# TESTING FOR THE VERIFICATION OF COMPLIANCE OF PV INVERTER WITH:

# TECHNICAL PRESCRIPTION C10/11 OF SYNERGRID. EDITION 2.1 (01.09.2019)

## (REQUIREMENTS FOR TYPE A GENERATING PLANT)

**Procedure: PE.T-LE-62**

| | | |
|---|---|---|
| Test Report Number | : | **2221 / 0055-2** |
| Type | : | **AC Coupled Storage Converter** |
| Tested Model | : | **ME 3000SP** |
| Variant Models | : | **N/A** |

**APPLICANT**

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

**TESTING LABORATORY**

| | | |
|---|---|---|
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| Conducted (tested) by | : | Roger Hu<br>(Project Engineer) |
| Reviewed and Approved by | : | Jacobo Tevar<br>(Technical Reviewer) |

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

| | | |
|---|---|---|
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**Test Report Historical Revision:**

| Test Report Version | Date | Resume |
| --- | --- | --- |
| 2221/0055-2 | 25/02/2021 | First issuance |

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## 1 SCOPE

SGS Tecnos, S.A. (Electrical Testing Laboratory) has been contract by **Shenzhen SOFARSOLAR Co., Ltd.**, in order to perform testing according to Technical Prescription C10/11 of Synergrid. Edition 2.1 (01.09.2019). Specific technical prescriptions regarding power-generating plants operating in parallel to the distribution network.

EUT comply with requirements for **type A** generating plant connect to LV grid define in the standard as following:

The power limits considered for application in the scope of this regulation are the following:

- Type A: 0.8kw ≤ $P_{MAX\ Capacity}$ < 1MW
- Type B: 1MW ≤ $P_{MAX\ Capacity}$ < 25MW

## 2 GENERAL INFORMATION

### 2.1 TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed on 20th Novermber 2020 and 18th February 2021

All the tests and checks have been performed at 25 ± 5ºC, 96 kPa ± 10 kPa and 40% RH ± 10% RH).

**SITE TEST**

Name .....: Shenzhen SOFARSOLAR Co., Ltd.

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

### 2.2 EQUIPMENT UNDER TESTING

Apparatus type ..... : AC Coupled Storage Converter

Installation..... : Fixed installation

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

Trade mark..... : SOFAR SOLAR

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

Serial Number ..... : ZE1ES050M31999

Software Version..... : V2.80

Checksum ..... : N/A

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

Date of manufacturing: 2020

Test item particulars

Input..... : DC

Output..... L/N/PE

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

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

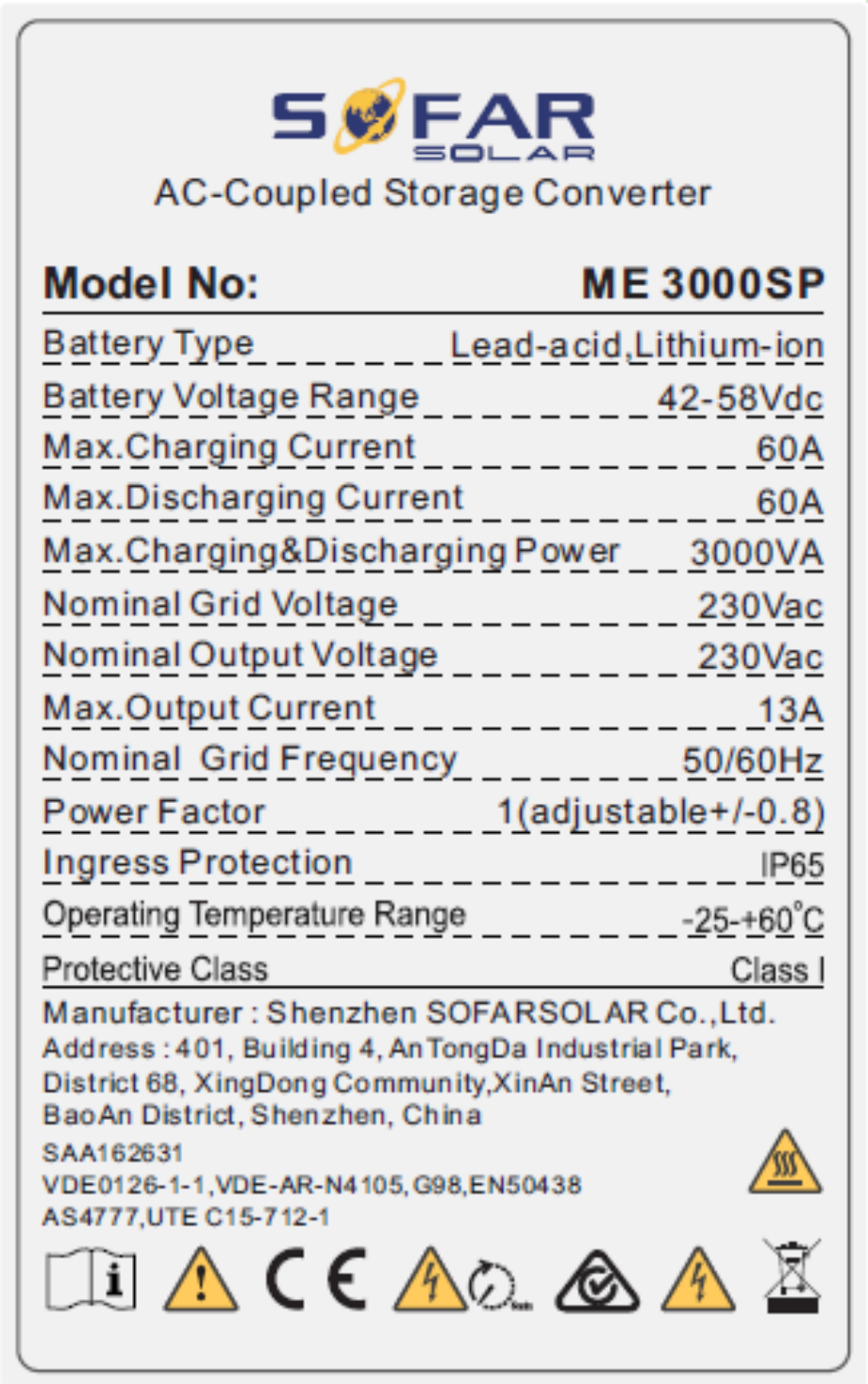
Type of connection to the main supply..... : Signal phase – Fixed installation

Cooling group..... : Heat sink

Modular..... : No

Internal Transformer..... : No

**Copy of marking plate:**




**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 ME 3000SP's except the parameters of rating.

Equipment under testing:

- **ME 3000SP**

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

## 2.3 Factory information

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

## 2.4 Reference Values

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

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

## 2.5 TEST EQUIPMENT LIST

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

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

**From 2021/01/06 to 2021/02/18:**

| From | No. | Equipment Name | Model No. | Equipment No. | Calibration Date | Equipment calibration due date |
|---|---|---|---|---|---|---|
| Sofar Solar | 1 | Voltage probe | SanHua / SI-9110 | 111539 | 2021/01/05 | 2022/01/04 |
| | 2 | Voltage probe | SanHua / SI-9110 | 111134 | 2021/01/05 | 2022/01/04 |
| | 3 | Power analyzer | ZLG / PA3000 | C820200565180922 0002 | 2021/01/05 | 2022/01/04 |
| | 4 | Current probe | CYBERTEK / CP1000A | C181000922 | 2021/01/05 | 2022/01/04 |
| | 5 | Current probe | CYBERTEK / CP1000A | C181000929 | 2021/01/05 | 2022/01/04 |
| | 6 | Temperature & Humidity meter | Anymeters / HTC-1 | WSDJ-007 | 2020/12/28 | 2021/12/28 |
| | 7 | Oscilloscope | Keysight / DS0X3014T | MY59243036 | 2021/01/05 | 2022/01/04 |
| SGS | 8 | True RMS Multimeter | Fluke / 289C | 22930028 (GZE012-53) | 2020/02/21 | 2021/02/20 |

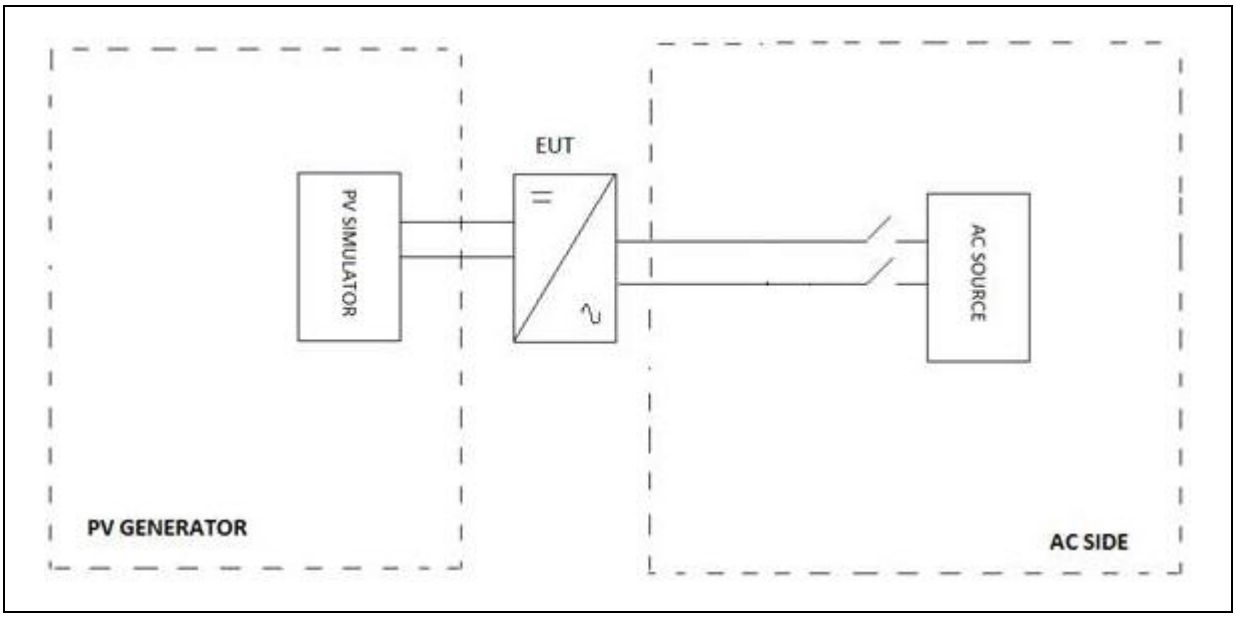
### 2.6 MEASUREMENT UNCERTAINTY

Associated uncertainties through measurements showed in this 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.<br>Note2: Where the standard requires lower uncertainties that those in this table. Most restrictive uncertainty has been considered. | |

## 2.7 TEST SET UP

Below is the simplified construction of the test set up.




| Test Conditions | | |
|---|---|---|
| **Condition** | **Value** | **Comments** |
| Point of measurement | EUT Output (Low Voltage) | Equipment enounced in section 2.4 of this report has been used in the point of measurement |
| Short circuit ratio at the measurement point ($S_k$ /Sn) | $S_k$ /Sn =60kVA / 3KVA = 20 | |
| 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. | Connect to LV grid only | |
| 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) | -- | Transformerless |
| LV Isolation transformer: Short circuit voltage $U_k$ (%) | -- | Transformerless |
| LV Isolation transformer: Tap possition | -- | Transformerless |

| Test Conditions | | |
|---|---|---|
| **Condition** | **Value** | **Comments** |
| MV Side:<br>Additional impedance | -- | Not applicable measured in Low voltage side |
| LV Side:<br>Additional impedance | Active 0 Ω<br>Reactive 0 Ω | |
| The THDSU of the voltage which includes all integer harmonics up to the 50th order must be smaller than 5%. It is measured as the 10-minute mean at the PGU terminals while the PGU is not generating any power. | See section 2.5.2 of this report | |
| 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%<br>Phase B: 0.07%<br>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 fre-quency, 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<br>Tested Min. Value 49.993Hz<br>Tested Avg. Value:50.002Hz | |
| Note 1: These test conditions have been used in all the test performed in Sections 4 of this report.<br>Note 2: See also the test bench information table in this section | | |

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

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

**The test bench used includes:**

| EQUIPMENT | MARK / MODEL | RATED CHARACTERISTICS | OWNER / ID. CODE |
|---|---|---|---|
| AC source | Keysight / N8957APV | 60kVA max. 45-65Hz | Sofar Solar / DE17202422 |
| PV source | Chroma / 61860 | 60kVA max. | Sofar Solar / 6186038000446 |

## 2.8 DEFINITIONS

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

## 3 RESUME OF TEST RESULTS

**INTERPRETATION KEYS**

Test object does meet the requirement ..... : **P** Pass

Test object does not meet the requirement ..... : **F** Fails

Test case does not apply to the test object ..... : **N/A** Not applicable

To make a reference to a table or an annex..... : See additional sheet

To indicate that the test has not been realized ..... : **N/R** Not realized

| REPORT SECTION | C10/11: 2019 SECTION | CHAPTER OF THE STANDARD | RESULT |
|---|---|---|---|
| **4.1** | **4.1.7 (2)** | **Automatic Separation System** | **--** |
| **4.2** | **8.2** | **Power quality** | **--** |
| 4.2.1 | 8.2.2 | Rapid voltage changes | P |
| 4.2.2 | 8.2.3 | Flickers | P |
| 4.2.3 | 8.2.4 | Harmonic | P |
| 4.2.4 | 8.2.5 | Unbalances | N/A |
| **4.3** | **D.3** | **Integrated automatic separation system** | P |
| **4.4** | **D.4** | **Operating ranges** | **--** |
| 4.4.1 | D.4.1 | Operating frequency range | P |
| 4.4.1 | D.4.2 | Maximum admissible power reduction in case of underfrequency | P |
| 4.4.2 | D.4.3 | Continuous operating voltage range | P |
| **4.5** | **D.5** | **Inmunity to disturbance** | **--** |
| 4.5.1 | D.5.1 | RoCoF immunity | P |
| 4.5.2 | D.5.2 | Under-voltage ride through UVRT | N/A |
| 4.5.2 | D.5.3 | Over-voltage ride through (OVRT) | N/A |
| **4.6** | **D.6** | **Active response to frequency deviations** | **--** |
| 4.6.1 | D.6.1 | Power response to overfrequency | P |
| 4.6.2 | D.6.2 | Power response to underfrequency | P |
| **4.7** | **D.7** | **Power response to voltage changes** | **--** |
| 4.7.1 | D.7.1 | Q(P) Capabilities | P |
| 4.7.2 | D.7.1 | Q(U) capabilities | P |
| 4.7.3 | D.7.1 | Cos φ setpoint | P |
| 4.7.4 | D.7.1 | Cos φ(P) capabilities | P |
| 4.7.5 | D.7.1.1 | Specific for a small power-generating plant | P |
| 4.7.6 | D.7.1.2 | Specific for another (not small) power-generating plant | N/A |
| 4.7.7 | D.7.2 | Voltage related active power reduction P(U) | P |
| 4.7.8 | D.7.3 | Provision of additional fast reactive current during faults and voltage steps | N/A |
| **4.8** | **D.8** | **Connection and starting to generate electrical power** | **--** |
| 4.8.1 | -- | Automatic reconnection after tripping | P |
| 4.8.2 | -- | Starting to generate electrical power | P |
| **4.9** | **D.9** | **Ceasing and reduction of active power on set point** | **--** |
| 4.9.1 | 4.9.1 | Ceasing active power | P |
| 4.9.2 | 4.9.2 | Reduction of active power on set point | N/A |
| **4.10** | **D.10** | **Communication – Remote monitoring and control** | N/A |

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

# 4 TEST RESULTS

## 4.1 AUTOMATIC SEPARATION SYSTEM

The grid parameters for the connection point of the EUT (Measured at LV side of the transformer) are offered below.

Each power-generating unit must be equipped with an automatic separation system.

This automatic separation system can be either integrated in the power-generating unit itself (which is generally the case), or external to it. When using an external system,

- it must have a “single fault tolerance” according to EN 50549-1, and
- it must be of a type approved by Synergrid, as listed in the C10/21 list of Synergrid published on the website http://www.synergrid.be/download.cfm?fileId=C10-21_DecouplingRelays_NF_20200515.pdf

According to user’s manual, an external AC relays needs to be installed on at the final plant. This external realy, as defined on the user’s manual on page 20, must be approved by Synergrid:

For Belgium, one of the following links is required for external AC relays.
http://www.synergrid.be/download.cfm?fileId=C10-21_DecouplingRelays_NF_20200515.pdf

### 4.2 POWER QUALITY.

The test has been done according to the clause 8.2 of the standard. The grid parameters for the connection point of the EUT (Measured at LV side of the transformer) are offered below.

| R (Ω) | X (Ω) | Z (Ω) | Ψ (°) | $S_k$/Sn |
|---|---|---|---|---|
| 0.24 | 0.15 | 0.39 | 0.04 | 10 |

### 4.2.1 Rapid voltage changes

The test method is according to VDE-AR-N 4105:2018-11. During operation, any sudden power variation may not influence the voltage level at the point of con-nection by more than 3%.

$$\Delta u_{max} \leq 3\ \%$$

$$\Delta u_{max} = k_{imax} \frac{S_{Emax}}{S_{kV}} = \frac{I_a}{I_{rE}} \cdot \frac{S_{Emax}}{S_{kV}}$$

- SEmax is the maximum apparent power of inverter.
- Skv is the network short circuit power.
- Ia is staring current
- IrE is rated current

$$k_{imax} = \frac{I_a}{I_{rE}}$$

Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/12/30 | 100ms values | 10kHz |

The following are the result for calculated $k_i$

| | | |
| --- | --- | --- |
| Making operation at reference conditions (of primary energy carrier) | $k_i$ | 0.046 |
| Worst case at switch over of generator sections | $k_i$ | --(*) |
| Making operation without default (of primary energy carrier) | $k_i$ | --(*) |
| Breaking operation at nominal power | $k_i$ | 0.238 |
| Worst-case value of all switching operations | $k_{imax}$ | 0.238 |

(*) Due to the input side is batteries, the voltage will not rapid changed.

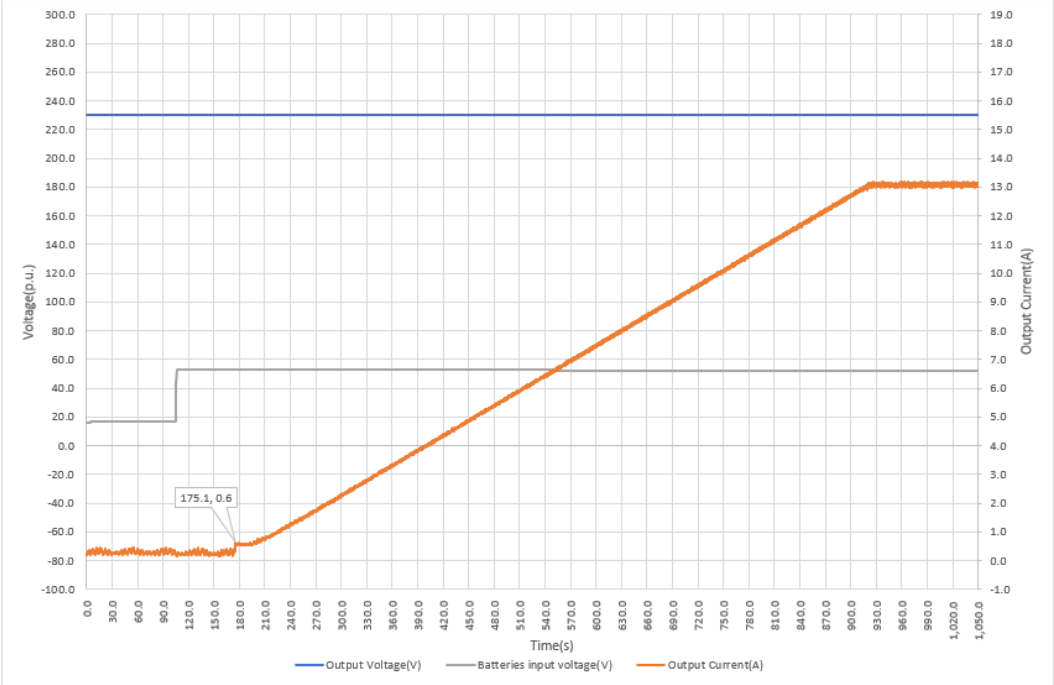
According to the performed tests, the Skv minimum for with the inverter can be installed is 60kVA.

After calculating:

**Δumax= 1.19%**

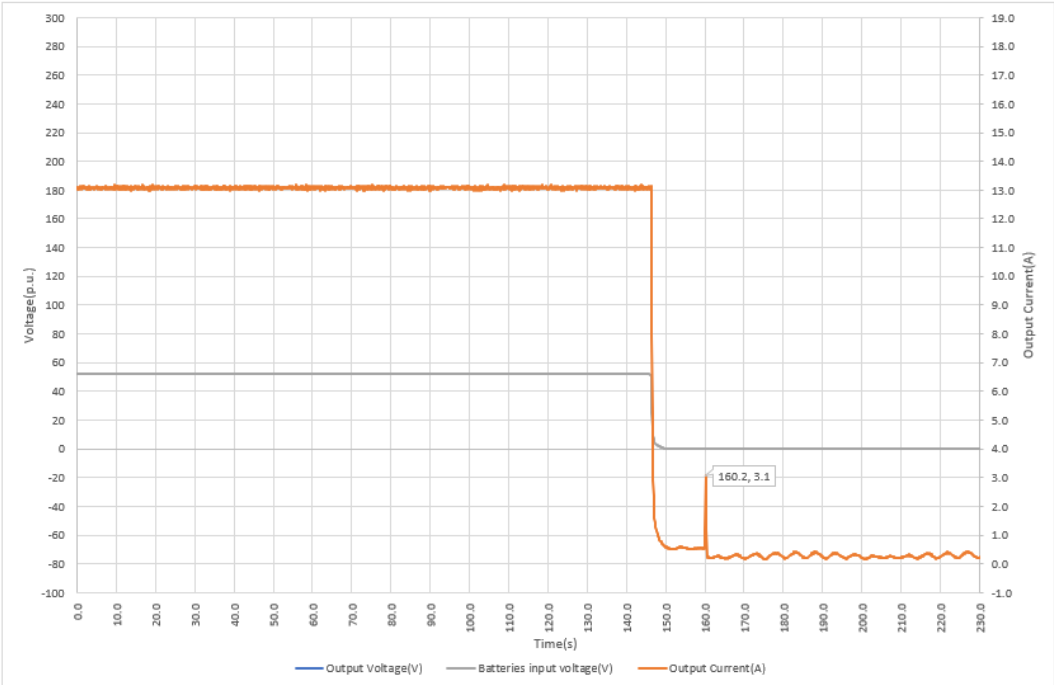
The information provided above should be taken into account for the particular conditions of the installation of the inverter.

**Making operation at reference conditions (of primary energy carrier)**
**(Normal start working)**




$k_i = I_a / I_{re} = 0.046$

**Breaking operation at nominal power**
**(PV input shut down)**




$k_i = I_a / I_{re} = 0.238$

### 4.2.2 Flickers

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

This requirement is according to point 8.2.3 of the standard. It applies to both PV and storage systems.

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

Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/11/20, 2020/11/21 | 100ms values | 10kHz |

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

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

| **Test at 33 %Pn** | | |
|---|---|---|
| **Pbin (%)** | **Limit** | **Test Value** |
| $P_{ST}$ | ≤ 1.0 | 0.061 |
| $P_{LT}$ | ≤ 0.65 | 0.054 |
| dc | ≤ 3.30 % | 0.108% |
| dmax | 4 % | 0.219% |

| **Test at 66 %Pn** | | |
|---|---|---|
| **Pbin (%)** | **Limit** | **Test Value** |
| $P_{ST}$ | ≤ 1.0 | 0.062 |
| $P_{LT}$ | ≤ 0.65 | 0.058 |
| dc | ≤ 3.30 % | 0.108% |
| dmax | 4 % | 0.205% |

| **Test at 100%Pn** | | |
|---|---|---|
| **Pbin (%)** | **Limit** | **Test Value** |
| $P_{ST}$ | ≤ 1.0 | 0.207 |
| $P_{LT}$ | ≤ 0.65 | 0.204 |
| dc | ≤ 3.30 % | 0.089% |
| dmax | 4 % | 0.246% |

## Test at 33 %Pn


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

## Test at 66 %Pn


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

## Test at 100 %Pn


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

### 4.2.3 Harmonic

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

Test performed according to point 8.2.4 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 5 minutes average values of line to neutral current.

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 (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 (according to Synergrid technical prescriptions C10/17(HV connection) and C10/19 (LV connection)), the results shown in this chapter are performed at inverter level. The results shown are informative.

- PGU operation mode; Q (VAr) — Q setpoint = 0 VAr
- Voltage range (V) — 230 V
- Voltage unbalance — Same conditions as point 4.2.4 of this test report (*) (Umbalace Chapter)
- Measured period (min) — 5 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 |
| --- | --- |
| 2 % | 1 |
| 10 % | 1 |
| 20 % | 1 |
| 30 % | 1 |
| 40 % | 1 |
| 50 % | 1 |
| 60 % | 1 |
| 70 % | 1 |
| 80 % | 1 |
| 90 % | 1 |
| 100 % | 1 |

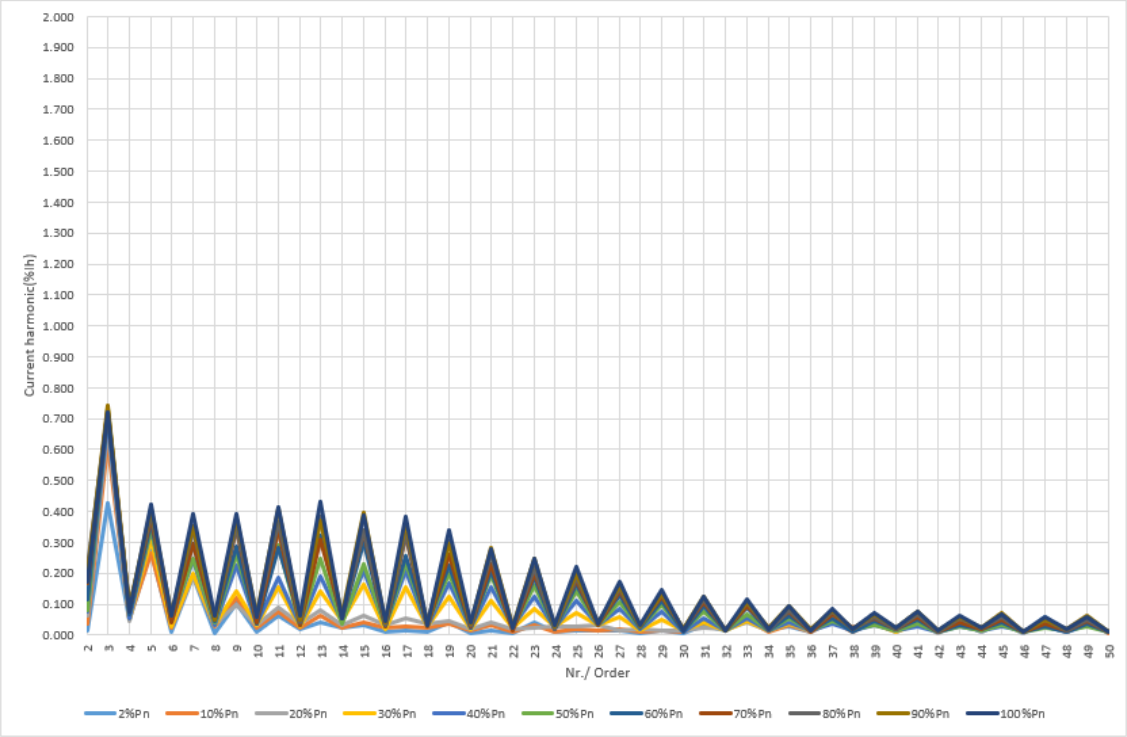
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
| --- | --- | --- | --- |
| PA5000H | 2021/1/5 | 100ms values | 10kHz |

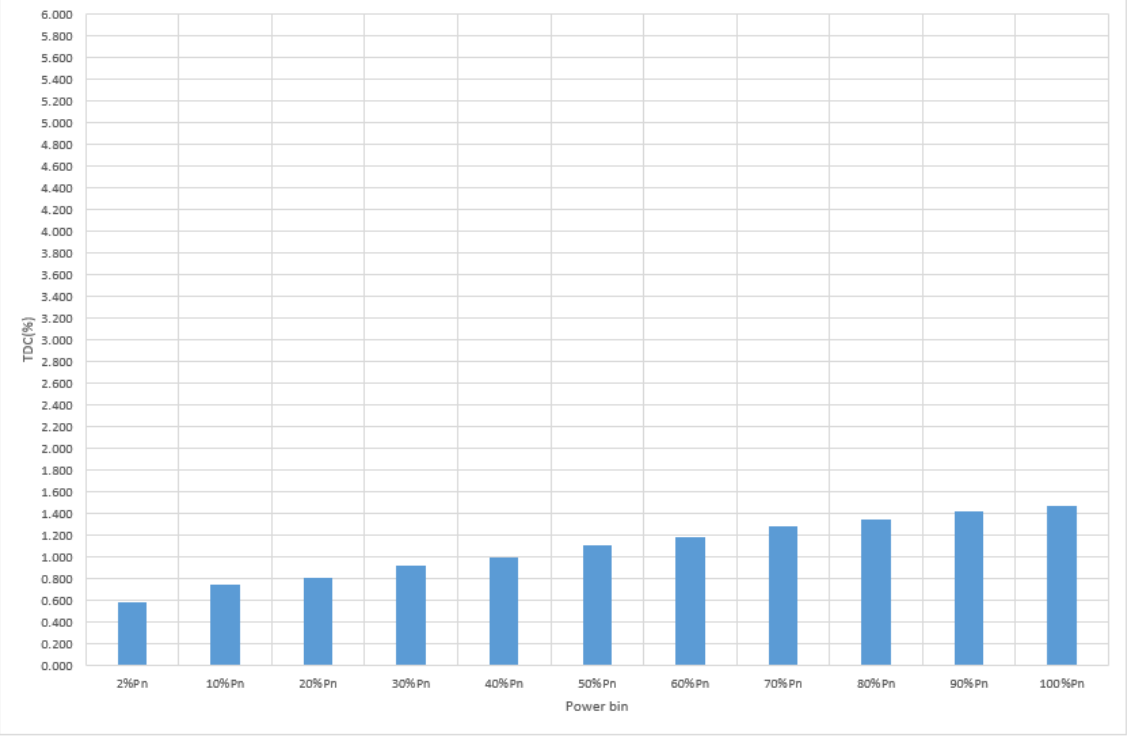
#### 4.2.3.1 Current harmonics

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

## Current Harmonics




## Total Distortion Current Harmonic

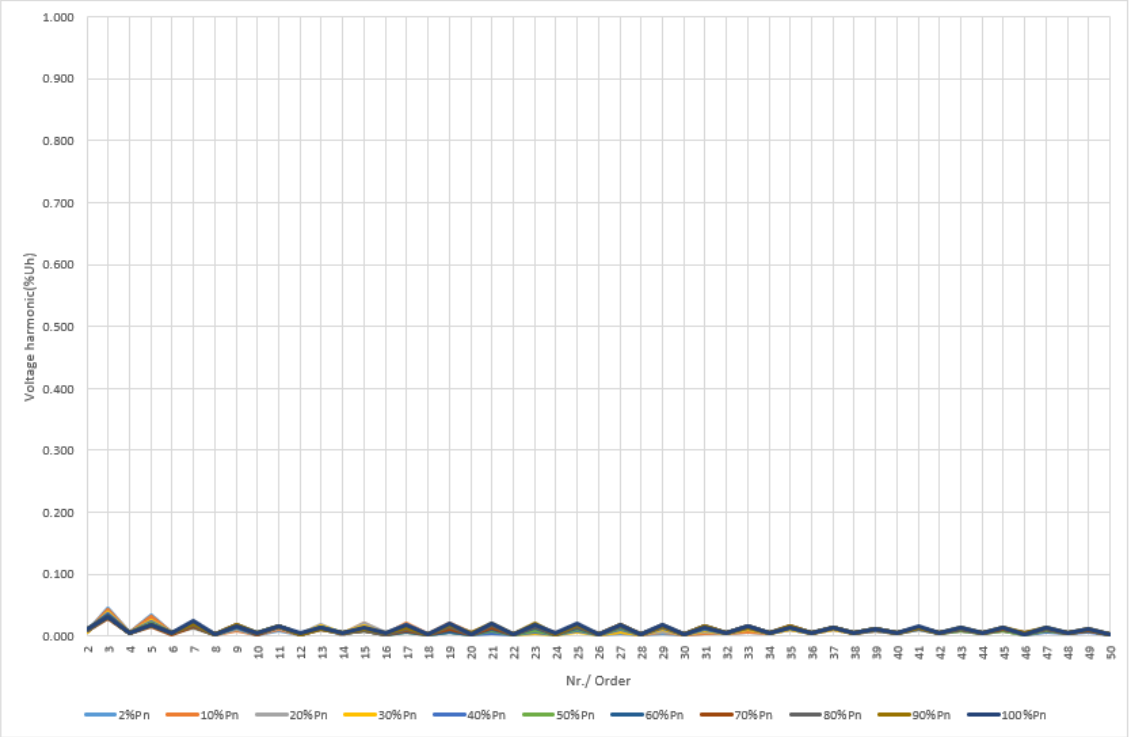


#### 4.2.3.2 Voltage harmonics

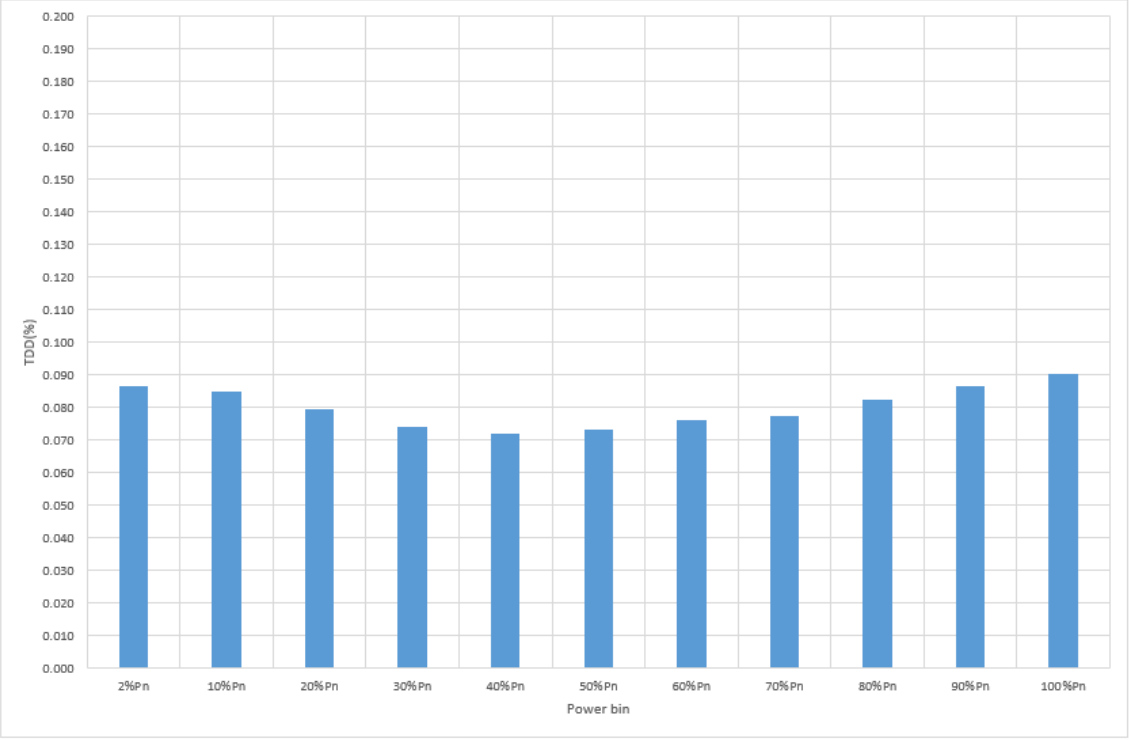
Measurements of voltage harmonics at continuous operation are done according to IEC 61000-4-7:2002

| $P_n$ (%) | 2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | Max (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nr./ Order | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | $U_h$(%) | |
| 2 | 0.007 | 0.008 | 0.008 | 0.007 | 0.010 | 0.010 | 0.012 | 0.009 | 0.010 | 0.013 | 0.012 | 0.013 |
| 3 | 0.045 | 0.042 | 0.039 | 0.038 | 0.035 | 0.032 | 0.033 | 0.030 | 0.032 | 0.032 | 0.032 | 0.045 |
| 4 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| 5 | 0.035 | 0.031 | 0.026 | 0.025 | 0.022 | 0.020 | 0.017 | 0.017 | 0.018 | 0.019 | 0.017 | 0.035 |
| 6 | 0.005 | 0.004 | 0.004 | 0.004 | 0.005 | 0.004 | 0.005 | 0.004 | 0.005 | 0.004 | 0.005 | 0.005 |
| 7 | 0.021 | 0.018 | 0.014 | 0.015 | 0.016 | 0.015 | 0.016 | 0.017 | 0.018 | 0.020 | 0.026 | 0.026 |
| 8 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.003 | 0.004 | 0.004 |
| 9 | 0.012 | 0.010 | 0.011 | 0.013 | 0.015 | 0.016 | 0.017 | 0.018 | 0.019 | 0.019 | 0.017 | 0.019 |
| 10 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 |
| 11 | 0.010 | 0.012 | 0.015 | 0.015 | 0.015 | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 | 0.017 | 0.017 |
| 12 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 |
| 13 | 0.014 | 0.017 | 0.017 | 0.015 | 0.014 | 0.013 | 0.013 | 0.012 | 0.012 | 0.011 | 0.013 | 0.017 |
| 14 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| 15 | 0.017 | 0.020 | 0.020 | 0.016 | 0.013 | 0.010 | 0.009 | 0.009 | 0.010 | 0.012 | 0.013 | 0.020 |
| 16 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| 17 | 0.018 | 0.020 | 0.018 | 0.012 | 0.009 | 0.007 | 0.007 | 0.010 | 0.012 | 0.015 | 0.018 | 0.020 |
| 18 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| 19 | 0.019 | 0.020 | 0.017 | 0.012 | 0.007 | 0.006 | 0.008 | 0.012 | 0.016 | 0.017 | 0.021 | 0.021 |
| 20 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| 21 | 0.017 | 0.018 | 0.014 | 0.009 | 0.006 | 0.009 | 0.011 | 0.013 | 0.018 | 0.020 | 0.021 | 0.021 |
| 22 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 |
| 23 | 0.015 | 0.015 | 0.011 | 0.006 | 0.007 | 0.010 | 0.014 | 0.016 | 0.017 | 0.021 | 0.019 | 0.021 |
| 24 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 | 0.003 | 0.004 | 0.003 | 0.004 | 0.004 | 0.004 |
| 25 | 0.011 | 0.012 | 0.009 | 0.006 | 0.009 | 0.012 | 0.014 | 0.015 | 0.017 | 0.018 | 0.021 | 0.021 |
| 26 | 0.004 | 0.004 | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 | 0.005 |
| 27 | 0.006 | 0.008 | 0.007 | 0.008 | 0.011 | 0.014 | 0.016 | 0.017 | 0.017 | 0.018 | 0.018 | 0.018 |
| 28 | 0.004 | 0.004 | 0.004 | 0.004 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.003 | 0.004 | 0.004 |
| 29 | 0.006 | 0.006 | 0.008 | 0.011 | 0.013 | 0.015 | 0.017 | 0.017 | 0.018 | 0.016 | 0.018 | 0.018 |
| 30 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| 31 | 0.006 | 0.005 | 0.008 | 0.010 | 0.012 | 0.015 | 0.016 | 0.016 | 0.015 | 0.016 | 0.014 | 0.016 |
| 32 | 0.005 | 0.006 | 0.005 | 0.005 | 0.005 | 0.005 | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 | 0.006 |
| 33 | 0.008 | 0.008 | 0.011 | 0.012 | 0.014 | 0.015 | 0.016 | 0.015 | 0.016 | 0.015 | 0.016 | 0.016 |
| 34 | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 | 0.004 | 0.005 | 0.004 | 0.005 |
| 35 | 0.011 | 0.011 | 0.012 | 0.012 | 0.014 | 0.015 | 0.015 | 0.016 | 0.014 | 0.016 | 0.014 | 0.016 |
| 36 | 0.005 | 0.006 | 0.005 | 0.006 | 0.006 | 0.006 | 0.005 | 0.004 | 0.005 | 0.005 | 0.005 | 0.006 |
| 37 | 0.012 | 0.011 | 0.013 | 0.012 | 0.013 | 0.013 | 0.014 | 0.013 | 0.015 | 0.014 | 0.015 | 0.015 |
| 38 | 0.005 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.004 | 0.005 | 0.005 | 0.005 | 0.004 | 0.005 |
| 39 | 0.012 | 0.010 | 0.011 | 0.009 | 0.010 | 0.012 | 0.012 | 0.013 | 0.012 | 0.013 | 0.012 | 0.013 |
| 40 | 0.005 | 0.005 | 0.005 | 0.005 | 0.006 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.006 |
| 41 | 0.012 | 0.013 | 0.013 | 0.012 | 0.012 | 0.013 | 0.013 | 0.013 | 0.015 | 0.014 | 0.015 | 0.015 |
| 42 | 0.005 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.005 | 0.005 | 0.004 | 0.005 | 0.005 | 0.005 |
| 43 | 0.013 | 0.012 | 0.011 | 0.009 | 0.009 | 0.010 | 0.012 | 0.013 | 0.012 | 0.013 | 0.013 | 0.013 |
| 44 | 0.004 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.004 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 |
| 45 | 0.011 | 0.012 | 0.011 | 0.010 | 0.010 | 0.011 | 0.011 | 0.011 | 0.013 | 0.013 | 0.014 | 0.014 |
| 46 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| 47 | 0.013 | 0.011 | 0.010 | 0.009 | 0.008 | 0.009 | 0.011 | 0.012 | 0.012 | 0.013 | 0.013 | 0.013 |
| 48 | 0.005 | 0.005 | 0.004 | 0.005 | 0.005 | 0.005 | 0.004 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| 49 | 0.010 | 0.010 | 0.010 | 0.009 | 0.008 | 0.009 | 0.009 | 0.010 | 0.011 | 0.011 | 0.013 | 0.013 |
| 50 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 |
| TDD (%) | 0.086 | 0.085 | 0.079 | 0.074 | 0.072 | 0.073 | 0.076 | 0.077 | 0.082 | 0.086 | 0.090 | 0.090 |

## Voltage Harmonics




## Total Voltage Distortion



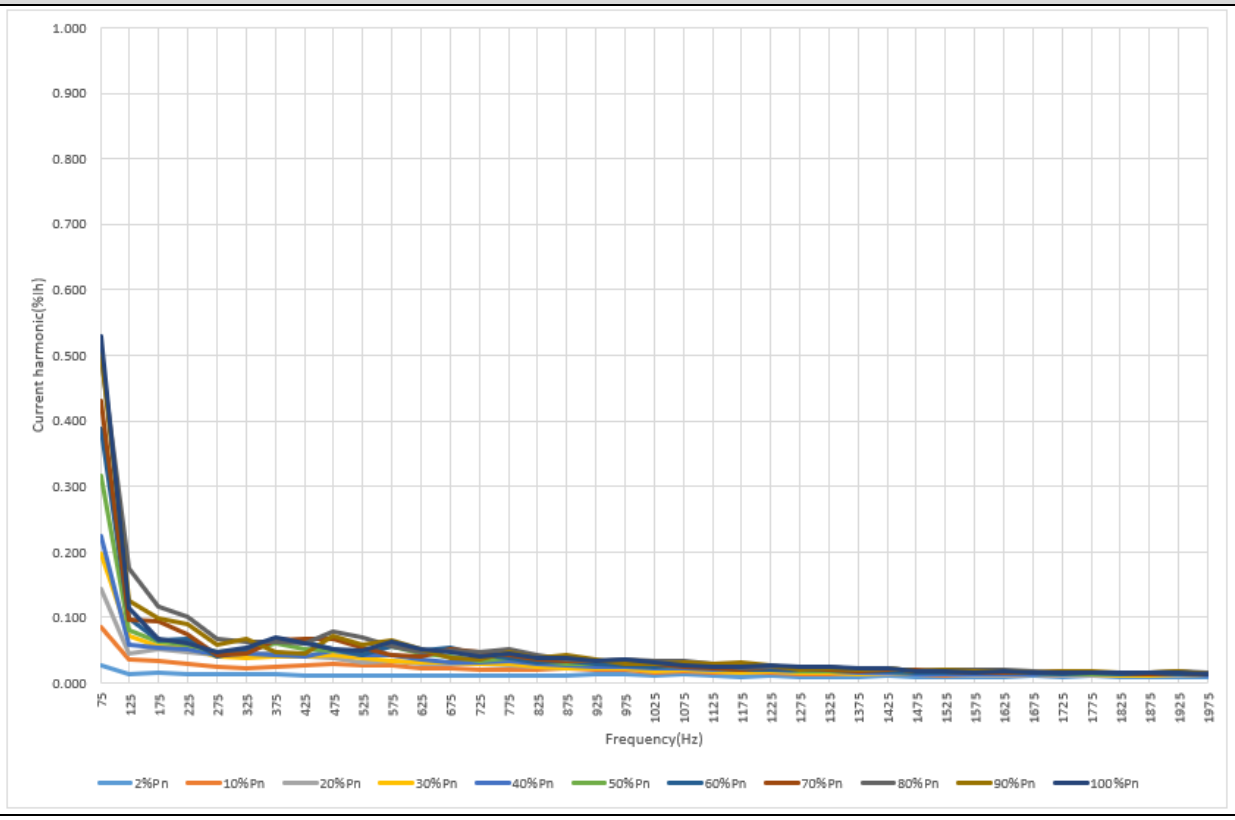
#### 4.2.3.3 Interharmonics at continuous operation

Test performed according to point 8.2 of the standard.

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

| $P_n$ (%) | 2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | MAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F [Hz] | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | (%) |
| 75 | 0.026 | 0.085 | 0.143 | 0.197 | 0.224 | 0.315 | 0.389 | 0.431 | 0.499 | 0.504 | 0.529 | 0.529 |
| 125 | 0.014 | 0.035 | 0.045 | 0.072 | 0.059 | 0.080 | 0.100 | 0.096 | 0.175 | 0.126 | 0.114 | 0.175 |
| 175 | 0.015 | 0.034 | 0.051 | 0.056 | 0.055 | 0.063 | 0.064 | 0.093 | 0.117 | 0.100 | 0.068 | 0.117 |
| 225 | 0.014 | 0.028 | 0.047 | 0.055 | 0.052 | 0.058 | 0.067 | 0.074 | 0.100 | 0.089 | 0.062 | 0.100 |
| 275 | 0.013 | 0.025 | 0.042 | 0.039 | 0.042 | 0.047 | 0.041 | 0.043 | 0.067 | 0.058 | 0.046 | 0.067 |
| 325 | 0.013 | 0.022 | 0.043 | 0.039 | 0.046 | 0.050 | 0.050 | 0.045 | 0.062 | 0.067 | 0.054 | 0.067 |
| 375 | 0.013 | 0.026 | 0.046 | 0.041 | 0.043 | 0.061 | 0.068 | 0.065 | 0.063 | 0.047 | 0.069 | 0.069 |
| 425 | 0.012 | 0.028 | 0.041 | 0.040 | 0.040 | 0.051 | 0.062 | 0.067 | 0.061 | 0.045 | 0.061 | 0.067 |
| 475 | 0.012 | 0.028 | 0.038 | 0.044 | 0.049 | 0.050 | 0.052 | 0.067 | 0.079 | 0.072 | 0.051 | 0.079 |
| 525 | 0.012 | 0.027 | 0.032 | 0.038 | 0.042 | 0.046 | 0.043 | 0.055 | 0.070 | 0.059 | 0.050 | 0.070 |
| 575 | 0.011 | 0.026 | 0.034 | 0.033 | 0.042 | 0.055 | 0.056 | 0.043 | 0.057 | 0.064 | 0.062 | 0.064 |
| 625 | 0.011 | 0.022 | 0.030 | 0.031 | 0.035 | 0.044 | 0.049 | 0.041 | 0.047 | 0.053 | 0.051 | 0.053 |
| 675 | 0.011 | 0.021 | 0.030 | 0.033 | 0.032 | 0.040 | 0.054 | 0.051 | 0.050 | 0.039 | 0.046 | 0.054 |
| 725 | 0.012 | 0.020 | 0.029 | 0.030 | 0.031 | 0.034 | 0.042 | 0.047 | 0.047 | 0.037 | 0.040 | 0.047 |
| 775 | 0.011 | 0.020 | 0.026 | 0.028 | 0.033 | 0.037 | 0.039 | 0.043 | 0.051 | 0.048 | 0.045 | 0.051 |
| 825 | 0.011 | 0.021 | 0.025 | 0.025 | 0.029 | 0.035 | 0.032 | 0.035 | 0.043 | 0.039 | 0.039 | 0.043 |
| 875 | 0.011 | 0.023 | 0.023 | 0.023 | 0.028 | 0.030 | 0.034 | 0.034 | 0.036 | 0.042 | 0.037 | 0.042 |
| 925 | 0.013 | 0.019 | 0.022 | 0.022 | 0.025 | 0.029 | 0.029 | 0.033 | 0.033 | 0.037 | 0.034 | 0.037 |
| 975 | 0.014 | 0.020 | 0.022 | 0.022 | 0.025 | 0.029 | 0.027 | 0.033 | 0.036 | 0.029 | 0.035 | 0.036 |
| 1025 | 0.011 | 0.016 | 0.019 | 0.019 | 0.022 | 0.026 | 0.025 | 0.028 | 0.033 | 0.028 | 0.030 | 0.033 |
| 1075 | 0.013 | 0.018 | 0.020 | 0.021 | 0.023 | 0.027 | 0.027 | 0.024 | 0.034 | 0.032 | 0.027 | 0.034 |
| 1125 | 0.010 | 0.015 | 0.018 | 0.017 | 0.021 | 0.024 | 0.024 | 0.022 | 0.029 | 0.028 | 0.025 | 0.029 |
| 1175 | 0.010 | 0.015 | 0.017 | 0.017 | 0.020 | 0.021 | 0.021 | 0.021 | 0.023 | 0.031 | 0.024 | 0.031 |
| 1225 | 0.011 | 0.016 | 0.017 | 0.018 | 0.021 | 0.021 | 0.021 | 0.025 | 0.024 | 0.027 | 0.027 | 0.027 |
| 1275 | 0.010 | 0.014 | 0.015 | 0.016 | 0.017 | 0.019 | 0.020 | 0.023 | 0.023 | 0.021 | 0.026 | 0.026 |
| 1325 | 0.010 | 0.014 | 0.015 | 0.016 | 0.017 | 0.019 | 0.021 | 0.021 | 0.025 | 0.022 | 0.025 | 0.025 |
| 1375 | 0.010 | 0.013 | 0.014 | 0.014 | 0.016 | 0.017 | 0.019 | 0.018 | 0.021 | 0.020 | 0.022 | 0.022 |
| 1425 | 0.010 | 0.013 | 0.014 | 0.015 | 0.016 | 0.017 | 0.019 | 0.020 | 0.022 | 0.021 | 0.022 | 0.022 |
| 1475 | 0.009 | 0.013 | 0.013 | 0.014 | 0.015 | 0.016 | 0.016 | 0.019 | 0.018 | 0.019 | 0.018 | 0.019 |
| 1525 | 0.009 | 0.012 | 0.013 | 0.014 | 0.015 | 0.016 | 0.016 | 0.019 | 0.020 | 0.020 | 0.019 | 0.020 |
| 1575 | 0.009 | 0.012 | 0.012 | 0.013 | 0.014 | 0.015 | 0.015 | 0.017 | 0.020 | 0.017 | 0.016 | 0.020 |
| 1625 | 0.010 | 0.012 | 0.012 | 0.013 | 0.014 | 0.016 | 0.016 | 0.017 | 0.020 | 0.018 | 0.018 | 0.020 |
| 1675 | 0.011 | 0.013 | 0.013 | 0.013 | 0.014 | 0.015 | 0.015 | 0.017 | 0.018 | 0.016 | 0.017 | 0.018 |
| 1725 | 0.010 | 0.012 | 0.012 | 0.013 | 0.013 | 0.014 | 0.014 | 0.017 | 0.017 | 0.017 | 0.017 | 0.017 |
| 1775 | 0.011 | 0.013 | 0.012 | 0.013 | 0.013 | 0.014 | 0.015 | 0.016 | 0.016 | 0.018 | 0.016 | 0.018 |
| 1825 | 0.010 | 0.011 | 0.012 | 0.012 | 0.013 | 0.014 | 0.014 | 0.015 | 0.016 | 0.016 | 0.016 | 0.016 |
| 1875 | 0.009 | 0.011 | 0.011 | 0.011 | 0.012 | 0.013 | 0.013 | 0.014 | 0.016 | 0.016 | 0.016 | 0.016 |
| 1925 | 0.010 | 0.011 | 0.012 | 0.012 | 0.014 | 0.014 | 0.014 | 0.015 | 0.017 | 0.017 | 0.016 | 0.017 |
| 1975 | 0.010 | 0.011 | 0.012 | 0.011 | 0.012 | 0.013 | 0.013 | 0.014 | 0.015 | 0.015 | 0.014 | 0.015 |

**Inter-Harmonics Current**



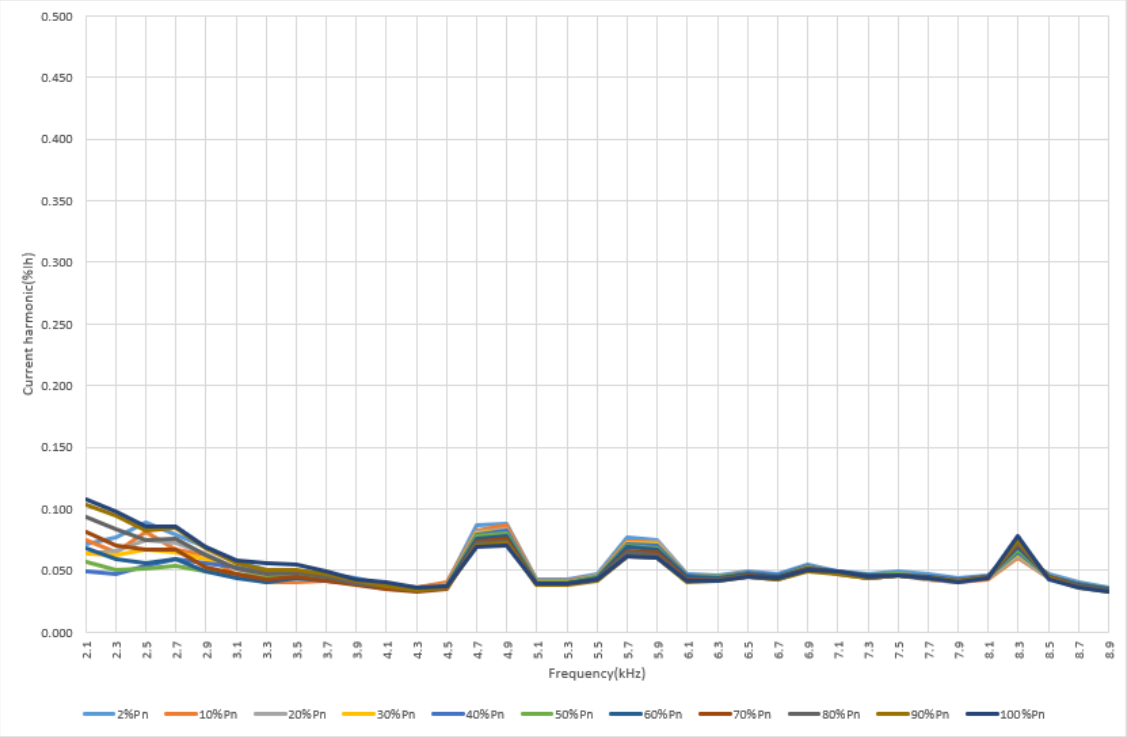
#### 4.2.3.4 Higher frequency components

Test performed according to point 8.2 of the standard.

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

| $P_{bin}$ (%) | 2 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | MAX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F [kHz] | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | $I_h$(%) | (%) |
| **2.1** | 0.071 | 0.075 | 0.063 | 0.063 | 0.049 | 0.057 | 0.068 | 0.081 | 0.093 | 0.103 | 0.108 | 0.108 |
| **2.3** | 0.076 | 0.065 | 0.065 | 0.062 | 0.048 | 0.051 | 0.060 | 0.070 | 0.083 | 0.094 | 0.098 | 0.098 |
| **2.5** | 0.089 | 0.081 | 0.075 | 0.067 | 0.054 | 0.052 | 0.056 | 0.067 | 0.075 | 0.083 | 0.086 | 0.089 |
| **2.7** | 0.080 | 0.067 | 0.073 | 0.065 | 0.059 | 0.053 | 0.059 | 0.067 | 0.076 | 0.085 | 0.085 | 0.085 |
| **2.9** | 0.069 | 0.062 | 0.064 | 0.059 | 0.056 | 0.050 | 0.049 | 0.053 | 0.062 | 0.068 | 0.069 | 0.069 |
| **3.1** | 0.058 | 0.046 | 0.051 | 0.052 | 0.053 | 0.047 | 0.044 | 0.047 | 0.051 | 0.056 | 0.058 | 0.058 |
| **3.3** | 0.050 | 0.040 | 0.045 | 0.046 | 0.048 | 0.044 | 0.041 | 0.043 | 0.047 | 0.050 | 0.056 | 0.056 |
| **3.5** | 0.048 | 0.041 | 0.043 | 0.045 | 0.047 | 0.045 | 0.044 | 0.044 | 0.048 | 0.051 | 0.055 | 0.055 |
| **3.7** | 0.047 | 0.041 | 0.043 | 0.044 | 0.047 | 0.044 | 0.042 | 0.042 | 0.045 | 0.047 | 0.050 | 0.050 |
| **3.9** | 0.044 | 0.040 | 0.040 | 0.040 | 0.041 | 0.041 | 0.040 | 0.039 | 0.040 | 0.041 | 0.043 | 0.044 |
| **4.1** | 0.038 | 0.037 | 0.035 | 0.036 | 0.038 | 0.036 | 0.036 | 0.035 | 0.037 | 0.038 | 0.040 | 0.040 |
| **4.3** | 0.036 | 0.036 | 0.033 | 0.034 | 0.034 | 0.034 | 0.033 | 0.033 | 0.034 | 0.034 | 0.036 | 0.036 |
| **4.5** | 0.040 | 0.041 | 0.038 | 0.037 | 0.037 | 0.037 | 0.037 | 0.036 | 0.036 | 0.036 | 0.037 | 0.041 |
| **4.7** | 0.086 | 0.083 | 0.081 | 0.080 | 0.079 | 0.078 | 0.076 | 0.074 | 0.073 | 0.070 | 0.069 | 0.086 |
| **4.9** | 0.088 | 0.087 | 0.084 | 0.082 | 0.082 | 0.080 | 0.078 | 0.076 | 0.074 | 0.072 | 0.070 | 0.088 |
| **5.1** | 0.043 | 0.042 | 0.041 | 0.040 | 0.041 | 0.040 | 0.040 | 0.039 | 0.039 | 0.038 | 0.040 | 0.043 |
| **5.3** | 0.042 | 0.041 | 0.041 | 0.041 | 0.041 | 0.040 | 0.040 | 0.039 | 0.039 | 0.038 | 0.040 | 0.042 |
| **5.5** | 0.047 | 0.046 | 0.046 | 0.045 | 0.045 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.043 | 0.047 |
| **5.7** | 0.077 | 0.073 | 0.072 | 0.073 | 0.071 | 0.070 | 0.069 | 0.066 | 0.065 | 0.061 | 0.061 | 0.077 |
| **5.9** | 0.075 | 0.073 | 0.074 | 0.071 | 0.071 | 0.069 | 0.067 | 0.065 | 0.063 | 0.060 | 0.060 | 0.075 |
| **6.1** | 0.047 | 0.046 | 0.046 | 0.046 | 0.046 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.042 | 0.047 |
| **6.3** | 0.047 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.042 | 0.047 |
| **6.5** | 0.049 | 0.048 | 0.048 | 0.048 | 0.049 | 0.047 | 0.047 | 0.046 | 0.045 | 0.044 | 0.045 | 0.049 |
| **6.7** | 0.047 | 0.045 | 0.045 | 0.045 | 0.046 | 0.045 | 0.045 | 0.044 | 0.043 | 0.042 | 0.044 | 0.047 |
| **6.9** | 0.055 | 0.053 | 0.053 | 0.053 | 0.053 | 0.053 | 0.052 | 0.051 | 0.051 | 0.050 | 0.050 | 0.055 |
| **7.1** | 0.049 | 0.047 | 0.047 | 0.048 | 0.048 | 0.048 | 0.049 | 0.048 | 0.048 | 0.048 | 0.049 | 0.049 |
| **7.3** | 0.047 | 0.044 | 0.044 | 0.045 | 0.046 | 0.046 | 0.046 | 0.045 | 0.044 | 0.044 | 0.045 | 0.047 |
| **7.5** | 0.049 | 0.046 | 0.046 | 0.047 | 0.047 | 0.047 | 0.046 | 0.046 | 0.046 | 0.046 | 0.046 | 0.049 |
| **7.7** | 0.047 | 0.043 | 0.043 | 0.044 | 0.045 | 0.044 | 0.044 | 0.044 | 0.044 | 0.043 | 0.044 | 0.047 |
| **7.9** | 0.044 | 0.041 | 0.041 | 0.042 | 0.042 | 0.042 | 0.042 | 0.042 | 0.041 | 0.041 | 0.041 | 0.044 |
| **8.1** | 0.046 | 0.043 | 0.043 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.044 | 0.044 | 0.046 |
| **8.3** | 0.062 | 0.060 | 0.062 | 0.064 | 0.065 | 0.067 | 0.069 | 0.071 | 0.073 | 0.074 | 0.078 | 0.078 |
| **8.5** | 0.047 | 0.044 | 0.044 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.044 | 0.044 | 0.043 | 0.047 |
| **8.7** | 0.041 | 0.038 | 0.038 | 0.039 | 0.039 | 0.038 | 0.038 | 0.037 | 0.037 | 0.036 | 0.037 | 0.041 |
| **8.9** | 0.037 | 0.034 | 0.034 | 0.035 | 0.036 | 0.035 | 0.035 | 0.034 | 0.034 | 0.033 | 0.033 | 0.037 |

## Current high frequency harmonics



### 4.2.4 Unbalances

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

Requirements according to point 8.2.5 of the standard.

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

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

It is not applicable because the EUT is single phase output inverter.

### 4.3 INTEGRATED AUTOMATIC SEPARATION SYSTEM

These tests have been done according to chapter D.3 of the standard. The aim is to verify the protection settings of the EUT for both voltage and frequency.

It has been tested, for both frequency and voltage, two different protection stages for both undervoltage/underfrequency and overvoltage/overfrequency.

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

The standard present for each protection stage a defined threshold as well as an operation time response. These configurations are:

| **Function** | **Trip setting** |
|---|---|
| Overvoltage 10 min mean | 230 V + 10 %<br>no delay* |
| Overvoltage | 230 V +15 %<br>no delay* |
| Undervoltage | 230 V -20 %<br>no delay* |
| Overfrequency | 51,5 Hz<br>no delay* |
| Underfrequency | 47,5 Hz<br>no delay* |
| LoM | according to EN 62116 |
| ** « No delay » means that no time delay is added to the intrinsic technical duration required to initiate the disconnection. The operate time may not exceed 200ms.* | |

The compliances with the requirements of clause D.3 of the standard is stated in section 4.6 of following test report:

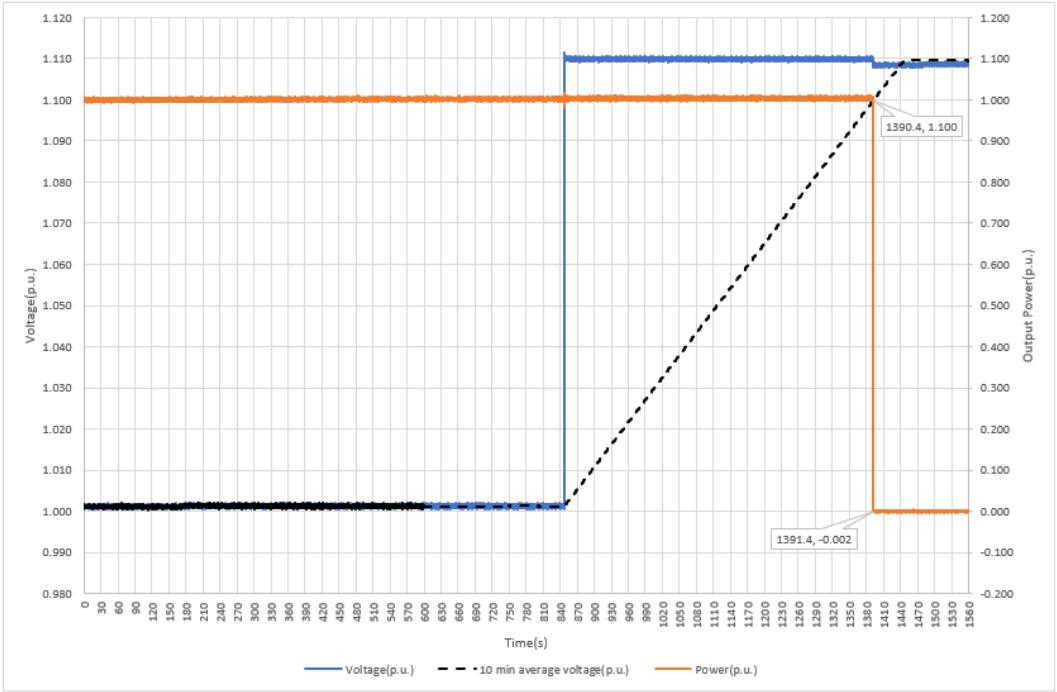
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/12/30, 2021/1/5, 2021/1/15, | 100ms values | 10kHz |

### 4.3.1 Overvoltage 10 min mean Test

| Test Item | Setting Value | Measured Value | Setting disconnect time | Measured disconnect time |
| --- | --- | --- | --- | --- |
| Overvoltage 10 min mean | 253.0 V | 253.0 V | 1 s | 1.000 s |

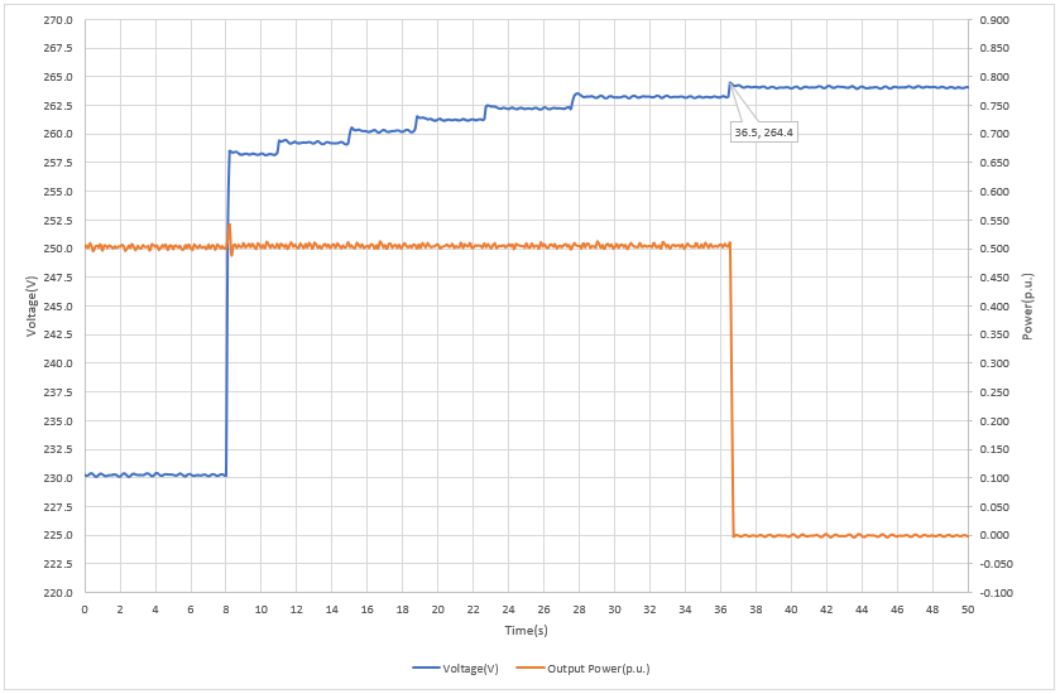
**Test of Overvoltage 10min mean**



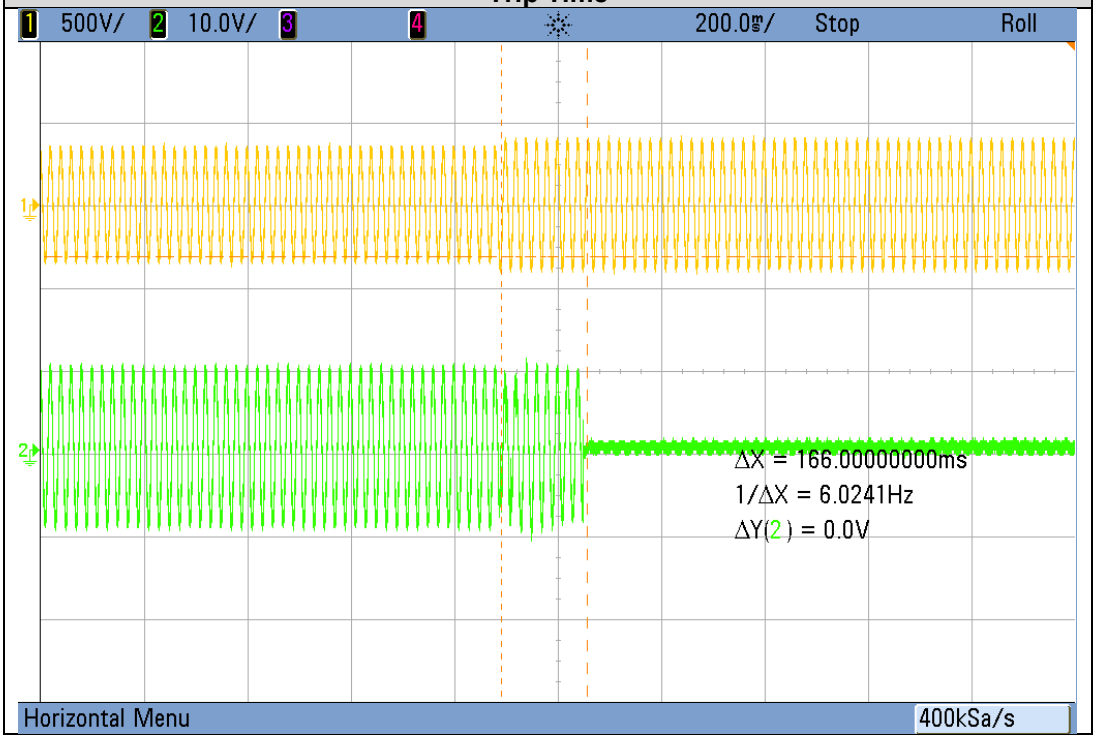
### 4.3.2 Overvoltage Test

| Test Item | Setting Value | Measured Value | Measured disconnect time | Limited Disconnect time |
|---|---|---|---|---|
| Overvoltage | 264.5 V | 264.4 V | 166 ms | 200 ms |

**Trip Voltage**



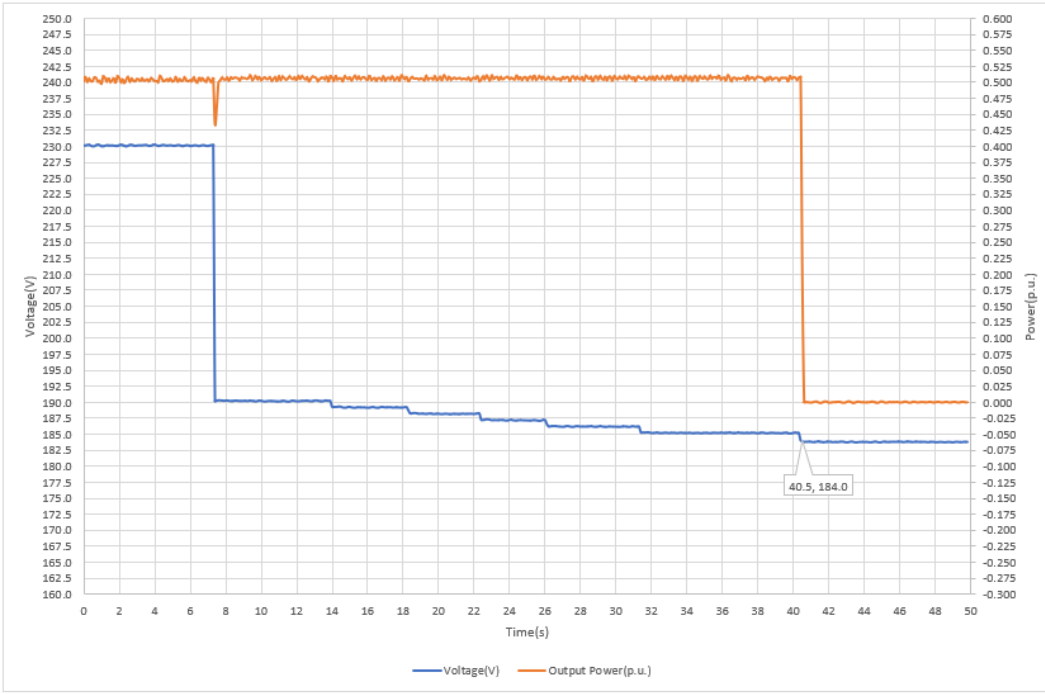

**Trip Time**



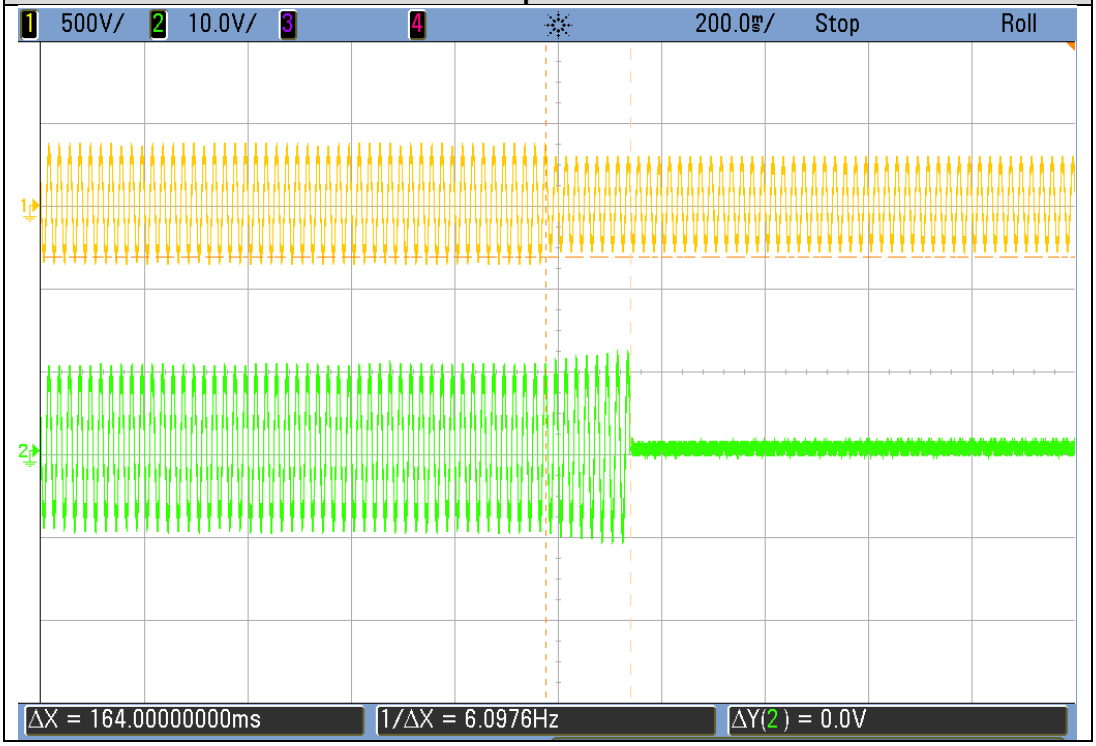
### 4.3.3 Undervoltage Test

| Test Item | Setting Value | Measured Value | Measured disconnect time | Limited Disconnect time |
|---|---|---|---|---|
| Undervoltage | 184.0 V | 184.0 V | 164 ms | 200 ms |

**Trip Voltage**



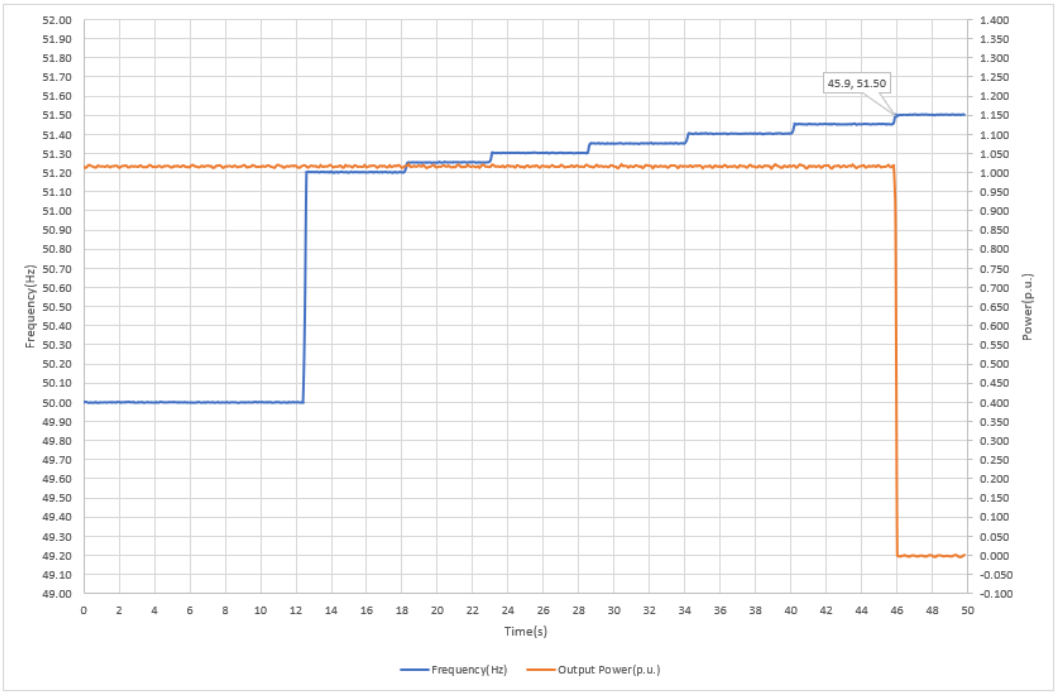

**Trip Time**



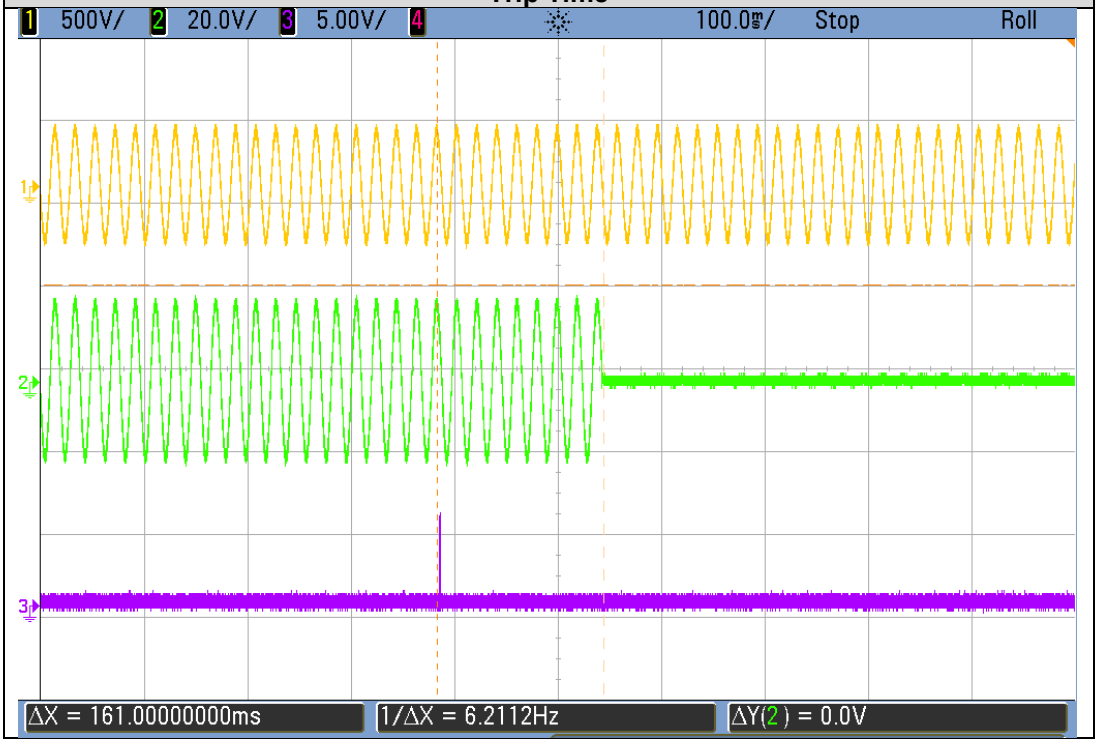
### 4.3.4 Overfrequency Test

| Test Item | Setting Value | Measured Value | Measured disconnect time | Limited Disconnect time |
|---|---|---|---|---|
| Overfrequency | 51.50 Hz | 51.50 Hz | 161 ms | 200 ms |

**Trip Voltage**



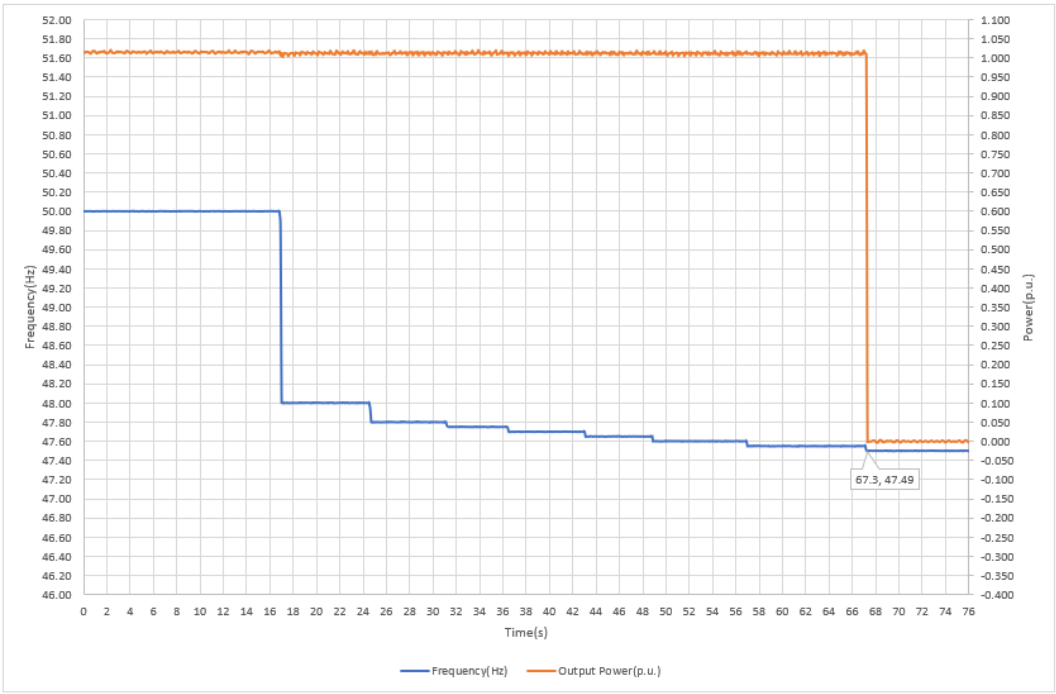

**Trip Time**



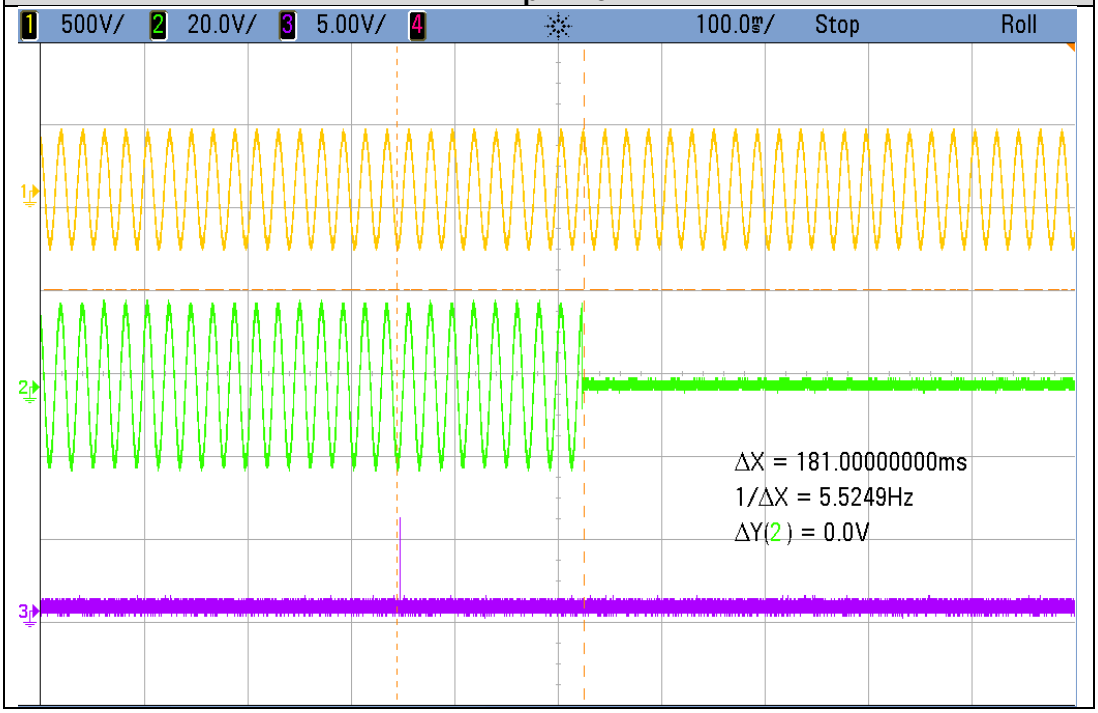
### 4.3.5 Underfrequency Test

| Test Item | Setting Value | Measured Value | Measured disconnect time | Limited Disconnect time |
|---|---|---|---|---|
| Overfrequency | 47.50 Hz | 47.49 Hz | 181 ms | 200 ms |

**Trip Voltage**




**Trip Time**



### 4.3.6 LoM Test

The test has been done according to EN 62116 of the standard. Test A is at full power, Test B is at 66 %Pn, Test C is at 33 %Pn.

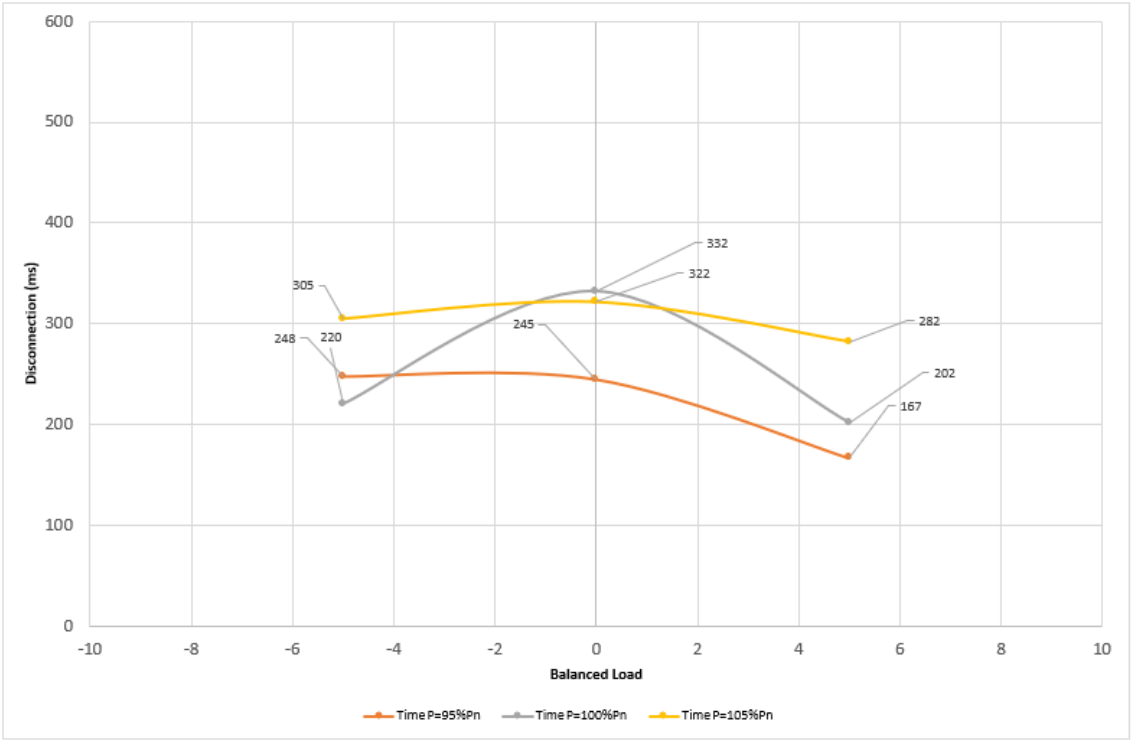
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/5 | 100ms values | 10kHz |
| DS05014A | 2021/1/5 | -- | 100kHz |

#### 4.3.6.1 Active Power > 90 %Pn. Test A

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

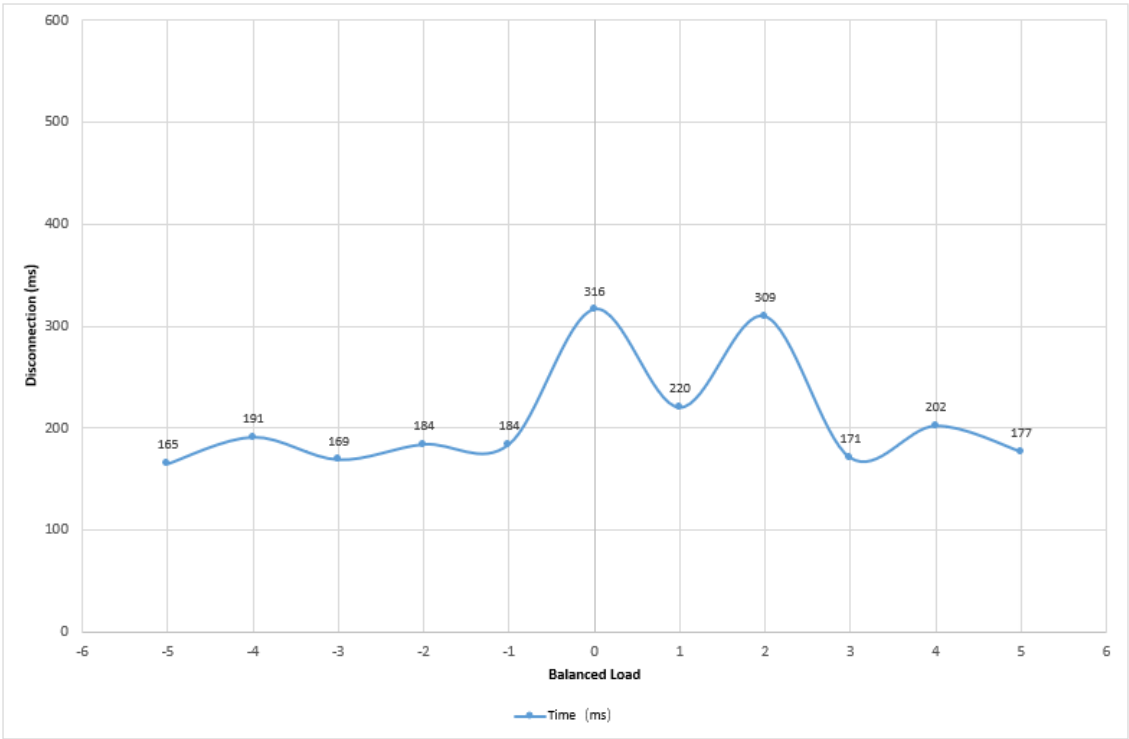
**Curve for Test A**



#### 4.3.6.2 Active Power 50-66 %Pn. Test B

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

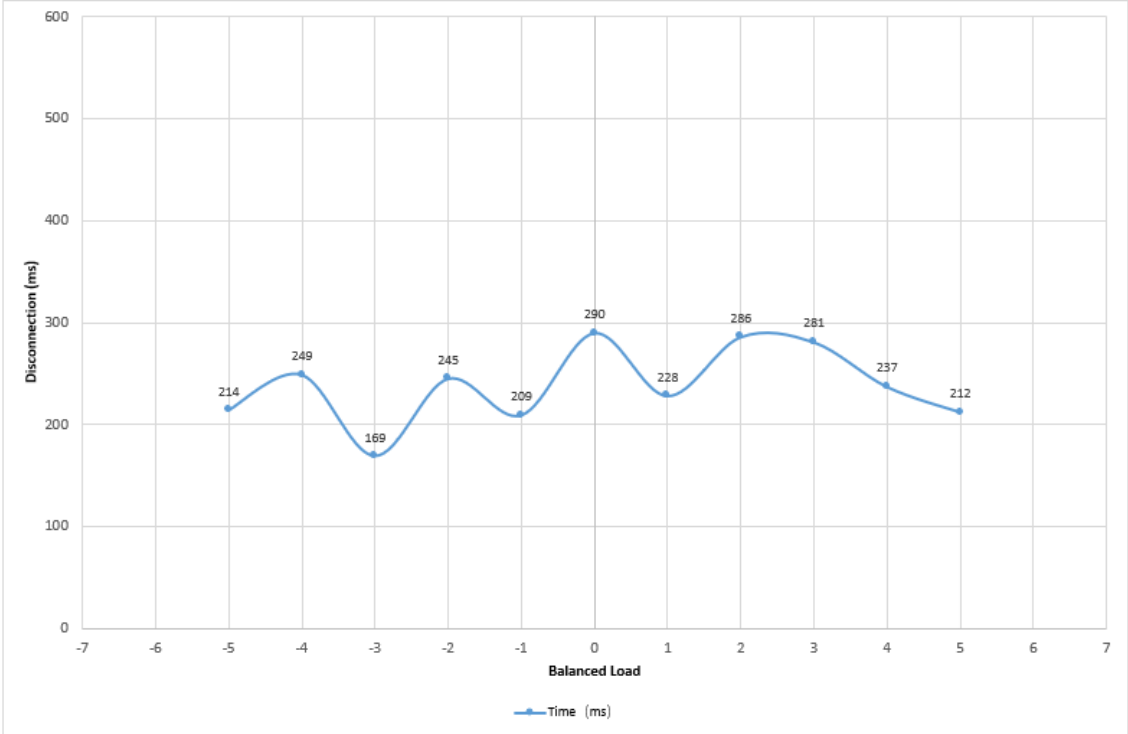
**Curve for Test B**



#### 4.3.6.3 Active Power 25-33 %Pn. Test C

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

**Curve for Test C**



## 4.4 OPERATING RANGES

### 4.4.1 Operating frequency range and Maximum admissible power reduction in case of underfrequency

This test has been done according to chapter D.4.1 of the standard. The aim of the test is to verify if the EUT is capable of operating at different frequency ranges without disconnection and power reduction for the amount of time.
According to the standard, the capability of the power-generating unit to operate in the frequency range from 51.5 Hz and 52.5 Hz and, where appropriate, the maximum duration of operation in this frequency range. The additional test performed to verify the capability to work at 52.5Hz.
Note: protective functions for disconnection due to abnormal frequency variations were disabled for the performance of this test.

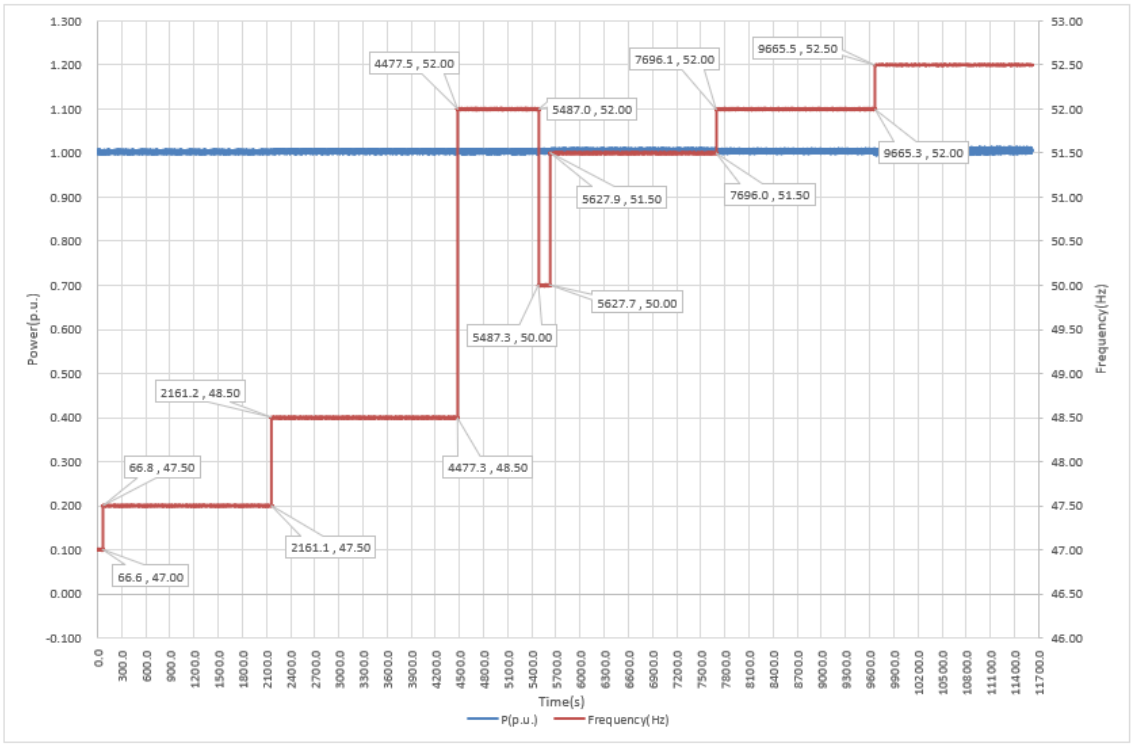
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/12/30, 2021/1/16 | 100ms values | 10kHz |

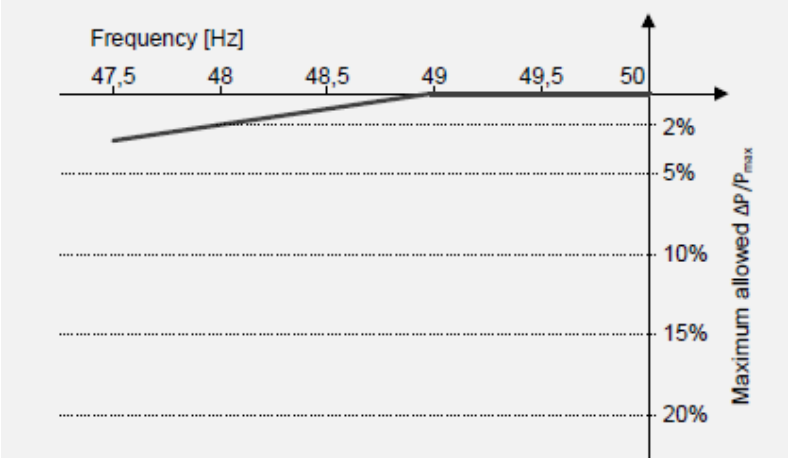
Test result and graph as following:

| Steps | f (Hz) setting | Time requirement | f Measured (Hz) | Time measured (min) | Power measured (p.u.) |
|---|---|---|---|---|---|
| 1 | 47.0 | > 30 s | 47.00 | 1.1 | 1.003 |
| 2 | 47.5 | > 30 min | 47.50 | 34.9 | 1.003 |
| 3 | 48.5 | > 30 min | 48.50 | 38.6 | 1.004 |
| 4 | 52.0 | > 15 min | 52.00 | 16.8 | 1.004 |
| 5 | 50.0 | > 1 min | 50.00 | 2.3 | 1.004 |
| 6 | 51.5 | > 30 min | 51.50 | 34.5 | 1.005 |
| 7 | 52.0 | > 30 min | 52.00 | 32.8 | 1.005 |
| 8 | 52.5 | > 30 min | 52.50 | 32.5 | 1.004 |

**Operating frequency range**



For frequencies below 49.0 Hz, according to chapter D.4.2 of the standard, the EUT shall be capable of keeping its active power output constant and not lower than the following characteristic:



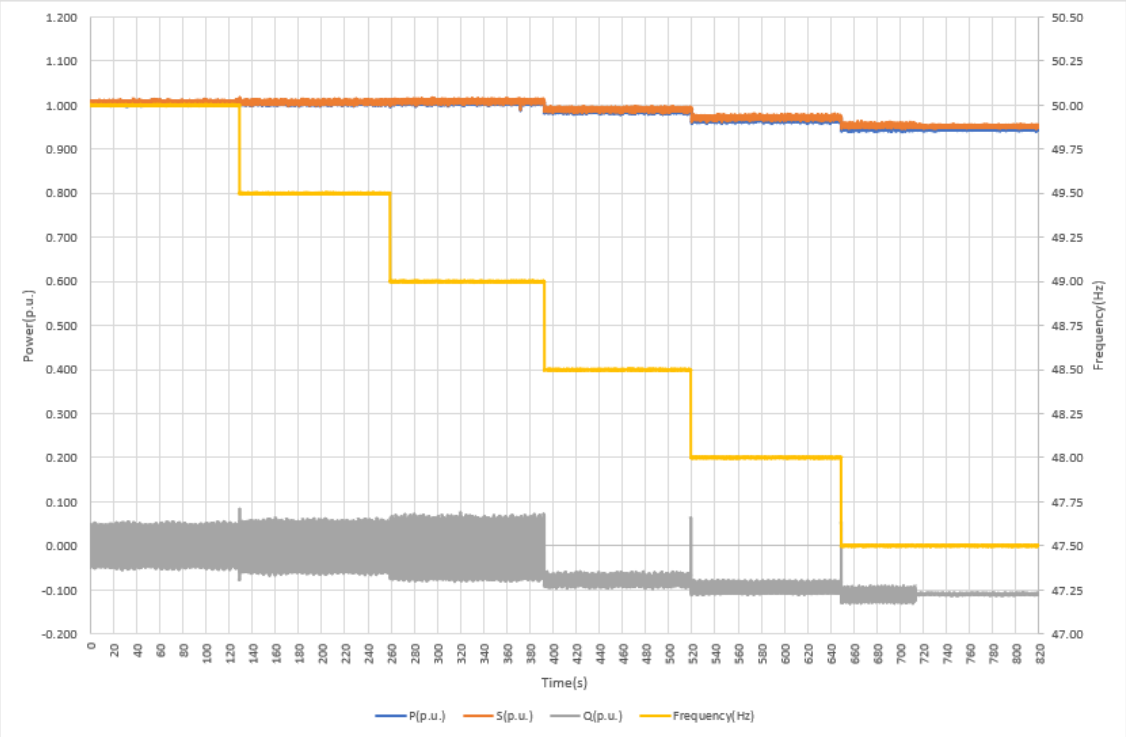

According to the standard, following test will perform to verify it.

| Parameter | Value |
|---|---|
| Frequency threshold | 49 Hz |
| Slope | 2 %/Hz |

Test results are presented in the following table and graphs:

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

**Maximum admissible power reduction in case of underfrequency**



### 4.4.2 Continuous operating voltage range

This test has been done according to chapter D.4.3 of the standard. The aim of the test is to verify that the EUT is capable of operating continuously when the voltage stays inside of following ranges:

- For LV connections: Inside of the range of 85-110%Un.
- For HV connections: Inside of the range of 90-110%Un.

For voltages below 95%Un, it is allowed to reduce apparent power to maintain the current limits of the generating plant. This reduction shall be as small as technically possible.

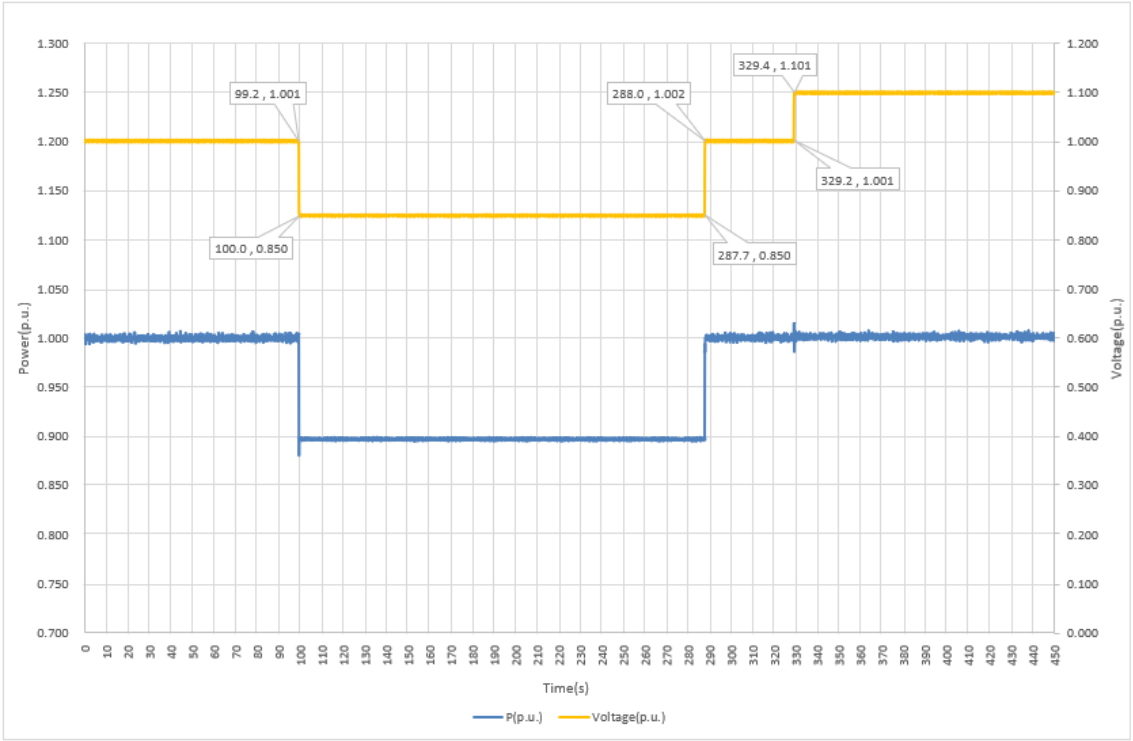
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/12/31 | 100ms values | 10kHz |

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

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

**Continuous operating voltage range**

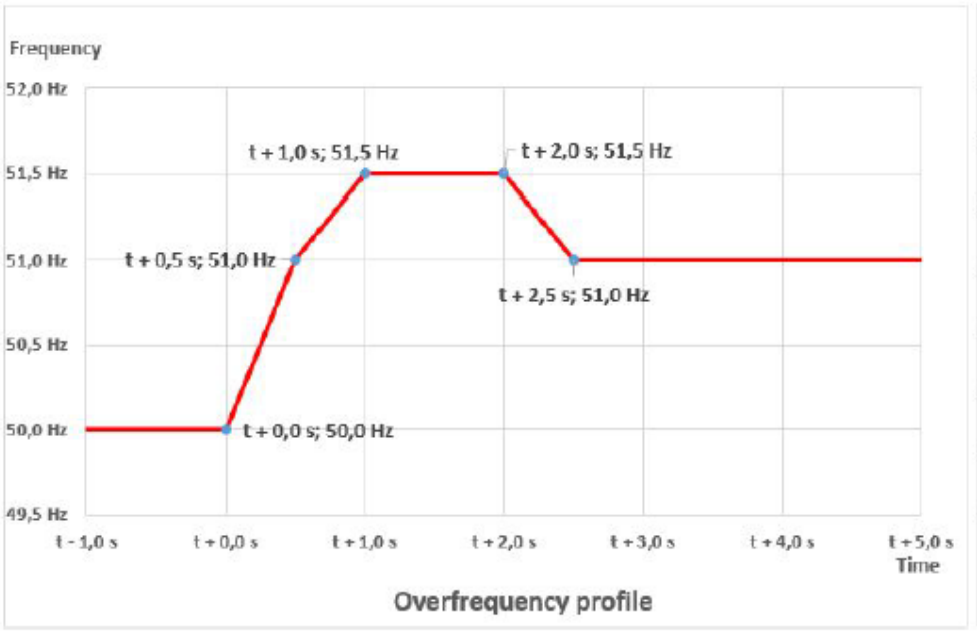


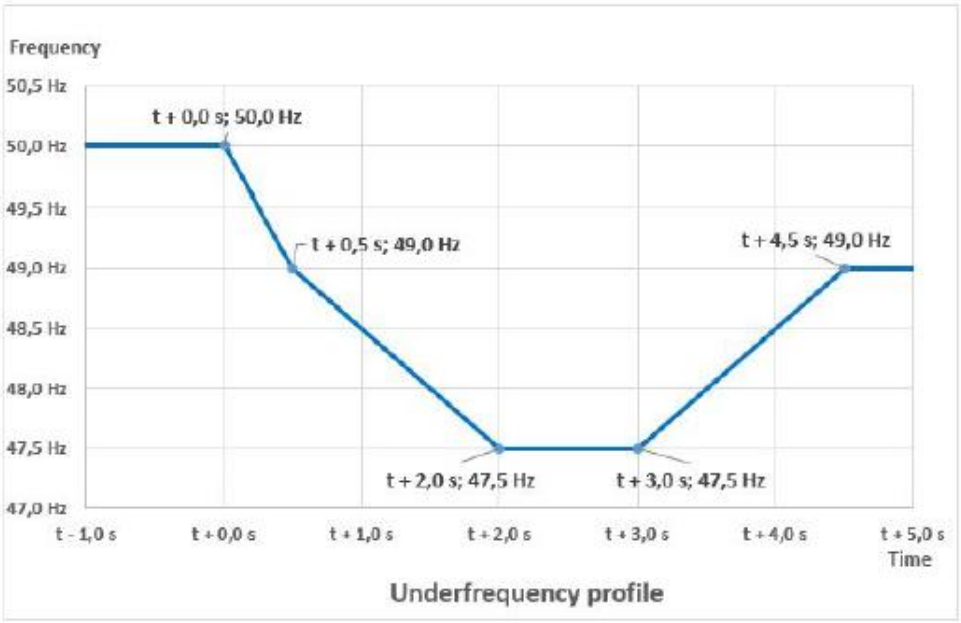
## 4.5 INMUNITY TO DISTURBANCE

### 4.5.1 RoCoF inmunity

This test has been done according to chapter D.5.1 of the standard. The aim of the test is to verify if the EUT is capable of operating without disconnection when submitted to frequency jumps.

The test has been done according following graphs.



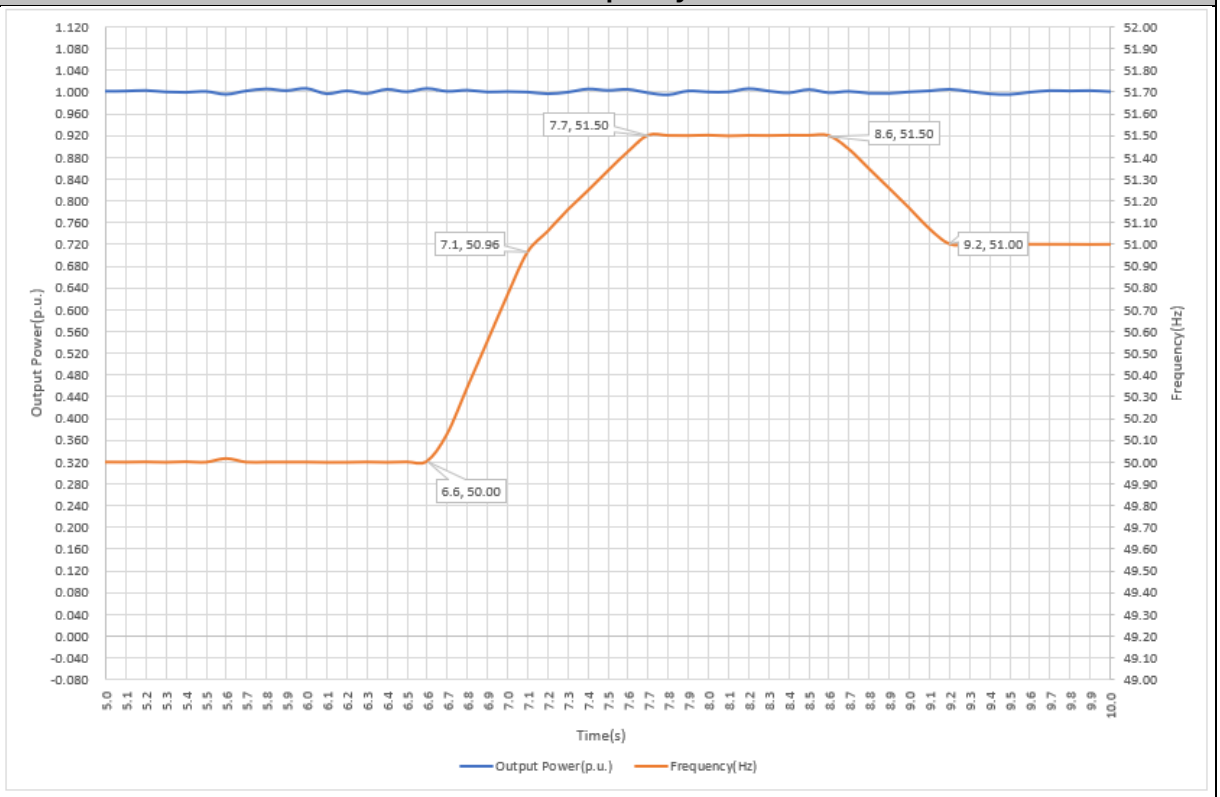

Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/12/31 | 100ms values | 10kHz |

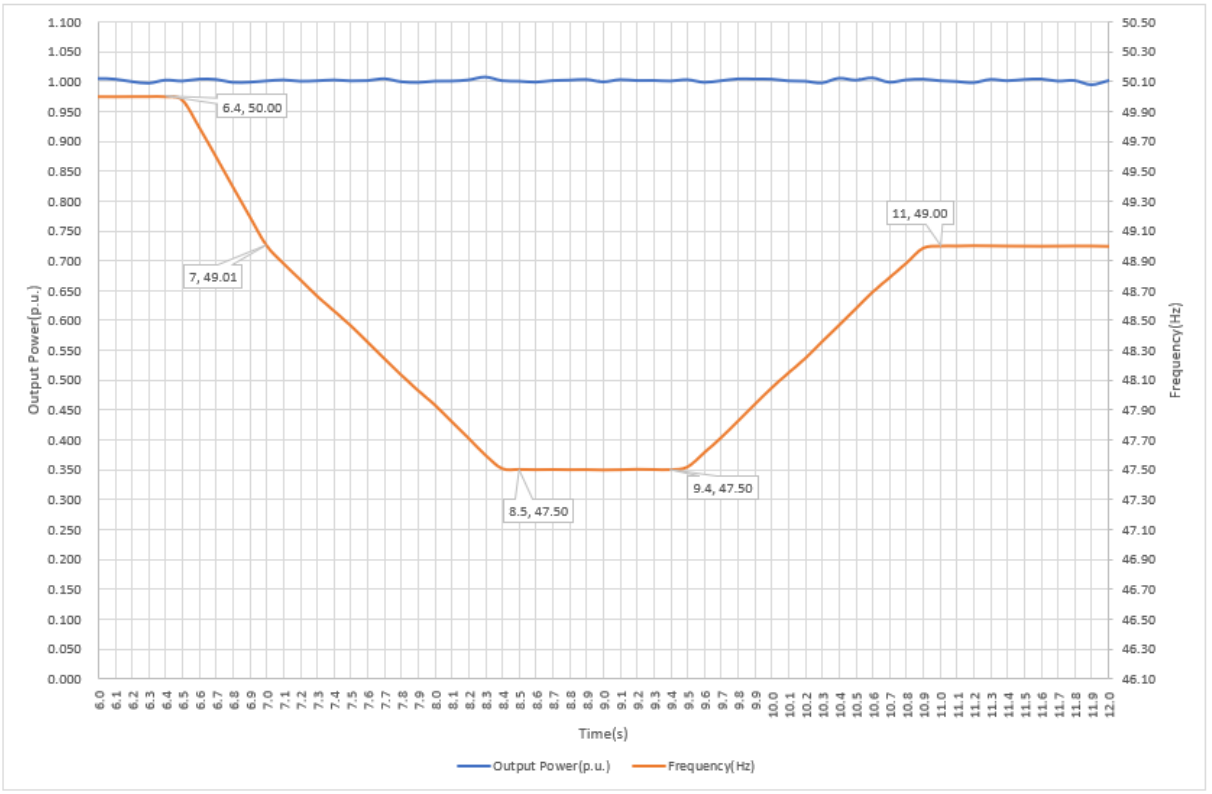
Results are presented in the following table and graphs:

| | Ramp range desired | Time Setting (s) | Time Measeured (s) | Final Value (Hz) | Ramp (Hz/s) | Disconnection |
|---|---|---|---|---|---|---|
| Positive frequency drift | 50.0 Hz | 0 | -- | -- | -- | ☒ NO ☐ YES |
| | 50.0Hz to 51.0Hz | 0.5 | 0.5 | 50.98 | 1.960 | ☒ NO ☐ YES |
| | 50.0Hz to 51.0Hz | 0.5 | 0.5 | 50.96 | 1.920 | ☒ NO ☐ YES |
| | 51.5Hz | 1.0 | 0.9 | 51.50 | 0.000 | ☒ NO ☐ YES |
| | 51.0Hz to 51.5Hz | 0.5 | 0.6 | 51.50 | 0.833 | ☒ NO ☐ YES |
| Negative frequency drift | 50.0 Hz | 0 | -- | 50 | -- | ☒ NO ☐ YES |
| | 50.0Hz to 49.0Hz | 0.5 | 0.6 | 48.95 | -1.750 | ☒ NO ☐ YES |
| | 49.0Hz to 47.5Hz | 0.5 | 0.6 | 49.01 | -1.650 | ☒ NO ☐ YES |
| | 47.5 Hz | 1.0 | 0.9 | 47.50 | 0.000 | ☒ NO ☐ YES |
| | 47.5Hz to 49.0Hz | 1.5 | 1.5 | 47.50 | -1.007 | ☒ NO ☐ YES |

**Positive frequency drift**



**Negative frequency drift**



### 4.5.2 Voltage ride through (UVRT/OVRT)

These tests have been required according to chapters D.5.2 and D.5.3 of the standard. The aim is to determine whether the EUT is capable of detecting a grid fault and riding through it without disconnecting.

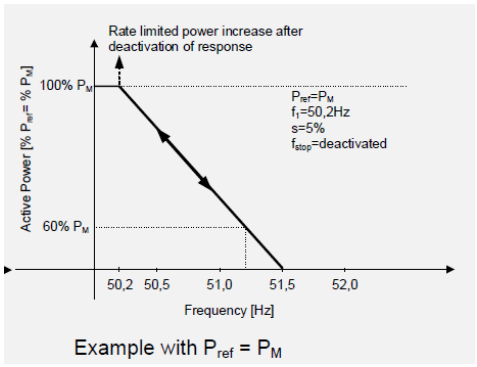
It is not applicable due to the EUT is type A in accordance with NC RfG, which is not goint to connection to the plant above 1MW.

## 4.6 ACTIVE RESPONSE TO FREQUENCY DEVIATIONS

### 4.6.1 Power response to overfrequency

This test has been done according to chapter D.6.1 of the standard in order to verify the capability of the EUT of activating power response to overfrequency.

For this automatic response function, an initial delay of less than 2 seconds, between the intentional and the intrinsic delay, shall be configured. This function shall activate once frequency rises over a frequency threshold configurable between 50.2-52.0 Hz Hz. Once activated, this function shall be capable of reducing active power with a configurable droop in a range of 2-12%.



Example with $P_{ref} = P_M$

For every step of power decrease (grid frequency increase), an active power rise time of maximum 10s is to be observed for 50 % Pmax. Maximum settling time shall be a maximum of 30 s.

For every step of power increase (grid frequency decrease), an active power rise time of maximum 2s is to be observed for 50 % Pmax. Maximum settling time shall be a maximum of 20 s.

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

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

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

Note: Threshold for discconnection overfrequency protection is set at 52.0 Hz at each test items.

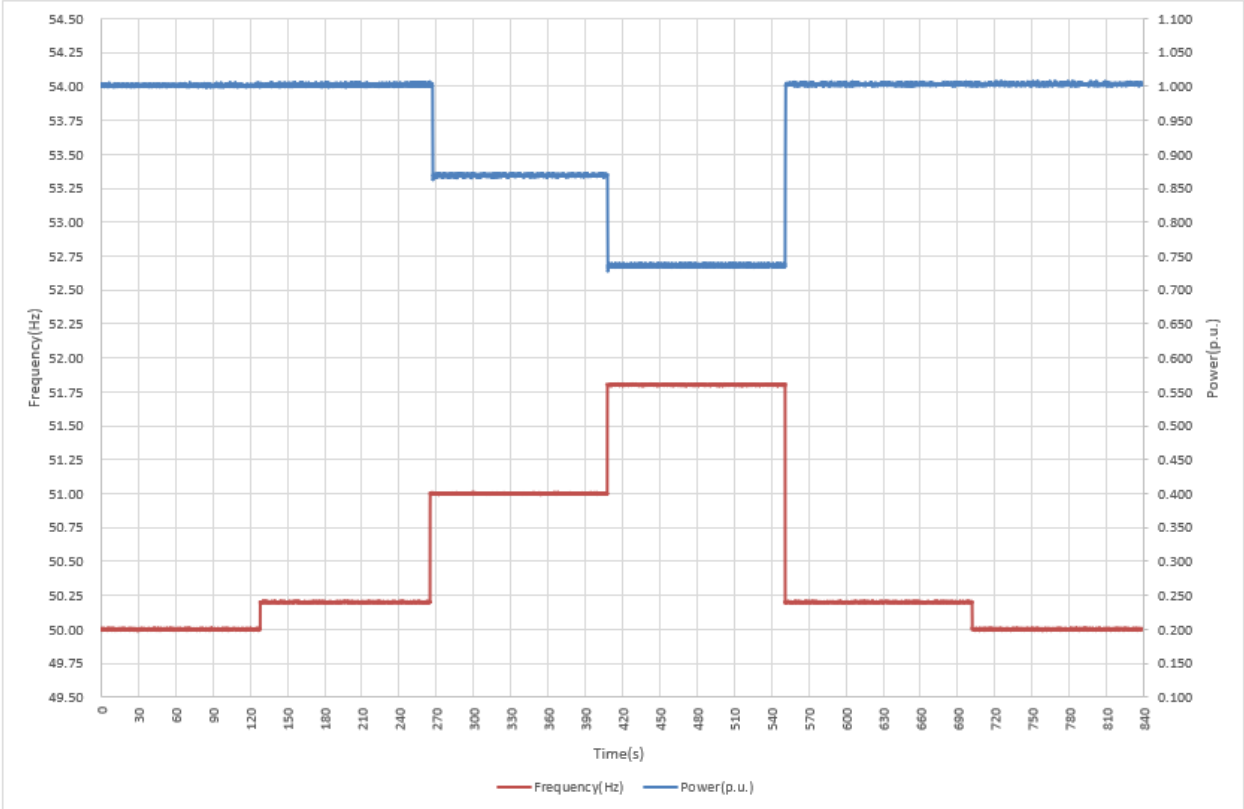
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/2/18 | 100ms values | 10kHz |

Test results are offered at the table below:

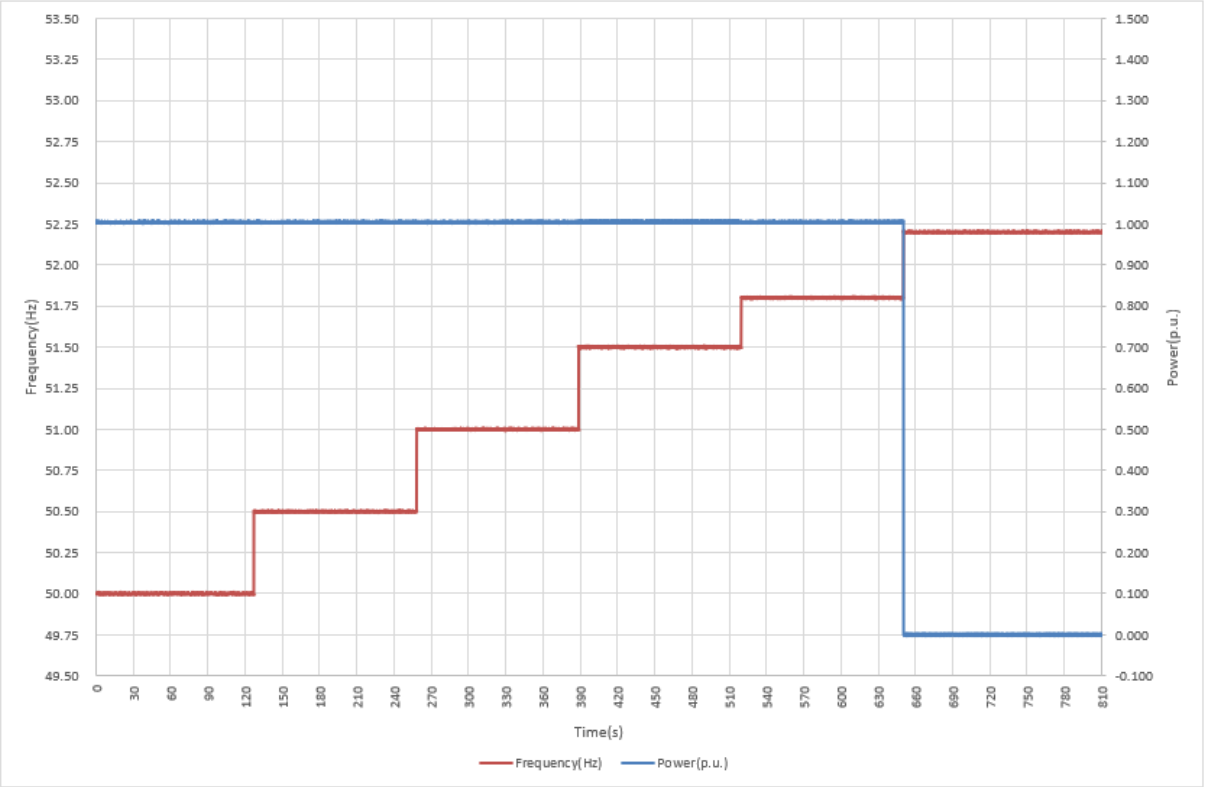
| Test 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step | f (Hz) | P desired (%Pn) | Frequency meas. (Hz) | P meas. (%Pn) | P deviation (%Pn) (Within ± 10 %) | Step response time Tsr(s) | Settling time Ts(s) |
| 1 | 50.00 ± 0.05 Hz | 100.0 | 50.00 | 100.1 | 0.1 | -- | -- |
| 2 | 50.20 ± 0.05 Hz | 100.0 | 50.20 | 100.2 | 0.2 | 0.1 | 0.1 |
| 3 | 51.00 ± 0.05 Hz | 86.7 | 51.00 | 86.9 | 0.2 | 2.2 | 2.2 |
| 4 | 51.80 ± 0.05 Hz | 73.3 | 51.80 | 73.6 | 0.3 | 0.4 | 0.4 |
| 5 | 50.20 ± 0.05 Hz | 100.0 | 50.20 | 100.3 | 0.3 | 0.4 | 0.4 |
| 6 | 50.00 ± 0.05 Hz | 100.0 | 50.00 | 100.3 | 0.3 | 0.2 | 0.2 |

**P vs f chart for Test 1**



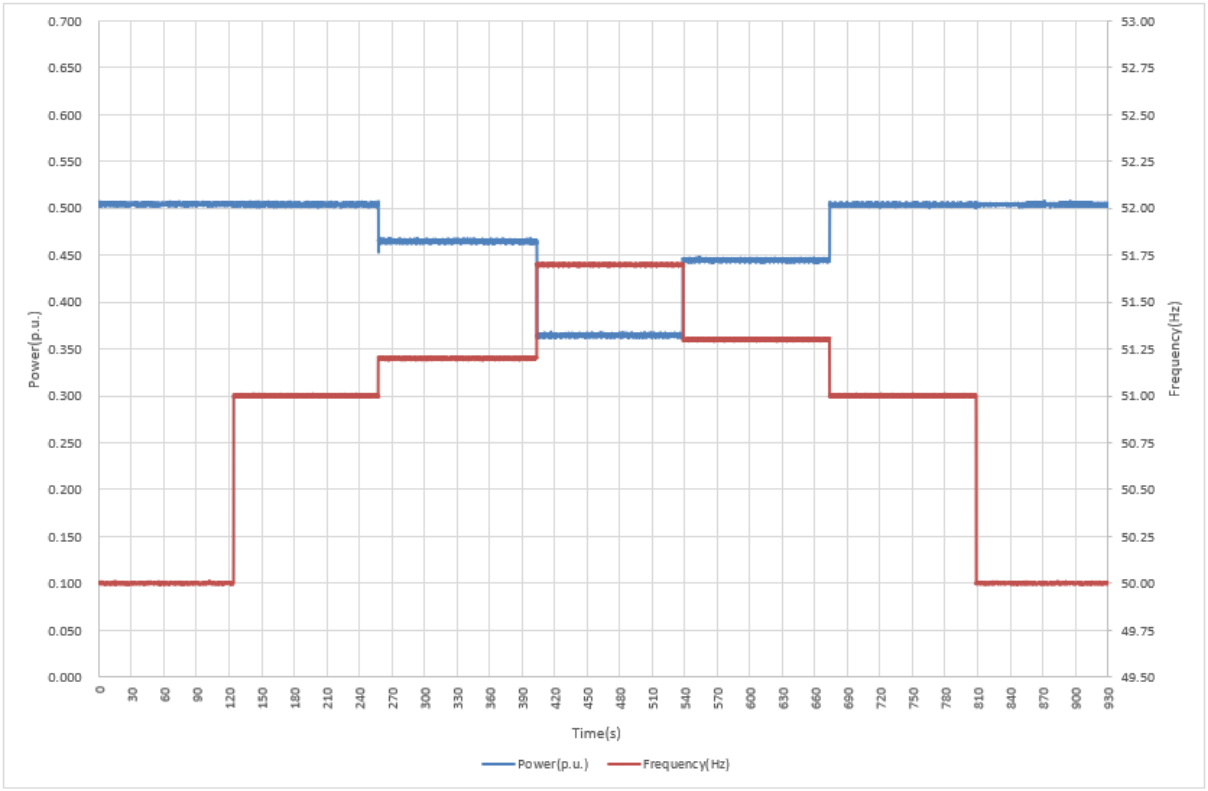
| Test 2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step | f (Hz) | P desired (%Pn) | Frequency meas. (Hz) | P meas. (%Pn) | P deviation (%Pn) (Within ± 10 %) | Step response time Tsr(s) | Settling time Ts(s) |
| 1 | 50.00 ± 0.05 Hz | 100.0 | 50.00 | 100.4 | 0.4 | -- | -- |
| 2 | 50.50 ± 0.05 Hz | 100.0 | 50.50 | 100.4 | 0.4 | -- | -- |
| 3 | 51.00 ± 0.05 Hz | 100.0 | 51.00 | 100.4 | 0.4 | 0.2 | 0.2 |
| 4 | 51.50 ± 0.05 Hz | 100.0 | 51.50 | 100.5 | 0.5 | 0.2 | 0.2 |
| 5 | 51.80 ± 0.05 Hz | 100.0 | 51.80 | 100.4 | 0.4 | 0.1 | 0.1 |
| 6 | 52.20 ± 0.05 Hz | 0.0 | 52.20 | 0.0 | 0.0 | 0.2 | 0.2 |

**P vs f chart for Test 2**



| Test 3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step | f (Hz) | P desired (%Pn) | Frequency meas. (Hz) | P meas. (%Pn) | P deviation (%Pn) (Within ± 10 %) | Step response time Tsr(s) | Settling time Ts(s) |
| 1 | 50.00 ± 0.05 Hz | 50.0 | 50.00 | 50.4 | 0.4 | -- | -- |
| 2 | 51.00 ± 0.05 Hz | 50.0 | 51.00 | 50.4 | 0.4 | 0.2 | 0.2 |
| 3 | 51.20 ± 0.05 Hz | 46.0 | 51.20 | 46.5 | 0.5 | 0.2 | 0.2 |
| 4 | 51.70 ± 0.05 Hz | 36.0 | 51.70 | 36.5 | 0.5 | 0.4 | 0.4 |
| 5 | 51.30 ± 0.05 Hz | 44.0 | 51.30 | 44.5 | 0.5 | 0.2 | 0.2 |
| 6 | 51.00 ± 0.05 Hz | 50.0 | 51.00 | 50.4 | 0.4 | 0.3 | 0.3 |
| 7 | 50.00 ± 0.05 Hz | 50.0 | 50.00 | 50.4 | 0.4 | 0.2 | 0.2 |

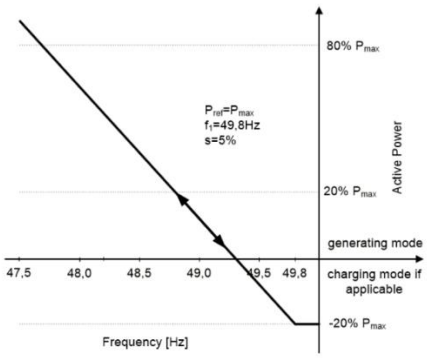
**P vs f chart for Test 3**



### 4.6.2 Power response to underfrequency

This test has been done according to chapter D.6.2 of the standard in order to verify the capability of the EUT of activating power response to underfrequency.

For this automatic response function, an initial delay of less than 2 seconds, between the intentional and the intrinsic delay, shall be configured. This function shall activate once frequency rises over a frequency threshold configurable between 49.8-46.0 Hz. Once activated, this function shall be capable of reducing active power with a configurable droop in a range of 2-12%.




For every step of power decrease (grid frequency increase), an active power rise time of maximum 10s is to be observed. Maximum settling time shall be a maximum of 30 s.

For every step of power increase (grid frequency decrease), an active power rise time of maximum 2s is to be observed. Maximum settling time shall be a maximum of 20 s.

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

- Test 1： $P_M$ = -20 %Pn; f1 = 49.8 Hz; droop = 12 %; f-stop deactivated, with delay of 2 s (*)
- Test 2： $P_M$ = -20 %Pn; f1 = 48 Hz; droop = 2 %; f-stop deactivated, no delay
- Test 3： $P_M$ = 50 %Pn; f1 = 49.8 Hz; droop = 5 %; f-stop deactivated, no delay

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

Note 1: Active power in negative value means that the unit is working in charging operation method. While when active power values are given in positive value, this menas that the unit is working discharge operation mode.

Note 2: Threshold for discconnection underfrequency protection is set at 45.8Hz at each test items.

Used settings of the measurement device for this measurement:

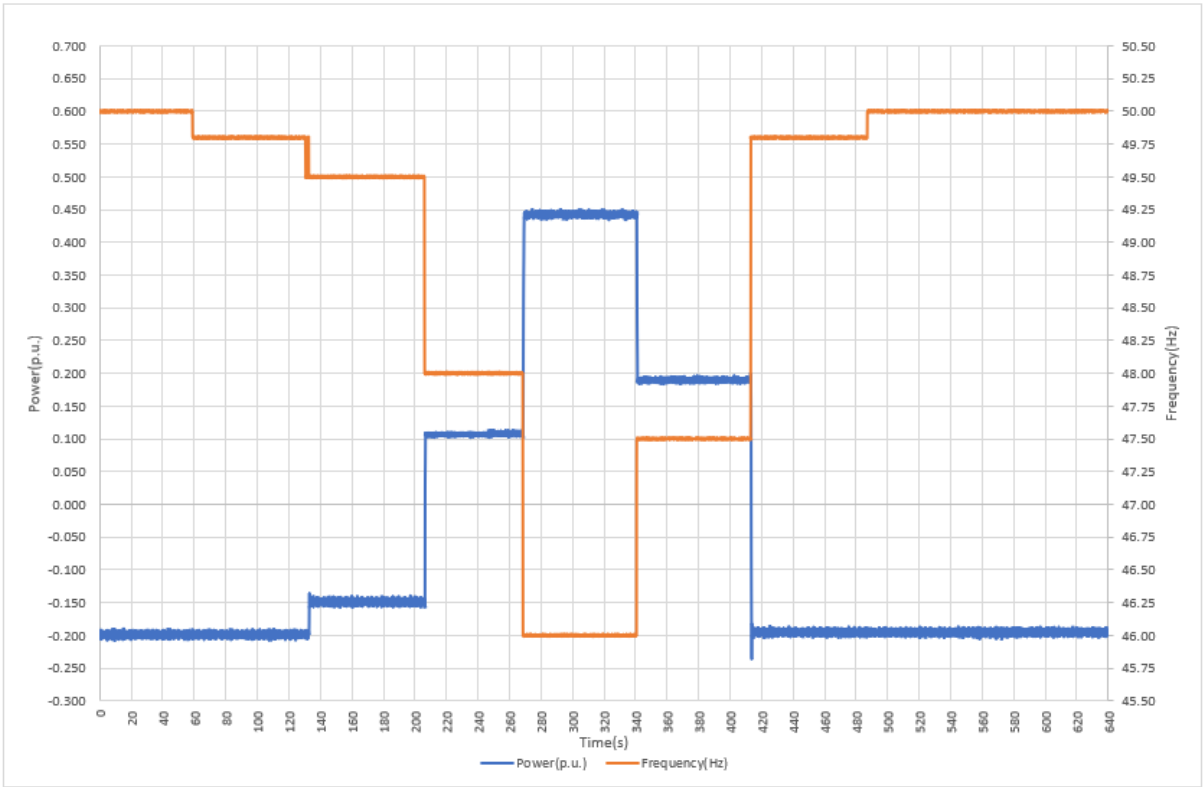
| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/5 | 100ms values | 10kHz |

Test results are offered at the table below:

| Test 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step | f (Hz) | P desired (%Pn) | Frequency meas. (Hz) | P meas. (%Pn) | P deviation (%Pn) (Within ± 10 %) | Step response time Tsr(s) | Settling time Ts(s) |
| 1 | 50.00 ± 0.05 Hz | -20.0 | 50.00 | -19.9 | 0.1 | -- | -- |
| 2 | 49.80 ± 0.05 Hz | -20.0 | 49.80 | -19.9 | 0.1 | 0.2 | 0.2 |
| 3 | 49.50 ± 0.05 Hz | -15.0 | 49.50 | -14.9 | 0.1 | 0.4 | 0.4 |
| 4 | 48.00 ± 0.05 Hz | 10.0 | 48.00 | 10.8 | 0.8 | 0.7 | 0.7 |
| 5 | 46.00 ± 0.05 Hz | 43.3 | 46.00 | 44.2 | 0.9 | 0.8 | 0.8 |
| 6 | 47.50 ± 0.05 Hz | 18.3 | 47.50 | 19.0 | 0.7 | 0.7 | 0.7 |
| 7 | 49.80 ± 0.05 Hz | -20.0 | 49.80 | -19.6 | 0.4 | 0.6 | 0.8 |
| 8 | 50.00 ± 0.05 Hz | -20.0 | 50.00 | -19.6 | 0.4 | 0.2 | 0.2 |

Note: Active power in negative value means that the unit is working in charging operation method. While when active power values are give in positive value, this menas that the unit is working discharge operation mode.

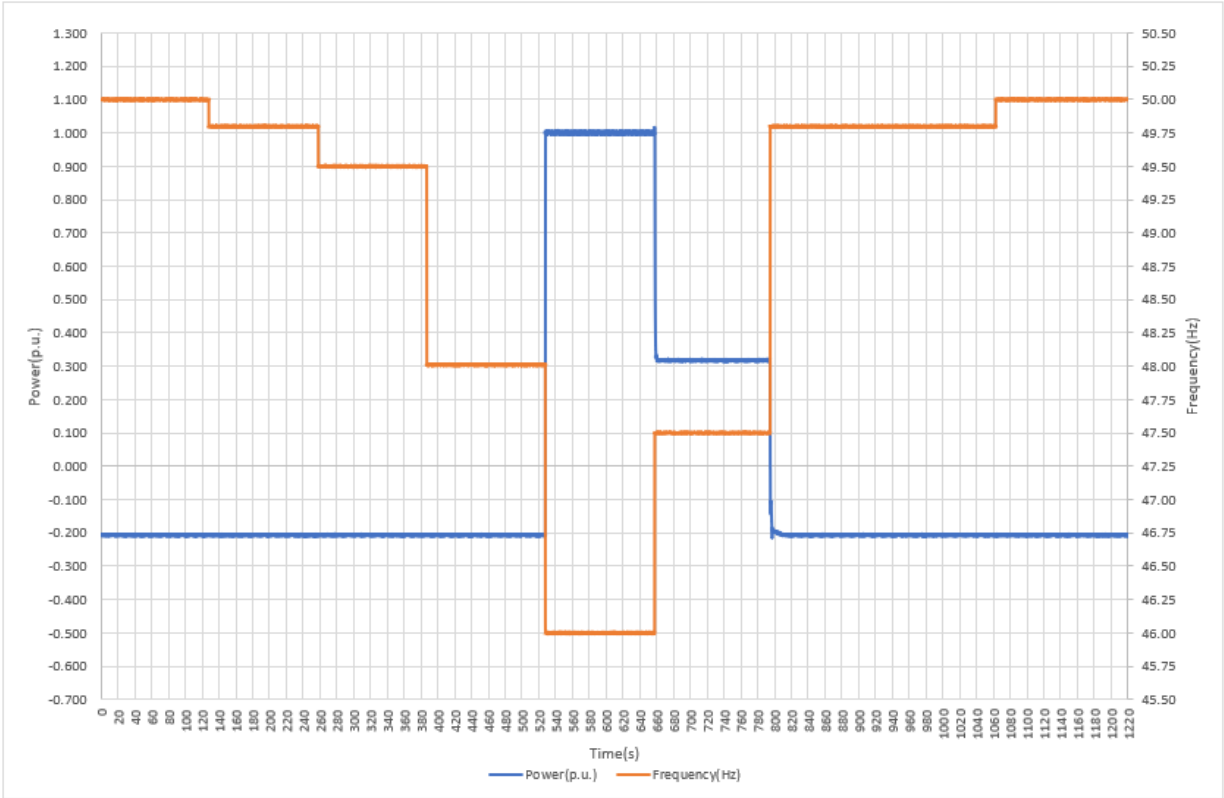
**P vs f chart for Test 1**



| Test 2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step | f (Hz) | P desired (%Pn) | Frequency meas. (Hz) | P meas. (%Pn) | P deviation (%Pn) (Within ± 10 %) | Step response time Tsr(s) | Settling time Ts(s) |
| 1 | 50.00 ± 0.05 Hz | -20 | 50.00 | -20.7 | -0.7 | -- | -- |
| 2 | 49.80 ± 0.05 Hz | -20 | 49.79 | -20.7 | -0.7 | 0.2 | 0.2 |
| 3 | 49.50 ± 0.05 Hz | -20 | 49.50 | -20.7 | -0.7 | 0.1 | 0.1 |
| 4 | 48.00 ± 0.05 Hz | -20 | 48.01 | -20.7 | -0.7 | 0.2 | 0.2 |
| 5 | 46.00 ± 0.05 Hz | 100 | 46.00 | 100.1 | 0.1 | 0.3 | 0.3 |
| 6 | 47.50 ± 0.05 Hz | 30 | 47.50 | 31.8 | 1.8 | 1.8 | 1.8 |
| 7 | 49.80 ± 0.05 Hz | -20 | 49.80 | -20.7 | -0.7 | 2.1 | 2.1 |
| 8 | 50.00 ± 0.05 Hz | -20 | 50.00 | -20.7 | -0.7 | 0.2 | 0.2 |

Note: Active power in negative value means that the unit is working in charging operation method. While when active power values are given in positive value, this menas that the unit is working discharge operation mode.

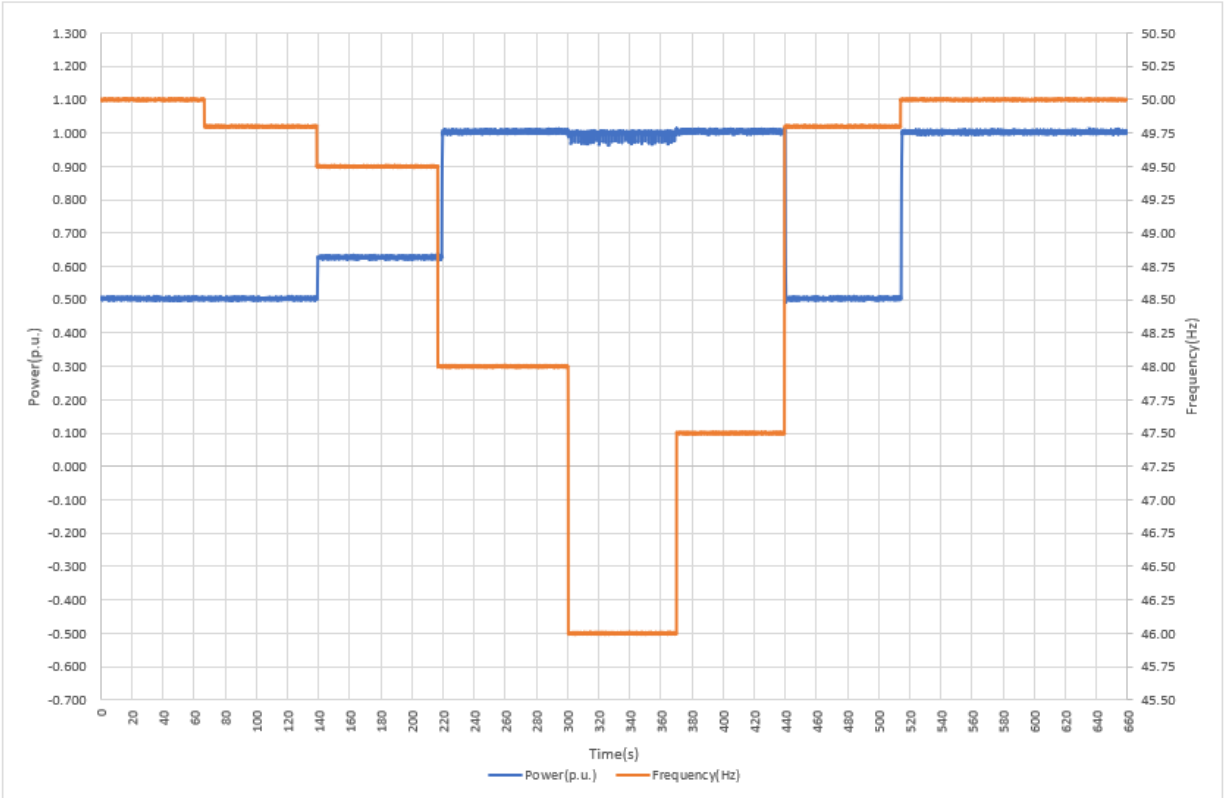
**P vs f chart for Test 2**



| Test 3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step | f (Hz) | P desired (%Pn) | Frequency meas. (Hz) | P meas. (%Pn) | P deviation (%Pn) (Within ± 10 %) | Step response time Tsr(s) | Settling time Ts(s) |
| 1 | 50.00 ± 0.05 Hz | 50 | 50.00 | 50.3 | 0.3 | -- | -- |
| 2 | 49.80 ± 0.05 Hz | 50 | 49.80 | 50.3 | 0.3 | 0.2 | 0.2 |
| 3 | 49.50 ± 0.05 Hz | 62 | 49.50 | 62.7 | 0.7 | 0.5 | 0.5 |
| 4 | 48.00 ± 0.05 Hz | 100 | 48.00 | 100.4 | 0.4 | 3.0 | 3.0 |
| 5 | 46.00 ± 0.05 Hz | 100 | 46.00 | 99.8 | -0.2 | 0.2 | 0.2 |
| 6 | 47.50 ± 0.05 Hz | 100 | 47.50 | 100.5 | 0.5 | 0.1 | 0.1 |
| 7 | 49.80 ± 0.05 Hz | 50 | 49.80 | 50.4 | 0.4 | 0.9 | 0.9 |
| 8 | 50.00 ± 0.05 Hz | 100 | 50.00 | 100.3 | 0.3 | 0.8 | 0.8 |

Note: Active power in negative value means that the unit is working in charging operation method. While when active power values are given in positive value, this menas that the unit is working discharge operation mode.

**P vs f chart for Test 3**



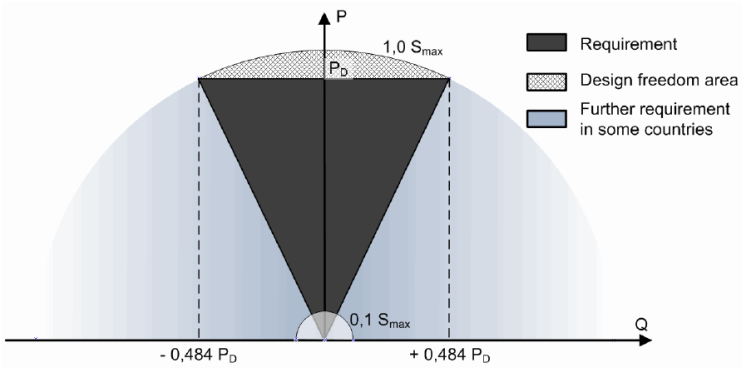
## 4.7 POWER RESPONSE TO VOLTAGE CHANGES

The aim of this test is to evaluate the reactive power capability of the EUT both at registered capacity and below registered capacity

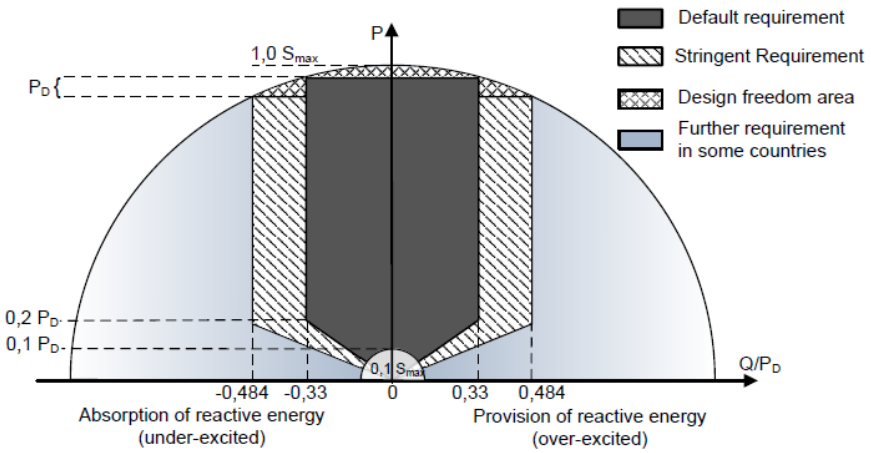
### 4.7.1 Q(P) Capabilities

These tests have been done according to chapter D.7.1 of the standard. The aim is to verify compliance with the following characteristic included in the standard at rated voltage:

For LV connections:




For HV connections:




Note: for HV connections default requirements of the curve above shall be considered.

Just operating conditions as requested by the customer LV shall be verified.

The compliances with the requirements of clause D.6.1 of the standard is stated in section 4.4.1 of following test report:

Additionally, the following result is recalculated with $P_D$ is 5.4kW

Used settings of the measurement device for this measurement:

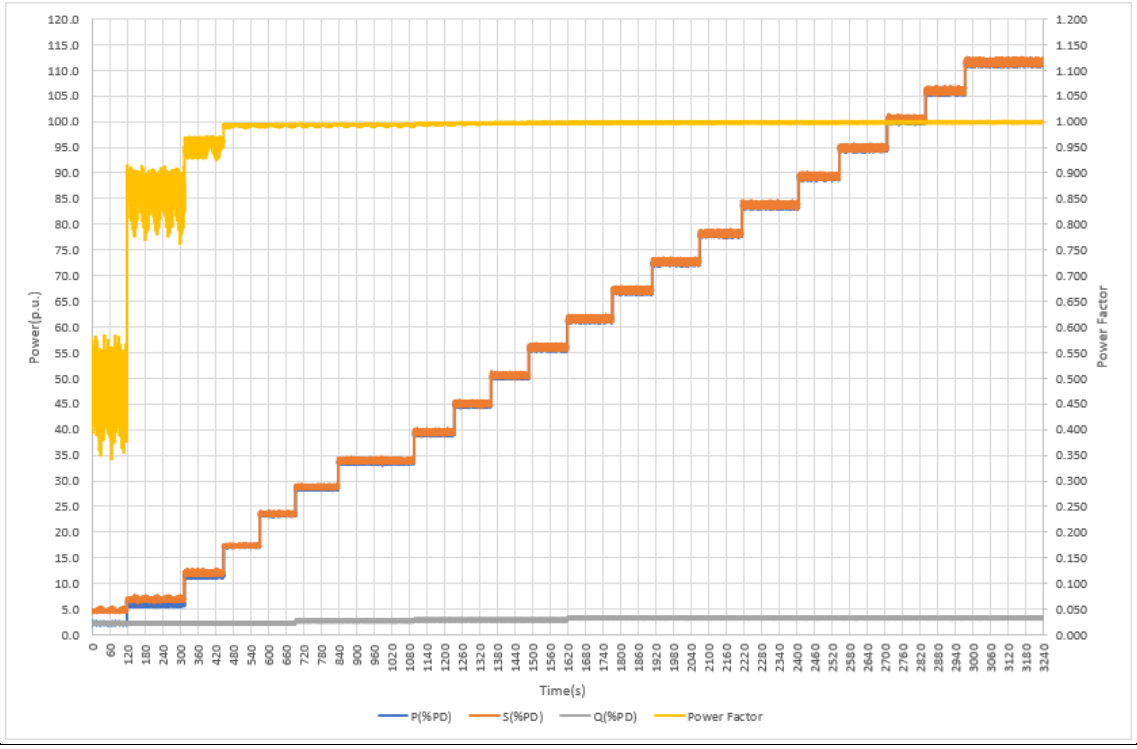
| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2020/12/31, 2021/1/4, 2020/1/18 | 100ms values | 10kHz |

#### 4.7.1.1 Fixed Power Factor (PF = 1)

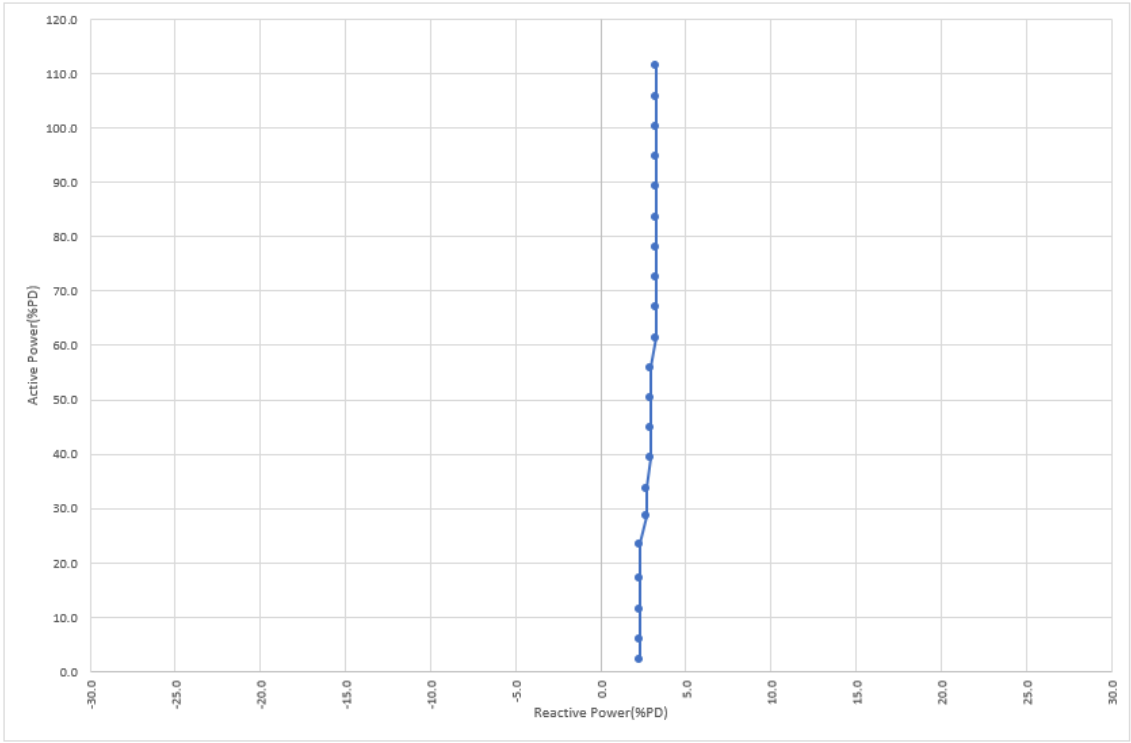
This test has been done configuring a reactive power setpoint of 0 kVAr, therefore obtaining a power factor of 1. Steps measured and results are included in the following table and graph:

| Fixed Power Factor (PF=1) | | | | | | |
|---|---|---|---|---|---|---|
| **P Desired (%$P_D$)** | **Power DC (kW)** | **P measured (%$P_D$)** | **Q measured (%$P_D$)** | **Power Factor desired (cos φ)** | **Power Factor measured (cos φ)** | **Power Factor Deviation (cos φ)** |
| **0** | 0.102 | 2.2 | 2.3 | -- | 0.481 | -- |
| **6** | 0.203 | 6.0 | 2.3 | -- | 0.860 | -- |
| **11** | 0.358 | 11.6 | 2.3 | -- | 0.955 | -- |
| **17** | 0.509 | 17.3 | 2.3 | 1 | 0.993 | -0.007 |
| **22** | 0.687 | 23.5 | 2.3 | 1 | 0.993 | -0.007 |
| **28** | 0.836 | 28.6 | 2.7 | 1 | 0.993 | -0.007 |
| **33** | 0.978 | 33.8 | 2.7 | 1 | 0.994 | -0.006 |
| **39** | 1.133 | 39.3 | 2.9 | 1 | 0.995 | -0.005 |
| **44** | 1.291 | 44.8 | 2.9 | 1 | 0.996 | -0.004 |
| **50** | 1.449 | 50.4 | 2.9 | 1 | 0.997 | -0.003 |
| **56** | 1.607 | 55.9 | 2.9 | 1 | 0.997 | -0.003 |
| **61** | 1.768 | 61.4 | 3.2 | 1 | 0.998 | -0.002 |
| **67** | 1.928 | 67.0 | 3.2 | 1 | 0.998 | -0.002 |
| **72** | 2.089 | 72.6 | 3.2 | 1 | 0.998 | -0.002 |
| **78** | 2.249 | 78.1 | 3.2 | 1 | 0.998 | -0.002 |
| **83** | 2.411 | 83.6 | 3.2 | 1 | 0.998 | -0.002 |
| **89** | 2.576 | 89.2 | 3.2 | 1 | 0.999 | -0.001 |
| **94** | 2.740 | 94.8 | 3.2 | 1 | 0.999 | -0.001 |
| **100** | 2.906 | 100.3 | 3.2 | 1 | 0.999 | -0.001 |
| **106** | 3.072 | 105.9 | 3.2 | 1 | 0.999 | -0.001 |
| **111** | 3.240 | 111.5 | 3.2 | 1 | 0.999 | -0.001 |

## Power factor and powers vs Time




## Active power vs Reactive power



#### 4.7.1.2 Rectangular curve – Fixed reactive power

This requriment has been done for the verification of the rectangular curve at a fixed reactive power level at both the inductive and the capacitive side.

t is not applicable due to the EUT is not going to connect to HV grid.

#### 4.7.1.3 Triangular curve – Fixed power factor (PF = 0.9)

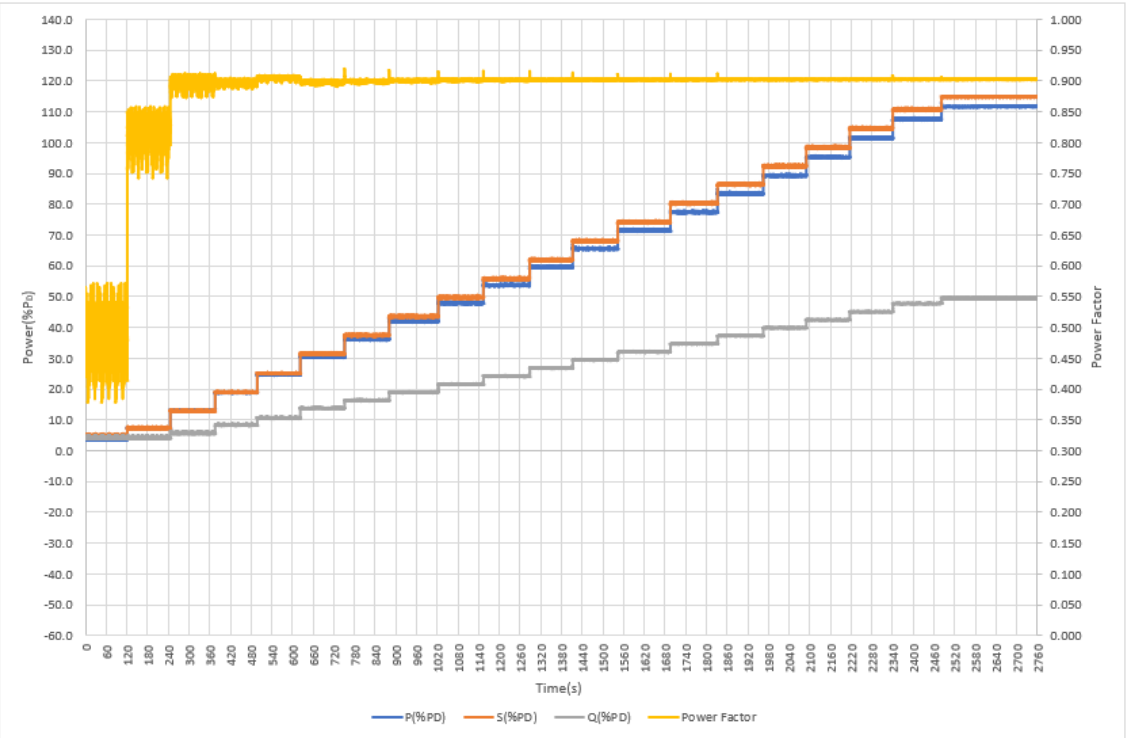
This test has been done for verification of the triangular curve, at both the inductive and the capacitive side:

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

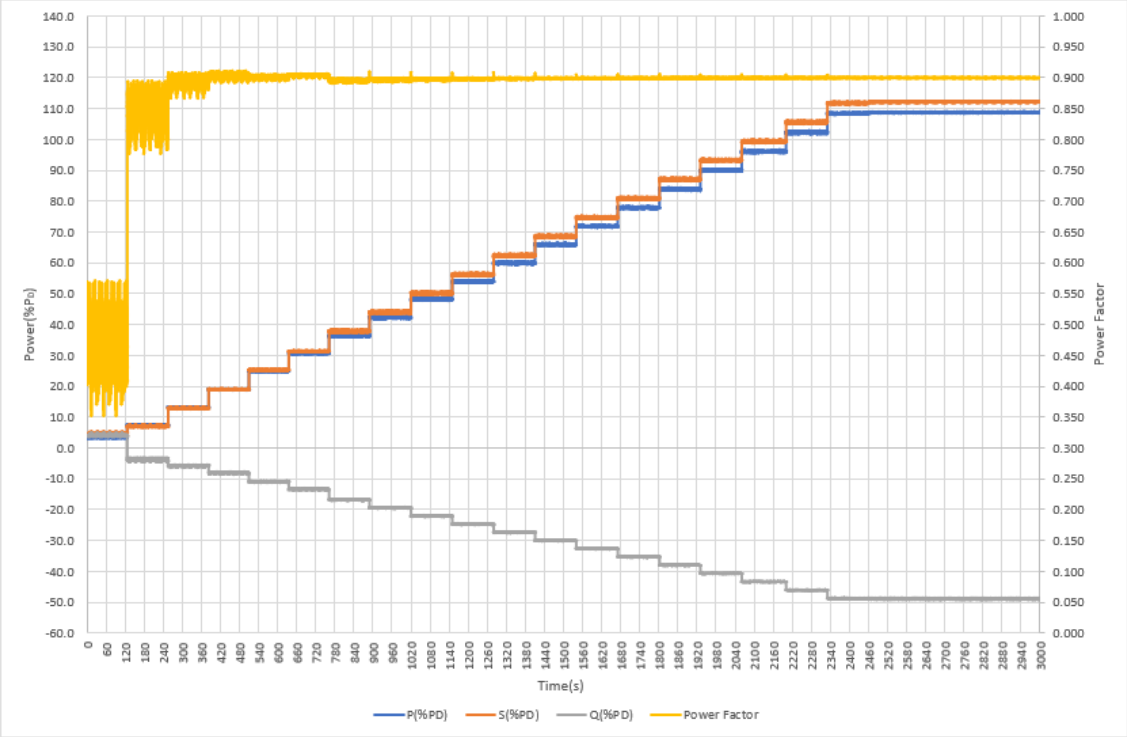
(*) The inverter does not reach the fixed power factor value of 0.9 due to the current limitation function.

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

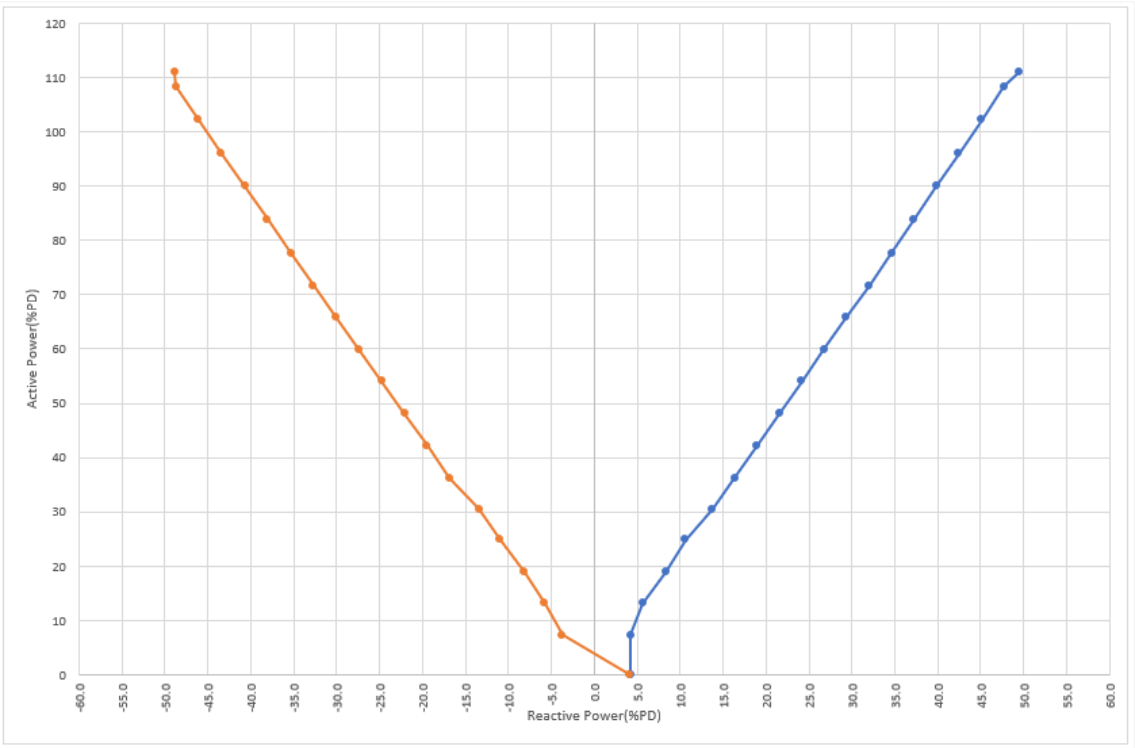
**Triangular Curve (PF=0.9), Inductive: Power factor and powers vs Time**




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



**Triangular Curve: Active power vs Reactive power**



#### 4.7.1.4 Semicircular curve – Maximum apparent power

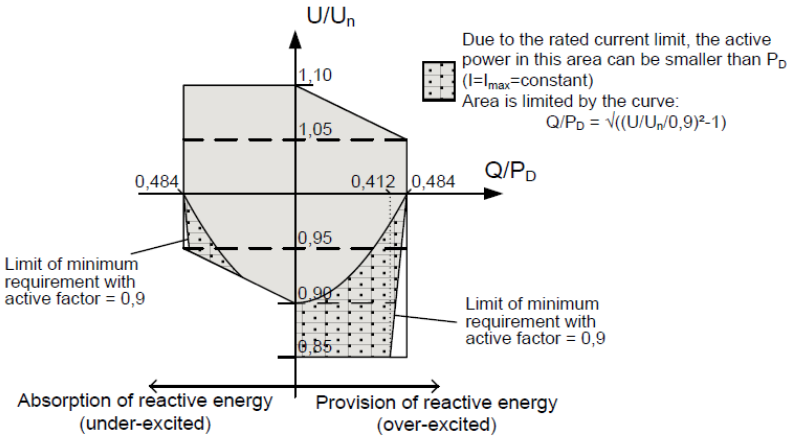
This requriment is for verification of the semicircular characteristic at rated voltage at both the inductive and the capacitive side.

It is not test due to it is optional.

### 4.7.2 Q(U) capabilities

This test has been done according to chapter D.7.1 of the standard. The aim is to verify the reactive power capabilities of the EUT at different voltage levels than the rated level. For verification of this requirement, the following characteristic from the standard shall be tested:

For LV connections:




The max. Q seting as following table with is stricter than the standard. Only the condition for connection to LV grid had been verified as following,

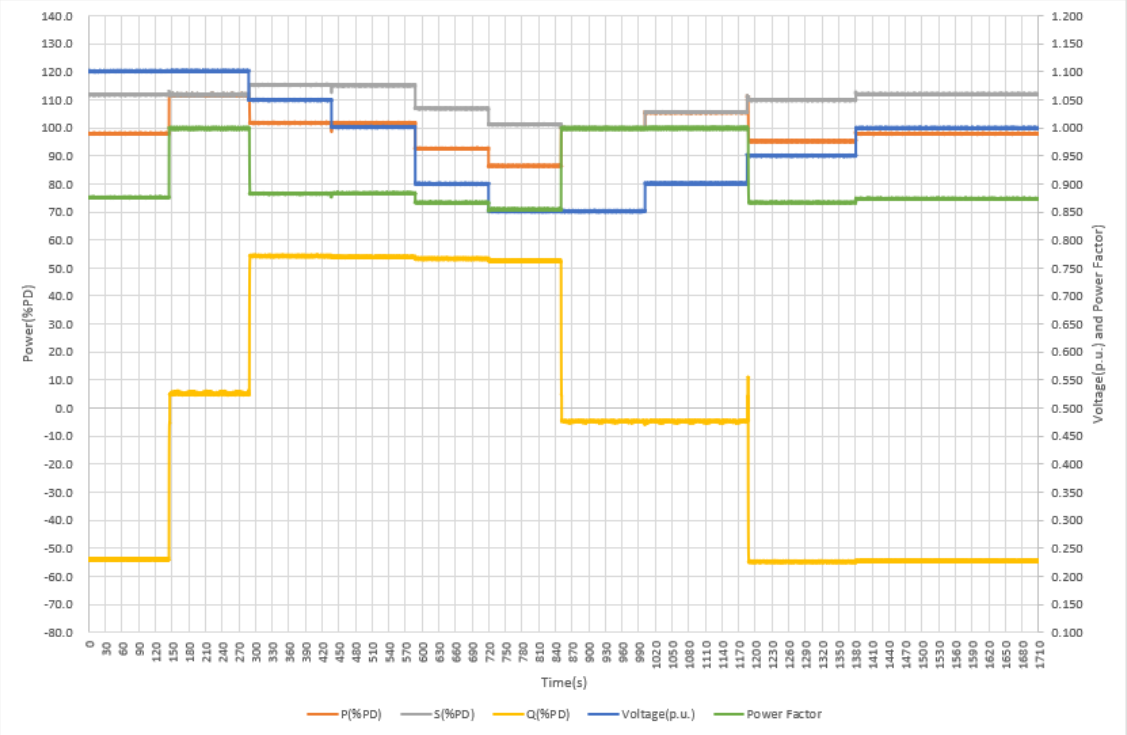
Used settings of the measurement device for this measurement:

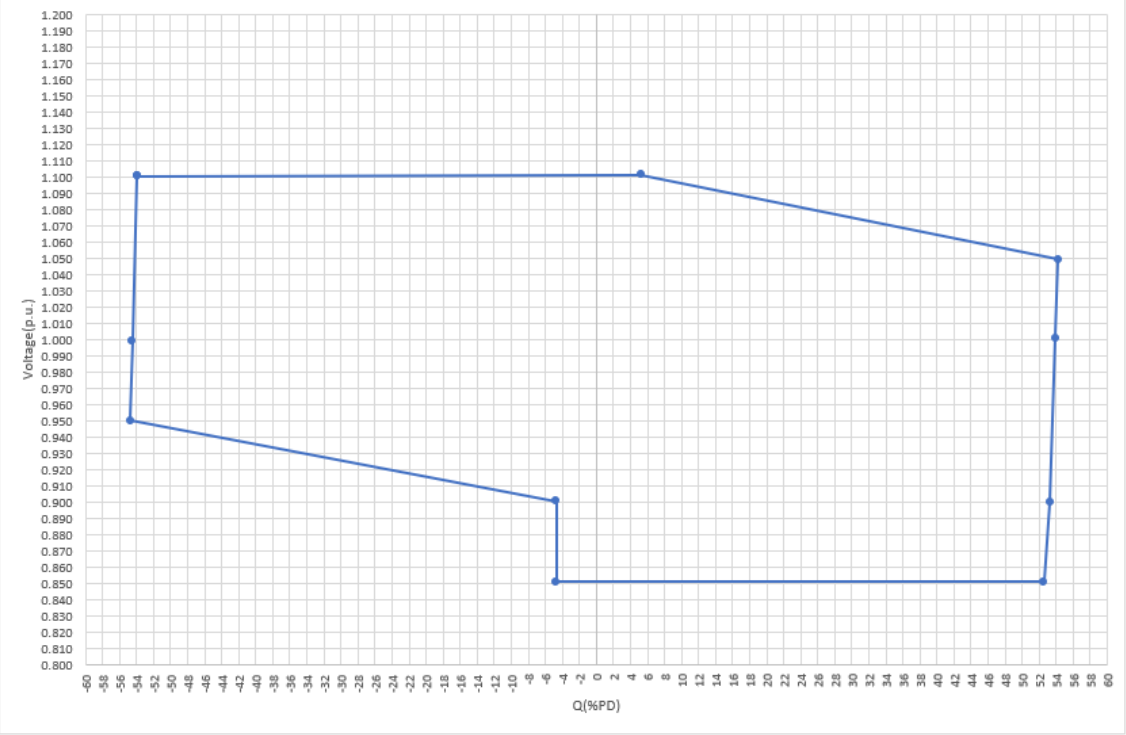
| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/01/04 | 100ms values | 10kHz |

Test results are presented in the following table and graph:

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

**Q(U) capabilities**



### 4.7.3 Cos φ setpoint

This test has been done according to chapter D.7.1 of the standard.

The dynamic accuracy shall be in accordance with Figure 15 of EN50549-1:2019 in the standard with a maximum tolerance of ±5 % of $P_D$ plus a time delay of up to 3 seconds deviating from an ideal first order filter response.

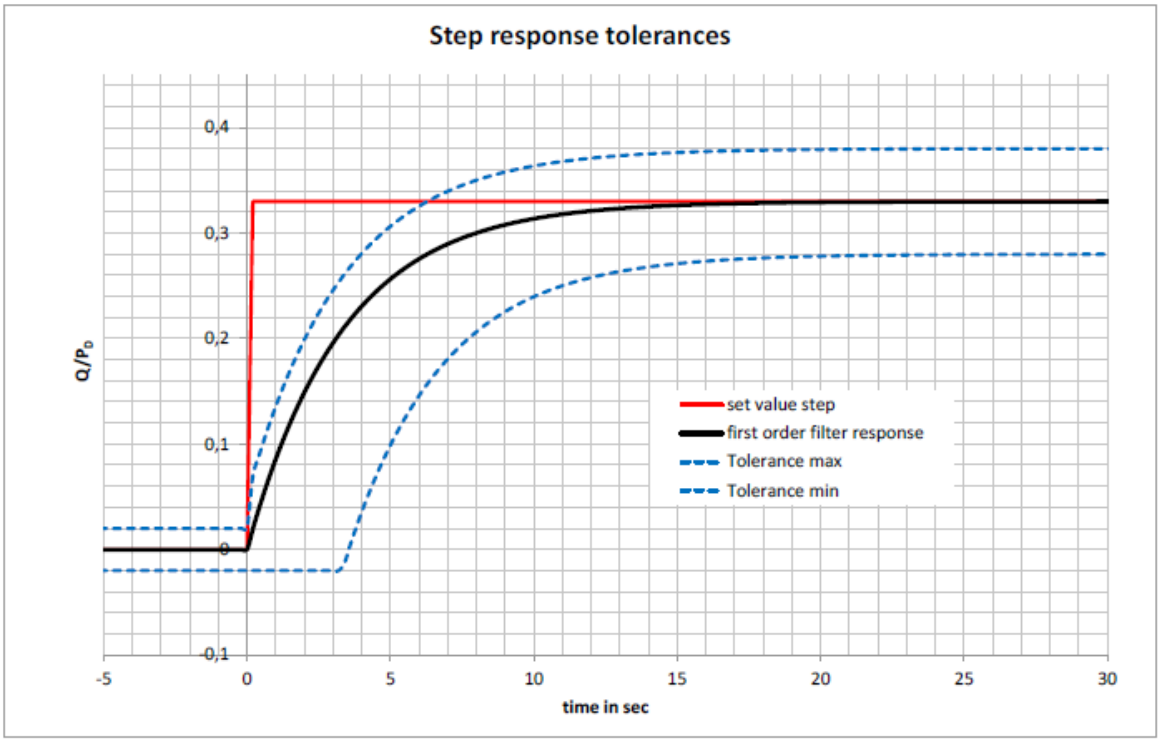



**Figure 15 — Example of dynamic control response and tolerance band for a step from Q=0 to Q= 33%$P_D$ with τ=3,33s**

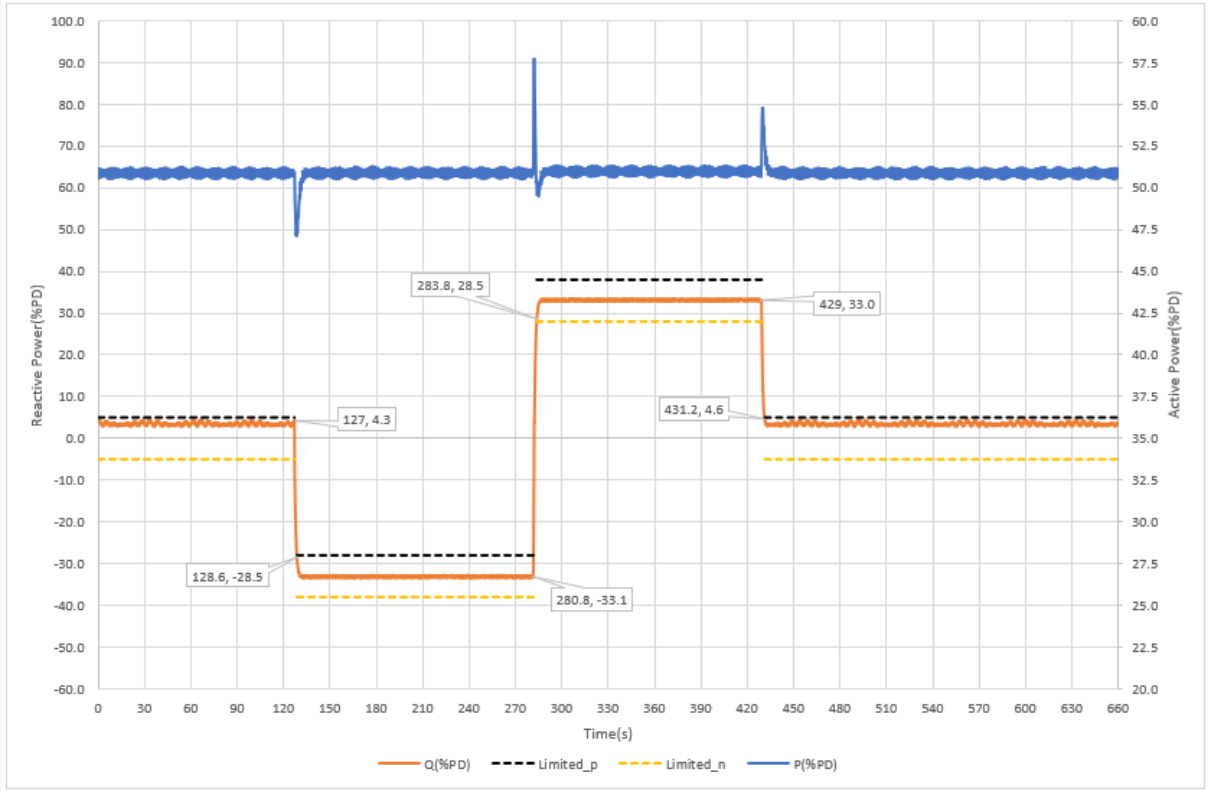
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/4, | 100ms values | 10kHz |

Test results are offered at the tables below.

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

**Reactive power injection in relation with the Voltage (inductive)**



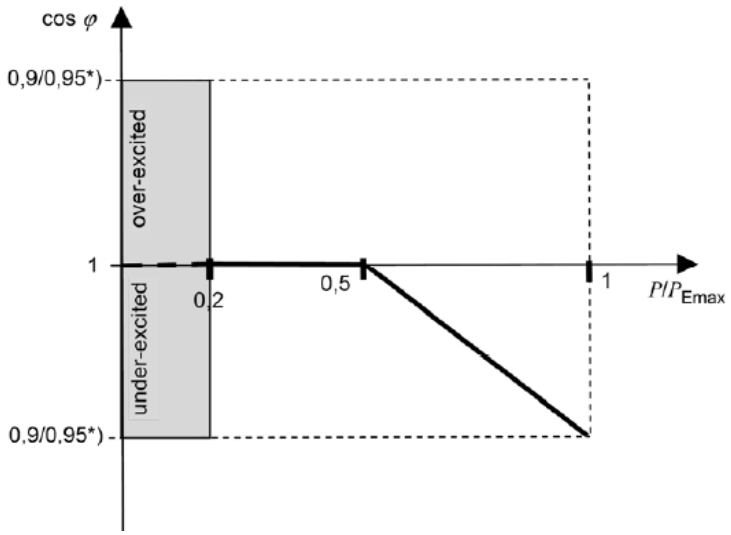
### 4.7.4 Cos φ(P) capabilities

This test has been done according to chapter D.7.1 of the standard.

The compliances with the requirements of clause D.7.1 of the standard is stated in section 4.4.2.4 of EN 50549-1:2019.

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

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




Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached. The static accuracy of each cos φ set point shall be according to 4.7.2.2 of EN 50549-1:2019.

Used settings of the measurement device for this measurement:

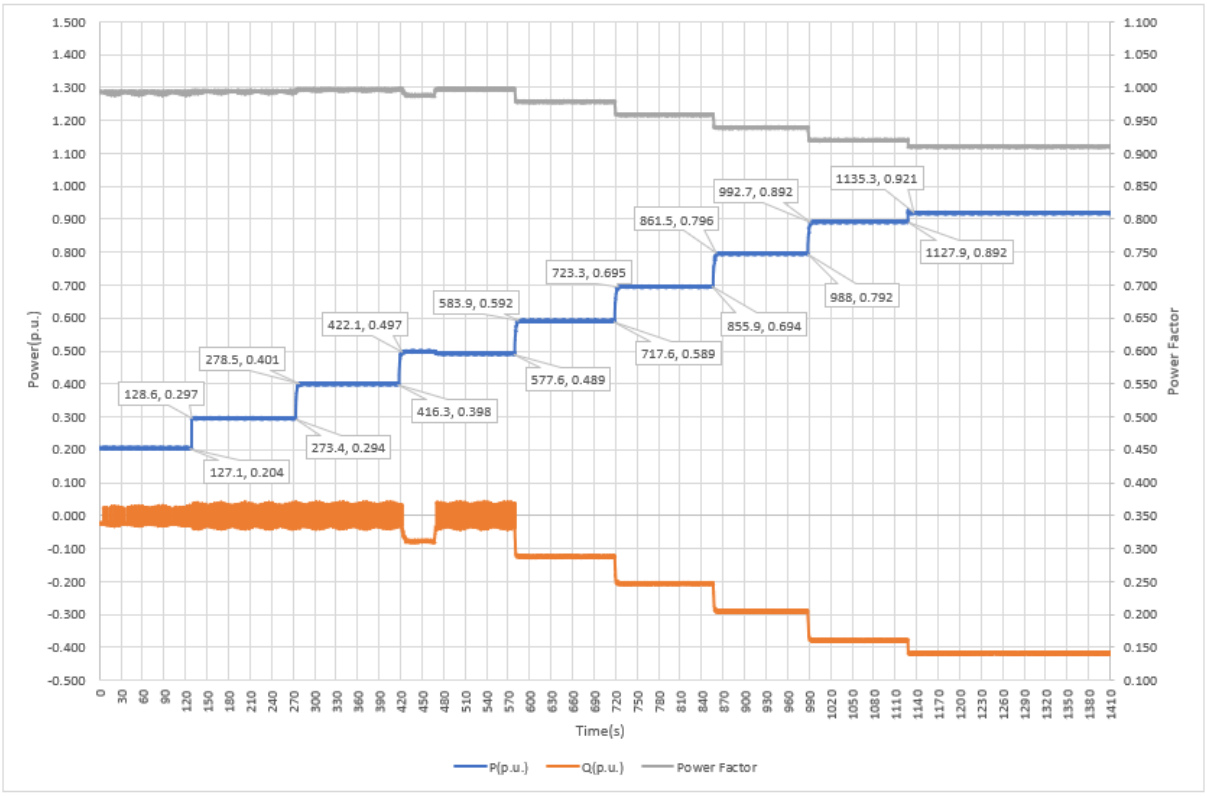
| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/4 | 100ms values | 10kHz |

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

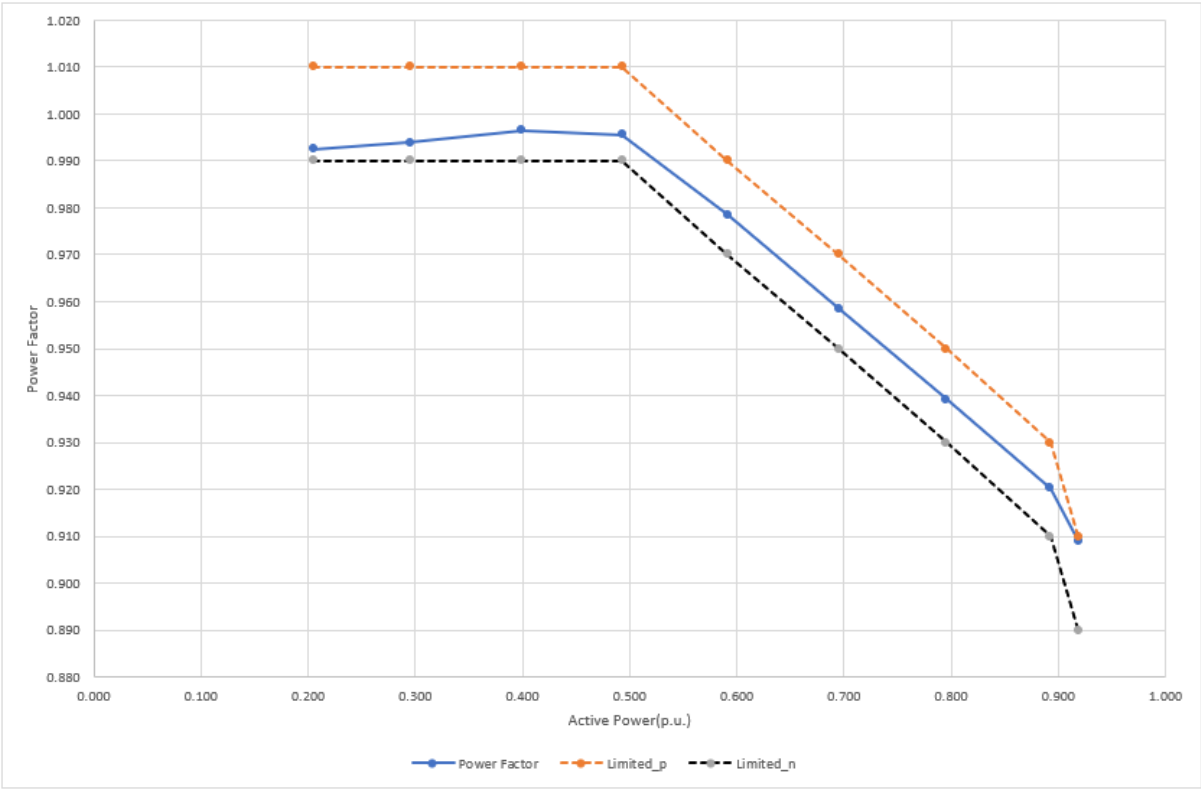
| **Setting cos φ(P) with the standard characteristic curve (20%Pn to 100%Pn)** | | | | | | |
|---|---|---|---|---|---|---|
| **Active power setting (%$P_{Emax}$)** | **Active power measured (p.u.)** | **Reactive power measured (p.u.)** | **cos φ measured** | **Desired cos φ** | **Δ cos φ (< 0.01)**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

(*) Because of limited by apparent power, the active does not reach to 100 % when cos φ = 0.9

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




## Power factor vs Active Power



### 4.7.5 Specific for a small power-generating plant

This test has been done according to chapter D.7.1.1 of the standard.

- When the voltage ≤ 105 % Un: cos phi = 1 (Q=0)
- When the voltage > 105 % Un: free operation with 1 ≥ cos phi > $0,9_{\text{under-excited}}$. (no over-excited operation allowed)

Used settings of the measurement device for this measurement:

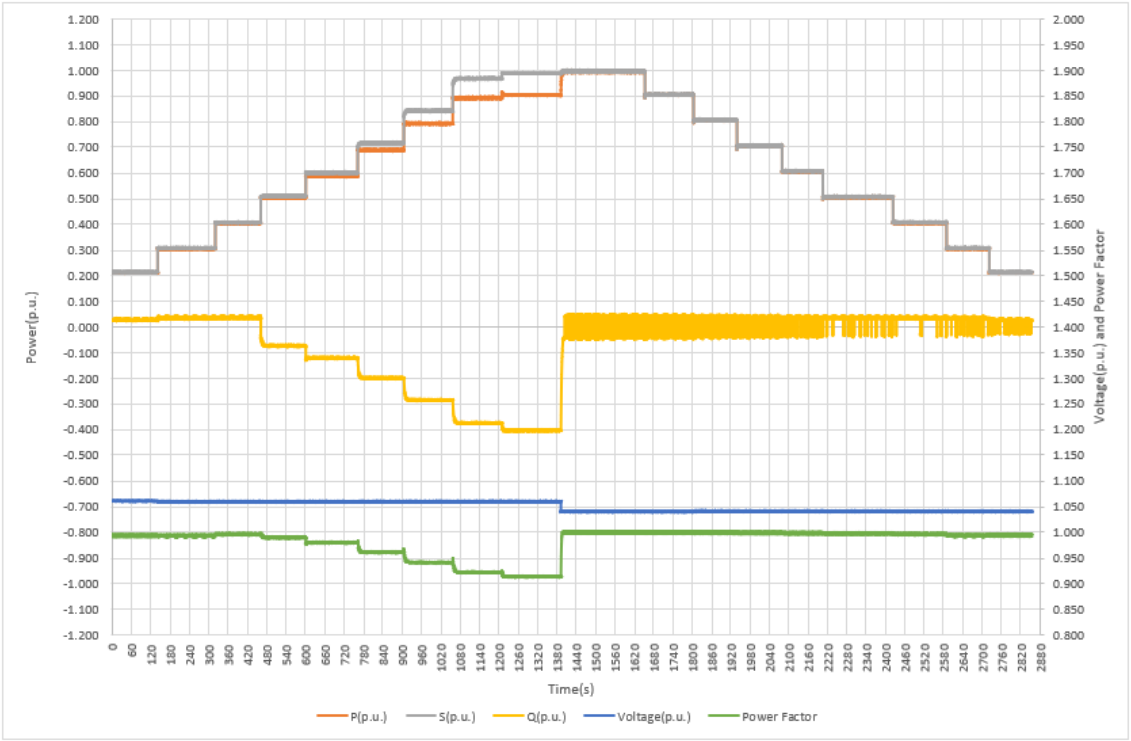
| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/18 | 100ms values | 10kHz |

The compliances with the requirements of clause D.7.1.1 of the standard is stated in section 4.4.2.4 of following test report:

| PF vs Voltage | | | | | | |
|---|---|---|---|---|---|---|
| **P setpoint (%Pn)** | **Voltage setpoint** | **V measured (p.u.)** | **P measured (p.u.)** | **cos φ measured** | **Desired cos φ** | **Δ cos φ (< 0.01)** |
| 20 | 1.060 | 1.061 | 0.212 | 0.994 | 1.000 | 0.006 |
| 30 | 1.060 | 1.059 | 0.305 | 0.993 | 1.000 | 0.007 |
| 40 | 1.060 | 1.059 | 0.405 | 0.996 | 1.000 | 0.004 |
| 50 | 1.060 | 1.059 | 0.505 | 0.989 | 1.000 | 0.011 |
| 60 | 1.060 | 1.059 | 0.588 | 0.980 | 0.980 | 0.000 |
| 70 | 1.060 | 1.060 | 0.688 | 0.961 | 0.960 | -0.001 |
| 80 | 1.060 | 1.060 | 0.792 | 0.941 | 0.940 | -0.001 |
| 90 | 1.060 | 1.060 | 0.892 | 0.922 | 0.920 | -0.002 |
| 100(*) | 1.060 | 1.060 | 0.903 | 0.913 | 0.900 | -0.013 |
| 100 | 1.040 | 1.040 | 0.996 | 0.999 | 1.000 | 0.001 |
| 90 | 1.040 | 1.040 | 0.905 | 0.999 | 1.000 | 0.001 |
| 80 | 1.040 | 1.041 | 0.805 | 0.999 | 1.000 | 0.001 |
| 70 | 1.040 | 1.041 | 0.705 | 0.998 | 1.000 | 0.002 |
| 60 | 1.040 | 1.041 | 0.605 | 0.998 | 1.000 | 0.002 |
| 50 | 1.040 | 1.041 | 0.505 | 0.997 | 1.000 | 0.003 |
| 40 | 1.040 | 1.041 | 0.406 | 0.996 | 1.000 | 0.004 |
| 30 | 1.040 | 1.040 | 0.305 | 0.994 | 1.000 | 0.006 |
| 20 | 1.040 | 1.040 | 0.212 | 0.994 | 1.000 | 0.006 |

(*) The inverter does not reach 100%Pn due to the current limitation function.

**PF vs Voltage**



### 4.7.6 Specific for another (not small) power-generating plant

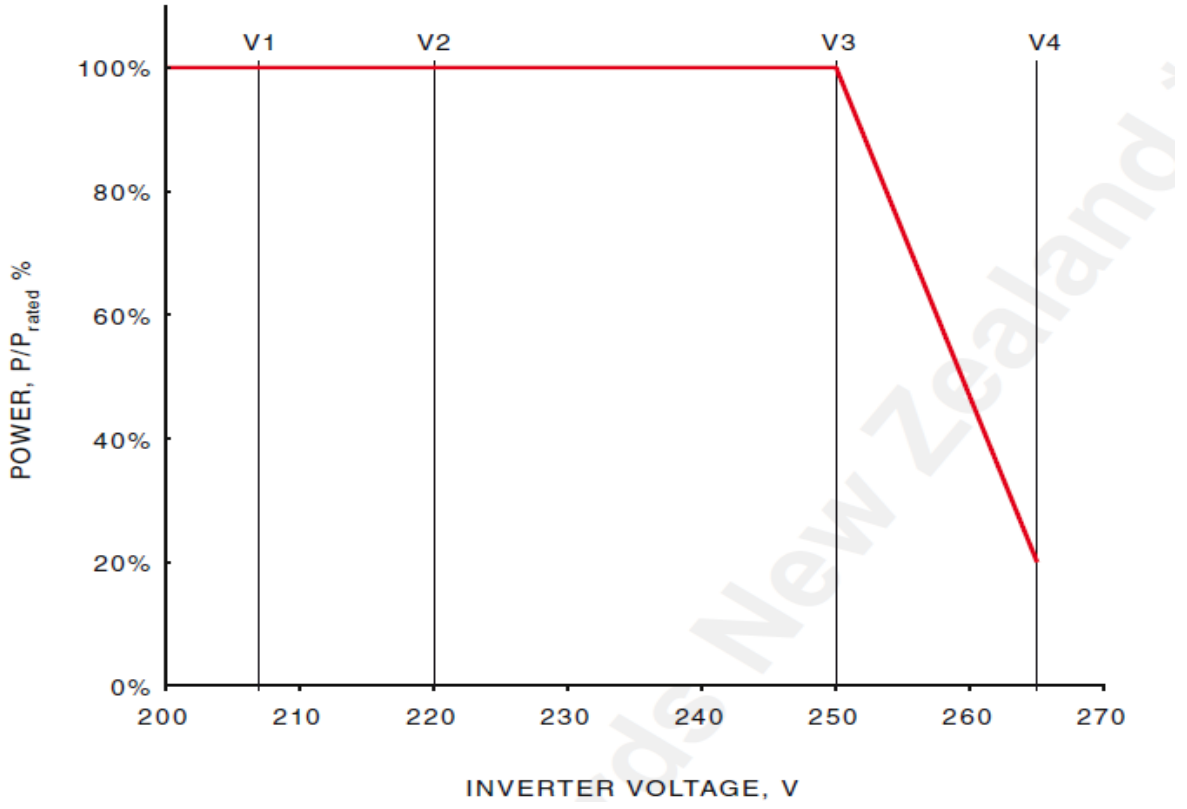
This test has been required according to chapter D.7.1.2 of the standard.

It is not applicable due to the EUT is type A in accordance with NC RfG, which is not goint to connection to the plant above 1MW.

### 4.7.7 Voltage related active power reduction P(U)

This test has been done according to chapter D.7.2 of the standard. The aim is to verify that the EUT is capable of reducing active power in overvoltage situations to avoid disconnection without causing

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




Test 1 and Test 2 setpoint as following:

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

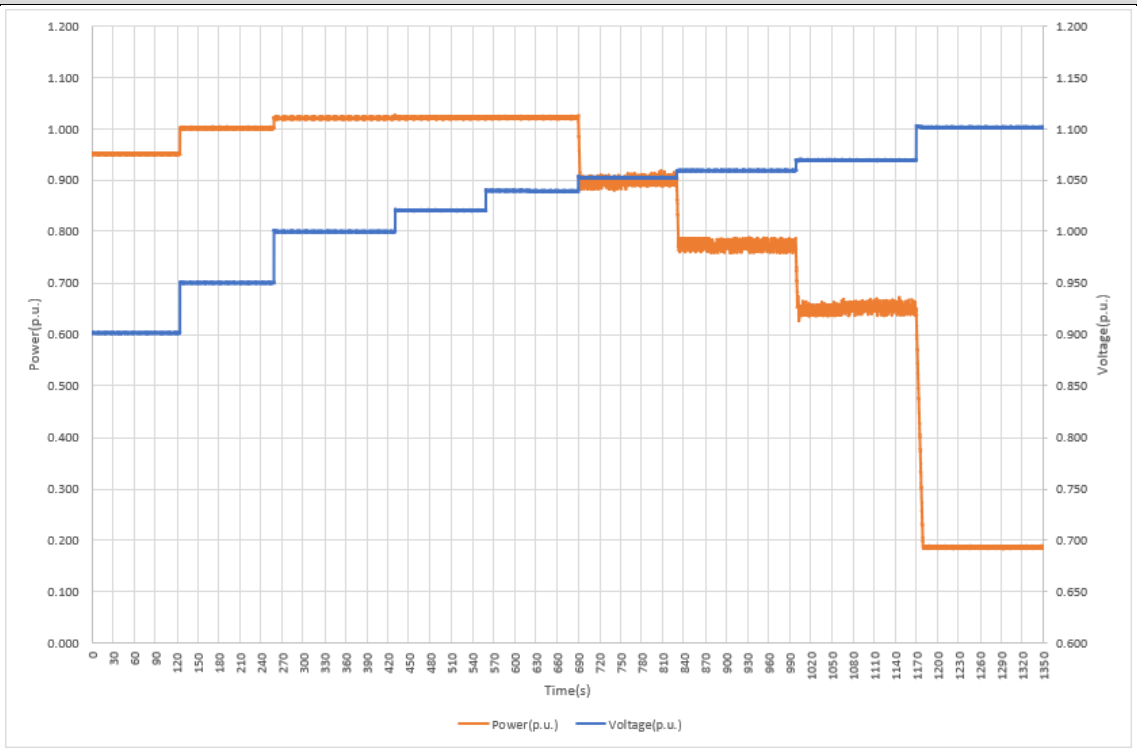
Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/4 | 100ms values | 10kHz |

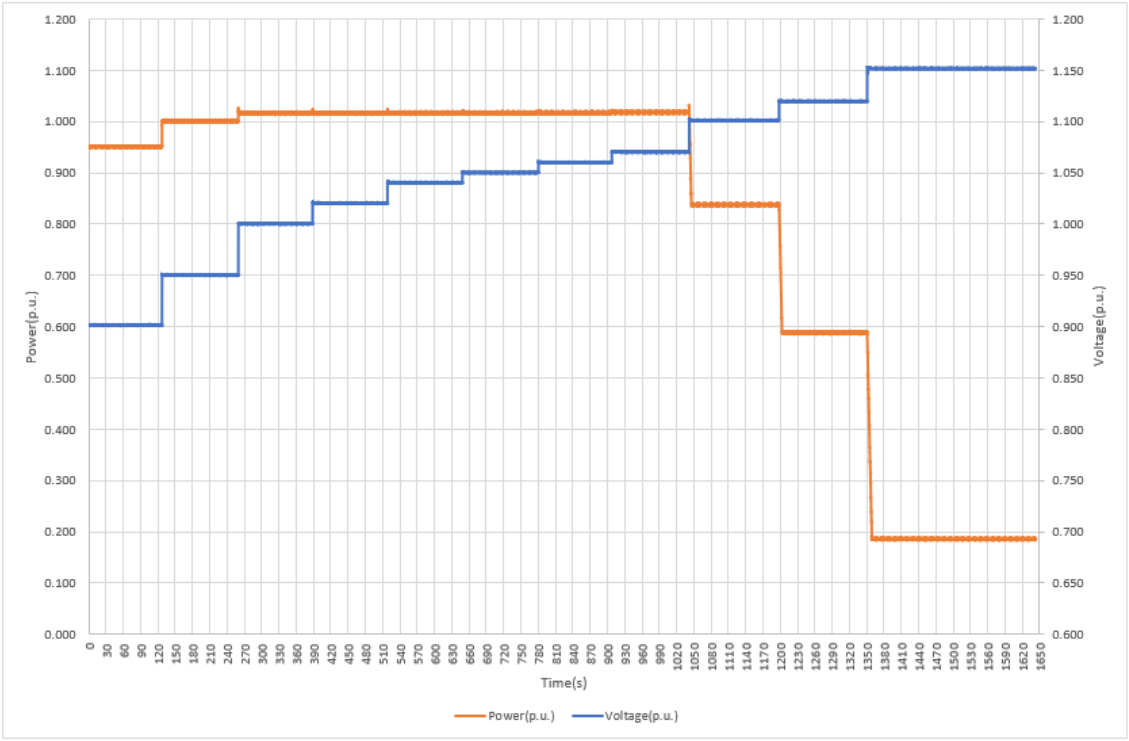
Test results are offered at tables below.

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

**Volt-Watt Test 1**



**Vatt-Watt Test 2**




### 4.7.8 Provision of additional fast reactive current during faults and voltage steps

This test has been done according to chapter D.7.3 of the standard.

It is not applicable due to the EUT is type A in accordance with NC RfG, which is not goint to connection to the plant above 1MW.

## 4.8 CONNECTION AND STARTING TO GENERATE ELECTRICAL POWER

### 4.8.1 Automatic reconnection after tripping

This test has been done according to chapter D.8 of the standard. The aim of the test is to verify that the EUT reconnects after tripping if set conditions are met. This function shall have configurable thresholds for both voltage and frequency as well as configurable observation time and recuperation gradient. After a disconnection due to a fault, the EUT is allowed to reconnect when frequency and voltage values have been within the thresholds for at least the observation time configured. When reconnecting, this shall occur with the ramp rate stablished.

The following table include default values presented in the standard:

Just operating conditions as requested by the customer LV shall be verified.

| Parameter | Reconnection after tripping of the interface protection relay | Normal operation starting |
|---|---|---|
| Lower frequency | 49,9 Hz | 49,9 Hz |
| Upper frequency | 50,1 Hz | 50,1 Hz |
| Lower voltage | If connection to the LV distribution network: 85% $U_n$ | If connection to the LV distribution network: 85% $U_n$ |
| | If connection to the HV distribution network: 90 % $U_c$ | If connection to the HV distribution network: 90 % $U_c$ |
| Upper voltage | If connection to the LV distribution network: 110 % $U_n$ | If connection to the LV distribution network: 110 % $U_n$ |
| | If connection to the HV distribution network: 110 % $U_c$ | If connection to the HV distribution network: 110 % $U_c$ |
| Observation time | 60 s | 60 s |
| Maximum active power increase gradient | 10 %/min* | 20 %/min |
| ** Power-generating units that have not the ability to apply a certain gradient shall take into account an additional delay.* | | |

Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/4 | 100ms values | 10kHz |

Test results are presented in the following table and graphs:

| Operation mode | Observation time measured (s) | Gradient measured (%Pn/min) |
|---|---|---|
| Overvoltage | 67.6 | 7.89 |
| Undervoltage | 71.0 | 7.88 |
| Overfrequency | 70.7 | 7.84 |
| Underfrequency | 70.7 | 7.84 |

Note: the test graph see in section 4.8.2 of this report.

### 4.8.2 Starting to generate electrical power

This test has been done according to chapter D.8 of the standard. The aim of the test is to verify that the EUT starts to generate power within previously configured conditions. This function shall have configurable thresholds for both voltage and frequency as well as configurable observation time and recuperation gradient. Once the EUT is connected. when frequency and voltage values get within the thresholds for at least the observation time configured, it shall start to generate power with the configured ramp rate.

The following table include default values presented in the standard:

Just operating conditions as requested by the customer LV shall be verified.

| Parameter | Reconnection after tripping of the interface protection relay | Normal operation starting |
|---|---|---|
| Lower frequency | 49,9 Hz | 49,9 Hz |
| Upper frequency | 50,1 Hz | 50,1 Hz |
| Lower voltage | If connection to the LV distribution network: 85% $U_n$ | If connection to the LV distribution network: 85% $U_n$ |
| | If connection to the HV distribution network: 90 % $U_c$ | If connection to the HV distribution network: 90 % $U_c$ |
| Upper voltage | If connection to the LV distribution network: 110 % $U_n$ | If connection to the LV distribution network: 110 % $U_n$ |
| | If connection to the HV distribution network: 110 % $U_c$ | If connection to the HV distribution network: 110 % $U_c$ |
| Observation time | 60 s | 60 s |
| Maximum active power increase gradient | 10 %/min* | 20 %/min |
| ** Power-generating units that have not the ability to apply a certain gradient shall take into account an additional delay.* | | |

Used settings of the measurement device for this measurement:

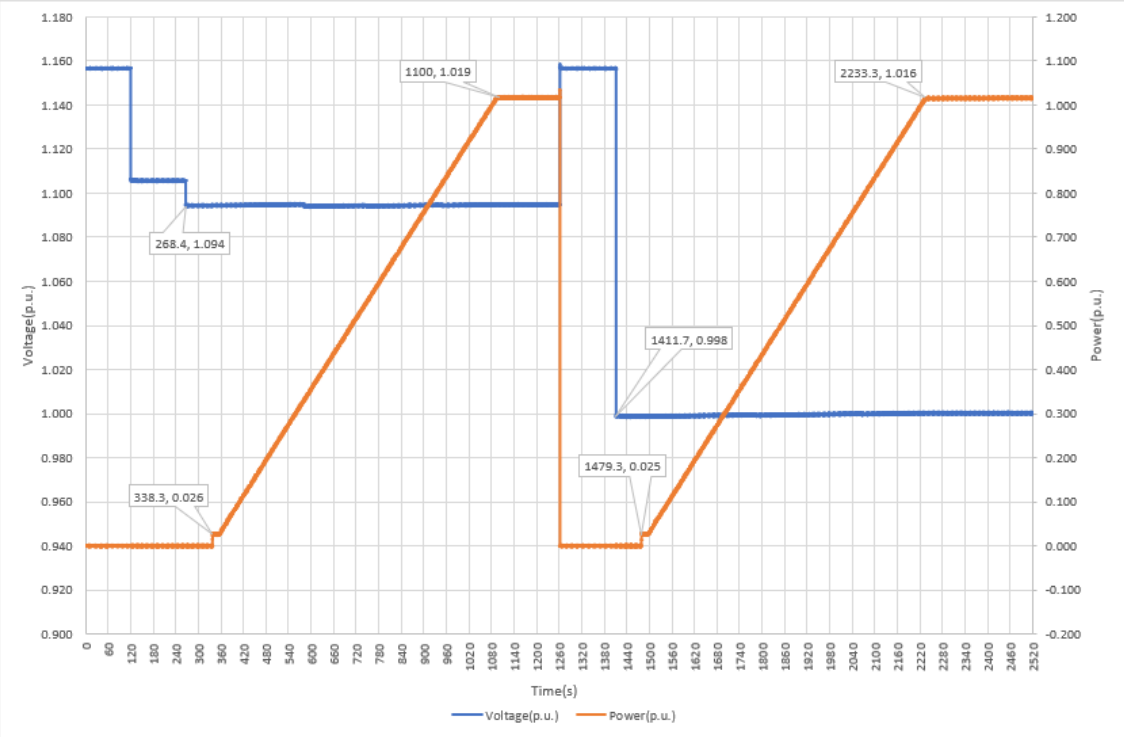
| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| PA3000 | 2021/1/4 | 100ms values | 10kHz |

Test results are presented in the following table and graphs:

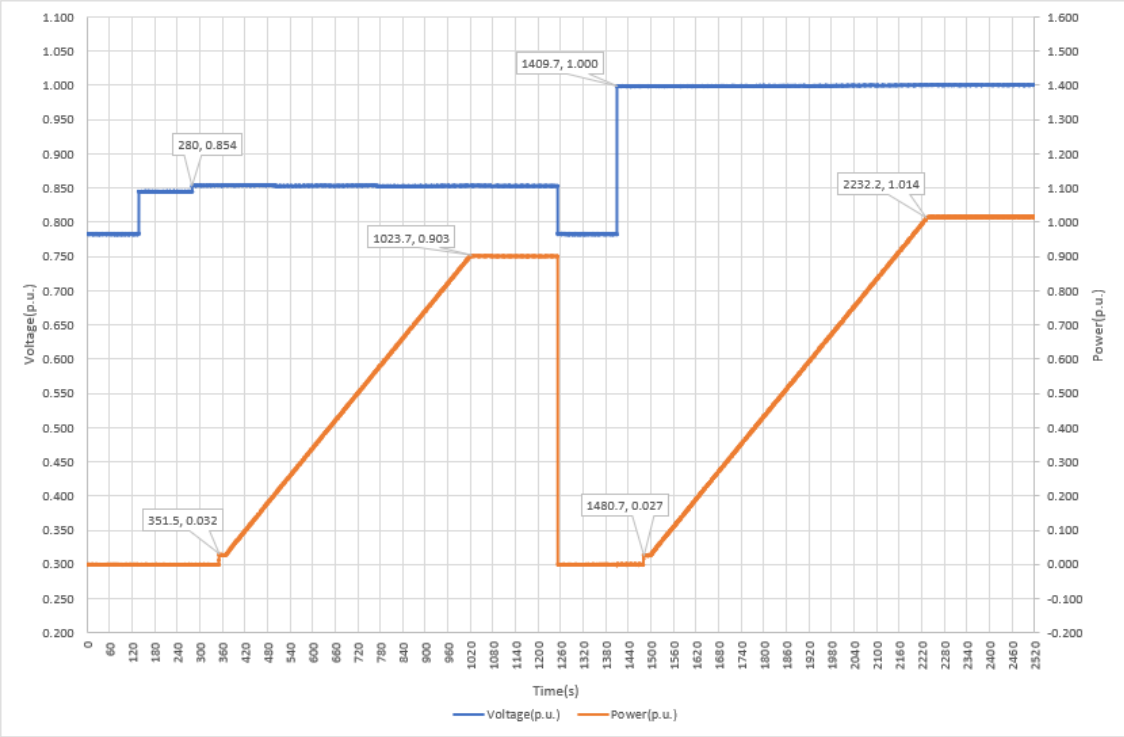
| Operation mode | Observation time measured (s) | Gradient measured (%Pn/min) |
|---|---|---|
| Overvoltage | 69.9 | 8.41 |
| Undervoltage | 71.5 | 7.77 |
| Overfrequency | 71.6 | 7.86 |
| Underfrequency | 71.4 | 7.83 |

Test results are presented in the following graphs for connection and reconnection

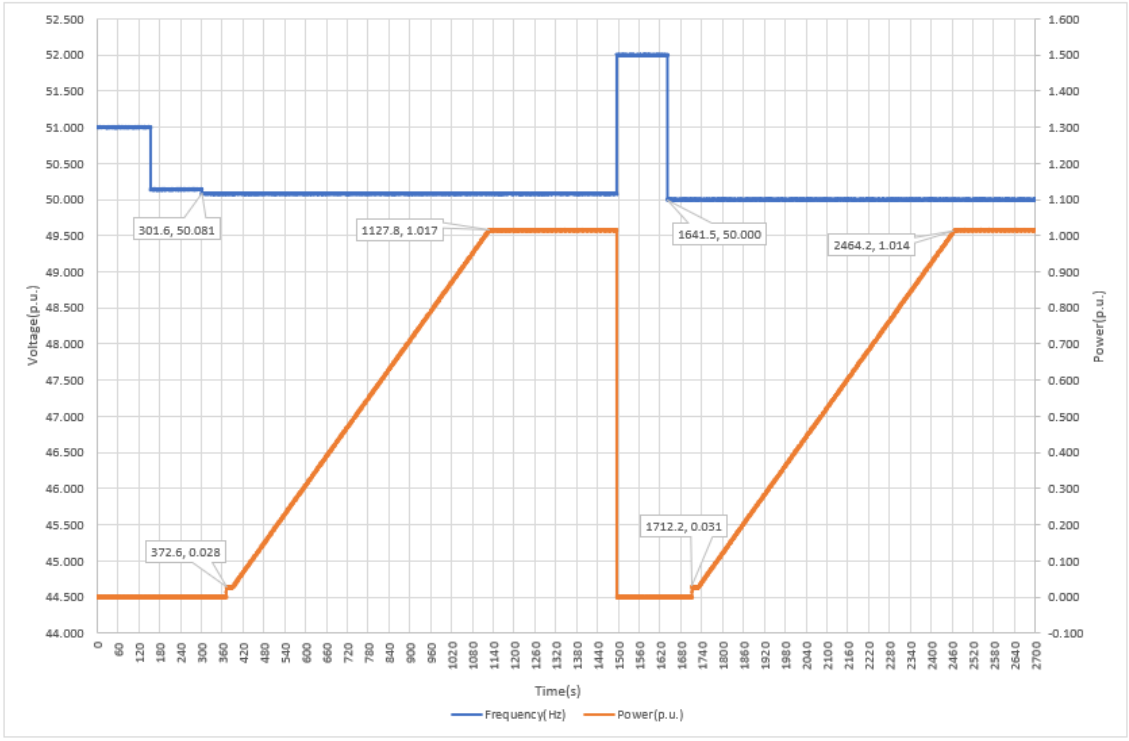
## Overvoltage Connection and Reconnection



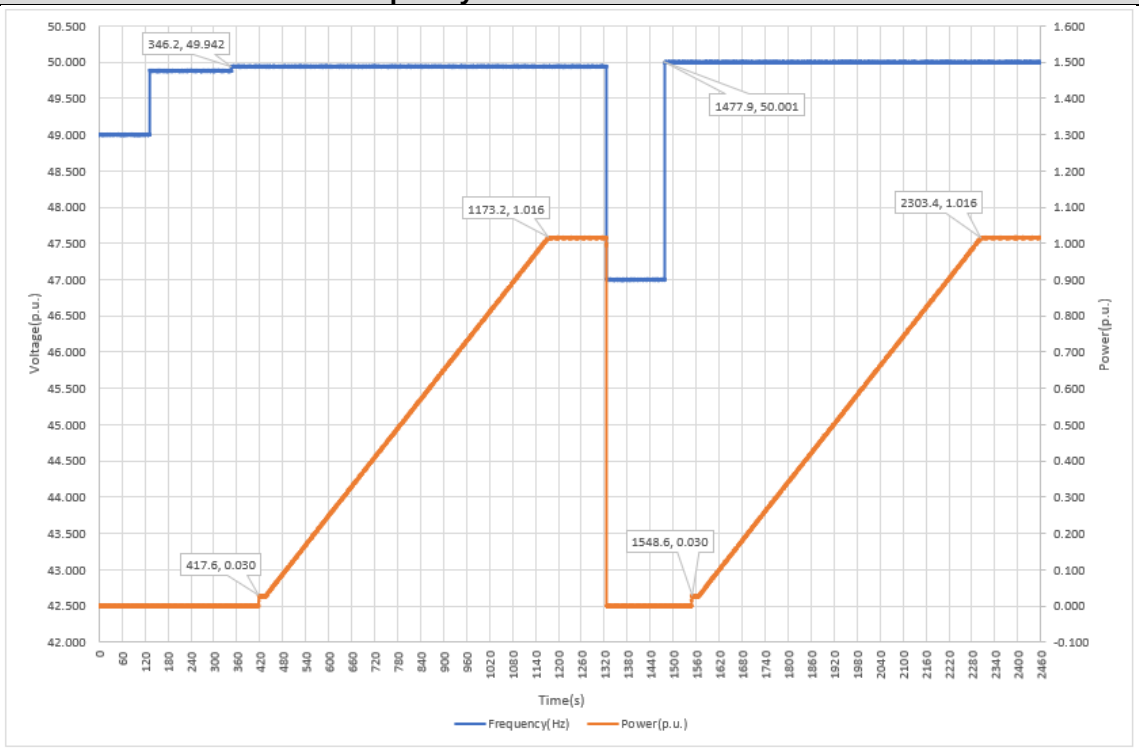

## Undervoltage Connection and Reconnection



## Overfrequency Connection and Reconnection




## Underfrequency Connection and Reconnection



## 4.9 CEASING AND REDUCTION OF ACTIVE POWER ON SET POINT

### 4.9.1 Ceasing active power

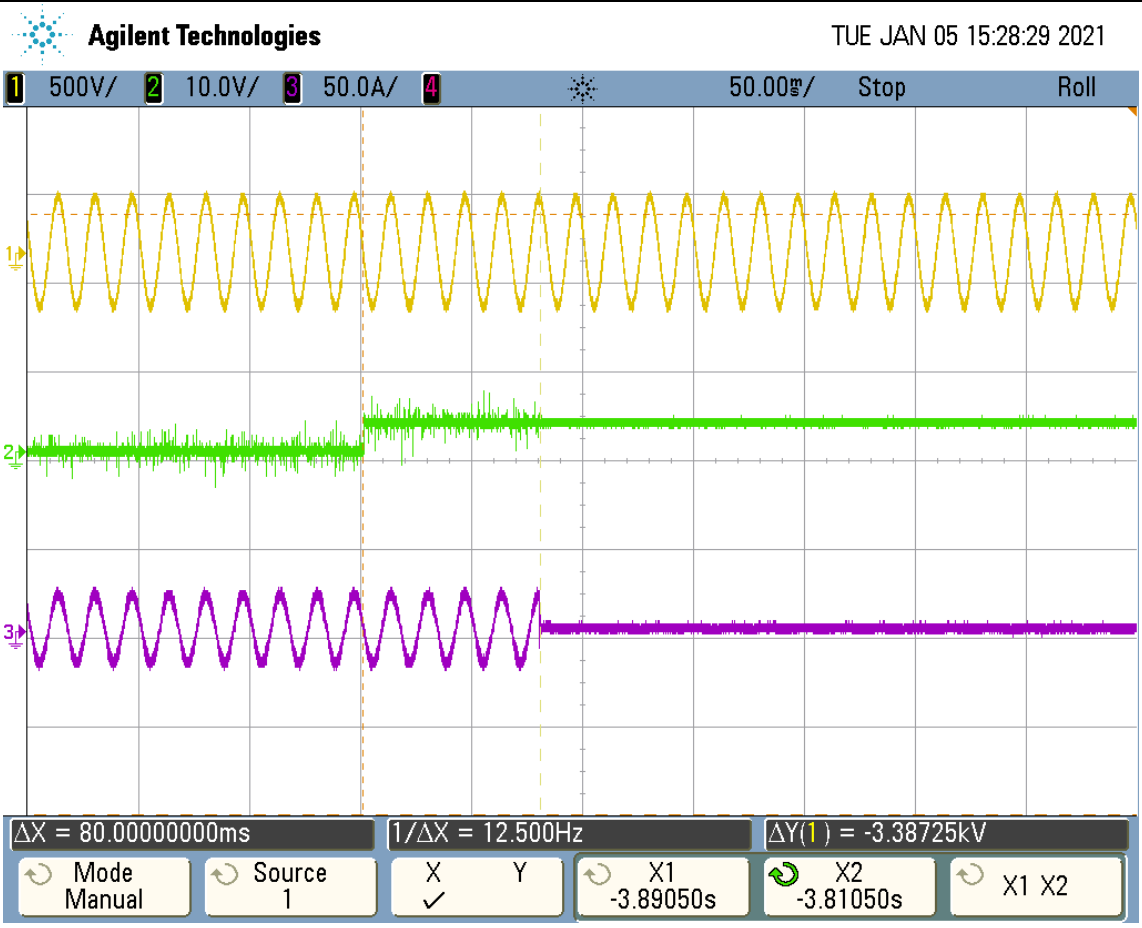
The test has been required according to the clause D.9.1 of the standard.

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

Used settings of the measurement device for this measurement:

| Measurement device | Date of measurement | Recording | Sampling frequency |
|---|---|---|---|
| DS05014A | 2021/1/5 | -- | 100kHz |

**Trip time**




Tested ceasing active power time: 80ms

Ch1: Grid voltage, Ch3: Output current, Ch2 Ceasing active power signal

### 4.9.2 Active power reduction following setpoint

This test has been done according to chapter D.9.2 of the standard. The aim is to verify the capacity of the EUT of reducing active power following an instruction at the input port.

It is not test due to it is not mandatory for connections of <1MW, and the inverter is tested only according to requirements for Type A plant generation.

### 4.10 COMMUNICATION – REMOTE MONITORING AND CONTROL

The requirements of this Section are applicable only to the power-generating units that are part of:

- a power-generating module with a maximum power ≥ 1 MW
- a power-generating plant with a maximum power > 250 kVA, if so required by the DSO, respecting the regional regulatory provisions.

The power-generating unit must have the necessary functionalities to meet the requirements of the section 7.13 of the standard concerning the communication (remote control and monitoring).

- Communication signals of the power-generating module to the DSO

| Information | Nature | Max refresh time | Comment |
|---|---|---|---|
| Voltages at the point of connection | Measurement | 1 s | |
| Active poser at the point of connection | Measurement | 1 s | |
| Reactive power at the point of connection | Measurement | 1 s | |
| Active power on the terminals of the power-generating module | Measurement | 1 s | Only required if at least one of the following conditions has been met:<br>• $\frac{\text{local consumption power of the DSU}}{P_n \text{ of the power-generating module}} > 30\ \%$<br>• Local consumption power of the DSU >300 kVA |
| Reactive power on the terminals of the power-generating module | Measurement | 1 s | Only required if at least one of the following conditions has been met:<br>• $\frac{\text{local consumption power of the DSU}}{P_n \text{ of the power-generating module}} > 30\ \%$<br>• Local consumption power of the DSU >300 kVA |
| Unavailability of the communication system | | 1 s | Can be specific to the protocol used |
| Power-generating plant connected to the distribution network | Binary signal | 1 s | For every disconnection breaker and backup disconnection breaker a signal must be given that indicates the status (open/closed) of the breaker. |
| Watchdog on RTU auxiliary energy source | | | |

- Communication signals from DSO to power-generating module

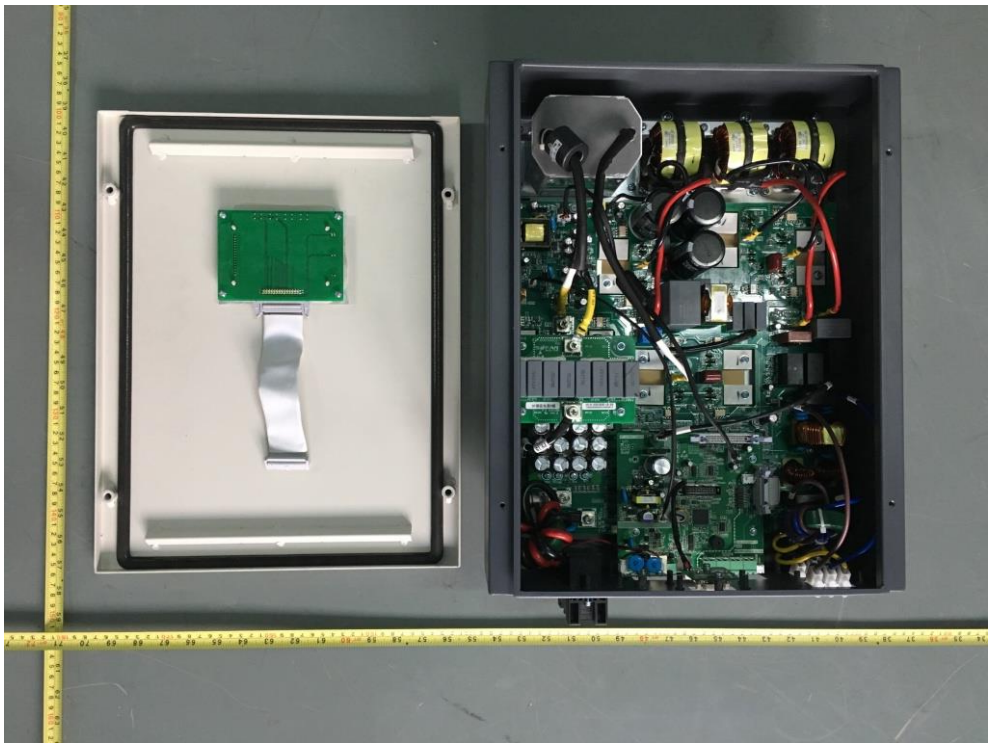
| Operation parameter | Type of signal | Max. operation time[22] | Comment |
|---|---|---|---|
| Request for disconnect | Binary signal | 1 s | 1 = Request for disconnection<br>0 = End of request for disconnection |
| Limit for the request to limit the produced active power | Value | 1 s | Value from 0 to 100 % of Pn |
| Value of fixed setpoint for reactive power | Value | 1 s | -100 %..., 100 % of Pn |
| Selection of the reactive power control modus | | 1 s | No control (free use of reactive power capabilities by DSU)<br>Q setpoint<br>Q(U)<br>Q(P)<br>Cosϕ setpoint<br>Cosϕ(P) |

It is not evidenced due to power-generating units is not one of above.

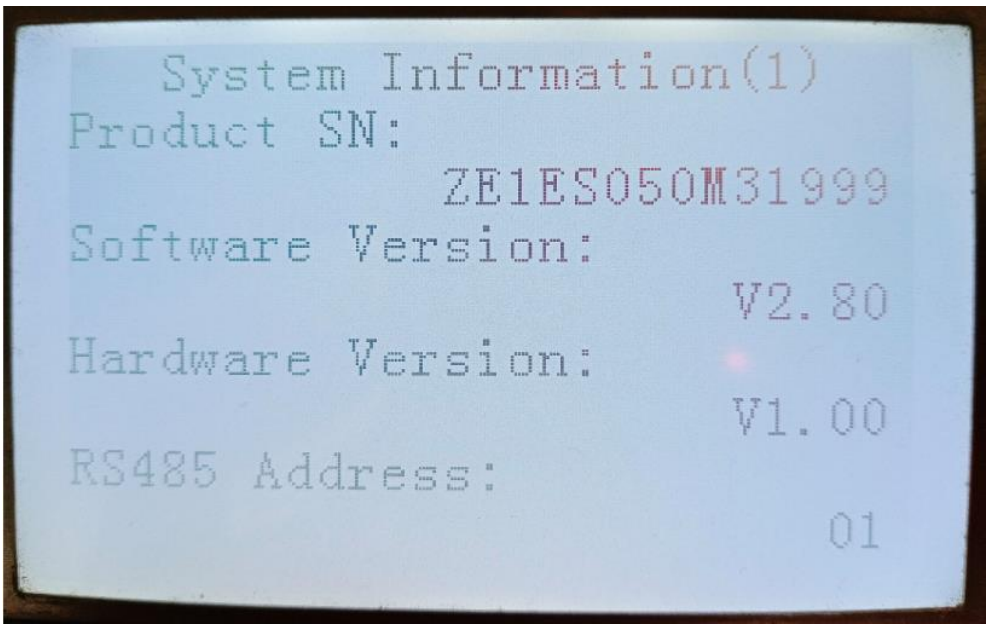
## 5 PICTURES

| Front |
| --- |
|  |
| **Back Side** |
|  |

**Internal View**



**Software Version and Serial Number of the EUT**



## 6 ELECTRICAL SCHEMES

**Equipment under testing**