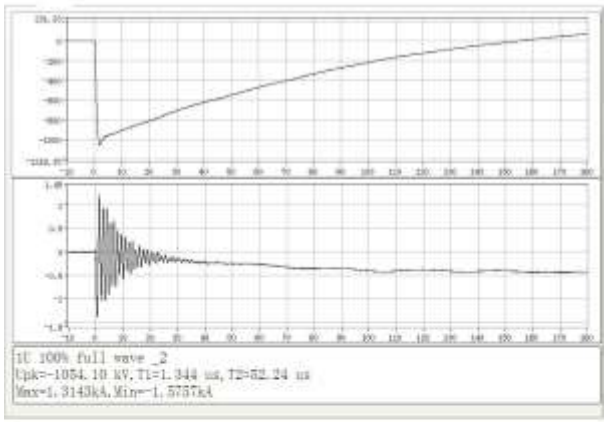
Full wave and chopped wave waveforms of lightning impulse test as follow:

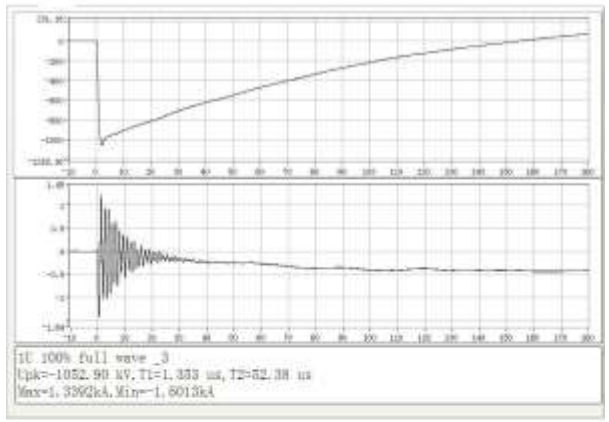


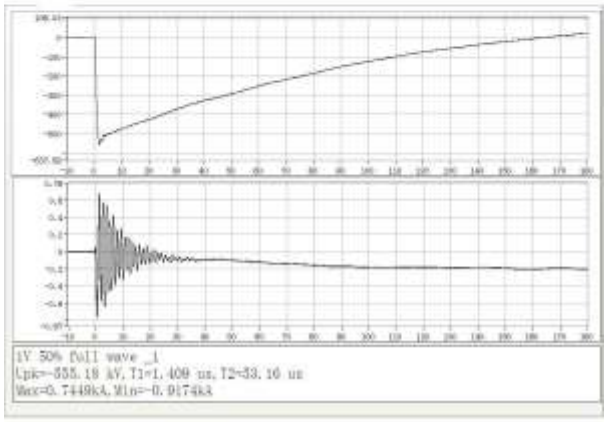


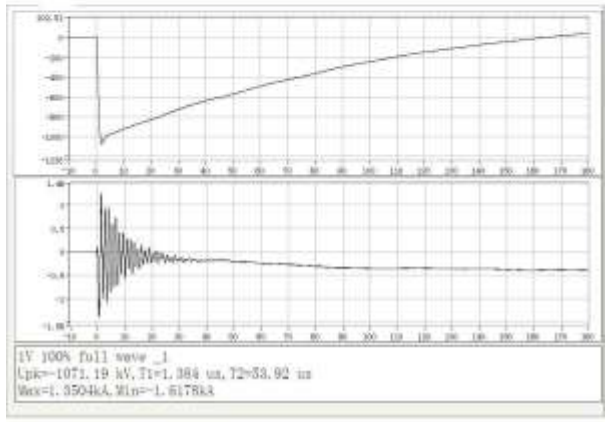


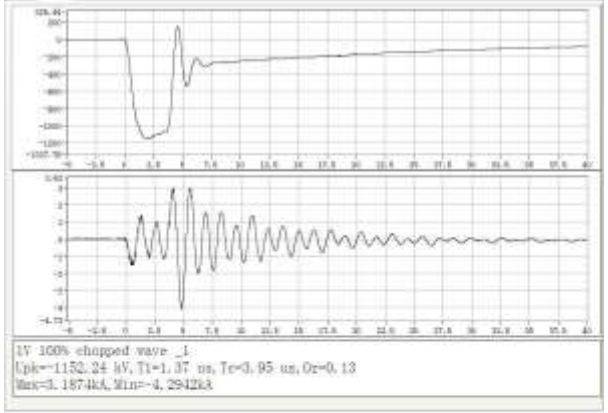


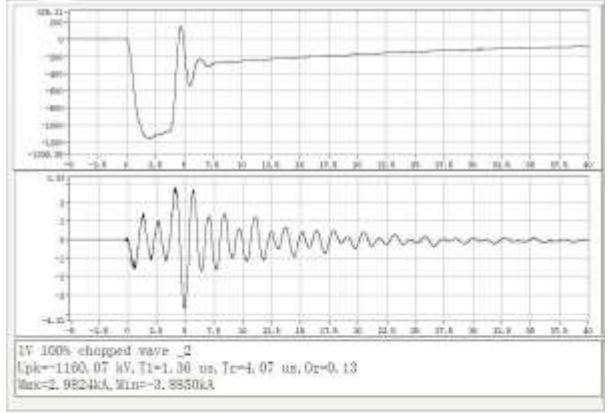

1U 100% full wave _2
Upk=-1054.10 kV, T1=1.344 us, T2=62.24 us
Wmax=1.3143kA, Wmin=-1.5737kA

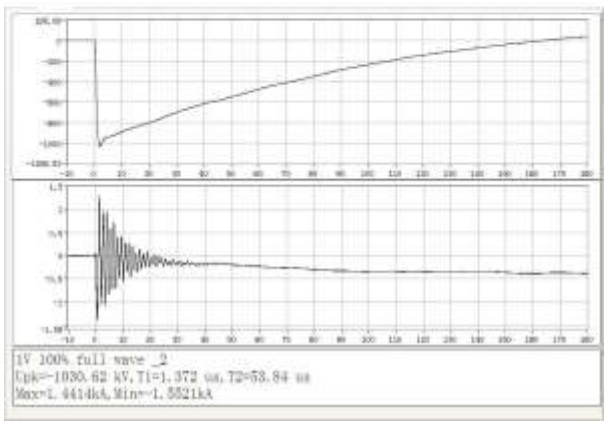

1U 100% full wave _3
Upk=-1052.90 kV, T1=1.333 us, T2=62.38 us
Wmax=1.3392kA, Wmin=-1.6013kA

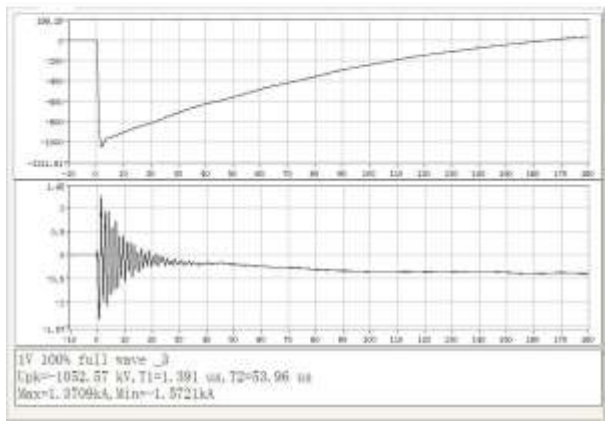

1V 50% full wave _1
Upk=-555.18 kV, T1=1.409 us, T2=53.16 us
Wmax=0.7449kA, Wmin=-0.9174kA

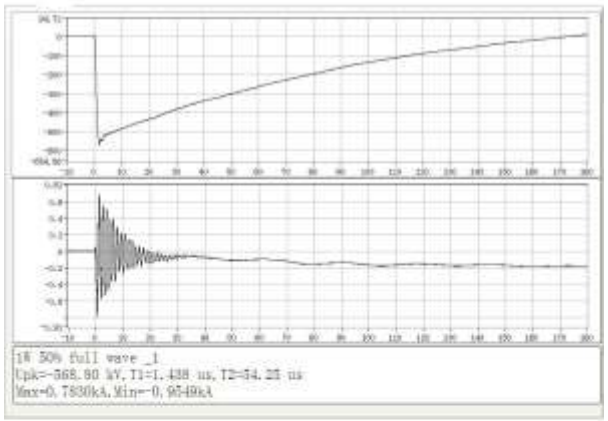

1V 100% full wave _1
Upk=-1071.19 kV, T1=1.384 us, T2=53.92 us
Wmax=1.3504kA, Wmin=-1.6178kA

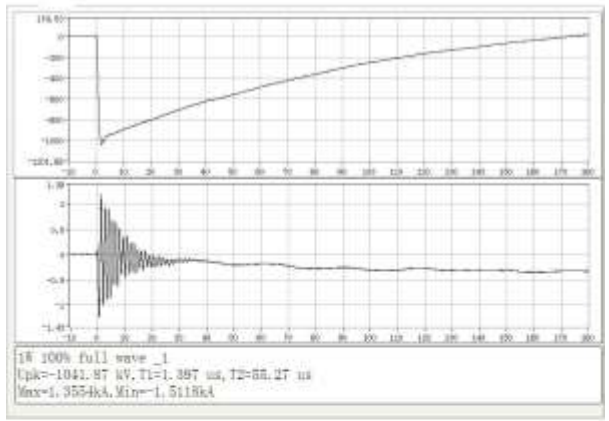

1V 100% chopped wave _1
Upk=-1152.24 kV, T1=1.37 us, Tc=3.95 us, Or=0.13
Wmax=3.1874kA, Wmin=-4.2942kA

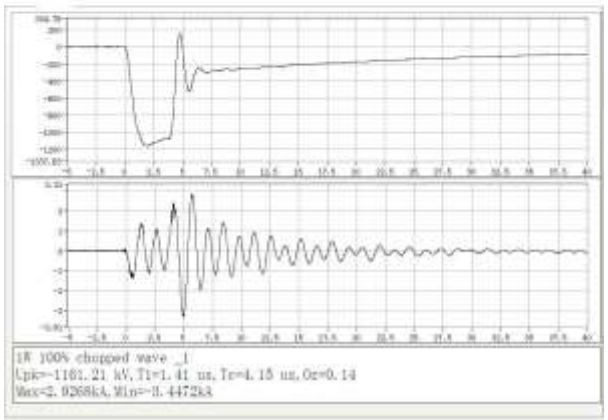

1V 100% chopped wave _2
Upk=-1160.07 kV, T1=1.36 us, Tc=4.07 us, Or=0.13
Wmax=2.9824kA, Wmin=-3.8850kA

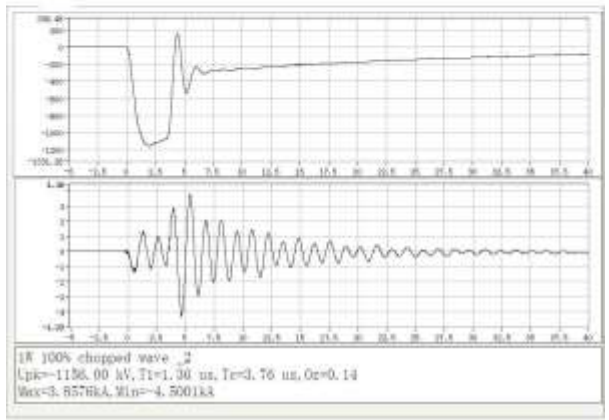

1V 100% full wave _2
Upk=-1030.62 kV, T1=1.372 us, T2=53.84 us
Wmax=1.4414kA, Wmin=-1.5521kA

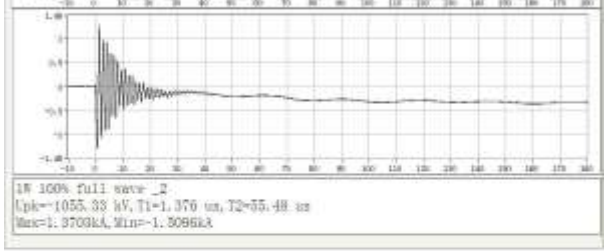

1V 100% full wave _3
Upk=-1052.57 kV, T1=1.391 us, T2=53.96 us
Wmax=1.3709kA, Wmin=-1.5721kA

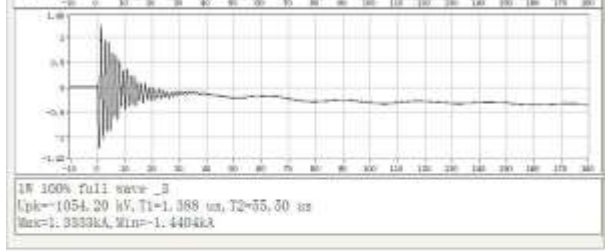

1N 50% full wave _1
Upk=-868.90 kV, T1=1.438 us, T2=54.25 us
Max=0.7830kA, Min=-0.9549kA

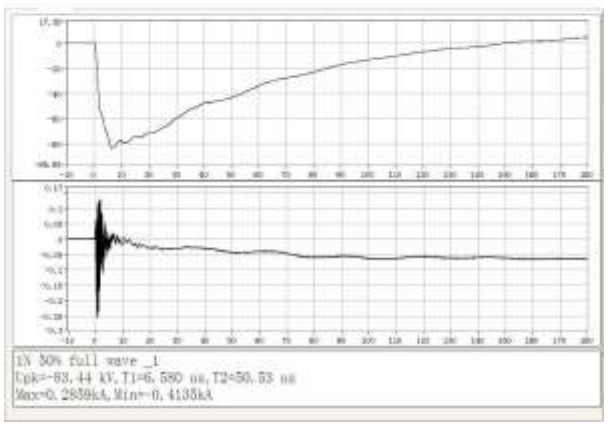

1N 100% full wave _1
Upk=-1041.97 kV, T1=1.397 us, T2=55.27 us
Max=1.3554kA, Min=-1.5118kA

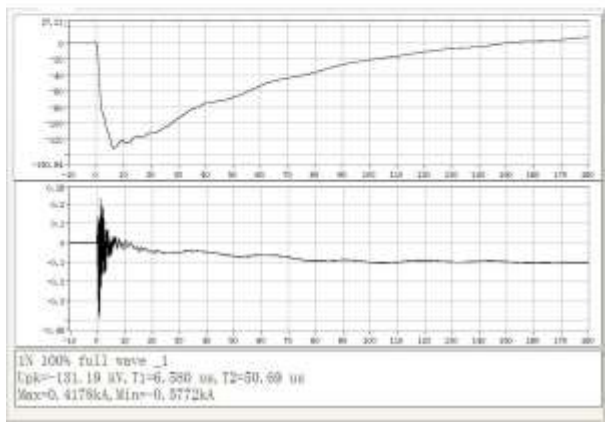

1N 100% chopped wave _1
Upk=-1161.21 kV, T1=1.41 us, Tc=4.15 us, Oz=0.14
Max=2.9268kA, Min=-3.4472kA

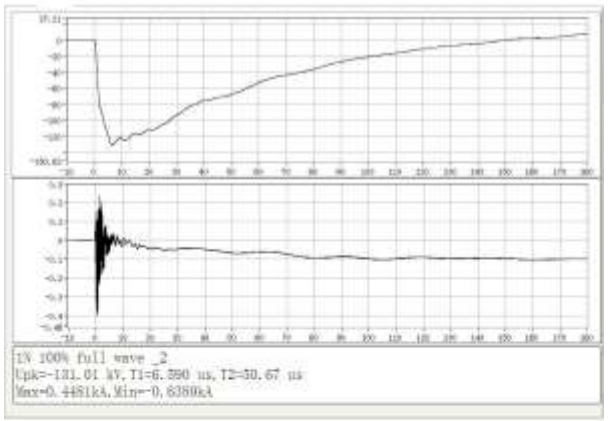

1N 100% chopped wave _2
Upk=-1156.00 kV, T1=1.30 us, Tc=3.76 us, Oz=0.14
Max=3.8576kA, Min=-4.5001kA

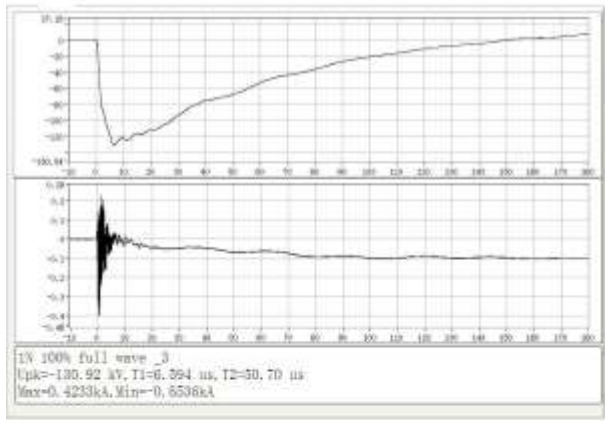

1N 100% full wave _2
Upk=-1055.33 kV, T1=1.376 us, T2=55.48 us
Max=1.3703kA, Min=-1.5096kA

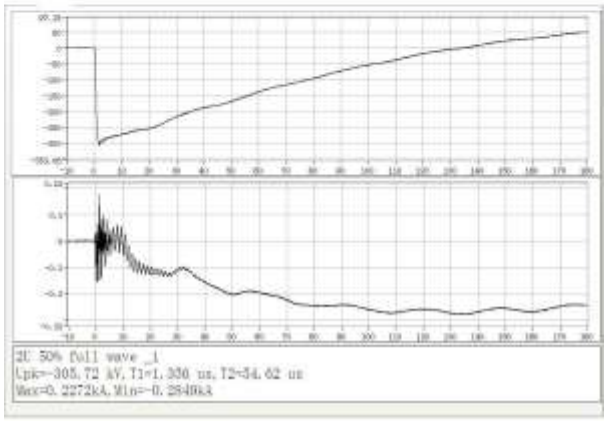

1N 100% full wave _3
Upk=-1054.20 kV, T1=1.388 us, T2=55.30 us
Max=1.3553kA, Min=-1.4804kA


1N 50% full wave _1
Upk=-83.44 kV, T1=6.580 us, T2=50.53 us
Max=0.2859kA, Min=-0.4135kA

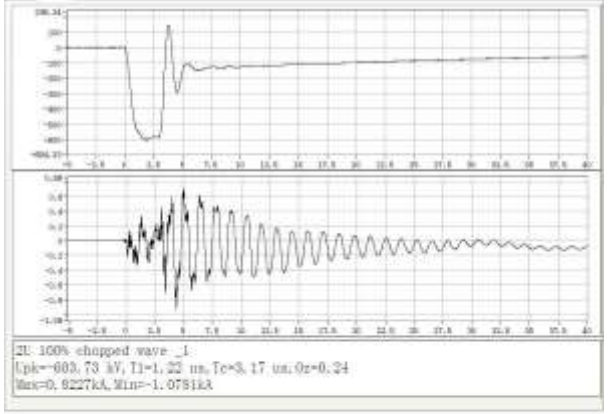

1N 100% full wave _1
Upk=-131.19 kV, T1=6.580 us, T2=50.69 us
Max=0.4178kA, Min=-0.5772kA

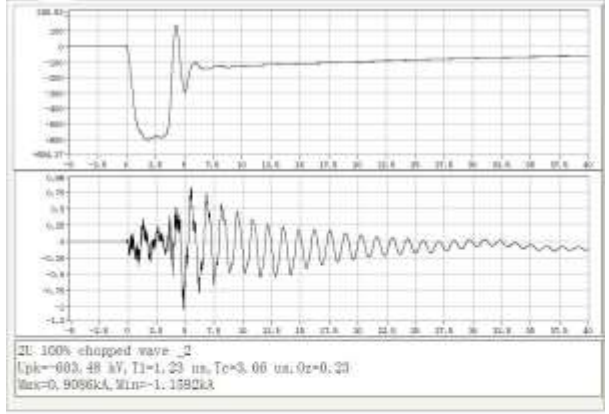

1N 100% full wave _2
Upk=-131.01 kV, T1=6.380 us, T2=50.67 us
Wmx=0.4481kA, Min=-0.6380kA

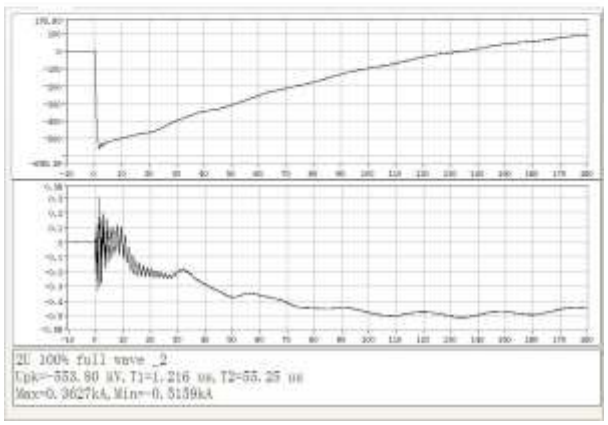

1N 100% full wave _3
Upk=-130.92 kV, T1=6.394 us, T2=50.70 us
Wmx=0.4233kA, Min=-0.6536kA

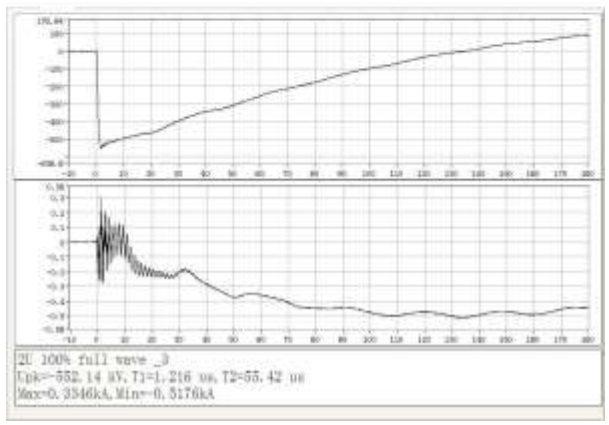

2U 50% full wave _1
Upk=-305.72 kV, T1=1.336 us, T2=54.62 us
Wmx=0.2272kA, Min=-0.2840kA

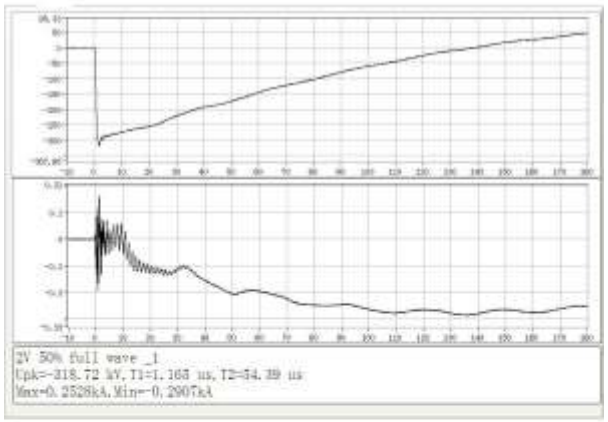

2U 100% full wave _1
Upk=-647.48 kV, T1=1.210 us, T2=55.26 us
Wmx=0.3690kA, Min=-0.5117kA

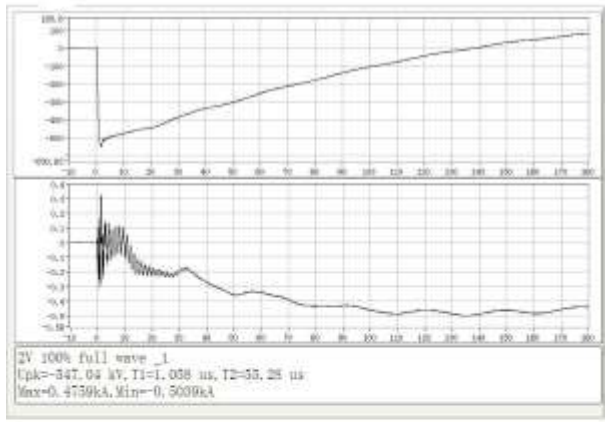

2U 100% chopped wave _1
Upk=-603.73 kV, T1=1.23 us, Tc=3.17 us, Oz=0.24
Wmx=0.9227kA, Min=-1.0791kA

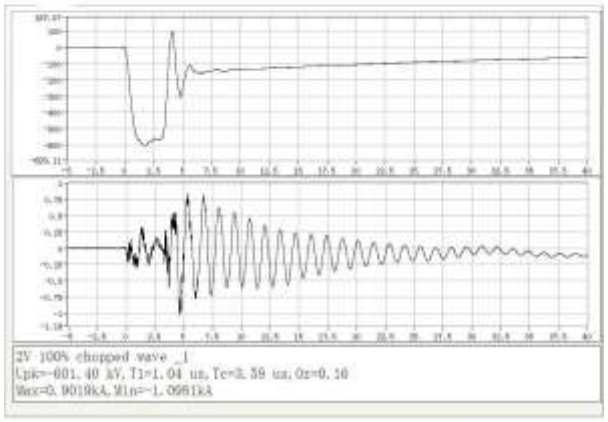

2U 100% chopped wave _2
Upk=-603.48 kV, T1=1.23 us, Tc=3.06 us, Oz=0.23
Wmx=0.9056kA, Min=-1.1382kA

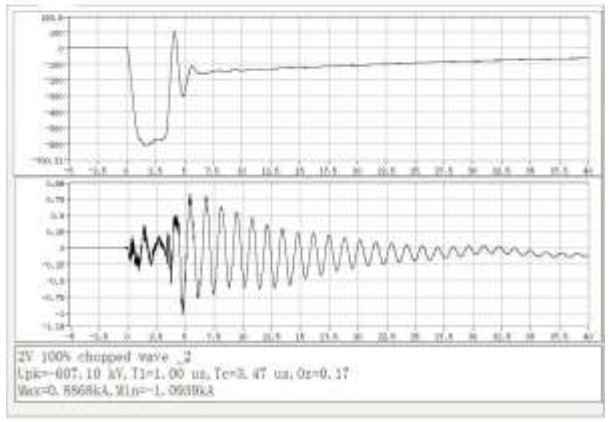

2U 100% full wave _2
Upk=-553.80 kV, T1=1.216 us, T2=55.25 us
Wmx=0.3627kA, Min=-0.5139kA

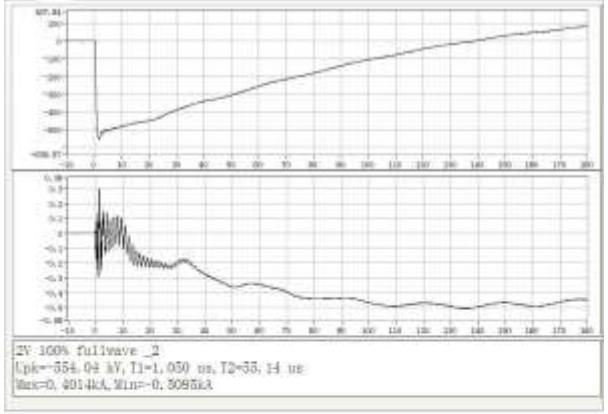

2U 100% full wave _3
Upk=-552.14 kV, T1=1.216 us, T2=55.42 us
Wmx=0.3546kA, Min=-0.5176kA

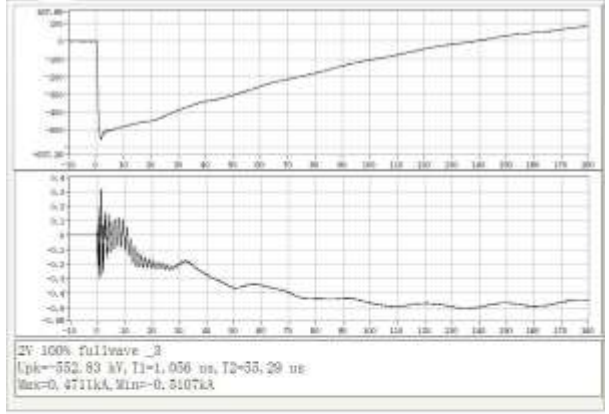

2V 50% full wave _1
Upk=-318.72 kV, T1=1.168 us, T2=54.39 us
Wmax=0.2528kA, Min=-0.2907kA

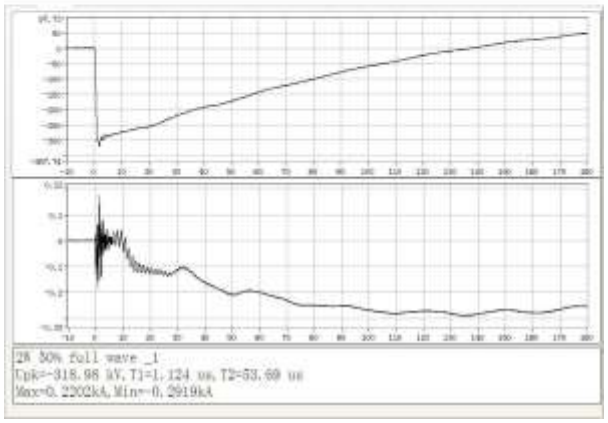

2V 100% full wave _1
Upk=-347.04 kV, T1=1.058 us, T2=53.25 us
Wmax=0.4739kA, Min=-0.5039kA

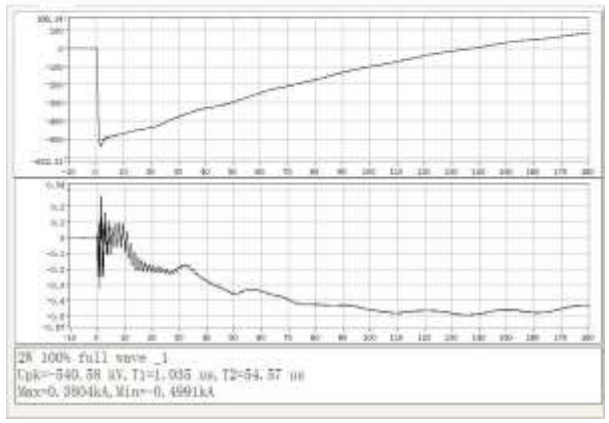

2V 100% chopped wave _1
Upk=-601.40 kV, T1=1.04 us, Tc=3.58 us, Oz=0.16
Wmax=0.9019kA, Min=-1.0961kA

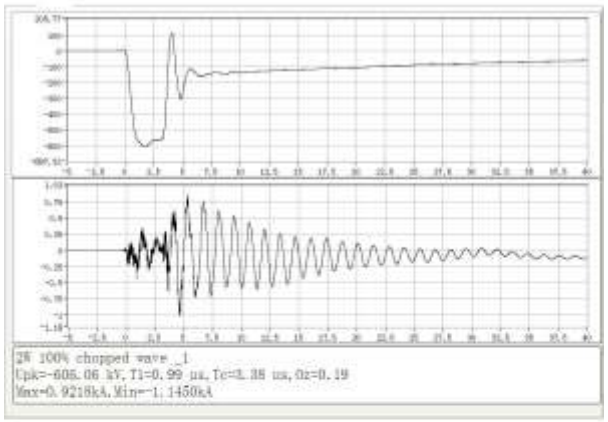

2V 100% chopped wave _2
Upk=-607.10 kV, T1=1.00 us, Tc=3.47 us, Oz=0.17
Wmax=0.8968kA, Min=-1.0939kA

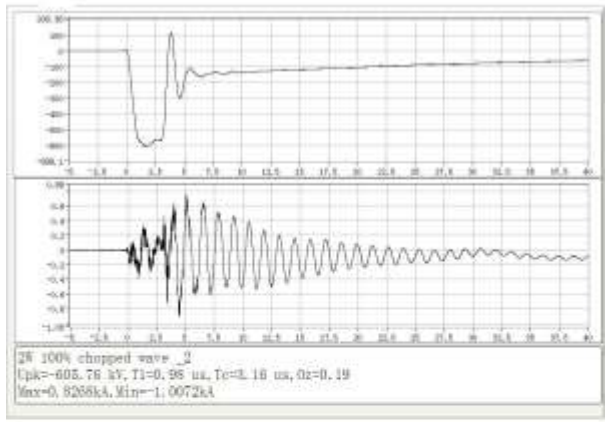

2V 100% fullwave _2
Upk=-554.04 kV, T1=1.050 us, T2=55.14 us
Wmax=0.4014kA, Min=-0.5095kA


2V 100% fullwave _2
Upk=-552.83 kV, T1=1.056 us, T2=55.29 us
Wmax=0.4711kA, Min=-0.5107kA


2A 50% full wave _1
Upk=-318.98 kV, T1=1.124 us, T2=53.69 us
Wmax=0.2202kA, Min=-0.2919kA

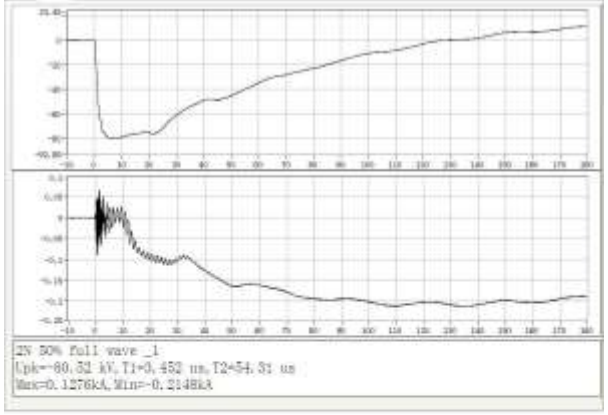

2A 100% full wave _1
Upk=-540.58 kV, T1=1.035 us, T2=54.57 us
Wmax=0.3804kA, Min=-0.4991kA

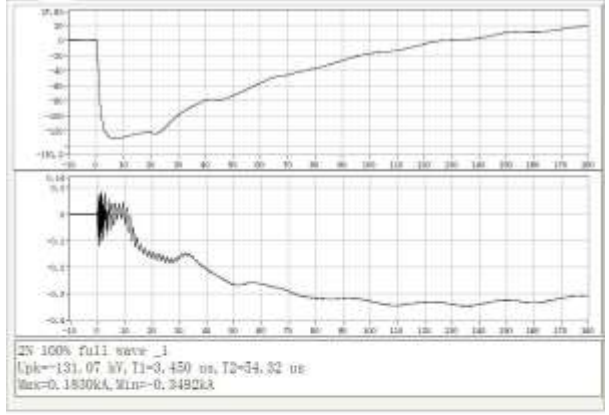

2N 100% chopped wave _1
Upk=-605.06 kV, T1=0.99 us, Tc=3.38 us, Oz=0.19
Max=0.9218kA, Min=-1.1450kA

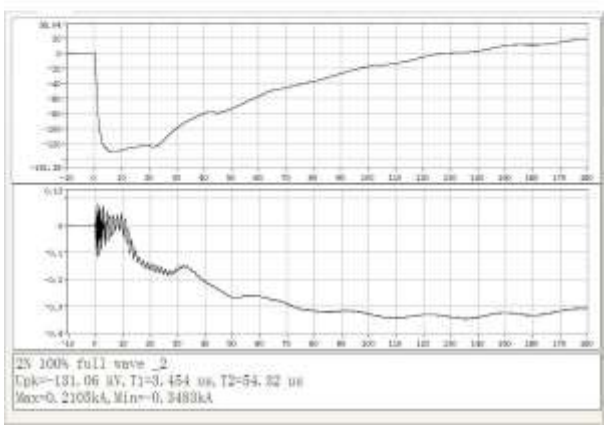

2N 100% chopped wave _2
Upk=-605.76 kV, T1=0.98 us, Tc=3.16 us, Oz=0.19
Max=0.8266kA, Min=-1.0072kA

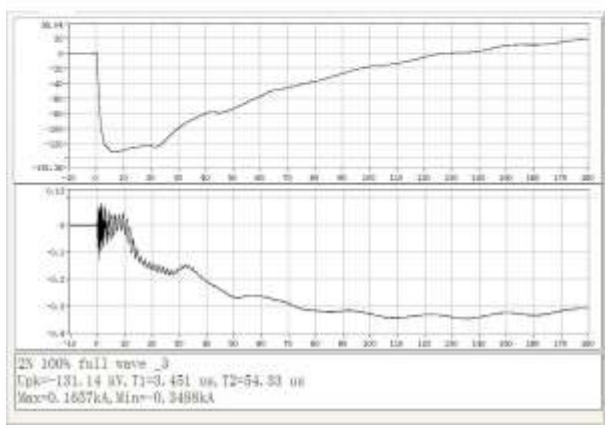

2N 100% full wave _2
Upk=-552.69 kV, T1=1.010 us, T2=54.34 us
Max=0.3712kA, Min=-0.5084kA


2N 100% full wave _3
Upk=-550.38 kV, T1=1.010 us, T2=54.56 us
Max=0.3727kA, Min=-0.5099kA

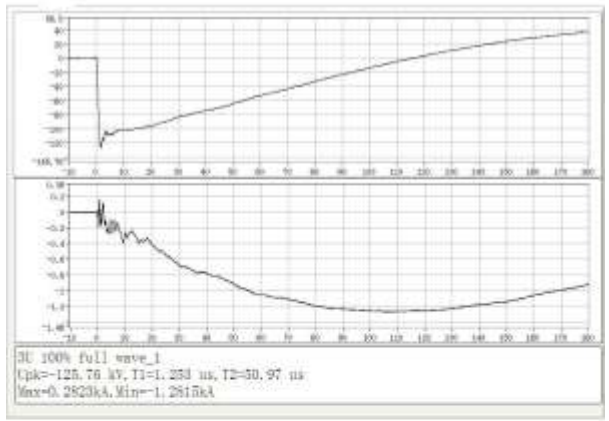

2N 50% full wave _1
Upk=-60.32 kV, T1=0.452 us, T2=54.31 us
Max=0.1276kA, Min=-0.2148kA

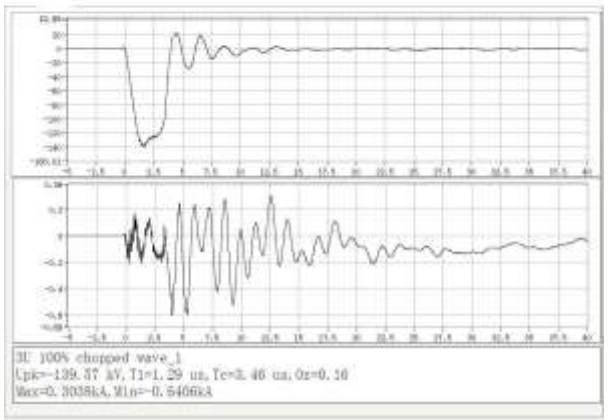

2N 100% full wave _1
Upk=-131.07 kV, T1=3.450 us, T2=54.32 us
Max=0.1830kA, Min=-0.3492kA

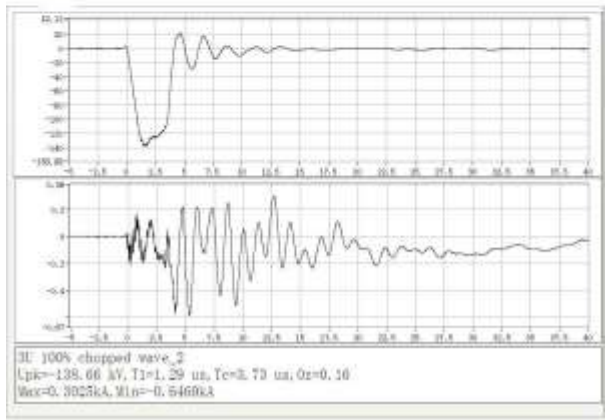

2N 100% full wave _2
Upk=-131.06 kV, T1=3.454 us, T2=54.32 us
Max=0.2103kA, Min=-0.3483kA

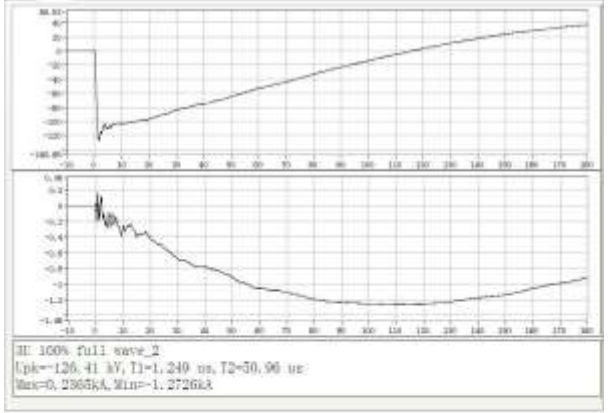

2N 100% full wave _3
Upk=-131.14 kV, T1=3.451 us, T2=54.33 us
Max=0.1657kA, Min=-0.3498kA

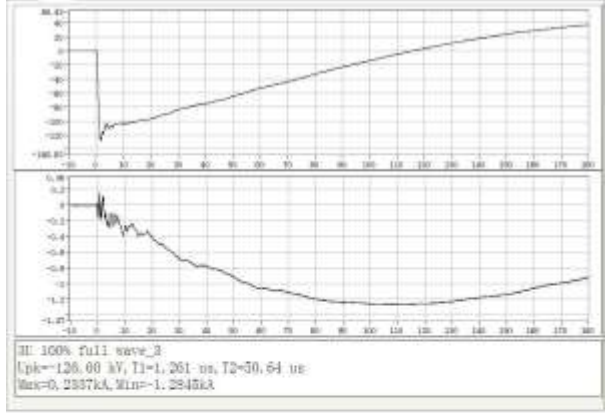

3U 50% full wave_1
Upk=-78.77 kV, T1=1.263 us, T2=51.09 us
Max=0.1739kA, Min=-0.7631kA

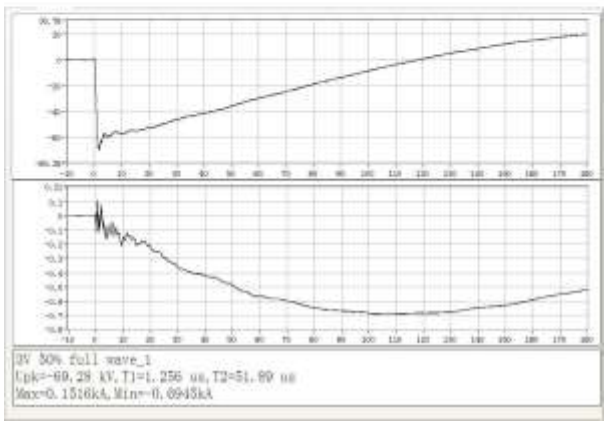

3U 100% full wave_1
Upk=-125.76 kV, T1=1.253 us, T2=50.97 us
Max=0.2823kA, Min=-1.2815kA

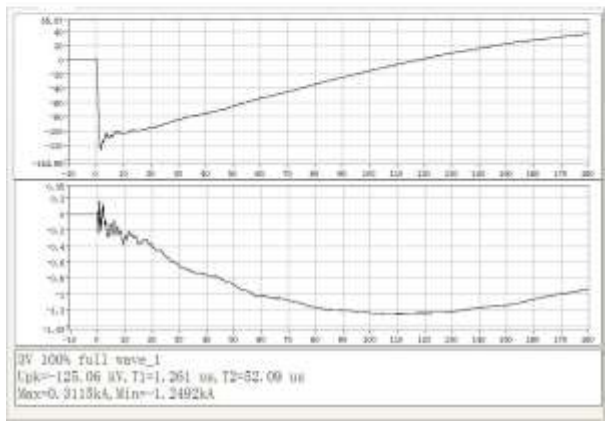

3U 100% chopped wave_1
Upk=-139.37 kV, T1=1.29 us, Tc=3.46 us, Oz=0.16
Max=0.3038kA, Min=-0.5406kA

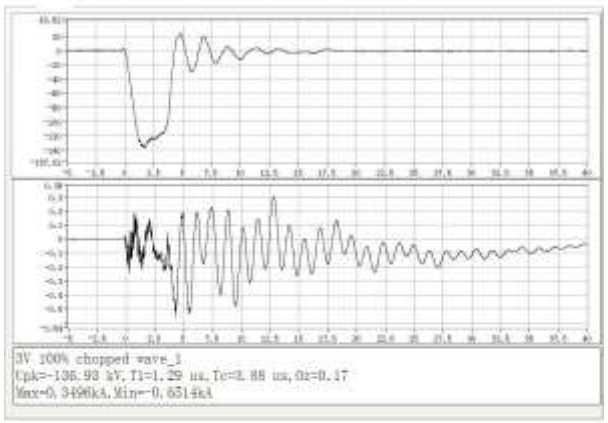

3U 100% chopped wave_2
Upk=-139.66 kV, T1=1.29 us, Tc=3.73 us, Oz=0.16
Max=0.3023kA, Min=-0.5460kA

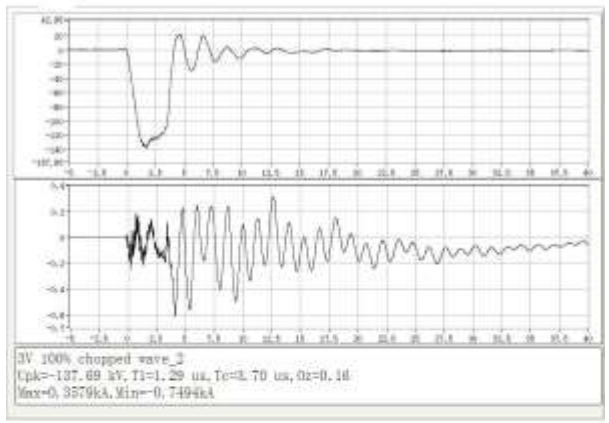

3U 100% full wave_2
Upk=-126.41 kV, T1=1.249 us, T2=50.96 us
Max=0.2365kA, Min=-1.2726kA


3U 100% full wave_3
Upk=-126.00 kV, T1=1.261 us, T2=50.64 us
Max=0.2337kA, Min=-1.2845kA

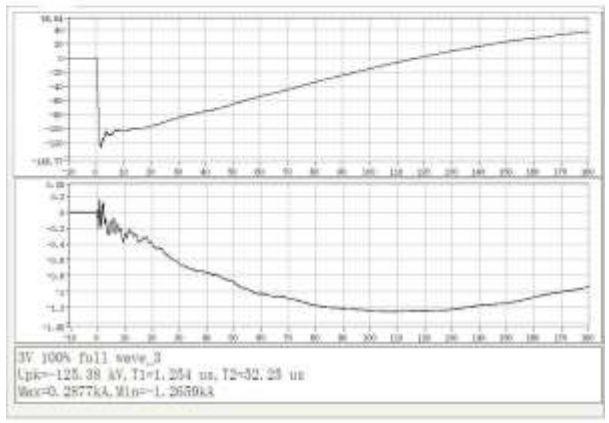

3V 50% full wave_1
Upk=-69.28 kV, T1=1.256 us, T2=51.89 us
Max=0.1516kA, Min=-0.6945kA

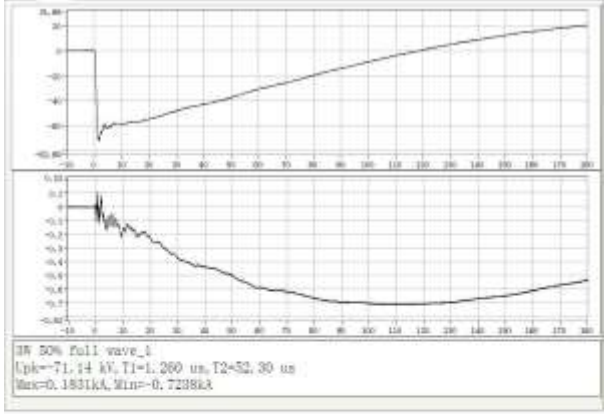

3V 100% full wave_1
Upk=-125.06 kV, T1=1.261 us, T2=52.09 us
Max=0.3113kA, Min=-1.2492kA


3V 100% chopped wave_1
Upk=-136.93 kV, T1=1.29 us, Tc=3.88 us, Oz=0.17
Imax=0.3496kA, Imin=-0.6514kA

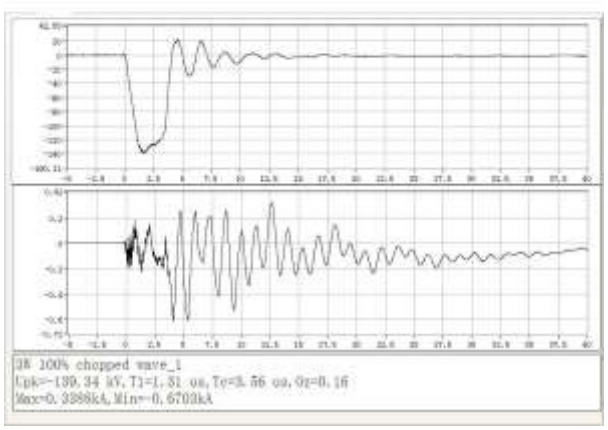

3V 100% chopped wave_3
Upk=-137.69 kV, T1=1.29 us, Tc=3.70 us, Oz=0.16
Imax=0.3579kA, Imin=-0.7494kA

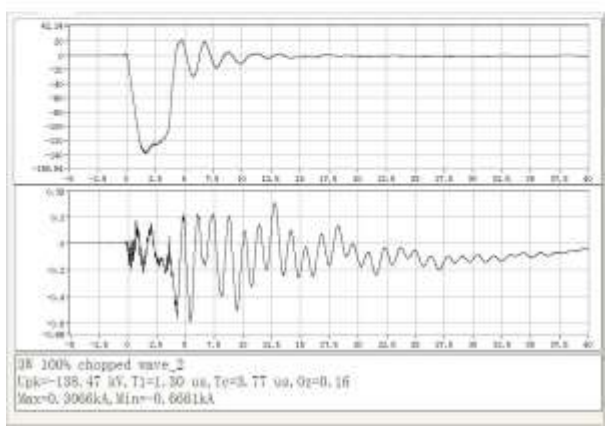

3V 100% full wave_2
Upk=-126.00 kV, T1=1.249 us, T2=52.18 us
Imax=0.2671kA, Imin=-1.2663kA

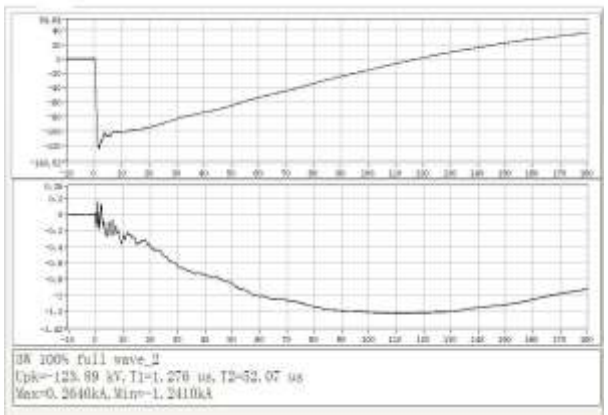

3V 100% full wave_3
Upk=-125.38 kV, T1=1.254 us, T2=52.25 us
Imax=0.2577kA, Imin=-1.2659kA

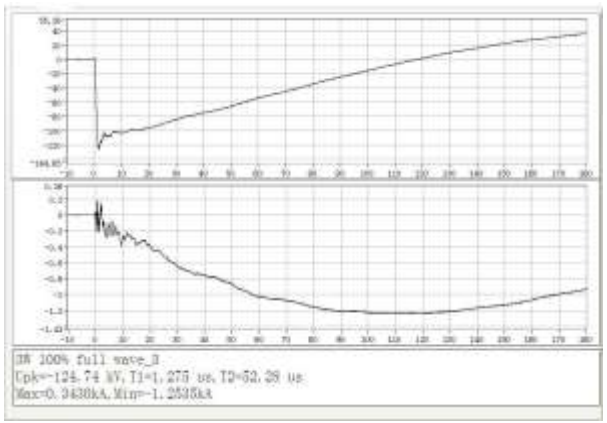

3N 50% full wave_1
Upk=-71.14 kV, T1=1.260 us, T2=52.30 us
Imax=0.1831kA, Imin=-0.7238kA


3N 100% full wave_1
Upk=-125.09 kV, T1=1.281 us, T2=52.23 us
Imax=0.2561kA, Imin=-1.2647kA


3N 100% chopped wave_1
Upk=-139.34 kV, T1=1.31 us, Tc=3.56 us, Oz=0.16
Imax=0.3388kA, Imin=-0.6703kA


3N 100% chopped wave_2
Upk=-138.47 kV, T1=1.30 us, Tc=3.77 us, Oz=0.16
Imax=0.3066kA, Imin=-0.6681kA

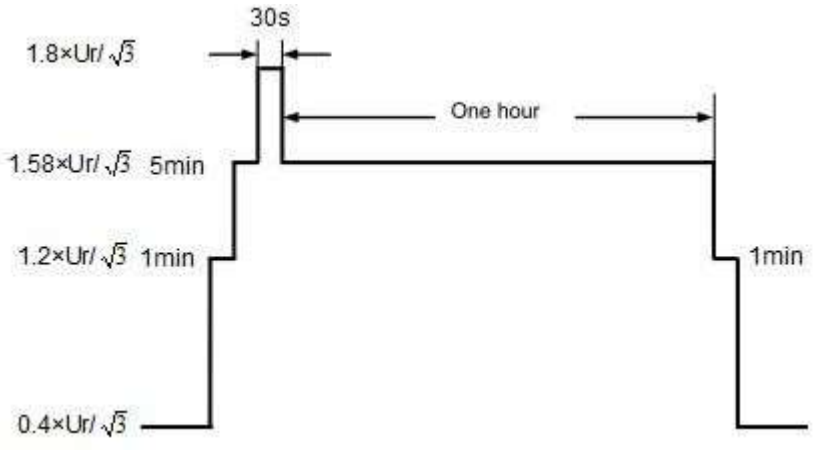




18. Applied voltage test

Terminals to be tested	Test voltage (kV)	Frequency (Hz)	Duration (s)	Conclusion
HV & HVN - LV & MV & G	50	50	60	Passed
MV & MVN - LV & HV & G	50	50	60	
LV - HV & MV & G	38	50	60	

19. Induced-voltage test with partial discharge measurement (IVPD)



Ur is the rated voltage

Time sequence (min)	Test voltage (kV) (HV to ground)	Quantity of partial discharge (pC)					
		1U	1V	1W	2U	2V	2W
/	0.4×Ur/$\sqrt{3}$	37	48	24	20	20	16
0	1.2×Ur/$\sqrt{3}$	39	44	22	20	21	16
1	1.2×Ur/$\sqrt{3}$	40	45	23	20	20	16
0	1.58×Ur/$\sqrt{3}$	40	44	22	20	21	16
5	1.58×Ur/$\sqrt{3}$	41	55	25	21	25	17
30s	1.8×Ur/$\sqrt{3}$	40	60	25	22	29	18
0	1.58×Ur/$\sqrt{3}$	38	53	24	21	26	17
5	1.58×Ur/$\sqrt{3}$	38	56	25	21	26	17
10	1.58×Ur/$\sqrt{3}$	39	57	25	21	26	17
15	1.58×Ur/$\sqrt{3}$	39	57	26	21	26	17
20	1.58×Ur/$\sqrt{3}$	39	57	26	21	26	17
25	1.58×Ur/$\sqrt{3}$	40	59	26	21	26	17
30	1.58×Ur/$\sqrt{3}$	39	57	24	21	26	17
35	1.58×Ur/$\sqrt{3}$	39	57	24	21	26	17
40	1.58×Ur/$\sqrt{3}$	39	57	24	21	26	17
45	1.58×Ur/$\sqrt{3}$	39	57	24	21	26	17
50	1.58×Ur/$\sqrt{3}$	39	57	24	20	26	17
55	1.58×Ur/$\sqrt{3}$	39	57	24	21	25	17

60	1.58×Ur/$\sqrt{3}$	39	57	24	20	21	16
0	1.2×Ur/$\sqrt{3}$	37	48	24	20	21	16
1	1.2×Ur/$\sqrt{3}$	37	48	24	20	21	15
/	0.4×Ur/$\sqrt{3}$	35	48	24	19	20	15

Note: HV side is at tap 11, Test frequency: 200Hz

20. Temperature rise test

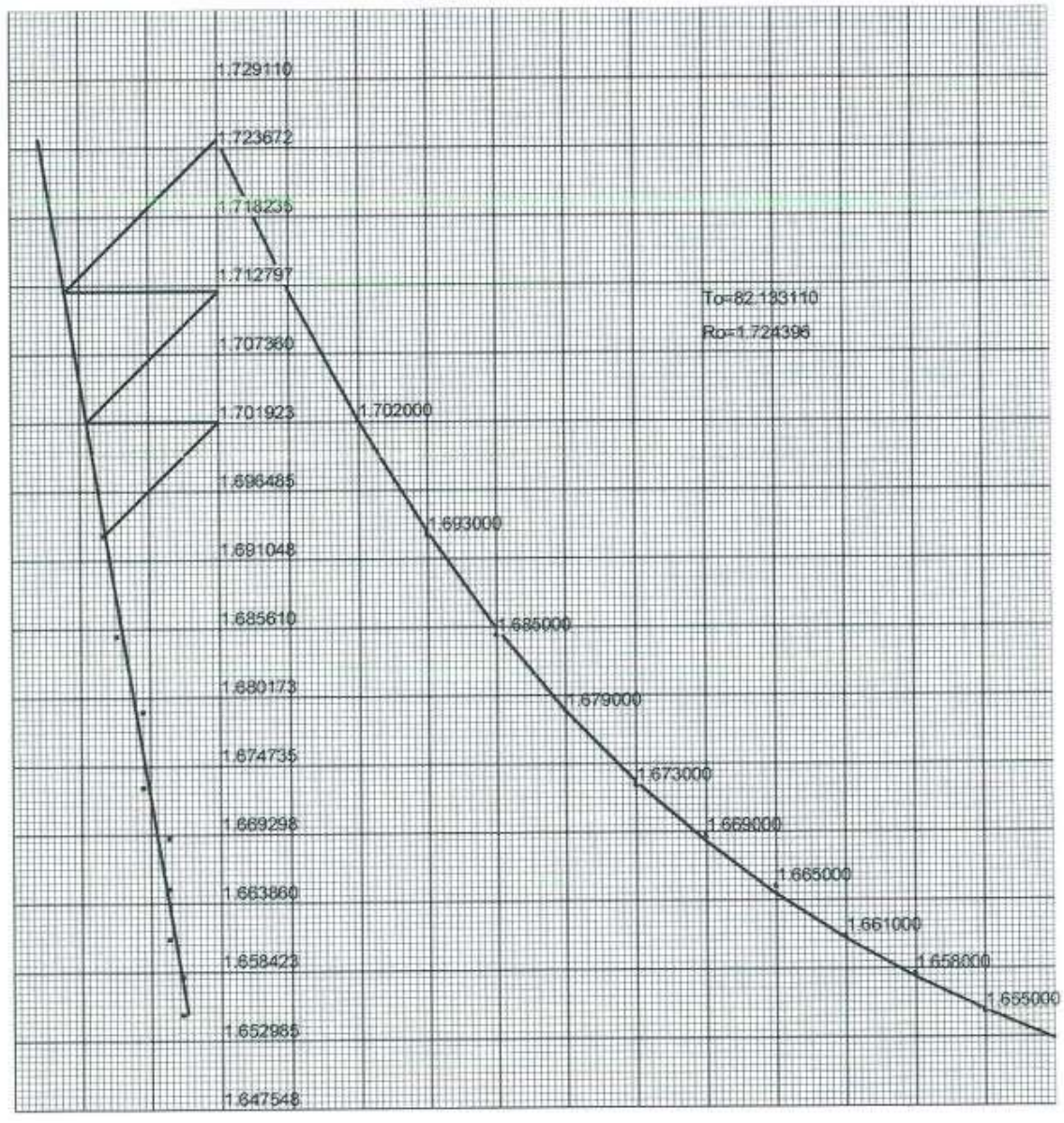
Measured data

Winding	Average oil temperature (°C)		Bottom oil temperature (°C)		Ambient temperature (°C)		
	Under total loss	Under rated current	Under total loss	Under rated current	Measured cold resistance	Under total loss	Under rated current
HV	71.6	70.9	55.4	55.1	25.6	26.8	27.5
MV	71.6	70.9	55.4	55.1	25.6	26.8	27.5
LV	71.6	61.5	55.4	43.8	25.6	26.8	28.0

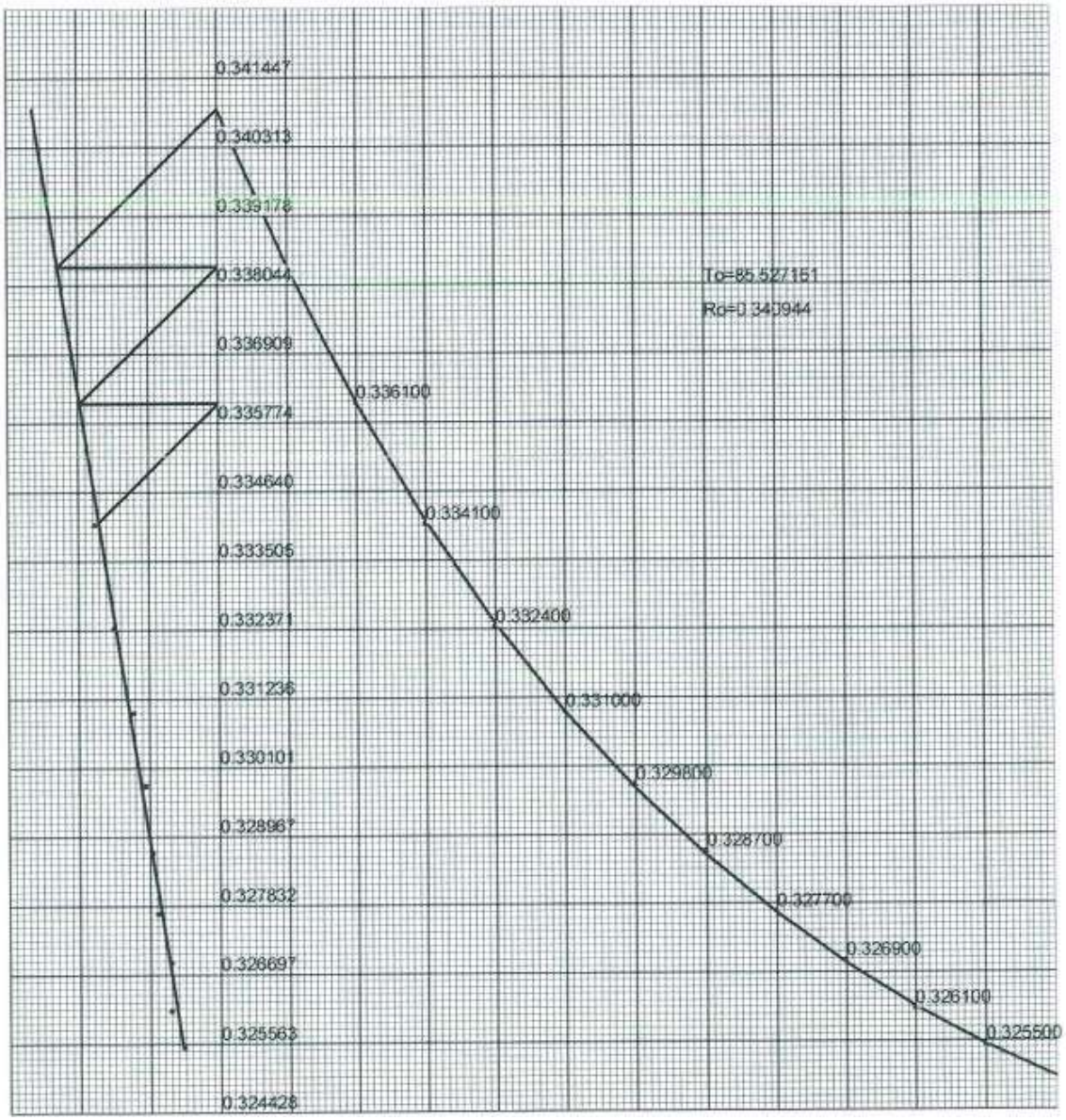
Winding	Measured cold resistance at 25.6°C (Ω)	Top oil temperature (°C)		Measured hot resistance when power supply was switched off (Ω)
		Under total loss	Under rated current	
HV	1.4170	84.1	82.9	1.7244 (1V-1N)
MV	0.2772	84.1	82.9	0.3409 (2V-2N)
LV	0.09126	84.1	70.9	0.10534 (3V-3W)

	Calculated value of temperature rise	Guaranteed value
Top oil temperature rise (K)	57.0	≤ 60
HV winding temperature rise (K)	55.8	≤ 65
MV winding temperature rise (K)	59.2	≤ 65
LV winding temperature rise (K)	48.9	≤ 65

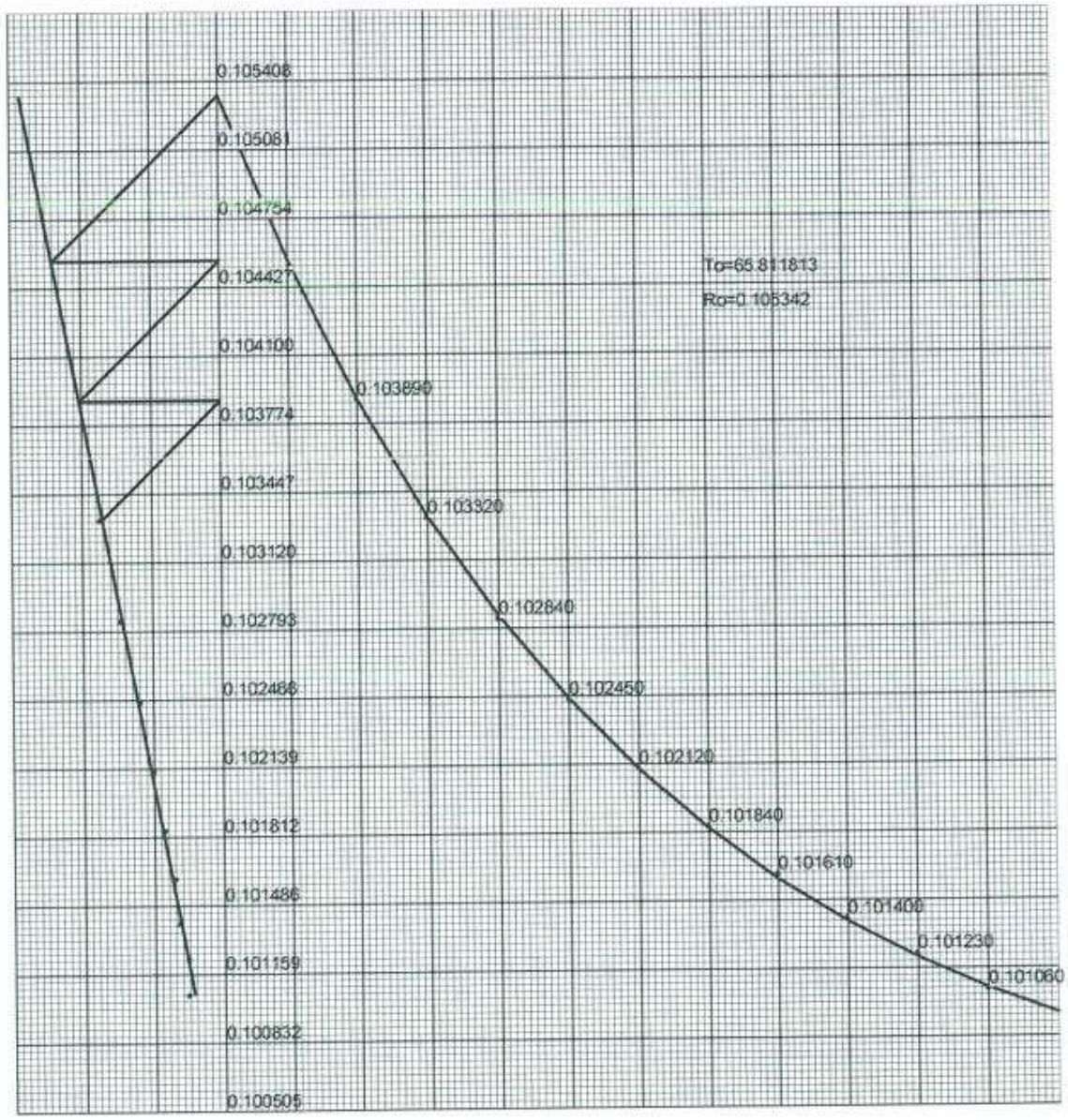
Curve of HV 1V-1N hot resistance



Curve of MV 2V-2N hot resistance



Curve of LV 3V-3W hot resistance



21. CT tests

Bushing	Sequence number	Terminal number	Nameplate value	Measured ratio	Polarity
HV 1U	T1	S1-S2	200/1	200/1	Same polarity
	T1	S1-S2	200/1	200/1	Same polarity
HV 1V	T1	S1-S2	200/1	200/1	Same polarity
	T1	S1-S2	200/1	200/1	Same polarity
	T2	S1-S2	200/2	200/2	Same polarity
HV 1W	T1	S1-S2	200/1	200/1	Same polarity
	T1	S1-S2	200/1	200/1	Same polarity
HV 1N	T3	S1-S2	200/1	200/1	Same polarity
		S1-S3	400/1	400/1	Same polarity
MV 2U	T4	S1-S2	400/1	400/1	Same polarity
	T4	S1-S2	400/1	400/1	Same polarity
MV 2V	T4	S1-S2	400/1	400/1	Same polarity
	T4	S1-S2	400/1	400/1	Same polarity
	T5	S1-S2	350/2	350/2	Same polarity
MV 2W	T4	S1-S2	400/1	400/1	Same polarity
	T4	S1-S2	400/1	400/1	Same polarity
MV 2N	T3	S1-S2	200/1	200/1	Same polarity
		S1-S3	400/1	400/1	Same polarity
LV 3V	T6	S1-S2	370/2	370/2	Same polarity

22. Frequency response analysis test

See report of transformer sweep frequency response analysis in appendix A.

23. Auxiliary wiring insulation test

The wiring for auxiliary power, and control circuitry had carried out 1min AC separate source test of 2kV to earth. The test is passed.

The wiring for current transformer secondary windings had carried out 2.5kV AC to earth for 1 min. The test is passed.

24. Test conclusion

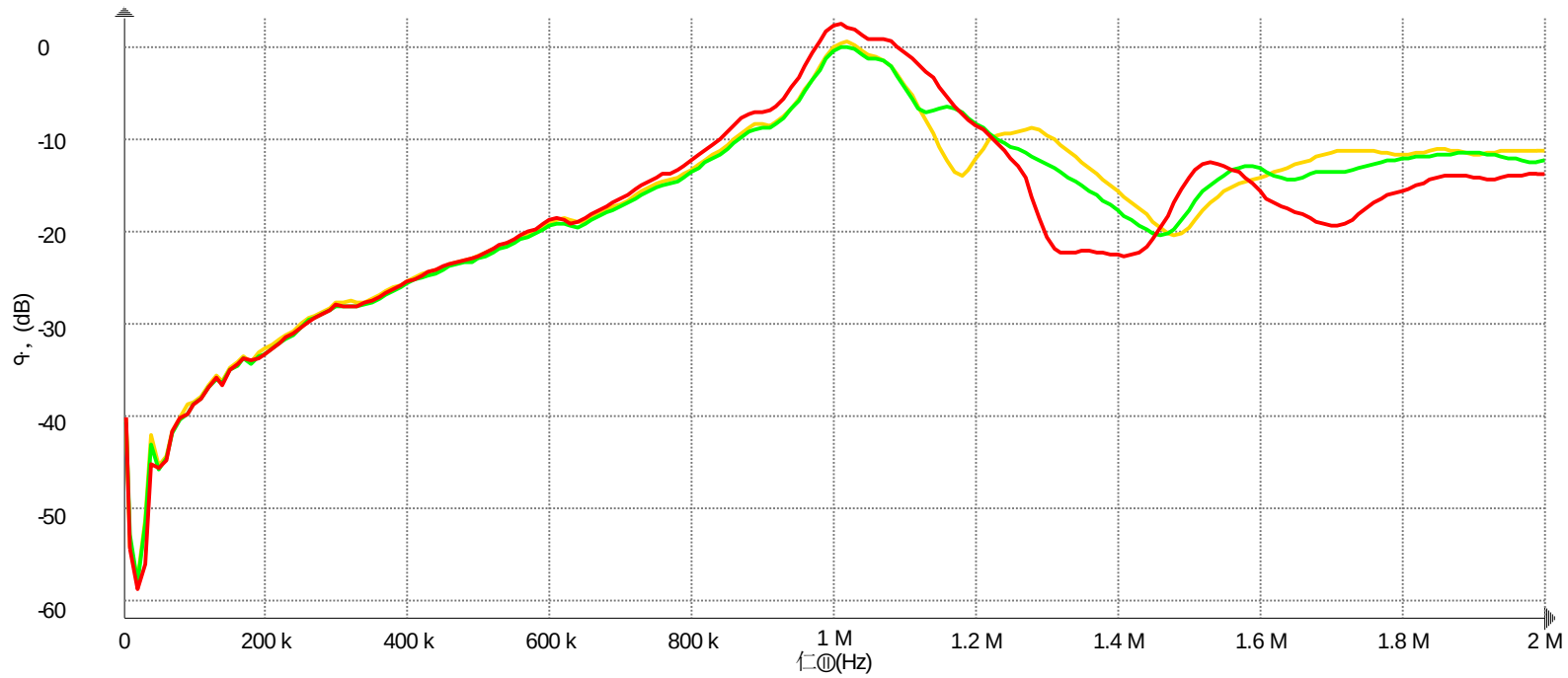
Test passed.

Appendix A:

Frequency Response Analysis Report

Customer	LAP SE RÍO TOLTÉN Station	Substation	LAP SE RÍO TOLTÉN Station
Winding	High voltage windings	Serial No.	100643
Test Equipment	FRAX-99	Test Date	2014-12-15

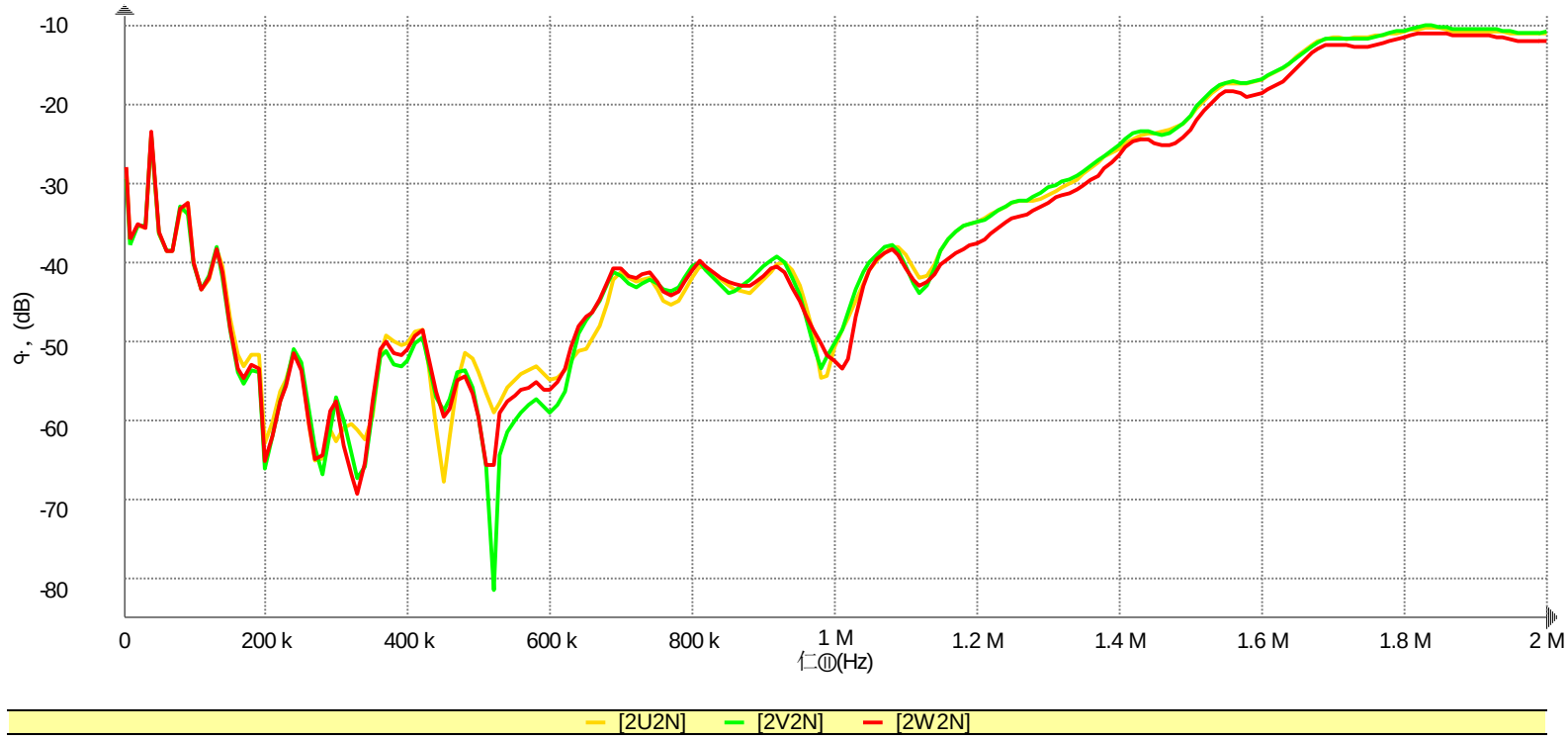
Magnitude



Frequency Response Analysis Report

Customer	LAP SE RÍO TOLTÉN Station	Substation	LAP SE RÍO TOLTÉN Station
Winding	Medium voltage windings	Serial No.	100643
Test Equipment	FRAX-99	Test Date	2014-12-15

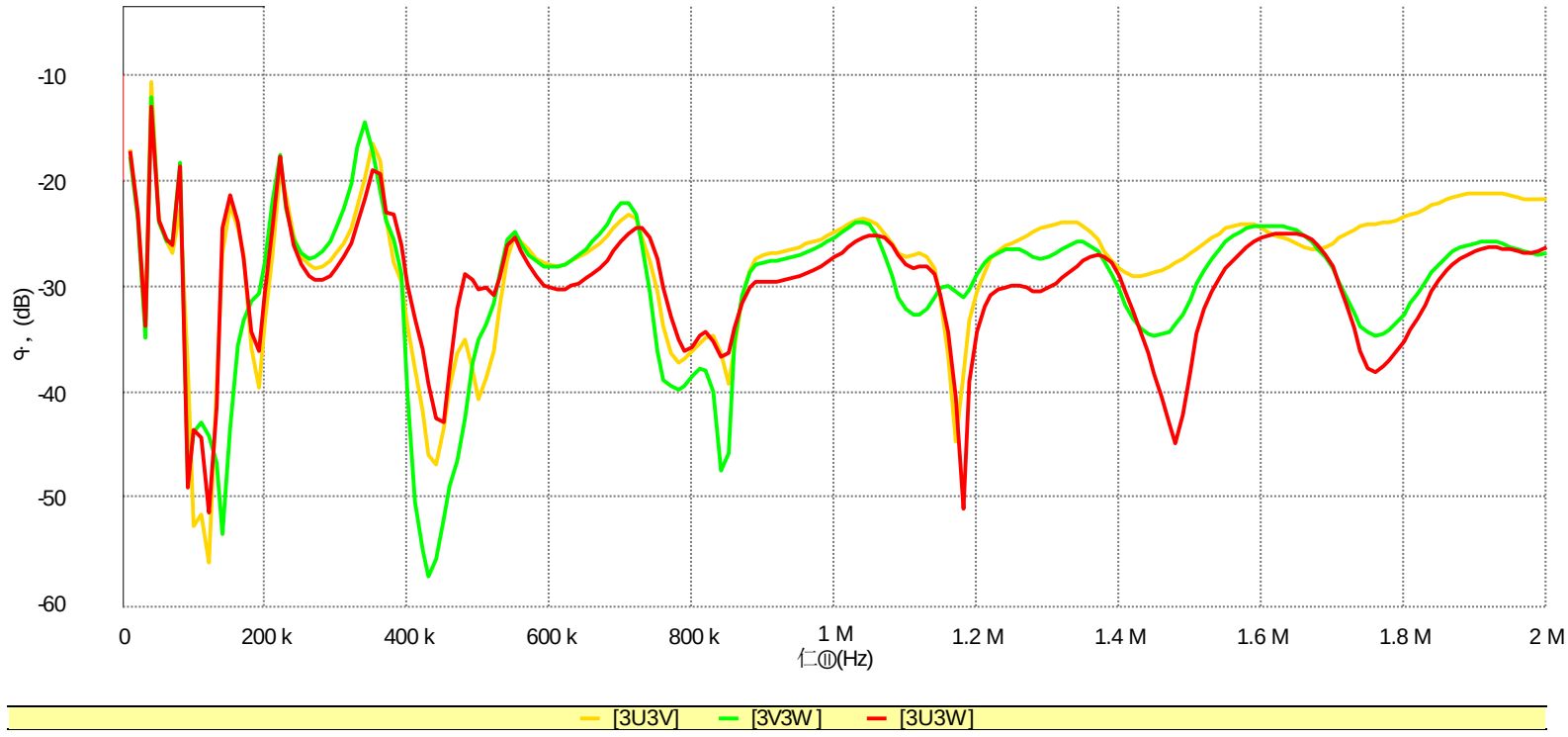
Magnitude



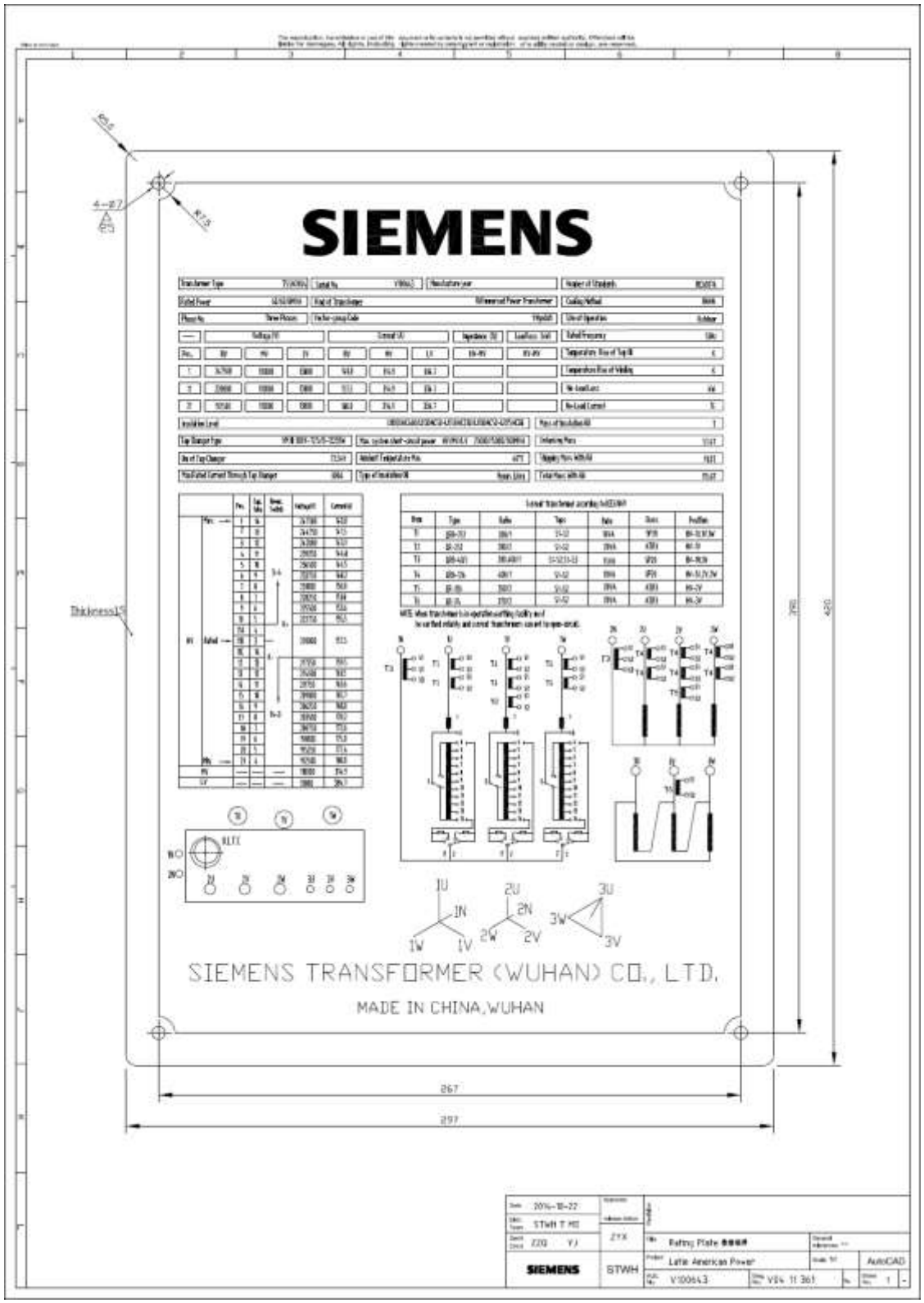
Frequency Response Analysis Report

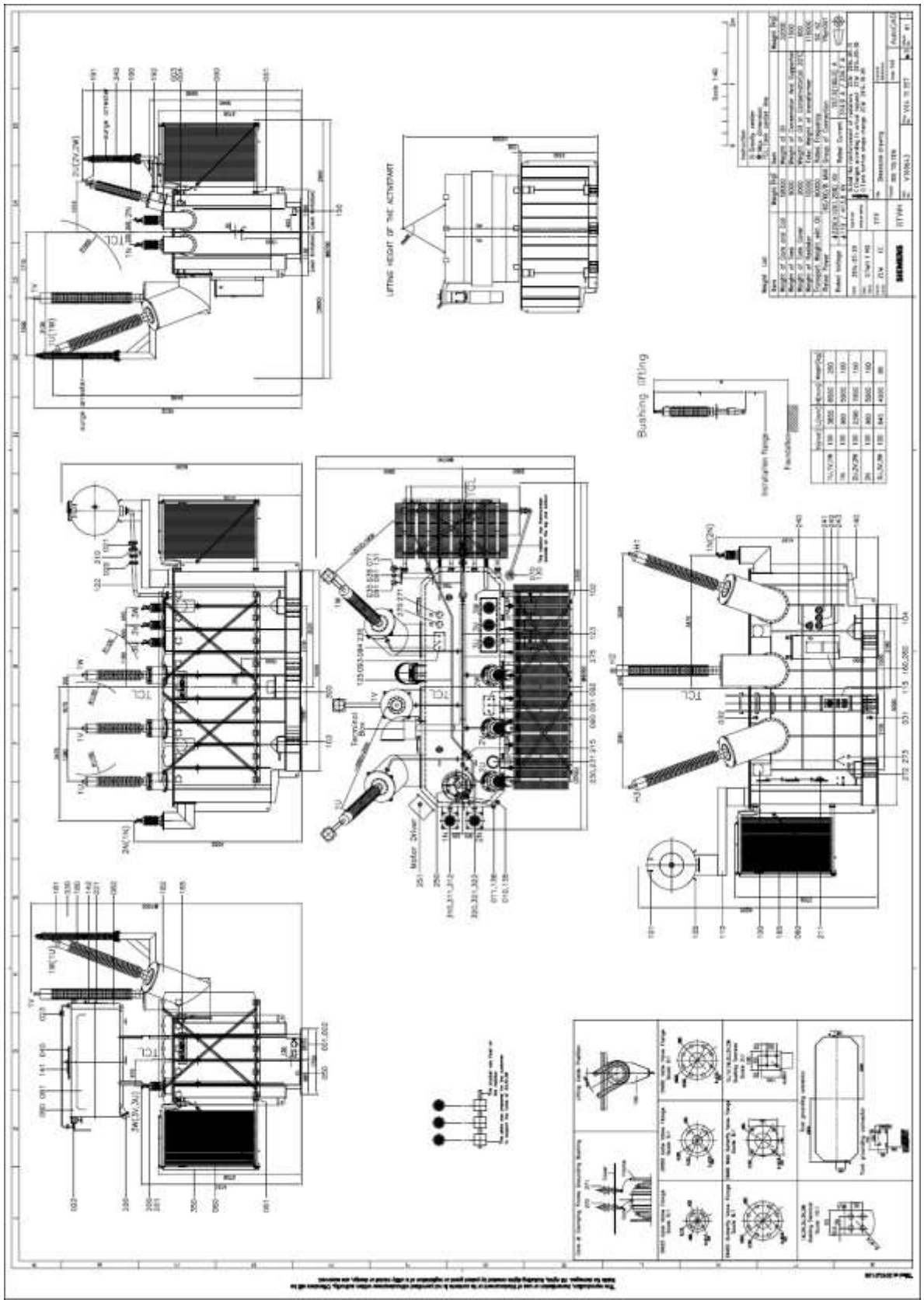
Customer	LAP SE RÍO TOLTÉN Station	Substation	LAP SE RÍO TOLTÉN Station
Winding	Low voltage windings	Serial No.	100643
Test Equipment	FRAX-99	Test Date	2014-12-15

Magnitude



ANNEX N DRAWINGS





ANNEX O PHOTOGRAPHS

Photo 1 Transformer during lightning impulse test

Photo 2 Transformer during temperature rise test