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 ....:	**PVTH190628N073-2**
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Testing laboratory name ....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
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Accreditation ....:	ilac-MRA; A2LA ACCREDITED Certificate # 2951.01
Applicant's name............................:	**Shenzhen SOFARSOLAR 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, EN 61727:1995, DIN EN 61727:1996 IEC 62116:2008, EN 62116:2011, DIN EN 62116:2012 Deviations for Thailand according the grid-connected inverter regulations of the Metropolitan Electricity Authority (MEA 2015)
Test Report Form No. ....:	IEC61727/IEC62116_MEA VER.2
TRF Originator ....:	Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Master TRF ....:	Dated 2020-03-20
Test item description ....:	**Energy storage integrated inverter**
Trademark.......................................:	SOFAR SOLAR
Model / Type ....:	HYD 6000-EP

Ratings ....:	HYD 6000-EP
Input DC voltage [V] ....:	600 Max.
MPP DC voltage range [V] ....:	90-580
Input DC current [A] ....:	Max.13/13
Isc PV [A]...:	18 / 18
Output AC voltage [V] ....:	230Va.c., 50/60Hz
Max. Output AC current [A] ....:	27,3
Rated Output power [kVA] ....:	6
Max Output power [kVA] ....:	6,0
Battery input voltage [V] ....:	42-58
Battery current [A] ....:	100 Max.

Testing Location ....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address ....:	No. 96, Guantai Road (Houjie Section), Houjie Town, Dongguan City, Guangdong Province, 523942, People's Republic of China
Tested by (name and signature) ....:	Lukes Lin
Approved by (name and signature) ....:	James Huang
Manufacturer's name ....:	**Shenzhen SOFARSOLAR 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.**
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Document History

Date	Internal reference	Modification / Change / Status	Revision
2020-10-29	Lukes Lin	Initial report was written	0

Supplementary information:

Test items particulars

Equipment mobility ....:	Permanent connection
Operating condition ....:	Continuous
Class of equipment ....:	Class I
Mass of equipment [kg] ....:	21,5

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 ....:	2019-06-28
Date(s) of performance of test ....:	2019-06-28 to 2020-10-21

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.

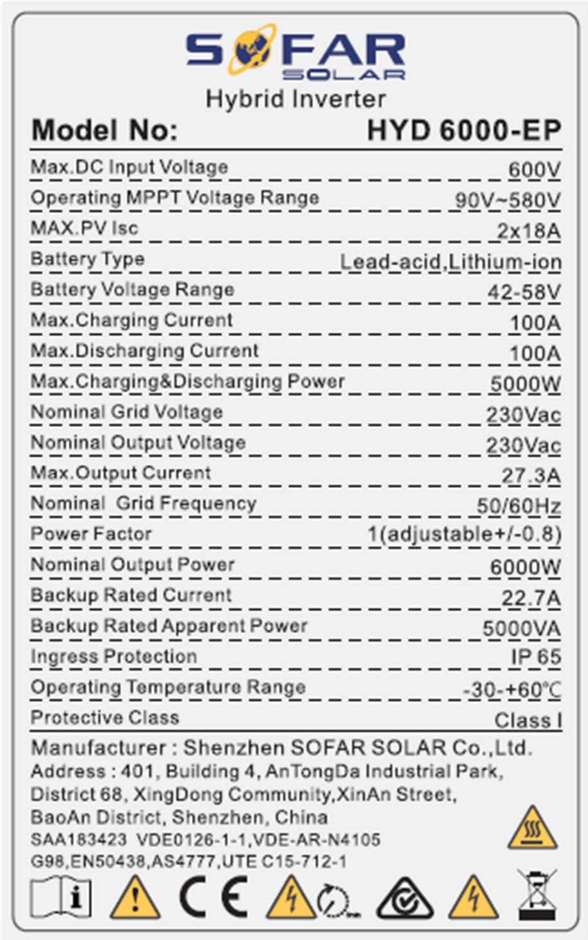
"(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

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 – Pictures of the unit
3. Annex No. 2 – Test equipment list

Copy of marking plate:



General product information:

The Solar converter converts DC voltage into AC voltage.
The DC input of Energy storage integrated inverter can be supplied from PV array and batteries.
The unit is providing EMC filtering at the output toward mains. The unit does not provide galvanic separation from input to output (transformerless). The output is switched off redundant by the high power switching bridge and a two relays. This assures that the opening of the output circuit will also operate in case of one error.

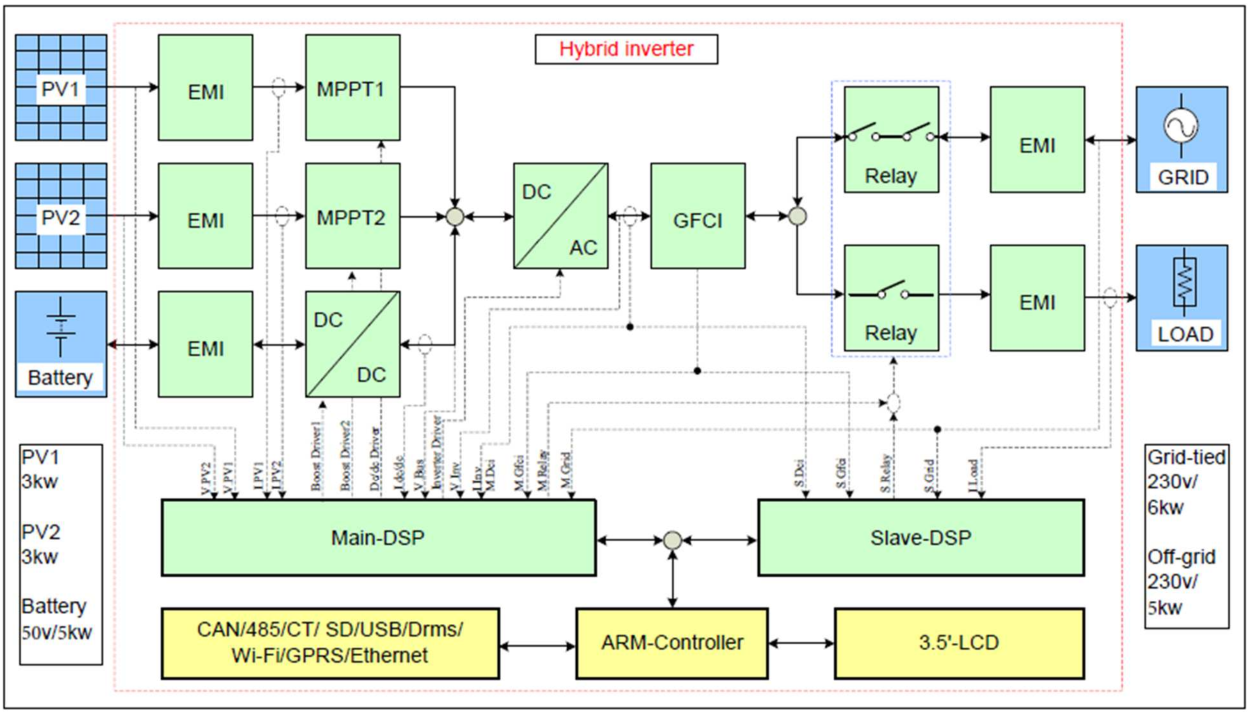


Figure 1-Block diagram

The internal control is redundant built. It consists of MCU(U4) and slave MCU(U43).

The Main MCU(U4) can control the relays, measures voltage, and frequency, AC current with injected DC, insulation resistance and residual current, In addition it tests the array insulation resistance and the RCMU circuit before each start up.

The slave MCU (U43) is using for controlling the relays, measuring the voltage , frequency, inject a dc AC current, the residual current, and communicating with the master MCU (U4). And if the communicating with the master DSP, the slave DSP will disconnect the relays.

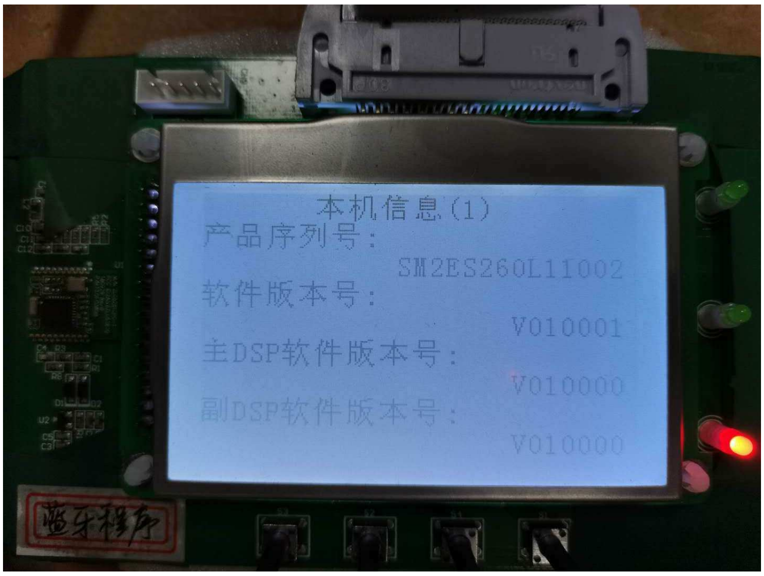
The unit provides two relays in series on Line and Neutral conductors. When single-fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the PV array and the mains. All the relays are tested before start up. Both controllers MCU(U4), Slave slave MCU(U43) can open the relays.

The product was tested on:

Hardware version: V001

Software version: V010000

Figure 2 – Photo of software version



Interface protection settings with deviations according the grid-connected inverter regulations of the Metropolitan Electricity Authority (MEA:2015) **For gird-connected inverter which connected to the grid at low voltage(230/400)** **(Thailand MEA)**		
Parameter	**Max. clearance time***	**Trip setting(Line to Neutral)**
Over voltage (level 2)	0,05s	311V
Over voltage (level 1)	2,0s	241V
Under voltage (level 1)	2,0s	199V
Under voltage (level 2)	0,1s	114V
Over frequency	0,1s	52,0Hz
Under frequency	0,1s	47,0Hz
Reconnection time	at least 120s	
Permanent DC-injection	0,5% of rated inverter output current	
Loss of main IEC 62116:2008	Inverter shall detect and disconnect within 0,3s	
* 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.		

Interface protection settings with deviations according the grid-connected inverter regulations of the Metropolitan Electricity Authority (MEA:2015) **For gird-connected inverter which connected to the grid at voltage ≥ 12kV** **(Thailand MEA)**		
Parameter	**Max. clearance time***	**Trip setting(Line to Neutral)**
Over voltage (level 2)	0,05s	≥135%Un (310,5V)
Over voltage (level 1)	2,0s	>110%Un(254V)
Under voltage (level 1)	2,0s	<85%Un(195V)
Under voltage (level 2)	0,1s	<50%Un(114V)
Over frequency	0,1s	52,0Hz
Under frequency	0,1s	47,0Hz
Reconnection time	at least 120s	
Permanent DC-injection	0,5% of rated inverter output current	
Loss of main IEC 62116:2008	Inverter shall detect and disconnect within 0,3s	
* 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: Metropolitan Electricity Authority (MEA 2015) 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: Metropolitan Electricity Authority (MEA 2015) See table 4.5 and 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: Metropolitan Electricity Authority (MEA 2015) 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 4.7	**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: Metropolitan Electricity Authority (MEA 2015) See table 5.3	**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: Metropolitan Electricity Authority (MEA 2015) 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: Metropolitan Electricity Authority (MEA 2015) 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: Metropolitan Electricity Authority (MEA 2015) 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: Metropolitan Electricity Authority (MEA 2015) See table 5.3(1) and 5.3(2)	**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:

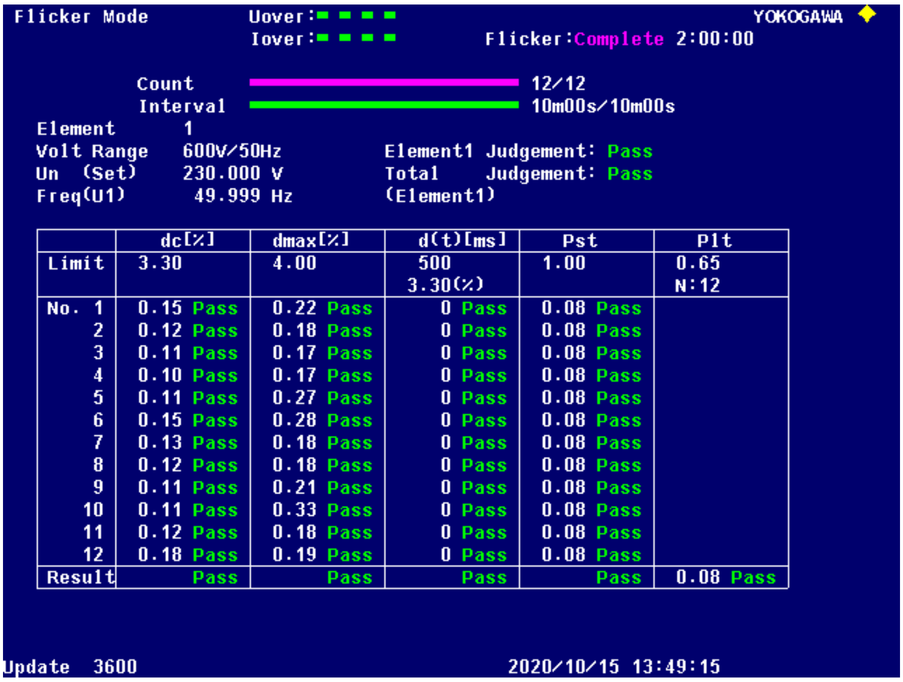
IEC 61727:2004		
Clause	**Test**	**Result**
4	Type test:	
4.3	Voltage Fluctuations and Flicker	**P**
4.4	Monitoring of DC-Injection	**P**
4.5	Normal frequency operating range (see 5.2.2 below)	**P**
4.6	Harmonics and waveform distortion	**P**
4.7	Power factor	**P**
5.2.1	Voltage monitoring	**P**
5.2.2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

IEC 62116:2008		
Clause	**Test**	**Result**
	Type test:	
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**

Test Results

4.3 Voltage fluctuation and flicker 3.1.2, 4.3.2 Voltage fluctuation and flicker (MEA:2015)					P
Test conditions:	Maximum permissible voltage fluctuation (expressed as a percentage of nominal voltage at 100 % power) and flicker as per EN 61000-3-3				
	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		


Flicker Mode Uover:- - - - Iover:- - - - YOKOGAWA Flicker:Complete 2:00:00

Count 12/12
Interval 10m00s/10m00s
Element 1
Volt Range 600V/50Hz
Un (Set) 230.000 V
Freq(U1) 49.999 Hz
Element1 Judgement: Pass
Total Judgement: Pass
(Element1)

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.15 Pass	0.22 Pass	0 Pass	0.08 Pass	
2	0.12 Pass	0.18 Pass	0 Pass	0.08 Pass	
3	0.11 Pass	0.17 Pass	0 Pass	0.08 Pass	
4	0.10 Pass	0.17 Pass	0 Pass	0.08 Pass	
5	0.11 Pass	0.27 Pass	0 Pass	0.08 Pass	
6	0.15 Pass	0.28 Pass	0 Pass	0.08 Pass	
7	0.13 Pass	0.18 Pass	0 Pass	0.08 Pass	
8	0.12 Pass	0.18 Pass	0 Pass	0.08 Pass	
9	0.11 Pass	0.21 Pass	0 Pass	0.08 Pass	
10	0.11 Pass	0.33 Pass	0 Pass	0.08 Pass	
11	0.12 Pass	0.18 Pass	0 Pass	0.08 Pass	
12	0.18 Pass	0.19 Pass	0 Pass	0.08 Pass	
Result	Pass	Pass	Pass	Pass	0.08 Pass

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Test value

Note:

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

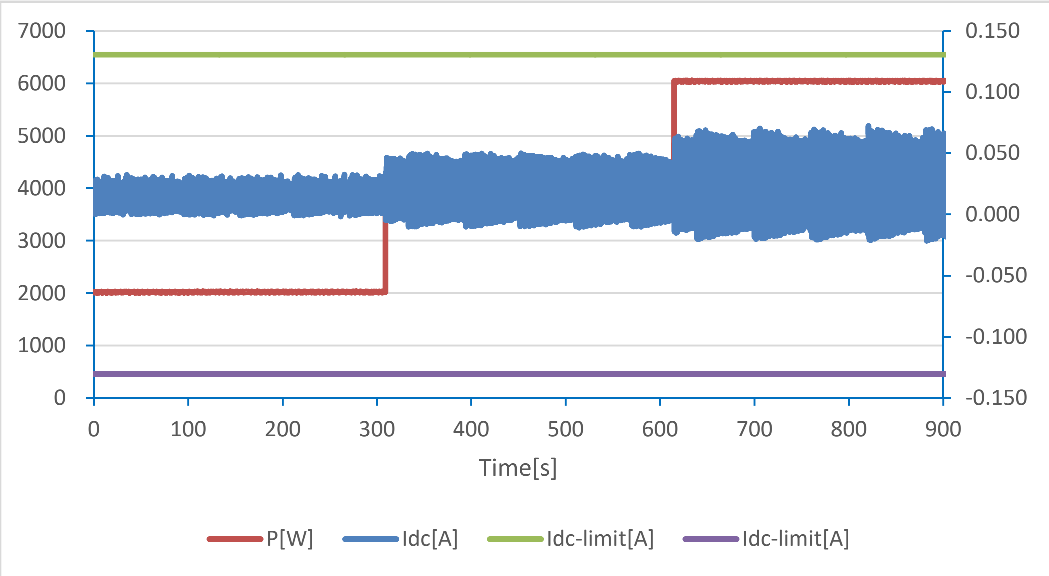
Mains Impedance according EN61000-3-3: **R_{max} = 0,24Ω; jX_{max}= 0,15Ω @50Hz (|Z_{max}| = 0,283 Ω)**
for single phase inverter use also **R_n = 0,16Ω; jX_n= 0,1Ω**

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 3.1.3, 4.3.3 Direct Current Injection (MEA 2015)			P
MEA Limit:	**0,5% of I_{nom} : = 130mA**		
Output power:	33%	66%	100%
Max. test value (mA):	32	50	72
Average test value (mA):	15	21	27

Diagram



Note:/

4.6 Harmonic Current Limit Test 3.1.1, 4,3,1 Harmonic Current Limit Test (MEA 2015)	P

33% Output Power	
Watts (kW)	2,023
VA (kVA)	2,025
Vrms (V)	229,48
Arms (A)	8,823
PF	0,9990
Frequency (Hz)	50,00
THD50 (%)	1,260

Harmonics	Current Magnitude [A]	% of Rated Current	Phase	Harmonic Current Limits [%]
1st	8,819	33,806	Single Phase	--
2nd	0,011	0,120	Single Phase	1
3rd	0,149	1,691	Single Phase	4
4th	0,005	0,057	Single Phase	1
5th	0,074	0,844	Single Phase	4
6th	0,004	0,043	Single Phase	1
7th	0,040	0,458	Single Phase	4
8th	0,003	0,032	Single Phase	1
9th	0,021	0,237	Single Phase	4
10th	0,002	0,028	Single Phase	1
11th	0,014	0,156	Single Phase	2
12th	0,002	0,022	Single Phase	0,5
13th	0,008	0,088	Single Phase	2
14th	0,002	0,018	Single Phase	0,5
15th	0,005	0,057	Single Phase	2
16th	0,001	0,013	Single Phase	0,5
17th	0,005	0,060	Single Phase	1,5
18th	0,001	0,013	Single Phase	0,375
19th	0,005	0,054	Single Phase	1,5
20th	0,001	0,011	Single Phase	0,375
21th	0,006	0,063	Single Phase	1,5
22th	0,001	0,009	Single Phase	0,375
23th	0,005	0,057	Single Phase	0,6
24th	0,001	0,009	Single Phase	0,15
25th	0,005	0,062	Single Phase	0,6
26th	0,001	0,007	Single Phase	0,15
27th	0,005	0,060	Single Phase	0,6
28th	0,001	0,007	Single Phase	0,15
29th	0,005	0,058	Single Phase	0,6
30th	0,001	0,006	Single Phase	0,15
31th	0,005	0,060	Single Phase	0,6
32th	0,000	0,005	Single Phase	0,15
33th	0,005	0,060	Single Phase	0,6
34th	0,000	0,005	Single Phase	0,15
35th	0,005	0,056	Single Phase	0,3
36th	0,001	0,006	Single Phase	0,075

37th	0,005	0,054	Single Phase	0,3
38th	0,000	0,005	Single Phase	0,075
39th	0,005	0,054	Single Phase	0,3
40th	0,000	0,005	Single Phase	0,075
41th	0,004	0,049	Single Phase	N/A
42th	0,000	0,005	Single Phase	N/A
43th	0,004	0,048	Single Phase	N/A
44th	0,000	0,005	Single Phase	N/A
45th	0,004	0,043	Single Phase	N/A
46th	0,000	0,005	Single Phase	N/A
47th	0,004	0,041	Single Phase	N/A
48th	0,001	0,006	Single Phase	N/A
49th	0,004	0,042	Single Phase	N/A
50th	0,004	0,051	Single Phase	N/A

66% Output Power				
Watts (kW)		4,024		
VA (kVA)		4,025		
Vrms (V)		229,98		
Arms (A)		17,503		
PF		0,9996		
Frequency (Hz)		50,00		
THD50 (%)		1,048		
Harmonics	**Current Magnitude [A]**	**% of Rated Current**	**Phase**	**Harmonic Current Limits [%]**
1st	17,499	67,079	Single Phase	--
2nd	0,020	0,114	Single Phase	1
3rd	0,158	0,902	Single Phase	4
4th	0,010	0,056	Single Phase	1
5th	0,070	0,403	Single Phase	4
6th	0,007	0,038	Single Phase	1
7th	0,039	0,221	Single Phase	4
8th	0,006	0,032	Single Phase	1
9th	0,024	0,137	Single Phase	4
10th	0,004	0,025	Single Phase	1
11th	0,012	0,071	Single Phase	2
12th	0,004	0,020	Single Phase	0,5
13th	0,008	0,047	Single Phase	2
14th	0,003	0,016	Single Phase	0,5
15th	0,009	0,052	Single Phase	2
16th	0,002	0,014	Single Phase	0,5
17th	0,011	0,061	Single Phase	1,5
18th	0,002	0,011	Single Phase	0,375
19th	0,009	0,052	Single Phase	1,5
20th	0,001	0,008	Single Phase	0,375
21th	0,009	0,049	Single Phase	1,5
22th	0,001	0,008	Single Phase	0,375
23th	0,008	0,049	Single Phase	0,6
24th	0,001	0,007	Single Phase	0,15

25th	0,008	0,046	Single Phase	0,6
26th	0,001	0,005	Single Phase	0,15
27th	0,008	0,044	Single Phase	0,6
28th	0,001	0,006	Single Phase	0,15
29th	0,006	0,037	Single Phase	0,6
30th	0,001	0,005	Single Phase	0,15
31th	0,006	0,037	Single Phase	0,6
32th	0,001	0,004	Single Phase	0,15
33th	0,006	0,034	Single Phase	0,6
34th	0,001	0,004	Single Phase	0,15
35th	0,005	0,030	Single Phase	0,3
36th	0,001	0,004	Single Phase	0,075
37th	0,005	0,030	Single Phase	0,3
38th	0,001	0,004	Single Phase	0,075
39th	0,006	0,032	Single Phase	0,3
40th	0,001	0,003	Single Phase	0,075
41th	0,004	0,023	Single Phase	N/A
42th	0,001	0,003	Single Phase	N/A
43th	0,004	0,025	Single Phase	N/A
44th	0,001	0,003	Single Phase	N/A
45th	0,004	0,025	Single Phase	N/A
46th	0,001	0,003	Single Phase	N/A
47th	0,004	0,021	Single Phase	N/A
48th	0,001	0,006	Single Phase	N/A
49th	0,004	0,020	Single Phase	N/A
50th	0,005	0,028	Single Phase	N/A

100% Output Power	
Watts (kW)	6,042
VA (kVA)	6,045
Vrms (V)	230,50
Arms (A)	26,226
PF	0,9996
Frequency (Hz)	50,00
THD50 (%)	1,260

Harmonics	**Current Magnitude [A]**	**% of Rated Current**	**Phase**	**Harmonic Current Limits [%]**
1st	26,221	100,513	Single Phase	--
2nd	0,029	0,112	Single Phase	1
3rd	0,264	1,007	Single Phase	4
4th	0,014	0,054	Single Phase	1
5th	0,154	0,585	Single Phase	4
6th	0,010	0,036	Single Phase	1
7th	0,097	0,371	Single Phase	4
8th	0,007	0,028	Single Phase	1
9th	0,057	0,216	Single Phase	4
10th	0,006	0,022	Single Phase	1
11th	0,022	0,085	Single Phase	2
12th	0,005	0,020	Single Phase	0,5

13th	0,012	0,044	Single Phase	2
14th	0,005	0,018	Single Phase	0,5
15th	0,018	0,069	Single Phase	2
16th	0,003	0,013	Single Phase	0,5
17th	0,018	0,067	Single Phase	1,5
18th	0,003	0,011	Single Phase	0,375
19th	0,010	0,040	Single Phase	1,5
20th	0,002	0,009	Single Phase	0,375
21th	0,006	0,021	Single Phase	1,5
22th	0,002	0,009	Single Phase	0,375
23th	0,006	0,021	Single Phase	0,6
24th	0,002	0,007	Single Phase	0,15
25th	0,007	0,027	Single Phase	0,6
26th	0,002	0,006	Single Phase	0,15
27th	0,008	0,032	Single Phase	0,6
28th	0,001	0,005	Single Phase	0,15
29th	0,005	0,019	Single Phase	0,6
30th	0,002	0,007	Single Phase	0,15
31th	0,005	0,018	Single Phase	0,6
32th	0,001	0,005	Single Phase	0,15
33th	0,003	0,013	Single Phase	0,6
34th	0,001	0,005	Single Phase	0,15
35th	0,003	0,012	Single Phase	0,3
36th	0,001	0,003	Single Phase	0,075
37th	0,004	0,016	Single Phase	0,3
38th	0,001	0,004	Single Phase	0,075
39th	0,005	0,018	Single Phase	0,3
40th	0,001	0,004	Single Phase	0,075
41th	0,003	0,012	Single Phase	N/A
42th	0,001	0,003	Single Phase	N/A
43th	0,003	0,011	Single Phase	N/A
44th	0,001	0,004	Single Phase	N/A
45th	0,003	0,011	Single Phase	N/A
46th	0,001	0,004	Single Phase	N/A
47th	0,002	0,008	Single Phase	N/A
48th	0,003	0,011	Single Phase	N/A
49th	0,004	0,014	Single Phase	N/A
50th	0,008	0,029	Single Phase	N/A

Note:
The harmonics are tested and evaluated according the IEEE1547.1-2005 clause 5.11.1 according the grid-connected inverter regulations of the Metropolitan Electricity Authority (MEA).

4.7 Power factor					**P**
Test conditions:					
Output power / **Test model:**	**~10%** **0,2kW**	**~25%** **0,5kW**	**~50%** **1,0kW**	**~75%** **1,5kW**	**~100%** **2,0kW**
230	0,9996	0,9995	0,9992	0,9987	0,9981

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.

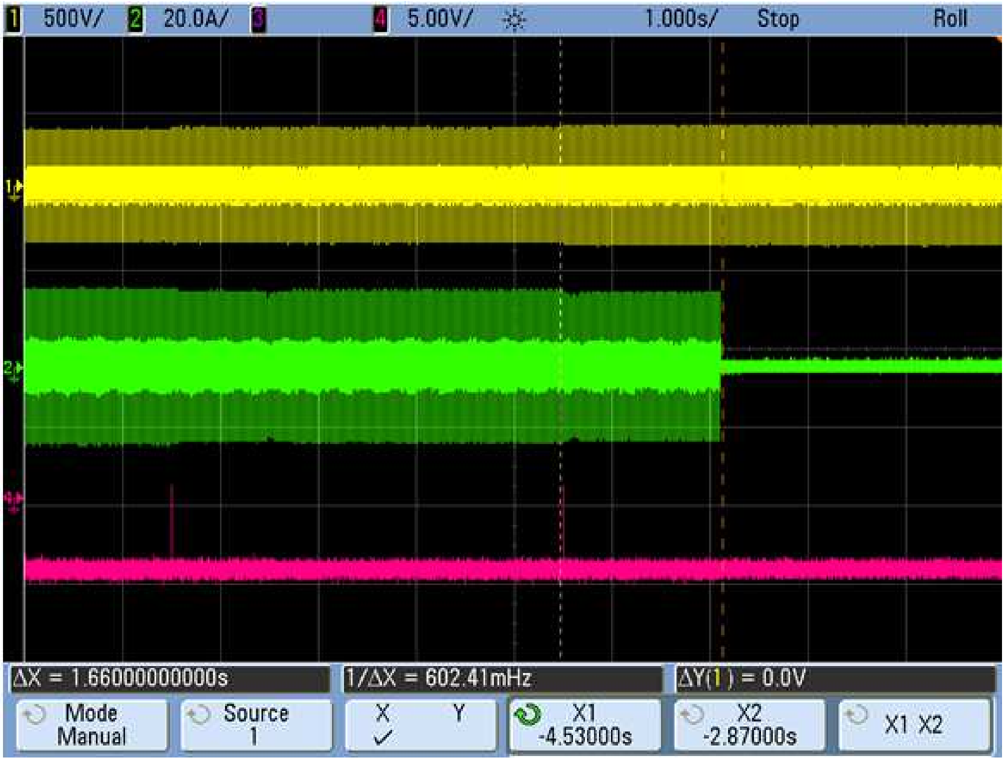
5.2.1 Voltage monitoring 3.2.1, 4.3.4 Operating Voltaga Range (MEA 2015) (For gird-connected inverter which connected to the grid at low voltage(230/400))											P
First Level											
Test conditions:	Output power: 3,0kW Frequency: 50Hz										
	Under Voltage					**Over Voltage**					
		Voltage [V]					Voltage [V]				
Set value		**199V**					**241V**				
Measured trip value		All	L1	L2	L3		All	L1	L2	L3	
		198,9	--	--	--		241,8	--	--	--	
		198,9	--	--	--		241,8	--	--	--	
		198,9	--	--	--		241,8	--	--	--	
		198,9	--	--	--		241,8	--	--	--	
		198,9	--	--	--		241,8	--	--	--	
Parameter		Time [ms]					Time [ms]				
Limit		**<= 2,0s**					**<= 2,0s**				
Disconnetion time	230V to 204V (4s min) to 198V	All	L1	L2	L3	230V to 236V (4s min) to 242V	All	L1	L2	L3	
		1,66	--	--	--		1,66	--	--	--	
		1,69	--	--	--		1,66	--	--	--	
		1,66	--	--	--		1,66	--	--	--	
		1,65	--	--	--		1,66	--	--	--	
		1,66	--	--	--		1,65	--	--	--	

Second Level										
Test conditions:	Output power: 3,0kW Frequency: 50Hz									
	Under Voltage					**Over Voltage**				
Parameter		Voltage [V]					Voltage [V]			
Set value		**114V**					**311V**			
Measured trip value		All	L1	L2	L3		All	L1	L2	L3
		113,5					311,0			
		113,5					311,1			
		113,7					311,1			
		113,5					311,1			
		114,0					311,1			
Parameter		Time [ms]					Time [ms]			
Limit		**<= 100ms**					**<= 50ms**			
Disconnection time	230V to 204V (0,2s min) to 113V	All	L1	L2	L3	230V to 236V (0,1s min) to 296V	All	L1	L2	L3
		88,0					13,0			
		81,0					8,6			
		79,0					9,8			
		73,5					9,2			
		74,5					10,0			

Note:
The tests according to the grid-connected inverter regulation Metropolitan Electricity Authority 2015.
The voltage settings of the EUT are set for the tests as stated to 199V, 114V for undervoltage and 241V, 311V for overvoltage.
Set all other parameter to the normal operating conditions for inverter.
Suddenly increase testing voltage to overvoltage trip setting -1V/+1 V and maintain this value until the inverter stop energize.
For 3 phase inverter, the test must perform on each phase and all 3 phases together. During the test in each phase, the voltage in other phase shall be at normal operating condition.

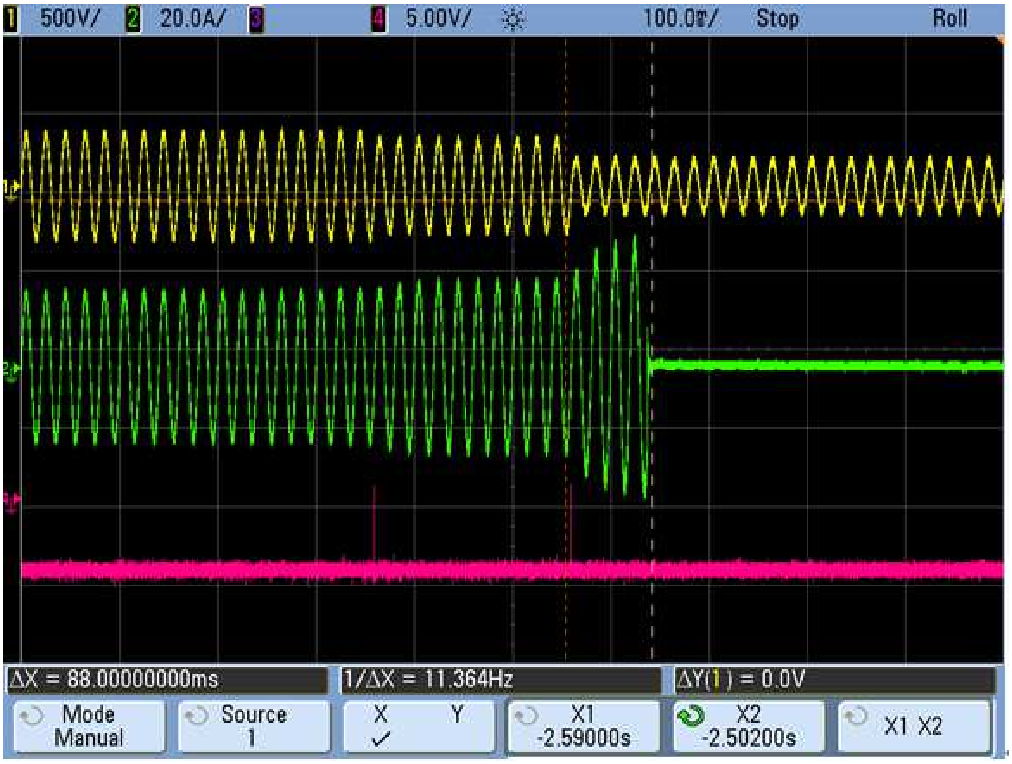
Under Voltage First Level for single phase

Over voltage First Level for single phase

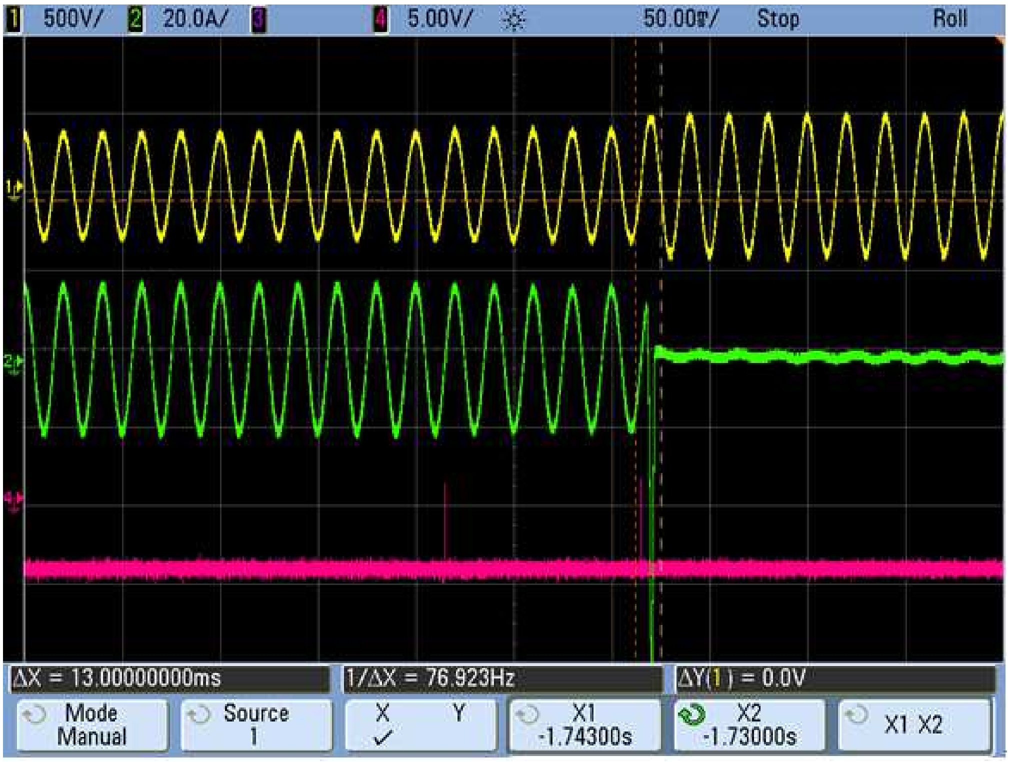


Note: CH1: grid voltage(500V/div); CH2: Current of EUT(20A/div); CH4: trip signal

Under Voltage SecondLevel for single phase



Over voltage Second Level for single phase



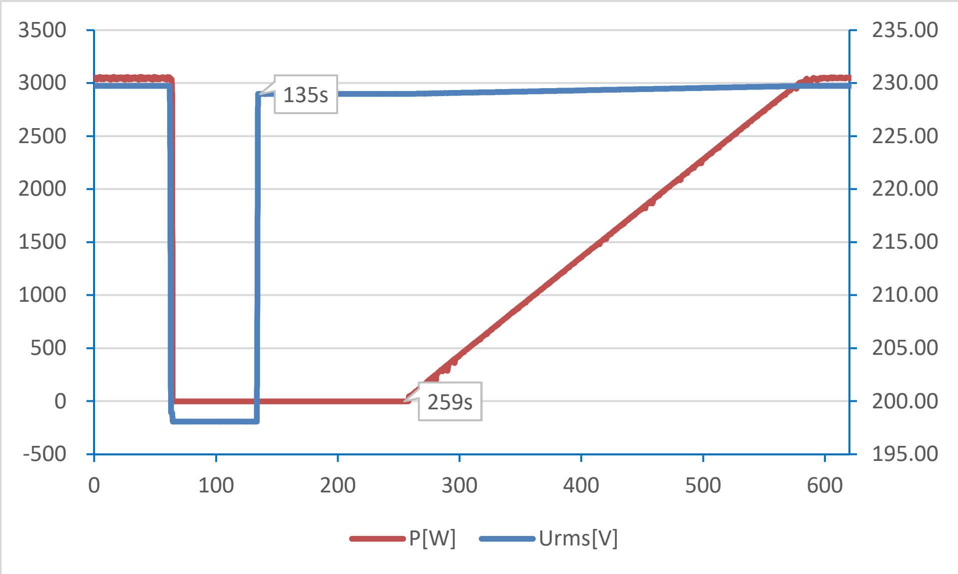
Note:
CH1: grid voltage(500V/div); CH2: Current of EUT(20A/div); CH4: trip signal

5.2.1 Voltage monitoring **3.2.4, 4.3.7 Response to Utility Recovery (MEA 2015)**					**P**
First Level					
Test conditions:	Output power: 3,0kW Frequency: 50Hz				
Reconnection time(Sec)	at least 120s	124 s	at least 120s	125 s	
Second Level					
Test conditions:	Output power: 15,0kW Frequency: 50Hz				
Reconnection time(Sec)	at least 120s	125 s	at least 120s	125 s	

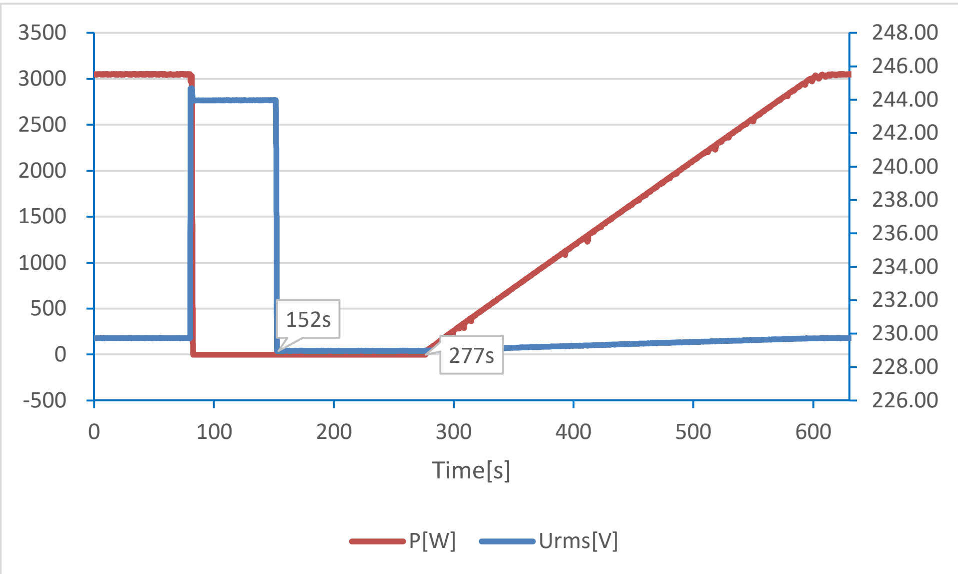
Note:

Response to Utility Recovery Test:
The test methods shall be in accordance with IEEE 1547.1-2005 clause 5.10 and evaluation criteria refer to clause 3.2.4 in this regulation.

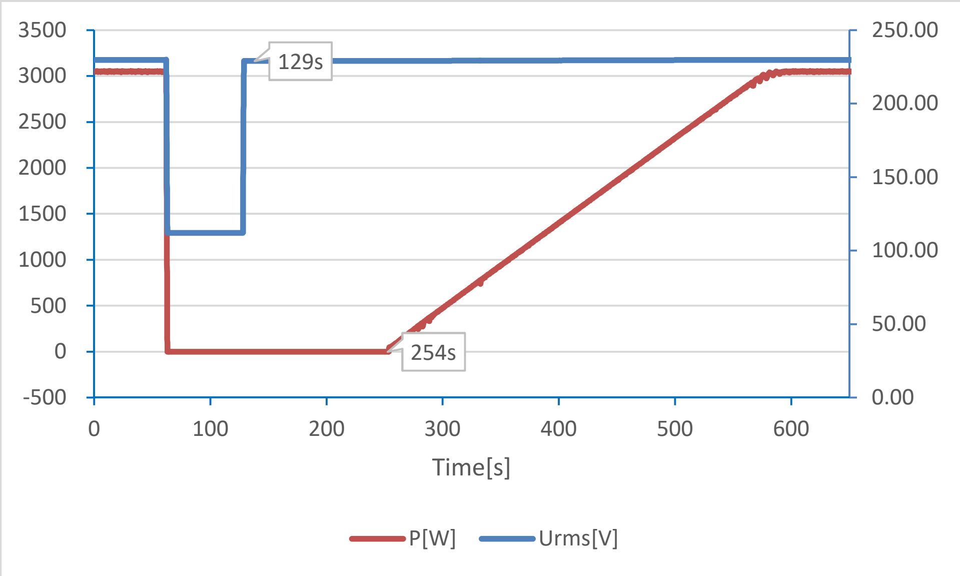
Reconnection after Under Voltage First Level



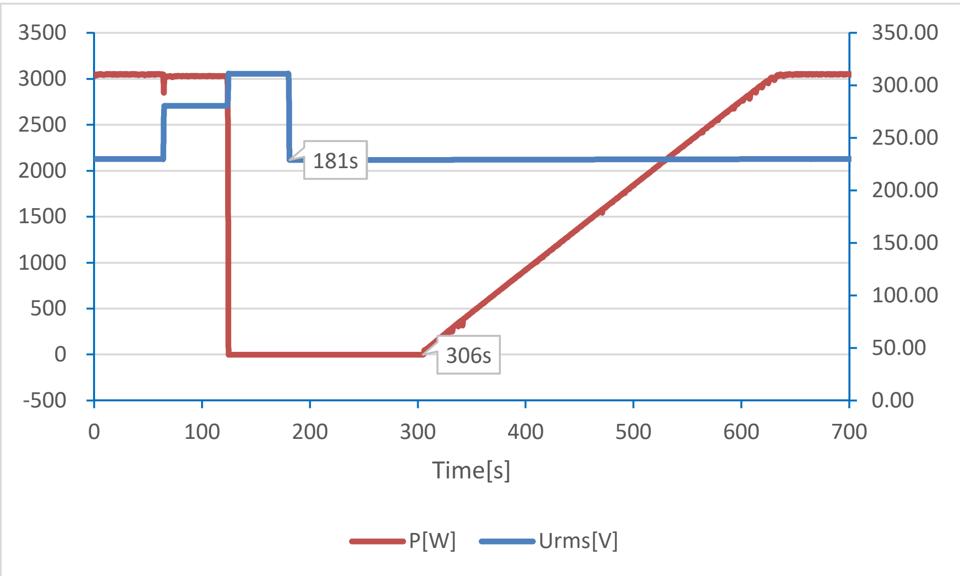
Reconnection after Over voltage First Level



Reconnection after Under Voltage Second Level



Reconnection after Over voltage Second Level



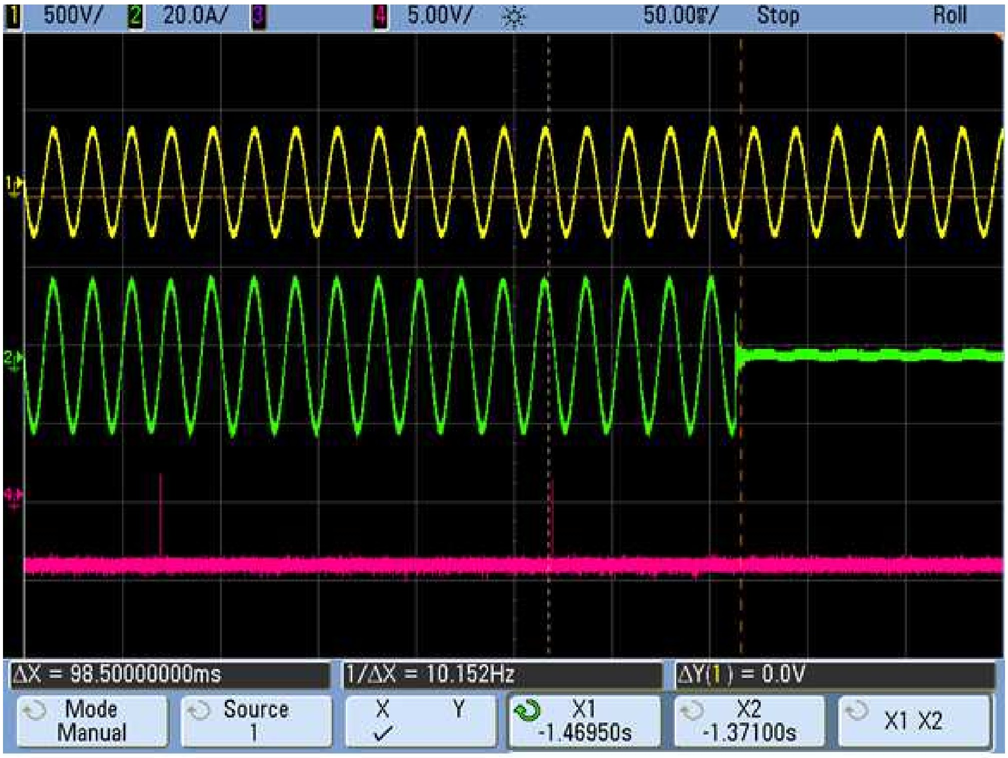
5.2.2 Frequency monitoring **3.2.2, 4.3.5 Operating Voltaga Range (MEA 2015)** **3.2.4, 4.3.7 Response to Utility Recovery**					**P**
Test conditions:	Any output power level				
	Under frequency		**Over frequency**		
Parameter		Frequency [Hz]		Frequency [Hz]	
Output Voltage		U_N		U_N	
Set value		**47,00Hz**		**52,00Hz**	
Measured trip value(Hz)		46,97		52,02	
		46,97		52,01	
		46,97		52,02	
		46,97		52,02	
		46,96		52,02	
		Time [ms]		Time [ms]	
Limit		**<= 100ms**		**<= 100ms**	
Disconnection time(ms)	49,40 Hz to 48,80 Hz	98,5	50,60 Hz To 51,20 Hz	93,0	
		96,0		88,0	
		94,0		81,0	
		93,0		92,0	
		86,5		85,0	
Reconnection time (Sec)	at least 120s	124 s	at least 120s	124 s	

Note:
Set all other parameter to the normal operating conditions for inverter.
Suddenly increase testing frequency to overfrequency trip setting +/-0.1 Hz and maintain this value until the inverter stop energize. And the time it takes to cut off the power must be within 0.1 second.

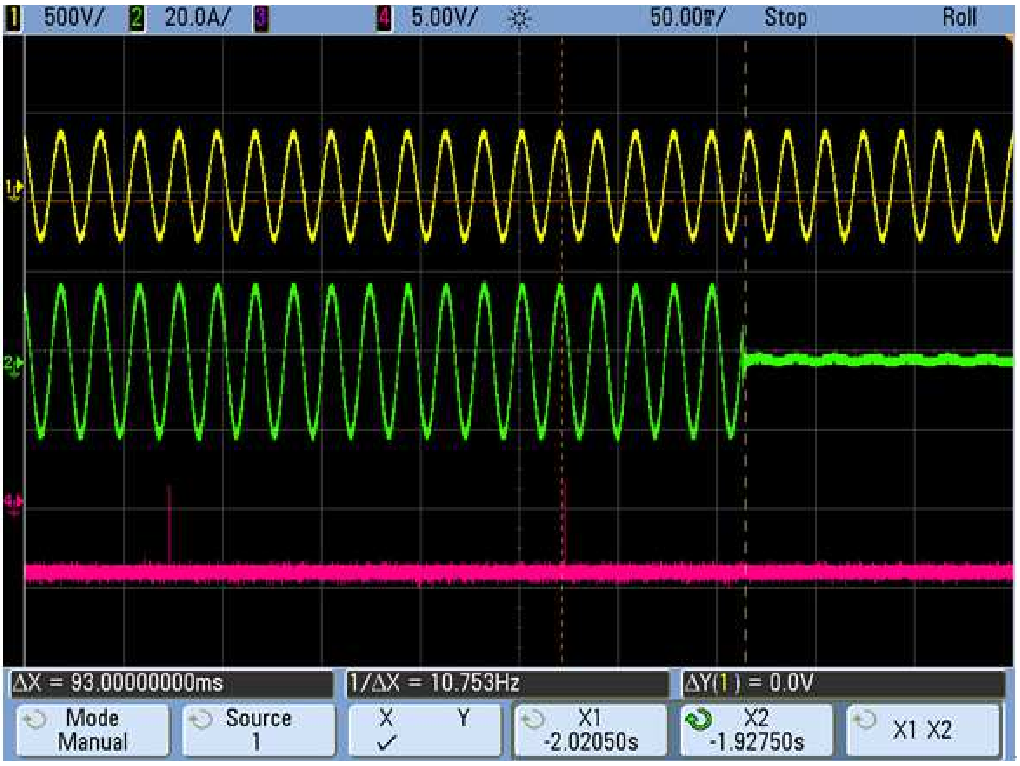
The tests according to the grid-connected inverter regulation Metropolitan Electricity Authority 2015. The frequency settings are set for the test as stated to 47,0Hz and 52,0Hz.

Response to Utility Recovery Test:
The test methods shall be in accordance with IEEE 1547.1-2005 clause 5.10 and evaluation criteria refer to clause 3.2.4 in this regulation.

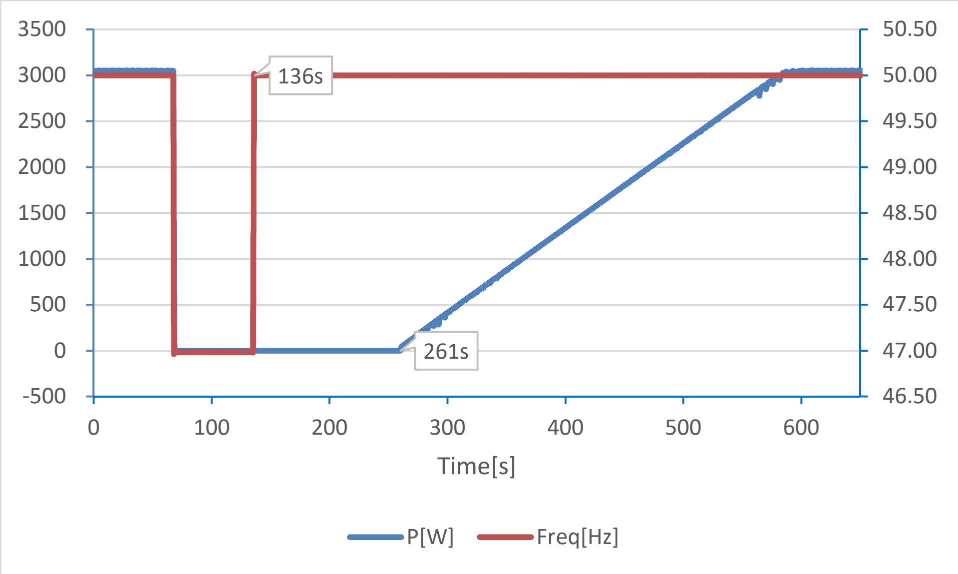
Under Frequency:



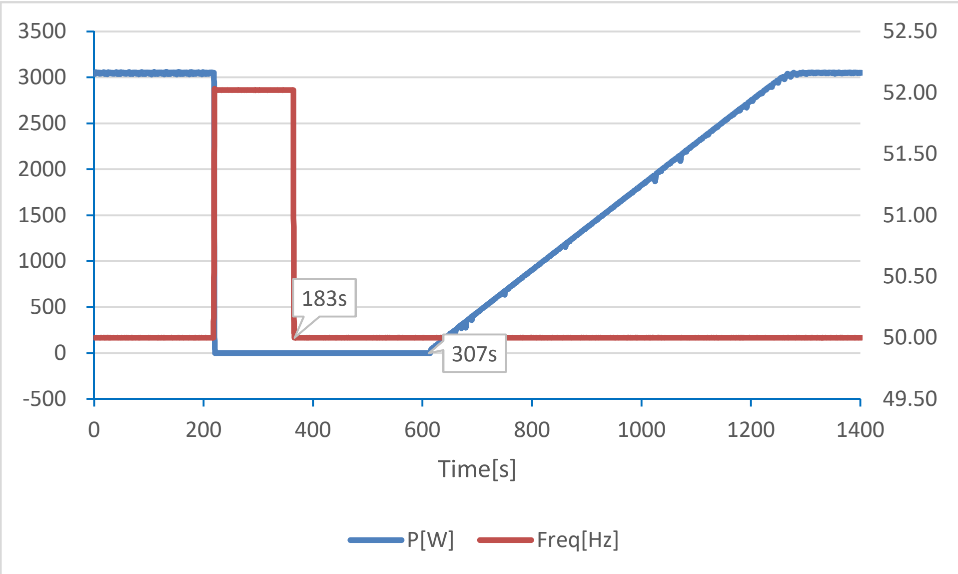
Over Frequency:



Reconnection after Under Frequency:



Reconnection after Over Frequency:



6.1 Islanding protection
3.2.3, 4.3.6 Islanding Protection (MEA:2015)

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

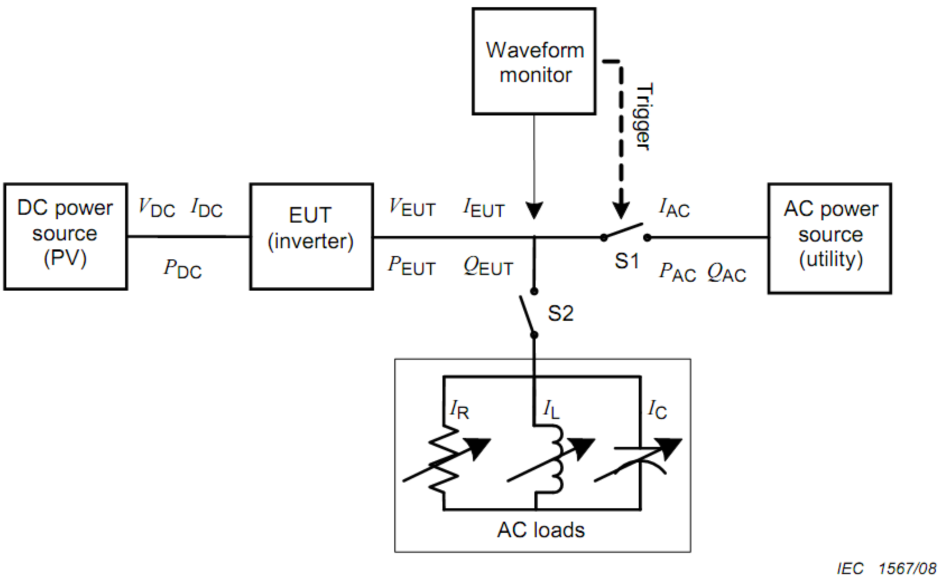


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

6.1 Islanding protection according table 6 - Load imbalance (real, reactive load) for test condition A (EUT ouput = 100%) **3.2.3, 4.3.6 Islanding Protection (MEA:2015)**	**P**

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality = 1
Disconnection limit	0,3s for MEA

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	225	6000	1,000	383	Test A at BL
4	100	100	-5	-5	208	6000	1,026	383	Test A at IB
5	100	100	-5	0	216	6000	1,053	383	Test A at IB
6	100	100	-5	+5	206	6000	1,079	383	Test A at IB
7	100	100	0	-5	207	6000	0,975	383	Test A at IB
8	100	100	0	+5	210	6000	1,025	383	Test A at IB
9	100	100	+5	-5	148	6000	0,928	383	Test A at IB
10	100	100	+5	0	208	6000	0,952	383	Test A at IB
11	100	100	+5	+5	200	6000	0,976	383	Test A at IB

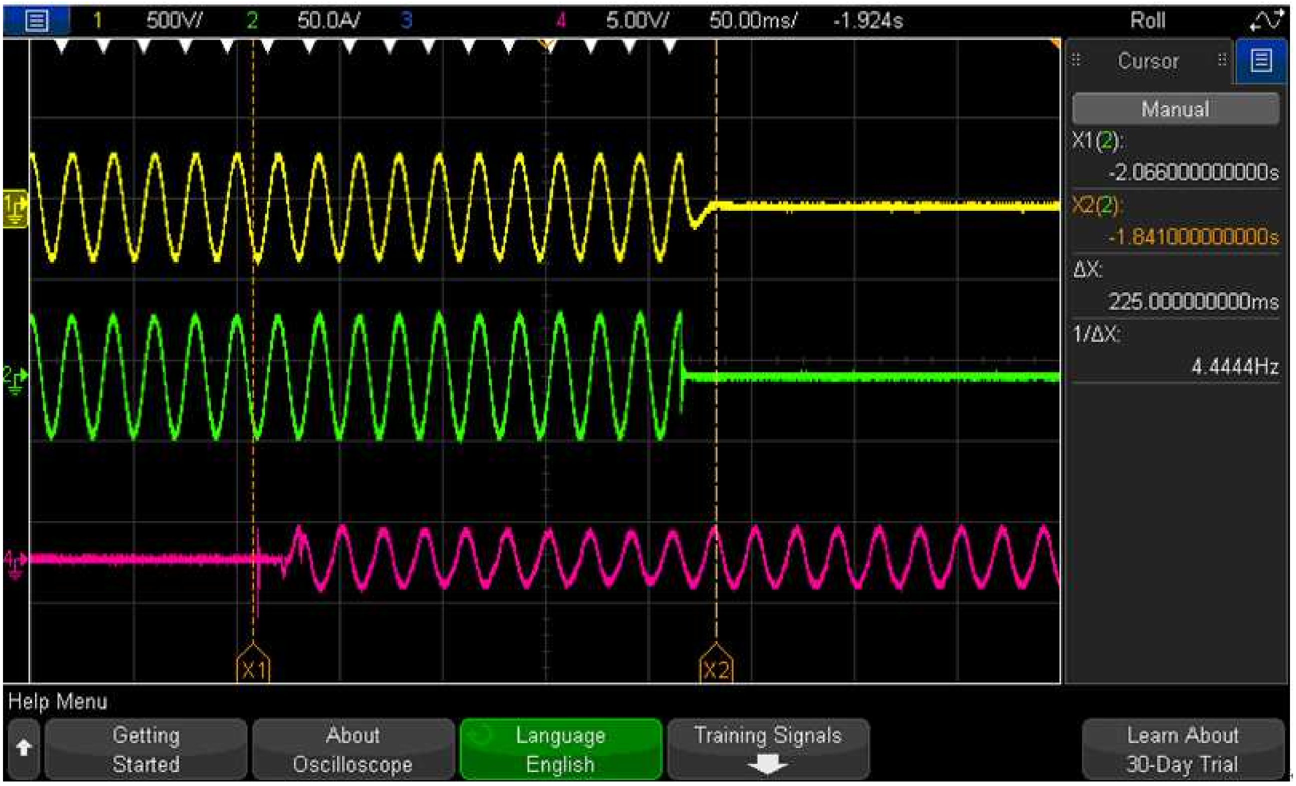
Parameter at 0% per phase	L= 28,05 mH	R= 8,81 Ω	C= 361,21 µF
IAC fundamental current	110 mA		

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); CH4: trip signal

6.1 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %) 3.2.3, 4.3.6 Islanding Protection (MEA:2015)	**P**

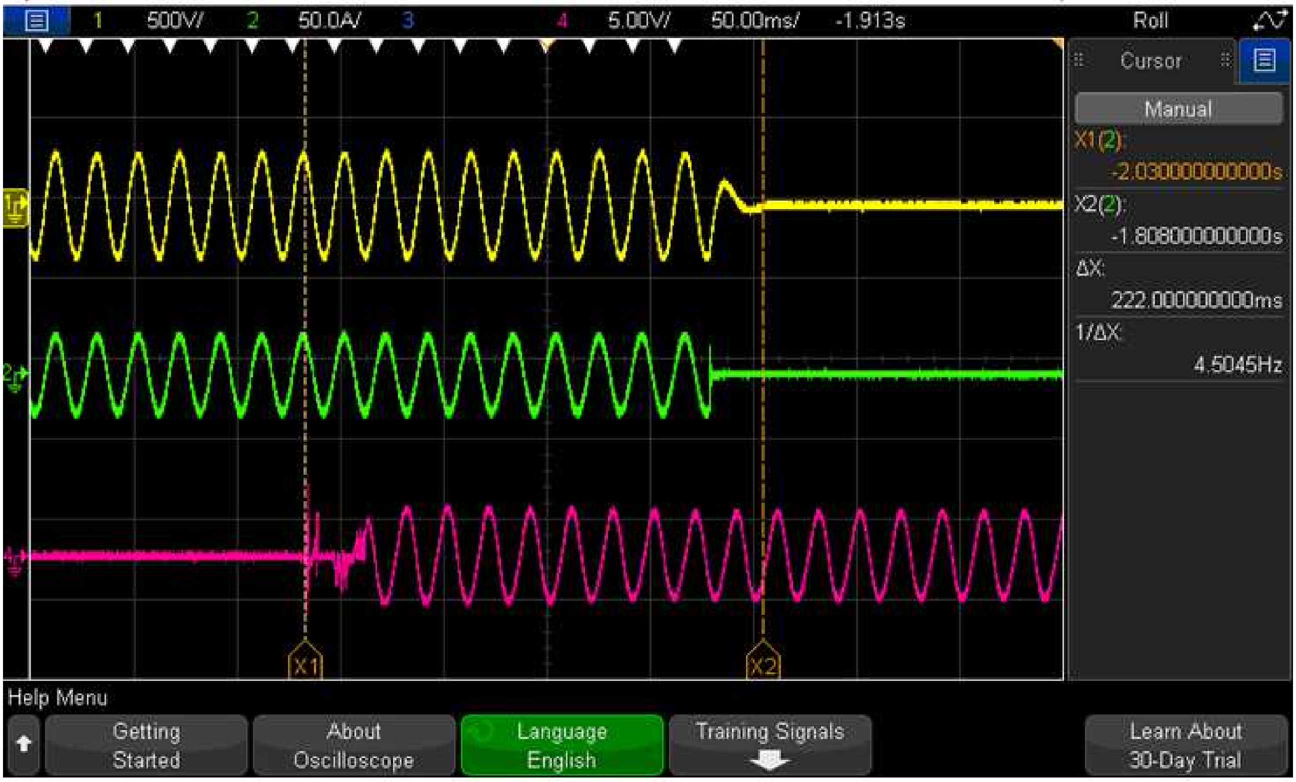
Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	0,3s for MEA

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)	Remarks4)
1	66	66	0	-5	149	3960	0,975	285	Test B at IB
2	66	66	0	-4	222	3960	0,980	285	Test B at IB
3	66	66	0	-3	200	3960	0,985	285	Test B at IB
4	66	66	0	-2	199	3960	0,990	285	Test B at IB
5	66	66	0	-1	201	3960	0,995	285	Test B at IB
6	66	66	0	0	197	3960	1,000	285	Test B at BL
7	**66**	**66**	**0**	**1**	**217**	3960	1,005	285	**Test B at IB**
8	66	66	0	2	203	3960	1,010	285	Test B at IB
9	66	66	0	3	213	3960	1,015	285	Test B at IB
10	66	66	0	4	215	3960	1,020	285	Test B at IB
11	66	66	0	5	154	3960	1,025	285	Test B at IB

Parameter at 0% per phase	L=42,10 mH	R= 13,23 Ω	C= 240,69 µF
I_{AC} fundamental current at balance condition	145 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, 90 % 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} -4% reactive load No. 2



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); CH4: trip signal

6.1 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %) 3.2.3, 4.3.6 Islanding Protection (MEA:2015)	**P**

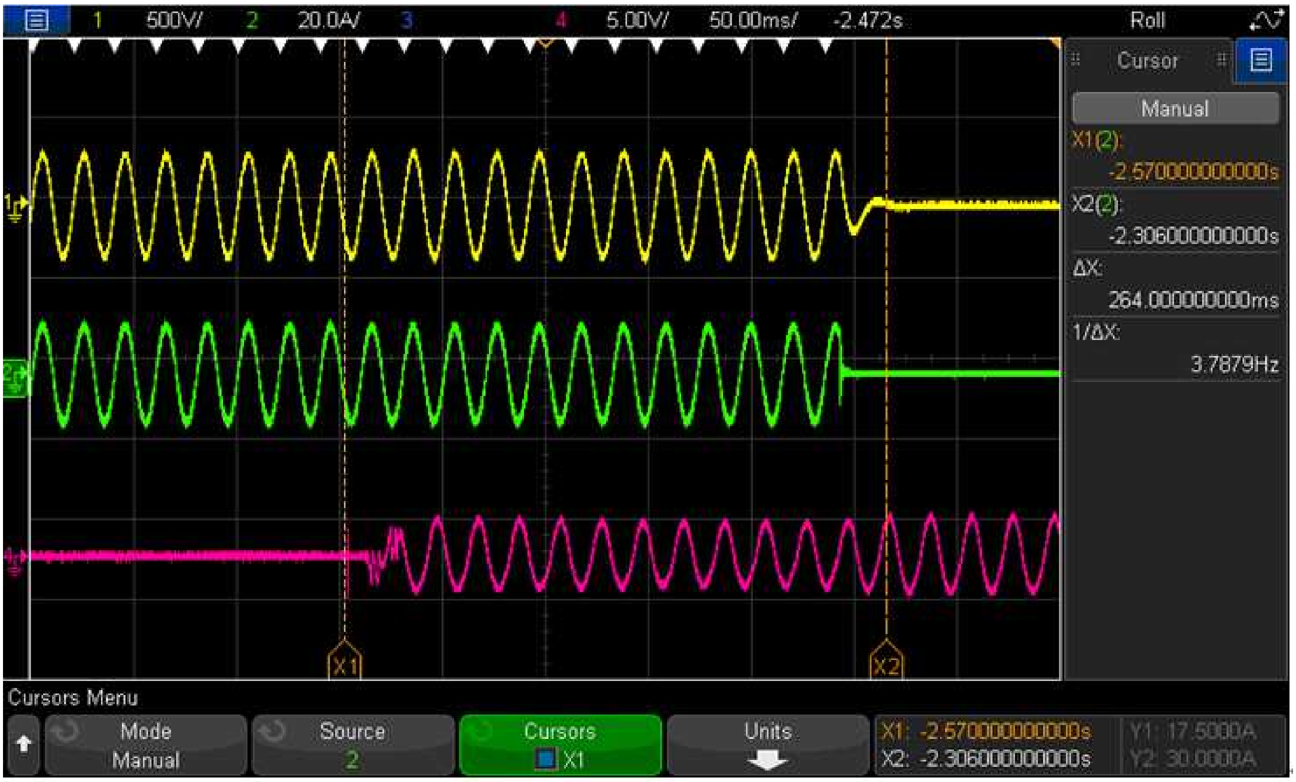
Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	0,3s for MEA

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}	Remarks4)
1	33	33	0	-5	114	1980	0,973	168	Test C at IB
2	33	33	0	-4	195	1980	0,978	168	Test C at IB
3	33	33	0	-3	130	1980	0,983	168	Test C at IB
4	33	33	0	-2	216	1980	0,988	168	Test C at IB
5	33	33	0	-1	209	1980	0,993	168	Test C at IB
6	33	33	0	0	214	1980	0,998	168	Test C at BL
7	**33**	**33**	**0**	**1**	**264**	1980	1,003	168	**Test C at IB**
8	33	33	0	2	211	1980	1,008	168	Test C at IB
9	33	33	0	3	138	1980	1,013	168	Test C at IB
10	33	33	0	4	208	1980	1,018	168	Test C at IB
11	33	33	0	5	129	1980	1,023	168	Test C at IB

Parameter at 0% per phase	L= 83,53 mH	R= 26,21 Ω	C= 121,31 µF
I_{AC} fundamental current at balance condition	91 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, 90 % 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} 1% reactive load No. 7



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.

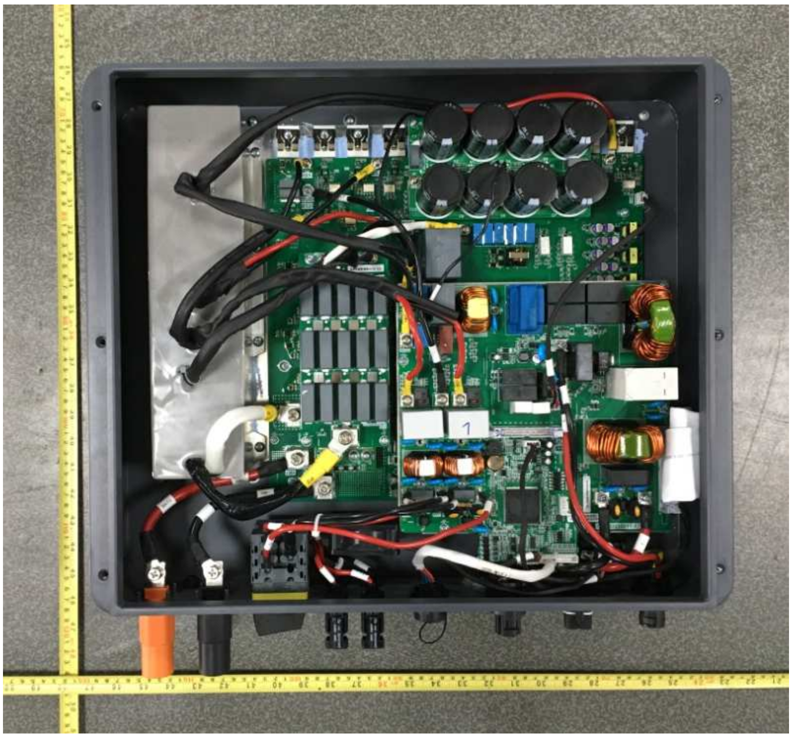
Note:
CH1: grid voltage(500V/div); CH2: Current of EUT(20A/div); CH4: trip signal

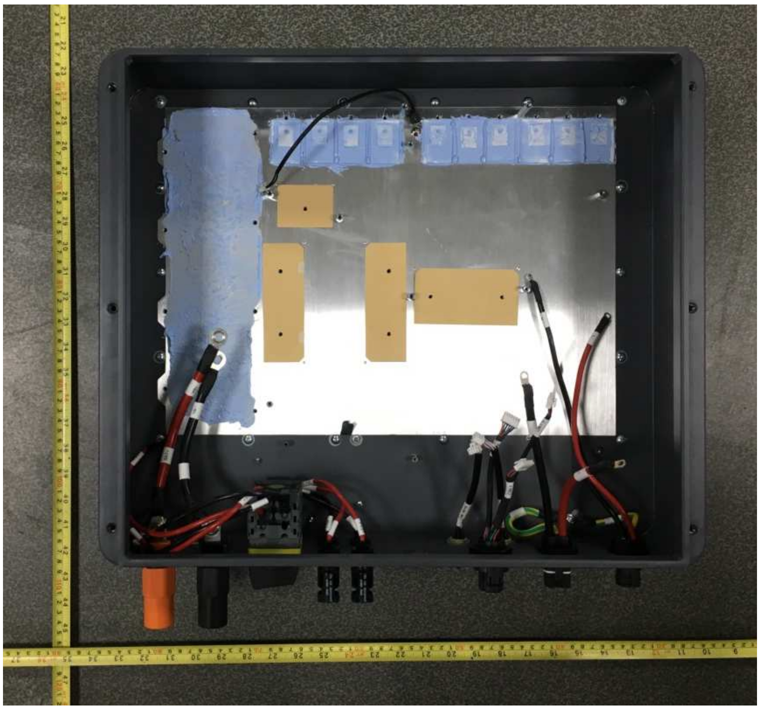
Annex 1
Pictures of the unit

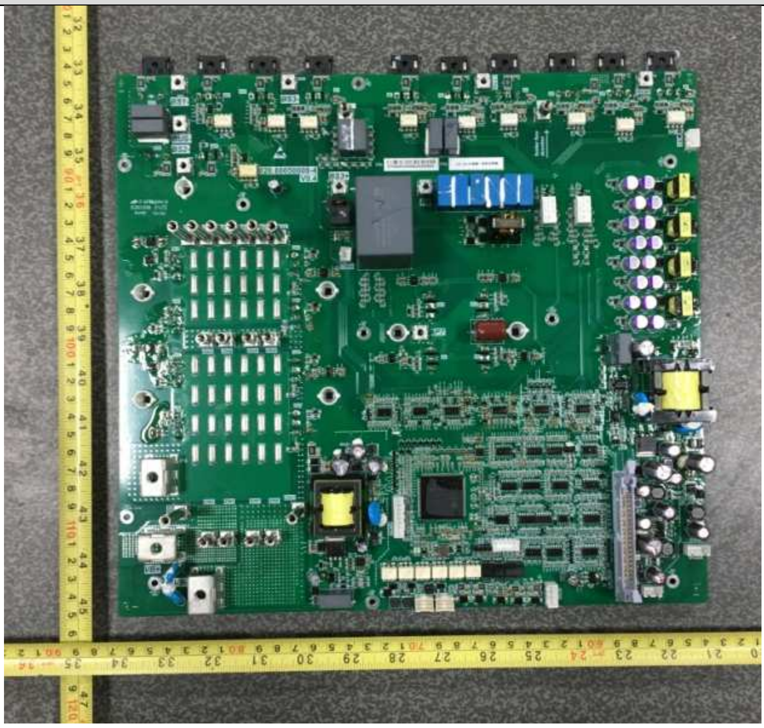
General view - 1

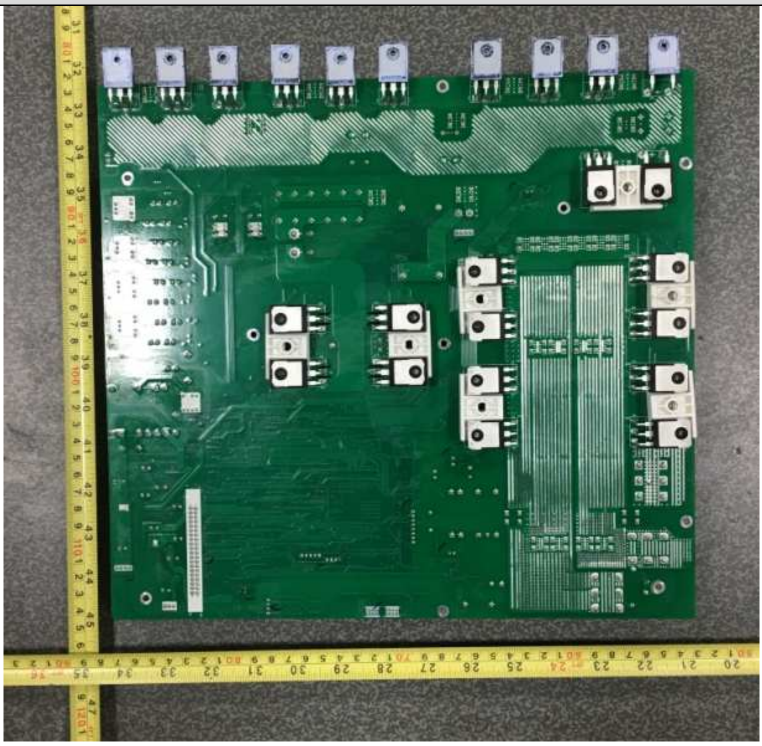
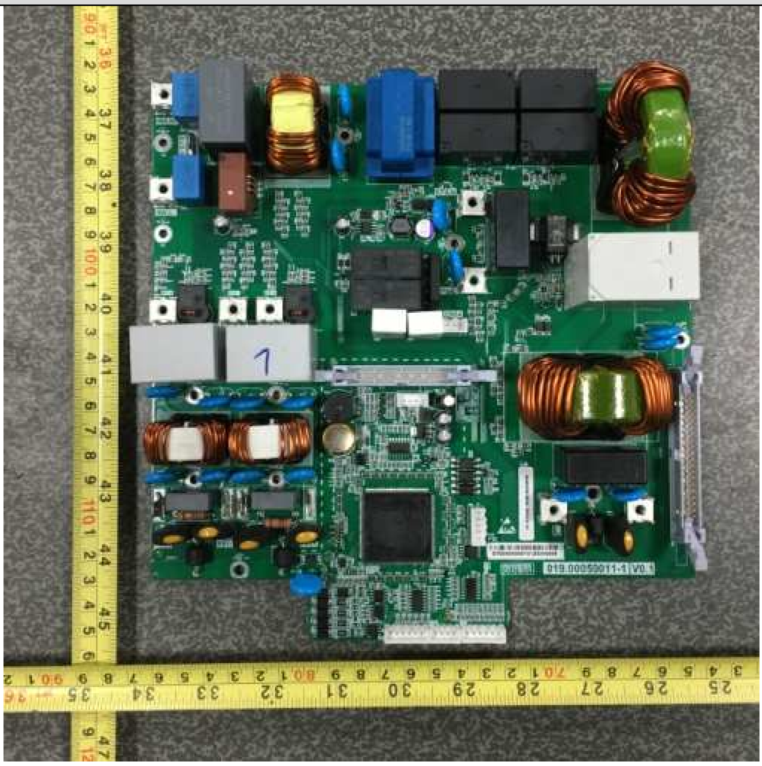
Enclosure front view

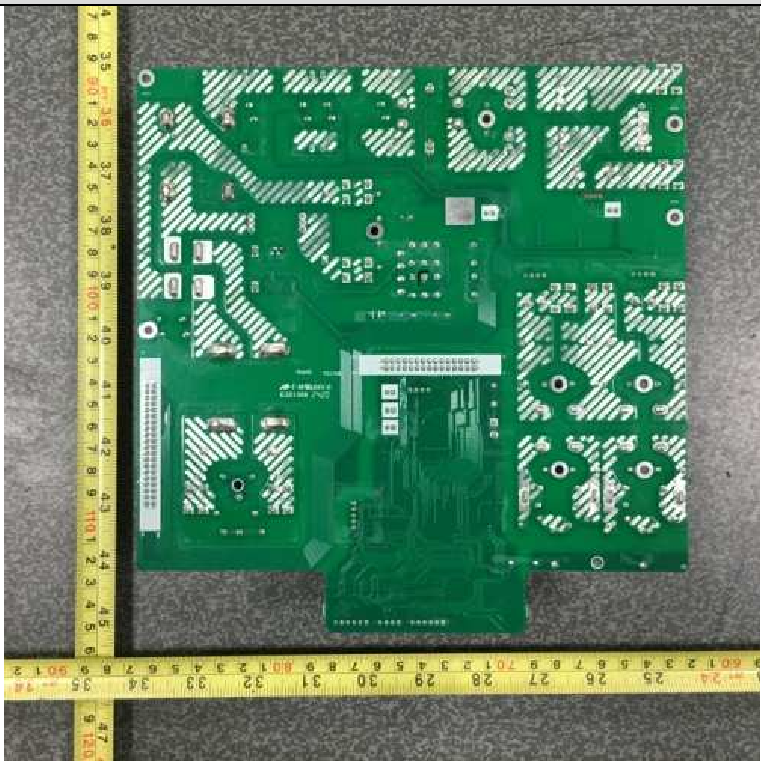
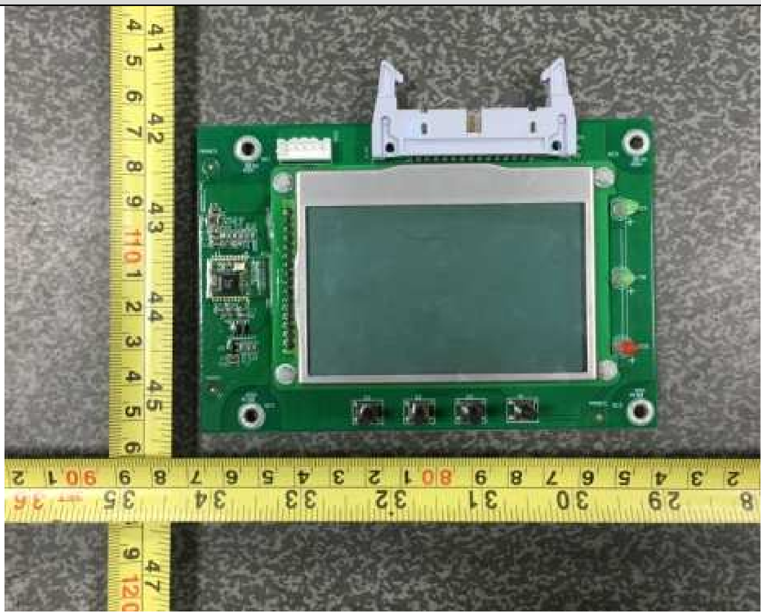
Enclosure terminal view

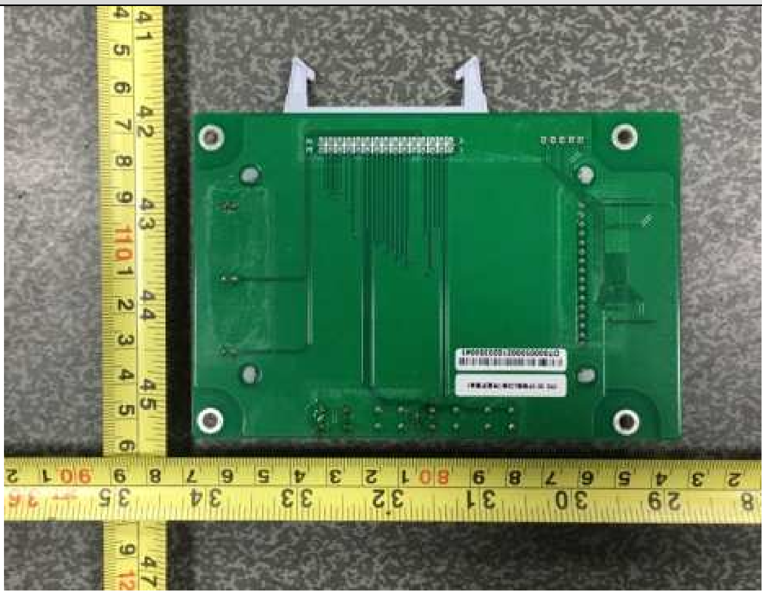
Internal view-1（HYD 6000-EP）


Internal view-2


Control board -component side view


Control board-solder side view

Communication board -component side view


Communication board -solder side view

Display board -component side view


Display board -solder side view


Annex 2

Test equipment list

Date(s) of performance of test 2019-06-28 to 2020-10-21

Equipment	Internal No.	Manufacturer	Type	Serial No.	Last Calibration
DC power supply	SB9540/02	Chroma	62150H-1000S	62150EF01653	Monitored by Power Analyzer
		Chroma	62150H-1000S	62150EF00450	
		Chroma	A620028	620028E00098	
		Chroma	A620028	620028E00102	
		Chroma	A620028	620028E00104	
		Chroma	A620028	620028E00106	
		Chroma	A620028	620028E00107	
		Chroma	A620028	620028E00108	
		Chroma	A620028	620028E00109	
RLC Load	SB9605	Qunling	ACLT-3830H	--	
AC Simulator	SB14325	Chroma	61860	618603800236	
	//	Chroma	61860	618603800387	
Power analyzer	SB11178	YOKOGAWA	WT3000	91P215776	2021-03-18
	//	DEWETRON	DEWE2-PA7	C7190048-CHN	2021-03-03
Current sensor	SB14641	YOKOGAWA	CT200	8173420022	2020-12-03
	SB14642	YOKOGAWA	CT200	8173420030	2020-12-03
	SB14643	YOKOGAWA	CT200	8173420024	2020-12-03
Oscilloscope probel	SB9149	TEKTRONIX	P5100A	--	2021-03-12
	SB9155	TEKTRONIX	P5100A	--	2020-12-26
	SB9159	TEKTRONIX	P5100A	--	2020-12-26
Four Channel Digital Phosphor Oscilloscope	//	Agilent	DS05014A	MY5007288	2020-11-21