VERIFICATION REPORT

The requirement on Grid Connection of Provincial Electricity Authority B.E. 2559 (2016)

Report No... .....:	**162/62-088**
EUT No......:	**SC-62-0087**
Laboratory Name .....:	**Electrical and Electronic Products Testing Center**
Address .....:	141 Thailand Science Park, Innovation Cluster 2 Tower D, Phahonyothin Rd., Khlong Nueng, Khlong Luang, Pathum Thani 12120, Thailand
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 .....:	The requirement on Grid Connection of Provincial Electricity Authority Thailand B.E. 2559 (2016)
Non-standard test method .....:	-
Test item description .....:	Hybrid inverter
Trademark .....:	SOFAR SOLAR
Model and/or type reference .....:	HYD 5000-ES
Date of receipt .....:	26 July 2019
Date of report issue .....:	30 July 2019

Prepare by

Mr. Ruengrit Ninae
Section Head

Approved by

Mr. Anake Meemoosor
Operation Manager

Detail of reference test report	
Test Report No. .....:	PVTH190322N026
Total number of page. .....:	46
Testing Laboratory.....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch** No. 34, Chenwulu Section, Guantai Rd., Houjie Town, Dongguan City, Guangdong 523942, China
Testing location .....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch** No. 34, Chenwulu Section, Guantai Rd., Houjie Town, Dongguan City, Guangdong 523942, China
Test specification.....:	IEC 61727:2004, IEC 62116:2008, Deviations for Thailand according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016)
Tested by.....:	Dora Zhang
Reviewed by.....:	-
Approved by	James Huang
Date of report issue .....:	2019-04-26

Test item description .....:	Hybrid inverter
Trademark .....:	SOFAR SOLAR
Model and/or type reference .....:	HYD 5000-ES
Rating	
Input DC MPP voltage range [V] :	250-520
Input DC voltage Max [V] .....:	600
Input DC current [A].....:	2x12
Output AC voltage [V].....:	230Vac, 50Hz
Output AC current [A].....:	Max.13.2
Output power [VA].....:	3000
Firmware Version	V1.00

Summary of verification report

Test result of report No. **PVTH190322N026** was result of Photovoltaic Grid- Tied Inverter model **HYD 5000-ES**. It was verified by Electrical and Electronic Products Testing Center (PTEC) and **compiled** according to Requirements on Grid Connection of Provincial Electricity Authority BE 2559 (2016) as following;

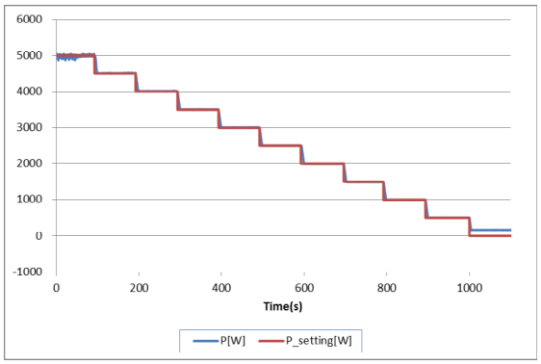
No.	Item	Reference Report No.	Standard Reference	Verdict
1	Active power control	PVTH190322N026	PEA	Pass
2	Reactive power control	-	-	--
2.1	A Fixed Displacement Factor cos θ (PF.0.90)	PVTH190322N026	PEA	Pass
2.2	A variable reactive power depending on the voltage Q(U)	--	--	--
3	Under/over frequency protection	PVTH190322N026	IEC 61727	Pass
4	Voltage fluctuation	PVTH190322N026	IEC 61000-3-11	Pass
5	Harmonics	PVTH190322N026	IEEE 1547.1	Pass
6	DC injection	PVTH190322N026	IEC 61727	Pass
7	Low voltage fault ride through	--	--	--
8	Under/over voltage protection	PVTH190322N026	IEC 61727	Pass
9	Anti-islanding	PVTH190322N026	IEC 62116	Pass
10	Response to utility recovery	PVTH190322N026	IEC 61727	Pass

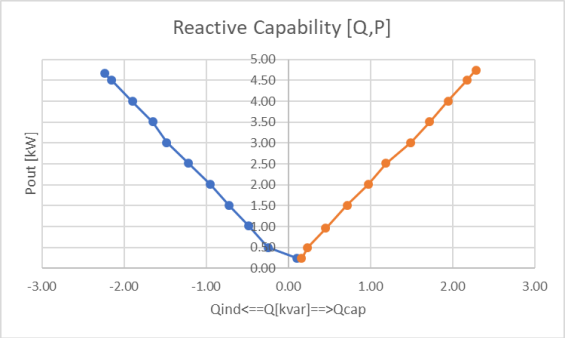
This report consists of the following document:

1. Verification Result (10 Page)
2. Attach Document Reference Report No. PVTH190322N026 (46 Page)

Standard Reference;

- **IEEE 1547.1 2005** Interconnecting Distributed Resources with Electric Power Systems
- **IEC 62116:2008**: Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
- **IEC 61727** Photovoltaic (PV) systems - Characteristics of the utility interface
- **IEC 61000-3-11**: Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current > 75 A
- **PEA**: Thailand according to the grid-connected inverter regulations of the Provincial Electricity Authority (PEA):2016

VERIFICATION REPORT			
Clause	PEA Requirement	Result – Remark	Verdict
8.1.2	**Active Power Control** The power generating system of VSPP must be capable of reducing electric power from 100 %to zero by decreasing 10 % electric power per one minute .In this regard, if there is any abnormality occurred in the grid system or any incident considered by PEA as an impact affecting safety and stability of the grid system, PEA would inform and/or give an order to the VSPP to reduce electric power as appropriate.	**Active Power Control** **1) Requirement** The requirements on Grid Connection of Provincial Electricity Authority **2) Test result** See Test report no :PVTH190322N026, Page 42 **3) Verification test result** The PV inverter is capable of reducing electric power from 100 %to zero by decreasing 10 % electric power per one minute.  -Maximum active power deviation to set point 4.30%	Pass
8.1.3	**Reactive Power Control** The power generating system of VSPP must be able to control power factor)PF (or reactive power to maintain voltage level at PCC aligned with PEA's standards .The power generating system of service applicants must have capacity as stated in Table 1.	**Reactive Power Control** **1) Requirement** The requirements on Grid Connection of Provincial Electricity Authority **2) Test result** See Test report no :PVTH190322N026, - Page 38 Reactive power capability - Page 39-40 A Fixed Displacement Factor cos θ test result	Pass

VERIFICATION REPORT			
Clause	PEA Requirement	Result – Remark	Verdict
		3) Verification test result 3.1 Reactive power capability 	Pass
		3.2 A Fixed Displacement Factor cos θ (PF 0.90) test PF. Set point / PF. Measurement* (Max / Min) 1.0: 0.9991 / 0.9903 0.90 lagging: 0.9046 / 0.8967 0.90 Leading: 0.9048 / 0.8963 *@Pout =10% to 100% and	Pass
		3.3 A variable reactive power depending on the voltage Q(U) test -- No test result --	--

<table>
<tr><th colspan="4">VERIFICATION REPORT</th></tr>
<tr><th>Clause</th><th>PEA Requirement</th><th>Result – Remark</th><th>Verdict</th></tr>
<tr><td>8.2</td><td>Under and Over Frequency Protection
The power generating system of VSPP must disconnect itself from the grid system within 0.1 seconds if the frequency at PCC is not in the range of 47 Hz-52 Hz.</td><td>Under and Over Frequency Protection
1) Reference Standard
IEC 61727

2) Test result
See Test report no: PVTH190322N026
Page 27-28

3) Verification test result
<table><tr><th>Frequency at PCC</th><th>Measured (Sec)</th><th>Limit (Sec)</th><th>Result</th></tr><tr><td>f < 47</td><td>0.090</td><td><0.1</td><td>Pass</td></tr><tr><td>f > 52</td><td>0.060</td><td><0.1</td><td>Pass</td></tr></table></td><td>Pass</td></tr>
<tr><td>8.3</td><td>Voltage Fluctuation
The power generating system of VSPP must not create voltage fluctuation exceeding the limit based on the PEA’s rules concerning the Regulations on Grid Connection B.E.2559.

Regulations on Grid Connection B.E.2559.
The operation of the inverter should not cause voltage flicker in excess of limits :
Short-term Severity Values (Pst) not exceed 1.0
Long-term Severity Values (Plt) not exceed 0.8</td><td>Voltage Fluctuation
1) Reference Standard
IEC 61000-3-5

2) Test result
See Test report no :PVTH190322N026,
Page 13

3) Verification test result
<table><tr><th>Test item</th><th>Limit</th><th>Result</th><th>Verdict</th></tr><tr><td>Pst</td><td>1.0</td><td>0.10</td><td>Pass</td></tr><tr><td>Plt</td><td>0.8</td><td>0.10</td><td>Pass</td></tr></table></td><td>Pass</td></tr>
</table>

VERIFICATION REPORT

Clause	PEA Requirement	Result – Remark	Verdict
8.4	**Harmonic** The power generating system of VSPP must not inject harmonic current to the grid system exceeding the limit based on the PEA's rules concerning the Regulations of Grid Connection B.E.2559. Regulations of Grid Connection B.E.2559. The Inverter output should have low current-distortion and low voltage distortion levels to ensure that no adverse effects are caused to other equipment connected to the utility system .Each individual harmonic shall be limited to the listed in Table 5.1 and Table 5-2 of attach 4. ตารางที่ 5-1 ขีดจำกัดกระแสฮาร์มอนิกสำหรับผู้ใช้ไฟฟ้ารายใดๆที่จุดต่อร่วม * ตารางที่ 5-2 ขีดจำกัดความเพี้ยนฮาร์มอนิกของแรงดันสำหรับผู้ใช้ไฟฟ้ารายใดๆที่จุดต่อร่วม (รวมทั้งระดับความเพี้ยนที่มีอยู่เดิม)	**Harmonics** **1) Reference Standard** IEEE1547.1-2005 Total harmonic current distortion is less than 5 %at rated inverter output Individual harmonics don't exceed the given distortion limit **2) Test result** See Test report no :PVTH190322N026, Page 15 to 19 **3) Verification test result**	Pass
8.5	**DC Injection** The power generating system of VSPP must not supply direct current to the grid system exceeding the limit based on the PEA's regulations concerning the Regulations on Grid Connection B.E.2559. Regulations on Grid Connection B.E.2559. The inverter shall not inject DC current greater than 0.5 % of the rated inverter output current, into the utility AC interface under any operating condition.	**DC Injection** **1) Referrence Standard** IEC 61727 **2) Test result** See Test report no: PVTH190322N026, Page 14 **3) Verification test result**	Pass

ตารางที่ 5-1
ขีดจำกัดกระแสฮาร์มอนิกสำหรับผู้ใช้ไฟฟ้ารายใดๆที่จุดต่อร่วม *

ระดับแรงดันไฟฟ้าที่จุดต่อร่วม (kV)	อันดับฮาร์มอนิกและขีดจำกัดของกระแส (A rms)																	
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
0.400	48	34	22	56	11	40	9	8	7	19	6	16	5	5	5	6	4	6
11 and 12	13	8	6	10	4	8	3	3	3	7	2	6	2	2	2	2	1	1
22 , 24 and 33	11	7	5	9	4	6	3	2	2	6	2	5	2	1	1	2	1	1
69	8.8	5.9	4.3	7.3	3.3	4.9	2.3	1.6	1.6	4.9	1.6	4.3	1.6	1	1	1.6	1	1
115 and above	5	4	3	4	2	3	1	1	1	3	1	3	1	1	1	1	1	1

ตารางที่ 5-2
ขีดจำกัดความเพี้ยนฮาร์มอนิกของแรงดันสำหรับผู้ใช้ไฟฟ้ารายใดๆที่จุดต่อร่วม (รวมทั้งระดับความเพี้ยนที่มีอยู่เดิม)

ระดับแรงดันไฟฟ้าที่จุดต่อร่วม (kV)	ค่าความเพี้ยนฮาร์มอนิกรวมของแรงดัน (%)	ค่าความเพี้ยนฮาร์มอนิกของแรงดันแต่ละอันดับ (%)	
		อันดับคี่	อันดับคู่
0.400	5	4	2
11 , 12 , 22 and 24	4	3	1.75
33	3	2	1
69	2.45	1.63	0.82
115 and above	1.5	1	0.5

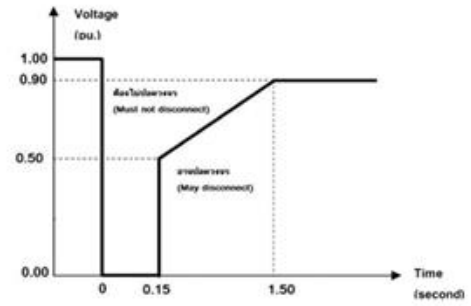
Item	Verdict
THDi in each harmonic not exceed in table 5-1	Pass
Total harmonic current distortion less than 5 %	Pass
THDv in each harmonic not exceed in table 5-2	Pass
Total harmonic voltage distortion less than 5 %	Pass

Output Power	Limit [%]	Max.DC [%]	Verdict
33%	0.5	0.06	Pass
66%	0.5	0.18	Pass
100%	0.5	0.22	Pass

VERIFICATION REPORT

Clause	PEA Requirement	Result – Remark	Verdict
12.1	**Low Voltage Fault Ride Through** The power system of VSPP must not disconnect itself from the grid system within the required period during temporary low voltage of the grid system .The voltage at PCC is determined as shown in Table Fault Ride Through Duration of Low Voltage Fault Ride Through	**Low Voltage Fault Ride Through** **1) Requirement** The requirements on Grid Connection of Provincial Electricity Authority **2) Test result** -- **3) Verification test result** **3.1) Output Power >0.9Pn**	--

Voltage at PCC	Duration Time (Second)
1) Low voltage 2) Moderate voltage or high voltage (electrical installation not exceeding 500 kilowatt).	Not required.
3) Moderate voltage or high voltage (electrical installation exceeding 500 kilowatt).	As shown in Picture 1.



Picture 1. Low Voltage Fault Ride Through

Test List	V (V/Vn)	Duration (mS)	Limit (mS)	verdict
Three-phase faults	0.7-0.8 Vn		>993.75	
	0.3-0.5 Vn		>150	
	0-0.049Vn		>150	
Phase to phase faults	0.7-0.8 Vn		>993.75	
	0.3-0.5 Vn		>150	
	0-0.049Vn		>150	
Phase to ground faults	0.7-0.8 Vn		>993.75	
	0.3-0.5 Vn		>150	
	0-0.049Vn		>150	

3.2) Output Power 0.3Pn

Test List	V (V/Vn)	Duration (mS)	Limit (mS)	verdict
Three-phase faults	0.7-0.8 Vn		>993.75	
	0.3-0.5 Vn		>150	
	0-0.049Vn		>150	
Phase to phase faults	0.7-0.8 Vn		>993.75	
	0.3-0.5 Vn		>150	
	0-0.049Vn		>150	
Phase to ground faults	0.7-0.8 Vn		>993.75	
	0.3-0.5 Vn		>150	
	0-0.049Vn		>150	

VERIFICATION REPORT

Clause	PEA Requirement	Result – Remark	Verdict
		3.3) Output Power 0.1Pn Test List / V (V/Vn) / Duration (mS) / Limit (mS) / verdict Three-phase faults: 0.7-0.8 Vn — >993.75; 0.3-0.5 Vn — >150; 0-0.049Vn — >150 Phase to Phase faults: 0.7-0.8 Vn — >993.75; 0.3-0.5 Vn — >150; 0-0.049Vn — >150 Phase to ground faults: 0.7-0.8 Vn — >993.75; 0.3-0.5 Vn — >150; 0-0.049Vn — >150	--
12.2	**Under and Over Voltage Protection** The power system of VSPP must disconnect itself from the grid system if voltage level of line to neutral in the utility system is out of ranges as stated in Table 3. Table 3. The Disconnect Duration of Falling Voltage Out of Rated Voltage Ranges Voltage at PCC / Disconnect Duration (Second) V < 50% — 0.3 50% ≤ V< 90% — 2.0 90% ≤ V ≤ 110% — continual voltage 110% < V < 120% — 1.0 V ≥ 120% — 0.16	**Under and Over Voltage Protection** **1) Reference Standard** IEC 61727 **2) Test result** See Test report no: PVTH190322N026 Page 21-24 **3) Verification test result** Voltage at PCC / Max Meas. (Sec) / Limit (Sec) / Result V < 50% — 0.180 — <0.3 — Pass 50% ≤ V< 90% — 1.680 — <2.0 — Pass 90% ≤ V ≤ 110% — No trip — Cont. — Pass 110% < V < 120% — 0.720 — <1.0 — Pass V ≥ 120% — 0.090 — <0.16 — Pass	Pass

<table>
<tr><th colspan="4">VERIFICATION REPORT</th></tr>
<tr><th>Clause</th><th>PEA Requirement</th><th>Result – Remark</th><th>Verdict</th></tr>
<tr><td>12.3</td><td>Anti-Islanding
In order to prevent anti-islanding while there is no electricity in grid system to be supplied to the power system of VSPP, the power generating system of VSPP must disconnect itself from the utility system within 1 seconds.</td><td>Anti-Islanding
1) Reference Standard
IEC 62116

2) Test result
See Test report no: PVTH190322N026
Page 30-37

3) Verification test result

<table>
<tr><th>% Off Pout_{rating}</th><th>Maximum Runtime (Sec)</th><th>Limit (Sec)</th><th>Result</th></tr>
<tr><td>100</td><td>0.404</td><td>< 1.0</td><td>Pass</td></tr>
<tr><td>66</td><td>0.410</td><td>< 1.0</td><td>Pass</td></tr>
<tr><td>33</td><td>0.412</td><td>< 1.0</td><td>Pass</td></tr>
</table>
</td><td>Pass</td></tr>
<tr><td>12.4</td><td>Response to Utility Recovery
After the power generating system of VSPP disconnect itself from the grid system because of power outage or voltage/frequency is out of the ranges, when the grid system is back to normal, the power system of VSPP must delay the time to reconnect itself to the grid system at a minimum of 20 seconds to 5 minutes.</td><td>Response to Utility Recovery
1) Reference Standard
IEC 61727

2) Test result
See Test report no: PVTH190322N026
Page 21-22, 25-27,29,

3) Verification test result

<table>
<tr><th>Limit Recovery time (Sec)</th><th>Max. Mesurement Recovery time (Sec)</th><th>Result</th></tr>
<tr><td>20 - 300</td><td>70</td><td>Pass</td></tr>
</table>
</td><td>Pass</td></tr>
</table>

---------- END OF REPORT ----------

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, 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.....:	SOFAR SOLAR
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].....: [Battery charge].....:	42-58Vdc
Input DC current [A] .....: [Battery charge].....:	Max.65A
Output DC current [A].....: [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.

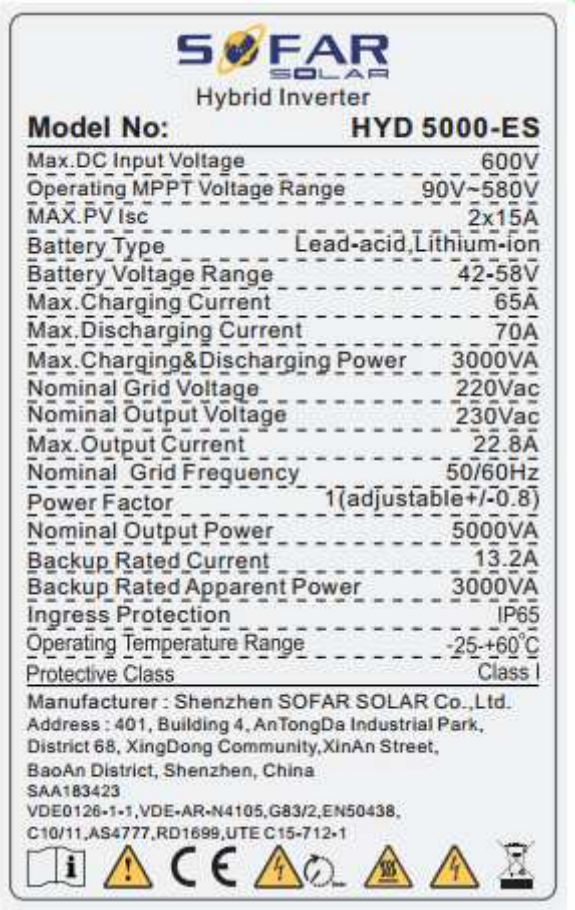
"(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

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:

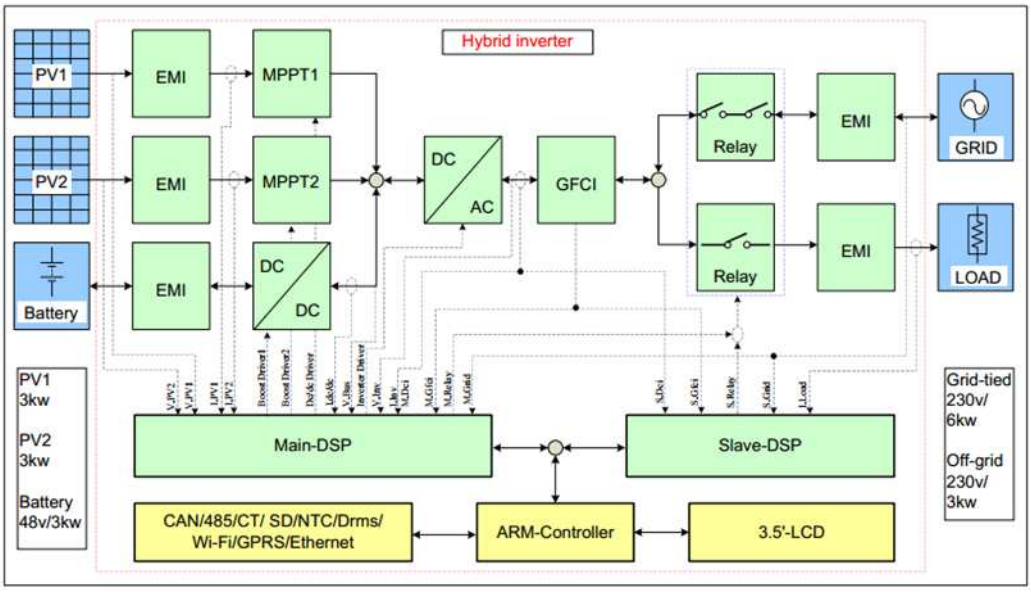


Figure 1 – Block diagram

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) **(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** 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. 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** 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** 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** 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** 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: Provincial Electricity Authority (PEA:2016) See table 4.4	**P**
4.5	**Normal frequency operating range** 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: Provincial Electricity Authority (PEA:2016) See table 5.2.2	**P**

IEC61727:2004			
Clause	Requirement – Test	Result – Remark	Verdict
SECTION 4: Utility compatibility			
4.6	**Harmonics and waveform distortion** 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. 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. 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. 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: Provincial Electricity Authority (PEA:2016) See tables 4.6 (1) and 4.6 (2)	**P**
4.7	**Power factor** 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** 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** 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. 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. 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: Provincial Electricity Authority (PEA:2016)	**P**
5.2	**Over/under voltage and frequency** 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: Provincial Electricity Authority (PEA:2016) See table 5.2.1 and 5.2.2	**P**
5.2.1	**Over/under voltage** 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. 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. (see clause 5.2.1 Table 2 – Response to abnormal voltages) 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: Provincial Electricity Authority (PEA:2016) 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** 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. 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: Provincial Electricity Authority (PEA:2016) See table 5.2.2	**P**
5.3	**Islanding protection** The PV system must cease to energize the utility line within 2 s of loss of utility.	The following deviations were used: Provincial Electricity Authority (PEA:2016) See table 6.1	**P**
5.4	**Response to utility recovery** 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** 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** 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** 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 **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 3.30(%)	1.00	0.65 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; jX_{max}= 0,15Ω @50Hz (|Z_{max}| = 0,283 Ω)**
for single phase inverter use also **R_n = 0,16Ω; jX_n= 0,1Ω**

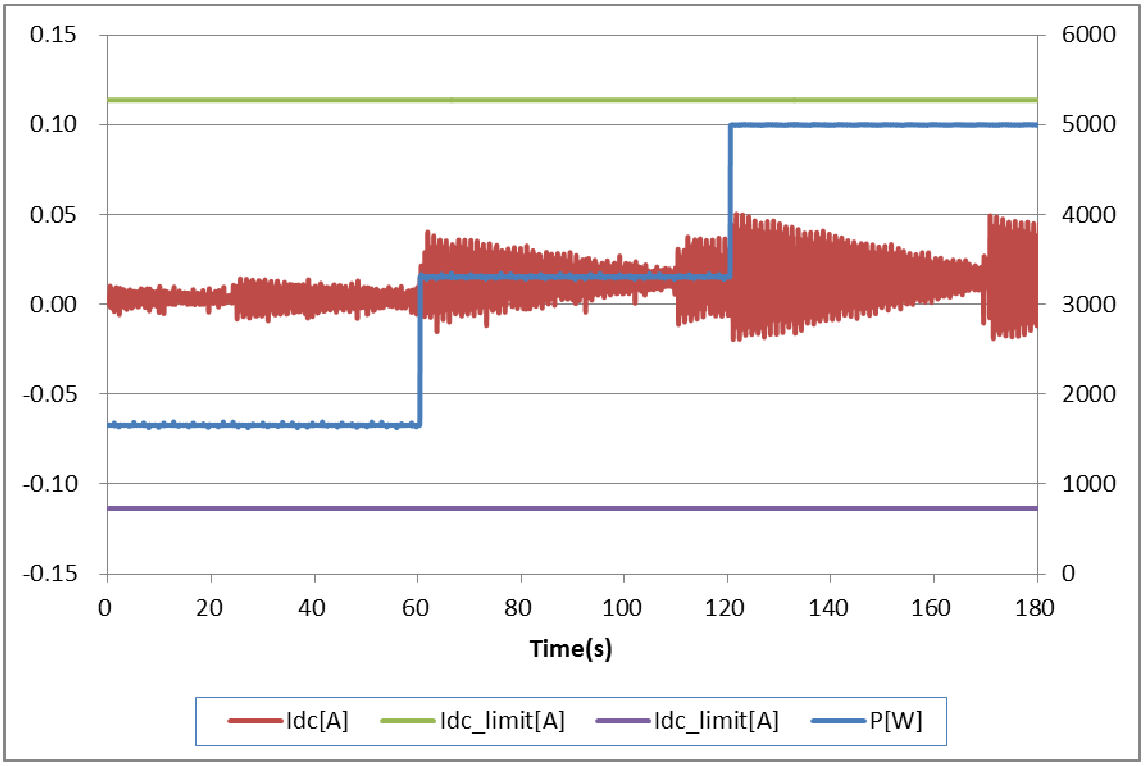
Calculation of the maximum permissible grid impedance at the point of common coupling based on d_c:
$Z_{max} = Z_{ref} * 3,3\% / d_c(P_n)$

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 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 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 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) **3.1, 8.4 Harmonic Regulation (PEA: 2016)**					**P**
Test conditions:					
Output power [kW] / **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 **3.7, 12.3 Under and Over Voltage Protection (PEA:2016)** **3.10, 12.5 Response to utility recovery (PEA:2016)**	**P**

First Level (Phase to Neutral)

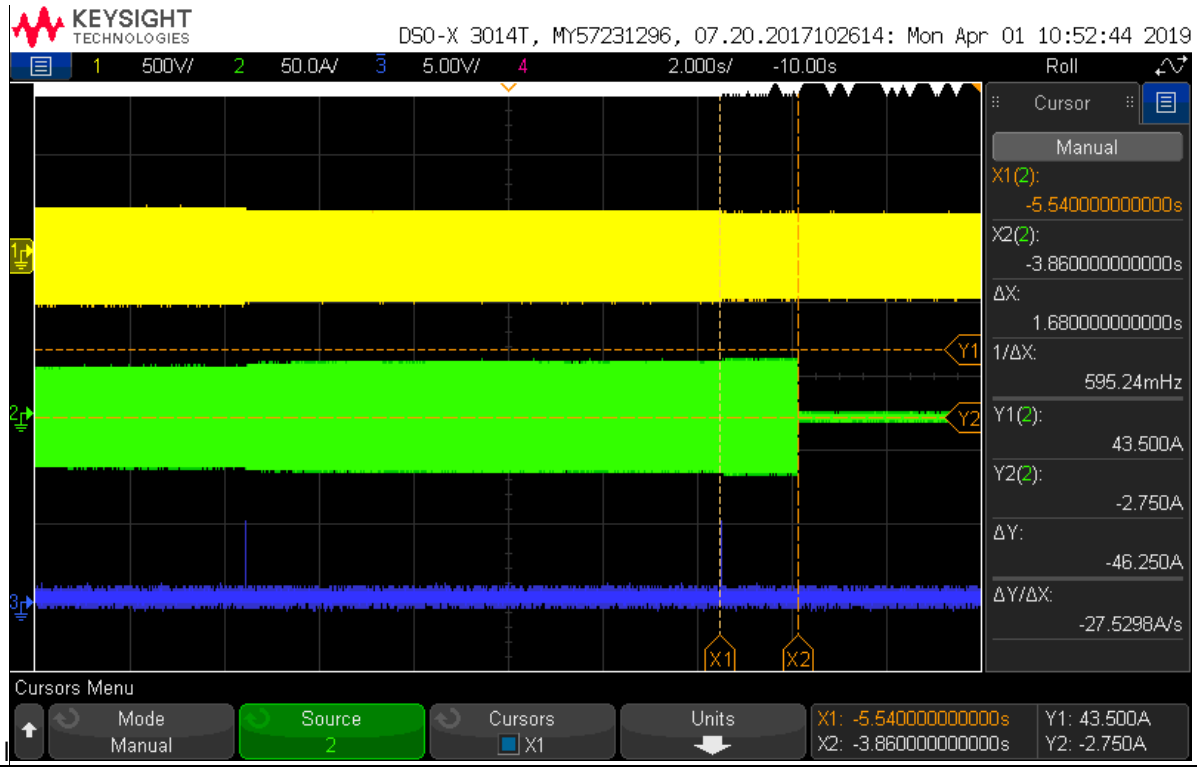
Test conditions:	Output power: 4,9KW Frequency: 50Hz									
	Under Voltage					**Over Voltage**				
		Voltage [V]					Voltage [V]			
Set value		**198V**					**242V**			
Measured trip value		All	L1	L2	L3		All	L1	L2	L3
		--	197,9	--	--		--	242,1	--	--
		--	197,9	--	--		--	242,1	--	--
Parameter		Time [s]					Time [s]			
Limit		**<= 2,0s**					**<= 1,0s**			
Disconnetion time	220V to 203V (4s min) to 193V	All	L1	L2	L3	220V to 237V (2s min) 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 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			

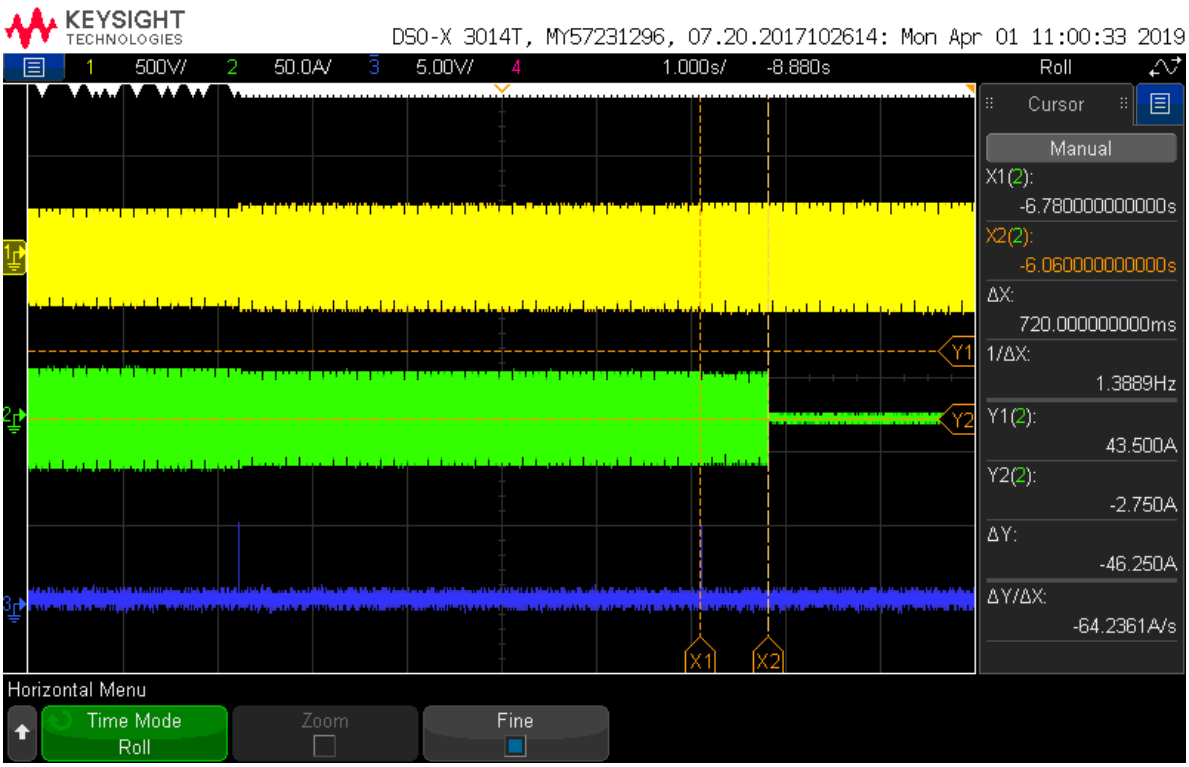
Note:
The tests are according PEA 8/9/2556. The voltage settings of the EUT are set for the tests as stated to 198V, 110V for undervoltage and 242V, 264V for overvoltage.

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

Under Voltage First Level single phase

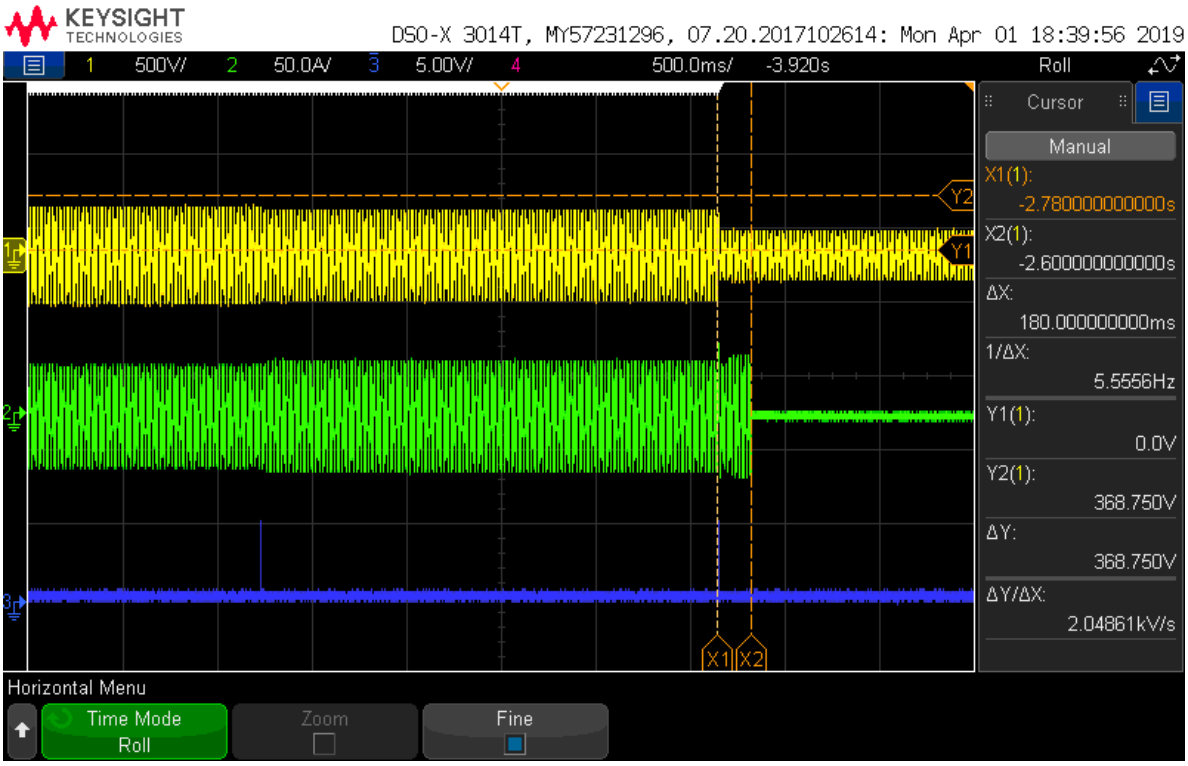


Over voltage First Level single phase

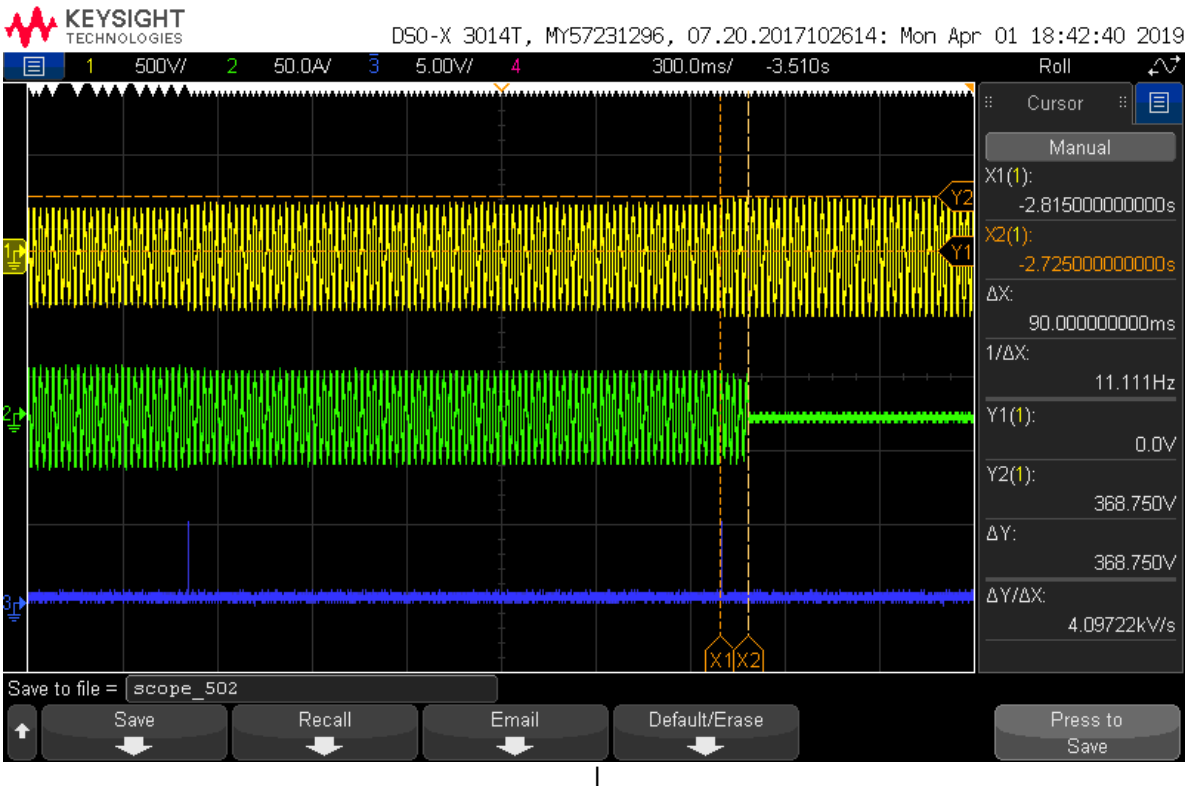


Note: CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

Under Voltage Second Level single phase

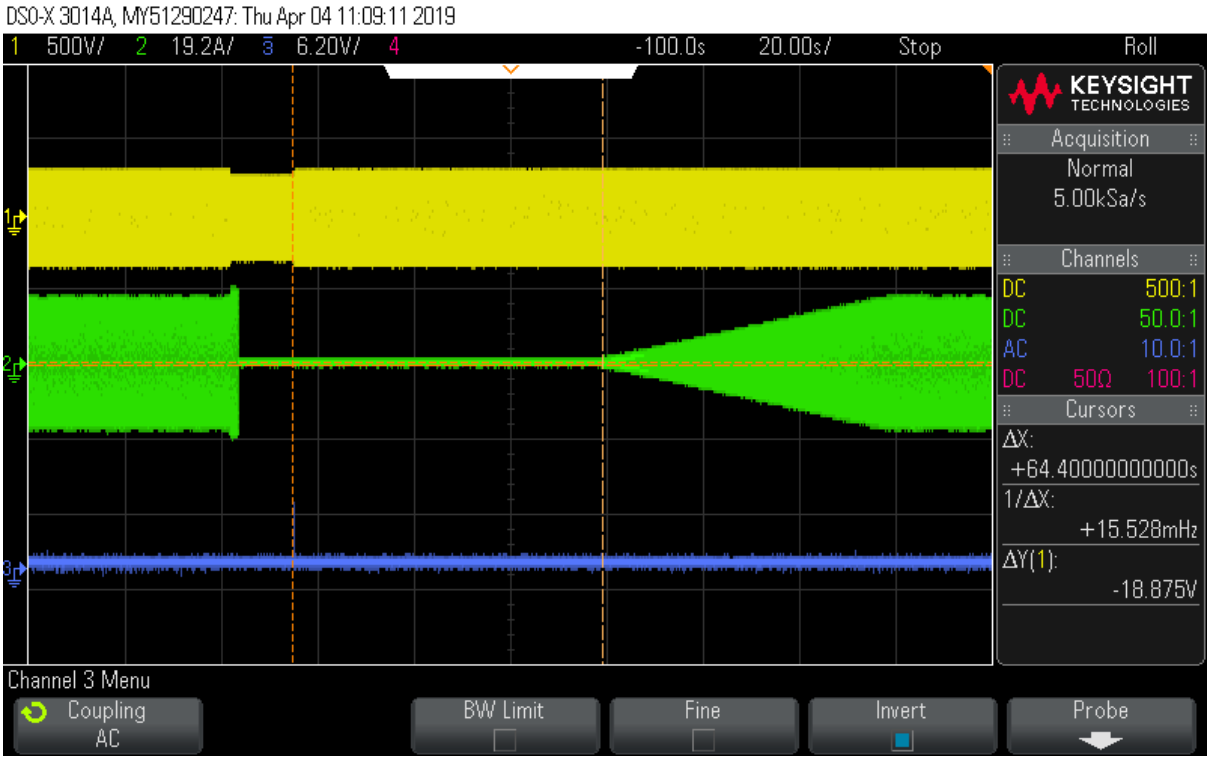


Over voltage Second Level single phase

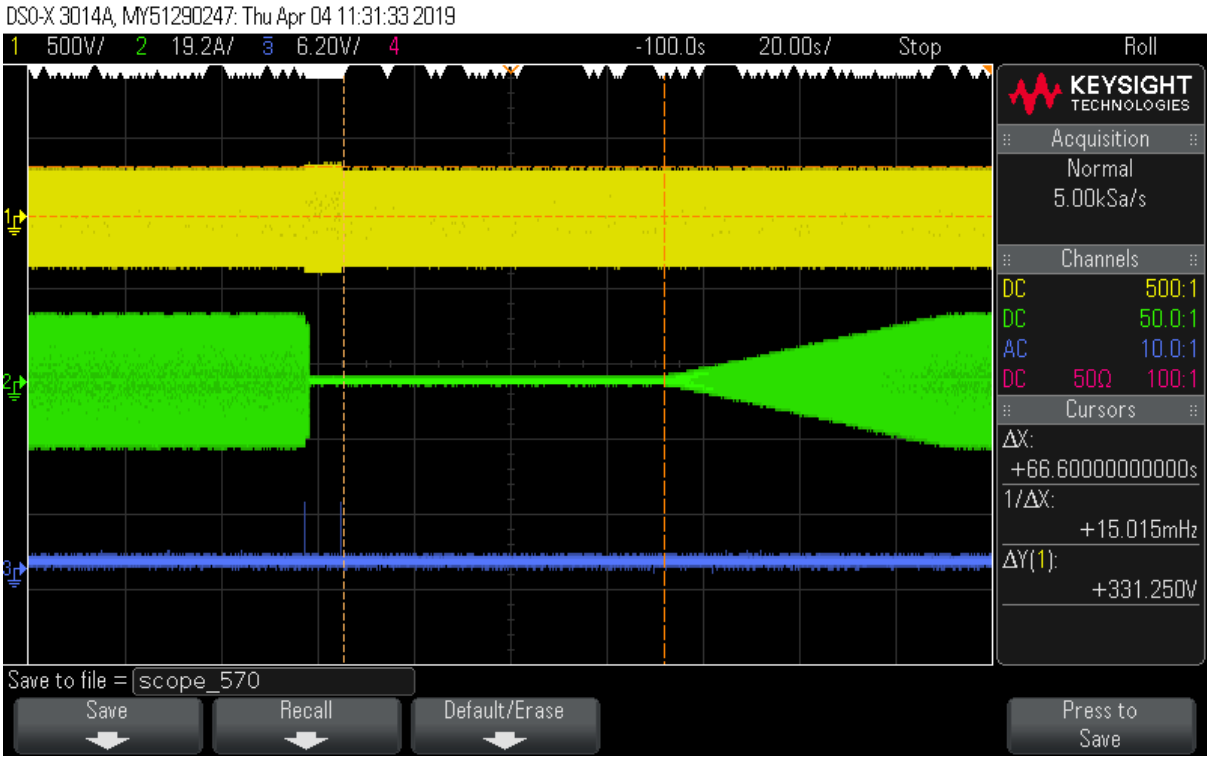


Note: CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

Reconnection after Under Voltage First Level

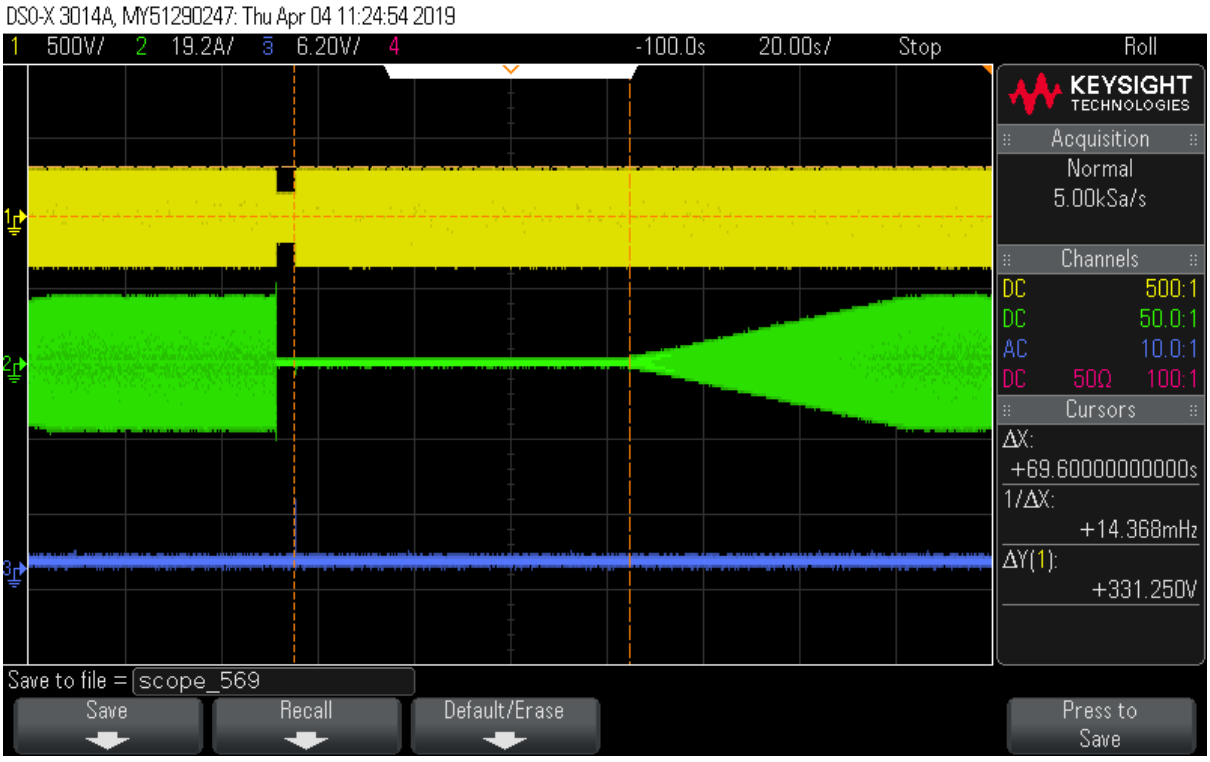


Reconnection after Over Voltage First Level

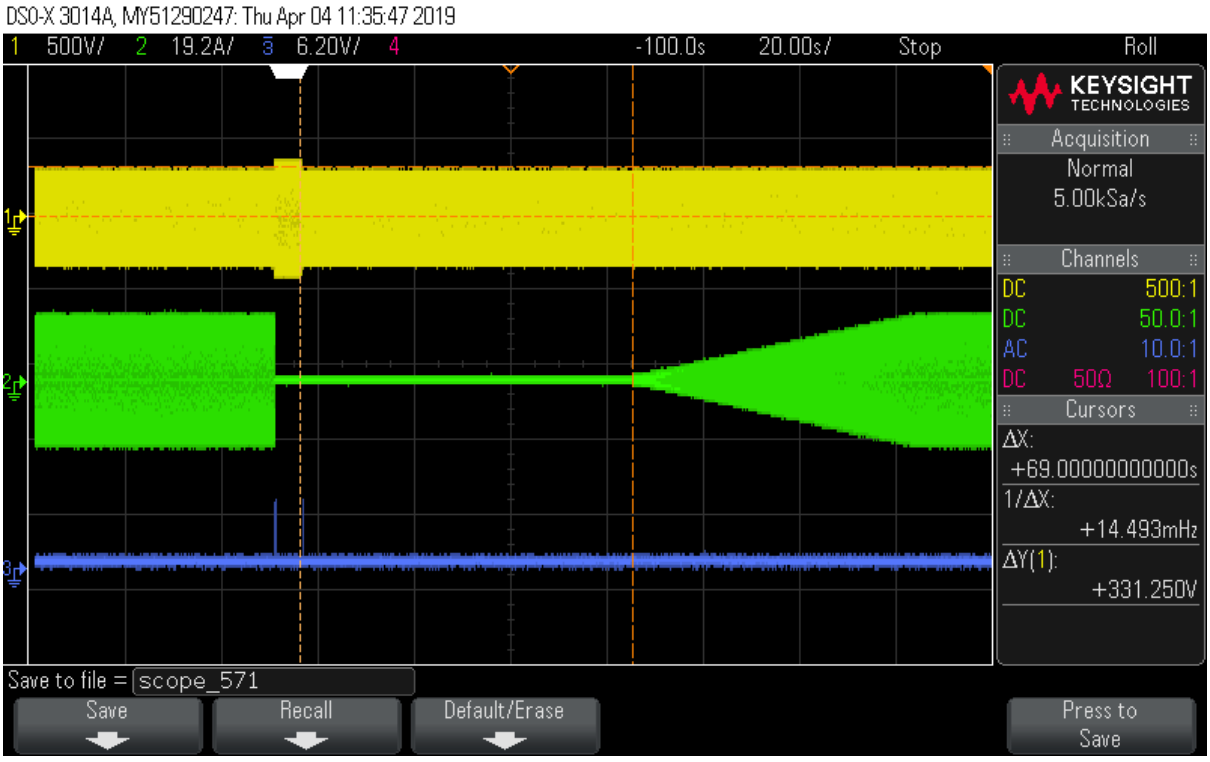


Note: CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

Reconnection after Under Voltage Second Level



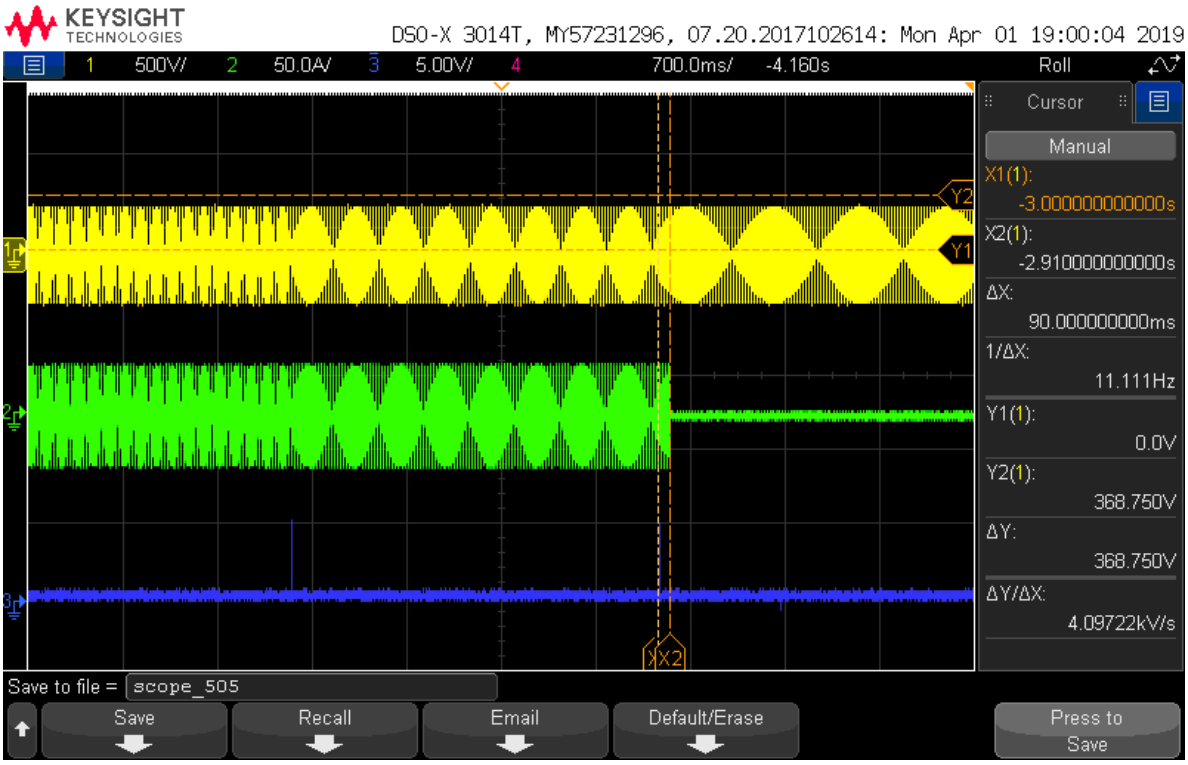
Reconnection after Over Voltage Second Level



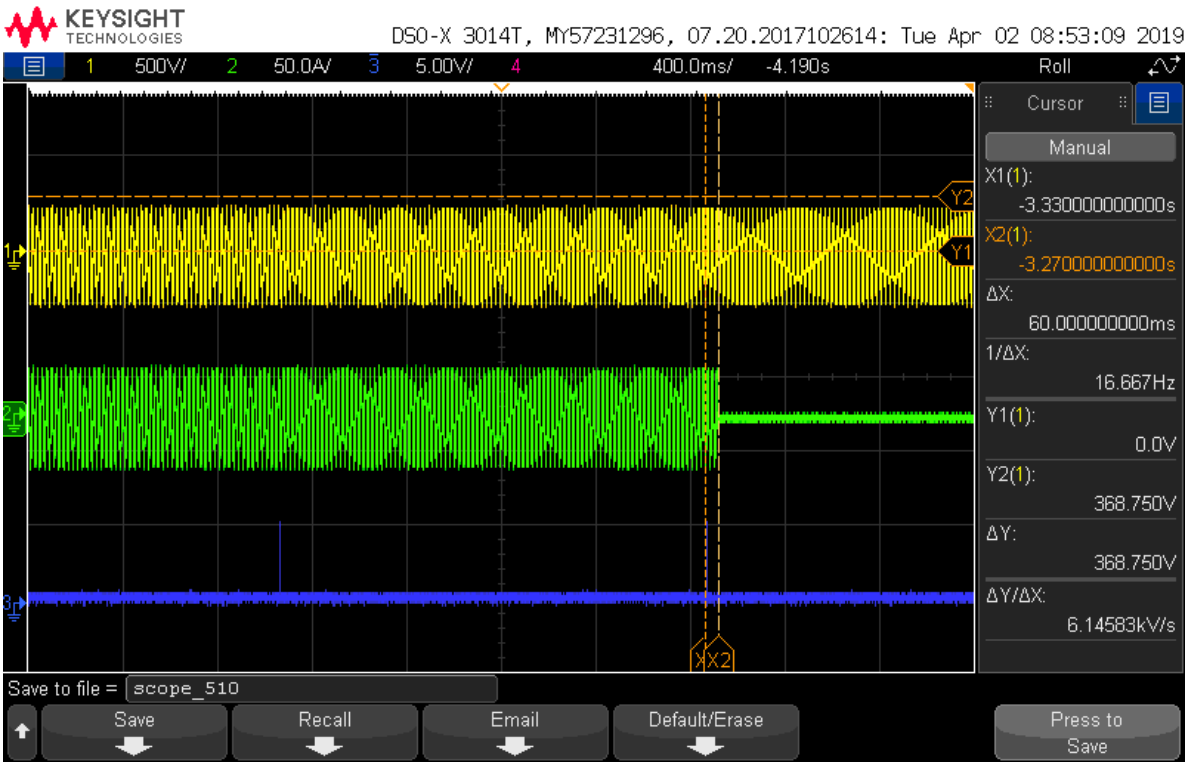
Note: CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

5.2.2 Frequency monitoring					**P**
IEC 61727 **8.2 Under and Over Frequency Protection (PEA:2016)** **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: 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. The tests are performed according the IEEE 1547.1-2005, annex A. The reconnection time follows the test procedure of IEEE 1547.1, clause 5.10.					

Under Frequency:

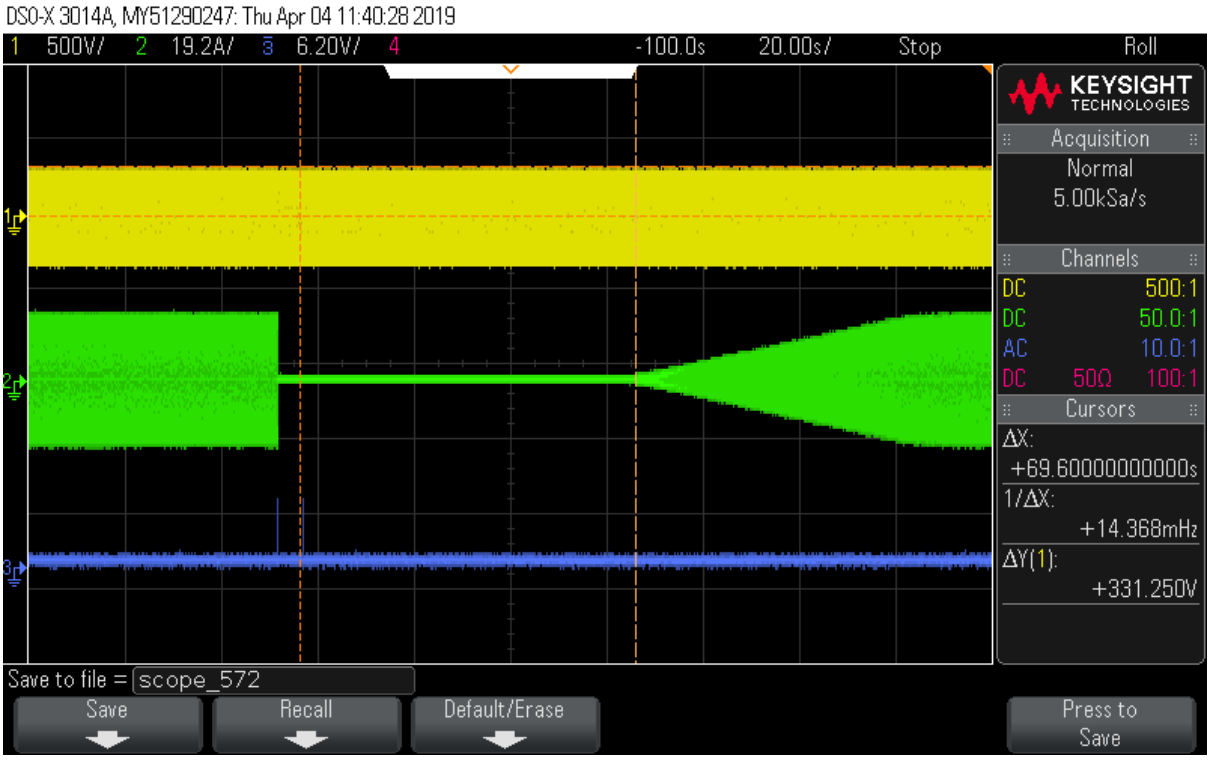


Over Frequency:

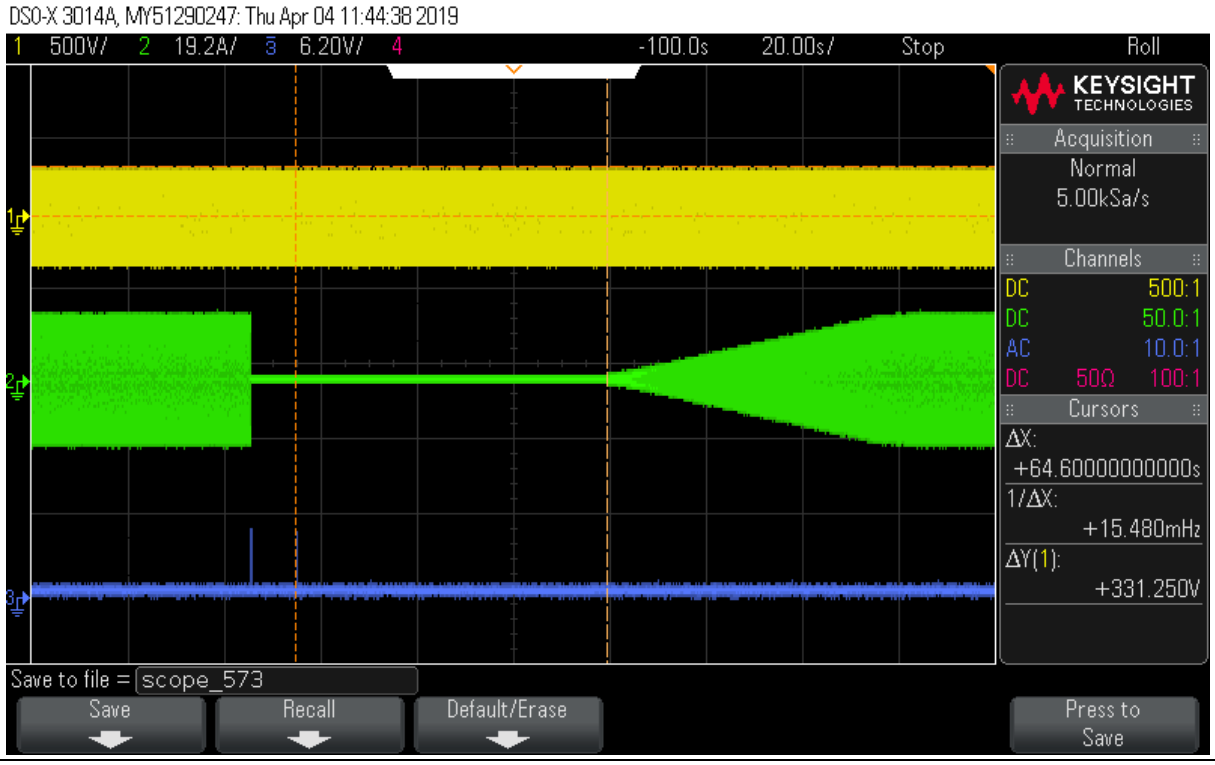


Note:
CH1: grid voltage(500V/div); CH2: Current of EUT(50A/div); CH3: trip signal

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

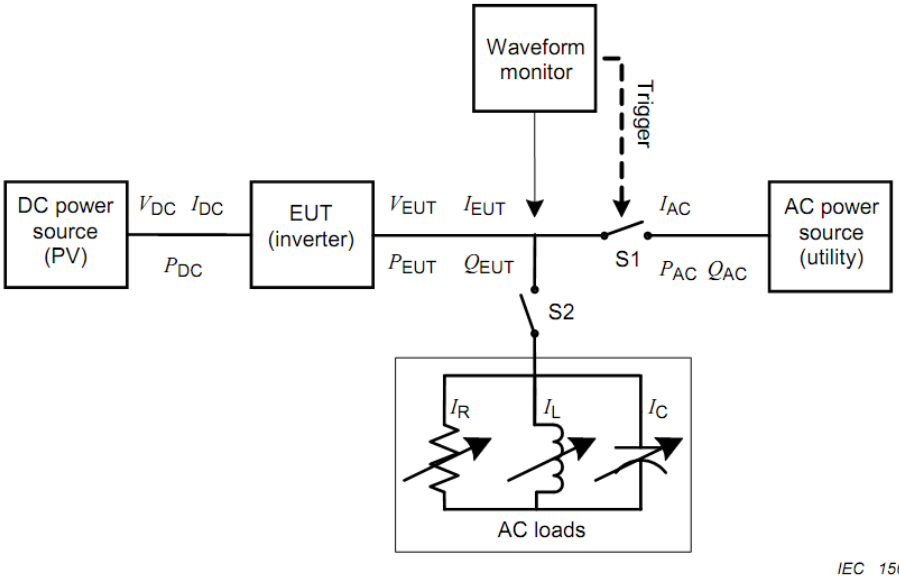


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

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

Test conditions	Frequency: 50+/-0,1Hz U_N=220+/-3Vac Distortion factor of chokes < 2% 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

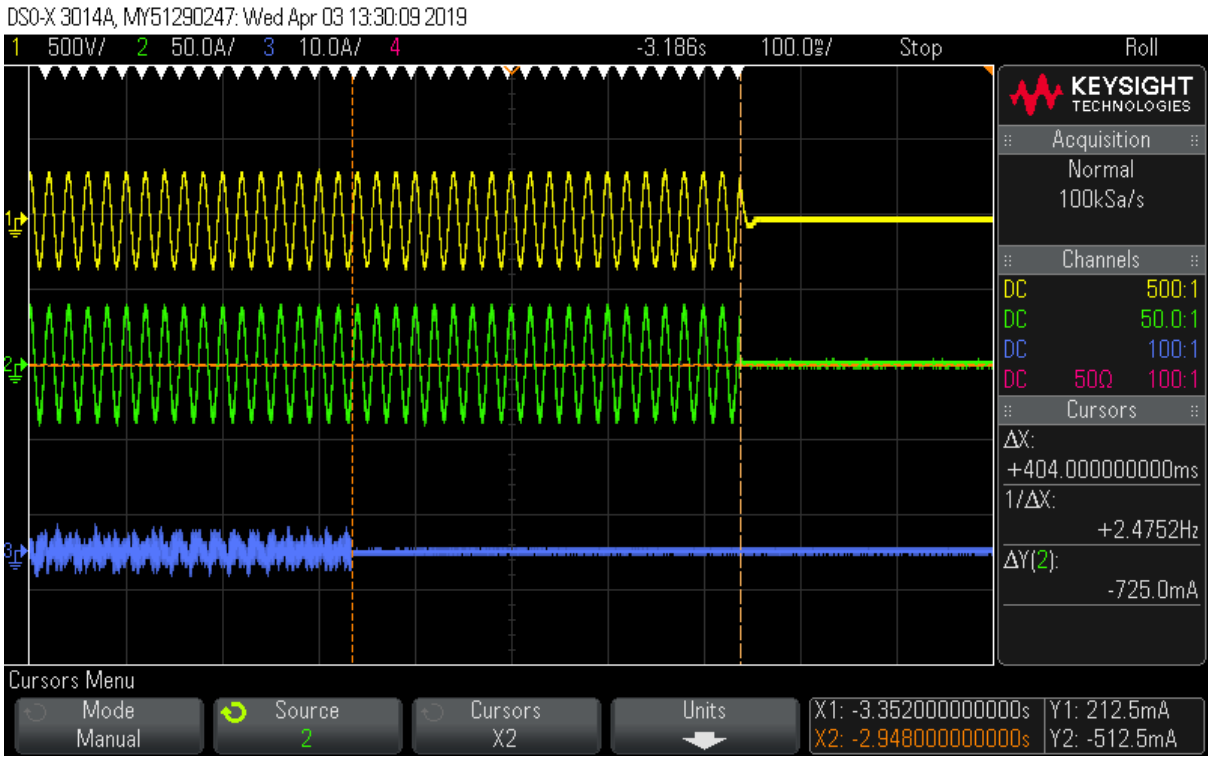
46	100	100	+10	+5	320	4980	0,934	445	Test A at IB
47	100	100	+10	+10	322	4980	0,956	445	Test A at IB
Parameter at 0% per phase			L= 30,84 mH			R= 9,72 Ω		C= 328,50 µF	
IAC fundamental current(A)			156 mA						

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 %) **3.9, 12.4 Anti-Islanding (PEA:2016)**	**P**

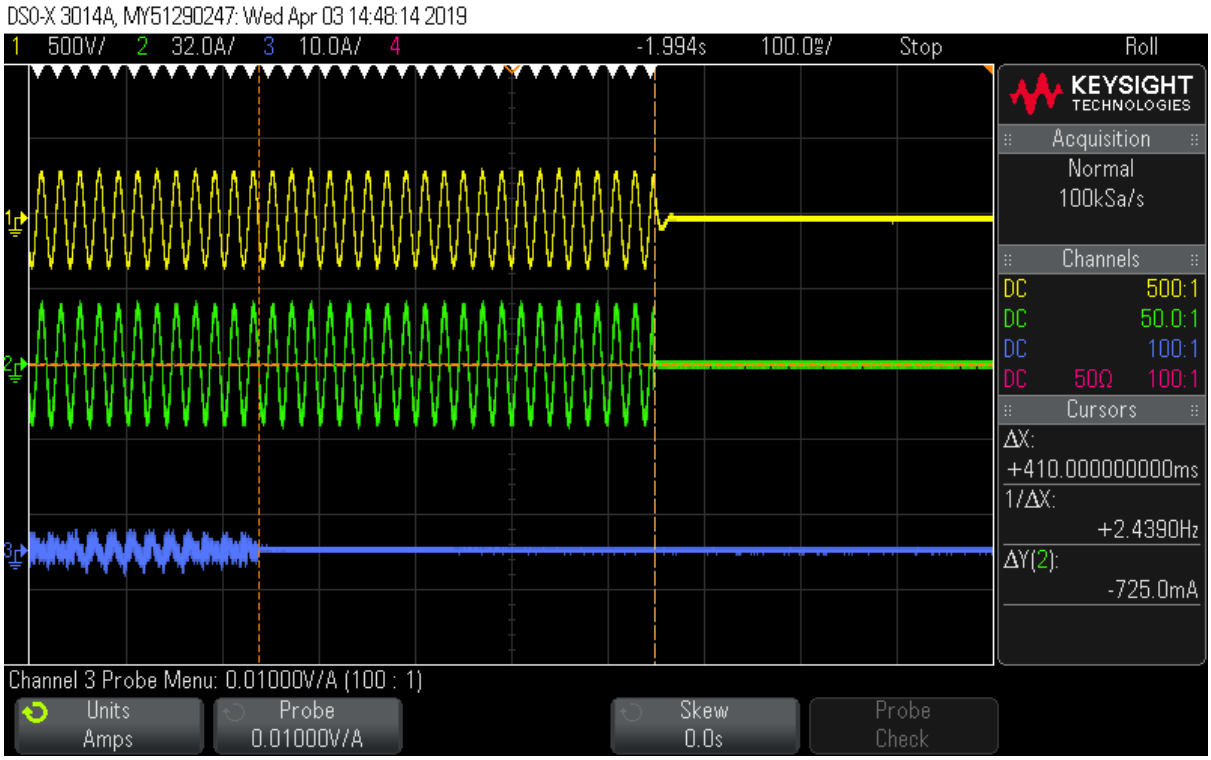
Test conditions	Frequency: 50+/-0,1Hz U_N=220+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	1s

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 %) **3.9, 12.4 Anti-Islanding (PEA:2016)**	**P**

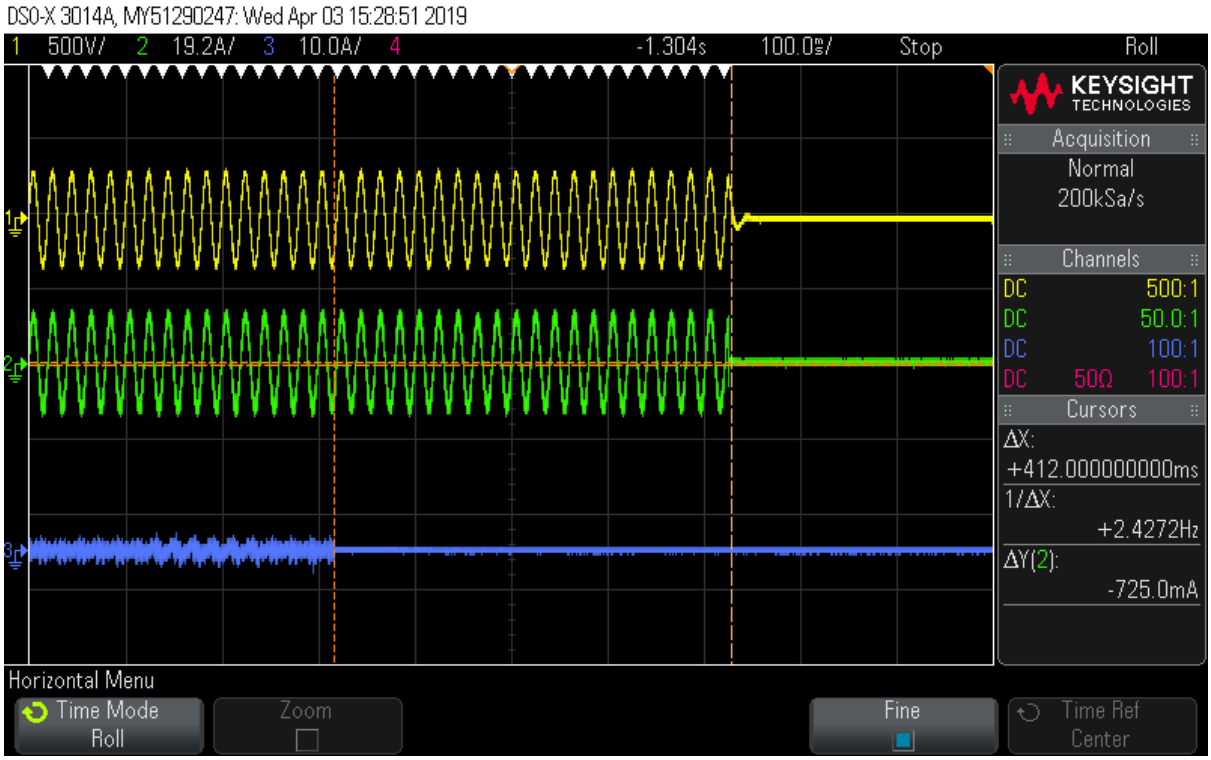
Test conditions	Frequency: 50+/-0,1Hz U_N=220+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	1s

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.

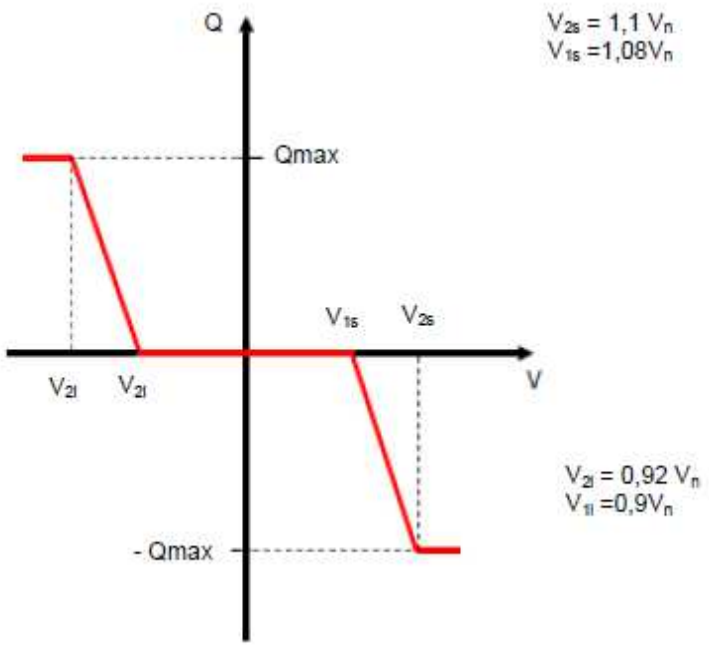
Activation must be at the Distributor's request, when the Operating Regulations are issued. The Distributor shall also specify the values of the parameters that uniquely characterise the curve, i.e.: V1i, V2i, V1s and V1s as well as the lock-in value of active power (default value P = 0,2 P_n).

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

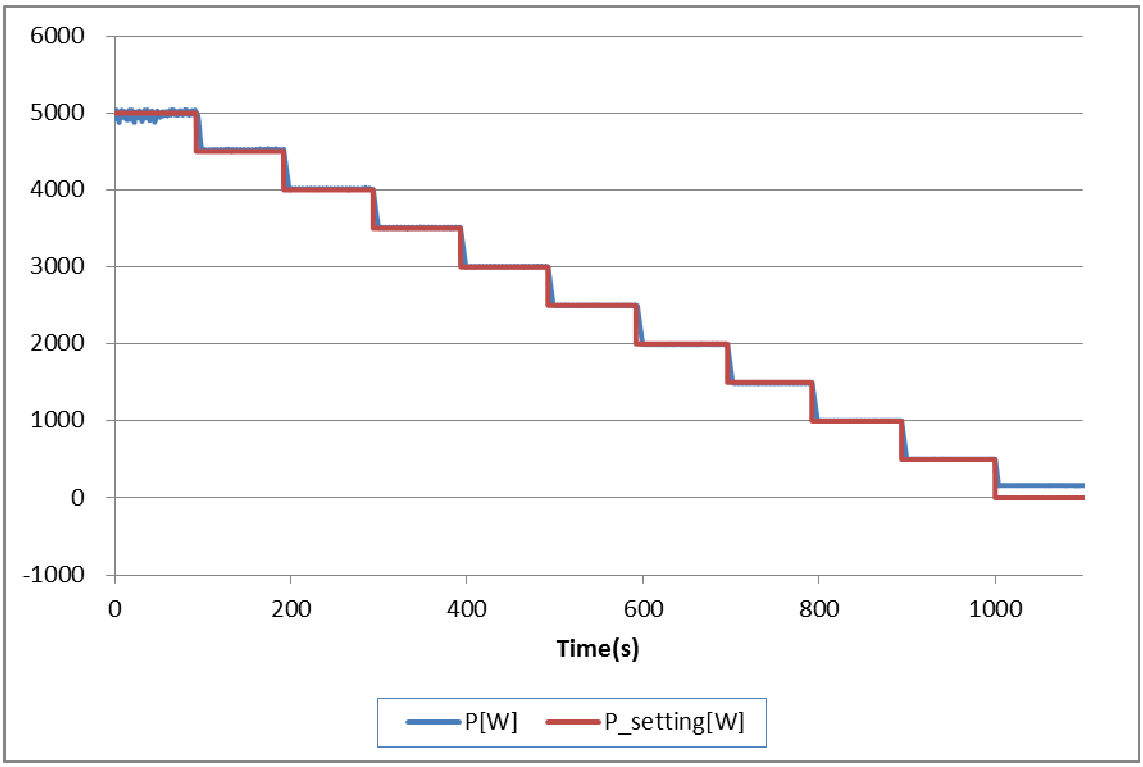
and the active power lock-in value (default value P = 0,2 P_n).



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>0,9P_n*		
Three-phase faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,05V_n	---
Phase to phase faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,05V_n	---
Single phase to ground faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,05V_n	---
Test P=0,3P_n		
Three-phase faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,049V_n	---
Phase to phase faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,049V_n	---
Single phase to ground faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,049V_n	---
Test P=0,1 Pn		
Three-phase faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,049V_n	---
Phase to phase faults	0,7-0,8V_n	---
	0,3-0,5V_n	---
	0-0,049V_n	---

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

Note:

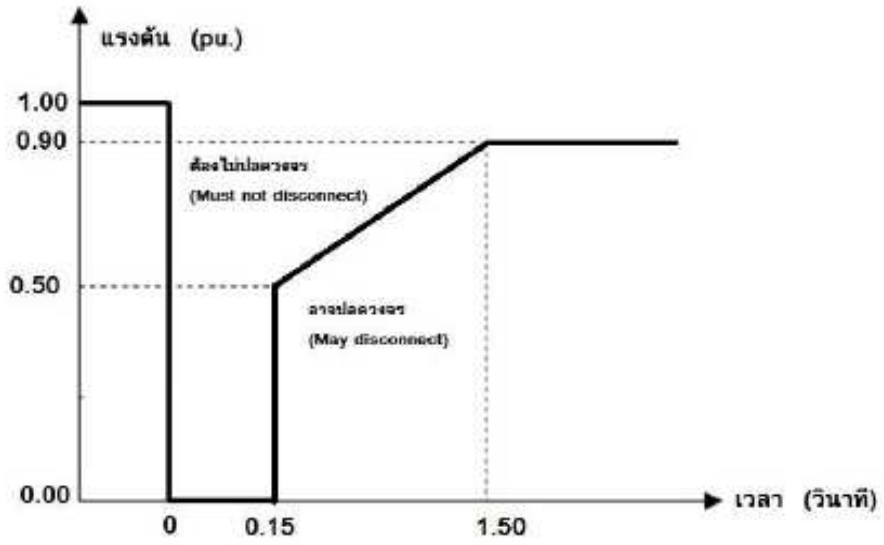
The PGS must not disconnected from gird while the PCC voltage dip period less than below curve limit.

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

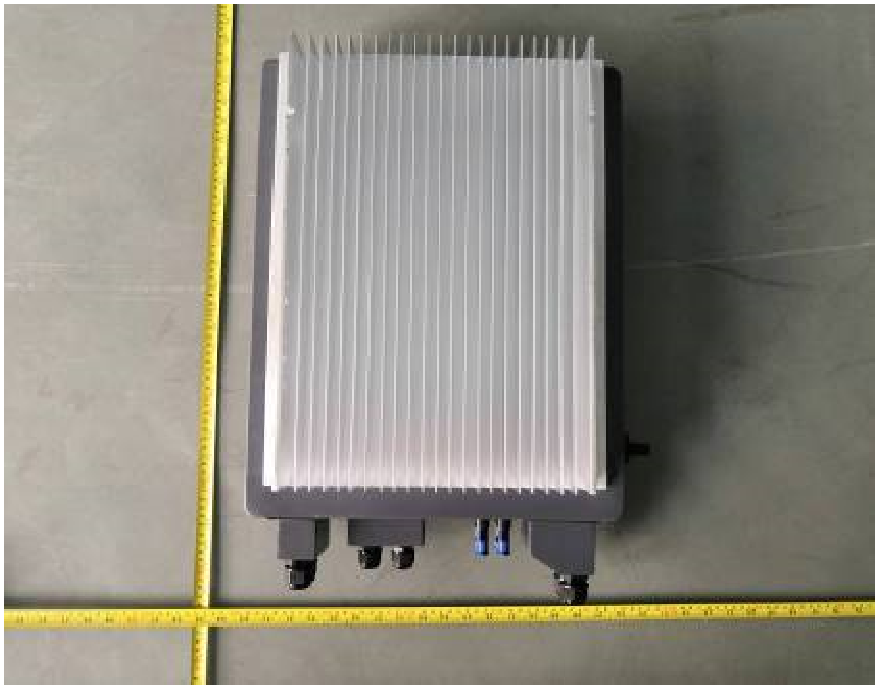
Test local: Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Date(s) of performance of test 2019-03-22 to 2019-04-22

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

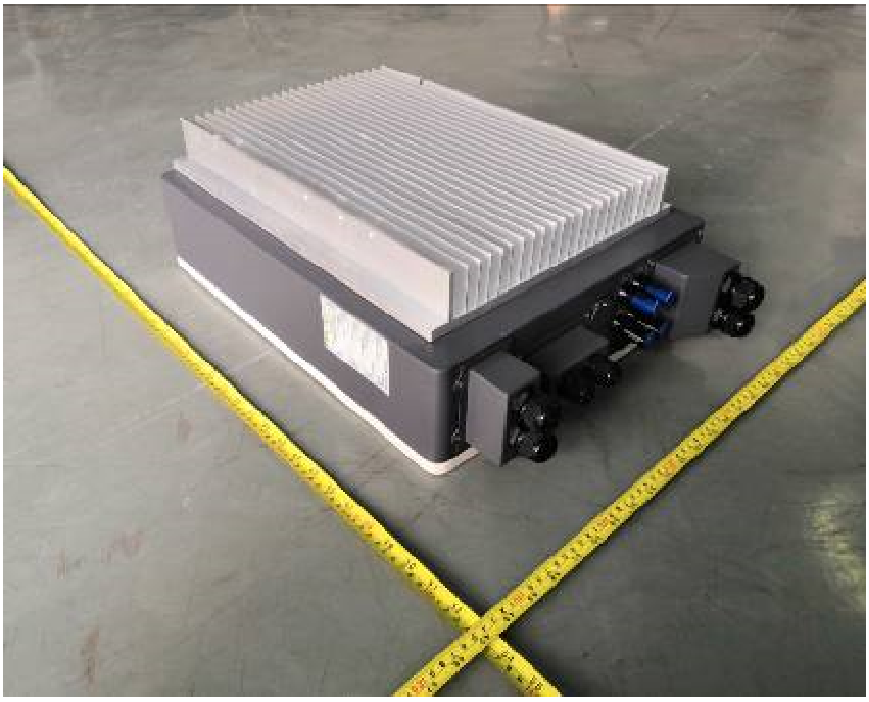
Pictures of the unit

Enclosure front view

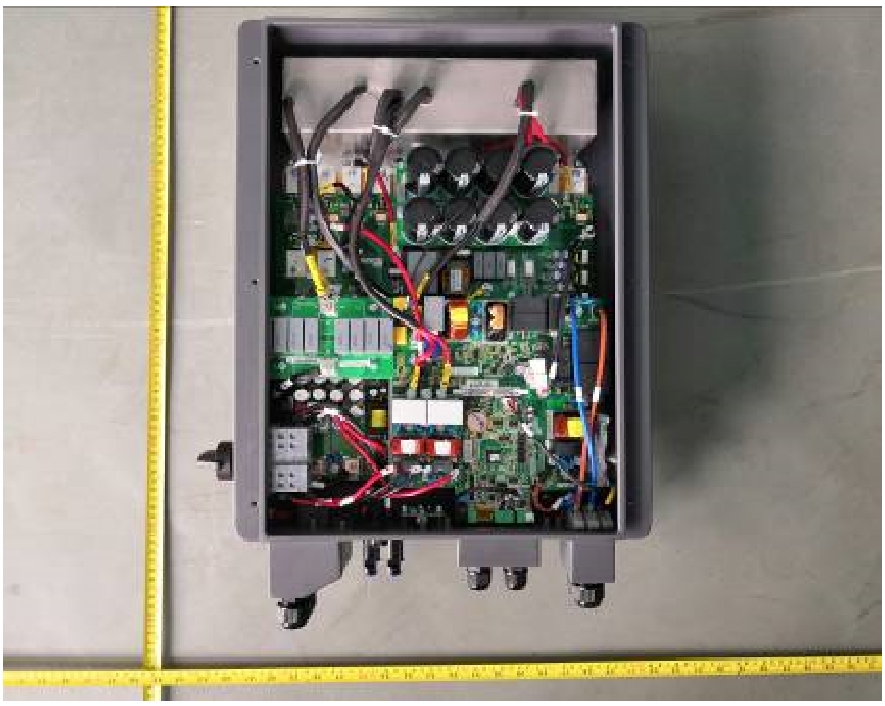
Enclosure rear view

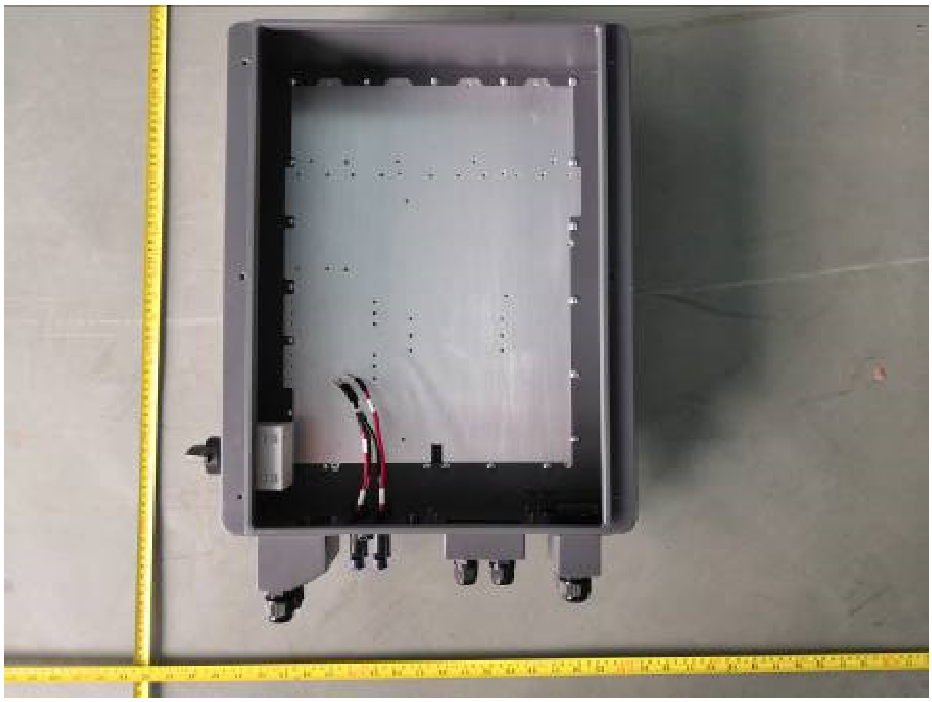


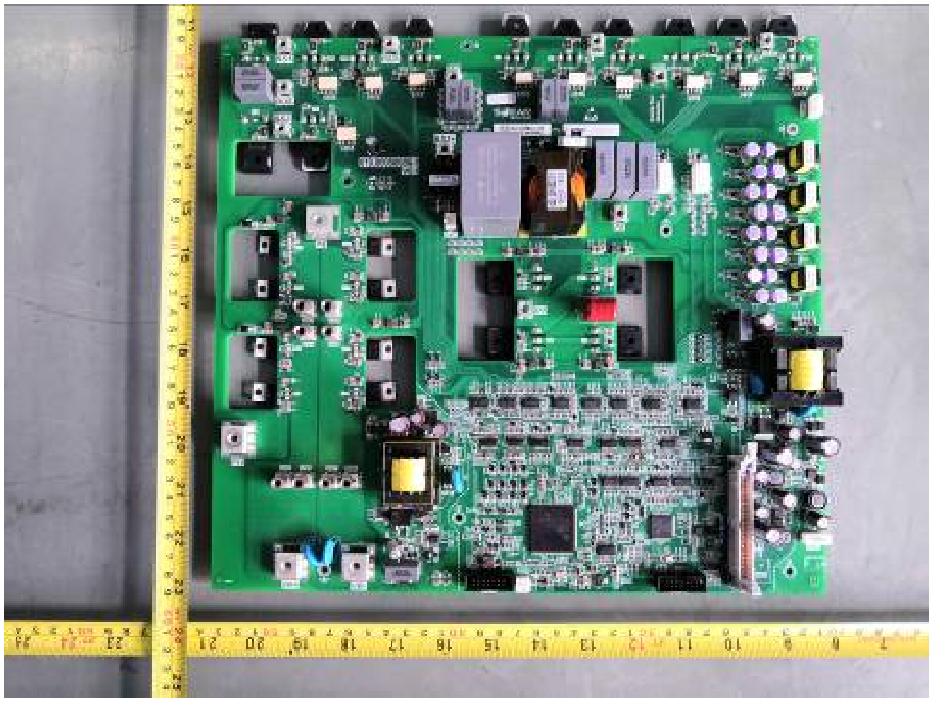
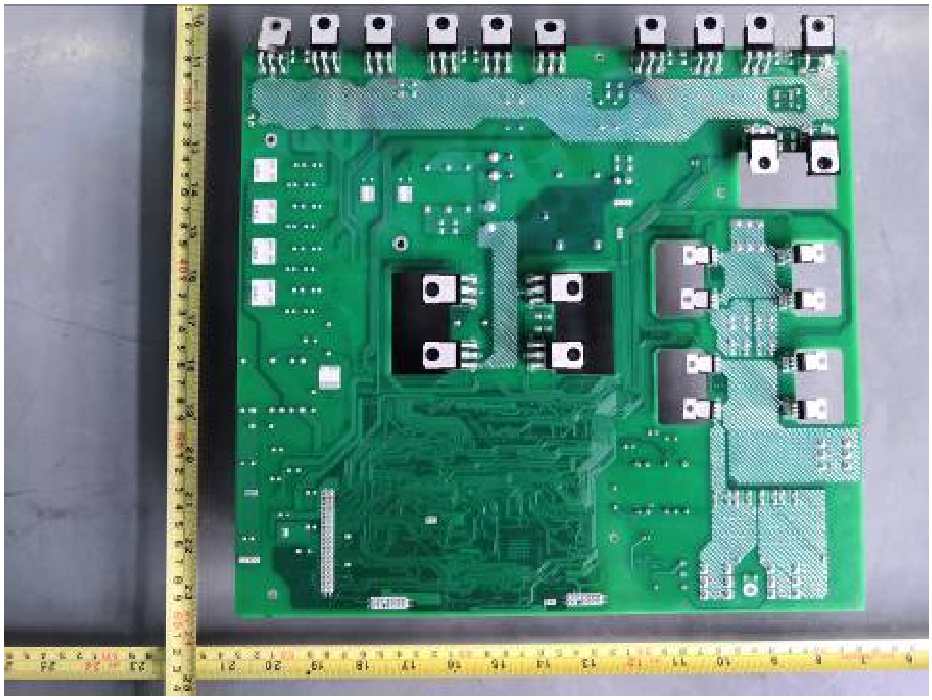
Enclosure front view

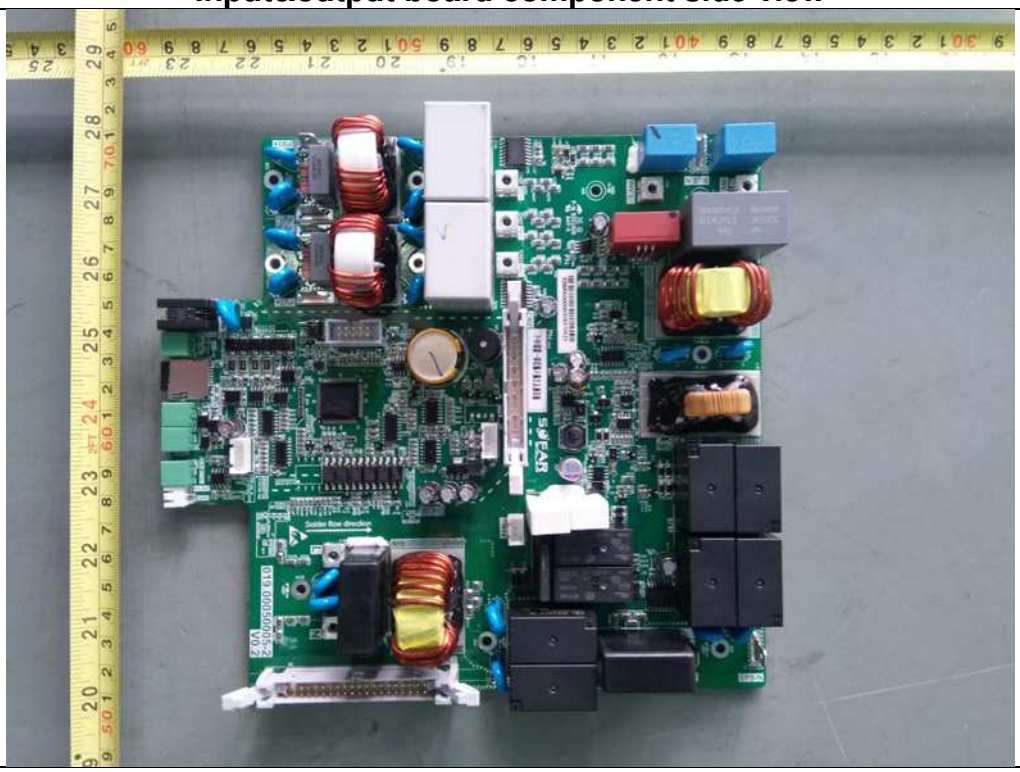
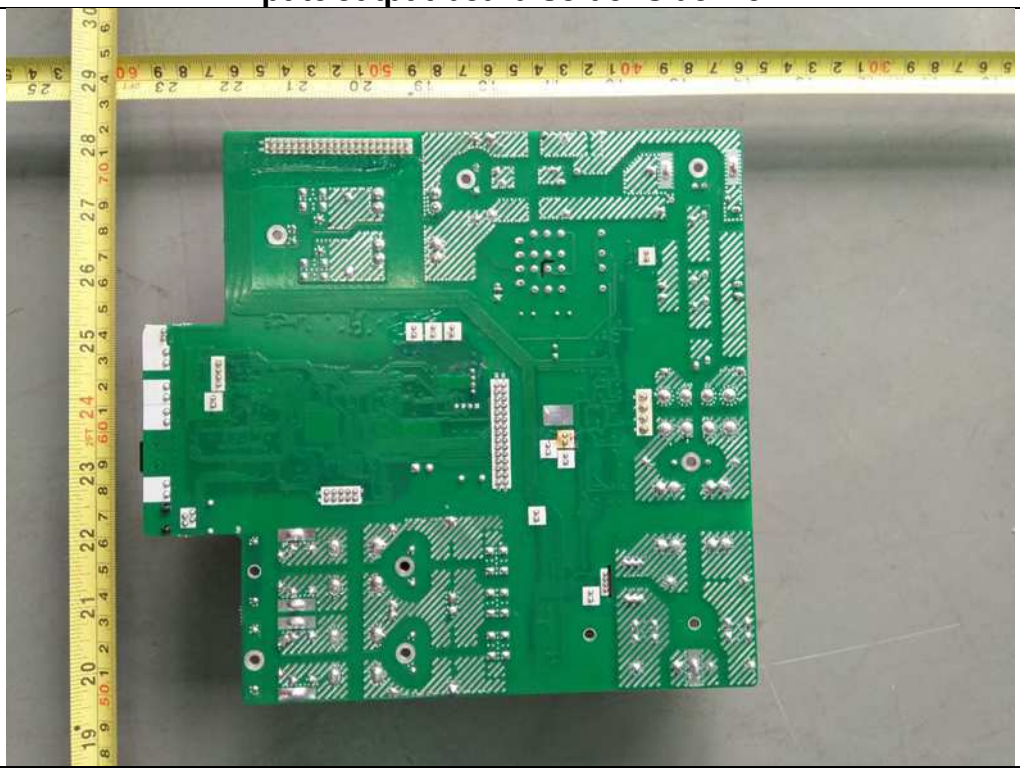
Enclosure rear view


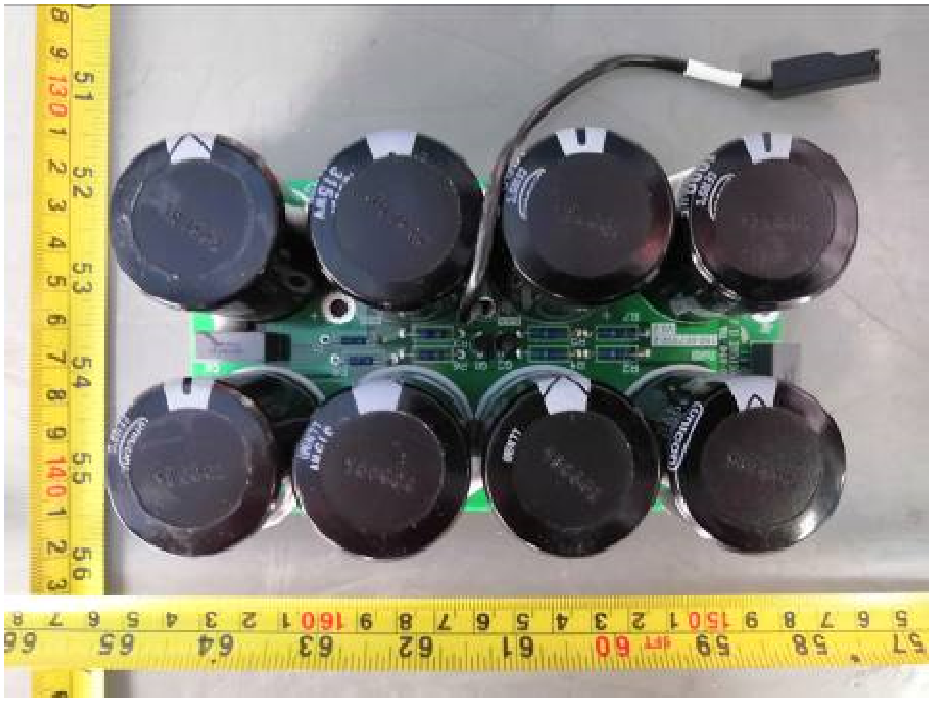
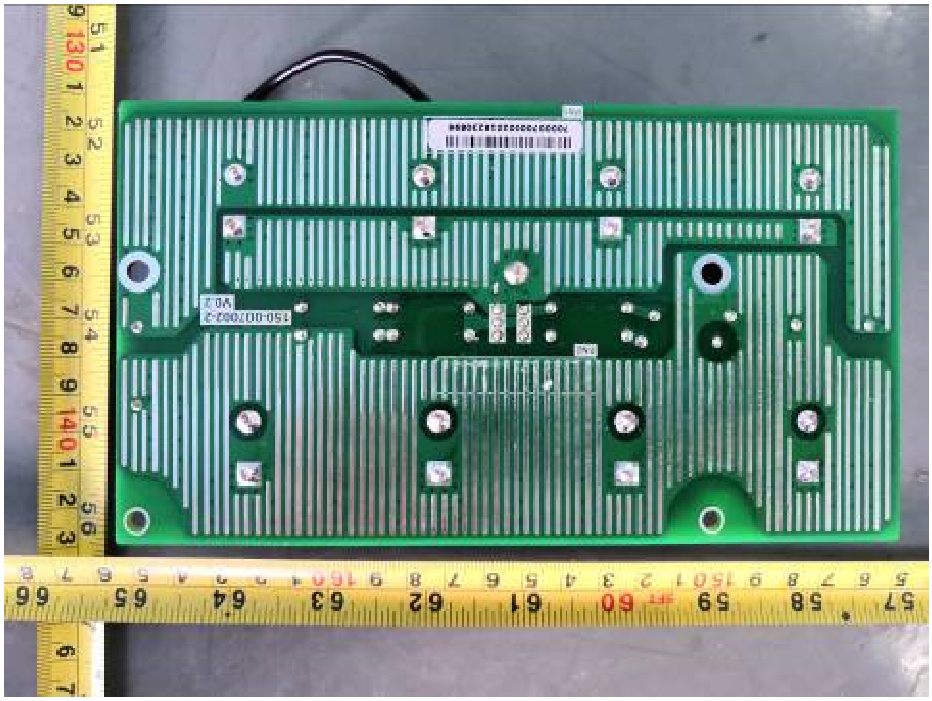
Enclosure Bottom view

Internal view-1


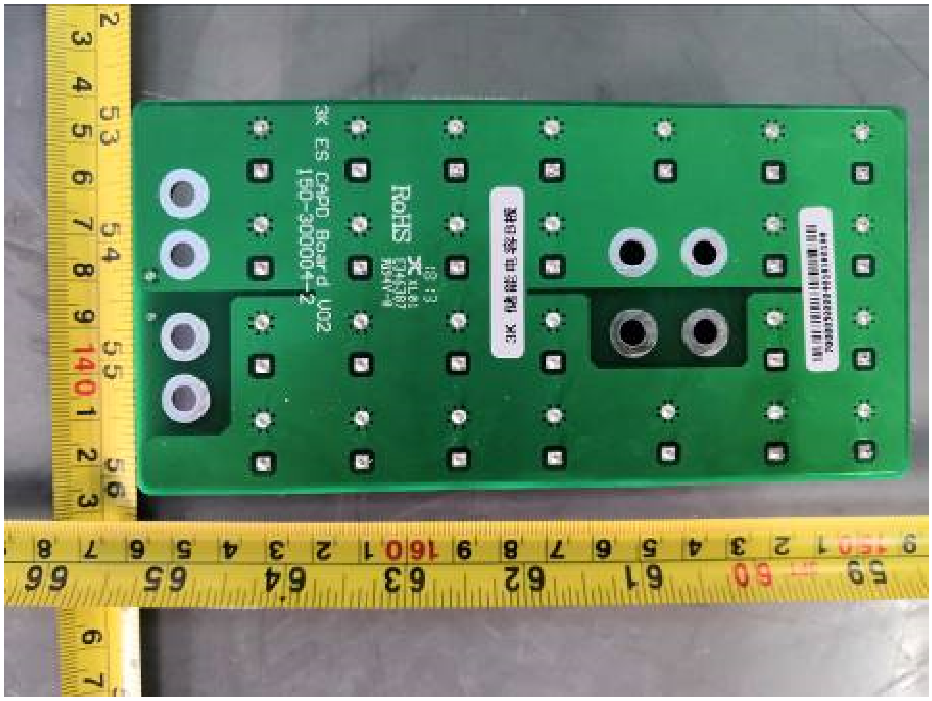
Internal view-2

Internal view: Ground terminal

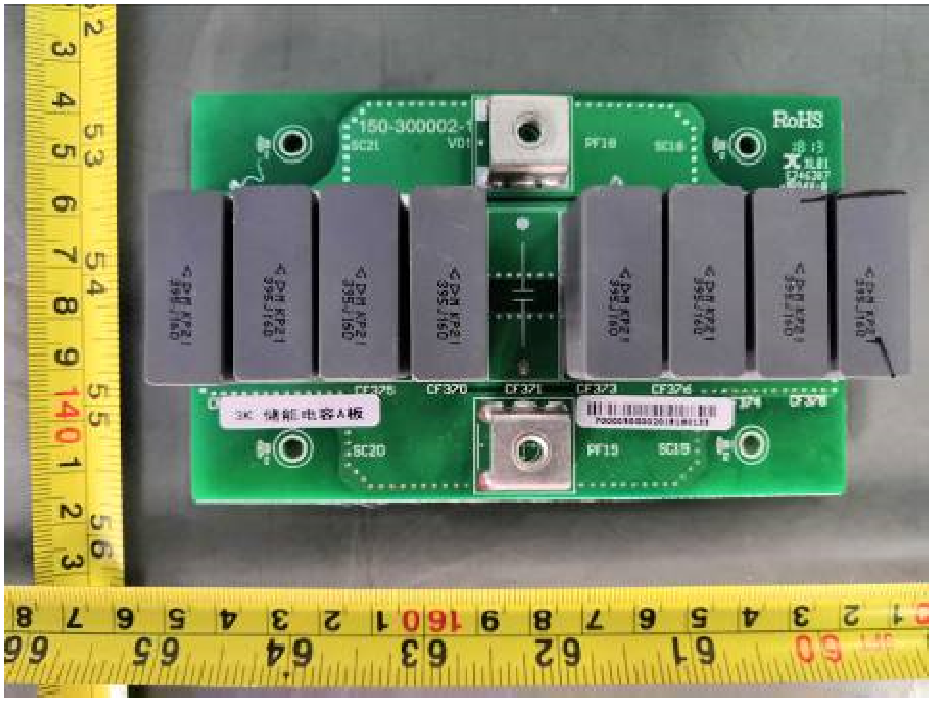
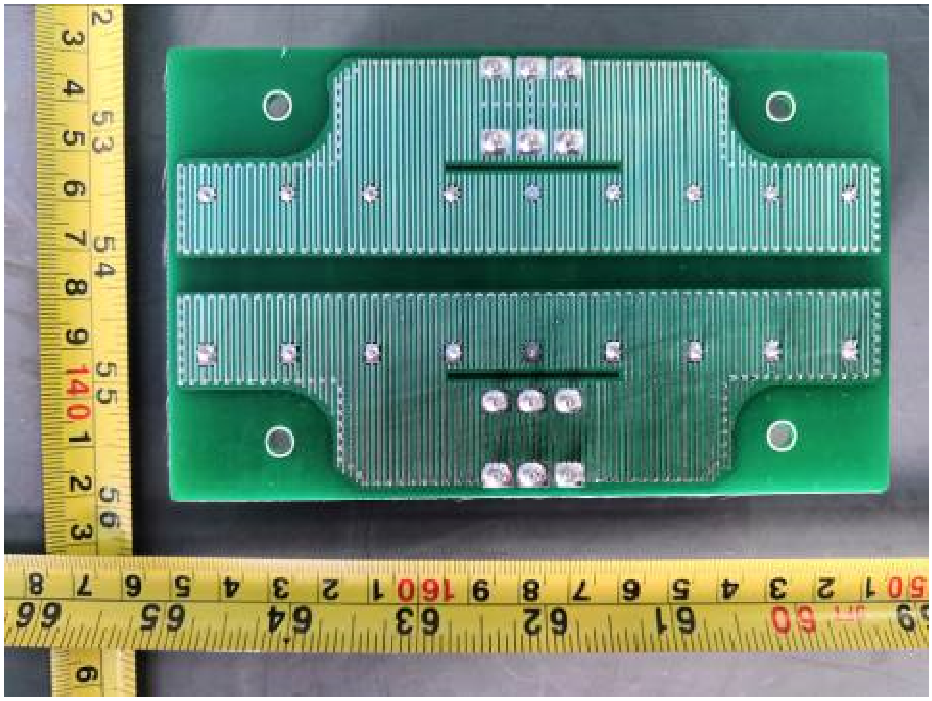

Main power board component side view

Main power board solder side view


Input&output board component side view

Input&output board solder side view


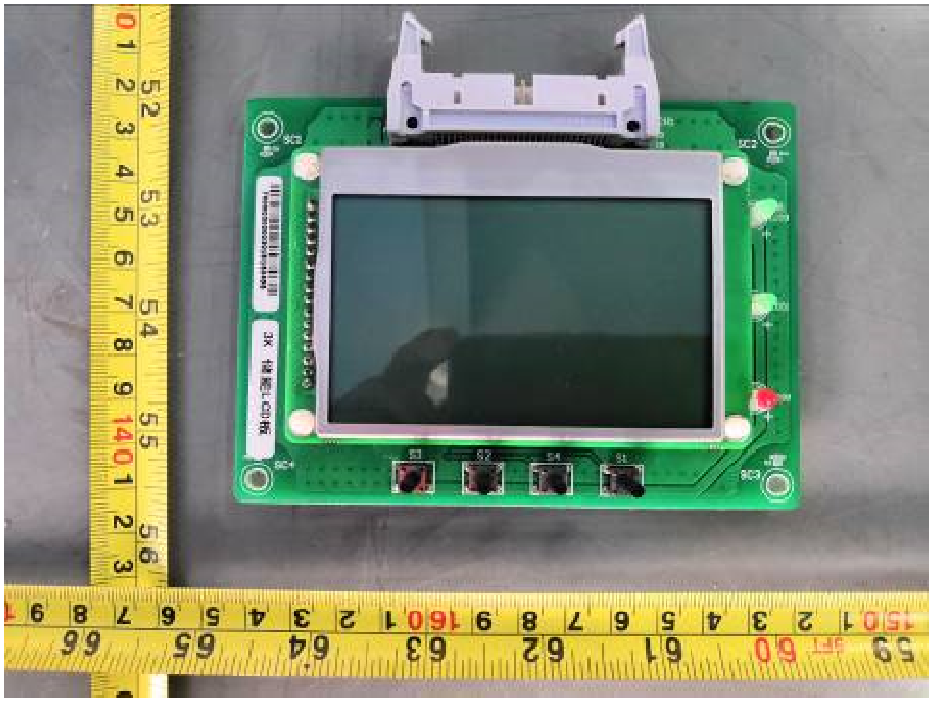
Capcitance board component side view

Capcitance board solder side view


Capcitance B board component side view

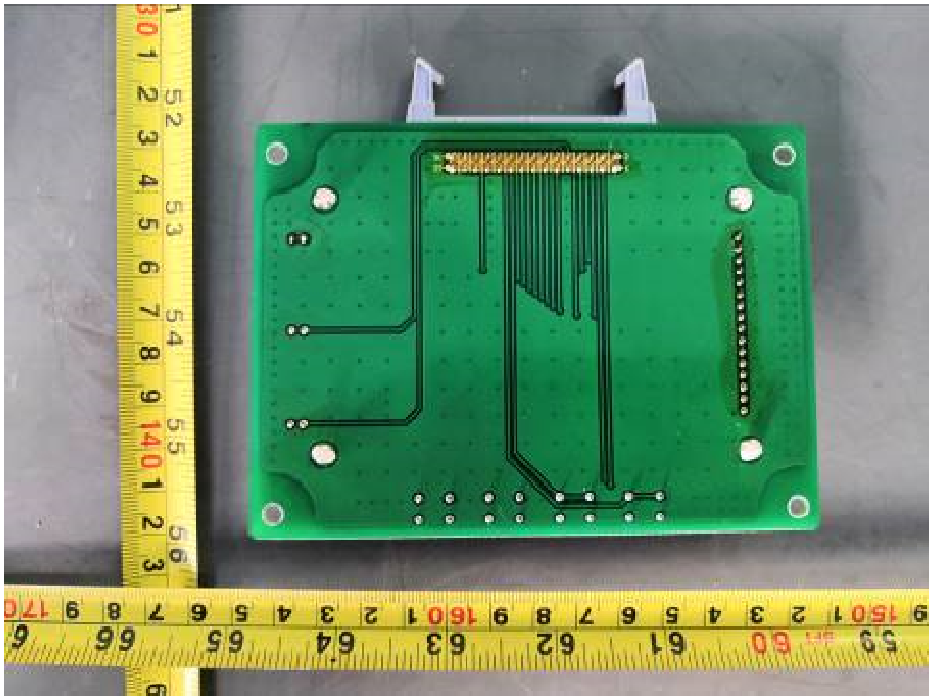
Capcitance B board solder side view


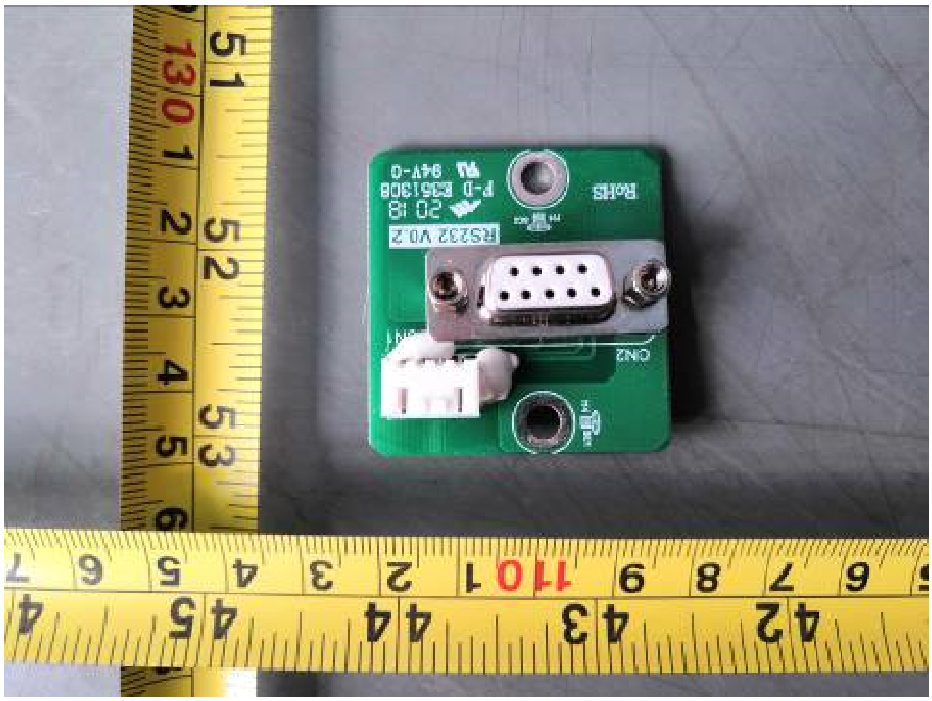
Capcitance A board component side view

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