VERIFICATION REPORT

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

Report No.	:	**162/63-159**
EUT No.	:	**SC-63-0136**
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	:	Solar Grid-tied inverter
Trademark	:	SOFAR SOLAR
Model and/or type reference	:	SOFAR 1600TL-G3
Date of receipt	:	10 August 2020
Date of report issue	:	13 August 2020

Prepare by

T. Eakkachai

Eakkachai Taesanoo
Engineer

Approved by

N. Ruengrit

Ruengrit Ninae
Operation Manager

Detail of reference test report	
Test Report No..... :	PVTH200601N032-1
Total number of pages..... :	48
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 ..... :	Lukes Lin
Reviewed by..... :	-
Approved by	James Huang
Date of report issue..... :	2020-07-14

Test item description ..... :	Solar Inverter
Trademark ..... :	SOFAR SOLAR
Model and/or type reference .... :	SOFAR 1600TL-G3
Rating	
Input DC MPP voltage range [V]:	50-500
Input DC voltage Max [V]..... :	500
Input DC current [A]..... :	Max.12A
Output AC voltage [V]..... :	220
Output AC current [A]..... :	Max. 7.7A
Output power [kW] ..... :	1.6
Firmware Version	V2.40

Summary of verification report

Test result of report No. **PVTH200601N032-1** was result of Photovoltaic Grid- Tied Inverter model **SOFAR 1600TL-G3**. 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.

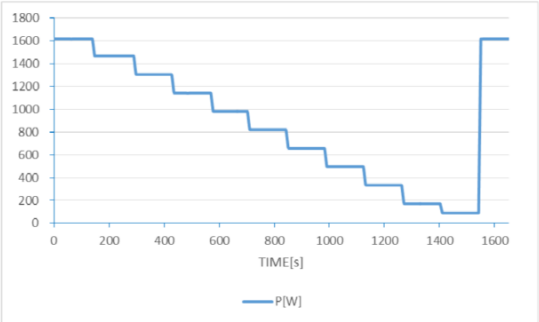
No.	Item	Reference Report No.	Standard Reference	Verdict
1	Active power control	PVTH200601N032-1	PEA	Pass
2	Reactive power control	-	-	--
2.1	A Fixed Displacement Factor cos θ	PVTH200601N032-1	PEA	Pass
2.2	A variable reactive power depending on the voltage Q(U)	--	--	--
3	Under/over frequency protection	PVTH200601N032-1	IEC 61727	Pass
4	Voltage fluctuation	PVTH200601N032-1	IEC 61000-3-11	Pass
5	Harmonics	PVTH200601N032-1	IEEE 1547.1	Pass
6	DC injection	PVTH200601N032-1	IEC 61727	Pass
7	Low voltage fault ride through	--	--	--
8	Under/over voltage protection	PVTH200601N032-1	IEC 61727	Pass
9	Anti-islanding	PVTH200601N032-1	IEC 62116	Pass
10	Response to utility recovery	PVTH200601N032-1	IEC 61727	Pass

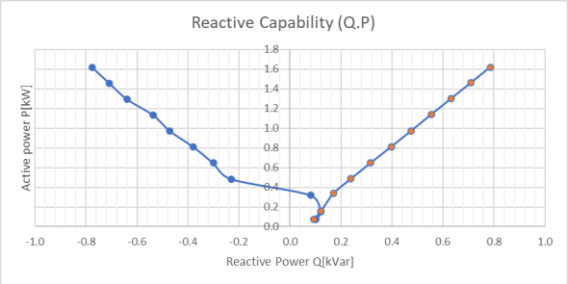
This report consists of the following document:

1. Verification Result (10 Page)
2. Attach Document Reference Report No. PVTH200601N032-1 (48 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: PVTH200601N032-1, 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 8.12%	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 : PVTH200601N032-1, - Page 38 Reactive power capability - Page 39- 40 A Fixed Displacement Factor cos θ test result - No A variable reactive power depending on the voltage Q(U) test result.	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></td><td></td><td>3) Verification test result
3.1 Reactive power capability
 
</td><td>Pass</td></tr>
<tr><td></td><td></td><td>3.2 A Fixed Displacement Factor cos θ test
<table><tr><th rowspan="2">PF.
Set point</th><th colspan="2">PF. Measurement*</th></tr><tr><th>Max</th><th>Min</th></tr><tr><td>1.0</td><td>1.000</td><td>0.942</td></tr><tr><td>0.90 lagging</td><td>0.907</td><td>0.771</td></tr><tr><td>0.90 Leading</td><td>0.900</td><td>0.790</td></tr></table>*@Pout =10% to 100%</td><td>Pass</td></tr>
<tr><td></td><td></td><td>A variable reactive power depending on the voltage Q(U) test result

-- No test result --</td><td>--</td></tr>
</table>

<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: PVTH200601N032-1
Page 28-29

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>0.093</td><td><0.1</td><td>Pass</td></tr><tr><td>f > 52</td><td>0.094</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 61000-3-3

2) Test result
See Test report no : PVTH200601N032-1,
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>0.07</td><td>Pass</td></tr><tr><td>Plt</td><td>0.8</td><td>0.07</td><td>Pass</td></tr></table></td><td>Pass</td></tr>
</table>

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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 * 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 (%): อันดับที่ / 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	**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 : PVTH200601N032-1, Page 16 to 20 **3) Verification test result** 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	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: PVTH200601N032-1, Page 15 **3) Verification test result** Output Power / Limit [%] / Max.DC [%] / Verdict 33% — 0.5 — 0.17 — Pass 66% — 0.5 — 0.24 — Pass 100% — 0.5 — 0.25 — Pass	Pass

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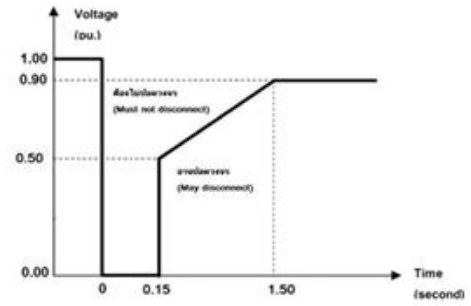
Clause	PEA Requirement	Result – Remark	Verdict
12.1	**Low Voltage Fault Ride Through** The power system of VSPP must not disconnect itself from the grid system within the required period during temporary low voltage of the grid system .The voltage at PCC is determined as shown in Table Fault Ride Through 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** See Test report no: N/A, Page: N/A **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	

Clause	PEA Requirement	Result – Remark	Verdict
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.	**Under and Over Voltage Protection** **1) Reference Standard** IEC 61727 **2) Test result** See Test report no: PVTH200601N032-1 Page 22-25 **3) Verification test result**	Pass

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

Voltage at PCC	Max Meas. (Sec)	Limit (Sec)	Result
V < 50%	0.248	<0.3	Pass
50% ≤ V< 90%	1.680	<2.0	Pass
90% ≤ V ≤ 110%	No trip	Cont.	Pass
110% < V < 120%	0.640	<1.0	Pass
V ≥ 120%	0.094	<0.16	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: PVTH200601N032-1
Page 32-37

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>0.612</td><td>< 1.0</td><td>Pass</td></tr><tr><td>66</td><td>0.618</td><td>< 1.0</td><td>Pass</td></tr><tr><td>33</td><td>0.620</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: PVTH200601N032-1
Page 22-27, 28,30

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>77</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 ..... :	PVTH200601N032-1
Date of issue ..... ::	2020-07-14
Total number of pages ..... :	48
Testing laboratory name ..... :	**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
Accreditation ..... :	ilac-MRA, A2LA ACCREDITED Certificate # 2951.01
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)
Test Report Form No. ..... :	IEC61727/IEC62116_PEA VER.2
TRF Originator ..... :	Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Master TRF ..... :	Dated 2020-03-20
Test item description ..... :	**Solar Grid-tied Inverter**
Trademark..... :	SOFAR SOLAR
Model / Type ..... :	SOFAR 1600TL-G3

Ratings .....:	SOFAR 1600TL-G3
MPP DC voltage range [V] .....:	50-500
Input DC voltage range [V].....:	50-500
Input DC current [A] .....:	Max.12A
Output AC voltage [V] .....:	L/N/PE, 220Vac
Output AC current [A].....:	Max.7,7A
Nominal Output power [kW] .....:	1,6
Maximum Output power [kVA] .....:	1,6

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 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 1 ..... :	**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**
2020-07-14	Lukes Lin	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 ..... :	2020-06-01
Date(s) of performance of test ..... :	2020-06-01 to 2020-07-13

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.

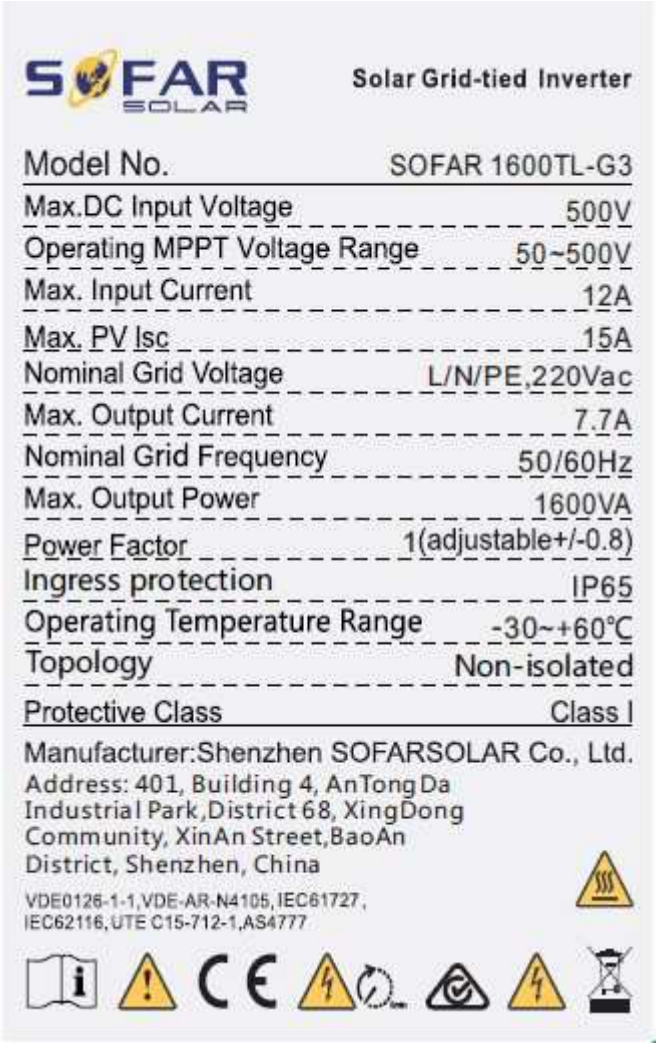
"(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

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 input and output are protected by Varistors to Earth. 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.

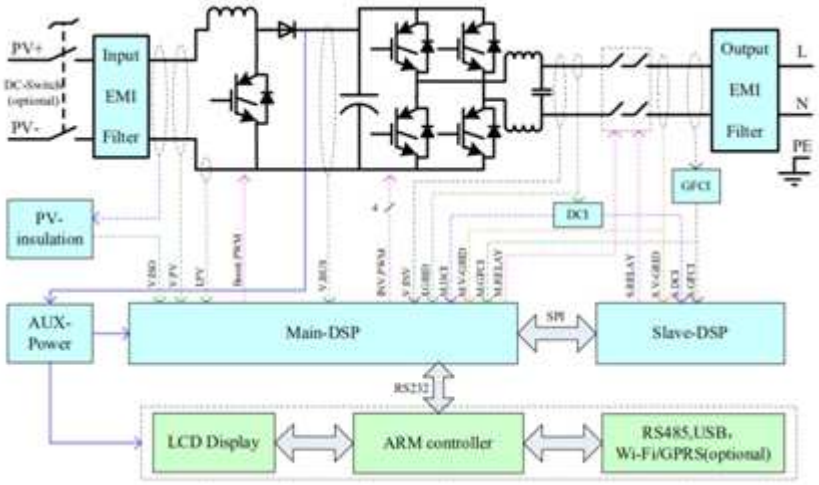


Figure 1 – Block diagram

Description of the electrical circuit: (Figure 1):

The internal control is redundant built. It consists of Microcontroller CPU2 (U03) and CPU1 (UC34).

The CPU1 (UC34) 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 CPU2 (U03) is measures the grid voltage, grid frequency, DCI and residual current, also can switch off the relays independently, and communicate with the CPU1 (UC34) each other.

The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the CPU1 (UC34). The CPU1 (UC34) 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: V1.00

Software version: V2.40

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				

Flicker Mode Uover:■ ■ ■ ■ I1 : 30A YOKOGAWA ◆
Iover:■ ■ ■ ■ Flicker:Complete 2:00:00

Count 12/12
Interval 10m00s/10m00s
Element 1
Volt Range 300V/50Hz Element1 Judgement: Pass
Un (U1) 219.729 V Total Judgement: Pass
Freq(U1) 49.999 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	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
2	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
3	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
4	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
5	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
6	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
7	0.07 Pass	0.15 Pass	0 Pass	0.07 Pass	
8	0.05 Pass	0.16 Pass	0 Pass	0.07 Pass	
9	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
10	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
11	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
12	0.00 Pass	0.00 Pass	0 Pass	0.07 Pass	
Result	Pass	Pass	Pass	Pass	0.07 Pass

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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**

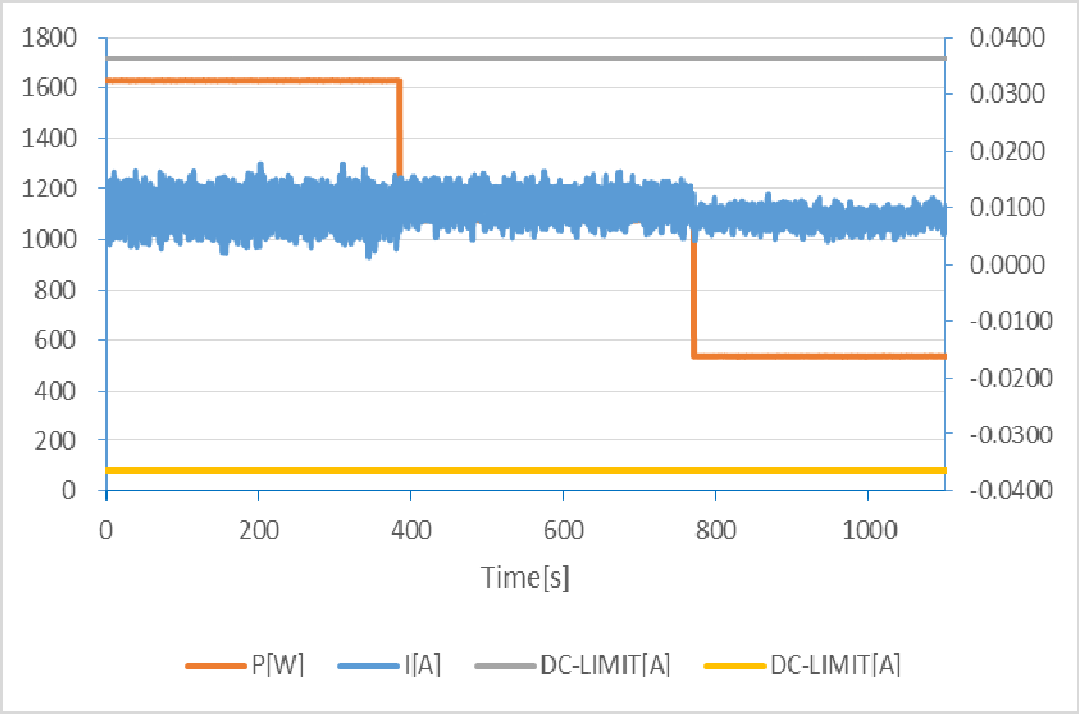
Calculation of the maximum permissible grid impedance at the point of common coupling based on d_c:
$Z_{max} = Z_{ref} * 3,3\% / d_c(P_n)$

The tests should be based on the limits of the EN 61000-3-3 for less 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} : 36mA**		
Output power:	33%	66%	100%
Max. test value (mA): L1 phase	12	17	18
Mean test value(mA) : L1 phase	8	11	10

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)	0,541							
VA (kVA)	0,541							
Vrms (V)	220,24							
Arms (A)	2,456							
PF	0,9992							
Frequency (Hz)	50,00							
THD50 (%)	0,434							
Harmonics	**Current Magnitude [A]**			**% of Rated Current**			**Phase**	**Harmonic Current Limits [%]**
1st	2,455	-	-	0,338	-	-	Single Phase	--
2nd	0,004	-	-	0,052	-	-	Single Phase	1
3rd	0,003	-	-	0,047	-	-	Single Phase	4
4th	0,002	-	-	0,029	-	-	Single Phase	1
5th	0,016	-	-	0,220	-	-	Single Phase	4
6th	0,002	-	-	0,032	-	-	Single Phase	1
7th	0,005	-	-	0,074	-	-	Single Phase	4
8th	0,002	-	-	0,029	-	-	Single Phase	1
9th	0,003	-	-	0,044	-	-	Single Phase	4
10th	0,002	-	-	0,025	-	-	Single Phase	1
11th	0,010	-	-	0,138	-	-	Single Phase	2
12th	0,001	-	-	0,013	-	-	Single Phase	0,5
13th	0,011	-	-	0,156	-	-	Single Phase	2
14th	0,002	-	-	0,022	-	-	Single Phase	0,5
15th	0,002	-	-	0,025	-	-	Single Phase	2
16th	0,001	-	-	0,017	-	-	Single Phase	0,5
17th	0,006	-	-	0,084	-	-	Single Phase	1,5
18th	0,000	-	-	0,007	-	-	Single Phase	0,375
19th	0,010	-	-	0,143	-	-	Single Phase	1,5
20th	0,001	-	-	0,015	-	-	Single Phase	0,375
21th	0,001	-	-	0,013	-	-	Single Phase	1,5
22th	0,001	-	-	0,012	-	-	Single Phase	0,375
23th	0,010	-	-	0,142	-	-	Single Phase	0,6
24th	0,000	-	-	0,005	-	-	Single Phase	0,15
25th	0,004	-	-	0,049	-	-	Single Phase	0,6
26th	0,001	-	-	0,008	-	-	Single Phase	0,15
27th	0,001	-	-	0,015	-	-	Single Phase	0,6
28th	0,001	-	-	0,009	-	-	Single Phase	0,15
29th	0,008	-	-	0,112	-	-	Single Phase	0,6
30th	0,000	-	-	0,005	-	-	Single Phase	0,15
31th	0,007	-	-	0,100	-	-	Single Phase	0,6
32th	0,000	-	-	0,005	-	-	Single Phase	0,15
33th	0,002	-	-	0,025	-	-	Single Phase	0,6
34th	0,001	-	-	0,008	-	-	Single Phase	0,15
35th	0,004	-	-	0,049	-	-	Single Phase	0,3

36th	0,000	-	-	0,006	-	-	Single Phase	0,075
37th	0,003	-	-	0,041	-	-	Single Phase	0,3
38th	0,000	-	-	0,006	-	-	Single Phase	0,075
39th	0,002	-	-	0,027	-	-	Single Phase	0,3
40th	0,001	-	-	0,007	-	-	Single Phase	0,075

66% Output Power	
Watts (kW)	0,541
VA (kVA)	0,541
Vrms (V)	220,24
Arms (A)	2,456
PF	0,9992
Frequency (Hz)	50,00
THD50 (%)	0,434

Harmonics	**Current Magnitude [A]**			**% of Rated Current**			**Phase**	**Harmonic Current Limits [%]**
1st	4,908	-	-	0,675	-	-	Single Phase	--
2nd	0,006	-	-	0,101	-	-	Single Phase	1
3rd	0,004	-	-	0,072	-	-	Single Phase	4
4th	0,003	-	-	0,053	-	-	Single Phase	1
5th	0,015	-	-	0,241	-	-	Single Phase	4
6th	0,003	-	-	0,049	-	-	Single Phase	1
7th	0,005	-	-	0,086	-	-	Single Phase	4
8th	0,003	-	-	0,048	-	-	Single Phase	1
9th	0,004	-	-	0,061	-	-	Single Phase	4
10th	0,002	-	-	0,036	-	-	Single Phase	1
11th	0,011	-	-	0,175	-	-	Single Phase	2
12th	0,001	-	-	0,018	-	-	Single Phase	0,5
13th	0,011	-	-	0,174	-	-	Single Phase	2
14th	0,002	-	-	0,026	-	-	Single Phase	0,5
15th	0,002	-	-	0,032	-	-	Single Phase	2
16th	0,002	-	-	0,028	-	-	Single Phase	0,5
17th	0,004	-	-	0,074	-	-	Single Phase	1,5
18th	0,001	-	-	0,010	-	-	Single Phase	0,375
19th	0,008	-	-	0,140	-	-	Single Phase	1,5
20th	0,001	-	-	0,021	-	-	Single Phase	0,375
21th	0,001	-	-	0,019	-	-	Single Phase	1,5
22th	0,001	-	-	0,017	-	-	Single Phase	0,375
23th	0,006	-	-	0,099	-	-	Single Phase	0,6
24th	0,000	-	-	0,008	-	-	Single Phase	0,15
25th	0,003	-	-	0,052	-	-	Single Phase	0,6
26th	0,001	-	-	0,010	-	-	Single Phase	0,15
27th	0,002	-	-	0,034	-	-	Single Phase	0,6
28th	0,000	-	-	0,007	-	-	Single Phase	0,15
29th	0,006	-	-	0,096	-	-	Single Phase	0,6
30th	0,000	-	-	0,008	-	-	Single Phase	0,15
31th	0,009	-	-	0,150	-	-	Single Phase	0,6
32th	0,000	-	-	0,007	-	-	Single Phase	0,15

33th	0,002	-	-	0,034	-	-	Single Phase	0,6
34th	0,000	-	-	0,008	-	-	Single Phase	0,15
35th	0,002	-	-	0,038	-	-	Single Phase	0,3
36th	0,001	-	-	0,009	-	-	Single Phase	0,075
37th	0,006	-	-	0,101	-	-	Single Phase	0,3
38th	0,001	-	-	0,009	-	-	Single Phase	0,075
39th	0,002	-	-	0,030	-	-	Single Phase	0,3
40th	0,001	-	-	0,010	-	-	Single Phase	0,075

100% Output Power	
Watts (kW)	1,636
VA (kVA)	1,637
Vrms (V)	220,90
Arms (A)	7,411
PF	0,9995
Frequency (Hz)	50,00
THD50 (%)	0,491

Harmonics	**Current Magnitude [A]**			**% of Rated Current**			**Phase**	**Harmonic Current Limits [%]**
1st	7,409	-	-	1,019	-	-	Single Phase	--
2nd	0,009	-	-	0,122	-	-	Single Phase	1
3rd	0,006	-	-	0,086	-	-	Single Phase	4
4th	0,005	-	-	0,063	-	-	Single Phase	1
5th	0,015	-	-	0,210	-	-	Single Phase	4
6th	0,004	-	-	0,060	-	-	Single Phase	1
7th	0,006	-	-	0,082	-	-	Single Phase	4
8th	0,005	-	-	0,063	-	-	Single Phase	1
9th	0,005	-	-	0,067	-	-	Single Phase	4
10th	0,003	-	-	0,038	-	-	Single Phase	1
11th	0,011	-	-	0,150	-	-	Single Phase	2
12th	0,002	-	-	0,023	-	-	Single Phase	0,5
13th	0,012	-	-	0,171	-	-	Single Phase	2
14th	0,002	-	-	0,026	-	-	Single Phase	0,5
15th	0,003	-	-	0,042	-	-	Single Phase	2
16th	0,002	-	-	0,023	-	-	Single Phase	0,5
17th	0,003	-	-	0,046	-	-	Single Phase	1,5
18th	0,001	-	-	0,011	-	-	Single Phase	0,375
19th	0,010	-	-	0,143	-	-	Single Phase	1,5
20th	0,001	-	-	0,020	-	-	Single Phase	0,375
21th	0,001	-	-	0,018	-	-	Single Phase	1,5
22th	0,001	-	-	0,016	-	-	Single Phase	0,375
23th	0,007	-	-	0,090	-	-	Single Phase	0,6
24th	0,001	-	-	0,009	-	-	Single Phase	0,15
25th	0,004	-	-	0,061	-	-	Single Phase	0,6
26th	0,001	-	-	0,011	-	-	Single Phase	0,15
27th	0,002	-	-	0,026	-	-	Single Phase	0,6
28th	0,001	-	-	0,008	-	-	Single Phase	0,15
29th	0,007	-	-	0,091	-	-	Single Phase	0,6

30th	0,001	-	-	0,009	-	-	Single Phase	0,15
31th	0,011	-	-	0,147	-	-	Single Phase	0,6
32th	0,001	-	-	0,007	-	-	Single Phase	0,15
33th	0,002	-	-	0,027	-	-	Single Phase	0,6
34th	0,001	-	-	0,009	-	-	Single Phase	0,15
35th	0,002	-	-	0,034	-	-	Single Phase	0,3
36th	0,001	-	-	0,010	-	-	Single Phase	0,075
37th	0,012	-	-	0,160	-	-	Single Phase	0,3
38th	0,001	-	-	0,008	-	-	Single Phase	0,075
39th	0,002	-	-	0,022	-	-	Single Phase	0,3
40th	0,001	-	-	0,010	-	-	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)				220,90				
Frequency (Hz)				50,00				
THD50 (%)				0,179				
Harmonics	**Voltage Magnitude [V]**			**% of Rated Voltage**			**Phase**	**Limits [%]**
2nd	0,032	-	-	0,015	-	-	Single Phase	0,2
3rd	0,317	-	-	0,144	-	-	Single Phase	4
4th	0,043	-	-	0,019	-	-	Single Phase	0,2
5th	0,058	-	-	0,026	-	-	Single Phase	4
6th	0,030	-	-	0,014	-	-	Single Phase	0,2
7th	0,082	-	-	0,037	-	-	Single Phase	4
8th	0,022	-	-	0,010	-	-	Single Phase	0,2
9th	0,072	-	-	0,033	-	-	Single Phase	2
10th	0,014	-	-	0,007	-	-	Single Phase	0,2
11th	0,054	-	-	0,025	-	-	Single Phase	0,1
12th	0,015	-	-	0,007	-	-	Single Phase	0,1
13th	0,052	-	-	0,024	-	-	Single Phase	0,1
14th	0,009	-	-	0,004	-	-	Single Phase	0,1
15th	0,031	-	-	0,014	-	-	Single Phase	0,1
16th	0,011	-	-	0,005	-	-	Single Phase	0,1
17th	0,022	-	-	0,010	-	-	Single Phase	0,1
18th	0,007	-	-	0,003	-	-	Single Phase	0,1
19th	0,068	-	-	0,031	-	-	Single Phase	0,1
20th	0,010	-	-	0,005	-	-	Single Phase	0,1
21th	0,038	-	-	0,017	-	-	Single Phase	0,1
22th	0,010	-	-	0,004	-	-	Single Phase	0,1
23th	0,071	-	-	0,032	-	-	Single Phase	0,1
24th	0,007	-	-	0,003	-	-	Single Phase	0,1
25th	0,020	-	-	0,009	-	-	Single Phase	0,1
26th	0,006	-	-	0,003	-	-	Single Phase	0,1
27th	0,018	-	-	0,008	-	-	Single Phase	0,1
28th	0,006	-	-	0,003	-	-	Single Phase	0,1
29th	0,037	-	-	0,017	-	-	Single Phase	0,1
30th	0,006	-	-	0,003	-	-	Single Phase	0,1
31th	0,076	-	-	0,035	-	-	Single Phase	0,1
32th	0,006	-	-	0,003	-	-	Single Phase	0,1
33th	0,017	-	-	0,008	-	-	Single Phase	0,1
34th	0,007	-	-	0,003	-	-	Single Phase	0,1
35th	0,016	-	-	0,007	-	-	Single Phase	0,1
36th	0,008	-	-	0,003	-	-	Single Phase	0,1
37th	0,083	-	-	0,038	-	-	Single Phase	0,1
38th	0,006	-	-	0,003	-	-	Single Phase	0,1
39th	0,019	-	-	0,009	-	-	Single Phase	0,1
40th	0,007	-	-	0,003	-	-	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%**
--	0,9449i	0,9965i	0,9995i	0,9997i	0,9998i

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:1,6 KW 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
		197,7	--	--	--		242,4	--	--	--
		197,7	--	--	--		242,4	--	--	--
		197,6	--	--	--		242,4	--	--	--
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
		1,66	--	--	--		0,62	--	--	--
		1,64	--	--	--		0,64	--	--	--
		1,68	--	--	--		0,64	--	--	--
Reconnection time	20s - 5min	73s				20s - 5min	73s			

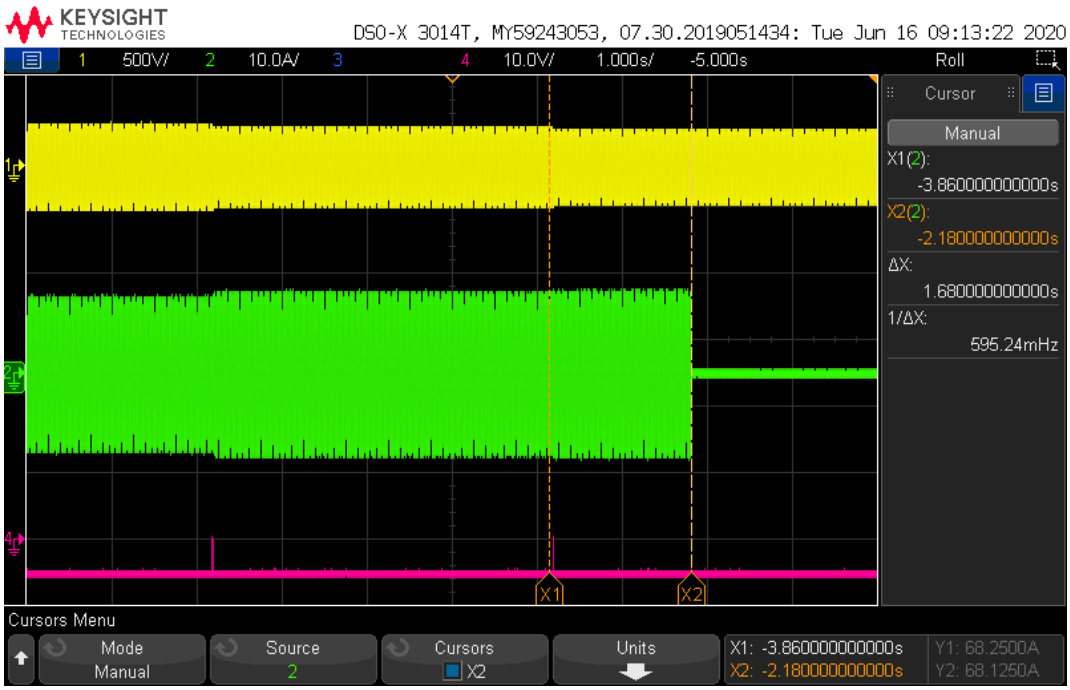
Second Level (Phase to Neutral)										
Test conditions:	Output power: 10KW Frequency: 50Hz									
	Under Voltage					**Over Voltage**				
Parameter		Voltage [V]					Voltage [V]			
Set value		**110V**					**264V**			
Measured trip value		All	L1	L2	L3		All	L1	L2	L3
		109,6	--	--	--		265,1	--	--	--
		109,1	--	--	--		265,2	--	--	--
		109,5	--	--	--		264,6	--	--	--
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
		0,248	--	--	--		0,092	--	--	--
		0,244	--	--	--		0,094	--	--	--
		0,234	--	--	--		0,080	--	--	--
Reconnection time	20s - 5min	75s				20s - 5min	73s			

Note:

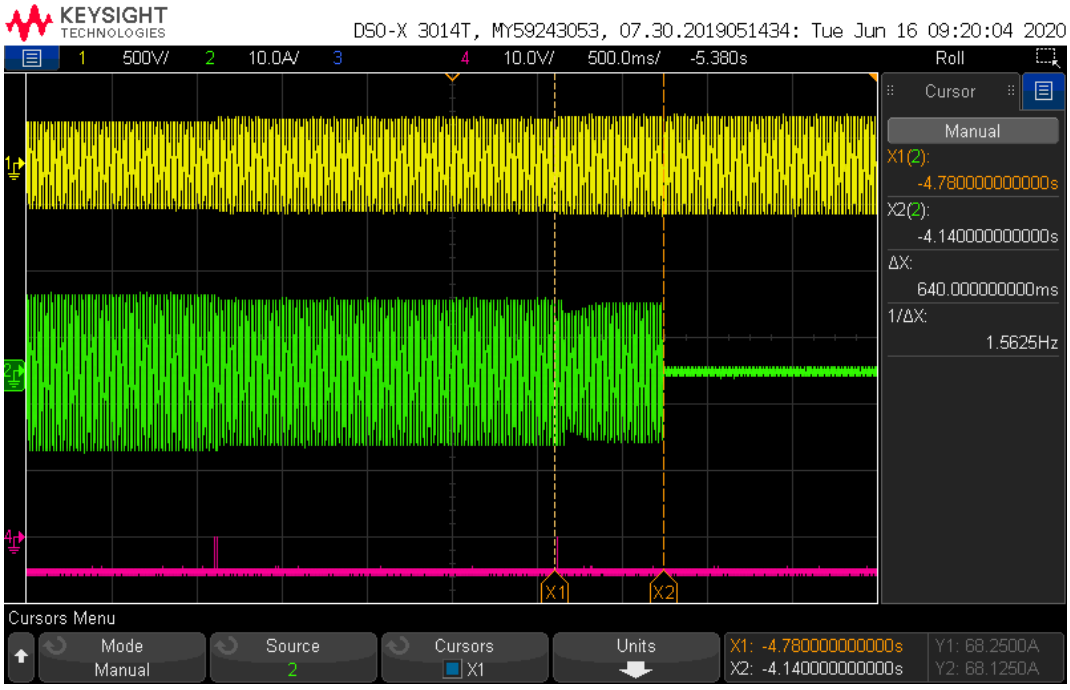
The tests are according PEA:2016. The voltage settings of the EUT are set for the tests as stated to 198V, 110V for undervoltage and 242V, 264V for overvoltage.

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

Under Voltage First Level single phase

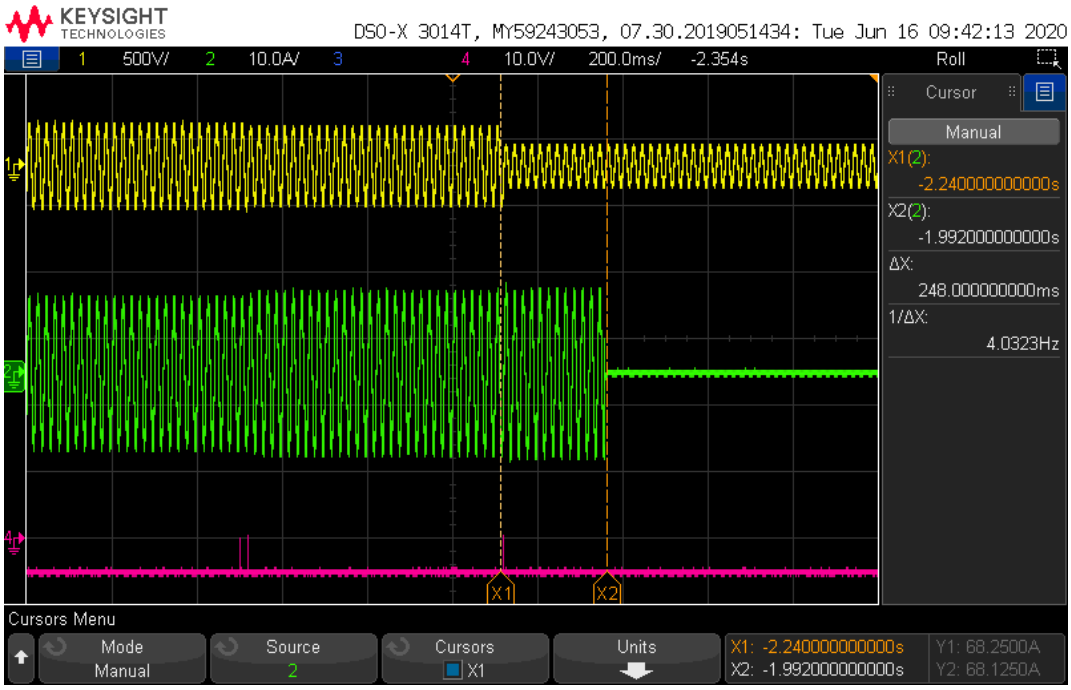


Over voltage First Level single phase

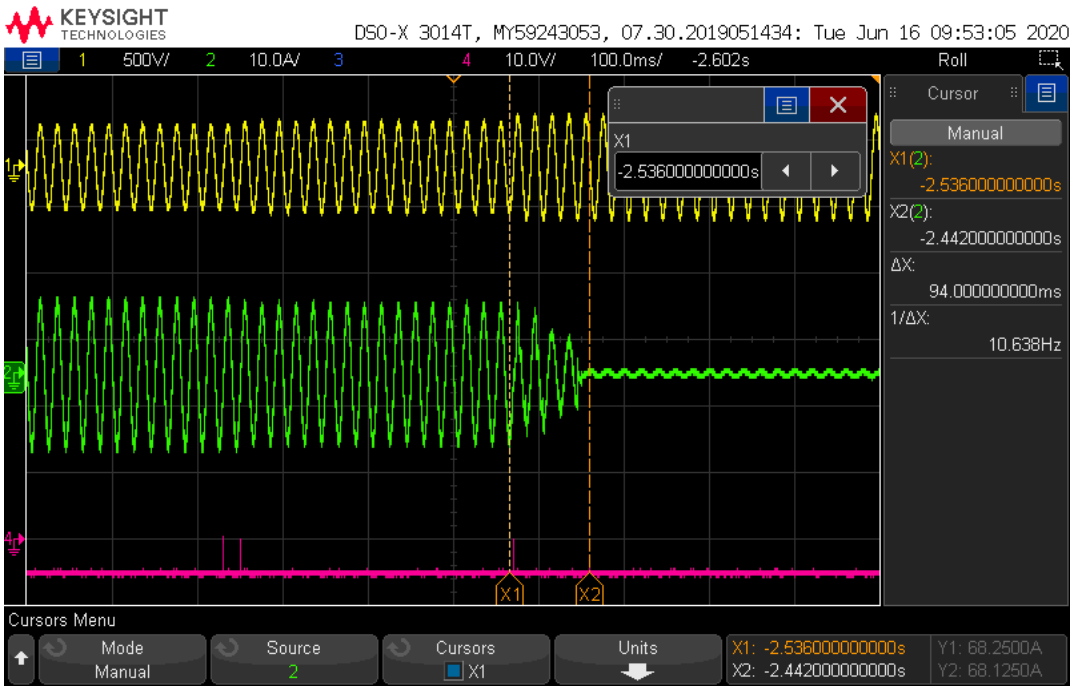


Note: CH1:grid voltage(500V/div); CH4: trip signal; CH2: current of EUT(10A/div)

Under Voltage Second Level single phase

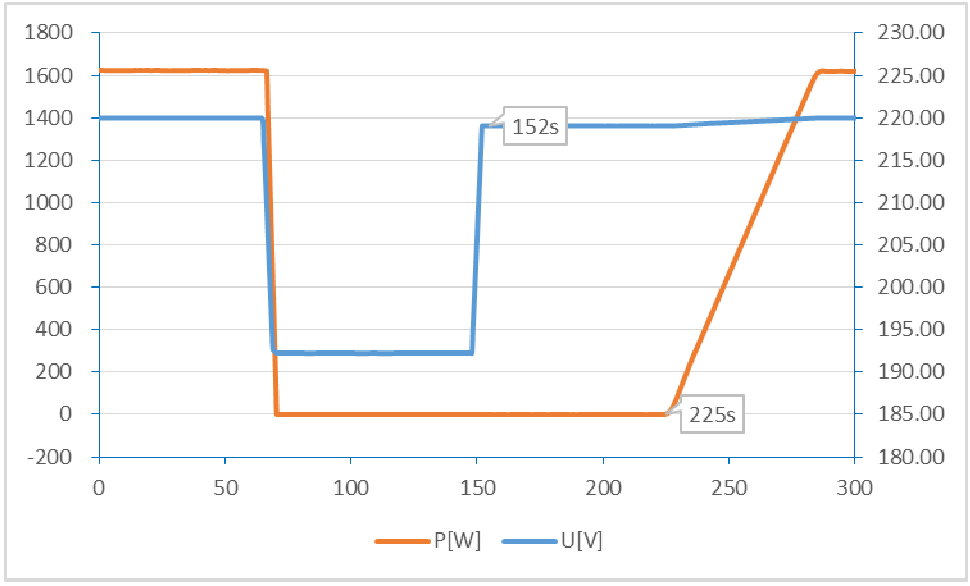


Over voltage Second Level single phase

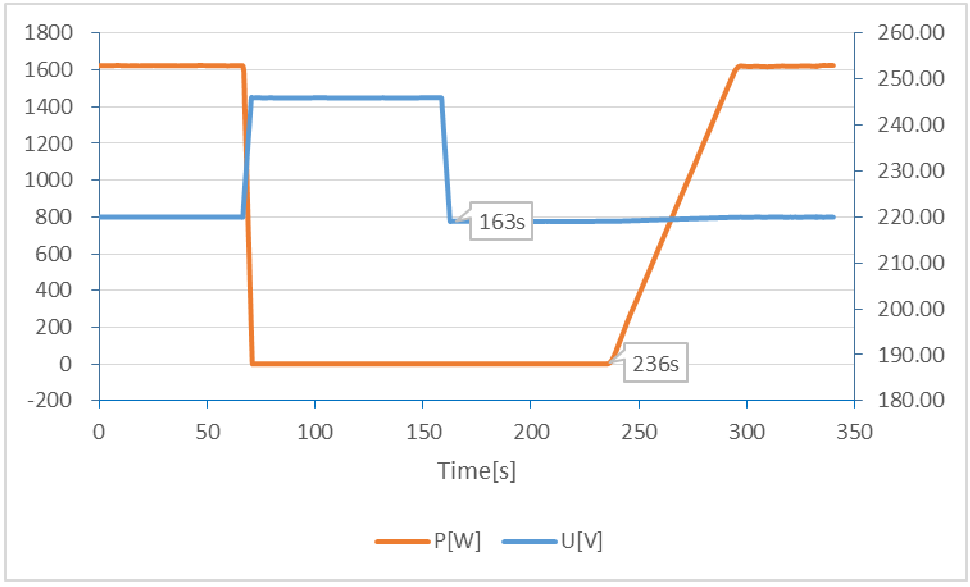


Note: CH1:grid voltage(500V/div); CH4: trip signal; CH2: current of EUT(10A/div)

Reconnection after Under Voltage First Level

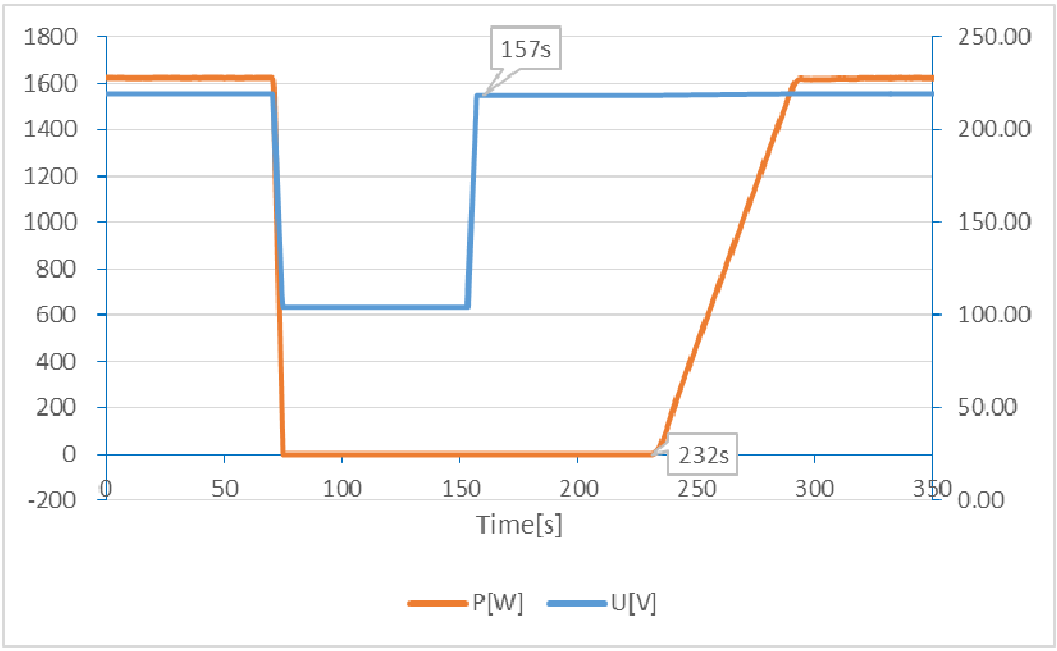


Reconnection after Over Voltage First Level

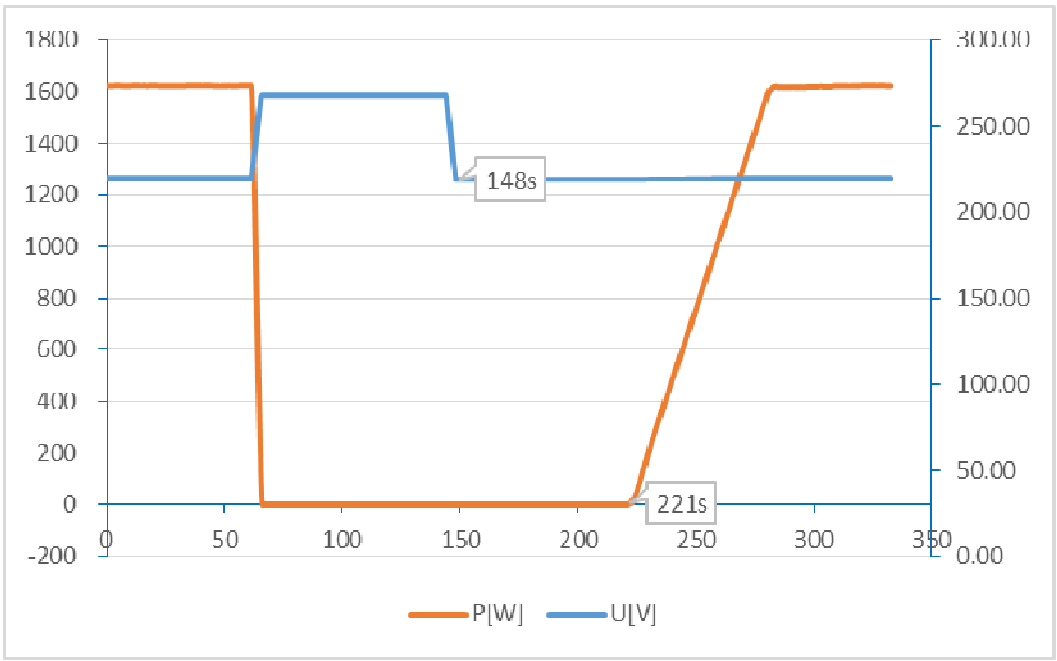


Note:

Reconnection after Under Voltage Second Level



Reconnection after Over Voltage Second Level



Note:

5.2.2 Frequency monitoring	**P**

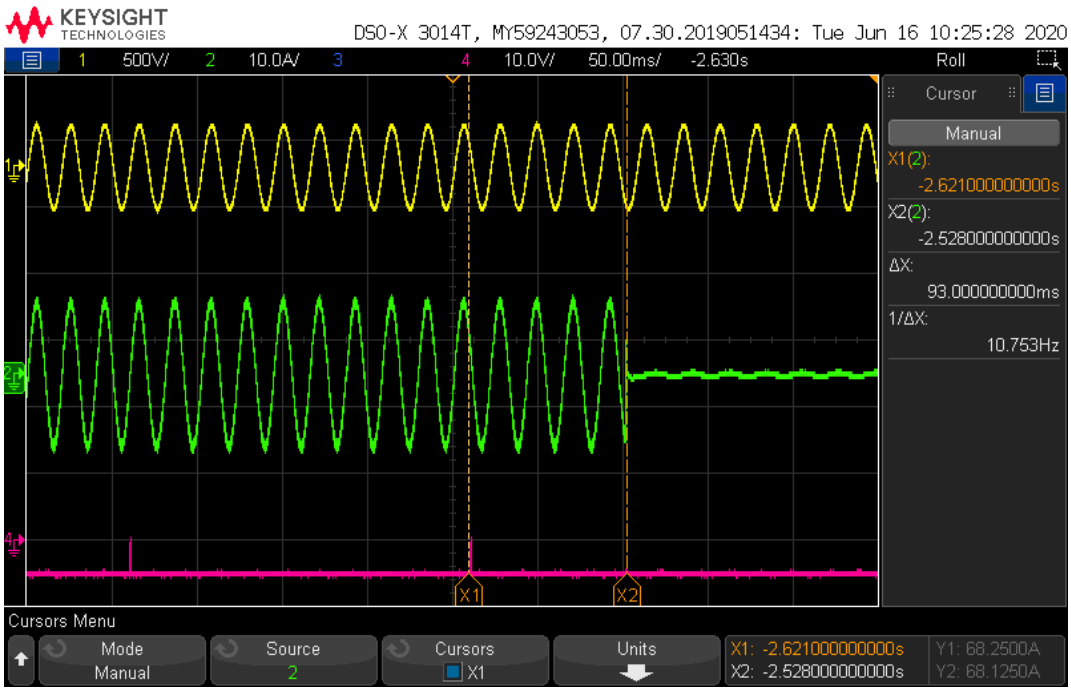
IEC 61727
8.2 Under and Over Frequency Protection (PEA:2016)
3.10, 12.5 Response to utility recovery (PEA:2016)

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)		46,99		52,02
		46,99		52,02
		46,99		52,02
		Time [ms]		Time [ms]
Limit		**<= 100ms**		**<= 100ms**
Disconnection time(ms)	50,0Hz to 47,2 Hz (0,2s min) to 46,5 Hz	90,0	50,0 Hz to 51,80 Hz (0,2s min) to 52,5Hz	81,0
		83,0		94,0
		93,0		88,0
Reconnection time (Sec)	20s – 5min	73,0	20s-5min	77,0

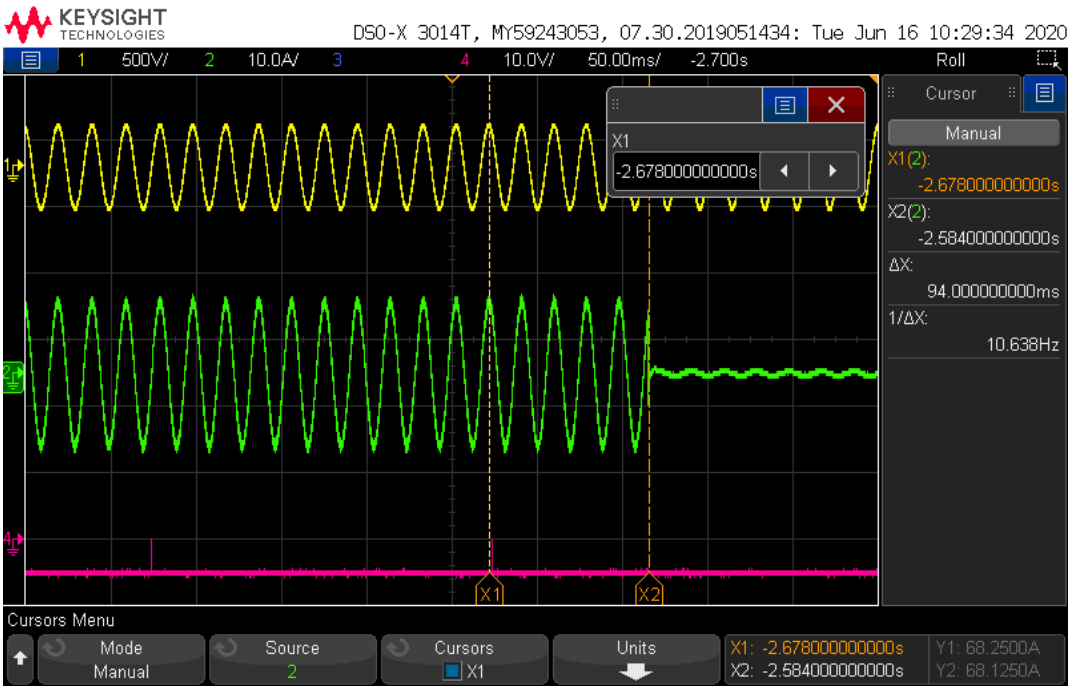
Note:
The frequency which inverter stops feeding power to electrical system in each test must be in the range of the frequency trip setting +/- 0,1Hz and the time it takes to cut off the power must be within 0.1 second.

The tests are performed according the IEEE 1547.1-2005, annex A.
Response to utility recovery is according to the appropriate IEEE or IEC standard test methods.

Under Frequency:

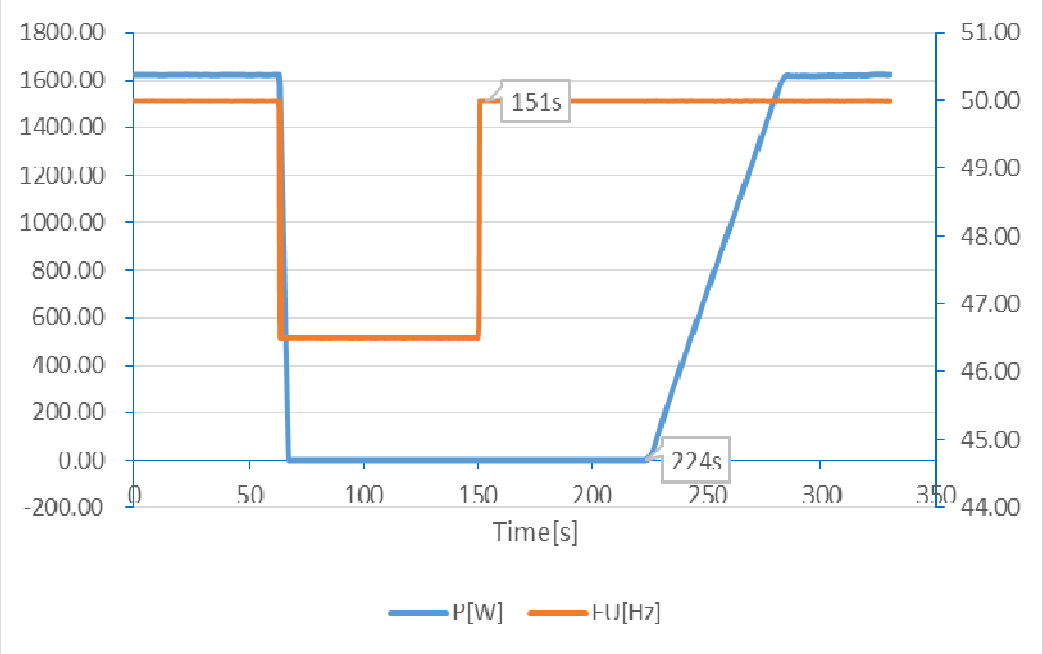


Over Frequency:

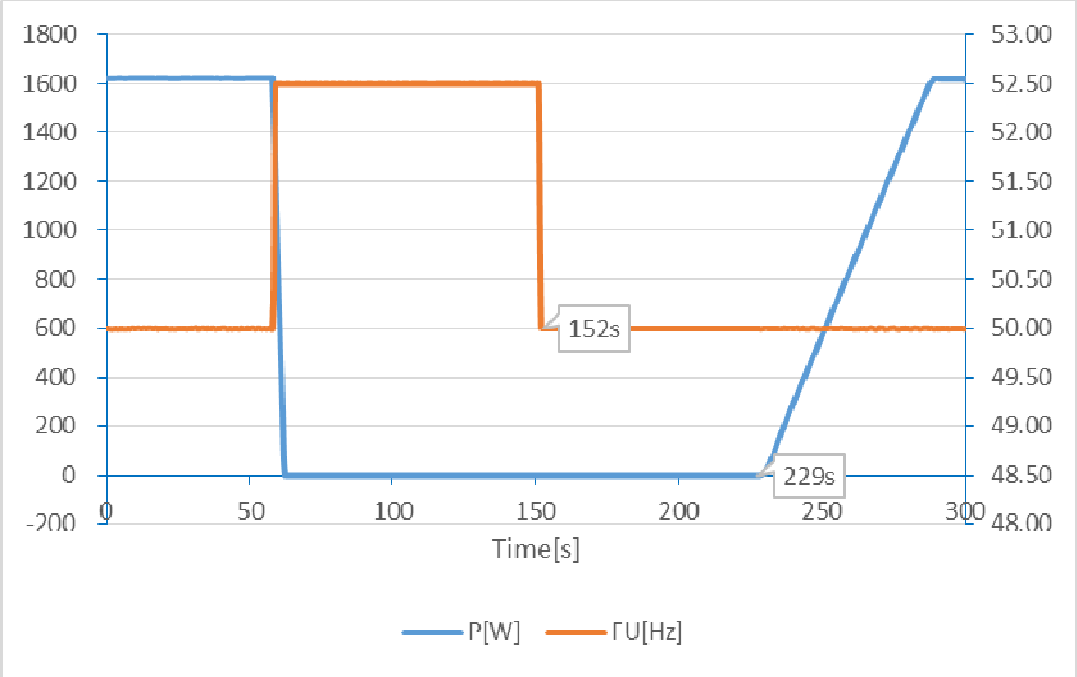


Note:
CH1:grid voltage(500V/div); CH4: trip signal; CH2: current of EUT(10A/div)

Reconnection after Under Frequency:



Reconnection after Over Frequency:



Note:

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

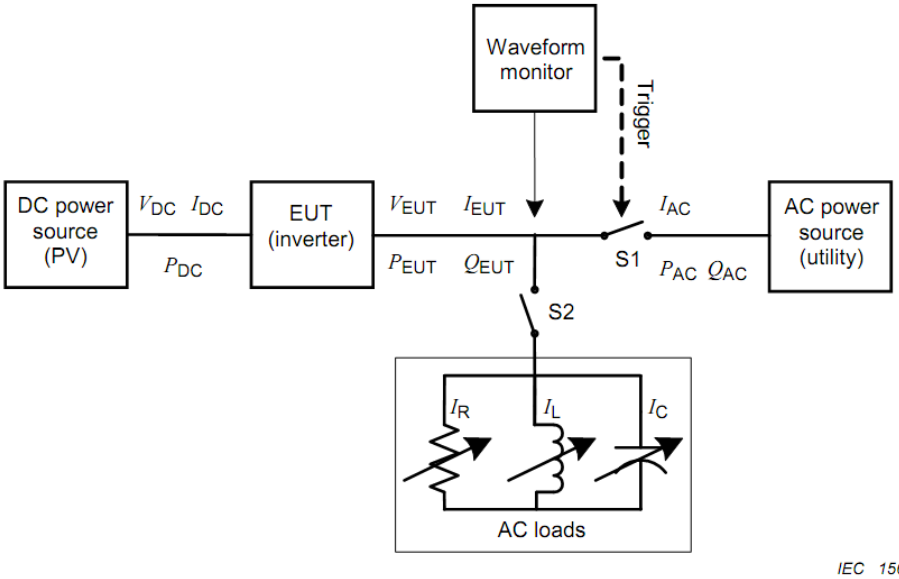


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

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	612	1600	1,000	313	Test A at BL
8	100	100	-5	-5	592	1600	1,026	313	Test A at BL
9	100	100	-5	0	580	1600	1,053	313	Test A at BL
10	100	100	-5	+5	588	1600	1,079	313	Test A at BL
13	100	100	0	-5	440	1600	0,975	313	Test A at BL
14	100	100	0	+5	560	1600	1,025	313	Test A at BL
17	100	100	+5	-5	566	1600	0,928	313	Test A at BL
18	100	100	+5	0	594	1600	0,952	313	Test A at BL
19	100	100	+5	+5	548	1600	0,976	313	Test A at BL

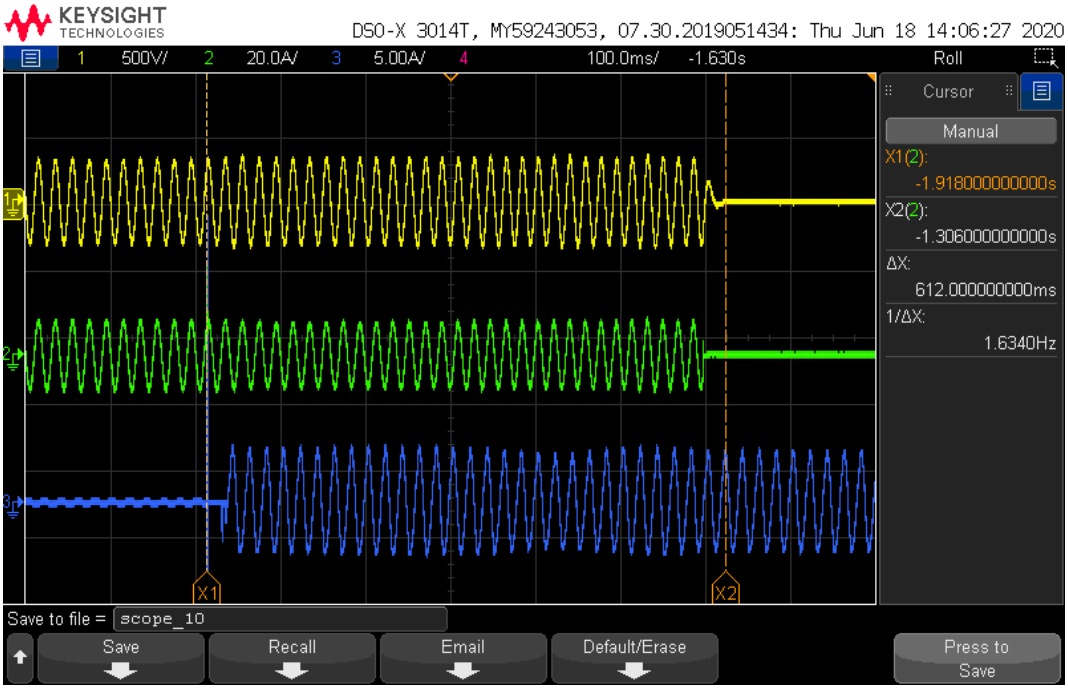
Parameter at 0% per phase	L= 95,10 mH	R= 29,88 Ω	C= 106,54 µF
IAC fundamental current(A)	82mA		

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: Voltage of EUT(500V/div). CH2: current of EUT(10A/div), CH3: Trip value(5A/div)

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**

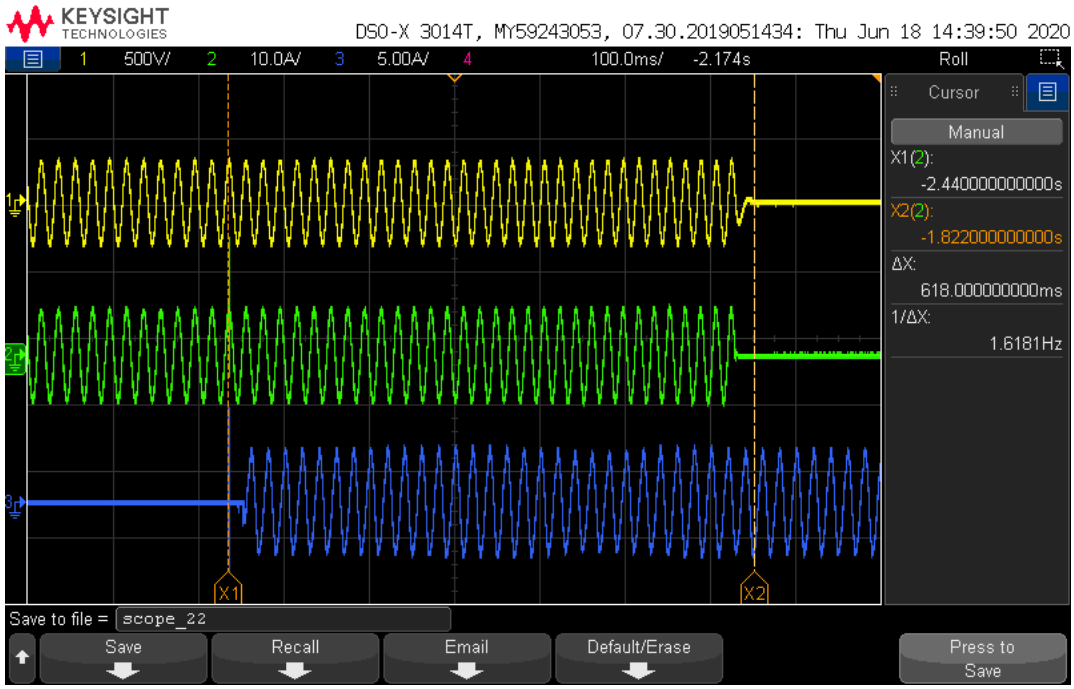
Test conditions	Frequency: 50+/-0,1Hz U_N=220+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	1s

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	522	1056	0,973	225	Test B at IB
2	66	66	0	-4	588	1056	0,978	225	Test B at IB
3	66	66	0	-3	602	1056	0,984	225	Test B at IB
4	66	66	0	-2	546	1056	0,989	225	Test B at IB
5	66	66	0	-1	552	1056	0,994	225	Test B at IB
6	66	66	0	0	618	1056	0,999	225	Test B at BL
7	66	66	0	1	590	1056	1,004	225	Test B at IB
8	66	66	0	2	580	1056	1,009	225	Test B at IB
9	66	66	0	3	564	1056	1,014	225	Test B at IB
10	66	66	0	4	558	1056	1,018	225	Test B at IB
11	66	66	0	5	556	1056	1,023	225	Test B at IB

Parameter at 0% per phase	L=136,58 mH	R= 73,99 Ω	C=73,99 µF
IAC fundamental current(A)	L1: 122mA		

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: Voltage of EUT(500V/div). CH2: current of EUT(10A/div), CH3: Trip value(5A/div)

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**

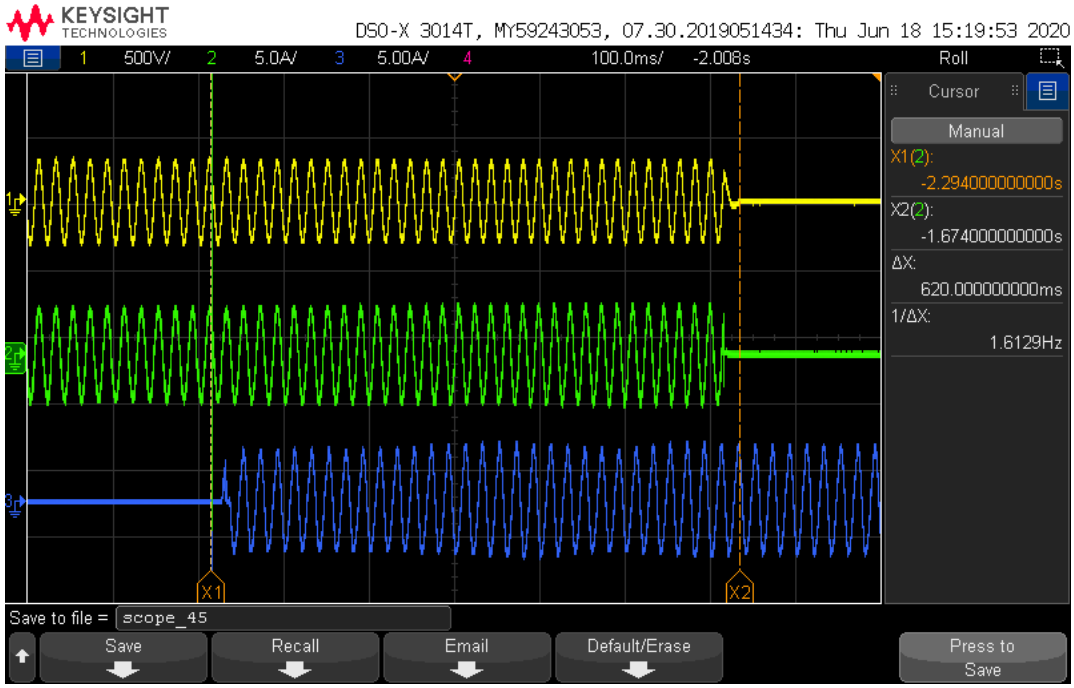
Test conditions	Frequency: 50+/-0,1Hz U_N=220+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	1s

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)	Remarks[4]
1	33	33	0	-5	550	528	0,975	120	Test C at IB
2	33	33	0	-4	602	528	0,980	120	Test C at IB
3	33	33	0	-3	514	528	0,985	120	Test C at IB
4	33	33	0	-2	562	528	0,990	120	Test C at IB
5	33	33	0	-1	532	528	0,995	120	Test C at IB
6	33	33	0	0	620	528	1,000	120	Test C at BL
7	33	33	0	1	598	528	1,005	120	Test C at IB
8	33	33	0	2	586	528	1,010	120	Test C at IB
9	33	33	0	3	606	528	1,015	120	Test C at IB
10	33	33	0	4	600	528	1,020	120	Test C at IB
11	33	33	0	5	558	528	1,025	120	Test C at IB

Parameter at 0% per phase	L= 273,64 mH	R= 85,97 Ω	C= 37,03 µF
IAC fundamental current(A)	L1: 148mA		

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: Voltage of EUT(500V/div). CH2: current of EUT(10A/div), CH3: Trip value(5A/div)

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

Test conditions:	Input: 345 Vdc Output: 220 Vac

P (setting)	P(kW)ind	P(kW)cap	Q(kVar)ind, max	Q(kVar)cap, max	PFind, max	PFcap, max
0%	0,072	0,074	0,100	0,093	0,5588	0,6102
10%	0,154	0,156	0,120	0,121	0,7706	0,7901
20%	0,319	0,337	0,081	0,170	0,9053	0,8930
30%	0,484	0,485	-0,231	0,238	0,9025	0,8975
40%	0,646	0,648	-0,301	0,316	0,9065	0,8987
50%	0,810	0,812	-0,379	0,397	0,9057	0,8985
60%	0,973	0,975	-0,471	0,476	0,9000	0,8985
70%	1,135	1,139	-0,537	0,554	0,9039	0,8987
80%	1,295	1,300	-0,639	0,632	0,8966	0,8990
90%	1,457	1,460	-0,708	0,709	0,8995	0,8994
100%	1,618	1,619	-0,775	0,786	0,9017	0,8995

Note:

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

Test conditions:	Input: 345Vdc Output: 220Vac

P (setting)	PF (setting)	P(kW)	Q(kVar)	PF
0%	0,90 lagging	0,072	0,100	0,5588
10%	0,90 lagging	0,154	0,120	0,7706
20%	0,90 lagging	0,319	0,081	0,9053
30%	0,90 lagging	0,484	-0,231	0,9025
40%	0,90 lagging	0,646	-0,301	0,9065
50%	0,90 lagging	0,0810	-0,379	0,9057
60%	0,90 lagging	0,973	-0,471	0,9000
70%	0,90 lagging	1,135	-0,537	0,9039
80%	0,90 lagging	1,295	-0,639	0,8966
90%	0,90 lagging	1,457	-0,708	0,8995
100%	0,90 lagging	1,618	-0,775	0,9017

P (setting)	PF (setting)	P(kW)	Q(kVar)	PF
0%	0,90 leading	0,074	0,093	0,6102
10%	0,90 leading	0,156	0,121	0,7901
20%	0,90 leading	0,337	0,170	0,8930
30%	0,90 leading	0,485	0,238	0,8975
40%	0,90 leading	0,648	0,316	0,8987
50%	0,90 leading	0,812	0,397	0,8985
60%	0,90 leading	0,975	0,476	0,8985
70%	0,90 leading	1,139	0,554	0,8987
80%	0,90 leading	1,300	0,632	0,8990
90%	0,90 leading	1,460	0,709	0,8994
100%	0,90 leading	1,619	0,786	0,8995

P (setting)	PF (setting)	P(kW)	Q(kVar)	PF
0%	1,00	0,073	0,060	0,7640
10%	1,00	0,155	0,054	0,9419
20%	1,00	0,319	0,037	0,9931
30%	1,00	0,485	0,031	0,9979

40%	1,00	0,648	0,027	0,9991
50%	1,00	0,813	0,026	0,9995
60%	1,00	0,975	0,027	0,9996
70%	1,00	1,140	0,028	0,9997
80%	1,00	1,301	0,029	0,9998
90%	1,00	1,464	0,031	0,9998
100%	1,00	1,624	0,033	0,9998
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.

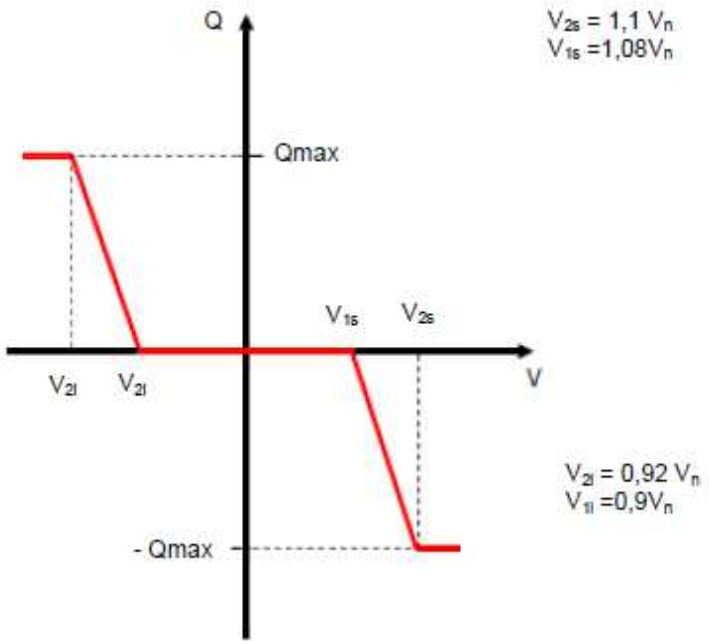
Activation must be at the Distributor's request, when the Operating Regulations are issued. The Distributor shall also specify the values of the parameters that uniquely characterise the curve, i.e.: V1i, V2i, V1s and V1s as well as the lock-in value of active power (default value P = 0,2 P_n).

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

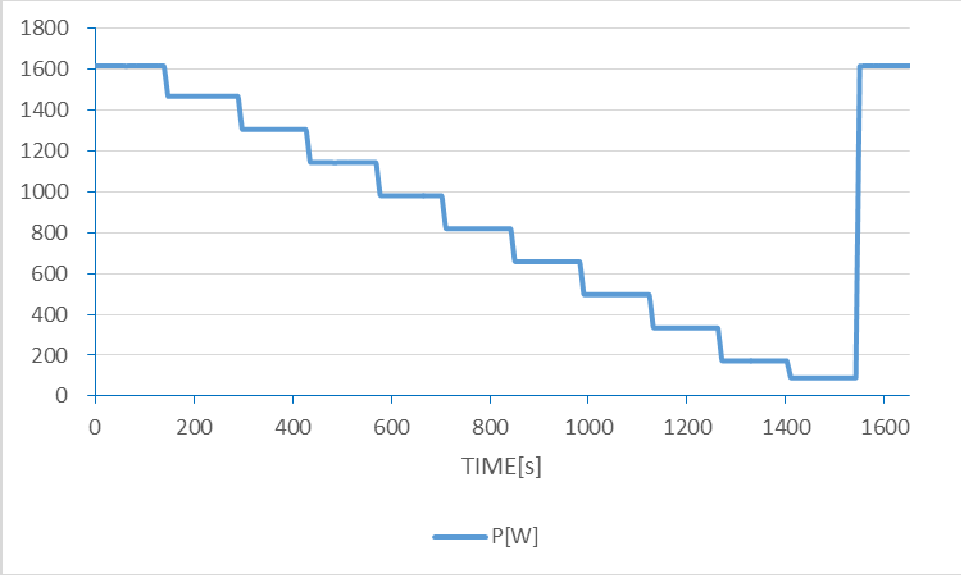
and the active power lock-in value (default value P = 0,2 P_n).



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%	1,600	1,618	
90%	1,440	1,469	7s
80%	1,280	1,306	9s
70%	1,120	1,144	9s
60%	0,960	0,982	9s
50%	0,800	0,821	8s
40%	0,640	0,659	8s
30%	0,480	0,497	9s
20%	0,320	0,334	9s
10%	0,160	0,173	8s
0%	0,000	0,089	7s

Graph of the setting accuracy



Note:

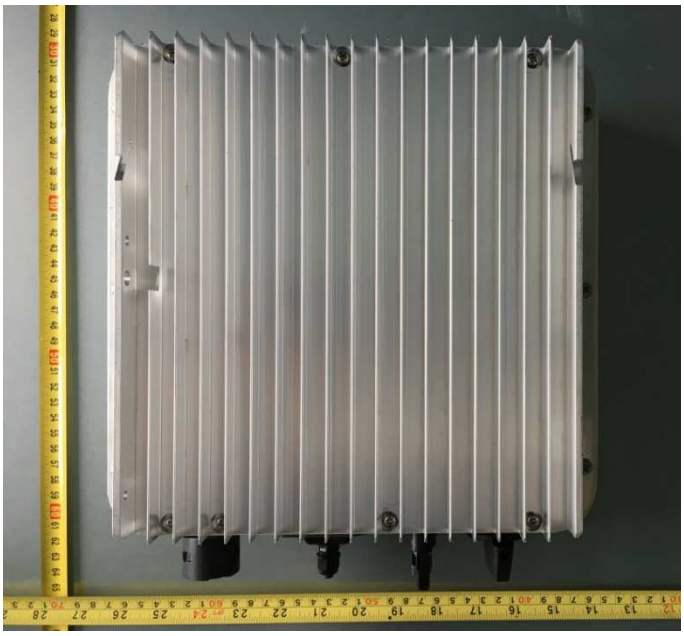
PEA:2016 additional test		**N/A**
3.6, 12.2	**Low voltage fault Ride through capability (PEA:2016) (Power generation system is greater than 500kW)**	**N/A**

Annex 1

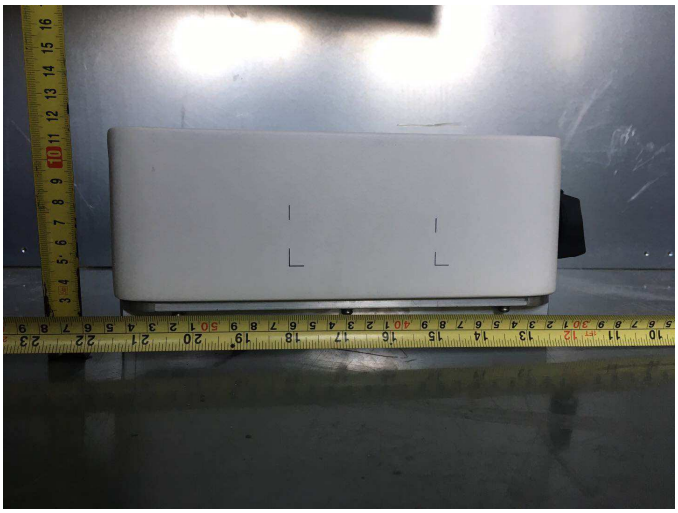
Pictures of the unit
The full pictures refer to PHOTO DOCUMENT
Project No.: 200601N032-2
Date: 20200714

Enclosure front view

Enclosure top view



Enclosure side view



Enclosure bottom view

Annex 2

Test equipment list

Date(s) of performance of test: 2020-06-01 to 2020-07-13

Equipment	Internal No.	Manufacturer	Type	Serial No.	Last Calibration
Power Analyzer	A4080002DG	YOKOGAWA	WT3000	91M210852	2019-09-12
AC Source	A7040019DG	Chroma	61512	61512000439	Monitored by Power Analyzer
AC Source	A7040020DG	Chroma	61512	61512000438	
DC Simulation Power Supply	A7040015DG	Chroma	62150H-1000S	62150EF00488	
	A7040016DG	Chroma	62150H-1000S	62150EF00490	
RLC Load	A7150027DG	Qunling	ACLT-3803H	93VOO2869	
Four Channel Digital Phosphor Oscilloscope	MY57231269	KEYSIGHT	DSOX3014T	HK200110222	2020-01-14
Four Channel Digital Phosphor Oscilloscope	A4089003DG	Tektronix	DPO4104B	C010624	2019-09-24
Oscilloscope probel	A1490008DG	YOKOGAWA	701901	//	2019-09-20
	A1490009DG	YOKOGAWA	701901	//	2019-09-20
	A1490010DG	YOKOGAWA	701901	//	2019-09-20
Current transducer	A1060008DG	YOKOGAWA	CT200	1130700017	2019-09-12
	A1060009DG	YOKOGAWA	CT200	1130700019	2019-09-12
	A1060010DG	YOKOGAWA	CT200	1130700016	2019-09-12