TESTING FOR THE VERIFICATION OF COMPLIANCE OF PV INVERTER WITH:

EN 50549-1: 2019:

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

Procedure: PE.T-LE-62

Test Report Number	:	**2220/0177**
Type	:	Solar Grid-tied Inverter
Tested Model	:	SOFAR 3000TL
Variant Models	:	SOFAR 1100TL, SOFAR 1600TL, SOFAR 2200TL, SOFAR 2700TL

APPLICANT

Name	:	Shenzhen SOFAR SOLAR Co., Ltd.
Address	:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen City, Guangdong Province, P.R. China

TESTING LABORATORY

Name	:	SGS Tecnos, S.A. (Electrical Testing Laboratory)
Address	:	C/ Trespaderne, 29 - Edificio Barajas 1 28042 Madrid (Spain)
Conducted (tested) by	:	Alawn Yao (Project Engineer) Roger Hu (Project Engineer)
Approved by	:	Jacobo Tévar (Technical Reviewer)
Date of issue	:	2020/06/03
Number of pages	:	133

SGS Tecnos, S.A.
Laboratorio de Ensayos E&E

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Test Report Historical Revision:

Test Report Version	Date	Resume
2220/0177	2020/06/03	First issuance

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1. SCOPE

SGS Tecnos, S.A. (Electrical Testing Laboratory) has been contract by Shenzhen SOFAR SOLAR Co., Ltd. to perform the testing according the EN 50549 – 1: 2019: 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.

The tests offered at this test report evaluate the EUT compliance with the requirements of Type **B.**

2. GENERAL INFORMATION

2.1. TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed along between 15th April and 11th May of 2020 for the standard to EN 50549-1: 2019.

All the tests and checks have been performed at 25 ± 5 ºC, 96 ± 10 kPa and 50 ± 10 %RH.

SITE TEST

Name ..... : Shenzhen SOFAR SOLAR Co., Ltd.

Address ..... : 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen City, Guangdong Province, P.R. China

2.2. EQUIPMENT UNDER TESTING

Apparatus type ..... : Solar Grid-tied Inverter

Installation ..... : Fixed installation

Manufacturer ..... : Shenzhen SOFAR SOLAR Co., Ltd.

Trade mark ..... :

Model / Type reference ..... : SOFAR 3000TL

Serial Number ..... : ZA1ES028KAC000

Software Version ..... : V1.00

Rated Characteristics ..... : DC input: 100-500 V, Max. 13 A
AC output: 230 Vac, 50 Hz, 12.2 A (max.13 A), 2800 W

Date of manufacturing: 2019

Test item particulars

Input ..... : DC

Output ..... L/N/PE

Class of protection against electric shock ... : Class I

Degree of protection against moisture ..... : IP65

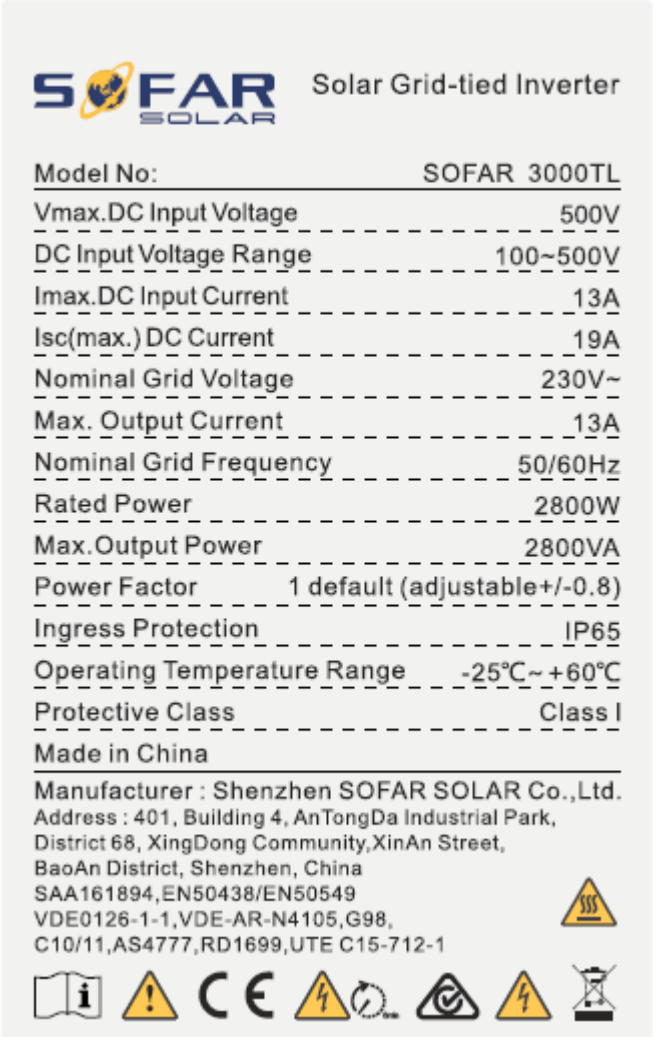
Type of connection to the main supply ..... : Sigle phase – Fixed installation

Cooling group ..... : Fans

Modular ..... : No

Internal Transformer ..... : No

Copy of marking plate (representative):



Note:

1. The above markings are the minimum requirements required by the safety standard. For the final production samples, the additional markings which do not give rise to misunderstanding may be added.
2. Label is attached on the side surface of enclosure and visible after installation.
3. Labels of other models are as the same with SOFAR 3000TL's except the parameters of rating.

Equipment under testing:

- SOFAR 3000TL

The variant models are:
- SOFAR 1100TL
- SOFAR 1600TL
- SOFAR 2200TL
- SOFAR 2700TL

The variant models have been included in this test report without tests because the following features don´t change regarding to the tested model:

- Same connection system and hardware topology.
- Same control algorithm.
- Output power within 1/√10 and 2 times of the rated output power of the EUT or Modular inverters.
- Same Firmware Version.

Following table shows the full ratings of the variant models:

Model Number	SOFAR 1100TL	SOFAR 1600TL	SOFAR 2200TL	SOFAR 2700TL	SOFAR 3000TL
Input (DC)					
Max. input voltage	450		500 Vd.c		
Max. input current	10 Ad.c.		13 Ad.c.		
Operating MPPT voltage range	90-450 Vd.c.		100-500 Vd.c.		
Full load DC Voltage Range	155-380 Vd.c.	160-380 Vd.c.	165-450 Vd.c.	205-450 Vd.c.	225-455 Vd.c.
Rated voltage	360V				
Ouput (AC)					
Rated grid voltage	L/N/PE, 230Va.c.				
Rated grid frequency	50Hz				
Rated output power	1500 W	1550 W	2100 W	2500 W	2800 W
Max. output power	1500 VA	1550 VA	2100 VA	2500 VA	2800 VA
Rated. Output Current **(*)**	6.5 Aa.c.	6.7 Aa.c.	9.1 Aa.c.	10.9 Aa.c.	12.2 Aa.c.
Max. Output Current	6.8 Aa.c.	7 Aa.c.	9.5 Aa.c.	11.5 Aa.c.	13 Aa.c.
Power factor	1default (adjustable +/- 0.8)				
Ambient temperature	-25 ℃ ~ 60 ℃				
Ingress protection	IP65				
Protective class	Class I				

(*) Output at 230 Vac @P_{rated}, these current values are used as "In" in this report.

The results obtained apply only to the particular sample tested that is the subject of the present test report. The most unfavorable result values of the verifications and tests performed are contained herein. Throughout this report a point (~~comma~~) is used as the decimal separator.

2.3. TEST EQUIPMENT LIST

From	No.	Equipment Name	Model No.	Equipment No.	Calibration Date	Equipment calibration due date
Sofarsolar	1	Digital oscilloscope	KEYSIGHT / DSOX3014T	MY57231269	2020/01/14	2021/01/13
	2	Digital oscilloscope	KEYSIGHT / DSO5014A	MY50070288	2020/01/14	2021/01/13
	3	Voltage probe	SANHUA / SI-9110	152627	2020/01/14	2021/01/13
	4	Voltage probe	SANHUA / SI-9110	111134	2020/01/14	2021/01/13
	5	Voltage probe	SANHUA / SI-9110	111152	2020/01/14	2021/01/13
	6	Power analyzer	ZLG / PA3000	PA3004-P0004-1422	2020/01/14	2021/01/13
	7	Power analyzer	YOKOGAWA / WT3000	91N610888	2020/01/14	2021/01/13
	8	Power analyzer	ZLG / PA5000H	C82029090820021 10002	2020/03/02	2021/03/01
	9	Current probe	CYBERTEK / CP1000A	C181000922	2020/01/14	2021/01/13
	10	Current probe	CYBERTEK / CP1000A	C181000925	2020/01/14	2021/01/13
	11	Current probe	CYBERTEK / CP1000A	C181000929	2020/01/14	2021/01/13
	12	Current probe	CYBERTEK / CP1000A	C181000931	2020/01/14	2021/01/13
	13	Temperature & Humidity meter	Anymeters / TH101B	ZB-WSDJ-001	2020/01/14	2021/01/13
SGS	11	True RMS Multimeter	Fluke / 289C	GZE012-53	2020/1/14	2021/1/13

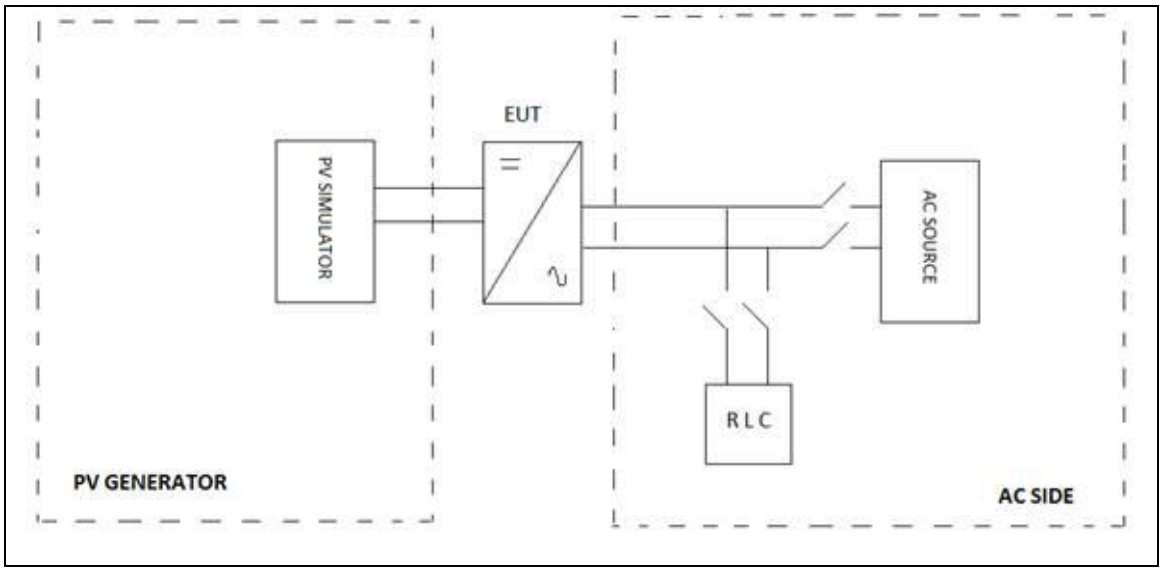
2.4. MEASUREMENT UNCERTAINTY

Associated uncertainties through measurements showed in this report are the maximum allowable uncertainties.

Magnitude	Uncertainty
Voltage measurement	±1.5 %
Current measurement	±2.0 %
Frequency measurement	±0.2 %
Time measurement	±0.2 %
Power measurement	±2.5 %
Phase Angle	±1 º
Temperature	±3 ºC
Note1: Measurements uncertainties showed in this table are maximum allowable uncertainties. The measurement uncertainties associated with other parameters measured during the tests are in the laboratory at disposal of the petitioner. Note2: Where the standard requires lower uncertainties that those in this table. Most restrictive uncertainty has been considered.	

2.5. TEST SET UP OF THE DIFFERENT STANDARD

Below is the simplified construction of the test set up.



Different equipment have been used to take measures as it shows in chapter 2.3. Current and voltage clamps have been connected to the inverter input / output for all the tests.

All the tests described in the following pages have used this specified test setup.

The test bench used includes:

EQUIPMENT	MARK / MODEL	RATED CHARACTERISTICS	OWNER / ID.CODE
AC source	Kwell / AFG-S-33800	Voltage: 0-600 V 750 kVA	Sofarsolar / EP-026
PV source	Kwell / TVS-630 kW	Voltage: 0 - 1000 V 630 kW	Sofarsolar / EP-027
RLC load	Qunlin / ACLT3820H	68 kW, 68 kVAr	Sofarsolar / EP-029

2.6. DEFINITIONS

EUT	Equipment Under Testing	Hz	Hertz
A	Ampere	V	Volt
Un	Nominal Voltage	p.u	Per unit
In	Nominal Current	Pn	Rated Active Power
Ia	Active Current	Qn	Rated Reactive Power
Ir	Reactive Current	Sn	Rated Apparent Power
MV	Medium Voltage	THC	Total Harmonic Current
LV	Low Voltage	TDD	Total Demand Distortion
UVRT	Under-Voltage Ride Through	I_h	Harmonic Current
OVRT	Over-Voltage Ride Through	Plt	Severity of Flicker Long-Term
Pst	Severity of Flicker Short-Term	ms	Millisecond
dc	Maximum Variation of Voltage	s	Second
d max	Maximum Absolute Value of Voltage Variation	min	Minute
		P	Active Power
fn	Nominal frequency	Q	Reactive Power
IGBT	Insulated-Gate Bipolar Transistor	PF	Power Factor
RMS	Root Mean Square	Nr.	Number
$S_{k,fic}$	Short-circuit apparent power	POC	Point of Connection
AC	Alternating Current	Meas.	Measured
DC	Direct Current	Des.	Desired
DSO	Distribution System Operator	PGU	Power Generating Unit
EESS	Electrical energy storage system	P_D	Design active power
EES	Electrical energy storage	P_M	Momentary active power
Pmax	Maximum active power	Smax	Maximum apparent power
P_A	Available active power		

3. RESUME OF TEST RESULTS

INTERPRETATION KEYS

Test object does meet the requirement ..... **P** Pass
Test object does not meet the requirement..... **F** Fails
Test case does not apply to the test object..... **N/A** Not applicable
To make a reference to a table or an annex. ..... See additional sheet
To indicate that the test has not been realized..... **N/R** Not realized

EN 50549-1:2019 – Requirements for plant category Type B have been considered.				
REPORT SECTION	**STANDARD SECTION**	**CHAPTER OF THE STANDARD**	**Plant category**	**Result**
4.1	4.4	Normal operating range	--	--
4.1.1	4.4.2	Operating frequency range	≥ A	P
4.1.2	4.4.3	Minimal requirement for active power delivery at underfrequency	≥ A	P
4.1.3	4.4.4	Continuous operating voltage range	≥ A	P
4.2	4.5	Immunity to disturbances	≥ A	P
4.2.1	4.5.2	Rate of change of frequency (ROCOF) immunity	≥ A	P
4.2.2	4.5.3	Under-voltage ride through (UVRT)	B	P
4.2.3	4.5.4	Over-voltage ride through (OVRT)	≥ A	P
4.3	4.6	Active response to frequency deviation	≥ A	P
4.3.1	4.6.1	Power response to overfrequency	≥ A	P
4.3.2	4.6.2	Power response to underfrequency	≥ A	P
4.4	4.7	Power response to voltage changes	≥ A	P
4.4.1 and 4.4.2	4.7.2	Voltage support by reactive power	≥ A	P
4.4.3	4.7.3	Voltage related active power reduction	≥ A	P
4.4.4	4.7.4	Short circuit current requirements on generating plants	B	P
4.5	4.8	EMC and power quality	≥ A	N/R
4.5.1	4.8	Harmonic emissions	≥ A	P
4.5.2	4.8	Flicker and voltage fluctuations	≥ A	P
4.6	4.9	Interface protection	≥ A	P
4.6.1	4.9.3	Requirements on voltage and frequency protection	≥ A	P
4.6.2	4.9.4	Means to detect island situation	≥ A	P
4.6.3	4.9.5	Digital input to the interface protection	≥ A	P
4.7	4.10	Connection and starting to generate electrical power	≥ A	P
4.7.1	4.10.2	Automatic reconnection after tripping	≥ A	P
4.7.2	4.10.3	Starting to generate electrical power	≥ A	P
4.7.3	4.10.4	Synchronization	≥ A	P
4.8	4.11	Ceasing and reduction of active power on set point	≥ A	P
4.8.1	4.11.1	Ceasing active power	≥ A	P
4.8.2	4.11.2	Reduction of active power on set point	B	P
4.9	4.13	Requirements regarding single fault tolerance of interface protection system and interface switch	≥ A	N/R

Note: The declaration of conformity has been evaluated taking into account the IEC Guide 115

4. TEST RESULTS

4.1. NORMAL OPERATING RANGE

4.1.1. Operating frequency range

The test has been done according to the clause 4.4.2 of the standard, the requirement as following:

Table 1 — Minimum time periods for operation in underfrequency and overfrequency situations

Frequency Range	Time period for operation Minimum requirement	Time period for operation stringent requirement
47,0 Hz – 47,5 Hz	not required	20 s
47,5 Hz – 48,5 Hz	30 min [a]	90 min
48,5 Hz – 49,0 Hz	30 min [a]	90 min [a]
49,0 Hz – 51,0 Hz	Unlimited	Unlimited
51,0 Hz – 51,5 Hz	30 min [a]	90 min
51,5 Hz – 52,0 Hz	not required	15 min

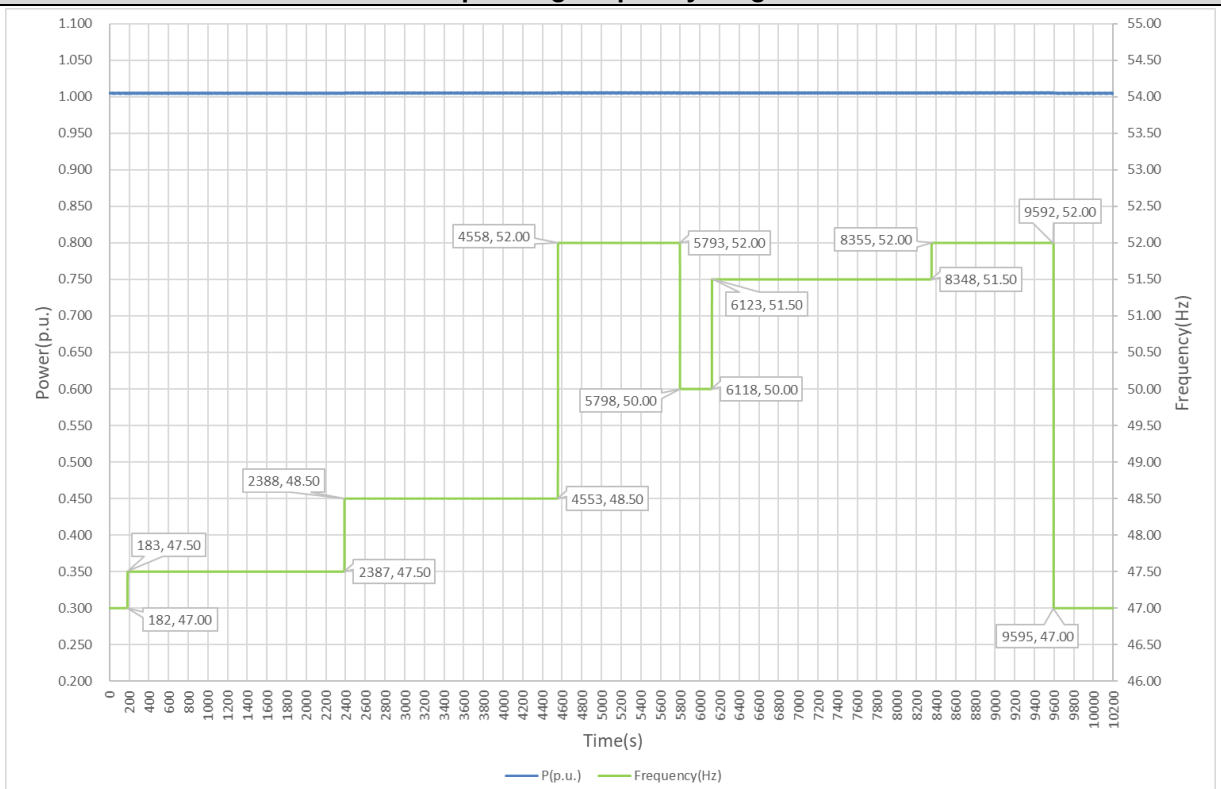
[a] Respecting the legal framework, it is possible that longer time periods are required by the responsible party in some synchronous areas.

"Time period for operation, Minimum requirement" (first column of the table) has been considered for this test.

In order to verify this function, parameter settings as in the following table have been considered to perform the test. Time requirements considered are the "minum requirement" according to Table 1 from the standard:

Steps	f (Hz) setting	Time requirement	f measured (Hz)	Time measured (min)	Power measured (p.u.)
1	47.0	> 30 s	47.00	3.0	1.005
2	47.5	> 30 min	47.50	36.7	1.005
3	48.5	> 30 min	48.50	36.1	1.005
4	52.0	> 15 min	52.00	20.6	1.005
5	50.0	> 1 min	50.00	5.3	1.005
6	51.5	> 30 min	51.50	37.1	1.005
7	52.0	--	52.00	20.6	1.005

Operating frequency range



4.1.2. Minimal requirement for active power delivery at underfrequency

The test has been done according to the clause 4.4.3 of the standard, the requirement as following:

A generating plant shall be resilient to the reduction of frequency at the point of connection while reducing the maximum active power as little as possible.

The admissible active power reduction due to underfrequency is limited by the full line in Figure 5 of the standard and is characterized by a maximum allowed reduction rate of 10 % of Pmax per 1 Hz for frequencies below 49.5 Hz.

It is possible that a more stringent power reduction characteristic is required by the responsible party. Nevertheless this requirement is expected to be limited to an admissible active power reduction represented by the dotted line in Figure 5 which is characterised by a reduction rate of 2 % of the maximum power Pmax per 1 Hz for frequencies below 49 Hz.

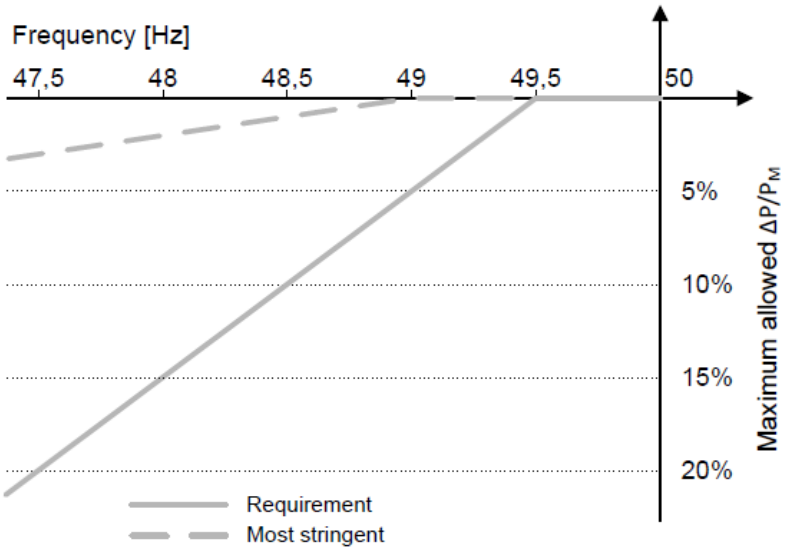
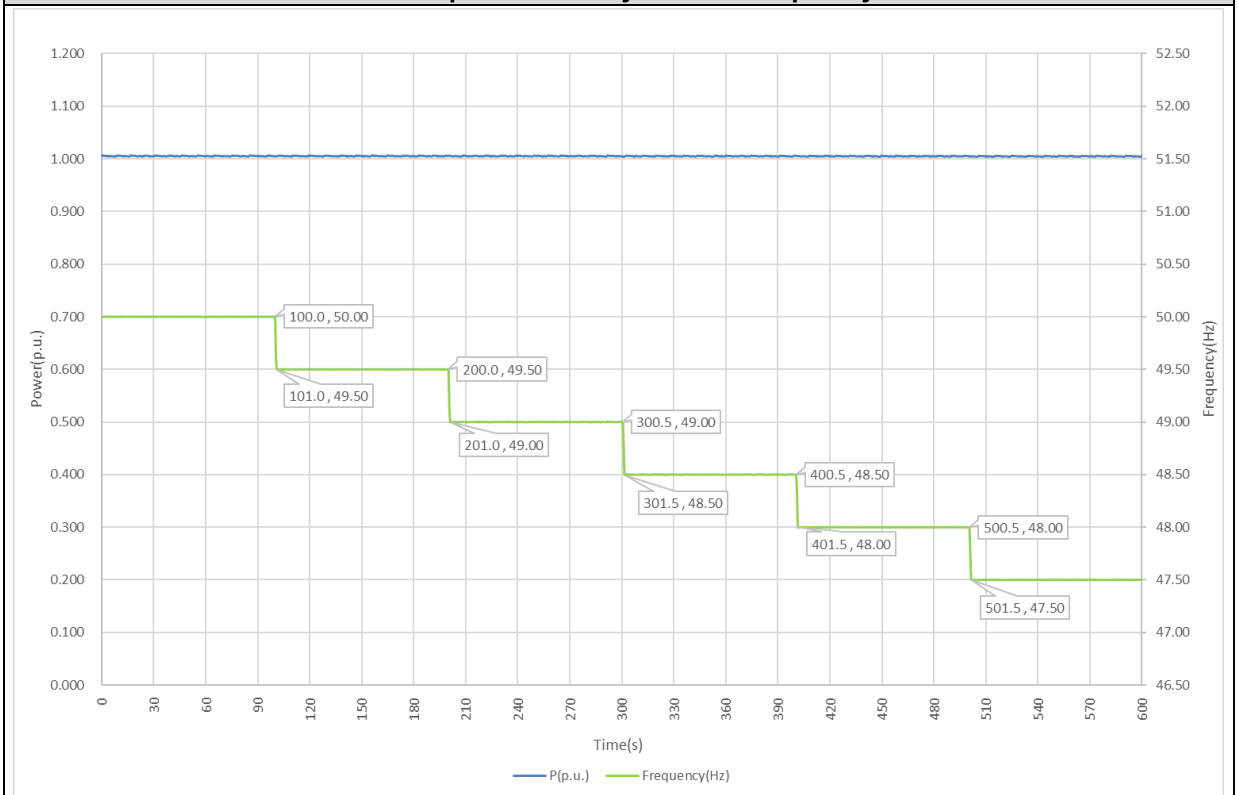


Figure 5 — Maximum allowable power reduction in case of underfrequency

As defined by manufacturer, the power will not reduce when the frequency is below 49.5Hz

Step	f (Hz)	f meas. (Hz)	T (s)	T meas. (s)	P desired (p.u.)	P Meas. (p.u.)	P deviation (p.u.)
1	50.00 ± 0.05	50.00	> 60	100.0	1.000	1.006	0.006
2	49.50 ± 0.05	49.50	> 60	99.0	1.000	1.006	0.006
3	49.00 ± 0.05	49.00	> 60	99.5	1.000	1.006	0.006
4	48.50 ± 0.05	48.50	> 60	99.0	1.000	1.005	0.005
5	48.00 ± 0.05	48.00	> 60	99.0	1.000	1.005	0.005
6	47.50 ± 0.05	47.50	> 60	98.5	1.000	1.005	0.005

Active power delivery at underfrequency



4.1.3. Continuous operating voltage range

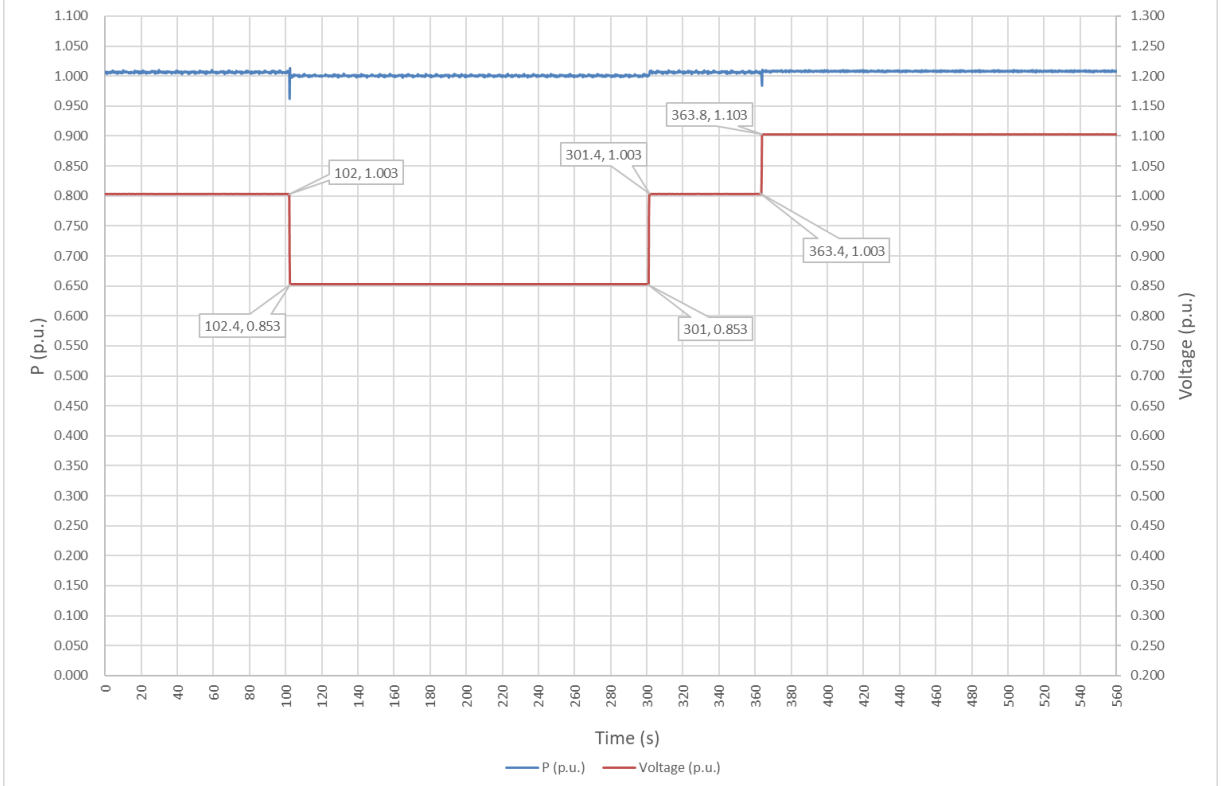
The test has been done according to the clause 4.4.4 of the standard, the requirement as following:

The generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85 %Un to 110 %Un.

In order to verify this function, the parameter setting as following to perform the test:

Step	Voltage (p.u.)	P desired (p.u.)	Time requirement (s)	Time measured (s)	P meas. (p.u.)
1	1.003	1.000	> 60	102.0	1.007
2	0.853	1.000	> 120	198.6	1.001
3	1.003	1.000	> 5	62.0	1.007
4	1.103	1.000	> 120	196.2	1.008

Continuous operating voltage range



4.2. IMMUNITY TO DISTURBANCES

4.2.1. Rate of change of frequency (ROCOF) immunity

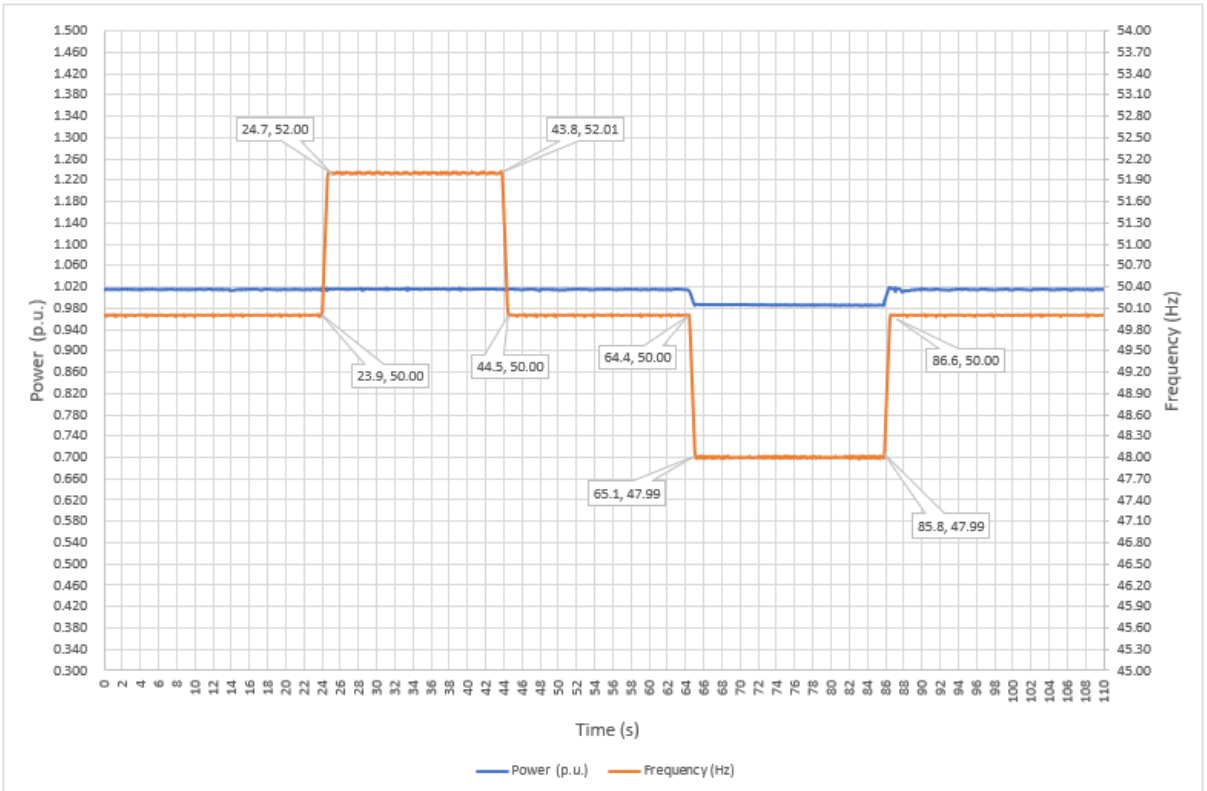
The test has been done according to the clause 4.5.2 of the standard, the requirement as following:

- **Non-synchronous generating technology: at least 2 Hz/s**

The ROCOF immunity is defined with a sliding measurement window of 50 ms as following:

Steps	f (Hz)	ROCOF requirement (Hz/s)	Step time	Measured Frequency (Hz)	Measured step change time (s)	ROCOF meas. (Hz/s)	Disconnection
1	50.00 ± 0.05	N/A	> 10 s	50.00	--	--	No
2	52.00 ± 0.05	> 2	> 10 s	52.00	0.80	2.50	No
3	50.00 ± 0.05	> 2	> 10 s	50.00	0.70	-2.86	No
4	48.00 ± 0.05	> 2	> 10 s	48.00	0.70	-2.86	No
5	50.00 ± 0.05	> 2	> 10 s	50.00	0.80	2.50	No

Rate of change of frequency (ROCOF) immunity



4.2.2. Under-voltage ride through (UVRT)

The requirements from clause 4.5.3 of the standard apply.

4.2.2.1. No load Test

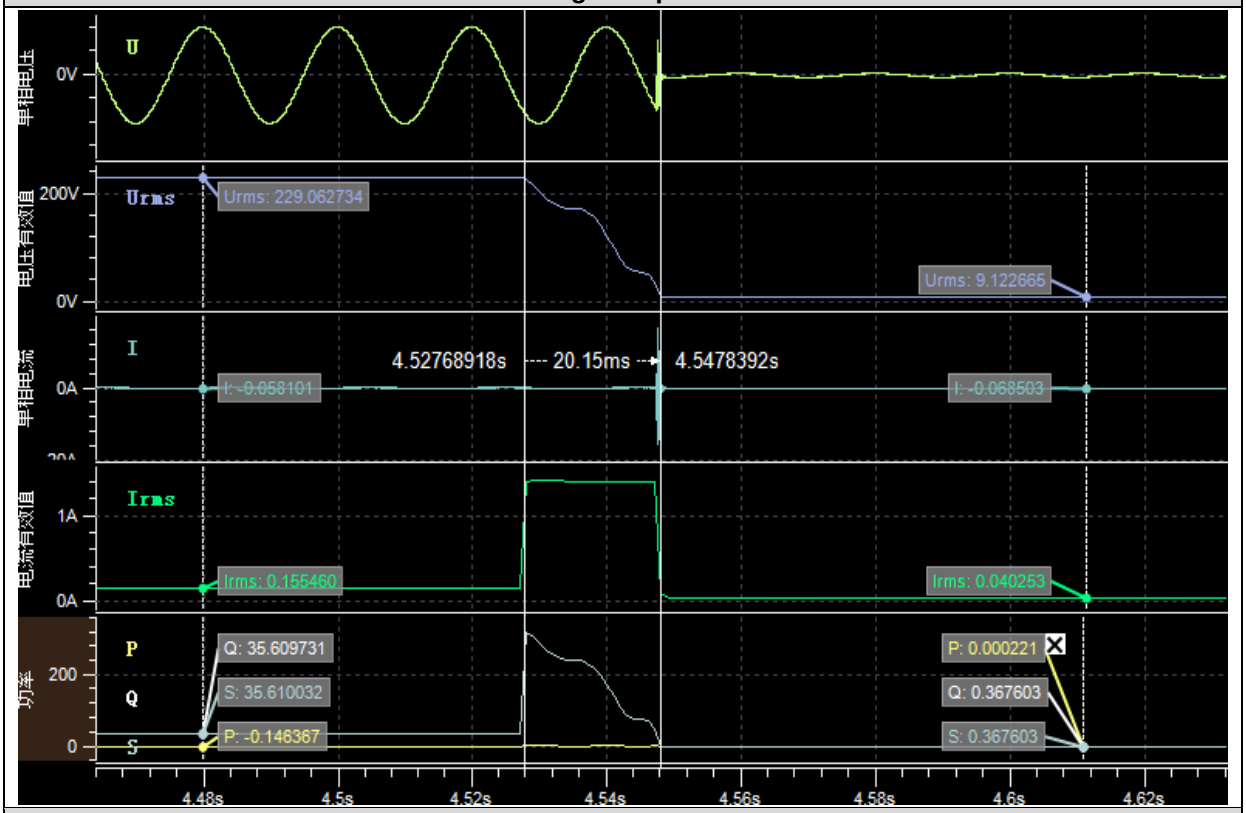
Test results of different no-load cases performed are offered below:

No Load							
Phase type	**Residual voltage desired (%Un)**	**Voltage measured (%Un)**	**Voltage drop time (ms)**	**Dip time desired (ms)**	**Time measured (ms)**	**Power recovery time (ms)**	**Voltage after recovery (%Un)**
L-N	0-5	4.0	20	≥ 400	401	--	99.6
L-N	25	24.9	20	≥ 1000	1002	--	99.6
L-N	50	49.8	20	≥ 1850	1854	--	99.6
L-N	75	74.7	19	≥ 3000	3006	--	99.6

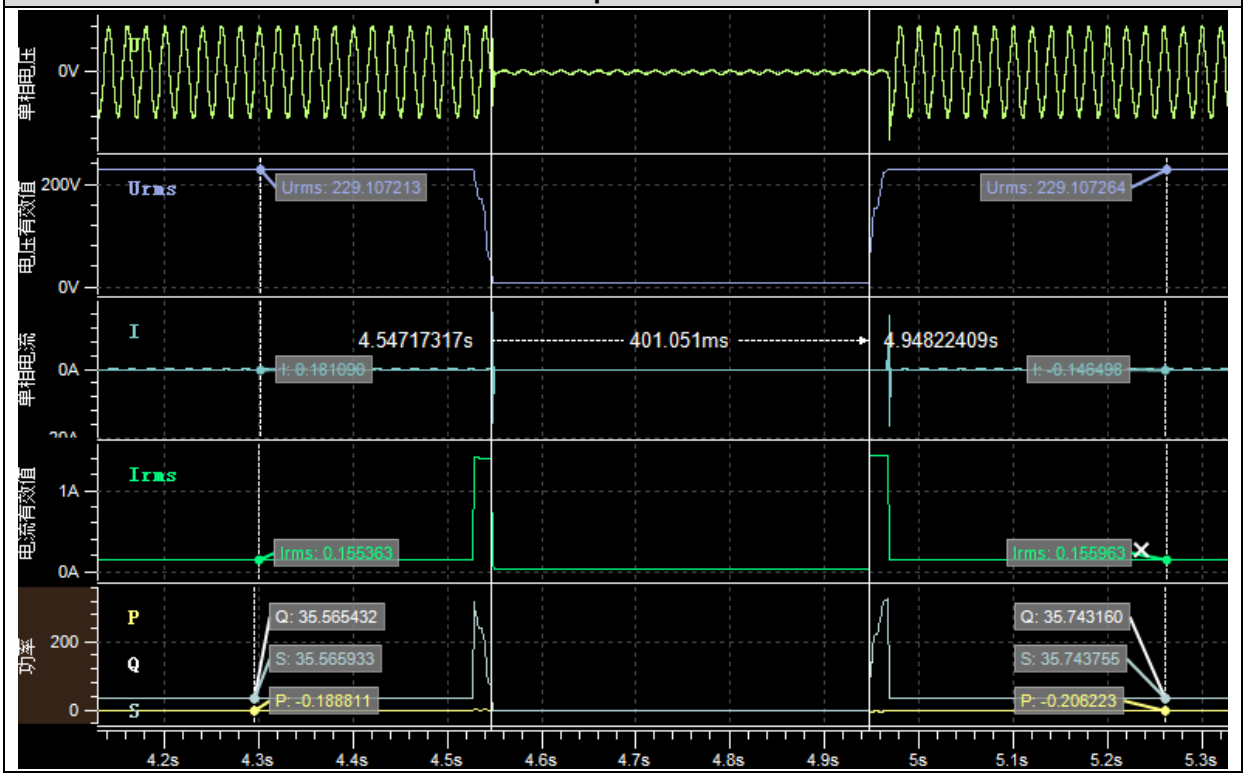
Test results are graphically represented at following pages.

No Load	Residual voltage: 0~5 %Un

Voltage Drop Time

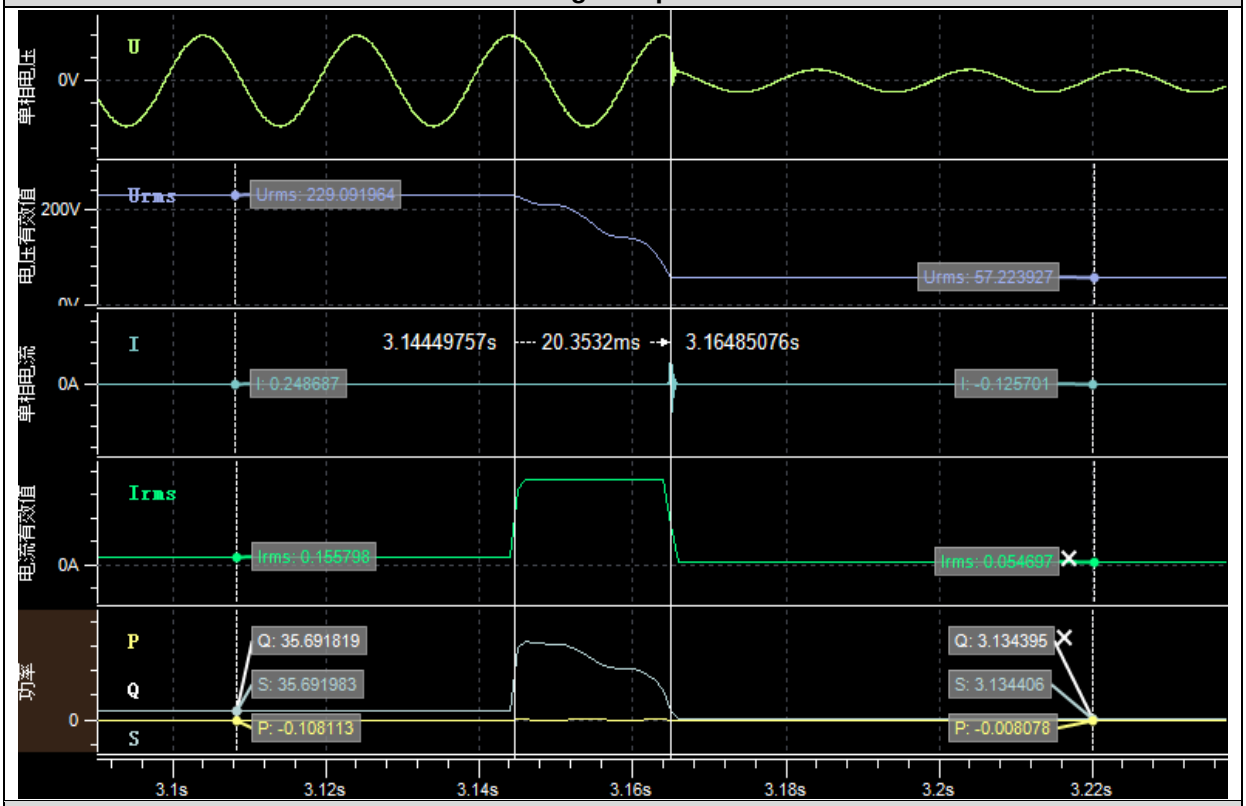


Dip Time

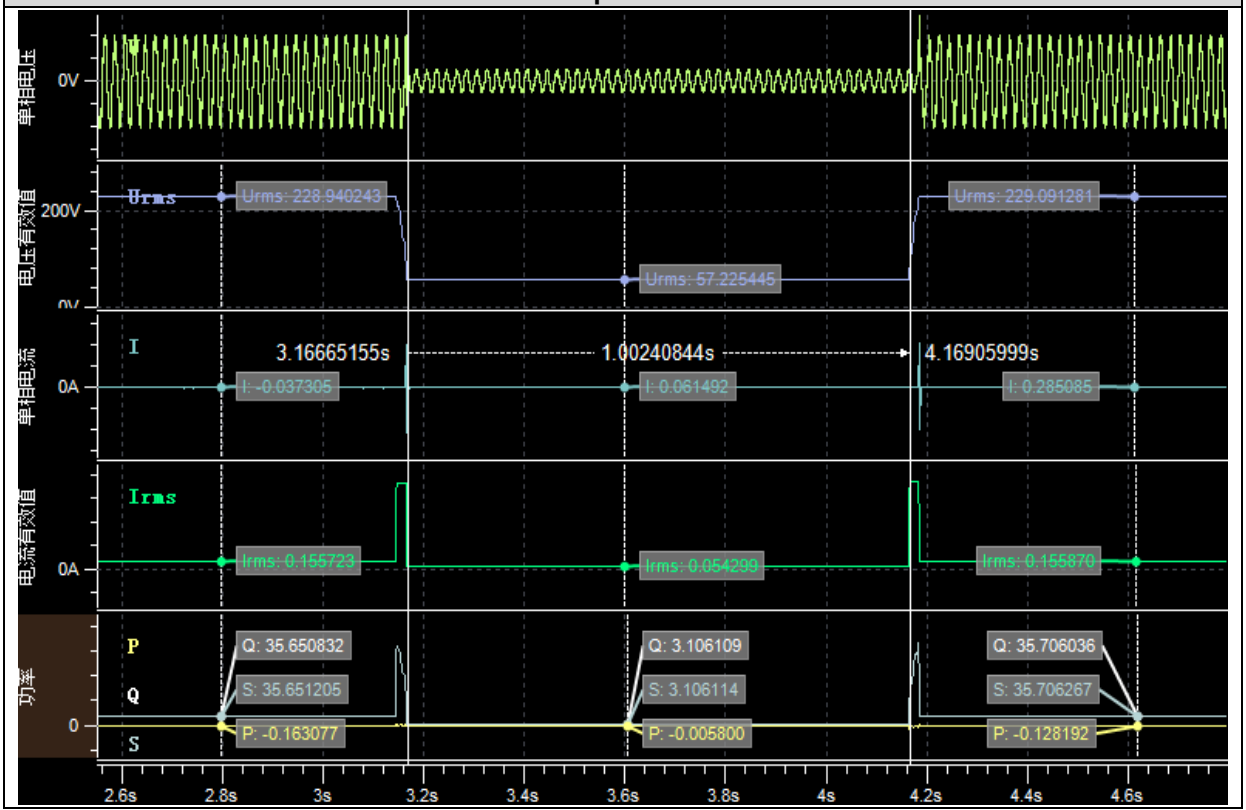


No Load	Residual voltage: 25 %Un

Voltage Drop Time

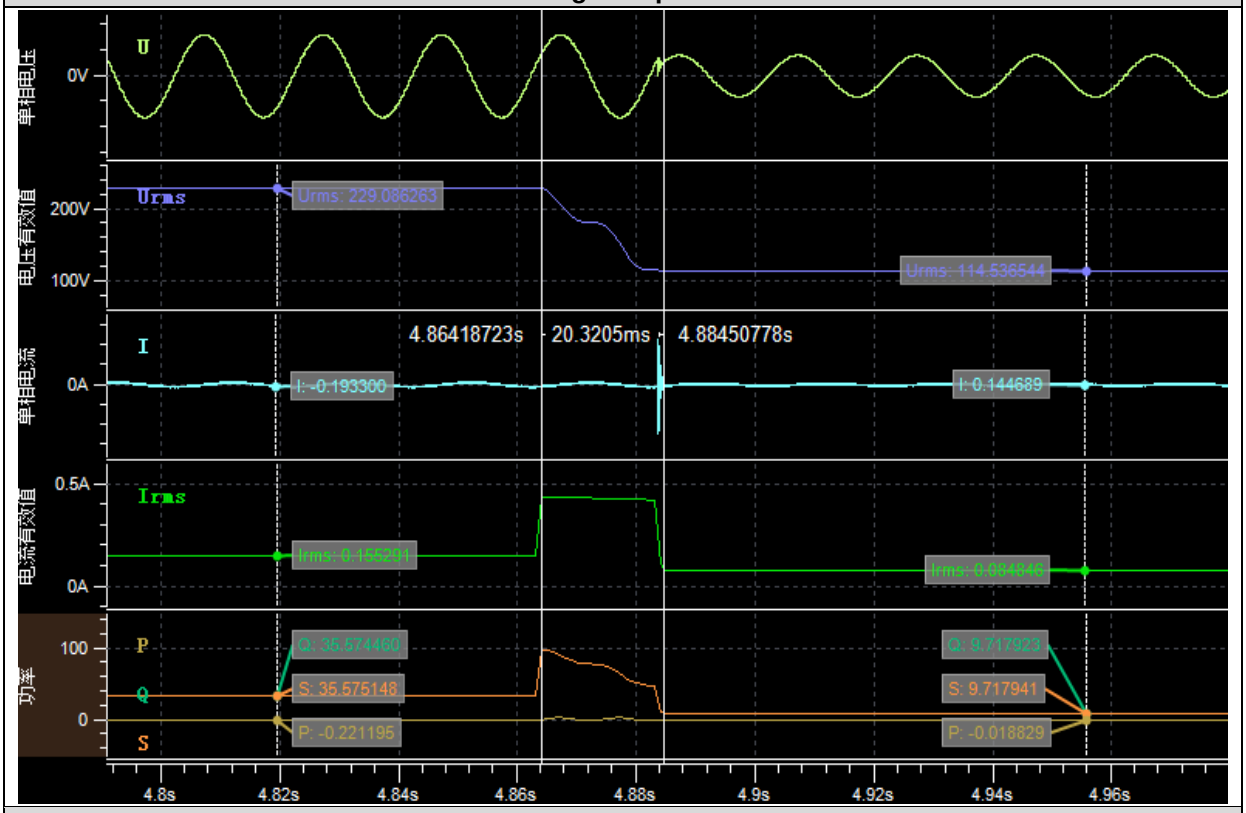


Dip Time

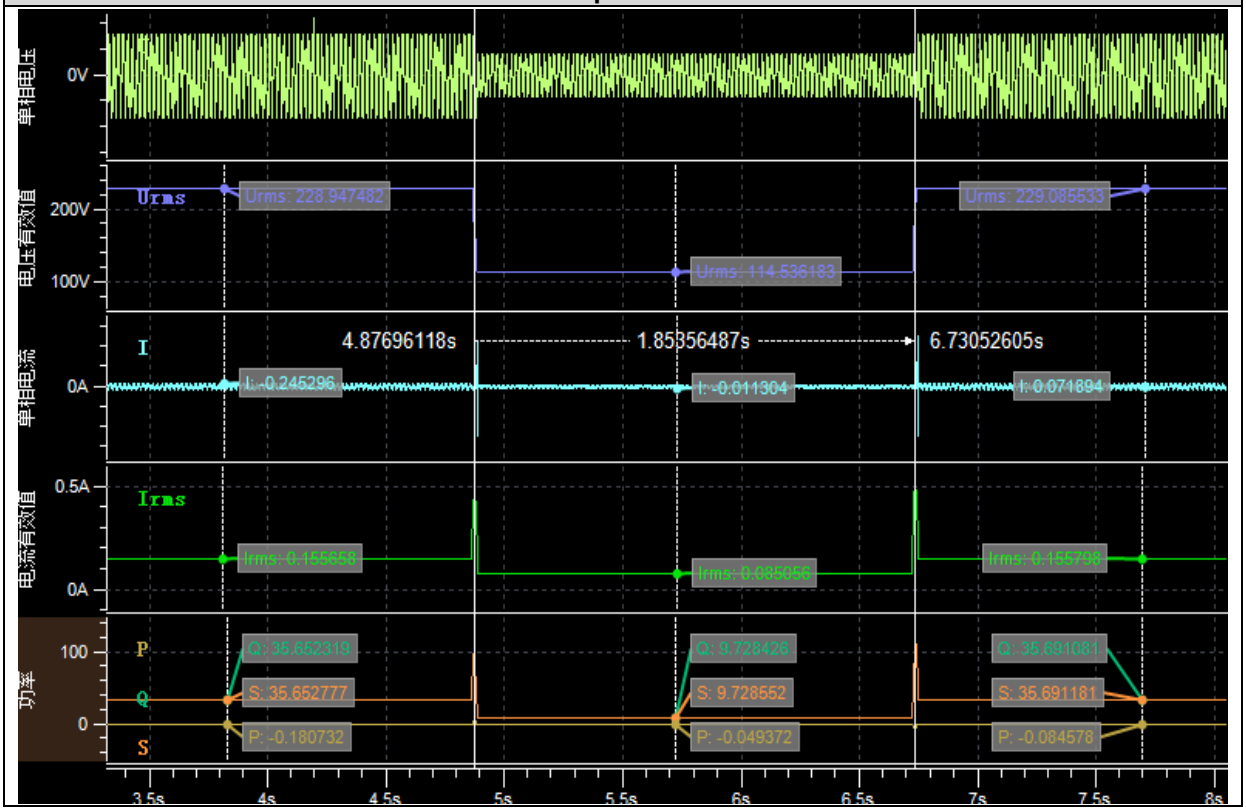


No Load	Residual voltage: 50 %Un

Voltage Drop Time

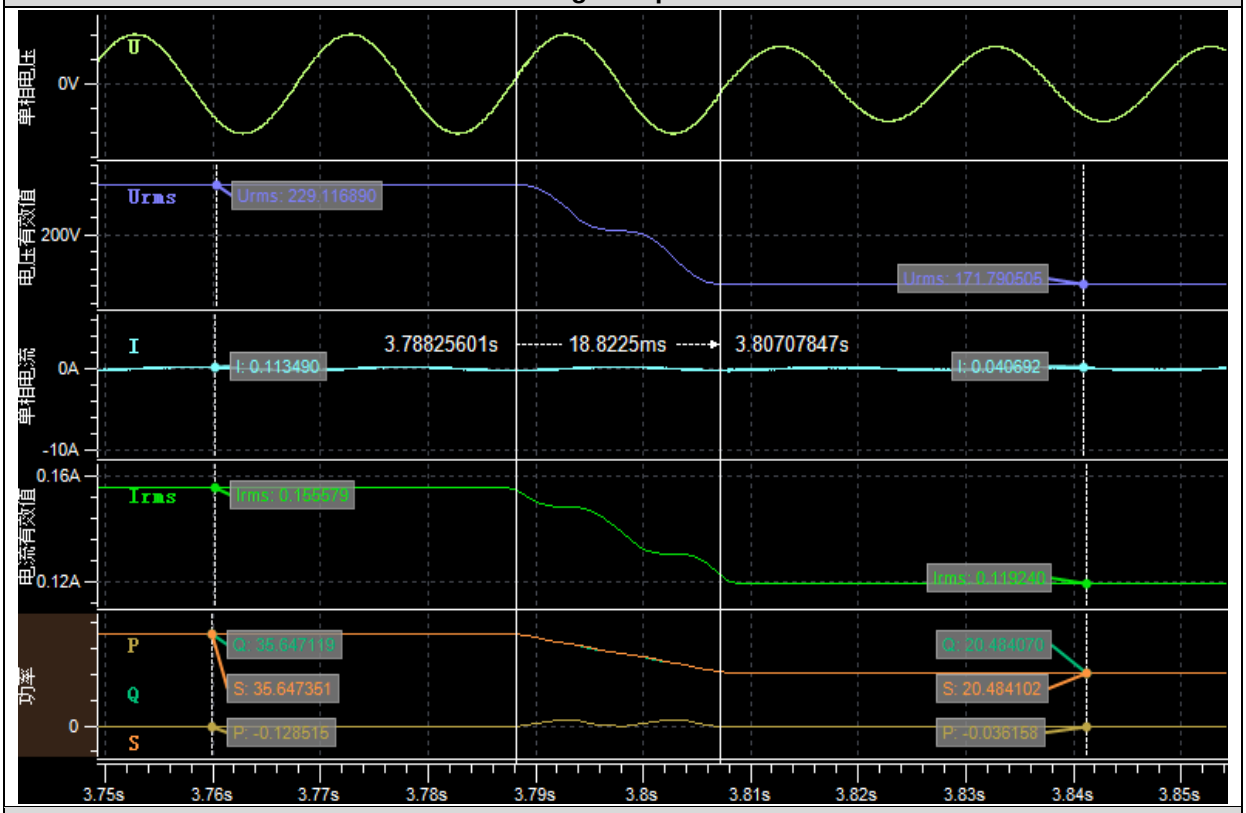


Dip Time

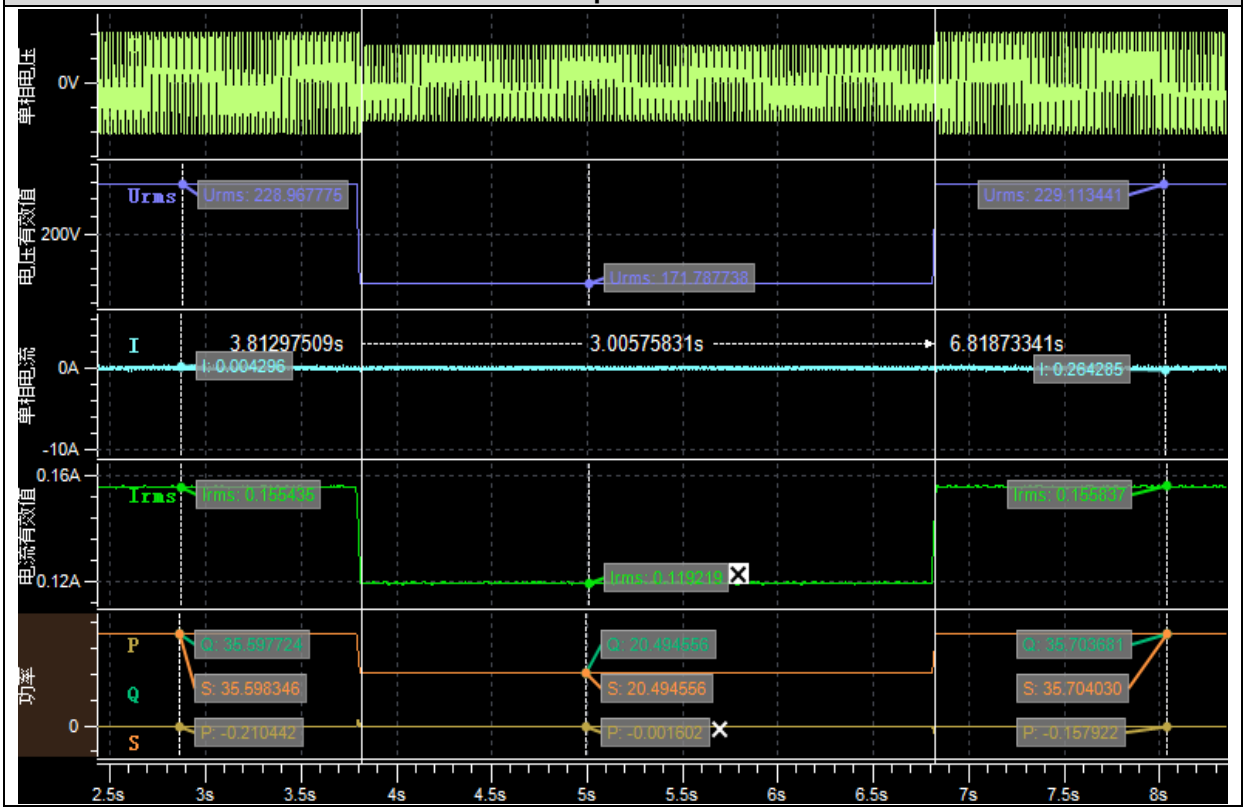


No Load	Residual voltage: 75 %Un

Voltage Drop Time



Dip Time



4.2.2.2. Load Tests: Partial load (20 %Pn)

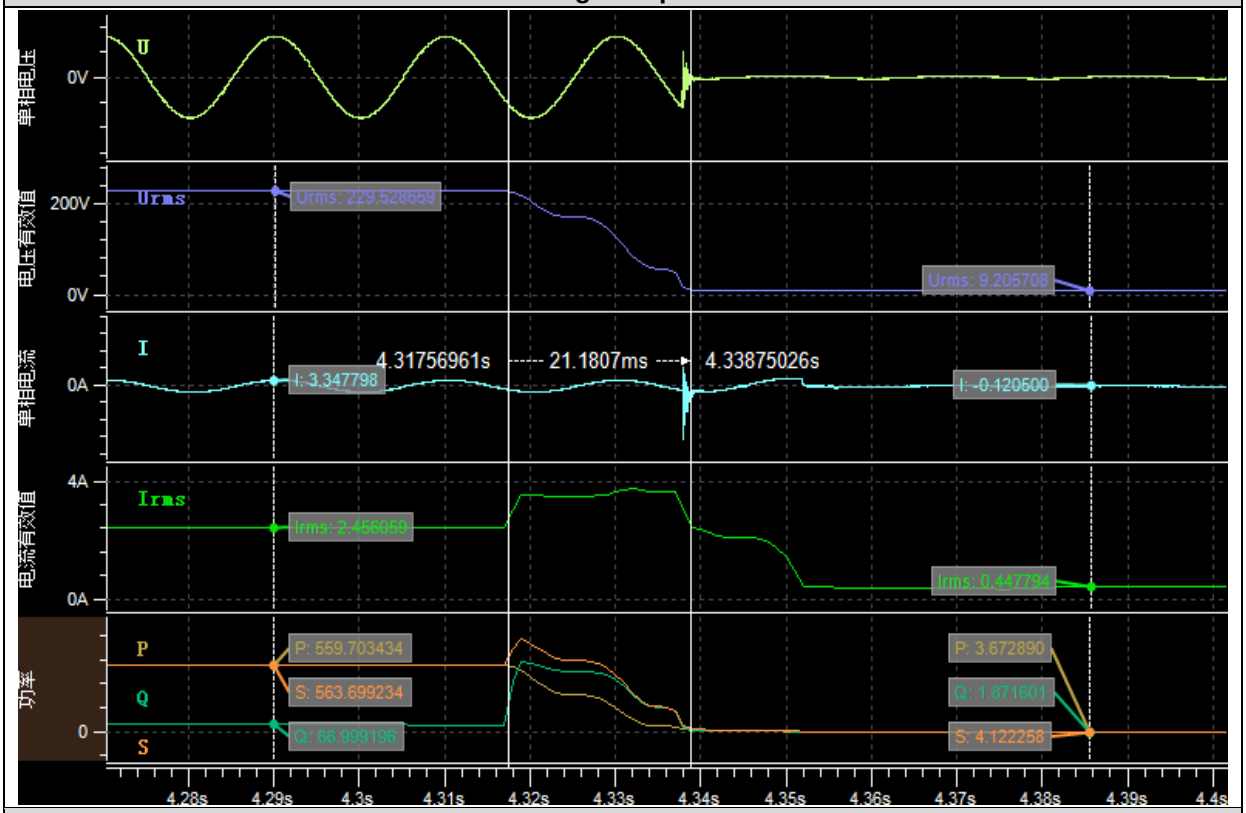
Test results of different partial load cases performed are offered below:

20 %Pn Load							
Phase type	**Residual voltage desired (%Un)**	**Voltage measured (%Un)**	**Voltage drop time (ms)**	**Dip time desired (ms)**	**Time measured (ms)**	**Power recovery time (ms)**	**Voltage after recovery (%Un)**
L-N	0-5	4.0	21	≥ 400	403	46	99.6
L-N	25	24.9	21	≥ 1000	1004	20	99.8
L-N	50	49.8	19	≥ 1850	1854	37	99.8
L-N	75	74.7	20	≥ 3000	3010	36	99.8

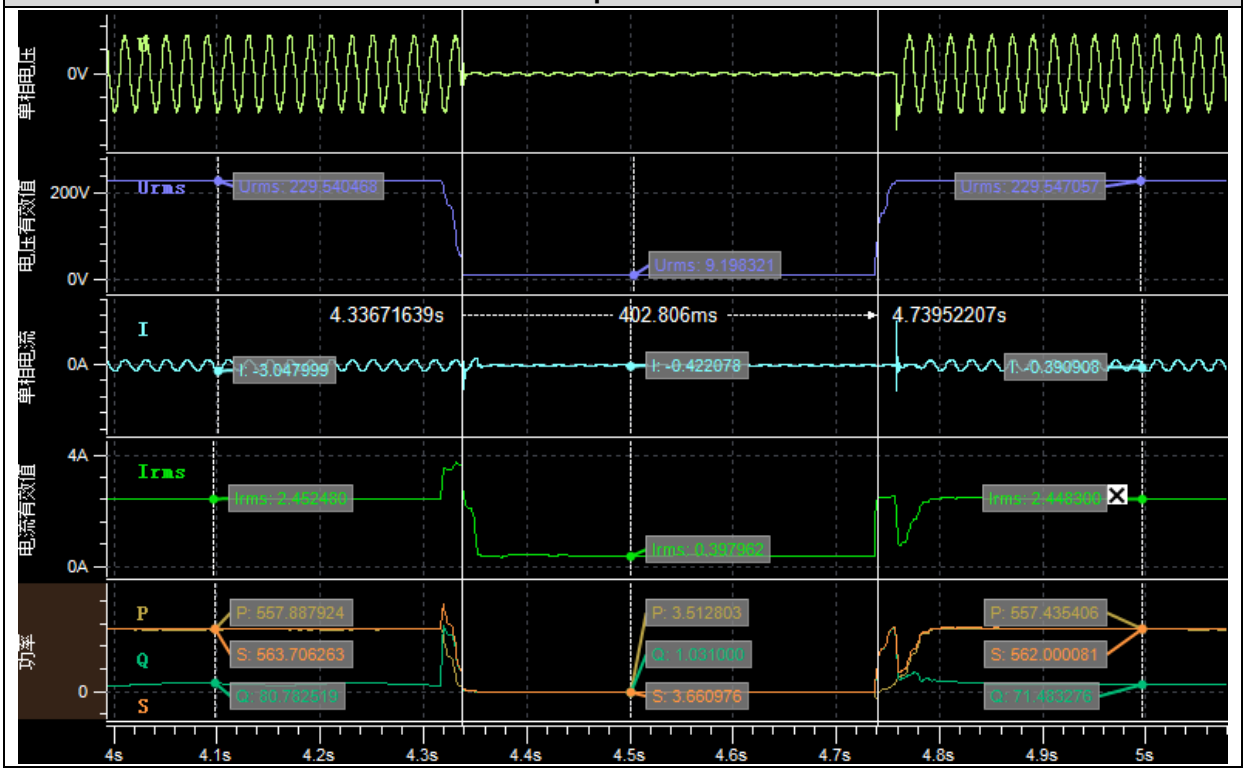
Test results are graphically represented below.

20 %Pn Load	Residual voltage: 0~5 %Un

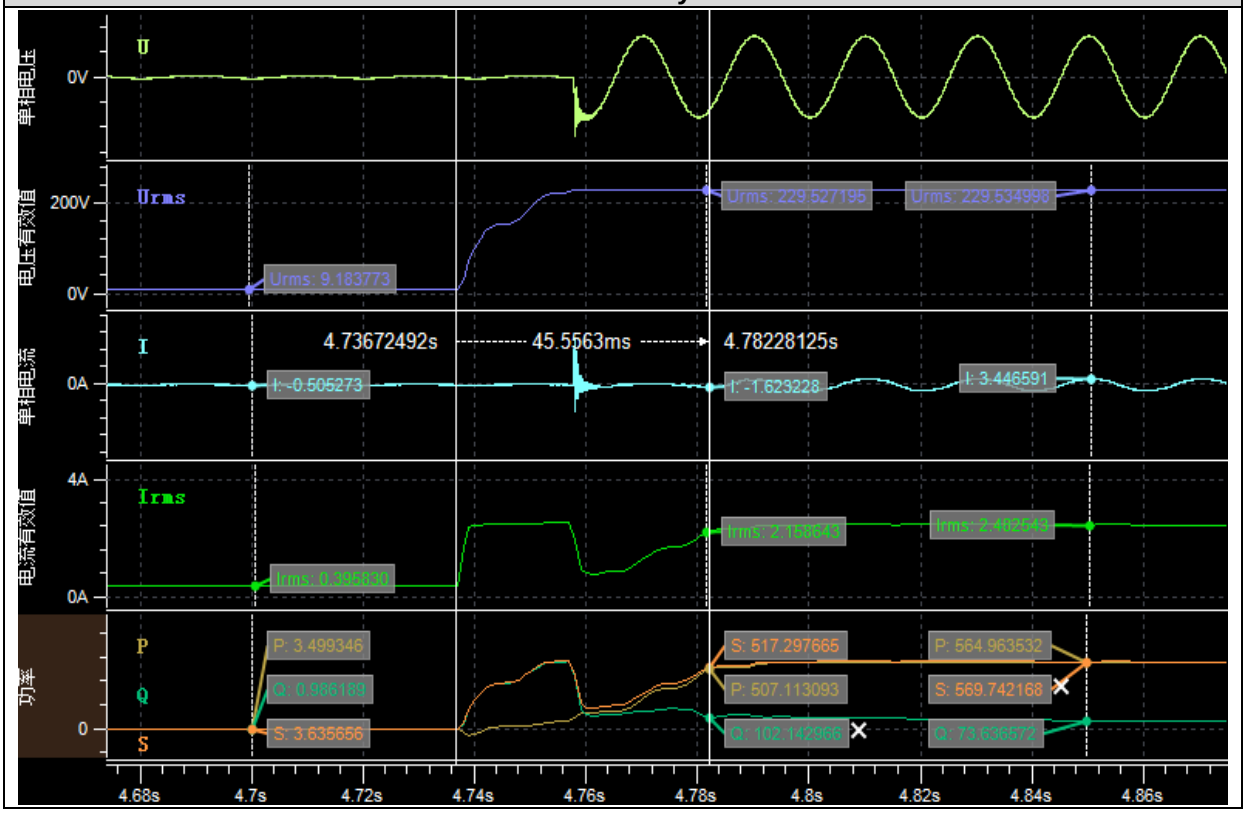
Voltage Drop time



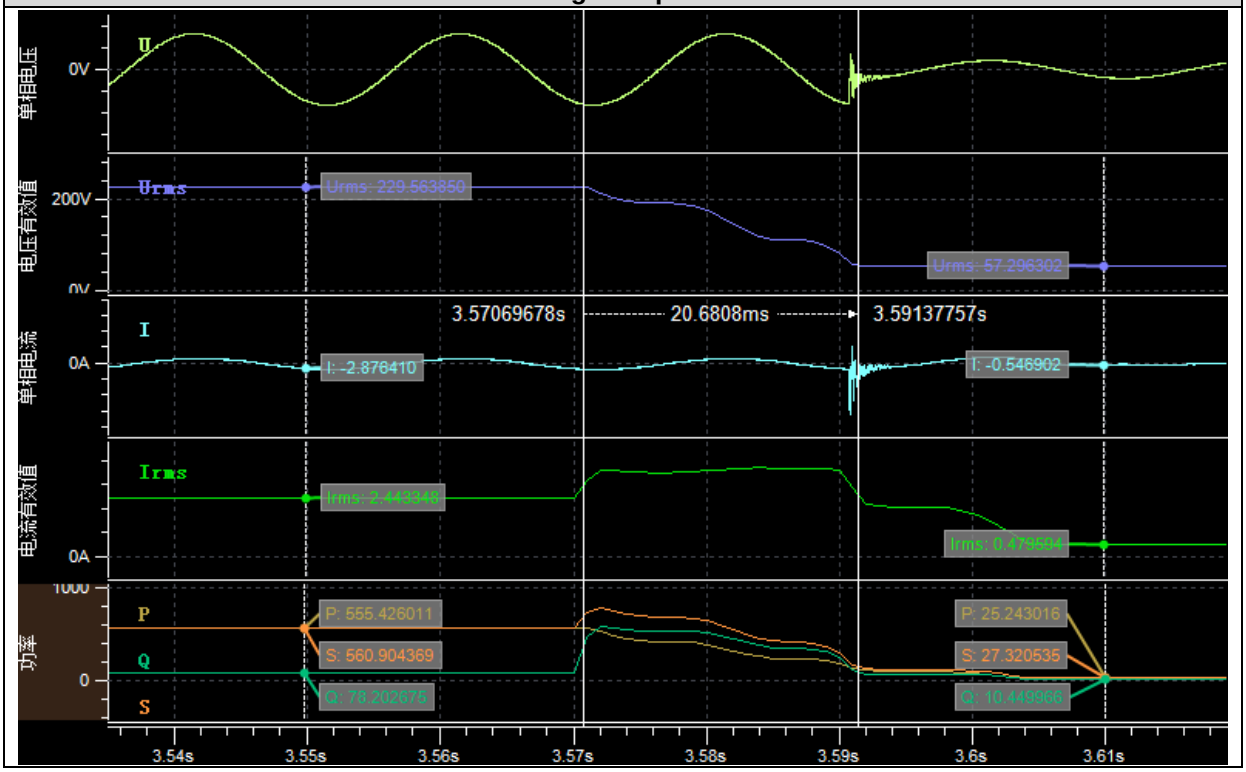
Dip Time



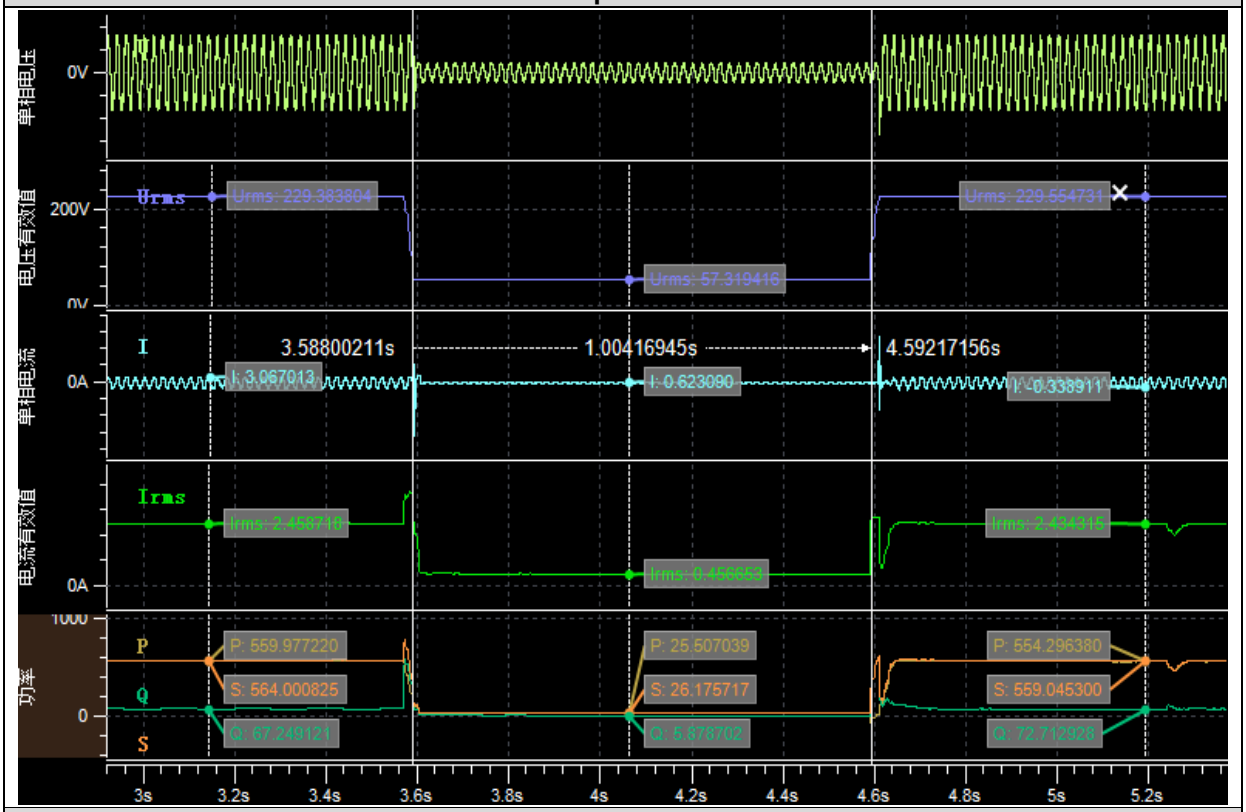
Power Recovery Time



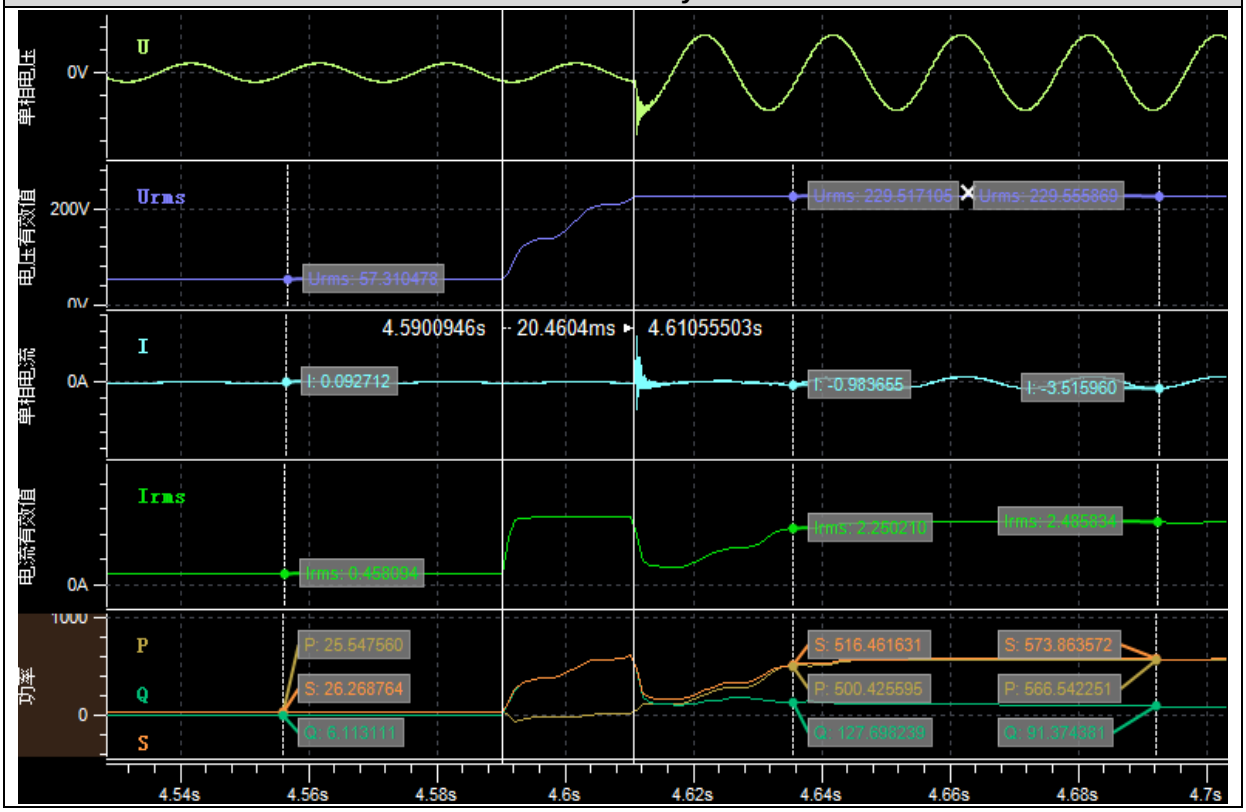
20 %Pn Load	Residual voltage: 25 %Un
Voltage Drop Time	



Dip Time

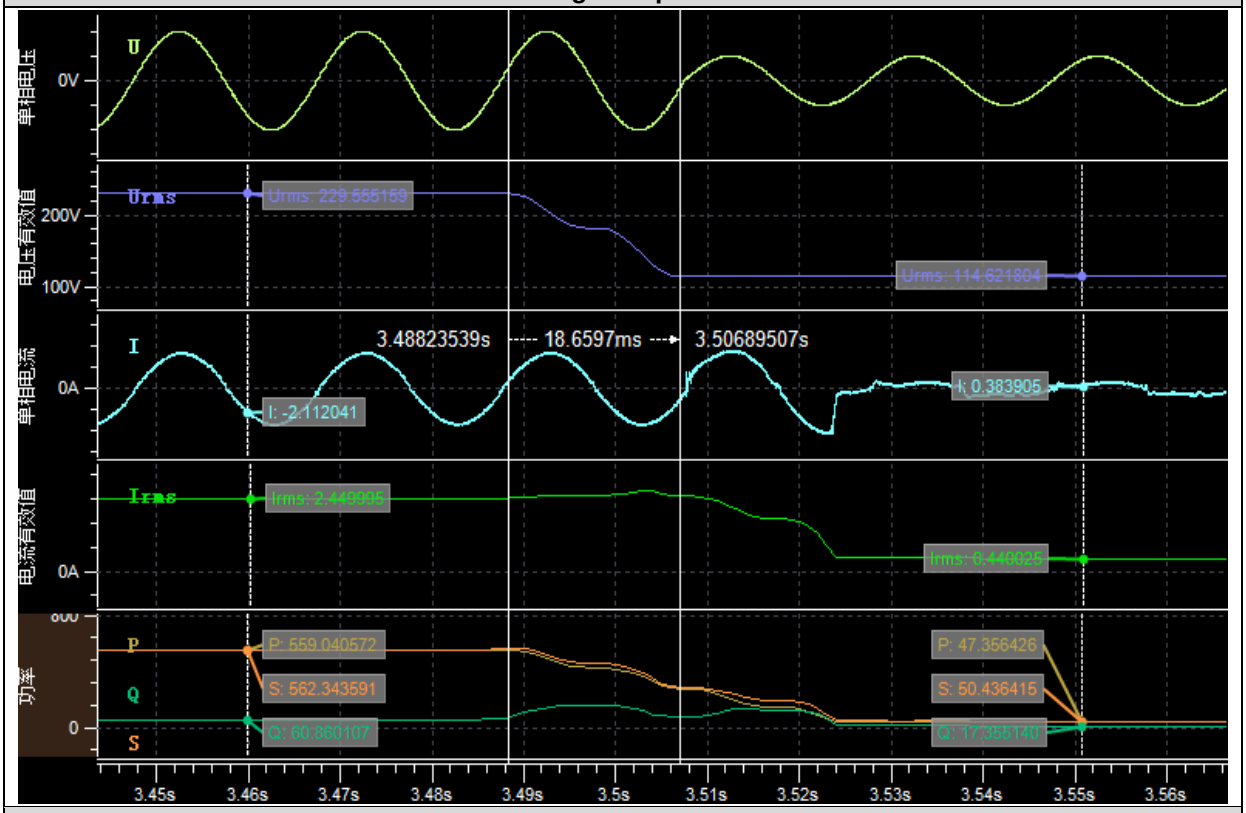


Power Recovery time

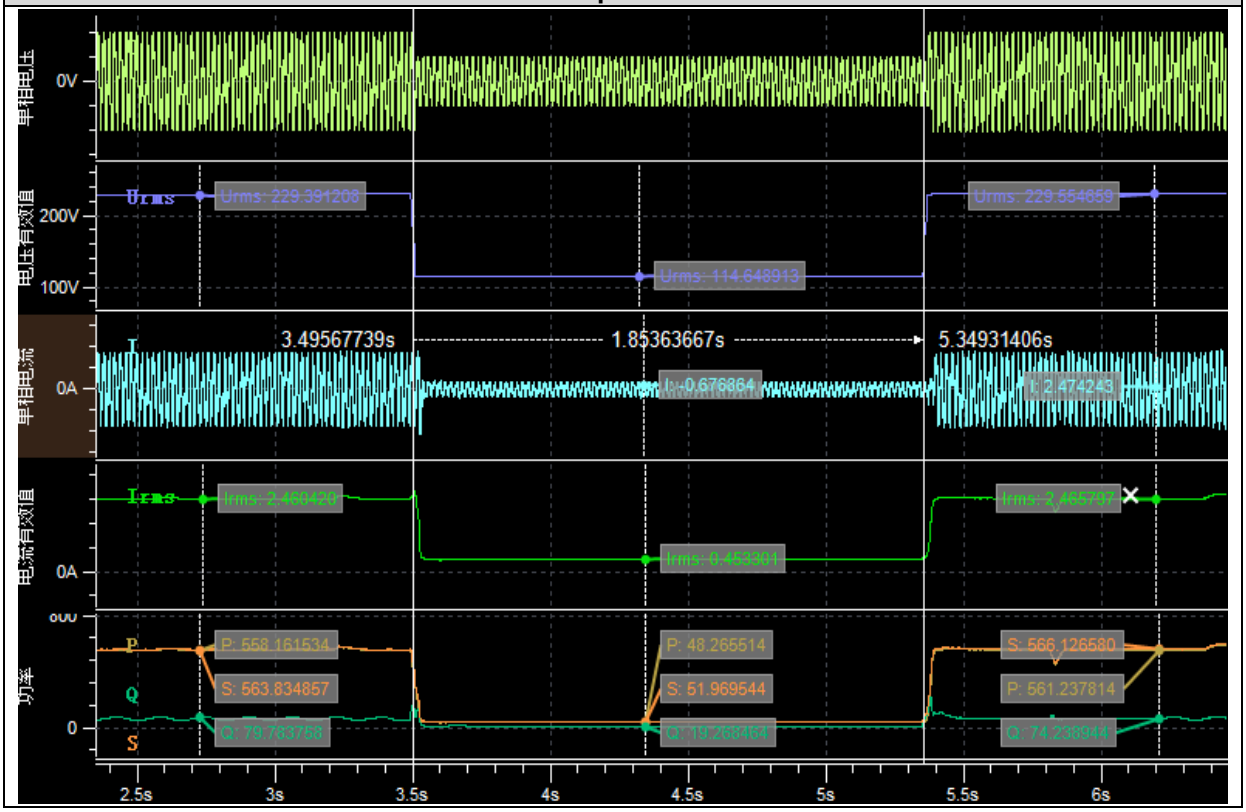


20 %Pn Load	Residual voltage: 50 %Un

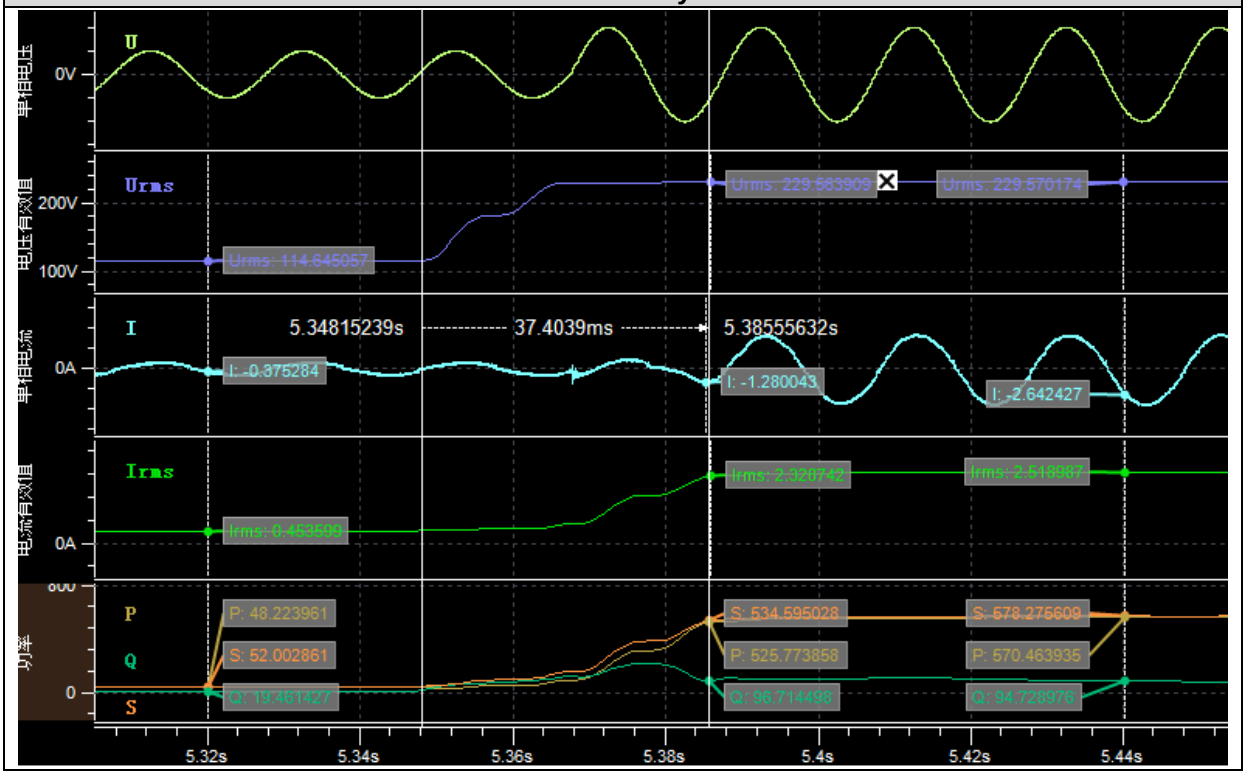
Voltage Drop Time



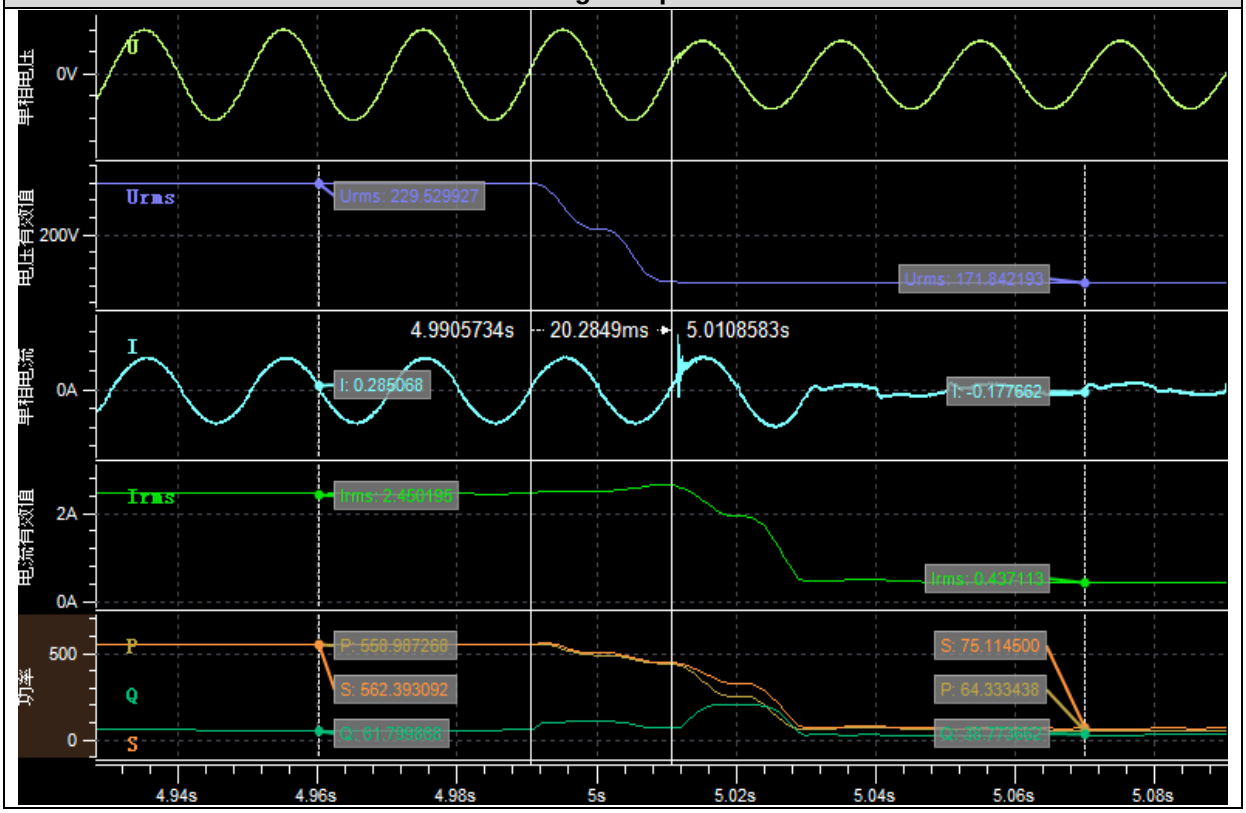
DipTime



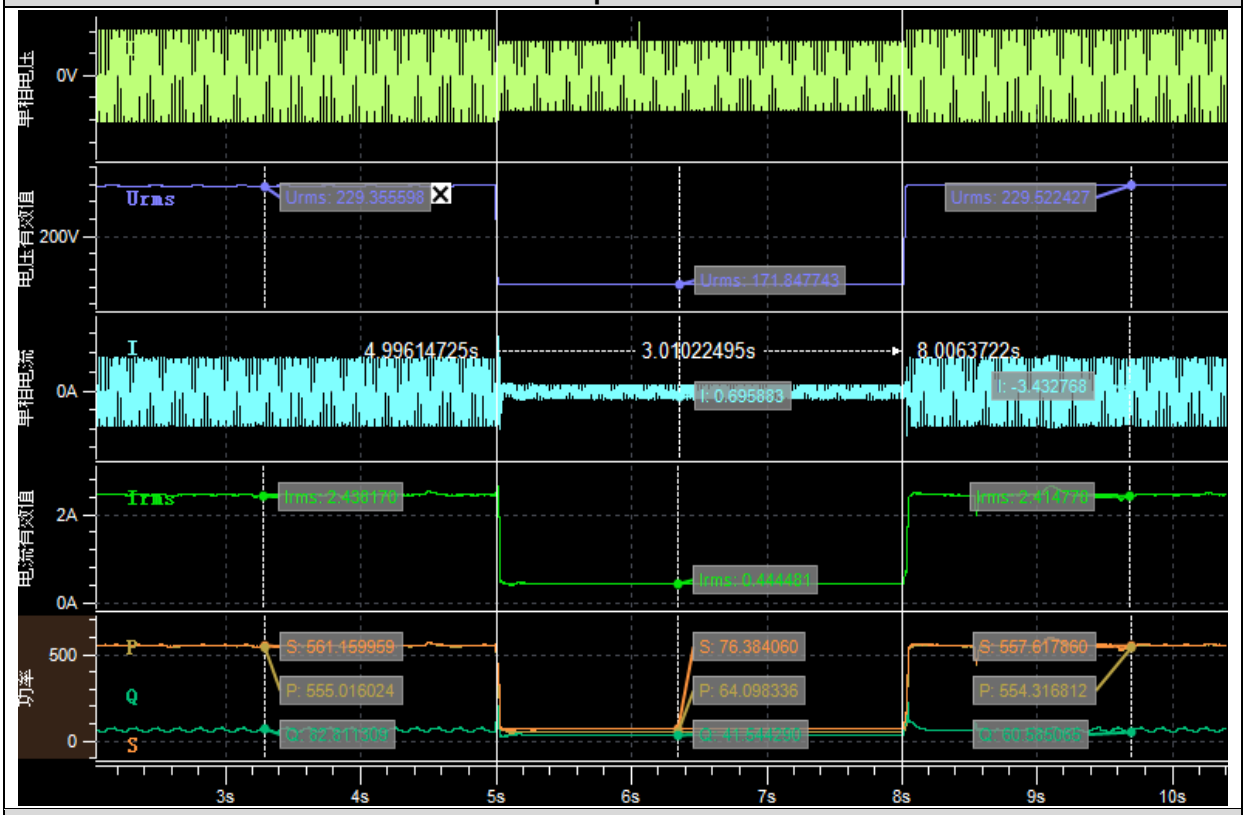
Power Recovery Time



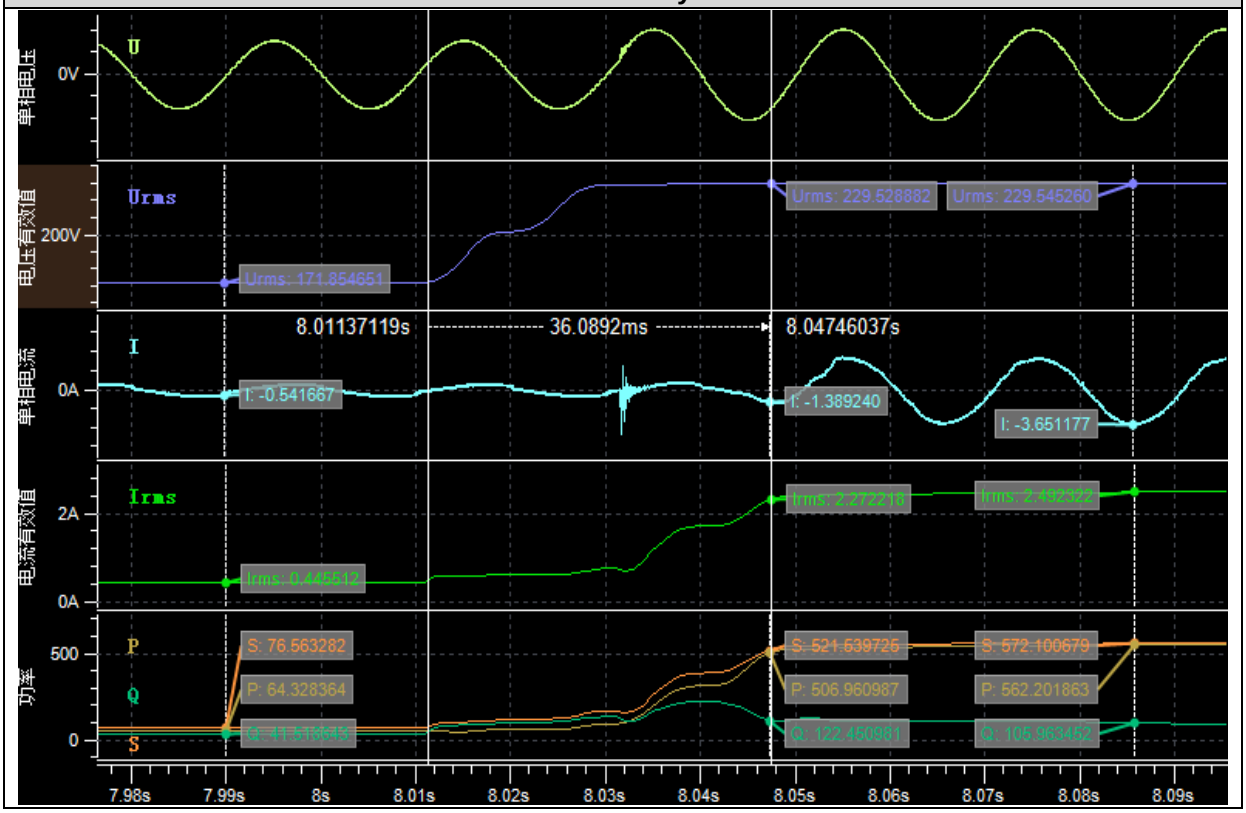
20 %Pn Load	Residual voltage: 75 %Un
Voltage Drop time	



Dip Time



Power Recovery Time



4.2.2.3. Load Tests: Full load (>90 %Pn)

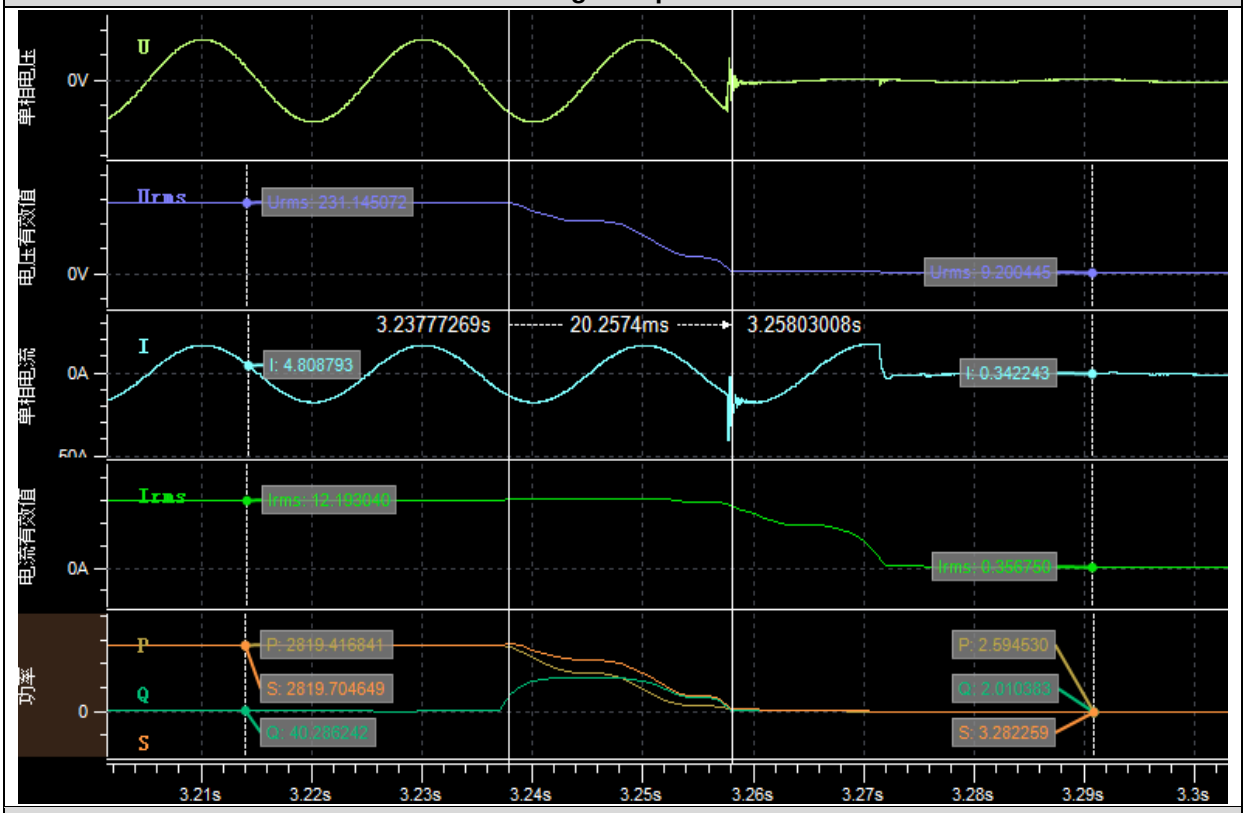
Test results of different Full load cases performed are offered below:

>90 %Pn Load							
Phase type	**Residual voltage desired (%Un)**	**Voltage measured (%Un)**	**Voltage drop time (ms)**	**Dip time desired (ms)**	**Time measured (ms)**	**Power recovery time (ms)**	**Voltage after recovery (%Un)**
L-N	0-5	4.0	20	≥ 400	400	104	100.6
L-N	25	24.9	20	≥ 1000	1006	98	100.5
L-N	50	49.8	20	≥ 1850	1853	96	100.5
L-N	75	74.7	20	≥ 3000	3004	88	100.5

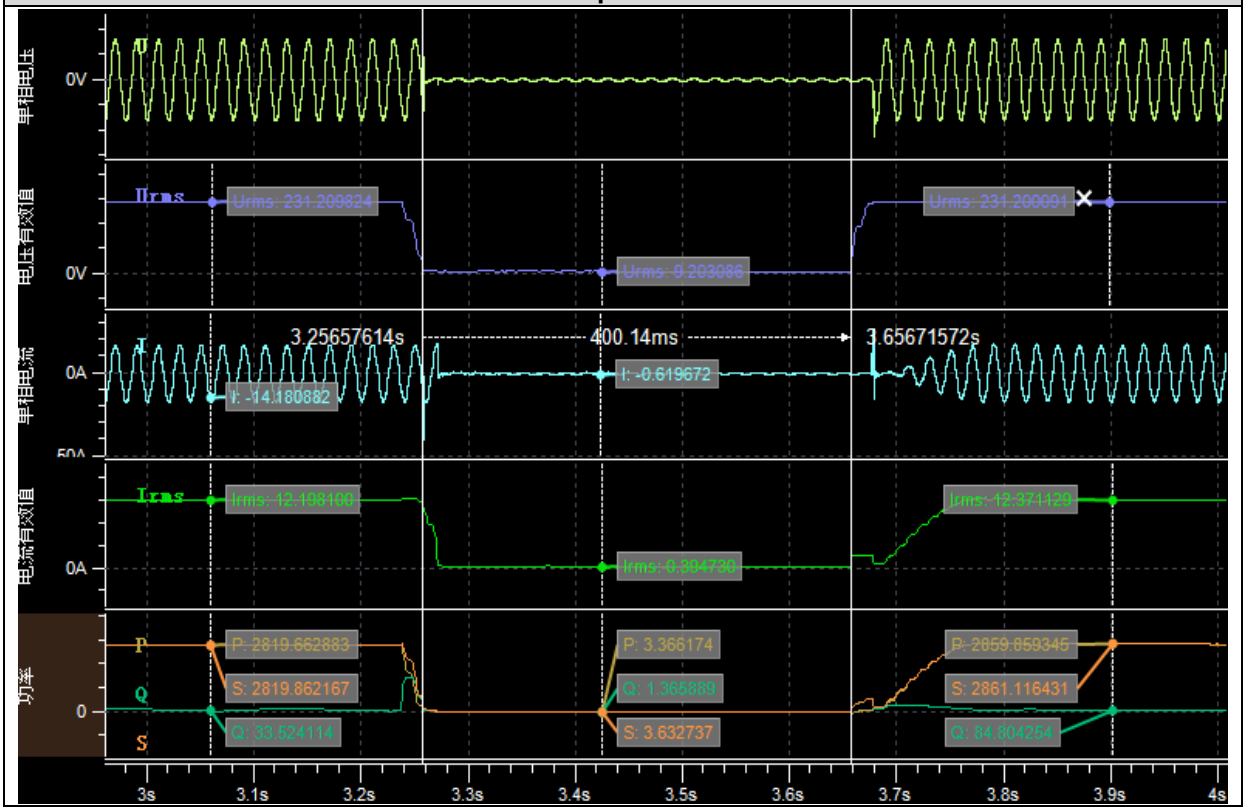
Test results are graphically represented in following pages.

100 %Pn Load	Residual voltage: 0~5 %Un

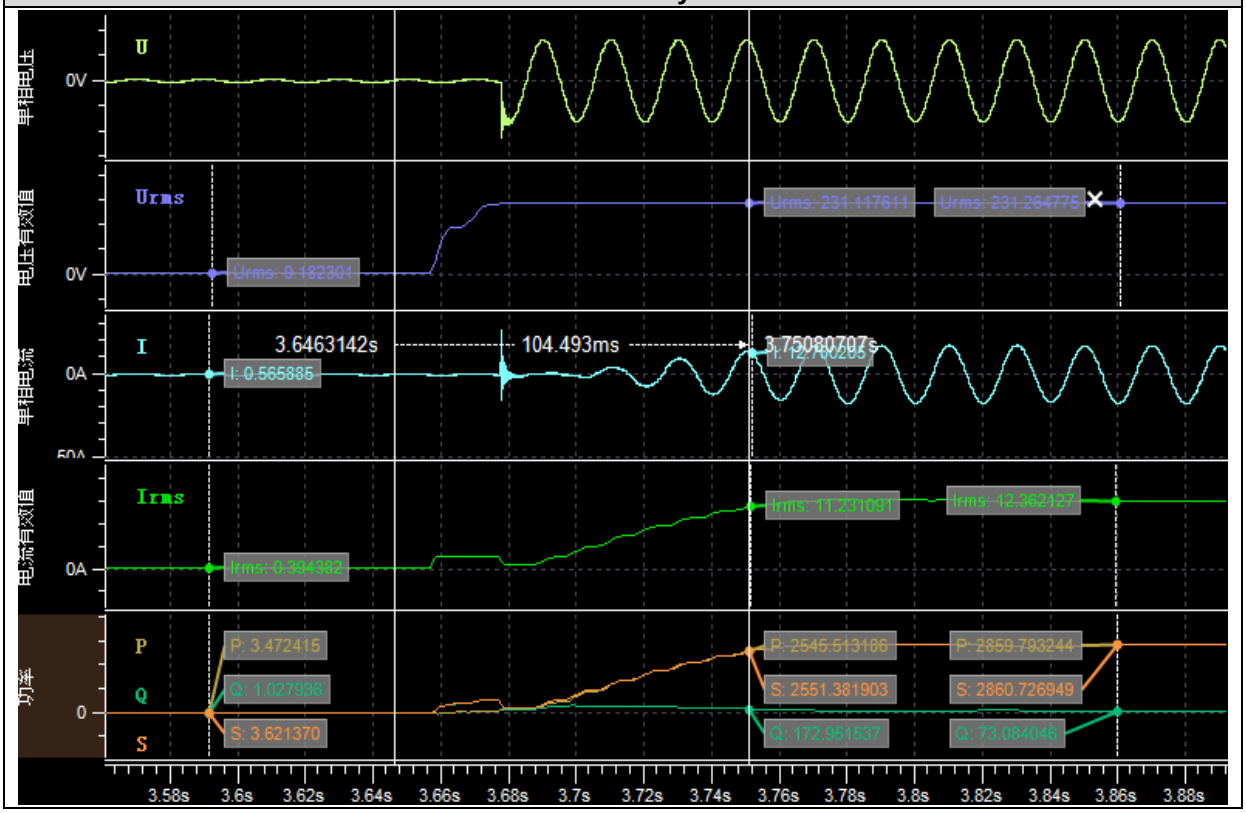
Voltage Drop Time



DipTime

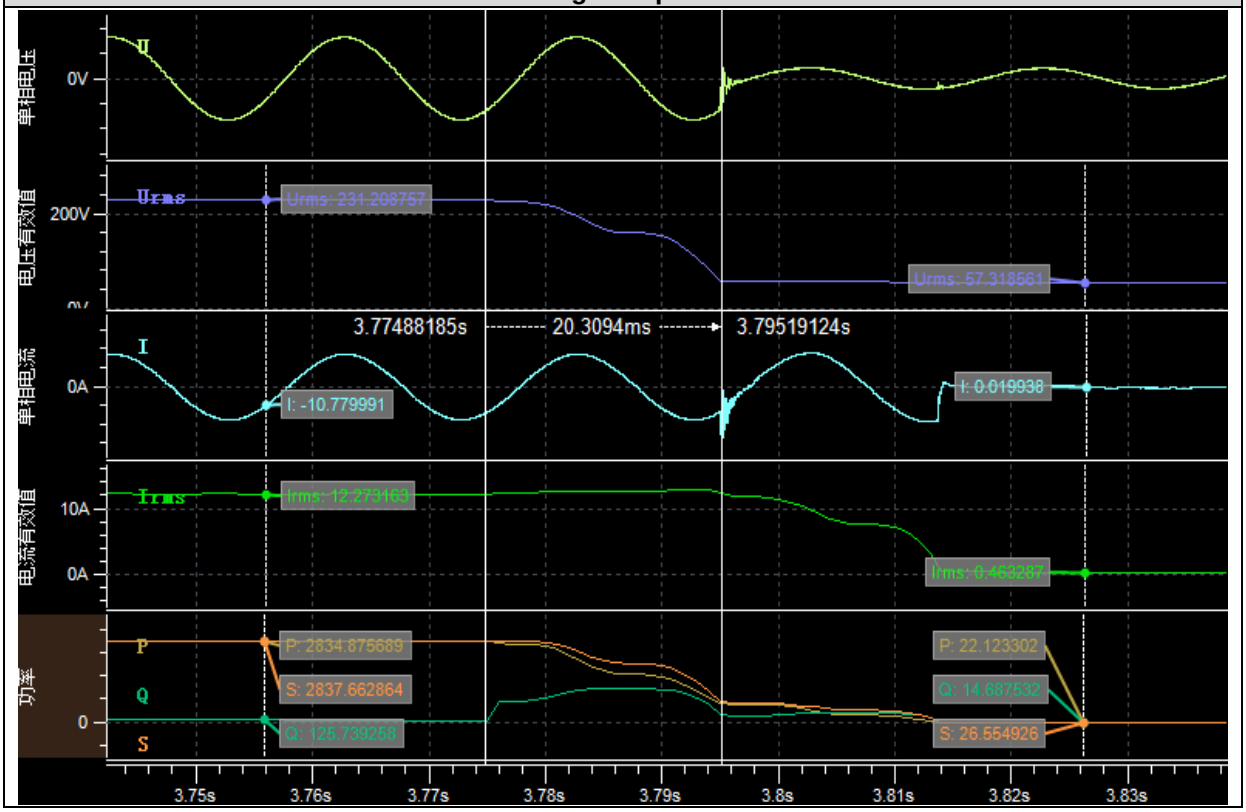


Power Recovery Time

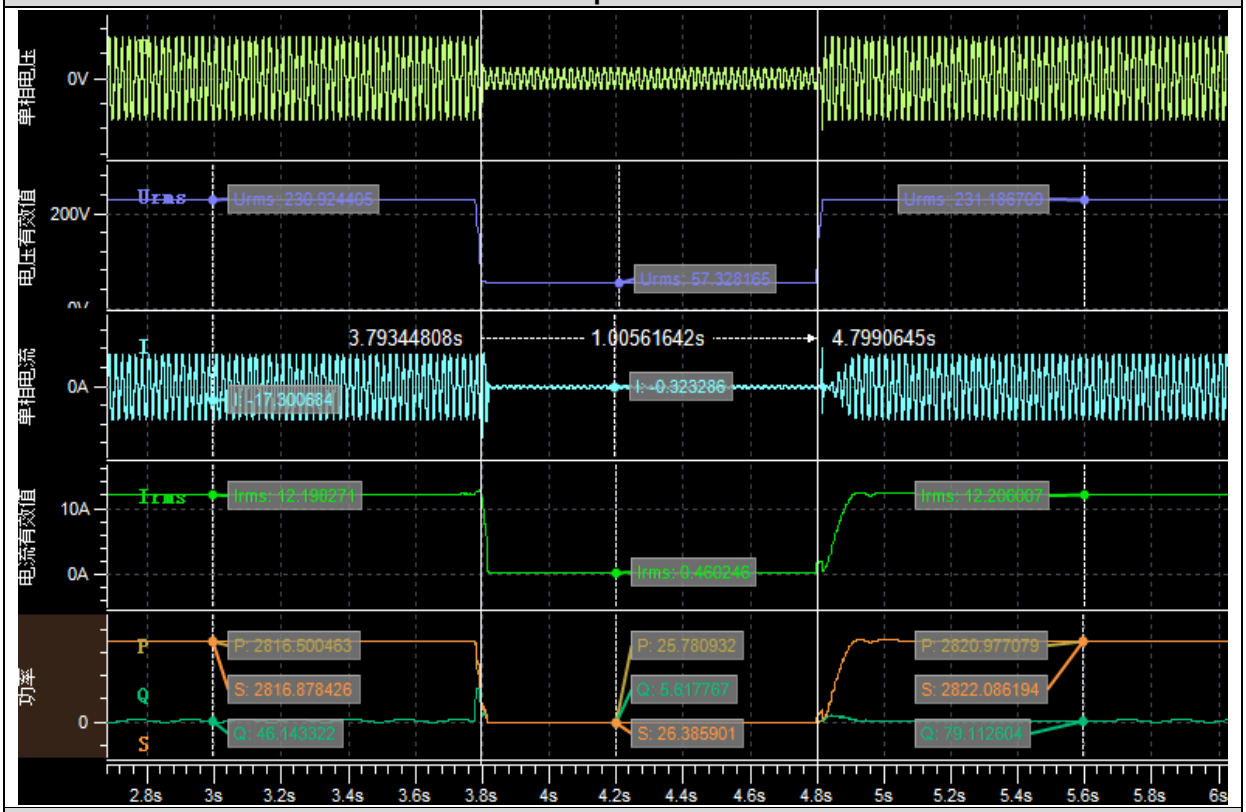


100 %Pn Load	Residual voltage: 25 %Un

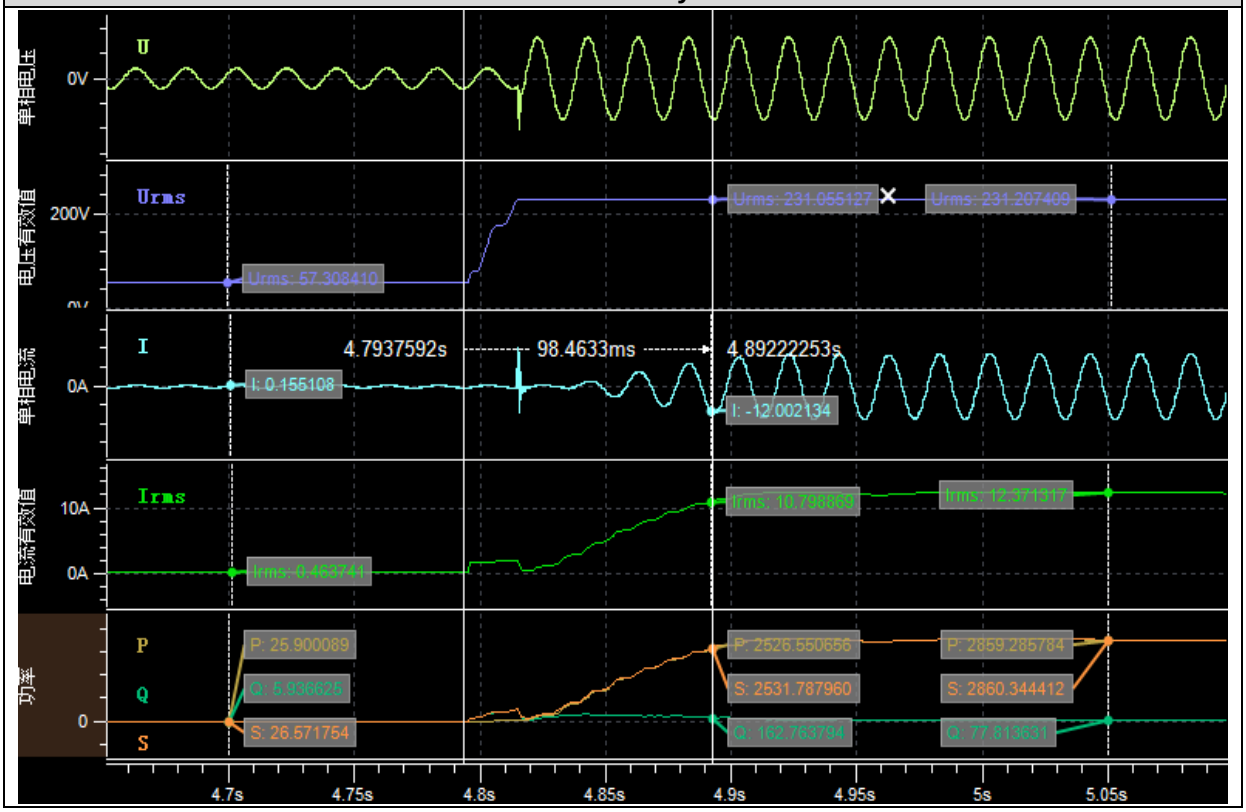
Voltage Drop Time



Dip Time

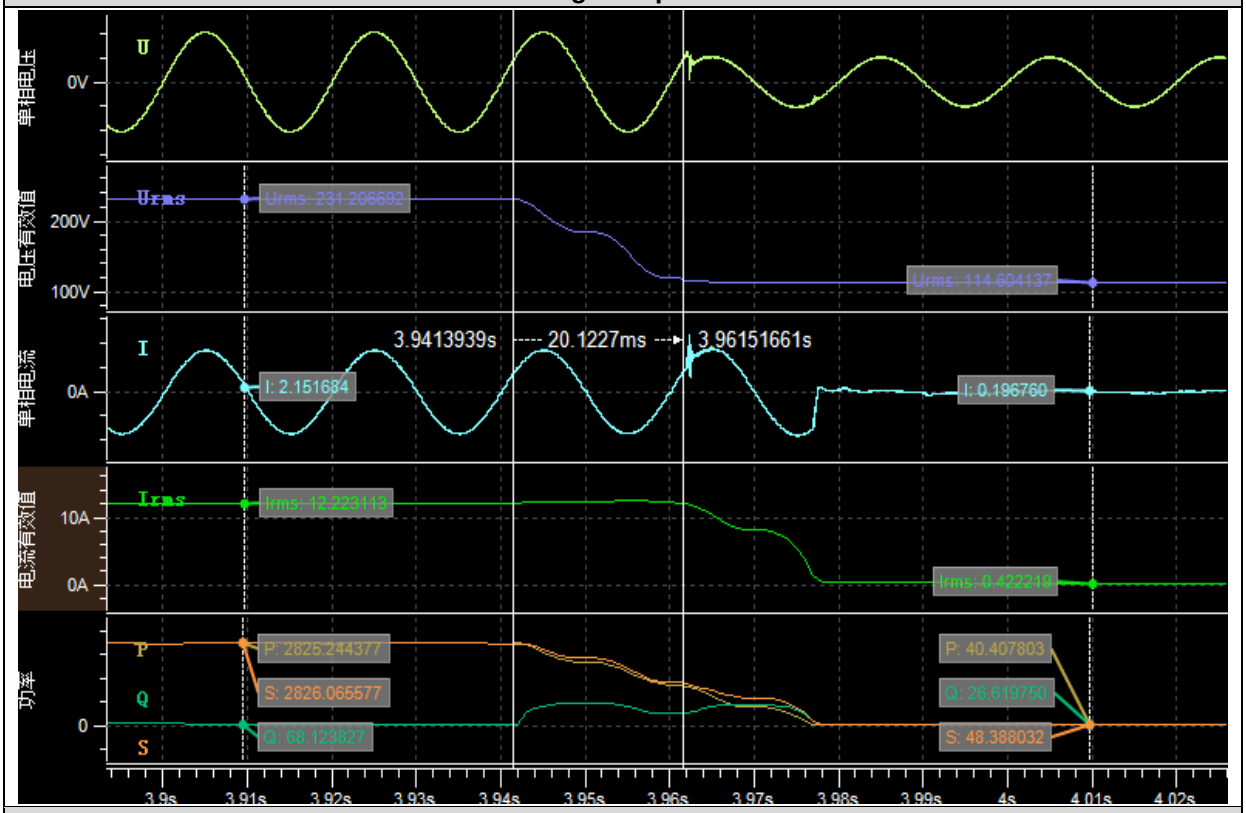


Power Recovery Time

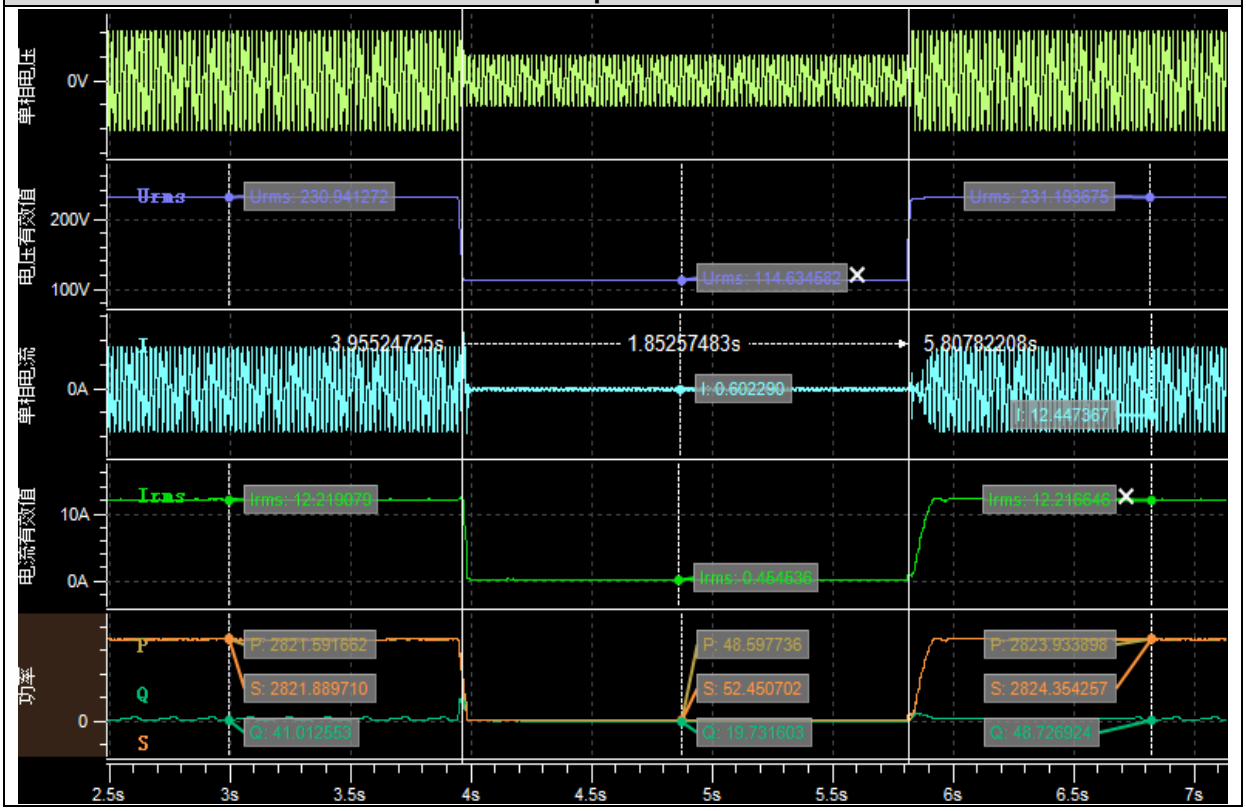


100 %Pn Load	Residual voltage: 50 %Un

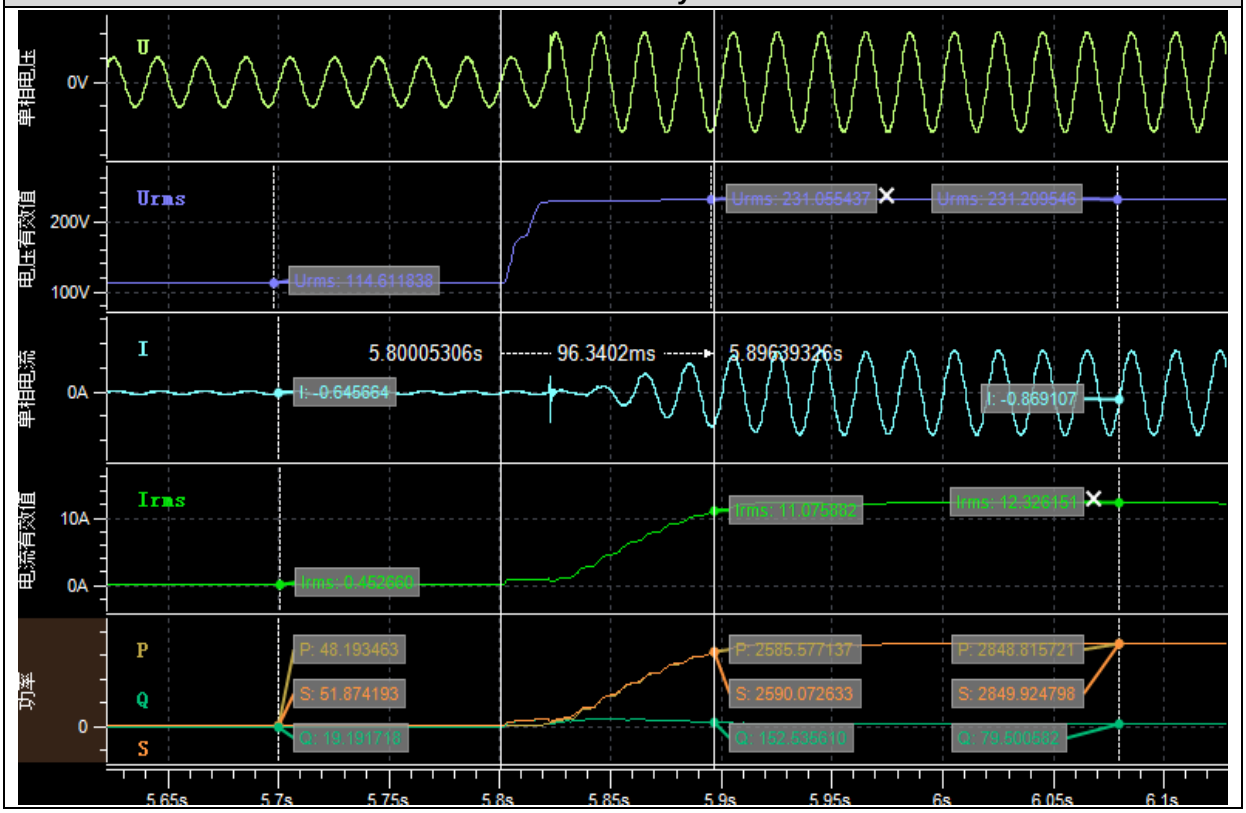
Voltage Drop Time



Dip Time

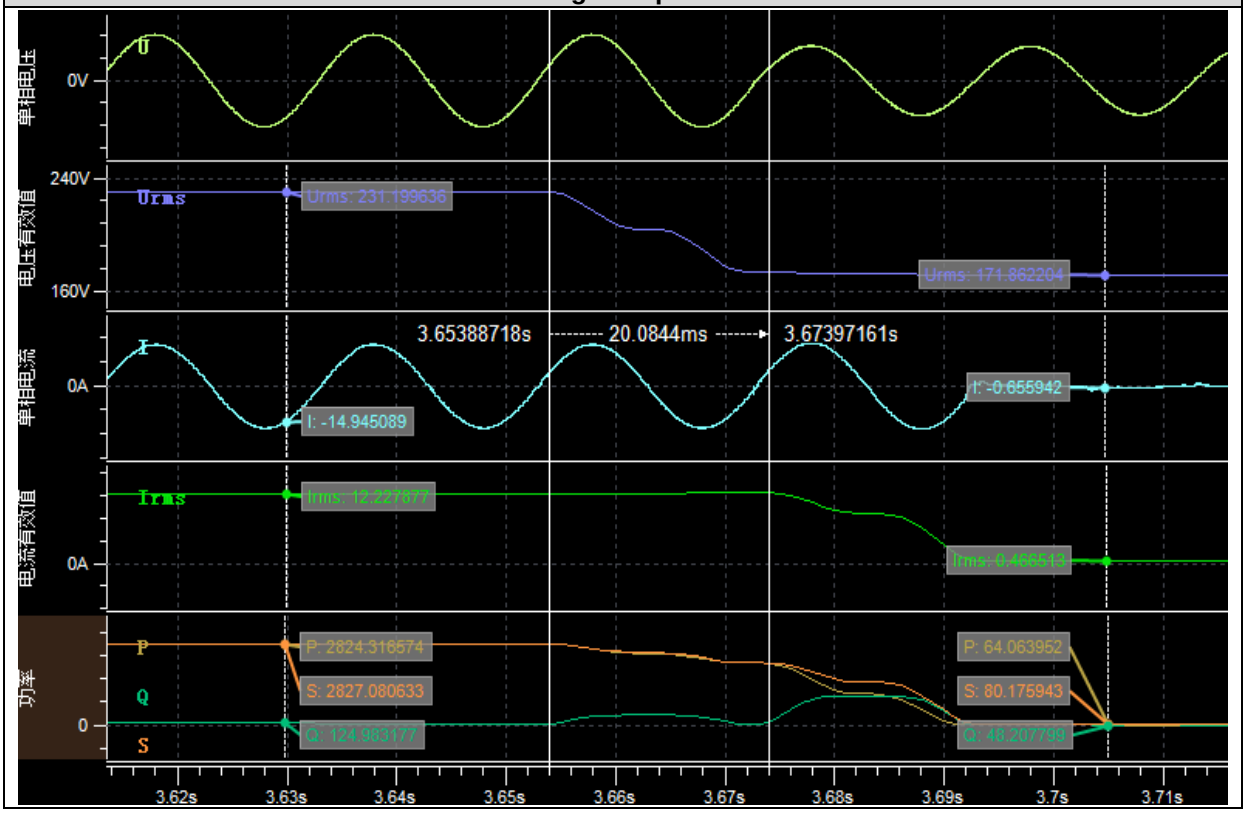


Power Recovery Time

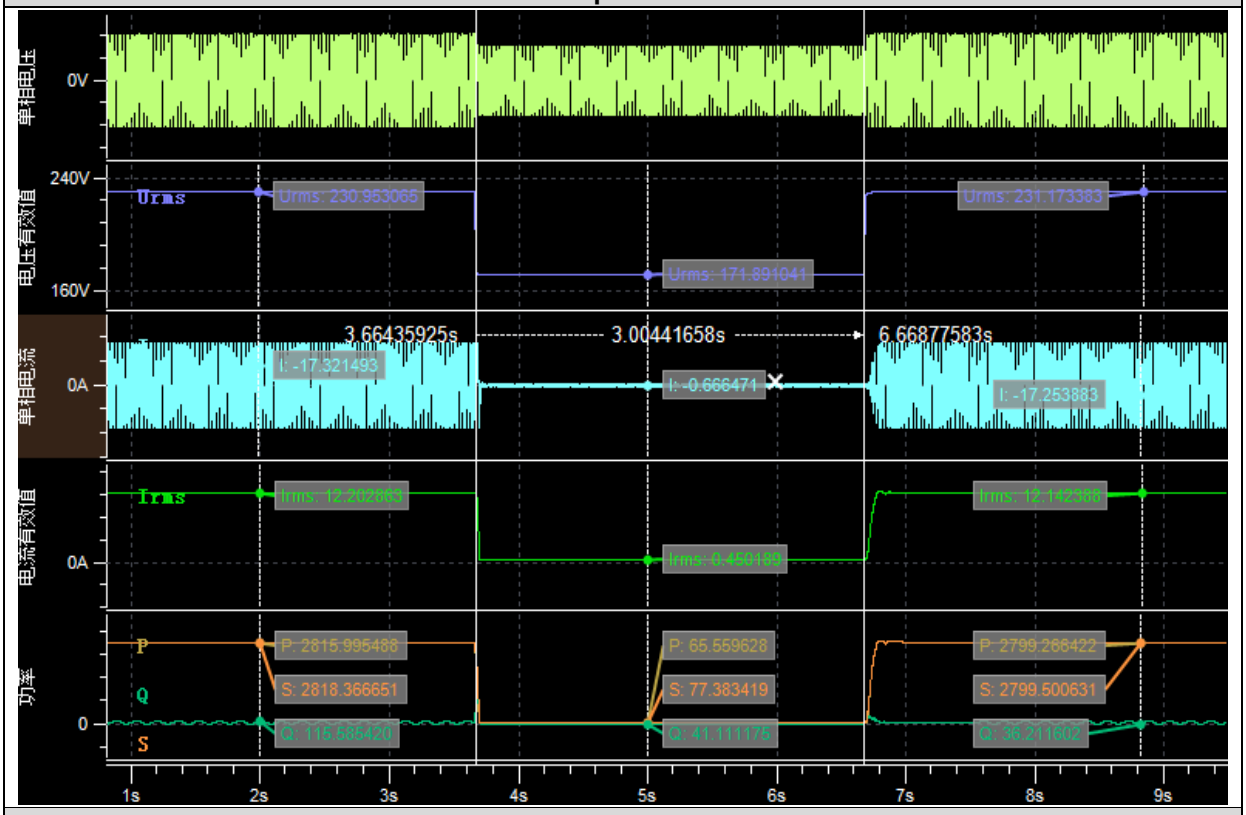


100 %Pn Load	Residual voltage: 75 %Un

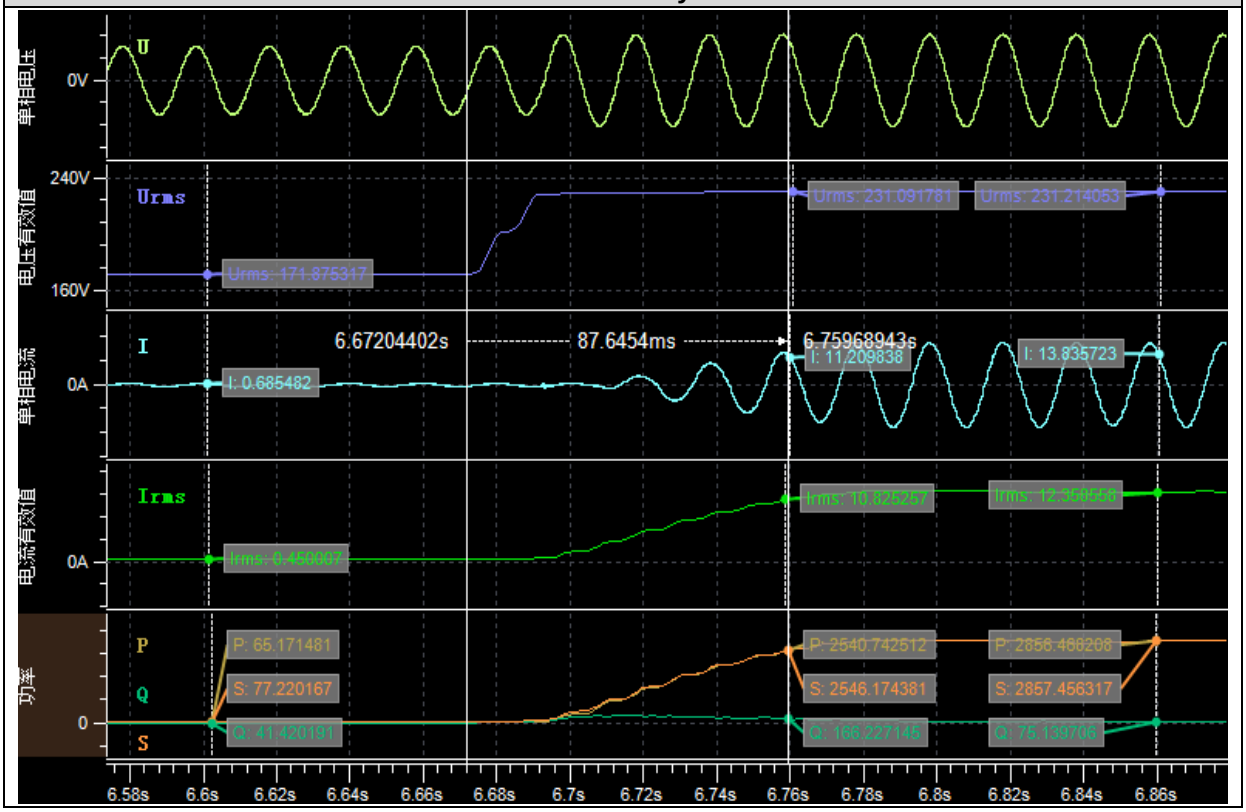
Voltage Drop Time



Dip Time



Power Recovery Time



4.2.3. Over-voltage ride through (OVRT)

The test has been done according to the clause 4.5.4 of the standard. The setting of over-voltage ride through capability as following:

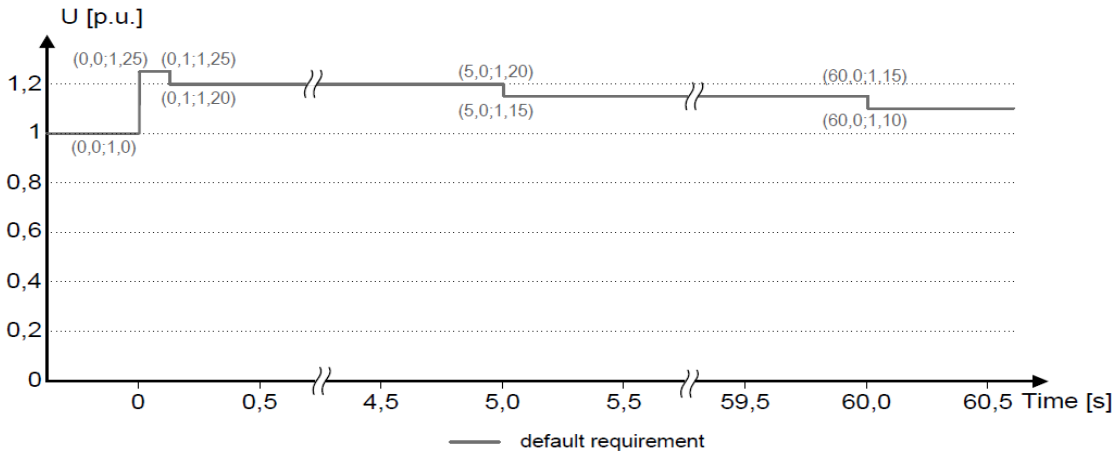
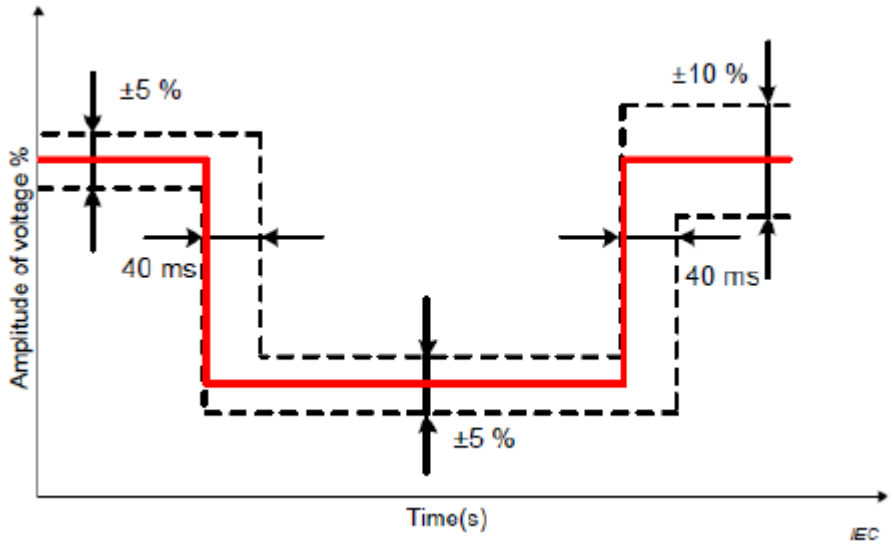


Figure 8 — Over-voltage ride through capability

4.2.3.1. No load Test

It is not specified in the reference standard, but the following tolerances have been applied. Tolerances for drop depth and duration during no-load tests shall not exceed the values shown in the next figure:



The tolerance for voltage magnitude is ±5 %Un for the period before and during the voltage drop. The tolerance for voltage magnitude is ±10 %Un during the period after voltage is recovered.

The tolerance range for both drop duration and rise time prefers 40 ms.

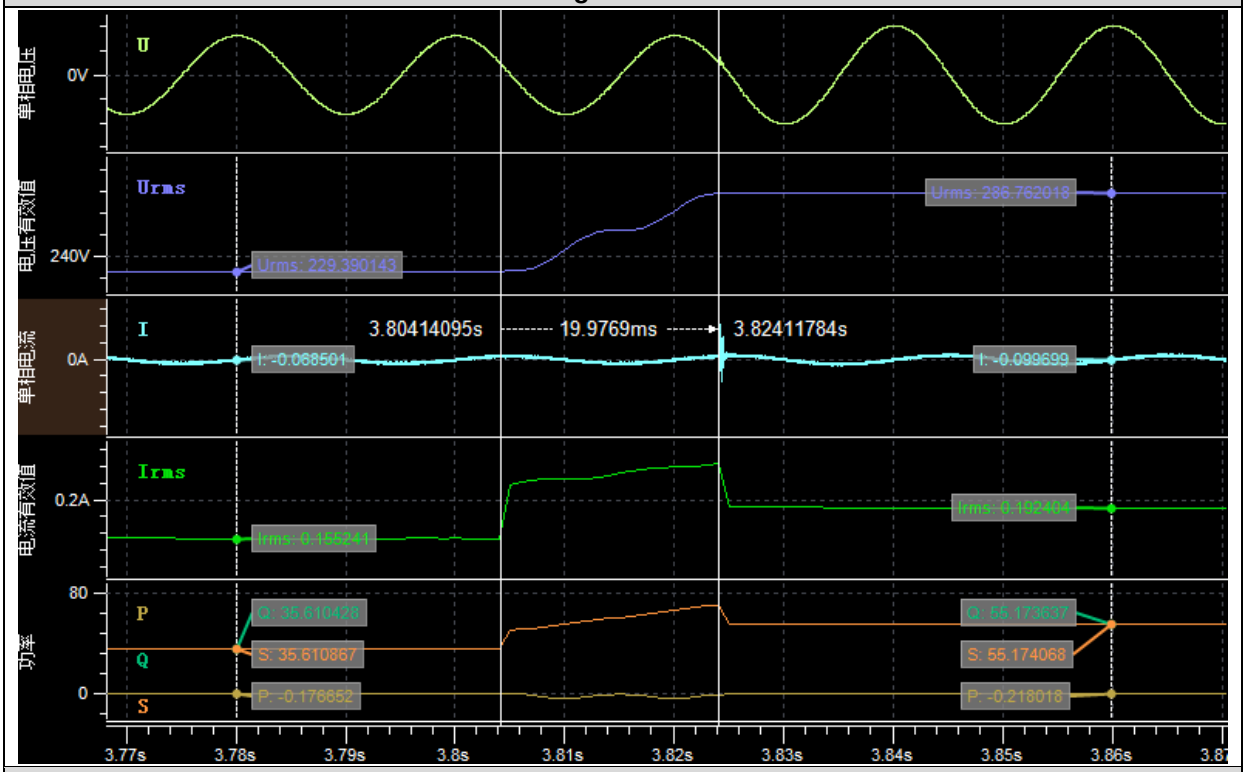
Test results of different no-load cases performed are offered below:

Residual voltage desired (%Un)	Voltage before recovery (%Un)	Voltage rise time (ms)	Residual voltage measured (%Un)	DipTime (ms)		Power recovery time (ms)	Voltage after recovery (%Un)
				Desired	Meas.		
125.0	99.7	20	124.7	> 120	123	--	99.7
120.0	99.7	20	119.8	> 5000	5023	--	99.7
115.0	99.6	20	114.6	> 60000	60040	--	99.5

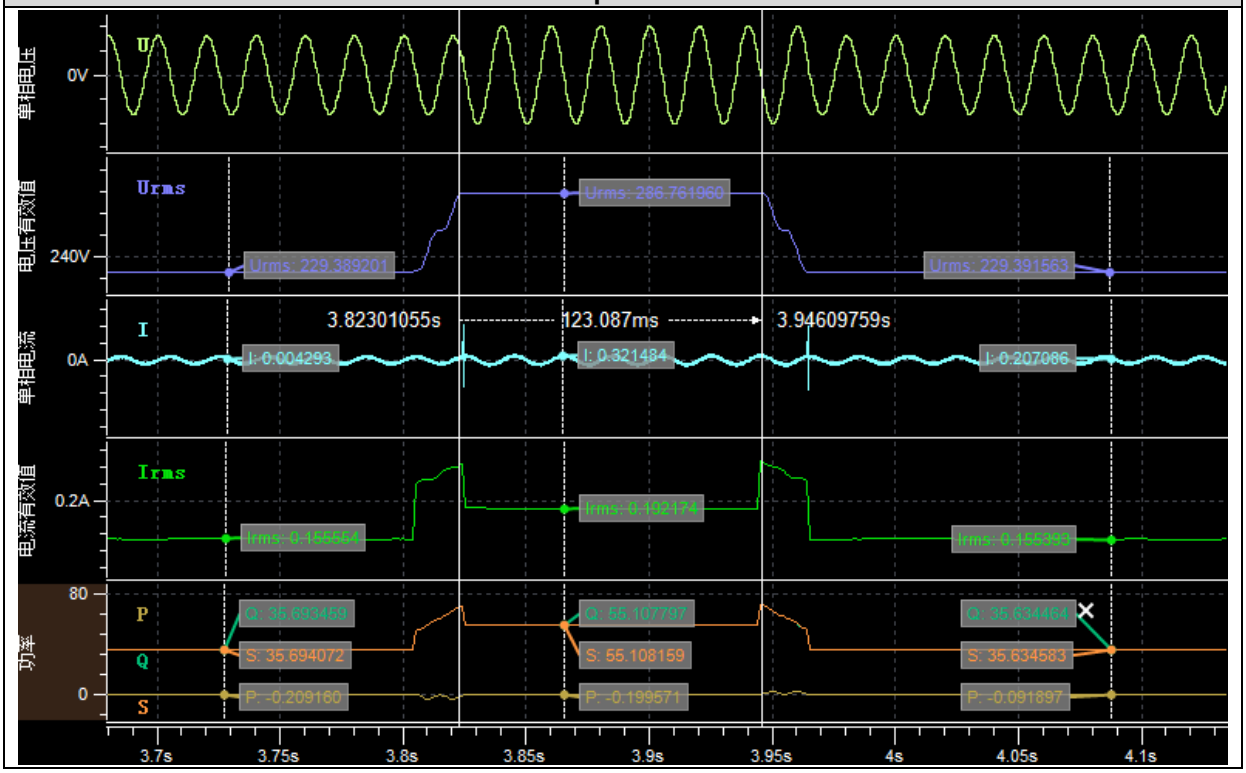
Test results are graphically represented at following pages.

No Load	Residual voltage: 125.0 %Un

Voltage Rise Time

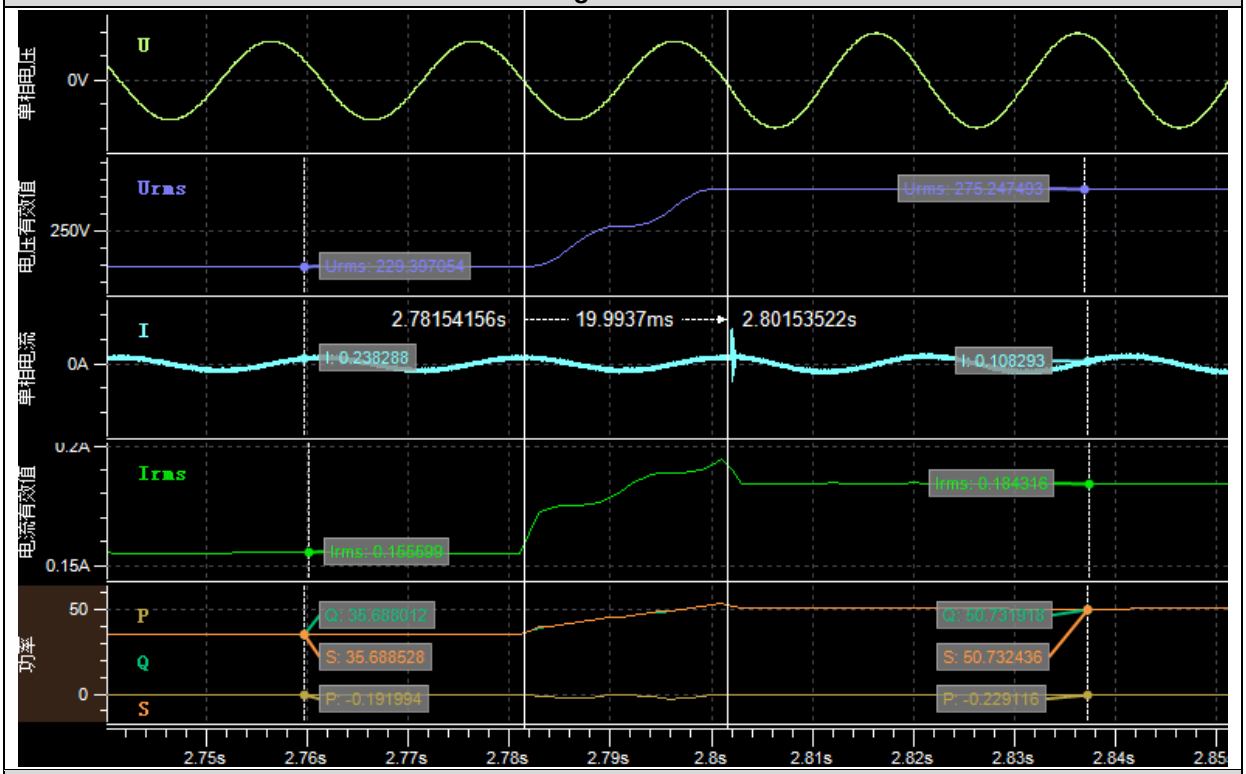


Dip Time

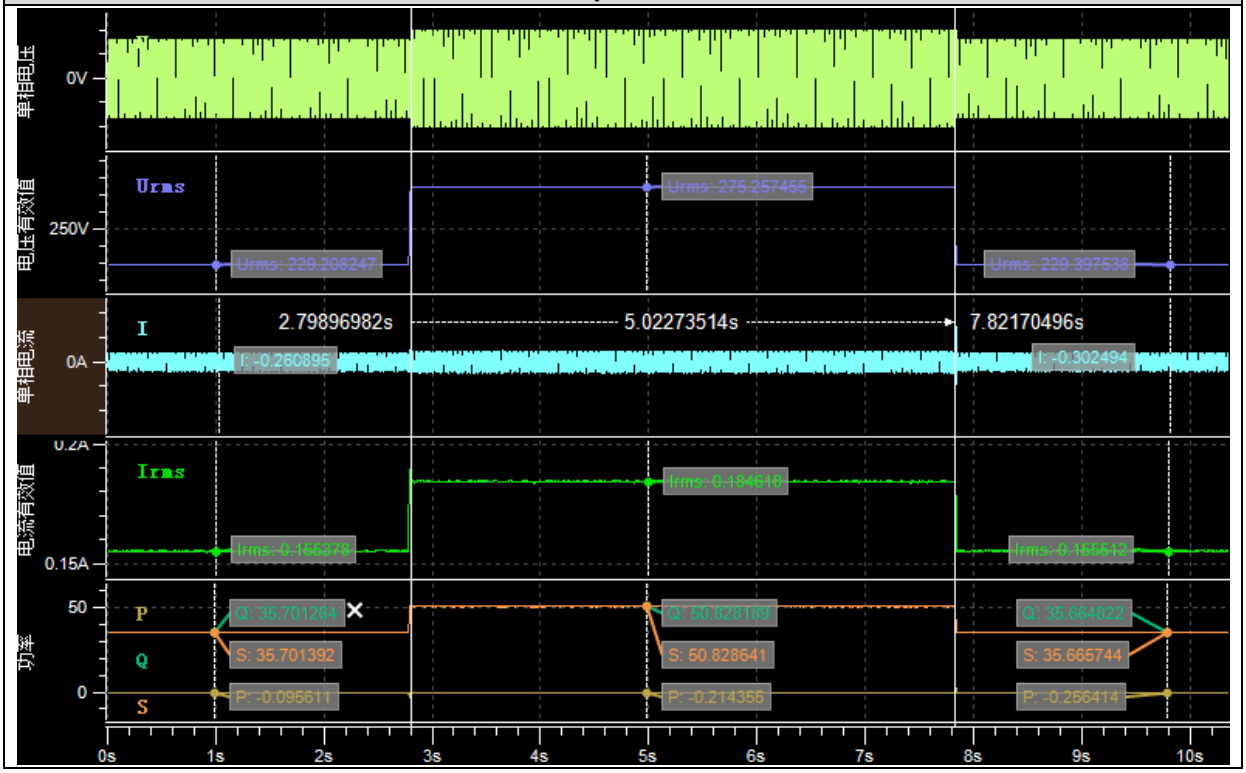


No Load	Residual voltage: 120.0 %Un

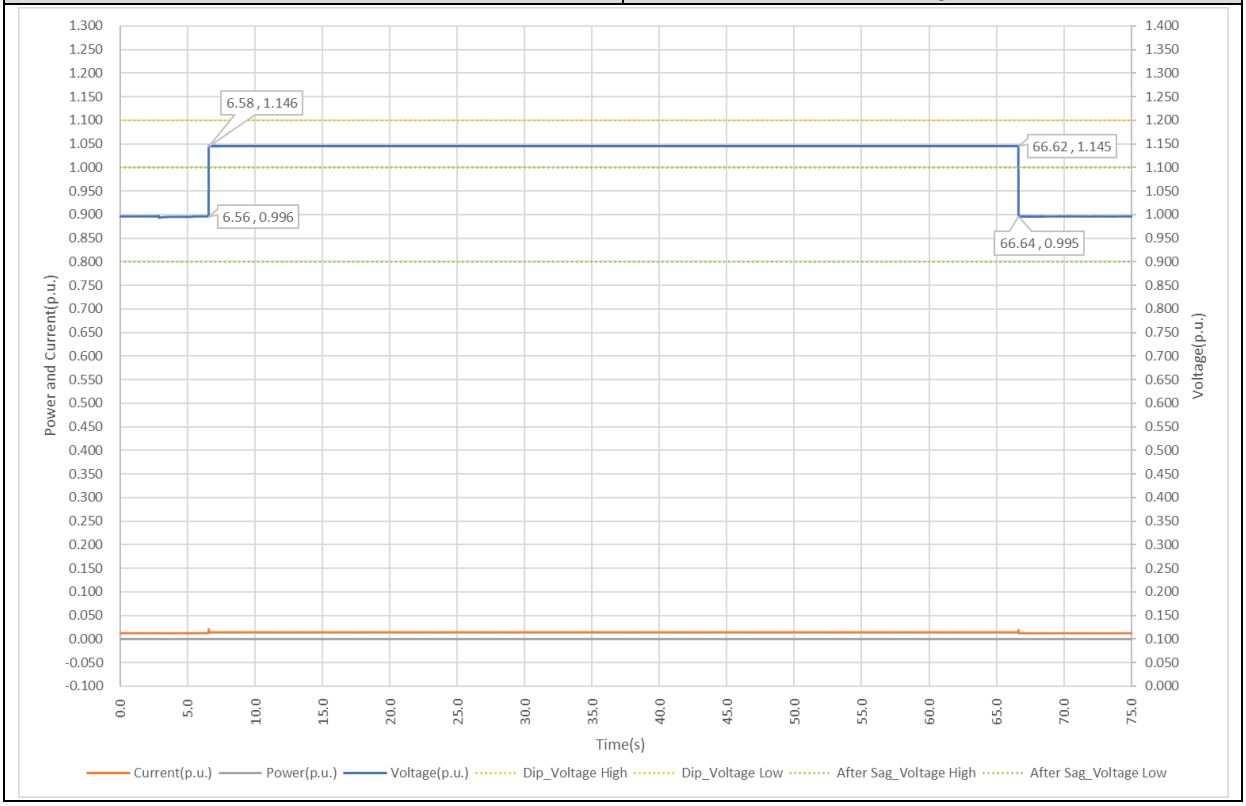
Voltage Rise Time



Dip Time



Single-Phase fault	
No Load	**Residual voltage: 115.0 %Un**



4.2.3.2. Load Tests: Partial load (20 %Pn)

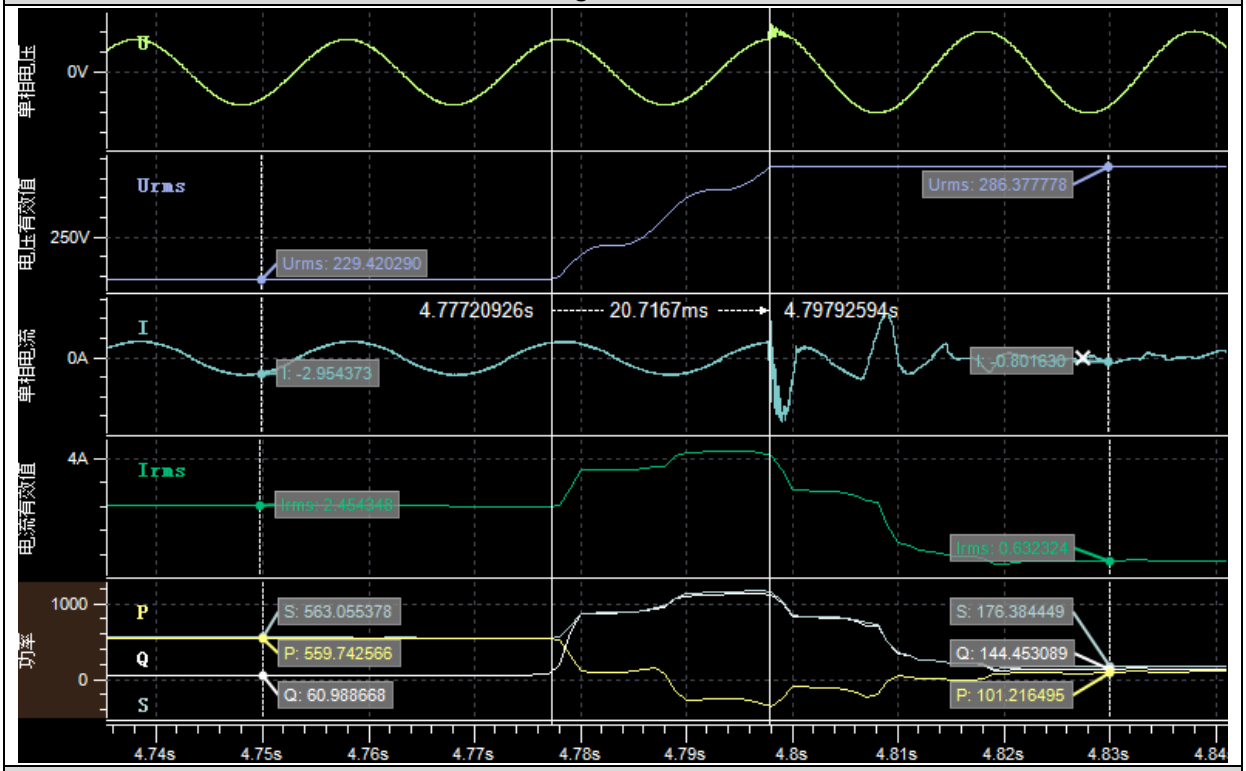
Test results of partial power cases performed are offered below:

Single-Phase fault							
Residual voltage desired (%Un)	Voltage before recovery (%Un)	Voltage rise time (ms)	Residual voltage measured (%Un)	DipTime (ms)		Power recovery time (ms)	Voltage after recovery (%Un)
				Desired	Meas.		
125.0	99.8	21	124.5	> 120	120	74	99.8
120.0	99.9	21	119.7	> 5000	5022	71	99.9
115.0	99.8	20	114.7	> 60000	60030	30	99.6

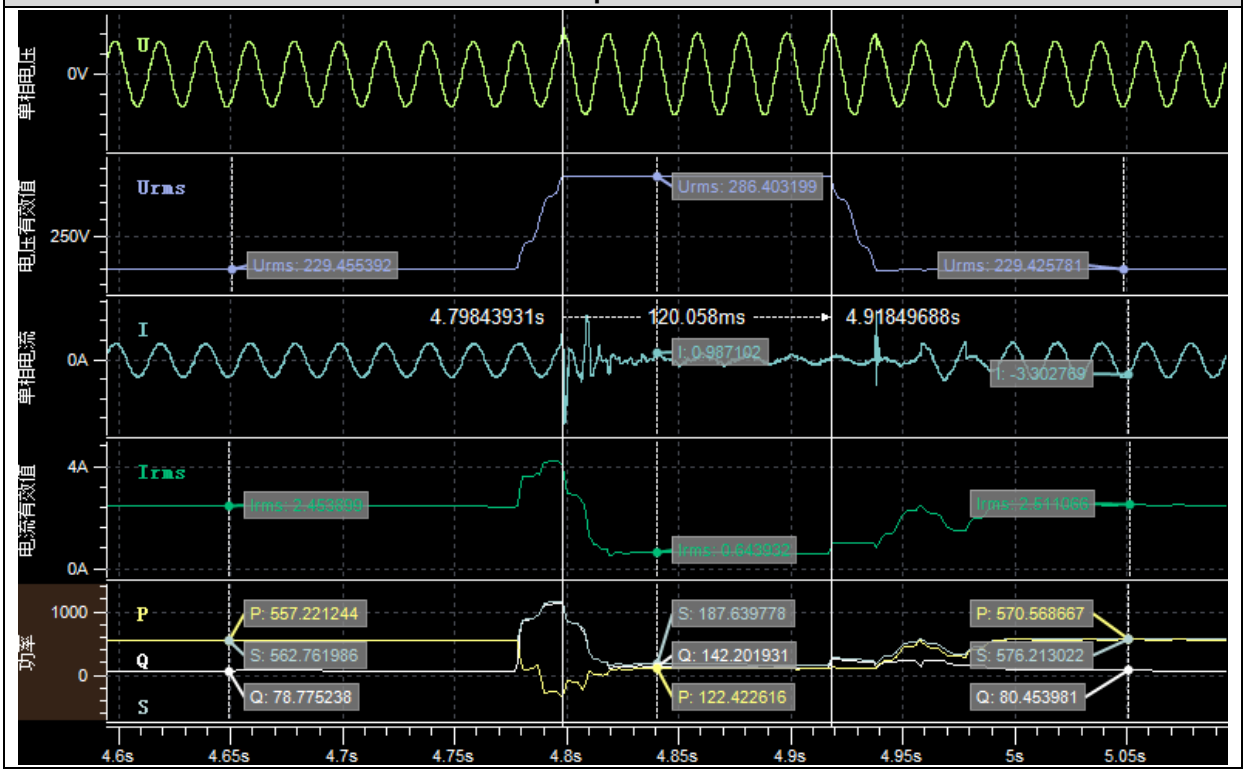
Test results are graphically represented at following pages.

Single-Phase fault	
Partial load (20 %Pn)	Residual voltage: 125.0 %Un

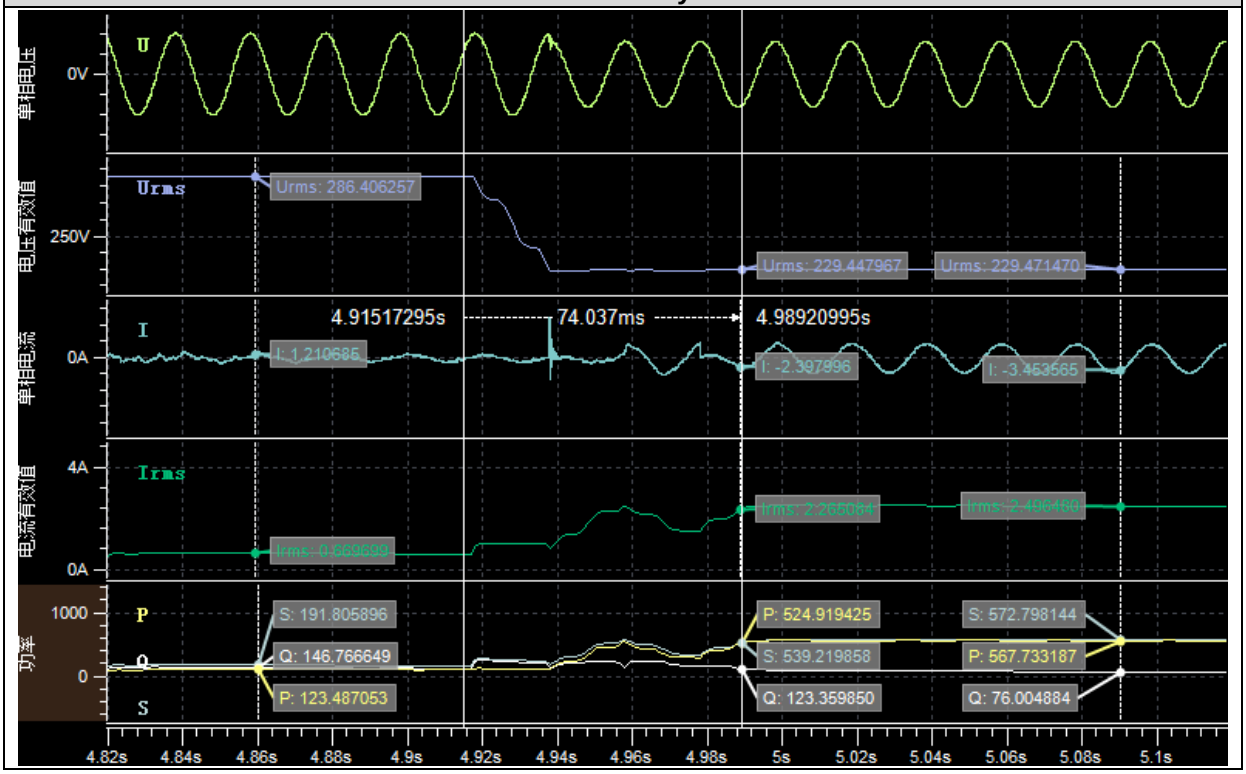
Voltage Rise Time



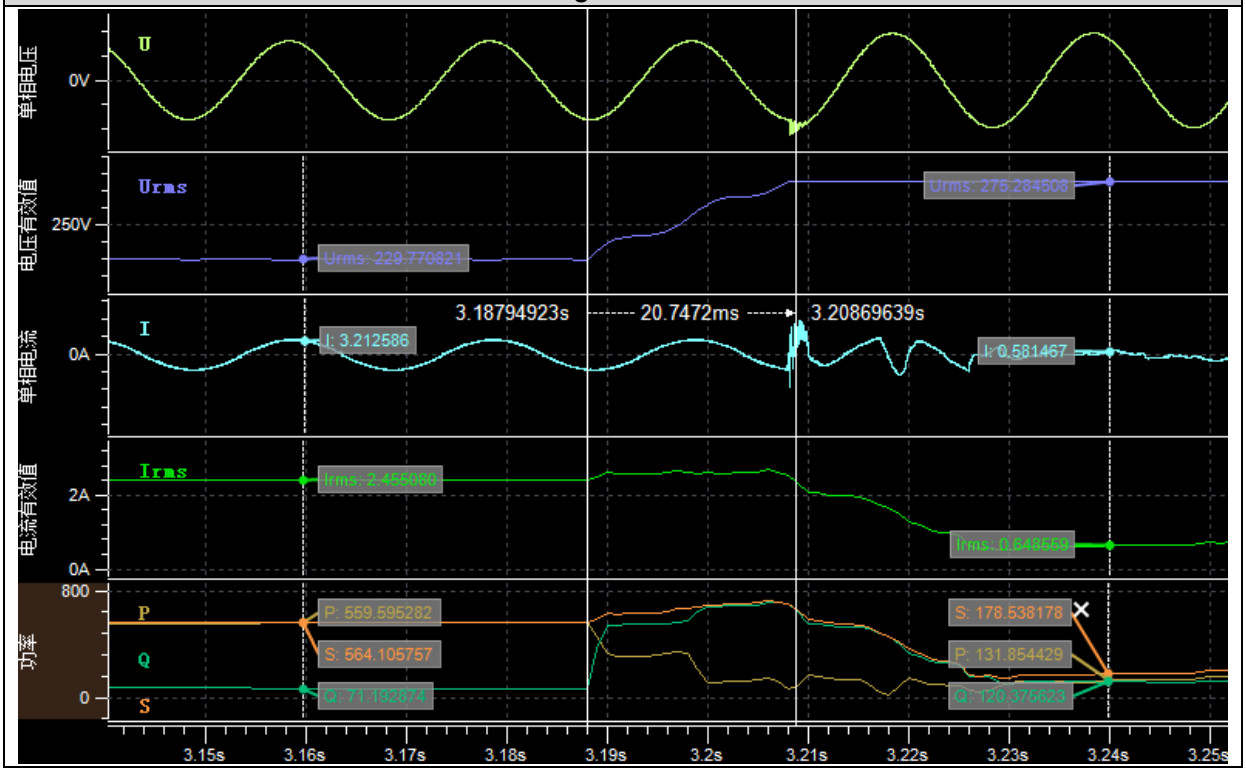
Dip Time



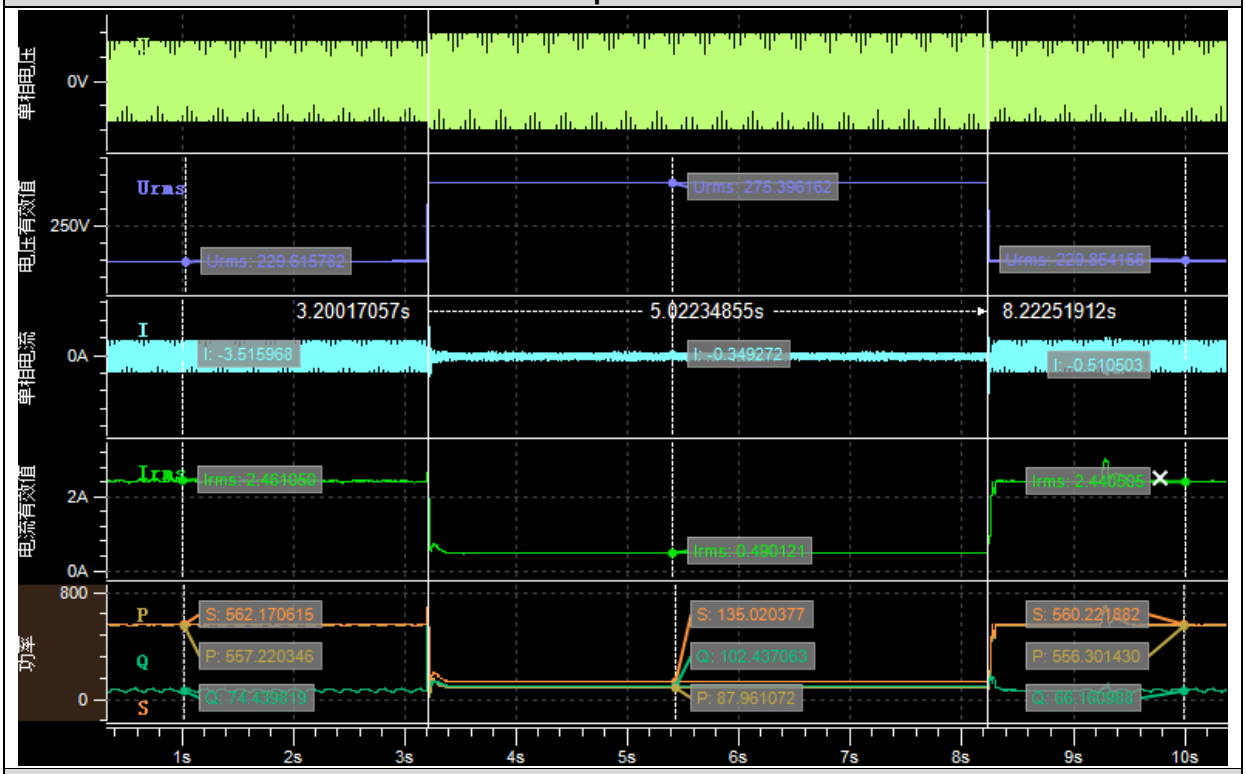
Power Recovery Time



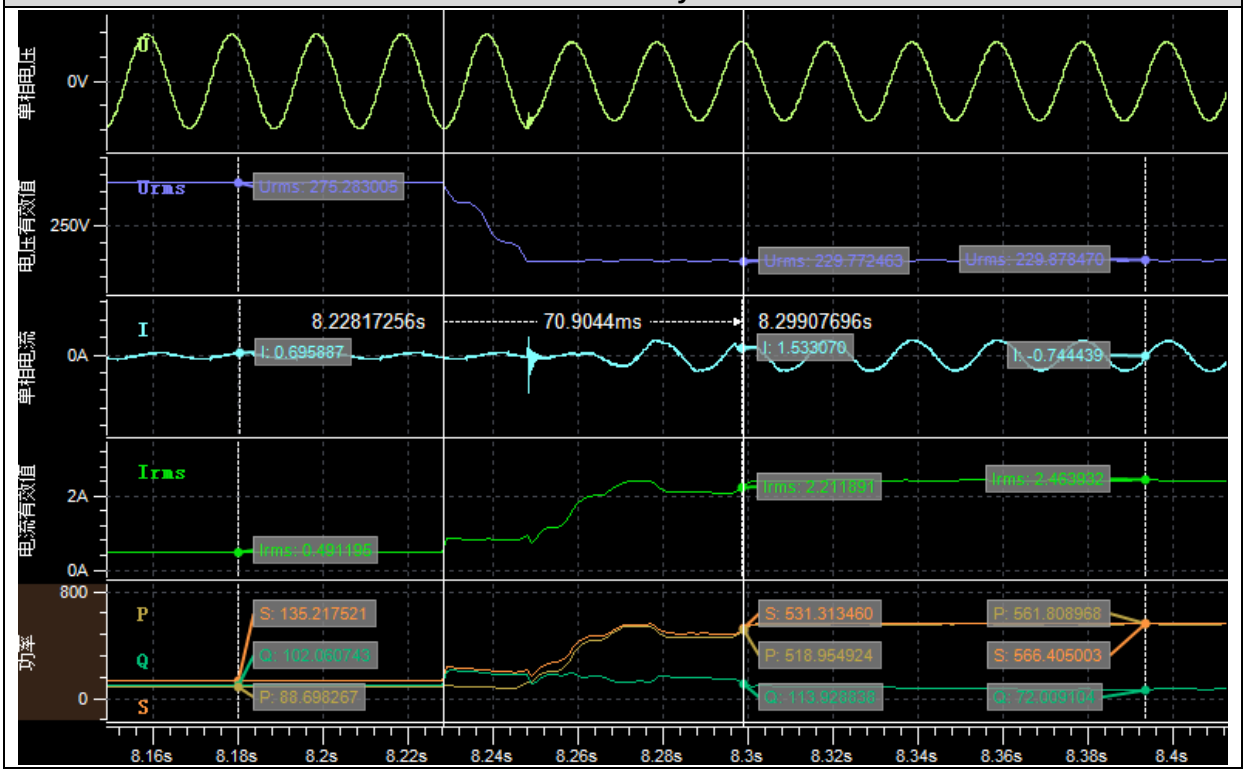
Single-Phase fault	
Partial load (20 %Pn)	Residual voltage: 120.0 %Un
Voltage Rise Time	



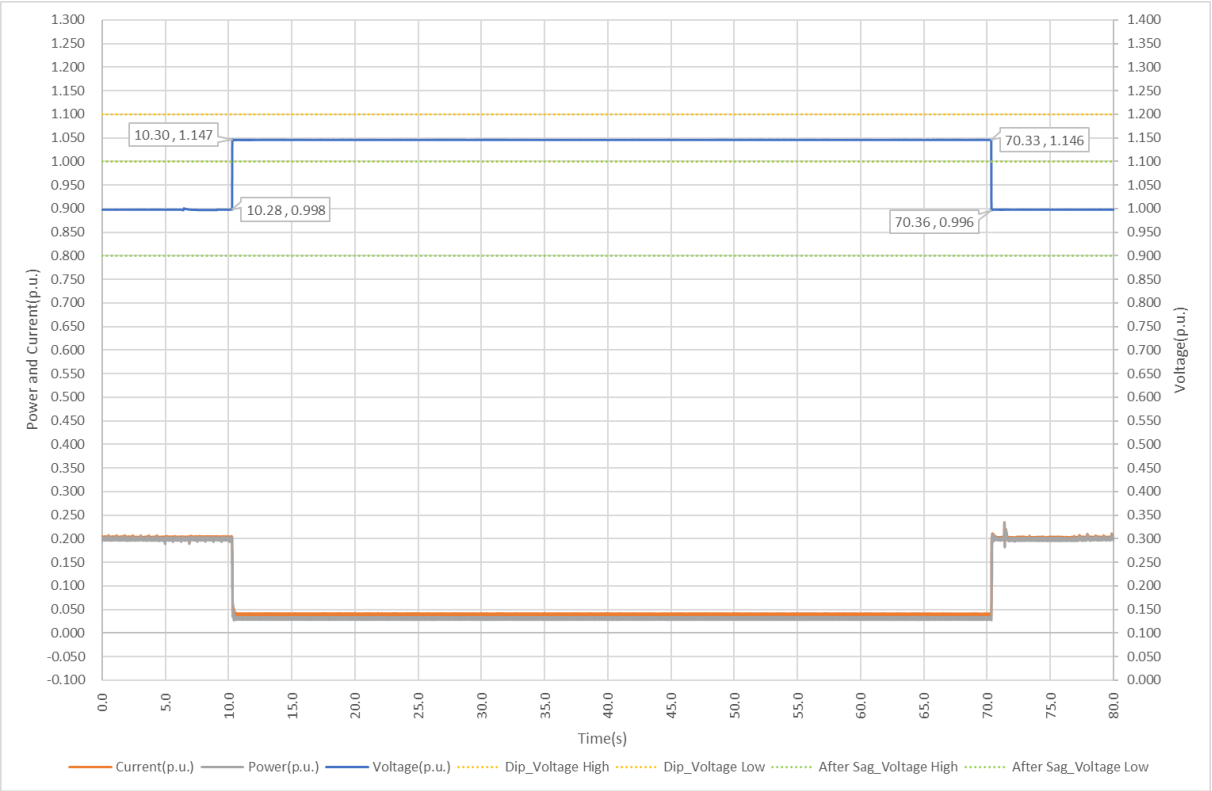
Dip Time



Power Recovery Time



Single-Phase fault	
Partial load (20 %Pn)	Residual voltage: 115.0 %Un



4.2.3.3. Load Tests: Full Load (100 %Pn)

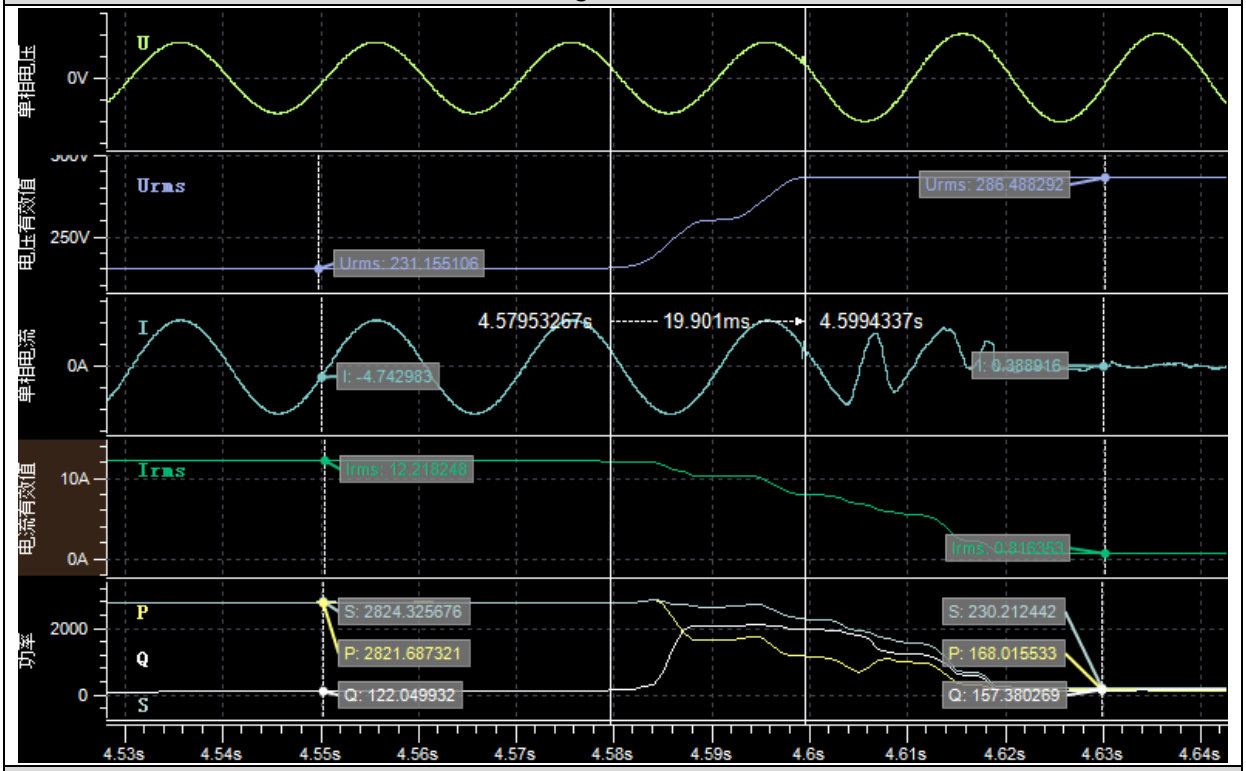
Test results of full power cases performed are offered below:

Single-Phase fault							
Residual voltage desired (%Un)	Voltage before recovery (%Un)	Voltage rise time (ms)	Residual voltage measured (%Un)	DipTime (ms)		Power recovery time (ms)	Voltage after recovery (%Un)
				Desired	Meas.		
125.0	100.5	20	124.6	> 120	122	107	100.5
120.0	100.5	21	119.6	> 5000	5026	114	100.5
115.0	100.5	20	114.6	> 60000	60040	30	100.5

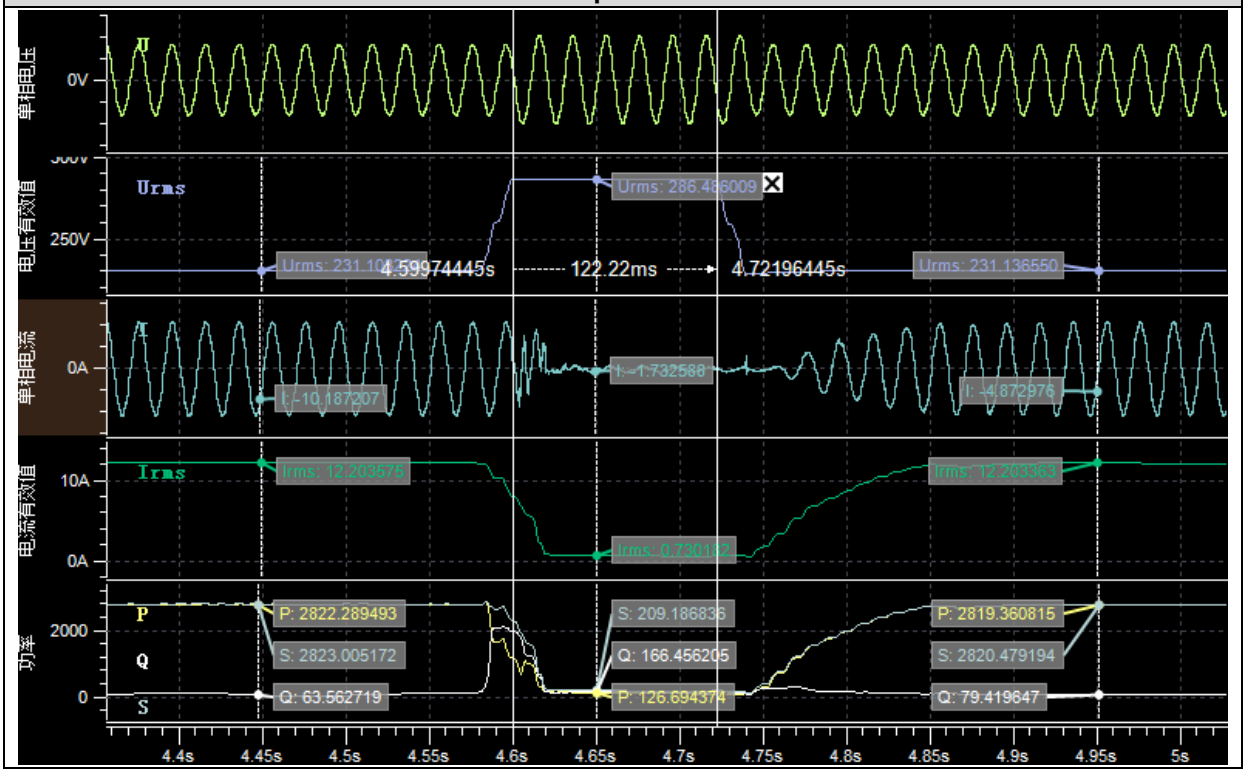
Test results are graphically represented in the following pages.

Single-Phase fault	
Full load (100 %Pn)	Residual voltage: 125.0 %Un

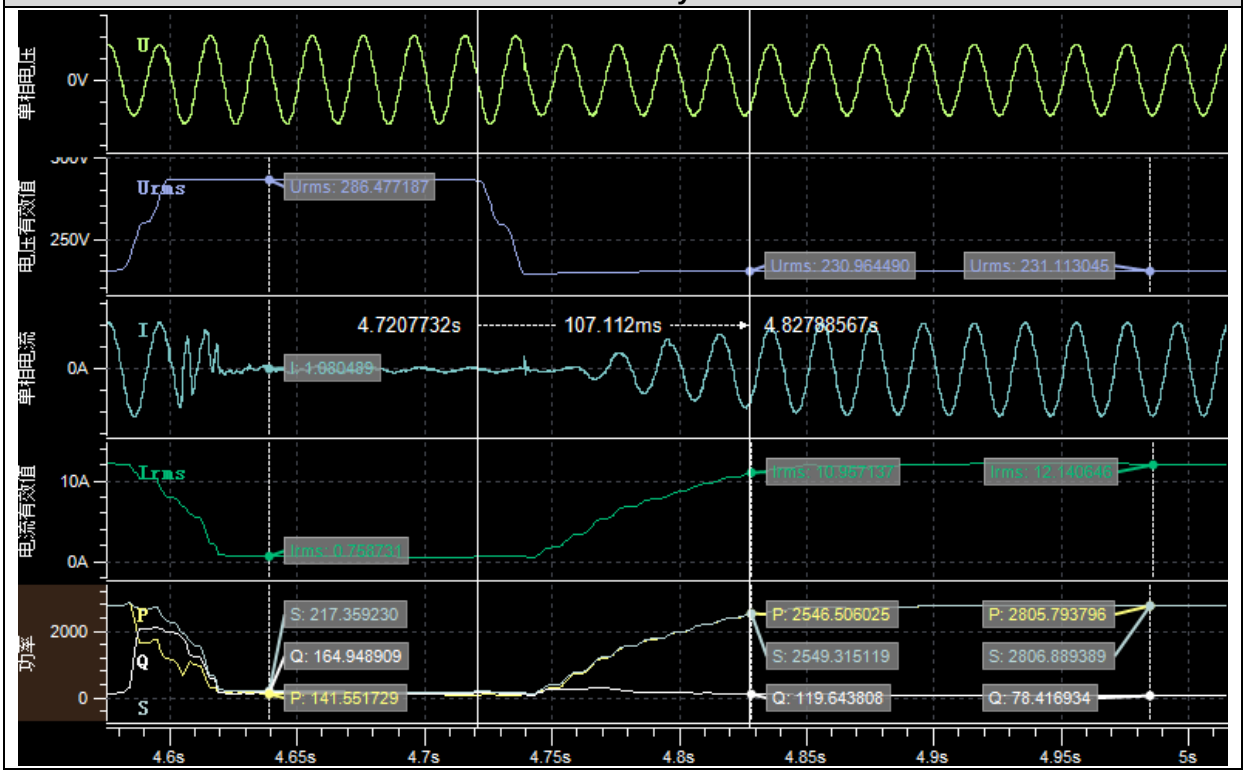
Voltage Rise Time



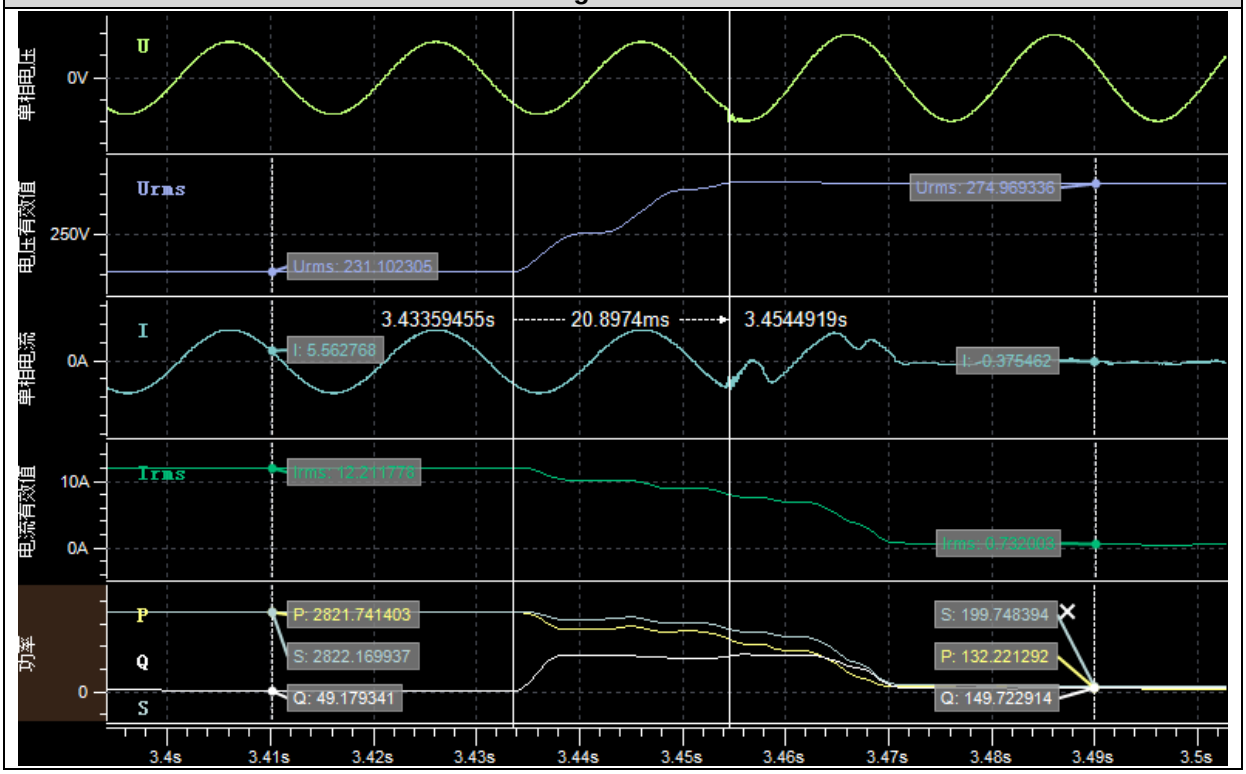
Dip Time



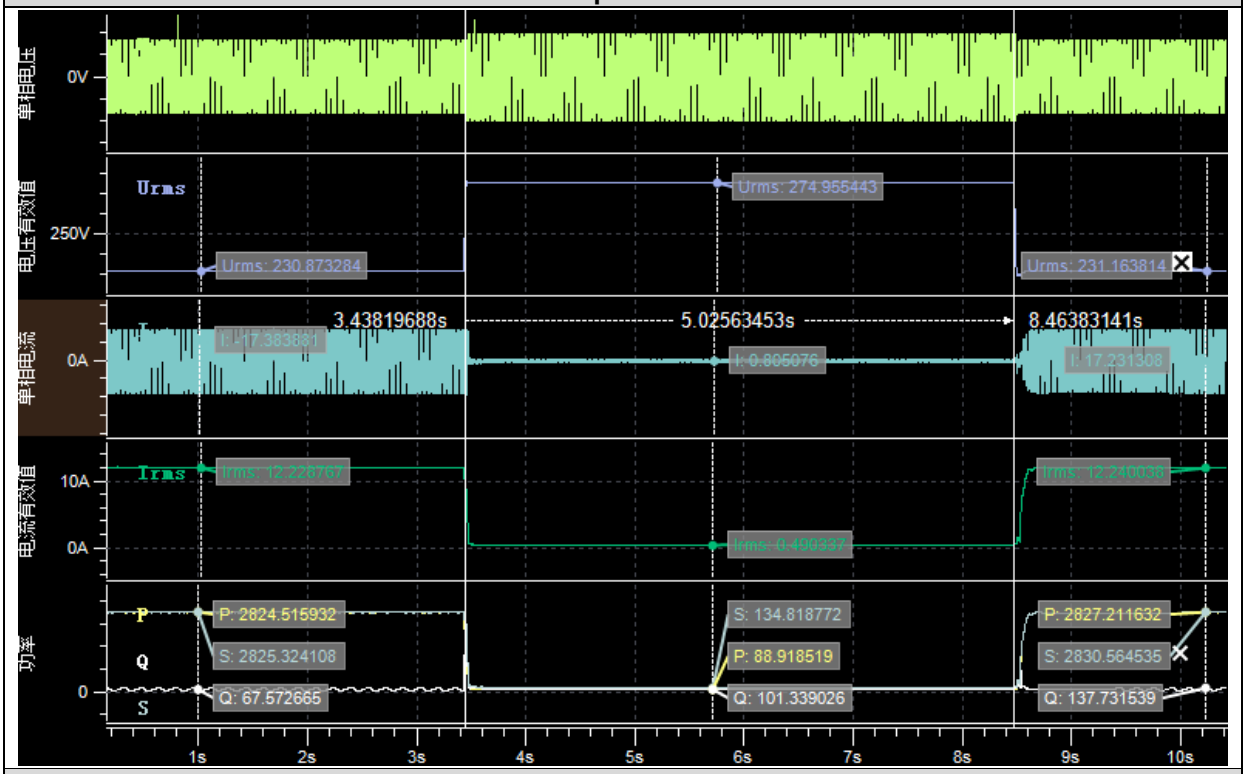
Power Recovery Time



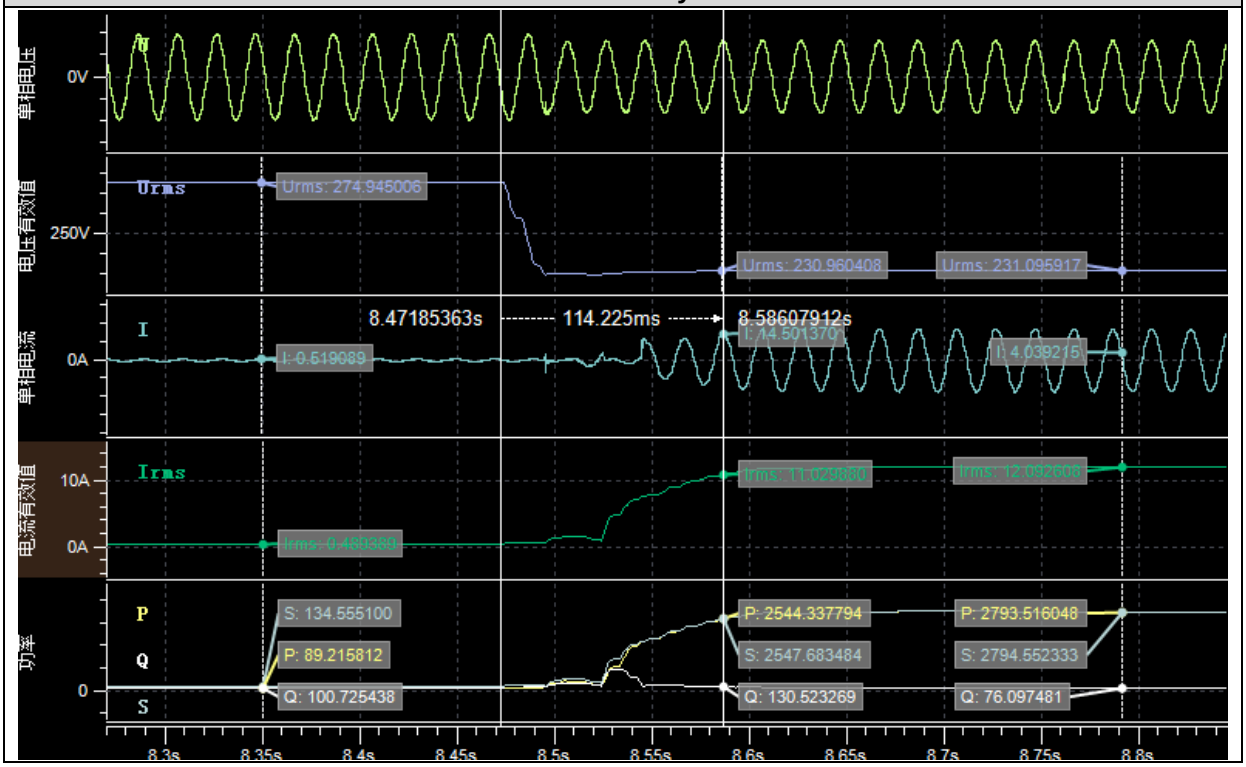
Single-Phase fault	
Full load (100 %Pn)	Residual voltage: 120.0 %Un
Voltage Rise Time	



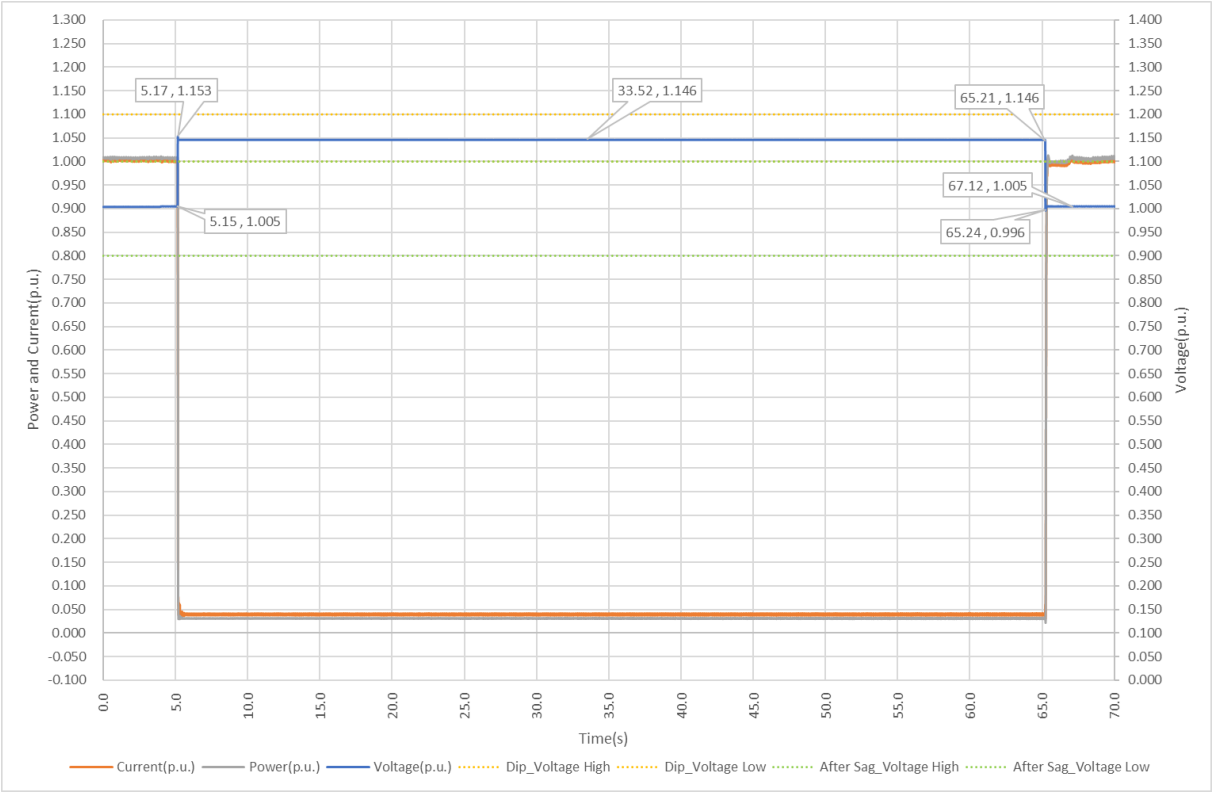
Dip Time



Power Recovery Time



Single-Phase fault	
Full load (100 %Pn)	Residual voltage: 115.0 %Un



4.3. ACTIVE RESPONSE TO FREQUENCY DEVIATION

4.3.1. Power response to overfrequency

The test has been done according to the clause 4.6.1 of the standard. The following definitions apply to the test to verify the clause:

- Test 1： P = 100 %Pn ; f1 = 50.2 Hz; droop = 12 %; f-stop deactivated, with delay of 2 s (*).
- Test 2： P = 100 %; f1 = 52 Hz; droop = 2 %; f-stop deactivated, no delay.
- Test 3： P = 50 %; f1 = 51 Hz; droop = 5 %; f-stop deactivated, no delay.
- Test 4： P = 100 %, f1 = 50.2 Hz; droop = 5 %; f-stop = 50.1 Hz (hysteresis), no delay.

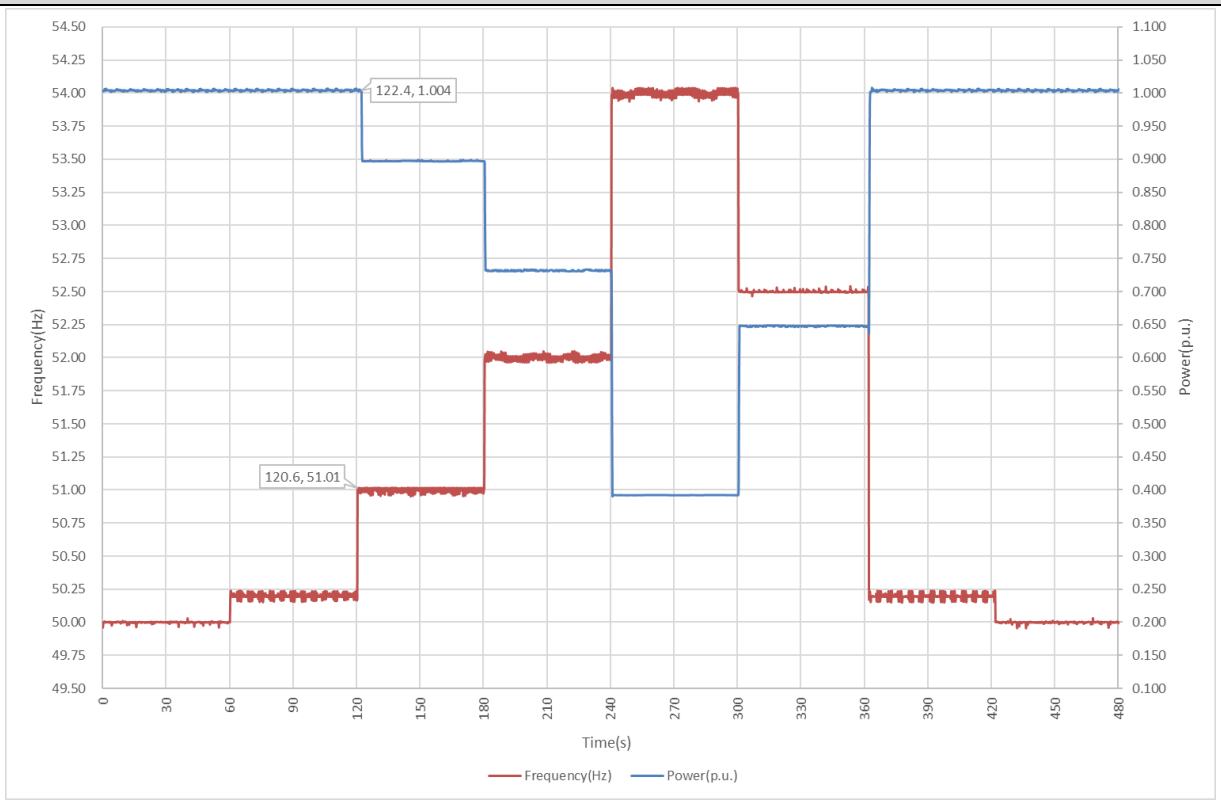
(*) The intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

Test results are offered at the table below.

Test 1						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4
2	50.20 ± 0.05 Hz	100.0	50.20	> 30	100.4	0.4
3	51.00 ± 0.05 Hz	86.7	51.00	> 30	89.7	3.0
4	52.00 ± 0.05 Hz	70.0	52.00	> 30	73.2	3.2
5	54.00 ± 0.05 Hz	36.7	54.00	> 30	39.2	2.5
6	52.50 ± 0.05 Hz	61.7	52.50	> 30	64.8	3.1
7	50.20 ± 0.05 Hz	100.0	50.20	> 30	100.4	0.4
8	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4
Time delay setting from step 2 to step 3						
Initial of change time		120.6 s				
End of change (*)		122.4 s				
Delay time		1.8 s				

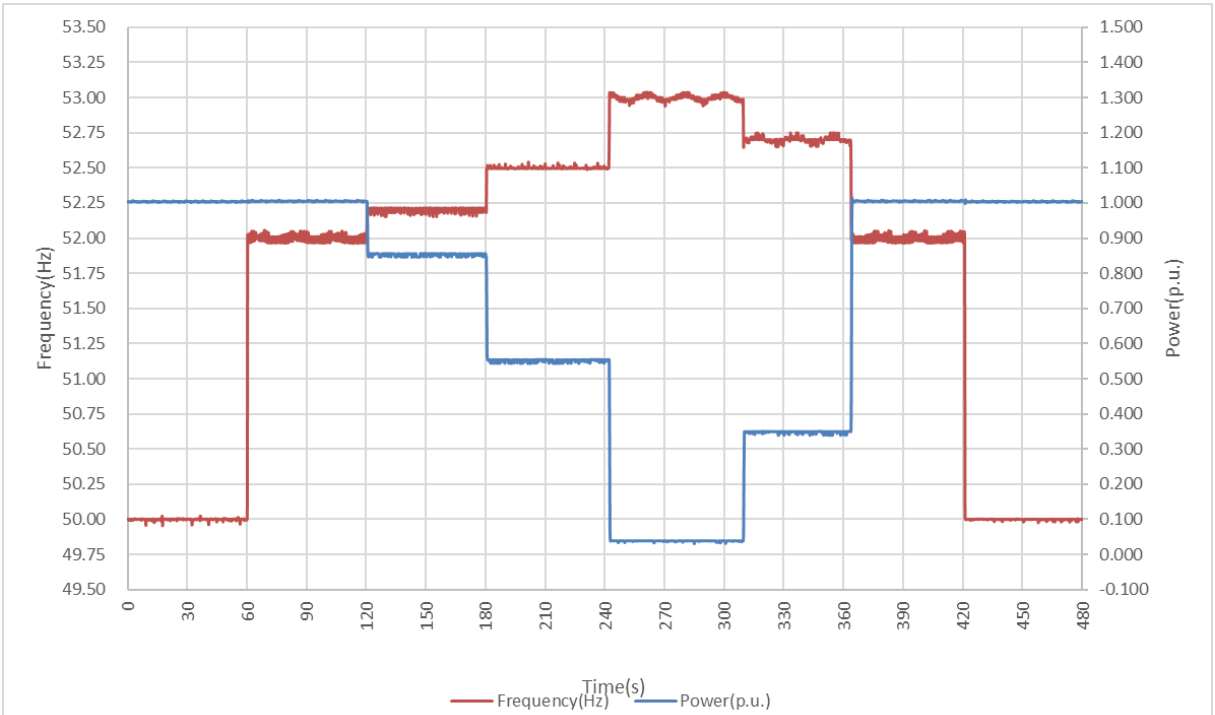
(*) With an accuracy of ±10 % of the nominal power

P vs f chart for Test 1



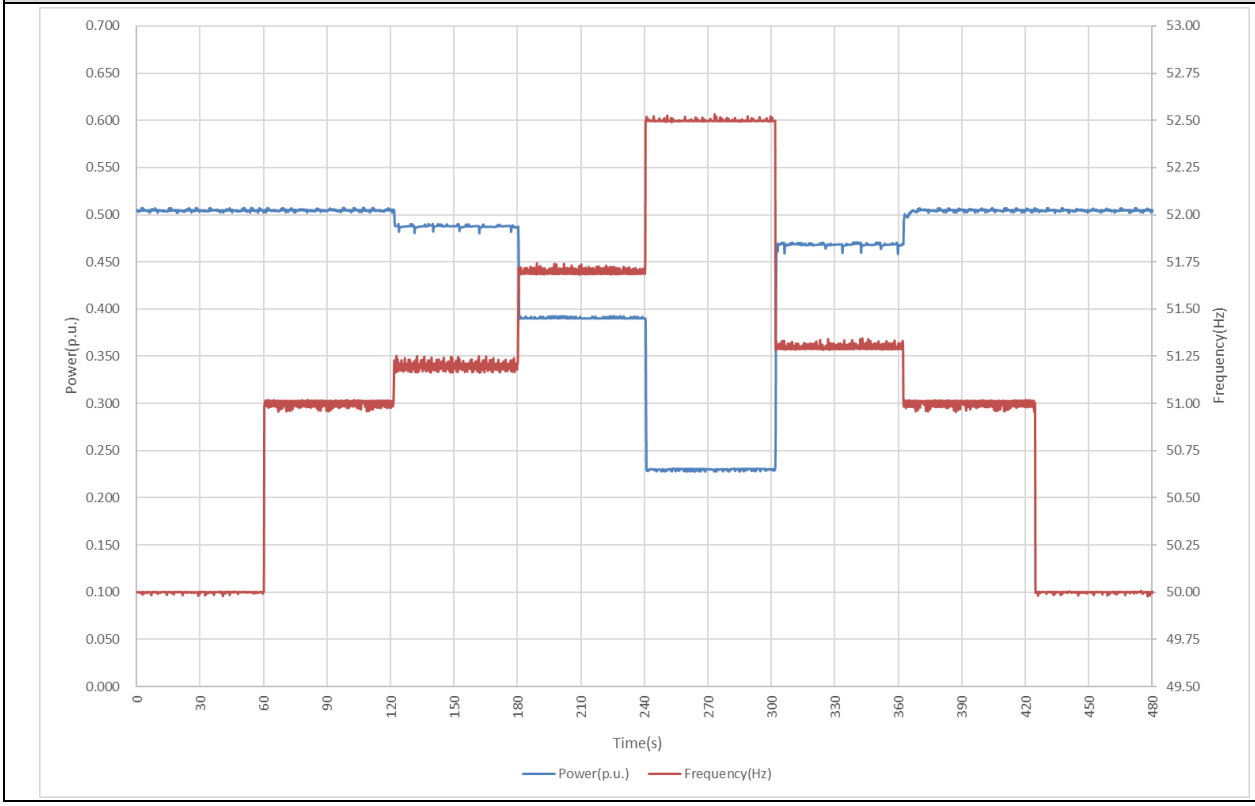
Test 2						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4
2	52.00 ± 0.05 Hz	100.0	52.00	> 30	100.5	0.5
3	52.20 ± 0.05 Hz	80.0	52.20	> 30	85.3	5.3
4	52.50 ± 0.05 Hz	50.0	52.50	> 30	55.1	5.1
5	53.00 ± 0.05 Hz	0.0	53.00	> 30	3.8	3.8
6	52.70 ± 0.05 Hz	30.0	52.70	> 30	34.8	4.8
7	52.00 ± 0.05 Hz	100.0	52.00	> 30	100.5	0.5
8	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4

P vs f chart for Test 2



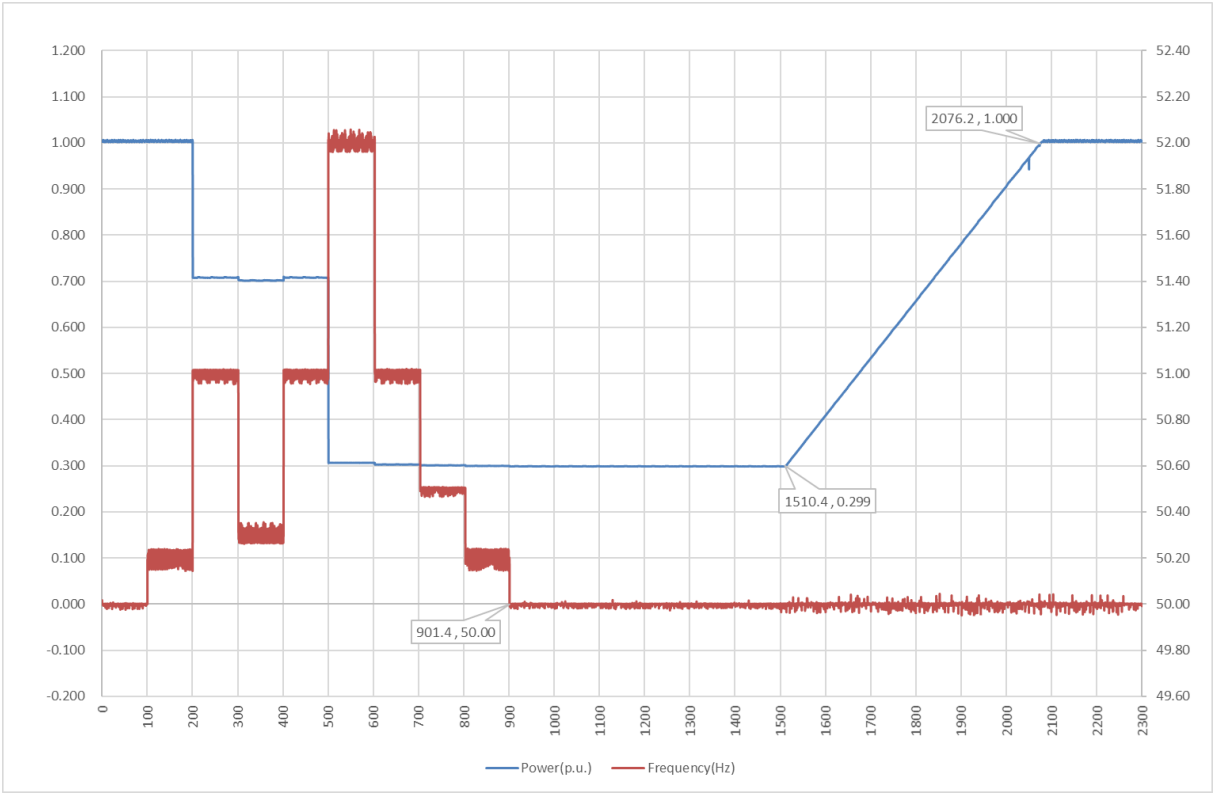
Test 3						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	50	50.00	> 30	50.5	0.5
2	51.00 ± 0.05 Hz	50	51.00	> 30	50.5	0.5
3	51.20 ± 0.05 Hz	46	51.21	> 30	48.8	2.8
4	51.70 ± 0.05 Hz	36	51.70	> 30	39.1	3.1
5	52.50 ± 0.05 Hz	20	52.50	> 30	23.0	3.0
6	51.30 ± 0.05 Hz	44	51.30	> 30	46.8	2.8
7	51.00 ± 0.05 Hz	50	51.00	> 30	50.5	0.5
8	50.00 ± 0.05 Hz	50	50.00	> 30	50.5	0.5

P vs f chart for Test 3



Test 4						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4
2	50.20 ± 0.05 Hz	100.0	50.20	> 30	100.4	0.4
3	51.00 ± 0.05 Hz	68.0	51.00	> 30	70.8	2.8
4	50.30 ± 0.05 Hz	68.0	50.30	> 30	70.2	2.2
5	51.00 ± 0.05 Hz	68.0	51.00	> 30	70.8	2.8
6	52.00 ± 0.05 Hz	28.0	52.00	> 30	30.6	2.6
7	51.00 ± 0.05 Hz	28.0	51.00	> 30	30.3	2.3
8	50.50 ± 0.05 Hz	28.0	50.50	> 30	30.1	2.1
9	50.20 ± 0.05 Hz	28.0	50.20	> 30	30.0	2.0
10	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4
Reconnection Time(s)		609.0		Power ramp gradient		7.43 %Pn/min

P vs f chart for Test 4



4.3.2. Power response to underfrequency

The test has been done according to the clause 4.6.2 of the standard. This test has been performed to show the capability of the inverter, although it is only mandatory for Energy Storage Systems according to the standard. The following definitions apply to the test to verify the clause:

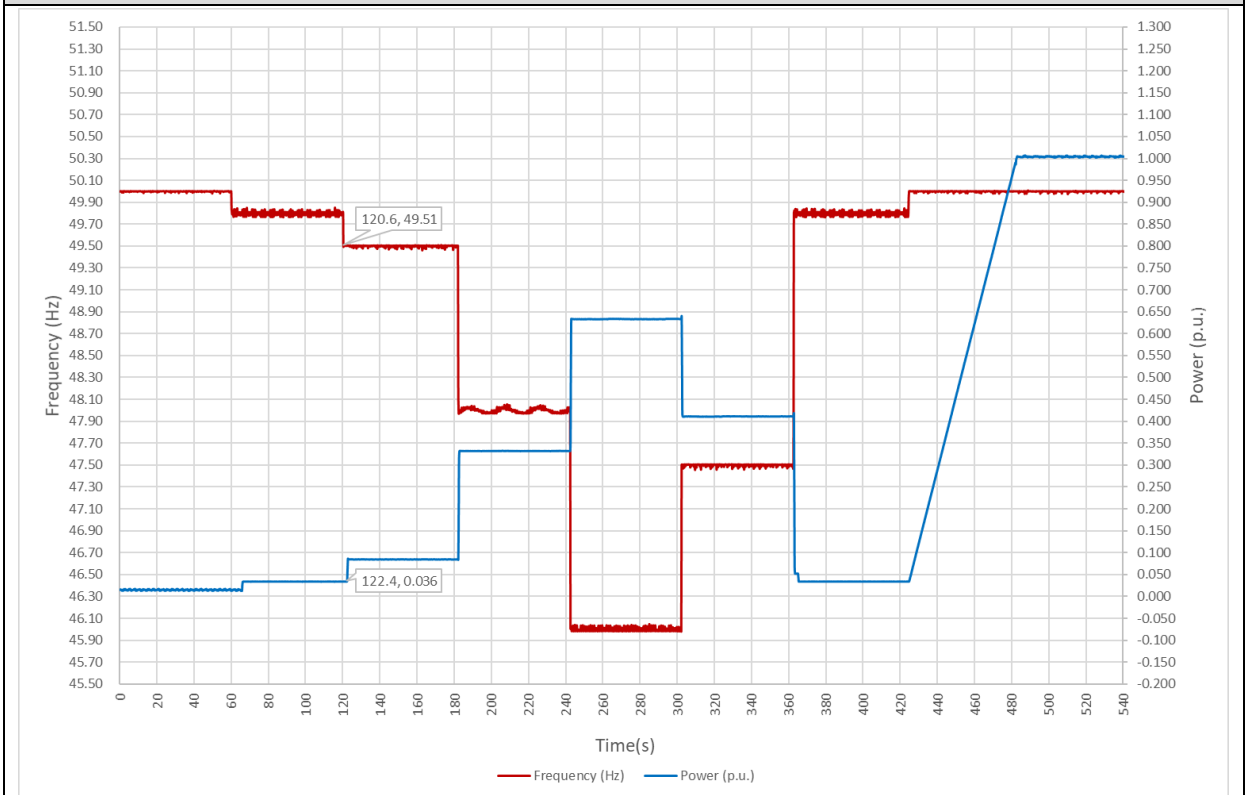
- Test 1: P_M = 0 %Pn; f1 = 49.8 Hz; droop = 12 %; f-stop deactivated, with delay of 2 s (*).
- Test 2: P_M = 0 %Pn; f1 = 48 Hz; droop = 2 %; f-stop deactivated, no delay.
- Test 3: P_M = 50 %Pn; f1 = 49.8 Hz; droop = 5 %; f-stop deactivated, no delay.

(*) The intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

Test results are offered at the table below.

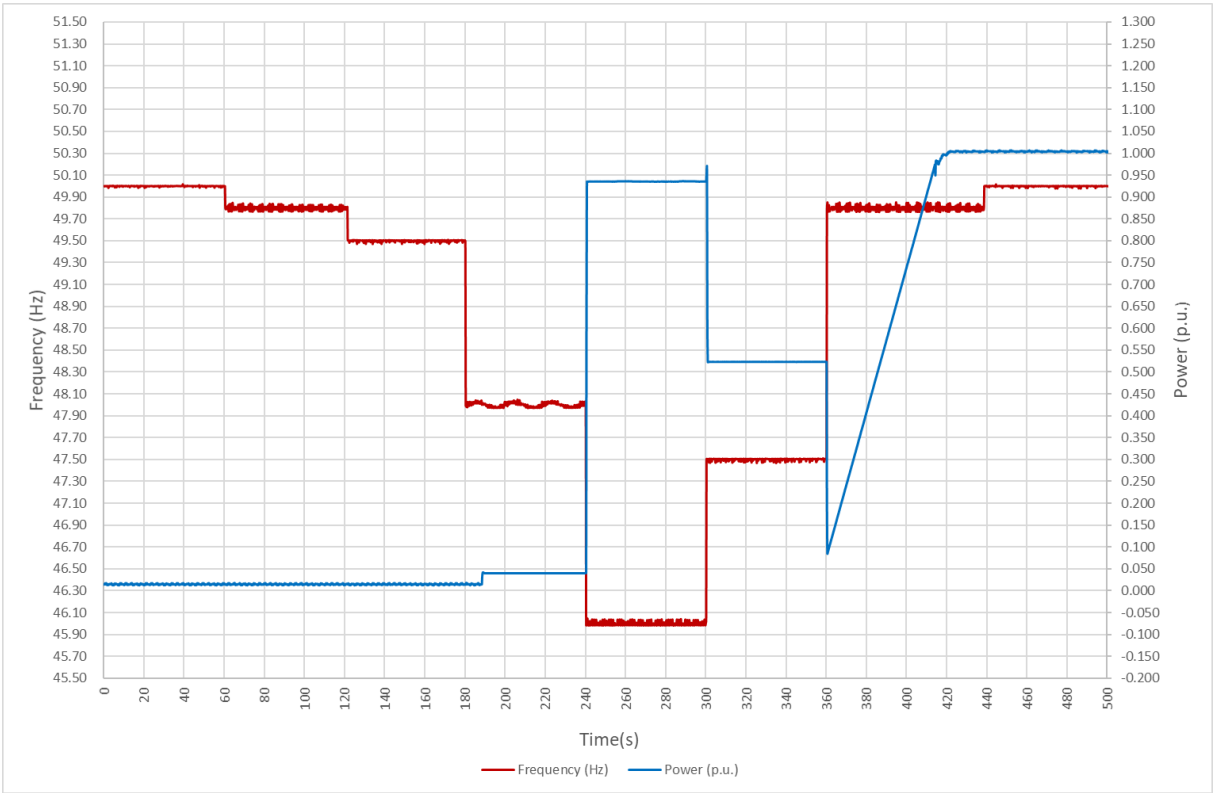
Test 1						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	0.0	50.00	> 30	1.5	1.5
2	49.80 ± 0.05 Hz	0.0	49.80	> 30	3.4	3.4
3	49.50 ± 0.05 Hz	5.0	49.50	> 30	8.5	3.5
4	48.00 ± 0.05 Hz	30.0	48.00	> 30	33.2	3.2
5	46.00 ± 0.05 Hz	63.3	46.00	> 30	63.3	0.0
6	47.50 ± 0.05 Hz	38.3	47.50	> 30	41.1	2.8
7	49.80 ± 0.05 Hz	0.0	49.80	> 30	3.4	3.4
8	50.00 ± 0.05 Hz	100	50.00	> 30	100.4	0.4
Time delay setting from step 2 to step 3						
Initial of change time		120.6 s				
End of change		122.4 s				
Delay time		1.8 s				

P vs f chart for Test 1



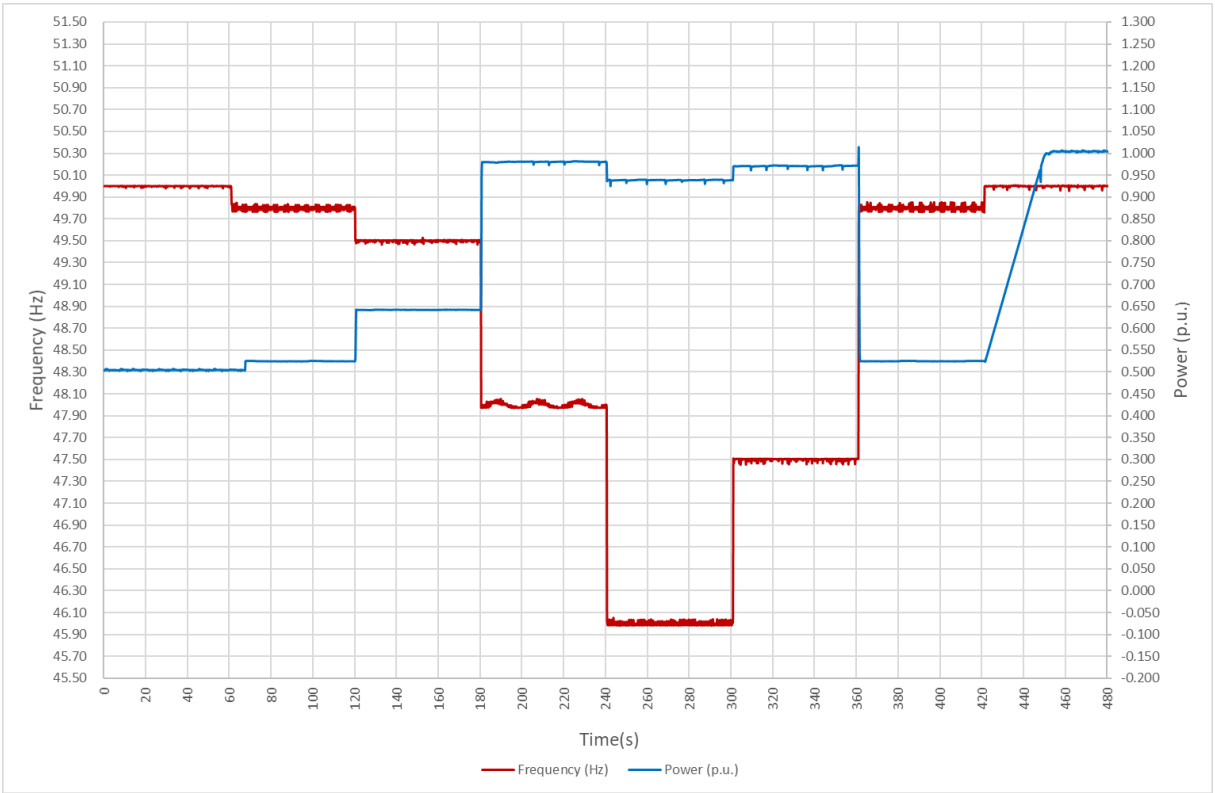
Test 2						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	0.0	50.00	> 30	1.5	1.5
2	49.80 ± 0.05 Hz	0.0	49.80	> 30	1.5	1.5
3	49.50 ± 0.05 Hz	0.0	49.50	> 30	1.5	1.5
4	48.00 ± 0.05 Hz	0.0	48.00	> 30	4.0	4.0
5	46.00 ± 0.05 Hz	100.0	46.00	> 30	93.6	-6.4
6	47.50 ± 0.05 Hz	50.0	47.50	> 30	52.3	2.3
7	49.80 ± 0.05 Hz	100.0	49.81	> 30	100.4	0.4
8	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4

P vs f chart for Test 2



Test 3						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	50.0	50.00	> 30	50.5	0.5
2	49.80 ± 0.05 Hz	50.0	49.80	> 30	52.5	2.5
3	49.50 ± 0.05 Hz	62.0	49.50	> 30	64.2	2.2
4	48.00 ± 0.05 Hz	100.0	48.00	> 30	98.1	-1.9
5	46.00 ± 0.05 Hz	100.0	46.00	> 30	93.9	-6.1
6	47.50 ± 0.05 Hz	100.0	47.50	> 30	97.1	-2.9
7	49.80 ± 0.05 Hz	50.0	49.80	> 30	52.5	2.5
8	50.00 ± 0.05 Hz	100.0	50.00	> 30	100.4	0.4

P vs f chart for Test 3



4.4. POWER RESPONSE TO VOLTAGE CHANGES

The generating unit shall be capable of operating in the control modes specified below within the limits specified in 4.7.2.2. The control modes are exclusive; only one mode may be active at a time.

- Q setpoint mode
- Q (U)
- Cos φ setpoint mode
- Cos φ (P)

4.4.1. Q Setpoint control modes

The test has been done according to the clause 4.7.2.3.2 of the standard. The following definitions apply to the test to verify the clause:

- Test 1: Q Zero (Q = 0 %Sn)
- Test 2: Rectangular Curve (Q = ±48.43 %Sn)
- Test 3: Triangular Curve (PF = ±0.9)

4.4.1.1. Test 1: Q Zero (Q = 0 %Sn)

This test verifies the capability of the inverter to provide a fixed value of reactive power. In addition, it is verified the Q control mode.

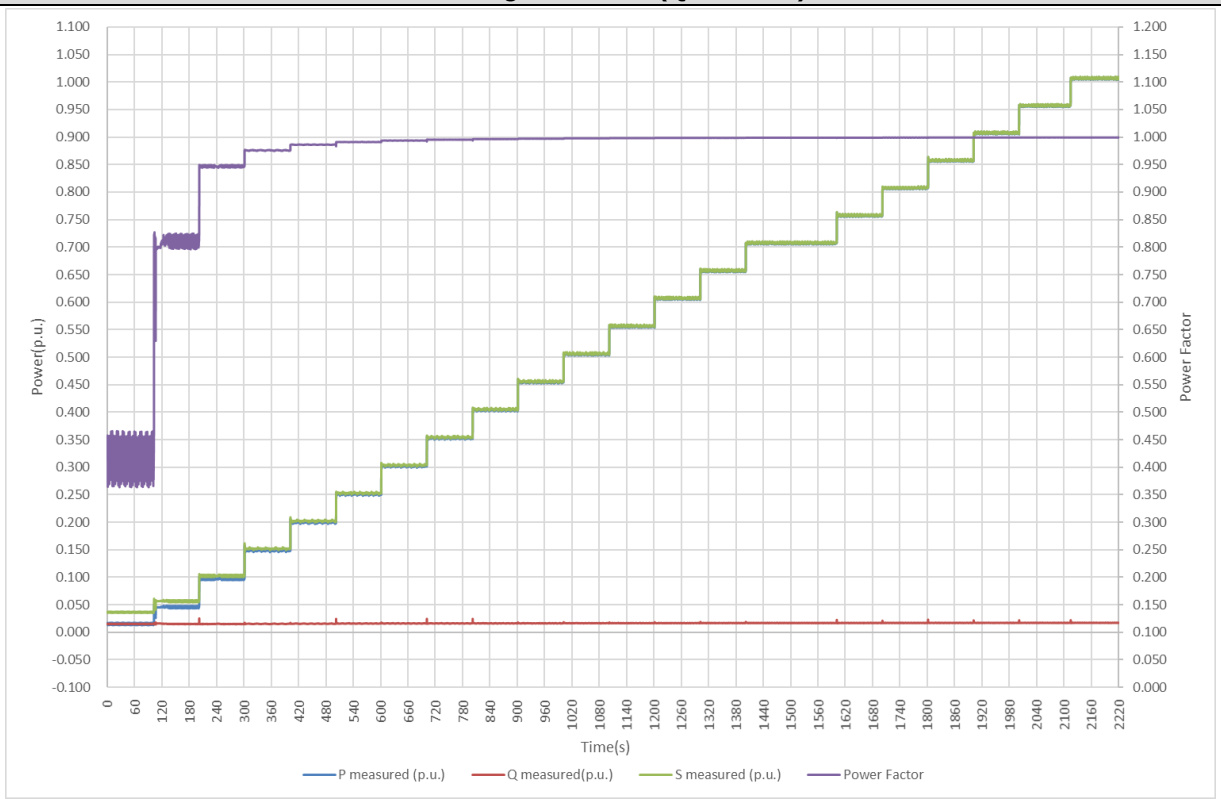
Allowed tolerance for reactive power measurements is to be considered inside ±2 %Sn for measurements above 10 %Sn.

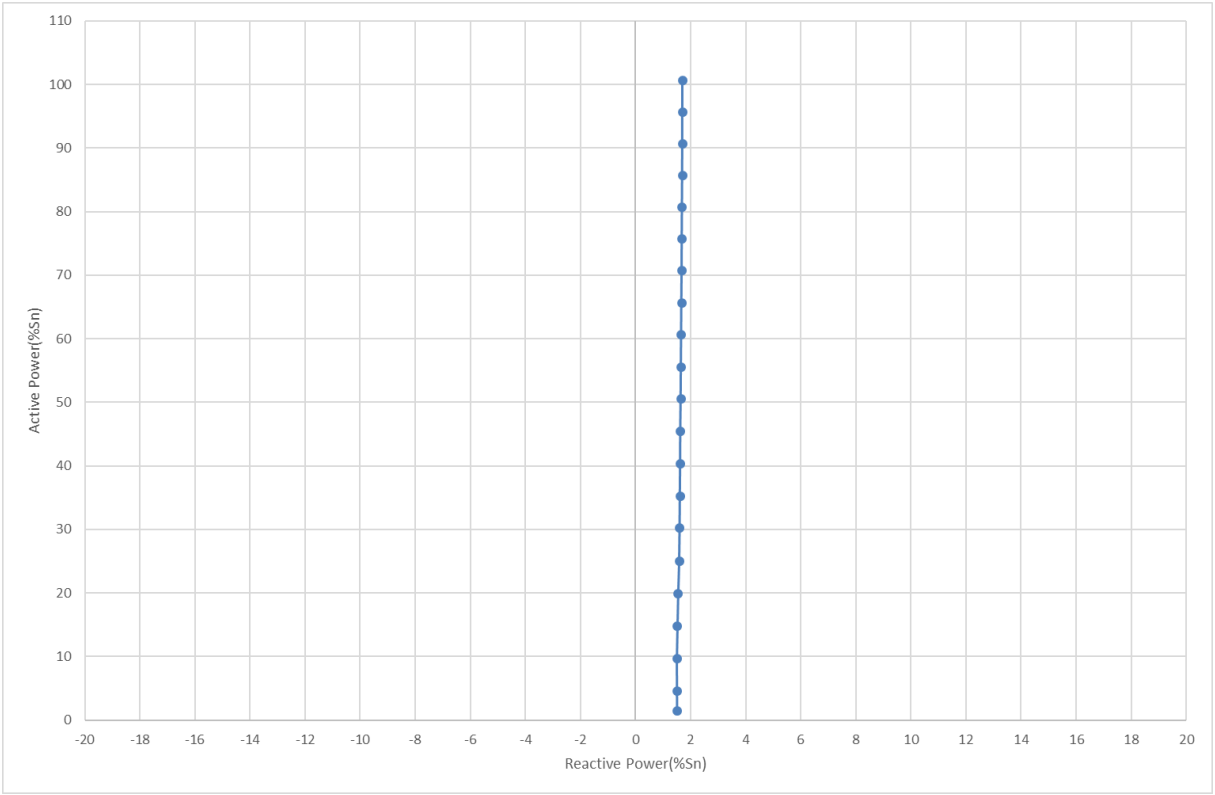
Test results are offered at tables below.

Rectangular Curve (Q = 0 %Sn)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q desired (%Sn)**	**Q measured (%Sn)**	**Q deviation (%Sn)**	**Power factor (cos φ)**
0	0.057	1.502	--	1.510	--	0.414
5	0.144	4.575	--	1.504	--	0.812
10	0.290	9.704	--	1.503	--	0.947
15	0.436	14.830	0.000	1.526	1.526	0.976
20	0.581	19.946	0.000	1.553	1.553	0.986
25	0.728	25.064	0.000	1.590	1.590	0.991
30	0.874	30.179	0.000	1.605	1.605	0.994
35	1.019	35.281	0.000	1.615	1.615	0.995
40	1.165	40.381	0.000	1.623	1.623	0.996
45	1.311	45.461	0.000	1.629	1.629	0.997
50	1.456	50.532	0.000	1.645	1.645	0.998
55	1.601	55.584	0.000	1.654	1.654	0.998
60	1.746	60.648	0.000	1.662	1.662	0.998
65	1.891	65.685	0.000	1.672	1.672	0.999
70	2.036	70.712	0.000	1.681	1.681	0.999
75	2.181	75.724	0.000	1.687	1.687	0.999
80	2.325	80.730	0.000	1.694	1.694	0.999
85	2.470	85.729	0.000	1.702	1.702	0.999
90	2.614	90.728	0.000	1.707	1.707	0.999
95	2.758	95.698	0.000	1.709	1.709	0.999
100	2.902	100.666	0.000	1.713	1.713	0.999

Test results are represented at diagrams below.

Rectangular Curve (Q = 0 %Sn)





4.4.1.2. Test 2: Rectangular Curve (Q = ±48.43 %Sn)

This test verifies the capability of the inverter to provide a fixed value of reactive power. In addition, it is verified the Q control mode.

Allowed tolerance for reactive power measurements is to be considered inside ±2 %Sn for measurements above 10 %Sn.

Test results are offered at tables below.

Rectangular Curve (Q = 48.43 %Sn / Inductive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q desired (%Sn)**	**Q measured (%Sn)**	**Q deviation (%Sn)**	**Power factor (cos φ)**
0	0.057	1.459	--	3.191	--	0.397
5	0.144	4.518	--	8.223	--	0.536
10	0.290	8.954	--	47.832	--	0.161
15	0.435	14.109	48.43	48.377	-0.053	0.247
20	0.581	19.422	48.43	48.188	-0.242	0.375
25	0.727	24.563	48.43	48.293	-0.137	0.455
30	0.873	29.703	48.43	48.383	-0.047	0.525
35	1.018	34.822	48.43	48.437	0.007	0.585
40	1.164	39.937	48.43	48.489	0.059	0.637
45	1.309	45.019	48.43	48.504	0.074	0.682
50	1.455	50.102	48.43	48.530	0.100	0.720
55	1.600	55.168	48.43	48.555	0.125	0.752
60	1.745	60.230	48.43	48.585	0.155	0.779
65	1.889	65.264	48.43	48.606	0.176	0.803
70	2.034	70.305	48.43	48.621	0.191	0.823
75	2.178	75.321	48.43	48.642	0.212	0.841
80	2.323	80.329	48.43	48.698	0.268	0.856
85	2.467	85.330	48.43	48.729	0.299	0.869
90	2.611	90.324	48.43	48.723	0.293	0.881
95	2.755	95.300	48.43	48.729	0.299	0.891
100 (*)	2.816	97.356	48.43	48.750	0.320	0.895

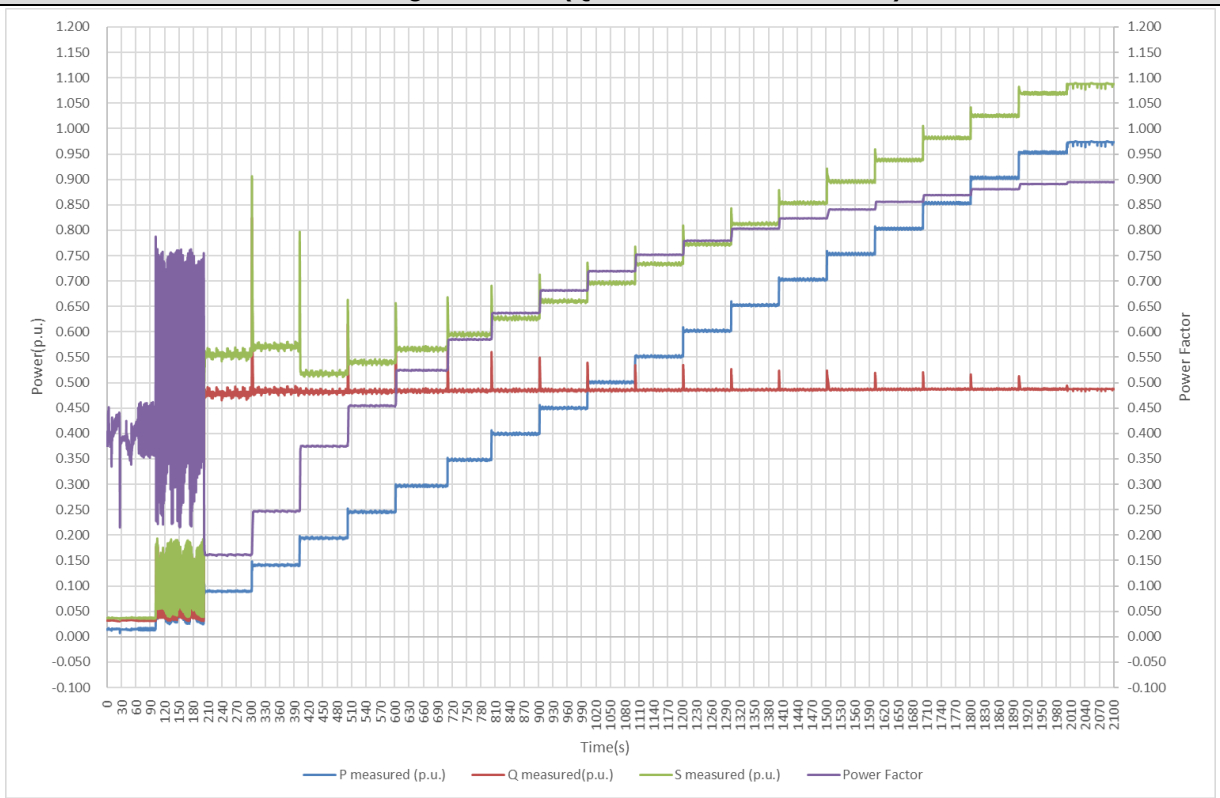
(*) When the EUT setting at Q value mode, the max reactive power setting range is ±48.43 %Sn. Because of current limited Smax = 1.00Pn, at Q control mode the active cannot reach the setting value.

Rectangular Curve (Q = 48.43 %Sn / Capacitive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q desired (%Sn)**	**Q measured (%Sn)**	**Q deviation (%Sn)**	**Power factor (cos φ)**
0	0.057	1.505	--	3.291	--	0.415
5	0.144	4.540	--	-1.494	--	0.725
10	0.290	8.956	--	-49.067	--	0.180
15	0.435	14.125	-48.430	-48.586	-0.156	0.279
20	0.581	19.289	-48.430	-48.357	0.073	0.370
25	0.727	24.445	-48.430	-48.216	0.214	0.452
30	0.873	29.586	-48.430	-48.126	0.304	0.524
35	1.019	34.715	-48.430	-48.049	0.381	0.586
40	1.164	39.828	-48.430	-47.985	0.445	0.639
45	1.309	44.917	-48.430	-47.961	0.469	0.684
50	1.455	50.004	-48.430	-47.945	0.485	0.722
55	1.600	55.070	-48.430	-47.917	0.513	0.754
60	1.745	60.136	-48.430	-47.902	0.528	0.782
65	1.889	65.180	-48.430	-47.873	0.557	0.806
70	2.034	70.210	-48.430	-47.859	0.571	0.826
75	2.179	75.237	-48.430	-47.861	0.569	0.844
80	2.323	80.250	-48.430	-47.884	0.546	0.859
85	2.468	85.256	-48.430	-47.879	0.551	0.872
90	2.612	90.255	-48.430	-47.843	0.587	0.884
95	2.769	95.306	-48.430	-47.862	0.568	0.894
100 (*)	2.784	95.665	-48.430	-48.062	0.368	0.894

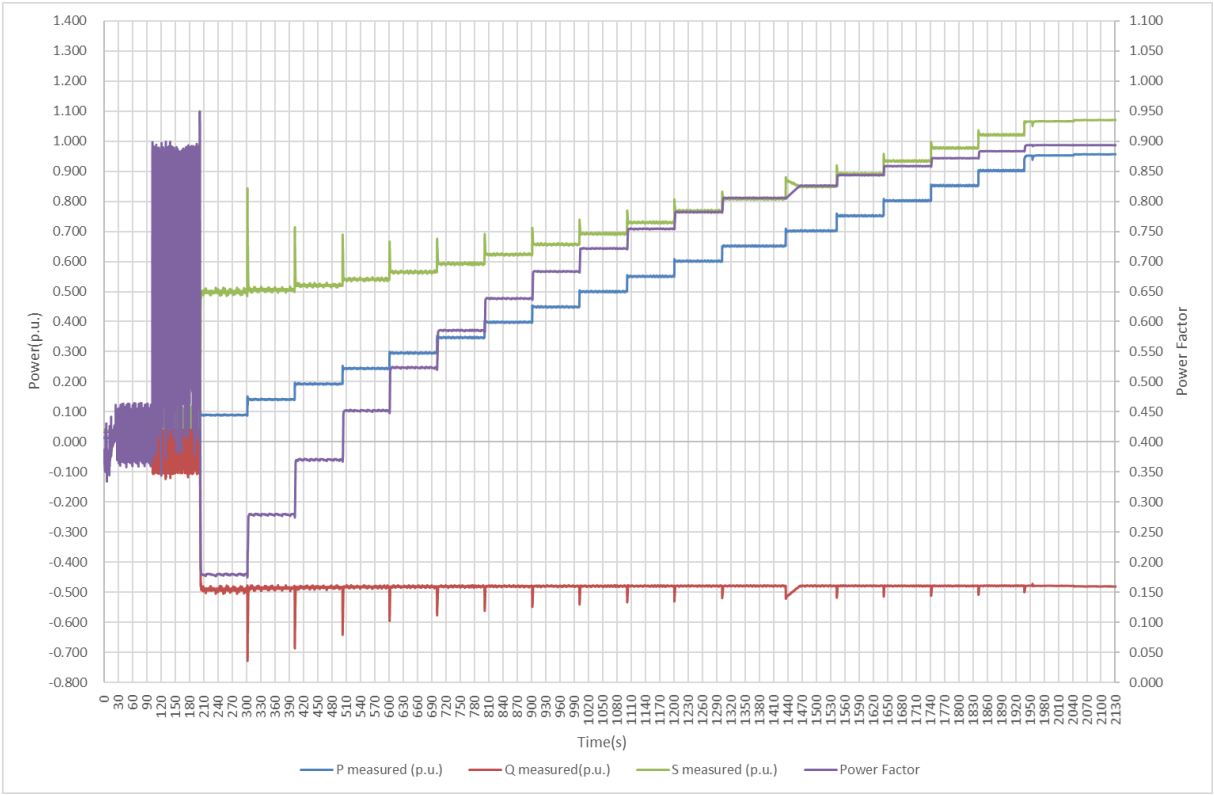
(*) When the EUT setting at Q value mode, the max reactive power setting range is ±48.43 %Sn. Because of current limited Smax = 1.00Pn, at Q control mode the active cannot reach the setting value.

Test results are represented at diagrams below.

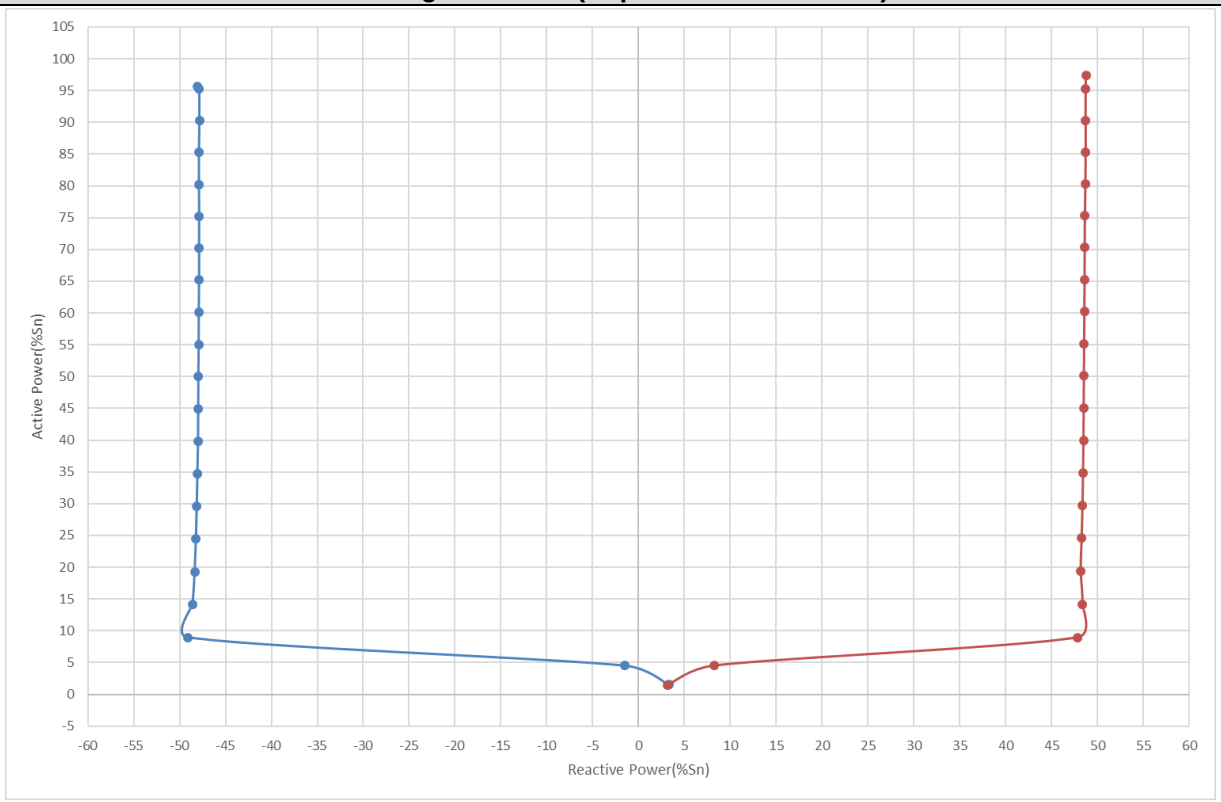
Rectangular Curve (Q = 48.43 %Sn / Inductive)



Rectangular Curve (Q = 48.43 %Sn / Capacitive)



Rectangular Curve (Capacitive vs Inductive)



4.4.1.3. Test 3: Triangular Curve (PF = ±0.9)

This test verifies the capability of the inverter to provide a fixed value of power factor. In addition, it is verified the PF control mode.

The maximum tolerance considered for the measured Power Factor is ±0.01, for measurements above 10 %Pn.

Test results are offered at the tables below.

Triangular Curve (PF = 0.9 / Inductive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q measured (%Sn)**	**Power factor desired (cos φ)**	**Power factor measured (cos φ)**	**Power factor deviation (cos φ)**
0	0.057	1.5	3.3	--	0.416	--
5	0.144	4.6	4.0	--	0.751	--
10	0.290	9.7	5.0	--	0.891	--
15	0.435	14.8	7.2	0.900	0.900	0.000
20	0.581	19.9	10.0	0.900	0.894	-0.006
25	0.727	25.0	11.8	0.900	0.905	0.005
30	0.873	30.1	15.4	0.900	0.905	0.005
35	1.019	35.2	17.6	0.900	0.895	-0.005
40	1.165	40.3	19.7	0.900	0.898	-0.002
45	1.310	45.4	21.9	0.900	0.901	0.001
50	1.455	50.4	25.5	0.900	0.893	-0.007
55	1.600	55.5	27.8	0.900	0.894	-0.006
60	1.745	60.5	30.0	0.900	0.896	-0.004
65	1.890	65.5	32.3	0.900	0.897	-0.003
70	2.035	70.5	34.6	0.900	0.898	-0.002
75	2.179	75.5	36.8	0.900	0.899	-0.001
80	2.323	80.5	39.1	0.900	0.900	0.000
85	2.467	85.5	41.3	0.900	0.900	0.000
90	2.612	90.4	43.6	0.900	0.901	0.001
95	2.755	95.4	45.8	0.900	0.901	0.001
100 (*)	2.833	98.0	47.0	0.900	0.902	0.002

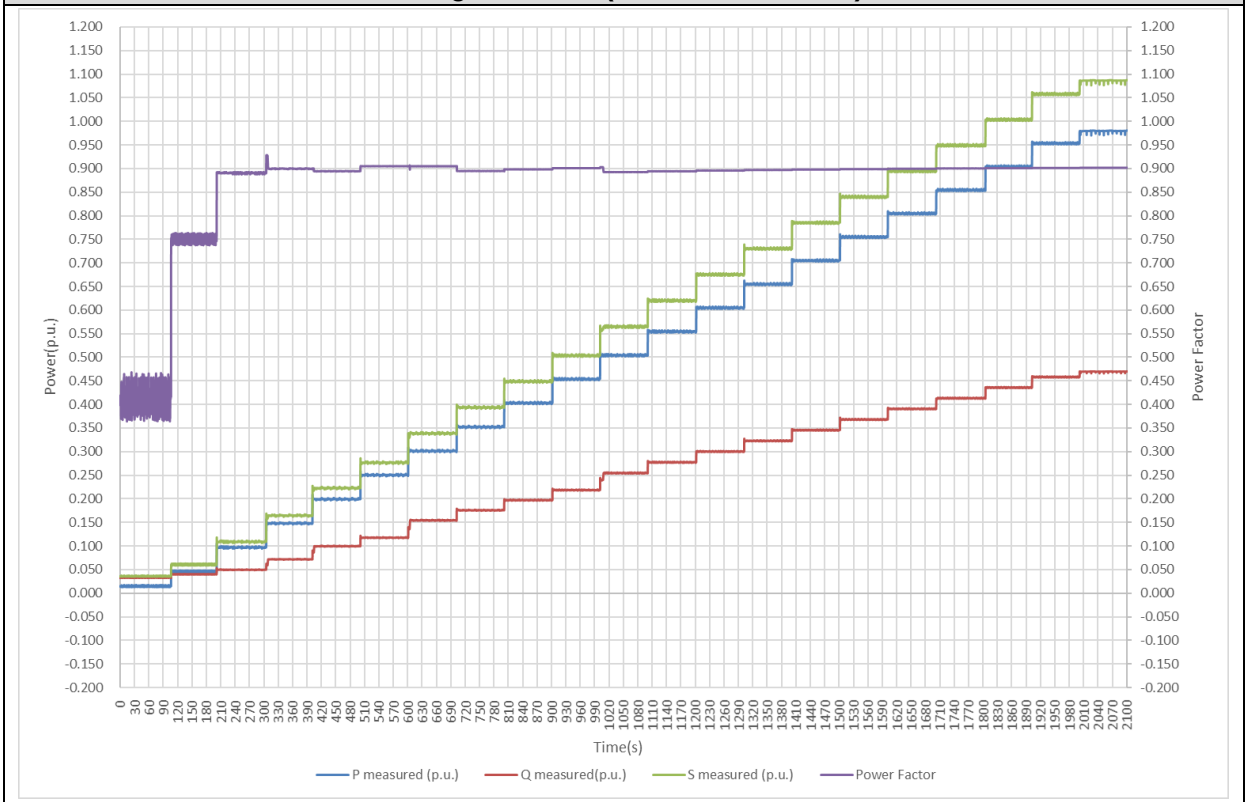
(*)The desired value of active power has not been reached due to power factor is 0.9 of the inverter.

Triangular Curve (PF = 0.9 / capacitive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q measured (%Sn)**	**Power factor desired (cos φ)**	**Power factor measured (cos φ)**	**Power factor deviation (cos φ)**
0	0.057	1.5	3.3	--	0.416	--
5	0.144	4.6	-2.3	--	0.895	--
10	0.290	9.7	-4.8	--	0.896	--
15	0.435	14.8	-7.0	0.900	0.904	0.004
20	0.581	19.9	-10.0	0.900	0.893	-0.007
25	0.727	25.0	-12.5	0.900	0.895	-0.005
30	0.873	30.1	-14.6	0.900	0.899	-0.001
35	1.019	35.2	-17.5	0.900	0.896	-0.004
40	1.165	40.3	-20.3	0.900	0.893	-0.007
45	1.310	45.3	-21.9	0.900	0.900	0.000
50	1.455	50.4	-24.6	0.900	0.898	-0.002
55	1.600	55.4	-27.3	0.900	0.897	-0.003
60	1.746	60.4	-30.0	0.900	0.896	-0.004
65	1.890	65.4	-32.7	0.900	0.895	-0.005
70	2.035	70.4	-35.3	0.900	0.894	-0.006
75	2.179	75.4	-38.0	0.900	0.893	-0.007
80	2.324	80.4	-38.5	0.900	0.902	0.002
85	2.468	85.4	-41.0	0.900	0.902	0.002
90	2.612	90.3	-43.5	0.900	0.901	0.001
95	2.756	95.3	-46.0	0.900	0.901	0.001
100 (*)	2.781	96.1	-46.4	0.900	0.900	0.000

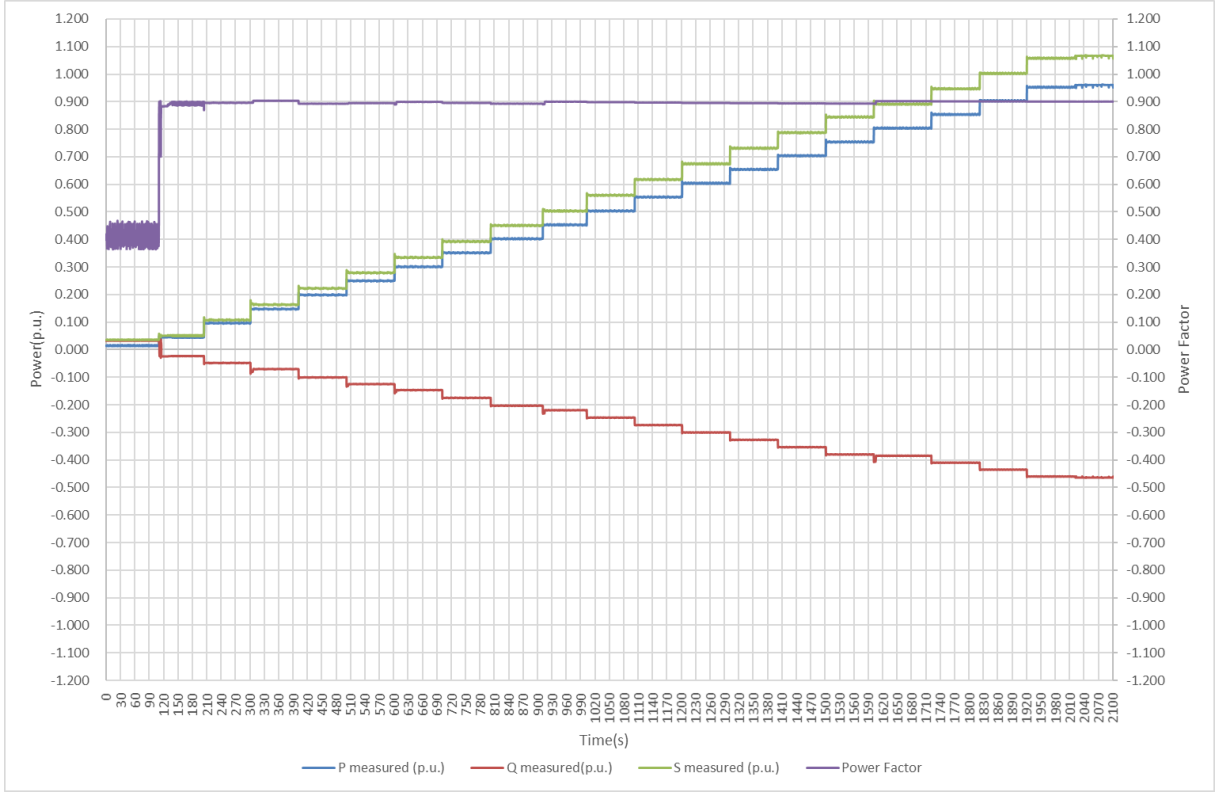
(*)The desired value of active power has not been reached due to power factor is 0.9 of the inverter.

Test results are represented at the diagrams below.

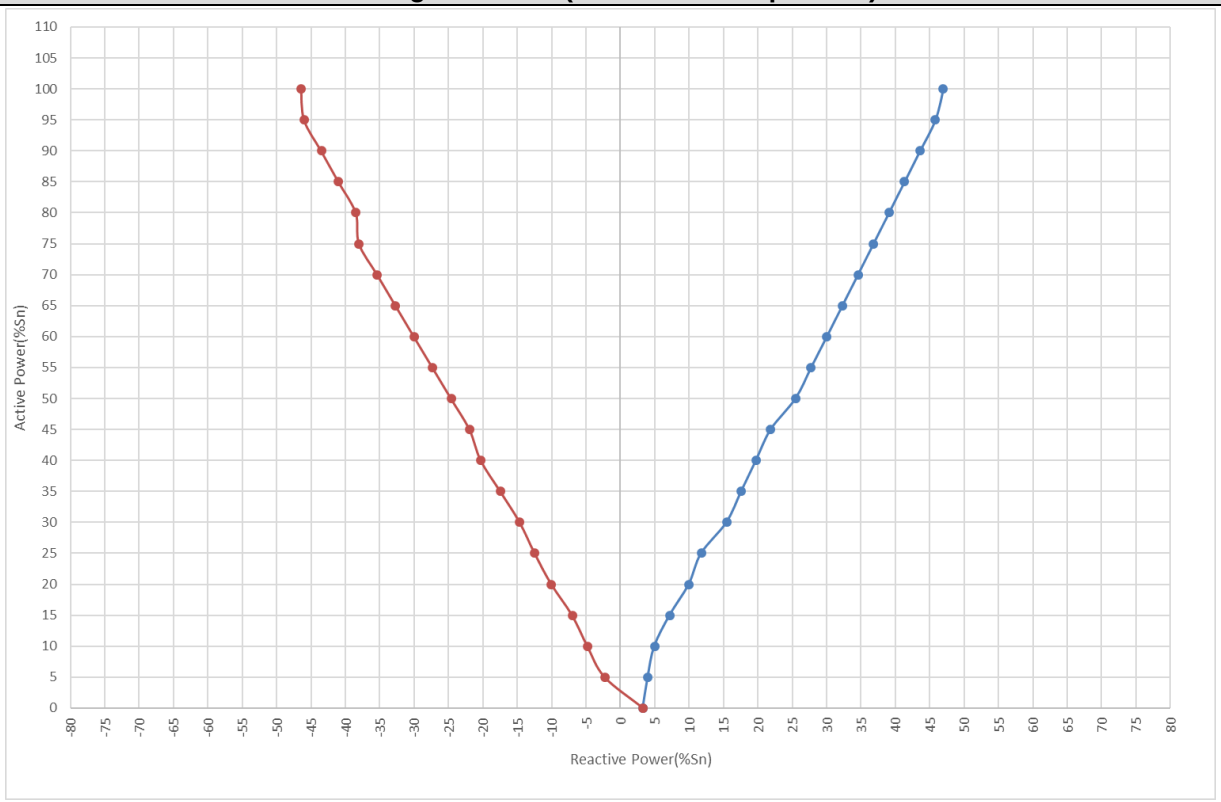
Triangular Curve (PF = 0.9 / Inductive)



Triangular Curve (PF = 0.9 / Capacitive)



Triangular Curve (Inductive vs Capacitive)



4.4.2. Voltage related control mode

4.4.2.1. Voltage related control mode Q(U)

The test has been done according to the clause 4.7.2.3.3 of the standard.

Setting the characteristic as following to prove configurability of the inverter:

- U1 = 0.93, Qmax
- U2 = 0.96, Q = 0.1 p.u.
- U3 = 1.04, Q = -0.1 p.u.
- U4 = 1.07, -Qmax

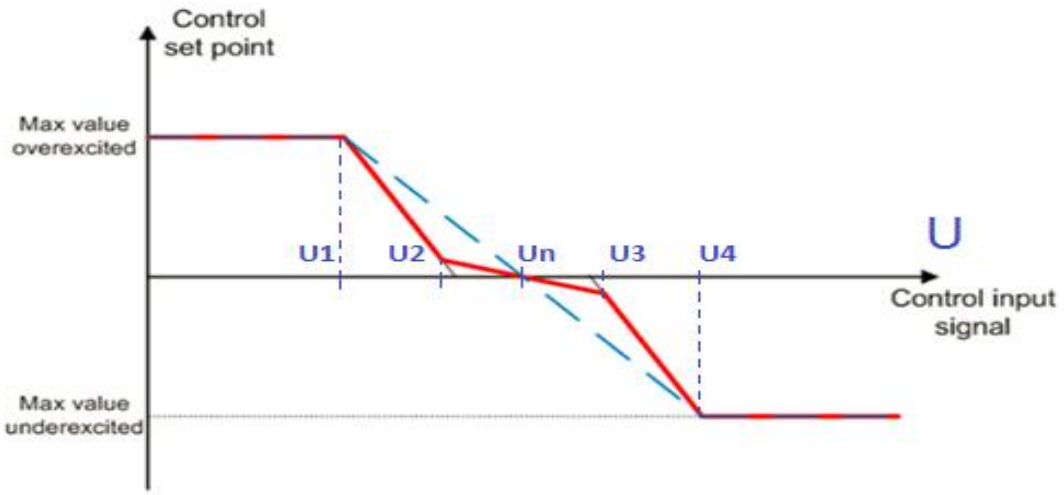


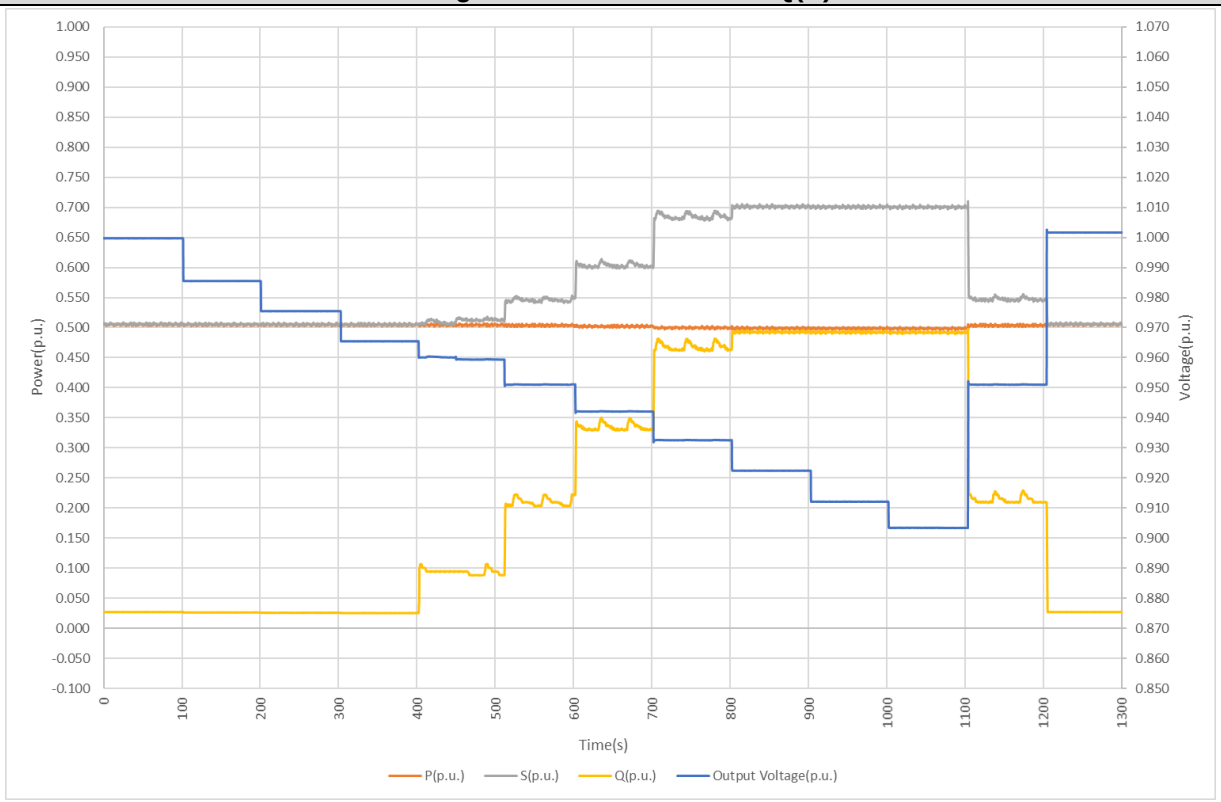
Figure 16 — Example characteristics for Q respectively cos φ control mode

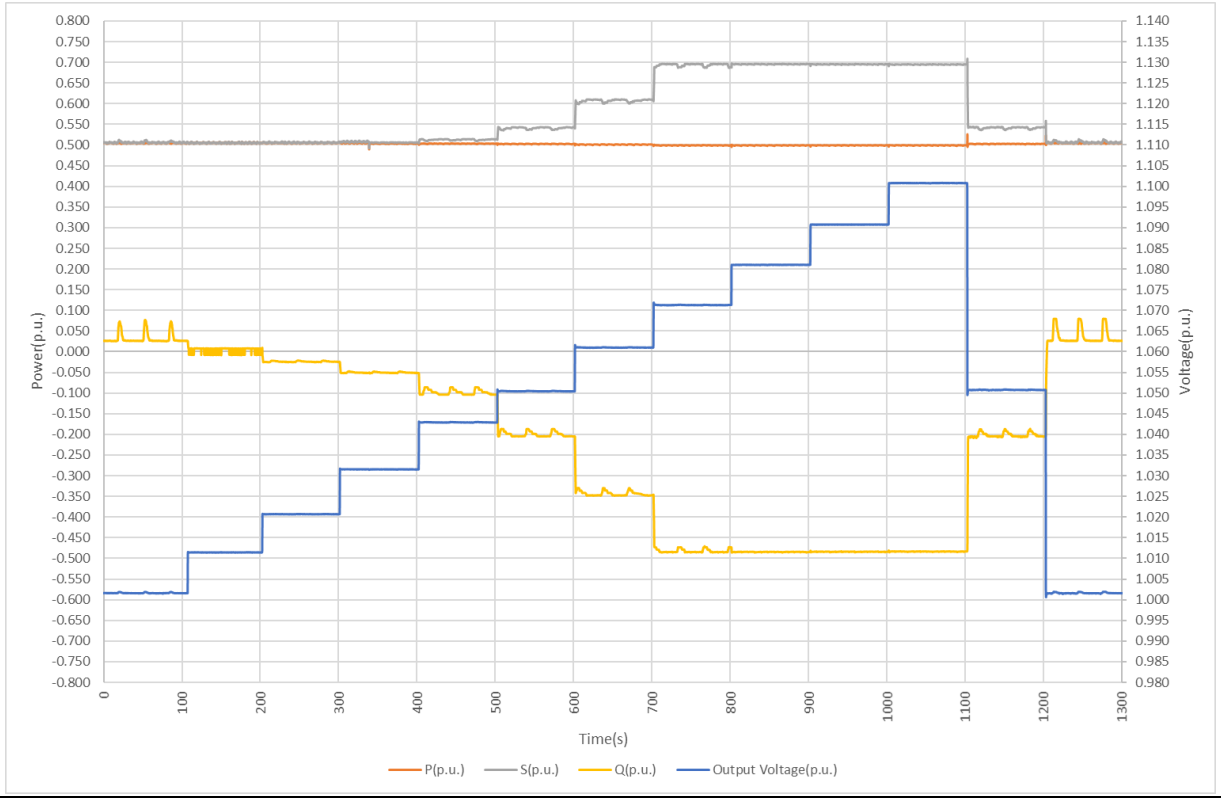
Test results are offered at the tables below.

P/Pn setpoint (%)	U setpoint	P measured (p.u.)	V measured (p.u.)	Q measured (p.u.)	Q desired (p.u.)	ΔQ (< ±0.05 p.u.)
50	1.00 Un	0.505	1.00	0.027	0.000	0.027
50	0.99 Un	0.505	0.99	0.026	0.025	0.001
50	0.98 Un	0.505	0.98	0.026	0.050	-0.024
50	0.97 Un	0.505	0.97	0.025	0.075	-0.050
50	0.96 Un	0.505	0.96	0.093	0.100	-0.007
50	0.95 Un	0.504	0.95	0.210	0.228	-0.018
50	0.94 Un	0.502	0.94	0.336	0.356	-0.020
50	0.93 Un	0.500	0.93	0.468	0.484	-0.016
50	0.92 Un	0.499	0.92	0.493	0.484	0.009
50	0.91 Un	0.499	0.91	0.492	0.484	0.008
50	0.90 Un	0.499	0.90	0.492	0.484	0.008
50	0.95 Un	0.504	0.95	0.215	0.228	-0.013
50	1.00 Un	0.505	1.00	0.027	0.000	0.027

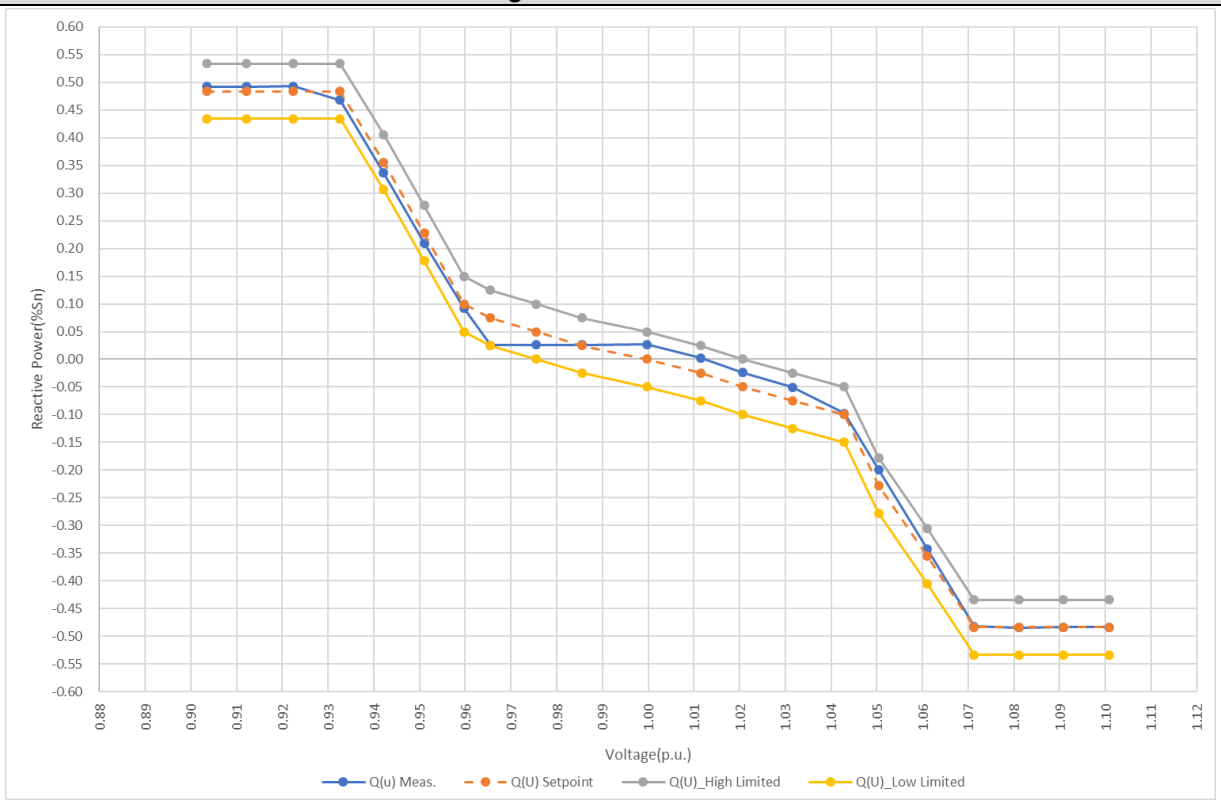
P/Pn setpoint (%)	U setpoint	P measured (p.u.)	V measured (p.u.)	Q measured (p.u.)	Q desired (p.u.)	ΔQ (< ±0.05 p.u.)
50	1.00 Un	0.505	1.00	0.033	0.000	0.033
50	1.01 Un	0.505	1.01	0.003	-0.025	0.028
50	1.02 Un	0.506	1.02	-0.024	-0.050	0.026
50	1.03 Un	0.504	1.03	-0.050	-0.075	0.025
50	1.04 Un	0.504	1.04	-0.098	-0.100	0.002
50	1.05 Un	0.503	1.05	-0.199	-0.228	0.029
50	1.06 Un	0.501	1.06	-0.343	-0.356	0.013
50	1.07 Un	0.499	1.07	-0.482	-0.484	0.002
50	1.08 Un	0.499	1.08	-0.484	-0.484	0.000
50%	1.09 Un	0.499	1.09	-0.484	-0.484	0.000
50	1.10 Un	0.499	1.10	-0.483	-0.484	0.001
50	1.05 Un	0.503	1.05	-0.201	-0.228	0.027
50	1.00 Un	0.505	1.00	0.037	0.000	0.037

Voltage related control mode- Q(U)





Voltage vs Reactive Power



4.4.2.2. Voltage related control mode Q(U) with lock-in/lock-out function

The test has been done according to the clause 4.7.2.3.3 of the standard.

Two active power levels shall be configurable both at least in the range of 0 % to 100 % of PD. The lock-in value turns the Q(U) mode on, the lock-out value turns Q(U) off. If lock-in is larger than lock-out a hysteresis is given. See also Figure 14 in the standard.

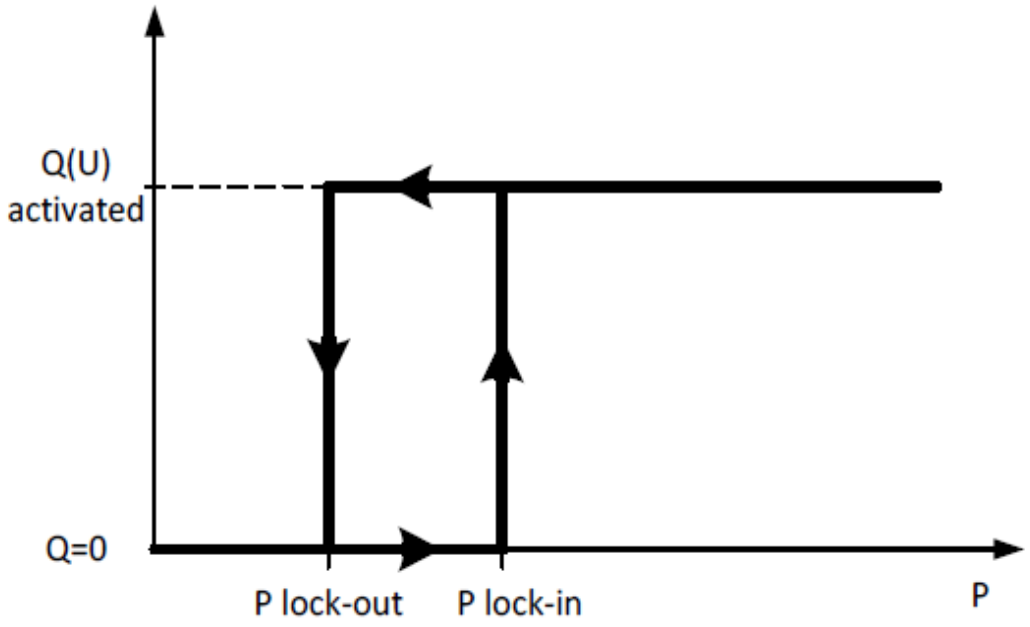


Figure 14 – Example of lock-in and lock-out values for Q(U) mode

Setting the characteristic as following to prove configurability of the inverter:

- U1 = 0.93, Qmax
- U2 = 0.96, Q = 0.1 p.u.
- U3 = 1.04, Q = -0.1 p.u.
- U4 = 1.07, -Qmax

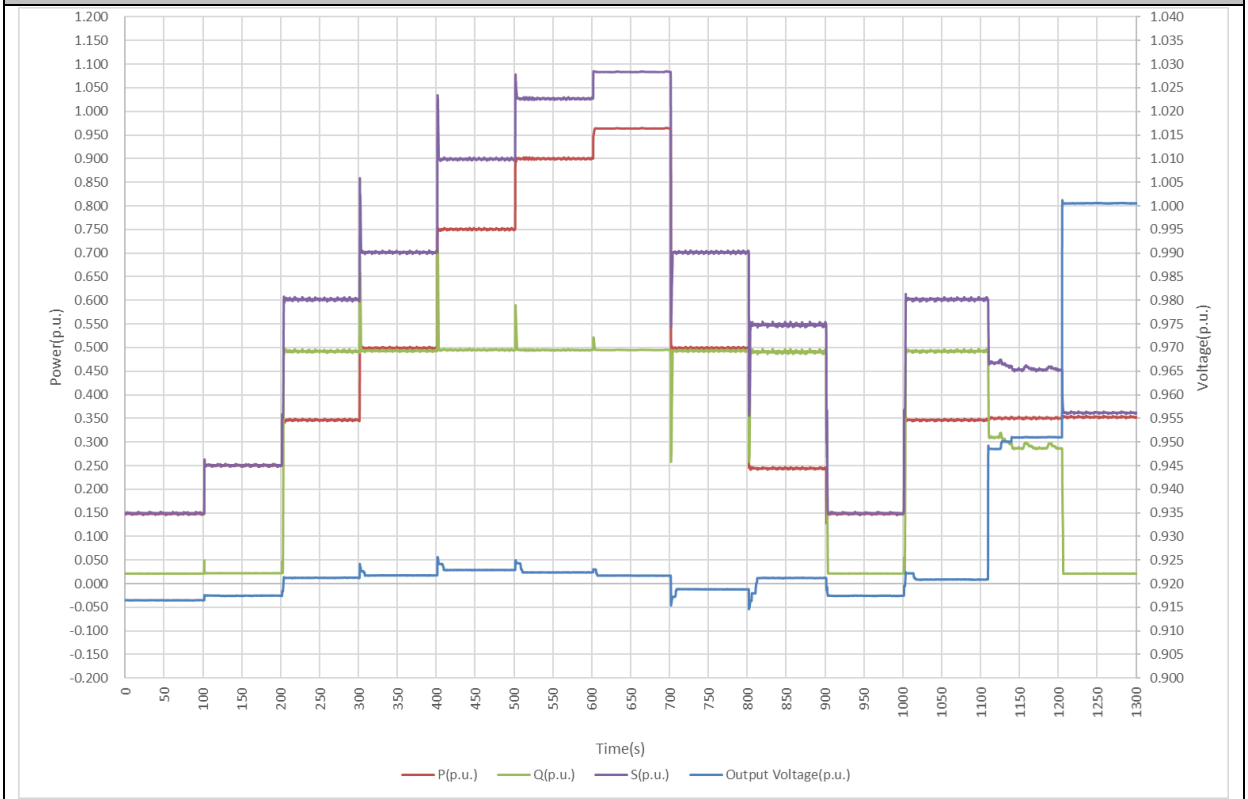
P lock-in = 30 %, P lock-out = 20 %

Test results are offered at the tables below.

Reactive power injection in relation with the Voltage (inductive)						
P/Pn setpoint	**U setpoint**	**P measured (p.u.)**	**V measured (p.u.)**	**Q measured (p.u.)**	**Q desired (p.u.)**	**ΔQ (< ±0.05 p.u.)**
< 20 %Pn	0.920	0.148	0.916	0.021	0.000	0.021
25 %Pn	0.920	0.250	0.917	0.022	0.000	0.022
35 %Pn	0.920	0.347	0.921	0.492	0.484	0.008
50 %Pn	0.920	0.499	0.922	0.493	0.484	0.009
75 %Pn	0.920	0.751	0.923	0.495	0.484	0.011
90 %Pn	0.920	0.900	0.922	0.495	0.484	0.011
100 %Pn (*)	0.920	0.964	0.922	0.495	0.484	0.011
50 %Pn	0.920	0.499	0.919	0.493	0.484	0.009
25 %Pn	0.920	0.244	0.921	0.491	0.484	0.007
< 20 %Pn	0.920	0.148	0.917	0.022	0.000	0.022
35 %Pn	0.920	0.347	0.921	0.492	0.484	0.008
35 %Pn	0.950	0.351	0.951	0.291	0.242	0.050
35 %Pn	1.000	0.353	1.001	0.021	0.000	0.021

(*) The max reactive power setting range is ±48.43 %Sn. Because of current limited Smax = 1.00Pn function, at Q(u) mode the active cannot reach the setting value.

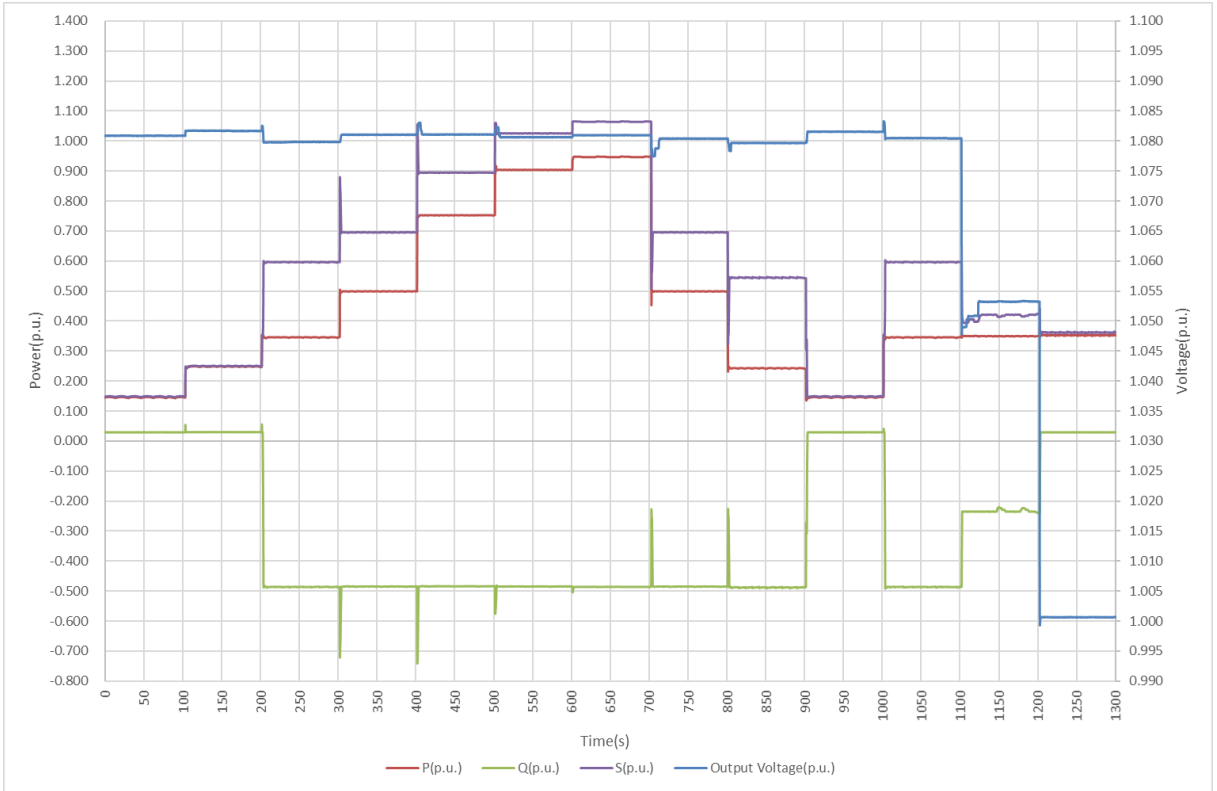
Reactive power injection in relation with the Voltage (inductive)



Reactive power injection in relation with the Voltage (capacitive)						
P/Pn setpoint	U setpoint	P measured (p.u.)	V measured (p.u.)	Q measured (p.u.)	Q desired (p.u.)	ΔQ (< ±0.05 p.u.)
<20% Pn	1.08	0.146	1.081	0.029	0.000	0.029
25% Pn	1.08	0.249	1.082	0.030	0.000	0.030
35% Pn	1.08	0.346	1.080	-0.486	-0.484	-0.002
50% Pn	1.08	0.499	1.081	-0.485	-0.484	0.000
75% Pn	1.08	0.753	1.081	-0.484	-0.484	0.000
90% Pn	1.08	0.904	1.081	-0.484	-0.484	0.000
100% Pn(*)	1.08	0.947	1.081	-0.486	-0.484	-0.001
50% Pn	1.08	0.499	1.080	-0.485	-0.484	0.000
25% Pn	1.08	0.243	1.080	-0.488	-0.484	-0.003
<20% Pn	1.08	0.146	1.082	0.029	0.000	0.029
35% Pn	1.08	0.346	1.080	-0.486	-0.484	-0.002
35% Pn	1.05	0.350	1.053	-0.232	-0.242	0.010
35% Pn	1.00	0.353	1.001	0.029	0.000	0.029

(*) The max reactive power setting range is ±48.43 %Sn. Because of current limited Smax = 1.00Pn function, at Q(u) mode the active cannot reach the setting value.

Reactive power injection in relation with the Voltage (capacitive)



4.4.2.3. Static accuracy

The test has been done according to the clause 4.7.2.3.3 of the standard.

The dynamic accuracy shall be in accordance with Figure 15 in the standard with a maximum tolerance of +/- 5 % of P_D plus a time delay of up to 3 seconds deviating from an ideal first order filter response.

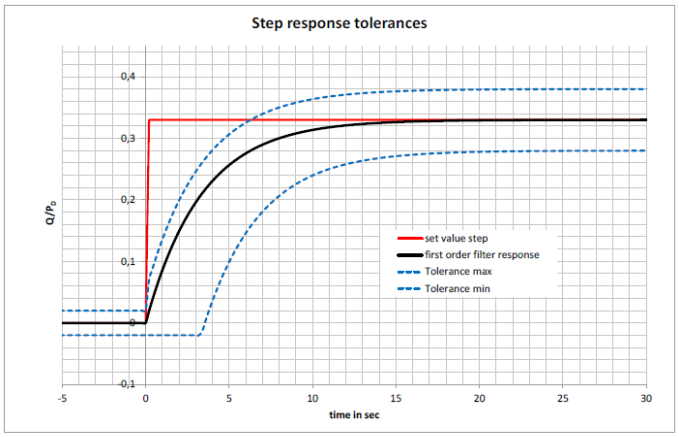
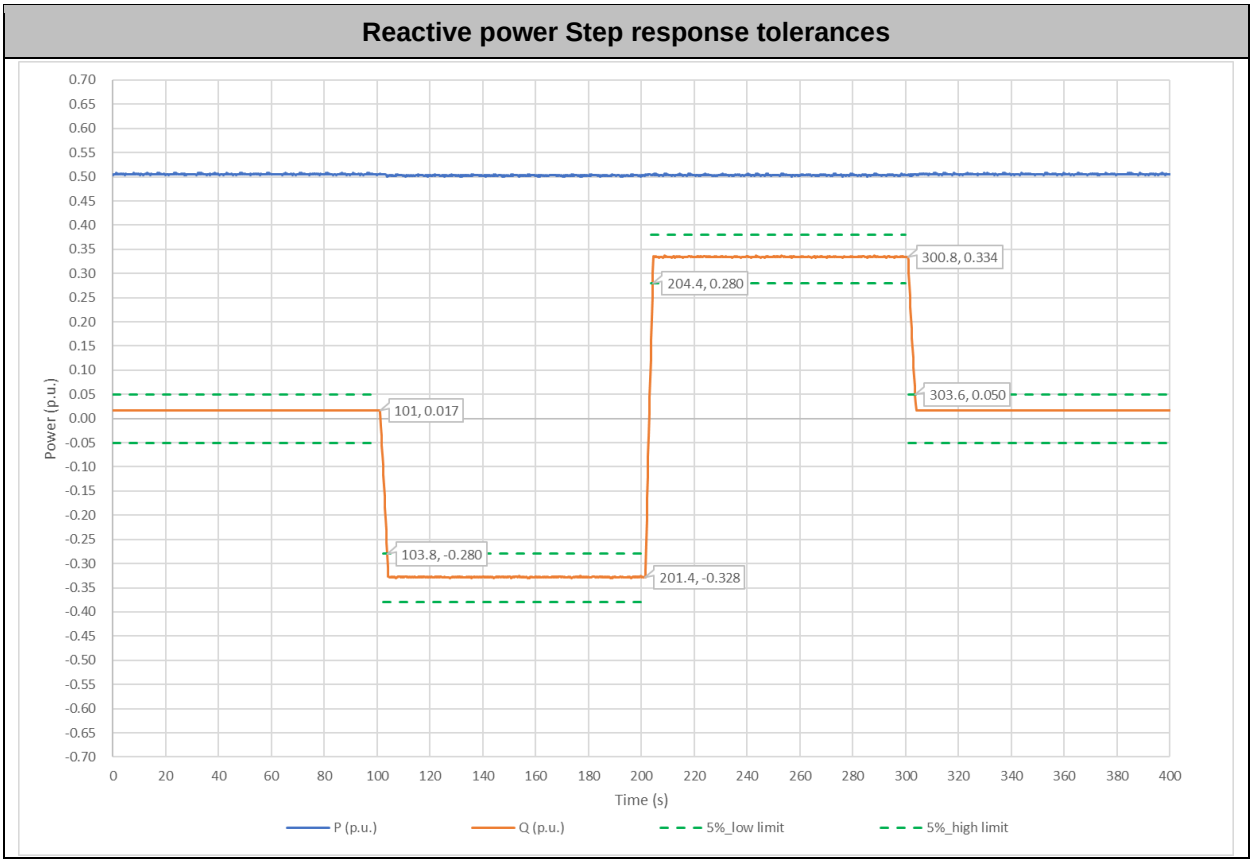


Figure 15 — Example of dynamic control response and tolerance band for a step from Q=0 to Q= 33%P_D with τ=3,33s

Test results are offered at the tables below.

% Pn	Steps	Time measured (s)
50	Q = 0 → Q = 33 %Sn	t = 2.8
	Q = 33 %Sn → Q = 33 %Sn	t = 3.0
	Q = 33 %Sn → Q = 0	t = 2.8

Reactive power Step response tolerances

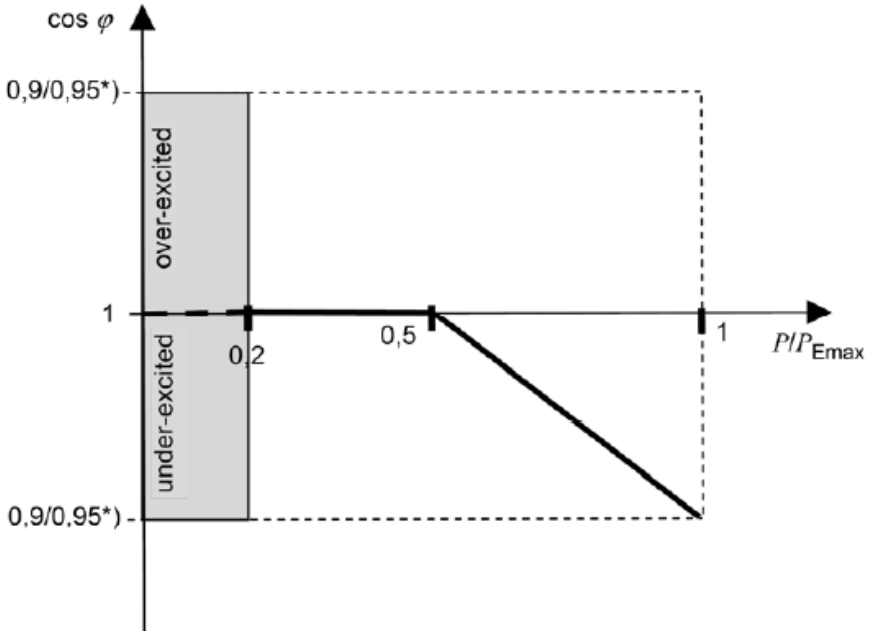


4.4.2.4. Power related control mode

The test has been done according to the clause 4.7.2.3.4 of the standard.

The power related control mode cos φ (P) controls the cos φ of the output as a function of the active power output.

For power related control modes, a characteristic defined by the manufacturer as following:



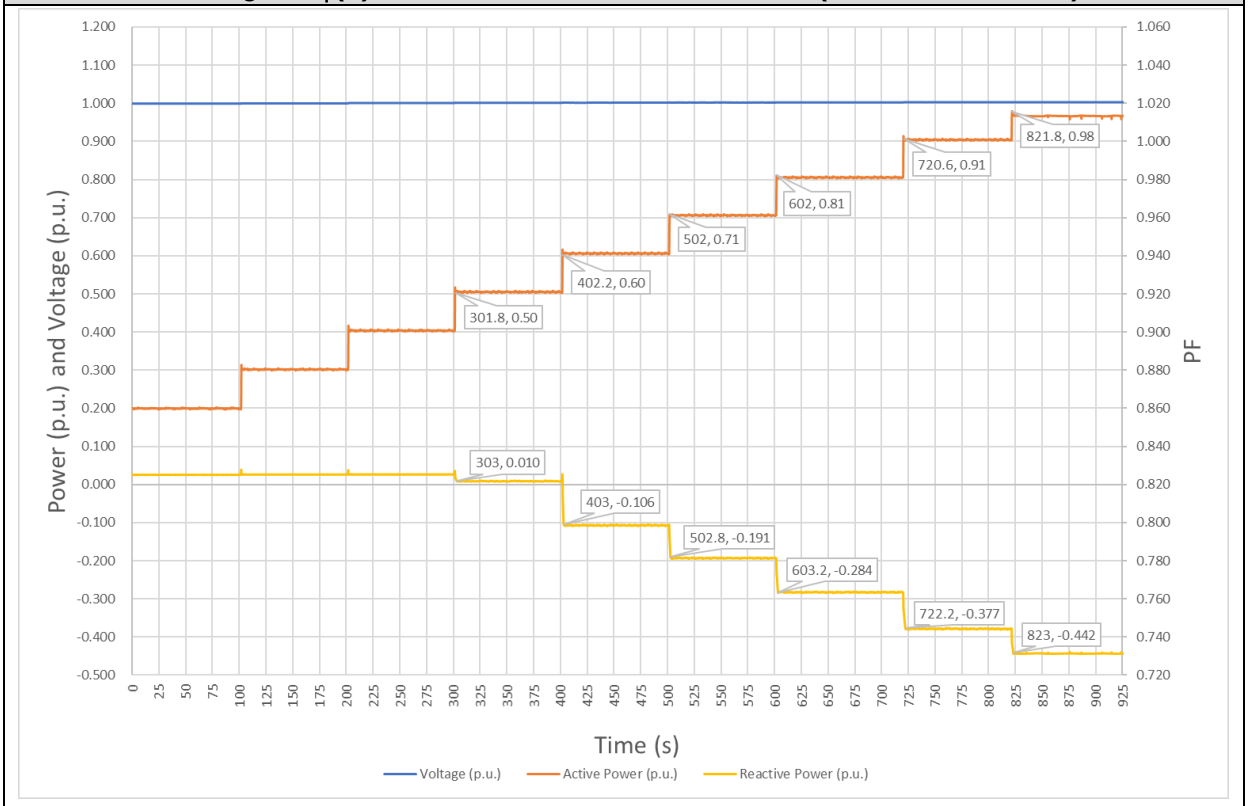
Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached. The static accuracy of each cos φ set point shall be according to 4.7.2.2.

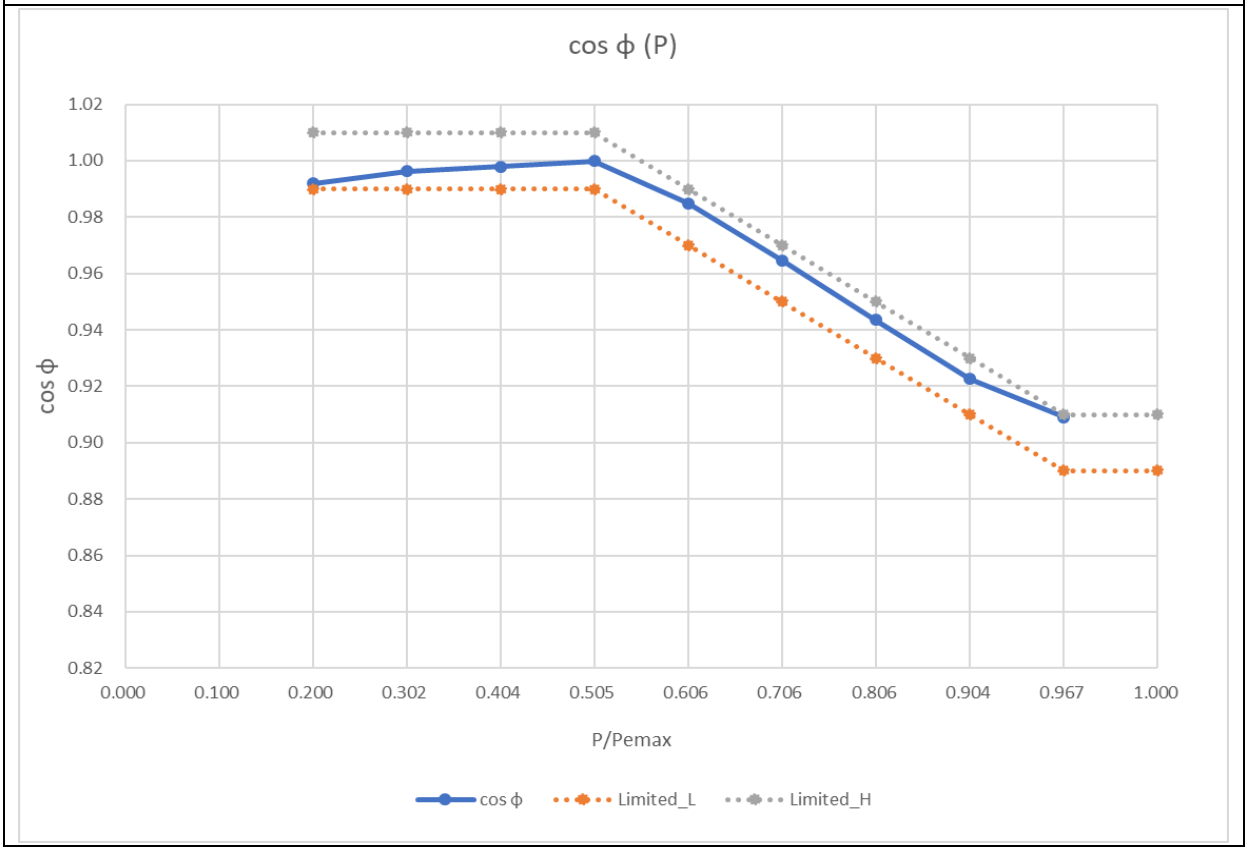
The results are offered in the table below (Note: 10 %Pn have not measured in following test):

Setting cos φ(P) with the standard characteristic curve (20 %Pn to 100 %Pn)						
Active power setting (% P_{Emax})	**Active power measured (p.u.)**	**Reactive power measured (p.u.)**	**cos φ measured**	**Desired cos φ**	**Δ cos φ (< 0.01)**	**Transient period (< 10s)**
20	0.200	0.026	0.992	1.000	-0.008	
30	0.302	0.026	0.996	1.000	-0.004	0.0 s
40	0.404	0.026	0.998	1.000	-0.002	0.0 s
50	0.505	0.009	1.000	1.000	0.000	0.0 s
60	0.606	-0.107	0.985	0.980	0.005	1.2 s
70	0.706	-0.193	0.965	0.960	0.005	0.8 s
80	0.806	-0.283	0.944	0.940	0.004	1.2 s
90	0.904	-0.378	0.923	0.920	0.003	1.6 s
100 (*)	0.967	-0.443	0.909	0.920	0.009	1.2 s

(*) Because of current limited Smax = 1.00Pn function, the active does not reach to 100 % when cos φ = 0.9.

Setting cos φ(P) with standard characteristic curve (20 %Pn to 100 %Pn)

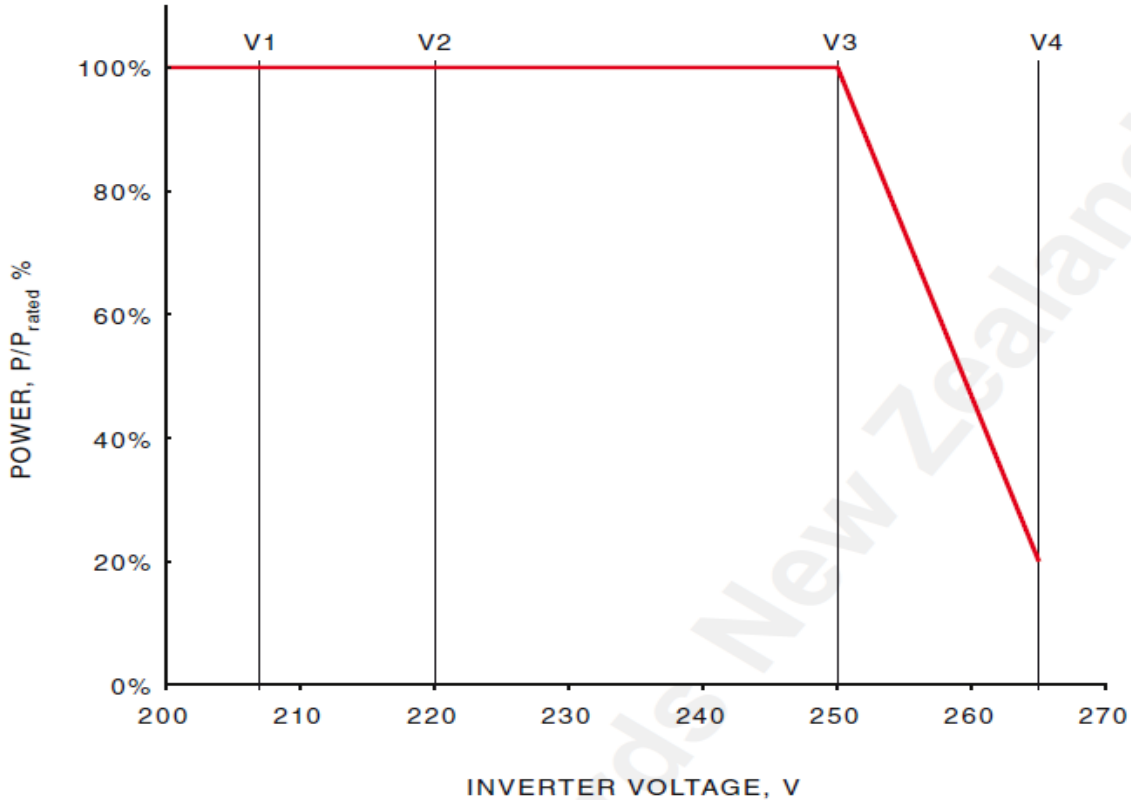




4.4.3. Voltage related active power reduction (Volt-Watt)

The test has been done according to the clause 4.7.3 of the standard.

The following paramaeters have been set by the manufacturer for this test:



Test 1 and Test 2 setpoint as following:

Reference	Test 1 Set points		Test 2 Set points	
	Volt. (%Un)	Power (%Pn)	Volt. (%Un)	Power (%Pn)
V1	90.0%	100%	90.0%	100%
V2	95.6%	100%	95.6%	100%
V3	104.0%	100%	108.7%	100%
V4	110.0%	20%	115.2%	20%

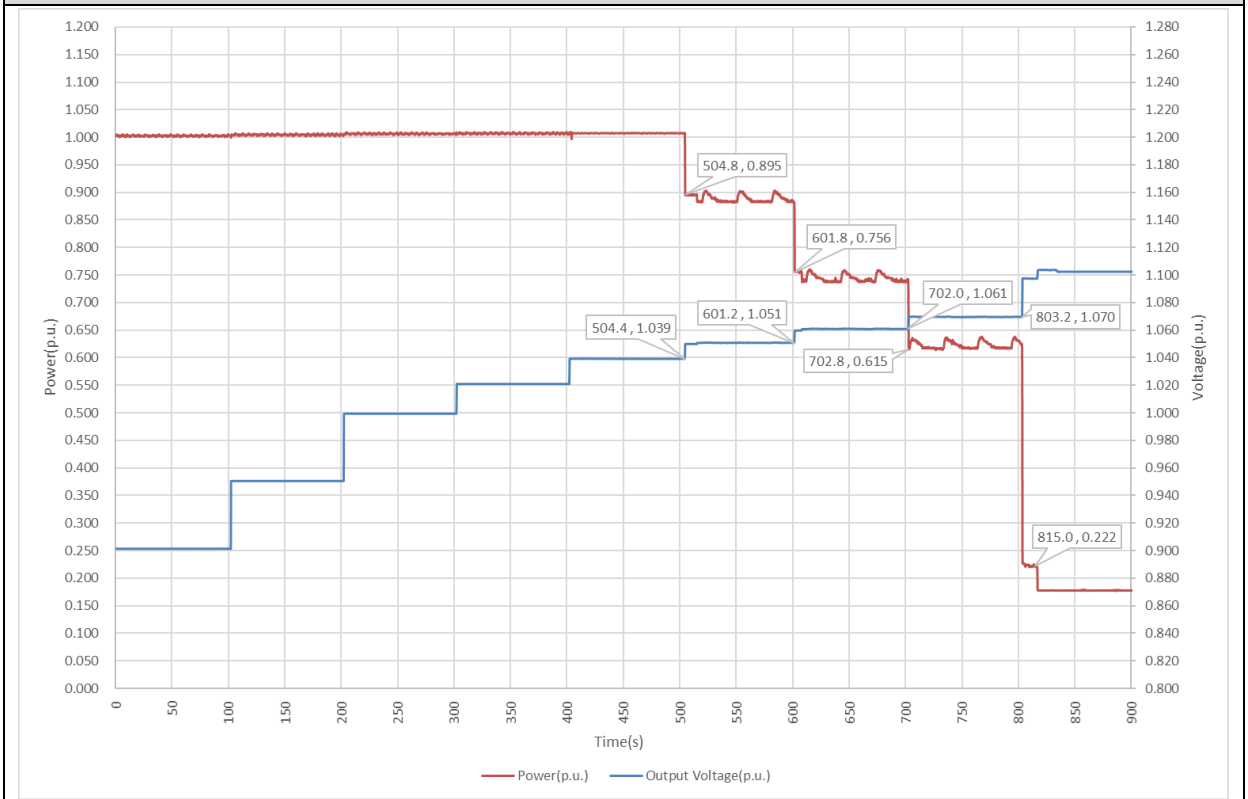
Test results are offered at tables below.

Volt-Watt TEST 1					
V setting (p.u.)	V meas. (p.u.)	P desired (p.u.)	P meas. (p.u.)	P deviation (p.u.)	Response time (s)
0.900	0.901	1.000	1.003	0.003	0.0
0.950	0.951	1.000	1.005	0.005	0.0
1.000	0.999	1.000	1.006	0.006	0.0
1.020	1.021	1.000	1.007	0.007	0.0
1.040	1.039	1.000	1.007	0.007	0.0
1.050	1.051	0.886	0.887 (*)	0.001	0.4
1.060	1.061	0.771	0.744 (*)	-0.027	0.6
1.070	1.070	0.657	0.623 (*)	-0.034	0.8
1.100	1.102	0.200	0.178	-0.022	1.8

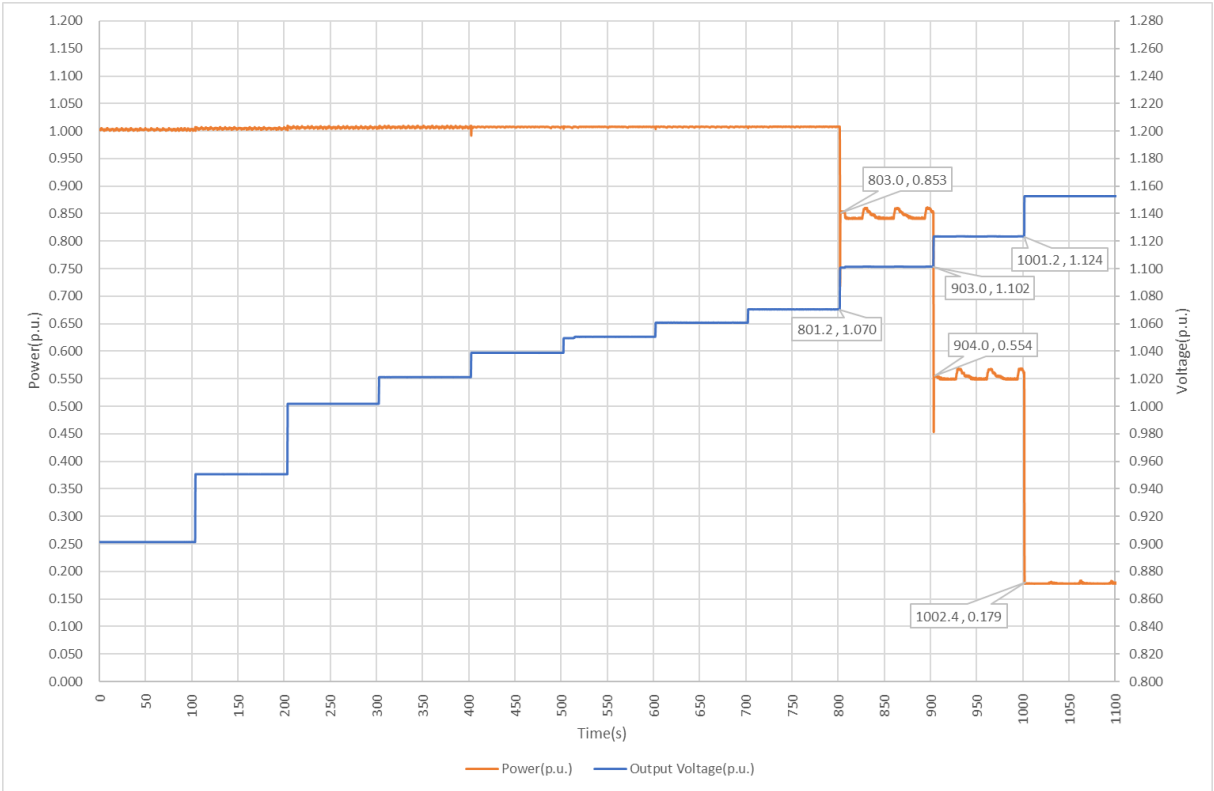
Volt-Watt TEST 2					
V setting (p.u.)	V meas. (p.u.)	P desired (p.u.)	P meas. (p.u.)	P deviation (p.u.)	Response time (s)
0.900	0.901	1.000	1.003	0.003	0.0
0.950	0.951	1.000	1.005	0.005	0.0
1.000	1.002	1.000	1.006	0.006	0.0
1.020	1.021	1.000	1.007	0.007	0.0
1.040	1.039	1.000	1.008	0.008	0.0
1.050	1.051	1.000	1.008	0.008	0.0
1.060	1.061	1.000	1.008	0.008	0.0
1.070	1.070	1.000	1.008	0.008	0.0
1.100	1.101	0.840	0.846 (*)	0.006	1.8
1.120	1.123	0.584	0.554 (*)	-0.030	1.0
1.152	1.153	0.200	0.178	-0.022	1.2

(*) Oscillations of power happened during the test. There is no aplicable limit defined in the standard for these oscillations, so a maximum tolerance of 5 %Pn has been agreed with the manufacturer.

Volt-Watt Test 1



Vatt-Watt Test 2



4.4.4. Short circuit current requirements on generating plants

4.4.4.1. Generating plant with non-synchronous generating technology

4.4.4.1.1 Voltage support during faults and voltage steps

The requirements from clause 4.7.4.2.1 of the standard.

The EUT is classified as Type B. This is no voltage support during faults and voltage steps.

4.4.4.1.2 Zero current mode for converter connected generating technology

The requirements from clause 4.7.4.2.2 of the standard.

The EUT is classified as Type B. Refer to Sections 4.2.2 and 4.2.3 of this report. During UVRT and OVRT, the EUT is always work at zero current mode.

4.4.4.1.3 Induction generator based units

The requirements from clause 4.7.4.2.3 of the standard.

The EUT is no voltage support during faults and voltage steps. This clause is not applicable.

4.4.4.2. Generating plant with synchronous generating technology - Synchronous generator based units

The requirements from clause 4.7.4.3 of the standard.

The EUT is with non-synchronous generating technology. This clause is not applicable.

4.5. EMC AND POWER QUALITY

As required in clause 4.8 of the standard, all electric and electronic equipment to be installed under the scope of this standard shall be in compliance with relative standards for Electromagnetic Compatibility.

The customer provides as informative the following EMC test report:CE200423N070, issued by Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch according to EN 61000-6-3:2007+A1:2011+AC:2012, EN IEC 61000-3-2:2019, EN 61000-3-3:2013+A1:2019 and EN 61000-6-2:2005.

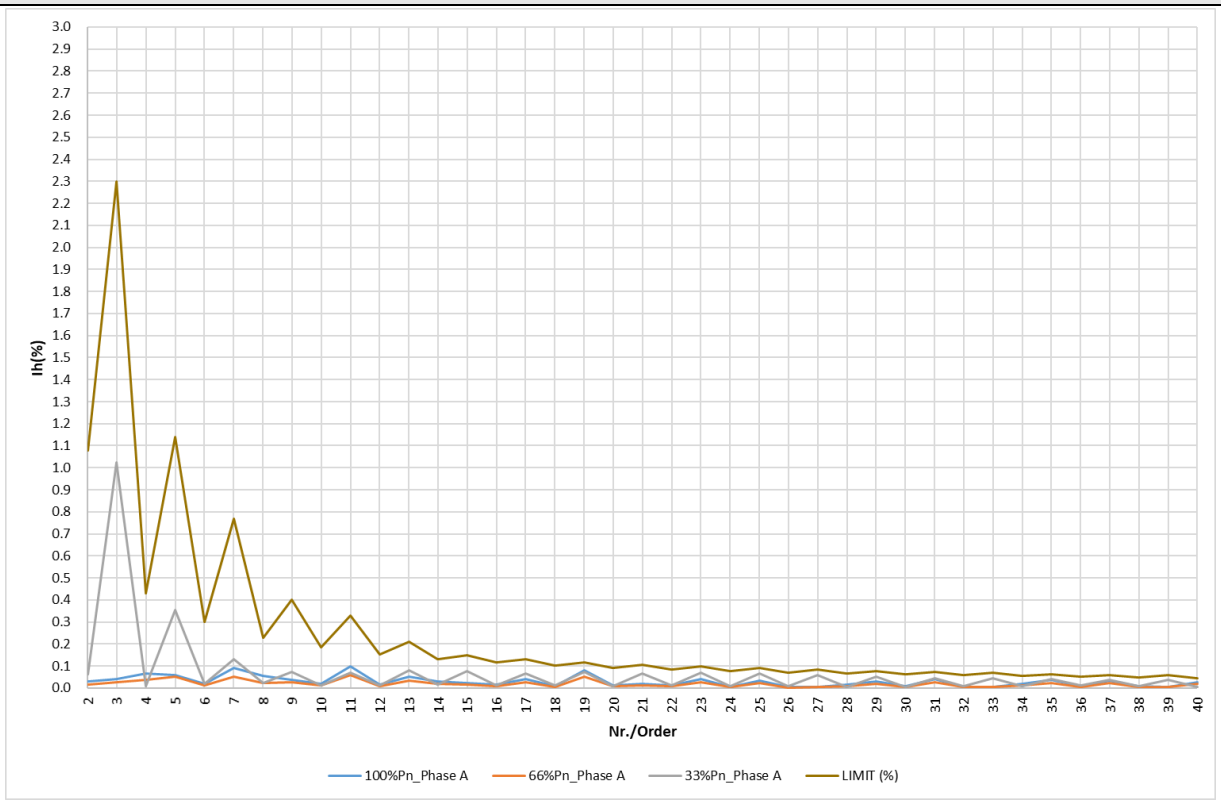
Despite of this fact, harmonic emissions and flickers have been mesaured for informative purposes and are presented on points 4.5.1 and 4.5.2.

4.5.1. Harmonic emissions

The test has been done according to the standard EN 61000-3-2.

P_{bin} (%)	100	66	33	LIMIT (%)
Nr. / Order	I_h (%)	I_h (%)	I_h (%)	
2	0.029	0.014	0.063	1.08
3	0.042	0.026	1.026	2.30
4	0.067	0.039	0.009	0.43
5	0.061	0.052	0.355	1.14
6	0.021	0.013	0.018	0.30
7	0.093	0.053	0.132	0.77
8	0.055	0.023	0.022	0.23
9	0.038	0.027	0.074	0.40
10	0.020	0.011	0.013	0.18
11	0.099	0.058	0.070	0.33
12	0.015	0.009	0.011	0.15
13	0.052	0.032	0.080	0.21
14	0.031	0.019	0.017	0.13
15	0.022	0.016	0.078	0.15
16	0.015	0.010	0.012	0.12
17	0.042	0.026	0.067	0.13
18	0.008	0.006	0.011	0.10
19	0.079	0.051	0.072	0.12
20	0.011	0.007	0.009	0.09
21	0.018	0.013	0.066	0.11
22	0.012	0.008	0.013	0.08
23	0.039	0.026	0.069	0.10
24	0.006	0.004	0.009	0.08
25	0.034	0.022	0.067	0.09
26	0.004	0.003	0.009	0.07
27	0.007	0.006	0.059	0.08
28	0.014	0.010	0.006	0.07
29	0.030	0.019	0.053	0.08
30	0.008	0.005	0.005	0.06
31	0.041	0.027	0.046	0.07
32	0.006	0.004	0.009	0.06
33	0.007	0.005	0.044	0.07
34	0.020	0.014	0.010	0.05
35	0.038	0.024	0.040	0.06
36	0.009	0.006	0.011	0.05
37	0.034	0.022	0.039	0.06
38	0.009	0.006	0.008	0.05
39	0.006	0.005	0.037	0.06
40	0.028	0.019	0.007	0.05

Current Harmonics



4.5.2. Flicker and voltage fluctuations

The test has been done according to the clause 4.8 of the standard.

The measurements of voltage fluctuations have been measured at 33 %, 66 % and 100 % of the nominal power value of the inverter according to the standard IEC 61000-3-11:2017.

This test has two steps and 10min for each step:

1.Starting operation
2.Stopping operation

The values took of Pst and Plt are the most unfavorable of the 12 steps.

Starting operation and Stopping operation				
Pbin (%)	**Limit**	**33 %Pn**	**66 %Pn**	**100 %Pn**
PST	≤ 1.0	0.07	0.07	0.09
PLT	≤ 0.65	0.07	0.07	0.07
dc	≤ 3.30 %	0.07 %	0.08 %	0.44 %
dmax	4 %	0.16 %	0.20 %	0.47 %

33 %Pn

Flicker Mode   Uover:■ ■ ■ ■   I1 : 30A   YOKOGAWA ◆
Iover:■ ■ ■ ■   Flicker:Complete 2:00:00

Count 12/12
Interval 10m00s/10m00s

Element 1
Volt Range 300V/50Hz   Element1 Judgement: Pass
Un (U1) 229.674 V   Total Judgement: Pass
Freq(U1) 49.999 Hz   (Element1)

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
2	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
3	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
4	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
5	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
6	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
7	0.07 Pass	0.15 Pass	0 Pass	0.07 Pass	
8	0.05 Pass	0.16 Pass	0 Pass	0.07 Pass	
9	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
10	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
11	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
12	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
Result	Pass	Pass	Pass	Pass	0.07 Pass

Update 3600   2020/04/28 13:06:07

66 %Pn

Flicker Mode Uover:▬ ▬ ▬ ▬ YOKOGAWA ◆
Iover:▬ ▬ ▬ ▬ Flicker:Complete 2:00:

Flicker Form
Measurement
Flicker dmax

Count ▬▬▬▬▬▬▬▬▬▬▬▬ 12/12
Interval ▬▬▬▬▬▬▬▬▬▬▬▬ 10m00s/10m00s

Element 1
Volt Range 300V/50Hz Element1 Judgement: Pass
Un (U1) 230.091 V Total Judgement: Pass
Freq(U1) 49.999 Hz (Element1)

Initialize Exec

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
2	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
3	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
4	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
5	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
6	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
7	0.08 Pass	0.20 Pass	0 Pass	0.07 Pass	
8	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
9	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
10	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
11	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
12	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
Result	Pass	Pass	Pass	Pass	0.07

Start
Reset
Flicker Settings

Update 3600 2020/04/28 15:16:28

100 %Pn

Flicker Mode Uover:▬ ▬ ▬ ▬ YOKOGAWA ◆
Iover:▬ ▬ ▬ ▬ Flicker:Complete 2:00:00

Count ▬▬▬▬▬▬▬▬▬▬▬▬ 12/12
Interval ▬▬▬▬▬▬▬▬▬▬▬▬ 10m00s/10m00s

Element 1
Volt Range 300V/50Hz Element1 Judgement: Pass
Un (U1) 230.358 V Total Judgement: Pass
Freq(U1) 49.999 Hz (Element1)

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
2	0.44 Pass	0.47 Pass	0 Pass	0.09 Pass	
3	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
4	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
5	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
6	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
7	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
8	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
9	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
10	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
11	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
12	0.05 Pass	0.18 Pass	0 Pass	0.07 Pass	
Result	Pass	Pass	Pass	Pass	0.07 Pass

Update 3600 2020/04/28 17:28:55

4.6. INTERFACE PROTECTION

4.6.1. Requirements on voltage and frequency protection

The test has been done according to the clause 4.9.3 of the standard. The minimum required accuracy for protection is:

- For frequency measurement ±0.05 Hz;
- For voltage measurement ±1 % of Un.
- The reset time shall be ≤ 50ms
- The interface protection relay shall not conduct continuous starting and disengaging operations of the interface protection relay. Therefore, a reasonable reset ratio shall be implemented which shall not be zero but be below 2 % of nominal value for voltage and below 0.2 Hz for frequency.

4.6.1.1. Undervoltage protection

Undervoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.
Undervoltage threshold stage 1 [27 <]:

- Threshold (0.2 – 1) Un adjustable by steps of 0.01 Un
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Undervoltage threshold stage 2 [27 <<]:

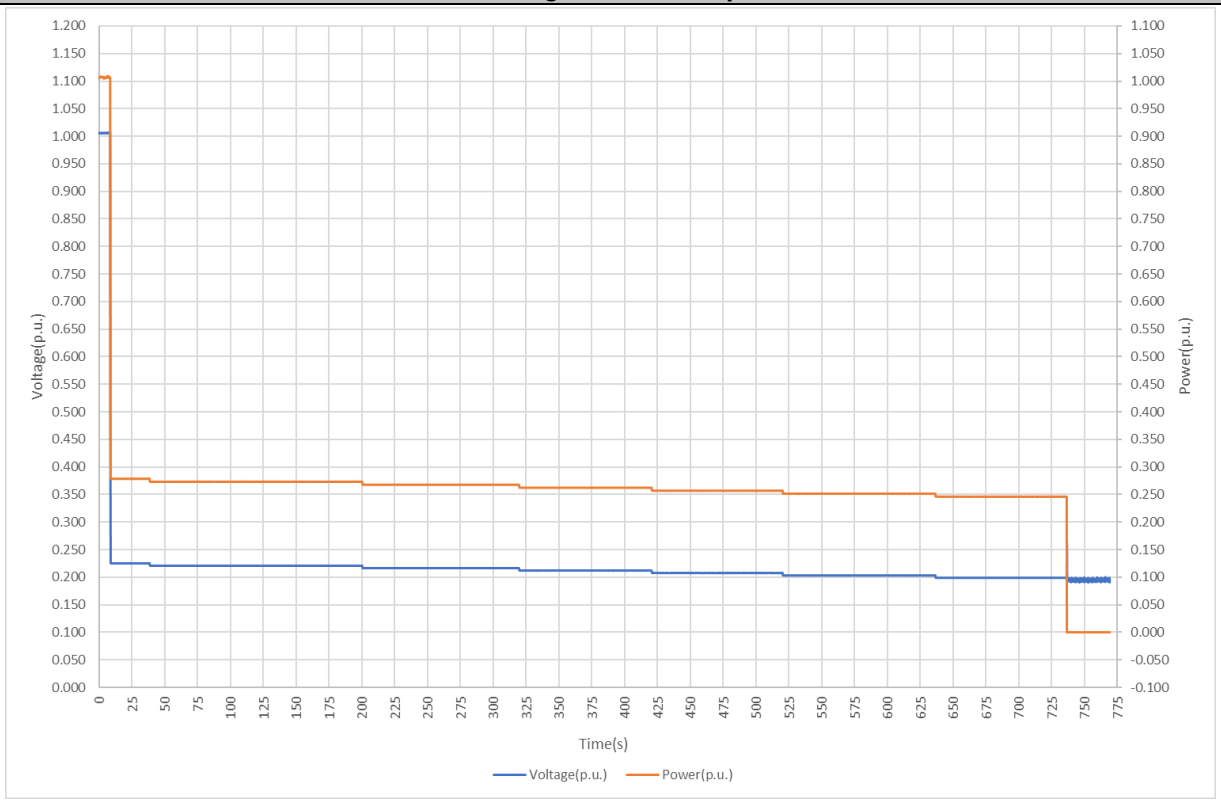
- Threshold (0.2 – 1) Un adjustable by steps of 0.01 Un
- Operate time (0.1 – 5) s adjustable in steps of 0.05 s
-

The undervoltage threshold stage 2 is not applicable for micro-generating plants

The following definitions apply to the test to verify the clause:

Undervoltage	Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [27 <]	1	0.200	0.199	-0.001	100.000	99.800	-0.200
	2	1.000	0.998	-0.002	0.100	0.094	-0.006
Stage 2 [27 <<]	3	0.200	0.197	-0.003	5.000	4.880	-0.120
	4	1.000	0.999	-0.001	0.100	0.100	0.000

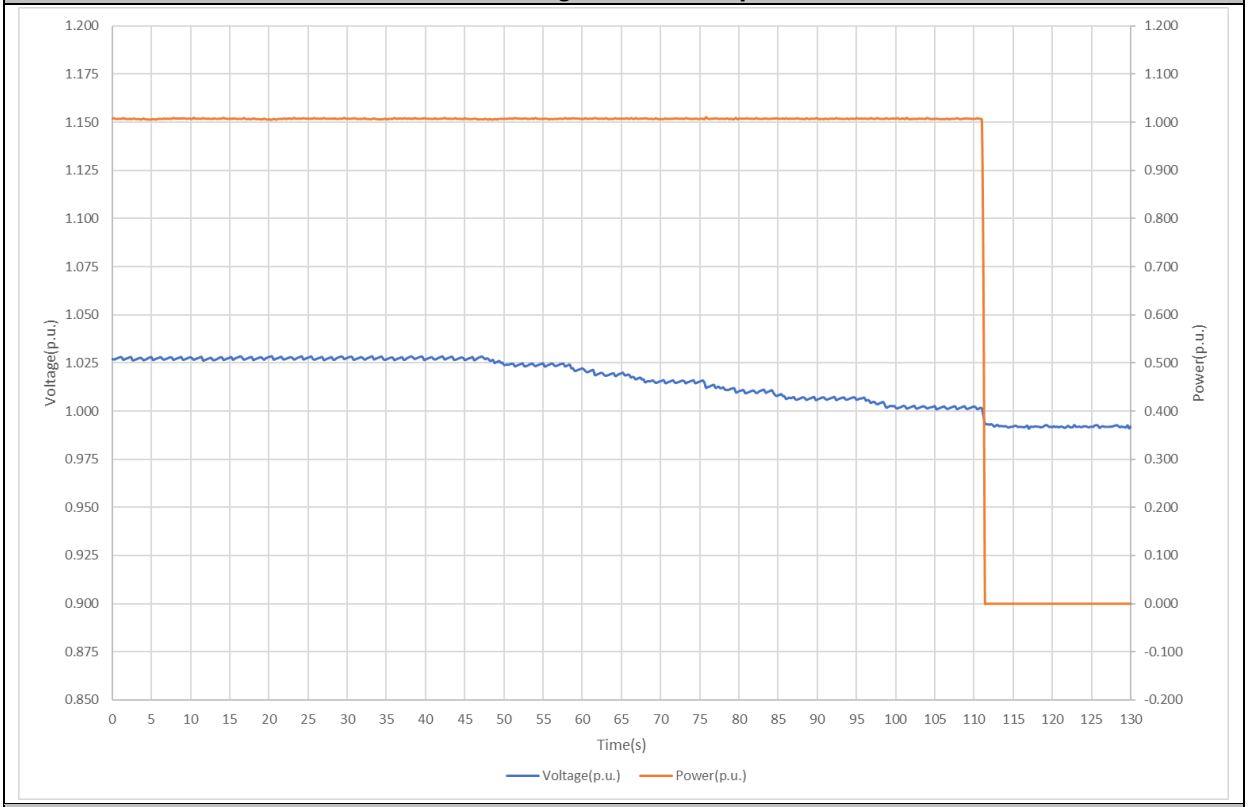
Undervoltage - Test 1: Trip value



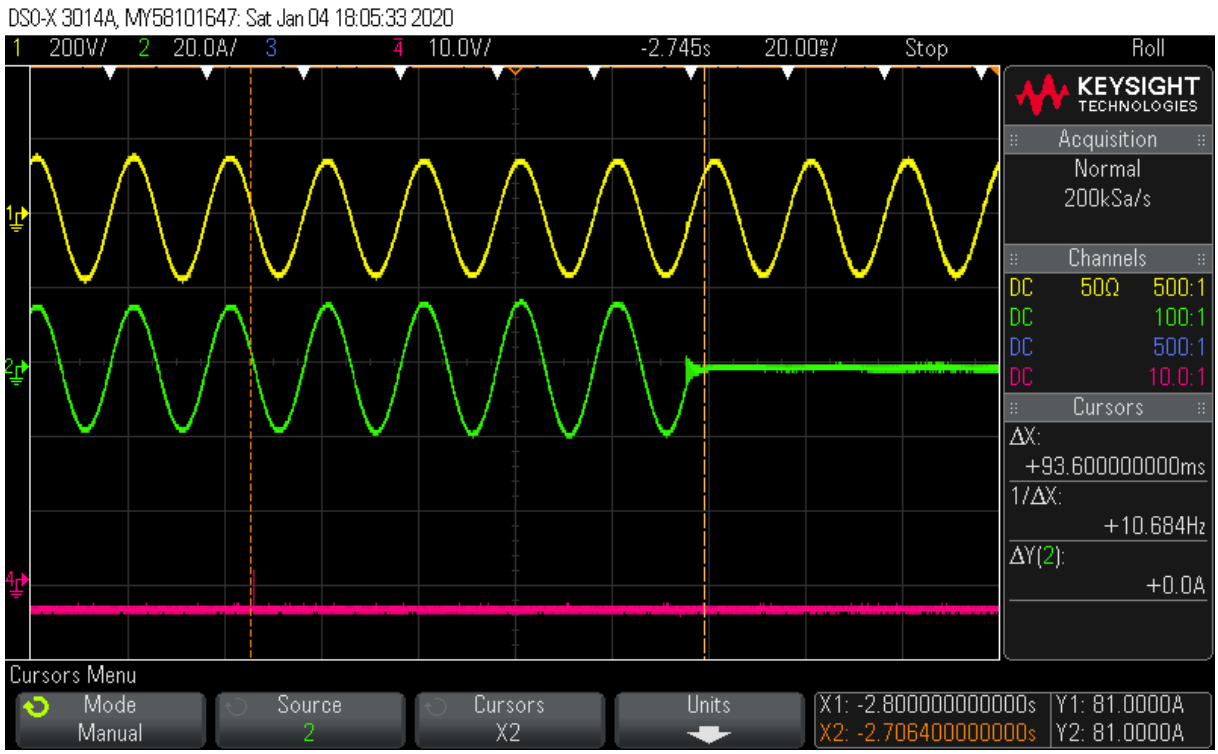
Undervoltage - Test 1: Trip time

(*) For this Oscilloscope records showed wrong date - "Jan 4", actually it was "April 21" keeping same with raw data of the Power analyzer used.

Undervoltage - Test 2: Trip value

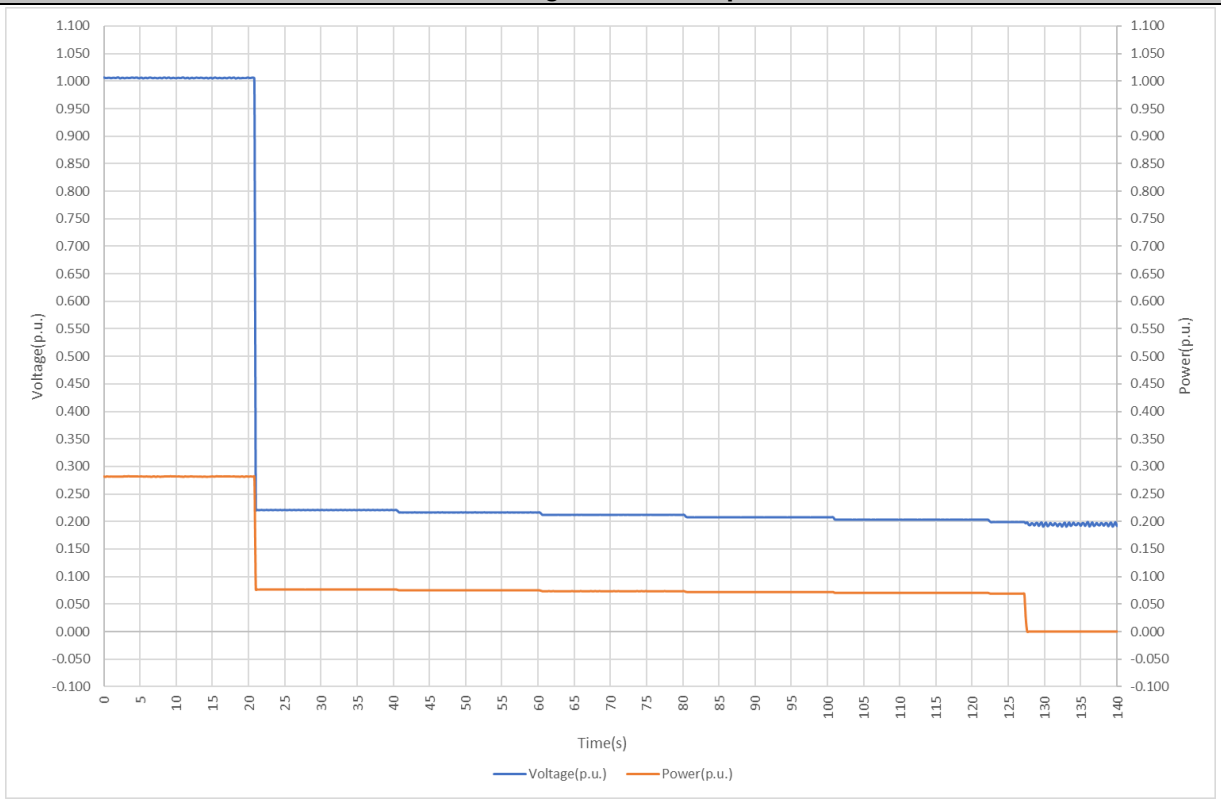


Undervoltage - Test 2: Trip time

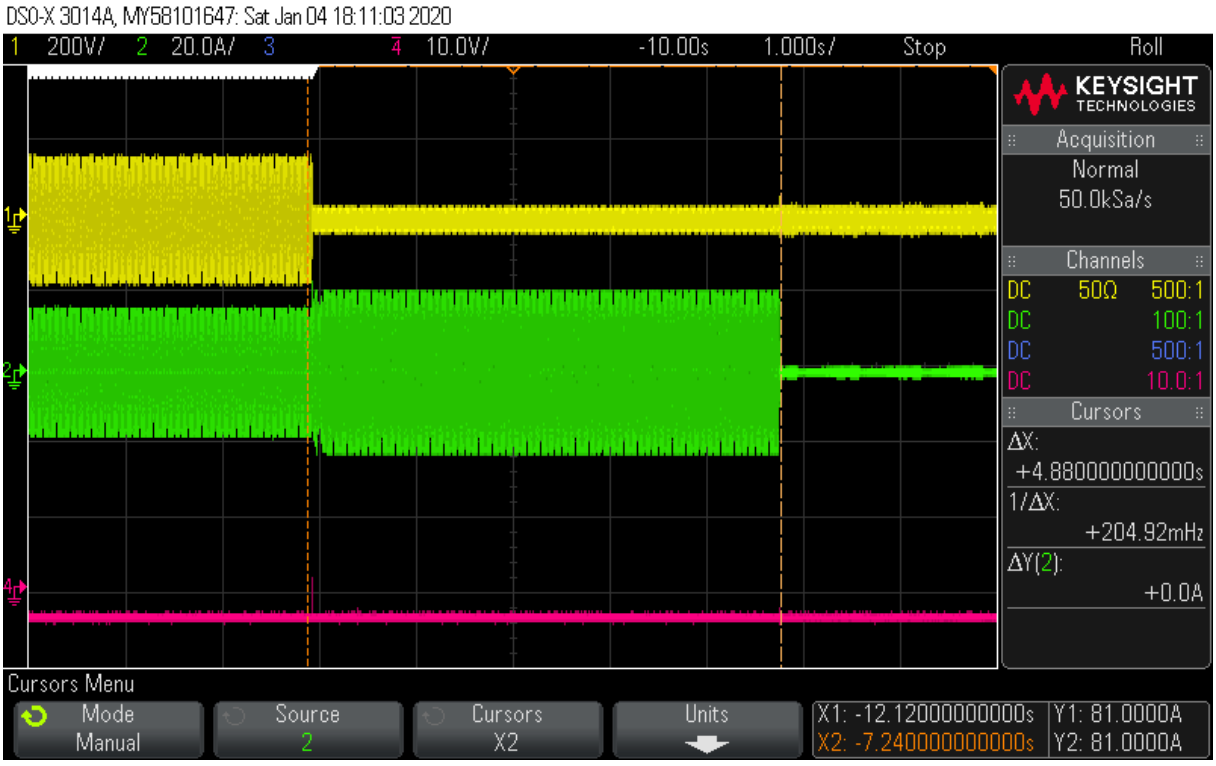


(*) For this Oscilloscope records showed wrong date - "Jan 4", actually it was "April 21" keeping same with raw data of the Power analyzer used.

Undervoltage - Test 3: Trip value

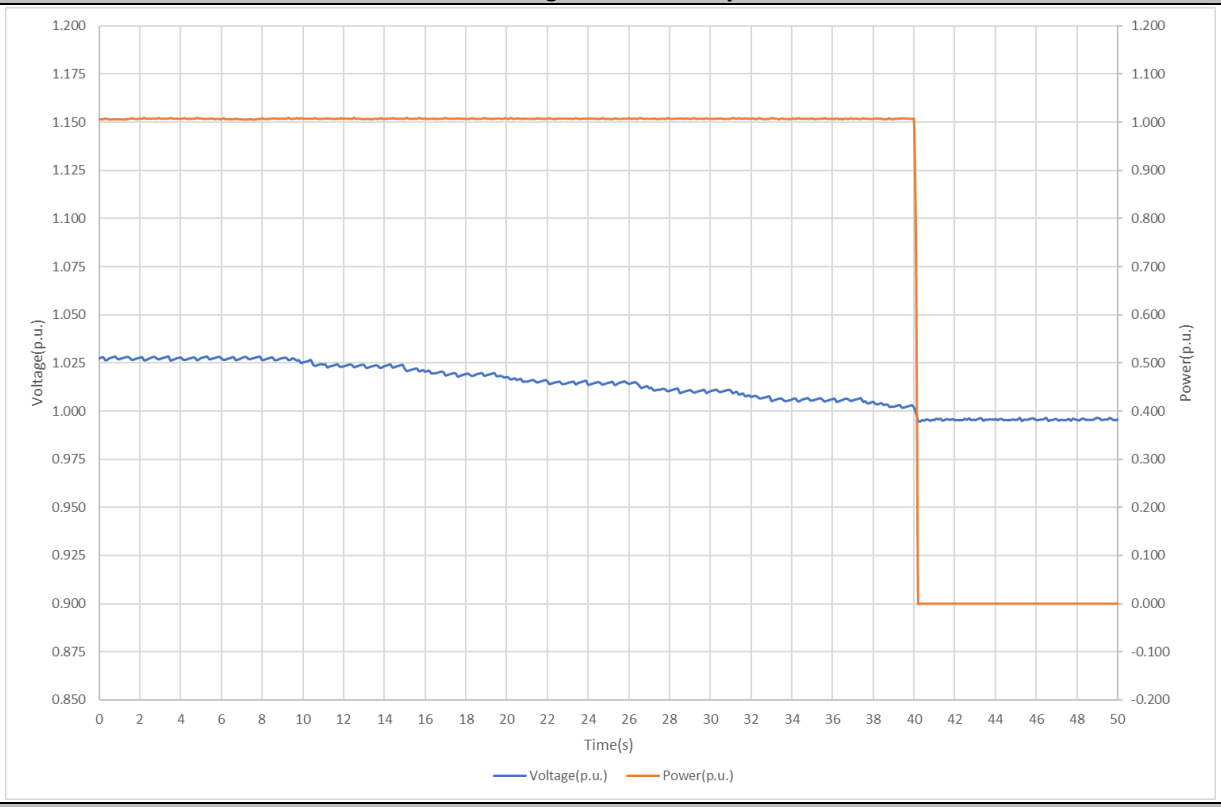


Undervoltage - Test 3: Trip time

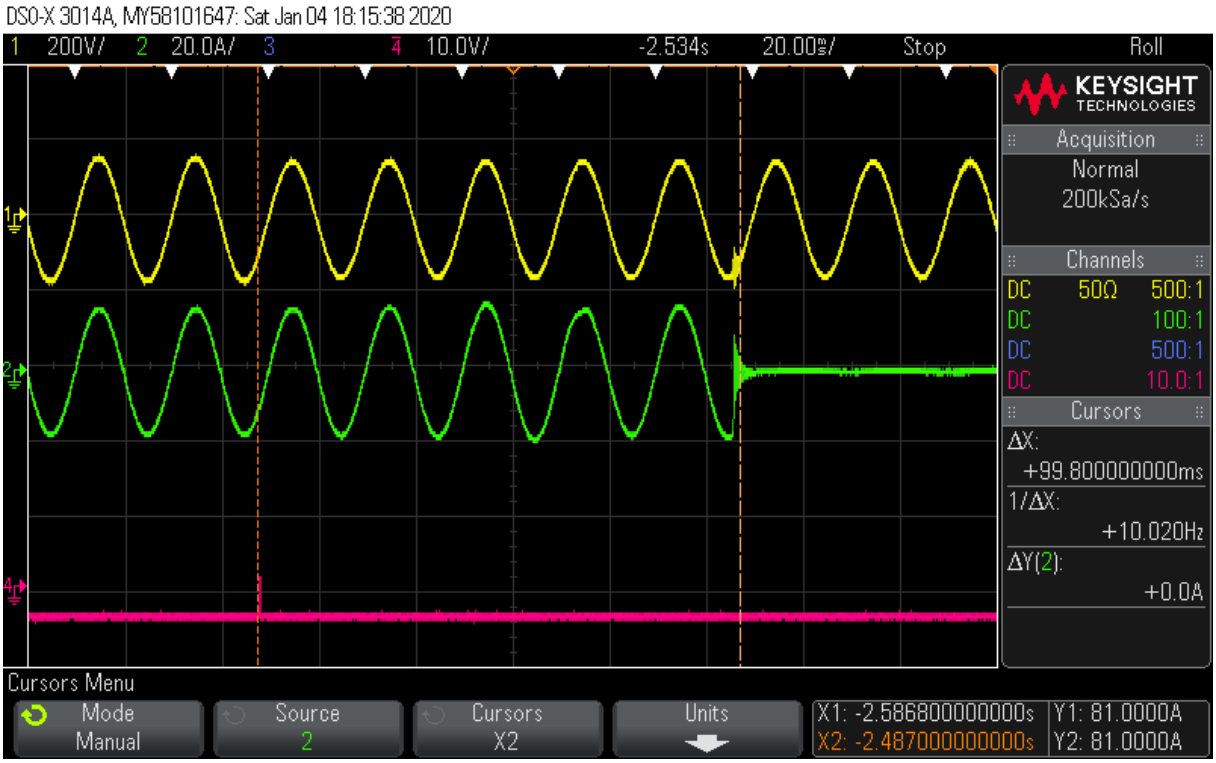


(*) For this Oscilloscope records showed wrong date - "Jan 4", actually it was "April 21" keeping same with raw data of the Power analyzer used.

Undervoltage - Test 4: Trip value



Undervoltage - Test 4: Trip time



(*) For this Oscilloscope records showed wrong date - "Jan 4", actually it was "April 21" keeping same with raw data of the Power analyzer used.

4.6.1.2. Overvoltage protection

Overvoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

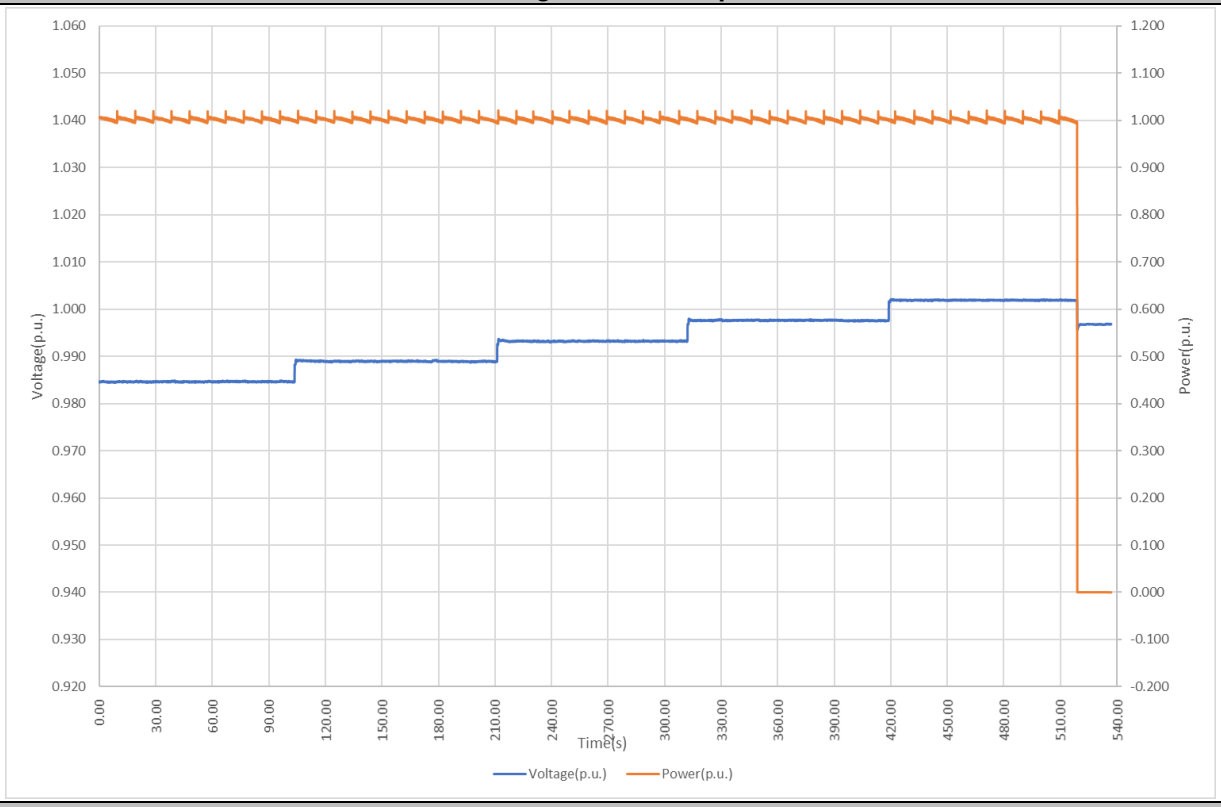
Overvoltage threshold stage 1 [59 >]:
- Threshold (1.0 – 1.2) Un adjustable by steps of 0.01 Un.
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Overvoltage threshold stage 2 [59 >>]:
- Threshold (1.0 – 1.30) Un adjustable by steps of 0.01 Un
- Operate time (0.1 – 5) s adjustable in steps of 0.05 s

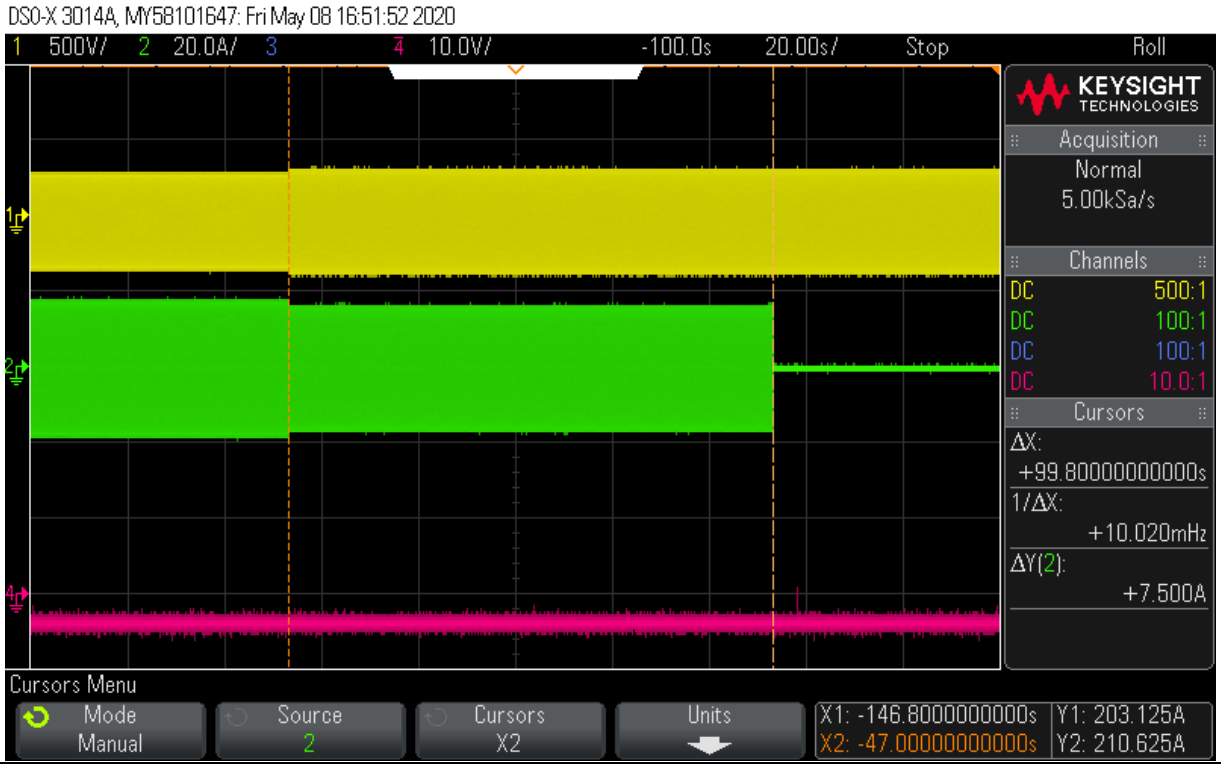
The following definitions apply to the test to verify the clause:

Overvoltage	Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [59 >]:	1	1.000	1.002	0.002	100.000	99.800	-0.200
	2	1.200	1.198	-0.002	0.100	0.092	-0.008
Stage 2 [59 >>]	3	1.000	1.006	0.006	5.000	4.860	-0.140
	4	1.300	1.301	0.001	0.100	0.095	-0.005

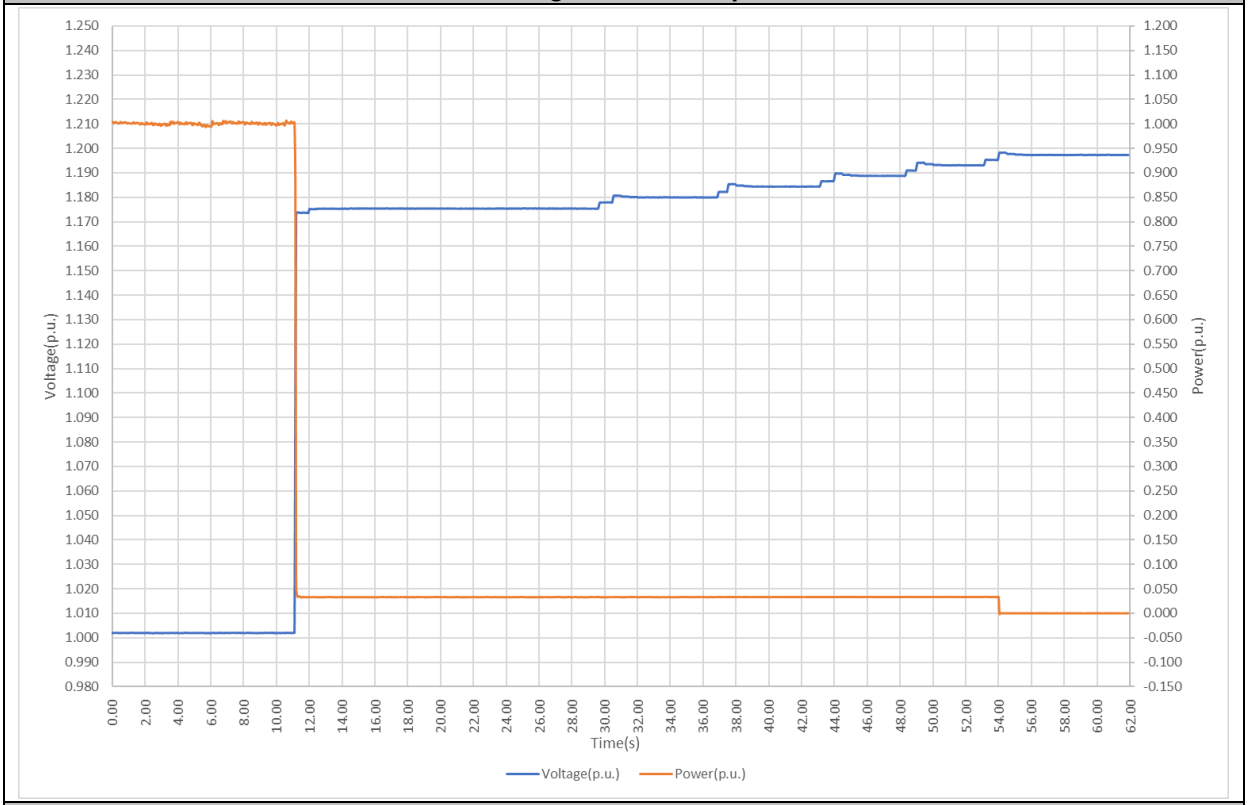
Overvoltage - Test 1: Trip value



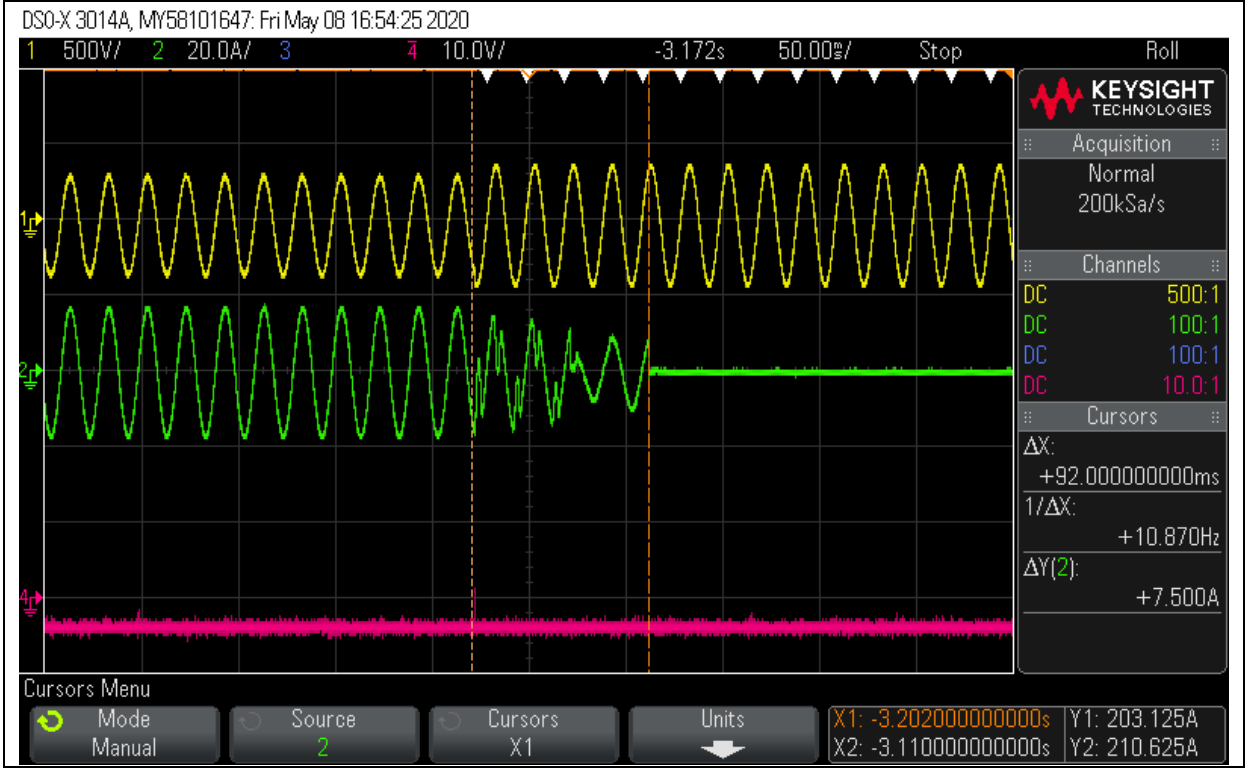
Overvoltage - Test 1: Trip time



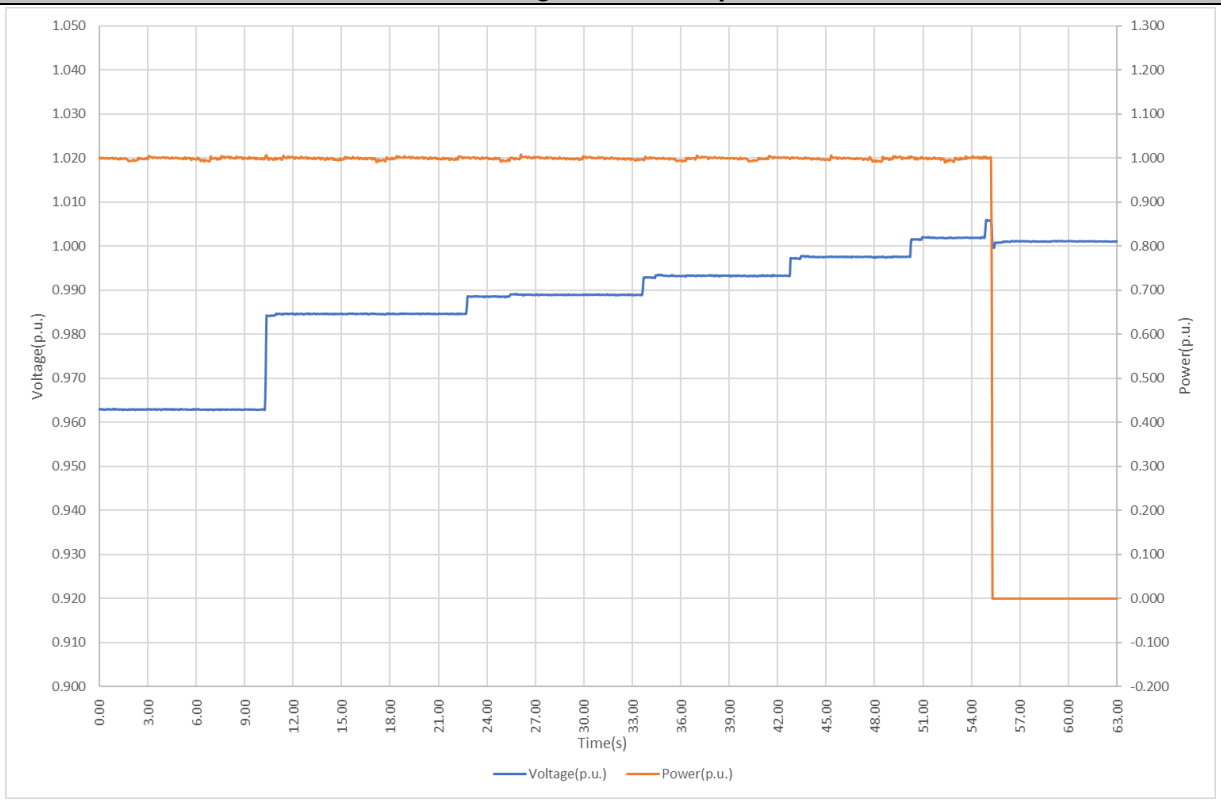
Overvoltage - Test 2: Trip value



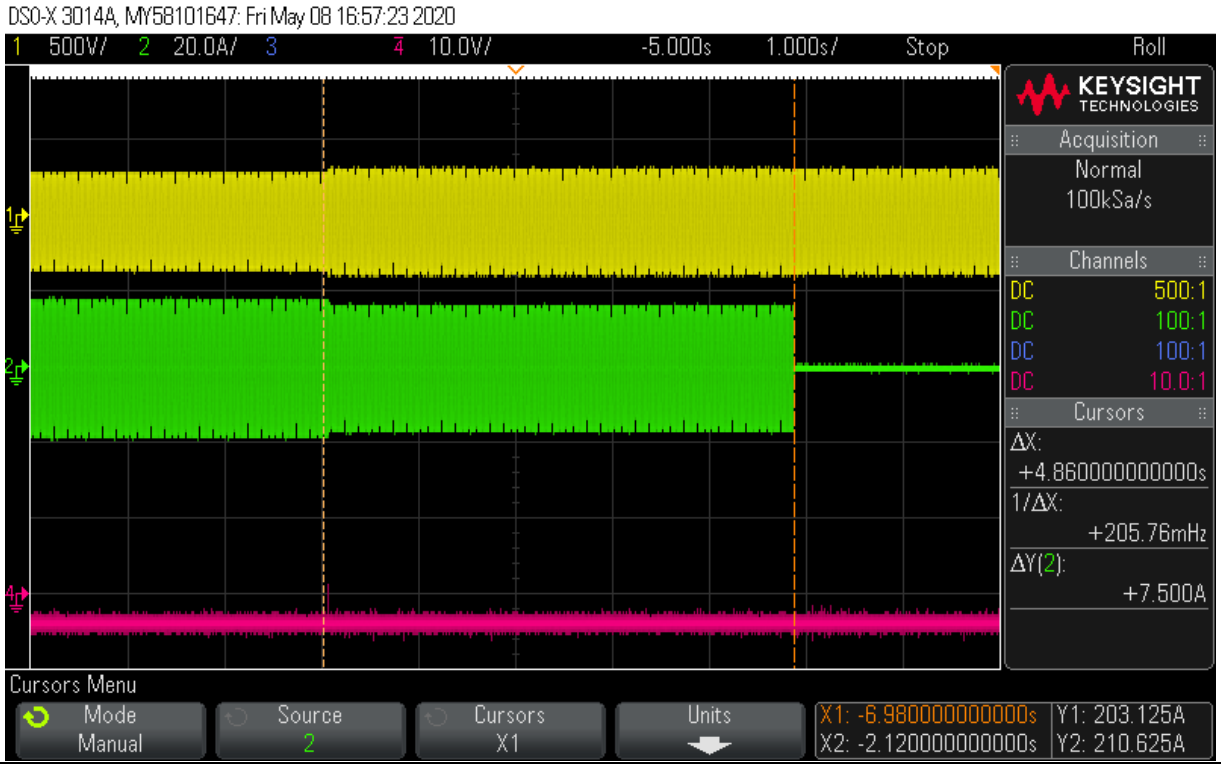
Overvoltage - Test 2: Trip time



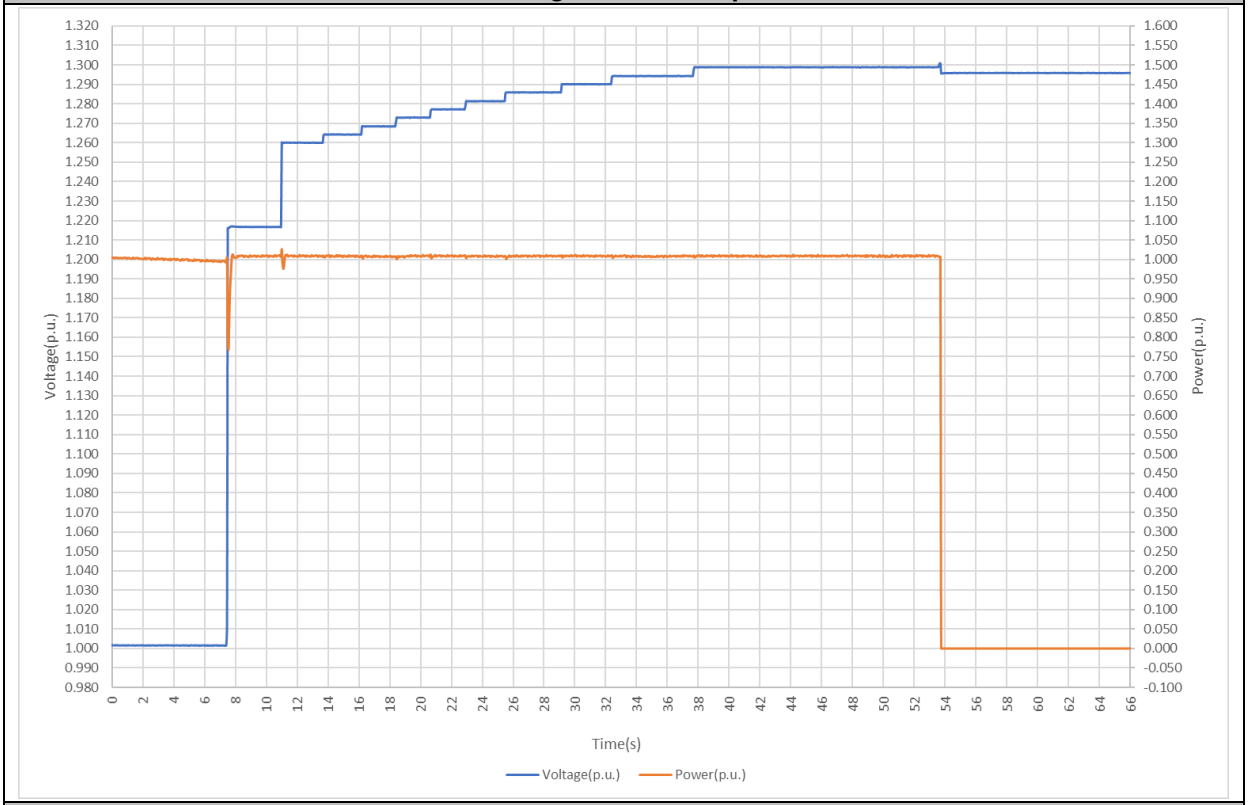
Overvoltage - Test 3: Trip value



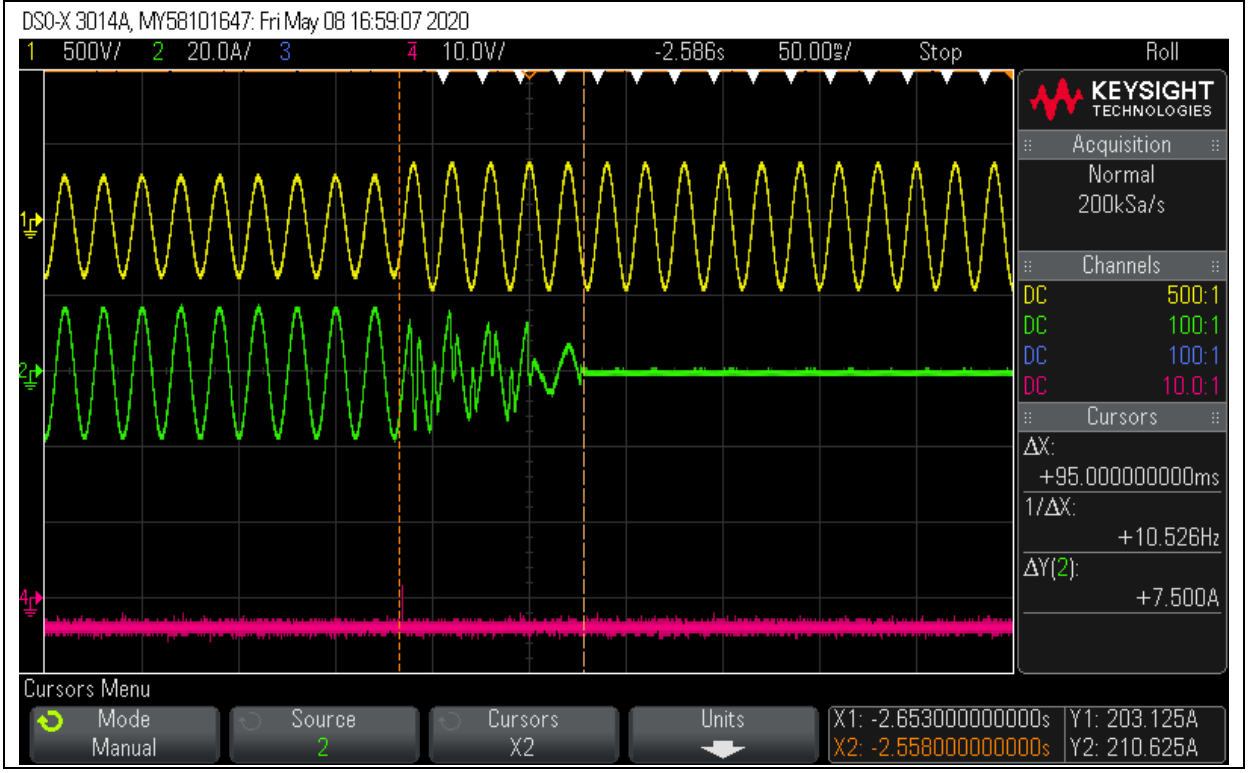
Overvoltage - Test 3: Trip time



Overvoltage - Test 4: Trip value



Overvoltage - Test 4: Trip time



4.6.1.3. Overvoltage 10 min mean protection

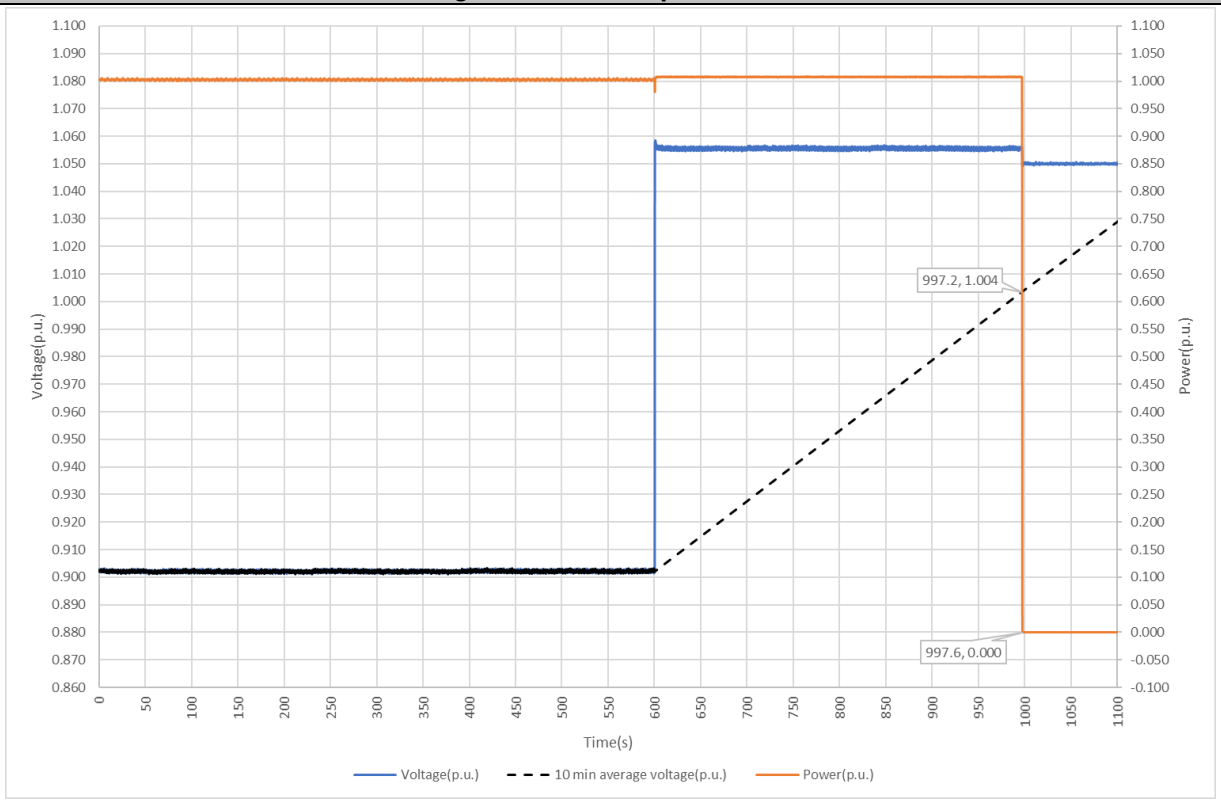
The function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. The calculation of a new 10 min value at least every 3 s is sufficient, which is then to be compared with the threshold value.

- Threshold (1.0 – 1.15) Un adjustable by steps of 0.01 Un
- Start time ≤ 3 s not adjustable
- Time delay setting = 0 ms

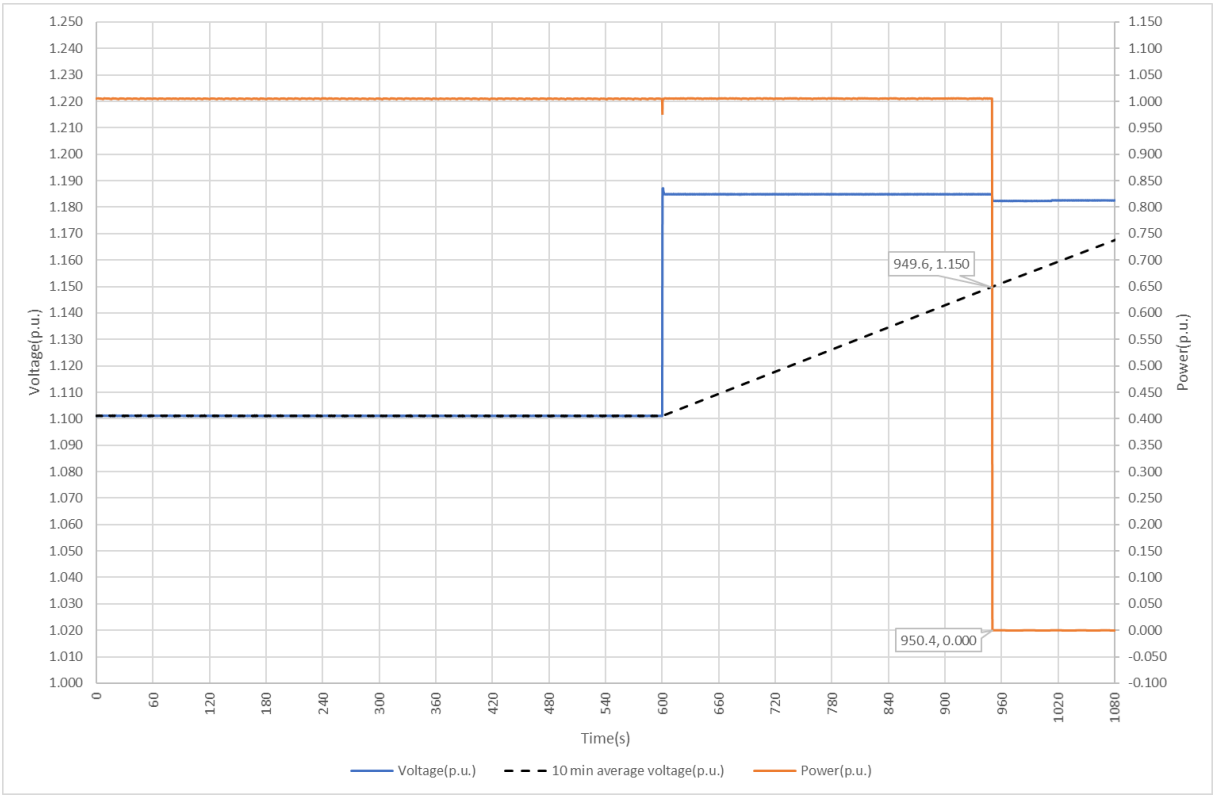
The following definitions apply to the test to verify the clause:

Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time meas. (s)	Trip time limited
1	1.000	1.004	0.004	0.4	≤ 3 s
2	1.150	1.150	0.000	0.8	≤ 3 s

Overvoltage 10 min mean protection - Test 1



Overvoltage 10 min mean protection - Test 2



4.6.1.4. Underfrequency protection

Underfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Underfrequency threshold stage 1 [81 <]:
- Threshold (47.0 – 50.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Underfrequency threshold stage 2 [81 < <]:
• Threshold (47.0 – 50.0) Hz adjustment by steps of 0.1 Hz
• Operate time (0.1 – 5) s adjustable in steps of 0.05 s

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.

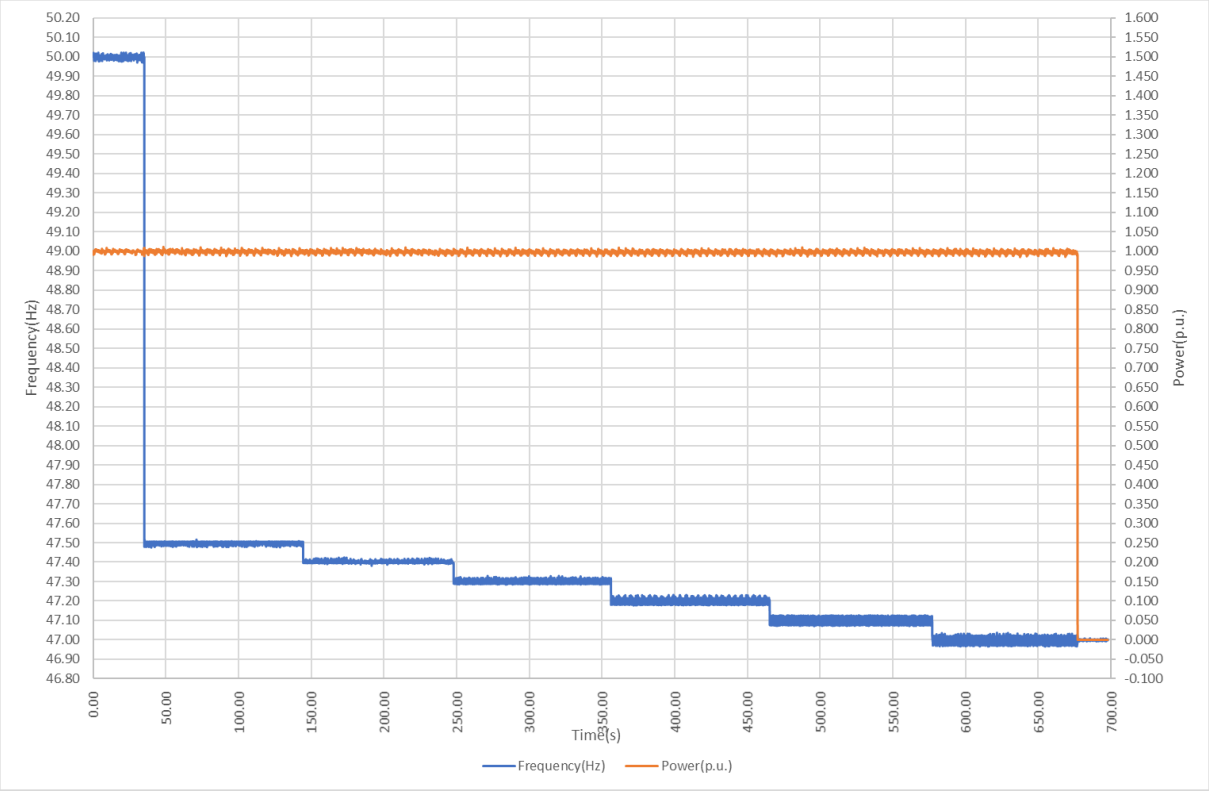
The frequency protection shall function correctly in the input voltage range between 20 %Un and 120 %Un and shall be inhibited for input voltages of less than 20 %Un.

Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.

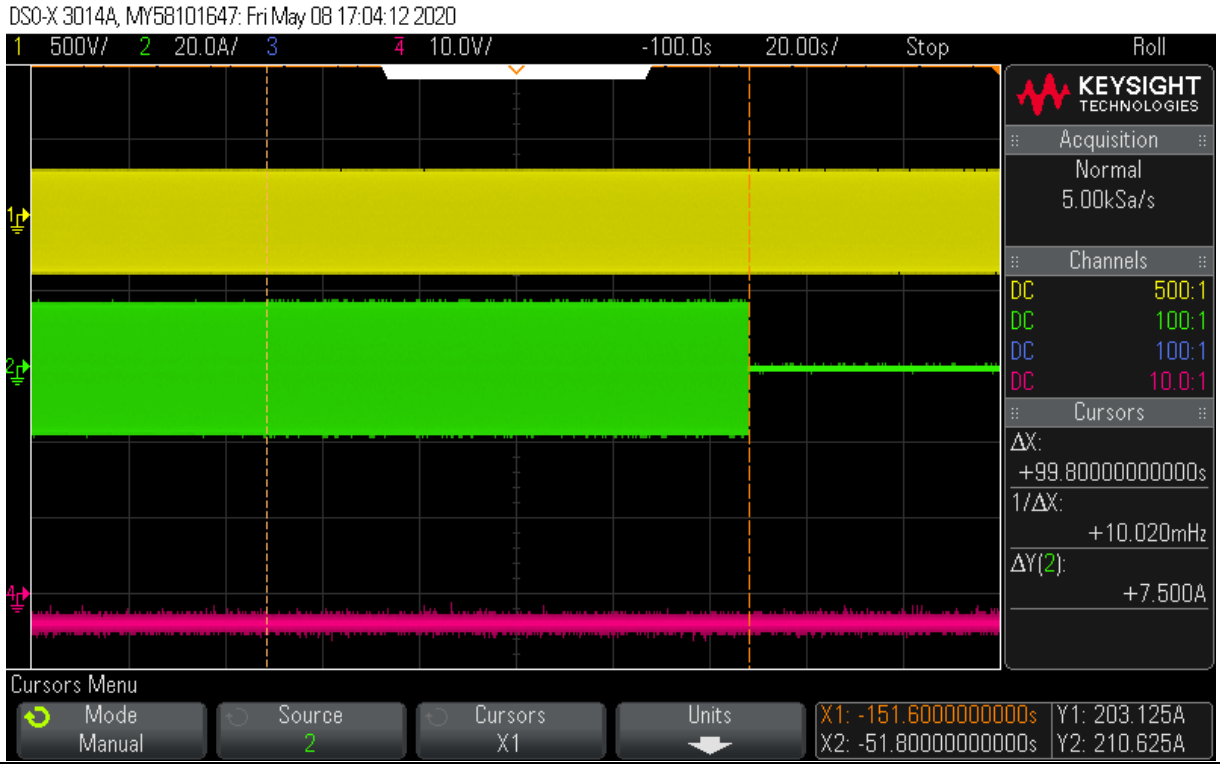
The following definitions apply to the test to verify the clause:

Under frequency	Test No.	Frequency setting (p.u.)	Frequency meas. (p.u.)	Frequency deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [81 <]	1	47.00	47.01	0.01	100.000	99.800	-0.200
	2	50.00	50.00	0.00	0.100	0.092	-0.008
Stage 2 [81 <<]	3	47.00	46.97	-0.03	5.000	4.980	-0.020
	4	50.00	50.00	0.00	0.100	0.092	-0.008

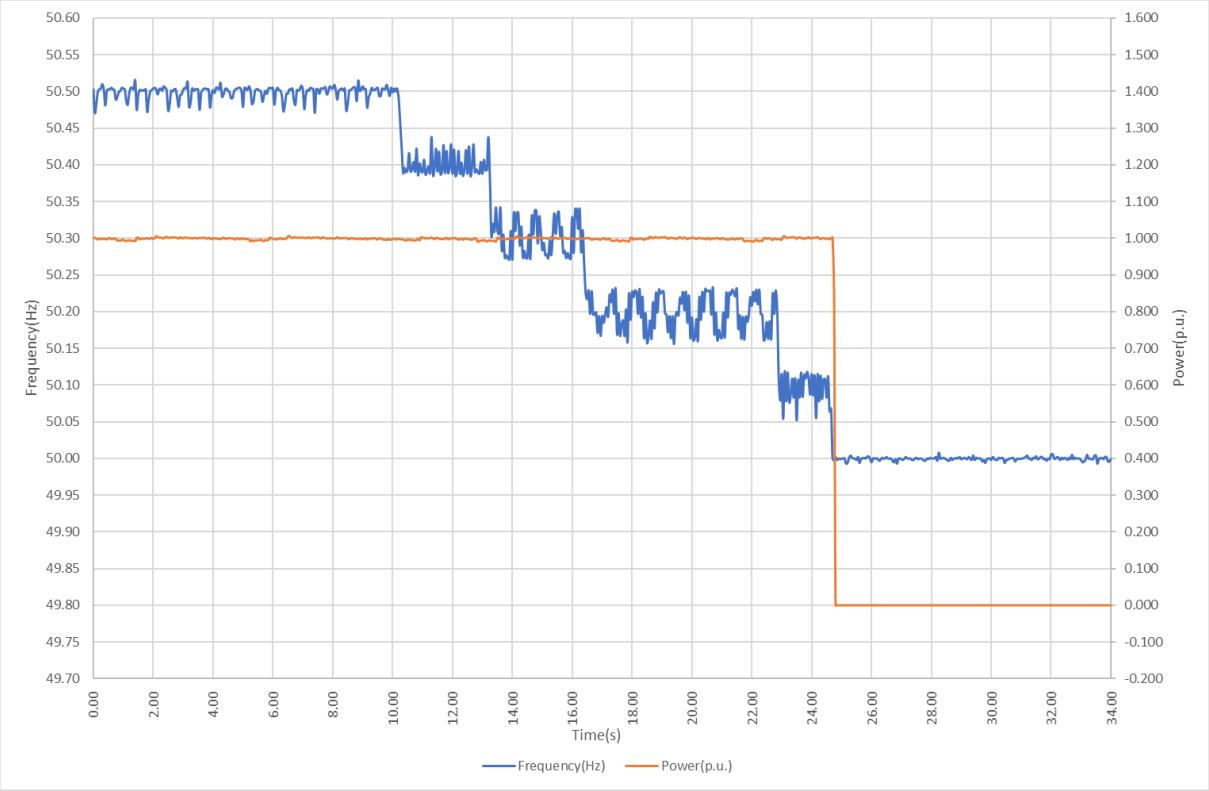
Underfrequency - Test 1: Trip value



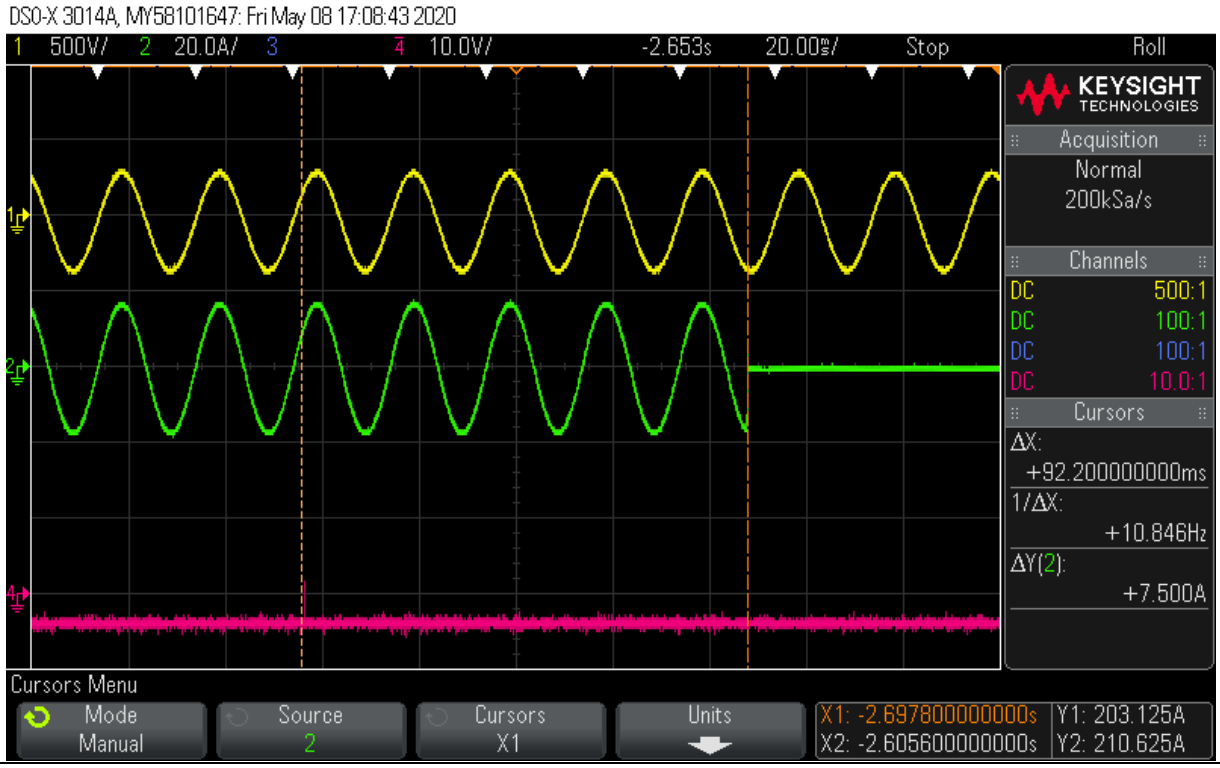
Underfrequency - Test 1: Trip time



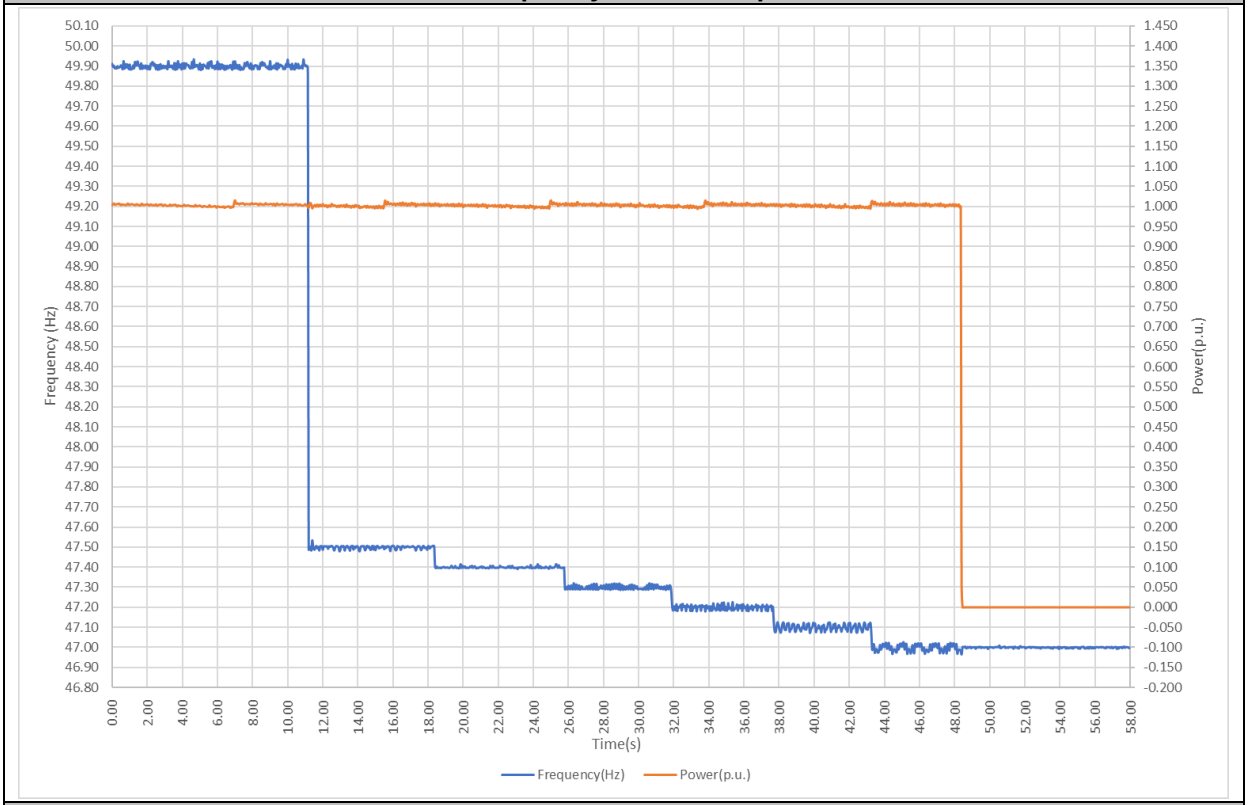
Underfrequency - Test 2: Trip value



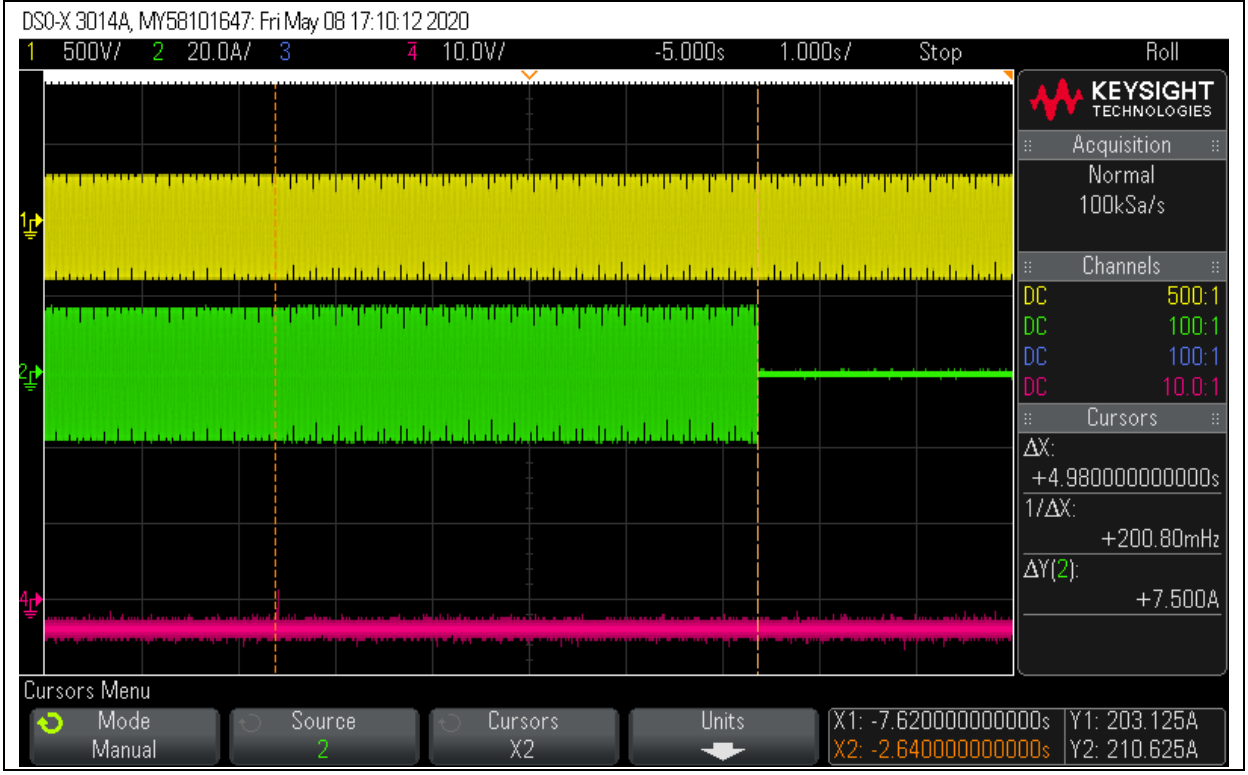
Underfrequency - Test 2: Trip time



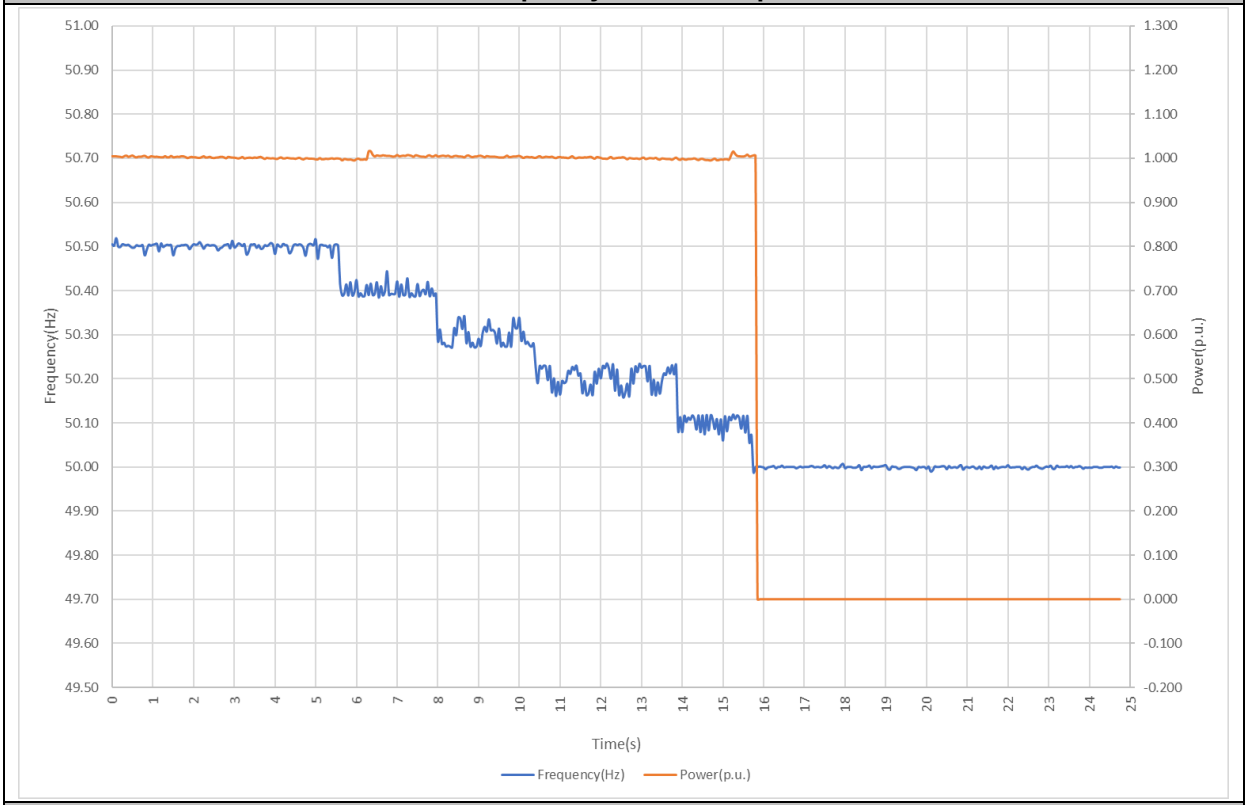
Underfrequency - Test 3: Trip value



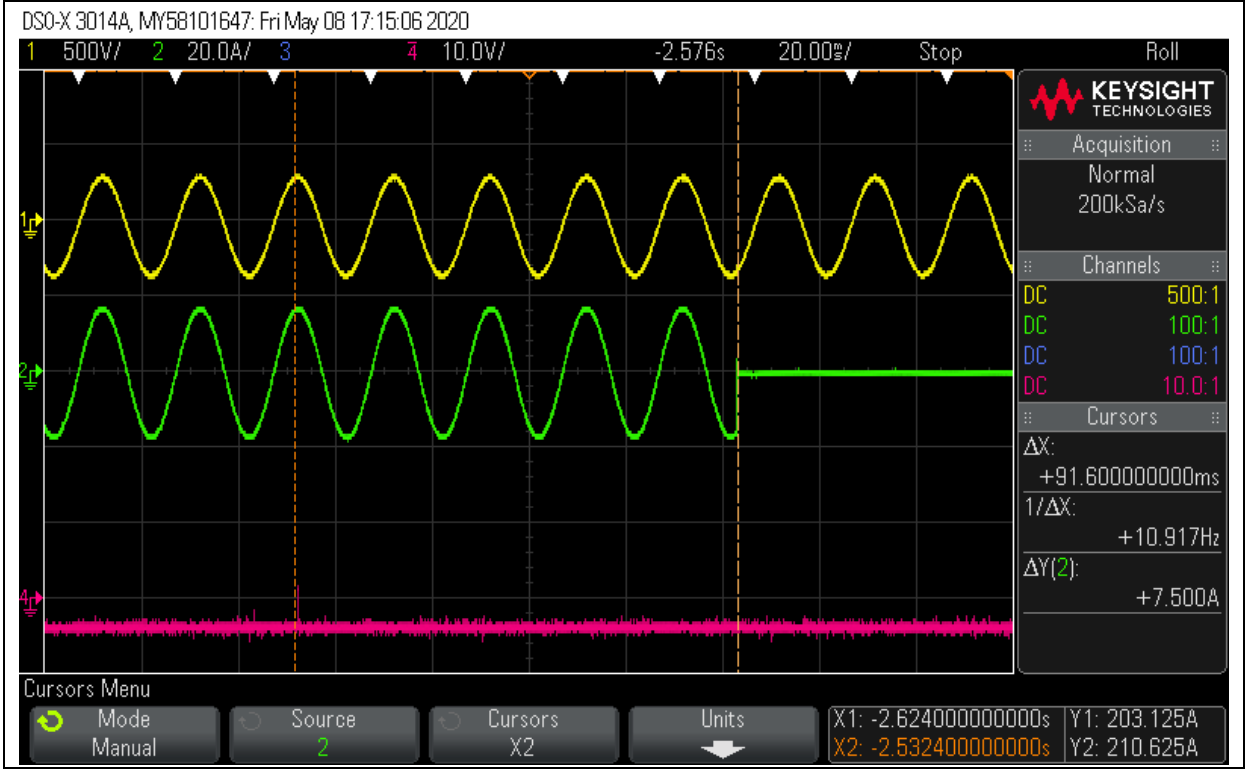
Underfrequency - Test 3: Trip time



Underfrequency - Test 4: Trip value



Underfrequency - Test 4: Trip time



4.6.1.5. Overfrequency protection

Overfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Overfrequency threshold stage 1 [81 >]:
- Threshold (50.0 – 52.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Overfrequency threshold stage 2 [81 > >]:
- Threshold (50.0 – 52.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 - 5) s adjustable in steps of 0.05 s

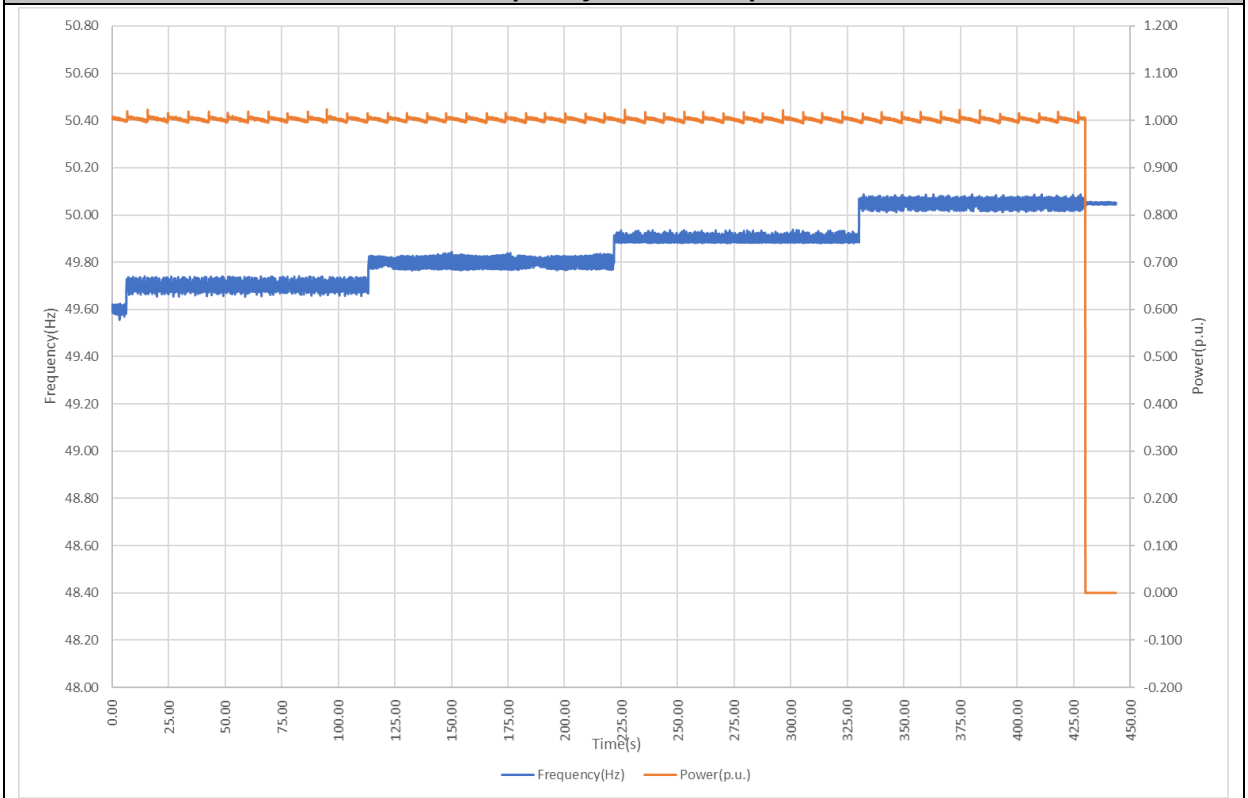
In order to use narrow frequency thresholds for islanding detection (see4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.

The frequency protection shall function correctly in the input voltage range between 20 %Un and 120 %Un and shall be inhibited for input voltages of less than 20 %Un.

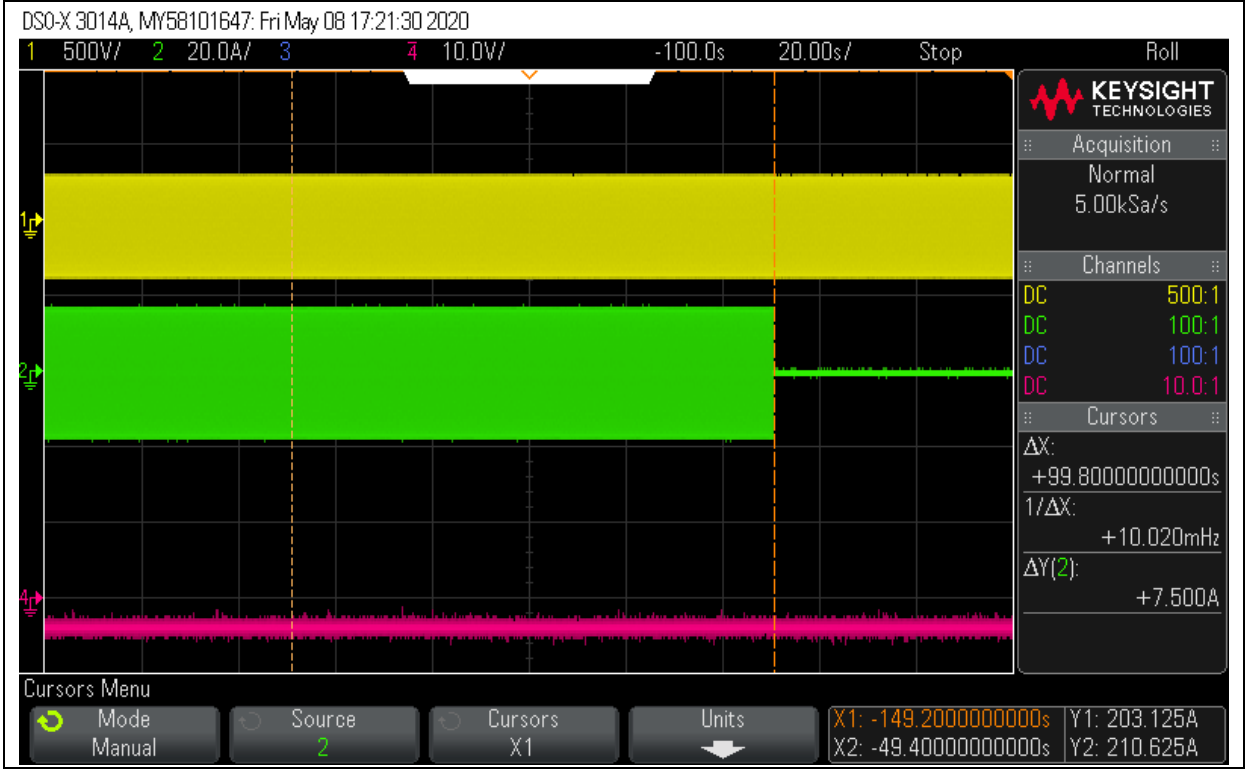
The following definitions apply to the test to verify the clause:

Over frequency	Test No.	Frequency setting (p.u.)	Frequency meas. (p.u.)	Frequency deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [81 >]	1	50.00	50.04	0.04	100.000	99.800	-0.200
	2	52.00	52.03	0.03	0.100	0.094	-0.006
Stage 2 [81 >>]	3	50.00	50.02	0.02	5.000	4.880	-0.120
	4	52.00	52.05	0.05	0.100	0.091	-0.009

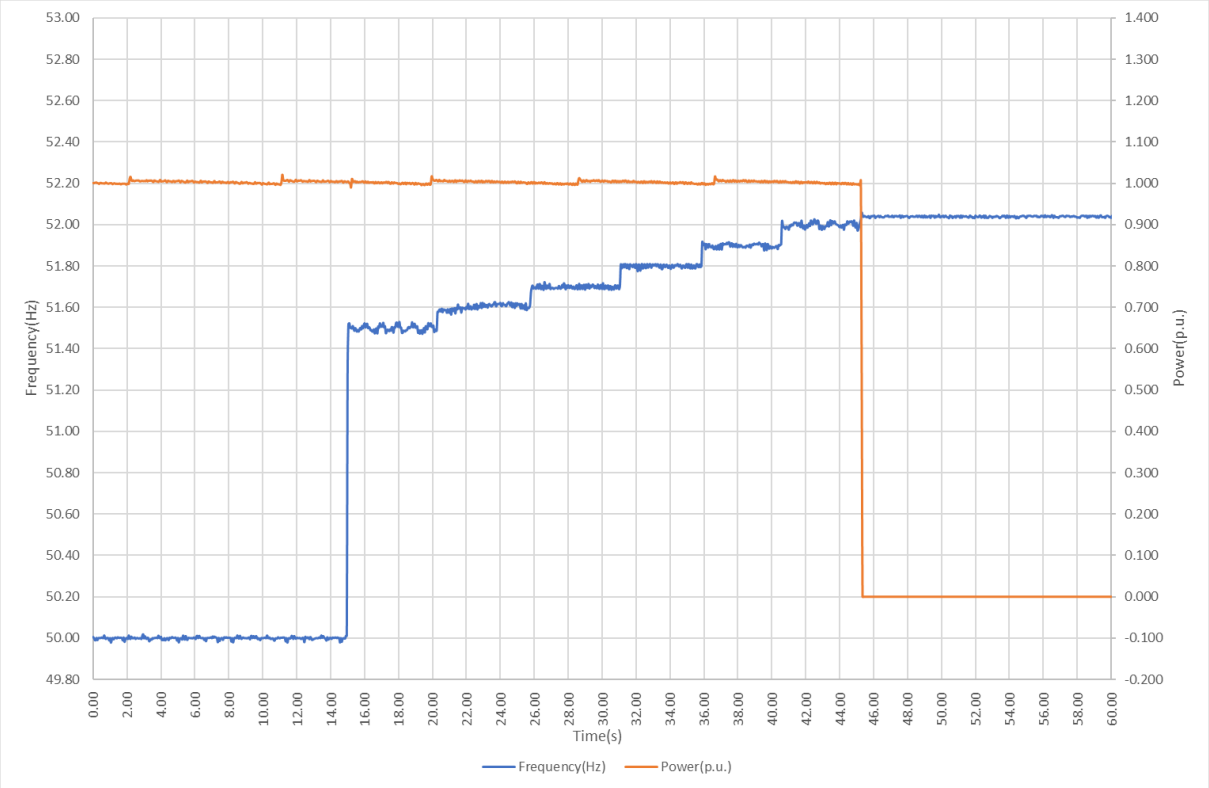
Overfrequency - Test 1: Trip value



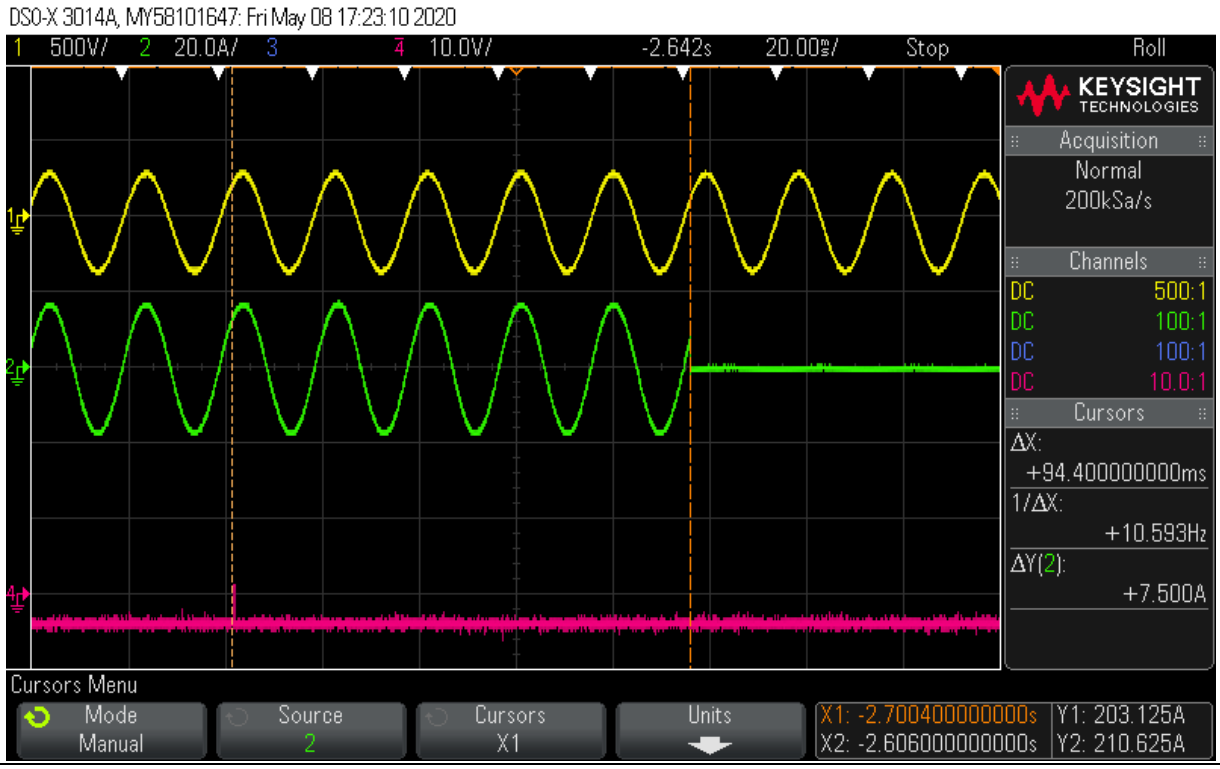
Overfrequency - Test 1: Trip time



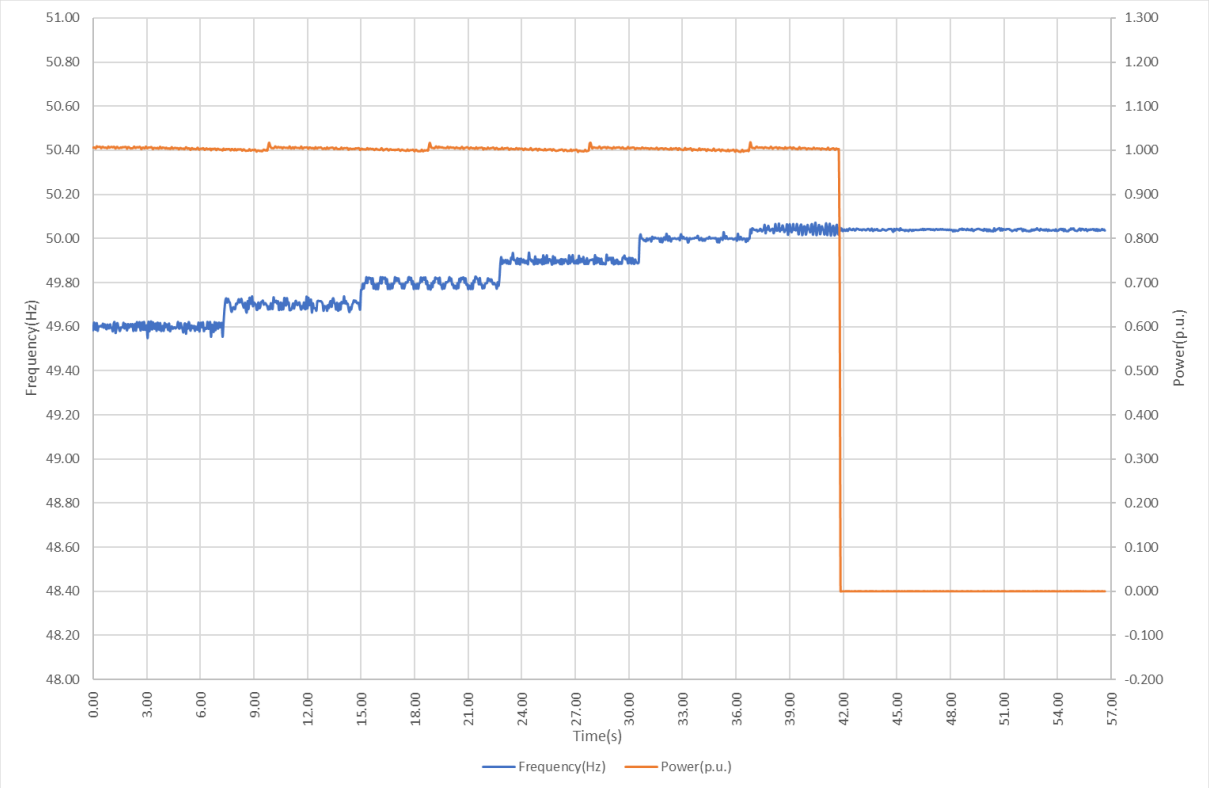
Overfrequency - Test 2: Trip value



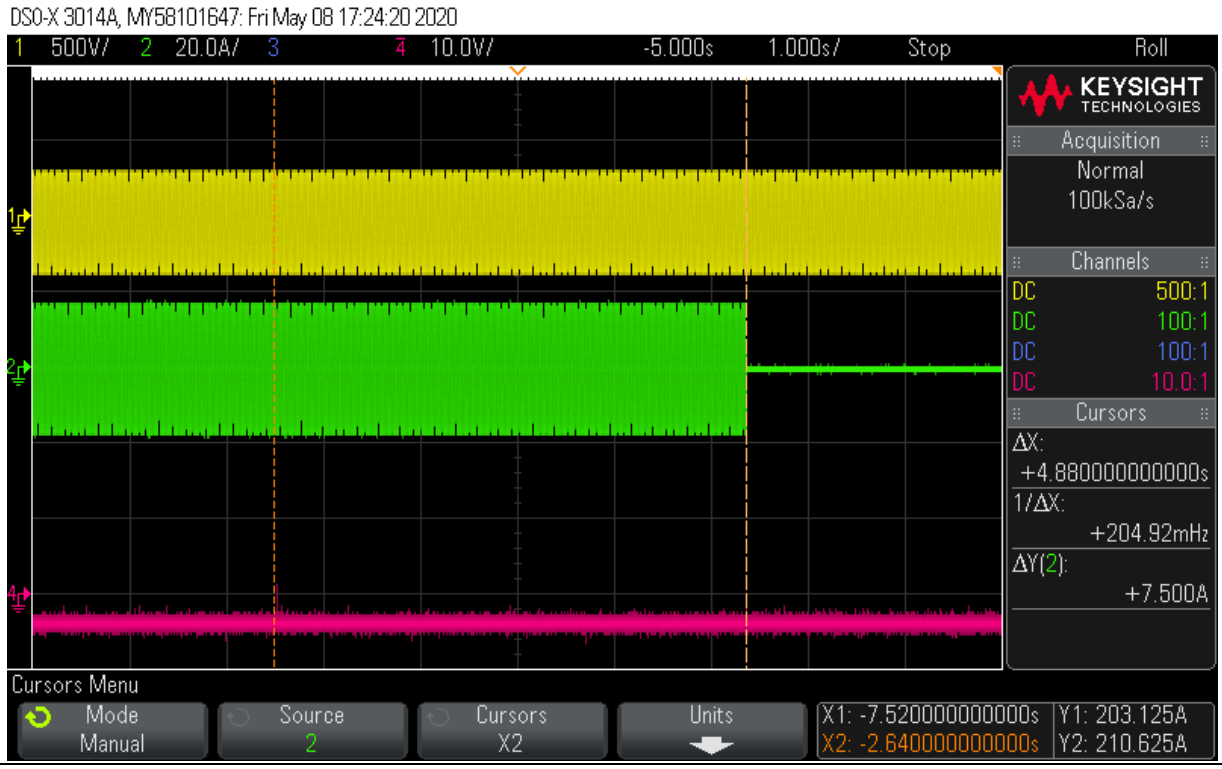
Overfrequency - Test 2: Trip time



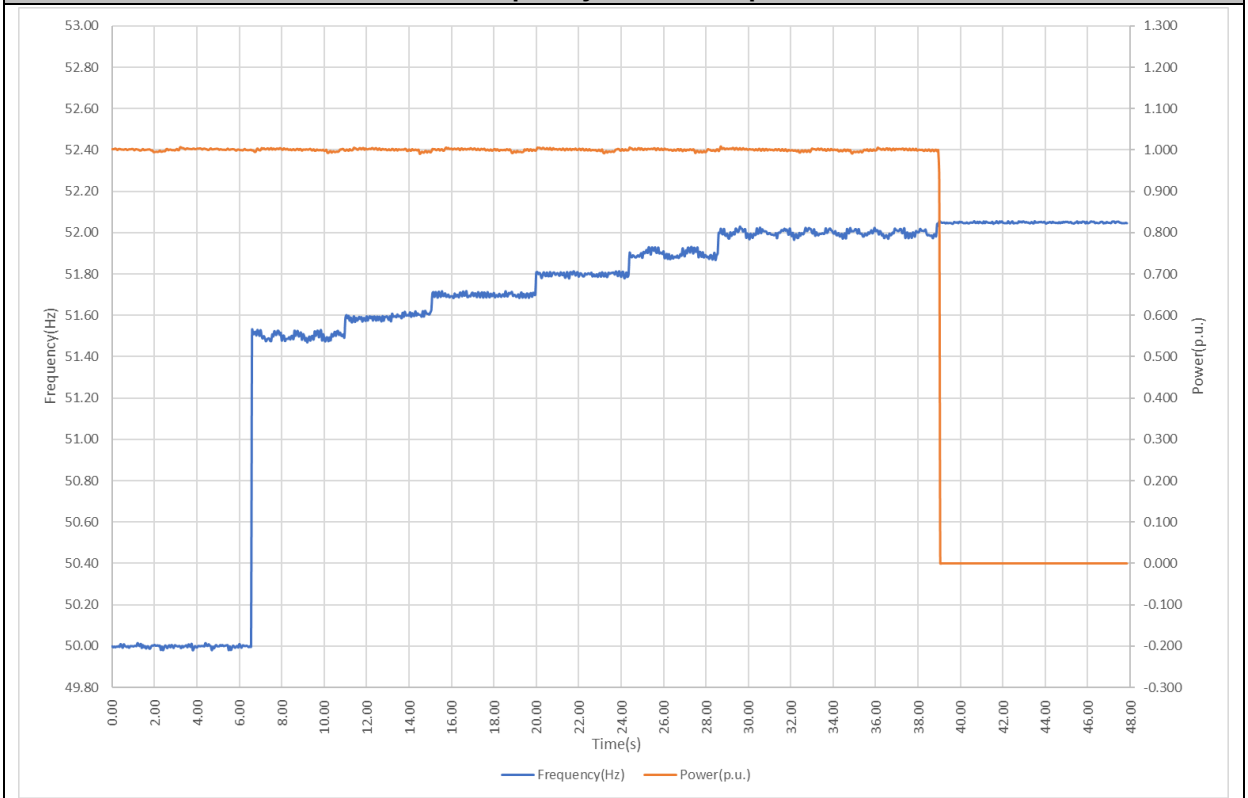
Overfrequency - Test 3: Trip value



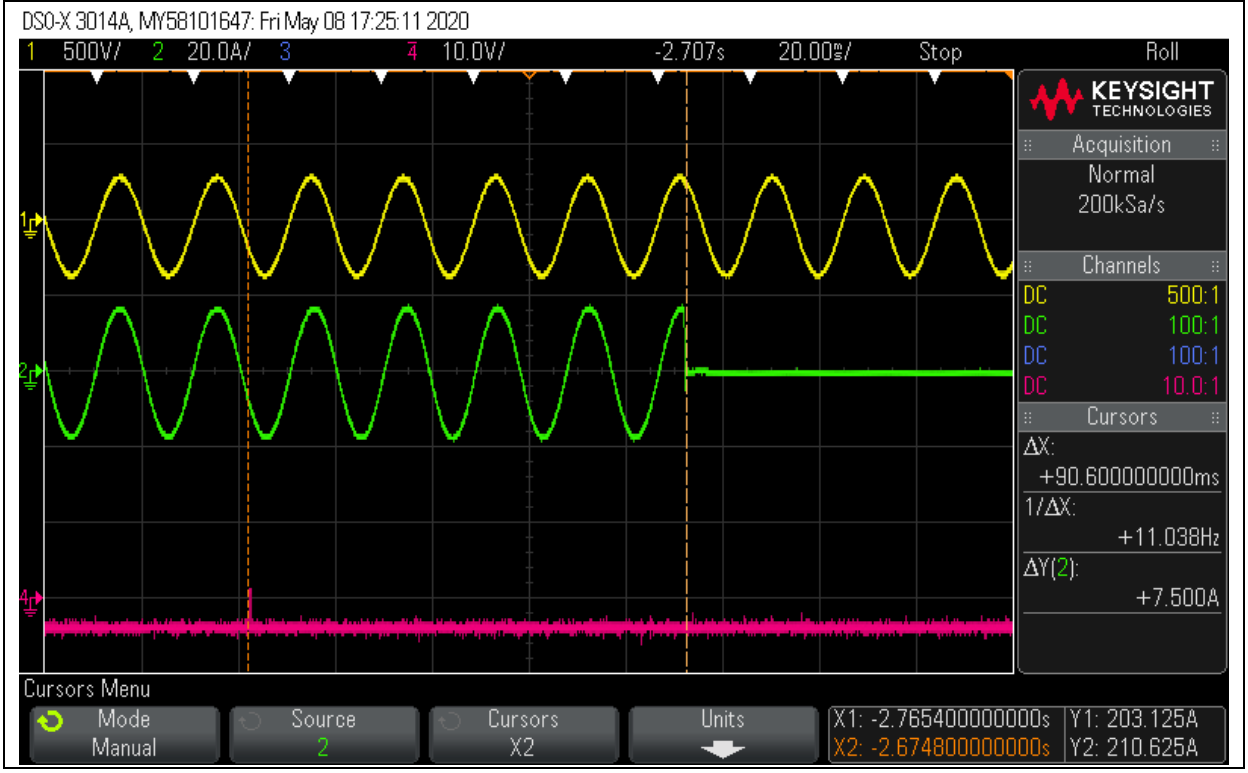
Overfrequency - Test 3: Trip time



Overfrequency - Test 4: Trip value



Overfrequency - Test 4: Trip time



4.6.2. Means to detect island situation

The test has been done according to the clause 4.9.4 of the standard.

This protection device is also able to detect islanded situations and disconnect the equipment from the grid. Active methods tested with a resonant circuit used for detecting islanding situations.

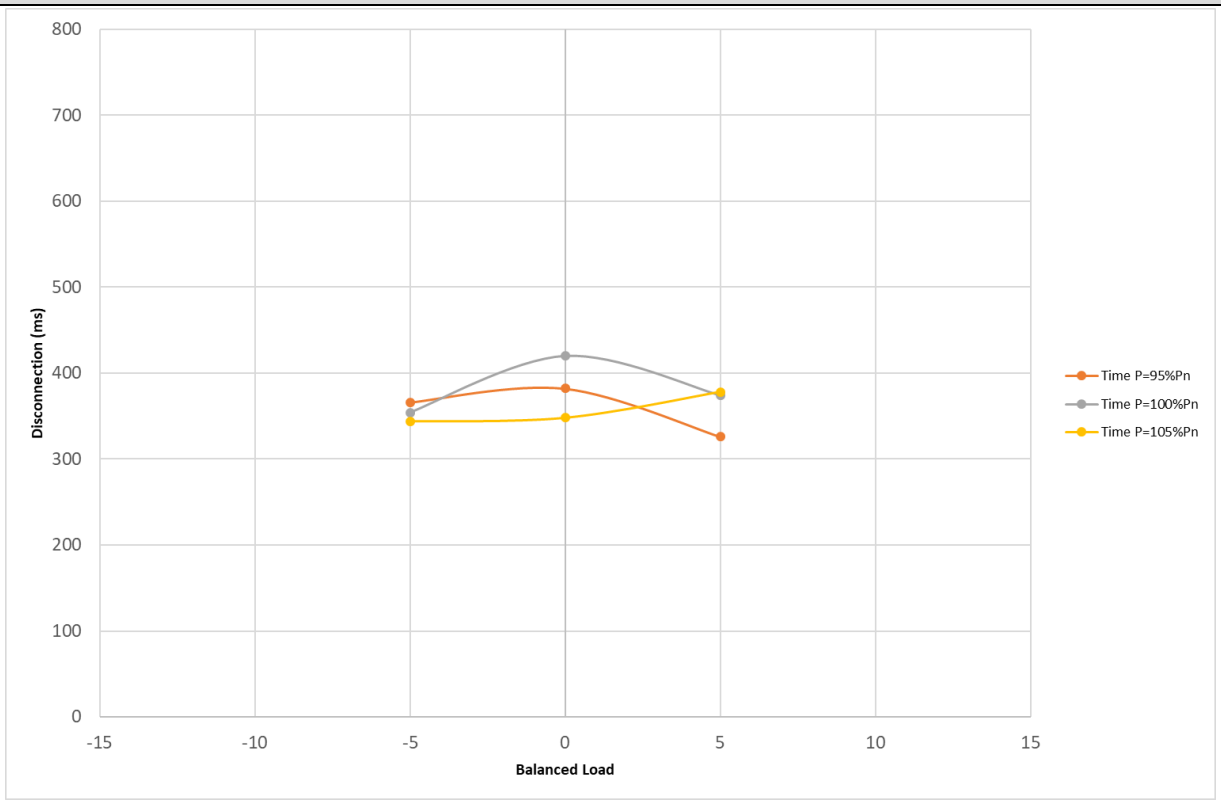
The compliances with these requirements are stated in the according to EN 62116. An EUT is considered to comply with the requirements for islanding protection when each case of recorded run-on time is less than 2 s or meets the requirements of local codes.

Table: tested condition and run-on time									
No.	**P_{EUT} (% of EUT rating)**	**Reactive load (% of normal)**	**P_{AC}**	**Q_{AC}**	**Run-on time (ms)**	**P_{EUT} (kW)**	**Actual Q_f**	**V_{DC} (d.c. V)**	**Which load is selected to be adjusted (R or C)**
Test Condition A									
1	100	100	-10	10	--	--	--	--	--
2	100	100	-10	5	--	--	--	--	--
3	100	100	-10	0	--	--	--	--	--
4	100	100	-10	-5	--	--	--	--	--
5	100	100	-10	-10	--	--	--	--	--
6	100	100	-5	10	--	--	--	--	--
7	100	100	-5	5	326	2.665	1.041	410	R/C
8	100	100	-5	0	382	2.665	1.074	410	R
9	100	100	-5	-5	366	2.698	1.079	410	R/C
10	100	100	-5	-10	--	--	--	--	--
11	100	100	0	10	--	--	--	--	--
12	100	100	0	5	374	2.810	0.988	410	C
13	**100**	**100**	**0**	**0**	420	2.820	1.006	410	--
14	100	100	0	-5	354	2.790	1.041	410	C
15	100	100	0	-10	--	--	--	--	--
16	100	100	5	10	--	--	--	--	--
17	100	100	5	5	872	2.943	0.937	410	R/C
18	100	100	5	0	554	2.930	0.970	410	R
19	100	100	5	-5	538	2.935	0.993	410	R/C
20	100	100	5	-10	--	--	--	--	--
21	100	100	10	10	--	--	--	--	--
22	100	100	10	5	--	--	--	--	--
23	100	100	10	0	--	--	--	--	--
24	100	100	10	-5	--	--	--	--	--
25	100	100	10	-10	--	--	--	--	--
Test Condition B									
10	66	66	0	0	398	1.850	0.991	305	--
11	66	66	0	-5	338	1.880	1.012	305	C
12	66	66	0	-4	362	1.845	0.990	305	C
13	66	66	0	-3	386	1.875	0.980	305	C
14	66	66	0	-2	354	1.873	0.975	305	C
15	66	66	0	-1	366	1.863	0.987	305	C
16	66	66	0	1	376	1.858	0.981	305	C
17	66	66	0	2	378	1.850	0.979	305	C
18	66	66	0	3	336	1.870	0.964	305	C
19	66	66	0	4	366	1.863	0.964	305	C
20	66	66	0	5	356	1.858	0.962	305	C
Test Condition C									
21	33	33	0	0	388	0.983	0.998	183	--
22	33	33	0	-5	278	0.963	1.043	183	C

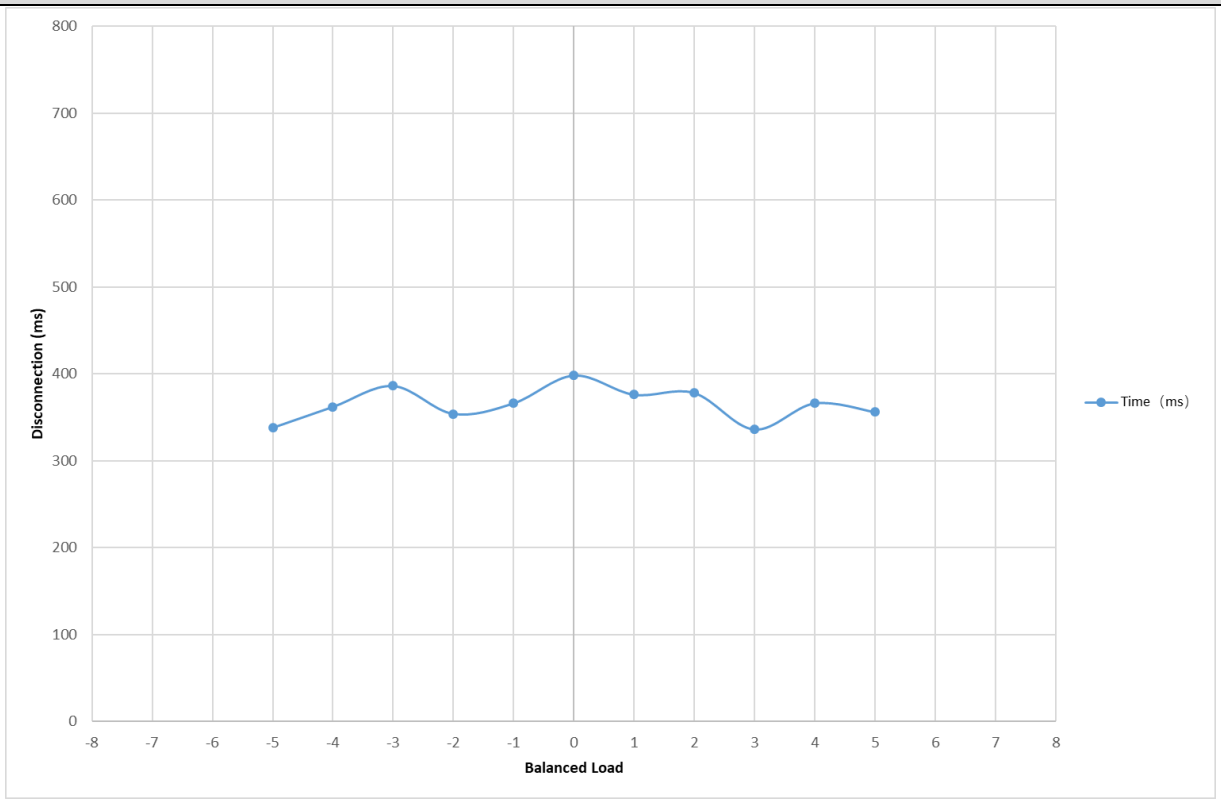
Table: tested condition and run-on time									
No.	**P_{EUT} (% of EUT rating)**	**Reactive load (% of normal)**	**P_{AC}**	**Q_{AC}**	**Run-on time (ms)**	**P_{EUT} (kW)**	**Actual Q_f**	**V_{DC} (d.c. V)**	**Which load is selected to be adjusted (R or C)**
23	33	33	0	-4	288	0.968	1.035	183	C
24	33	33	0	-3	268	0.965	1.035	183	C
25	33	33	0	-2	282	0.966	1.023	183	C
26	33	33	0	-1	334	0.962	1.024	183	C
27	33	33	0	1	272	0.968	1.017	183	C
28	33	33	0	2	278	0.974	1.005	183	C
29	33	33	0	3	298	0.970	1.004	183	C
30	33	33	0	4	288	0.973	1.002	183	C
31	33	33	0	5	272	0.968	1.007	183	C

Remark:
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional 1 % increments is taken until run-on times begin decreasing.

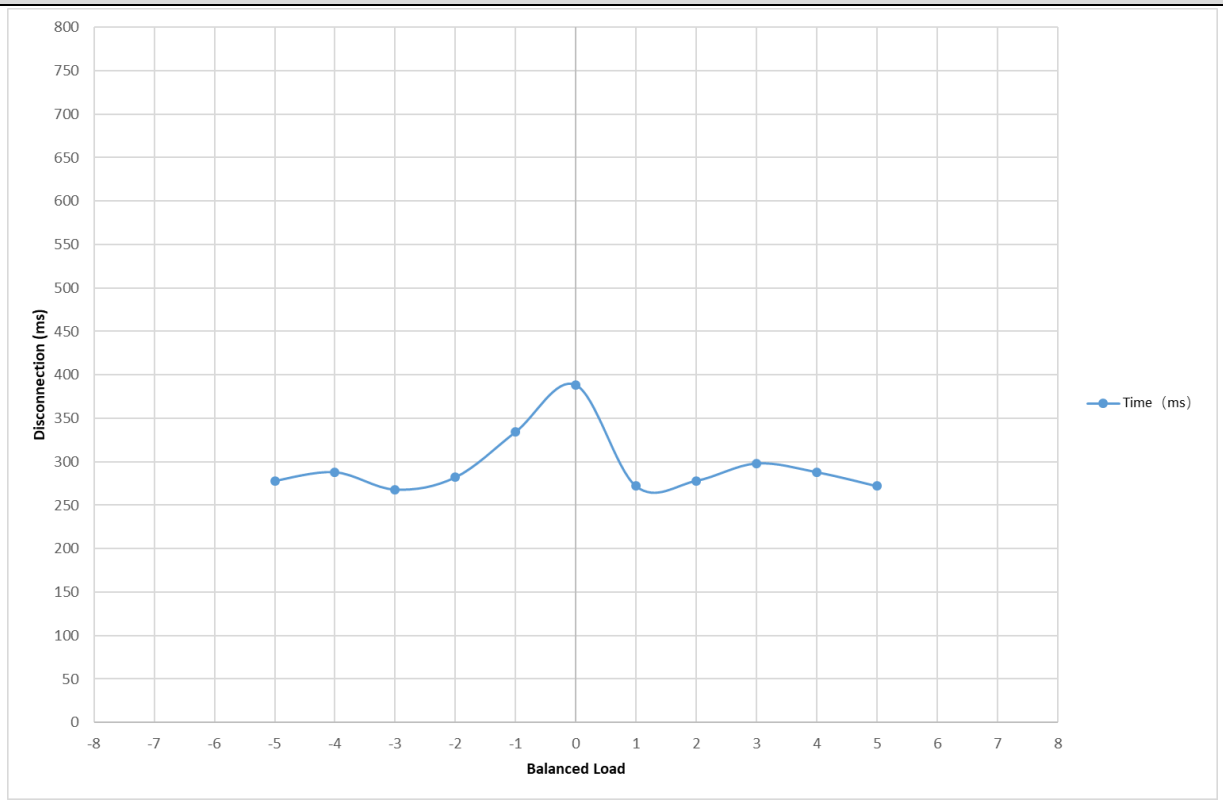
Test Condition A



Test Condition B



Test Condition C



4.6.3. Digital input to the interface protection

The test has been done according to the clause 4.9.5 of the standard.

The interface protection shall have at least two configurable digital inputs, EUT used active methods tested with a resonant circuit and ROCOF to comply to the clause.

4.7. CONNECTION AND STARTING TO GENERATE ELECTRICAL POWER

The test has been done according to the clause 4.10 of the standard.

4.7.1. Automatic reconnection after tripping

The test has been done according to the clause 4.10.2 of the standard.

The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 3 column 2. If no settings are specified by the DSO and the responsible party, the default settings for the reconnection after tripping of the interface protection are according to Table 3 column 3.

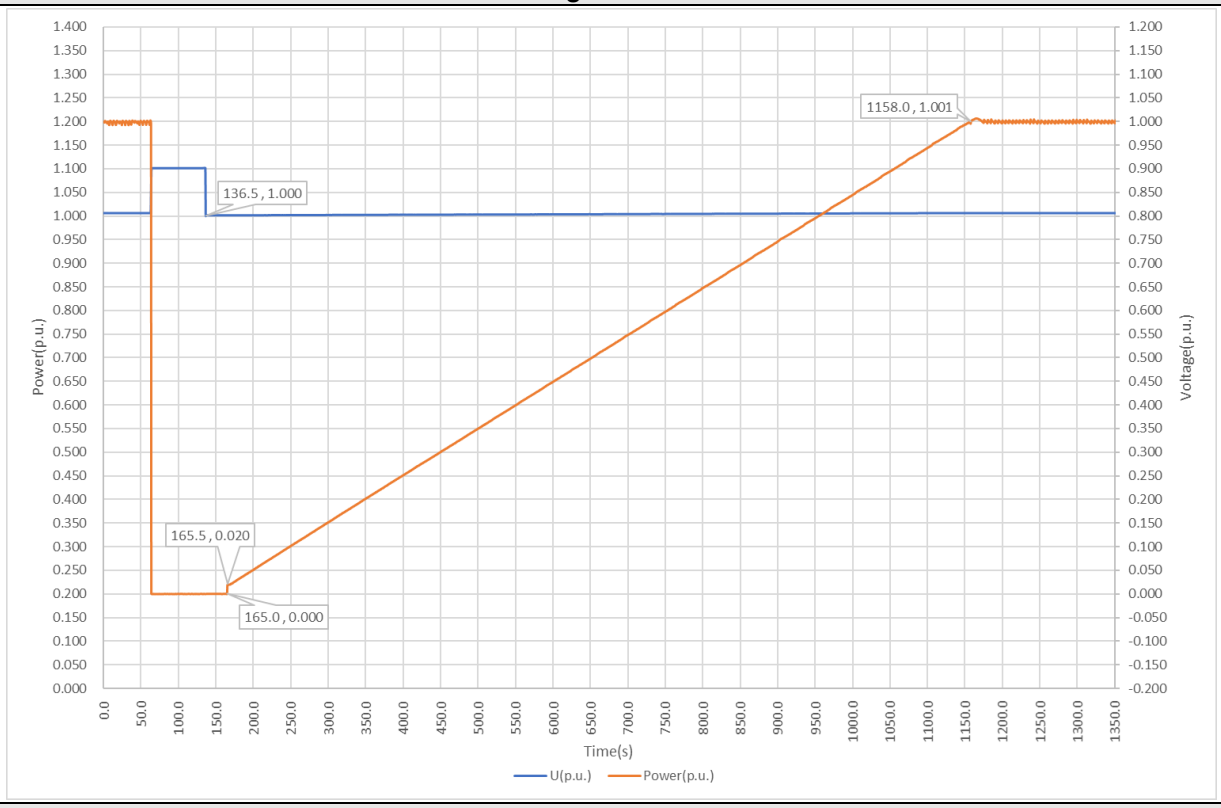
Table 3 — Automatic reconnection after tripping

Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz
Upper frequency	50,0Hz – 52,0Hz	50,2Hz
Lower voltage	50% – 100%U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	10%/min

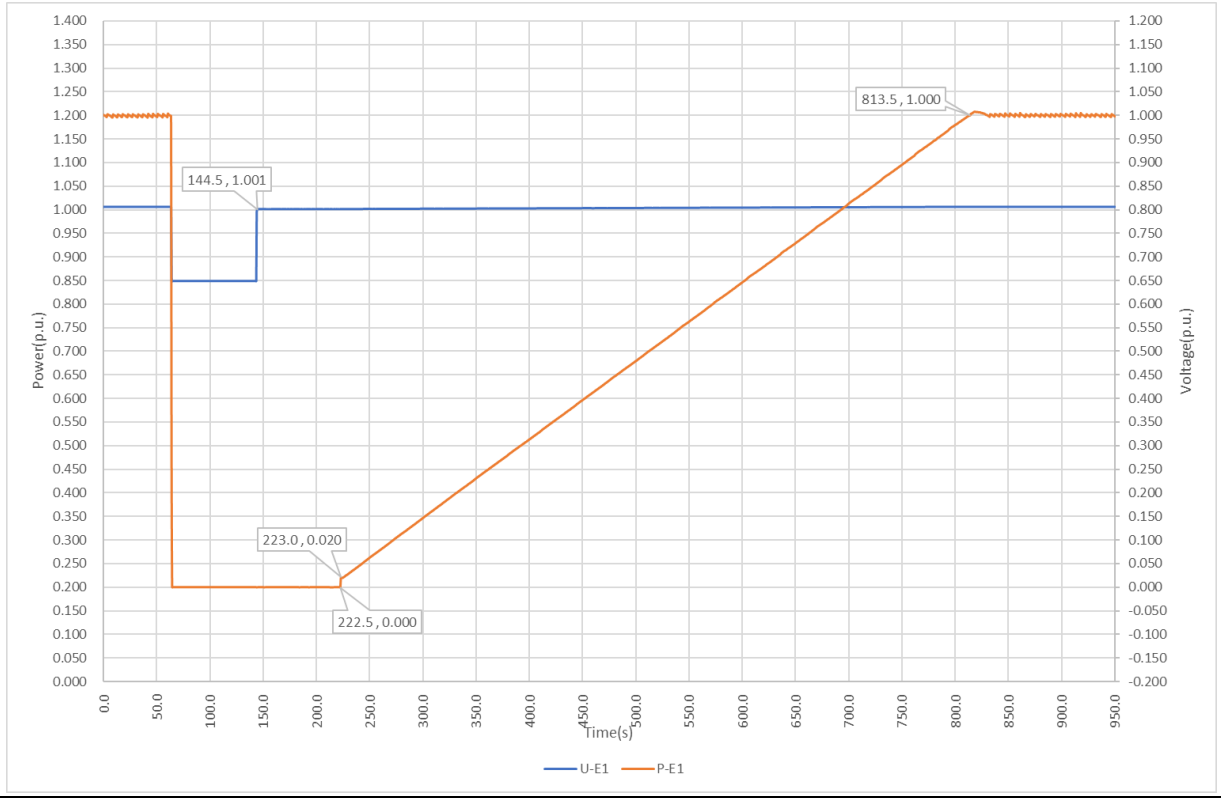
The following definitions apply to the test to verify the clause:

Disconnection		Connection		Setting connection time (s)	Meas. connection time (s)	Setting gradient (%Pn/min)	Meas. gradient (%Pn/min)
U = 110 %Un	Yes	85 % < U < 110 %Un	Yes	10	28.5	6.0	5.9
U = 85 %Un	Yes	85 % < U < 110 %Un	Yes	60	78.0	10.0	10.0
f = 52.00 Hz	Yes	49.50 < f < 50.20 Hz	Yes	600	601.8	3000.0	2751.8
f = 49.50 Hz	Yes	49.50 < f < 50.20 Hz	Yes	60	73.5	10.0	9.0

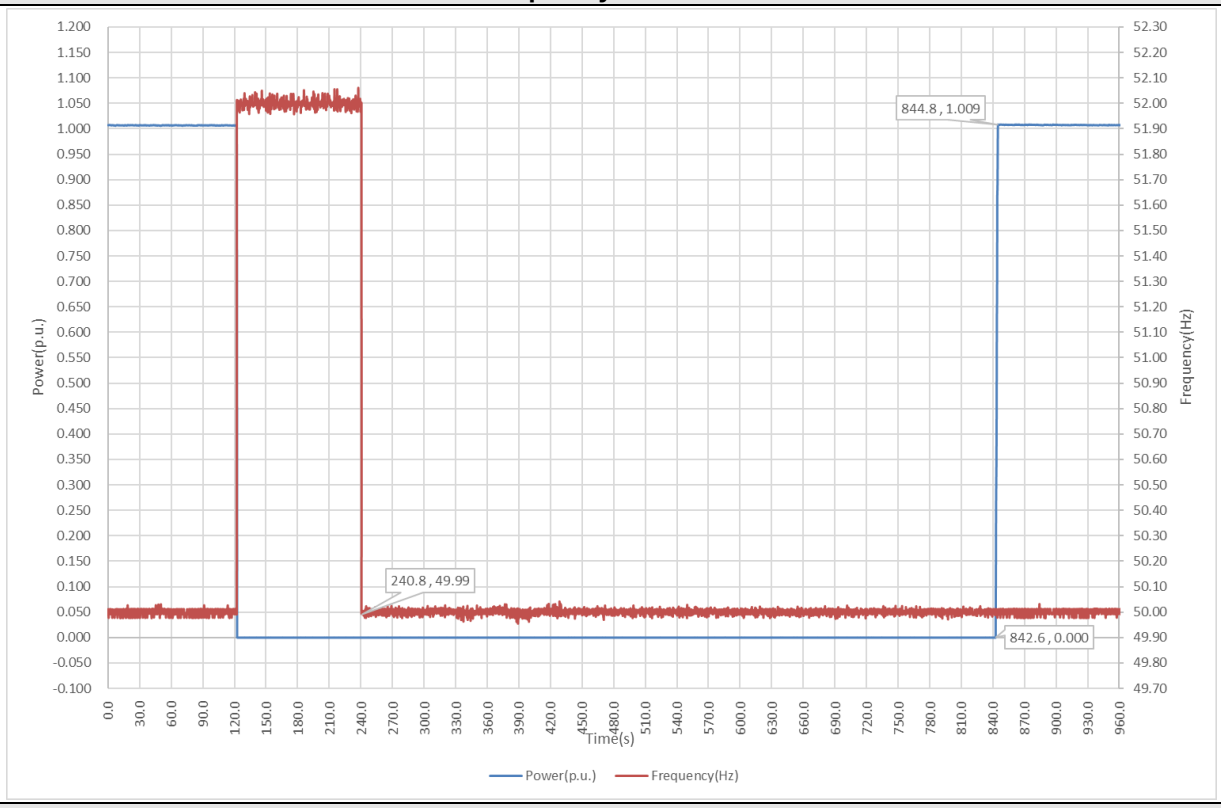
Overvoltage re-connection



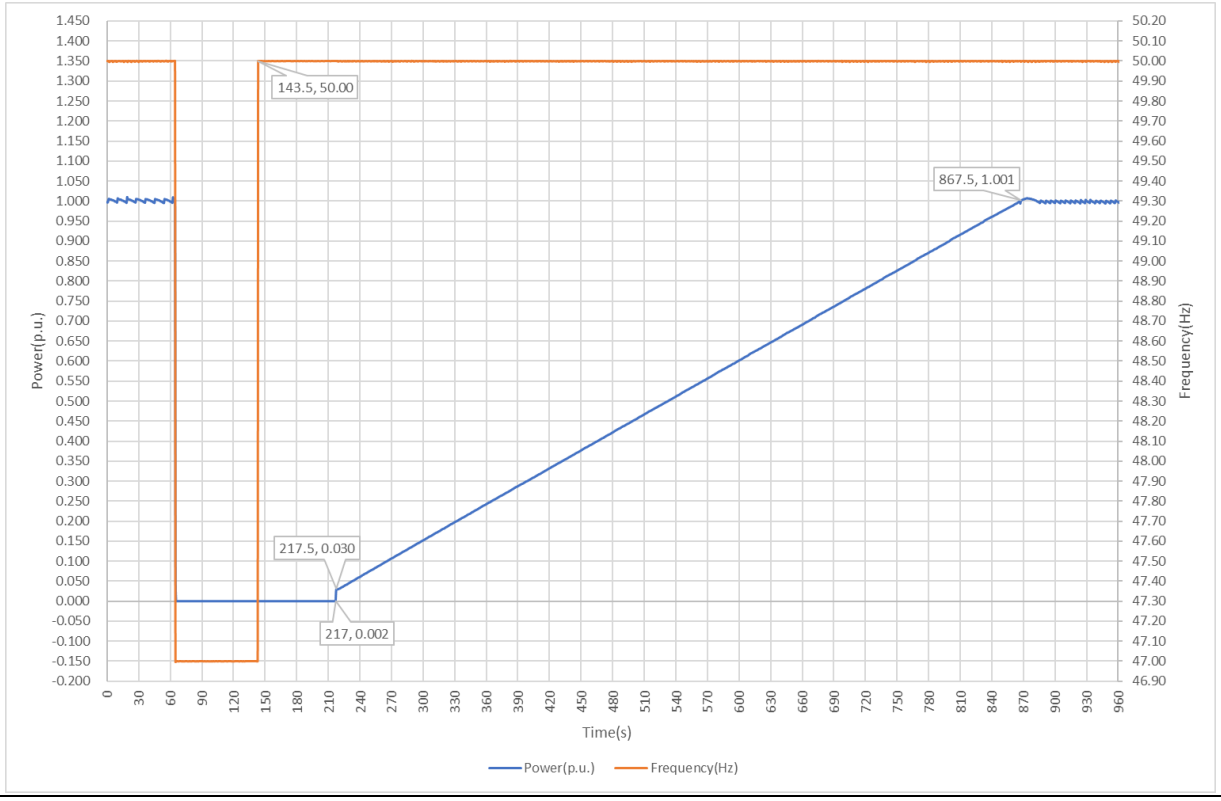
Undervoltage re-connection



Overfrequency re-connection



Underfrequency re-connection



4.7.2. Starting to generate electrical power

The test has been done according to the clause 4.10.3 of the standard.

The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 4 column 2. If no settings are specified by the DSO and the responsible party, the default settings for connection or starting to generate electrical power due to normal operational startup or activity are according to Table 4 column 3.

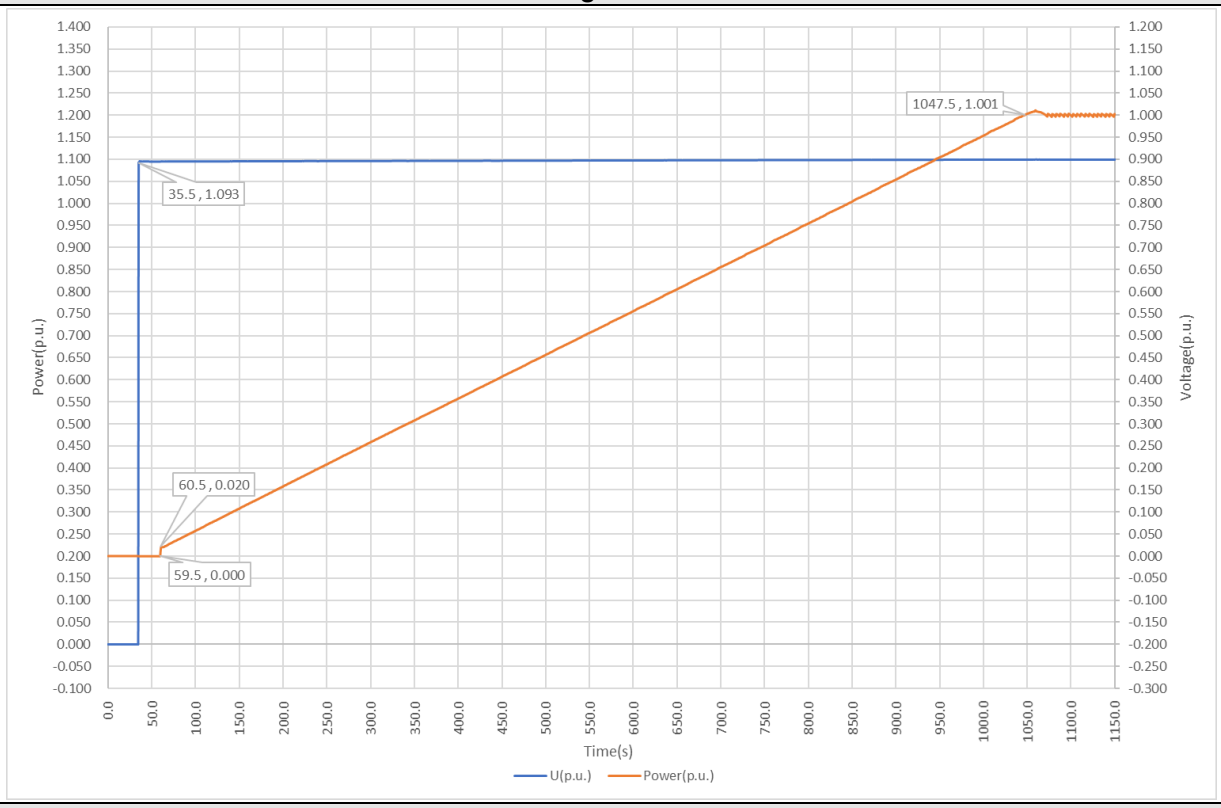
Table 4 — Starting to generate electrical power

Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz
Upper frequency	50,0Hz – 52,0Hz	50,1Hz
Lower voltage	50% – 100% U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	disabled

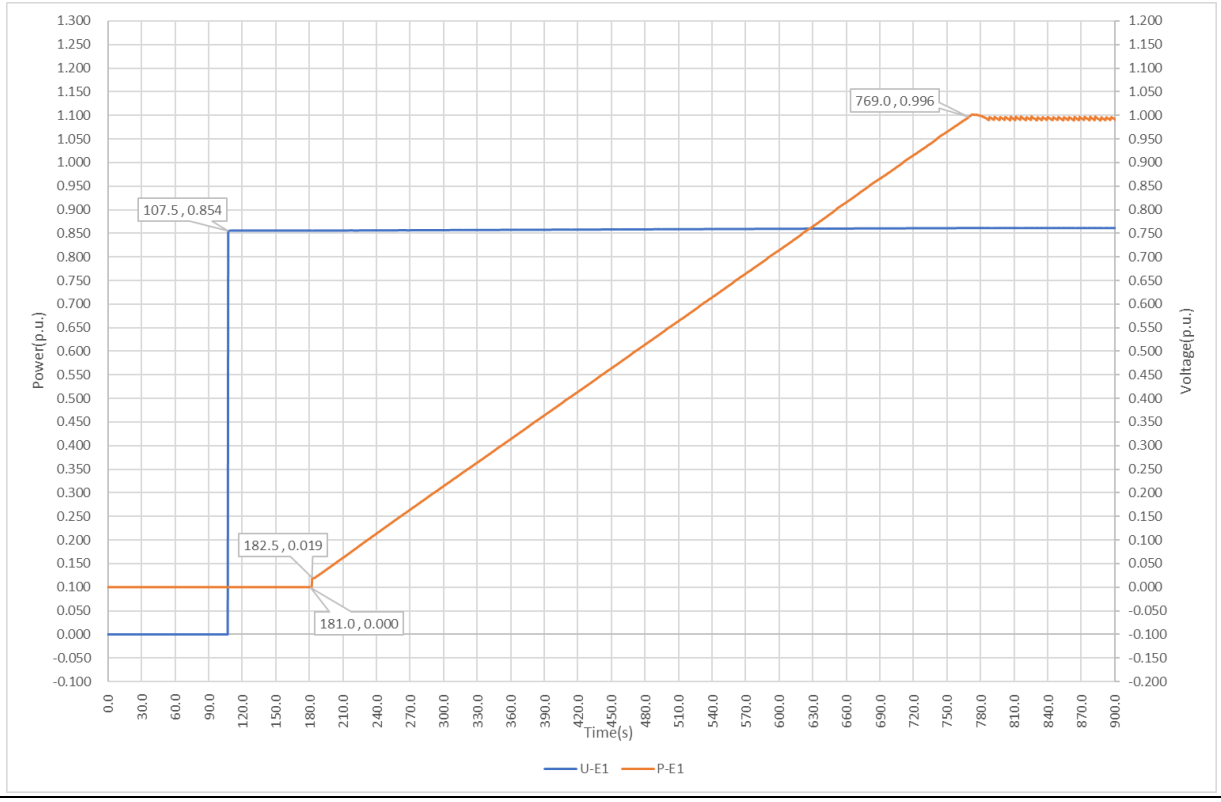
The following definitions apply to the test to verify the clause:

Connection		Setting connection time (s)	Meas. connection time (s)	Setting gradient (%Pn/min)	Meas. gradient (%Pn/min)
U < 110 %Un	Yes	10.0	24	6.0	6.0
85 % < U	Yes	60.0	73.5	10.0	10.0
f < 50.20 Hz	Yes	600.0	601.4	3000.0	2330.8
49.50 < f	Yes	60.0	73.0	10.0	8.9

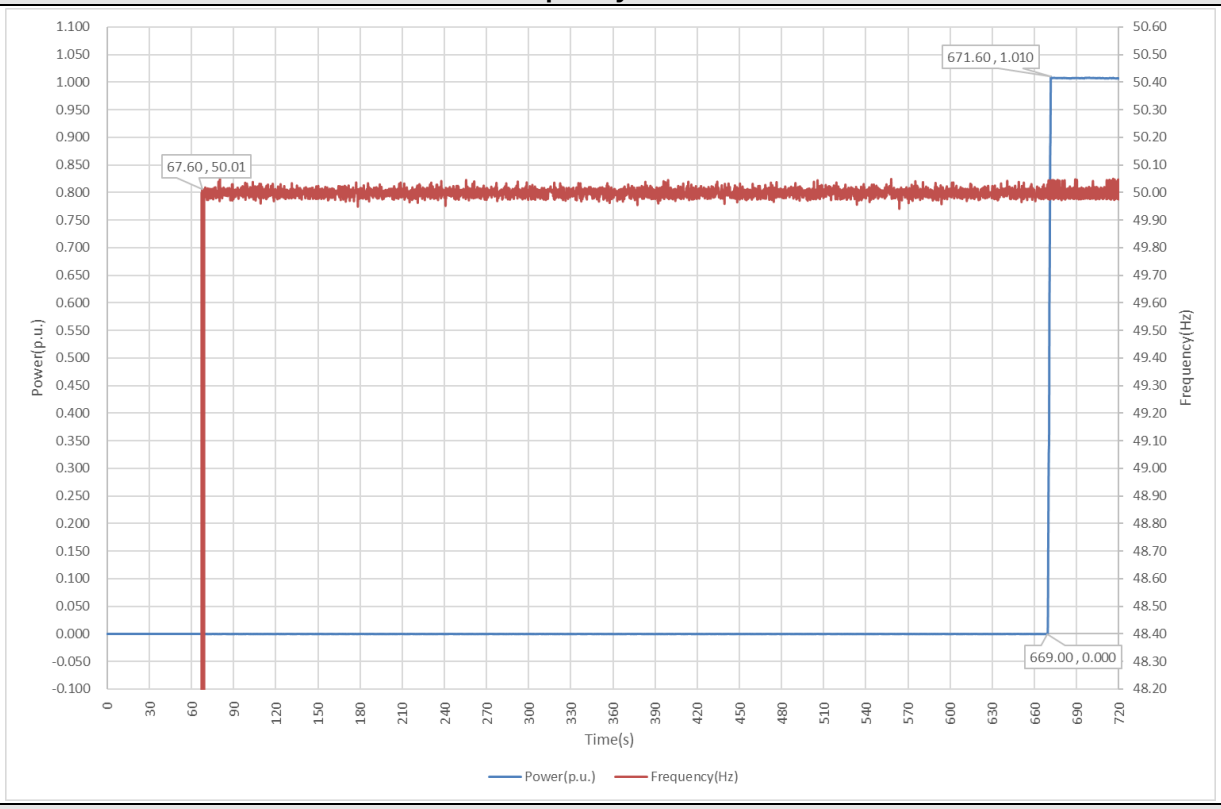
Overvoltage Connection



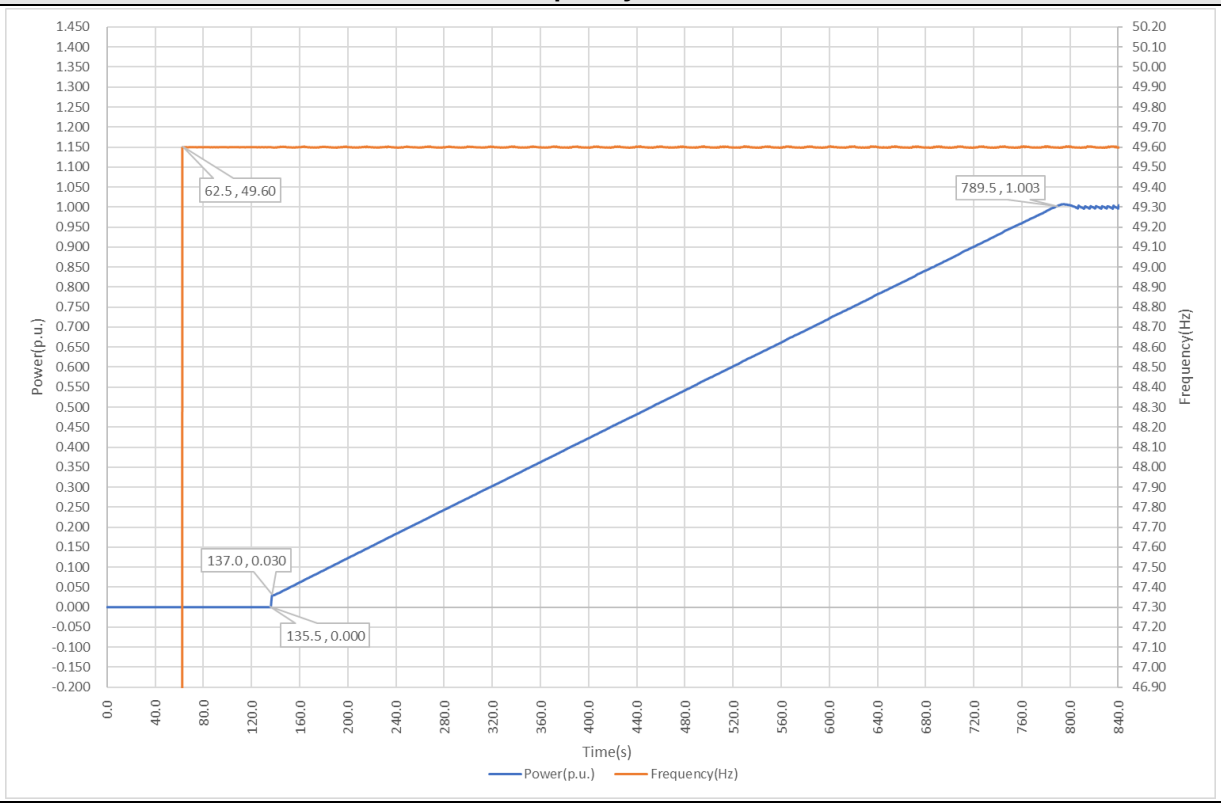
Undervoltage Connection



Overfrequency connection



Underfrequency connection



4.7.3. Synchronization

The requirements are from clause 4.10.4 of the standard.

The EUT fully automatic to connect to distribution network

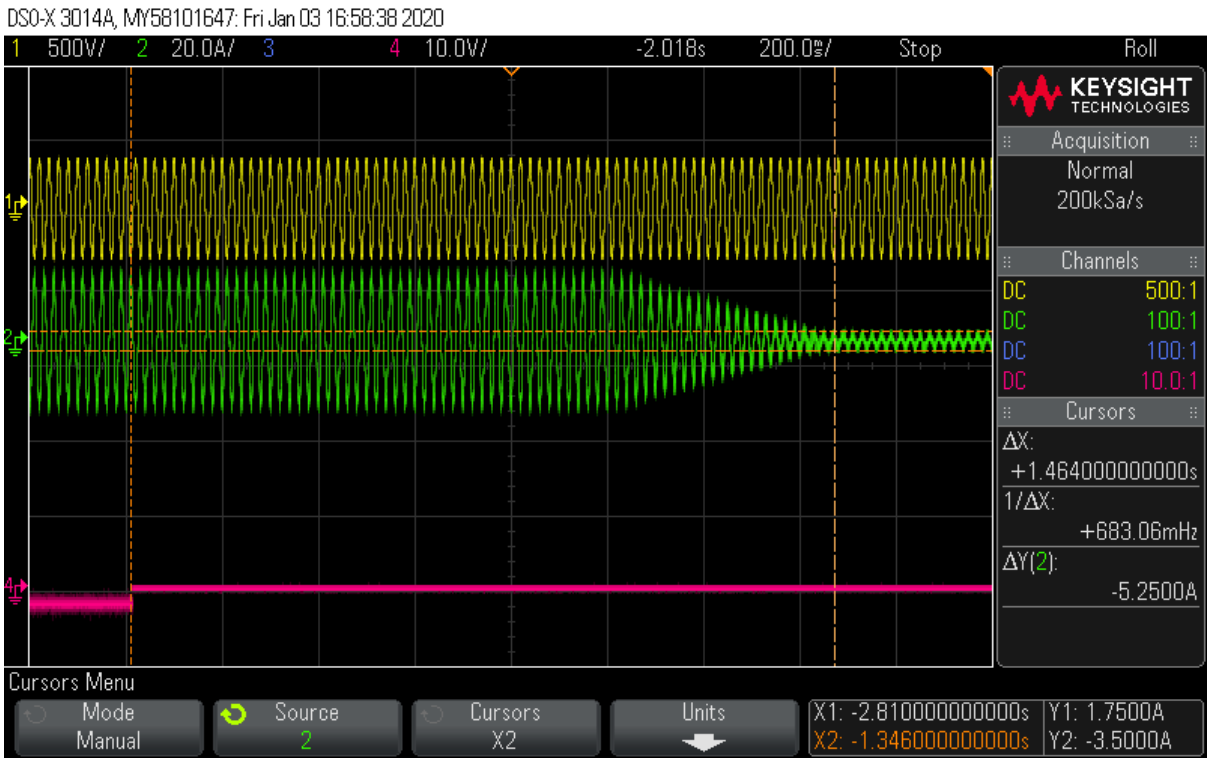
4.8. CEASING AND REDUCTION OF ACTIVE POWER ON SET POINT

4.8.1. Ceasing active power

The test has been done according to the clause 4.11.1 of the standard.

Generating plants with a maximum capacity of 0.8 kW or more shall be equipped with a logic interface (input port) in order to cease active power output within 5 seconds following an instruction being received at the input port. If required by the DSO and the responsible party, this includes remote operation.

Trip time



(*) For this Oscilloscope records showed wrong date - "Jan 3", actually it was "April 20" keeping same with raw data of the Power analyzer used.

Tested ceasing active power time: 1.46 s

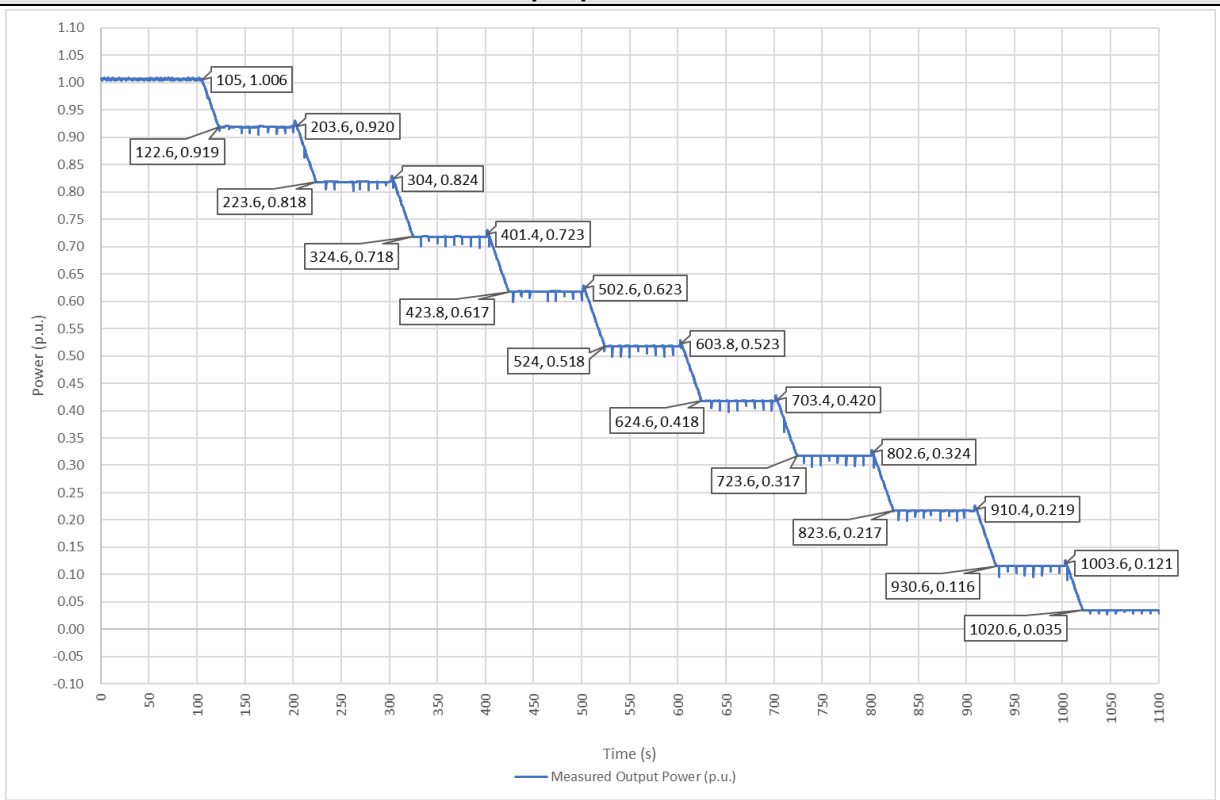
Ch1: Grid voltage, Ch2 Output current, Ch4 Ceasing active power signal

4.8.2. Reduction of active power on set point

Test requirements according to the clause 4.11.2 of the standard.

Active Power step ($\%P_n$)	Setpoint value		Actual value		Deviation < ±5 %		Gradient 0.66 %Pn/s to 0.33 %Pn/s
	(kW)	(%Pn)	(kW)	($\%P_n$)	(kW)	($\%P_n$)	(%Pn/s)
100	2.8	100.00	2.819	100.7	0.019	0.7	--
90	2.5	90.00	2.573	91.9	0.053	1.9	0.49
80	2.2	80.00	2.291	81.8	0.051	1.8	0.51
70	2.0	70.00	2.010	71.8	0.050	1.8	0.51
60	1.7	60.00	1.730	61.8	0.050	1.8	0.47
50	1.4	50.00	1.450	51.8	0.050	1.8	0.49
40	1.1	40.00	1.169	41.8	0.049	1.8	0.50
30	0.8	30.00	0.888	31.7	0.048	1.7	0.51
20	0.6	20.00	0.606	21.7	0.046	1.7	0.51
10	0.3	10.00	0.323	11.5	0.043	1.5	0.51
0	0.0	0.00	0.096	3.4	0.096	3.4	0.51

Output power curve



4.9. REQUIREMENTS REGARDING SINGLE FAULT TOLERANCE OF INTERFACE PROTECTION SYSTEM AND INTERFACE SWITCH

The requriments are from clause 4.13 of the standard.

The compliance with these requirements are stated in section 4.4 of following test report:

IEC/EN 62109-1:2010, IEC/EN 62109-2:2011: Test Report nº LD200423N070 on 26th May.,2020 which issued by Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch.

5. PICTURES

General view

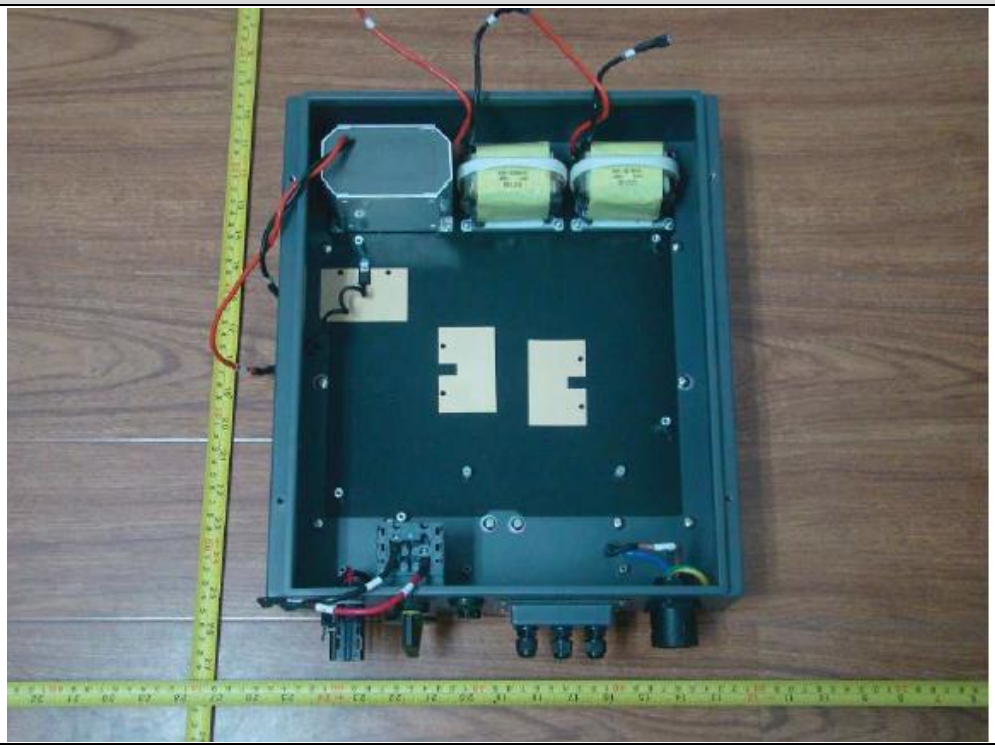
Rear view


Connection interface

Internal View - 1

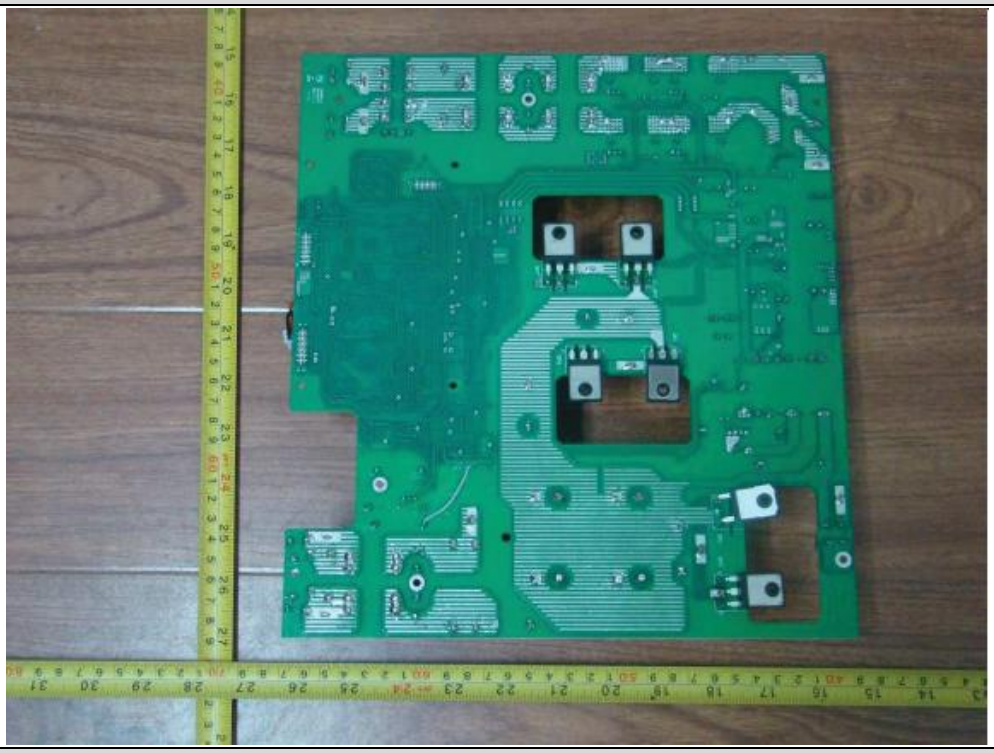

Internal View - 2

Internal View - 3

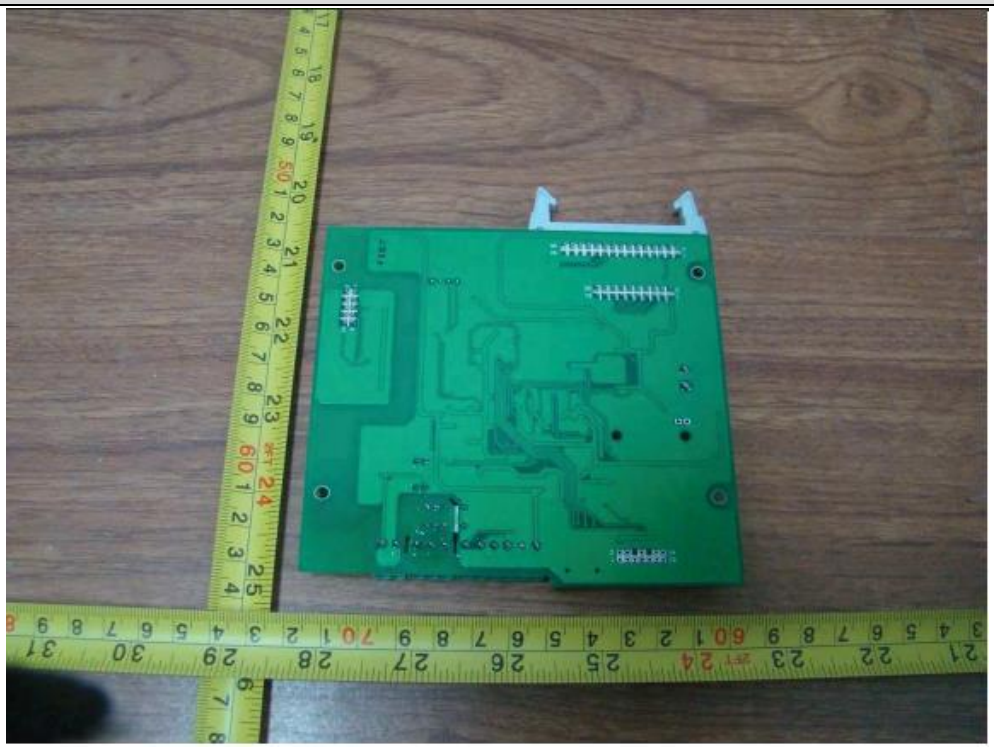


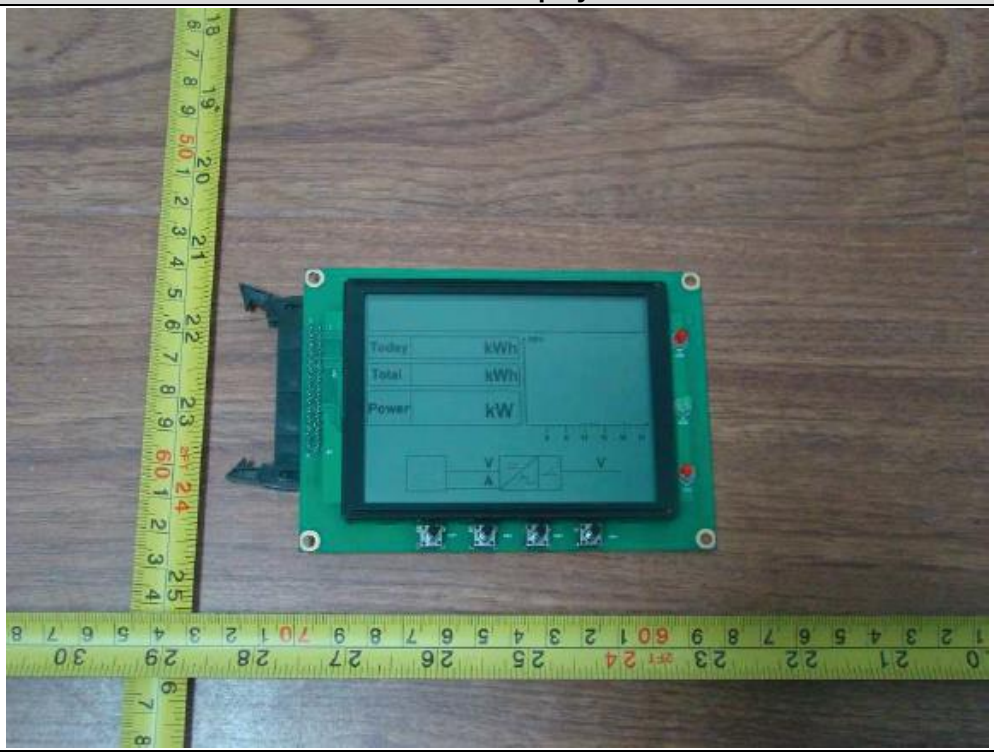
Internal View - 4

Front view of Main board

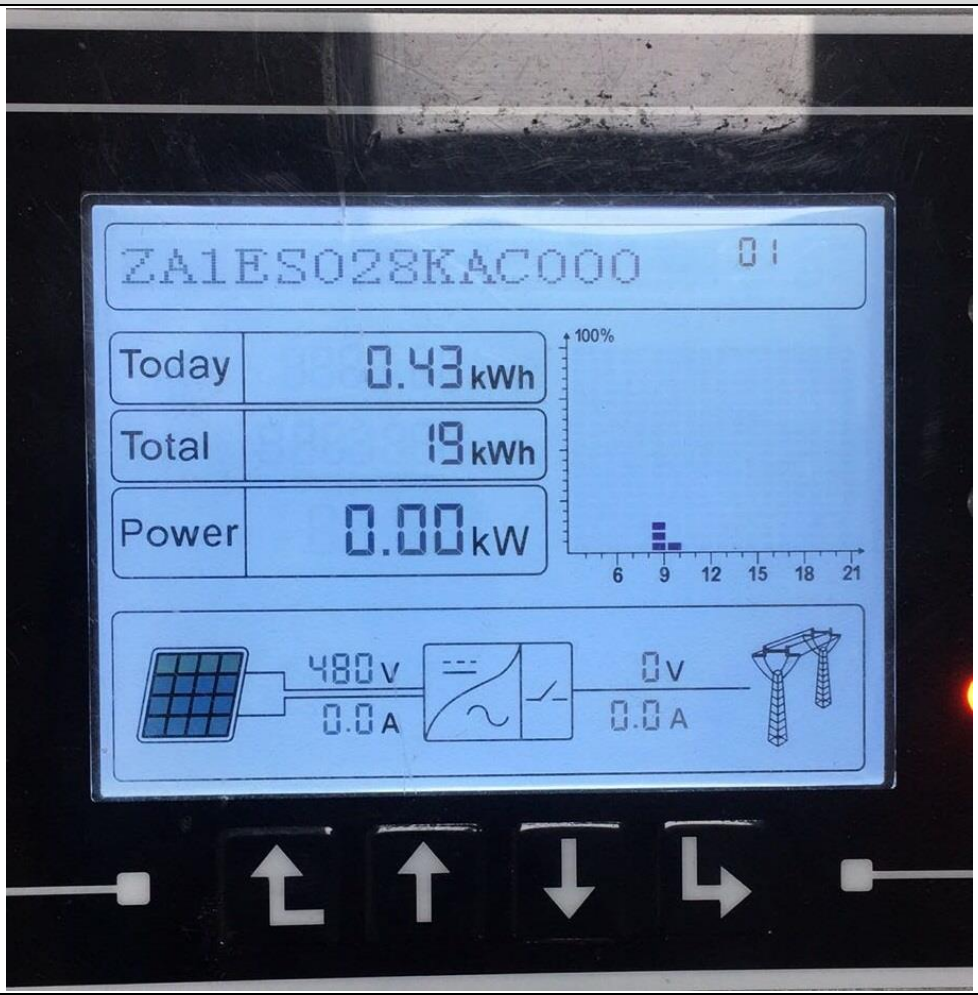

Solder side view of Main board


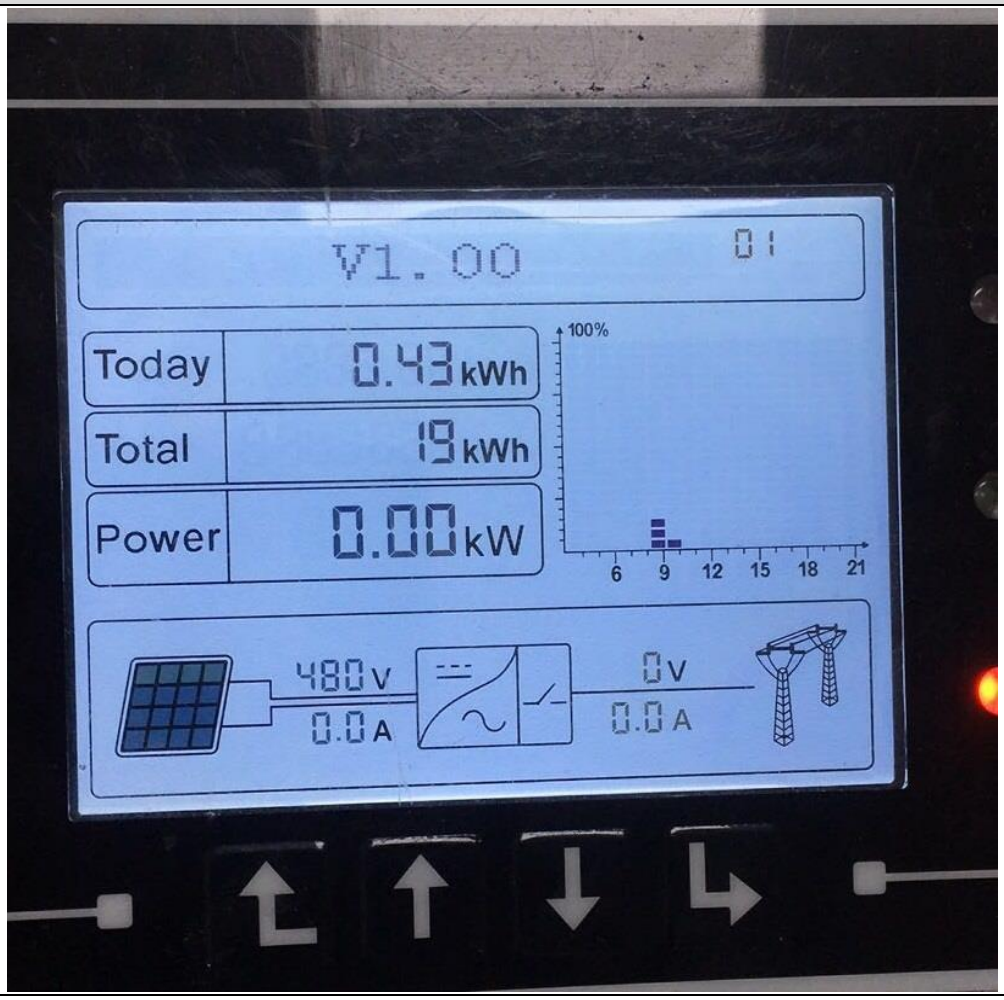
Front view of Control board


Solder side view of Control board


Front view of Display board


Rear view of Display board

Serial Number


Software Version


6. ELECTRICAL SCHEMES