TESTING FOR THE VERIFICATION OF COMPLIANCE OF PV INVERTER WITH:

FGW TG3: DETERMINATION OF THE ELECTRICAL CHARACTERISTICS OF POWER GENERATING UNITS AND SYSTEMS, STORAGE SYSTEMS AS WELL FOR THEIR COMPONENTS IN MV, HV AND EHV GRIDS.

(REVISION 25 DATED 01/09/2018 + SUPPLEMENT 1 DATED ON 22/01/2019)

Procedure: PE.T-LE-62

Test Report Number ....: **2219 / 0163 – A**

Type ....: 3 Phase Grid Connected PV Inverter

Tested Model ....: **SOFAR 33000TL-G2**

Variant Models ....: SOFAR 30000TL-G2, SOFAR 25000TL-G2, SOFAR 20000TL-G2

APPLICANT

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

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(Technical Reviewer)

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Total Number of pages..................................: 455

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Test Report Historical Revision:

Test Report Version	Date	Resume
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1 SCOPE

SGS Tecnos, S.A. (Electrical Testing Laboratory) has been contract by **Shenzhen SOFAR SOLAR Co., Ltd.** to perform testing according to FGW-TG3: Technical Guidelines for Power Generating Units and Systems. TG3 (Revision 25 Dated 01/09/2018 + Supplement 1 Dated 22/01/2019): Determination of Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well for their Components in MV, HV and EHV grids.

The following standards are covered with testing of FGW-TG3 (Revision 25 Dated 01/09/2018) (*):

- **VDE-AR-N 4110: 2018-11**. Technical requirements for the connection and operation of customer installations to the medium voltage network (TAR medium voltage).

(*) As stated in chapter 11.2.1 of VDE-AR-N 4110.

2 GENERAL INFORMATION

2.1 TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed along between 20th Nov. 2019 to 26th Dec. 2019, 1st Mar. 2020 to 03rd Sep. 2020.

All the tests and checks have been performed at climatic conditions:

Temperature	25 ± 10 ºC
Relative Humidity	50 ± 20 %
Pressure	90 ± 10 kPa

SITE TEST 1

Name...: **Dongguan BALUN Technology Co., Ltd.**

Address ....: Room 104, 204, 205, Building 1, No. 6, Industrial South Road, Songshan Lake Park, Dongguan, Guangdong Province, P. R. China523808

2.2 EQUIPMENT UNDER TESTING

Apparatus type .... : **Grid-Connected PV Inverter**

Installation .... : Fixed installation

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

Trade mark.. : SOFAR SOLAR

Model / Type reference .... : **SOFAR 33000TL-G2**

Serial Number .... : SL1CS033KB5179

Software Version... : V2.50

Checksum .... : N/A

Rated Characteristics.................................. : Input: 1100 $V_{dc,max}$ (230-960 $V_{dc,MPPT,}$ Full load range MPPT: 580V_{dc} – 850V_{dc}), ; 30A_{dc}/30A_{dc} Max.
Output: 3/N/PE 230/400Vac; 50 Hz; 3x47.8A_{ac}.; 33000W Rated; 36300VA Max.

Date of manufacturing: 2019

Test item particulars

Input .... : DC

Output .... 3 Phase ~

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

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

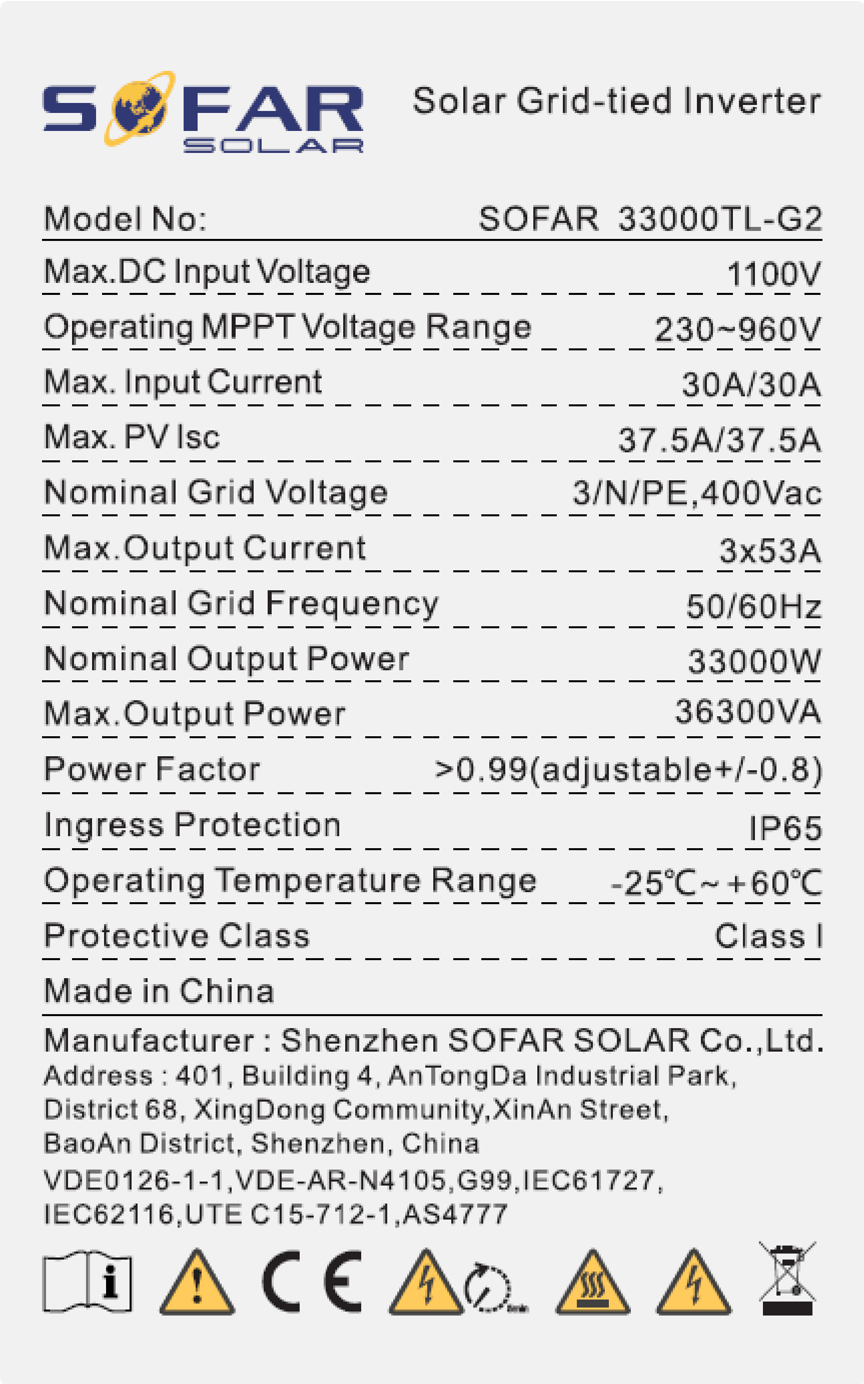
Type of connection to the main supply .... : Three-phase – Fixed installation

Cooling group.. : Forced ventilation (Fan)

Modular .... : No

Internal Transformer .... : No

Copy of marking plate (representative):



Note:

1. The above markings are the minimum requirements required by the safety standard. For the final production samples, the additional markings which do not give rise to misunderstanding may be added.
2. Label is attached on the side surface of enclosure and visible after installation
3. Labels of other models are as the same with SOFAR 33000TL-G2’s except the parameters of rating.

Equipment under testing:

- **SOFAR 33000TL-G2**

The variants models are:

- **SOFAR 30000TL-G2**
- **SOFAR 25000TL-G2**
- **SOFAR 20000TL-G2**

Model Number	SOFAR 20000TL-G2	SOFAR 25000TL-G2	SOFAR 30000TL-G2	SOFAR 33000TL-G2
Max. PV input voltage	$1100V_{dc}$			
Operating MPPT voltage range	$230V_{dc}$ - $960V_{dc}$			
Full load MPPT voltage range	$480V_{dc}$ – $850V_{dc}$	$460V_{dc}$ – $850V_{dc}$	$520V_{dc}$ – $850V_{dc}$	$580V_{dc}$ – $850V_{dc}$
No. Of MPP inputs	2			
Max. input current	$24A_{dc}$ / $24A_{dc}$	$28A_{dc}$ / $28A_{dc}$	$30A_{dc}$ / $30A_{dc}$	$30A_{dc}$ / $30A_{dc}$
Rated grid voltage	3P/N/PE $230/400V_{ac}$			
Rated grid frequency	50Hz			
Rated output power	20000W	25000W	30000W	33000W
Max. output power	22000VA	27500VA	33000VA	36300VA
Max. AC output Current	$3x32A_{ac}$	$3x40A_{ac}$	$3x48A_{ac}$	$3x53A_{ac}$
Rated AC output Current	$3x29.0A_{ac}$	$3x36.2A_{ac}$	$3x43.5A_{ac}$	$3x47.8A_{ac}$
Power factor range	0.8 lagging to 0.8 leading			

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

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

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.

2.2.1 Reference Values

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

Reference Values	
Rated power, **Pn** in kW	33
Max. output power, **Pmax** in kW	36.3
Rated apparent power, **Sn** in kVA	33
Rated wind speed (only WT), **vn** in m/s	Not applicable
Rated current (determined), **In** in A	47.8
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 **Pn** -For Currents p.u values, the reference is always **In** -For Voltages p.u values, the reference is always **Un**	

2.3 SGS TEST EQUIPMENT LIST

Test date from 20th Nov. 2019 to 26th Dec. 2019

From	No.	Equipment Name	MARK/Model No.	Equipment No.	Equipment calibration due date
Balun	1	Current clamp	HIOKI / CT6863-05	150613621/BZ-EP-L006	2019/2/28 to 2020/2/27
	2	Current clamp	HIOKI / CT6863-05	150613623/BZ-EP-L007	2019/2/28 to 2020/2/27
	3	Current clamp	HIOKI / CT6863-05	150613626/BZ-EP-L008	2019/2/28 to 2020/2/27
	4	Current clamp	HIOKI / CT6863-05	150613627/BZ-EP-L009	2019/2/28 to 2020/2/27
	5	Power analyzer	DEWETRON / DEWE2-A4	B0180377-Aut	2019/10/10 to 2020/10/9
Sofar Solar	6	Temperature & Humidity meter	Anymeters / TH101B	201030245220	2019/2/13 to 2020/2/12
	7	Digital oscilloscope	Agilent / DS05014A	MY50070266	2019/2/13 to 2020/2/12
	8	Voltage probe	SANHUA / SI-9110	111541	2019/2/13 to 2020/2/12
	9	Voltage probe	SANHUA / SI-9110	152627	2019/2/13 to 2020/2/12
	10	Voltage probe	SANHUA / SI-9110	111134	2019/2/13 to 2020/2/12
	11	Power analyzer	ZLG / PA3000	PA3005-P0005-1246	2019/2/13 to 2020/2/12
	12	Current probe	FLUKE / i1000s	29503223	2019/2/13 to 2020/2/12
	13	Current probe	FLUKE / i1000s	30413448	2019/2/13 to 2020/2/12
	14	Current probe	CYBERTEK / CP5150	C150150008	2019/2/13 to 2020/2/12
SGS	15	True RMS Multimeter	Fluke / 289C	GZE012-53	2019/2/26 to 2020/2/25

Test date from 1st Mar. 2020 to 3rd Sep. 2020

From	No.	Equipment Name	MARK/Model No.	Equipment No.	Equipment calibration due date
Sofar Solar	6	Temperature & Humidity meter	Anymeters / TH101B	ZB-WSDJ-001	2020/1/14 to 2021/1/13
	7	Digital oscilloscope	Agilent / DS05014A	MY50070288	2020/1/14 to 2021/1/13
	8	Voltage probe	SANHUA / SI-9110	111152	2020/1/14 to 2021/1/13
	9	Voltage probe	SANHUA / SI-9110	152627	2020/1/14 to 2021/1/13
	10	Voltage probe	SANHUA / SI-9110	111134	2020/1/14 to 2021/1/13
	11	Power analyzer	ZLG / PA5000	C820290908200 2110001	2020/3/2 to 2021/3/1
	12	Current probe	CP1000A	C181000922	2020/1/14 to 2021/1/13
	13	Current probe	CP1000A	C181000925	2020/1/14 to 2021/1/13
	14	Current probe	CP1000A	C181000929	2020/1/14 to 2021/1/13
SGS	15	True RMS Multimeter	Fluke / 289C	GZE012-53	2020/02/21 to 2021/02/20

2.4 Measurement uncertainty and Data Sampling Rates

Associated uncertainties through measurements showed in this 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	±1º
Temperature	±3º C
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.	

Applicable to measurement and testing equipment (without current and voltage transformers), The following measurements uncertainties have been taken into account for the performance of the testing process:

	Measurement uncertainty (K=2)
Voltage (Fundamental frequency)	≤ 0.5 % of Un
Current (Fundamental frequency)	≤ 0.5 % of In
Harmonic current up to 9 kHz	
≥ 0.1 % In	≤ 30 % relative to the measured value
< 0.1 % In	≤ 0.03 % of In
Setpoint signals	≤ 0.5 % of the reference variable (e.g 20 mA corresponding to Pn)
Flicker	≤ 5.8 % relative to Pst = 1
Grid protection	Specific voltage ≤ 0.5 % of Un
	Specific frequency ≤ 0.01 % of fn
Note: regarding flicker measurement uncertainty: IEC 61000-4-15 relates to a tolerance (accuracy) of <5%. Based on the assumption that the tolerance follows a rectangular distribution, the simple uncer-tainty is: (5%) / √3 = 2.89%. This results in an extended uncertainty at k=2 of 5.8%.	

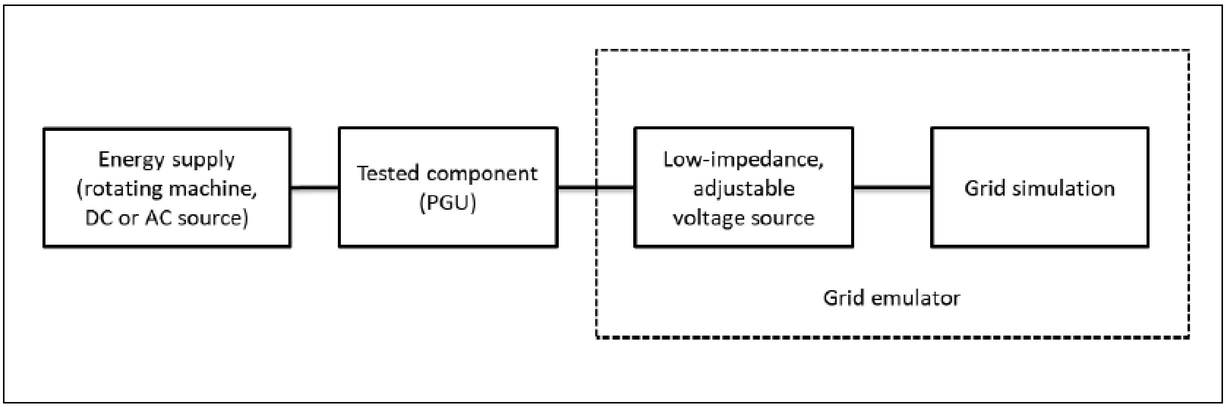
Data sampling rates have been applied complying with the chapter 3.3 of the standard:

	Chapter of standard	Voltage, currents	Setpoint and actual value signals	External signals
Active power output	4.1	≥ 3 kHz	≥ 3 kHz	≥ 1 Hz
Reactive power provision	4.2	≥ 3 kHz	≥ 3 kHz	≥ 1 Hz
Switching operations, flicker	4.3.2, 4.3.3	≥ 3 kHz	- -	≥ 1 Hz
Harmonics	4.3.4	≥ 20 kHz	- -	≥ 1 Hz
PGU disconnection from the grid	0	≥ 10 kHz	- -	≥ 10 kHz
Verification of cut-in conditions	4.5	≥ 3 kHz	- -	≥ 1 Hz
Response during grid faults	4.6	≥ 10 kHz	- -	≥ 1 Hz

2.5 TEST SET UP & TEST CONDITIONS

2.5.1 Test set up & Test Conditions.

Below is the simplified construction of the test set up used in all test of this report



Test Conditions		
Condition	**Value**	**Comments**
Point of measurement	EUT Output (Low Voltage)	Equipment enounced in section 2.3 of this report has been used in the point of measurement
Short circuit ratio at the measurement point (S_k /Sn)	2.27	$S_{k\,=}$ 75KVA, S_n=33KVA
If the PGU is connected directly to the medium-voltage grid and a step-up transformer is installed between the PGU and the grid (which is not part of the PGU), a standard transformer must be used, the rated apparent power of which corresponds at least to the rated apparent power of the PGU being evaluated.	All the tests have been performed measuring at the output of the PGU. No MV transformer used for the test measurments.	
MV Tansformer: Short circuit Power	--	Not applicable measured in Low voltage side
MV Tansformer: Network impedance Phase Angle	--	Not applicable measured in Low voltage side
MV Tansformer: Service voltage Uc	--	Not applicable measured in Low voltage side
LV Isolation transformer: Nominal Power (kVA)	--	AC simulator used for the test
LV Isolation transformer: Short circuit voltage U_k (%)	--	AC simulator used for the test
LV Isolation transformer: Tap possition	--	AC simulator used for the test
MV Side: Additional impedance	--	Not applicable measured in Low voltage side
LV Side: Additional impedance	Active 0 Ω Reactive 0 Ω	
The THDSU of the voltage which includes all integer harmonics up to the 50th order must be smaller	See section 2.5.2 of this report	

Test Conditions		
Condition	**Value**	**Comments**
than 5%. It is measured as the 10-minute mean at the PGU terminals while the PGU is not generating any power.		
The voltage, measured as a 10-minute mean at the PGU terminals, must lie within a range of ±10% of the rated voltage	Phase A: 0.11% Phase B: 0.07% Phase C: 0.14%	
The voltage unbalance, measured as a 10-minute mean at the PGU terminals, must be less than 2%.	-0.335%	
The grid frequency, measured as a 0.2 second mean, must lie within a range of ±1% of the rated frequency around the rated frequency. The rate of change of the grid frequency, measured as a 0.2 second mean, must be smaller than 0.2% of the rated fre-quency per 0.2 seconds.	Tested Max. Value 50.008Hz Tested Min. Value 49.993Hz Tested Avg. Value:50.002Hz	
Note 1: These test conditions have been used in all the test performed in Section 4 of this report. Note 2: See also the test bench information table in this section		

2.5.2 Voltage harmonic for Test bench

Measurements of voltage harmonics at continuous operation are done according to IEC 61000-4-7:2002

Nr./ Order	Phase A U_h(%)	Phase A U_h(%)	Phase A U_h(%)	Limited
2	0.465	0.075	0.098	5
3	0.370	0.234	0.234	5
4	0.305	0.050	0.062	5
5	0.167	0.170	0.175	5
6	0.123	0.018	0.018	5
7	0.142	0.105	0.106	5
8	0.051	0.021	0.012	5
9	0.073	0.063	0.063	5
10	0.021	0.015	0.016	5
11	0.069	0.040	0.051	5
12	0.011	0.009	0.010	5
13	0.063	0.040	0.045	5
14	0.019	0.020	0.020	5
15	0.050	0.039	0.046	5
16	0.019	0.024	0.023	5
17	0.036	0.042	0.037	5
18	0.010	0.018	0.020	5
19	0.018	0.031	0.029	5
20	0.009	0.011	0.014	5
21	0.009	0.018	0.018	5
22	0.012	0.009	0.010	5
23	0.009	0.014	0.010	5
24	0.012	0.012	0.012	5
25	0.013	0.013	0.009	5
26	0.012	0.010	0.012	5
27	0.018	0.013	0.013	5
28	0.010	0.008	0.008	5
29	0.026	0.015	0.016	5
30	0.008	0.009	0.010	5
31	0.026	0.013	0.015	5
32	0.009	0.011	0.012	5
33	0.025	0.014	0.014	5
34	0.012	0.012	0.012	5
35	0.020	0.012	0.012	5
36	0.012	0.012	0.012	5
37	0.014	0.012	0.010	5
38	0.012	0.010	0.009	5
39	0.009	0.010	0.009	5
40	0.010	0.008	0.007	5
41	0.008	0.010	0.008	5
42	0.009	0.006	0.007	5
43	0.007	0.011	0.008	5
44	0.009	0.006	0.007	5
45	0.007	0.009	0.007	5
46	0.008	0.006	0.007	5
47	0.009	0.009	0.007	5
48	0.008	0.007	0.007	5
49	0.012	0.009	0.008	5
50	0.010	0.008	0.008	5
TDD (%)	0.734	0.349	0.360	--

Test bench used includes:

	EQUIPMENT	MARK / MODEL	RATED CHARACTERISTICS	OWNER / ID.CODE
Test Bay	AC source	Wogo / WLPA-330-75kVA	75kVA 5-300Vrms 45-65Hz	BALUN / BZ-DGD-L014
	DC source	Wogo / WLPA-150kW	0 – 1500Vdc (0.01V step) 0 – 200A (0.01A step)	BALUN / BZ-DGD-L013
Load Bank	RLC load	Qunlin / ACLT3820H	68kW, 68kVAr	BALUN / BZ-DGD-L063

Test bench requirements according to Annex D from the standard.

2.6 DEFINITIONS

EUT	Equipment Under Testing	W	Watt
A	Ampere	p.u.	Per unit
VAr	Volt-Ampere reactive	Pn	Nominal Active Power
Un	Nominal Voltage	P_{mom}	Instantaneous Active Power
In	Nominal Current	P_{ref}	P_{mom} in case of PV and Storage
MV	Medium Voltage	P_{10}	Active power as 10 s mean value
LV	Low Voltage	Qn	Nominal Reactive Power
LVRT	Low Voltage Ride Through	Sn	Nominal Apparent Power
V1+ / V_{AC+}	Voltage positive sequence	S_k	Symetrical Fault level
V1- / V_{AC-}	Voltage negative sequence	I_h	Harmonic Current
K_f (Ψ_k)	Flicker Form Factor	TDC	Total Demand Current Distortion
K_u (Ψ_k)	Voltage Variation Factor	TDD	Total Demand Distortion
P_{st}	Short-term flicker disturbance factor	$THDS_U$	Subgroup Total Harmonic Distortion
PGU	Power Genaration Unit	Ui	Current Imbalance
Hz	Hertz	Uv	Voltage Imbalance
V	Volt	I+	Current Positive Sequence
		I1-	Current Negative Sequence

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

VDE-AR-N 4110 SECTION	FGW TG3 SECTION	CHAPTER OF THE STANDARD FGW-TG3	RESULT
--	**4.1**	**Active Power Output**	**P**
11.2.7	4.1.1	Active power peaks	P
10.2.4.1 10.2.4.2 11.2.7	4.1.2	Operating power limited by grid operator	P
10.2.4.3 11.2.8	4.1.3	Active power feed-in as a function of grid frequency	P
10.2.4. 11.2.11	4.1.4	Active power gradient following disconnection from the grid	P
--	**4.2**	**Reactive Power Provision**	**P**
10.2.2.4 11.2.4	4.2.1	Reactive power response in the normal operating mode (Q=0 kVAr)	P
10.2.2.4 11.2.4	4.2.2	Measuring the maximum reactive power range (PQ Diagram)	P
10.2.2 11.2.4	4.2.3	Measuring separate operating points in the voltage-dependent PQ diagram	P
10.2.2.4 11.2.4	4.2.4	Reactive power following setpoints	P
10.2.2.4 11.2.4	4.2.5	Q (U) control	P
10.2.2.4 11.2.4	4.2.6	Q (P) Control	P
10.2.2.4 11.2.4	4.2.7	Reactive Power Q with voltage Limitation Function.	N/A
--	**4.3**	**System Perturbations**	**P**
--	4.3.1	General procedures	P
5.4.2 11.2.2.1	4.3.2	Switching operations	P
5.4.3 11.2.2.2	4.3.3	Flickers	P
5.4.4 11.2.2.3	4.3.4	Harmonics	P
5.4.6 11.2.2.5	4.3.5	Unbalances of the current	P
10.3.3.1 10.3.3.2 10.3.3.3 10.3.4.2.2 11.2.10	**4.4**	**PGU disconnection from the grid**	**P**
--	**4.5**	**Verification of connection conditions**	**P**
10.4.1 11.2.11	4.5.1	Connection without previous protection trigger	P
10.4.2 11.2.11	4.5.2	Connection after triggering of the uncoupling protection	P
10.2.3 11.2.5	**4.6**	**Response during grid faults (FRT)**	**P (*)**

VDE-AR-N 4110 SECTION	FGW TG3 SECTION	CHAPTER OF THE STANDARD	RESULT
		FGW-TG3	
10.2.1.2 11.2.3	**4.7**	**Verification of the working range with regard to voltage and frequency**	**P**

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

(*) Results are shown in Atachment I (Report No. 2219 / 0163 – A Attachment I). That Attachment must be considered together with this report

4 TEST RESULTS

4.1 ACTIVE POWER OUTPUT

4.1.1 Active power peaks

The aim of the test is to determine the maximum active power peaks from different averaging intervals. The active power in the output will be measured in function of the DC input voltage applied. In this way, the DC input voltage is increased in steps, or continuously, from the minimum value of the MPPT range up until the EUT limits active power or the maximum value of the MPPT is reached. This method applies not only for PV, but also for Storage equipment.
The point of maximum active power is adopted at least twice.

The reactive power setpoint prior to the test was set to Q=0, and was maintained during the whole test.

The test has been performed following the testing method detailed in the point 4.1.1 of the reference standard, maximum values of injected active power by the EUT for averaging times of 0.2 s; 60 s and 600 s.

Used settings of the measurement device for this active power peaks testing.

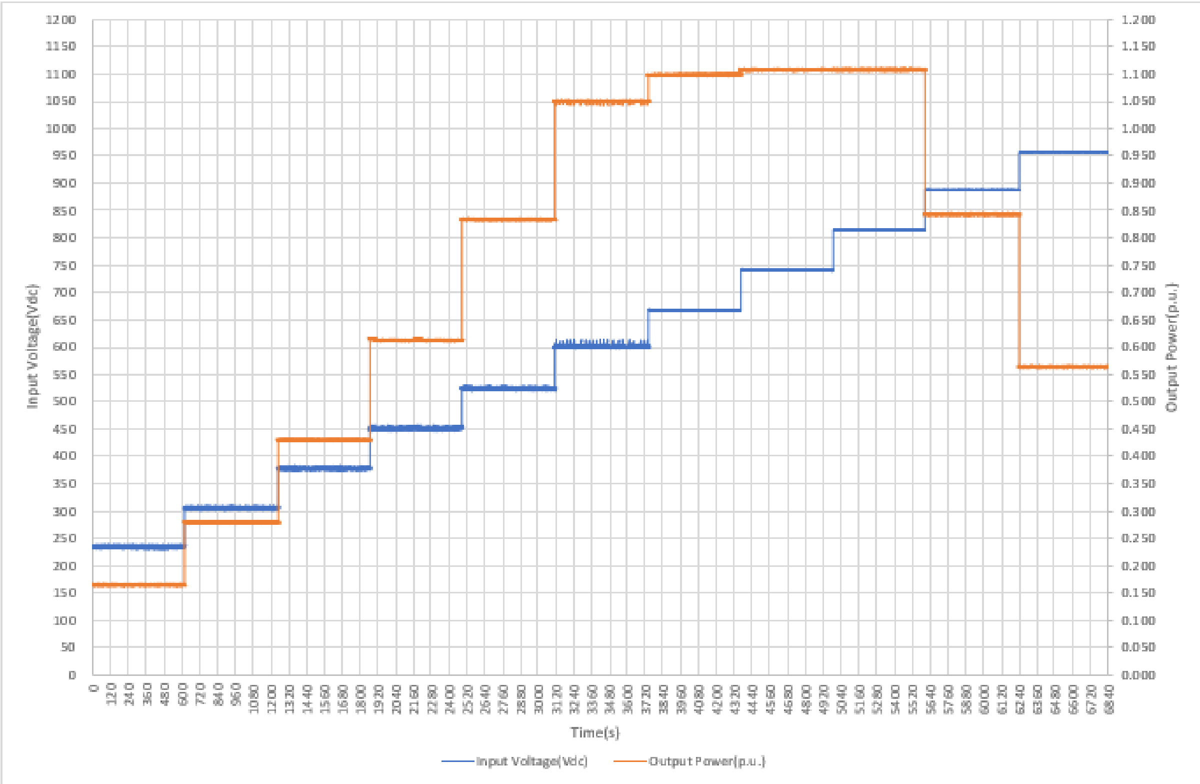
Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2020/8/17	100ms values	10kHz

Test results are offered in the following table:

DC Voltage (V)	Active power peaks (W)			Normalized active power peaks (p.u.)			No. of used 600 seconds records
	$P_{0.2}$	P_{60}	P_{600}	$P_{0.2}$	P_{60}	P_{600}	
230	5459	5444	5441	0.165	0.165	0.165	10
303	9242	9224	9223	0.280	0.280	0.279	
376	14214	14198	14196	0.431	0.430	0.430	
449	20311	20258	20219	0.615	0.614	0.613	
522	27538	27513	27506	0.834	0.834	0.834	
595	34664	34645	34641	1.050	1.050	1.050	
668	36305	36278	36266	1.100	1.099	1.099	
741	36573	36542	36540	1.108	1.107	1.107	
814	36580	36559	36554	1.108	1.108	1.108	
887	27838	27819	27818	0.844	0.843	0.843	
960	18627	18617	18615	0.564	0.564	0.564	

Reactive Power Measured (p.u.)	0.032

Active Power Peaks



4.1.2 Operating power limited by grid operator

The aim of the test is to determine how fast (Settling time) and how precisely (setting accuracy) the PGU can follow an active power setpoint input, e.g. from a grid operator. Additionally, the capacity of following a setpoint with a specific gradient is to be tested.

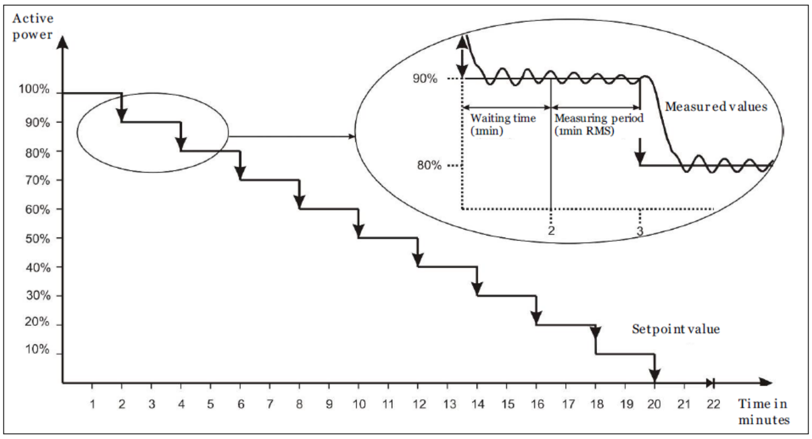
Interface information	
Interface used	Solar communication tools, RS485
Interface version used	V250
Other interfaces in the equipment	N/A
Name or code of the parameter for active power setting	Active and ON/OFF control
If the EUT has several different interfaces for defining the setpoint, it has been tested the interface returning the most unfavourable results according to the manufacturer information.	

4.1.2.1 Active Power setting accuracy

This test has been performed according to the point 4.1.2.2 of the standard.

Test procedure applied consist on active output power reductions in steps of 10% Pn from 100% Pn to 0% Pn. During these reduction steps there was no disconnection of the generating unit.

Between each power step, the EUT has a maximum of 1 minute to adjust to the new setpoint. After this, measurements of the setpoint are taken as 1-minute mean values as stated in the image represented below.



The active power and the reactive power have been represented in the positive phase sequence system and as 200 ms means for every setpoint step.

Measurement equipment settings used for this tes are shown in the following table:

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/2	100ms values	10 kHz

EUT Settings used for this test are provided in the following table:

EUT Settings	
Active Power Ramp Rate (%Pn/s)	300
Operanting mode	Active power priority
Active control modes	Active power control Active Power VS Frequency mode LVRT mode Fixed Reactive power control Reactive power VS Voltage Reactive power VS Active power Cos Phi

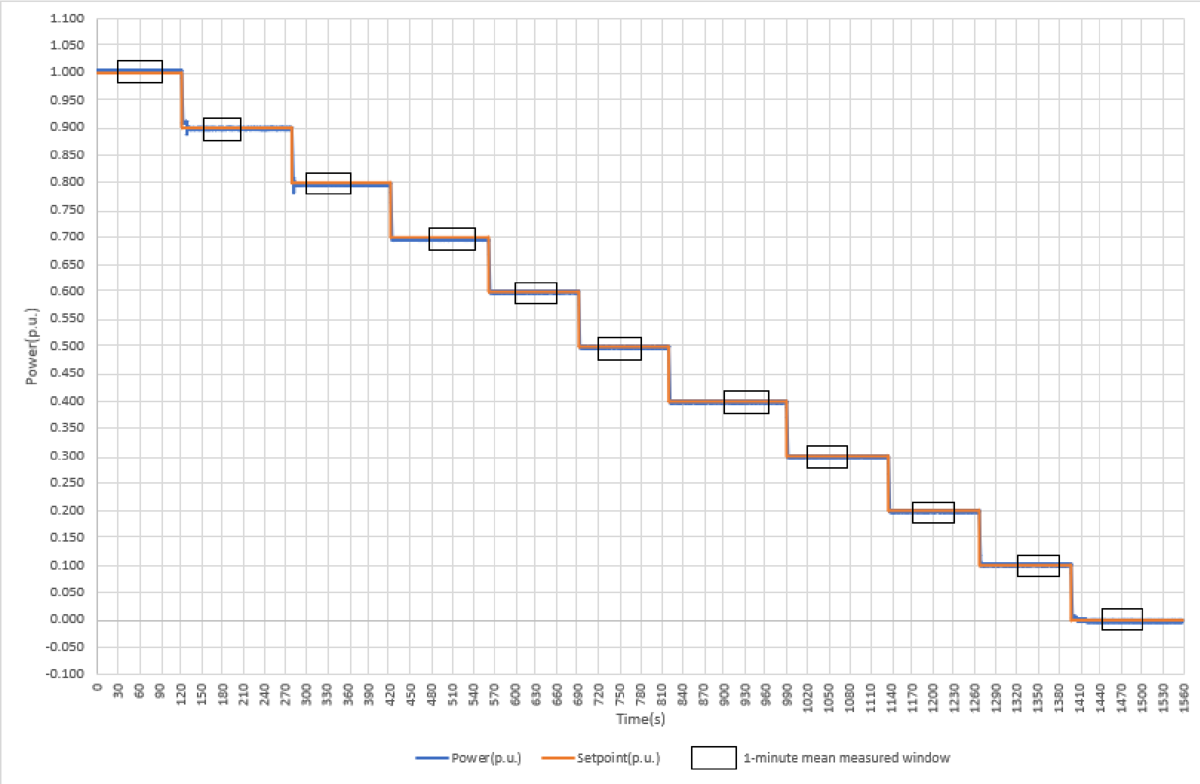
The table below shows measured values:

Active Power step (%P_n)	**Setpoint value**		**Actual value**		**Deviation**	
	(W)	**(%Pn)**	**(W)**	**(%P_n)**	**(W)**	**(%P_n)**
100%	33000	100.0%	33106	100.3%	106	0.3%
90%	29700	90.0%	29656	89.9%	-44	-0.1%
80%	26400	80.0%	26312	79.7%	-88	-0.3%
70%	23100	70.0%	22962	69.6%	-138	-0.4%
60%	19800	60.0%	19786	60.0%	-14	0.0%
50%	16500	50.0%	16455	49.9%	-45	-0.1%
40%	13200	40.0%	13163	39.9%	-37	-0.1%
30%	9900	30.0%	9841	29.8%	-59	-0.2%
20%	6600	20.0%	6553	19.9%	-47	-0.1%
10%	3300	10.0%	3331	10.1%	31	0.1%
0%	0	0.0%	-49	-0.1%	-49	-0.1%

Maximum active power above the defined setpoint (1-minute mean)	0.3%Pn
Maximum active power below the defined setpoint (1-minute mean)	-0.4%Pn

In the following graph, test results are represented after the test has been performed:

Output power reduction by steps (100 % to 0% Pn)



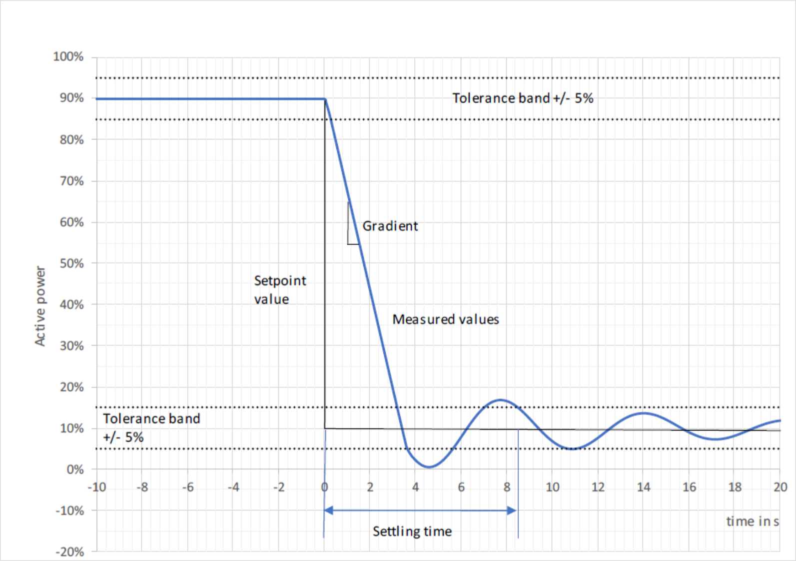
4.1.2.2 Active Power settling time and active power gradient.

This test has been performed according to the point 4.1.2.2 of the standard for settling time and active power gradient.

Two tests have been done in order to determine both the maximum and the minimum active power gradient. The evidence for the maximum active power gradient has to be provided by a step from 90% P_n to P_{min}, whereas, for the minimum active power gradient, this step has to be from 70% P_n to 50% P_n. Settling time and gradient measurements have been taken in the range of 65%P_n and 55%P_n.

Both tests have been repeated testing these steps in the opposite direction.

The settling times for the maximum active power gradients have been measured taking into account the tolerance band of ± 5% P_n as shown in the following image:



The active power and the reactive power have been represented in the positive phase sequence system and as 200 ms means for every setpoint step.

Used settings of the measurement device for Active Power settling time test.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/2	100ms values	10 kHz

EUT Settings	
Maximum Active Power Gradient (%Pn/s)	0.66
Minimum Active Power Gradient (%Pn/s)	0.33
Operanting mode	Active power priority
Active control modes	Active power control Active Power VS Frequency mode LVRT mode Reactive power control Reactive power VS Voltage Reactive power VS Active power Cos Phi

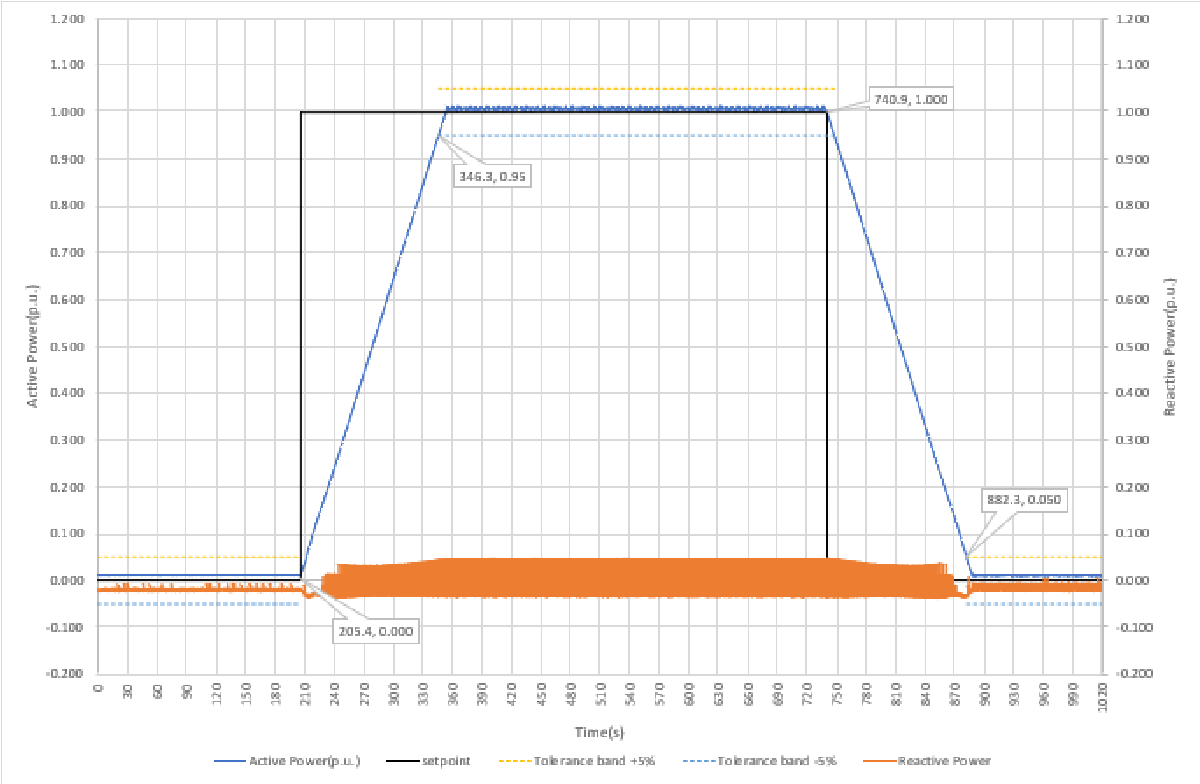
The table below shows measured values:

Test at maximum power gradient		
Active Power step (Setpoint)	**Settling time measured (s)**	**Gradient measured (%Pn/s)**
100.0% to 0% Pn	140.9	0.674
0% to 100.0% Pn	141.4	0.672
90.0% to 10.0% Pn	111.4	0.673
10.0% to 90.0% Pn	111.9	0.670
Note: 10% has been used as Pmin for testing purposes (Type 2 PGU). Pmin that can be configured is 0 %Pn. Stated in the standard: The evidence for the maximum active power gradient has to be provided by a step of the active power setpoint from P0 = 90% Pn to Pmin, i.e. the minimum technical power or to 10% Pn (for other Type 2 systems).		

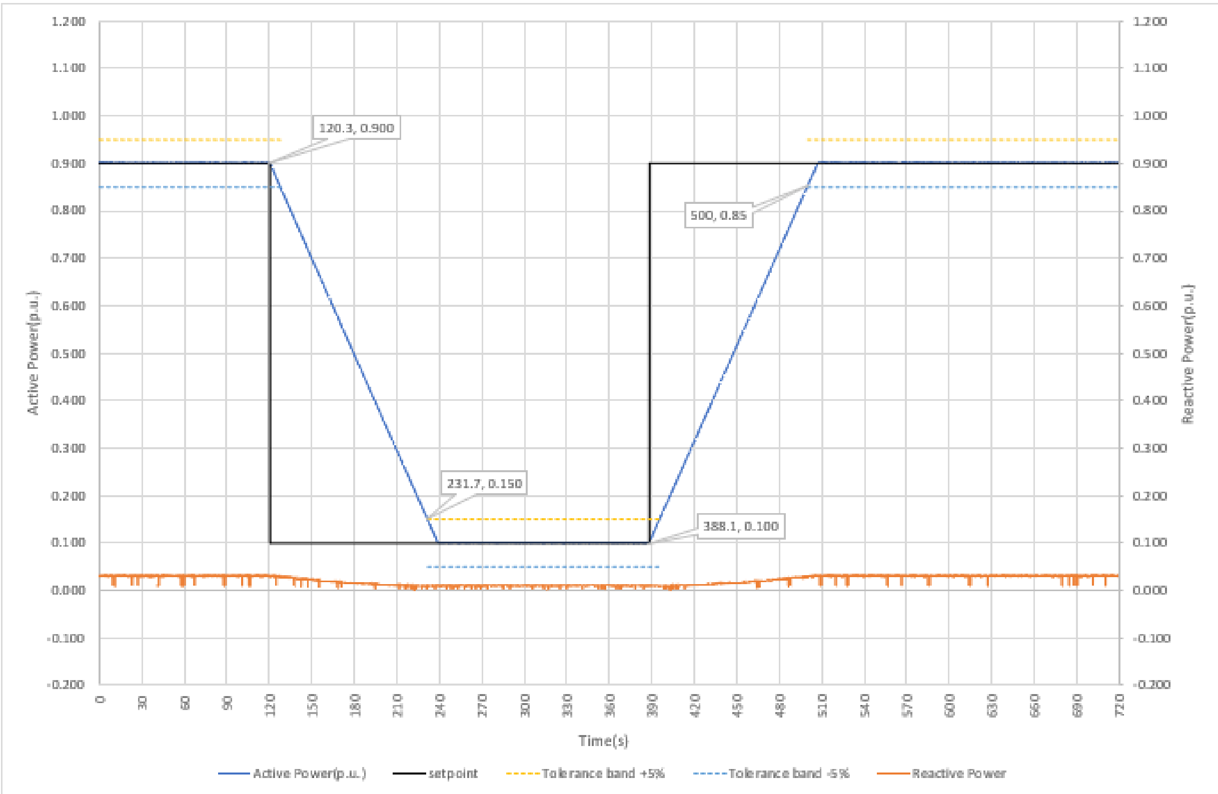
Test at minimum power gradient		
Active Power step (Setpoint)	**Settling time measured (s)**	**Gradient measured (%Pn/s)**
100.0% to 0% Pn	280.9	0.338
0% to 100.0% Pn	285.7	0.333
70.0% to 50.0% Pn	44.6	0.336
50.0% to 70.0% Pn	45.1	0.333
Note: 10% has been used as Pmin for testing purposes (Type 2 PGU). Pmin that can be configured is 0 %Pn Stated in the standard: The evidence for the maximum active power gradient has to be provided by a step of the active power setpoint from P0 = 90% Pn to Pmin, i.e. the minimum technical power or to 10% Pn (for other Type 2 systems).		

The following charts shows the gradient and the settling time:

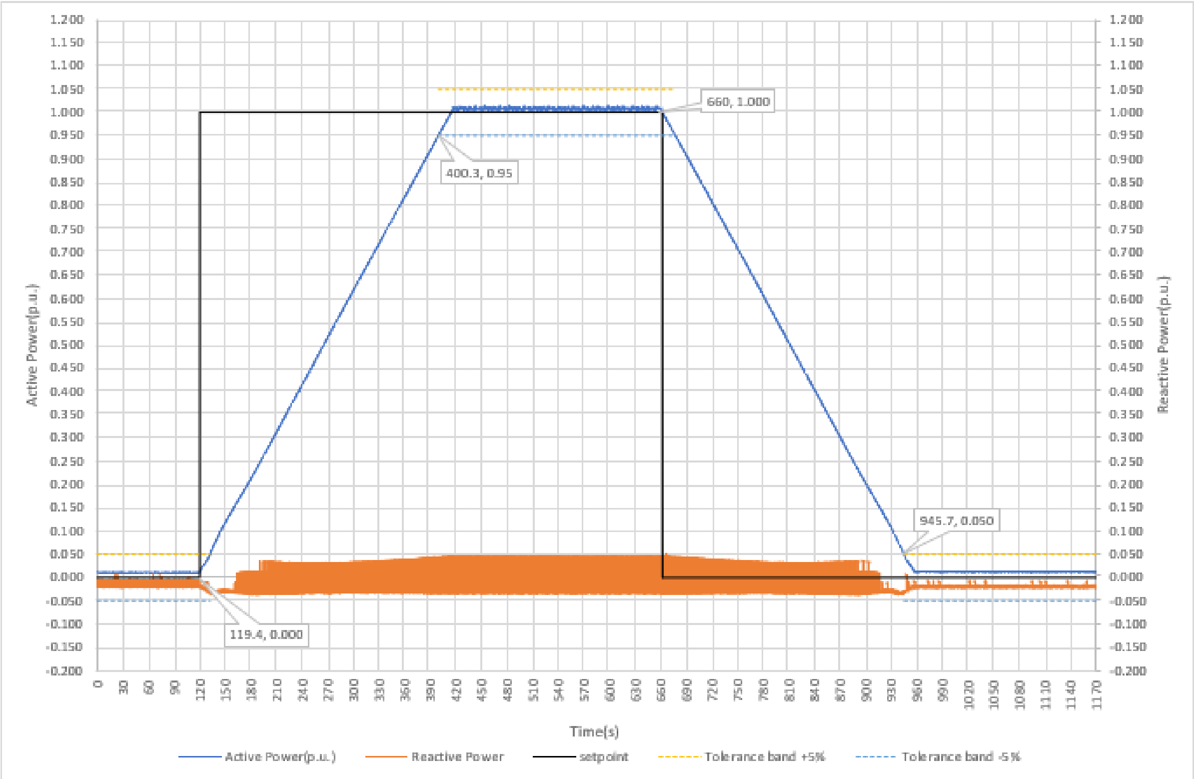
Test at maximum power gradient
Output power reduction (100% to 0% of Pn) and Output power increase (0% to 100% of Pn)



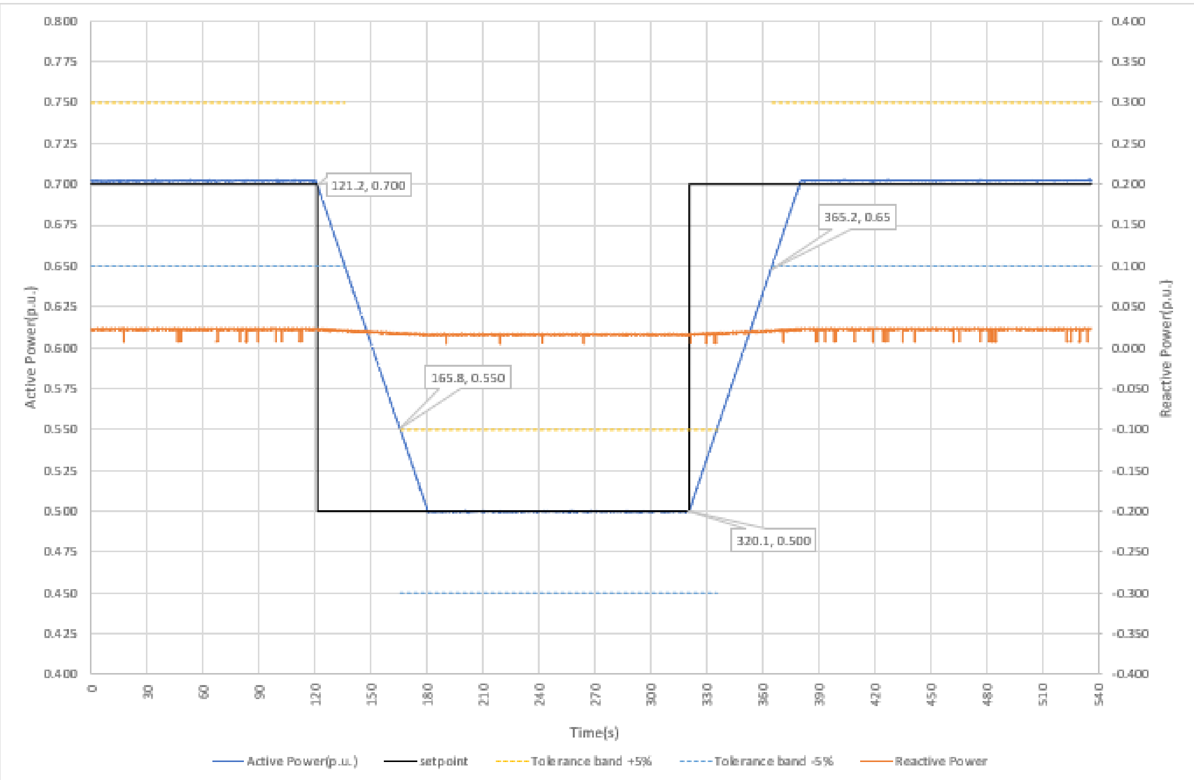
Test at maximum power gradient
Output power reduction (90% to 10% of Pn) and Output power increase (10% to 90% of Pn)



Test at minimum power gradient
Output power reduction (100% to 0% of Pn) and Output power increase (0% to 100% of Pn)



Test at minimum power gradient
Output power reduction (70% to 50% of Pn) and Output power increase (50% to 70% of Pn)



4.1.3 Active Power feed-in as a function of grid frequency

The aim of the test is to demonstrate the response of the EUT due to a deviation in grid frequency from rated value in terms of speed (rise/settling time) and the active power gradient.

This test has been performed according to the point 4.1.3.1 of the standard, changing the parameters in the PGU control system. The following figure has been performed.

Two tests have been done for both over and underfrequency tests:

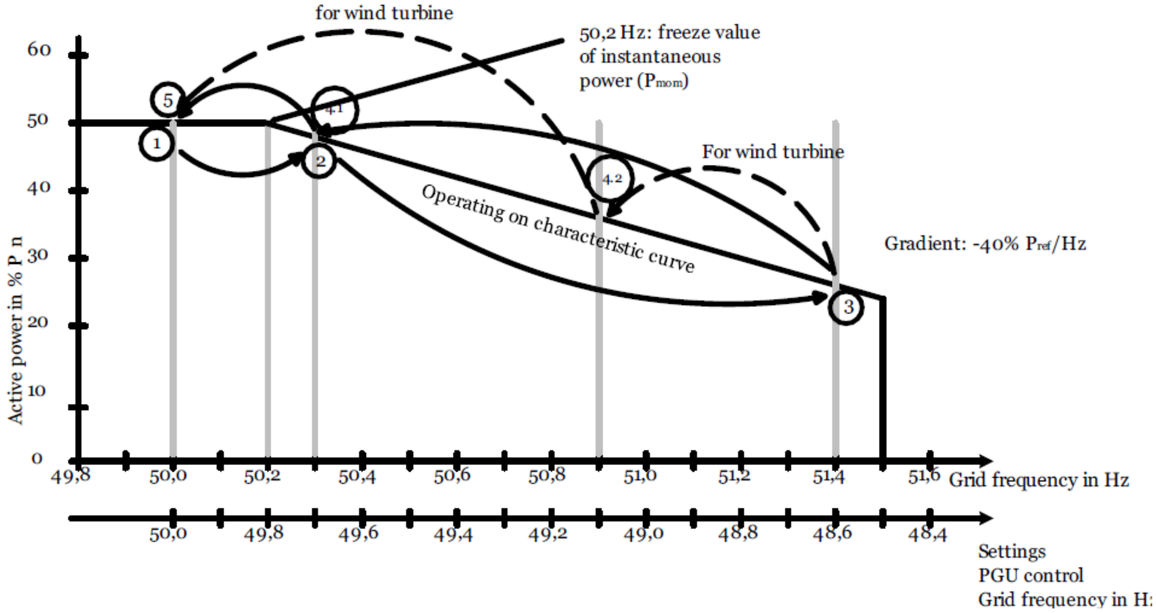
- Overfrequency test (LFSM-O): According to chapter 4.1.3.1.a).
- Underfrequency test (LFSM-U): According to chapter 4.1.3.1.b).

Testing Method Used (LFSM-O & LFSM-U)		Comments
Changing parameters in the PGU control system	☐	
Signal input to control system	☐	
Grid simulator	☒	By changing the grid simulator's frequency by setpoint and measuring the unit output.
Alternative procedures	☐	

4.1.3.1 Overfrequency (LFSM-O)

For this test, power reduction has been applied with a gradient of -40% P_{ref}/Hz in the range of 50.2 Hz to 51.5 Hz. Once the grid frequency falls below the 50.2 Hz threshold, the active power recuperation must be with a maximum gradient of 10%P_n/min.

For the test, at the beginning, active power was set over 100%Pn and, before the power reduction started, active power was reduced to a 50%Pn through a setpoint.
Frequency values must be inside next ranges (referred to the points on the figure):



Frequency Step	Simulated grid frequencies	Note
1	50.00 Hz ± 0.05 Hz	
2	50.30 Hz ± 0.05 Hz	
3	51.40 Hz ± 0.05 Hz	Verification of adherence to characteristic
4	50.30 Hz ± 0.05 Hz	
5	50.00 Hz ± 0.05 Hz	Power increase to the maximum possible active power with a maximum gradient P(t) of 10%Pn/min

60s after reaching point 5, the power reduction applied at the beginning of the test is disabled in order to verify the recuperation gradient limit of 10%Pn/min**.**

Starting at P_{ref}, it has been performed the frequency steps that can be seen on the table above, taking measures of the active power at every set point of frequency. Every point has a measured duration of 30 seconds at least.

Gradient has been calculated as follows:

$$\frac{\Delta P}{\Delta f} = \frac{P_{Step\ i+1} - P_{Step\ i}}{|f_{Step\ i+1} - f_{Step\ i}|}$$

$P_{Step\ i+1}$	10-s-mean of the active power which is calculated at the end of frequency step i+1.
$P_{Step\ i}$	10-s-mean of the active power which is calculated at the end of frequency step i.
$f_{Step\ i+1}$	10-s-mean of the grid frequency, at which PStep i+1 is determined.
$f_{Step\ i}$	10-s-mean of the grid frequency, at which PStep i is determined.

To determine the rise and settling times, a tolerance band of ± 5% of Pn is applied around the controlled active power end value.

Used settings of the measurement device for this power limitation for an increase in grid frequency testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/2	100ms values	10 kHz

The tables below show measured values:

a) Accuracy results – test at 100%Pn

LSFM-O						
Step	**Simulated grid frequency (Hz)**	**Measured grid frequency (Hz)**	**Normalized Active Power *Setpoint* (P/Pn)**	**Normalized Active Power *Measured* (P/Pn)**		**Active power gradient P(f) relative to the reference frequency**
				Whole step	**P_{10}**	
1	50.00 ± 0.01	50.00	1.000	1.002	1.002	-------
(*)	50.20 to 50.30	50.20	1.000	1.002	1.002	-------
2	50.30 ± 0.05	50.30	0.960	0.964	0.963	-------
3	51.40 ± 0.05	51.40	0.520	0.522	0.521	-40.2% P_{ref}/Hz
4	50.30 ± 0.05	50.30	0.960	0.963	0.963	-40.2% P_{ref}/Hz
5	50.00 ± 0.05	50.00	1.000	1.001	1.001	-------
(*): As the EUT is Type 2, according to the standard **Pmom = Pref** is defined as the mean value of the active power immediately prior to frequency transition at 50.2 Hz. Here, the manufacturer specifies the averaging time 100ms						

ΔP/Δf	
Mean active power gradient while frequency limit is exceeded	-40.2% P_{ref}/Hz
Defined active power gradient ΔP/Δf	-40.0% P_{ref}/Hz

b) Settling time and Rise time results – test at 100%Pn

Frequency step	Rise Time (s)	Settling time (s)
Step 2 → Step 3	0.2	0.2
Step 3 → Step 4	0.5	0.5

c) Accuracy results – test at 50%Pn

LSFM-O						
Step	**Simulated grid frequency (Hz)**	**Measured grid frequency (Hz)**	**Normalized Active Power *Setpoint* (P/Pn)**	**Normalized Active Power *Measured* (P/Pn)**		**Active power gradient P(f) relative to the reference frequency**
				Whole step	**P_{10}**	
1	50.00 ± 0.01	50.00	0.500	0.501	0.502	-------
(*)	50.20 to 50.30	50.20	0.500	0.501	0.502	-------
2	50.30 ± 0.05	50.30	0.480	0.483	0.482	-------
3	51.40 ± 0.05	51.40	0.260	0.262	0.262	-40.1% P_{ref}/Hz
4	50.30 ± 0.05	50.30	0.480	0.482	0.482	-40.0% P_{ref}/Hz
5	50.00 ± 0.05	50.00	1.000	1.001	1.001	-------
(*): As the EUT is Type 2, according to the standard **Pmom = Pref** is defined as the mean value of the active power immediately prior to frequency transition at 50.2 Hz. Here, the manufacturer specifies the averaging time 100ms						

ΔP/Δf	
Mean active power gradient while frequency limit is exceeded	-40.1% P_{ref}/Hz
Defined active power gradient ΔP/Δf	-40.0% P_{ref}/Hz

d) Settling time and Rise time results – test at 50%Pn

Frequency step	Rise Time (s)	Settling time (s)
Step 2 → Step 3	0.2	0.2
Step 3 → Step 4	0.2	0.2

e) Output power increase – test at 50%Pn

ΔP/Δt	
Maximum active power gradient	8.97% Pn/min
Mean active power gradient	8.97% Pn/min
Defined gradient ΔP/Δt	10.0% Pn/min

The gradient of active power after removal of the active power limitation has been measured as follows:

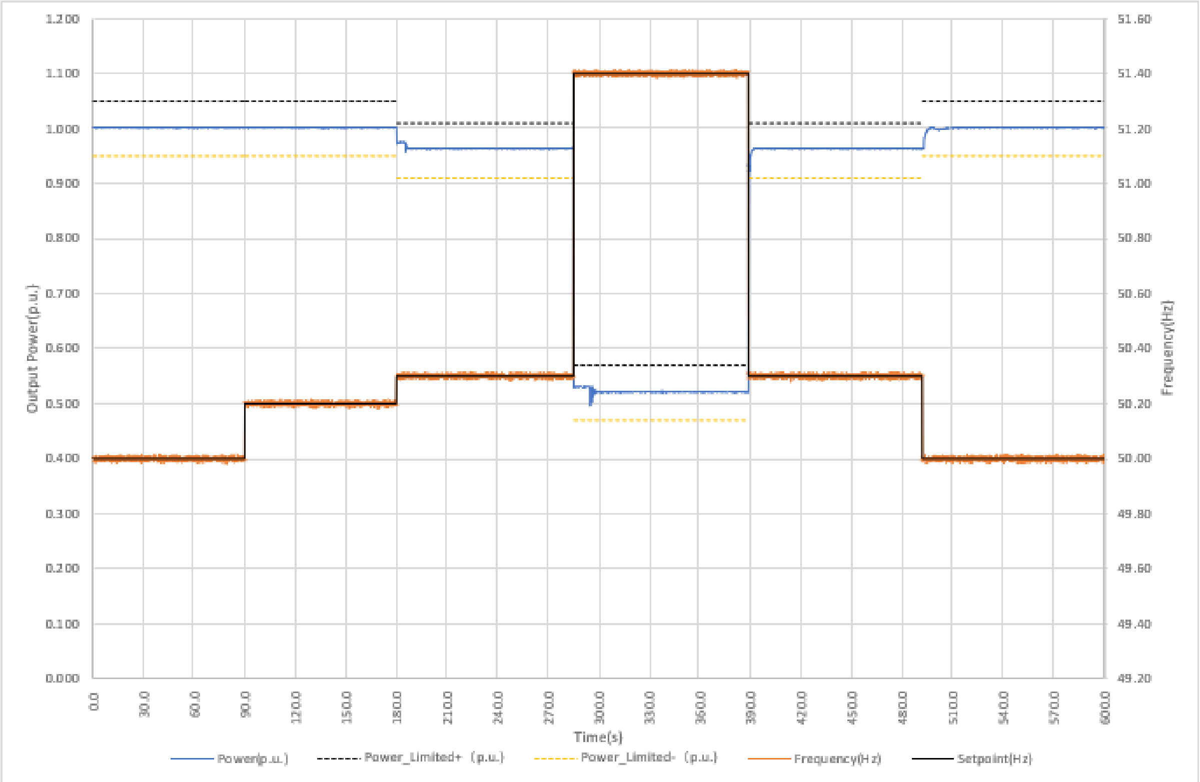
The active power has to be calculated as a 0.2 second mean.

The mean 1-minute power is determined at intervals of 1 min.
The first averaging interval starts 1 min prior to the removal of the active power limitation. The last averaging interval ends after reaching the stationary final value of active power.

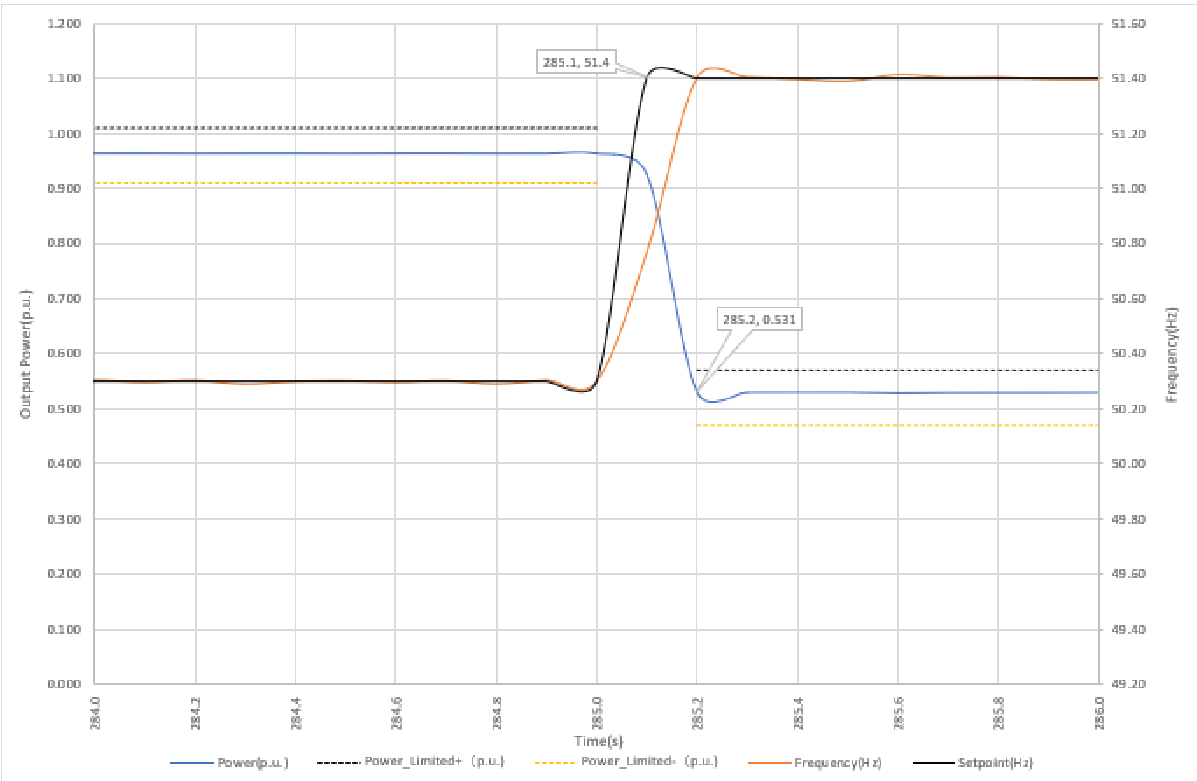
The gradient of the active power increase ΔP/Δt is determined from the difference between consecutive 1-minute mean values with reference to 1 min in each case for the time point at the boundary between two averaging intervals.

In following graphs, test results are represented:

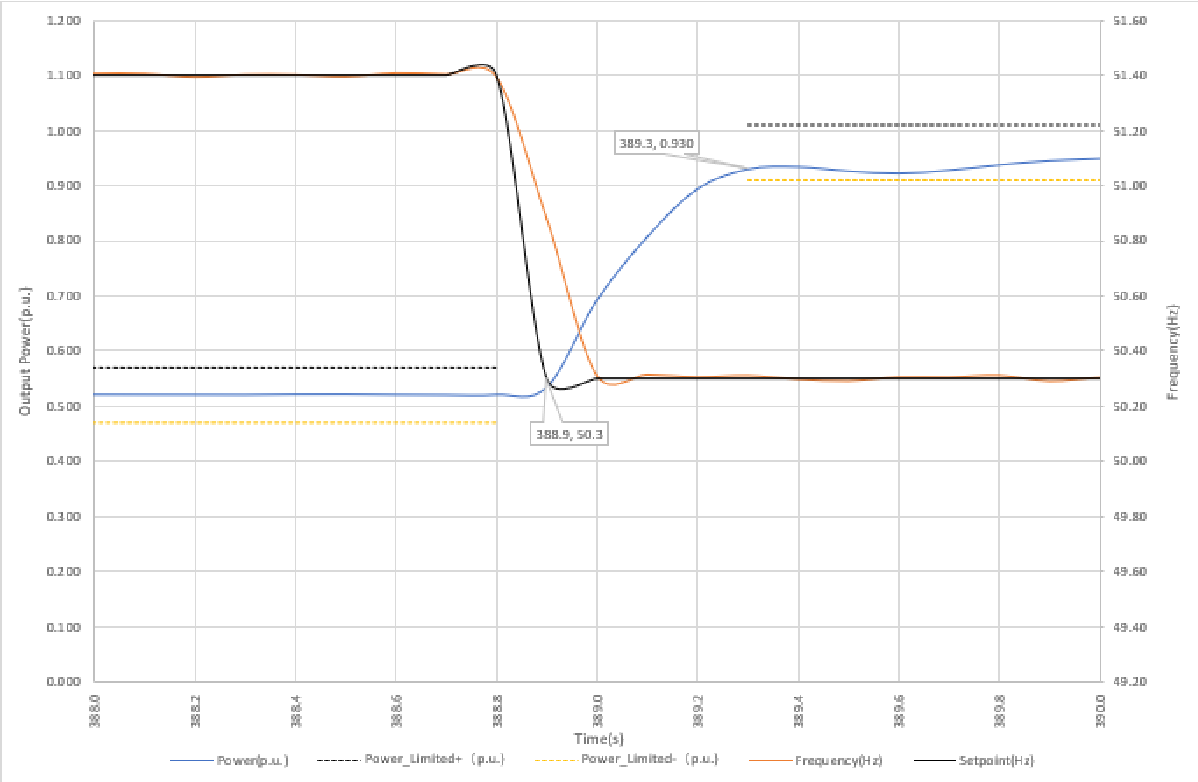
Output power reduction: Active power and Frequency over time – test at 100%Pn

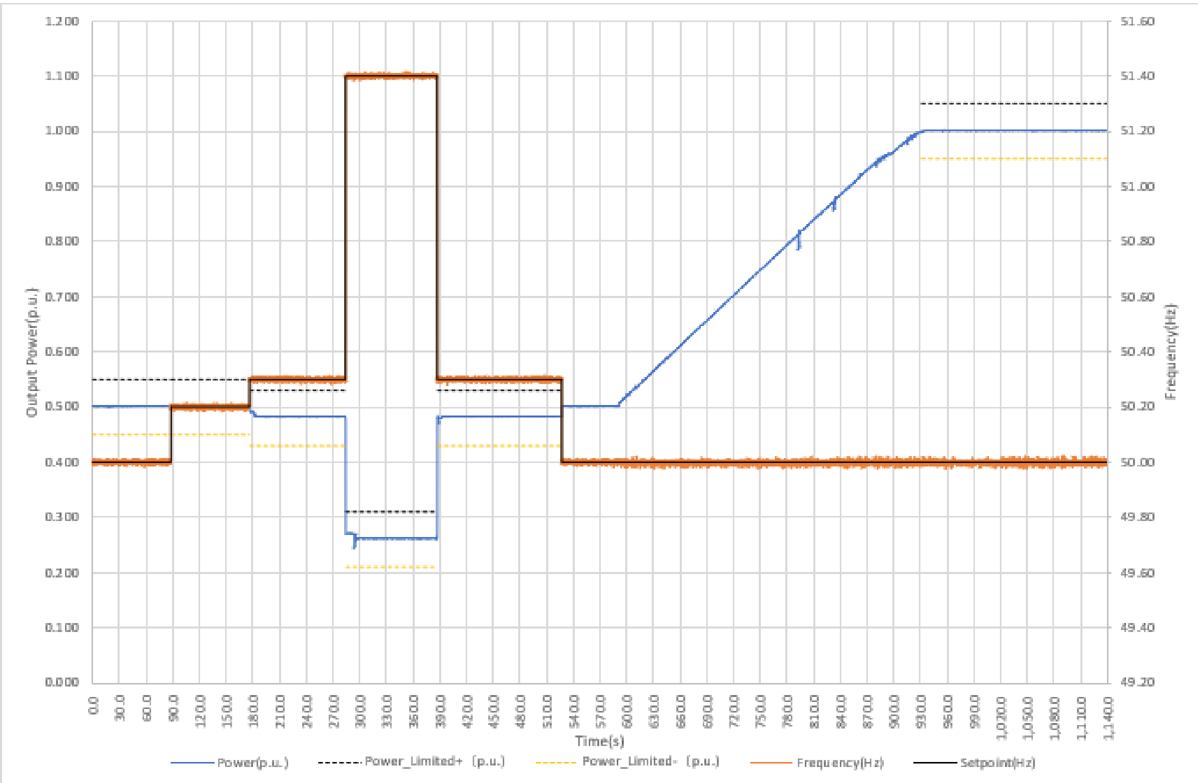


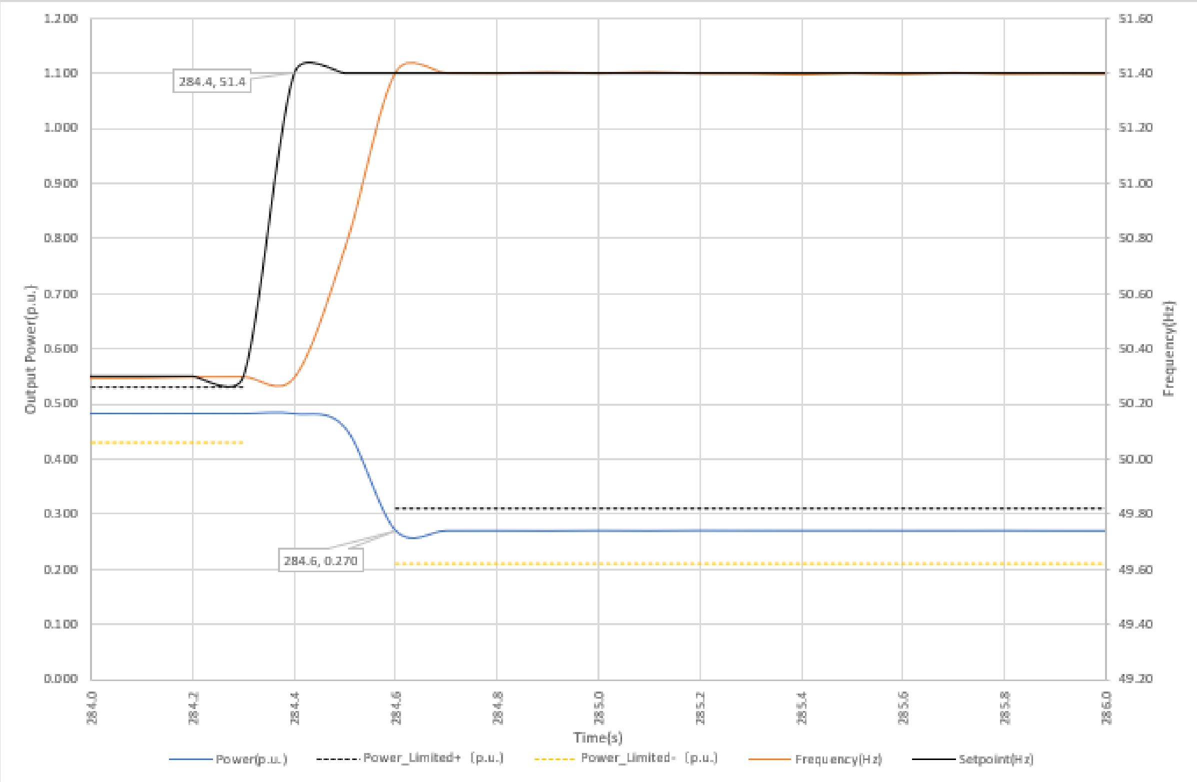
Power gradient (Step 2 to Step 3) – test at 100%Pn

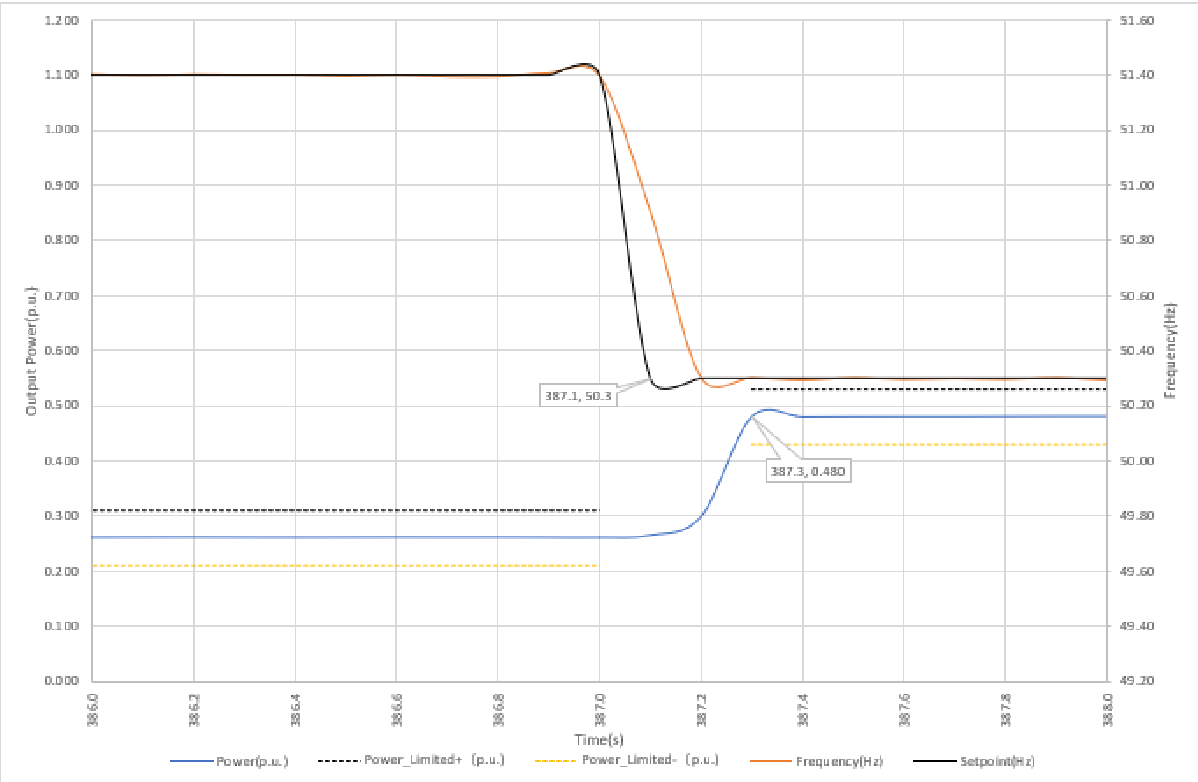


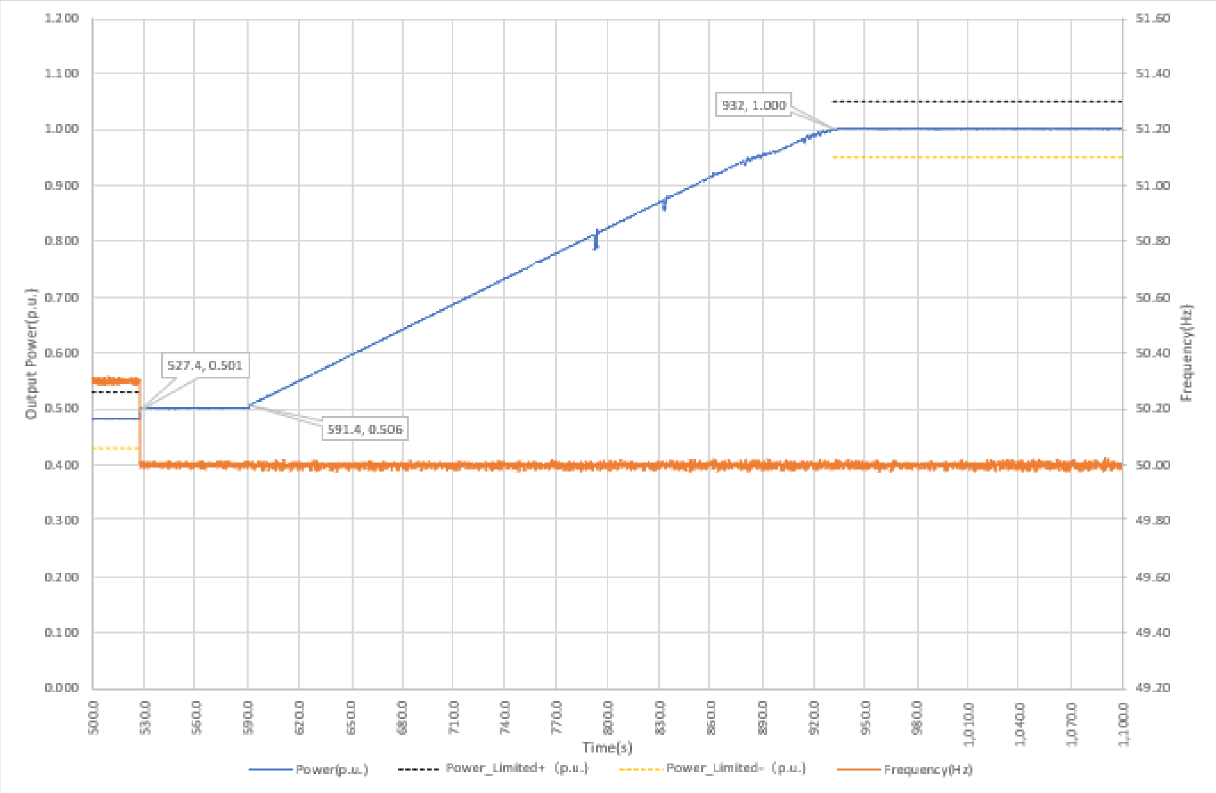
dP(f) desired: -40.0% P_{ref}/Hz	dP(f) measured: -40.2% P_{ref}/Hz

Power gradient (Step3 to Step 4) – test at 100%Pn	
	
dP(f) desired: -40.0% P_{ref}/Hz	dP(f) measured: -40.2% P_{ref}/Hz

Output power reduction: Active power and Frequency over time – test at 50%Pn


Power gradient (Step 2 to Step3) – test at 100%Pn	
	
dP(f) desired: -40.0% P_{ref}/Hz	dP(f) measured: -40.1% P_{ref}/Hz

Power gradient (Step 3 to Step 4) – test at 100%Pn	
	
dP(f) desired: -40.0% P_{ref}/Hz	dP(f) measured: -40.0% P_{ref}/Hz

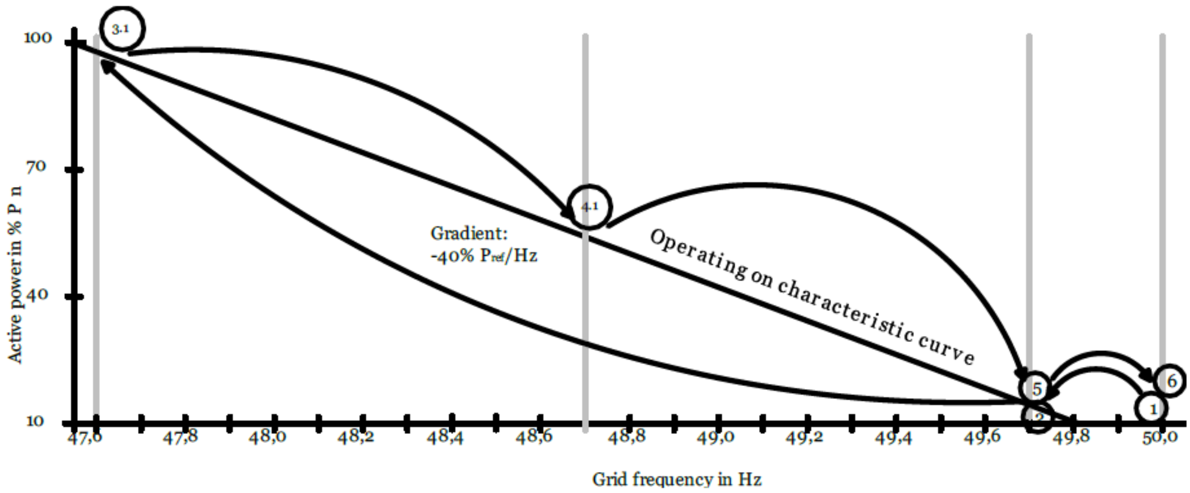
Output power increase: Active power over Frequency_test at 50%Pn	
	
Defined active power gradient ΔP/Δt: <10%Pn/min	ΔP/Δt: measured: 8.70% Pn/min

4.1.3.2 Underfrequency (LSFM-U)

For this test, power increase has been applied with a gradient of 40% P_{ref}/Hz in the range of 49.8Hz to 47.5 Hz. Once the grid frequency falls below the 49.8 Hz threshold, the active power recuperation must be with a maximum gradient of 10%P_n/min.

For the test, before the power reduction starts, active power has been reduced to a 10%Pn through a setpoint.

Frequency values must be inside next ranges (referred to the points on the figure):



Frequency Step	Simulated grid frequencies	Note
1	50.00 Hz ± 0.05 Hz	
2	49.70 Hz ± 0.05 Hz	
3	3.1: 47.60 Hz ± 0.05 Hz	
4	4.1: 48.70 Hz ± 0.05 Hz	
5	49.70 Hz ± 0.05 Hz	
6	50.00 Hz ± 0.05 Hz	Charge of active power with a maximum gradient of 10%Pn/min

60s after reaching point 5, the power reduction applied at the beginning of the test is disabled in order to verify the recuperation gradient limit of 10%Pn/min

Starting at P_{ref}, it has been performed the frequency steps that can be seen on the table above, taking measures of the active power at every set point of frequency. Every point has a measured duration of 30 seconds at least.

Gradient has been calculated as follows:

$$\frac{\Delta P}{\Delta f} = \frac{P_{Step\ i+1} - P_{Step\ i}}{|f_{Step\ i+1} - f_{Step\ i}|}$$

$P_{Step\ i+1}$	10-s-mean of the active power which is calculated at the end of frequency step i+1.
$P_{Step\ i}$	10-s-mean of the active power which is calculated at the end of frequency step i.
$f_{Step\ i+1}$	10-s-mean of the grid frequency, at which PStep i+1 is determined.
$f_{Step\ i}$	10-s-mean of the grid frequency, at which PStep i is determined.

To determine the rise and settling times, a tolerance band of ± 5% of Pn is applied around the controlled active power end value.

Used settings of the measurement device for this power limitation for an increase in grid frequency testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/2	100ms values	10 kHz

The tables below show measured values:

a) Accuracy results – test at 50%Pn

LSFM-U						
Step	**Simulated grid frequency (Hz)**	**Measured grid frequency (Hz)**	**Normalized Active Power Setpoint (P/Pn)**	**Normalized Active Power *Measured* (P/Pn)**		**Active power gradient P(f) relative to the reference frequency**
				Whole step	**P_{10}**	
1	50.00 ± 0.05	50.00	0.500	0.501	0.501	-------
(*)	50.00 to 49.70	49.80	0.500	0.501	0.501	-------
2	49.70 ± 0.05	49.70	0.540	0.543	0.543	-------
3	47.60 ± 0.05	47.60	1.000	1.001	1.002	43.7% Pref/Hz
4	48.70 ± 0.05	48.70	0.760	0.760	0.760	43.9% Pref/Hz
5	49.70 ± 0.05	49.70	0.540	0.544	0.543	43.1% Pref/Hz
6	50.00 ± 0.05	50.00	1.000	1.001	1.001	-------
(*): As the EUT is Type 2, according to the standard **Pmom = Pref** is defined as the mean value of the active power immediately prior to frequency transition at 48.8 Hz. Here, the manufacturer specifies the averaging time 100ms						

ΔP/Δf	
Mean active power gradient while frequency limit is exceeded	43.8 % Pref/Hz
Defined active power gradient ΔP/Δf	40.0 % Pref/Hz

b) Settling time and Rise time results – test at 50%Pn

Frequency step	Rise Time (s)	Settling time (s)
Step 2 → Step 3	0.4	0.4
Step 3 → Step 4	0.2	0.2
Step 4 → Step 5	0.2	0.2

c) Accuracy results – test at 25%Pn

LSFM-U						
Step	Simulated grid frequency (Hz)	Measured grid frequency (Hz)	Normalized Active Power Setpoint (P/Pn)	Normalized Active Power *Measured* (P/Pn)		Active power gradient P(f) relative to the reference frequency
				Whole step	P_{10}	
1	50.00 ± 0.05	50.00	0.250	0.250	0.251	-------
(*)	50.00 to 49.80	49.80	0.250	0.250	0.251	-------
2	49.70 ± 0.05	49.70	0.290	0.291	0.292	40.1 Pref/Hz
3	47.60 ± 0.05	47.60	1.000	1.001	1.001	33.8 Pref/Hz (**)
4	48.70 ± 0.05	48.70	0.690	0.690	0.690	28.3 Pref/Hz (**)
5	49.70 ± 0.05	49.70	0.290	0.292	0.292	39.9 Pref/Hz
6	50.00 ± 0.05	50.00	1.000	1.001	1.001	-------

(*): As the EUT is Type 2, according to the standard **Pmom = Pref** is defined as the mean value of the active power immediately prior to frequency transition at 48.8 Hz. Here, the manufacturer specifies the averaging time 100ms
(**): Setting active power gradient P(f) is 40%Pn/Hz, when test P_M = 25%Pn, it will be rise 100%Pn at 47.92Hz, when the frequency is below 47.92Hz, It will be lock at 100%Pn output.

ΔP/Δf	
Mean active power gradient while frequency limit is exceeded	40.0 % P_{ref}/Hz
Defined active power gradient ΔP/Δf	40.0 % P_{ref}/Hz

d) Settling time and Rise time results – test at 25%Pn

Frequency step	Rise Time (s)	Settling time (s)
Step 2 → Step 3	0.3	0.3
Step 3 → Step 4	0.2	0.2
Step 4 → Step 5	0.2	0.2

ΔP/Δt	
Maximum active power gradient	9.12 % Pn/min
Mean active power gradient	8.93 % Pn/min
Defined gradient ΔP/Δt	9.00 % Pn/min

The gradient of active power after removal of the active power limitation has been measured as follows:

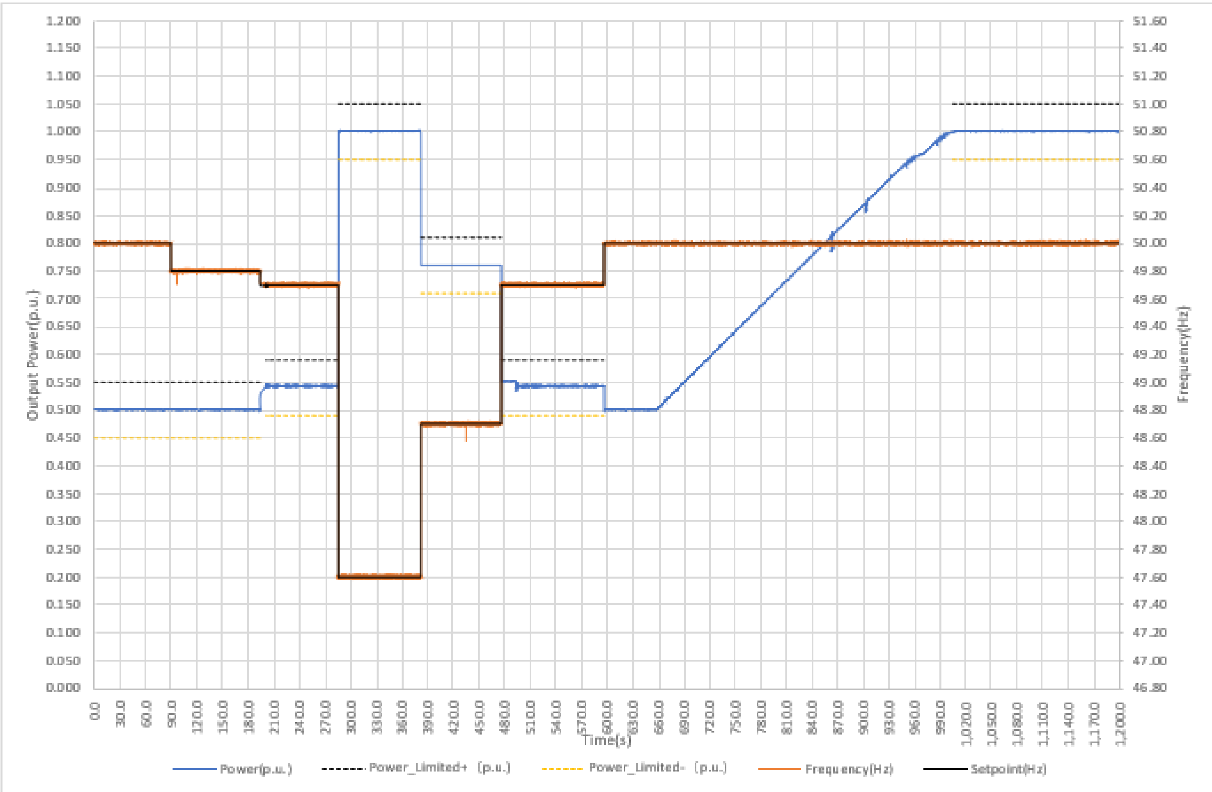
The active power has to be calculated as a 0.2 second mean.

The mean 1-minute power is determined at intervals of 1 min.
The first averaging interval starts 1 min prior to the removal of the active power limitation. The last averaging interval ends after reaching the stationary final value of active power.

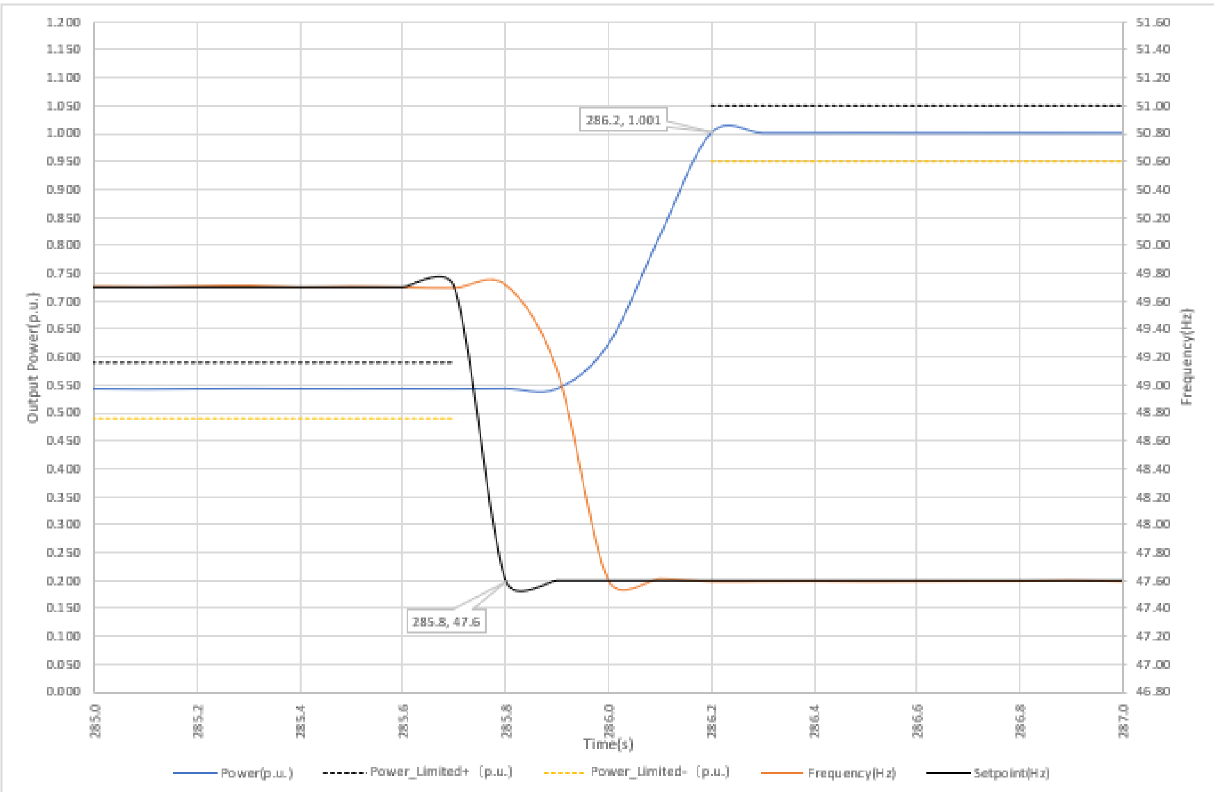
The gradient of the active power increase ΔP/Δt is determined from the difference between consecutive 1-minute mean values with reference to 1 min in each case for the time point at the boundary between two averaging intervals.

In following graphs, test results are represented after the test has been performed:

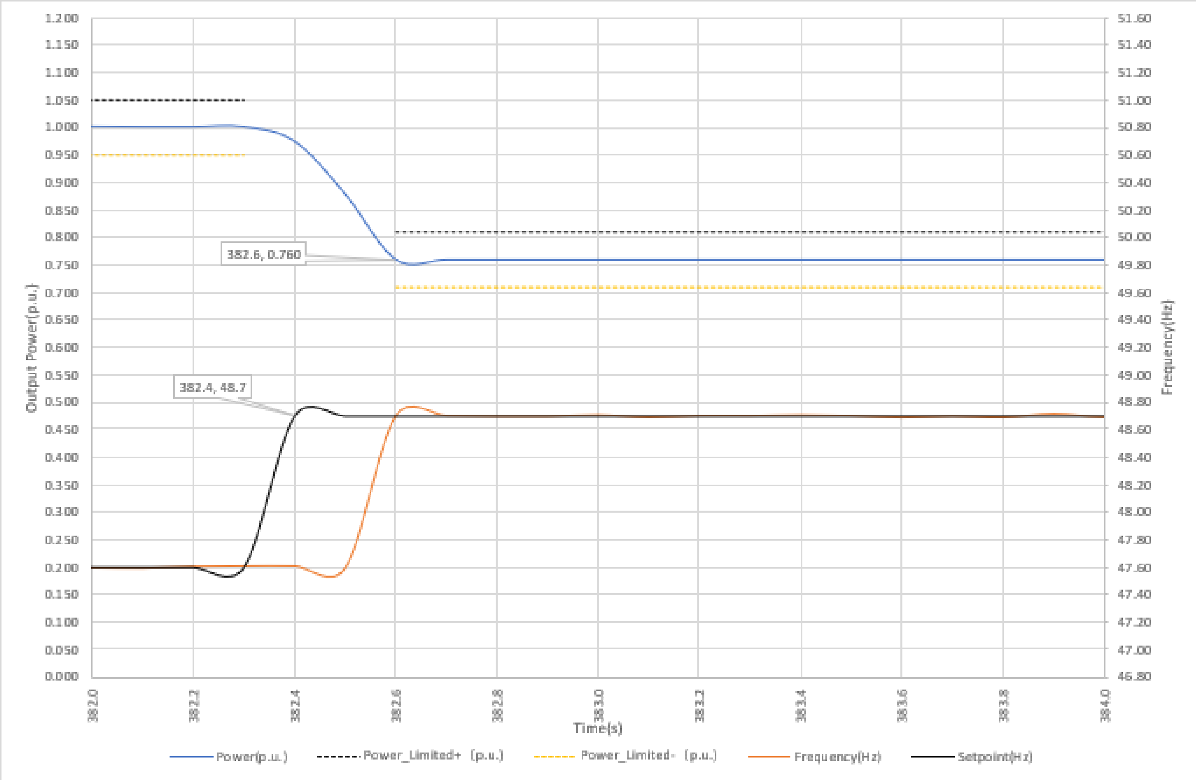
Output power increase: Active power and Frequency over time_test at 50%Pn



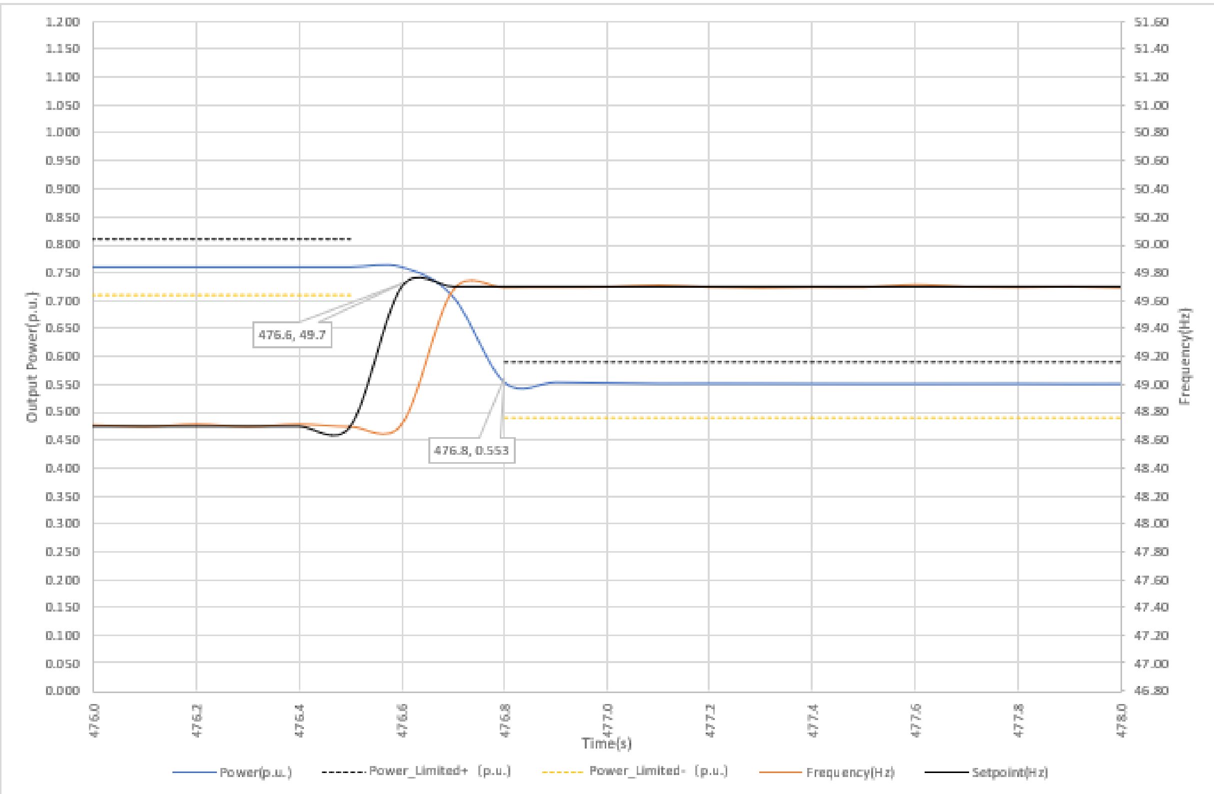
Power gradient (Step2 to Step3) _test at 50%Pn

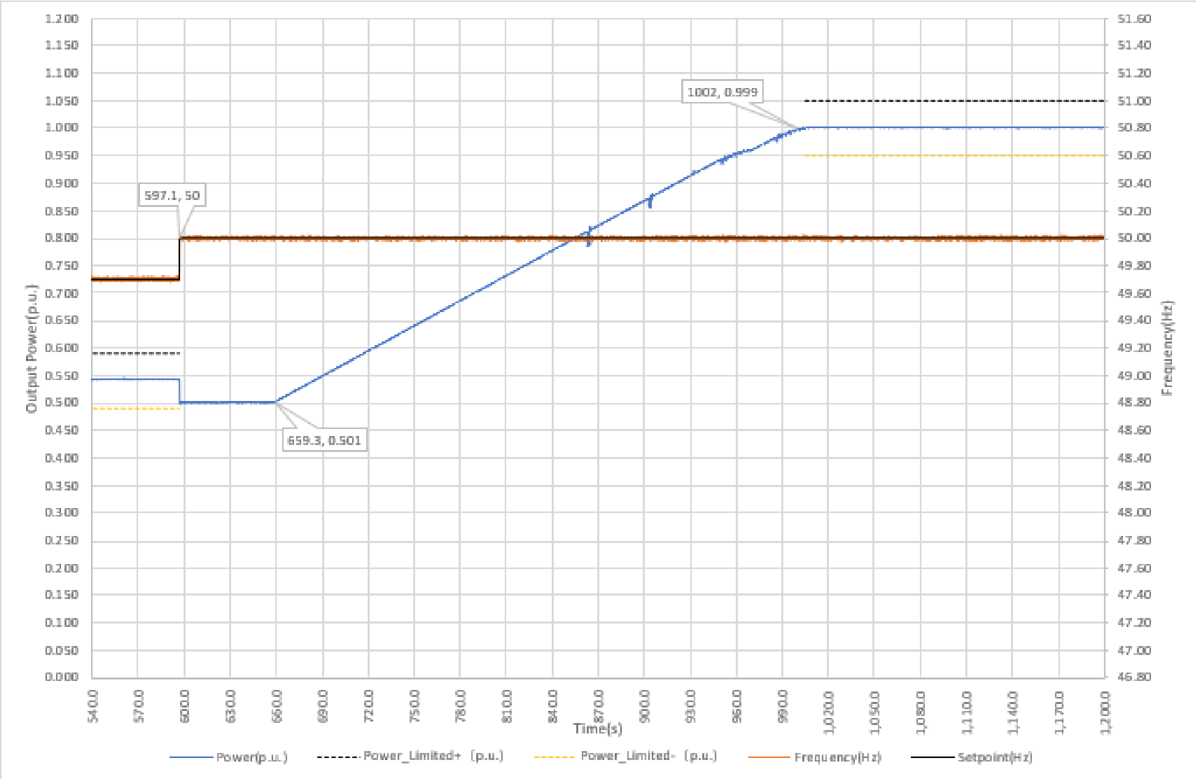


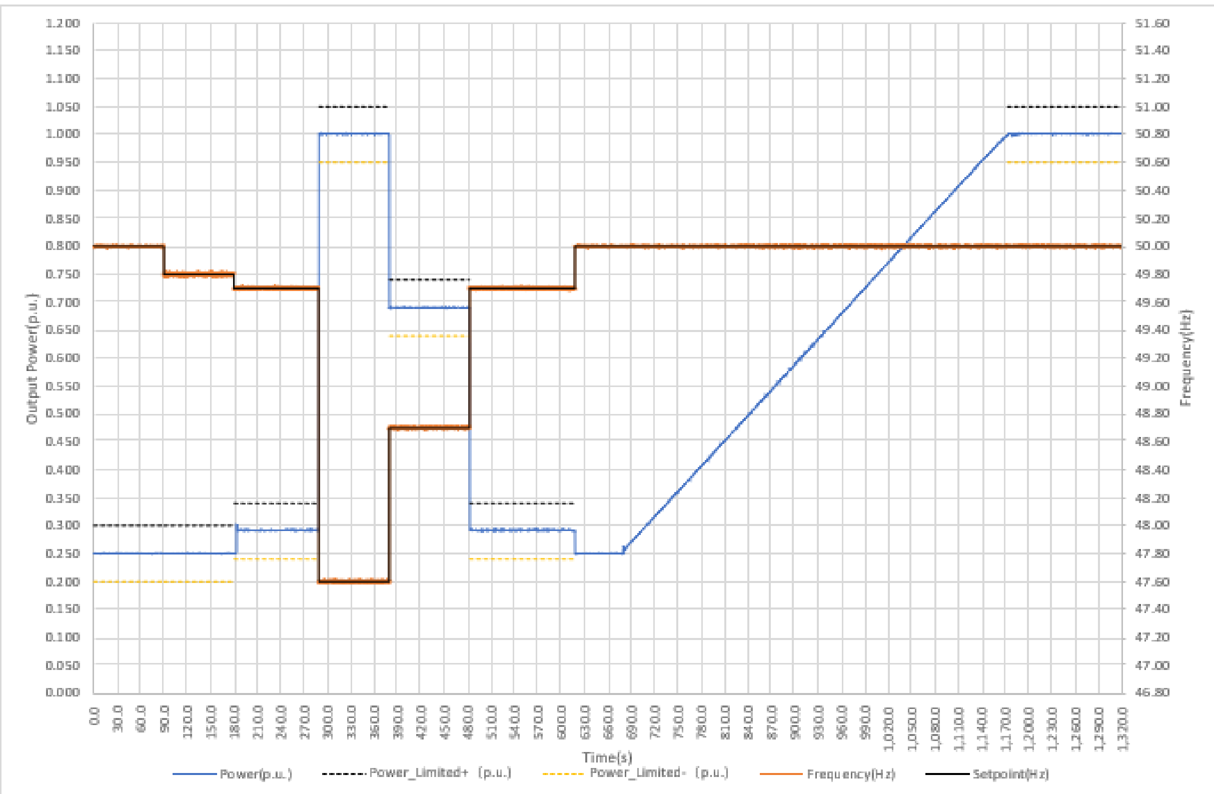
Power gradient (Step 3 to Step 4) _test at 50%Pn



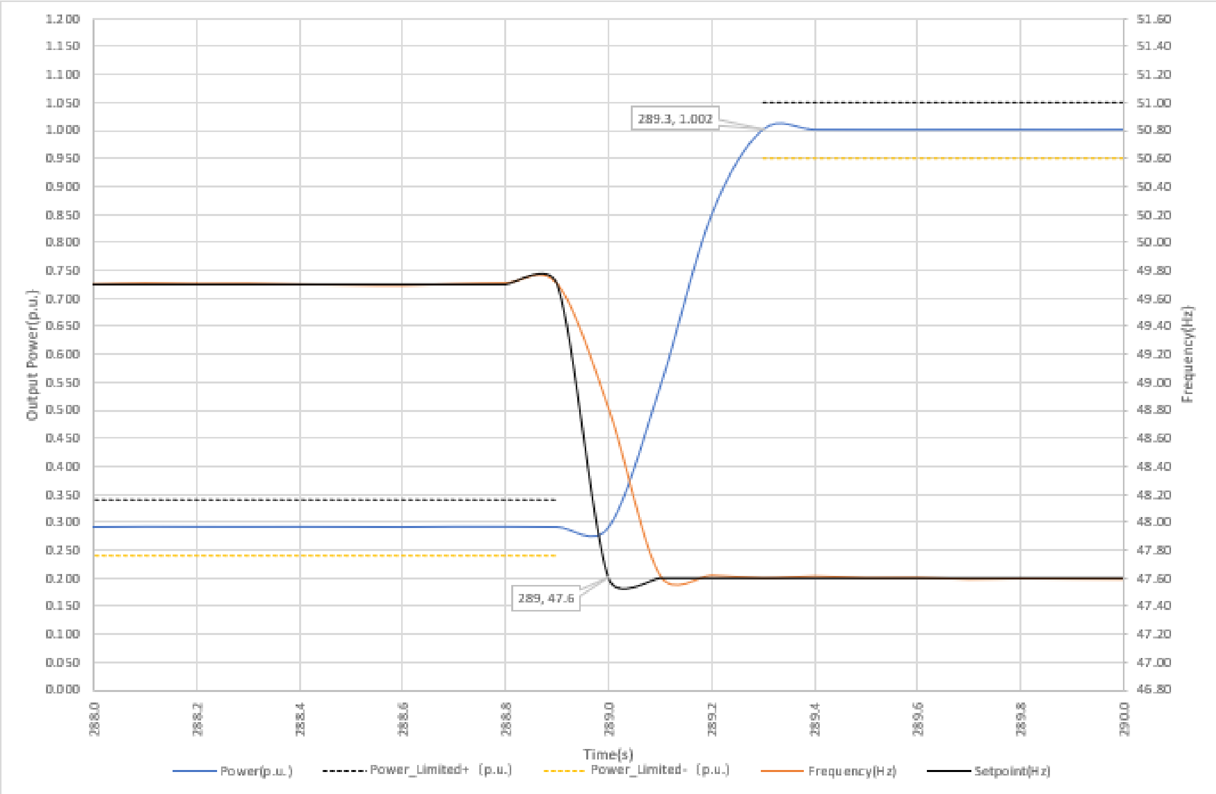
Power gradient (Step 4 to Step 5) _test at 50%Pn



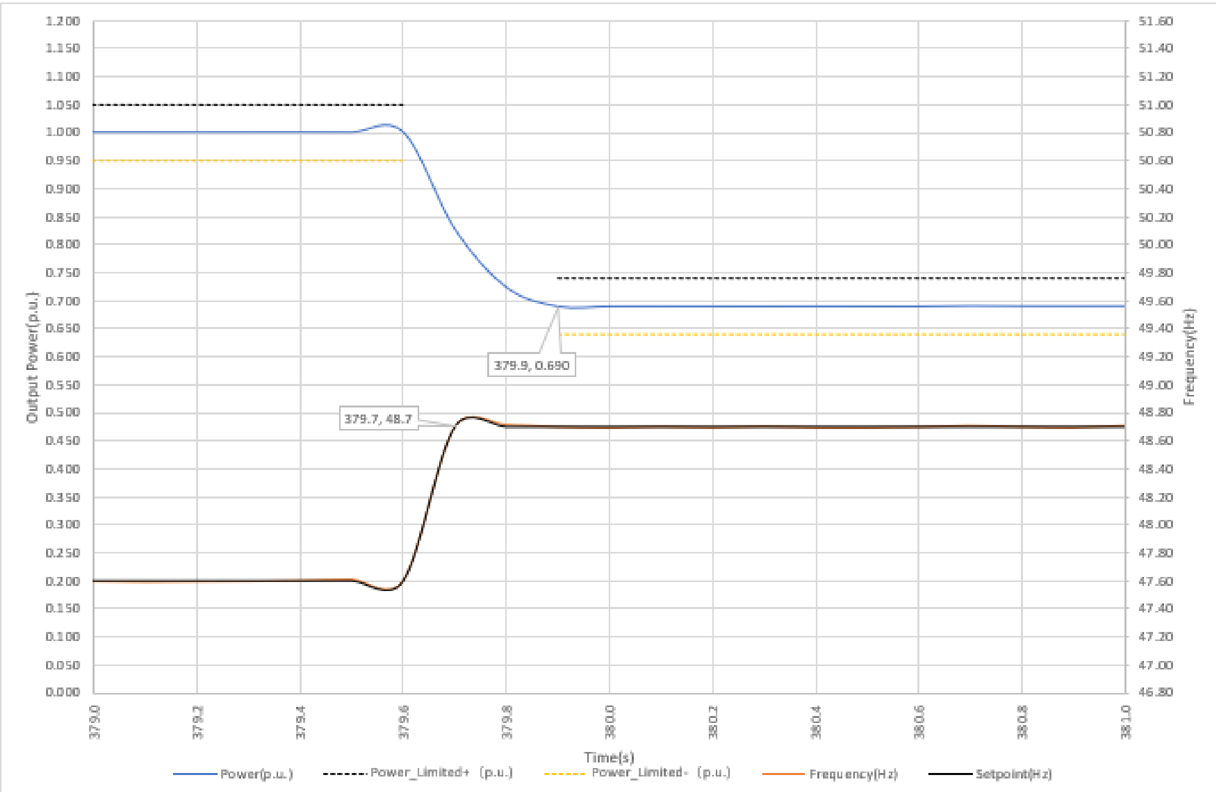
Output power increase: Active power over Frequency_test at 50%Pn	
	
Defined active power gradient ΔP/Δt: <10%Pn/min	ΔP/Δt: measured: 8.74% Pn/min

Output power increase: Active power and Frequency over time_test at 25%Pn


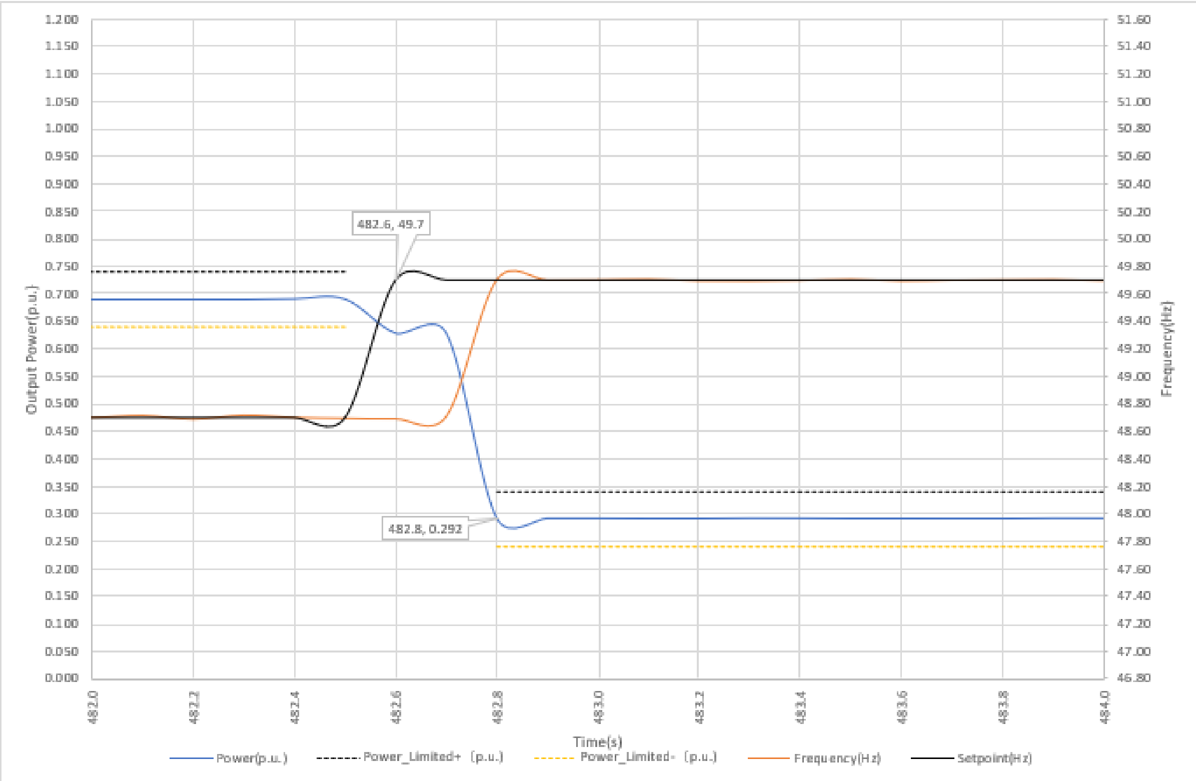
Power gradient (Step2 to Step3) _test at 25%Pn



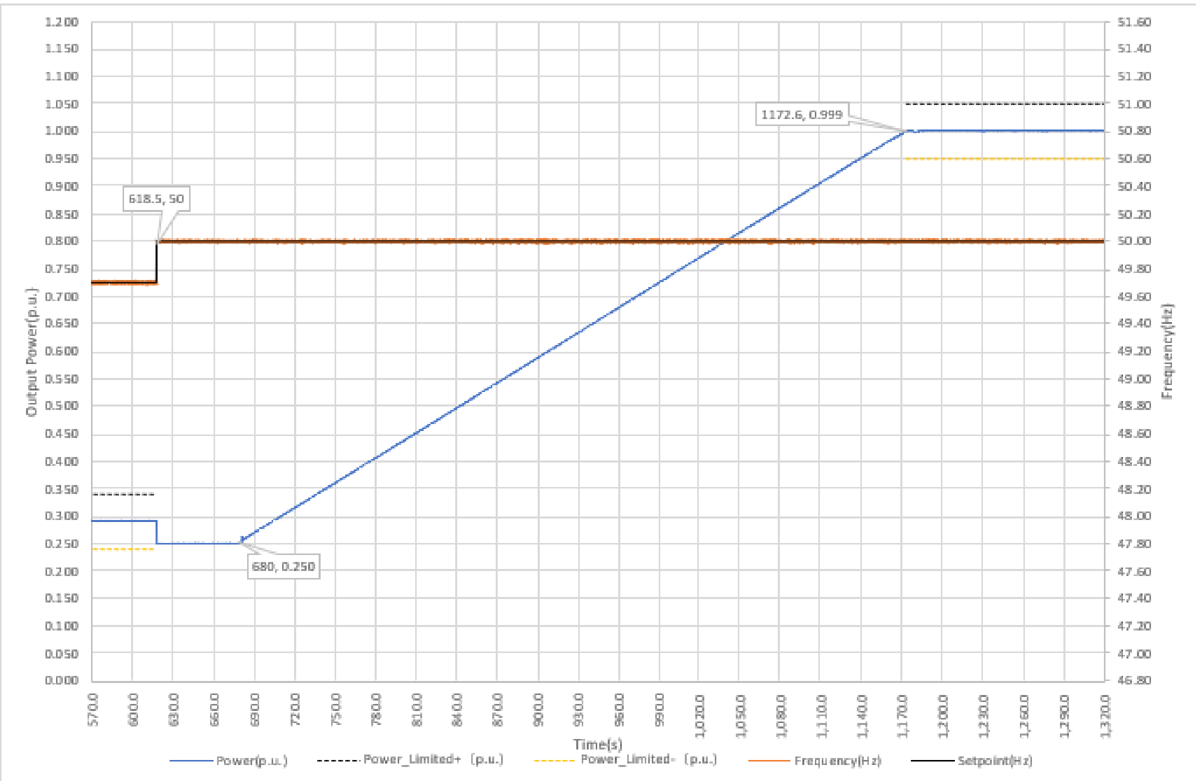
Power gradient (Step 3 to Step 4) _test at 50%Pn



Power gradient (Step 4 to Step 5) _test at 25%Pn



Output power increase: Active power over Frequency_test at 25%Pn

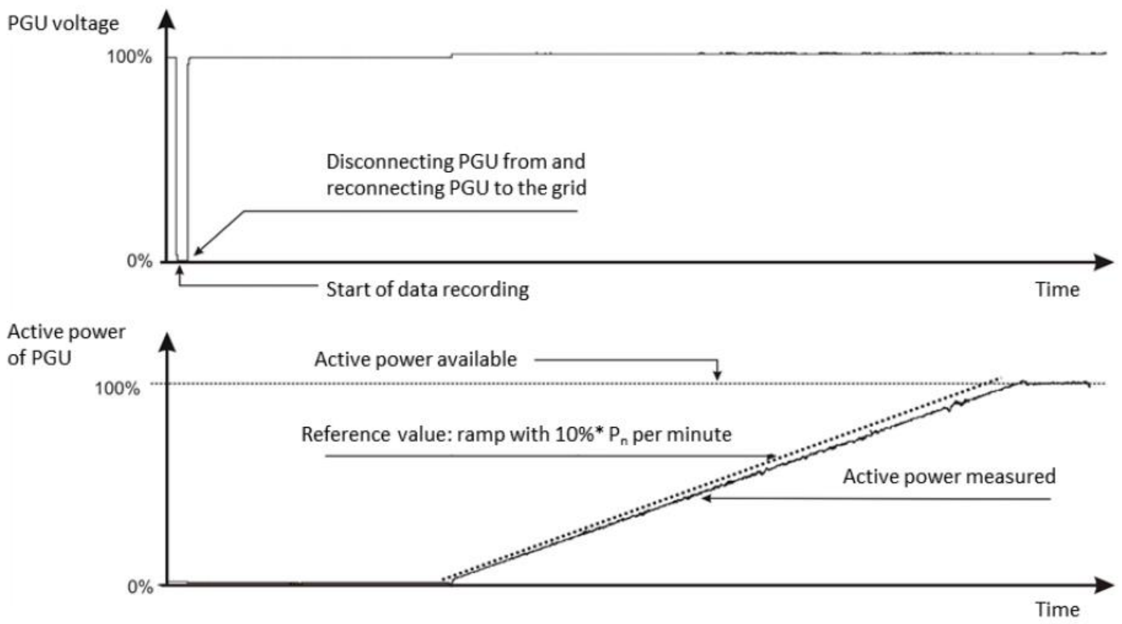


Defined active power gradient ΔP/Δt: <10%Pn/min	ΔP/Δt: measured: 9.12% Pn/min

4.1.4 Active Power gradient following disconnection from the grid

The aim of this test is to measure the PGU's active power gradient when restarting following disconnection from the grid.

The test was performed according to the point 4.1.4 of the standard. By the following graph, it is represented the test to be done:



In the example tested, the inverter was adjusted to be disconnected from the grid when the output voltage is lower than 75% of the rated voltage in less than 100ms.

After this, the inverter was set to be reconnected when the voltage grid is recovered over 75% of the rated voltage for more than 70 seconds and not exceeding more than 75 seconds.

Once reconnected, the inverter shall start to inject active power into the grid following a soft ramp according to requirements stated in VDE AR-N 4110:2018 (19.8%Pn/min – 39.6%Pn/min). For the tested case, the active power gradient was set to follow a ramp rate corresponding to 30%Pn/min.

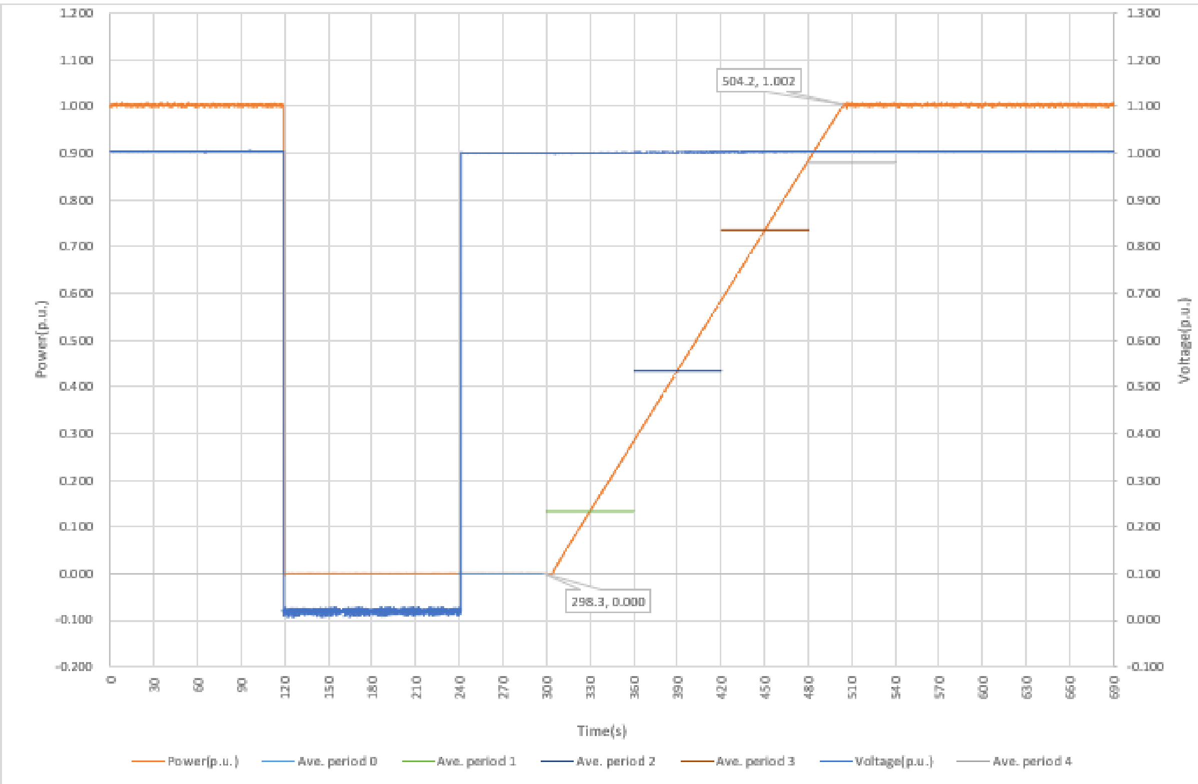
Active output power and output voltage have been represented as 0.1 seconds mean as shown in the graphs below.

Used settings of the measurement device for the active power gradient testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2020/6/24	100ms values	10 kHz

By the following graph, test results are represented after the test has been performed:

Graphical representation of the test over time



As it can be seen in the graph above, the active power gradient has been done according with option 2 of FGW Rev.25 as seen in the picture below:

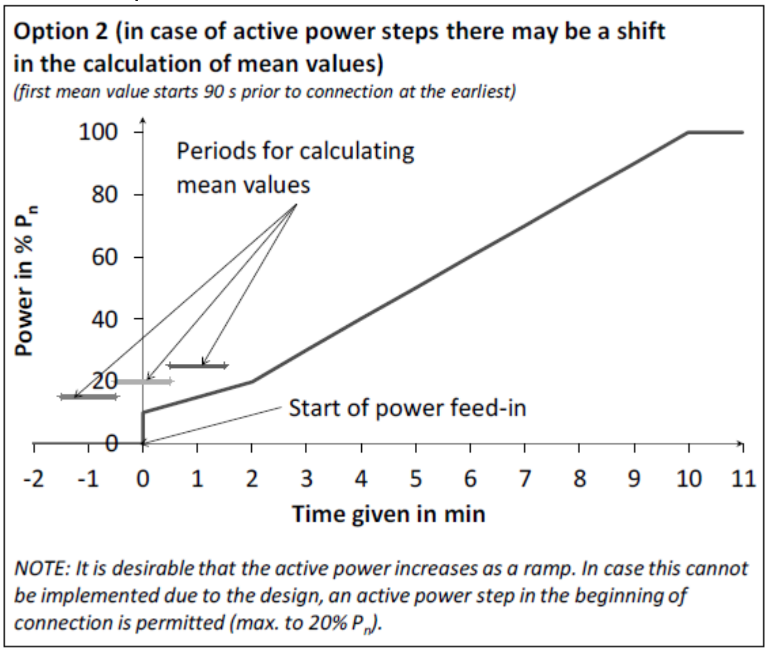


Fig. 4–10: Example with the first averaging interval 90 s before power increase

Gradients are calculated using averaging periods of 60 seconds starting at -90 seconds before the connection starts.

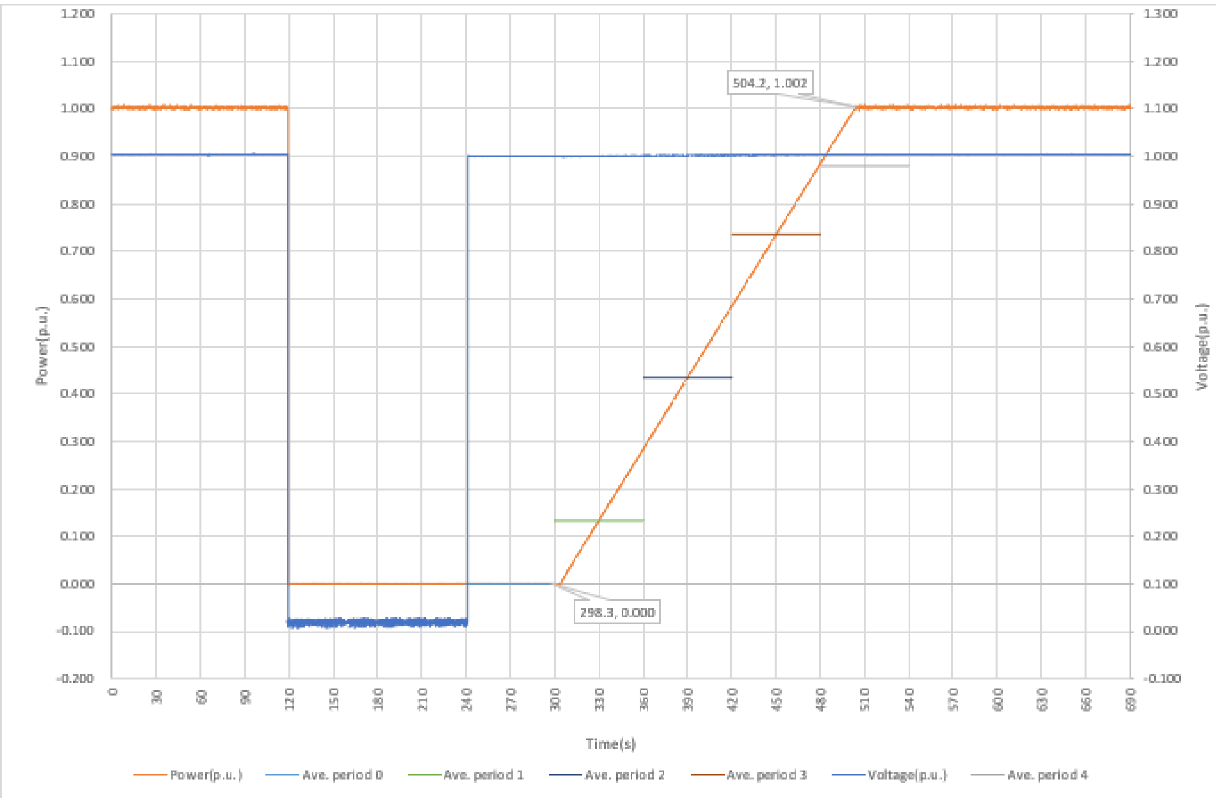
For each one of this averaging periods, the active power gradient is calculated according to the following equation:

$$\frac{\Delta p}{1\ min} = \frac{P_{t=t1+1min} - P_{t=t1}}{1\ min}$$

Here t1 is the time commencing the generator active power feed in after reconnection until the end of power limitation.

For the example tested, they have been calculated up to 5 averaging periods as represented in the image below:

Active Power Gradient over time



In the following table, they are summarized all active power gradients calculated. They are as well calculated the maximum and the mean active power gradients take in to account all power gradients determined

Active power gradient determined for the averaging period 0	0.0 % P_n/min
Active power gradient determined for the averaging period 1	13.3 % P_n/min
Active power gradient determined for the averaging period 2	30.1 % P_n/min
Active power gradient determined for the averaging period 3	30.1 % P_n/min
Active power gradient determined for the averaging period 4	24.4 % P_n/min
Maximum active power gradient	30.1 % P_n/min
Mean active power gradient (averaging periods 0 to 4)	19.6 % P_n/min
Mean active power gradient (averaging periods 2 to 3)	30.1 % P_n/min
Defined gradient ΔP/Δt	30 % P_n/min

4.2 REACTIVE POWER PROVISION

4.2.1 Reactive Power response in the normal operating mode and Maximum Reactive Power

Aims of these tests are to determine the PGU's active and reactive power response in normal operating mode for a specified setpoint of Q=0 and the maximum capacitive (overexcited) and inductive (underexcited) reactive power provision of the EUT.

For all tests, the active power of the inverter must vary from 0% to 100%. This variation must be done such as 3 steps of each 10%Pn increasing range are taken. Each step was maintained for at least 1 minute, taken for the calculations 1-minute displacement factor cos φ, voltage and reactive power mean.

Five different tests have been performed:

- According to the point 4.2.1 of the standard, the first test has been performed with a specified setpoint Q=0 kVAr in normal operating mode.
- According to the point 4.2.2 of the standard, the second test has been performed in order to determine the maximum capacitive (overexcited) and inductive (underexcited) reactive power provision of the PGU (PQ diagram). In this test the apparent power, S, has been kept at 100%Sn.
- In addition to point 4.2.2, it has been done a rectangular curve to prove that the inverter is capable of providing a fixed amount of reactive power at any active power level.
  The reactive power value has been set at 48.43%Pn (inductive and capacitive).
- In addition to point 4.2.2, it has been done a triangular curve to prove that the inverter is capable of providing a fixed amount of reactive power in relation to its power factor.
  Power factor value has been set at 0.90 (inductive and capacitive)
- According to the point 4.2.3 of the standard, the fifth test has been performed in order to verify the maximum capacitive (overexcited) and inductive (underexcited) recative power provision of the PGU with under/over voltage situations (voltage-dependent PQ diagram)
  This capability has been verified at 90%Un as well as 110%Un

The maximum steady-state error between the desired and actual value in the range P ≥ 0.10 p.u. will be ±2%. It will be allowed ±4% for equipments with capacity below 300 kVA.

Below a power of 0.10 p.u, an underexcited operation in the amount of up to 5% will be permitted. While for overexcited, the maximum deviation allowed will be a maximum of 2%.

The positive phase sequence values of the active and reactive power, as well as the displace-ment factor, have been determined from each measured record.

In following points are offered all test results after tests above detailed.

Interface information	
Interface used	Solar communication tools, RS485
Interface version used	V250
Other interfaces in the equipment	N/A
Name or code of the parameter for active power setting	Active and ON/OFF control
Name or code of the parameter for reactive power setting	Reactive parameters
If the EUT has several different interfaces for defining the setpoint, it has been tested the interface returning the most unfavourable results according to the manufacturer information.	

EUT Settings used for these tests are provided in the following table:

EUT Settings	
Operanting mode	Active power priority
Active control modes	Active power control Active Power VS Frequency mode LVRT mode Reactive power control Reactive power VS Voltage Reactive power VS Active power Cos Phi

4.2.1.1 Reactive Power Fixed (Q=0)

Used settings of the measurement device for Normal operating mode (Q=0kVAr).

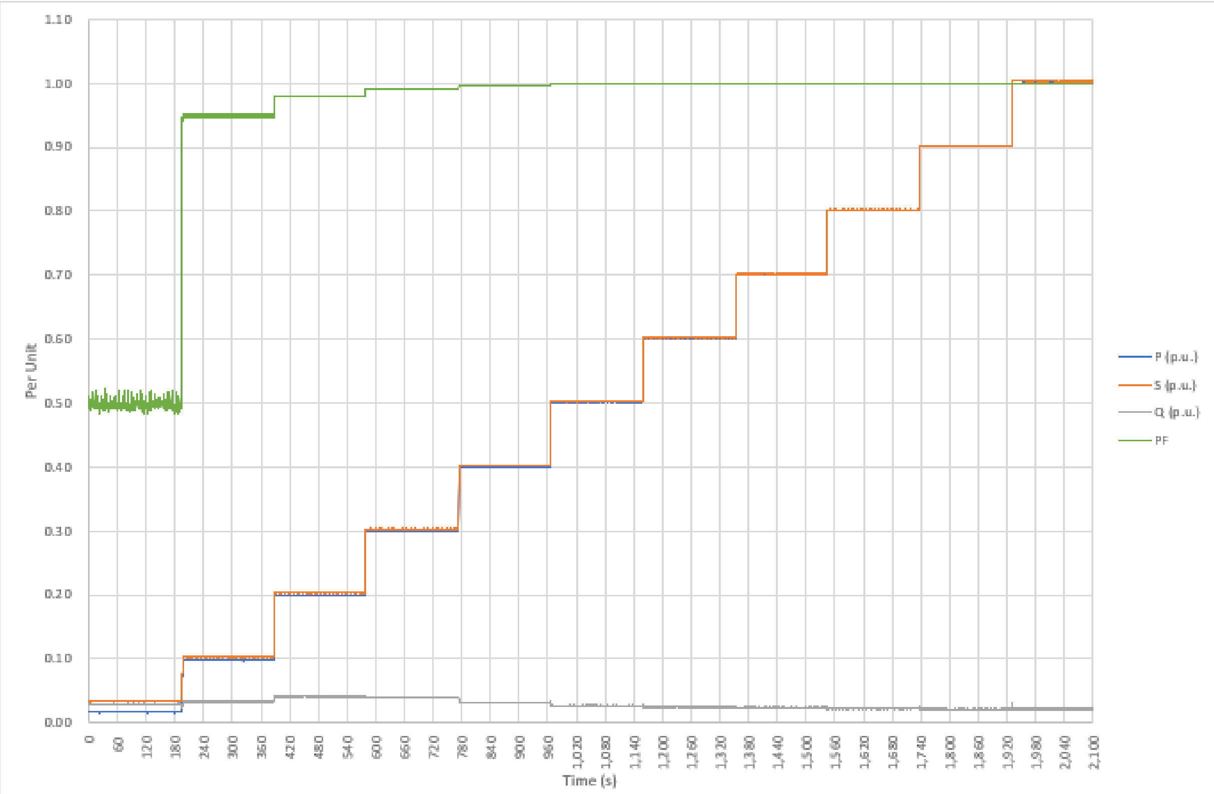
Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/03	100ms values	10kHz

The table below shows measured values for each power step tested:

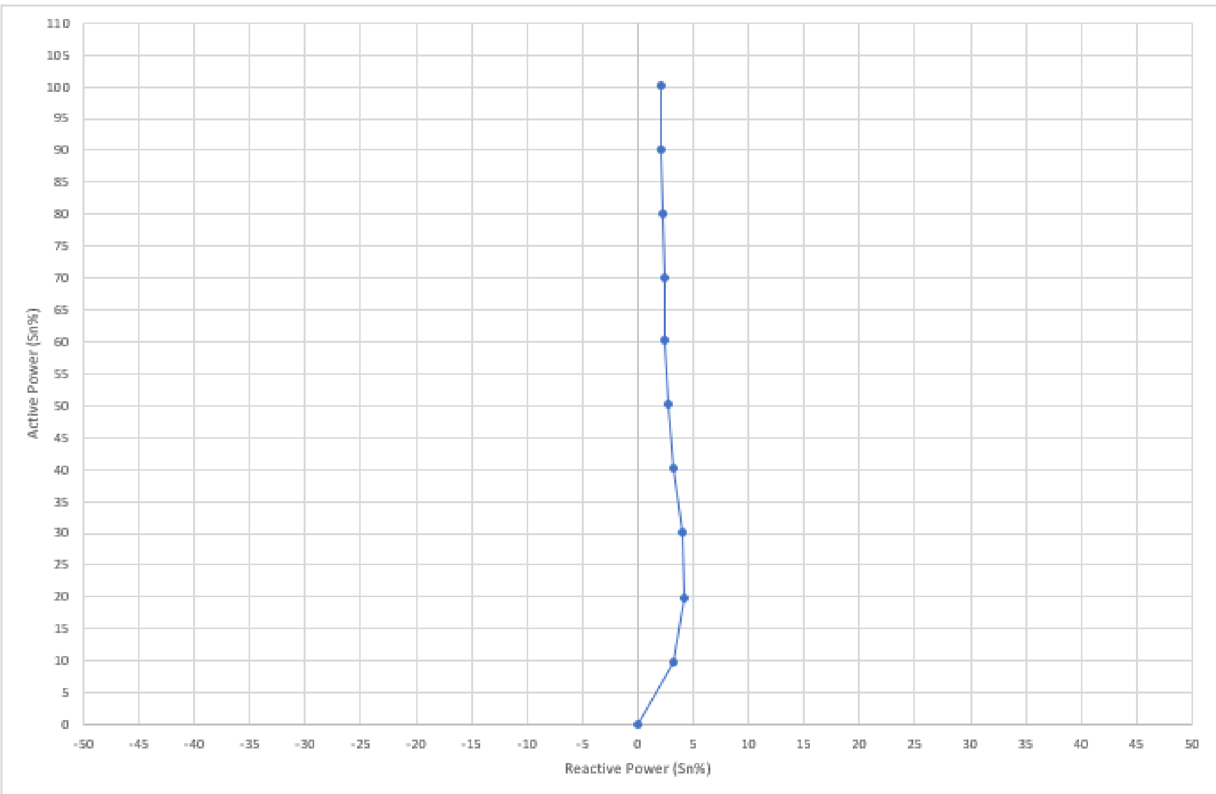
Reactive Power Fixed: Q = 0 kVAr						
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**Q Deviation (kVAr)**	**Power Factor (cos φ)**	**V_{AC} + (V)**	**Number of records**
0%	-0.051	0.331	0.331	-0.152	229.825	1
10%	3.295	0.316	0.316	0.995	230.063	1
20%	6.617	0.292	0.292	0.999	230.174	1
30%	9.938	0.352	0.352	0.999	230.280	1
40%	13.227	0.425	0.425	0.999	230.306	1
50%	16.555	0.504	0.504	1.000	230.384	1
60%	19.856	0.598	0.598	1.000	230.469	1
70%	23.169	0.712	0.712	1.000	230.593	1
80%	26.516	0.846	0.846	0.999	230.703	1
90%	29.788	0.979	0.979	0.999	230.804	1
100%	33.098	1.034	1.034	1.000	230.928	1

In following graphs, test results are represented after the test has been performed:

Q = 0 kVAr. Power Factor and Powers over time



Q = 0 kVAr. Active Power over Reactive Power



4.2.1.2 Semicircular Curve: Maximum Apparent Power

Used settings of the measurement device for this semicircular curve testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/06	100ms values	10kHz

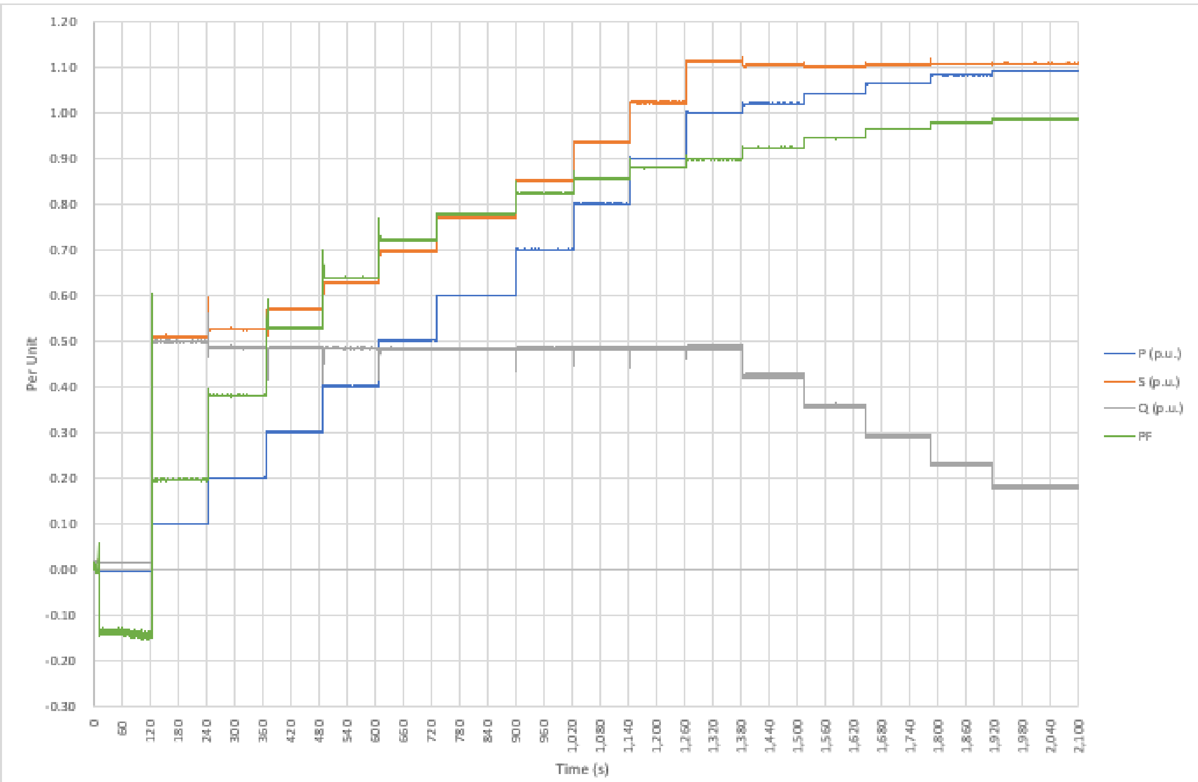
Tables below show measured values for each power step tested, at both the inductive and the capacitive sides:

Semicircular Curve (U = 100% Un) – Inductive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVA)**	**S deviation (kVA)**	**Power Factor (cos φ)**	**V_{AC} + (V)**	**Number of records**
0%	-0.073	0.516	0.521	35.779	-0.141	228.890	1
10%	3.318	16.488	16.819	19.481	0.197	229.295	1
20%	6.642	16.073	17.392	18.908	0.382	229.405	1
30%	9.978	16.021	18.874	17.426	0.529	229.672	1
40%	13.265	15.998	20.782	15.518	0.638	229.849	1
50%	16.572	15.975	23.018	13.282	0.720	230.018	1
60%	19.818	15.958	25.445	10.855	0.779	230.129	1
70%	23.137	15.964	28.110	8.190	0.823	230.307	1
80%	26.443	15.979	30.896	5.404	0.856	230.487	1
90%	29.696	16.009	33.737	2.563	0.880	230.672	1
100%	33.011	16.066	36.714	-0.414	0.899	230.867	1
102%	33.665	14.033	36.473	-0.173	0.923	230.886	1
104%	34.353	11.842	36.337	-0.037	0.945	230.421	1
106%	35.133	9.654	36.436	-0.136	0.964	230.434	1
108%	35.714	7.655	36.525	-0.225	0.978	230.444	1
110%	36.053	6.019	36.552	-0.252	0.986	230.461	1

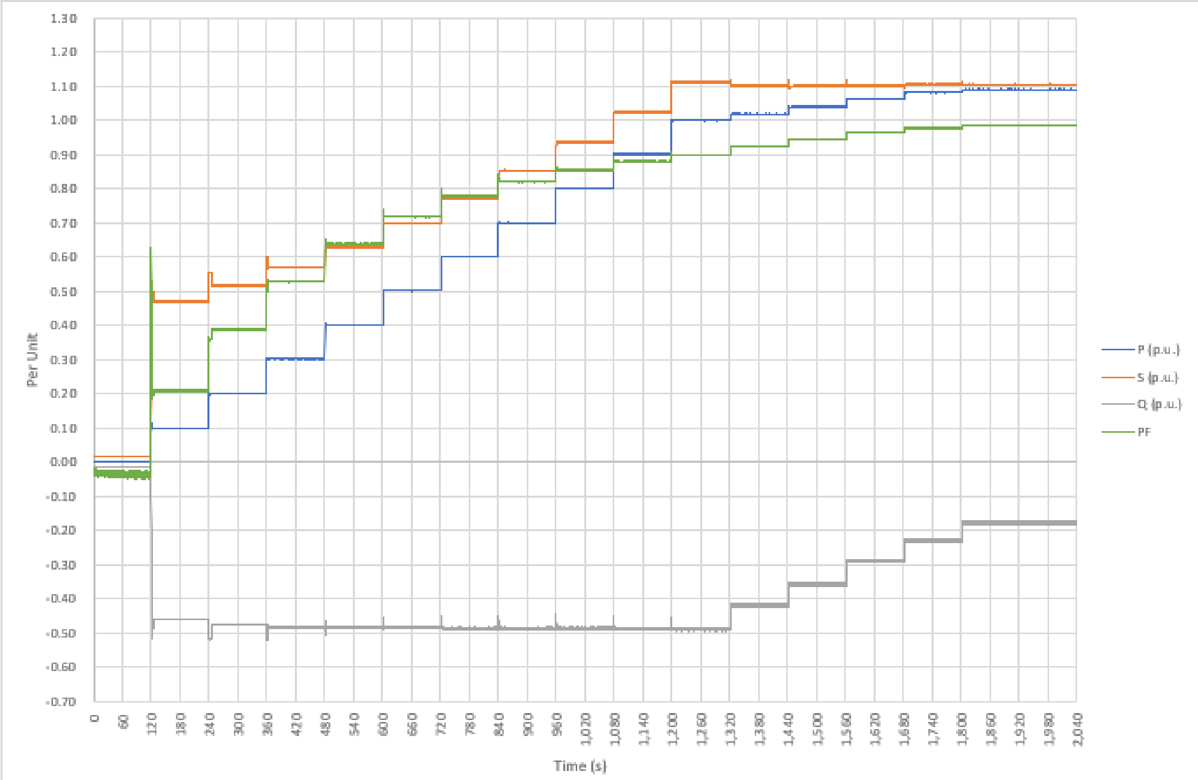
Semicircular Curve (U = 100% Un) – Capacitive							
P Desired (%Pn)	P measured (kW)	Q measured (kVAr)	S measured (kVA)	S deviation (kVA)	Power Factor (cos φ)	V_{AC} + (V)	Number of records
0%	-0.018	-0.486	0.486	35.814	-0.037	228.903	1
10%	3.238	-15.207	15.547	20.753	0.208	228.736	1
20%	6.613	-15.709	17.045	19.255	0.388	229.094	1
30%	9.942	-15.952	18.797	17.503	0.529	229.098	1
40%	13.261	-15.995	20.778	15.522	0.638	229.365	1
50%	16.565	-16.032	23.052	13.248	0.719	229.537	1
60%	19.861	-16.058	25.541	10.759	0.778	229.712	1
70%	23.105	-16.068	28.143	8.157	0.821	229.889	1
80%	26.411	-16.077	30.919	5.381	0.854	230.044	1
90%	29.739	-16.122	33.828	2.472	0.879	230.277	1
100%	32.983	-16.161	36.729	-0.429	0.898	230.460	1
102%	33.618	-13.837	36.354	-0.054	0.925	230.548	1
104%	34.314	-11.848	36.302	-0.002	0.945	230.629	1
106%	35.102	-9.532	36.373	-0.073	0.965	230.676	1
108%	35.691	-7.550	36.481	-0.181	0.978	230.760	1
110%	35.985	-5.888	36.464	-0.164	0.987	230.745	1

In following graphs, test results are represented after the test has been performed:

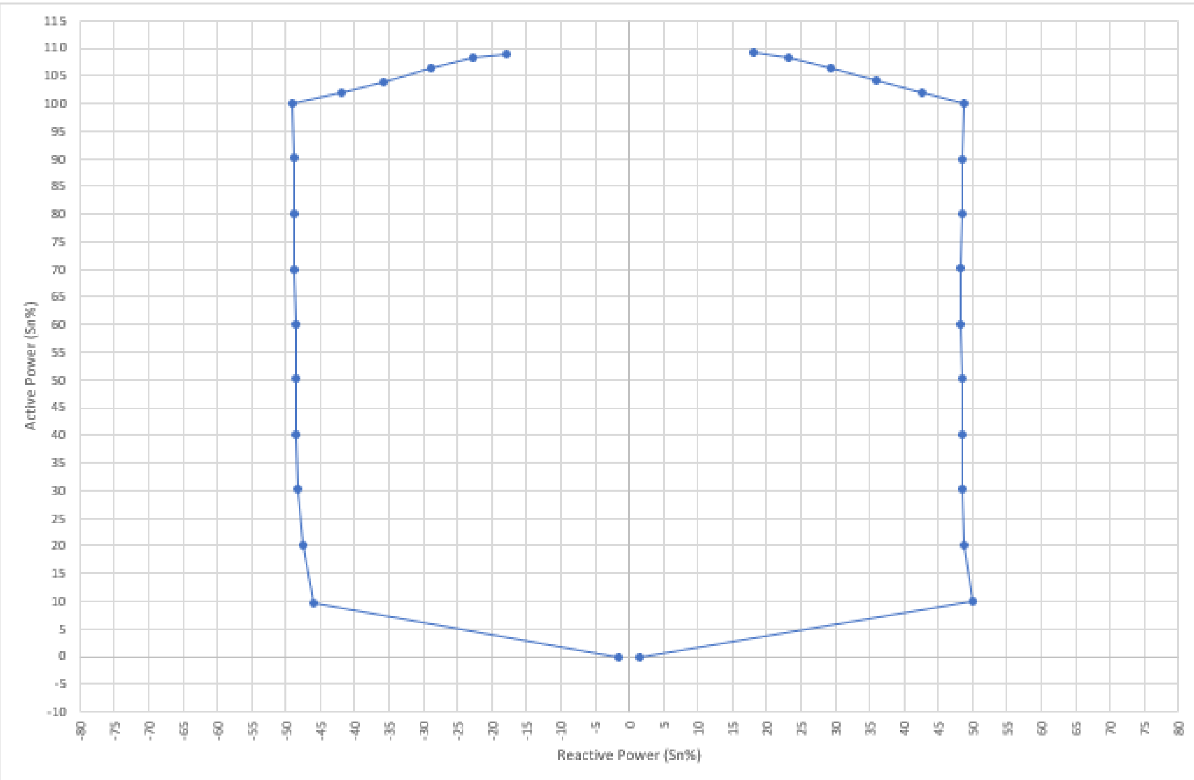
Semicircular Curve (100%Un), Inductive side: Power Factor and Powers over time



Semicircular Curve (100%Un), Capacitive side: Power Factor and Powers over time



Semicircular Curve (100%Un): Active Power over Reactive Power



4.2.1.3 Rectangular Curve: Fixed Reactive Power (Q = 48.43 % Pn)

Used settings of the measurement device for this rectangular curve (Q = 48.43% Pn) testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/06	100ms values	10kHz

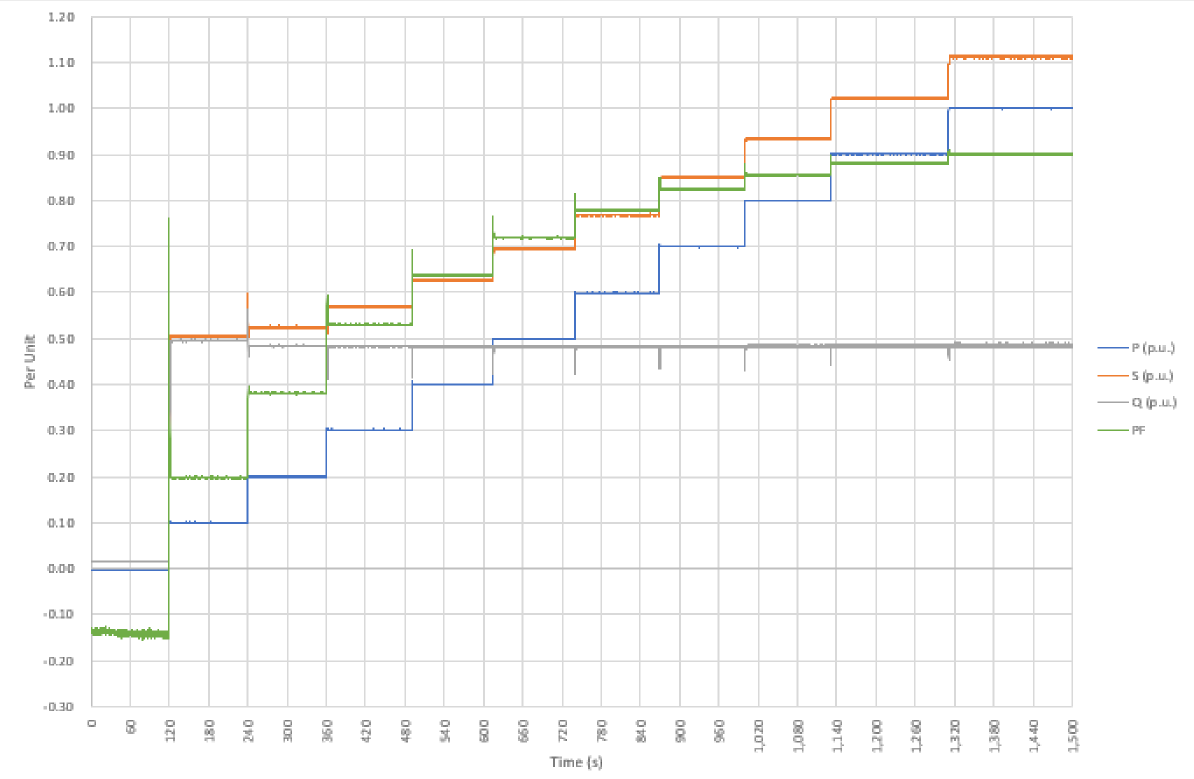
Tables below show measured values for each power step tested, at both the inductive and the capacitive sides:

Rectangular Curve (Q=48 %P_n) – Inductive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVAr)**	**Q Deviation (kVAr)**	**Power Factor (cos φ)**	**V_{AC} + (V)**	**Number of records**
0%	-0.076	0.528	0.533	15.312	-0.142	229.869	1
10%	3.304	16.347	16.678	-0.507	0.198	230.298	1
20%	6.611	15.990	17.302	-0.150	0.382	230.408	1
30%	9.973	15.952	18.813	-0.112	0.530	230.479	1
40%	13.190	15.937	20.687	-0.097	0.638	230.513	1
50%	16.490	15.917	22.919	-0.077	0.719	230.647	1
60%	19.773	15.905	25.376	-0.065	0.779	230.699	1
70%	23.098	15.911	28.048	-0.071	0.824	230.845	1
80%	26.398	15.919	30.827	-0.079	0.856	230.890	1
90%	29.730	15.953	33.740	-0.113	0.881	231.033	1
100%	33.010	16.012	36.689	-0.172	0.900	231.145	1

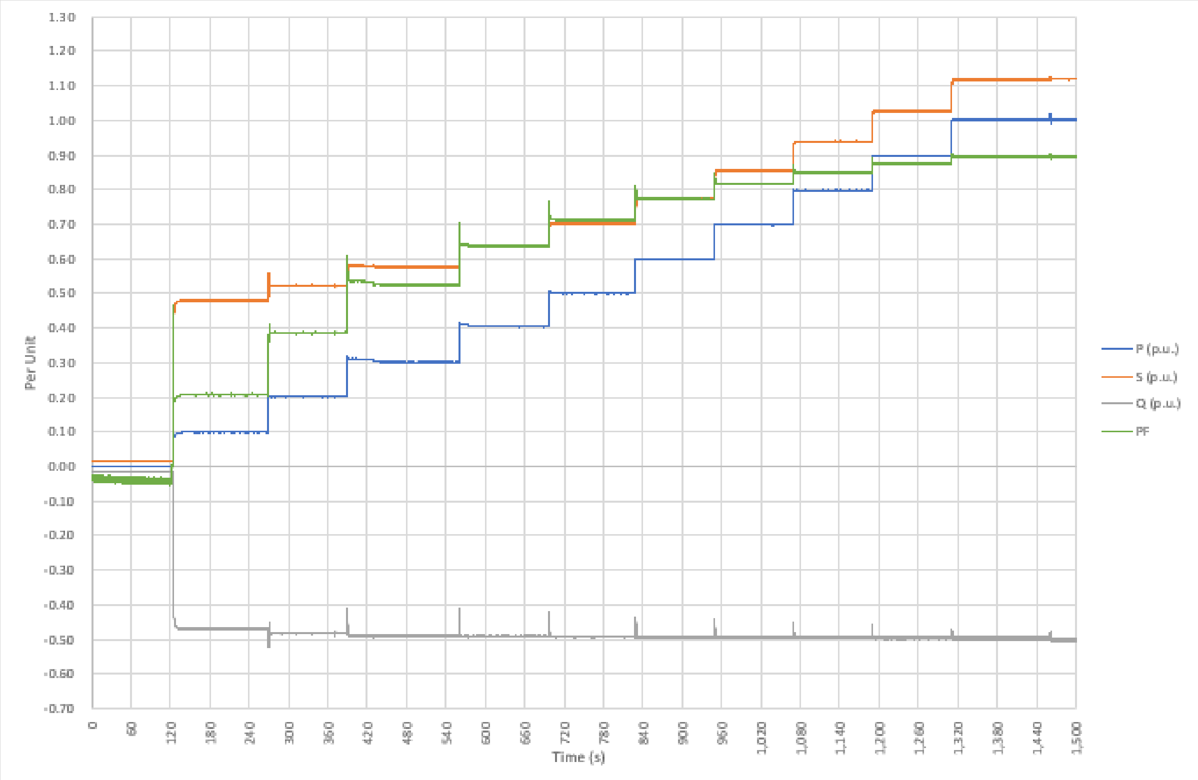
Rectangular Curve (Q=48.43 %P_n) – Capacitive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVAr)**	**Q Deviation (kVAr)**	**Power Factor (cos φ)**	**V_{AC} + (V)**	**Number of records**
0%	-0.020	-0.490	0.491	-15.350	-0.041	229.896	1
10%	3.293	-15.486	15.833	-0.354	0.208	229.774	1
20%	6.663	-15.931	17.269	0.091	0.386	229.917	1
30%	9.961	-16.163	18.986	0.323	0.525	230.035	1
40%	13.356	-16.204	20.998	0.364	0.636	230.016	1
50%	16.521	-16.235	23.163	0.395	0.713	230.144	1
60%	19.771	-16.263	25.601	0.423	0.772	230.252	1
70%	23.061	-16.282	28.230	0.442	0.817	230.372	1
80%	26.349	-16.294	30.980	0.454	0.851	230.478	1
90%	29.659	-16.345	33.865	0.505	0.876	230.590	1
100%	33.072	-16.467	36.945	0.627	0.895	230.722	1

In following graphs, test results are represented after the test has been performed:

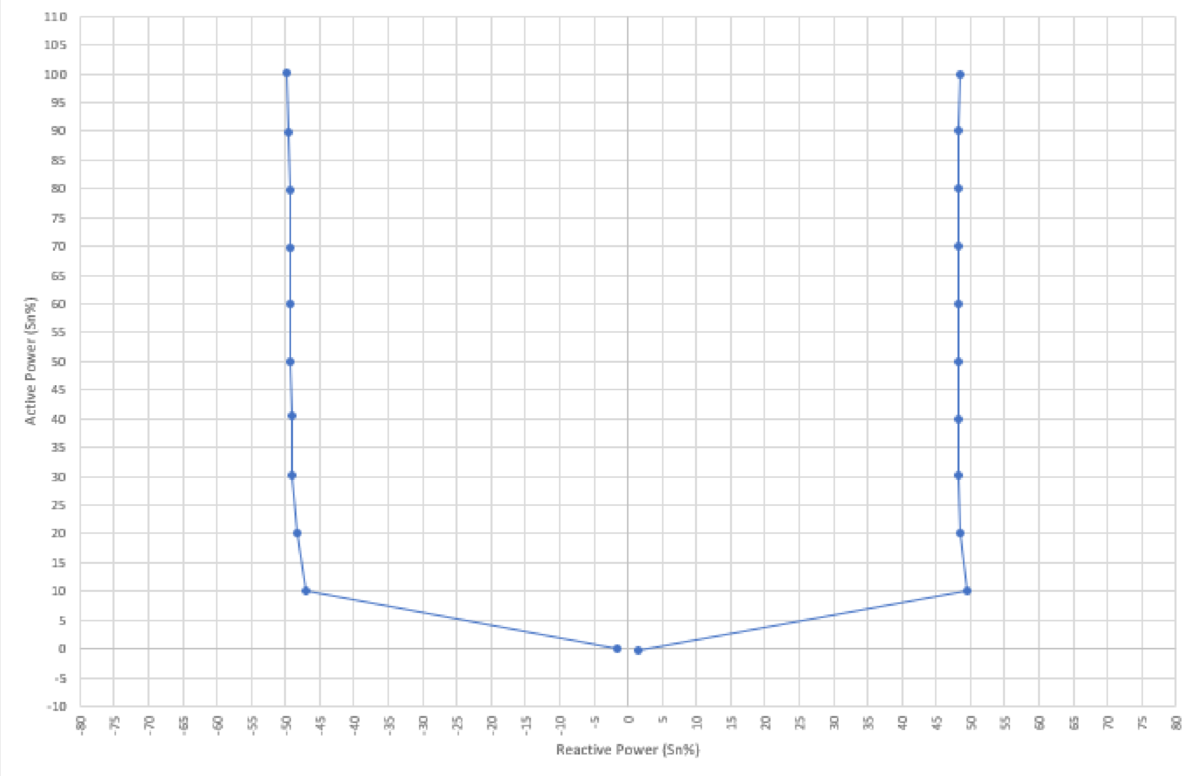
Rectangular Curve (Q=48.43%S_n), Inductive side: Power Factor and Powers over time



Rectangular Curve (Q=48.43%S_n), Capacitive side: Power Factor and Powers over time



Rectangular Curve: Active Power over Reactive Power



4.2.1.4 Triangular Curve: Fixed Power Factor (PF = 0.9)

Used settings of the measurement device for this triangular curve (PF=0.9) testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/03	100ms values	10kHz

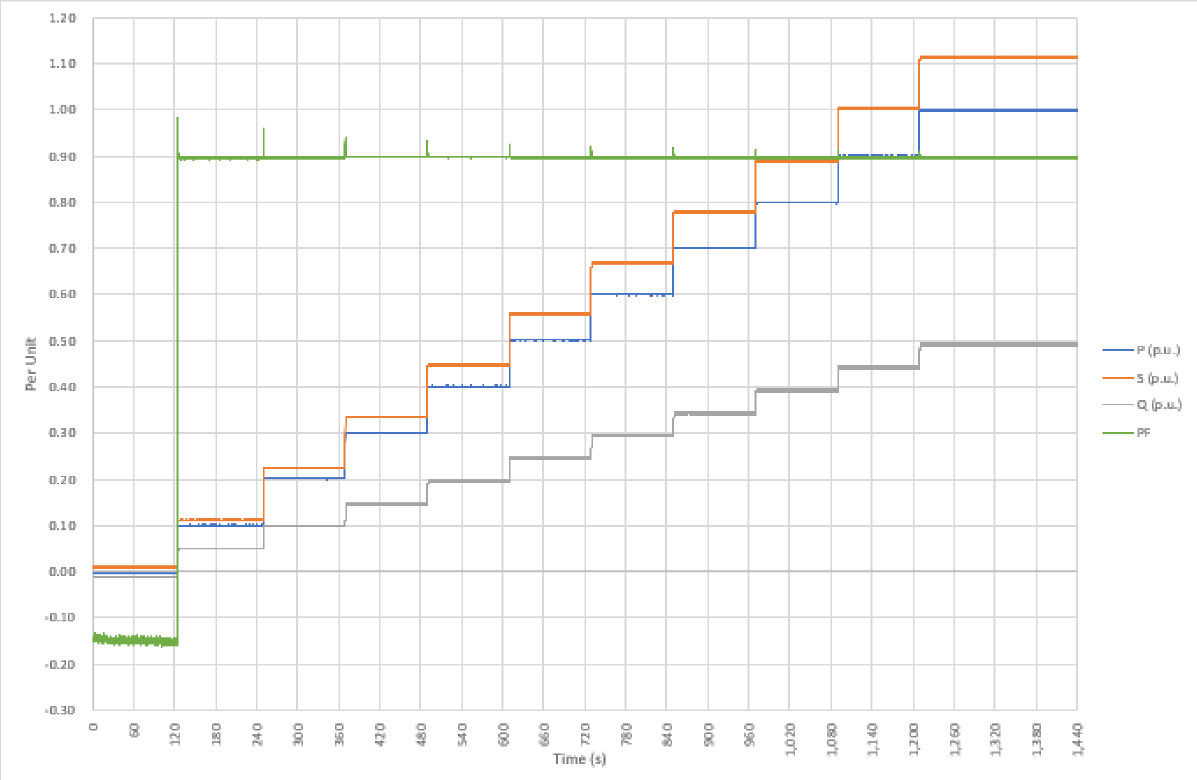
Tables below show measured values for each power step tested, at both the inductive and the capacitive sides:

Triangular Curve (PF=0.9) – Inductive						
P Desired (%Pn)	P measured (kW)	Q measured (kVAr)	Power Factor Measured (cos φ)	Power Factor Deviation (cos φ)	V_{AC} + (V)	Number of records
0%	-0.051	-0.334	-0.151	-1.051	229.887	1
10%	3.331	1.656	0.895	-0.005	229.933	1
20%	6.644	3.280	0.897	-0.003	230.175	1
30%	9.954	4.865	0.898	-0.002	230.254	1
40%	13.254	6.486	0.898	-0.002	230.484	1
50%	16.541	8.115	0.898	-0.002	230.601	1
60%	19.814	9.734	0.898	-0.002	230.674	1
70%	23.095	11.354	0.897	-0.003	230.746	1
80%	26.355	12.968	0.897	-0.003	230.853	1
90%	29.704	14.634	0.897	-0.003	230.971	1
100%	32.983	16.244	0.897	-0.003	231.126	1

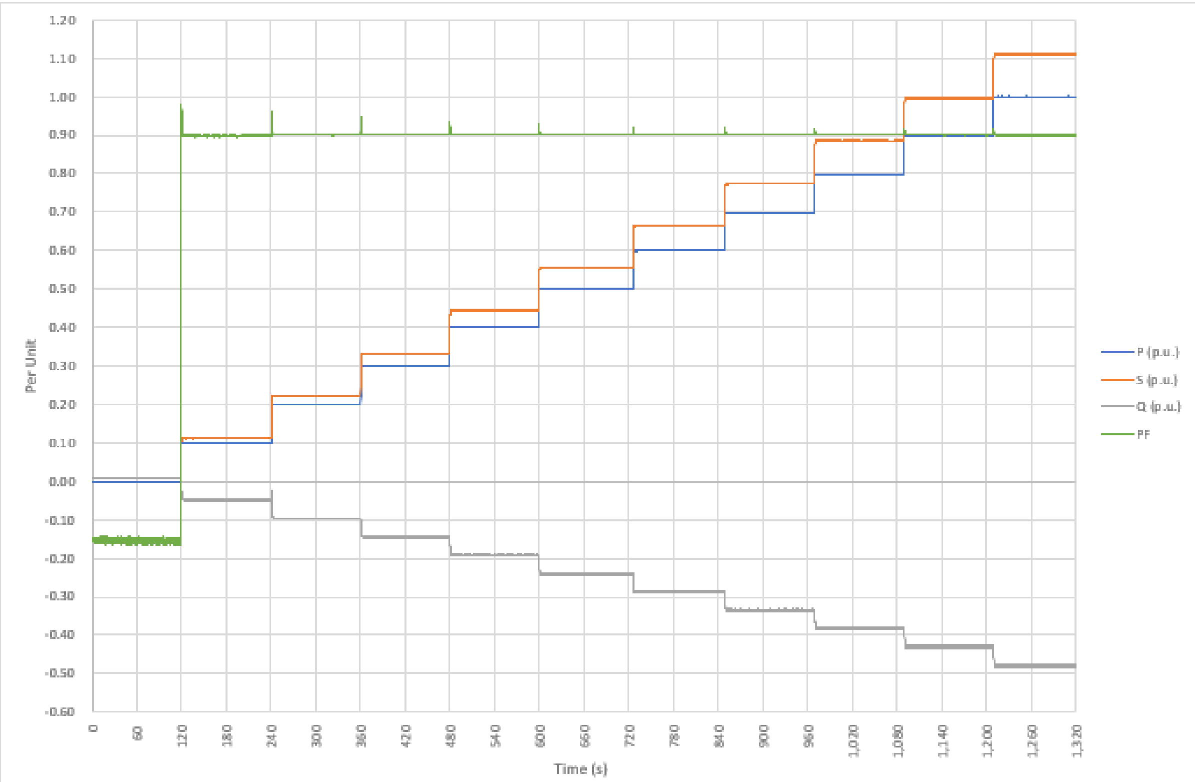
Triangular Curve (PF=0.9) – Capacitive						
P Desired (%Pn)	P measured (kW)	Q measured (kVAr)	Power Factor Measured (cos φ)	Power Factor Deviation (cos φ)	V_{AC} + (V)	Number of records
0%	-0.052	0.332	-0.156	-1.056	229.867	1
10%	3.314	-1.621	0.898	-0.002	229.919	1
20%	6.618	-3.169	0.902	0.002	230.059	1
30%	9.915	-4.753	0.902	0.002	230.055	1
40%	13.207	-6.330	0.902	0.002	230.215	1
50%	16.519	-7.916	0.902	0.002	230.263	1
60%	19.812	-9.493	0.902	0.002	230.341	1
70%	23.047	-11.045	0.902	0.002	230.438	1
80%	26.334	-12.622	0.902	0.002	230.525	1
90%	29.634	-14.213	0.902	0.002	230.642	1
100%	32.995	-15.847	0.901	0.001	230.713	1

In following graphs, test results are represented after the test has been performed:

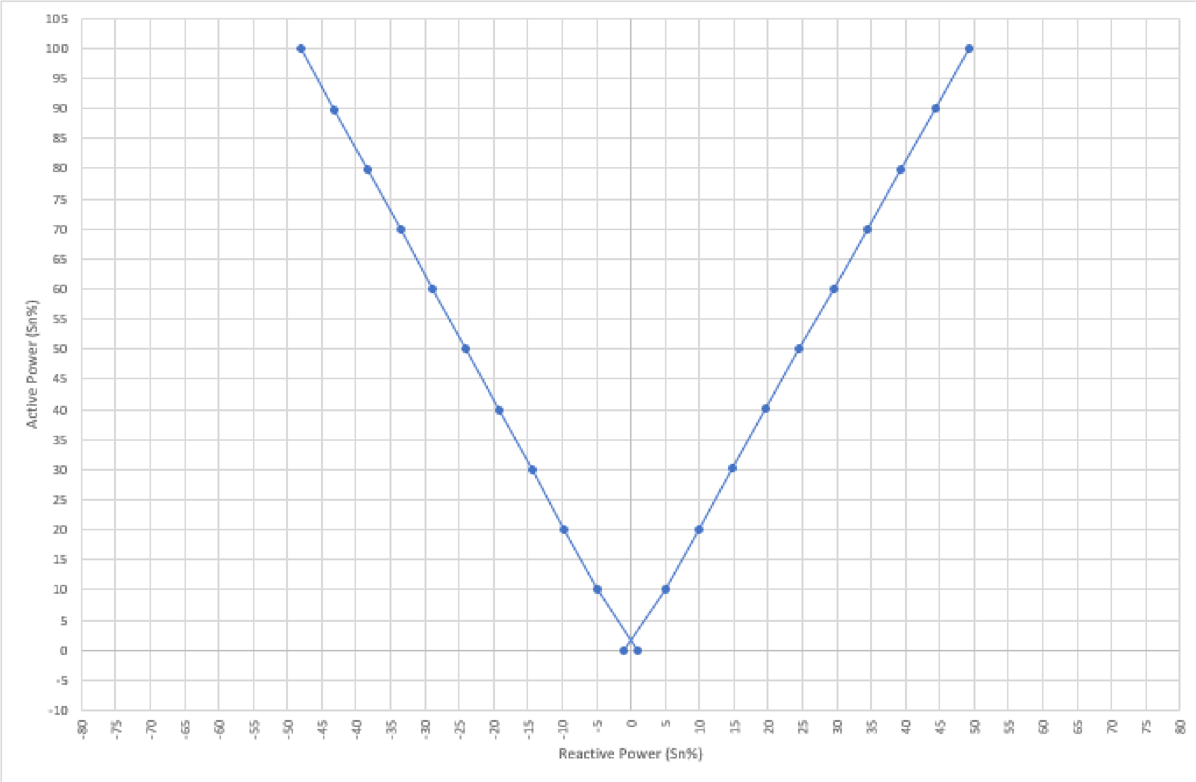
Triangular Curve (PF=0.9), Inductive side: Power Factor and Powers over time



Triangular Curve (PF=0.9), Capacitive side: Power Factor and Powers over time



Triangular Curve: Active Power over Reactive Power



4.2.1.5 Voltage-Dependent PQ diagram: Semicircular Curve

Testing Method Used for voltage variation		Comments
LVRT and/or HVRT container	☐	
PGU transformer tap-changer	☐	
Grid simulator	☒	
Autotransformer	☐	
Alternative test method	☐	

4.2.1.5.1 Test 1 (90 % Un)

Used settings of the measurement device for this voltage-dependant PQ diagram (90% Un) testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/03 and 2019/12/04	100ms values	10kHz

Tables below show measured values for each power step tested, at both the inductive and the capacitive sides:

Semicircular Curve (U = 90% Un) – Inductive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVA)**	**S deviation (kVA)**	**Power Factor (cos φ)**	**V_{AC+} (V)**	**Number of records**
0%	-0.084	0.468	0.475	32.525	-0.177	206.9	1
10%	3.265	16.432	16.753	16.247	0.195	207.3	1
20%	6.579	16.051	17.347	15.653	0.379	207.1	1
30%	9.946	16.009	18.847	14.153	0.528	207.1	1
40%	13.263	15.994	20.778	12.222	0.638	207.2	1
50%	16.562	15.972	23.009	9.991	0.720	207.3	1
60%	19.841	15.964	25.466	7.534	0.779	207.4	1
70%	23.130	15.976	28.111	4.889	0.823	207.3	1
80%	26.390	16.015	30.869	2.131	0.855	207.4	1
90%	29.261(*)	16.110	33.403	-0.403	0.876	207.5	1
100%	29.258(*)	16.110	33.400	-0.400	0.876	207.5	1

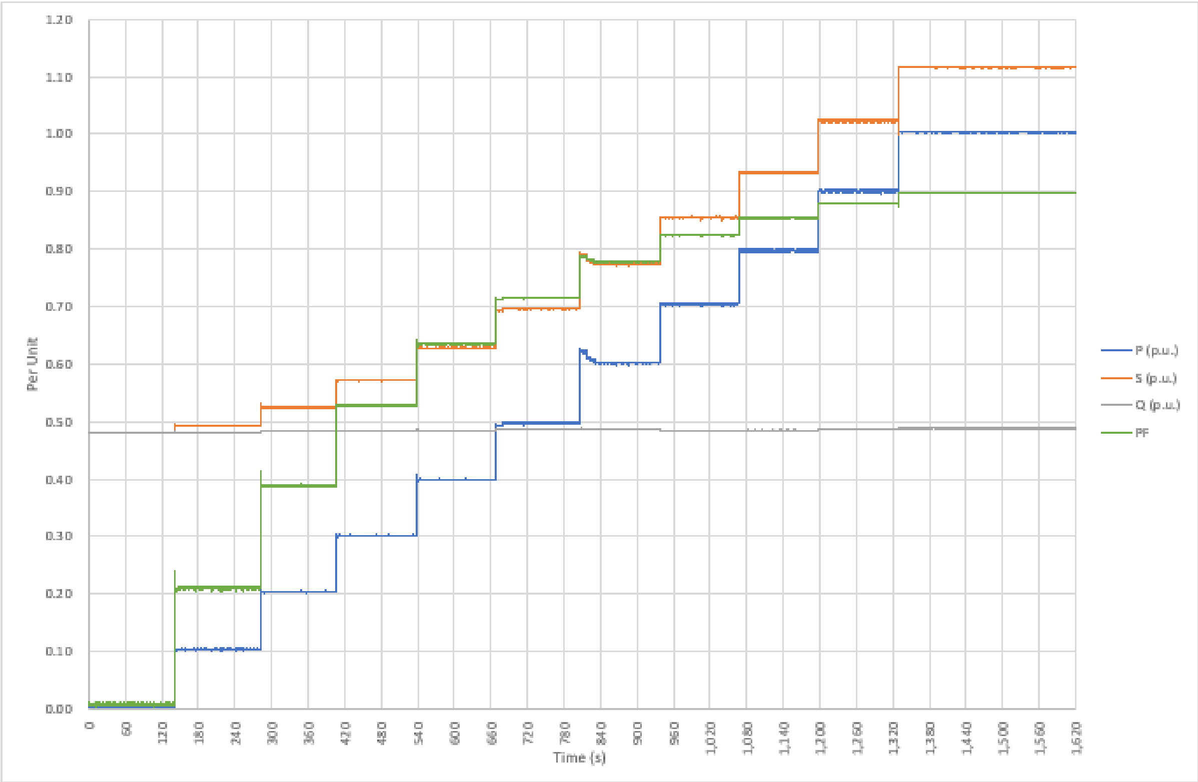
(*) Working at 90% Un the inverter does not reach 100% Sn due to the current limitation function. Maximum apparent power that can be reached corresponds to 100%Sn, approximately. Deviations are calculated in relation to this expected semicircular value. See further details in figure below.

Semicircular Curve (U = 90% Un) – Capacitive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVA)**	**S deviation (kVA)**	**Power Factor (cos φ)**	**V_{AC+} (V)**	**Number of records**
0%	-0.024	-0.452	0.453	32.547	-0.053	206.9	1
10%	3.325	-15.493	15.845	17.155	0.210	206.7	1
20%	6.662	-15.507	16.877	16.123	0.395	206.9	1
30%	9.992	-15.518	18.457	14.543	0.541	206.9	1
40%	13.276	-15.531	20.432	12.568	0.650	207.1	1
50%	16.541	-15.555	22.706	10.294	0.728	207.2	1
60%	19.808	-15.569	25.194	7.806	0.786	207.3	1
70%	23.094	-15.584	27.860	5.140	0.829	207.4	1
80%	26.425	-15.646	30.710	2.290	0.860	207.6	1
90%	29.031(*)	-15.775	33.040	-0.040	0.879	207.7	1
100%	29.033(*)	-15.774	33.042	-0.042	0.879	207.711	1

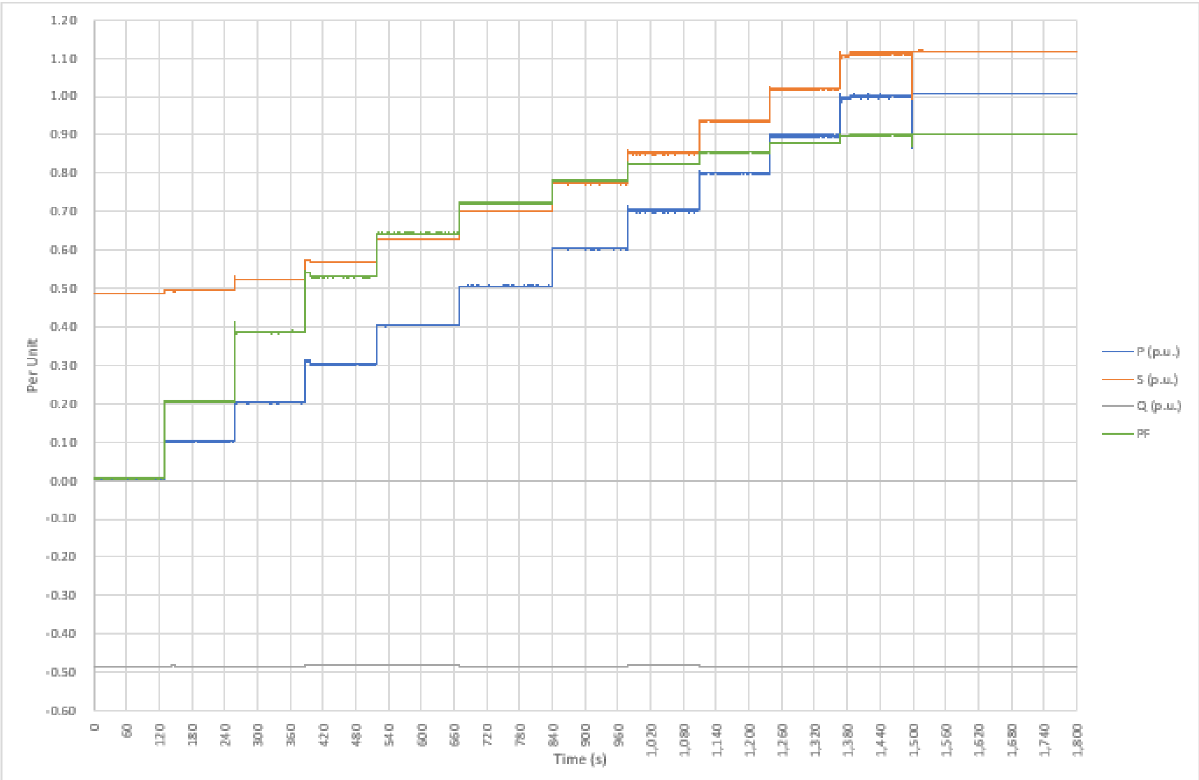
(*) Working at 90% Un the inverter does not reach 100% Pn due to the current limitation function while reactive power priority. Maximum apparent power that can be reached corresponds to 100%Sn, approximately. Deviations are calculated in relation to this expected semicircular value. See further details in figure below.

In following graphs, test results are represented after the test has been performed:

Semicircular Curve (90%Un), Inductive side: Power Factor and Powers over time



Semicircular Curve (90%Un), Capacitive side: Power Factor and Powers over time



4.2.1.5.2 Test 2 (110 % Un)

Used settings of the measurement device for this voltage-dependant PQ diagram (110% Un) testing.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2020/08/27	100ms values	10kHz

Tables below show measured values for each power step tested, at both the inductive and the capacitive sides:

Semicircular Curve (U = 110% Un) – Inductive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVA)**	**S deviation (kVA)**	**Power Factor (cos φ)**	**V_{AC+} (V)**	**Number of records**
0%	0.133	15.860	15.861	-0.121	0.008	252.7	1
10%	3.431	15.912	16.278	-0.041	0.211	252.8	1
20%	6.741	15.967	17.332	0.041	0.389	252.8	1
30%	9.963	16.015	18.862	0.062	0.528	252.9	1
40%	13.171	16.001	20.725	-0.003	0.636	253.0	1
50%	16.443	16.052	22.979	0.008	0.716	253.1	1
60%	19.884	16.043	25.549	0.104	0.778	253.2	1
70%	23.280	15.965	28.229	0.139	0.825	253.3	1
80%	26.319	16.016	30.809	-0.051	0.854	253.4	1
90%	29.729	16.072	33.795	0.068	0.880	253.4	1
100%	33.109	16.130	36.829	0.162	0.899	253.5	1
108% (*)	33.108	16.130	36.828	-2.834	0.899	253.5	1

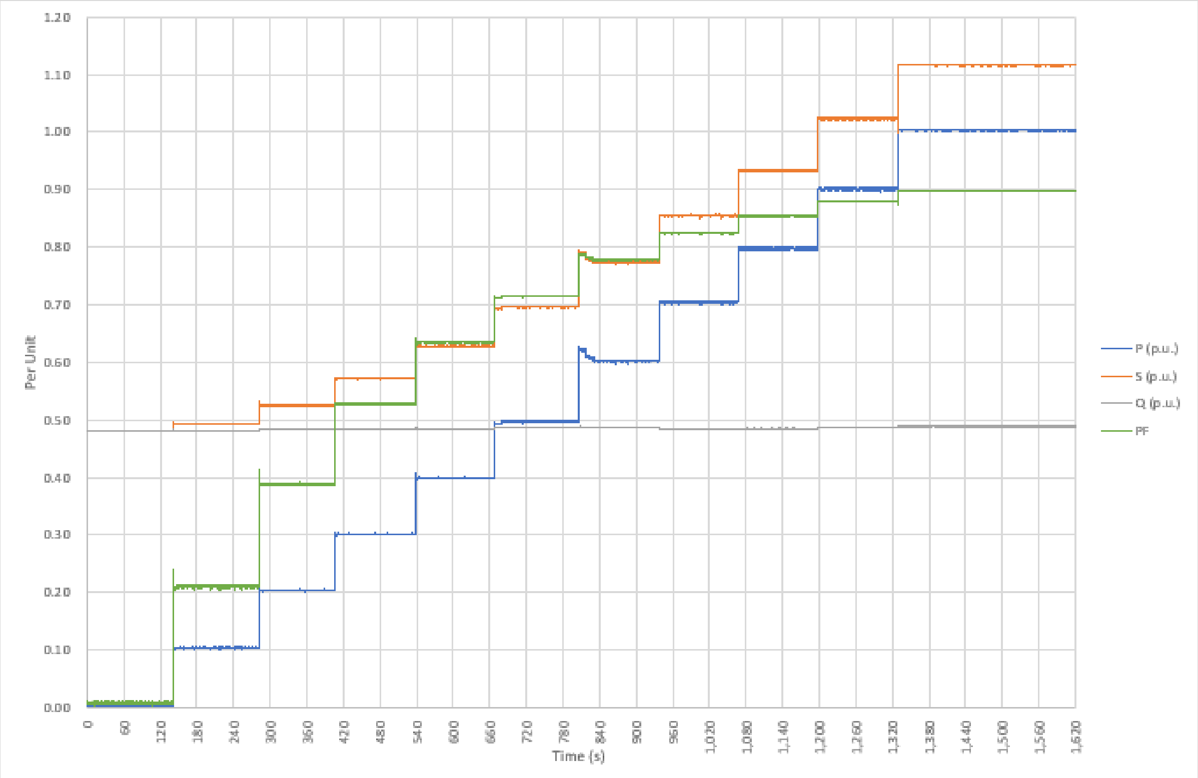
(*) Working at 110% Un the inverter can reach 108% Pn while reactive power priority. Maximum apparent power that can be reached corresponds to 110%Sn, approximately. Deviations are calculated in relation to this expected semicircular value. See further details in figure below.

Semicircular Curve (U = 110% Un) – Capacitive							
P Desired (%Pn)	**P measured (kW)**	**Q measured (kVAr)**	**S measured (kVA)**	**S deviation (kVA)**	**Power Factor (cos φ)**	**V_{AC+} (V)**	**Number of records**
0%	0.091	-16.092	16.093	0.112	0.006	252.6	1
10%	3.368	-15.998	16.349	0.030	0.206	252.7	1
20%	6.686	-15.957	17.301	0.010	0.386	252.8	1
30%	9.984	-15.916	18.788	-0.011	0.531	252.9	1
40%	13.340	-15.871	20.732	0.004	0.643	253.0	1
50%	16.716	-16.018	23.151	0.180	0.722	253.1	1
60%	19.978	-15.976	25.580	0.135	0.781	253.2	1
70%	23.218	-15.936	28.161	0.071	0.824	253.2	1
80%	26.410	-16.060	30.910	0.049	0.854	253.3	1
90%	29.645	-16.021	33.697	-0.030	0.880	253.4	1
100%	33.065	-15.977	36.722	0.056	0.900	253.5	1
110%	33.244(*)	-15.984	36.887	-2.775	0.901	253.5	1

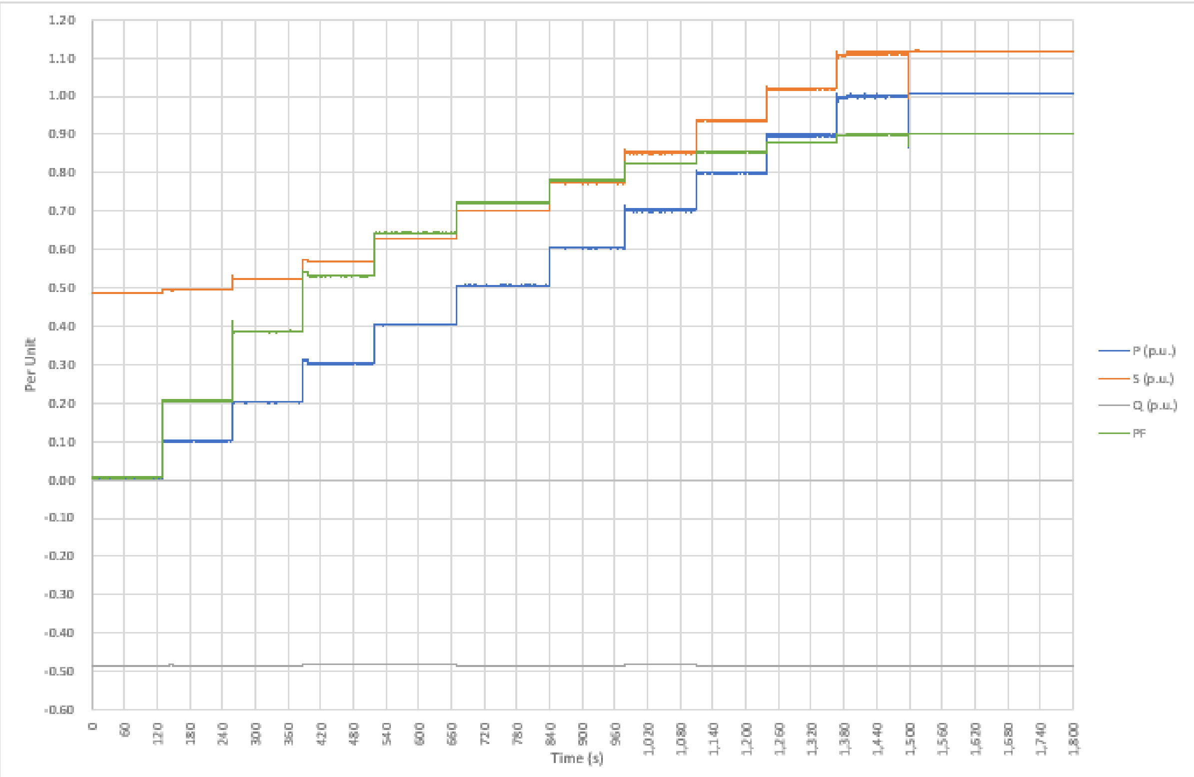
(*) Working at 110% Un the inverter can reach 108% Pn while reactive power priority. Maximum apparent power that can be reached corresponds to 110%Sn, approximately. Deviations are calculated in relation to this expected semicircular value. See further details in figure below.

In following graphs, test results are represented after the test has been performed:

Semicircular Curve (110%Un), Inductive side: Power Factor and Powers over time



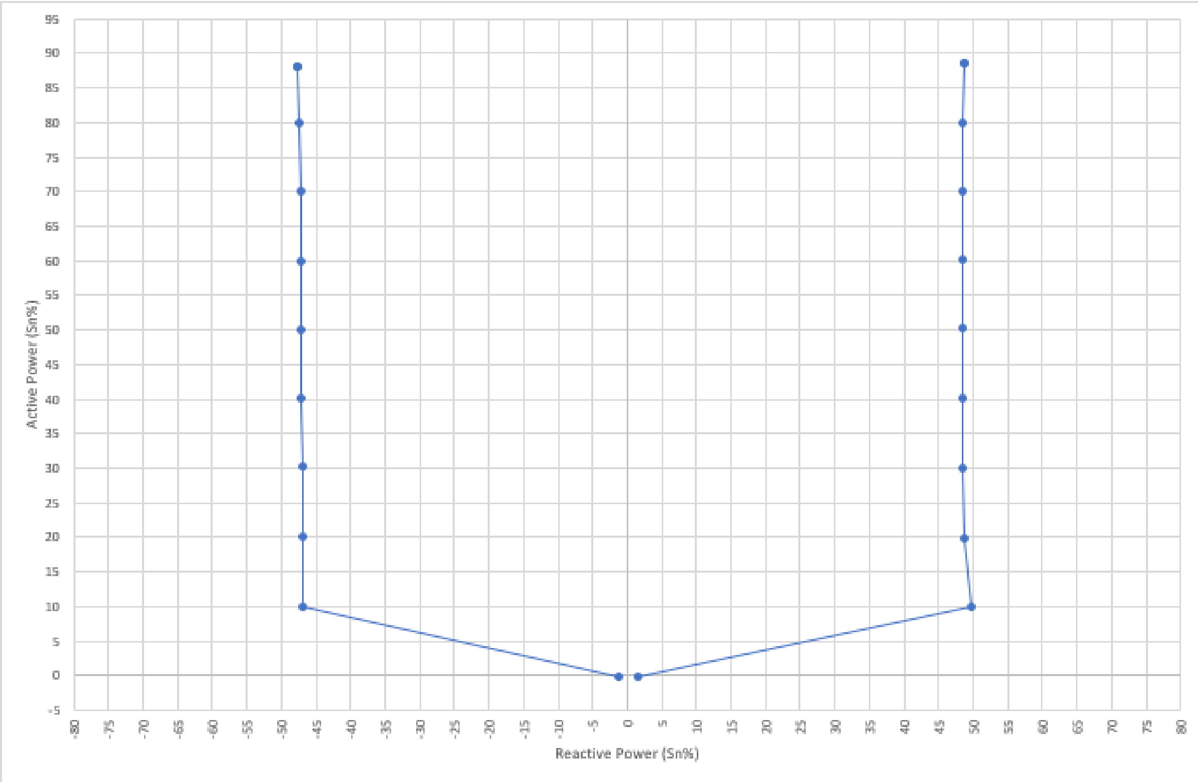
Semicircular Curve (110%Un), Capacitive side: Power Factor and Powers over time



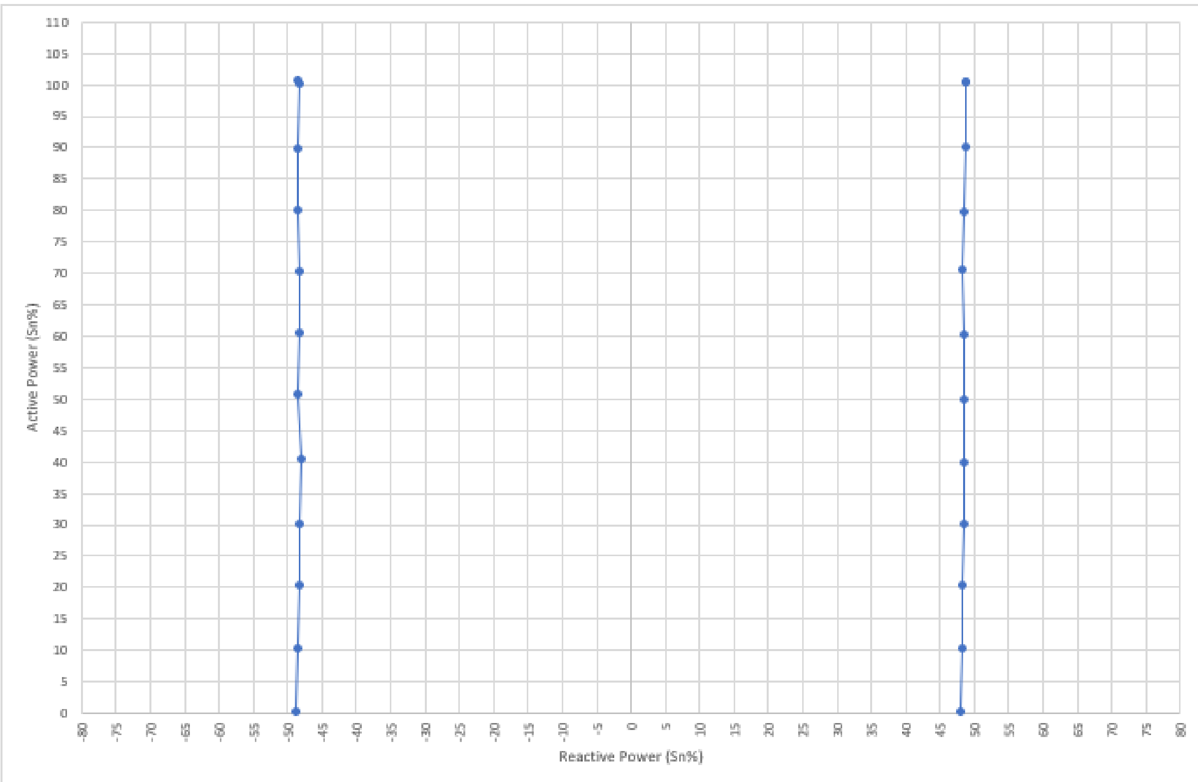
4.2.1.5.3 Voltage-Dependent PQ diagram: resume of results

In following graphs, semicircular curves are represented for tests above detailed.

Semicircular Curve (90%Un): Active Power over Reactive Power



Semicircular Curve (110%Un): Active Power over Reactive Power



4.2.2 Reactive Power Following Setpoints

The aim of this test is to determine the PGU’s reaction to the reactive power setpoint input in relation to the setting accuracy and the settling time.

The required testing has been performed according to the point 4.2.4 of the standard. It can be applied to both PV and storage systems

Different reactive power Q setpoint signals were applied to the inverter in order to verify the proper behavior working at different active power levels. In addition, it was verified the capability of the inverter to set different setting values for the time response.

For all test, the displacement factor, the active power and the reactive power measurements in the positive phase sequence system have been represented as 20 milisecond means for every setpoint step.

Interface information	
Interface used	Solar communication tools, RS485
Interface version used	V250
Other interfaces in the equipment	N/A
Name or code of the parameter for Reactive power setpoint & settling time	Reactive parameters
If the EUT has several different interfaces for defining the setpoint, it has been tested the interface returning the most unfavourable results according to the manufacturer information.	

EUT Settings used for this test are provided in the following table:

EUT Settings	
Operanting mode	Reactive power priority
Active control modes	Active power control LVRT mode Fixed Reactive power control

Test results are offered in following points.

4.2.2.1 Determining the settling time

Different tests have been performed at two different power levels:

- Test 1: 50% of P_n (settling time shortest as possible); Configured time setting value: 6 s
- Test 2: 80% of P_n (settling time longest as possible); Configured time setting value: 60 s

(Due to the maximum reactive power range lies within an active power level of 48.43%Pn).

Time setting values that may be parametrized in the control as given by manufacturer's specifications: Range from 0 to 60 s

The following table shows de reactive power range:

Q range at 50% P_n	0 to 48.43 % Pn
Maximum Q range	0 to 48.48 % Pn
Note: Maxímum power range is acchivied with an Active power of 93.0%Pn	

- **Test 1: Active power at 50%Pn**

Operating at this active power level, the inverter was subjected to following reactive power step changes providing its maximum Q level available corresponding to 48.43%Pn.

Step	Comments	
1	$t_1 = 0$ s	Recording is started
2	$t_2 = 10$ s	Setting the setpoint to the maximum possible reactive power in overexcited operation with the selected active power level $Q_{max,oe}$
3	$t_3 \geq t_2 + t_{settling} + 10$ s	Setting the setpoint to the maximum possible reactive power in underexcited operation with the selected active power level $Q_{max,ue}$
4	$t_4 \geq t_3 + t_{settling} + 10$ s	Setpoint set to cosφ = 1 (Q=0)
5	$t_5 \geq t_4 + t_{settling} + 10$ s	Recording is stopped

The settling time for this test was set to be the shortest as possible (but no longer than 6s) corresponding to 5.8 seconds, approximately.

- **Test 2: Active power at 80 %Pn**

Operating at this active power level, the inverter was subjected to following reactive power step changes providing its maximum Q level available corresponding to 48.43%Pn.

Step	Comments	
1	$t_1 = 0$ s	Recording is started
2	$t_2 = 10$ s	Setting the setpoint to the maximum possible reactive power in overexcited operation with the selected active power level 50%$Q_{max,oe}$
3	$t_3 \geq t_2 + t_{settling} + 10$ s	Setting the setpoint to the maximum possible reactive power in underexcited operation with the selected active power level 50%$Q_{max,ue}$
4	$t_4 \geq t_3 + t_{settling} + 10$ s	Setpoint set to cosφ = 1 (Q=0)
5	$t_5 \geq t_4 + t_{settling} + 10$ s	Recording is stopped

The settling time for this test was set to be the shortest as possible (but no longer than 6s) corresponding to 60 seconds, approximately.

Used settings of the measurement device for the testing of reactive power following setpoins (Settling time). According to the standard, measurements must be taken every 20 ms.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/04	100ms values	10kHz

Test results are offered in following points:

The settling time for all steps is determined and given while taking the ±5%Pn tolerance band into consideration.

4.2.2.1.1 Test 1

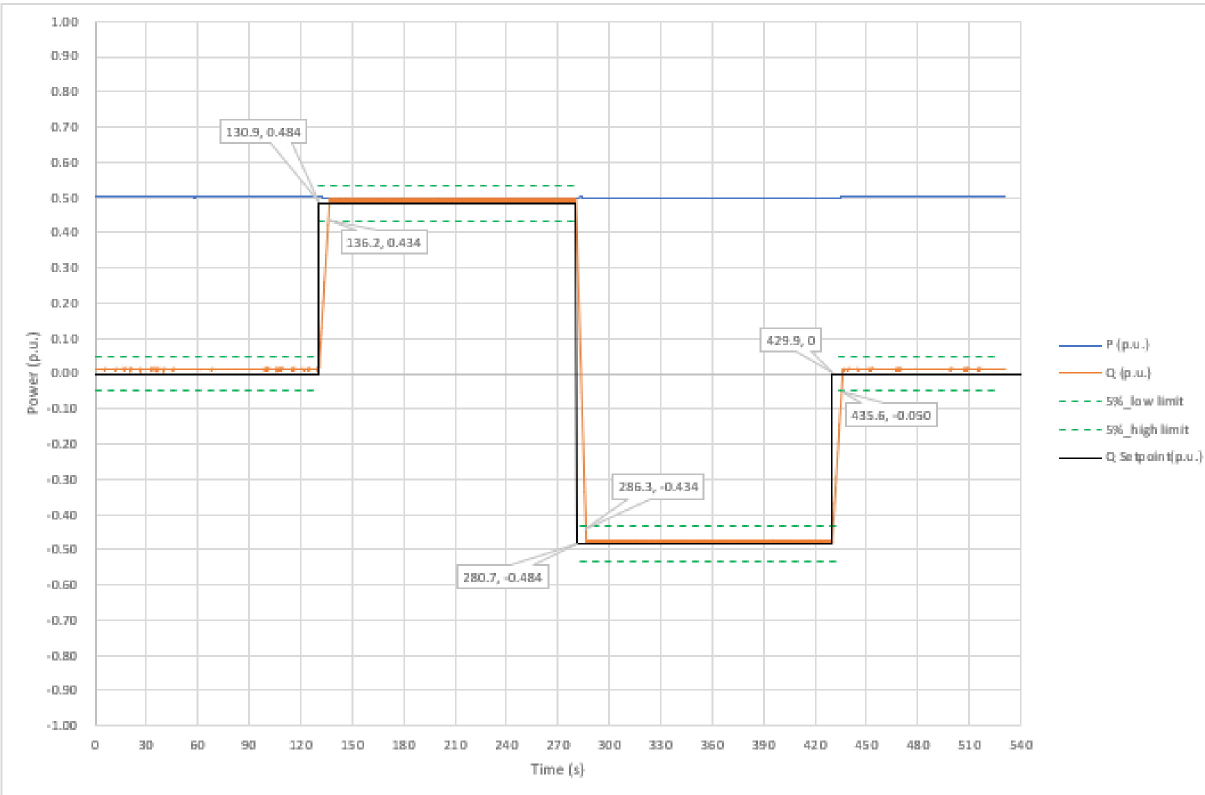
The following table show test results of the settling time determined after each step.

Settling time (shortest possible)						
Power		Reactive Power Steps		Point in time of setpoint Change (s)	Point in time of settling (s)	Time Difference / Settling time (s)
Desired (% Pn)	Measured (% Pn)	Step	Description			
50%	50.1%	1	0% Q_{max}	-	-	-
		2	0% Q_{max} → +100% Q_{max}	130.9	136.2	5.3
		3	+100% Q_{max} → -100% Q_{max}	280.7	286.3	5.6
		4	-100% Q_{max} → 0% Q_{max}	429.9	435.6	5.7
		5	0% Q_{max}	-	-	-

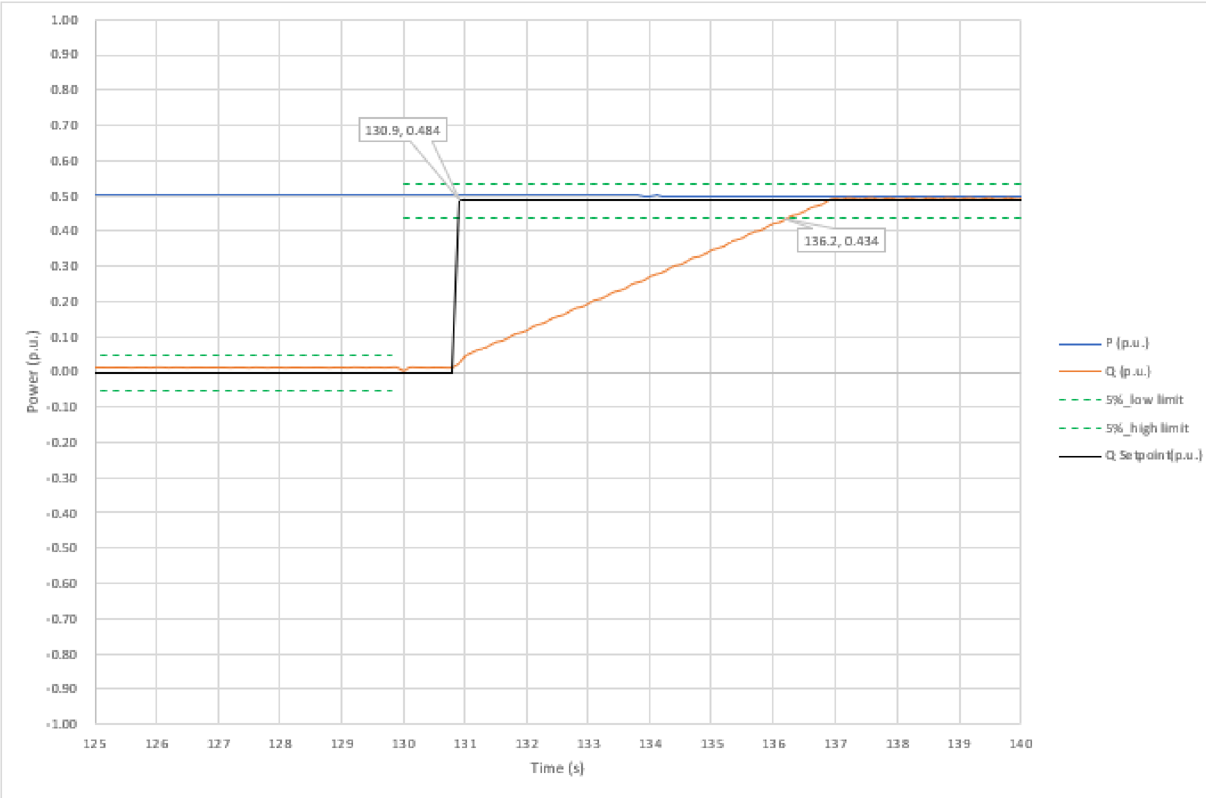
Longest measured setting time (s)	5.7

In following graphs, test results are represented after the test has been performed:

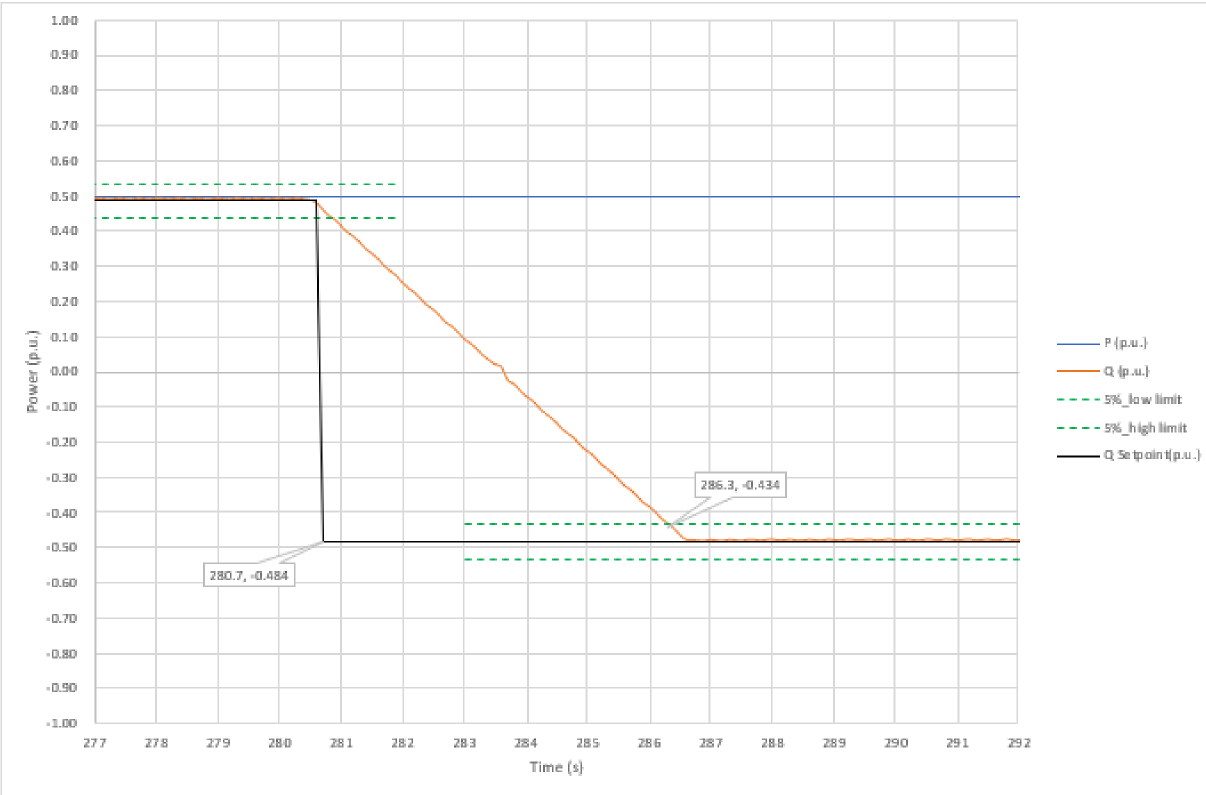
Test over Time



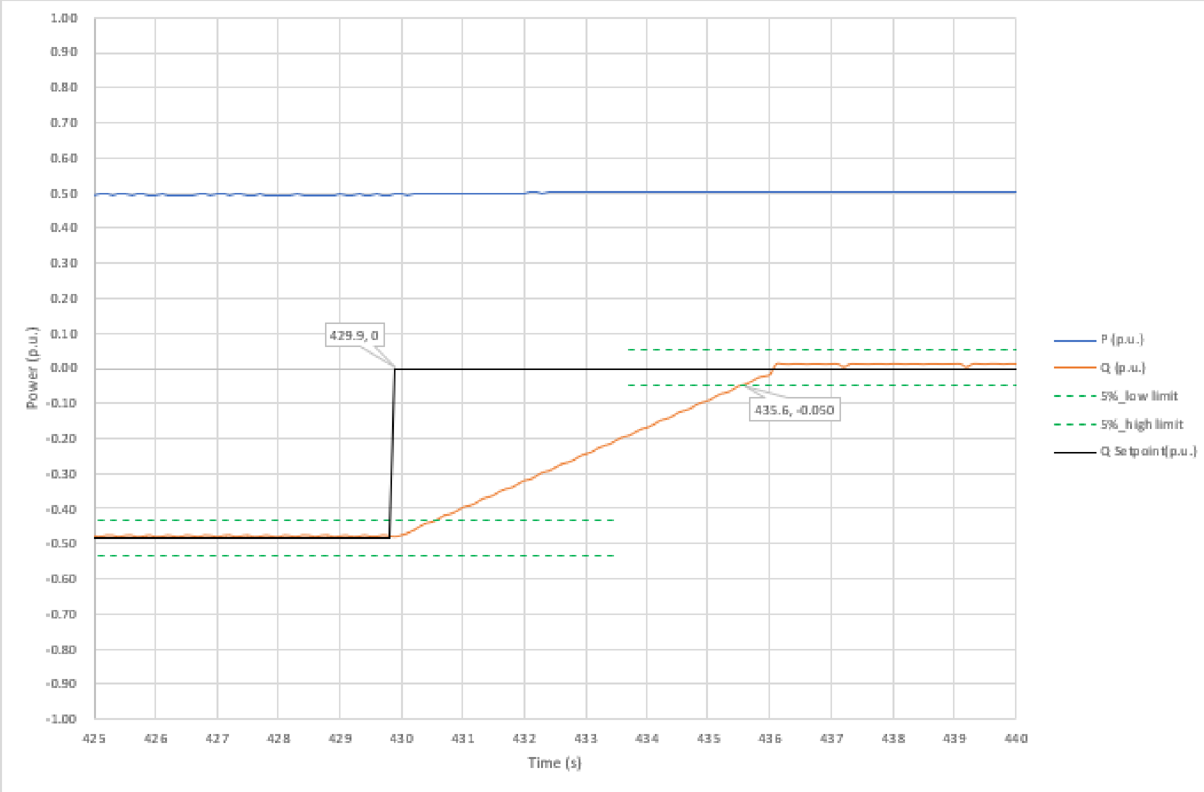
Test 1: zoom time of the step 2



Test 1: zoom time of the step 3



Test 1: zoom time of the step 4



4.2.2.1.2 Test 2

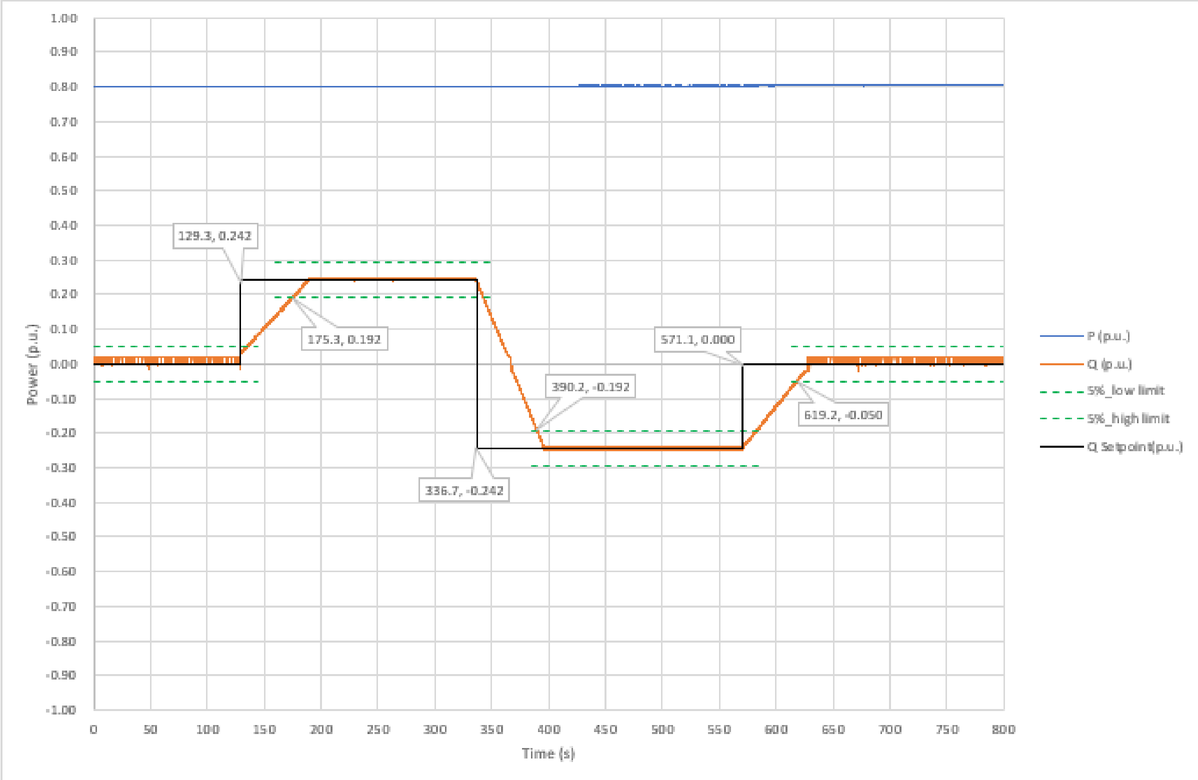
The following table show test results of the settling time determined after each step.

Settling time (longest possible but lower than 60 seconds)						
Power		Reactive Power Steps		Point in time of setpoint Change (s)	Point in time of settling (s)	Time Difference (s)
Desired (% Pn)	Measured (% Pn)	Step	Description			
80.0%	80.2%	1	0% Q_{max}	-	-	-
		2	0% Q_{max} → +50% Q_{max}	129.3	175.3	46.0
		3	+50% Q_{max} → -50% Q_{max}	336.7	390.2	53.5
		4	-50% Q_{max} → 0% Q_{max}	571.1	619.2	48.1
		5	0% Q_{max}	-	-	-

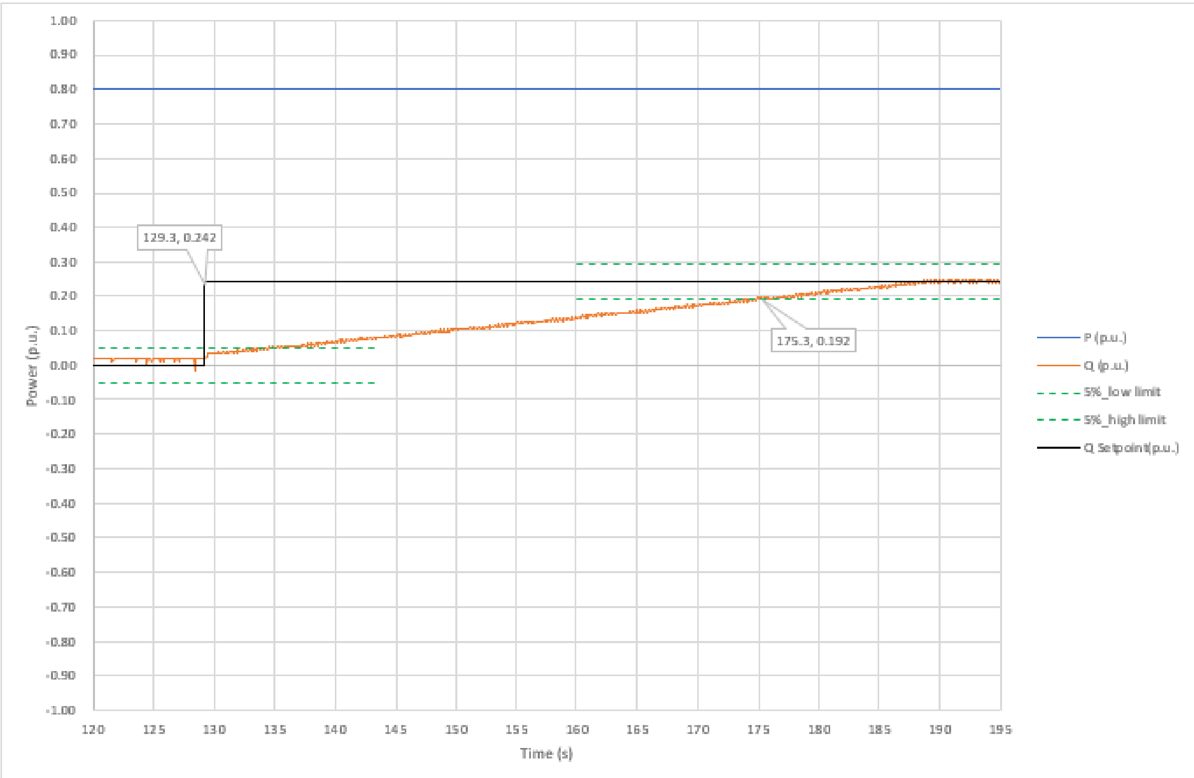
Longest measured setting time (s)	53.5

In following graphs, test results are represented after the test has been performed:

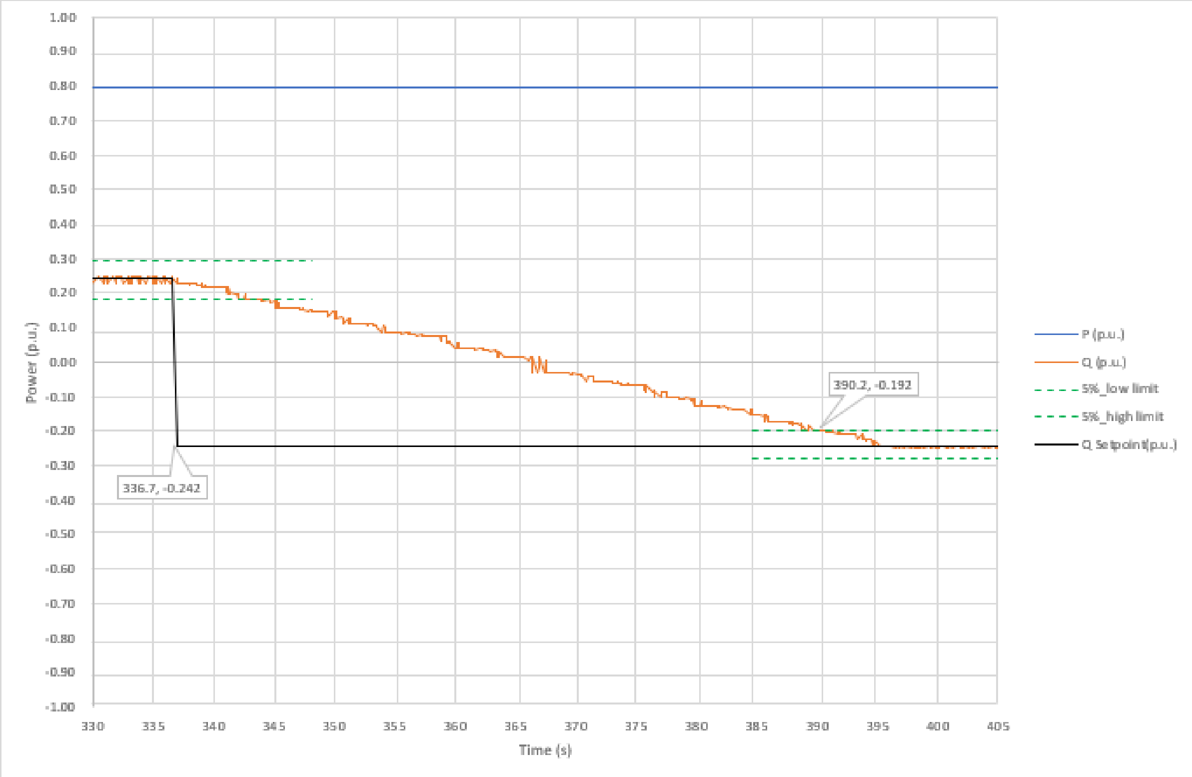
Test over Time



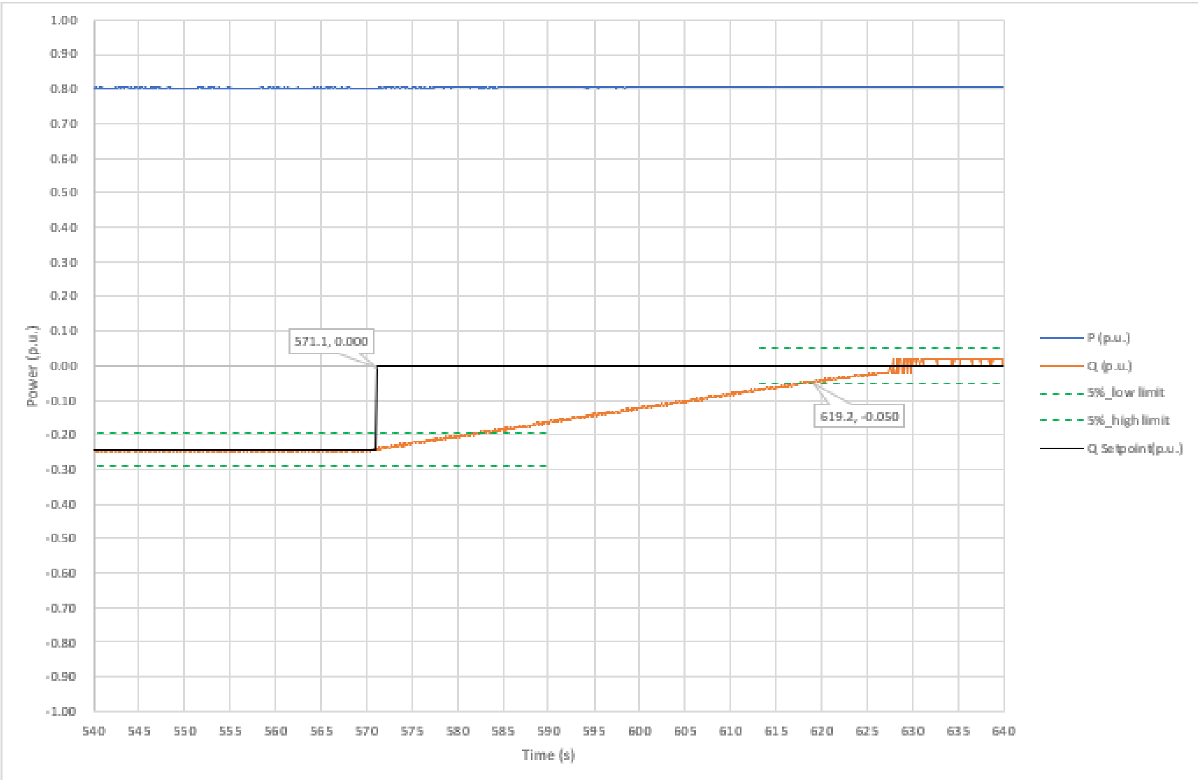
Zoom time of the step 2



Zoom time of the step 3



Zoom time of the step 4



4.2.2.2 Determining the setting accuracy

They have been done following steps measuring the time from leaving the initial Q set point until reaching the final.

Step	Comments	
1	t_1 = 0 s	Recording is started
2	t_2 = 10 s	Setpoint set to 50.0% $Q_{max, oe}$
3	$t_3 = t_2$ + 120 s	Setpoint set to 50.0% $Q_{max,ue}$
4	$t_4 = t_3$ + 120 s	Setpoint set to cosφ = 1 (Q=0)
5	$t_5 = t_4$ + 120 s	Recording is stopped

Used settings of the measurement device for the testing of reactive power following setpoins (Accuracy).

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/04	100ms values	10kHz

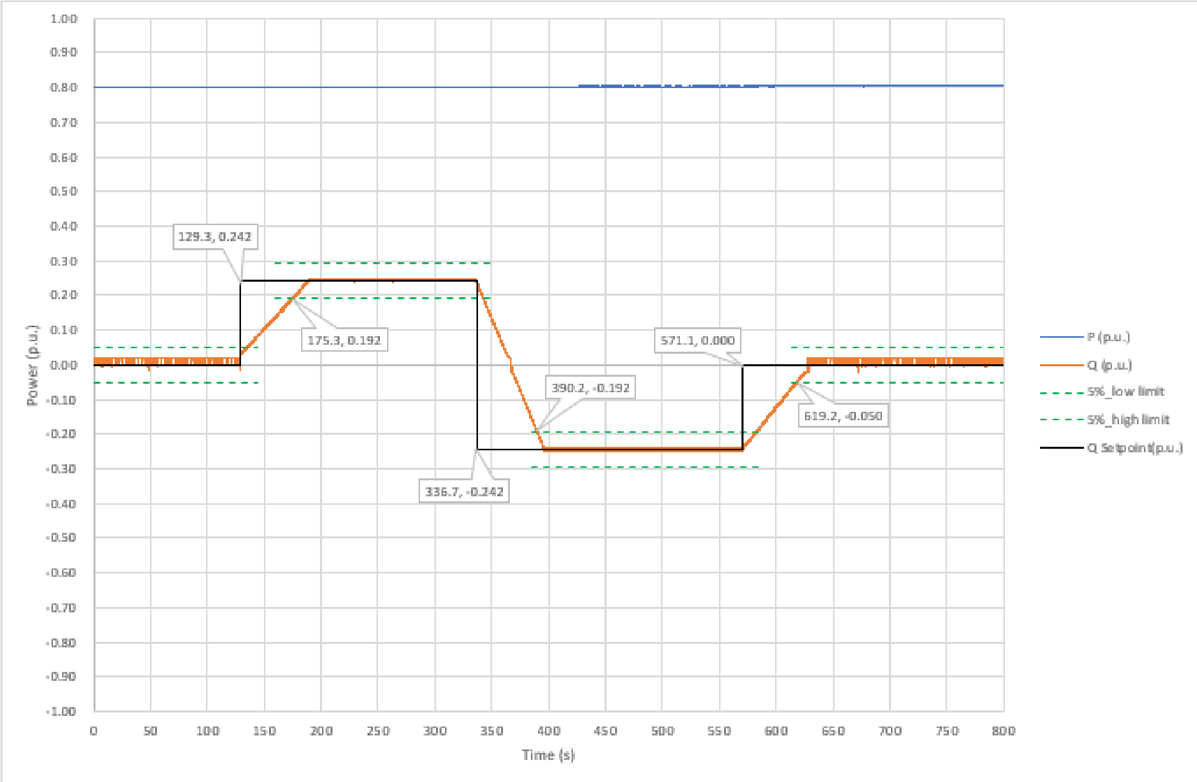
The following table shows the results of reactive power, active power, displacement factor and output voltage measured for the test performed under partial load (50%Pn). Setpoints of reactive power fixed, as 1 minute mean values, have a maximum tolerance allowed up to ± 5% Pn.
All values are in the positive sequence system.

Accuracy test						
Reactive Power steps	**Setpoint value (kVAr)**	**Actual value (kVAr)**	**Setpoint - actual value (kVAr)**	**cos φ**	**Grid voltage (V)**	**Measured Active Power (kW)**
Q_0	0	0.788	-0.788	1.000	230.9	26.467
50% Q_{max} Overexcited	7.991	8.051	-0.060	0.957	230.9	26.438
50% Q_{max} Underexcited	-7.991	-8.063	0.072	0.957	230.7	26.502

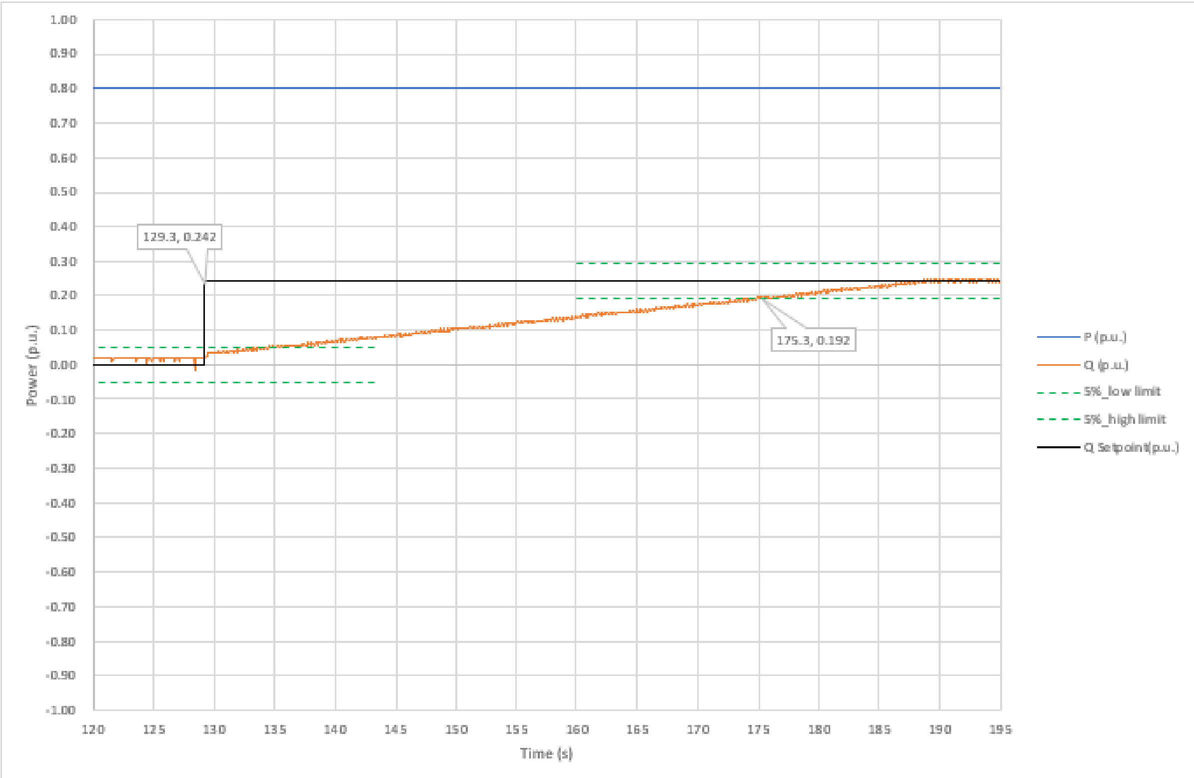
Maximum deviation from the setpoint (kVAr)	0.788
Q range at 50%P_n	0 to 48.43%Pn
Maximum Q range	48.43%Pn

In following graphs, test results are represented after the test has been performed:

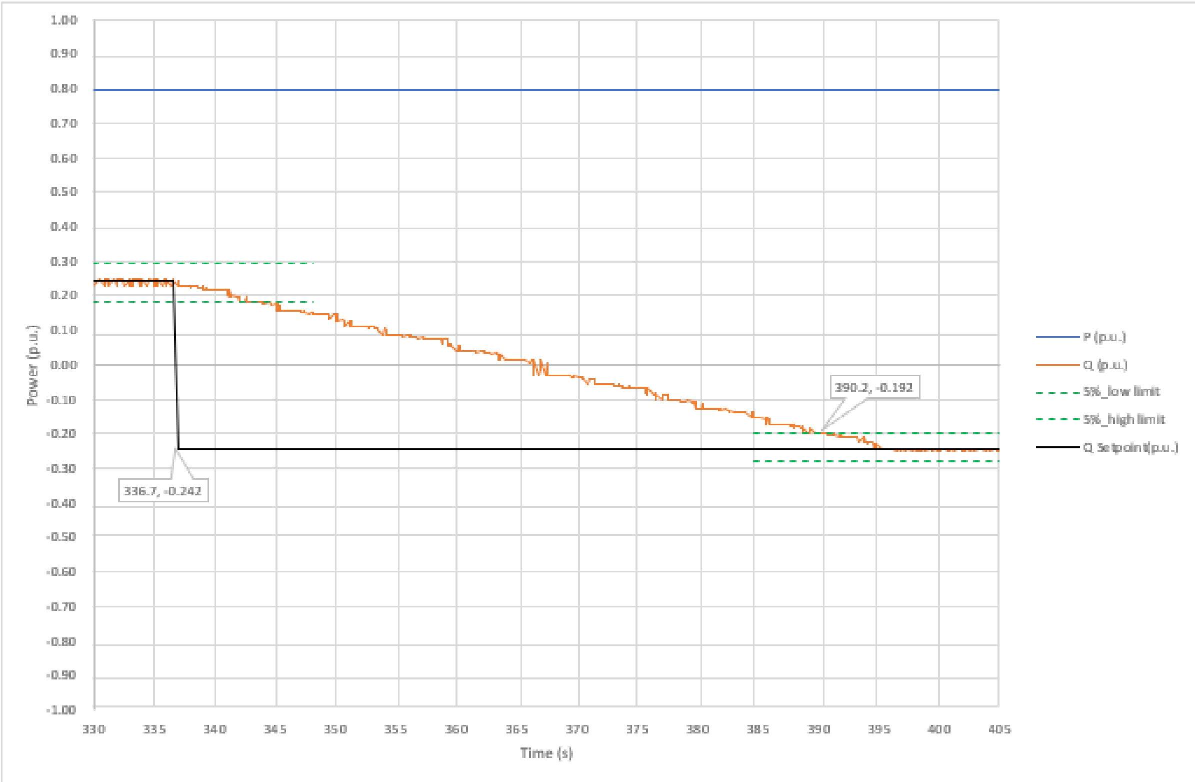
Test over Time



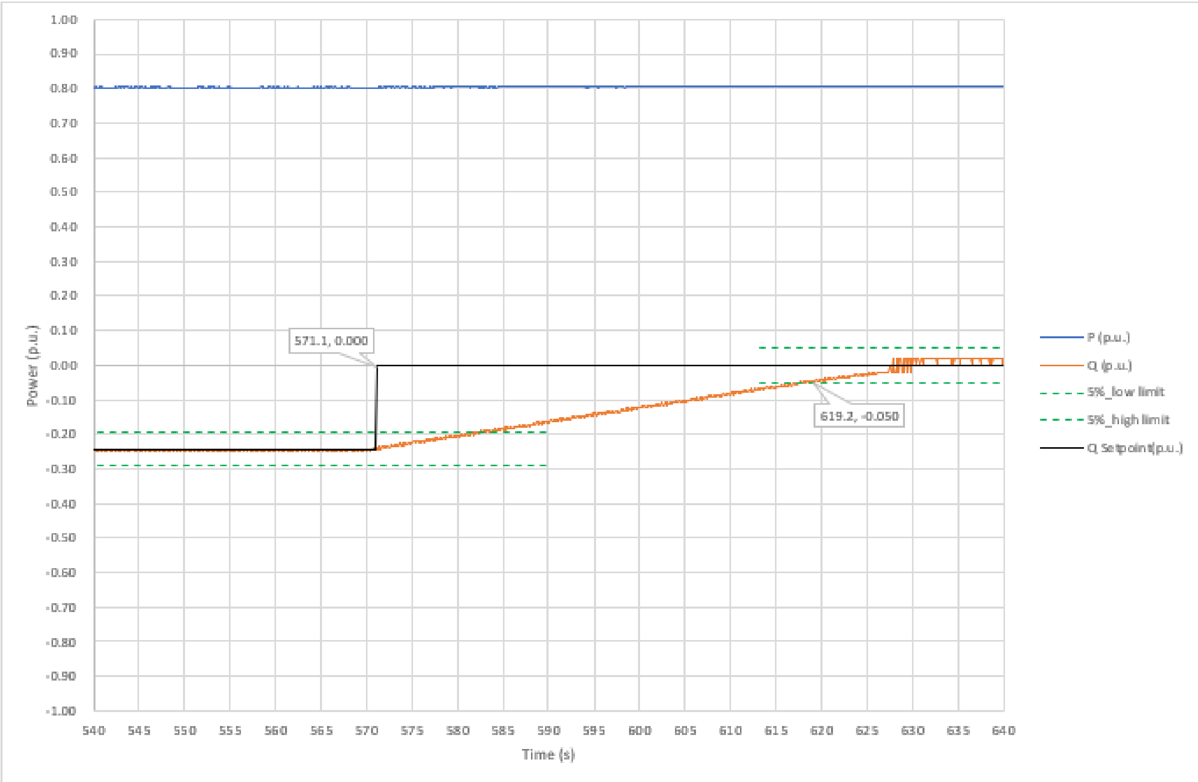
Zoom time of the step 1: 0% to +50% Q_{max}



Zoom time of the step 2: +50% to -50% Q_{max}



Zoom time of the step 3: -50% to 0% Q_{max}

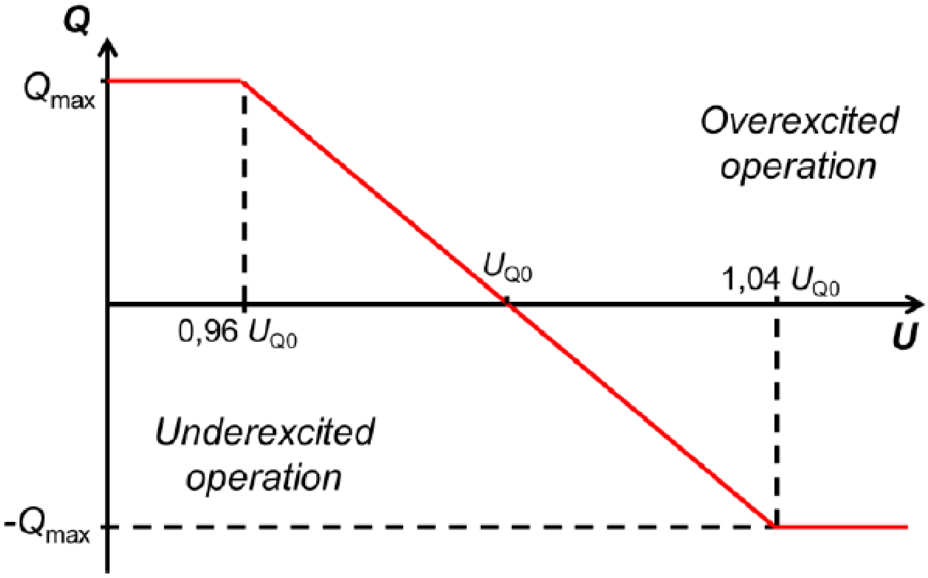


4.2.3 Q (U) Control (Voltage regulation)

The aim of this test is to examine the voltage regulation method by means of reactive power or displacement factor control as a function of the voltage.

These tests have been performed according to the point 4.2.5 of the standard. It can be applied to both PV and storage systems.

The Q(U) characteristic curve was set to follow a response as represented in the following image:



Being defined this Q(U) curve as follows:

Output Voltage, U	0.96 Un	Un	1.04 Un
Reactive Power, Q	48.43%Pn (leading)	0%Pn	48.43%Pn (lagging)

Different tests have been done to determinate both the setting accuracy and the setting time. In both cases, the setting time was adjusted to be the shortest as possible.

For all test, the active power, reactive power and voltage have been measured in the positive phase sequence system and have been represented as 200 milisecond means for every setpoint step.

Interface information	
Interface used	Solar communication tools, RS485
Interface version used	V250
Other interfaces in the equipment	N/A
Name or code of the parameter for Reactive power setpoint & settling time	Reactive parameters
If the EUT has several different interfaces for defining the setpoint, it has been tested the interface returning the most unfavourable results according to the manufacturer information.	

EUT Settings used for this test are provided in the following table:

EUT Settings	
Operanting mode	Reactive power priority
Active control modes	Active power control LVRT mode Fixed Reactive power control Reactive power VS Voltage

Test results are offered in following points.

4.2.3.1 Determining the accuracy

This test verifies the capability of the inverter to modify the injection of reactive power under voltage variations inside the normal operation range.

Used settings of the measurement device for the testing of Q (U) control:

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2020/04/13	100ms values	10kHz

Steps have been commanded as follow that can be seen on the following table:

Step	Step time	Voltage desired (p.u)	Reactive Power expected (%Pn)
1	t1 = 0 s	1.00	0 %
2	t2 = t1 + 120 s	0.97	36.32%
3	t3 = t2 + 120 s	1.03	-36.32%
4	t4 = t3 + 120 s	1.00	0 %
5	t5 = t4 + 120 s	1.00	0 %

Each voltage step was maintained for at least 60 seconds and the complete test was performed maintaining an active power level corresponding to 50%Pn, as the standard requires a power level superior to 50%Pn.

The maximum tolerance allowed for reactive power measurements is ± 5 % Pn and they have been verified for the last 1 minute mean average at the end of the step.

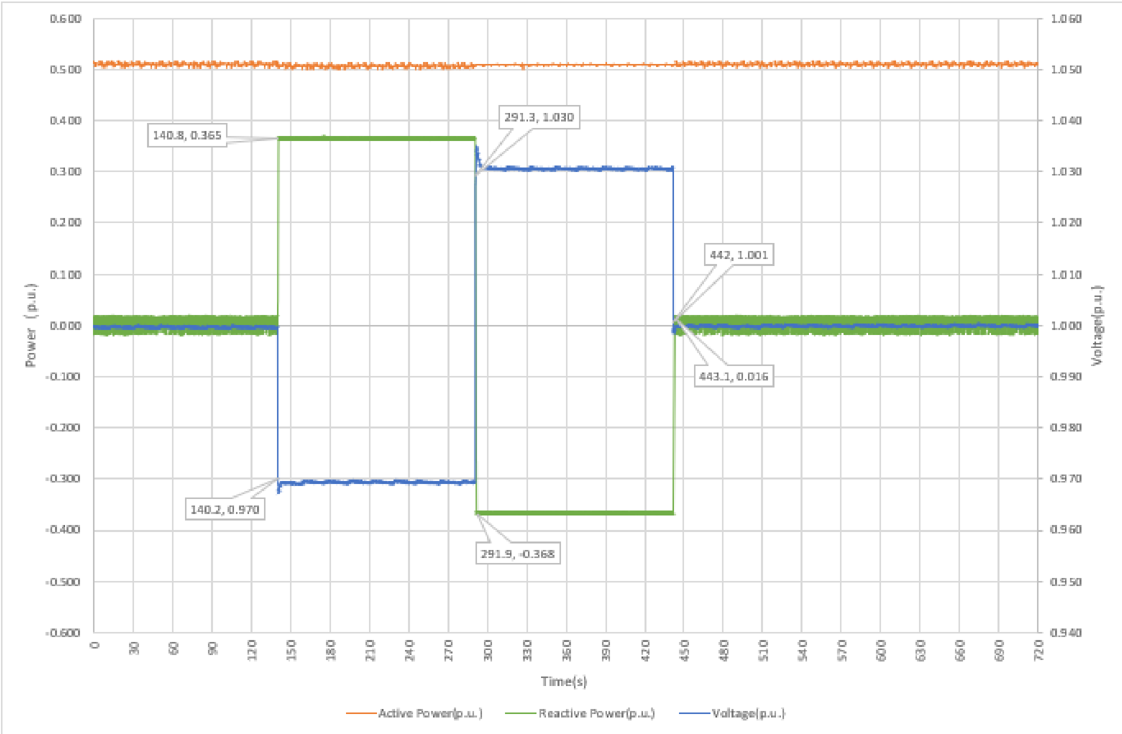
The following table shows the test results for the last 60 seconds average of each step:

Step	Measured Vac +		Measured P		Measured Q		Q deviation (kVAr)	Measured Power Factor
	(p.u)	(V)	(%Sn)	(kW)	(%Sn)	(kVAr)		
1	1.000	229.9	51.01	16.833	0.57	0.187	0.187	1.000
2	0.969	223.0	50.70	16.730	36.47	12.035	0.050	0.810
3	1.031	237.0	50.91	16.801	-36.65	-12.096	-0.110	0.813
4	1.000	230.0	51.01	16.832	0.52	0.173	0.173	1.000
5	1.000	230.0	51.01	16.833	0.58	0.191	0.191	1.000

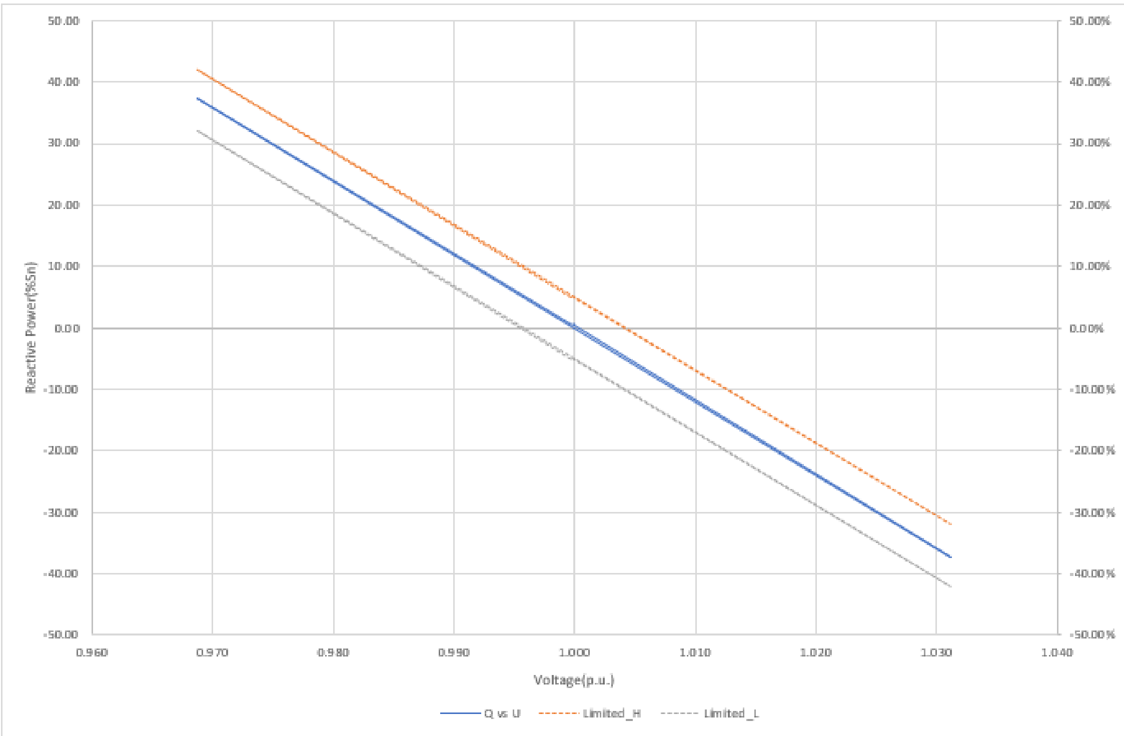
Maximum deviation from the setpoint (kVAr)	0.191

In following graphs, test results are represented after test has been performed:

Test over Time



Reactive Power over Voltage



4.2.3.2 Determining the settling time

This test determines the time response of the inverter to modify the injection of reactive power under voltage variations inside the normal operation range.

Used settings of the measurement device for the testing of Q (U) control:

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2020/04/13	100ms values	10kHz

Operating at an active power level corresponding to 50%Pn, the inverter was subjected to following voltage step changes:

Step	Comment	
1	t_1=0s	Recording is started
2	t_2=120s	Step change to 0.97 Un
3	t_3= t_2 + 120s	Step change to 1.03 Un
4	t_4= t_3 + 120s	Step change to Un
5	t_5= t_4 + 120s	Recording is stopped

The settling time for all steps is determined and given while taking the ±5%Pn tolerance band into consideration.

Two tests have been carried out, one with the case of settling time set as the shortest as possible and another with the settling time set as the longest as possible.

- Test 1: Settling time shortest as possible: Configured time setting value: 1 s
- Test 2: Settling time longest as possible: Configured time setting value: 60 s

Time setting values that may be parametrized in the control as given by manufacturer's specifications: Range from 1 to 60 s.

4.2.3.2.1 Test 1

The following table shows test results:

The actual value is predefined by the network operator, then a value of 1 s applies. Due to the installations may have adjustable settling time between 1 s and 5 s (step response time)

Settling time (shortest possible)						
Power		Step	Comments	Point in time of setpoint change (s)	Point in time of settling inside the tolerance band (s)	Time different (s)
Desired (% Pn)	Measured (% Pn)					
≥ 50%	50.9%	1	$U_0 = 0.93\ U_n$	--	--	--
		2	$0.93\ U_n \rightarrow 0.97\ U_n$	140.2	140.8	0.6
		3	$0.97\ U_n \rightarrow 1.03\ U_n$	291.3	291.9	0.6
		4	$1.03\ U_n \rightarrow U_n$	442.1	443.1	1.0
		5	Recording is Stopped	--	--	--

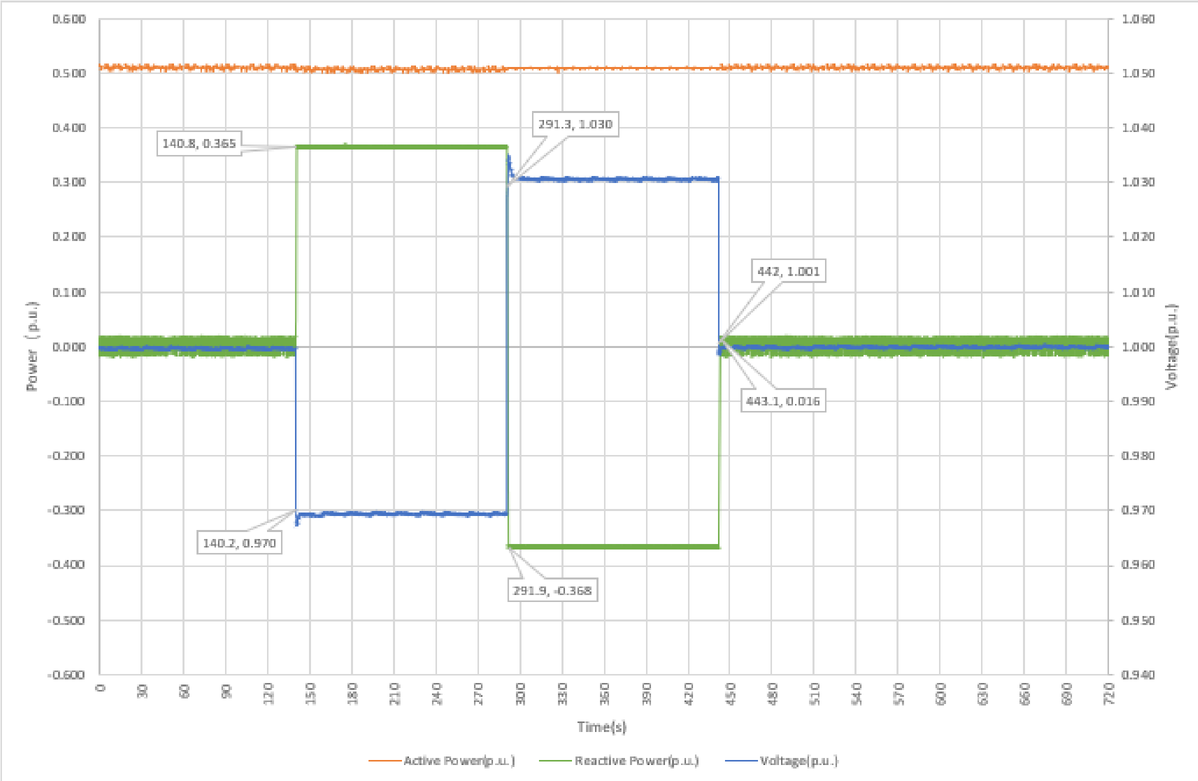
Longest Measured settling time (s)	1.0

The following table shows the reactive power variation to time (ΔQ/Δt) during the settling time:

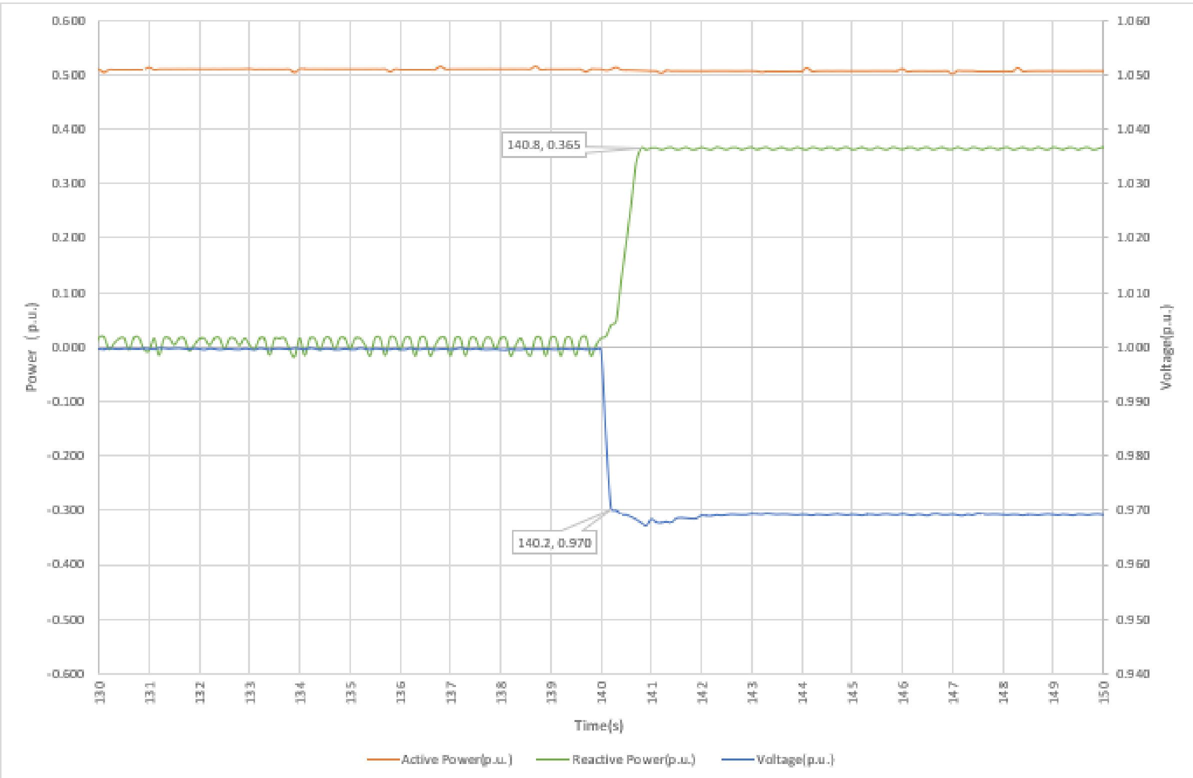
Step	Q at the start (kVAr)	Q at the end (kVAr)	Time Response (s)	ΔQ/Δt (kVAr/s)
2	1.335	12.045	0.6	17.850
3	12.111	-12.144	0.6	-40.425
4	-12.210	0.528	1.0	12.738

In following graphs, they are represented test results after the test performed:

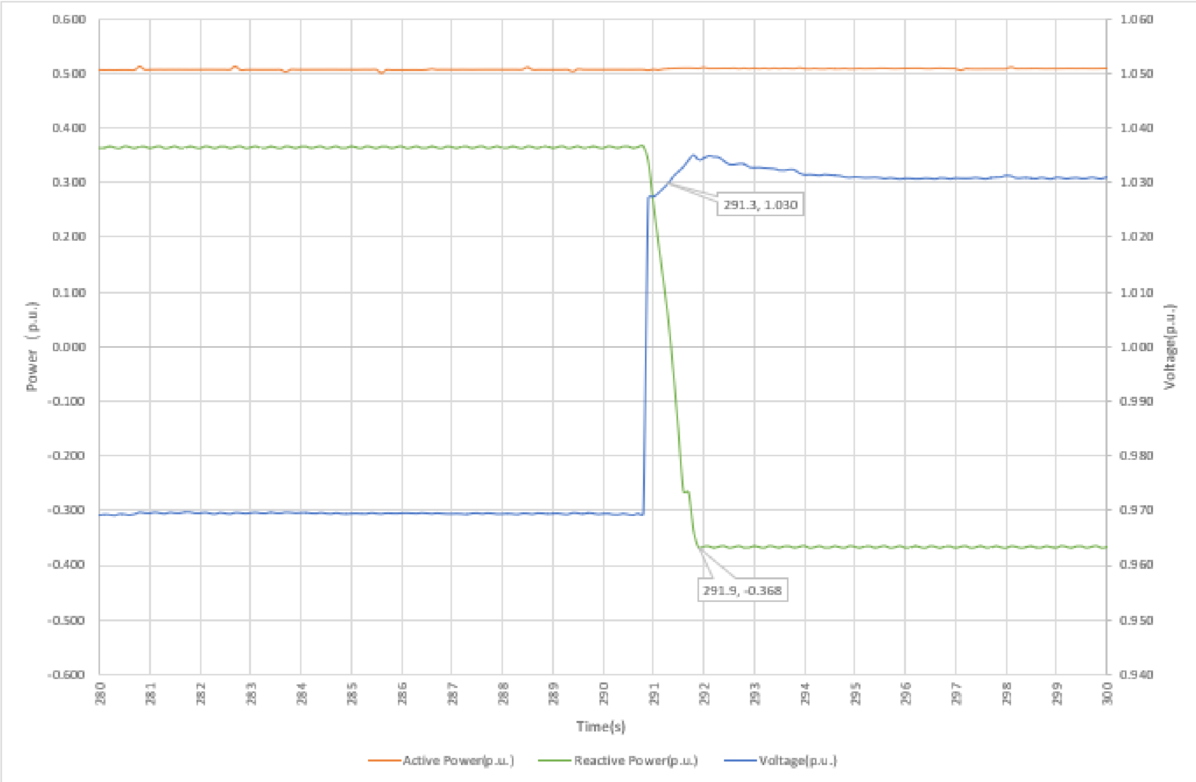
Test over Time



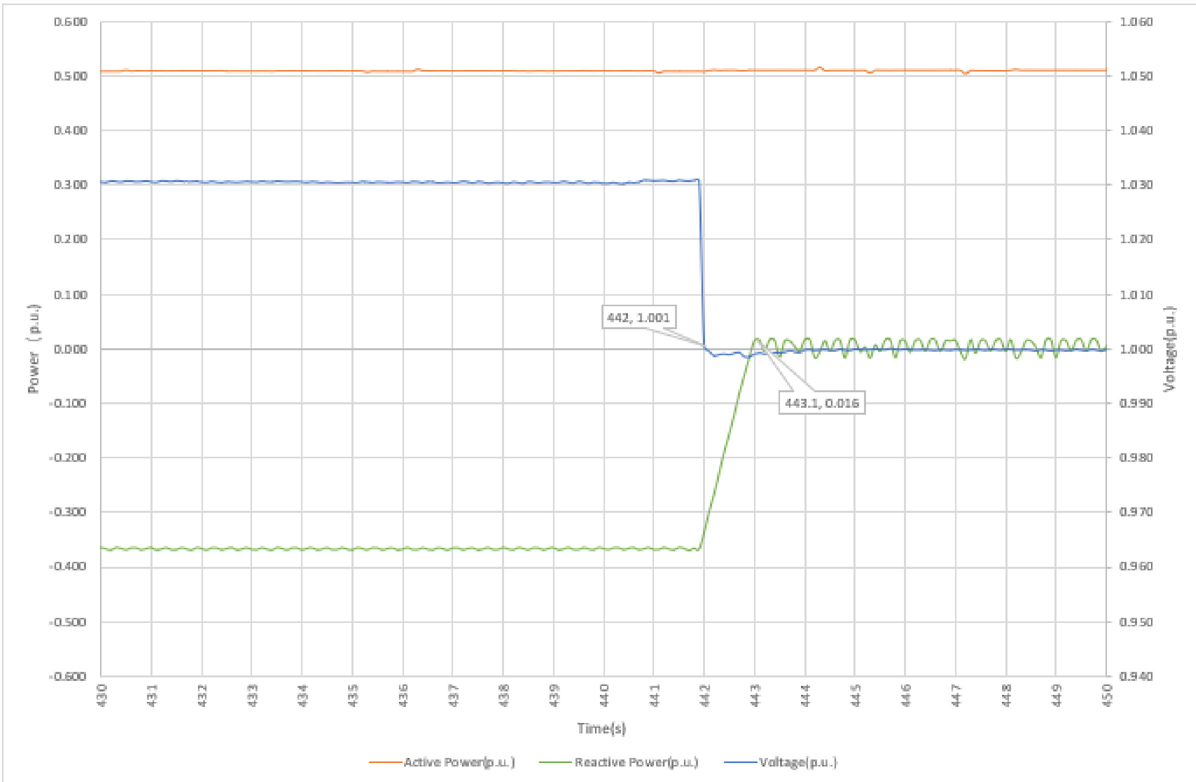
Zoom time of the step 2: Un to 0.97 Un



Zoom time of the step 3: 0.97 Un to 1.03 Un



Zoom time of the step 4: 1.03 Un to Un



4.2.3.2.2 Test 2

The following table shows test results:

The actual value is predefined by the network operator, then a value of 60 s applies. Due to the installations may have adjustable settling time between 6 s and 60 s (step response time)

Settling time (longest possible)						
Power		Step	Comments	Point in time of setpoint change (s)	Point in time of settling inside the tolerance band (s)	Time different (s)
Desired (% Pn)	Measured (% Pn)					
≥ 50%		1	$U_0 = 0.93\ U_n$	--	--	--
		2	$0.93\ U_n \rightarrow 0.97\ U_n$	224.4	282.0	57.6
		3	$0.97\ U_n \rightarrow 1.03\ U_n$	451.9	511.6	59.7
		4	$1.03\ U_n \rightarrow U_n$	643.3	703.0	59.7
		5	Recording is Stopped	--	--	--

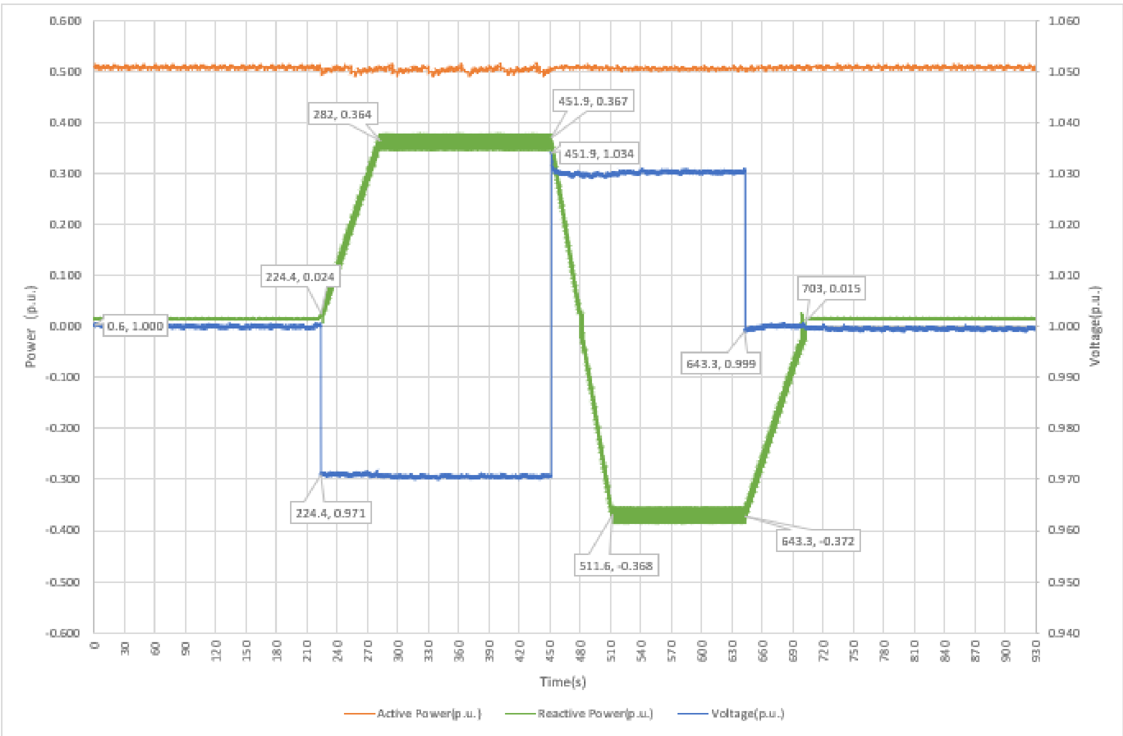
Longest Measured settling time (s)	59.7

The following table shows the reactive power variation to time (ΔQ/Δt) during the settling time:

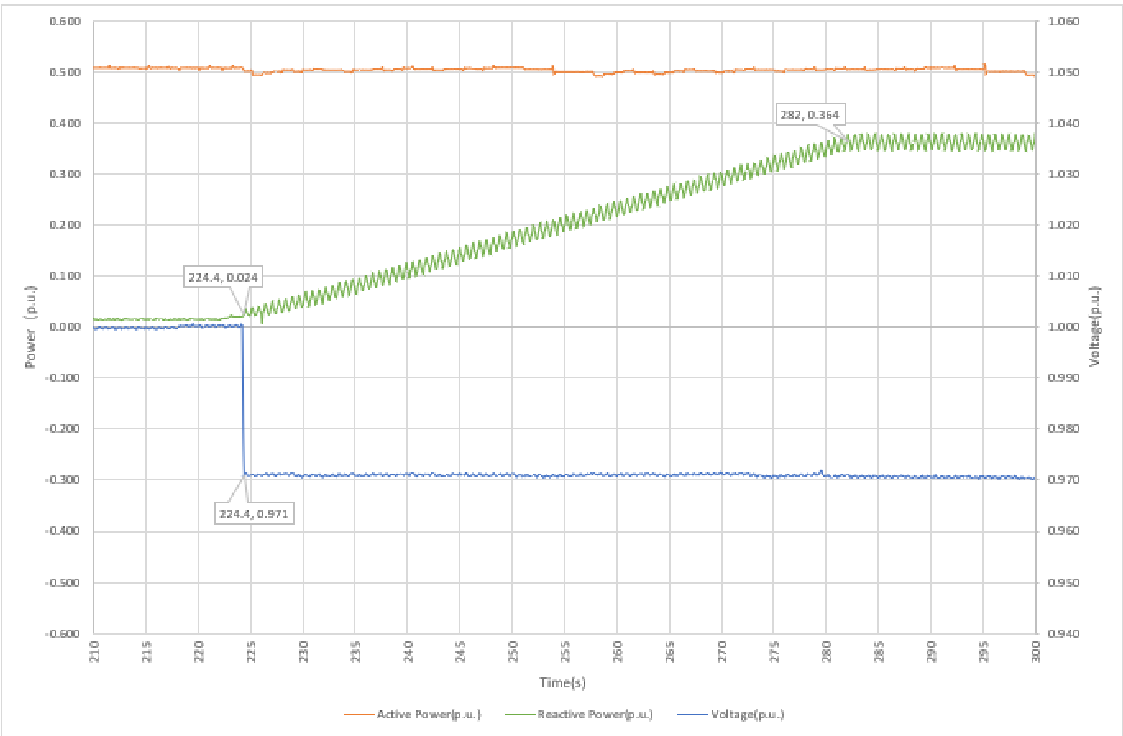
Step	Q at the start (kVAr)	Q at the end (kVAr)	Time Response (s)	ΔQ/Δt (kVAr/s)
2	0.792	12.012	57.6	0.195
3	12.111	-12.144	59.7	-0.406
4	-12.276	0.495	59.7	0.214

following graphs, they are represented test results after the test performed:

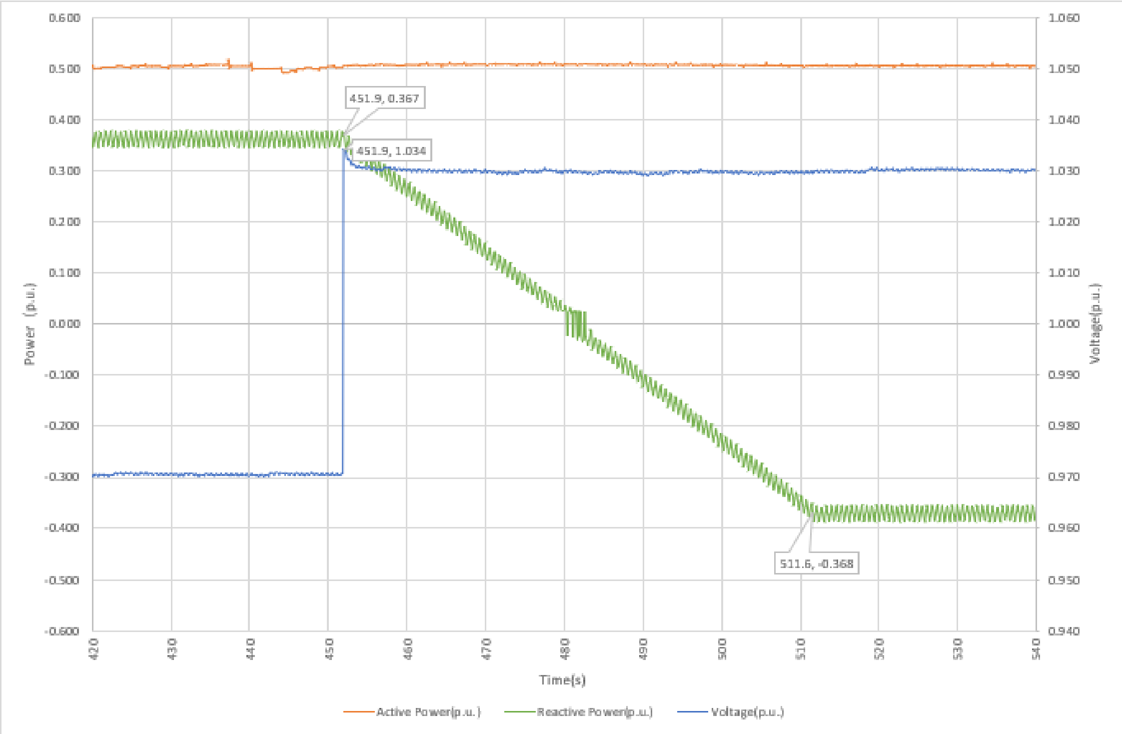
Test over Time



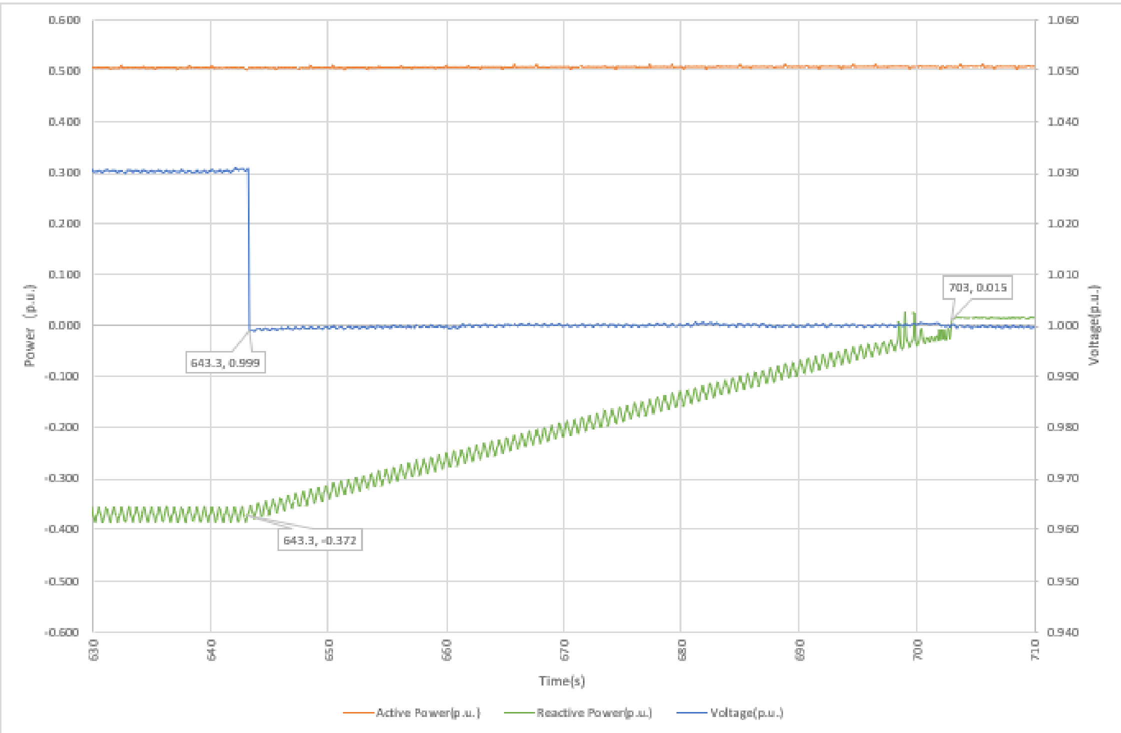
Zoom time of the step 2: Un to 0.97 Un



Zoom time of the step 3: 0.97 Un to 1.03 Un



Zoom time of the step 4: 1.03 Un to Un

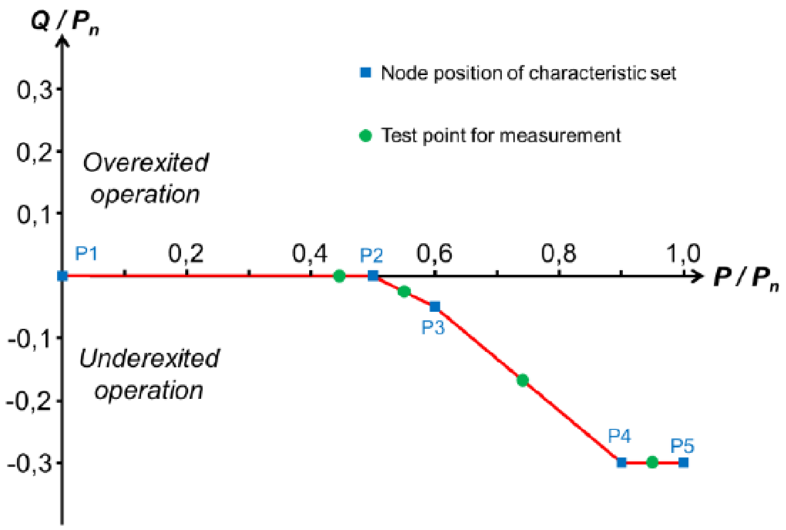


4.2.4 Q(P) control

The aim of this test is to examine the reactive power control method as a function of the active power.

These tests have been performed according to the point 4.2.6 of the standard. Although this test is optional, it has been tested nevertheless.

The Q(P) characteristic curve was set to follow a response as represented in the following image:



Being defined this Q(P) curve as follows:

Node Position	P_{mom} / P_n	Q / P_n
P1	0	0
P2	0.5	0
P3	0.6	-0.109
P4	0.9	-0.436
P5	1.0	-0.436

The response time was adjusted to be the shortest as possible.

Test results are offered in following points.

Interface information	
Interface used	Solar communication tools, RS485
Interface version used	V250
Other interfaces in the equipment	N/A
Name or code of the parameter for Q (P) & settling time	Reactive parameters
If the EUT has several different interfaces for defining the setpoint, it has been tested the interface returning the most unfavourable results according to the manufacturer information. As the interface tested has different versions it has been tested the most unfauvorable version according to manufacturer information.	

EUT Settings used for this test are provided in the following table:

EUT Settings	
Operanting mode	Reactive power priority
Active control modes	Active power control LVRT mode Reactive power VS Active power

- Test 1: Settling time shortest as possible: Configured time setting value: 1 s

Time setting values that may be parametrized in the control as given by manufacturer's specifications: Range from 0 to 60 s

4.2.4.1 Determining the setting accuracy

This test verifies the capability of the inverter to modify the reactive power under changes in the active power commanded by setpoint.

Used settings of the measurement device for the testing of Q(P) control:

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2020/04/13	100ms values	10kHz

They have been commanded steps that can be seen on the following table:

Step	Active power desired (%Sn)	Reactive Power expected
1	10.0%	0.0%
2	45.0%	0.0%
3	55.0%	5.5%
4	75.0%	27.2%
5	95.0%	43.6%

The inverter shall calculate automatically the reactive power setpoint from the measured active power.

Each active power step was maintained for at least 120 seconds, being calculated voltage, powers and power factor signals for the last 60 seconds mean average at the end of the step.
The response time was adjusted to be the shortest as possible (but no longer than 6s).

According to testing method of the standard, the 1-minute mean value at the end of the step is measured. Dropping below or exceeding the active power node points in the stationary condition of a step has to be avoided.

The following table shows the test results for the last 60 second average of each step, showing the positive phase sequence components:

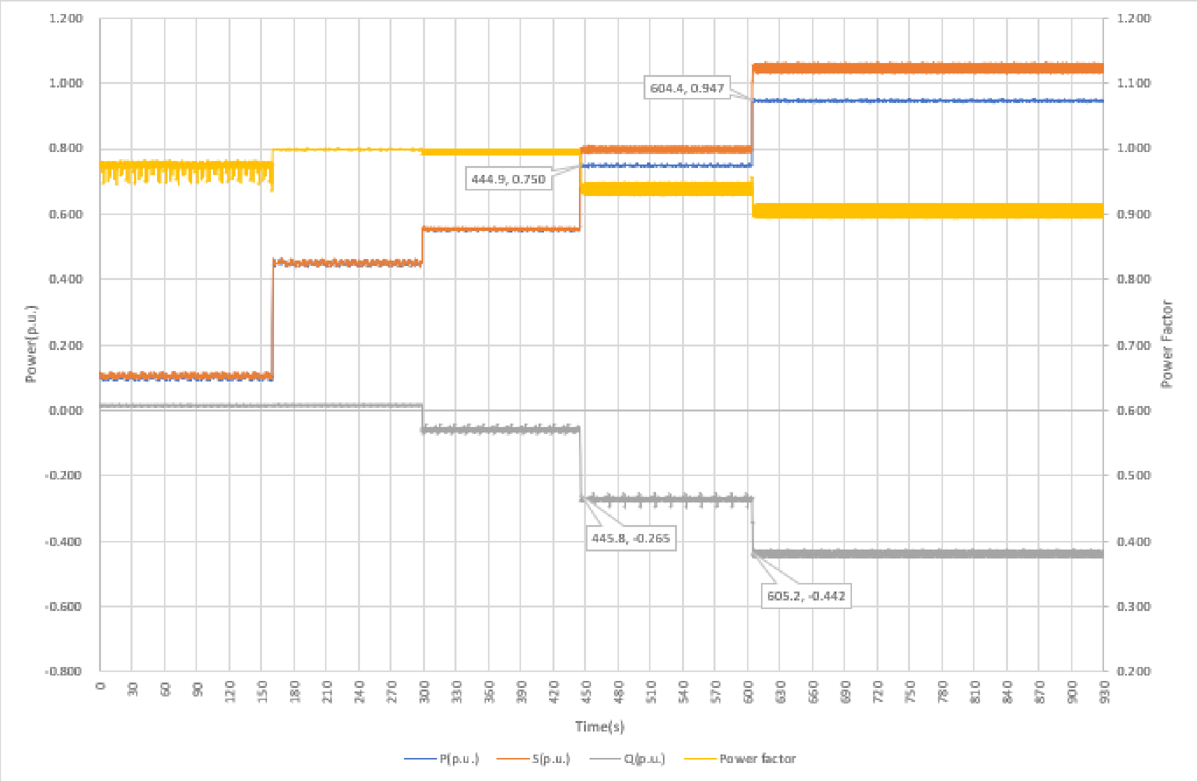
Step	P Setpoint		Measured P		Q Setpoint		Measured Q		Q deviation (kVAr)
	(%Pn)	(kW)	(%Pn)	(kW)	(%Pn)	(kVAr)	(%Pn)	(kVAr)	
1	10.00%	3.3	10.17%	3.357	0.00%	0	1.50%	0.495	0.495
2	45.00%	14.85	44.95%	14.833	0.00%	0	1.55%	0.511	0.511
3	55.00%	18.15	55.12%	18.189	-5.50%	-1.815	-5.71%	-1.886	-0.071
4	75.00%	24.75	74.82%	24.691	-27.20%	-8.976	-27.30%	-9.009	-0.033
5	95.00%	31.35	94.62%	31.225	-43.60%	-14.388	-44.13%	-14.564	-0.176

Maximum deviation from the Q calculated setpoint (kVAr)	0.511
Settling time (s)	0.9

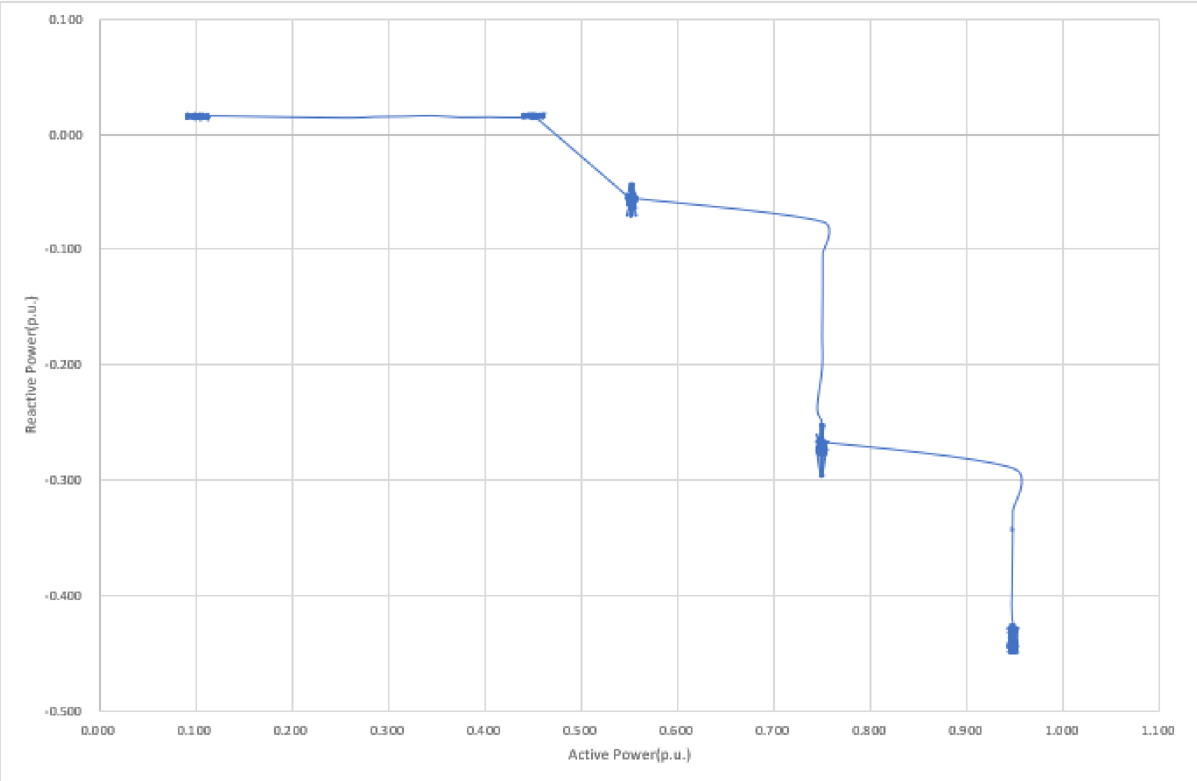
The maximum tolerance allowed for each value is 2% of the rated value per each value.

In following graphs, test results are represented using 200 ms mean values of active power, reactive power and calculated reactive power set-point input after the test has been performed:

Test over Time



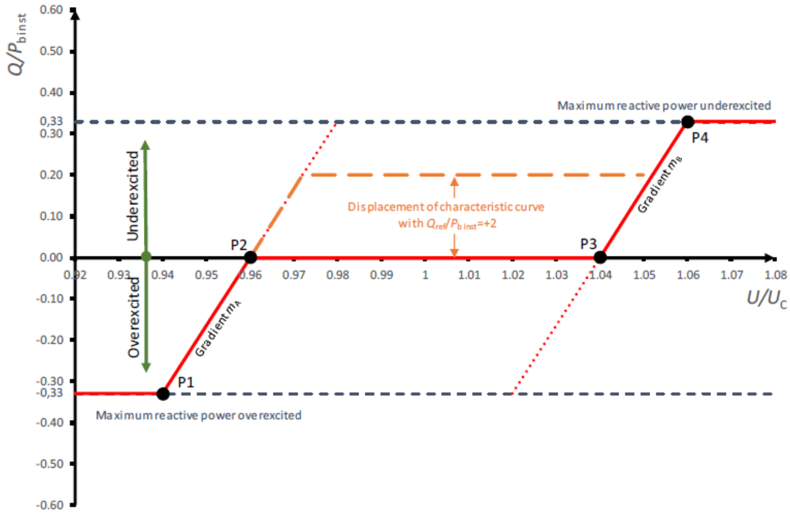
Reactive Power over Active Power



4.2.5 Reactive Power Q with voltage limitation function

These tests have been requriment with chapter 4.2.7, 6.1.3.2 and 6.1.4.2 of the standards.

The aim of these tests is to show compliance with the characteristic curve from both VDE AR-N 4110:2018 presented below:



The active power at the beginning of this test should be ≥40% of the total rated active power of the operating PGU. Each step has been measured at least 2 min. The 1-minute mean value at the end of each step have been measured.

Different tests have been done to determinate both the setting accuracy and the setting time. In both cases, the setting time was adjusted to be the shortest as possible.

As commnunite with customer, this test is not performed due to this test is optional.

4.3 SYSTEM PERTURBATIONS.

4.3.1 Switching operations

The aim of this test is to determine the grid-dependent voltage variation factors K_u (Ψ_k) and flicker form factors K_f (Ψ_k) in order to estimate systems perturbations at the point of common coupling.

This test has been performed according to the 4.3.2. of the standard.

These measures have been done following the reference IEC 61400-21

The following definitions apply to the test:

• Maximum number of switching operations within a time period of 10 min. N_{10}

• Maximum number of switching operations within a time period of 120 min. N_{120}

The following switching operations should be investigated at each impedance angle (30º, 50º, 70º, 85º):

- Test 1: Switching at Pavailable <10 % Pn. N_{10} = 20, N_{120} = 240. T_p =65 s.
- Test 2: Switching at Pavailable = Pn. N_{10} = 20, N_{120} = 240. T_p =65 s
- Test 3: Service shutdown at rated power (no emergency stop).

Note: T_p ≡ Time per switching operation $T_p = t_3 - t_0$. T_p includes the following times:

1. Start of measurement.
2. Beginning of recording analysis range ($t=t_0$)
3. Beginning of switching operation ($t=t_1$)
4. Switching operation's transient phenomena have dissipated, PGU feeds in active power in line with the active power setpoint ($t=t_2$)
5. End of recording analysis range ($t=t_3$)
6. End of measurement.

The following parameters are to be reported:

Flicker factor $k_f(\Psi_k)$:

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

Voltage variation factor $k_u(\Psi_k)$:

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

General specifications:

- PGU operation mode Q setpoint = 0
- $S_{k,fic}/S_n$ 2.273
- Voltage range 230 V
- Grid frequency range 50 Hz

Used settings of the measurement device for switching operations measurement

Measurement device	Date of measurement	Recording	Sampling frequency
DEWE2-A4	2019/12/24, 2020/08/20	10min values	200kHz

The switching operations tests results are offered below with more detail.

4.3.1.1 Test 1: Switch-on at P<10%Pn

Test conditions:

- T_p = 65 s.
- Voltage output = 230Vac

Results obtained from the test are offered at the table below.

Flicker factor and voltage change factor are determined for each record of measured voltage and measured current per phase according to the table below:

Case of switching operation	**Switch-on at $P_{available}$ < 10% P_n**			
Max, number of switching operations, N_{10}	20			
Max, number of switching operations, N_{120}	240			
Grid impedance angle	30º	50º	70º	85º
Flicker step factor, k_f (Ψ_k)	0.002	0.002	0.001	0.001
Voltage change factor, k_u (Ψ_k)	0.001	0.001	0.001	0.001

4.3.1.2 Test 2: Switch-on at P=110%Pn

Test conditions:

- T_p = 65s.
- Voltage output = 230Vac

Results obtained from the test are offered at the table below.

Flicker factor and voltage change factor are determined for each record of measured voltage and measured current per phase according to the table below:

Case of switching operation	**Switch-on at $P_{available}$ P=110%Pn**			
Max, number of switching operations, N_{10}	20			
Max, number of switching operations, N_{120}	240			
Grid impedance angle	30º	50º	70º	85º
Flicker step factor, k_f (Ψ_k)	0.018	0.014	0.012	0.006
Voltage change factor, k_u (Ψ_k)	0.001	0.001	0.001	0.001

4.3.1.3 Test 3: Service shutdown P=110%Pn

Test conditions:

- T_p = 65s.
- Voltage output = 230Vac

Case of switching operation	**Service shutdown P=110%Pn**			
Max, number of switching operations, N_{10}	10			
Max, number of switching operations, N_{120}	120			
Grid impedance angle	30º	50º	70º	85º
Flicker step factor, k_f (Ψ_k)	0.014	0.013	0.007	0.007
Voltage change factor, ku (Ψk)	0.014	0.014	0.014	0.014

4.3.2 Flickers

The aim of this test is to determine the flicker coefficient c as a function of the grid impedance phase angle.

Test performed according point 4.3.3 of the standard. It applies to both PV and storage systems.

According to standard, it has been measured at least 12 P_{st} in total between 0%-90% of P_n, at least one P_{st} per 10% of P_n and at least 3 P_{st} in total between 90% and 100% P_n per each phase and per each operation point. The power bins tested can be found on the table of results offered at this chapter of the test report.

The value of $S_{k,fic}/S_n$ used for the analysis has been 2.273.

The flicker coefficient c (Ψ_k) is determinate per each flicker emission value $P_{st,fic}$:

$$\mathrm{c}\ (\Psi\mathrm{k}) = \mathrm{Pst}(\Psi\mathrm{k})\ x\ \frac{Sk}{Sn}$$

NOTE: According to Standard, the requirements for Flicker test are applicable at plant level, the results shown in this chapter are performed at inverter level. The results shown are informative.

Used settings of the measurement device for flicker measurement.

Measurement device	Date of measurement	Recording	Sampling frequency
DEWE2-A4	2020/03/16, 2020/03/17, 2020/08/20	10min values	200kHz

The conditions during testing are specified below:

- PGU operation mode Q setpoint = 0
- Voltage range 230 V
- Grid frequency range 50 Hz
- Voltage unbalance Same conditions as point 4.3.4 of this test report (*) (Umbalance chapter)
- Date 2020/03/16 and 2020/03/17
- Measured period 0h 10min 0 sec for each power bin

(*) As the test procedure for both tests is similar, representing the inverter working in continuous operation in a wide range of power bins, it is considered that the voltage unbalance conditions will be similar at both tests.

The system flicker coefficient is the maximum value of all measurements, the following table shows the results obtained.

Phase A				
Network impedance phase angle, Ψk	30º	50º	70º	85º
Average active power, P (%Pn)	Flicker coefficient, C (Ψk, P_{bin})			
0	0.041	0.041	0.041	0.041
10	0.041	0.041	0.041	0.041
20	0.041	0.041	0.041	0.041
30	0.041	0.041	0.041	0.041
40	0.041	0.041	0.041	0.041
50	0.041	0.041	0.041	0.041
60	0.041	0.041	0.041	0.041
70	0.041	0.041	0.041	0.041
80	0.041	0.041	0.041	0.041
90	0.041	0.041	0.041	0.041
100	0.055	0.067	0.077	0.080
110	0.064	0.054	0.074	0.080

Phase B				
Network impedance phase angle, Ψk	30º	50º	70º	85º
Average active power, P (%Pn)	Flicker coefficient, C (Ψk, P_{bin})			
0	0.041	0.041	0.041	0.041
10	0.041	0.041	0.041	0.041
20	0.041	0.041	0.041	0.041
30	0.041	0.041	0.041	0.041
40	0.041	0.041	0.041	0.041
50	0.041	0.041	0.041	0.041
60	0.041	0.041	0.041	0.041
70	0.041	0.041	0.041	0.041
80	0.041	0.041	0.041	0.041
90	0.041	0.041	0.041	0.041
100	0.055	0.067	0.076	0.079
110	0.049	0.066	0.076	0.079

Phase C				
Network impedance phase angle, Ψk	30º	50º	70º	85º
Average active power, P (%Pn)	Flicker coefficient, C (Ψk, P_{bin})			
0	0.041	0.041	0.041	0.041
10	0.041	0.041	0.041	0.041
20	0.041	0.041	0.041	0.041
30	0.041	0.041	0.041	0.041
40	0.041	0.041	0.041	0.041
50	0.041	0.041	0.041	0.041
60	0.041	0.041	0.041	0.041
70	0.041	0.041	0.041	0.041
80	0.041	0.041	0.041	0.041
90	0.041	0.041	0.041	0.041
100	0.057	0.069	0.077	0.080
110	0.057	0.069	0.071	0.074

4.3.3 Harmonic

The aim of this test is to determine relevant values for PGU continuous operation.

Test performed according to point 4.3.4 of the standard. It can be applied at both PV and storage systems.

The reactive power setpoint is 0 VAr, the harmonics have been measured 10 minutes average values of line current, at least three records consisting of 3-phase measurements.

They have been verified limits at different power levels, from 10%Pn to 100% Pn, in 10%Pn steps.

The arithmetic average is formed over the 10 minutes record for each harmonic, interharmonic and higher frequency component of the current.

The total distortion of the current harmonics (TDC) has been calculated according to standard:

$$\mathrm{TDC} = \frac{\sqrt{\sum_{h=2}^{50} I_h^2}}{I_n} \cdot 100$$

See point 2.6 (Definitions) of this report.
The total distortion of the voltage harmonics (TDD) has been determined using the same procedure.

NOTE: According to Standard, the requirements for Harmonics test are applicable at plant level, the results shown in this chapter are performed at inverter level. The results shown are informative.

Used settings of the measurement device for harmonic measurement.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/04	100ms values	10kHz
PA5000H	2020/4/13, 2020/4/14, 2020/8/19	100ms values	10kHz

• PGU operation mode; Q (VAr)	Q setpoint = 0 VAr
• Voltage range (V)	230 V
• Voltage unbalance	Same conditions as point 4.3.4 of this test report (*) (Umbalace Chapter)
• Measured period (min)	3 min each active power level

(*) As the test procedure for both tests is similar, representing the inverter working in continuous operation in a wide range of power bins, it is considered that the voltage unbalance conditions will be similar at both tests.

Power bin (%Pn)	Number of records
0 %	1
10 %	1
20 %	1
30 %	1
40 %	1
50 %	1
60 %	1
70 %	1
80 %	1
90 %	1
100 %	1
110%	1

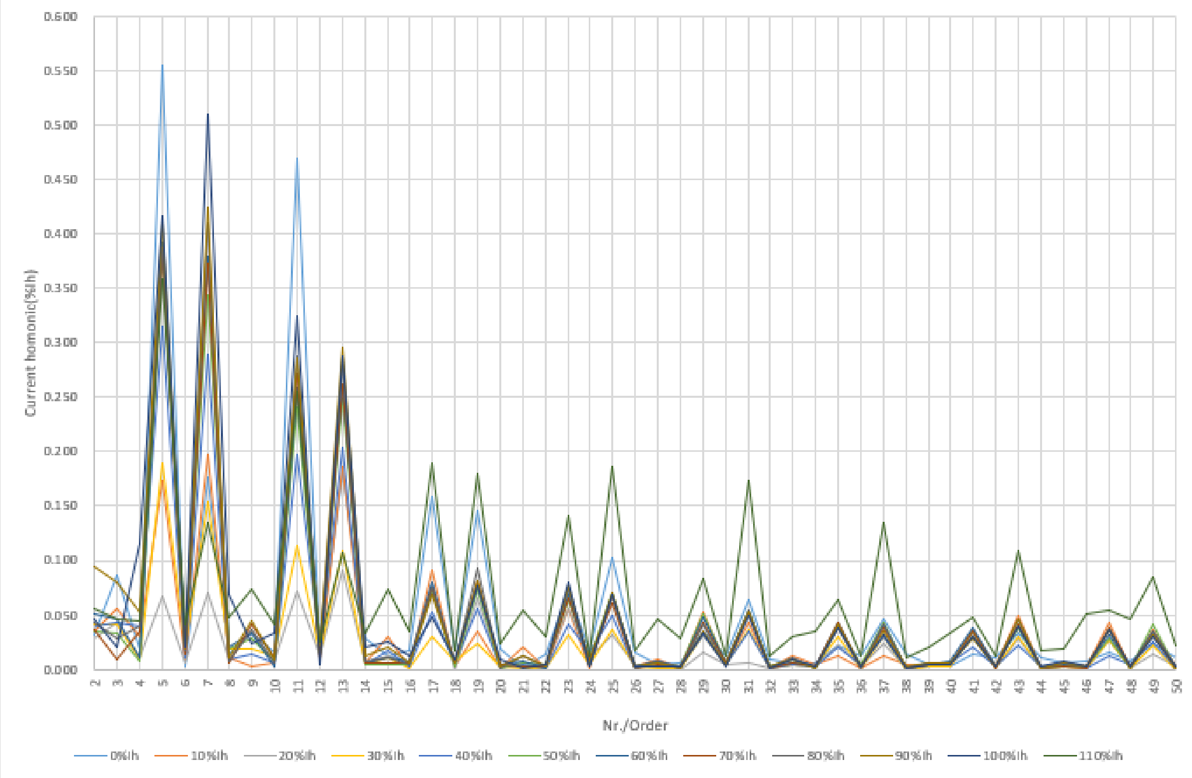
4.3.3.1 Current harmonics

Phase A													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	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(%)	I_h(%)	
2	0.031	0.035	0.029	0.041	0.040	0.034	0.052	0.036	0.043	0.094	0.046	0.056	0.094
3	0.086	0.055	0.043	0.042	0.044	0.034	0.046	0.010	0.029	0.079	0.021	0.047	0.086
4	0.019	0.030	0.011	0.010	0.040	0.008	0.011	0.035	0.039	0.053	0.115	0.045	0.115
5	0.554	0.173	0.067	0.189	0.315	0.383	0.393	0.380	0.387	0.409	0.415	0.358	0.554
6	0.003	0.010	0.006	0.021	0.011	0.020	0.026	0.014	0.016	0.020	0.021	0.042	0.042
7	0.176	0.197	0.071	0.153	0.288	0.344	0.379	0.373	0.411	0.424	0.510	0.135	0.510
8	0.015	0.011	0.010	0.019	0.008	0.019	0.020	0.006	0.007	0.011	0.069	0.047	0.069
9	0.033	0.003	0.034	0.019	0.014	0.029	0.033	0.042	0.036	0.044	0.024	0.074	0.074
10	0.015	0.006	0.007	0.012	0.005	0.008	0.004	0.011	0.006	0.010	0.033	0.042	0.042
11	0.469	0.257	0.071	0.113	0.198	0.241	0.258	0.272	0.288	0.287	0.324	0.255	0.469
12	0.017	0.009	0.013	0.014	0.022	0.015	0.019	0.011	0.022	0.021	0.004	0.025	0.025
13	0.181	0.186	0.091	0.110	0.204	0.249	0.260	0.262	0.279	0.296	0.288	0.107	0.296
14	0.029	0.006	0.006	0.004	0.005	0.005	0.006	0.006	0.007	0.012	0.020	0.033	0.033
15	0.012	0.030	0.013	0.011	0.018	0.005	0.010	0.006	0.010	0.021	0.026	0.073	0.073
16	0.017	0.002	0.006	0.001	0.003	0.005	0.008	0.006	0.004	0.006	0.012	0.034	0.034
17	0.159	0.091	0.081	0.029	0.053	0.072	0.080	0.075	0.074	0.068	0.048	0.190	0.190
18	0.017	0.003	0.000	0.007	0.005	0.003	0.006	0.006	0.006	0.006	0.009	0.017	0.017
19	0.145	0.034	0.066	0.024	0.057	0.073	0.078	0.081	0.092	0.082	0.077	0.180	0.180
20	0.019	0.002	0.002	0.002	0.003	0.001	0.004	0.004	0.001	0.003	0.010	0.024	0.024
21	0.001	0.020	0.006	0.002	0.004	0.006	0.008	0.002	0.012	0.013	0.001	0.054	0.054
22	0.014	0.001	0.004	0.001	0.002	0.004	0.001	0.003	0.003	0.003	0.004	0.030	0.030
23	0.072	0.056	0.056	0.032	0.041	0.063	0.069	0.066	0.073	0.077	0.080	0.141	0.141
24	0.017	0.002	0.010	0.005	0.016	0.010	0.003	0.010	0.002	0.007	0.002	0.012	0.017
25	0.102	0.068	0.032	0.037	0.049	0.070	0.069	0.061	0.067	0.070	0.068	0.185	0.185
26	0.016	0.002	0.004	0.003	0.001	0.001	0.003	0.001	0.001	0.003	0.003	0.017	0.017
27	0.005	0.010	0.002	0.001	0.007	0.006	0.007	0.005	0.008	0.005	0.003	0.046	0.046
28	0.005	0.002	0.000	0.001	0.003	0.002	0.001	0.002	0.001	0.001	0.002	0.029	0.029
29	0.035	0.053	0.015	0.031	0.032	0.051	0.047	0.043	0.041	0.035	0.034	0.084	0.084
30	0.013	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.002	0.005	0.004	0.012	0.013
31	0.064	0.043	0.006	0.036	0.035	0.054	0.052	0.052	0.055	0.053	0.050	0.174	0.174
32	0.010	0.002	0.002	0.001	0.001	0.002	0.002	0.000	0.001	0.002	0.002	0.013	0.013
33	0.007	0.012	0.005	0.004	0.004	0.009	0.006	0.006	0.011	0.010	0.010	0.030	0.030
34	0.006	0.005	0.004	0.002	0.003	0.002	0.003	0.002	0.001	0.001	0.003	0.034	0.034
35	0.023	0.012	0.022	0.031	0.021	0.039	0.042	0.043	0.039	0.041	0.037	0.063	0.063
36	0.013	0.001	0.002	0.001	0.004	0.005	0.002	0.001	0.001	0.002	0.002	0.012	0.013
37	0.047	0.013	0.024	0.030	0.029	0.044	0.041	0.038	0.042	0.034	0.031	0.135	0.135
38	0.013	0.004	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.000	0.011	0.013
39	0.005	0.003	0.003	0.003	0.006	0.005	0.004	0.004	0.005	0.005	0.004	0.020	0.020
40	0.002	0.003	0.004	0.003	0.006	0.004	0.007	0.005	0.004	0.005	0.004	0.033	0.033
41	0.014	0.037	0.031	0.030	0.021	0.036	0.038	0.035	0.030	0.029	0.029	0.047	0.047
42	0.011	0.002	0.001	0.001	0.004	0.002	0.003	0.002	0.002	0.003	0.003	0.013	0.013
43	0.033	0.049	0.028	0.030	0.021	0.039	0.039	0.041	0.046	0.047	0.040	0.109	0.109
44	0.011	0.001	0.001	0.001	0.003	0.001	0.002	0.001	0.002	0.002	0.002	0.016	0.016
45	0.005	0.006	0.003	0.003	0.006	0.003	0.004	0.002	0.006	0.006	0.007	0.018	0.018
46	0.008	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.003	0.002	0.003	0.051	0.051
47	0.015	0.043	0.027	0.027	0.012	0.029	0.032	0.038	0.037	0.036	0.037	0.054	0.054
48	0.008	0.002	0.001	0.002	0.004	0.001	0.002	0.003	0.001	0.001	0.003	0.047	0.047
49	0.024	0.037	0.014	0.022	0.025	0.041	0.035	0.031	0.036	0.032	0.030	0.085	0.085
50	0.011	0.003	0.002	0.000	0.001	0.001	0.001	0.001	0.003	0.001	0.003	0.022	0.022
TDC (%)	0.678	0.206	0.047	0.100	0.286	0.424	0.476	0.464	0.524	0.573	0.675	0.474	0.678

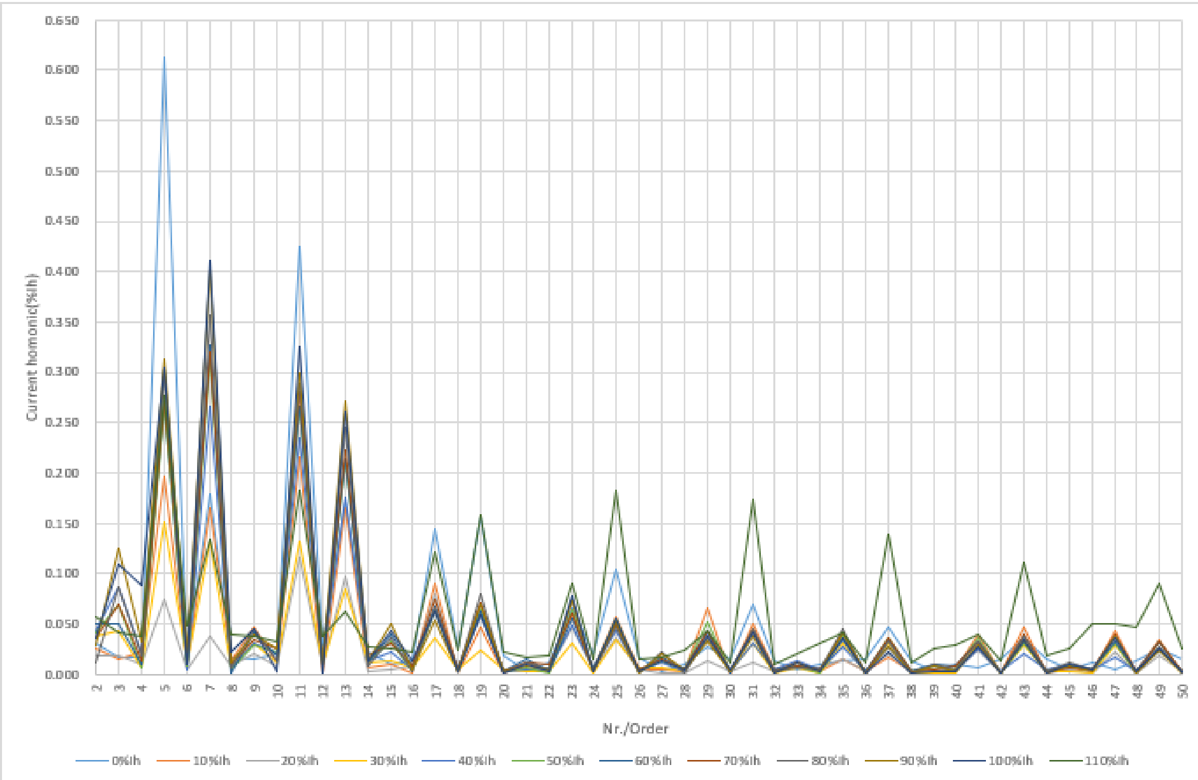
Phase B													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	Max (%)
Nr./ Order	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	
2	0.030	0.026	0.018	0.038	0.043	0.041	0.051	0.036	0.012	0.030	0.037	0.057	0.057
3	0.017	0.016	0.018	0.042	0.086	0.070	0.050	0.069	0.087	0.125	0.110	0.041	0.125
4	0.016	0.023	0.011	0.007	0.020	0.007	0.010	0.013	0.019	0.033	0.088	0.038	0.088
5	0.614	0.196	0.075	0.151	0.269	0.267	0.303	0.271	0.297	0.313	0.304	0.277	0.614
6	0.018	0.010	0.005	0.012	0.006	0.008	0.013	0.021	0.014	0.022	0.011	0.049	0.049
7	0.179	0.165	0.039	0.132	0.267	0.312	0.327	0.321	0.357	0.402	0.410	0.134	0.410
8	0.017	0.013	0.007	0.006	0.006	0.006	0.002	0.010	0.007	0.012	0.022	0.040	0.040
9	0.016	0.046	0.021	0.031	0.032	0.029	0.042	0.034	0.045	0.039	0.045	0.038	0.046
10	0.020	0.011	0.008	0.012	0.020	0.022	0.019	0.026	0.014	0.025	0.003	0.032	0.032
11	0.426	0.215	0.117	0.131	0.235	0.266	0.267	0.279	0.289	0.299	0.325	0.183	0.426
12	0.029	0.002	0.009	0.010	0.015	0.011	0.014	0.009	0.011	0.010	0.002	0.038	0.038
13	0.172	0.165	0.097	0.085	0.175	0.213	0.214	0.223	0.245	0.271	0.260	0.061	0.271
14	0.023	0.007	0.003	0.011	0.014	0.014	0.012	0.018	0.009	0.014	0.013	0.027	0.027
15	0.010	0.010	0.004	0.013	0.022	0.033	0.039	0.031	0.037	0.051	0.044	0.026	0.051
16	0.013	0.001	0.008	0.006	0.005	0.003	0.008	0.007	0.003	0.004	0.013	0.021	0.021
17	0.143	0.090	0.079	0.036	0.063	0.065	0.067	0.075	0.066	0.054	0.062	0.121	0.143
18	0.026	0.001	0.001	0.004	0.004	0.003	0.006	0.005	0.002	0.003	0.003	0.025	0.026
19	0.157	0.046	0.070	0.025	0.059	0.064	0.063	0.071	0.080	0.070	0.058	0.159	0.159
20	0.019	0.001	0.003	0.004	0.003	0.003	0.004	0.004	0.002	0.002	0.001	0.022	0.022
21	0.003	0.011	0.004	0.004	0.004	0.007	0.016	0.011	0.012	0.008	0.010	0.017	0.017
22	0.011	0.004	0.005	0.004	0.006	0.001	0.003	0.010	0.004	0.004	0.004	0.018	0.018
23	0.066	0.060	0.046	0.031	0.049	0.064	0.056	0.061	0.074	0.072	0.078	0.089	0.089
24	0.020	0.004	0.004	0.001	0.007	0.003	0.006	0.004	0.002	0.003	0.004	0.016	0.020
25	0.104	0.057	0.036	0.034	0.043	0.056	0.050	0.049	0.047	0.051	0.056	0.182	0.182
26	0.018	0.005	0.005	0.006	0.005	0.004	0.002	0.004	0.001	0.001	0.003	0.015	0.018
27	0.002	0.005	0.002	0.007	0.011	0.013	0.016	0.014	0.023	0.020	0.014	0.017	0.023
28	0.009	0.003	0.002	0.003	0.002	0.004	0.004	0.004	0.002	0.005	0.005	0.024	0.024
29	0.027	0.065	0.013	0.037	0.041	0.052	0.043	0.043	0.036	0.032	0.037	0.043	0.065
30	0.016	0.000	0.003	0.002	0.004	0.003	0.001	0.003	0.003	0.003	0.004	0.012	0.016
31	0.069	0.050	0.012	0.032	0.031	0.044	0.042	0.044	0.045	0.038	0.041	0.174	0.174
32	0.013	0.004	0.003	0.002	0.005	0.003	0.004	0.004	0.004	0.002	0.002	0.011	0.013
33	0.005	0.011	0.009	0.007	0.013	0.009	0.009	0.009	0.006	0.012	0.012	0.021	0.021
34	0.010	0.004	0.006	0.002	0.005	0.001	0.004	0.005	0.004	0.003	0.004	0.030	0.030
35	0.014	0.016	0.016	0.031	0.027	0.037	0.034	0.041	0.046	0.041	0.036	0.041	0.046
36	0.015	0.003	0.003	0.001	0.003	0.001	0.002	0.001	0.000	0.001	0.002	0.011	0.015
37	0.046	0.018	0.021	0.031	0.028	0.036	0.035	0.036	0.032	0.027	0.023	0.139	0.139
38	0.014	0.002	0.002	0.001	0.003	0.002	0.003	0.004	0.002	0.002	0.002	0.012	0.014
39	0.003	0.004	0.005	0.002	0.009	0.007	0.009	0.005	0.010	0.008	0.002	0.026	0.026
40	0.010	0.004	0.005	0.002	0.003	0.005	0.008	0.009	0.005	0.003	0.004	0.028	0.028
41	0.006	0.040	0.023	0.029	0.026	0.037	0.032	0.032	0.032	0.030	0.027	0.040	0.040
42	0.014	0.002	0.001	0.001	0.003	0.000	0.002	0.001	0.001	0.001	0.002	0.013	0.014
43	0.036	0.047	0.031	0.029	0.021	0.032	0.032	0.040	0.037	0.034	0.035	0.111	0.111
44	0.016	0.001	0.001	0.002	0.005	0.002	0.003	0.002	0.002	0.001	0.001	0.019	0.019
45	0.005	0.006	0.004	0.002	0.010	0.008	0.008	0.006	0.012	0.008	0.010	0.025	0.025
46	0.012	0.002	0.002	0.002	0.005	0.004	0.005	0.004	0.004	0.002	0.005	0.050	0.050
47	0.005	0.044	0.023	0.028	0.018	0.031	0.032	0.039	0.039	0.037	0.036	0.051	0.051
48	0.013	0.003	0.002	0.002	0.002	0.001	0.003	0.002	0.000	0.002	0.003	0.046	0.046
49	0.026	0.034	0.019	0.024	0.024	0.033	0.033	0.032	0.027	0.024	0.026	0.090	0.090
50	0.014	0.001	0.003	0.002	0.003	0.002	0.002	0.003	0.001	0.003	0.004	0.026	0.026
TDC (%)	0.698	0.175	0.050	0.081	0.260	0.322	0.351	0.344	0.402	0.470	0.486	0.320	0.698

Phase C													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	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(%)	I_h(%)	
2	0.008	0.022	0.021	0.013	0.046	0.024	0.040	0.047	0.029	0.086	0.010	0.027	0.086
3	0.100	0.038	0.037	0.073	0.079	0.090	0.104	0.089	0.085	0.103	0.102	0.081	0.104
4	0.006	0.016	0.013	0.005	0.027	0.004	0.008	0.034	0.042	0.064	0.075	0.029	0.075
5	0.577	0.206	0.028	0.089	0.201	0.266	0.276	0.302	0.314	0.312	0.298	0.307	0.577
6	0.016	0.008	0.005	0.011	0.014	0.014	0.013	0.026	0.010	0.014	0.013	0.037	0.037
7	0.184	0.163	0.074	0.121	0.255	0.288	0.327	0.321	0.371	0.388	0.462	0.085	0.462
8	0.005	0.008	0.010	0.012	0.013	0.018	0.020	0.013	0.007	0.018	0.048	0.034	0.048
9	0.030	0.043	0.025	0.046	0.042	0.050	0.028	0.035	0.015	0.006	0.049	0.100	0.100
10	0.008	0.010	0.015	0.020	0.016	0.022	0.021	0.016	0.019	0.031	0.030	0.028	0.031
11	0.483	0.225	0.102	0.088	0.198	0.238	0.276	0.275	0.298	0.330	0.351	0.209	0.483
12	0.012	0.005	0.004	0.005	0.008	0.005	0.005	0.002	0.013	0.012	0.004	0.026	0.026
13	0.178	0.176	0.094	0.096	0.191	0.230	0.229	0.239	0.243	0.246	0.262	0.101	0.262
14	0.012	0.004	0.009	0.011	0.012	0.010	0.015	0.011	0.011	0.013	0.008	0.026	0.026
15	0.004	0.022	0.006	0.020	0.030	0.029	0.031	0.034	0.027	0.026	0.017	0.083	0.083
16	0.003	0.002	0.005	0.007	0.003	0.005	0.002	0.004	0.004	0.010	0.002	0.023	0.023
17	0.154	0.084	0.089	0.044	0.075	0.086	0.096	0.101	0.093	0.066	0.067	0.156	0.156
18	0.010	0.004	0.001	0.004	0.002	0.001	0.002	0.001	0.004	0.003	0.006	0.019	0.019
19	0.157	0.055	0.067	0.028	0.056	0.069	0.071	0.080	0.074	0.071	0.063	0.194	0.194
20	0.012	0.003	0.002	0.004	0.006	0.003	0.006	0.007	0.002	0.003	0.009	0.021	0.021
21	0.007	0.012	0.011	0.005	0.006	0.005	0.002	0.006	0.010	0.009	0.014	0.077	0.077
22	0.003	0.005	0.002	0.004	0.005	0.006	0.004	0.008	0.002	0.003	0.002	0.026	0.026
23	0.073	0.046	0.052	0.034	0.050	0.068	0.070	0.070	0.084	0.086	0.088	0.111	0.111
24	0.012	0.005	0.006	0.003	0.009	0.006	0.005	0.008	0.001	0.003	0.003	0.015	0.015
25	0.105	0.074	0.033	0.034	0.042	0.054	0.063	0.061	0.057	0.054	0.057	0.205	0.205
26	0.012	0.005	0.002	0.005	0.003	0.002	0.003	0.004	0.004	0.004	0.001	0.017	0.017
27	0.004	0.004	0.004	0.004	0.007	0.007	0.009	0.008	0.011	0.004	0.010	0.051	0.051
28	0.005	0.005	0.003	0.005	0.002	0.001	0.003	0.003	0.002	0.004	0.005	0.028	0.028
29	0.031	0.063	0.013	0.038	0.043	0.055	0.055	0.056	0.048	0.038	0.043	0.065	0.065
30	0.013	0.004	0.002	0.001	0.001	0.002	0.002	0.001	0.001	0.004	0.002	0.014	0.014
31	0.075	0.046	0.014	0.033	0.030	0.047	0.051	0.054	0.047	0.043	0.042	0.188	0.188
32	0.013	0.002	0.003	0.003	0.004	0.005	0.003	0.004	0.005	0.001	0.004	0.015	0.015
33	0.010	0.007	0.003	0.002	0.006	0.010	0.011	0.010	0.006	0.019	0.016	0.035	0.035
34	0.006	0.002	0.001	0.002	0.004	0.003	0.002	0.001	0.001	0.006	0.001	0.033	0.033
35	0.018	0.021	0.018	0.035	0.030	0.043	0.048	0.049	0.052	0.044	0.047	0.039	0.052
36	0.011	0.003	0.002	0.001	0.004	0.002	0.002	0.002	0.002	0.003	0.003	0.013	0.013
37	0.052	0.016	0.026	0.031	0.025	0.038	0.037	0.034	0.030	0.031	0.029	0.147	0.147
38	0.015	0.005	0.004	0.001	0.004	0.002	0.002	0.003	0.005	0.001	0.004	0.014	0.015
39	0.003	0.003	0.002	0.003	0.002	0.003	0.006	0.006	0.005	0.006	0.007	0.028	0.028
40	0.008	0.004	0.003	0.004	0.002	0.007	0.003	0.002	0.000	0.003	0.003	0.032	0.032
41	0.012	0.044	0.026	0.031	0.031	0.041	0.041	0.040	0.040	0.033	0.035	0.028	0.044
42	0.017	0.004	0.001	0.000	0.002	0.003	0.002	0.001	0.002	0.001	0.005	0.015	0.017
43	0.040	0.043	0.031	0.029	0.013	0.031	0.035	0.043	0.039	0.037	0.038	0.117	0.117
44	0.015	0.002	0.002	0.000	0.003	0.002	0.001	0.003	0.002	0.003	0.001	0.020	0.020
45	0.004	0.002	0.004	0.002	0.004	0.005	0.003	0.006	0.008	0.008	0.004	0.020	0.020
46	0.004	0.004	0.001	0.001	0.005	0.002	0.001	0.003	0.002	0.004	0.004	0.051	0.051
47	0.012	0.046	0.024	0.029	0.022	0.034	0.040	0.046	0.049	0.038	0.042	0.049	0.049
48	0.017	0.002	0.001	0.001	0.004	0.001	0.002	0.000	0.001	0.002	0.004	0.048	0.048
49	0.028	0.033	0.016	0.022	0.016	0.032	0.034	0.032	0.028	0.028	0.026	0.094	0.094
50	0.013	0.002	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.024	0.024
TDC (%)	0.723	0.187	0.049	0.061	0.214	0.310	0.366	0.383	0.435	0.474	0.549	0.413	0.723

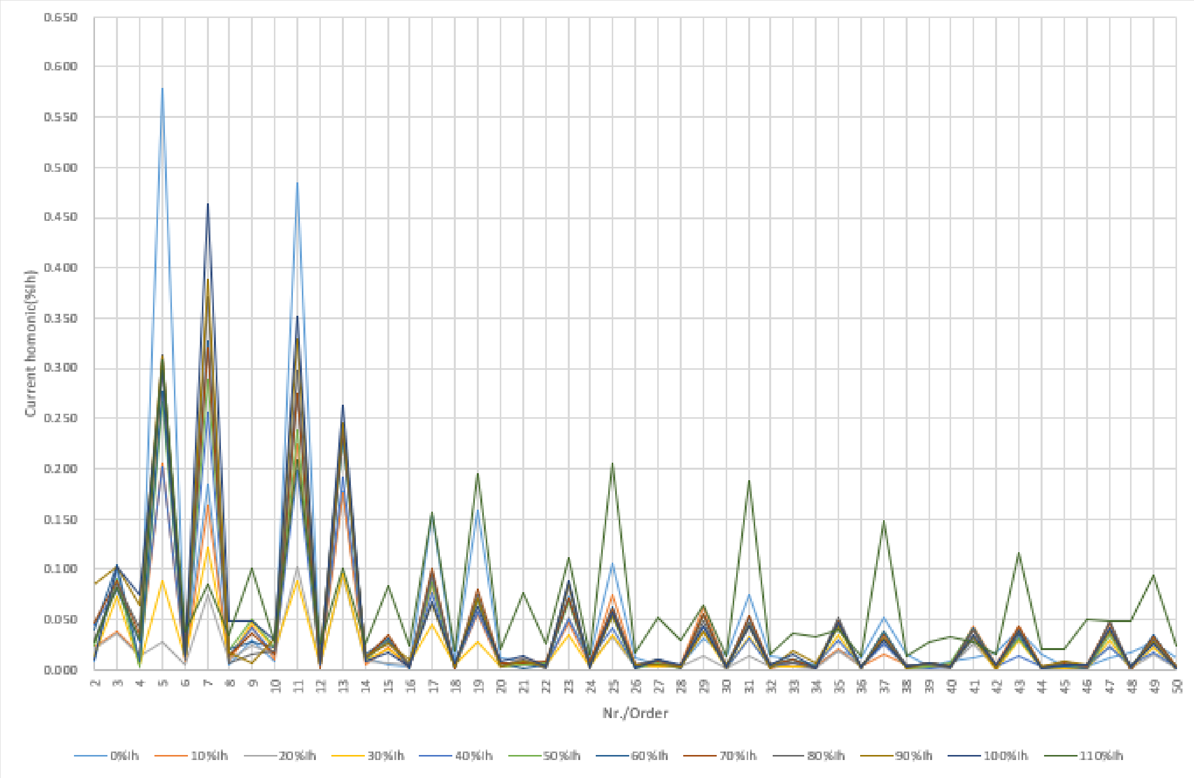
Current Harmonics_Phase A



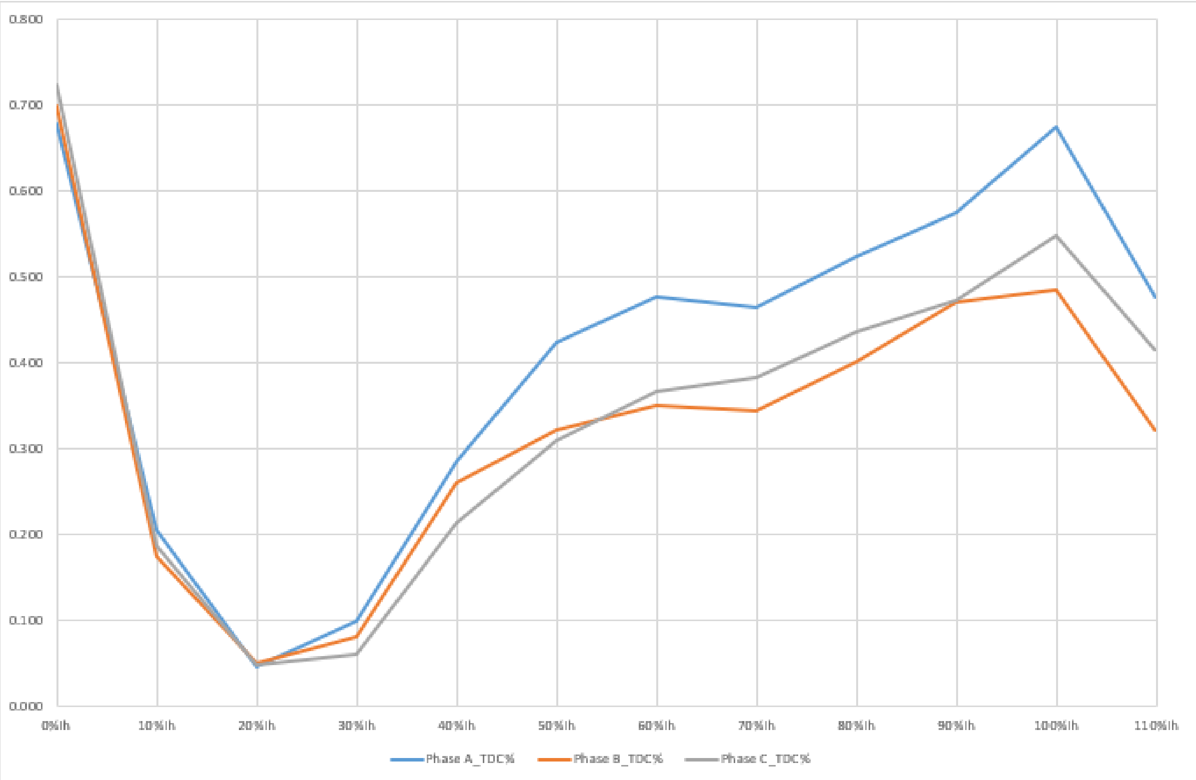
Current Harmonics_Phase B



Current Harmonics_Phase C



Total Distortion Current Harmonic



4.3.3.2 Voltage harmonics

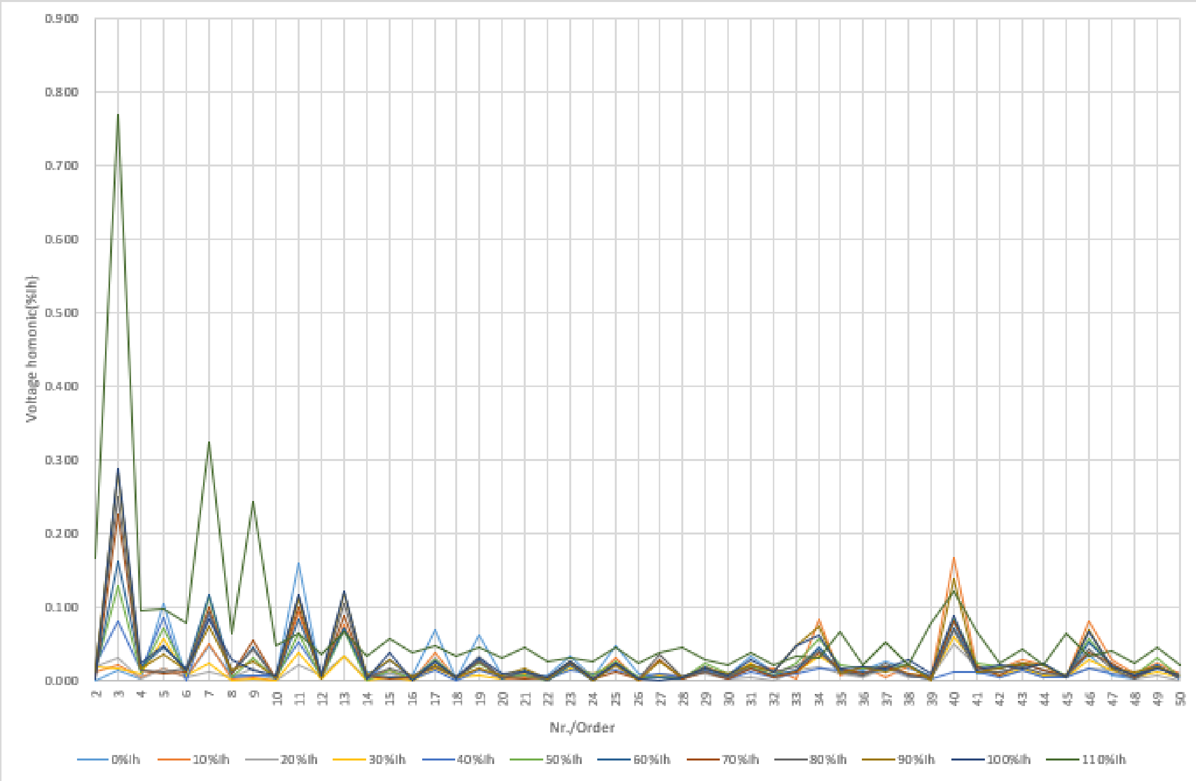
Measurements of voltage harmonics at continuous operation are done according to IEC 61000-4-7:2002

Phase A													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	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(%)	I_h(%)	
2	0.001	0.012	0.020	0.019	0.022	0.014	0.009	0.005	0.019	0.012	0.004	0.020	0.022
3	0.014	0.021	0.032	0.018	0.081	0.128	0.162	0.226	0.250	0.284	0.288	0.137	0.288
4	0.003	0.005	0.003	0.009	0.016	0.013	0.019	0.014	0.015	0.017	0.024	0.021	0.024
5	0.105	0.016	0.018	0.058	0.087	0.072	0.046	0.009	0.013	0.036	0.047	0.033	0.105
6	0.005	0.005	0.006	0.007	0.000	0.010	0.017	0.011	0.016	0.015	0.014	0.018	0.018
7	0.048	0.050	0.012	0.024	0.091	0.115	0.117	0.101	0.093	0.075	0.084	0.041	0.117
8	0.007	0.002	0.004	0.001	0.006	0.004	0.009	0.009	0.013	0.014	0.029	0.014	0.029
9	0.008	0.004	0.017	0.004	0.006	0.031	0.046	0.056	0.044	0.027	0.015	0.034	0.056
10	0.005	0.001	0.001	0.001	0.007	0.004	0.003	0.004	0.002	0.004	0.007	0.015	0.015
11	0.161	0.094	0.022	0.039	0.053	0.064	0.084	0.101	0.115	0.112	0.117	0.031	0.161
12	0.003	0.004	0.007	0.002	0.008	0.006	0.010	0.004	0.006	0.003	0.008	0.013	0.013
13	0.071	0.076	0.033	0.034	0.071	0.070	0.072	0.088	0.106	0.119	0.121	0.017	0.121
14	0.011	0.005	0.003	0.001	0.002	0.001	0.008	0.007	0.005	0.006	0.004	0.014	0.014
15	0.010	0.014	0.011	0.006	0.029	0.014	0.006	0.003	0.016	0.030	0.039	0.020	0.039
16	0.007	0.000	0.003	0.001	0.002	0.002	0.006	0.004	0.007	0.006	0.001	0.014	0.014
17	0.069	0.038	0.031	0.018	0.015	0.028	0.027	0.021	0.018	0.023	0.027	0.034	0.069
18	0.004	0.002	0.003	0.004	0.000	0.004	0.004	0.006	0.005	0.006	0.006	0.013	0.013
19	0.063	0.016	0.034	0.007	0.014	0.023	0.029	0.026	0.027	0.017	0.030	0.038	0.063
20	0.009	0.002	0.002	0.002	0.005	0.004	0.002	0.005	0.005	0.008	0.009	0.013	0.013
21	0.003	0.005	0.010	0.011	0.008	0.007	0.016	0.004	0.011	0.017	0.011	0.022	0.022
22	0.008	0.003	0.002	0.003	0.002	0.001	0.001	0.004	0.001	0.002	0.006	0.014	0.014
23	0.034	0.024	0.027	0.017	0.014	0.022	0.022	0.024	0.027	0.026	0.026	0.025	0.034
24	0.004	0.002	0.008	0.009	0.010	0.007	0.001	0.003	0.001	0.001	0.004	0.013	0.013
25	0.048	0.032	0.019	0.023	0.015	0.028	0.025	0.013	0.025	0.022	0.024	0.038	0.048
26	0.009	0.001	0.002	0.003	0.005	0.004	0.004	0.003	0.002	0.001	0.003	0.013	0.013
27	0.007	0.009	0.011	0.007	0.009	0.005	0.004	0.029	0.036	0.025	0.001	0.015	0.036
28	0.004	0.005	0.006	0.004	0.006	0.002	0.004	0.002	0.005	0.005	0.006	0.014	0.014
29	0.015	0.020	0.009	0.019	0.015	0.025	0.020	0.013	0.013	0.018	0.016	0.020	0.025
30	0.007	0.007	0.002	0.005	0.003	0.011	0.005	0.003	0.006	0.009	0.007	0.013	0.013
31	0.033	0.020	0.005	0.025	0.012	0.018	0.018	0.018	0.021	0.022	0.029	0.036	0.036
32	0.013	0.016	0.001	0.005	0.005	0.007	0.008	0.005	0.011	0.012	0.011	0.013	0.016
33	0.011	0.003	0.014	0.013	0.009	0.025	0.015	0.012	0.020	0.048	0.048	0.015	0.048
34	0.045	0.084	0.019	0.033	0.018	0.057	0.045	0.038	0.040	0.073	0.061	0.014	0.084
35	0.010	0.007	0.010	0.017	0.016	0.021	0.014	0.018	0.011	0.011	0.016	0.020	0.021
36	0.014	0.019	0.004	0.008	0.007	0.017	0.013	0.009	0.006	0.019	0.020	0.013	0.020
37	0.026	0.005	0.016	0.019	0.019	0.020	0.015	0.018	0.023	0.013	0.016	0.031	0.031
38	0.017	0.020	0.006	0.010	0.007	0.021	0.023	0.011	0.008	0.023	0.028	0.013	0.028
39	0.008	0.006	0.004	0.004	0.002	0.002	0.006	0.006	0.003	0.001	0.011	0.015	0.015
40	0.082	0.166	0.050	0.060	0.013	0.084	0.071	0.081	0.070	0.138	0.087	0.015	0.166
41	0.010	0.018	0.018	0.021	0.013	0.023	0.020	0.019	0.013	0.012	0.014	0.019	0.023
42	0.013	0.018	0.005	0.008	0.005	0.019	0.016	0.007	0.012	0.016	0.023	0.014	0.023
43	0.020	0.029	0.014	0.018	0.016	0.022	0.025	0.024	0.020	0.025	0.018	0.027	0.029
44	0.009	0.022	0.005	0.009	0.006	0.021	0.014	0.014	0.011	0.022	0.024	0.014	0.024
45	0.006	0.005	0.008	0.004	0.004	0.007	0.004	0.007	0.009	0.004	0.005	0.014	0.014
46	0.035	0.081	0.018	0.029	0.017	0.057	0.053	0.037	0.042	0.070	0.066	0.029	0.081
47	0.007	0.028	0.015	0.014	0.010	0.020	0.023	0.024	0.017	0.017	0.020	0.020	0.028
48	0.003	0.010	0.003	0.005	0.004	0.009	0.007	0.006	0.004	0.012	0.007	0.030	0.030
49	0.017	0.025	0.008	0.013	0.022	0.031	0.021	0.019	0.019	0.020	0.017	0.026	0.031
50	0.010	0.011	0.001	0.005	0.002	0.004	0.004	0.006	0.004	0.007	0.007	0.015	0.015
TDC (%)	0.072	0.069	0.012	0.018	0.036	0.069	0.075	0.099	0.115	0.156	0.151	0.042	0.156

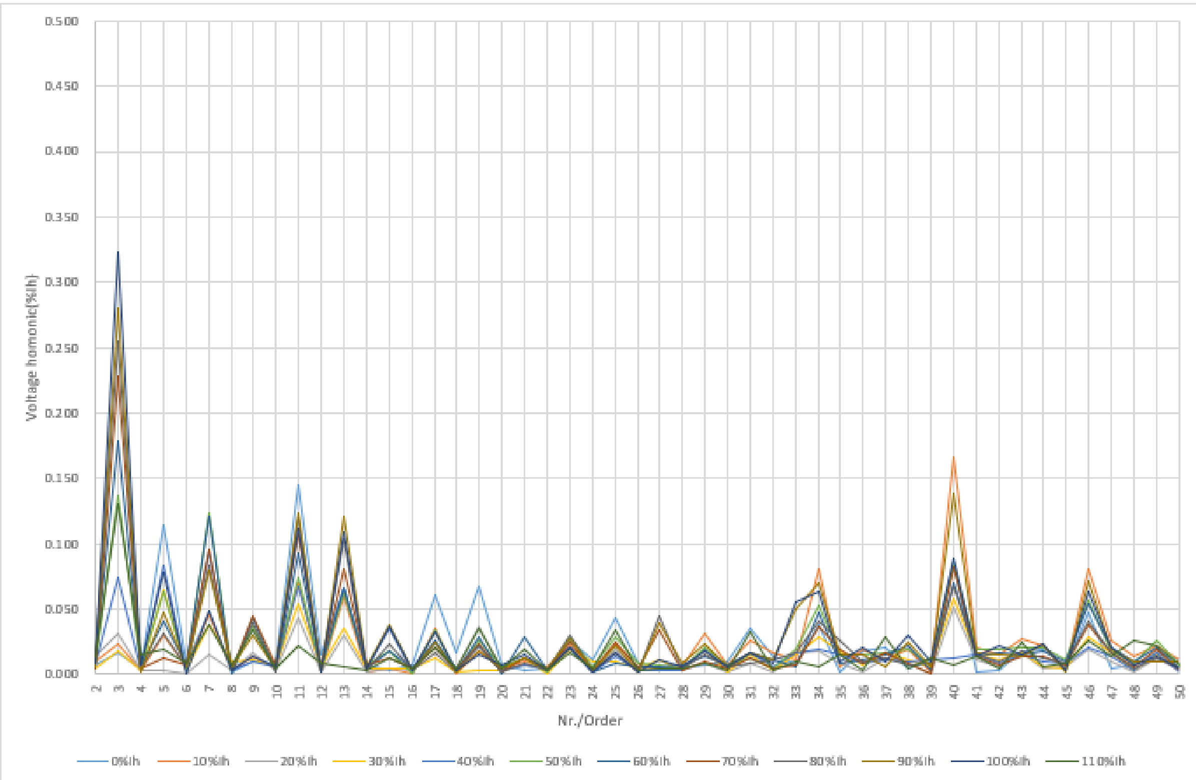
Phase B													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	Max (%)
Nr./ Order	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	
2	0.008	0.010	0.014	0.004	0.008	0.008	0.011	0.005	0.008	0.006	0.008	0.014	0.014
3	0.017	0.024	0.032	0.018	0.074	0.137	0.179	0.228	0.255	0.281	0.323	0.131	0.323
4	0.005	0.004	0.004	0.004	0.004	0.006	0.006	0.004	0.005	0.003	0.007	0.015	0.015
5	0.114	0.030	0.004	0.065	0.084	0.064	0.040	0.013	0.032	0.048	0.078	0.020	0.114
6	0.009	0.006	0.001	0.003	0.003	0.004	0.007	0.008	0.006	0.006	0.001	0.009	0.009
7	0.047	0.047	0.016	0.038	0.095	0.124	0.121	0.095	0.084	0.080	0.048	0.038	0.124
8	0.003	0.003	0.004	0.010	0.003	0.002	0.000	0.004	0.003	0.007	0.003	0.007	0.010
9	0.010	0.014	0.017	0.011	0.011	0.037	0.044	0.045	0.040	0.030	0.014	0.034	0.045
10	0.008	0.005	0.003	0.006	0.007	0.006	0.003	0.007	0.002	0.004	0.007	0.004	0.008
11	0.145	0.070	0.044	0.054	0.067	0.074	0.092	0.108	0.120	0.124	0.112	0.022	0.145
12	0.016	0.002	0.003	0.006	0.005	0.005	0.006	0.006	0.004	0.003	0.003	0.009	0.016
13	0.067	0.059	0.031	0.035	0.066	0.062	0.067	0.081	0.103	0.121	0.109	0.006	0.121
14	0.007	0.002	0.001	0.005	0.005	0.007	0.004	0.007	0.003	0.007	0.005	0.004	0.007
15	0.003	0.004	0.004	0.004	0.036	0.017	0.017	0.013	0.023	0.038	0.037	0.012	0.038
16	0.007	0.001	0.003	0.004	0.003	0.001	0.004	0.005	0.004	0.003	0.004	0.005	0.007
17	0.060	0.035	0.033	0.012	0.024	0.034	0.026	0.020	0.017	0.025	0.033	0.021	0.060
18	0.017	0.001	0.003	0.001	0.005	0.003	0.002	0.003	0.003	0.002	0.003	0.005	0.017
19	0.068	0.018	0.037	0.003	0.022	0.026	0.029	0.023	0.022	0.019	0.016	0.036	0.068
20	0.008	0.004	0.004	0.004	0.004	0.005	0.001	0.002	0.002	0.004	0.007	0.005	0.008
21	0.004	0.010	0.007	0.013	0.007	0.013	0.029	0.013	0.008	0.013	0.016	0.019	0.029
22	0.005	0.005	0.005	0.001	0.005	0.002	0.004	0.003	0.003	0.004	0.003	0.004	0.005
23	0.026	0.022	0.019	0.020	0.020	0.028	0.020	0.025	0.030	0.027	0.021	0.017	0.030
24	0.011	0.002	0.002	0.010	0.002	0.007	0.002	0.003	0.003	0.004	0.002	0.004	0.011
25	0.044	0.024	0.020	0.010	0.015	0.028	0.009	0.025	0.017	0.022	0.016	0.034	0.044
26	0.009	0.006	0.003	0.004	0.003	0.008	0.005	0.005	0.002	0.001	0.002	0.003	0.009
27	0.005	0.004	0.011	0.011	0.003	0.008	0.007	0.034	0.045	0.039	0.012	0.004	0.045
28	0.005	0.006	0.003	0.003	0.004	0.005	0.007	0.003	0.004	0.009	0.006	0.005	0.009
29	0.008	0.031	0.008	0.019	0.019	0.020	0.014	0.010	0.015	0.023	0.018	0.009	0.031
30	0.010	0.007	0.002	0.002	0.005	0.007	0.007	0.005	0.007	0.005	0.006	0.003	0.010
31	0.035	0.026	0.009	0.015	0.017	0.013	0.017	0.013	0.009	0.016	0.016	0.033	0.035
32	0.014	0.017	0.002	0.003	0.006	0.005	0.011	0.005	0.011	0.011	0.009	0.004	0.017
33	0.009	0.012	0.017	0.015	0.016	0.019	0.006	0.008	0.016	0.050	0.055	0.010	0.055
34	0.038	0.080	0.018	0.029	0.020	0.053	0.047	0.037	0.041	0.070	0.064	0.007	0.080
35	0.002	0.006	0.009	0.018	0.016	0.015	0.009	0.019	0.026	0.016	0.010	0.016	0.026
36	0.018	0.019	0.001	0.007	0.009	0.015	0.011	0.009	0.009	0.016	0.021	0.004	0.021
37	0.021	0.011	0.013	0.017	0.011	0.017	0.015	0.016	0.012	0.007	0.009	0.029	0.029
38	0.005	0.020	0.008	0.011	0.010	0.020	0.022	0.009	0.007	0.024	0.030	0.004	0.030
39	0.010	0.002	0.001	0.006	0.012	0.008	0.004	0.001	0.009	0.006	0.010	0.013	0.013
40	0.086	0.167	0.052	0.058	0.013	0.084	0.070	0.083	0.067	0.138	0.089	0.007	0.167
41	0.002	0.020	0.011	0.016	0.016	0.019	0.014	0.014	0.015	0.017	0.014	0.014	0.020
42	0.004	0.015	0.006	0.011	0.008	0.019	0.017	0.007	0.010	0.015	0.022	0.004	0.022
43	0.018	0.027	0.017	0.017	0.015	0.021	0.015	0.015	0.019	0.014	0.016	0.025	0.027
44	0.019	0.021	0.005	0.005	0.010	0.021	0.018	0.014	0.012	0.023	0.024	0.006	0.024
45	0.005	0.005	0.007	0.005	0.009	0.011	0.010	0.007	0.009	0.001	0.004	0.009	0.011
46	0.048	0.081	0.020	0.028	0.021	0.058	0.055	0.039	0.041	0.071	0.064	0.026	0.081
47	0.004	0.025	0.010	0.017	0.015	0.019	0.020	0.017	0.017	0.020	0.020	0.014	0.025
48	0.007	0.014	0.003	0.003	0.003	0.009	0.010	0.005	0.005	0.010	0.008	0.026	0.026
49	0.017	0.023	0.013	0.015	0.017	0.026	0.021	0.019	0.013	0.010	0.014	0.022	0.026
50	0.012	0.012	0.003	0.004	0.002	0.007	0.004	0.003	0.005	0.010	0.005	0.008	0.012
TDC (%)	0.068	0.063	0.013	0.020	0.038	0.071	0.081	0.098	0.116	0.160	0.165	0.031	0.165

Phase C													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	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(%)	I_h(%)	
2	0.004	0.011	0.019	0.015	0.023	0.016	0.016	0.013	0.008	0.022	0.020	0.006	0.023
3	0.019	0.018	0.036	0.044	0.103	0.154	0.185	0.244	0.261	0.283	0.331	0.123	0.331
4	0.001	0.002	0.004	0.005	0.010	0.007	0.006	0.010	0.010	0.014	0.016	0.008	0.016
5	0.104	0.042	0.002	0.049	0.068	0.055	0.023	0.004	0.028	0.045	0.075	0.026	0.104
6	0.004	0.005	0.005	0.005	0.002	0.002	0.004	0.009	0.007	0.008	0.011	0.008	0.011
7	0.043	0.049	0.005	0.033	0.076	0.108	0.110	0.094	0.086	0.075	0.067	0.034	0.110
8	0.007	0.005	0.003	0.009	0.003	0.005	0.006	0.005	0.002	0.005	0.016	0.004	0.016
9	0.012	0.011	0.021	0.019	0.019	0.012	0.038	0.045	0.041	0.030	0.016	0.035	0.045
10	0.005	0.005	0.005	0.004	0.001	0.003	0.007	0.004	0.006	0.015	0.013	0.004	0.015
11	0.162	0.074	0.043	0.028	0.049	0.063	0.086	0.109	0.120	0.127	0.124	0.020	0.162
12	0.002	0.003	0.002	0.002	0.003	0.002	0.002	0.005	0.005	0.005	0.006	0.004	0.006
13	0.069	0.059	0.038	0.028	0.068	0.065	0.065	0.083	0.098	0.109	0.117	0.007	0.117
14	0.002	0.004	0.005	0.004	0.002	0.004	0.008	0.004	0.005	0.006	0.001	0.005	0.008
15	0.007	0.009	0.006	0.013	0.019	0.010	0.014	0.009	0.013	0.028	0.036	0.018	0.036
16	0.001	0.003	0.003	0.003	0.003	0.001	0.002	0.004	0.001	0.003	0.001	0.005	0.005
17	0.066	0.035	0.038	0.023	0.022	0.035	0.030	0.030	0.023	0.022	0.034	0.027	0.066
18	0.003	0.003	0.003	0.001	0.000	0.003	0.002	0.003	0.001	0.002	0.004	0.004	0.004
19	0.064	0.020	0.035	0.007	0.020	0.022	0.029	0.021	0.020	0.018	0.019	0.039	0.064
20	0.005	0.005	0.001	0.001	0.002	0.002	0.004	0.001	0.001	0.002	0.004	0.004	0.005
21	0.003	0.010	0.016	0.009	0.011	0.011	0.021	0.010	0.006	0.021	0.017	0.027	0.027
22	0.002	0.005	0.001	0.004	0.002	0.002	0.003	0.003	0.001	0.001	0.003	0.005	0.005
23	0.030	0.018	0.023	0.014	0.017	0.026	0.021	0.030	0.029	0.024	0.026	0.012	0.030
24	0.005	0.003	0.001	0.006	0.001	0.004	0.001	0.005	0.000	0.003	0.001	0.004	0.006
25	0.048	0.033	0.013	0.018	0.011	0.020	0.021	0.018	0.020	0.019	0.014	0.041	0.048
26	0.004	0.001	0.002	0.002	0.005	0.003	0.003	0.003	0.004	0.002	0.004	0.004	0.005
27	0.004	0.004	0.013	0.006	0.011	0.003	0.007	0.025	0.032	0.024	0.004	0.012	0.032
28	0.005	0.007	0.004	0.000	0.006	0.003	0.002	0.001	0.004	0.006	0.006	0.006	0.007
29	0.008	0.029	0.006	0.023	0.014	0.015	0.029	0.023	0.016	0.012	0.020	0.013	0.029
30	0.010	0.006	0.003	0.003	0.003	0.009	0.003	0.004	0.006	0.006	0.003	0.004	0.010
31	0.031	0.018	0.008	0.015	0.016	0.019	0.028	0.031	0.017	0.019	0.012	0.036	0.036
32	0.004	0.015	0.002	0.004	0.005	0.009	0.011	0.008	0.013	0.015	0.009	0.004	0.015
33	0.012	0.009	0.017	0.011	0.012	0.025	0.018	0.016	0.018	0.051	0.050	0.011	0.051
34	0.041	0.080	0.016	0.032	0.020	0.055	0.046	0.037	0.041	0.073	0.063	0.007	0.080
35	0.006	0.011	0.008	0.018	0.012	0.014	0.023	0.021	0.022	0.016	0.023	0.009	0.023
36	0.006	0.018	0.002	0.006	0.012	0.016	0.012	0.013	0.008	0.018	0.023	0.004	0.023
37	0.031	0.005	0.012	0.018	0.015	0.020	0.014	0.011	0.012	0.010	0.002	0.032	0.032
38	0.017	0.025	0.007	0.014	0.005	0.023	0.025	0.011	0.007	0.025	0.031	0.004	0.031
39	0.006	0.007	0.003	0.005	0.003	0.004	0.005	0.005	0.003	0.006	0.012	0.013	0.013
40	0.081	0.166	0.053	0.059	0.014	0.083	0.071	0.081	0.068	0.135	0.087	0.008	0.166
41	0.006	0.024	0.013	0.015	0.021	0.022	0.021	0.015	0.021	0.016	0.009	0.010	0.024
42	0.012	0.014	0.004	0.010	0.005	0.019	0.018	0.006	0.012	0.016	0.025	0.005	0.025
43	0.026	0.020	0.016	0.014	0.011	0.016	0.014	0.016	0.017	0.017	0.020	0.028	0.028
44	0.023	0.020	0.005	0.008	0.006	0.021	0.013	0.010	0.012	0.022	0.024	0.006	0.024
45	0.001	0.002	0.005	0.002	0.003	0.003	0.003	0.009	0.008	0.008	0.005	0.009	0.009
46	0.033	0.078	0.019	0.029	0.018	0.055	0.053	0.033	0.042	0.075	0.067	0.027	0.078
47	0.009	0.031	0.013	0.019	0.019	0.022	0.025	0.026	0.024	0.018	0.022	0.013	0.031
48	0.019	0.013	0.001	0.005	0.008	0.010	0.007	0.006	0.004	0.008	0.005	0.027	0.027
49	0.017	0.022	0.009	0.014	0.015	0.020	0.025	0.017	0.012	0.011	0.012	0.025	0.025
50	0.005	0.011	0.001	0.002	0.001	0.004	0.007	0.005	0.005	0.009	0.007	0.008	0.011
TDC (%)	0.070	0.063	0.014	0.018	0.034	0.068	0.080	0.107	0.118	0.157	0.178	0.031	0.178

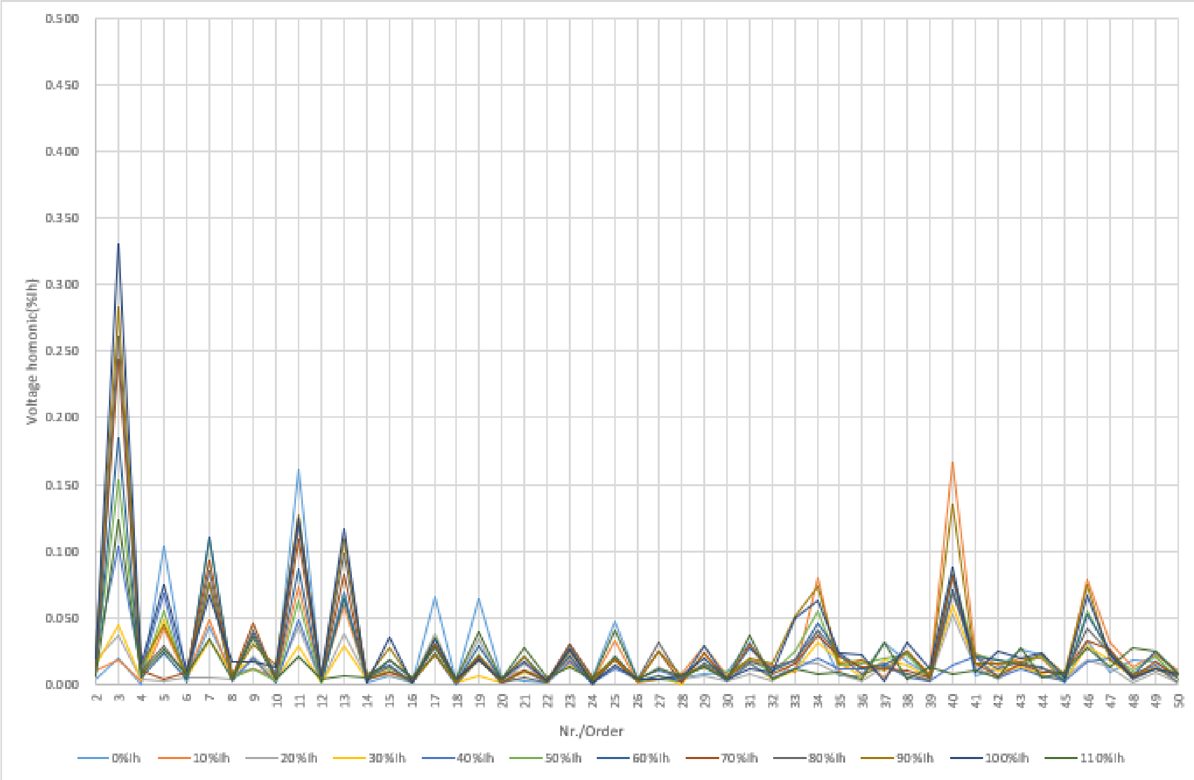
Voltage Harmonics_Phase A



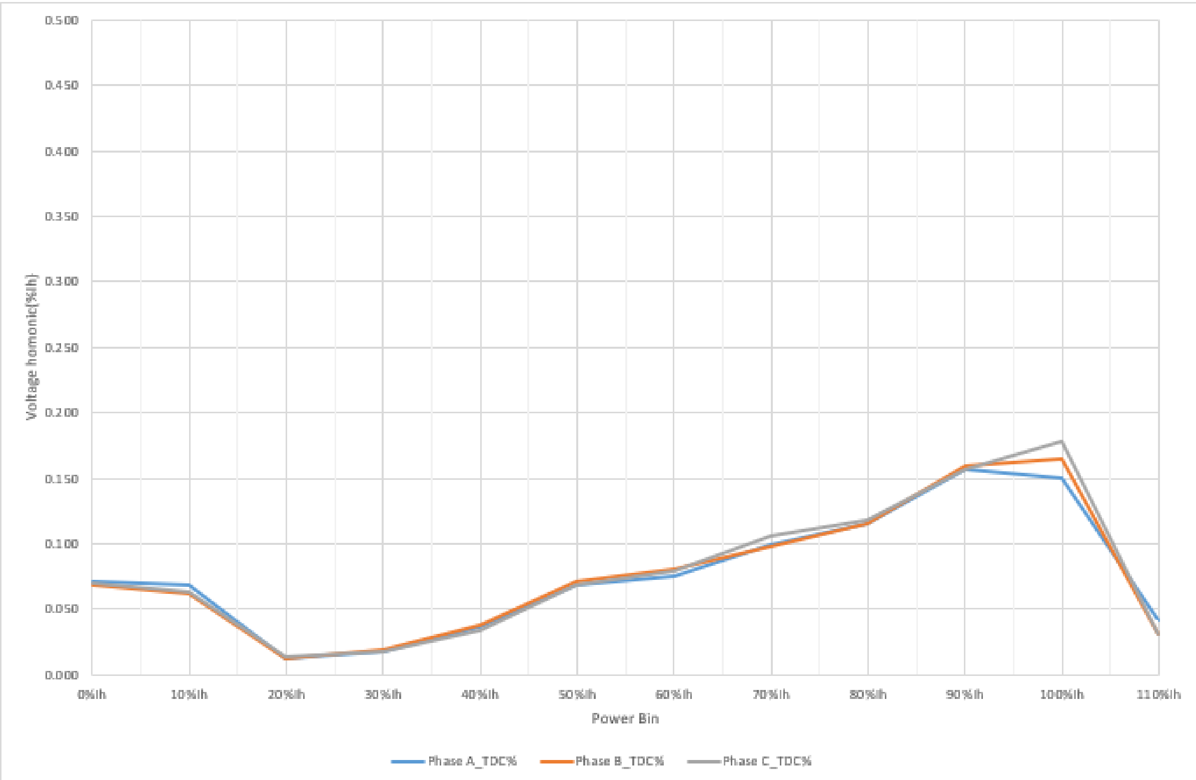
Voltage Harmonics_Phase B



Voltage Harmonics_Phase C



Total Voltage Distortion



4.3.3.3 Interharmonics at continuous operation

Test performed according to point 4.3.4 of the standard.

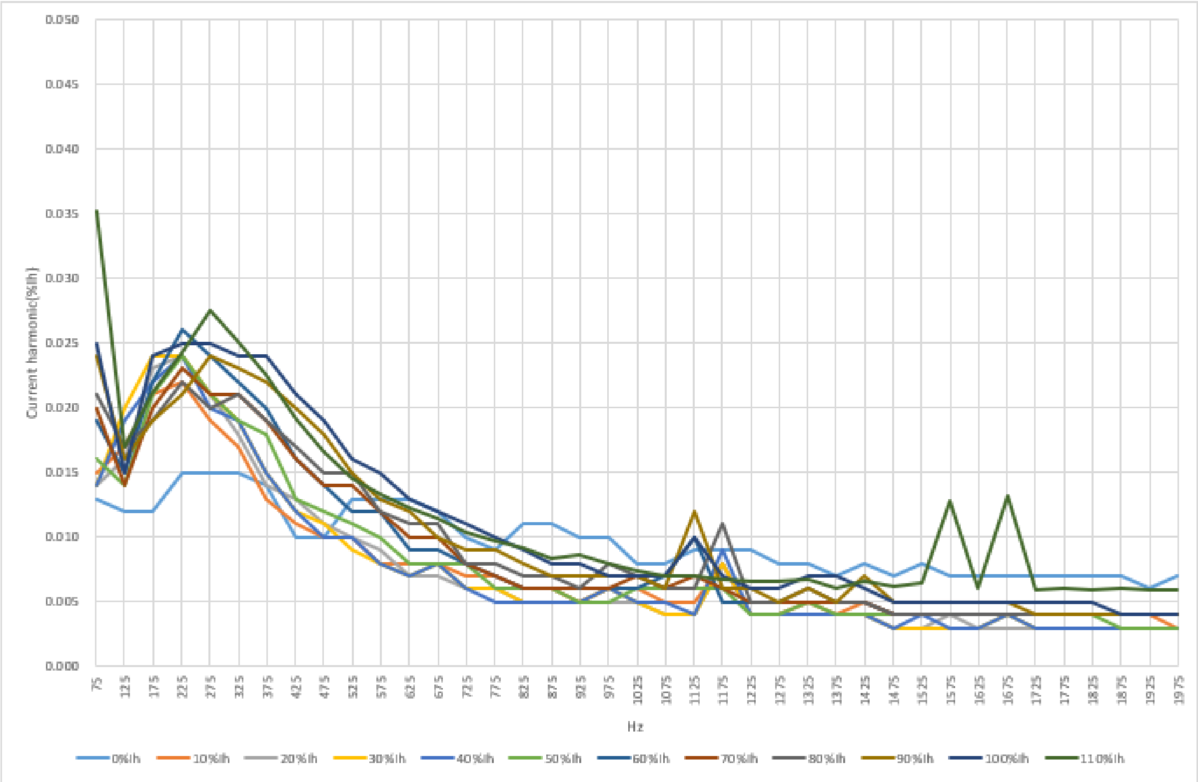
Measurements of interharmonics at continuous operation are done according to IEC 61000-4-7:2002.

Phase A													
P_n (%)	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**MAX (%)**
F [Hz]	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	**I_h(%)**	
75	0.013	0.015	0.014	0.014	0.014	0.016	0.019	0.020	0.021	0.024	0.025	0.035	0.035
125	0.012	0.017	0.016	0.020	0.019	0.014	0.015	0.014	0.017	0.016	0.015	0.017	0.020
175	0.012	0.021	0.023	0.024	0.022	0.021	0.022	0.020	0.019	0.019	0.024	0.021	0.024
225	0.015	0.022	0.024	0.024	0.024	0.024	0.026	0.023	0.022	0.021	0.025	0.024	0.026
275	0.015	0.019	0.021	0.021	0.020	0.021	0.024	0.021	0.020	0.024	0.025	0.028	0.028
325	0.015	0.017	0.018	0.019	0.019	0.019	0.022	0.021	0.021	0.023	0.024	0.025	0.025
375	0.014	0.013	0.014	0.015	0.015	0.018	0.020	0.019	0.019	0.022	0.024	0.022	0.024
425	0.010	0.011	0.013	0.012	0.012	0.013	0.016	0.016	0.017	0.020	0.021	0.019	0.021
475	0.010	0.010	0.011	0.011	0.010	0.012	0.014	0.014	0.015	0.018	0.019	0.017	0.019
525	0.013	0.010	0.010	0.009	0.010	0.011	0.012	0.014	0.015	0.015	0.016	0.015	0.016
575	0.013	0.008	0.009	0.008	0.008	0.010	0.012	0.012	0.012	0.013	0.015	0.013	0.015
625	0.013	0.008	0.007	0.007	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.012	0.013
675	0.012	0.008	0.007	0.008	0.008	0.008	0.009	0.010	0.011	0.010	0.012	0.012	0.012
725	0.010	0.007	0.006	0.006	0.006	0.008	0.008	0.008	0.008	0.009	0.011	0.010	0.011
775	0.009	0.007	0.006	0.006	0.005	0.006	0.007	0.007	0.008	0.009	0.010	0.010	0.010
825	0.011	0.006	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.008	0.009	0.009	0.011
875	0.011	0.006	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.008	0.008	0.011
925	0.010	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.008	0.009	0.010
975	0.010	0.006	0.005	0.006	0.006	0.005	0.006	0.006	0.008	0.007	0.007	0.008	0.010
1025	0.008	0.006	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.008
1075	0.008	0.005	0.004	0.004	0.005	0.006	0.007	0.006	0.006	0.006	0.007	0.007	0.008
1125	0.009	0.005	0.004	0.004	0.004	0.006	0.010	0.007	0.006	0.012	0.010	0.007	0.012
1175	0.009	0.008	0.008	0.008	0.009	0.006	0.005	0.006	0.011	0.006	0.007	0.007	0.011
1225	0.009	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.009
1275	0.008	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.007	0.008
1325	0.008	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.008
1375	0.007	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.007	0.006	0.007
1425	0.008	0.005	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.007	0.006	0.007	0.008
1475	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.007
1525	0.008	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.008
1575	0.007	0.004	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.013	0.013
1625	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.007
1675	0.007	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.013	0.013
1725	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1775	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1825	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1875	0.007	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.007
1925	0.006	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.006
1975	0.007	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.007

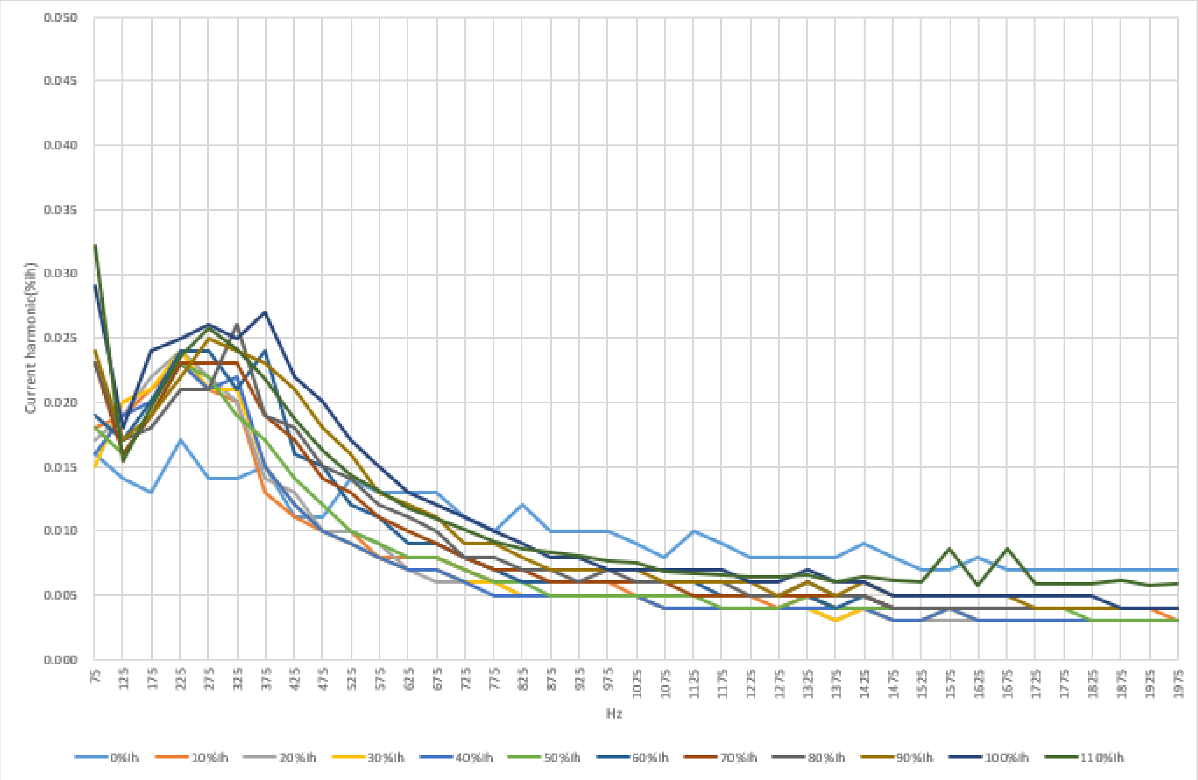
Phase B													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	MAX (%)
F [Hz]	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	
75	0.016	0.018	0.017	0.015	0.016	0.018	0.019	0.023	0.023	0.024	0.029	0.032	0.032
125	0.014	0.019	0.019	0.020	0.019	0.016	0.017	0.016	0.017	0.017	0.018	0.015	0.020
175	0.013	0.021	0.022	0.021	0.020	0.019	0.020	0.019	0.018	0.019	0.024	0.020	0.024
225	0.017	0.023	0.024	0.024	0.023	0.023	0.024	0.023	0.021	0.022	0.025	0.024	0.025
275	0.014	0.021	0.022	0.021	0.021	0.022	0.024	0.023	0.021	0.025	0.026	0.026	0.026
325	0.014	0.020	0.020	0.021	0.022	0.019	0.021	0.023	0.026	0.024	0.025	0.024	0.026
375	0.015	0.013	0.014	0.015	0.015	0.017	0.024	0.019	0.019	0.023	0.027	0.022	0.027
425	0.011	0.011	0.013	0.012	0.012	0.014	0.016	0.017	0.018	0.021	0.022	0.019	0.022
475	0.011	0.010	0.010	0.010	0.010	0.012	0.015	0.014	0.015	0.018	0.020	0.016	0.020
525	0.014	0.010	0.010	0.009	0.009	0.010	0.012	0.013	0.014	0.016	0.017	0.014	0.017
575	0.013	0.008	0.009	0.008	0.008	0.009	0.011	0.011	0.012	0.013	0.015	0.013	0.015
625	0.013	0.008	0.007	0.007	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.012	0.013
675	0.013	0.008	0.006	0.007	0.007	0.008	0.009	0.009	0.010	0.011	0.012	0.011	0.013
725	0.011	0.007	0.006	0.006	0.006	0.007	0.008	0.008	0.008	0.009	0.011	0.010	0.011
775	0.010	0.006	0.006	0.006	0.005	0.006	0.007	0.007	0.008	0.009	0.010	0.009	0.010
825	0.012	0.006	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.009	0.009	0.012
875	0.010	0.006	0.005	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.010
925	0.010	0.006	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.008	0.008	0.010
975	0.010	0.006	0.005	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.007	0.008	0.010
1025	0.009	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.008	0.009
1075	0.008	0.005	0.004	0.004	0.004	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.008
1125	0.010	0.005	0.004	0.004	0.004	0.005	0.006	0.005	0.006	0.006	0.007	0.007	0.010
1175	0.009	0.005	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.007	0.007	0.009
1225	0.008	0.005	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.008
1275	0.008	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.006	0.008
1325	0.008	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.008
1375	0.008	0.004	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.008
1425	0.009	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.009
1475	0.008	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.008
1525	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.007
1575	0.007	0.004	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.009	0.009
1625	0.008	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.008
1675	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.009	0.009
1725	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1775	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1825	0.007	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1875	0.007	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.007
1925	0.007	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.007
1975	0.007	0.003	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.007

Phase C													
P_n (%)	0	10	20	30	40	50	60	70	80	90	100	110	MAX (%)
F [Hz]	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	
75	0.014	0.014	0.013	0.013	0.014	0.015	0.019	0.019	0.019	0.024	0.027	0.036	0.036
125	0.014	0.016	0.017	0.018	0.016	0.015	0.016	0.015	0.015	0.017	0.018	0.017	0.018
175	0.014	0.022	0.023	0.024	0.023	0.021	0.022	0.020	0.019	0.020	0.024	0.021	0.024
225	0.017	0.022	0.024	0.023	0.023	0.024	0.024	0.023	0.022	0.022	0.025	0.025	0.025
275	0.013	0.020	0.022	0.021	0.021	0.022	0.025	0.023	0.022	0.025	0.026	0.026	0.026
325	0.013	0.020	0.020	0.021	0.021	0.020	0.023	0.023	0.025	0.025	0.026	0.024	0.026
375	0.014	0.014	0.015	0.015	0.015	0.019	0.024	0.020	0.019	0.023	0.027	0.022	0.027
425	0.012	0.012	0.013	0.012	0.012	0.013	0.016	0.017	0.018	0.021	0.022	0.020	0.022
475	0.011	0.011	0.011	0.011	0.010	0.011	0.014	0.015	0.015	0.018	0.020	0.017	0.020
525	0.014	0.010	0.010	0.010	0.010	0.010	0.012	0.013	0.015	0.016	0.017	0.014	0.017
575	0.013	0.009	0.009	0.008	0.008	0.010	0.012	0.012	0.012	0.014	0.016	0.013	0.016
625	0.012	0.008	0.007	0.007	0.007	0.008	0.009	0.010	0.011	0.012	0.013	0.012	0.013
675	0.013	0.008	0.007	0.007	0.007	0.008	0.009	0.009	0.010	0.011	0.012	0.011	0.013
725	0.011	0.007	0.006	0.006	0.006	0.007	0.008	0.008	0.009	0.010	0.011	0.011	0.011
775	0.010	0.006	0.006	0.006	0.006	0.006	0.007	0.008	0.008	0.009	0.010	0.010	0.010
825	0.012	0.007	0.005	0.005	0.005	0.006	0.007	0.007	0.007	0.008	0.009	0.009	0.012
875	0.012	0.006	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.008	0.008	0.008	0.012
925	0.010	0.006	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.008	0.008	0.010
975	0.010	0.006	0.005	0.006	0.005	0.005	0.006	0.006	0.007	0.007	0.007	0.008	0.010
1025	0.009	0.006	0.005	0.005	0.005	0.005	0.006	0.007	0.007	0.007	0.007	0.008	0.009
1075	0.008	0.005	0.004	0.004	0.004	0.005	0.006	0.006	0.006	0.006	0.008	0.007	0.008
1125	0.009	0.005	0.004	0.004	0.004	0.005	0.008	0.006	0.006	0.010	0.009	0.007	0.010
1175	0.010	0.007	0.006	0.007	0.007	0.005	0.005	0.006	0.009	0.006	0.007	0.007	0.010
1225	0.009	0.005	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.009
1275	0.008	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.007	0.008
1325	0.008	0.005	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.008
1375	0.007	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.006	0.006	0.007
1425	0.009	0.005	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.009
1475	0.008	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.008
1525	0.008	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.008
1575	0.008	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.005	0.009	0.009
1625	0.007	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.007
1675	0.007	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.009	0.009
1725	0.008	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.008
1775	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.005	0.006	0.007
1825	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1875	0.007	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1925	0.007	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	0.006	0.007
1975	0.006	0.004	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.006	0.006

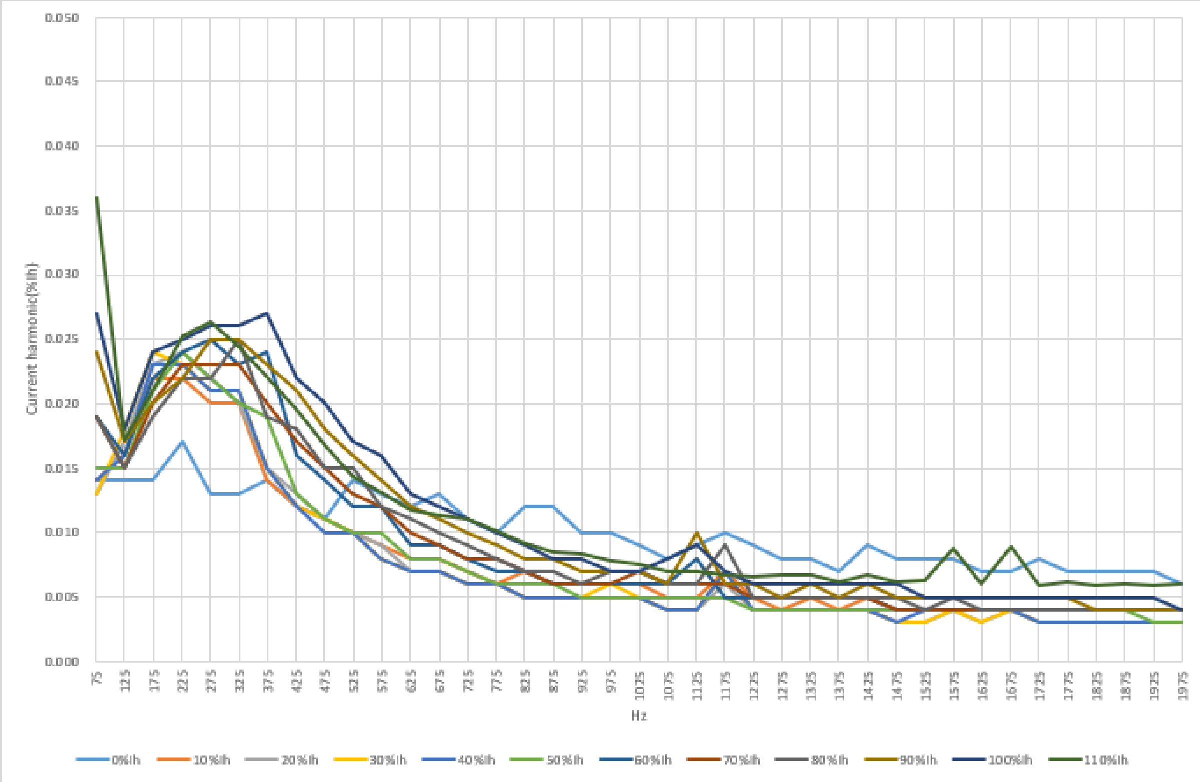
Inter-Harmonics Current (Phase A)



Inter-Harmonics Current (Phase B)



Inter-Harmonics Current (Phase C)



4.3.3.4 Higher frequency components

Test performed according to point 4.3.4 of the standard.

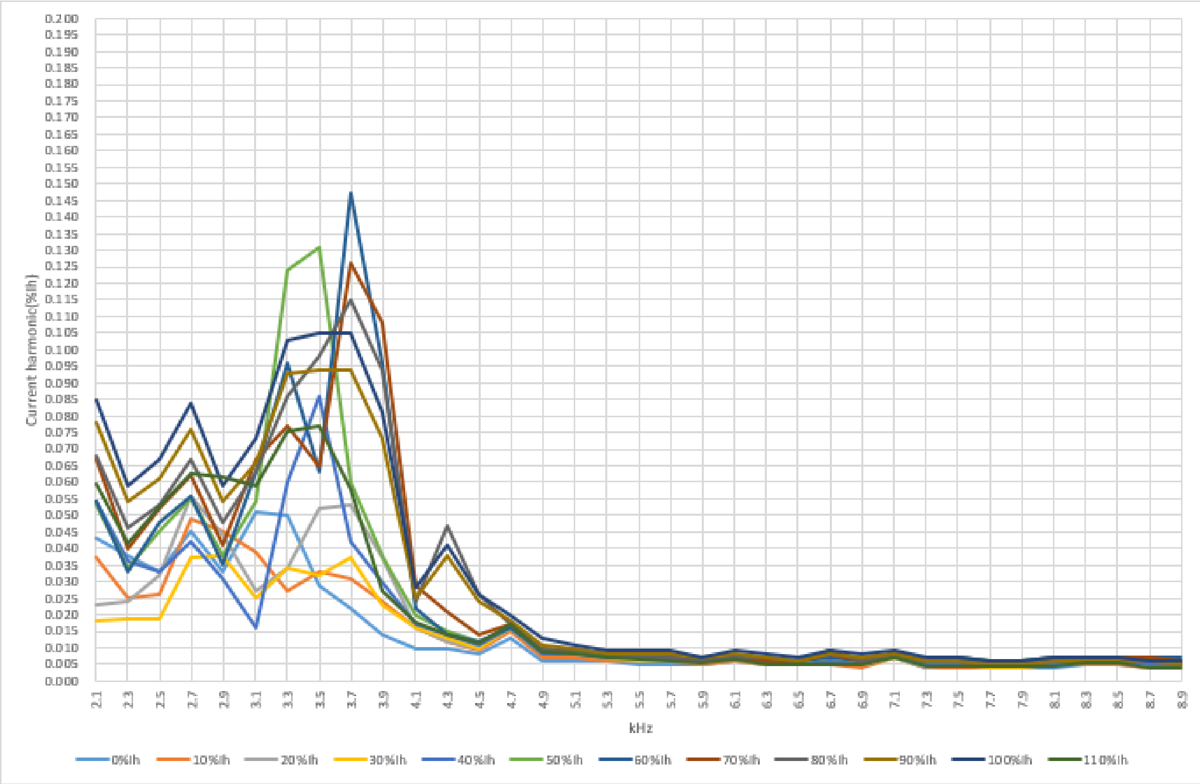
Measurements of Higher frequency are done according to IEC 61000-4-7:2002.

Phase A													
P_{bin} (%)	0	10	20	30	40	50	60	70	80	90	100	110	MAX
F [kHz]	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	(%)
2.1	0.043	0.037	0.023	0.018	0.054	0.053	0.054	0.067	0.068	0.078	0.085	0.060	0.085
2.3	0.038	0.025	0.024	0.019	0.036	0.034	0.033	0.040	0.046	0.054	0.059	0.042	0.059
2.5	0.033	0.026	0.032	0.019	0.033	0.045	0.048	0.052	0.053	0.061	0.067	0.053	0.067
2.7	0.045	0.049	0.056	0.037	0.042	0.055	0.056	0.062	0.067	0.076	0.084	0.063	0.084
2.9	0.033	0.045	0.044	0.038	0.031	0.038	0.035	0.041	0.048	0.054	0.059	0.062	0.062
3.1	0.051	0.039	0.027	0.025	0.016	0.054	0.063	0.067	0.063	0.066	0.073	0.059	0.073
3.3	0.050	0.027	0.034	0.034	0.060	0.124	0.096	0.077	0.086	0.093	0.103	0.075	0.124
3.5	0.029	0.033	0.052	0.032	0.086	0.131	0.063	0.065	0.098	0.094	0.105	0.077	0.131
3.7	0.022	0.031	0.053	0.037	0.042	0.060	0.147	0.126	0.115	0.094	0.105	0.058	0.147
3.9	0.014	0.024	0.037	0.023	0.030	0.038	0.096	0.108	0.094	0.073	0.081	0.027	0.108
4.1	0.010	0.016	0.016	0.016	0.017	0.020	0.022	0.029	0.024	0.025	0.028	0.018	0.029
4.3	0.010	0.012	0.012	0.013	0.014	0.015	0.014	0.021	0.047	0.038	0.041	0.014	0.047
4.5	0.008	0.009	0.010	0.010	0.011	0.012	0.012	0.014	0.026	0.024	0.026	0.012	0.026
4.7	0.013	0.015	0.016	0.016	0.016	0.016	0.016	0.017	0.017	0.018	0.020	0.017	0.020
4.9	0.006	0.007	0.008	0.008	0.008	0.009	0.009	0.009	0.010	0.011	0.013	0.009	0.013
5.1	0.006	0.007	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.010	0.011	0.008	0.011
5.3	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.009	0.007	0.009
5.5	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.008	0.009	0.007	0.009
5.7	0.005	0.006	0.007	0.006	0.007	0.007	0.007	0.007	0.007	0.008	0.009	0.006	0.009
5.9	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.007
6.1	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.009	0.007	0.009
6.3	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.008	0.005	0.008
6.5	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.007	0.005	0.007
6.7	0.009	0.005	0.006	0.006	0.006	0.007	0.007	0.008	0.009	0.008	0.009	0.005	0.009
6.9	0.005	0.004	0.005	0.005	0.005	0.007	0.006	0.006	0.006	0.007	0.008	0.005	0.008
7.1	0.007	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.009	0.007	0.009
7.3	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.007	0.005	0.007
7.5	0.004	0.004	0.005	0.005	0.005	0.007	0.007	0.006	0.006	0.006	0.007	0.005	0.007
7.7	0.004	0.004	0.004	0.004	0.005	0.006	0.006	0.005	0.005	0.005	0.006	0.004	0.006
7.9	0.004	0.004	0.004	0.004	0.005	0.006	0.006	0.005	0.005	0.005	0.006	0.004	0.006
8.1	0.004	0.005	0.005	0.005	0.005	0.007	0.007	0.007	0.006	0.006	0.007	0.004	0.007
8.3	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.006	0.006	0.007	0.005	0.007
8.5	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.006	0.006	0.007	0.005	0.007
8.7	0.004	0.004	0.005	0.004	0.005	0.007	0.007	0.007	0.006	0.006	0.006	0.004	0.007
8.9	0.004	0.004	0.004	0.004	0.005	0.006	0.007	0.006	0.005	0.005	0.006	0.004	0.007

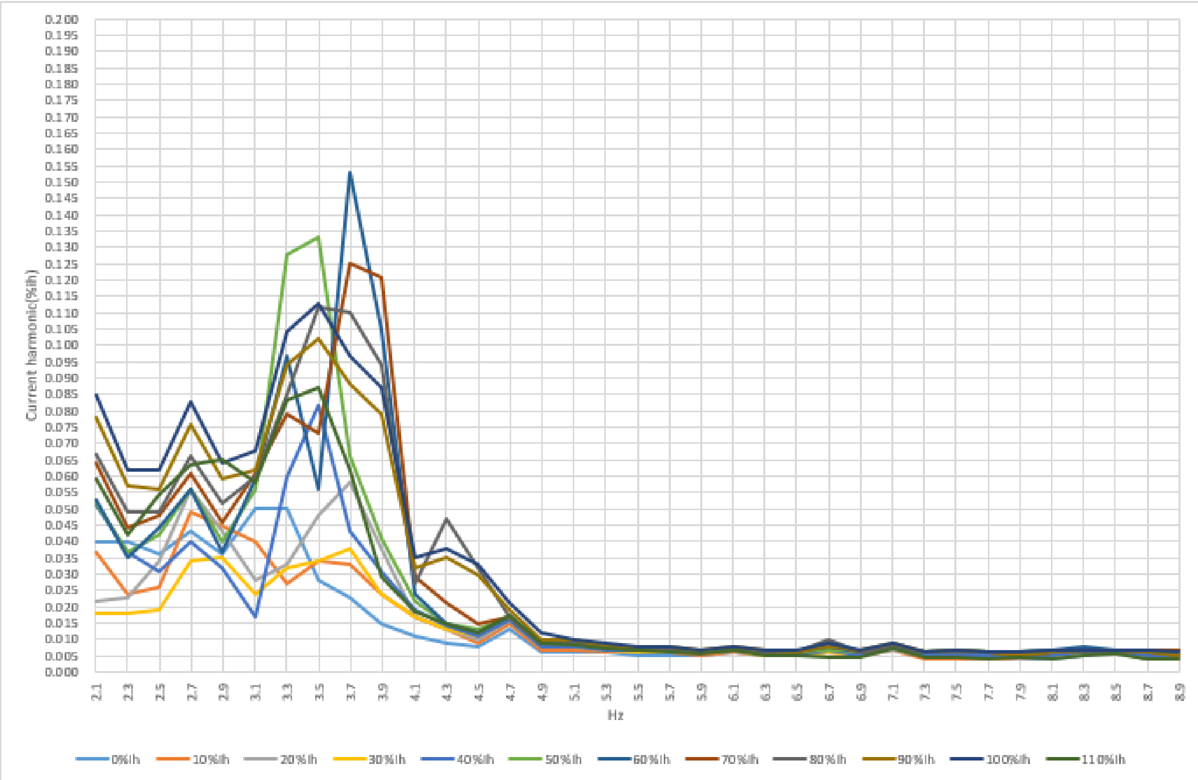
Phase B													
P_{bin} (%)	0	10	20	30	40	50	60	70	80	90	100	110	MAX
F [kHz]	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	(%)
2.1	0.040	0.037	0.022	0.018	0.051	0.052	0.053	0.064	0.067	0.078	0.085	0.059	0.085
2.3	0.040	0.024	0.023	0.018	0.037	0.037	0.035	0.044	0.049	0.057	0.062	0.042	0.062
2.5	0.036	0.026	0.034	0.019	0.031	0.042	0.044	0.048	0.049	0.056	0.062	0.055	0.062
2.7	0.043	0.049	0.056	0.034	0.040	0.056	0.056	0.061	0.066	0.076	0.083	0.064	0.083
2.9	0.036	0.045	0.043	0.035	0.032	0.040	0.037	0.046	0.052	0.059	0.064	0.065	0.065
3.1	0.050	0.040	0.028	0.024	0.017	0.056	0.059	0.061	0.060	0.062	0.068	0.058	0.068
3.3	0.050	0.027	0.033	0.032	0.060	0.128	0.097	0.079	0.085	0.094	0.104	0.083	0.128
3.5	0.028	0.034	0.048	0.034	0.082	0.133	0.056	0.073	0.112	0.102	0.113	0.087	0.133
3.7	0.023	0.033	0.058	0.038	0.043	0.066	0.153	0.125	0.110	0.088	0.097	0.062	0.153
3.9	0.015	0.024	0.038	0.024	0.031	0.041	0.105	0.121	0.094	0.079	0.087	0.029	0.121
4.1	0.011	0.017	0.017	0.017	0.019	0.022	0.024	0.029	0.027	0.032	0.035	0.019	0.035
4.3	0.009	0.013	0.013	0.013	0.014	0.015	0.015	0.021	0.047	0.035	0.038	0.015	0.047
4.5	0.008	0.009	0.010	0.011	0.011	0.013	0.012	0.015	0.032	0.030	0.033	0.012	0.033
4.7	0.013	0.015	0.016	0.016	0.016	0.017	0.017	0.017	0.017	0.019	0.021	0.018	0.021
4.9	0.006	0.007	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.010	0.012	0.009	0.012
5.1	0.006	0.007	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.010	0.010	0.008	0.010
5.3	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.009	0.007	0.009
5.5	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.007	0.008
5.7	0.005	0.006	0.007	0.006	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.006	0.008
5.9	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.007
6.1	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.007	0.008
6.3	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.006	0.007	0.007	0.005	0.007
6.5	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.007	0.005	0.007
6.7	0.009	0.006	0.006	0.006	0.007	0.007	0.008	0.009	0.010	0.008	0.009	0.005	0.010
6.9	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.005	0.007
7.1	0.008	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.009	0.009	0.007	0.009
7.3	0.005	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.005	0.006
7.5	0.004	0.004	0.005	0.005	0.005	0.007	0.007	0.006	0.006	0.007	0.007	0.005	0.007
7.7	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.004	0.006
7.9	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.005	0.005	0.005	0.006	0.004	0.006
8.1	0.004	0.005	0.005	0.005	0.005	0.007	0.007	0.006	0.006	0.006	0.007	0.004	0.007
8.3	0.005	0.006	0.006	0.006	0.006	0.007	0.008	0.007	0.006	0.007	0.007	0.005	0.008
8.5	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.006	0.007	0.007	0.005	0.007
8.7	0.004	0.004	0.004	0.005	0.005	0.007	0.007	0.007	0.006	0.006	0.007	0.004	0.007
8.9	0.004	0.004	0.004	0.005	0.005	0.006	0.007	0.007	0.005	0.005	0.006	0.004	0.007

Phase C													
P_{bin} (%)	0	10	20	30	40	50	60	70	80	90	100	110	MAX
F [kHz]	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	I_h(%)	Ih(%)	Ih(%)	Ih(%)	(%)
2.1	0.042	0.038	0.023	0.016	0.053	0.055	0.058	0.068	0.071	0.083	0.090	0.060	0.090
2.3	0.039	0.025	0.024	0.019	0.038	0.038	0.038	0.046	0.052	0.059	0.065	0.041	0.065
2.5	0.032	0.026	0.033	0.019	0.030	0.042	0.047	0.049	0.050	0.059	0.064	0.058	0.064
2.7	0.042	0.049	0.057	0.037	0.040	0.055	0.058	0.063	0.068	0.079	0.086	0.064	0.086
2.9	0.026	0.046	0.045	0.037	0.029	0.040	0.039	0.048	0.055	0.061	0.067	0.065	0.067
3.1	0.053	0.040	0.028	0.027	0.017	0.052	0.060	0.061	0.059	0.061	0.068	0.064	0.068
3.3	0.046	0.026	0.033	0.033	0.064	0.122	0.099	0.080	0.086	0.094	0.103	0.074	0.122
3.5	0.028	0.034	0.050	0.035	0.087	0.126	0.055	0.071	0.106	0.103	0.114	0.078	0.126
3.7	0.021	0.031	0.053	0.037	0.040	0.062	0.143	0.118	0.110	0.085	0.094	0.055	0.143
3.9	0.015	0.023	0.037	0.023	0.029	0.037	0.098	0.106	0.095	0.074	0.082	0.026	0.106
4.1	0.011	0.016	0.016	0.016	0.018	0.021	0.022	0.029	0.030	0.026	0.029	0.017	0.030
4.3	0.009	0.012	0.012	0.013	0.013	0.015	0.014	0.020	0.042	0.034	0.037	0.014	0.042
4.5	0.008	0.009	0.010	0.011	0.011	0.013	0.012	0.014	0.030	0.026	0.029	0.011	0.030
4.7	0.013	0.015	0.016	0.016	0.016	0.017	0.016	0.017	0.017	0.018	0.020	0.017	0.020
4.9	0.006	0.007	0.008	0.008	0.008	0.009	0.009	0.009	0.010	0.011	0.012	0.009	0.012
5.1	0.006	0.007	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.010	0.011	0.008	0.011
5.3	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.009	0.007	0.009
5.5	0.005	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.006	0.008
5.7	0.005	0.006	0.007	0.006	0.007	0.007	0.007	0.007	0.007	0.008	0.009	0.006	0.009
5.9	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.008	0.006	0.008
6.1	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.007	0.008
6.3	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.005	0.008
6.5	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.007	0.005	0.007
6.7	0.009	0.006	0.006	0.006	0.007	0.008	0.008	0.009	0.010	0.008	0.009	0.005	0.010
6.9	0.005	0.005	0.005	0.005	0.005	0.007	0.006	0.006	0.006	0.007	0.007	0.005	0.007
7.1	0.008	0.007	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.009	0.010	0.007	0.010
7.3	0.005	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.005	0.006	0.006	0.005	0.006
7.5	0.004	0.004	0.005	0.005	0.005	0.007	0.007	0.006	0.006	0.007	0.007	0.005	0.007
7.7	0.004	0.004	0.005	0.005	0.005	0.006	0.007	0.006	0.006	0.006	0.007	0.004	0.007
7.9	0.004	0.004	0.004	0.004	0.005	0.006	0.006	0.005	0.005	0.005	0.006	0.004	0.006
8.1	0.004	0.005	0.005	0.005	0.005	0.007	0.007	0.007	0.006	0.006	0.007	0.004	0.007
8.3	0.005	0.006	0.006	0.006	0.006	0.007	0.008	0.007	0.007	0.007	0.007	0.005	0.008
8.5	0.005	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.006	0.006	0.007	0.005	0.007
8.7	0.004	0.004	0.005	0.005	0.005	0.007	0.007	0.007	0.006	0.006	0.007	0.004	0.007
8.9	0.004	0.004	0.004	0.005	0.005	0.006	0.007	0.007	0.006	0.005	0.006	0.004	0.007

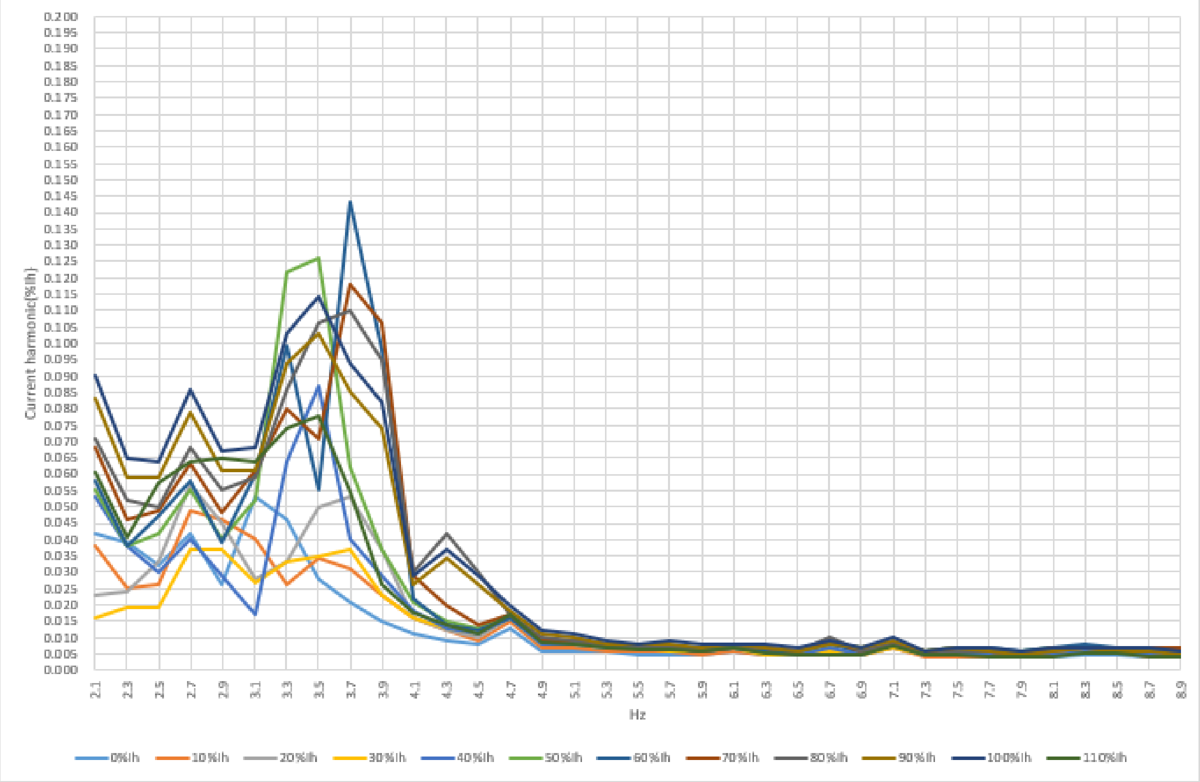
Current high frequency harmonics (Phase A)



Current high frequency harmonics (Phase B)



Current high frequency harmonics (Phase C)



4.3.4 Unbalances

The aim of this test is to determinate the unbalance in the PGU's fed-in current.

This test was performed according to point 4.3.5 of the standard.

They have been determined the unbalance between positive and negative sequences for currents (U_i) using following equation:

$$U_i = (I_{1-} / I_{1+}) \cdot 100\ \%$$

They have been measured currents and voltages at each power level, taking into account the positive and negative phase sequence system components, as well as the active power positive sequence.

All measurements have been recorded, at least 2 minutes per power level.

Additional information about the testing is provided below:

Measurement device	Date of measurement	Recording	Sampling frequency
DEWE2-A4	2020/03/13, 2020/8/19	100 ms values	10 kHz

Test results represented in the table below are calculated as 1 minute mean values and they represent the maximum unbalance. Voltage calculations are represented as line values.

P_n (%Sn)	P Measured (%Sn)	V_{1+} (V)	V_{1-} (V)	I_{1+} (A)	I_{1-} (A)	U_i (%)	Number of records
0%	83.6	230.0	0.2	1.4	0.1	4.7	1
10%	10.5	230.0	0.2	5.1	0.1	1.4	1
20%	19.8	230.0	0.2	9.5	0.1	0.8	1
30%	30.2	230.1	0.2	14.5	0.1	0.5	1
40%	40.0	230.1	0.2	19.1	0.1	0.4	1
50%	50.3	230.1	0.2	24.0	0.1	0.3	1
60%	60.5	230.1	0.2	28.9	0.1	0.3	1
70%	70.5	230.1	0.2	33.7	0.1	0.2	1
80%	80.6	230.1	0.2	38.5	0.1	0.2	1
90%	90.6	230.2	0.2	43.3	0.1	0.1	1
100%	100.4	230.2	0.2	48.0	0.1	0.1	1
110%	109.5	230.8	1.7	52.2	0.7	1.4	1

According to VDE-AR-N 4110: 2018-11, from the 10%Pn, the generating unit shall not exceed a maximum limit defined at 1.5% for VDE-AR-N 4110: 2018-11.

4.4 DISCONNECTING THE PGU FROM THE GRID

These tests have been performed according to point 4.4 of the standard.

The aim of this test is to determine the functional capability of the grid protection and the operating range of the PGU-protection for type testing purposes.

Two different levels of voltage and frequency have been set (In overvoltage, undervoltage, overfrequency and underfrequency) in order to see that this value is configurable and all the values are in compliance with the trip limits, according to the mínimum and máximum possible trigger values and times.

Measurement for determination of under and overvoltage as well as under- and over-frequency characteristics (release values, release times and disengaging ratio) of EUT's grid protection unit are carried out as described subsequent. The settings of internal variable for the grid protection unit are given by the manufacturer.

The under and overvoltage conditions have been applied to each phase alone and to all the phases at the same time in order to see that the place of the fault is not a condition for the inverter to trip.

This test has been done performing two different tests:

- Trip voltage or frequency test, to asses that the protection function of the inverter works as the voltage and frequency levels stated by the standard.
- Trip time test, to asses that the disconnection of the inverter takes place into the time limits established by the standard.

In accordance with the table 4-49 of the standard, recommended grid protection parameters for compliance with standards VDE AR-N 4110:2018 are presented below:

Function	Test case	Trigger threshold	Trigger time
Overvoltage U>	U1	Min. threshold	Max. time
		100% Un	180.00 s
	U2	Max. threshold	Min. time
		130% Un	0.00 s
Overvoltage U>>	U3	Min. threshold	Max. time
		100% Un	0.10 s
	U4	Max. threshold	Min. time
		130% Un	0.10 s
Under-voltage U<	U5	Min. threshold	Min. time
		10% Un	0.00 s
	U6	Max. threshold	Max. time
		100% Un	2.40 s
Under-voltage U<<	U7	Min. threshold	Min. time
		10% Un	0.00 s
	U8	Max. threshold	Max. time
		100%Un	0.80 s

Function	Test case	Trigger threshold	Trigger time
Overfrequency F>	F1	Min. threshold	Max. time
		50 Hz	5.00 s
	F2	Max. threshold	Min. time
		55 Hz	0.00 s
	F3	Min. threshold	Min. time
		50 Hz	0.00 s
	F4	Max. threshold	Max. time
		55 Hz	5.00 s
Overfrequency F>>	F5	Min. threshold	Min. time
		50 Hz	0.00 s
	F6	Max. threshold	Max. time
		55 Hz	0.10 s
	F7	Min. threshold	Max. time
		50 Hz	0.10 s
	F8	Max. threshold	Min. time
		55 Hz	0.00 s
Underfrequency F<	F9	Min. threshold	Min. time
		45 Hz	0.00 s
	F10	Max. threshold	Max. time
		50 Hz	0.10 s
	F11	Min. threshold	Max. time
		45 Hz	0.10 s
	F12	Max. threshold	Min. time
		50 Hz	0.00 s

Following indications shall be taken into account to for test results offered.

Information relating trip pictures

Variable name	Colour	Definition
CH1		Trip Single
CH2		Output current (Phase A)
CH3		Output current (Phase B)
CH4		Output current (Phase C)

For testing the accuracy of trigger value, the procedure followed has been the following:

- For undervoltage protection: Starting from a voltage level 2% Un above the trip value of the protection function to be tested, the voltage is decreased 0.5% Un in steps of at least 150% of the trip time delay stated in the protection function to be tested, with a minimum step time of 0,1 seconds.

- For overvoltage protection: Starting from a voltage level 2% Un below the trip value of the protection function to be tested, the voltage is increased 0.5% Un in steps of at least 150% of the trip time delay stated in the protection function to be tested, with a minimum step time of 0,1 seconds.

- For underfrequency protection: Starting from a frequency level 0.2 Hz above the trip value of the protection function to be tested, the frequency is decreased 0.05Hz in steps of at least 150% of the trip time delay stated in the protection function to be tested, with a minimum step time of 0,1 seconds.

- For overfrequency protection: Starting from a frequency level 0.2 Hz below the trip value of the protection function to be tested, the frequency is increased 0.05 Hz in steps of at least 150% of the trip time delay stated in the protection function to be tested, with a minimum step time of 0,1 seconds.

Maximum deviation allowed in accuracy of trigger value threshold is 1% Un for abnormal voltage protection and 0.01Hz for abnormal frequency protection.

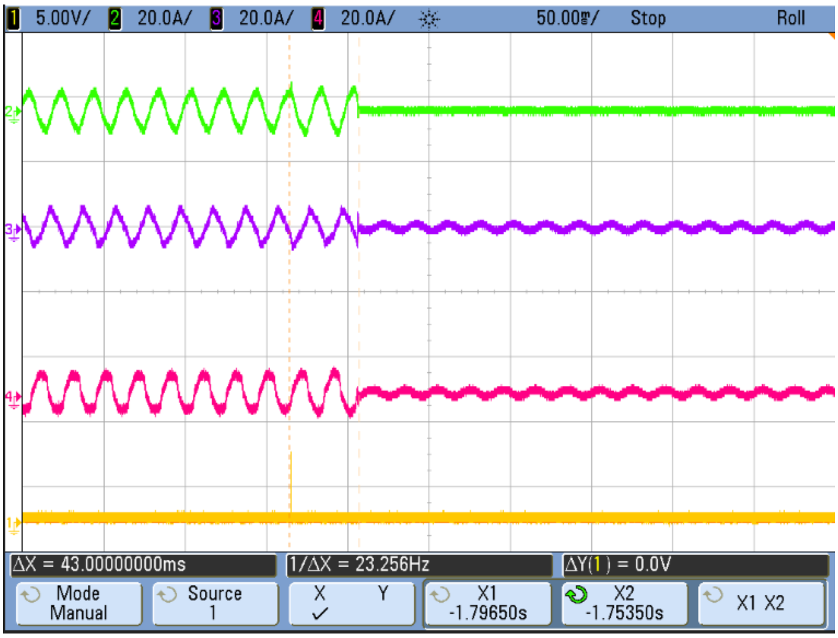
4.4.1 Circuit breaker operating time

The operation time of circuit breaker is always the same < 50 ms, this table shows the circuit breaker operation time:

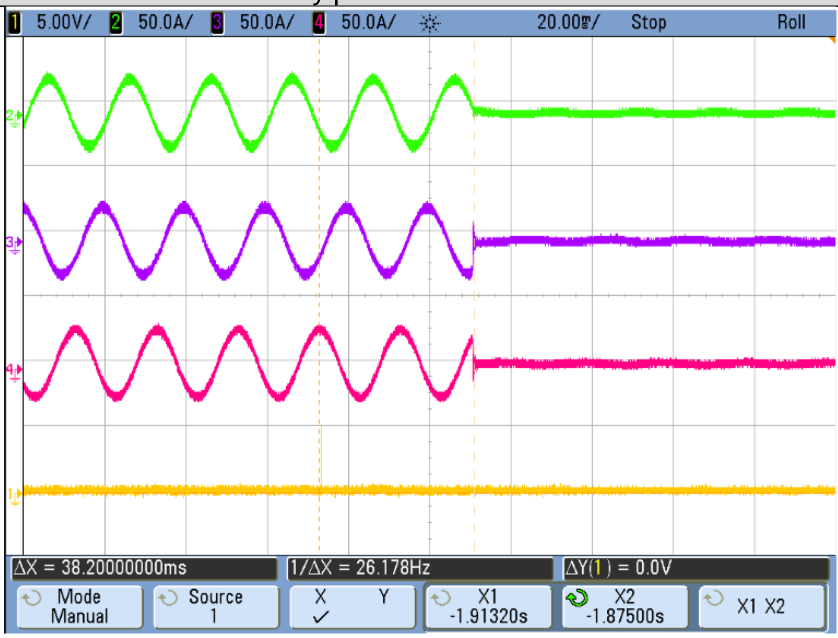
Testing the complete functional chain led to successful shutdown	☐ NO ☒ YES
Circuit breaker operating time	40 ms
Failure of auxiliary power led to immediate shutdown	☐ NO ☒ YES

The following picture shows an example of the circuit breaker operation.

Testing the complete functional chain led to successful shutdown



Failure of auxiliary power led to immediate shutdown



4.4.2 Over & undervoltage protection

Used settings of the measurement device for Over and undervoltage protection measurement.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000 PA5000H	2019/12/05, 2019/12/07,2019/12/08, 2019/12/09, 2019/12/10, 2020/03/06, 2020/03/08, 2020/03/14, 2020/03/16, 2020/03/19, 2020/03/24, 2020/04/30,2020/05/01	100 ms values	10kHz

For Over and Undervoltage protection test, the measurements have been carried out individually for all 3 phases and 3 phase test per each protection.

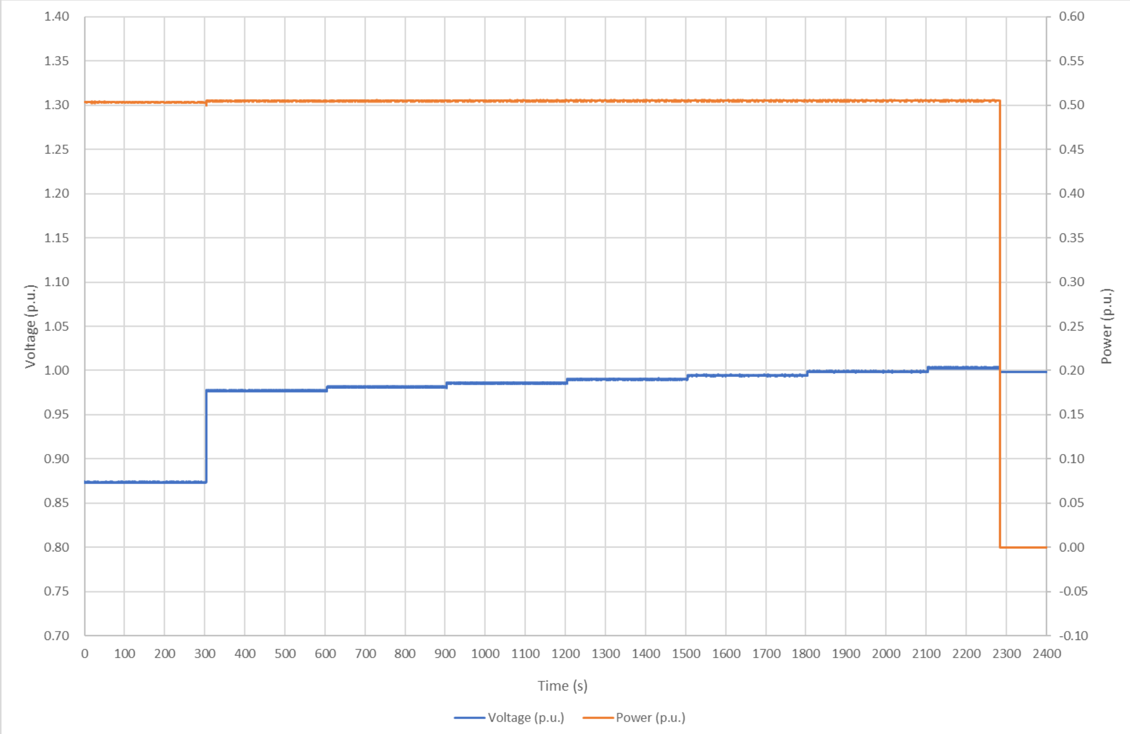
The following tables show the test results for trip value test and trip time test:

Overvoltage (U>)					
Settings	**Setting values**	**Trigger values/times**			
		3-phase	**U_{A-N}**	**U_{B-N}**	**U_{C-N}**
Min. threshold (Test case U1)	1.00Un	1.003Un	1.003Un	1.004Un	1.004Un
Max. time (Test case U1)	180.00s	179.990s	180.000s	180.000s	180.010s
Max. threshold (Test case U2)	1.30Un	1.299Un	1.304Un	1.304Un	1.303Un
Min. time (Test case U2)	0.0s	0.027s	0.040s	0.033s	0.035s
Overvoltage (U>>)					
Settings	**Setting values**	**Trigger values/times**			
		3-phase	**U_{A-N}**	**U_{B-N}**	**U_{C-N}**
Min. threshold (Test case U3)	1.00Un	0.998Un	1.002 Un	1.002 Un	1.002 Un
Max. time (Test case U3)	0.1s	0.125s	0.112s	0.112s	0.122s
Max. threshold (Test case U4)	1.30Un	1.304Un	1.303Un	1.304Un	1.304Un
Min. time (Test case U4)	0.1s	0.105s	0.101s	0.095s	0.102s
Undervoltage (U<)					
Settings	**Setting values**	**Trigger values/times**			
		3-phase	**U_{A-N}**	**U_{B-N}**	**U_{C-N}**
Min. threshold (Test case U5)	0.10Un	0.096Un	0.096Un	0.096Un	0.096Un
Min. time (Test case U5)	0.0s	0.035s	0.034s	0.035s	0.043s
Max. threshold (Test case U6)	1.00Un	0.999Un	0.998Un	0.999Un	0.998Un
Max. time (Test case U6)	2.40s	2.390s	2.390s	2.400s	2.395s

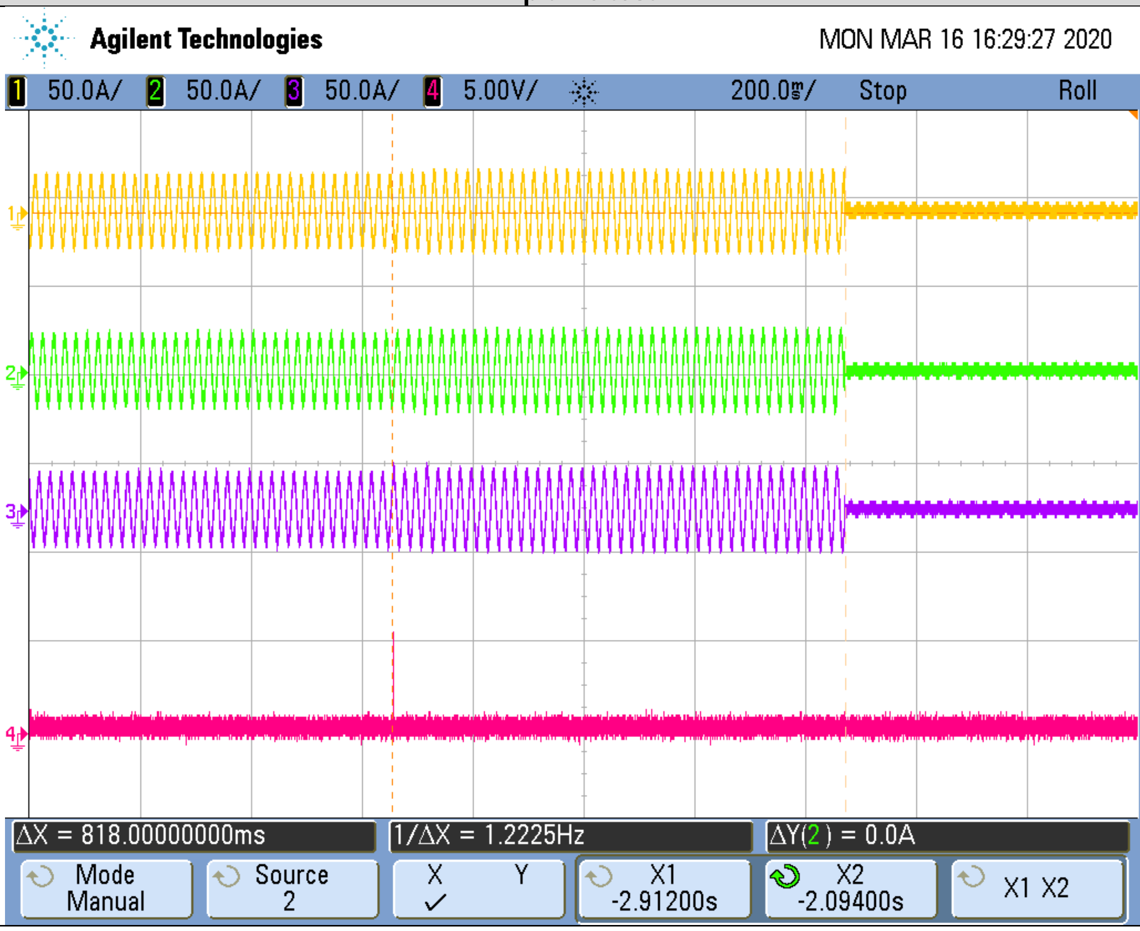
Undervoltage (U<<)					
Settings	**Setting values**	**Trigger values/times**			
		3-phase	**U_{A-N}**	**U_{B-N}**	**U_{C-N}**
Min. threshold (Test case U7)	0.10Un	0.099Un	0.099Un	0.099Un	0.099Un
Min. time (Test case U7)	0.10s	0.105s	0.093s	0.099s	0.090s
Max. threshold (Test case U8)	1.00Un	0.998 Un	0.999Un	0.998 Un	0.998 Un
Max. time (Test case U8)	0.800s	0.818s	0.814s	0.816s	0.820s

The following pictures show the result obtained:

Overvoltage (U>) (Test case U1)_3 Phases
Trip value test



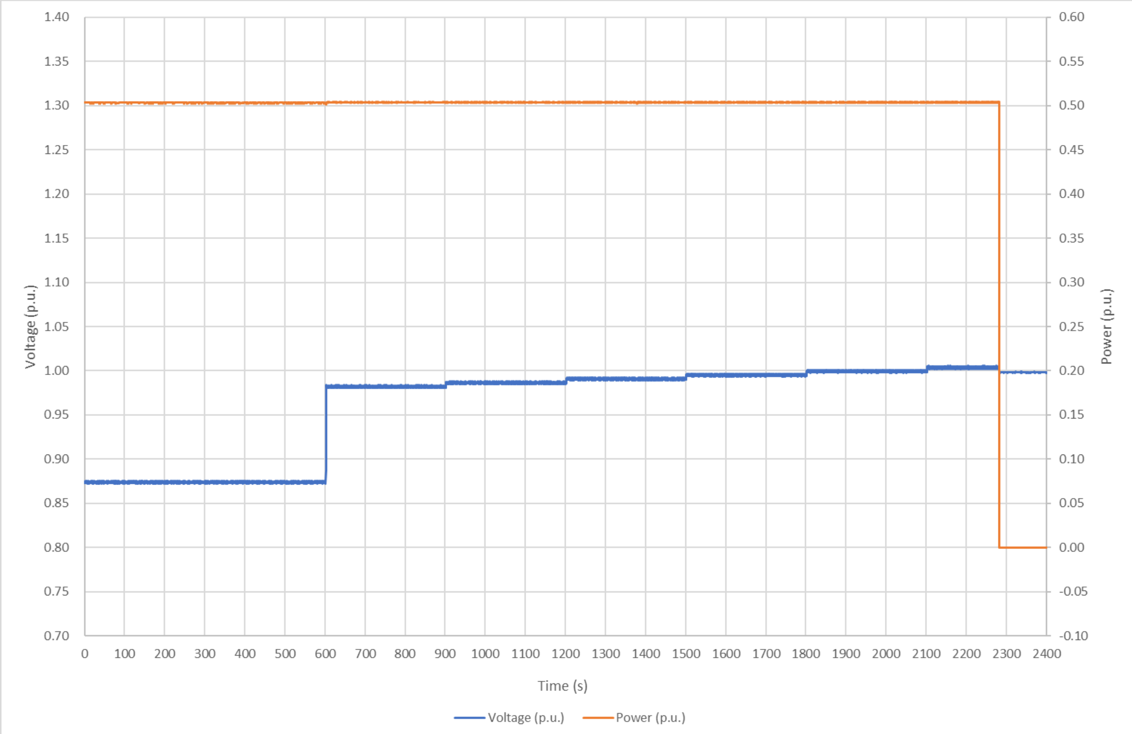
Trip time test



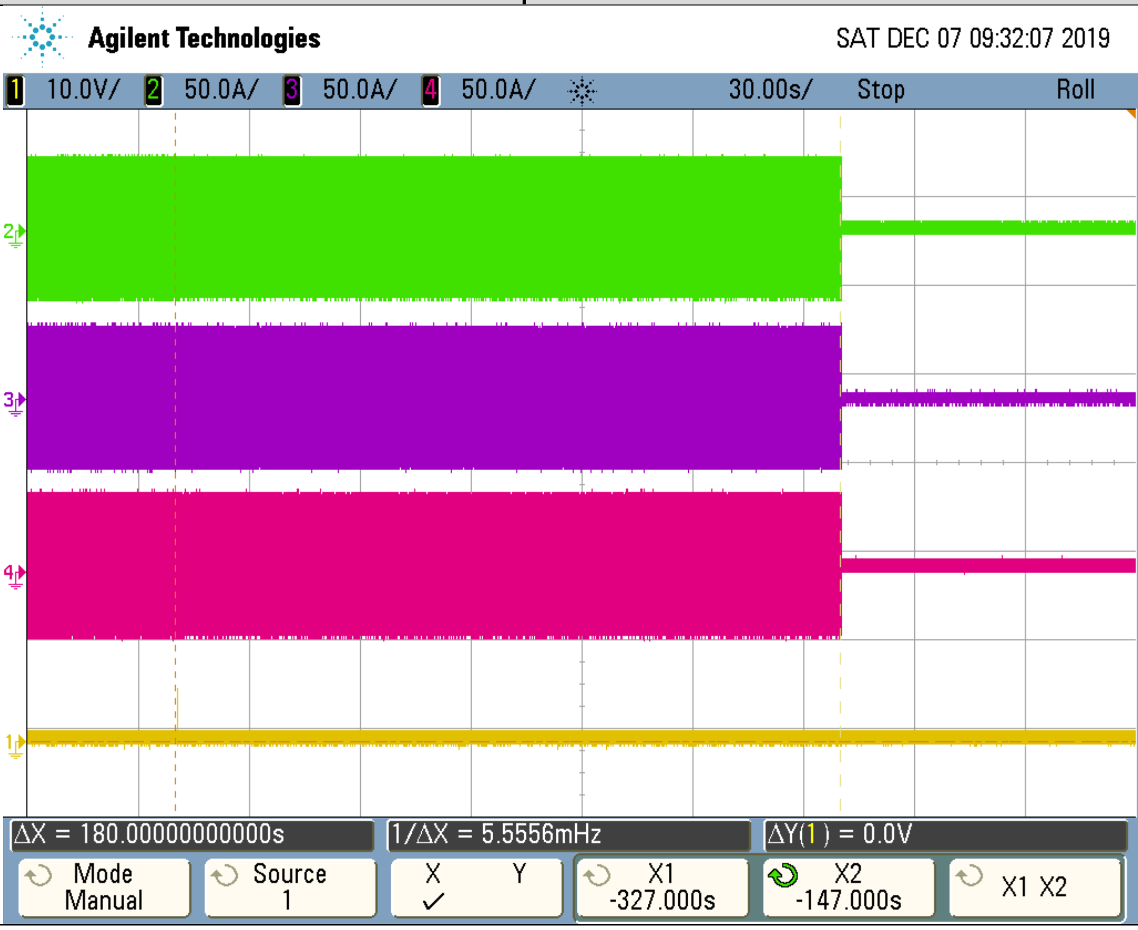
Trip time measured: 0.818 s

Overvoltage (U>) (Test case U1)_Phase A – Phase N

Trip value test

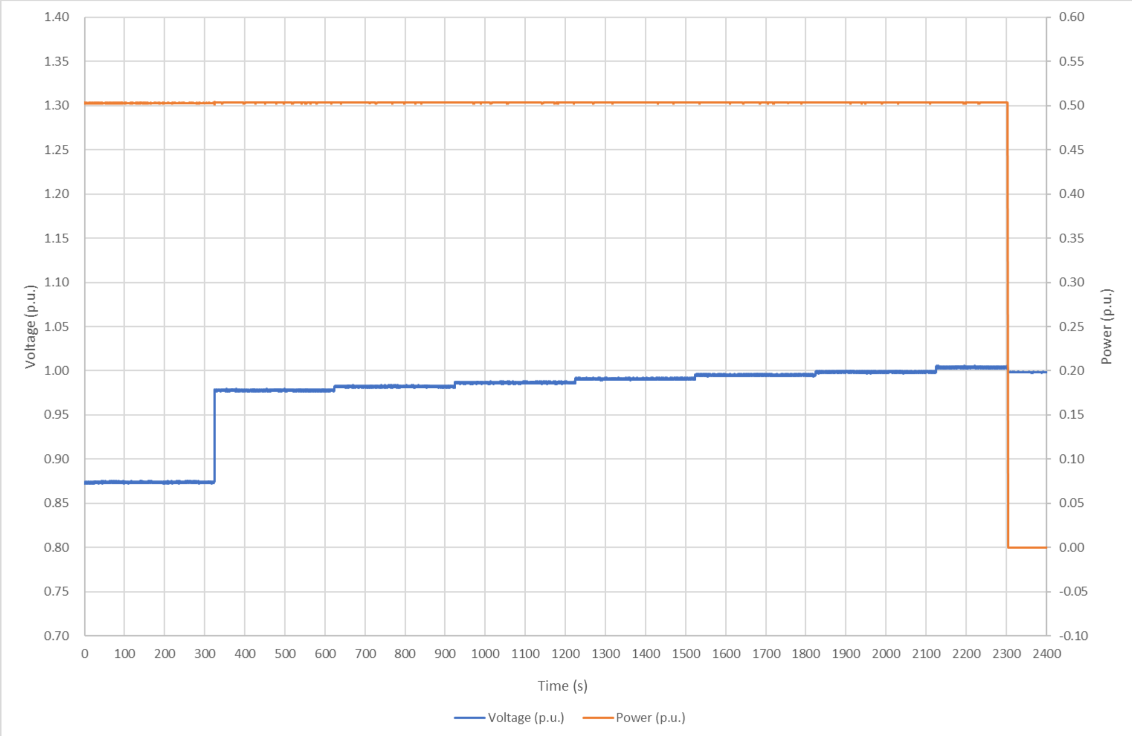


Trip time test

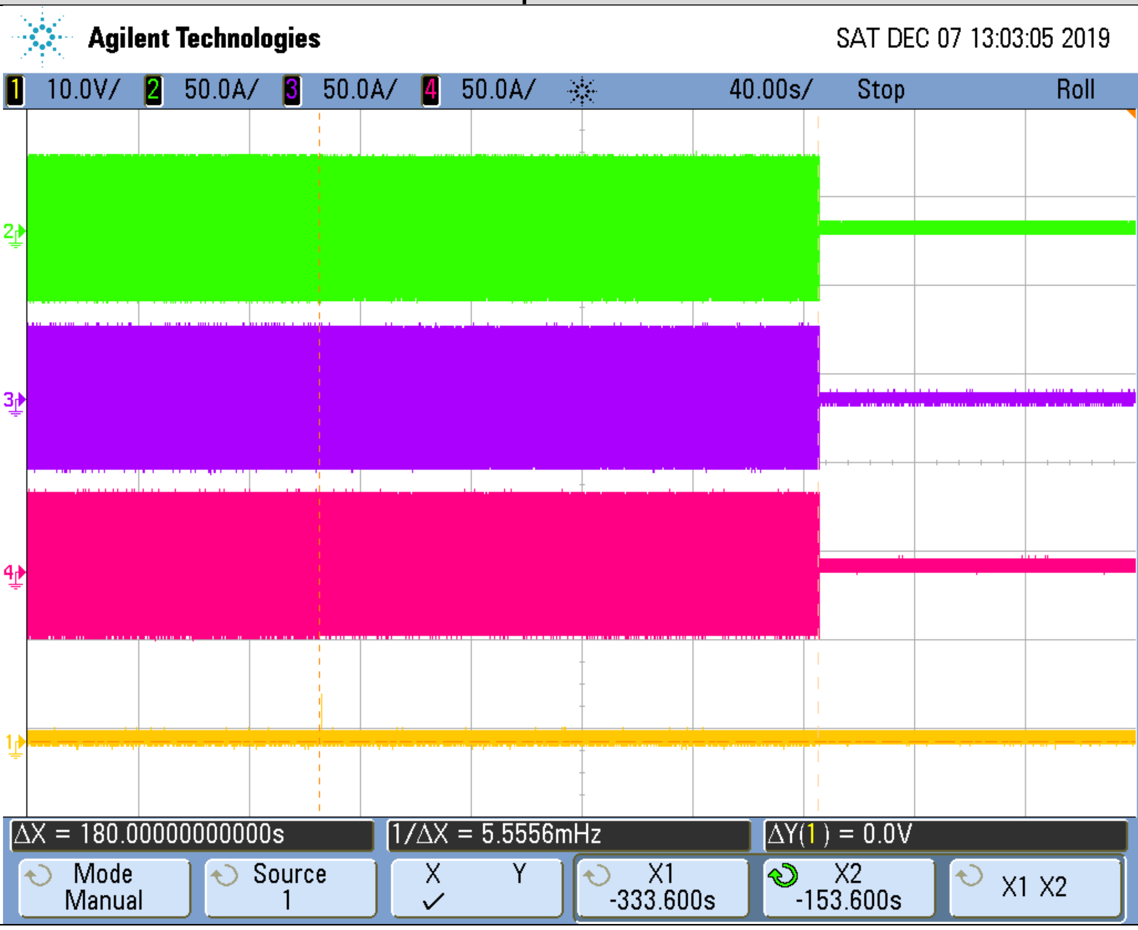


Trip time measured: 180.000 s

Overvoltage (U>) (Test case U1) _Phase B – Phase N
Trip value test

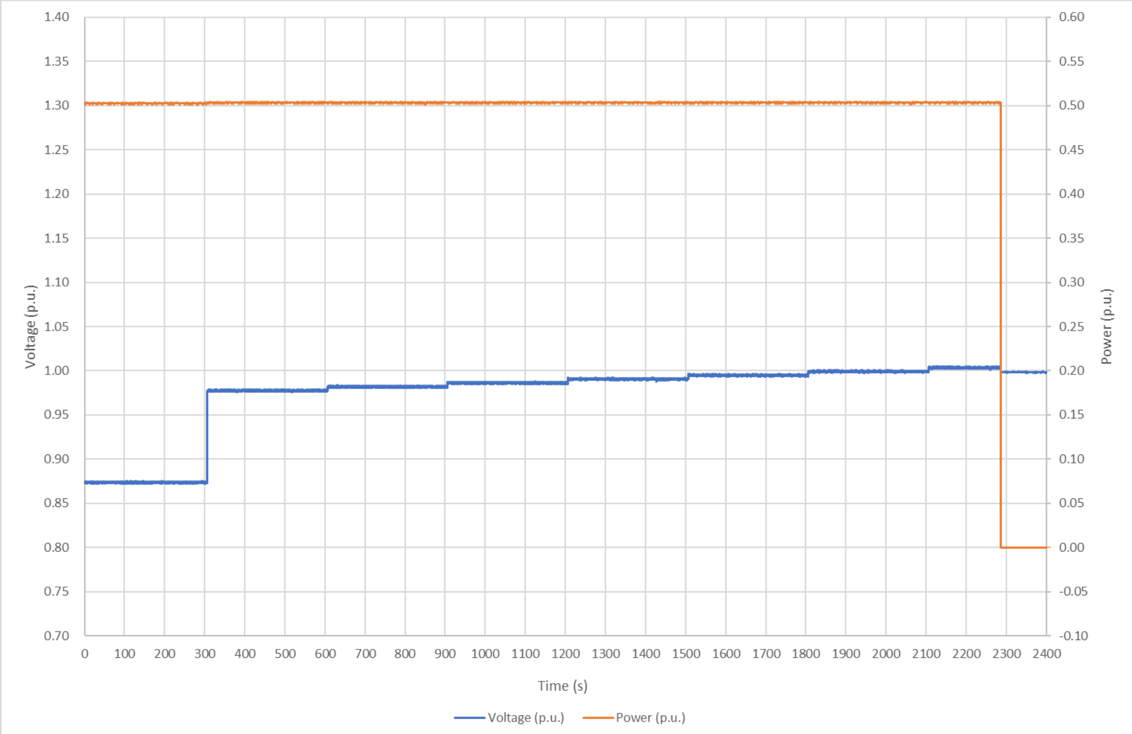


Trip time test

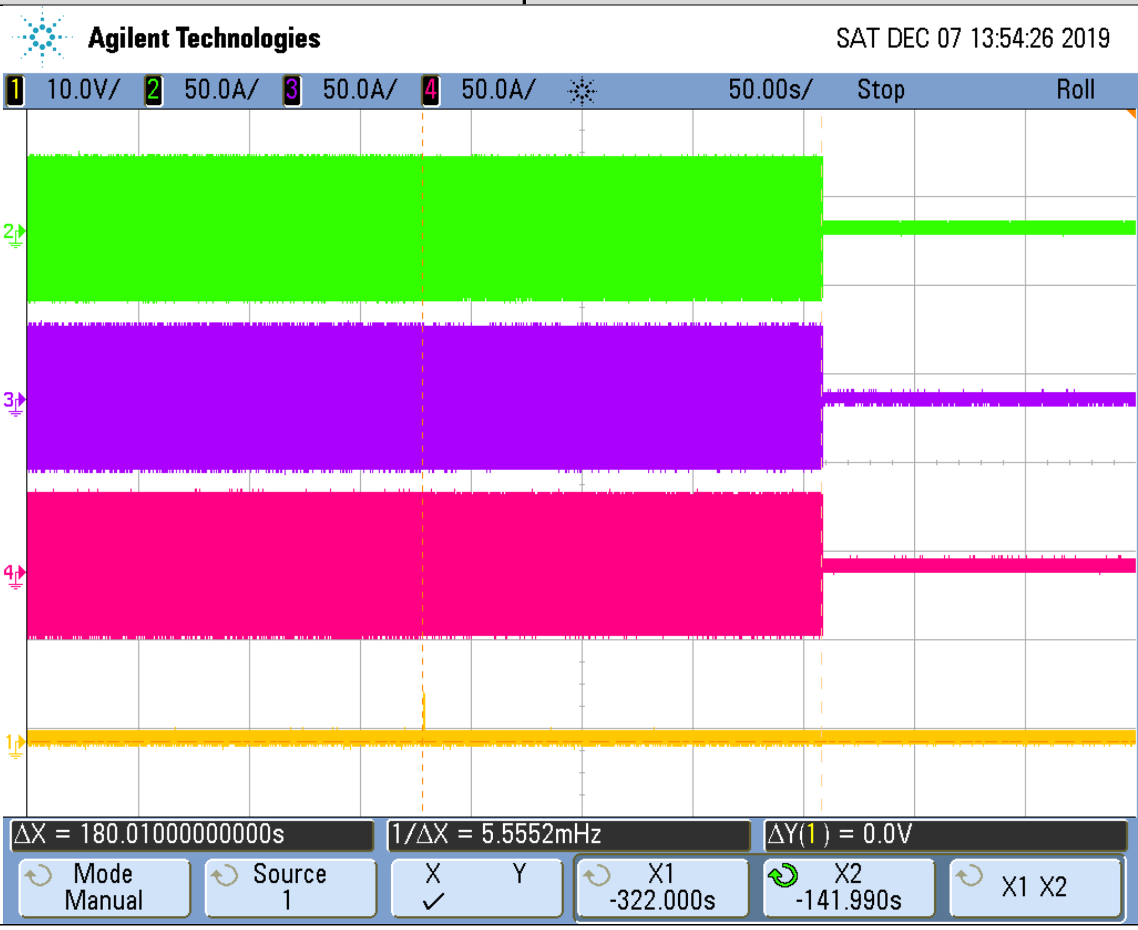


Trip time measured: 180.000 s

Overvoltage (U>) (Test case U1) _Phase C – Phase N
Trip value test

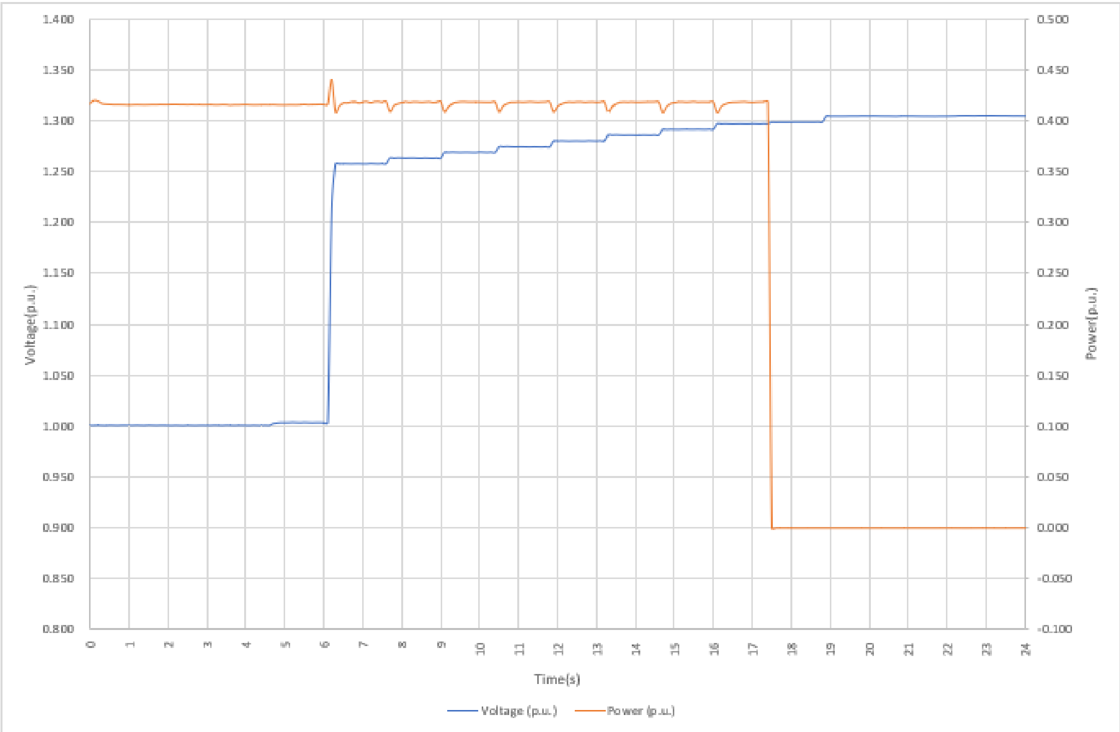


Trip time test

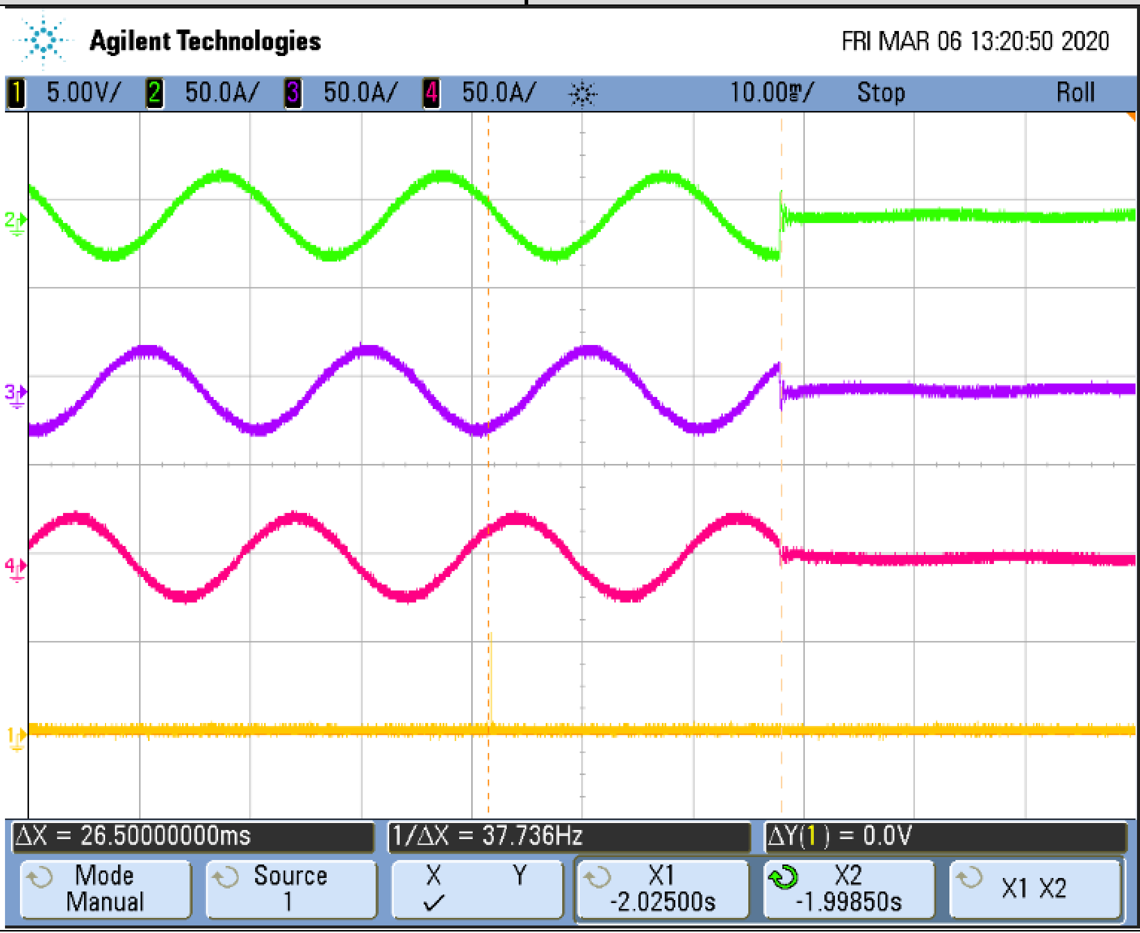


Trip time measured: 180.010 s

Overvoltage (U>) (Test case U2) _3 Phases
Trip value test

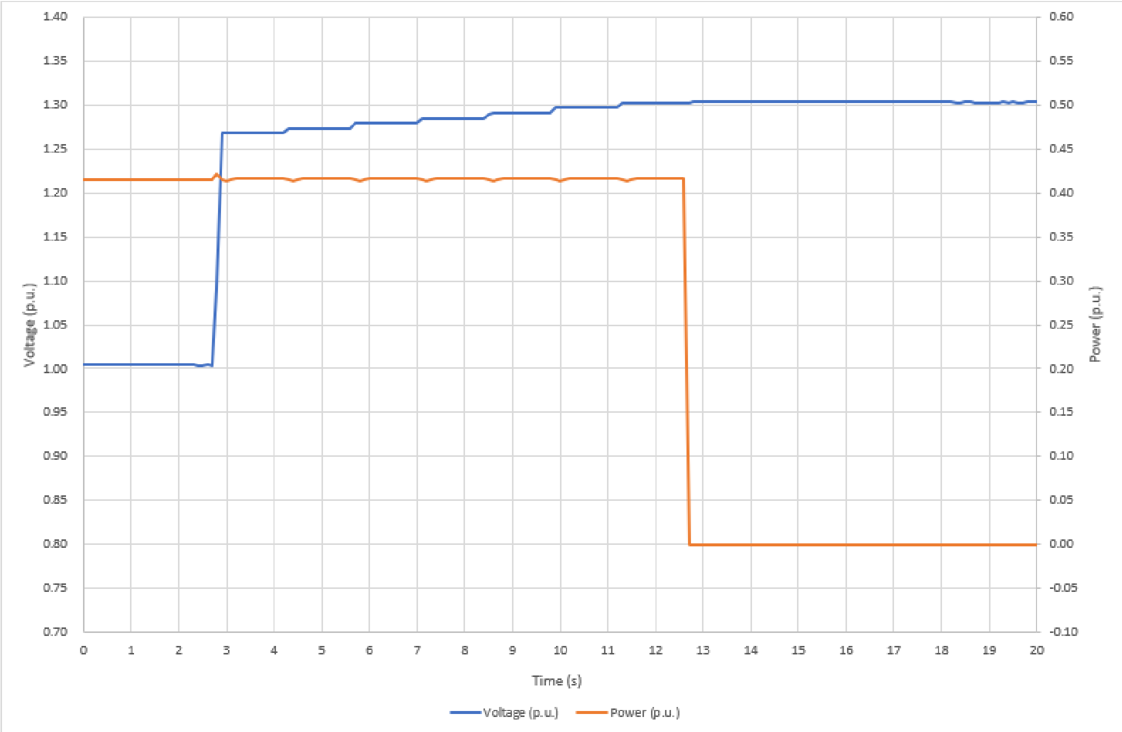


Trip time test

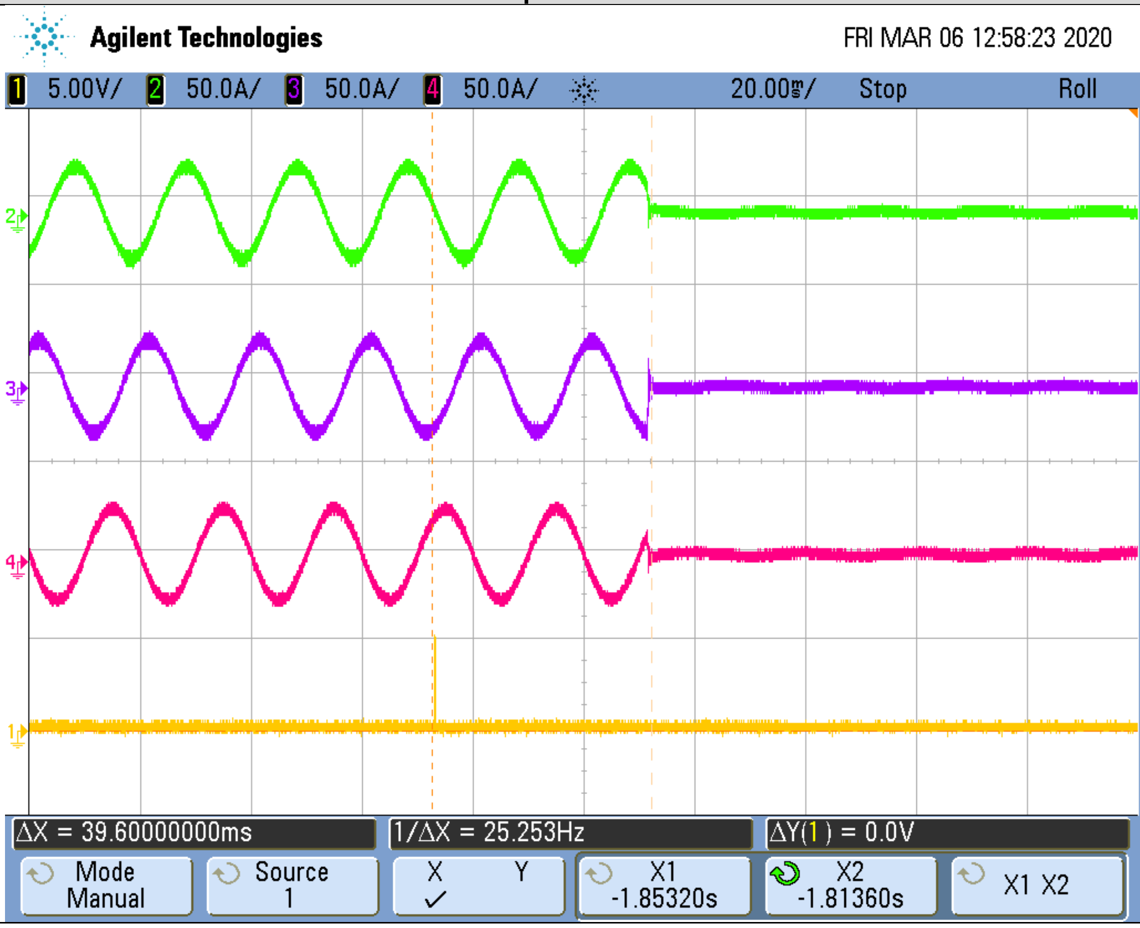


Trip time measured: 0.027s

Overvoltage (U>) (Test case U2) _Phase A – Phase N
Trip value test

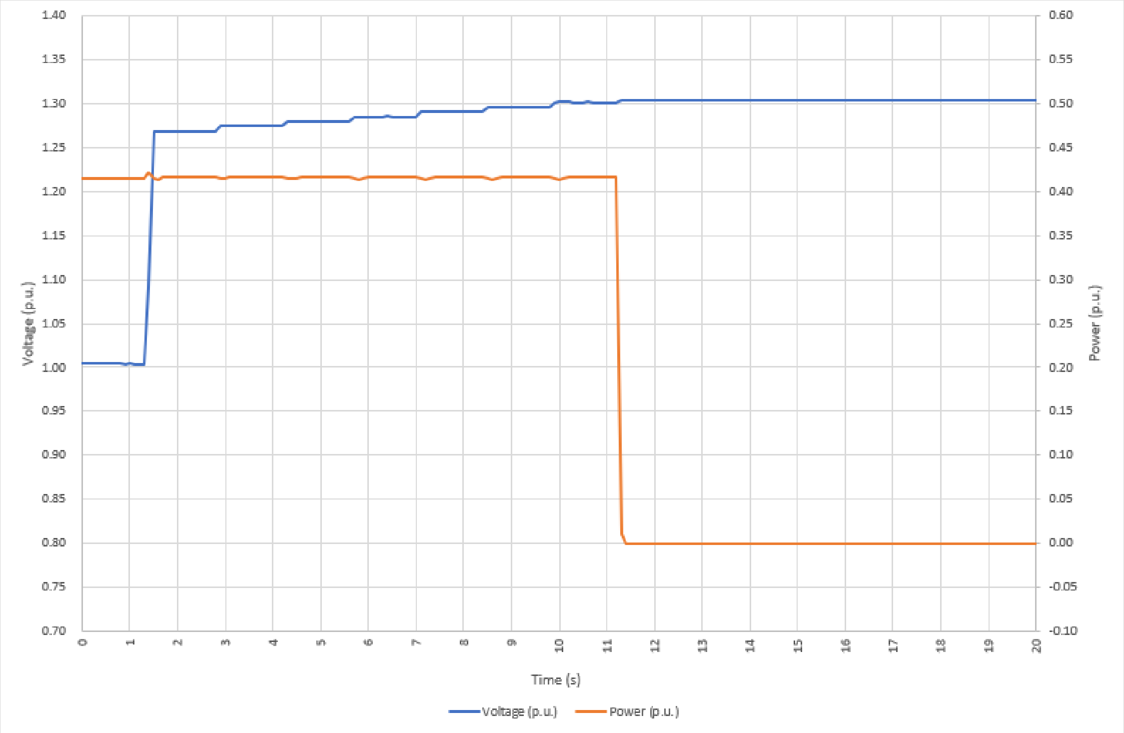


Trip time test

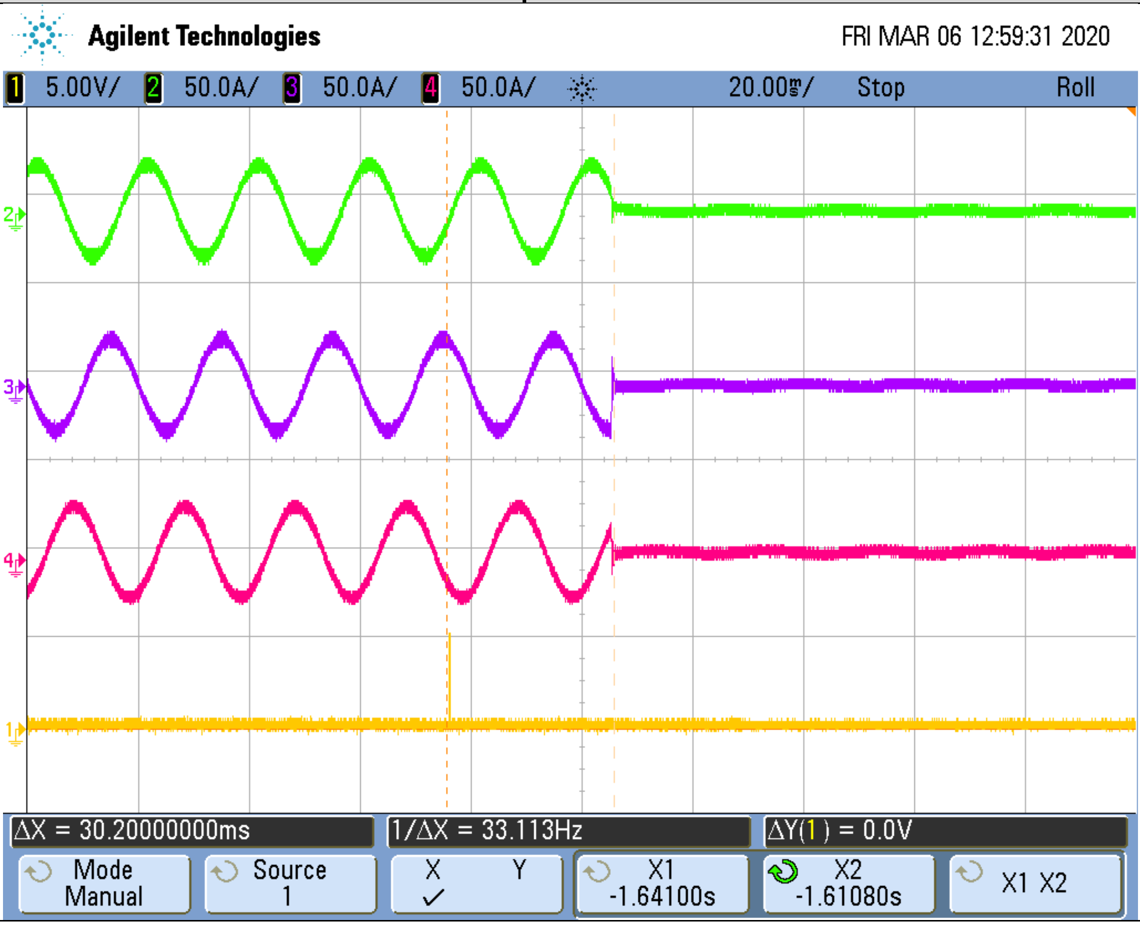


Trip time measured: 0.040s

Overvoltage (U>) (Test case U2) _Phase B – Phase N
Trip value test



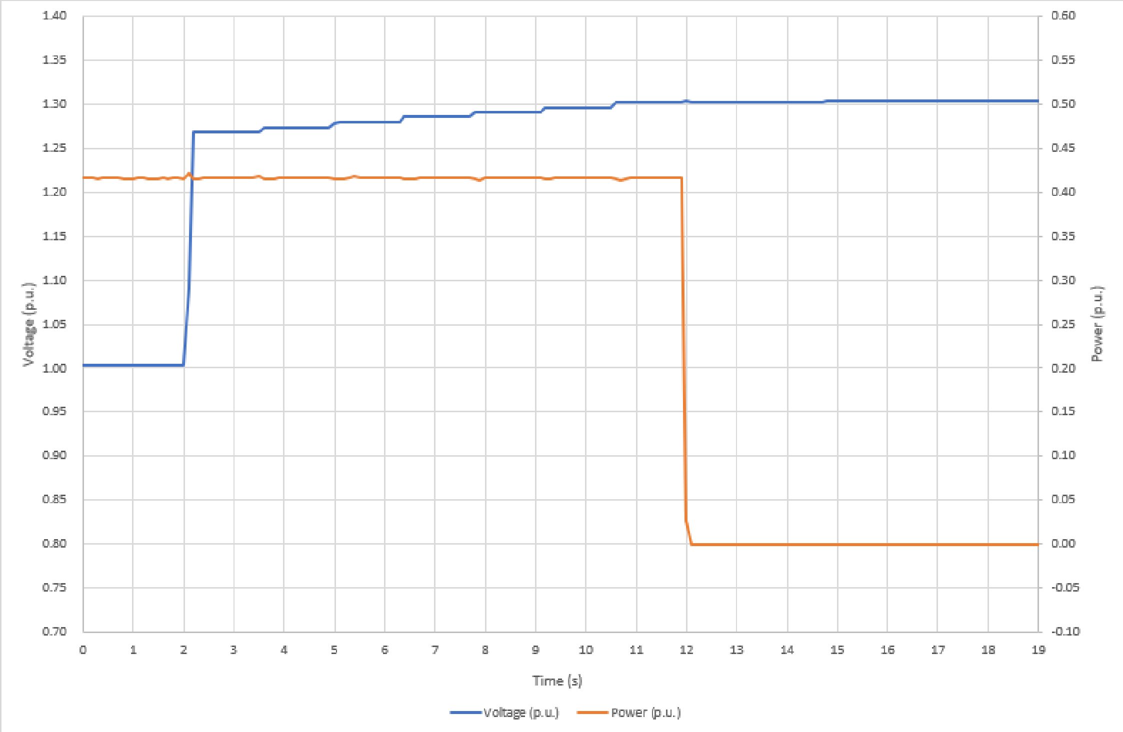
Trip time test



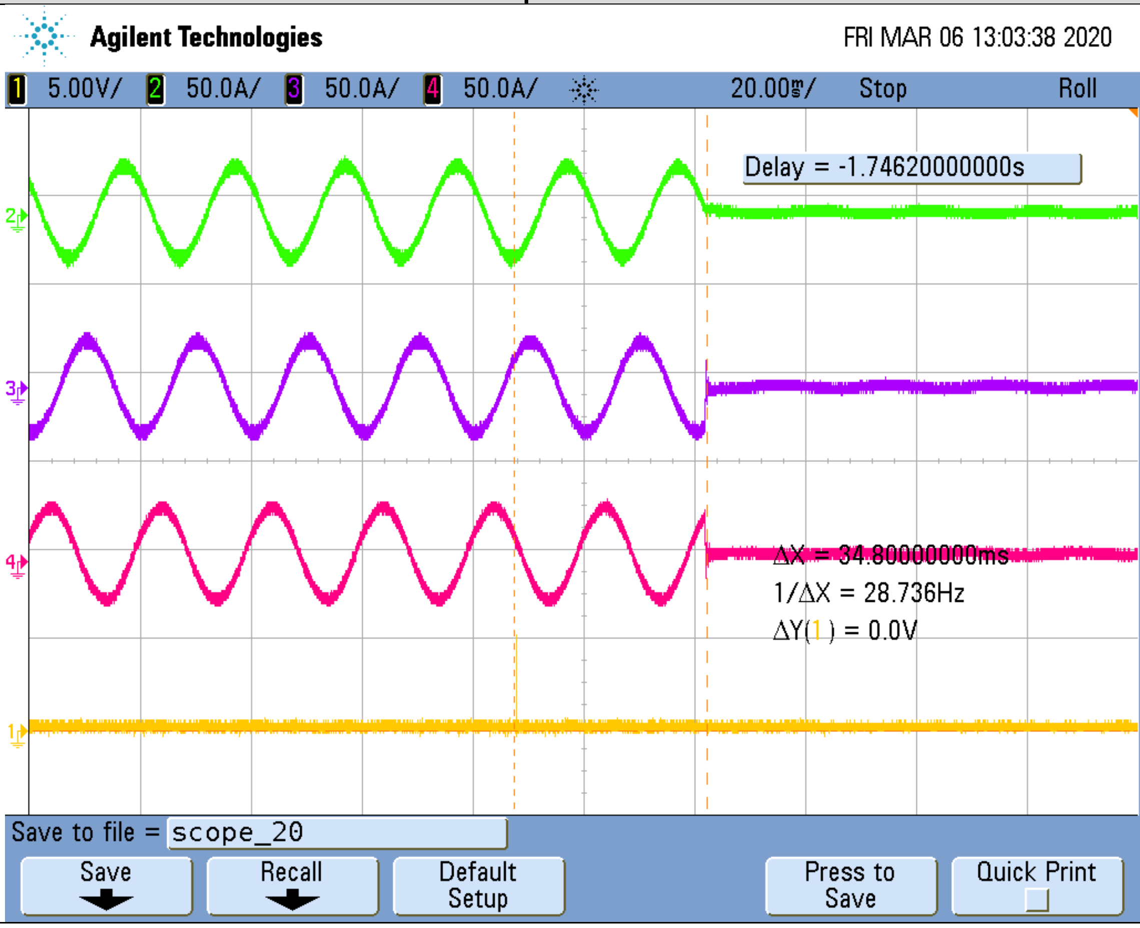
Trip time measured: 0.033s

Overvoltage (U>) (Test case U2) _Phase C – Phase N

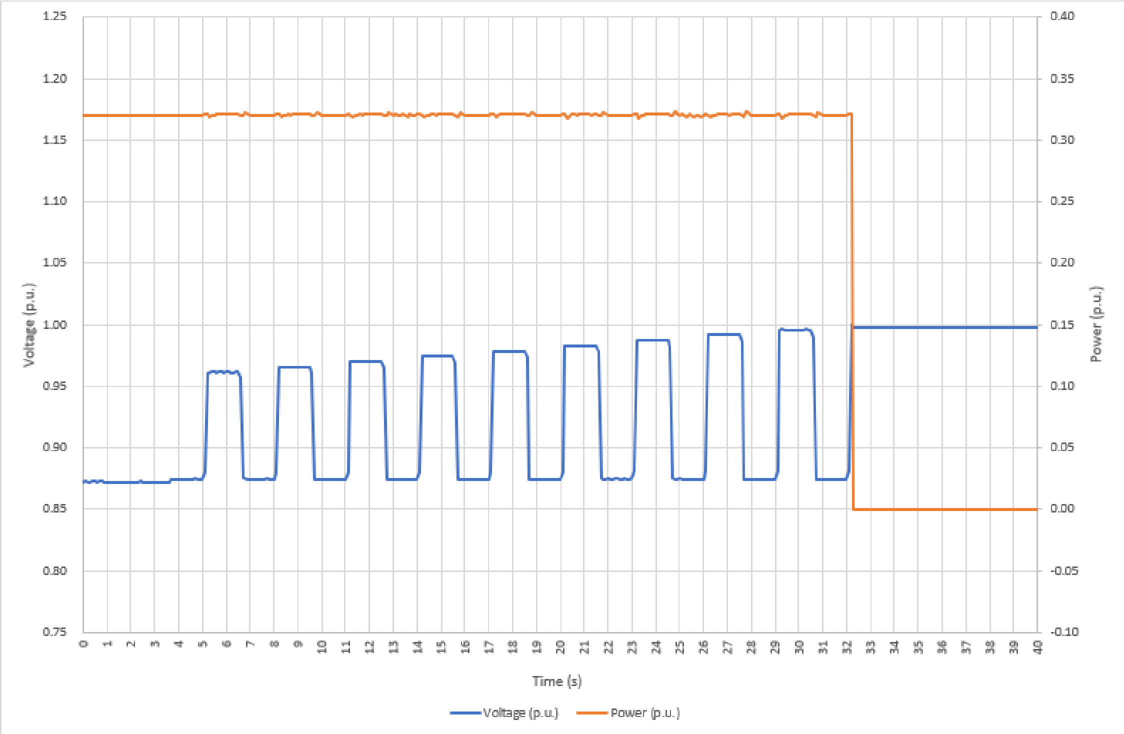
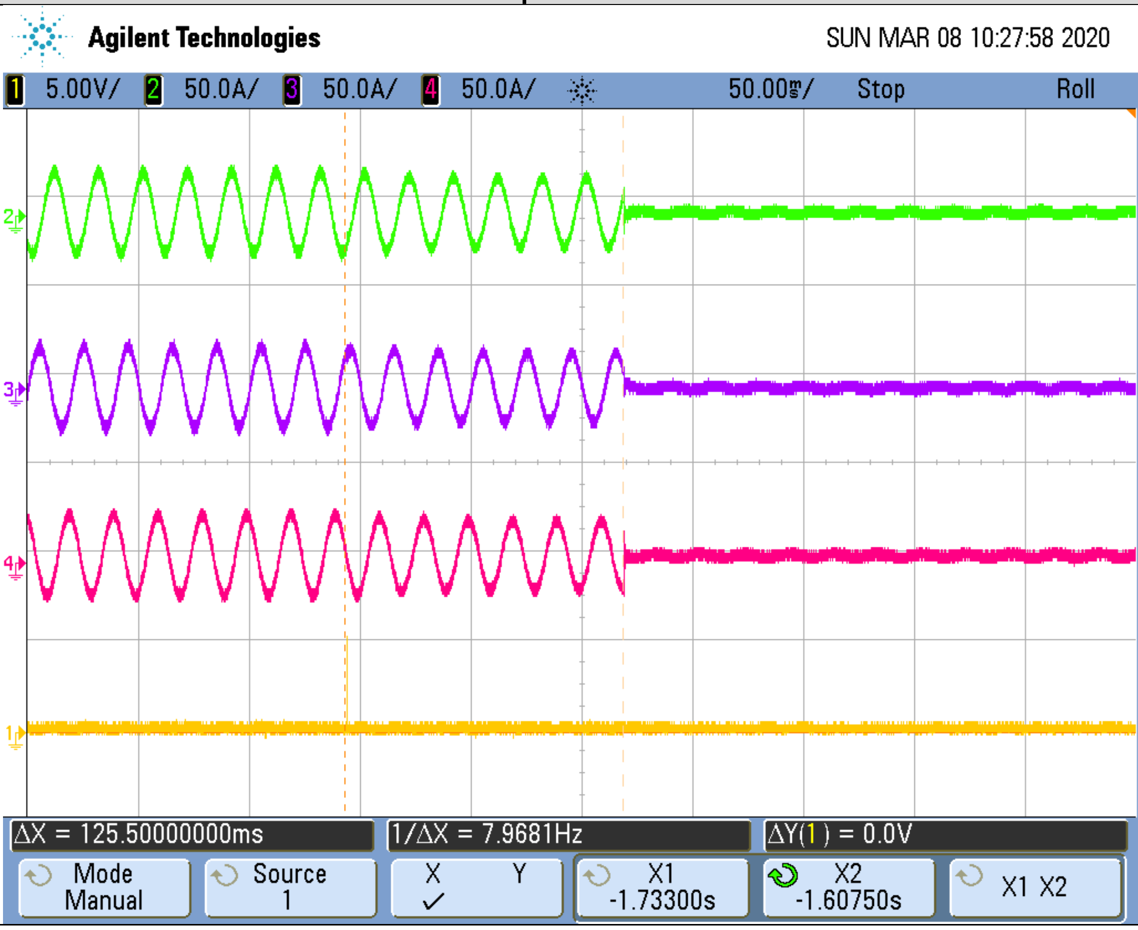
Trip value test



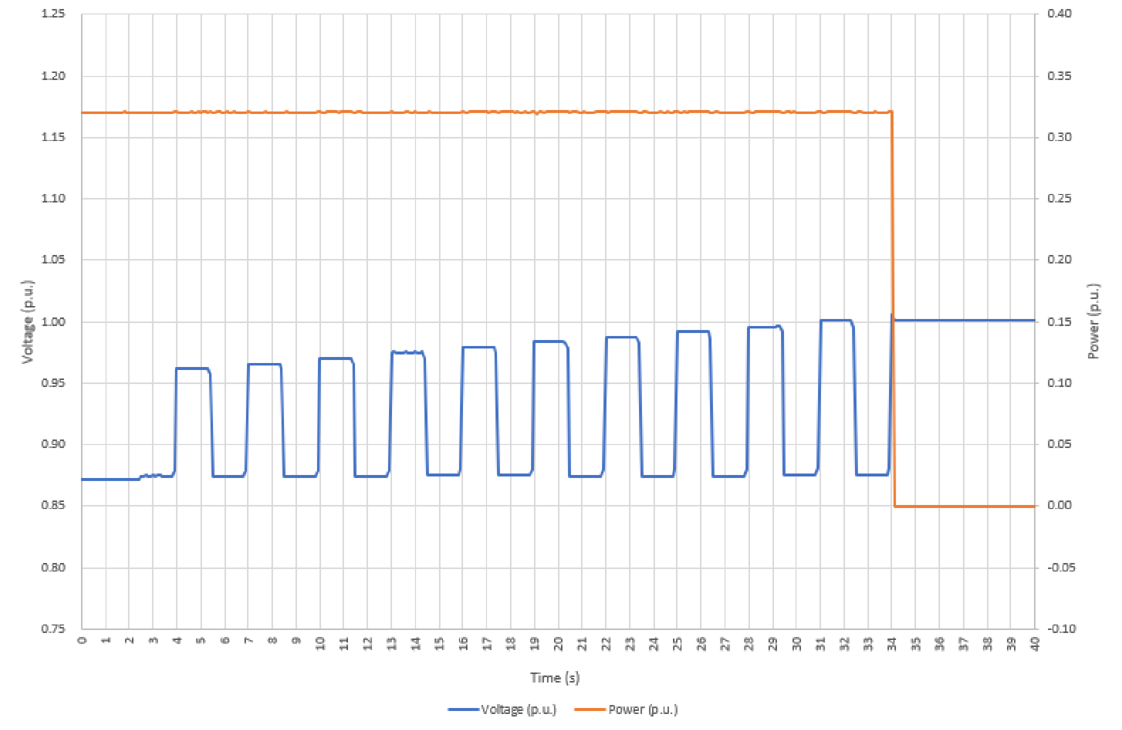
Trip time test



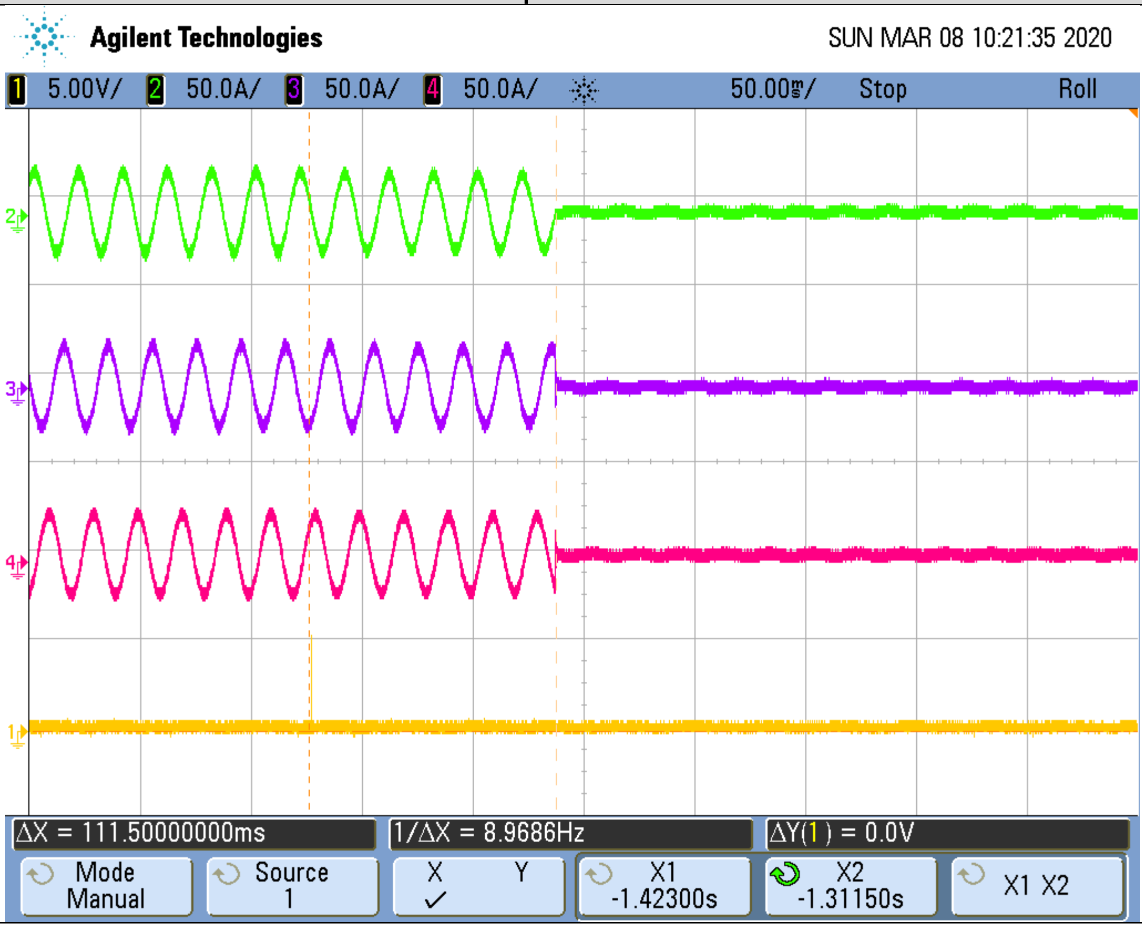
Trip time measured: 0.035s

Overvoltage (U>>) (Test case U3) _ 3 Phases
Trip value test

Trip time test

Trip time measured: 0.126s

Overvoltage (U>>) (Test case U3) _Phase A – Phase N
Trip value test



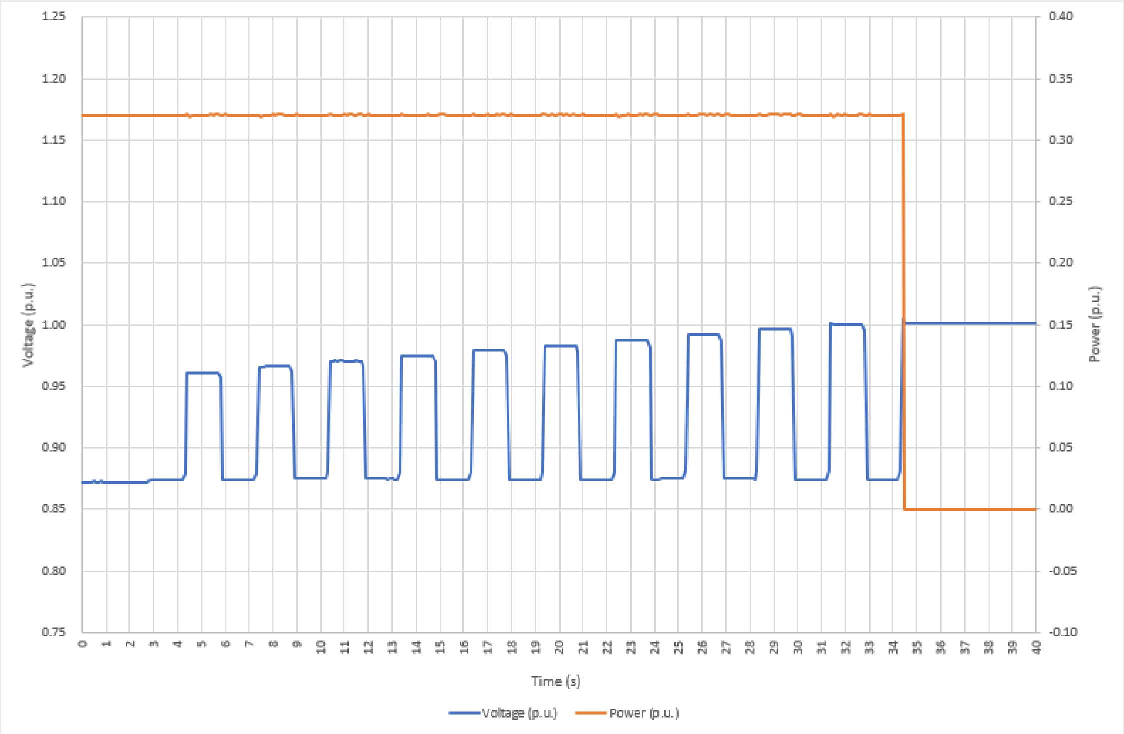
Trip time test



Trip time measured:0.112 s

Overvoltage (U>>) (Test case U3) _Phase B – Phase N

Trip value test

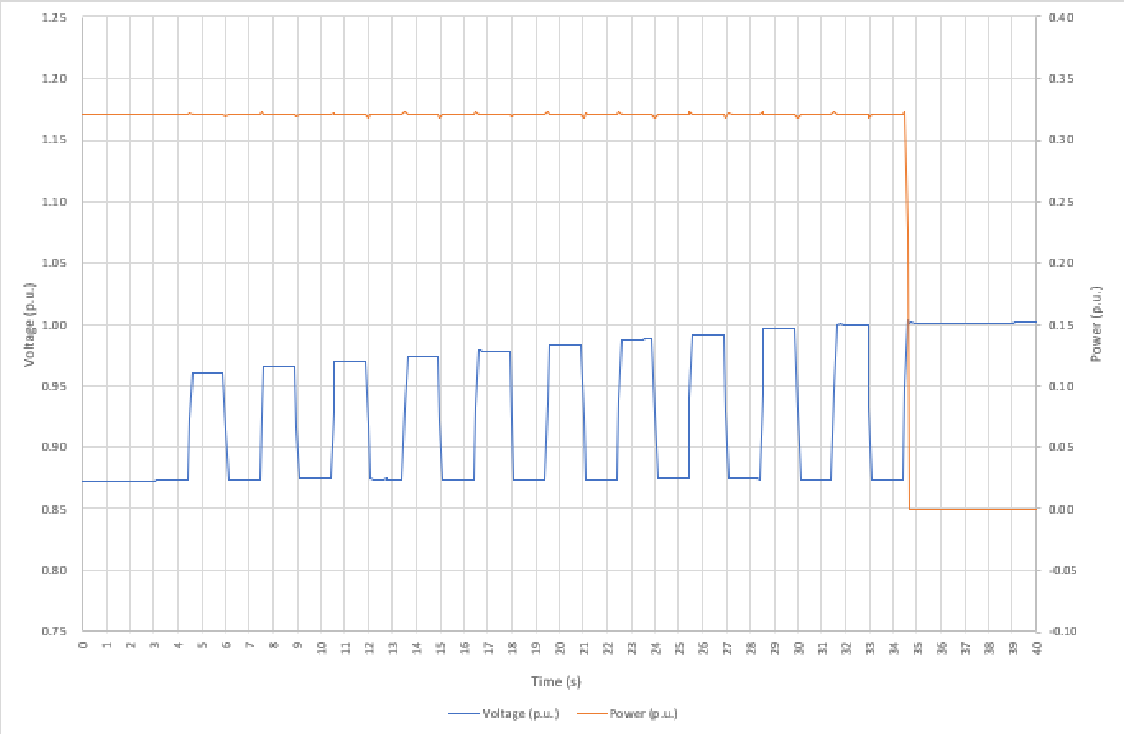


Trip time test

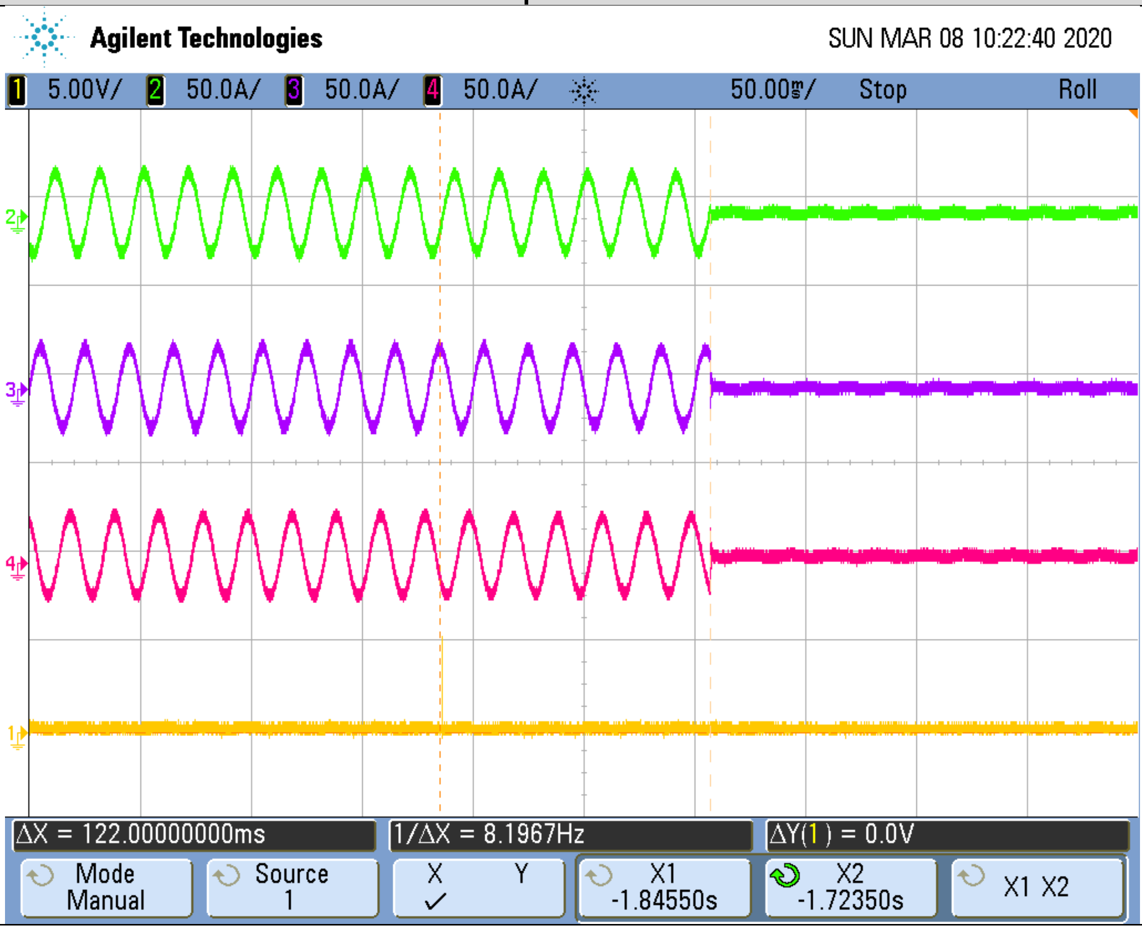
Trip time measured:0.112 s

Overvoltage (U>>) (Test case U3) _ Phase C – Phase N

Trip value test



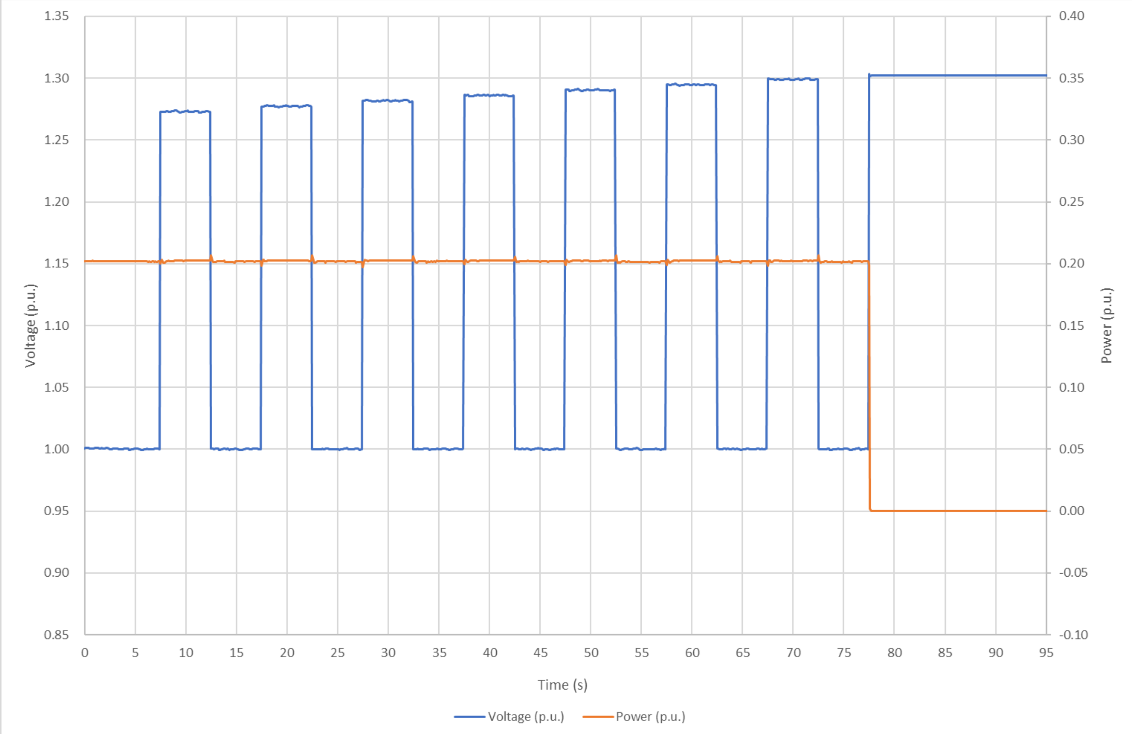
Trip time test



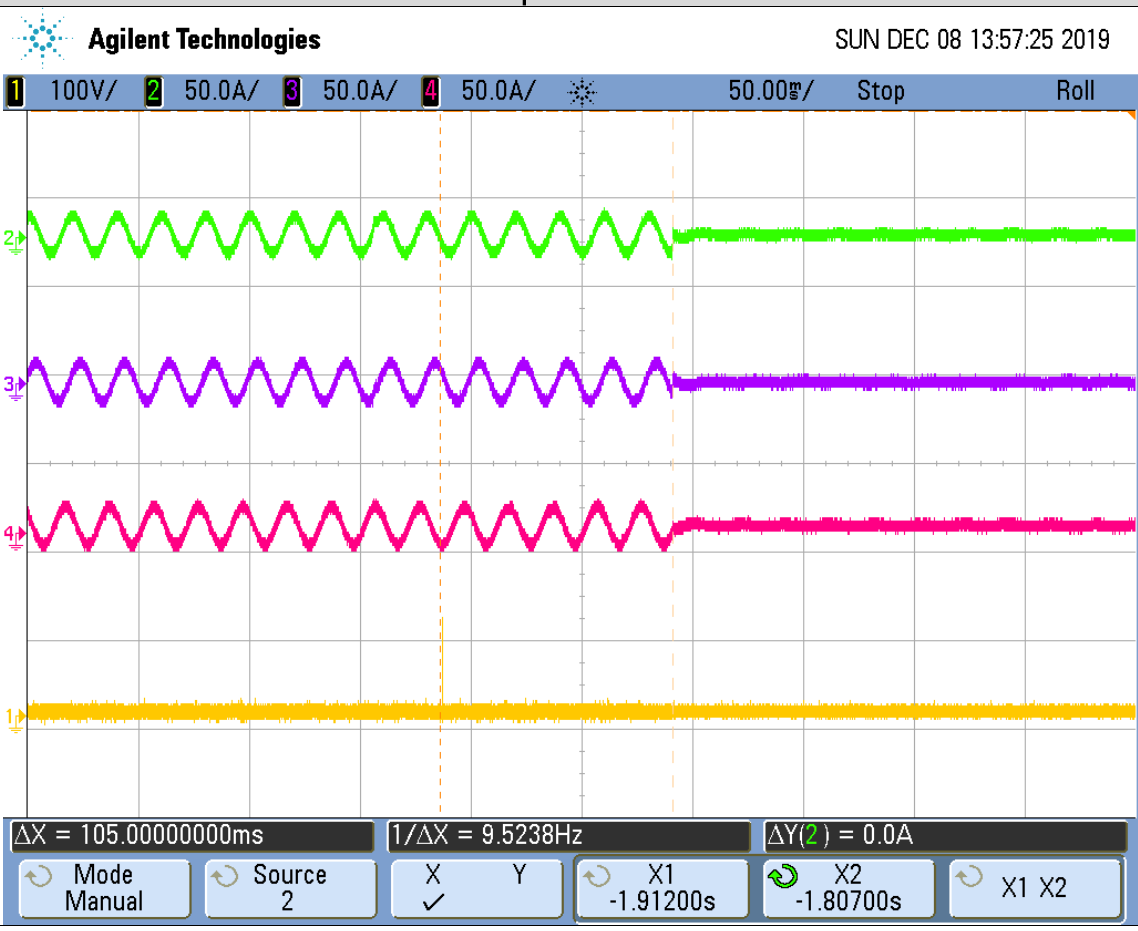
Trip time measured: 0.122s

Overvoltage (U>>) (Test case U4) _ 3 Phase

Trip value test



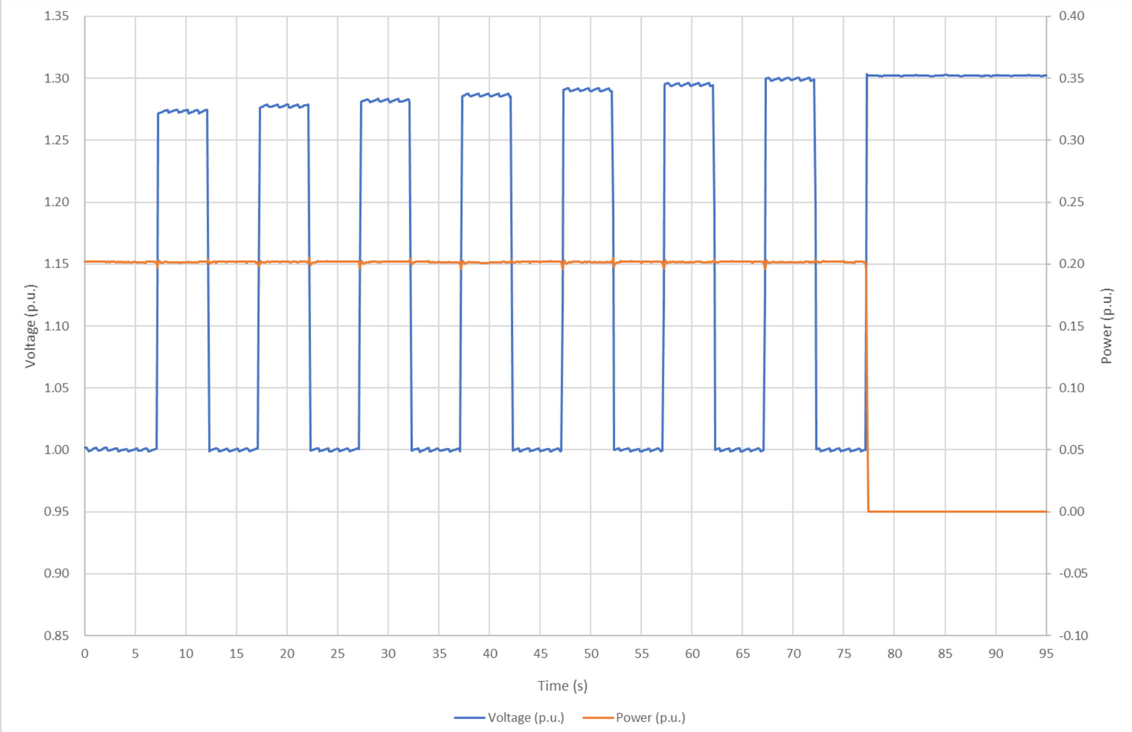
Trip time test



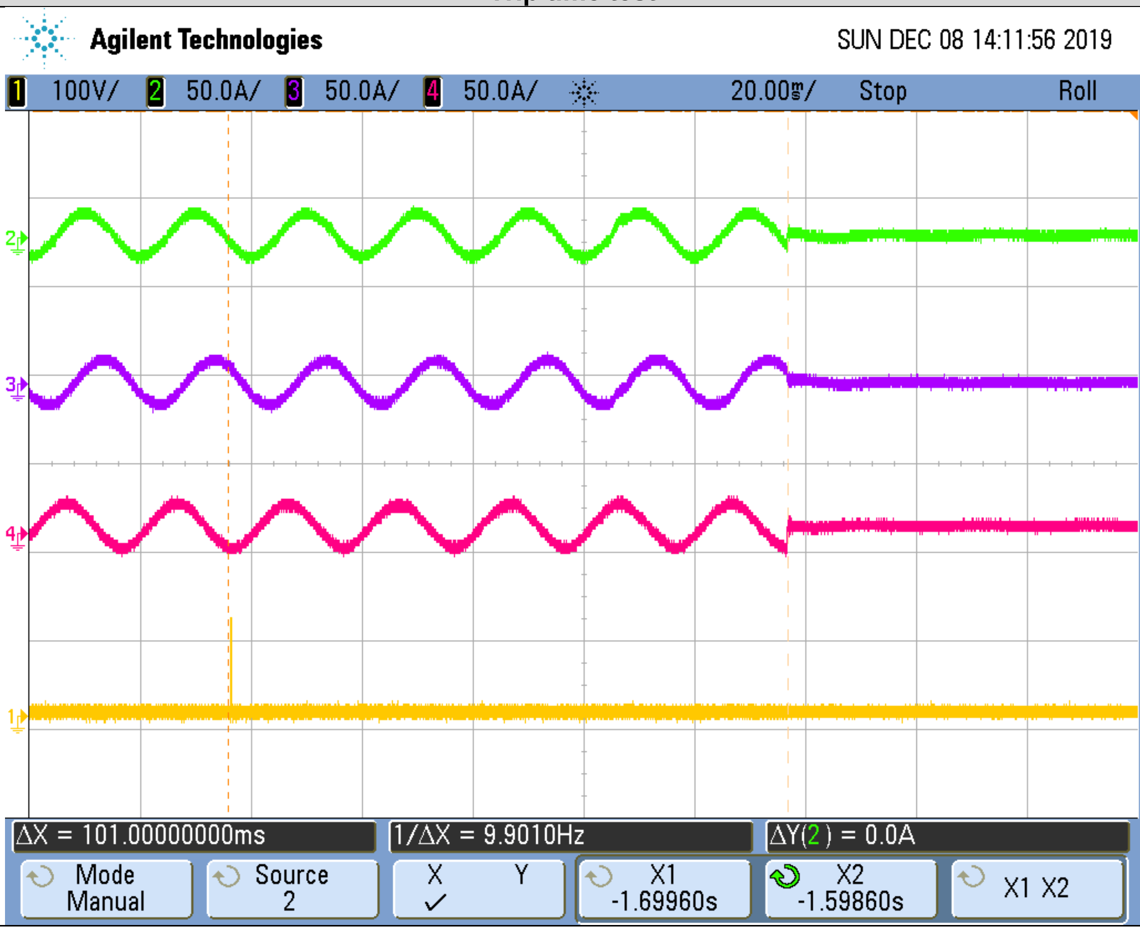
Trip time measured: 0.105 ms

Overvoltage (U>>) (Test case U4) _ Phase A – Phase N

Trip value test



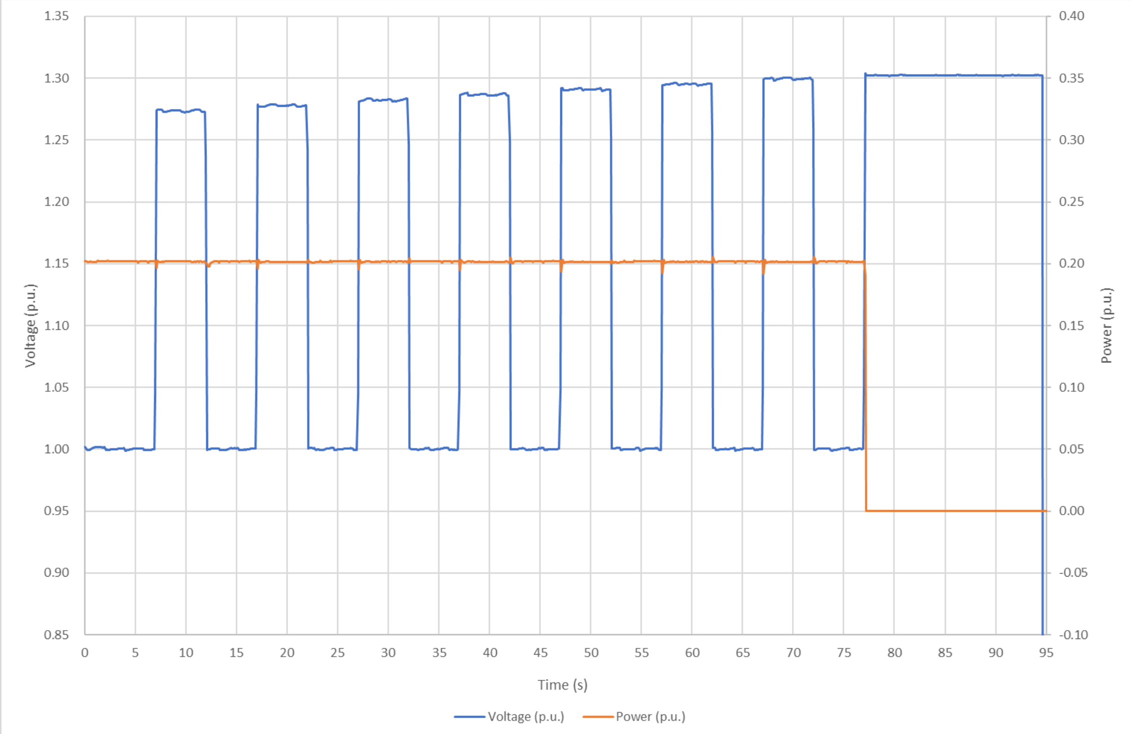
Trip time test



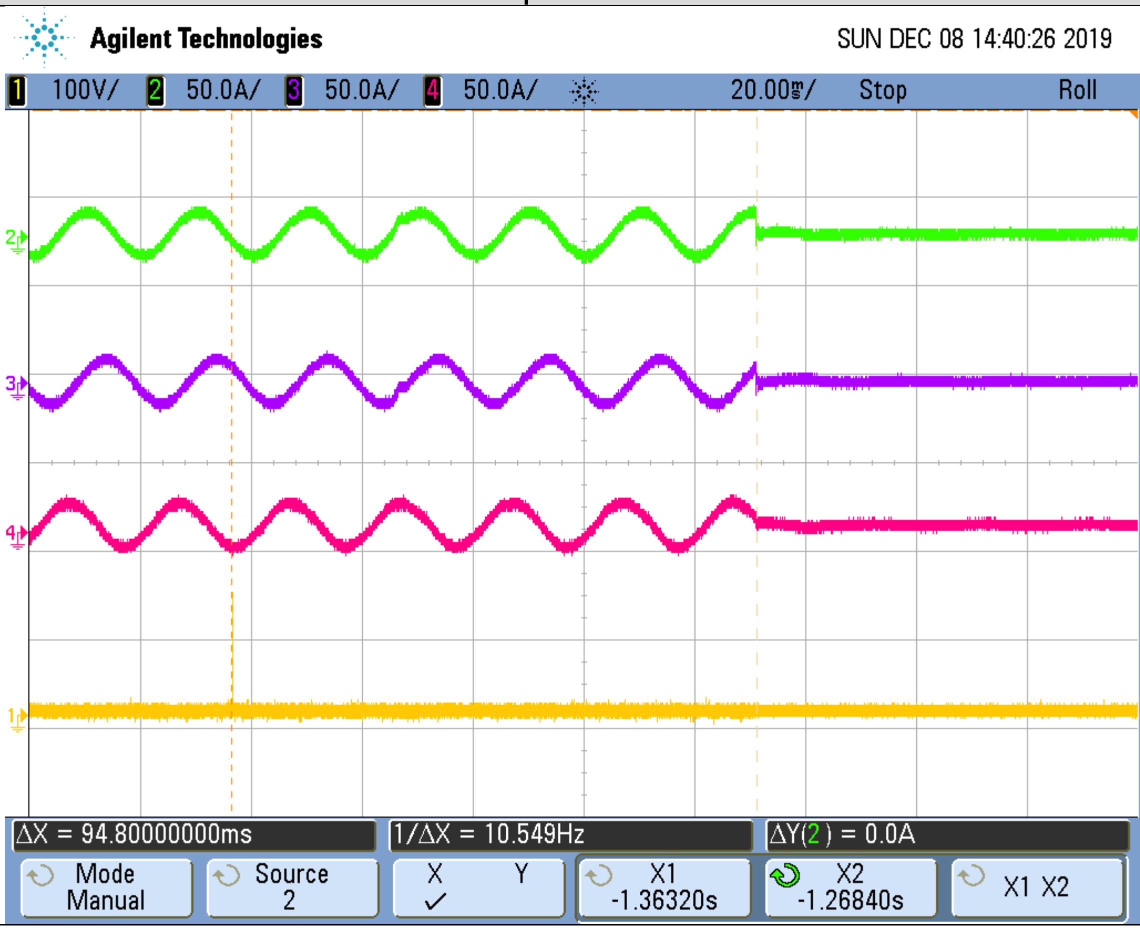
Trip time measured: 0.101ms

Overvoltage (U>>) (Test case U4) _ Phase B – Phase N

Trip value test

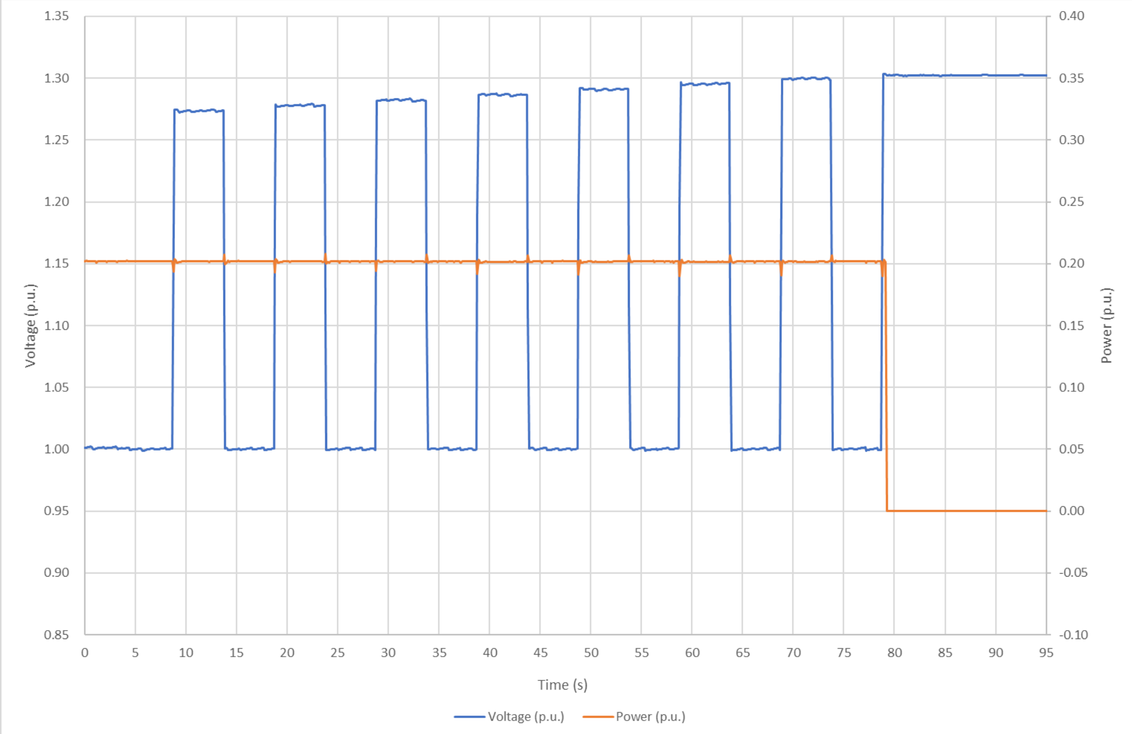


Trip time test

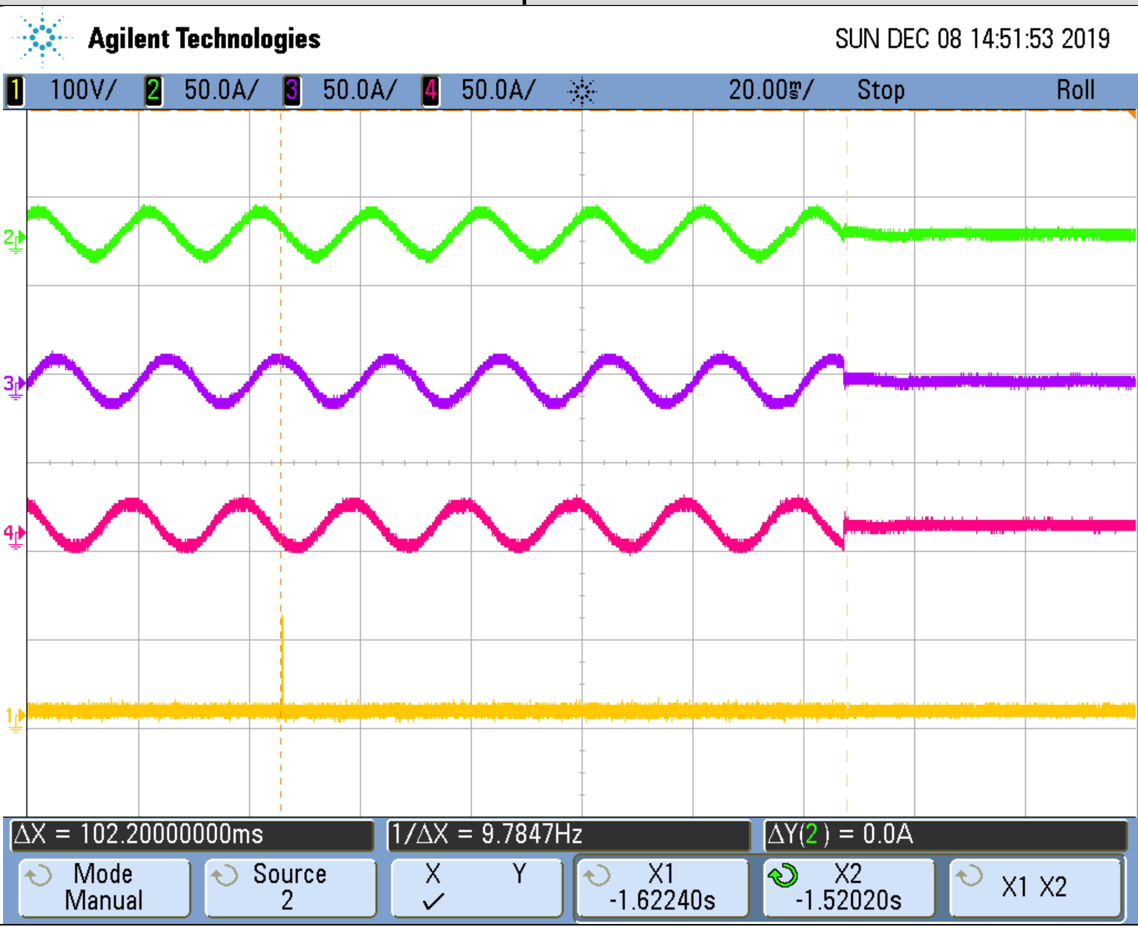


Trip time measured: 0.095ms

Overvoltage (U>>) (Test case U4) _ Phase C – Phase N
Trip value test

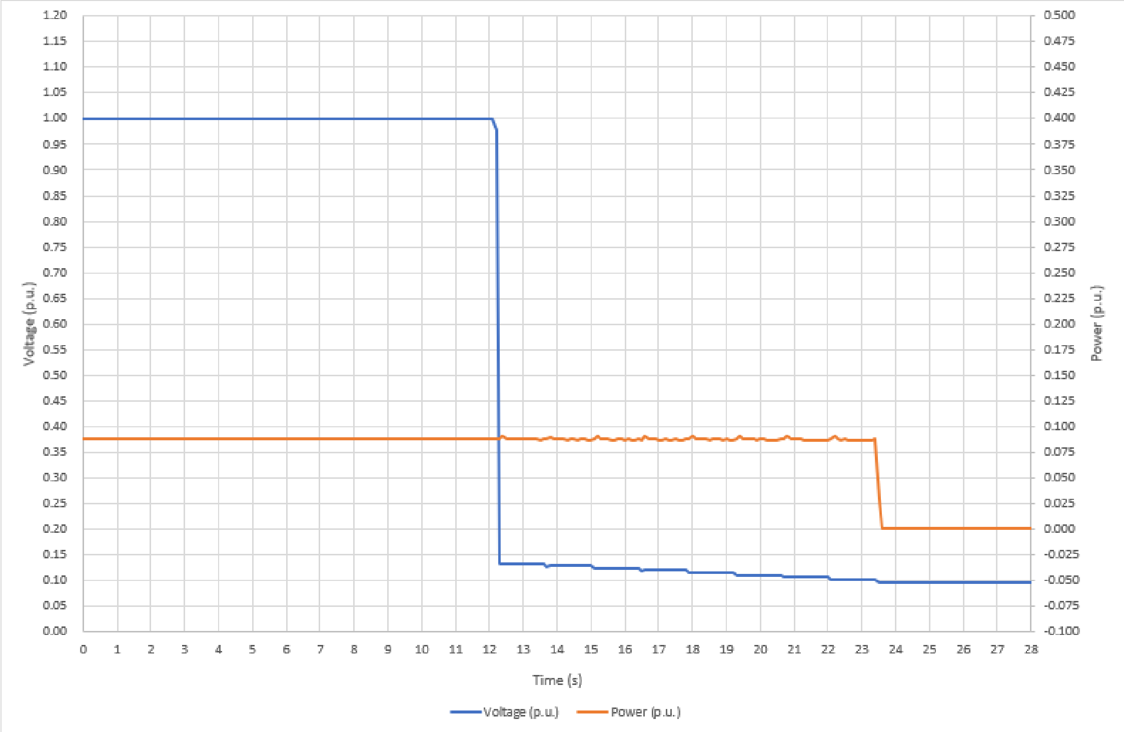


Trip time test

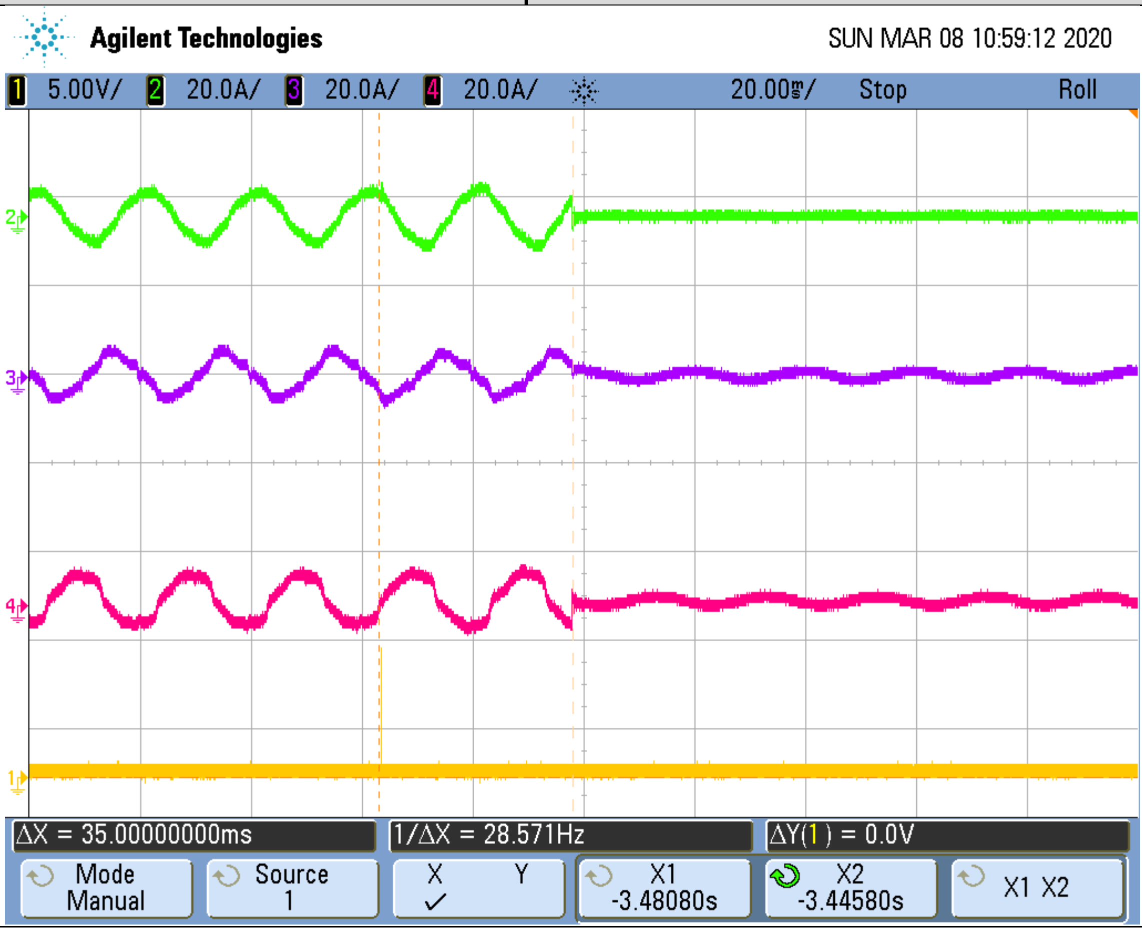


Trip time measured: 0.102 ms

Undervoltage (U<) (Test case U5) _ 3 Phase
Trip value test

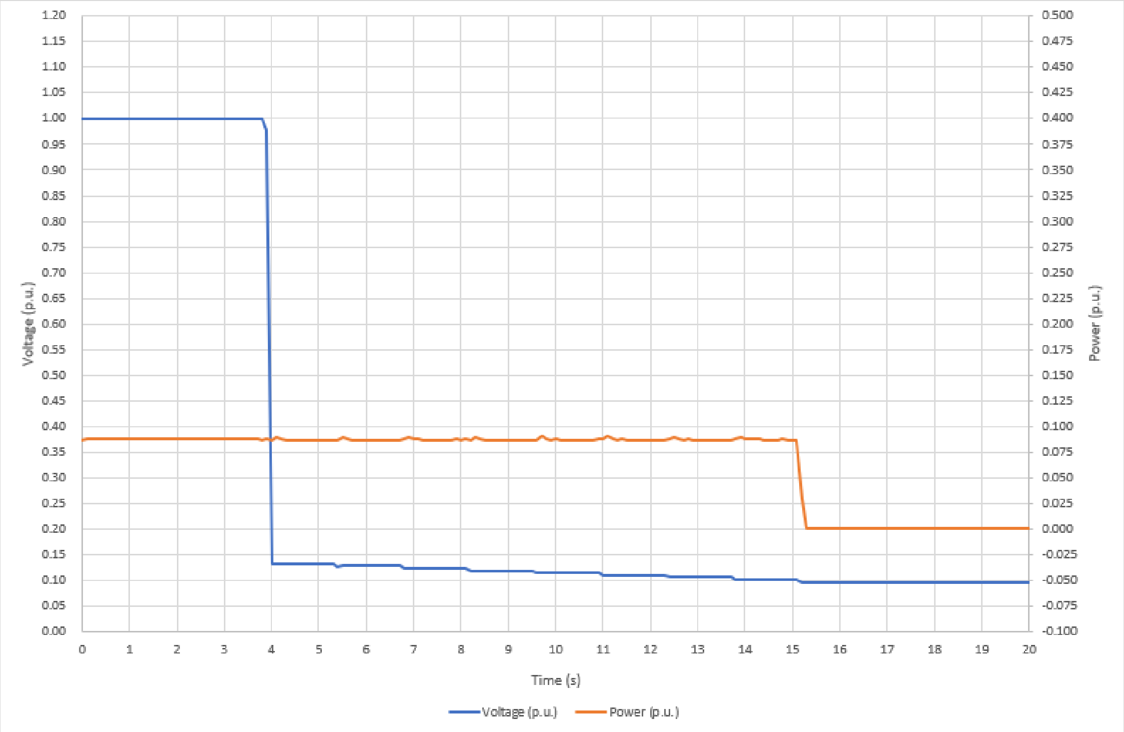


Trip time test

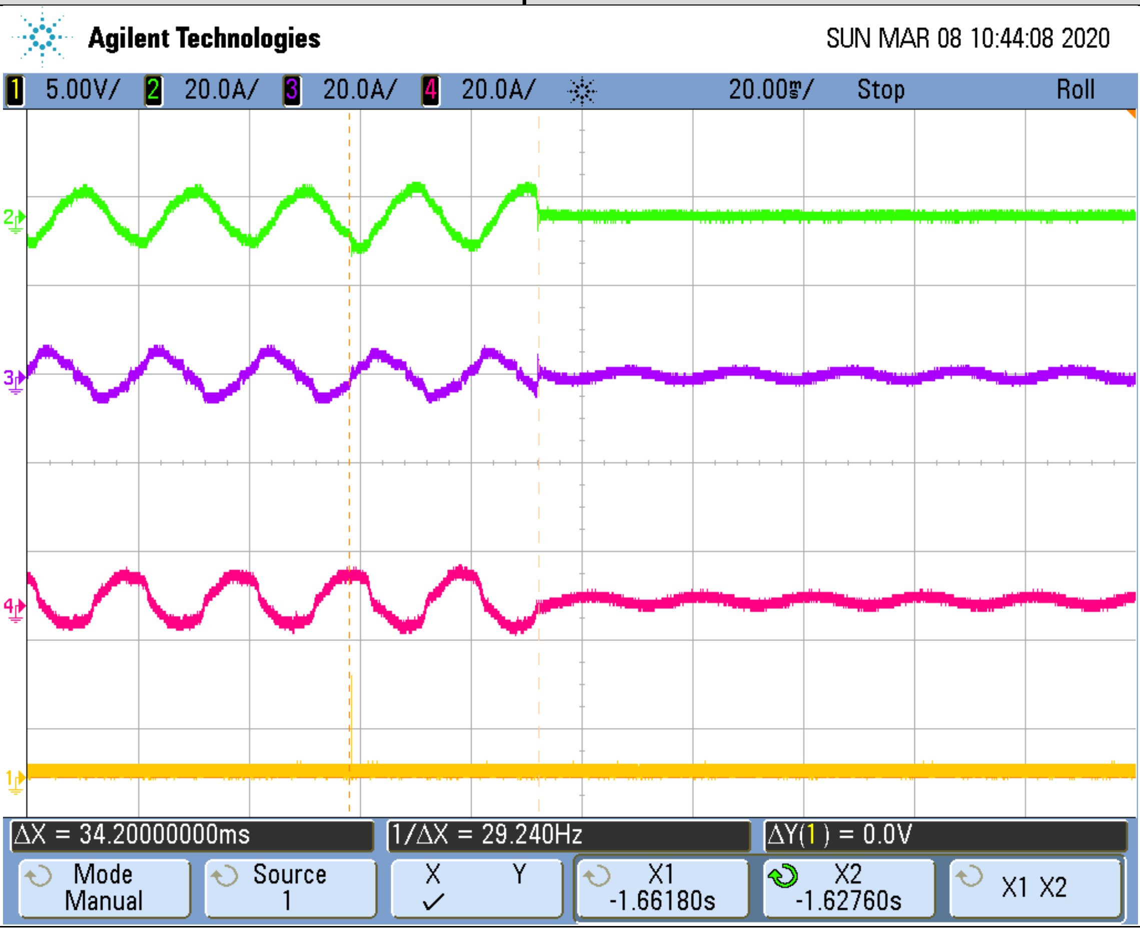


Trip time measured: 0.035s

Undervoltage (U<) (Test case U5) _ Phase A - Phase N
Trip value test



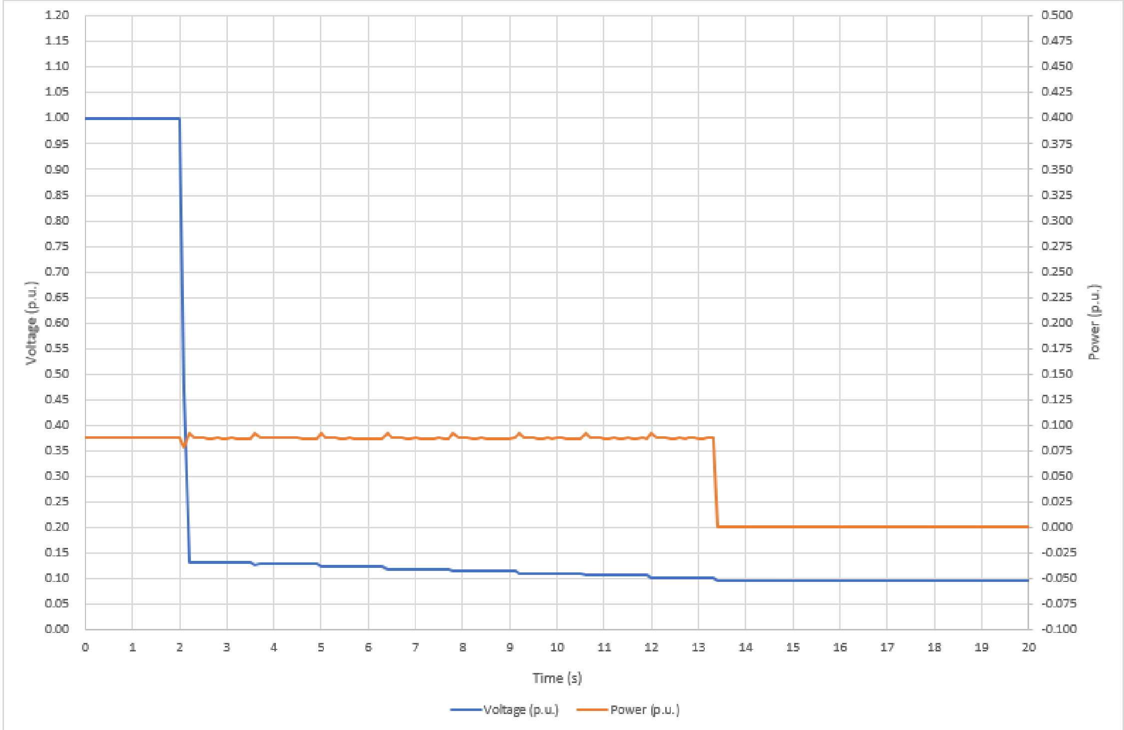
Trip time test



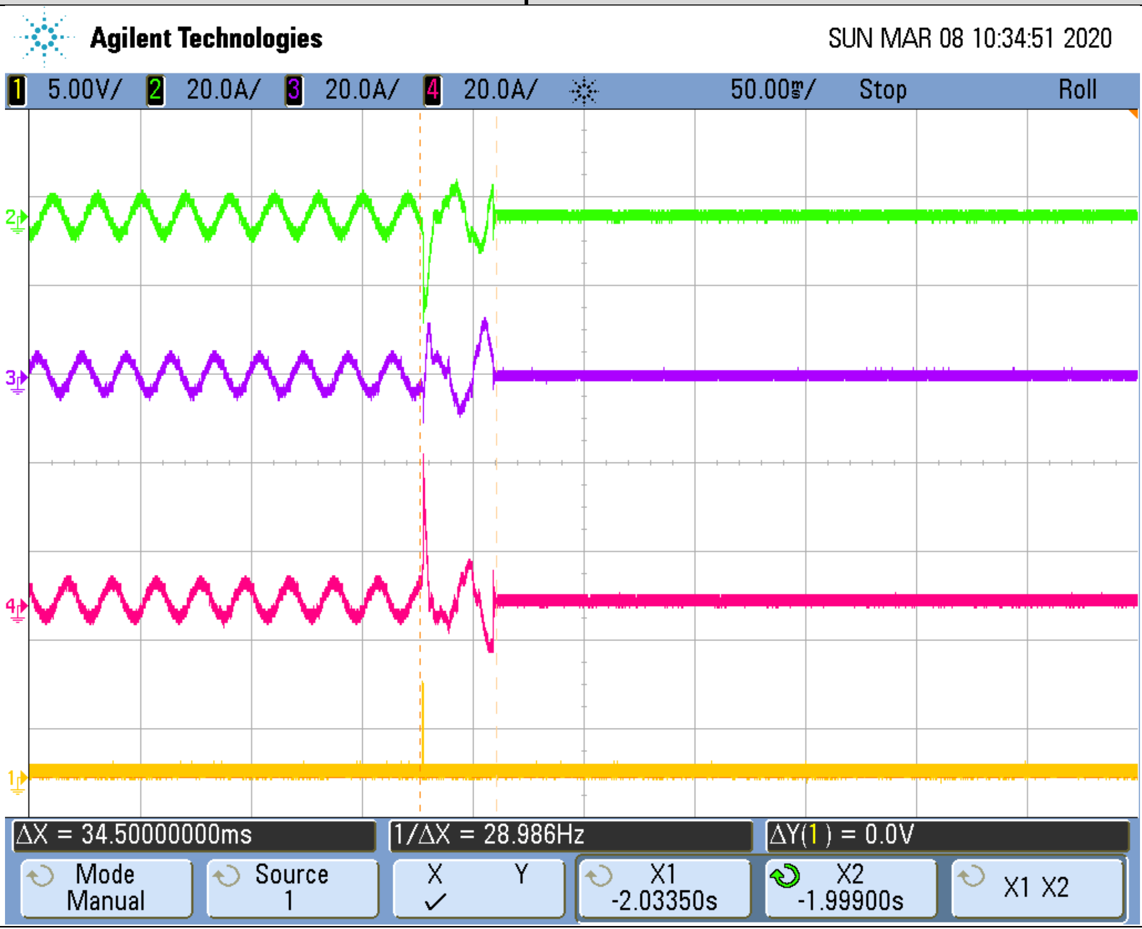
Trip time measured: 0.034s

Undervoltage (U<) (Test case U5) _ Phase B - Phase N

Trip value test

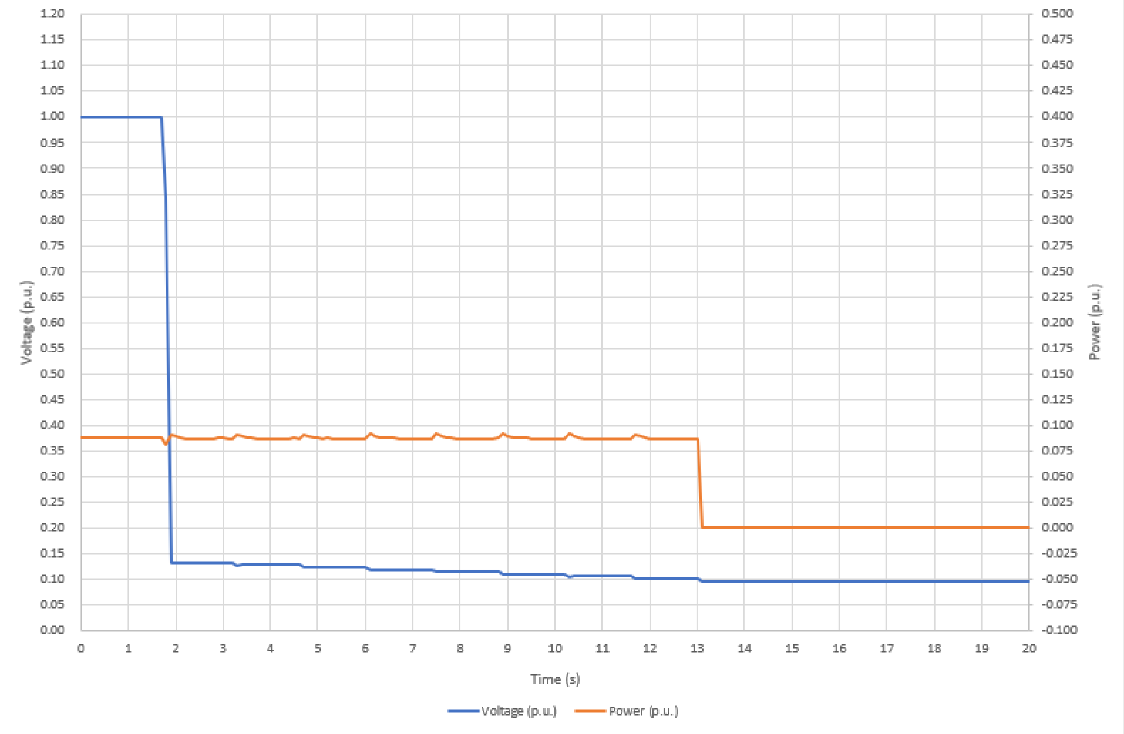


Trip time test

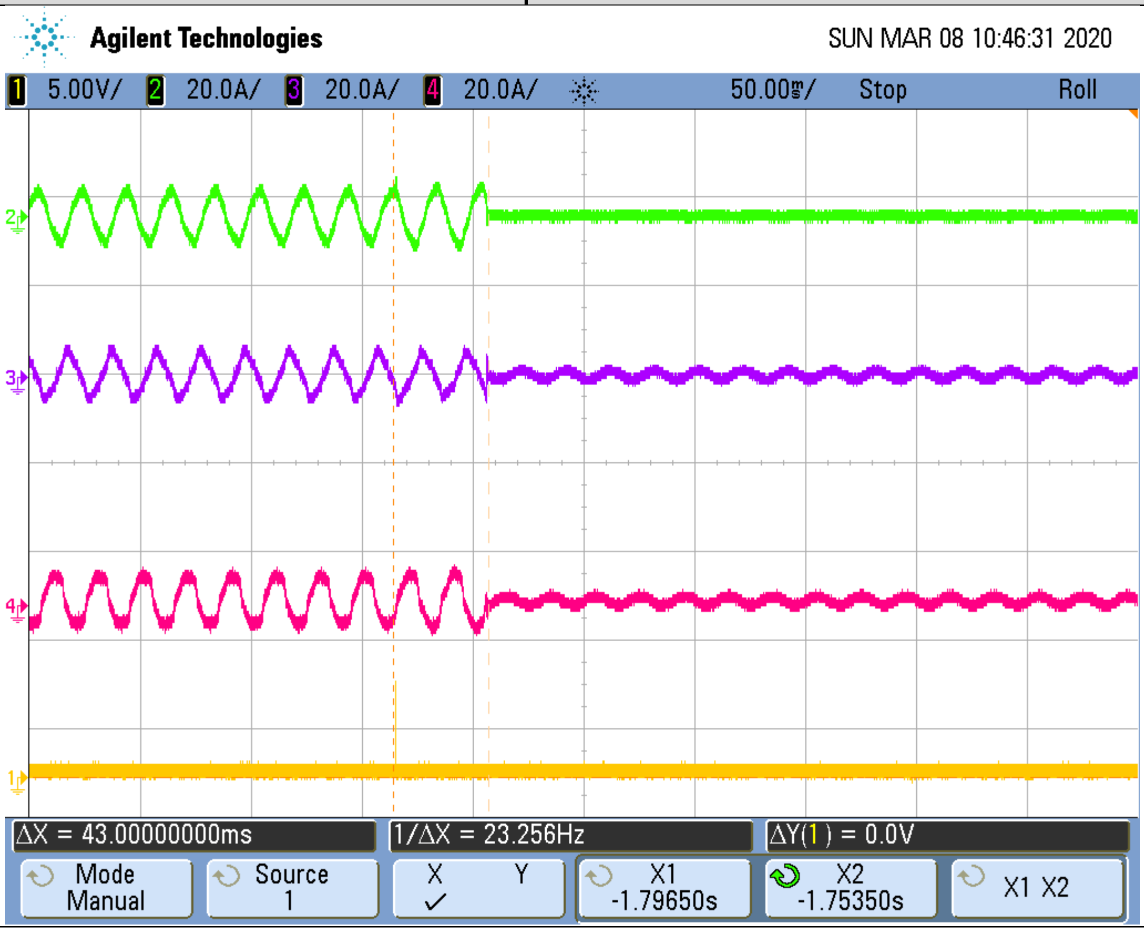


Trip time measured: 0.035s

Undervoltage (U<) (Test case U5) _ Phase C - Phase N
Trip value test



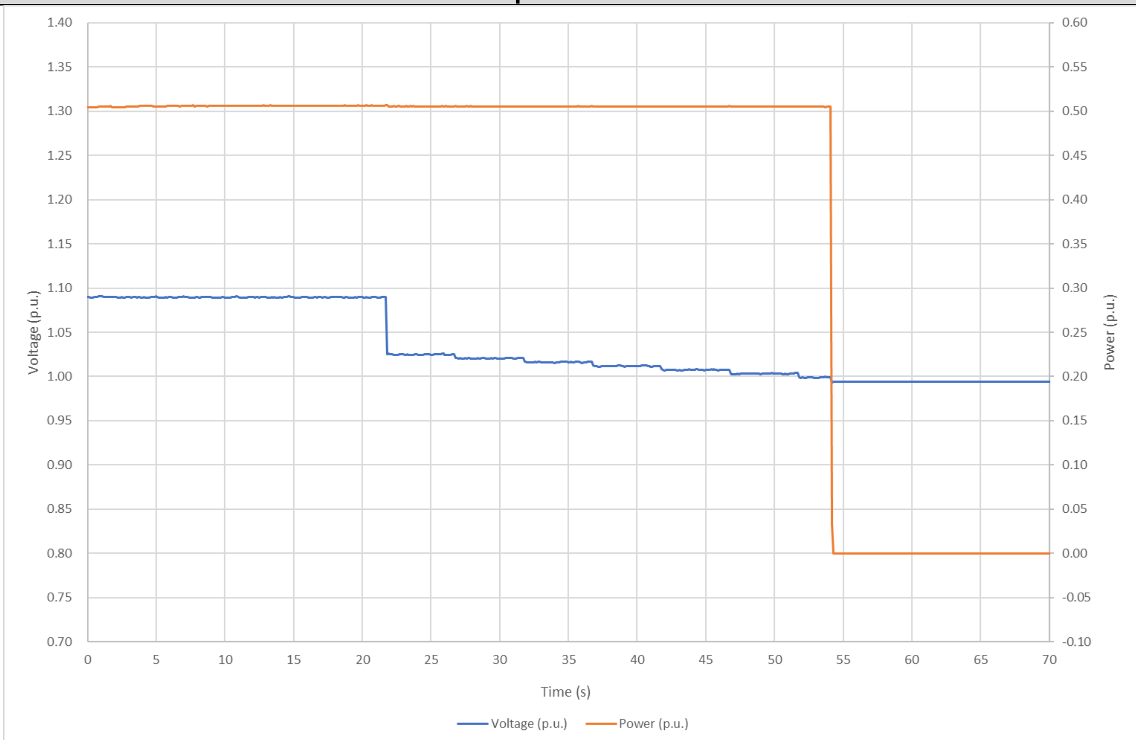
Trip time test



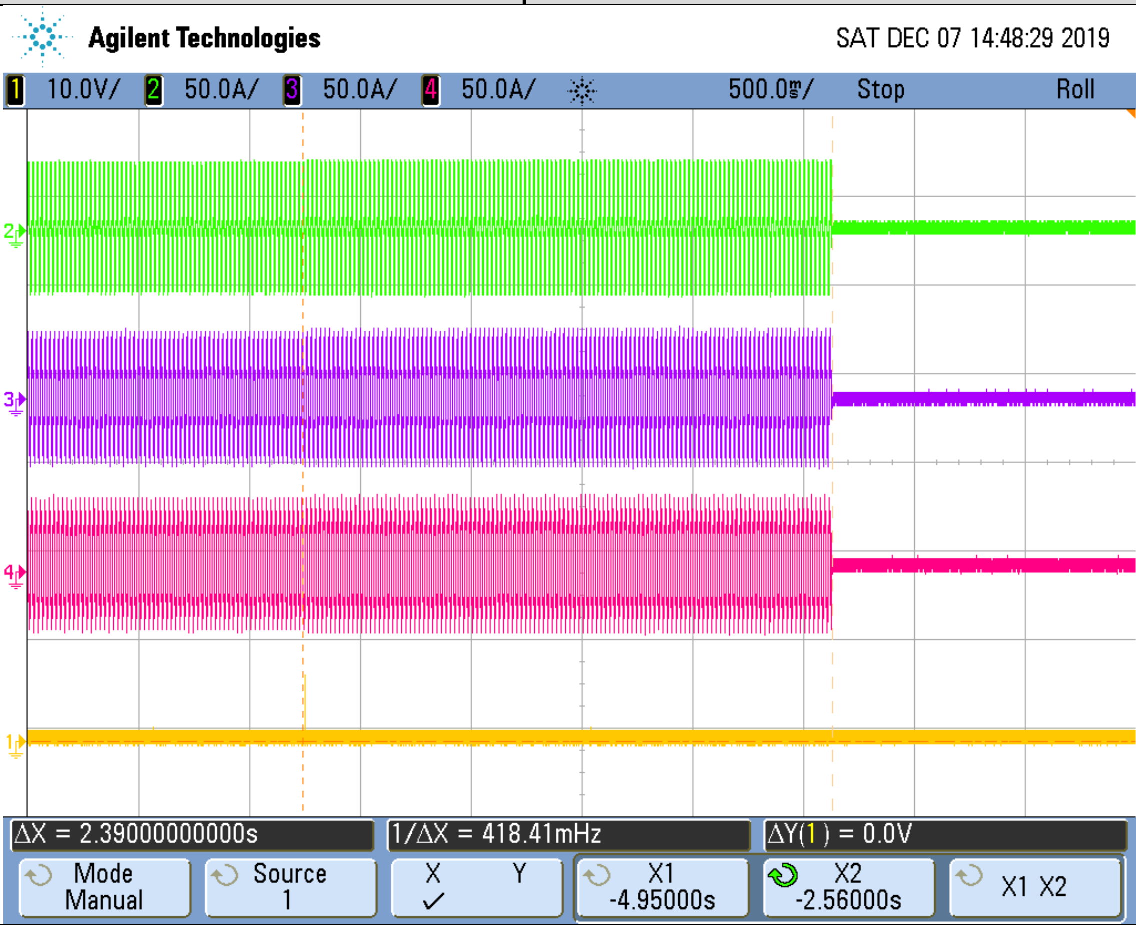
Trip time measured: 0.043s

Undervoltage (U<) (Test case U6) _ 3 Phase

Trip value test



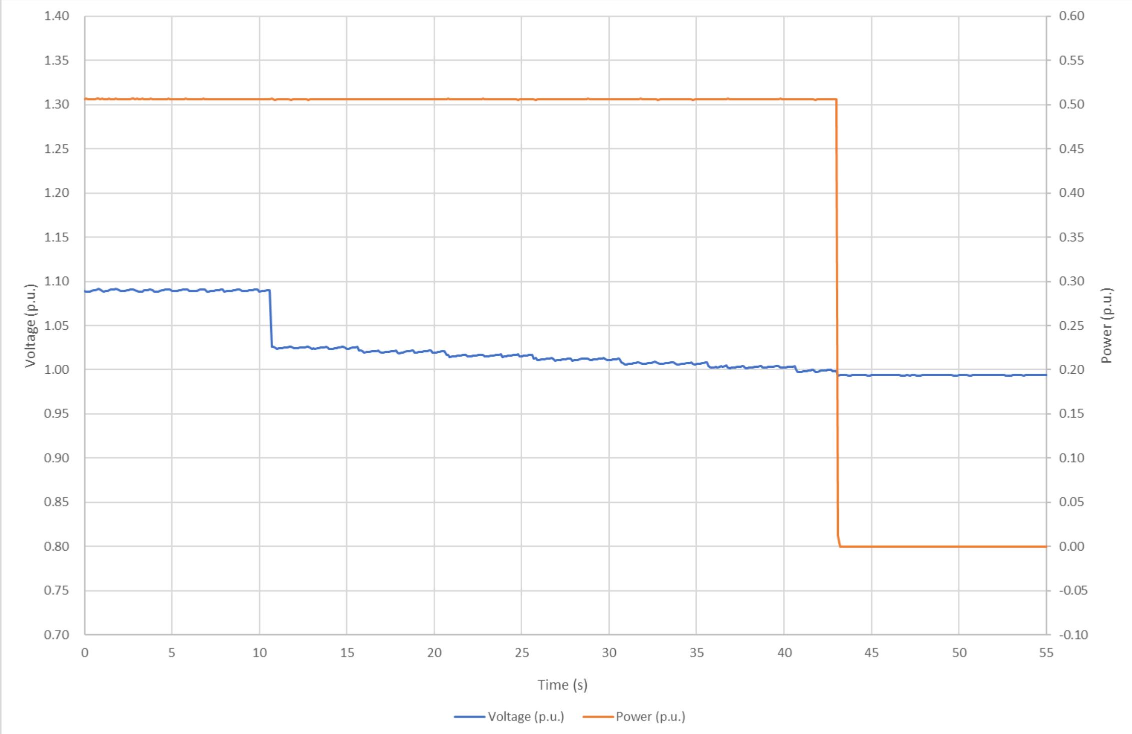
Trip time test



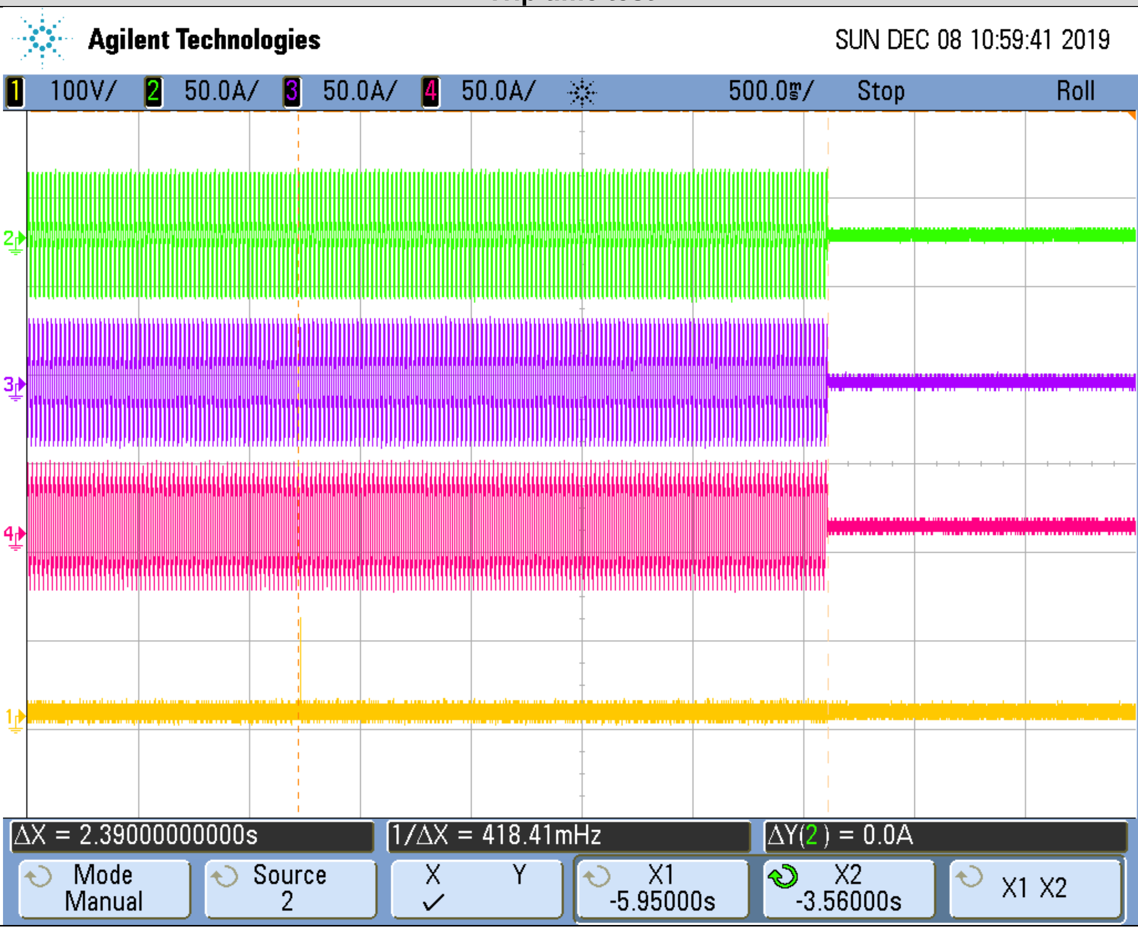
Trip time measured: 2.390s

Undervoltage (U<) (Test case U6) Phase A – Phase N

Trip value test



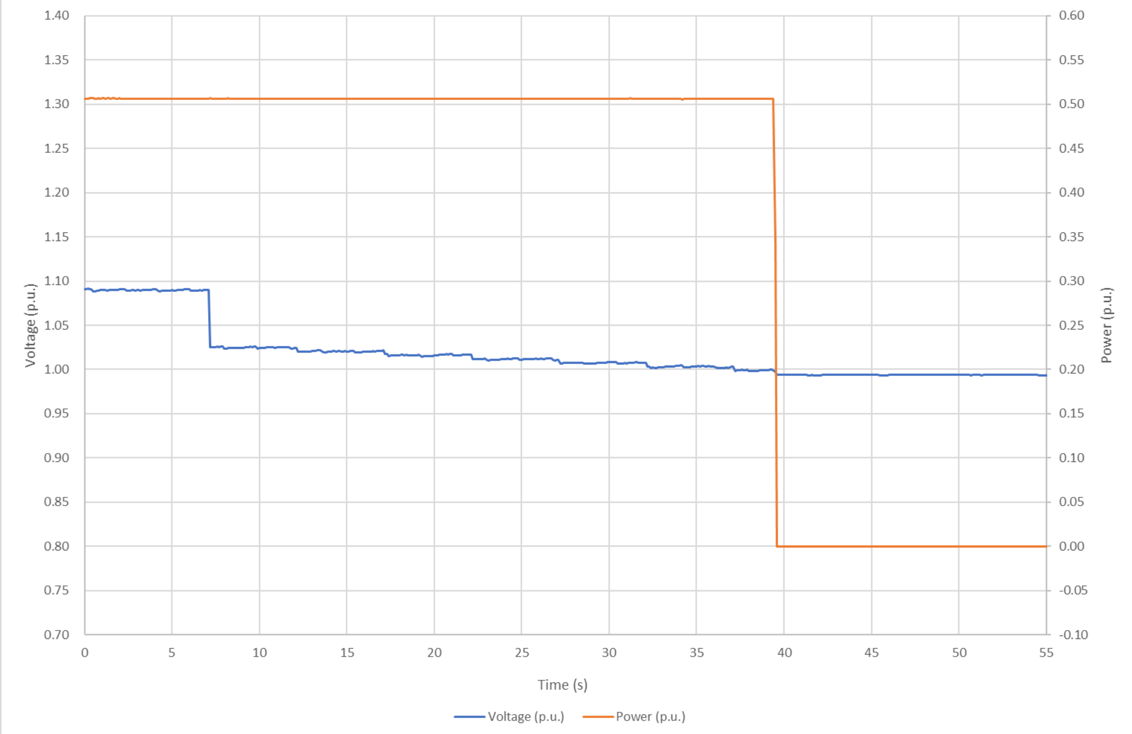
Trip time test



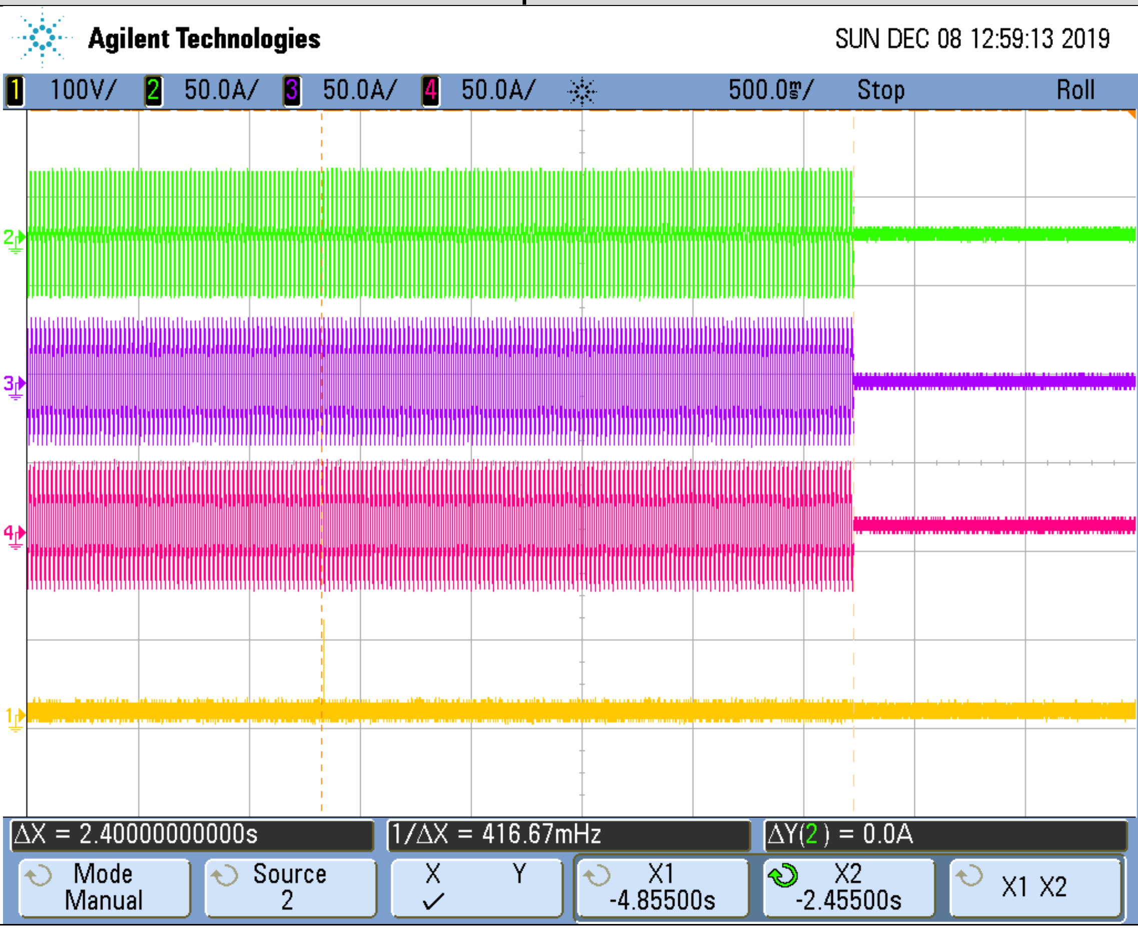
Trip time measured: 2.390s

Undervoltage (U<) (Test case U6) Phase B – Phase N

Trip value test



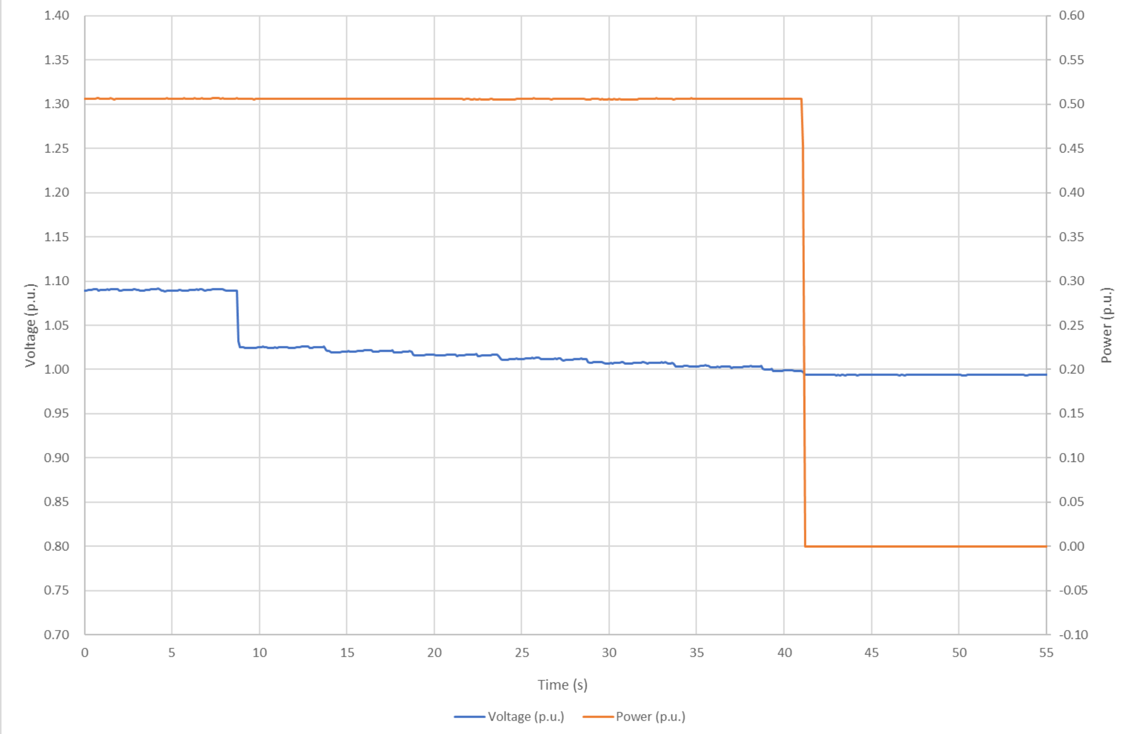
Trip time test



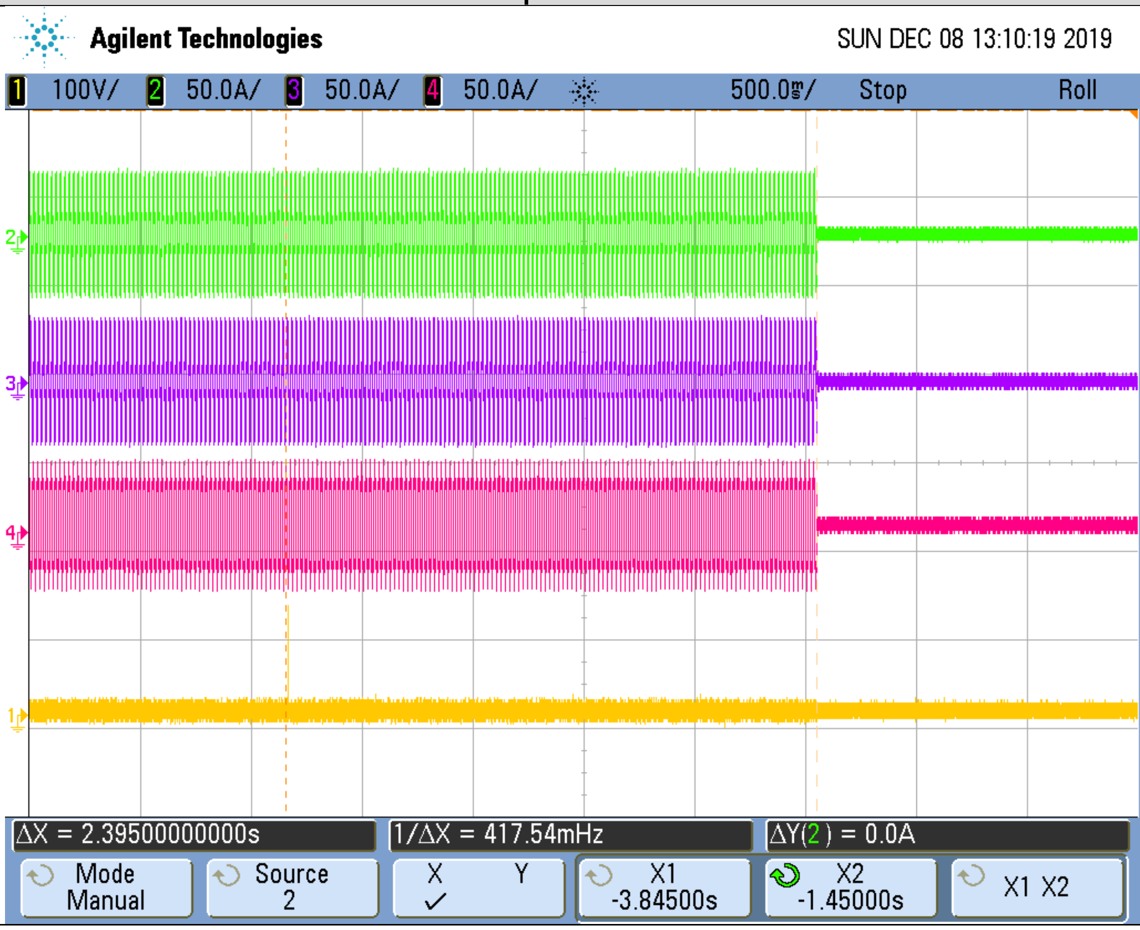
Trip time measured: 2.400s

Undervoltage (U<) (Test case U6) Phase C – Phase N

Trip value test



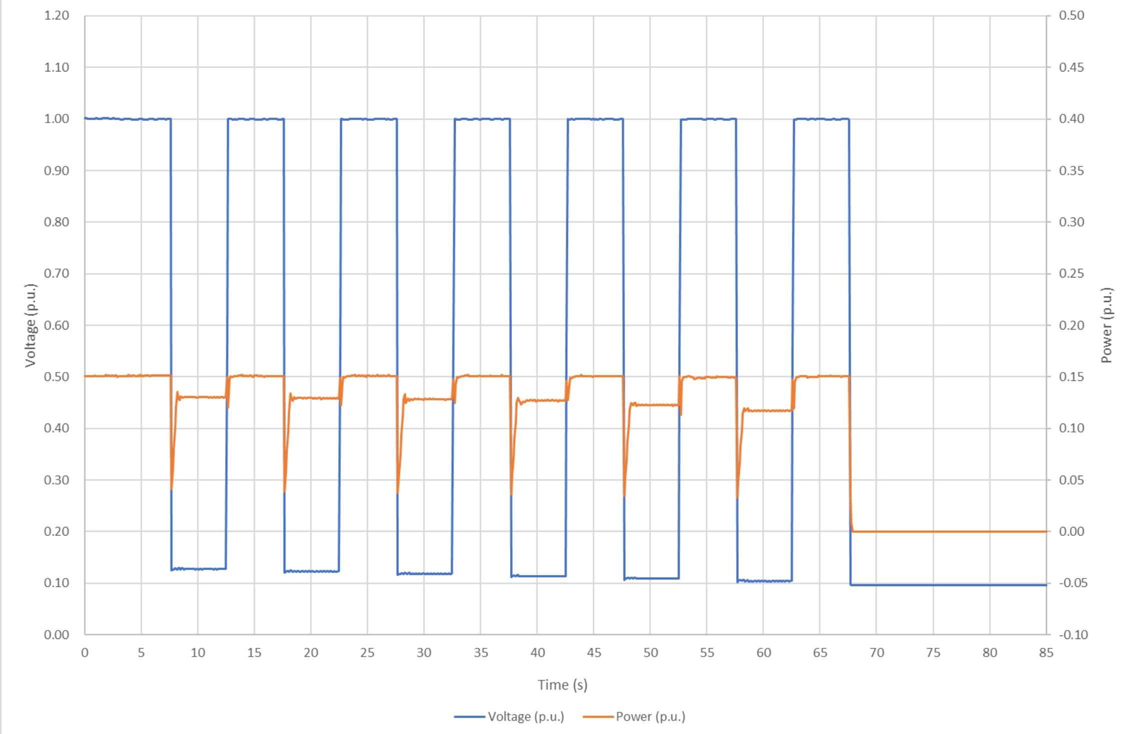
Trip time test



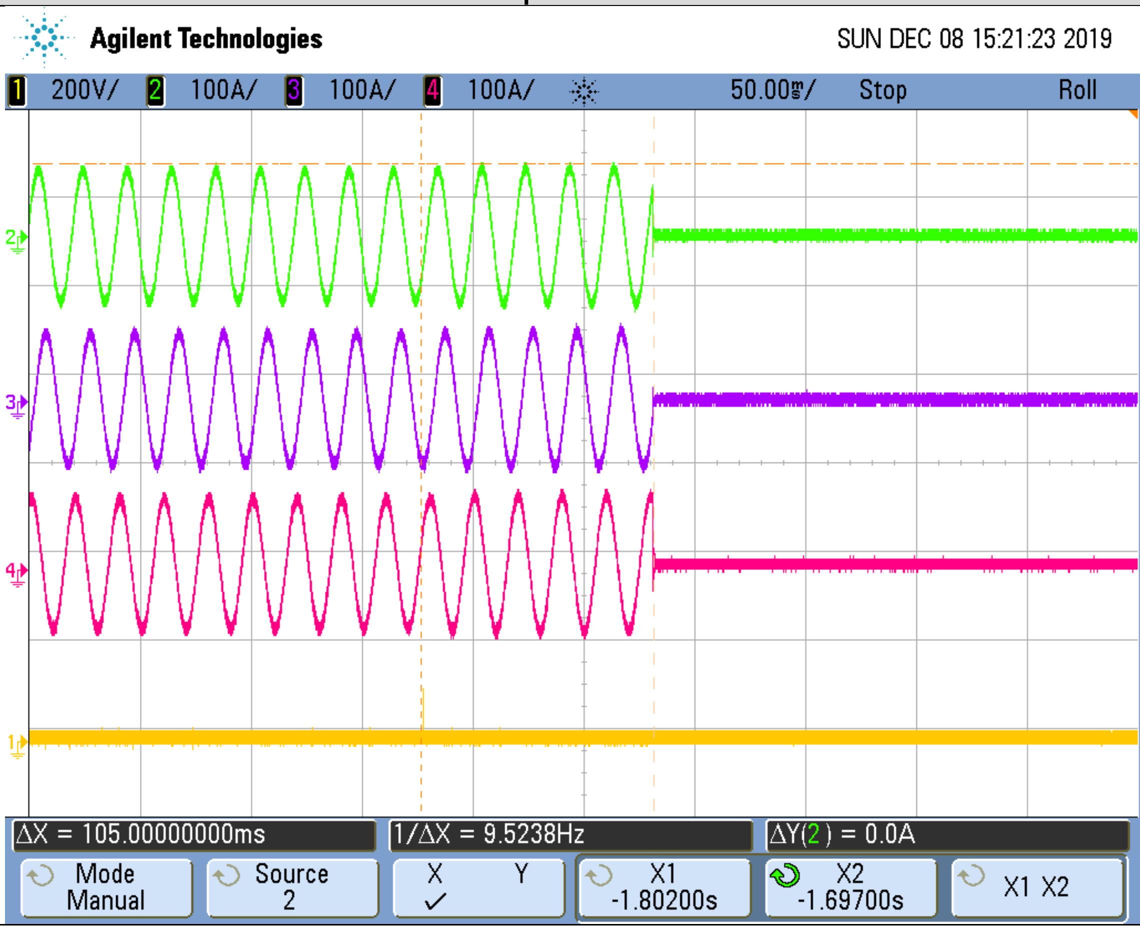
Trip time measured: 2.395s

Undervoltage (U<<) (Test case U7) _ 3 Phases

Trip value test



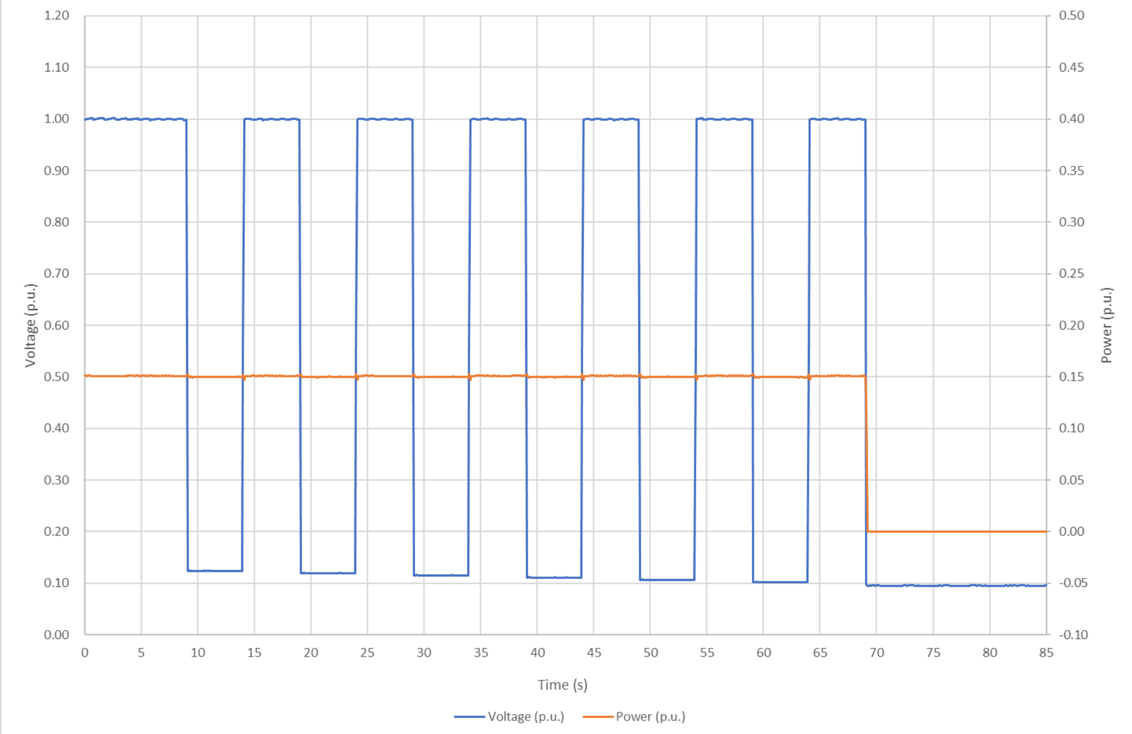
Trip time test



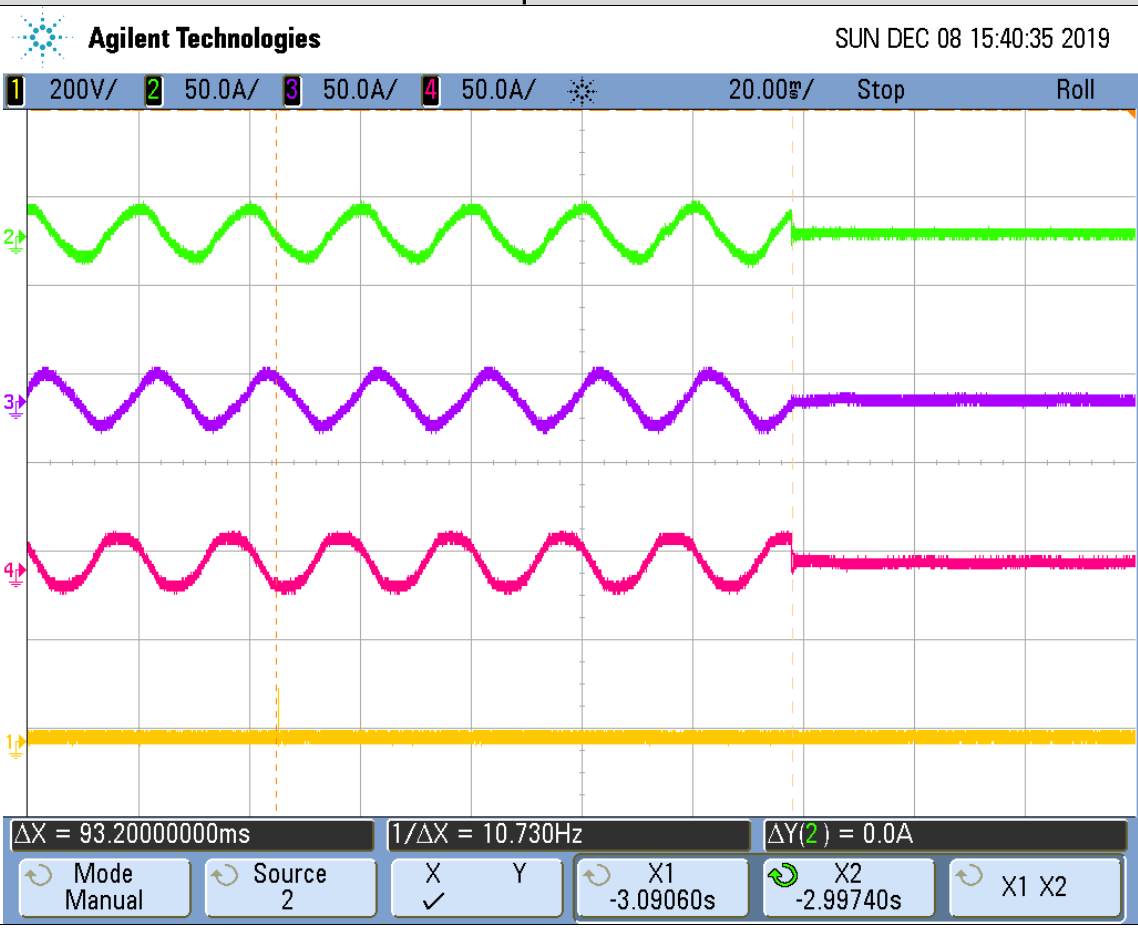
Trip time measured: 0.105s

Undervoltage (U<<) (Test case U7) _ Phase A – Phase N

Trip value test



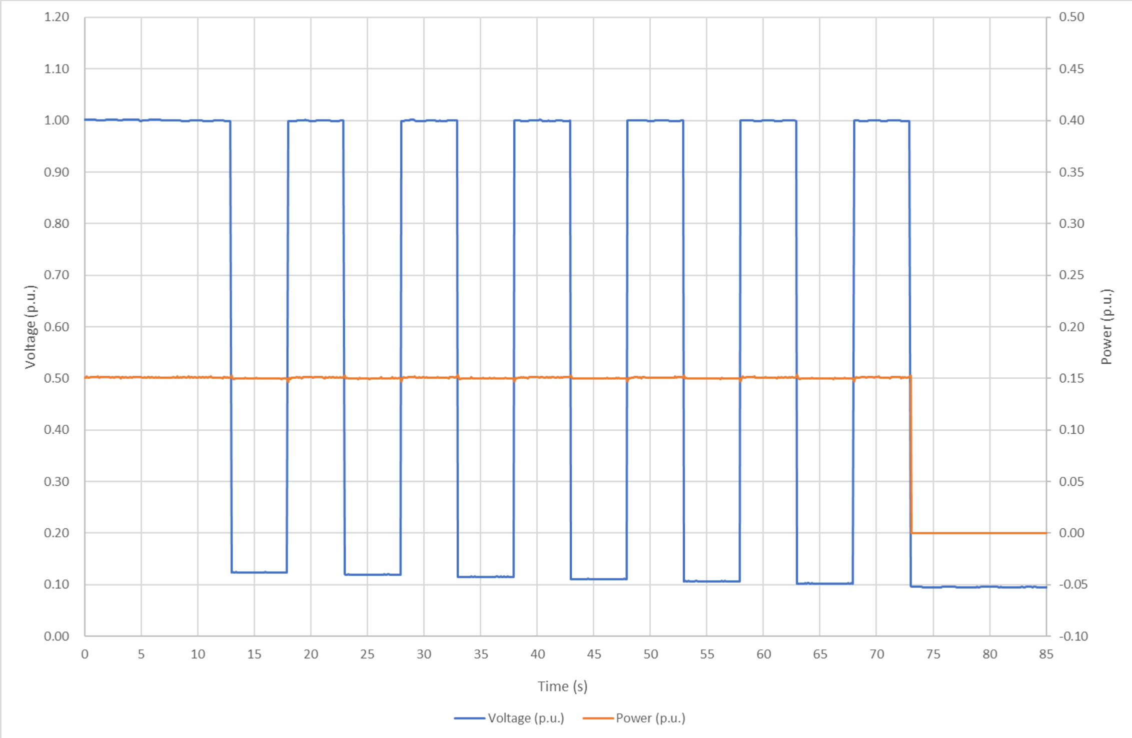
Trip time test



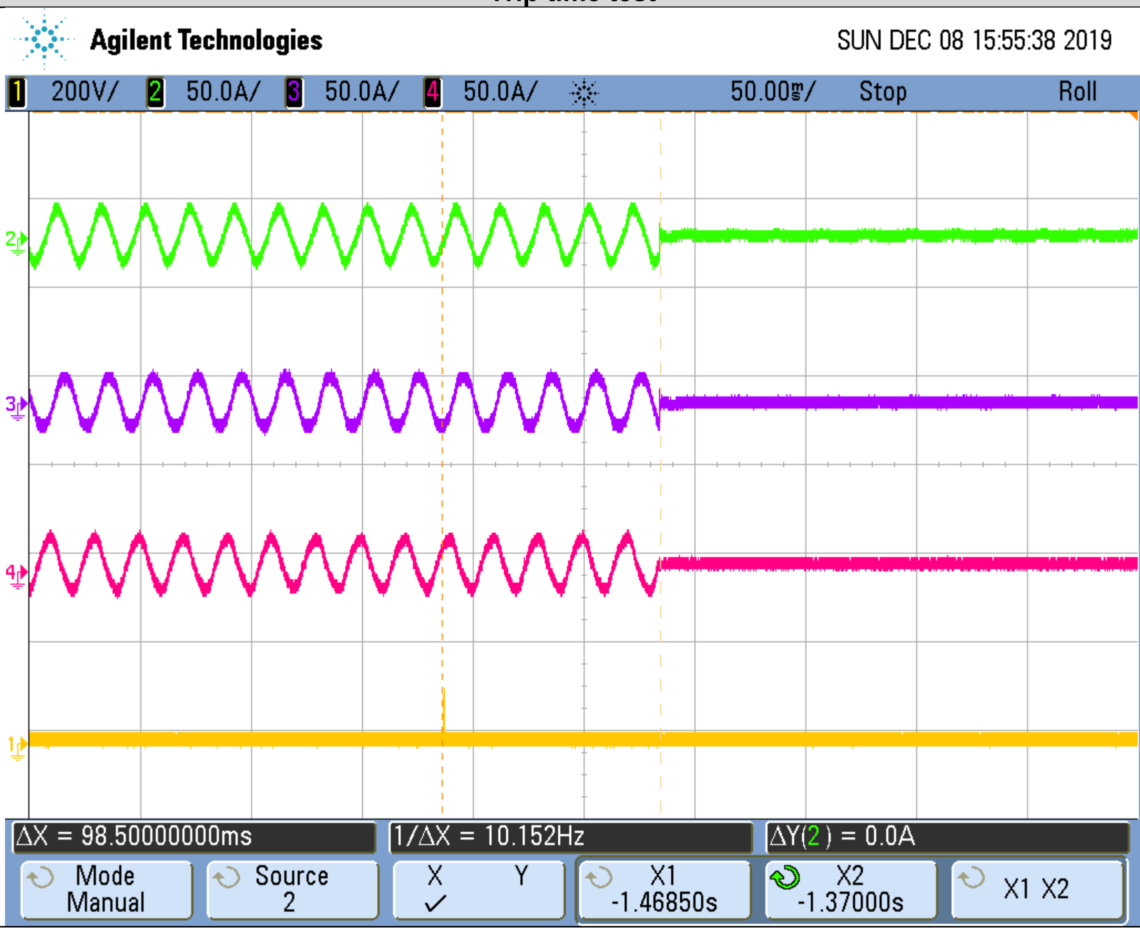
Trip time measured: 0.093s

Undervoltage (U<<) (Test case U7) _ Phase B – Phase N

Trip value test



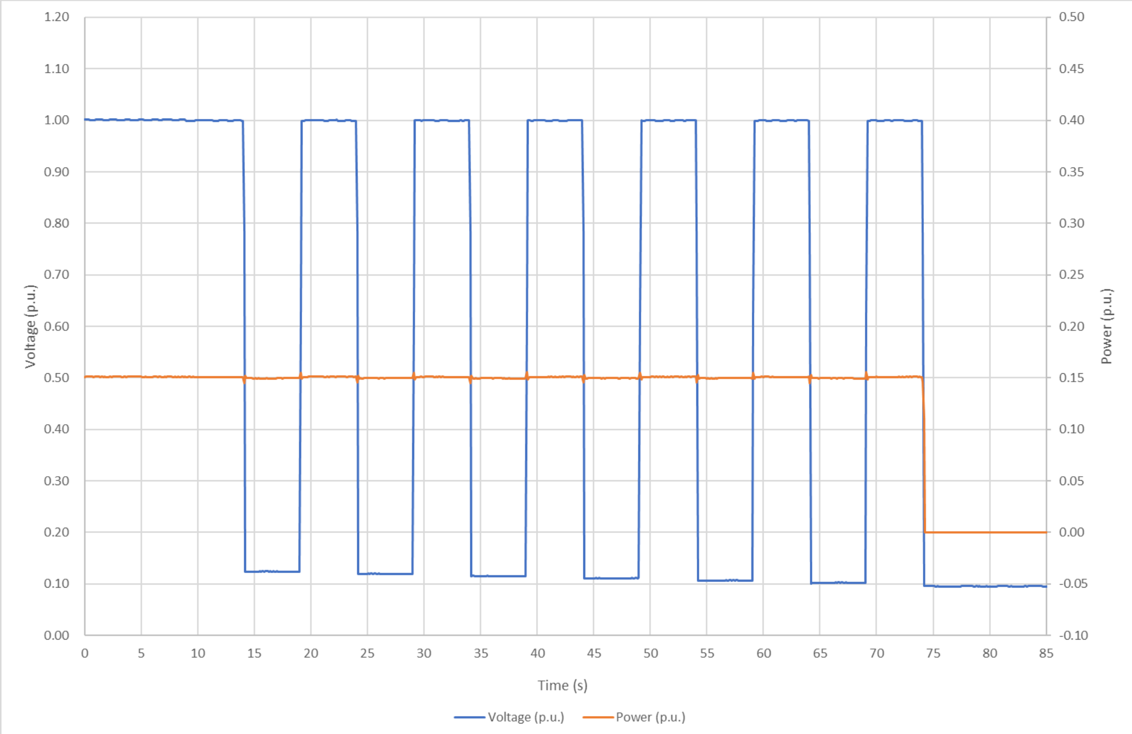
Trip time test



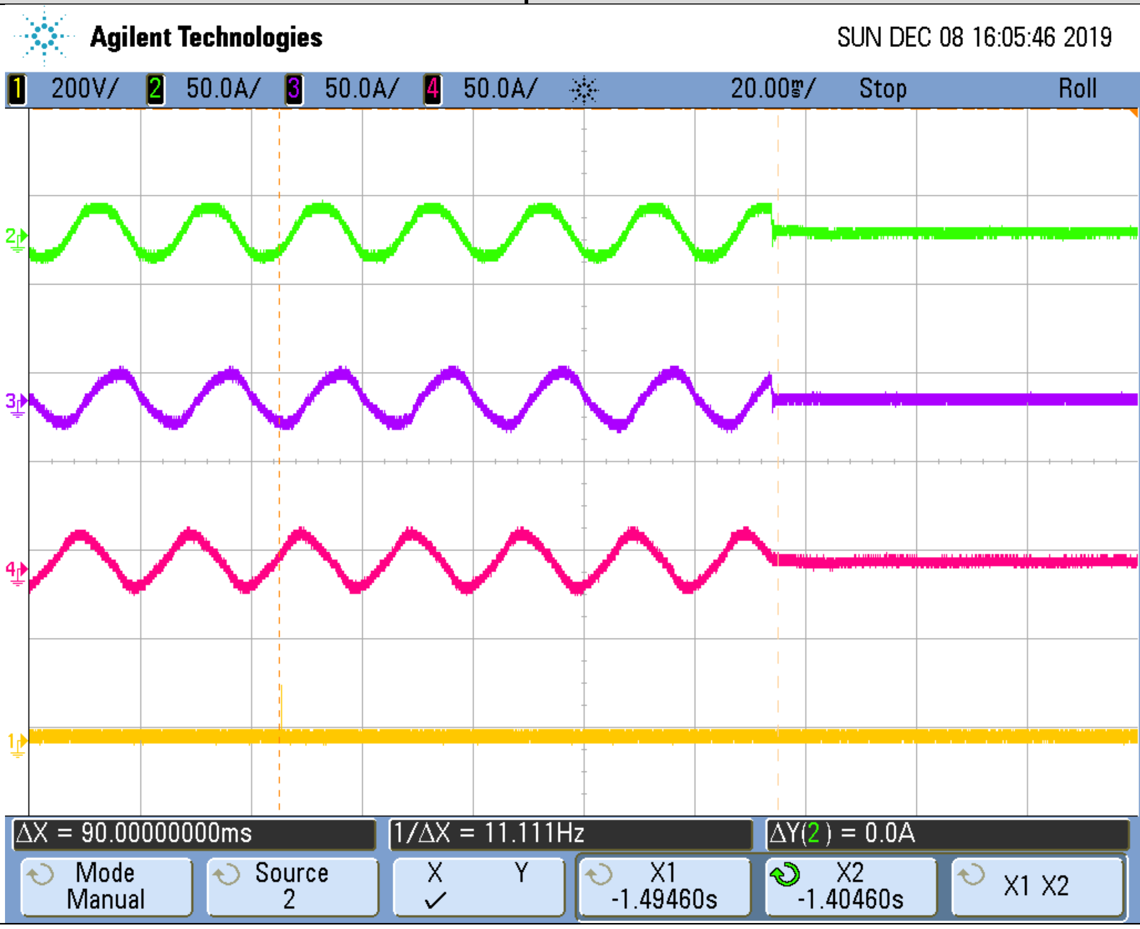
Trip time measured: 0.099s

Undervoltage (U<<) (Test case U7) _ Phase C – Phase N

Trip value test

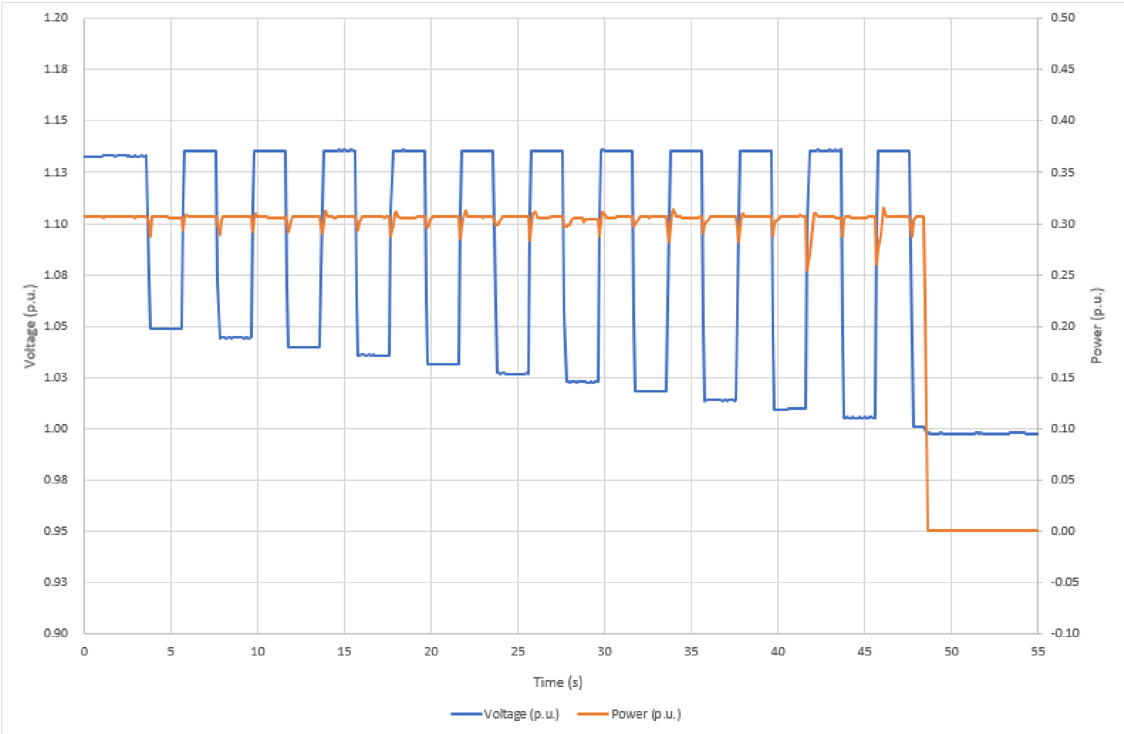


Trip time test

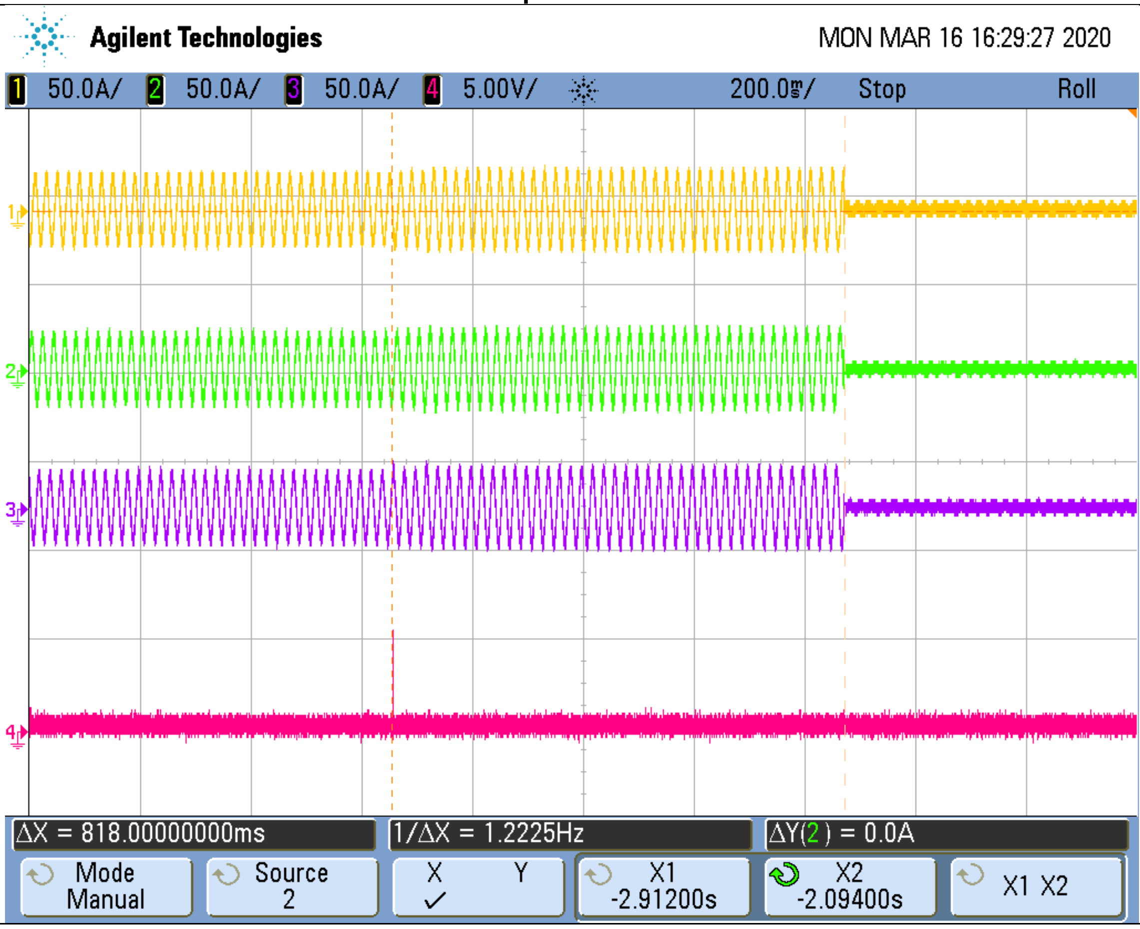


Trip time measured: 0.090s

Undervoltage (U<<) (Test case U8) _ 3 Phases
Trip value test

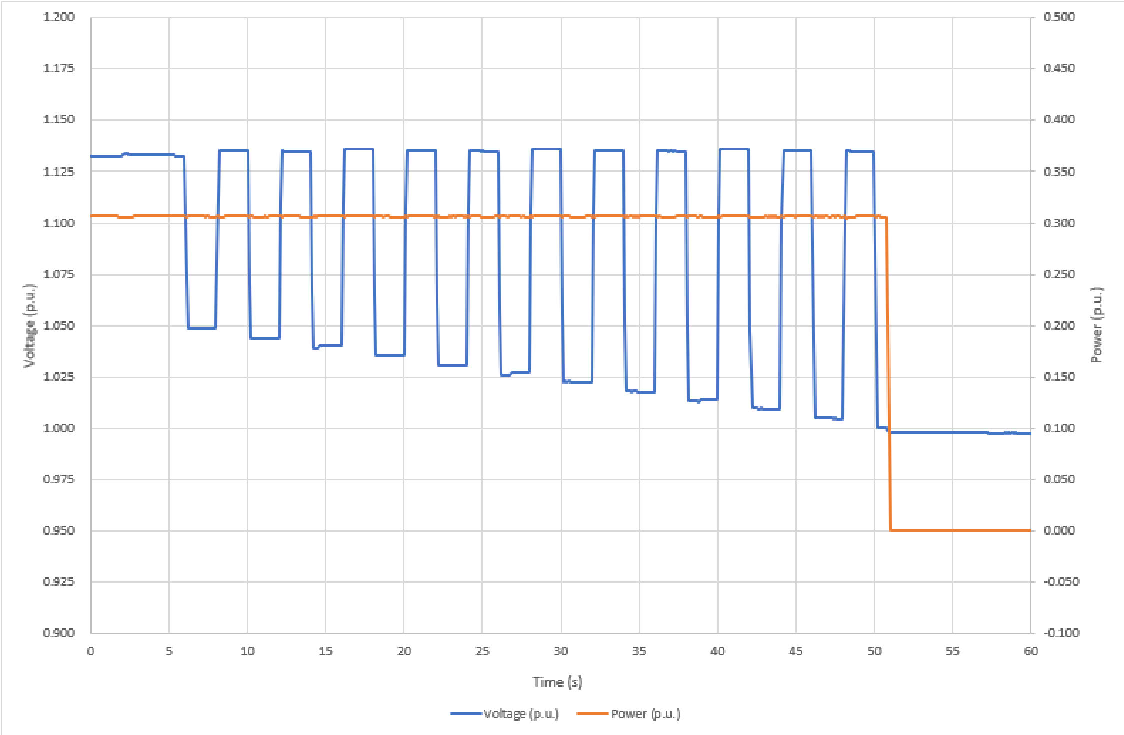


Trip time test

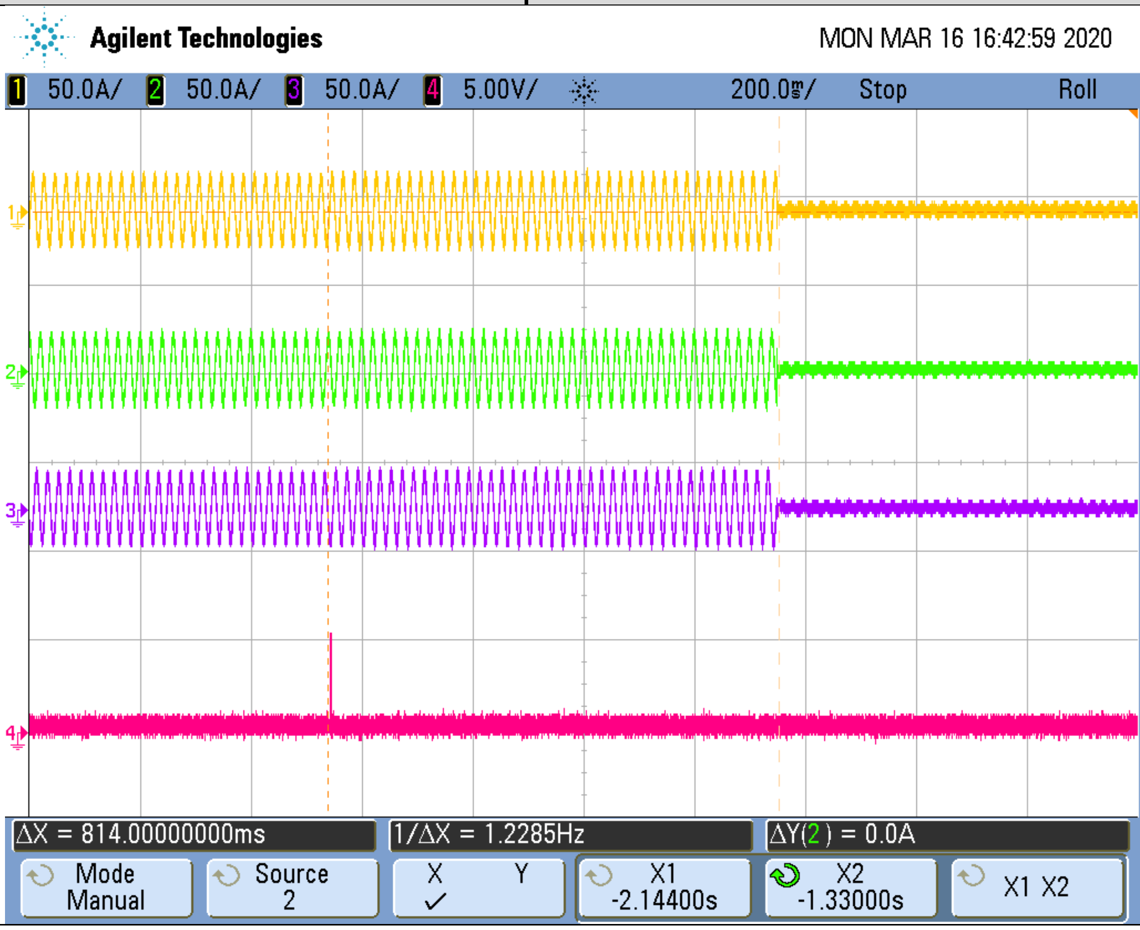


Trip time measured: 0.818s

Undervoltage (U<<) (Test case U8) _ Phase A – Phase N
Trip value test



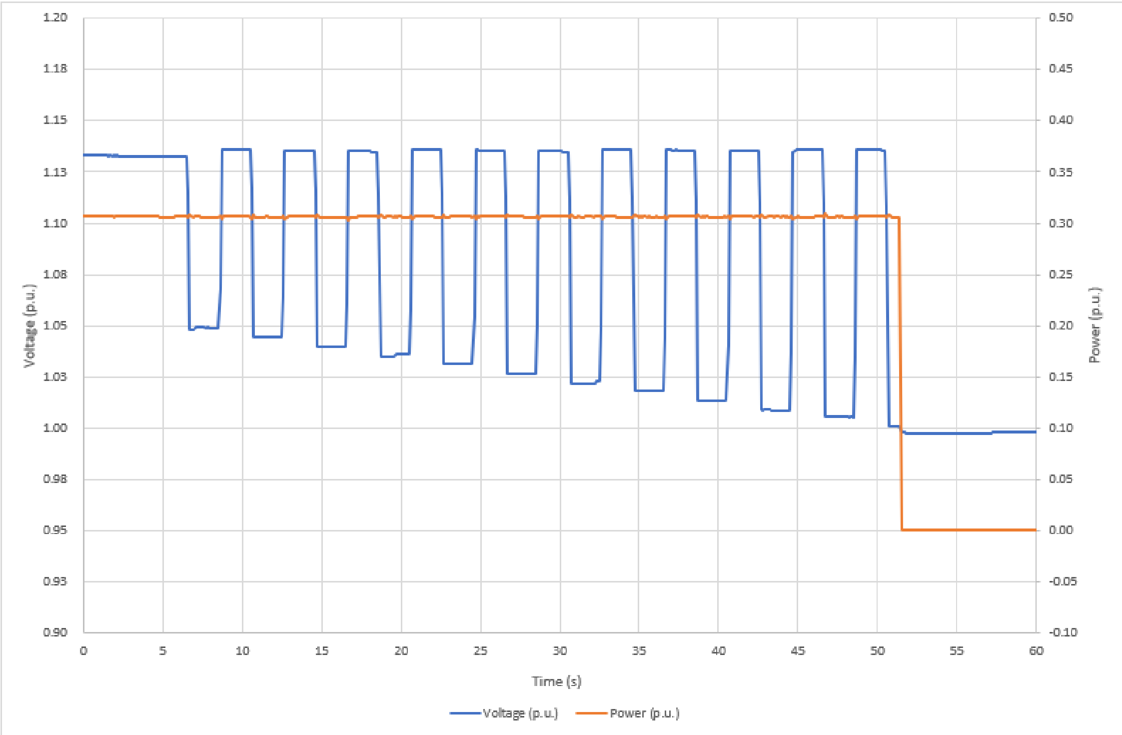
Trip time test



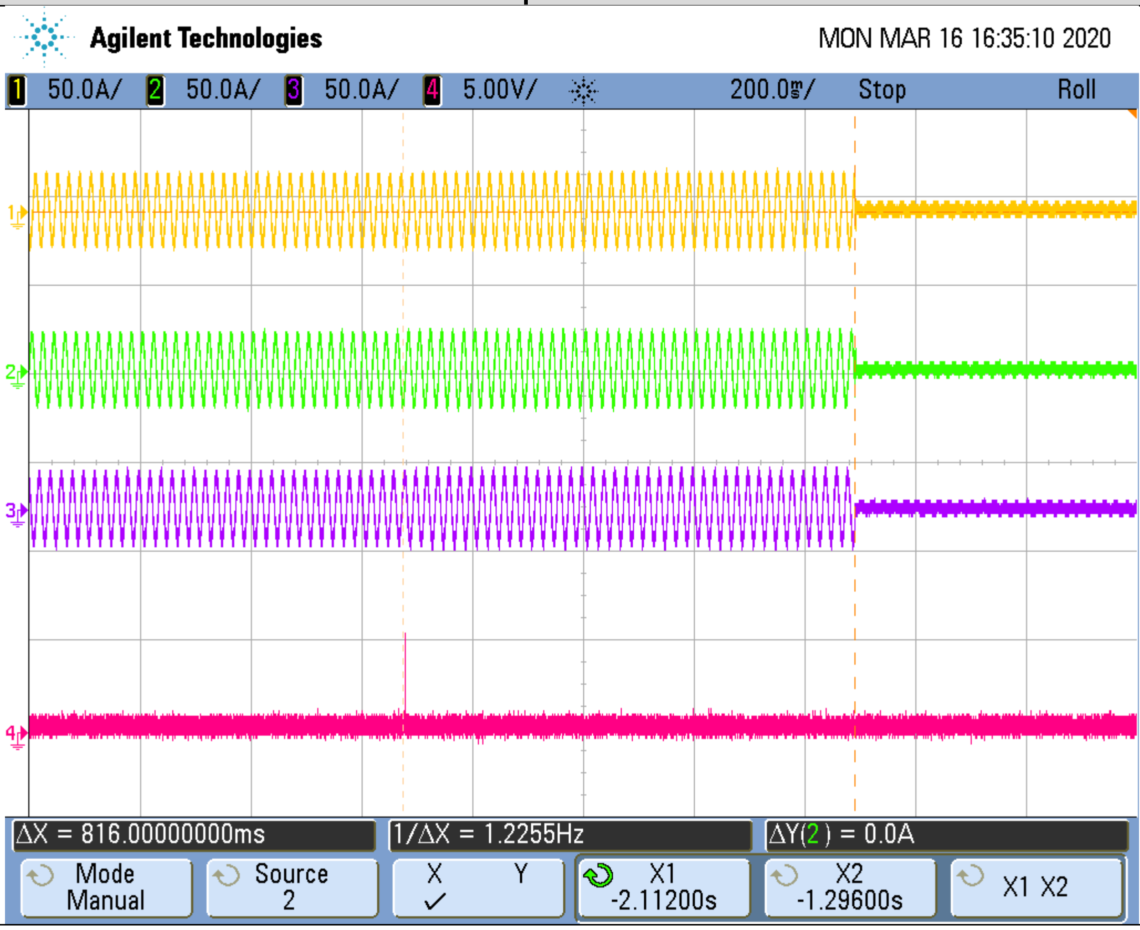
Trip time measured: 0.814s

Undervoltage (U<<) (Test case U8) _ Phase B – Phase N

Trip value test

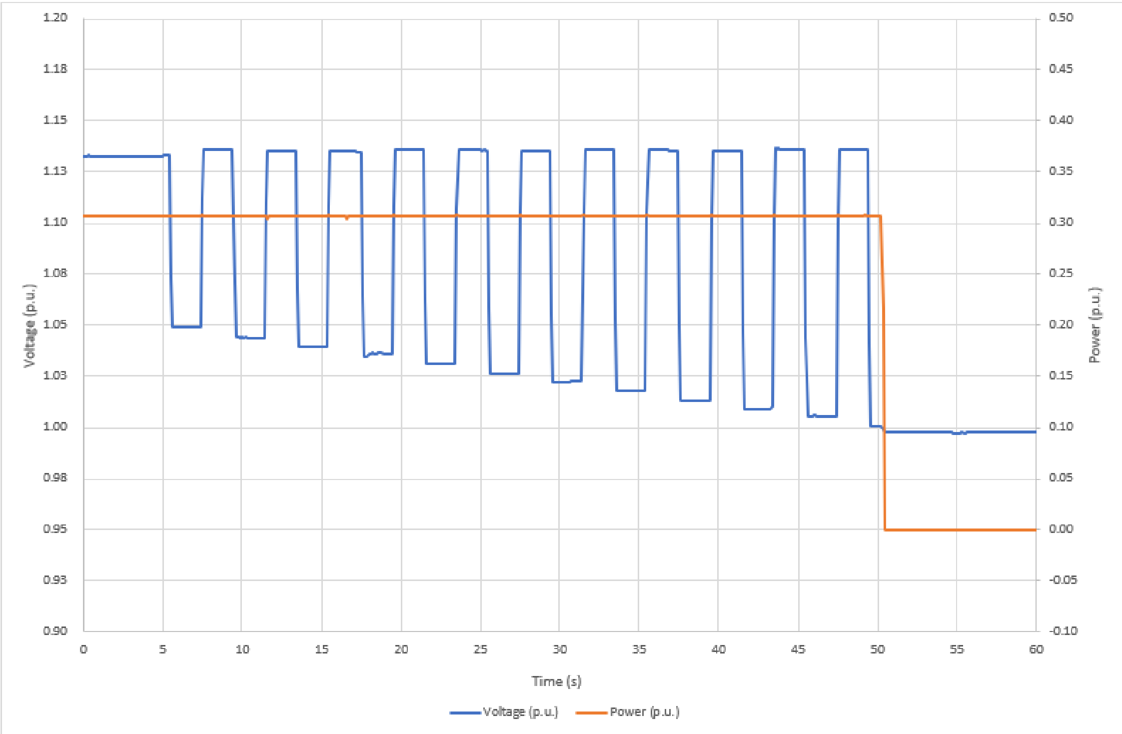


Trip time test

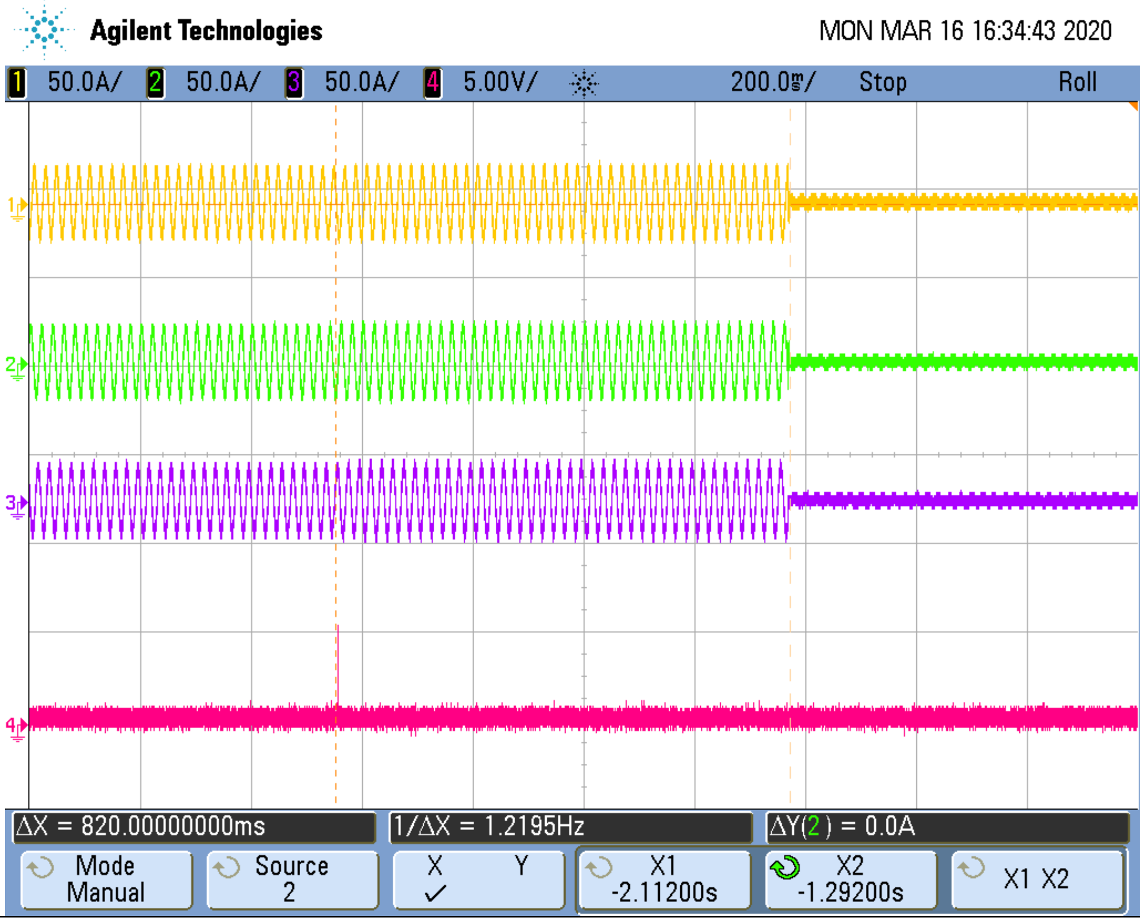


Trip time measured: 0.816s

Undervoltage (U<<) (Test case U8) _ Phase C – Phase N
Trip value test



Trip time test



Trip time measured: 0.820 s

4.4.3 Over & underfrequency protection

Used settings of the measurement device for Over and undervoltage protection measurement.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000 PA5000H	2019/12/05, 2019/12/07,2019/12/08, 2019/12/09, 2019/12/10, 2020/03/06, 2020/03/08, 2020/03/14, 2020/03/16, 2020/03/19, 2020/03/24, 2020/04/30,2020/05/01	100 ms values	10kHz

For over and underfrequency protection test, the measurements have been carried out at the same time for all 3 phases.

The following tables show the test results for trip value test and trip time test:

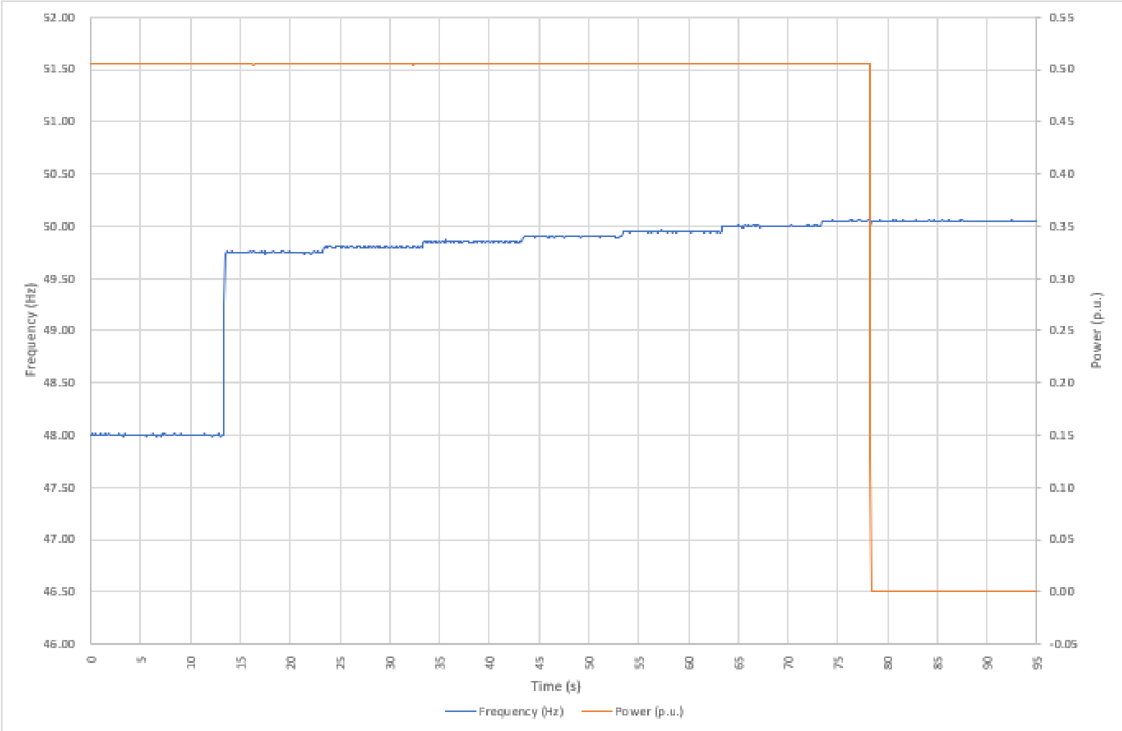
Overfrequency (F>)				
Settings	**Min. threshold**		**Max. threshold**	
	Min. time (Test case F3)	**Max. time (Test case F1)**	**Min. time (Test case F2)**	**Max. time (Test case F4)**
Setting value	50.00Hz		55.00Hz	
Trigger value	49.998Hz	50.004Hz	55.002Hz	55.001
Time setting value	0s	5.000s	0s	5s
Trigger time	0.035s	4.990s	0.036s	5.008s

Overfrequency (F>>)				
Settings	**Min. threshold**		**Max. threshold**	
	Min. time (Test case F5)	**Max. time (Test case F7)**	**Min. time (Test case F8)**	**Max. time (Test case F6)**
Setting value	50.00Hz		55.00Hz	
Trigger value	49.993Hz	50.006 Hz	55.050Hz	54.997Hz
Time setting value	0s	0.1s	0s	0.1s
Trigger time	0.041s	0.103s	0.035s	0.082s

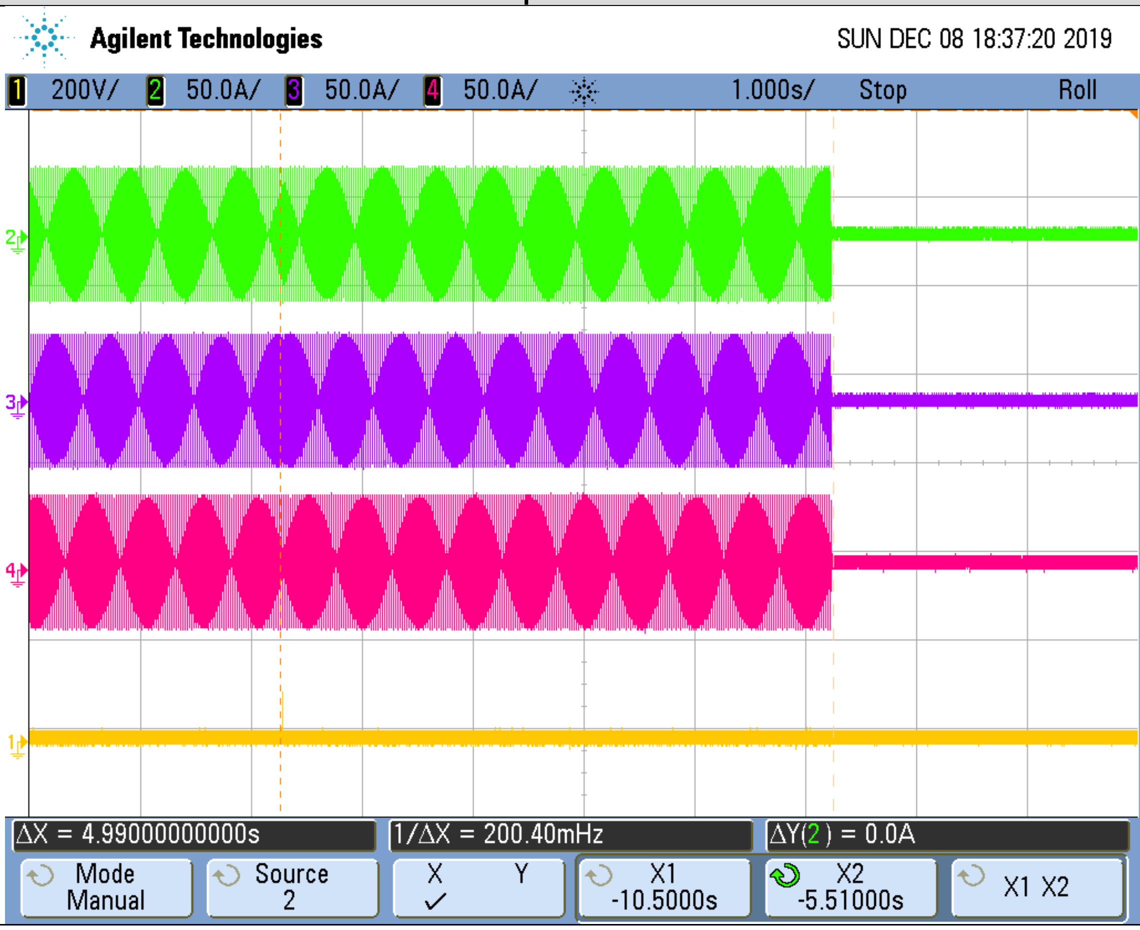
Underfrequency (F<)				
Settings	**Min. threshold**		**Max. threshold**	
	Min. time (Test case F9)	**Max. time (Test case F11)**	**Min. time (Test case F12)**	**Max. time (Test case F10)**
Setting value	45.00Hz		50.00Hz	
Trigger value	44.994Hz	45.005Hz	49.996Hz	50.002Hz
Time setting value	0s	0.1s	0s	0.1s
Trigger time	0.036s	0.104s	0.037s	0.089s

Overfrequency (Test case F1)

Trip value test

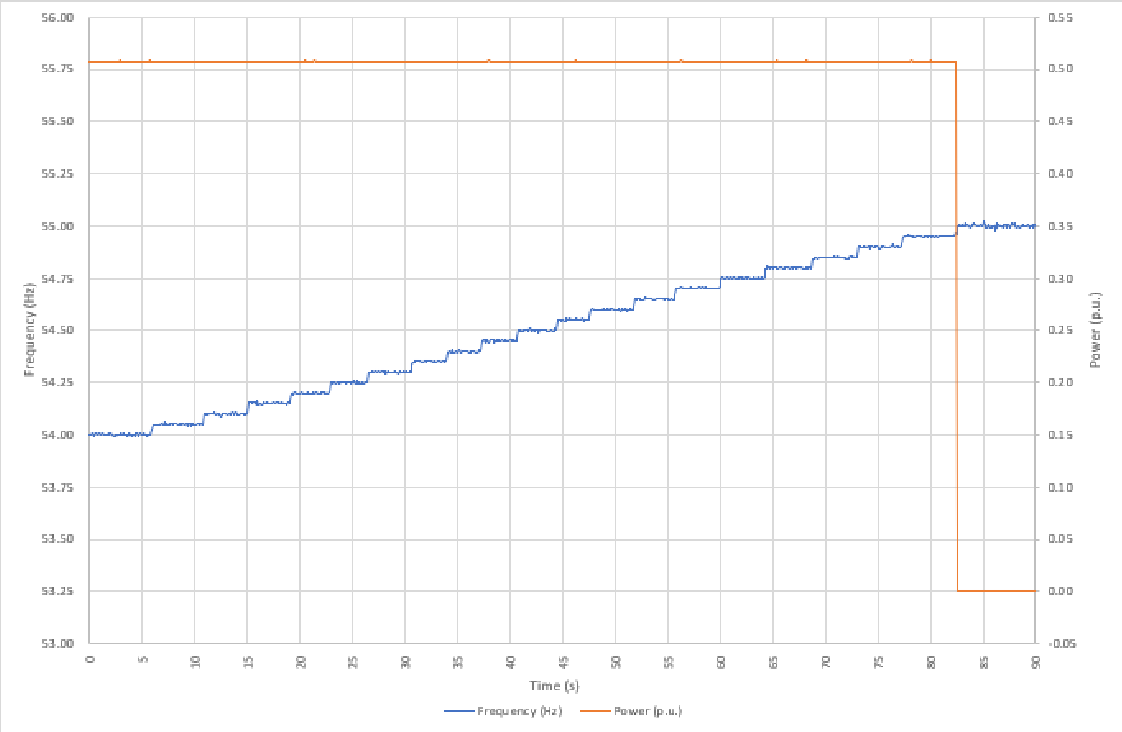


Trip time test

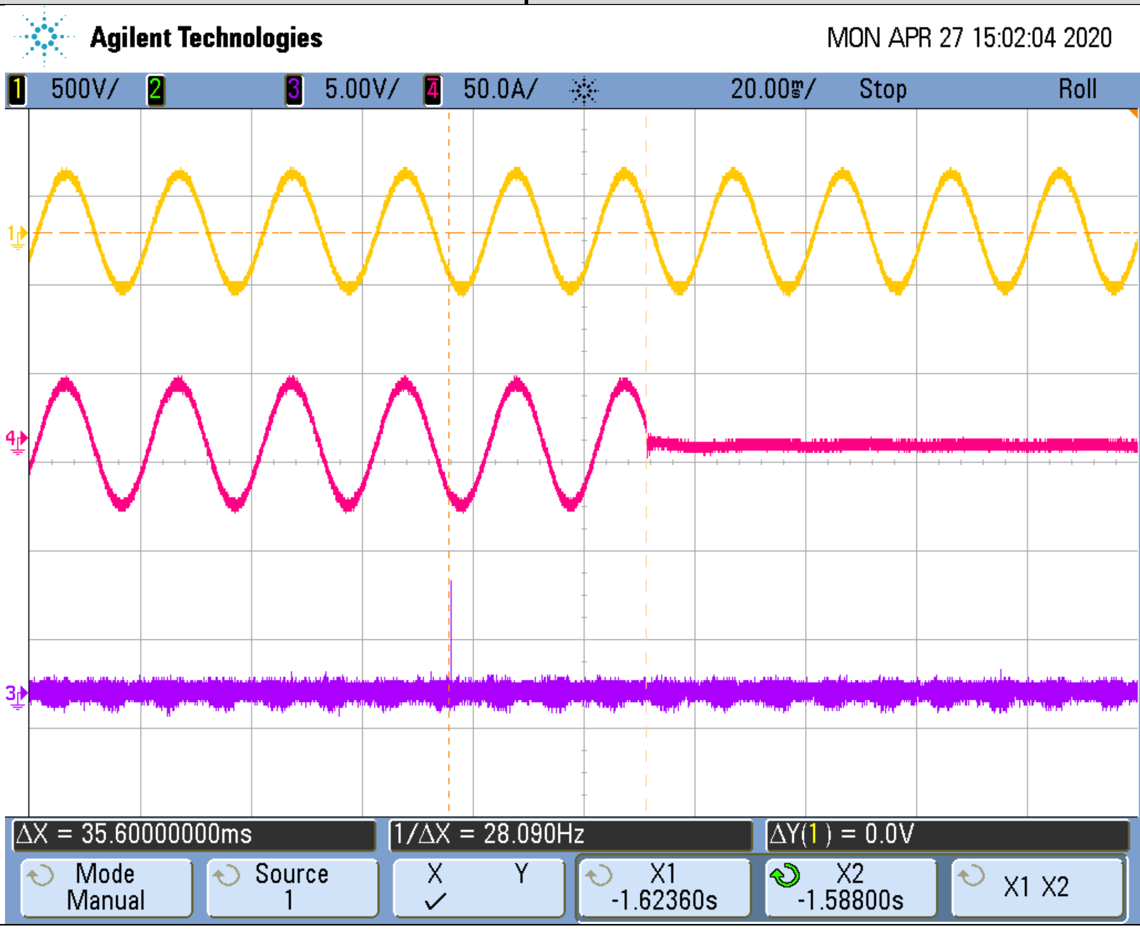


Trip time measured: 4.990s

Overfrequency (Test case F2)
Trip value test

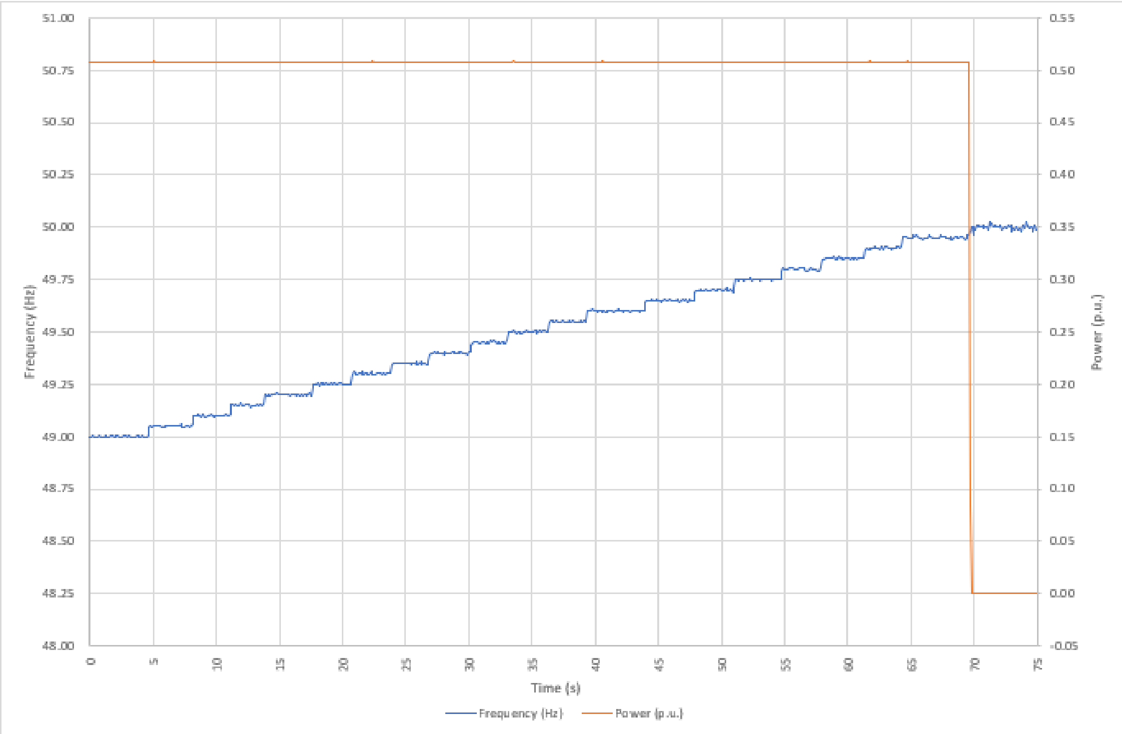


Trip time test

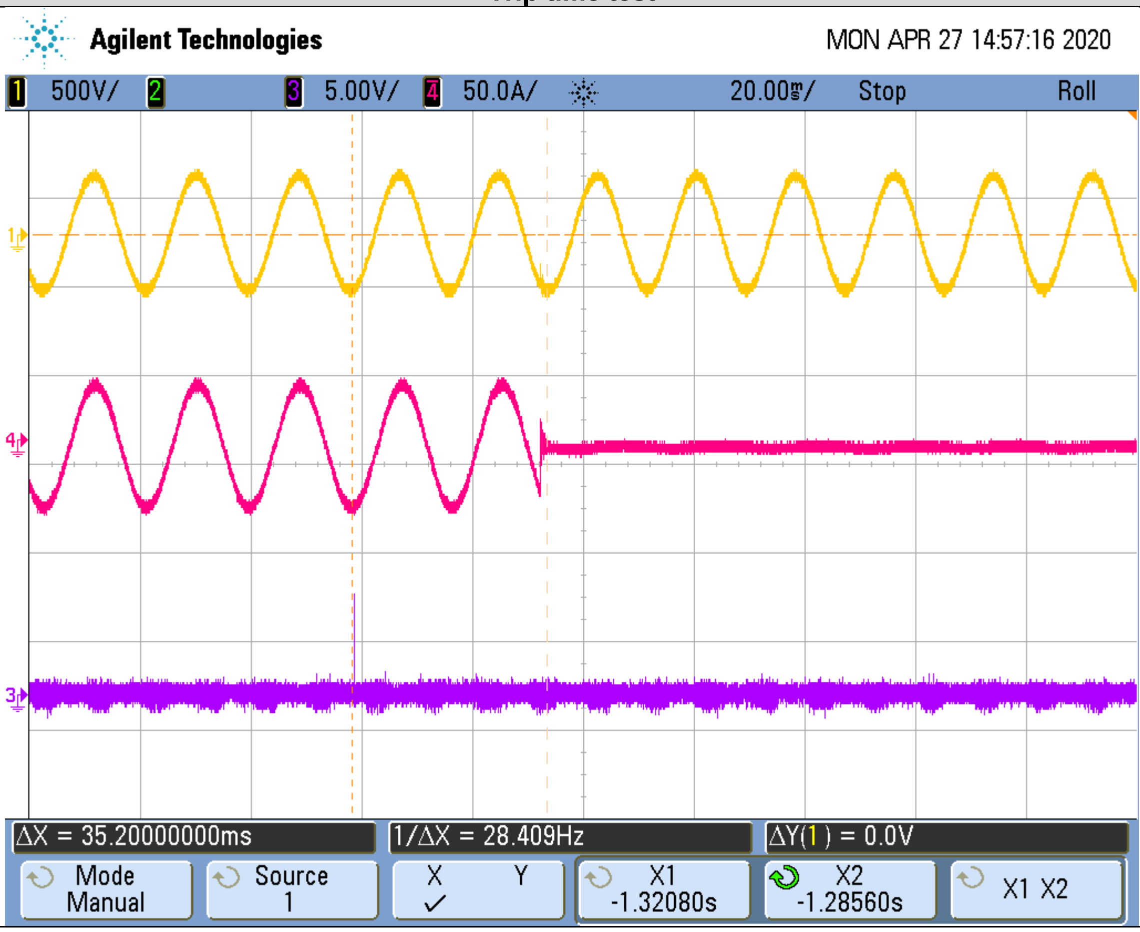


Trip time measured: 0.036s

Overfrequency (Test case F3)
Trip value test



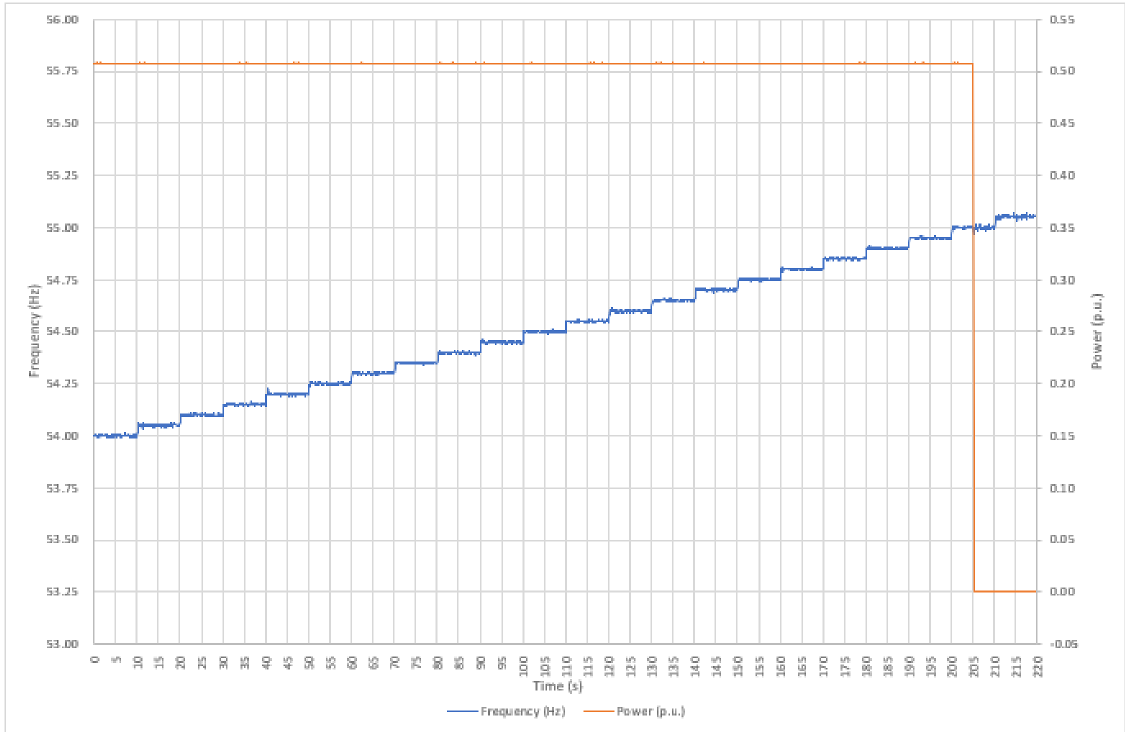
Trip time test



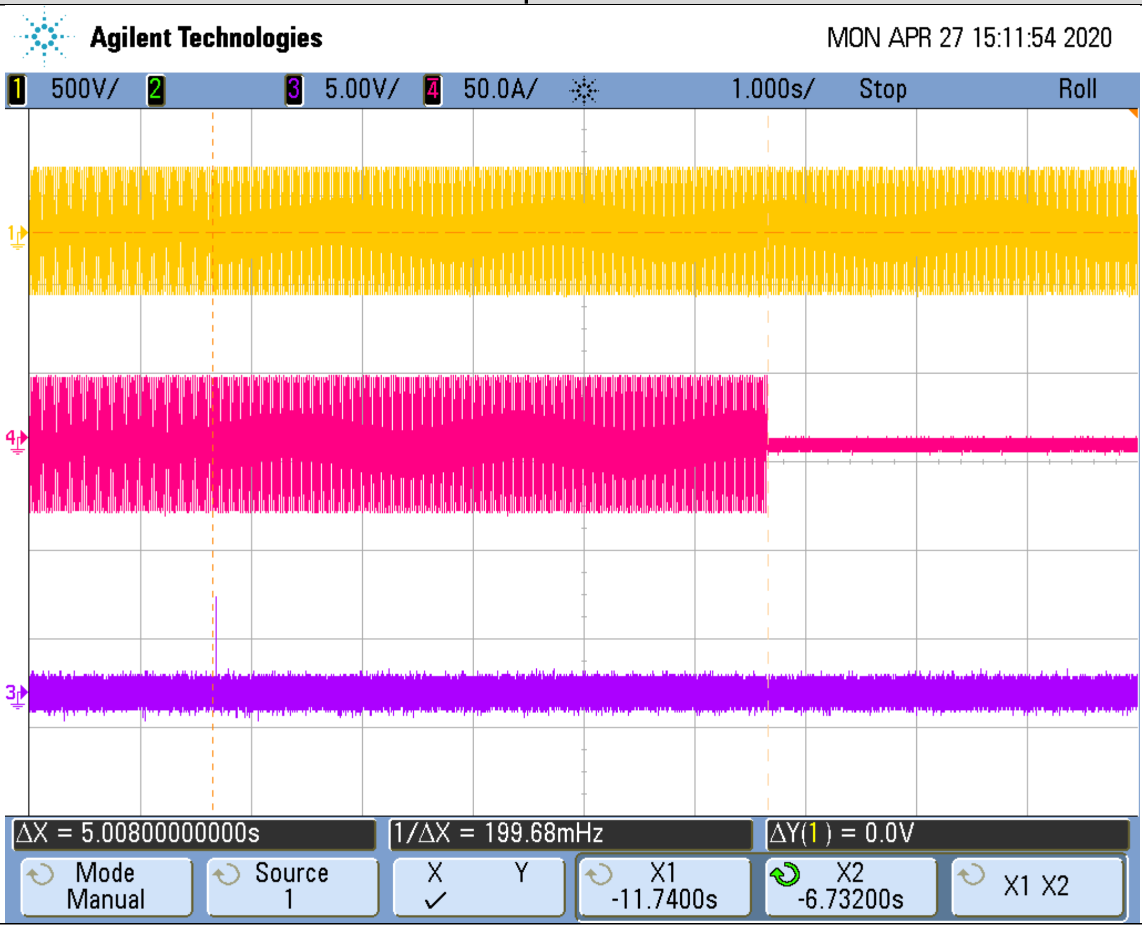
Trip time measured: 0.035s

Overfrequency (Test case F4)

Trip value test



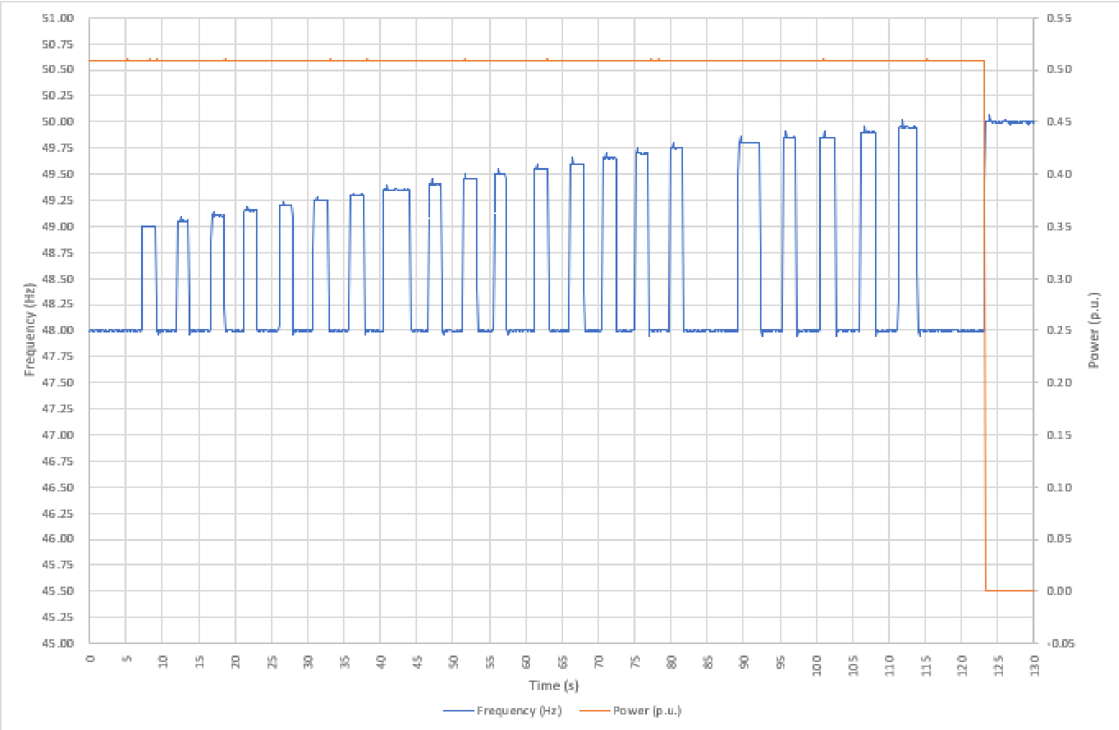
Trip time test



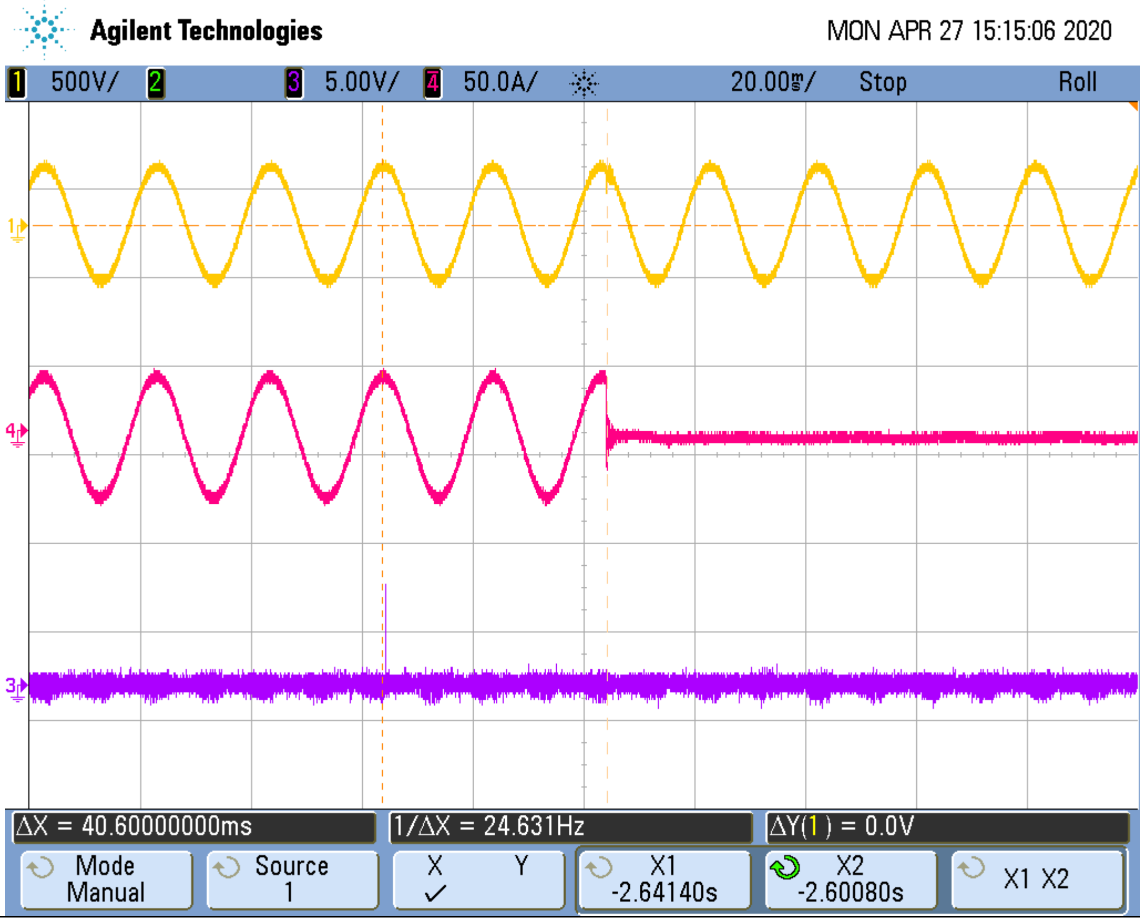
Trip time measured: 5.008 s

Overfrequency (Test case F5)

Trip value test



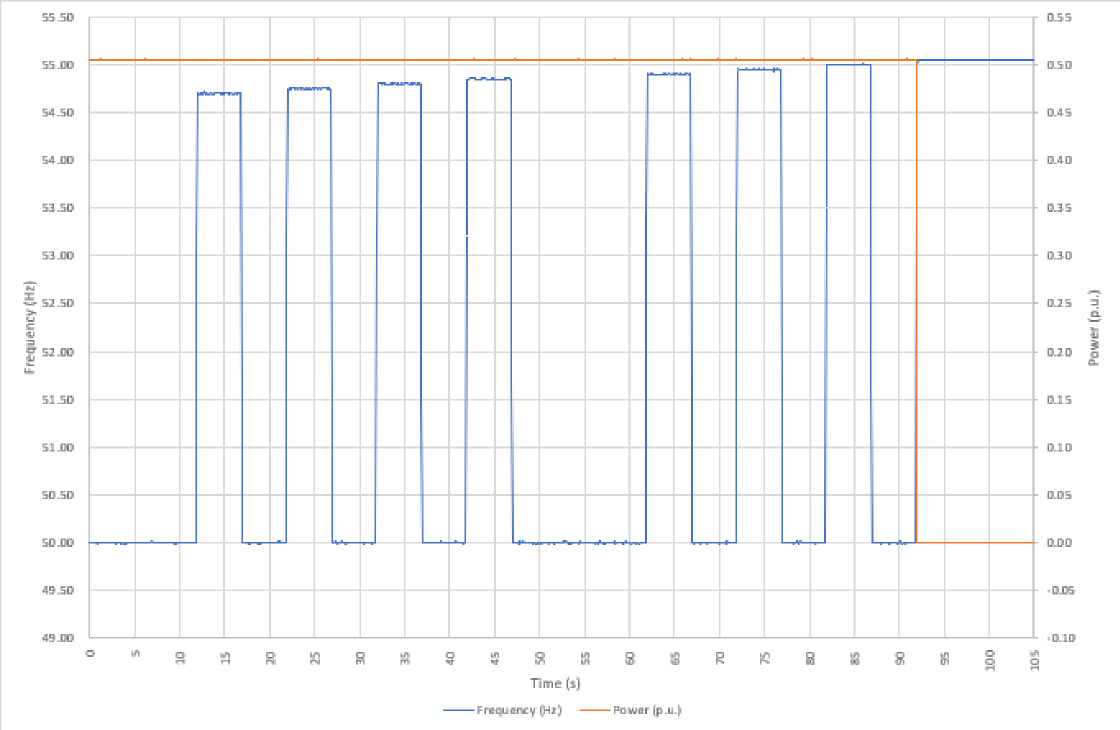
Trip time test



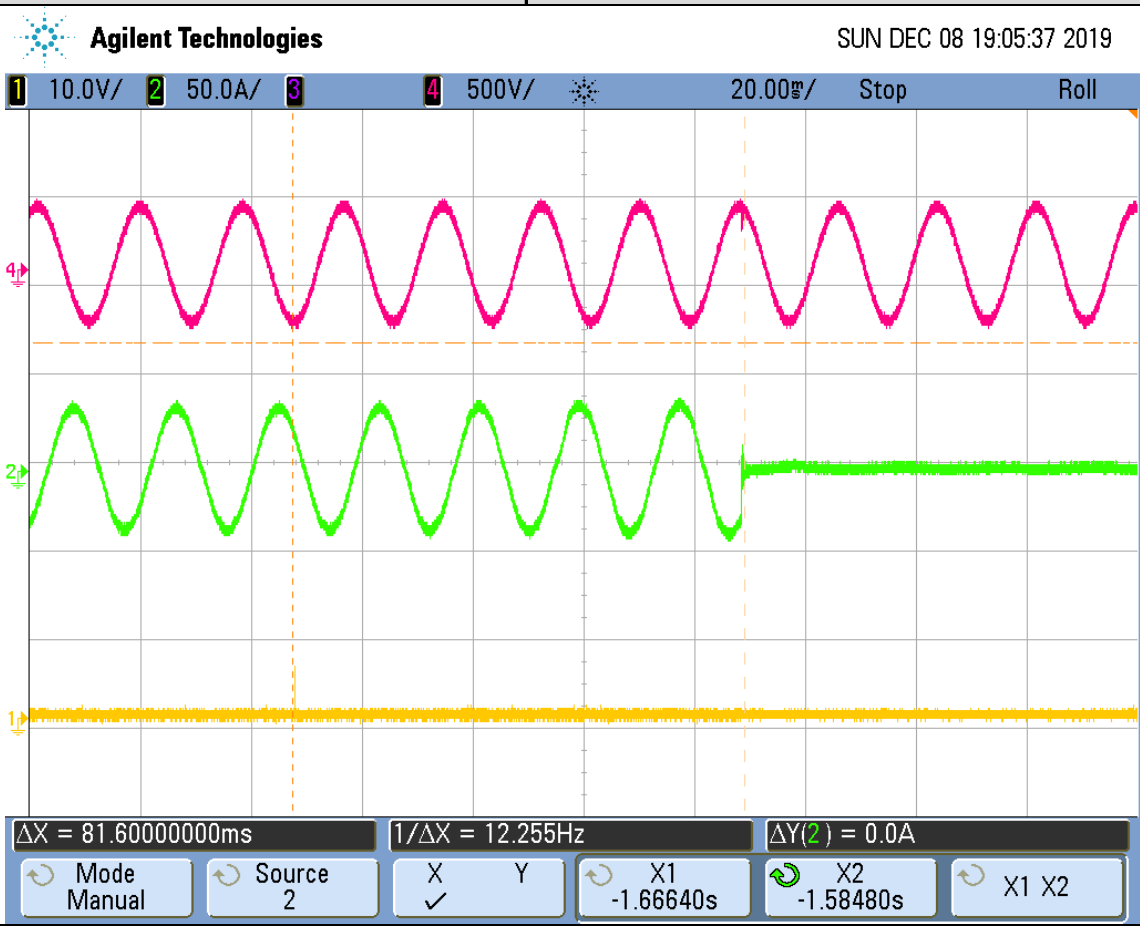
Trip time measured: 0.041s

Overfrequency (Test case F6)

Trip value test

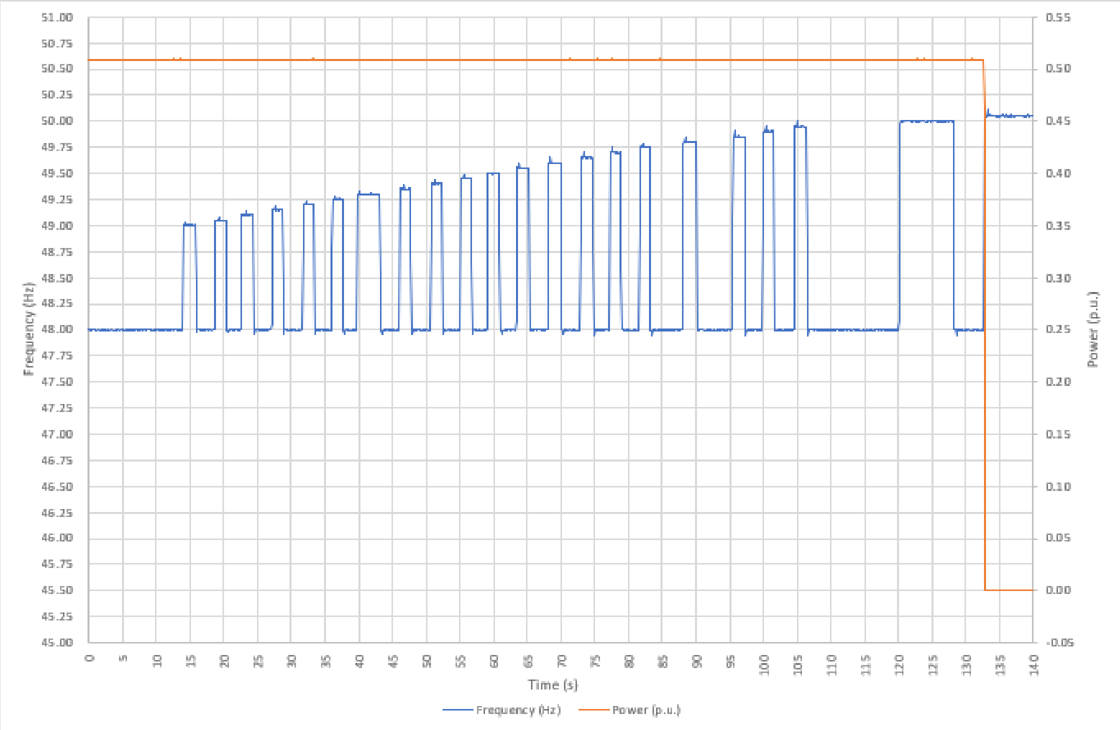


Trip time test

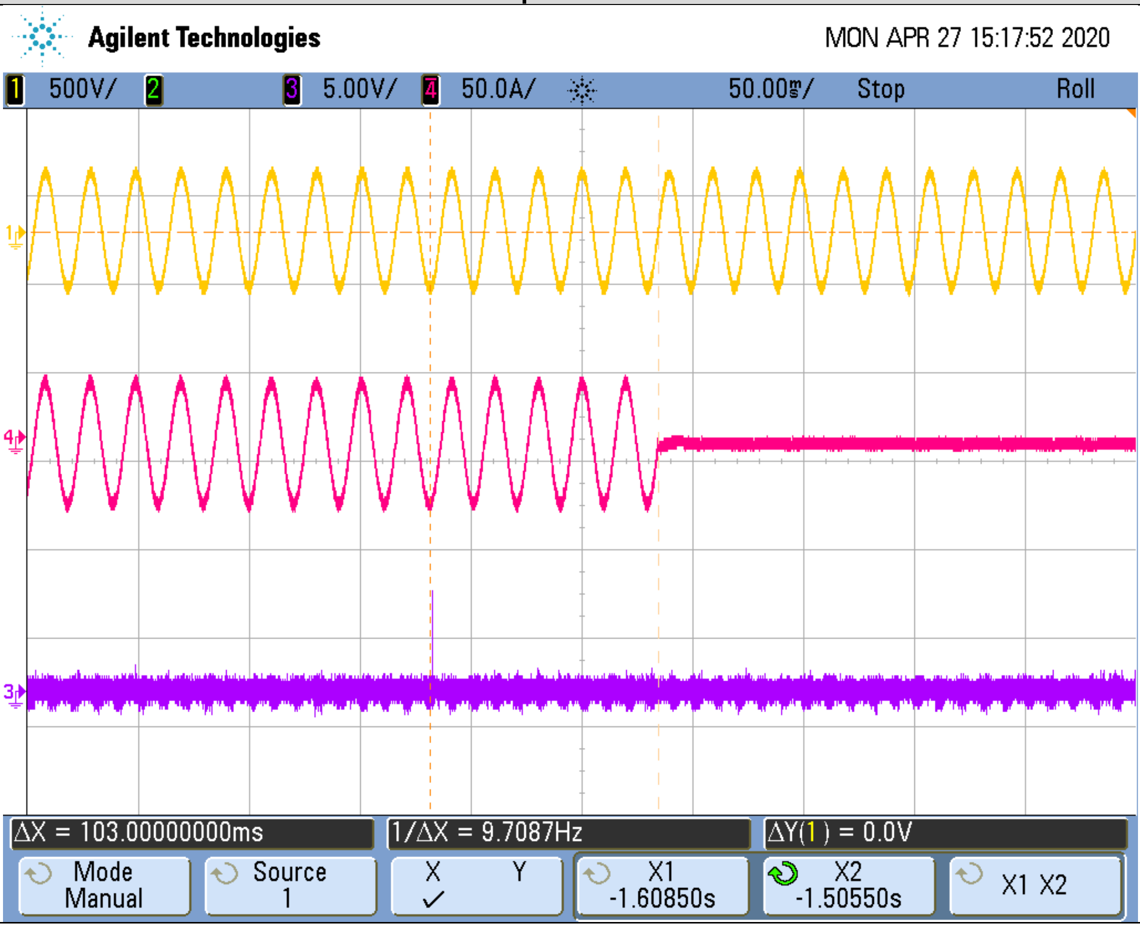


Trip time measured: 0.082s

Overfrequency (Test case F7)
Trip value test

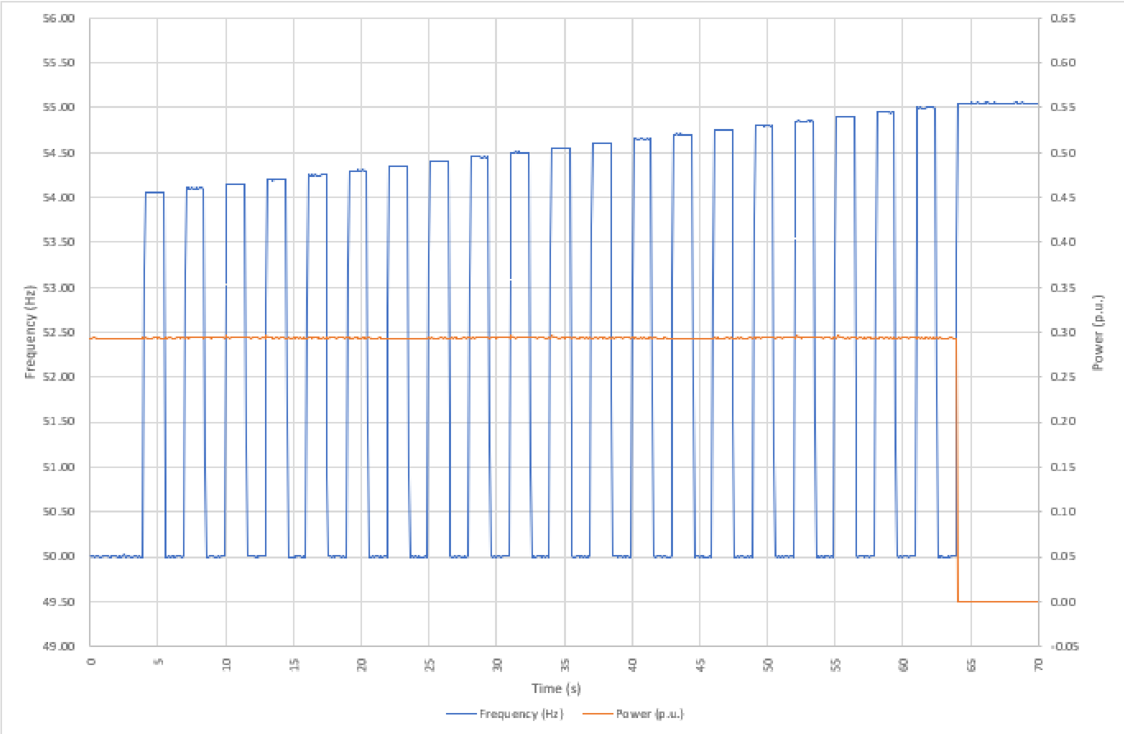


Trip time test

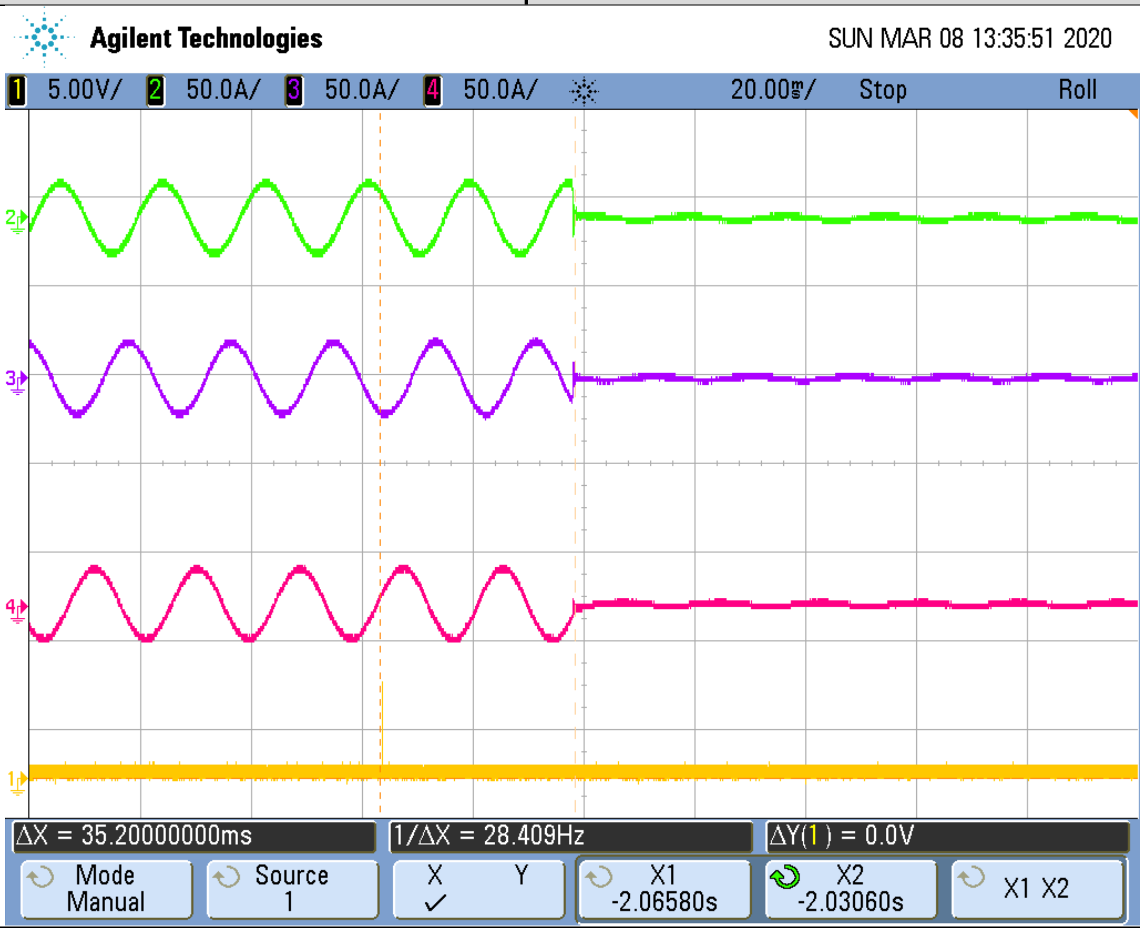


Trip time measured: 0.103 ms

Overfrequency (Test case F8)
Trip value test



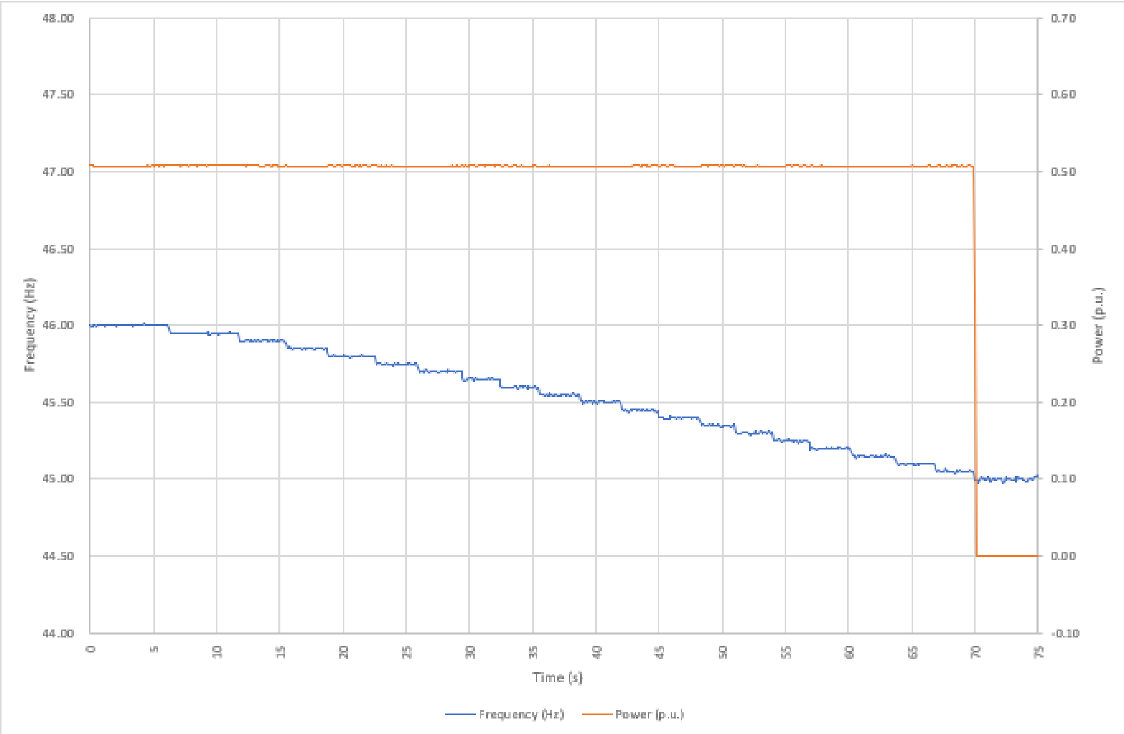
Trip time test



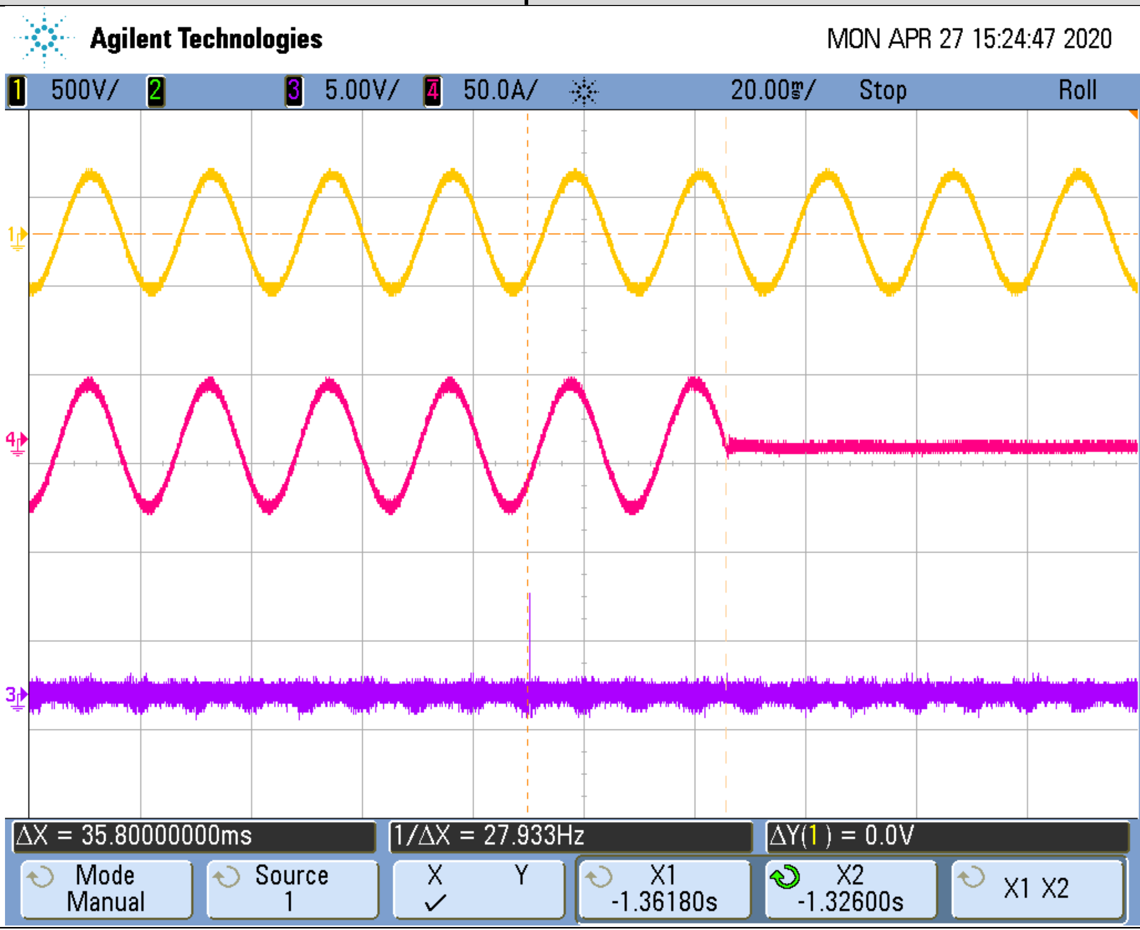
Trip time measured: 0.035s

Underfrequency (Test case F9)

Trip value test

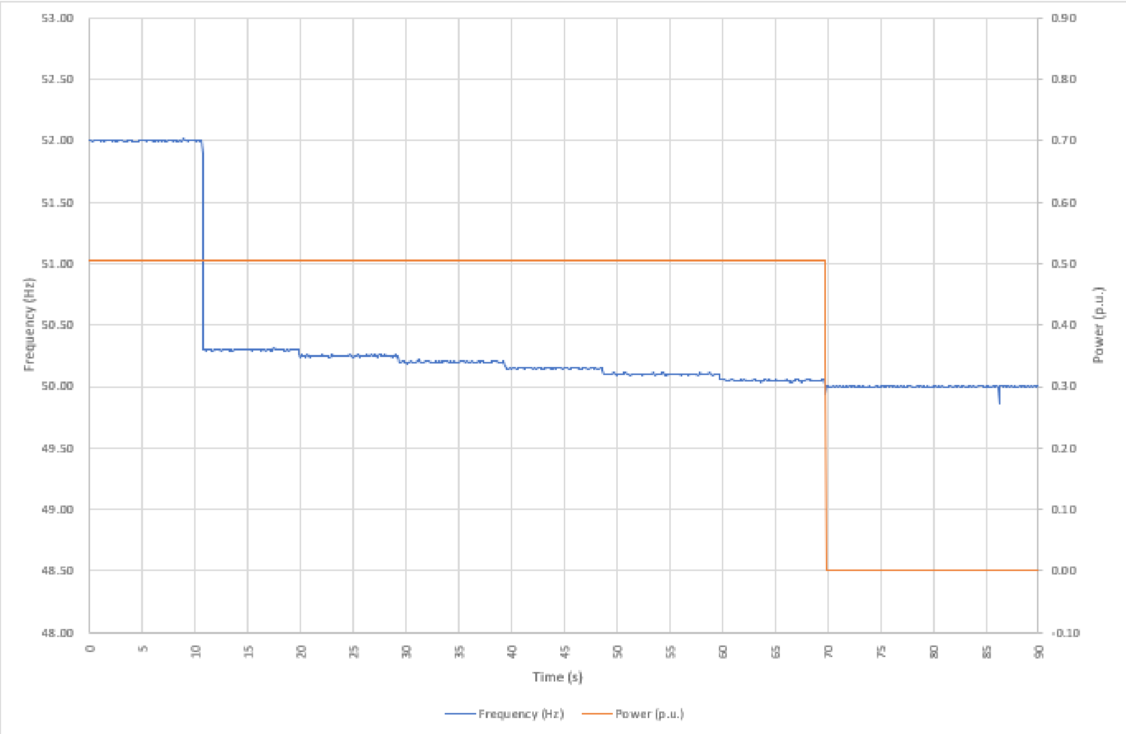


Trip time test

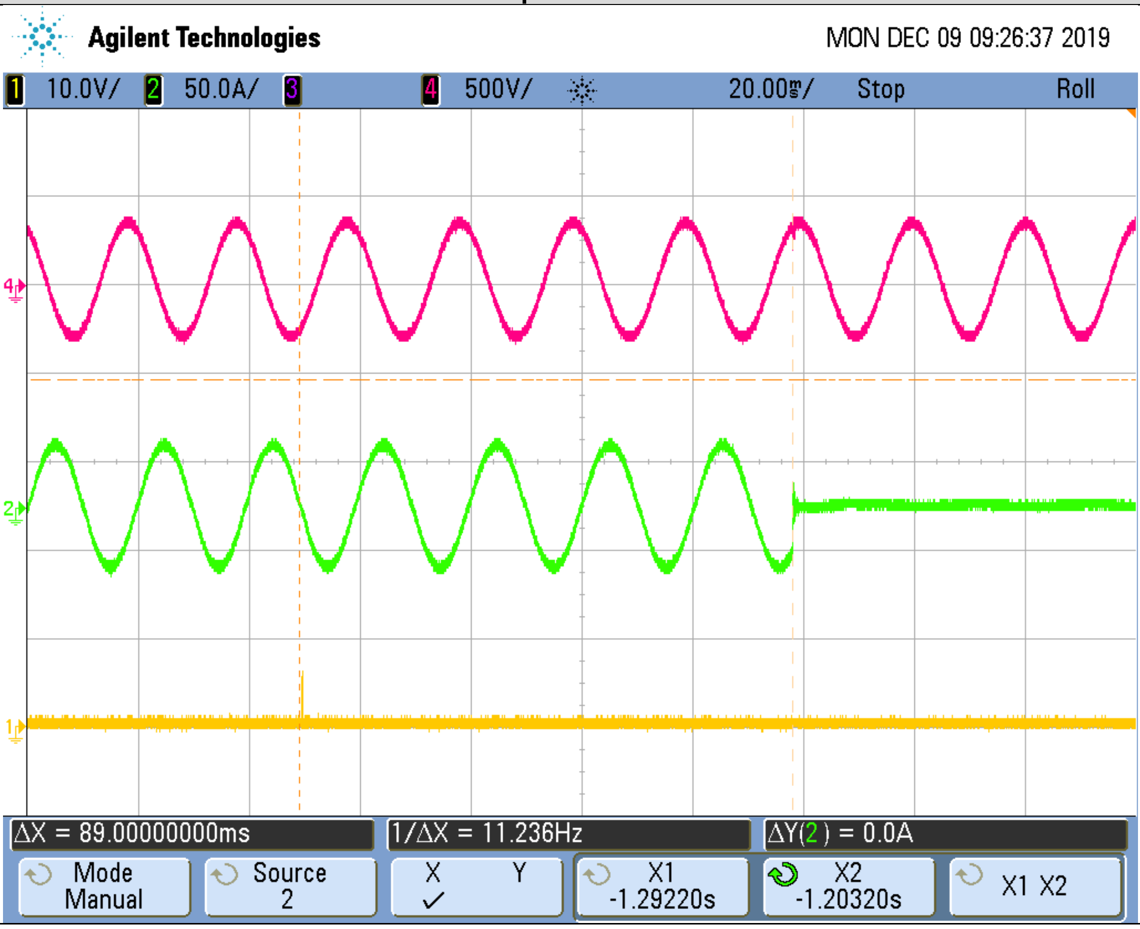


Trip time measured: 0.036s

Underfrequency (Test case F10)
Trip value test

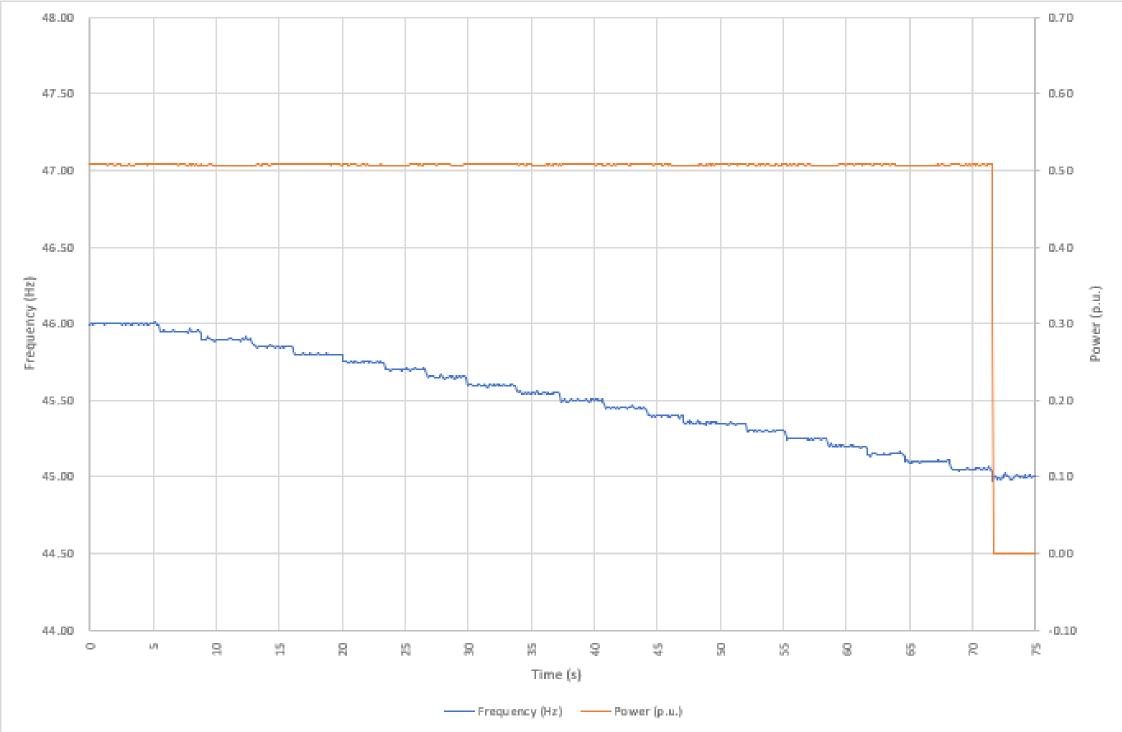


Trip time test

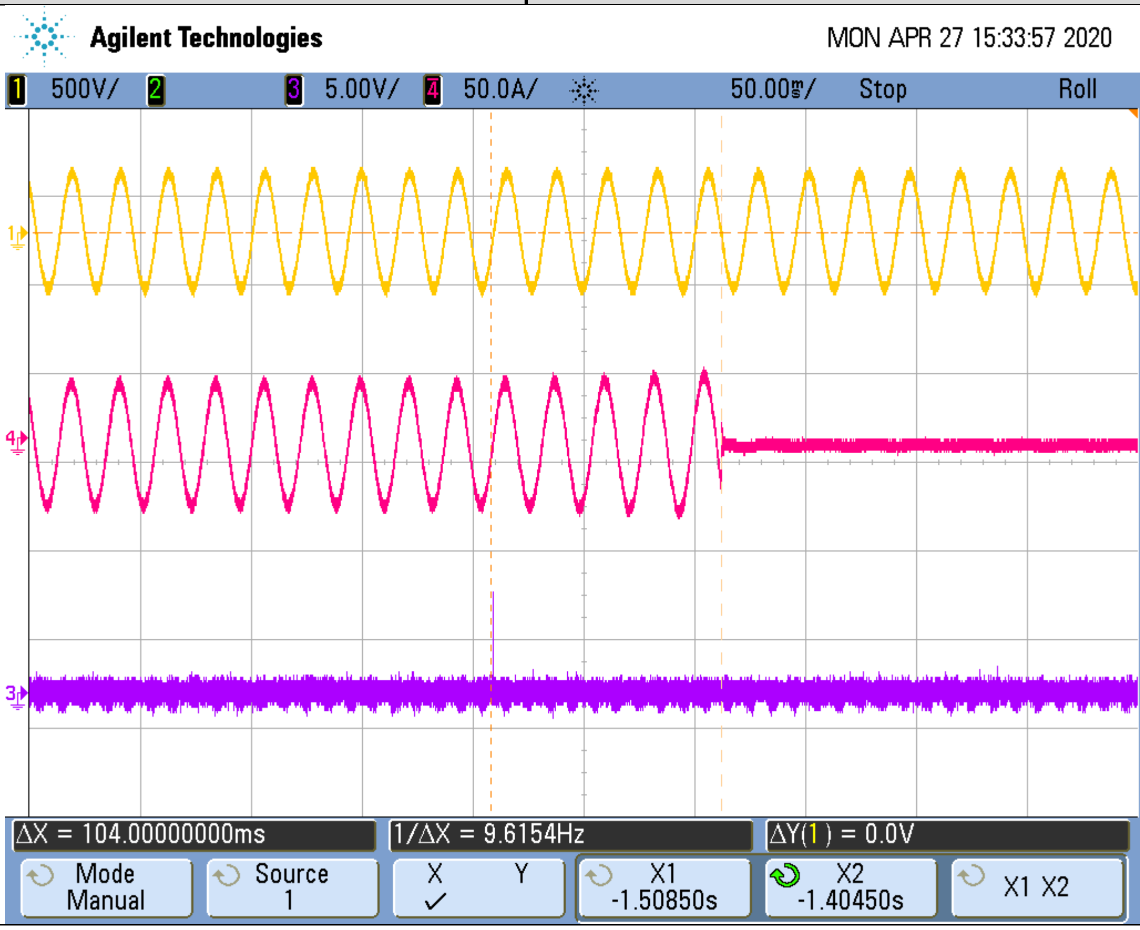


Time measured: 0.089s

Underfrequency (Test case F11)
Trip value test

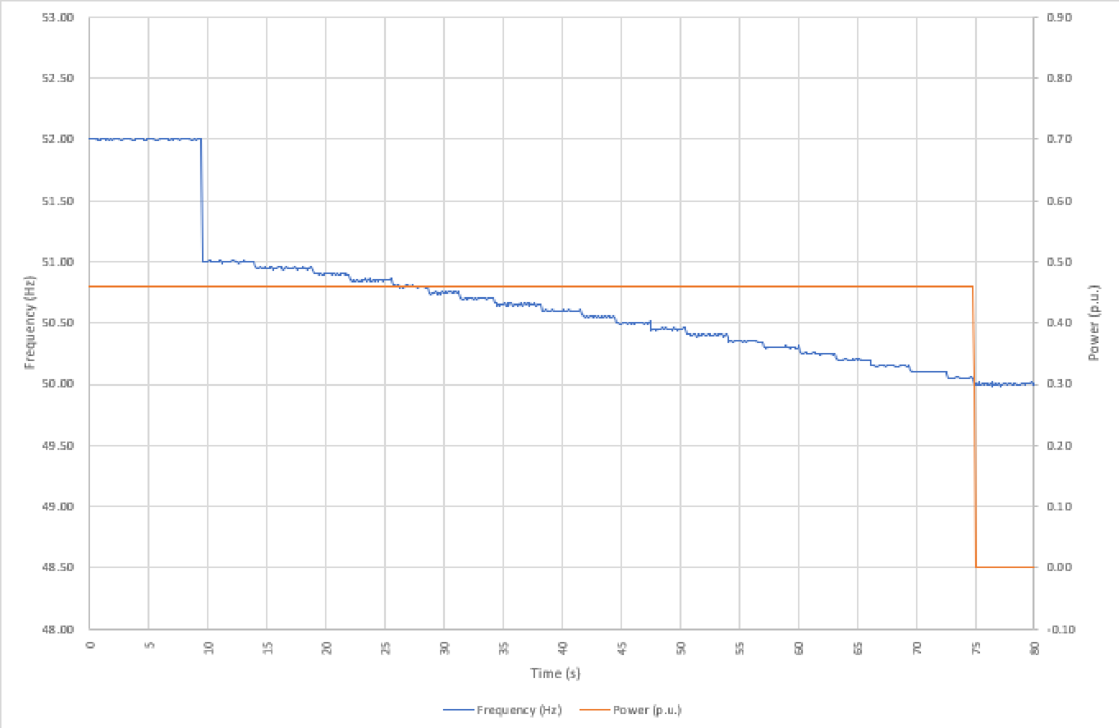


Trip time test

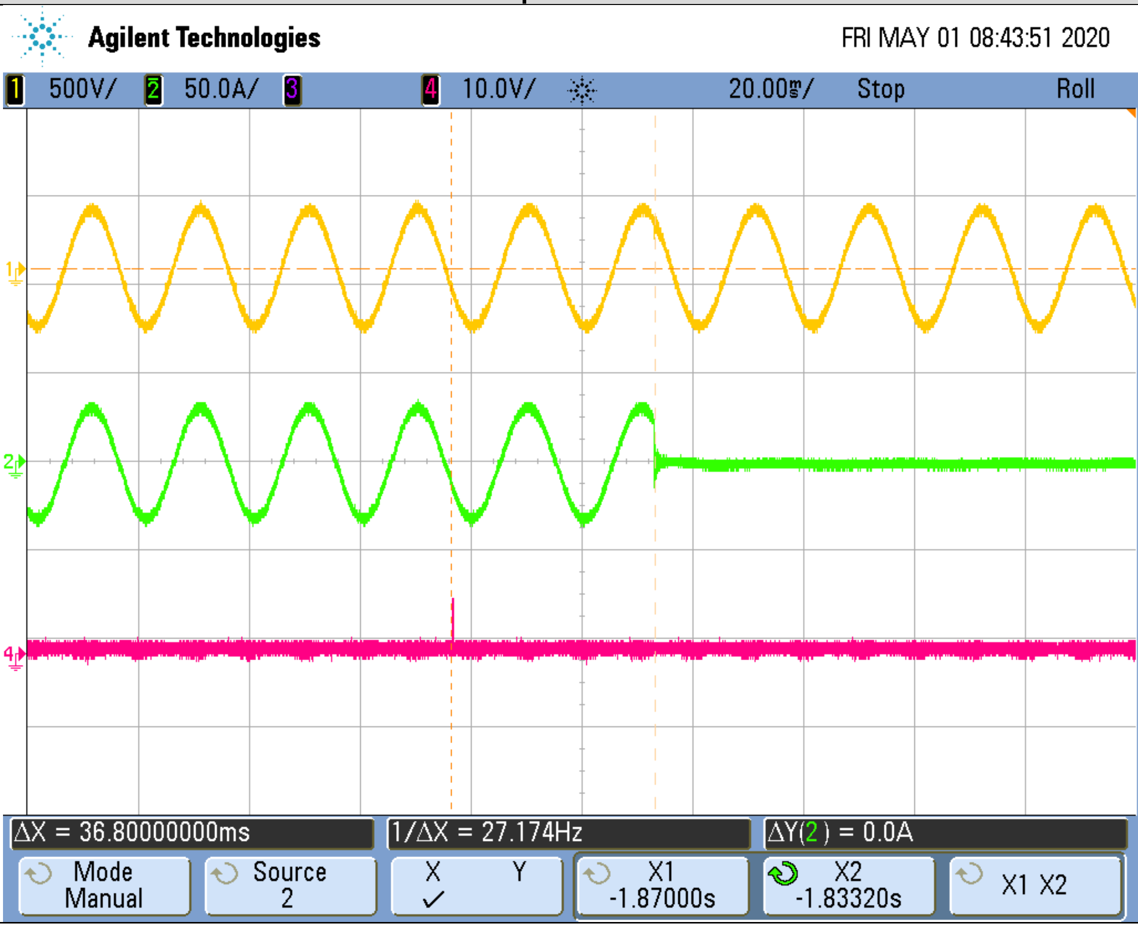


Trip time measured: 0.104s

Underfrequency (Test case F12)
Trip value test



Trip time test



Trip time measured: 0.037 s

4.4.4 Resetting Ratio

These tests have been done in order to see that if the time of the abnormal voltage conditions is lower in comparison with the setting time the inverter do not trip. These tests are only carried out on three phases. Trigger time has been set at 1.000 seconds and trigger values for over-voltage and under-voltaege at 110%Un and 80%Un respectively. Test procedure is detailed below in the following table and graphs from the standard:

TEST PROCEDURE	
Resetting ratio Over-voltage protection	Starting from a voltage of 0.98*trigger value (S tep 1), the voltage steps to 1.02*trigger value for 500 ms (Step 2). The voltage then steps back to a value of 0.98*trigger value for 5s (Step 3). After another 5s the voltage steps to 1.02*trigger value and remains there until it triggers (Step 4).
Resetting ratio Under-voltage protection	Starting from a voltage of 1.02*trigger value (Step 1), the voltage steps to 0.98*trigger value for 500 ms (Step 2). The voltage then steps back to a value of 1.02*trigger value for 5s (Step 3). After another 5s the voltage steps to 0.98*trigger value and remains there until it triggers (Step 4).

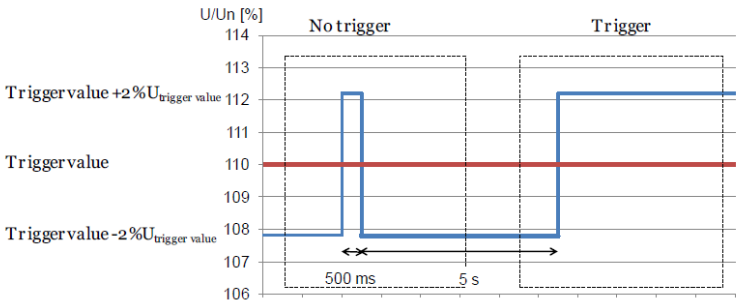


Fig. 4–23: Resetting ratio test for overvoltage protection

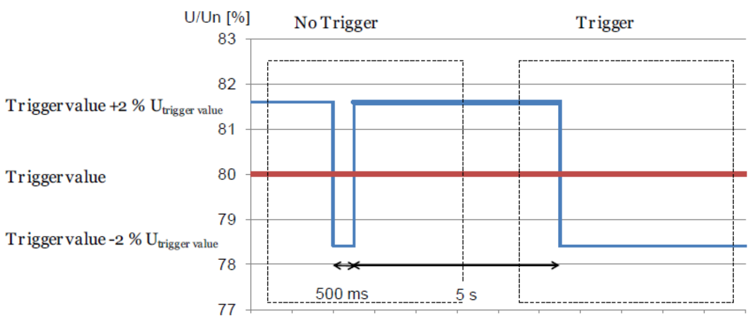


Fig. 4–24: Resetting ratio test for undervoltage protection

Used settings of the measurement device for resetting ratio.

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/11	100 ms values	10 kHz

The following table shows the result of resetting ratio results:

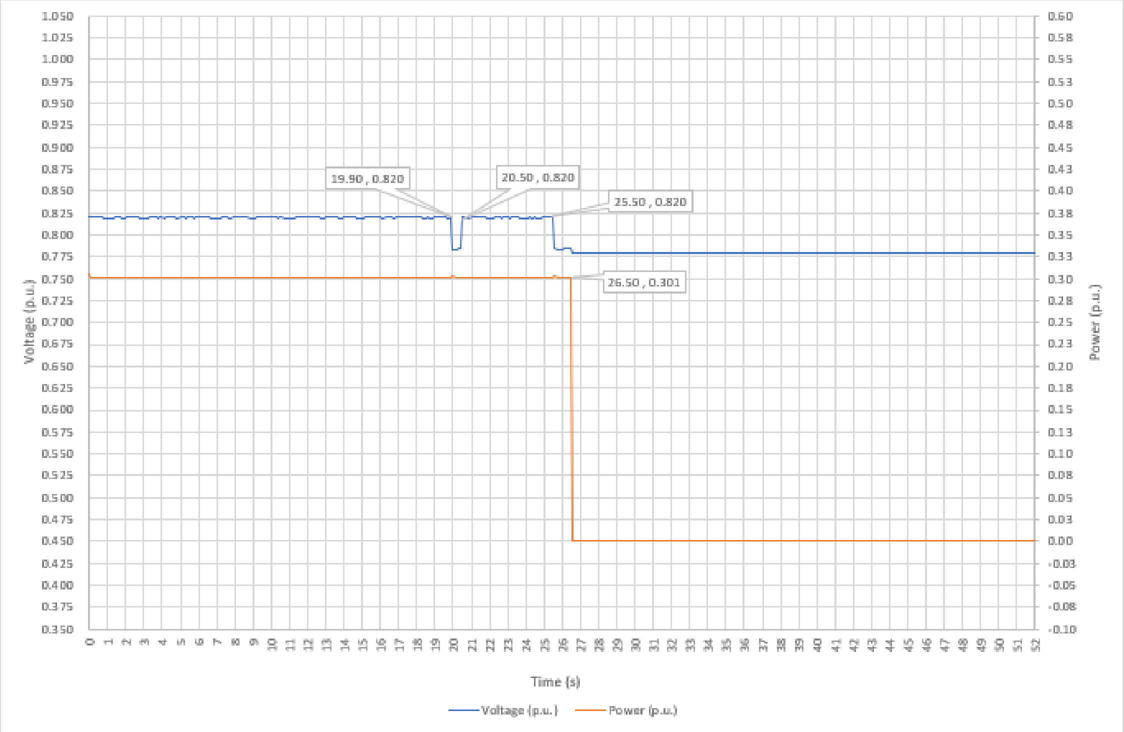
Resetting Ratio test					
Stage/Prot Function	Step 1		Step 2		
	Voltage measured (% Un)	Time measured (s)	Voltage measured (% Un)	Time required (s)	Time measured (s)
UV 80% Un	0.820Un	19.900s	0.784Un	0.5s	0.600s
OV 120% Un	1.184Un	22.600	1.220Un	0.5s	0.600s

Resetting Ratio test					
Stage/Prot Function	Step 3			Step 4	
	Voltage measured (% Un)	Time required (s)	Time measured (s)	Disconnection	Disconection time (s)
UV 80% Un	0.820Un	5.000s	5.000s	☐ NO ☒ YES	1.000s
OV 120% Un	1.184Un	5.000s	5.000s	☐ NO ☒ YES	1.000s

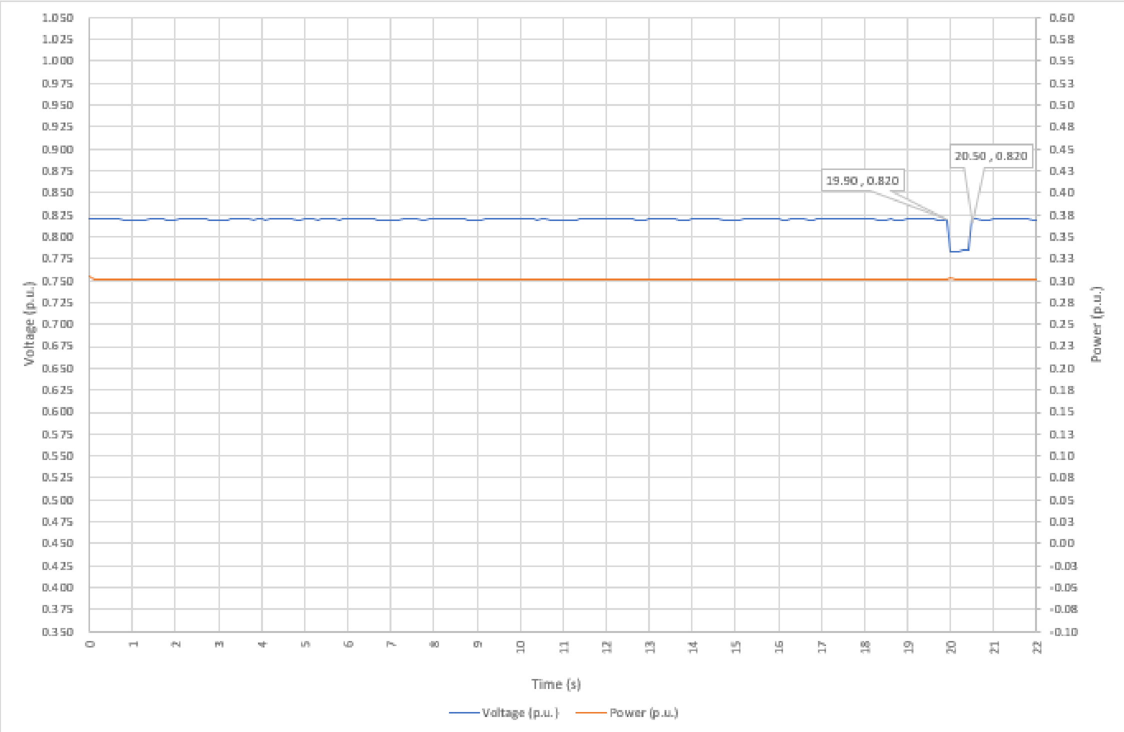
Resetting ratio		
Type Protection	Requirement	Measurement
Overvoltage Protection	>0.98	1.016
Undervoltage Protection	<1.02	1.025

Under voltage

Over view

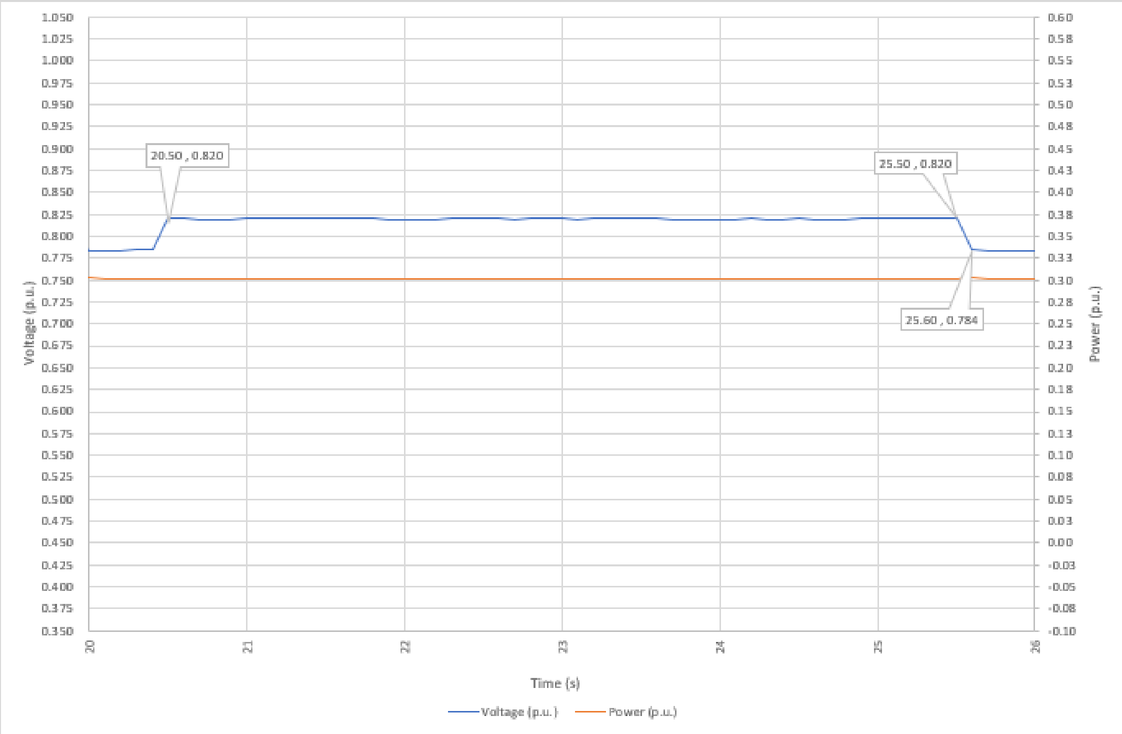


(Step 1 and Step 2)

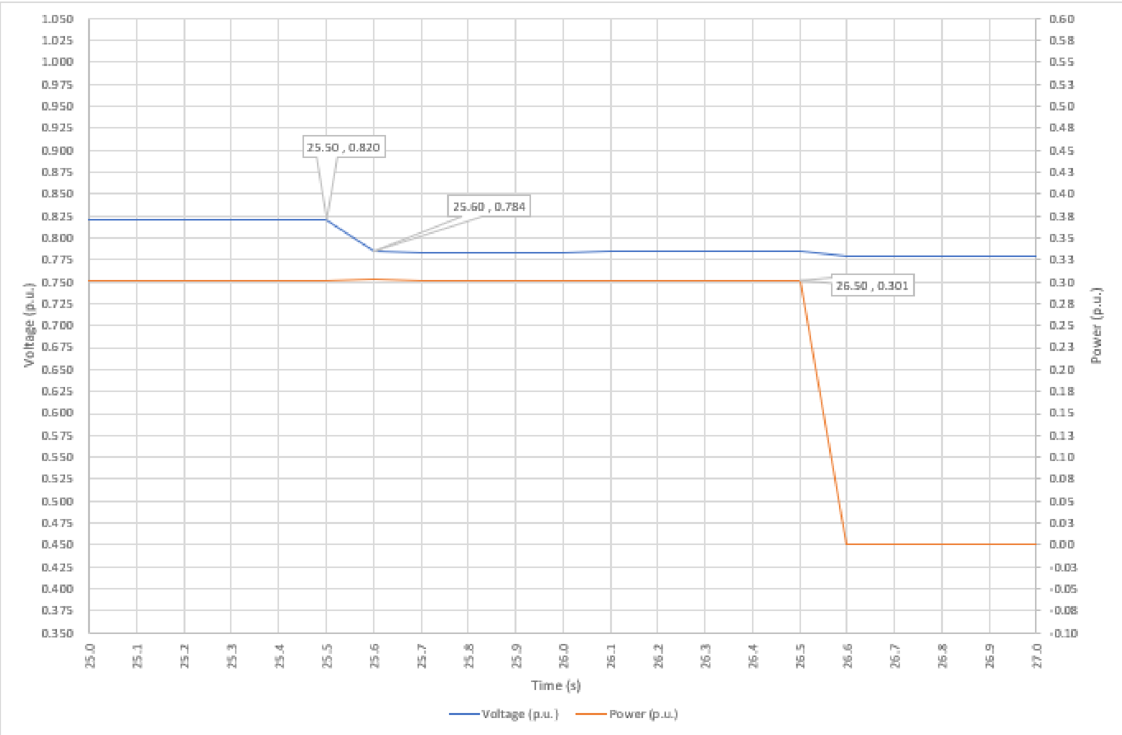


Under voltage

(Step 3)

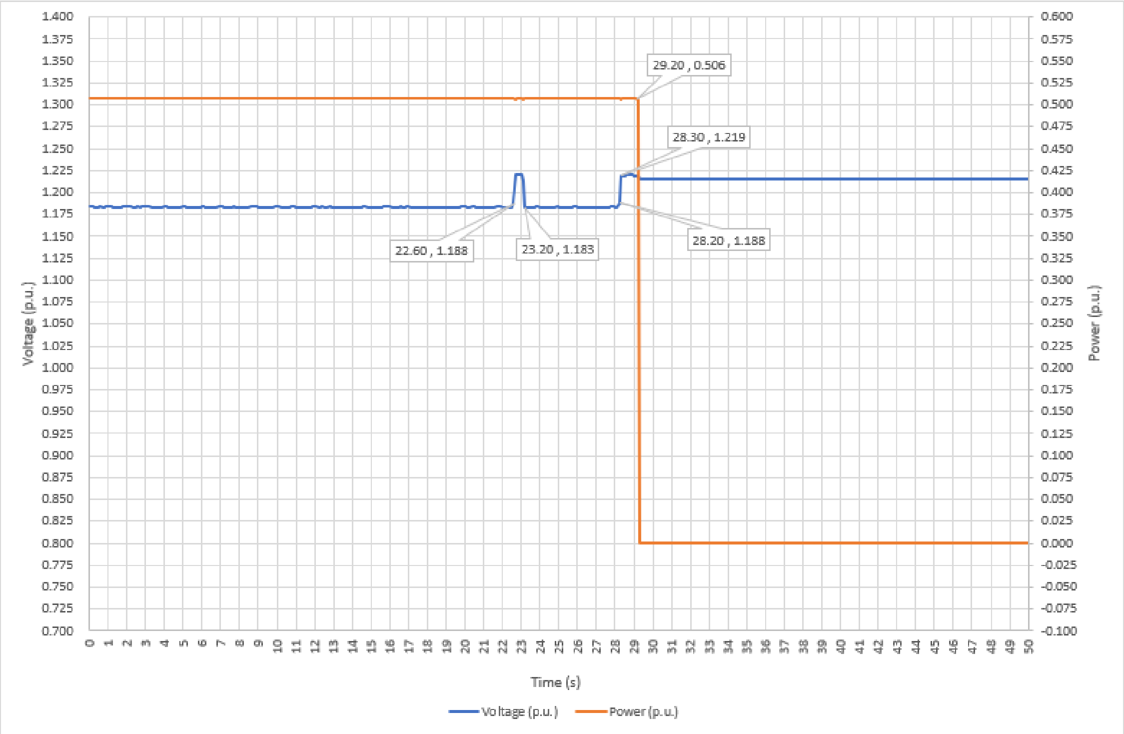


(Step 4)

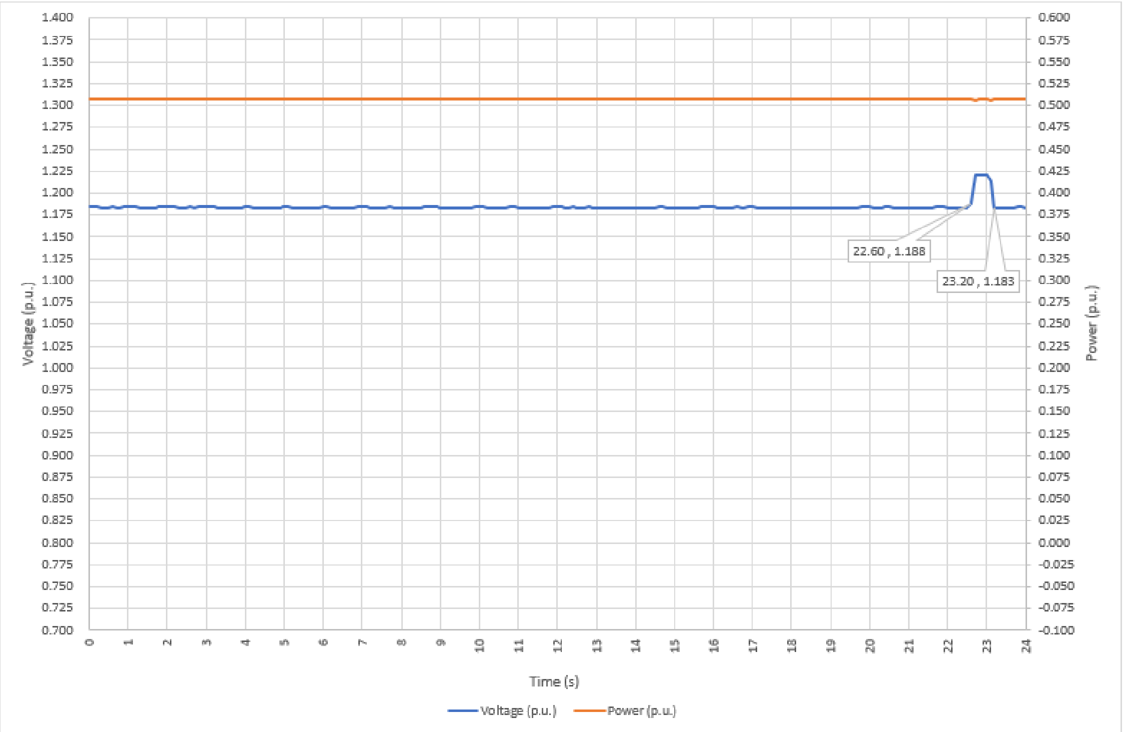


Over voltage

Over View

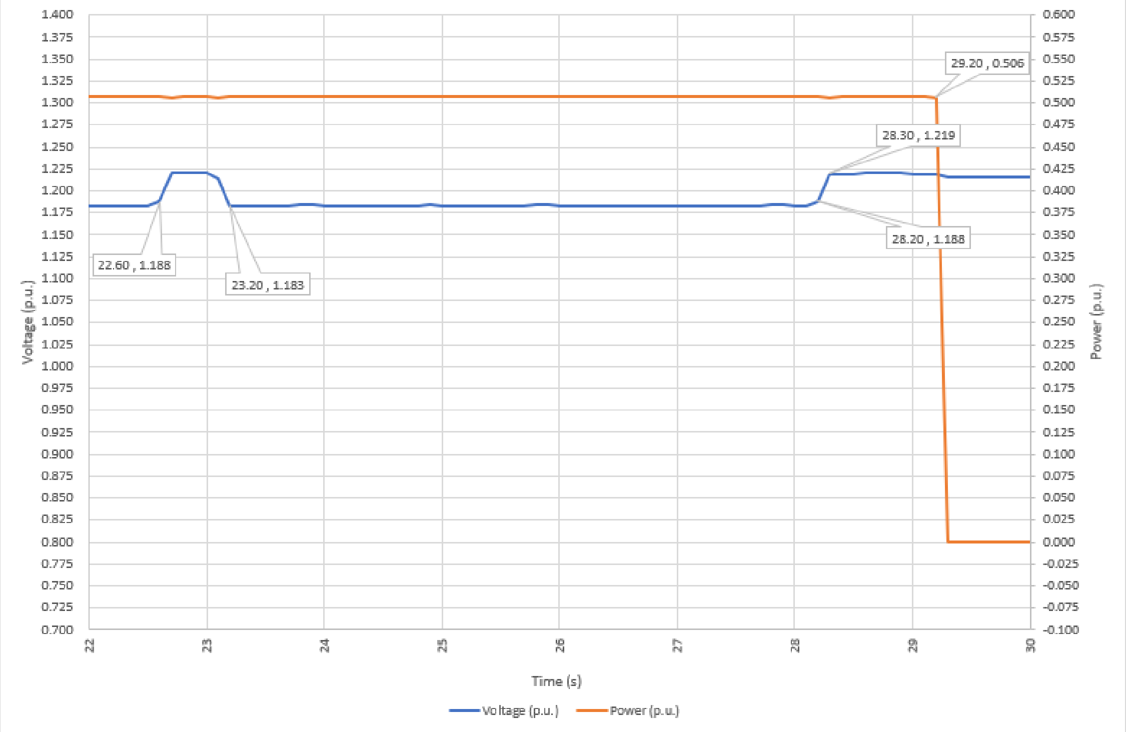


(Step 1 and Step 2)

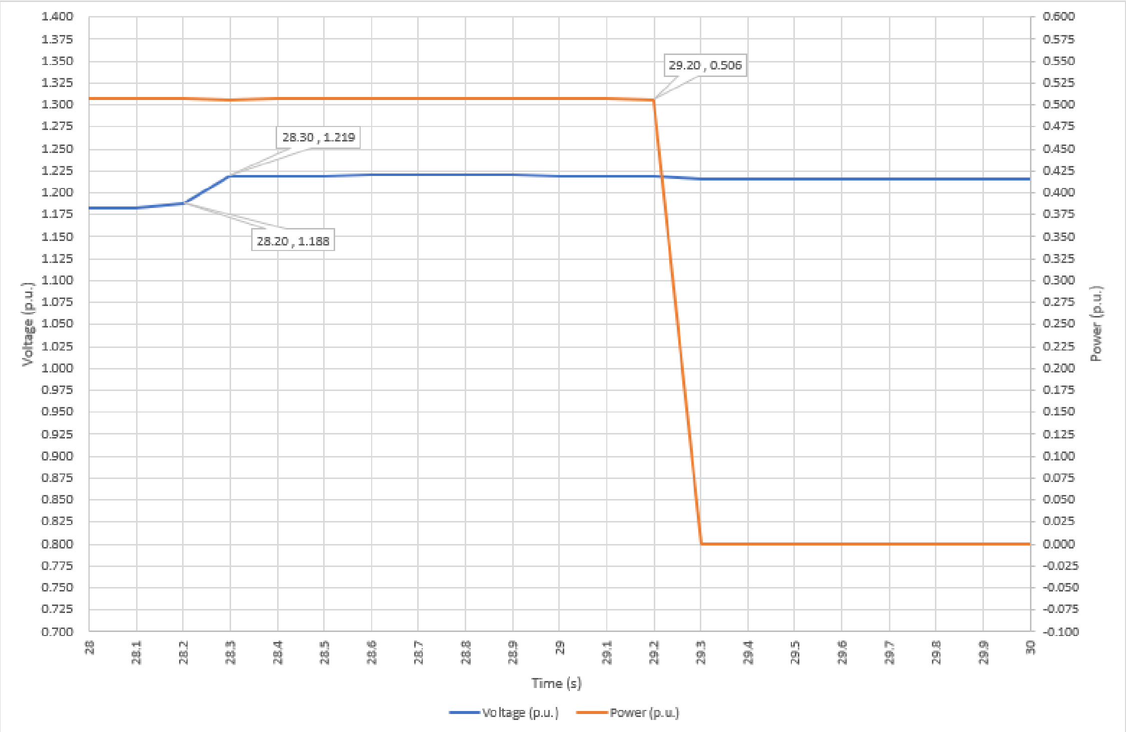


Over voltage

(Step 3)



(Step 4)



4.5 VERIFICATION OF CONNECTION CONDITIONS

4.5.1 Connection without previous protection trigger

The aim of this test is to demonstrate that a connection and reconnection of the EUT at the voltage and frequency ranges included below. This test is optional but has been tested nevertheless.

This test has been done according to chapter 4.5.1 of the standard.

Ranges for compliance with VDE AR-N 4110:2019 is:

Type	Inferior Threshold	Superior Threshold
Voltage	90%Un ± 2%Un	110%Un ± 2%Un
Frequency	47.5 Hz ± 0.1 Hz	50.2 Hz ± 0.1 Hz

Used settings of the measurement device for connection conditions are:

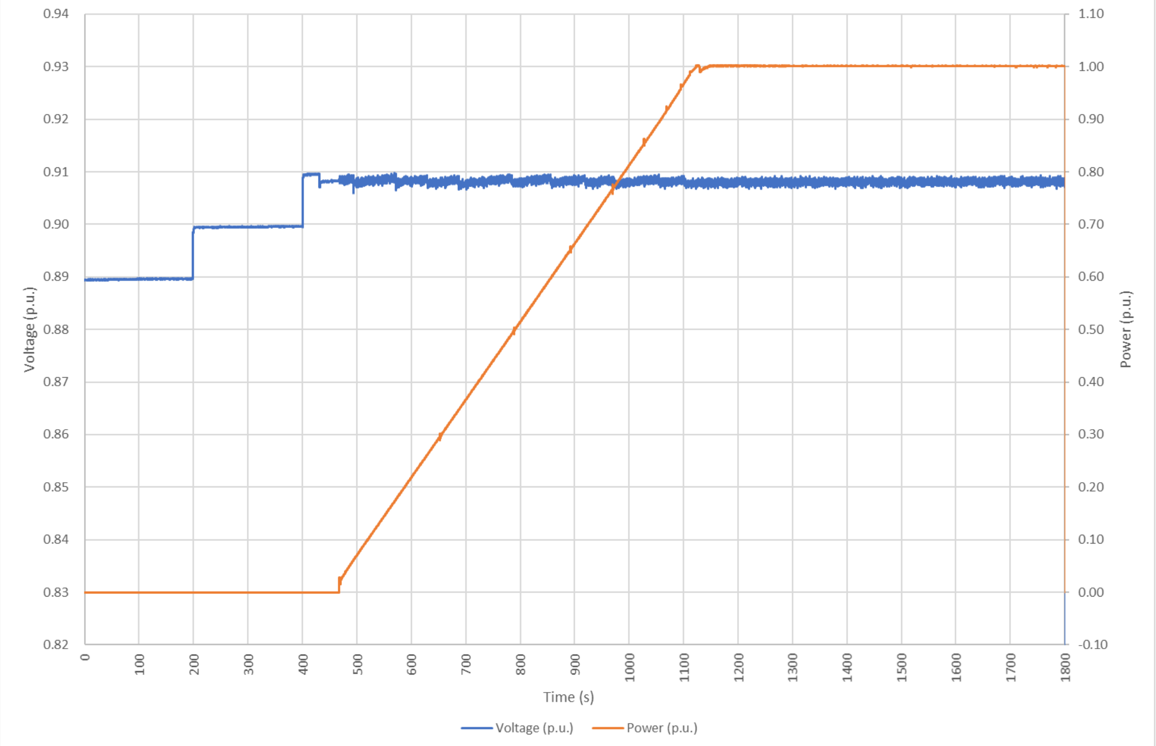
Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/05 & 2019/12/06, 2020/4/23	100 ms values	10 kHz

Tests consists in steps as included in table below. Each step has been maintained for 5 min and, once the EUT connects, the test is stopped.

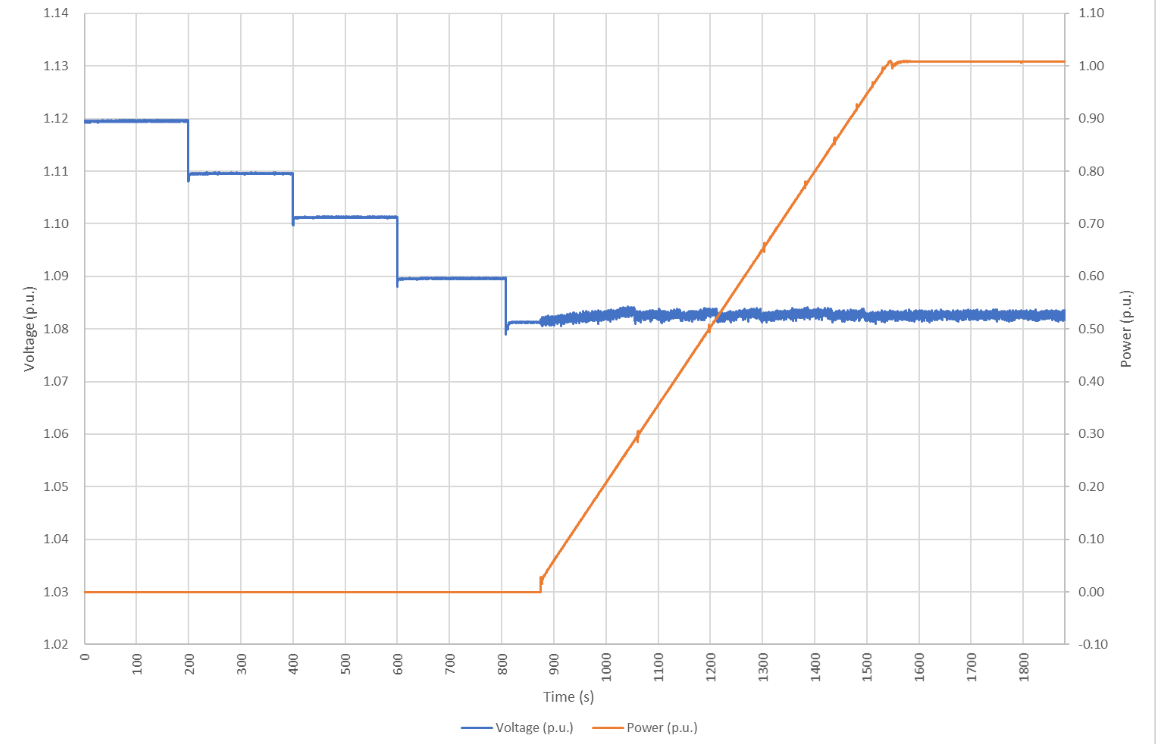
The following table shows the test results:

Undervoltage test		Overvoltage test		Underfrequency test		Overfrequecy test	
Step (% of U_n)	Connection (Yes/No)	Step (% of Un)	Connection (Yes/No)	Step (Hz)	Connection (Yes/No)	Step (Hz)	Connection (Yes/No)
89	☒ NO ☐ YES	112	☒ NO ☐ YES	47.3	☒ NO ☐ YES	50.4	☒ NO ☐ YES
90	☒ NO ☐ YES	111	☒ NO ☐ YES	47.4	☒ NO ☐ YES	50.3	☒ NO ☐ YES
91	☐ NO ☒ YES	110	☒ NO ☐ YES	47.5	☒ NO ☐ YES	50.2	☒ NO ☐ YES
		109	☒ NO ☐ YES	47.6	☐ NO ☒ YES	50.1	☐ NO ☒ YES
		108	☐ NO ☒ YES	47.7	☐ NO ☐ YES	50.0	☐ NO ☐ YES

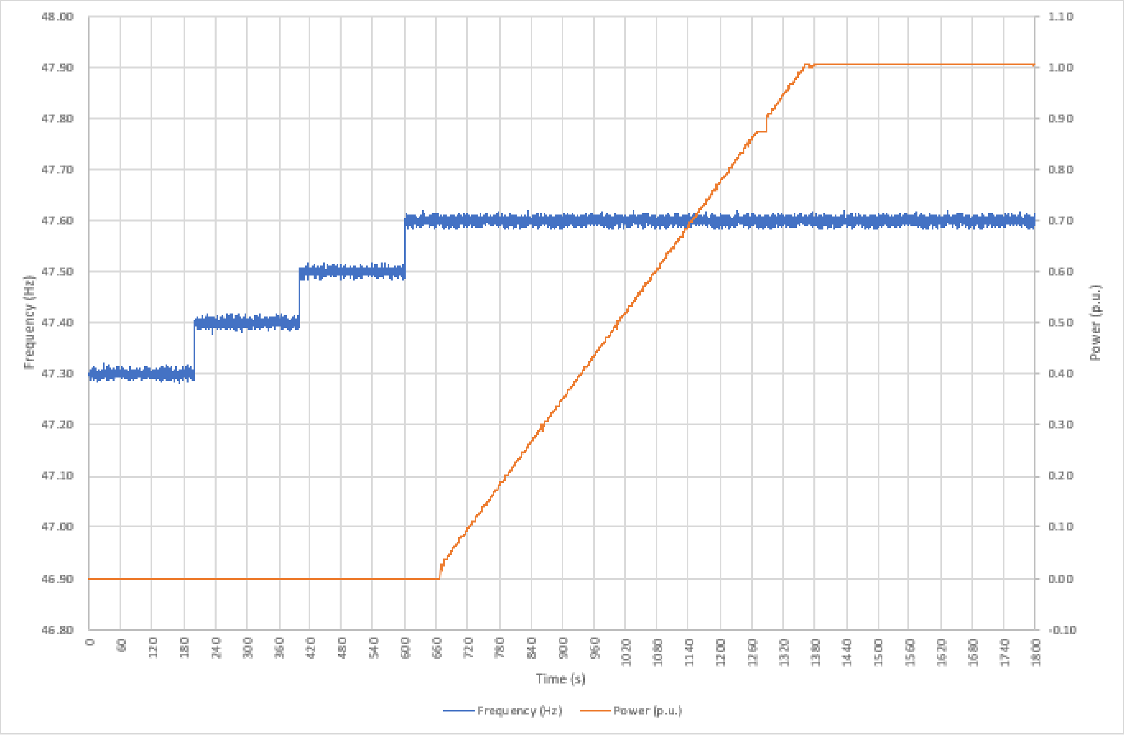
(U > 90% Un)



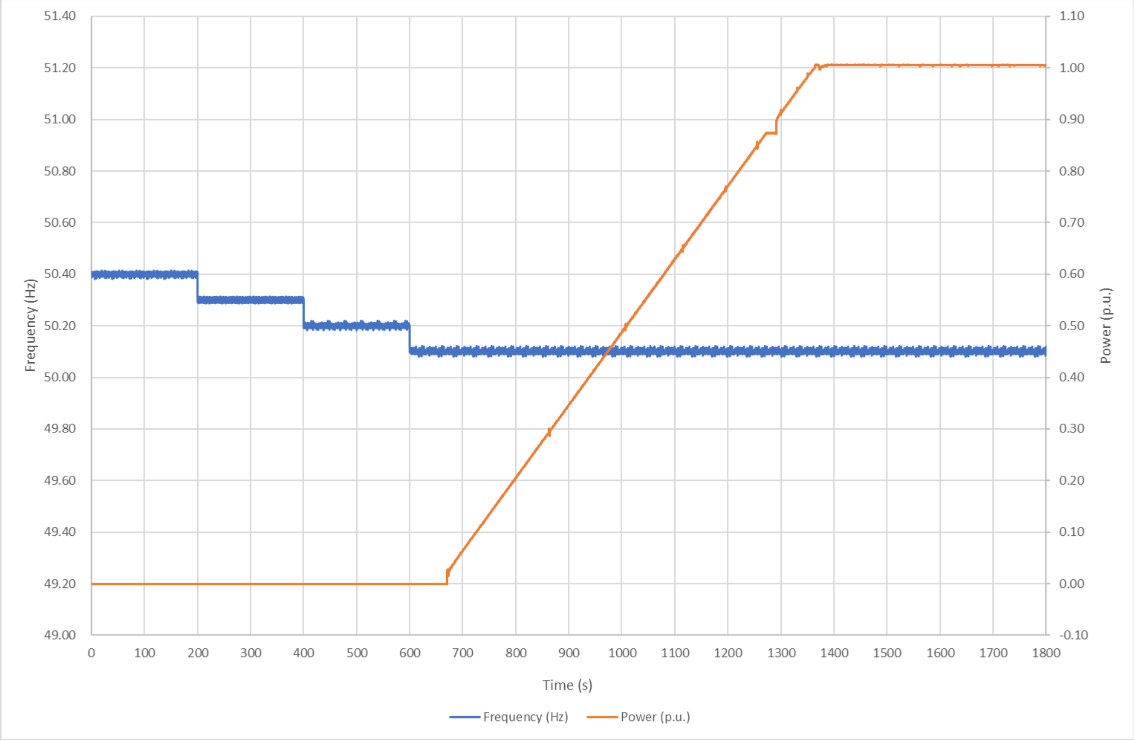
(U < 110% Un)



(f > 47.5 Hz)



(f < 50.1 Hz)



4.5.2 Connection after triggering of the uncoupling protection

The aim of this test is to demonstrate that the PGU does not connect within the voltage and frequency ranges given below.

This test has been performed according to point 4.5.2 of the standard.

This test allows to realize that the inverter does not connect to the grid when is out of normal operation range conditions; on the test performing time spend on each set point is greater than set reconnection time in order to see that the inverter does not connect to the grid before the normal operation conditions are reached.

Ranges for compliance with VDE AR-N 4110:2019 is:

Type	Inferior Threshold	Superior Threshold
Voltage	95%Un	--
Frequency	49.9 Hz	50.1 Hz

Used settings of the measurement device for connection conditions measurement:

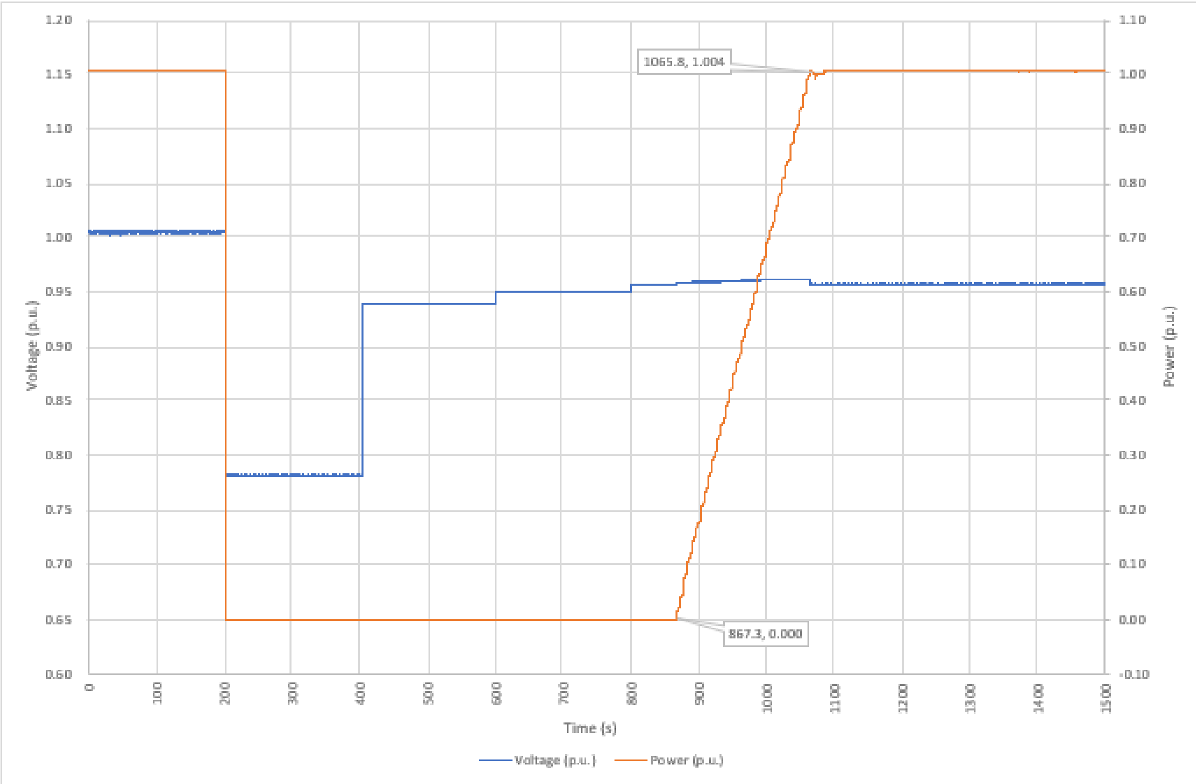
Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/05,2020/08/14，2020/09/03	100 ms values	10 kHz

Tests consists in steps as included in table below. Each step has been maintained for 5 min and, once the EUT connects, the test is stopped.

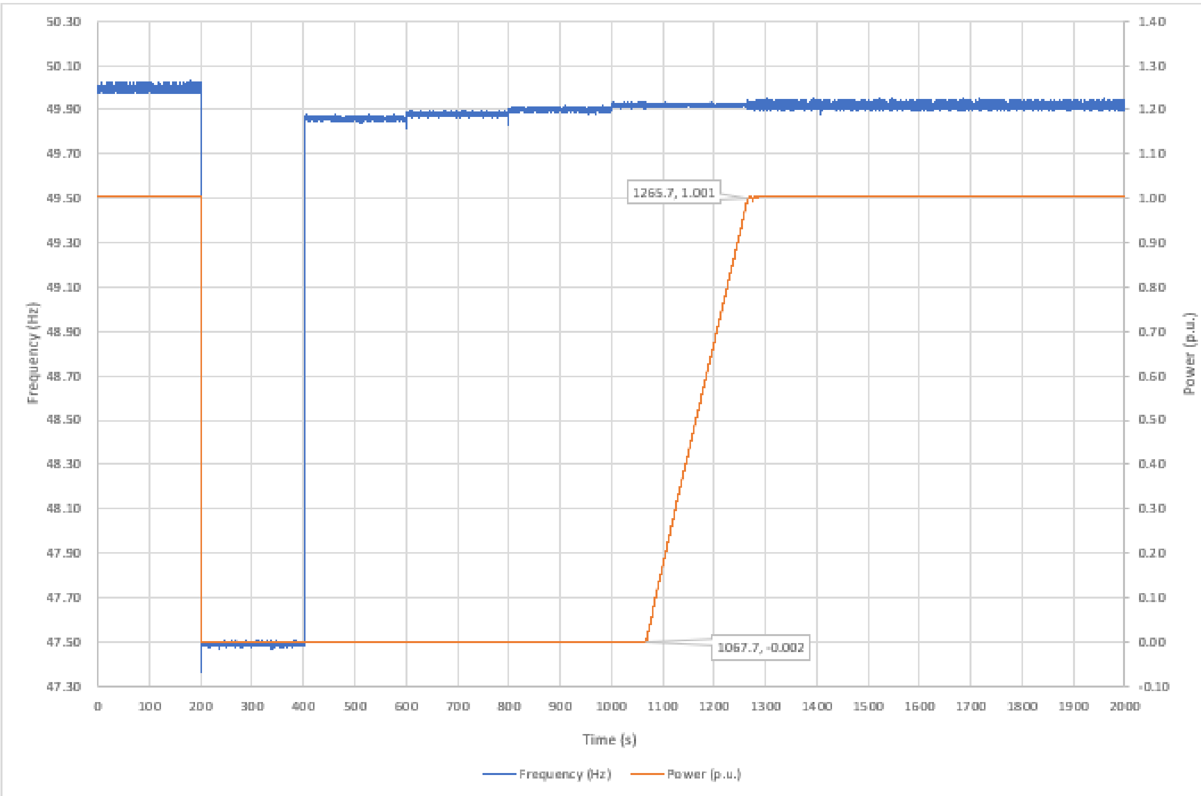
The following table shows the test results:

Evidence of connection with previous protection triggering (under VDE-AR-N 4110)					
Undervoltage test		**Underfrequency test**		**Overfrequecy test**	
Step (% of U_n)	**Connection (Yes/No)**	**Step (Hz)**	**Connection (Yes/No)**	**Step (Hz)**	**Connection (Yes/No)**
94	☒ NO ☐ YES	49.86	☒ NO ☐ YES	50.14	☒ NO ☐ YES
95	☒ NO ☐ YES	49.88	☒ NO ☐ YES	50.12	☒ NO ☐ YES
96	☐ NO ☒ YES	49.90	☒ NO ☐ YES	50.10	☐ NO ☒ YES
		49.92	☐ NO ☒ YES	50.08	☐ NO ☐ YES
		49.94	☐ NO ☐ YES	50.06	☐ NO ☐ YES

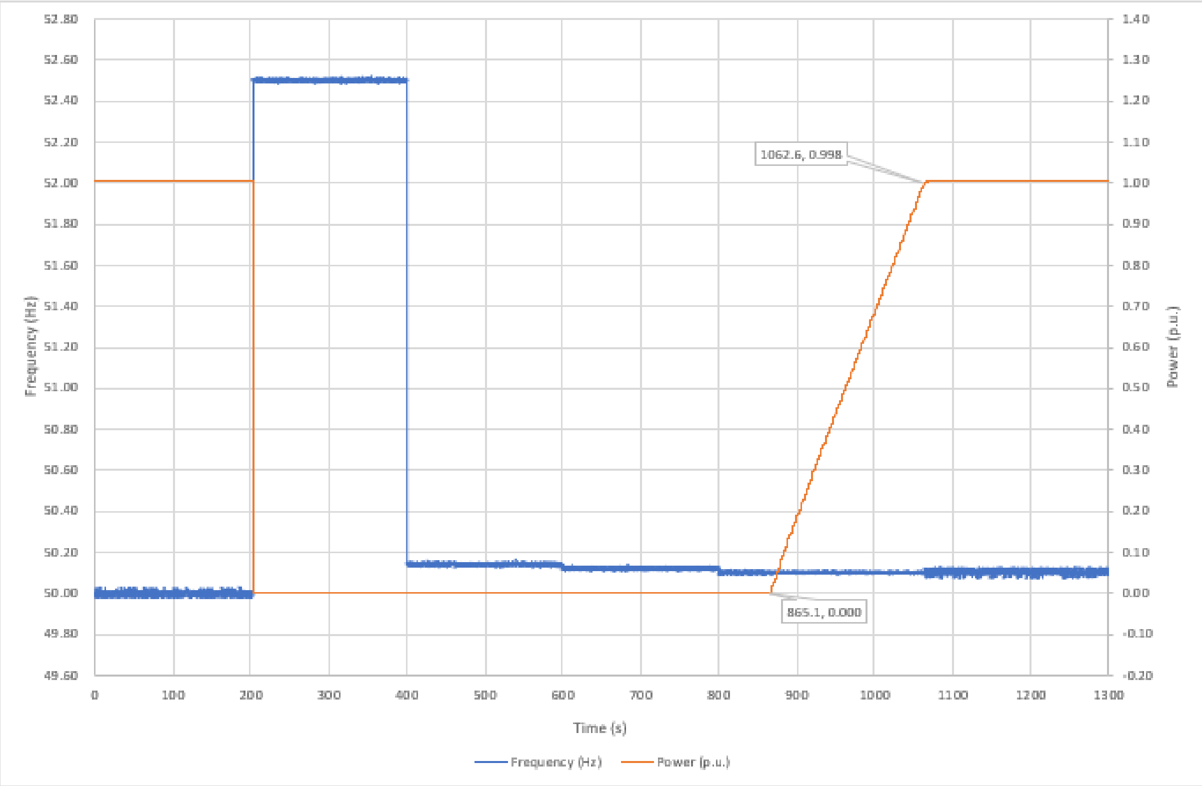
(U > 95% Un)



(f > 49.9 Hz)



(f < 50.1 Hz)



1062.6, 0.998
865.1, 0.000
Frequency (Hz)
Power (p.u.)
Time (s)
Frequency (Hz)
Power (p.u.)

Used settings of the measurement device for connection conditions measurement:

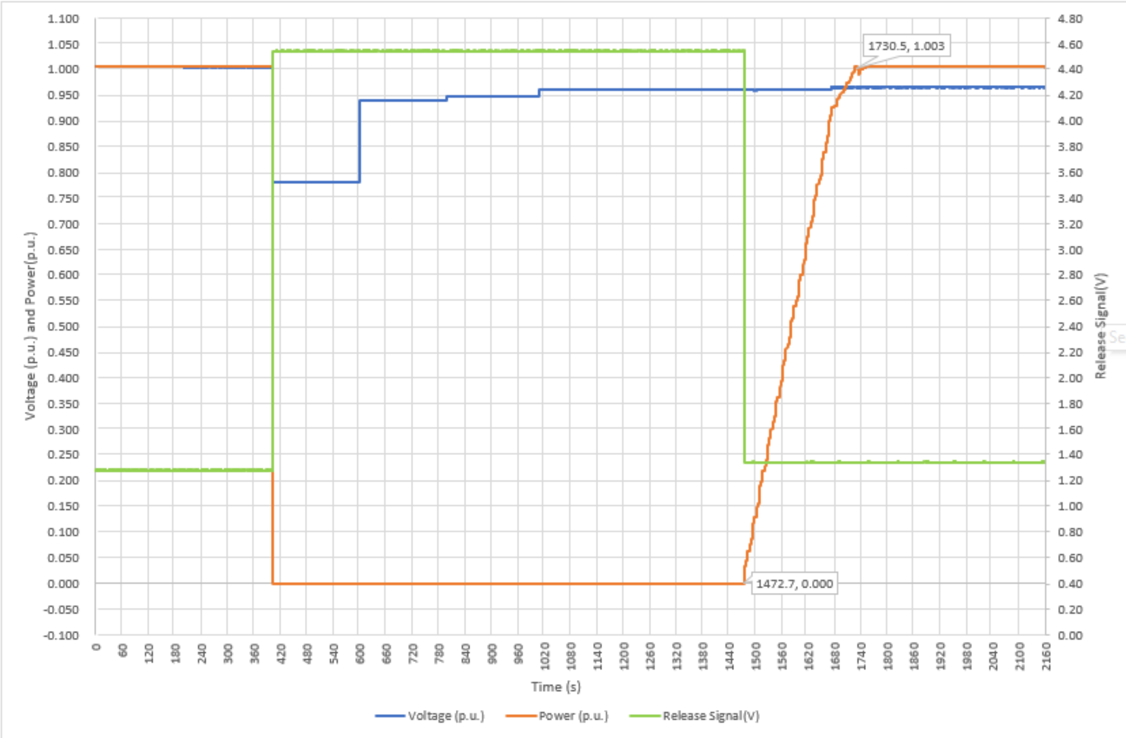
Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/05,2020/09/03	100 ms values	10 kHz

Tests consists in steps as included in table below. Each step has been maintained for 5 min and, once the EUT connects, the test is stopped.

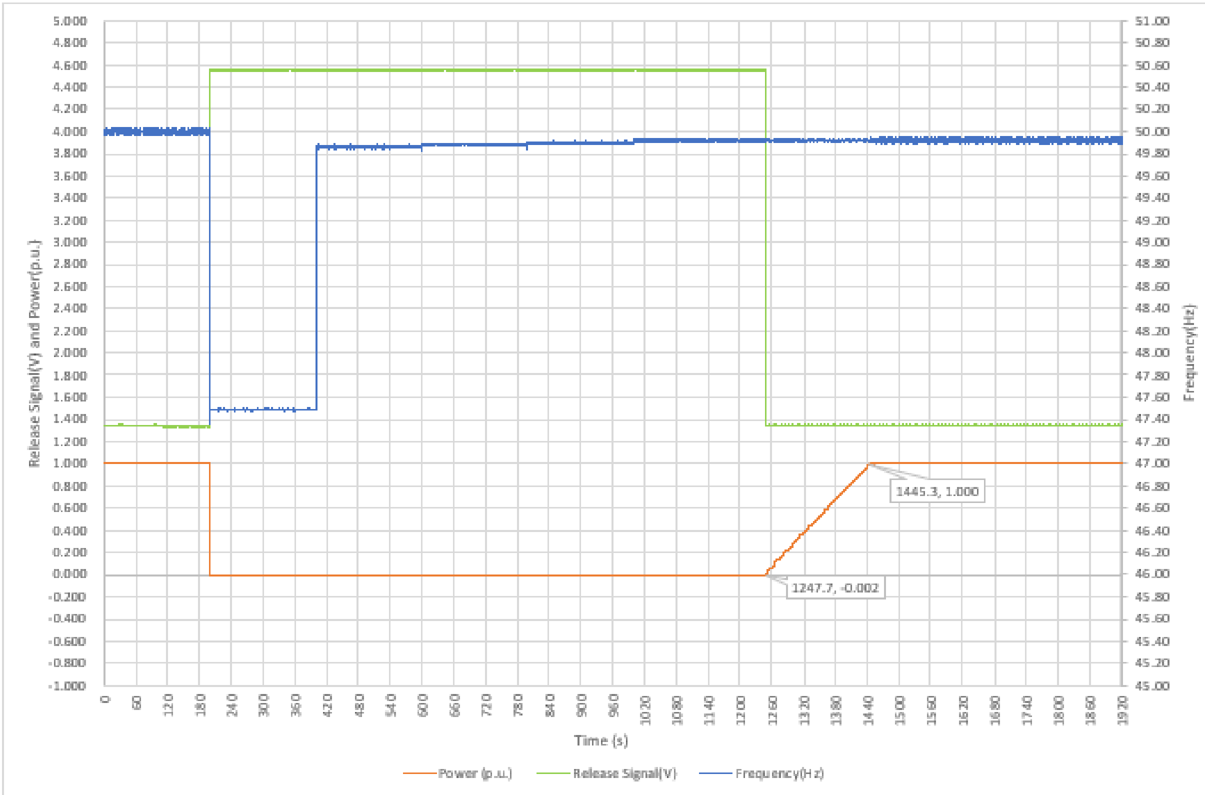
The following table shows the test results:

Evidence of connection with Release Signal (under VDE-AR-N 4110)								
Undervoltage test			**Underfrequency test**			**Overfrequecy test**		
Step (% of Un)	**Release Signal**	**Connection (Yes/No)**	**Step (Hz)**	**Release Signal**	**Connection (Yes/No)**	**Step (Hz)**	**Release Signal**	**Connection (Yes/No)**
94	OFF	☒ NO ☐ YES	49.84	OFF	☒ NO ☐ YES	50.14	OFF	☒ NO ☐ YES
95	OFF	☒ NO ☐ YES	49.86	OFF	☒ NO ☐ YES	50.12	OFF	☒ NO ☐ YES
96	OFF	☒ NO ☐ YES	49.88	OFF	☒ NO ☐ YES	50.10	OFF	☒ NO ☐ YES
	ON	☐ NO ☒ YES	49.90	OFF	☐ NO ☒ YES	50.08	OFF	☒ NO ☐ YES
			49.92	OFF	☒ NO ☐ YES	50.06	OFF	☒ NO ☐ YES
				ON	☐ NO ☒ YES		ON	☐ NO ☒ YES

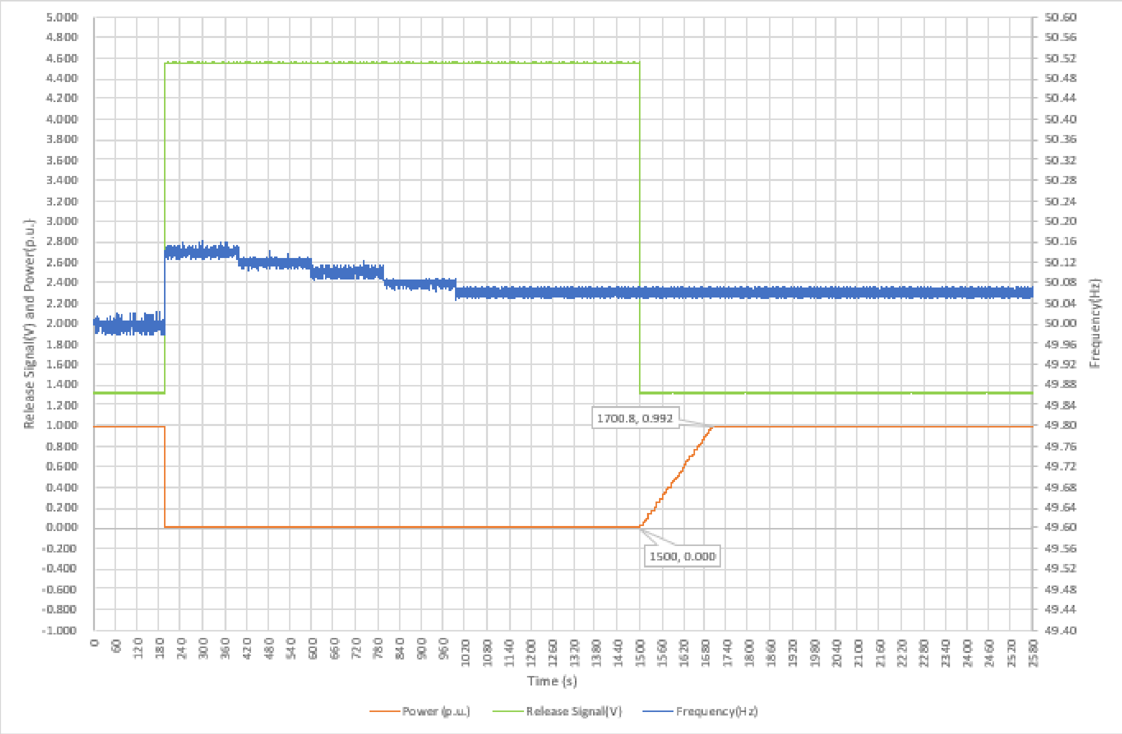
(U > 95% Un)



(f > 49.9 Hz)



(f < 50.1 Hz)



Release Signal(V) and Power(p.u.)
Frequency(Hz)
Time (s)
1700.8, 0.992
1500, 0.000
Power (p.u.)
Release Signal(V)
Frequency(Hz)

4.6 RESPONSE DURING GRID FAULTS

The aim of this test is to determinate whether the EUT is able to detect a voltage dip and to ride through this undamaged. It can be applied to both PV and storage equipment.

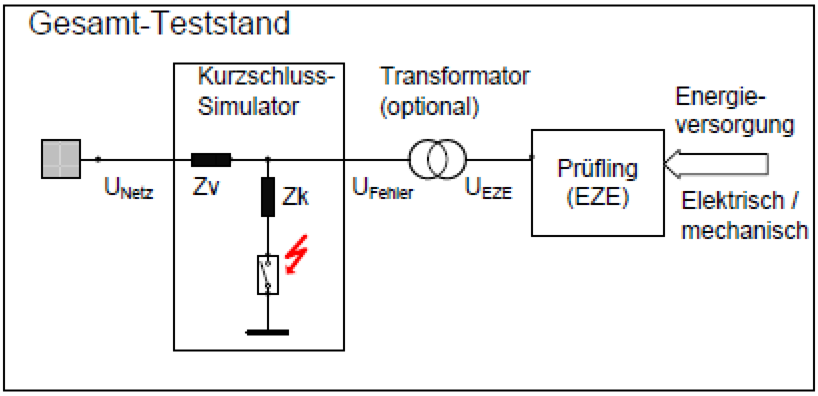
These tests have been done according to point 4.6 of the standard.

The voltage dead band declared by the manufacturer is Un ± 10% Un for all the tests.

The inverter is configurated to limit the current when it reaches 100% In.

The test has been carried out using a short circuit simulator which automatically adjusts the value of the series impedances and shotcircuit impedances in order to obtain the type of fault configurated for each test.

At the electric scheme below it can be seen the connection configuration for the short circuit simulator:



In the page below it is provided a table with the test conditions based on tables 4-68 and 4-69 of the FGW-TG3 standard.

Remaining phase-to-phase voltaje [p.u]	Fault type	Fault duration compliant with: AR-N-4110 [ms]	Fault duration compliant with: AR-N-4120 AR-N-4130 [ms]	Load	Reactive power Q/Pn	K	Test no.
≤ 0,05	Three phase	Not required	≥ 150 (for U = 0)	Full load	0 %-10 %	K = 2	0.1
			≥ 318 (for U = 0,05)	Partial load			0.2
	Two phase		≥ 220 (for U = 0)	Full load			0.3
			≥ 406 (for U = 0,05)	Partial load			0.4
0,20 - 0,30	Three phase	≥ 354 (for U = 0,2) ≥ 760 (for U = 0,3)	≥ 821 (for U = 0,2) ≥ 1156 (for U = 0,3)	Full load	0 %-10 %	K = 2	25.1
				Partial load			25.2
		Optional: Test sequence for multiple faults: Duration: 140 - 160 Pause: 300 - 2000 Duration: 550 - 600 Pause: 20 s - 30 s Duration: 950 - 1050 Pause: 20 s - 30s Duration: 140 - 160 Pause: 300 - 2000 Duration: 950 - 1050		P>0.7Pn			25.3
	Two phase	≥ 452 (for U = 0,2) ≥ 915 (for U = 0,3)	≥ 962 (for U = 0,2) ≥ 1332 (for U = 0,3)	Full load			25.4
				Partial load			25.5
0,45-0,60	Three phase	≥1371(for U = 0,45) ≥ 1982 (for U = 0,6)	≥ 1659 (for U = 0,45) ≥ 2162 (for U = 0,6)	Full load	0 %-10 %	K = 2	50.1
				Partial load			50.2
	Two phase	≥1610(for U = 0,45) ≥ 2305 (for U = 0,6)	≥ 1888 (for U = 0,45) ≥ 2444 (for U = 0,6)	Full load			50.3
				Partial load			50.4
	Three phase	≥1371(for U = 0,45) ≥ 1982 (for U = 0,6)	-	Full load	0 %-10 %	K = 2	50.5
	Two phase	≥1610(for U = 0,45) ≥ 2305 (for U = 0,6)	-	Full load	0 %-10 %	K = 2	50.6
0,70 - 0,80	Three phase	≥ 2389 (for U = 0,7) ≥ 2796 (for U = 0,8)	≥ 2498 (for U = 0,7) ≥ 2833 (for U = 0,8)	Full load	0 %-10 %	K = 2	75.1
				Partial load	0 %-10 %		75.2
					Max.underexcited		75.3
					Max.overexcited		75.4
				(P>0,1Pn)	0 %-10 %	K = 4	75.5
	Two phase	≥ 2764(for U = 0,7) ≥ 3000 (for U = 0,8)	≥ 2815 (for U = 0,7) ≥ 3000 (for U = 0,8)	Full load	0 %-10 %	K = 2	75.6
				Partial load			75.7
				(P>0,1Pn)		K = 4	75.8
0,75 - 0,85	Three phase	≥2593(for U = 0,75) ≥3000(for U = 0,85)	-	Full load	0 %-10 %	K = 2	80.1
		≥ 3000			≤ 0.1	K = 0	80.2
0,85 - 0,90	Three phase	> 60000 s		(P>0,1Pn)	0 %-10 %	K = 2	85.1

Remaining phase-to-phase voltaje [p.u]	Fault type	Fault duration compliant with:			Load	Reactive power Q/Pn	K	Test no.
		AR-N-4110 [ms]	AR-N-4120 [ms]	AR-N-4130 [ms]				
Increase by ≥ 0.1 to a value > 1.10	Three phase	≥ 5000			Full load	0 %-10 %	K = 2	115.1
					Partial Load			115.2
Rise by ≥0.1 to a value ≥ 1.10 as largest external vonductor voltage	Two phase	≥ 5000			Full load	0 %-10 %	K = 2	110.1
					Partial Load			110.2
> 1.10	Three phase	≥ 60000			(P>0,1Pn)	0 %-10 %	K = 2	110.3

Apart from test attached in the table above, idle tests have been performed to chech that the equipment is capable of producing te relevant voltage drop or increase with tolerances following the next images:

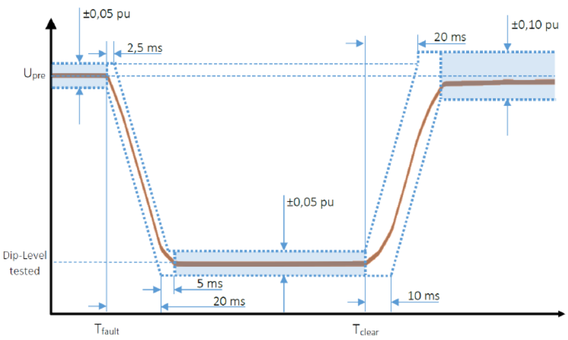


Fig. 4–26: Tolerances for voltage drop tests [2]

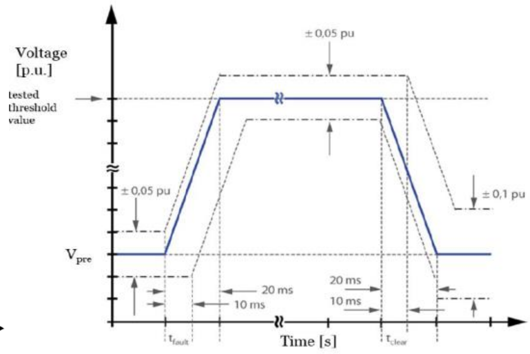


Fig. 4–27: Tolerances for overvoltage tests [2]

For all tests, as stated in the standard, two repetitions have been done and measurements have been taken for 10s before and after the fault. For asymmetric thwo-phase faults, different conductor voltages have been used in different tests as required by FGW TG3 Rev. 25.

Tests 50.5, 50.6 and 80.1 are done to comply with chapter 10.2.3.3.3 of VDE AR-N 4110:2018, where it is required that active and reactive current components shall be 0 A, with a maximum feed-in of apparent current ob 10%In.

The capability of a Type-2 power generating unit to ride through several consecutive voltage dips is deemed to be proven, when the power generating unit is able to dissipate, during these network faults, at least the energy PEmax for a duration of 2 seconds without taking into account the energy fed into the network. This has been verified by testing optional test 25.3, where multiple faults are tested in sequence.

As required by the standard, power generating systems must be capable of feeding a reactive current of 100% of the design current in each conductor. Regarding this, it has to be cheched that the following requirement is fulfilled:

$$|I_{B1}| + |I_{B2}| \geq I_r$$

I_{B1} – Positive sequence reactive current

I_{B1} – Negative sequence reactive current

I_r – Rated current of the PGU

For compliance with VDE AR-N 4110:2018, it has been checked that limits for rise time and settling time for both positive and negative sequence of the reactive current comply with:

$T_{Rise\ Time} \leq 30$ ms
$T_{Settling\ Time} \leq 60$ ms

Tolerance bands for reactive current is included in the graph below:

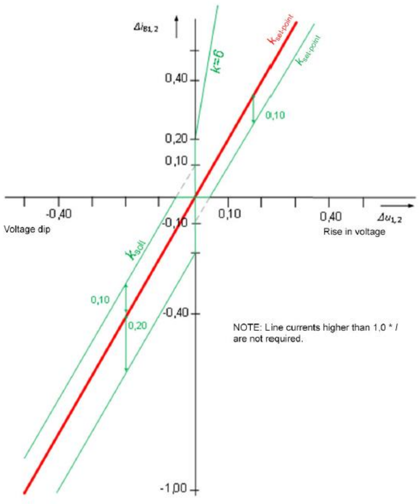


Figure C.1 – Tolerance range for Δi_B

For drops in voltage below 15%Un, rise time and settling time of reactive current is not required, and reactive current value measurement are substituted with apparent current value of positive sequence measurements.

Result tables and graphs have been included in 2219 / 0163 – A Attachment 1 of this report.

4.7 VERIFICATION OF THE WORKING RANGE WITH REGARD TO VOLTAGE AND FREQUENCY

This test has been done according to chapter 4.7 of the standard in order to verify operation times of the EUT across the complete voltage and frequency range.

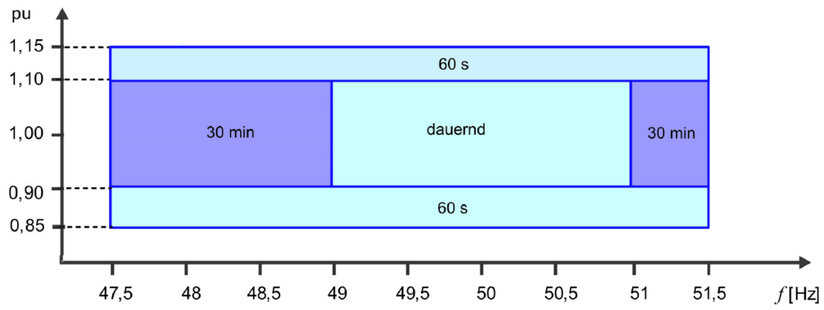
The test consists on verification of operation time at different measurement points. The test starts at rated values and then it goes through the measurements points with a gradient of maximum 5% Un / min or 0.5% fn / min. In case both frequency and voltage have to change to a different setpoint, voltage changes first and then frequency, as stated in the standard. During the test, power feed-in of the EUT is set over 80%Pn

Measurement points included in the standard are:

- Measurement point 1: U=1.15 p.u., f=47.5 Hz recording period at least 60 s from reaching the measurement points.
- Measurement point 2: U=0.85 p.u., f=51.5 Hz recording period at least 60 s from reaching the measurement points.
- Measurement point 3: U=1.10 p.u., f=51.0 Hz recording period at least 60 min from reaching the measurement points.
- Measurement point 4: U=0.90 p.u., f=49.0 Hz recording period at least 60 min from reaching the measurement points.
- Measurement point 5: U=0.90 p.u., f=47.5 Hz recording period at least 30 min from reaching the measurement points.
- Measurement point 6: U=1.09 p.u., f=51.5 Hz recording period at least 30 min from reaching the measurement points.

For each measurement point the 200 ms average values of the phase conductor voltages, the frequency as well as the active power habe been presented graphically.

These measurement points are used to verify chapters 10.2.1.2 and 11.2.3.1 of VDE AR-N 4110:2018 as, they require compliance with the following figure:



Used settings of the measurement device for connection conditions measurement:

Measurement device	Date of measurement	Recording	Sampling frequency
PA3000	2019/12/05	100 ms values	10 kHz

The following tables show the results of the tests performed:

Measurement Point 1		Over Voltage + Under Frequency			
Voltage	**Frequency**	**Active Power Desired (p.u)**	**Active Power measured**	**Minimum Operation Time**	**Time measured**
115%Un	**47.5Hz**	> 80.0%Pn	> 95%Pn	60 seconds	252s
Disconnection		☒ NO ☐ YES			

Measurement Point 2		Under Voltage + Over Frequency			
Voltage	**Frequency**	**Active Power Desired (p.u)**	**Active Power measured**	**Minimum Operation Time**	**Time measured**
85%Un	**51.5Hz**	> 80.0%Pn	> 95%Pn	60 seconds	114s
Disconnection		☒ NO ☐ YES			

Measurement Point 3		Over Voltage + Over Frequency			
Voltage	**Frequency**	**Active Power Desired (p.u)**	**Active Power measured**	**Minimum Operation Time**	**Time measured**
110%Un	**51.0Hz**	> 80.0%Pn	> 95%Pn	60 minutes	72.6min
Disconnection		☒ NO ☐ YES			

Measurement Point 4		Under Voltage + Under Frequency			
Voltage	**Frequency**	**Active Power Desired (p.u)**	**Active Power measured**	**Minimum Operation Time**	**Time measured**
90%Un	**49.0Hz**	> 80.0%Pn	> 95%Pn	60 minutes	63.9min
Disconnection		☒ NO ☐ YES			

Measurement Point 5		Under Voltage + Under Frequency			
Voltage	**Frequency**	**Active Power Desired (p.u)**	**Active Power measured**	**Minimum Operation Time**	**Time measured**
90%Un	**47.5Hz**	> 80.0%Pn	> 95%Pn	30 minutes	42min
Disconnection		☒ NO ☐ YES			

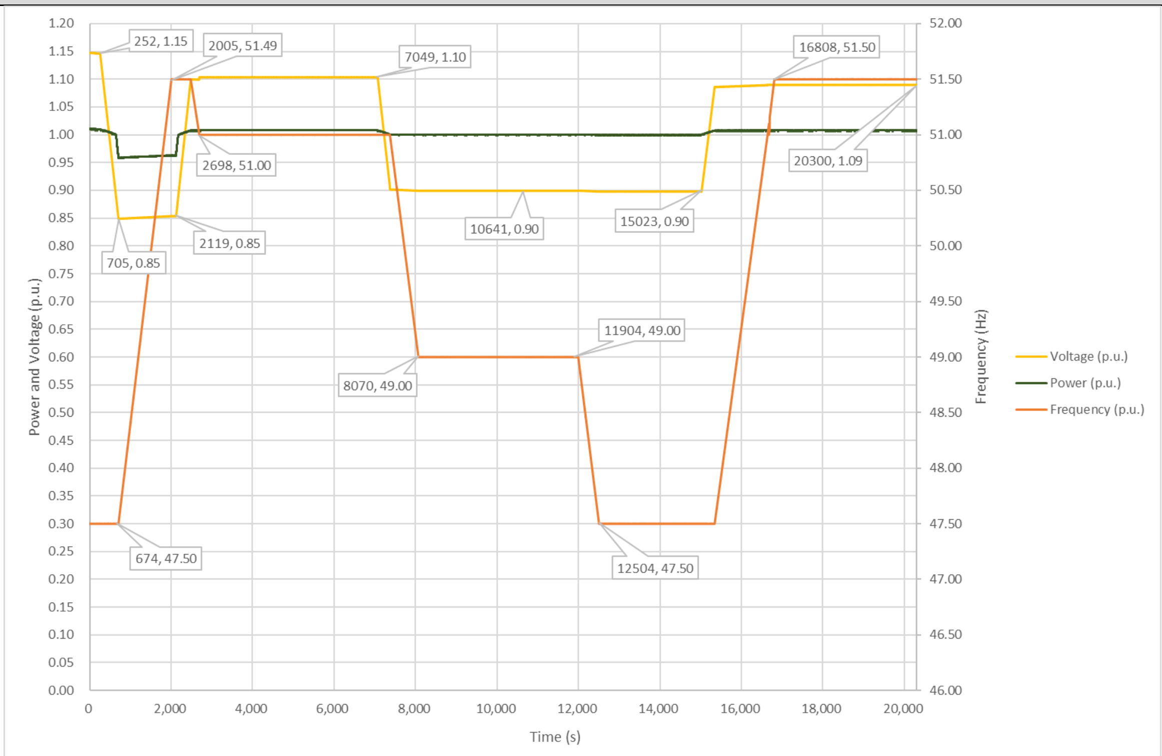
Measurement Point 6		Over Voltage + Over Frequency			
Voltage	**Frequency**	**Active Power Desired (p.u)**	**Active Power measured**	**Minimum Operation Time**	**Time measured**
109%Un	**51.5Hz**	> 80.0%Pn	> 95%Pn	30 minutes	58.2min
Disconnection		☒ NO ☐ YES			

The following table shows the gradients obtained between measurement points:

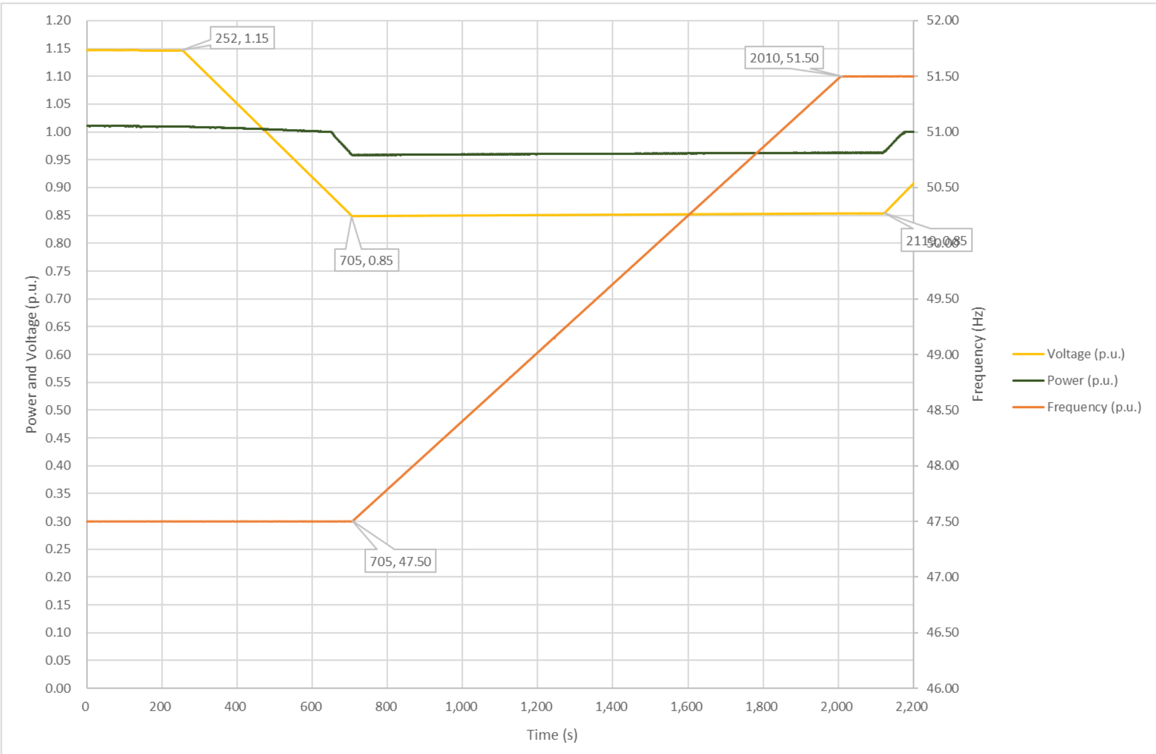
Between Measurement Points	Voltage Gradient Required ($\%U_n$/min)	Voltage Gradient Measured ($\%U_n$/min)	Frequency Gradient Required ($\%f_n$/min)	Frequency Gradient Measured ($\%f_n$/min)
Point 1-2	< 5	3.97	< 0.5	0.184
Point 2-3	< 5	4.17	< 0.5	0.143
Point 3-4	< 5	3.99	< 0.5	0.170
Point 4-5	< 5	-	< 0.5	0.170
Point 5-6	< 5	3.34	< 0.5	0.164

Verification of the Working Range

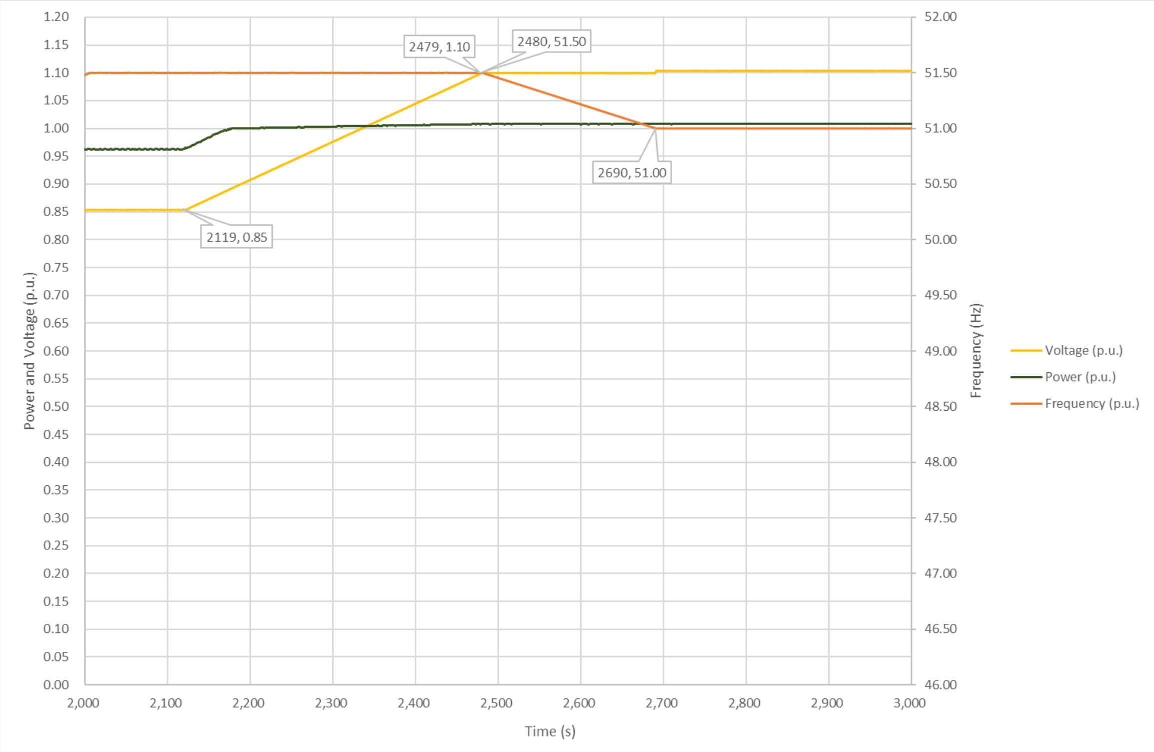
General View



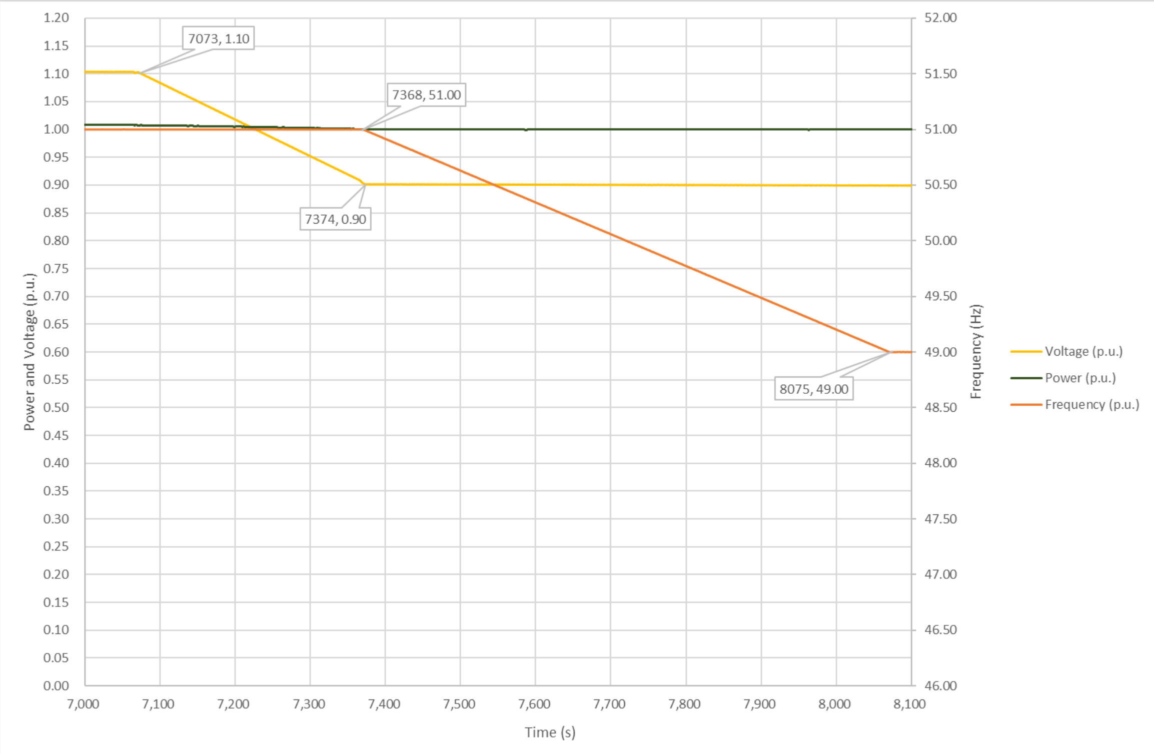
Between points 1-2



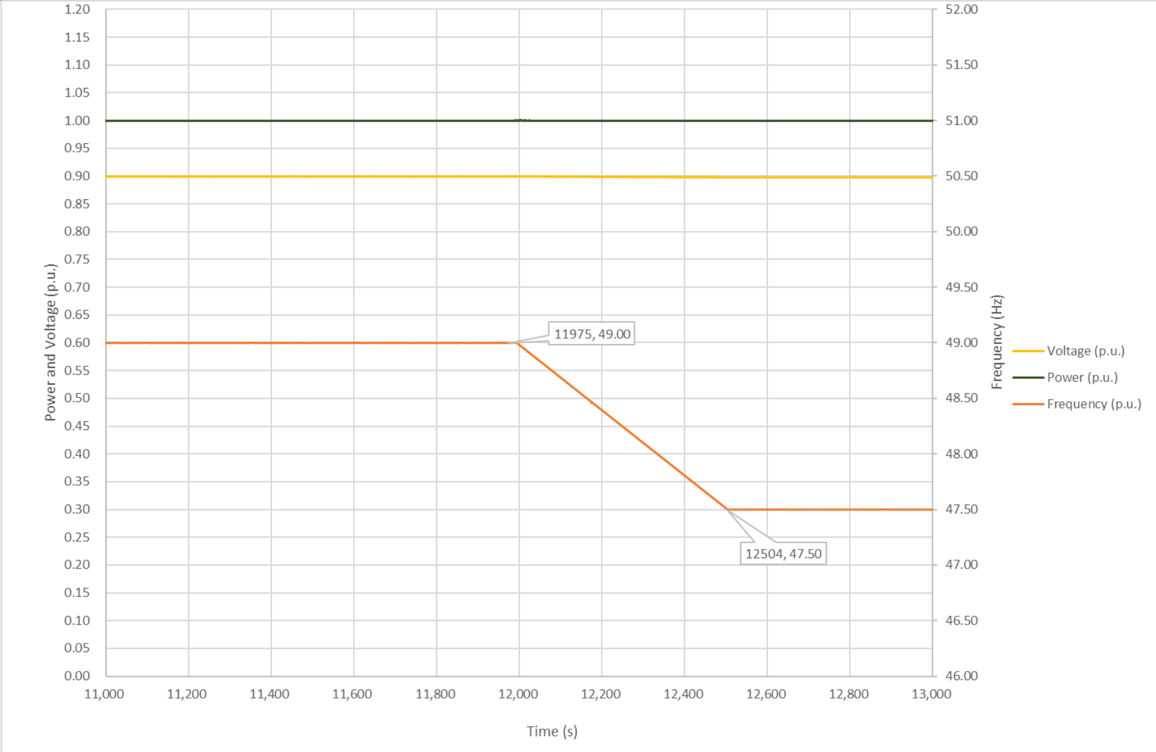
Between points 2-3



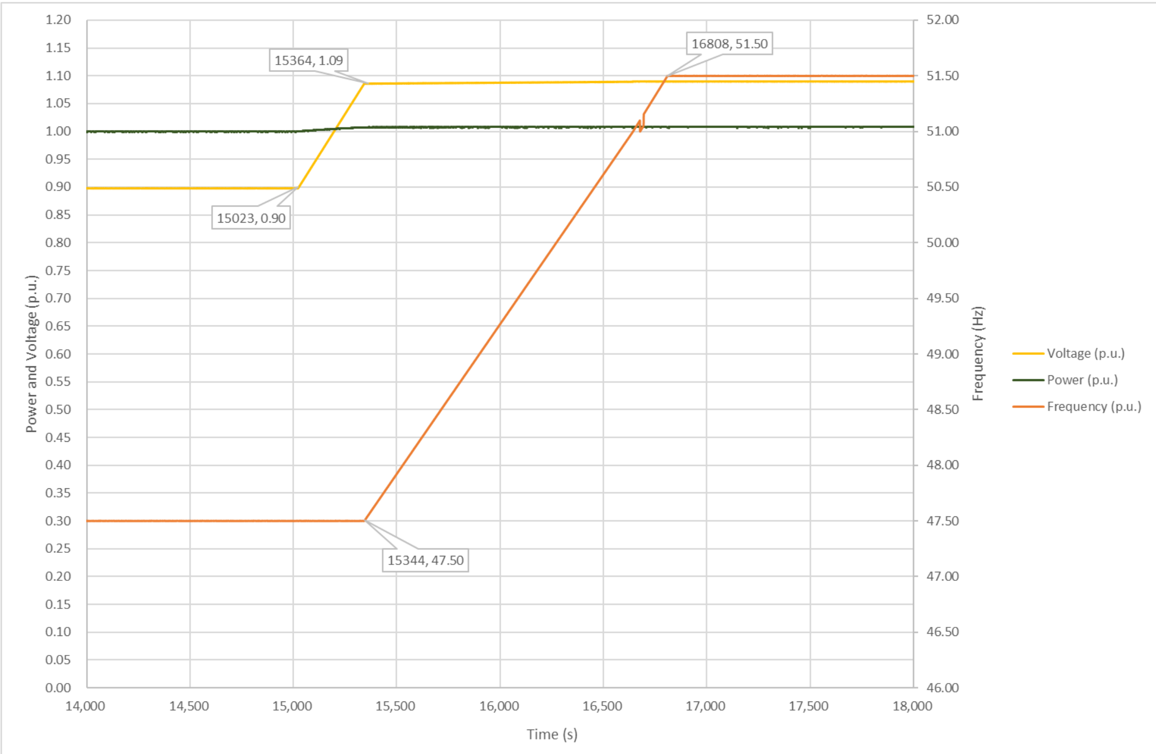
Between points 3-4



Between points 4-5

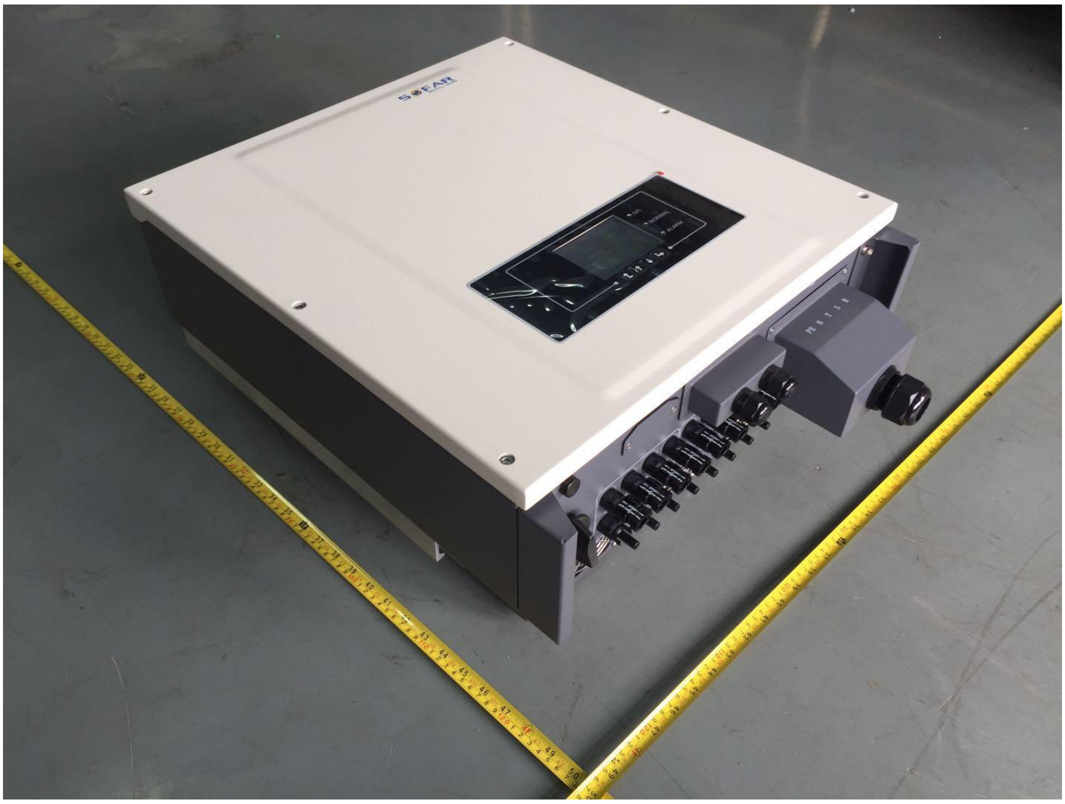


Between points 5-6

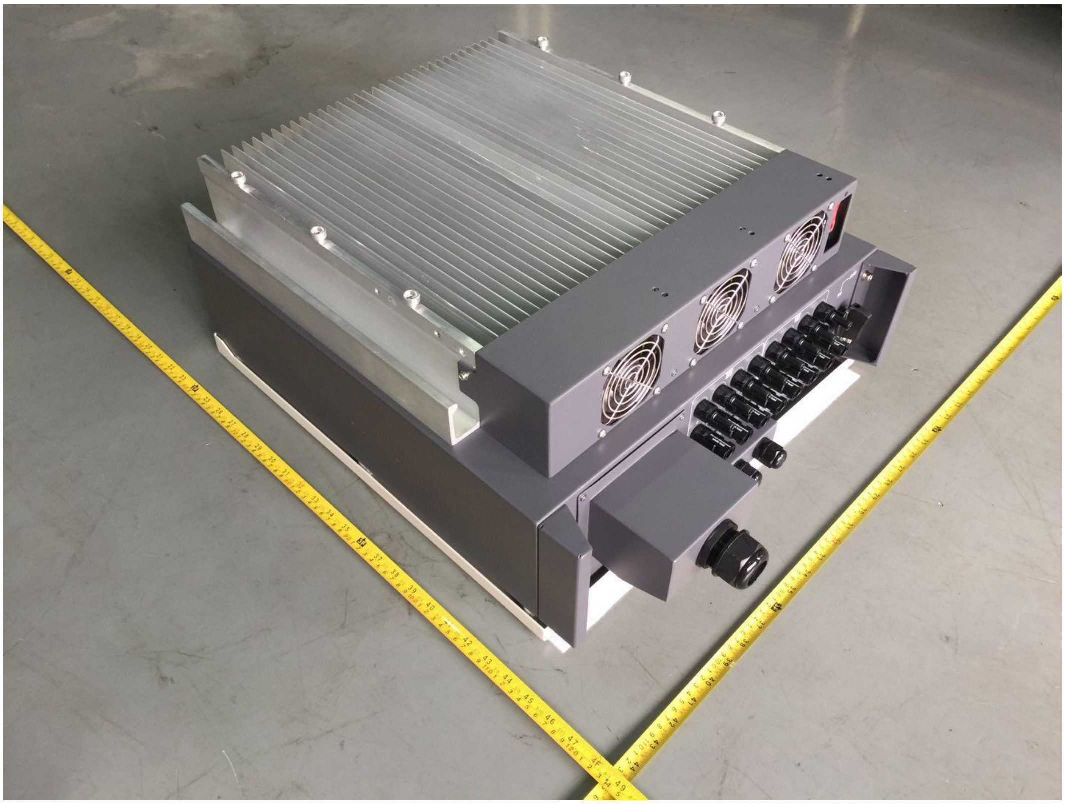


5 PICTURES

Front view

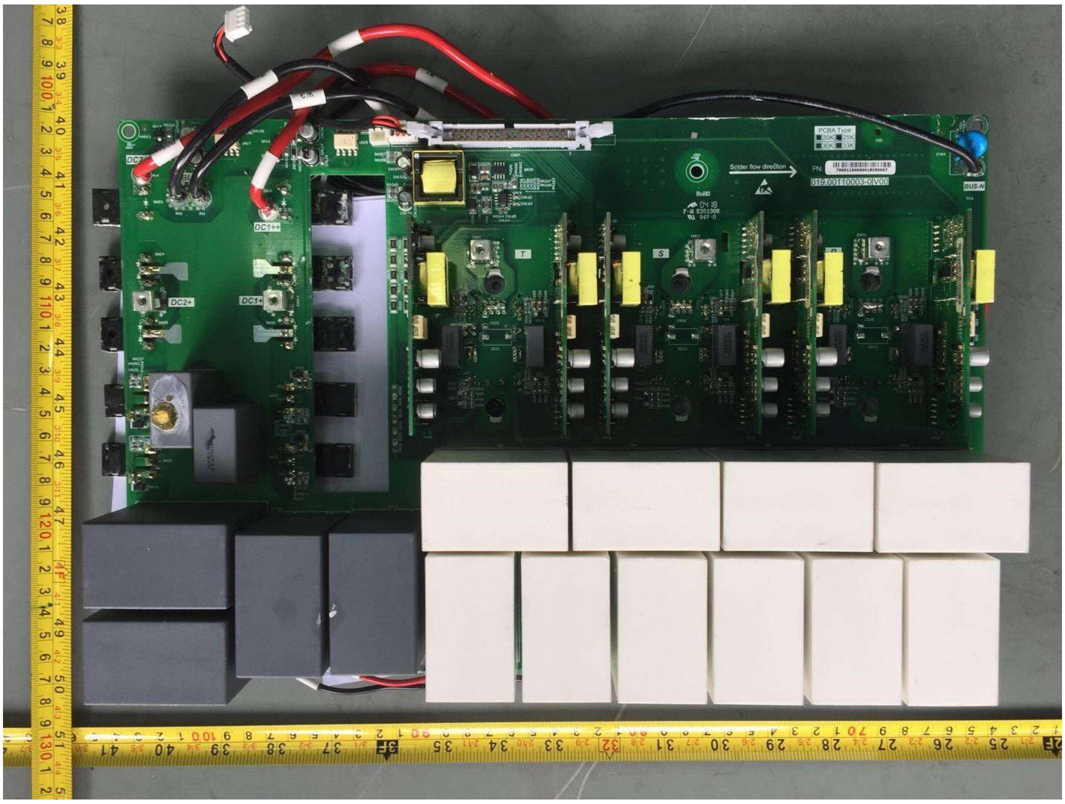
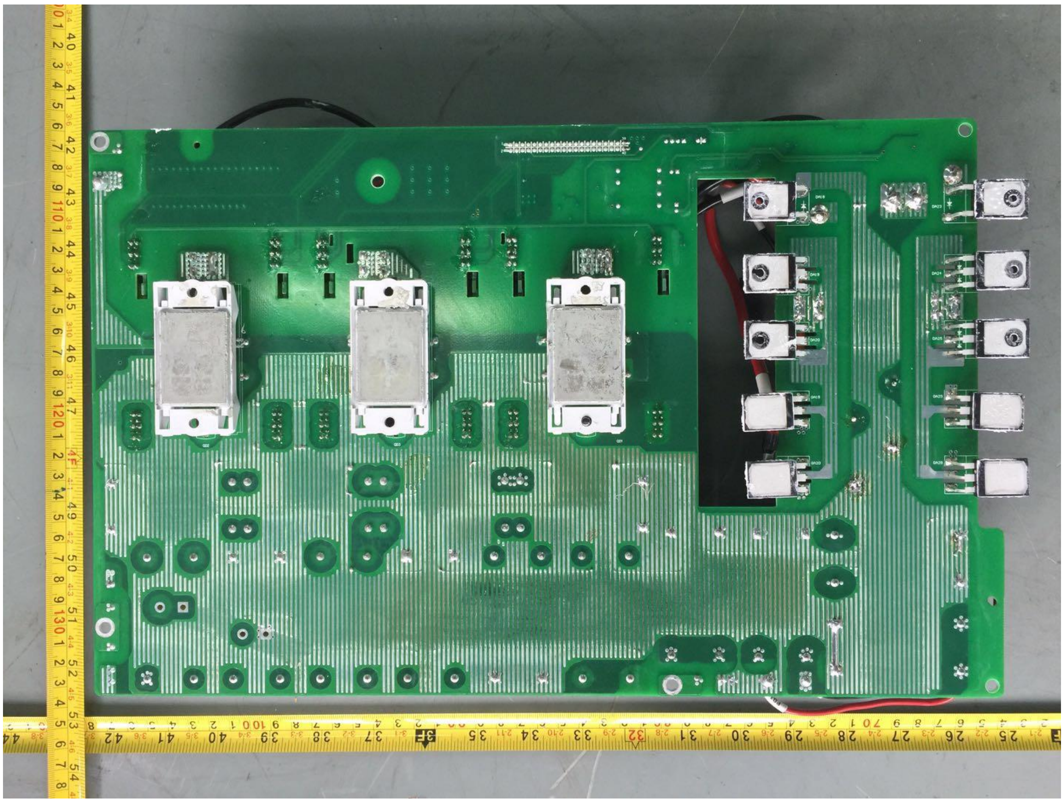


Back View

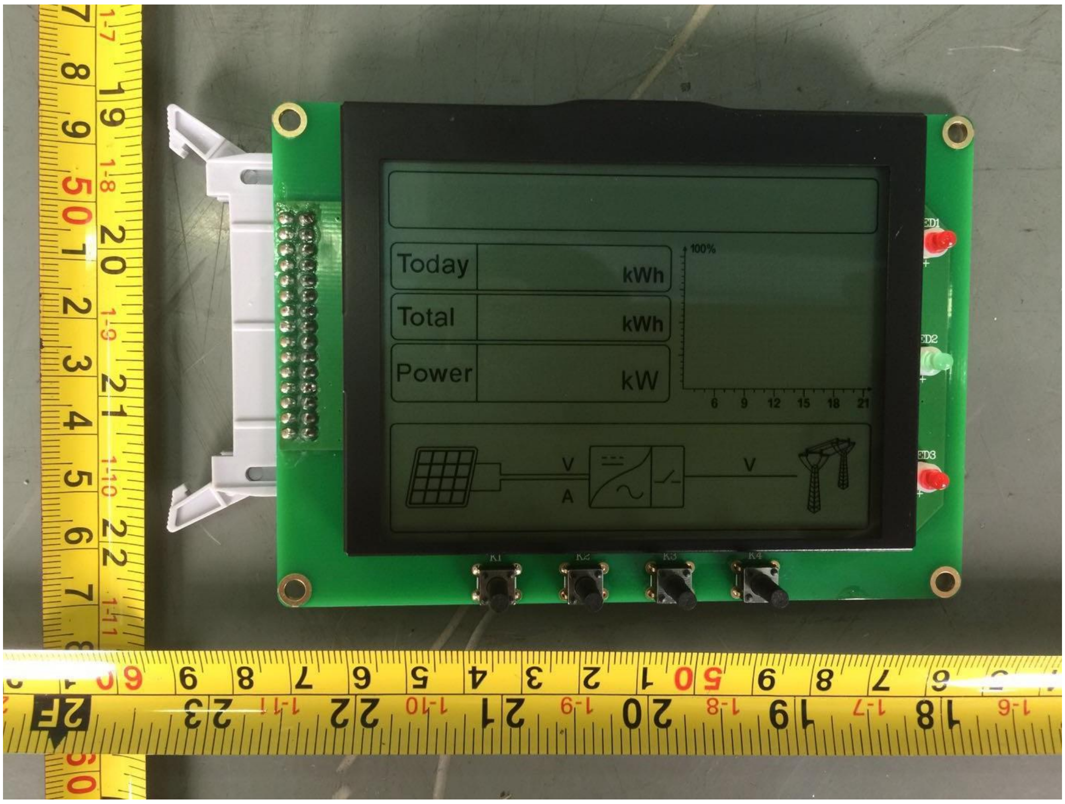


Internal View

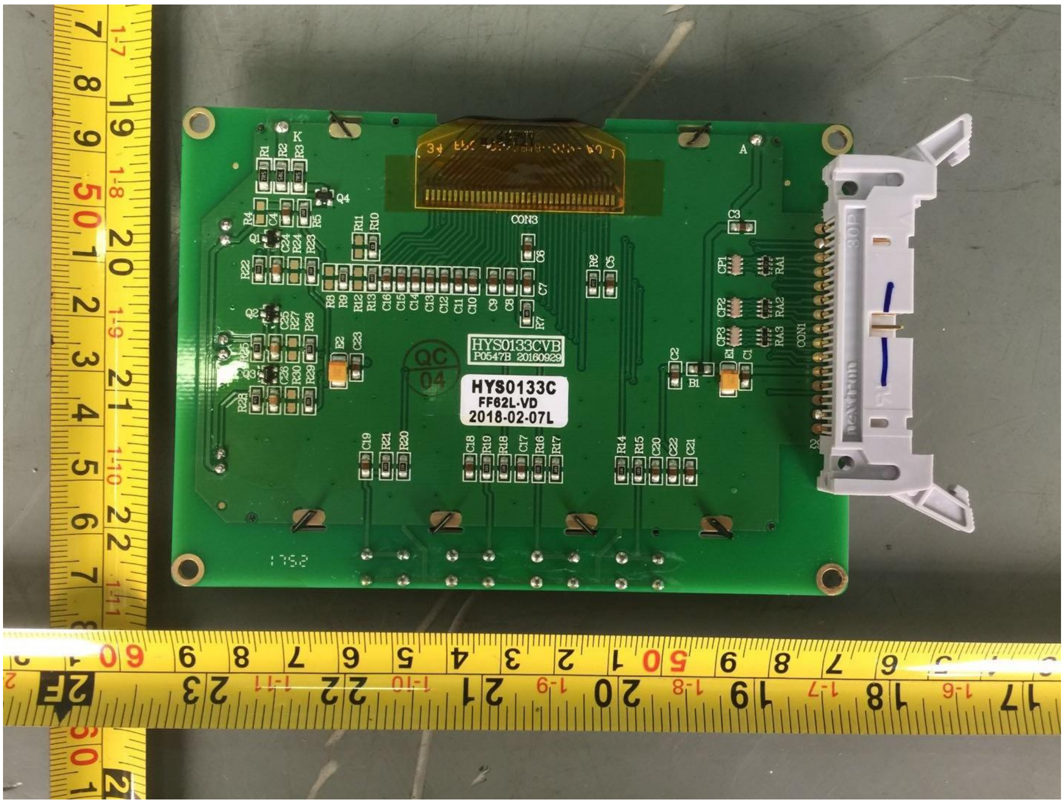
Connection interface

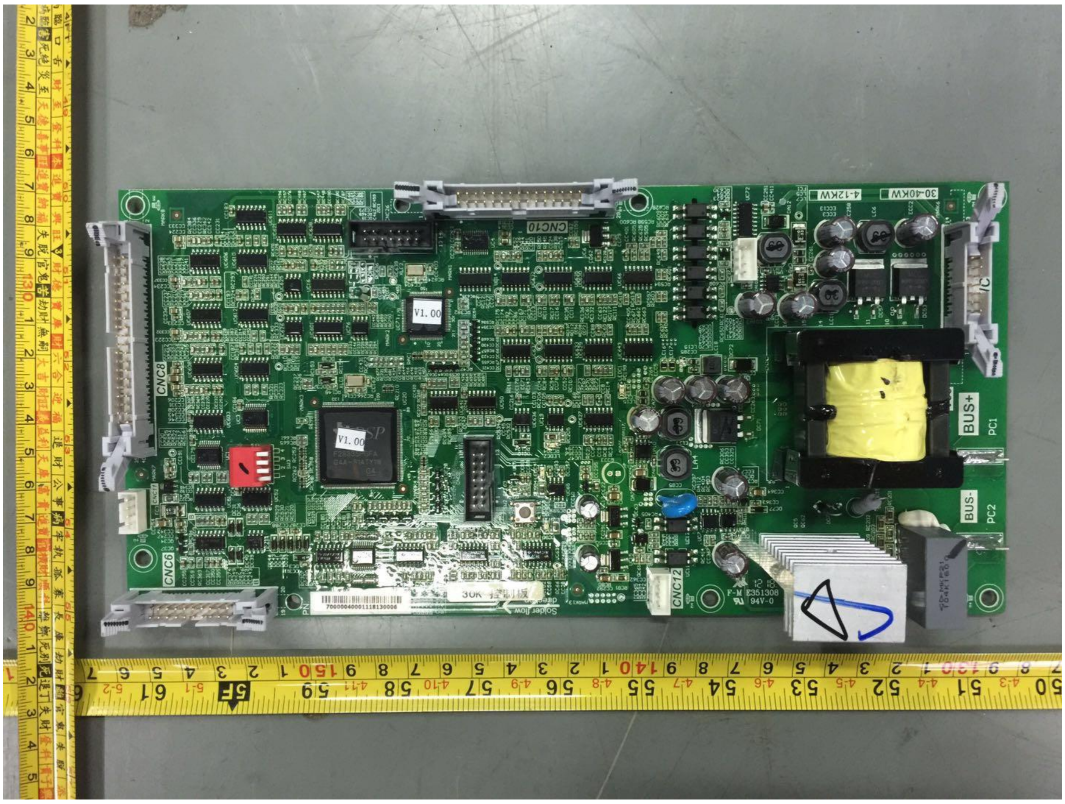
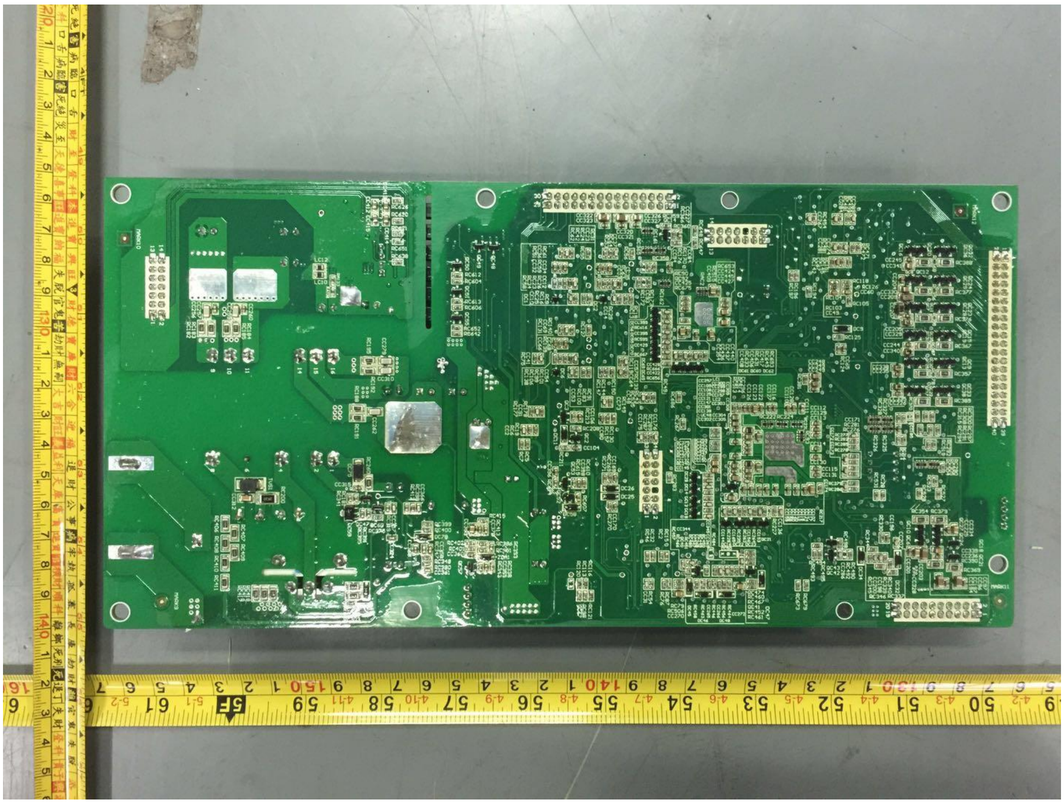
Front view of main board

Back view of main board


Front view of display board

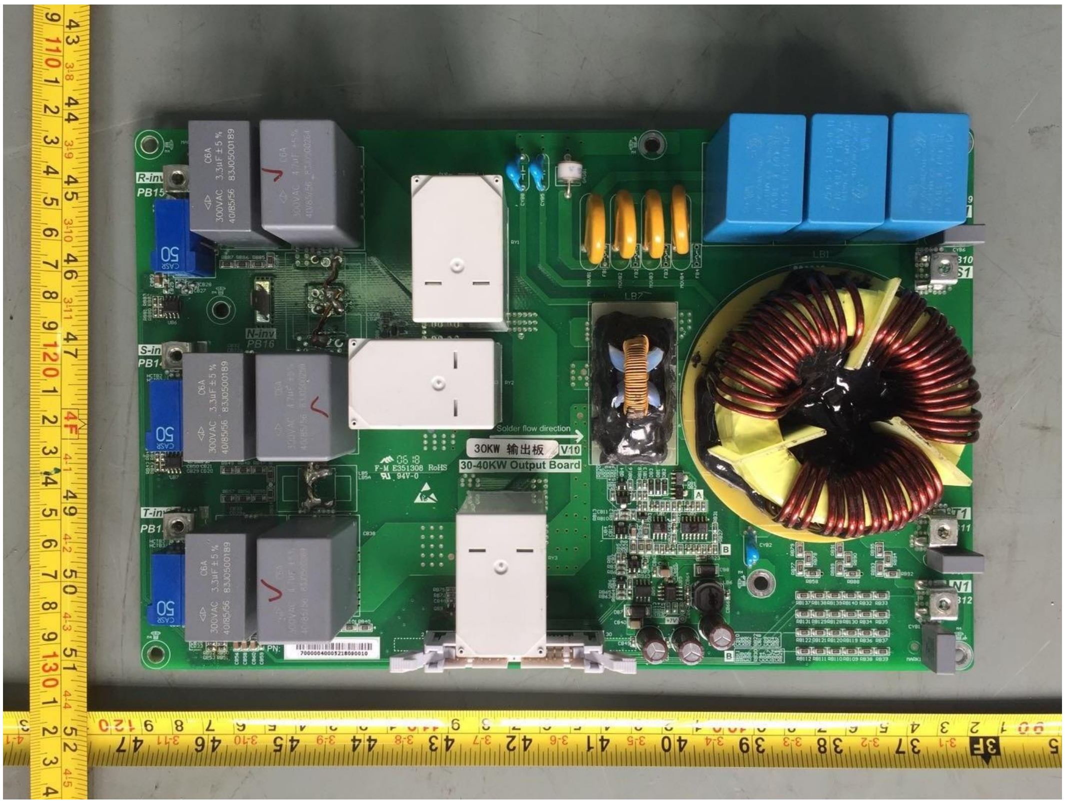


Back view of display board

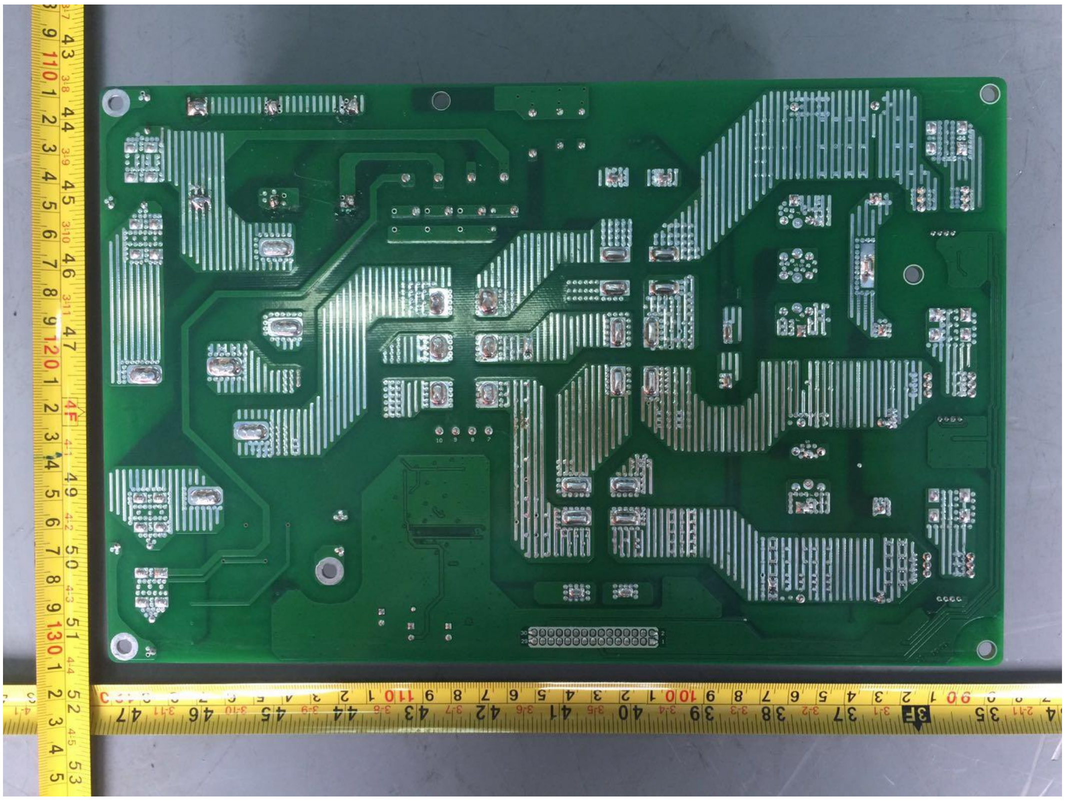


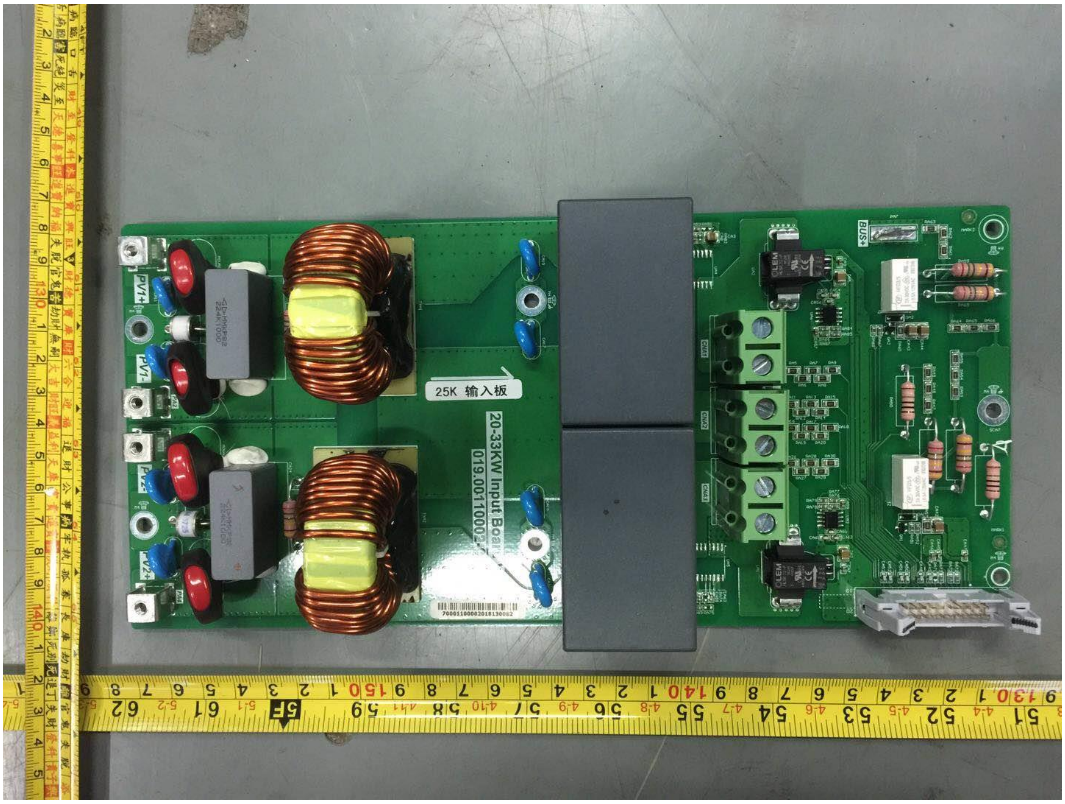
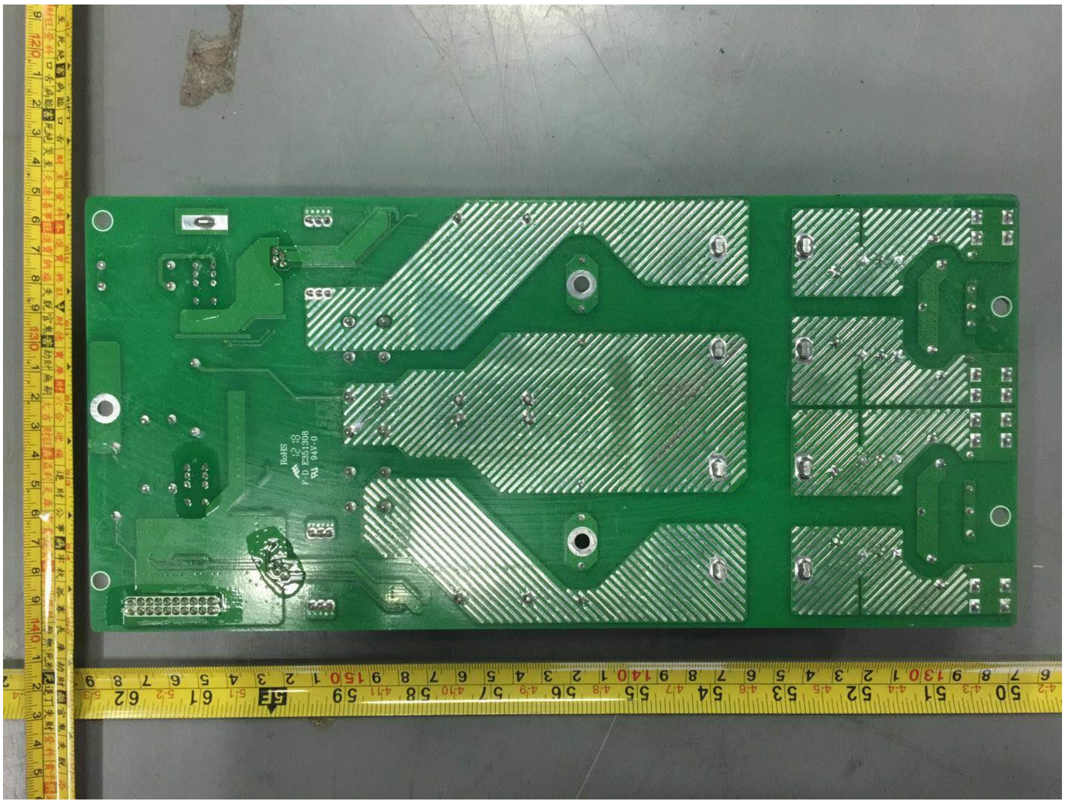
Front view of control board

Back view of control board


Front view of AC output board

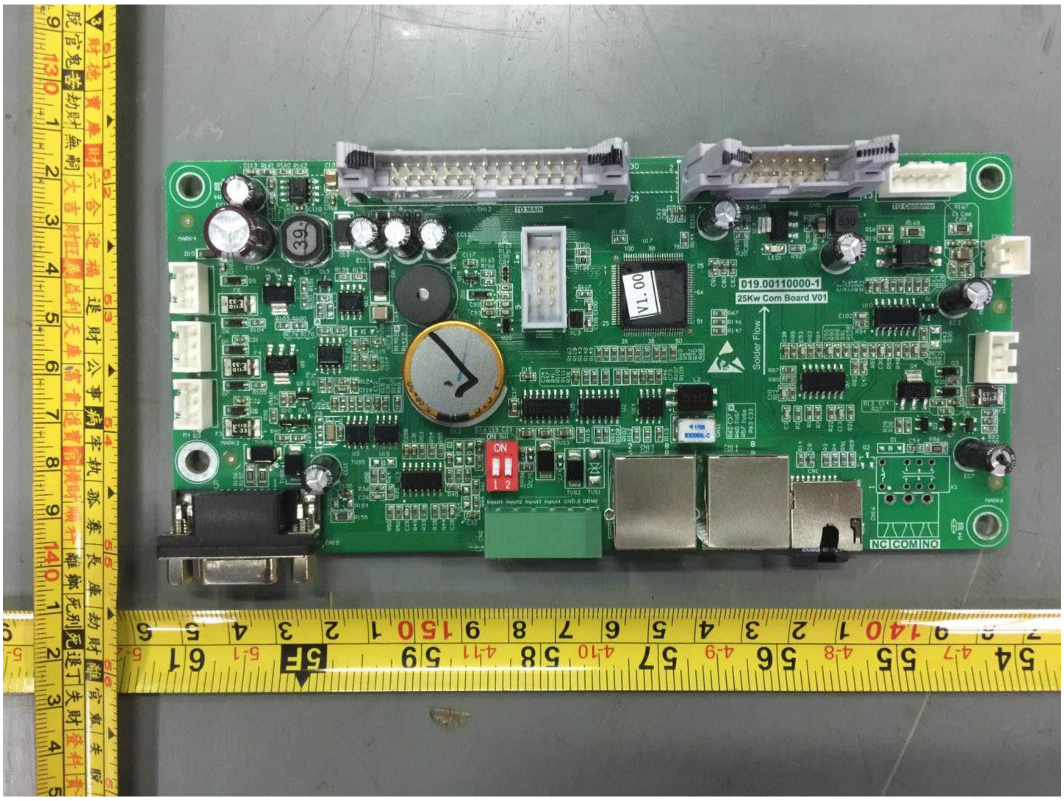


Back view of AC output board

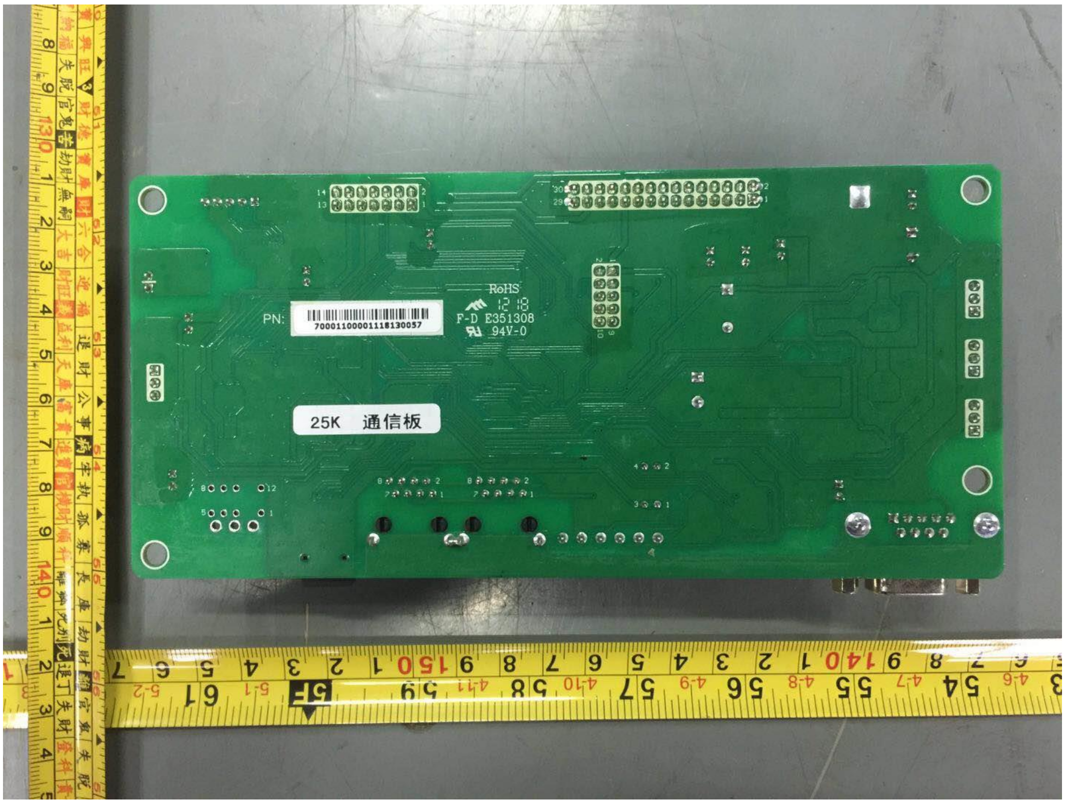


Front view of DC input board

Back view of DC input board


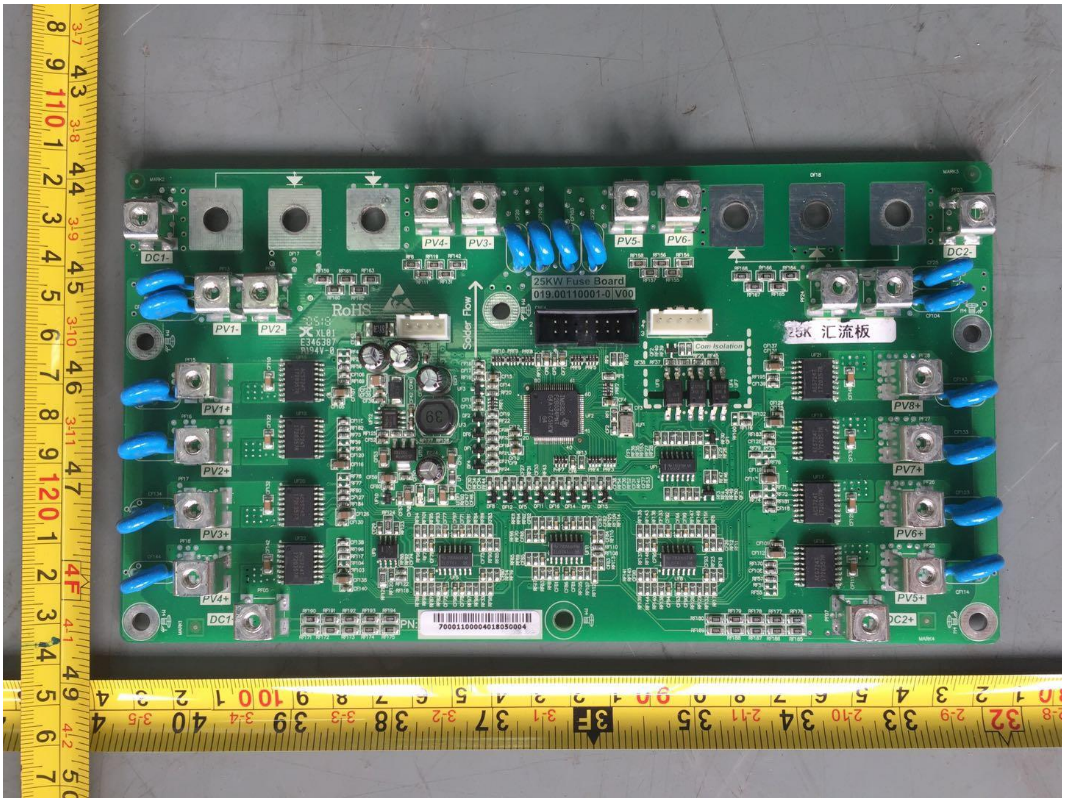
Front view of communication board



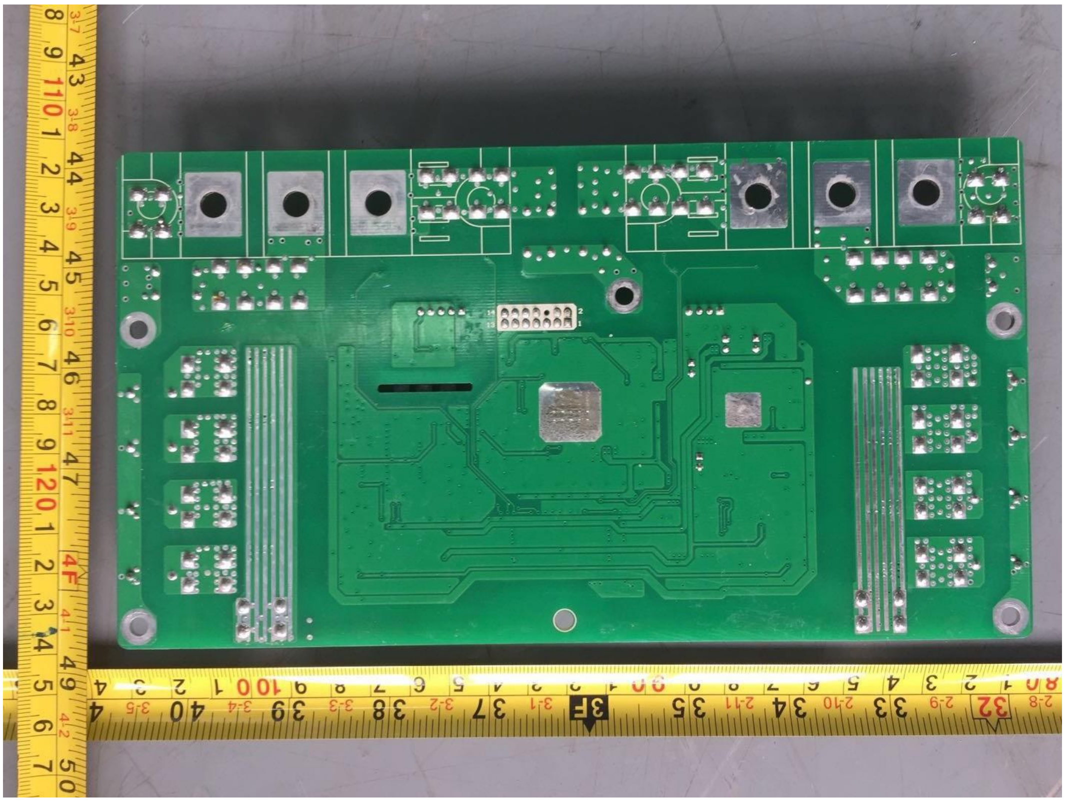
Back view of DC input board

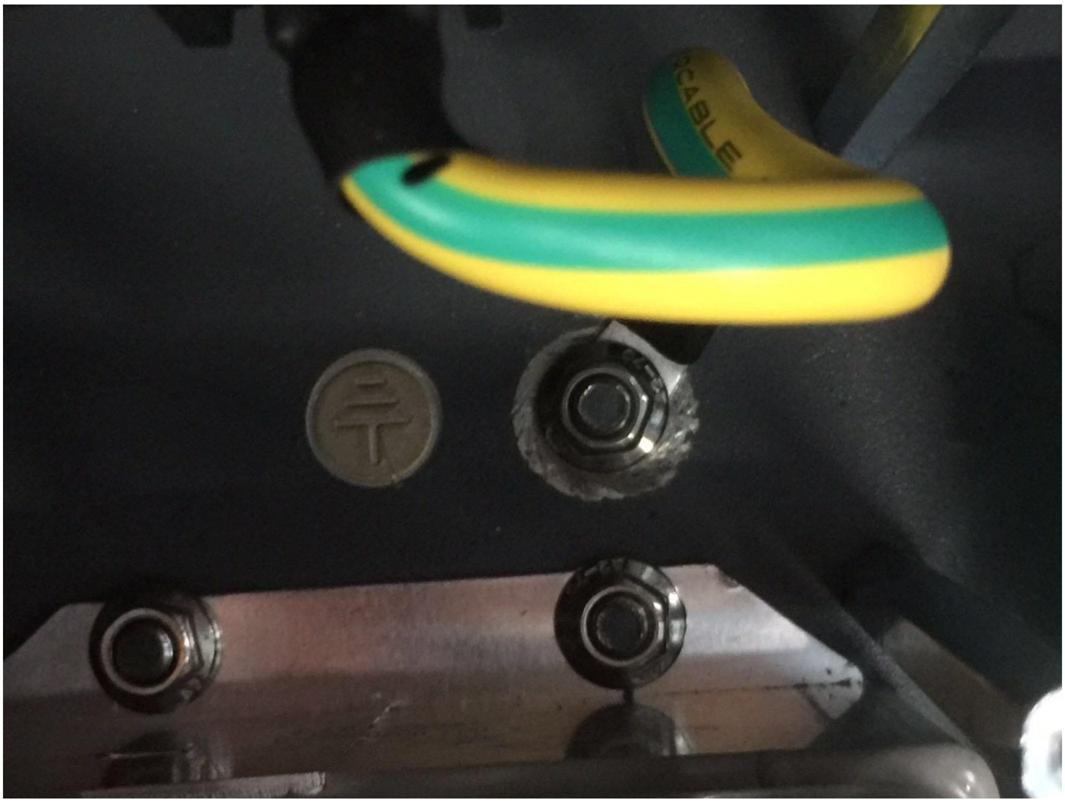
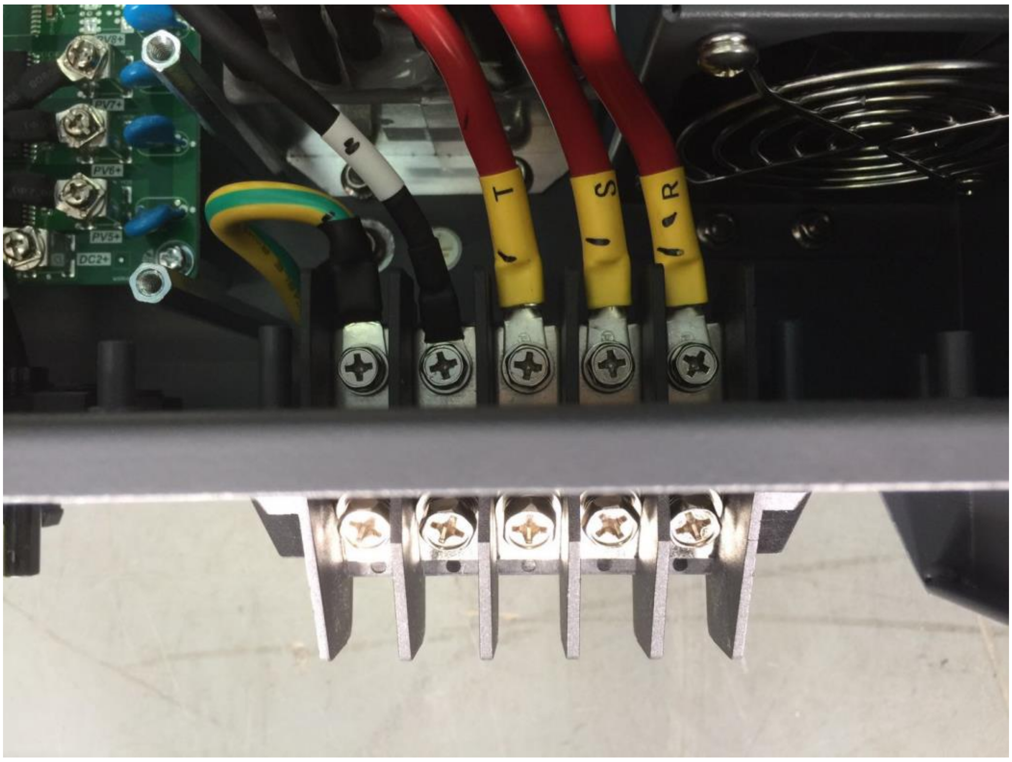


Front view of combine board

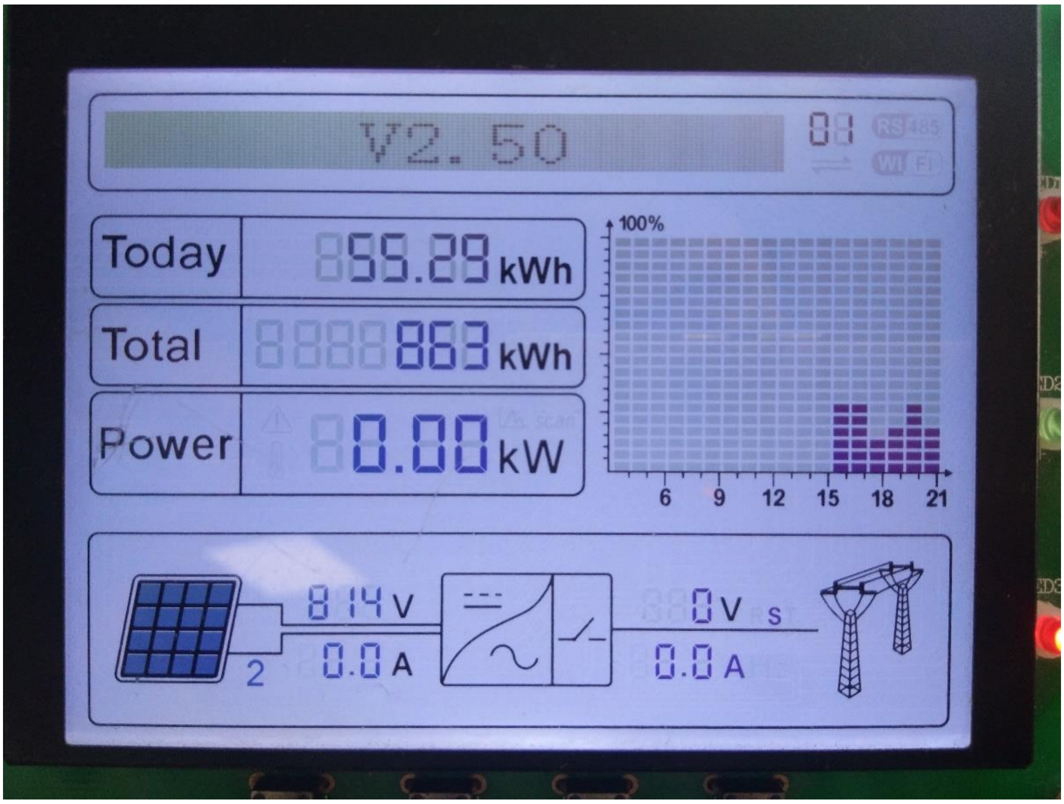


Back view of combin board

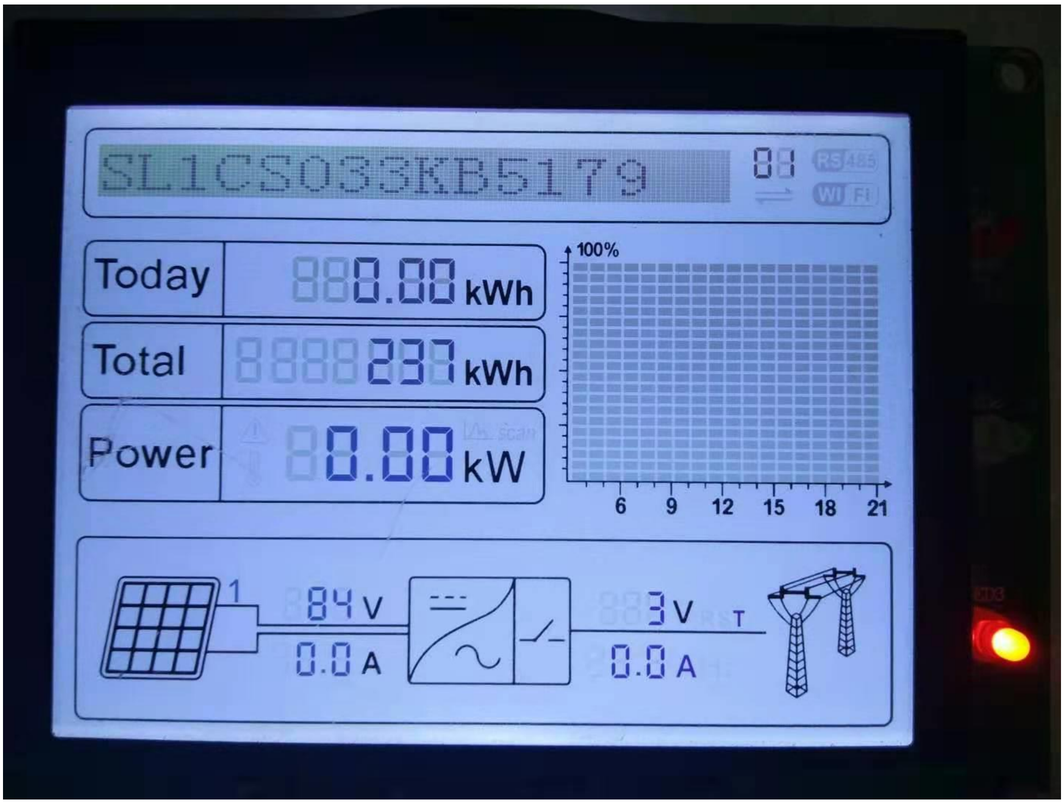


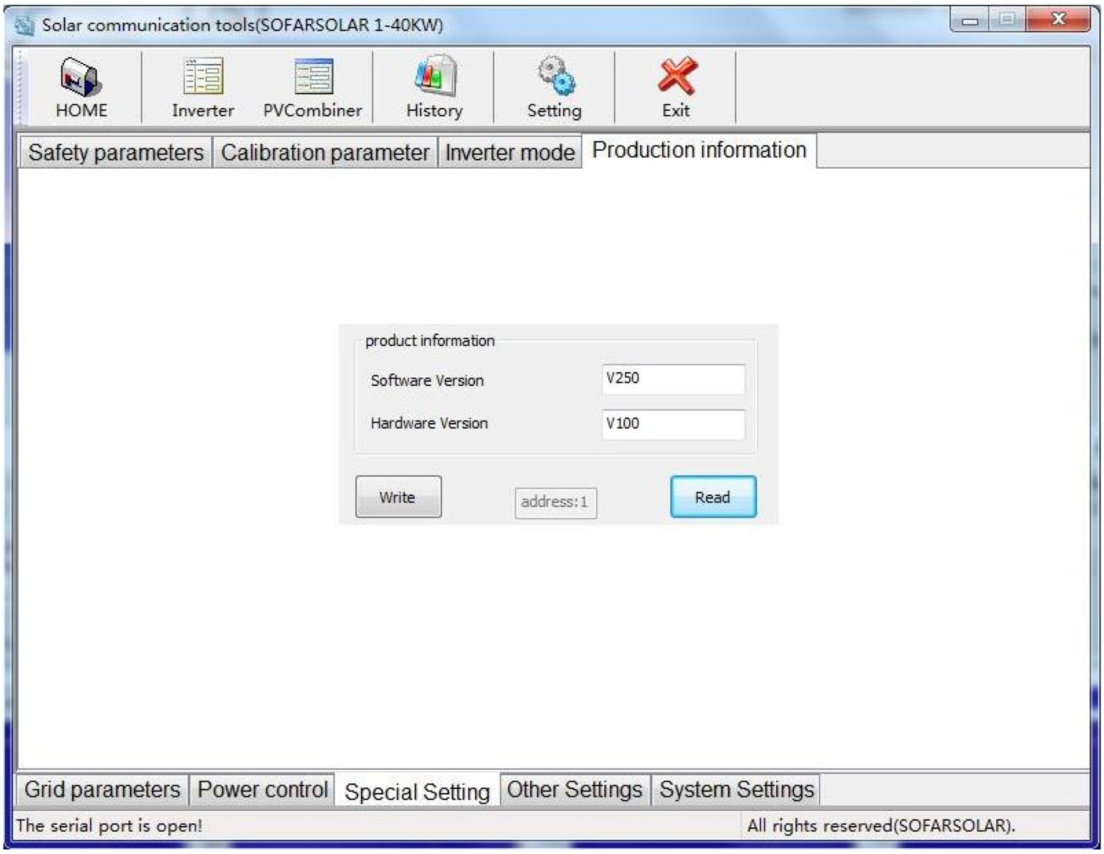
Earthing terminal

AC output connection terminal


Software revision



Serial No.



Interface software revision


6 ELECTRICAL SCHEMES

Equipment under testing