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

(REQUIREMENTS FOR PLANTS TYPE A)

Procedure: PE.T-LE-62

Test Report Number ..... :	**2221/0055-1**
Type ..... :	AC Coupled Storage Converter
Tested Model ..... :	**ME 3000SP**
Trade Mark ..... :	
Variant Models ..... :	N/A

APPLICANT

Name ..... :	SGS Tecnos, S.A. (Certification Body)
Address ..... :	C/ Trespaderne, 29 - Edificio Barajas 1 28042 Madrid (Spain)

HIRED BY

Name ..... :	**Ningbo Deye Inverter Technology Co., Ltd.**
Address ..... :	No. 26 South YongJiang Road, Daqi, Beilun, NingBo, 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 ..... :	Roger Hu (Project Engineer)
Approved by ..... :	Jacobo Tévar (Technical Reviewer)
Date of issue ..... :	2021/02/25
Number of pages ..... :	114

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

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Test Report Historical Revision:

Test Report Version	Date	Resume
2221/0055-1	2021/02/25	First issuance

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1. SCOPE

SGS Tecnos, S.A. (Electrical Testing Laboratory) has been contracted by SGS Tecnos, S.A. (Certification Body) 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.

Note: The tests offered at this test report evaluate the EUT compliance with the requirements of **type A.**

2. GENERAL INFORMATION

2.1. TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed along between 20th November 2020 and 19th February 2021.

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

SITE TEST

Name .....: Shenzhen SOFARSOLAR 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 ..... : AC Coupled Storage Converter

Installation ..... : Fixed installation

Manufacturer ..... : Shenzhen SOFARSOLAR Co., Ltd.

Trade mark .....: SOFAR SOLAR

Model / Type reference ..... : ME 3000SP

Serial Number..... : ZE1ES050M21999

Software Version ..... : V2.80

Rated Characteristics..... : Battery side: 42-58Vdc, Max. Charging/Discharging Current: 60A, Max. Charging/Discharging Power: 3000VA,
AC side: 230Vac,13A, 3000VA, 50Hz

Date of manufacturing: 2020

Test item particulars

Input..... : DC

Output..... L/N/PE

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

Degree of protection against moisture..... : IP 65

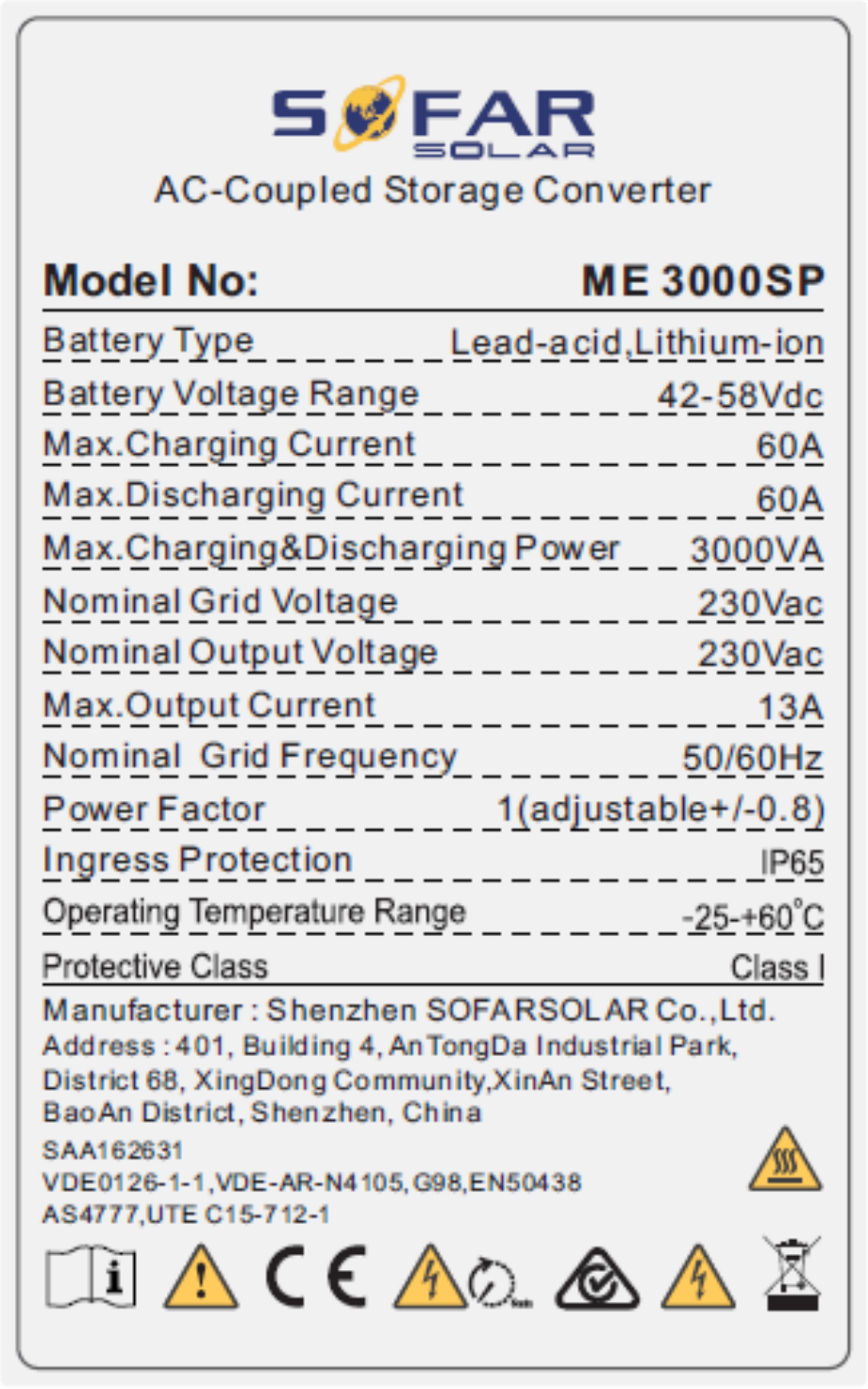
Type of connection to the main supply..... : Signal phase – Fixed installation

Cooling group..... : Heat sink

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.

Equipment under testing:

- **ME 3000SP**

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 comma ~~(point)~~ is used as the decimal separator.

2.3. FACTORY INFORMATION

Factory Name .....: **Dongguan SOFAR SOLAR Co., Ltd.**
Factory Address.....: 1F - 6F, Building E, No. 1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City, Guangdong Province,P.R. China.

2.4. REFERENCE VALUES

The values presented in the following table have been used for calculation of referenced values (p.u.; %) thougth the report.

Reference Values	
Design active power, P_D in kW	2.7
Rated apparent power, **Sn** in kVA	3
Rated wind speed (only WT), **vn** in m/s	N/A
Rated current (determined), **In** in A	13.0
Rated output voltage, (phase to phase) **Un** in Vac	230
Note: In this report p.u. values are calculated as follows: -For Active & Reactive Power p.u values are reference to**Sn** -For Currents p.u values, the reference is always **In** -For Voltages p.u values, the reference is always **Un**	

2.5. TEST EQUIPMENT LIST

From 2020/11/20 to 2021/01/05:

From	No.	Equipment Name	Model No.	Equipment No.	Calibration Date	Equipment calibration due date
Sofar Solar	1	Voltage probe	SanHua / SI-9110	152627	2020/01/14	2021/01/13
	2	Voltage probe	SanHua / SI-9110	111134	2020/01/14	2021/01/13
	3	Power analyzer	ZLG / PA3000	PA3004-P0004-1422	2020/01/14	2021/01/13
	4	Current probe	CYBERTEK / CP1000A	C181000922	2020/01/14	2021/01/13
	5	Current probe	CYBERTEK / CP1000A	C181000925	2020/01/14	2021/01/13
	6	Temperature & Humidity meter	Anymeters / TH101B	ZB-WSDJ-001	2020/01/14	2021/01/13
	7	Oscilloscope	Agicent / DS05014A	MY50070266	2020/01/14	2021/01/13
SGS	8	True RMS Multimeter	Fluke / 289C	22930028 (GZE012-53)	2020/02/21	2021/02/20

From 2021/01/06 to 2021/02/19:

From	No.	Equipment Name	Model No.	Equipment No.	Calibration Date	Equipment calibration due date
Sofar Solar	1	Voltage probe	SanHua / SI-9110	111539	2021/01/05	2022/01/04
	2	Voltage probe	SanHua / SI-9110	111134	2021/01/05	2022/01/04
	3	Power analyzer	ZLG / PA3000	C8202005651809220002	2021/01/05	2022/01/04
	4	Current probe	CYBERTEK / CP1000A	C181000922	2021/01/05	2022/01/04
	5	Current probe	CYBERTEK / CP1000A	C181000929	2021/01/05	2022/01/04
	6	Temperature & Humidity meter	Anymeters / HTC-1	WSDJ-007	2020/12/28	2021/12/28
	7	Oscilloscope	Keysight / DS0X3014T	MY59243036	2021/01/05	2022/01/04
SGS	8	True RMS Multimeter	Fluke / 289C	22930028 (GZE012-53)	2020/02/21	2021/02/20

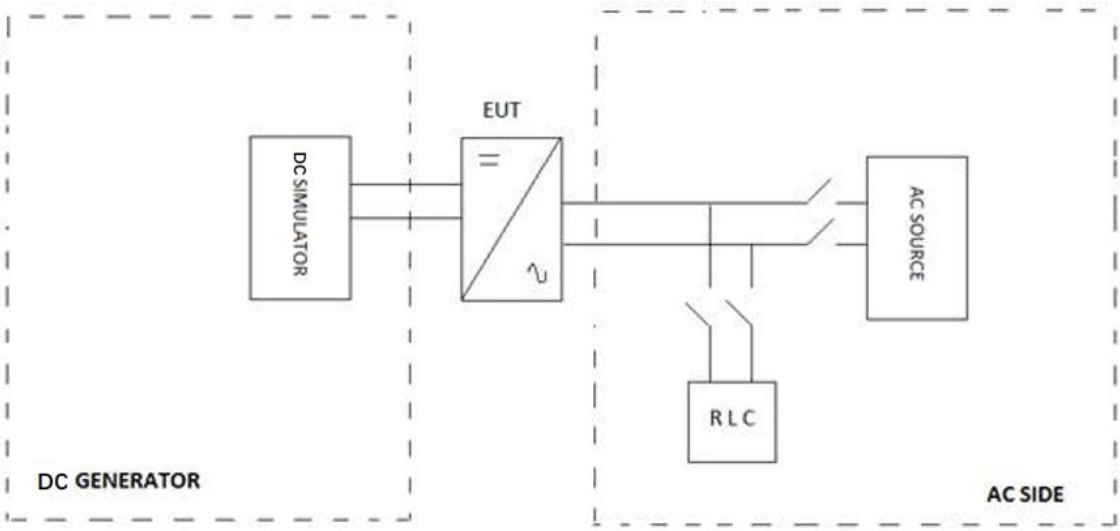
2.6. MEASUREMENT UNCERTAINTY

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.	

2.7. TEST SET UP OF THE DIFFERENT STANDARD

Below is the simplified construction of the test set up.



Different equipments have been used to take measures as shown 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	Keysight / N8957APV	60kVA max. 45-65Hz	Sofar Solar / DE17202422
DC source	Chroma / 61860	60kVA max.	Sofar Solar / 6186038000446

2.8. 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 A 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	N/A (1)
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	N/A (1)
4.5	4.8	EMC and power quality	≥A	N/R (1)
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	N/A (1)
4.9	4.13 & 4.3	Requirements regarding single fault tolerance of interface protection system and interface switch	≥A	N/R (1)

(1) See the corresponding report section for further details.

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 is as follows:

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

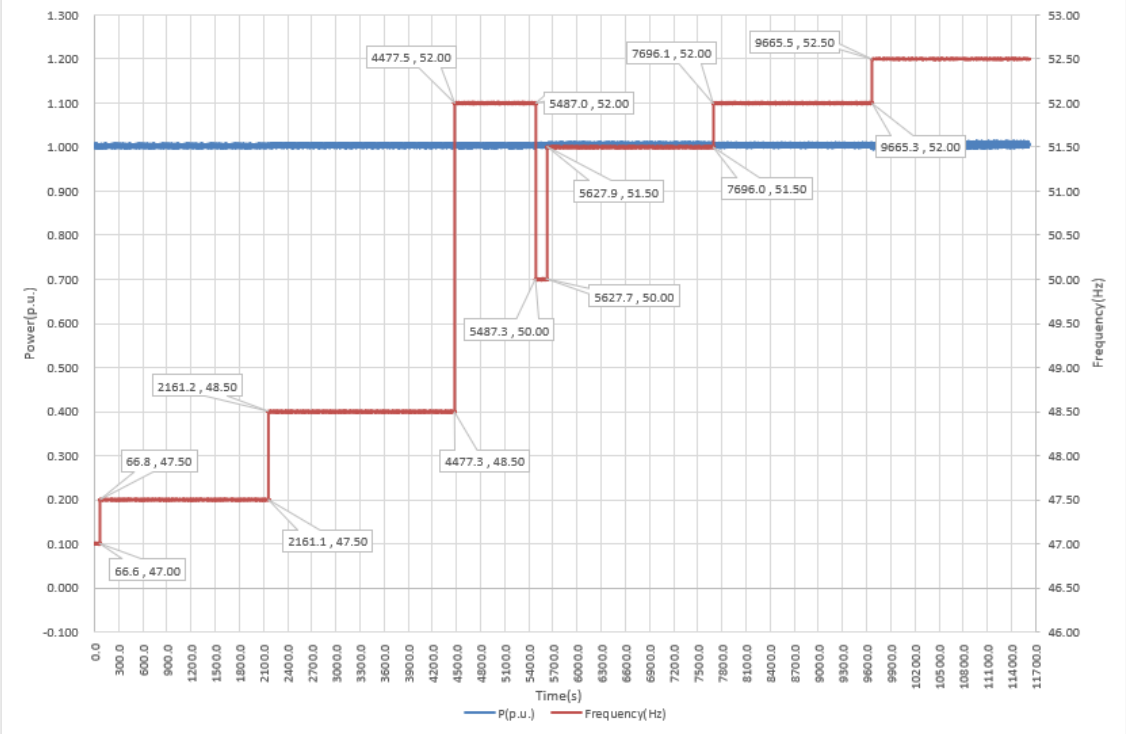
Frequency Range	Time period for operation Minimum requirement	Time period for operation stringent requirement
47,0 Hz – 47,5 Hz	not required	20 s
47,5 Hz – 48,5 Hz	30 min [a]	90 min
48,5 Hz – 49,0 Hz	30 min [a]	90 min [a]
49,0 Hz – 51,0 Hz	Unlimited	Unlimited
51,0 Hz – 51,5 Hz	30 min [a]	90 min
51,5 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 "minimum requirement" according to Table 1 of the standard:

Steps	f (Hz) setting	Time requirement	f Measured (Hz)	Time measured (min)	Power measured (p.u.)
1	47	> 30 s	47.00	1.1	1.003
2	47.5	> 30 min	47.50	34.9	1.003
3	48.5	> 30 min	48.50	38.6	1.004
4	52	> 15 min	52.00	16.8	1.004
5	50	> 1 min	50.00	2.3	1.004
6	51.5	> 30 min	51.50	34.5	1.005
7	52	> 30 min	52.00	32.8	1.005
8	52.5	> 30 min	52.50	32.5	1.004

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 is as follows:

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.

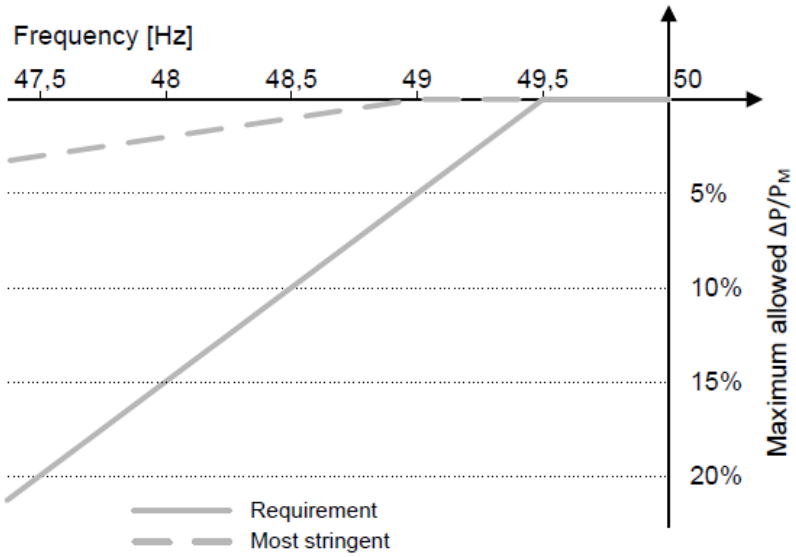


Figure 5 — Maximum allowable power reduction in case of underfrequency

In order to verify this function, parameter settings as in the following table have been considered to perform the test

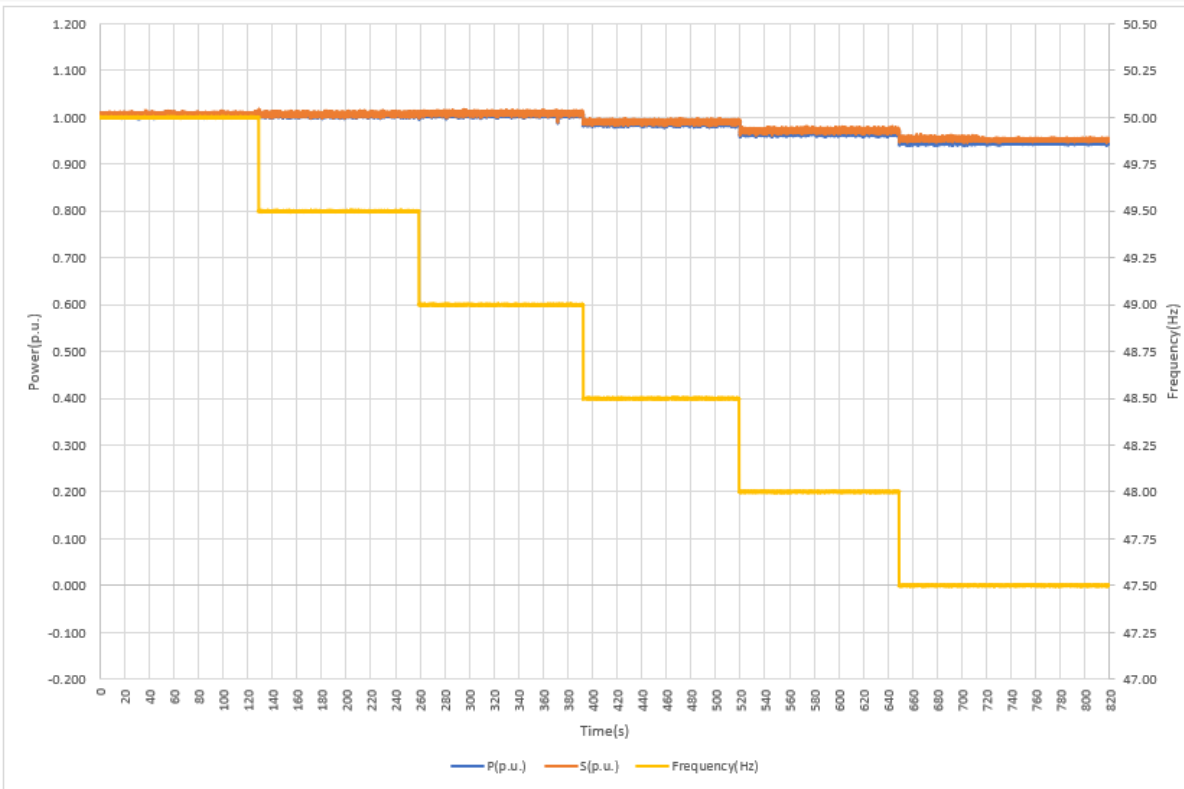
Test No.	Parameter	Value
Test 1	Frequency threshold	49.0 Hz
	Slope	2%/Hz
	T	>30 seconds
Test 2	Frequency threshold	49.5 Hz
	Slope	10%/Hz
	T	>30 min

Test results are presented in the following table and graphs:

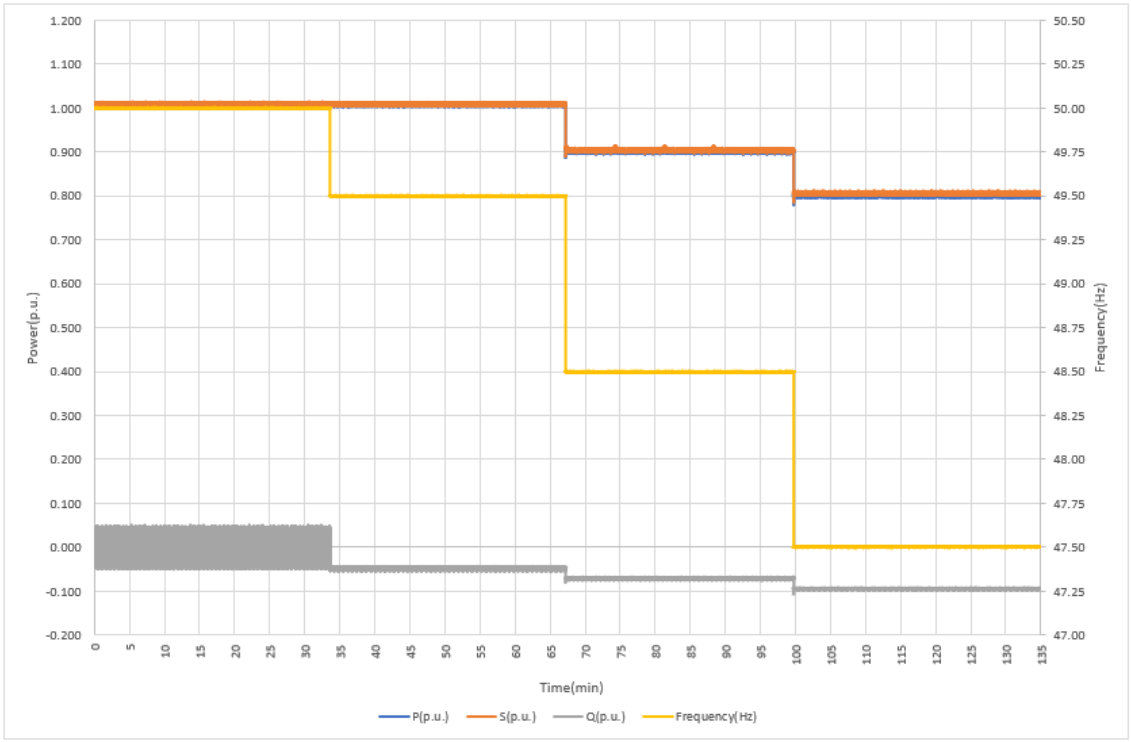
Test 1						
Step	f (Hz)	f Meas. (Hz)	T (s)	P desired (p.u.)	P Meas. (p.u.)	P deviation (p.u.)
1	50.00 ± 0.05	50.00	>30	1.000	1.005	0.005
2	49.50 ± 0.05	50.00	>30	1.000	1.006	0.006
3	49.00 ± 0.05	50.00	>30	1.000	1.006	0.006
4	48.50 ± 0.05	50.00	>30	0.980	0.987	0.007
5	48.00 ± 0.05	50.00	>30	0.960	0.967	0.007
6	47.50 ± 0.05	50.00	>30	0.940	0.947	0.007

Test 2						
Step	f (Hz)	f Meas. (Hz)	T (min)	P desired (p.u.)	P Meas. (p.u.)	P deviation (p.u.)
1	50.00 ± 0.05	50.00	>30	1.000	1.007	0.007
2	49.50 ± 0.05	50.00	>30	1.000	1.008	0.008
3	48.50 ± 0.05	50.00	>30	0.900	0.901	0.001
4	47.50 ± 0.05	50.00	>30	0.800	0.801	0.001

Test 1



Test 2


1.200
1.100
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
-0.100
-0.200
Power(p.u.)
50.50
50.25
50.00
49.75
49.50
49.25
49.00
48.75
48.50
48.25
48.00
47.75
47.50
47.25
47.00
Frequency(Hz)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135
Time(min)
P(p.u.)
S(p.u.)
Q(p.u.)
Frequency(Hz)

4.1.3. Continuous operating voltage range

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

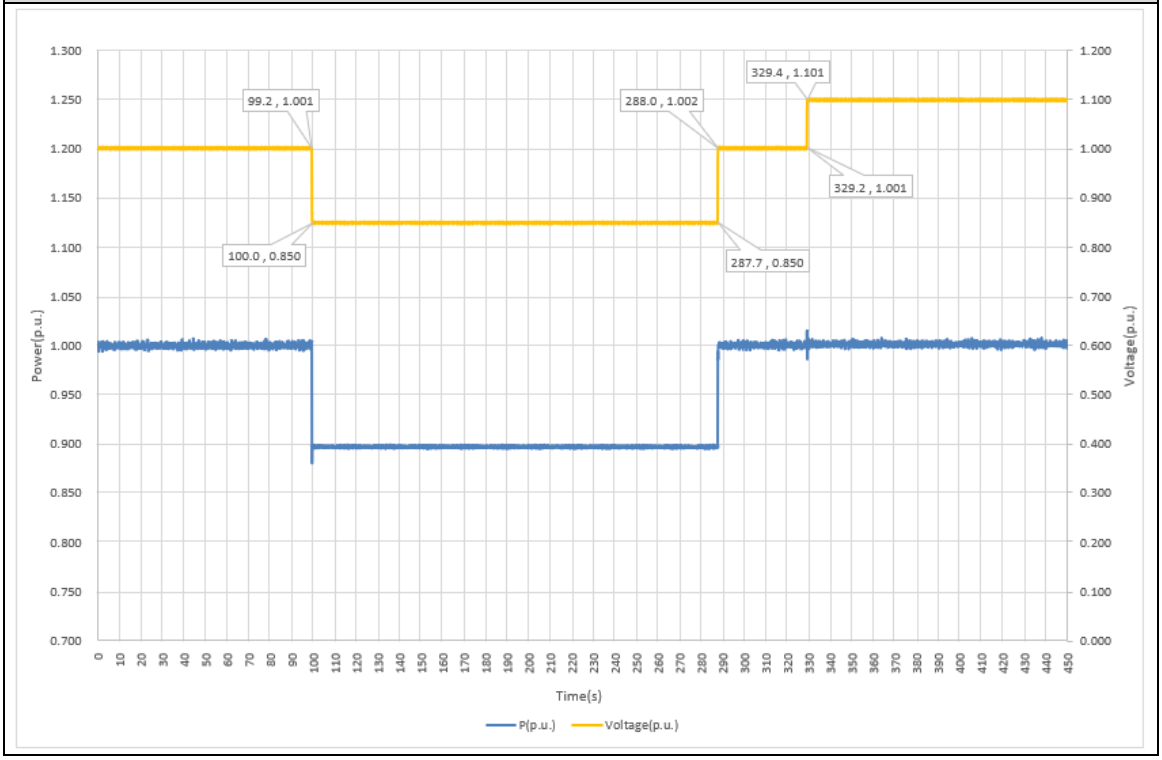
The generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85 %Un to 110 %Un.

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

Step	Voltage (p.u.)	P desired (p.u.)	Time requirement (s)	Time measured (s)	P meas. (p.u.)
1	1.00	1	> 60	99.2	1.000
2	0.85	1	> 120	187.7	0.897 (*)
3	1.00	1	> 5	41.2	1.000
4	1.10	1	> 120	120.6	1.001

(*) Active power reduction is allowed due to current limitation.

Continuous operating voltage range



4.2. IMMUNITY TO DISTURBANCES

4.2.1. Rate of change of frequency (ROCOF) immunity

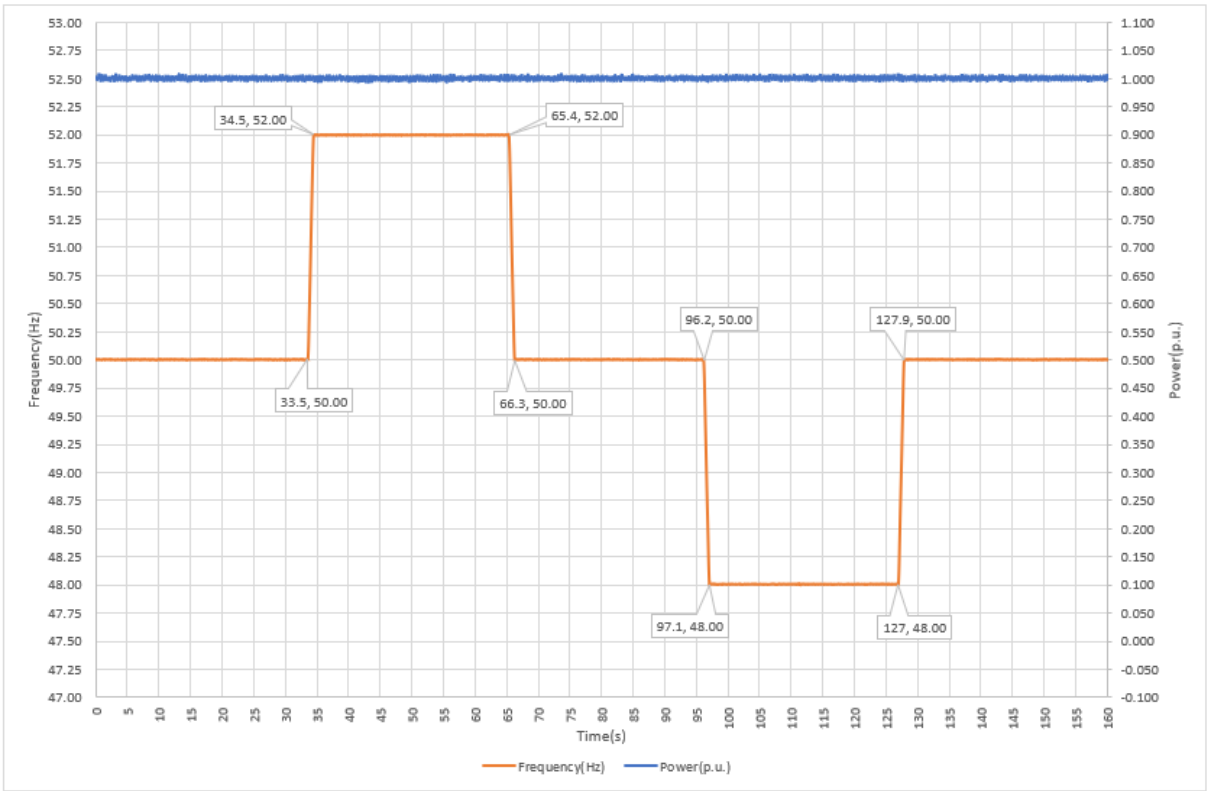
The test has been done according to the clause 4.5.2 of the standard, the requirement is as follows:

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

The ROCOF immunity is defined with a sliding measurement window of 500 ms as follows:

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	--	--	No
2	52.00 ± 0.05	>2	>10 s	52	1.0	2.00	No
3	50.00 ± 0.05	>2	>10 s	50	0.9	-2.22	No
4	48.00 ± 0.05	>2	>10 s	48	0.9	-2.22	No
5	50.00 ± 0.05	>2	>10 s	50	0.9	2.22	No

Rate of change of frequency (ROCOF) immunity



4.2.2. Under-voltage ride through (UVRT)

The requirements are defined in the clause 4.5.3 of the standard.

The EUT is classified as Type A. This test is not applicable.

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 is as follows:

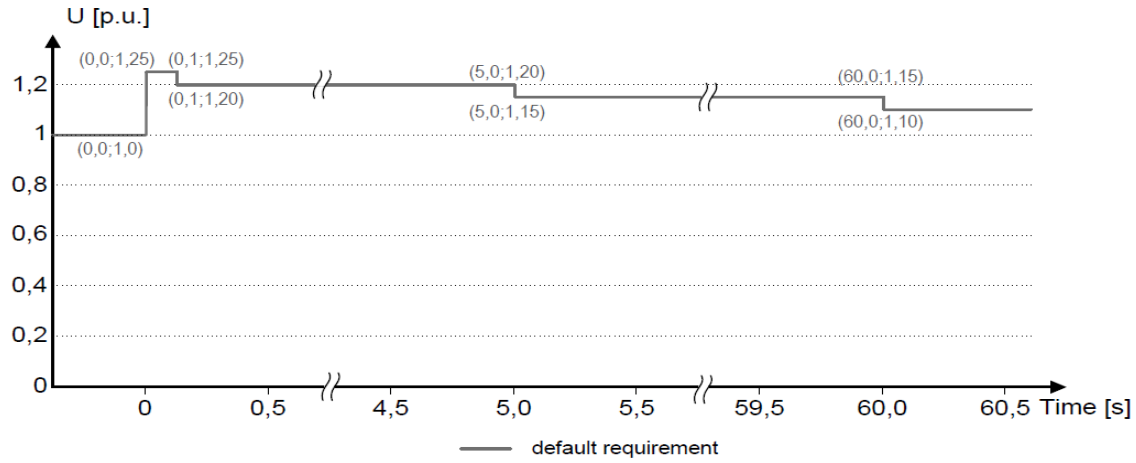


Figure 8 — Over-voltage ride through capability

4.2.3.1. No load Tests

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

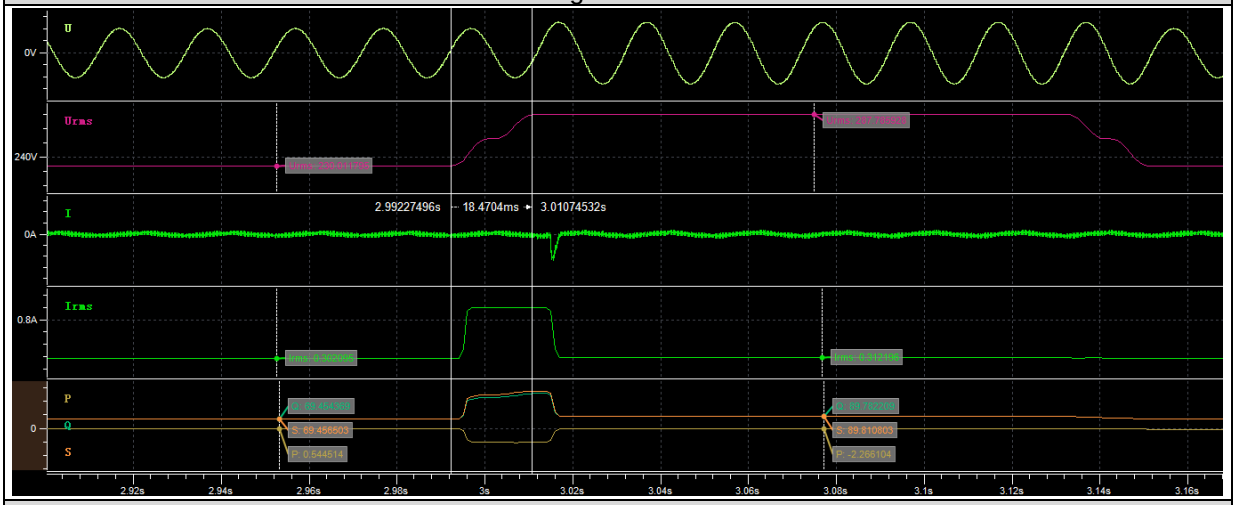
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage rise time (ms)	Residual voltage measured (%Un)	DipTime (ms)		Power recovery time (ms)	Voltage after sag (%Un)
				Desired	Meas.		
125.0	100	18	125.1	>100	123	--	100
120.0	100	17	120.1	>5000	5062	--	100
115.0	100	18	115.1	>60000	60500	--	100

Note: Test results have been evaluated using line to neutral test results.

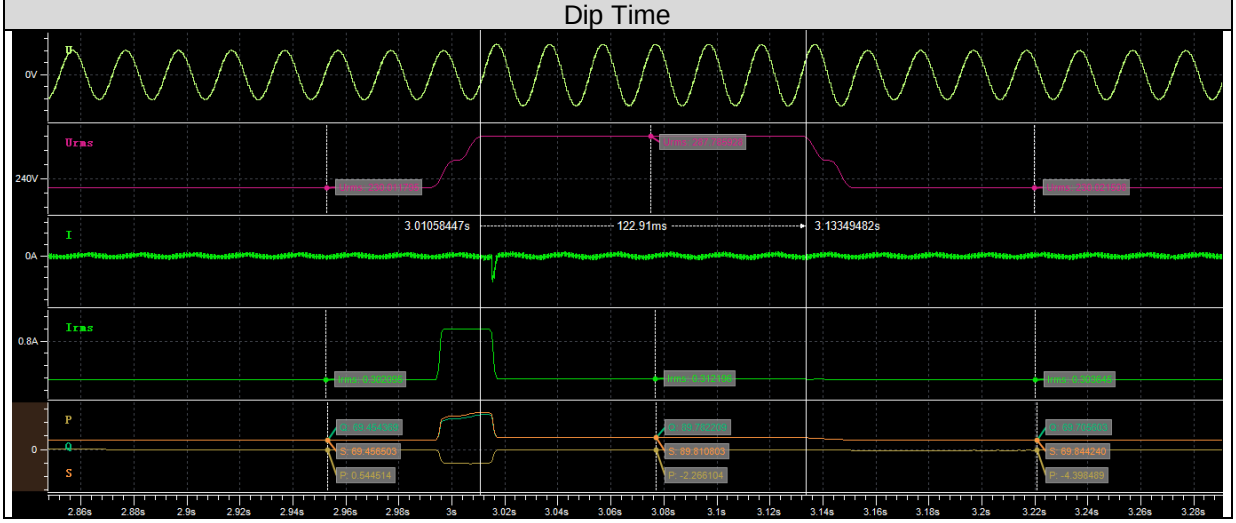
Test results are graphically represented in the following pages.

No Load	Residual voltage: 125.0 %Un

Voltage Rise Time

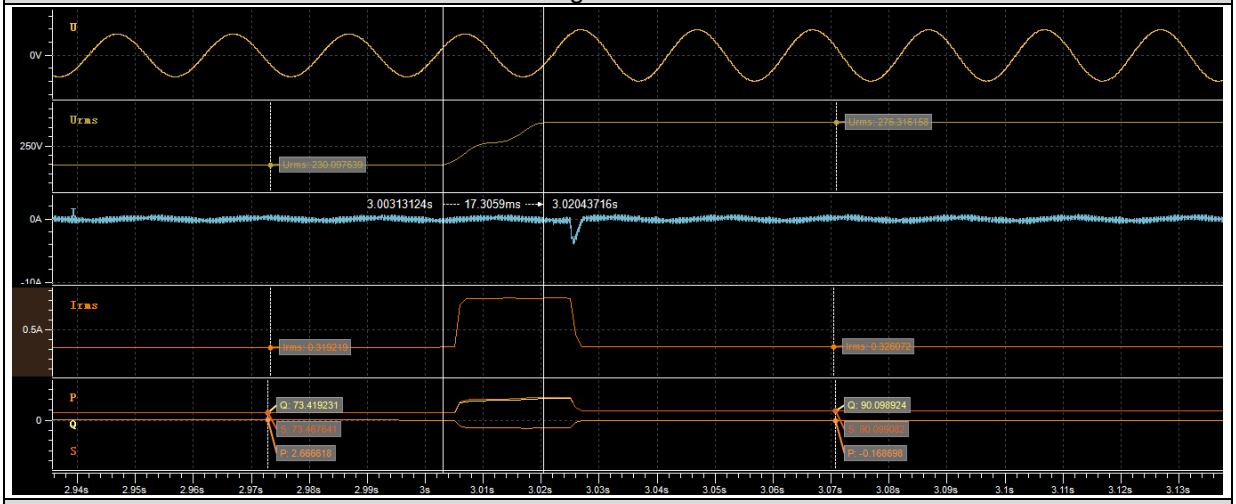


Dip Time

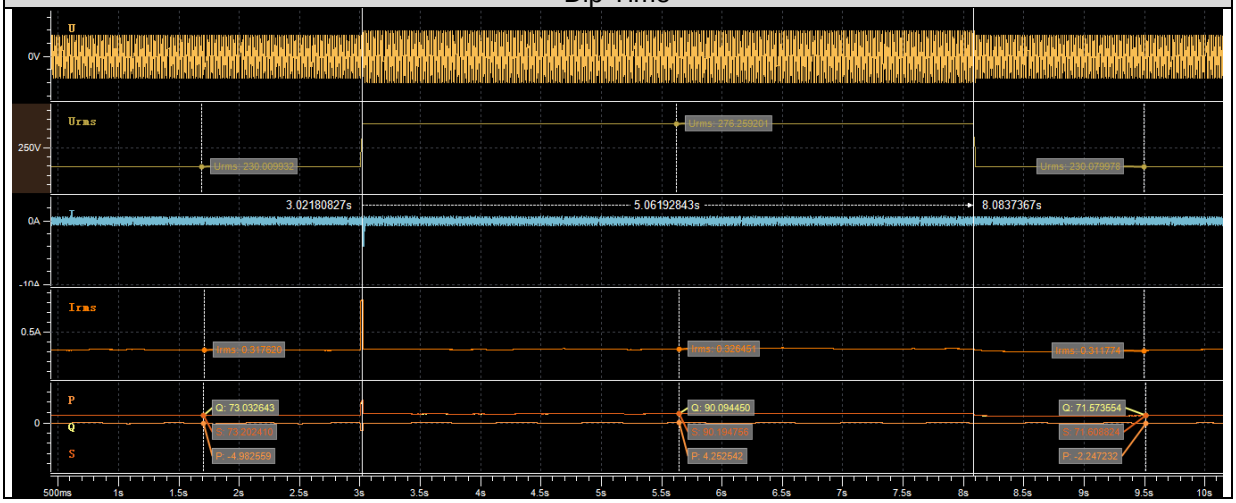


No Load	Residual voltage: 120.0 %Un

Voltage Rise Time

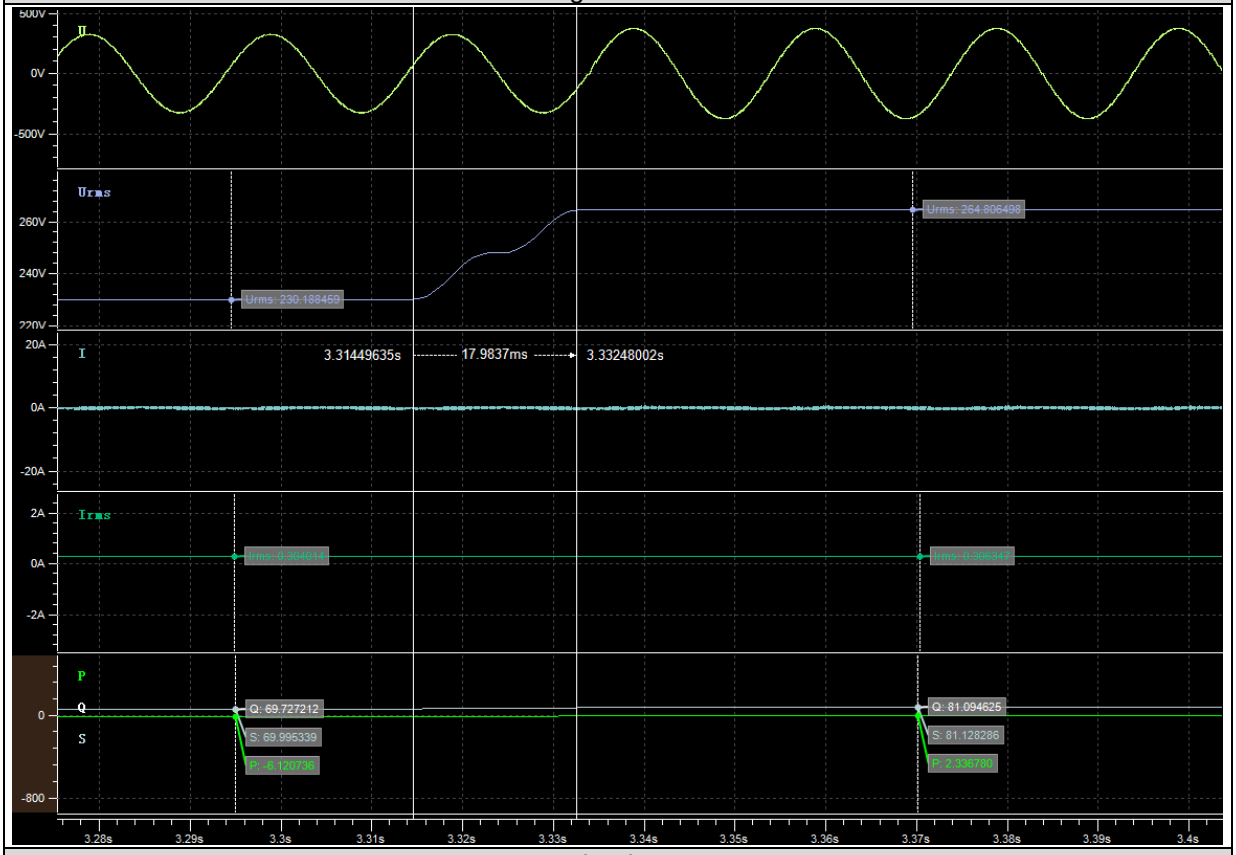


Dip Time

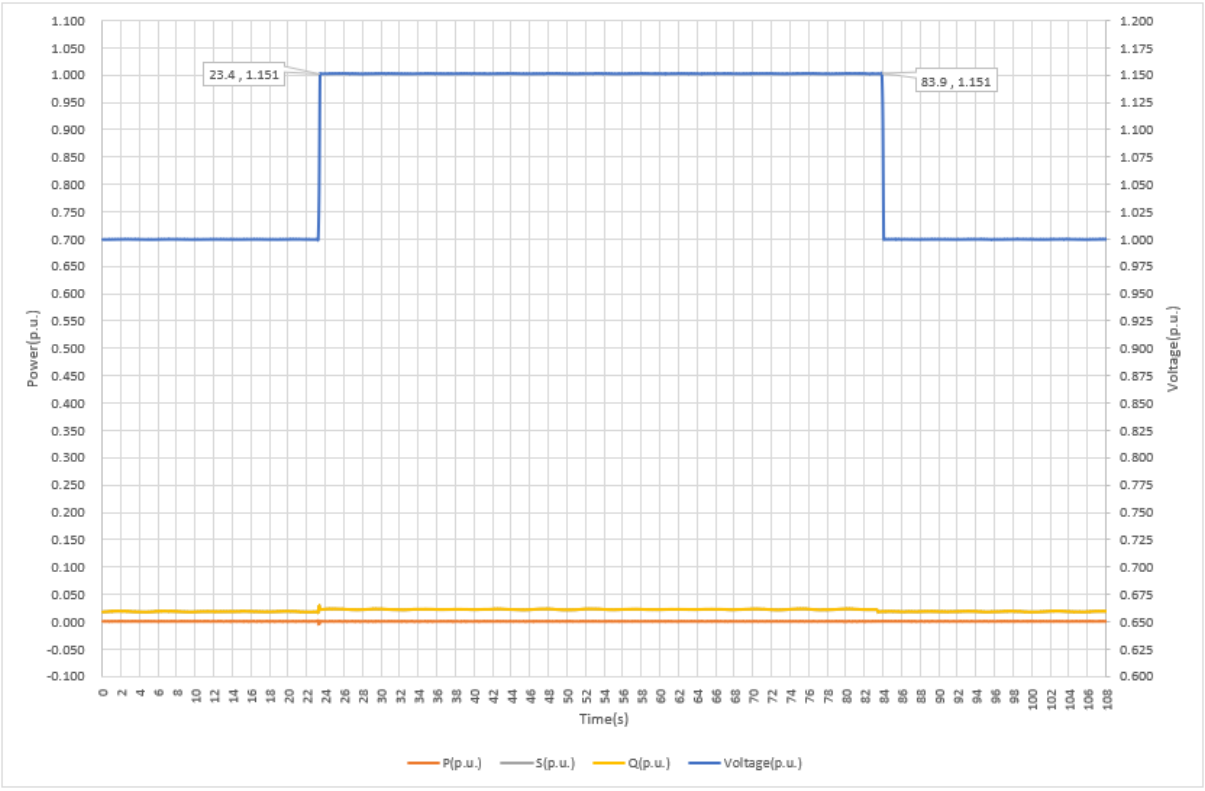


No Load	Residual voltage: 115.0 %Un

Voltage Rise Time



Dip Time



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

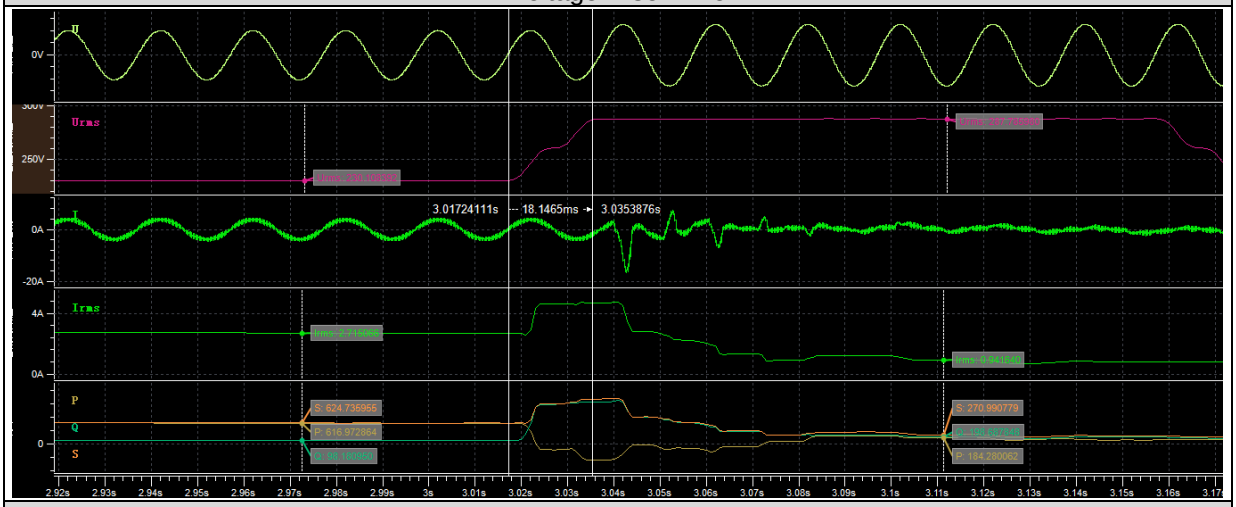
Test results of partial power cases performed are offered below:

Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage rise time (ms)	Residual voltage measured (%Un)	DipTime (ms)		Power recovery time (ms)	Voltage after sag (%Un)
				Desired	Meas.		
125.0	100	18	125.0	>100	123	72	100
120.0	100	17	120.0	>5000	5063	48	100
115.0	100	18	115.0	>60000	60100	58	100

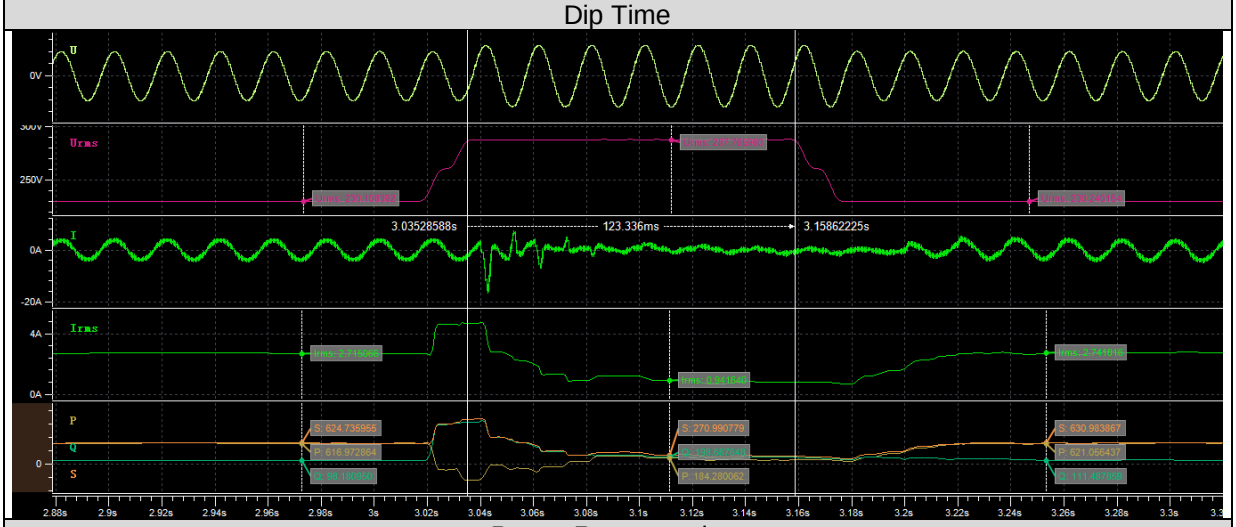
Test results are graphically represented at following pages.

Partial load (20%Pn)	Residual voltage: 125.0 %Un

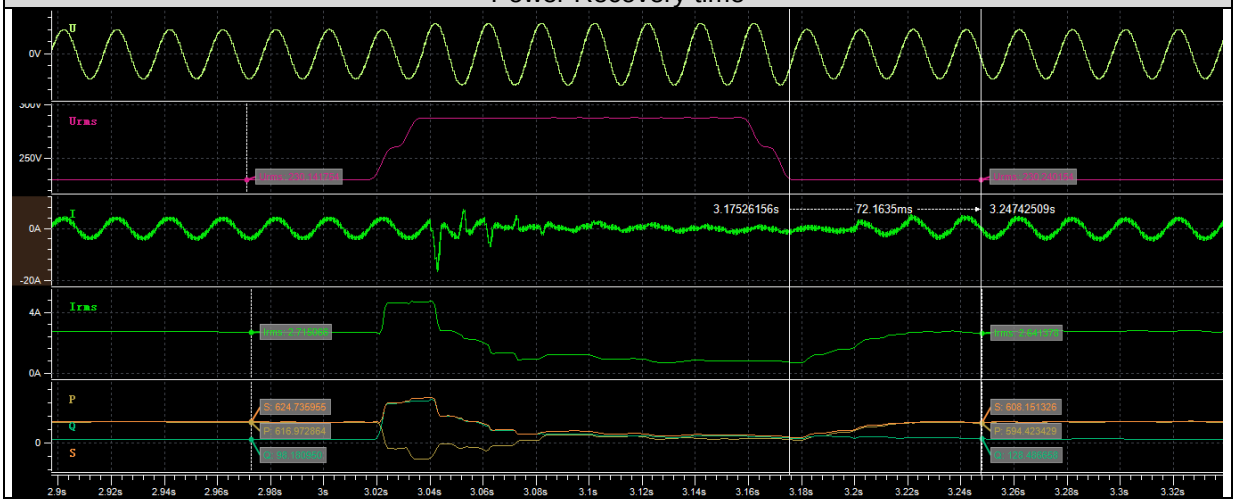
Voltage Rise Time



Dip Time

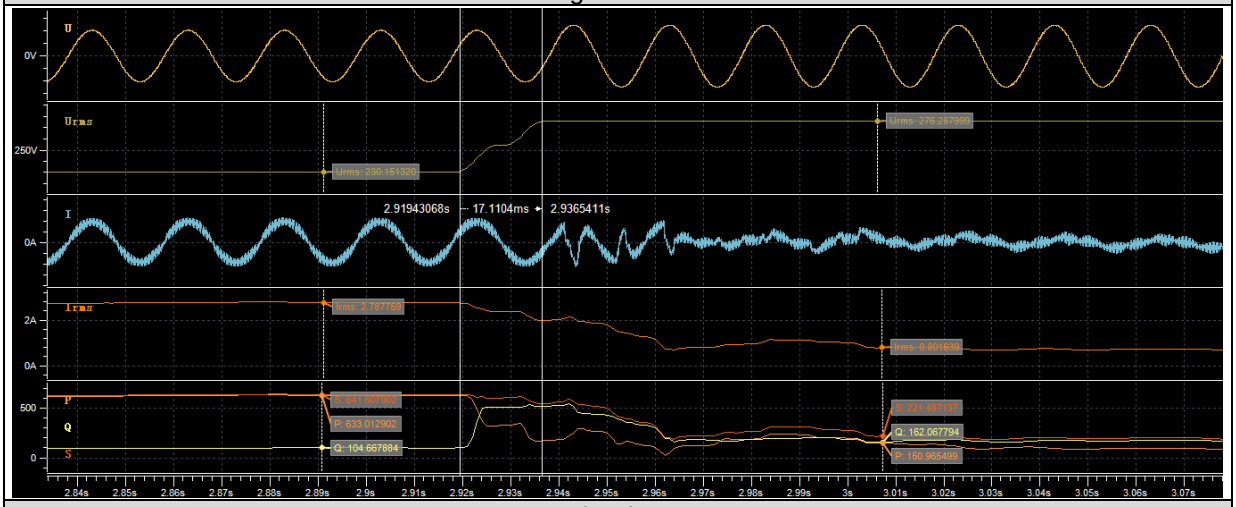


Power Recovery time

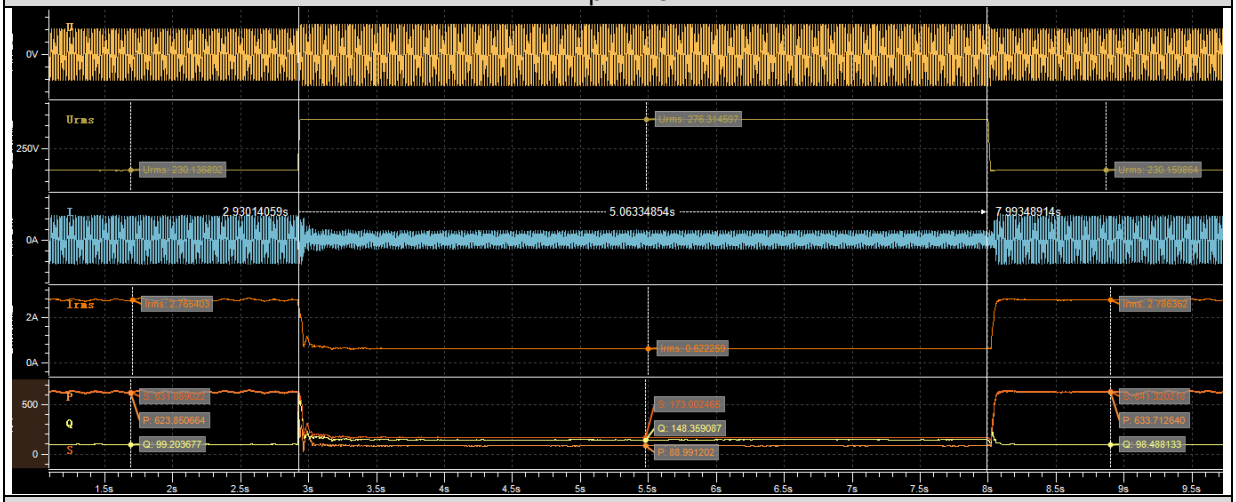


Partial load (20%Pn)	Residual voltage: 120.0 %Un

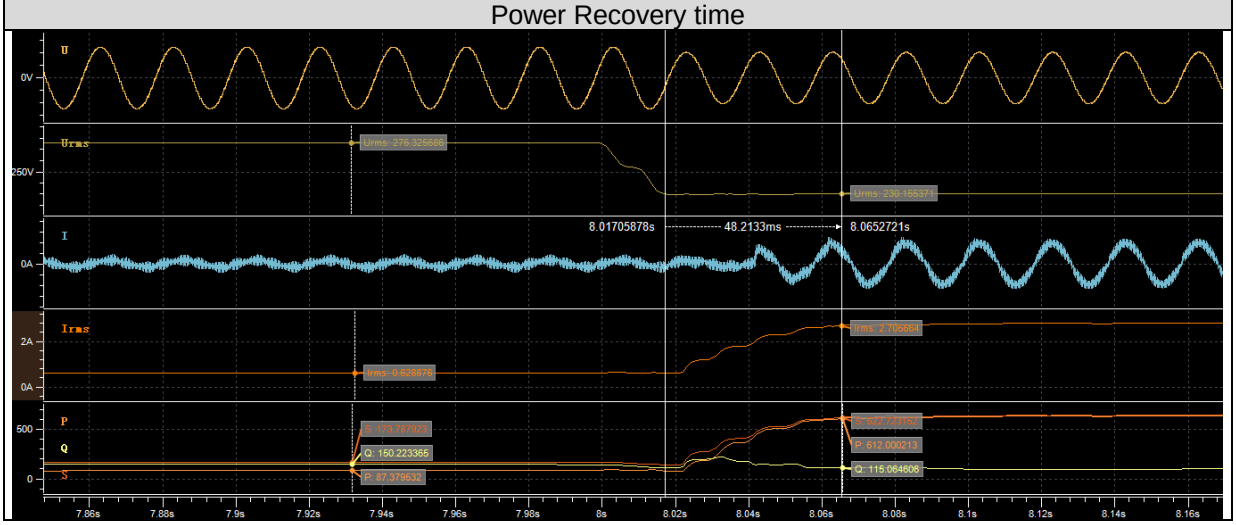
Voltage Rise Time



Dip Time

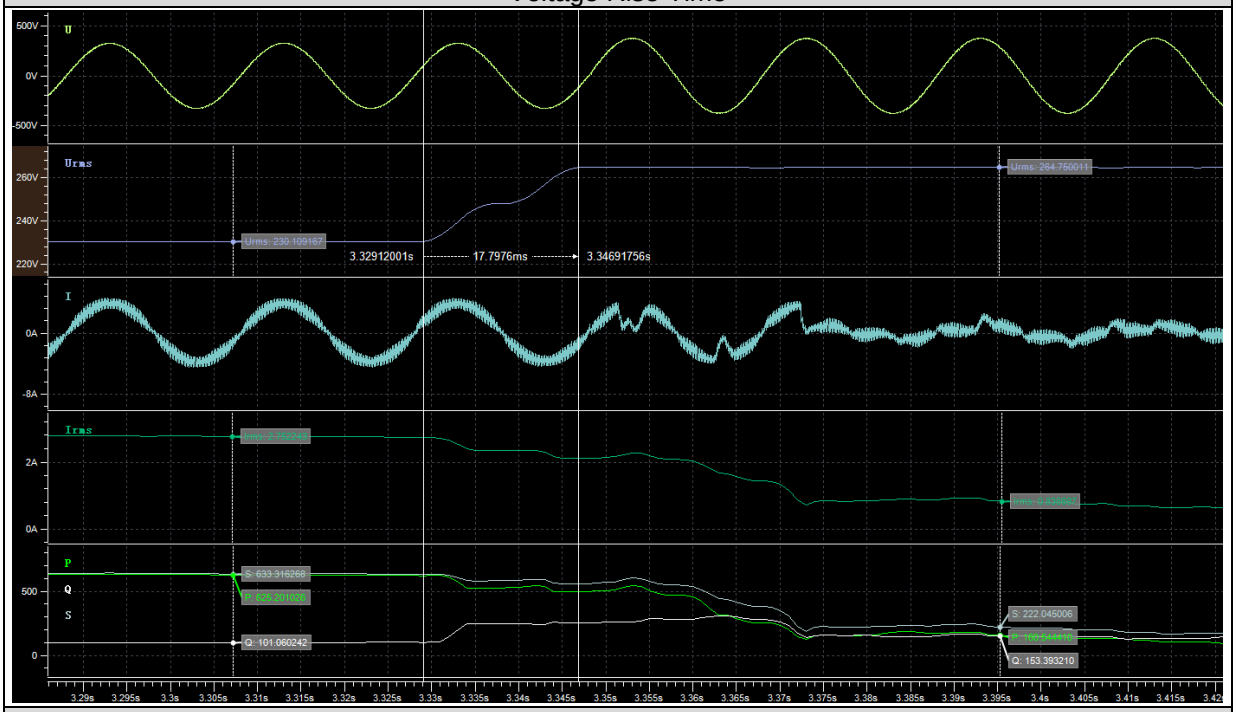


Power Recovery time

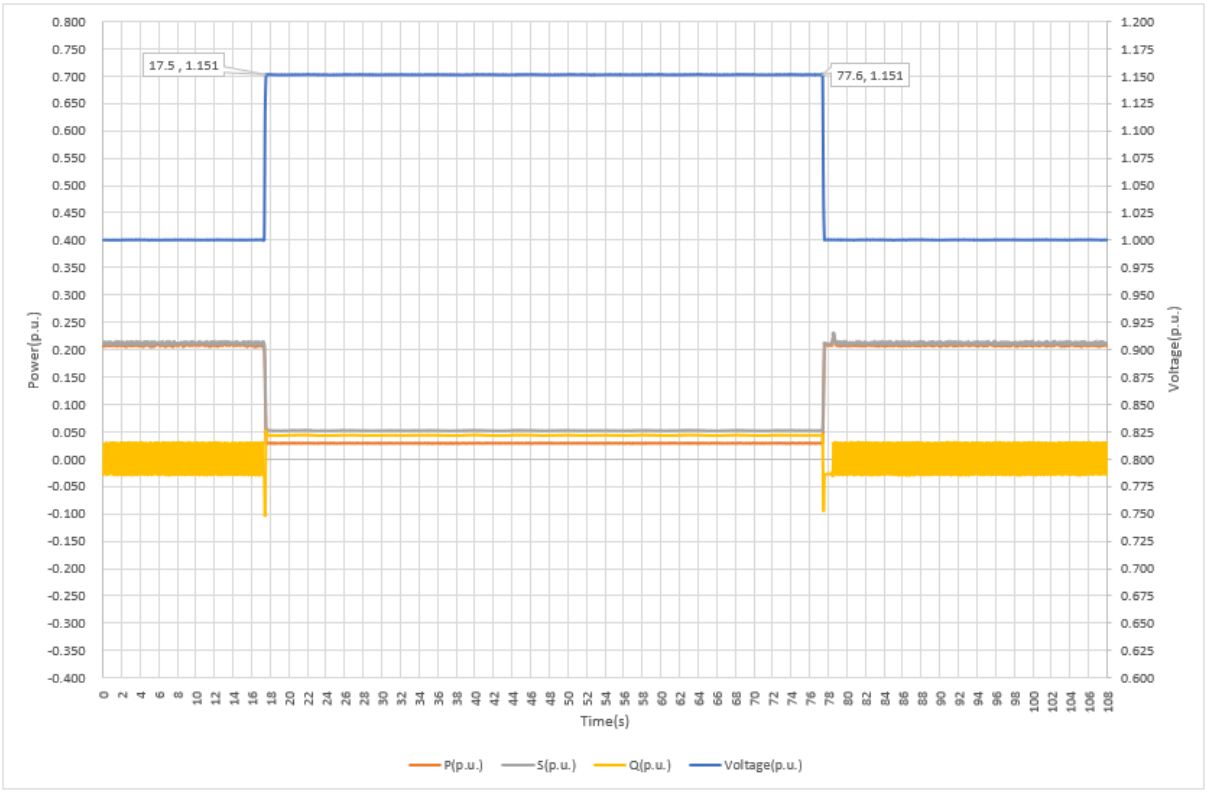


Partial load (20%Pn)	Residual voltage: 115.0 %Un

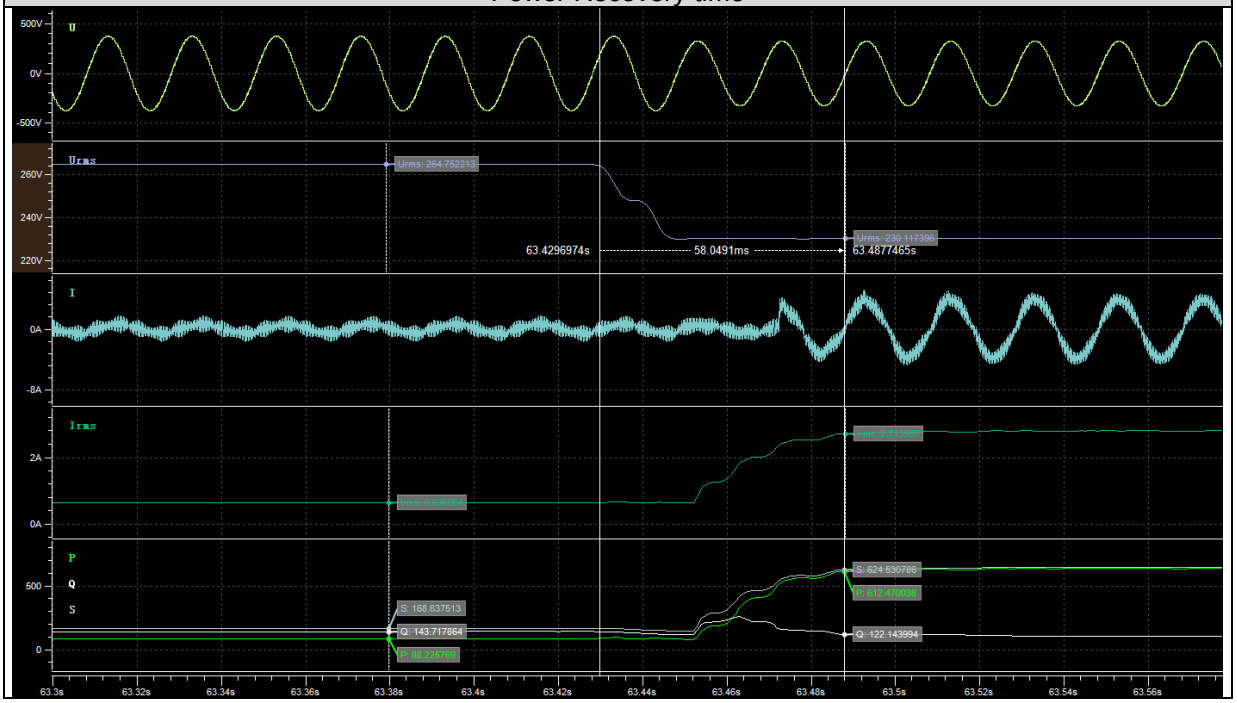
Voltage Rise Time



Dip Time



Power Recovery time



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

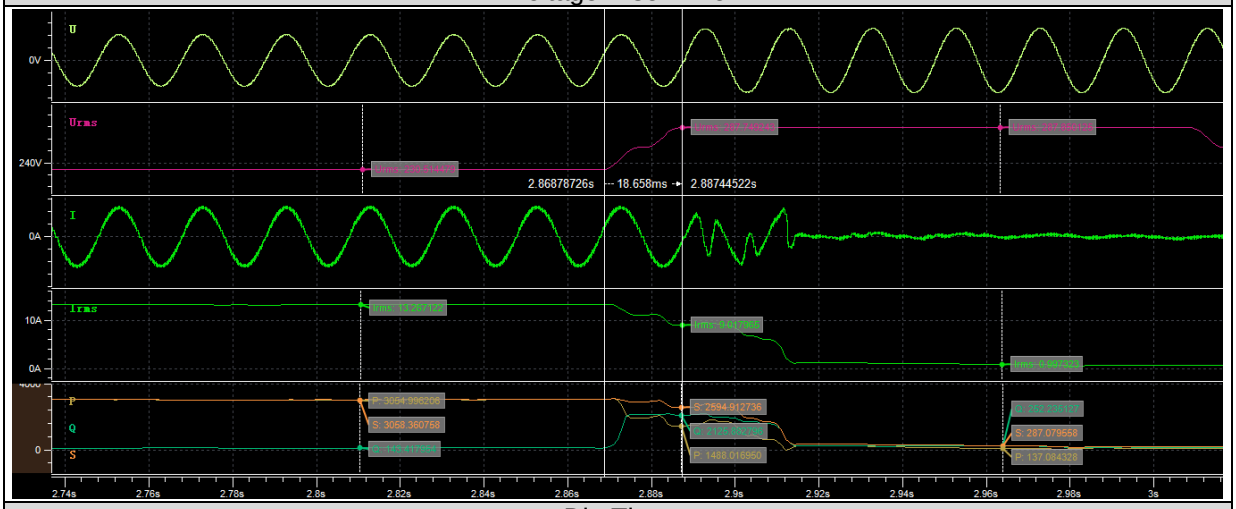
Test results of full power cases performed are offered below:

Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power recovery time (ms)	Voltage after sag (%Un)
				Desired	Meas.		
125.0	100	19	125.0	> 100	124	90	100
120.0	100	17	120.0	> 5000	5062	99	100
115.0	100	19	115.0	> 60000	60100	109	100

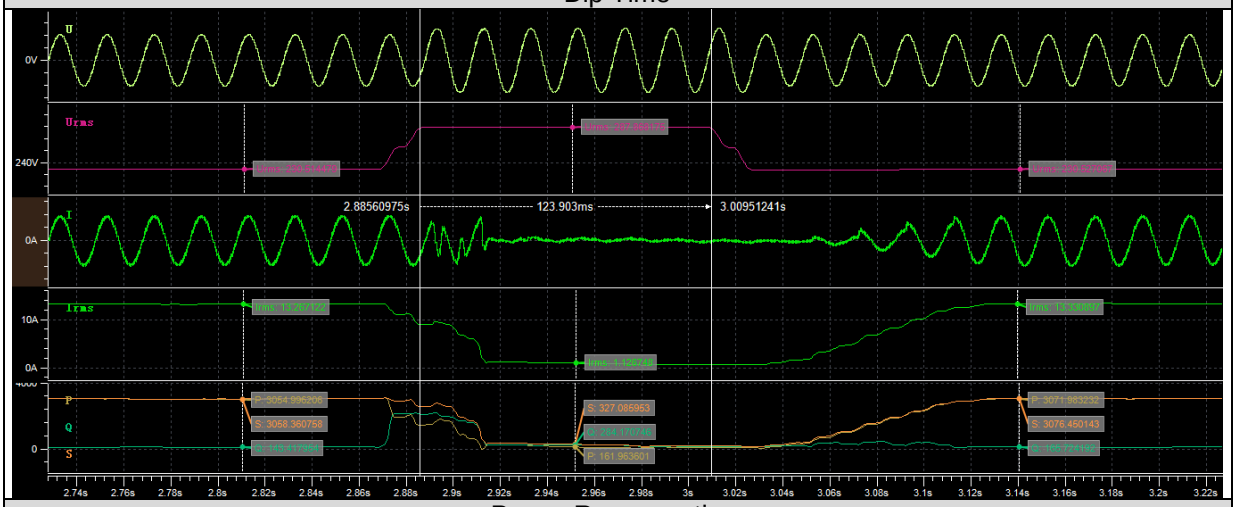
Test results are graphically represented at following pages.

Full load (100%Pn)	Residual voltage: 125.0 %Un

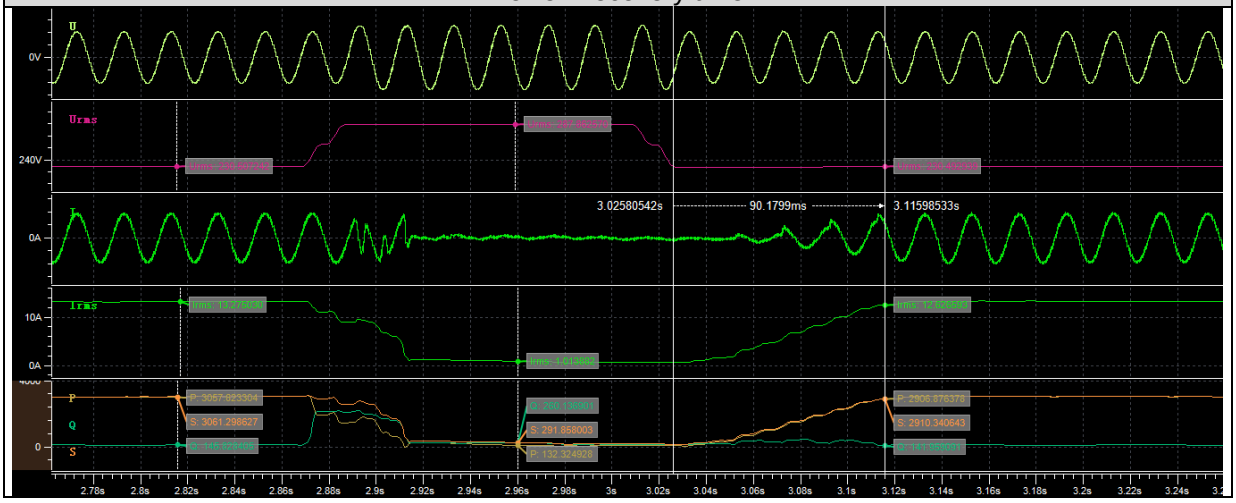
Voltage Rise Time



Dip Time

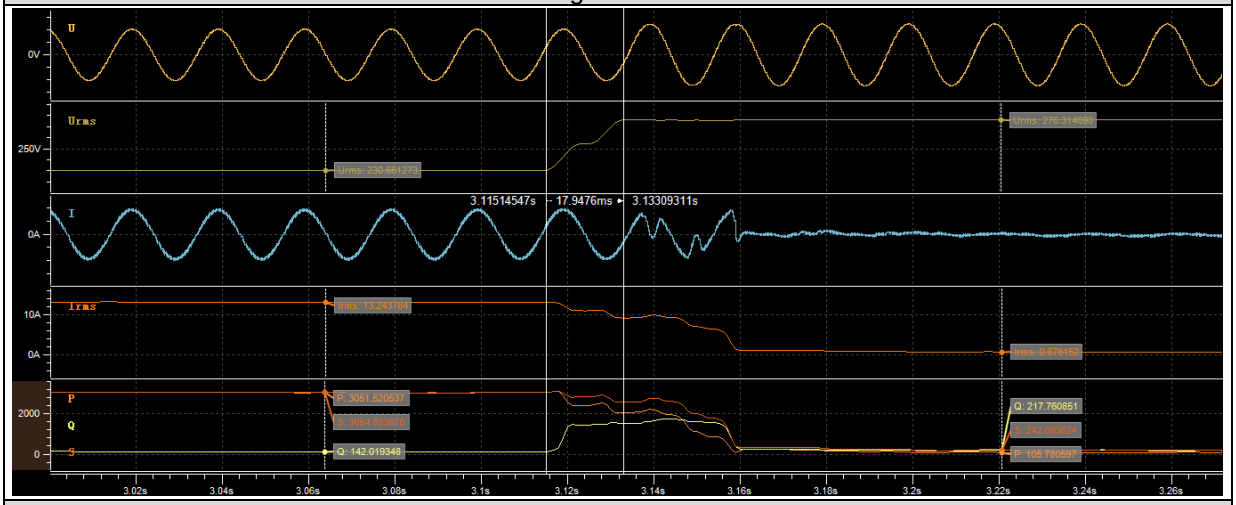


Power Recovery time

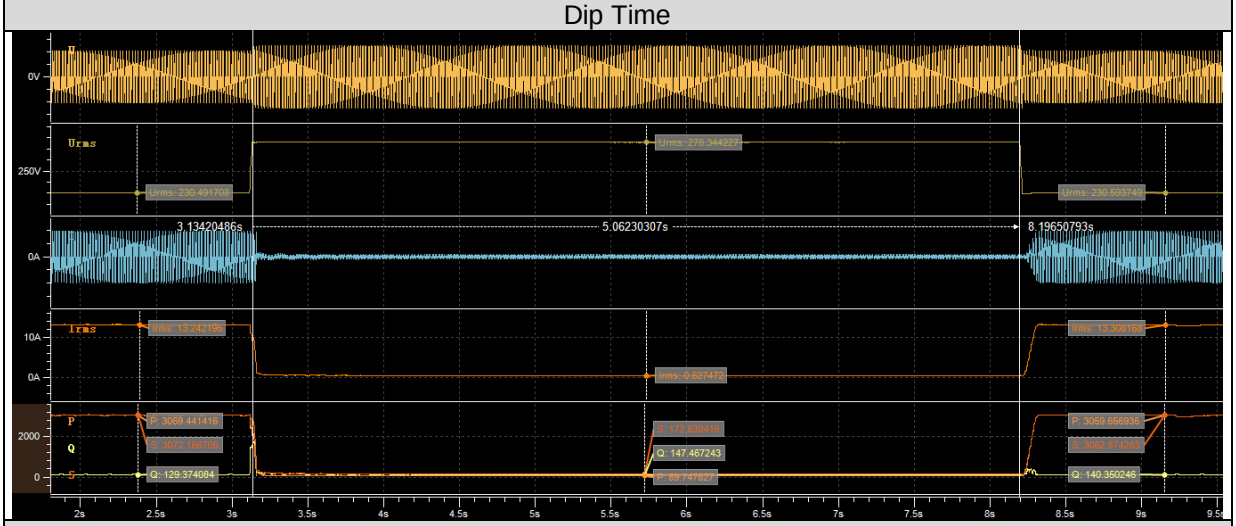


Full load (100%Pn)	Residual voltage: 120.0 %Un

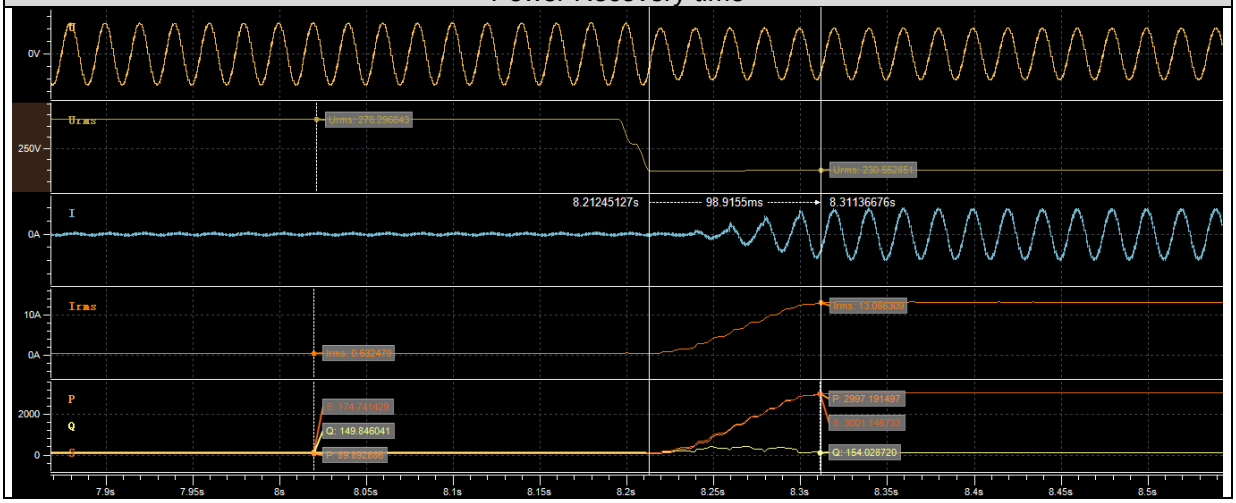
Voltage Rise Time



Dip Time

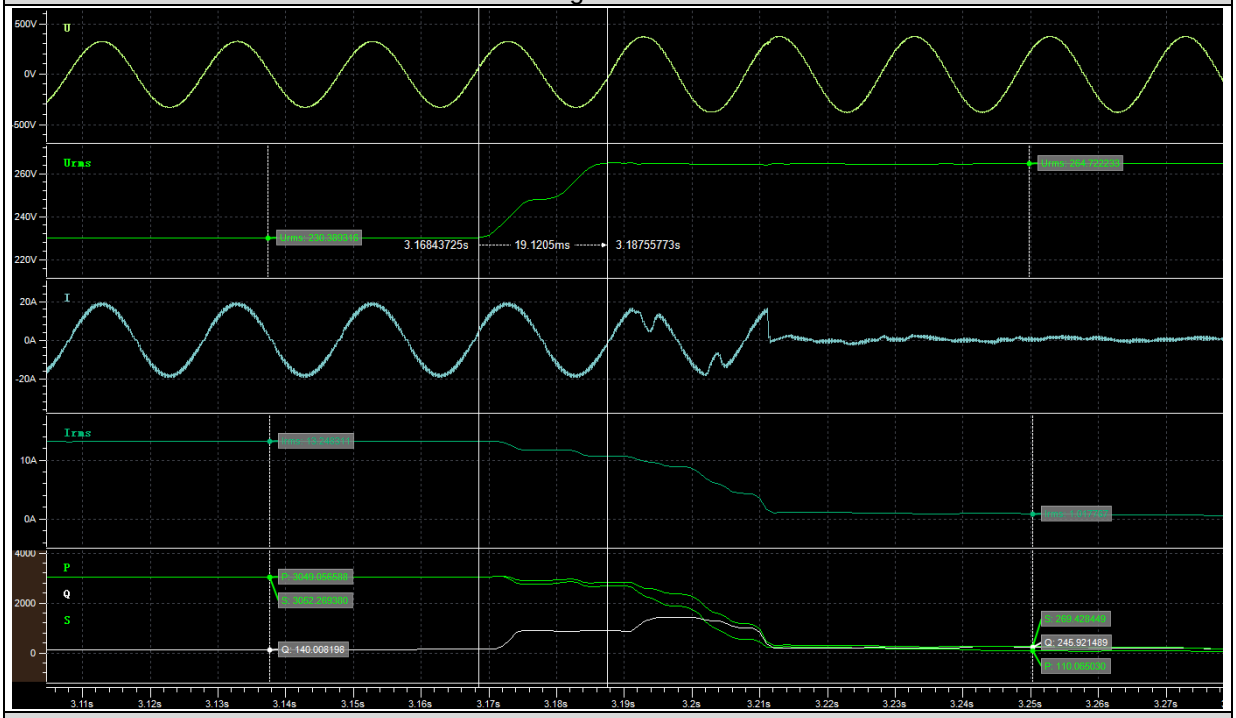


Power Recovery time

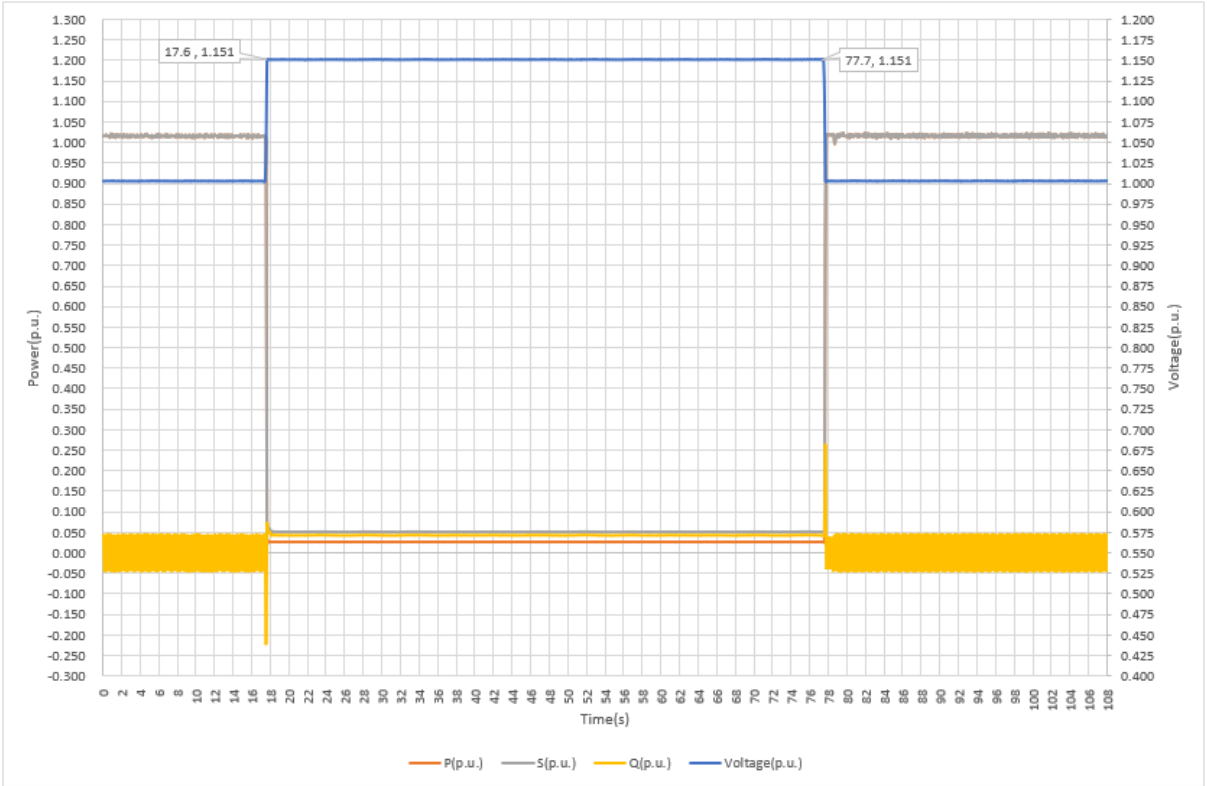


Full load (100%Pn)	Residual voltage: 115.0 %Un

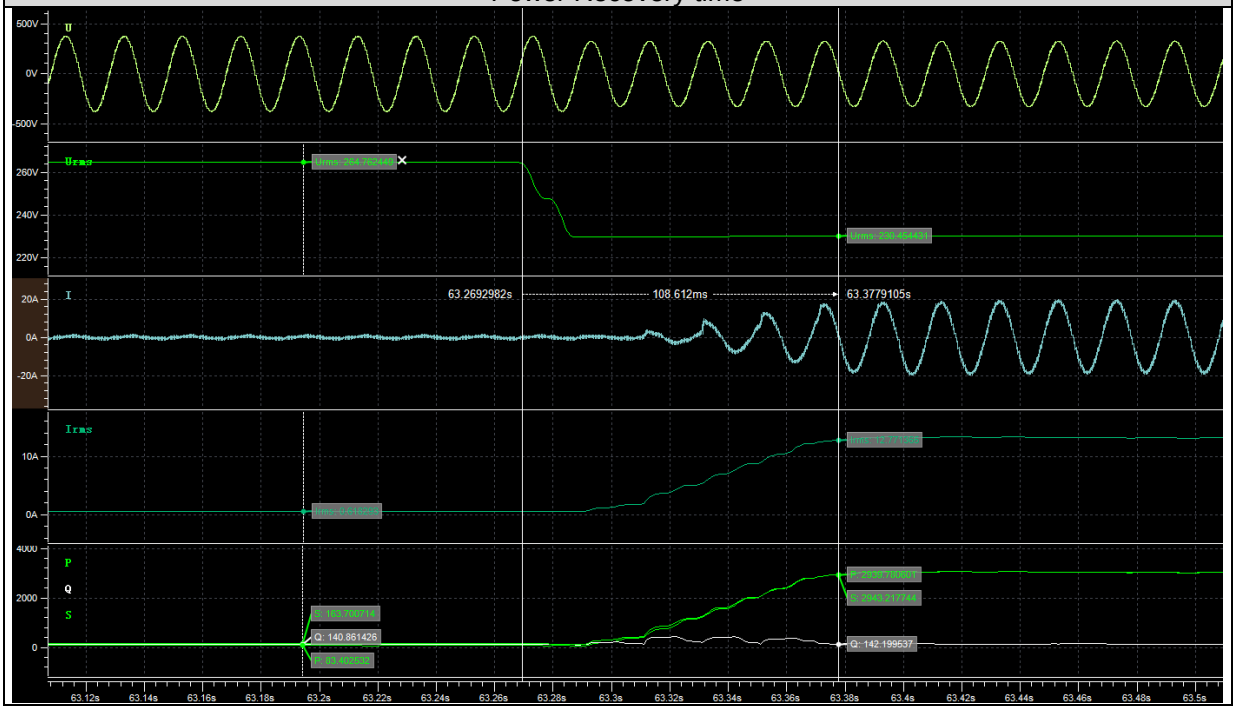
Voltage Rise Time



Dip Time



Power Recovery time



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 %Pn; f1 = 52 Hz; droop = 2 %; f-stop deactivated, no delay
- Test 3：P = 50 %Pn; 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

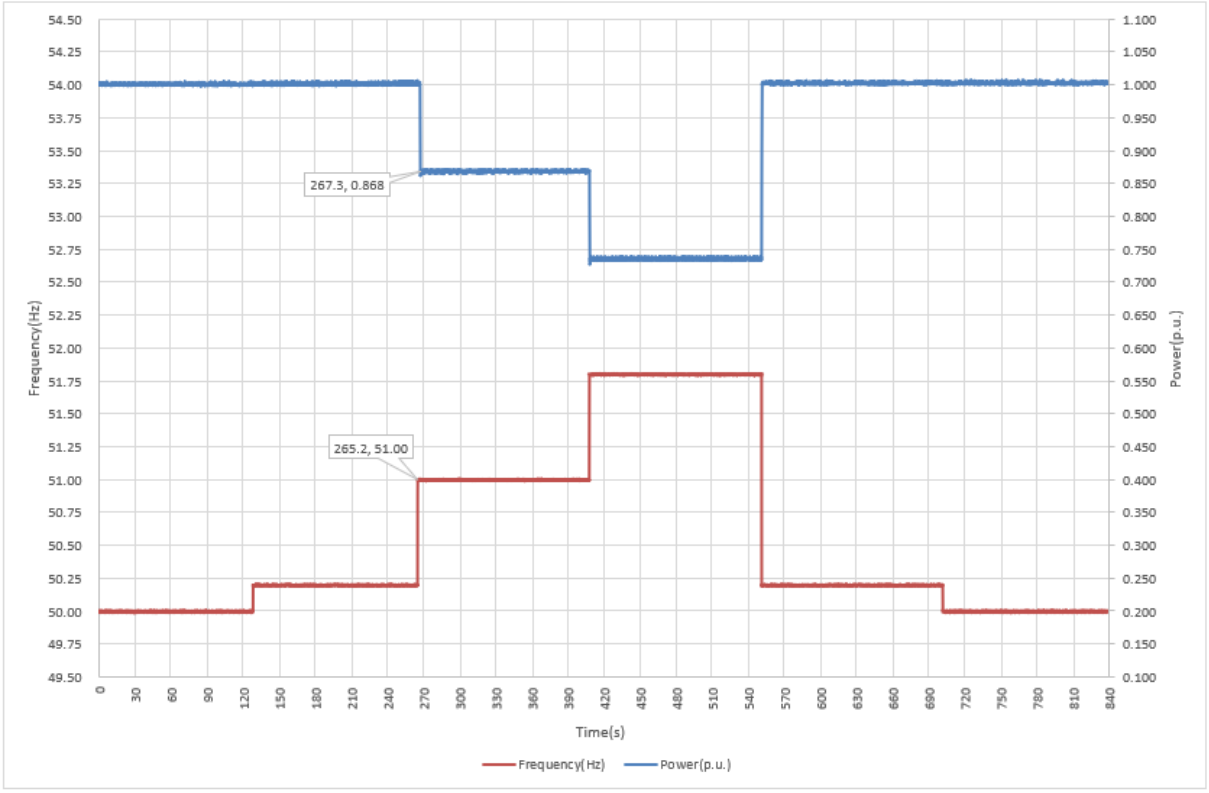
(*) The intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

Note: Threshold for discconnection overfrequency protection is set at 52.1 Hz at each test items.

Test results are offered at the table below.

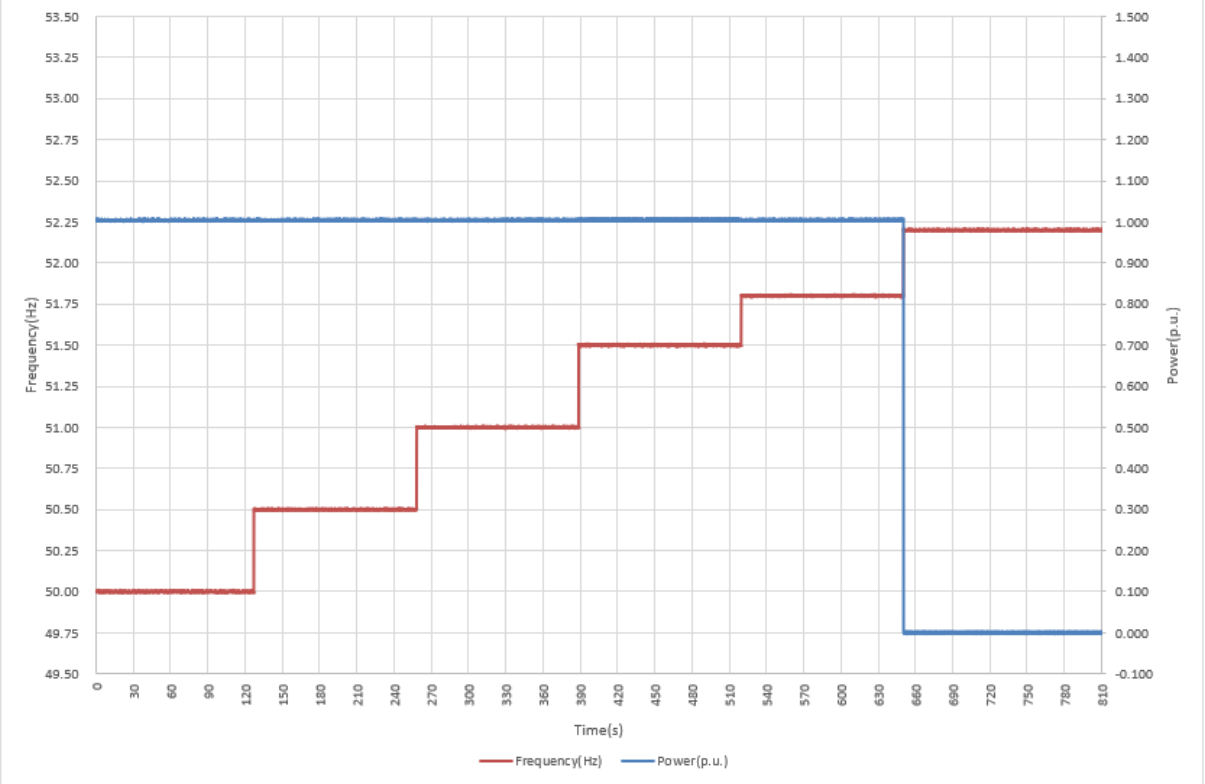
Test 1					
Step	f (Hz)	P desired (%Pn)	Frequency meas. (Hz)	P meas. (%Pn)	P deviation (%Pn) (Within ± 10 %)
1	50.00 ± 0.05 Hz	100.0	50.00	100.1	0.1
2	50.20 ± 0.05 Hz	100.0	50.20	100.2	0.2
3	51.00 ± 0.05 Hz	86.7	51.00	86.9	0.2
4	51.80 ± 0.05 Hz	73.3	51.80	73.6	0.3
5	50.20 ± 0.05 Hz	100.0	50.20	100.3	0.3
6	50.00 ± 0.05 Hz	100.0	50.00	100.3	0.3
Time delay setting from step 2 to step 3					
Time reference of change		265.2 s			
End of change		267.3 s			
Delay time		2.1 s			

P vs f chart for Test 1



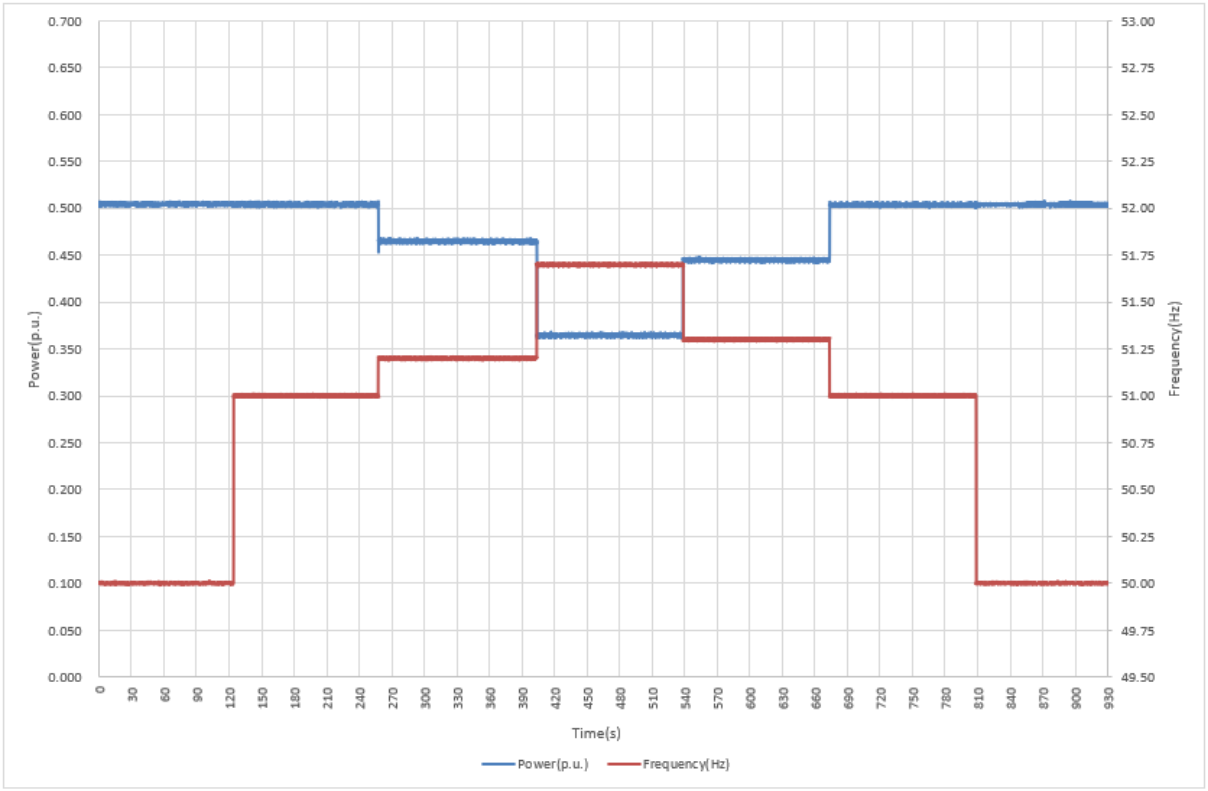
Test 2					
Step	f (Hz)	P desired (%Pn)	Frequency meas. (Hz)	P meas. (%Pn)	P deviation (%Pn) (Within ± 10 %)
1	50.00 ± 0.05 Hz	100.0	50.00	100.4	0.4
2	50.50 ± 0.05 Hz	100.0	50.50	100.4	0.4
3	51.00 ± 0.05 Hz	100.0	51.00	100.4	0.4
4	51.50 ± 0.05 Hz	100.0	51.50	100.5	0.5
5	51.80 ± 0.05 Hz	100.0	51.80	100.4	0.4
6	52.20 ± 0.05 Hz	0.0	52.20	0.0	0.0

P vs f chart for Test 2



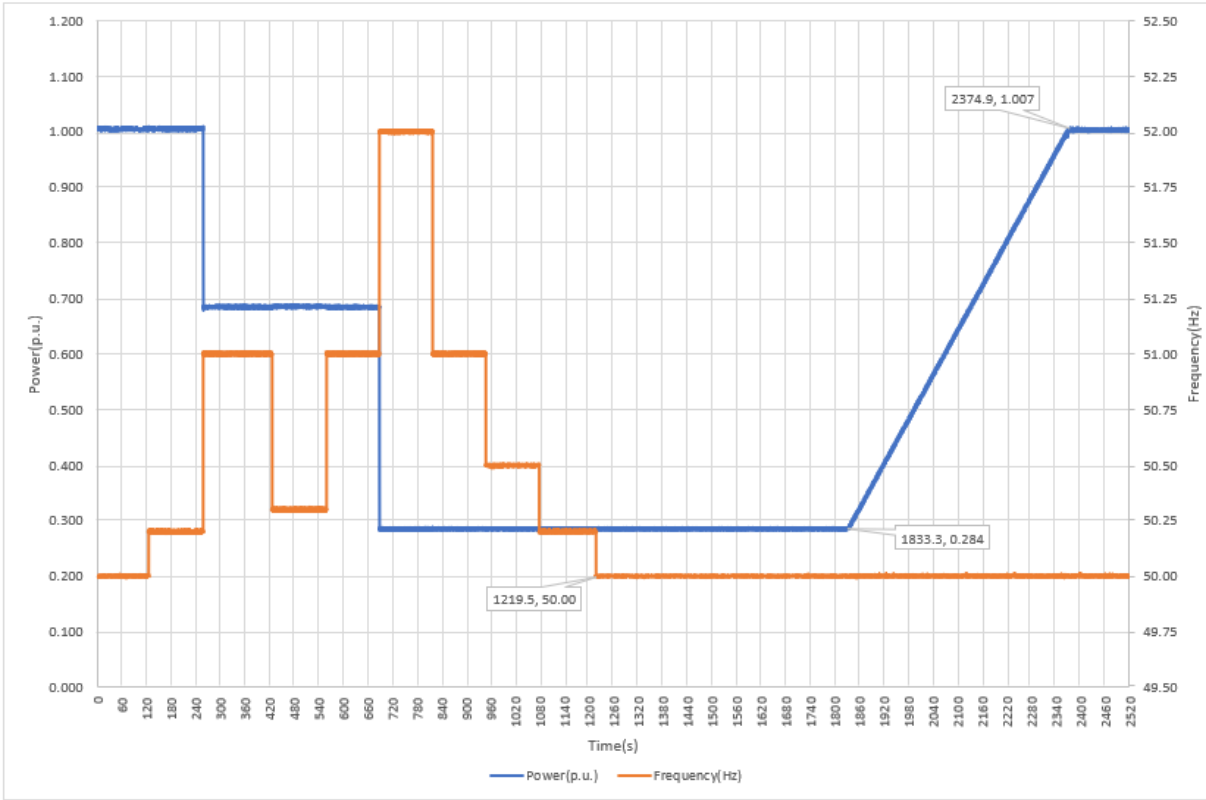
Test 3					
Step	f (Hz)	P desired (%Pn)	Frequency meas. (Hz)	P meas. (%Pn)	P deviation (%Pn) (Within ± 10 %)
1	50.00 ± 0.05 Hz	50.0	50.00	50.4	0.4
2	51.00 ± 0.05 Hz	50.0	51.00	50.4	0.4
3	51.20 ± 0.05 Hz	46.0	51.20	46.5	0.5
4	51.70 ± 0.05 Hz	36.0	51.70	36.5	0.5
5	51.30 ± 0.05 Hz	44.0	51.30	44.5	0.5
6	51.00 ± 0.05 Hz	50.0	51.00	50.4	0.4
7	50.00 ± 0.05 Hz	50.0	50.00	50.4	0.4

P vs f chart for Test 3



Test 4					
Step	f (Hz)	P desired (%Pn)	Frequency meas. (Hz)	P meas. (%Pn)	P deviation (%Pn) (Within ± 10 %)
1	50.00 ± 0.05 Hz	100.0	50.00	100.4	0.4
2	50.20 ± 0.05 Hz	100.0	50.20	100.5	0.5
3	51.00 ± 0.05 Hz	68.0	51.00	68.5	0.5
4	50.30 ± 0.05 Hz	68.0	50.30	68.5	0.5
5	51.00 ± 0.05 Hz	68.0	51.00	68.5	0.5
6	52.00 ± 0.05 Hz	28.0	52.00	28.5	0.5
7	51.00 ± 0.05 Hz	28.0	51.00	28.5	0.5
8	50.50 ± 0.05 Hz	28.0	50.50	28.5	0.5
9	50.20 ± 0.05 Hz	28.0	50.20	28.5	0.5
10	50.00 ± 0.05 Hz	100.0	50.00	100.2	0.2
Reconnection Time(s)		541.6		Power ramp gradient	8.0%Pn/min

Test 4



4.3.2. Power response to underfrequency

This test has been done according to clause 4.6.2 of the standard in order to verify the capability of the EUT of activating power response to underfrequency.
In order to verify this function, the parameter setting as following to perform the test:

- Test 1： P_M = -20 %Pn; f1 = 49.8 Hz; droop = 12 %; f-stop deactivated, with delay of 2 s (*)
- Test 2： P_M = -20 %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

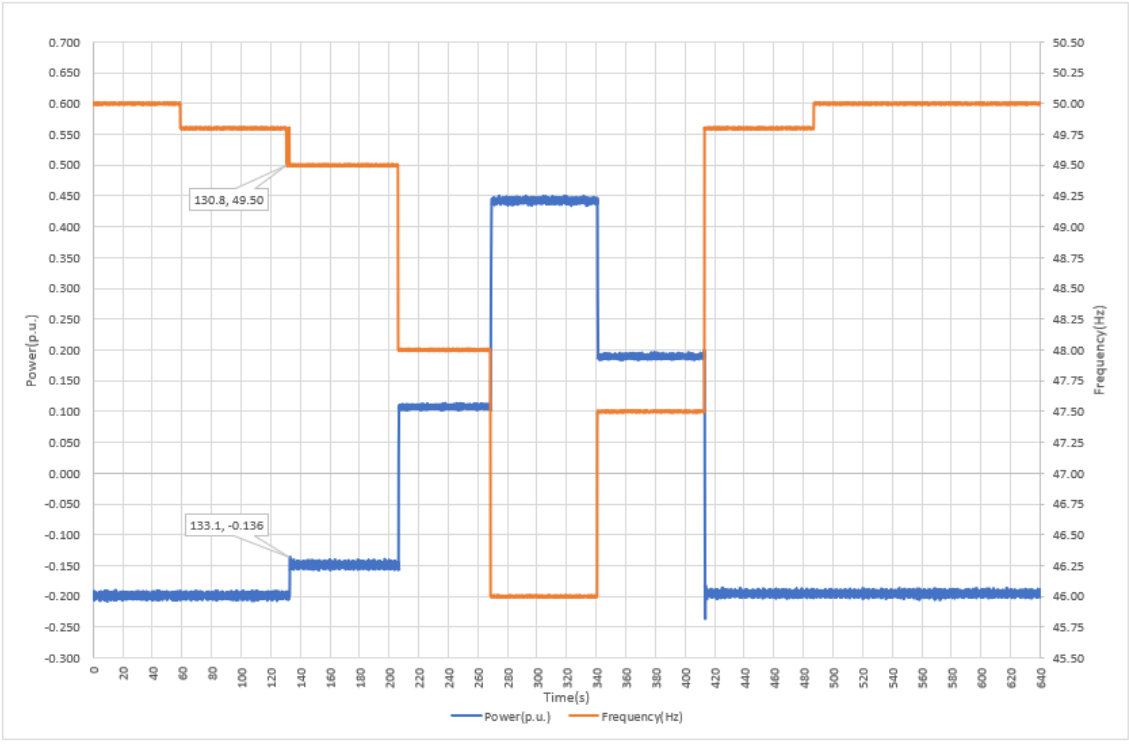
(*) The intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

Note: Threshold for discconnection underfrequency protection is set at 45Hz at each test items.

Test results are offered at the table below:

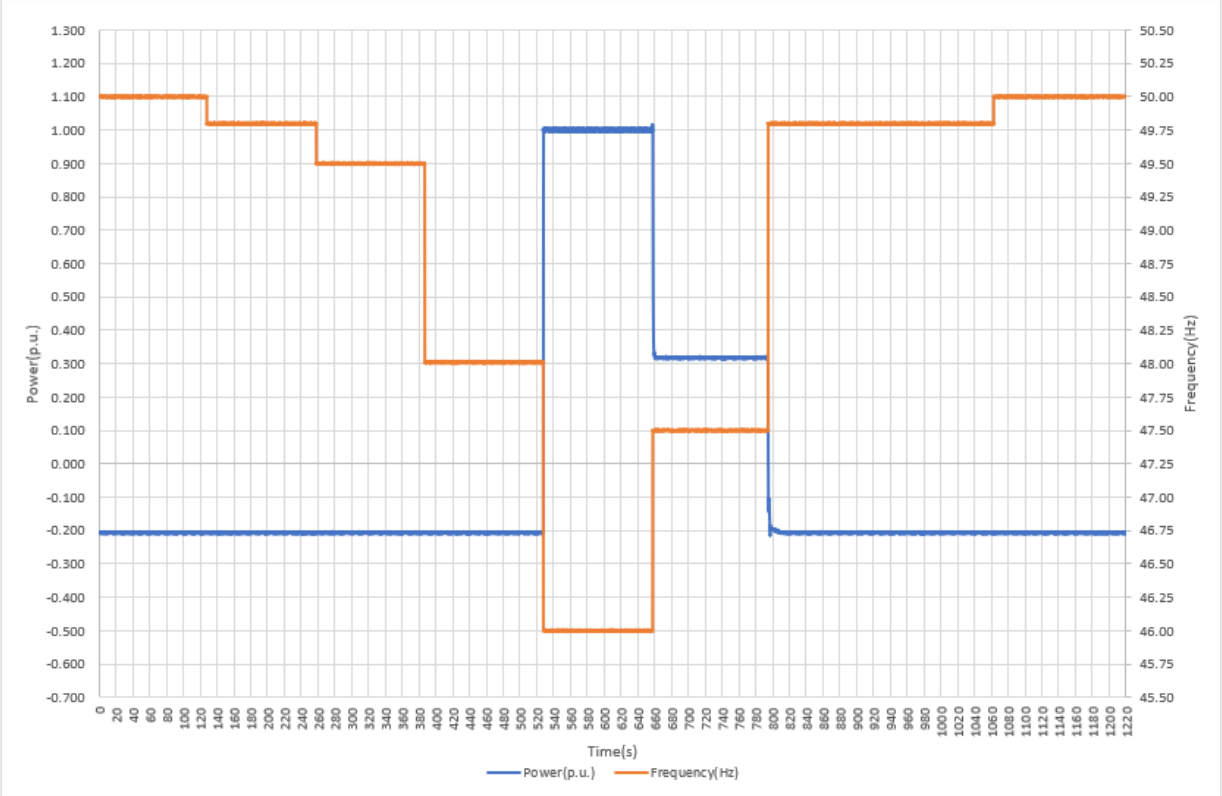
Test 1						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (Within ± 10 %)**
1	50.00 ± 0.05 Hz	-20.0	50.00	> 30	-19.9	-1.0
2	49.80 ± 0.05 Hz	-20.0	49.80	> 30	-19.9	-1.0
3	49.50 ± 0.05 Hz	-15.0	49.50	> 30	-14.9	-0.8
4	48.00 ± 0.05 Hz	10.0	48.00	> 30	10.8	0.6
5	46.00 ± 0.05 Hz	43.3	46.00	> 30	44.2	2.3
6	47.50 ± 0.05 Hz	18.3	47.50	> 30	19.0	1.2
7	49.80 ± 0.05 Hz	-20.0	49.80	> 30	-19.6	-1.0
8	50.00 ± 0.05 Hz	-20.0	50.00	> 30	-19.6	-1.0
Time delay setting from step 2 to step 3						
Initial of change time		130.8s				
End of change		133.1s				
Delay time		2.3s				

P vs f chart for Test 1



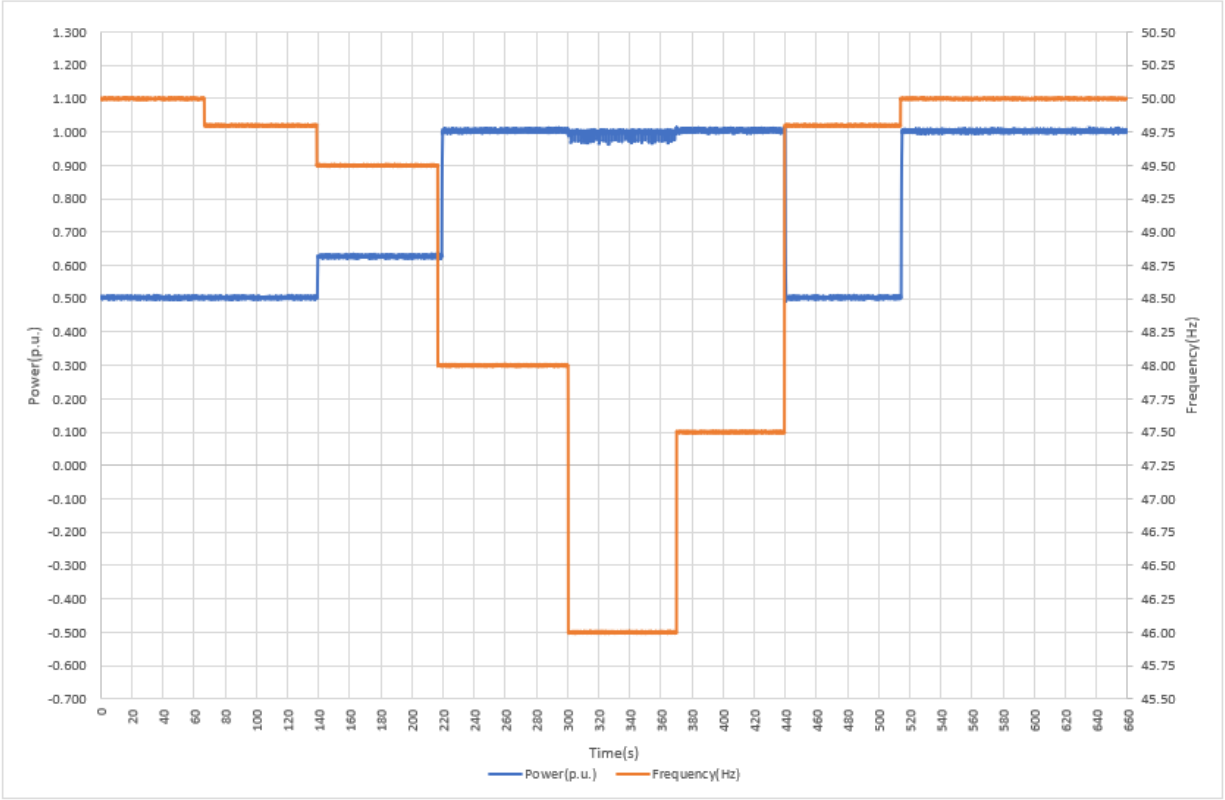
Test 2						
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**t meas. (s)**	**P meas. (%Pn)**	**P deviation (%Pn) (Within ± 10 %)**
1	50.00 ± 0.05 Hz	-20	50.00	> 30	-20.7	-1.1
2	49.80 ± 0.05 Hz	-20	49.79	> 30	-20.7	-1.7
3	49.50 ± 0.05 Hz	-20	49.50	> 30	-20.7	-1.2
4	48.00 ± 0.05 Hz	-20	48.01	> 30	-20.7	-1.0
5	46.00 ± 0.05 Hz	100	46.00	> 30	100.1	0.5
6	47.50 ± 0.05 Hz	30	47.50	> 30	31.8	-0.5
7	49.80 ± 0.05 Hz	-20	49.80	> 30	-20.7	-1.0
8	50.00 ± 0.05 Hz	-20	50.00	> 30	-20.7	-1.0

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	50.3	0.7
2	49.80 ± 0.05 Hz	50	49.80	> 30	50.3	0.6
3	49.50 ± 0.05 Hz	62	49.50	> 30	62.7	-0.8
4	48.00 ± 0.05 Hz	100	48.00	> 30	100.4	0.3
5	46.00 ± 0.05 Hz	100	46.00	> 30	99.8	0.1
6	47.50 ± 0.05 Hz	100	47.50	> 30	100.5	0.2
7	49.80 ± 0.05 Hz	50	49.80	> 30	50.4	0.6
8	50.00 ± 0.05 Hz	100	50.00	> 30	100.3	0.5

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. 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 = ±48.4 %Sn)
- Test 3: Triangular Curve (PF = ±0.8)
- Test 4: Reactive power capability at active power PD in the voltage range (0.85Un ~ 1.1Un)

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.

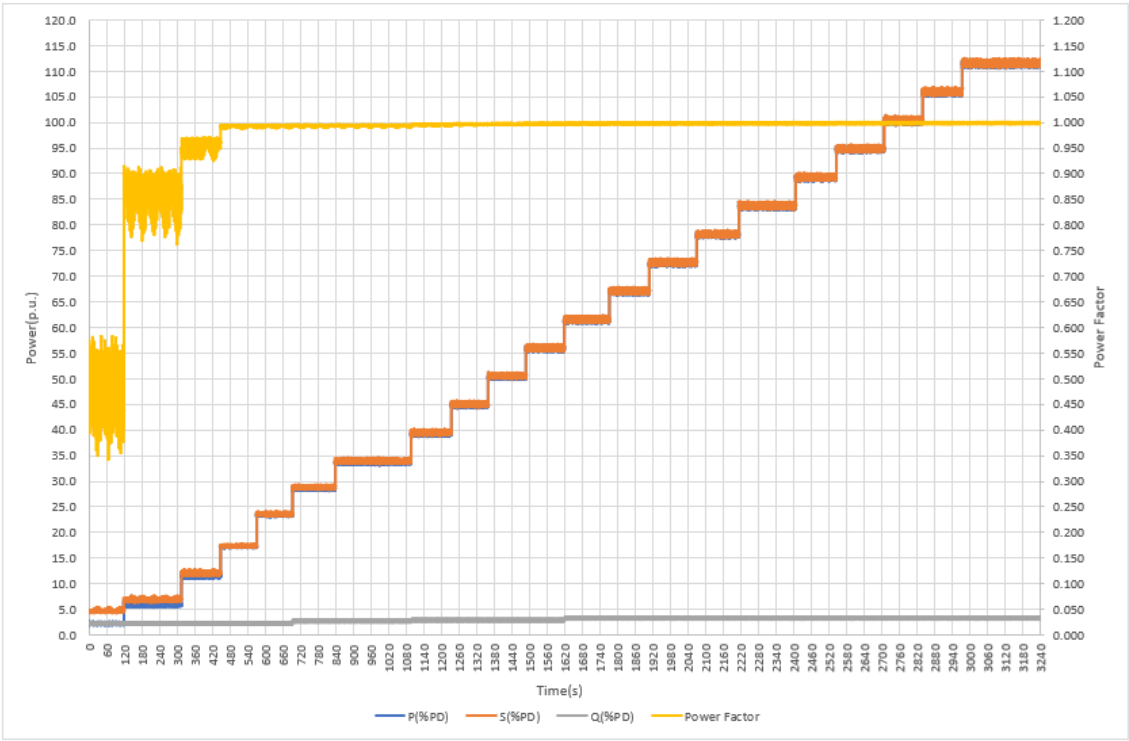
When the measurement is equal to or greater than 10% Sn, the allowable tolerance of reactive power measurement should be within ±2% Sn.

Test results are offered at tables below.

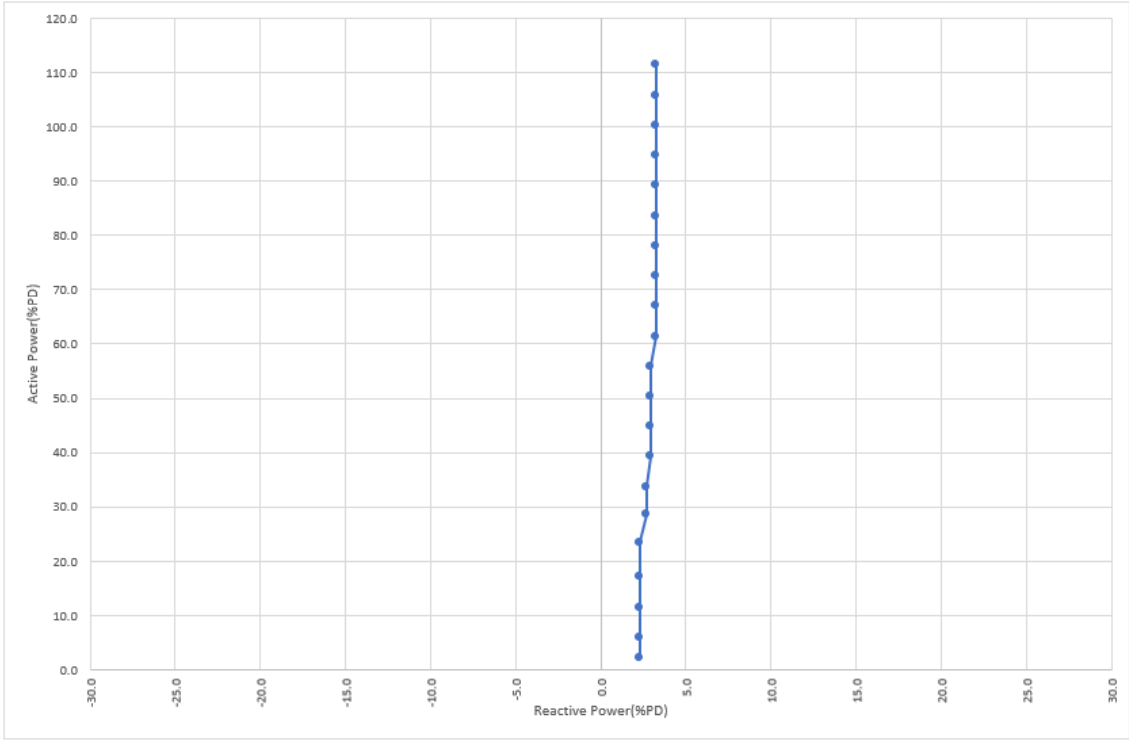
Q Zero (Q = 0 %Sn)						
P Desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q desired (%Sn)**	**Q measured (%Sn)**	**Q Deviation (%Sn)**	**Power Factor (cos φ)**
0	0.117	2.0	0.0	1.0	1.0	0.957
5	0.219	5.4	0.0	1.0	1.0	0.989
10	0.373	10.4	0.0	1.0	1.0	0.996
15	0.525	15.5	0.0	1.0	1.0	0.998
20	0.702	21.1	0.0	1.0	1.0	0.999
25	0.854	25.8	0.0	1.2	1.2	0.999
30	0.996	30.4	0.0	1.2	1.2	0.999
35	1.153	35.4	0.0	1.3	1.3	0.999
40	1.311	40.4	0.0	1.3	1.3	1.000
45	1.469	45.3	0.0	1.3	1.3	1.000
50	1.627	50.3	0.0	1.3	1.3	1.000
55	1.789	55.3	0.0	1.4	1.4	1.000
60	1.950	60.3	0.0	1.4	1.4	1.000
65	2.111	65.3	0.0	1.4	1.4	1.000
70	2.271	70.3	0.0	1.4	1.4	1.000
75	2.433	75.3	0.0	1.4	1.4	1.000
80	2.598	80.3	0.0	1.4	1.4	1.000
85	2.762	85.3	0.0	1.4	1.4	1.000
90	2.928	90.3	0.0	1.4	1.4	1.000
95	3.094	95.3	0.0	1.4	1.4	1.000
100	3.262	100.3	0.0	1.4	1.4	1.000

Test results are represented at diagrams below.

Power factor and powers vs Time



Active power vs Reactive power



4.4.1.2. Test 2: Rectangular Curve (Q = ±53.8 % P_D)

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 = 53.8 % P_D / Inductive)						
P Desired (%P_D)	**Power DC (kW)**	**P measured (%P_D)**	**Q desired (%P_D)**	**Q measured (%P_D)**	**Q Deviation (%P_D)**	**Power Factor (cos φ)**
6	0.203	5.0	--	35.1	--	0.142
11	0.358	11.4	--	52.7	--	0.211
17	0.509	17.0	**53.8**	53.3	-0.5	0.304
22	0.687	22.6	**53.8**	53.6	-0.2	0.389
28	0.836	28.1	**53.8**	53.7	-0.1	0.464
33	0.978	33.6	**53.8**	53.7	-0.1	0.531
39	1.133	39.2	**53.8**	53.8	0.0	0.589
44	1.291	44.7	**53.8**	53.9	0.1	0.639
50	1.449	50.4	**53.8**	53.9	0.1	0.683
56	1.607	55.9	**53.8**	53.9	0.1	0.719
61	1.768	61.4	**53.8**	53.9	0.1	0.752
67	1.928	67.0	**53.8**	53.9	0.1	0.779
72	2.089	72.6	**53.8**	54.0	0.2	0.802
78	2.249	78.2	**53.8**	54.0	0.2	0.823
83	2.411	83.7	**53.8**	54.0	0.2	0.840
89	2.576	89.3	**53.8**	54.0	0.2	0.856
94	2.74	94.9	**53.8**	54.1	0.3	0.869
100	2.906	100.6	**53.8**	54.1	0.3	0.881
106(*)	3.072	101.6	**53.8**	54.1	0.3	0.883
111(*)	3.240	101.6	**53.8**	54.1	0.3	0.883

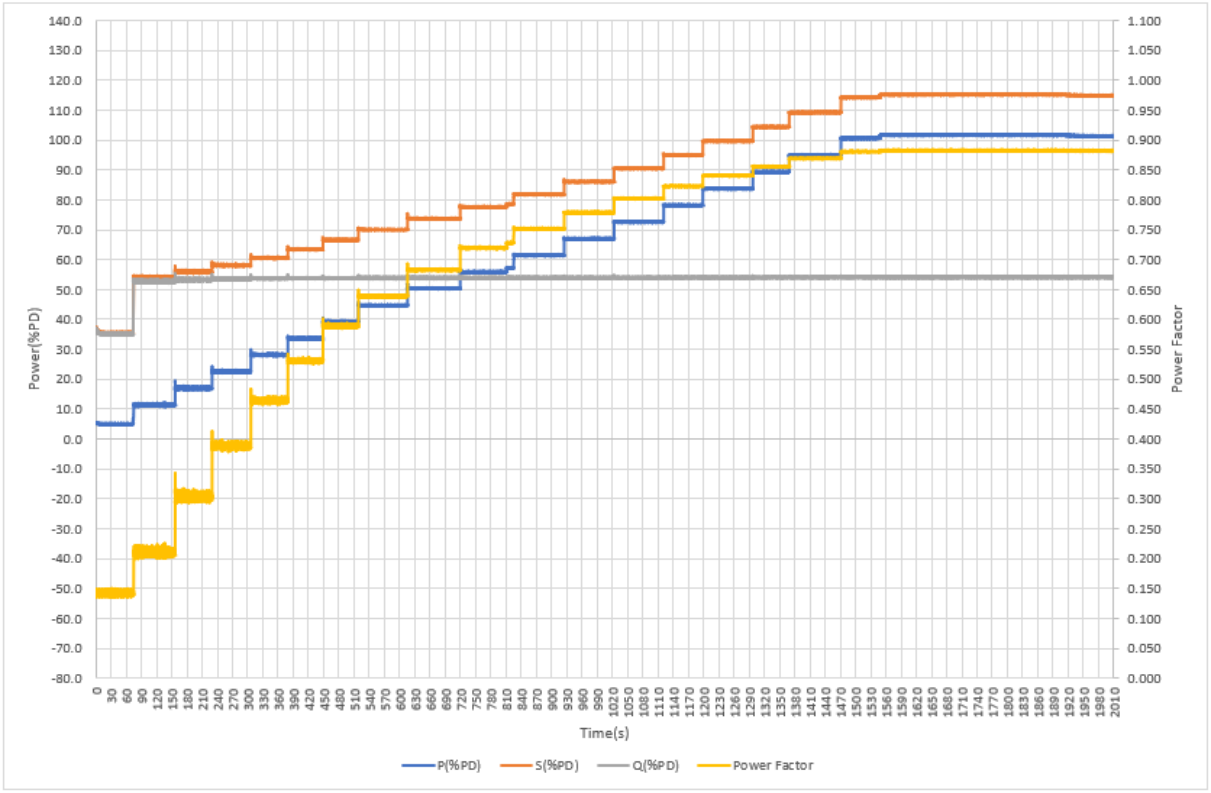
(*) The EUT does not reach the setting active power due to the current limitation function.

Rectangular Curve (Q = 53.8 % P_D / Capacitive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q desired (%Sn)**	**Q measured (%Sn)**	**Q deviation (%Sn)**	**Power Factor (cos φ)**
6	0.203	6.2	--	-38.3		0.160
11	0.358	11.6	--	-52.6		0.209
17	0.509	17.0	**-53.8**	-54.0	-0.2	0.299
22	0.687	22.5	**-53.8**	-53.8	0.0	0.385
28	0.836	27.9	**-53.8**	-53.8	0.0	0.460
33	0.978	33.7	**-53.8**	-54.4	-0.6	0.526
39	1.133	39.2	**-53.8**	-54.3	-0.5	0.586
44	1.291	45.5	**-53.8**	-54.3	-0.5	0.642
50	1.449	50.2	**-53.8**	-54.2	-0.4	0.680
56	1.607	56.5	**-53.8**	-54.1	-0.3	0.722
61	1.768	62.0	**-53.8**	-54.1	-0.3	0.753
67	1.928	67.6	**-53.8**	-54.1	-0.3	0.781
72	2.089	73.2	**-53.8**	-54.1	-0.3	0.804
78	2.249	78.8	**-53.8**	-54.1	-0.3	0.824
83	2.411	84.3	**-53.8**	-54.1	-0.3	0.842
89	2.576	90.0	**-53.8**	-54.1	-0.3	0.857
94	2.74	95.6	**-53.8**	-54.2	-0.4	0.870
100(*)	2.906	97.9	**-53.8**	-54.2	-0.4	0.875
106(*)	3.072	97.9	**-53.8**	-54.2	-0.4	0.875
111(*)	3.24	97.9	**-53.8**	-54.2	-0.4	0.875

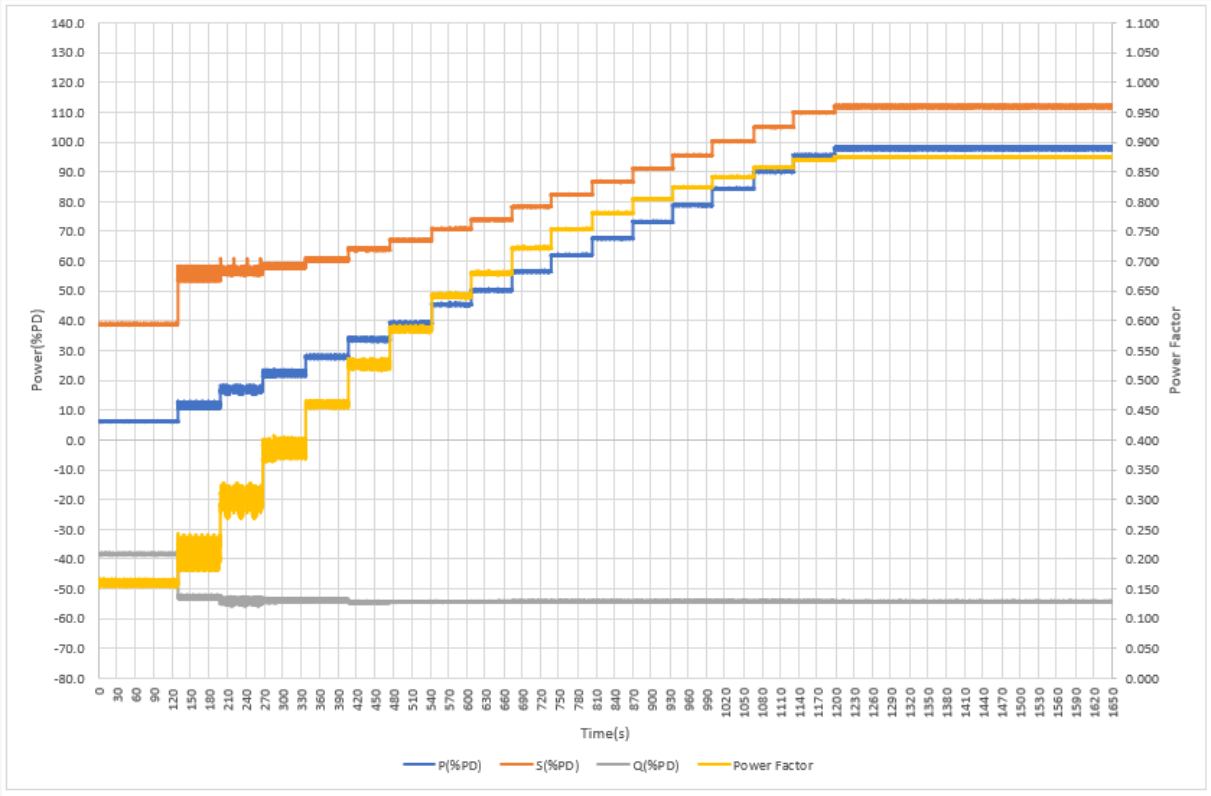
(*) The EUT does not reach the setting active power due to the current limitation function.

Test results are represented at diagrams below.

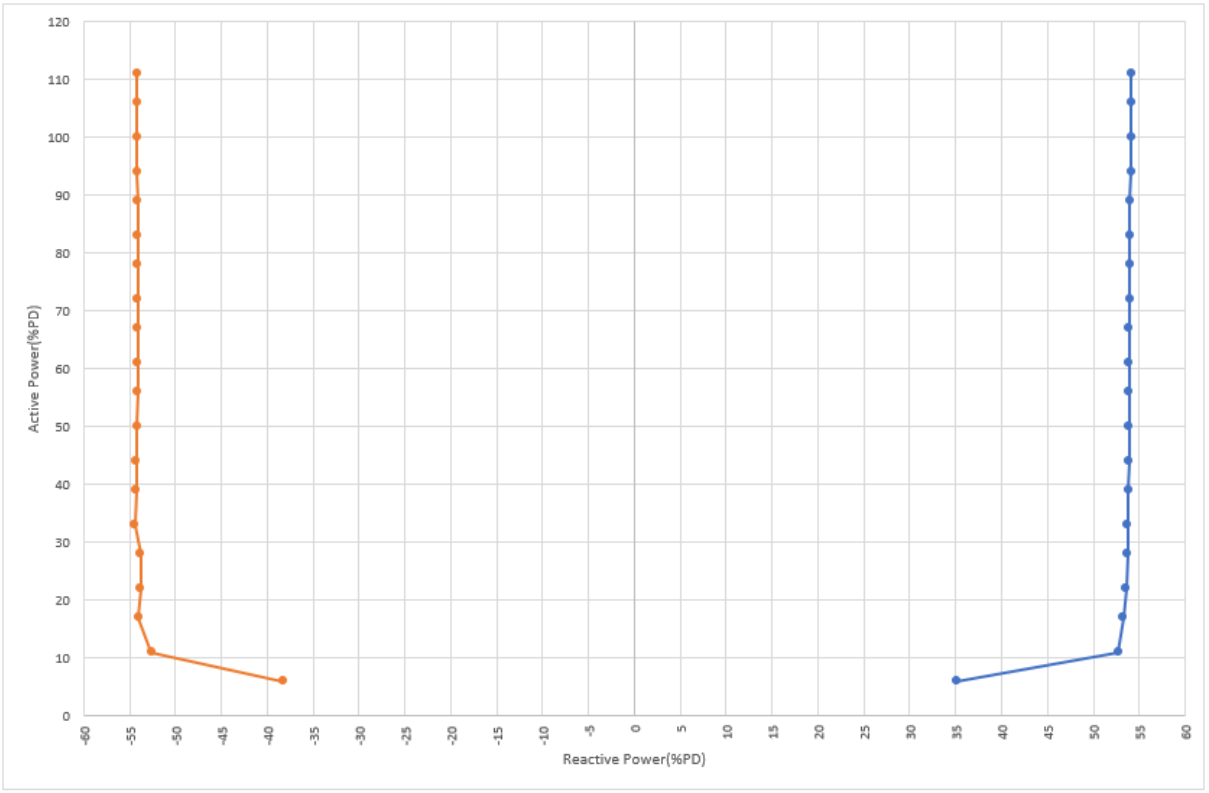
Rectangular Curve (Q = 53.8 % P_D / Inductive)



Rectangular Curve (Q = 53.8 % P_D / 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.

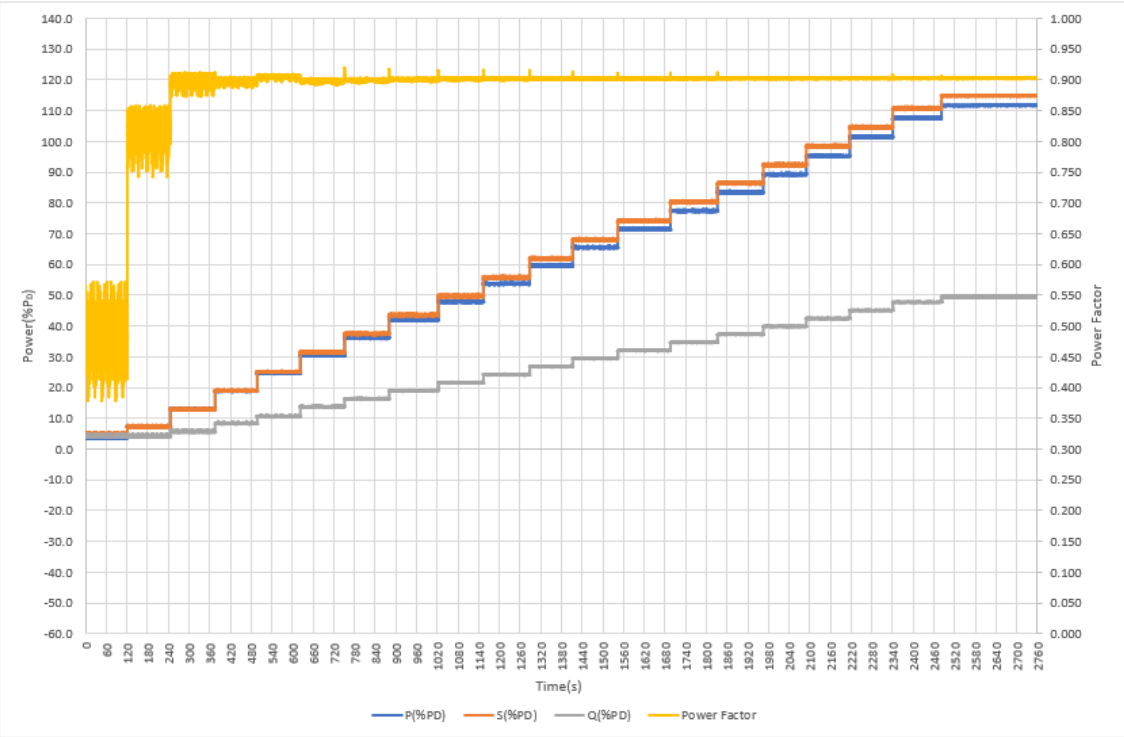
Test results are offered at the tables below.

Triangular Curve (PF=0.9 / capacitive)						
P Desired (%P_D)	**Power DC (kW)**	**P measured (%P_D)**	**Q measured (%P_D)**	**Power Factor desired (cos φ)**	**Power Factor measured (cos φ)**	**Power Factor Deviation (cos φ)**
0	0.1	3.5	4.0	--	0.474	--
7	0.2	7.4	-3.7	--	0.850	--
13	0.4	13.1	-5.8	--	0.894	--
19	0.5	18.9	-8.1	0.9	0.903	0.003
25	0.7	24.8	-11.0	0.9	0.901	0.001
31	0.8	30.6	-13.4	0.9	0.904	0.004
36	1.0	36.4	-16.8	0.9	0.895	-0.005
42	1.1	42.2	-19.5	0.9	0.897	-0.003
48	1.3	48.1	-22.1	0.9	0.897	-0.003
54	1.5	54.0	-24.7	0.9	0.898	-0.002
60	1.6	59.9	-27.4	0.9	0.899	-0.001
66	1.8	65.9	-30.1	0.9	0.899	-0.001
72	1.9	71.8	-32.7	0.9	0.899	-0.001
78	2.1	77.8	-35.3	0.9	0.899	-0.001
84	2.3	83.8	-38.0	0.9	0.900	0.000
90	2.4	89.9	-40.7	0.9	0.900	0.000
96	2.6	96.0	-43.4	0.9	0.900	0.000
102	2.8	102.2	-46.1	0.9	0.900	0.000
108	2.9	108.4	-48.8	0.9	0.900	0.000
111(*)	2.9	108.7	-48.9	0.9	0.900	0.000

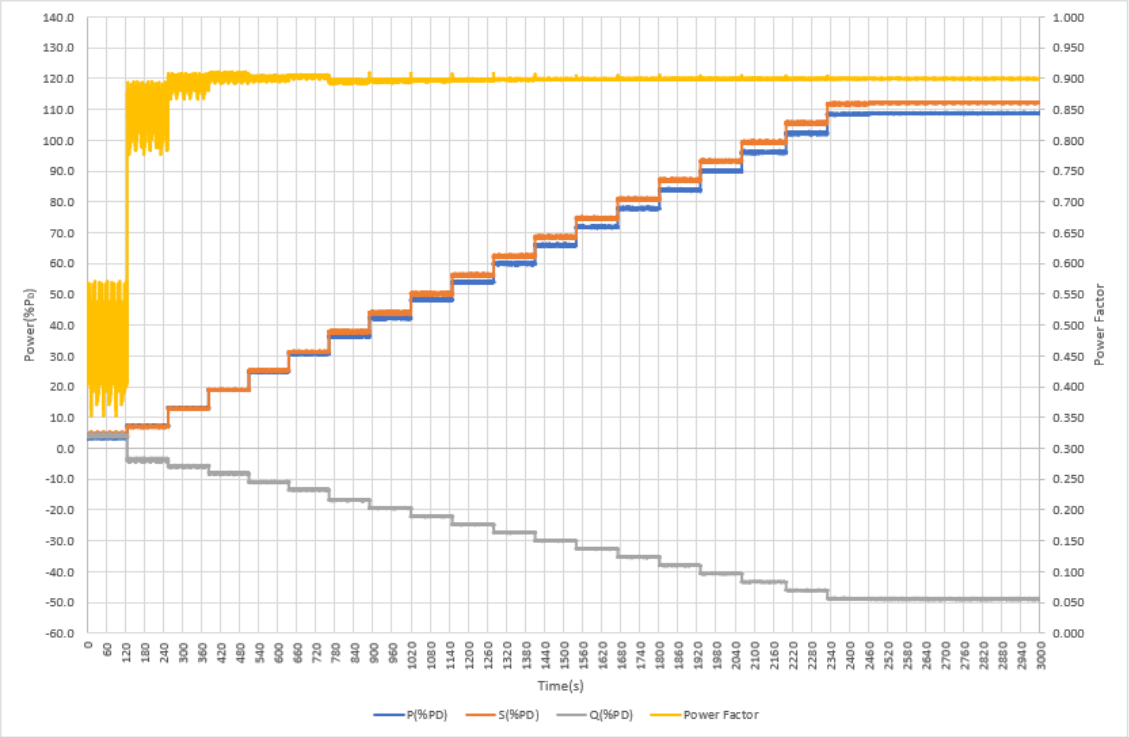
(*) The EUT does not reach the setting active power due to the current limitation function.

Triangular Curve (PF=0.9 / inductive)						
P Desired (%P_D)	Power DC (kW)	P measured (%P_D)	Q measured (%P_D)	Power Factor desired (cos φ)	Power Factor measured (cos φ)	Power Factor Deviation (cos φ)
0	0.1	3.6	4.3	--	0.483	--
7	0.2	7.3	4.2	--	0.819	--
13	0.4	13.1	5.7	--	0.898	--
19	0.5	18.8	8.4	0.9	0.898	-0.002
25	0.7	24.6	10.7	0.9	0.905	0.005
31	0.8	30.4	13.8	0.9	0.898	-0.002
36	1.0	36.1	16.4	0.9	0.899	-0.001
42	1.1	41.9	18.9	0.9	0.900	0.000
48	1.3	47.8	21.5	0.9	0.901	0.001
54	1.4	53.7	24.1	0.9	0.902	0.002
60	1.6	59.6	26.8	0.9	0.902	0.002
66	1.8	65.5	29.4	0.9	0.902	0.002
72	1.9	71.5	32.0	0.9	0.902	0.002
78	2.1	77.4	34.6	0.9	0.902	0.002
84	2.3	83.4	37.3	0.9	0.902	0.002
90	2.4	89.2	39.8	0.9	0.902	0.002
96	2.6	95.3	42.4	0.9	0.902	0.002
102	2.7	101.3	45.1	0.9	0.902	0.002
108	2.9	107.5	47.7	0.9	0.902	0.002
111	3.0	111.6	49.5	0.9	0.902	0.002

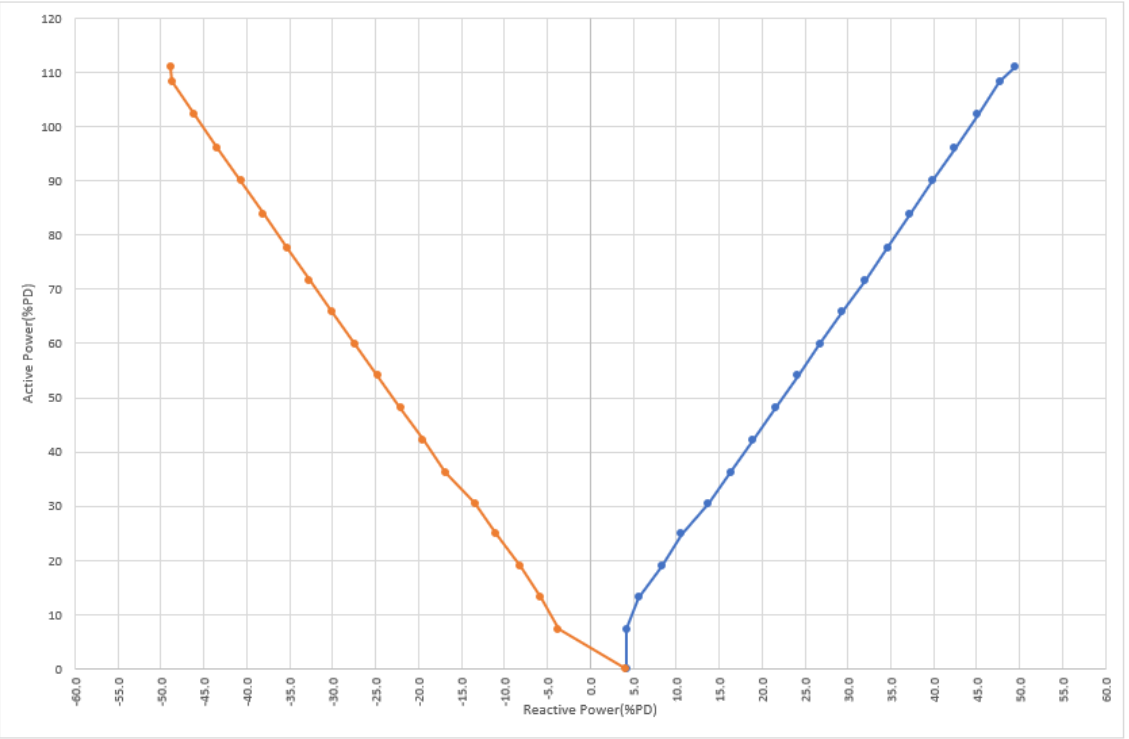
Triangular Curve (PF=0.9), Inductive: Power factor and powers vs Time



Triangular Curve (PF=0.9), Capacitive side: Power Factor and Powers vs Time



Triangular Curve: Active power vs Reactive power



4.4.1.4. Test 4: Reactive power capability at active power PD in the voltage range (0.85Un~1.1Un)

This test verifies the capability of the inverter to provide reactive power capability at active power PD in the voltage range, as the Figure 13 of standard:

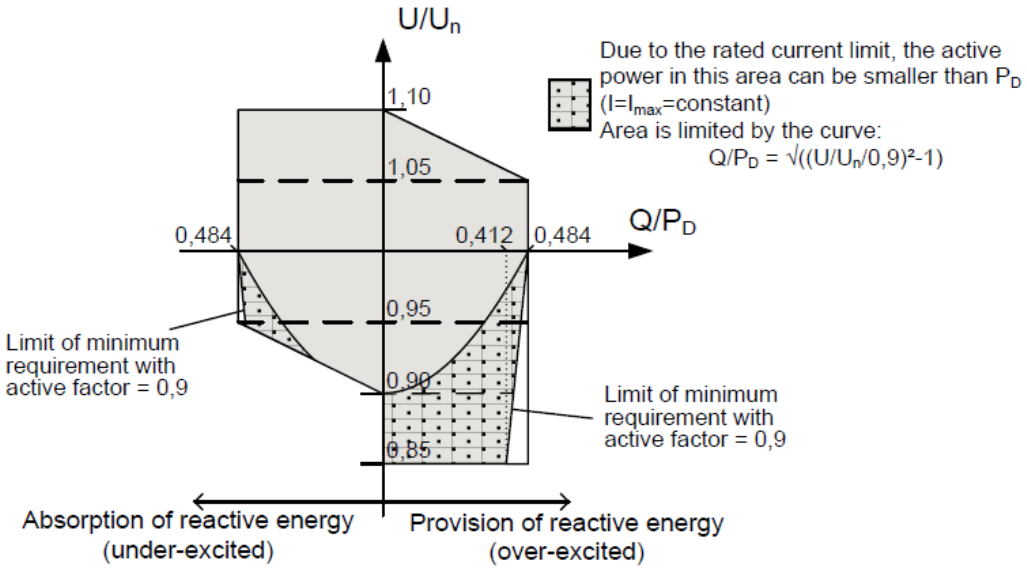


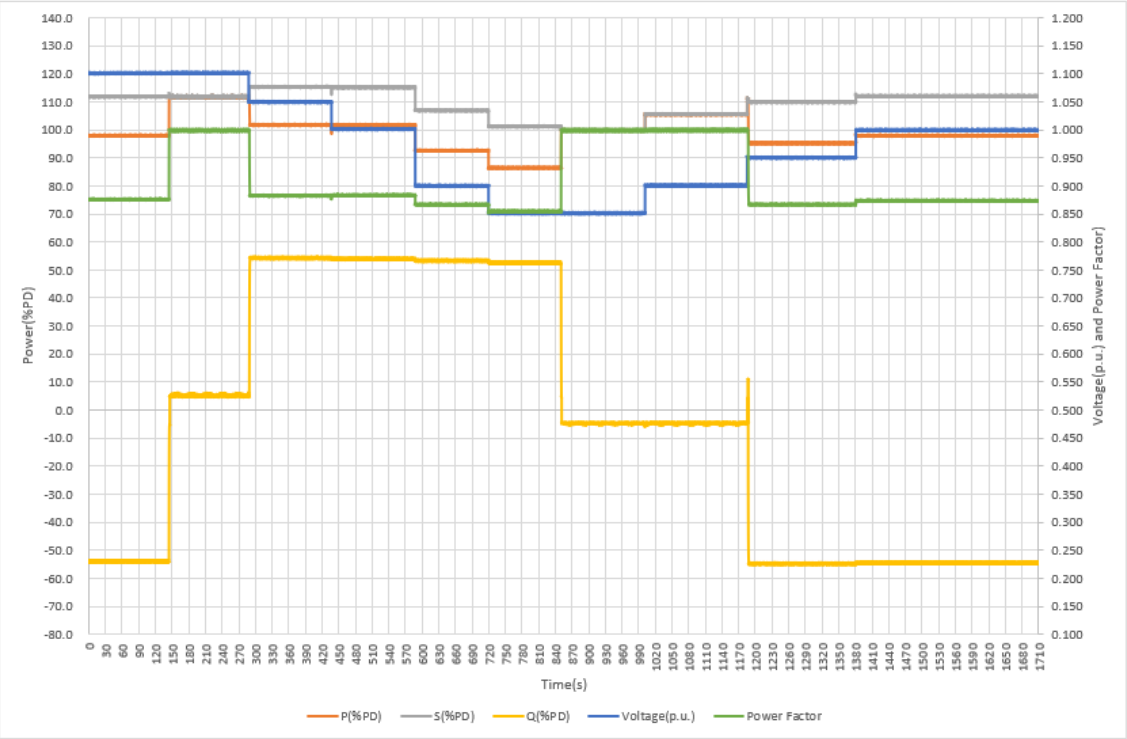
Figure 13 — Reactive power capability at active power P_D in the voltage range (positive sequence component of the fundamental)

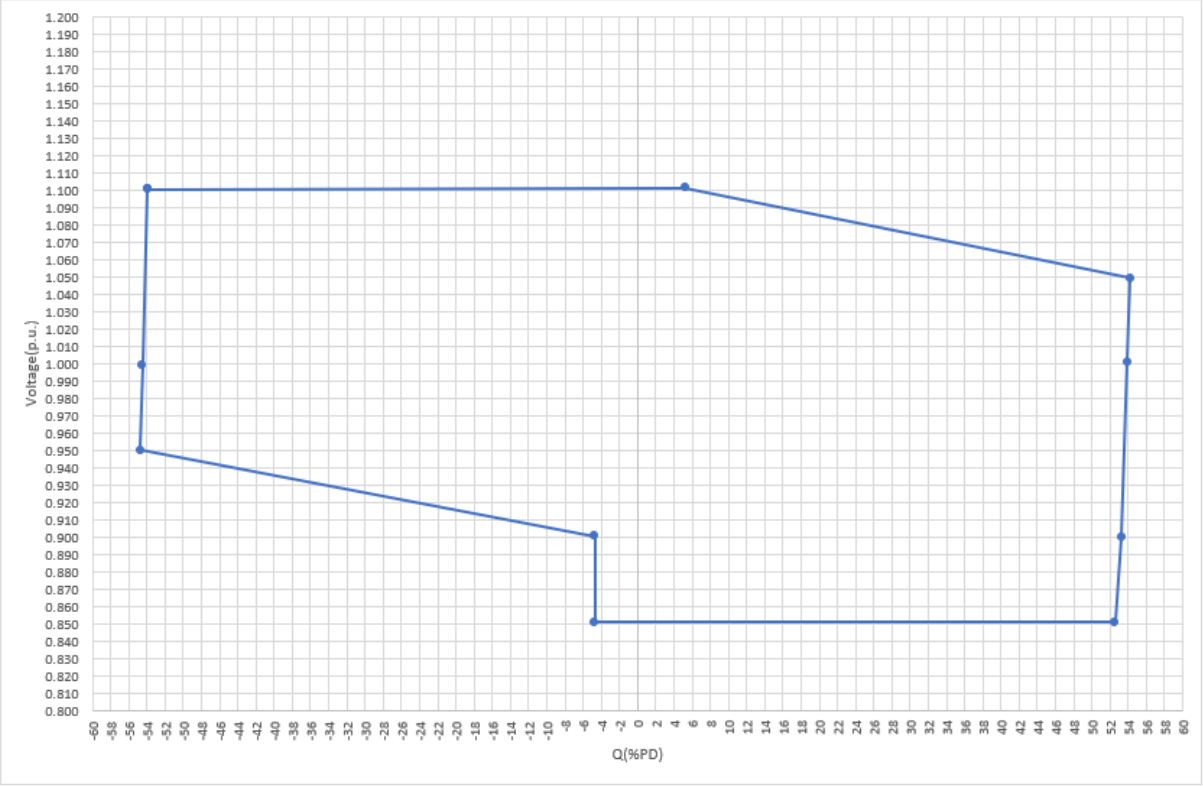
Allowed tolerance for reactive power measurements is to be considered inside ±2 %Sn (±2.2 %PD)

Test results are presented in the following table and graph:

Reactive power capability at active power PD in the voltage range							
Step	**Voltage desired (p.u.)**	**Voltage Meas. (p.u.)**	**P measured (%PD)**	**Q measured (%PD)**	**Q desired (%PD)**	**Q devation (%PD)**	**Power Factor measured (cos φ)**
1	1.100	1.101	97.9	-53.9	-53.8	-0.1	0.876
2	1.100	1.101	111.7	5.3	0.0	5.3	0.999
3	1.050	1.050	101.7	54.3	53.8	0.5	0.882
4	1.000	1.001	101.7	53.9	53.8	0.1	0.884
5	0.900	0.900	92.6	53.3	53.8	-0.5	0.867
6	0.850	0.851	86.5	52.5	53.8	-1.3	0.855
7	0.850	0.851	99.8	-4.7	0.0	-4.7	0.999
8	0.900	0.901	105.4	-4.7	0.0	-4.7	0.999
9	0.950	0.950	95.2	-54.8	-53.8	-1.0	0.867
10	1.000	1.000	97.9	-54.5	-53.8	-0.7	0.874

Q(U) capabilities





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.

Note: The activation and deactivation of the function and its settings can be field adjustable through SunSpec Dashboard interface, under the menu of Volt_var, ModEna = 0 indicating function deactivation, while ModEna = 1 indicating function activation; means to setting the parameter are protected by key of the SunSpec Dashboard.

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

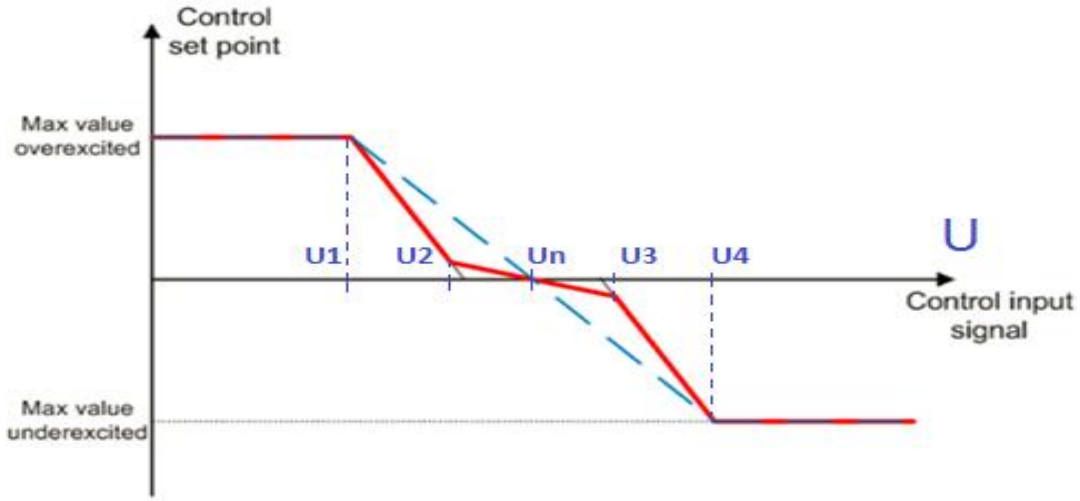


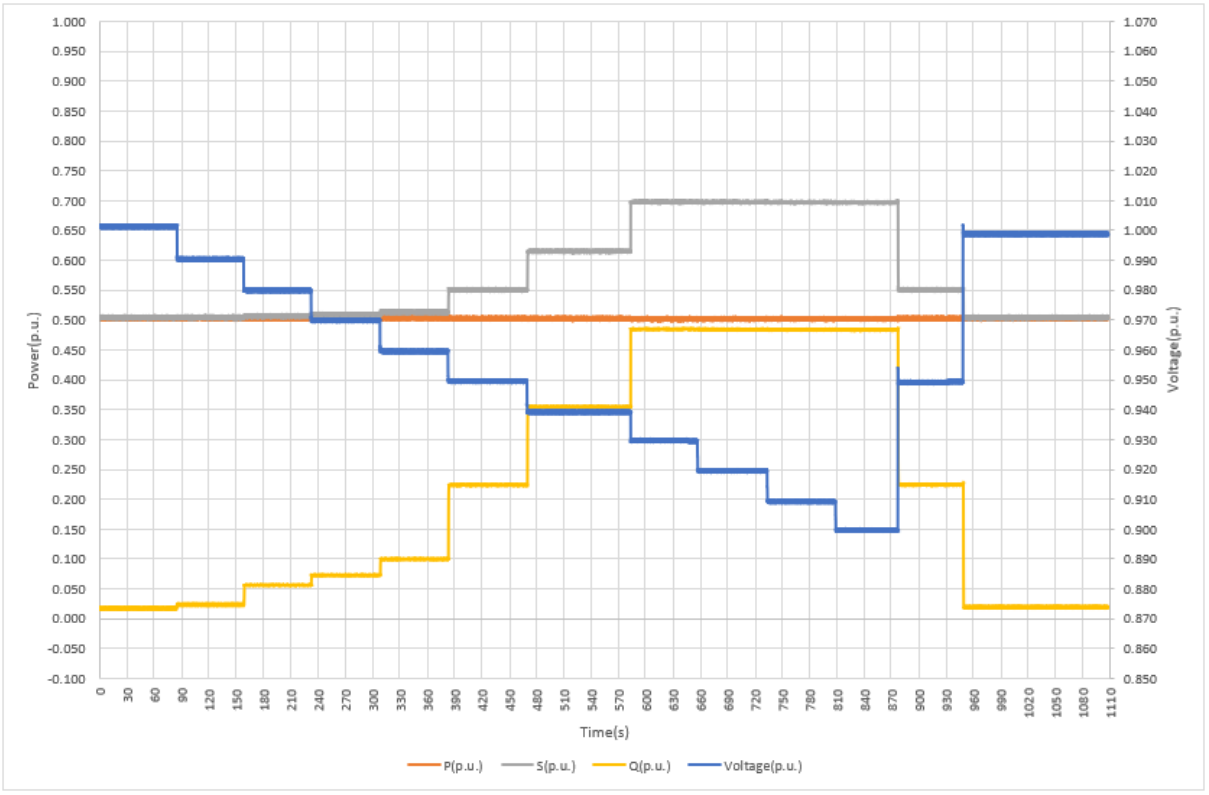
Figure 16 — Example characteristics for Q respectively cos φ control mode

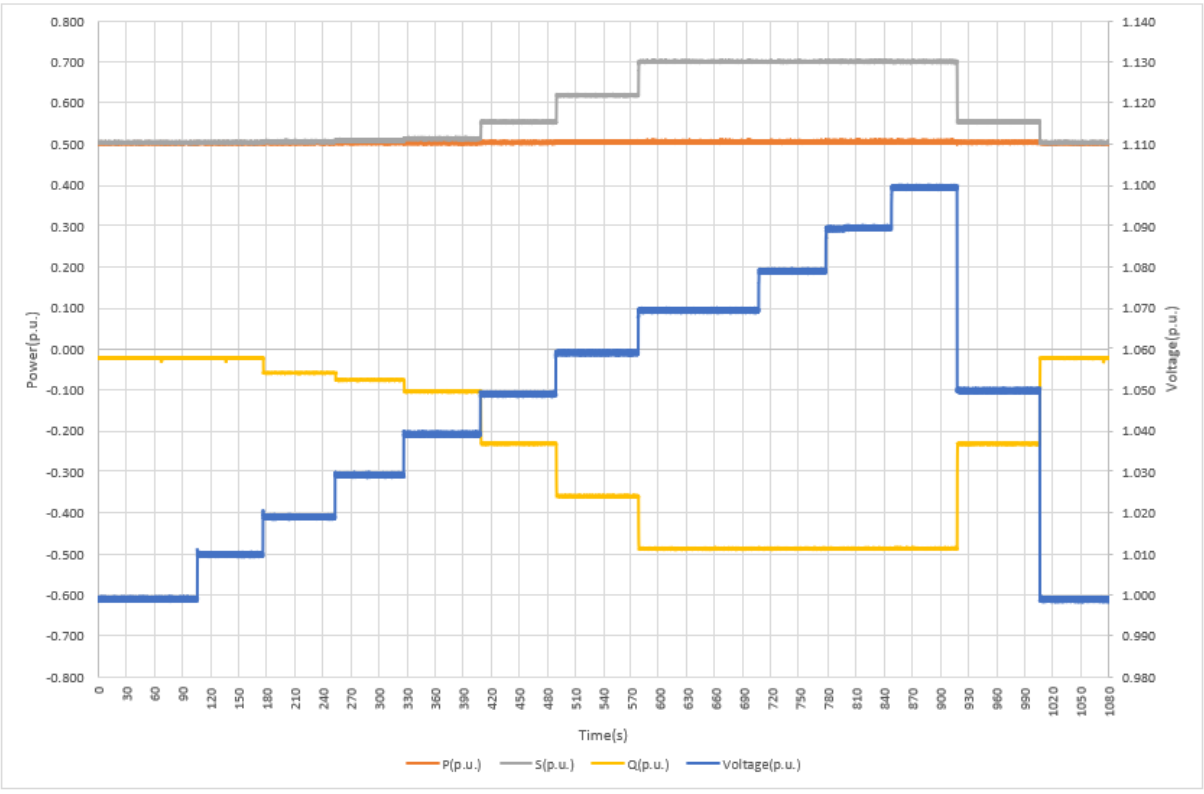
Test results are offered at the tables below.

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	1.000 Un	0.503	1.001	0.018	0.000	0.018
50	0.990 Un	0.503	0.990	0.024	0.025	-0.001
50	0.980 Un	0.503	0.980	0.056	0.050	0.006
50	0.970 Un	0.503	0.970	0.073	0.075	-0.002
50	0.960 Un	0.503	0.960	0.100	0.100	0.000
50	0.950 Un	0.503	0.950	0.224	0.228	-0.004
50	0.940 Un	0.503	0.939	0.355	0.356	-0.001
50	0.930 Un	0.502	0.930	0.485	0.484	0.001
50	0.920 Un	0.502	0.919	0.484	0.484	0.000
50	0.910 Un	0.502	0.909	0.484	0.484	0.000
50	0.900 Un	0.502	0.900	0.483	0.484	-0.001
50	0.950 Un	0.503	0.949	0.224	0.228	-0.004
50	1.000 Un	0.503	0.999	0.019	0.000	0.019

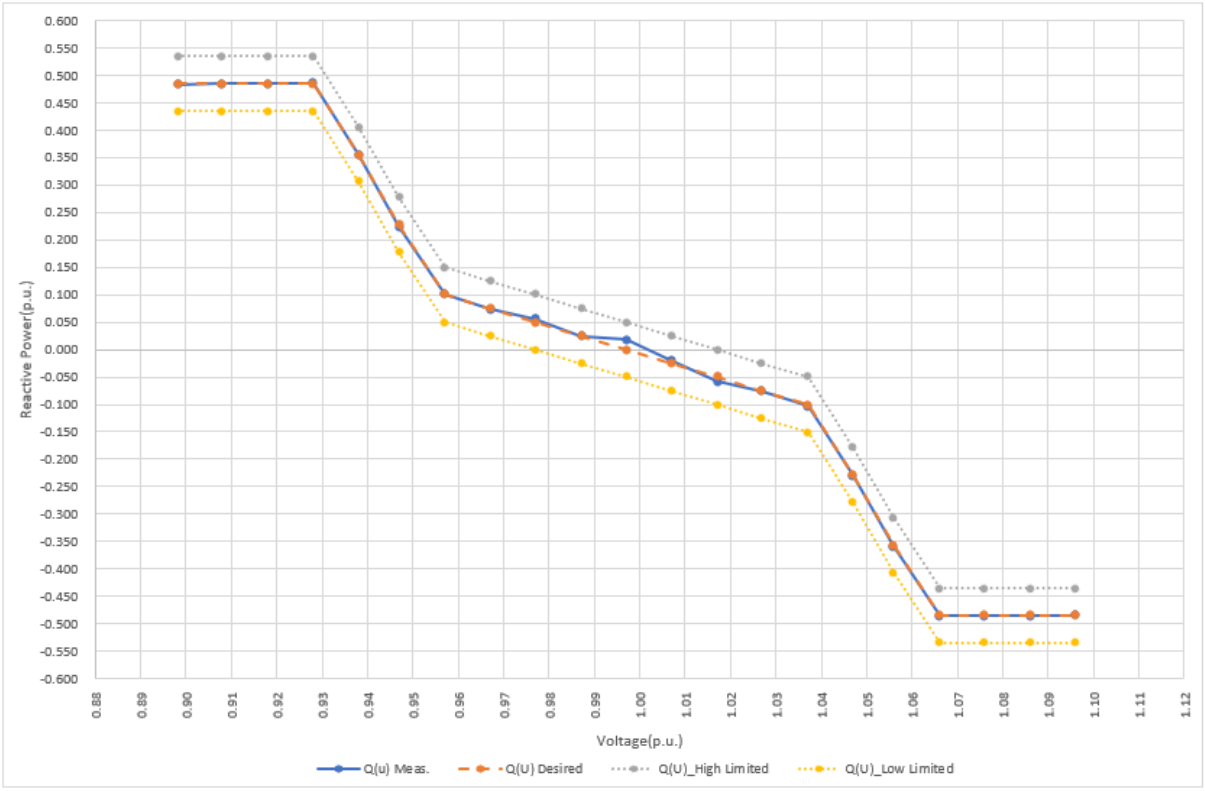
P/Pn setpoint (%)	U setpoint	P measured (p.u.)	V measured (p.u.)	Q measured (p.u.)	Q desired (p.u.)	ΔQ (< ±0.05 p.u.)
50	1.000 Un	0.503	0.999	-0.021	0.000	-0.021
50	1.010 Un	0.503	1.010	-0.021	-0.025	0.004
50	1.020 Un	0.504	1.019	-0.058	-0.050	-0.008
50	1.030 Un	0.504	1.029	-0.075	-0.075	0.000
50	1.040 Un	0.504	1.039	-0.103	-0.100	-0.003
50	1.050 Un	0.504	1.049	-0.230	-0.228	-0.002
50	1.060 Un	0.506	1.059	-0.358	-0.356	-0.002
50	1.070 Un	0.506	1.069	-0.486	-0.484	-0.002
50	1.080 Un	0.506	1.079	-0.486	-0.484	-0.002
50	1.090 Un	0.507	1.090	-0.486	-0.484	-0.002
50	1.100 Un	0.507	1.100	-0.485	-0.484	-0.001
50	1.050 Un	0.505	1.050	-0.230	-0.228	-0.002
50	1.000 Un	0.503	0.999	-0.022	0.000	-0.022

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.

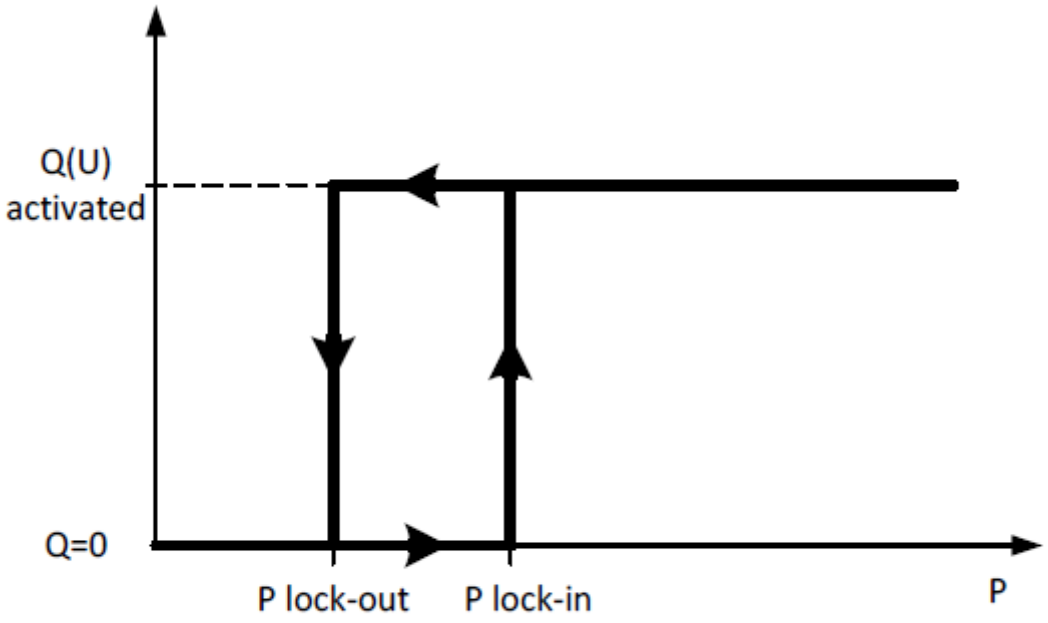


Figure 14 – Example of lock-in and lock-out values for Q(U) mode

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

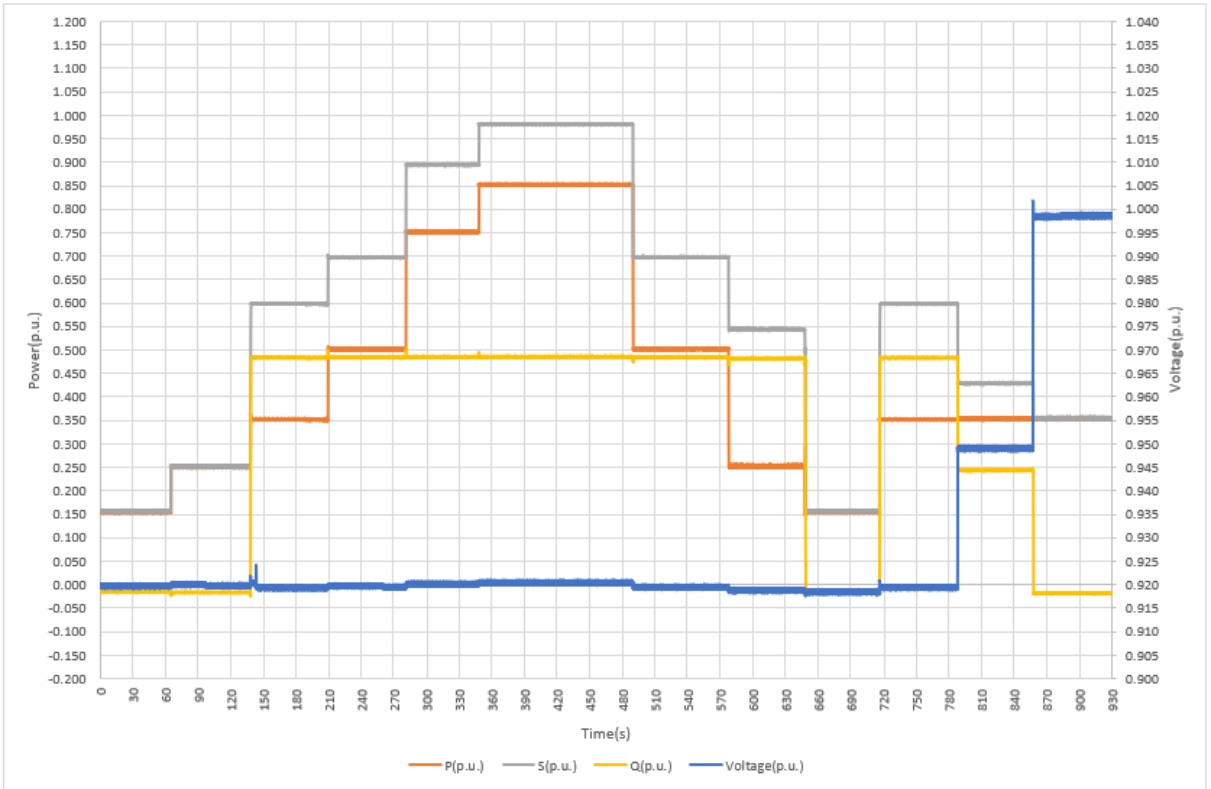
P lock-in = 30 %, P lock-out = 20 %

Test results are offered at the tables below.

Reactive power injection in relation with the Voltage (inductive)						
P/Pn setpoint (%Pn)	U setpoint (p.u.)	P meas. (p.u.)	V meas. (p.u.)	Q meas. (p.u.)	Q desired (p.u.)	ΔQ (< ±0.05 p.u.)
<20	0.920	0.154	0.920	-0.016	0.000	-0.016
25	0.920	0.250	0.920	-0.016	0.000	-0.016
35	0.920	0.352	0.919	0.484	0.484	0.000
50	0.920	0.502	0.920	0.484	0.484	0.000
75	0.920	0.751	0.920	0.485	0.484	0.001
90(*)	0.920	0.852	0.920	0.486	0.484	0.002
100(*)	0.920	0.852	0.920	0.486	0.484	0.002
50	0.920	0.502	0.919	0.485	0.484	0.001
25	0.920	0.252	0.919	0.482	0.484	-0.002
<20	0.920	0.155	0.918	-0.017	0.000	-0.017
35	0.920	0.352	0.919	0.483	0.484	-0.001
35	0.950	0.353	0.949	0.244	0.242	0.002
35	1.000	0.353	0.999	-0.019	0.000	-0.019

(*) The EUT does not reach the setpoint power value due to the current limitation function.

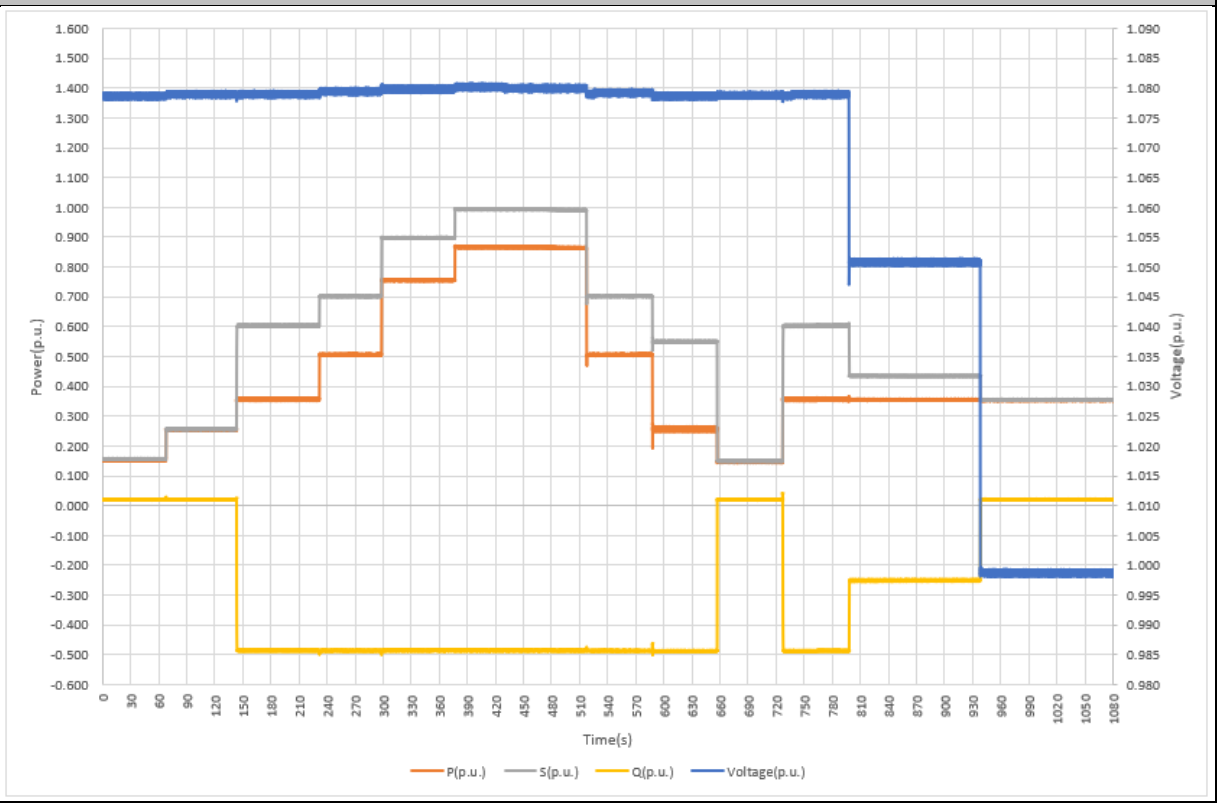
Reactive power injection in relation with the Voltage (inductive)



Reactive power injection in relation with the Voltage (capacitive)						
P/Pn setpoint (%Pn)	U setpoint (p.u.)	P meas. (p.u.)	V meas. (p.u.)	Q meas. (p.u.)	Q desired (p.u.)	ΔQ (< ±0.05 p.u.)
<20	1.080	0.153	1.079	0.020	0.000	0.020
25	1.080	0.254	1.079	0.021	0.000	0.021
35	1.080	0.356	1.079	-0.486	-0.484	-0.002
50	1.080	0.506	1.079	-0.486	-0.484	-0.002
75	1.080	0.756	1.080	-0.485	-0.484	-0.001
90(*)	1.080	0.867	1.080	-0.485	-0.484	-0.001
100(*)	1.080	0.865	1.080	-0.485	-0.484	-0.001
50	1.080	0.506	1.079	-0.486	-0.484	-0.002
25	1.080	0.257	1.079	-0.487	-0.484	-0.003
<20	1.080	0.146	1.079	0.020	0.000	0.020
35	1.080	0.357	1.079	-0.486	-0.484	-0.002
35	1.050	0.355	1.051	-0.251	-0.242	-0.009
35	1.000	0.353	0.999	0.021	0.000	0.021

(*) The EUT does not reach the setpoint power value due to the current limitation function.

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 $\%P_D$ plus a time delay of up to 3 seconds deviating from an ideal first order filter response.

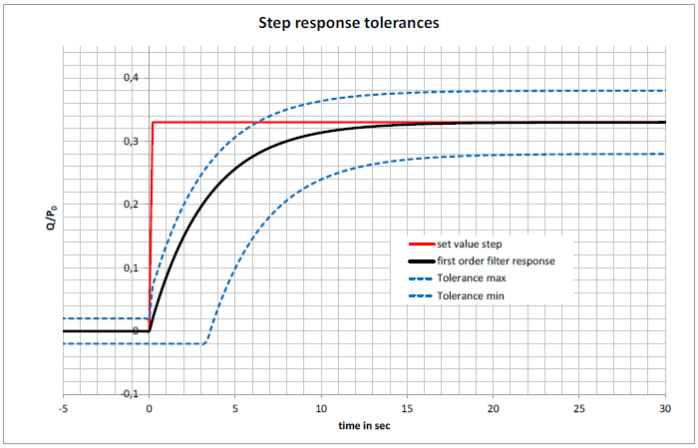
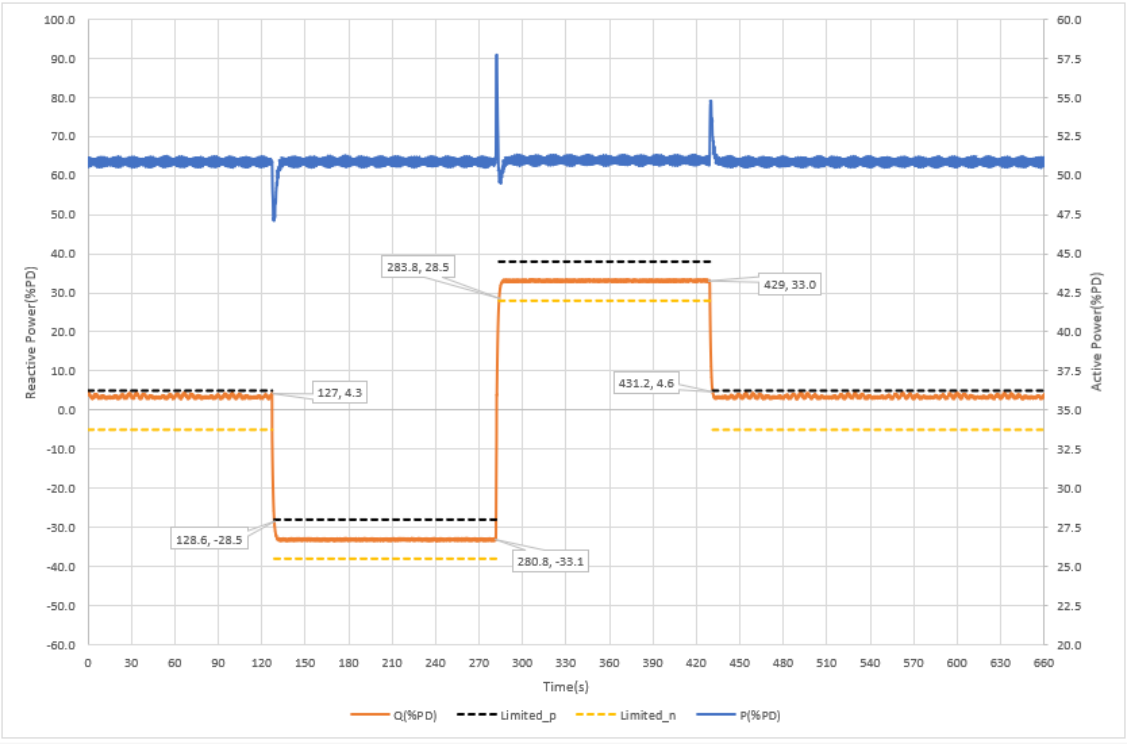


Figure 15 — Example of dynamic control response and tolerance band for a step from Q=0 to Q= 33%P_D with τ=3,33s

Test results are offered at the tables below.

%Pn	Steps	Time measured (s)
50	Q = 0 → Q = 33 %Sn	t = 1.6
	Q = 33 %Sn → Q = 33 %Sn	t = 3.0
	Q = 33 %Sn → Q = 0	t = 1.2

Reactive power injection in relation with the Voltage (inductive)

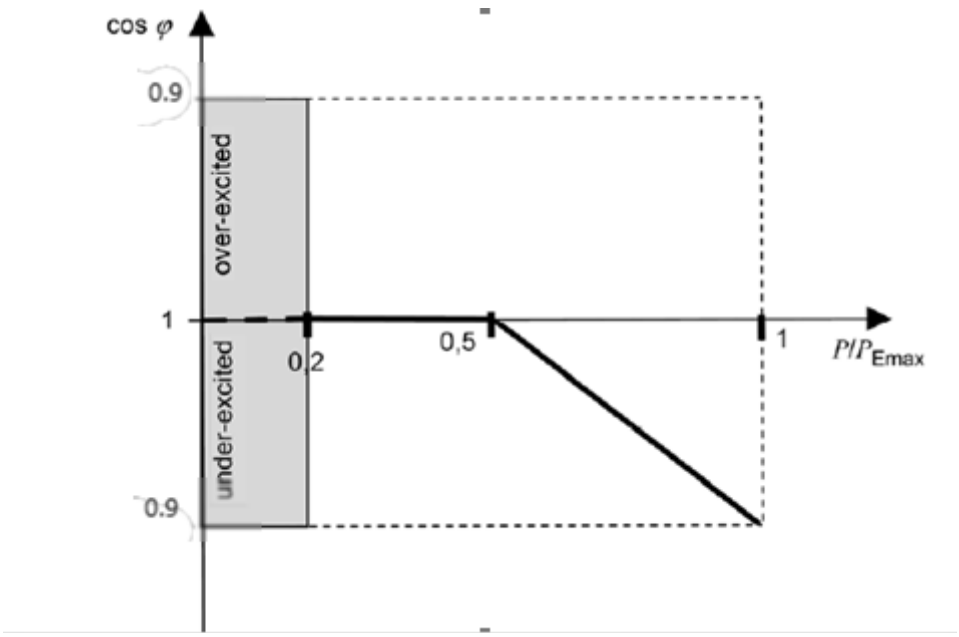


4.4.2.4 Power related control mode

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 follows:



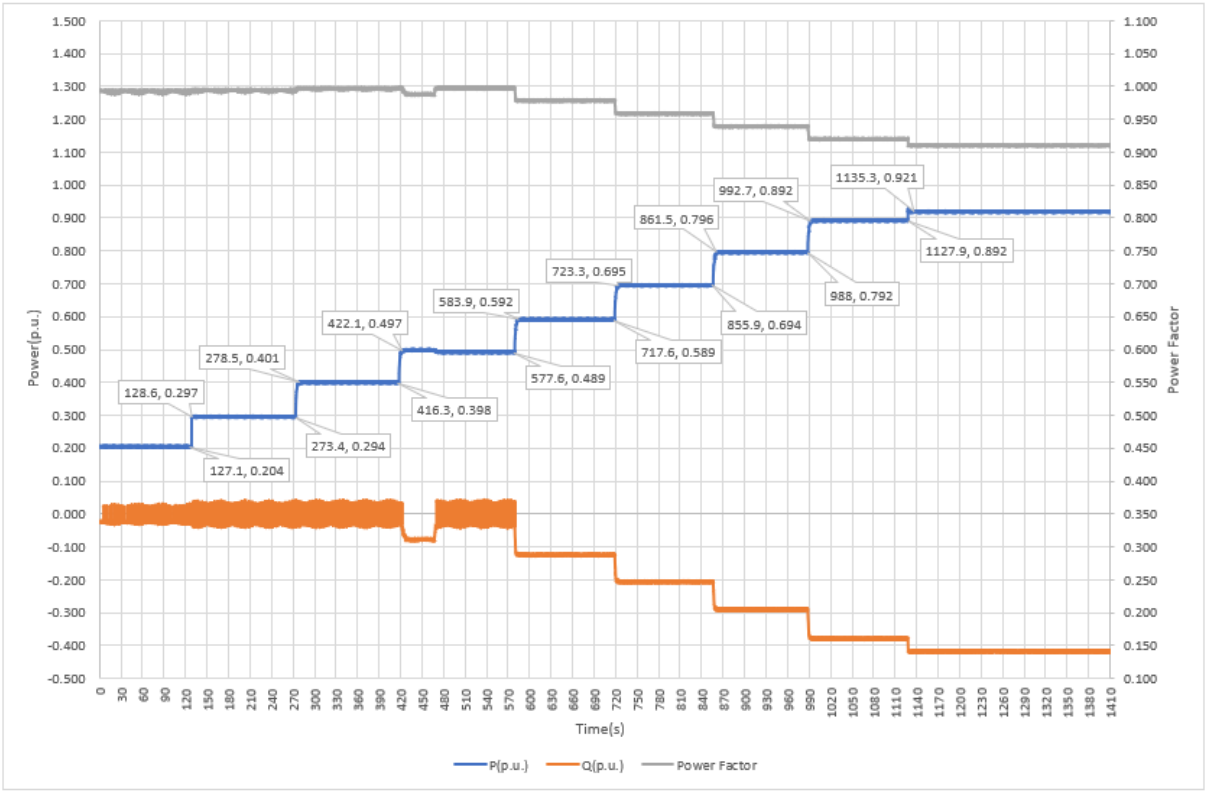
Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive 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 has not measured in the following test):

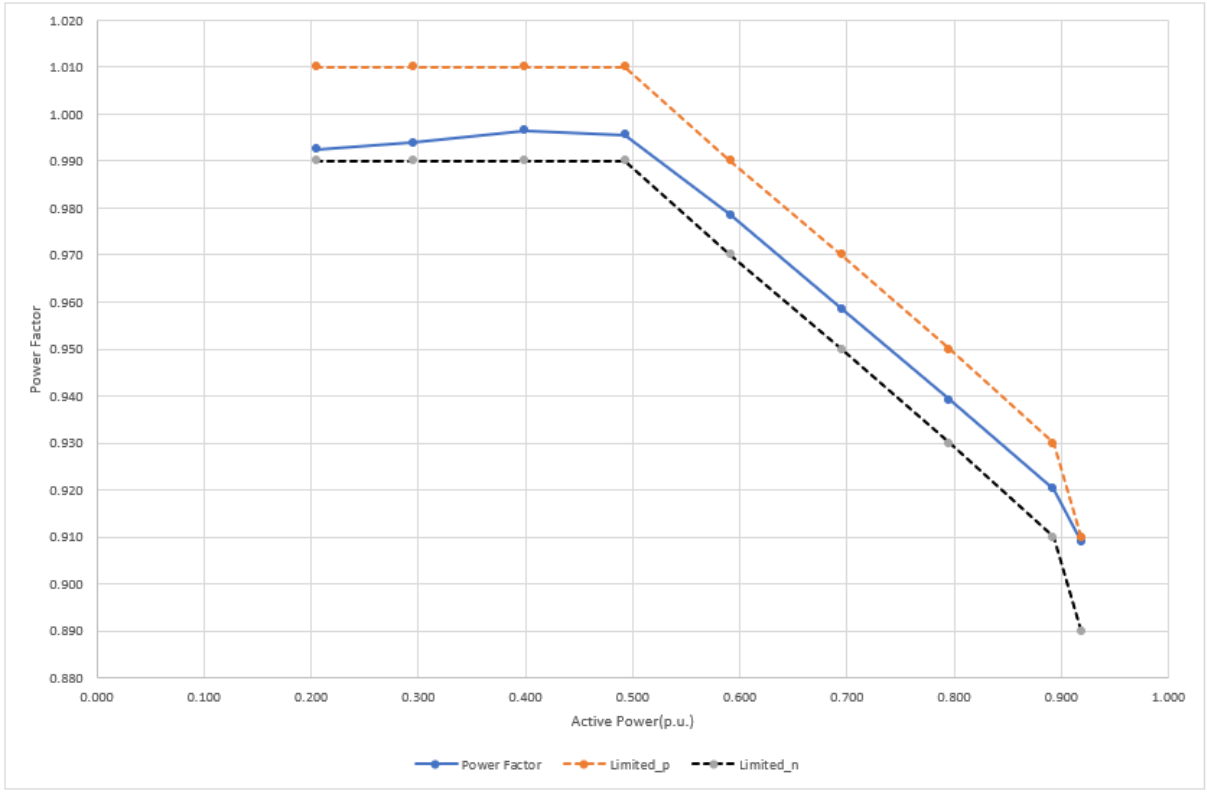
Setting cos φ(P) with the standard characteristic curve (20%Pn to 100%Pn)						
Active power setting (%P_{Emax})	**Active power measured (p.u.)**	**Reactive power measured (p.u.)**	**cos φ measured**	**Desired cos φ**	**Δ cos φ (< 0.01)**	**Transient period (< 10 s)**
20	0.205	-0.021	0.992	1	-0.008	
30	0.295	-0.014	0.994	1	-0.006	1.5
40	0.400	0.003	0.996	1	-0.004	5.1
50	0.493	-0.016	0.996	1	-0.004	5.6
60	0.592	-0.125	0.979	0.98	-0.001	6.3
70	0.695	-0.207	0.959	0.96	-0.001	5.7
80	0.796	-0.291	0.939	0.94	-0.001	5.6
90	0.892	-0.379	0.920	0.92	0.000	4.7
100 (*)	0.919	-0.418	0.909	0.90	0.009	7.4

(*) Because of limited by apparent power, 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)



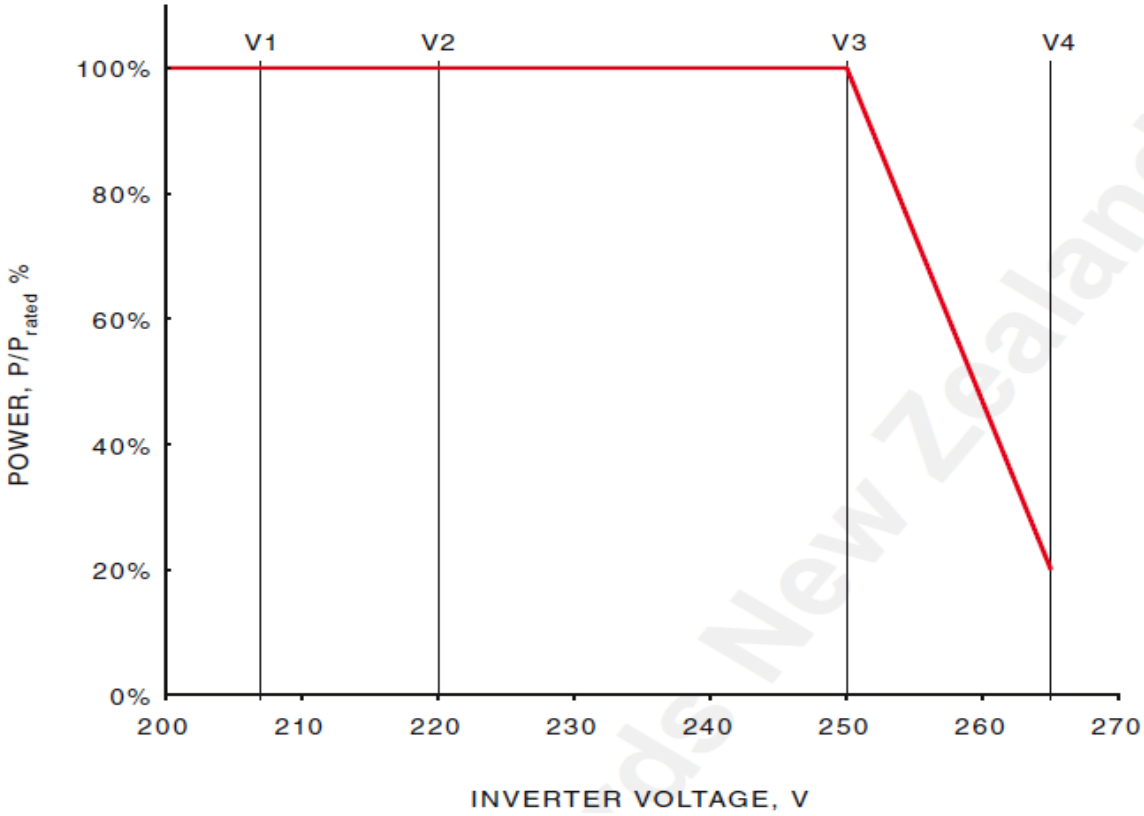
Power factor vs Active Power



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 final implemented logic can be chosen by the manufacturer. Nevertheless, this logic shall not cause steps or oscillations in the output power. The power reduction caused by such a function may not be faster than an equivalent of a time constant tau = 3 s (= 33 %/s at a 100 % change).
I
The following paramaeters have been set by the manufacturer for this test:



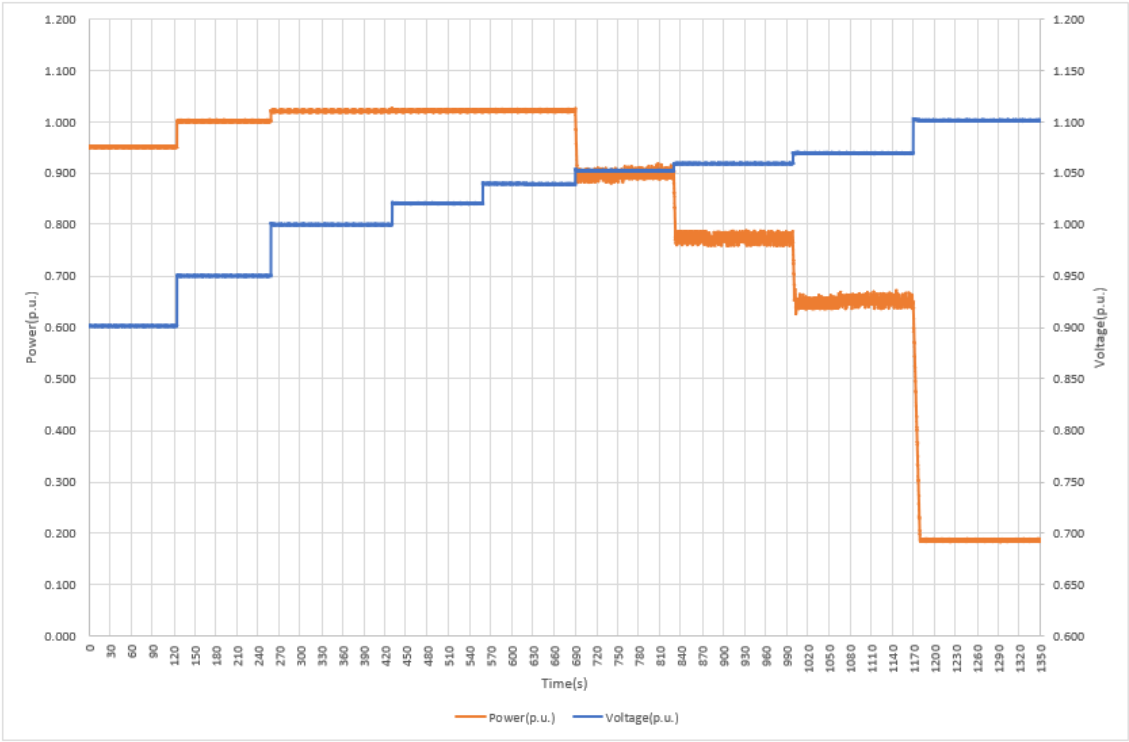
Test 1 and Test 2 setpoint as following:

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%

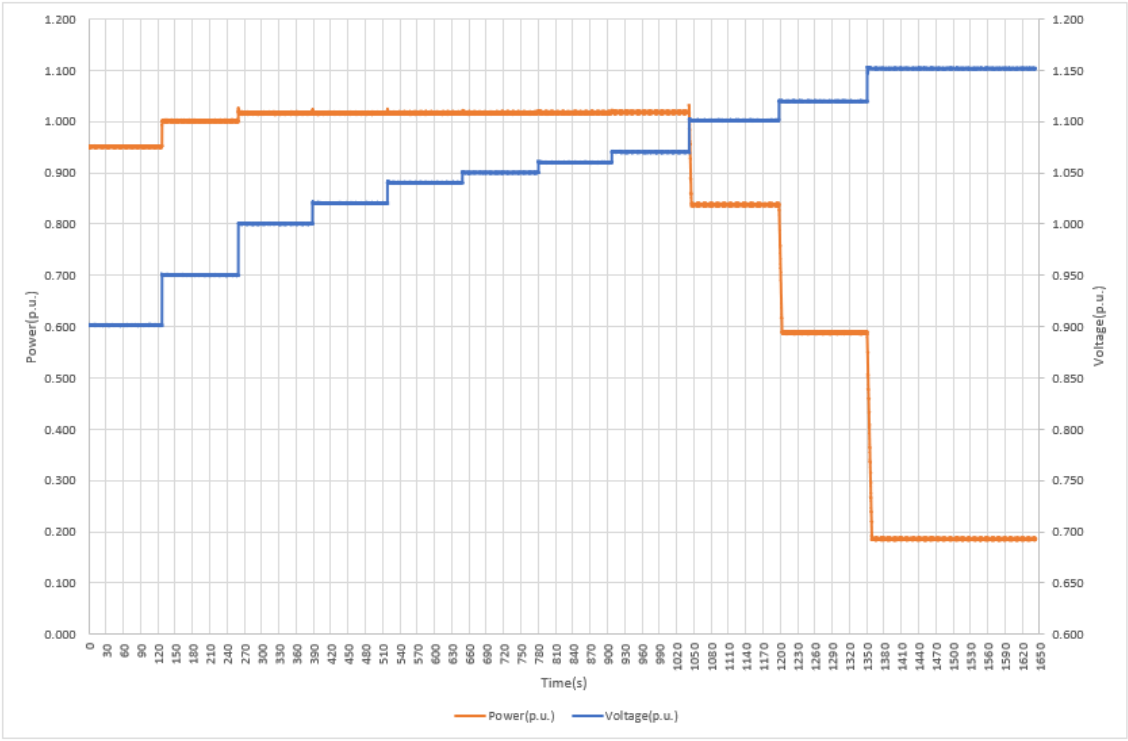
Test results are offered at tables below.

Volt-Watt TEST 1				
V setting (p.u.)	**V meas. (p.u.)**	**P desired (p.u.)**	**P meas. (p.u.)**	**P deviation (p.u.)**
0.900	0.901	1.000	0.951	-0.049
0.950	0.950	1.000	1.001	0.001
1.000	1.000	1.000	1.021	0.021
1.020	1.021	1.000	1.021	0.021
1.040	1.040	1.000	1.022	0.022
1.050	1.053	0.886	0.895	0.009
1.060	1.059	0.771	0.771	0.000
1.070	1.070	0.657	0.647	-0.010
1.100	1.101	0.200	0.186	-0.014
Volt-Watt TEST 2				
V setting (p.u.)	**V meas. (p.u.)**	**P desired (p.u.)**	**P meas. (p.u.)**	**P deviation (p.u.)**
0.900	0.901	1.000	0.951	-0.049
0.950	0.950	1.000	1.001	0.001
1.000	1.000	1.000	1.016	0.016
1.020	1.021	1.000	1.016	0.016
1.040	1.040	1.000	1.017	0.017
1.050	1.050	1.000	1.017	0.017
1.060	1.060	1.000	1.017	0.017
1.070	1.070	1.000	1.018	0.018
1.100	1.101	0.840	0.838	-0.002
1.120	1.120	0.584	0.588	0.004
1.152	1.152	0.200	0.186	-0.014

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 are stated in clause 4.7.4.2.1 of the standard.

The EUT is classified as Type A. This test is not applicable.

4.4.4.1.2 Zero current mode for converter connected generating technology

The requirements are stated in clause 4.7.4.2.2 of the standard.

The EUT is classified as Type A. This test is not applicable.

4.4.4.1.3 Induction generator based units

The requirements are stated in 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 are stated in 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 compliances with these requirements are stated in the test report: n. 201008077GZU-001 dated on 2020/11/29, issued by Intertek Testing Services Shenzhen Ltd. Guangzhou Branch, covering the following standards:

EN 61000-6-1:2007
EN 61000-6-3: 2007+A1: 2011
EN 61000-6-2:2005
EN 61000-6-4:2007+A1: 2011

Note: Aside of EMC evidences of compliances, the harmonic and flicker content has been measured just to provide further information of the tested unit, and the results are stated in the following items 4.5.1 and 4.5.2 of the report.

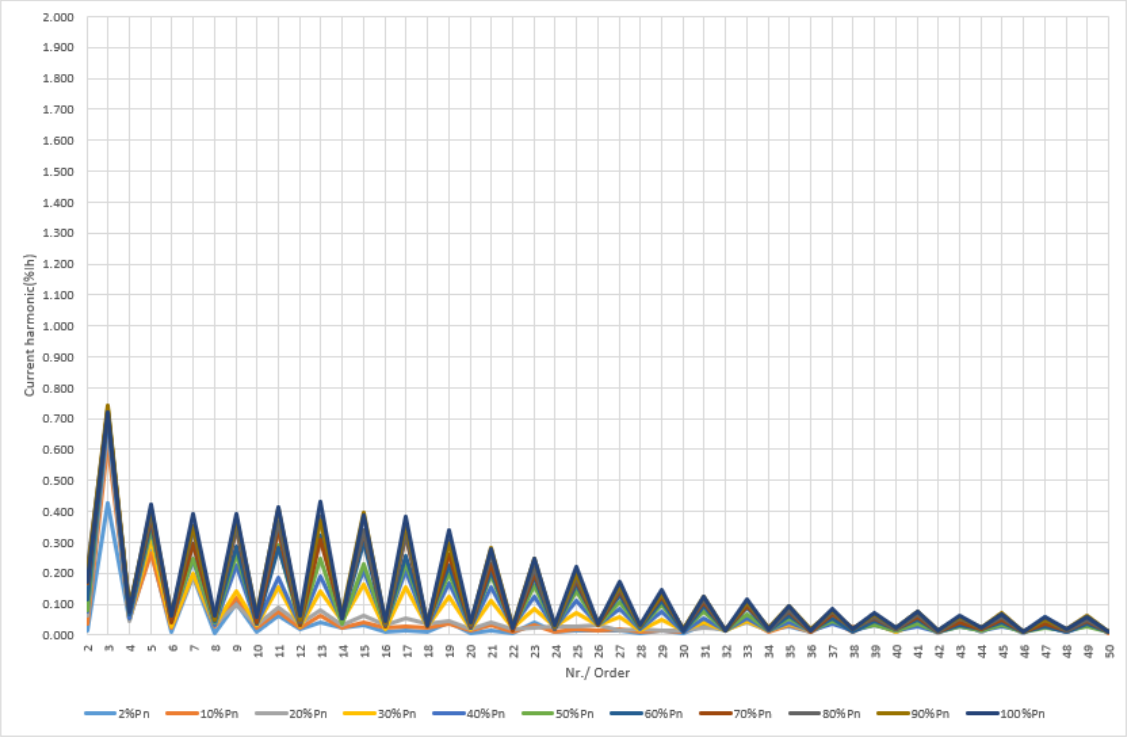
4.5.1. Harmonic emissions

Requirements according to the clause 4.8 of the standard.

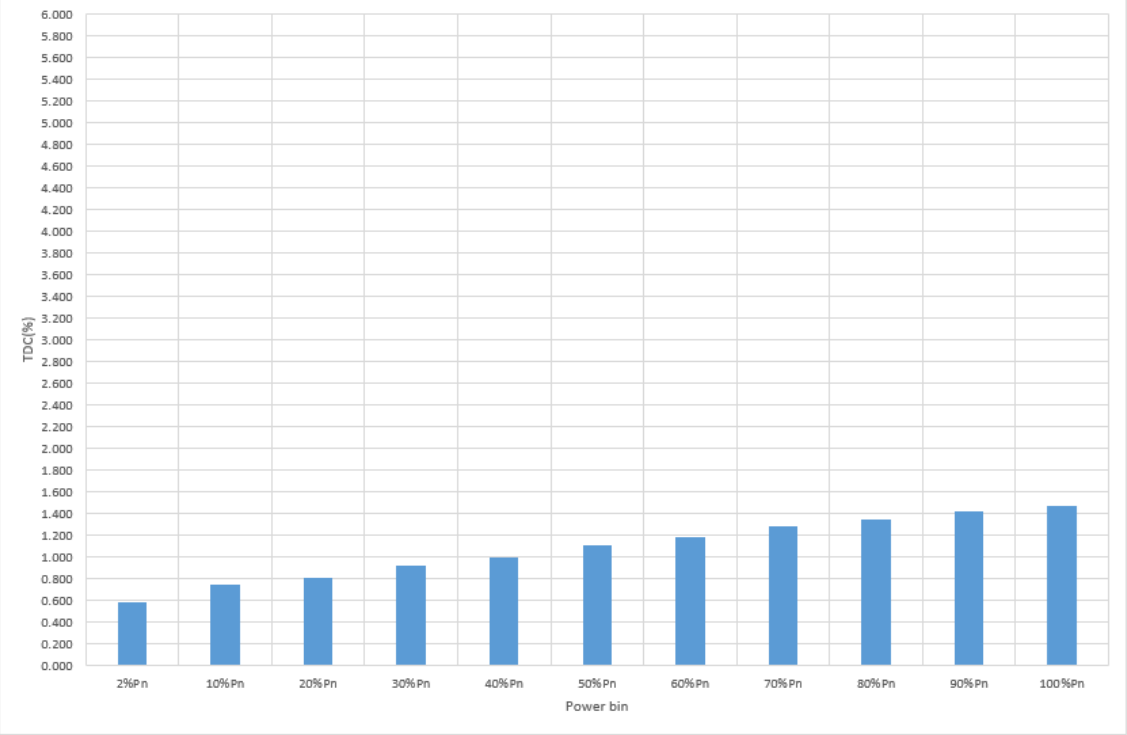
The values measured for current harmonics are respectively offered in the following points.

P_n (%)	2	10	20	30	40	50	60	70	80	90	100	Max (%)
Nr./ Order	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	
2	0.014	0.038	0.063	0.085	0.075	0.080	0.115	0.170	0.214	0.193	0.173	0.214
3	0.426	0.619	0.664	0.718	0.696	0.733	0.711	0.729	0.720	0.744	0.721	0.744
4	0.048	0.056	0.043	0.056	0.052	0.075	0.068	0.086	0.090	0.090	0.075	0.090
5	0.272	0.266	0.334	0.310	0.344	0.342	0.360	0.379	0.392	0.410	0.422	0.422
6	0.011	0.024	0.037	0.030	0.044	0.054	0.055	0.043	0.064	0.066	0.063	0.066
7	0.191	0.196	0.190	0.201	0.244	0.248	0.295	0.294	0.337	0.353	0.390	0.390
8	0.008	0.028	0.038	0.032	0.034	0.041	0.044	0.051	0.053	0.050	0.061	0.061
9	0.104	0.122	0.098	0.143	0.226	0.260	0.284	0.342	0.348	0.379	0.394	0.394
10	0.011	0.022	0.030	0.033	0.037	0.046	0.036	0.041	0.058	0.067	0.061	0.067
11	0.062	0.078	0.089	0.156	0.187	0.292	0.281	0.338	0.363	0.409	0.412	0.412
12	0.018	0.022	0.037	0.028	0.034	0.033	0.052	0.030	0.039	0.051	0.062	0.062
13	0.041	0.063	0.082	0.142	0.189	0.247	0.323	0.309	0.384	0.370	0.430	0.430
14	0.022	0.026	0.033	0.046	0.046	0.039	0.056	0.059	0.053	0.068	0.055	0.068
15	0.034	0.043	0.062	0.164	0.205	0.230	0.300	0.336	0.339	0.394	0.387	0.394
16	0.011	0.025	0.034	0.018	0.030	0.027	0.034	0.029	0.034	0.043	0.043	0.043
17	0.015	0.029	0.053	0.154	0.209	0.234	0.258	0.321	0.325	0.359	0.383	0.383
18	0.011	0.023	0.037	0.026	0.030	0.036	0.035	0.029	0.043	0.034	0.031	0.043
19	0.041	0.035	0.045	0.125	0.168	0.199	0.224	0.261	0.303	0.295	0.339	0.339
20	0.007	0.015	0.019	0.021	0.022	0.029	0.024	0.030	0.033	0.036	0.040	0.040
21	0.015	0.030	0.043	0.109	0.154	0.194	0.208	0.228	0.262	0.282	0.278	0.282
22	0.008	0.012	0.019	0.022	0.026	0.023	0.022	0.014	0.024	0.029	0.022	0.029
23	0.043	0.034	0.023	0.083	0.125	0.159	0.186	0.200	0.216	0.247	0.245	0.247
24	0.010	0.012	0.026	0.029	0.025	0.025	0.018	0.033	0.018	0.029	0.034	0.034
25	0.013	0.021	0.026	0.072	0.111	0.142	0.163	0.179	0.187	0.197	0.221	0.221
26	0.016	0.016	0.032	0.034	0.033	0.033	0.036	0.032	0.039	0.036	0.039	0.039
27	0.015	0.018	0.016	0.057	0.084	0.108	0.126	0.144	0.151	0.160	0.173	0.173
28	0.006	0.009	0.018	0.016	0.018	0.022	0.022	0.031	0.028	0.029	0.034	0.034
29	0.014	0.014	0.016	0.051	0.076	0.099	0.112	0.123	0.134	0.135	0.145	0.145
30	0.007	0.011	0.014	0.013	0.012	0.013	0.010	0.018	0.018	0.020	0.017	0.020
31	0.033	0.042	0.025	0.043	0.054	0.076	0.094	0.105	0.117	0.123	0.124	0.124
32	0.014	0.019	0.019	0.016	0.014	0.014	0.014	0.014	0.017	0.015	0.015	0.019
33	0.051	0.051	0.040	0.046	0.052	0.067	0.087	0.095	0.105	0.107	0.116	0.116
34	0.017	0.011	0.014	0.016	0.015	0.016	0.015	0.026	0.015	0.023	0.018	0.026
35	0.027	0.034	0.036	0.036	0.042	0.053	0.064	0.075	0.081	0.093	0.092	0.093
36	0.010	0.012	0.011	0.013	0.016	0.015	0.013	0.012	0.013	0.017	0.014	0.017
37	0.050	0.044	0.047	0.044	0.039	0.046	0.055	0.067	0.076	0.082	0.087	0.087
38	0.014	0.010	0.015	0.013	0.014	0.019	0.012	0.025	0.018	0.021	0.020	0.025
39	0.049	0.043	0.036	0.035	0.030	0.033	0.045	0.054	0.061	0.069	0.071	0.071
40	0.010	0.013	0.010	0.010	0.013	0.015	0.019	0.019	0.018	0.022	0.024	0.024
41	0.050	0.050	0.041	0.037	0.027	0.037	0.048	0.058	0.066	0.074	0.077	0.077
42	0.008	0.009	0.008	0.010	0.011	0.009	0.008	0.011	0.010	0.013	0.013	0.013
43	0.044	0.048	0.039	0.042	0.027	0.026	0.034	0.043	0.053	0.058	0.063	0.063
44	0.008	0.014	0.012	0.013	0.013	0.016	0.018	0.020	0.022	0.025	0.025	0.025
45	0.043	0.036	0.040	0.036	0.027	0.032	0.043	0.051	0.059	0.072	0.069	0.072
46	0.006	0.010	0.008	0.011	0.013	0.010	0.009	0.009	0.008	0.012	0.012	0.013
47	0.058	0.046	0.046	0.044	0.027	0.026	0.030	0.037	0.048	0.050	0.059	0.059
48	0.009	0.011	0.009	0.010	0.009	0.013	0.011	0.015	0.015	0.018	0.021	0.021
49	0.054	0.050	0.045	0.040	0.032	0.030	0.039	0.047	0.050	0.062	0.058	0.062
50	0.008	0.008	0.009	0.009	0.012	0.011	0.009	0.008	0.009	0.012	0.011	0.012
TDC (%)	0.584	0.745	0.812	0.923	0.999	1.109	1.182	1.278	1.351	1.425	1.465	1.465

Current Harmonics



Total Distortion Current Harmonic



4.5.2. Flicker and voltage fluctuations

Requirements 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.

Each step of this test running for 10 minutes, total of 12 steps:

The values took of the most unfavorable of the 12 steps.

Test at 33 %Pn				
Pbin (%)	**Limit**	**Phase A**	**Phase B**	**Phase C**
P_{ST}	≤ 1.0	0.061	--	--
P_{LT}	≤ 0.65	0.054	--	--
dc	≤ 3.30 %	0.108%	--	--
dmax	4 %	0.219%	--	--

Test at 66 %Pn				
Pbin (%)	**Limit**	**Phase A**	**Phase B**	**Phase C**
P_{ST}	≤ 1.0	0.062	--	--
P_{LT}	≤ 0.65	0.058	--	--
dc	≤ 3.30 %	0.108%	--	--
dmax	4 %	0.205%	--	--

Test at 100%Pn				
Pbin (%)	**Limit**	**Phase A**	**Phase B**	**Phase C**
P_{ST}	≤ 1.0	0.207	--	--
P_{LT}	≤ 0.65	0.204	--	--
dc	≤ 3.30 %	0.089%	--	--
dmax	4 %	0.246%	--	--

Test at 33 %Pn

Count 12/12 Complete
Interval 00:00s/10:00s

Element 1
Volt Range 600 V/50Hz
Un (U1) 231.214V
Freq (U1) 50.000Hz
Dmin 0.10%

Element1 Judgement Pass
Total Judgement Pass
(Element1)

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.00%		1.00		0.65 N:12	
No. 1	0.095	Pass	0.148	Pass	0.0	Pass	0.041	Pass		
2	0.092	Pass	0.138	Pass	0.0	Pass	0.035	Pass		
3	0.105	Pass	0.130	Pass	0.0	Pass	0.049	Pass		
4	0.105	Pass	0.156	Pass	0.0	Pass	0.056	Pass		
5	0.099	Pass	0.219	Pass	0.0	Pass	0.055	Pass		
6	0.101	Pass	0.135	Pass	0.0	Pass	0.055	Pass		
7	0.106	Pass	0.140	Pass	0.0	Pass	0.057	Pass		
8	0.102	Pass	0.150	Pass	0.0	Pass	0.056	Pass		
9	0.100	Pass	0.142	Pass	0.0	Pass	0.056	Pass		
10	0.108	Pass	0.142	Pass	0.0	Pass	0.058	Pass		
11	0.102	Pass	0.134	Pass	0.0	Pass	0.061	Pass		
12	0.100	Pass	0.147	Pass	0.0	Pass	0.060	Pass		
Result		Pass		Pass		Pass		Pass	0.054	Pass

Test at 66 %Pn

Count 12/12 Complete
Interval 00:00s/10:00s

Element 1
Volt Range 600 V/50Hz
Un (U1) 231.388V
Freq (U1) 50.000Hz
Dmin 0.10%

Element1 Judgement Pass
Total Judgement Pass
(Element1)

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.00%		1.00		0.65 N:12	
No. 1	0.093	Pass	0.151	Pass	0.0	Pass	0.056	Pass		
2	0.098	Pass	0.135	Pass	0.0	Pass	0.062	Pass		
3	0.108	Pass	0.194	Pass	0.0	Pass	0.060	Pass		
4	0.096	Pass	0.170	Pass	0.0	Pass	0.059	Pass		
5	0.106	Pass	0.147	Pass	0.0	Pass	0.058	Pass		
6	0.099	Pass	0.205	Pass	0.0	Pass	0.059	Pass		
7	0.104	Pass	0.142	Pass	0.0	Pass	0.058	Pass		
8	0.098	Pass	0.137	Pass	0.0	Pass	0.056	Pass		
9	0.099	Pass	0.134	Pass	0.0	Pass	0.056	Pass		
10	0.101	Pass	0.134	Pass	0.0	Pass	0.056	Pass		
11	0.101	Pass	0.164	Pass	0.0	Pass	0.056	Pass		
12	0.099	Pass	0.194	Pass	0.0	Pass	0.055	Pass		
Result		Pass		Pass		Pass		Pass	0.058	Pass

Test at 100 %Pn

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.00%		1.00		0.65 N:12	
No. 1	0.070	Pass	0.246	Pass	0.0	Pass	0.205	Pass		
2	0.074	Pass	0.210	Pass	0.0	Pass	0.204	Pass		
3	0.070	Pass	0.230	Pass	0.0	Pass	0.204	Pass		
4	0.057	Pass	0.169	Pass	0.0	Pass	0.204	Pass		
5	0.068	Pass	0.218	Pass	0.0	Pass	0.204	Pass		
6	0.089	Pass	0.197	Pass	0.0	Pass	0.207	Pass		
7	0.073	Pass	0.179	Pass	0.0	Pass	0.204	Pass		
8	0.074	Pass	0.175	Pass	0.0	Pass	0.204	Pass		
9	0.065	Pass	0.191	Pass	0.0	Pass	0.206	Pass		
10	0.081	Pass	0.198	Pass	0.0	Pass	0.203	Pass		
11	0.080	Pass	0.201	Pass	0.0	Pass	0.206	Pass		
12	0.080	Pass	0.234	Pass	0.0	Pass	0.203	Pass		
Result		Pass		Pass		Pass		Pass	0.204	Pass

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 %Un.
- The reset time shall be ≤50 ms.
- 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 <<]:

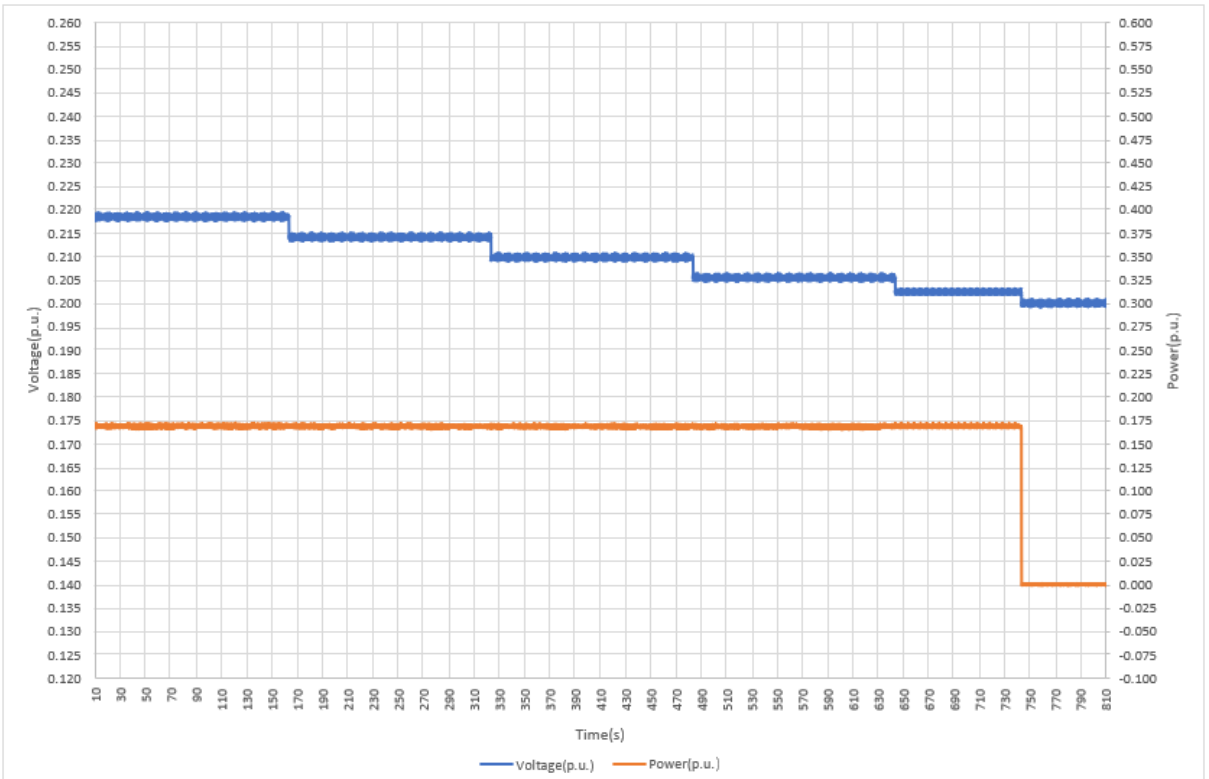
- Threshold (0.2 – 1) Un adjustable by steps of 0.01 Un
- Operate time (0.1 – 5) s adjustable in steps of 0.05 s

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

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

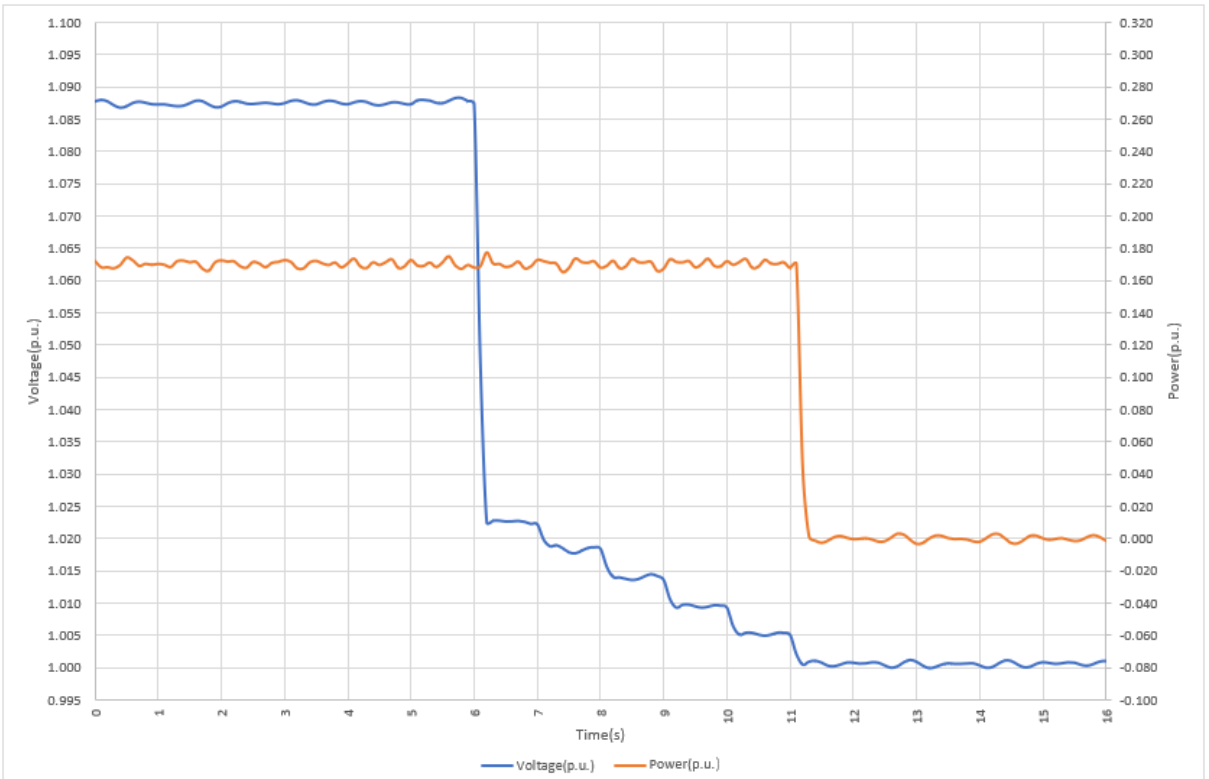
Undervoltage	Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [27 <]	1	0.200	0.199	-0.001	100.000	100.020	0.020
	2	1.000	1.000	0.000	0.100	0.101	0.001
Stage 2 [27 <<]	3	0.200	0.202	0.002	5.000	4.980	-0.020
	4	1.000	1.001	0.001	0.100	0.100	0.000

Undervoltage - Test 1: Trip value

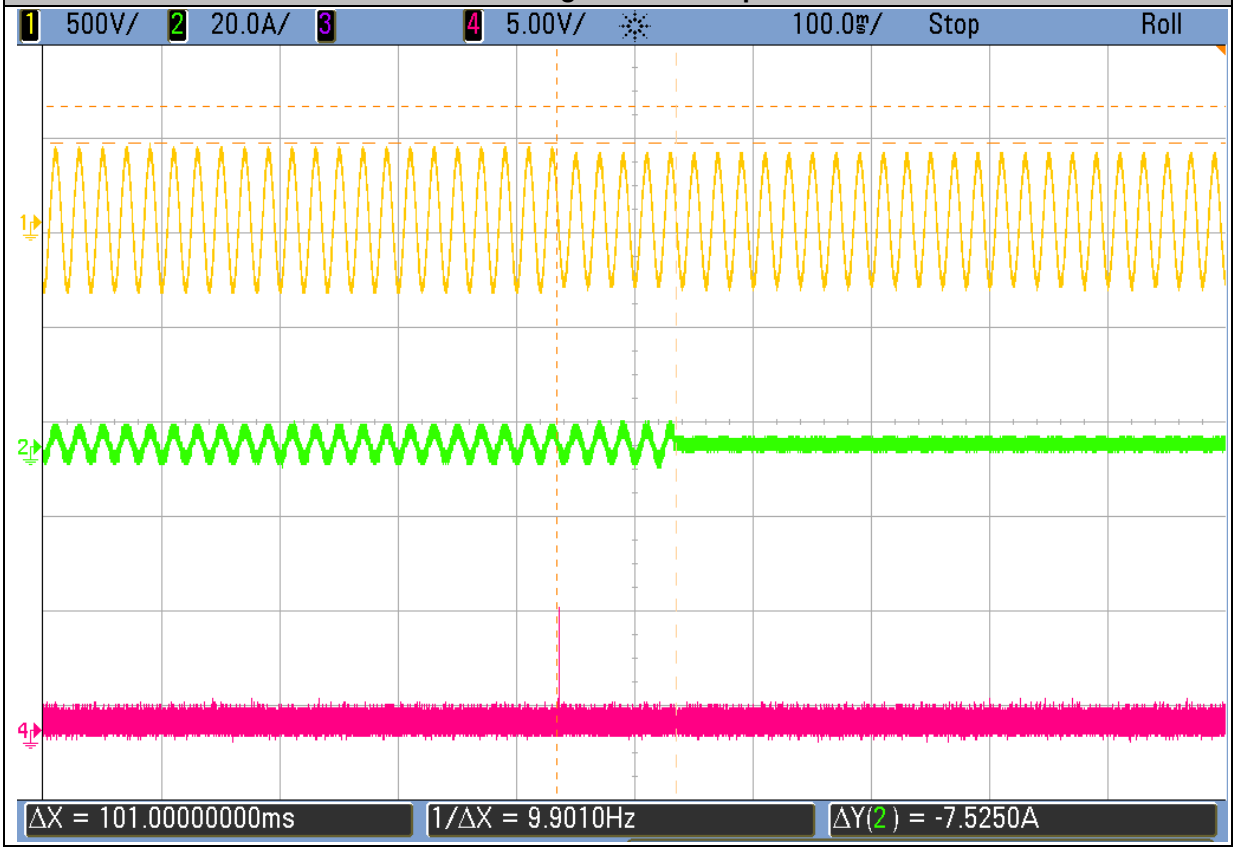


Undervoltage - Test 1: Trip time

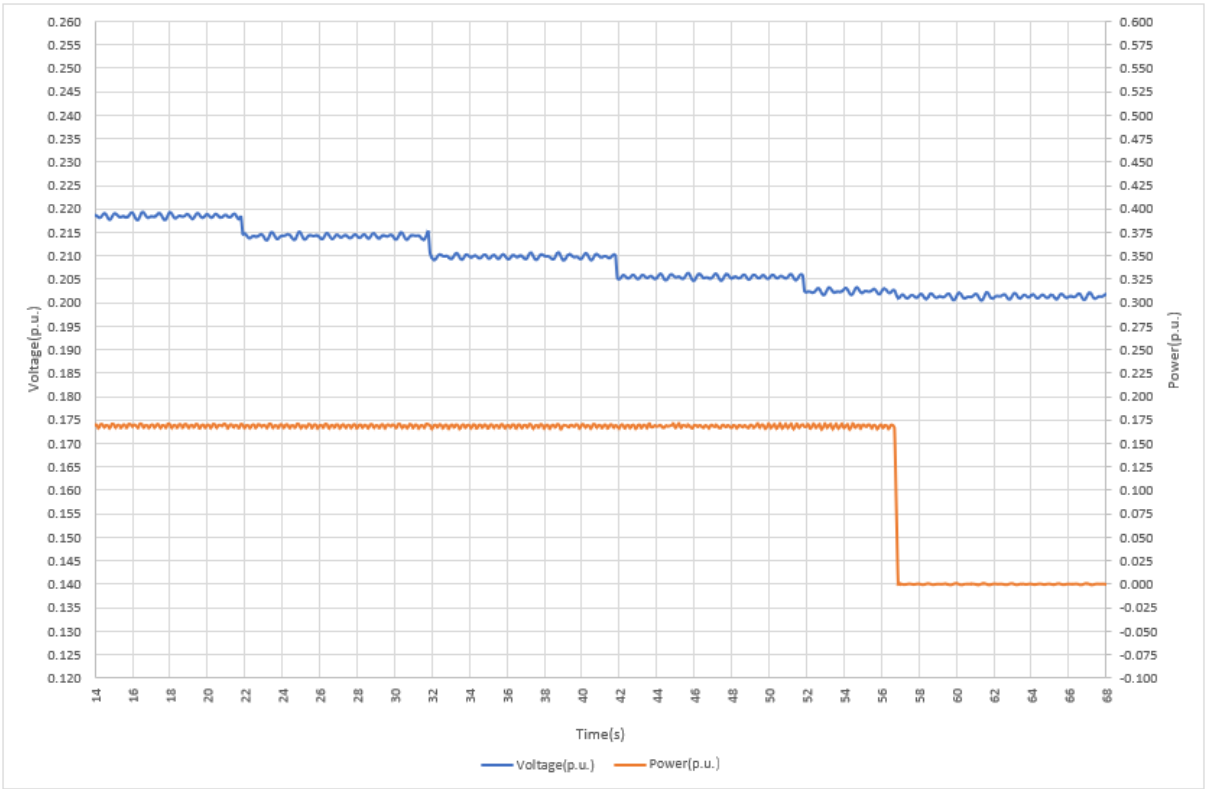
Under voltage - Test 2: Trip value



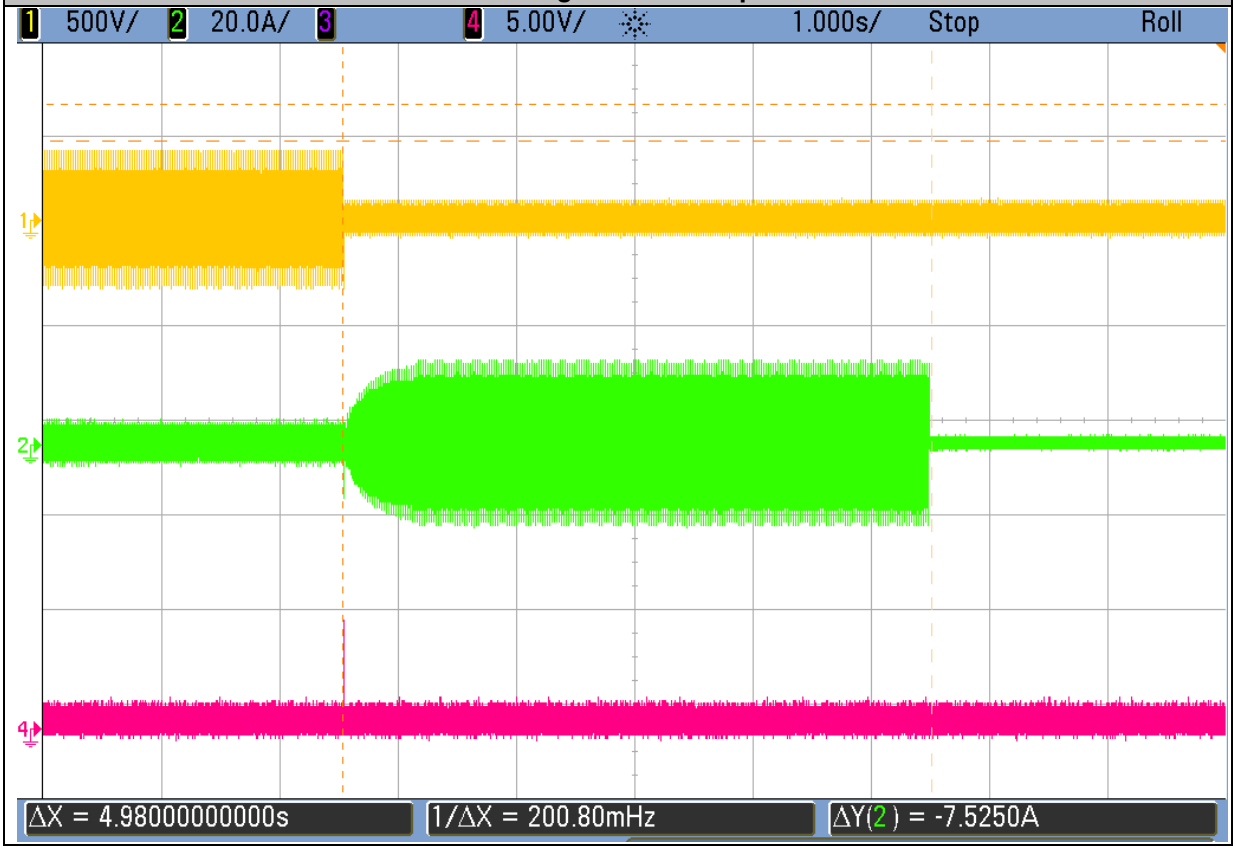
Under voltage - Test 2: Trip time



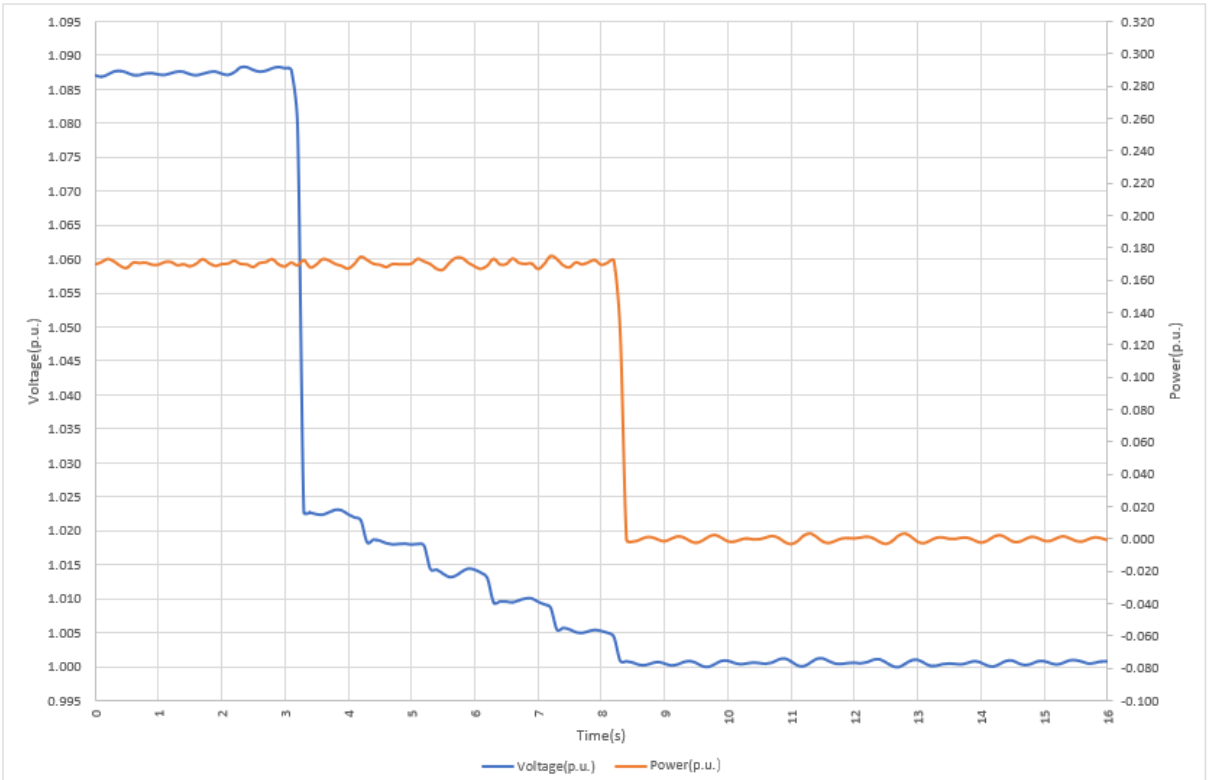
Undervoltage - Test 3: Trip value



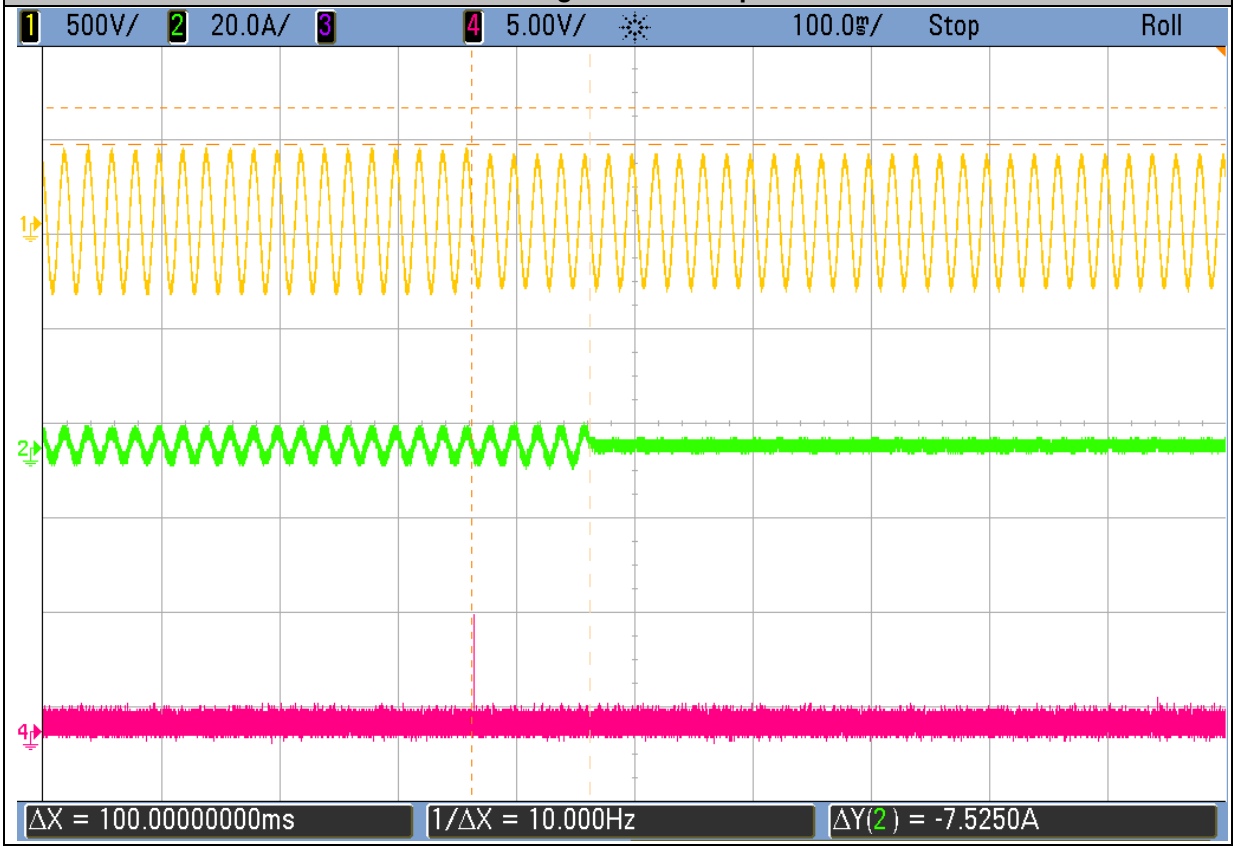
Undervoltage - Test 3: Trip time



Undervoltage - Test 4: Trip value



Undervoltage - Test 4: Trip time



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.

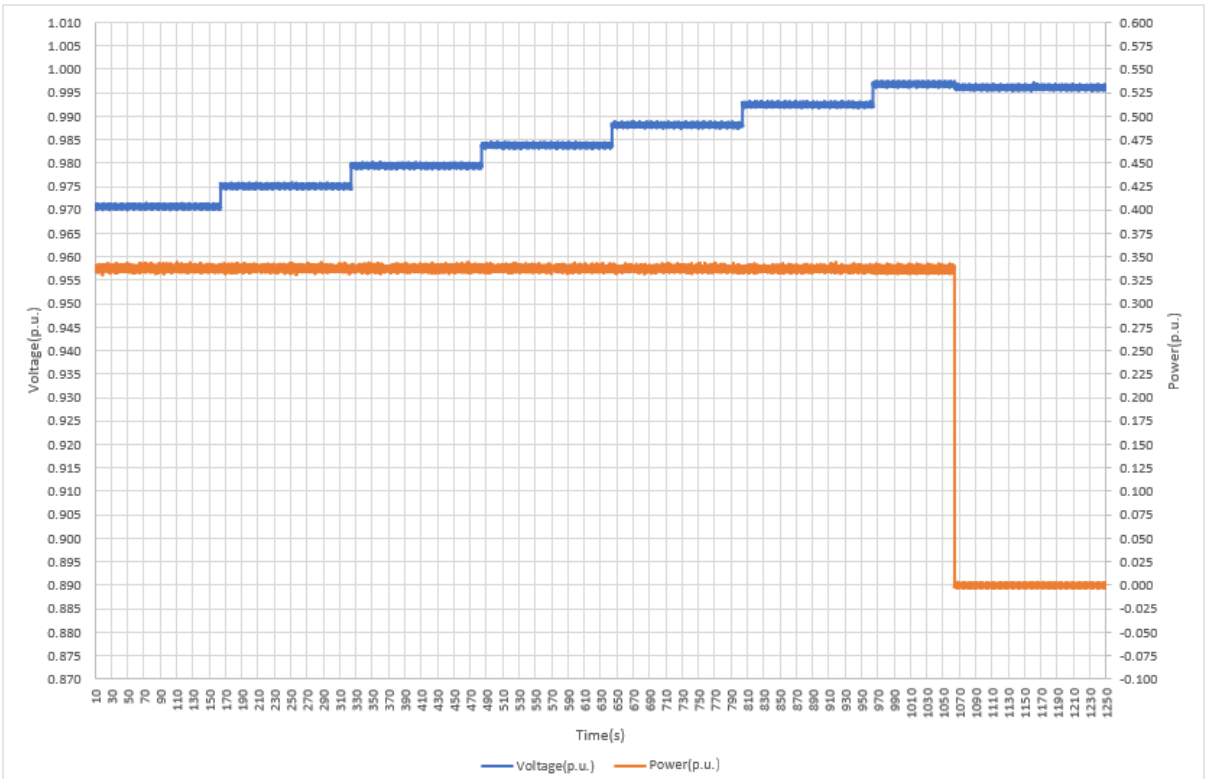
Overvoltage threshold stage 1 [59 >]:
- Threshold (1.0 – 1.2) *Un* adjustable by steps of 0.01 *Un*
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

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

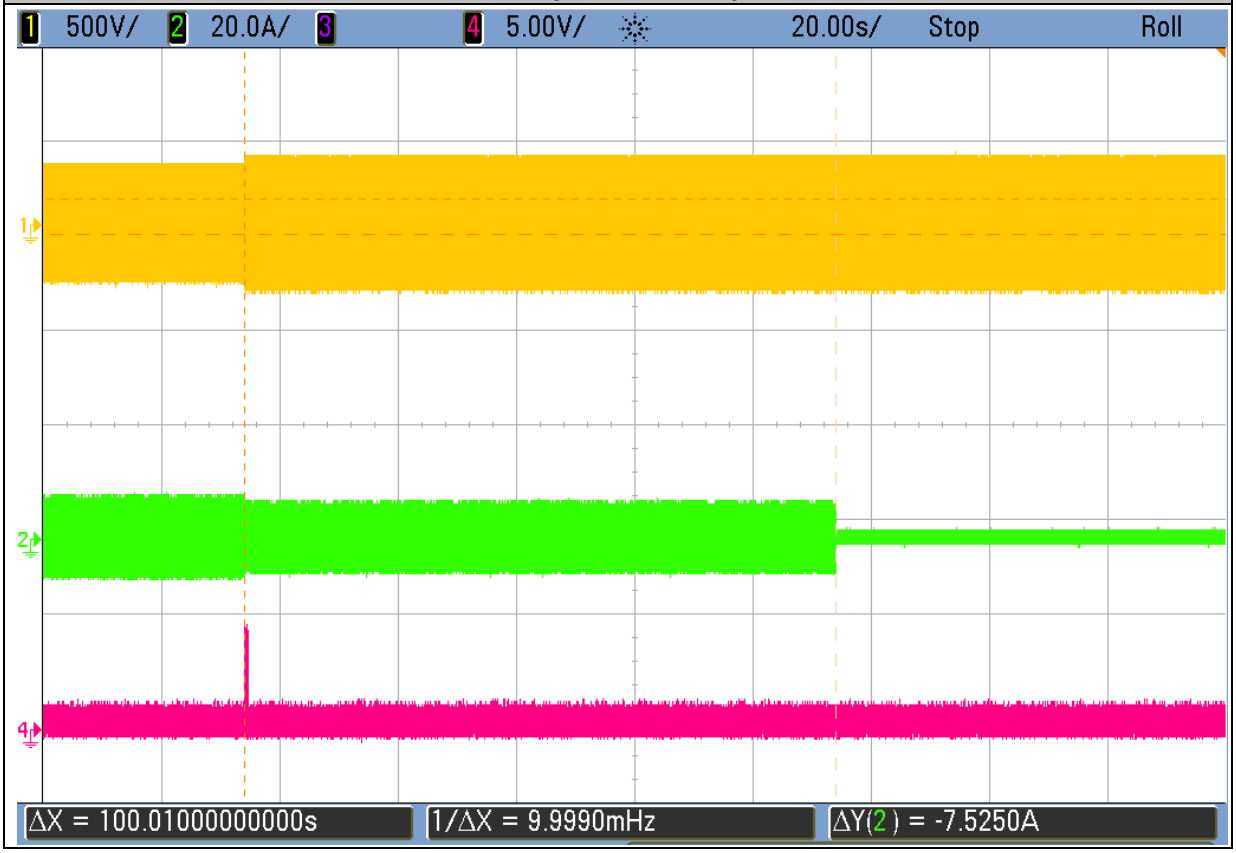
The following definitions apply to the test to verify the clause:

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	0.996	-0.004	100.000	100.010	0.010
	2	1.200	1.201	0.001	0.100	0.098	-0.002
Stage 2 [59 > >]	3	1.000	1.001	0.001	5.000	5.000	0.000
	4	1.300	1.301	0.001	0.100	0.106	0.006

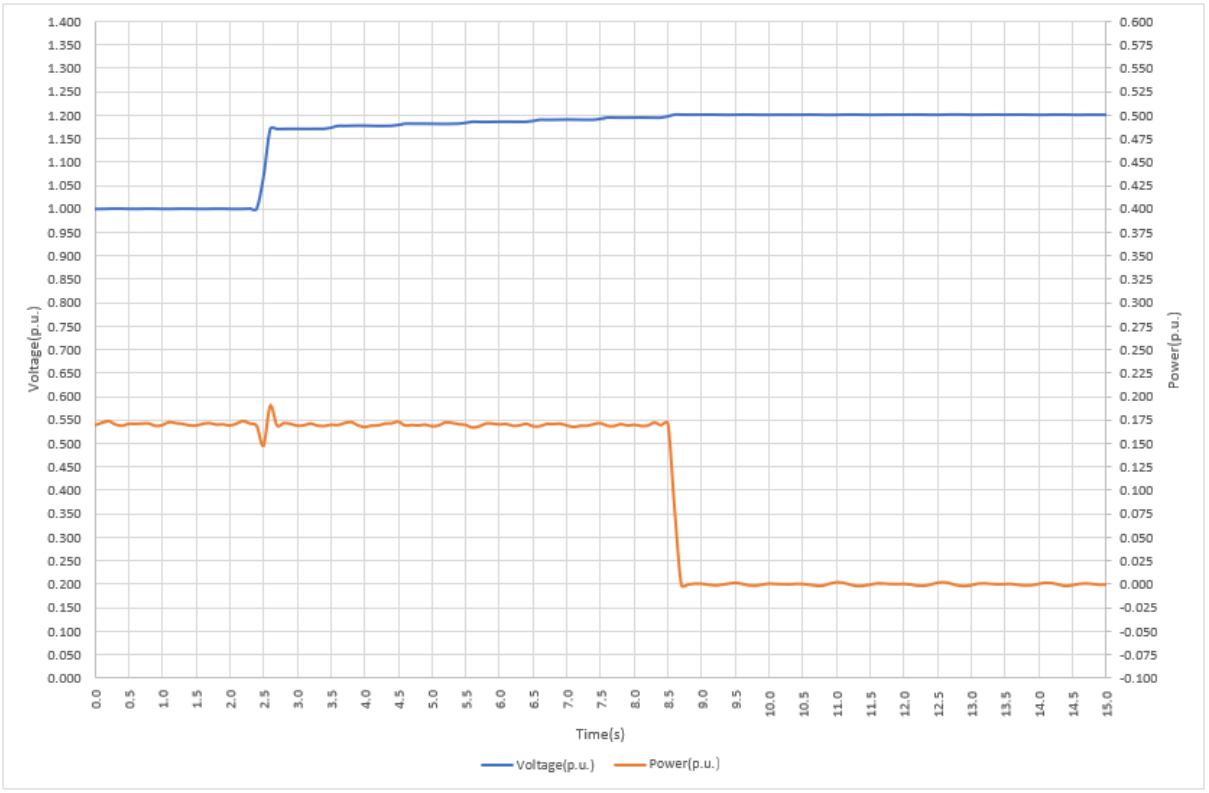
Overvoltage - Test 1: Trip value



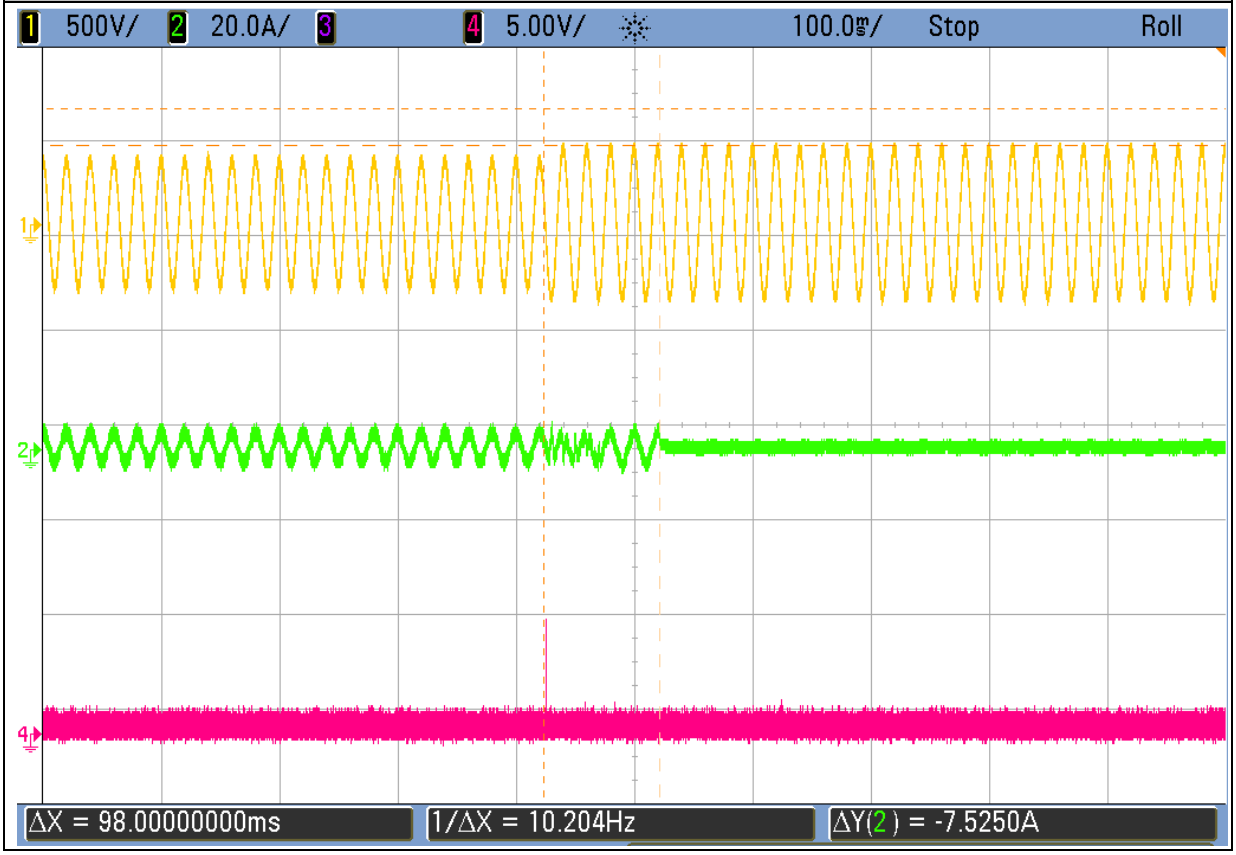
Overvoltage - Test 1: Trip time



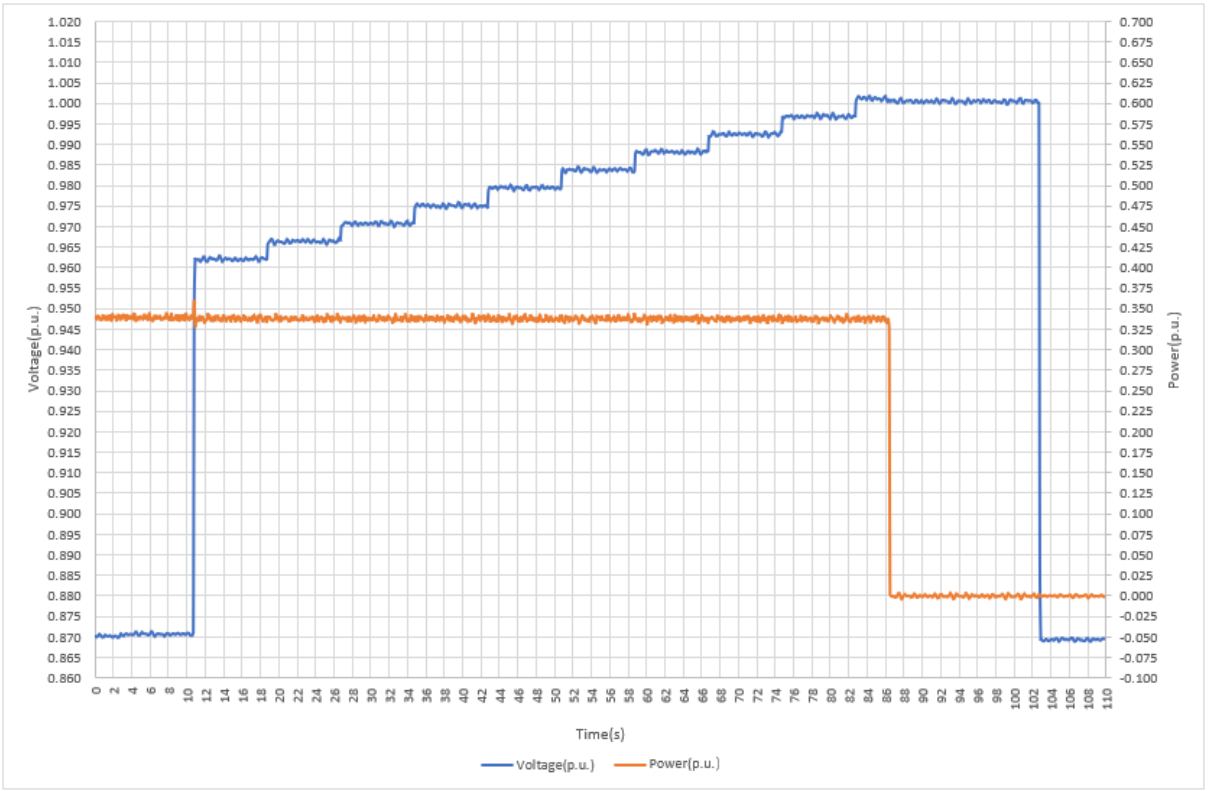
Overvoltage - Test 2: Trip value



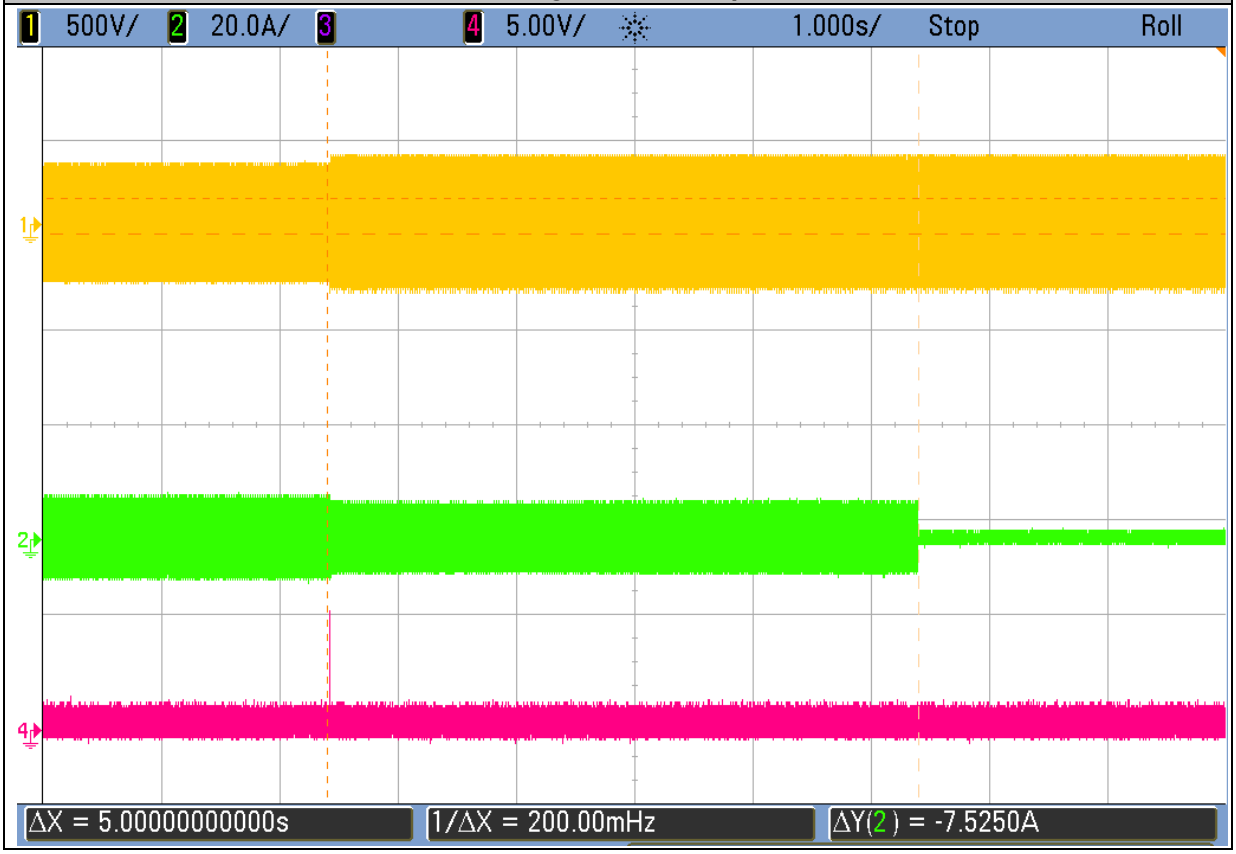
Overvoltage - Test 2: Trip time



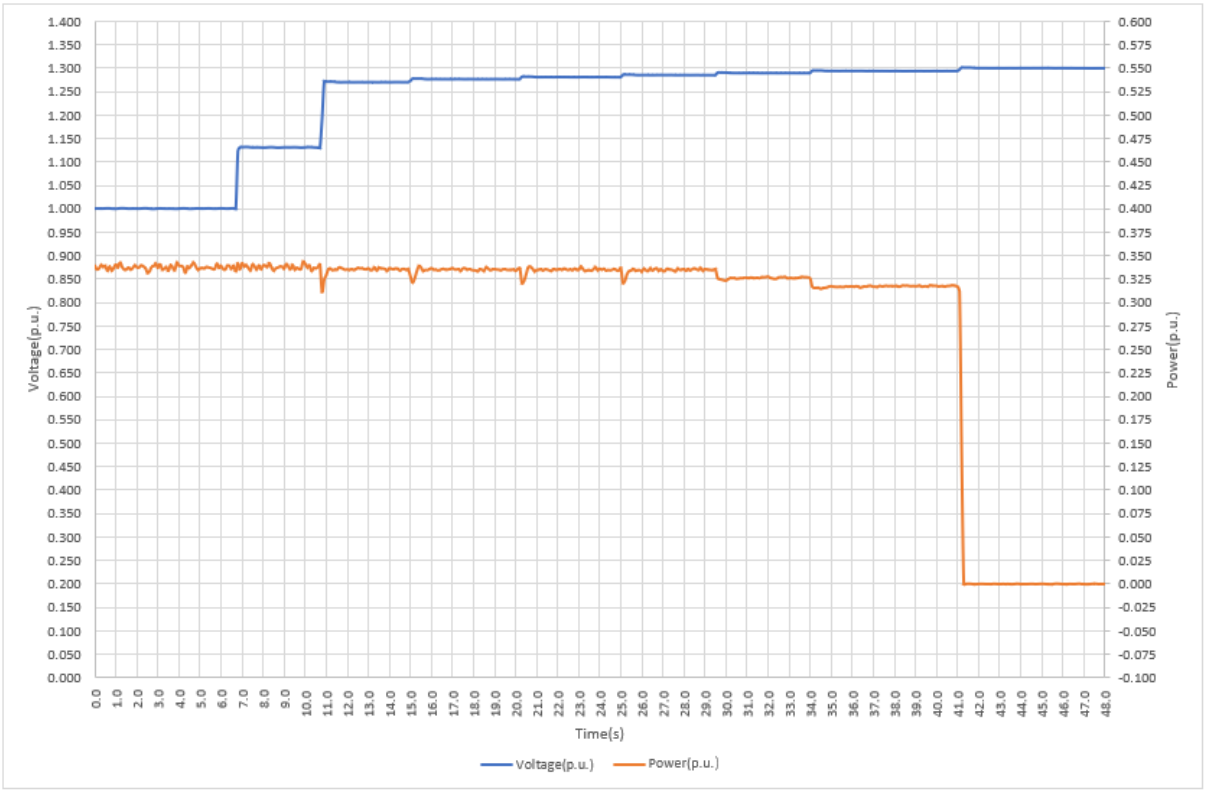
Overvoltage - Test 3: Trip value



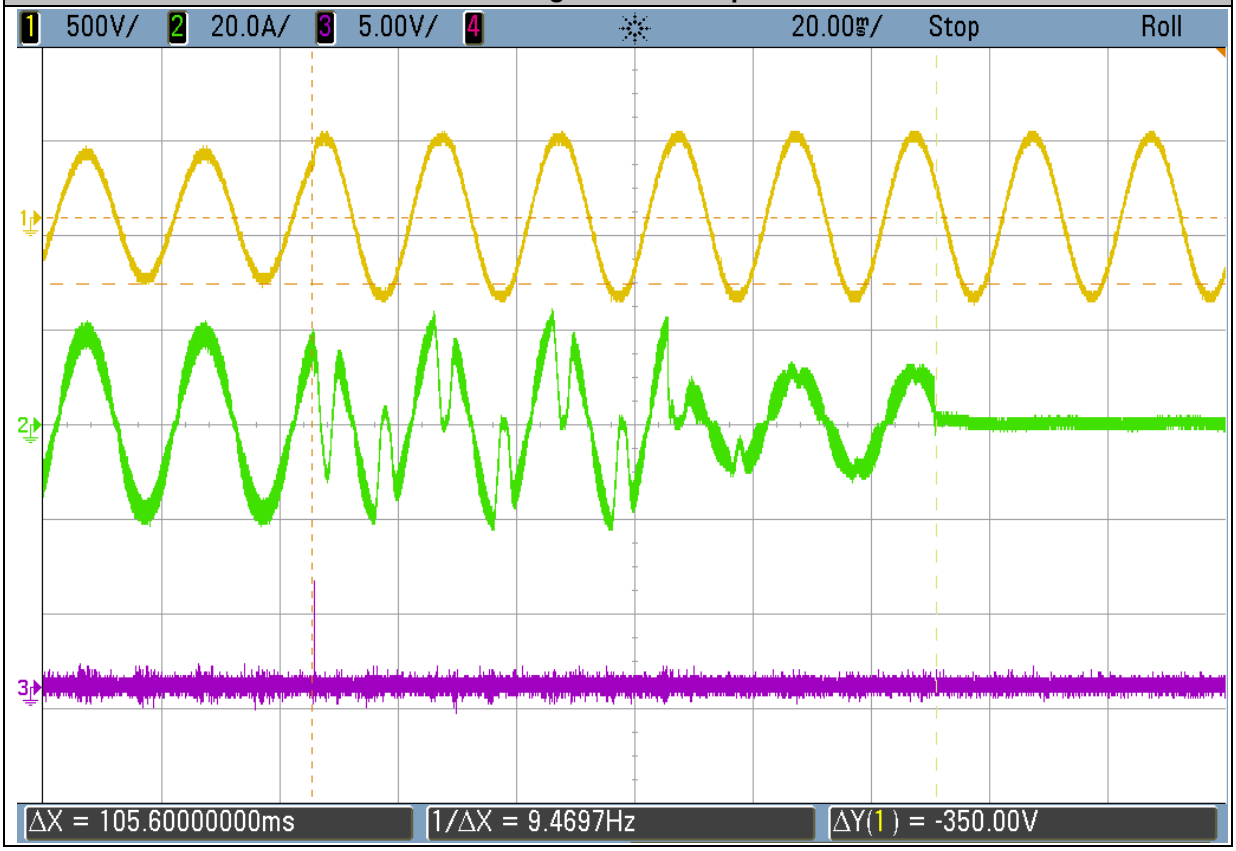
Overvoltage - Test 3: Trip time



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.

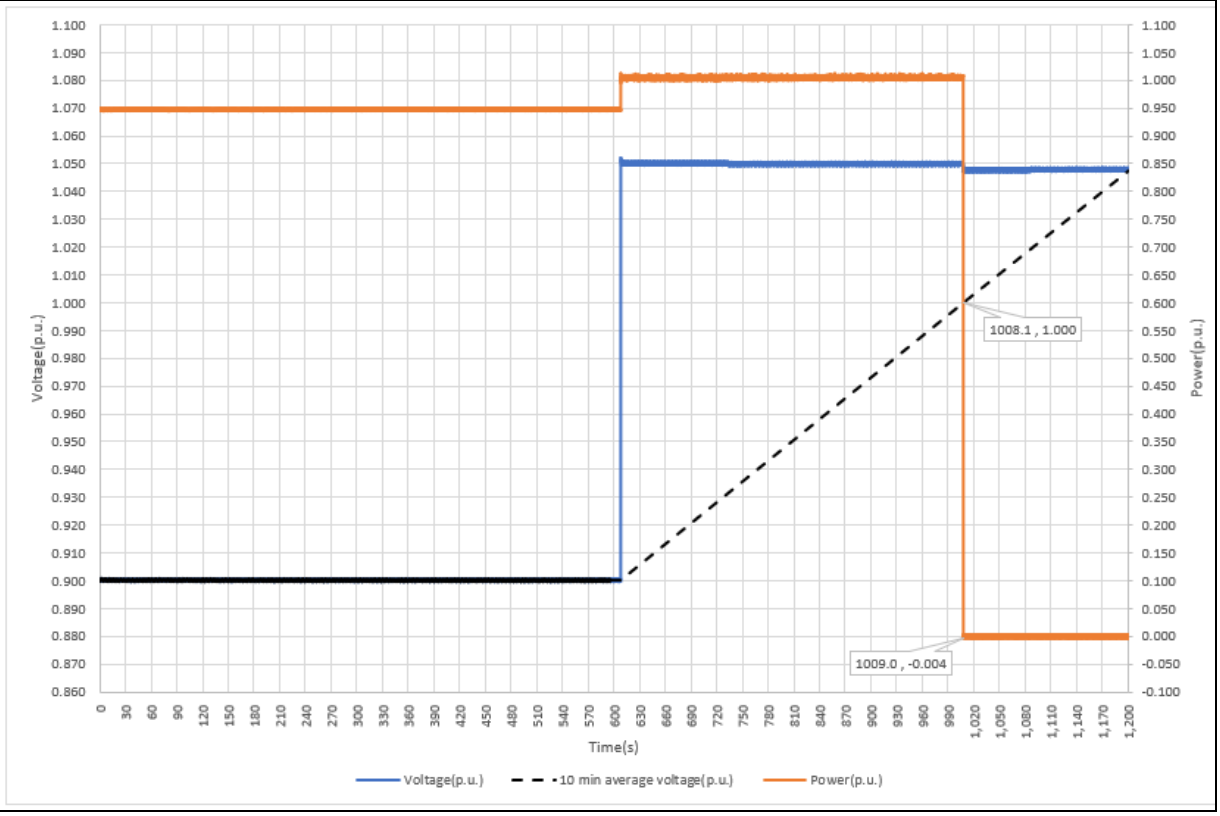
- Threshold (1.0 – 1.15) *Un* adjustable by steps of 0.01 *Un*
- Start time ≤ 3s not adjustable
- Time delay setting = 0 ms

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

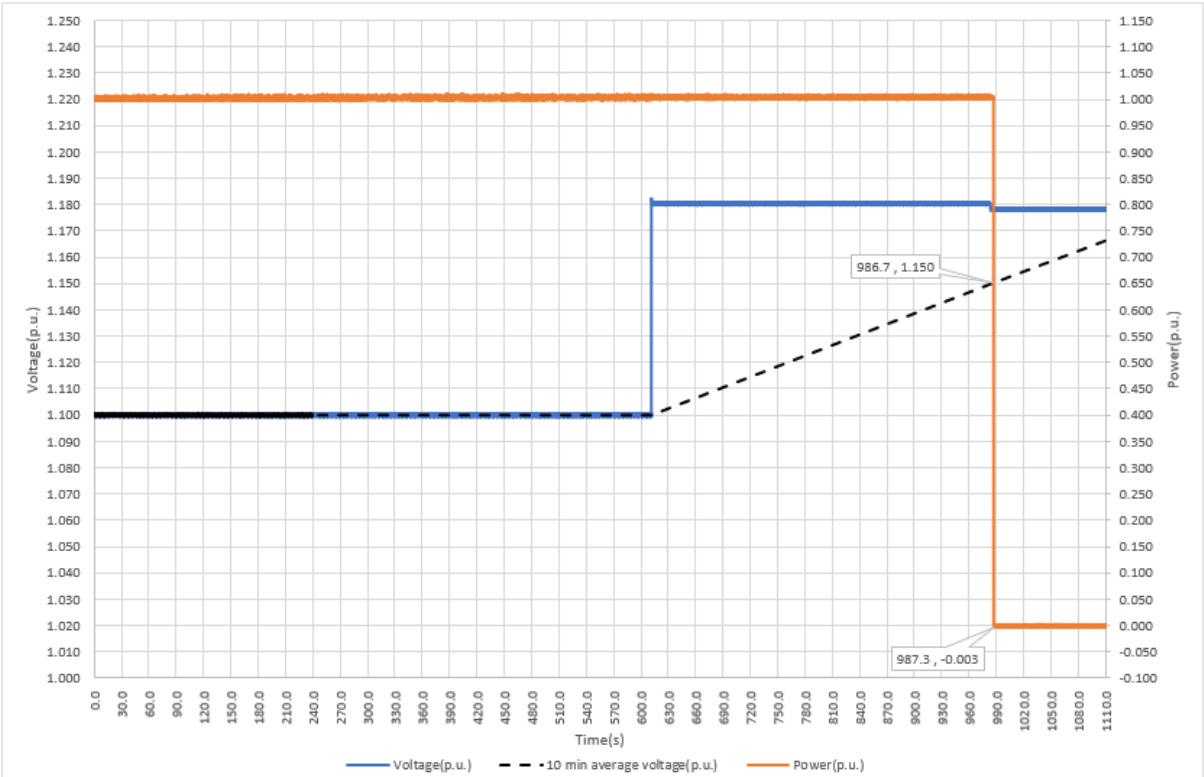
Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time meas. (s)	Trip time limited
1	1.000	1.000	0.000	0.9	≤ 3s
2	1.150	1.150	0.000	0.6	≤ 3s

Note: The trip voltage accuracy tolerance is ±0.01 Un

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 following definitions apply to the test to verify the clause:

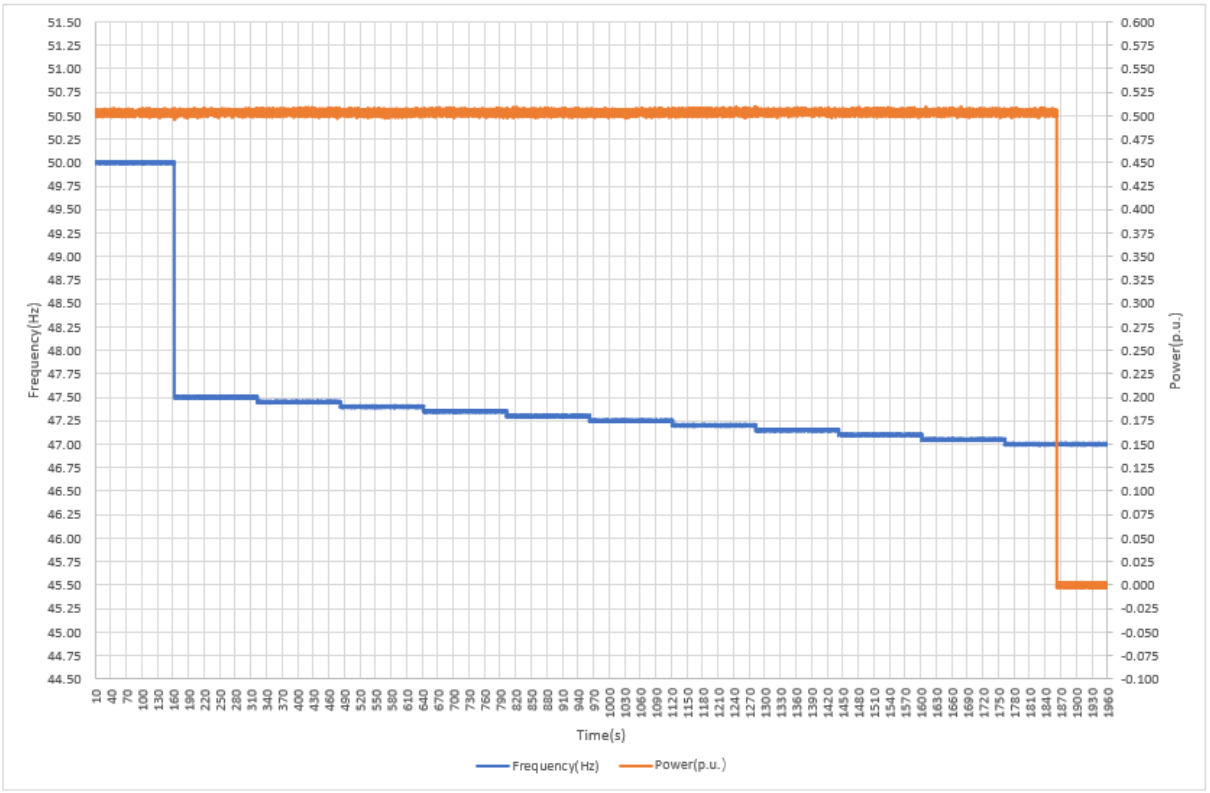
Under frequency	Test No.	Frequency setting (Hz)	Frequency meas. (Hz)	Frequency deviation (Hz)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [81 <]	1	47.00	47.00	0.00	100.000	100.010	0.010
	2	50.00	50.00	0.00	0.100	0.117	0.017
Stage 2 [81 < <]	3	47.00	47.00	0.00	5.000	5.010	0.010
	4	50.00	50.00	0.00	0.100	0.105	0.005

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.

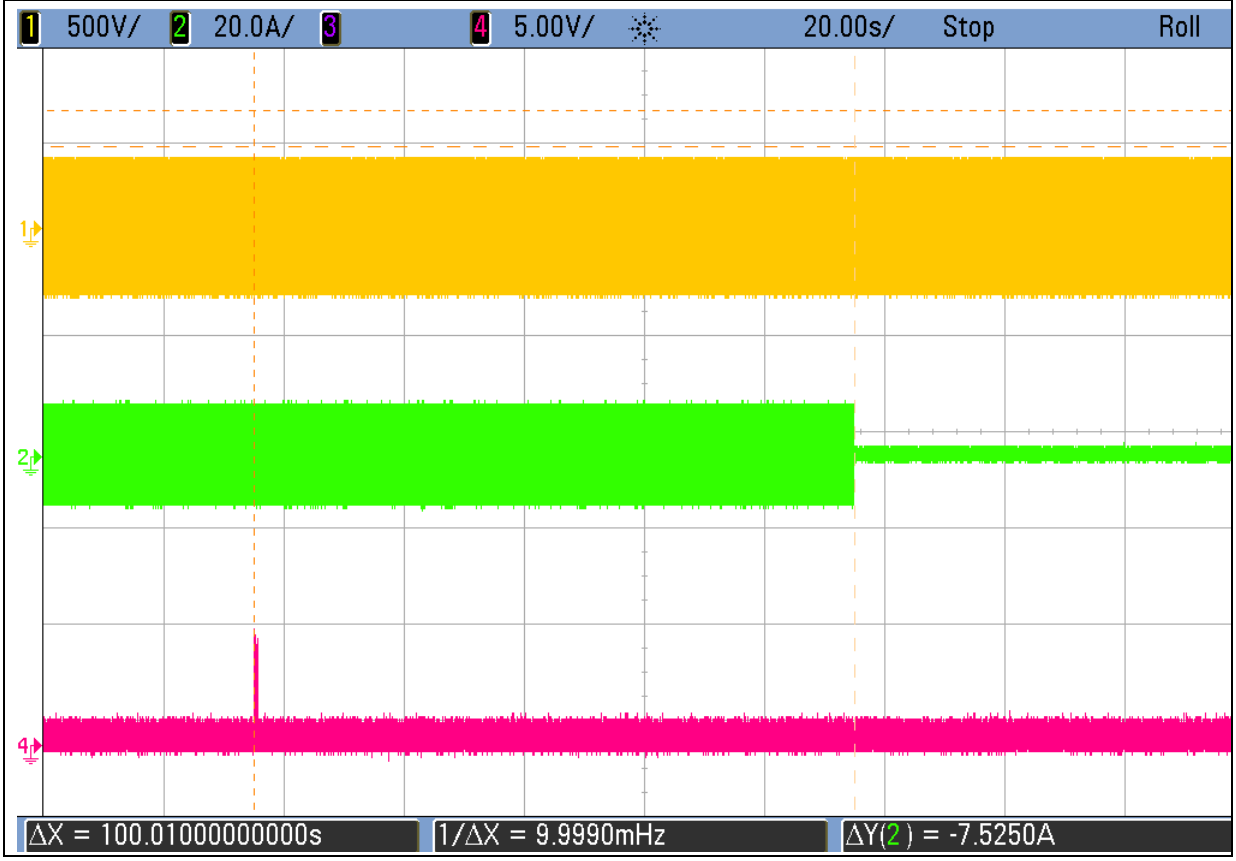
Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.

Voltage protection threshold setting (p.u.)	Test No.	Frequency setting (Hz)	Voltage setting (p.u.)	Voltage meas. (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
0.18	5	47.00	0.21	0.21	5.000	5.100	0.100
	6	47.00	1.19	1.18	5.000	5.000	0.000
	7	47.00	0.19	0.19	Not protected	--	--
		47.00	0.17	0.17	5.000	5.100	0.100

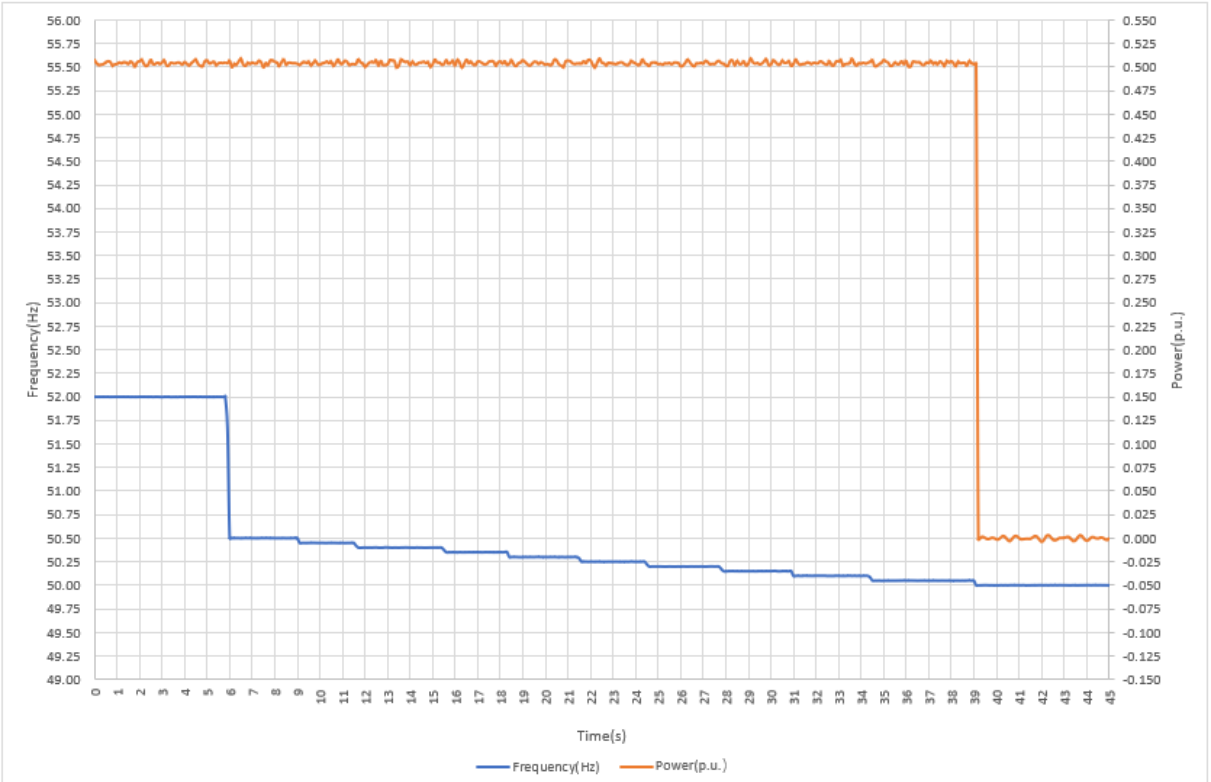
Underfrequency - Test 1: Trip value



Underfrequency - Test 1: Trip time

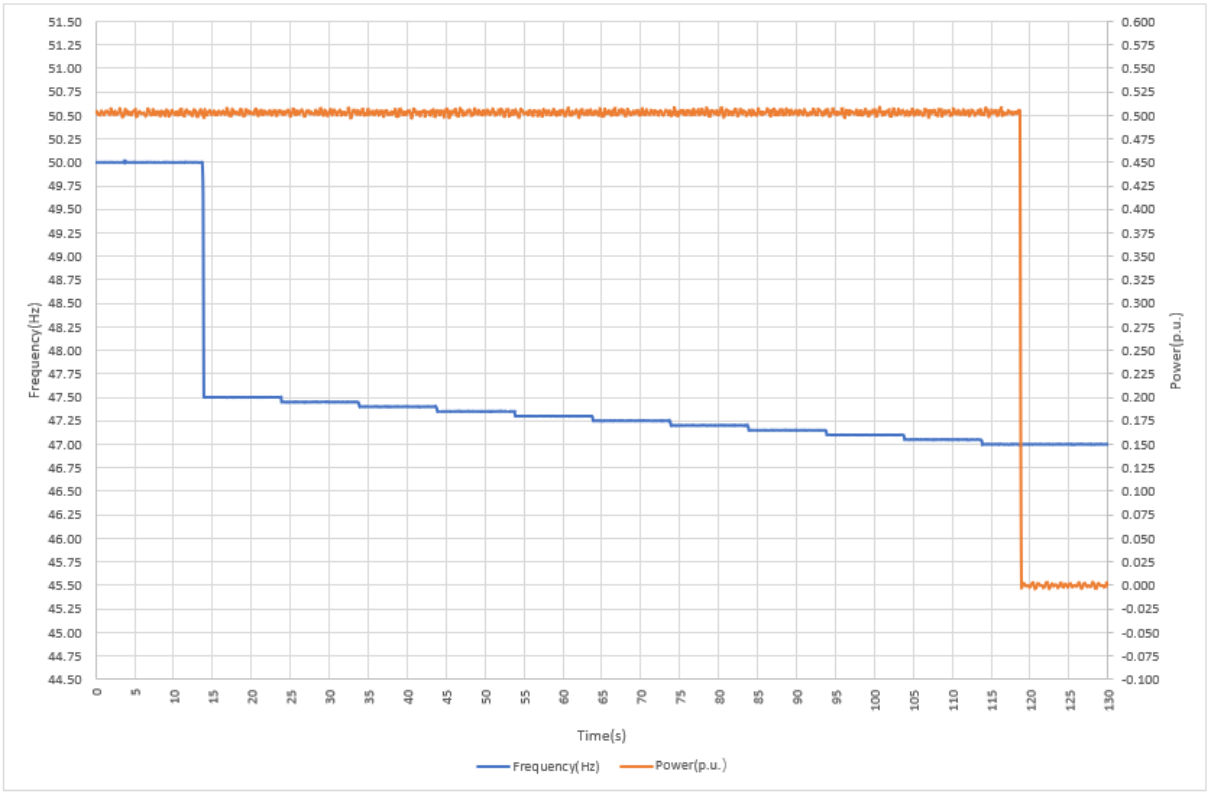


Underfrequency - Test 2: Trip value

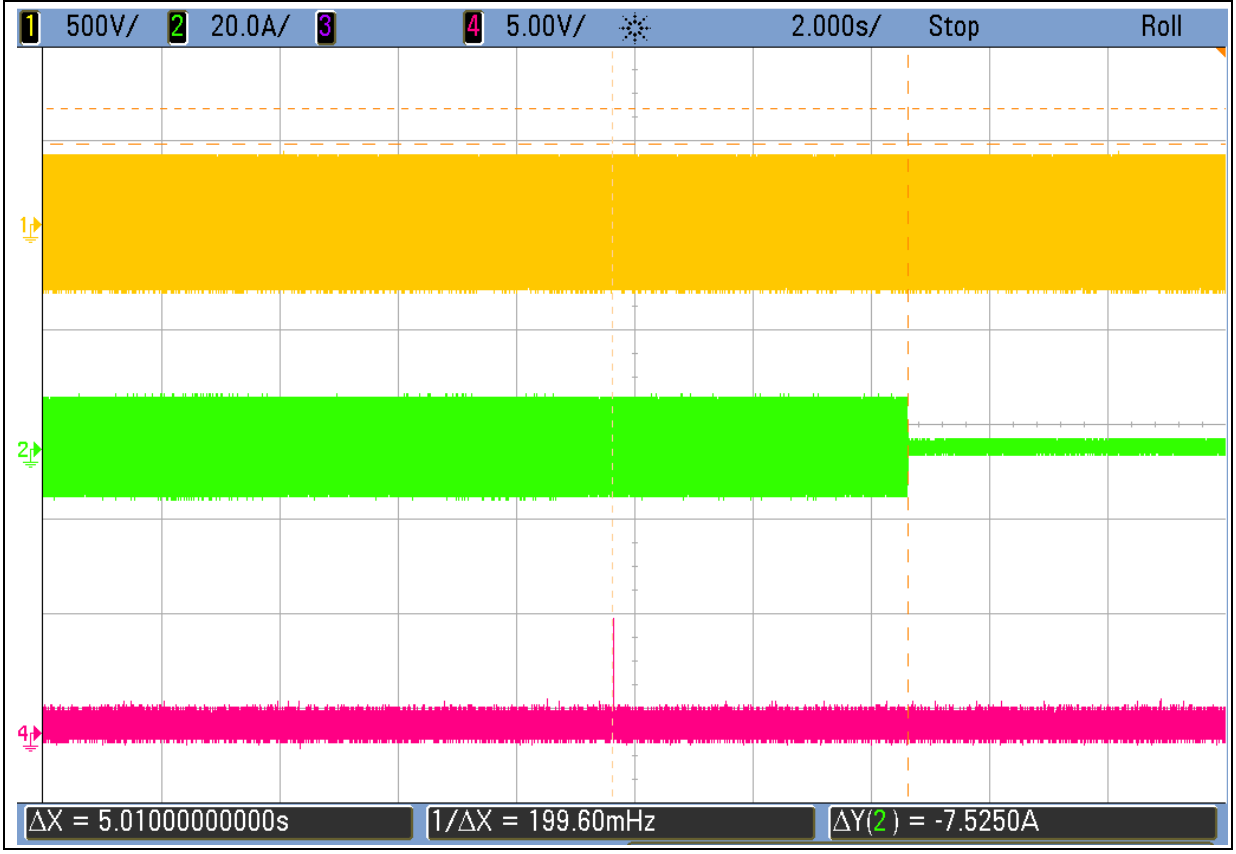


Underfrequency - Test 2: Trip time

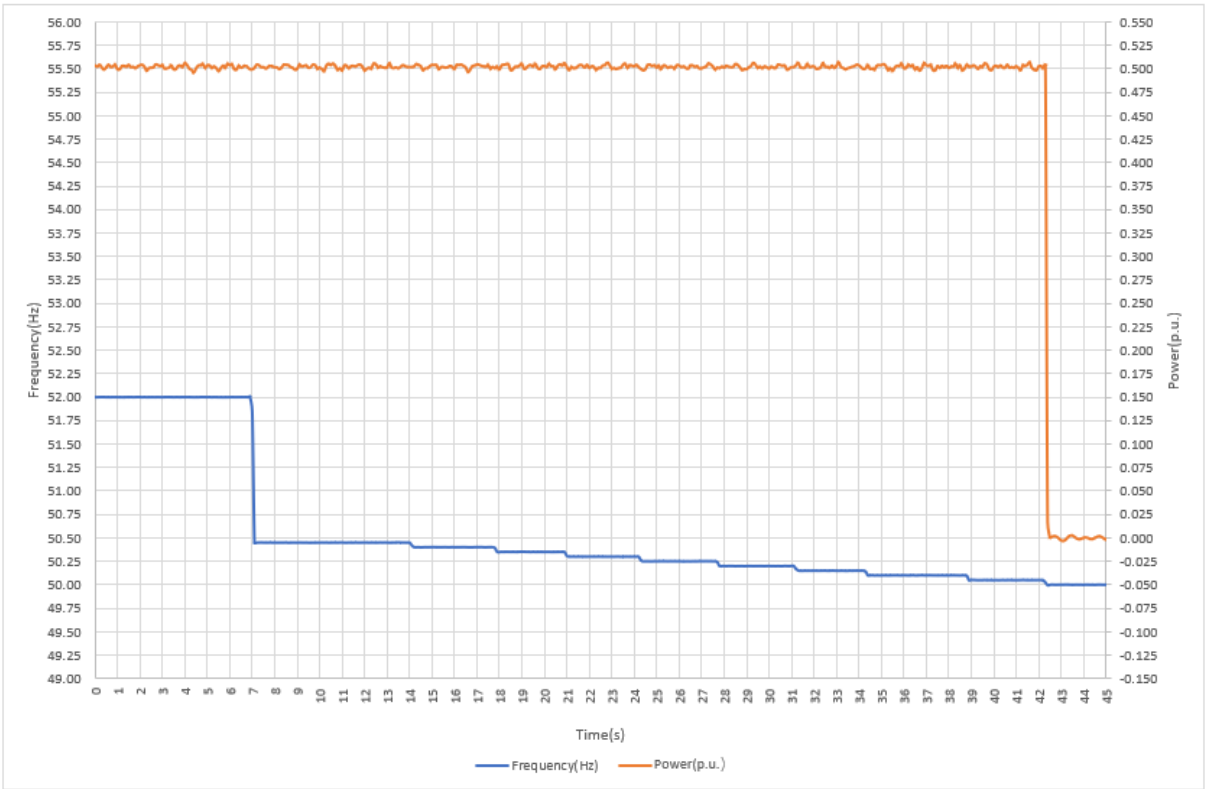
Underfrequency - Test 3: Trip value



Underfrequency - Test 3: Trip time

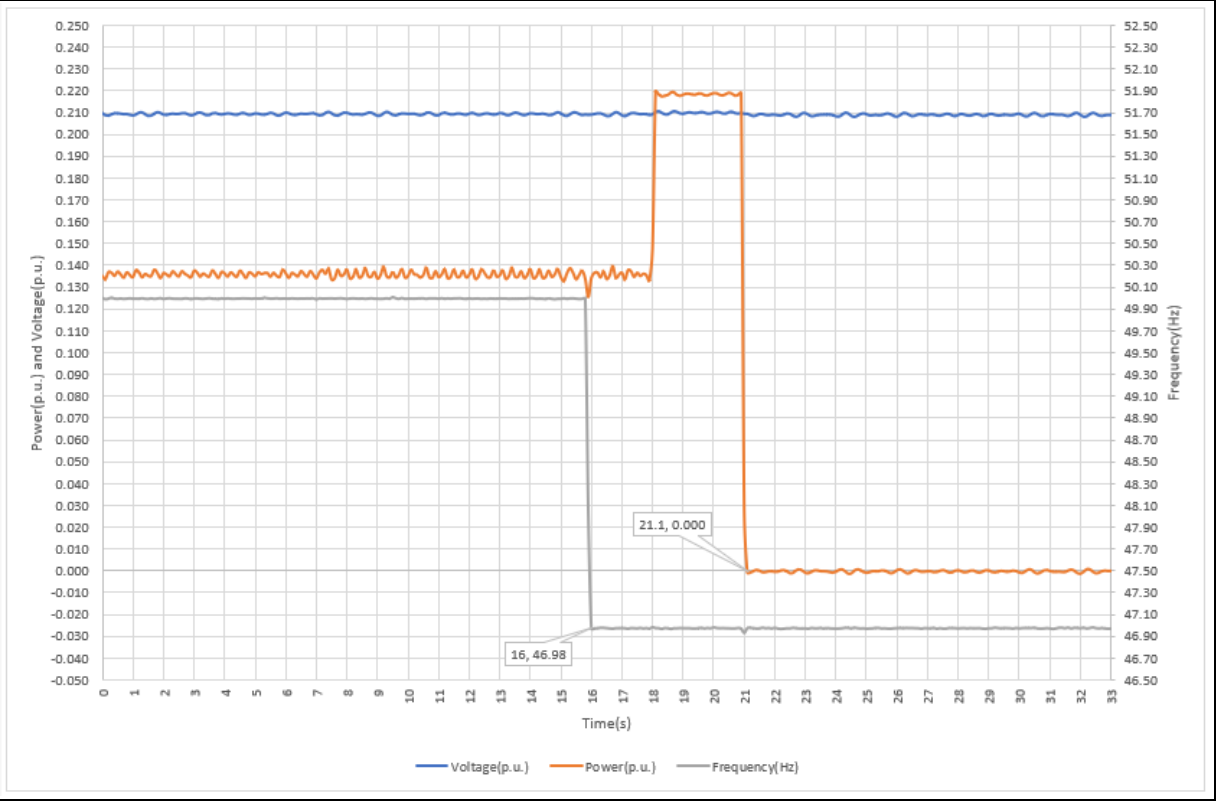


Underfrequency - Test 4: Trip value

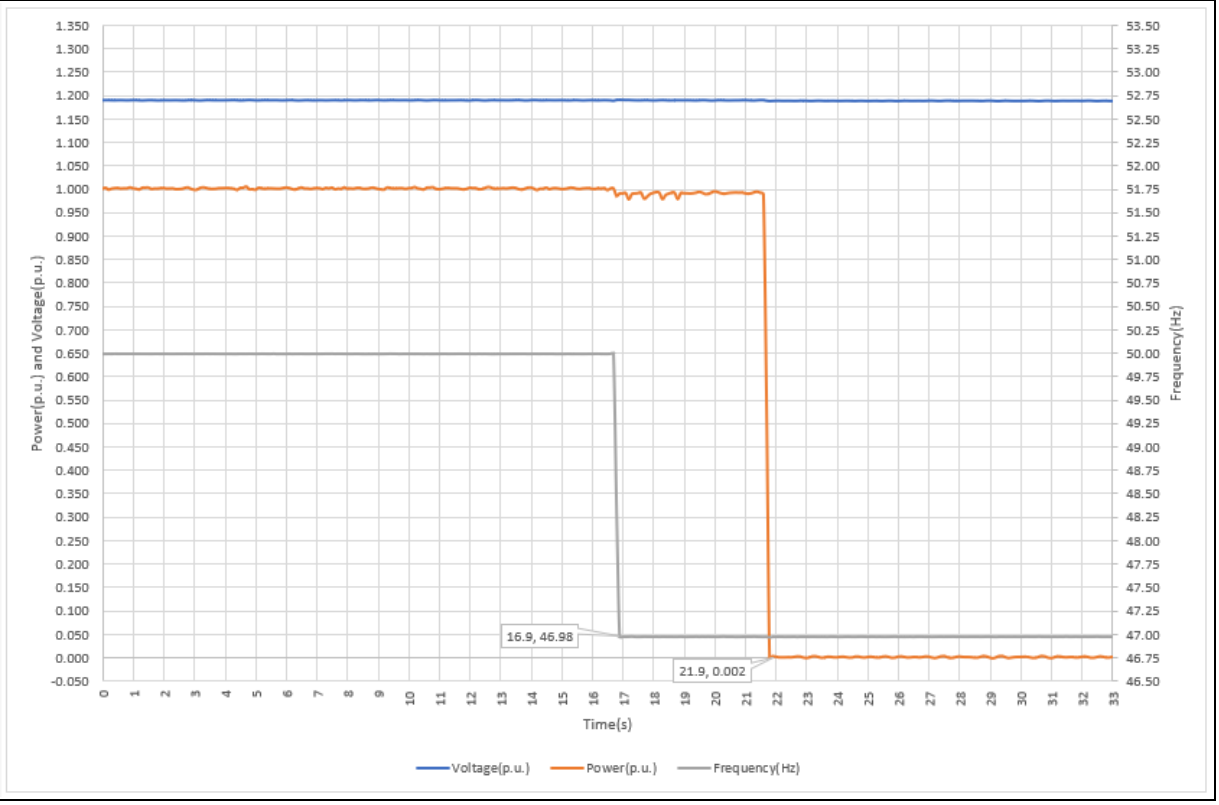


Underfrequency - Test 4: Trip time

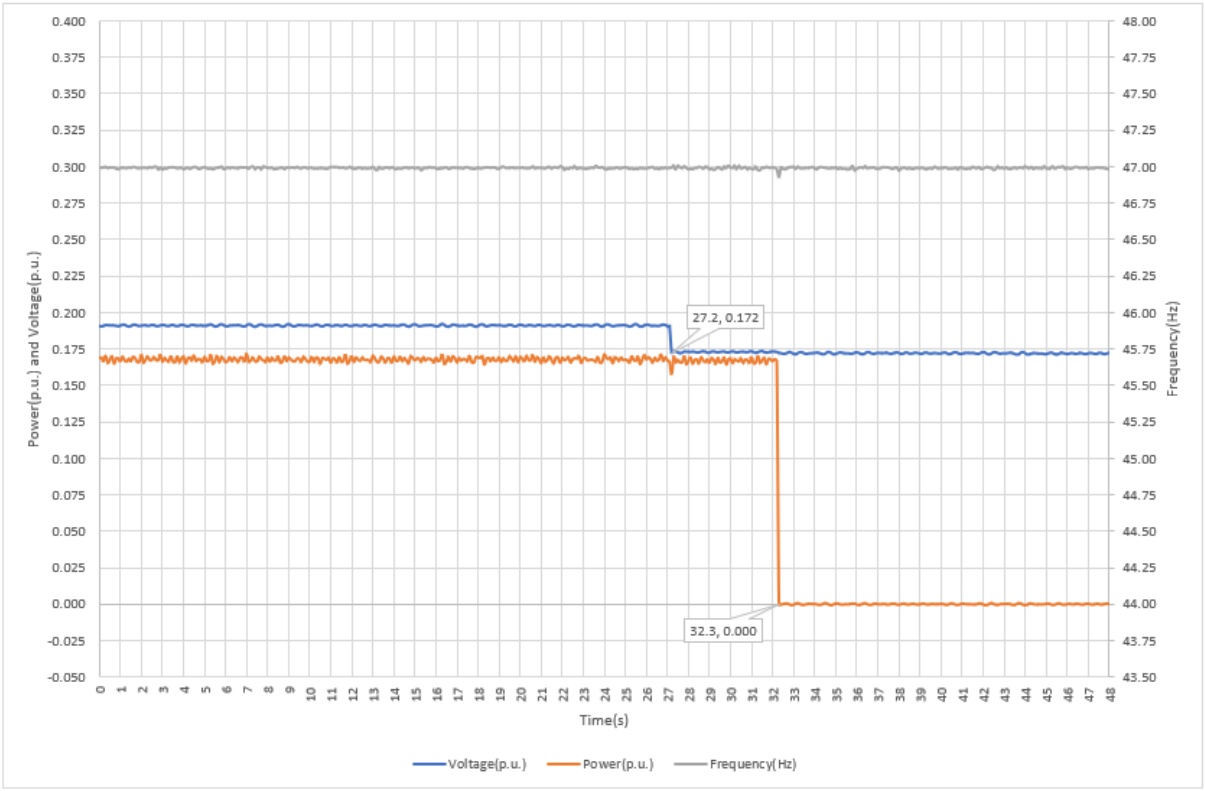
Underfrequency - Test 5: Under frequency protection test >20 %Un



Underfrequency - Test 6: Under frequency protection test at <120 %Un



Underfrequency - Test 7: Under frequency protection test at <20%Un



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 following definitions apply to the test to verify the clause:

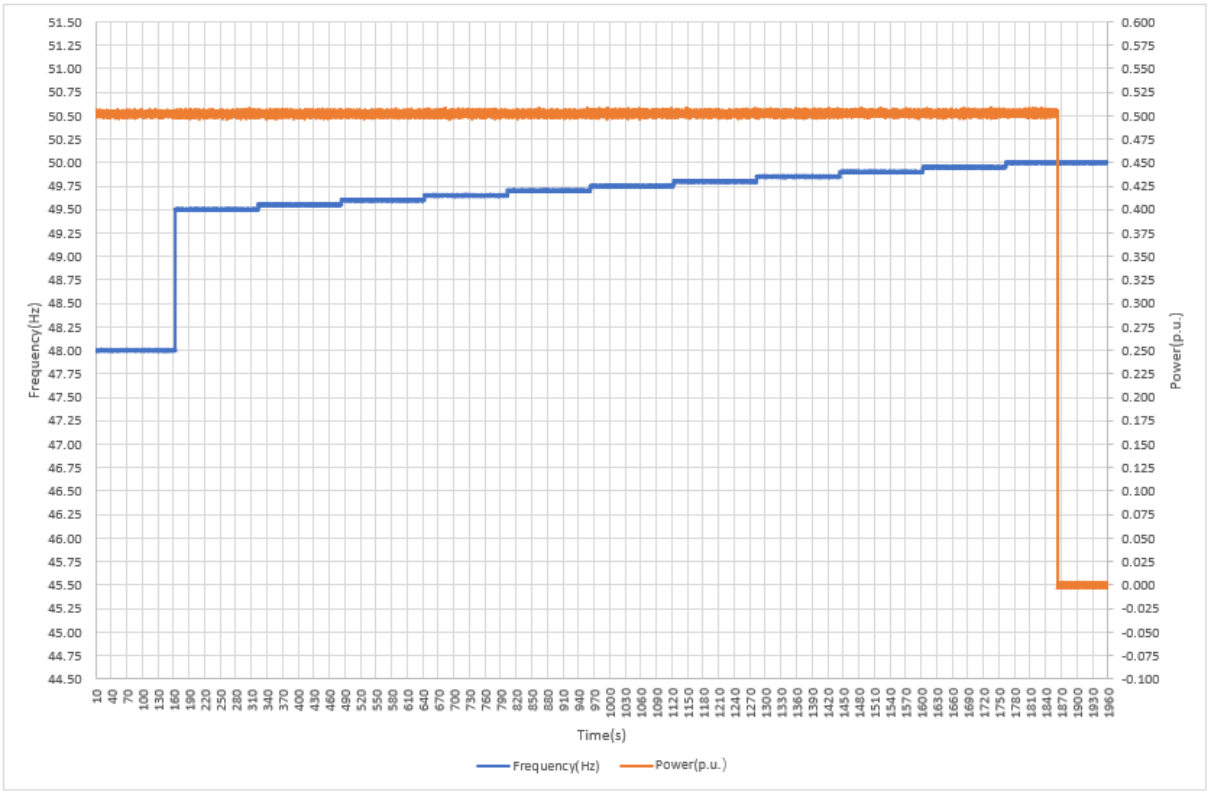
Over frequency	Test No.	Frequency setting (Hz)	Frequency meas. (Hz)	Frequency deviation (Hz)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [81 >]	1	50.00	50.00	0.00	100.000	100.010	0.010
	2	52.00	52.00	0.00	0.100	0.100	0.000
Stage 2 [81 > >]	3	50.00	50.00	0.00	0.100	0.096	-0.004
	4	52.00	52.00	0.00	0.100	0.098	-0.002

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.

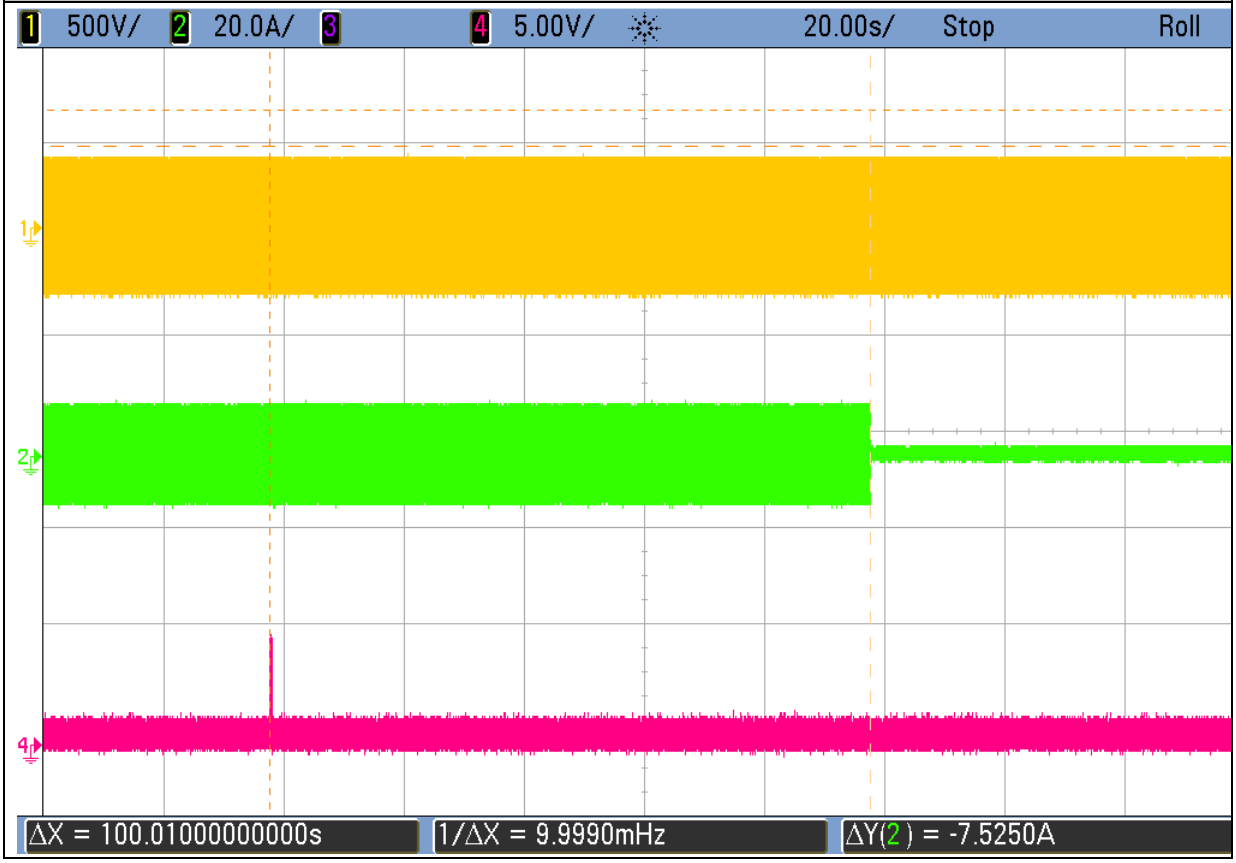
Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.

Voltage protection threshold setting (p.u.)	Test No.	Frequency setting (Hz)	Voltage setting (p.u.)	Voltage meas. (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
0.18	5	52.00	0.21	0.21	5.000	5.300	0.300
	6	52.00	1.19	1.19	5.000	5.000	0.000
	7	52.00	0.19	0.19	Not protected	--	--
		52.00	0.17	0.17	5.000	5.100	0.300

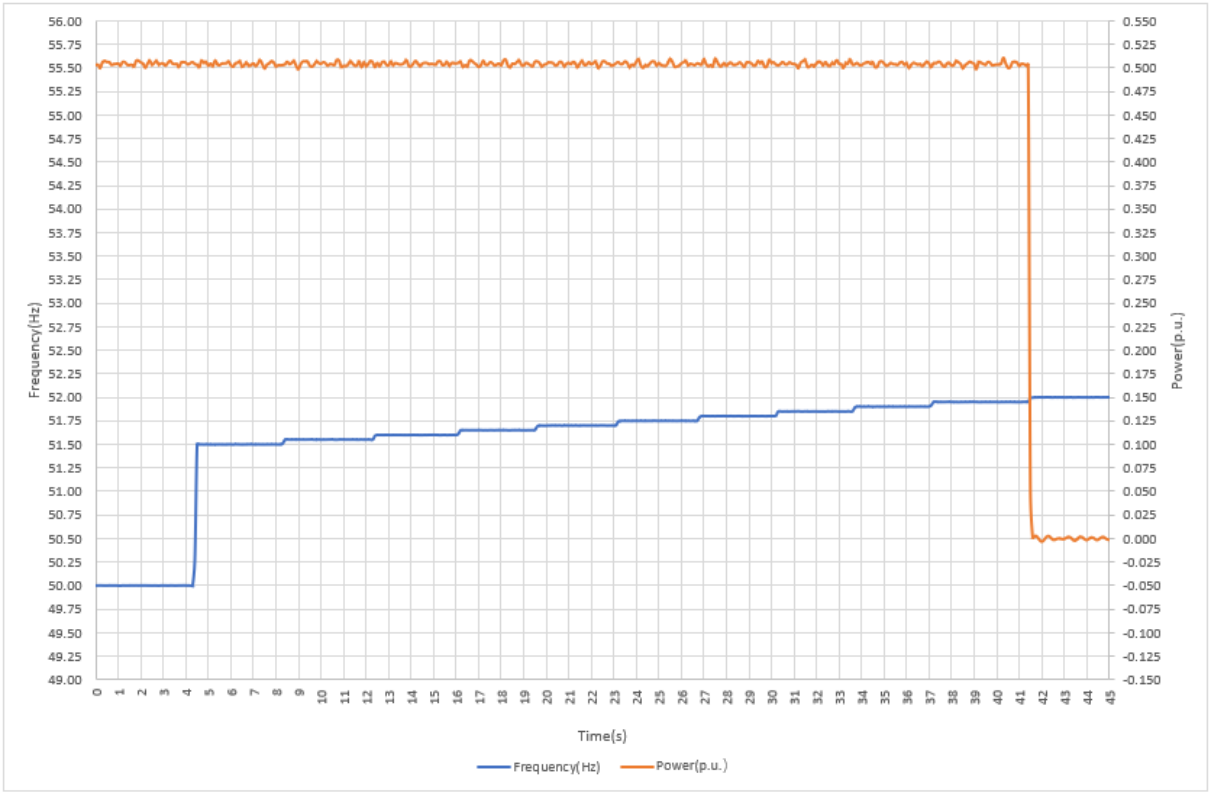
Overfrequency - Test 1: Trip value



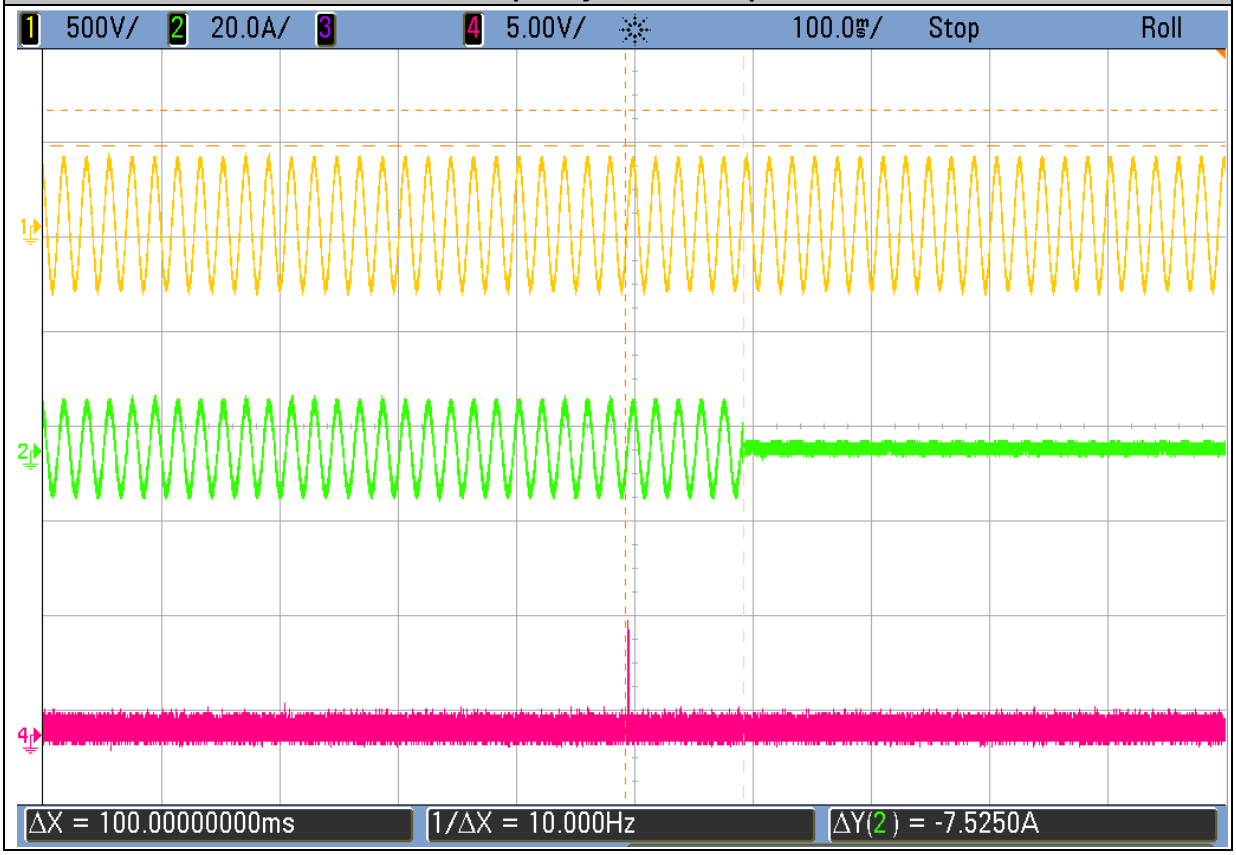
Overfrequency - Test 1: Trip time



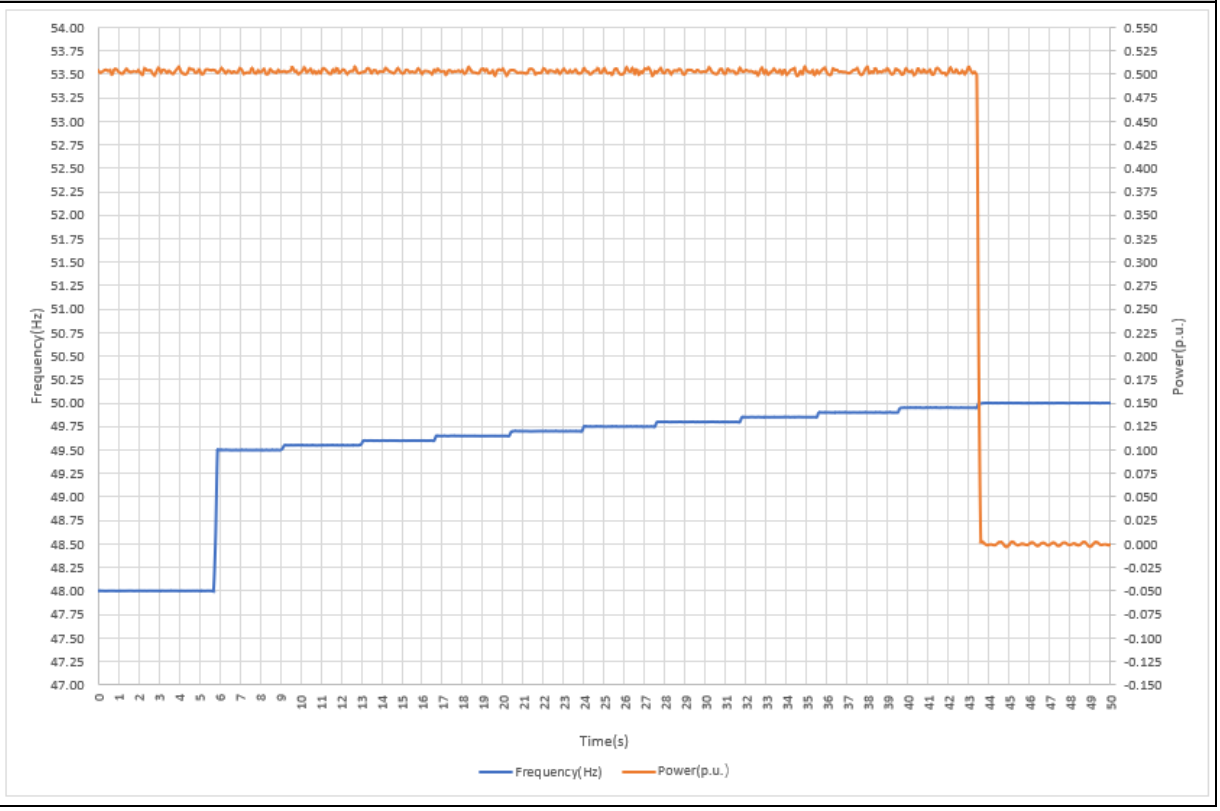
Overfrequency - Test 2: Trip value



Overfrequency - Test 2: Trip time

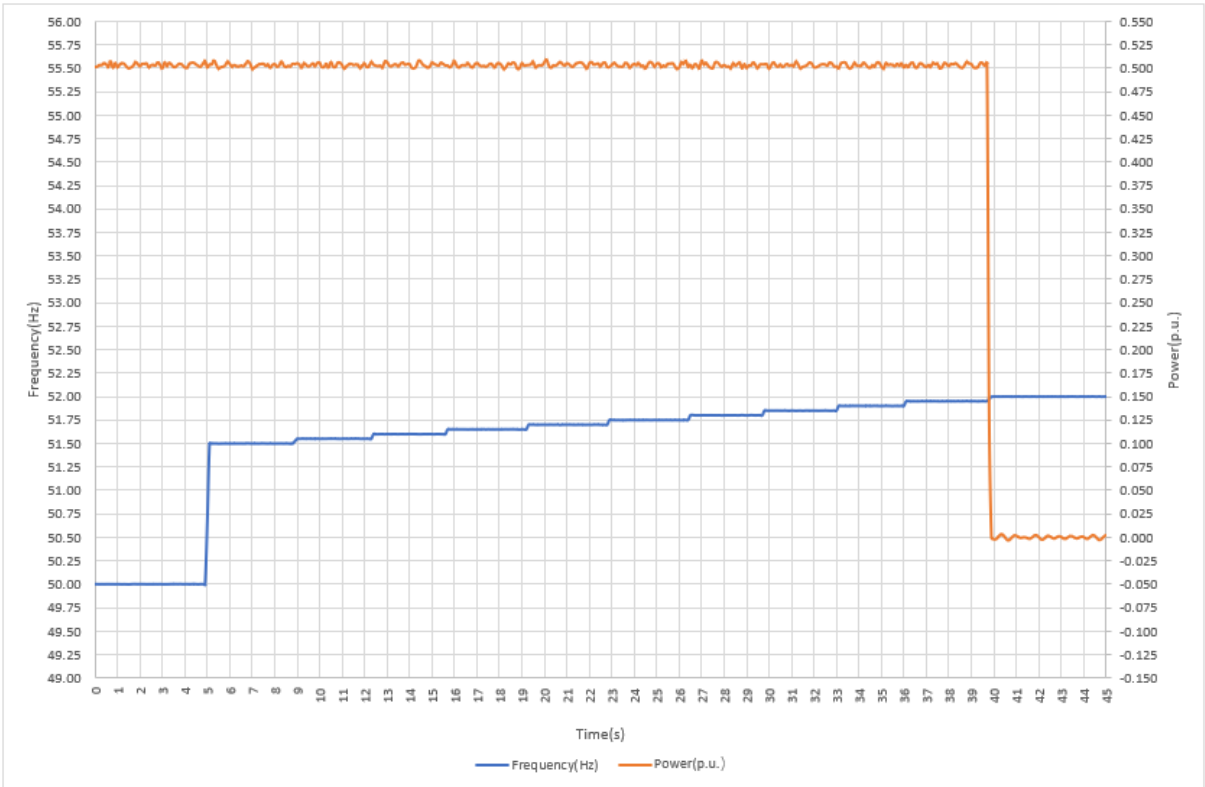


Overfrequency - Test 3: Trip value



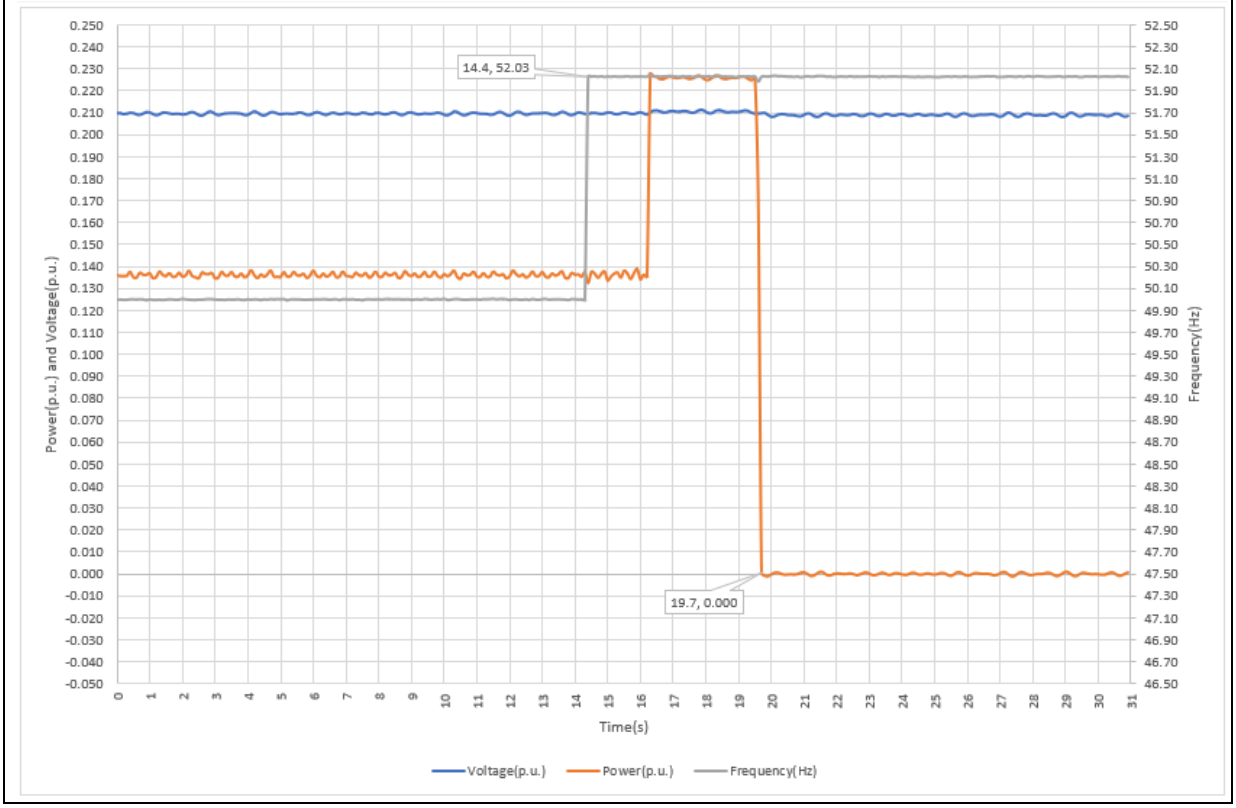
Overfrequency - Test 3: Trip time

Overfrequency - Test 4: Trip value

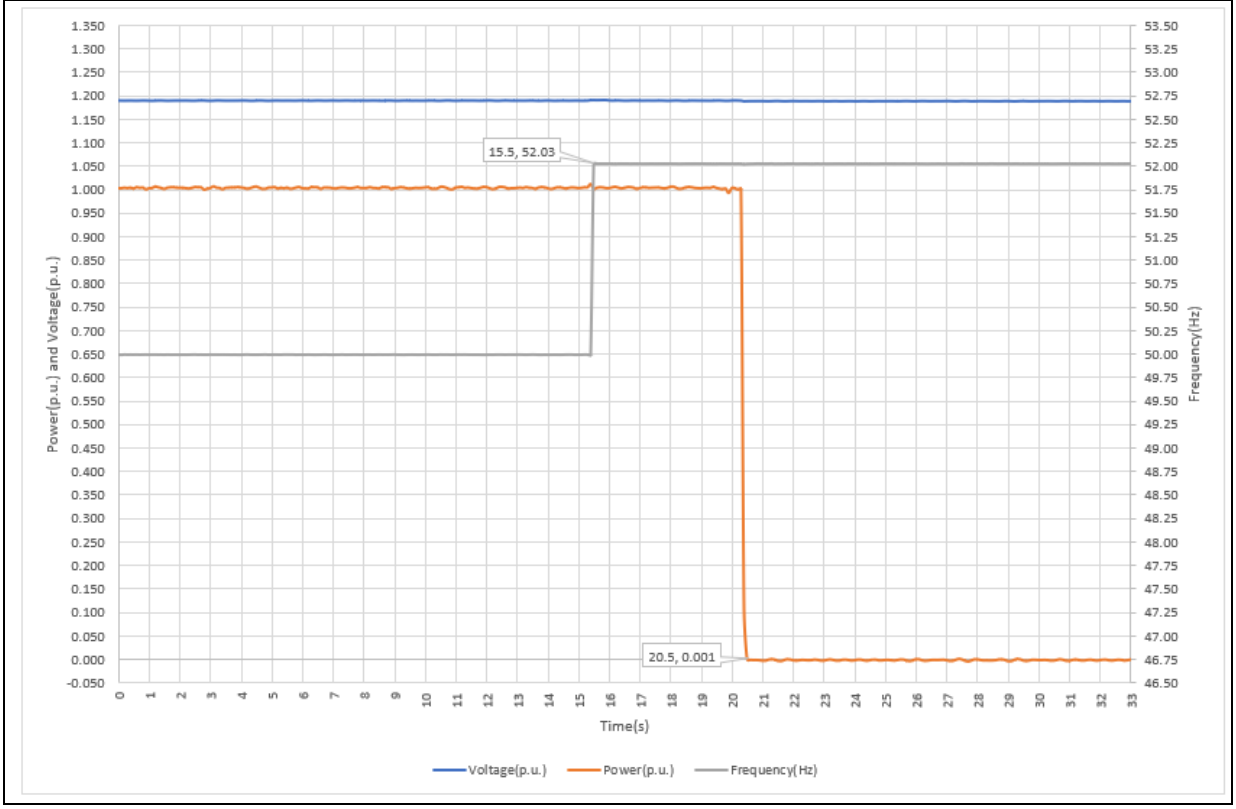


Overfrequency - Test 4: Trip time

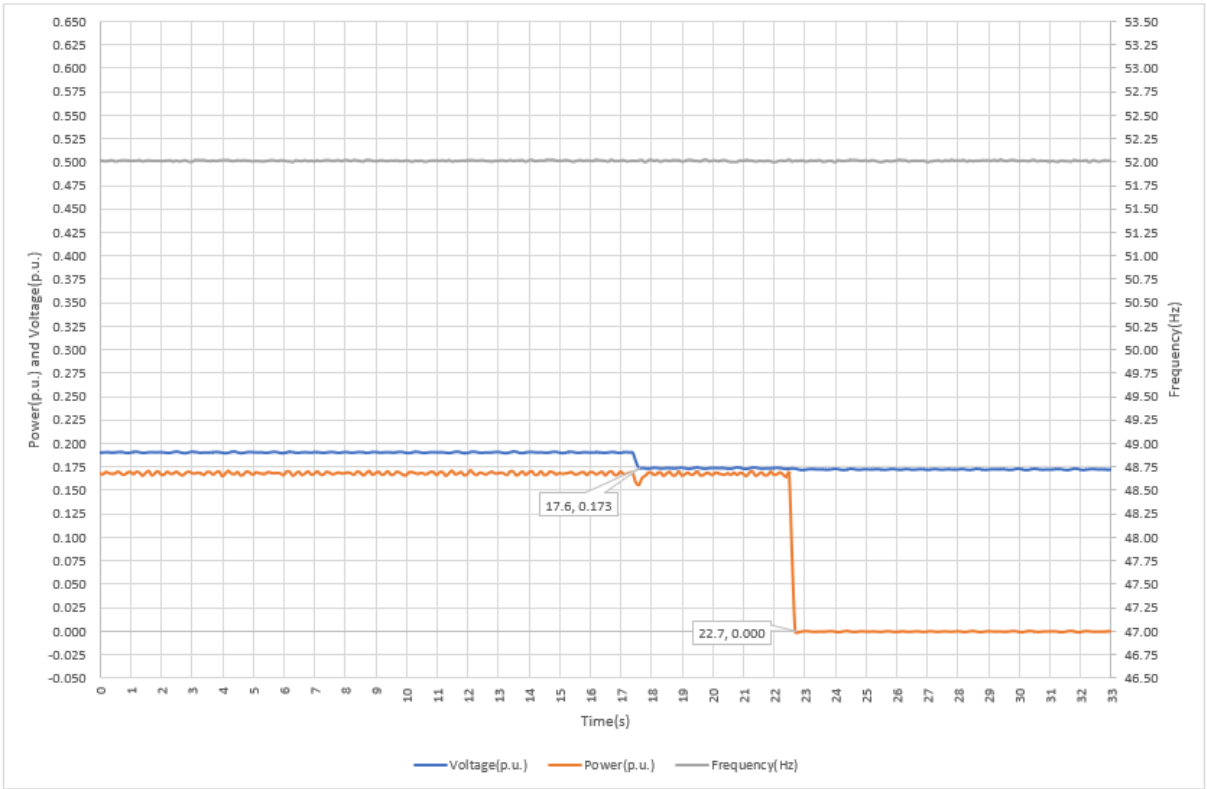
Overfrequency - Test 5: Over frequency protection test at >20 %Un



Overfrequency - Test 6: Over frequency protection test at <120 %Un



Overfrequency - Test 7: Over frequency protection test at <20%Un



4.6.2. Means to detect island situation

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

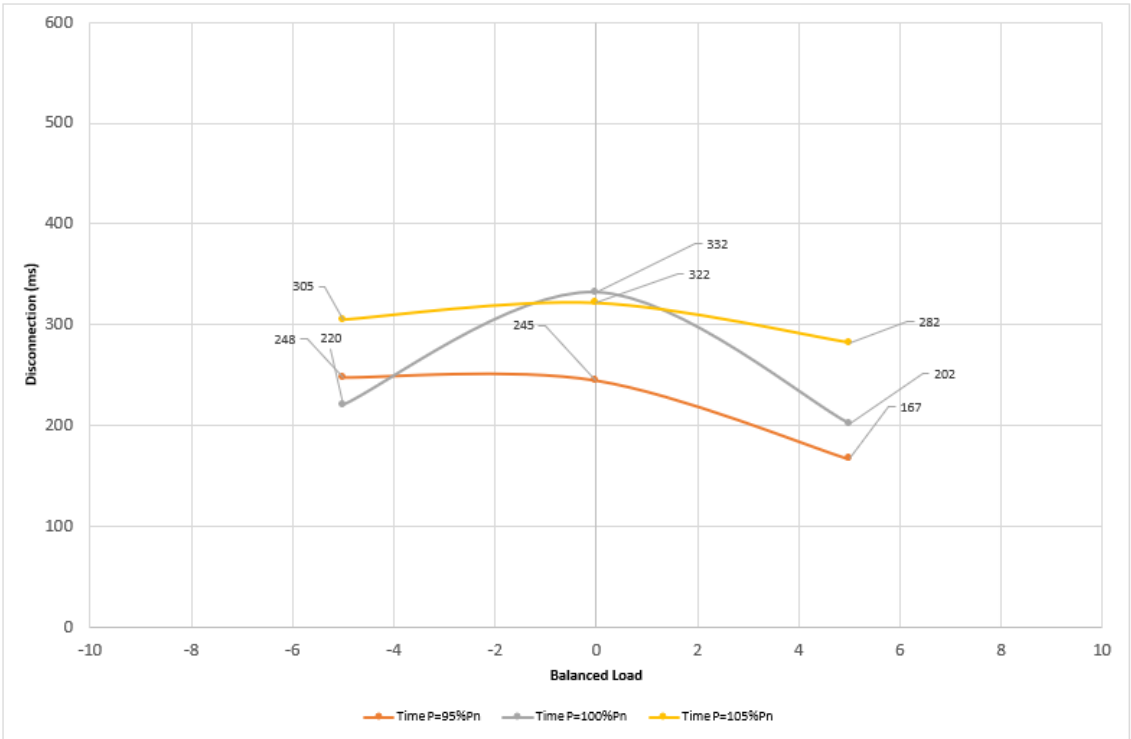
The compliances with these requirements are stated in the according to EN 62116. An EUT is considered to comply with the requirements for islanding protection when each case of recorded run-on time is less than 2 s or meets the requirements of local codes.

Test A is at full power, Test B is at 66 %Pn, Test C is at 33 %Pn.

Active Power > 90 %Pn. Test A

Balanced Load		
M (%)	**N (%)**	**Disconnection (ms) (limit at t=2s)**
-5	+5	305
-5	0	220
-5	-5	248
0	+5	322
0	0	332
0	-5	245
+5	+5	282
+5	0	202
+5	-5	167

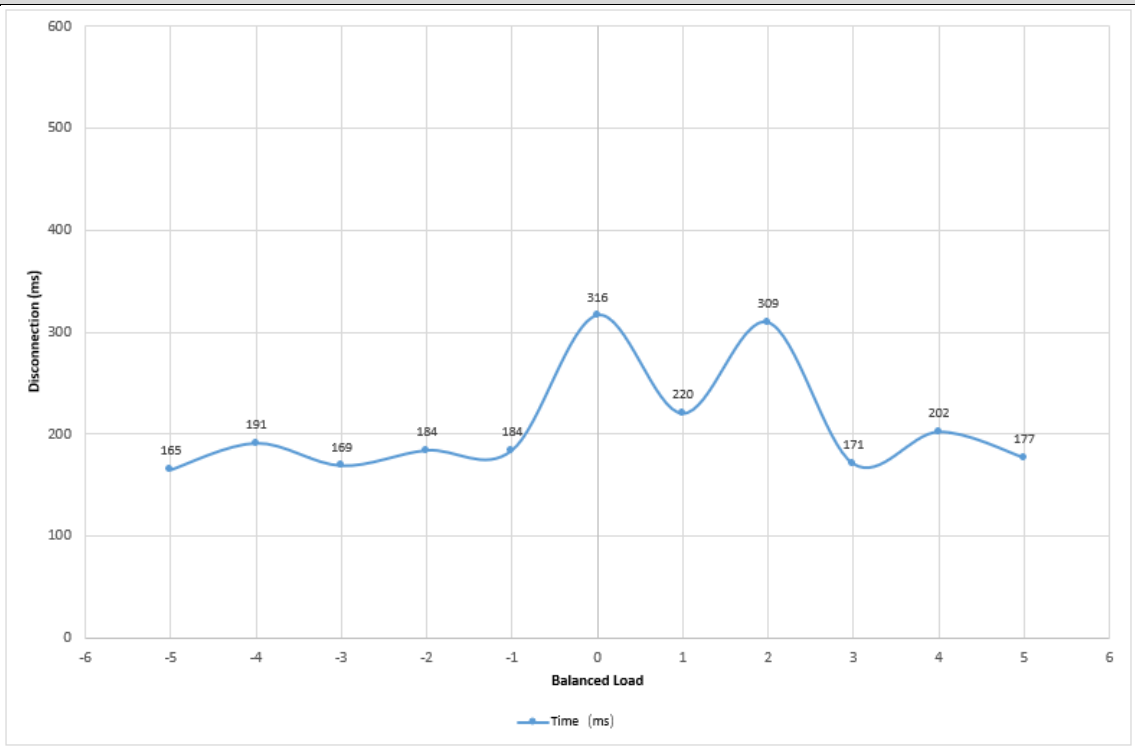
Curve for Test A



Active Power 50-66 %Pn. Test B

Balanced Load		
M (%)	N (%)	Disconnection (ms) (limit at t=2s)
0	-5	165
0	-4	191
0	-3	169
0	-2	184
0	-1	184
0	0	316
0	+1	220
0	+2	309
0	+3	171
0	+4	202
0	+5	177

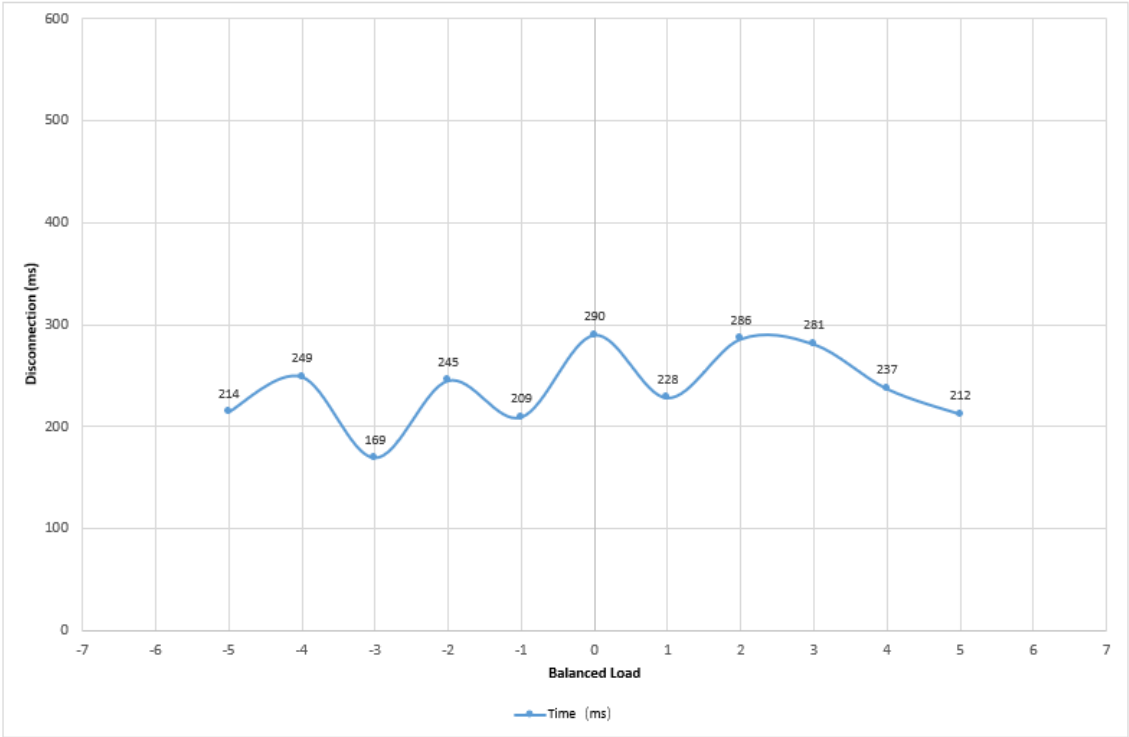
Curve for Test B



Active Power 25-33 %Pn. Test C

Balanced Load		
M (%)	N (%)	Disconnection (ms) (limit at t=2s)
0	-5	214
0	-4	249
0	-3	169
0	-2	245
0	-1	209
0	0	290
0	+1	228
0	+2	286
0	+3	281
0	+4	237
0	+5	212

Curve for Test 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 Setting		Reconnection Setting		Setting Reconnection time (s) (*)	Meas. Reconnection time (s)	Meas. gradient (%Pn/min)
U = 115%Un	Yes	U = 110 %Un	Yes	70	67.6	7.89
U = 50%Un	Yes	U = 85 %Un	Yes	70	71.0	7.88
f = 52.00 Hz	Yes	f = 50.10 Hz	Yes	70	70.7	7.84
f = 48.00 Hz	Yes	f = 49.90 Hz	Yes	70	70.7	7.84

(*) tolerance of reconnection time is ±5s

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

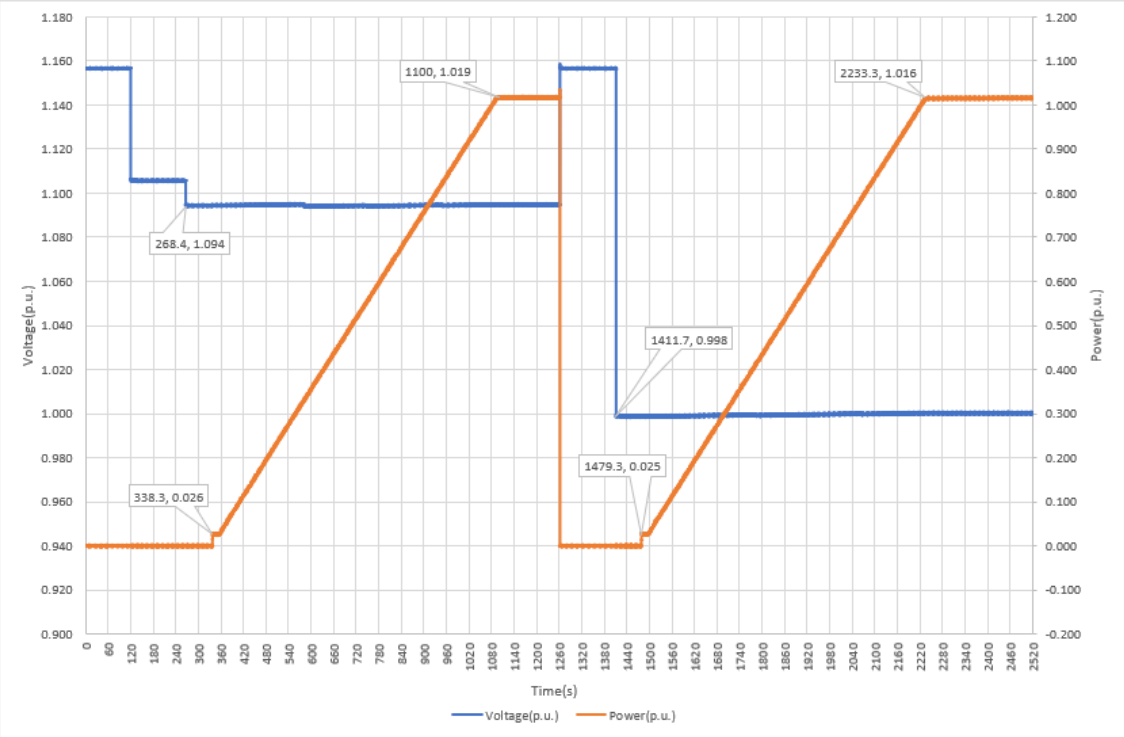
Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz
Upper frequency	50,0Hz – 52,0Hz	50,1Hz
Lower voltage	50% – 100% U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	disabled

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

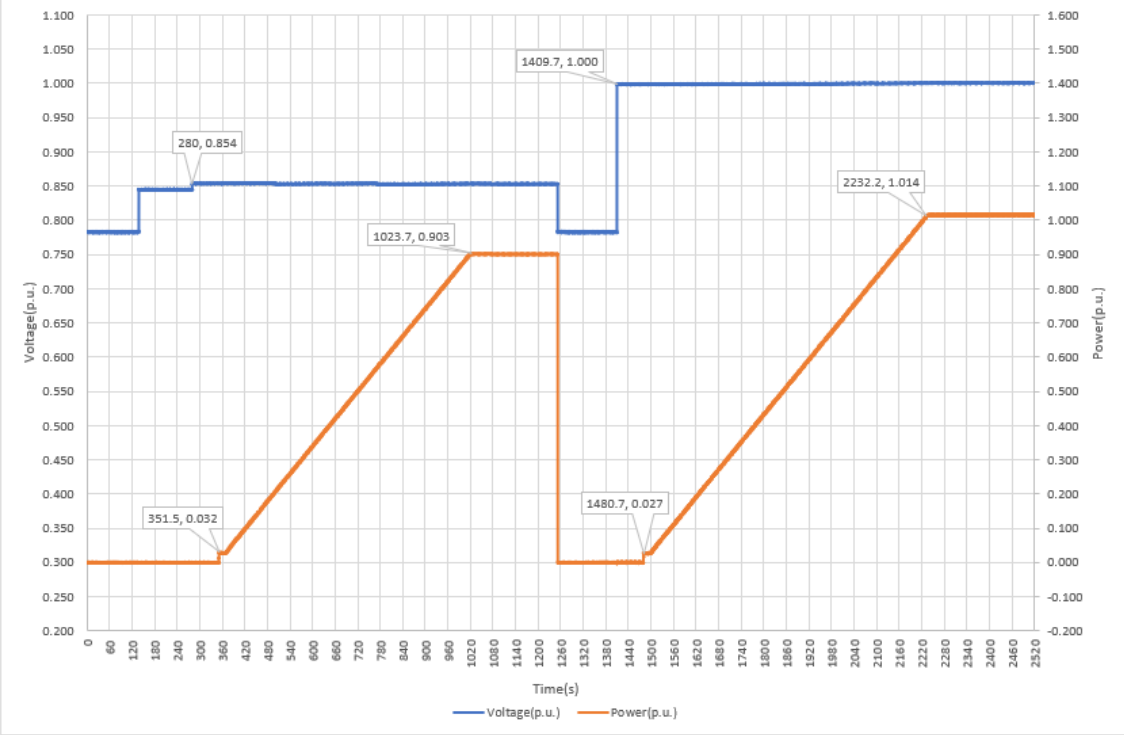
Connection		Setting Connection time (s)	Meas. Connection time (s)	Meas. gradient (%Pn/min)
U < 110 %Un	Yes	70	69.9	8.41
U > 85 %Un	Yes	70	71.5	7.77
f < 50.10 Hz	Yes	70	71.6	7.86
f > 49.90 Hz	Yes	70	71.4	7.83

(*) tolerance of reconnection time is ±5s

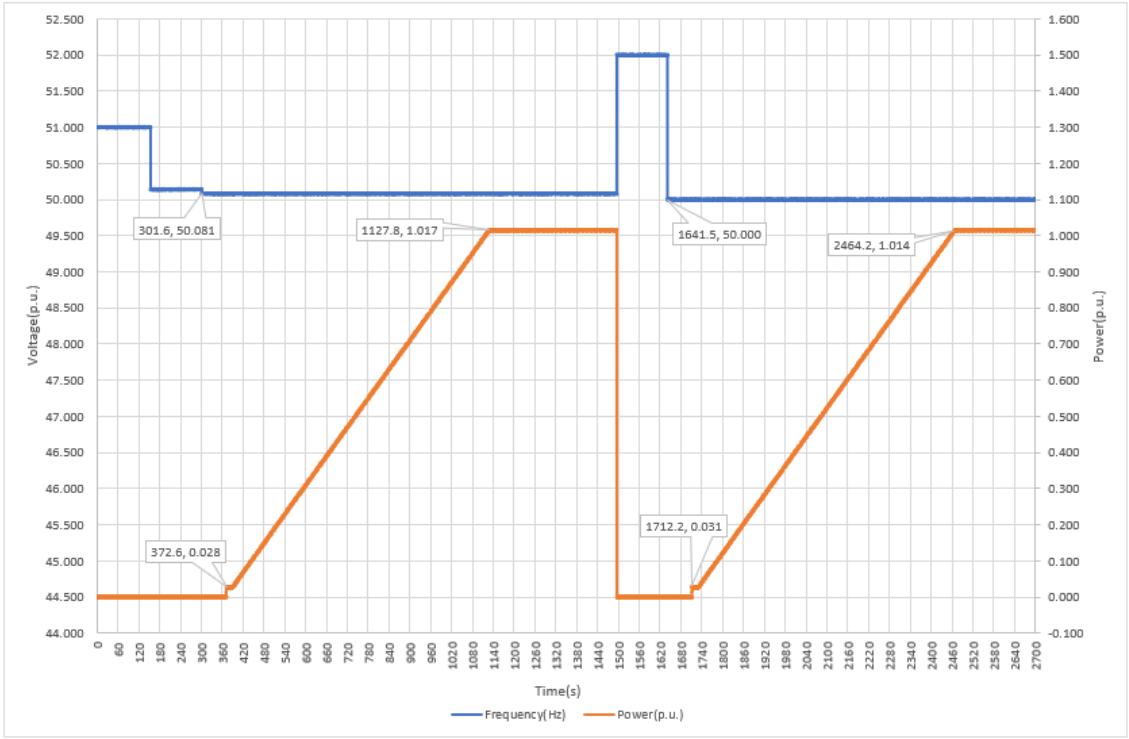
Overvoltage Connection and Reconnection



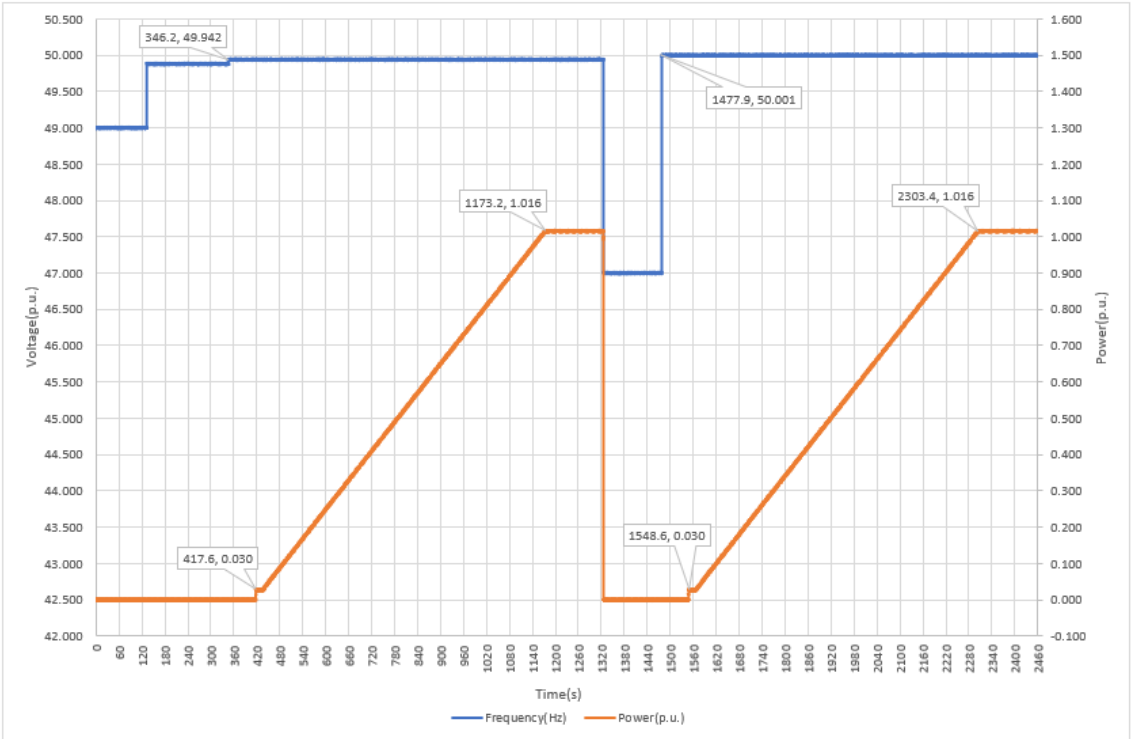
Undervoltage Connection and Reconnection



Overfrequency Connection and Reconnection



Underfrequency Connection and Reconnection



4.7.3. Synchronization

The requirements are from clause 4.10.4 of the standard. Synchronizing a generating plant/unit with the distribution network shall be fully automatic.

The EUT is fully automatic in the connection to the distribution network.

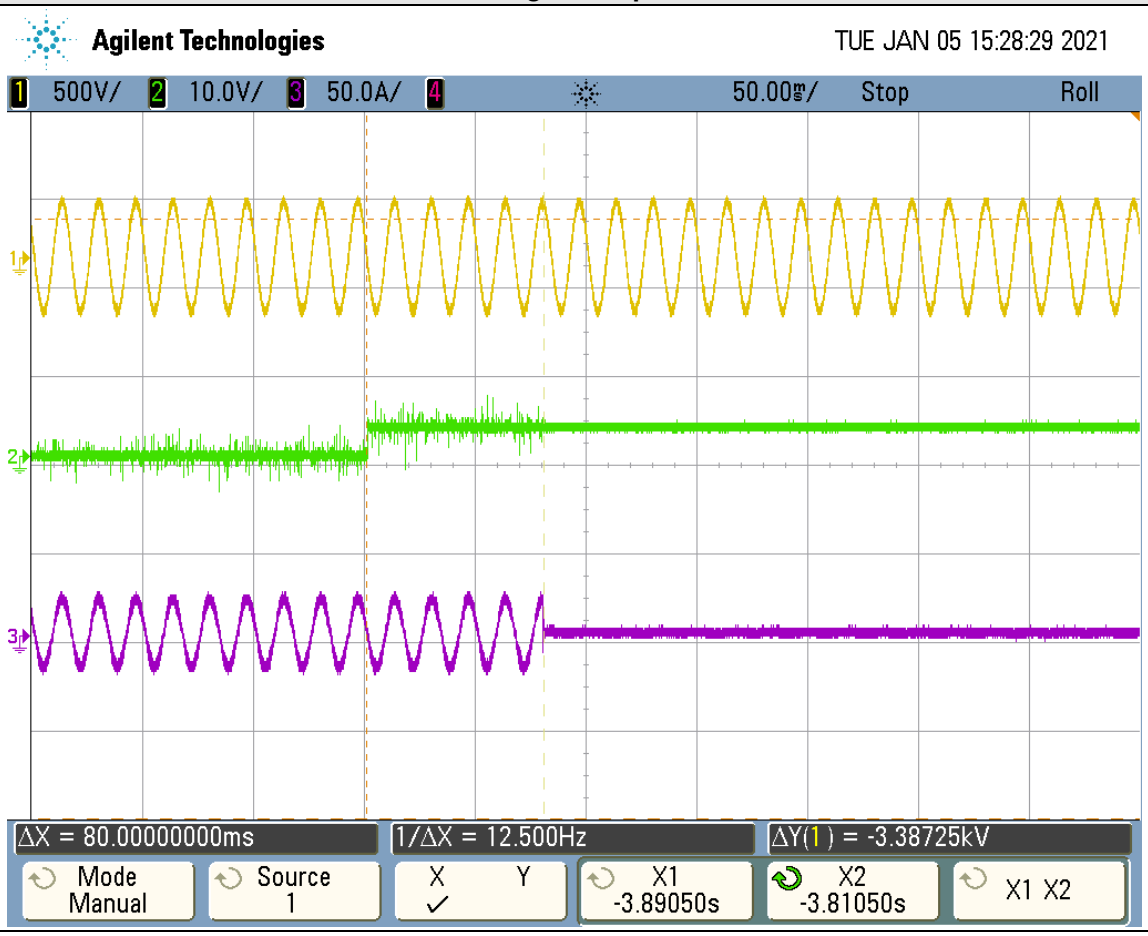
4.8. CEASING AND REDUCTION OF ACTIVE POWER ON SET POINT

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.

Ceasing active power



Tested ceasing active power time: 80 ms

Ch1: Grid voltage, Ch3: Output current, Ch2 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.

The EUT is classified as Type A. This test is not applicable.

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

The requeriments are from clause 4.3.2 and 4.13 of the standard.

1) The compliances with the requirements of clause 4.3.2 are met with the following structure:

The output is switched off redundant by the high power switching bridge and two relay in series. This assures that the opening of the output circuit will also operate in case of one error.
AC Relay model ALFG2PF12, rated: 250 Vac / 31 A;

2) The compliances with the requirements of clause 4.13 are stated in section 4.4 of following test reports:

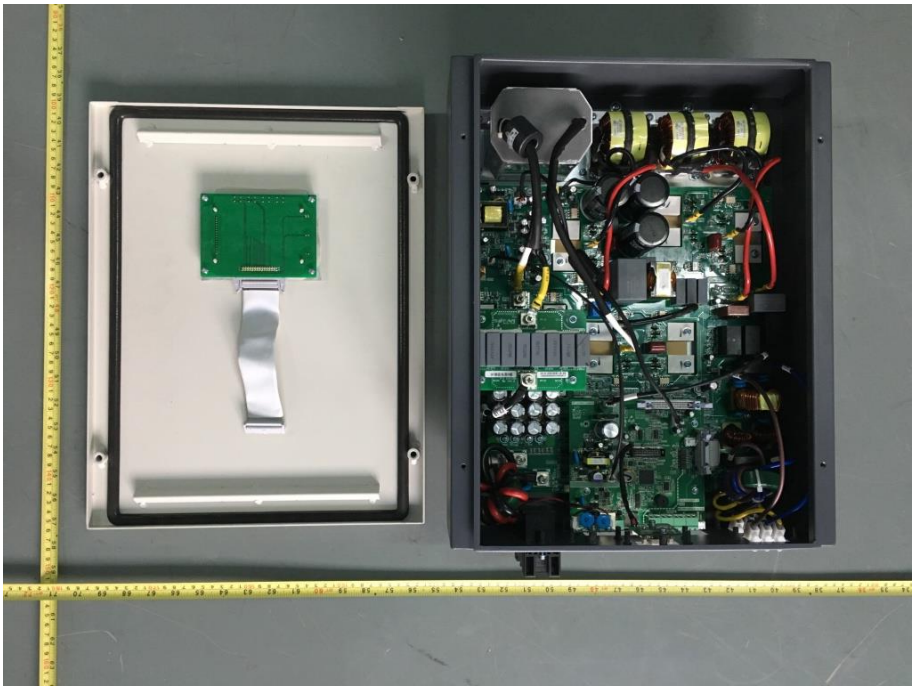
EN 62109-1:2010: Test Report nº 201008062GZU-002 on 2020/11/18 which was issued by Intertek Testing Services Shenzhen Ltd. Guangzhou Branch

5. PICTURES

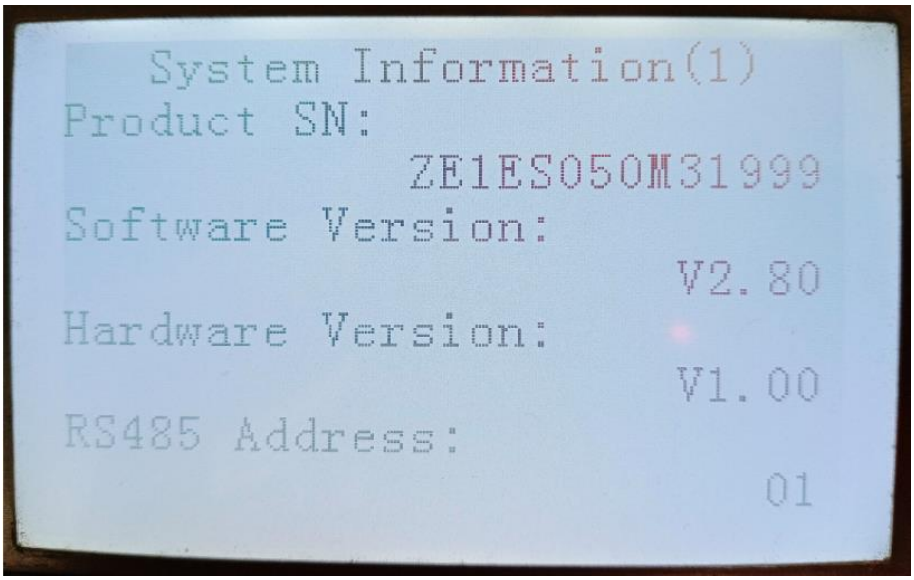
Front

Back Side


Internal View



Software Version and Serial Number of the EUT



6. ELECTRICAL SCHEME