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Evaluation Report No. TRPVP02041/26E/002

Commission Testing for Three Phase AC Coupler
according to EN 50549-1:2019+A1:2023 & EN 50549-10:2022

Applicant: **Solenso electronic materials Co.,LTD.**
4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320,
TAIWAN, CHINA

File No.: PVP02041/26E-002

Designed:

by:



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Evaluation Report

File No.: PVP02041/26E-002

Report No.: TRPVP02041/26E/002

Applicant	Solenso electronic materials Co.,LTD. 4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320, TAIWAN, CHINA
Manufacturer	Solenso electronic materials Co.,LTD. 4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320, TAIWAN, CHINA
Factory	Solenso electronic materials Co.,LTD. 4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320, TAIWAN, CHINA
Order No.	HZZHPVP02041/26E
Date of Application [YYYY-MM-DD]	2026-03-05
Product(s)	Three Phase AC Coupler
Model type(s)	Sowave-TL8, Sowave-TL10, Sowave-TL12
Type of examination	Commission testing only
Certification program:	BOS-P-01 Rev. 02
Certification fundamental(s)	EN 50549-1:2019+A1:2023 EN 50549-10:2022
Testing Period [YYYY-MM-DD] start/end	2026-01-04/2026-05-11
Testing Laboratory	TÜV NORD Testing (Suzhou) Co., Ltd. Zone E, 1/F, East Side of South Building, Building 3, No.50, Beiguandu Road, Yuexi Subdistrict, Suzhou, Jiangsu, China
Annex(es)	Annex 1: Test report no. RDPVP02041/26E/02 (302 pages)

Test results listed in this test report refer exclusively to the mentioned test sample.

Partly copying is not permitted without explicit agreement of the owner.

The submitted test samples as described in the reports hereunder are in compliance with the requirements / are tested according to the requirements:

EN 50549-1:2019+A1:2023 "Requirements for generating plants to be connected in parallel with distribution networks, Part 1: Connection to a LV distribution network - Generating plants up to and including Type B".
EN 50549-10:2022 "Requirements for generating plants to be connected in parallel with distribution networks - Part 10: Tests for conformity assessment of generating units".



Test Report No. RDPVP02041/26E/02

Commission Testing for Three Phase AC Coupler
according to EN 50549-1:2019+A1:2023 & EN 50549-10:2022

Applicant: **Solenso electronic materials Co.,LTD.**
4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320,
TAIWAN, CHINA

Project No.: HZHZRDPVP02041/26E-02

Tested by:

Chris
May 14. 2026

Reviewed by:

Tao Zhang
May 14. 2026



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Test Report

Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

Applicant..... :	Solenso electronic materials Co.,LTD.
Address of Applicant..... :	4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320, TAIWAN, CHINA
Manufacturer :	Solenso electronic materials Co.,LTD.
Address of Manufacturer :	4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320, TAIWAN, CHINA
Factory..... :	Solenso electronic materials Co.,LTD.
Address of Factory :	4F., NO.56, ZILI 5TH ST., ZHONGLI DIST., TAOYUAN CITY 320, TAIWAN, CHINA
Equipment Type. :	Three Phase AC Coupler
Model Name. :	Sowave-TL8, Sowave-TL10, Sowave-TL12
Brand Name :	
Ratings :	See copy of general product information.
Test Date :	Jan.04,2026 to May.11,2026
Date of Issue :	May.14,2026

Test results listed in this test report refer exclusively to the mentioned test sample.

Partly copying is not permitted without explicit agreement of the owner.

The submitted test samples as described in the reports hereunder are tested according to the requirements:

EN 50549-1:2019+A1:2023 "Requirements for generating plants to be connected in parallel with distribution networks Part 1: Connection to a LV distribution network -Generating plants up to and including Type B"

EN 50549-10:2022 "Requirements for generating plants to be connected in parallel with distribution networks -Part 10: Tests for conformity assessment of generating units"

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Test Report

Project No.: HZH ZRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

History of report	
File no.:	N/A
Date of issue.....:	N/A
Report no.:	N/A
Type designation(s) :	N/A
Update contents::	N/A
Supplementary information: Commission testing only.	

Summary of testing	
Tests performed (name of test and test clause): ☒ 5.2 Normal operating range ☒ 5.3 Immunity to disturbances ☒ 5.4 Active response to frequency deviation ☒ 5.5 Power specification and response to voltage variations ☒ 5.6 Voltage related active power reduction - P(U) ☒ 5.7 EMC and power quality ☒ 5.8 Interface protection ☒ 5.9 Connection and reconnection ☒ 5.10 Active power reduction on set point ☒ 5.11 Remote information exchange ☒ 5.12 Requirements regarding single fault tolerance of interface protection system and interface switch	Testing location: TÜV NORD Testing (Suzhou) Co., Ltd. Zone E, 1/F, East Side of South Building, Building 3, No.50, Beiguandu Road, Yuexi Subdistrict, Suzhou, Jiangsu, China
The product fulfils the requirements of EN 50549-1:2019+A1:2023&EN 50549-10:2022.	

Test Report

Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

General remarks

Possible test case verdicts:	
Test case does not apply to the test object.....:	Not Applicable (N/A)
Test object does meet the requirement.....:	Pass (P)
Test object does not meet the requirement.....:	Fail (F)
Other remarks:	
The test verdicts presented in this report relate only to the object tested. This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory. “(see Annex #)” refers to additional information appended to the report. “(see Table #)” refers to a table appended to the report. Throughout this report, a point is used as the decimal separator.	

General product information

Model type: Engineering sample

Copy of marking plate:

Solenso

Model:
SoWave-TL

8

10

12

AC INPUT

Nominal voltage 3LNPE 230/400V a.c.

Max. phase current 23.2A a.c.

Nominal frequency 50/60Hz

Max. apparent power 16000VA

Max. power 16000W

Power factor 0.8 leading to 0.8 lagging

AC OUTPUT

Nominal voltage 3LNPE 230/400V a.c.

Max. phase current 11.5A a.c.

Nominal frequency 50/60Hz

Max. apparent power 8000VA

Nominal power 8000W

AC output power factor 0.8 leading to 0.8 lagging

Battery

Battery type Li-ionLead-acid

Battery voltage range 40Vd.c./40Vd.c.

Max. charging/discharging current 180Ad.c./180Ad.c.

GENERAL DATA

Ingress protection IP65

Operating Temperature Range -25-60°C/+45°C derating)

Inverter topology Non-isolated

Over voltage category III(AC), I(DC)

Protective class I

S/N

Note: Reactive power relative tests conducted under the PF from 0.8 lagging to 0.8 leading.

Test Report

Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

Test item particulars:	
Equipment mobility	Permanent connection
Operating condition	Continuous
Class of equipment.....	Class I
IP protection class	IP65
Mass of equipment (kg).....	See model list.

General product information:

The equipment under test (EUT) is an energy storage inverter. During the operation of the inverter, the direct current generated from the battery side is converted into stable alternating current, which can be used for grid-connected or off-grid loads. For the Sowave-TL12 unit, in power-saving mode, the battery's maximum charging power and maximum discharging power are 12,000 watts. The AC input port can output a maximum power of 24,000 watts when simultaneously charging the battery and operating the load.

Differences of the models:

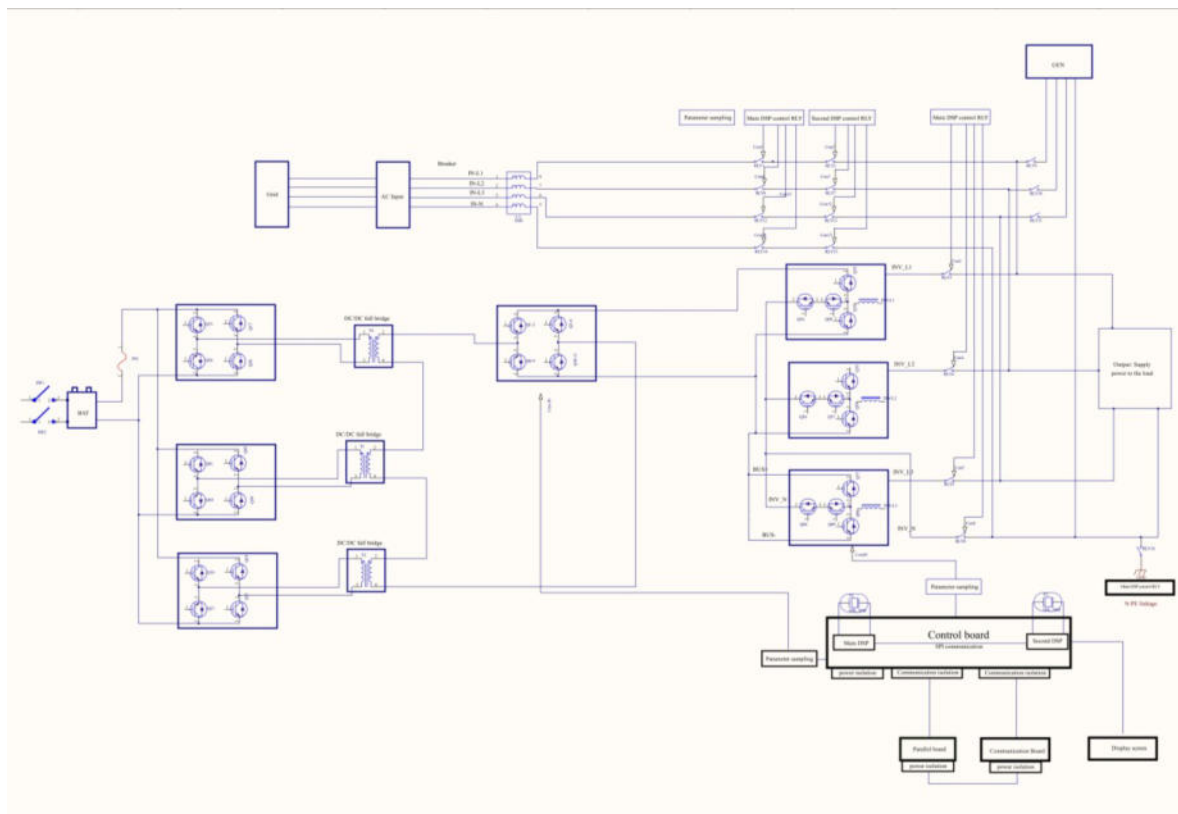
Three Phase AC Coupler: Sowave-TL8, Sowave-TL10, Sowave-TL12 with the same appearance, topology, PCB board and software, the output power and input power are different and controlled by software.

Unless otherwise specified, all the tests were conducted on the model Sowave-TL12 (SN:022326010024).

Hardware Version: V3.0

Software Version: V9.40

Block diagram:



Model list:

Model or Type designation		Sowave-TL8	Sowave-TL10	Sowave-TL12
BAT Side	Battery Type	Lead-acid / Li-ion		
	Battery voltage range [Vd.c.]	40~60		
	Battery voltage range for nominal power [Vd.c.]	48V		
	Max. Charge/Discharge Current [Ad.c.]	180/180	220/220	260/260
On-grid input	Rated Input Voltage [Va.c.]	3L/N/PE 230/400		
	Rated Input Frequency [Hz]	50/60		
	Max. phase current [Aa.c.]	23.2	29	35
	Max apparent power [VA]	16000	20000	24000
	Power Factor cosφ [λ]	0.8 leading to 0.8 lagging		
On-grid/Off-grid output	Rated Output Voltage [Va.c.]	3L/N/PE 230/400		
	Rated Output Frequency [Hz]	50/60		
	Rated Output Power [W]	8000	10000	12000
	Max. Output Power [VA]	8000	10000	12000
	Max. Output Current [Aa.c.]	11.6	14.5	17.4
	Power Factor cosφ [λ]	0.8 leading to 0.8 lagging		
	Overvoltage Category (OVC)	III		
System	Type of inverter	Non-isolated		
	Protective Class	Class I		
	Enclosure Protection (IP)	IP65		
	Operating Temperature Range [°C]	-25~60 (>45 derate)		
	Dimensions W*L*H [mm]	670*440*240		
	Weight [kg]	39		

General remarks:

The uncertainty of the measurement was not given in test report. Please see below information of measurement uncertainty:

- - Voltage

Type A uncertainty: $u(X_i)=0.012$ combined standard uncertainty: $U_c (\%) = 0.29$

Expansion uncertainty: $U (\%) = 0.58$ (factor $k=2$)

- - Current

Type A uncertainty: $u(X_i)=0.011$ combined standard uncertainty: $U_c (\%) = 0.49$

Expansion uncertainty: $U (\%) = 0.98$ (factor $k=2$)

- - Power

Type A uncertainty: $u(X_i)=0.017$ combined standard uncertainty: $U_c (\%) = 0.29$

Expansion uncertainty: $U (\%) = 0.59$ (factor $k=2$)

- - harmonics

Error in Measurement: 0.04%

- - flicker

Error in Measurement: 0.04%

- - current transducer

Expansion uncertainty:

DC current $U_{rel} = 0.7\%$ (factor $k=2$) AC current $U_{rel} = 0.7\%$ (factor $k=2$)

combined standard uncertainty: $U_c (\%) = 0.49$

Test Report

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Test results

Model type: Engineering sample

EN 50549-10:2022		
Clause	Test items	Remark
5.2	Normal operating range	
5.2.1	Frequency operating range	P
5.2.2	Voltage operating range	P
5.3	Immunity to disturbances	
5.3.1	Rate of change of frequency (ROCOF)	P
5.3.2	Phase jump	P
5.3.3	Fault ride through, over-voltage (OVRT) and under-voltage (UVRT)	P
5.4	Active response to frequency deviation	
5.4.3.2	Power response to over-frequencies	P
5.4.3.3	Power response to under-frequencies	P
5.5	Power specification and response to voltage variations	
5.5.1	Power capabilities assessment - voltage support by reactive power	P
5.5.2	Voltage support by reactive power - test to determine the reactive power control modes	
5.5.2.3	Verification procedure for Set point control	P
5.5.2.4	Verification procedure for voltage related control mode for reactive power Q(U)	P
5.6	Voltage related active power reduction - P(U)	
5.6.3	Test procedure for steady-state behaviour	P
5.6.4	Test procedure for dynamic behaviour	P
5.7	EMC and power quality	
5.7.1	EMC	P
5.7.2	Power Quality	

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5.7.2.2	Verification procedure for harmonics, interharmonics and higher frequencies up to 9 kHz	P
5.7.2.3	Verification procedure for flicker and rapid voltage changes	P
5.7.2.3.2	Flicker - Generation units with a rated currents 75 A	P
5.7.2.3.3	Flicker - Generation units with a rated currents >75 A	N/A
5.7.2.3.4	Rapid voltage changes - Generation units with a rated current 75A	P
5.7.2.3.5	Rapid voltage changes - Generation units with a rated current > 75 A	N/A
5.7.2.4	Verification procedure for DC injection	P
5.8	Interface protection	
5.8.3	Verification procedure for generating plants to be connected to a LV distribution network with Interface protection as internal device	
5.8.3.2	Voltage and frequency protections	P
5.8.3.3	Overvoltage 10 min mean protection	P
5.8.3.4	ROCOF protection	P
5.8.4	Verification procedure for generating plants to be connected to a LV distribution network with Interface protection as dedicated device	
5.8.5	Verification procedure for generating plants to be connected to a MV distribution network	
5.8.5.1	Voltage protections	N/A
5.8.5.2	Overvoltage 10 min mean protection	N/A
5.8.5.3	Frequency protections	N/A
5.8.6	Islanding detection	P
5.9	Connection and starting	
5.9.3	Automatic reconnection after tripping	P
5.9.4	Starting to generate electrical power	P
5.9.7	Synchronisation	P
5.10	Active power reduction on set point	
5.10.3.2	Verification of the accuracy	P

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5.10.3.3	Test procedure for dynamic behaviour	P
5.11	Remote information exchange	P
5.12	Requirements regarding single fault tolerance of interface protection system and interface switch	
5.12.2	Single fault tolerance of the interface protection system	P
5.12.3	Single fault tolerance of the interface switch	P

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Clause(s) / subclause(s) of EN 50549-1:2019	Clause(s) / subclause(s) of EN 50549-10:2022	Remark	Verdict
4.4.2 Operating frequency range	5.2.1 Frequency operating range		P
4.4.3 Minimal requirement for active power delivery at underfrequency	5.2.1 Frequency operating range		P
4.4.4 Continuous Operating voltage range	5.2.2 Voltage operating range		P
4.5.2 Rate of change of frequency (ROCOF) immunity	5.3.1 Immunity to disturbances - Rate of change of frequency (ROCOF)		P
4.5.3.2 Generating plant with non-synchronous generating technology	5.3.3 Immunity to disturbances - Fault ride through, over-voltage (OVRT) and under-voltage (UVRT)		P
4.5.3.3 Generating plant with synchronous generating technology	5.3.3 Immunity to disturbances - Fault ride through, over-voltage (OVRT) and under-voltage (UVRT)		N/A
4.5.4 Over-voltage ride through (OVRT)	5.3.3 Immunity to disturbances - Fault ride through, over-voltage (OVRT) and under-voltage (UVRT)		P
4.6.1 Power response to over-frequency	5.4 Active response to frequency deviation		P
4.6.2 Power response to under-frequency	5.4 Active response to frequency deviation		P
4.7.2.2 Voltage support by reactive power, Capabilities	5.5.1 Power capabilities assessment		P
4.7.2.3 Voltage support by reactive power, control modes	5.5.2 Voltage support by reactive power - test to determine the reactive power control modes		P
4.7.2.3.2 Setpoint control modes	5.5.2.3 Verification procedure for Set point control		P
4.7.2.3.3 Voltage related control mode	5.5.2.5 Verification procedure for power related control modes for reactive power		P

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4.7.2.3.4 Power related control mode	5.5.2.5 Verification procedure for power related control modes for reactive power		P
4.7.4.2.2 Zero current mode for converter connected generating technology	5.5.2.5 Verification procedure for power related control modes for reactive power		P
4.9.3 Requirements on voltage and frequency protection	5.8.3 Verification procedure for generating plants to be connected to a LV distribution network with Interface protection as internal device 5.8.4 Verification procedure for generating plants to be connected to a LV distribution network with Interface protection as dedicated device		P
4.9.4.2 4.9.4 Means to detect island situation	5.8.6 Islanding detection		P
4.10.2 Automatic reconnection after tripping	5.9.3 Automatic reconnection after tripping		P
4.10.3 Starting to generate electrical power	5.9.4 Starting to generate electrical power		P
4.11.1 Ceasing active power	5.10 Active power reduction on set point		P
4.11.2 Reduction of active power on set point	5.10 Active power reduction on set point		P
4.12 Remote information exchange	5.11 Remote information exchange		P
4.13 Requirements regarding single fault tolerance of interface protection system and interface switch	5.12 Requirements regarding single fault tolerance of interface protection system and interface switch		P

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Annex 1: List of equipment

No.	Equipment name	Equipment model	Equipment No.	Calibration date	Calibration due date
1.	PV analog source	62150H-1000S	TNRDES001-1	2025/11/20	2026/11/19
2.		62150H-1000S	TNRDES001-2	2025/11/20	2026/11/19
3.		62150H-1000S	TNRDES001-3	2025/11/20	2026/11/19
4.		62150H-1000S	TNRDES001-4	2025/11/20	2026/11/19
5.		62150H-1000S	TNRDES001-5	2025/11/20	2026/11/19
6.		62150H-1000S	TNRDES001-6	2025/11/20	2026/11/19
7.	Grid simulation source	61860	TNRDES002	2025/11/20	2026/11/19
8.	Oscilloscope power meter	DEWE3-A4	TNRDES003	2025/11/23	2026/11/22
9.	Functional analyzer	WT5000	TNRDES004	2025/08/25	2026/08/24
10.	Oscillogram	DL950+701251	TNRDES006	2025/11/20	2026/11/19
11.	Passive voltage probe	702902	TNRDES007-1	2025/11/20	2026/11/19
12.		702902	TNRDES007-2	2025/11/20	2026/11/19
13.	High voltage differential probe	701978	TNRDES008-1	2025/11/20	2026/11/19
14.		701978	TNRDES008-2	2025/11/20	2026/11/19
15.		701978	TNRDES008-3	2025/11/20	2026/11/19
16.	Current probe	701930	TNRDES009-1	2025/11/20	2026/11/19
17.		701930	TNRDES009-2	2025/11/20	2026/11/19
18.		701930	TNRDES009-3	2025/11/20	2026/11/19
19.		701930	TNRDES009-4	2025/11/20	2026/11/19
20.		701930	TNRDES009-5	2025/11/20	2026/11/19
21.		701930	TNRDES009-6	2025/11/20	2026/11/19
22.	Thermometer	COS-04	TNRDES012	2025/11/24	2026/11/23

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Annex 2: Test records

Model type: Engineering sample

5.2.1 5.2.2		Frequency operating range Voltage operating range			P
Setting values		Over-voltage [V]:	253.0		
		Under-voltage [V]:	195.5		
		Over-frequency [Hz]:	51.50		
		Under-frequency [Hz]:	47.50		
- Test 1: U = 230.0 V; f = 47.5 Hz; P = 1.00 S_n; cosφ = 1 - Test 2: U = 230.0 V; f = 48.5 Hz; P = 1.00 S_n; cosφ = 1 - Test 3: U = 230.0 V; f = 51.5 Hz; P = 1.00 S_n; cosφ = 1 - Test 4: U = 230.0 V; f = 47.0 Hz; P = 1.00 S_n; cosφ = 1 - Test 5: U = 230.0 V; f = 52.0 Hz; P = 1.00 S_n; cosφ = 1 - Test 6-1: U = 195.5 V; f = 50.0 Hz; P = 1.00 S_n; cosφ = 1; Test 6-2: U = 230.0 V; f = 50.0 Hz; P = 1.00 S_n; cosφ = 1; Test 6-3: U = 253.0 V; f = 50.0 Hz; P = 1.00 S_n; cosφ = 1; - Test 6-4: U = 230.0 V; f = 50.0 Hz; P = 1.00 S_n; cosφ = 1;					
Test :					
Test sequence	Voltage [V]	Frequency [Hz]	Output power [W]	Cos φ	
1	229.98	47.50	11806.69	0.9974	
2	229.98	48.50	11813.30	0.9976	
3	229.96	51.50	11807.44	0.9974	
4	229.98	47.00	11807.88	0.9969	
5	229.96	52.00	11815.69	0.9974	
6	195.90	50.00	10350.65	0.9973	
	230.05	50.00	11825.70	0.9970	
	253.24	50.00	11864.21	0.9977	
	230.33	50.00	11819.18	0.9970	

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Note:

Operating points test 1, test 2, test 3, test 4, test 5 and test 6 must be kept for at least 30 minutes.

During the tests the interface protection and activating active power response to over/under frequency and voltage shall be disabled.

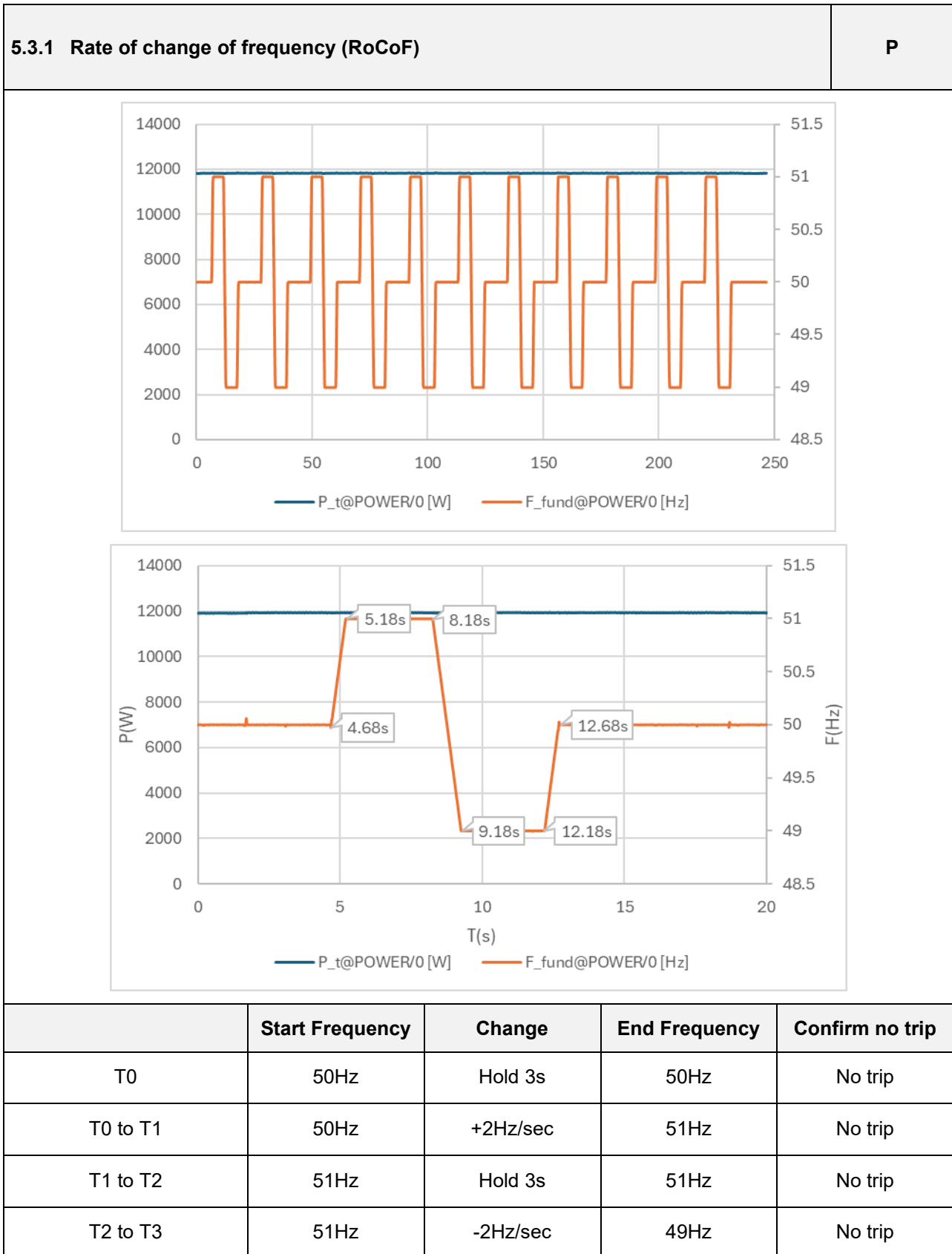
Operation at reduced power is allowed during test 1, equal to the maximum power that can be supplied on reaching the maximum output current limit ($P \geq 0.85 S_n$).

The power supplied by the primary energy source shall be kept stable with a maximum error of 2 % x S_n

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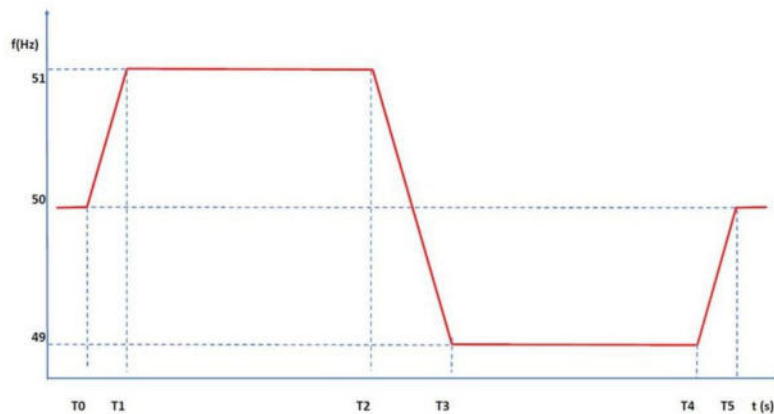
T3 to T4	49Hz	Hold 3s	49Hz	No trip
T4 to T5	49Hz	+2Hz/sec	50Hz	No trip
T5	50Hz	Hold 6s	50Hz	No trip

Note:

The test shall be conducted on a grid simulator able to control the frequency within the required range and with the required dynamic. Initial status of the generating unit before the test shall be as follows:

The generating unit, connected to a grid simulator, shall be operating between 100 % and 80 % of the nominal power with an active factor equal to 1.

Then the test shall be conducted following the sequence represented in the Figure 4 below.



During the Overfrequency and Underfrequency verification, once the higher, respectively, lower values of frequency have been reached, the frequency shall be maintained for a time period equal or longer than 3 s which normally corresponds to the time requested by the system to stabilize during a real event.

During the test, the frequency, RMS voltage, RMS current and active and reactive power measured at the output terminals of the generating unit shall be recorded as 10 cycle average values.

During the tests the interface protection and activating active power response to over/under frequency and voltage shall be disabled.

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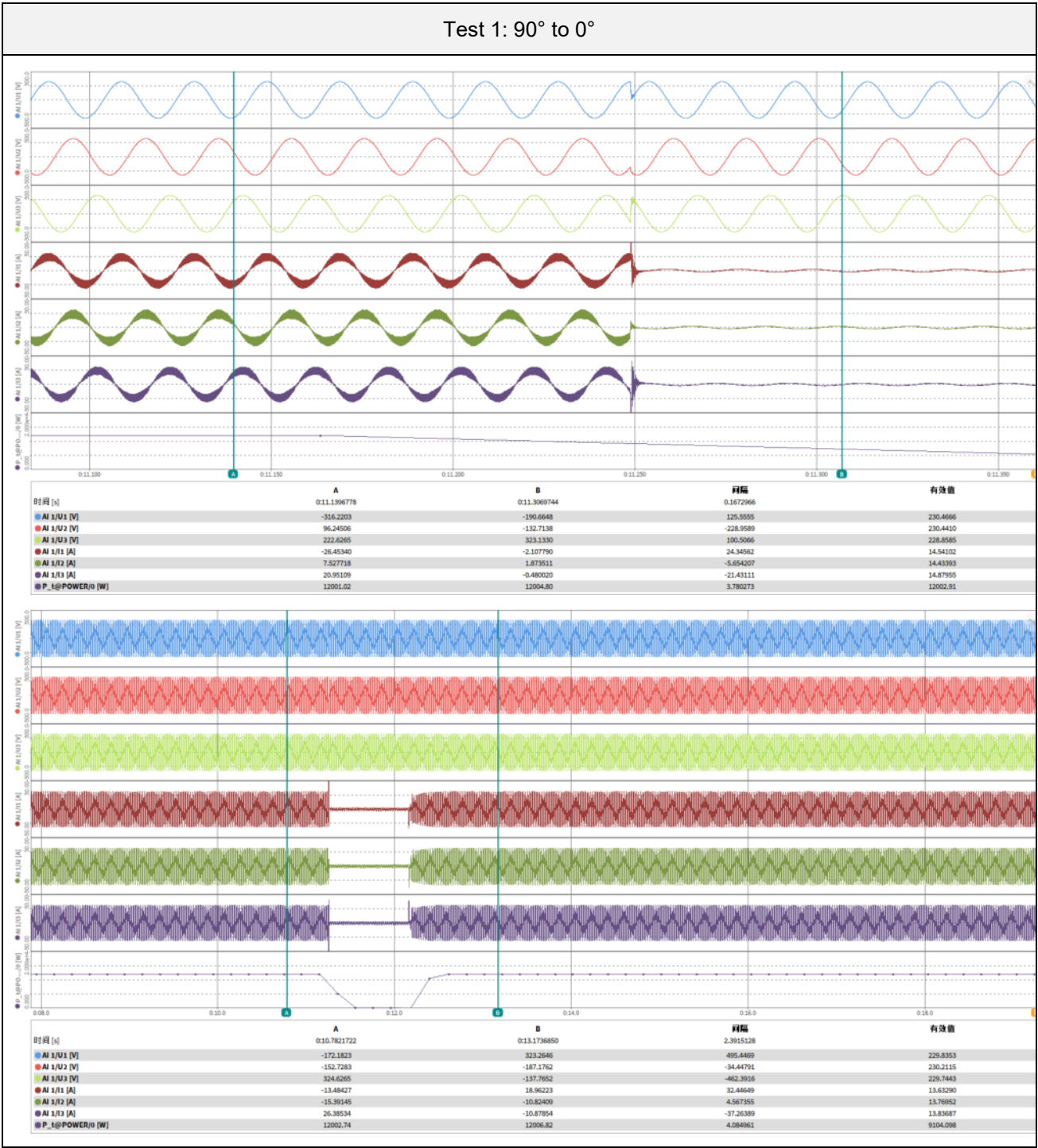
5.3.2 Phase jump			P
Test results			
Test 1:			
P _{EMAX} in %	Phase shift angle		Result an
100% ±5%	90° to 0°	L1-N	Unit shut down, no damage, no hazard.
		L2-N	Unit shut down, no damage, no hazard.
		L3-N	Unit shut down, no damage, no hazard.
		L1+L2+L3	Unit shut down, no damage, no hazard.
Test 2:			
P _{EMAX} in %	Phase shift angle		Result
100% ±5%	0° to 90°	L1-N	Unit shut down, no damage, no hazard.
		L2-N	Unit shut down, no damage, no hazard.
		L3-N	Unit shut down, no damage, no hazard.
		L1+L2+L3	Unit shut down, no damage, no hazard.
Test 3:			
P _{EMAX} in %	Phase shift angle		Result
100% ±5%	180° to 0°	L1-N	Unit shut down, no damage, no hazard.
		L2-N	Unit shut down, no damage, no hazard.
		L3-N	Unit shut down, no damage, no hazard.
		L1+L2+L3	Unit shut down, no damage, no hazard.
Test 4:			
P _{EMAX} in %	Phase shift angle		Result
100% ±5%	0° to 180°	L1-N	Unit shut down, no damage, no hazard.
		L2-N	Unit shut down, no damage, no hazard.
		L3-N	Unit shut down, no damage, no hazard.

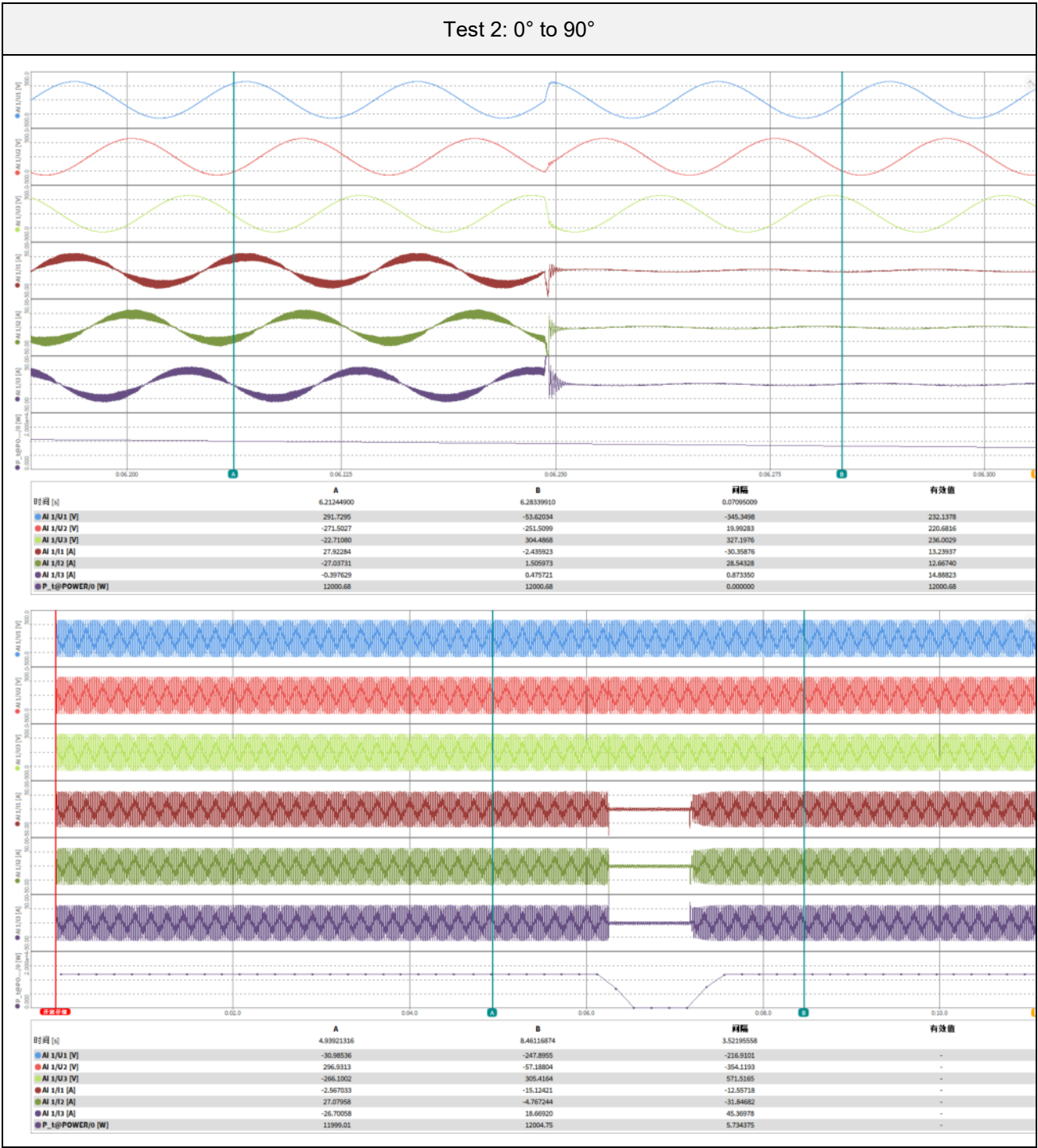
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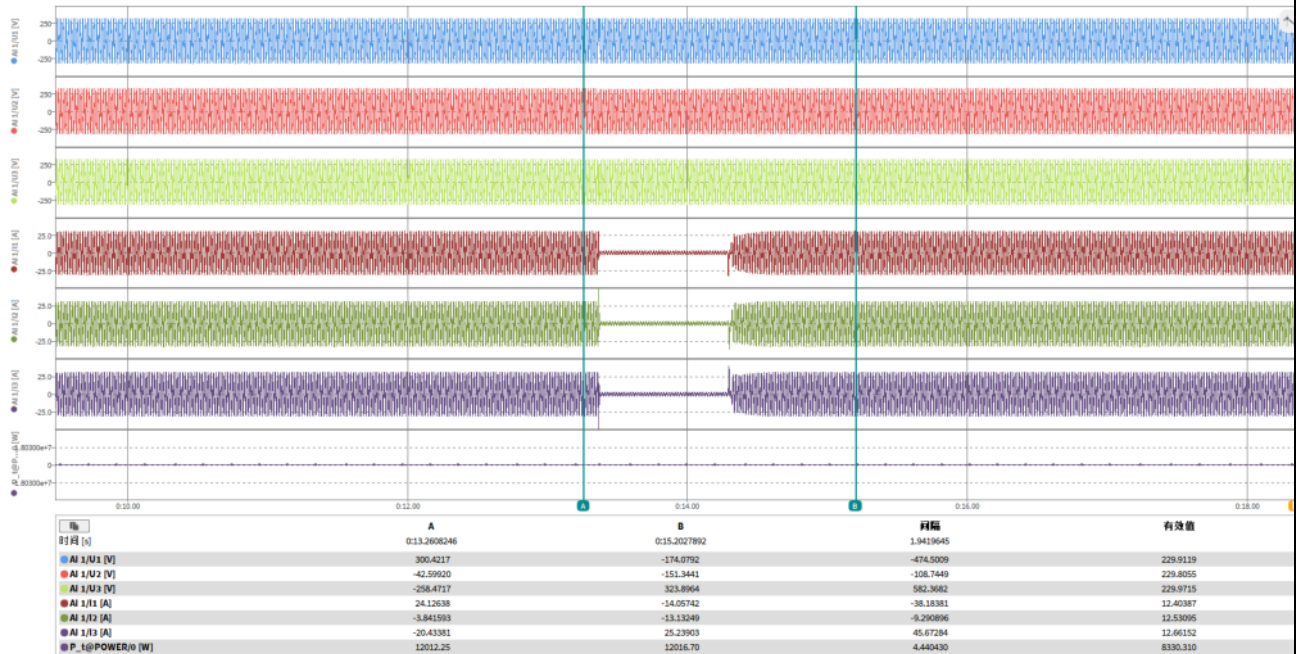
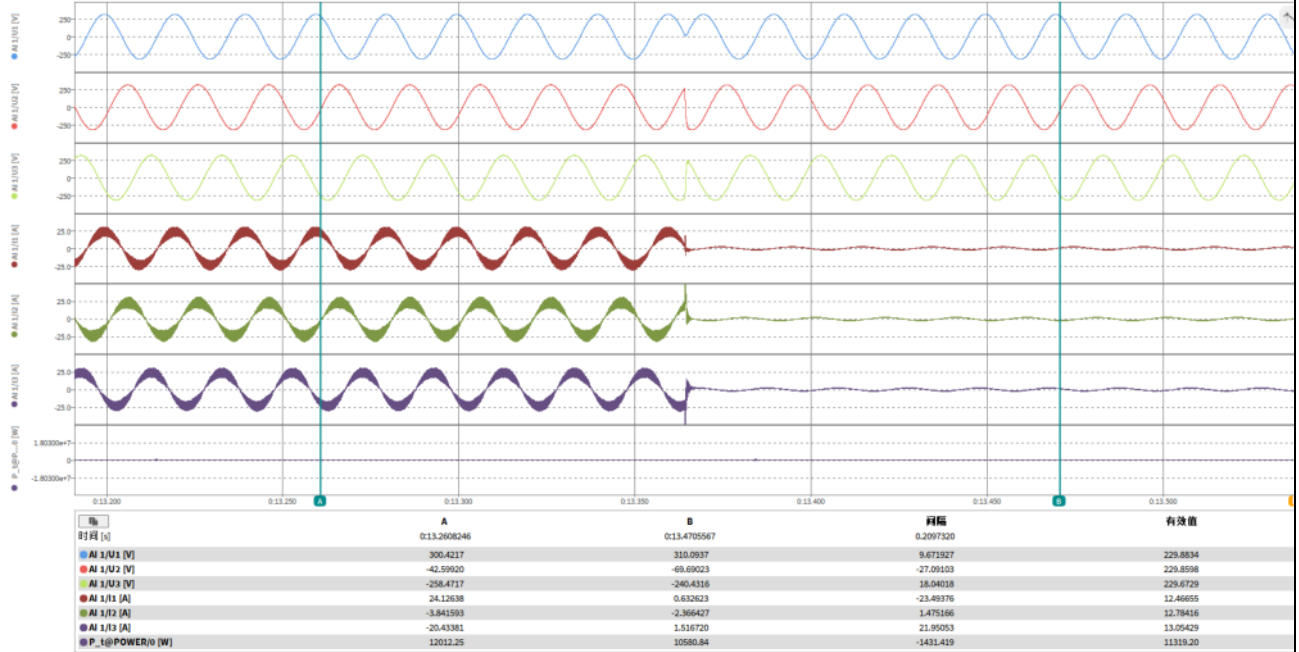
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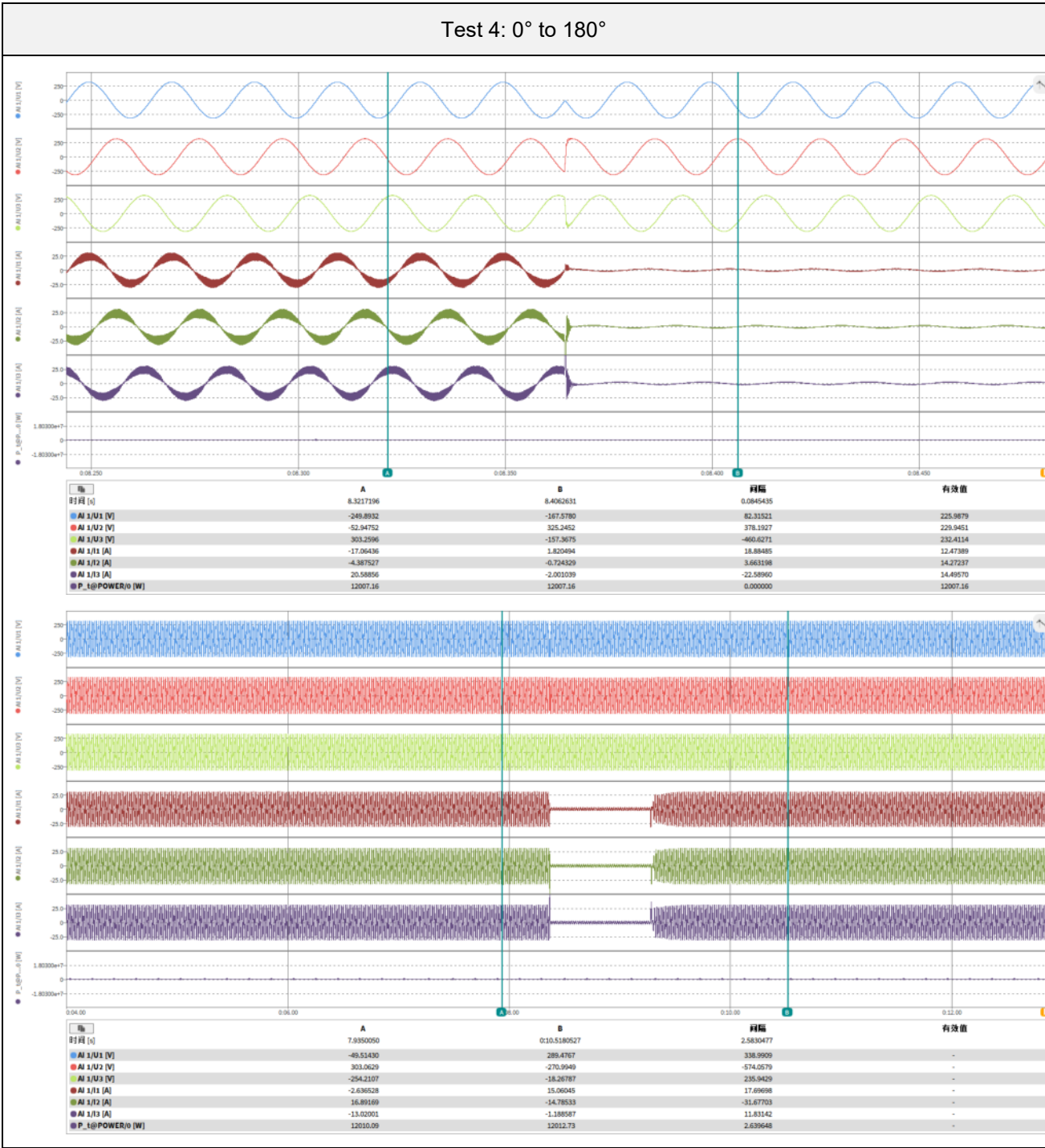
		L1+L2+L3	Unit shut down, no damage, no hazard.
Limit	The generation must be no damage		





Test 3: 180° to 0°





5.3.3 Fault ride through, over-voltage (OVRT) and under-voltage (UVRT)**P****General:**

To define the effect of the generating unit on the voltage magnitude, the short circuit power of the test setup shall be in the range of 2 times to 40 times the nominal power of the generating unit. The X/R ratio of the test impedance shall be at least 3.

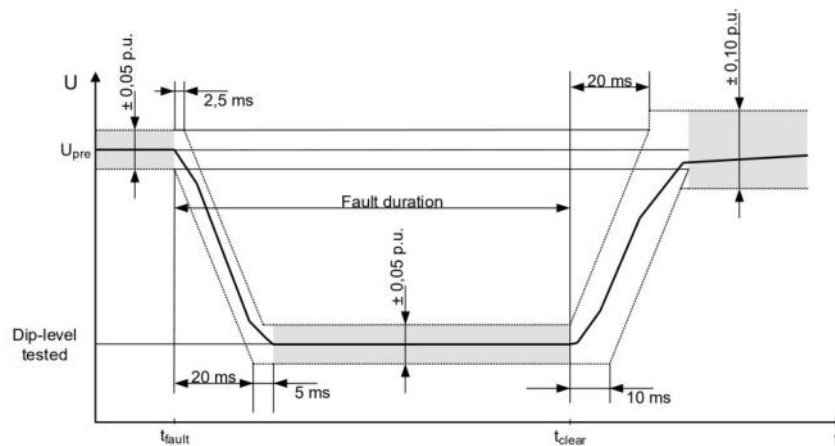


Figure 5 - Tolerances of the positive sequence voltage for the undervoltage event

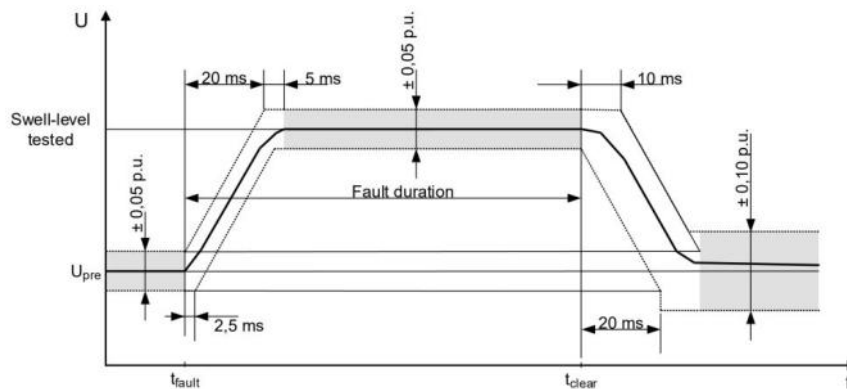


Figure 6 - Tolerances of the positive sequence voltage for the overvoltage event

Each test according to Table 4 and Table 5 in EN 50549-10: 2023 represents one point in the voltage-time diagram to be verified e.g. Figure 6, 7, 8 of EN 50549-1:2019 and EN 50549-2:2019. If the voltage-time diagram includes vertical sections as Figure 7 and 8 of EN 50549-1:2019 and EN 50549-2:2019, the voltage level and duration according to Table 4 and Table 5 shall be chosen in a way that the most severe voltage level at this duration shall be tested. For each vertical section at least one test shall be included. If necessary additional tests shall be added to Table 4 and Table 5.

If the test is intended to provide evidence of controlled short circuit current contribution, at least the voltage levels for undervoltage according to Table 4 and at least the voltage levels for overvoltage according to Table 5 of EN 50549-10: 2023 shall be tested, with each level tested for (at least) a symmetric event and an asymmetric event (simulated two- phase fault).

Table 4 of EN 50549-10: 2023 specifies magnitudes for the undervoltage testing. Voltage levels refer to no-load-tests. U_{min} is the minimum voltage the generating unit can ride through, $UVRC$ is the under voltage range capability calculated as $U_{UVRC} = U_n - U_{min}$

Table 5 of EN 50549-10: 2023 specifies magnitudes for the overvoltage testing. Voltage levels refer to no-load-tests. U_{max} is the maximum voltage the generating unit can ride through, $UOVRC$ is the over voltage range capability calculated as $UOVRC = U_{max} - U_n$

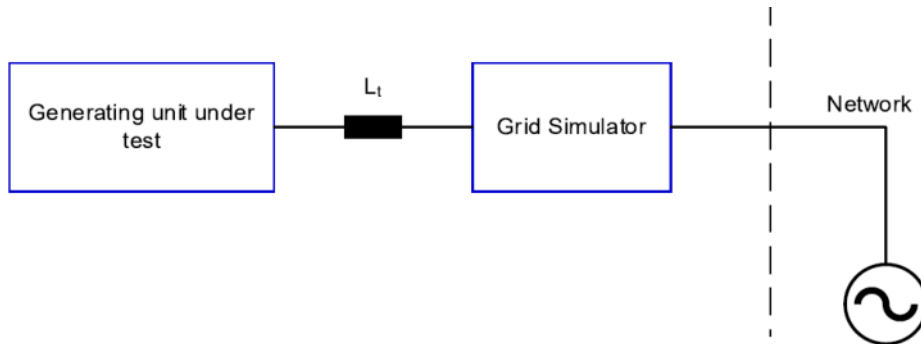


Figure A.3 — Example test setup with AC grid simulator

Regarding phase relationship in the test event:

- 1) Symmetrical three-phase fault (Table 4, tests VD1, 2, 3, 4, 5), see Figure A.4.

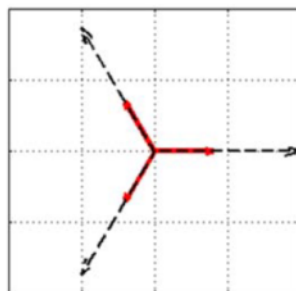


Figure A.4 — Vectorial representation of a symmetrical three-phase fault

- 2) asymmetric two-phase fault (Table 4, Tests VD 6, 7, 8, 9, 10), see Figure A.5.

A fault in the medium voltage or high voltage grid is causing a variation in LV in voltage amplitude as well as phase relationship (the case considered envisages a Dy transformer to connect the generator to the MV line or secondary station).

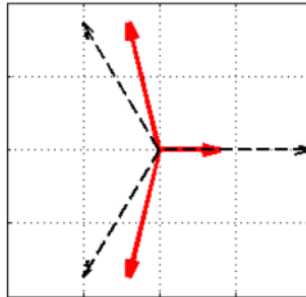


Figure A.5 — Vectorial representation of an asymmetric two-phase fault

During the asymmetric two-phase fault, the residual amplitude of the 3 voltages and phase shifts shall conform to the values given in the following Table A.1 and Table A.2.

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Graph of LVRT test one							
List of tests Voltage dip	to (p.u.)	Limit for fault duration [ms]	Duration fault [ms]	Recover time [ms]	Limit percentage of Injected current after 60ms [p.u. In]	Percentage of Injected current after 60ms [p.u. In]	Result*
Symmetrical Three phase fault - UVRT							
VD1.0 (P = 0)	0.03	≥ 250	281	--	--	--	--
VD1.1 (P = 1)	0.03	≥ 250	280	646	≤0.1 p.u	0.00	P
VD1.2 (P = 0.2)	0.03	≥ 250	280	408	≤0.1 p.u	0.01	P
VD2.0 (P = 0)	0.25	≥950	980	--	--	--	--
VD2.1 (P = 1)	0.25	≥950	979	658	≤0.1 p.u	0.03	P
VD2.2 (P = 0.2)	0.25	≥950	981	376	≤0.1 p.u	0.03	P
VD3.0 (P = 0)	0.52	≥1800	1829	--	--	--	--
VD3.1 (P = 1)	0.52	≥1800	1830	747	≤0.1 p.u	0.06	P
VD3.2 (P = 0.2)	0.52	≥1800	1831	457	≤0.1 p.u	0.06	P
VD4.0 (P = 0)	0.76	≥2700	2731	--	--	--	--
VD4.1 (P = 1)	0.76	≥2700	2730	570	≤0.1 p.u	0.08	P
VD4.2 (P = 0.2)	0.76	≥2700	2730	418	≤0.1 p.u	0.08	P

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VD5.0 (P = 0)	0.90	≥60020	60048	--	--	--	--
VD5.1 (P = 1)	0.90	≥60020	60049	423	--	1.10	P
VD5.2 (P = 0.2)	0.90	≥60020	60049	108	--	0.24	P
Asymmetrical Two phase fault - UVRT							
VD6.0 (P = 0)	0.03	≥ 250	280	--	--	--	--
VD6.1 (P = 1)	0.03	≥ 250	280	706	≤0.1 p.u	0.09	P
VD6.2 (P = 0.2)	0.03	≥ 250	280	398	≤0.1 p.u	0.06	P
VD7.0 (P = 0)	0.22	≥950	997	--	--	--	--
VD7.1 (P = 1)	0.22	≥950	979	658	≤0.1 p.u	0.10	P
VD7.2 (P = 0.2)	0.22	≥950	980	490	≤0.1 p.u	0.09	P
VD8.0 (P = 1)	0.52	≥1800	1829	--	--	--	--
VD8.1 (P = 1)	0.52	≥1800	1830	828	≤0.1 p.u	0.10	P
VD8.2 (P = 0.2)	0.52	≥1800	1830	510	≤0.1 p.u	0.09	P
VD9.0 (P = 1)	0.76	≥2700	2731	--	--	--	--
VD9.1 (P = 1)	0.76	≥2700	2725	839	≤0.1 p.u	0.10	P

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VD9.2 (P = 0.2)	0.76	≥2700	2731	410	≤0.1 p.u	0.10	P
VD10.0 (P = 1)	0.90	≥60020	60052	--	--	--	--
VD10.1 (P = 1)	0.90	≥60020	60050	92	--	1.02	P
VD10.2 (P = 0.2)	0.90	≥60020	60050	50	--	0.22	P
Symmetrical Three phase fault - OVRT							
VS1.0 (P = 0)	1.25	≥ 120	150	--	--	--	P
VS1.1 (P = 1)	1.25	≥ 120	150	973	≤0.1 p.u	0.08	P
VS1.2 (P = 0.2)	1.25	≥ 120	150	913	≤0.1 p.u	0.08	P
VS2.1.0 (P = 0)	1.20	≥ 5020	5049	--	--	--	P
VS2.1.1 (P = 1)	1.20	≥ 5020	5050	882	≤0.1 p.u	0.08	P
VS2.1.2 (P = 0.2)	1.20	≥ 5020	5050	492	≤0.1 p.u	0.08	P
VS2.2.0 (P = 0)	1.15	≥60020	60051	--	--	--	P
VS2.2.1 (P = 1)	1.15	≥60020	60050	32	--	0.94	P
VS2.2.2 (P = 0.2)	1.15	≥60020	60050	154	--	0.19	P
Asymmetrical Two phase fault - OVRT							
VS3.0 (P = 0)	1.25	≥ 120	151	--	--	--	--

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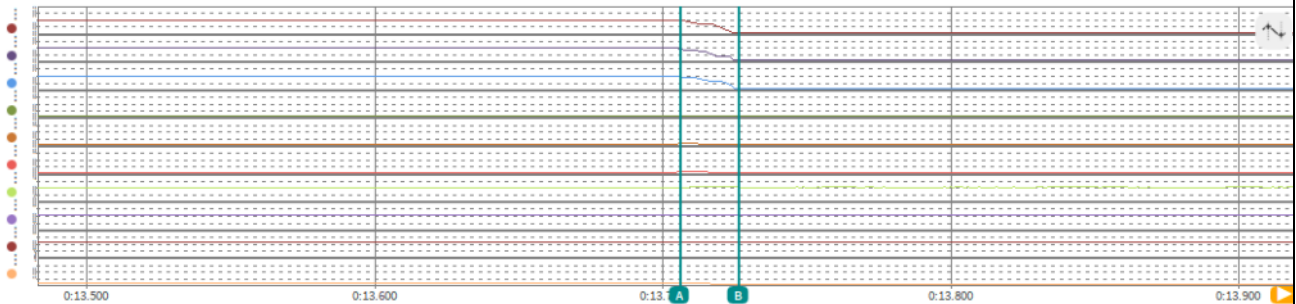
Test Report No.: RDPVP02041/26E/02

VS3.1 (P = 1)	1.25	≥ 120	151	971	≤ 0.1 p.u	0.08	P
VS3.2 (P = 0.2)	1.25	≥ 120	150	819	≤ 0.1 p.u	0.08	P
VS4.1.0 (P = 0)	1.20	≥ 5020	5050	--	--	--	--
VS4.1.1 (P = 1)	1.20	≥ 5020	5050	893	≤ 0.1 p.u	0.08	P
VS4.1.2 (P = 0.2)	1.20	≥ 5020	5050	576	≤ 0.1 p.u	0.07	P
VS4.2.0 (P = 0)	1.15	≥ 60020	60051	--	--	--	--
VS4.2.1 (P = 1)	1.15	≥ 60020	60050	78	--	0.96	P
VS4.2.2 (P = 0.2)	1.15	≥ 60020	60050	164	--	0.22	P

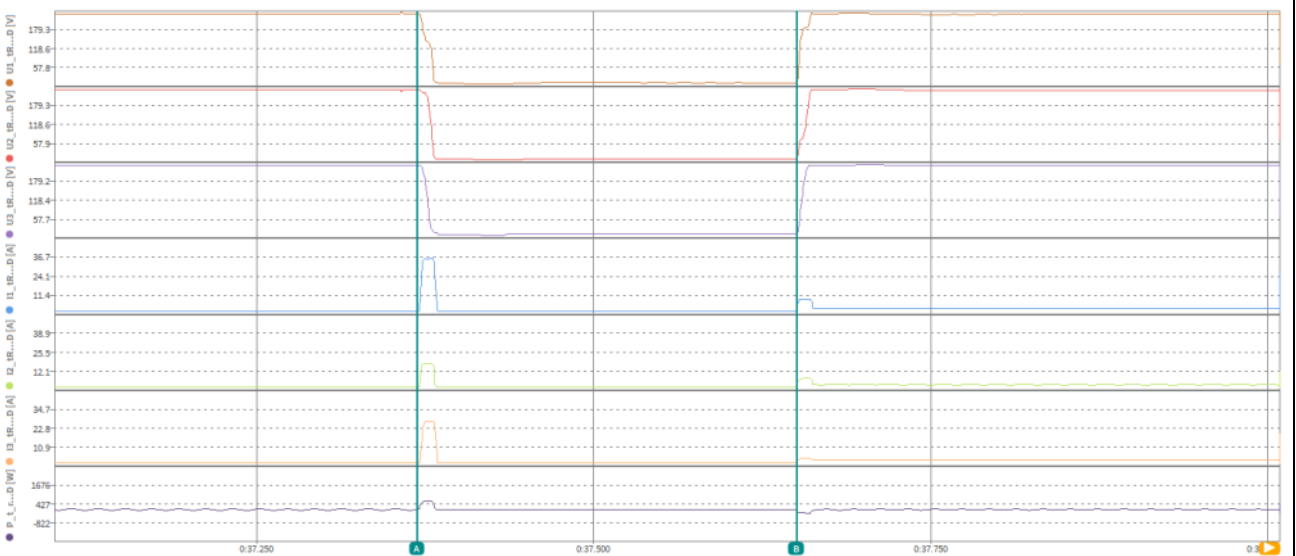
Note: The voltage change requires 20ms, so 30ms after crossing it should be $30 + 20 = 50$ ms; 60ms after crossing, it should be $60 + 20 = 80$ ms.

Test - VD1.0

Duration fault time



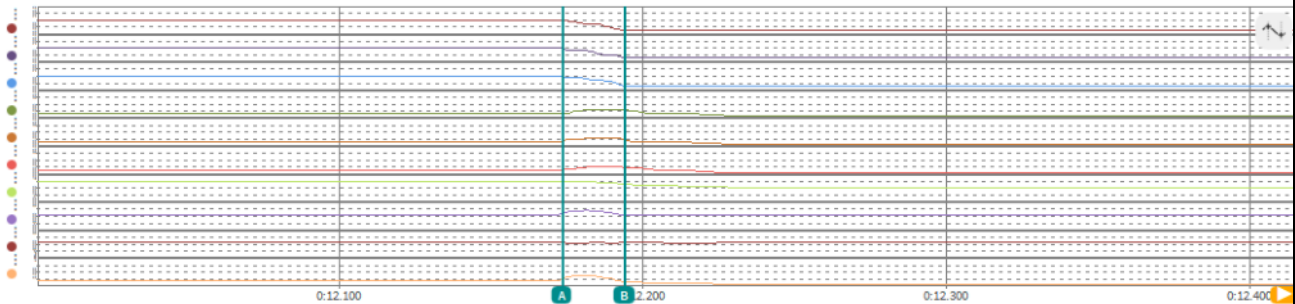
时间 [s]	A	B	间隔
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U1_tRMS_rc@POWER/0 [V]	226.2862	6.895881	-219.3903
U2_tRMS_rc@POWER/0 [V]	230.9086	6.933351	-223.9753
U3_tRMS_rc@POWER/0 [V]	232.4766	6.917217	-225.5594
I1_tRMS_rc@POWER/0 [A]	0.567614	0.039327	-0.528287
I2_tRMS_rc@POWER/0 [A]	0.610427	0.029858	-0.580568
I3_tRMS_rc@POWER/0 [A]	0.624430	0.037907	-0.586523
P_t_rc@POWER/0 [W]	-28.25102	0.015602	28.26662
Q_t_rc@POWER/0 [var]	413.5977	0.740264	-412.8575
Q_fund_rc@POWER/0 [var]	362.2077	0.337839	-361.8698
S_t_rc@POWER/0 [VA]	414.5615	0.740428	-413.8210



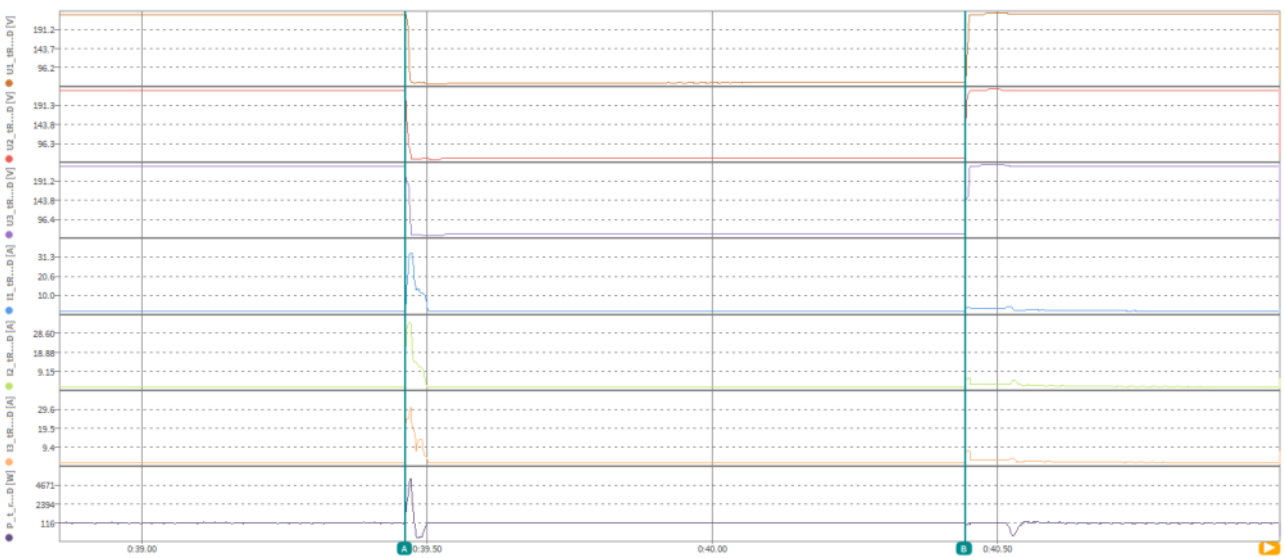
时间 [s]	A	B	间隔
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U1_tRMS_rc@GRID [V]	230.0020	7.714413	-222.2875
U2_tRMS_rc@GRID [V]	229.9985	6.770098	-223.2284
U3_tRMS_rc@GRID [V]	229.9531	8.547270	-221.4058
I1_tRMS_rc@GRID [A]	0.315100	0.049165	-0.265935
I2_tRMS_rc@GRID [A]	0.391049	0.045856	-0.345193
I3_tRMS_rc@GRID [A]	0.281894	0.128994	-0.152900
P_t_rc@GRID [W]	16.02479	0.813204	-15.21158

Test – VD2.0

Duration fault time



时间 [s]	A	B	间隔
	0:12.17364110	0:12.19427988	0.02063879
U1_tRMS_rc@POWER/0 [V]	228.5396	57.79485	-170.7448
U2_tRMS_rc@POWER/0 [V]	230.1143	56.88395	-173.2303
U3_tRMS_rc@POWER/0 [V]	231.5455	57.05937	-174.4861
I1_tRMS_rc@POWER/0 [A]	2.268354	7.317522	5.049168
I2_tRMS_rc@POWER/0 [A]	2.241537	5.715419	3.473882
I3_tRMS_rc@POWER/0 [A]	2.274867	6.390119	4.115252
P_t_rc@POWER/0 [W]	1556.940	972.8262	-584.1143
Q_t_rc@POWER/0 [var]	111.8561	539.9927	428.1365
Q_fund_rc@POWER/0 [var]	48.55275	23.25989	-25.29287
S_t_rc@POWER/0 [VA]	1560.953	1112.647	-448.3064



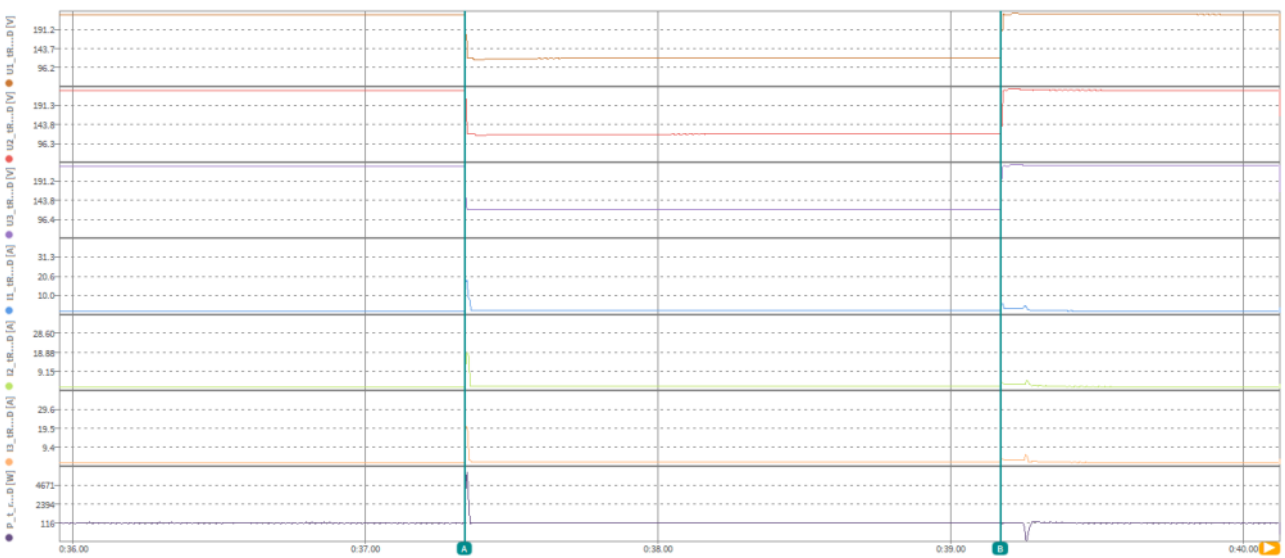
时间 [s]	A	B	间隔
	0:39.462500	0:40.442500	0.980000
U1_tRMS_rc@GRID [V]	229.9948	57.28880	-172.7060
U2_tRMS_rc@GRID [V]	230.1087	57.83066	-172.2780
U3_tRMS_rc@GRID [V]	229.9339	57.67124	-172.2627
I1_tRMS_rc@GRID [A]	0.319922	0.482685	0.162763
I2_tRMS_rc@GRID [A]	0.346484	0.449838	0.103354
I3_tRMS_rc@GRID [A]	0.307481	0.353930	0.046449
P_t_rc@GRID [W]	-44.08289	-7.397586	36.68531

Test – VD3.0

Duration fault time



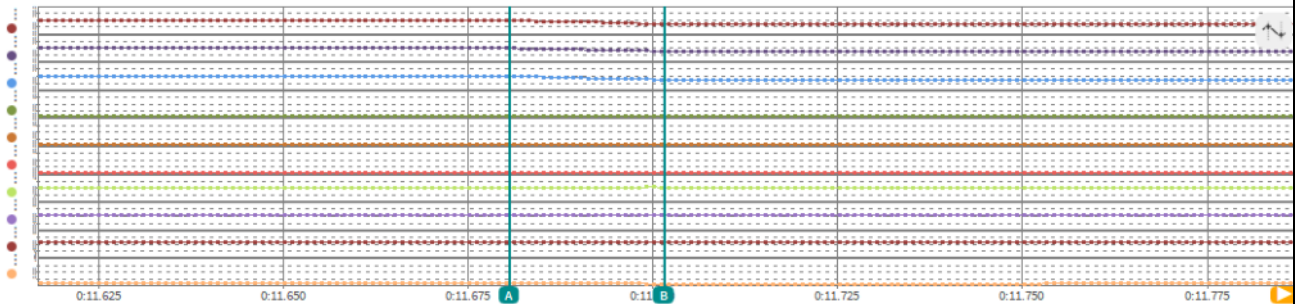
时间 [s]	A	B	间隔
	0:11.72343221	0:11.74410930	0.02067709
U1_tRMS_rc@POWER/0 [V]	228.9634	119.6435	-109.3199
U2_tRMS_rc@POWER/0 [V]	229.7091	119.6431	-110.0660
U3_tRMS_rc@POWER/0 [V]	229.7491	119.6419	-110.1072
I1_tRMS_rc@POWER/0 [A]	0.557631	0.274908	-0.282723
I2_tRMS_rc@POWER/0 [A]	0.601149	0.275692	-0.325457
I3_tRMS_rc@POWER/0 [A]	0.627429	0.272626	-0.354803
P_t_rc@POWER/0 [W]	-24.82222	-0.199187	24.62303
Q_t_rc@POWER/0 [var]	409.1656	98.49290	-310.6727
Q_fund_rc@POWER/0 [var]	361.8470	98.14120	-263.7058
S_t_rc@POWER/0 [VA]	409.9178	98.49311	-311.4247



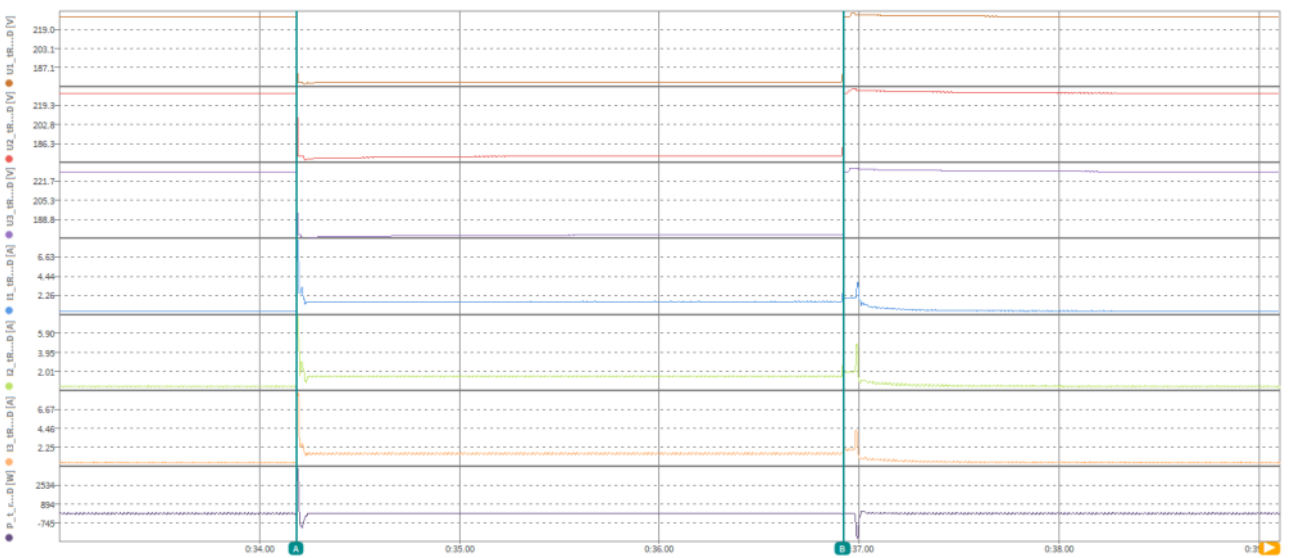
时间 [s]	A	B	间隔
	0:37.343000	0:39.172000	1.829000
U1_tRMS_rc@GRID [V]	229.9887	119.6711	-110.3176
U2_tRMS_rc@GRID [V]	229.9321	119.8943	-110.0378
U3_tRMS_rc@GRID [V]	229.9606	118.9660	-110.9946
I1_tRMS_rc@GRID [A]	0.328168	0.980343	0.652175
I2_tRMS_rc@GRID [A]	0.362977	1.020683	0.657706
I3_tRMS_rc@GRID [A]	0.317306	0.973235	0.655929
P_t_rc@GRID [W]	45.31526	-13.90280	-59.21806

Test – VD4.0

Duration fault time



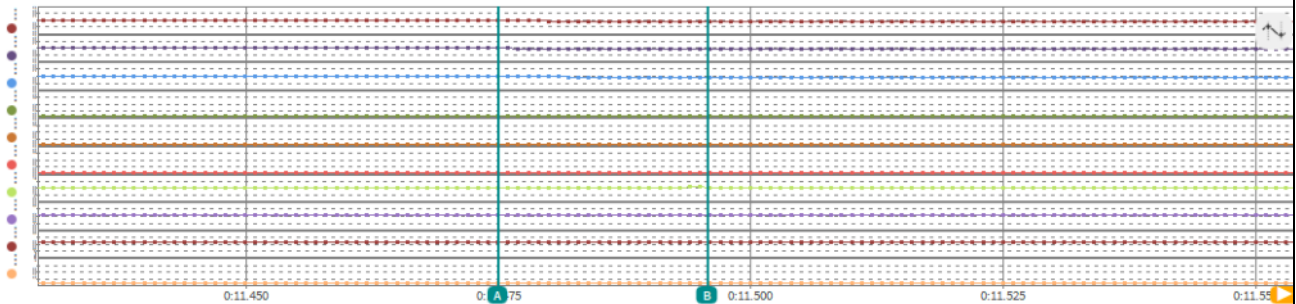
时间 [s]	A	B	间隔
0:11.6807055	0:11.7015908	0.0208853	
U1_tRMS_rc@POWER/0 [V]	229.5044	174.8444	-54.66000
U2_tRMS_rc@POWER/0 [V]	230.2335	174.8607	-55.37280
U3_tRMS_rc@POWER/0 [V]	230.4708	174.8797	-55.59114
I1_tRMS_rc@POWER/0 [A]	0.560627	0.401921	-0.158706
I2_tRMS_rc@POWER/0 [A]	0.562866	0.403997	-0.158869
I3_tRMS_rc@POWER/0 [A]	0.558898	0.398419	-0.160479
P_t_rc@POWER/0 [W]	-41.34744	-0.286821	41.06062
Q_t_rc@POWER/0 [var]	384.8518	210.5919	-174.2599
Q_fund_rc@POWER/0 [var]	365.5916	210.1634	-155.4283
S_t_rc@POWER/0 [VA]	387.0666	210.5921	-176.4744



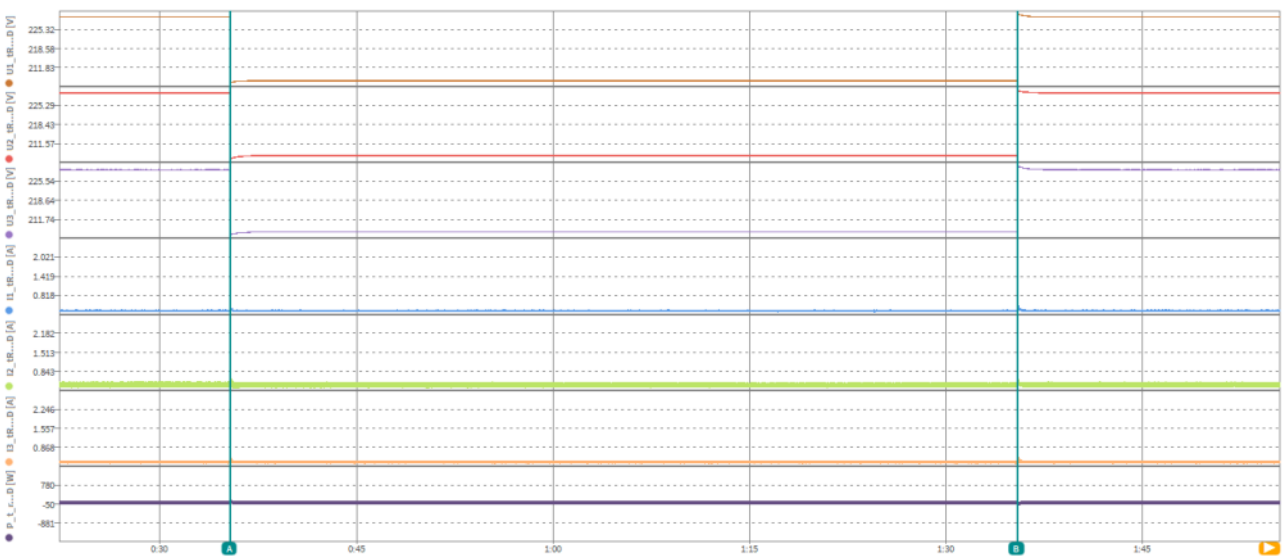
时间 [s]	A	B	间隔
0:34.18890	0:36.91990	2.73100	
U1_tRMS_rc@GRID [V]	230.0036	174.7279	-55.27573
U2_tRMS_rc@GRID [V]	230.0038	174.7936	-55.21021
U3_tRMS_rc@GRID [V]	229.9574	174.6994	-55.25809
I1_tRMS_rc@GRID [A]	0.305598	1.425873	1.120275
I2_tRMS_rc@GRID [A]	0.392530	1.459826	1.067296
I3_tRMS_rc@GRID [A]	0.286727	1.431512	1.164785
P_t_rc@GRID [W]	11.02832	-16.62500	-27.65332

Test – VD5.0

Duration fault time



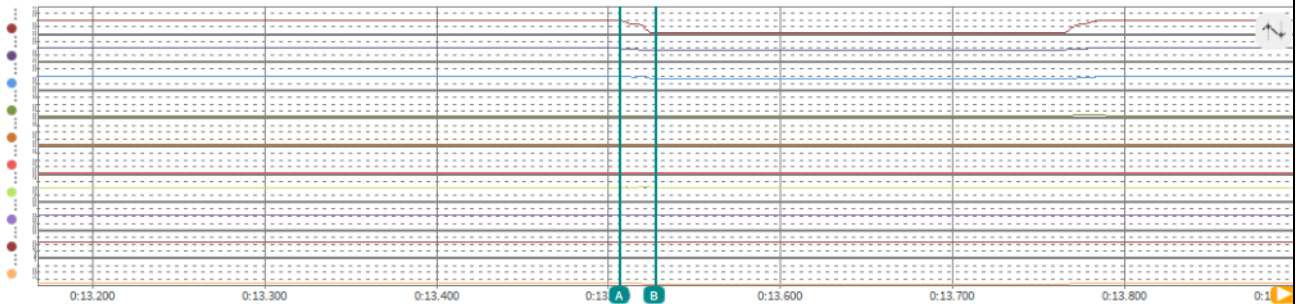
时间 [s]	A	B	间隔
0:11.4750069	0:11.4957265	0:0207196	
U1_tRMS_rc@POWER/0 [V]	230.0581	207.0423	-23.01581
U2_tRMS_rc@POWER/0 [V]	230.0446	207.1410	-22.90355
U3_tRMS_rc@POWER/0 [V]	230.0345	207.1472	-22.88725
I1_tRMS_rc@POWER/0 [A]	0.561644	0.478009	-0.083635
I2_tRMS_rc@POWER/0 [A]	0.563031	0.477549	-0.085482
I3_tRMS_rc@POWER/0 [A]	0.557687	0.472640	-0.085046
P_t_rc@POWER/0 [W]	-41.29710	0.647609	41.94470
Q_t_rc@POWER/0 [var]	384.8104	295.7935	-89.01694
Q_fund_rc@POWER/0 [var]	365.4993	295.1156	-70.38376
S_t_rc@POWER/0 [VA]	387.0200	295.7942	-91.22583



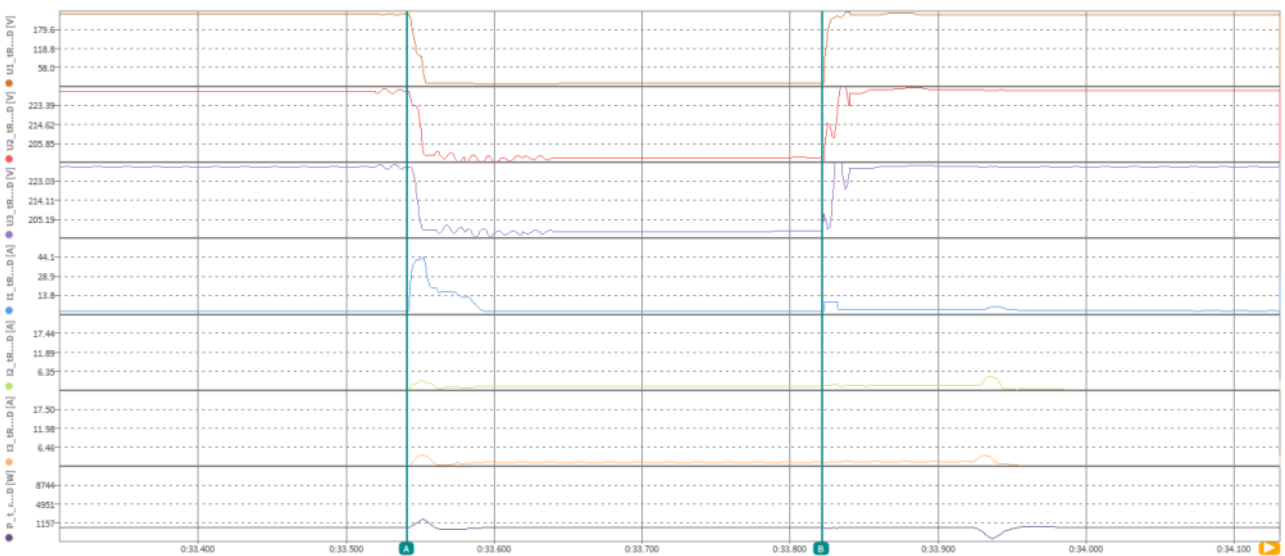
时间 [s]	A	B	间隔
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U1_tRMS_rc@GRID [V]	229.9226	207.0082	-22.91440
U2_tRMS_rc@GRID [V]	230.0092	207.0552	-22.95401
U3_tRMS_rc@GRID [V]	229.9042	206.9570	-22.94717
I1_tRMS_rc@GRID [A]	0.304893	0.310664	5.771e-3
I2_tRMS_rc@GRID [A]	0.332421	0.370700	0.038279
I3_tRMS_rc@GRID [A]	0.328336	0.273711	-0.054625
P_t_rc@GRID [W]	-5.585989	-6.922754	-1.336765

Test – VD6.0

Duration fault time



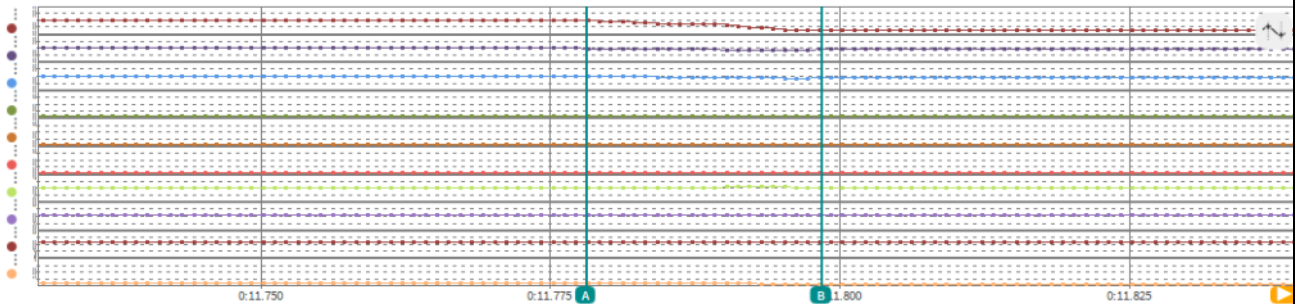
时间 [s]	A	B	间隔
	0:13.5068316	0:13.5272155	0.0203839
U1_tRMS_rc@POWER/0 [V]	226.5722	6.924709	-219.6475
U2_tRMS_rc@POWER/0 [V]	230.3677	199.2205	-31.14714
U3_tRMS_rc@POWER/0 [V]	233.2336	199.2921	-33.94145
I1_tRMS_rc@POWER/0 [A]	0.569138	0.037072	-0.532066
I2_tRMS_rc@POWER/0 [A]	0.560568	0.463969	-0.096599
I3_tRMS_rc@POWER/0 [A]	0.549958	0.456426	-0.093531
P_t_rc@POWER/0 [W]	-39.38673	-1.347572	38.03916
Q_t_rc@POWER/0 [var]	384.3433	183.6461	-200.6972
Q_fund_rc@POWER/0 [var]	365.3915	183.3029	-182.0886
S_t_rc@POWER/0 [VA]	386.3561	183.6510	-202.7051



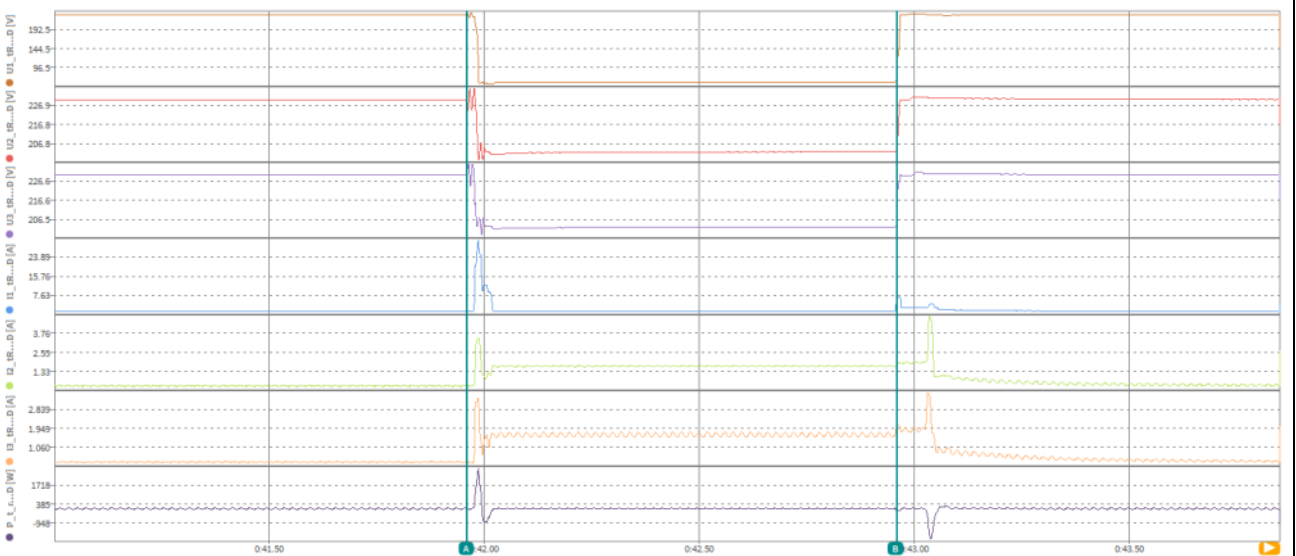
时间 [s]	A	B	间隔
	0:33.541500	0:33.821500	0.280000
U1_tRMS_rc@GRID [V]	229.9218	5.345570	-224.5762
U2_tRMS_rc@GRID [V]	229.9927	199.0540	-30.93867
U3_tRMS_rc@GRID [V]	229.9037	199.2000	-30.70363
I1_tRMS_rc@GRID [A]	0.308862	0.080028	-0.228834
I2_tRMS_rc@GRID [A]	0.321588	1.645182	1.323594
I3_tRMS_rc@GRID [A]	0.344311	1.672520	1.328208
P_t_rc@GRID [W]	-10.54606	-17.49685	-6.950795

Test – VD7.0

Duration fault time



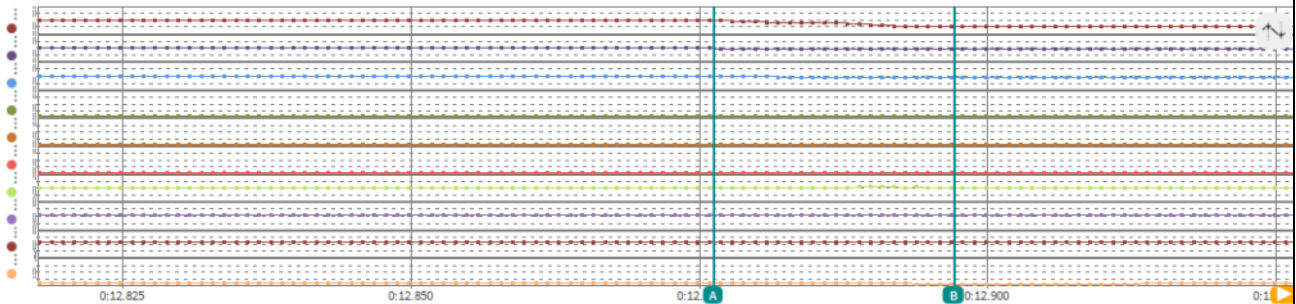
	A	B	间隔
时间 [s]	0:11.7781076	0:11.7984328	0.0203251
U1_tRMS_rc@POWER/0 [V]	228.9555	57.51954	-171.4360
U2_tRMS_rc@POWER/0 [V]	230.4436	202.4340	-28.00963
U3_tRMS_rc@POWER/0 [V]	230.8361	202.4535	-28.38260
I1_tRMS_rc@POWER/0 [A]	0.552330	0.135345	-0.416985
I2_tRMS_rc@POWER/0 [A]	0.563965	0.467644	-0.096321
I3_tRMS_rc@POWER/0 [A]	0.559038	0.459801	-0.099237
P_t_rc@POWER/0 [W]	-44.06453	-0.642221	43.42231
Q_t_rc@POWER/0 [var]	382.9403	195.5393	-187.4010
Q_fund_rc@POWER/0 [var]	357.5599	195.2088	-162.3511
S_t_rc@POWER/0 [VA]	385.4672	195.5404	-189.9268



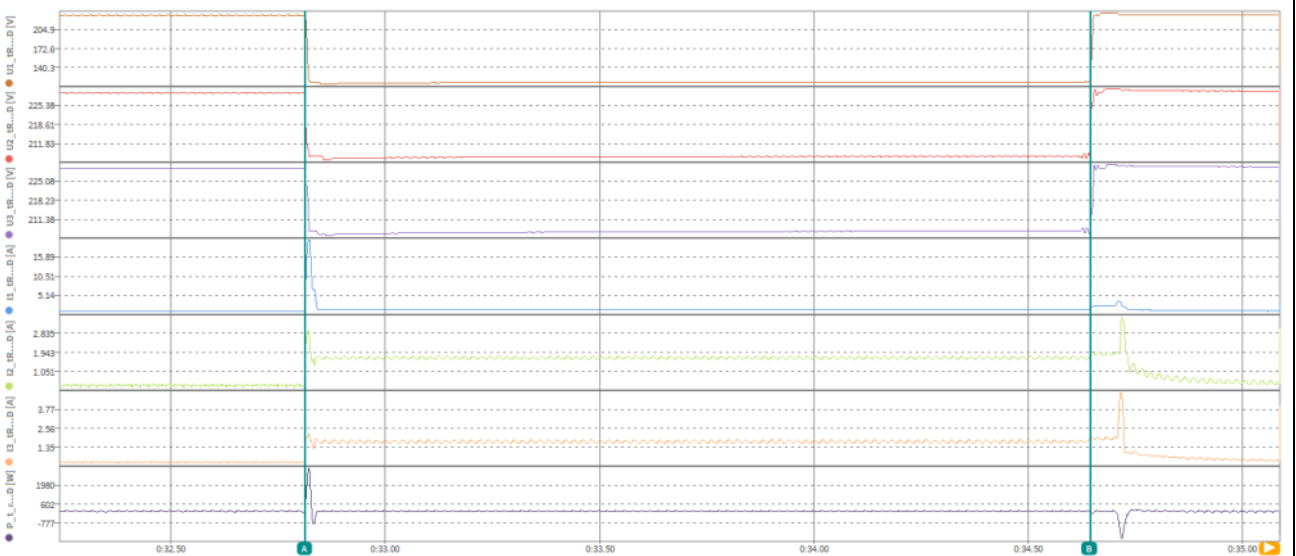
时间 [s]	A	B	间隔
0:41.961000	0:42.958000	0.997000	
U1_tRMS_rc@GRID [V]	229.9379	57.82775	-172.1102
U2_tRMS_rc@GRID [V]	229.9145	202.0946	-27.81982
U3_tRMS_rc@GRID [V]	229.9235	202.1856	-27.73787
I1_tRMS_rc@GRID [A]	0.294776	0.429204	0.134427
I2_tRMS_rc@GRID [A]	0.372642	1.575881	1.203239
I3_tRMS_rc@GRID [A]	0.303871	1.659641	1.355770
P_t_rc@GRID [W]	47.83159	29.75821	-18.07339

Test – VD8.0

Duration fault time



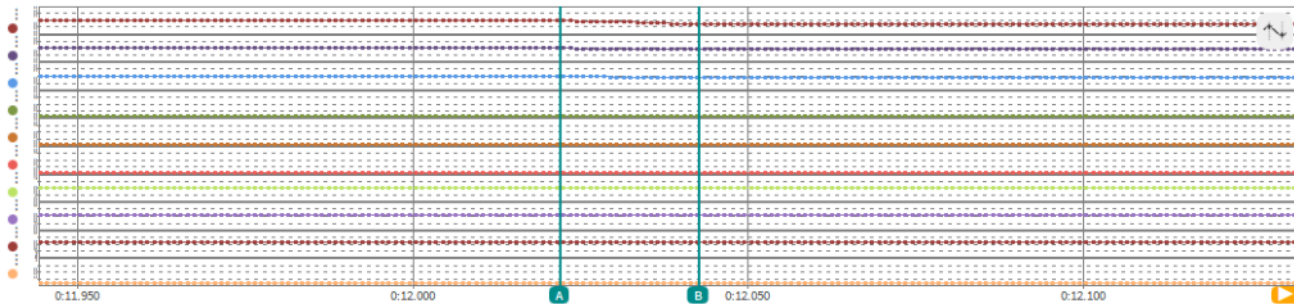
时间 [s]	A	B	间隔
0:12.8762593	0:12.8970857	0.0208264	
U1_tRMS_rc@POWER/0 [V]	230.3397	115.0301	-115.3096
U2_tRMS_rc@POWER/0 [V]	228.7577	207.0607	-21.69691
U3_tRMS_rc@POWER/0 [V]	230.7948	207.0471	-23.74770
I1_tRMS_rc@POWER/0 [A]	0.540337	0.265216	-0.275121
I2_tRMS_rc@POWER/0 [A]	0.561022	0.478853	-0.082169
I3_tRMS_rc@POWER/0 [A]	0.552927	0.469325	-0.083602
P_t_rc@POWER/0 [W]	-39.38647	-0.726784	38.65968
Q_t_rc@POWER/0 [var]	378.3674	226.8308	-151.5367
Q_fund_rc@POWER/0 [var]	357.3240	226.5193	-130.8047
S_t_rc@POWER/0 [VA]	380.4119	226.8320	-153.5799



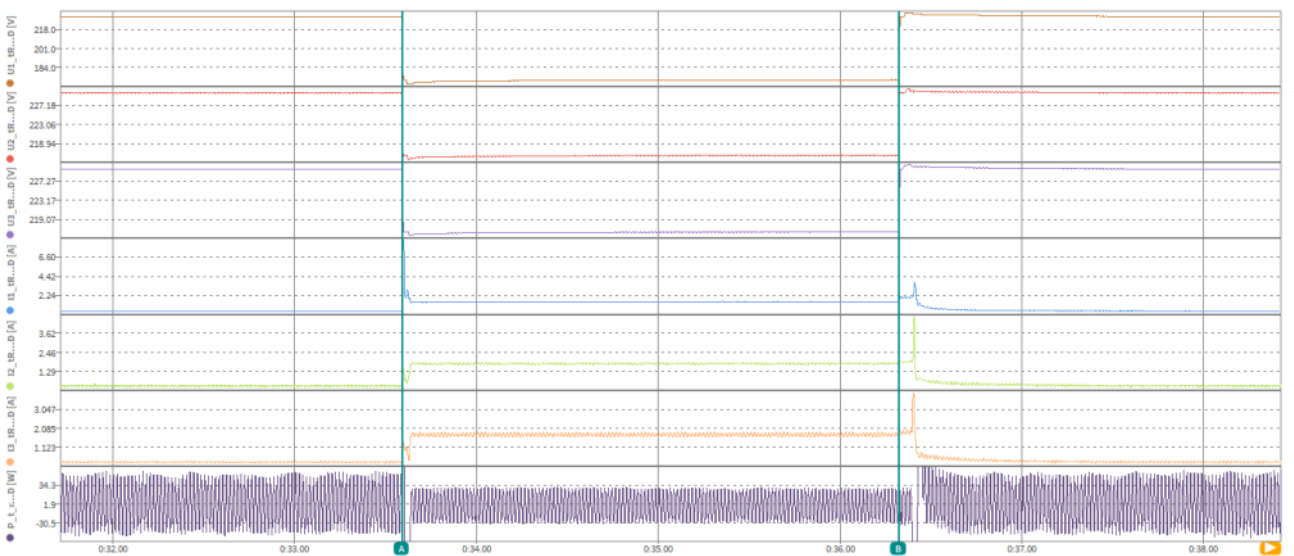
时间 [s]	A	B	间隔
0:32.81430	0:34.64330	1.82900	
U1_tRMS_rc@GRID [V]	229.9787	114.8966	-115.0821
U2_tRMS_rc@GRID [V]	230.0612	207.7316	-22.32964
U3_tRMS_rc@GRID [V]	229.9343	205.9106	-24.02373
I1_tRMS_rc@GRID [A]	0.324613	0.889267	0.564655
I2_tRMS_rc@GRID [A]	0.371895	1.669034	1.297139
I3_tRMS_rc@GRID [A]	0.290153	1.762134	1.471381
P_t_rc@GRID [W]	-27.68762	21.35969	49.04731

Test – VD9.0

Duration fault time



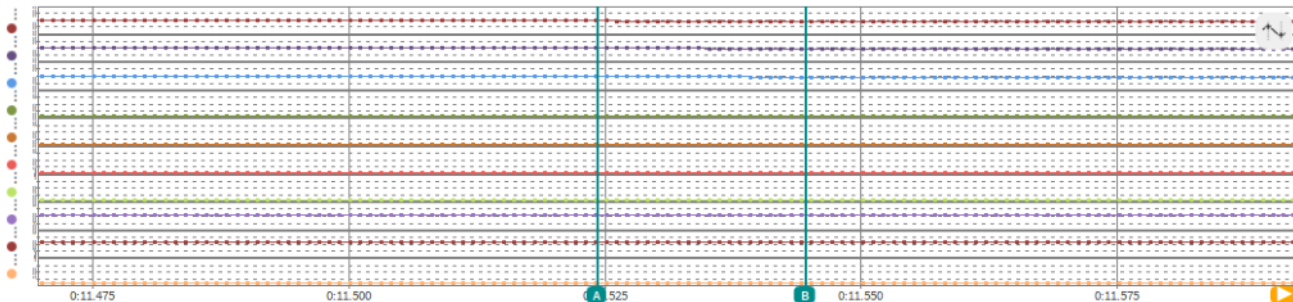
时间 [s]	A	B	间隔
0:12.0219529	0:12.0426360	0:0206831	
U1_tRMS_rc@POWER/0 [V]	229.5217	172.9839	-56.53781
U2_tRMS_rc@POWER/0 [V]	230.3309	215.8297	-14.50116
U3_tRMS_rc@POWER/0 [V]	230.3792	215.9251	-14.45409
I1_tRMS_rc@POWER/0 [A]	0.564258	0.399917	-0.164341
I2_tRMS_rc@POWER/0 [A]	0.568266	0.501079	-0.067186
I3_tRMS_rc@POWER/0 [A]	0.562423	0.521873	-0.040549
P_t_rc@POWER/0 [W]	-44.77693	-11.54995	33.22698
Q_t_rc@POWER/0 [var]	387.3900	289.7824	-97.60751
Q_fund_rc@POWER/0 [var]	364.4153	283.5869	-80.82849
S_t_rc@POWER/0 [VA]	389.9691	290.0125	-99.95660



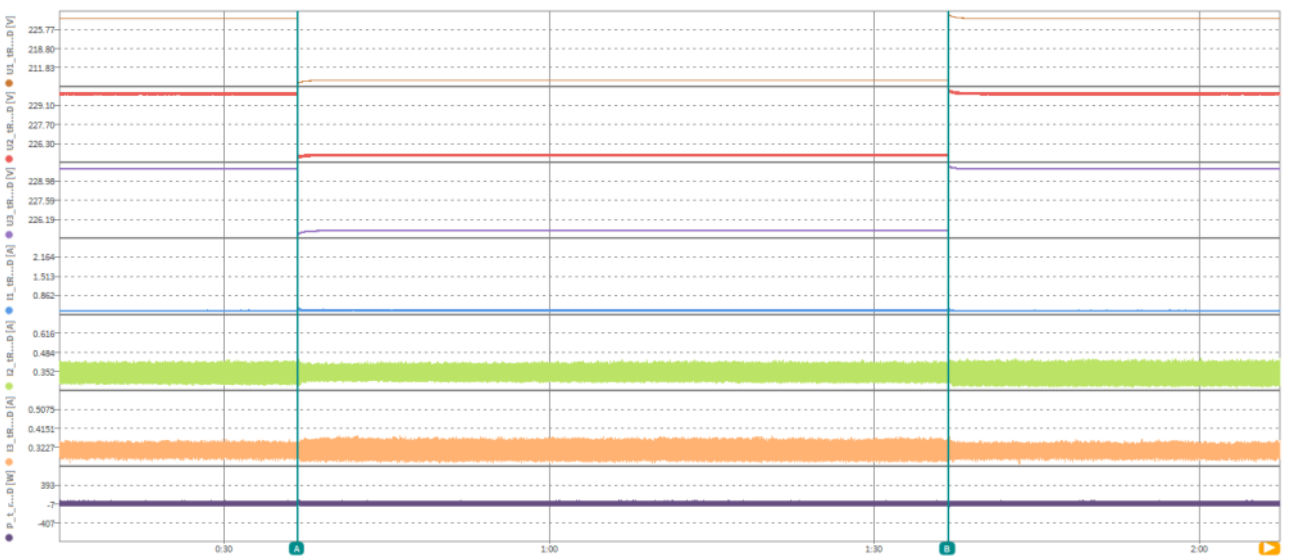
时间 [s]	A	B	间隔
0:33.59190	0:36.32290	2.73100	
U1_tRMS_rc@GRID [V]	229.9643	172.4529	-57.51144
U2_tRMS_rc@GRID [V]	229.9128	216.2646	-13.64822
U3_tRMS_rc@GRID [V]	229.9429	216.1145	-13.82848
I1_tRMS_rc@GRID [A]	0.295408	1.416204	1.120797
I2_tRMS_rc@GRID [A]	0.362301	1.727735	1.365434
I3_tRMS_rc@GRID [A]	0.305073	1.636490	1.331417
P_t_rc@GRID [W]	53.74807	-28.65678	-82.40485

Test – VD10.0

Duration fault time



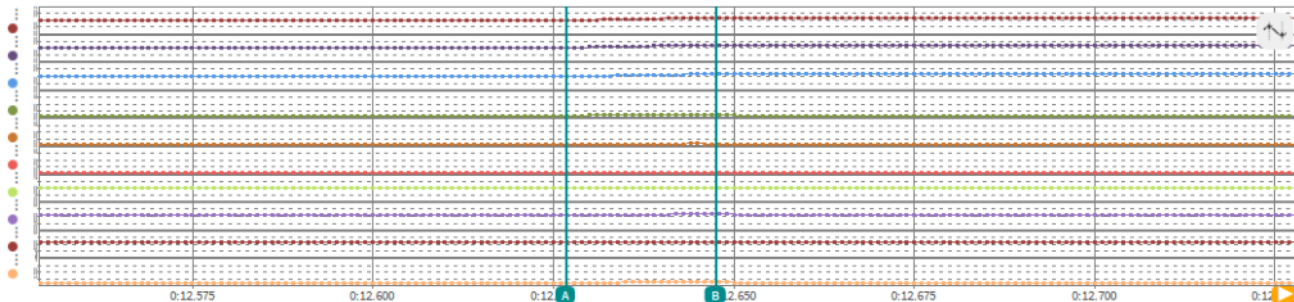
时间 [s]	A	B	间隔
0:11.5242741	0:11.5445679	0.0202938	
U1_tRMS_rc@POWER/0 [V]	229.3812	207.0581	-22.32312
U2_tRMS_rc@POWER/0 [V]	229.4201	225.4999	-3.920227
U3_tRMS_rc@POWER/0 [V]	230.8007	225.4480	-5.352753
I1_tRMS_rc@POWER/0 [A]	0.552403	0.475952	-0.076451
I2_tRMS_rc@POWER/0 [A]	0.562922	0.562515	-4.071e-4
I3_tRMS_rc@POWER/0 [A]	0.555824	0.553539	-2.285e-3
P_t_rc@POWER/0 [W]	-39.24123	-31.03012	8.211105
Q_t_rc@POWER/0 [var]	382.1316	348.8136	-33.31802
Q_fund_rc@POWER/0 [var]	362.1919	332.7230	-29.46890
S_t_rc@POWER/0 [VA]	384.1411	350.1910	-33.95010



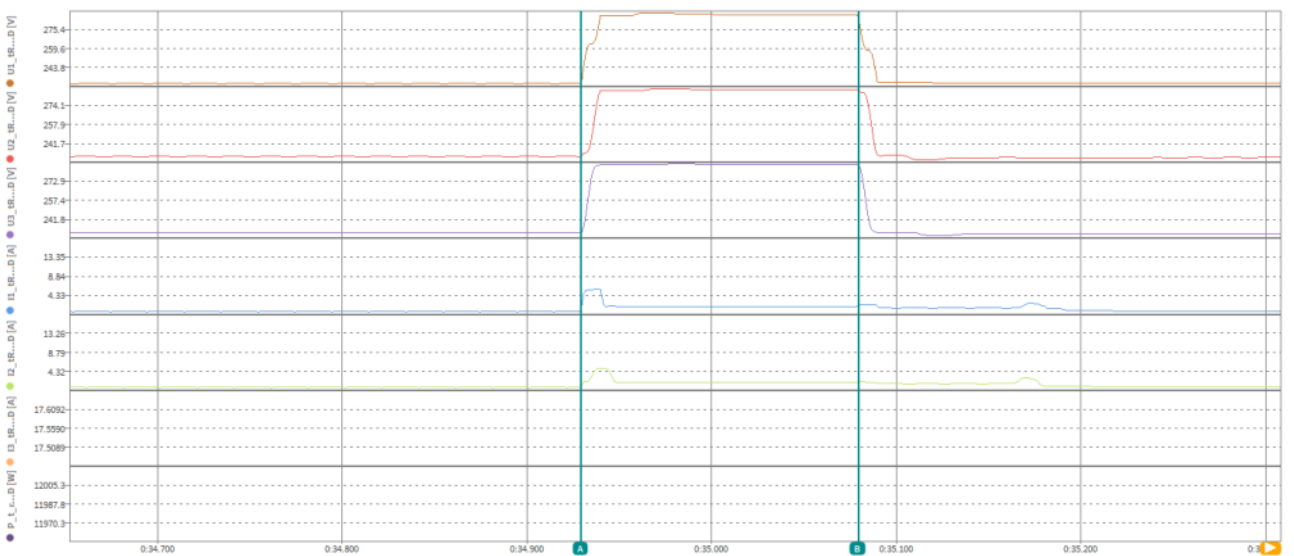
时间 [s]	A	B	间隔
0:36.75120	1:36.80320	1:00.05200	
U1_tRMS_rc@GRID [V]	229.9518	206.9454	-23.00641
U2_tRMS_rc@GRID [V]	230.0797	225.3134	-4.766251
U3_tRMS_rc@GRID [V]	229.8962	225.3235	-4.572647
I1_tRMS_rc@GRID [A]	0.314455	0.316079	1.624e-3
I2_tRMS_rc@GRID [A]	0.319769	0.381787	0.062018
I3_tRMS_rc@GRID [A]	0.297481	0.316276	0.018795
P_t_rc@GRID [W]	-50.10759	47.94373	98.05132

Test – VS1.0

Duration fault time



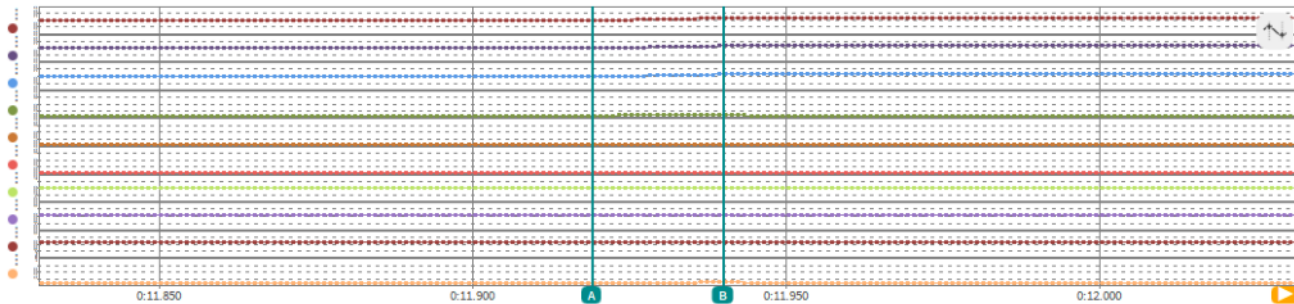
时间 [s]	A	B	间隔
0:12.6268161	0:12.6475763	0.0207602	
U1_tRMS_rc@POWER/0 [V]	230.0785	287.6231	57.54463
U2_tRMS_rc@POWER/0 [V]	230.5999	287.6219	57.02206
U3_tRMS_rc@POWER/0 [V]	230.6756	287.6168	56.94119
I1_tRMS_rc@POWER/0 [A]	0.564031	1.524029	0.959997
I2_tRMS_rc@POWER/0 [A]	0.589661	0.698967	0.109306
I3_tRMS_rc@POWER/0 [A]	0.564429	0.680318	0.115889
P_t_rc@POWER/0 [W]	-51.67662	-199.7696	-148.0930
Q_t_rc@POWER/0 [var]	392.5605	810.8075	418.2469
Q_fund_rc@POWER/0 [var]	366.3620	618.0612	251.6992
S_t_rc@POWER/0 [VA]	395.9473	835.0549	439.1076



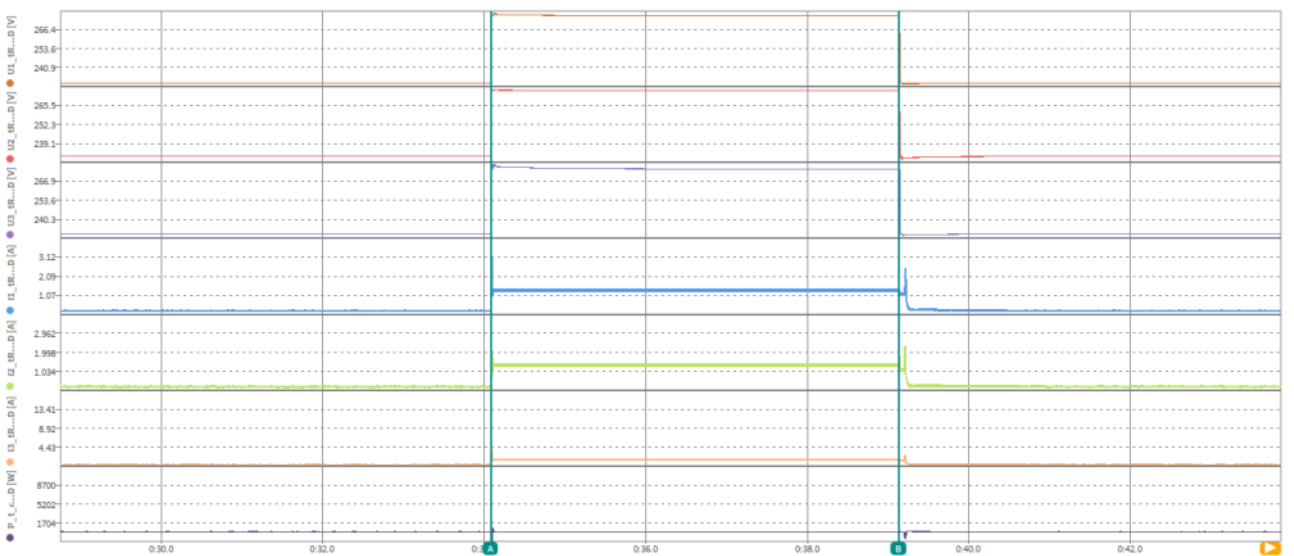
时间 [s]	A	B	间隔
0:34.9295000	0:35.0795000	0.1500000	
U1_tRMS_rc@GRID [V]	229.9770	288.2049	58.22787
U2_tRMS_rc@GRID [V]	229.9354	287.9740	58.03853
U3_tRMS_rc@GRID [V]	229.9498	287.1647	57.21489
I1_tRMS_rc@GRID [A]	0.204817	1.319356	1.114539
I2_tRMS_rc@GRID [A]	0.215204	1.449622	1.234418
I3_tRMS_rc@GRID [A]	0.140913	1.398122	1.257208
P_t_rc@GRID [W]	14.40635	-14.95668	-29.36303

Test – VS2.1.0

Duration fault time



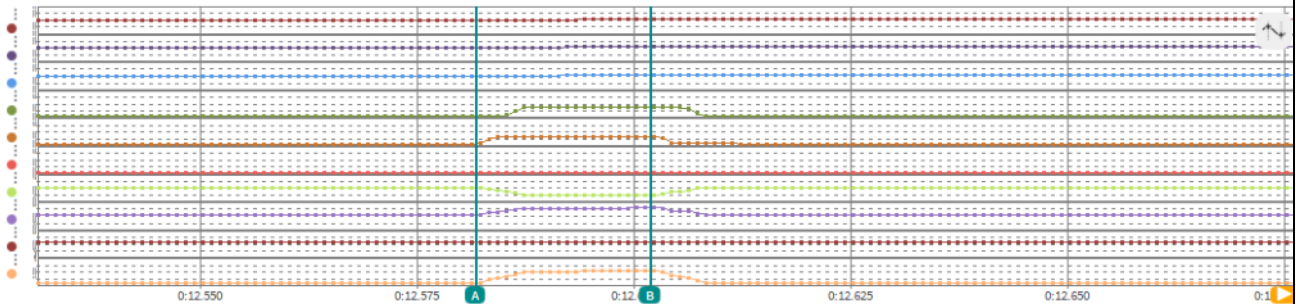
时间 [s]	A	B	间隔
0:11.9190922	0:11.9400150	0:0209229	
U1_tRMS_rc@POWER/0 [V]	230.0978	276.1338	46.03600
U2_tRMS_rc@POWER/0 [V]	230.0668	275.9799	45.91306
U3_tRMS_rc@POWER/0 [V]	230.0934	276.0489	45.95549
I1_tRMS_rc@POWER/0 [A]	0.560498	1.325175	0.764677
I2_tRMS_rc@POWER/0 [A]	0.564544	0.674535	0.109992
I3_tRMS_rc@POWER/0 [A]	0.558969	0.654943	0.095975
P_t_rc@POWER/0 [W]	-41.14105	-166.0023	-124.8612
Q_t_rc@POWER/0 [var]	385.2766	713.8321	328.5555
Q_fund_rc@POWER/0 [var]	365.7110	559.5181	193.8072
S_t_rc@POWER/0 [VA]	387.4670	732.8799	345.4130



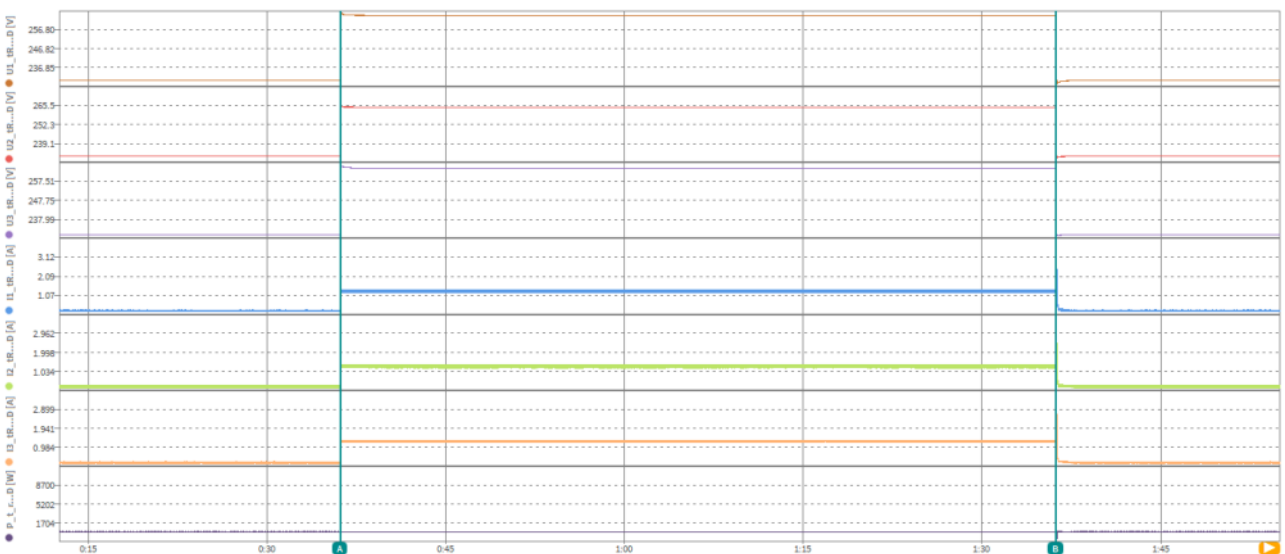
时间 [s]	A	B	间隔
0:34.08780	0:39.13680	5.04900	
U1_tRMS_rc@GRID [V]	230.2332	275.9102	45.67702
U2_tRMS_rc@GRID [V]	230.6771	275.9888	45.31171
U3_tRMS_rc@GRID [V]	230.0696	275.8927	45.82408
I1_tRMS_rc@GRID [A]	0.546518	1.295656	0.749138
I2_tRMS_rc@GRID [A]	0.906034	1.395444	0.489410
I3_tRMS_rc@GRID [A]	0.384135	1.291168	0.927033
P_t_rc@GRID [W]	-50.97196	-11.79842	39.17353

Test – VS2.2.0

Duration fault time



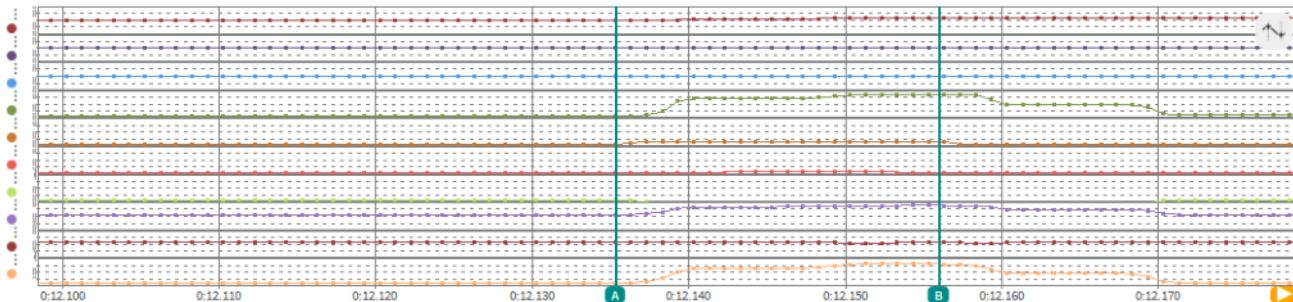
时间 [s]	A	B	间隔
0:12.5818330	0:12.6019616	0:0201285	
U1_tRMS_rc@POWER/0 [V]	230.0951	264.4058	34.31068
U2_tRMS_rc@POWER/0 [V]	230.4597	264.2458	33.78609
U3_tRMS_rc@POWER/0 [V]	230.5202	264.4845	33.96431
I1_tRMS_rc@POWER/0 [A]	0.569533	9.944722	9.375189
I2_tRMS_rc@POWER/0 [A]	0.583892	9.280107	8.696215
I3_tRMS_rc@POWER/0 [A]	0.562725	0.630514	0.067789
P_t_rc@POWER/0 [W]	-52.07385	-2509.054	-2456.980
Q_t_rc@POWER/0 [var]	391.8853	4609.847	4217.962
Q_fund_rc@POWER/0 [var]	366.2568	85.38490	-280.8719
S_t_rc@POWER/0 [VA]	395.3299	5248.433	4853.103



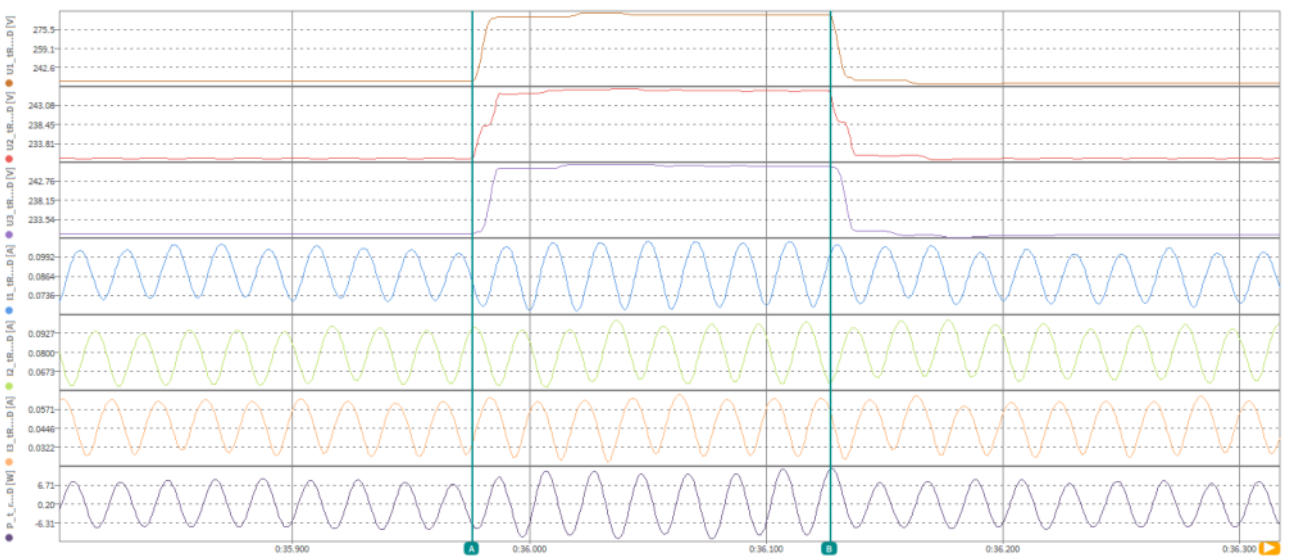
时间 [s]	A	B	间隔
0:36.1649	1:36.2159	1:00.0510	
U1_tRMS_rc@GRID [V]	229.9743	264.3955	34.42119
U2_tRMS_rc@GRID [V]	230.0852	264.4167	34.33145
U3_tRMS_rc@GRID [V]	229.9217	264.3418	34.42014
I1_tRMS_rc@GRID [A]	0.196882	1.316990	1.120109
I2_tRMS_rc@GRID [A]	0.202079	1.305018	1.102938
I3_tRMS_rc@GRID [A]	0.171997	1.243436	1.071439
P_t_rc@GRID [W]	-8.866178	8.564669	17.43085

Test – VS3.0

Duration fault time



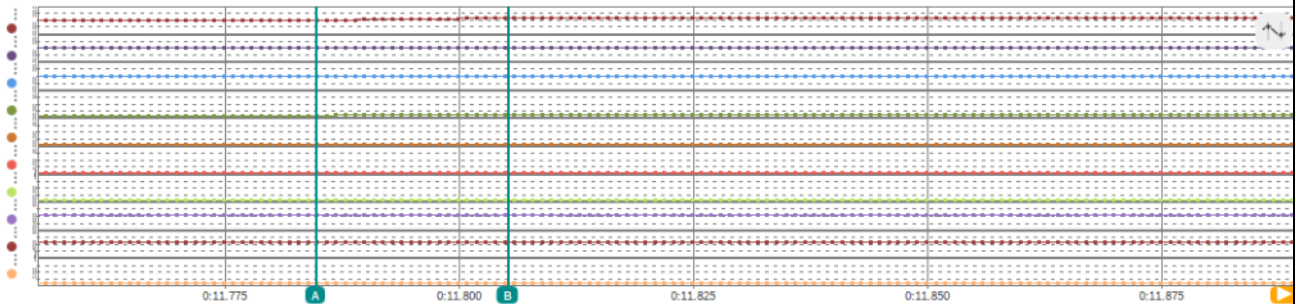
时间 [s]	A	B	间隔
0:12.13536088	0:12.1559096	0.02063008	
U1_tRMS_rc@POWER/0 [V]	230.0781	287.1375	57.05937
U2_tRMS_rc@POWER/0 [V]	230.0863	246.2299	16.14359
U3_tRMS_rc@POWER/0 [V]	230.0634	246.1890	16.12560
I1_tRMS_rc@POWER/0 [A]	0.571750	24.55716	23.98541
I2_tRMS_rc@POWER/0 [A]	0.571057	2.881245	2.310188
I3_tRMS_rc@POWER/0 [A]	0.566827	0.711984	0.145156
P_t_rc@POWER/0 [W]	-45.25550	-5074.453	-5029.198
Q_t_rc@POWER/0 [var]	390.7337	6101.657	5710.923
Q_fund_rc@POWER/0 [var]	367.1051	19.46821	-347.6369
S_t_rc@POWER/0 [VA]	393.3457	7936.012	7542.666



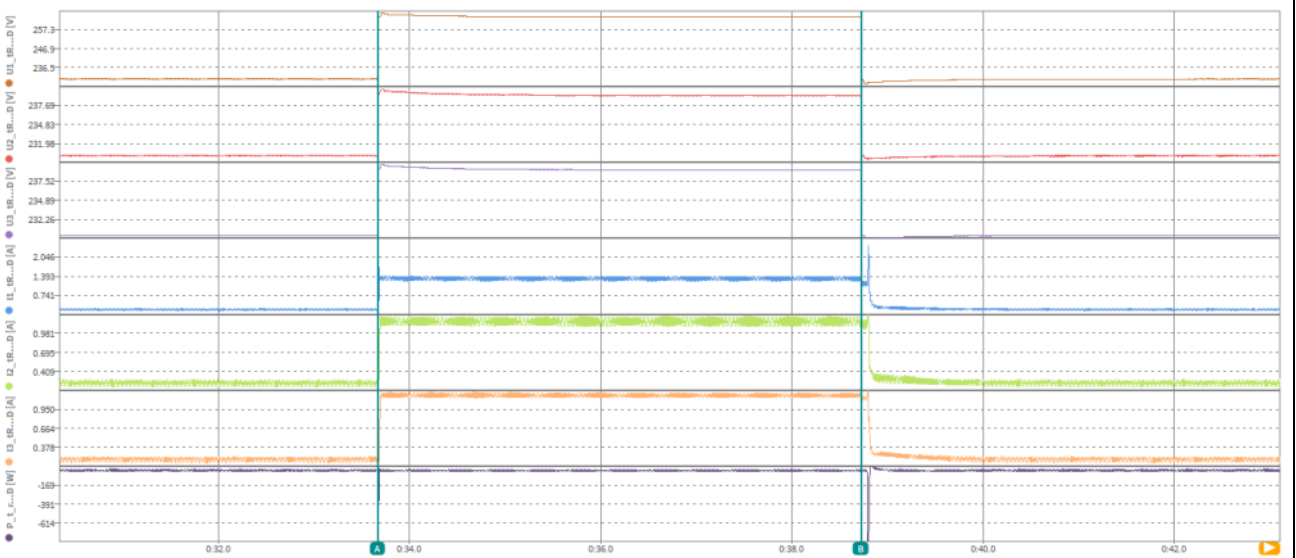
时间 [s]	A	B	间隔
0:35.975900	0:36.126900	0.151000	
U1_tRMS_rc@GRID [V]	229.9295	288.4525	58.52303
U2_tRMS_rc@GRID [V]	229.9616	246.7198	16.75822
U3_tRMS_rc@GRID [V]	229.9084	246.5243	16.61588
I1_tRMS_rc@GRID [A]	0.085572	0.098516	0.012944
I2_tRMS_rc@GRID [A]	0.094859	0.058955	-0.035904
I3_tRMS_rc@GRID [A]	0.030882	0.058160	0.027278
P_t_rc@GRID [W]	-6.174742	11.61204	17.78678

Test – VS4.1.0

Duration fault time



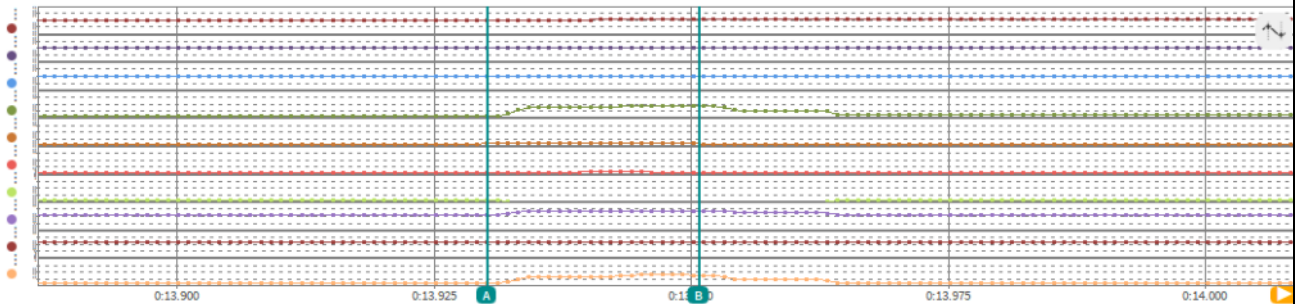
时间 [s]	A	B	间隔
	0:11.7847088	0:11.8051944	0.0204856
U1_tRMS_rc@POWER/0 [V]	230.3497	276.1645	45.81474
U2_tRMS_rc@POWER/0 [V]	230.3016	241.5720	11.27040
U3_tRMS_rc@POWER/0 [V]	229.6632	241.5230	11.85976
I1_tRMS_rc@POWER/0 [A]	0.576854	1.307557	0.730703
I2_tRMS_rc@POWER/0 [A]	0.563933	0.557419	-6.515e-3
I3_tRMS_rc@POWER/0 [A]	0.562210	0.547088	-0.015122
P_t_rc@POWER/0 [W]	-42.15607	-129.6675	-87.51140
Q_t_rc@POWER/0 [var]	389.5978	614.3568	224.7590
Q_fund_rc@POWER/0 [var]	369.4592	474.6239	105.1647
S_t_rc@POWER/0 [VA]	391.8719	627.8917	236.0197



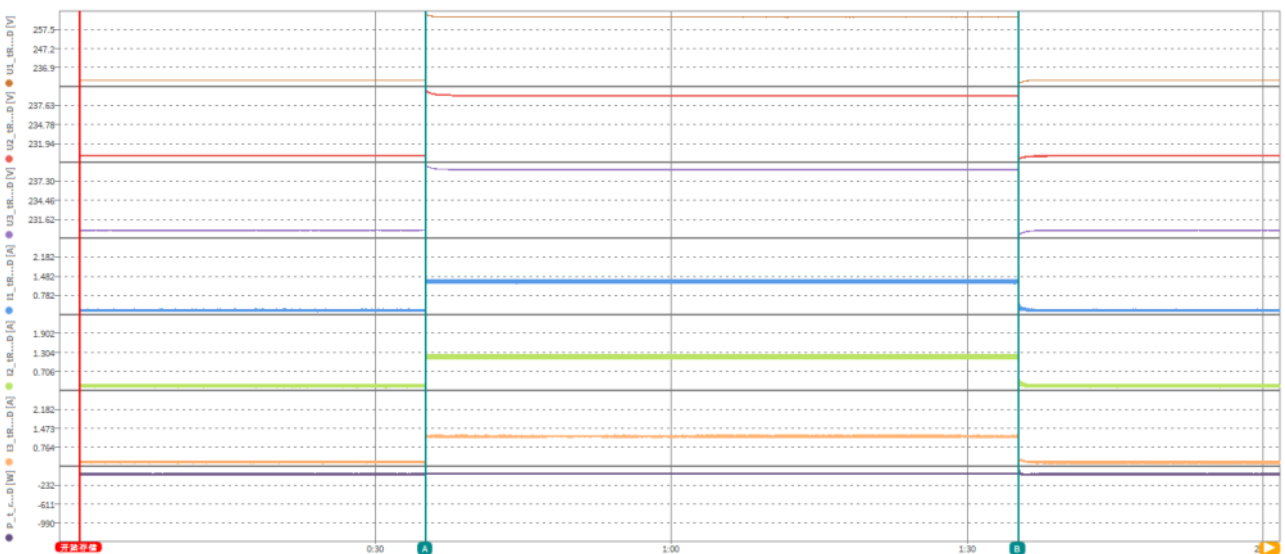
时间 [s]	A	B	间隔
	0:33.67510	0:38.72510	5.05000
U1_tRMS_rc@GRID [V]	229.9588	264.4471	34.48820
U2_tRMS_rc@GRID [V]	230.0813	239.1315	9.050186
U3_tRMS_rc@GRID [V]	229.9026	239.1273	9.224731
I1_tRMS_rc@GRID [A]	0.198705	1.363434	1.164729
I2_tRMS_rc@GRID [A]	0.211119	1.139061	0.927942
I3_tRMS_rc@GRID [A]	0.179877	1.135953	0.956076
P_t_rc@GRID [W]	-11.11313	4.237337	15.35047

Test – VS4.2.0

Duration fault time



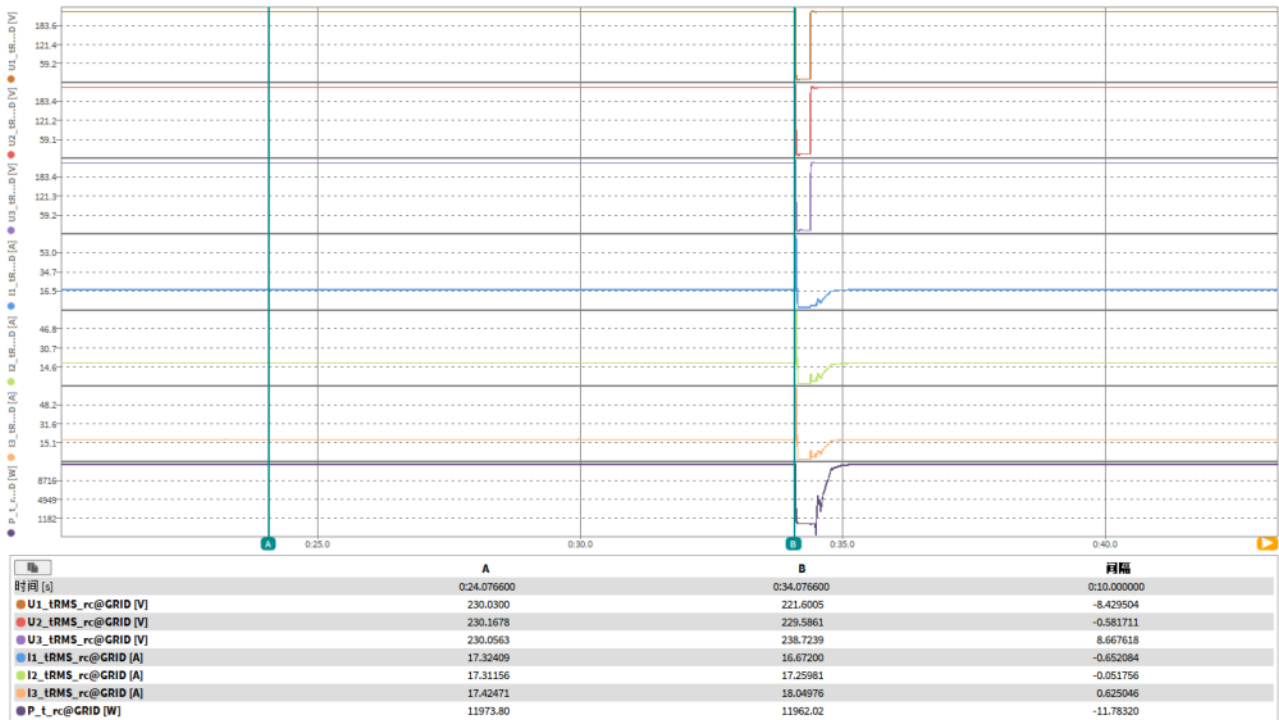
时间 [s]	A	B	间隔
0:13.9301841	0:13.9507554	0.0205713	
U1_tRMS_rc@POWER/0 [V]	230.4372	264.2027	33.76550
U2_tRMS_rc@POWER/0 [V]	230.4751	239.4808	9.005753
U3_tRMS_rc@POWER/0 [V]	229.6802	239.3067	9.626511
I1_tRMS_rc@POWER/0 [A]	0.578632	11.93911	11.36048
I2_tRMS_rc@POWER/0 [A]	0.584350	0.952697	0.368347
I3_tRMS_rc@POWER/0 [A]	0.568015	0.684030	0.116015
P_t_rc@POWER/0 [W]	-51.25530	-2203.219	-2151.963
Q_t_rc@POWER/0 [var]	395.1681	2778.722	2383.554
Q_fund_rc@POWER/0 [var]	369.6157	73.30357	-296.3121
S_t_rc@POWER/0 [VA]	398.4783	3546.190	3147.712



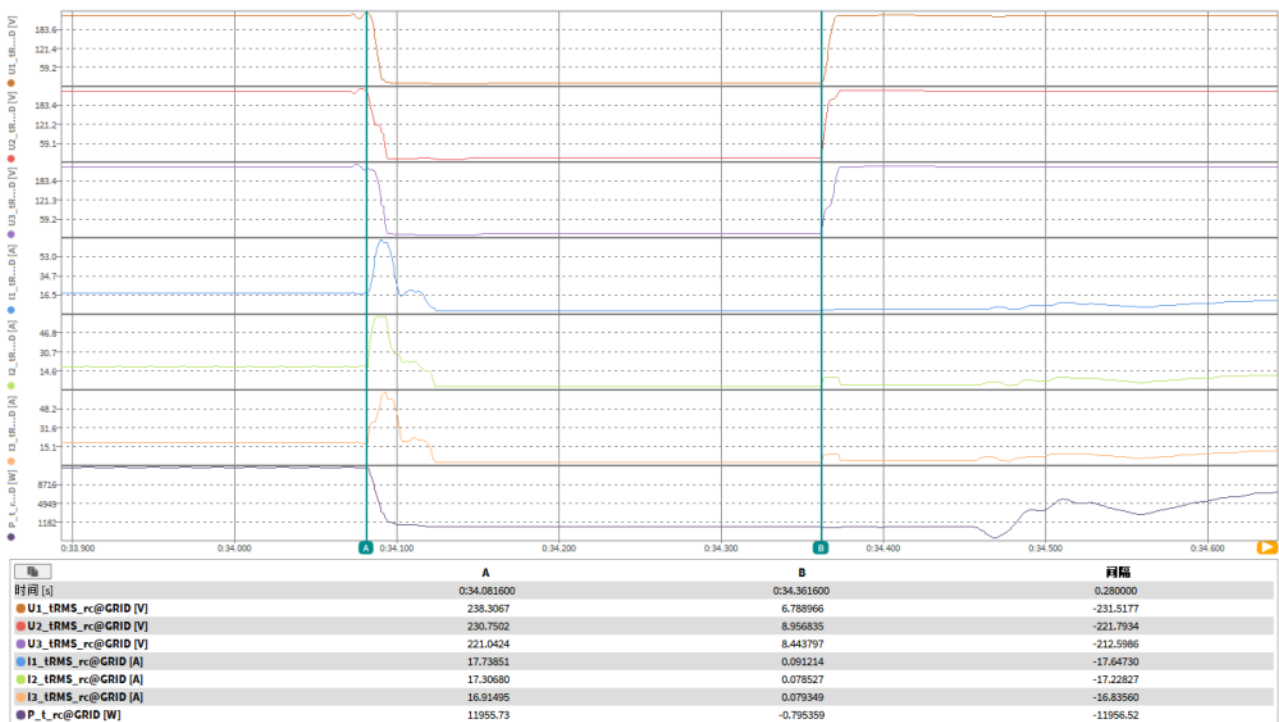
时间 [s]	A	B	间隔
0:35.09500	1:35.14600	1:00.05100	
U1_tRMS_rc@GRID [V]	229.9346	264.3336	34.39900
U2_tRMS_rc@GRID [V]	230.0111	239.1104	9.099319
U3_tRMS_rc@GRID [V]	229.8937	239.1323	9.238632
I1_tRMS_rc@GRID [A]	0.210319	1.355105	1.144786
I2_tRMS_rc@GRID [A]	0.219768	1.107868	0.888100
I3_tRMS_rc@GRID [A]	0.191539	1.165434	0.973896
P_t_rc@GRID [W]	-19.98395	24.09127	44.07522

Test - VD1.1

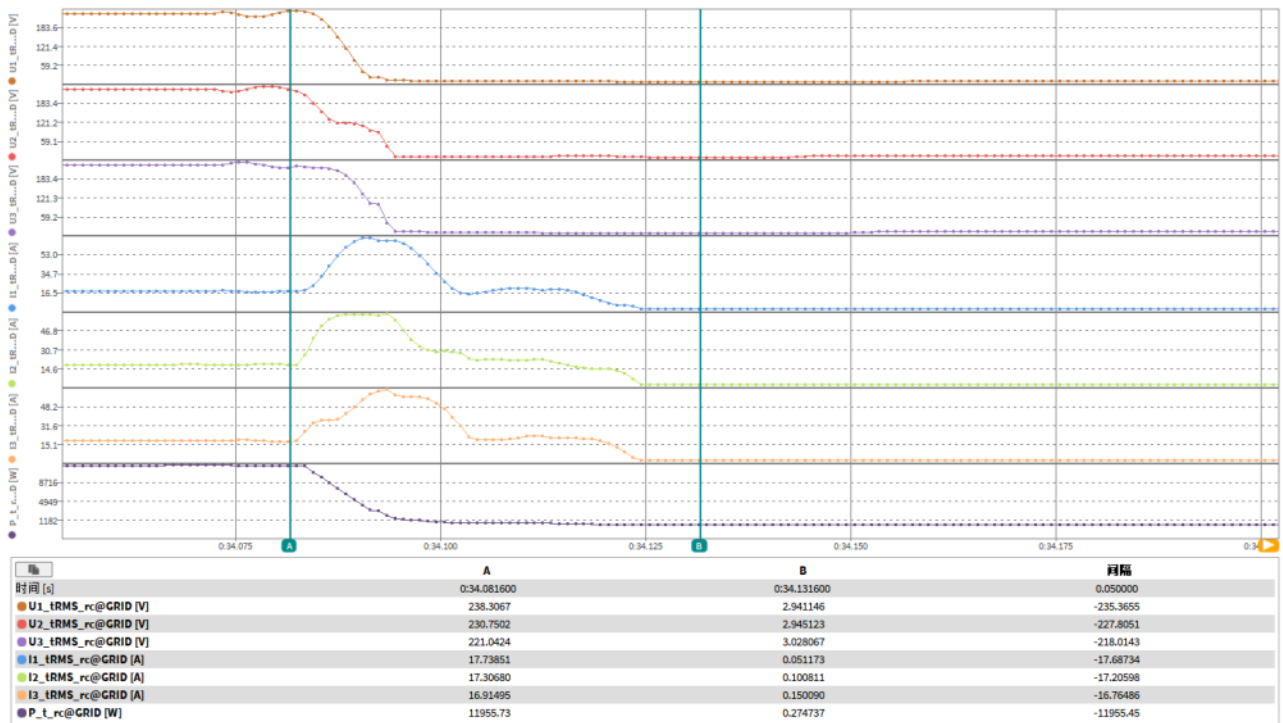
Before fault



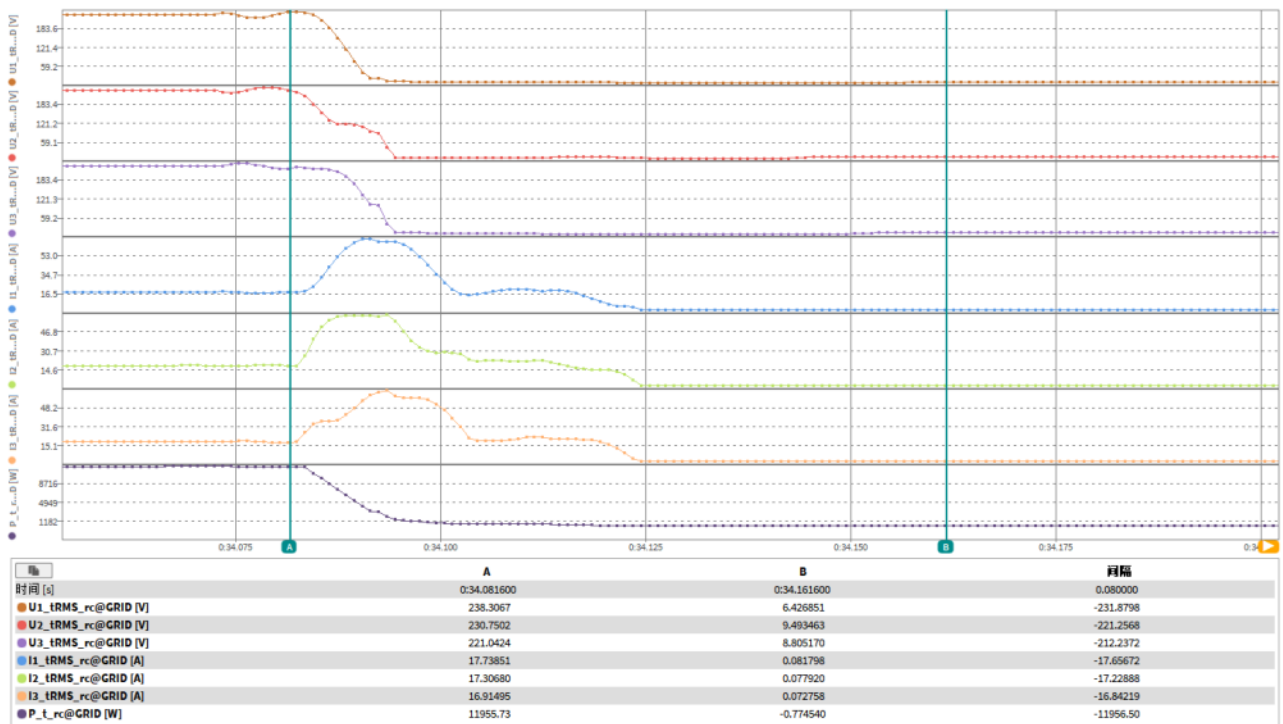
Duration fault time

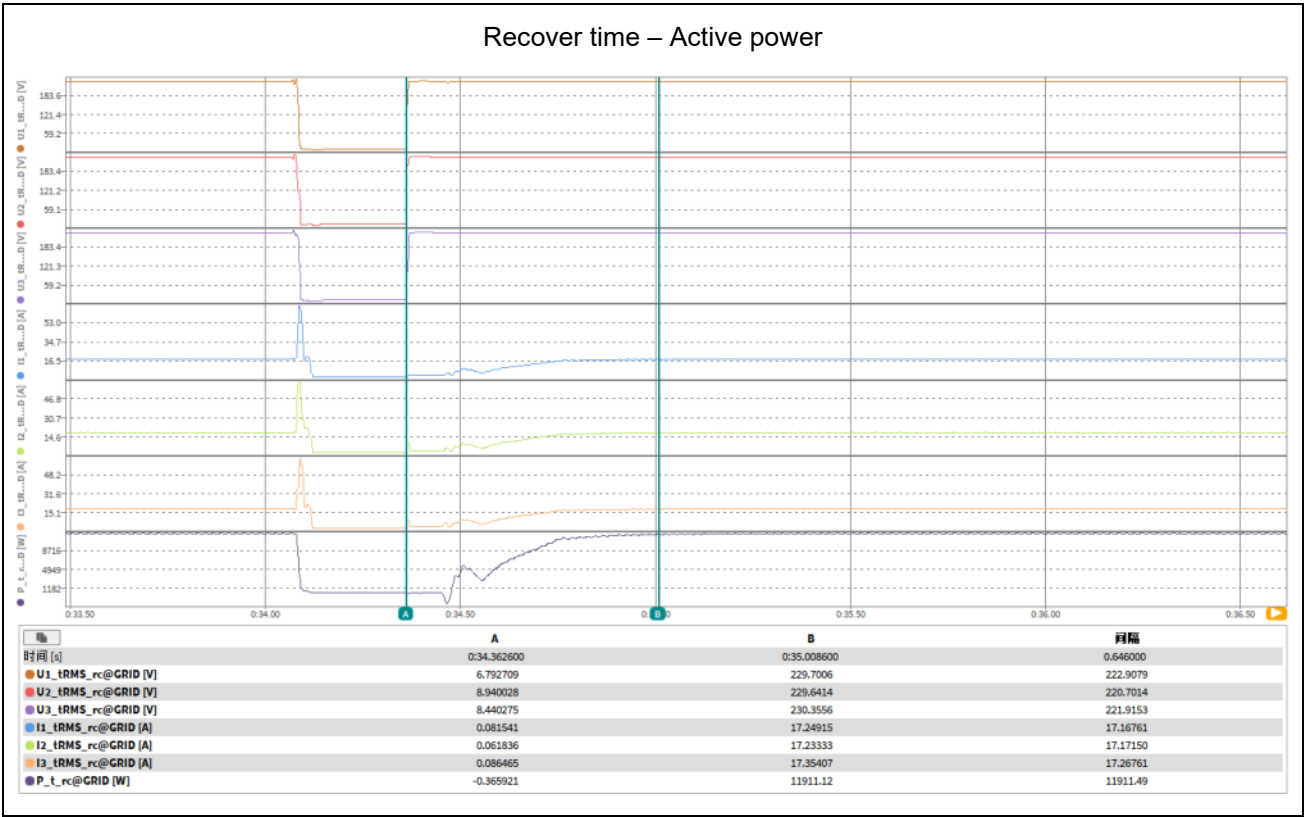


0-30ms



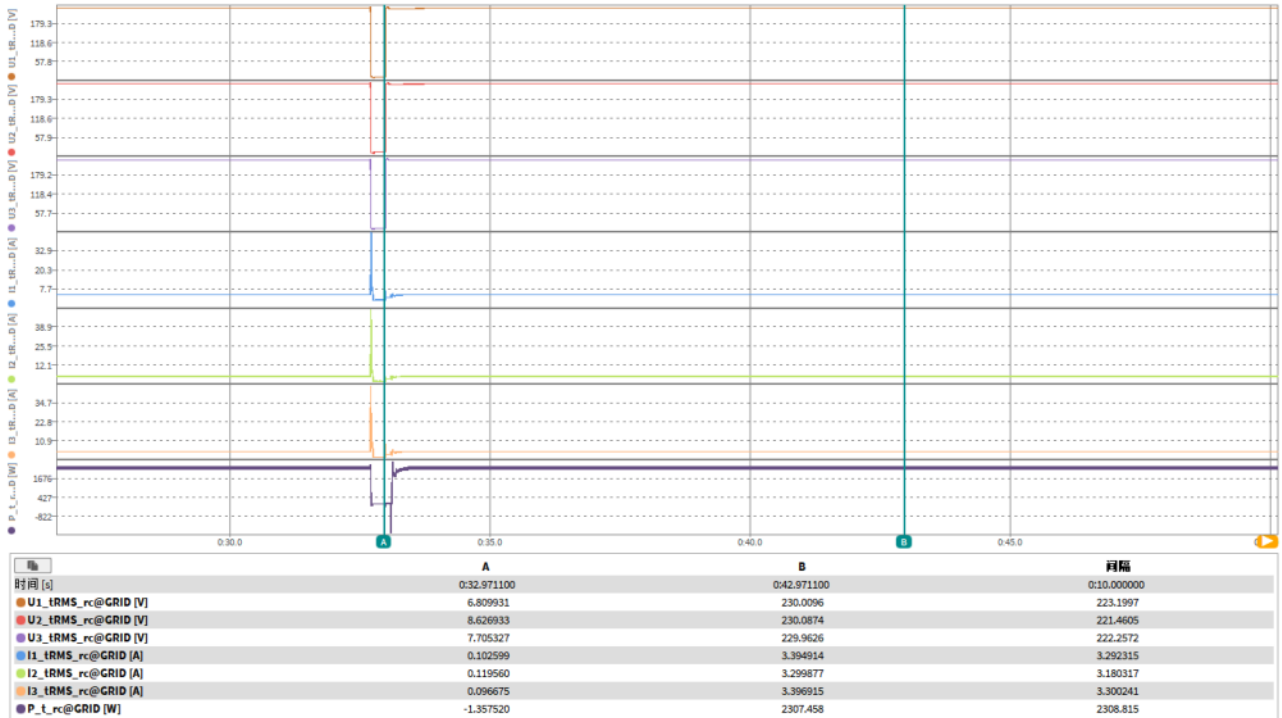
0-60ms



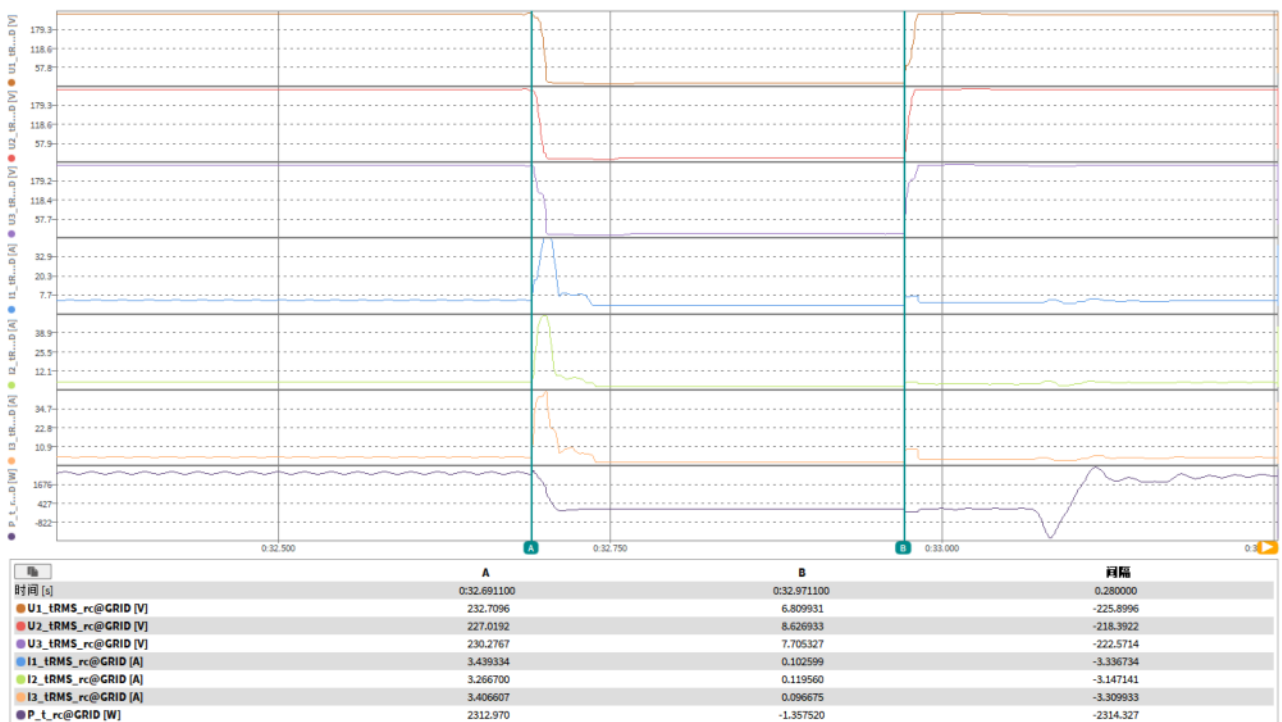


Test - VD1.2

Before fault



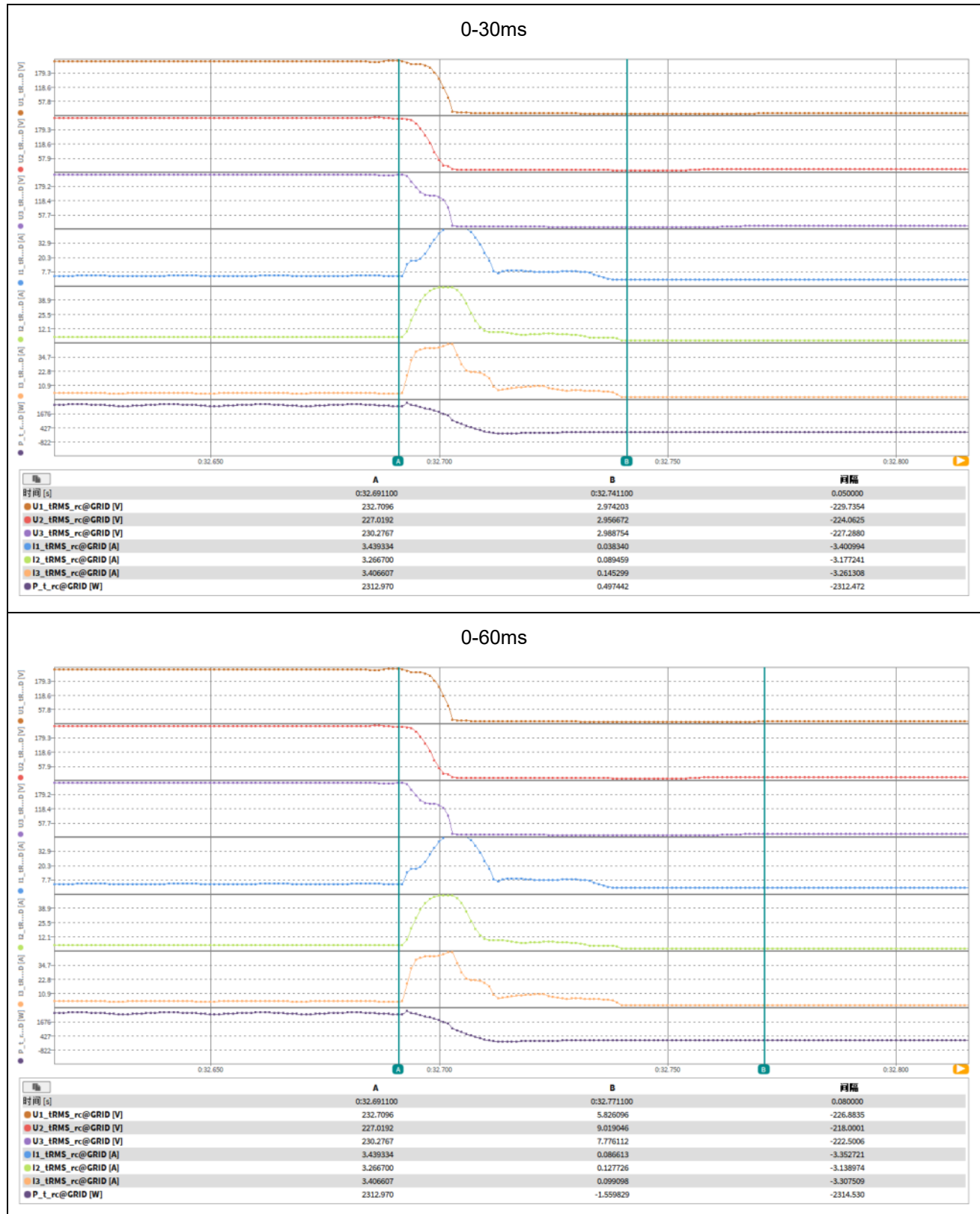
Duration fault time



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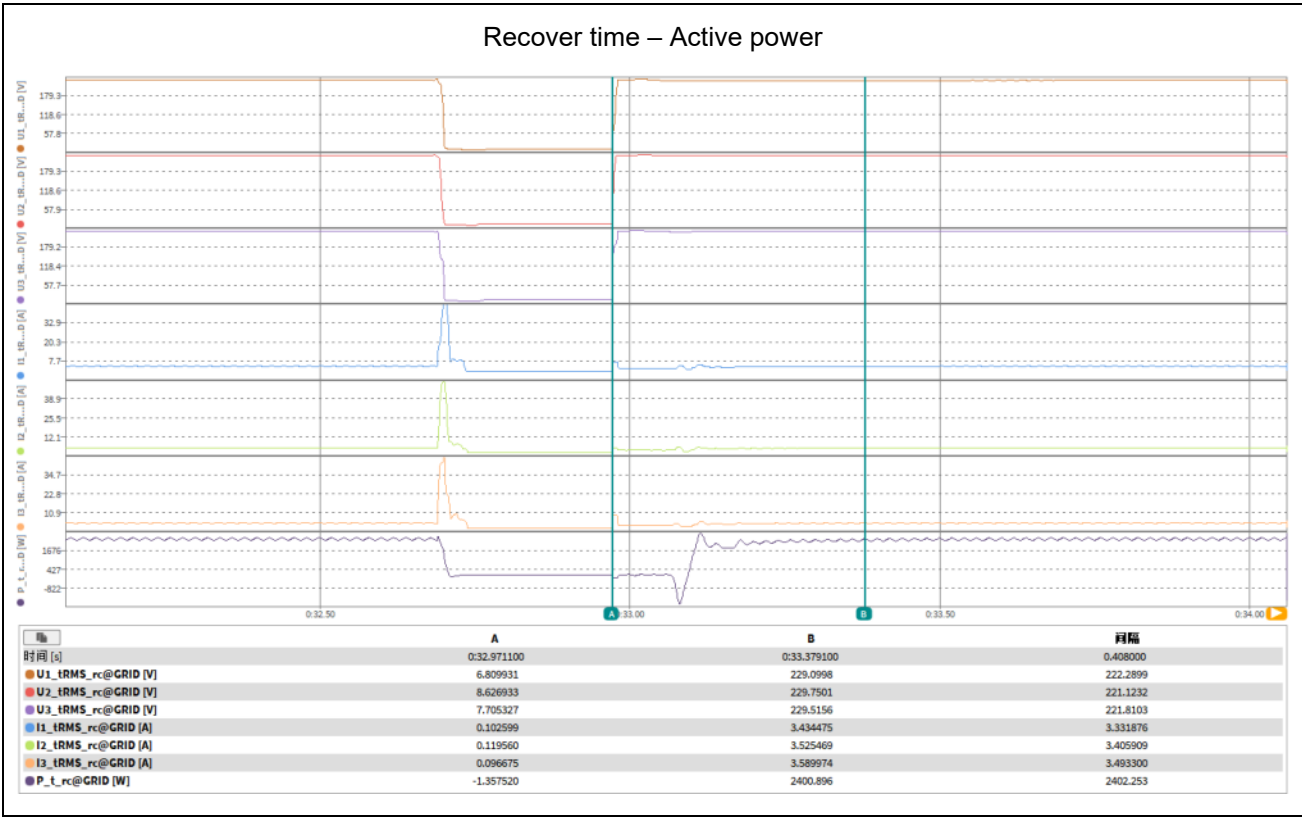
Test Report No.: RDPVP02041/26E/02



Test Report

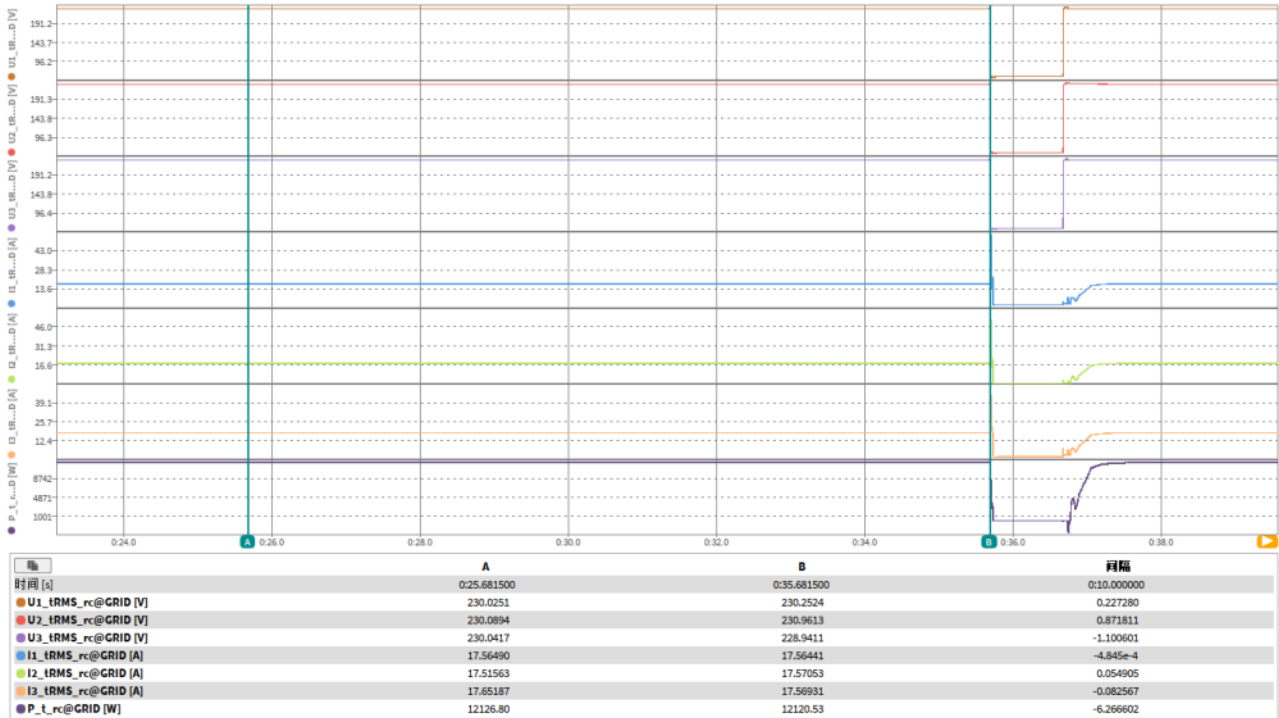
Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

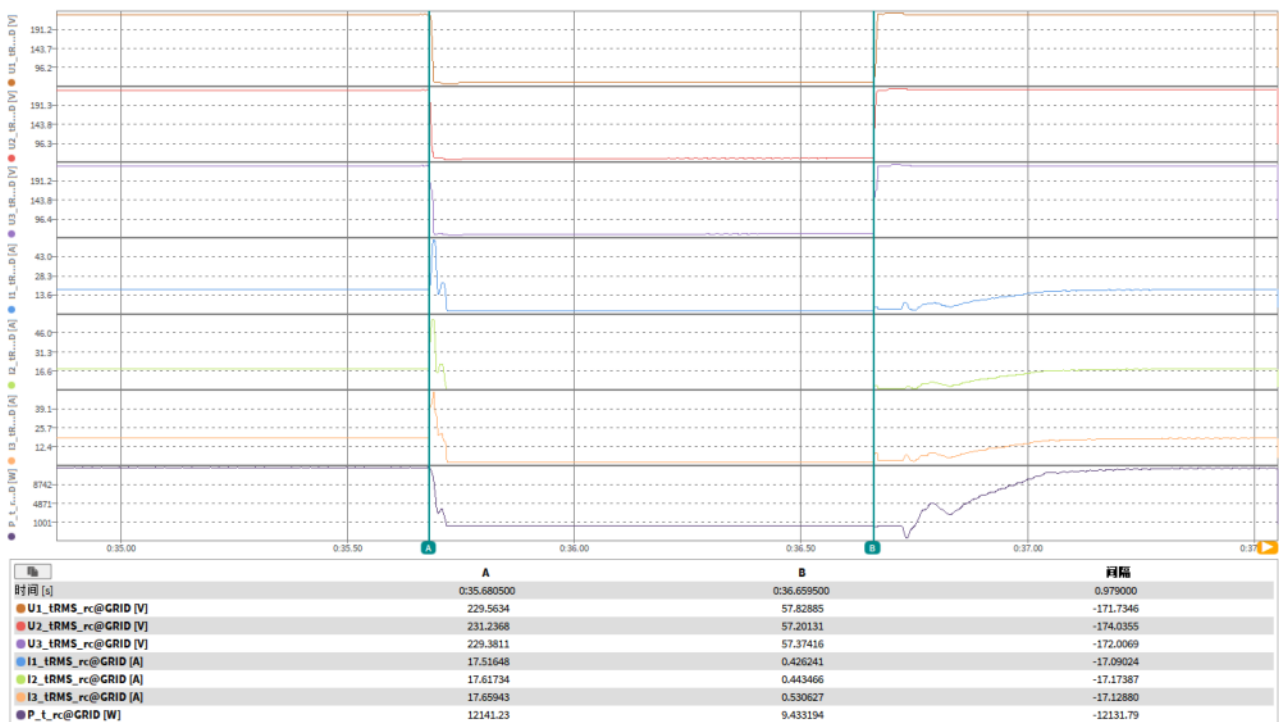


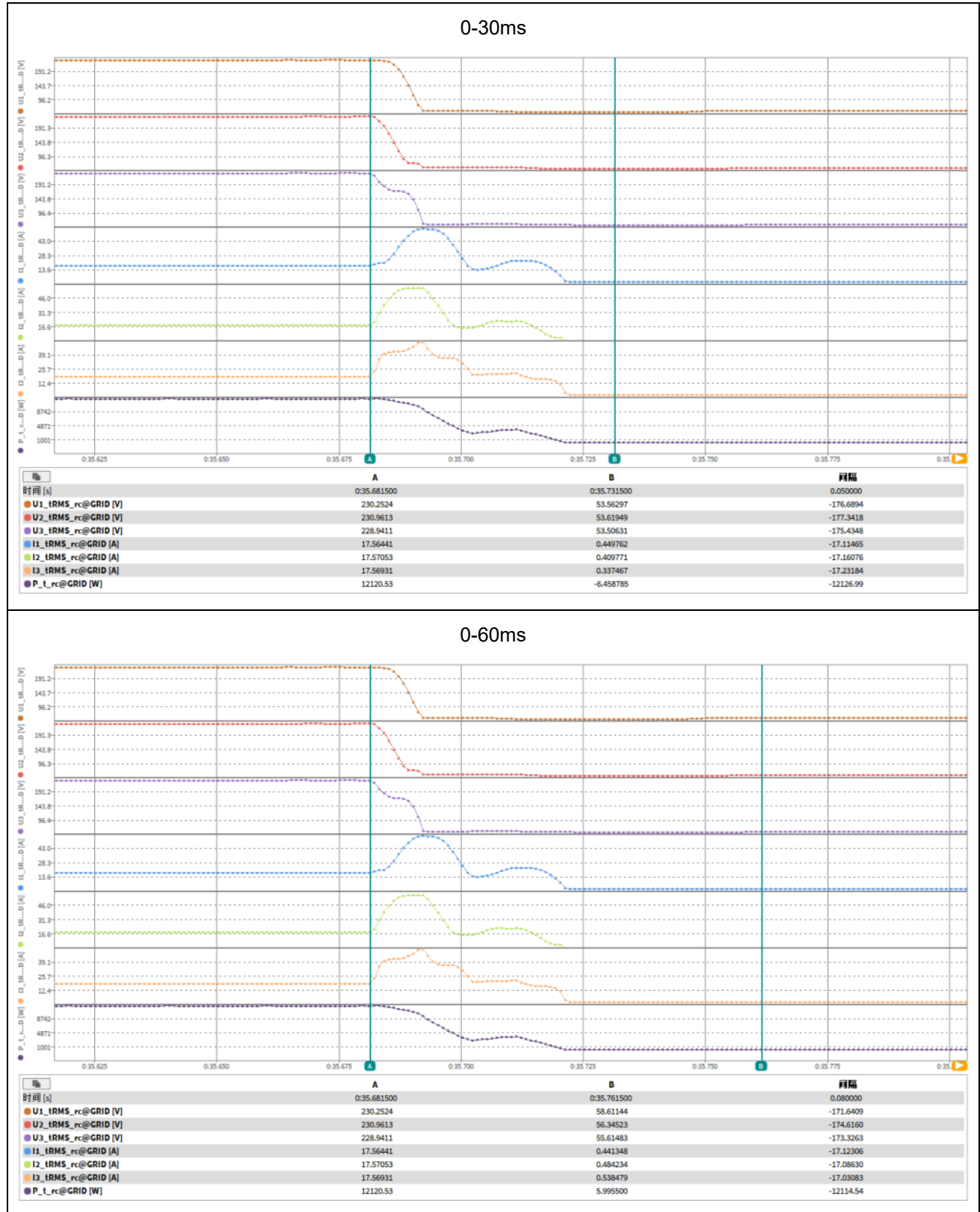
Test – VD2.1

Before fault

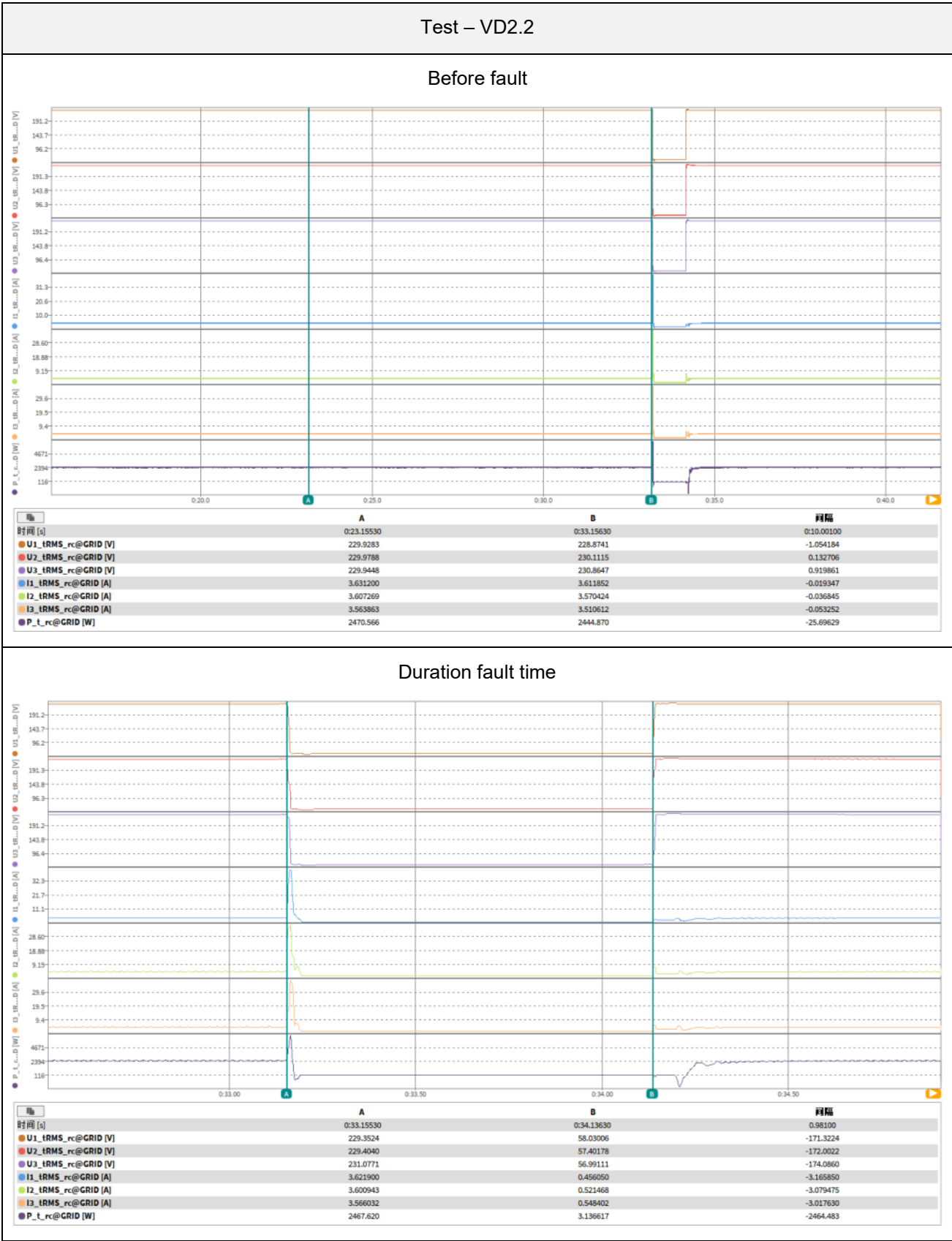


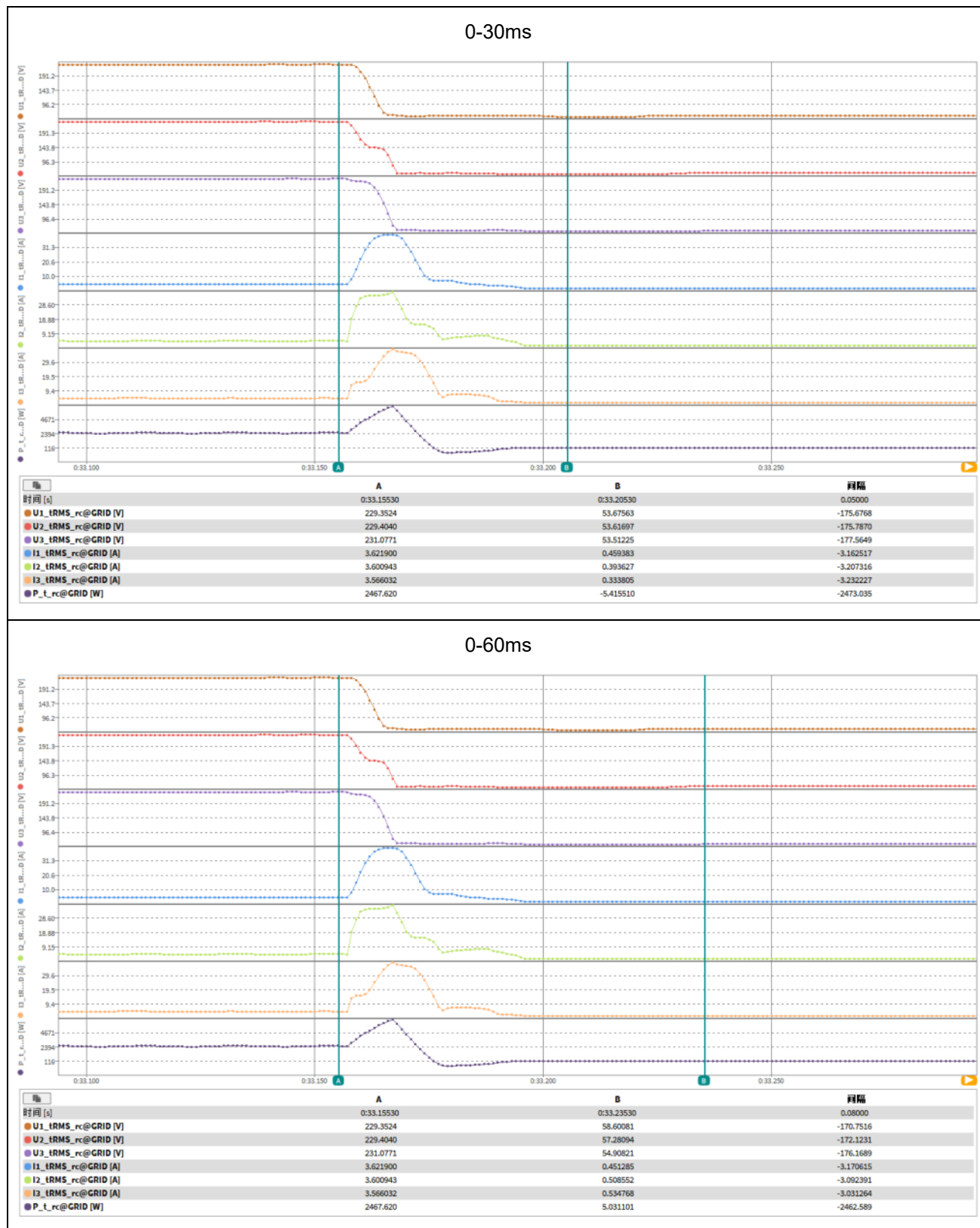
Duration fault time

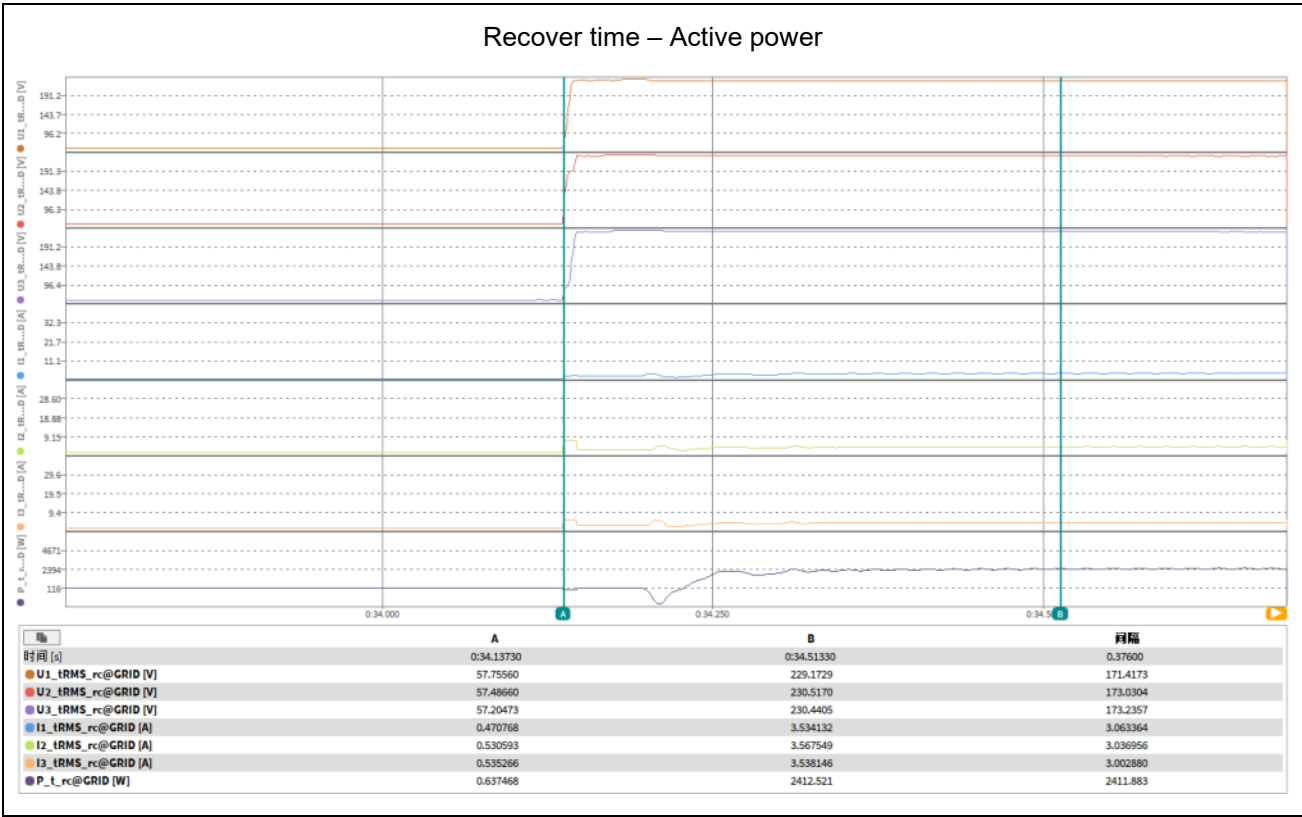










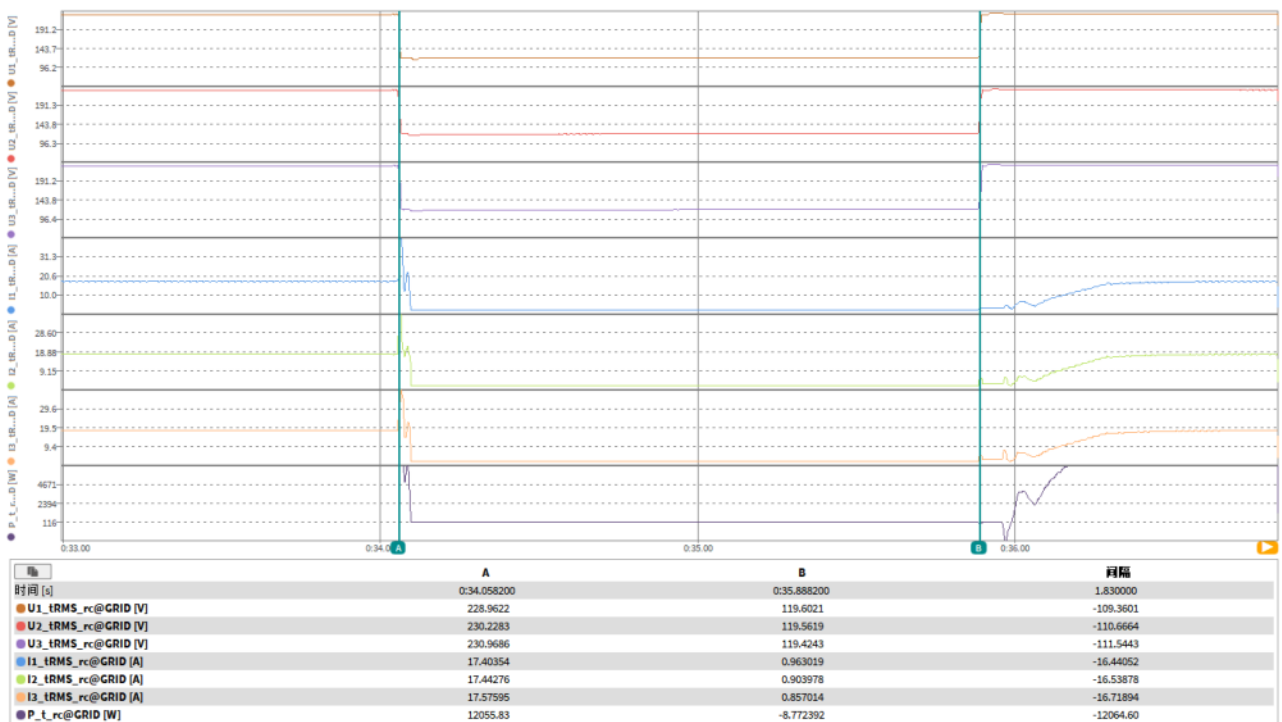


Test – VD3.1

Before fault



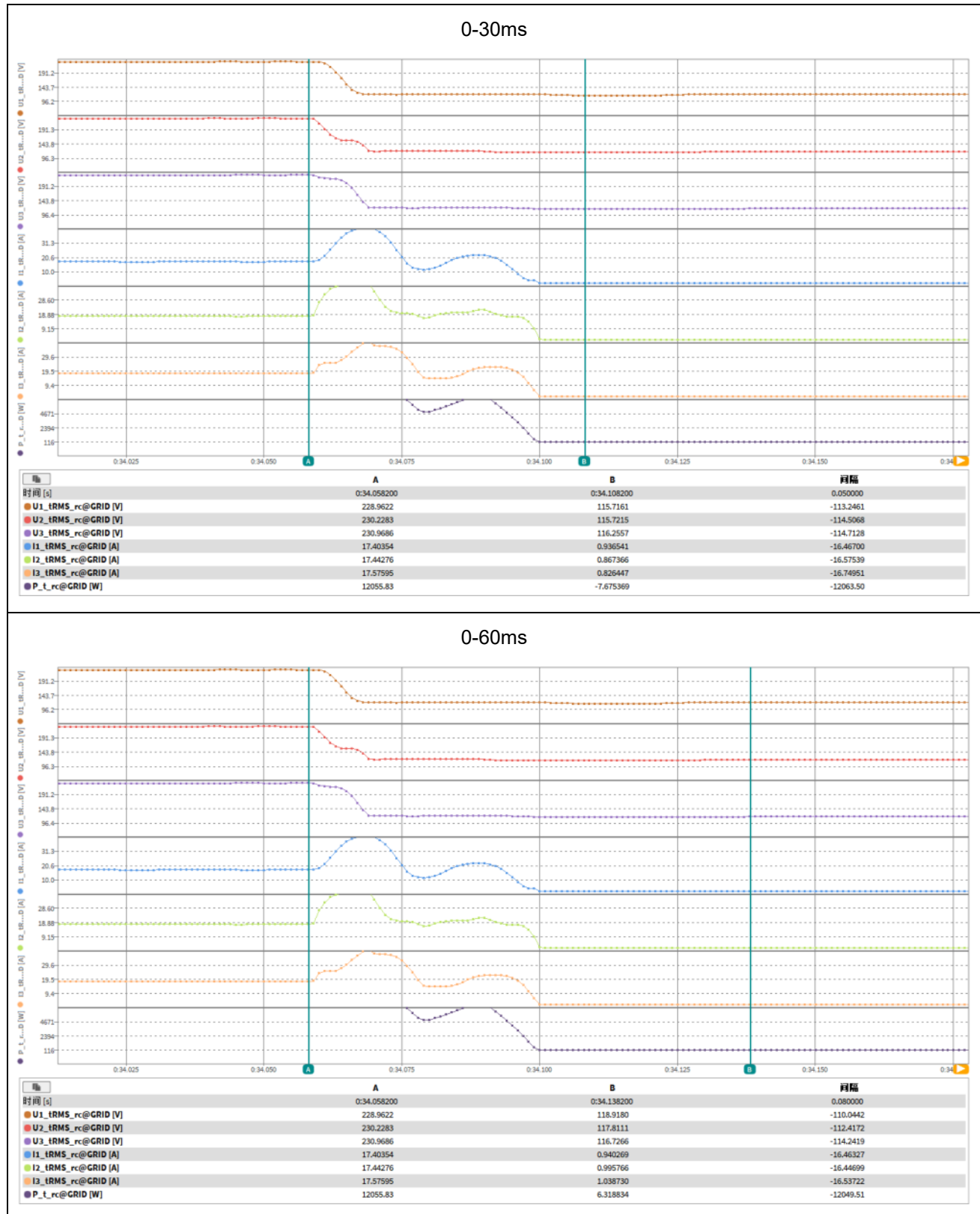
Duration fault time

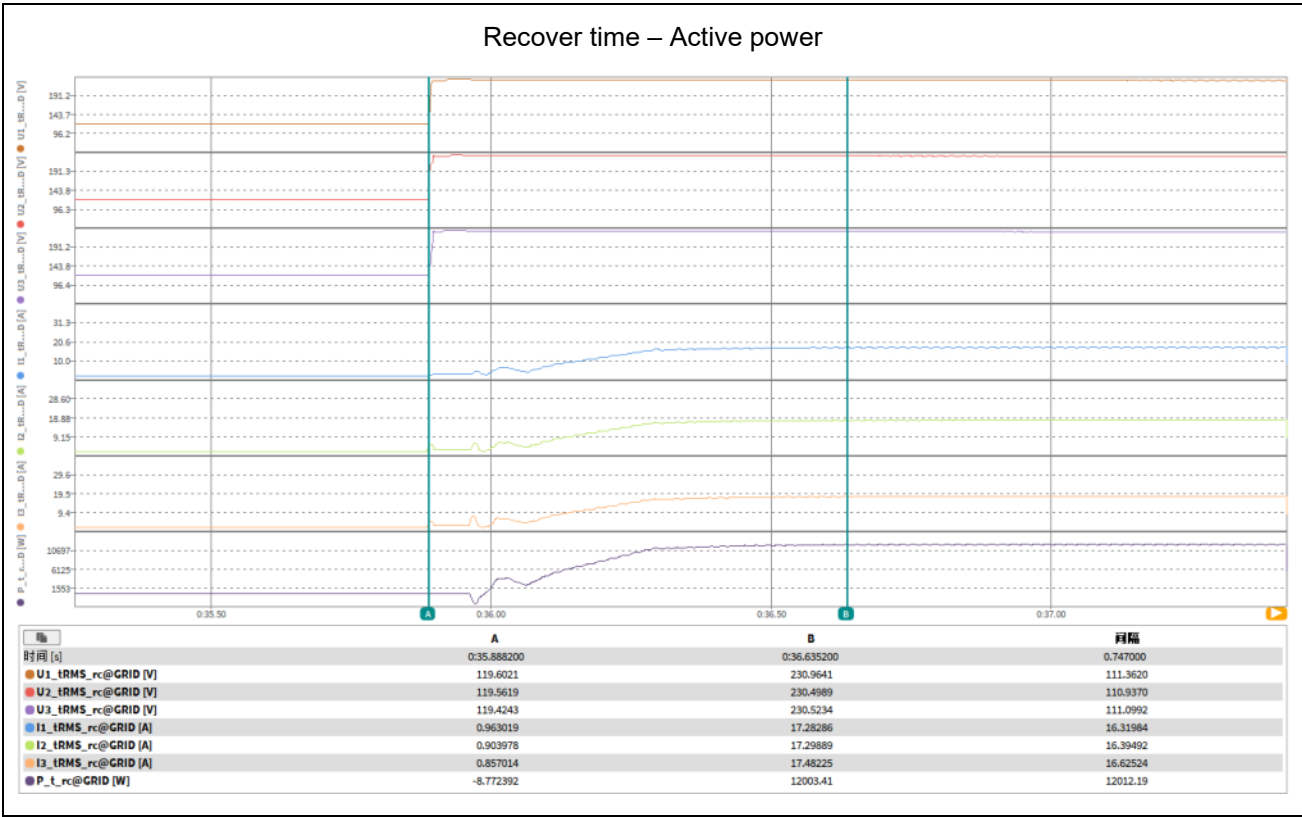


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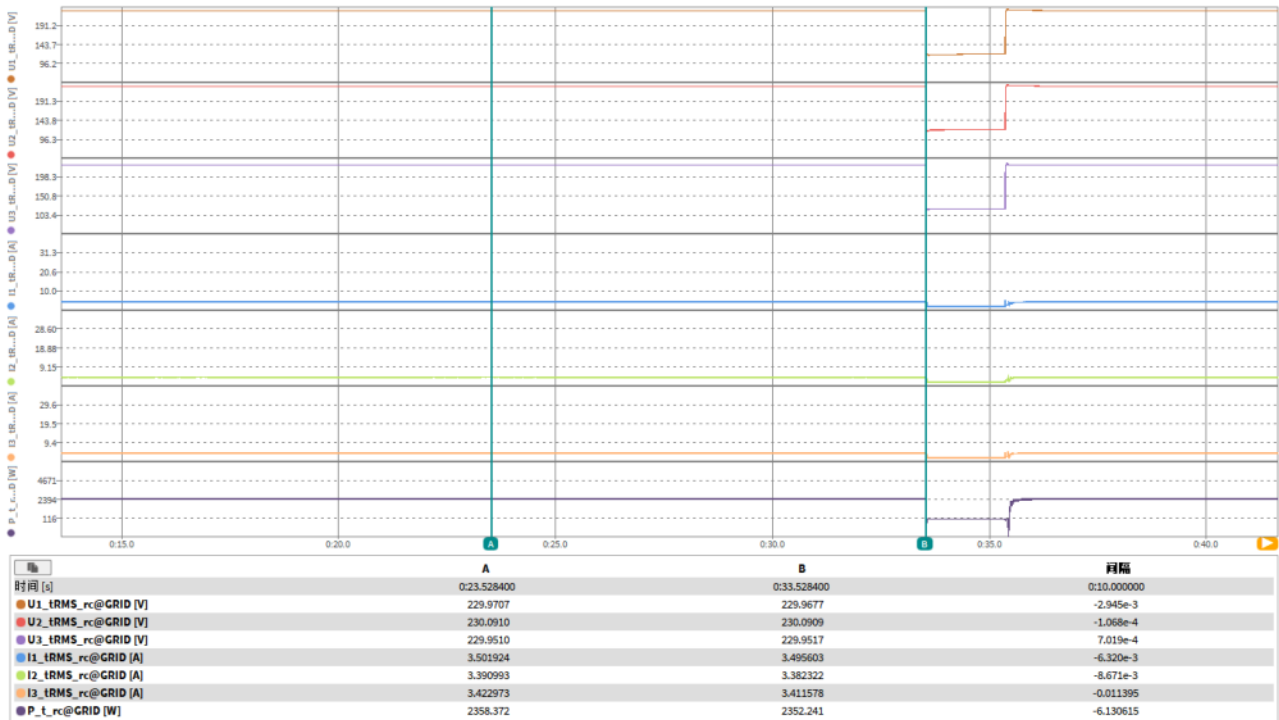
Test Report No.: RDPVP02041/26E/02



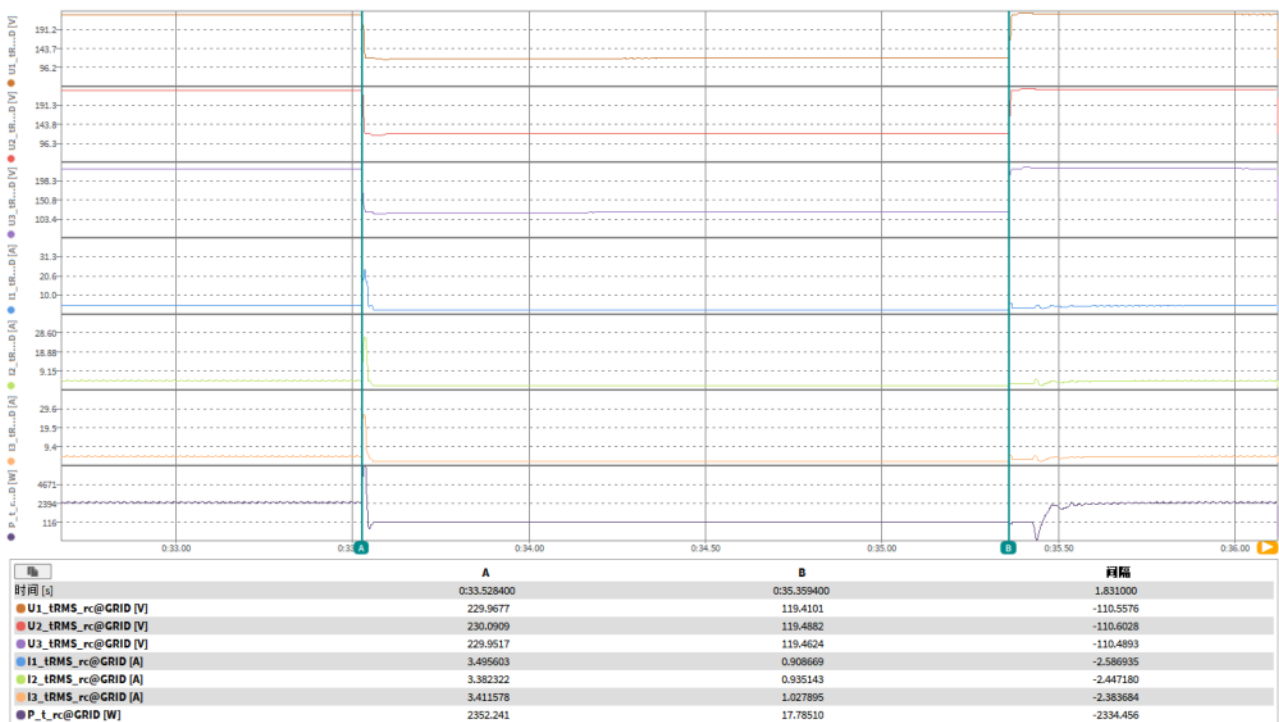


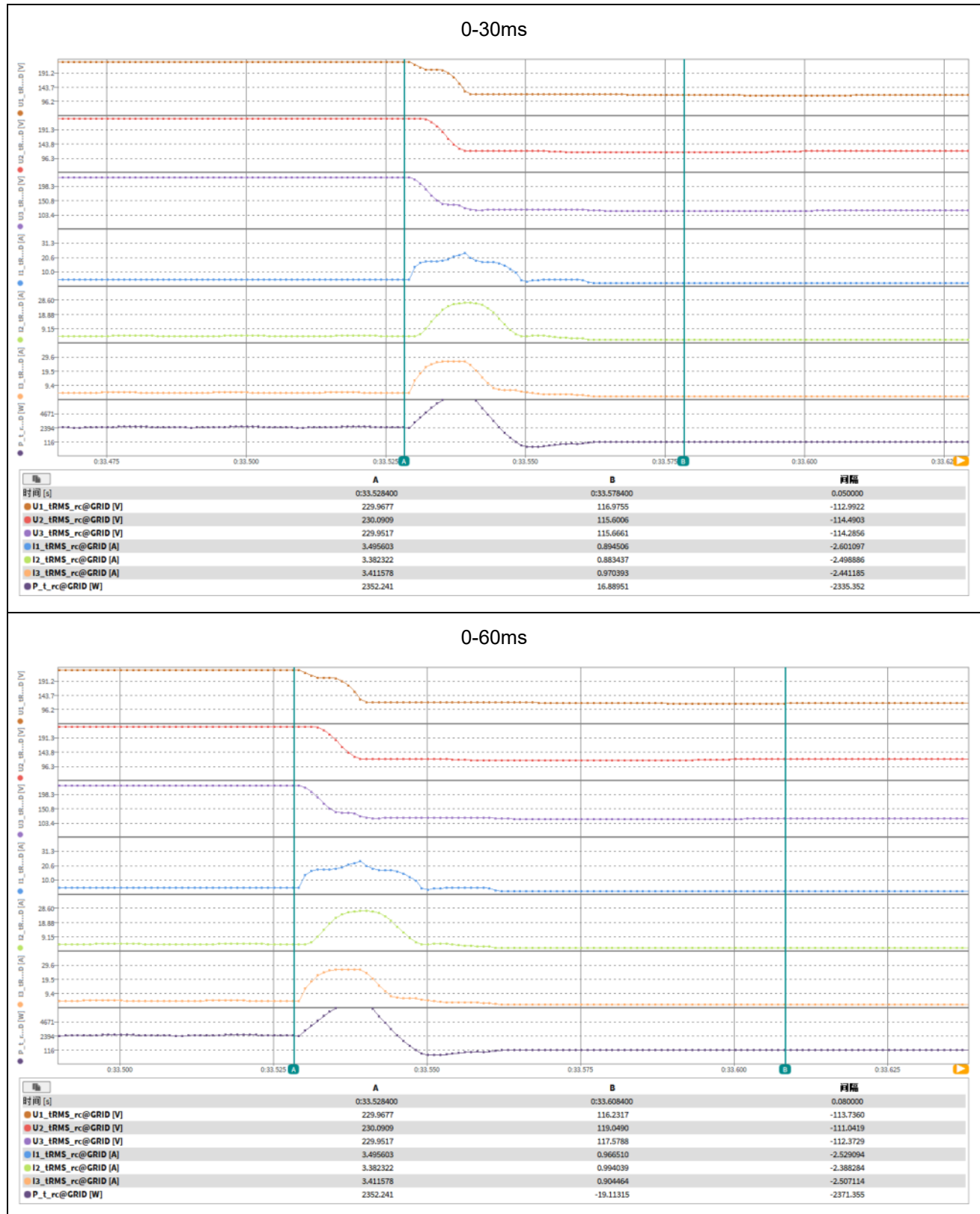
Test – VD3.2

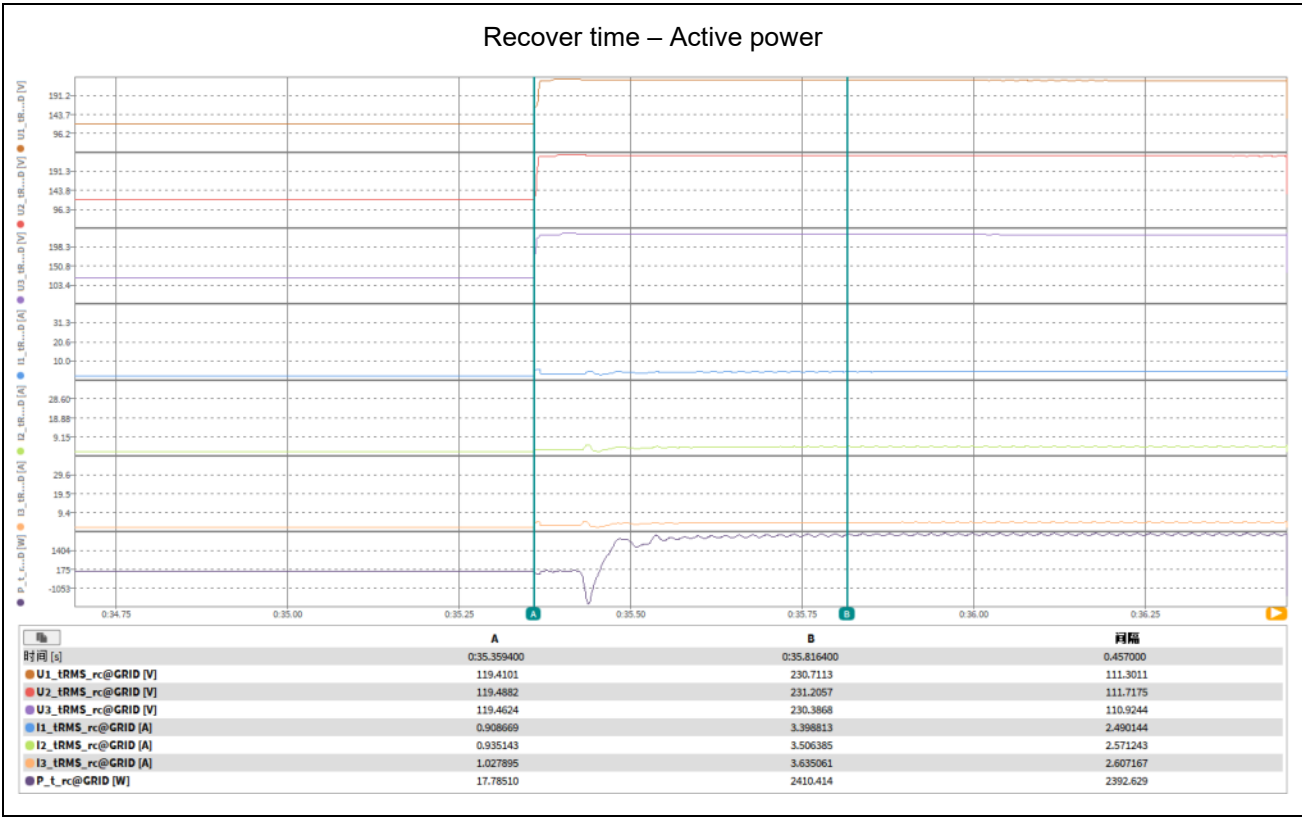
Before fault



Duration fault time







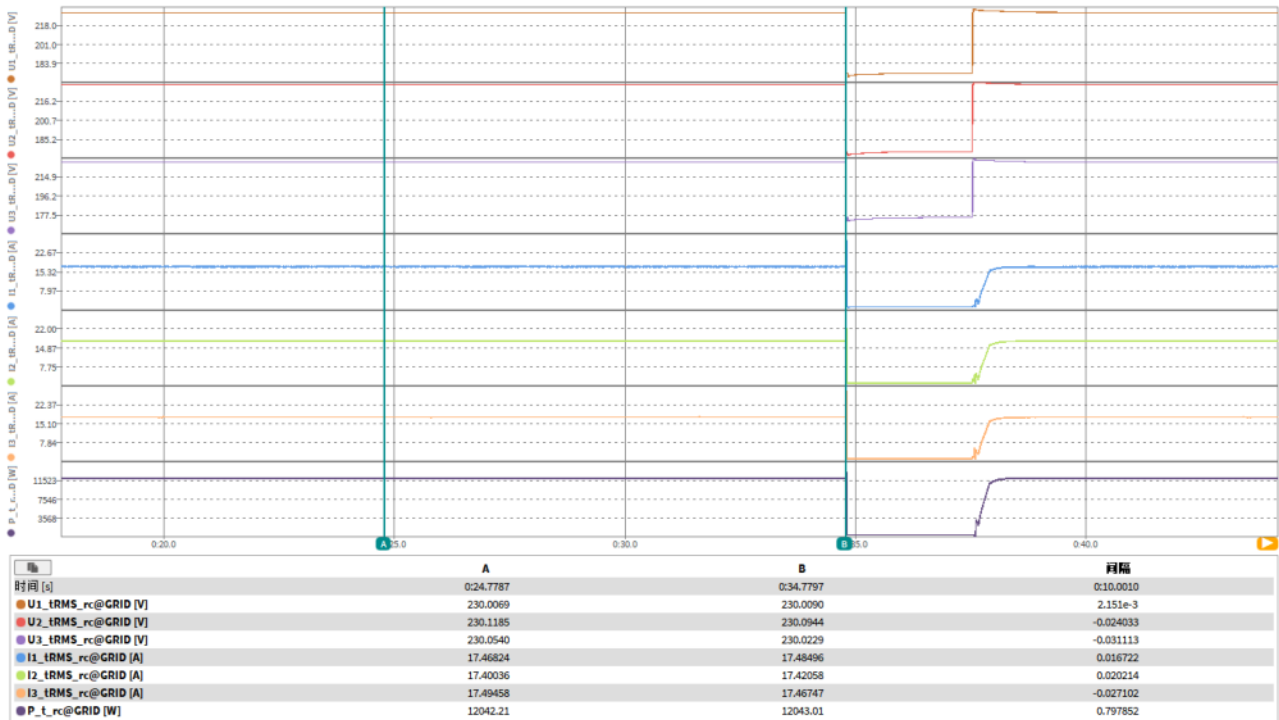
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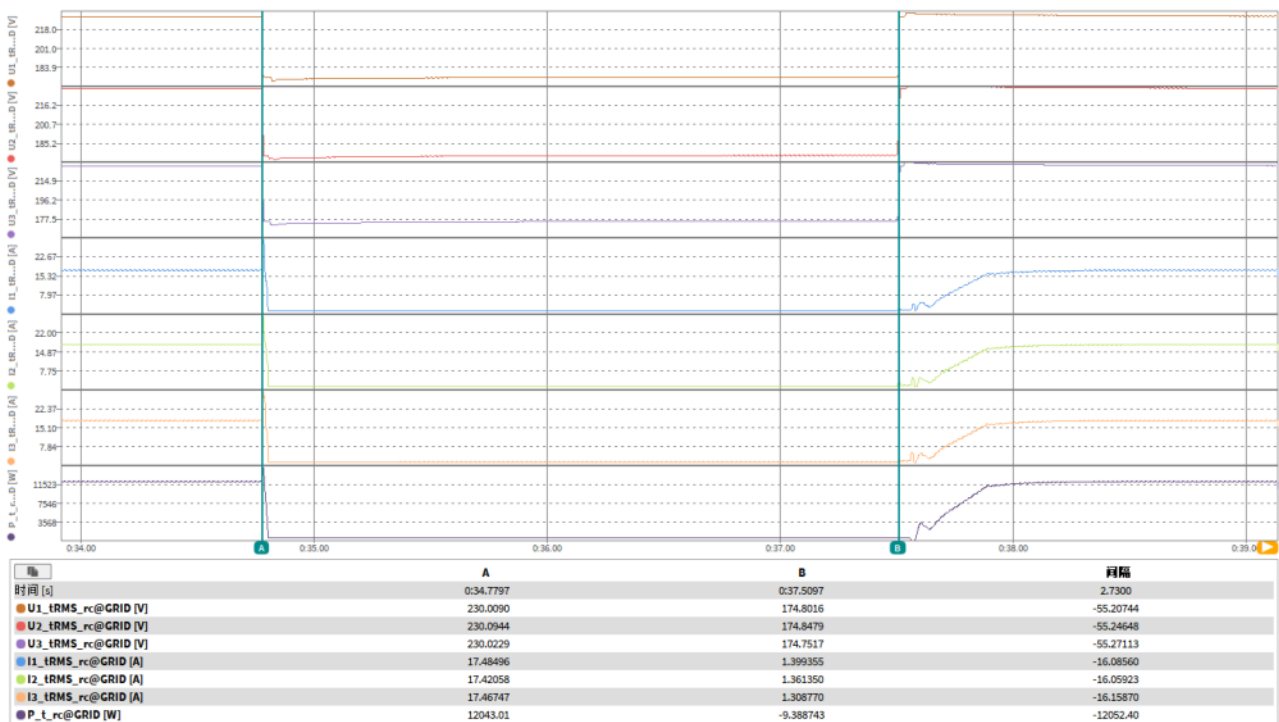
Test Report No.: RDPVP02041/26E/02

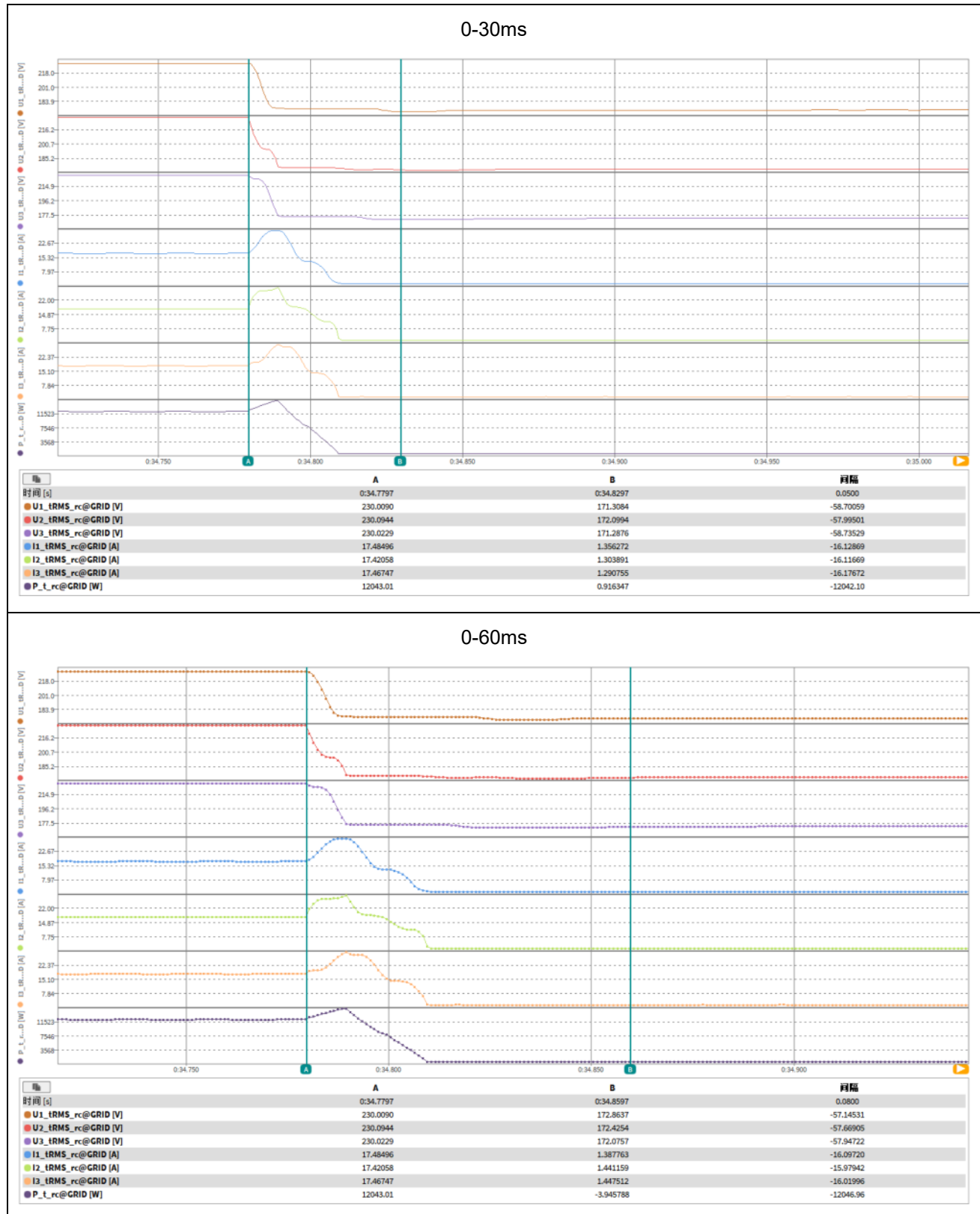
Test – VD4.1

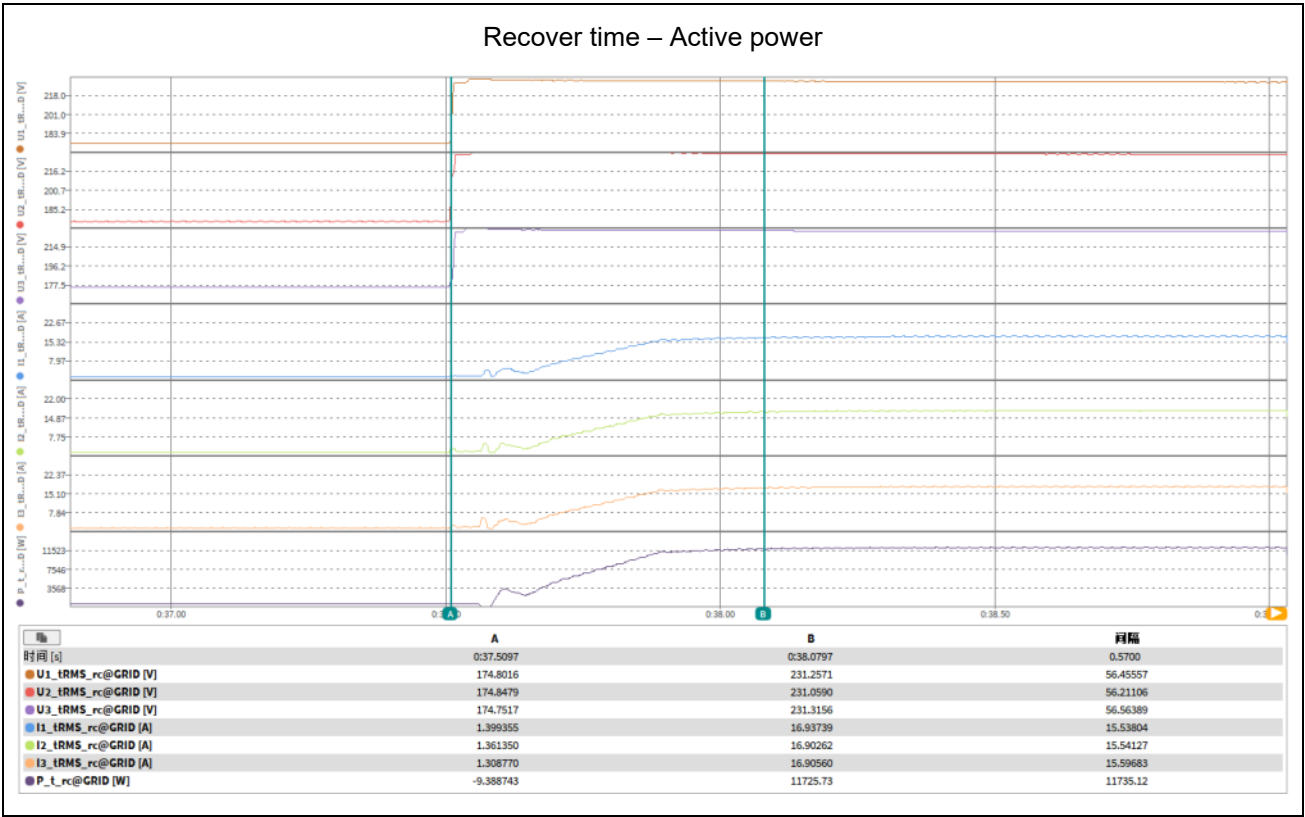
Before fault



Duration fault time

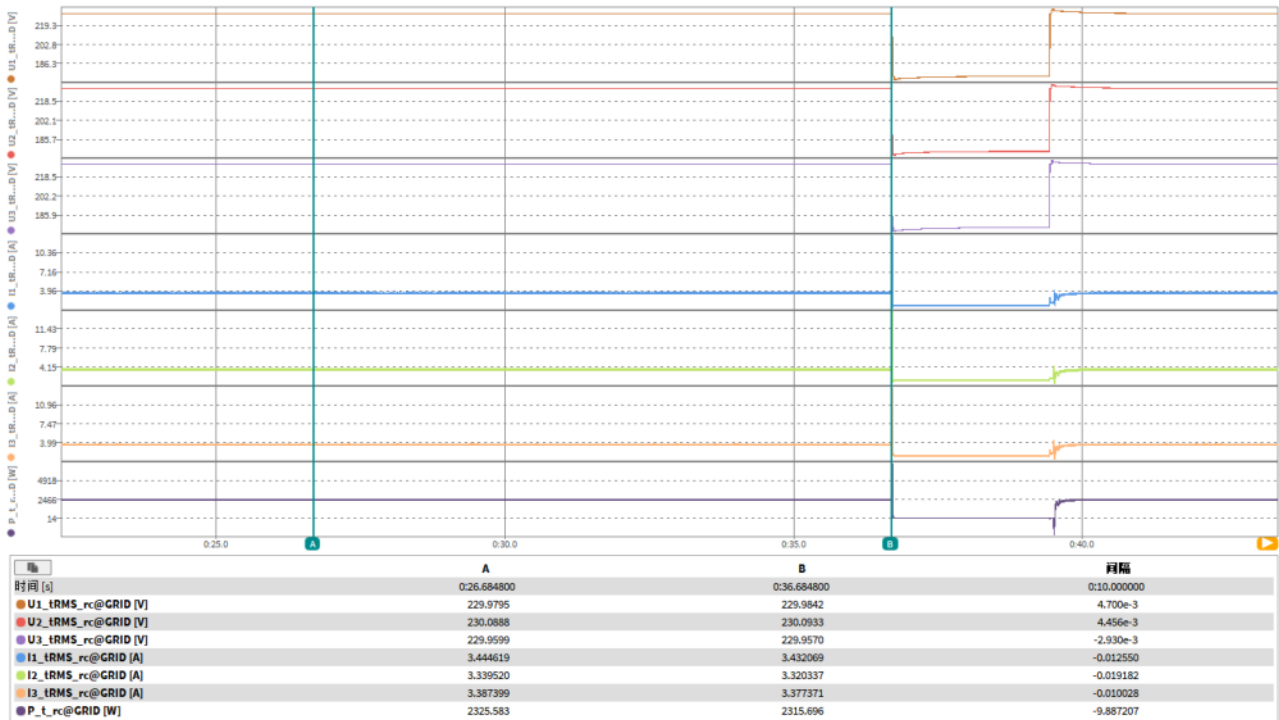




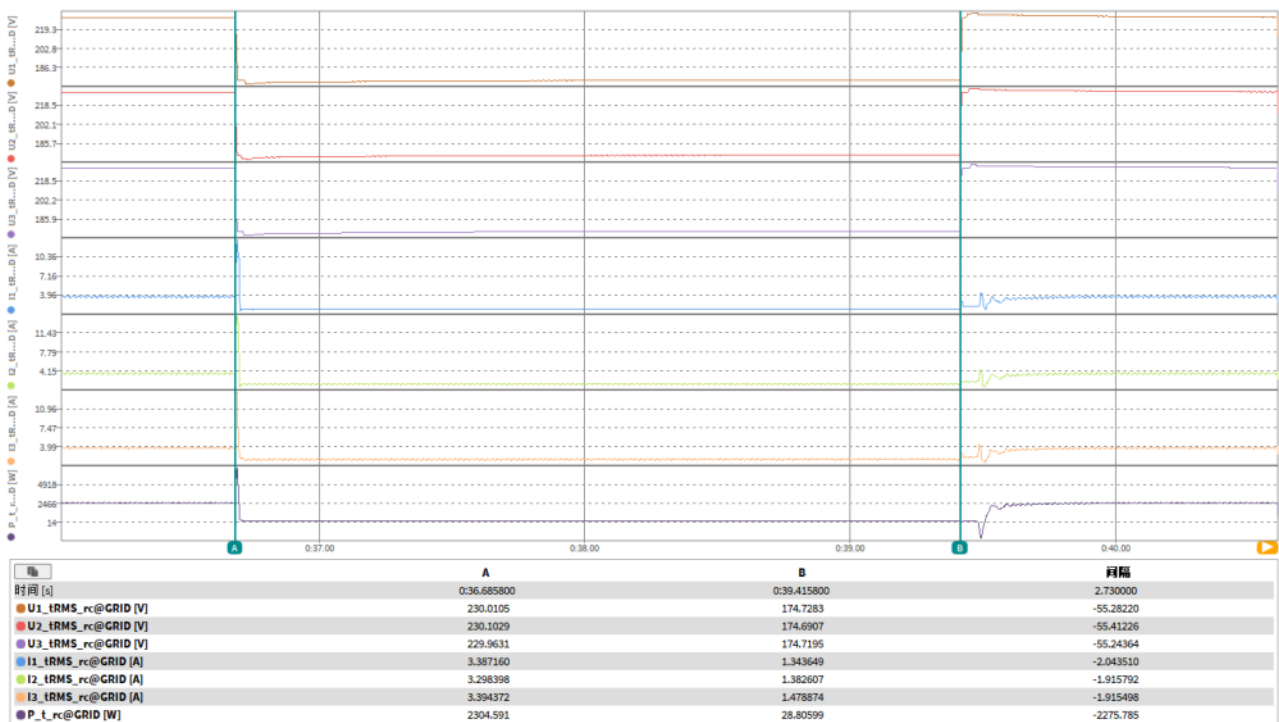


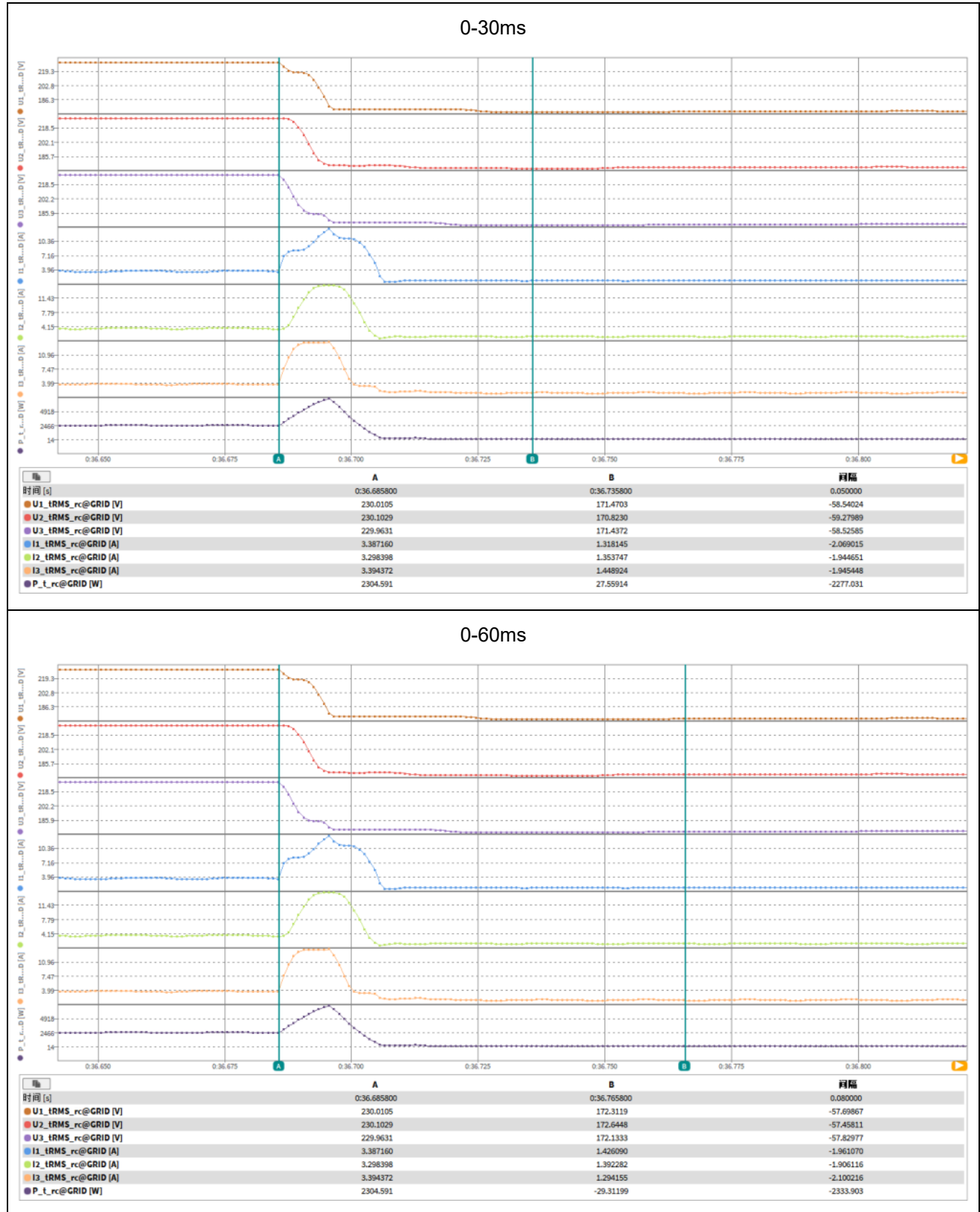
Test – VD4.2

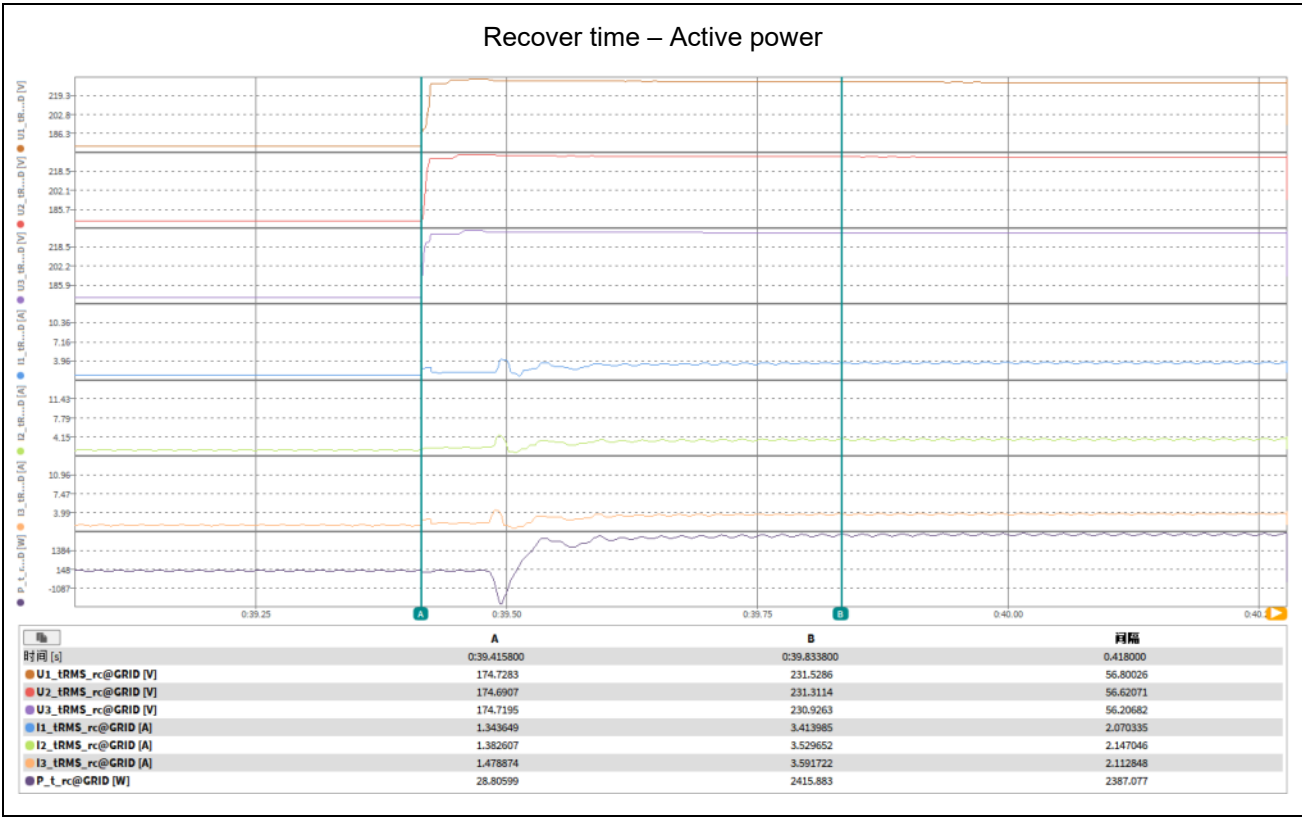
Before fault



Duration fault time

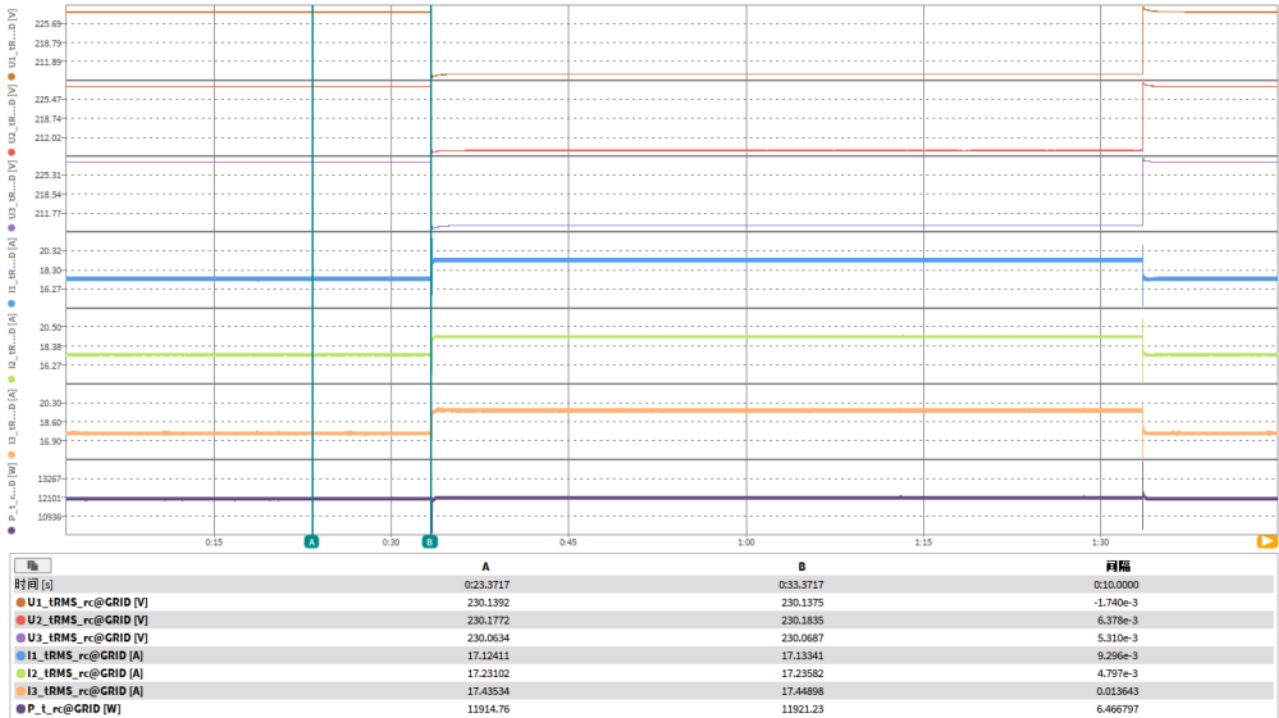




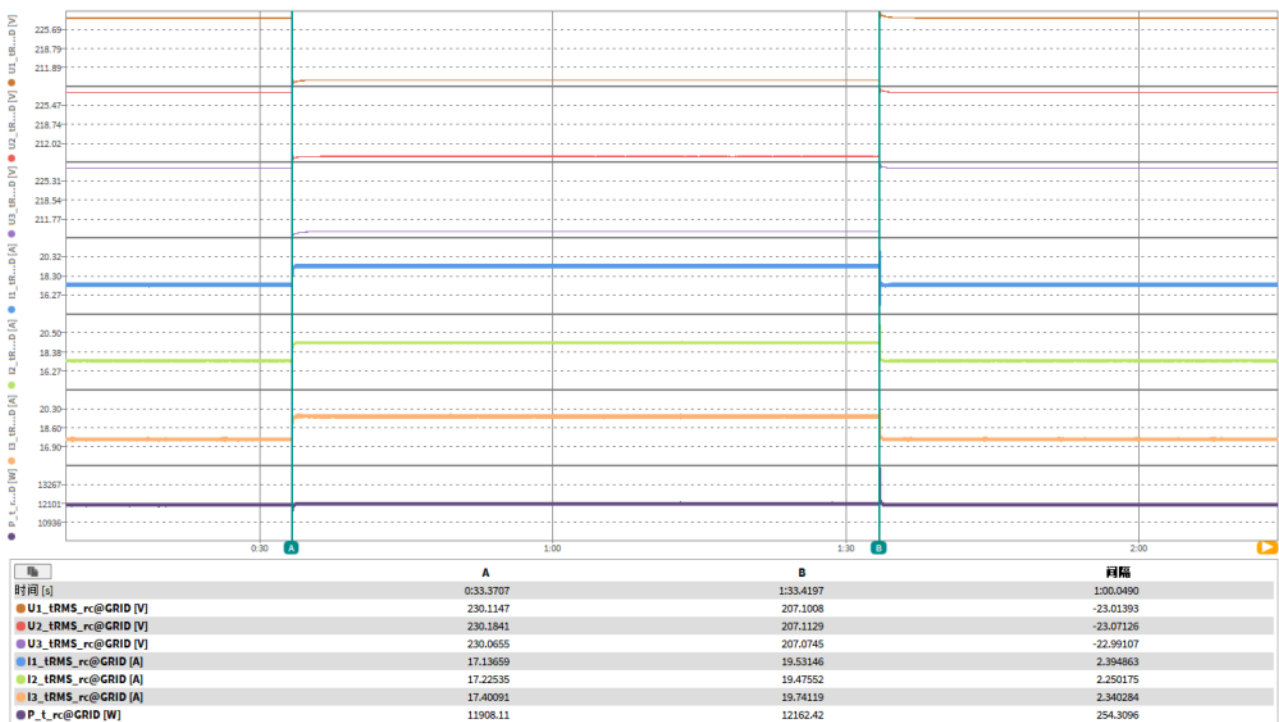


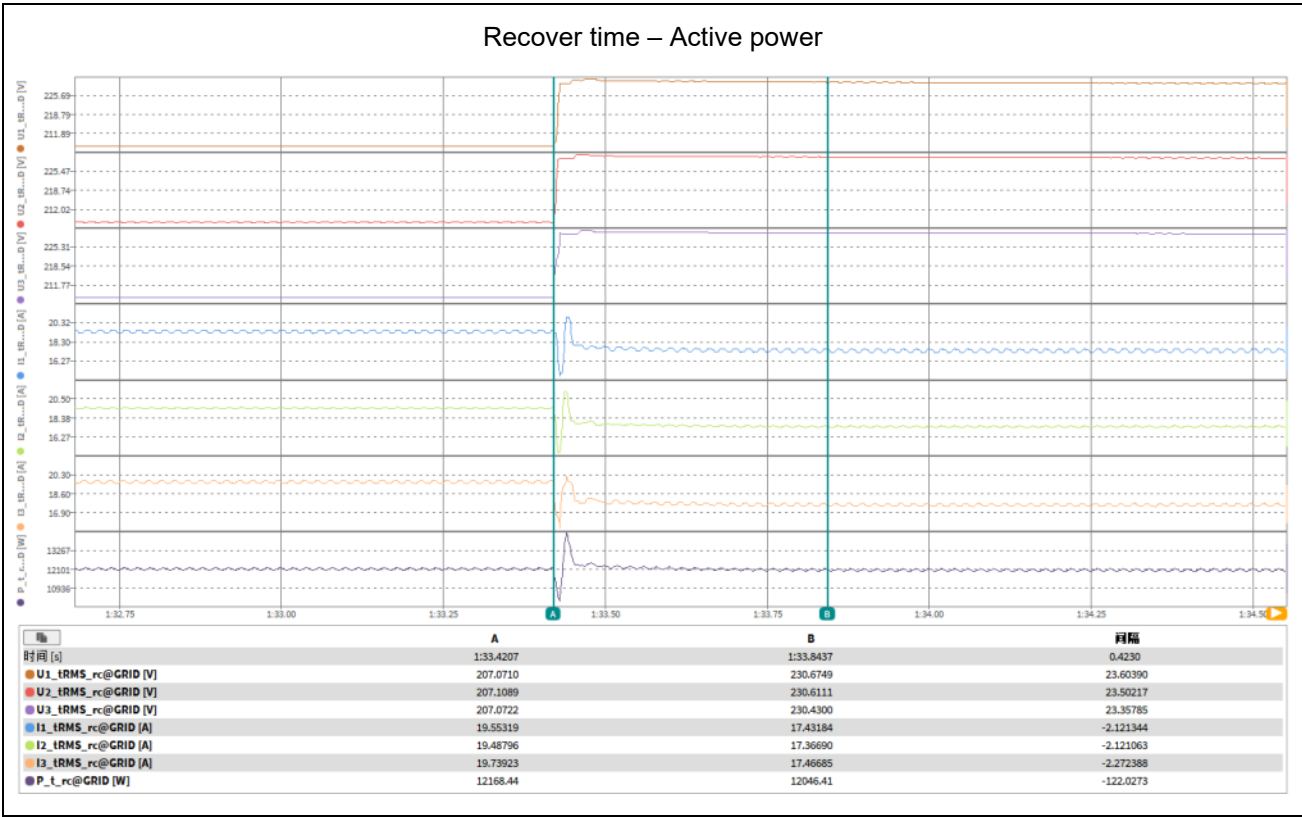
Test – VD5.1

Before fault



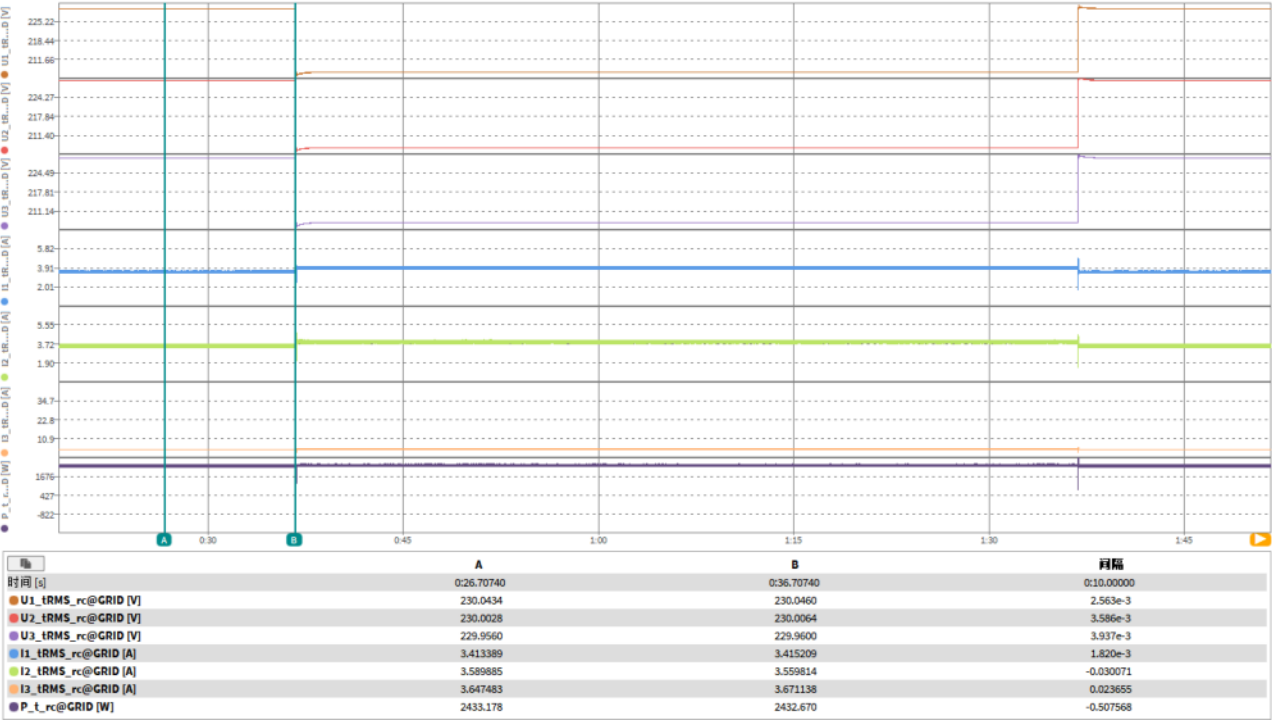
Duration fault time



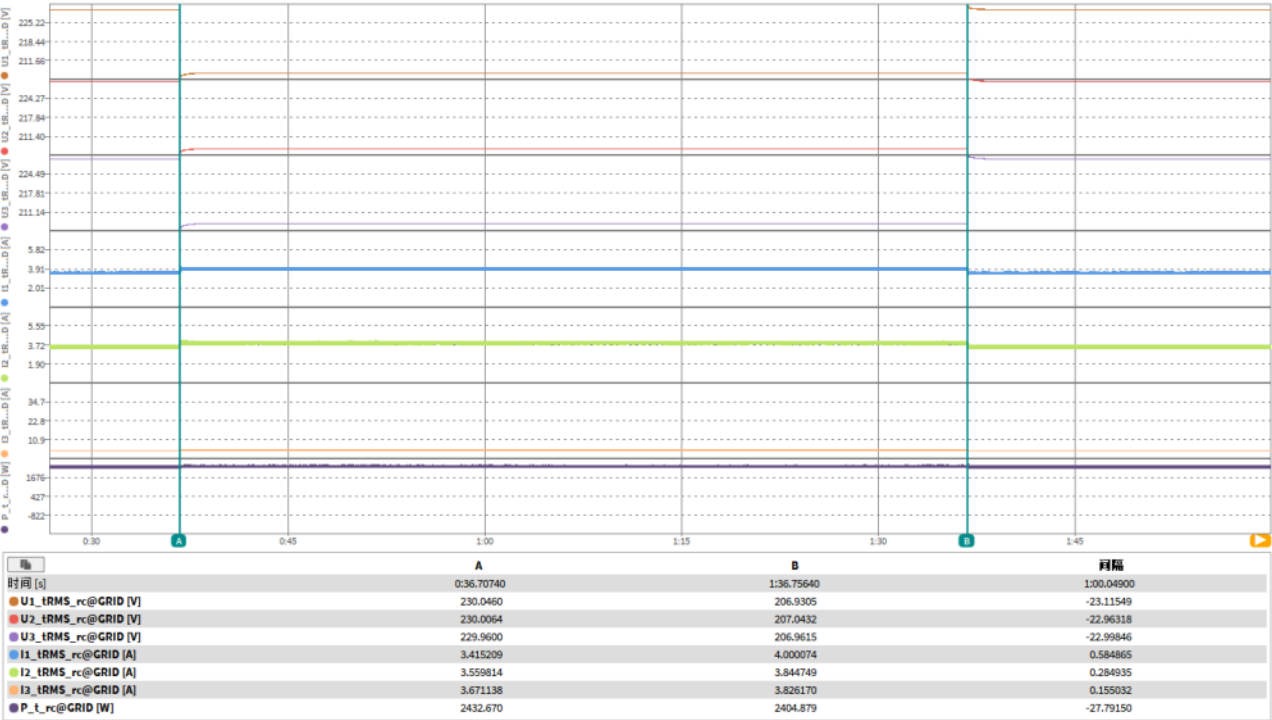


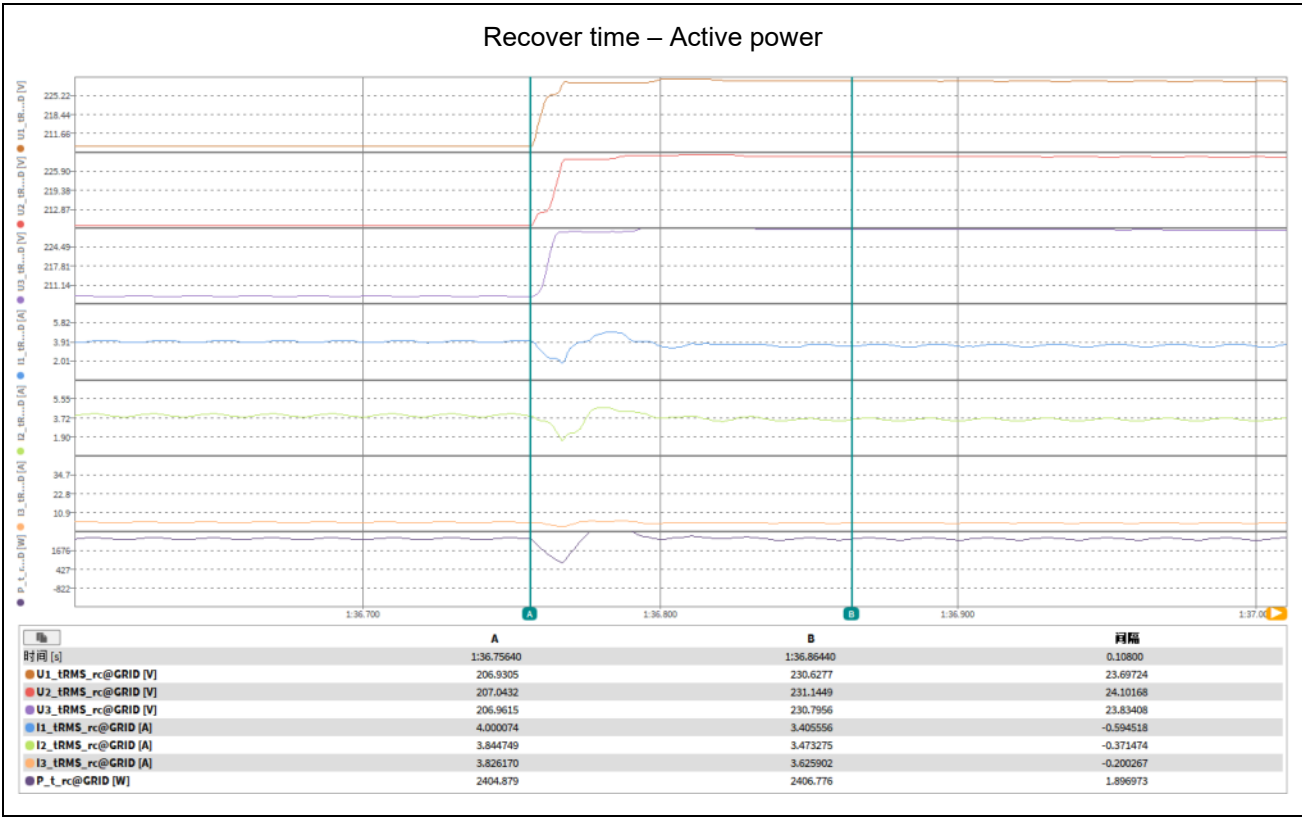
Test – VD5.2

Before fault



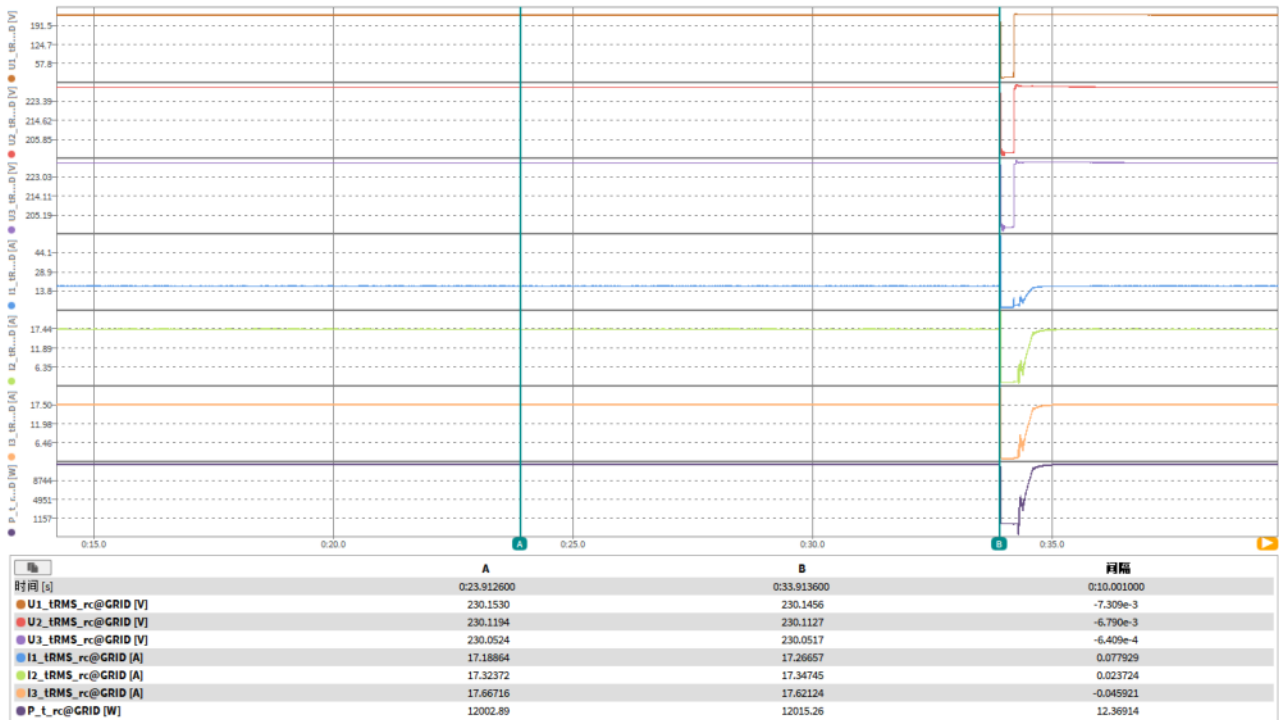
Duration fault time



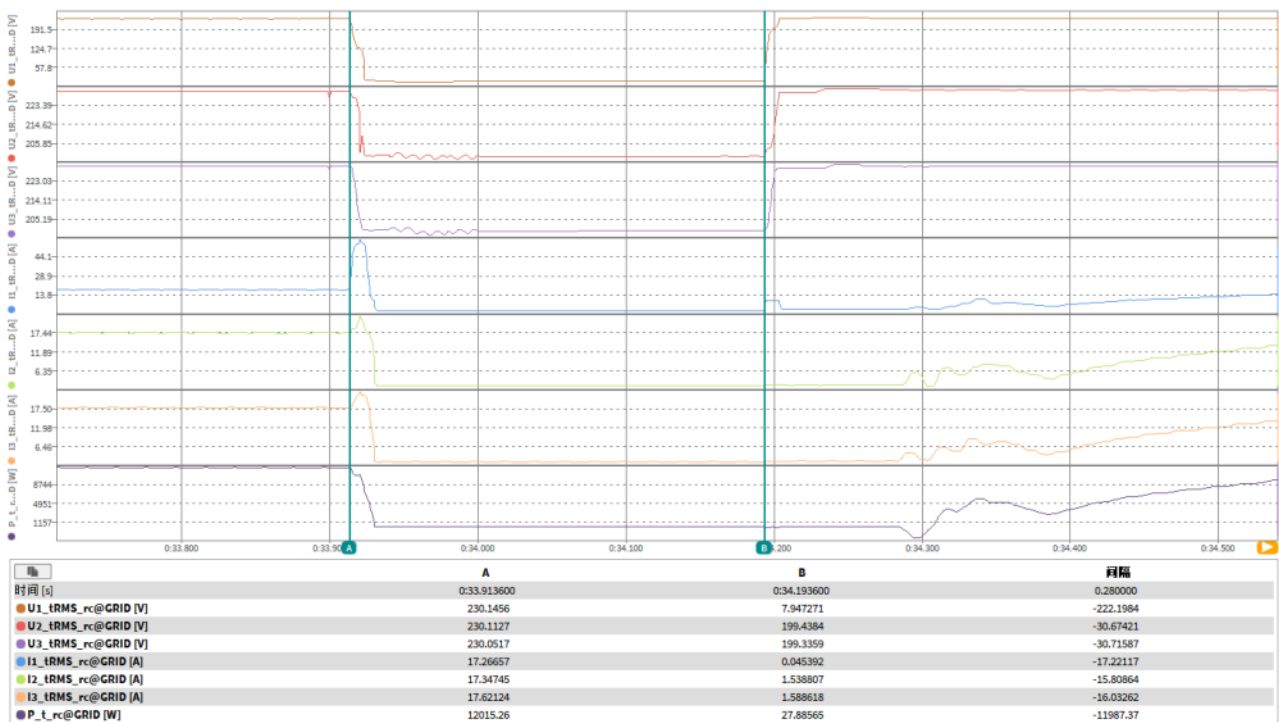


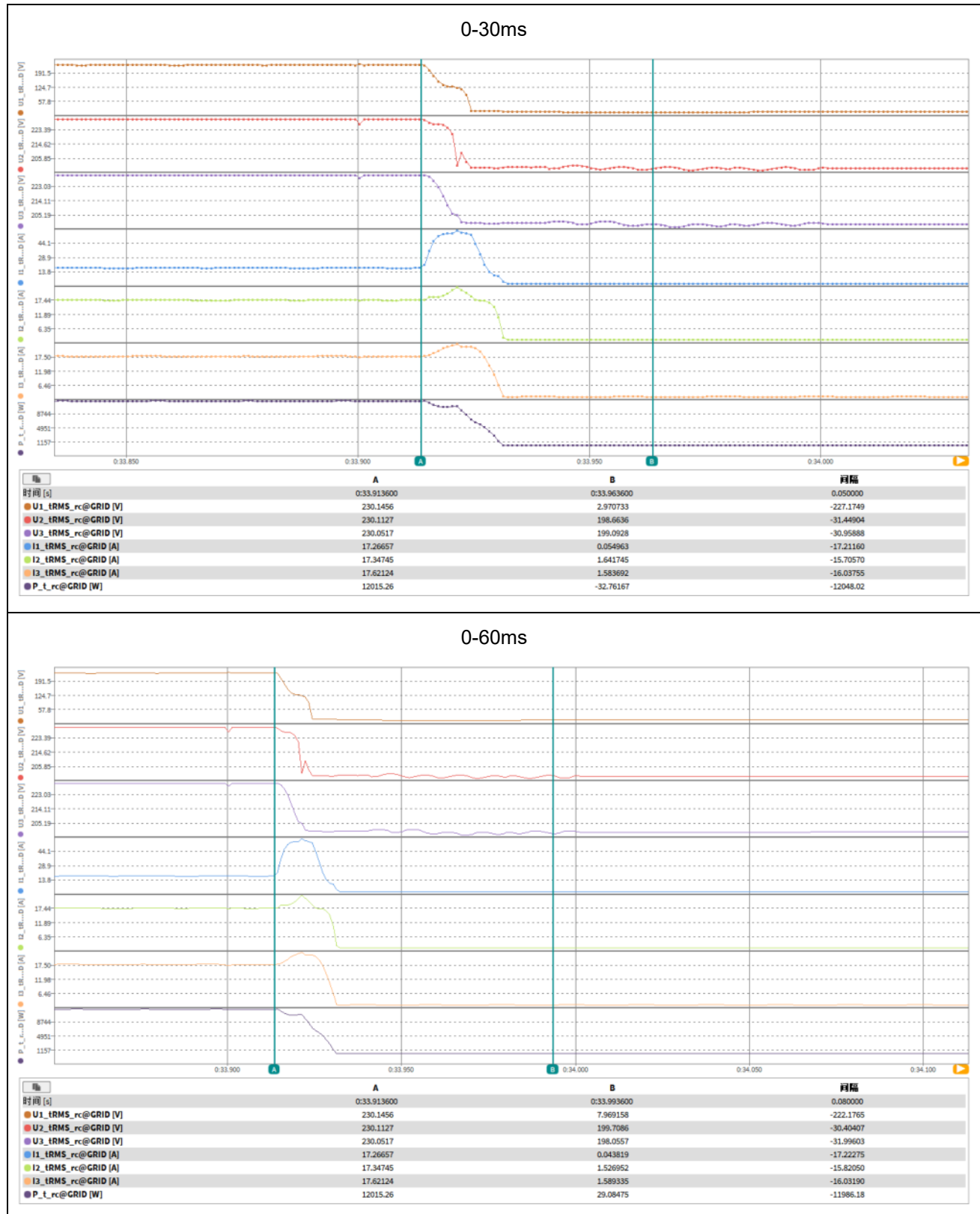
Test – VD6.1

Before fault



Duration fault time

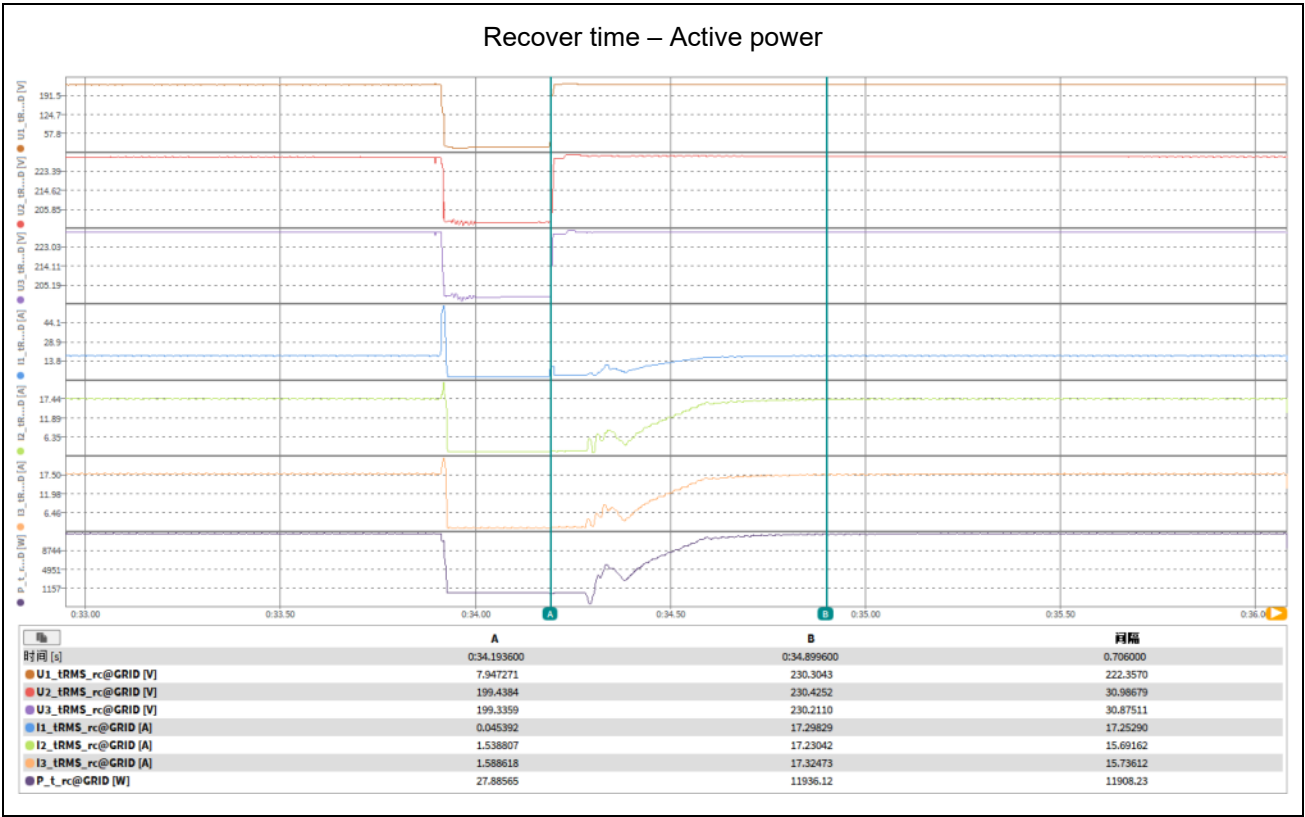




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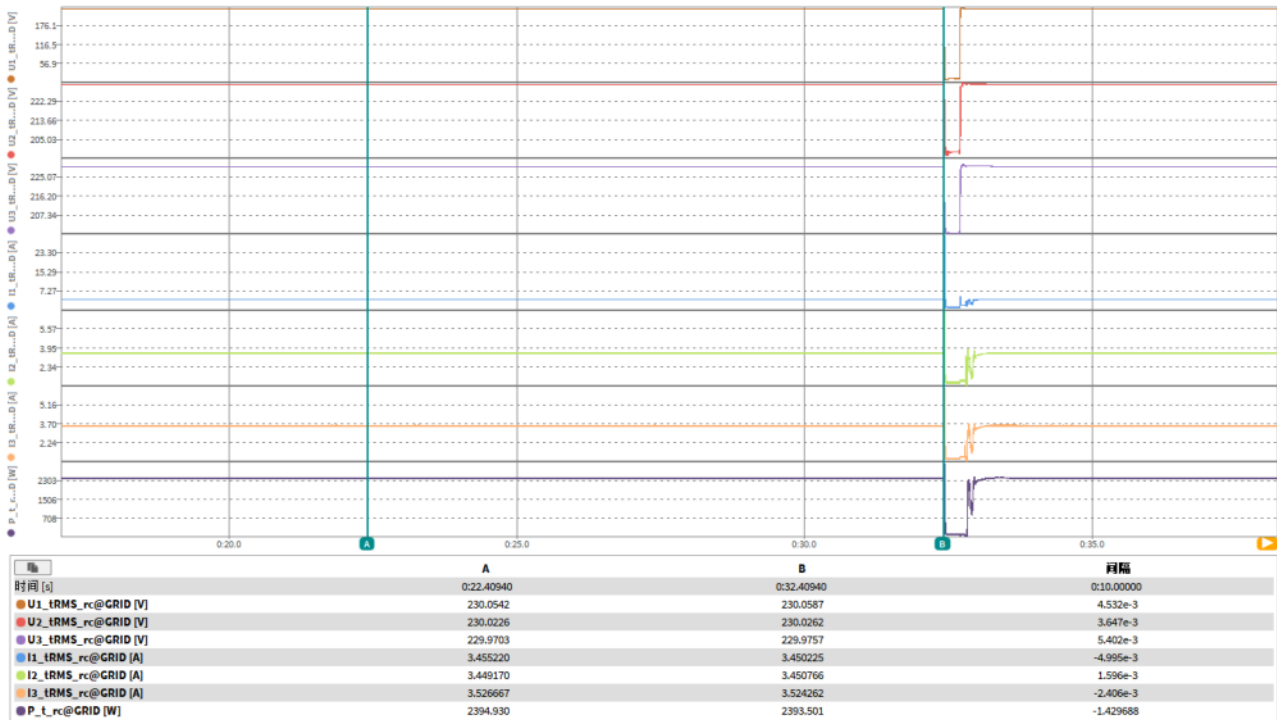
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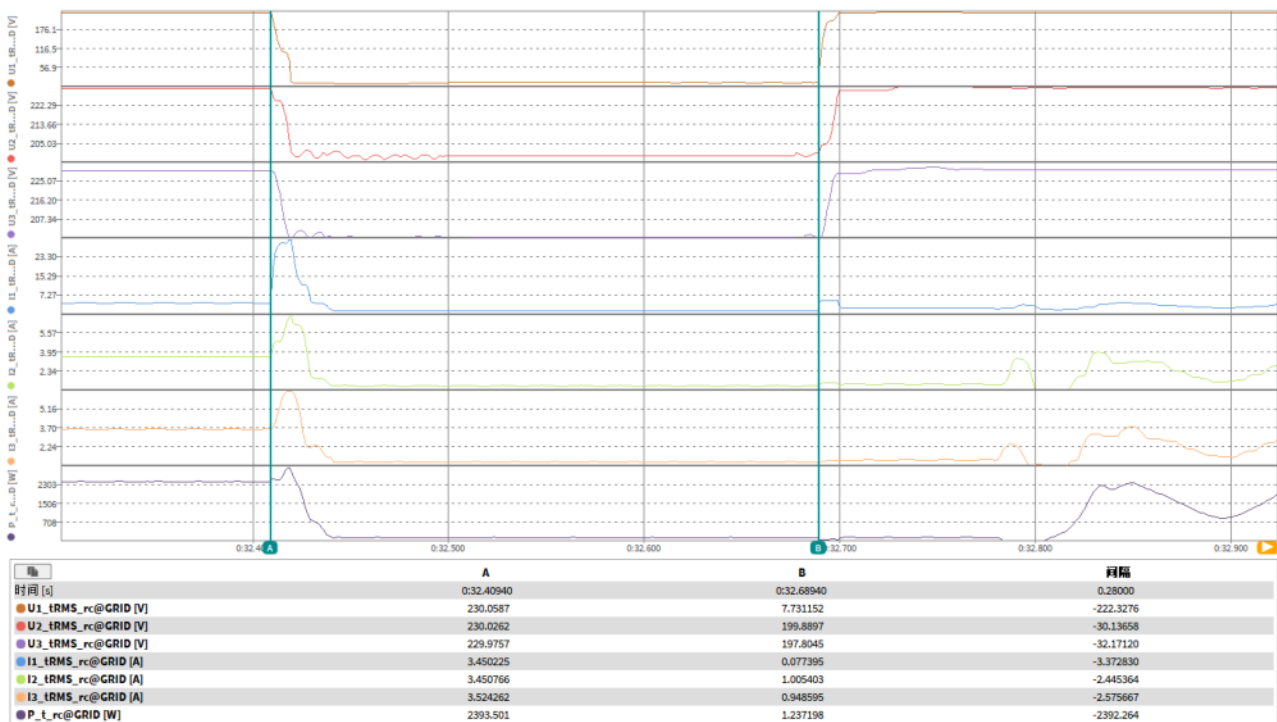


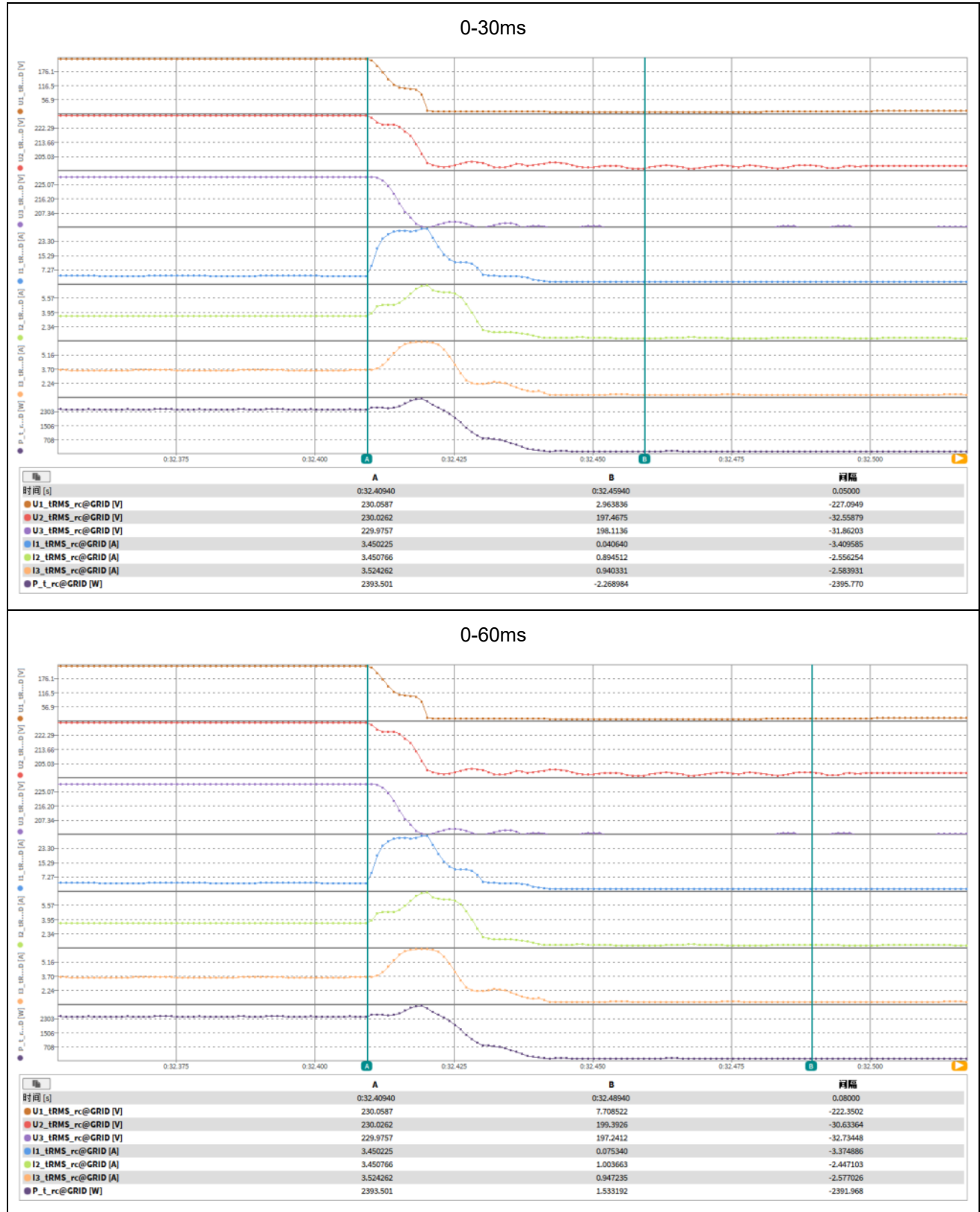
Test – VD6.2

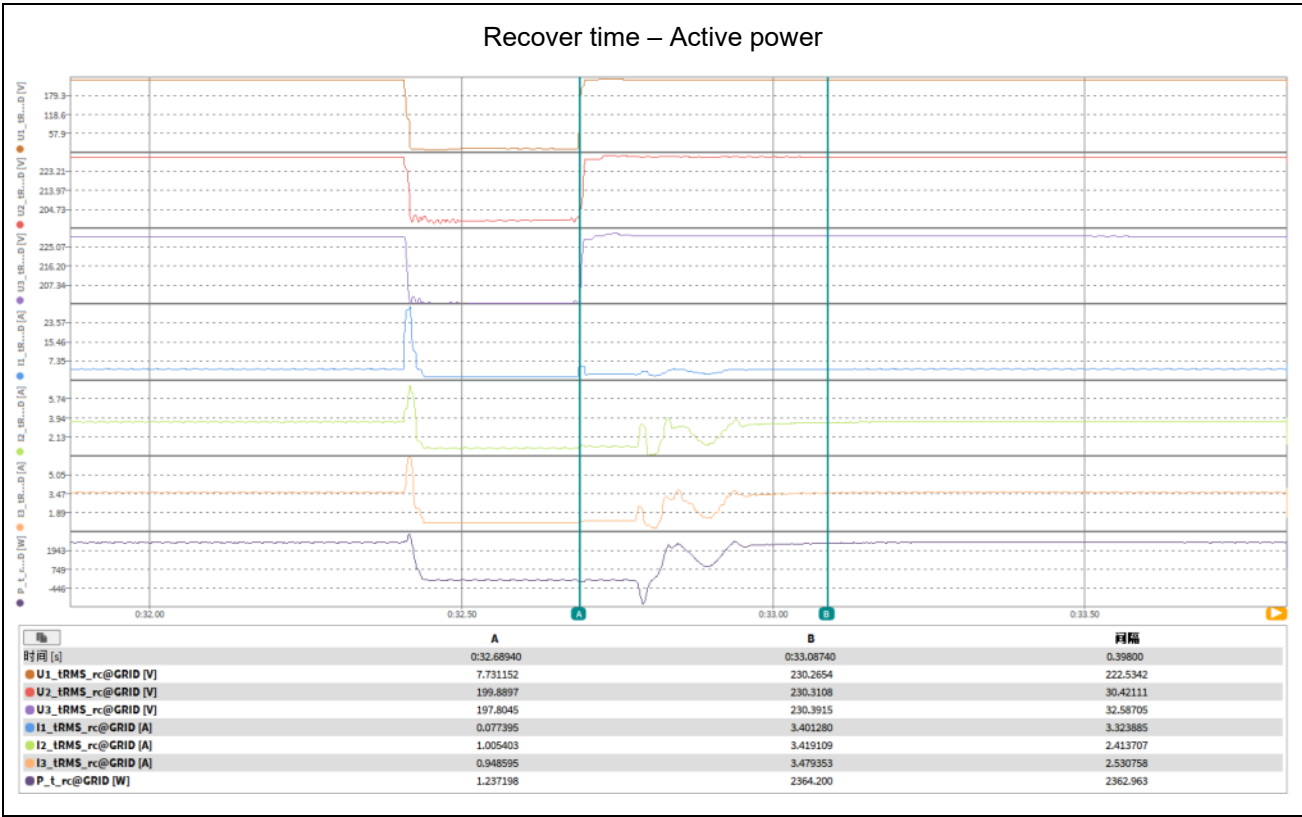
Before fault

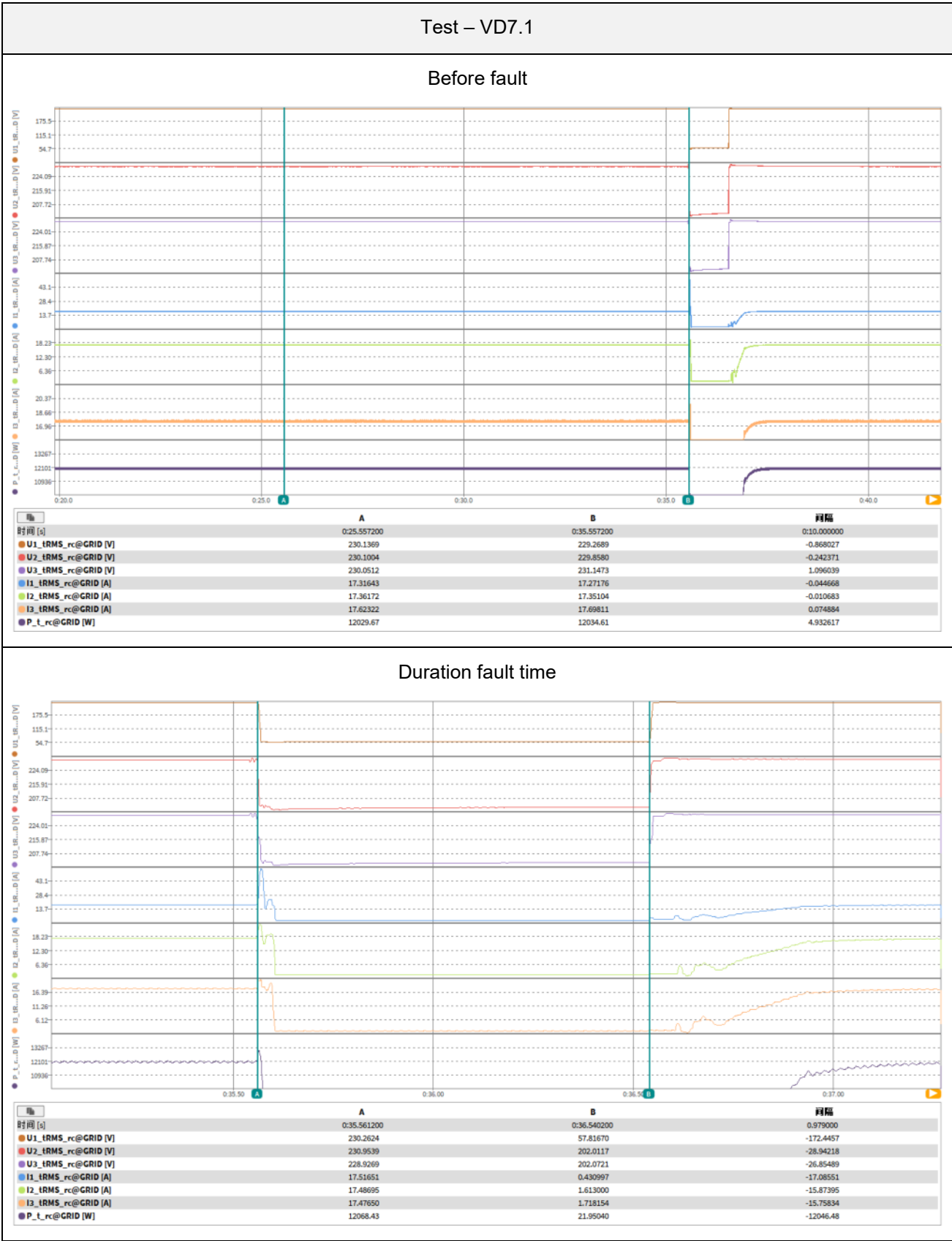


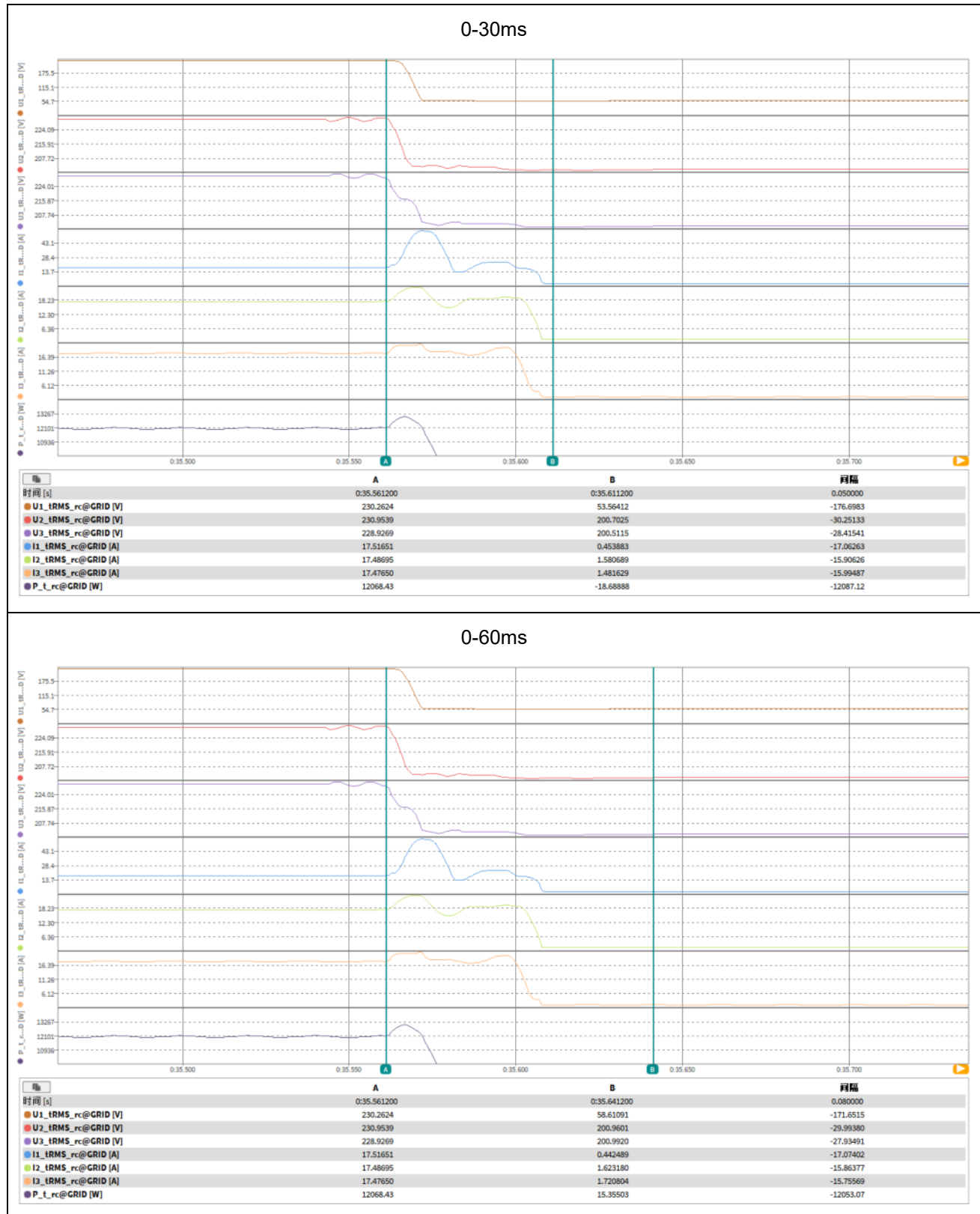
Duration fault time

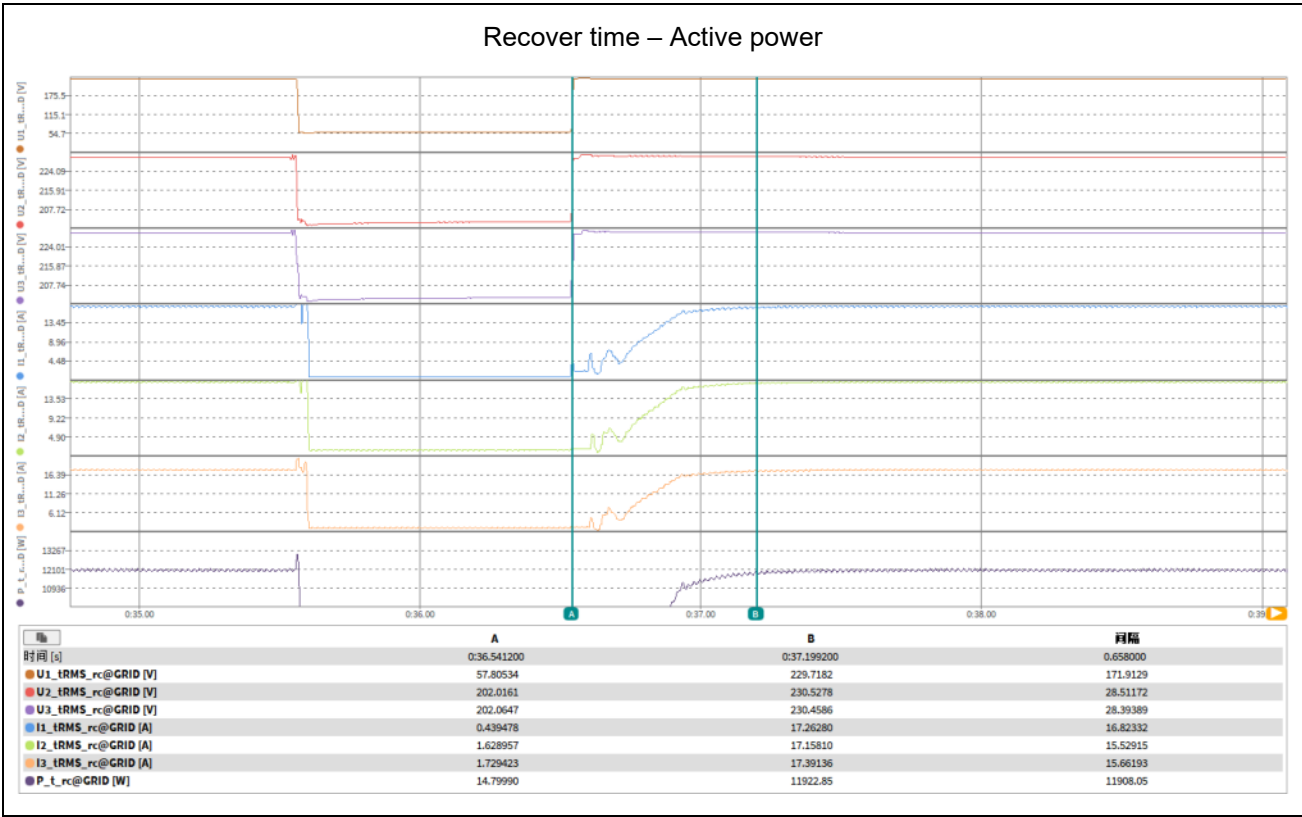






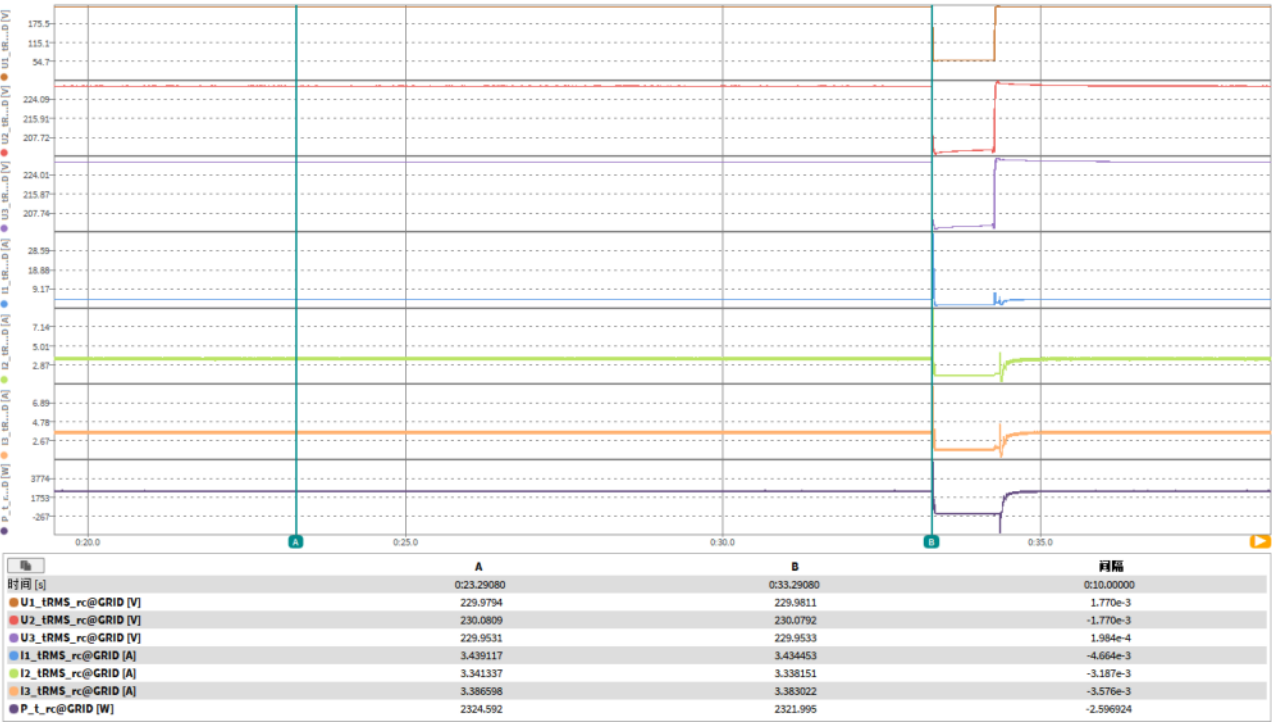




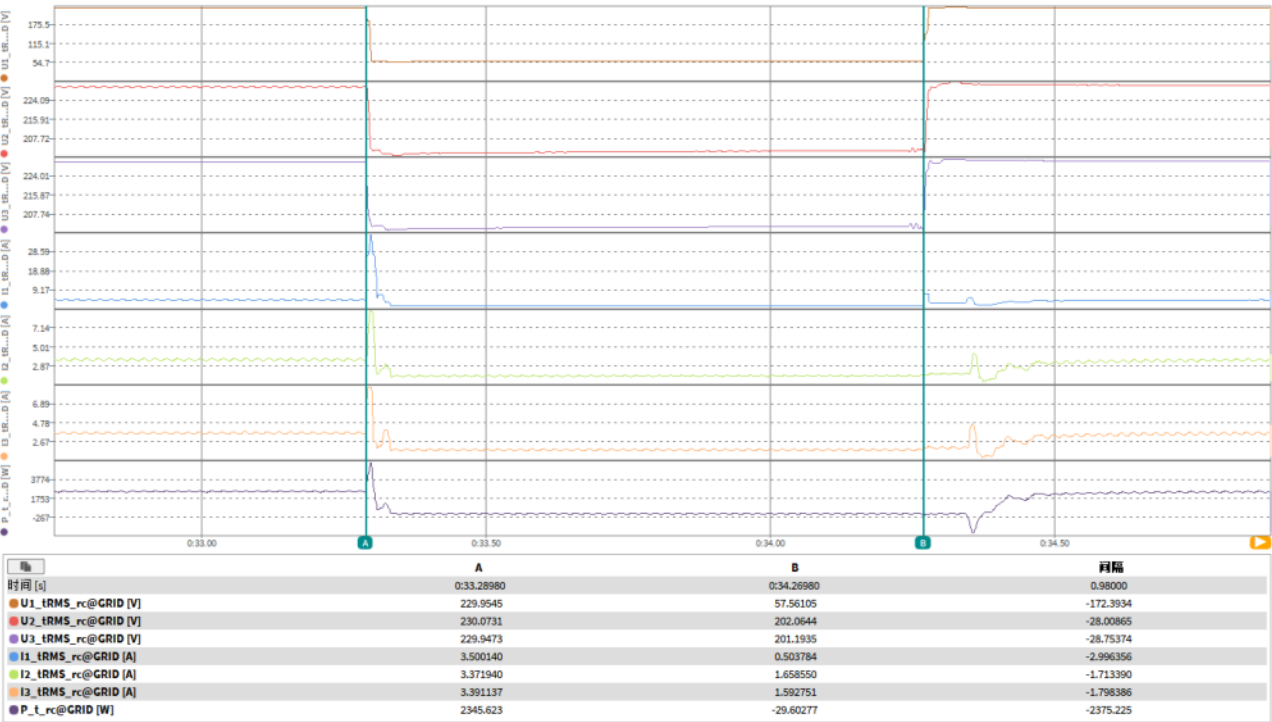


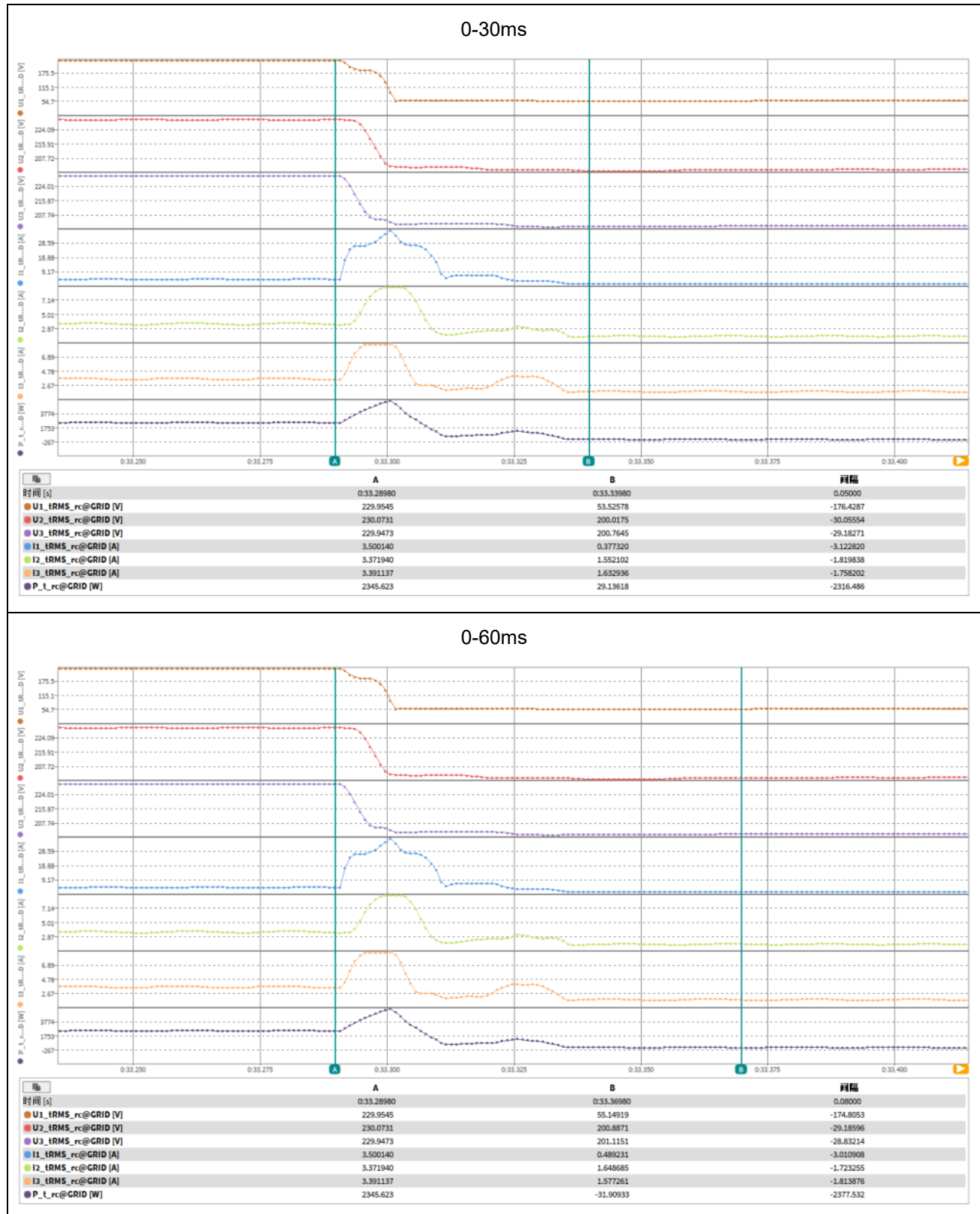
Test – VD7.2

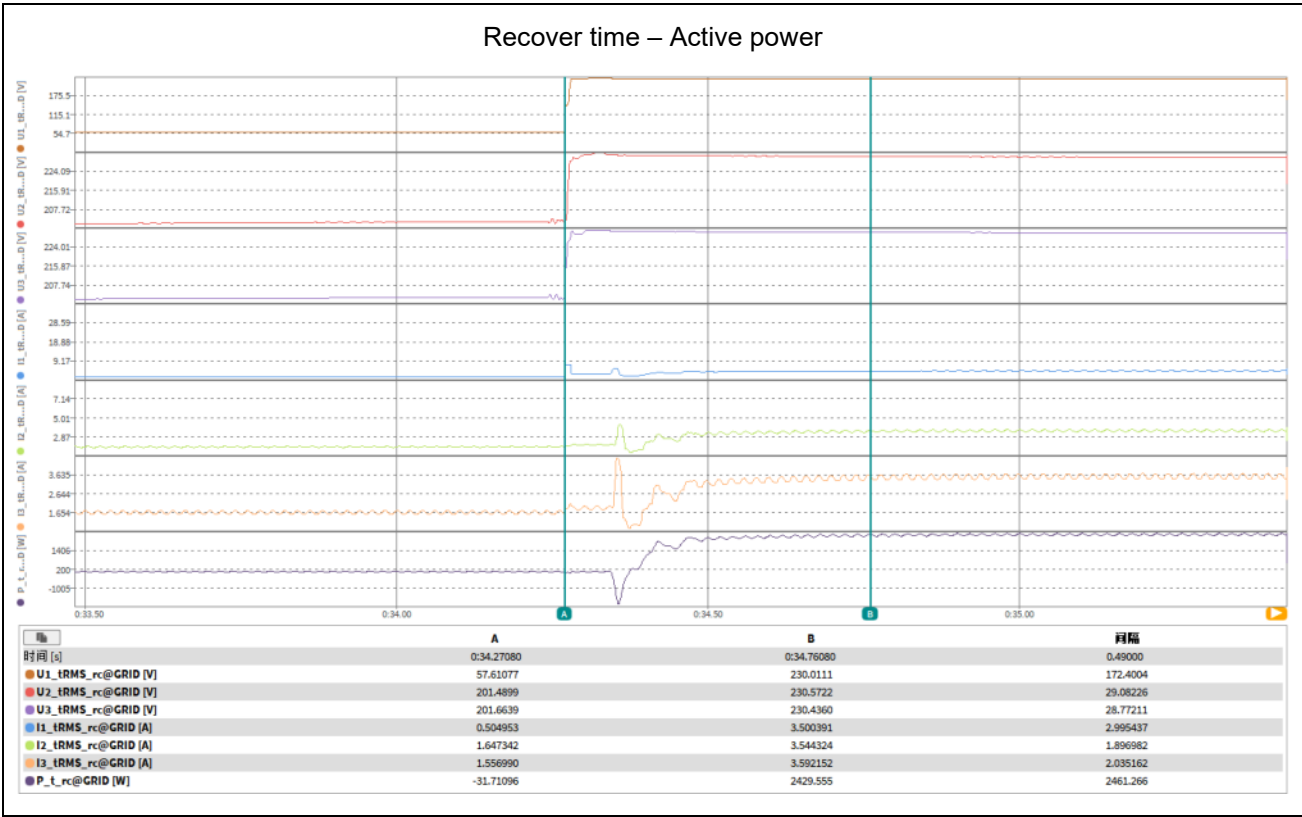
Before fault



Duration fault time







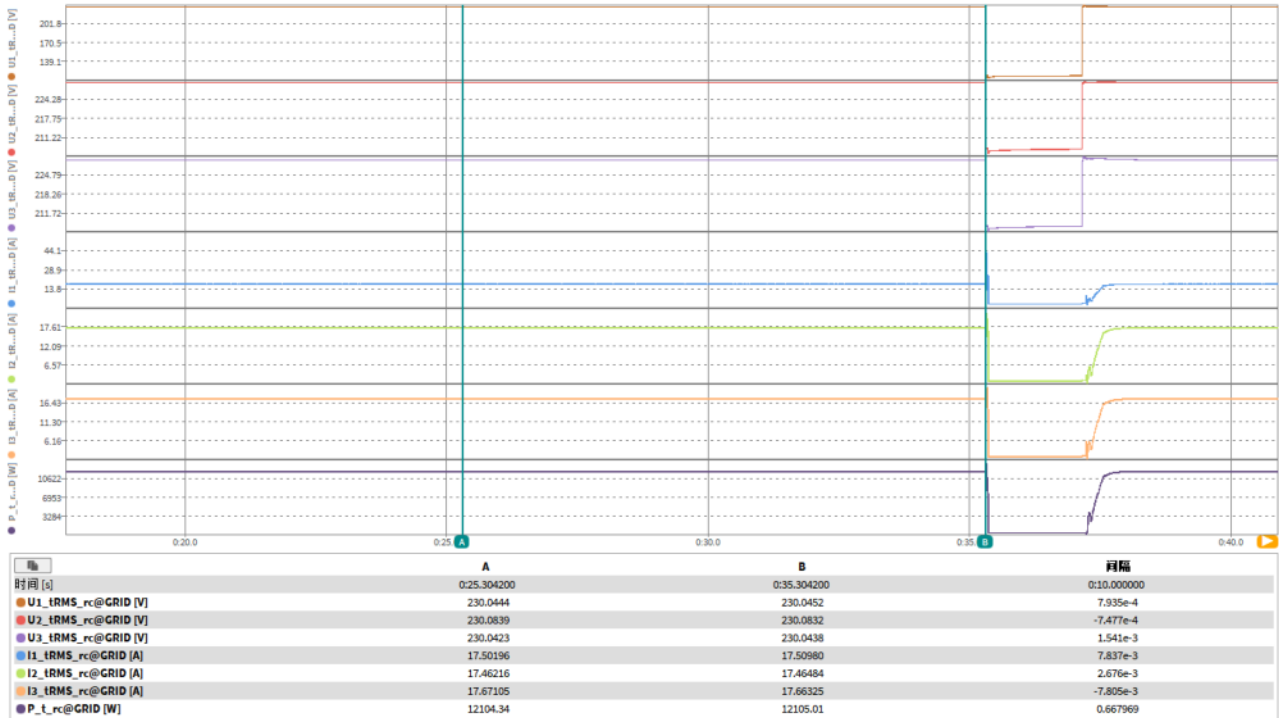
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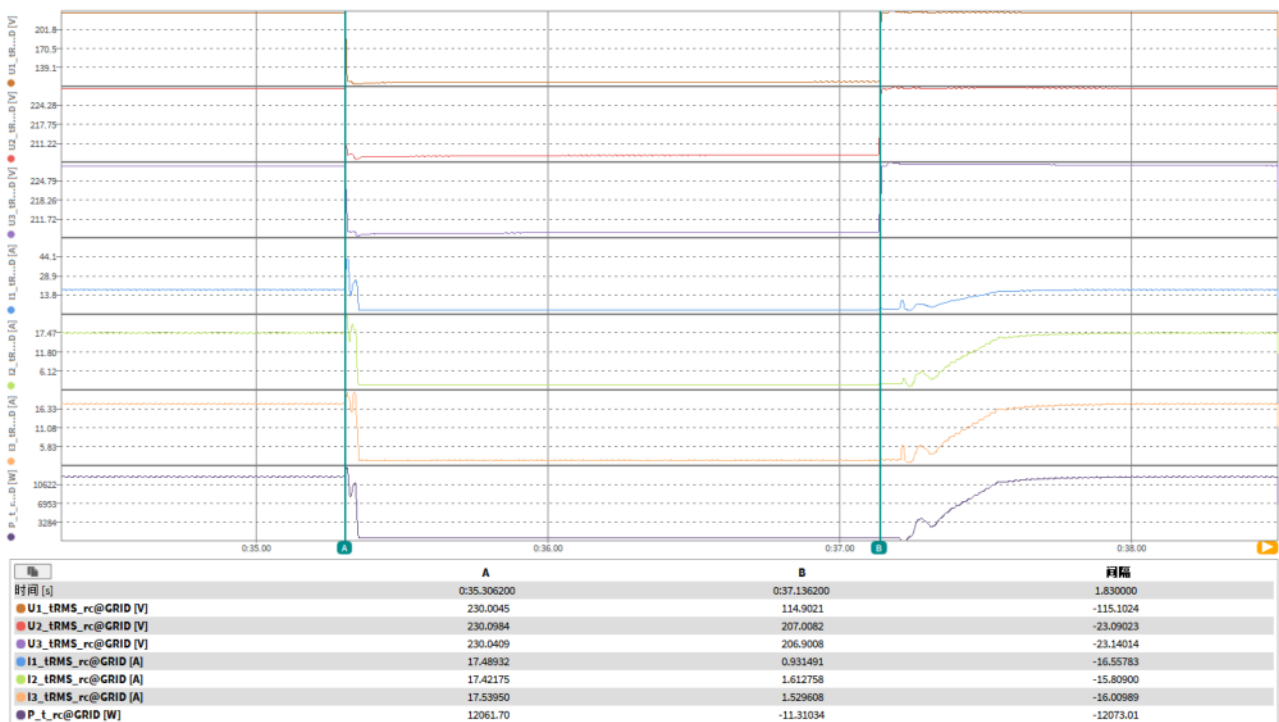
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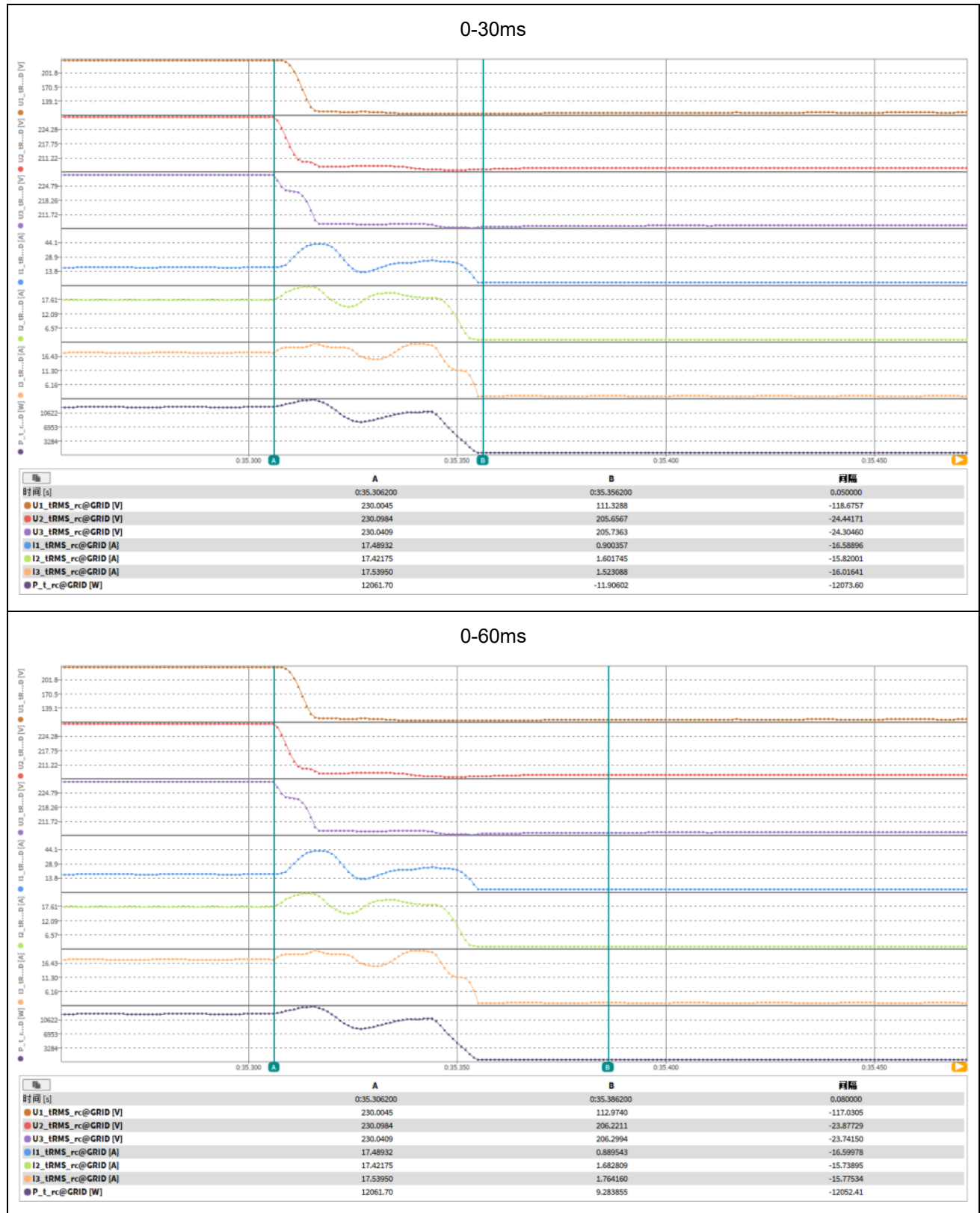
Test – VD8.1

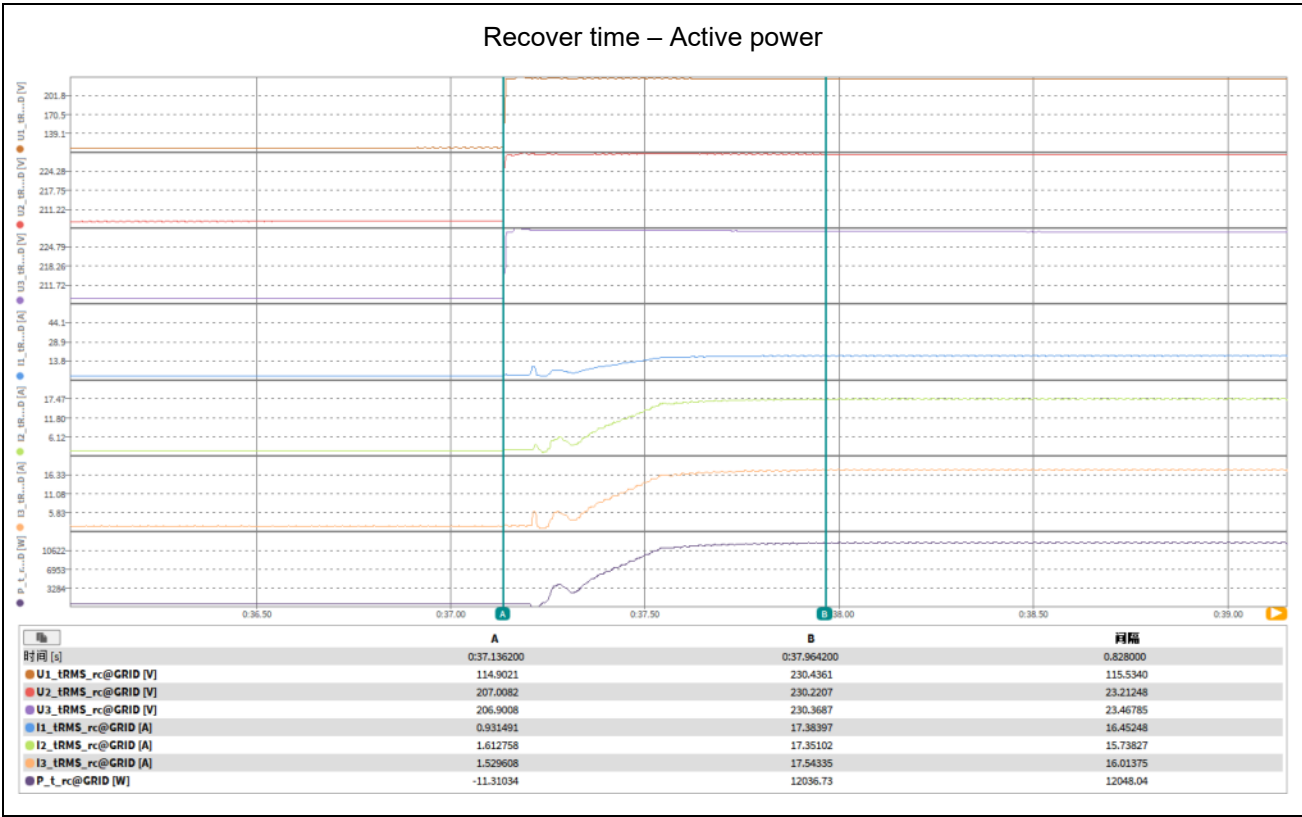
Before fault



Duration fault time







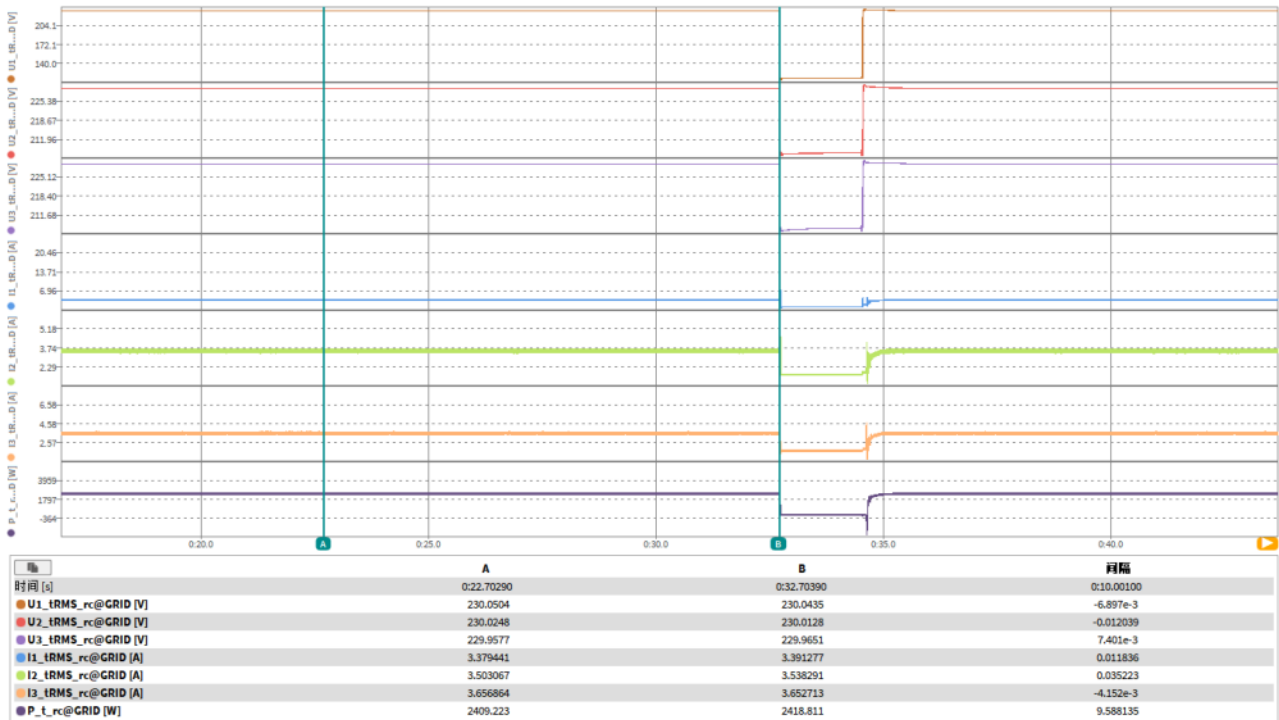
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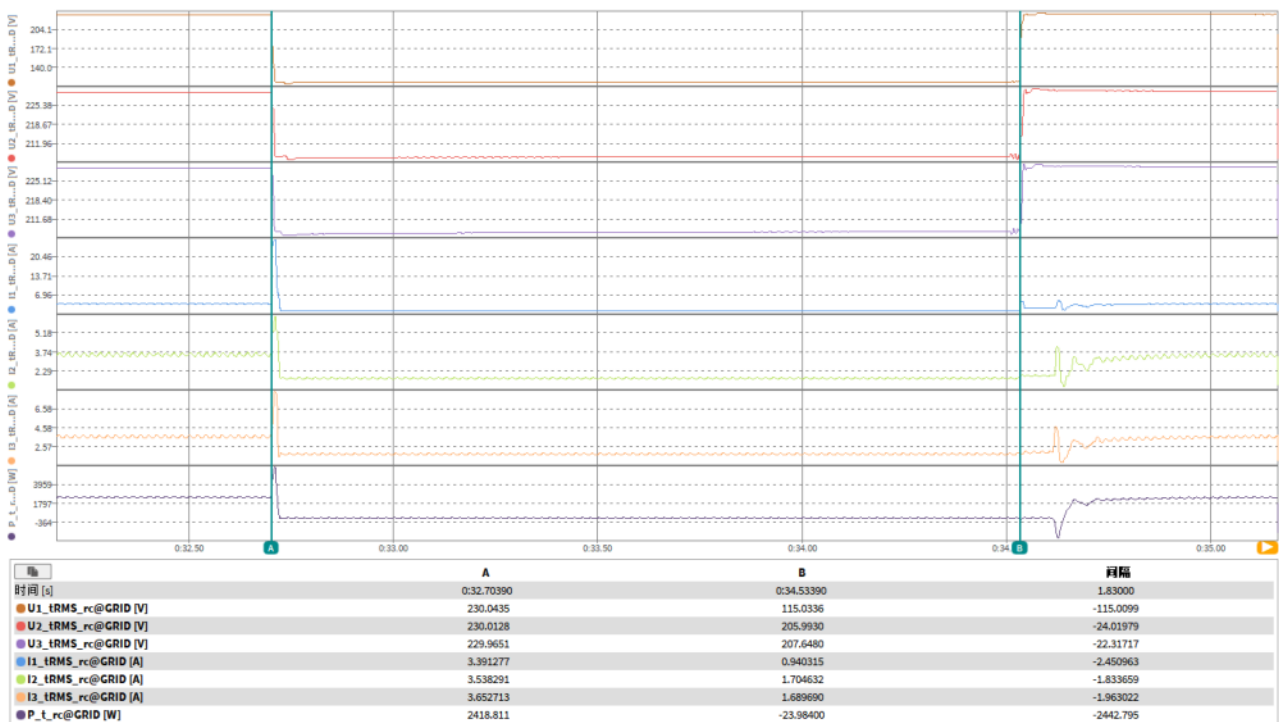
Test Report No.: RDPVP02041/26E/02

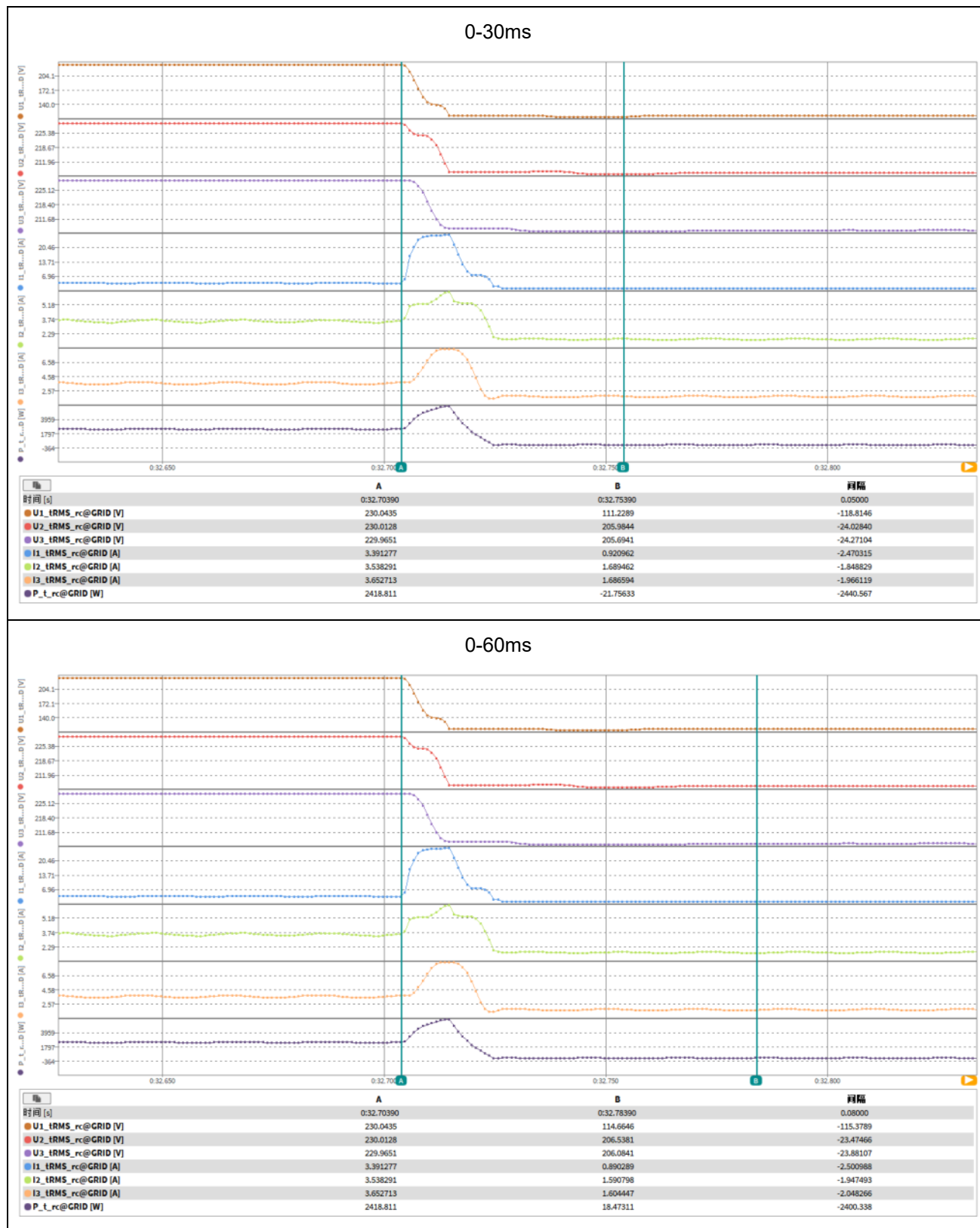
Test – VD8.2

Before fault



Duration fault time

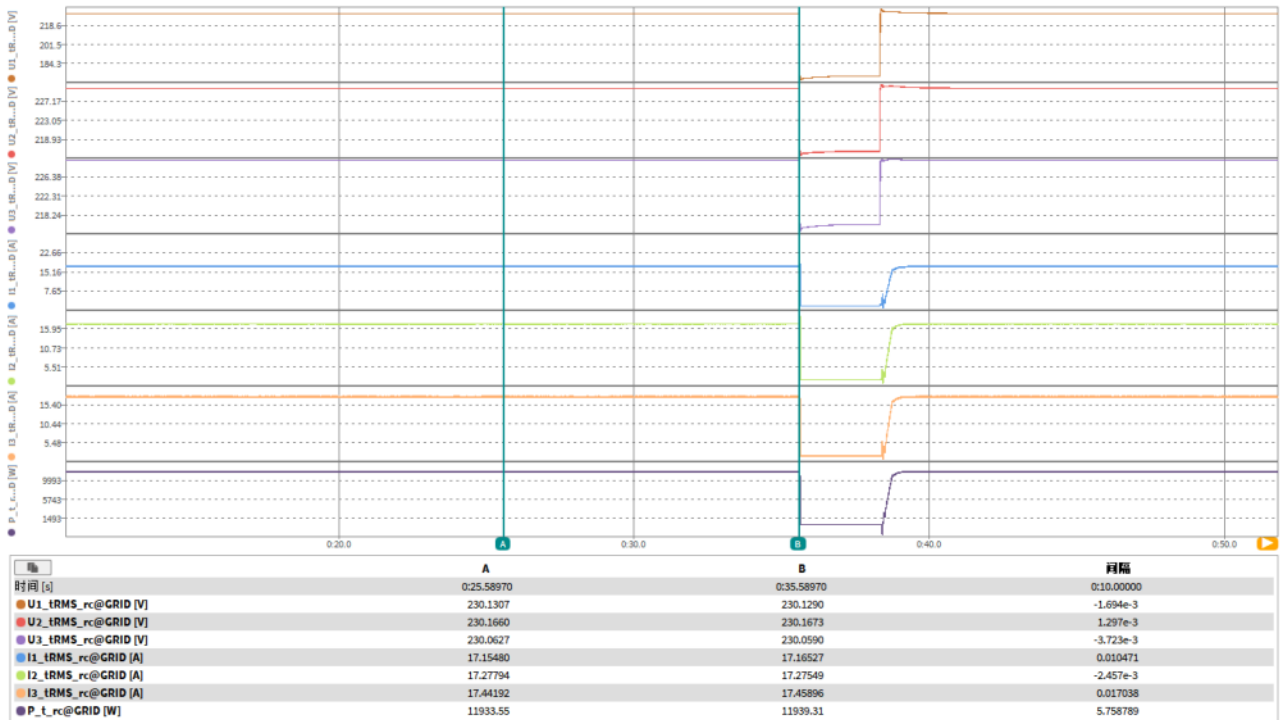




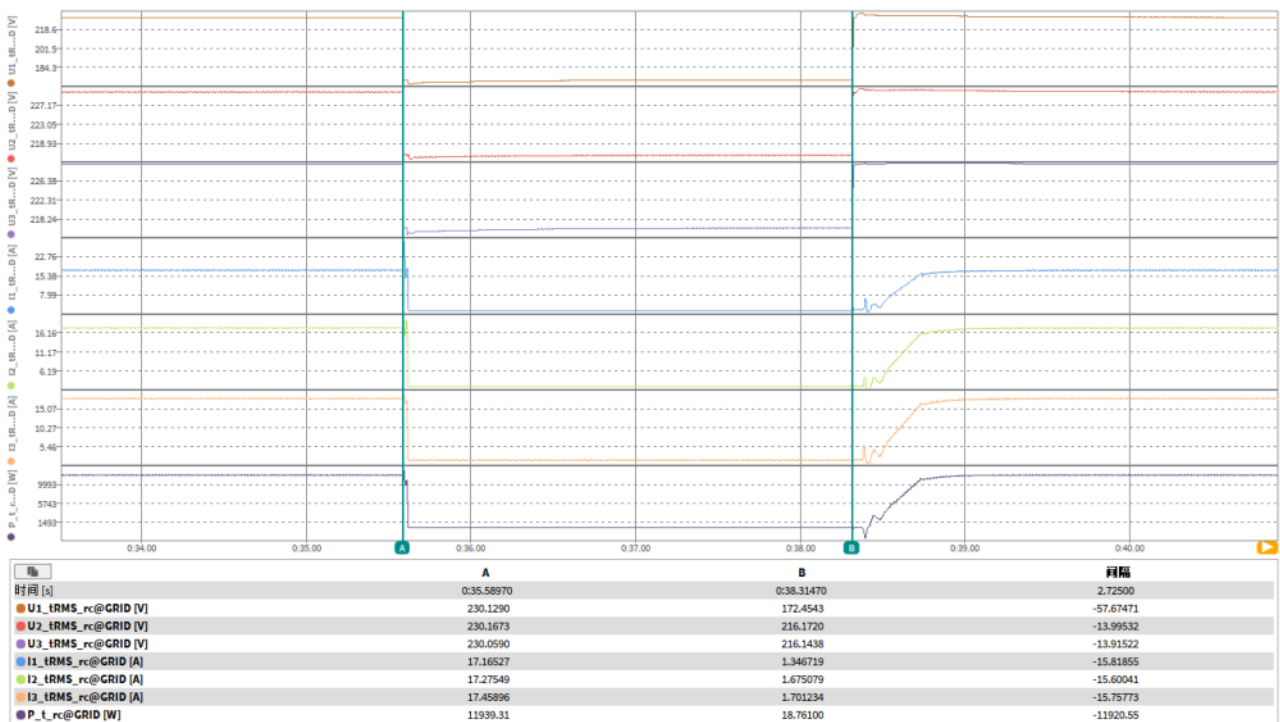


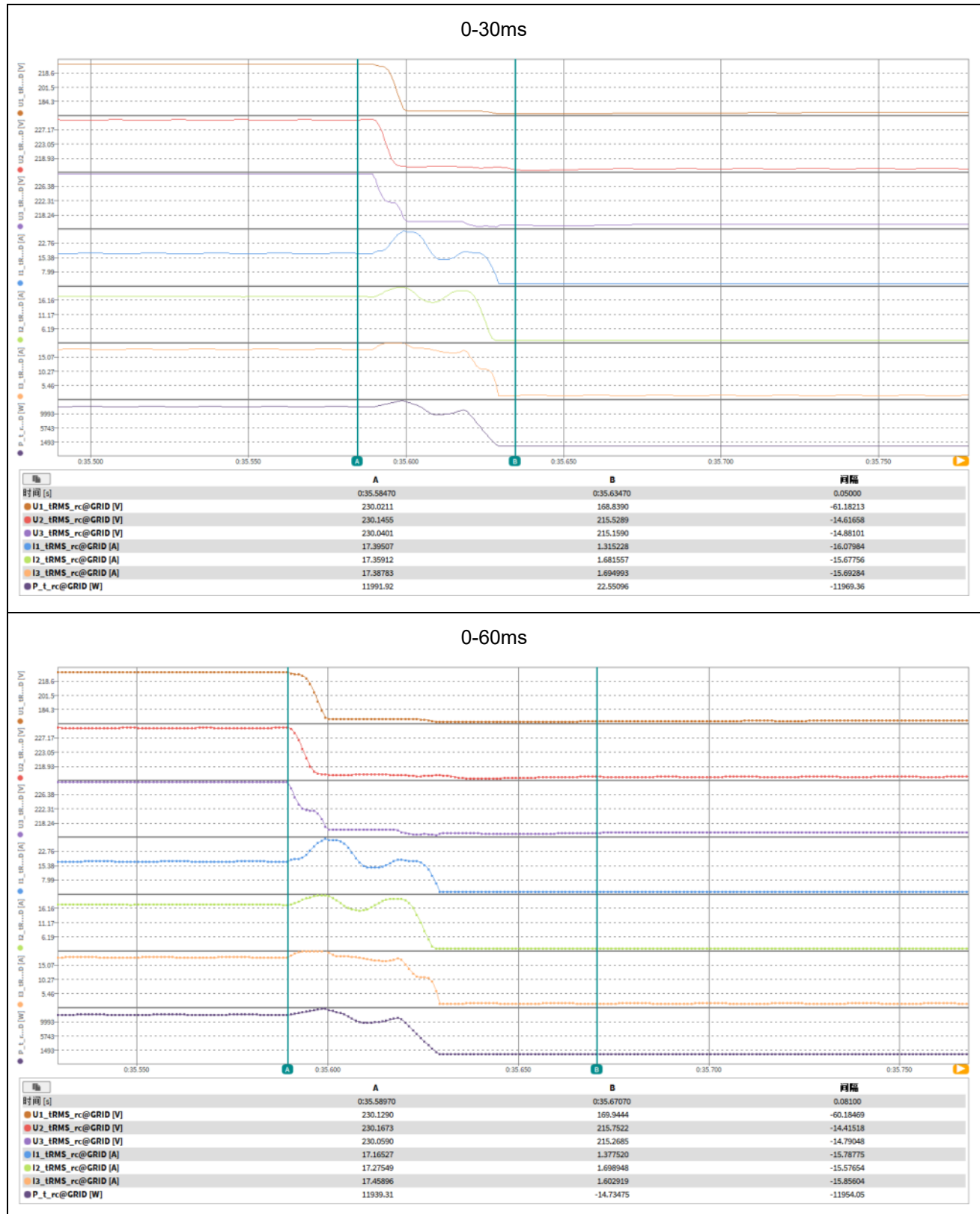
Test – VD9.1

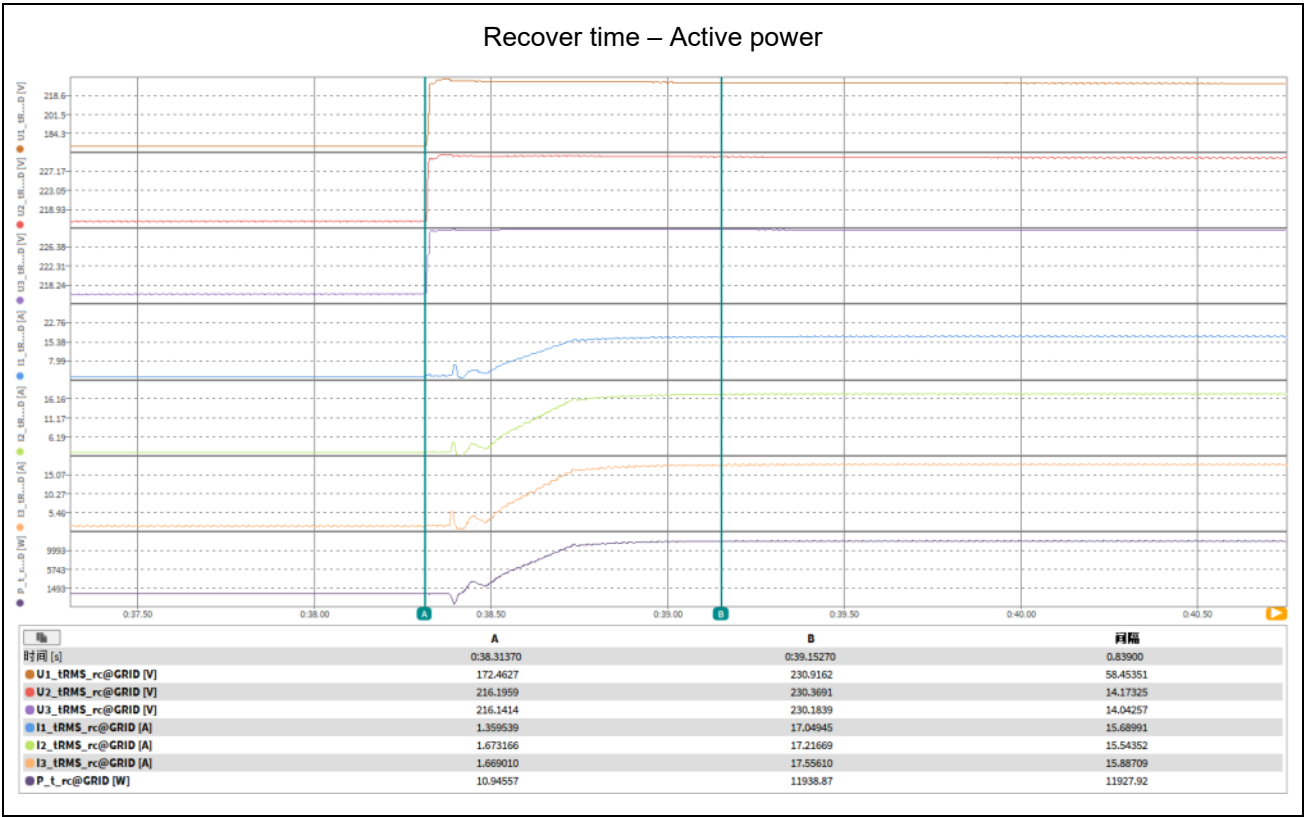
Before fault



Duration fault time

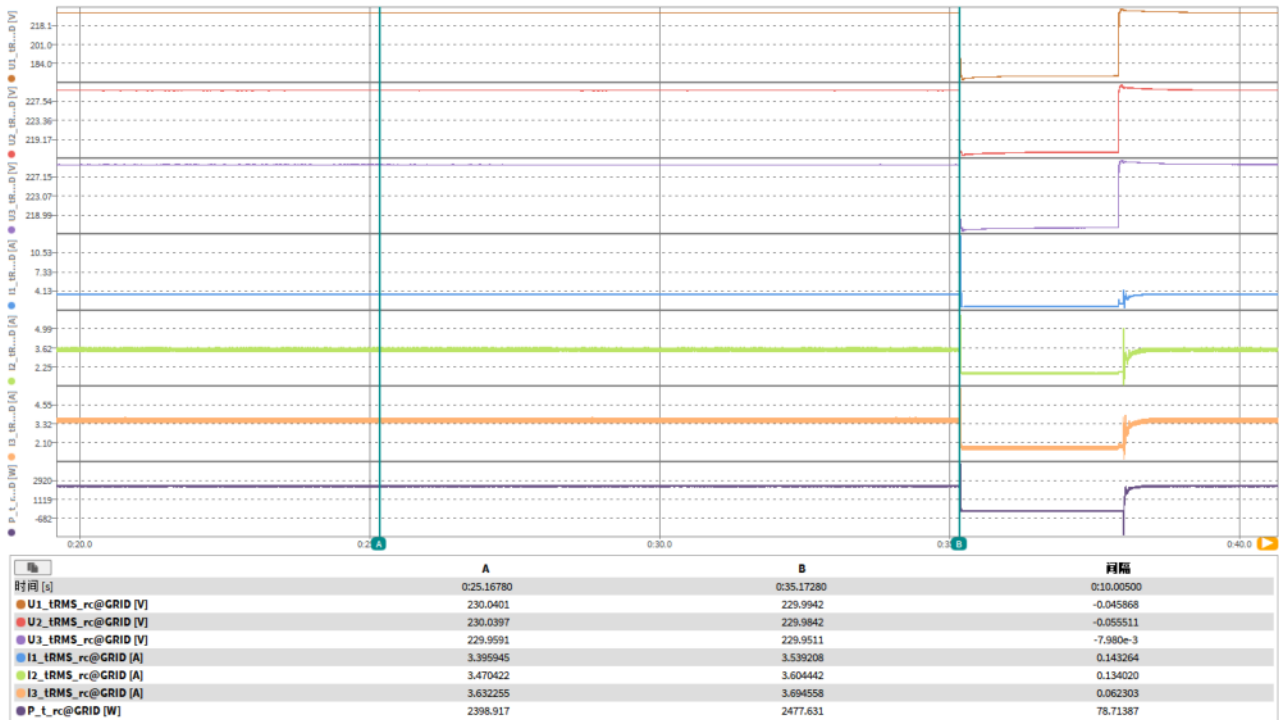




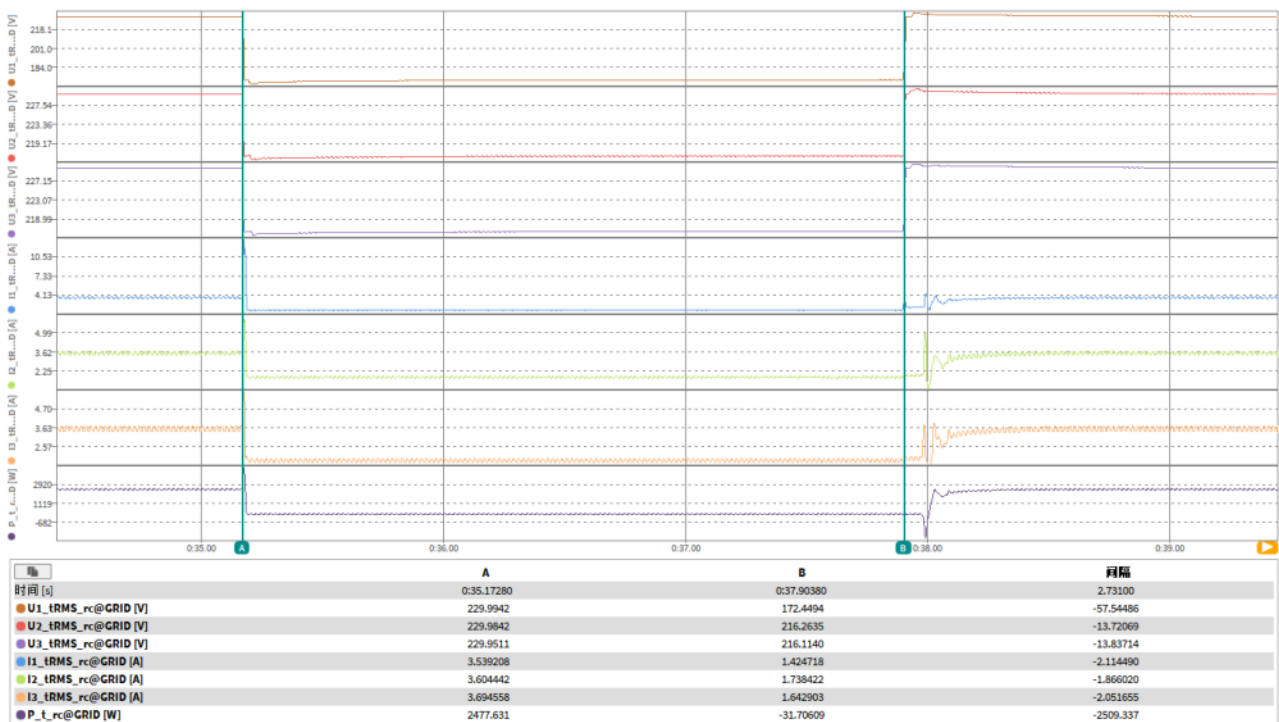


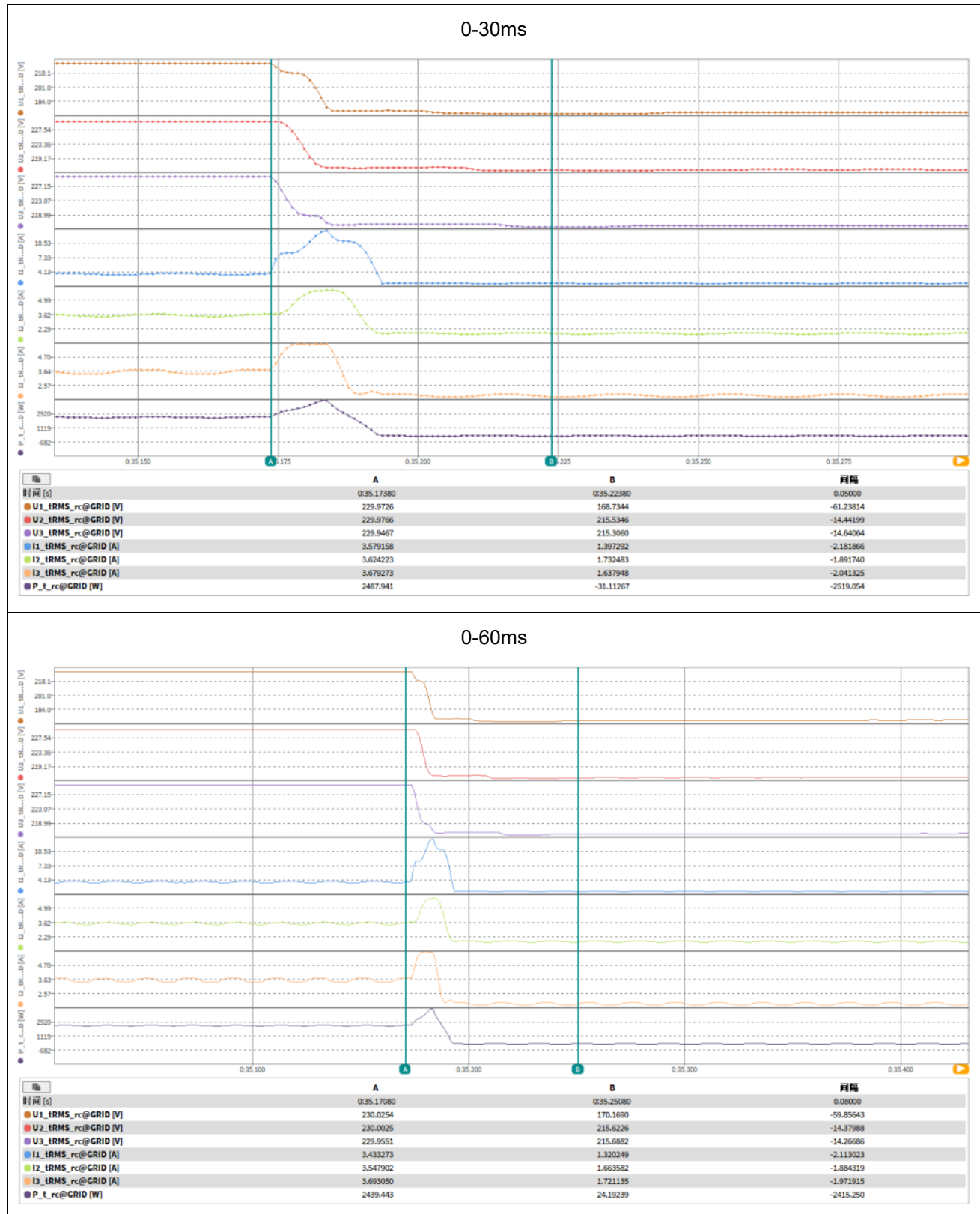
Test – VD9.2

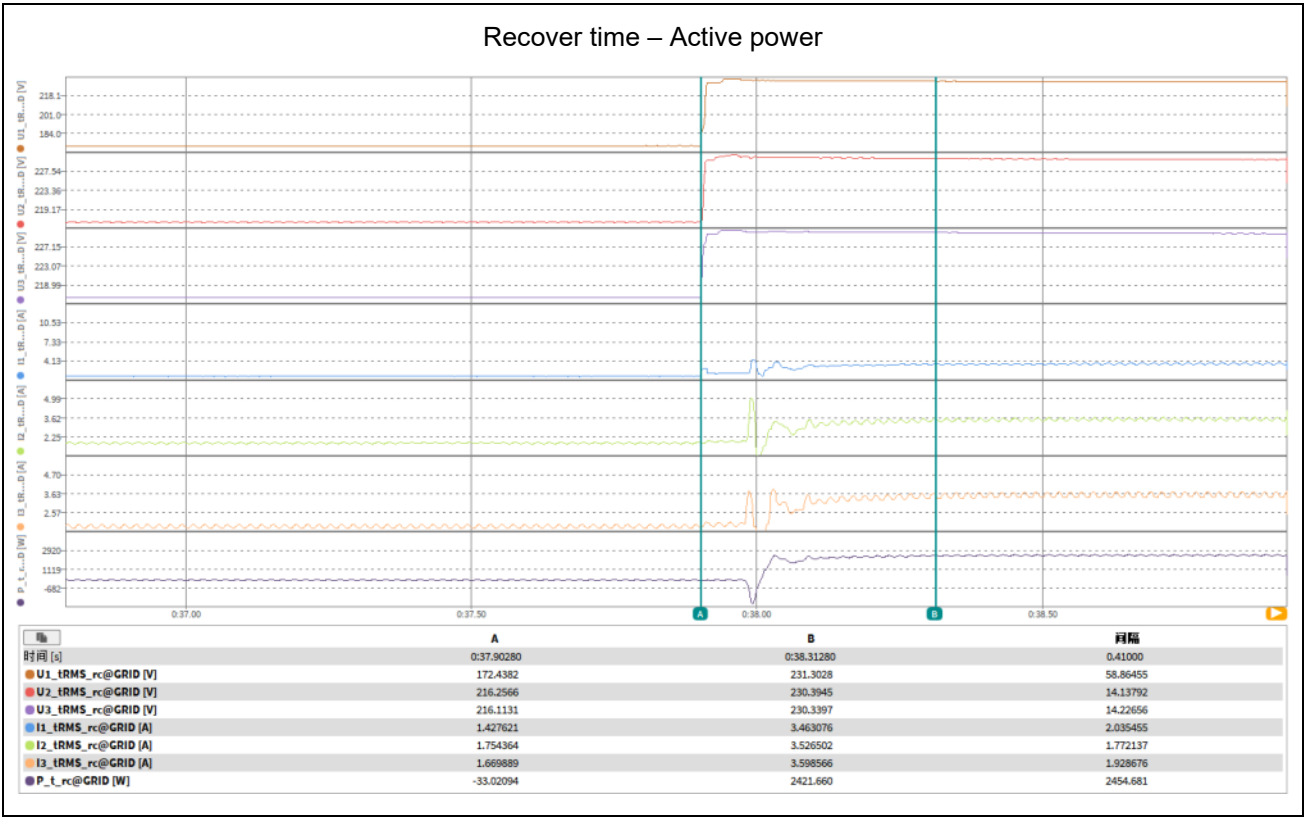
Before fault



Duration fault time

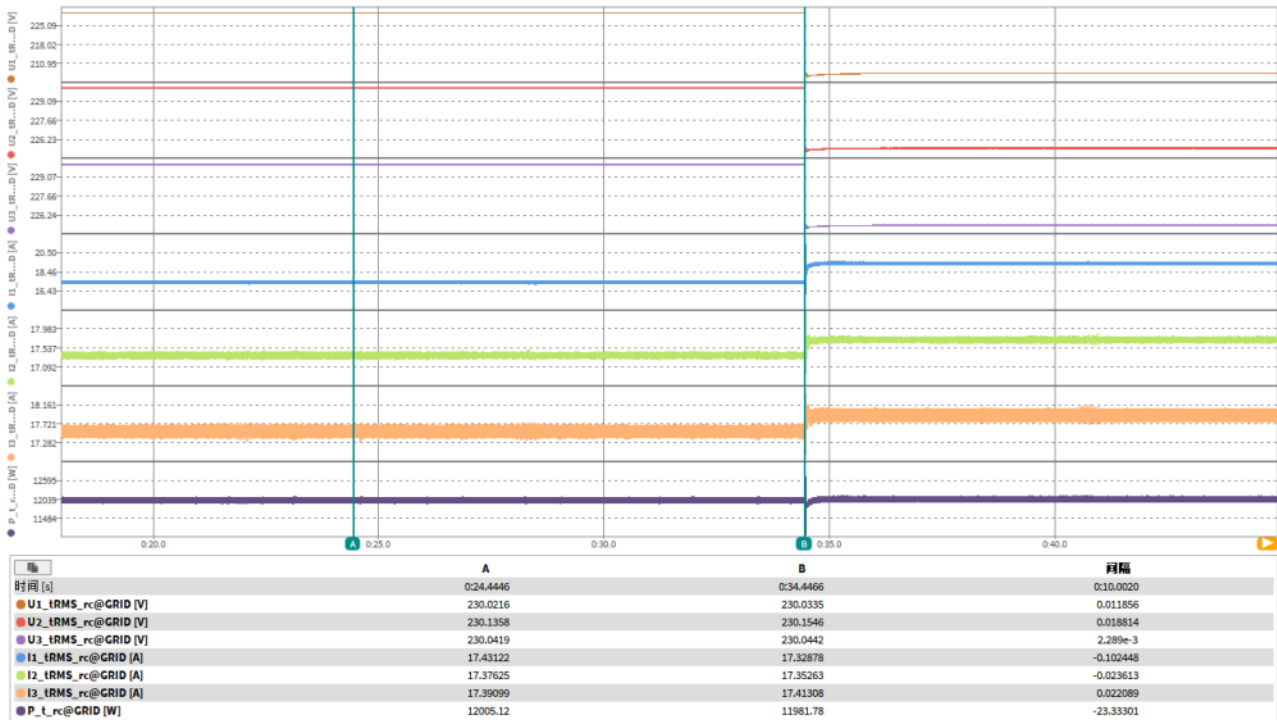




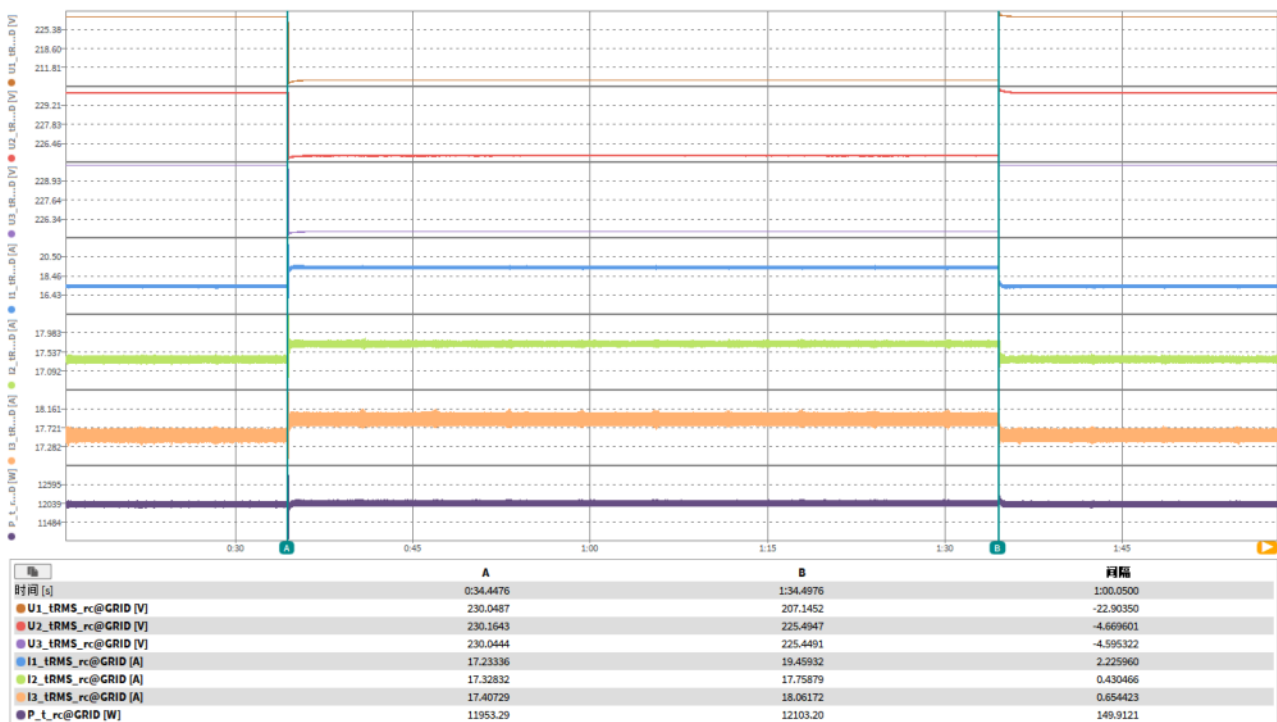


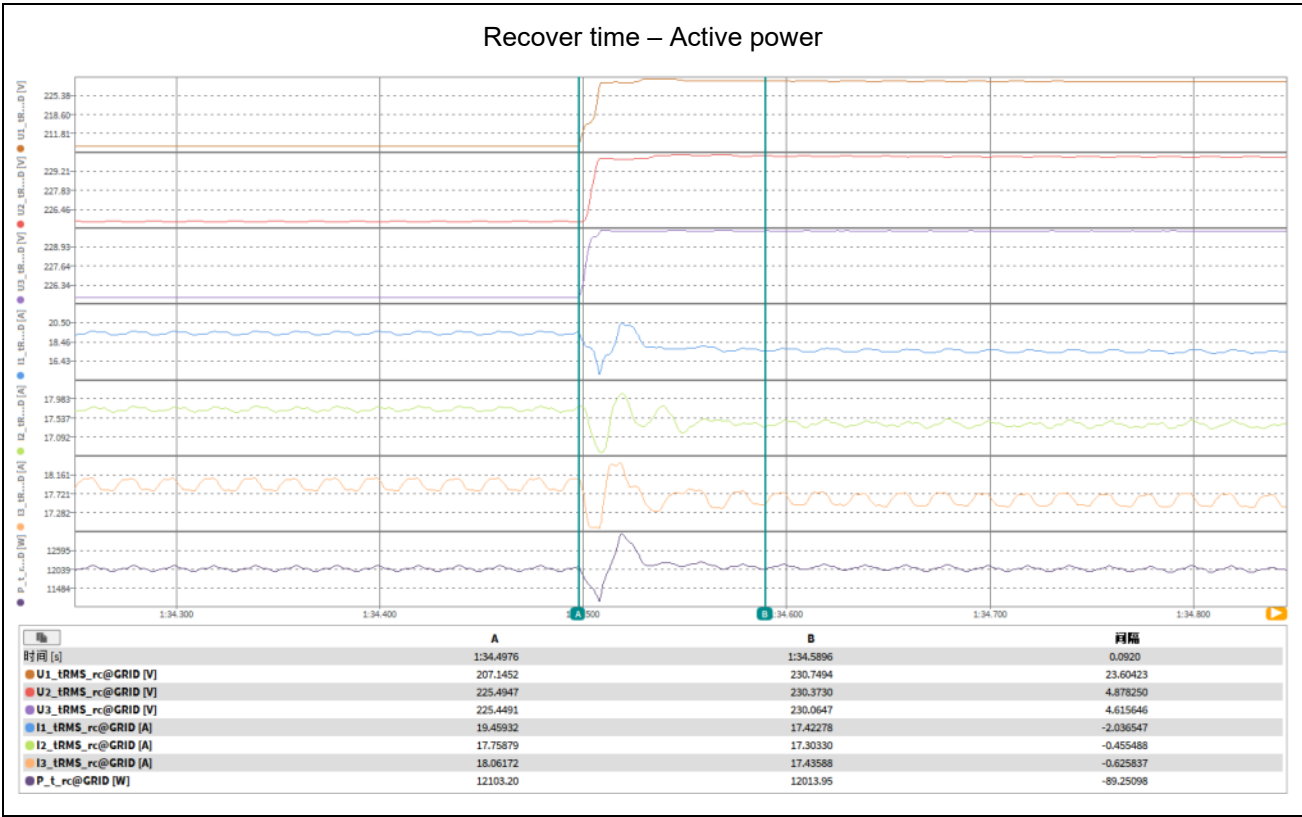
Test – VD10.1

Before fault



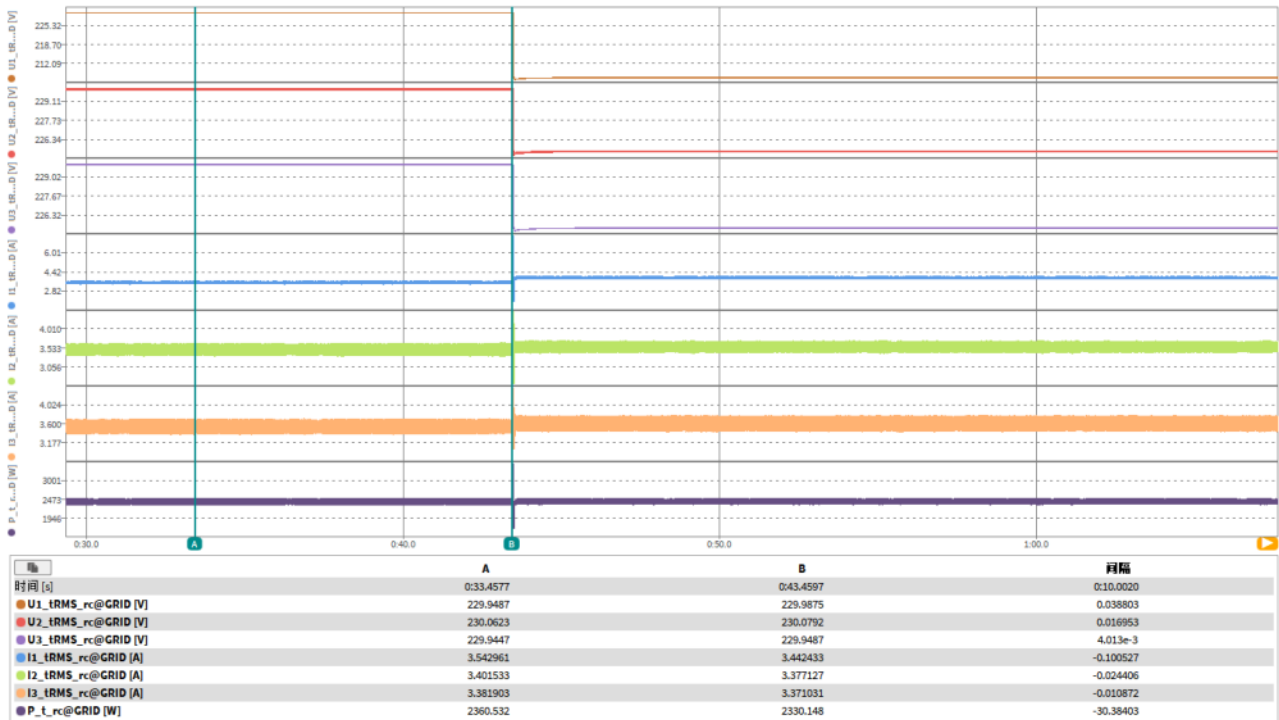
Duration fault time



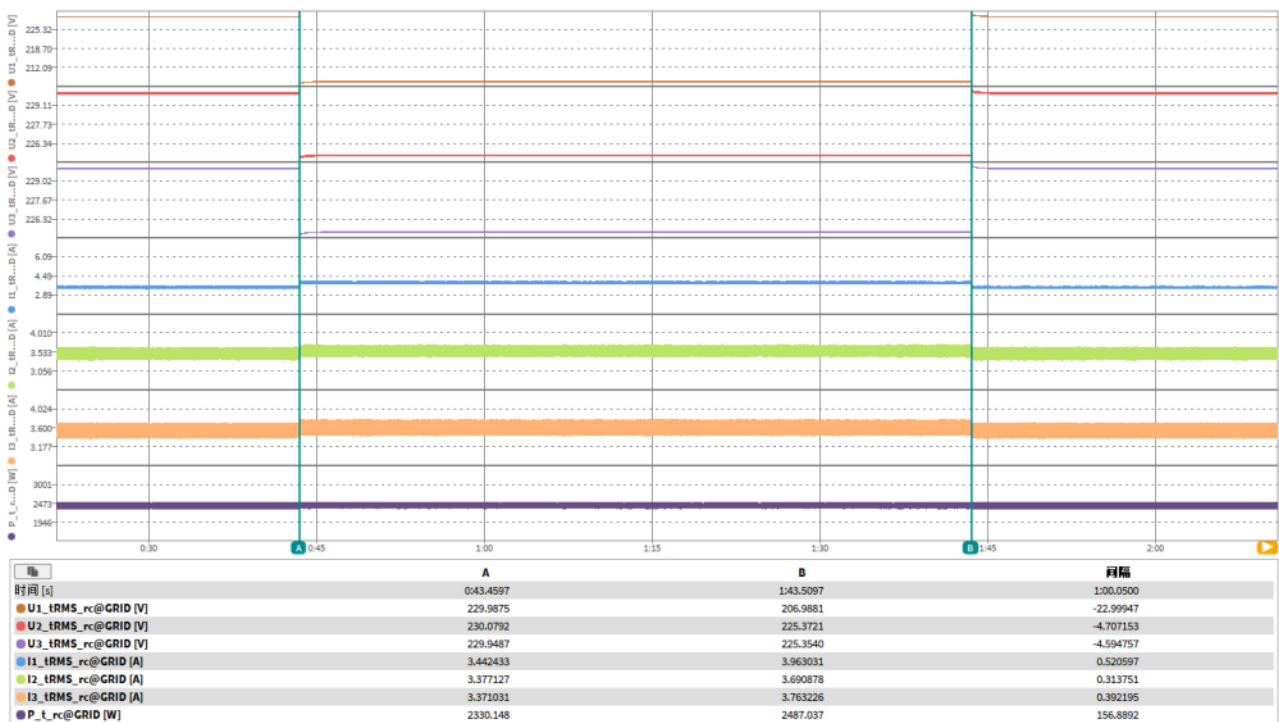


Test – VD10.2

Before fault



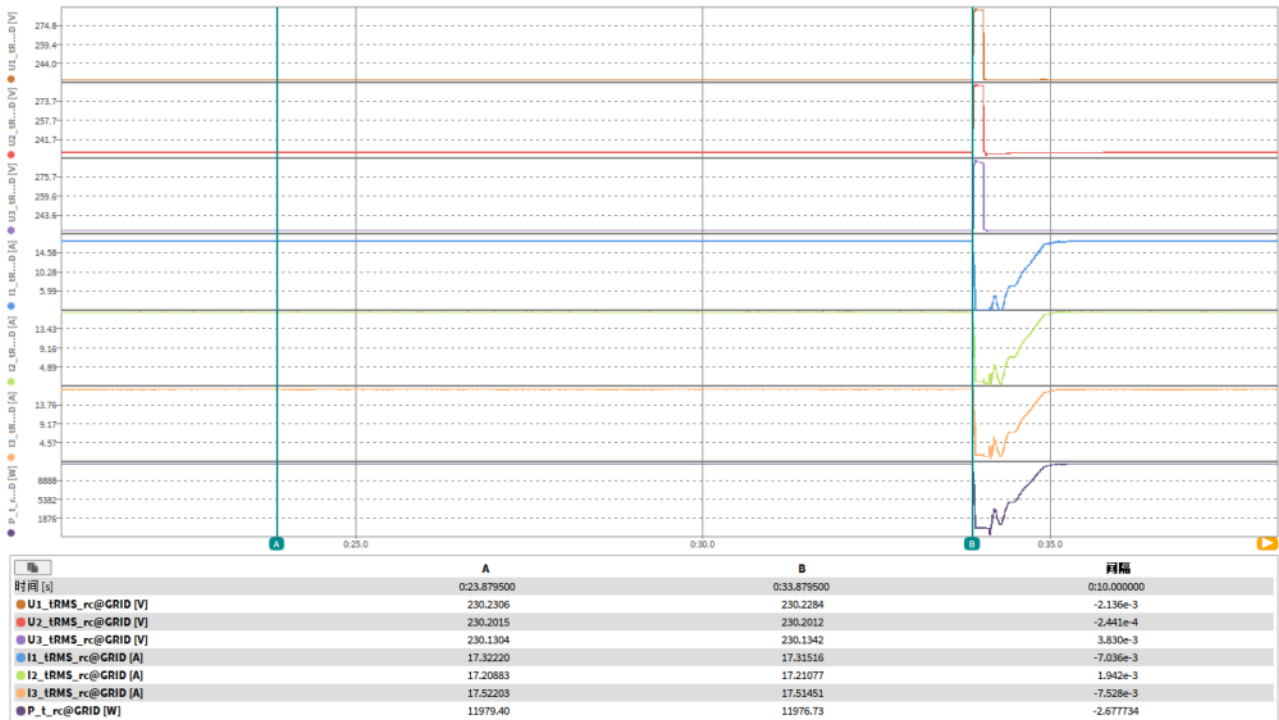
Duration fault time



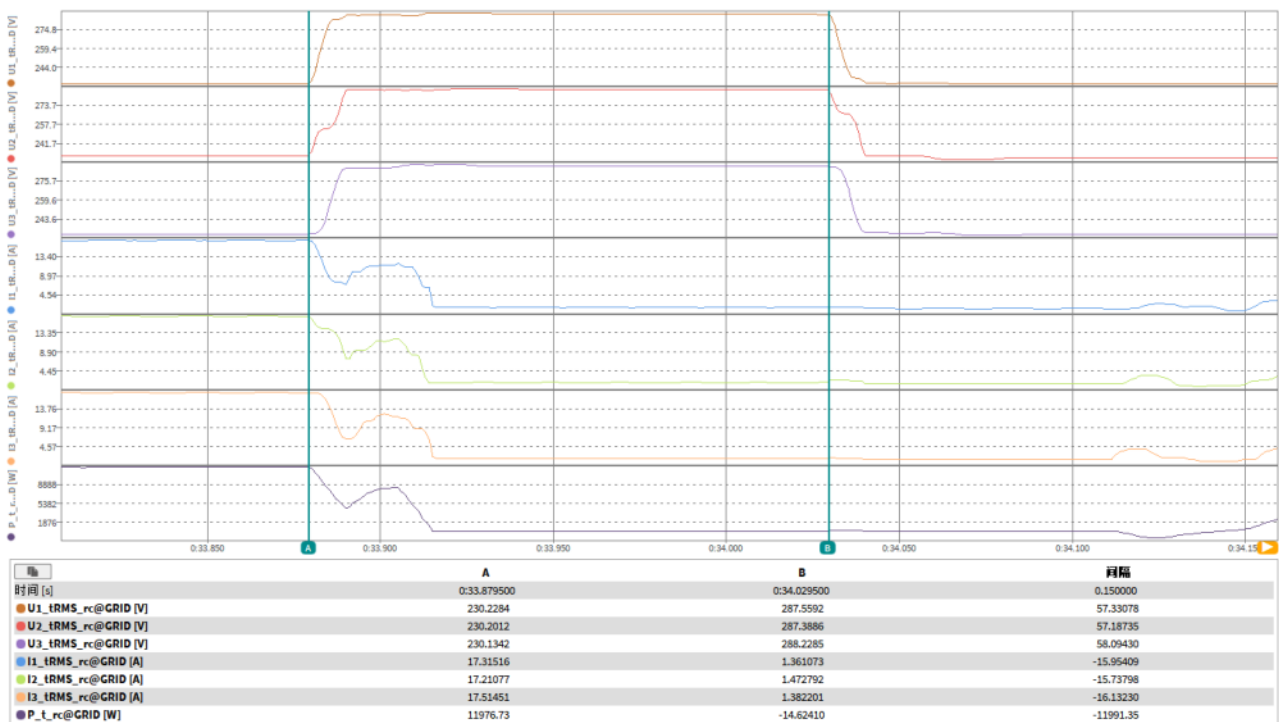


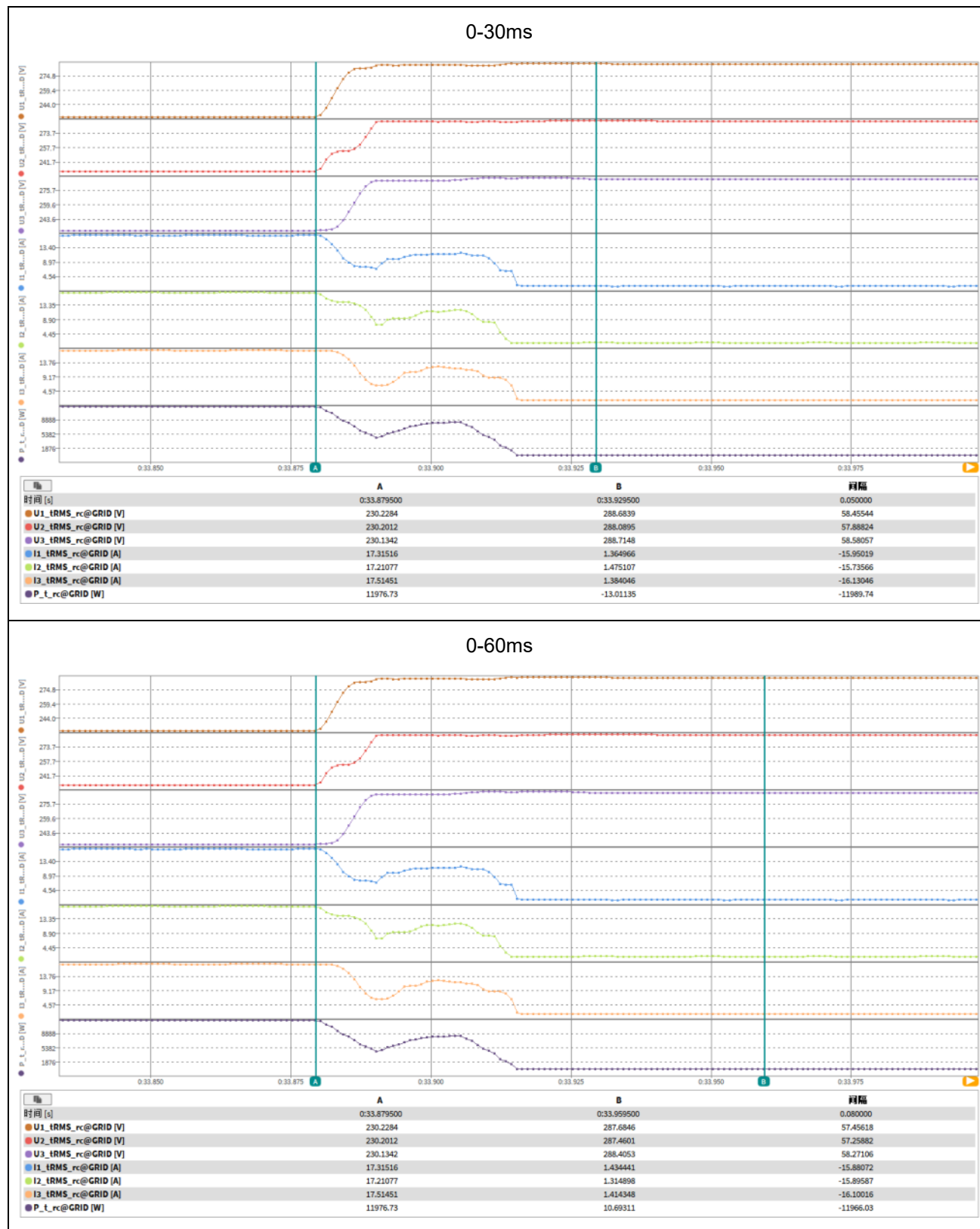
Test – VS1.1

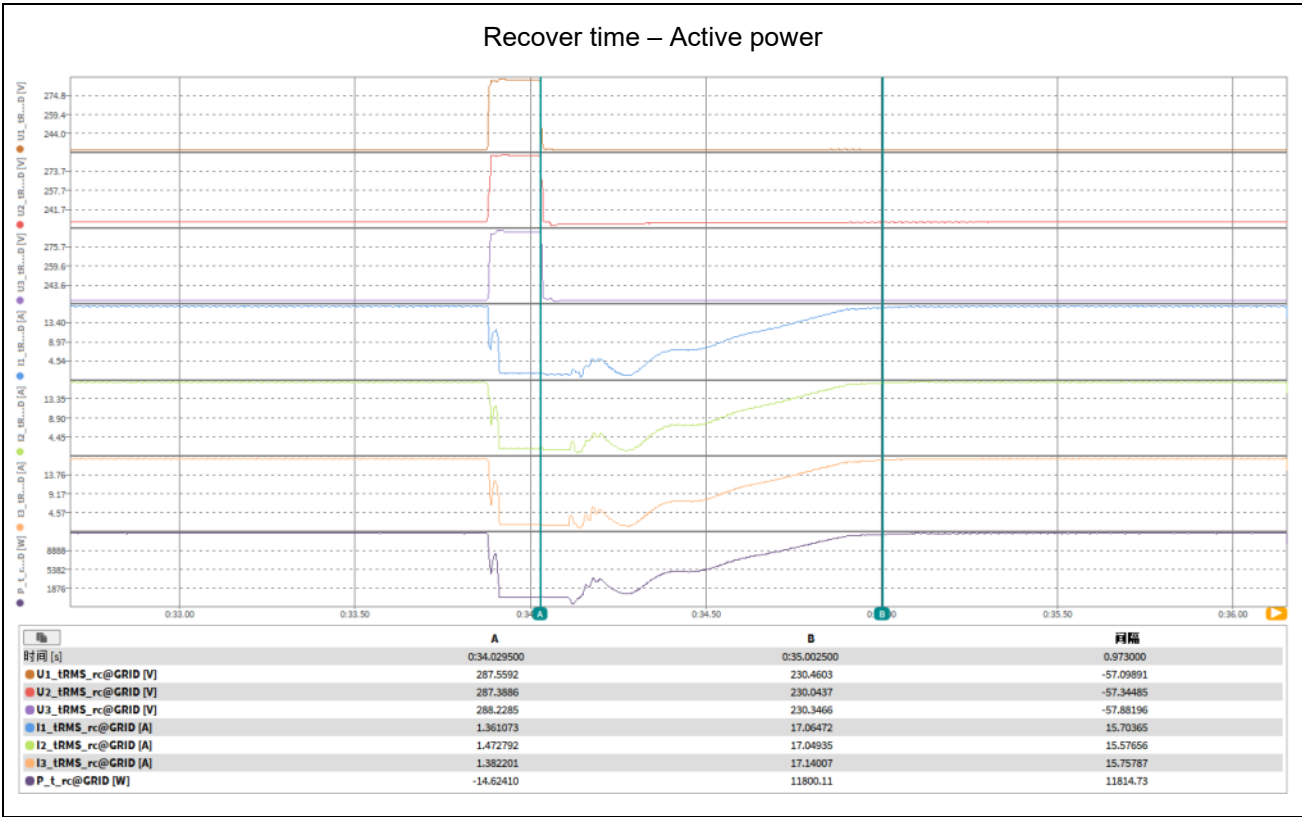
Before fault



Duration fault time

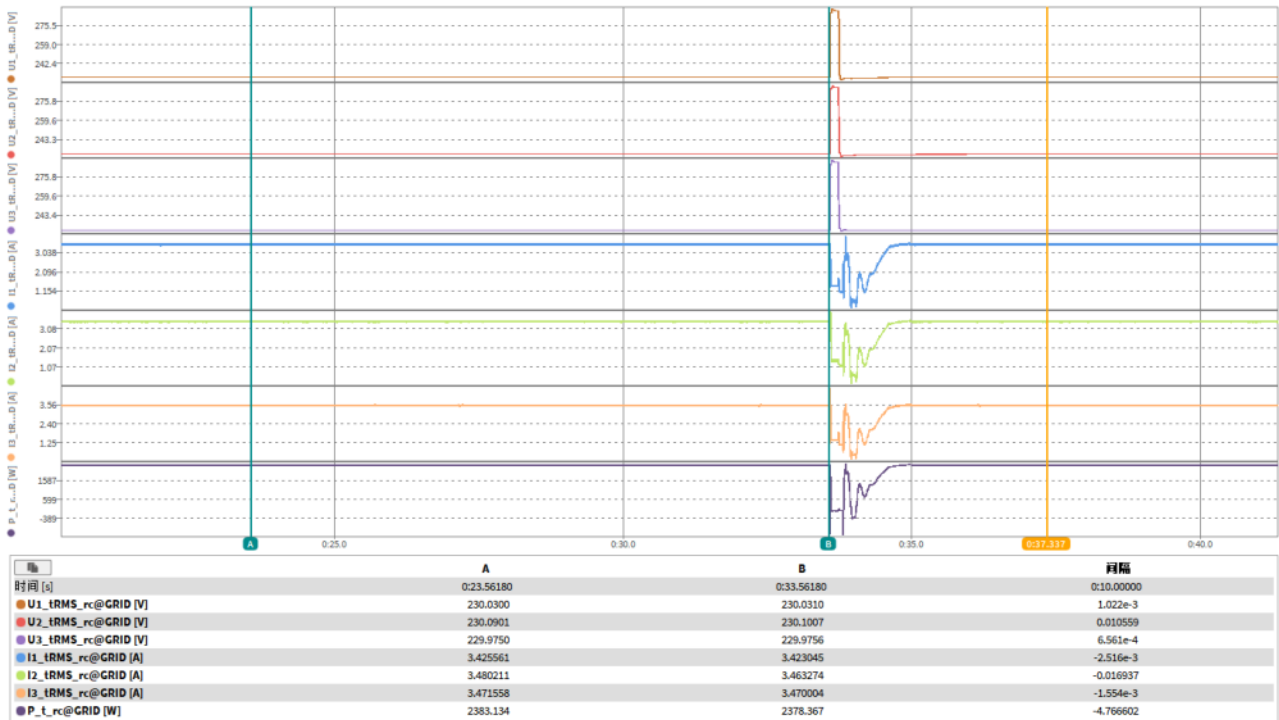




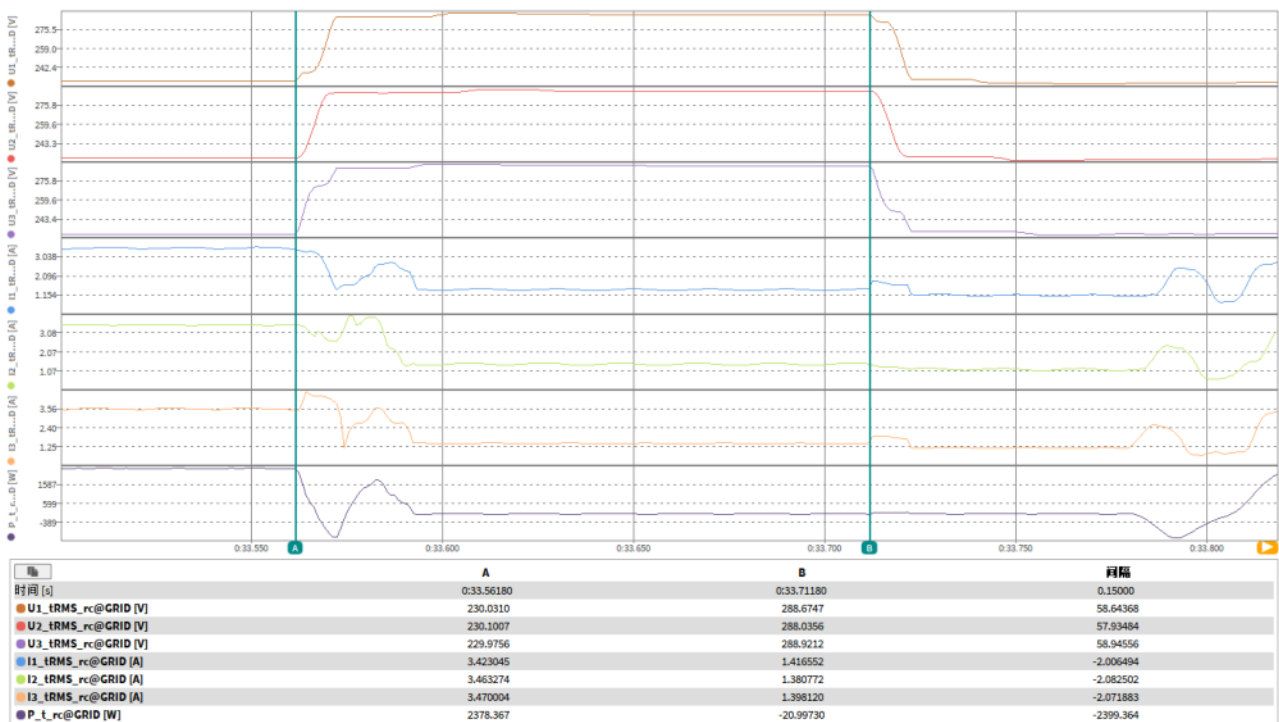


Test – VS1.2

Before fault



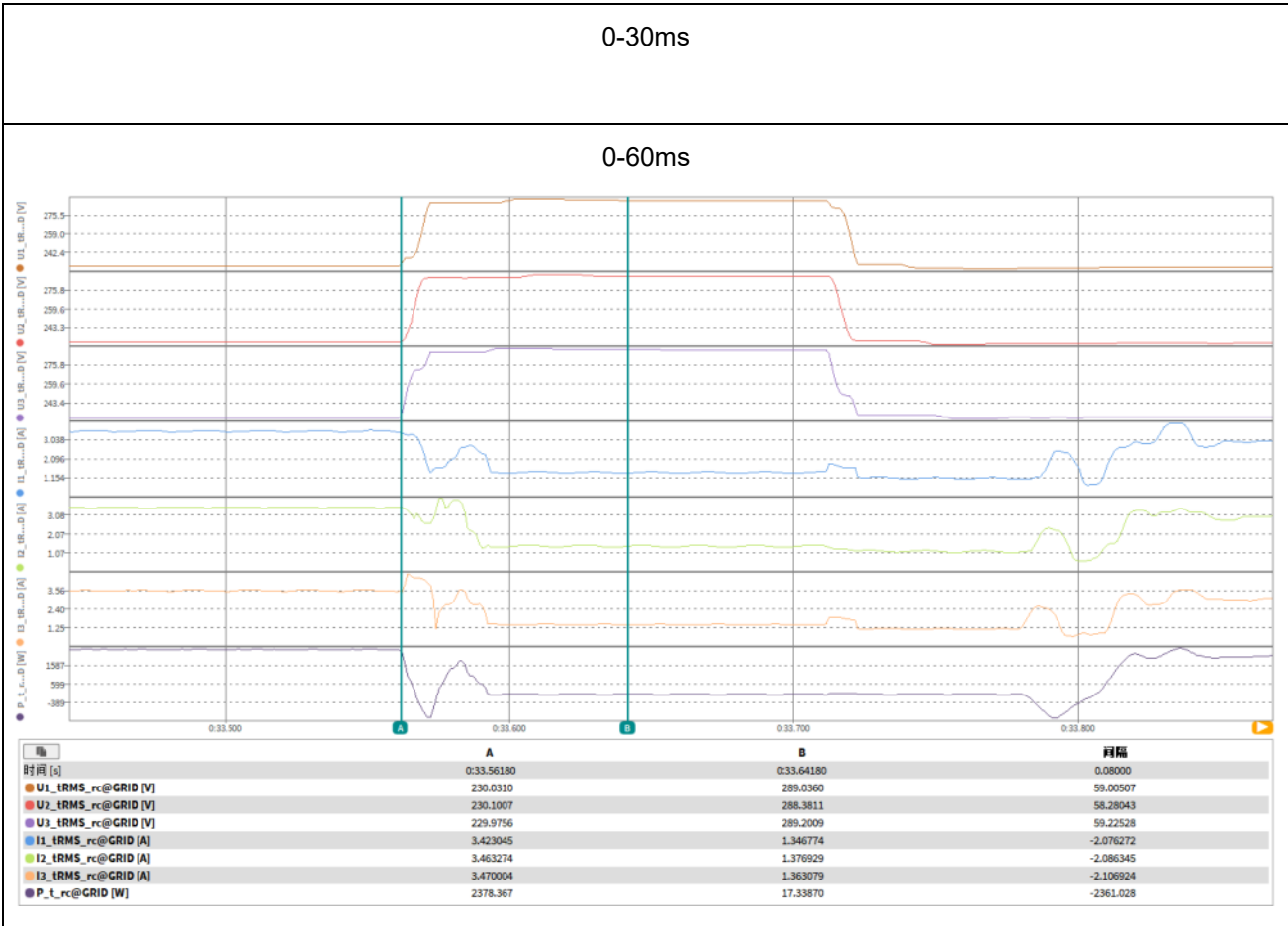
Duration fault time



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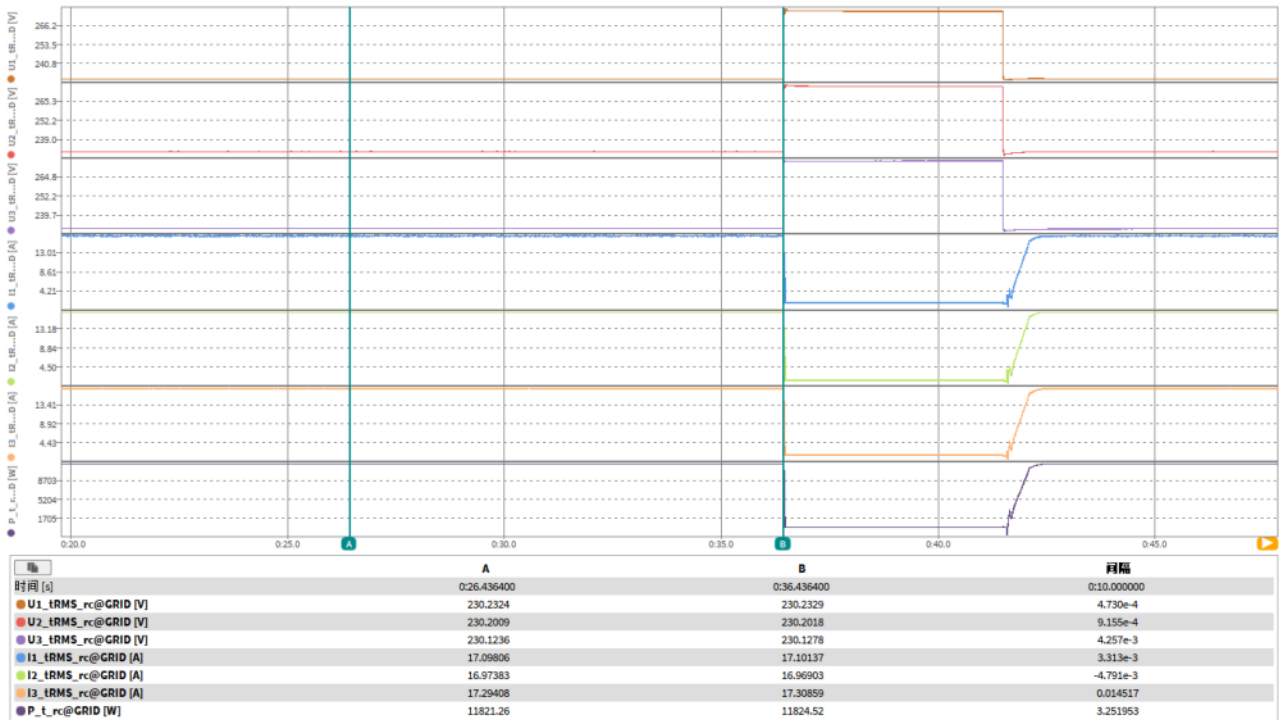
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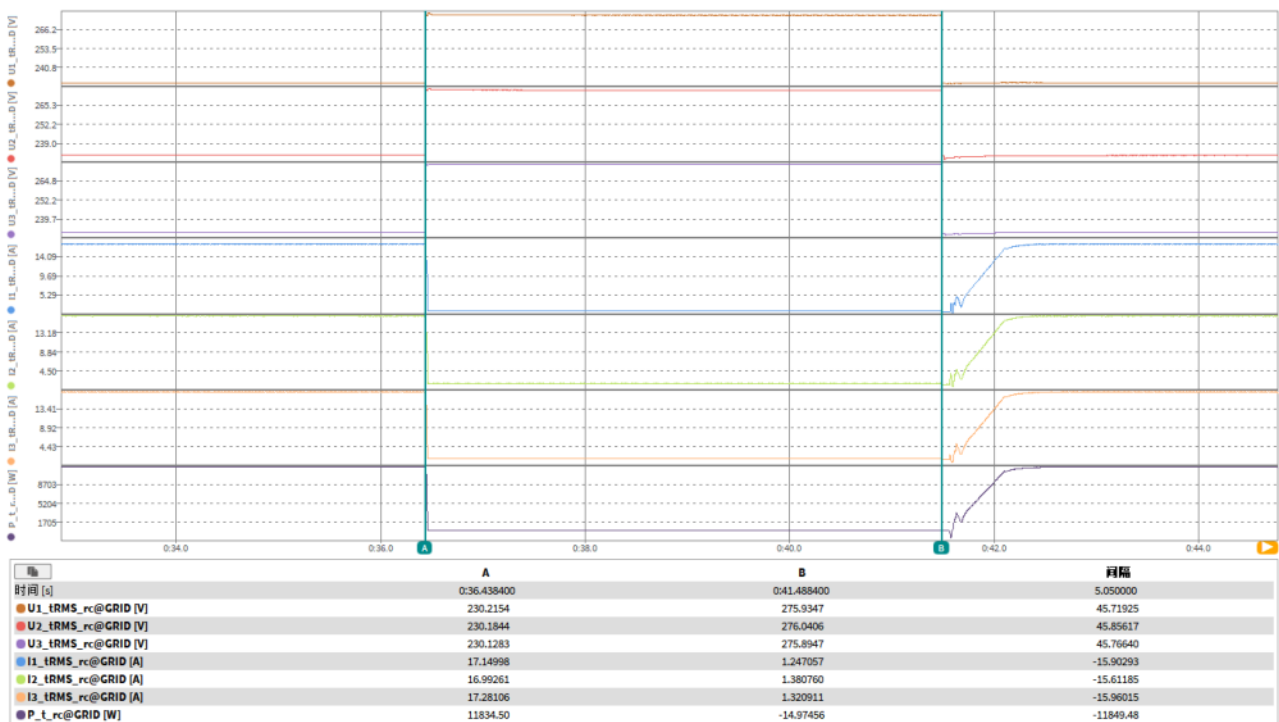
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Test – VS2.1.1

Before fault



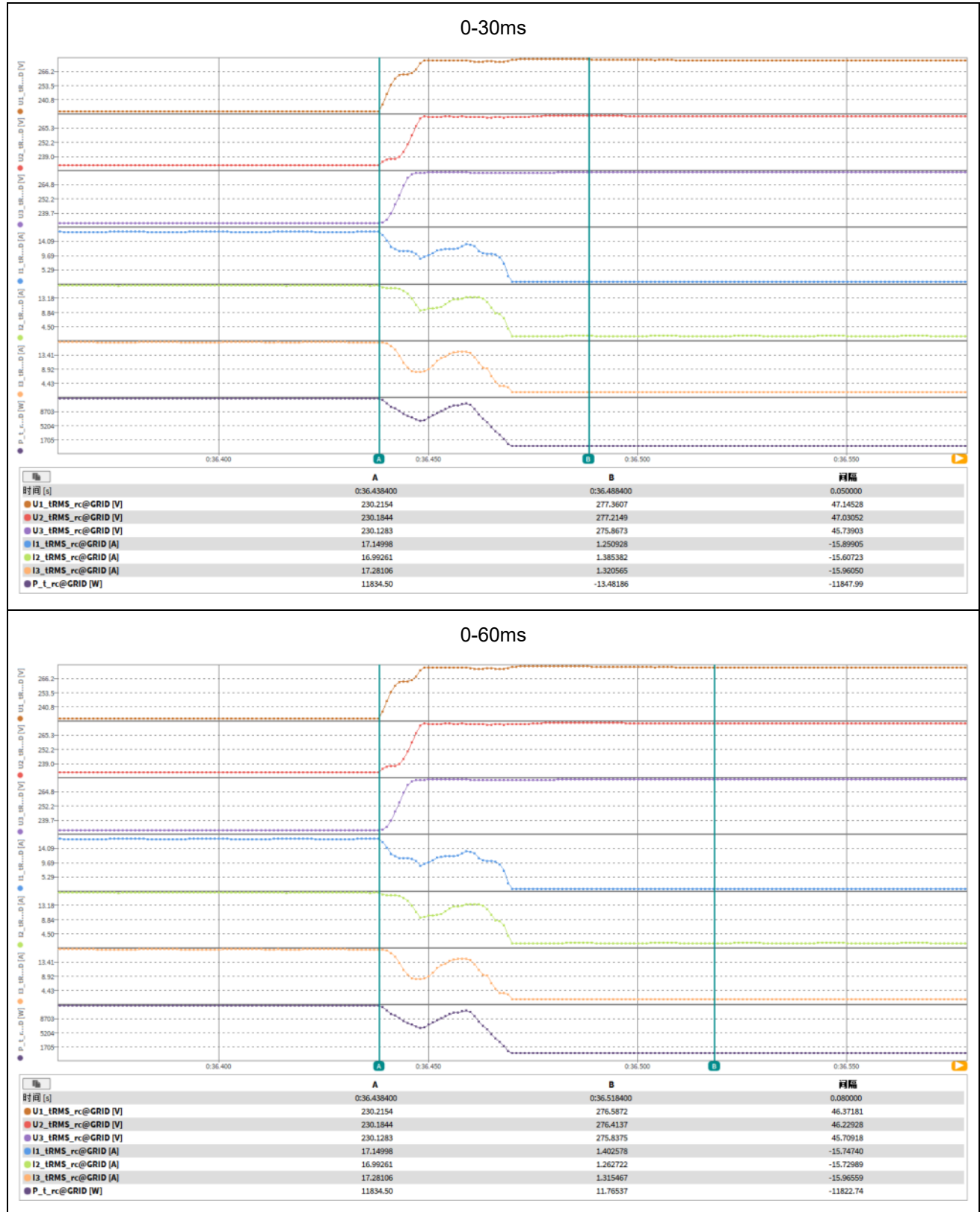
Duration fault time

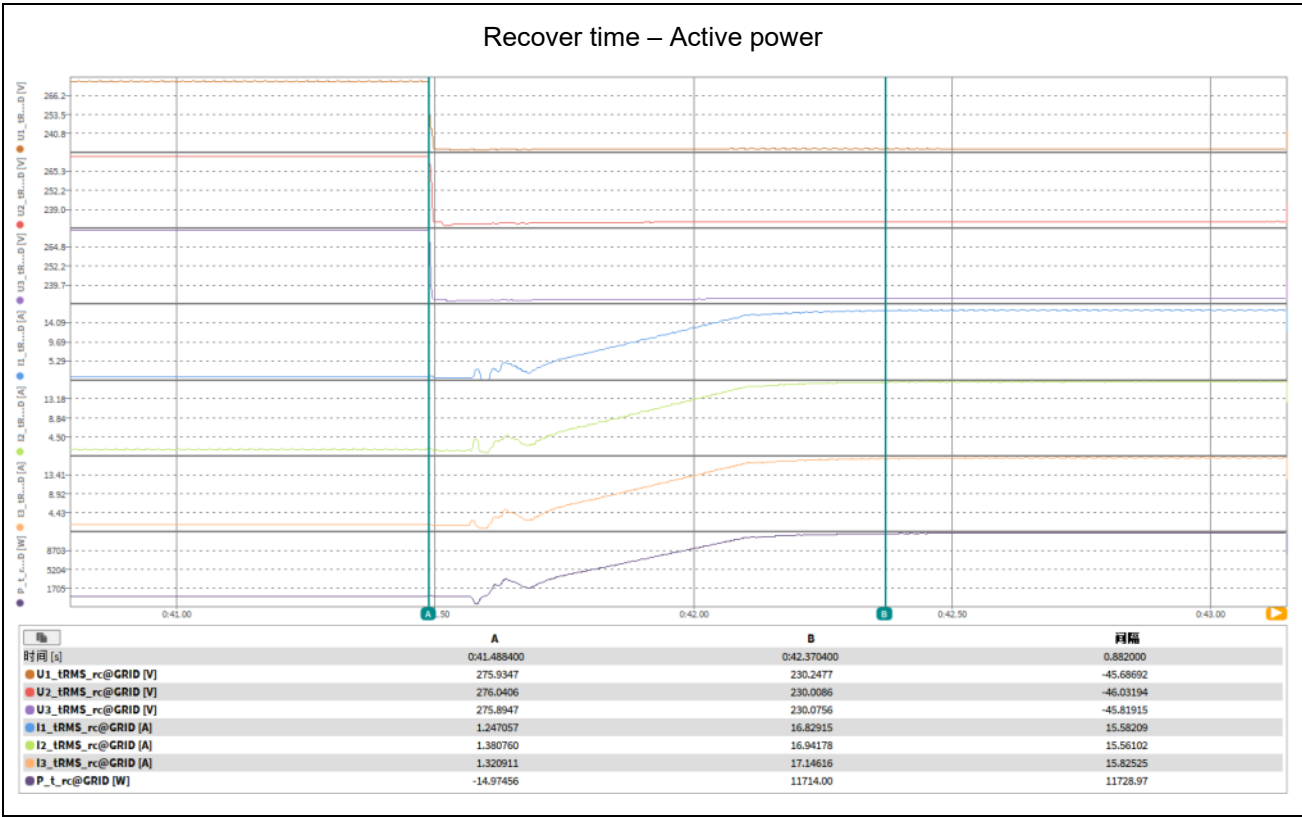


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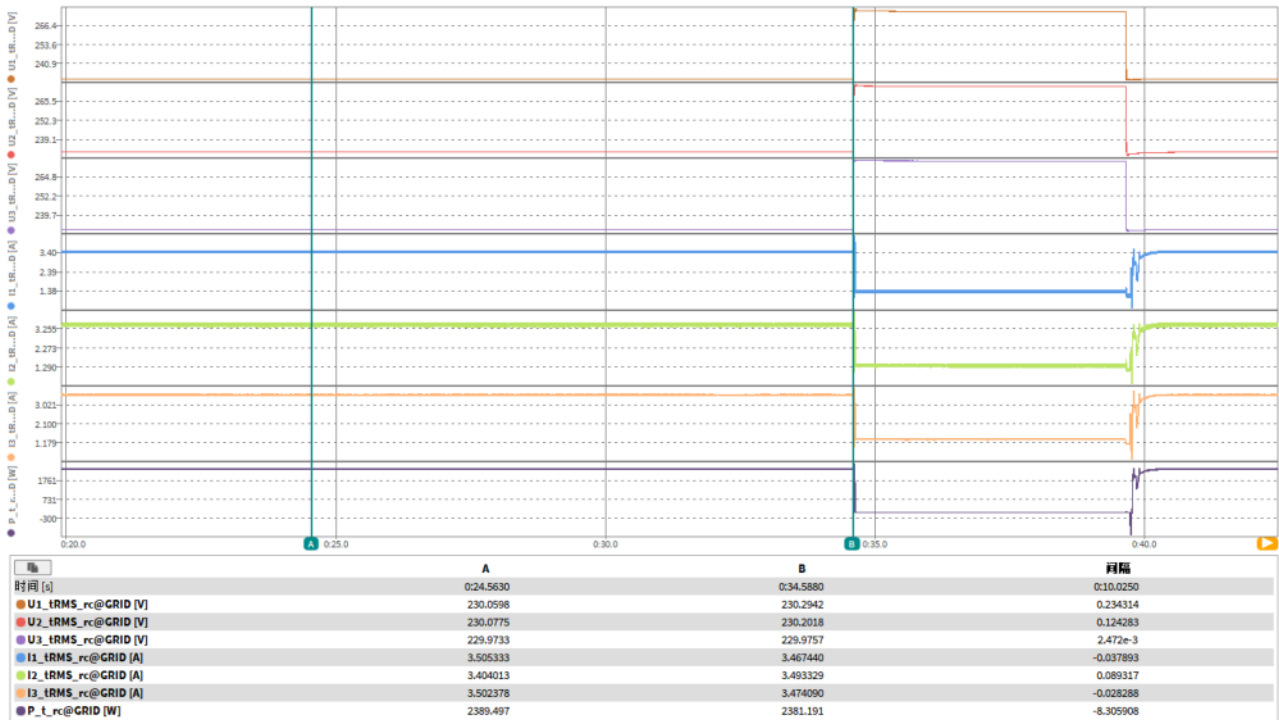
Test Report

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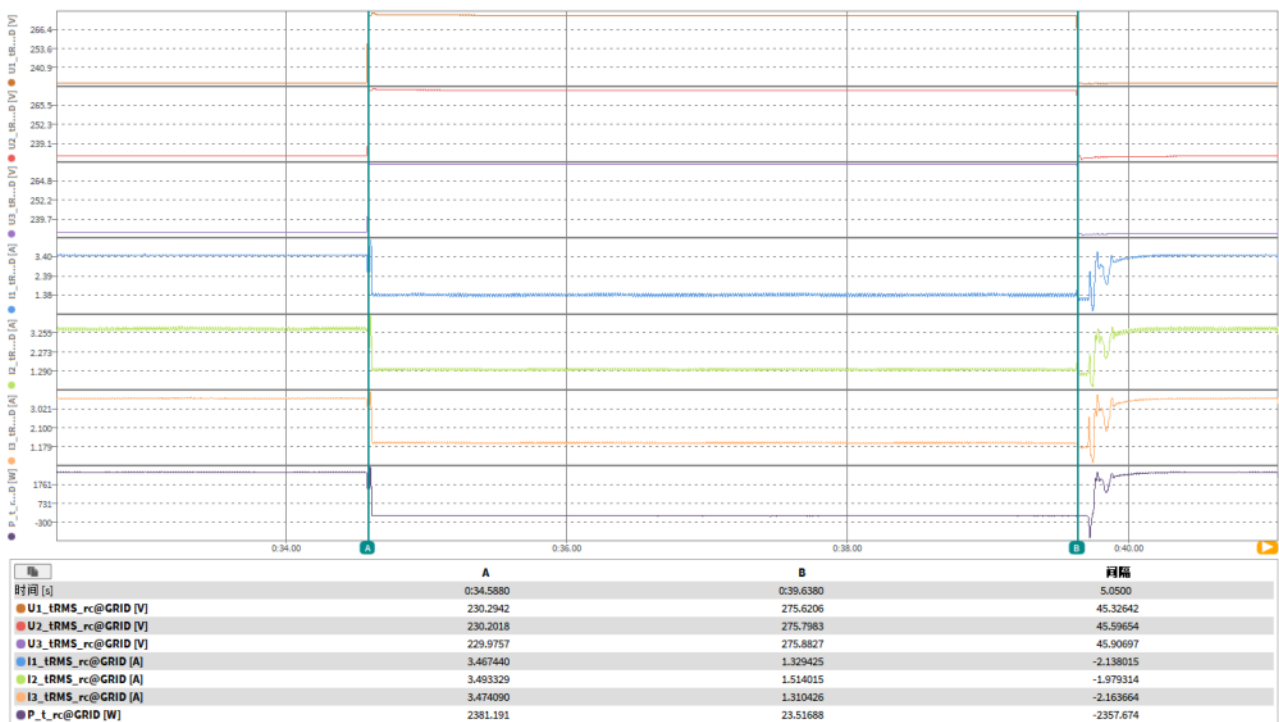
Test Report No.: RDPVP02041/26E/02

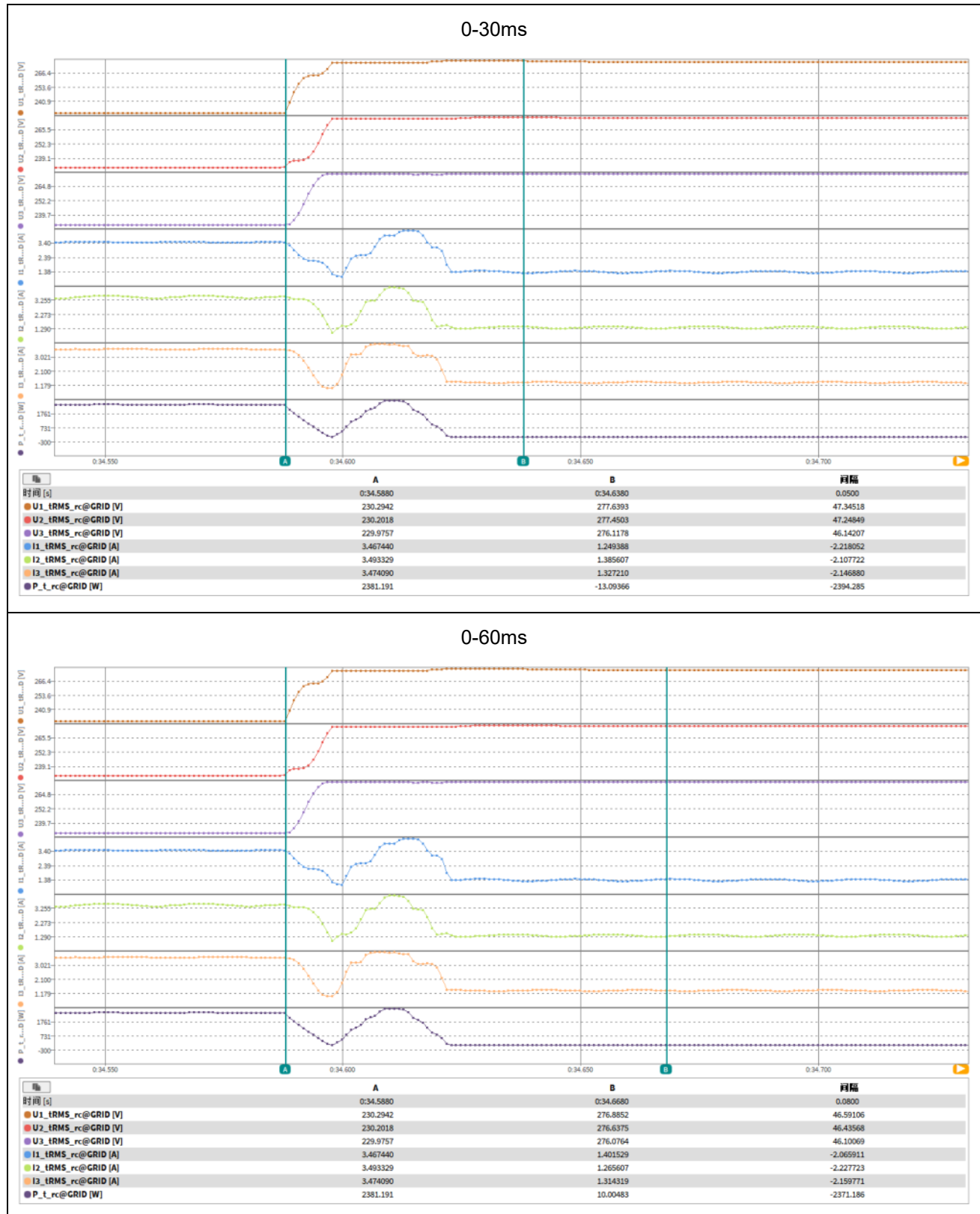
Test – VS2.1.2

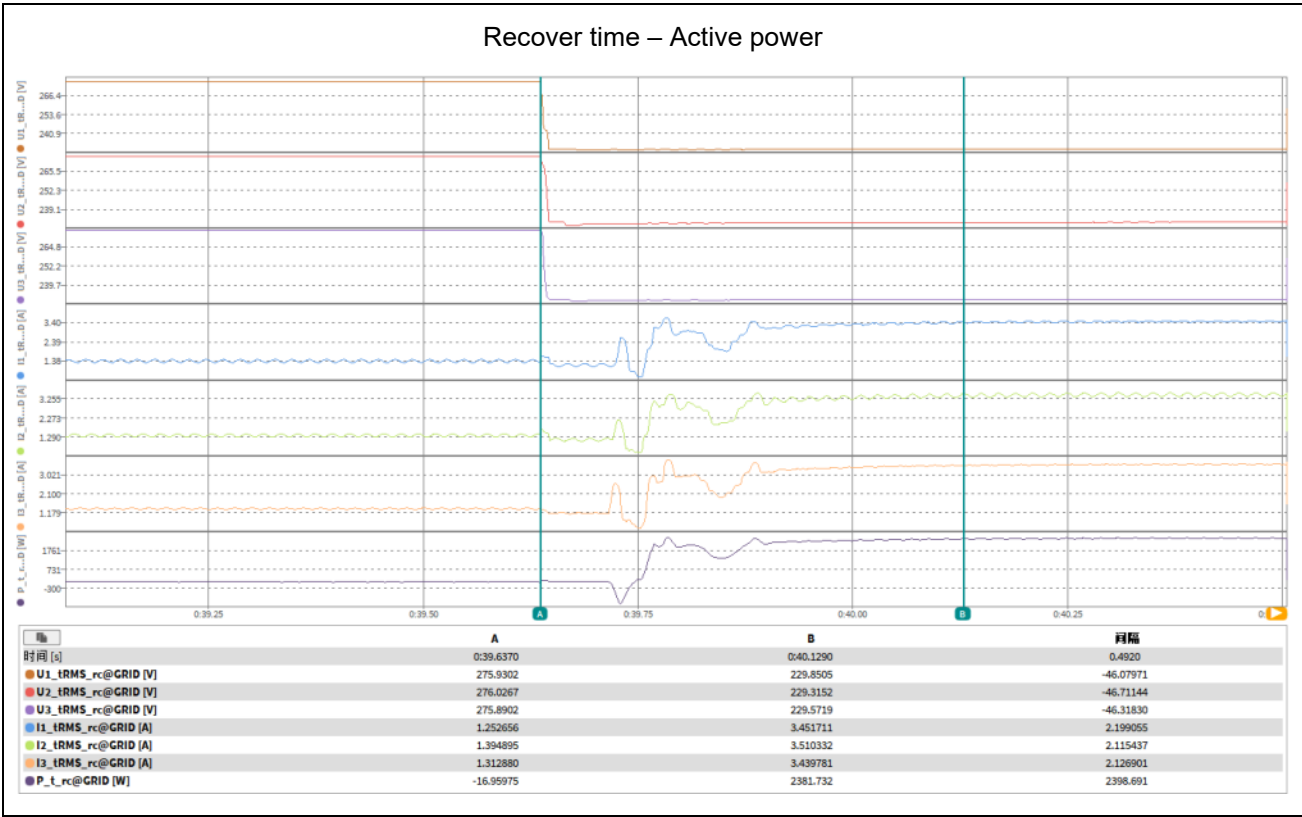
Before fault



Duration fault time

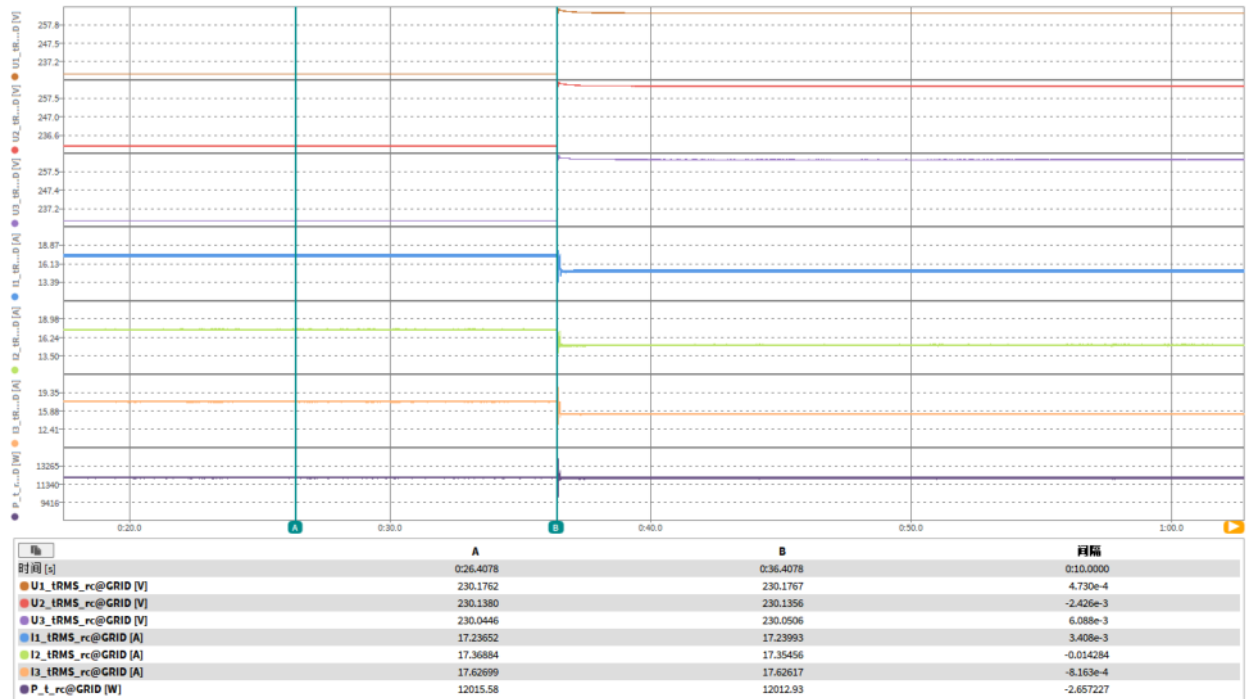




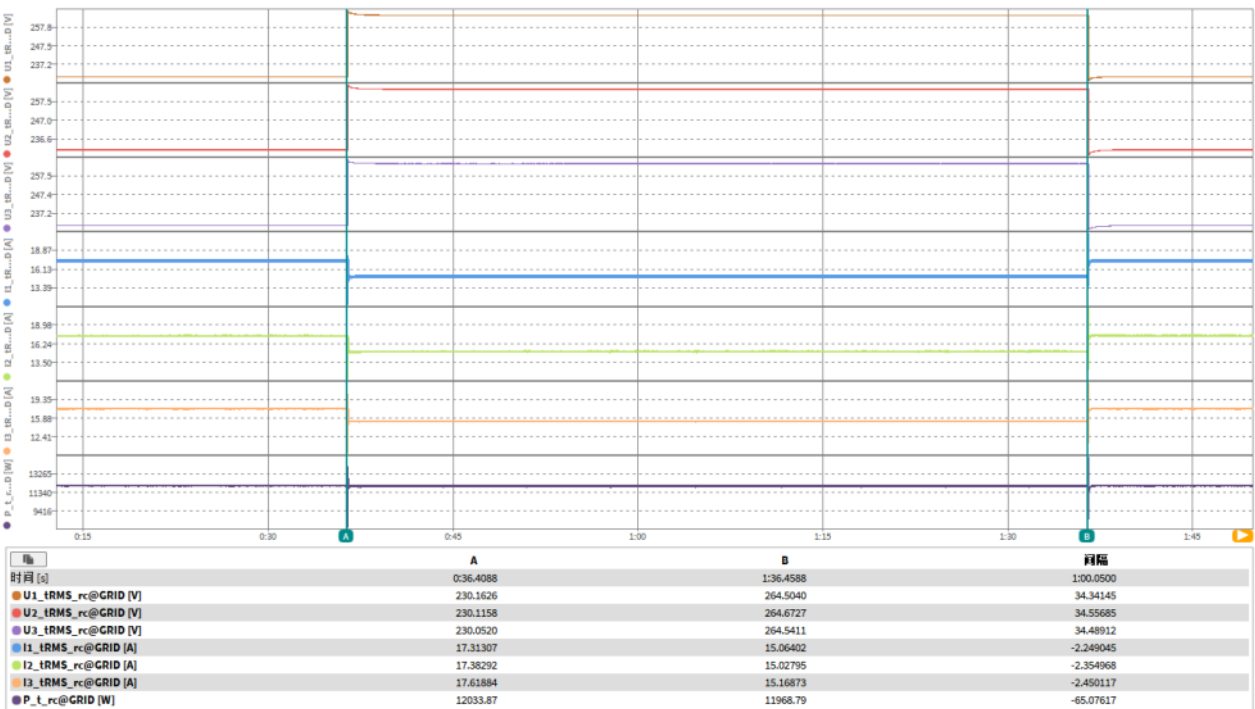


Test – VS2.2.1

Before fault



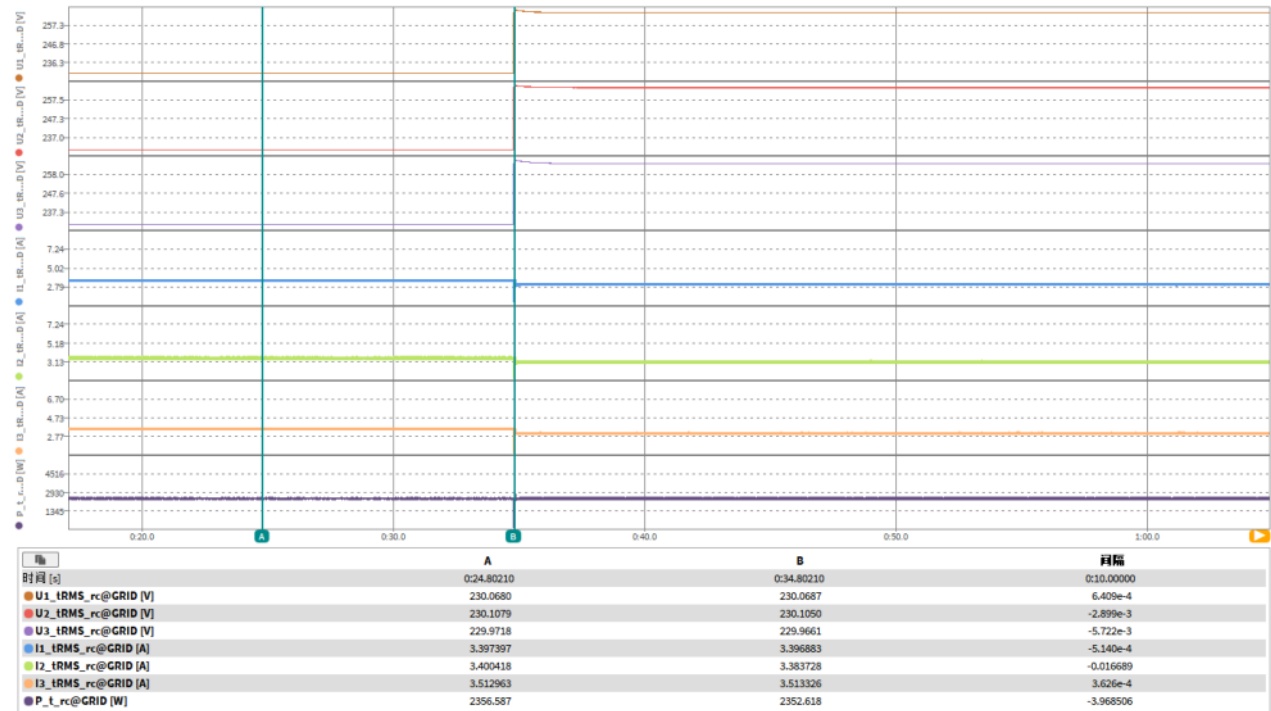
Duration fault time



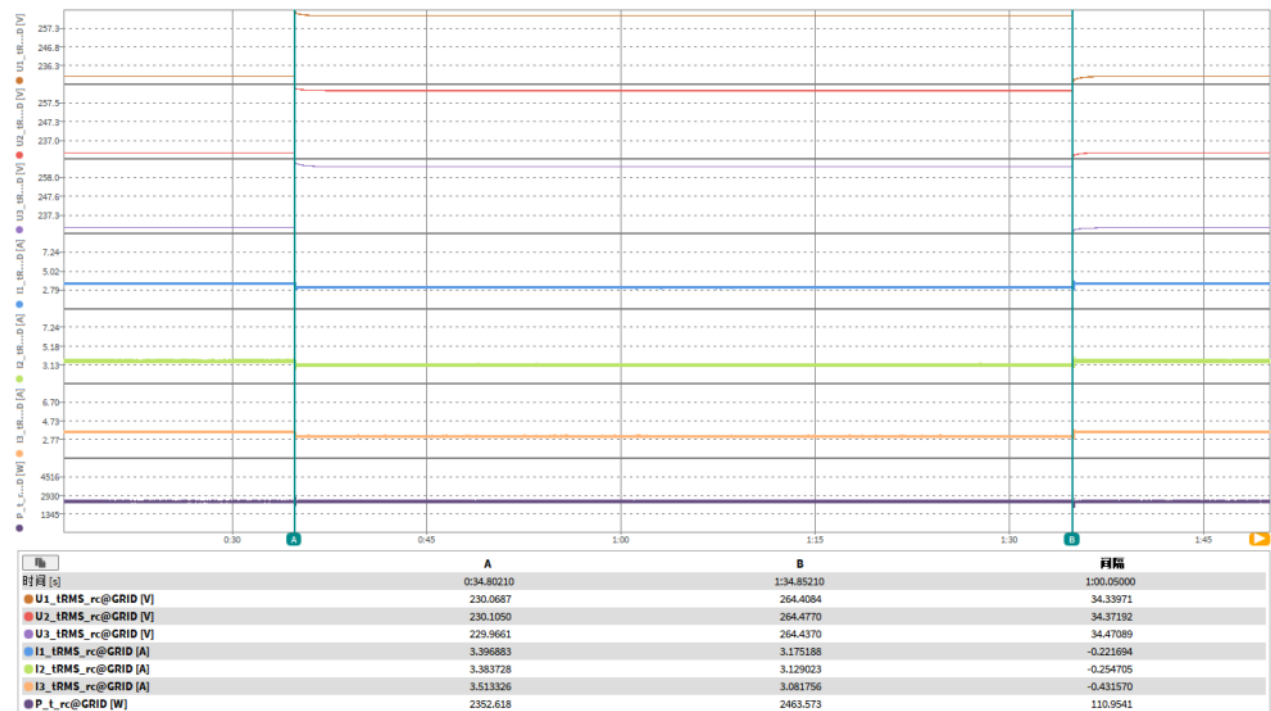


Test – VS2.2.2

Before fault



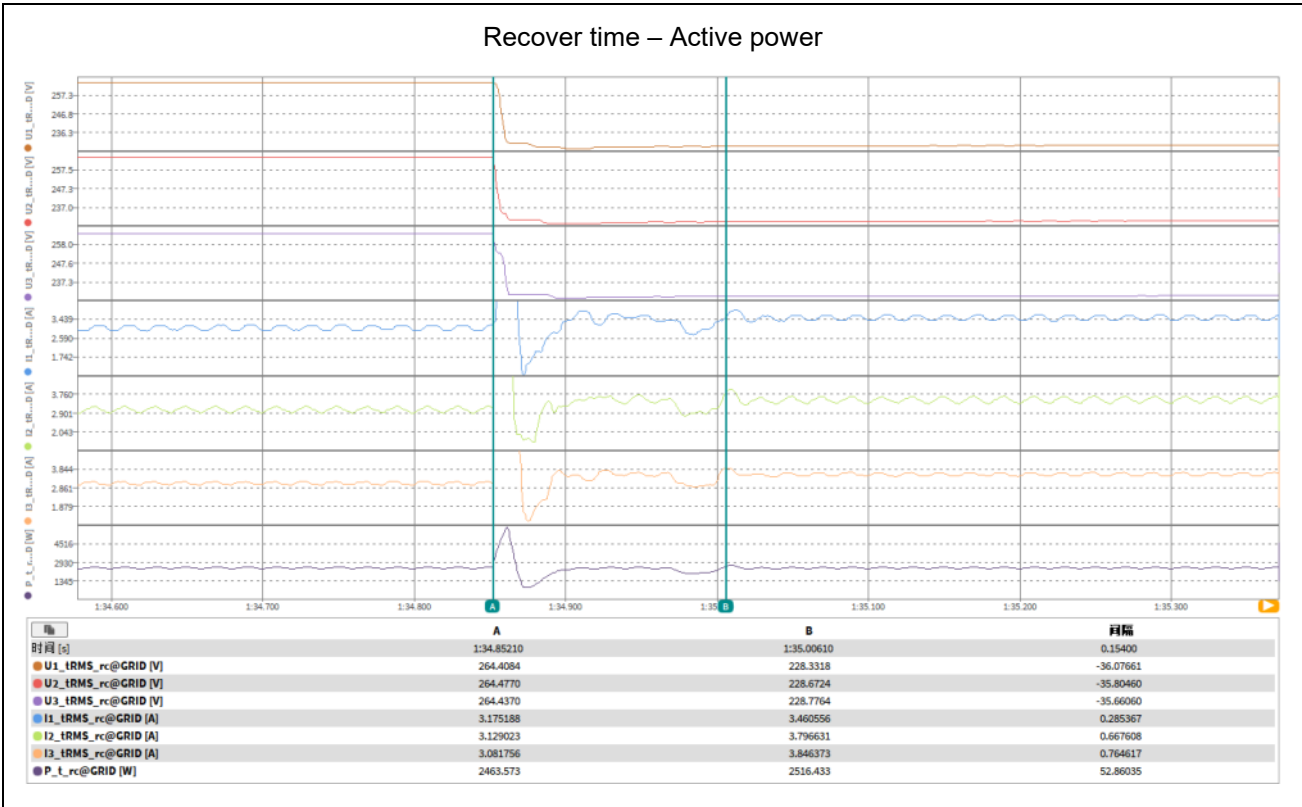
Duration fault time



Test Report

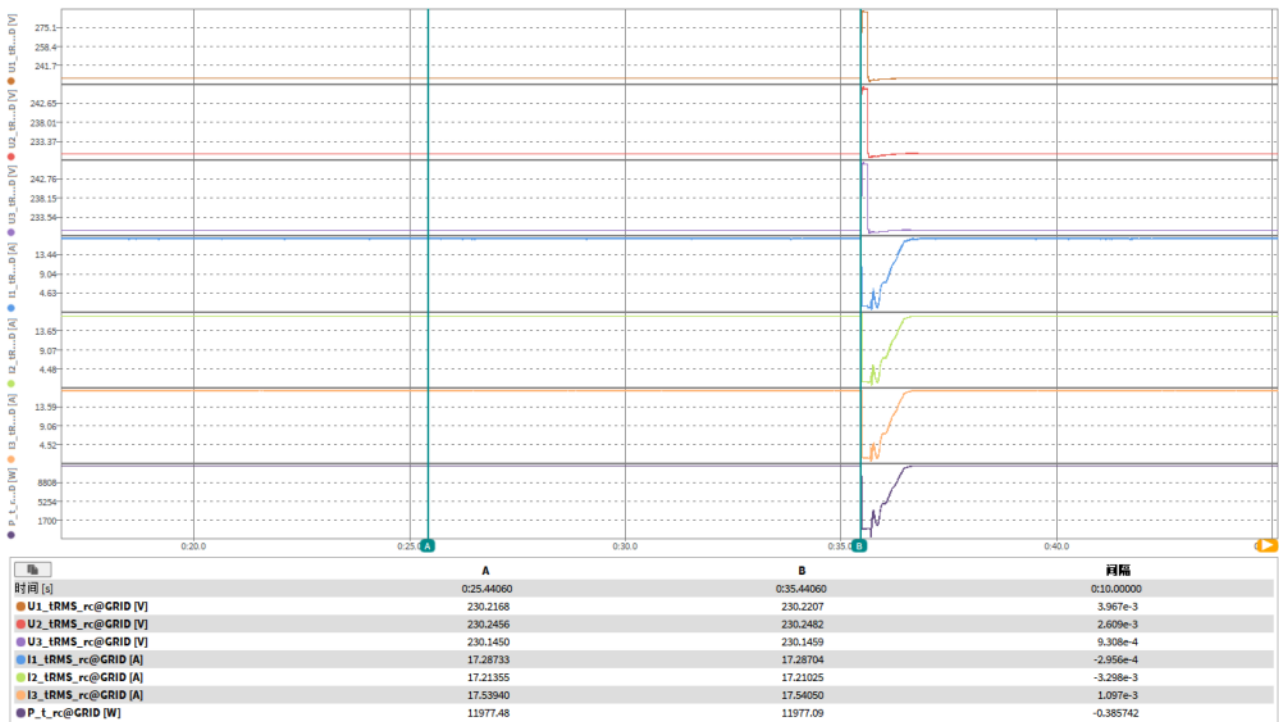
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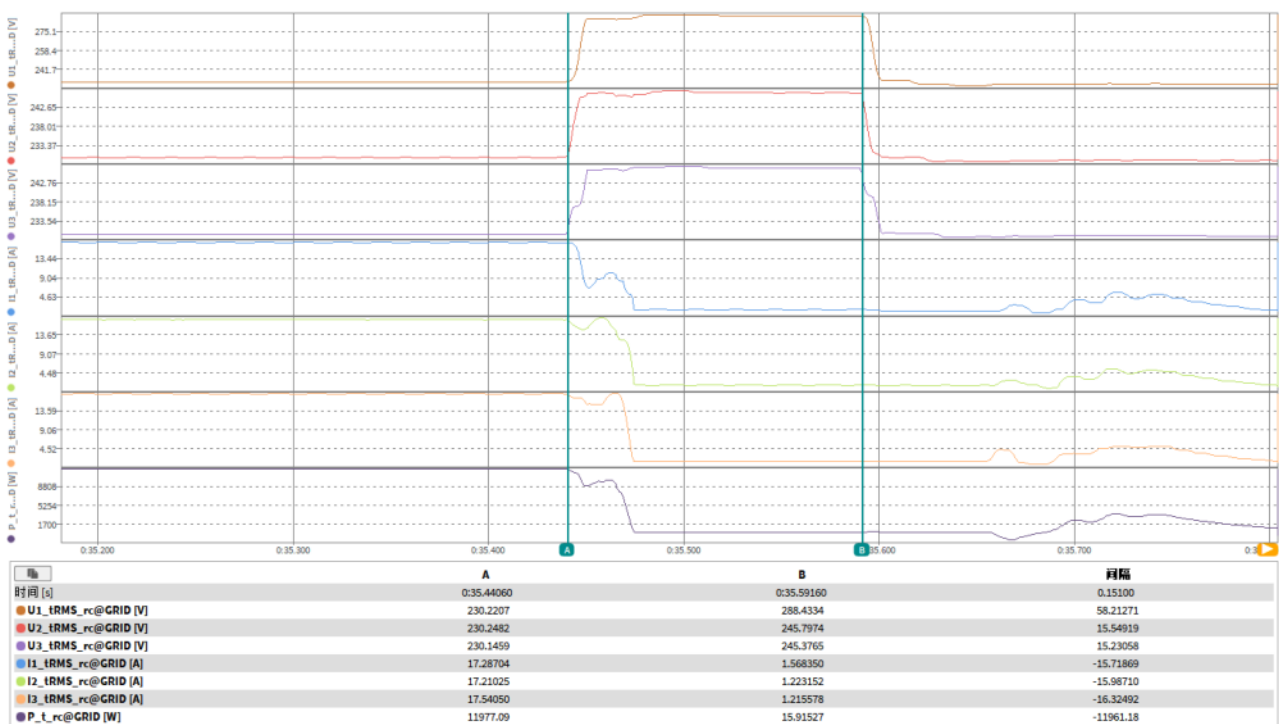


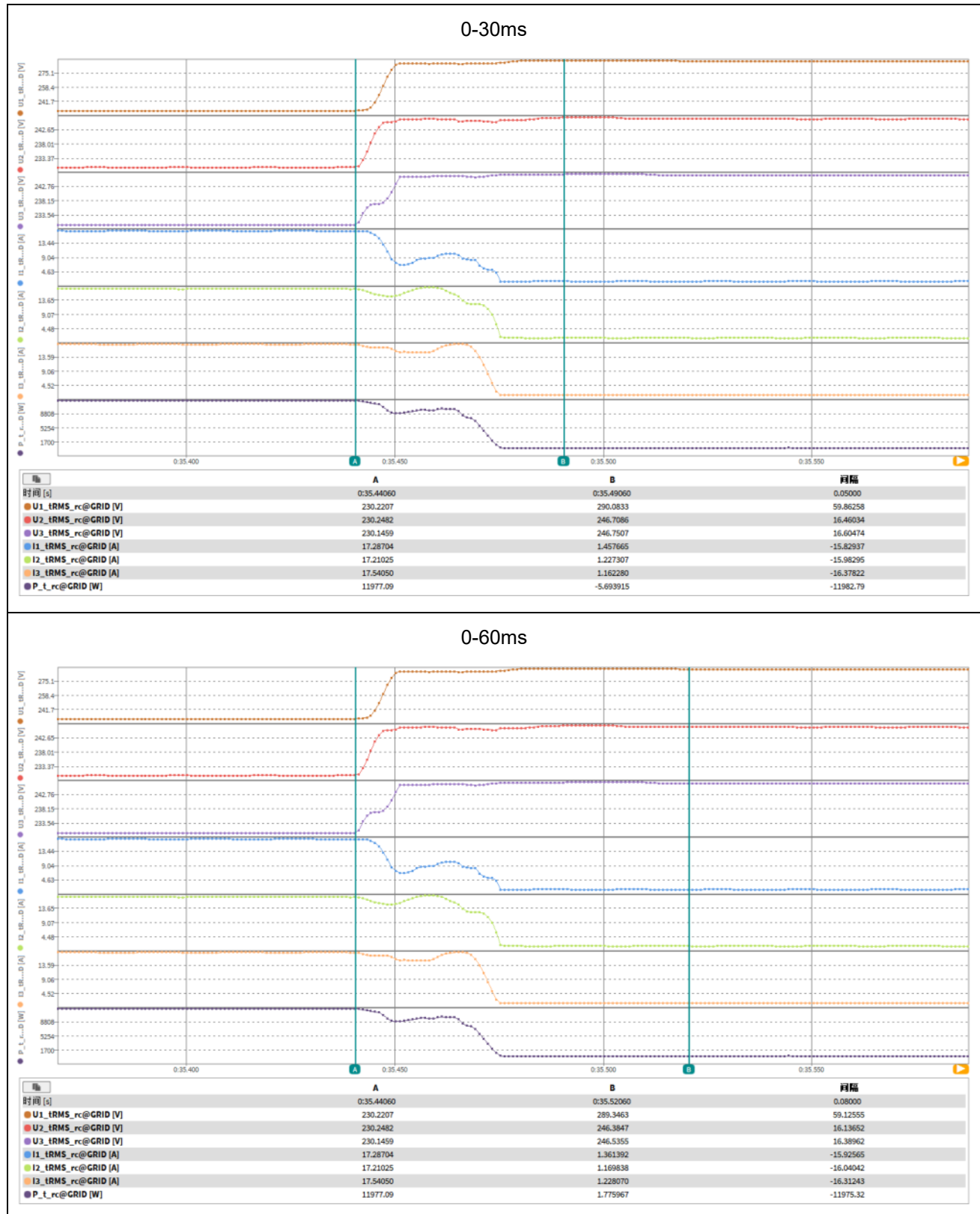
Test – VS3.1

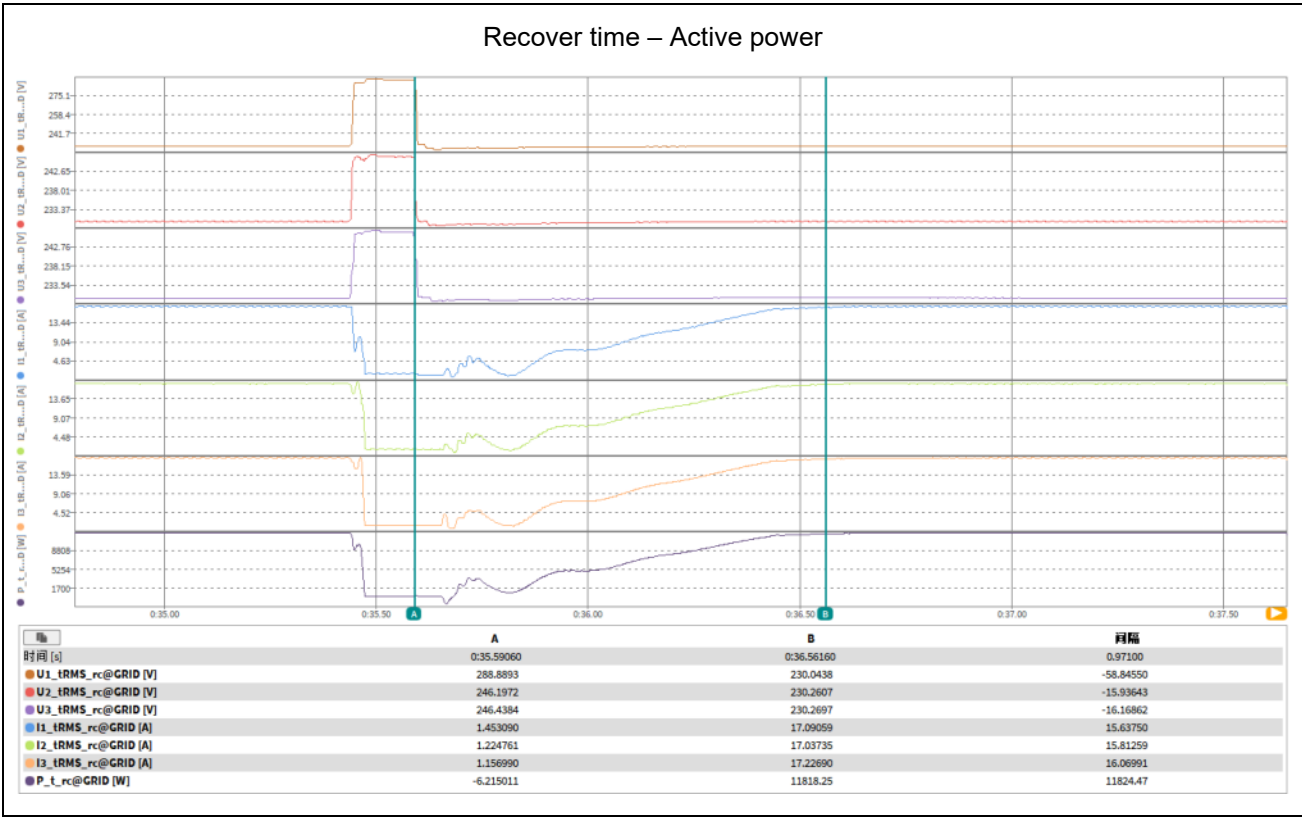
Before fault



Duration fault time

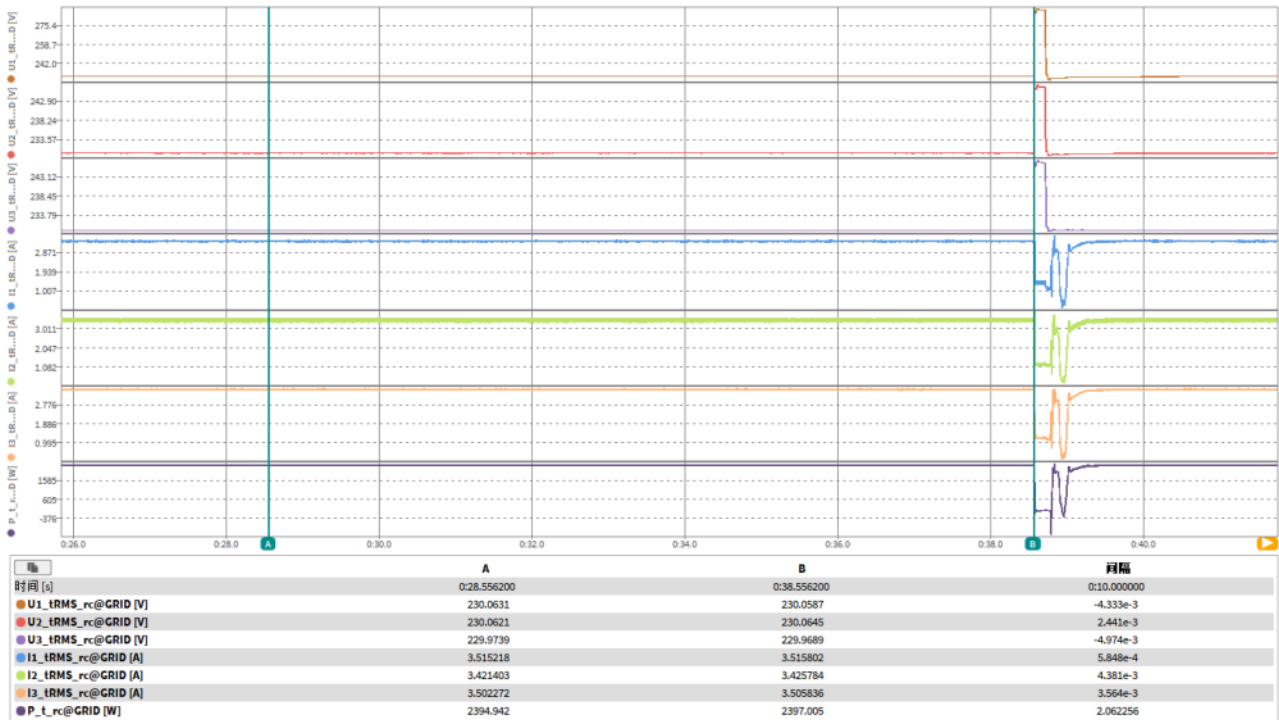




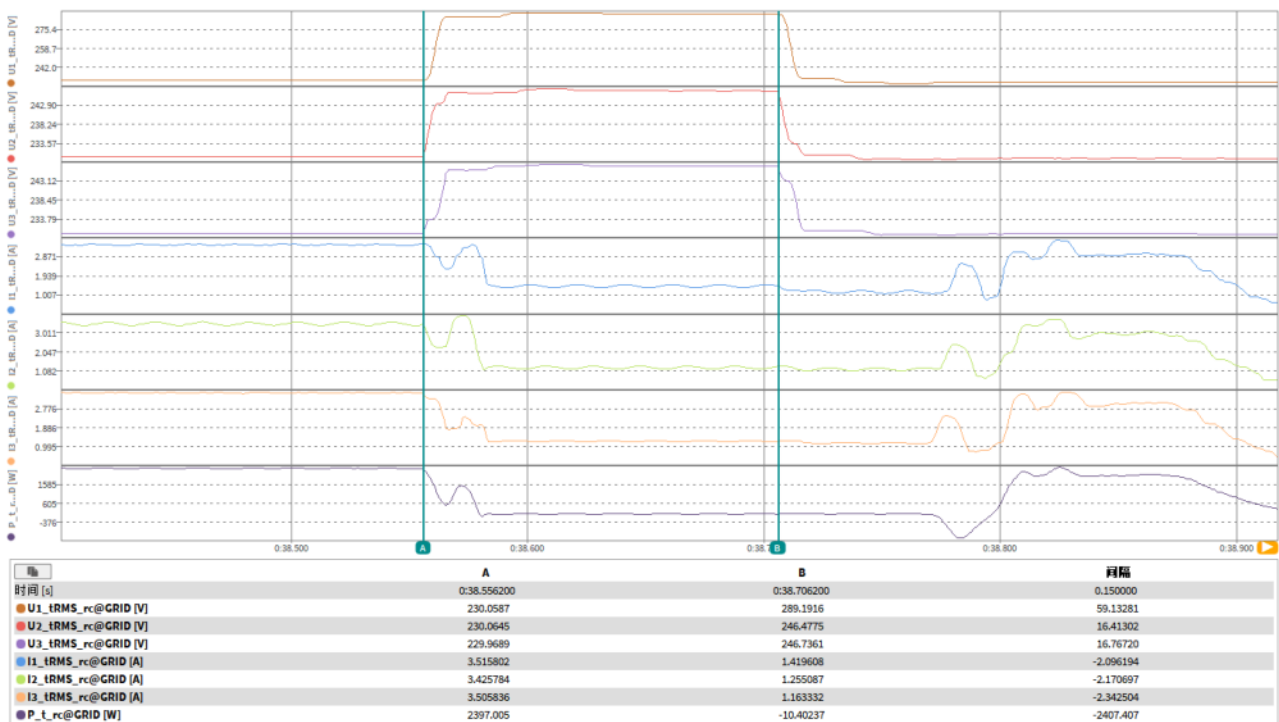


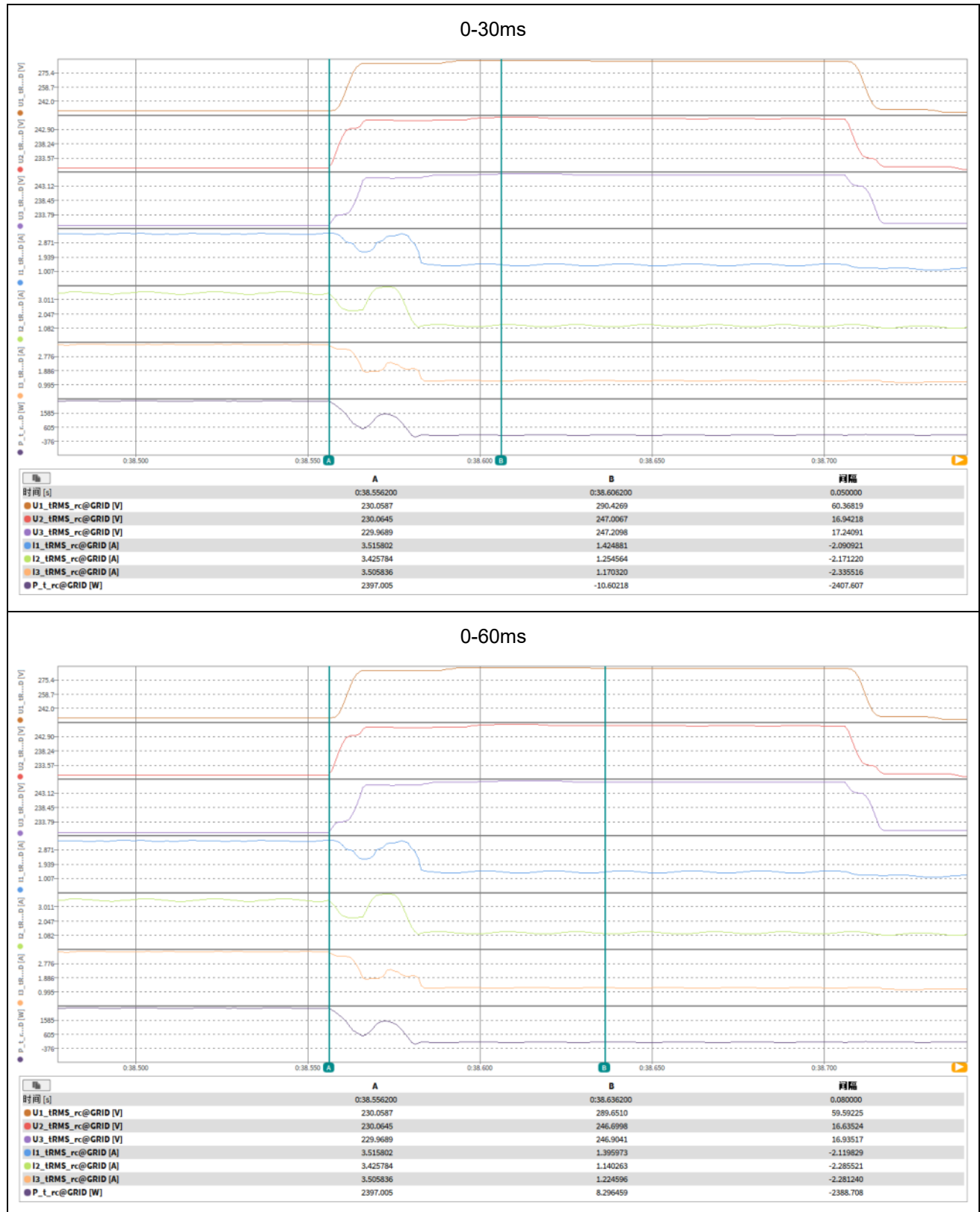
Test – VS3.2

Before fault



Duration fault time







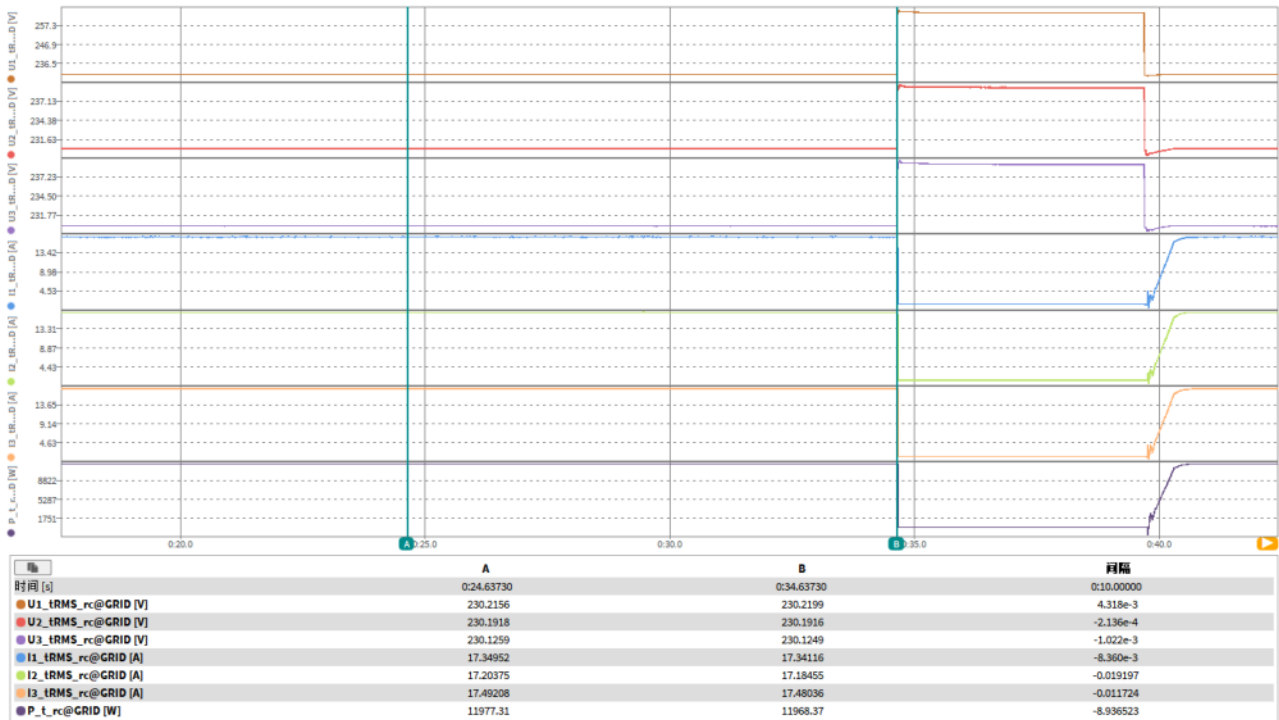
Test Report

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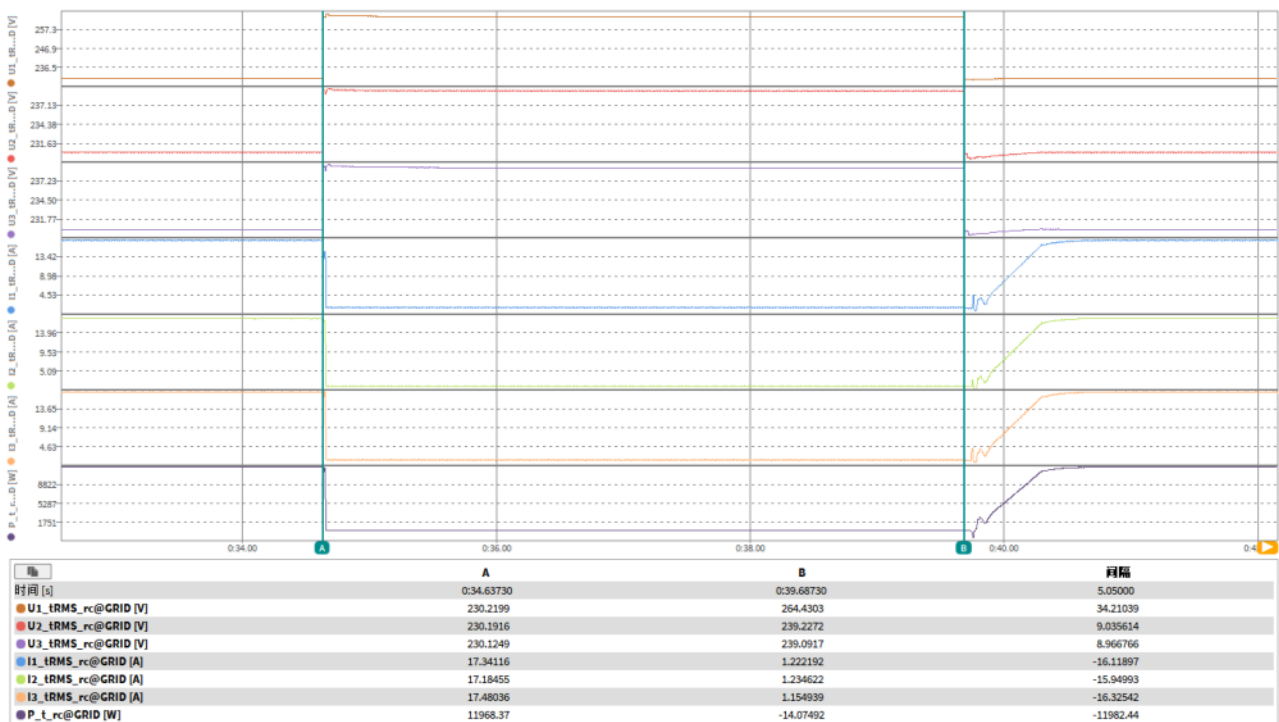
Test Report No.: RDPVP02041/26E/02

Test – VS4.1.1

Before fault



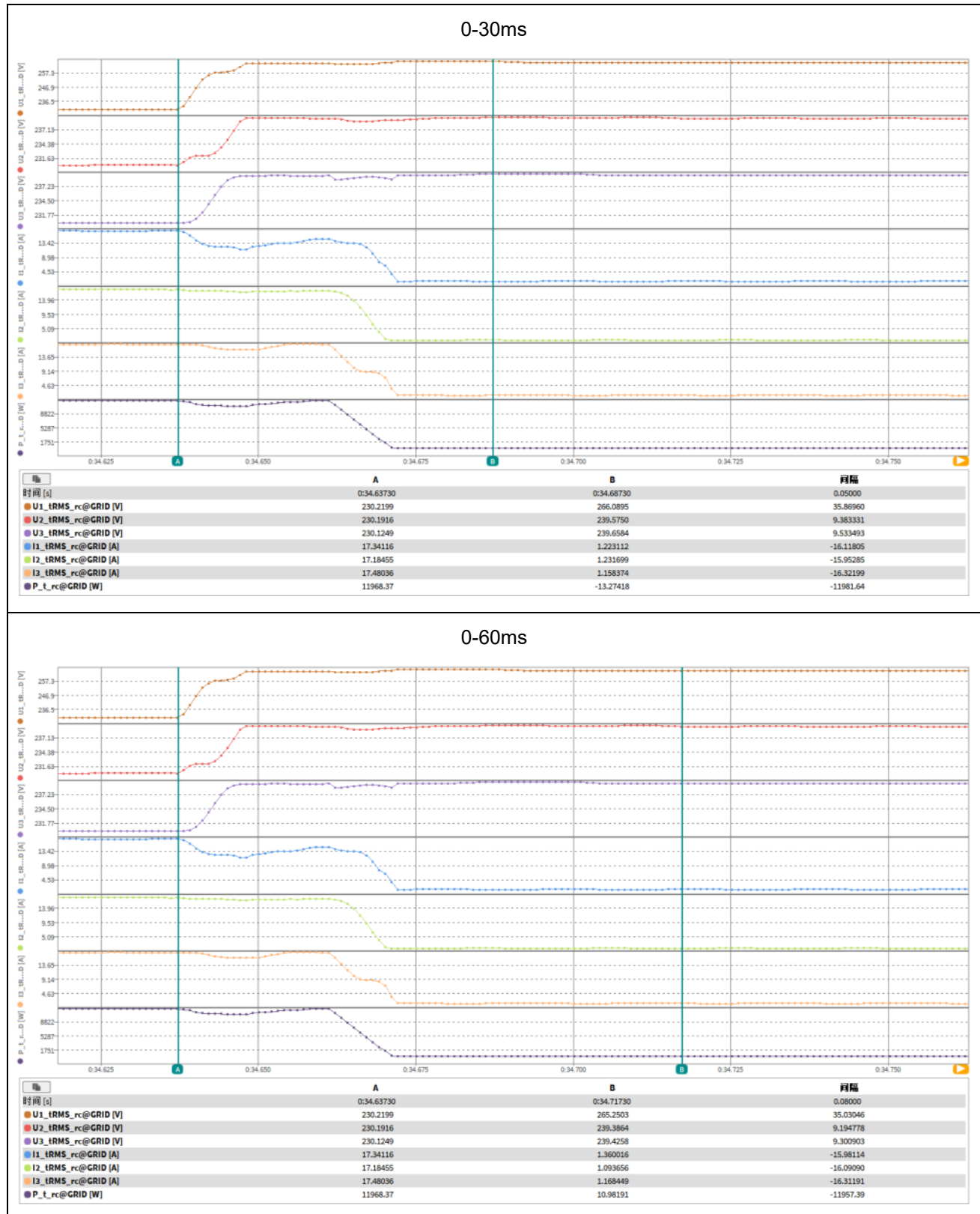
Duration fault time

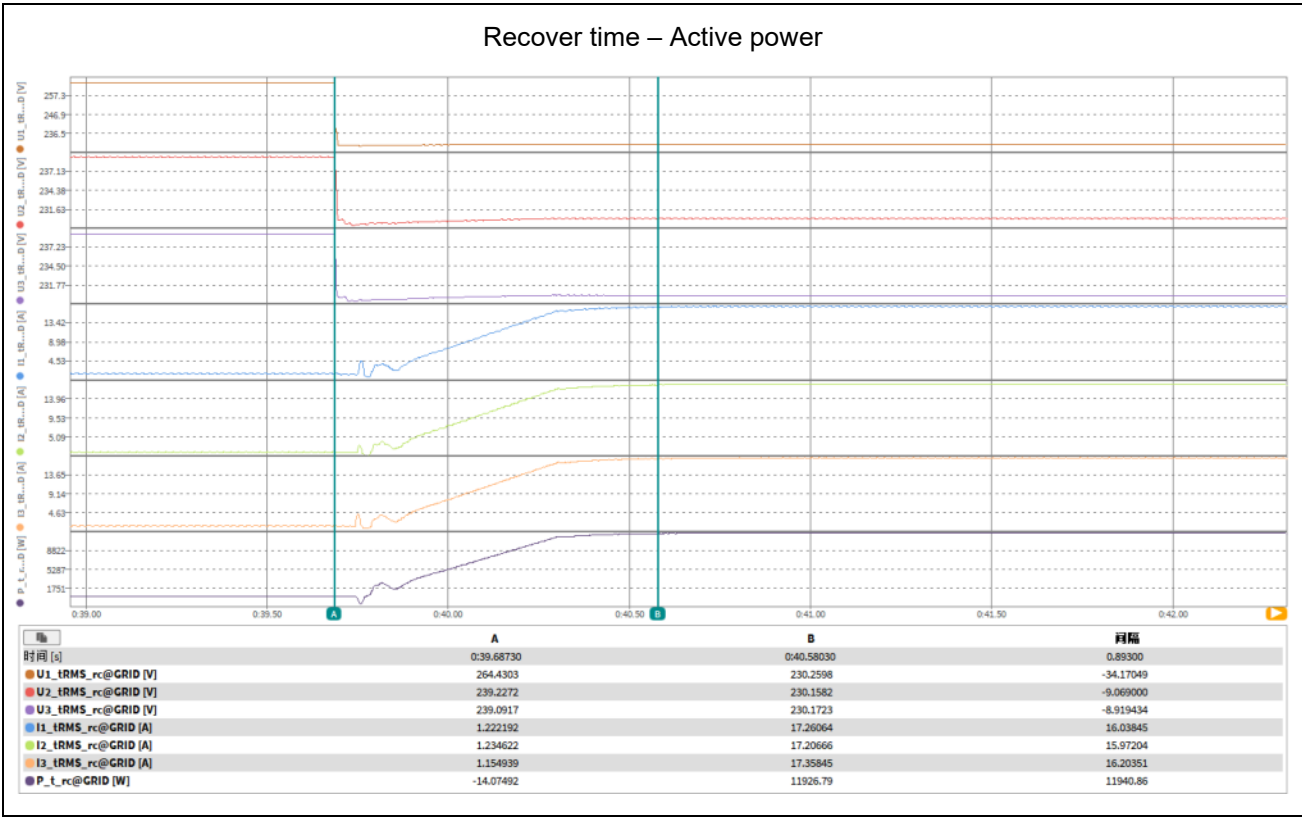


Test Report

Project No.: HZH ZRDPVP02041/26E-02

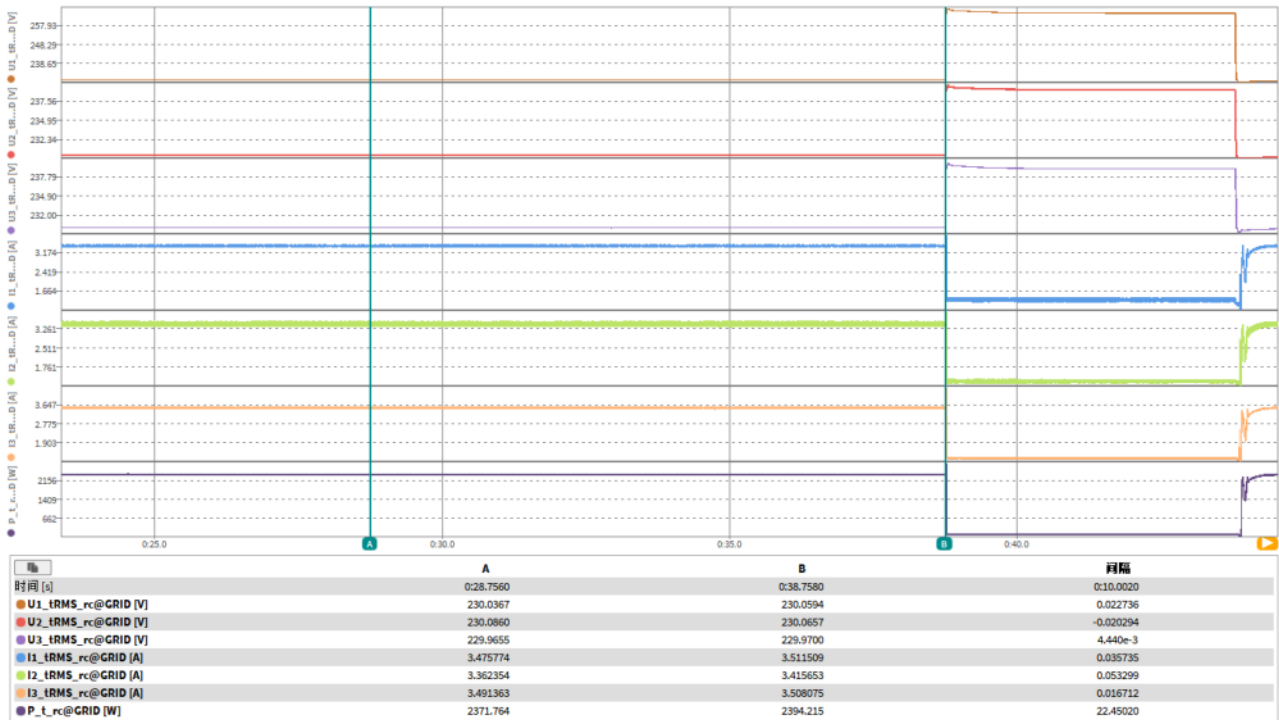
Test Report No.: RDPVP02041/26E/02



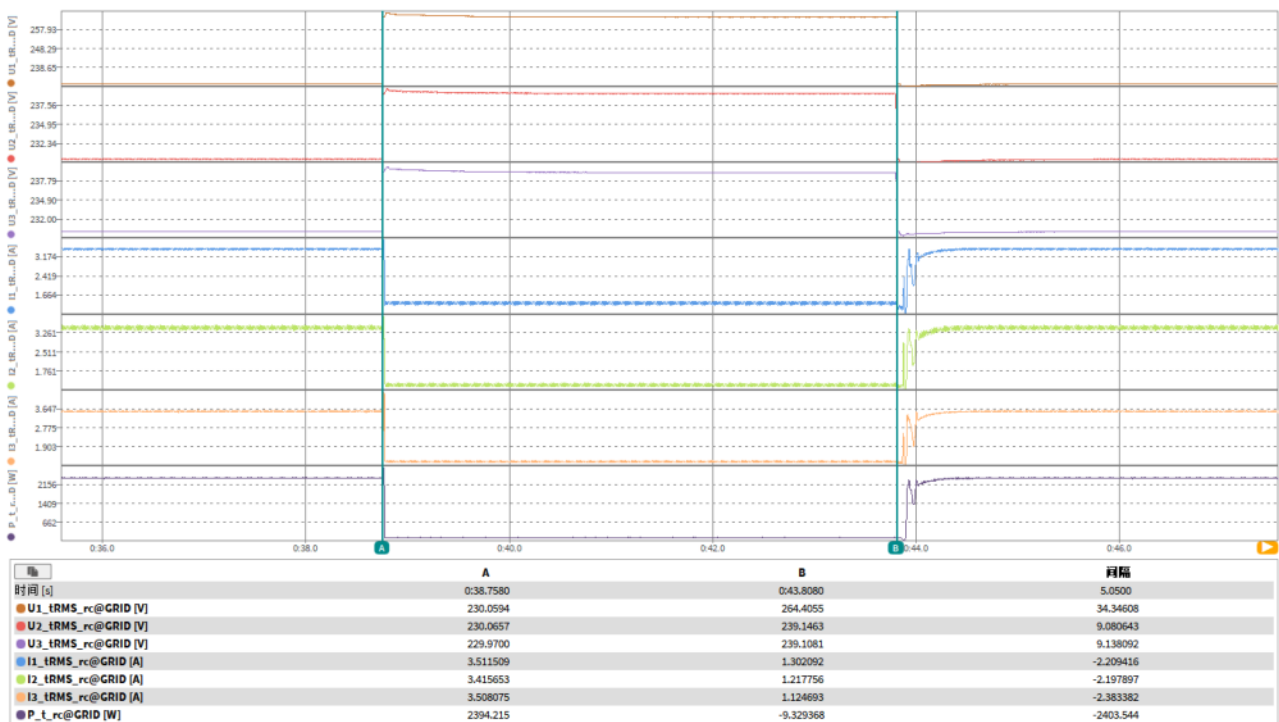


Test – VS4.1.2

Before fault



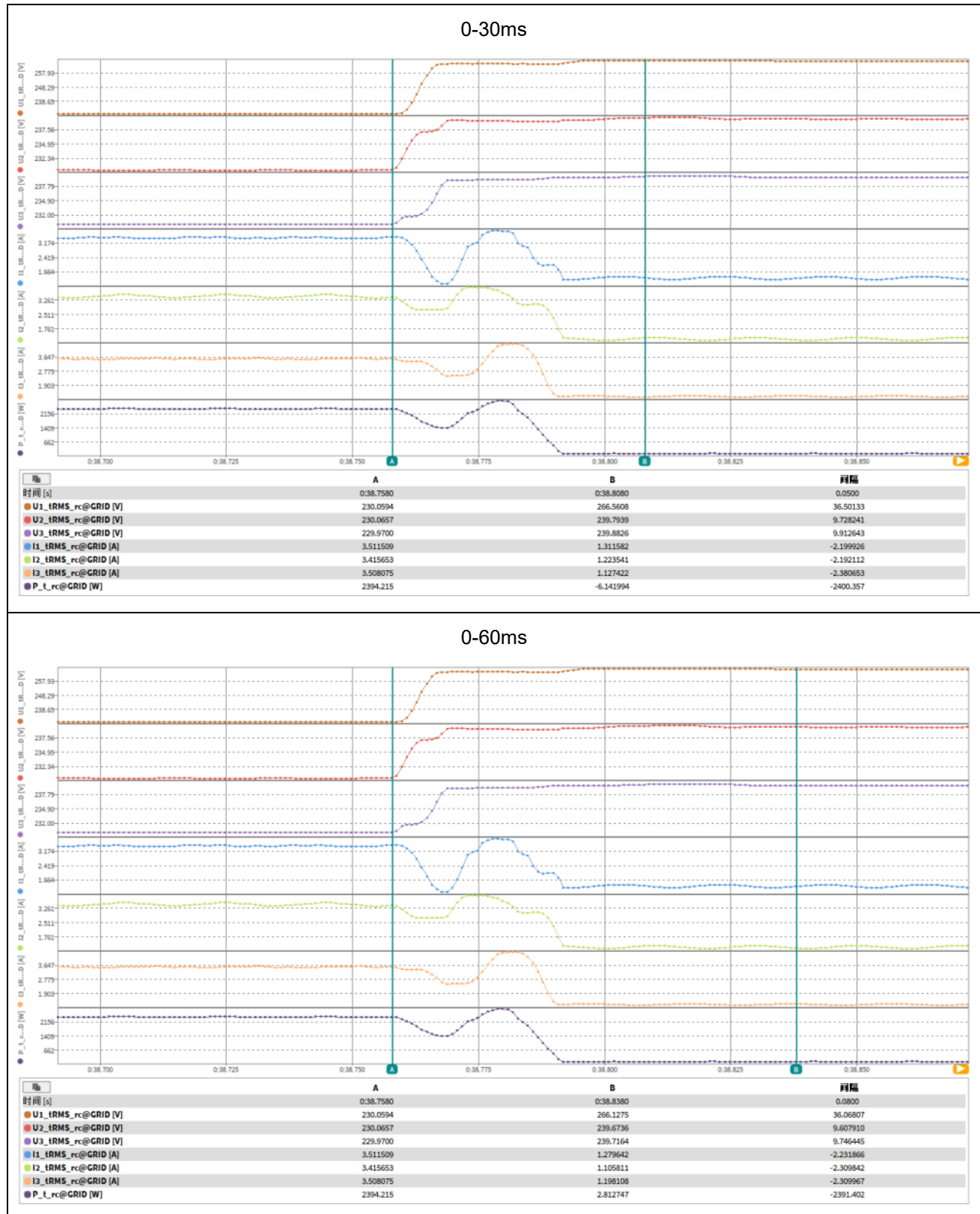
Duration fault time

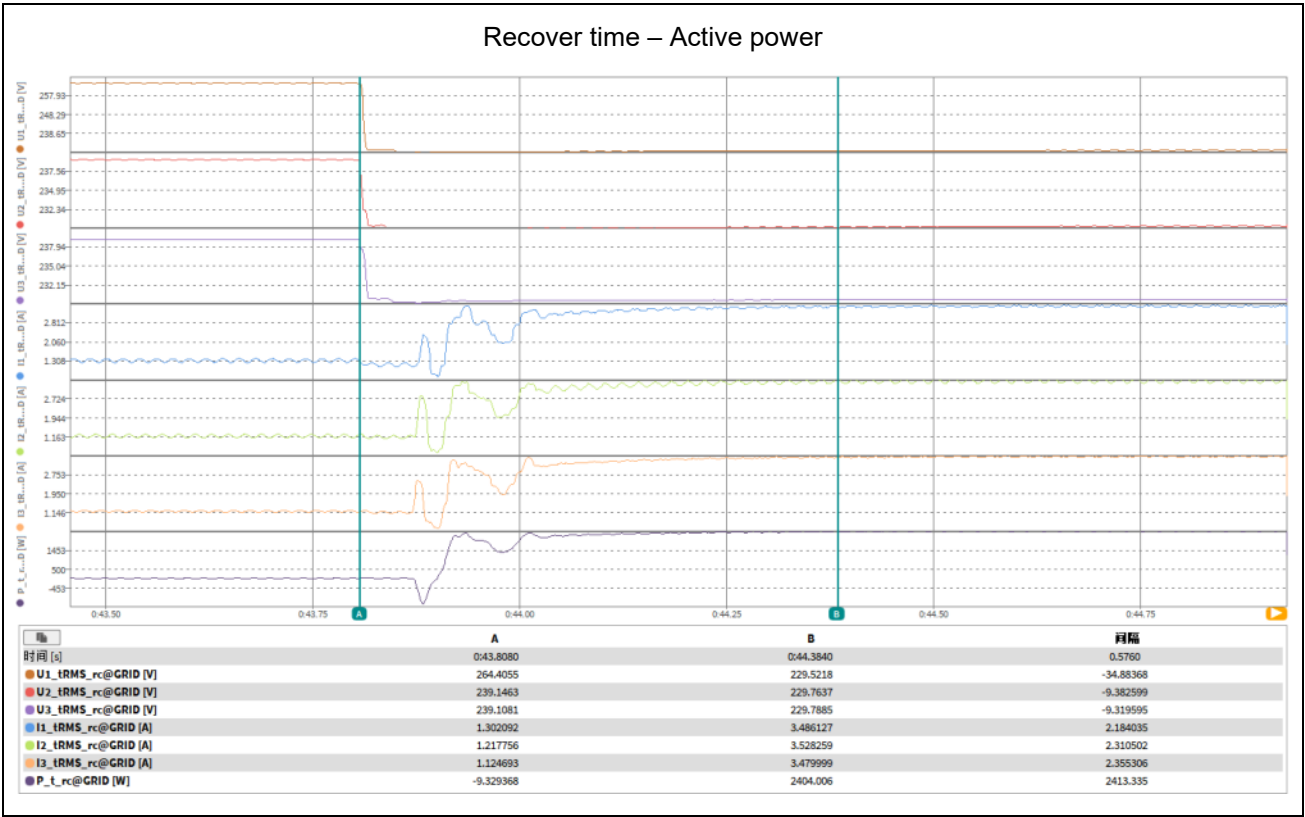


Test Report

Project No.: HZH ZRDPVP02041/26E-02

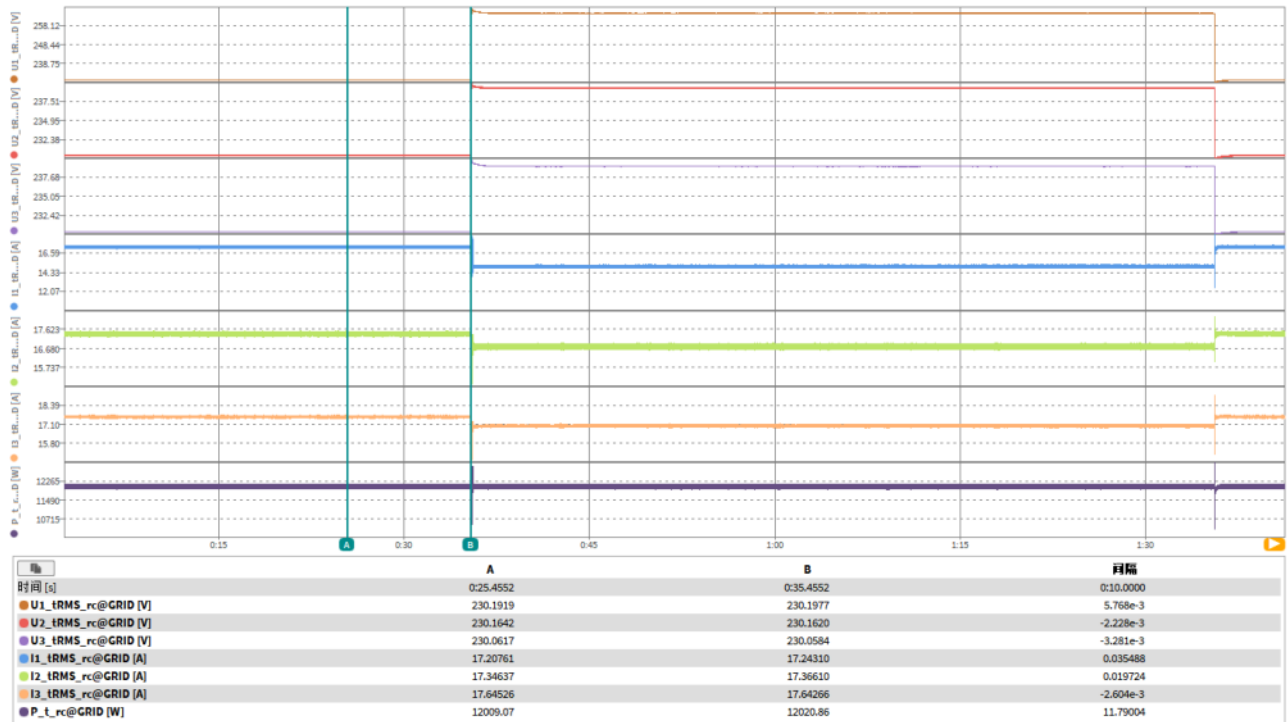
Test Report No.: RDPVP02041/26E/02



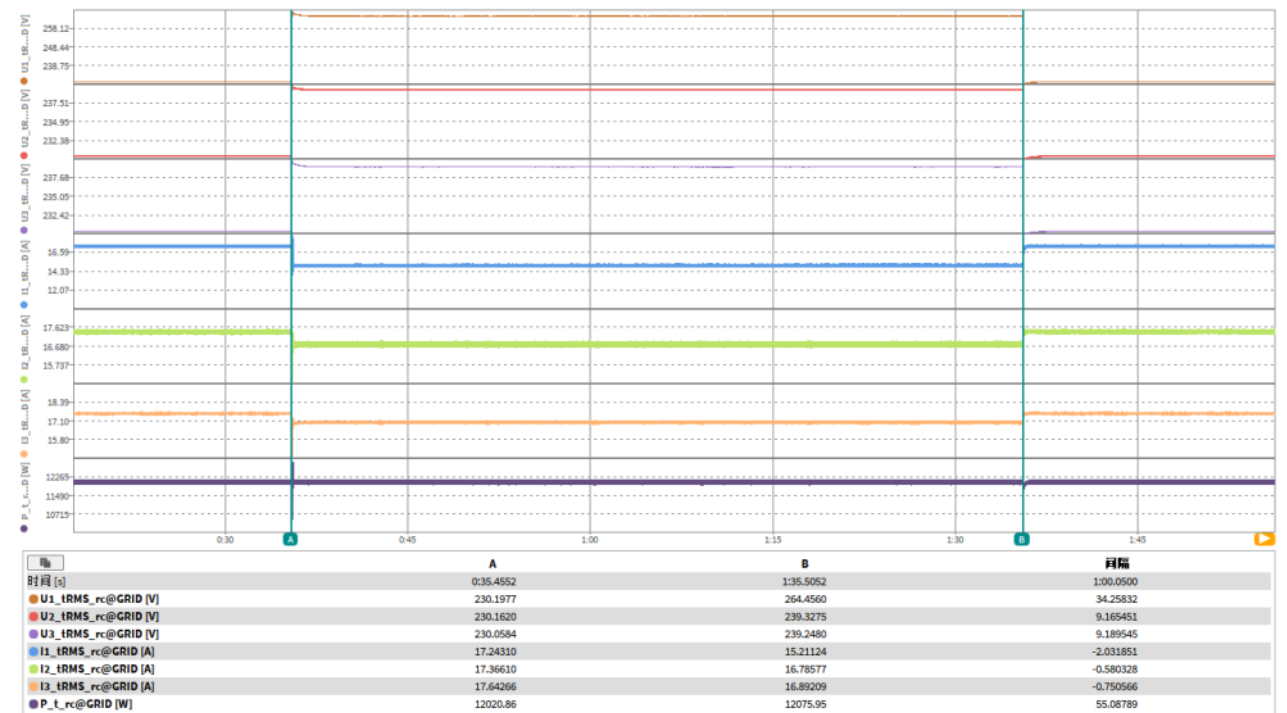


Test – VS4.2.1

Before fault



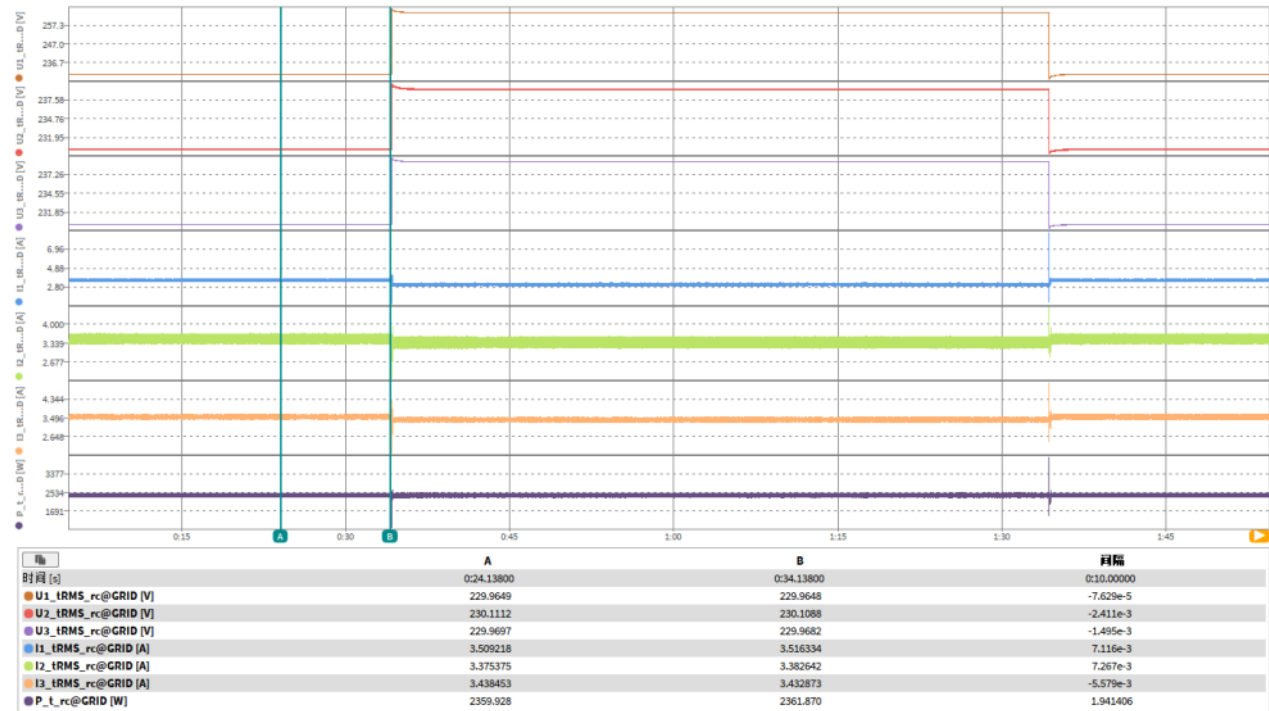
Duration fault time



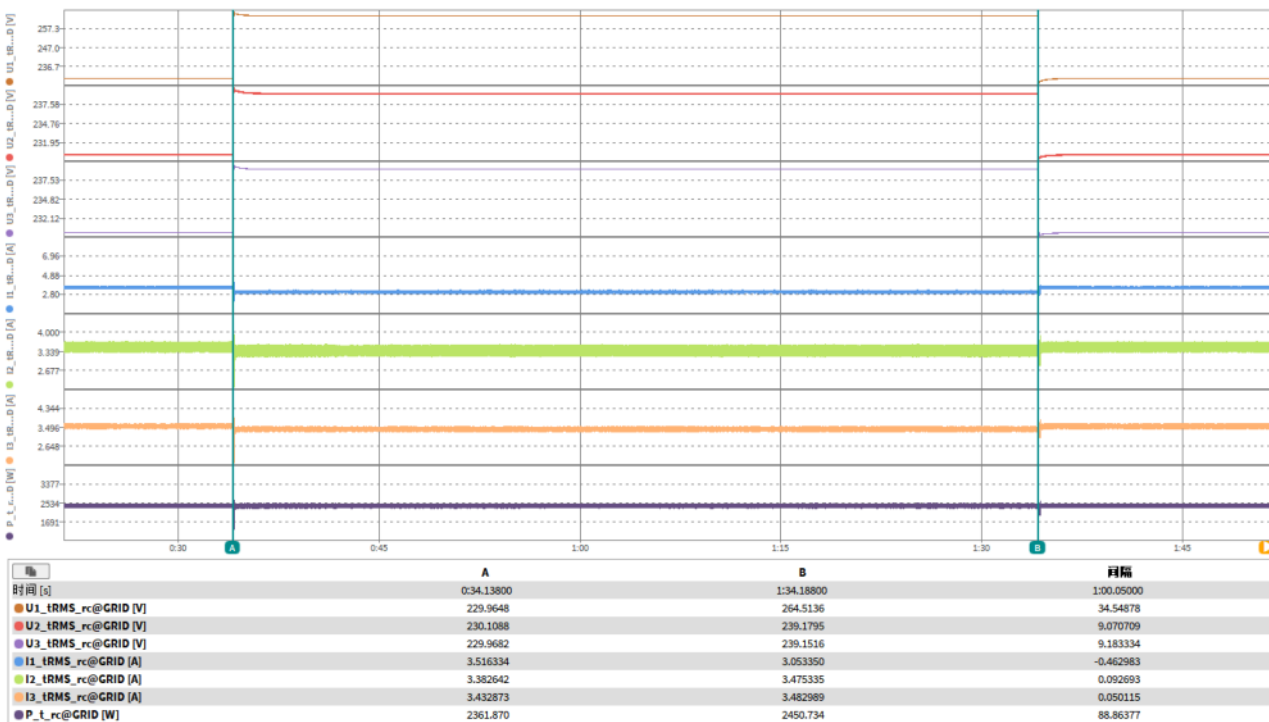


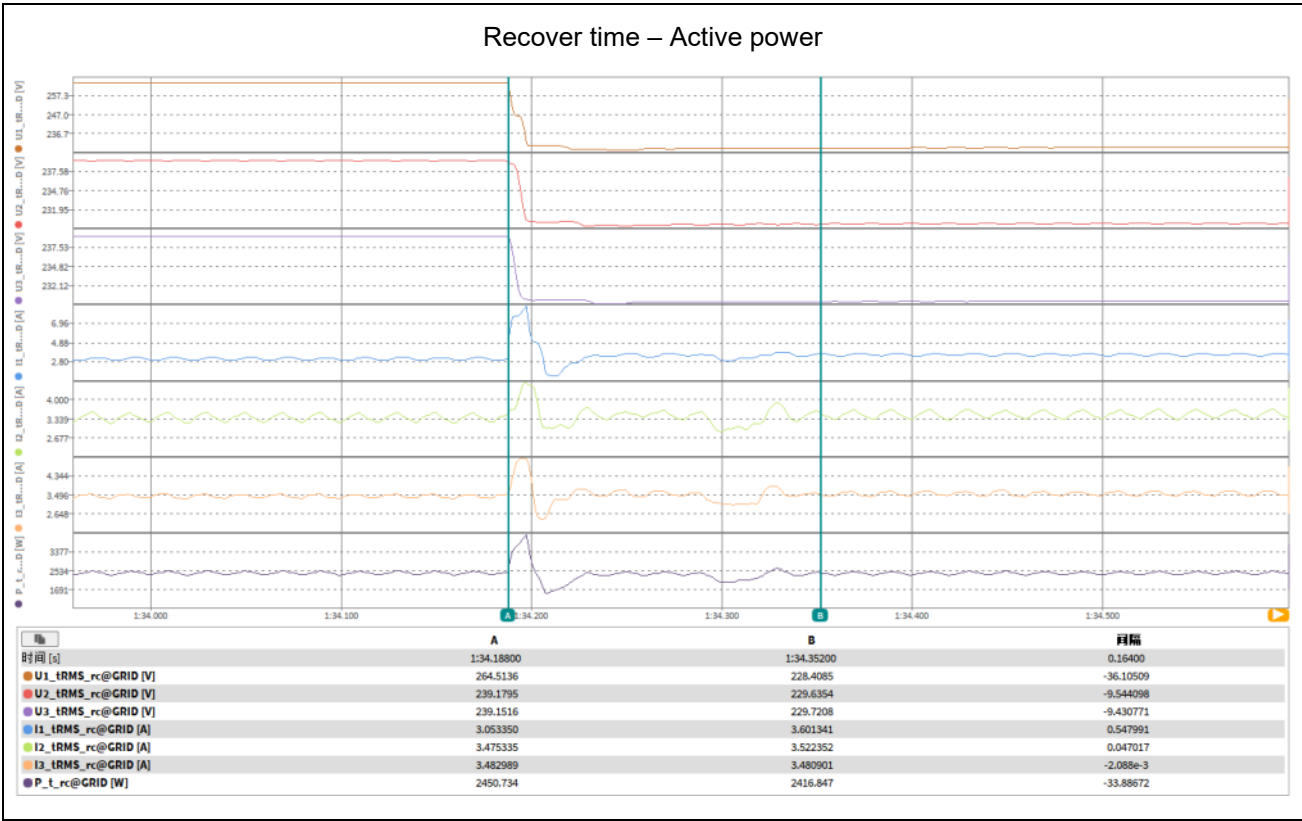
Test – V4.2.2

Before fault



Duration fault time



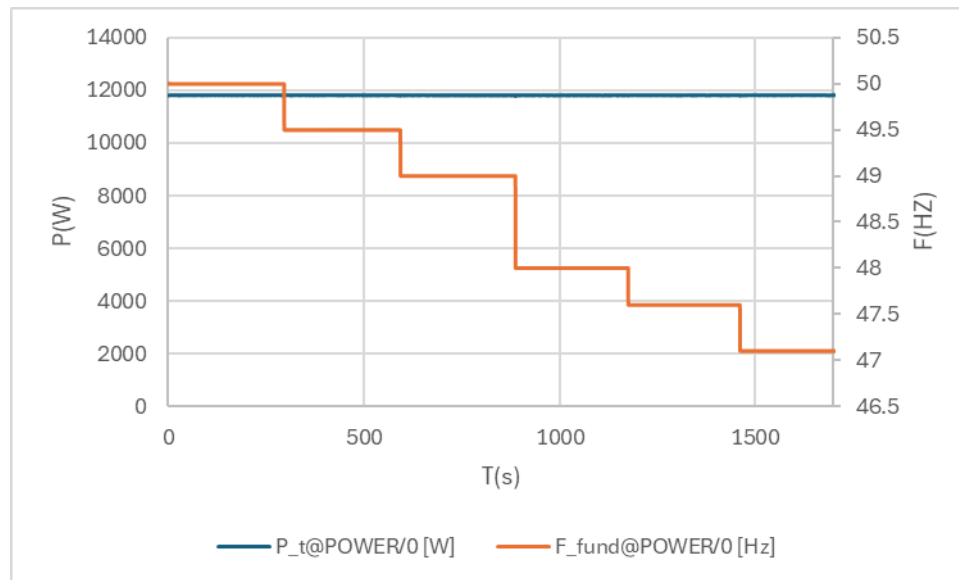


5.4 Active response to frequency deviation

Minimal requirement for active power delivery at under-frequency

P

Graph of frequency a) to b) to c) to d) to e):



Switch to:

5-min mean value (each)	a) 49.50 [Hz]	b) 49.00 [Hz]	c) 48.00 [Hz]	d) 47.60 [Hz]	e) 47.10 [Hz]
Frequency [Hz]:	49.50	49.00	48.00	47.60	47.10
Active power [W]:	11812.90	11816.99	11815.95	11816.04	11816.28
$\Delta P/P_M$ [%] per 1 Hz:	-	0.07	0.02	0.01	0.01

Test:

Test method refer clause A.7.3.2 of G99/1-6.

Operating points a) to d) must be kept for at least 5 minutes.

Operating points e) must be kept for at least 5 minutes.

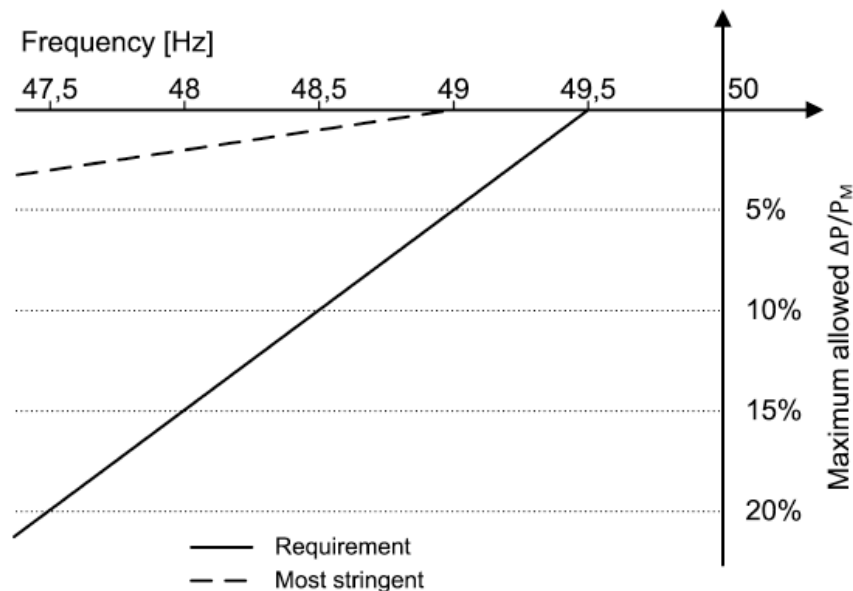
The test must be carried out at 100% P_n .

With a programmable AC source, the PGU is operated at 100% P_n and 49.50 ± 0.01 Hz, Since then the frequency has changed to 49.00Hz, 48.00Hz, 47.60Hz, 47.10Hz, A 5-min mean value is recorded both before and after the frequency change.

Assessment criterion:

The test is passed when the micro-generator

- The frequency should then be set to 49.5 Hz for 5 minutes. The output should remain at 100% of registered Capacity.
- The frequency should then be set to 49.0 Hz and once the output has stabilised, held at this frequency for 5 minutes. The Active Power output must not be below 99% of registered Capacity.
- The frequency should then be set to 48.0 Hz and once the output has stabilised, held at this frequency for 5 minutes. The Active Power output must not be below 97% of registered Capacity.
- The frequency should then be set to 47.6 Hz and once the output has stabilised, held at this frequency for 5 minutes. The Active Power output must not be below 96.2% of registered Capacity.
- The frequency should then be set to 47.1 Hz and held at this frequency for 20s. The Active Power output must not be below 95.0% of registered Capacity and the Synchronous Power Generating Module must not trip in less than the 20s



Maximum allowable power reduction in case of under-frequency

Test Report

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5.4.3.2 Power response to over-frequency (For system with energy storage)									P
Test:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 50.10 ±0.01	c) 50.80 ±0.01	e) 51.40 ±0.01	d) 52.00 ±0.01	f) 51.40 ±0.01	g) 50.80 ±0.01	h) 50.10 ±0.01	i) 50.00 ±0.01
1. Measurement a) to i): Active power output =100% P _{Emax} s=5% (40% P _{ref} / Hz), threshold frequency for start/return: 50.2Hz, P _{ref} = P _{Emax}									
Frequency [Hz]:	50.00	50.10	50.80	51.40	52.00	51.40	50.80	50.10	50.00
P _M [W]:	12000	12000	9120	6240	3360	6240	9120	12000	12000
P _{E60} [W]:	11964	11963	9146	6239	3358	6210	9074	11993	11958
ΔP _{E60} /P _{Emax} [%]:	-0.30	-0.31	0.22	-0.01	-0.02	-0.25	-0.38	-0.06	-0.35
Dead time(≤2s)	-	-	0.2	0.4	0.2	0.2	0.4	-	-
Step response time(≤30s)	-	-	0.4	0.8	0.6	0.4	0.8	-	-
Setting time(s)	-	-	0.4	0.8	0.6	0.4	0.8	-	-
Limit ΔP/P _{1min} :	± 10 % of P _n								
Test:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 50.10 ±0.01	c) 50.80 ±0.01	e) 51.40 ±0.01	d) 52.00 ±0.01	f) 51.40 ±0.01	g) 50.80 ±0.01	h) 50.10 ±0.01	i) 50.00 ±0.01
2. Measurement a) to i): Active power output 50%P _{Emax} after freezing = 100% P _{Emax} s=5%(40% P _{ref} / Hz), threshold frequency for start/return: 50.2Hz, P _{ref} = P _{Emax}									
Frequency [Hz]:	50.00	50.10	50.80	51.40	52.00	51.40	50.80	50.10	50.00
P _M [W]:	6000	6000	3120	240	-2640	240	3120	12000	12000
P _{E60} [W]:	5914	5914	3078	163	-2723	136	3009	11833	11872
ΔP _{E60} /P _{Emax} [%]:	-0.72	-0.72	-0.35	-0.64	-0.70	-0.86	-0.92	-1.39	-1.07
Dead time(≤2s)	-	-	0.2	0.4	0.4	0.4	0.2	-	-

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Step response time(≤30s)	-	-	0.4	0.8	0.6	0.6	0.6	-	-
Setting time(s)	-	-	0.4	0.8	0.6	0.6	0.6	-	-
Limit ΔP/P _{1min} :	± 10 % of P _n								
Test:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 50.10 ±0.01	c) 50.80 ±0.01	e) 51.40 ±0.01	d) 52.00 ±0.01	f) 51.40 ±0.01	g) 50.80 ±0.01	h) 50.10 ±0.01	i) 50.00 ±0.01
3. Measurement a) to i): Active power output −50%P _{Emax} s=5%(40% P _{ref} / Hz), threshold frequency for start/return: 50.2Hz, P _{ref} = P _{Emax}									
Frequency [Hz]:	50.00	50.10	50.80	51.40	52.00	51.40	50.80	50.10	50.00
P _M [W]:	-6000	-6000	-8880	-11760	-12000	-11760	-8880	-6000	-6000
P _{E60} [W]:	-6099	-6100	-8982	-11960	-12307	-11980	-9012	-6108	-6100
ΔP _{E60} / P _{Emax} [%]:	-0.83	-0.83	-0.85	-1.66	-2.56	-1.83	-1.10	-0.90	-0.83
Dead time(≤2s)	-	-	0.2	0.4	0.2	0.2	0.4	-	-
Step response time(≤30s)	-	-	0.4	0.6	0.4	0.4	0.6	-	-
Setting time(s)	-	-	0.4	0.6	0.4	0.4	0.6	-	-
Limit ΔP/P _{1min} :	± 10 % of P _n								
Test:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 50.25 ±0.01	c) 51.00 ±0.01	e) 51.50 ±0.01	d) 52.00 ±0.01	f) 51.50 ±0.01	g) 51.00 ±0.01	h) 50.40 ±0.01	i) 50.00 ±0.01
4. Measurement a) to i): Active power output 60%P _{Emax} s=2%(100% P _{ref} / Hz), threshold frequency for start/return: 50.5Hz, P _{ref} = P _{Emax} , hold 1s									
Frequency [Hz]:	50.00	50.25	51.00	51.50	52.00	51.50	51.00	50.40	50.00
P _M [W]:	7200	7200	1200	-4800	-10800	-10800	-10800	7200	7200
P _{E60} [W]:	7120	7120	1072	-4954	-11251	-11306	-11304	7134	7120
ΔP _{E60} /P _{Emax} [%]:	-0.66	-0.67	-1.06	-1.28	-3.76	-4.22	-4.20	-0.55	-0.66
Dead time(≤2s)	-	-	0.4	0.4	0.6	-	-	-	-

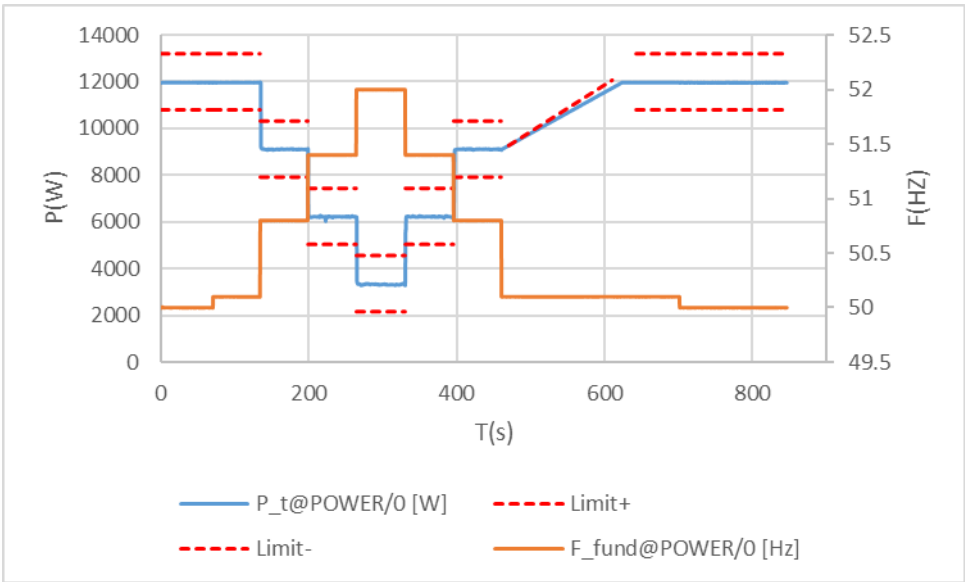
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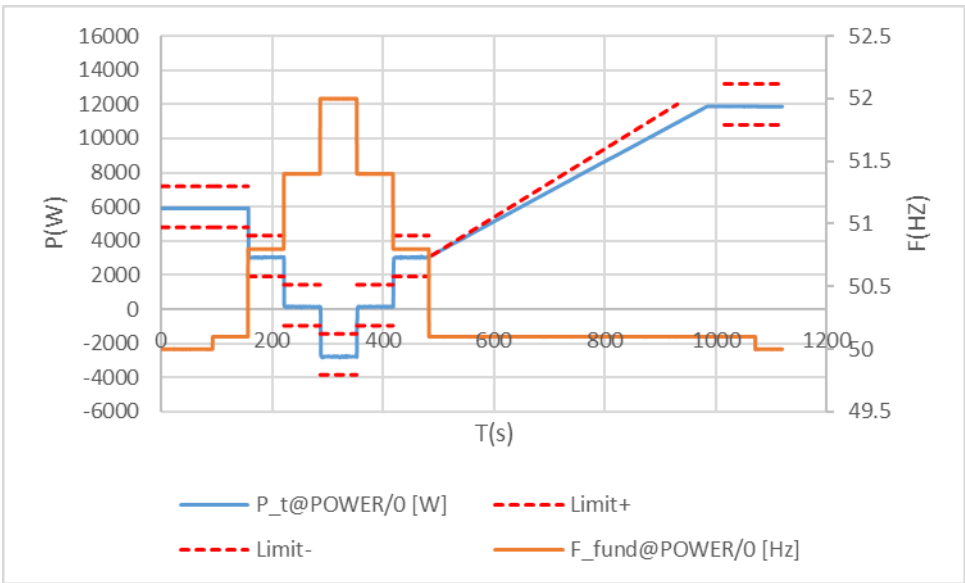
Test Report No.: RDPVP02041/26E/02

Step response time(≤30s)	-	-	0.6	0.6	1.0	-	-	-	-
Setting time(s)	-	-	0.6	0.6	1.0	-	-	-	-
Limit ΔP/P _{1min} :	± 10 % of P _n								
Test:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 50.10 ±0.01	c) 50.80 ±0.01	e) 51.40 ±0.01	d) 52.00 ±0.01	f) 51.40 ±0.01	g) 50.80 ±0.01	h) 50.10 ±0.01	i) 50.00 ±0.01
5. Measurement a) to i): Active power output 40% P _{Emax} s=12%(16.67% P _{ref} / Hz), threshold frequency for start: 50.2Hz, for return: 50.05Hz, P _{ref} = P _{Emax} , hold 600s									
Frequency [Hz]:	50.00	50.10	50.80	51.40	52.00	51.40	50.80	50.10	50.00
P _M [W]:	4800	4800	3600	2400	1200	1200	1200	1200	4800
P _{E60} [W]:	4708	4708	3506	2297	1095	1078	1078	1078	4810
ΔP _{E60} /P _{Emax} [%]:	-0.76	-0.76	-0.79	-0.86	-0.87	-1.02	-1.02	-1.02	0.08
Dead time(≤2s)	-	-	1.8	1.6	1.6	-	-	-	-
Step response time(≤30s)	-	-	2.0	2.0	2.0	-	-	-	-
Setting time(s)	-	-	2.0	2.0	2.0	-	-	-	-
Limit ΔP/P _{1min} :	± 10 % of P _n								

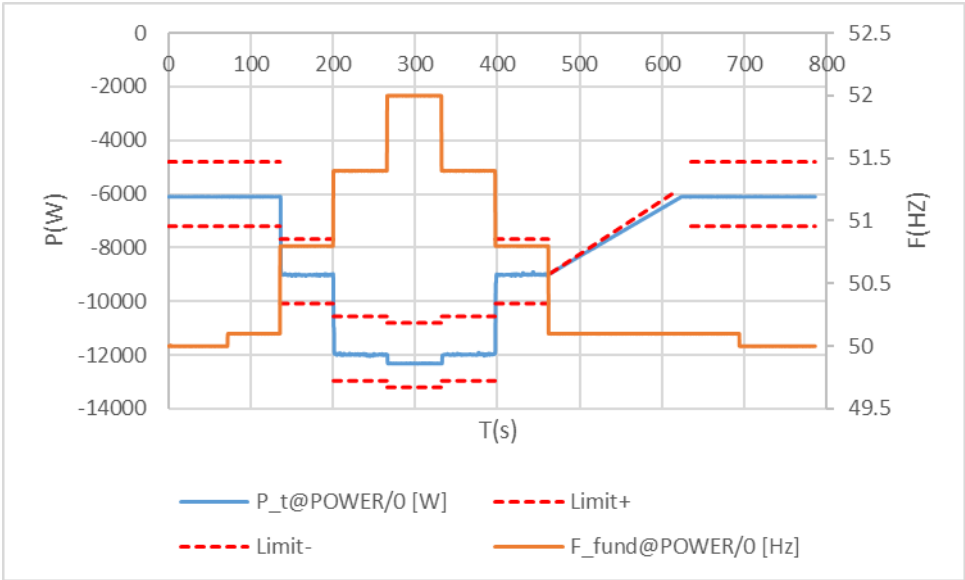
Graph of Measurement 1.: Active power output 100% P_Emax



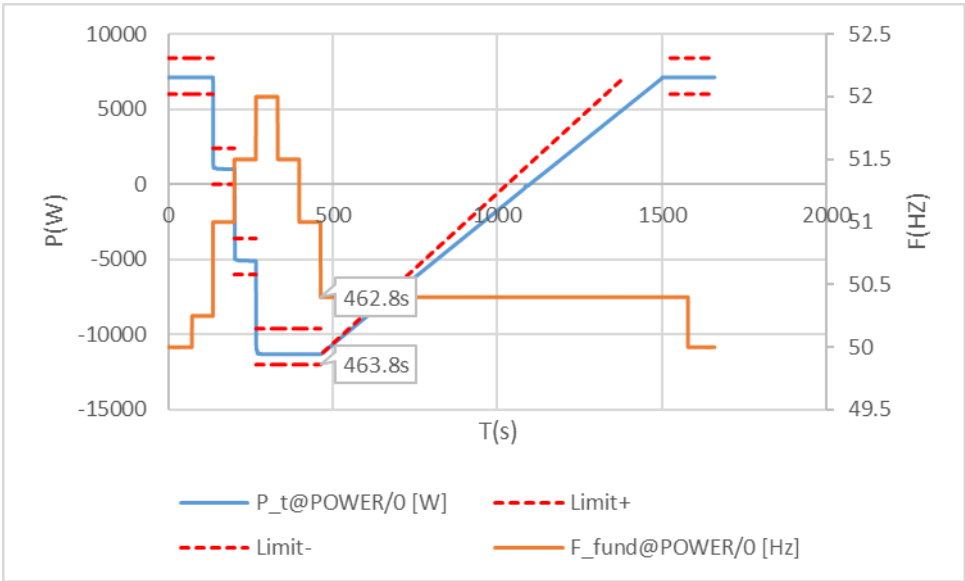
Graph of Measurement 2.: Active power output 50% P_Emax



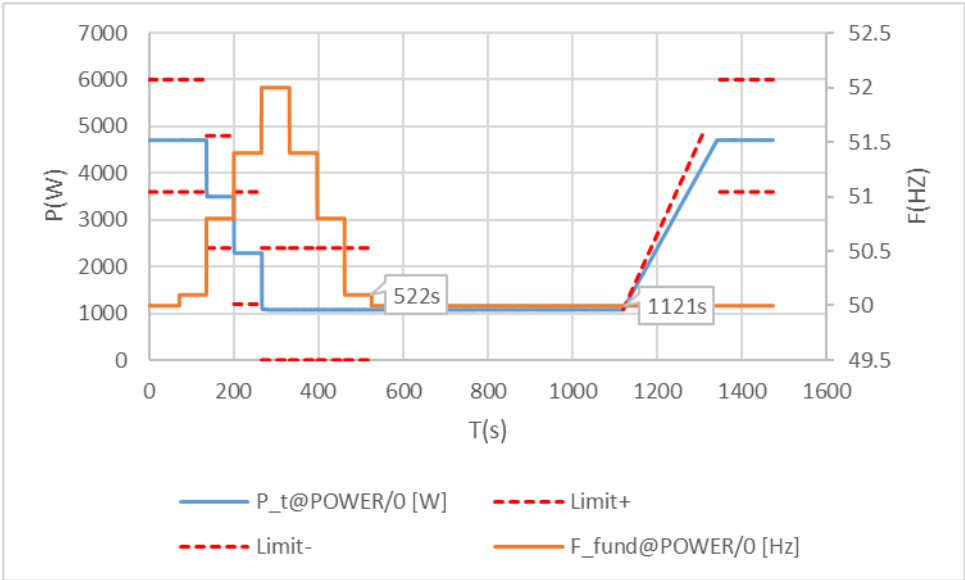
Graph of Measurement 3.: Active power output -50% P_{Emax}



Graph of Measurement 4.: Active power output 60% P_{Emax}



Graph of Measurement 5.: Active power output 40% P_{Emax}



Notes:

Setting (a) for ESS

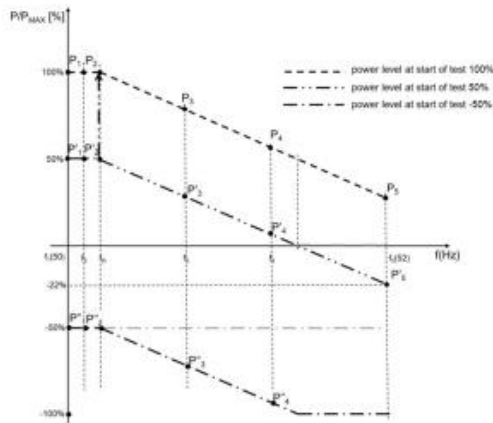


Figure 16 — Electrical energy storage systems ($P_{ref} = P_{max}$) without configured deactivation threshold, setting (a), example

Setting (b) for ESS

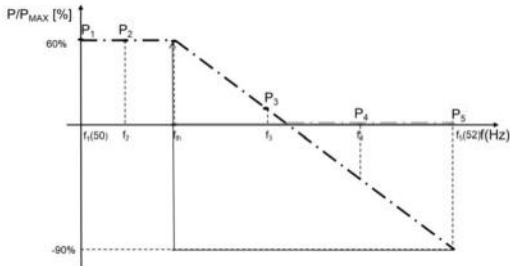


Figure 17 — Electrical energy storage systems ($P_{ref} = P_{max}$) with configured deactivation threshold, setting (b), example

Setting (c) for ESS

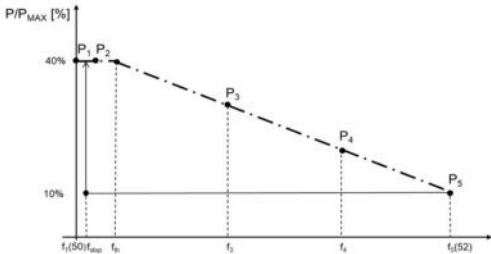


Figure 18 — Electrical energy storage systems ($P_{ref} = P_{max}$) with configured deactivation threshold, setting (c), example

NOTE 3 P_{max} in charging condition can be lower than P_{max} in discharging condition

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5.4.3.3 Power response to under-frequency (For system with energy storage)								P	
Test a:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 49.90 ±0.01	c) 49.00 ±0.01	e) 47.30 ±0.01	d) 46.05 ±0.01	f) 47.30 ±0.01	g) 49.00 ±0.01	h) 49.90 ±0.01	i) 50.00 ±0.01
1. Measurement a) to i): Active power output =-50% P _{E_{max}} s=5% (40% P _{ref} / Hz), threshold frequency for start/return: 49.8Hz, P _{ref} =P _{E_{max}}									
Frequency [Hz]:	50.00	49.90	49.00	47.30	46.05	47.30	49.00	49.90	50.00
P _M [W]:	-6000	-6000	-2160	6000	12000	6000	-2160	-6000	-6000
P _{E60} [W]:	-6101	-6101	-2225	5982	11818	6106	-2134	-6091	-6099
ΔP _{E60} / P _{E_{max}} [%]:	-0.84	-0.84	-0.54	-0.15	-1.51	0.88	0.21	-0.76	-0.83
Dead time(≤2s)	-	-	0.2	0.4	0.4	0.4	0.2	0.2	-
Step response time(≤30s)	-	-	0.6	0.6	0.8	0.6	0.4	0.4	-
Setting time(s)	-	-	0.6	0.6	0.8	0.6	0.4	0.4	-
Limit ΔP/P _{1min} :	± 10 % of P _n								
Test b:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 49.75 ±0.01	c) 49.25 ±0.01	e) 48.75 ±0.01	d) 46.00 ±0.01	f) 48.75 ±0.01	g) 49.25 ±0.01	h) 49.75 ±0.01	i) 50.00 ±0.01
2. Measurement a) to i): Active power output =0% P _{E_{max}} s=2% (100% P _{ref} / Hz), threshold frequency for start/return: 49.5Hz, P _{ref} =P _{E_{max}}									
Frequency [Hz]:	50.00	49.75	49.25	48.75	46.00	48.75	49.25	49.75	50.00
P _M [W]:	0	0	3000	9000	12000	9000	3000	0	0
P _{E60} [W]:	-116	-116	2886	8842	11866	8981	2977	-112	-115
ΔP _{E60} / P _{E_{max}} [%]:	-0.96	-0.96	-0.95	-1.32	-1.12	-0.16	-0.19	-0.93	-0.96
Dead time(≤2s)	-	-	0.2	0.6	0.2	0.4	0.2	0.2	-

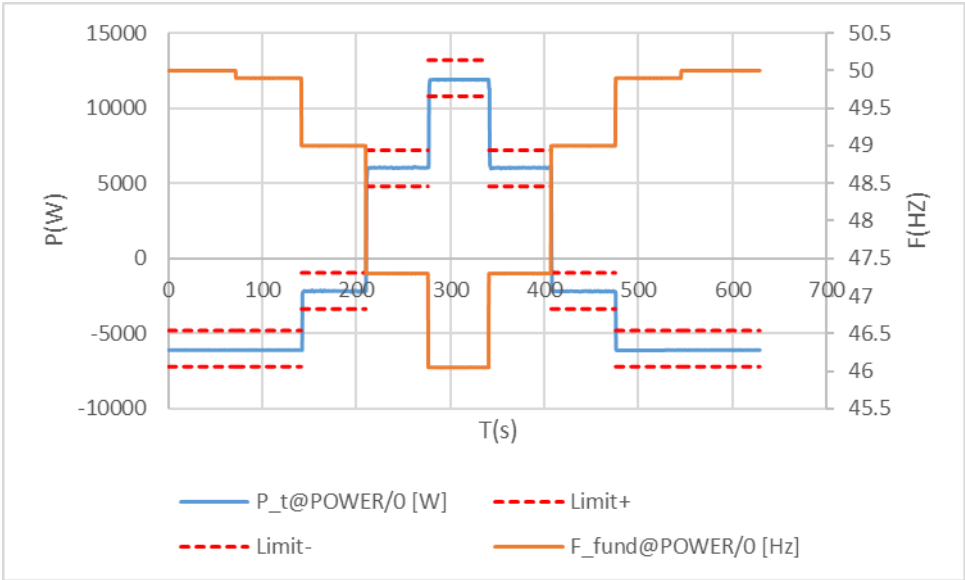
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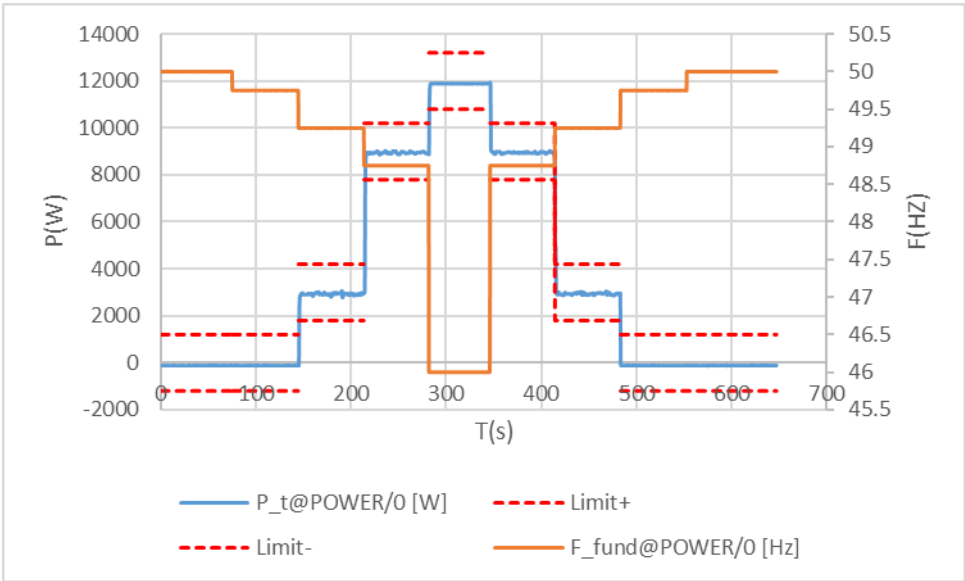
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Step response time(≤30s)	-	-	0.4	1.0	0.4	0.6	0.4	0.4	-
Setting time(s)	-	-	0.4	1.0	0.4	0.6	0.4	0.4	-
Limit ΔP/P _{1min} :	± 10 % of P _n								
Test c:									
1-min mean value [Hz]:	a) 50.00 ±0.01	b) 49.90 ±0.01	c) 49.20 ±0.01	e) 47.40 ±0.01	d) 46.00 ±0.01	f) 47.40 ±0.01	g) 49.20 ±0.01	h) 49.90 ±0.01	i) 50.00 ±0.01
3. Measurement a) to i): Active power output =50% P _{Emax} s=12% (16.67% P _{ref} / Hz), threshold frequency for start/return: 49.8Hz, P _{ref} =P _{Emax}									
Frequency [Hz]:	50.00	49.90	49.20	47.40	46.00	47.40	49.20	49.90	50.00
P _M [W]:	6000	6000	7200	10800	12000	10800	7200	6000	6000
P _{E60} [W]:	5914	5914	7097	10636	11885	10697	7149	5915	5913
ΔP _{E60} /P _{Emax} [%]:	-0.71	-0.72	-0.86	-1.37	-0.96	-0.86	-0.42	-0.70	-0.73
Dead time(≤2s)	-	-	1.6	1.6	1.8	1.8	1.6	1.6	-
Step response time(≤30s)	-	-	1.8	2.0	2.0	2.0	2.0	2.0	-
Setting time(s)	-	-	1.8	2.0	2.0	2.0	2.0	2.0	-
Limit ΔP/P _{1min} :	± 10 % of P _n								

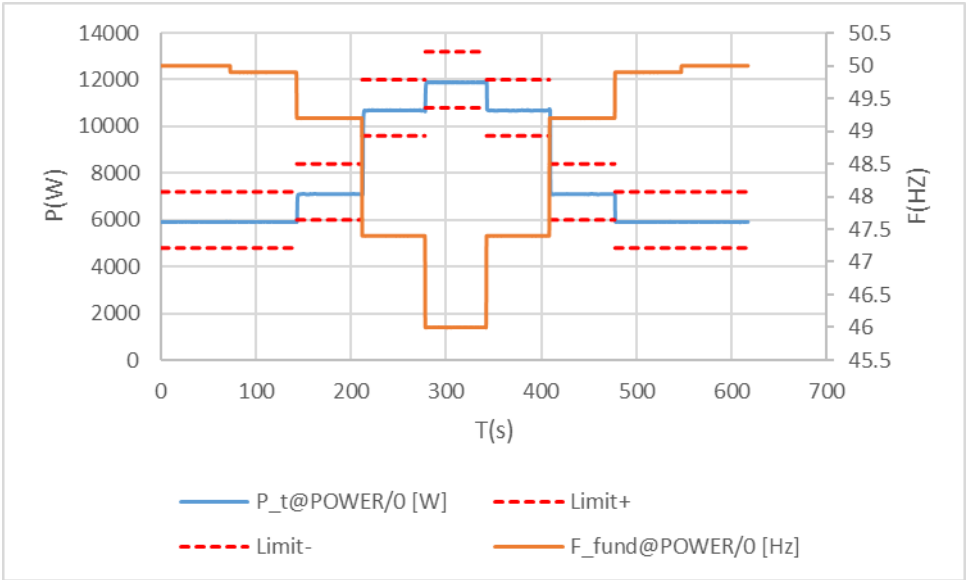
Graph of Measurement 1.: Active power output -50% P_Emax



Graph of Measurement 2.: Active power output 0% P_Emax



Graph of Measurement 3.: Active power output 50% P_Emax



Notes:

Setting (a) for ESS

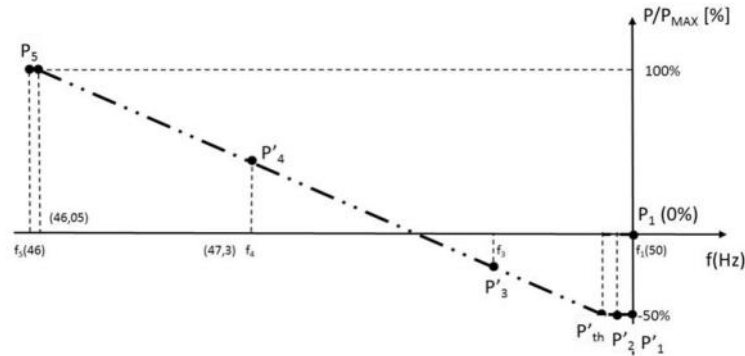


Figure 22 — default values, example for interval frequency 46 – 50 Hz, setting (a)

Setting (b) for ESS

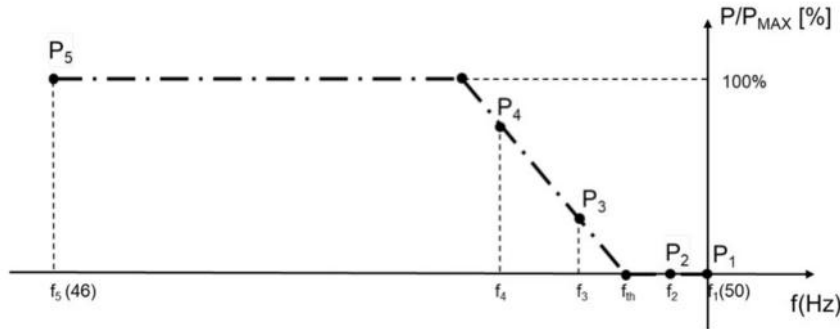


Figure 23 — Pref = Pmax, s = 2 %, fth = 49,5Hz, example for interval frequency 46 – 50 Hz, setting (b)

Setting (c) for ESS

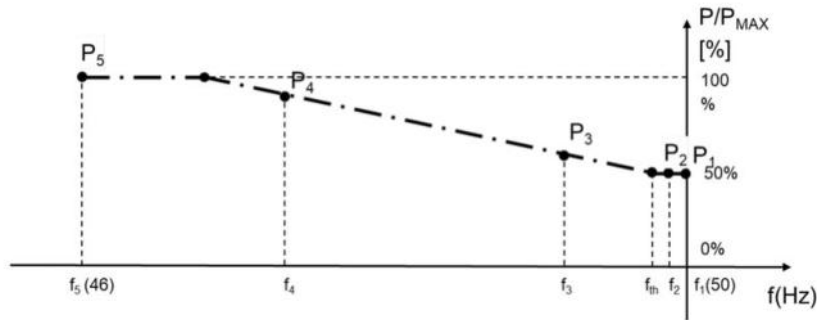


Figure 24 — Pref = Pmax, s = 12 %, fth = 49,8Hz, example for interval frequency 46 – 50 Hz, setting (c)

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5.5.1 Power capabilities assessment - voltage support by reactive power					P
5.5.1.3 Verification procedure to determine the power capability (active, reactive, apparent) at nominal voltage					
Q = 0 reactive power					
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]	ΔQ ≤ 2%Smax
10%	1204.05	4.42	0.9995	229.96	0.04
20%	2403.22	34.40	0.9999	229.97	0.29
30%	3599.21	41.82	0.9999	229.98	0.35
40%	4794.54	48.20	0.9999	229.98	0.40
50%	5987.56	53.39	0.9999	229.98	0.44
60%	7172.29	61.17	0.9999	229.99	0.51
70%	8363.37	66.28	0.9999	230.00	0.55
80%	9551.06	71.75	0.9999	230.00	0.60
90%	10739.32	77.80	0.9999	230.01	0.65
100%	11813.38	82.29	0.9999	230.01	0.69
Q _{max} under-excited					
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]	ΔQ ≤ 2%Smax
10%	1257.89	-7137.42	0.1735	229.97	0.52
20%	2452.84	-7132.58	0.3252	229.98	0.56
30%	3651.57	-7128.23	0.4560	229.98	0.60
40%	4844.75	-7123.80	0.5623	229.98	0.64
50%	6034.86	-7119.76	0.6466	229.99	0.67
60%	7221.77	-7115.65	0.7123	229.98	0.70
70%	8408.18	-7111.28	0.7635	230.00	0.74
80%	9600.58	-7221.69	0.7991	229.99	-0.18

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90%*	9600.75	-7221.70	0.7991	229.99	-0.18
100%*	9600.69	-7221.73	0.7990	229.99	-0.18
Q_{max} over-excited					
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]	$\Delta Q \leq 2\% S_{max}$
10%	1168.63	7133.10	0.1616	229.98	-0.56
20%	2366.69	7141.03	0.3145	229.98	-0.49
30%	3562.99	7149.74	0.4460	229.98	-0.42
40%	4757.58	7158.98	0.5535	229.99	-0.34
50%	5946.34	7169.56	0.6384	230.00	-0.25
60%	7134.95	7179.78	0.7049	230.00	-0.17
70%	8323.31	7190.37	0.7567	230.00	-0.08
80%	9511.85	7202.84	0.7972	230.00	0.02
90%*	9674.60	7188.68	0.8027	230.00	-0.09
100%*	9754.09	7069.65	0.8097	230.01	-1.09

The maximum reactive power claimed by the customer is 60% P_n, according to the test declared by the customer.

* Due to the limit of max. output current/apparent power, it can't reach target output power.

Assessment criterion:

The following shall be considered: Measurements shall be sampled during continuous operation only. Measurements shall be recorded and evaluated as 1 min average values. For the determination of the dynamic behaviour, 1 period RMS values shall be evaluated. During the test, the generated active power shall be kept stable within $\pm 5\% S_n$ compared to the value set for the entire duration of each test sequence. The active and reactive power shall be calculated based on the positive sequence component of the fundamental of the voltages and currents at the generating unit terminals. The active factor shall be calculated based on the positive sequence component of the fundamental of the voltages and currents at the generating unit terminals. The active power, reactive power and the active factor, frequency, RMS voltage, RMS current at the generating unit terminals shall be recorded during tests.

Verification procedure to determine the power capability (active, reactive, apparent) at 5.5.1.3 The verification shall be conducted operating the EUT at nominal voltage and frequency and different active power levels as follows: The generating unit manufacturer shall provide the capability curve (Figure 26 gives a graphical representation of the minimum and optional capabilities at nominal voltage). The maximum underexcited and overexcited reactive power shall be measured over a period of 1 min for each 10 % of P_n, from 0 % to maximum active power as declared by manufacturer. The values P_{max}, S_{max} and Q_{max over} and Q_{max under} shall be measured over a period of 10 min.

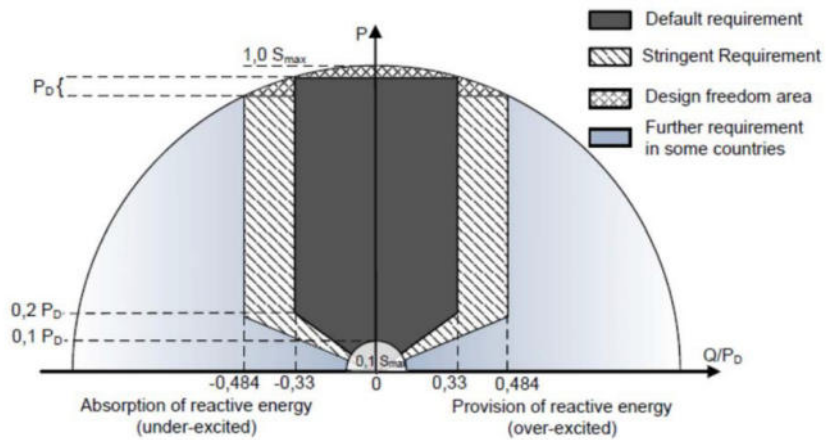


Figure 26 — reactive power capability at nominal voltage

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5.5.1 Power capabilities assessment - voltage support by reactive power				P
5.5.1.6 Verification procedure for reactive power capability considering voltage range				
Test: 85%U _n				
Inductive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	589.90	293.82	0.8951	195.49
10%	1096.87	-824.76	0.7992	195.48
20%	2288.56	-1695.02	0.8035	195.48
30%	3500.02	-2581.40	0.8047	195.49
40%	4702.88	-3471.35	0.8045	195.50
50%	5896.55	-4360.08	0.8040	195.49
60%	7075.62	-5247.01	0.8032	195.50
70%	8247.30	-6131.30	0.8025	195.50
80%*	8246.76	-6130.77	0.8025	195.50
90%*	8245.88	-6129.93	0.8025	195.50
100%*	8247.84	-6131.41	0.8025	195.51
Capacitive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	588.70	293.37	0.8950	195.49
10%	1096.36	848.70	0.7907	195.48
20%	2291.55	1745.89	0.7954	195.48
30%	3512.72	2658.89	0.7973	195.49
40%	4713.12	3566.42	0.7974	195.49
50%	5905.47	4473.66	0.7971	195.50
60%	7082.99	5378.51	0.7964	195.51

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70%	8182.10	6224.50	0.7958	195.51
80%*	8177.66	6222.08	0.7958	195.51
90%*	8178.03	6222.24	0.7958	195.50
100%*	8178.14	6222.82	0.7958	195.51

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Test: 90%U _n				
Inductive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	573.09	-433.16	0.7976	206.99
10%	1077.11	-814.29	0.7976	206.96
20%	2278.51	-1694.43	0.8024	206.98
30%	3498.09	-2586.35	0.8040	206.98
40%	4714.34	-3485.88	0.8040	206.98
50%	5907.51	-4374.62	0.8036	206.99
60%	7091.68	-5265.78	0.8028	206.99
70%	8274.03	-6156.01	0.8022	207.00
80%*	8701.24	-6477.14	0.8021	207.01
90%*	8700.17	-6475.34	0.8021	207.00
100%*	8701.19	-6476.23	0.8021	207.00
Capacitive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	569.72	272.96	0.9018	206.99
10%	1108.77	856.20	0.7915	206.98
20%	2295.49	1750.66	0.7951	206.98
30%	3517.26	2663.83	0.7971	206.98
40%	4727.17	3578.06	0.7973	207.00
50%	5924.77	4490.30	0.7969	207.00
60%	7116.27	5406.62	0.7962	207.00
70%	8298.98	6316.87	0.7957	207.01
80%*	8628.42	6569.30	0.7956	207.01

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90%*	8628.29	6568.43	0.7956	207.01
100%*	8623.90	6565.26	0.7956	207.01

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Test: 95%U _n				
Inductive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	552.20	-423.88	0.7891	218.47
10%	1080.59	-824.16	0.7950	218.49
20%	2292.07	-1713.14	0.8009	218.48
30%	3510.43	-2602.86	0.8032	218.48
40%	4720.56	-3495.89	0.8036	218.49
50%	5929.43	-4394.03	0.8034	218.49
60%	7104.94	-5277.71	0.8027	218.49
70%	8310.28	-6185.62	0.8021	218.50
80%*	9151.43	-6822.14	0.8017	218.50
90%*	9153.28	-6822.71	0.8017	218.50
100%*	9152.19	-6822.32	0.8017	218.50
Capacitive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	552.95	268.77	0.8983	218.48
10%	1102.38	861.12	0.7880	218.49
20%	2290.08	1742.46	0.7958	218.48
30%	3523.26	2648.20	0.7993	218.49
40%	4736.96	3547.37	0.8004	218.48
50%	5943.30	4448.04	0.8006	218.50
60%	7122.84	5338.69	0.8001	218.51
70%	8319.40	6243.29	0.7998	218.50
80%*	9079.41	6820.38	0.7995	218.51

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90%*	9077.53	6819.43	0.7995	218.50
100%*	9077.67	6820.52	0.7994	218.51

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Test: 100%U _n				
Inductive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	532.90	-397.61	0.7911	229.95
10%	1138.70	-854.10	0.7998	229.98
20%	2282.53	-1692.93	0.8031	229.98
30%	3508.15	-2588.43	0.8046	229.98
40%	4727.27	-3488.08	0.8046	229.98
50%	5926.26	-4380.08	0.8041	229.99
60%	7127.26	-5275.46	0.8037	229.99
70%	8327.31	-6178.98	0.8030	230.00
80%	9507.63	-7076.85	0.8021	230.00
90%*	9603.59	-7145.86	0.8022	229.99
100%*	9603.91	-7143.61	0.8023	230.00
Capacitive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	530.65	404.27	0.7954	229.98
10%	1111.49	864.56	0.7893	229.96
20%	2311.99	1763.65	0.7951	229.97
30%	3529.83	2664.81	0.7981	229.98
40%	4742.21	3569.13	0.7990	229.99
50%	5947.31	4471.52	0.7992	229.99
60%	7133.88	5376.81	0.7985	229.99
70%	8339.15	6291.70	0.7982	230.00
80%	9526.74	7198.70	0.7978	230.01

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90%*	9528.28	7197.45	0.7979	230.00
100%*	9528.95	7196.68	0.7979	230.00

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Test: 105%U _n				
Inductive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	507.47	-370.55	0.7766	241.49
10%	1099.41	-831.54	0.7975	241.47
20%	2291.95	-1704.75	0.8023	241.47
30%	3516.25	-2598.90	0.8041	241.47
40%	4740.06	-3499.58	0.8044	241.48
50%	5945.95	-4392.41	0.8043	241.48
60%	7139.03	-5291.25	0.8033	241.49
70%	8341.13	-6194.55	0.8028	241.49
80%	9543.96	-7102.43	0.8022	241.50
90%*	9588.24	-7136.34	0.8021	241.50
100%*	9588.45	-7136.58	0.8021	241.49
Capacitive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	506.02	257.46	0.8600	241.49
10%	1116.54	822.51	0.7979	241.47
20%	2305.09	1759.53	0.7949	241.48
30%	3534.61	2664.75	0.7985	241.48
40%	4752.26	3566.40	0.7998	241.47
50%	5958.92	4468.10	0.8000	241.49
60%	7152.88	5369.09	0.7997	241.49
70%	8344.76	6270.57	0.7994	241.49
80%	9510.86	7157.43	0.7990	241.50

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90%*	9511.44	7158.15	0.7990	241.50
100%*	9510.43	7158.02	0.7989	241.51

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Test: 110%U _n				
Inductive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	489.65	-378.35	0.7497	252.99
10%	1081.58	-814.05	0.7982	252.95
20%	2288.95	-1728.83	0.7979	252.96
30%	3524.65	-2632.69	0.8011	252.97
40%	4737.00	-3525.73	0.8021	252.98
50%	5951.78	-4427.94	0.8023	252.98
60%	7142.18	-5319.40	0.8020	252.98
70%	8354.23	-6227.03	0.8017	252.99
80%	9549.76	-7126.97	0.8014	252.99
90%*	9562.16	-7137.50	0.8013	252.99
100%*	9560.38	-7135.98	0.8013	252.99
Capacitive supply reactive power				
Rating power [%]	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0%	483.72	206.53	0.8300	252.98
10%	1105.38	838.31	0.7964	252.97
20%	2310.96	1771.71	0.7936	252.97
30%	3540.12	2679.30	0.7973	252.97
40%	4762.27	3586.87	0.7987	252.98
50%	5972.26	4492.25	0.7991	252.99
60%	7172.53	5400.21	0.7988	252.98
70%	8374.94	6308.31	0.7987	252.99
80%	9483.27	7151.24	0.7984	253.00

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90%*	9483.63	7150.51	0.7984	253.00
100%*	9483.18	7149.45	0.7985	252.99

Assessment criterion:

According to the tests declared by the customer, the power factor claimed by the customer is 0.80.

* Due to the limit of max. output current or apparent Power, it can't reach target output power.

Test method:

The voltage dependency of PQ-characteristic shall be evaluated according to the following procedures:
Non-synchronous generating units:

The manufacturer shall provide a characteristic or model of the voltage dependency of the reactive power capability represented in a P-Q diagram at different voltage values (e.g. 110 % Un, 100 % Un and 90 % Un); the voltage dependency can be also represented in the form of a U-Q/P diagram.

For the verification the following applies: two tests shall be conducted at the maximum power as verified according to 5.5.1.3. and for each Q and Q_{max under}. In case of generating units operating in a Q-priority mode, the test shall be conducted with an active factor not below 0,9_{max over}. The tests shall be conducted for under voltage and over voltage. The voltage level shall be chosen to show the declared characteristic. If the declared characteristic does not show a voltage dependency, the voltage deviation shall be at least 5 % of nominal voltage.

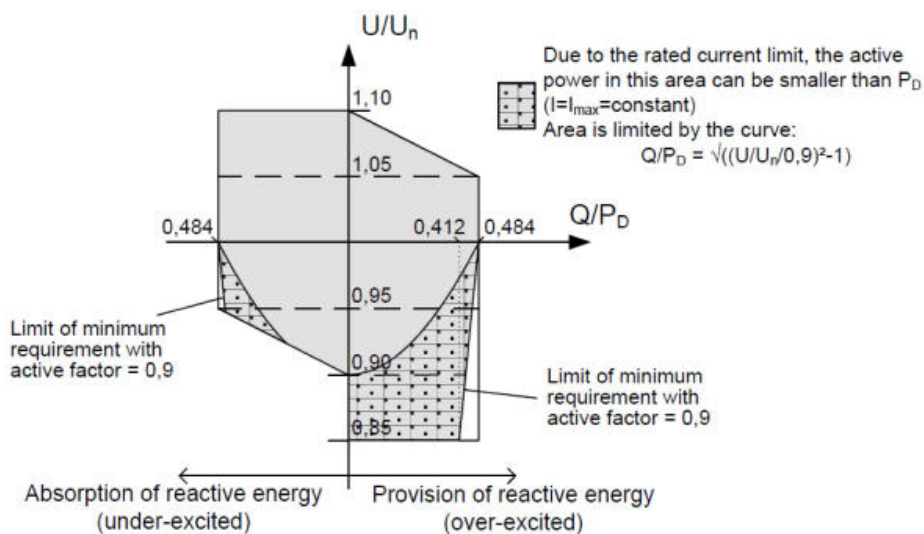


Figure 30 — Example: U-Q normalized diagram taken from the EN 50549-1

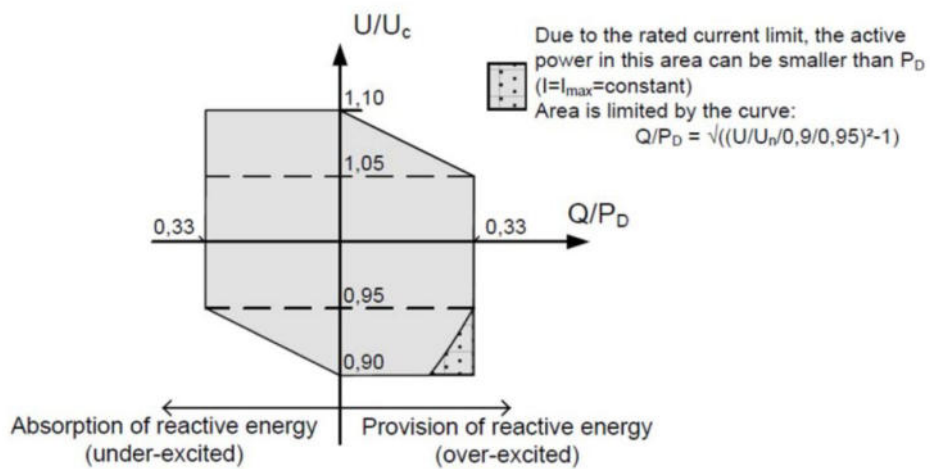


Figure 31 — Example of U-Q normalized diagram taken from the EN 50549-2

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5.5.2.3.2 Reactive power set point control accuracy							P
Q _{max} [Var]	7200		Q _{min} [Var]	-7200			
Test no.1: Test for reactive power set point control accuracy							
Test: 50%P _E max±10%P _n							
Reactive power step Q/P _n (p.u.)	Voltage	Set point value		Measure value		Deviation	
	(%)	Var	Q/S _{max} (%)	Var	Q/S _{max} (%)	Var	Q/S _{max} (%)
Q=0	100.0	0	0	33.57	0.28	33.57	0.28
Q _{max} (overexcited)	100.0	7200	60	7223.70	60.20	23.70	0.20
Q _{min} (underexcited)	100.0	-7200	-60	-7246.99	-60.39	-46.99	-0.39
Q=0	100.0	0	0	36.92	0.31	36.92	0.31
ΔLimit Q≤2%S _{max}							
Test no.2: Test for reactive power set point control accuracy							
50±10%P _n (Tau=3s) shortest time constant (not longer than 3s)							
Reactive power set point step p.u.	Generating unit response time setting	Measured response behaviour					
		dead time (s)		response time/ settling time (s)			
Q=0→Q=Q _{max} over	9s	0.4		7.8			
Q=Q _{max} over →Q=Q _{min} under	9s	0.2		9.2			
Q=Q _{min} under →Q=0	9s	0.2		7.4			
50±10%P _n (Tau=60s) (if longest time>60s, then test 60s)							
Reactive power set point step p.u.	Generating unit response time setting	Measured response behaviour					
		dead time (s)		response time/ settling time (s)			
Q=0→Q=Q _{max} over	180s	0.4		148.0			
Q=Q _{max} over →Q=Q _{min} under	180s	0.8		175.2			
Q=Q _{min} under →Q=0	180s	0.2		129.8			

Diagram for 50%P_n ((Tau=3s)) 0 → Q_{max over}

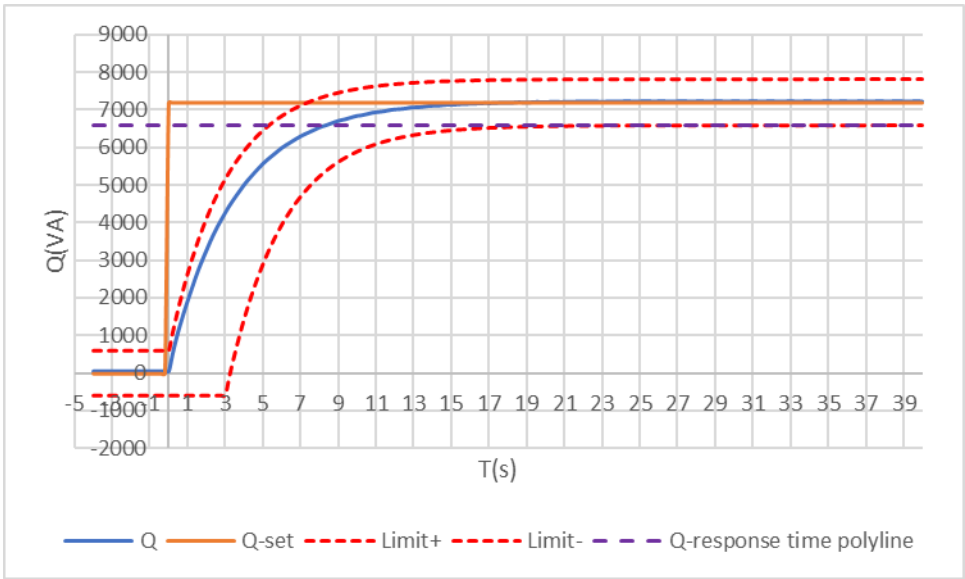


Diagram for 50%P_n ((Tau=3s)) Q_{max over} → Q_{min under}

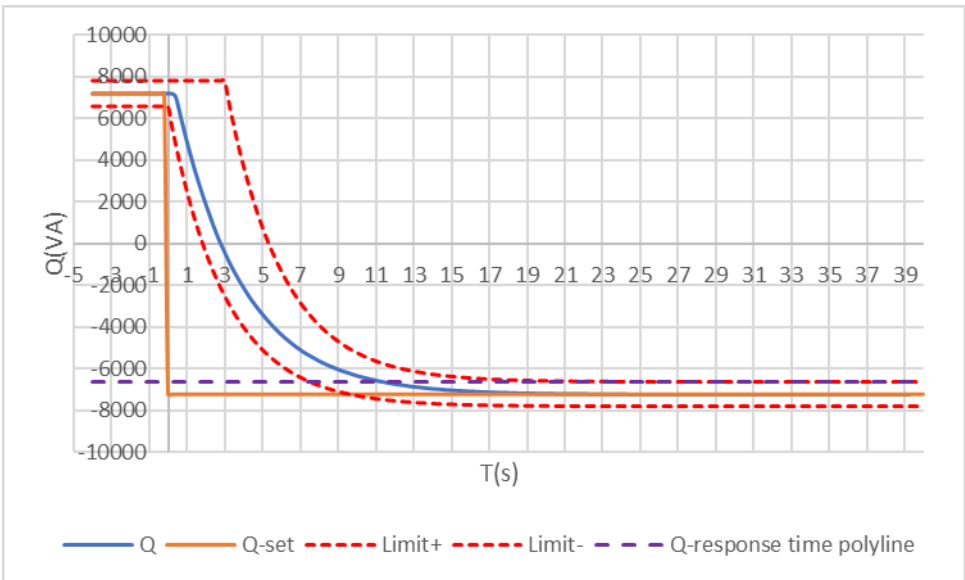


Diagram for 50%P_n ((Tau=3s)) Q_{min} under → 0

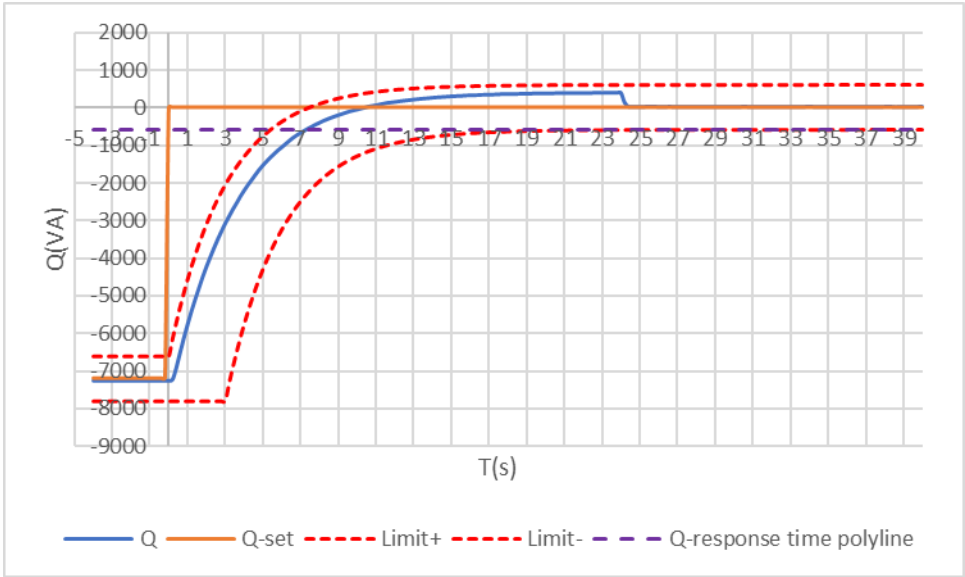


Diagram for 50%P_n ((Tau=60s)) 0 → Q_{max} over

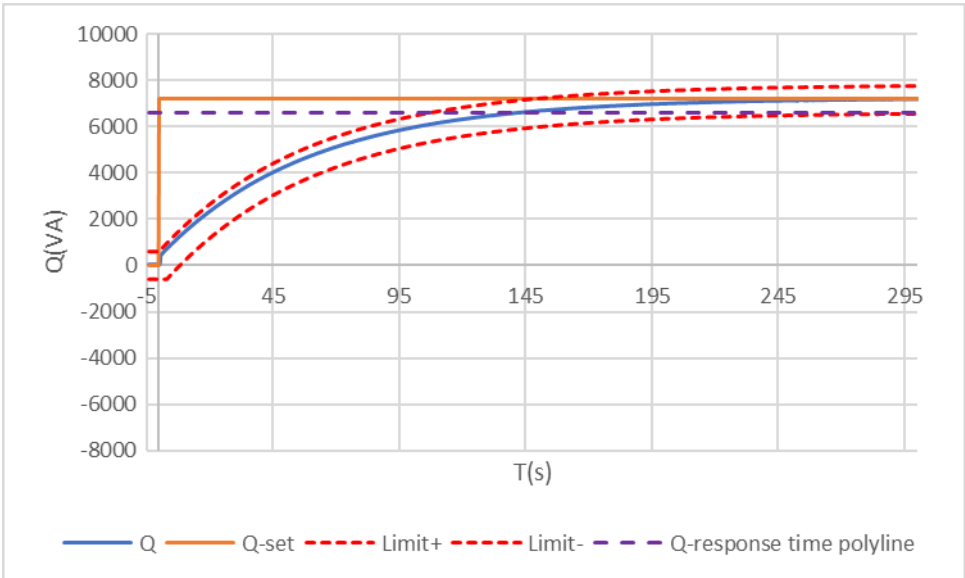


Diagram for 50%P_n ((Tau=60s)) Q_{max} over → Q_{min} under

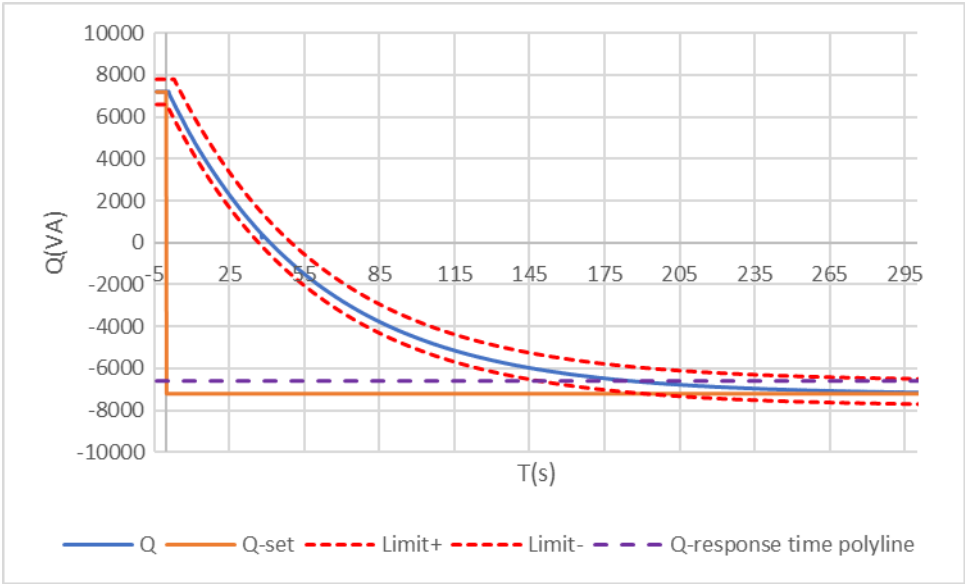
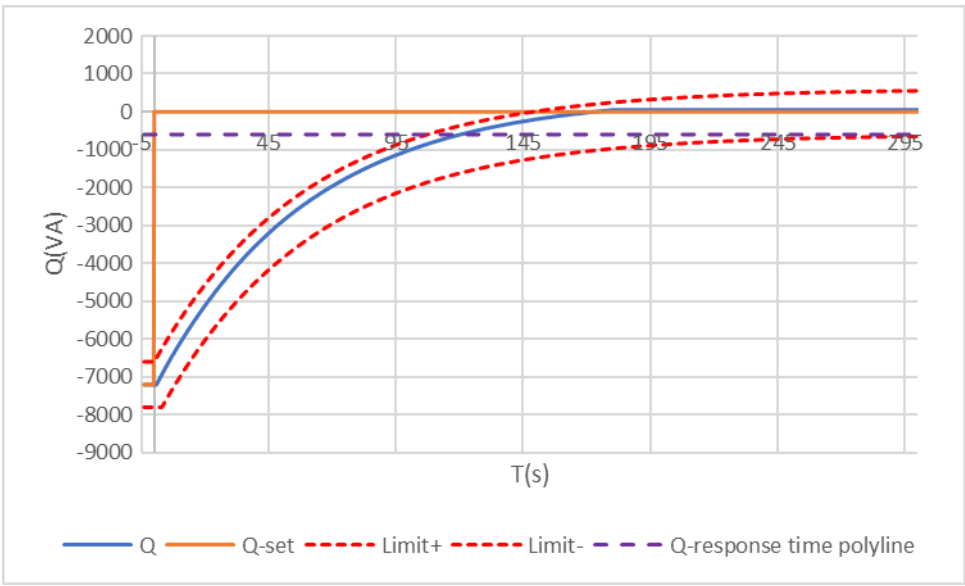


Diagram for 50%P_n ((Tau=60s)) Q_{min} under → 0



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5.5.2.4 Verification procedure for voltage related control mode for reactive power Q(U)								P
5.5.2.4.2 Test procedure for steady-state behaviour								
Qmax [Var]		7200		Qmin [Var]		-7200		
Setting (a)								
Setting value		Measurement value						Limit
Un	Pn	Grid voltage (%)	Active power (%)	Reactive power (Var)	Target Reactive power (Var)	Deviation Reactive power $\Delta Q \leq 2\% S_{max}$	PF	$\Delta U \leq \pm 1\% U_n$ $\Delta Q \leq \pm 2\% S_{max}$ Or PF ≥ 0.4
100%	100%	99.98	99.66	69.41	0	-0.58	0.9999	
103%	100%	102.98	99.58	45.20	0	-0.38	0.9999	
105%	100%	104.97	99.48	28.32	0	-0.24	0.9999	
106%	100%	105.98	99.44	21.53	0	-0.18	0.9999	
107%	100%*	107.02	95.34	-3584.94	-3600	-0.13	0.9542	
108%	100%*	108.09	79.80	-7196.47	-7200	-0.03	0.7993	
110%	100%*	109.97	79.73	-7154.44	-7200	-0.38	0.8007	
112%	100%*	111.97	79.64	-7255.88	-7200	0.47	0.7964	
115%	100%*	114.98	79.52	-7178.79	-7200	-0.18	0.7990	
112%	100%*	111.98	79.66	-7255.45	-7200	0.46	0.7964	
110%	100%*	109.97	79.72	-7155.13	-7200	-0.37	0.8007	
108%	100%*	108.07	81.44	-7164.98	-7200	-0.29	0.8182	
107%	100%*	107.02	91.48	-3552.37	-3600	-0.40	0.9514	
106%	100%	105.99	99.44	-196.09	0	1.63	0.9998	
105%	100%	104.97	99.48	28.23	0	-0.24	0.9999	
103%	100%	102.98	99.59	43.82	0	-0.37	0.9999	
100%	100%	99.99	99.67	68.70	0	-0.57	0.9999	
97%	100%*	96.99	96.82	93.90	0	-0.78	0.9999	

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94%	100%*	94.11	94.13	119.94	0	-1.00	0.9999
93%	100%*	92.85	71.95	7016.99	7200	1.53	0.7759
90%	100%*	89.99	68.20	7307.59	7200	-0.90	0.7458
87%	100%*	86.98	64.35	7248.66	7200	-0.41	0.7289
85%	100%*	84.99	61.72	7212.13	7200	-0.10	0.7163
87%	100%*	86.98	64.34	7250.08	7200	-0.42	0.7288
90%	100%*	89.99	68.23	7307.70	7200	-0.90	0.7459
93%	100%*	92.86	71.88	7027.78	7200	1.44	0.7751
94%	100%*	94.10	93.93	-5.75	0	0.05	0.9999
97%	100%*	96.97	96.81	92.61	0	-0.77	0.9999
100%	100%	99.99	99.67	68.30	0	-0.57	0.9999
100%	20%	99.97	19.47	27.19	0	-0.23	0.9996
103%	20%	102.95	19.34	-15.87	0	0.13	0.9997
105%	20%	104.96	19.26	-16.43	0	0.14	0.9996
106%	20%	105.96	19.23	-28.93	0	0.24	0.9996
107%	20%	107.21	19.39	-3531.10	-3600	-0.57	0.5502
108%	20%	108.08	19.42	-5365.58	-7200	pf≥0.4	0.4012
110%	20%	109.96	20.13	-5468.60	-7200	pf≥0.4	0.4040
112%	20%	111.95	19.31	-5271.29	-7200	pf≥0.4	0.4024
115%	20%	114.95	19.20	-5189.18	-7200	pf≥0.4	0.4057
112%	20%	111.96	19.32	-5275.12	-7200	pf≥0.4	0.4022
110%	20%	109.96	20.14	-5466.28	-7200	pf≥0.4	0.4043
108%	20%	108.08	19.42	-5353.27	-7200	pf≥0.4	0.4040
107%	20%	107.21	19.39	-3500.98	-3600	-0.83	0.5534
106%	20%	105.96	19.23	-38.02	0	0.32	0.9996
105%	20%	104.96	19.26	-37.06	0	0.31	0.9995

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103%	20%	102.96	19.34	-13.58	0	0.11	0.9996
100%	20%	99.96	19.48	14.64	0	-0.12	0.9997
97%	20%	96.97	19.60	40.75	0	-0.34	0.9995
94%	20%	94.19	19.72	96.20	0	-0.80	0.9988
93%	20%	92.85	19.58	5446.39	7200	pf≥0.4	0.4010
90%	20%	89.95	19.70	5374.82	7200	pf≥0.4	0.4025
87%	20%	86.96	19.81	5318.37	7200	pf≥0.4	0.4079
85%	20%	84.97	19.90	5290.34	7200	pf≥0.4	0.4112
87%	20%	86.97	19.82	5318.16	7200	pf≥0.4	0.4081
90%	20%	89.97	19.69	5376.77	7200	pf≥0.4	0.4023
93%	20%	92.85	19.58	5438.93	7200	pf≥0.4	0.4014
94%	20%	94.18	19.70	70.79	0	-0.59	0.9929
97%	20%	96.96	19.60	42.61	0	-0.36	0.9995
100%	20%	99.95	19.47	8.50	0	-0.07	0.9997

Setting (b)

Setting value		Measurement value						Limit
Un	Pn	Grid voltage (%)	Active power (%)	Reactive power (Var)	Target Reactive power (Var)	Deviation Reactive power $\Delta Q \leq 2\%S_{max}$	PF	$\Delta Q \leq \pm 2\%S_{max}$ $\Delta U \leq \pm 1\%U_n$
100%	100%	99.98	98.34	68.71	0	-0.57	0.9999	
103%	100%	102.97	98.32	-132.59	-216	-0.70	0.9999	
105%	100%	104.97	98.59	-282.80	-360	-0.64	0.9997	
106%	100%	105.97	98.58	-354.71	-432	-0.64	0.9995	
107%	100%	106.96	98.58	-426.46	-504	-0.65	0.9993	
108%	100%	107.97	98.54	-498.67	-576	-0.64	0.9991	
110%	100%	109.97	98.68	-641.64	-720	-0.65	0.9985	

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112%	100%	111.97	98.73	-644.98	-720	-0.63	0.9985
115%	100%	114.96	98.81	-637.83	-720	-0.68	0.9985
112%	100%	111.96	98.66	-645.01	-720	-0.62	0.9985
110%	100%	109.98	98.82	-641.09	-720	-0.66	0.9985
108%	100%	107.97	98.60	-498.22	-576	-0.65	0.9991
107%	100%	106.96	98.55	-426.51	-504	-0.65	0.9993
106%	100%	105.98	98.66	-346.53	-432	-0.71	0.9995
105%	100%	104.97	98.55	-283.07	-360	-0.64	0.9997
103%	100%	102.97	98.56	-138.17	-216	-0.65	0.9999
100%	100%	99.98	98.40	69.66	0	-0.58	0.9999
97%	100%*	96.97	97.04	274.69	216	-0.49	0.9997
94%	100%*	93.99	94.18	488.13	432	-0.47	0.9990
93%	100%*	92.98	93.20	563.42	504	-0.50	0.9987
90%	100%*	89.98	90.24	783.41	720	-0.53	0.9973
87%	100%*	86.98	87.39	784.61	720	-0.54	0.9972
85%	100%*	84.99	85.48	787.36	720	-0.56	0.9970
87%	100%*	86.98	87.38	784.99	720	-0.54	0.9971
90%	100%*	89.97	90.24	782.91	720	-0.52	0.9973
93%	100%*	92.98	93.18	563.66	504	-0.50	0.9987
94%	100%*	93.98	94.16	483.48	432	-0.43	0.9990
97%	100%*	96.98	97.05	266.58	216	-0.42	0.9997
100%	100%	99.97	98.34	68.15	0	-0.57	0.9999
100%	20%	99.98	19.45	20.60	0	-0.17	0.9999
103%	20%	102.96	19.33	-175.62	-216	-0.34	0.9971
105%	20%	104.96	19.26	-322.47	-360	-0.31	0.9903
106%	20%	105.96	19.24	-394.95	-432	-0.31	0.9856

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107%	20%	106.96	19.20	-467.99	-504	-0.30	0.9799
108%	20%	107.96	19.16	-539.70	-576	-0.30	0.9735
110%	20%	109.95	19.11	-681.97	-720	-0.32	0.9585
112%	20%	111.96	19.07	-701.23	-720	-0.16	0.9560
115%	20%	114.96	18.99	-694.60	-720	-0.21	0.9565
112%	20%	111.96	19.06	-701.49	-720	-0.15	0.9560
110%	20%	109.96	19.12	-682.96	-720	-0.31	0.9584
108%	20%	107.96	19.16	-540.49	-576	-0.30	0.9734
107%	20%	106.97	19.19	-468.22	-504	-0.30	0.9799
106%	20%	105.96	19.23	-395.85	-432	-0.30	0.9855
105%	20%	104.96	19.26	-323.79	-360	-0.30	0.9903
103%	20%	102.96	19.35	-176.81	-216	-0.33	0.9971
100%	20%	99.96	19.47	20.53	0	-0.17	0.9999
97%	20%	96.97	19.86	235.89	216	-0.17	0.9951
94%	20%	93.97	19.94	454.45	432	-0.19	0.9824
93%	20%	92.97	19.99	527.55	504	-0.20	0.9766
90%	20%	89.96	20.09	742.56	720	-0.19	0.9556
87%	20%	86.98	20.20	746.59	720	-0.22	0.9556
85%	20%	84.97	20.29	750.43	720	-0.25	0.9556
87%	20%	86.96	20.22	745.65	720	-0.21	0.9558
90%	20%	89.96	20.09	742.05	720	-0.18	0.9557
93%	20%	92.98	19.98	527.50	504	-0.20	0.9766
94%	20%	93.97	19.95	454.16	432	-0.18	0.9824
97%	20%	96.97	19.84	235.55	216	-0.16	0.9951
100%	20%	99.96	19.47	19.22	0	-0.16	0.9999

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Test method:

Standard	Parameter	X1	X2	X3	X4
EN 50549-10: 2022 (Setting a)	U (U/Un)	93%	94%	106%	108%
	Q (Q/Qmax)	100%	0%	0%	-100%

Standard	Parameter	X1	X2	X3
EN 50549-10: 2022 (Setting b)	U (U/Un)	90%	100%	110%
	Q (Q/Qmax)	10%	0%	-10%

Assessment criterion:

The actual tested configuration shall be chosen according the principle of 4.4. If the conformity assessment is conducted for a specific grid code, the EUT control shall be configured as defined in this grid code. If the conformity assessment is conducted in general, the configuration shall be chosen in a way that each parameter shall be tested once configured to its minimum and once to its maximum according to the principle given in Table 17 and Table 18.

Table 17 — Q(U) characteristic configuration

parameter of characteristic	Setting (a)	Setting (b)
dead band (horizontal section of the characteristic curve around U_n) db_{char}	as wide as possible but extending not more than from $-6\%U_n$ to $+6\%U_n$.	0
minimum and maximum reactive power of the characteristic $Q_{max\ char}^a$	$\geq 95\%$ of $Q_{max\ over}$ and $Q_{max\ under}$ respectively ^b	10 % of $Q_{max\ over}$ and $Q_{max\ under}$ respectively
Slope of the steepest section of the characteristic curve ^a	as steep as configurable, ^c	as flat as configurable ^d
^a If an unsymmetrical configuration is possible, this shall be apparent in the chosen configuration by using different steepness and different values for maximum reactive power $Q_{max\ char}$ for over voltage and under voltage. ^b if Q_{max} , based on the capability curve of the EUT, is above $60\%P_n$, $Q_{max\ char}$ shall not exceed $60\%P_n$. ^c if the maximum configurable steepness exceeds $100\%Q_{max} / 1\%U_n$ the configured value during the test shall not exceed $100\%Q_{max} / 1\%U_n$. ^d if the minimum configurable steepness is below $1\%Q_{max} / 1\%U_n$ the configured value during the test shall not be below $1\%Q_{max} / 1\%U_n$.		

Note:

* Due to the limit of output current, it can't reach target output power.

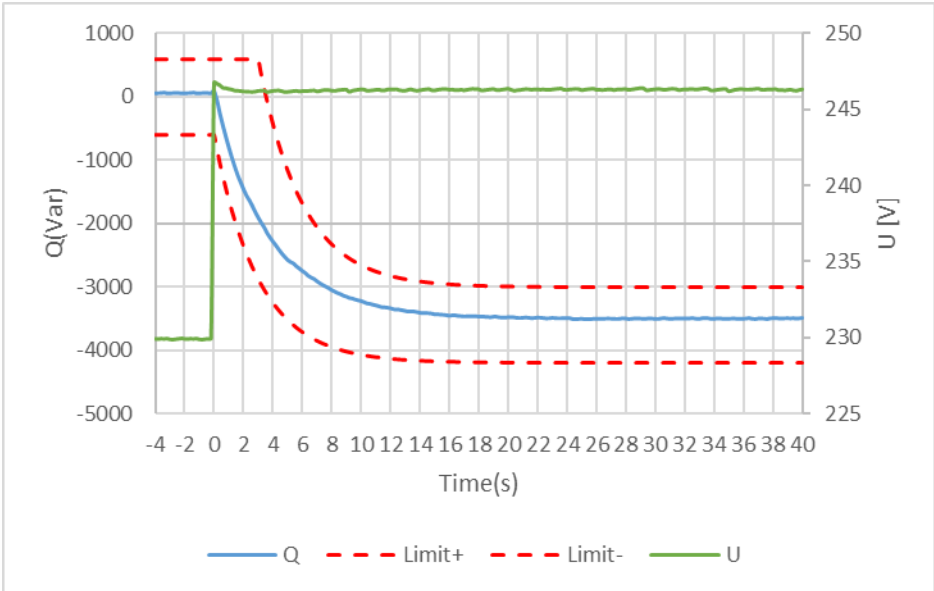
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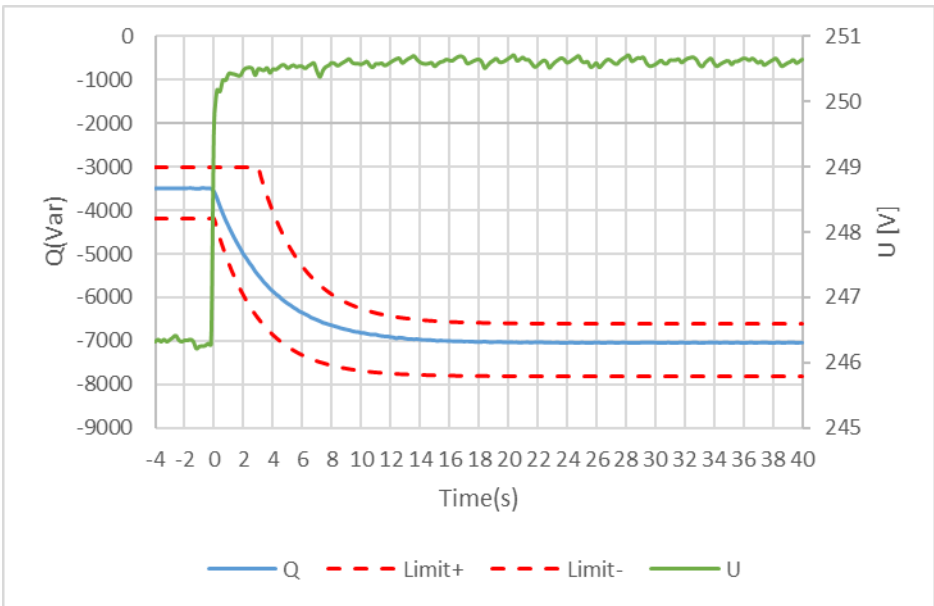
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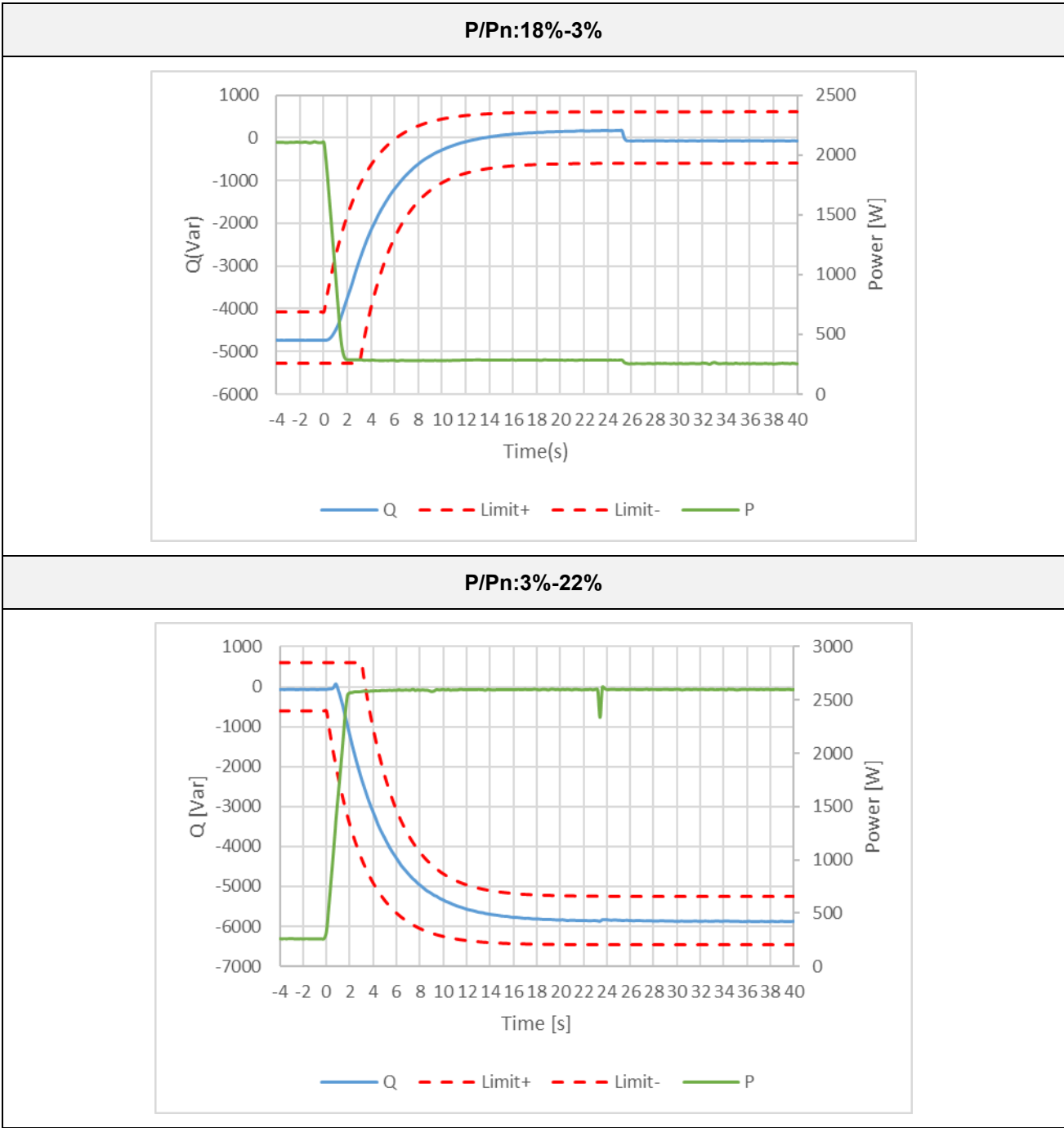
5.5.2.4 Verification procedure for voltage related control mode for reactive power Q(U)								P
5.5.2.4.3 Test procedure for dynamic behaviour								
Setting value		Measurement value						Limit
Un	Pn	Grid voltage (%)	Active power (%)	Reactive power (Var)	Target Reactive power (Var)	Deviation Reactive power $\Delta Q \leq 2\%S_{max}$	PF	$\Delta U \leq \pm 1\%U_n$ $\Delta Q \leq \pm 2\%S_{max}$ Or PF ≥ 0.4
1: 100%	>90%	99.97	98.41	66.13	0	-0.55	0.9999	
2: 107%	>90%	107.10	94.97	-3493.95	-3600	-0.88	0.9560	
3: 109%	>90%*	108.97	79.96	-7050.29	-7200	-1.25	0.8058	
4: 109%	18%	108.96	17.52	-4768.58	-7200	pf ≥ 0.4	0.4033	
5: 109%	3%	108.95	2.14	-66.63	0	0.56	0.9676	
6: 109%	22%	108.96	21.70	-5877.15	-7200	pf ≥ 0.4	0.4049	
7: 109%	100%*	108.97	79.98	-7052.18	-7200	-1.23	0.8057	
8: 100%	100%	99.98	98.40	65.34	0	-0.54	0.9999	
9: 92%	100%*	91.98	69.73	7243.28	7200	-0.36	0.7559	
10: 92%	18%	91.96	17.72	4847.36	7200	pf ≥ 0.4	0.4016	
11: 92%	3%	91.97	2.72	85.47	0	-0.71	0.9671	
12: 92%	22%	91.97	21.82	5991.53	7200	pf ≥ 0.4	0.4003	
13: 92%	>90%*	91.97	69.73	7243.56	7200	-0.36	0.7559	
14: 93%	>90%*	92.99	71.10	7225.97	7200	-0.22	0.7630	
15: 100%	>90%	99.97	98.29	65.94	0	-0.55	0.9999	
Note: * Due to the limit of max. output current/apparent power, it can't reach target output power. P lock-in: 20%Pn; P lock-out: 5%Pn. The ΔQ limit during dynamic is $\leq \pm 5\%S_n$, and the ΔQ limit is $\leq \pm 2\%S_{max}$ after stable.								

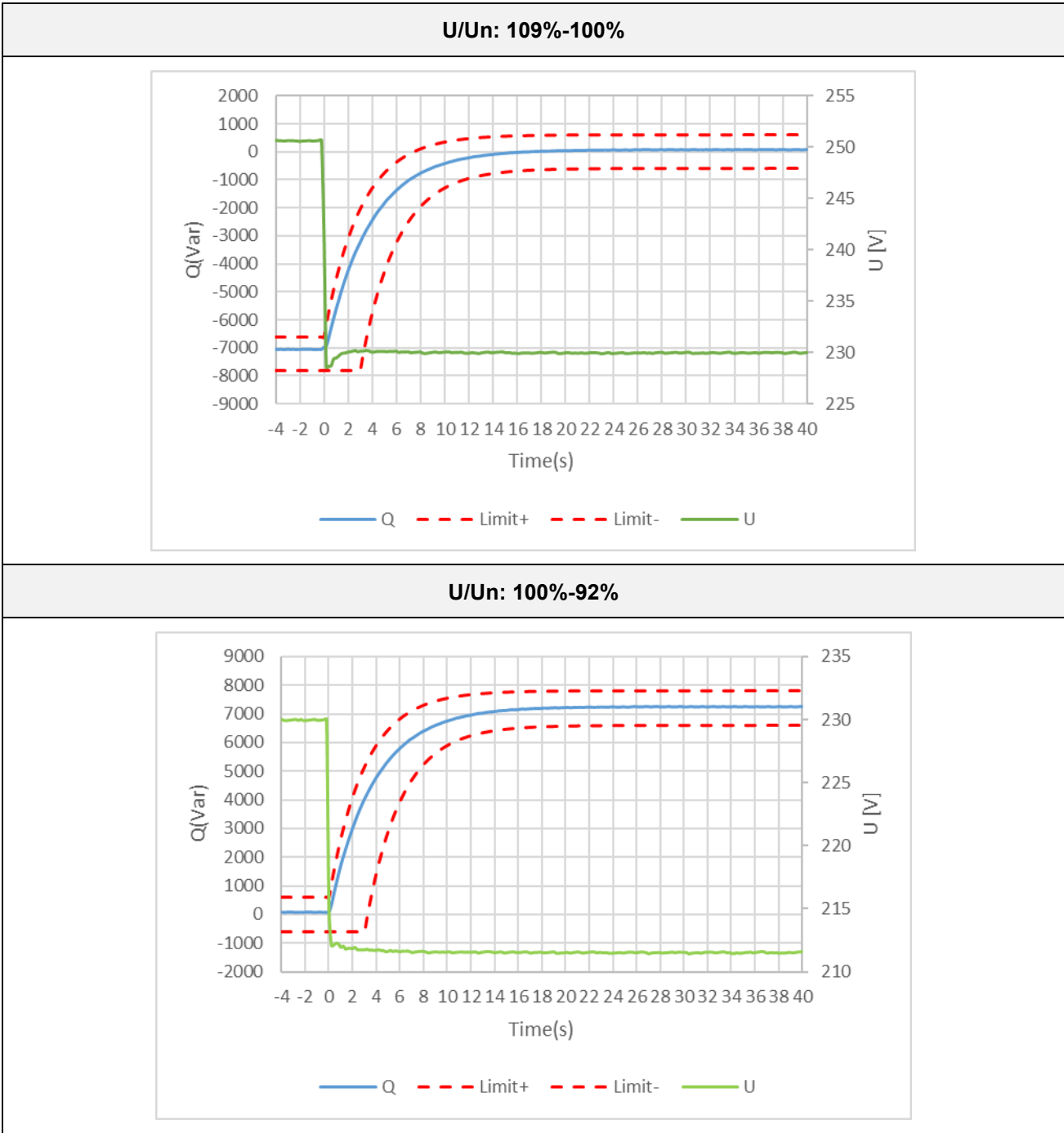
U/Un: 100%-107%

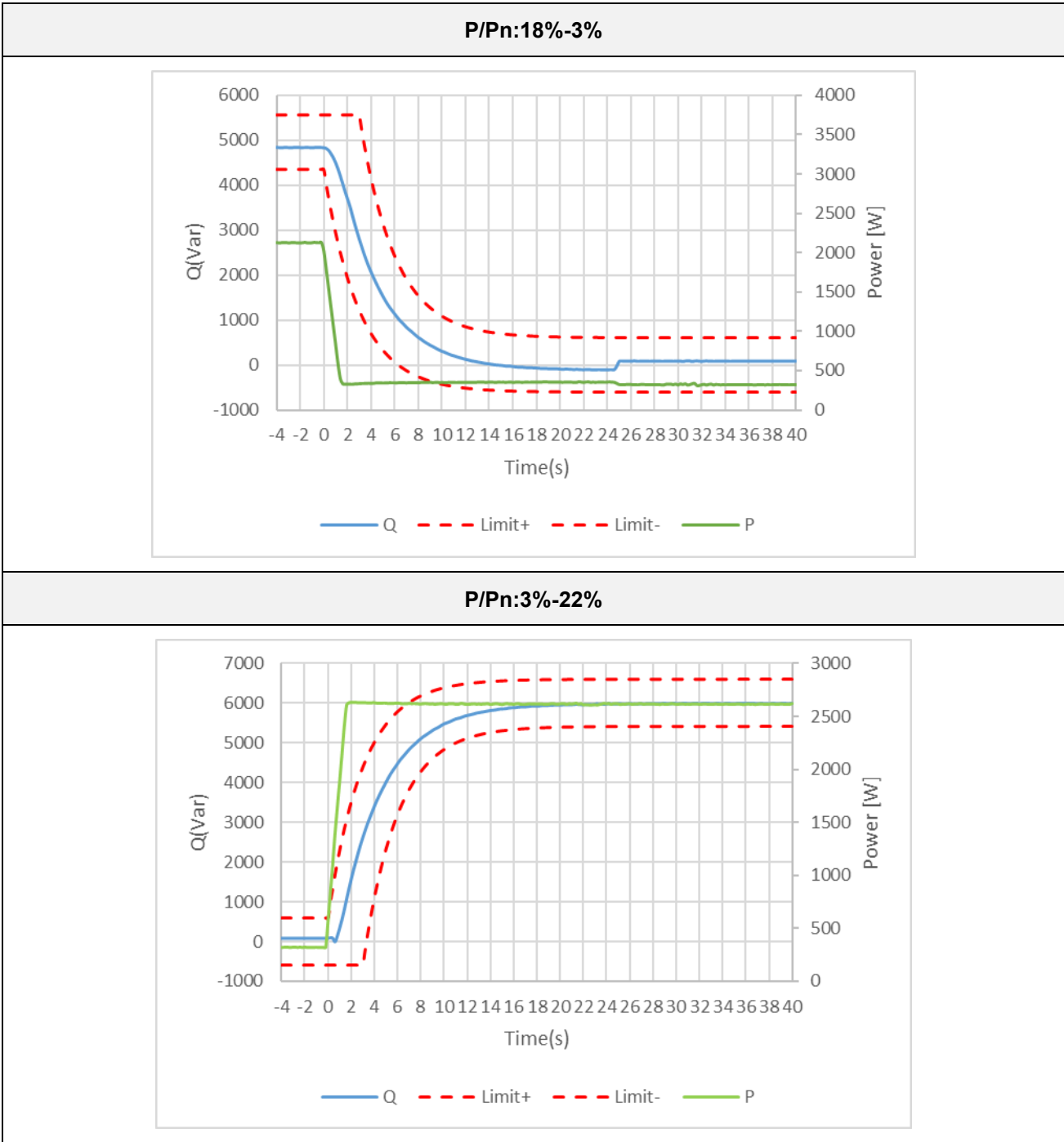


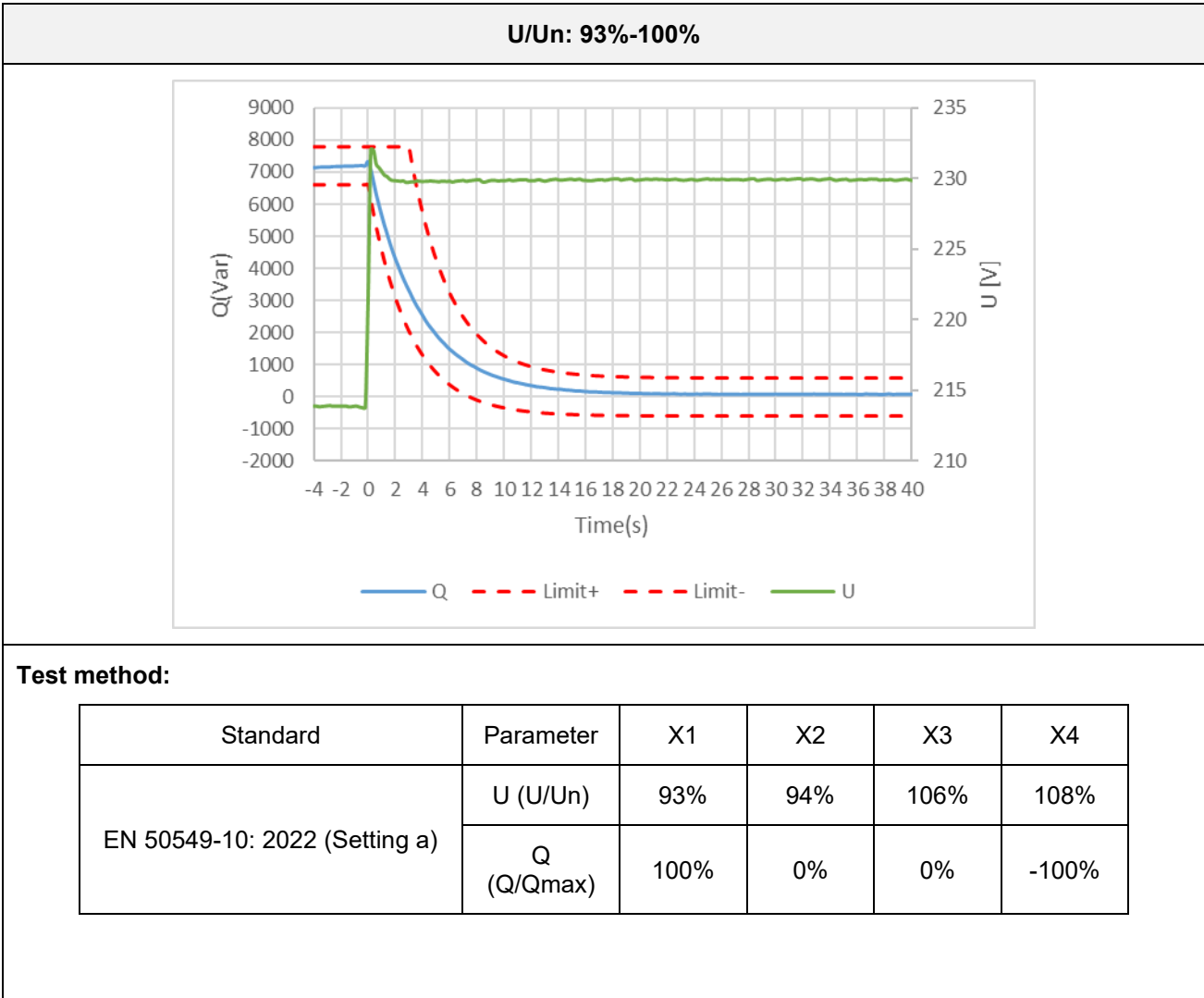
U/Un: 107%-109%











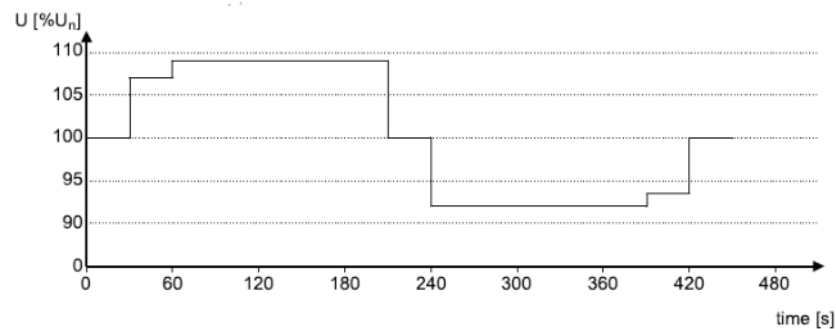


Figure 34 — Example voltage profile for setting (a) applied for the test of the dynamic behaviour of the $Q(U)$, assuming < 30 s for stabilization of P and Q

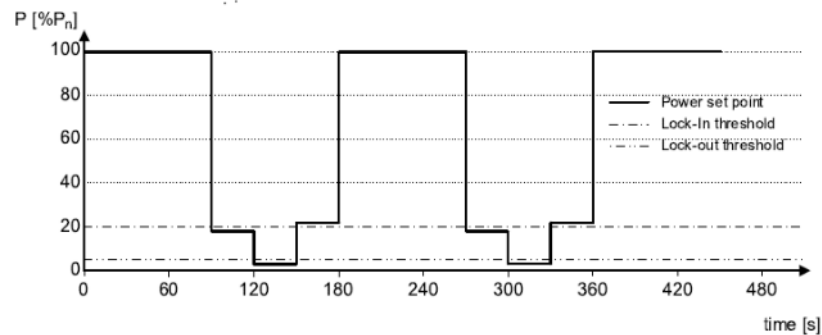


Figure 35 — Example active power set point profile for setting (a) applied for the test of the dynamic behaviour of the $Q(U)$ control, assuming < 30 s for stabilization of P and Q

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5.5.2.5 Verification procedure for power related control modes for reactive power										P
5.5.2.5.2 Test procedure for quasi-stationary behaviour										
Test a):										
P _n /P [%]	10	20	30	40	50	60	70	80	90*	100*
30 s mean value	10% to 100% P _{Emax}									
U [V]:	229.92	229.91	229.89	229.93	229.94	229.92	229.94	229.92	229.95	229.92
P _{E30} [W]:	1184	2398	3595	4806	6015	7217	8420	9624	10560	10559
P _{E30} of P _n [%]:	9.87	19.99	29.97	40.06	50.13	60.14	70.17	80.20	88.01	88.00
Q _{E30} [Var]:	7298	99	28	33	38	43	49	-211	-5702	-5701
Q _{E30} of P _n [%]:	60.82	0.83	0.23	0.28	0.32	0.36	0.41	-1.76	-47.52	-47.51
Q _{E30} target [%]:	60	0	0	0	0	0	0	0	(-60) -48	(-60) -48
P _n /P [%]	100*	90*	80	70	60	50	40	30	20	10
30 s mean value	100% to 10% P _{Emax}									
U [V]:	229.96	229.96	229.94	229.91	229.90	229.93	229.92	229.91	229.90	229.93
P _{E30} [W]:	10561	10560	9576	8421	7216	6013	4806	3596	2384	1150
P _{E30} of P _n [%]:	88.01	88.00	79.80	70.18	60.13	50.11	40.05	29.97	19.87	9.58
Q _{E30} [Var]:	-5701	-5702	-84	52	46	40	34	29	20	7298
Q _{E30} of P _n [%]:	-47.51	-47.52	-0.70	0.44	0.39	0.34	0.28	0.24	0.17	60.82
Q _{E30} target [%]:	(-60) -48	(-60) -48	0	0	0	0	0	0	0	60
Limit ΔQ:	±2%S _{max}									
Test c):										
P _n /P [%]	10	20	30	40	50	60	60	70	80	90*
30 s mean value	10% to 100% to 10%									
U [V]:	239.68	239.70	239.68	239.72	239.71	239.12	243.73	243.73	243.71	243.74

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P_{E30} [W]:	1130	2352	3601	4831	6010	7182	7174	8376	9578	10257
P_{E30} of P_n [%]:	9.41	19.60	30.01	40.26	50.09	59.85	59.78	69.80	79.82	85.47
Q_{E30} [Var]:	-23	-17	-10	-3	-81	-17	-1999	-3464	-5073	-6067
Q_{E30} [Var] target:	0	0	0	0	0	0	-2092	-3568	-5170	-6086
$\Delta Q_{E30}/S_{max}$ [%]:	-0.19	-0.14	-0.08	-0.03	-0.68	-0.14	0.78	0.87	0.81	0.16
$\cos \varphi_{E30}$:	0.9997	0.9999	0.9999	0.9999	0.9988	0.9999	0.9633	0.9240	0.8836	0.8606
$\cos \varphi_{E30}$ target:	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9600	0.9200	0.8800	(0.840) 0.8600
P_n/P [%]	100*	90*	80	70	60	60	50	40	30	20
30 s mean value	10% to 100% to 10%									
U [V]:	243.76	243.75	243.70	243.74	243.71	227.62	227.63	227.59	227.62	227.59
P_{E30} [W]:	10260	10260	9574	8376	7187	7191	6023	4802	3559	2331
P_{E30} of P_n [%]:	85.50	85.50	79.78	69.80	59.89	59.92	50.19	40.01	29.66	19.43
Q_{E30} [Var]:	-6068	-6067	-5078	-3482	-2004	55	48	42	37	29
Q_{E30} [Var] target:	-6088	-6088	-5167	-3568	-2096	0	0	0	0	0
$\Delta Q_{E30}/S_{max}$ [%]:	0.17	0.18	0.74	0.72	0.77	0.46	0.40	0.35	0.31	0.24
$\cos \varphi_{E30}$:	0.8607	0.8607	0.8833	0.9234	0.9632	0.9999	0.9999	0.9999	0.9999	0.9999
$\cos \varphi_{E30}$ target:	(0.800) 0.8600	(0.840) 0.8600	0.8800	0.9200	0.9600	1.0000	1.0000	1.0000	1.0000	1.0000
P_n/P [%]	10	--	--	--	--	--	--	--	--	--
30 s mean value	10% to 100% to 10%									
U [V]:	227.60	--	--	--	--	--	--	--	--	--
P_{E30} [W]:	1132	--	--	--	--	--	--	--	--	--
P_{E30} of P_n [%]:	9.43	--	--	--	--	--	--	--	--	--
Q_{E30} [Var]:	22	--	--	--	--	--	--	--	--	--

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Q_{E30} [Var] target:	0	--	--	--	--	--	--	--	--	--
$\Delta Q_{E30}/S_{max}$ [%]:	0.18	--	--	--	--	--	--	--	--	--
$\cos \varphi_{E30}$:	0.9999	--	--	--	--	--	--	--	--	--
$\cos \varphi_{E30}$ target:	1.0000	--	--	--	--	--	--	--	--	--
Limit ΔQ:	$\pm 2\% S_{max}$									

Note: * Due to the limit of max. output current/apparent power, it can't reach target output power.

Test method:

Table 19 — Q (P) or $\cos \varphi$ (P) characteristic configuration

parameter of characteristic	Setting (a)	Setting (b)	Setting (c)
minimum and maximum reactive power ($\cos \varphi$ ^b) of the characteristic $Q_{max \text{ char}}$ ^a	$\geq 95\%$ of $Q_{max \text{ over}}$ and $Q_{max \text{ under}}$ respectively but not more than $60\% P_n$	10% of $Q_{max \text{ over}}$ and $Q_{max \text{ under}}$ respectively	$Q_{max \text{ char over}} = 0\% P_n$ $Q_{max \text{ char over}} = 33\% P_n$
Slope of the steepest section of the characteristic curve ^a	as steep as configurable, but not more than $200\% Q_{max} / 10\% P_n$	as flat as configurable, but not less than $2\% Q_{max} / 10\% P_n$	0 below $50\% P_n$: $20\% Q_{max} / 10\% P_n$ above $50\% P_n$
Time constant	as fast as possible but not slower than 3 s	as slow as possible but not slower than 20 s ^c	3,33 s
^a If multiple sections with different steepness are configurable, this shall be apparent in the chosen configuration by using different steepness and different values for maximum reactive power $Q_{max \text{ char over}}$ and $Q_{max \text{ char under}}$. ^b The $\cos \varphi(P)$ characteristic shall be configured accordingly with the $\cos \varphi$ value representing the given reactive power value at P_n . ^c The test is considered significant also for slower values of the time constant, as slow time constants are technically less demanding. 20 s is chosen to reduce test duration compared to 60 s as defined in EN 50549-2:2019. Setting (c) represents a commonly applied characteristic.			

Table 20 — $\cos \varphi$ (P) optional additional parameter configuration if applicable

parameter	Setting (a)	Setting (b)	
Lock-in voltage	deactivated	$105\% U_n$	
Lock-out voltage	deactivated	$100\% U_n$	

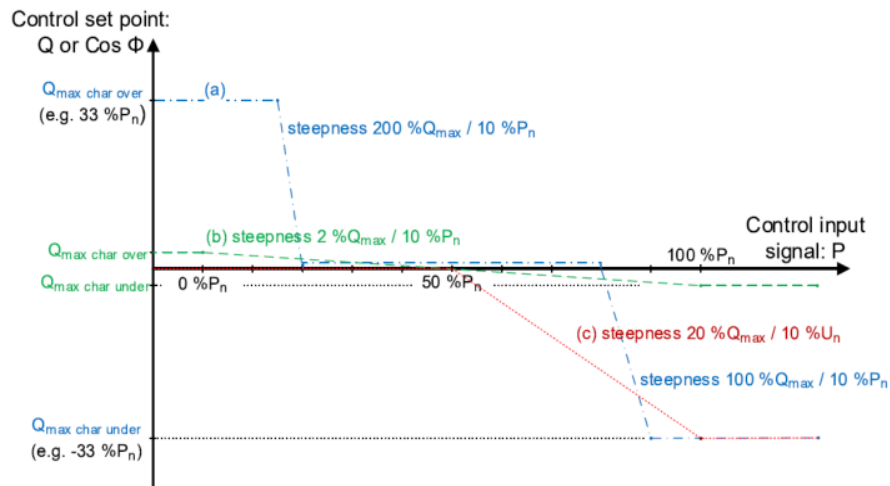


Figure 36 — $Q(P)$ and $\cos \varphi(P)$ and example characteristics for setting (a), (b) and (c) for the test

Assessment criterion:

Test of the accuracy of the $Q(P) \cos \varphi(P)$ control shall be considered passed if:

The measured 30-s averages of the reactive power during steady-state conditions are within a tolerance band of $\pm 2\%$ $S_{\max}$ around the reactive power set point resulting from the measured active power and the given $\cos \varphi$ (P) or Q (P) characteristic.

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5.5.2.5 Verification procedure for power related control modes for reactive power					P
5.5.2.5.3 Test procedure for dynamic behaviour					
Test a):					
P _{E_{max}} /P _n [%]	20	50	90*	50	20
30 s mean value	20% to 50% to 90% to 50% to 20%				
U [V]:	229.94	229.94	229.93	229.92	229.92
U _{target} [V]:	230.00	230.00	230.00	230.00	230.00
P _{E30} [W]:	2383	6015	10562	6015	2385
P _{E30} of P _n [%]:	19.86	50.12	88.02	50.12	19.88
Q _{E30} [Var]:	20	38	-5701	39	20
Q _{E30} of P _n [%]:	0.17	0.32	-47.51	0.32	0.17
Q _{E30} target [%]:	0	0	(-60) -48	0	0
cos φ _{E30} :	0.9999	0.9999	0.8799	0.9999	0.9999
Test condition	T _{dead time} [s]		T _{set response time} [s]		T _{settling time} [s]
50% P _n -90% P _n	0.4		8.0		8.0
90% P _n -50% P _n	0.2		10.0		10.0
Limit:	PT1:3s ΔQ=± 5 % P _n , delay time <3s				
Test c):					
P _{E_{max}} /P _n [%]	20		50		90*
30 s mean value	20% to 50% to 90% to 50% to 20%				
U [V]:	246.00		246.02		246.02
U _{target} [V]:	246.10		246.10		246.10
P _{E30} [W]:	2351		5929		10257

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P_{E30} of P_n [%]:	19.59	49.41	85.48
Q_{E30} [Var]:	-39	-19	-6051
Q_{E30} of P_n [%]:	-0.32	-0.16	-50.43
Q_{E30} target [%]:	0	0	-50
$\cos \varphi_{E30}$:	0.9998	0.9999	0.8612
$\cos \varphi_{E30}$ target:	1.0000	1.0000	(0.8400) 0.8600
$P_{E_{max}}/P_n$ [%]	90*	90	90*
U [V]:	236.84	225.32	246.01
U_{target} [V]:	236.90	225.40	246.10
P_{E30} [W]:	10282	10837	10255
P_{E30} of P_n [%]:	85.68	90.31	85.45
Q_{E30} [Var]:	-6145	80	-6047
Q_{E30} of P_n [%]:	-51.21	0.67	-50.40
Q_{E30} target [%]:	-50	0	-50
$\cos \varphi_{E30}$:	0.8583	0.9999	0.8613
$\cos \varphi_{E30}$ target:	(0.8400) 0.8600	1.0000	(0.8400) 0.8600
$P_{E_{max}}/P_n$ [%]	90*	50	20
U [V]:	230.92	230.92	230.91
U_{target} [V]:	230.00	230.00	230.00
P_{E30} [W]:	10302	5964	2334
P_{E30} of P_n [%]:	85.85	49.70	19.45
Q_{E30} [Var]:	-6199	35	14
Q_{E30} of S_{max} [%]:	-51.65	0.29	0.12

Test Report

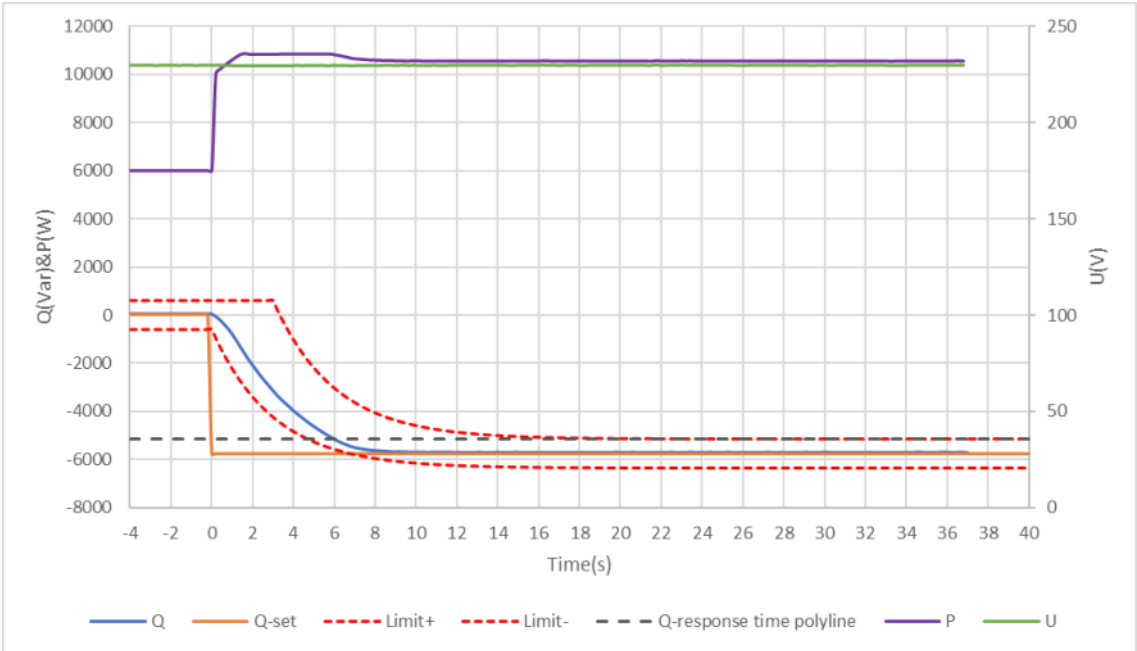
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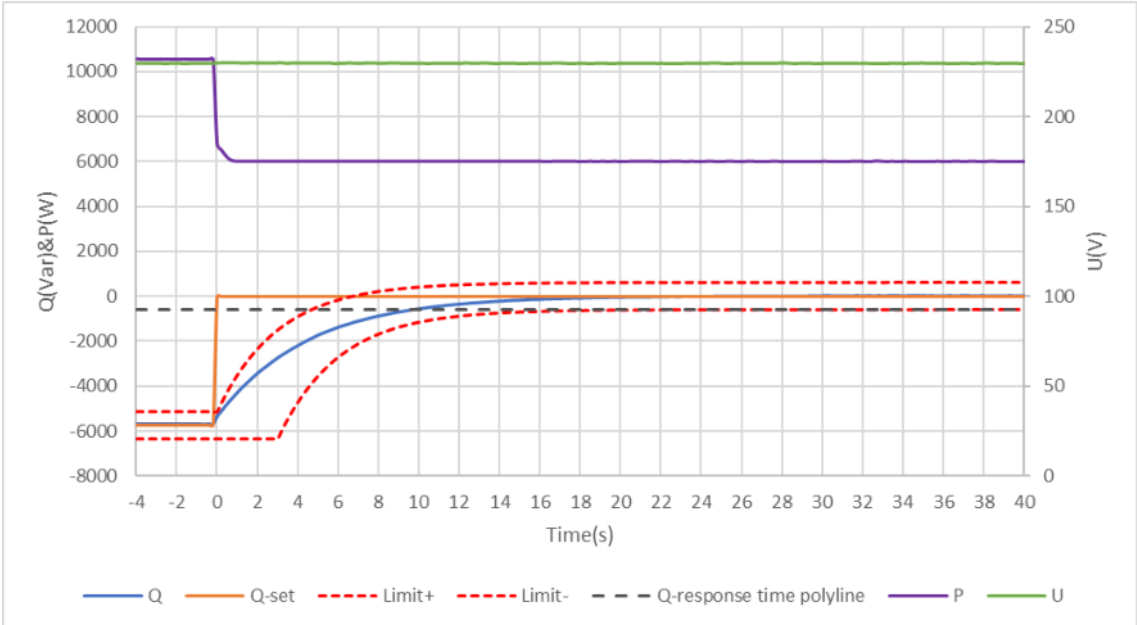
Q _{E30} target [%]:	-50	0	0
cos φ _{E30} :	0.8568	0.9999	0.9999
cos φ _{E30} target:	(0.8400) 0.8600	1.0000	1.0000
Test condition	T _{dead time} [s]	T _{set response time} [s]	T _{settling time} [s]
50% P _n -90% P _n (107%U _n -107%U _n)	0.2	9.8	9.8
90% P _n (103%U _n -98%U _n)	0.2	9.6	9.6
90% P _n (98%U _n -107%U _n)	0.2	8.8	8.8
90% P _n -50% P _n (100%U _n -100%U _n)	0.2	9.8	9.8
Limit:	Q PT1:3.33s, ΔQ=± 5 % P _n , delay time <3s		
Note: *Due to the limit of max output current, it can't reach target output power.			

Test a:

50%Pn -> 90%Pn:

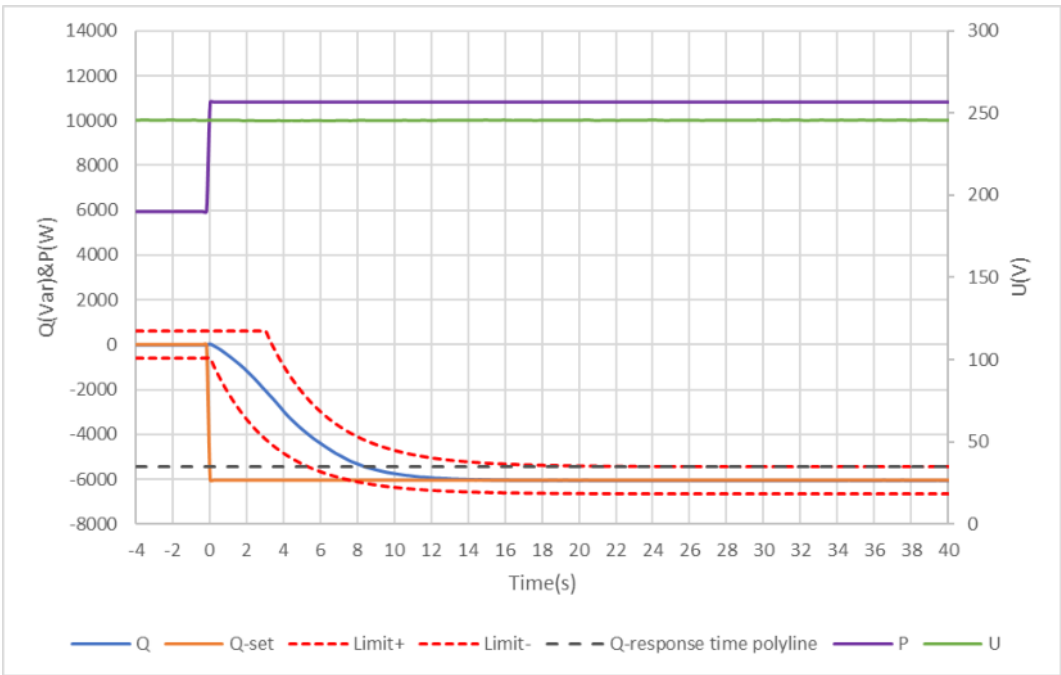


90%Pn -> 50%Pn:

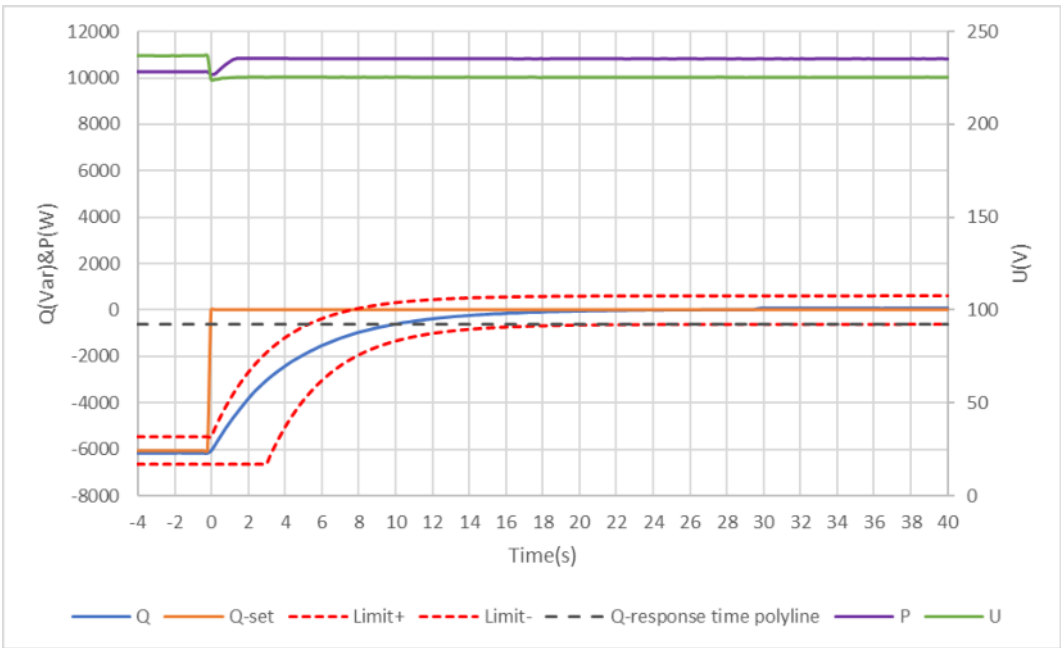


Test c:

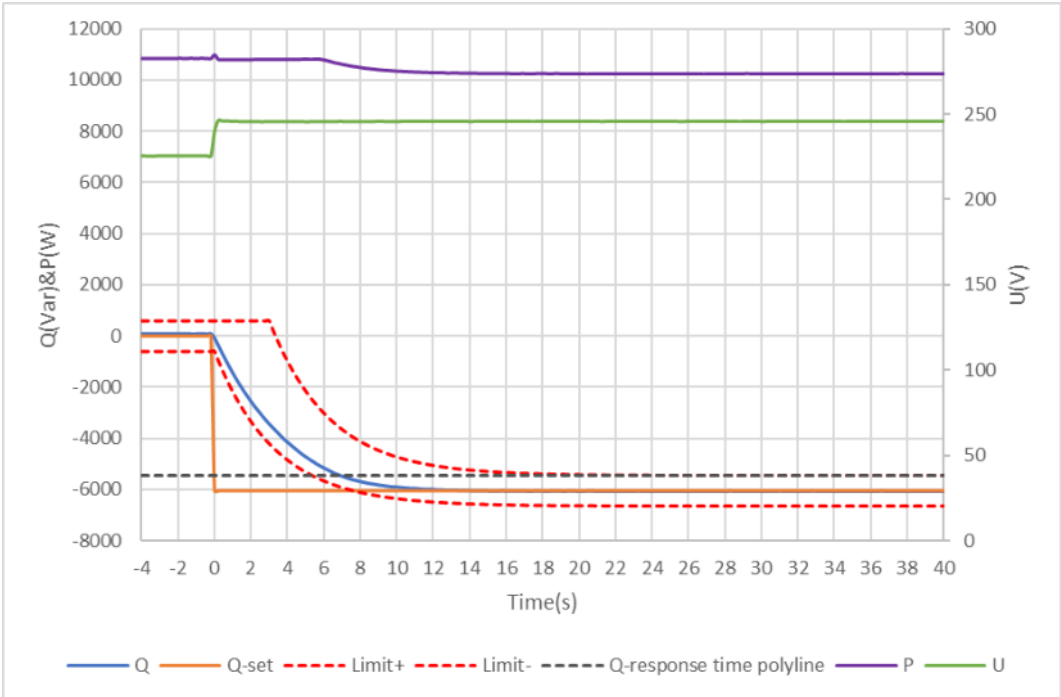
50%Pn -> 90%Pn



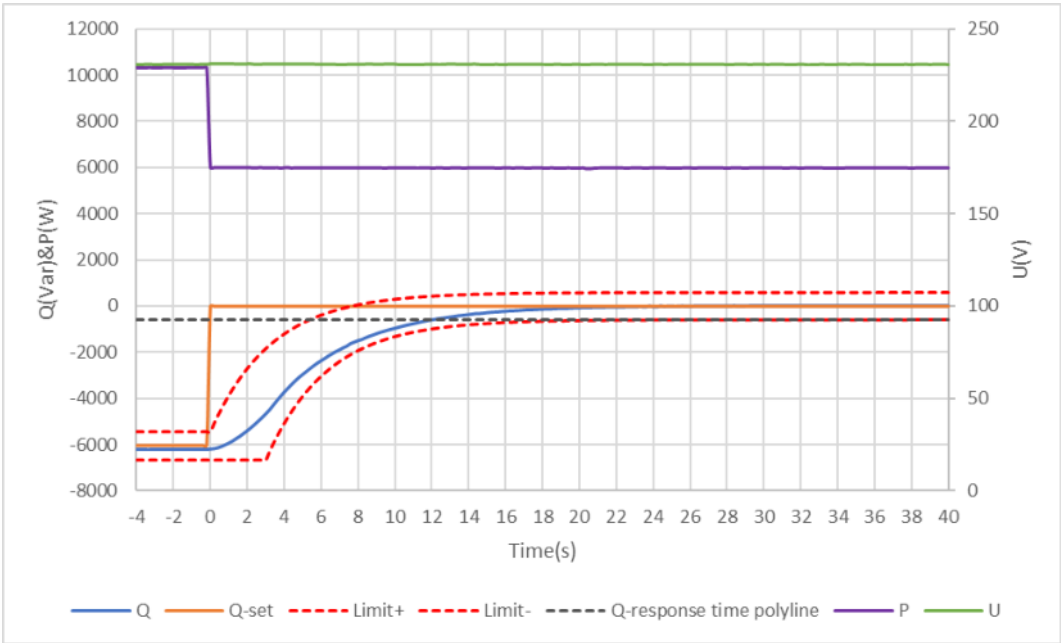
103%Un -> 98%Un



98%Un-> 107%Un



90%Pn -> 50%Pn



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5.6 Voltage related active power reduction (P(U) function)					P
5.6.3 Test procedure for steady-state behaviour					
Test condition	100% Pn				
V _{measured} [%]	100.05	102.97	105.97	108.95	
V _{Target} [%]	100	103	106	109	
P _{measured} [%]	98.42	98.43	98.50	79.99	
P _{Target} [%]	100	100	100	100.0*	
Q _{measured} [%]	0.54	0.35	0.16	-58.76	
Q _{Target} [%]	0.0	0.0	0.0	-60.0	
V _{measured} [%]	112.57	115.08	112.57	108.98	
V _{Target} [%]	112	115	112	109	
P _{measured} [%]	50.88	0.75	51.18	79.98	
P _{Target} [%]	60**	0	60**	100.0*	
Q _{measured} [%]	-58.77	-58.96	-58.79	-58.78	
Q _{Target} [%]	-60.0	-60.0	-60.0	-60.0	
V _{measured} [%]	105.96		102.97		
V _{Target} [%]	106		103		
P _{measured} [%]	98.64		98.49		
P _{Target} [%]	100		100		
Q _{measured} [%]	0.92		0.35		
Q _{Target} [%]	0.0		0.0		
Limits	ΔP=±2%Pn, ΔQ=±2%Smax, ΔU=±1%Un				
Note: * Due to the limit of max. output current/apparent power, it can't reach target output power.					

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****Due to voltage error. 112% U_n corresponds to 60% P_n , while 112.5% U_n should be 50% P_n .**

Assessment criterion:

P(U) setting

U/ U_n (%)	110	115
P/ P_n (%)	100	0

Unless further requirements apply for a specific grid code, the test shall be considered passed if:

The measured 30-s averages of the active power (positive sequence components) during steady-state conditions are within a tolerance band of $\pm 2\%$ S_{max} and $\pm 1\%$ U_n , of the set P(U) characteristic.

the time response of the active power during the measurement represents the applied configuration within the tolerance band resulting from the behaviour of an equivalent first order filter element and the configured time constant τ . Accepted tolerances are

-5 % P_n , for the active power values and 3 s for the time in case of a power decrease.

+5 % P_n , for the active power values and 3 s for the time in case of a power increase.

No discontinuities in the characteristic curve are detected and no oscillations of the active power after the end of the transient period of 5 τ as configured and no disconnection of the EUT occur.

The settings of the function, as well as the enabling and disabling of the function, are field adjustable and means are provided to protect these from unpermitted interference (e.g. password or seal).

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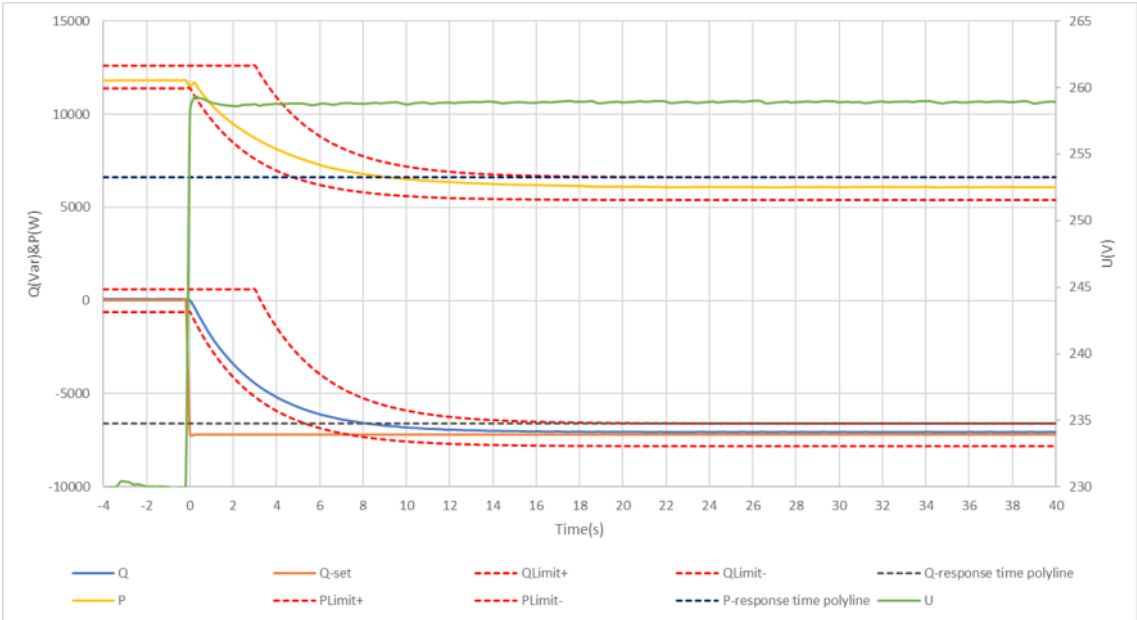
5.6 Voltage related active power reduction (P(U) function)						P
5.6.4 Test procedure for dynamic behaviour						
Test condition	100% Pn					
	Step 1	Step 2	Step 3	Step 4	Step 5	
V _{measured} [%]	100.03	112.57	115.08	112.57	99.98	
V _{Target} [%]	100	112.5	115	112.5	100	
P _{measured} [%]	98.42	50.95	0.65	51.04	98.39	
P _{Target} [%]	100	50	0	50	100	
Q _{measured} [%]	0.56	-58.76	-58.96	-58.79	0.48	
Q _{Target} [%]	0.0	-60.0	-60.0	-60.0	0.0	
Limit	P: Tau=3s, Q: Tau=3s ΔP=±2%Pn, ΔQ=±2%Smax, ΔU=±1%Un					
Test condition	100% Pn					
	Dead time[s]		response time[s]		settling time[s]	
	P	Q	P	Q	P	Q
Step 1- Step 2	0.4	0.2	8.2	8.8	8.2	8.8
Step 2- Step 3	0.2	-	9.8	-	9.8	-
Step 3- Step 4	0.2	-	9.8	-	9.8	-
Step 4- Step 5	0.2	0.2	6.4	8.8	6.4	8.8

Test Report

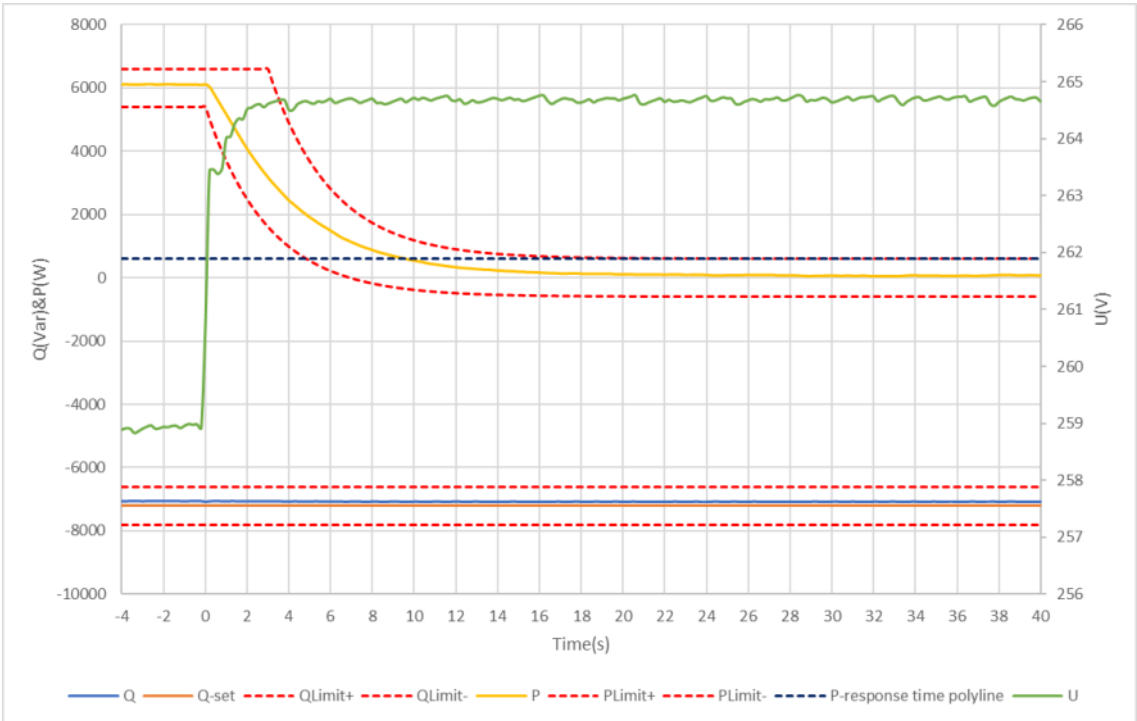
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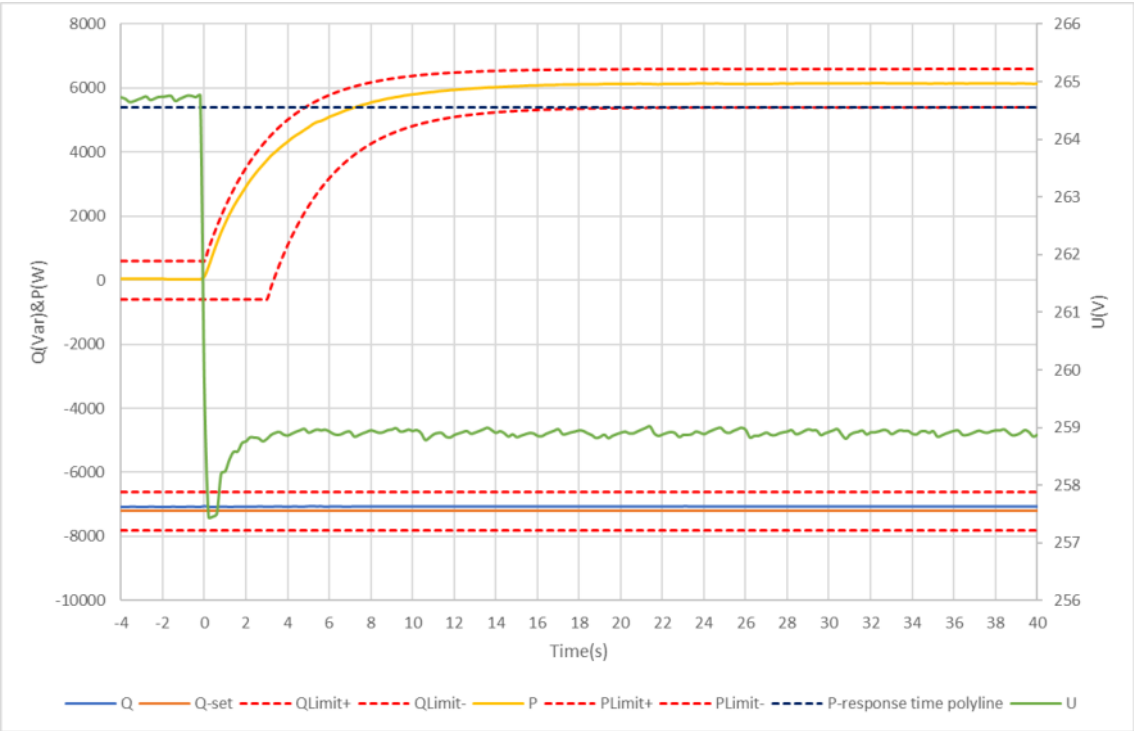
Step 1- Step 2



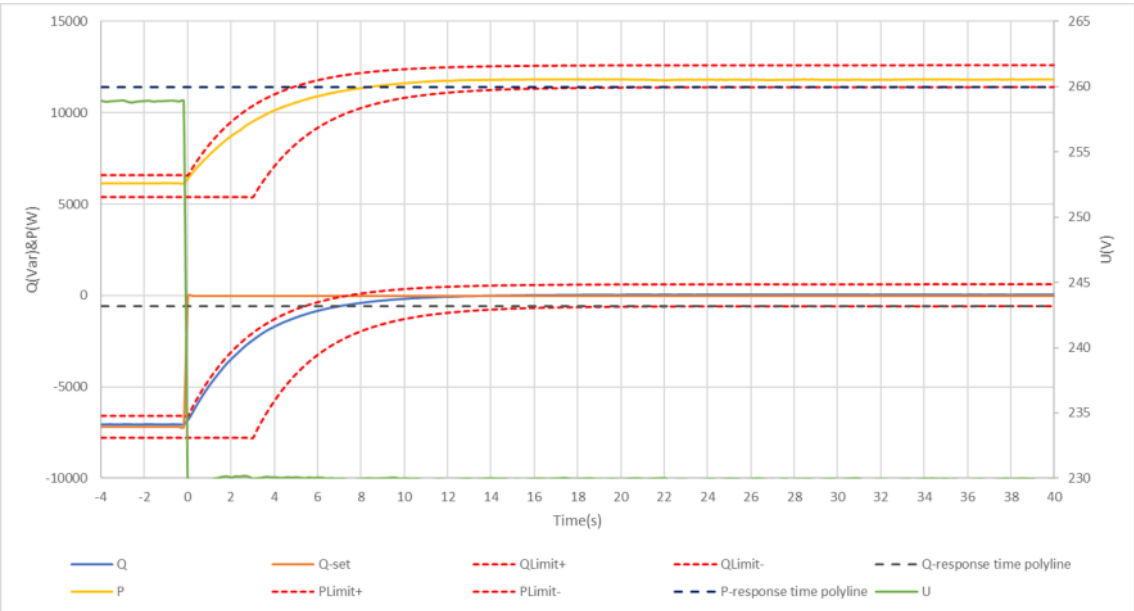
Step 2- Step 3



Step 3- Step 4



Step 4- Step 5



Assessment criterion:

P(U) setting

U/Un(%)	110	115
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	P/Pn(%)	100	0
Unless further requirements apply for a specific grid code, the test shall be considered passed if: The measured 30-s averages of the active power (positive sequence components) during steady-state conditions are within a tolerance band of $\pm 2\%$ S_{max} and $\pm 1\%$ U_n, of the set P(U) characteristic. the time response of the active power during the measurement represents the applied configuration within the tolerance band resulting from the behaviour of an equivalent first order filter element and the configured time constant tau. Accepted tolerances are -5 % P_n, for the active power values and 3 s for the time in case of a power decrease. +5 % P_n, for the active power values and 3 s for the time in case of a power increase. No discontinuities in the characteristic curve are detected and no oscillations of the active power after the end of the transient period of 5 τ as configured and no disconnection of the EUT occur. The settings of the function, as well as the enabling and disabling of the function, are field adjustable and means are provided to protect these from unpermitted interference (e.g. password or seal).			

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5.7 EMC and power quality 5.7.2.2 Verification procedure for harmonics, interharmonics and higher frequencies up to 9 kHz							P
Model: Sowave-TL8							
Power Level	33%		66%		100%		
Harmonic	Current Magnitude (A)	% of Fundamental	Current Magnitude (A)	% of Fundamental	Current Magnitude (A)	% of Fundamental	Harmonic Current Limits (A)
2nd	0.134	1.153	0.150	1.291	0.175	1.512	1.08
3rd	0.203	1.748	0.191	1.649	0.206	1.774	2.3
4th	0.026	0.223	0.032	0.274	0.026	0.225	0.43
5th	0.143	1.232	0.150	1.291	0.142	1.223	1.14
6th	0.015	0.133	0.007	0.062	0.009	0.079	0.3
7th	0.068	0.583	0.077	0.667	0.080	0.688	0.77
8th	0.006	0.050	0.007	0.060	0.017	0.145	0.23
9th	0.063	0.545	0.054	0.468	0.066	0.565	0.4
10th	0.008	0.069	0.017	0.149	0.012	0.103	0.184
11th	0.205	1.771	0.091	0.785	0.199	1.715	0.33
12th	0.007	0.058	0.004	0.036	0.012	0.106	0.153
13th	0.047	0.405	0.021	0.178	0.097	0.838	0.21
14th	0.005	0.043	0.002	0.019	0.008	0.065	0.131
15th	0.034	0.294	0.032	0.278	0.041	0.349	0.15
16th	0.005	0.040	0.004	0.031	0.005	0.039	0.115
17th	0.051	0.443	0.033	0.288	0.023	0.199	0.132
18th	0.002	0.019	0.003	0.029	0.004	0.031	0.102
19th	0.052	0.446	0.033	0.283	0.010	0.086	0.118
20th	0.003	0.030	0.004	0.032	0.005	0.044	0.092
21st	0.037	0.323	0.028	0.239	0.012	0.106	0.107

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22nd	0.003	0.024	0.004	0.038	0.003	0.023	0.084
23rd	0.025	0.217	0.017	0.150	0.021	0.185	0.098
24th	0.002	0.021	0.003	0.026	0.003	0.030	0.077
25th	0.016	0.138	0.012	0.100	0.020	0.174	0.09
26th	0.002	0.017	0.003	0.026	0.002	0.021	0.071
27th	0.030	0.258	0.003	0.027	0.025	0.214	0.083
28th	0.002	0.016	0.003	0.024	0.003	0.024	0.066
29th	0.032	0.280	0.005	0.046	0.023	0.195	0.078
30th	0.003	0.022	0.002	0.019	0.003	0.024	0.061
31st	0.021	0.179	0.005	0.040	0.022	0.188	0.073
32nd	0.002	0.015	0.002	0.014	0.003	0.022	0.058
33rd	0.005	0.046	0.007	0.059	0.020	0.175	0.068
34th	0.002	0.016	0.002	0.015	0.002	0.021	0.054
35th	0.014	0.124	0.005	0.042	0.018	0.156	0.064
36th	0.002	0.016	0.002	0.017	0.002	0.017	0.051
37th	0.015	0.128	0.005	0.039	0.015	0.129	0.061
38th	0.002	0.014	0.002	0.018	0.002	0.016	0.048
39th	0.006	0.048	0.012	0.105	0.009	0.076	0.058
40th	0.001	0.012	0.003	0.027	0.002	0.017	0.046
41st	0.011	0.098	0.014	0.121	0.007	0.064	N/A
42nd	0.002	0.014	0.004	0.036	0.002	0.020	N/A
43rd	0.018	0.152	0.016	0.139	0.006	0.049	N/A
44th	0.002	0.014	0.003	0.025	0.002	0.019	N/A
45th	0.013	0.112	0.018	0.158	0.004	0.031	N/A
46th	0.002	0.015	0.002	0.020	0.002	0.019	N/A
47th	0.007	0.064	0.017	0.148	0.004	0.039	N/A

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48th	0.002	0.019	0.002	0.017	0.003	0.025	N/A
49th	0.007	0.056	0.015	0.131	0.004	0.035	N/A
50th	0.002	0.016	0.002	0.013	0.002	0.017	N/A
THD [%]	--	3.285	--	2.799	--	3.452	5

Note:

Samplerate:20 kHz

Measured on each phase and choose the maximum value of three phase.

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5.7 EMC and power quality 5.7.2.2 Verification procedure for harmonics, interharmonics and higher frequencies up to 9 kHz							P
Model: Sowave-TL12							
Power Level	33%		66%		100%		
Harmonic	Current Magnitude (A)	% of Fundamental	Current Magnitude (A)	% of Fundamental	Current Magnitude (A)	% of Fundamental	Harmonic Current Limits (%)
2nd	0.133	0.766	0.171	0.985	0.213	1.222	8.000
3rd	0.193	1.112	0.207	1.190	0.230	1.321	21.600
4th	0.034	0.194	0.028	0.159	0.025	0.145	4.000
5th	0.153	0.879	0.140	0.807	0.149	0.856	10.700
6th	0.009	0.054	0.009	0.054	0.005	0.028	2.670
7th	0.072	0.411	0.080	0.460	0.077	0.440	7.200
8th	0.004	0.024	0.016	0.094	0.016	0.093	2.000
9th	0.049	0.279	0.068	0.389	0.058	0.336	3.800
10th	0.011	0.064	0.012	0.067	0.011	0.061	1.600
11th	0.122	0.699	0.199	1.144	0.212	1.220	3.100
12th	0.005	0.028	0.012	0.068	0.010	0.059	1.330
13th	0.085	0.489	0.096	0.550	0.133	0.766	2.000
14th	0.006	0.032	0.008	0.046	0.007	0.042	N/A
15th	0.051	0.295	0.039	0.225	0.076	0.437	N/A
16th	0.004	0.022	0.005	0.028	0.005	0.030	N/A
17th	0.030	0.170	0.022	0.126	0.056	0.325	N/A
18th	0.003	0.018	0.004	0.021	0.006	0.034	N/A
19th	0.009	0.049	0.009	0.054	0.040	0.233	N/A
20th	0.003	0.018	0.005	0.027	0.005	0.031	N/A
21st	0.006	0.035	0.014	0.083	0.028	0.159	N/A

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22nd	0.002	0.013	0.003	0.017	0.005	0.028	N/A
23rd	0.008	0.047	0.022	0.127	0.022	0.125	N/A
24th	0.002	0.013	0.004	0.021	0.004	0.021	N/A
25th	0.017	0.097	0.021	0.119	0.020	0.117	N/A
26th	0.003	0.016	0.002	0.013	0.004	0.025	N/A
27th	0.022	0.125	0.025	0.143	0.012	0.067	N/A
28th	0.003	0.019	0.003	0.016	0.004	0.021	N/A
29th	0.027	0.156	0.023	0.132	0.015	0.089	N/A
30th	0.003	0.020	0.003	0.016	0.004	0.022	N/A
31st	0.026	0.148	0.022	0.126	0.015	0.089	N/A
32nd	0.002	0.012	0.003	0.016	0.004	0.021	N/A
33rd	0.023	0.134	0.019	0.111	0.015	0.085	N/A
34th	0.002	0.013	0.002	0.014	0.004	0.022	N/A
35th	0.021	0.122	0.017	0.098	0.017	0.098	N/A
36th	0.003	0.016	0.002	0.011	0.004	0.022	N/A
37th	0.023	0.130	0.014	0.080	0.013	0.075	N/A
38th	0.003	0.015	0.002	0.012	0.004	0.022	N/A
39th	0.027	0.152	0.007	0.043	0.019	0.108	N/A
40th	0.002	0.013	0.002	0.012	0.004	0.023	N/A
41st	0.026	0.149	0.006	0.037	0.018	0.103	N/A
42nd	0.002	0.010	0.002	0.014	0.004	0.022	N/A
43rd	0.023	0.130	0.005	0.026	0.015	0.087	N/A
44th	0.002	0.012	0.002	0.012	0.003	0.020	N/A
45th	0.015	0.085	0.004	0.022	0.017	0.099	N/A
46th	0.002	0.013	0.002	0.012	0.003	0.019	N/A
47th	0.012	0.070	0.004	0.025	0.015	0.087	N/A

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48th	0.002	0.013	0.003	0.016	0.003	0.019	N/A
49th	0.009	0.054	0.004	0.024	0.012	0.067	N/A
50th	0.002	0.011	0.002	0.011	0.003	0.018	N/A
THD [%]	--	1.973	--	2.292	--	2.620	13
PWHD [%]	--	2.594	--	2.163	--	3.000	22

Note:

Samplerate : 20 kHz

Measured on each phase and choose the maximum value of three phase.

5.7 EMC and power quality Harmonic current emission (EN 61000-4-7)											P
The currents of the interharmonics to 2 kHz must be measured in accordance with DIN EN 61000-4-7 (VDE 0817-4-7), Annex A. The measurements of higher-frequency harmonic currents between 2 kHz and 9 kHz must be conducted in line with DIN EN 61000-4-7 (VDE 0847-4-7), Annex B.											
Model: Sowave-TL12											
Harmonics											
P/P _n [%]	0/5	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2	0.257	0.632	0.742	0.776	0.835	0.897	0.968	1.021	1.095	1.162	1.222
3	1.006	1.180	1.153	1.149	1.124	1.133	1.145	1.186	1.228	1.269	1.321
4	0.089	0.187	0.139	0.171	0.196	0.166	0.160	0.152	0.144	0.144	0.145
5	0.794	0.723	0.829	0.866	0.855	0.844	0.844	0.842	0.848	0.857	0.856
6	0.047	0.058	0.085	0.055	0.035	0.017	0.026	0.028	0.023	0.024	0.028
7	0.428	0.510	0.388	0.414	0.451	0.454	0.453	0.450	0.440	0.434	0.440
8	0.053	0.032	0.036	0.019	0.023	0.051	0.077	0.093	0.097	0.094	0.093
9	0.293	0.312	0.373	0.281	0.290	0.326	0.326	0.336	0.340	0.342	0.336
10	0.057	0.065	0.029	0.044	0.076	0.088	0.078	0.067	0.059	0.058	0.061
11	0.338	0.294	1.116	0.922	0.352	0.784	1.043	1.162	1.201	1.217	1.220
12	0.028	0.021	0.045	0.023	0.016	0.033	0.046	0.055	0.057	0.058	0.059
13	0.126	0.393	0.209	0.535	0.212	0.237	0.464	0.604	0.683	0.734	0.766
14	0.013	0.037	0.042	0.020	0.015	0.015	0.029	0.037	0.041	0.043	0.042
15	0.146	0.161	0.270	0.237	0.274	0.068	0.161	0.282	0.356	0.408	0.437
16	0.014	0.043	0.029	0.015	0.020	0.021	0.022	0.012	0.014	0.022	0.030
17	0.219	0.065	0.355	0.080	0.235	0.094	0.061	0.161	0.225	0.282	0.325
18	0.011	0.013	0.019	0.014	0.019	0.015	0.015	0.020	0.028	0.031	0.034
19	0.223	0.260	0.310	0.042	0.170	0.168	0.086	0.071	0.124	0.182	0.233

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20	0.011	0.019	0.028	0.014	0.024	0.012	0.019	0.028	0.035	0.034	0.031
21	0.139	0.198	0.176	0.089	0.101	0.177	0.120	0.055	0.063	0.112	0.159
22	0.009	0.015	0.019	0.015	0.022	0.015	0.014	0.010	0.013	0.020	0.028
23	0.029	0.112	0.058	0.140	0.059	0.148	0.144	0.112	0.085	0.090	0.125
24	0.015	0.011	0.012	0.015	0.011	0.013	0.014	0.013	0.015	0.018	0.021
25	0.047	0.171	0.122	0.169	0.038	0.124	0.141	0.103	0.080	0.083	0.117
26	0.009	0.015	0.011	0.012	0.008	0.020	0.016	0.009	0.016	0.021	0.025
27	0.046	0.128	0.172	0.174	0.036	0.088	0.153	0.138	0.102	0.064	0.067
28	0.011	0.018	0.017	0.012	0.007	0.010	0.015	0.013	0.013	0.015	0.021
29	0.058	0.066	0.125	0.148	0.020	0.056	0.126	0.131	0.111	0.084	0.089
30	0.008	0.016	0.021	0.014	0.007	0.010	0.012	0.013	0.017	0.020	0.022
31	0.057	0.134	0.018	0.120	0.019	0.032	0.113	0.123	0.106	0.081	0.089
32	0.007	0.010	0.010	0.009	0.011	0.010	0.014	0.009	0.011	0.016	0.021
33	0.069	0.085	0.090	0.144	0.061	0.023	0.076	0.129	0.134	0.109	0.085
34	0.014	0.010	0.010	0.013	0.012	0.011	0.011	0.013	0.016	0.019	0.022
35	0.054	0.070	0.104	0.171	0.090	0.032	0.061	0.121	0.139	0.121	0.098
36	0.011	0.011	0.014	0.013	0.018	0.011	0.011	0.008	0.018	0.021	0.022
37	0.044	0.054	0.057	0.177	0.103	0.024	0.049	0.096	0.110	0.093	0.075
38	0.009	0.009	0.012	0.012	0.019	0.008	0.010	0.008	0.015	0.019	0.022
39	0.041	0.022	0.081	0.143	0.130	0.038	0.011	0.072	0.113	0.118	0.108
40	0.010	0.016	0.009	0.009	0.016	0.007	0.011	0.009	0.012	0.018	0.023
41	0.034	0.051	0.120	0.109	0.122	0.020	0.012	0.061	0.097	0.105	0.103
42	0.008	0.018	0.012	0.008	0.014	0.009	0.014	0.007	0.010	0.017	0.022
43	0.049	0.023	0.098	0.079	0.114	0.014	0.016	0.050	0.085	0.094	0.087
44	0.009	0.012	0.010	0.010	0.011	0.010	0.009	0.008	0.008	0.013	0.020
45	0.032	0.019	0.036	0.062	0.100	0.034	0.027	0.026	0.066	0.093	0.099

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46	0.007	0.011	0.011	0.012	0.010	0.012	0.009	0.010	0.009	0.012	0.019
47	0.042	0.021	0.036	0.071	0.091	0.035	0.025	0.028	0.061	0.079	0.087
48	0.010	0.010	0.016	0.014	0.015	0.021	0.012	0.015	0.011	0.013	0.019
49	0.025	0.044	0.039	0.051	0.085	0.044	0.024	0.025	0.048	0.063	0.067
50	0.008	0.011	0.011	0.011	0.010	0.016	0.008	0.011	0.009	0.011	0.018
Interharmonics at continuous operation											
P/P _n [%]	0	10	20	30	40	50	60	70	80	90	100
f [Hz]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]
75	0.039	0.046	0.040	0.043	0.050	0.042	0.045	0.046	0.049	0.053	0.061
125	0.027	0.025	0.027	0.036	0.036	0.031	0.026	0.027	0.028	0.029	0.032
175	0.024	0.027	0.026	0.032	0.037	0.029	0.026	0.026	0.026	0.028	0.030
225	0.020	0.021	0.019	0.025	0.030	0.021	0.022	0.022	0.022	0.023	0.026
275	0.022	0.024	0.024	0.030	0.036	0.028	0.029	0.029	0.029	0.031	0.033
325	0.019	0.019	0.018	0.022	0.026	0.020	0.020	0.019	0.019	0.020	0.022
375	0.021	0.027	0.025	0.031	0.036	0.032	0.032	0.031	0.032	0.033	0.035
425	0.017	0.020	0.018	0.021	0.022	0.021	0.019	0.019	0.019	0.020	0.022
475	0.021	0.035	0.031	0.036	0.040	0.037	0.037	0.037	0.037	0.039	0.040
525	0.017	0.031	0.024	0.027	0.031	0.029	0.030	0.030	0.031	0.035	0.040
575	0.017	0.030	0.023	0.025	0.028	0.027	0.026	0.028	0.029	0.033	0.037
625	0.016	0.027	0.019	0.021	0.023	0.022	0.022	0.022	0.023	0.026	0.029
675	0.015	0.025	0.017	0.020	0.021	0.021	0.021	0.021	0.022	0.026	0.029
725	0.014	0.023	0.016	0.019	0.018	0.019	0.018	0.019	0.019	0.023	0.025
775	0.014	0.022	0.016	0.018	0.018	0.018	0.018	0.018	0.019	0.022	0.025
825	0.013	0.020	0.015	0.017	0.016	0.017	0.017	0.016	0.017	0.019	0.023
875	0.013	0.020	0.015	0.017	0.016	0.016	0.016	0.016	0.017	0.020	0.022
925	0.012	0.018	0.015	0.018	0.015	0.015	0.015	0.015	0.016	0.018	0.020

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975	0.012	0.015	0.014	0.018	0.015	0.016	0.016	0.016	0.016	0.019	0.021
1025	0.012	0.014	0.014	0.018	0.016	0.016	0.016	0.015	0.015	0.016	0.019
1075	0.011	0.014	0.014	0.018	0.015	0.016	0.016	0.015	0.014	0.016	0.019
1125	0.011	0.013	0.013	0.017	0.016	0.017	0.016	0.015	0.014	0.014	0.017
1175	0.010	0.013	0.013	0.018	0.016	0.017	0.016	0.015	0.015	0.015	0.018
1225	0.010	0.012	0.013	0.016	0.016	0.017	0.016	0.016	0.015	0.015	0.017
1275	0.011	0.012	0.013	0.015	0.016	0.017	0.016	0.016	0.015	0.015	0.018
1325	0.010	0.012	0.013	0.014	0.016	0.016	0.016	0.016	0.015	0.015	0.018
1375	0.011	0.012	0.013	0.013	0.016	0.015	0.016	0.016	0.016	0.016	0.018
1425	0.010	0.011	0.012	0.013	0.016	0.014	0.015	0.015	0.016	0.016	0.017
1475	0.011	0.012	0.012	0.013	0.016	0.015	0.015	0.015	0.017	0.018	0.020
1525	0.010	0.011	0.011	0.012	0.015	0.013	0.014	0.013	0.015	0.016	0.018
1575	0.010	0.011	0.011	0.012	0.014	0.012	0.013	0.013	0.014	0.016	0.020
1625	0.010	0.011	0.011	0.012	0.014	0.012	0.012	0.012	0.013	0.015	0.021
1675	0.010	0.012	0.011	0.012	0.013	0.012	0.013	0.012	0.013	0.015	0.022
1725	0.010	0.011	0.011	0.011	0.013	0.011	0.012	0.011	0.012	0.014	0.021
1775	0.010	0.012	0.011	0.012	0.012	0.012	0.012	0.011	0.012	0.014	0.017
1825	0.010	0.011	0.011	0.012	0.012	0.011	0.011	0.011	0.011	0.016	0.015
1875	0.010	0.012	0.011	0.012	0.012	0.011	0.012	0.011	0.012	0.022	0.015
1925	0.010	0.011	0.011	0.012	0.012	0.011	0.011	0.011	0.017	0.015	0.015
1975	0.011	0.012	0.013	0.012	0.012	0.011	0.012	0.015	0.020	0.012	0.015
Higher Frequencies components											
P/P _n [%]	0	10	20	30	40	50	60	70	80	90	100
f [kHz]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]	I _h [%]
2.1	0.221	0.219	0.231	0.147	0.259	0.097	0.099	0.131	0.159	0.187	0.211
2.3	0.207	0.472	0.416	0.204	0.165	0.095	0.108	0.125	0.149	0.188	0.210

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2.5	0.201	0.173	0.320	0.570	0.204	0.103	0.089	0.139	0.170	0.181	0.208
2.7	0.251	0.190	0.258	0.235	0.495	0.388	0.128	0.158	0.193	0.220	0.244
2.9	0.261	0.270	0.288	0.215	0.191	0.345	0.605	0.633	0.667	0.705	0.732
3.1	0.387	0.371	0.260	0.254	0.269	0.197	0.187	0.212	0.265	0.312	0.353
3.3	0.510	0.591	0.805	0.936	1.005	1.002	1.075	1.148	1.211	1.237	1.246
3.5	0.301	0.396	0.390	0.416	0.483	0.379	0.411	0.532	0.661	0.808	1.016
3.7	0.157	0.201	0.233	0.266	0.295	0.254	0.271	0.397	0.555	0.806	1.177
3.9	0.069	0.095	0.102	0.115	0.126	0.129	0.120	0.162	0.194	0.248	0.361
4.1	0.051	0.056	0.055	0.061	0.067	0.074	0.109	0.112	0.123	0.147	0.169
4.3	0.040	0.041	0.042	0.042	0.047	0.062	0.047	0.050	0.053	0.059	0.068
4.5	0.034	0.033	0.034	0.033	0.037	0.047	0.036	0.038	0.040	0.042	0.045
4.7	0.043	0.050	0.048	0.046	0.051	0.047	0.048	0.048	0.049	0.051	0.052
4.9	0.024	0.024	0.026	0.028	0.026	0.026	0.027	0.028	0.030	0.031	0.033
5.1	0.024	0.022	0.023	0.025	0.023	0.023	0.024	0.025	0.027	0.028	0.030
5.3	0.022	0.022	0.021	0.020	0.022	0.021	0.021	0.021	0.023	0.023	0.024
5.5	0.020	0.019	0.019	0.018	0.018	0.020	0.019	0.020	0.021	0.022	0.022
5.7	0.019	0.020	0.020	0.019	0.019	0.021	0.020	0.021	0.022	0.022	0.023
5.9	0.018	0.018	0.016	0.016	0.016	0.017	0.019	0.020	0.021	0.022	0.023
6.1	0.020	0.020	0.019	0.019	0.019	0.019	0.019	0.020	0.022	0.023	0.024
6.3	0.019	0.017	0.015	0.015	0.016	0.015	0.016	0.017	0.020	0.022	0.027
6.5	0.020	0.018	0.017	0.017	0.017	0.016	0.017	0.019	0.022	0.023	0.025
6.7	0.019	0.023	0.024	0.027	0.027	0.027	0.030	0.031	0.034	0.036	0.037
6.9	0.019	0.021	0.017	0.017	0.016	0.014	0.015	0.016	0.019	0.021	0.022
7.1	0.023	0.023	0.022	0.021	0.021	0.022	0.026	0.027	0.029	0.032	0.033
7.3	0.017	0.017	0.016	0.016	0.021	0.017	0.014	0.014	0.018	0.020	0.022
7.5	0.016	0.016	0.017	0.020	0.015	0.013	0.013	0.014	0.017	0.020	0.022

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7.7	0.015	0.018	0.017	0.014	0.014	0.012	0.012	0.013	0.017	0.020	0.022
7.9	0.014	0.016	0.015	0.013	0.014	0.012	0.012	0.013	0.016	0.020	0.023
8.1	0.015	0.016	0.015	0.014	0.014	0.012	0.012	0.013	0.016	0.020	0.023
8.3	0.016	0.017	0.017	0.016	0.015	0.015	0.014	0.015	0.018	0.021	0.025
8.5	0.016	0.017	0.017	0.017	0.016	0.015	0.014	0.015	0.017	0.021	0.024
8.7	0.013	0.014	0.013	0.015	0.014	0.011	0.011	0.011	0.014	0.018	0.022
8.9	0.013	0.012	0.012	0.014	0.014	0.011	0.011	0.011	0.014	0.017	0.021

Note:

The normalization current is 17.4A.

Samplerate:20 kHz

Measured on each phase and choose the maximum value of three phase.

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5.7.2.3 Verification procedure for flicker and rapid voltage change					P
5.7.2.3.2 Flicker - Generation units with a rated current≤75 A					
Test conditions:	Maximum permissible voltage fluctuation (expressed as a percentage of nominal voltage at 100 % power) and flicker as per EN 61000-3-3 and/or EN 61000-3-11				
Test: Sowave-TL8					
Value	P _{st}	P _{It} 2 hours	d(t) 500ms	d _c	d _{max}
Limit	1.0	0.65	3.3%	3.3%	4%
EN 61000-3-3(L1-N)	0.081	0.087	0.000%	0.129%	0.339%
EN 61000-3-3(L2-N)	0.077	0.069	0.000%	0.115%	0.319%
EN 61000-3-3(L3-N)	0.085	0.076	0.000%	0.127%	0.310%
Test: Sowave-TL12					
Value	P _{st}	P _{It} 2 hours	d(t) 500ms	d _c	d _{max}
Limit	1.0	0.65	3.3%	3.3%	4%
EN 61000-3-11(L1-N)	0.099	0.094	0.000%	0.180%	0.308%
EN 61000-3-11(L2-N)	0.085	0.079	0.000%	0.154%	0.300%
EN 61000-3-11(L3-N)	0.092	0.087	0.000%	0.169%	0.348%
Test method:					
EN 61000-3-3 for devices with a rated current of 16 A.					
EN IEC 61000-3-11 for devices with a rated current of 16 A and 75 A					
Note:					
Mains Impedance according EN 61000-3-3 / EN 61000-3-11:					
Calculation of the maximum permissible grid impedance at the point of common coupling based on dc:					
Zmax = Zref * 3.3% / dc (P _n)					
The tests should be based on the limits of the EN 61000-3-3 for less than 16A and on EN 61000-3-11 for more than 16A.					

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5.7.2.3 Verification procedure for flicker and rapid voltage change 5.7.2.3.3 Flicker - Generation units with a rated current > 75 A								N/A	
Model:									
Test:									
Test conditions:					The objective of the test is to determine the system flicker coefficient $c(\Psi_k)$ at the system impedance angles 30°, 50°, 70° and 85°. The flicker coefficient is determined according to the equation in 3.1.8.2. The system flicker coefficient $c(\Psi_k)$ is determined for continuous operation without disturbances. It shall be normalized to the nominal apparent power. The apparent short-circuit power S_k shall be referenced to a symmetrical short-circuit of the test source for a three-phase EUT, and to the single-phase short-circuit power in the case of a single-phase EUT.				
Test:									
%Pn	Pst				Flicker coefficient, $c(\Psi_k)$				
	30°	50°	70°	85°	30°	50°	70°	85°	
0	--	--	--	--	--	--	--	--	
10	--	--	--	--	--	--	--	--	
20	--	--	--	--	--	--	--	--	
30	--	--	--	--	--	--	--	--	
40	--	--	--	--	--	--	--	--	
50	--	--	--	--	--	--	--	--	
60	--	--	--	--	--	--	--	--	
70	--	--	--	--	--	--	--	--	
80	--	--	--	--	--	--	--	--	
90	--	--	--	--	--	--	--	--	
100	--	--	--	--	--	--	--	--	
Test method: Although EN IEC 61000-3-11 applies only to rated currents ≤ 75 A, flicker of the EUT with rated currents > 75 A is also determined according to DIN EN 61000-3-11. For controllable generating units with rated currents > 75 A, at least 12 measurements of 10 min each shall be performed. One measurement shall be made for each of the 10 % active power bins from 0 % Pn or									

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minimum regulating level, whichever is the higher to 90 % P_n and three measurements shall be made for the 10 % active power bin from 100 % P_n.

NOTE 2 This means the midpoints of the bins are near 0 % P_n, 10 % P_n, 20 % P_n to 100 % P_n of the EUT.

A measurement consists of determining the short-term flicker strength P_{st} as a 3-tuple (phases L1, L2 and L3).

The maximum over all P_{st} shall be selected as the value for the long-term flicker strength P_{lt}.

Note:

$$c(\Psi_k) = P_{st, fic} \times \frac{S_{k, fic}}{S_n}$$

Determination of the flicker coefficient:

Sk.fic/S_n set to 33.3

The normalization current is 28.99A.

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5.7.2.3 Verification procedure for flicker and rapid voltage change			P
5.7.2.3.4 Rapid voltage changes - Generation units with a rated current≤ 75 A			
EN 61000-3-3 (VDE 0838-3) for devices with a rated currents: 16 A.			
EN IEC 61000-3-11 (VDE 0838-11) for devices with a rated current > 16 A and ≤75 A.			
Test conditions:			
Frequency: 50 Hz ± 0.5%			
THD of the voltage supply: ≤ 2.5 %			
Voltage rise of the PGU at 100 P _E max %: ≤ 3 %			
Model: Sowave-TL8			
Switch-on for any capacity (10% P _n)			
	L1	L2	L3
Single period effective values of the current [A]	2.21	2.46	2.07
Single period effective values of the voltage [V]	229.73	230.00	230.60
ki value	0.19	0.21	0.18
kimax value	0.21		
Switch-on for nominal capacity			
	L1	L2	L3
Single period effective values of the current [A]	2.64	1.79	2.45
Single period effective values of the voltage [V]	229.73	230.67	229.92
ki value	0.23	0.15	0.21
kimax value	0.23		
Switch-off for nominal capacity			
	L1	L2	L3
Single period effective values of the current [A]	9.24	8.57	8.73
Single period effective values of the voltage [V]	230.33	229.84	229.42
ki value	0.80	0.74	0.75
kimax value	0.80		
Highest k _{imax} value for all switching operations			

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0.80			
Model: Sowave-TL12			
Switch-on for any capacity (10% P _n)			
	L1	L2	L3
Single period effective values of the current [A]	2.82	1.88	2.65
Single period effective values of the voltage [V]	229.97	230.69	229.71
ki value	0.16	0.11	0.15
kimax value	0.16		
Switch-on for nominal capacity			
	L1	L2	L3
Single period effective values of the current [A]	2.88	1.91	2.72
Single period effective values of the voltage [V]	229.97	230.69	229.72
ki value	0.17	0.11	0.16
kimax value	0.17		
Switch-off for nominal capacity			
	L1	L2	L3
Single period effective values of the current [A]	15.20	14.45	12.77
Single period effective values of the voltage [V]	229.69	230.44	229.40
ki value	0.87	0.83	0.73
kimax value	0.87		
Highest <i>k_{imax}</i> value for all switching operations			
0.87			

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5.7.2.3 Verification procedure for flicker and rapid voltage change					N/A
5.7.2.3.5 Rapid voltage changes - Generation units with a rated current > 75 A					
Model:					
Max, number of switching operations, N ₁₀		10			
Max, number of switching operations, N ₁₂₀		120			
Case of switching operation		Start up Cut-in at 10% of rated power			
Grid impedance angle, ψ _k	30°	50°	70°	85°	
Flicker step factor, k _f (ψ _k)	--	--	--	--	
Voltage change factor, k _u (ψ _k)	--				
Maximum inrush current factor k _{imax}	--				
Case of switching operation		Start-up Cut-in at 100% of rated power			
Grid impedance angle	30°	50°	70°	85°	
Flicker step factor, k _f (ψ _k)	--	--	--	--	
Voltage change factor, k _u (ψ _k)	--				
Maximum inrush current factor k _{imax}	--				
Case of switching operation		Service disconnection at rated power			
Grid impedance angle	30°	50°	70°	85°	
Flicker step factor, k _f (ψ _k)	--	--	--	--	
Voltage change factor, k _u (ψ _k)	--				
Maximum inrush current factor k _{imax}	--				
Worst-case over-all switching operations, k _{imax}		--			
Note:					
• The maximum number N _{10m} of the switching operation within a 10-minute period.					

- The maximum number N_{120m} of the switching operation within a 2-hour period.
- The flicker step factor $k_f(\psi_k)$ for the network impedance phase angles $\psi_k = 30^\circ, 50^\circ, 70^\circ$ and 85° .
- The voltage change factor $k_u(\psi_k)$ for the network impedance phase angles $\psi_k = 30^\circ, 50^\circ, 70^\circ$ and 85° .

$$k_f(\psi_k) = \frac{1}{130} \times \frac{S_{k, \text{fic}}}{S_n} \times P_{\text{st, fic}} \times T_p^{0,31}$$

Flicker step factor $k_f(\psi_k)$

$$k_u(\psi_k) = \sqrt{3} \times \frac{U_{\text{fic, max}} - U_{\text{fic, min}}}{U_n} \times \frac{S_{k, \text{fic}}}{S_n}$$

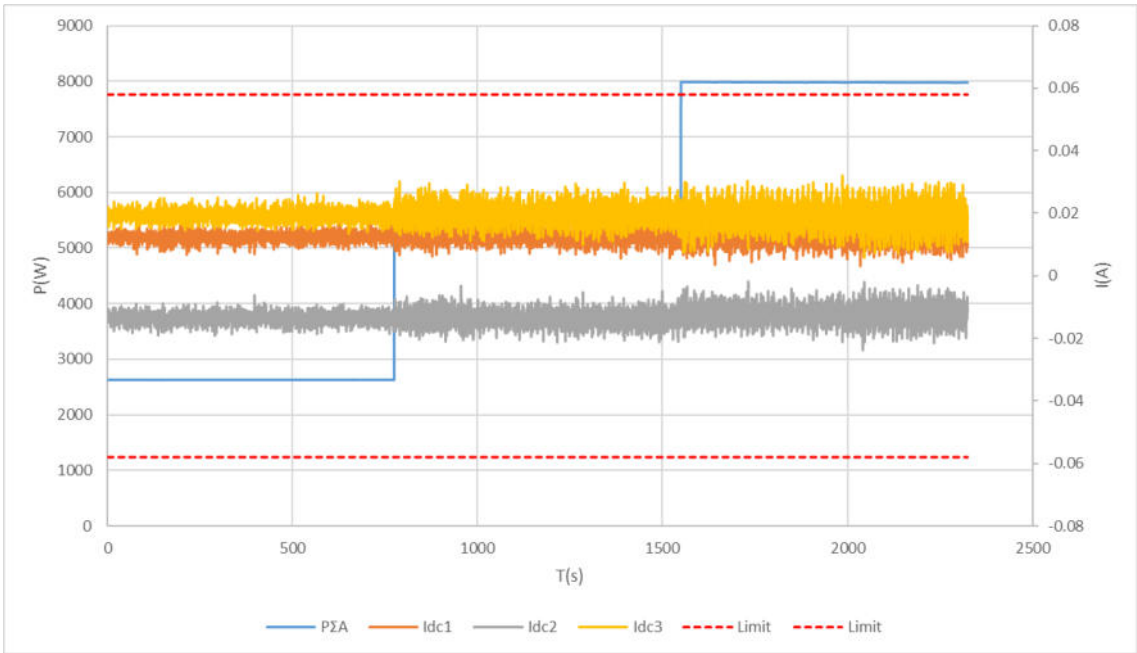
Voltage change factor $k_u(\psi_k)$

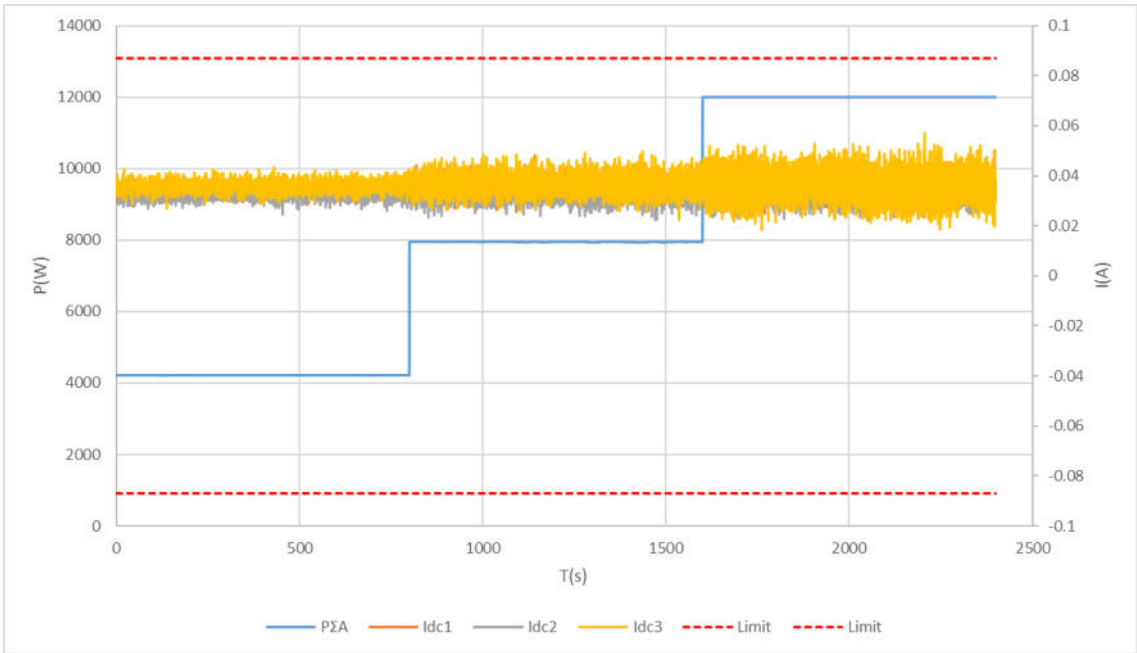
$U_{\text{fic, min}}$ is the minimum one period RMS value of the voltage on the fictitious grid during the switching operation;

$U_{\text{fic, max}}$ is the maximum one period RMS value of the voltage on the fictitious grid during the switching operation.

$S_{k, \text{fic}}/S_n$ in the fictitious grid was set to: 33.3

The normalization current is 28.9A.

5.7.2.4 verification procedure for DC injection			P
Model: Sowave-TL8			
Protection limit	Tested at four power levels limit 0.5% of $I_{AC;nom}$ (0.058A)		
Output power limit	30%-40%	60%-70%	>95%
Output power(W)	2634.4	5280.3	7993.4
Max. test value [mA] L1	18	23	22
Max. test value [mA] L2	-19	-21	-23
Max. test value [mA] L3	26	30	32
Diagram of permanent dc-injection 			
Note: The average rms value of the mains currents and mains voltages for each phase during the measurement period and the averaged values of the individual DC current components for each phase as percentages of I_{rated} must be written down in the protocol.			

5.7.2.4 verification procedure for DC injection			P
Model: Sowave-TL12			
Protection limit	Tested at four power levels limit 0.5% of $I_{AC;nom}$ (0.087A)		
Output power limit	30%-40%	60%-70%	>95%
Output power(W)	3904.46	7904.67	11811.89
Max. test value [mA] L1	41	48	50
Max. test value [mA] L2	39	43	47
Max. test value [mA] L3	43	50	27
Diagram of permanent dc-injection 			
Note: The average rms value of the mains currents and mains voltages for each phase during the measurement period and the averaged values of the individual DC current components for each phase as percentages of I_{rated} must be written down in the protocol.			

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5.7.2		EMC and power quality Unbalance					P
Setting values	cos φ = 1				1.00		
	cos φ over-excited				+0.80		
	cos φ under-excited				-0.80		
Test:							
1-min mean value	L1	L2	L3	L1 – L2	L2 – L3	L3 – L1	
a) cos φ = 1 at 100 % P _{rE} ± 5 % P _{Emax}							
S _{E60} [VA]	3983.00	3991.61	4031.55	-8.61	-39.94	48.55	
	3983.31	3991.88	4031.83	-8.58	-39.95	48.53	
	3983.00	3991.84	4031.40	-8.84	-39.56	48.39	
	3982.83	3992.03	4031.39	-9.20	-39.37	48.56	
	3983.03	3992.28	4032.22	-9.25	-39.94	49.19	
cos φ _{E60}	0.9999						
max. asymmetry [VA]	49.19						
b) maximum under-excited (i) at 100 % P _{rE} ± 5 % P _{Emax}							
S _{E60} [VA]	3993.49	4008.09	4049.49	-14.60	-41.40	56.00	
	3992.01	4006.69	4048.01	-14.68	-41.33	56.00	
	3990.85	4005.54	4046.84	-14.68	-41.30	55.99	
	3990.05	4004.76	4045.68	-14.71	-40.92	55.63	
	3991.30	4006.09	4046.48	-14.80	-40.38	55.18	
cos φ _{E60}	0.8001						
max. asymmetry [VA]	56.00						
c) maximum over-excited (c) at 100 % P _{rE} ± 5 % P _{Emax}							
S _{E60} [VA]	3979.56	3981.88	4024.10	-2.32	-42.22	44.54	
	3982.65	3984.70	4027.14	-2.06	-42.44	44.49	
	3980.37	3982.67	4024.57	-2.30	-41.90	44.20	

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	3981.39	3983.64	4026.11	-2.25	-42.47	44.72
	3977.60	3980.14	4022.20	-2.53	-42.06	44.60
COS φ_{E60}	0.7996					
max. asymmetry [VA]	44.72					
d) cos φ = 1 at 50 % $P_{rE} \pm 5\%$ P_{Emax}						
S _{E60} [VA]	1995.56	1992.88	2013.26	2.69	-20.38	17.69
	1995.72	1992.58	2013.37	3.14	-20.79	17.65
	1995.87	1992.86	2014.11	3.01	-21.25	18.23
	1995.79	1992.76	2013.88	3.03	-21.12	18.09
	1995.57	1992.67	2013.43	2.90	-20.76	17.86
COS φ_{E60}	0.9999					
max. asymmetry [VA]	-21.25					
e) maximum under-excited (i) at 50 % $P_{rE} \pm 5\%$ P_{Emax}						
S _{E60} [VA]	2479.26	2476.06	2507.00	3.20	-30.94	27.74
	2481.24	2478.87	2508.93	2.37	-30.06	27.68
	2481.70	2479.21	2509.74	2.49	-30.53	28.03
	2482.95	2480.80	2511.21	2.16	-30.41	28.26
	2479.27	2476.75	2507.58	2.51	-30.83	28.32
COS φ_{E60}	0.8002					
max. asymmetry [VA]	-30.94					
f) maximum over-excited (c) at 50 % $P_{rE} \pm 5\%$ P_{Emax}						
S _{E60} [VA]	2483.71	2493.22	2521.84	-9.51	-28.62	38.13
	2481.38	2490.97	2519.12	-9.60	-28.14	37.74
	2479.96	2489.25	2517.69	-9.30	-28.43	37.73
	2480.33	2489.86	2517.69	-9.53	-27.83	37.36
	2481.22	2490.86	2519.45	-9.63	-28.59	38.22

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cos φ_{E60} :	0.7993
max. asymmetry [VA]	38.22
Limit:	$\leq 5\% S_{E_{max}}$ and $\leq 4600VA$
Test: The maximum absolute difference between the apparent powers of the three phases is determined for each of the five measurements (1-min means) in the respective operating point. The maximum of these five values is again determined.	
Assessment criterion: The test is passed if the maximum value from the above measurements does not exceed 5 % $S_{E_{max}}$ and $\leq 4600 VA$.	

4.9.3 Requirements on voltage and frequency protection Checklist for type A			--	
Several points to check				
Clause(s) / subclause(s) of this EN 50549-1:2019	Parameter*	Configurable value range	Value default	
5.2 Operating frequency range	47.0 – 47.5 Hz Duration	0 – 20 s	0s	
	47.5 – 48.5 Hz Duration	30 – 90 min	30min	
	48.5 – 49.0 Hz Duration	30 – 90 min	30min	
	49.0 – 51.0 Hz Duration	not configurable	unlimited	
	51.0 – 51.5 Hz Duration	30 – 90 min	30min	
	51. 5 – 52 Hz Duration	0 – 15 min	0s	
4.4.3 Minimal requirement for active power delivery at underfrequency	Reduction threshold	not configurable	49.5Hz	
	Maximum reduction rate	not configurable	10% P _M /Hz	
4.4.4 Continuous operating voltage range	Upper limit	not configurable	110% Un	
	Lower limit	not configurable	85% Un	
4.5.2 Rate of change of frequency (ROCOF) immunity	ROCOF withstand capability (defined with a sliding measurement window of 500 ms) non-synchronous generating technology: synchronous generating technology:	not configurable	2 Hz/s	
4.5.3.2 Under-voltage ride through (UVRT) Generating plant with non-synchronous generating technology	Maximum power resumption time	not configurable	1 s	
	Voltage-Time-Diagram	see Figure 6	Time [s]	U [p.u.]
			0.0	0.2
			0.15	0.2
			1.5	0.85
			180	0.85

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			180	0.9
4.5.3.3 Under-voltage ride through (UVRT) Generating plant with synchronous generating technology	Maximum power resumption time	not configurable	N/A	
	Voltage-Time-Diagram	see Figure 7	N/A	
4.5.4 Over-voltage ride through (OVRT)	Voltage-Time-Diagram	not configurable see Figure 8	Time [s]	Time [s]
			0.0	1.25
			0.1	1.25
			0.1	1.20
			5.0	1.20
			5.0	1.15
			60	1.15
			60	1.10
4.6.1 Power response to overfrequency	Threshold frequency f1	50.2 Hz – 52 Hz	50.2 Hz	
	Droop	2 % – 12 %	5 %	
	Power reference	PM Pmax	P _{Max} for synchronous generating technology and EESS P _M for other non-synchronous generating technology	
	Intentional delay	0 – 2 s	0s	
	Deactivation threshold fstop	50.0 Hz – f1	deactivated	
	Deactivation time tstop	0 – 600 s	-	
	Acceptance of staged disconnection	yes no	yes	
4.6.2 Power response to underfrequency	Threshold frequency f1	49.8 Hz – 46 Hz	49.8 Hz	
	Droop	2 – 12 %	5 %	
	Power reference	PM Pmax	Pmax	

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	Intentional delay	0 – 2 s	0 s
4.7.2.2 voltage support by Capabilities	Active factor/ reactive power (%Pd) range overexcited	0.9 – 1 / 48%Pd-0 0.95 – 1 / 33%Pd-0	0.9 – 1 / 48%Pd-0
	Active factor/ reactive power (%Pd) range underexcited	0.9 – 1 / 48%Pd-0 0.95 – 1 / 33%Pd-0	0.9 – 1 / 48%Pd-0
4.7.2.3 voltage support by reactive power - Control modes	Enabled control mode	Q setp. Q(U) Q(P) cos φ setp. cos φ (P)	Q set point
4.7.2.3.2 voltage support by reactive power - Set point control modes	Q set point and excitation	0 – 48 % PD 0 – 33 % PD	0
	cos φ setpoint and excitation	1 – 0.9	1
4.7.2.3.3 voltage support by reactive power - Voltage related control modes	Characteristic curve	-	Indicate default characteristic
	Time constant	3 s – 60 s	10 s
	Min cos φ	0.0 – 1	0.9
	Lock in power	0 % – 20 %	deactivated
	Lock out power	0 % – 20 %	deactivated
4.7.2.3.4 voltage support by reactive power - Power related control mode	Characteristic curve	-	Indicate default characteristic
4.7.4.2.2 Zero current mode for converter connected generating technology / Generating Plant with non-synchronous generator	Enabling	enable disable	disabled
	Static voltage range overvoltage	100 % Un – 120 % Un	120 % Un
	Static voltage range undervoltage	20 % Un – 100 % Un	50 % Un
4.9.3 Requirements on voltage and frequency protection**	Threshold for protection as dedicated device [in A or kW. kVA]	16 A – 250 kVA	Interface protection integrated
	Undervoltage threshold stage 1	0.2 Un – 1 Un	0.85 Un

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	Undervoltage operate time stage 1	0.1 s – 5 s	99 s
	Undervoltage threshold stage 2	0.2 Un – 1 Un	0.2 Un
	Undervoltage operate time stage 2	0.1 s – 3 s	4 s
	Overvoltage threshold stage 1	1.0 Un – 1.2 Un	1.2 Un
	Overvoltage operate time stage 1	0.1 s – 5 s	99 s
	Overvoltage threshold stage 2	1.0 Un – 1.3 Un	1.25 Un
	Overvoltage operate time stage 2	0.1 s – 3 s	4 s
	Overvoltage threshold 10 min mean protection	1.0 Un – 1.15 Un	1.10 Un
	Underfrequency threshold stage 1	47.0 Hz– 50.0 Hz	47.5 Hz
	Underfrequency operate time stage 1	0.1 s – 5 s	99 s
	Underfrequency threshold stage 2	47.0 Hz – 50.0 Hz	47 Hz
	Underfrequency operate time stage 2	0.1 s – 3 s	4 s
	Overfrequency threshold stage 1	50.0 Hz – 52.0 Hz	51.5 Hz
	Overfrequency operate time stage 1	0.1 s – 5 s	99 s
	Overfrequency threshold stage 2	50.0 Hz – 52.0 Hz	52 Hz
	Overfrequency operate time stage 2	0.1 s – 3 s	4 s
4.10.2 Automatic reconnection after tripping	Lower frequency	47.0 Hz – 50.0 Hz	49.5 Hz
	Upper frequency	50.0 Hz – 52.0 Hz	50.2 Hz
	Lower voltage	50 % Un – 100 % Un	85 % Un
	Upper voltage	100 % Un – 120 % Un	110 % Un
	Observation time	10 s – 600 s	60 s

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	Active power increase gradient	6 % – 3000 %/min	10 %Pn /min
4.10.2 Automatic reconnection after tripping	Lower frequency	47.0 Hz – 50.0 Hz	49.5 Hz
	Upper frequency	50.0 Hz – 52.0 Hz	50.2 Hz
	Lower voltage	50 % Un – 100 % Un	85 % Un
	Upper voltage	100 % Un – 120 % Un	110 % Un
	Observation time	10 s – 600 s	60 s
	Active power increase gradient	6 % – 3000 %/min	10 % /min
4.10.3 Starting to generate electrical power	Lower frequency	47.0 Hz – 50.0 Hz	49.5 Hz
	Upper frequency	50.0 Hz – 52.0 Hz	50.1 Hz
	Lower voltage	50 % – 100 % Un	85 % Un
	Upper voltage	100 % – 120 % Un	110 % Un
	Observation time	10 s – 600 s	60 s
	Active power increase gradient	6 % – 3000 %/min	disabled
4.11.1 Ceasing active power	Activation option	--	Can be achieved by PGU. (Logic interface shall be specified by DNO)
4.11.2 Reduction of active power on set point	Activation option	--	Can be achieved by PGU. (Definition shall be specified by DNO)
4.12 Remote information exchange	Activation option	--	Can be achieved by PGU. (Definition shall be specified by DNO)
*If additional parameters have been evaluated during test, these shall be added as additional lines in the table. **This can be used for manufacturer specific parameter descriptions.			

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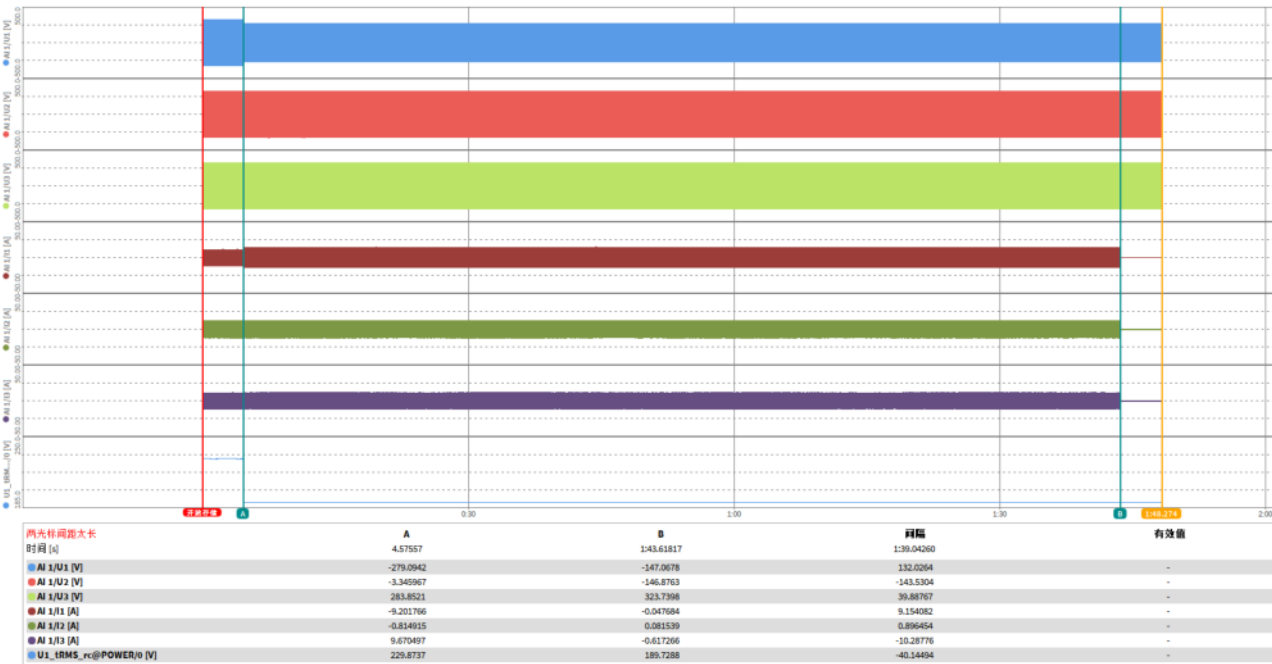
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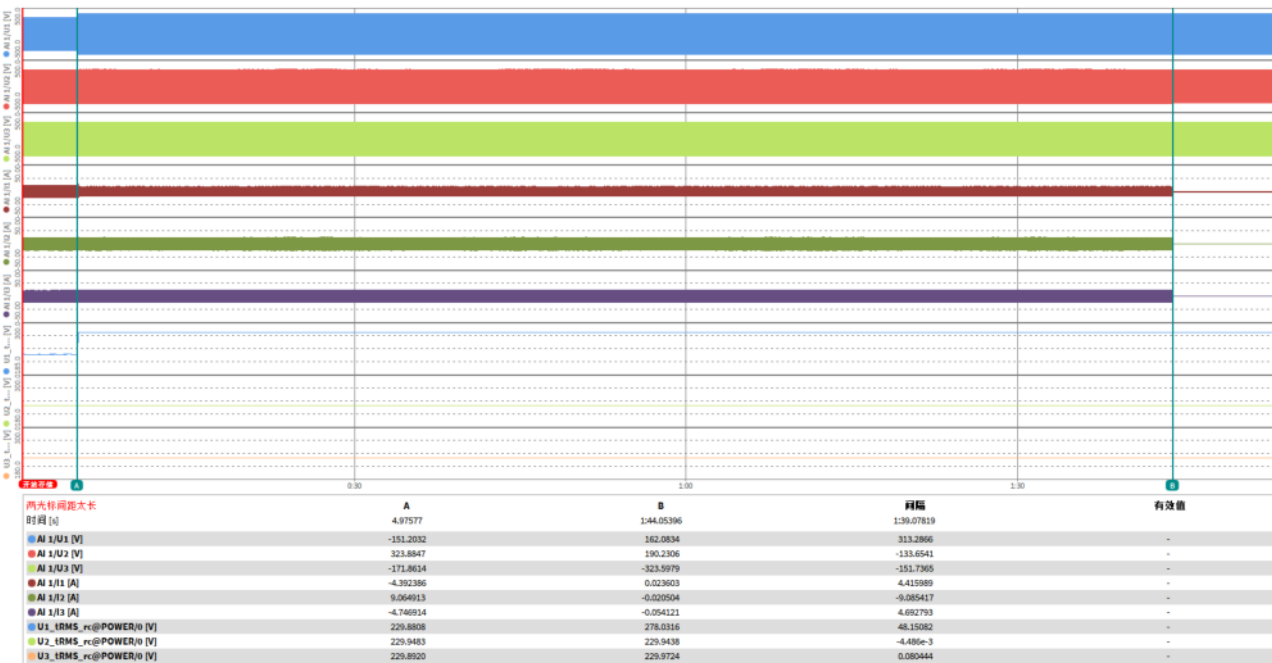
5.8 Interface protection 5.8.3.2 Voltage and frequency protections (L1-N)				P
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un±1% Un	99s ≤ t ≤ 99.1s	1.2Un±1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	195.87		276.32	
	195.93		276.36	
	195.96		276.51	
Trip time [s]	Un To Uth-low - 5%Un	99.011	Un To Uth-high + 5%Un	99.038
		99.039		99.064
		99.043		99.078
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un±1% Un	4.0s ≤ t ≤ 4.1s	1.30Un±1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	45.65		299.56	
	46.00		299.57	
	46.76		299.57	
Trip time [s]	Un To Uth-low - 5%Un	4.015	Un To Uth-high + 5%Un	4.026
		4.016		4.039
		4.023		4.046
Note:				

Scope pictures of the disconnection time

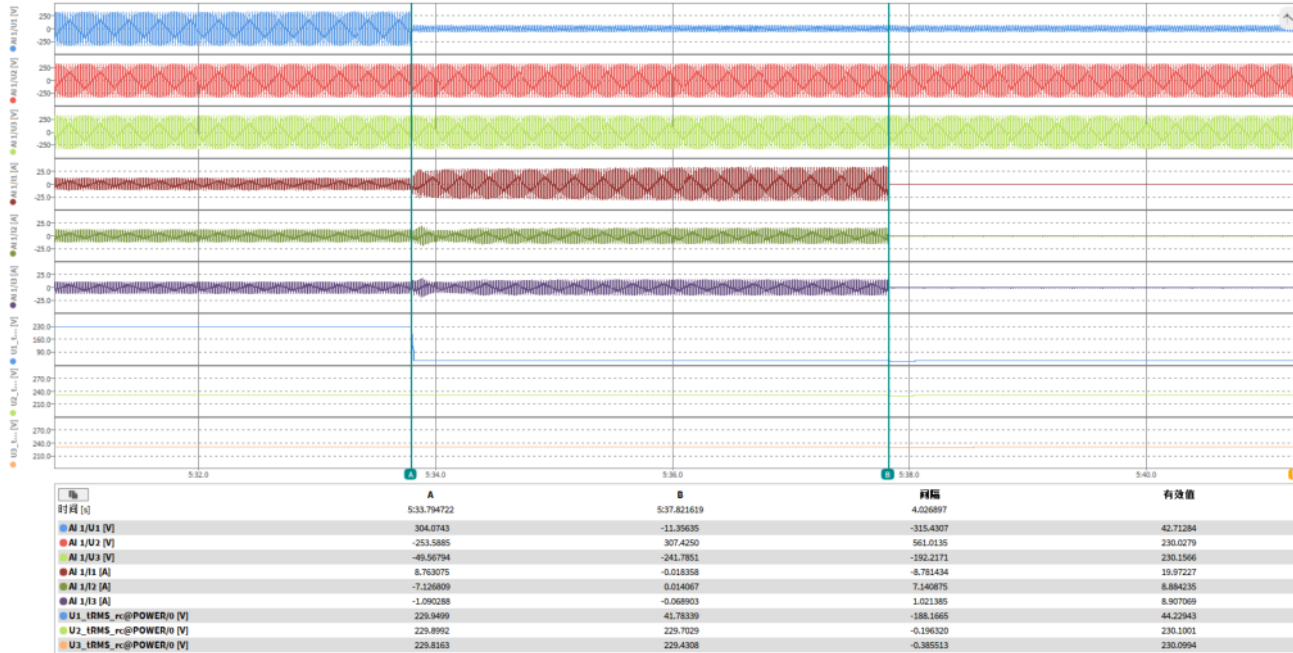
Under -voltage – Stage 1



Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

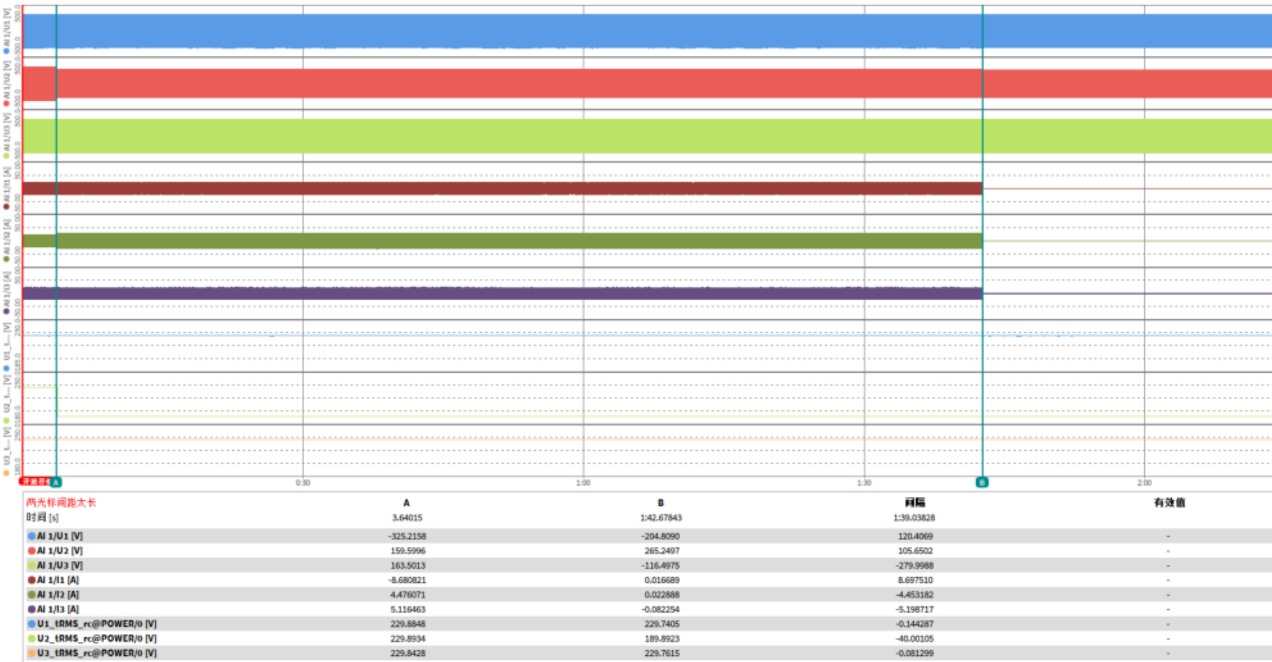
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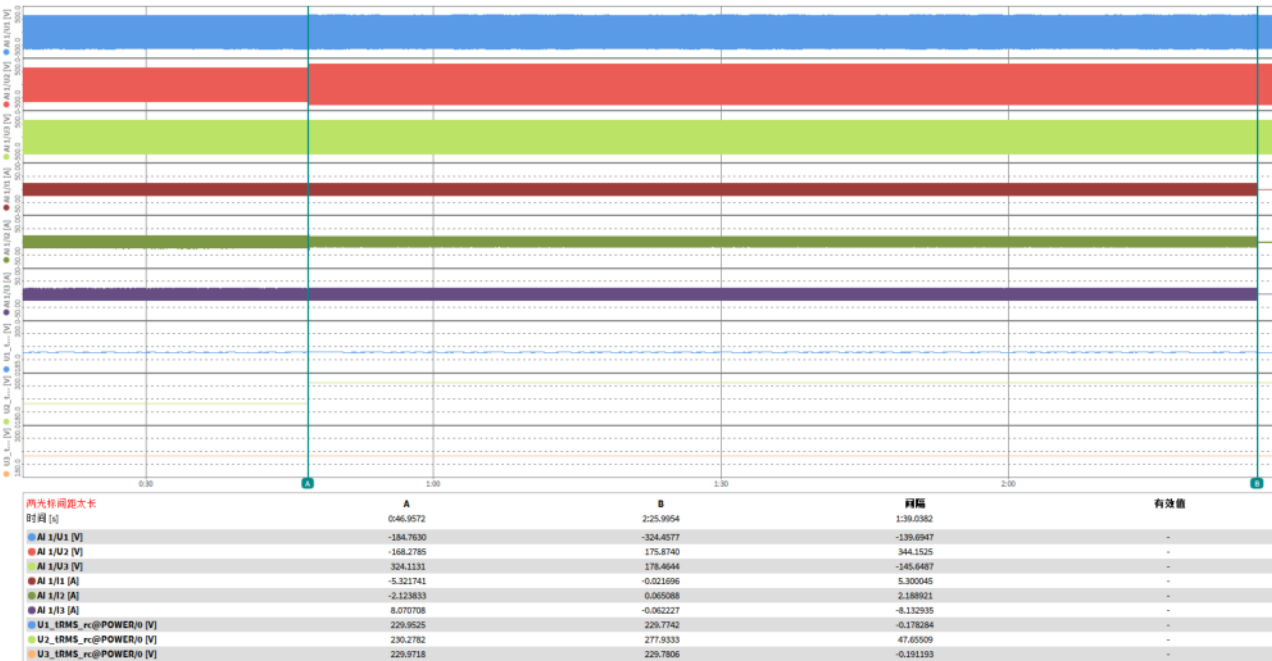
5.8 Interface protection 5.8.3.2 Voltage and frequency protections (L2-N)				P
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un±1% Un	99s ≤ t ≤ 99.1s	1.2Un±1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	196.12		276.08	
	196.14		276.38	
	196.24		276.48	
Trip time [s]	Un To U ^{th-low} - 5%Un	99.035	Un To U ^{th-high} + 5%Un	99.025
		99.037		99.037
		99.038		99.038
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un±1% Un	4.0s ≤ t ≤ 4.1s	1.30Un±1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	46.10		299.45	
	46.17		299.52	
	46.90		299.65	
Trip time [s]	Un To U ^{th-low} - 5%Un	4.024	Un To U ^{th-high} + 5%Un	4.028
		4.027		4.047
		4.038		4.055
Note:				

Scope pictures of the disconnection time

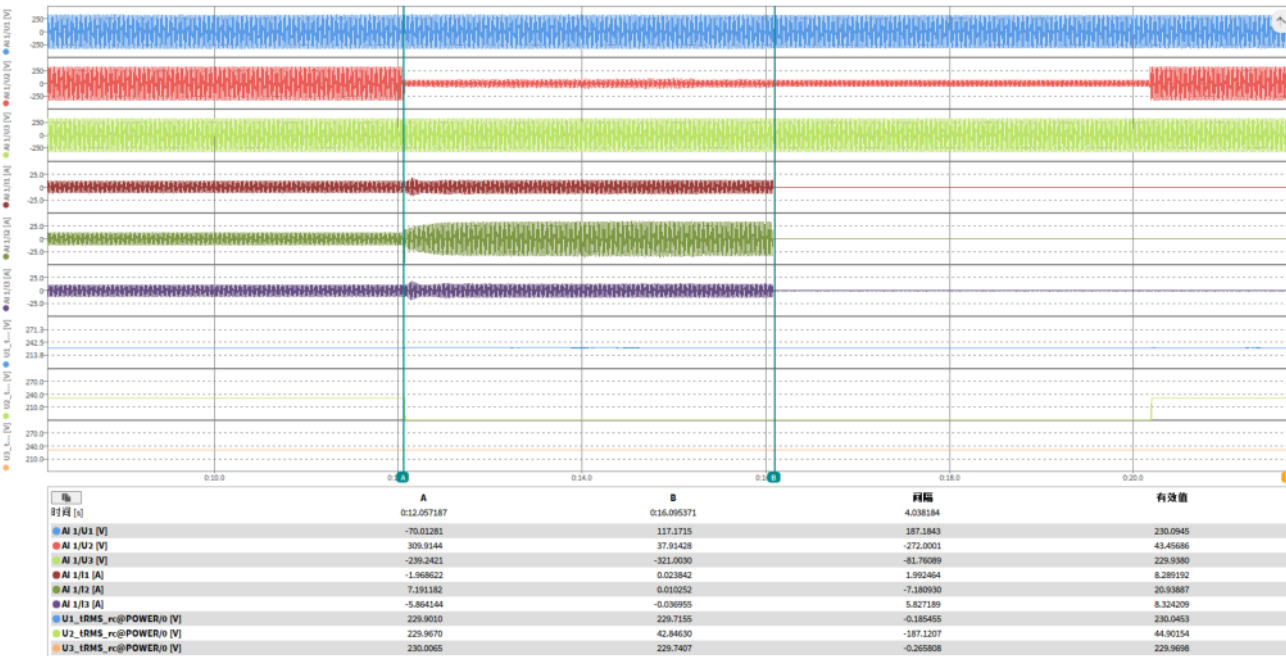
Under -voltage – Stage 1



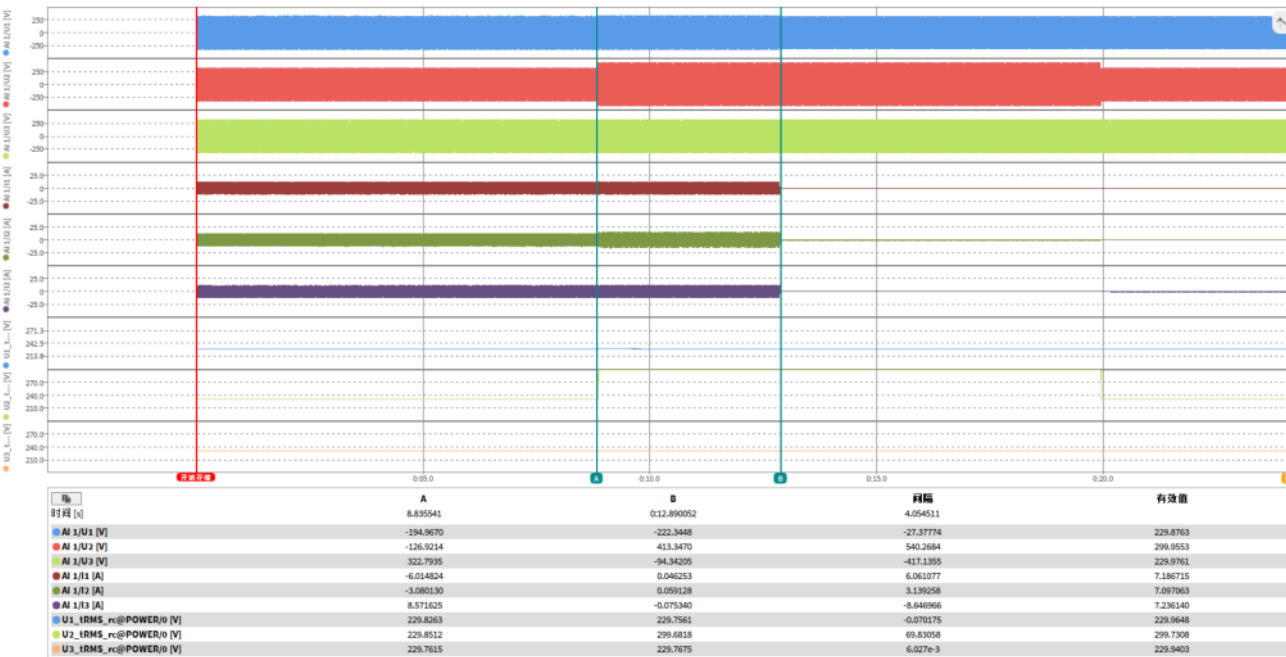
Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

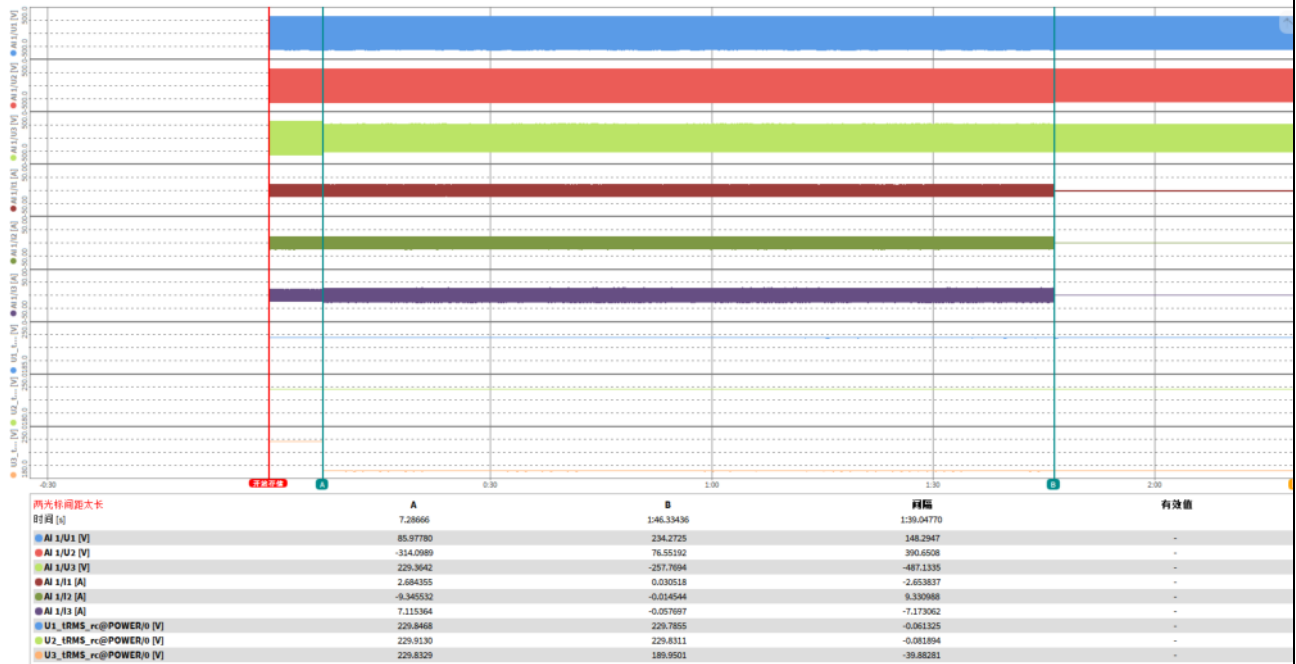
Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

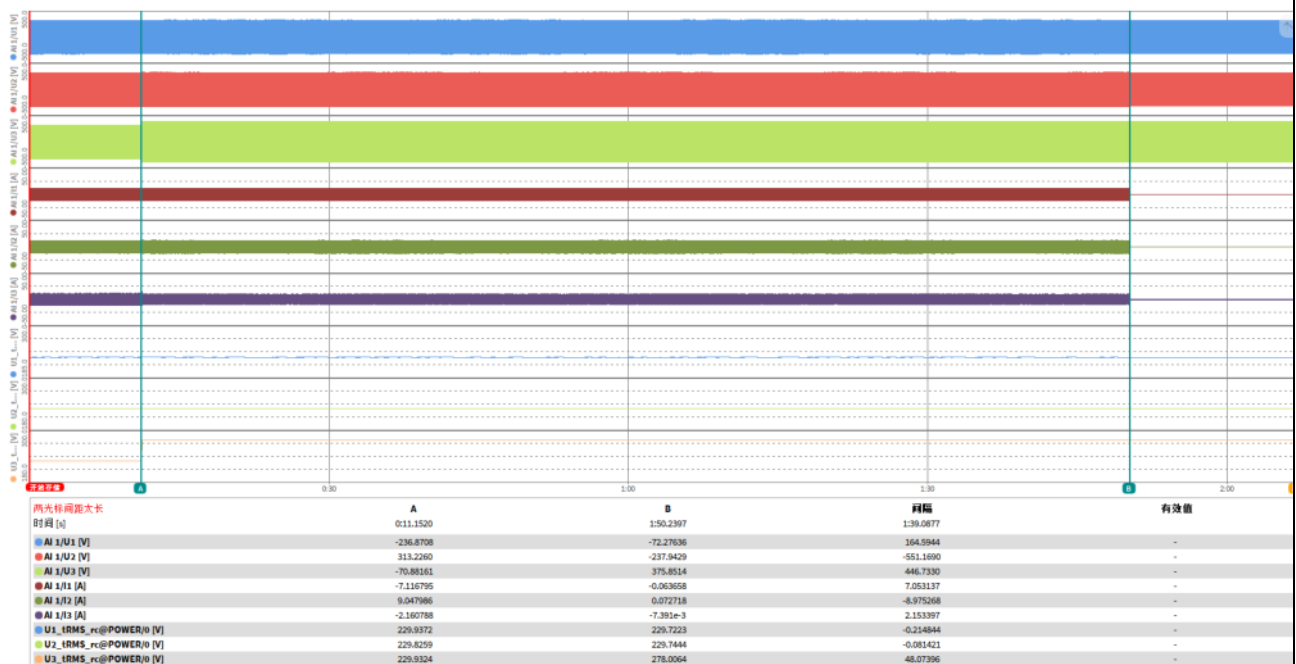
5.8 Interface protection				P
5.8.3.2 Voltage and frequency protections (L3-N)				
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un±1% Un	99s ≤ t ≤ 99.1s	1.2Un±1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	196.12		276.17	
	196.14		276.48	
	196.24		276.49	
Trip time [s]	Un To Uth-low - 5%Un	99.019	Un To Uth-high + 5%Un	99.030
		99.021		99.043
		99.047		99.088
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un±1% Un	4.0s ≤ t ≤ 4.1s	1.30Un±1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	46.65		299.28	
	46.82		299.43	
	46.89		299.46	
Trip time [s]	Un To Uth-low - 5%Un	4.018	Un To Uth-high + 5%Un	4.025
		4.024		4.038
		4.032		4.053
Note:				

Scope pictures of the disconnection time

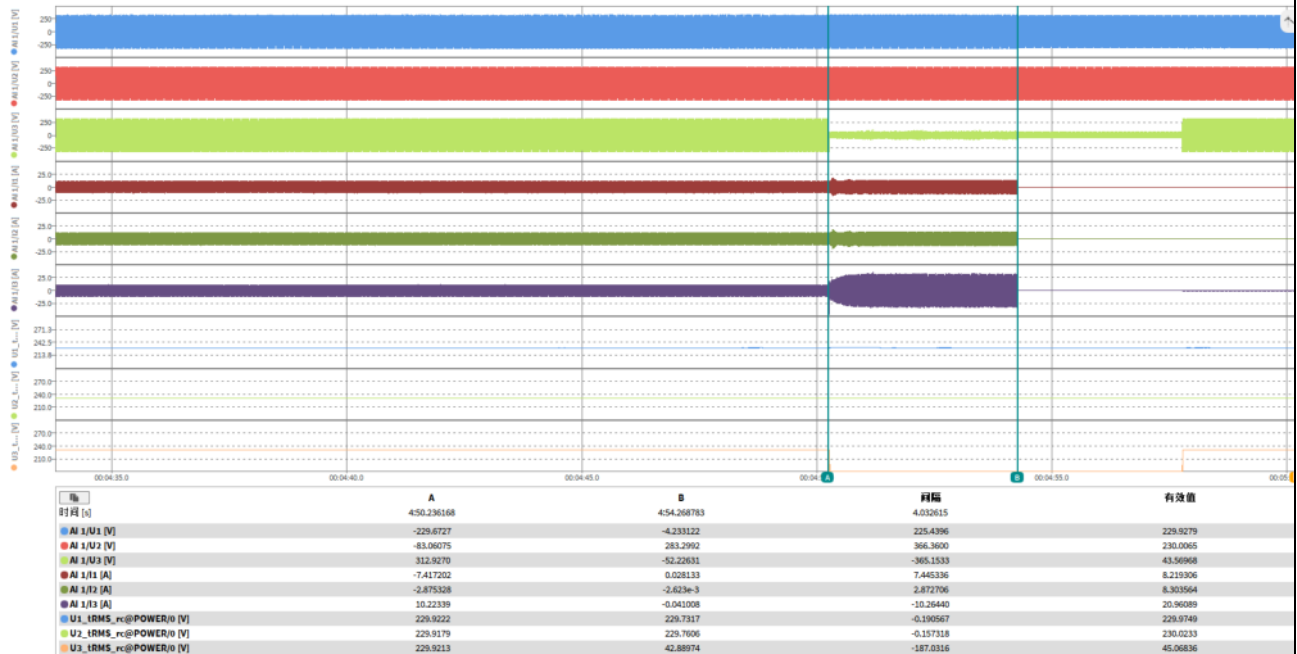
Under -voltage – Stage 1



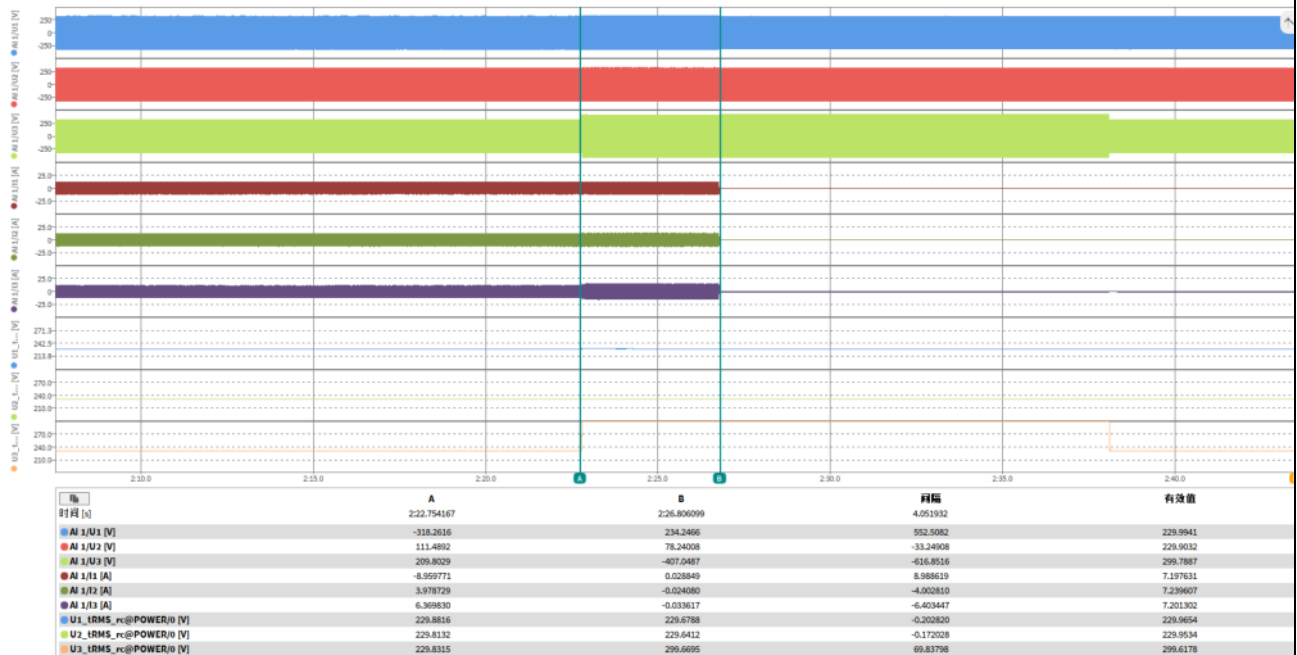
Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

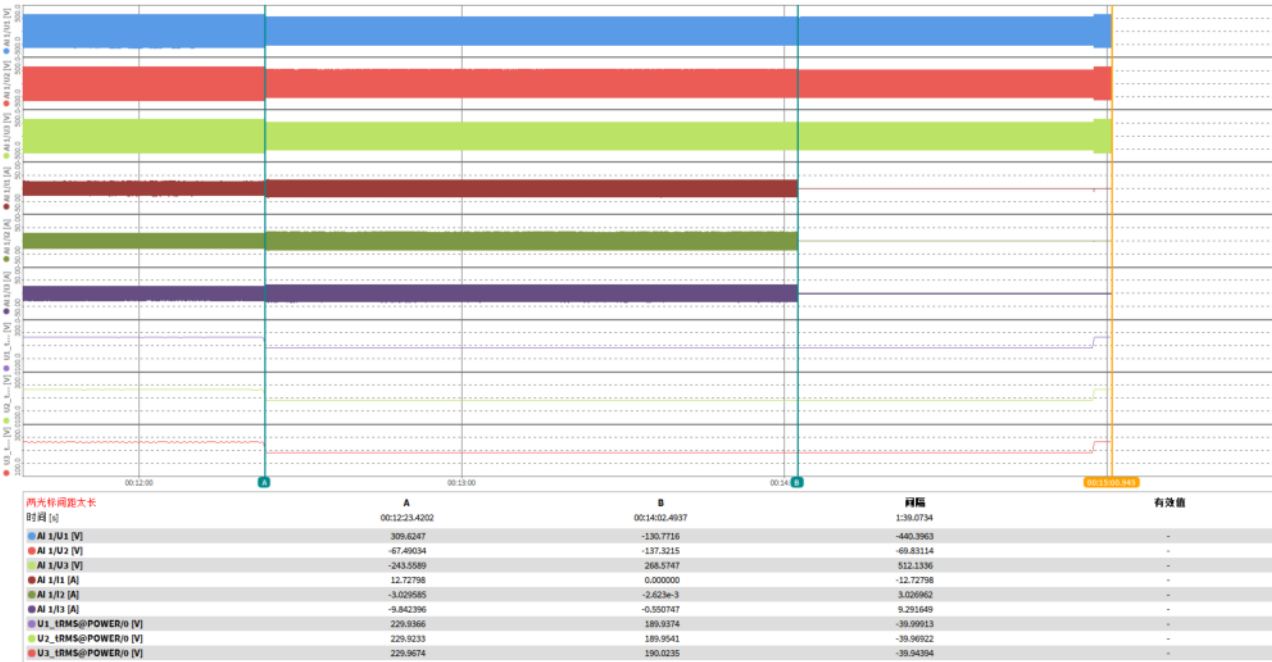
Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

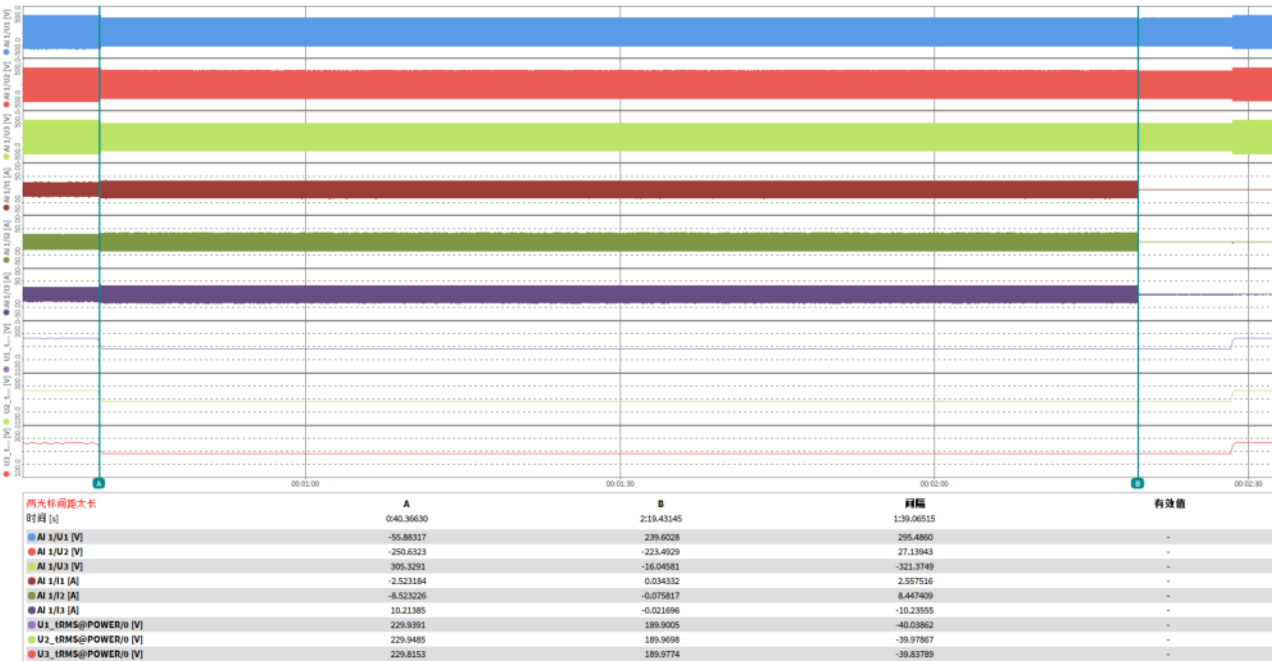
5.8 Interface protection				P
5.8.3.2 Voltage and frequency protections (L1&L2&L3-N)				
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un±1% Un	99s ≤ t ≤ 99.1s	1.2Un±1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	196.33		274.33	
	196.34		274.27	
	196.35		274.38	
Trip time [s]	Un To Uth-low - 5%Un	99.040	Un To Uth-high + 5%Un	99.056
		99.065		99.063
		99.073		99.065
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un±1% Un	4.0s ≤ t ≤ 4.1s	1.30Un±1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	46.55		299.62	
	46.45		299.62	
	46.61		299.73	
Trip time [s]	Un To Uth-low - 5%Un	4.041	Un To Uth-high + 5%Un	4.009
		4.050		4.033
		4.051		4.042
Note:				

Scope pictures of the disconnection time

Under -voltage – Stage 1



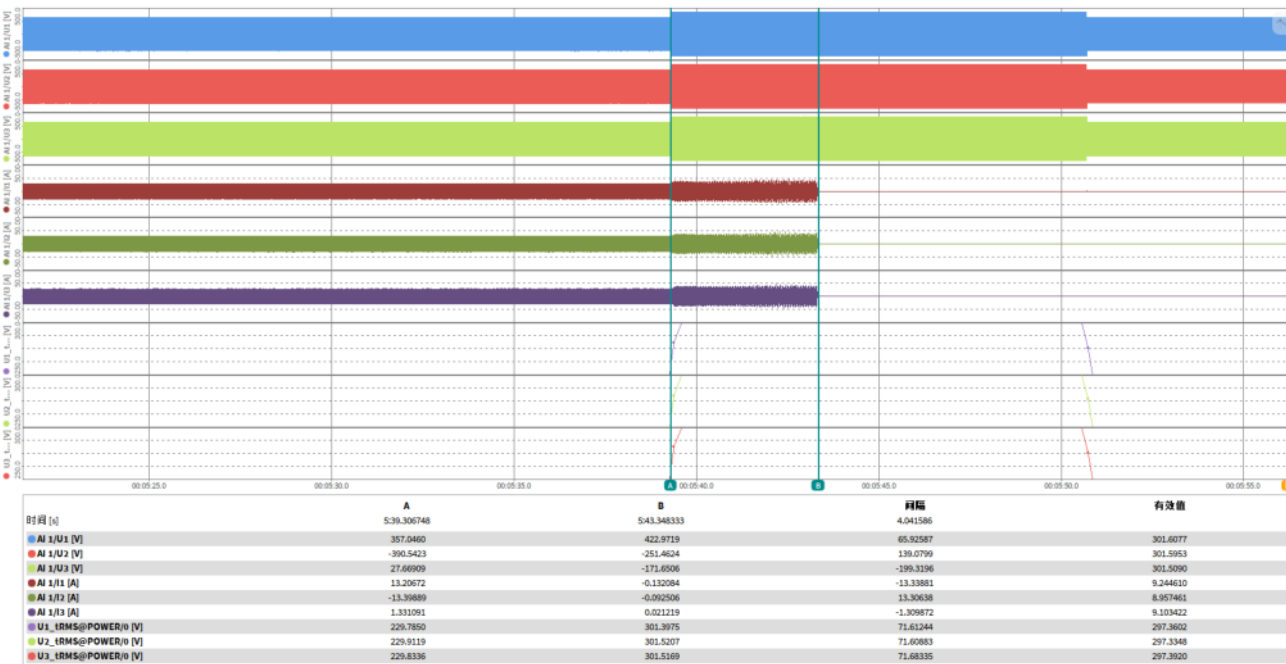
Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

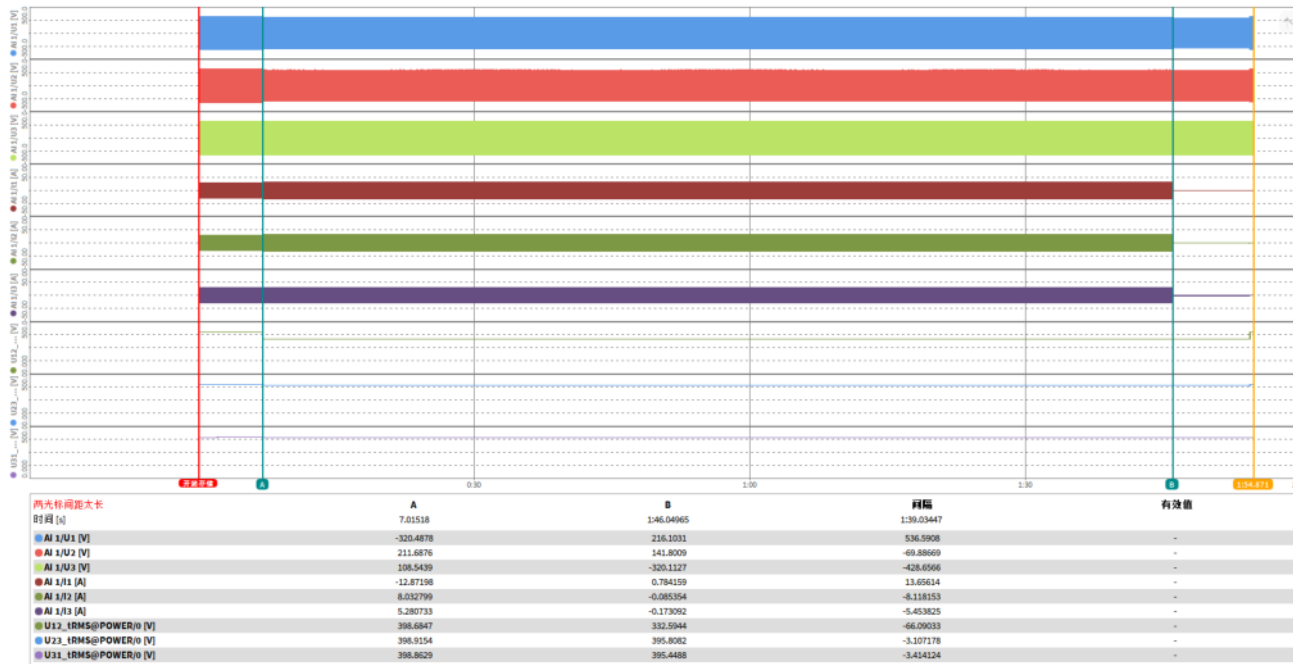
Project No.: HZHRRDPVP02041/26E-02

Test Report No.: RDPVP02041/26E/02

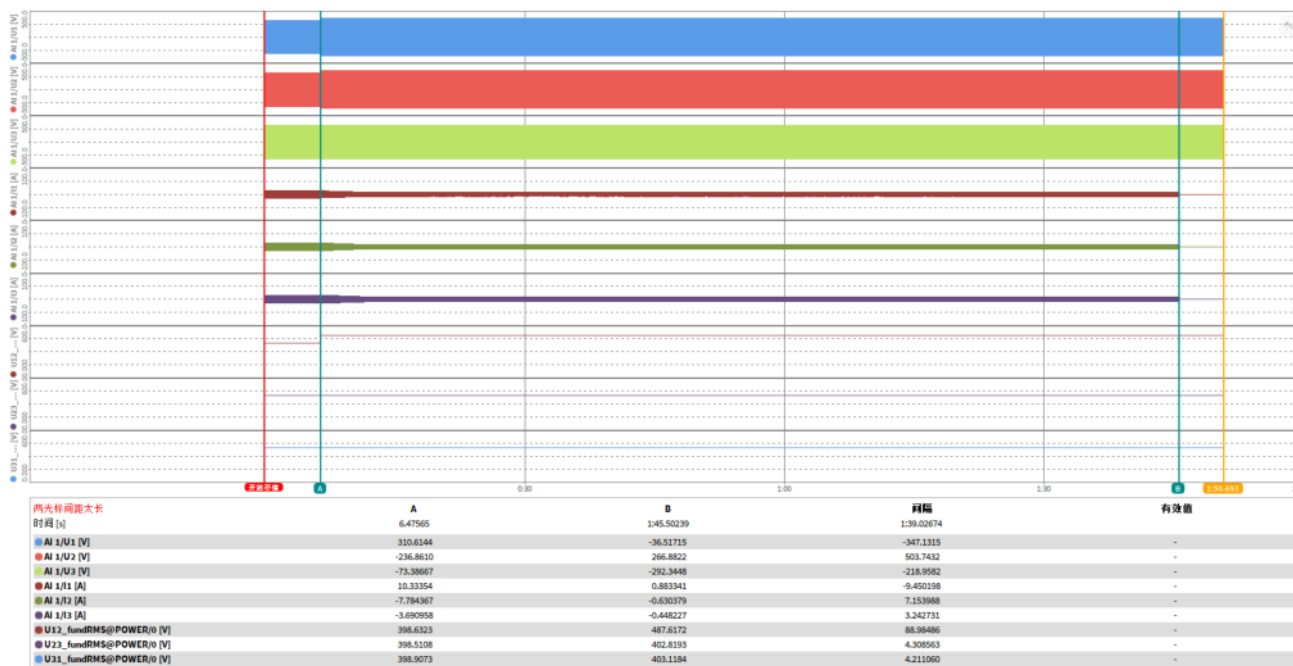
5.8 Interface protection 5.8.3.2 Voltage and frequency protections (L1-L2)				P
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un±1% Un	99s ≤ t ≤ 99.1s	1.2Un±1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	338.88		477.78	
	338.44		477.75	
	338.39		477.79	
Trip time [s]	Un To Uth-low - 5%Un	99.032	Un To Uth-high + 5%Un	99.022
		99.032		99.023
		99.034		99.027
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un±1% Un	4.0s ≤ t ≤ 4.1s	1.30Un±1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	79.64		517.05	
	79.72		517.60	
	79.56		517.61	
Trip time [s]	Un To Uth-low - 5%Un	4.030	Un To Uth-high + 5%Un	4.025
		4.035		4.027
		4.040		4.029
Note:				

Scope pictures of the disconnection time

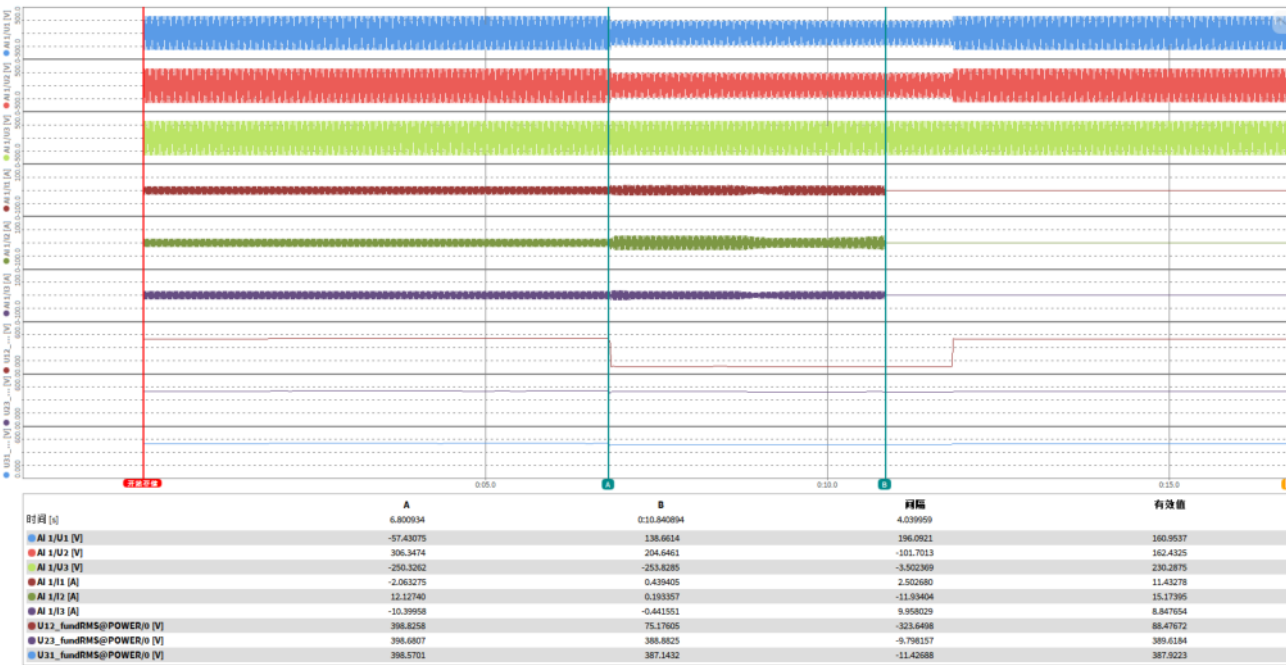
Under -voltage – Stage 1



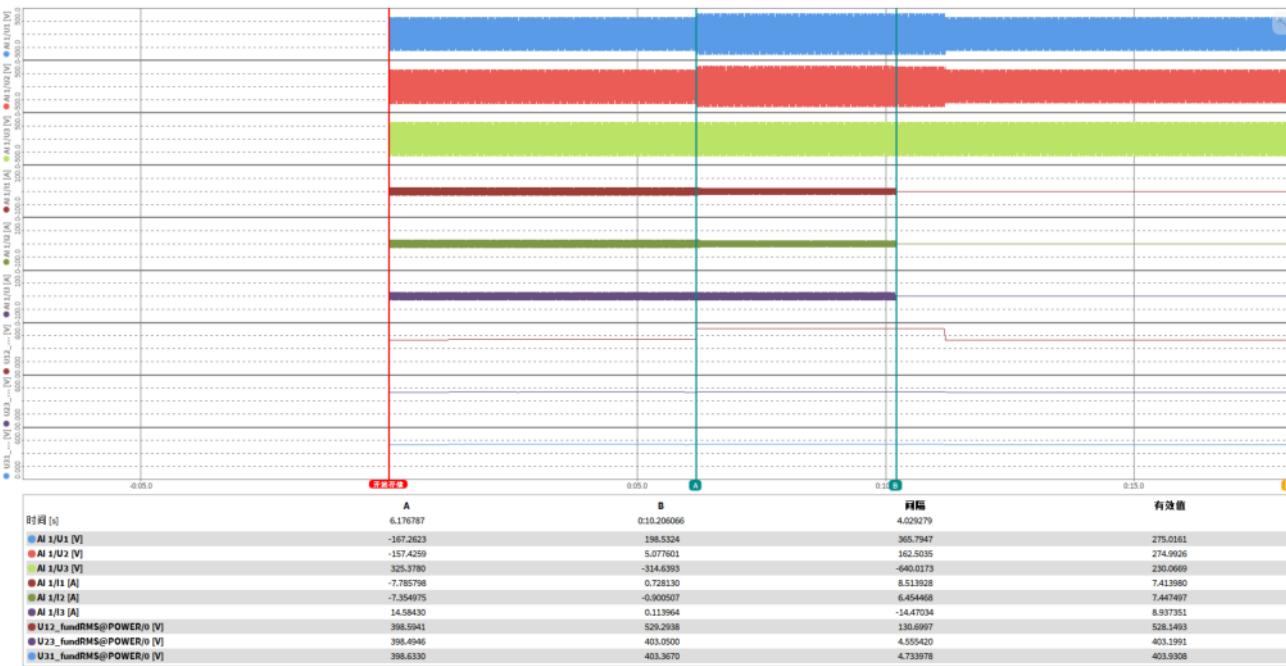
Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

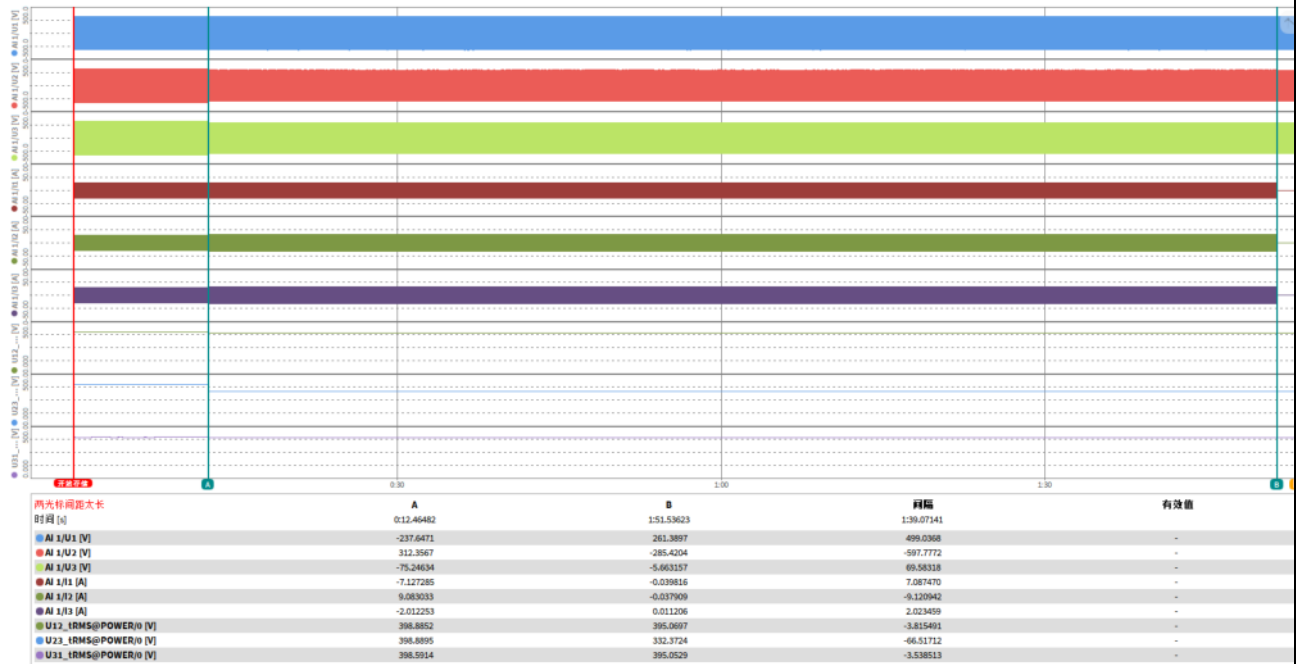
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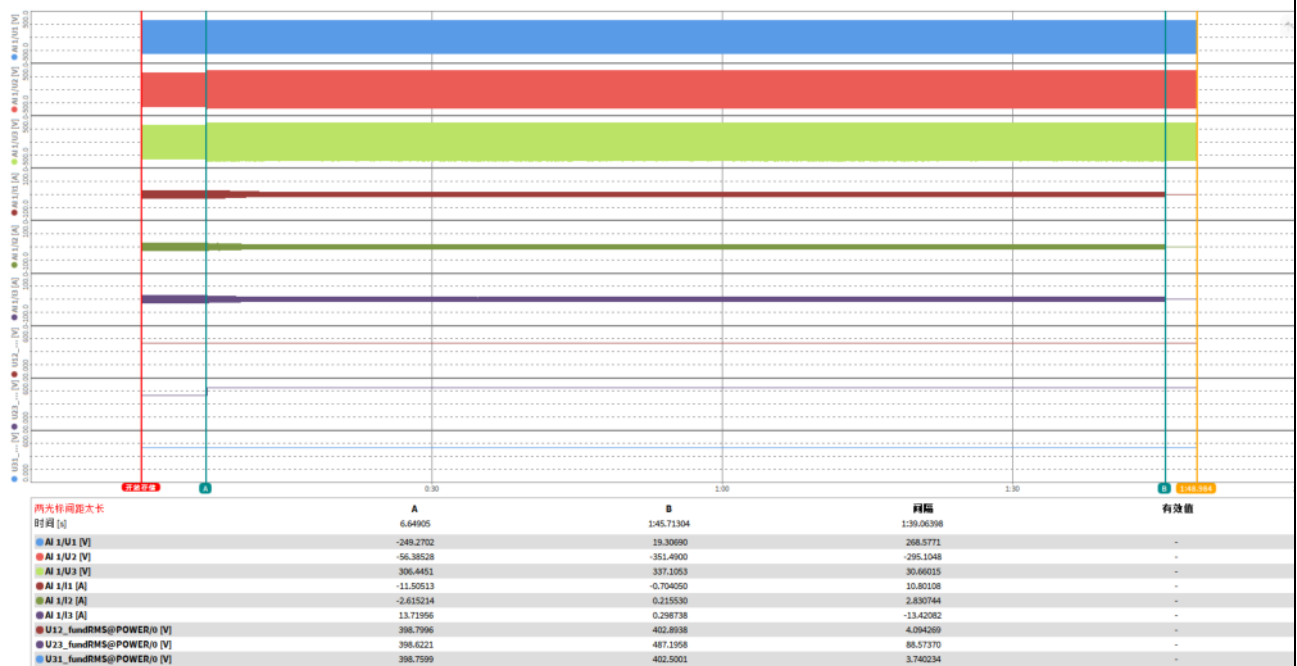
5.8 Interface protection 5.8.3.2 Voltage and frequency protections (L2-L3)				P
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un± 1% Un	99s ≤ t ≤ 99.1s	1.2Un± 1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	338.88		477.78	
	338.44		477.75	
	338.39		477.79	
Trip time [s]	Un To Uth-low - 5%Un	99.028	Un To Uth-high + 5%Un	99.035
		99.034		99.042
		99.071		99.064
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un± 1% Un	4.0s ≤ t ≤ 4.1s	1.30Un± 1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	79.64		517.05	
	79.72		517.60	
	79.56		517.61	
Trip time [s]	Un To Uth-low - 5%Un	4.034	Un To Uth-high + 5%Un	4.020
		4.036		4.027
		4.047		4.029
Note:				

Scope pictures of the disconnection time

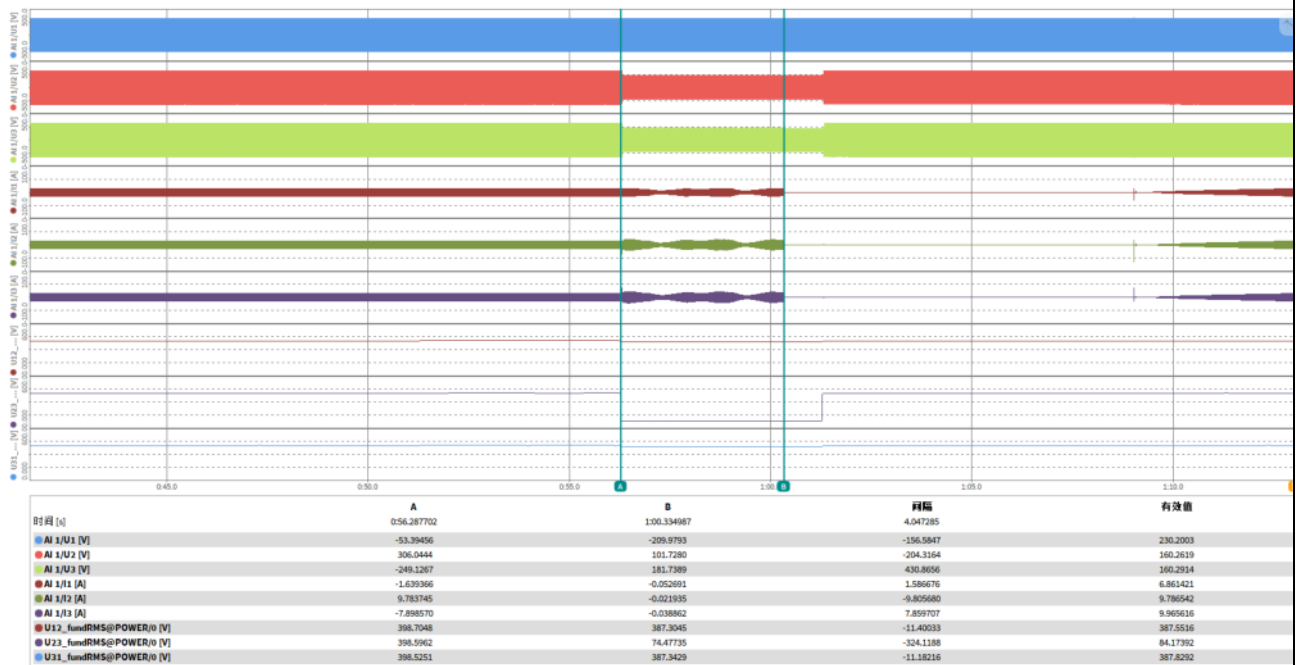
Under -voltage – Stage 1



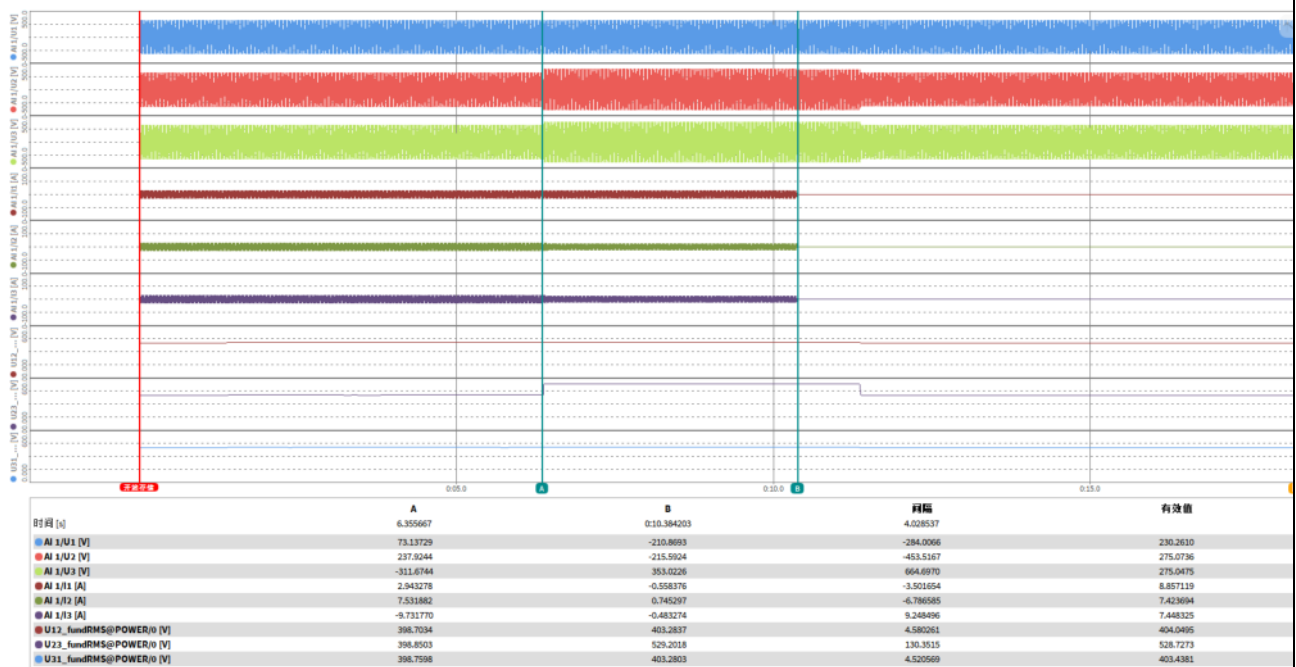
Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

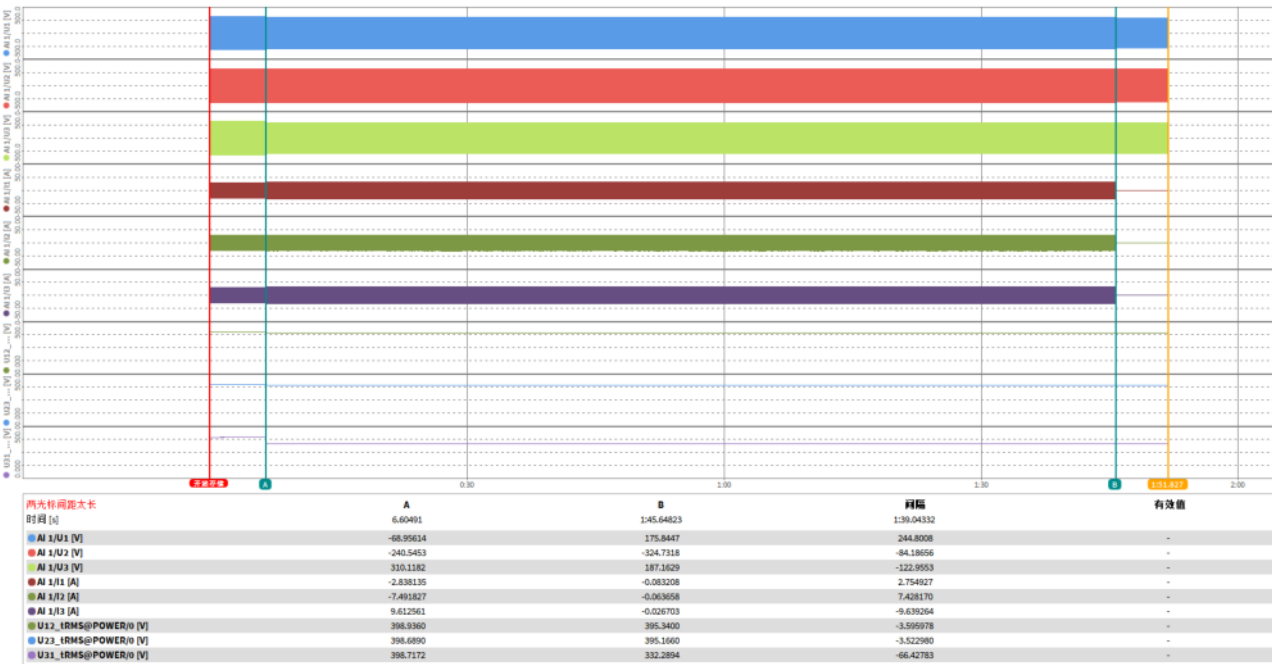
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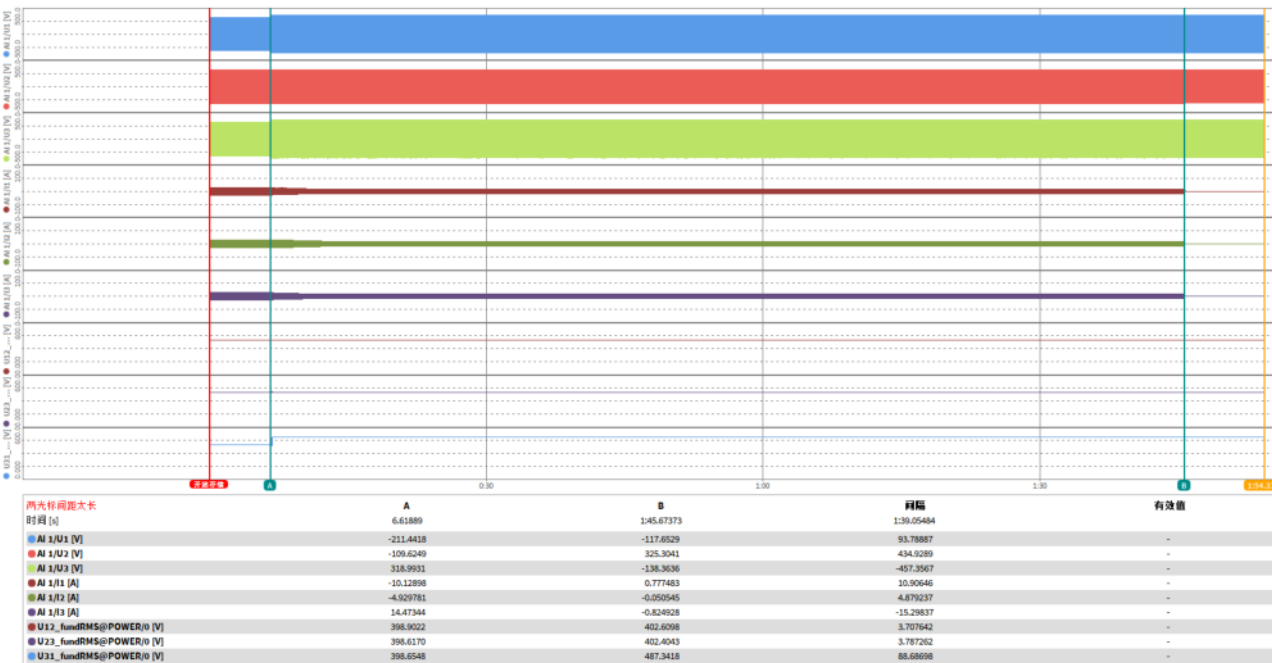
5.8 Interface protection				P
5.8.3.2 Voltage and frequency protections (L1-L3)				
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz			
Stage 1	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.85Un±1% Un	99s ≤ t ≤ 99.1s	1.2Un±1% Un	99s ≤ t ≤ 99.1s
Trip value [V]	338.31		477.69	
	338.41		477.72	
	338.41		477.72	
Trip time [s]	Un To Uth-low - 5%Un	99.022	Un To Uth-high + 5%Un	99.034
		99.042		99.036
		99.043		99.055
Stage 2	Under-voltage		Over-voltage	
Parameter	Voltage	Time	Voltage	Time
Limit	0.20Un±1% Un	4.0s ≤ t ≤ 4.1s	1.30Un±1% Un	4.0s ≤ t ≤ 4.1s
Trip value [V]	79.72		517.50	
	79.63		517.53	
	79.64		517.75	
Trip time [s]	Un To Uth-low - 5%Un	4.022	Un To Uth-high + 5%Un	4.022
		4.039		4.027
		4.043		4.033
Note:				

Scope pictures of the disconnection time

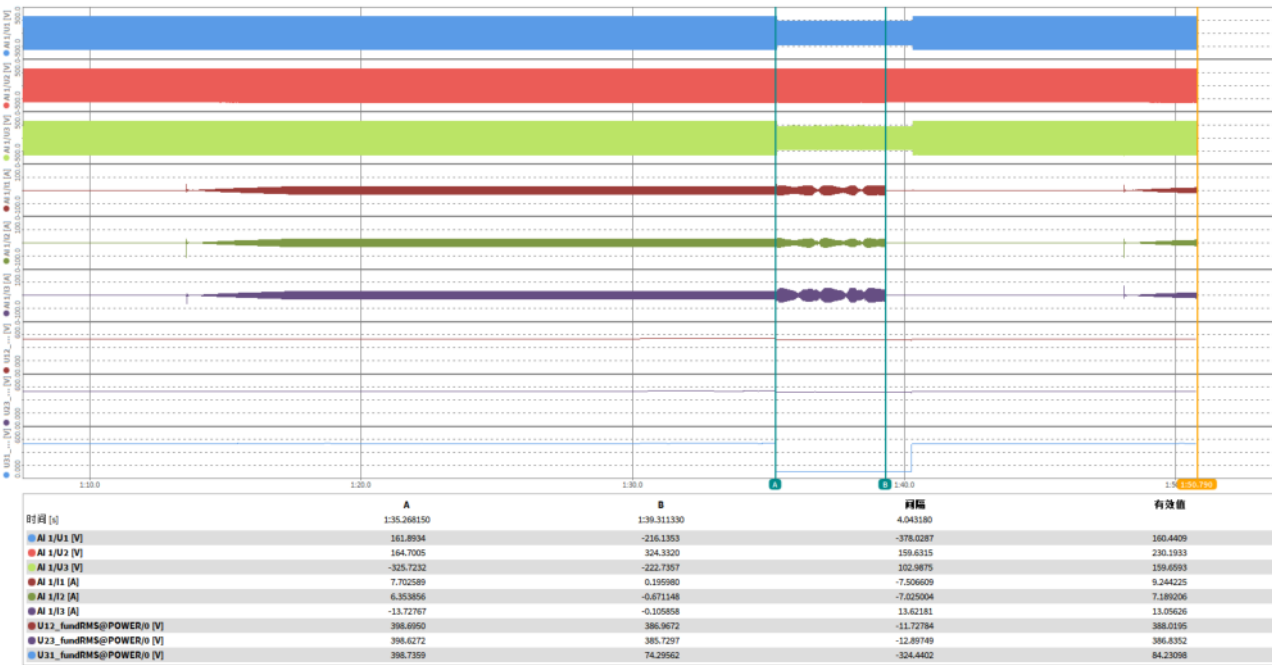
Under -voltage – Stage 1



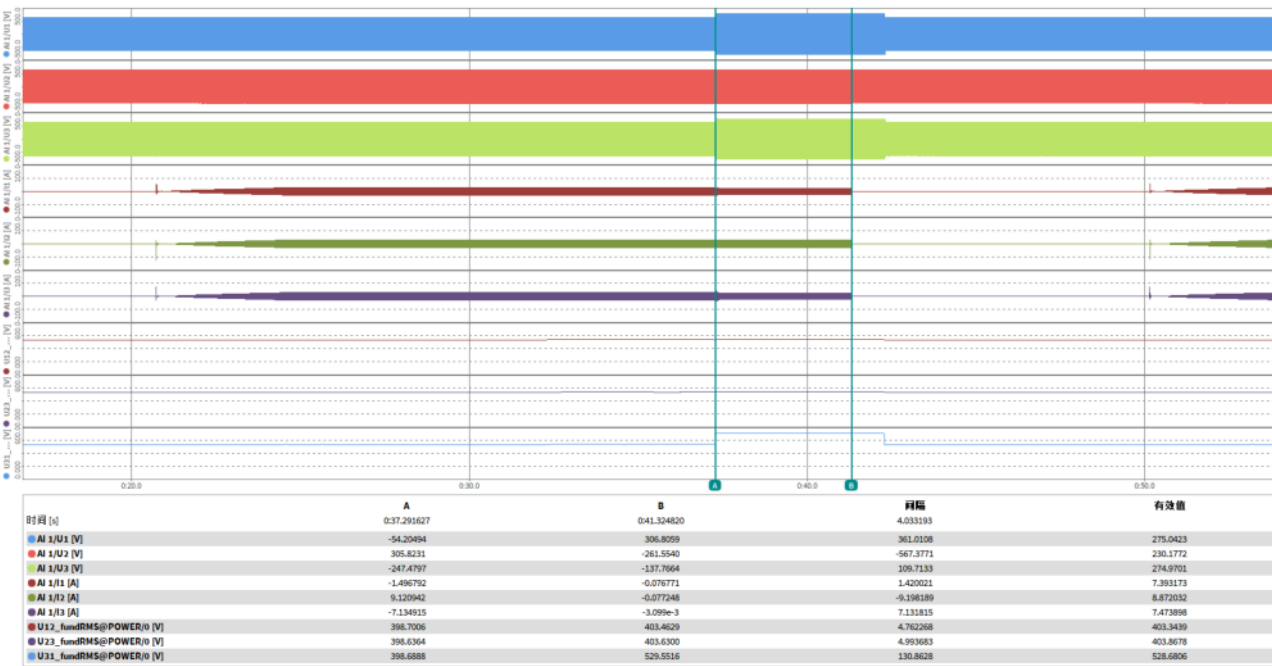
Over-voltage – Stage 1



Under -voltage – Stage 2



Over-voltage – Stage 2



Test Report

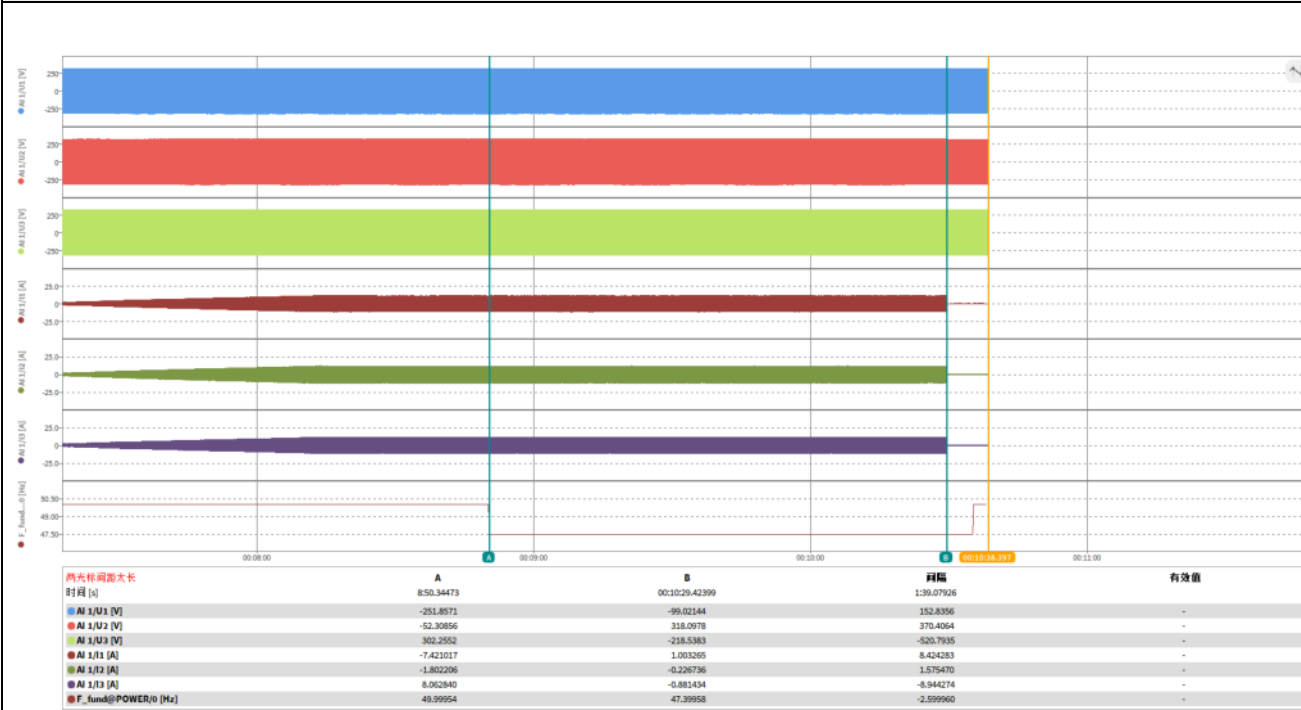
Project No.: HZHRRDPVP02041/26E-02

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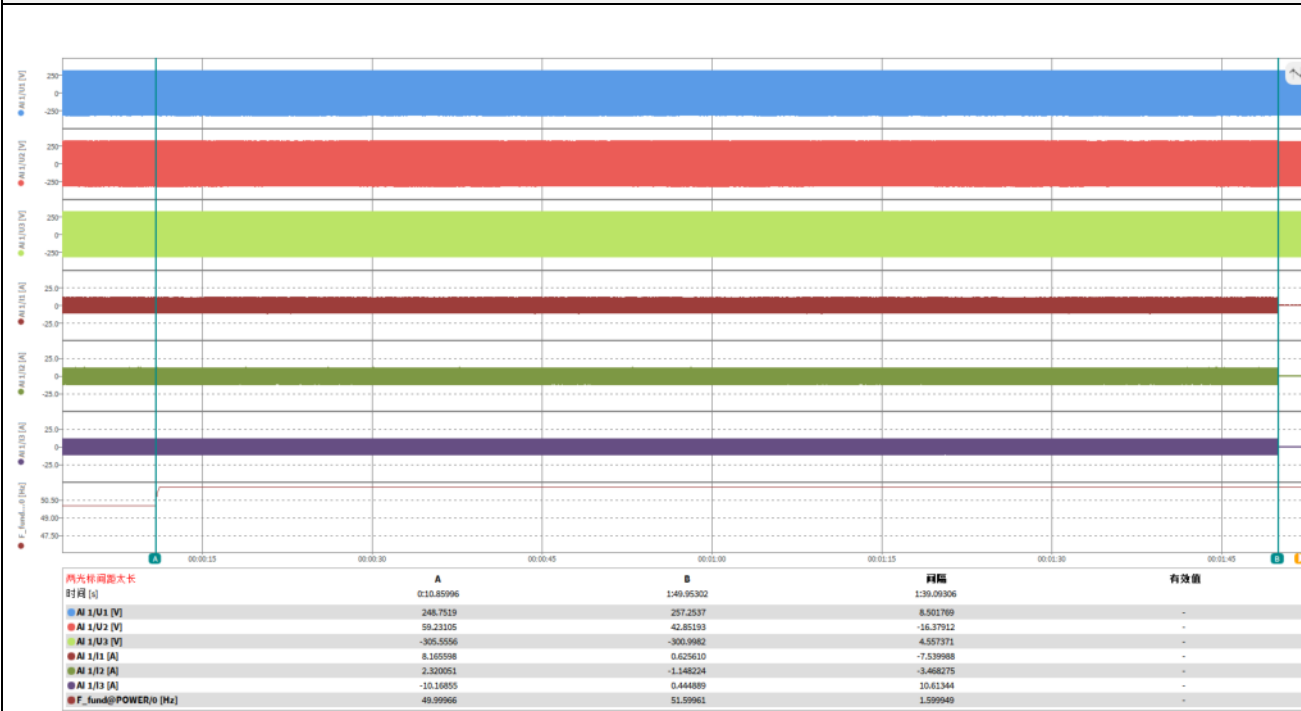
5.8 Interface protection 5.8.3.2 Voltage and frequency protections				P
Test conditions	Output power: ≥50%P _n U _n = 1.0U _n			
Stage 1	Under-frequency		Over-frequency	
Parameter	Frequency	Time	Frequency	Time
Limit	47.50 Hz±0.05 Hz	99s ≤ t ≤ 99.1s	51.50 Hz±0.05 Hz	99s ≤ t ≤ 99.1s
Trip value [Hz]	47.483		51.482	
	47.487		51.496	
	47.488		51.518	
Trip time [s]	50.0 Hz To 47.4 Hz	99.028	50.0 Hz To 51.6 Hz	99.093
		99.075		99.089
		99.079		99.089
Stage 2	Under-frequency		Over-frequency	
Parameter	Frequency	Time	Frequency	Time
Limit	47.00 Hz±0.05 Hz	4.0s ≤ t ≤ 4.1s	52.00 Hz±0.05 Hz	4.0s ≤ t ≤ 4.1s
Trip value [Hz]	46.995		52.002	
	46.997		52.004	
	47.010		52.017	
Trip time [s]	50.0 Hz To 46.9 Hz	4.026	50.0 Hz To 52.1 Hz	4.019
		4.022		4.020
		4.018		4.089
Note:				

Scope pictures of the disconnection time

Under-frequency stage 1



Over-frequency stage 1





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5.8 Interface protection 5.8.3.2.4 Reset time and reset ratio							P
Test conditions	Output power: $\geq 50\%P_n$, Frequency: $50 \pm 0.2\text{Hz}$						
Stage 1	Under-voltage			Over-voltage			
Parameter	Voltage /Time			Voltage /Time			
Setting value	$0.5U_n / 99000\text{ms}$			$1.2U_n / 99000\text{ms}$			
1.00U _n →0.82U _n (98940ms)→0.87U _n (99200ms)→1.00U _n	Phase	Reset time	Result	1.00U _n →1.23U _n (98940ms)→1.18U _n (99200ms)→1.00U _n	Phase	Reset time	Result
	L-N	$\leq 50\text{ms}$	No trip		L-N	$\leq 50\text{ms}$	No trip
	L1-N	$\leq 50\text{ms}$	No trip		L1-N	$\leq 50\text{ms}$	No trip
	L2-N	$\leq 50\text{ms}$	No trip		L2-N	$\leq 50\text{ms}$	No trip
	L3-N	$\leq 50\text{ms}$	No trip		L3-N	$\leq 50\text{ms}$	No trip
	L1-L2	$\leq 50\text{ms}$	No trip		L1-L2	$\leq 50\text{ms}$	No trip
	L2-L3	$\leq 50\text{ms}$	No trip		L2-L3	$\leq 50\text{ms}$	No trip
	L3-L1	$\leq 50\text{ms}$	No trip		L3-L1	$\leq 50\text{ms}$	No trip
Stage 2	Under-voltage			Over-voltage			
Parameter	Voltage /Time			Voltage /Time			
Setting value	$0.2U_n / 4000\text{ms}$			$1.3U_n / 4000\text{ms}$			
1.00U _n →0.17U _n (3940ms)→0.22U _n (4200ms)→1.00U _n	Phase	Reset time	Result	1.00U _n →1.32U _n (3940ms)→1.28U _n (4200ms)→1.00U _n	Phase	Reset time	Result
	L-N	$\leq 50\text{ms}$	No trip		L-N	$\leq 50\text{ms}$	No trip
	L1-N	$\leq 50\text{ms}$	No trip		L1-N	$\leq 50\text{ms}$	No trip
	L2-N	$\leq 50\text{ms}$	No trip		L2-N	$\leq 50\text{ms}$	No trip
	L3-N	$\leq 50\text{ms}$	No trip		L3-N	$\leq 50\text{ms}$	No trip
	L1-L2	$\leq 50\text{ms}$	No trip		L1-L2	$\leq 50\text{ms}$	No trip
	L2-L3	$\leq 50\text{ms}$	No trip		L2-L3	$\leq 50\text{ms}$	No trip
	L3-L1	$\leq 50\text{ms}$	No trip		L3-L1	$\leq 50\text{ms}$	No trip

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Stage 1	Under-frequency		Over-frequency		
Parameter	Frequency /Time		Frequency /Time		
Setting value	47.5Hz / 99000ms		51.5Hz / 99000ms		
50Hz→47.2Hz(98940ms)→47.7Hz(99200ms)→50Hz	Reset time	Result	50Hz→51.8Hz(98940ms)→51.3Hz(99200ms)→50Hz	Reset time	Result
	≤50ms	No trip		≤50ms	No trip
Stage 2	Under-frequency		Over-frequency		
Parameter	Frequency /Time		Frequency /Time		
Setting value	47.0Hz / 4000ms		52.0Hz / 4000ms		
50Hz→46.7Hz(3940ms)→47.2Hz(4200ms)→50Hz	Reset time	Result	50Hz→52.3Hz(3940ms)→51.8Hz(4200ms)→50Hz	Reset time	Result
	≤50ms	No trip		≤50ms	No trip
Note:					

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5.8.3.3 Overvoltage 10 min mean protection			P
Setting values of the protection:	Trip value Setting [V]	253	
	Setting T _{disconnection trip value} [s]	600	
	Setting T _{disconnection} [ms]	200	
Test:			
	Disconnection time [s]	Limit [s]	
a)	The voltage is set to 100% U _n and held for 600 s. Thereafter the voltage is set to 112% U _n . Disconnection must take place within 600 s.		
	Phase L1-N	529	450s-550s
	Phase L2-N	528	
	Phase L3-N	530	
b)	The voltage is set to U _n for 600 s and then to 108% U _n for 600 s. No disconnection should take place.		
	Phase L1-N, L2-N, L3-N	No disconnection	Disconnection should not take place.
c)	The voltage is set to 106 % U _n and held for 600 s. Thereafter the voltage is set to 114 % U _n . The disconnection should last for half the period as in Point a)*		
	Phase L1-N	339	The disconnection time should be about 50 % of the value measured in a). *(225s-375s)
	Phase L2-N	338	
	Phase L3-N	339	
Test:			
a) This test serves as proof of the measurement accuracy and the maximum set time.			
b) This test serves as proof of the measurement accuracy			
c) This test serves as proof of the correct formation of the 1 minute running mean value.			
Assessment criterion:			
The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1 % of U _N .			
Limit values:			
Rise-in voltage protection 1.1 U _N after a max. 600 s, the switch off after 200 ms.			
Note:			

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If only one integrated protection is used for the power generation systems, the value of the rise-in voltage protection of $1.1 U_N$ may not be changed.

*If the setting value is set to 600 s, then the disconnection time can be in the range between 225 s and 375 s.

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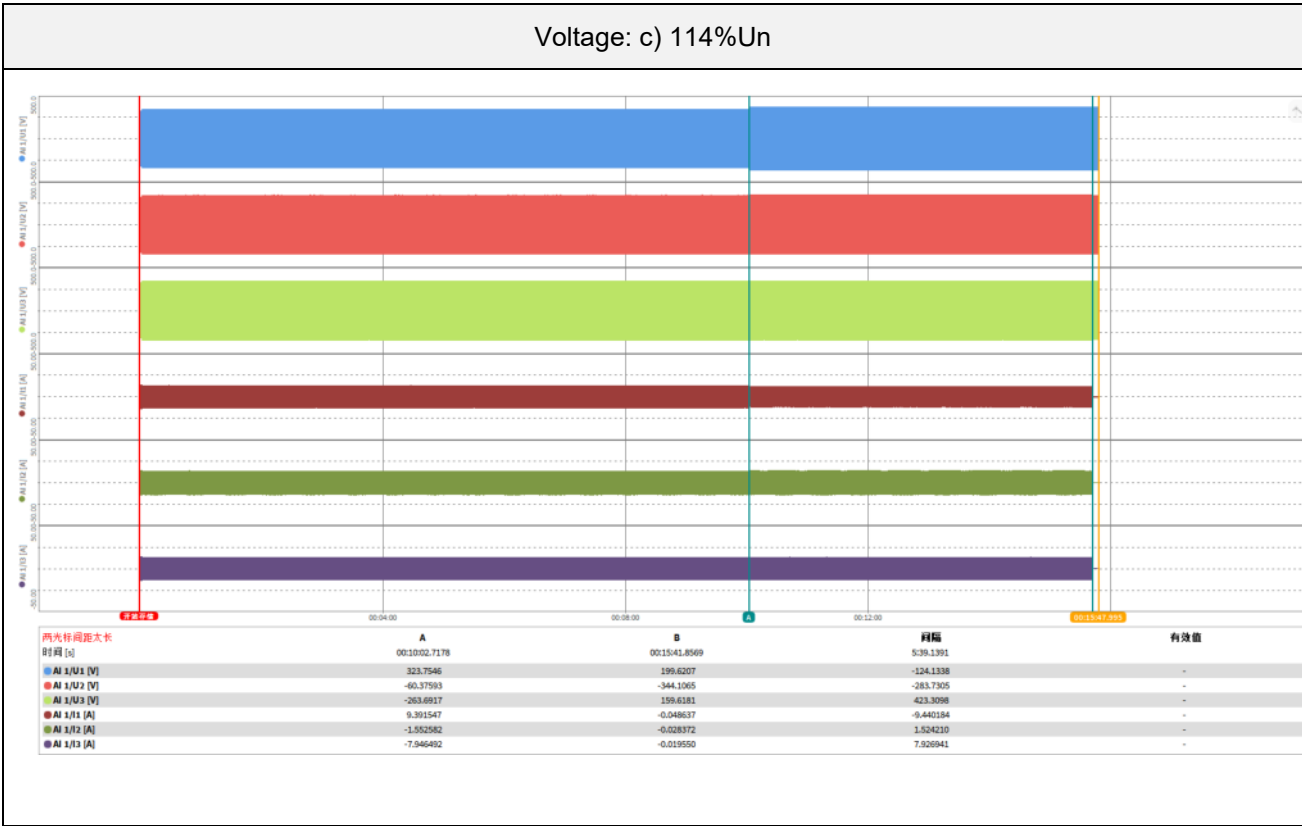
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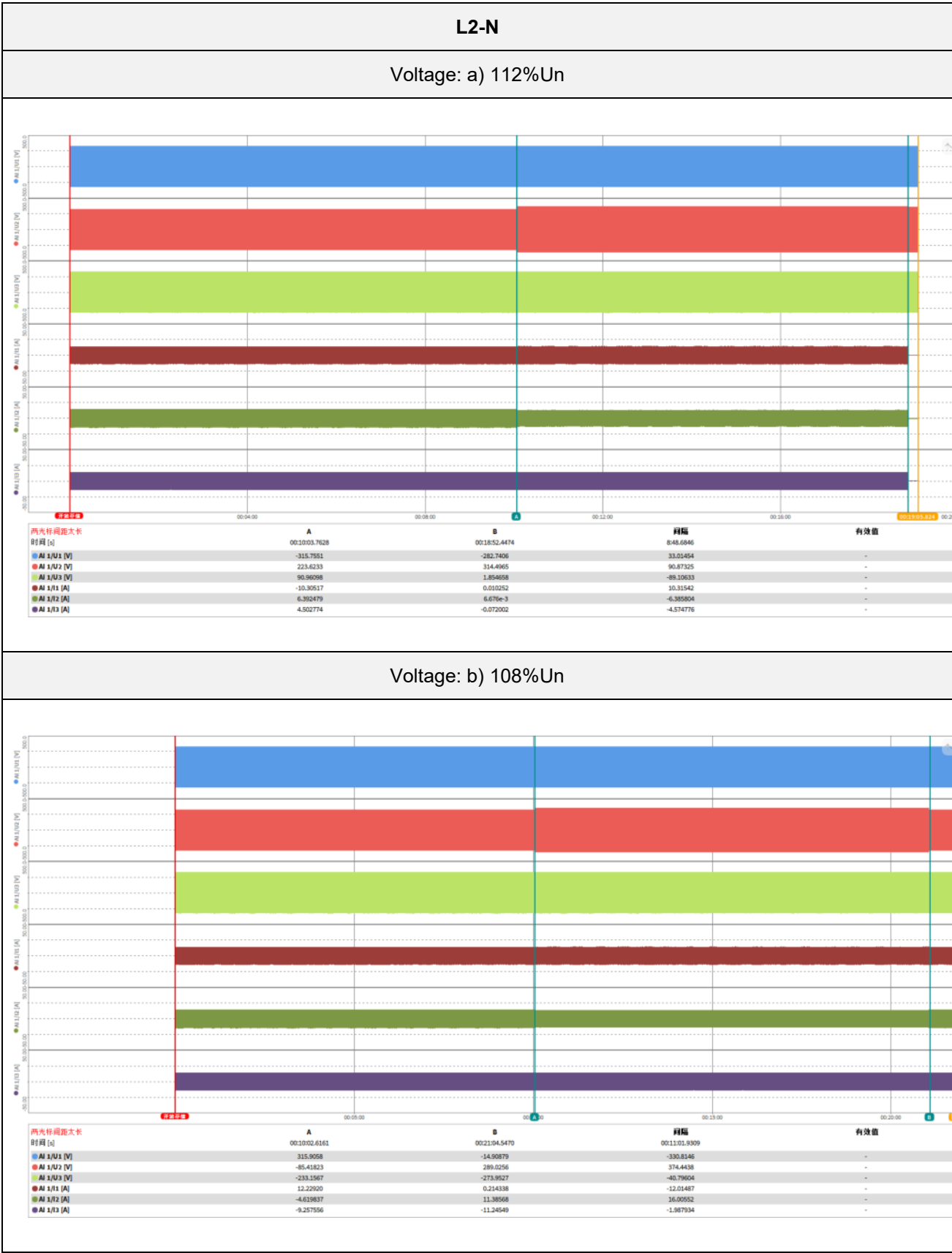
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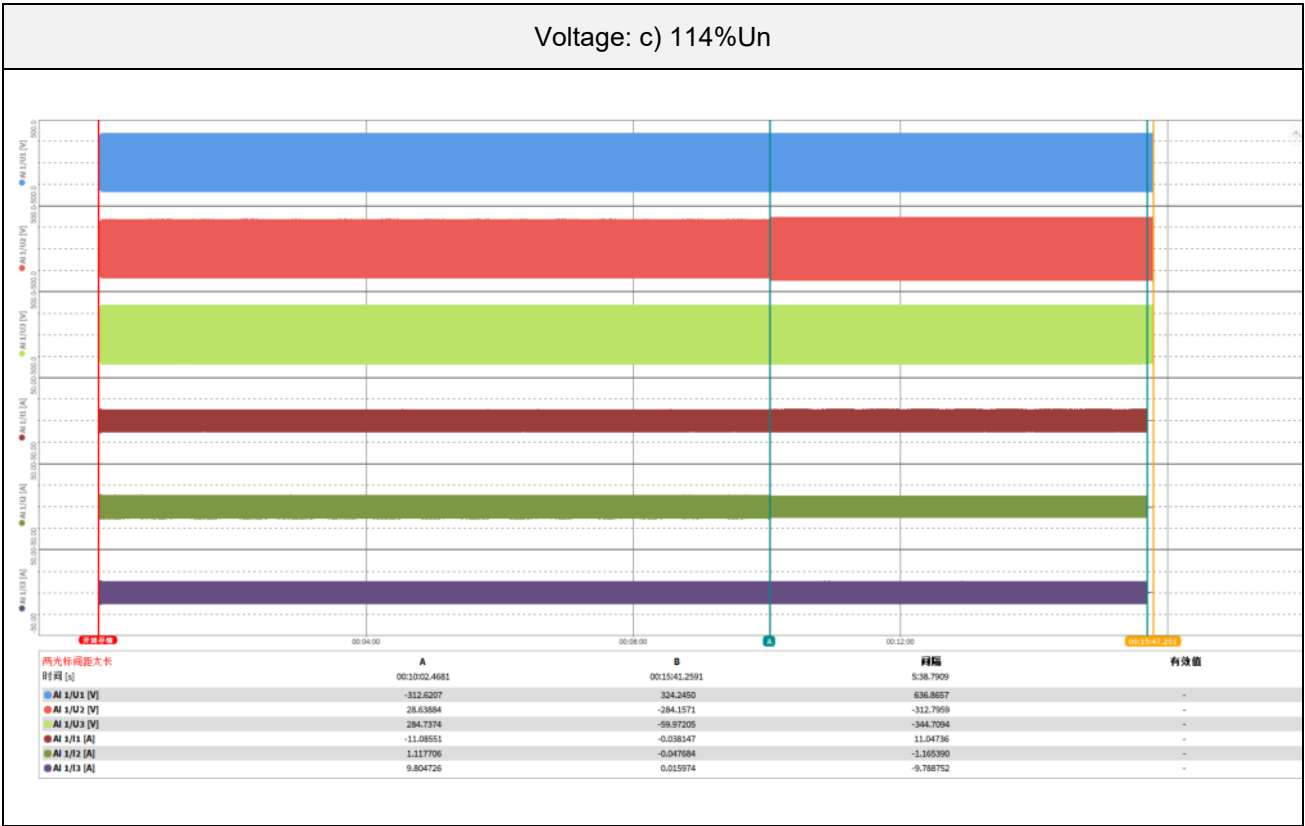


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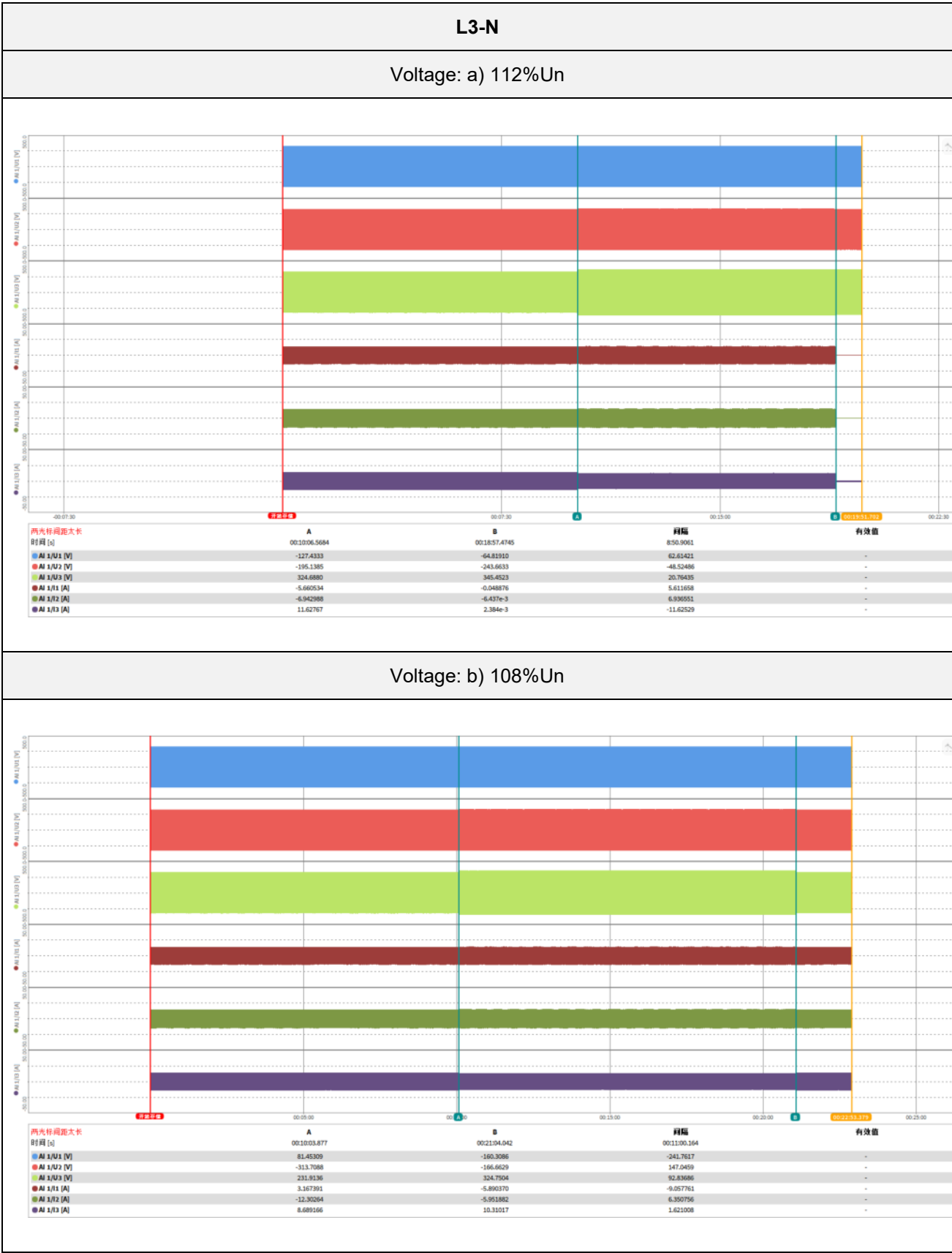




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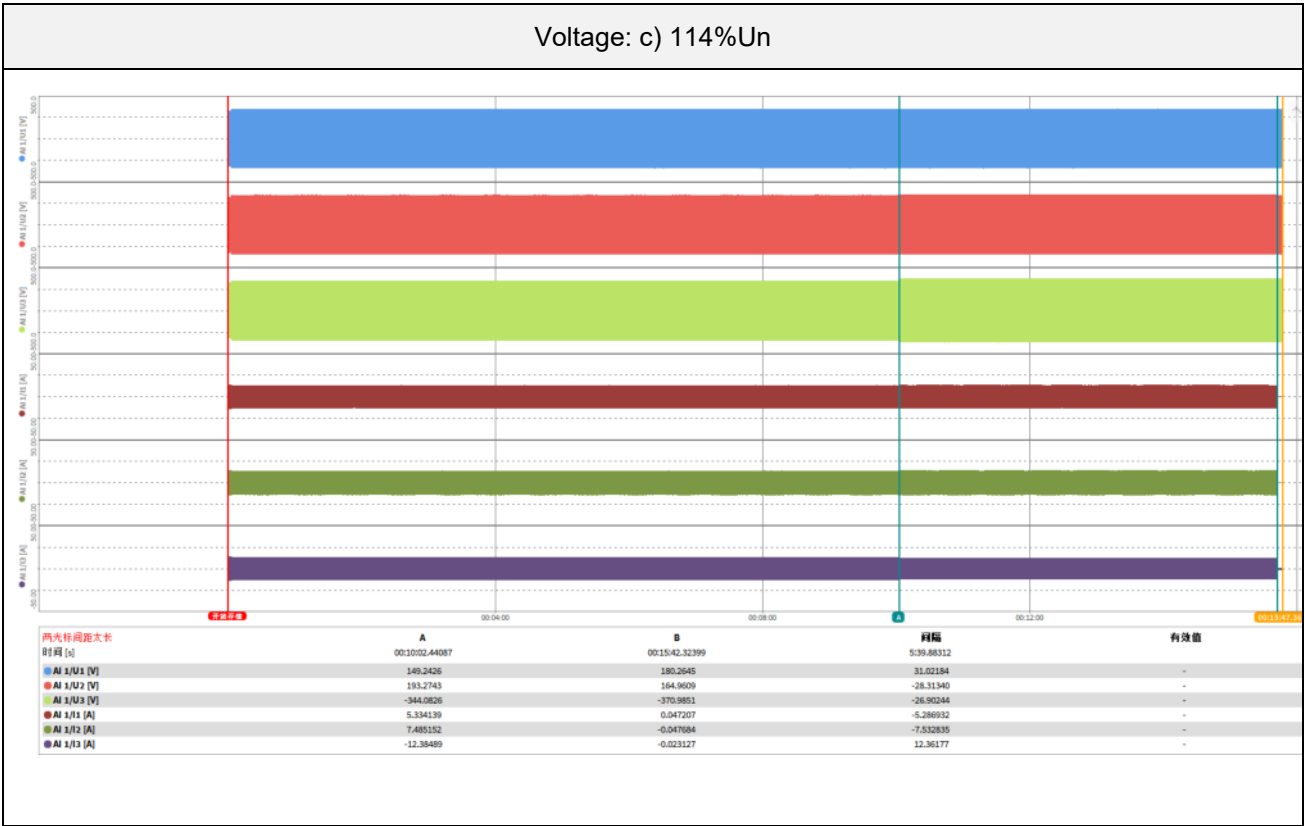
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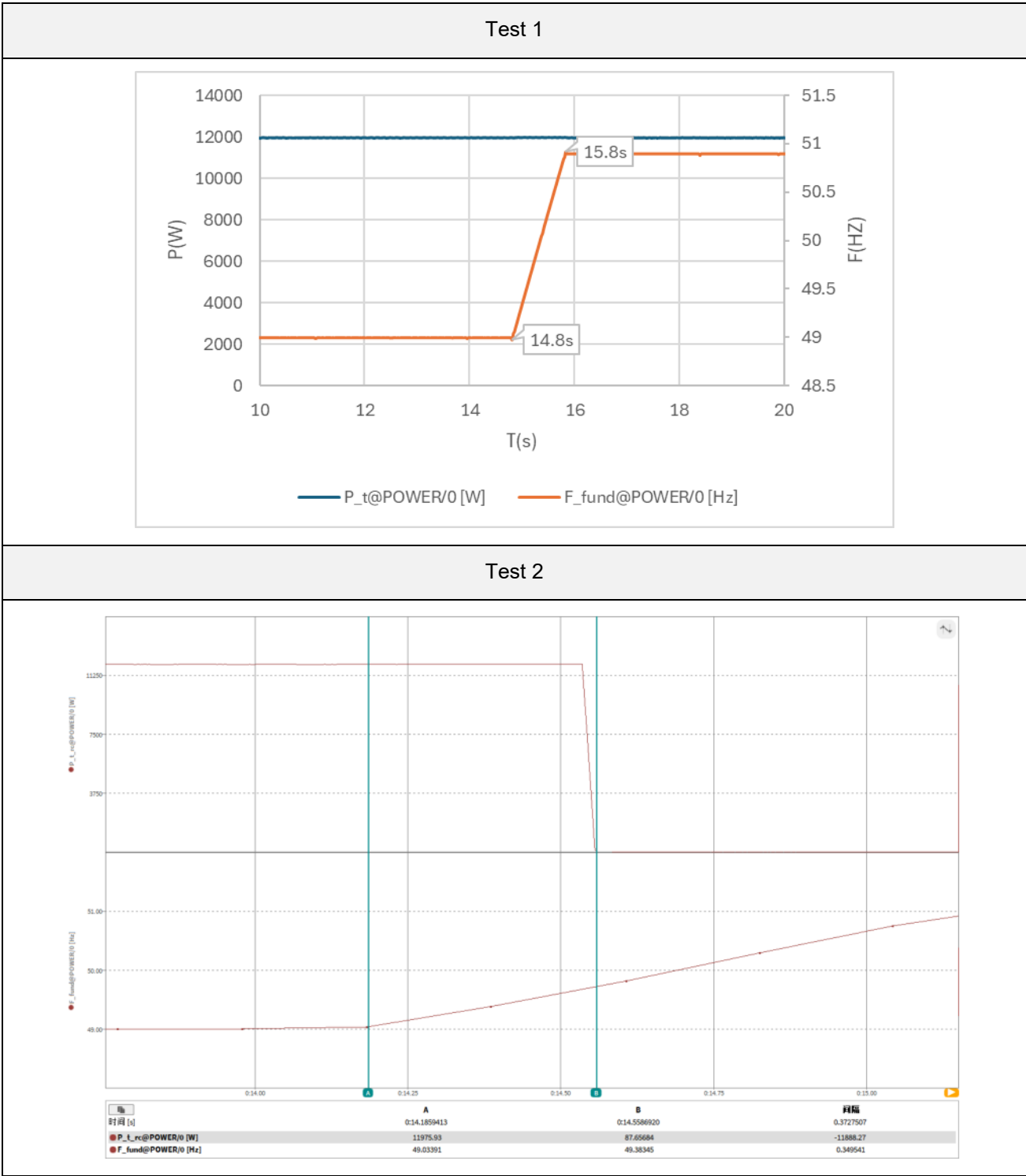
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5.8.3.4 ROCOF protect				P		
5.8.3.4.1 Accuracy of the ROCOF setting values and operate time: verification method						
Setting values	Frequency change df/dt [Hz/s]..... :			2.0Hz/s		
	Disconnecting time [s]..... :			<1s		
Test:						
P _E max in %	100% ±5%					
Test condition	Start Frequency	Change	End Frequency	Connection		
Test 1: (*)	49.0 Hz	1.9Hz/s	50.9 Hz	Always connected		
Test 2: (*)	49.0 Hz	2.1Hz/s	51.1 Hz	Disconnected in 0.373s		
Test 3: (*)	51.0 Hz	1.9Hz/s	49.1 Hz	Always connected		
Test 4: (*)	51.0 Hz	2.1Hz/s	48.9 Hz	Disconnected in 0.423s		
Limit	disconnected time <1s					
Note:						
Table 30 — ROCOF protection test items, accuracy of the setting values and operate time measurements (1/2)						
Test item	Protection function	ROCOF direction	Test signal start frequency (Hz)	ROCOF of the test (Hz/s)	Test signal end frequency (Hz)	Step remain times
RVAL POS 1	ROCOF	Increase	$f_n - \text{ROCOF} \times 0,5 \text{ s}$	$\text{ROCOF} = G_S + 2 \times A_r$	$f_n + \text{ROCOF} \times 0,5 \text{ s}$	1 s
RVAL POS 2	ROCOF	Increase	$f_n - \text{ROCOF} \times 0,5 \text{ s}$	$\text{ROCOF} = G_S - 2 \times A_r$	$f_n - \text{ROCOF} \times 0,5 \text{ s}$	1 s
RVAL NEG 1	ROCOF	Decrease	$f_n + \text{ROCOF} \times 0,5 \text{ s}$	$\text{ROCOF} = G_S + 2 \times A_r$	$f_n + \text{ROCOF} \times 0,5 \text{ s}$	1 s
RVAL NEG 2	ROCOF	Decrease	$f_n + \text{ROCOF} \times 0,5 \text{ s}$	$\text{ROCOF} = G_S - 2 \times A_r$	$f_n - \text{ROCOF} \times 0,5 \text{ s}$	1 s
For each test the signal shall be applied and the ROCOF shall be increased or decreased, as appropriate, according to the criteria below (statements below apply for a positive ROCOF):						
1. to start the test, a signal which is at frequency $f = f_n \pm \text{ROCOF}_{\text{test}} \times (\Delta t_2 / 2)$, where Δt_2 is defined in the next step, is applied for Δt_1 , equal to at least 1 s and longer than the time delay setting plus 200 ms;						
2. then a ROCOF equal to the activation setting value minus twice its required accuracy, or if no requirement is made, twice the manufacturer stated accuracy, in direction of the setting value, is applied to the signal and shall be maintained constant for $\Delta t_2 = T_{\text{op}} - (T_{\text{Res}} + T_{\text{ov}})$ where T_{op} is the operate time, T_{Res} is the maximum required reset time and T_{ov} is the overshoot time, a tolerance margin equal to 10 ms						
3. if the reset value is:						
within the band between the setting value and the setting values minus twice its required accuracy, then the signal is suddenly adjusted to the setting values minus twice its required accuracy (case shown in the Figure 42) for at least Δt_1						
4. below the setting value minus twice its accuracy, the signal is suddenly adjusted the reset value minus twice its accuracy for at least Δt_1 .						

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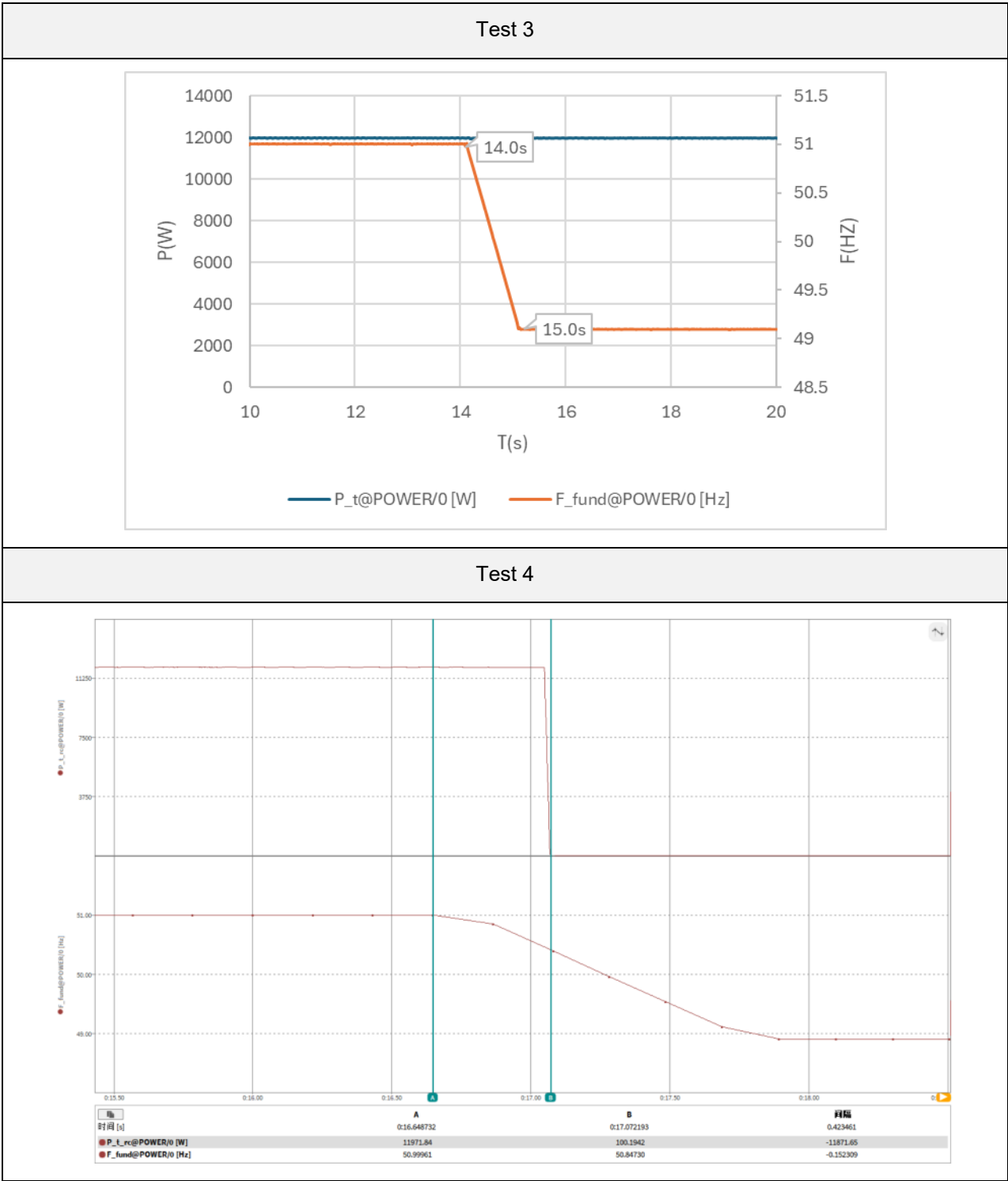
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5.8.3.4 ROCOF protect					P
5.8.3.4.2 Reset time and reset ratio					
Test conditions	Output power: >=50%Pn, Frequency: 50+/-0.2Hz				
	NOP POS		NOP NEG		
Parameter	ROCOF /Time		ROCOF /Time		
Setting value	2.0 Hz/s / 100ms		2.0 Hz/s / 100ms		
0Hz/s (49.56Hz hold at least 1000ms)→2.1 Hz/s (40ms)→1.9Hz/s(1000ms)	Reset time	Result	0Hz/s (50.44Hz hold at least 1000ms)→-2.1 Hz/s (40ms)→-1.9Hz/s(1000ms)	Reset time	Result
	≤50ms	No trip		≤50ms	No trip
	≤50ms	No trip		≤50ms	No trip
	≤50ms	No trip		≤50ms	No trip

Assessment criterion:

Table 31 — ROCOF protection test items, reset time and reset ratio requirements (2/2) (under consideration)

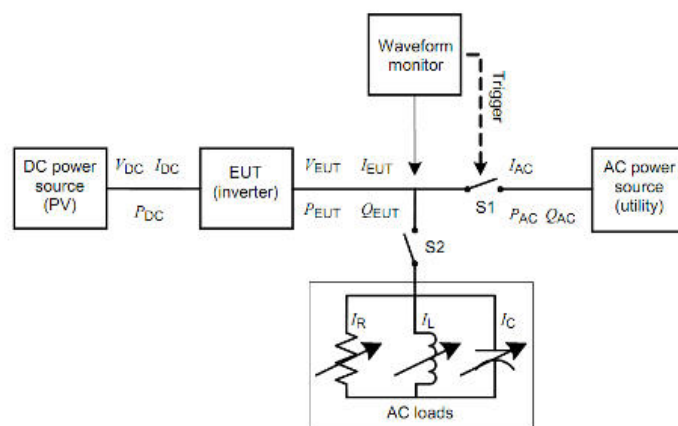
Test-item		NOP POS	NOP NEG
Protection function		ROCOF	ROCOF
ROCOF direction		Increase ($G_S > 0$)	Decrease ($G_S < 0$)
Step 0	Test signal frequency (Hz)	$f_n - ROCOF_1 \left(\frac{T_{Op} - T_{Res} - 10 \text{ ms}}{2} \right)$	$f_n + ROCOF_1 \left(\frac{T_{Op} - T_{Res} - 10 \text{ ms}}{2} \right)$
	Remain time	1 s	1 s
Step 1	ROCOF (Hz/s)	$ROCOF_1 = G_S + 2 \times A_r$	$ROCOF_1 = G_S - 2 \times A_r$
	Remain time	$T_{Op} - T_{Res} - 10 \text{ ms}$	$T_{Op} - T_{Res} - 10 \text{ ms}$
	Test signal end frequency (Hz)	$f_{1-2} = f_n + ROC_1 \left(\frac{T_{Op} - T_{Res} - 10 \text{ ms}}{2} \right)$	$f_{1-2} = f_n - ROCOF_1 \left(\frac{T_{Op} - T_{Res} - 10 \text{ ms}}{2} \right)$
Step 2	ROCOF (Hz/s)	$ROCOF_2 = \min(G_S - 2 \times A_c, Res - 2 \times A_r)$	$ROCOF_2 = \max(G_S + 2 \times A_r, Res + 2 \times A_r)$
	Remain time	1 s	1 s
	Test signal end frequency (Hz)	$f_{1-2} + ROCOF_2 \times 1 \text{ s}$	$f_{1-2} - ROCOF_2 \times 1 \text{ s}$

5.8.6 Islanding detection		
Test circuit and parameters		
Parameter	Symbol	Units
EUT DC Input		
DC voltage	V_{DC}	V
DC Current	I_{DC}	A
DC Power	P_{DC}	W
EUT AC output		
AC voltage	V_{EUT}	V
AC current	I_{EUT}	A
Real power	P_{EUT}	W
Reactive power	Q_{EUT}	Var
Test Load		
Resistive load current	I_R	A
Inductive load current	I_L	A
Capacitive load current	I_C	A
AC (utility) power source		
Utility real power	P_{AC}	W
Utility reactive power	Q_{AC}	Var
Utility current	I_{AC}	A
Block diagram test circuit IEC 62116:2014		

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IEC 1567/08

Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

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Load imbalance (real, reactive load) for test condition A (EUT output = 100%)									P
Test conditions		Frequency: 50±0.1Hz U _N =230±2.3Vac Distortion factor of chokes < 2% Quality = 1							
Disconnection limit		2s (IEC 62116)							
Test:									
No.	P _{EUT} ¹⁾ (% of EUT rating)	Reactive load (% of Q _L in 6.1.d) ¹⁾	P _{AC} ^{2) 5)} (% of nominal)	Q _{AC} ^{3) 5)} (% of nominal)	Run on Time [ms]	P _{EUT} Per-phase [W]	Q _f	V _{DC} [V]	Remarks ⁴⁾
1	100	100	0	0	1253	12000	1.002 1.000 1.000	530	Test A at BL
2	100	100	-5	-5	1243	12000	1.023 1.020 1.023	530	Test A at IB
3	100	100	-5	0	960	12000	1.047 1.051 1.048	530	Test A at IB
4	100	100	-5	+5	1028	12000	1.076 1.076 1.073	530	Test A at IB
5	100	100	0	-5	933	12000	0.975 0.973 0.973	530	Test A at IB
6	100	100	0	+5	725	12000	1.028 1.028 1.022	530	Test A at IB
7	100	100	+5	-5	1221	12000	0.932 0.926 0.930	530	Test A at IB

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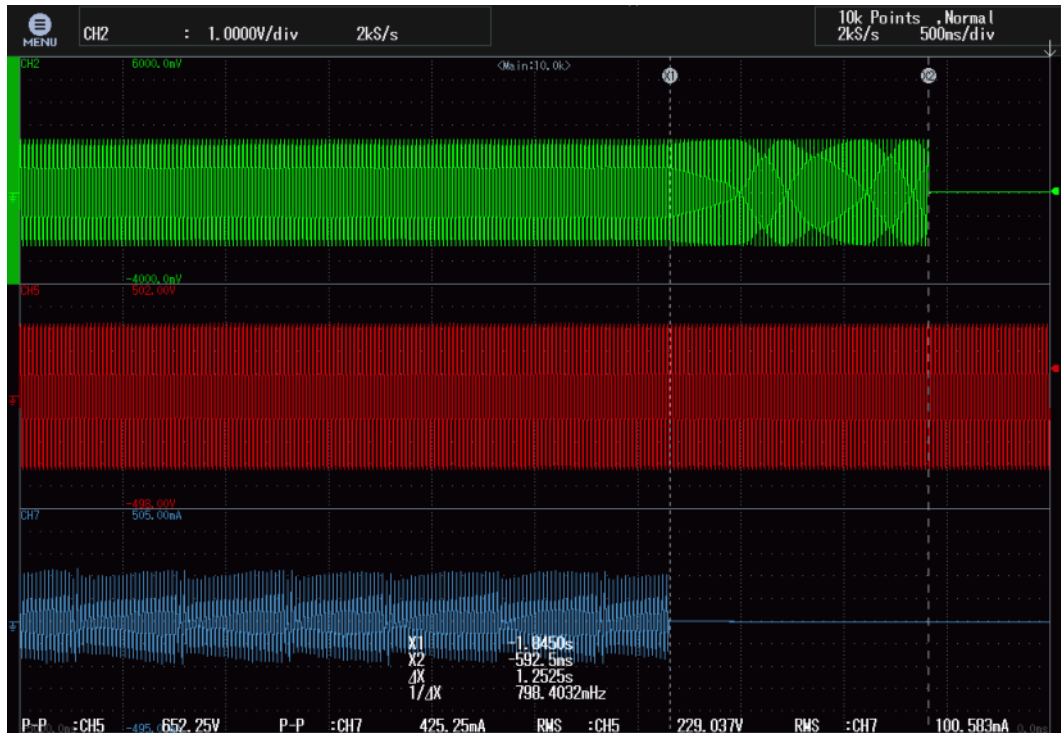
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8	100	100	+5	0	1020	12000	0.955 0.955 0.955	530	Test A at IB
9	100	100	+5	+5	1012	12000	0.979 0.979 0.977	530	Test A at IB
Parameter at 0% per phase			L= 14.04 mH		R= 4.41 Ω		C= 722.43 μF		
Note: RLC is adjusted to min. ±1% of the inverter rated output power 1) P_{EUT}: EUT output power 2) P_{AC}: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value. 3) Q_{AC}: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value. 4) Fundamental of I_{AC} when RLC is adjusted 5) BL: Balance condition. IB: Imbalance condition. Condition A: EUT output power P_{EUT} = Maximum ⁶⁾ EUT input voltage ⁶⁾ = >75% of rated input voltage range ⁶⁾ Maximum EUT output power condition should be achieved using the maximum allowable input power. Actual output power may exceed nominal rated output. ⁷⁾ Based on EUT rated input operating range. For example. If range is between X volts and Y volts. 75 % of range =$X + 0.75 \times (Y - X)$. Y shall not exceed $0.8 \times$ EUT maximum system voltage (i.e.. maximum allowable array open circuit voltage). In any case. the EUT should not be operated outside of its allowable input voltage range.									

Scope pictures of the disconnection time

Disconnection at No. 1



Note:

Blue[V]: Trip signal

Red [V]: Grid Voltage

Green [A]: EUT output current

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Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %)									P
Test conditions		Frequency: 50±0.1Hz U _N =230±2.3Vac Distortion factor of chokes < 2% Quality =1							
Disconnection limit		2s (IEC 62116)							
Test:									
No.	P _{EUT} ¹⁾ [% of EUT rating]	Reactive load [% of Q _L in 6.1.d] ¹⁾	P _{AC} ^{2) 5)} (% of nominal)	Q _{AC} ^{3) 5)} (% of nominal)	Run on Time [ms]	P _{EUT} Per-phase [W]	Q _f	V _{DC} [V]	Remarks ⁴⁾
1	66	66	0	-5	608	7920	0.971 0.970 0.970	420	Test B at IB
2	66	66	0	-4	1060	7920	0.976 0.982 0.982	420	Test B at IB
3	66	66	0	-3	1117	7920	0.982 0.982 0.984	420	Test B at IB
4	66	66	0	-2	652	7920	0.987 0.986 0.989	420	Test B at IB
5	66	66	0	-1	552	7920	0.992 0.994 0.994	420	Test B at IB
6	66	66	0	0	1260	7920	1.000 1.000 1.000	420	Test B at BL
7	66	66	0	1	723	7920	1.003 1.004 1.004	420	Test B at IB

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8	66	66	0	2	610	7920	1.007 1.007 1.010	420	Test B at IB
9	66	66	0	3	733	7920	1.011 1.014 1.014	420	Test B at IB
10	66	66	0	4	1058	7920	1.017 1.019 1.020	420	Test B at IB
11	66	66	0	5	828	7920	1.022 1.024 1.024	420	Test B at IB

Parameter at 0% per phase			L= 21.27 mH			R= 6.68 Ω		C= 476.80 μF	

Note:

RLC is adjusted to min. $\pm 1\%$ of the inverter rated output power

1) P_{EUT} : EUT output power

2) P_{AC} : Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.

3) Q_{AC} : Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.

4) Fundamental of I_{AC} when RLC is adjusted

5) BL: Balance condition. IB: Imbalance condition.

Condition B:

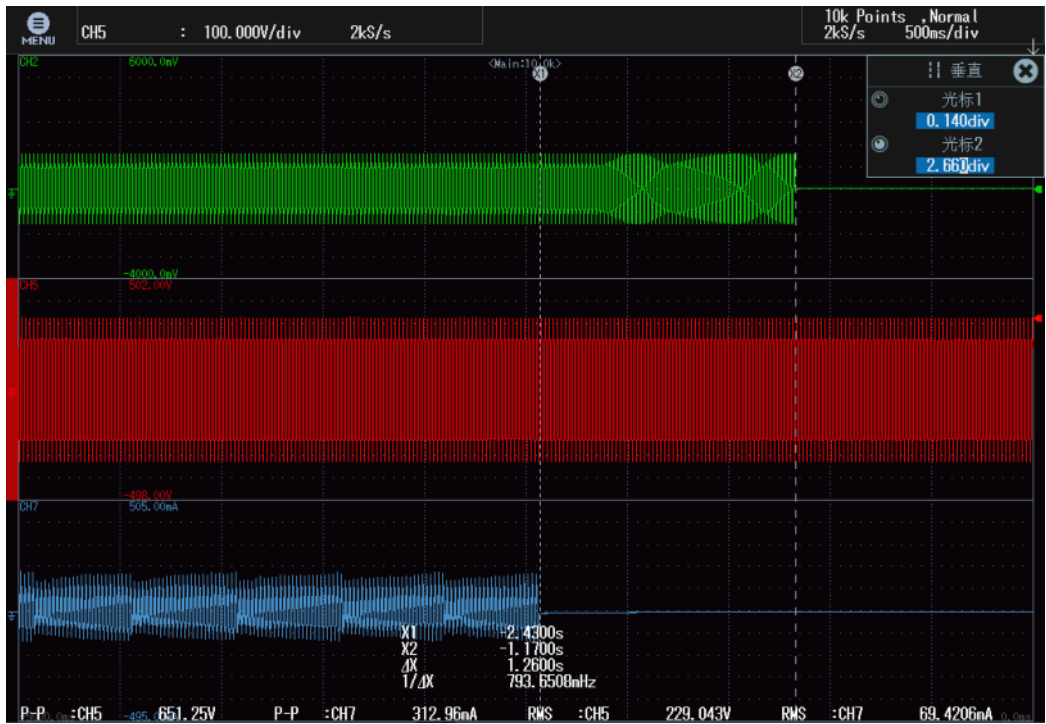
EUT output power $P_{EUT} = 50\% - 66\%$ of maximum

EUT input voltage ⁶⁾ = 50 % of rated input voltage range. $\pm 10\%$

⁶⁾ Based on EUT rated input operating range. For example. If range is between X volts and Y volts. 50 % of range = $X + 0.5 \times (Y - X)$. Y shall not exceed $0.8 \times$ EUT maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the EUT should not be operated outside of its allowable input voltage range.

Scope pictures of the disconnection time

Disconnection at No. 6



Note:

- Blue[V]: Trip signal
- Red [V]: Grid Voltage
- Green [A]: EUT output current

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Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %)									P
Test conditions			Frequency: 50±0.1Hz U _N =230±2.3Vac Distortion factor of chokes < 2% Quality =1						
Disconnection limit			2s (IEC 62116)						
Test:									
No	P _{EUT} ¹⁾ [% of EUT rating]	Reactive load [% of Q _L in 6.1.d] ¹⁾	P _{AC} ^{2) 5)} (% of nominal)	Q _{AC} ^{3) 5)} (% of nominal)	Run on Time [ms]	P _{EUT} Per- phase [W]	Q _f	V _{DC} [V]	Remarks ⁴⁾
1	33	33	0	-5	982	3960	0.974 0.968 0.974	288	Test C at IB
2	33	33	0	-4	998	3960	0.980 0.974 0.980	288	Test C at IB
3	33	33	0	-3	853	3960	0.986 0.986 0.986	288	Test C at IB
4	33	33	0	-2	850	3960	0.988 0.983 0.989	288	Test C at IB
5	33	33	0	-1	958	3960	0.994 0.989 0.994	288	Test C at IB
6	33	33	0	0	1190	3960	1.000 1.000 1.000	288	Test C at BL
7	33	33	0	1	840	3960	1.006 1.006 1.008	288	Test C at IB

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8	33	33	0	2	823	3960	1.008 1.006 1.006	288	Test C at IB
9	33	33	0	3	677	3960	1.014 1.014 1.014	288	Test C at IB
10	33	33	0	4	628	3960	1.020 1.020 1.020	288	Test C at IB
11	33	33	0	5	625	3960	1.025 1.025 1.025	288	Test C at IB

Parameter at 0% per phase			L=42.54 mH			R=13.36 Ω		C=238.40 μF	

Note:

RLC is adjusted to min. $\pm 1\%$ of the inverter rated output power

1) P_{EUT} : EUT output power

2) P_{AC} : Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.

3) Q_{AC} : Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.

4) Fundamental of I_{AC} when RLC is adjusted

5) BL: Balance condition. IB: Imbalance condition.

Condition B:

EUT output power $P_{EUT} = 25\% - 33\%$ ⁶⁾ of maximum

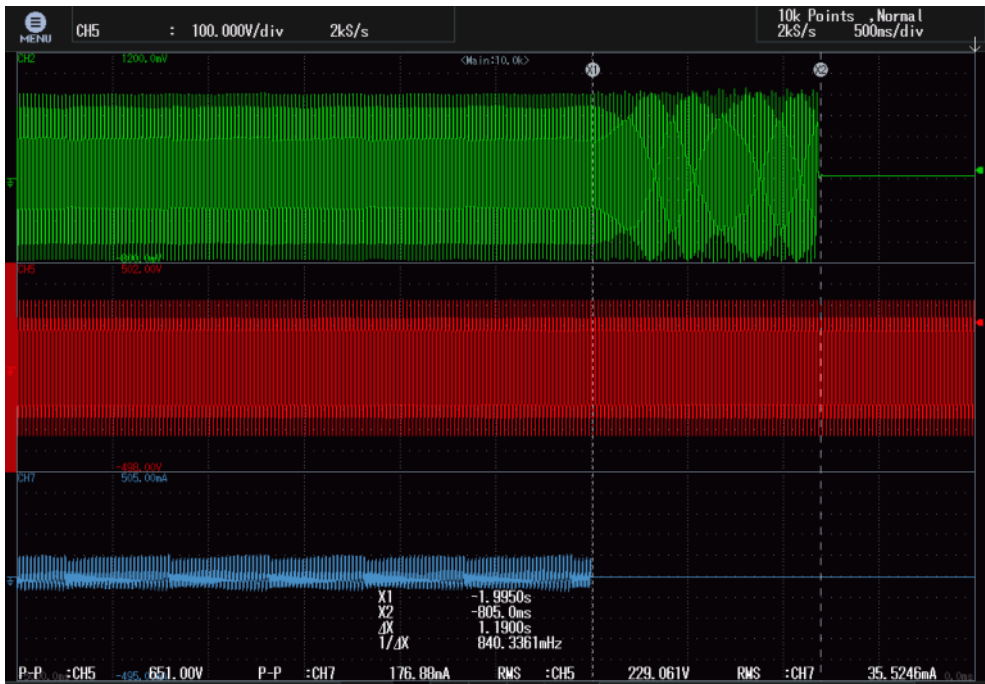
EUT input voltage ⁷⁾ = $< 20\%$ of rated input voltage range

⁶⁾ Or minimum allowable EUT output level if greater than 33 %.

⁷⁾ Based on EUT rated input operating range. For example. If range is between X volts and Y volts. 20 % of range = $X + 0.2 \times (Y - X)$. Y shall not exceed $0.8 \times$ EUT maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the EUT should not be operated outside of its allowable input voltage range.

Scope pictures of the disconnection time

Disconnection at No. 6



Note:

Blue[V]: Trip signal

Red [V]: Grid Voltage

Green [A]: EUT output current

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5.9 Connection and starting			P
5.9.3 Automatic reconnection after tripping			
5.9.4 Starting to generate electrical power			
Setting value	Min. voltage for connected to grid:		195.5V
	Max. voltage for connected to grid:		253.0V
	Min. Frequency for connected to grid:		49.50Hz
	Max. Frequency for connected to grid:		50.10Hz
	Observation time (≥60s):		60s
Test:			
	Voltage conditons		
a) Start up for voltage range	<84% Un for twice of observation time	>111% Un for twice of observation time	
Connection:	No connection	No connection	
Limit	No connection allowed		
b) In voltage range at start-up	≥86% Un within twice setting observation time	≤109% Un within twice setting observation time	
Reconnection time [s]	73.0	72.6	
Limit:	Connected after setting observation time (≥60s)		
Gradient:	The maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: disable. For recorded gradient see diagram below.		
c) In voltage range after voltage failure	≥86% Un for twice of setting observation time	≤109% Un for twice of setting observation time	
Reconnection time [s]	72.6	72.4	
Limit:	Reconnection after setting observation time (≥60s)		
Gradient:	For adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: 10%Pn/min.		

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	For non or partly adjustable generators the connection after trip of the interface protection is delayed by a randomised value between 1 min and 10 min. For recorded gradient see diagram below.	
	Frequency conditions	
d) Start up for frequency range	<49.45 Hz for twice of setting observation time	>50.10 Hz for twice of setting observation time
Connection:	No connection	No connection
Limit	No connection allowed	
e) In frequency range at start-up	≥49.55 Hz within twice of setting observation time	≤50.00 Hz within twice of setting observation time
Reconnection time [s]	72.6	72.6
Limit:	Connected after setting delay time(≥60s)	
Gradient:	The maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: disable. For recorded gradient see diagram below.	
f) In frequency range after frequency failure	≥49.55 Hz for twice of setting observation time	≤50.00 Hz for twice of setting observation time
Reconnection time [s]	72.6	72.8
Limit:	Reconnection after setting observation time (≥60s)	
Gradient:	For adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: 10%P_n/min. For non or partly adjustable generators the connection after trip of the interface protection is delayed by a randomised value between 1 min and 10 min. For recorded gradient see diagram below.	

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Test:

Test condition a), b), d) and e): Refer table 4

Test condition c) and f): Refer table 3

In order to avoid continuous starting and disengaging operations of the interface protection relay, the disengaging value of frequency and voltage functions shall be above 2 % deviating from the operate value.

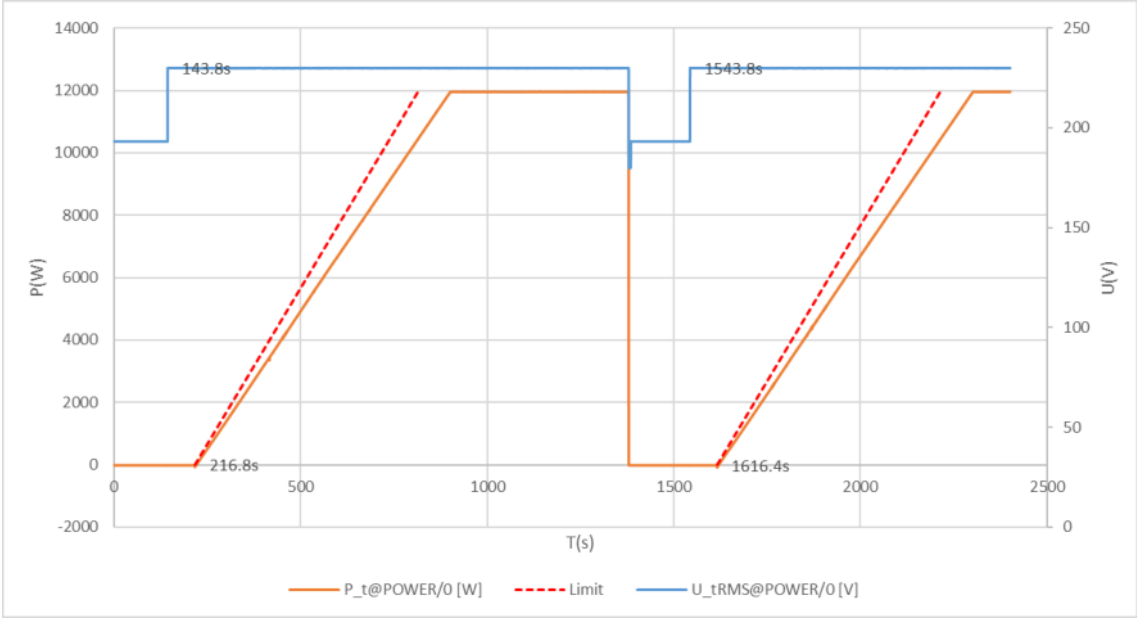
Table 3 – Automatic reconnection after tripping

Parameter	Range	Default setting
Low frequency	47.0-50.0Hz	49.5Hz
High frequency	50.0-52.0Hz	50.2Hz
Low voltage	50%-100%U _n	85%U _n ^a / 90%U _c ^b
High voltage	100%-120%U _n	110%U _n ^a / 110%U _c ^b
Observation	10s-600s	60s
Active power	6%-3000%/minute	10%/minute
a: in case of EN 50549-1:2019		
b: in case of EN 50549-2:2019		

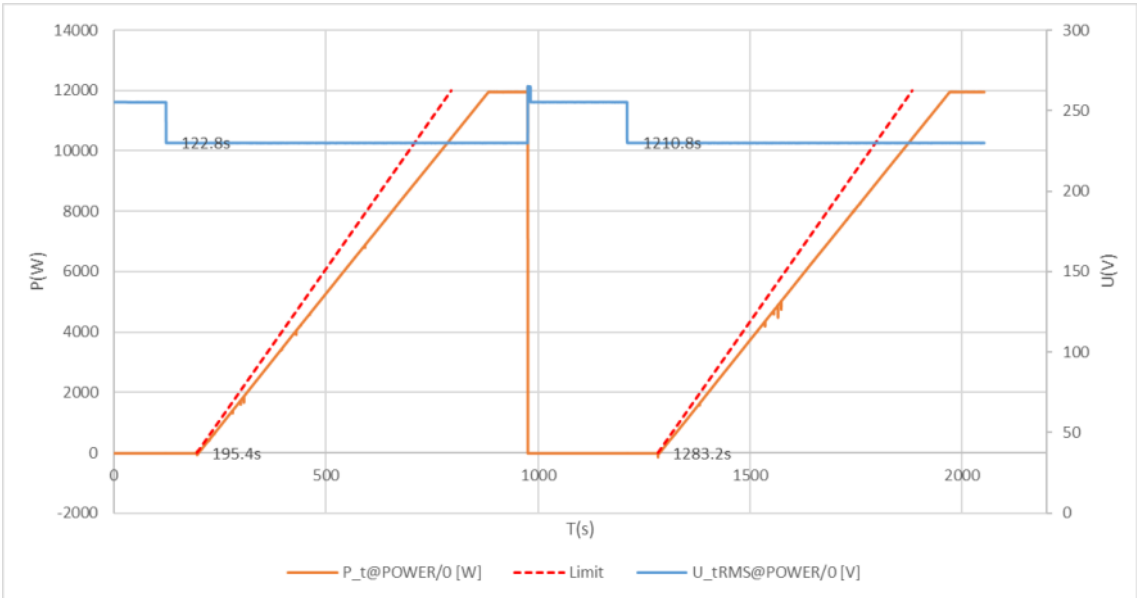
Table 4 – Starting to generate electric power

Parameter	Range	Default setting
Low frequency	47.0-50.0Hz	49.5Hz
High frequency	50.0-52.0Hz	50.1Hz
Low voltage	50%-100%U _n	85%U _n ^a / 90%U _c ^b
High voltage	100%-120%U _n	110%U _n ^a / 110%U _c ^b
Observation	10s-600s	60s
Active power	6%-3000%/minute	Disable
a: in case of EN 50549-1:2019		
b: in case of EN 50549-2:2019		

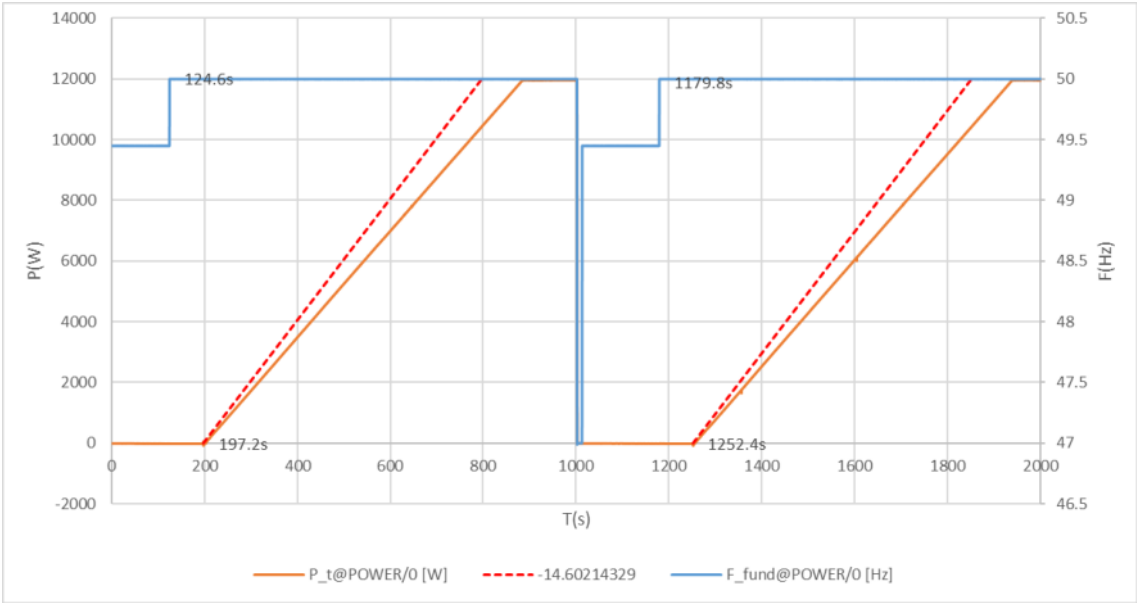
Graph of the gradual power supply: Test 1) for $\geq 86\% U_n$



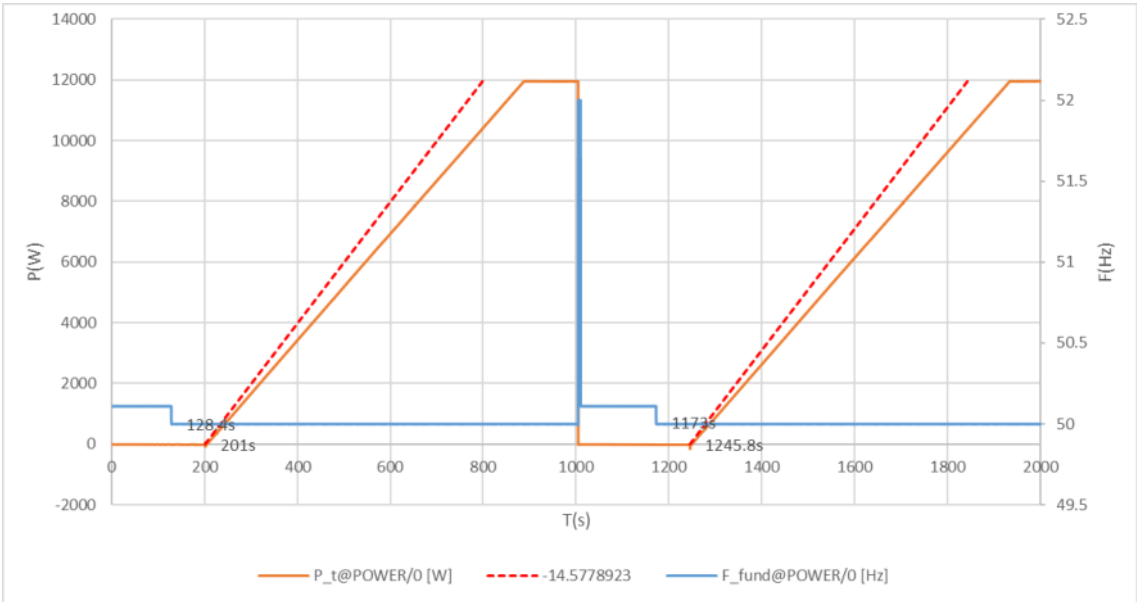
Graph of the gradual power supply: Test 2) for $\leq 109\% U_n$



Graph of the gradual power supply: Test 3) for $\geq 49.55\text{Hz}$



Graph of the gradual power supply: Test 4) for $\leq 50.05\text{Hz}$

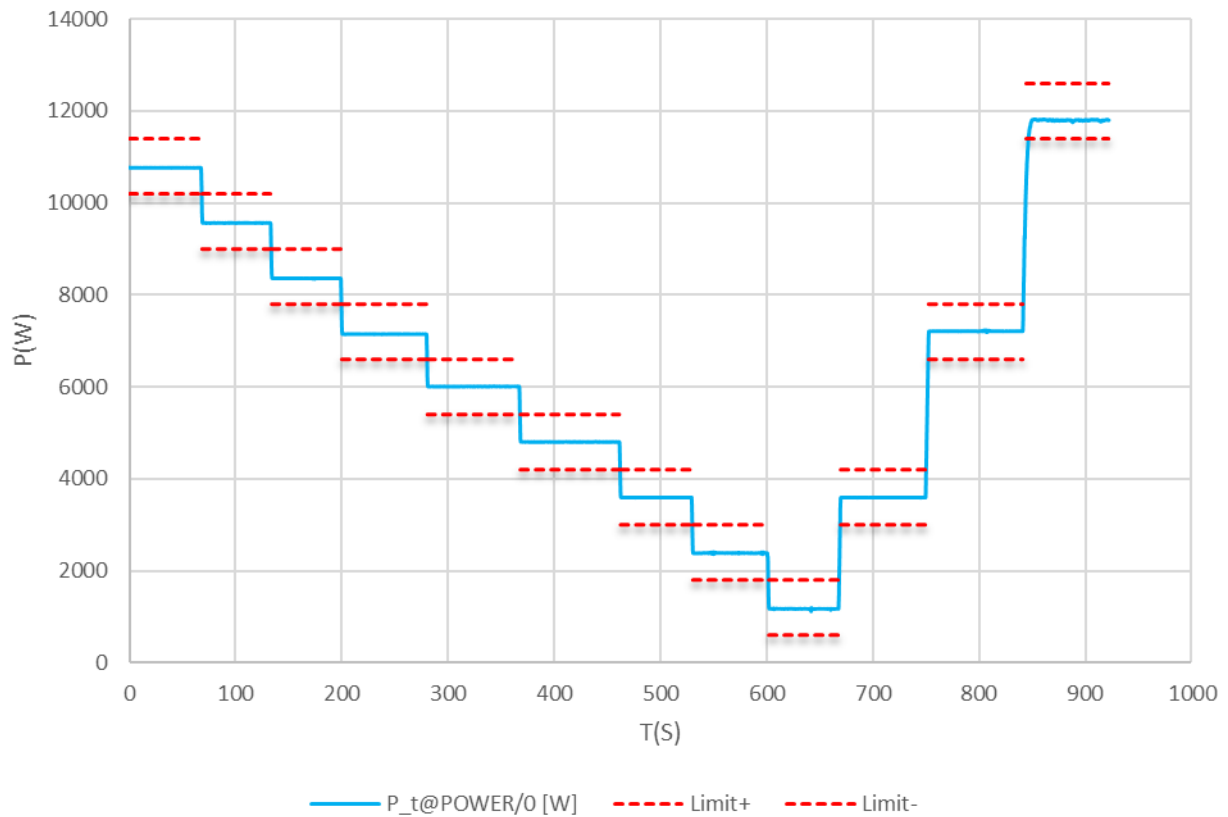


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5.10 Active power reduction on set point						P
5.10.3.2 Verification of the accuracy						
Test:						
Active power step [% of P _n]	Requested set point value		Actual value		Accuracy Actual value-set point	
	W	P/P _n [%]	W	P/P _n [%]	W	P/P _n [%]
90	10800	90.0	10767.7	89.73	32.3	0.27
80	9600	80.0	9567.5	79.73	32.5	0.27
70	8400	70.0	8363.7	69.70	36.3	0.30
60	7200	60.0	7148.5	59.57	51.5	0.43
50	6000	50.0	6010.3	50.09	-10.3	-0.09
40	4800	40.0	4804.0	40.03	-4.0	-0.03
30	3600	30.0	3595.5	29.96	4.5	0.04
20	2400	20.0	2386.1	19.88	13.9	0.12
10	1200	10.0	1172.3	9.77	27.7	0.23
Limit ΔP _{E60} /P _{Setpoint} :	± 5 % of P _{E_{max}}					
30	3600	30.0	3594.9	29.96	5.1	0.04
60	7200	60.0	7212.4	60.10	-12.4	-0.10
100	12000	100.0	11772.1	98.10	227.9	1.90
Limit ΔP _{E60} /P _{Setpoint} :	+ 5 % of P _{E_{max}}					
Graph of active power on set point						



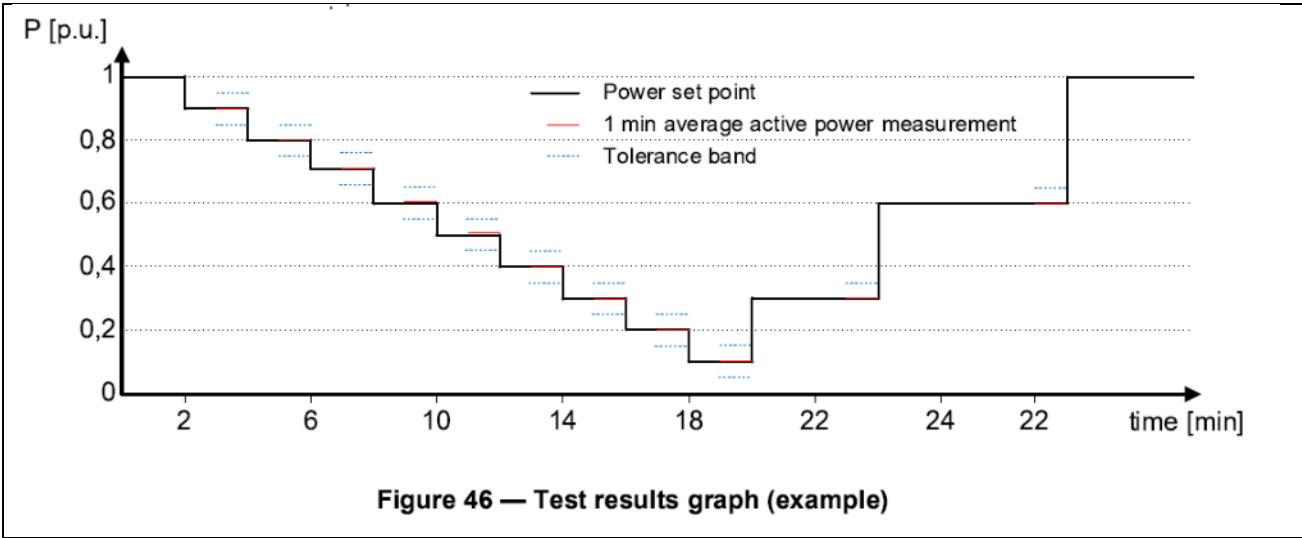
Assessment criterion:

a) for adjustable PGUs:

- no network disconnection
- the active power value does not exceed the setpoint by more than 5% P_{Emax}
- the setting time determined this way is ≤ 1 min

b) For all other PGUs:

- the active power value does not exceed the setpoint by more than 5% P_{Emax} or
- the setpoint is fallen below within 5 minutes or the PGU has switched off



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5.10 Active power reduction on set point				P
5.10.3.3 Verification procedure for dynamic behaviour				
Test:1				
1-min mean value	100% of P _{E_{max}}	90% of P _{E_{max}}	10% of P _{E_{max}}	
P _{Setpoint} [W]:	12000	10800	1200	
P _{E60} [W]:	11807.23	10734.09	1204.84	
ΔP _{E60} / P _{E_{max}} [%]:	1.60	0.55	-0.04	
Limit ΔP _{E60} / P _{E_{max}} :	± 5%of P _{E_{max}}			
Condition	100% of P _{E_{max}} to 90% of P _{E_{max}}		90% of P _{E_{max}} to 10% of P _{E_{max}}	
Measurements ΔP/Δt [%P _{rE} /s]	0.48		0.58	
Limit ΔP/Δt [%P _{rE} /s]	0.33-0.66			
Test:2				
1-min mean value	100% of P _{E_{max}}	70% of P _{E_{max}}	50% of P _{E_{max}}	
P _{Setpoint} [W]:	12000	8400	6000	
P _{E60} [W]:	11809.77	8361.68	5987.16	
ΔP _{E60} / P _{E_{max}} [%]:	1.59	0.32	0.11	
Limit ΔP _{E60} / P _{E_{max}} :	± 5%of P _{E_{max}}			
Condition	100% of P _{E_{max}} to 70% of P _{E_{max}}		90% of P _{E_{max}} to 50% of P _{E_{max}}	
Measurements ΔP/Δt [%P _{rE} /s]	0.58		0.59	
Limit ΔP/Δt [%P _{rE} /s]	0.33-0.66			
Test method:				
The test shall be carried out starting from an initial condition with the generating unit running at 0.9 p.u. active power and applying a step of the active power set point from 0.9 p.u. down to 0.1 p.u. of nominal power or minimum regulating power, whatever is the higher.				

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If this is not compatible with the specific test conditions, active power set point shall be stepped from 0.7 p.u. down to 0.5 p.u. of nominal power.

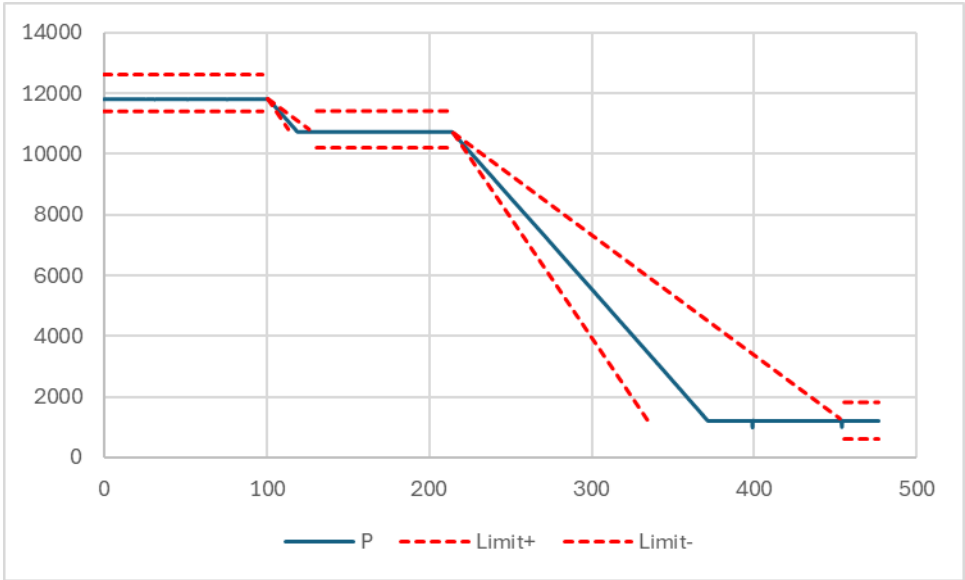
The step response behaviour is measured starting from the instance the set point change is transmitted to the EUT. For the step response time and the settling time a tolerance band of $\pm 5 \% P_{E_{max}}$ to the reactive power set point is considered.

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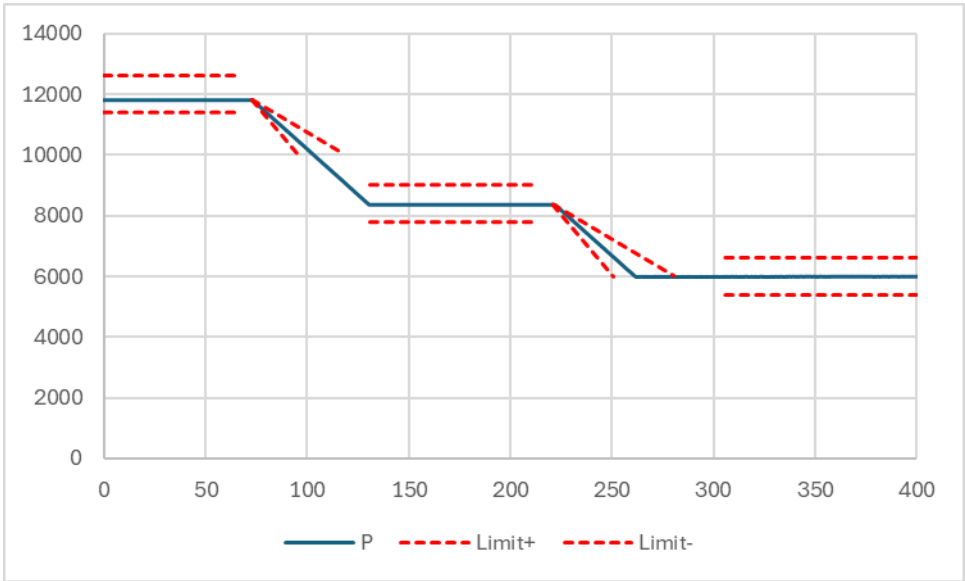
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Test 1: 100% of P_{Emax} to 90% of P_{Emax} to 10% of P_{Emax}



Test 2: 100% of P_{Emax} to 70% of P_{Emax} to 50% of P_{Emax}



5.12 Requirements regarding single fault tolerance of interface protection system and interface switch							P
No.	component No.	fault	test voltage (V)	test time	fuse No.	fuse current (A)	result
1.	Output	Short circuit	800Vdc /230 Vac	5S	--	--	EUT shut down immediately. No hazards.
2.	Ventilation hole	Blocked	800Vdc /230 Vac	60min	--	--	EUT work normally, no hazard. After 40minutes of "19",prototype over- temperature protection
3.	Fan for inductors	Blocked	800Vdc /230 Vac	60min	--	--	EUT work normally, no hazard, Alarm "21" fan fault, alarm "19" overtemperature protection after 15minutes, no output.
4.	Output	Overload	800Vdc /230 Vac	4h	--	--	EUT limit output power by software, overload is impossible.
5.	Output	Incorrect phase sequence	800Vdc /230 Vac	10s	--	--	EUT can't start. LCD displa "57" AC_gridphasesequ _fault. No hazards.
6.	IGBT Q21	SC	800Vdc /230 Vac	10min	--	--	AC and DC circuit breakers opened, no input and output after EUT work 1 seconds. No hazards.
7.	RLY7	SC	800Vdc /230 Vac	10min	--	--	Unit can not operate, no hazard, no fire, no damage.
8.	RLY17	SC	800Vdc /230 Vac	10min	--	--	Unit can not operate, no hazard, no fire, no damage.
9.	Bus capacitor C90	SC	800Vdc /230 Vac	10min	--	--	Unit can not operate, no hazard, no fire, no damage.
10.	X Capacitor C9	SC	800Vdc /230 Vac	10min	--	--	Unit can not operate, no hazard, no fire, no damage.
11.	X Capacitor C54	SC	800Vdc /230 Vac	10min	--	--	Unit can not operate, no hazard, no fire, no damage.
12.	Y Capacitor C7	SC	800Vdc /230 Vac	10min	--	--	EUT can't start to work. No Hazards.

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13.	Y Capacitor C74	SC	800Vdc /230 Vac	10min	--	--	EUT can't start to work. No Hazards.
14.	GFCI R191	OC before startup	650Vdc /230 Vac	10min	--	--	Fault reporting "57", the LED display red, no hazard, no fire, no damage.
15.	GFCI R191	SC before startup	650Vdc /230 Vac	10min	--	--	Fault reporting "57", the LED display red, no hazard, no fire, no damage.
16.	RELAY RLY1	SC before startup	650Vdc /230 Vac	10min	--	--	Unit can not operate, the LED display red, no hazard, no fire, no damage.
17.	RELAY RLY2	SC before startup	650Vdc /230 Vac	10min	--	--	Unit can not operate, the LED display red, no hazard, no fire, no damage.
18.	RELAY RLY3	SC before startup	650Vdc /230 Vac	10min	--	--	Unit can not operate, the LED display red, no hazard, no fire, no damage.
19.	RELAY RLY4	SC before startup	650Vdc /230 Vac	10min	--	--	Unit can not operate, the LED display red, no hazard, no fire, no damage.
Legend							
FID	Fault Indication			MT	Max. Temperature		
SD	PCE Shut Down:			DG	Disconnection To Grid		
RO	Recovered to Operate after removing the single fault setting			NCD	No Comp. or parts Damaged		
NH	No Hazards occurred			PEST	Pass the Electric Strength Test.		
BI	Basic insulation			SI	Supplementary insulation		
DI	Double insulation			RI	Reinforced insulation		
FI	Functional insulation			O.V.C	Overvoltage category		
S.C	short-circuited			O.C	open-circuited		

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O-L	Over-load.		
Note: The errors in the control circuit simulate that the safety is even ensured during a single fault. The test data in this section are from EMTEK (SHENZHEN) CO.,LTD. on Report No. ENS2404100132P002, Section 4.4 Testing in single fault condition.			
Assessment criterion: The NS protection must send a shutdown command to the coupling switch. If the error is detected, the device is switched off within 10 s after error detection. If the auxiliary voltage fails with the central NS protection or if the control fails with the integrated NS protection, the switch-off command must be given immediately.			

5.12 Requirements regarding single fault tolerance of interface protection system and interface switch							P
No.	component No.	fault	test voltage (V)	test time	fuse No.	fuse current (A)	result
a.	Error of an AD converter or measuring card for voltage measurement		DC:370V AC:230V	10s	--	--	The unit disconnect within 10 s , no damage, no fire, no hazard
							
b.	malfunction or freezing of a microprocessor or PLC		DC:370V AC:230V	10s	--	--	The unit disconnect within 10 s , no damage, no fire, no hazard
							

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c.	Merging or jamming of the contacts of the switching output	DC:370V AC:230V	10s	--	--	The unit disconnect within 10 s , no damage, no fire, no hazard
d.	overvoltage of the supply voltage	DC:370V AC:230V	10s	--	--	The unit disconnect within 10 s , no damage, no fire, no hazard



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	Cable break in connecting cables between the measuring input and the control output to the coupling switch	DC:370V AC:230V	10s	--	--	The unit disconnect within 10 s , no damage, no fire, no hazard
e.	 Max(C1) 360 V Min(C1) -360 V Rms(C1) 230.938 V Max(C2) 5.0 A Min(C2) -5.0 A Rms(C2) 2.69216 A Max(C3) 5.4 A Min(C3) -4.9 A Rms(C3) 2.83122 A Max(C4) 1.4 V Min(C4) -1.4 V Rms(C4) 0.99994 V Max(C2 A2) 4.9 A Min(C2 A2) -4.8 A Max(C3 A2) 5.0 A Min(C3 A2) -4.6 A T1 0.1602 s T2 0.1667 s ΔT 0.0065 s Zoom1 20ms/div Push 0.000div Z1 位置 0.170div					
f.	Failure of the supply voltage (auxiliary voltage)	DC:370V AC:230V	10s	--	--	The unit disconnect within 10 s , no damage, no fire, no hazard
	 Max(C1) 360 V Min(C1) -360 V Rms(C1) 230.938 V Max(C2) 5.0 A Min(C2) -5.0 A Rms(C2) 2.27520 A Max(C3) 5.4 A Min(C3) -4.9 A Rms(C3) 2.28960 A Max(C4) 0.7 V Min(C4) -0.7 V Rms(C4) 0.42889 V Max(C2 A2) 4.8 A Min(C2 A2) -4.6 A Max(C3 A2) 5.2 A Min(C3 A2) -4.6 A T1 1.9450 s T2 1.9513 s ΔT 0.0063 s Zoom1 20ms/div Push 0.000div Z1 位置 1.950div					

Annex 3: Photos

Model type: Engineering sample

Pictures of the unit

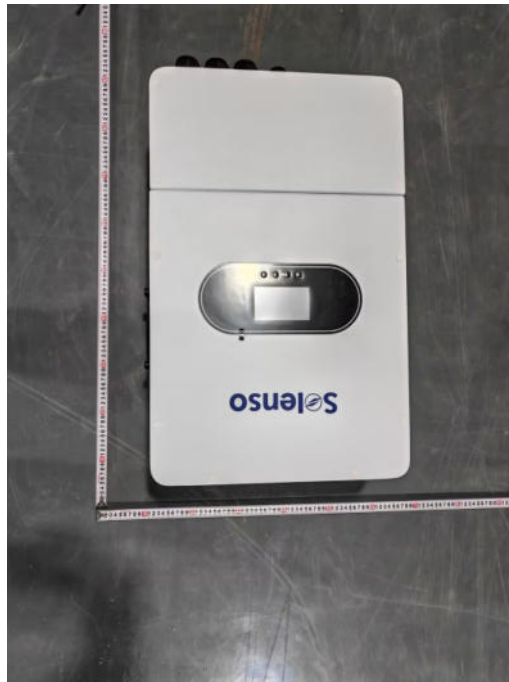


Figure 1. Overview I



Figure 2. Overview II

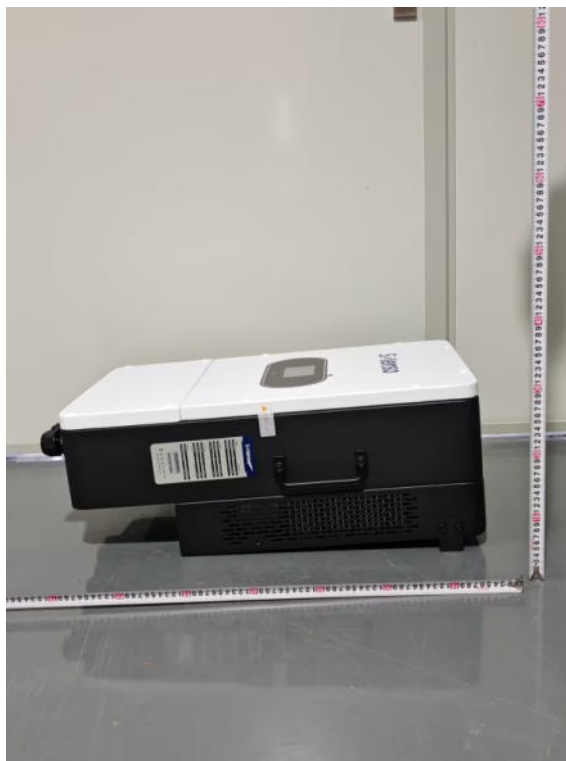


Figure 3. Overview III



Figure 4. Overview IV

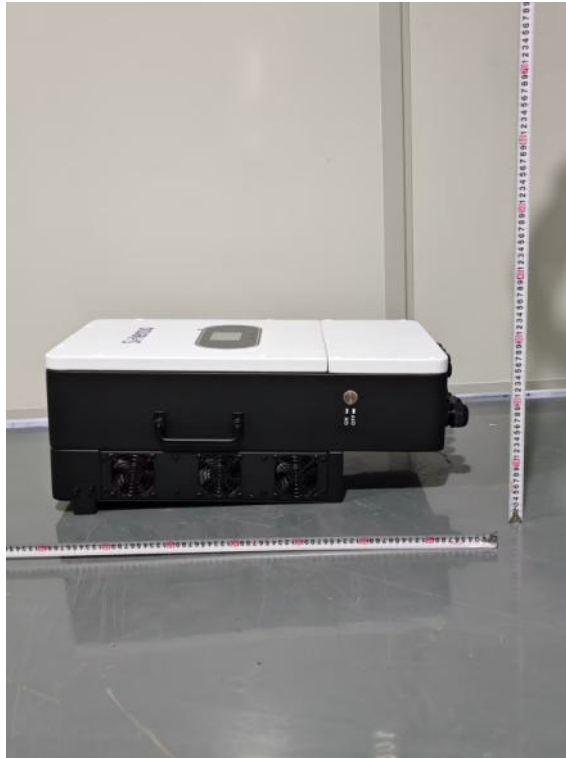


Figure 5. Overview V



Figure 6. Overview VI



Figure 7. Overview VII

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