# TEST REPORT

# IEC 61727 / IEC 62116

## Photovoltaic (PV) systems
## Characteristics of the utility interface

## Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters

| | |
|---|---|
| **Report reference number ..... :** | **PVTH190322N026** |
| Date of issue ..... :: | 2019-04-26 |
| **Testing laboratory name ..... :** | **Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch** |
| Address ..... : | No. 34, Chenwulu Section, Guantai Rd., Houjie Town, Dongguan City, Guangdong 523942, China |
| **Applicant's name..... :** | **Shenzhen SOFAR SOLAR Co., Ltd.** |
| Address ..... : | 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China. |
| **Test specification** | |
| Standard..... : | IEC 61727:2004, IEC 62116:2008,<br>Deviations for Thailand according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016) |
| **Certificate..... :** | **Certificate of compliance** |
| Test report form number ..... : | IEC 61727 |
| Master TRF ..... : | Bureau Veritas Consumer Products Services Germany GmbH |
| **Test item description** ..... : | **Hybrid inverter** |
| Trademark..... : | |
| Model / Type ..... : | HYD 5000-ES |

| **Ratings .....:** | **HYD 5000-ES** |
|---|---|
| Full load MPP DC voltage range [V] : | 250-520 |
| Input DC voltage range[V].....: | 90 - 580 |
| Input DC current [A] .....: | Max. 12.0 x 2 |
| Output AC voltage [V] .....: | 220, 50Hz |
| Output AC current [A].....: | Max.22.8 |
| Output power [VA].....: | 5000 |
| Output DC voltage range [V].....:<br>[Battery charge].....: | 42-58Vdc |
| Input DC current [A] .....:<br>[Battery charge].....: | Max.65A |
| Output DC current [A].....:<br>[Battery discharge].....: | Max. 70A |
| Charge and discharge power[VA] ....: | Max. 3000 |
| Output AC voltage [V] .....: | 230Vac, 50Hz |
| Output AC current [A].....: | Max.13.2 |
| Output power [VA].....: | 3000 |

| | |
|---|---|
| **Testing Location ..... :** | **Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch** |
| Address ..... : | No. 34, Chenwulu Section, Guantai Rd., Houjie Town, Dongguan City, Guangdong 523942, China |
| Tested by (name and signature) ..... : | Dora Zhang  |
| Approved by (name and signature) ..... : | James Huang  |
| **Manufacturer's name ..... :** | **Shenzhen SOFAR SOLAR Co., Ltd.** |
| **Manufacturer address..... :** | 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China. |
| **Factory's 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 |

**Document History**

| Date | Internal reference | Modification / Change / Status | Revision |
|---|---|---|---|
| 2019-04-26 | Dora Zhang | Initial report was written | 0 |

**Supplementary information:**

| **Test items particulars** | |
|---|---|
| Equipment mobility ..... : | Permanent connection |
| Operating condition ..... : | Continuous |
| Class of equipment ..... : | Class I |
| Protection against ingress of water .. : | IP65 according to EN 60529 |

**Test case verdicts**

| | |
|---|---|
| Test case does not apply to the test object ..... : | N/A |
| Test item does meet the requirement ..... : | P(ass) |
| Test item does not meet the requirement ..... : | F(ail) |

**Testing**

| | |
|---|---|
| Date of receipt of test item ..... : | 2019-03-22 |
| Date(s) of performance of test ..... : | 2019-03-22 to 2019-04-22 |

**General remarks:**

The test result presented in this report relate only to the object(s) tested.
This report must not be reproduced in part or in full without the written approval of the issuing testing laboratory.

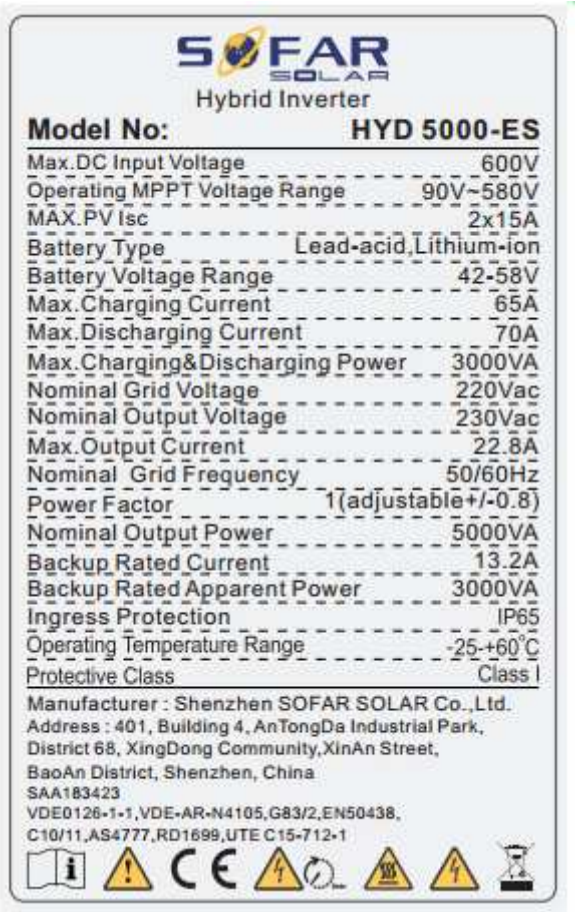
"(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

Throughout this report a comma is used as the decimal separator.

**This Test Report consists of the following documents:**

1. Test Results
2. Annex No. 1 –Test equipment list

**Copy of marking plate:**



**General product information:**

The Hybrid inverter converts DC voltage, generated by photovoltaic modules and batteries, into AC voltage.

The Hybrid inverter is a single-phase type and only one machine is allowed on each line conductor.

The input and output are protected by varistors to Earth. The unit is providing EMC filtering at the PV input and output toward mains. The unit does not provide galvanic separation from input to output (transformerless). The output is switched off redundantly by the high power switching bridge and two relays. This assures that the opening of the output circuit will also operate in case of a single error.

**Description of the electrical circuit:**

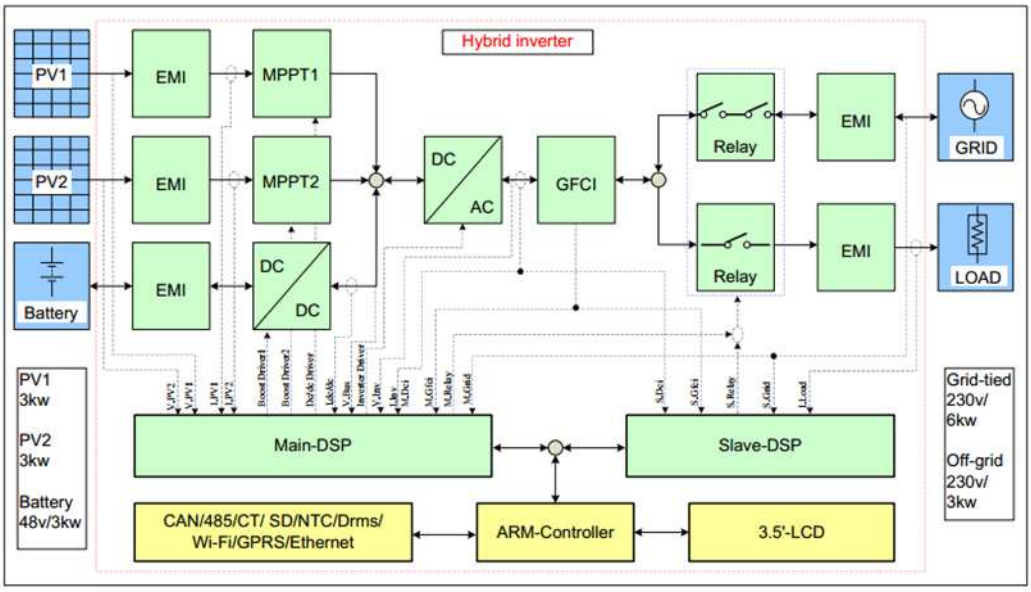



**Figure 1 – Block diagram**

The internal control is redundant built. It consists of Microcontroller Main DSP (U4) and slave DSP (U22).

The Main DSP (U4) control the relays by switching signals; measures the PV voltage, PV current, Bus voltage, grid voltage, frequency, AC current with injected DC and the array insulation resistance to ground. In addition it tests the current sensors and the RCMU circuit before each start up.

The slave DSP (U22) is measures the grid voltage, grid frequency and residual current, also can switch off the relays independently, and communicate with Main DSP (U4) each other.

The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the Main DSP(U4). The Main DSP(U4) tests and calibrates before each start up all current sensors. The unit provides two relays in series in all output conductors. When single fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the PV array and the mains. All the relays are tested before each start up.

**The product was tested on:**

Hardware version: V1.0
Software version: V1.00

| **Interface protection settings with deviations according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016)**<br>**(Thailand PEA)** | | |
|---|---|---|
| **Parameter** | **Max. clearance time*** | **Trip setting** |
| **Over voltage (level 2)** | 0,16s | 220V +20% (264V) |
| **Over voltage (level 1)** | 1,0s | 220V +10% (242V) |
| **Under voltage (level 1)** | 2,0s | 220V -10% (198V) |
| **Under voltage (level 2)** | 0,3s | 220V -50% (110V) |
| **Over frequency** | 0,1s | 50Hz +4% (52,0Hz) |
| **Under frequency** | 0,1s | 50Hz -6% (47,0Hz) |
| **Reconnection time** | 20s - 5min | |
| **Permanent DC-injection** | 0,5% of rated inverter output current | |
| **Loss of main IEC 62116:2008** | Inverter shall detect and disconnect within 1s | |
| * Trip time refers to the time between the abnormal condition occurring and the inverter ceasing to energize the utility line. The PV system control circuits shall actually remain connected to the utility to allow sensing of utility electrical conditions for use by the “reconnect” feature. | | |

| IEC61727:2004 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| **SECTION 4: Utility compatibility** | | | |
| **4** | **General**<br>The quality of power provided by the PV system for the on-site AC loads and for power delivered to the utility is governed by practices and standards on voltage, flicker, frequency, harmonics and power factor. Deviation from these standards represents out-of-bounds conditions and may require the PV system to sense the deviation and properly disconnect from the utility system.<br>All power quality parameters (voltage, flicker, frequency, harmonics, and power factor) must be measured at the utility interface/ point of common coupling unless otherwise specified. | Noticed | **P** |
| **4.1** | **Voltage, current and frequency**<br>The PV system AC voltage, current and frequency shall be compatible with the utility system. | Derived from tests | **P** |
| **4.2** | **Normal voltage operating range**<br>Utility-interconnected PV systems do not normally regulate voltage; they inject current into the utility. Therefore, the voltage operating range for PV inverters is selected as a protection function that responds to abnormal utility conditions, not as a voltage regulation function. | Derived from tests | **P** |
| **4.3** | **Flicker**<br>The operation of the PV system should not cause voltage flicker in excess of limits stated in the relevant sections of IEC 61000-3-3 for systems less than 16 A or IEC 61000-3-5 for systems with current of 16 A and above. | See table 4.3 | **P** |
| **4.4** | **DC injection**<br>The PV system shall not inject DC current greater than 1 % of the rated inverter output current, into the utility AC interface under any operating condition. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See table 4.4 | **P** |
| **4.5** | **Normal frequency operating range**<br>The PV system shall operate in synchronism with the utility system, and within the frequency trip limits defined in 5.2.2. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See table 5.2.2 | **P** |

| IEC61727:2004 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| **SECTION 4: Utility compatibility** | | | |
| **4.6** | **Harmonics and waveform distortion**<br>Low levels of current and voltage harmonics are desirable; the higher harmonic levels increase the potential for adverse effects on connected equipment. Acceptable levels of harmonic voltage and current depend upon distribution system characteristics, type of service, connected loads/apparatus, and established utility practice.<br>The PV system output should have low current-distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system.<br>Total harmonic current distortion shall be less than 5 % at rated inverter output. Each individual harmonic shall be limited to the percentages listed in Table 1.<br>Even harmonics in these ranges shall be less than 25 % of the lower odd harmonic limits listed. (see Clause 4.6 Table 1 – Current distortion limits) | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See tables 4.6 (1) and 4.6 (2) | **P** |
| **4.7** | **Power factor**<br>The PV system shall have a lagging power factor greater than 0,9 when the output is greater than 50 % of the rated inverter output power. | See table 3.4 | **P** |

| IEC61727:2004 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| **SECTION 5: Personnel safety and equipment protection** | | | |
| **5** | **General**<br>This Clause provides information and considerations for the safe and proper operation of the utility-connected PV systems. | Noticed | **P** |
| **5.1** | **Loss of utility voltage**<br>To prevent islanding, a utility connected PV system shall cease to energize the utility system from a de-energized distribution line irrespective of connected loads or other generators within specified time limits.<br>A utility distribution line can become de-energized for several reasons. For example, a substation breaker opening due to fault conditions or the distribution line switched out during maintenance.<br>If inverters (single or multiple) have DC SELV input and have accumulated power below 1 kW then no mechanical disconnect (relay) is required. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016) | **P** |
| **5.2** | **Over/under voltage and frequency**<br>Abnormal conditions can arise on the utility system that requires a response from the connected photovoltaic system. This response is to ensure the safety of utility maintenance personnel and the general public, as well as to avoid damage to connected equipment, including the photovoltaic system. The abnormal utility conditions of concern are voltage and frequency excursions above or below the values stated in this Clause, and the complete disconnection of the utility, presenting the potential for a distributed resource island. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See table 5.2.1 and 5.2.2 | **P** |
| **5.2.1** | **Over/under voltage**<br>When the interface voltage deviates outside the conditions specified in Table 2, the photovoltaic system shall cease to energize the utility distribution system. This applies to any phase of a multiphase system.<br>All discussions regarding system voltage refer to the local nominal voltage. The system shall sense abnormal voltage and respond. The following conditions should be met, with voltages in RMS and measured at the point of utility connection.<br>(see clause 5.2.1 Table 2 – Response to abnormal voltages)<br>The purpose of the allowed time delay is to ride through short-term disturbances to avoid excessive nuisance tripping. The unit does not have to cease to energize if the voltage returns to the normal utility continuous operation condition within the specified trip time. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See table 5.2.1 | **P** |

| IEC61727:2004 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Result – Remark | Verdict |
| **SECTION 5: Personnel safety and equipment protection** | | | |
| **5.2.2** | **Over/under frequency**<br>When the utility frequency deviates outside the specified conditions the photovoltaic system shall cease to energize the utility line. The unit does not have to cease to energize if the frequency returns to the normal utility continuous operation condition within the specified trip time.<br>When the utility frequency is outside the range of ±1 Hz, the system shall cease to energize the utility line within 0,2 s. The purpose of the allowed range and time delay is to allow continued operation for short-term disturbances and to avoid excessive nuisance tripping in weak-utility system conditions. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See table 5.2.2 | **P** |
| **5.3** | **Islanding protection**<br>The PV system must cease to energize the utility line within 2 s of loss of utility. | The following deviations were used:<br>Provincial Electricity Authority (PEA:2016)<br><br>See table 6.1 | **P** |
| **5.4** | **Response to utility recovery**<br>Following an out-of-range utility condition that has caused the photovoltaic system to cease energizing, the photovoltaic system shall not energize the utility line for 20 s to 5 min after the utility service voltage and frequency have recovered to within the specified ranges**.** | See table 5.2.1 and 5.2.2 | **P** |
| **5.5** | **Earthing**<br>The utility interface equipment shall be earthed/grounded in accordance with IEC 60364-7-712. | Stated in the manual. | **P** |
| **5.6** | **Short circuit protection**<br>The photovoltaic system shall have short-circuit protection in accordance with IEC 60364-7-712. | Stated in the manual. | **P** |
| **5.7** | **Isolation and switching**<br>A method of isolation and switching shall be provided in accordance with IEC 60364-7-712. | Stated in the manual. | **P** |

**Test overview:**

| IEC 61727:2004 | | |
|---|---|---|
| **Clause** | **Type Test** | **Result** |
| 4 | Type test: | |
| 4.3 | Voltage Fluctuations and Flicker (see Annex 1 EMC Report) | **P** |
| 4.4 | Monitoring of DC-Injection | **P** |
| 4.5 | Normal frequency operating range (see 5.2.2 below) | **P** |
| 4.6 | Harmonics and waveform distortion | **P** |
| 4.7 | Power factor | **P** |
| 5.2.1 | Voltage monitoring | **P** |
| 5.2.2 | Frequency monitoring | **P** |

| IEC 62116:2008 | | |
|---|---|---|
| **Clause** | **Type Test** | **Result** |
| 6.1 | Islanding protection according table 6 - Load imbalance (real, reactive load) for test condition A (EUT ouput = 100%) | **P** |
| 6.1 | Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %) | **P** |
| 6.1 | Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %) | **P** |

| Deviations for Thailand according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016) | | |
|---|---|---|
| **Clause** | **Type Test** | **Result** |
| 3.4 | Reactive power control | |
| 3.4.1, 8.1.2 | A fixed displacement factor cosφ | **P** |
| 3.4.2, 8.1.2 | A variable reactive power depending on the voltage Q(U) | **N/A** |
| 3.5, 12.1 | Active power control | **P** |
| 3.6, 12.2 | Low voltage fault ride through capability | **N/A** |

# Test Results

| **4.3 Voltage fluctuation and flicker**<br>**3.2, 8.3 Voltage Fluctuation Regulation (PEA 2016)** | | | | **P** |
|---|---|---|---|---|
| **Test conditions:** | Maximum permissible voltage fluctuation (expressed as a percentage of nominal voltage at 100 % power) and flicker as per EN 61000-3-11 | | | |
| | **Starting** | **Stopping** | **Running** | |
| **Limit** | 3,3% | 3,3% | $P_{st}$=1,0 | $P_{lt}$=0,65 |
| **Test value** | * | * | * | * |
| **inverter >16A** | | | | |
| **Limit** | dc% = 3,3 | | $P_{st}$=1,0 | $P_{lt}$=0,65 |
| **Test value** | See below | | | |

```
Volt Range    300V/50Hz          Element1 Judgement: Pass
Un   (U1)     219.964 V          Total    Judgement: Pass
Freq(U1)       49.998 Hz         (Element1)
```

| | dc[%] | dmax[%] | d(t)[ms] | Pst | Plt |
|---|---|---|---|---|---|
| Limit | 3.30 | 4.00 | 500<br>3.30(%) | 1.00 | 0.65<br>N:12 |
| No. 1 | 0.55 Pass | 0.67 Pass | 0 Pass | 0.10 Pass | |
| 2 | 0.58 Pass | 0.66 Pass | 0 Pass | 0.10 Pass | |
| 3 | 0.57 Pass | 0.65 Pass | 0 Pass | 0.10 Pass | |
| 4 | 0.55 Pass | 0.61 Pass | 0 Pass | 0.10 Pass | |
| 5 | 0.55 Pass | 0.65 Pass | 0 Pass | 0.10 Pass | |
| 6 | 0.56 Pass | 0.64 Pass | 0 Pass | 0.10 Pass | |
| 7 | 0.56 Pass | 0.66 Pass | 0 Pass | 0.10 Pass | |
| 8 | 0.57 Pass | 0.63 Pass | 0 Pass | 0.10 Pass | |
| 9 | 0.54 Pass | 0.64 Pass | 0 Pass | 0.10 Pass | |
| 10 | 0.55 Pass | 0.62 Pass | 0 Pass | 0.10 Pass | |
| 11 | 0.58 Pass | 0.65 Pass | 0 Pass | 0.10 Pass | |
| 12 | 0.58 Pass | 0.64 Pass | 0 Pass | 0.10 Pass | |
| Result | Pass | Pass | Pass | Pass | 0.10 Pass |

**Note:**
*The stationary deviance of dc% is more relevant than the dynamic deviance of $d_{max}$ at starting and stopping.

Mains Impedance according EN61000-3-11: **$R_{max}$ = 0,24Ω; j$X_{max}$= 0,15Ω @50Hz ($|Z_{max}|$ = 0,283 Ω)**
**for single phase inverter use also** **$R_n$ = 0,16Ω; j$X_n$= 0,1Ω**

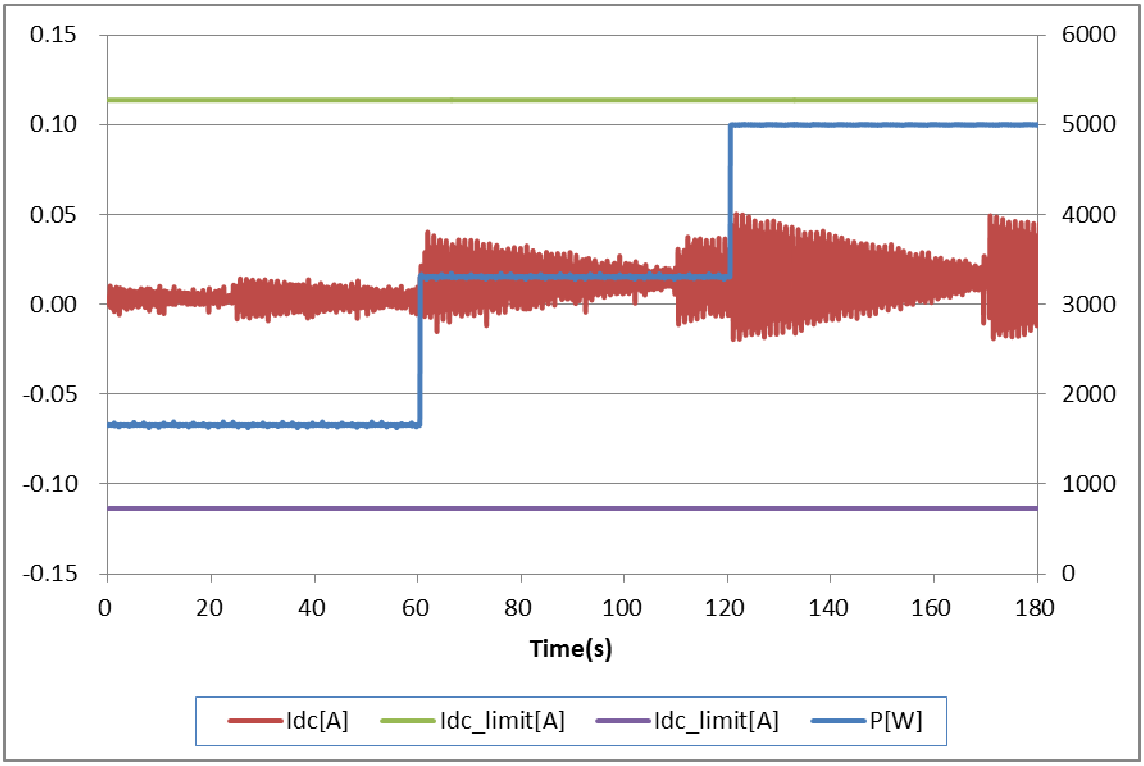
Calculation of the maximum permissible grid impedance at the point of common coupling based on $d_c$:
$Z_{max} = Z_{ref} * 3,3\% / d_c(P_n)$

The tests should be based on the limits of the EN 61000-3-11 for more than 16A.

| 4.4 Monitoring of Permanent DC-Injection<br>3.3, 8.5 Direct Current Dispatch to the Power Network System (PEA:2016) | P |
|---|---|

| **PEA Limit:** | **0,5% of $I_{nom}$ : 114mA** | | |
|---|---|---|---|
| **Output power:** | 33% | 66% | 100% |
| Max. test value (mA): | 14 | 40 | 50 |
| Mean test value(mA) : | 3 | 14 | 14 |

Diagram of permanent DC-injection




**Note:**

| 4.6 Harmonic Current Limit Test<br>the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016) | P |
|---|---|

| 33% Output Power | |
|---|---|
| **Watts (kW)** | 1,663 |
| **VA (kVA)** | 1,666 |
| **Vrms (V)** | 220,08 |
| **Arms (A)** | 7,570 |
| **PF** | 0,9979 |
| **Frequency (Hz)** | 50,00 |
| **THD50 (%)** | 0,643 |

| Harmonics | Current Magnitude [A] | % of Rated Current | Phase | Harmonic Current Limits [%] |
|---|---|---|---|---|
| 1st | 7,5490 | 33,2155 | Single Phase | -- |
| 2nd | 0,0059 | 0,0259 | Single Phase | 1 |
| 3rd | 0,1322 | 0,5818 | Single Phase | 4 |
| 4th | 0,0019 | 0,0085 | Single Phase | 1 |
| 5th | 0,0534 | 0,2352 | Single Phase | 4 |
| 6th | 0,0016 | 0,0072 | Single Phase | 1 |
| 7th | 0,0241 | 0,1061 | Single Phase | 4 |
| 8th | 0,0013 | 0,0057 | Single Phase | 1 |
| 9th | 0,0129 | 0,0566 | Single Phase | 4 |
| 10th | 0,0017 | 0,0074 | Single Phase | 1 |
| 11th | 0,0060 | 0,0266 | Single Phase | 2 |
| 12th | 0,0016 | 0,0070 | Single Phase | 0,5 |
| 13th | 0,0029 | 0,0126 | Single Phase | 2 |
| 14th | 0,0016 | 0,0069 | Single Phase | 0,5 |
| 15th | 0,0029 | 0,0126 | Single Phase | 2 |
| 16th | 0,0017 | 0,0075 | Single Phase | 0,5 |
| 17th | 0,0028 | 0,0125 | Single Phase | 1,5 |
| 18th | 0,0015 | 0,0068 | Single Phase | 0,375 |
| 19th | 0,0032 | 0,0143 | Single Phase | 1,5 |
| 20th | 0,0015 | 0,0065 | Single Phase | 0,375 |
| 21th | 0,0039 | 0,0172 | Single Phase | 1,5 |
| 22th | 0,0014 | 0,0061 | Single Phase | 0,375 |
| 23th | 0,0031 | 0,0137 | Single Phase | 0,6 |
| 24th | 0,0013 | 0,0056 | Single Phase | 0,15 |
| 25th | 0,0022 | 0,0099 | Single Phase | 0,6 |
| 26th | 0,0013 | 0,0057 | Single Phase | 0,15 |
| 27th | 0,0026 | 0,0114 | Single Phase | 0,6 |
| 28th | 0,0010 | 0,0045 | Single Phase | 0,15 |
| 29th | 0,0022 | 0,0095 | Single Phase | 0,6 |
| 30th | 0,0010 | 0,0045 | Single Phase | 0,15 |
| 31th | 0,0016 | 0,0070 | Single Phase | 0,6 |
| 32th | 0,0011 | 0,0047 | Single Phase | 0,15 |
| 33th | 0,0021 | 0,0094 | Single Phase | 0,6 |
| 34th | 0,0012 | 0,0054 | Single Phase | 0,15 |

| | | | | |
|---|---|---|---|---|
| 35th | 0,0024 | 0,0106 | Single Phase | 0,3 |
| 36th | 0,0013 | 0,0057 | Single Phase | 0,075 |
| 37th | 0,0026 | 0,0114 | Single Phase | 0,3 |
| 38th | 0,0016 | 0,0069 | Single Phase | 0,075 |
| 39th | 0,0031 | 0,0136 | Single Phase | 0,3 |
| 40th | 0,0016 | 0,0070 | Single Phase | 0,075 |

| **66% Output Power** | |
|---|---|
| **Watts (kW)** | 3,307 |
| **VA (kVA)** | 3,309 |
| **Vrms (V)** | 220,12 |
| **Arms (A)** | 15,034 |
| **PF** | 0,9992 |
| **Frequency (Hz)** | 50,00 |
| **THD50 (%)** | 0,706 |

| **Harmonics** | **Current Magnitude [A]** | **% of Rated Current** | **Phase** | **Harmonic Current Limits [%]** |
|---|---|---|---|---|
| 1st | 15,0217 | 66,0955 | Single Phase | -- |
| 2nd | 0,0125 | 0,0552 | Single Phase | 1 |
| 3rd | 0,1479 | 0,6506 | Single Phase | 4 |
| 4th | 0,0036 | 0,0159 | Single Phase | 1 |
| 5th | 0,0518 | 0,2281 | Single Phase | 4 |
| 6th | 0,0027 | 0,0119 | Single Phase | 1 |
| 7th | 0,0234 | 0,1030 | Single Phase | 4 |
| 8th | 0,0021 | 0,0093 | Single Phase | 1 |
| 9th | 0,0090 | 0,0395 | Single Phase | 4 |
| 10th | 0,0018 | 0,0081 | Single Phase | 1 |
| 11th | 0,0040 | 0,0178 | Single Phase | 2 |
| 12th | 0,0018 | 0,0081 | Single Phase | 0,5 |
| 13th | 0,0029 | 0,0128 | Single Phase | 2 |
| 14th | 0,0018 | 0,0077 | Single Phase | 0,5 |
| 15th | 0,0051 | 0,0226 | Single Phase | 2 |
| 16th | 0,0018 | 0,0079 | Single Phase | 0,5 |
| 17th | 0,0060 | 0,0265 | Single Phase | 1,5 |
| 18th | 0,0017 | 0,0076 | Single Phase | 0,375 |
| 19th | 0,0061 | 0,0269 | Single Phase | 1,5 |
| 20th | 0,0016 | 0,0071 | Single Phase | 0,375 |
| 21th | 0,0067 | 0,0297 | Single Phase | 1,5 |
| 22th | 0,0015 | 0,0066 | Single Phase | 0,375 |
| 23th | 0,0067 | 0,0296 | Single Phase | 0,6 |
| 24th | 0,0015 | 0,0068 | Single Phase | 0,15 |
| 25th | 0,0068 | 0,0299 | Single Phase | 0,6 |
| 26th | 0,0013 | 0,0056 | Single Phase | 0,15 |
| 27th | 0,0059 | 0,0260 | Single Phase | 0,6 |
| 28th | 0,0012 | 0,0053 | Single Phase | 0,15 |
| 29th | 0,0056 | 0,0247 | Single Phase | 0,6 |
| 30th | 0,0009 | 0,0040 | Single Phase | 0,15 |
| 31th | 0,0051 | 0,0226 | Single Phase | 0,6 |

| | | | | |
|---|---|---|---|---|
| 32th | 0,0012 | 0,0051 | Single Phase | 0,15 |
| 33th | 0,0045 | 0,0198 | Single Phase | 0,6 |
| 34th | 0,0012 | 0,0051 | Single Phase | 0,15 |
| 35th | 0,0049 | 0,0213 | Single Phase | 0,3 |
| 36th | 0,0012 | 0,0051 | Single Phase | 0,075 |
| 37th | 0,0046 | 0,0202 | Single Phase | 0,3 |
| 38th | 0,0013 | 0,0057 | Single Phase | 0,075 |
| 39th | 0,0042 | 0,0185 | Single Phase | 0,3 |
| 40th | 0,0015 | 0,0068 | Single Phase | 0,075 |

| **100% Output Power** | |
|---|---|
| **Watts (kW)** | 4,999 |
| **VA (kVA)** | 5,002 |
| **Vrms (V)** | 220,50 |
| **Arms (A)** | 22,685 |
| **PF** | 0,9994 |
| **Frequency (Hz)** | 50,00 |
| **THD50 (%)** | 0,762 |

| **Harmonics** | **Current Magnitude [A]** | **% of Rated Current** | **Phase** | **Harmonic Current Limits [%]** |
|---|---|---|---|---|
| 1st | 22,6977 | 99,8700 | Single Phase | -- |
| 2nd | 0,0207 | 0,0911 | Single Phase | 1 |
| 3rd | 0,1578 | 0,6945 | Single Phase | 4 |
| 4th | 0,0103 | 0,0455 | Single Phase | 1 |
| 5th | 0,0536 | 0,2359 | Single Phase | 4 |
| 6th | 0,0071 | 0,0310 | Single Phase | 1 |
| 7th | 0,0145 | 0,0637 | Single Phase | 4 |
| 8th | 0,0048 | 0,0211 | Single Phase | 1 |
| 9th | 0,0102 | 0,0448 | Single Phase | 4 |
| 10th | 0,0042 | 0,0184 | Single Phase | 1 |
| 11th | 0,0045 | 0,0199 | Single Phase | 2 |
| 12th | 0,0030 | 0,0133 | Single Phase | 0,5 |
| 13th | 0,0043 | 0,0191 | Single Phase | 2 |
| 14th | 0,0024 | 0,0107 | Single Phase | 0,5 |
| 15th | 0,0081 | 0,0357 | Single Phase | 2 |
| 16th | 0,0026 | 0,0115 | Single Phase | 0,5 |
| 17th | 0,0091 | 0,0399 | Single Phase | 1,5 |
| 18th | 0,0024 | 0,0104 | Single Phase | 0,375 |
| 19th | 0,0110 | 0,0482 | Single Phase | 1,5 |
| 20th | 0,0020 | 0,0089 | Single Phase | 0,375 |
| 21th | 0,0105 | 0,0463 | Single Phase | 1,5 |
| 22th | 0,0019 | 0,0085 | Single Phase | 0,375 |
| 23th | 0,0114 | 0,0503 | Single Phase | 0,6 |
| 24th | 0,0021 | 0,0091 | Single Phase | 0,15 |
| 25th | 0,0127 | 0,0559 | Single Phase | 0,6 |
| 26th | 0,0017 | 0,0075 | Single Phase | 0,15 |
| 27th | 0,0103 | 0,0452 | Single Phase | 0,6 |
| 28th | 0,0014 | 0,0061 | Single Phase | 0,15 |

| | | | | |
|---|---|---|---|---|
| 29th | 0,0102 | 0,0448 | Single Phase | 0,6 |
| 30th | 0,0013 | 0,0055 | Single Phase | 0,15 |
| 31th | 0,0105 | 0,0464 | Single Phase | 0,6 |
| 32th | 0,0012 | 0,0051 | Single Phase | 0,15 |
| 33th | 0,0096 | 0,0421 | Single Phase | 0,6 |
| 34th | 0,0013 | 0,0055 | Single Phase | 0,15 |
| 35th | 0,0095 | 0,0419 | Single Phase | 0,3 |
| 36th | 0,0013 | 0,0058 | Single Phase | 0,075 |
| 37th | 0,0089 | 0,0393 | Single Phase | 0,3 |
| 38th | 0,0014 | 0,0063 | Single Phase | 0,075 |
| 39th | 0,0082 | 0,0361 | Single Phase | 0,3 |
| 40th | 0,0018 | 0,0080 | Single Phase | 0,075 |
| **Note:** The harmonics are tested and evaluated according the IEEE1547.1-2005 clause 5.11.1 according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016). | | | | |

| 4.6 Harmonic Voltage Limit Test<br>the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016) | P |
|---|---|

| Vrms (V) | 220,17 |
|---|---|
| Frequency (Hz) | 50,00 |
| THD50 (%) | 0,033 |

| Harmonics | Voltage Magnitude [V] | % of Rated Voltage | Phase | Limits [%] |
|---|---|---|---|---|
| 2nd | 0,0331 | 0,0150 | Single Phase | 0,2 |
| 3rd | 0,0308 | 0,0140 | Single Phase | 4 |
| 4th | 0,0184 | 0,0083 | Single Phase | 0,2 |
| 5th | 0,0122 | 0,0055 | Single Phase | 4 |
| 6th | 0,0177 | 0,0080 | Single Phase | 0,2 |
| 7th | 0,0108 | 0,0049 | Single Phase | 4 |
| 8th | 0,0033 | 0,0015 | Single Phase | 0,2 |
| 9th | 0,0180 | 0,0082 | Single Phase | 2 |
| 10th | 0,0079 | 0,0036 | Single Phase | 0,2 |
| 11th | 0,0120 | 0,0055 | Single Phase | 0,1 |
| 12th | 0,0034 | 0,0015 | Single Phase | 0,1 |
| 13th | 0,0088 | 0,0040 | Single Phase | 0,1 |
| 14th | 0,0031 | 0,0014 | Single Phase | 0,1 |
| 15th | 0,0050 | 0,0023 | Single Phase | 0,1 |
| 16th | 0,0042 | 0,0019 | Single Phase | 0,1 |
| 17th | 0,0095 | 0,0043 | Single Phase | 0,1 |
| 18th | 0,0032 | 0,0014 | Single Phase | 0,1 |
| 19th | 0,0100 | 0,0046 | Single Phase | 0,1 |
| 20th | 0,0025 | 0,0011 | Single Phase | 0,1 |
| 21th | 0,0085 | 0,0039 | Single Phase | 0,1 |
| 22th | 0,0039 | 0,0018 | Single Phase | 0,1 |
| 23th | 0,0120 | 0,0055 | Single Phase | 0,1 |
| 24th | 0,0052 | 0,0023 | Single Phase | 0,1 |
| 25th | 0,0136 | 0,0062 | Single Phase | 0,1 |
| 26th | 0,0026 | 0,0012 | Single Phase | 0,1 |
| 27th | 0,0080 | 0,0037 | Single Phase | 0,1 |
| 28th | 0,0027 | 0,0012 | Single Phase | 0,1 |
| 29th | 0,0054 | 0,0025 | Single Phase | 0,1 |
| 30th | 0,0040 | 0,0018 | Single Phase | 0,1 |
| 31th | 0,0077 | 0,0035 | Single Phase | 0,1 |
| 32th | 0,0035 | 0,0016 | Single Phase | 0,1 |
| 33th | 0,0078 | 0,0035 | Single Phase | 0,1 |
| 34th | 0,0019 | 0,0009 | Single Phase | 0,1 |
| 35th | 0,0083 | 0,0038 | Single Phase | 0,1 |
| 36th | 0,0031 | 0,0014 | Single Phase | 0,1 |
| 37th | 0,0075 | 0,0034 | Single Phase | 0,1 |
| 38th | 0,0038 | 0,0017 | Single Phase | 0,1 |
| 39th | 0,0081 | 0,0037 | Single Phase | 0,1 |
| 40th | 0,0042 | 0,0019 | Single Phase | 0,1 |

**Note:** The harmonics are tested and evaluated according the IEEE1547.1-2005 clause 5.11.1 according the

grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016).

| **4.7 Power factor(PEA)**<br>**3.1, 8.4 Harmonic Regulation (PEA: 2016)** | | | | | **P** |
|---|---|---|---|---|---|
| **Test conditions:** | | | | | |
| **Output power [kW]**<br>**Test AC voltage [V]** | **~10%** | **~25%** | **~50%** | **~75%** | **~100%** |
| **--** | -- | -- | -- | -- | -- |

**Note:**

The PV system shall have a lagging power factor greater than 0,95 when the output is greater than 50% of the rated inverter output power.

The letter “i” is short for “inductive” and indicates inductive power factor. In case of capacitive power factor the letter “c” is used instead.

Test result refer to table 3.4.1, 8.1.2 1.

| **5.2.1 Voltage monitoring**<br>**3.7, 12.3 Under and Over Voltage Protection (PEA:2016)**<br>**3.10, 12.5 Response to utility recovery (PEA:2016)** | **P** |
|---|---|

**First Level (Phase to Neutral)**

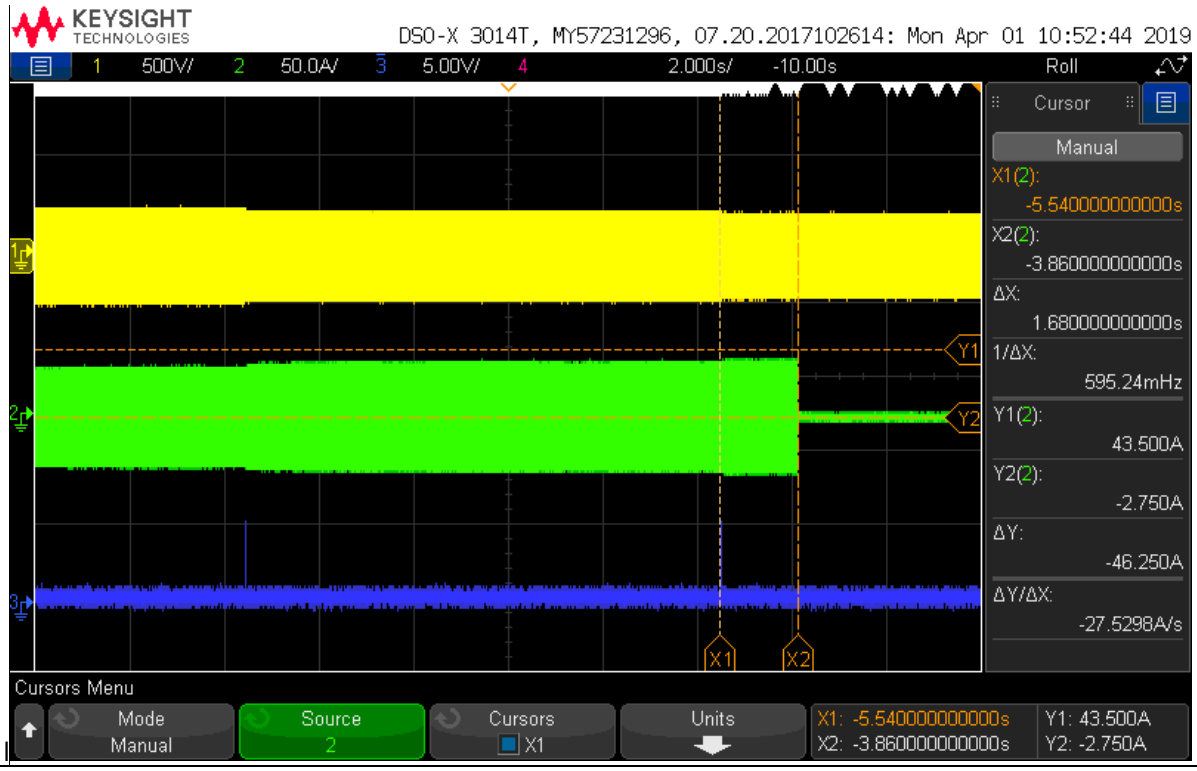
| **Test conditions:** | Output power: 4,9KW<br>Frequency: 50Hz | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Under Voltage** | | | | | **Over Voltage** | | | | |
| | | Voltage [V] | | | | | Voltage [V] | | | |
| Set value | | **198V** | | | | | **242V** | | | |
| Measured trip value | | All | L1 | L2 | L3 | | All | L1 | L2 | L3 |
| | | -- | 197,9 | -- | -- | | -- | 242,1 | -- | -- |
| | | -- | 197,9 | -- | -- | | -- | 242,1 | -- | -- |
| Parameter | | Time [s] | | | | | Time [s] | | | |
| Limit | | **<= 2,0s** | | | | | **<= 1,0s** | | | |
| Disconnetion time | 220V<br>to 203V<br>(4s min)<br>to 193V | All | L1 | L2 | L3 | 220V<br>to 237V<br>(2s min)<br>to 247V | All | L1 | L2 | L3 |
| | | -- | 1,680 | -- | -- | | -- | 0,720 | -- | -- |
| | | -- | 1,640 | -- | -- | | -- | 0,612 | -- | -- |
| Reconnection time | 20s - 5min | 64 s | | | | 20s - 5min | 67 s | | | |

| **Second Level (Phase to Neutral)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Test conditions:** | Output power: 4,9KW<br>Frequency: 50Hz | | | | | | | | | |
| | **Under Voltage** | | | | | **Over Voltage** | | | | |
| Parameter | | Voltage [V] | | | | | Voltage [V] | | | |
| Set value | | **110V** | | | | | **264V** | | | |
| Measured trip value | | All | L1 | L2 | L3 | | All | L1 | L2 | L3 |
| | | -- | 109,8 | -- | -- | | -- | 264,4 | -- | -- |
| | | -- | 109,8 | -- | -- | | -- | 264,4 | -- | -- |
| Parameter | | Time [ms] | | | | | Time [ms] | | | |
| Limit | | **<= 300ms** | | | | | **<= 160ms** | | | |
| Disconnection time | 220V to 203V (0.6s min) to 105V | All | L1 | L2 | L3 | 220V to 237V (0.32s min) to 269V | All | L1 | L2 | L3 |
| | | -- | 180 | -- | -- | | -- | 90 | -- | -- |
| | | -- | 117 | -- | -- | | -- | 67 | -- | -- |
| Reconnection time | 20s - 5min | 70 s | | | | 20s - 5min | 69 s | | | |

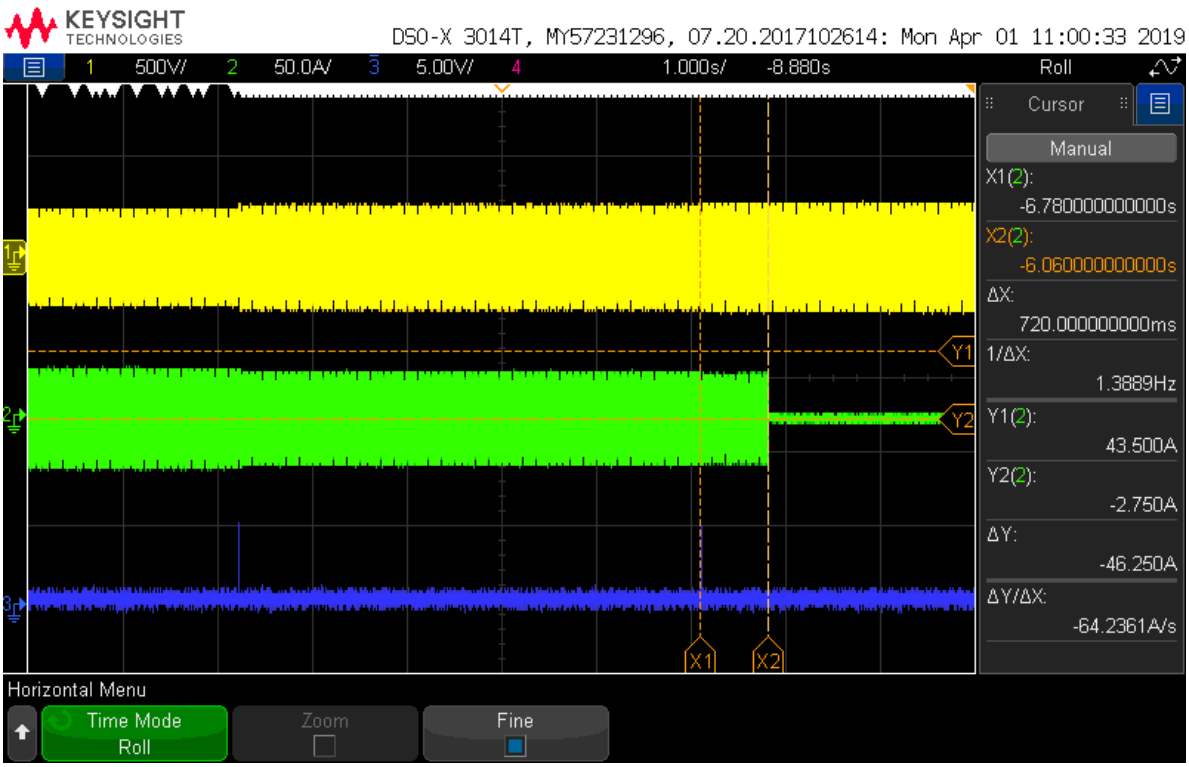
**Note:**
The tests are according PEA 8/9/2556. The voltage settings of the EUT are set for the tests as stated to 198V, 110V for undervoltage and 242V, 264V for overvoltage.

Response to utility recovery is according to the appropriate IEEE or IEC standard test methods.

**Under Voltage First Level single phase**

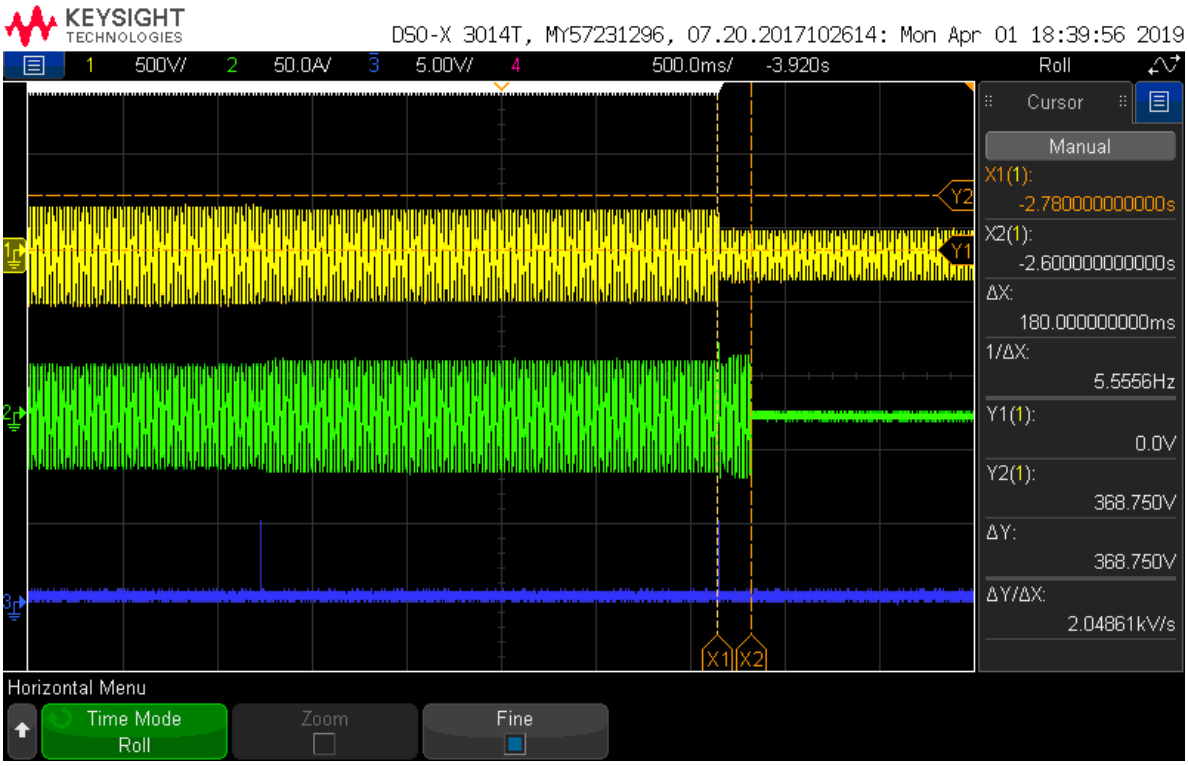



**Over voltage First Level single phase**

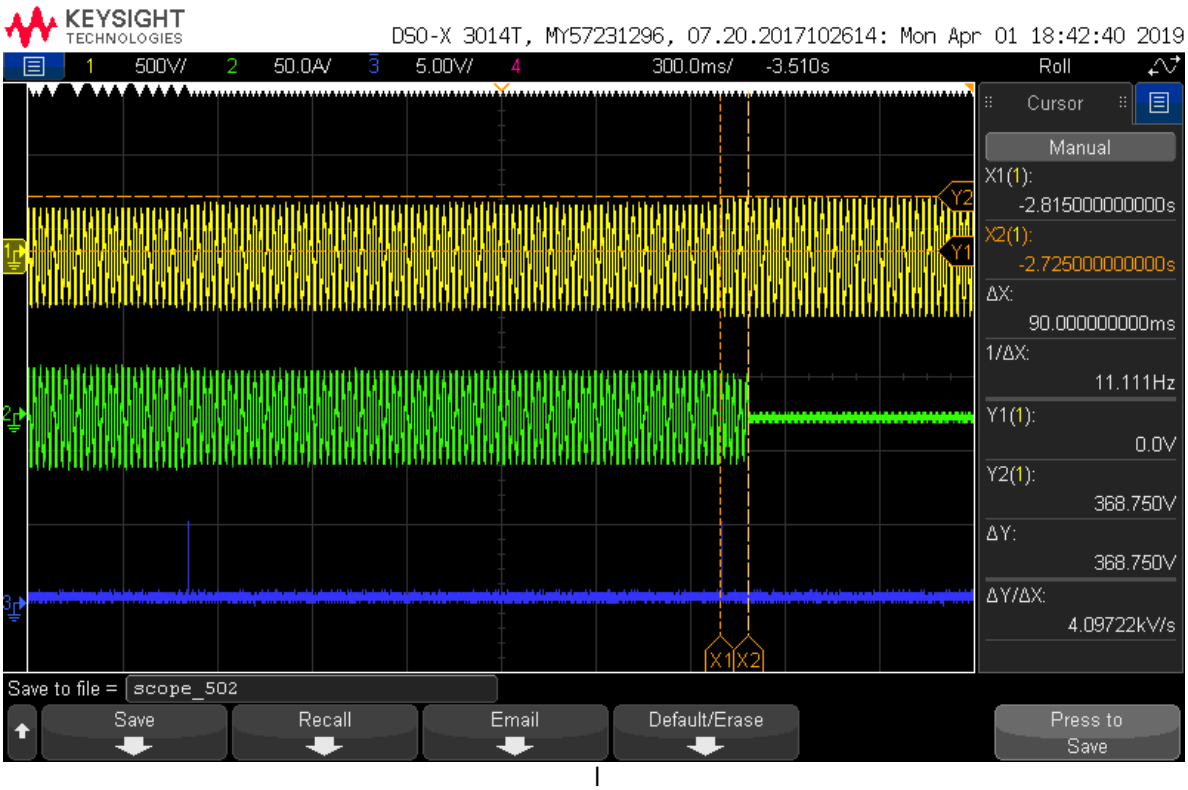



**Note:** CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

**Under Voltage Second Level single phase**

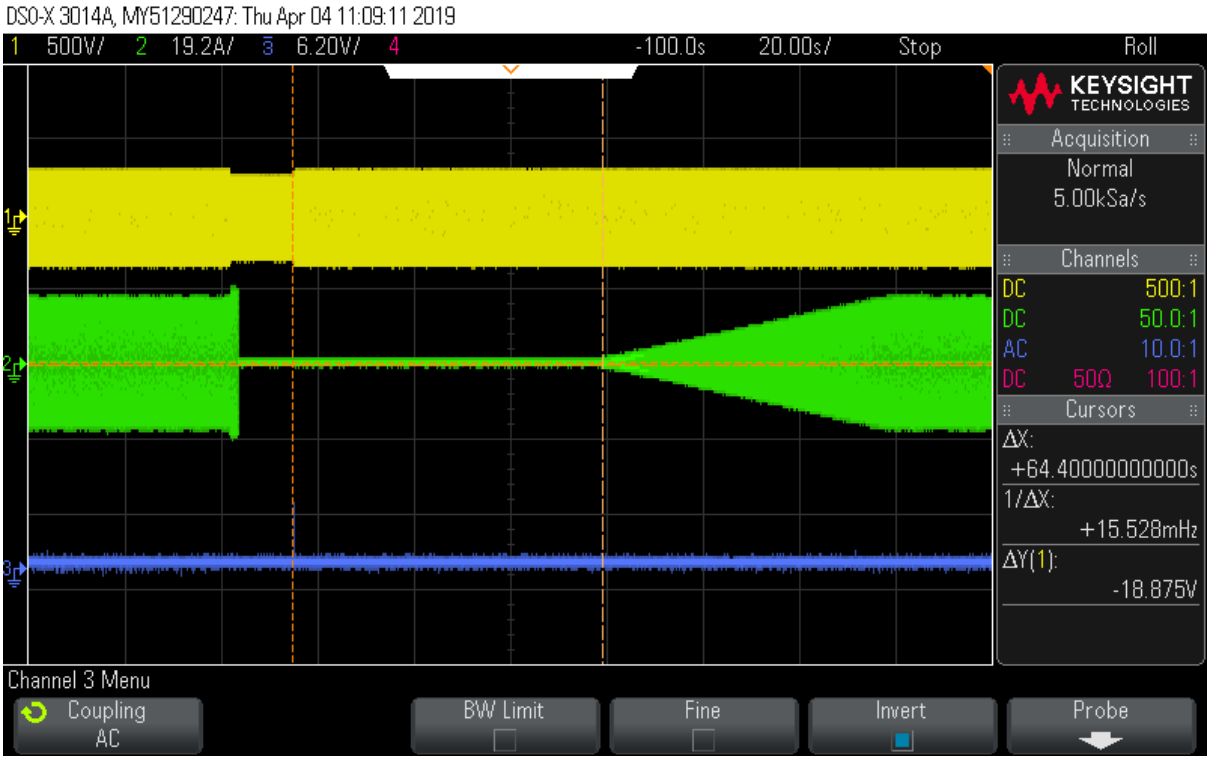



**Over voltage Second Level single phase**

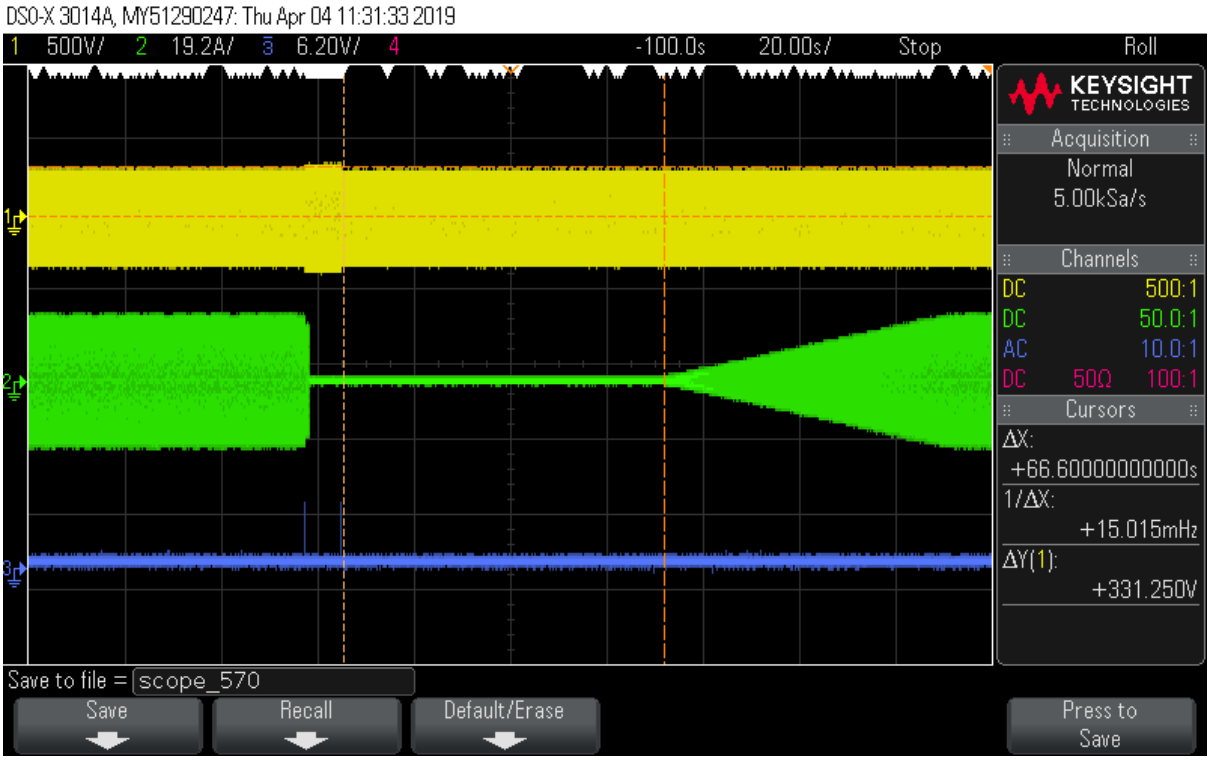



**Note:** CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

**Reconnection after Under Voltage First Level**

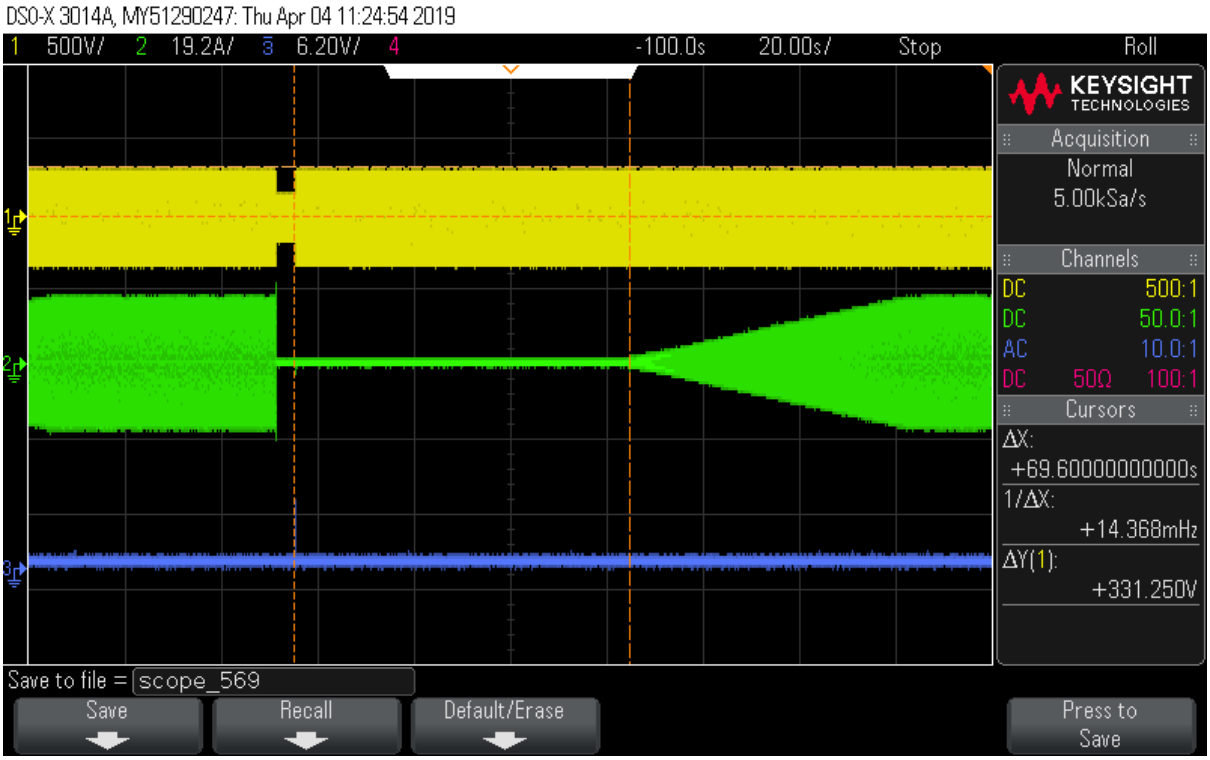



**Reconnection after Over Voltage First Level**

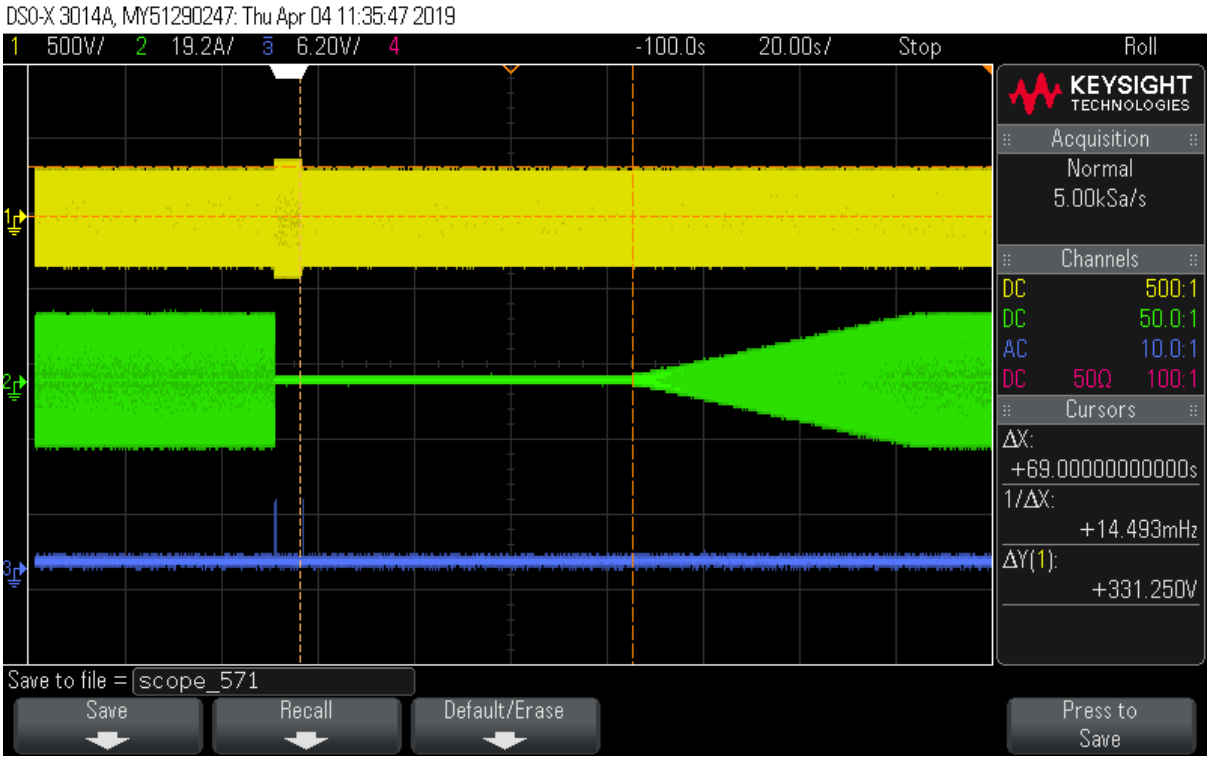



**Note:** CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

**Reconnection after Under Voltage Second Level**



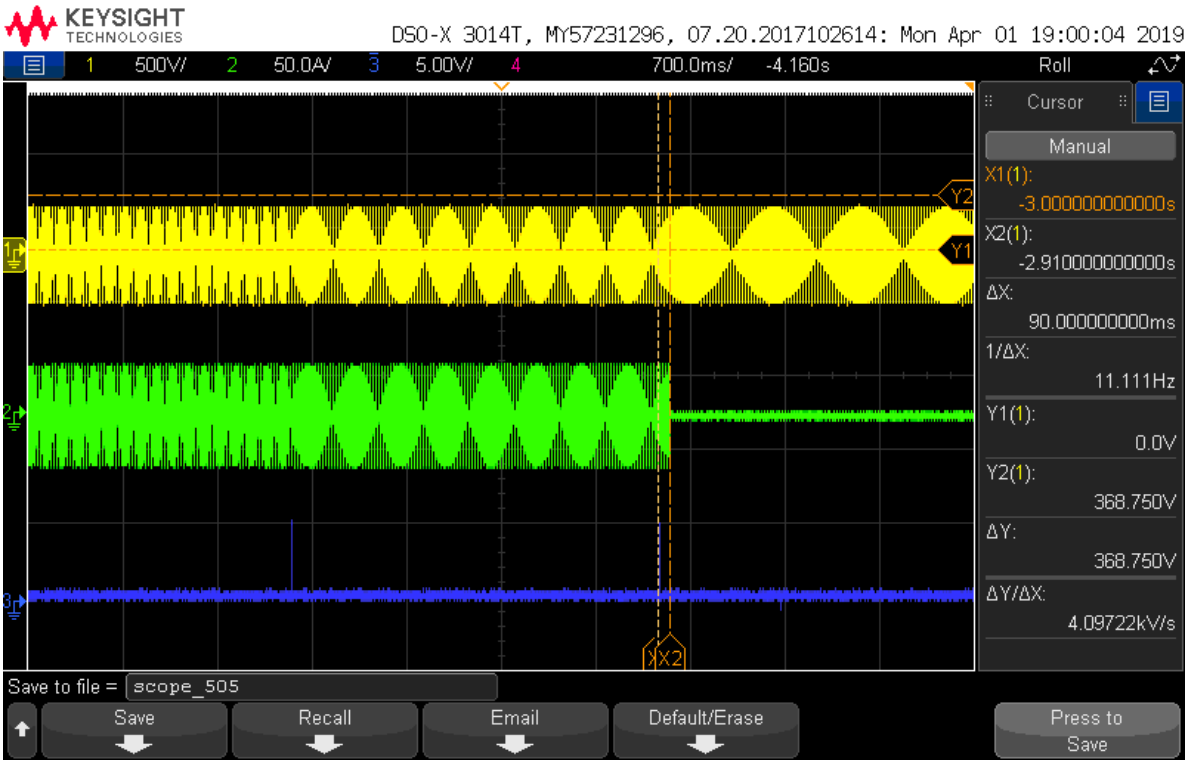

**Reconnection after Over Voltage Second Level**



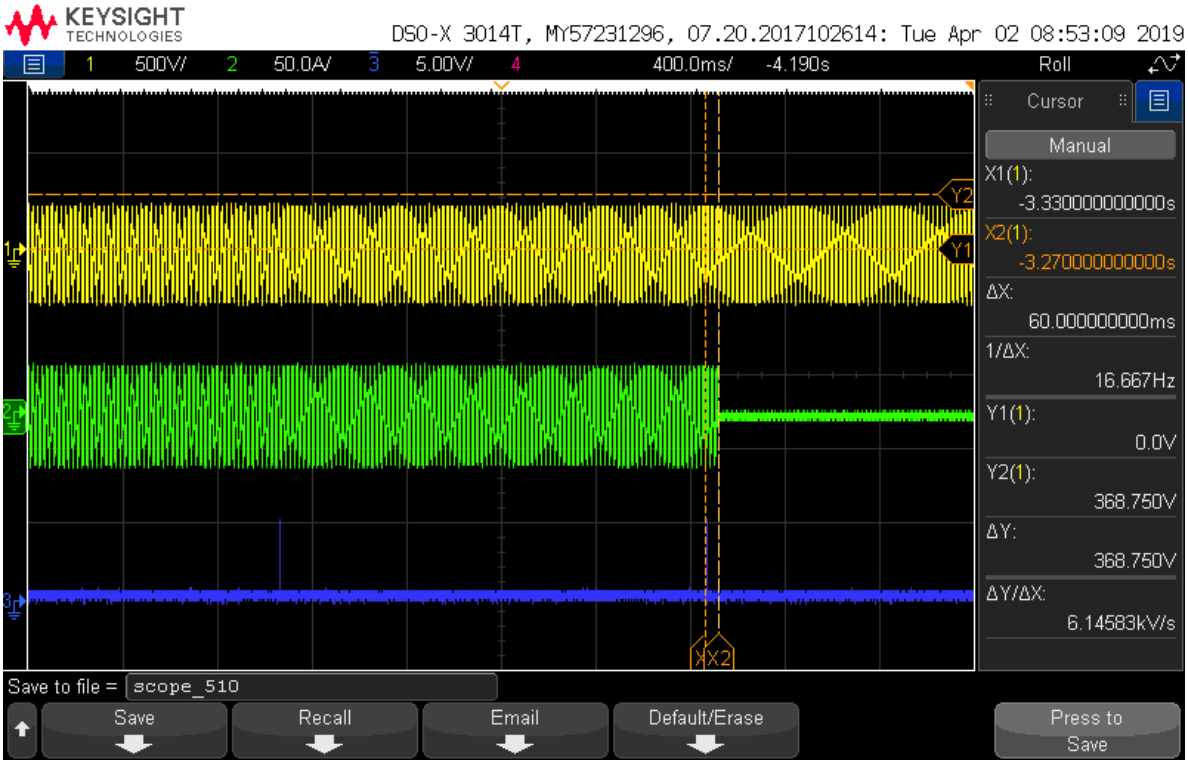

**Note:** CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

| **5.2.2 Frequency monitoring** | | | | | **P** |
|---|---|---|---|---|---|
| **IEC 61727**<br>**8.2 Under and Over Frequency Protection (PEA:2016)**<br>**3.10, 12.5 Response to utility recovery (PEA:2016)** | | | | | |
| **Test conditions:** | Any output power level | | | | |
| | **Under frequency** | | **Over frequency** | | |
| Parameter | | Frequency [Hz] | | Frequency [Hz] | |
| Output Voltage | | $U_N$ | | $U_N$ | |
| Set value | | **47,00Hz** | | **52,00Hz** | |
| Measured trip value(V) | | 46,98 | | 52,01 | |
| | | Time [ms] | | Time [ms] | |
| Limit | | **<= 100ms** | | **<= 100ms** | |
| Disconnection time(ms) | 50,0Hz to 47,2 Hz (0,2s min) to 46,5 Hz | 90 | 50,0 Hz to 51,80 Hz (0,2s min) to 52,5Hz | 60 | |
| Reconnection time (Sec) | 20s – 5min | 70 s | 20s-5min | 65 s | |
| **Note:**<br>The frequency which inverter stops feeding power to electrical system in each test must be in the range of the frequency trip setting +/- 0,1Hz and the time it takes to cut off the power must be within 0.1 second.<br><br>The tests are performed according the IEEE 1547.1-2005, annex A.<br>The reconnection time follows the test procedure of IEEE 1547.1, clause 5.10. | | | | | |

**Under Frequency:**

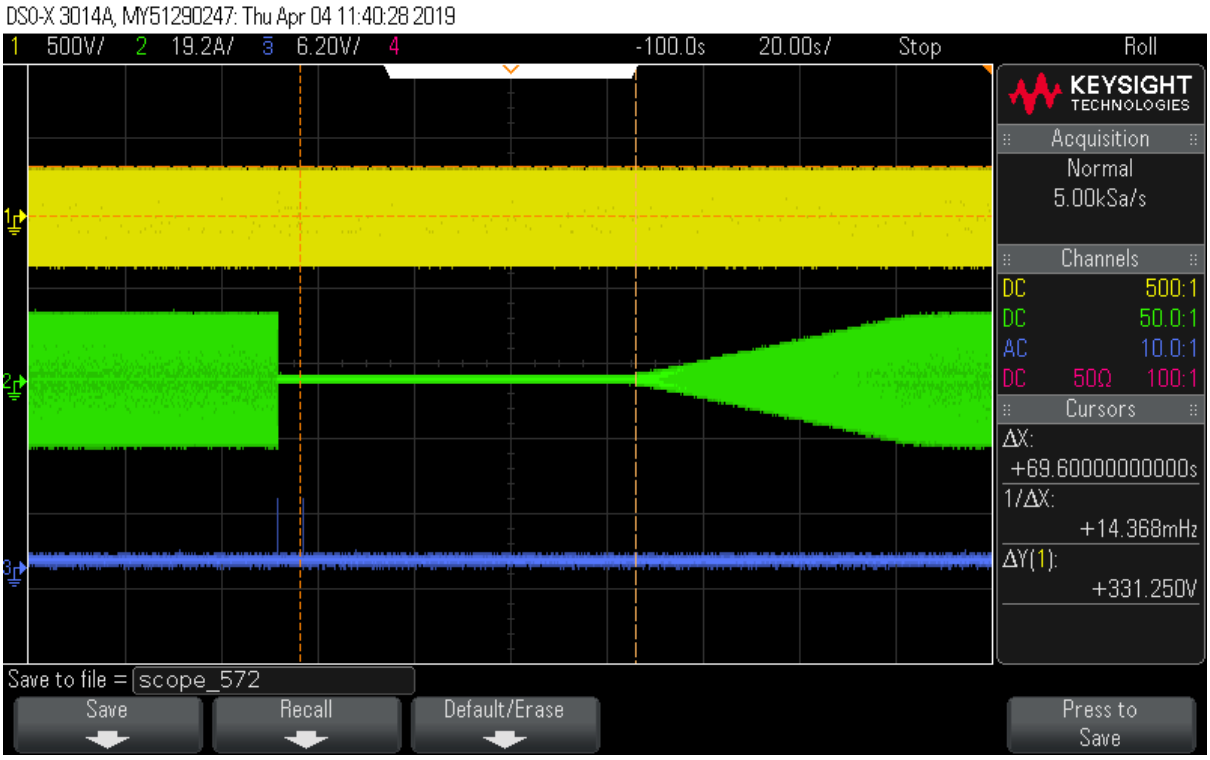



**Over Frequency:**

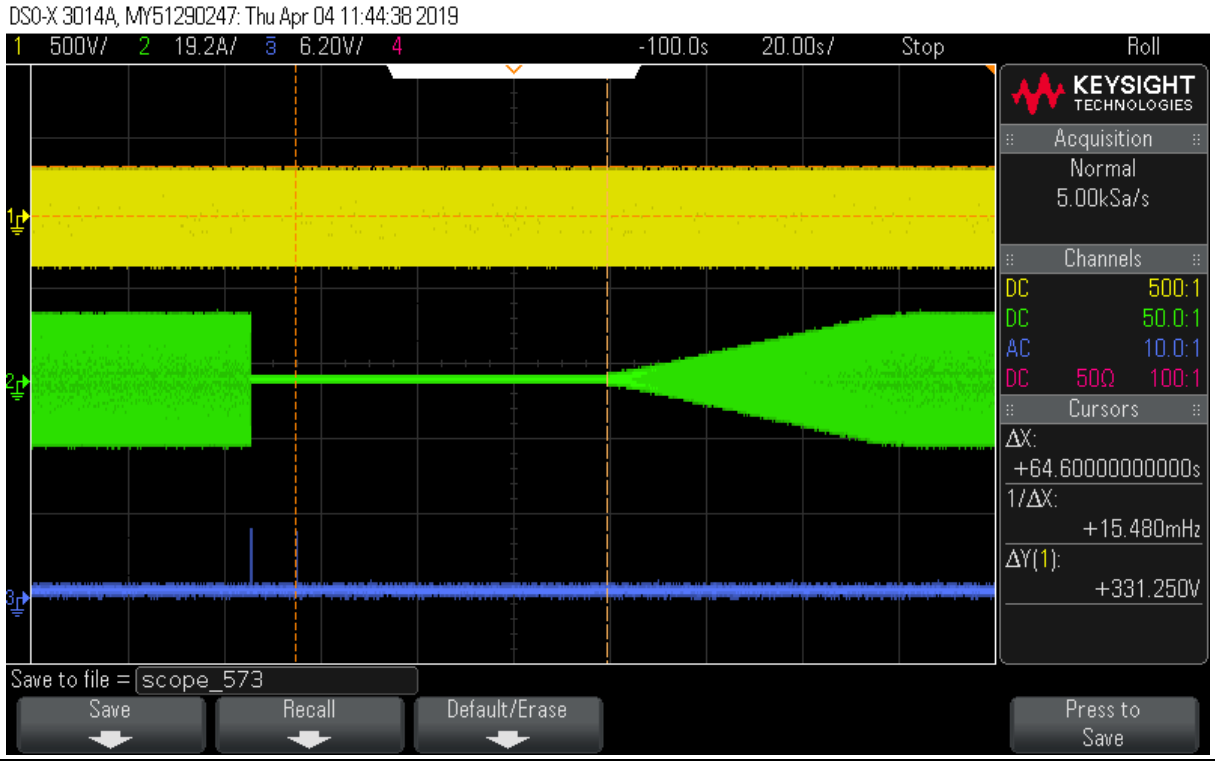



**Note:**
CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

**Reconnection after Under Frequency:**




**Reconnection after Over Frequency:**




**Note:**
CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

**6.1 Islanding protection**
**3.9, 12.4 Anti-Islanding (PEA:2016)**

Test circuit and parameters

| Parameter | Symbol | Units |
|---|---|---|
| **EUT DC Input** | | |
| DC voltage | $V_{DC}$ | V |
| DC Current | $I_{DC}$ | A |
| DC Power | $P_{DC}$ | W |
| **EUT AC ouput** | | |
| AC voltage | $V_{EUT}$ | V |
| AC current | $I_{EUT}$ | A |
| Real power | $P_{EUT}$ | W |
| Reactive power | $Q_{EUT}$ | VAr |
| **Test Load** | | |
| Resistive load current | $I_R$ | A |
| Inductive load current | $I_L$ | A |
| Capacitive load current | $I_C$ | A |
| **AC (utility) power source** | | |
| Utility real power | $P_{AC}$ | W |
| Utility reactive power | $Q_{AC}$ | VAr |
| Utility current | $I_{AC}$ | A |

Block diagram test circuit IEC 62116:2008

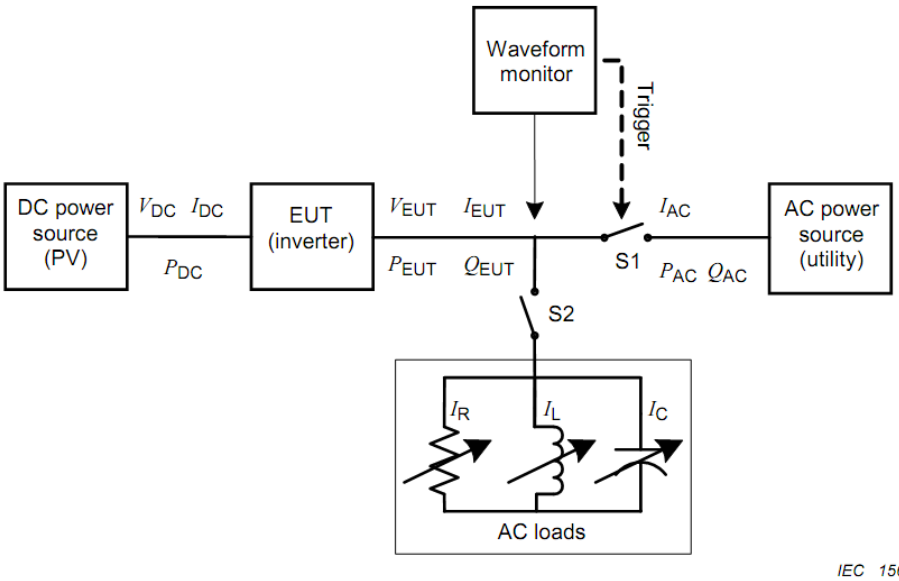



**Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)**

| **6.1 Islanding protection according table 6 - Load imbalance (real, reactive load) for test condition A (EUT ouput = 100%)**<br>**3.9, 12.4 Anti-Islanding (PEA:2016)** | **P** |
|---|---|

| Test conditions | Frequency: 50+/-0,1Hz<br>$U_N$=220+/-3Vac<br>Distortion factor of chokes < 2%<br>Quality = 1 |
|---|---|
| Disconnection limit | 1s |

| No | $P_{EUT}$ 1) (% of EUT rating) | Reactive load (% of $Q_L$ in 6.1.d) 1) | $P_{AC}$ 2) (% of nominal) | $Q_{AC}$ 3) (% of nominal) | Run on Time (ms) | $P_{EUT}$ (W per phase) | Actual $Q_f$ | $V_{DC}$ (V) | Remarks4) |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 100 | 100 | 0 | 0 | 404 | 4980 | 1,003 | 445 | Test A at BL |
| 32 | 100 | 100 | -10 | -10 | 372 | 4980 | 1,057 | 445 | Test A at IB |
| 33 | 100 | 100 | -10 | -5 | 288 | 4980 | 1,086 | 445 | Test A at IB |
| 34 | 100 | 100 | -10 | 0 | 328 | 4980 | 1,114 | 445 | Test A at IB |
| 35 | 100 | 100 | -10 | +5 | 302 | 4980 | 1,142 | 445 | Test A at IB |
| 36 | 100 | 100 | -10 | +10 | 364 | 4980 | 1,169 | 445 | Test A at IB |
| 37 | 100 | 100 | -5 | -10 | 310 | 4980 | 1,002 | 445 | Test A at IB |
| 4 | 100 | 100 | -5 | -5 | 282 | 4980 | 1,029 | 445 | Test A at IB |
| 5 | 100 | 100 | -5 | 0 | 372 | 4980 | 1,056 | 445 | Test A at IB |
| 6 | 100 | 100 | -5 | +5 | 358 | 4980 | 1,082 | 445 | Test A at IB |
| 38 | 100 | 100 | -5 | +10 | 336 | 4980 | 1,107 | 445 | Test A at IB |
| 39 | 100 | 100 | 0 | -10 | 322 | 4980 | 0,952 | 445 | Test A at IB |
| 7 | 100 | 100 | 0 | -5 | 312 | 4980 | 0,978 | 445 | Test A at IB |
| 8 | 100 | 100 | 0 | +5 | 324 | 4980 | 1,028 | 445 | Test A at IB |
| 40 | 100 | 100 | 0 | +10 | 382 | 4980 | 1,052 | 445 | Test A at IB |
| 41 | 100 | 100 | +5 | -10 | 310 | 4980 | 0,906 | 445 | Test A at IB |
| 9 | 100 | 100 | +5 | -5 | 286 | 4980 | 0,931 | 445 | Test A at IB |
| 10 | 100 | 100 | +5 | 0 | 390 | 4980 | 0,955 | 445 | Test A at IB |
| 11 | 100 | 100 | +5 | +5 | 398 | 4980 | 0,979 | 445 | Test A at IB |
| 42 | 100 | 100 | +5 | +10 | 292 | 4980 | 1,002 | 445 | Test A at IB |
| 43 | 100 | 100 | +10 | -10 | 344 | 4980 | 0,865 | 445 | Test A at IB |
| 44 | 100 | 100 | +10 | -5 | 378 | 4980 | 0,889 | 445 | Test A at IB |
| 45 | 100 | 100 | +10 | 0 | 324 | 4980 | 0,912 | 445 | Test A at IB |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 100 | 100 | +10 | +5 | 320 | 4980 | 0,934 | 445 | Test A at IB |
| 47 | 100 | 100 | +10 | +10 | 322 | 4980 | 0,956 | 445 | Test A at IB |
| | | | | | | | | | |

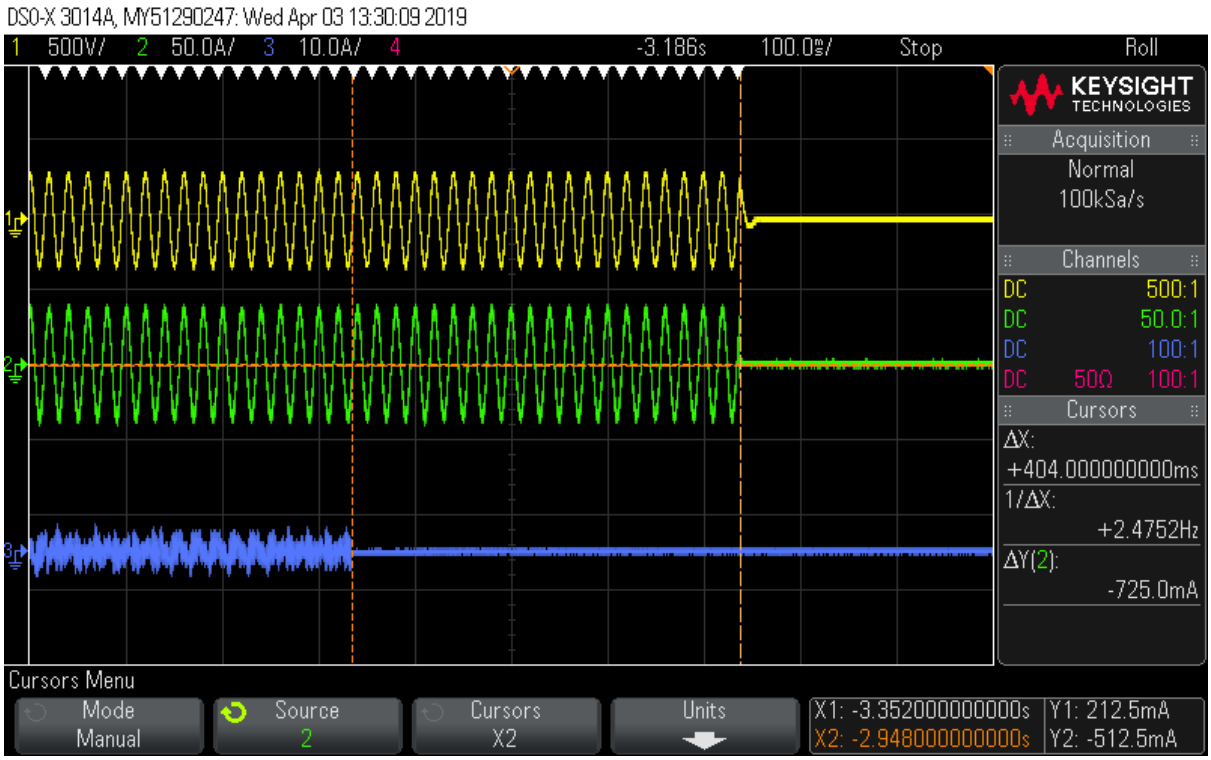
| | | | |
|---|---|---|---|
| Parameter at 0% per phase | L= 30,84 mH | R= 9,72 Ω | C= 328,50 µF |
| IAC fundamental current(A) | 156 mA | | |

**Note:**
RLC is adjusted to min. +/-1% of the inverter rated output power
[1] $P_{EUT}$: EUT output power
[2] $P_{AC}$: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
[3] $Q_{AC}$: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
[4] BL: Balance condition, IB: Imbalance condition.

Condition A:
EUT output power PEUT = Maximum [5]
EUT input voltage [6] = >90% of rated input voltage range

[5] Maximum EUT output power condition should be achieved using the maximum allowable input power. Actual output power may exceed nominal rated output.
[6] Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 90 % of range =X + 0,9 × (Y – X). Y shall not exceed 0,8 × EUT maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the EUT should not be operated outside of its allowable input voltage range.

**Disconnection at $P_{AC}$ 0% and $Q_{AC}$ 0% reactive load No. 1**




**Attention:**
**For Thailand only picture with all three current phases L1, L2 and L3 are accepted.**
All relays are direct coupled and open directly by receiving the islanding signal from the controller.

**Note:**
CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

| **6.1 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %)**<br>**3.9, 12.4 Anti-Islanding (PEA:2016)** | **P** |
|---|---|

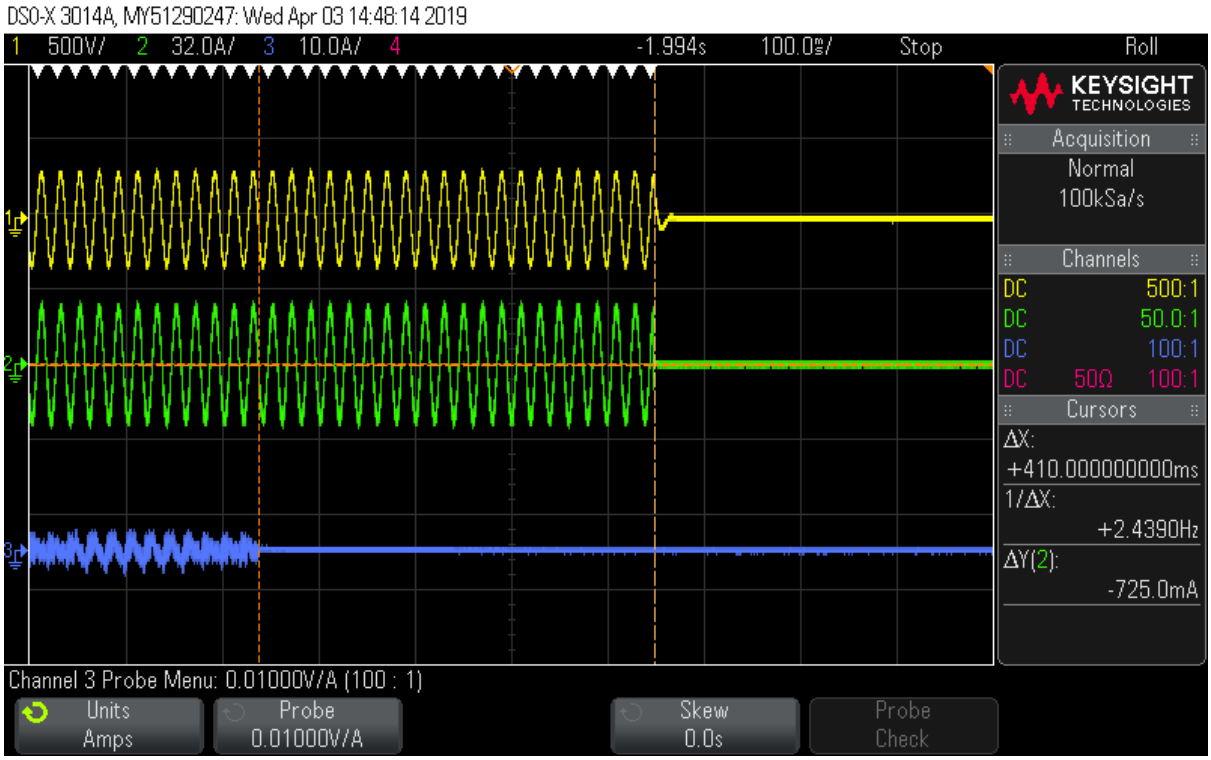
| Test conditions | Frequency: 50+/-0,1Hz<br>$U_N$=220+/-3Vac<br>Distortion factor of chokes < 2%<br>Quality =1 |
|---|---|
| Disconnection limit | 1s |

| No | $P_{EUT}$ [1] (% of EUT rating) | Reactive load (% of $Q_L$ in 6.1.d) 1) | $P_{AC}$ [2] (% of nominal) | $Q_{AC}$ [3] (% of nominal) | Run on Time (ms) | $P_{EUT}$ (W per phase) | Actual Qf | $V_{DC}$ (V) | Remarks[4] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 66 | 66 | 0 | -5 | 274 | 3408 | 0,985 | 357 | Test B at IB |
| 2 | 66 | 66 | 0 | -4 | 352 | 3408 | 0,990 | 357 | Test B at IB |
| 3 | 66 | 66 | 0 | -3 | 396 | 3408 | 0,995 | 357 | Test B at IB |
| 4 | 66 | 66 | 0 | -2 | 342 | 3408 | 1,001 | 357 | Test B at IB |
| 5 | 66 | 66 | 0 | -1 | 362 | 3408 | 1,006 | 357 | Test B at IB |
| 6 | 66 | 66 | 0 | 0 | 410 | 3408 | 1,011 | 357 | Test B at BL |
| 7 | 66 | 66 | 0 | 1 | 322 | 3408 | 1,016 | 357 | Test B at IB |
| 8 | 66 | 66 | 0 | 2 | 366 | 3408 | 1,021 | 357 | Test B at IB |
| 9 | 66 | 66 | 0 | 3 | 340 | 3408 | 1,026 | 357 | Test B at IB |
| 10 | 66 | 66 | 0 | 4 | 370 | 3408 | 1,031 | 357 | Test B at IB |
| 11 | 66 | 66 | 0 | 5 | 286 | 3408 | 1,036 | 357 | Test B at IB |

| Parameter at 0% per phase | L=44,71 mH | R= 14,20 Ω | C=226,60 µF |
|---|---|---|---|
| IAC fundamental current(A) | 122 mA | | |

**Note:**
RLC is adjusted to min. +/-1% of the inverter rated output power
[1] $P_{EUT}$: EUT output power
[2] $P_{AC}$: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
[3] $Q_{AC}$: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
[4] BL: Balance condition, IB: Imbalance condition.
Condition B:
EUT output power PEUT = 50 % – 66 % of maximum
EUT input voltage [5] = 50 % of rated input voltage range, ±10 %
[5] Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 50 % of range =X + 0,5 × (Y – X). Y shall not exceed 0,8 × EUT maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the EUT should not be operated outside of its allowable input voltage range.

**Disconnection at $P_{AC}$ 0% and $Q_{AC}$ 0% reactive load No. 6**




**Attention:**
**For Thailand only picture with all three current phases L1, L2 and L3 are accepted**
All relays are direct coupled and open directly by receiving the islanding signal from the controller.

**Note:**
CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

| **6.1 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %)**<br>**3.9, 12.4 Anti-Islanding (PEA:2016)** | **P** |
|---|---|

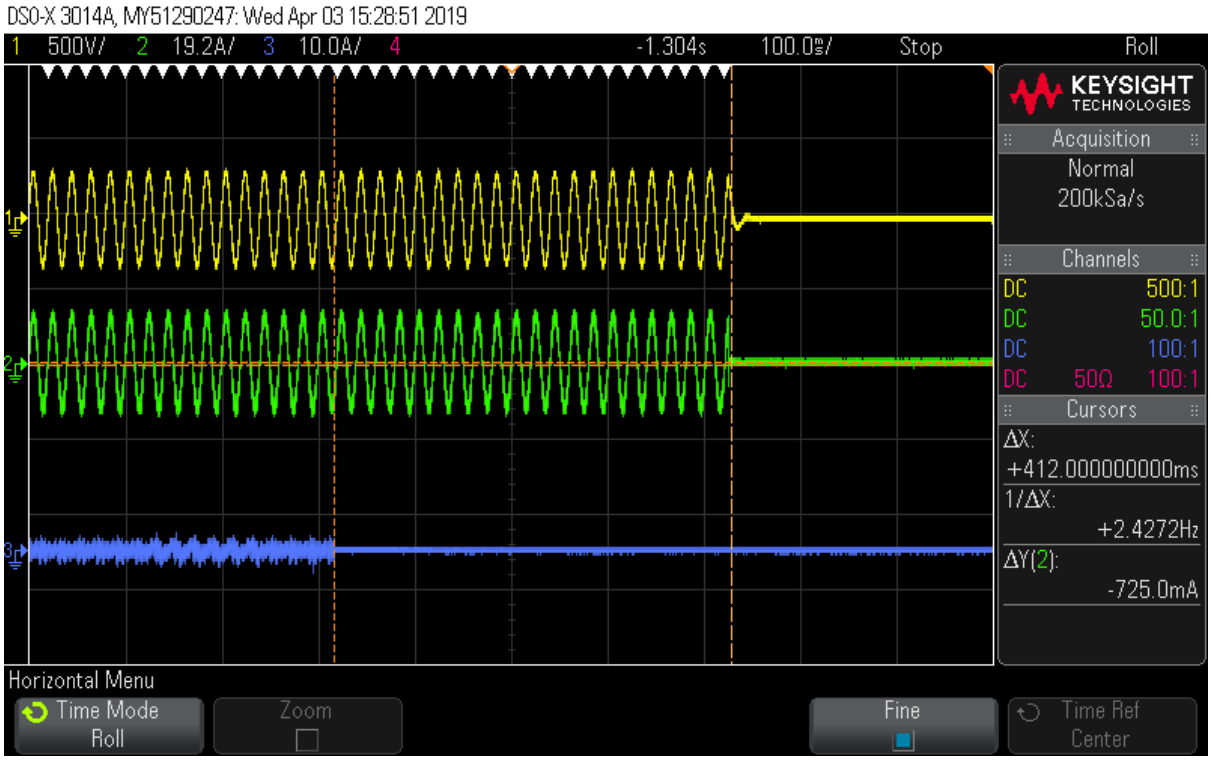
| Test conditions | Frequency: 50+/-0,1Hz<br>$U_N$=220+/-3Vac<br>Distortion factor of chokes < 2%<br>Quality =1 |
|---|---|
| Disconnection limit | 1s |

| No | $P_{EUT}$ 1) (% of EUT rating) | Reactive load (% of $Q_L$ in 6.1.d) 1) | $P_{AC}$ 2) (% of nominal) | $Q_{AC}$ 3) (% of nominal) | Run on Time (ms) | $P_{EUT}$ (W per phase) | Actual $Q_f$ | $V_{DC}$ (V) | Remarks4) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 33 | 33 | 0 | -5 | 320 | 1638 | 0,991 | 270 | Test C at IB |
| 2 | 33 | 33 | 0 | -4 | 384 | 1638 | 0,996 | 270 | Test C at IB |
| 3 | 33 | 33 | 0 | -3 | 314 | 1638 | 1,001 | 270 | Test C at IB |
| 4 | 33 | 33 | 0 | -2 | 360 | 1638 | 1,006 | 270 | Test C at IB |
| 5 | 33 | 33 | 0 | -1 | 355 | 1638 | 1,011 | 270 | Test C at IB |
| 6 | 33 | 33 | 0 | 0 | 412 | 1638 | 1,016 | 270 | Test C at BL |
| 7 | 33 | 33 | 0 | 1 | 398 | 1638 | 1,022 | 270 | Test C at IB |
| 8 | 33 | 33 | 0 | 2 | 364 | 1638 | 1,027 | 270 | Test C at IB |
| 9 | 33 | 33 | 0 | 3 | 322 | 1638 | 1,032 | 270 | Test C at IB |
| 10 | 33 | 33 | 0 | 4 | 404 | 1638 | 1,037 | 270 | Test C at IB |
| 11 | 33 | 33 | 0 | 5 | 330 | 1638 | 1,042 | 270 | Test C at IB |

| Parameter at 0% per phase | L= 92,57 mH | R= 29,55 Ω | C= 109,45 µF |
|---|---|---|---|
| IAC fundamental current(A) | 170 mA | | |

**Note:**
RLC is adjusted to min. +/-1% of the inverter rated output power
1) $P_{EUT}$: EUT output power
2) $P_{AC}$: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
3) $Q_{AC}$: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
4) BL: Balance condition, IB: Imbalance condition.
Condition C:
EUT output power PEUT = 25 % – 33 % 5) of maximum
EUT input voltage 6) = <10 % of rated input voltage range
5) Or minimum allowable EUT output level if greater than 33 %.
6) Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 10 % of range =X + 0,1 × (Y – X). Y shall not exceed 0,8 × EUT maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the EUT should not be operated outside of its allowable input voltage range.

**Disconnection at $P_{AC}$ 0% and $Q_{AC}$ 0% reactive load No. 6**




**Attention:**
**For Thailand only picture with all three current phases L1, L2 and L3 are accepted**
All relays are direct coupled and open directly by receiving the islanding signal from the controller.

**Note:**
CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

| **PEA:2016 additional test** | **P** |
|---|---|
| **3.4 Reactive power control(PEA:2016)** | **P** |

| **Test conditions:** | Output: 220 Vac,50Hz |
|---|---|

| P (setting) | P(kW)ind | P(kW)cap | Q(kVar)ind, max | Q(kVar)cap, max | PFind, max | PFcap, max |
|---|---|---|---|---|---|---|
| 0% | 0,241 | 0,239 | 0,099 | 0,162 | 0,9245 | 0,8274 |
| 10% | 0,498 | 0,499 | -0,246 | 0,235 | 0,8967 | 0,9048 |
| 20% | 1,009 | 0,961 | -0,481 | 0,454 | 0,9027 | 0,9040 |
| 30% | 1,505 | 1,507 | -0,720 | 0,713 | 0,9021 | 0,9040 |
| 40% | 2,010 | 2,011 | -0,948 | 0,973 | 0,9044 | 0,9002 |
| 50% | 2,510 | 2,512 | -1,214 | 1,188 | 0,9002 | 0,9040 |
| 60% | 3,007 | 3,011 | -1,480 | 1,490 | 0,8973 | 0,8963 |
| 70% | 3,505 | 3,507 | -1,652 | 1,718 | 0,9046 | 0,8981 |
| 80% | 3,999 | 4,001 | -1,901 | 1,944 | 0,9031 | 0,8994 |
| 90% | 4,506 | 4,501 | -2,158 | 2,174 | 0,9019 | 0,9005 |
| 100% | 4,668 | 4,743 | -2,241 | 2,285 | 0,9015 | 0,9009 |

**Note:**

| PEA:2016 additional test | P |
|---|---|
| 3.4.1, 8.1.2 1) A fixed displacement factor cosφ | P |

| Test conditions: | Output: 220 Vac,50Hz |
|---|---|

| P (setting) | PF (setting) | P(kW) | Q(kVar) | PF |
|---|---|---|---|---|
| 0% | 0,90 lagging | 0,241 | 0,099 | 0,9245 |
| 10% | 0,90 lagging | 0,498 | -0,246 | 0,8967 |
| 20% | 0,90 lagging | 1,009 | -0,481 | 0,9027 |
| 30% | 0,90 lagging | 1,505 | -0,720 | 0,9021 |
| 40% | 0,90 lagging | 2,010 | -0,948 | 0,9044 |
| 50% | 0,90 lagging | 2,510 | -1,214 | 0,9002 |
| 60% | 0,90 lagging | 3,007 | -1,480 | 0,8973 |
| 70% | 0,90 lagging | 3,505 | -1,652 | 0,9046 |
| 80% | 0,90 lagging | 3,999 | -1,901 | 0,9031 |
| 90% | 0,90 lagging | 4,506 | -2,158 | 0,9019 |
| 100% | 0,90 lagging | 4,668 | -2,241 | 0,9015 |

| P (setting) | PF (setting) | P(kW) | Q(kVar) | PF |
|---|---|---|---|---|
| 0% | 0,90 leading | 0,239 | 0,162 | 0,8274 |
| 10% | 0,90 leading | 0,499 | 0,235 | 0,9048 |
| 20% | 0,90 leading | 0,961 | 0,454 | 0,9040 |
| 30% | 0,90 leading | 1,507 | 0,713 | 0,9040 |
| 40% | 0,90 leading | 2,011 | 0,973 | 0,9002 |
| 50% | 0,90 leading | 2,512 | 1,188 | 0,9040 |
| 60% | 0,90 leading | 3,011 | 1,490 | 0,8963 |
| 70% | 0,90 leading | 3,507 | 1,718 | 0,8981 |
| 80% | 0,90 leading | 4,001 | 1,944 | 0,8994 |
| 90% | 0,90 leading | 4,501 | 2,174 | 0,9005 |
| 100% | 0,90 leading | 4,743 | 2,285 | 0,9009 |

| P (setting) | PF (setting) | P(kW) | Q(kVar) | PF |
|---|---|---|---|---|
| 0% | 1,00 | 0,242 | 0,120 | 0,8946 |
| 10% | 1,00 | 0,507 | 0,046 | 0,9958 |
| 20% | 1,00 | 1,013 | 0,142 | 0,9903 |
| 30% | 1,00 | 1,510 | 0,164 | 0,9942 |

| | | | | |
|---|---|---|---|---|
| 40% | 1,00 | 2,016 | 0,173 | 0,9963 |
| 50% | 1,00 | 2,519 | 0,178 | 0,9975 |
| 60% | 1,00 | 3,020 | 0,183 | 0,9982 |
| 70% | 1,00 | 3,517 | 0,189 | 0,9986 |
| 80% | 1,00 | 4,015 | 0,196 | 0,9988 |
| 90% | 1,00 | 4,510 | 0,204 | 0,9990 |
| 100% | 1,00 | 5,002 | 0,214 | 0,9991 |
| Note: | | | | |

| PEA:2016 additional test | N/A |
|---|---|
| **3.4.2, 8.1.2 2) A variable reactive power depending on the voltage Q(U) (PEA:2016) (Power generation system is greater than 500kW)** | **N/A** |

The purpose of the test is to ensure that the converter complies with the methods for automatically supplying reactive power according to the standard characteristic curve Q(U) indicated in 1.5.

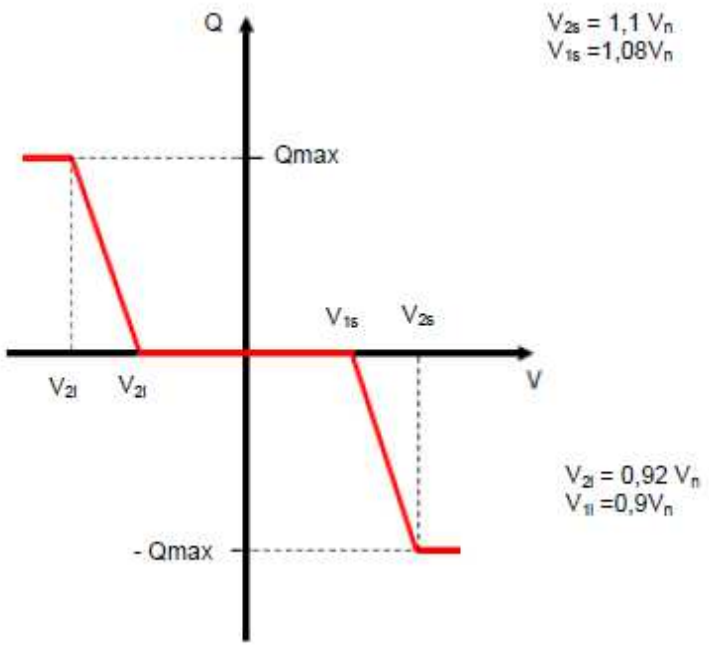
Activation must be at the Distributor's request, when the Operating Regulations are issued. The Distributor shall also specify the values of the parameters that uniquely characterise the curve, i.e.: V1i, V2i, V1s and V1s as well as the lock-in value of active power (default value P = 0,2 $P_n$).

The parameters V1i, V2i, V1s and V1s should be set in the range between 0,9 and 1,1 with 0,01 $V_n$ steps. In order to facilitate execution of the type tests, the characterising parameters are conventionally set as follows:

V1s =1,08 $V_n$; V2s = 1,1 $V_n$

V1i =0,92 $V_n$; V2i = 0,9 $V_n$

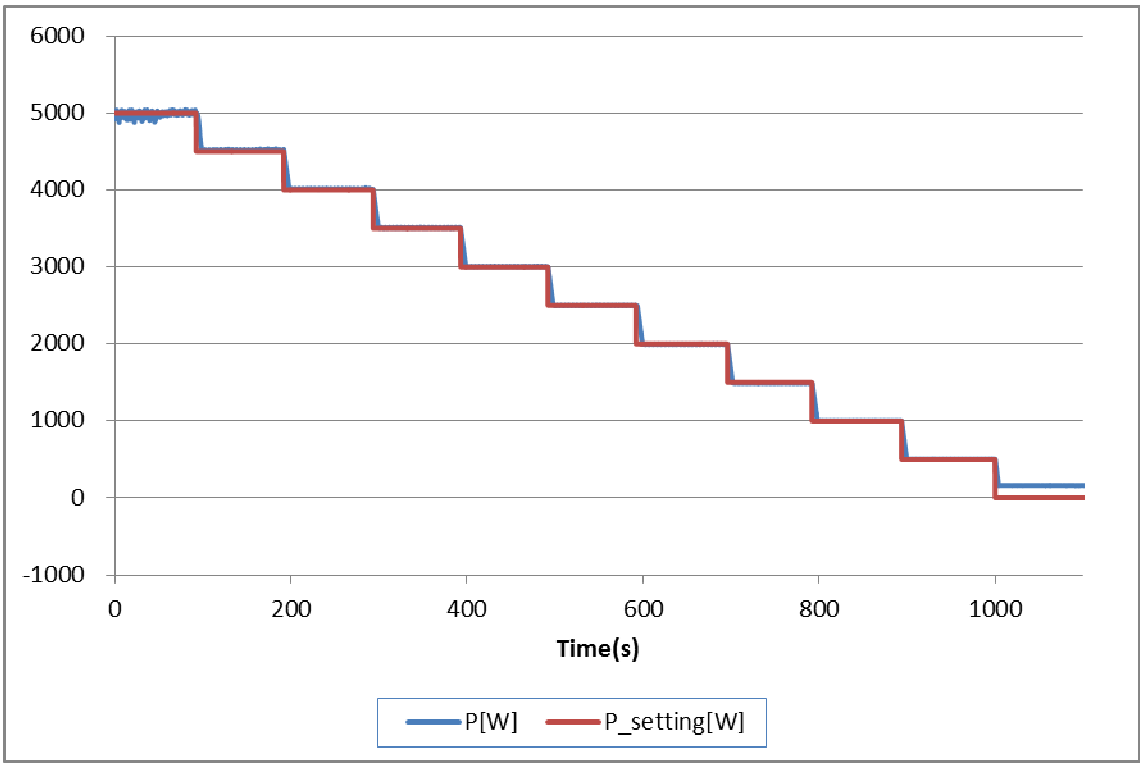
and the active power lock-in value (default value P = 0,2 $P_n$).



| PEA:2016 additional test | P |
|---|---|
| **3.5, 12.1 Active power control (PEA:2016)** | **P** |

| Setpoint in power bin [%] | $P_{setpoint}$ [kW] | $P_{60}$ [kW] | Decrease time (s) |
|---|---|---|---|
| 100% | 5,0 | 4,985 | |
| 90% | 4,5 | 4,518 | <10s |
| 80% | 4,0 | 4,012 | <10s |
| 70% | 3,5 | 3,508 | <10s |
| 60% | 3,0 | 3,006 | <10s |
| 50% | 2,5 | 2,449 | <10s |
| 40% | 2,0 | 1,995 | <10s |
| 30% | 1,5 | 1,491 | <10s |
| 20% | 1,0 | 0,957 | <10s |
| 10% | 0,5 | 0,505 | <10s |
| 0% | 0,0 | 0,161 | <10s |

**Graph of the setting accuracy**




Note:

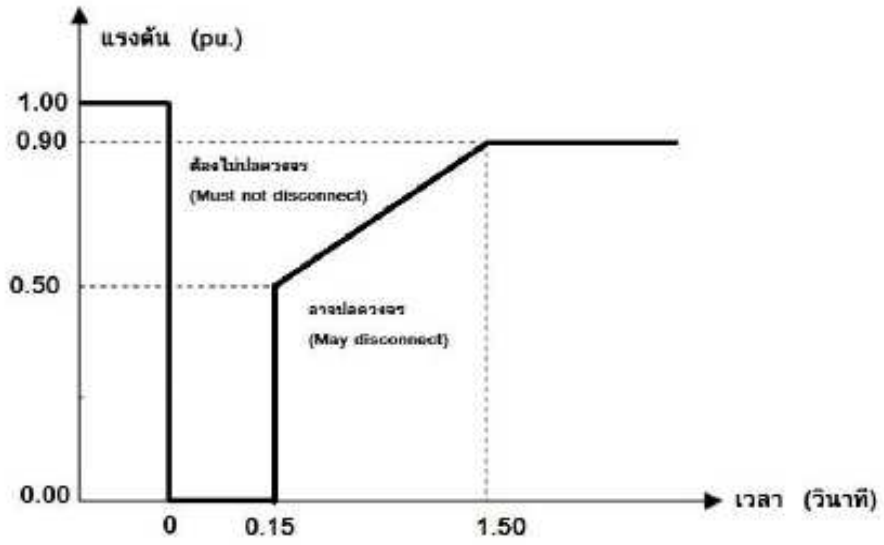
| PEA:2016 additional test | N/A |
|---|---|
| 3.6, 12.2 Low voltage fault Ride through capability (PEA:2016) (Power generation system is greater than 500kW) | N/A |

| Test List | V(V/$V_n$) | Duration time (Sec) |
|---|---|---|
| Test P>0,9$P_n$* | | |
| Three-phase faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,05$V_n$ | --- |
| | | |
| Phase to phase faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,05$V_n$ | --- |
| | | |
| Single phase to ground faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,05$V_n$ | --- |
| Test P=0,3$P_n$ | | |
| Three-phase faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,049$V_n$ | --- |
| | | |
| Phase to phase faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,049$V_n$ | --- |
| | | |
| Single phase to ground faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,049$V_n$ | --- |
| Test P=0,1 Pn | | |
| Three-phase faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,049$V_n$ | --- |
| | | |
| Phase to phase faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,049$V_n$ | --- |
| | | |

| | | |
|---|---|---|
| Single phase to ground faults | 0,7-0,8$V_n$ | --- |
| | 0,3-0,5$V_n$ | --- |
| | 0-0,049$V_n$ | --- |

Note:
The PGS must not disconnected from gird while the PCC voltage dip period less than below curve limit.

a) install and connect the PGS and recommendation of the technical requirements of the equipment manufacturer .
b) Check all parameters of power supply in normal conditions, the operation of power system equipment .
c) testing by simulation the voltage . ( I try to short-circuit in the power network ) in the electricity network to balance the pressure between 70-80%$V_n$ , 30-50%$V_n$, and less than 5 percent of the normal operating pressure .
d) Record the maximum time power system can still connect to the electricity network as shown on above table.



# Annex 1
## Test equipment list

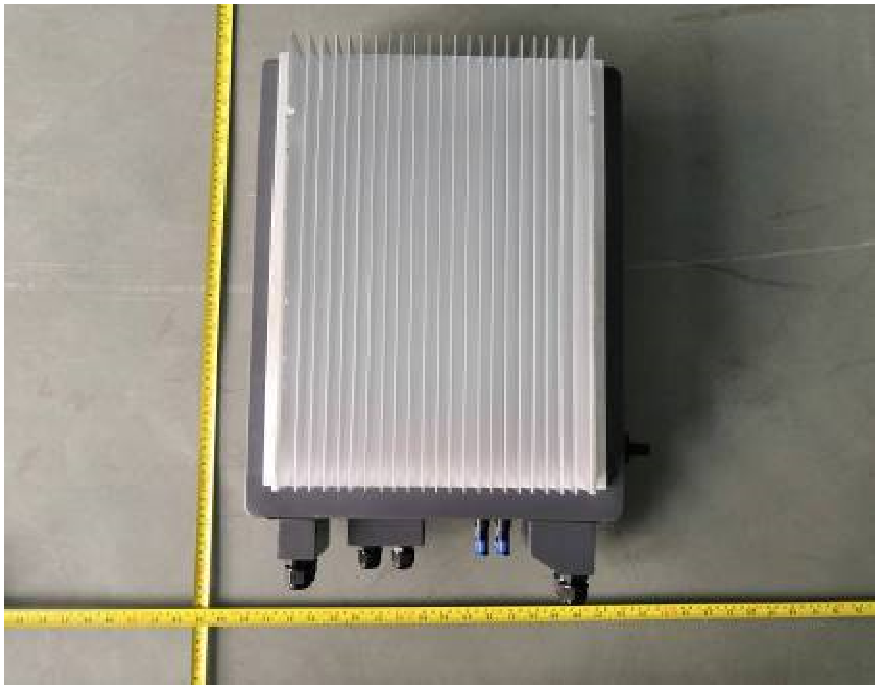
**Test local: Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
**Date(s) of performance of test 2019-03-22 to 2019-04-22**

| Equipment | Internal No. | Manufacturer | Type | Serial No. | Last Calibration |
|---|---|---|---|---|---|
| Power Analyzer | A4080002DG | YOKOGAWA | WT3000 | 91M210852 | Dec. 13, 2018 |
| AC Source | A7040019DG | Chroma | 61512 | 61512000439 | Monitored by Power Analyzer |
| | A7040020DG | Chroma | 61512 | 61512000438 | |
| DC Simulation Power Supply | A7040015DG | Chroma | 62150H-1000S | 62150EF00488 | |
| | A7040016DG | Chroma | 62150H-1000S | 62150EF00490 | |
| | A7040017DG | Chroma | 620028 | 620028EF00120 | |
| RLC Load | A7150027DG | Qunling | ACLT-3803H | 93VOO2869 | |
| Eight Channel Digital Phosphor Oscilloscope | A4089017DG | YOKOGAWA | DL850 | 91N726247 | Sep. 14, 2018 |
| Four Channel Digital Phosphor Oscilloscope | A4089003DG | Tektronix | DPO4104B | C010624 | Oct. 25, 2018 |
| Oscilloscope probel | A1490009DG | YOKOGAWA | 701901 | // | Nov. 01, 2018 |
| | A1490010DG | YOKOGAWA | 701901 | // | Nov. 01, 2018 |
| | A1490011DG | YOKOGAWA | 701901 | // | Nov. 01, 2018 |
| Current transducer | A1060008DG | YOKOGAWA | CT200 | 1130700017 | Nov. 17, 2018 |
| | A1060009DG | YOKOGAWA | CT200 | 1130700019 | Nov. 17, 2018 |
| | A1060009DG | YOKOGAWA | CT200 | 1130700019 | Nov. 17, 2018 |

# Pictures of the unit

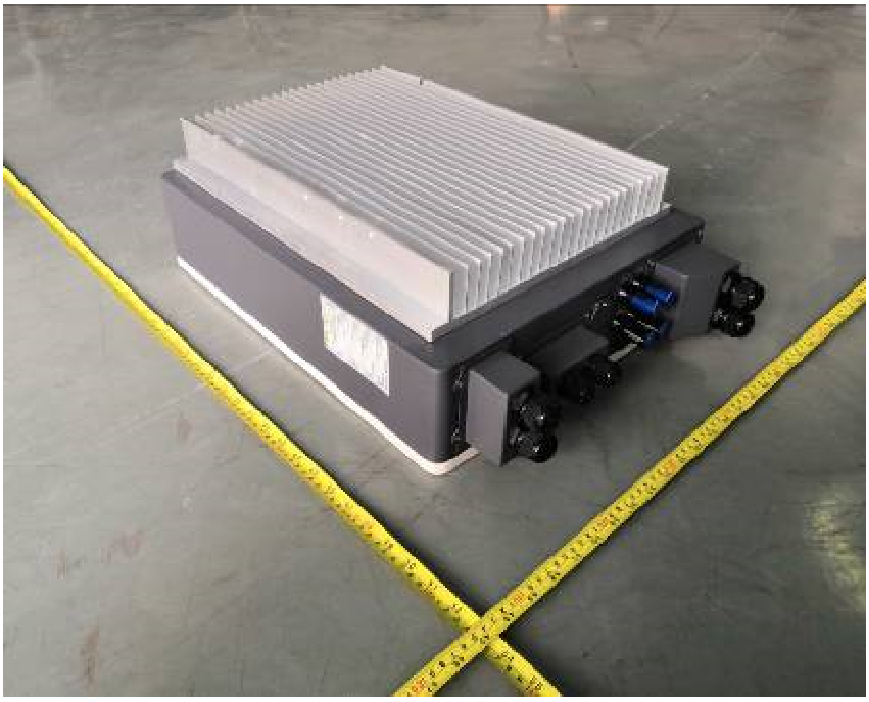
## Enclosure front view

## Enclosure rear view



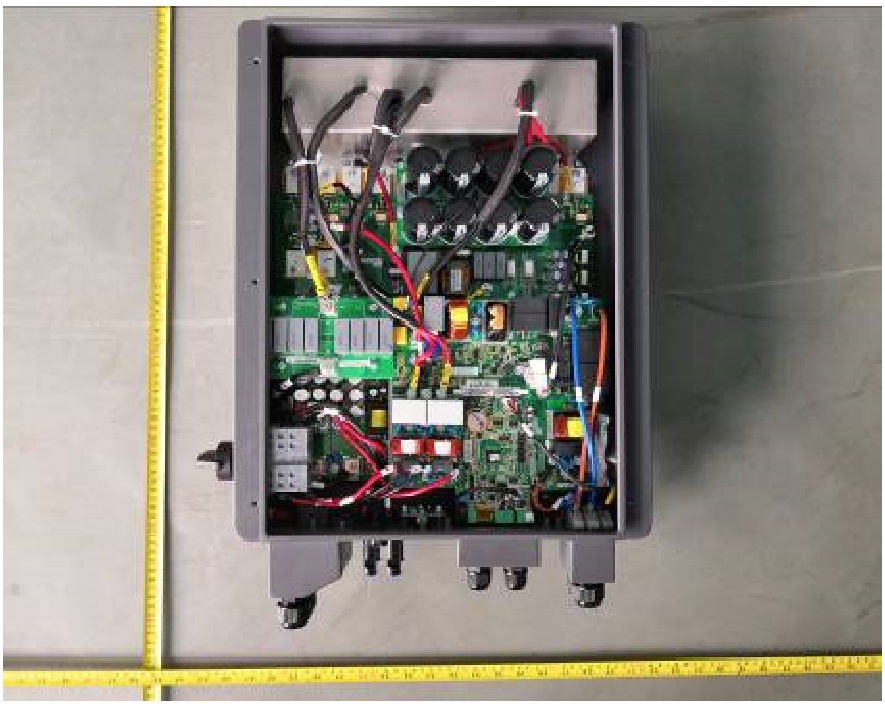
## Enclosure front view

## Enclosure rear view

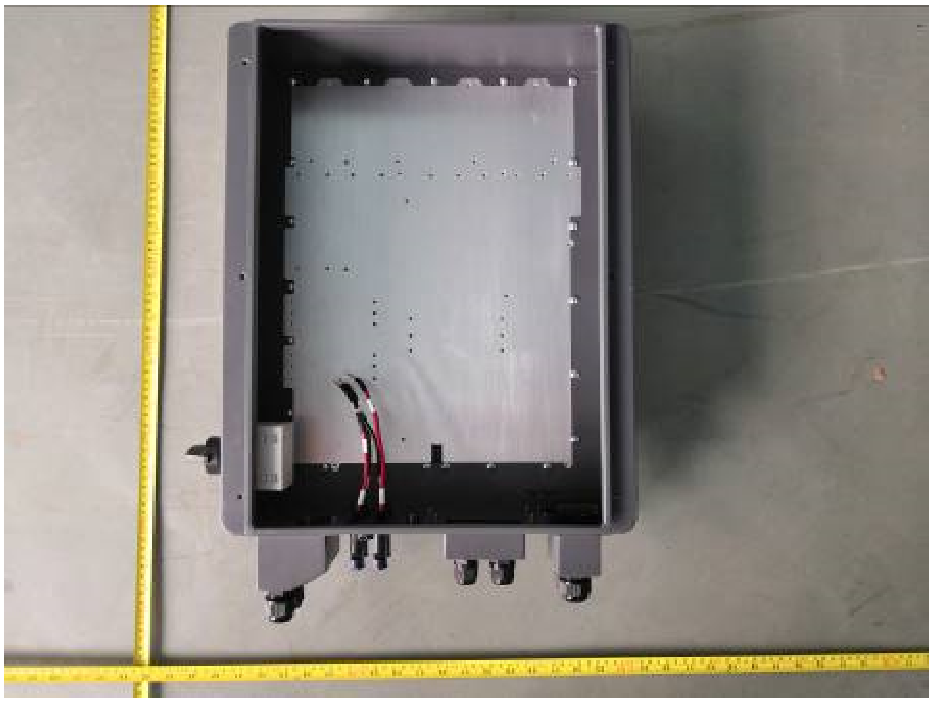


## Enclosure Bottom view


## Internal view-1

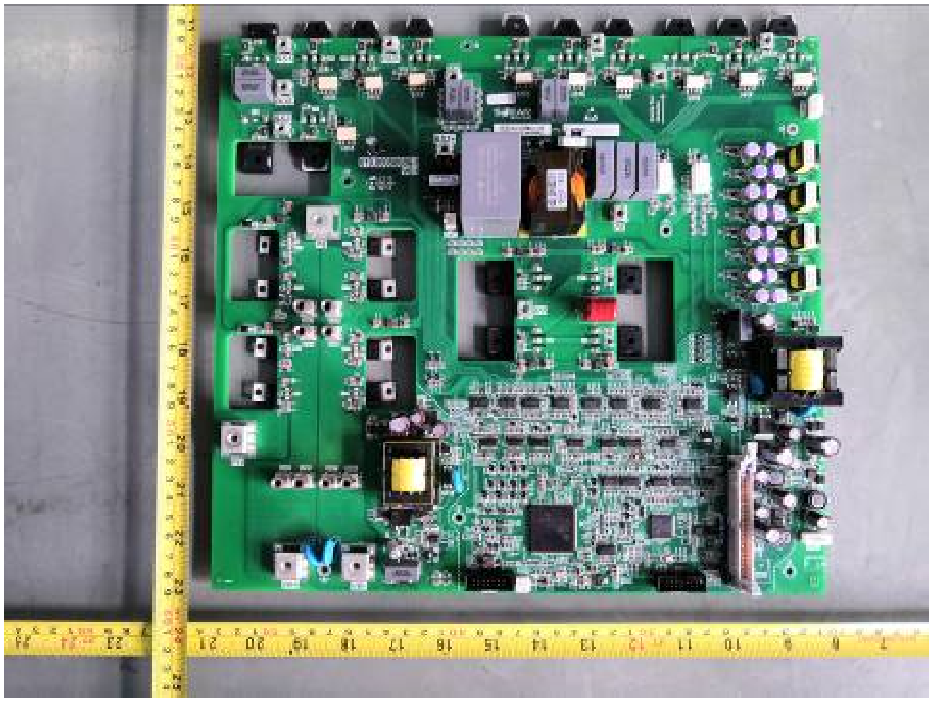


**Internal view-2**

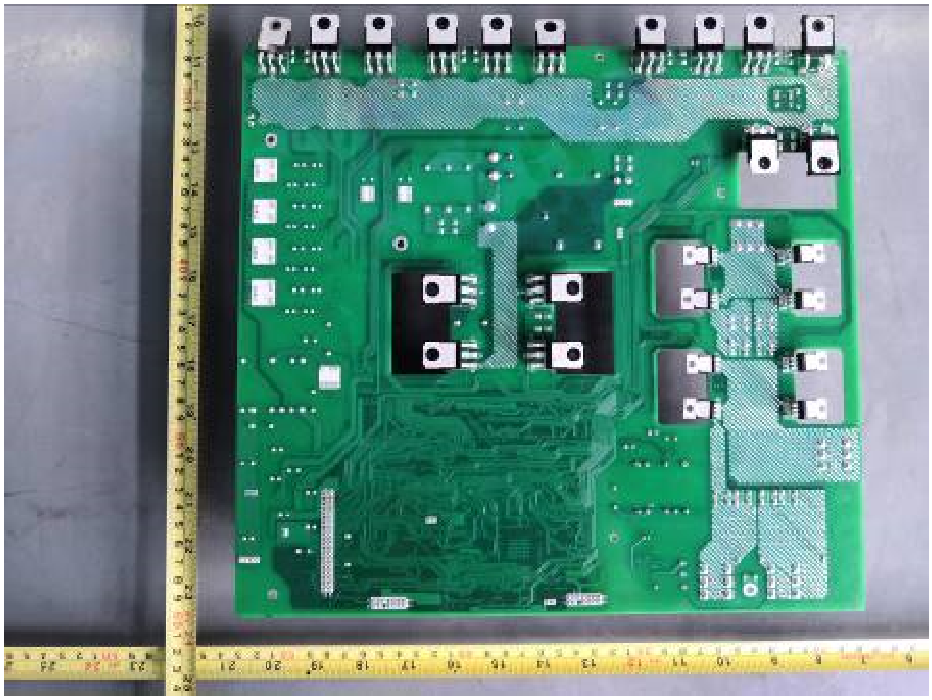


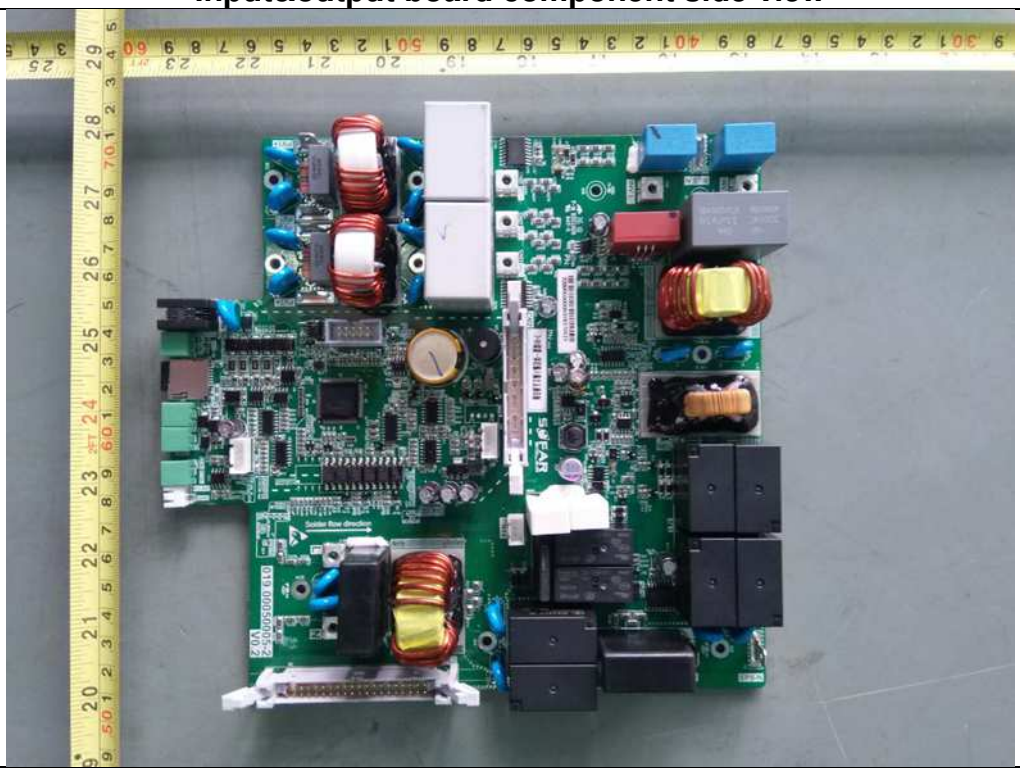
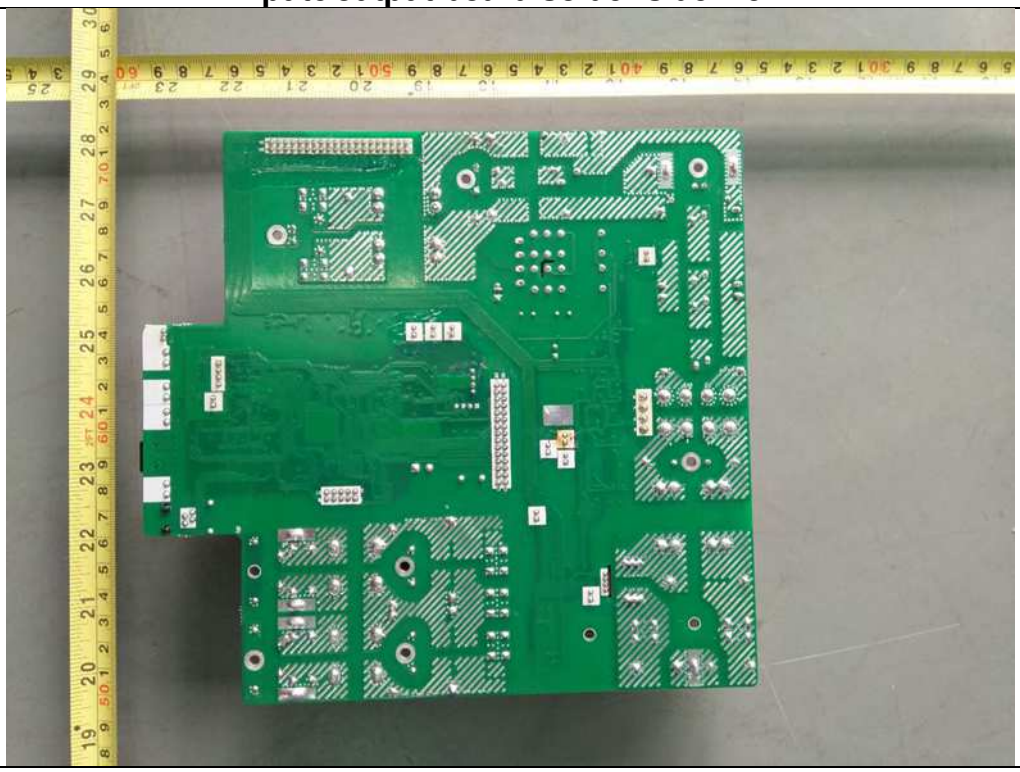
**Internal view: Ground terminal**

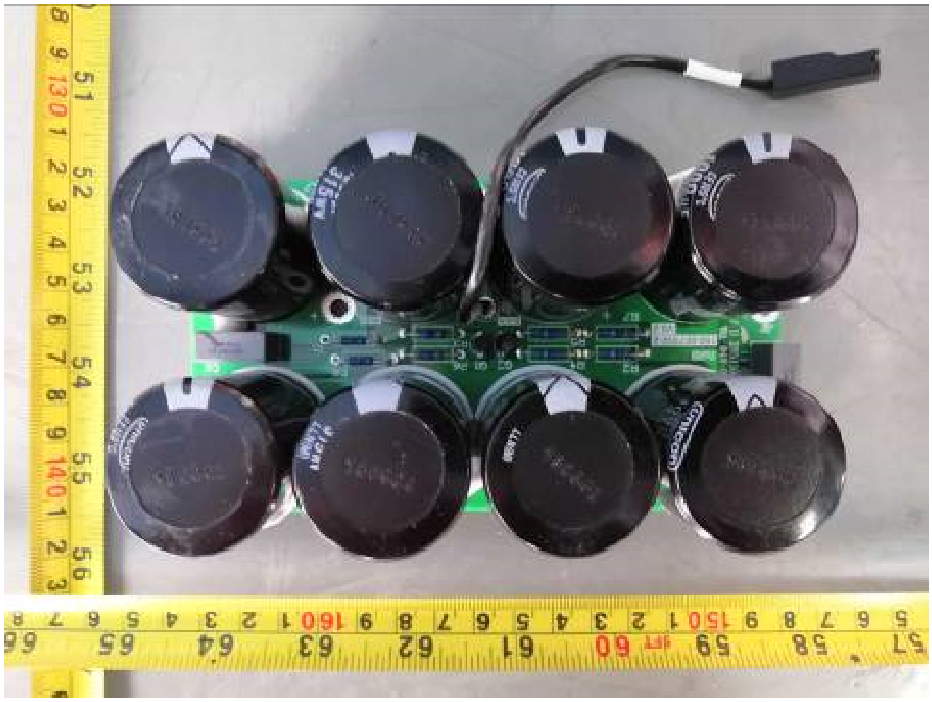
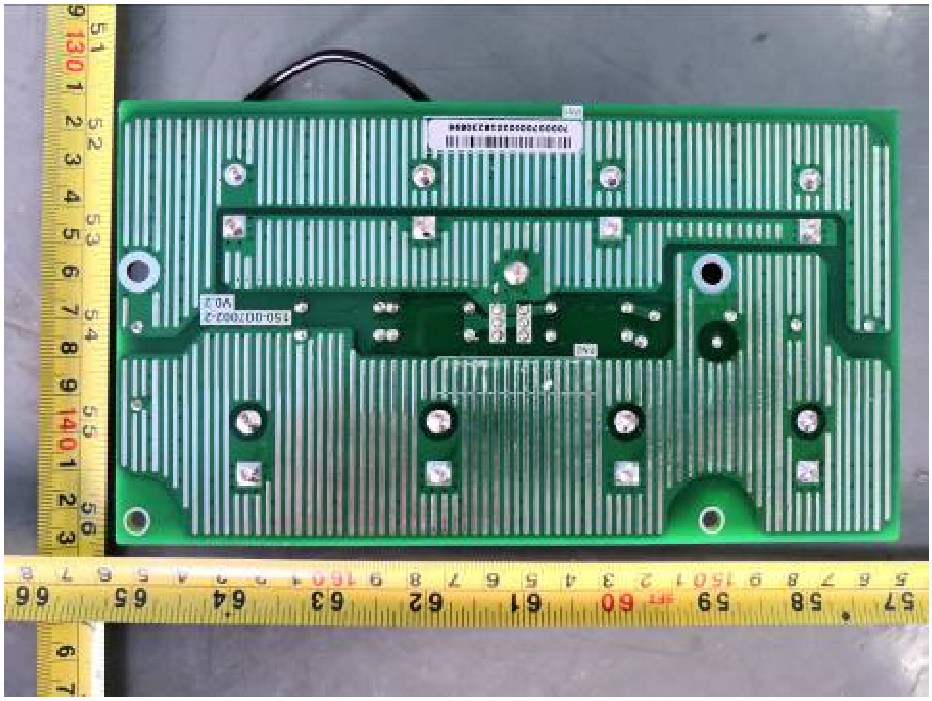
## Main power board component side view

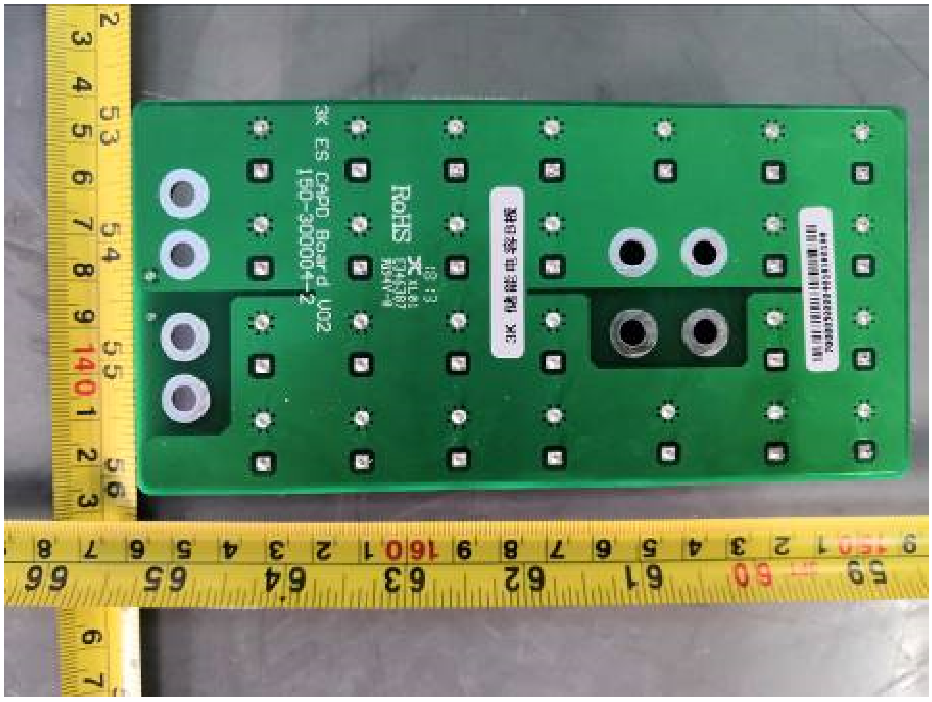


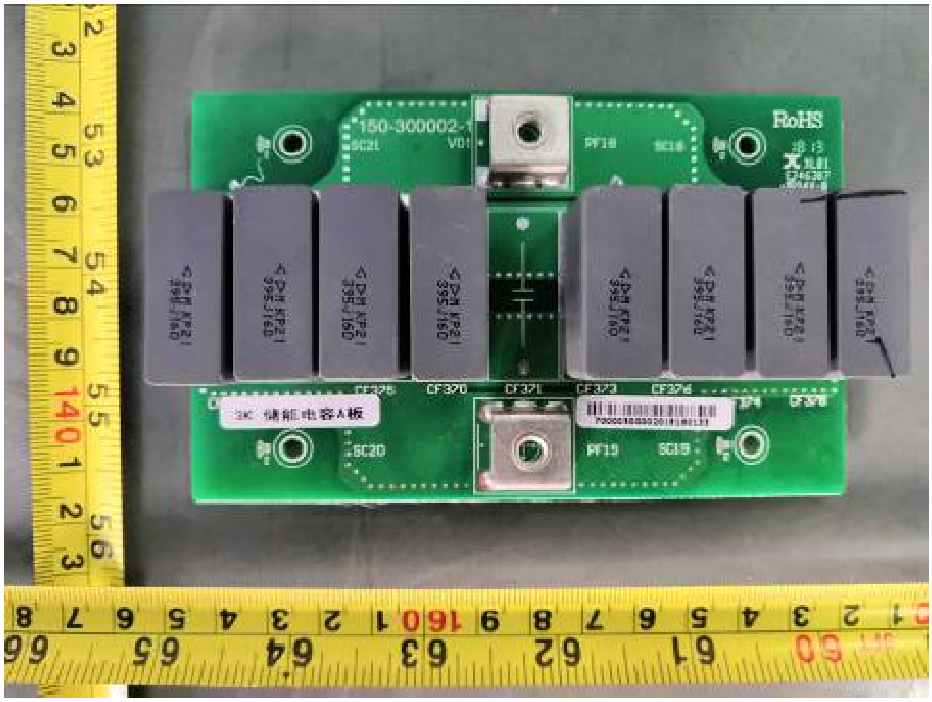
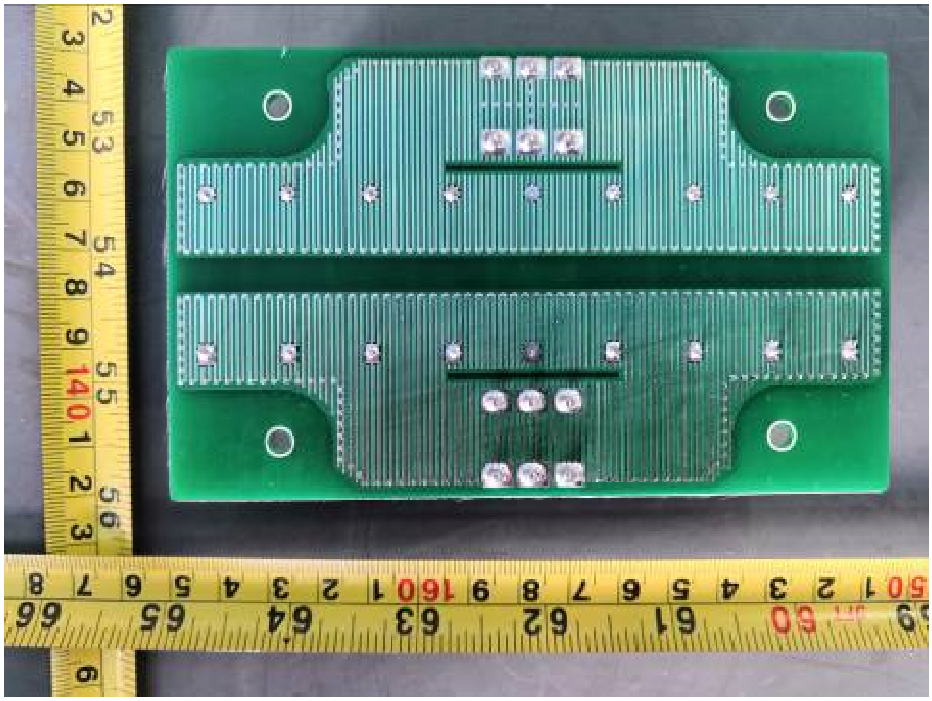
## Main power board solder side view



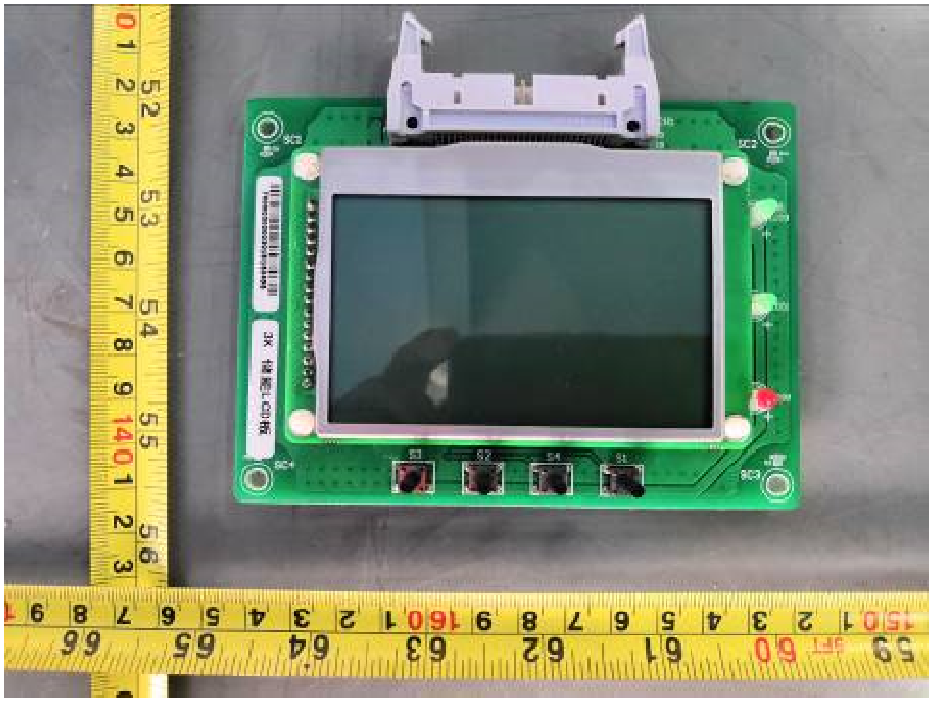
| Input&output board component side view |
| --- |
|  |
| **Input&output board solder side view** |
|  |

| Capcitance board component side view |
| --- |
|  |
| **Capcitance board solder side view** |
|  |

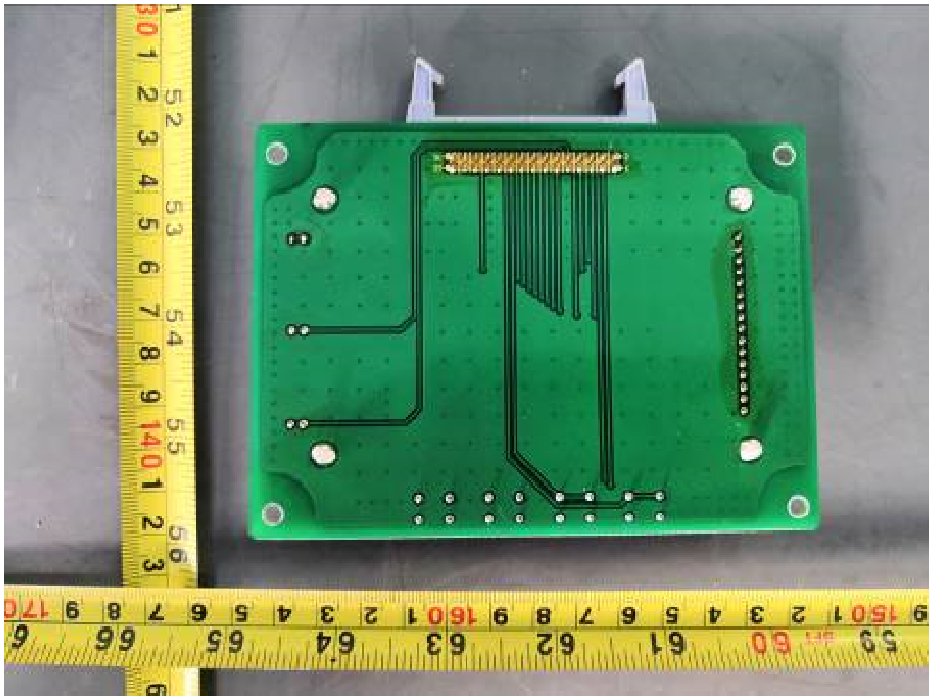
| Capcitance B board component side view |
| --- |
|  |
| **Capcitance B board solder side view** |
|  |

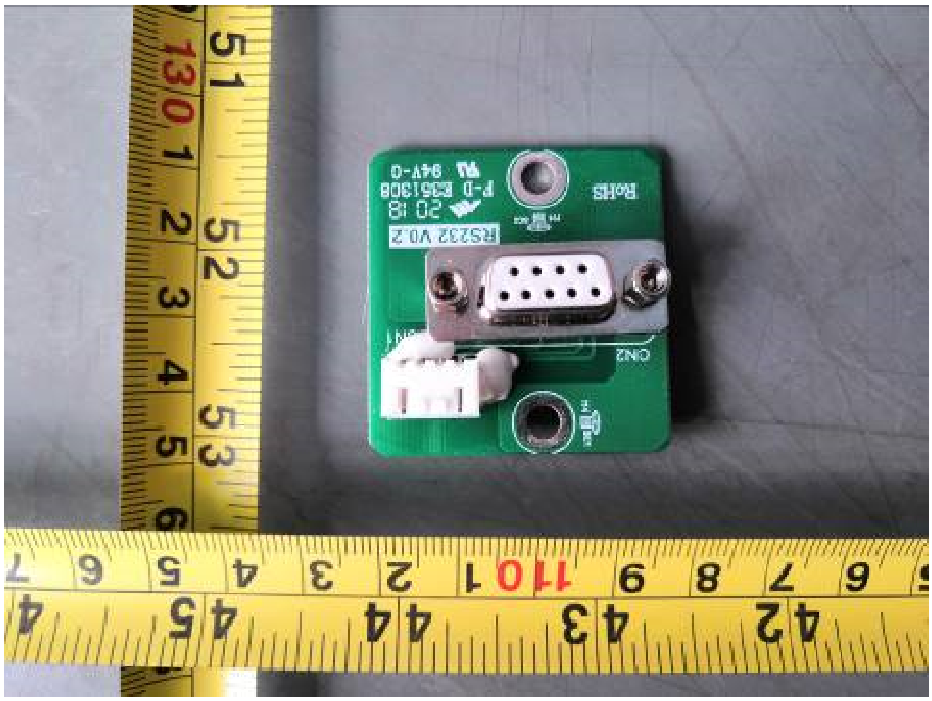
| Capcitance A board component side view |
| --- |
|  |
| **Capcitance A board solder side view** |
|  |

## LCD board component side view



## LCD board solder side view



| RS232 board component side view |
| --- |
|  |
| **RS232 board solder side view** |
|  |