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 ....:	**PVTH190322N025-1**
Date of issue ....:	2019-05-14
Testing laboratory name ....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address ....:	No. 34, Chenwulu Section, Guantai Rd., Houjie Town, Dongguan City, Guangdong 523942, China
Applicant's name...........................:	**Shenzhen SOFAR SOLAR Co., Ltd.**
Address ....:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China.
Test specification	
Standard..:	IEC 61727:2004, IEC 62116:2008, Deviations for Thailand according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016)
Certificate.......................................:	**Certificate of compliance**
Test report form number ....:	IEC 61727
Master TRF ....:	Bureau Veritas Consumer Products Services Germany GmbH
Test item description ....:	**Solar Grid-tied inverter**
Trademark.......................................:	SOFAR SOLAR
Model / Type ....:	**SOFAR 60000TL**

Ratings ....:	**SOFAR 60000TL**
Input DC voltage range [V]...............:	530-800
MPP DC voltage range [V]...............:	250-950, Max. 1000
Input DC current [A] ....:	Max. 40/40/40
Output AC voltage [V] ....:	3~/N/PE, 220/380Vac, 50Hz
Output AC current [A].......................:	Max. 90
Output power [W] ....:	60000

Testing Location ....:	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address ....:	No. 34, Chenwulu Section, Guantai Rd., Houjie Town, Dongguan City, Guangdong 523942, China
Tested by (name and signature).......................:	Dora Zhang
Approved by (name and signature).......................:	James Huang
Manufacturer's name ....:	**Shenzhen SOFAR SOLAR Co., Ltd.**
Manufacturer address ....:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China.
Factory's name ....:	**Dongguan SOFAR SOLAR Co.,Ltd.**
Factory address	1F - 6F, Building E, No. 1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City

Document History

Date	Internal reference	Modification / Change / Status	Revision
2019-05-14	Dora Zhang	Initial report was written	0

Supplementary information:

Test items particulars	
Equipment mobility.......................... :	Permanent connection
Operating condition .... :	Continuous
Class of equipment .... :	Class I
Protection against ingress of water .. :	IP65 according to EN 60529
Test case verdicts	
Test case does not apply to the test object.............................. :	N/A
Test item does meet the requirement .... :	P(ass)
Test item does not meet the requirement .... :	F(ail)
Testing	
Date of receipt of test item .... :	2019-03-22
Date(s) of performance of test .... :	2019-03-22 to 2019-05-11

General remarks:

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

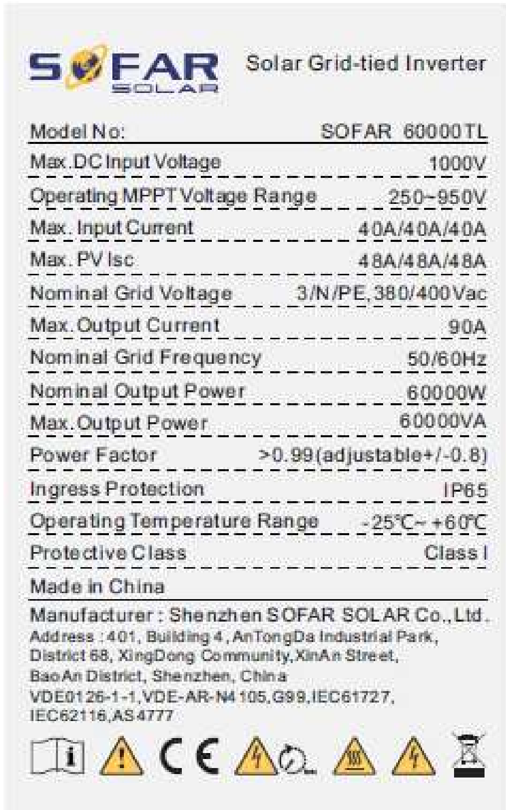
"(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

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

This Test Report consists of the following documents:

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

Copy of marking plate:



SOFAR SOLAR Solar Grid-tied Inverter

Model No:	SOFAR 60000TL
Max.DC Input Voltage	1000V
Operating MPPT Voltage Range	250~950V
Max. Input Current	40A/40A/40A
Max. PV Isc	48A/48A/48A
Nominal Grid Voltage	3/N/PE, 380/400Vac
Max. Output Current	90A
Nominal Grid Frequency	50/60Hz
Nominal Output Power	60000W
Max. Output Power	60000VA
Power Factor	>0.99(adjustable+/-0.8)
Ingress Protection	IP65
Operating Temperature Range	-25℃~ +60℃
Protective Class	Class I
Made in China	

Manufacturer : Shenzhen SOFAR SOLAR Co., Ltd.
Address : 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China
VDE0126-1-1, VDE-AR-N4105, G99, IEC61727, IEC62116, AS4777

General product information:

The Solar Grid-tied inverter converts DC voltage into AC voltage.

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 two relays for each phases in series. This assures that the opening of the output circuit will also operate in case of one error. Block diagram as following:

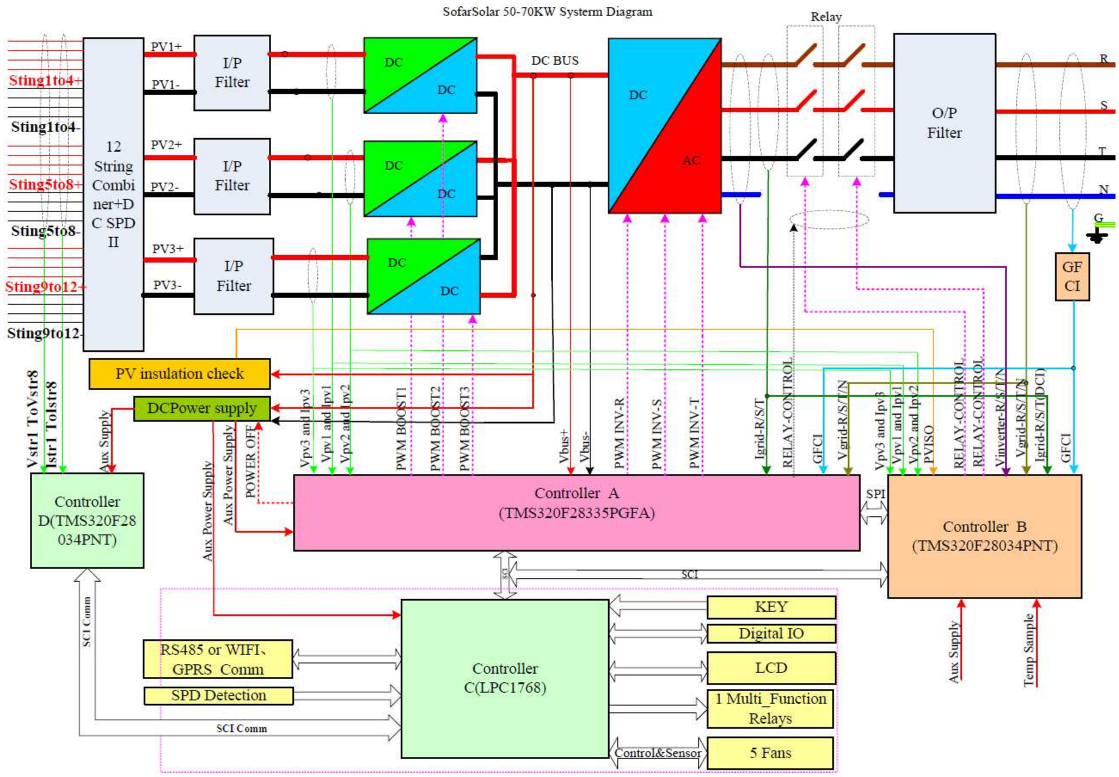


Figure 1 Block diagram

The internal control is redundant built. It consists of master DSP (UC20) and slave DSP (UC73).

The master DSP (UC20) can control the relays, measures voltage, and frequency, AC current with injected DC, array insulation resistance and residual current and the RCMU circuit before each start up.

The slave DSP (UC73) is using for sample the grid voltage, frequency, DC voltage, current and residual current, also can open the relays independently and communicate with master DSP (UC20) each other.

The grid voltage is measured before the relays. The voltage between polarity is calculated. The voltage signals are sent to both DSP. In addition this signal is used for the frequency measurement.

The unit provides two relays in series in each phase. The relays are tested before each start up. Each DSP switch off each relays.

The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the main DSP (UC20). The main DSP (UC20) tests and calibrates before each start up all current sensors.

The RCMU is located at the AC output. The RCMU is tested before each start up by the main DSP (UC20). While unit working, if a high level residual current occurs, the RCMU will give signal to DSP assuring that unit grid-off from AC mains.

The product was tested on:

Hardware version: V1.00
Software version: V1.40

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)	**P**
3.5, 12.1	Active power control	**P**
3.6, 12.2	Low voltage fault ride through capability	**P**

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				

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.11 Pass	0.28 Pass	0 Pass	0.17 Pass	
2	0.11 Pass	0.41 Pass	0 Pass	0.17 Pass	
3	0.11 Pass	0.30 Pass	0 Pass	0.17 Pass	
4	0.12 Pass	0.29 Pass	0 Pass	0.17 Pass	
5	0.12 Pass	0.90 Pass	0 Pass	0.23 Pass	
6	0.11 Pass	0.89 Pass	0 Pass	0.23 Pass	
7	0.19 Pass	0.85 Pass	0 Pass	0.23 Pass	
8	0.14 Pass	0.25 Pass	0 Pass	0.17 Pass	
9	0.13 Pass	0.95 Pass	0 Pass	0.23 Pass	
10	0.13 Pass	0.28 Pass	0 Pass	0.16 Pass	
11	0.11 Pass	0.28 Pass	0 Pass	0.16 Pass	
12	0.12 Pass	0.31 Pass	0 Pass	0.16 Pass	
Result	Pass	Pass	Pass	Pass	0.19 Pass

Test value(L1 phase)

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.12 Pass	0.42 Pass	0 Pass	0.15 Pass	
2	0.14 Pass	0.53 Pass	0 Pass	0.16 Pass	
3	0.16 Pass	0.37 Pass	0 Pass	0.16 Pass	
4	0.17 Pass	0.34 Pass	0 Pass	0.17 Pass	
5	0.15 Pass	0.93 Pass	0 Pass	0.22 Pass	
6	0.15 Pass	0.97 Pass	0 Pass	0.22 Pass	
7	0.16 Pass	0.90 Pass	0 Pass	0.23 Pass	
8	0.16 Pass	0.35 Pass	0 Pass	0.17 Pass	
9	0.18 Pass	0.91 Pass	0 Pass	0.22 Pass	
10	0.19 Pass	0.30 Pass	0 Pass	0.16 Pass	
11	0.16 Pass	0.26 Pass	0 Pass	0.16 Pass	
12	0.14 Pass	0.25 Pass	0 Pass	0.16 Pass	
Result	Pass	Pass	Pass	Pass	0.19 Pass

Test value(L2 phase)

	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	0.40 Pass	0 Pass	0.17 Pass	
2	0.00 Pass	0.50 Pass	0 Pass	0.18 Pass	
3	0.00 Pass	0.50 Pass	0 Pass	0.18 Pass	
4	0.00 Pass	0.50 Pass	0 Pass	0.19 Pass	
5	0.00 Pass	1.07 Pass	0 Pass	0.23 Pass	
6	0.00 Pass	1.07 Pass	0 Pass	0.23 Pass	
7	0.00 Pass	1.07 Pass	0 Pass	0.24 Pass	
8	0.00 Pass	1.07 Pass	0 Pass	0.19 Pass	
9	0.00 Pass	1.07 Pass	0 Pass	0.23 Pass	
10	0.00 Pass	1.07 Pass	0 Pass	0.18 Pass	
11	0.00 Pass	1.07 Pass	0 Pass	0.18 Pass	
12	0.00 Pass	1.07 Pass	0 Pass	0.18 Pass	
Result	Pass	Pass	Pass	Pass	0.20 Pass

Test value(L3 phase)

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

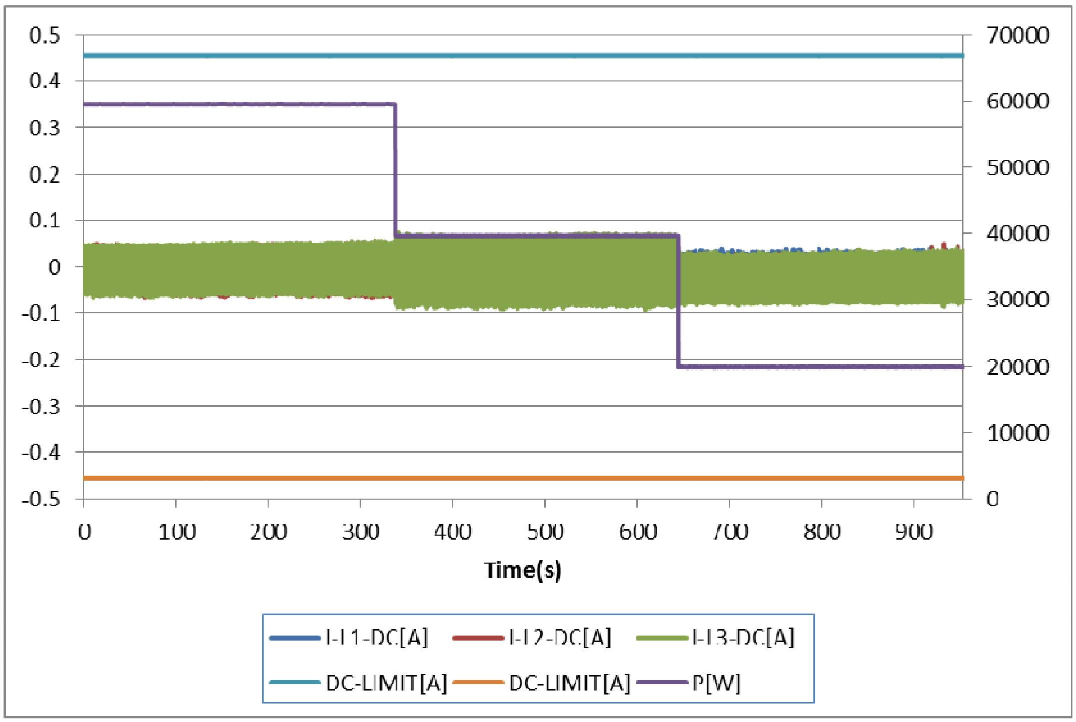
Mains Impedance according EN61000-3-11: **R_{max} = 0,24Ω; jX_{max}= 0,15Ω @50Hz (|Z_{max}| = 0,283 Ω)**
for single phase inverter use also **R_n = 0,16Ω; jX_n= 0,1Ω**

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

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

4.4 Monitoring of Permanent DC-Injection 3.3, 8.5 Direct Current Dispatch to the Power Network System (PEA:2016)			P
PEA Limit:	**0,5% of I_{nom} : 454mA**		
Output power:	33%	66%	100%
Max. test value (mA): L1 phase	76	59	39
Mean test value(mA) : L1 phase	7	14	25
Max. test value (mA): L2 phase	49	57	66
Mean test value (mA): L2 phase	14	12	9
Max. test value (mA): L3 phase	86	91	64
Mean test value (mA): L3 phase	37	31	20

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)	6,615/6,634/6,592
VA (kVA)	6,618/6,6352/6,592
Vrms (V)	220,2/220,0/220,1
Arms (A)	30,052/30,158/29,951
PF	0,999/0,999/0,999
Frequency (Hz)	50,00
THD50 (%)	0,418/0,270/0,356

Harmonics	**Current Magnitude [A]**			**% of Rated Current**			**Phase**	**Harmonic Current Limits [%]**
1st	30,049	30,157	29,949	33,054	33,172	32,944	Three Phase	--
2nd	0,151	0,058	0,107	0,166	0,064	0,118	Three Phase	1
3rd	0,213	0,061	0,156	0,235	0,067	0,172	Three Phase	4
4th	0,107	0,029	0,083	0,118	0,032	0,091	Three Phase	1
5th	0,108	0,157	0,162	0,119	0,173	0,178	Three Phase	4
6th	0,099	0,025	0,079	0,109	0,027	0,087	Three Phase	1
7th	0,104	0,129	0,067	0,115	0,141	0,074	Three Phase	4
8th	0,073	0,021	0,059	0,080	0,023	0,065	Three Phase	1
9th	0,101	0,040	0,068	0,111	0,044	0,075	Three Phase	4
10th	0,059	0,022	0,046	0,065	0,024	0,050	Three Phase	1
11th	0,057	0,042	0,089	0,062	0,047	0,098	Three Phase	2
12th	0,039	0,015	0,030	0,043	0,016	0,032	Three Phase	0,5
13th	0,053	0,054	0,049	0,058	0,060	0,054	Three Phase	2
14th	0,027	0,014	0,018	0,029	0,016	0,019	Three Phase	0,5
15th	0,017	0,009	0,013	0,019	0,009	0,014	Three Phase	2
16th	0,017	0,009	0,012	0,019	0,010	0,013	Three Phase	0,5
17th	0,018	0,014	0,017	0,019	0,015	0,019	Three Phase	1,5
18th	0,014	0,009	0,008	0,015	0,010	0,009	Three Phase	0,375
19th	0,018	0,015	0,013	0,020	0,016	0,014	Three Phase	1,5
20th	0,013	0,007	0,010	0,015	0,008	0,011	Three Phase	0,375
21th	0,011	0,007	0,012	0,012	0,008	0,013	Three Phase	1,5
22th	0,014	0,007	0,010	0,015	0,008	0,011	Three Phase	0,375
23th	0,016	0,011	0,011	0,018	0,013	0,012	Three Phase	0,6
24th	0,013	0,009	0,008	0,015	0,010	0,009	Three Phase	0,15
25th	0,014	0,008	0,011	0,015	0,008	0,013	Three Phase	0,6
26th	0,012	0,007	0,009	0,014	0,008	0,009	Three Phase	0,15
27th	0,012	0,010	0,014	0,013	0,011	0,015	Three Phase	0,6
28th	0,015	0,009	0,010	0,017	0,010	0,011	Three Phase	0,15
29th	0,010	0,012	0,015	0,011	0,013	0,016	Three Phase	0,6
30th	0,013	0,006	0,012	0,015	0,007	0,013	Three Phase	0,15
31th	0,012	0,011	0,008	0,014	0,012	0,009	Three Phase	0,6
32th	0,013	0,007	0,010	0,014	0,007	0,011	Three Phase	0,15
33th	0,012	0,009	0,008	0,013	0,010	0,009	Three Phase	0,6
34th	0,010	0,009	0,007	0,011	0,010	0,008	Three Phase	0,15

35th	0,010	0,011	0,013	0,011	0,012	0,014	Three Phase	0,3
36th	0,009	0,006	0,007	0,010	0,006	0,007	Three Phase	0,075
37th	0,011	0,008	0,008	0,012	0,009	0,008	Three Phase	0,3
38th	0,010	0,006	0,007	0,011	0,007	0,008	Three Phase	0,075
39th	0,008	0,007	0,007	0,009	0,007	0,008	Three Phase	0,3
40th	0,009	0,006	0,007	0,010	0,007	0,008	Three Phase	0,075

66% Output Power	
Watts (kW)	13,263/13,242/13,171
VA (kVA)	13,269/13,243/13,171
Vrms (V)	220,3/220,0/220,2
Arms (A)	60,223/60,198/59,817
PF	0,999/0,999/0,999
Frequency (Hz)	50,00
THD50 (%)	0,626/0,327/0,466

Harmonics	**Current Magnitude [A]**			**% of Rated Current**			**Phase**	**Harmonic Current Limits [%]**
1st	60,220	60,197	59,815	66,242	66,217	65,796	Three Phase	--
2nd	0,266	0,139	0,151	0,293	0,153	0,166	Three Phase	1
3rd	0,312	0,104	0,232	0,343	0,114	0,255	Three Phase	4
4th	0,163	0,050	0,121	0,179	0,055	0,133	Three Phase	1
5th	0,152	0,156	0,163	0,168	0,171	0,180	Three Phase	4
6th	0,150	0,046	0,110	0,165	0,050	0,122	Three Phase	1
7th	0,145	0,123	0,080	0,159	0,135	0,088	Three Phase	4
8th	0,109	0,028	0,090	0,120	0,030	0,099	Three Phase	1
9th	0,126	0,050	0,094	0,139	0,055	0,103	Three Phase	4
10th	0,088	0,024	0,069	0,097	0,026	0,076	Three Phase	1
11th	0,075	0,017	0,083	0,082	0,019	0,092	Three Phase	2
12th	0,064	0,023	0,047	0,071	0,025	0,052	Three Phase	0,5
13th	0,060	0,048	0,041	0,066	0,052	0,045	Three Phase	2
14th	0,045	0,020	0,029	0,050	0,022	0,032	Three Phase	0,5
15th	0,019	0,010	0,022	0,021	0,011	0,024	Three Phase	2
16th	0,030	0,014	0,021	0,033	0,015	0,024	Three Phase	0,5
17th	0,014	0,014	0,021	0,015	0,016	0,024	Three Phase	1,5
18th	0,017	0,012	0,011	0,019	0,013	0,012	Three Phase	0,375
19th	0,013	0,011	0,012	0,015	0,012	0,013	Three Phase	1,5
20th	0,016	0,012	0,010	0,018	0,013	0,011	Three Phase	0,375
21th	0,013	0,012	0,013	0,014	0,013	0,014	Three Phase	1,5
22th	0,015	0,006	0,015	0,017	0,007	0,016	Three Phase	0,375
23th	0,021	0,013	0,027	0,024	0,014	0,030	Three Phase	0,6
24th	0,016	0,009	0,009	0,017	0,010	0,010	Three Phase	0,15
25th	0,019	0,025	0,017	0,021	0,027	0,018	Three Phase	0,6
26th	0,012	0,009	0,008	0,013	0,009	0,009	Three Phase	0,15
27th	0,019	0,014	0,018	0,021	0,015	0,019	Three Phase	0,6
28th	0,013	0,008	0,010	0,014	0,008	0,011	Three Phase	0,15
29th	0,030	0,017	0,039	0,033	0,018	0,043	Three Phase	0,6
30th	0,012	0,008	0,010	0,014	0,009	0,011	Three Phase	0,15

31th	0,030	0,030	0,022	0,033	0,033	0,024	Three Phase	0,6
32th	0,010	0,006	0,008	0,011	0,006	0,009	Three Phase	0,15
33th	0,018	0,015	0,008	0,020	0,016	0,009	Three Phase	0,6
34th	0,009	0,008	0,007	0,010	0,009	0,007	Three Phase	0,15
35th	0,031	0,019	0,035	0,034	0,021	0,039	Three Phase	0,3
36th	0,009	0,006	0,007	0,010	0,007	0,008	Three Phase	0,075
37th	0,030	0,026	0,019	0,033	0,028	0,021	Three Phase	0,3
38th	0,007	0,005	0,006	0,008	0,006	0,007	Three Phase	0,075
39th	0,013	0,012	0,006	0,014	0,013	0,007	Three Phase	0,3
40th	0,008	0,006	0,005	0,008	0,007	0,006	Three Phase	0,075

100% Output Power								
Watts (kW)				19,936/19,847/19,730				
VA (kVA)				19,947/19,849/19,732				
Vrms (V)				220,3/219,9/220,1				
Arms (A)				90,526/90,276/89,649				
PF				0,999/0,999/0,999				
Frequency (Hz)				50,00				
THD50 (%)				0,719/0,439/0,523				
Harmonics	**Current Magnitude [A]**			**% of Rated Current**			**Phase**	**Harmonic Current Limits [%]**
1st	90,524	90,275	89,648	99,576	99,303	98,612	Three Phase	--
2nd	0,316	0,218	0,138	0,348	0,240	0,152	Three Phase	1
3rd	0,398	0,160	0,281	0,438	0,176	0,309	Three Phase	4
4th	0,174	0,057	0,130	0,191	0,062	0,143	Three Phase	1
5th	0,164	0,204	0,197	0,181	0,225	0,216	Three Phase	4
6th	0,127	0,047	0,096	0,140	0,052	0,105	Three Phase	1
7th	0,151	0,124	0,104	0,166	0,137	0,115	Three Phase	4
8th	0,126	0,036	0,095	0,138	0,040	0,104	Three Phase	1
9th	0,137	0,070	0,100	0,150	0,077	0,110	Three Phase	4
10th	0,090	0,026	0,071	0,099	0,029	0,078	Three Phase	1
11th	0,071	0,018	0,077	0,078	0,019	0,085	Three Phase	2
12th	0,068	0,025	0,049	0,075	0,027	0,054	Three Phase	0,5
13th	0,057	0,053	0,032	0,062	0,059	0,035	Three Phase	2
14th	0,044	0,021	0,033	0,048	0,023	0,036	Three Phase	0,5
15th	0,019	0,016	0,031	0,021	0,018	0,034	Three Phase	2
16th	0,032	0,014	0,022	0,035	0,015	0,024	Three Phase	0,5
17th	0,015	0,019	0,025	0,016	0,021	0,028	Three Phase	1,5
18th	0,019	0,014	0,011	0,021	0,016	0,012	Three Phase	0,375
19th	0,020	0,011	0,018	0,022	0,012	0,020	Three Phase	1,5
20th	0,016	0,011	0,009	0,018	0,012	0,010	Three Phase	0,375
21th	0,013	0,016	0,018	0,015	0,018	0,020	Three Phase	1,5
22th	0,015	0,008	0,014	0,016	0,008	0,015	Three Phase	0,375
23th	0,023	0,025	0,038	0,025	0,028	0,042	Three Phase	0,6
24th	0,014	0,009	0,009	0,015	0,010	0,010	Three Phase	0,15
25th	0,025	0,026	0,024	0,027	0,028	0,026	Three Phase	0,6
26th	0,010	0,007	0,010	0,011	0,008	0,011	Three Phase	0,15

27th	0,015	0,015	0,018	0,016	0,017	0,020	Three Phase	0,6
28th	0,013	0,008	0,009	0,014	0,009	0,010	Three Phase	0,15
29th	0,030	0,029	0,047	0,033	0,032	0,052	Three Phase	0,6
30th	0,011	0,007	0,010	0,012	0,008	0,011	Three Phase	0,15
31th	0,039	0,037	0,035	0,043	0,041	0,038	Three Phase	0,6
32th	0,009	0,006	0,006	0,010	0,007	0,007	Three Phase	0,15
33th	0,013	0,016	0,011	0,014	0,018	0,012	Three Phase	0,6
34th	0,009	0,009	0,006	0,010	0,009	0,007	Three Phase	0,15
35th	0,037	0,035	0,048	0,041	0,039	0,053	Three Phase	0,3
36th	0,008	0,006	0,007	0,009	0,007	0,008	Three Phase	0,075
37th	0,037	0,032	0,030	0,041	0,036	0,033	Three Phase	0,3
38th	0,007	0,005	0,006	0,008	0,006	0,007	Three Phase	0,075
39th	0,009	0,012	0,008	0,010	0,014	0,009	Three Phase	0,3
40th	0,008	0,007	0,005	0,009	0,008	0,005	Three 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)				220,3/219,9/220,1				
Frequency (Hz)				50,00				
THD50 (%)				0,510/0,426/0,518				
Harmonics	**Voltage Magnitude [V]**			**% of Rated Voltage**			**Phase**	**Limits [%]**
2nd	0,079	0,109	0,271	0,036	0,050	0,123	Three Phase	0,2
3rd	1,006	0,826	1,066	0,457	0,375	0,485	Three Phase	4
4th	0,144	0,057	0,117	0,066	0,026	0,053	Three Phase	0,2
5th	0,351	0,342	0,127	0,159	0,155	0,058	Three Phase	4
6th	0,101	0,033	0,054	0,046	0,015	0,025	Three Phase	0,2
7th	0,113	0,141	0,097	0,052	0,064	0,044	Three Phase	4
8th	0,122	0,042	0,058	0,055	0,019	0,026	Three Phase	0,2
9th	0,042	0,140	0,136	0,019	0,063	0,062	Three Phase	2
10th	0,101	0,032	0,050	0,046	0,014	0,023	Three Phase	0,2
11th	0,100	0,045	0,065	0,045	0,021	0,029	Three Phase	0,1
12th	0,094	0,035	0,043	0,043	0,016	0,020	Three Phase	0,1
13th	0,136	0,080	0,062	0,062	0,036	0,028	Three Phase	0,1
14th	0,040	0,028	0,041	0,018	0,013	0,019	Three Phase	0,1
15th	0,053	0,021	0,021	0,024	0,009	0,009	Three Phase	0,1
16th	0,021	0,021	0,019	0,010	0,010	0,009	Three Phase	0,1
17th	0,037	0,028	0,019	0,017	0,013	0,008	Three Phase	0,1
18th	0,015	0,021	0,015	0,007	0,010	0,007	Three Phase	0,1
19th	0,028	0,018	0,029	0,013	0,008	0,013	Three Phase	0,1
20th	0,015	0,018	0,015	0,007	0,008	0,007	Three Phase	0,1
21th	0,026	0,023	0,016	0,012	0,010	0,007	Three Phase	0,1
22th	0,021	0,012	0,018	0,010	0,005	0,008	Three Phase	0,1
23th	0,019	0,043	0,053	0,009	0,019	0,024	Three Phase	0,1
24th	0,017	0,012	0,013	0,008	0,005	0,006	Three Phase	0,1
25th	0,017	0,022	0,027	0,008	0,010	0,012	Three Phase	0,1
26th	0,013	0,010	0,012	0,006	0,005	0,005	Three Phase	0,1
27th	0,027	0,014	0,015	0,012	0,006	0,007	Three Phase	0,1
28th	0,012	0,011	0,012	0,005	0,005	0,005	Three Phase	0,1
29th	0,016	0,017	0,030	0,007	0,008	0,014	Three Phase	0,1
30th	0,010	0,011	0,012	0,005	0,005	0,006	Three Phase	0,1
31th	0,018	0,022	0,022	0,008	0,010	0,010	Three Phase	0,1
32th	0,010	0,010	0,011	0,004	0,004	0,005	Three Phase	0,1
33th	0,014	0,010	0,012	0,007	0,005	0,006	Three Phase	0,1
34th	0,011	0,010	0,011	0,005	0,005	0,005	Three Phase	0,1
35th	0,017	0,018	0,030	0,008	0,008	0,013	Three Phase	0,1
36th	0,011	0,010	0,011	0,005	0,004	0,005	Three Phase	0,1
37th	0,018	0,024	0,037	0,008	0,011	0,017	Three Phase	0,1
38th	0,010	0,010	0,011	0,005	0,005	0,005	Three Phase	0,1
39th	0,013	0,016	0,027	0,006	0,007	0,012	Three Phase	0,1
40th	0,010	0,010	0,011	0,004	0,005	0,005	Three Phase	0,1

Note: The harmonics are tested and evaluated according the IEEE1547.1-2005 clause 5.11.1 according the grid-connected inverter regulations of the Provincial Electricity Authority (PEA:2016).

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

Note:

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

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

Test result refer to table 3.4.1, 8.1.2 1.

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

First Level (Phase to Neutral)

Test conditions:	Output power: 60KW 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
		198,1	197,8	197,7	198,0		241,9	241,9	242,0	242,0
		198,1	197,8	197,7	198,0		241,9	241,9	242,0	242,0
Parameter		Time [s]					Time [s]			
Limit		**t ≤ 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
		1,635	1,625	1,613	1,633		0,612	0,616	0,595	0,609
		1,620	1,630	1,640	1,625		0,618	0,620	0,615	0,612
Reconnection time	20s - 5min	27 s				20s - 5min	26 s			

Second Level (Phase to Neutral)										
Test conditions:	Output power: 60KW 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
		109,9	109,8	109,5	110,0		264,5	264,2	264,1	264,6
		109,9	109,8	109,5	110,0		264,5	264,2	264,1	264,6
Parameter		Time [ms]					Time [ms]			
Limit		**t ≤ 300ms** **171ms ≤ t ≤ 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
		225	222	233	216		79	74	92	91
		229	218	230	215		84	75	93	93
Reconnection time	20s - 5min	27 s				20s - 5min	67 s			

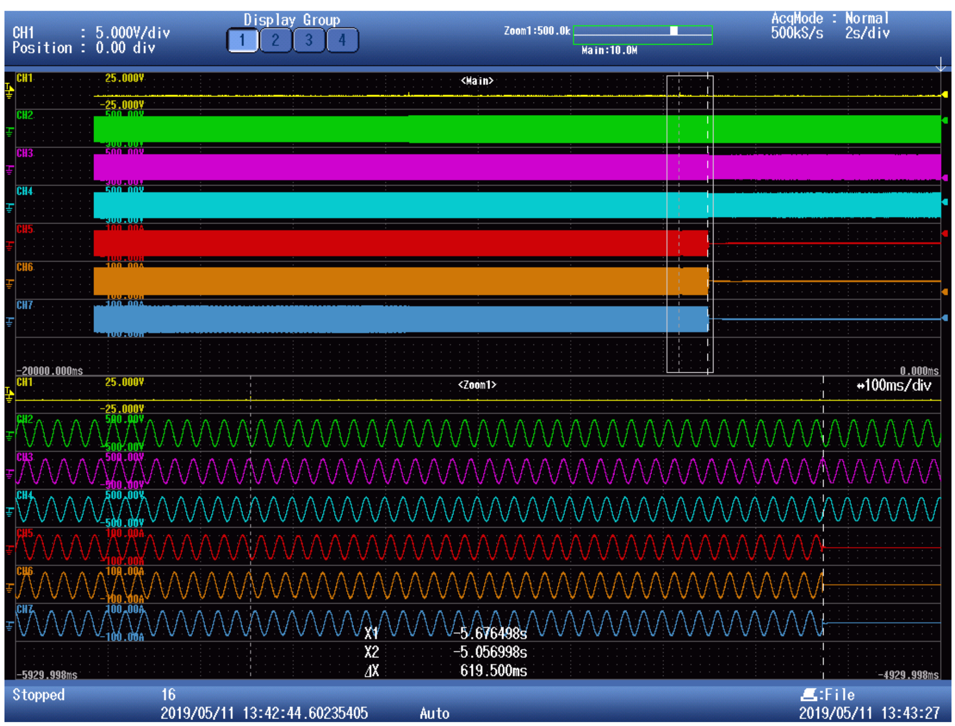
Note:

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.

*** For power generation system is greater than 500kW.**

Under Voltage First Level single phase

Over voltage First Level single phase

Note: CH1: trip signa, CH2, CH3, CH4: L1,L2,L3 grid voltage(100V/div); CH5,CH6,CH7: L1,L2L3 current of EUT(20A/div)

Under Voltage First Level all phases

Over voltage First Level all phases

Note: CH1: trip signa, CH2, CH3, CH4: L1,L2,L3 grid voltage(100V/div); CH5,CH6,CH7: L1,L2L3 current of EUT(20A/div)

Under Voltage Second Level single phase

Over voltage Second Level single phase

Note: CH1: trip signa, CH2, CH3, CH4: L1,L2,L3 grid voltage(100V/div); CH5,CH6,CH7: L1,L2L3 current of EUT(20A/div)

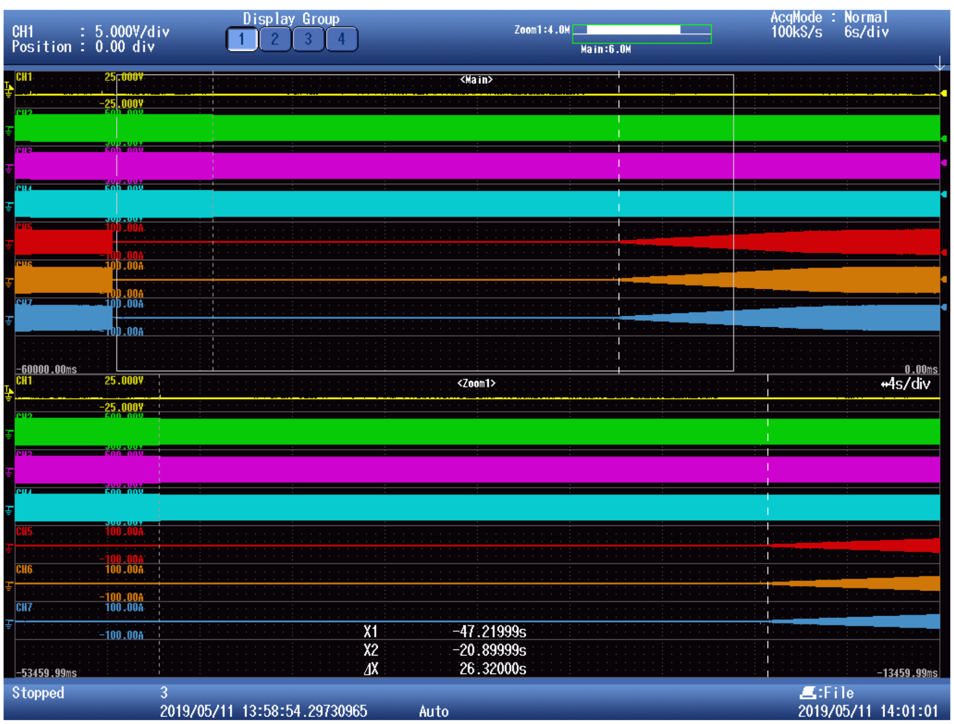
Under Voltage Second Level all phase

Over voltage Second Level all phase

Note: CH1: trip signa, CH2, CH3, CH4: L1,L2,L3 grid voltage(100V/div); CH5,CH6,CH7: L1,L2L3 current of EUT(20A/div)

Reconnection after Under Voltage First Level

Reconnection after Over Voltage First Level



Note: CH1: trip signa, CH2, CH3, CH4: L1,L2,L3 grid voltage(100V/div); CH5,CH6,CH7: L1,L2L3 current of EUT(10A/div)

Reconnection after Under Voltage Second Level

Reconnection after Over Voltage Second Level

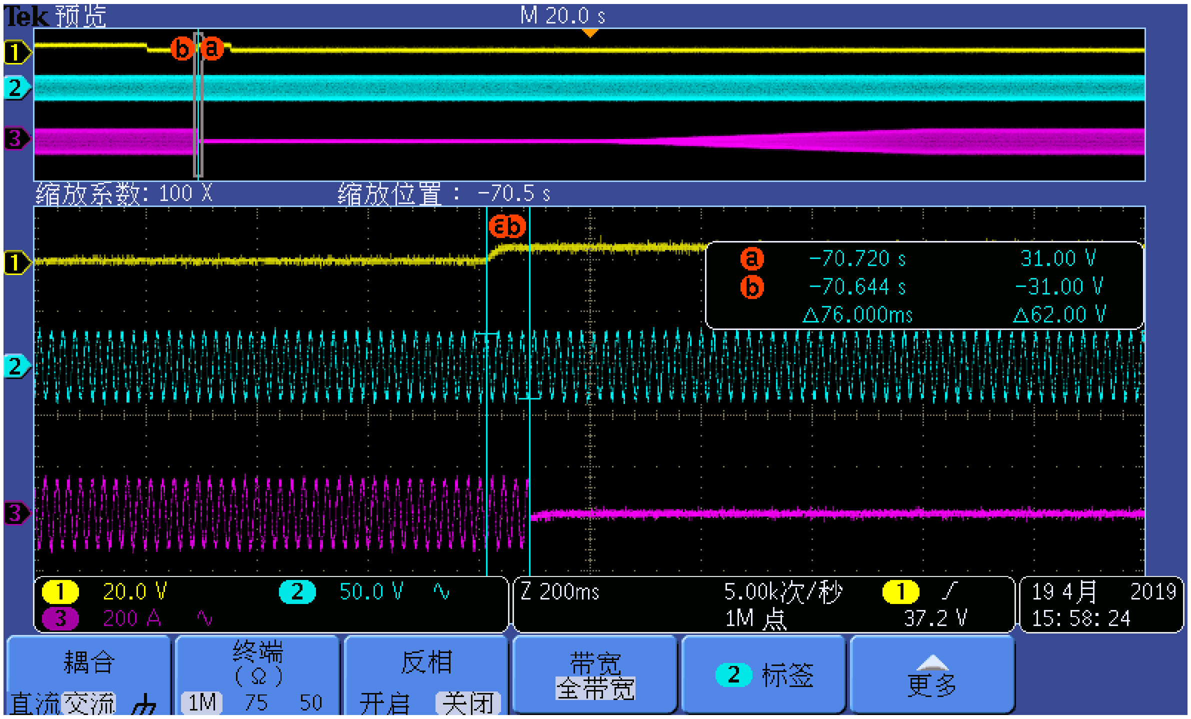
Note: CH1: trip signa, CH2, CH3, CH4: L1,L2,L3 grid voltage(100V/div); CH5,CH6,CH7: L1,L2L3 current of EUT(10A/div)

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		52,01
		Time [ms]		Time [ms]
Limit		**<= 100ms**		**<= 100ms**
Disconnection time(ms)	50,0Hz to 47,2 Hz (0,2s min) to 46,5 Hz	76	50,0 Hz to 51,80 Hz (0,2s min) to 52,5Hz	84
Reconnection time (Sec)	20s – 5min	70	20s-5min	71

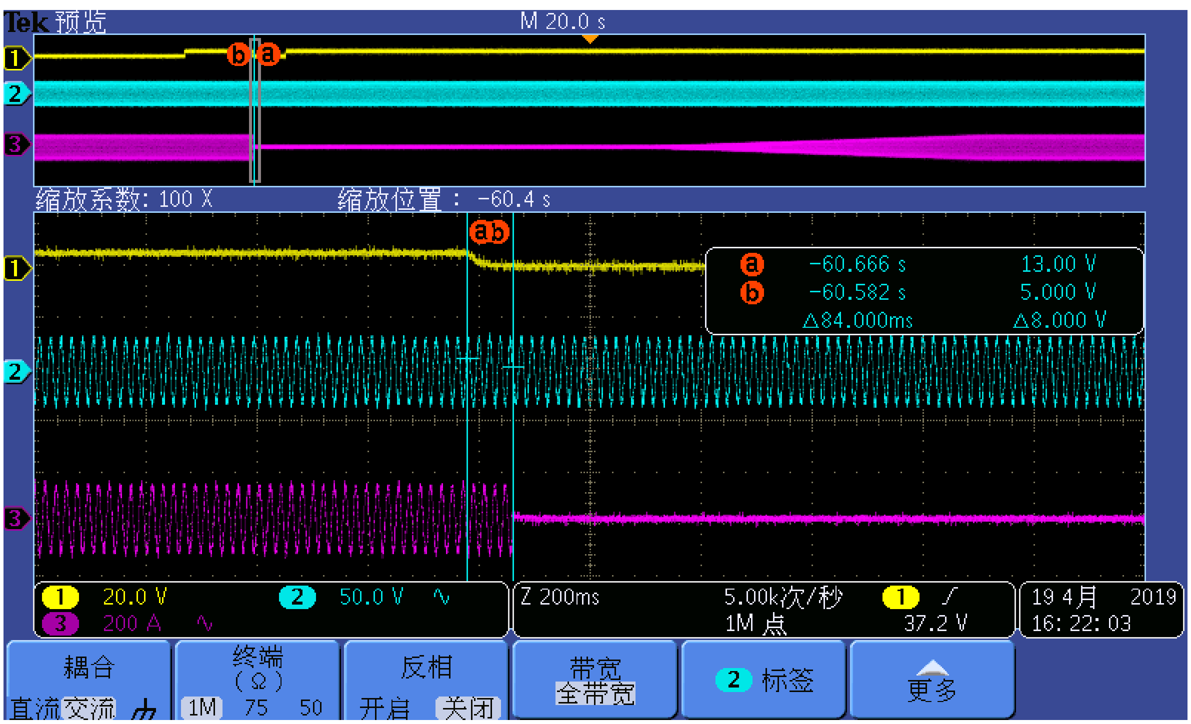
Note:
The frequency which inverter stops feeding power to electrical system in each test must be in the range of the frequency trip setting +/- 0,1Hz and the time it takes to cut off the power must be within 0.1 second.

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:

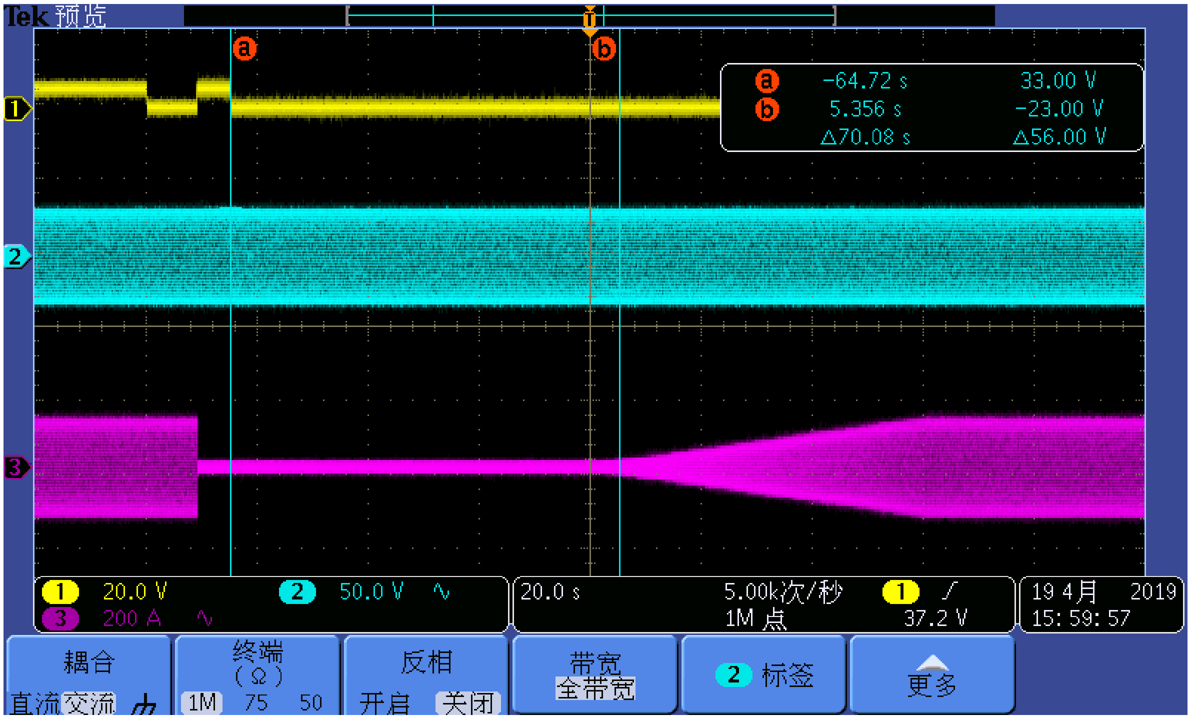


Over Frequency:

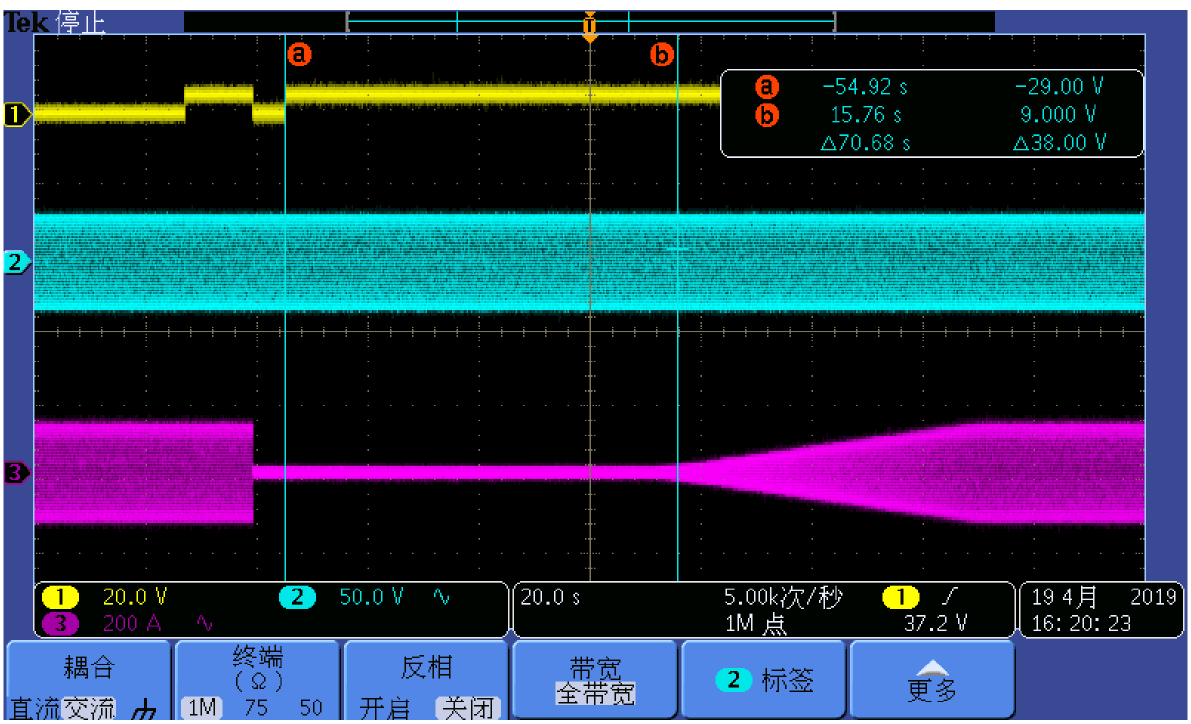


Note:
CH1: trip signal; CH2: grid voltage(500V/div); CH3: current of EUT(200A/div)

Reconnection after Under Frequency:



Reconnection after Over Frequency:



Note:
CH1: trip signal; CH2:grid voltage(500V/div); CH3: current of EUT(200A/div)

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

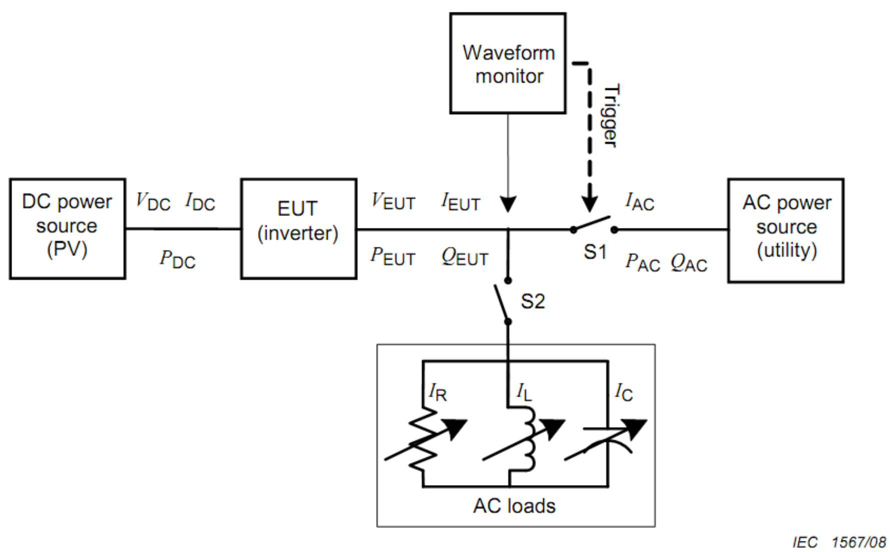


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

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=230+/-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} (KW per phase)	Actual Q_f	V_{DC} (V)	Remarks4)
1	100	100	0	0	151,4	20,180	1,001	663	Test A at BL
8	100	100	-5	-5	129,4	20,180	1,027	663	Test A at IB
9	100	100	-5	0	143,4	20,180	1,054	663	Test A at IB
10	100	100	-5	+5	137,4	20,180	1,080	663	Test A at IB
13	100	100	0	-5	109,4	20,180	0,976	663	Test A at IB
14	100	100	0	+5	133,4	20,180	1,026	663	Test A at IB
17	100	100	+5	-5	131,4	20,180	0,929	663	Test A at IB
18	100	100	+5	0	129,4	20,180	0,954	663	Test A at IB
19	100	100	+5	+5	137,4	20,180	0,977	663	Test A at IB

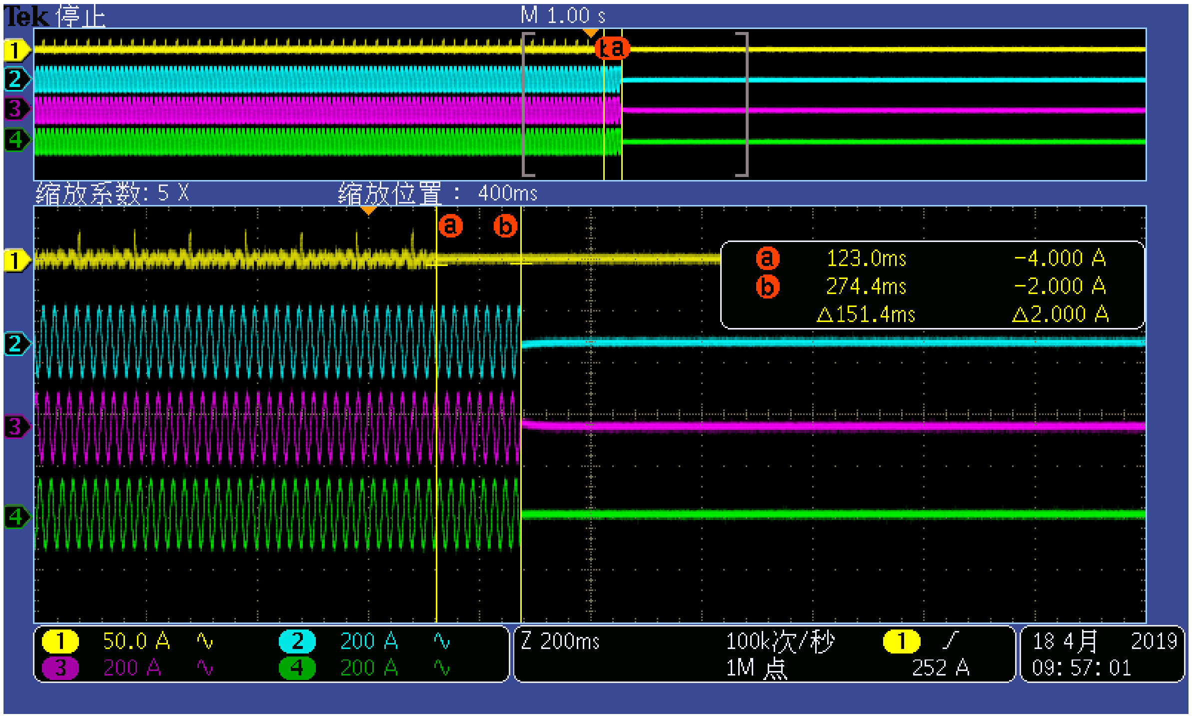
Parameter at 0% per phase	L= 8,34 mH	R= 2,62 Ω	C= 1215,49 µF
IAC fundamental current(A)	L1: 290mA	L2: 239mA	L3: 372mA

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:

CH2, CH3, CH4: L1, L2, L3 current of EUT(200A/div)., CH1: trip signal

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

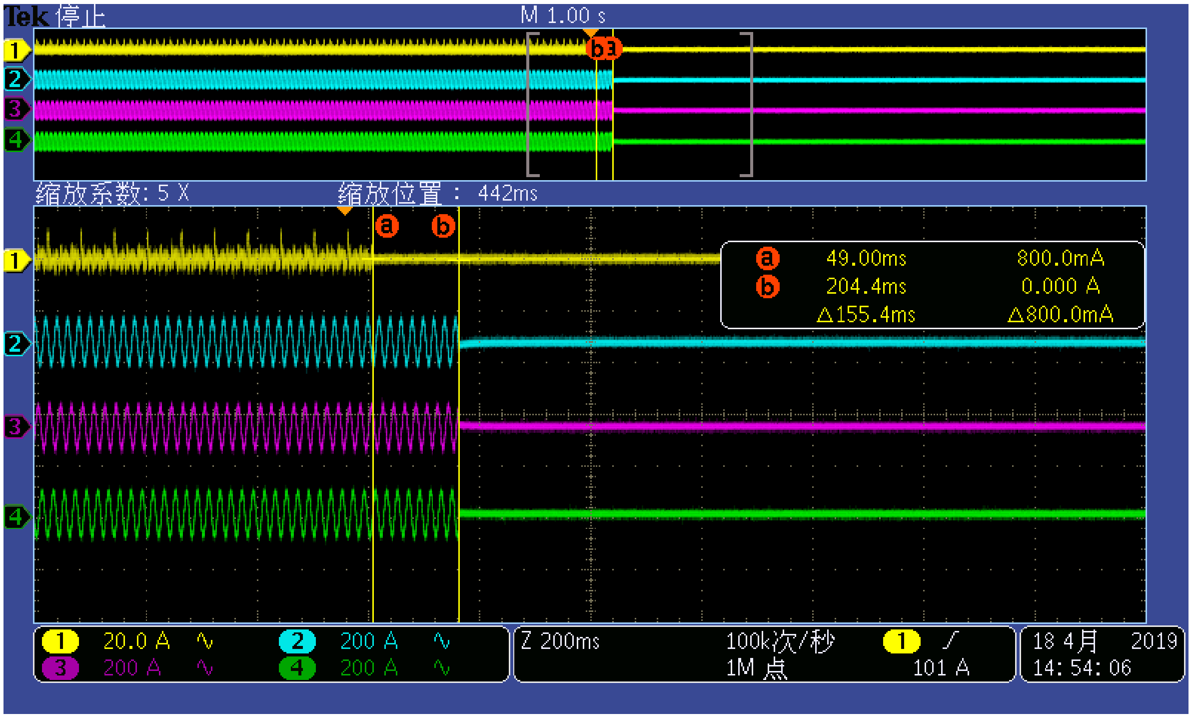
Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	1s

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} (KW per phase)	Actual Qf	V_{DC} (V)	Remarks4)
1	66	66	0	-5	131,4	13,440	0,979	525	Test B at IB
2	66	66	0	-4	145,4	13,440	0,984	525	Test B at IB
3	66	66	0	-3	123,4	13,440	0,989	525	Test B at IB
4	66	66	0	-2	135,4	13,440	0,994	525	Test B at IB
5	66	66	0	-1	103,4	13,440	0,999	525	Test B at IB
6	66	66	0	0	155,4	13,440	1,004	525	Test B at BL
7	66	66	0	1	147,4	13,440	1,009	525	Test B at IB
8	66	66	0	2	143,4	13,440	1,014	525	Test B at IB
9	66	66	0	3	143,4	13,440	1,019	525	Test B at IB
10	66	66	0	4	148,0	13,440	1,024	525	Test B at IB
11	66	66	0	5	138,0	13,440	1,029	525	Test B at IB

Parameter at 0% per phase	L= 12,48 mH	R= 3,94 Ω	C= 811,95 µF
IAC fundamental current(A)	L1: 168mA	L2: 192mA	L3: 234mA

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:
CH2, CH3, CH4: L1, L2, L3 current of EUT(200A/div)., CH1: trip signal

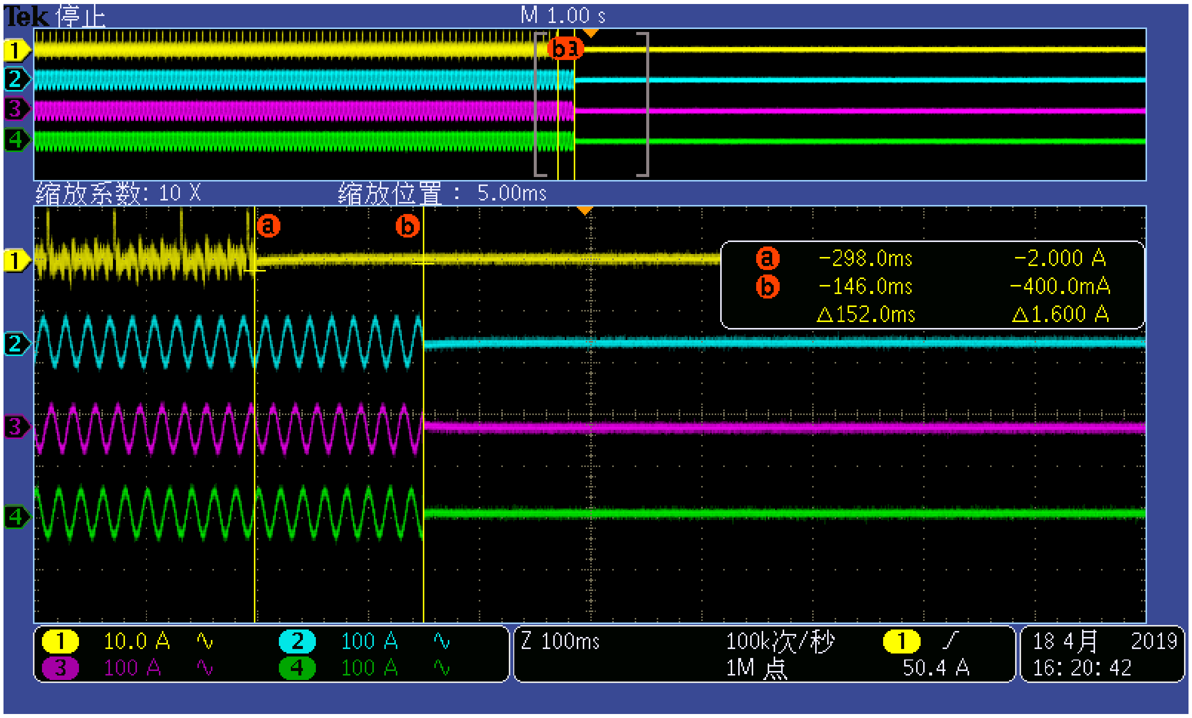
6.1 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %) **3.9, 12.4 Anti-Islanding (PEA:2016)**	**P**

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality =1								
Disconnection limit	1s								
No	P_{EUT} 1) (% of EUT rating)	Reactive load (% of Q_L in 6.1.d) 1)	P_{AC} 2) (% of nominal)	Q_{AC} 3) (% of nominal)	Run on Time (ms)	P_{EUT} (W per phase)	Actual Q_f	V_{DC} (V)	Remarks4)
1	33	33	0	-5	125,0	6,700	0,987	360	Test C at IB
2	33	33	0	-4	135,0	6,700	0,992	360	Test C at IB
3	33	33	0	-3	130,0	6,700	0,997	360	Test C at IB
4	33	33	0	-2	144,0	6,700	1,003	360	Test C at IB
5	33	33	0	-1	129,0	6,700	1,008	360	Test C at IB
6	33	33	0	0	152,0	6,700	1,013	360	Test C at BL
7	33	33	0	1	149,0	6,700	1,018	360	Test C at IB
8	33	33	0	2	140,0	6,700	1,023	360	Test C at IB
9	33	33	0	3	133,0	6,700	1,028	360	Test C at IB
10	33	33	0	4	136,0	6,700	1,033	360	Test C at IB
11	33	33	0	5	131,0	6,700	1,038	360	Test C at IB

Parameter at 0% per phase	L= 24,81 mH	R= 7,90 Ω	C= 408,39 µF
IAC fundamental current(A)	L1: 389mA	L2: 249mA	L3: 287mA

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:
CH2, CH3, CH4: L1, L2, L3 current of EUT(100A/div)., CH1: trip signal

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

Test conditions:	Output: 220 Vac					
P (setting)	P(kW)ind	P(kW)cap	Q(kVar)ind, max	Q(kVar)cap, max	PFind, max	PFcap, max
0%	2,812	2,854	-1,331	1,404	0,9039	0,8973
10%	5,856	5,941	-2,820	2,889	0,9008	0,8993
20%	11,920	12,099	-5,625	5,844	0,9044	0,9004
30%	17,980	18,231	-8,488	8,631	0,9043	0,9038
40%	24,006	24,338	-11,380	11,403	0,9036	0,9055
50%	30,005	30,415	-14,278	14,163	0,9030	0,9065
60%	35,961	36,560	-17,167	16,915	0,9024	0,9075
70%	41,906	41,948	-20,051	19,416	0,9021	0,9075
80%	47,818	47,869	-22,925	22,119	0,9017	0,9078
90%	53,427	53,480	-24,957	24,673	0,9060	0,9080
100%	52,923	53,480	-26,002	24,676	0,8975	0,9080
Note:						

PEA:2016 additional test	P
3.4.1, 8.1.2 1) A fixed displacement factor cos φ	P

Test conditions: Output: 220Vac

P (setting)	PF (setting)	P(kW)	Q(kVar)	PF
0%	0,90 lagging	2,854	1,404	0,8973
10%	0,90 lagging	5,941	2,889	0,8993
20%	0,90 lagging	12,099	5,844	0,9004
30%	0,90 lagging	18,231	8,631	0,9038
40%	0,90 lagging	24,338	11,403	0,9055
50%	0,90 lagging	30,415	14,163	0,9065
60%	0,90 lagging	36,560	16,915	0,9075
70%	0,90 lagging	41,948	19,416	0,9075
80%	0,90 lagging	47,869	22,119	0,9078
90%	0,90 lagging	53,480	24,673	0,9080
100%	0,90 lagging	53,480	24,676	0,9080

P (setting)	PF (setting)	P(kW)	Q(kVar)	PF
0%	0,90 leading	2,812	-1,331	0,9039
10%	0,90 leading	5,856	-2,820	0,9008
20%	0,90 leading	11,920	-5,625	0,9044
30%	0,90 leading	17,980	-8,488	0,9043
40%	0,90 leading	24,006	-11,380	0,9036
50%	0,90 leading	30,005	-14,278	0,9030
60%	0,90 leading	35,961	-17,167	0,9024
70%	0,90 leading	41,906	-20,051	0,9021
80%	0,90 leading	47,818	-22,925	0,9017
90%	0,90 leading	53,427	-24,957	0,9060
100%	0,90 leading	52,923	-26,002	0,8975

P (setting)	PF (setting)	P(kW)	Q(kVar)	PF
0%	1,00	2,810	0,087	0,9995
10%	1,00	5,866	0,044	0,9999
20%	1,00	11,958	-0,101	0,9999
30%	1,00	18,030	-0,196	0,9999

40%	1,00	24,078	-0,297	0,9999
50%	1,00	30,107	-0,423	0,9999
60%	1,00	36,112	-0,563	0,9999
70%	1,00	42,082	-0,704	0,9999
80%	1,00	48,033	-0,850	0,9998
90%	1,00	53,959	-0,997	0,9998
100%	1,00	59,562	-1,130	0,9998
Note:				

PEA:2016 additional test	P
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)	**P**

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.

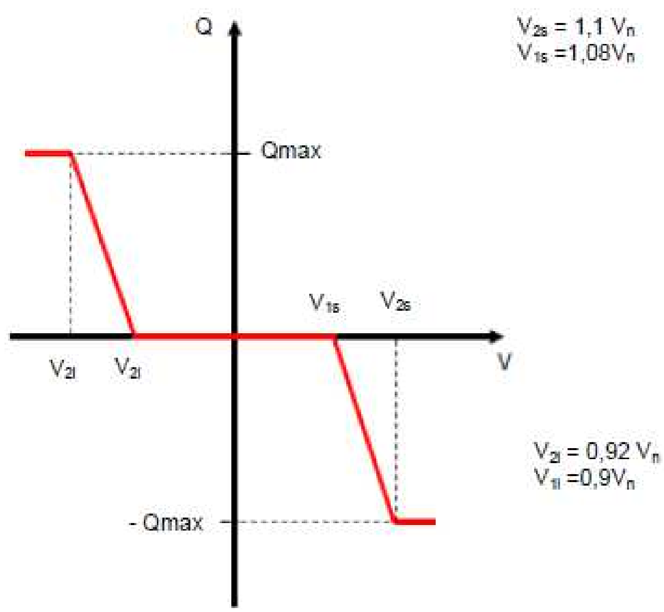
Activation must be at the Distributor's request, when the Operating Regulations are issued. The Distributor shall also specify the values of the parameters that uniquely characterise the curve, i.e.: V1i, V2i, V1s and V1s as well as the lock-in value of active power (default value P = 0,2 P_n).

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).

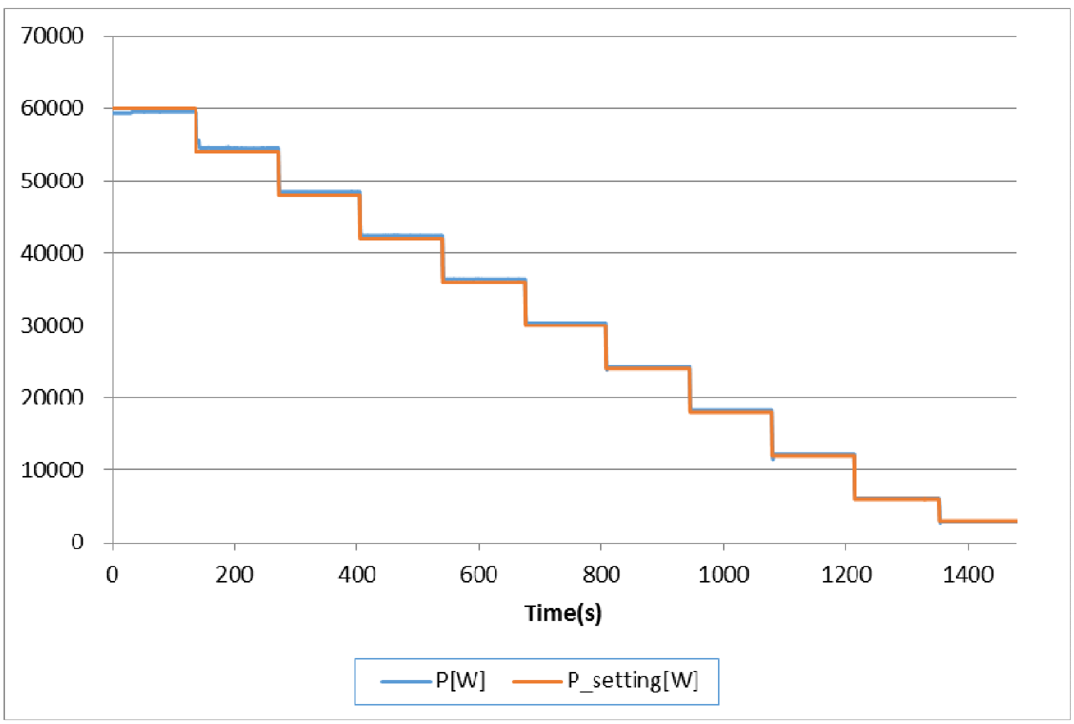


Qmin reactive power in accordance to standard characteristic curve Q=f(V)						
P/Pn	Vac [V] Set point	P[kW] measured	Vac [V] measured	Q [kVar] measured	Q [kVar] expected	ΔQ [kVar]
< 20%	1,07Vn	5,886	235,41	0,080	≈0(<±2.5%Pn)	0,080
< 20%	1,09Vn	5,892	239,98	0,090	≈0(<±2.5%Pn)	0,090
< 20%-30%	1,09Vn	17,969	239,88	-13,737	-14,529	0,792
40%	1,09Vn	24,042	239,88	-14,233	-14,529	0,296
50%	1,09Vn	30,093	239,89	-14,657	-14,529	-0,128
60%	1,09Vn	36,122	239,88	-15,108	-14,529	-0,579
70%	1,09Vn	42,112	239,89	-15,444	-14,529	-0,915
80%	1,09Vn	48,111	239,89	-15,368	-14,529	-0,839
90%	1,09Vn	54,078	239,89	-15,642	-14,529	-1,113
100%	1,09Vn	58,776	239,90	-15,484	-14,529	-0,955
100%	1,1 Vn	53,090	242,05	-30,465	-29,058	-1,407
100%-10%	1,1 Vn	5,925	242,17	-30,405	-29,058	-1,347
10%→ ≤5%	1,1 Vn	2,835	241,98	0,129	≈0(<±2.5%Pn)	0,129
Qmax reactive power in accordance to standard characteristic curve Q=f(V)						
P/Pn	Vac [V] Set point	P[kW] measured	Vac [V] measured	Q [kVar] measured	Q [kVar] expected	ΔQ [kVar]
< 20%	0,93Vn	5,861	203,25	0,013	≈0(<±2.5%Pn)	0,013
< 20%	0,91Vn	5,859	200,32	0,008	≈0(<±2.5%Pn)	0,008
< 20%-30%	0,91Vn	17,866	200,27	14,598	14,529	0,069
40%	0,91Vn	23,913	200,25	14,271	14,529	-0,258
50%	0,91Vn	29,924	200,20	14,278	14,529	-0,251
60%	0,91Vn	36,773	200,22	13,906	14,529	-0,623
70%	0,91Vn	41,847	200,23	13,681	14,529	-0,848
80%	0,91Vn	47,768	200,21	13,824	14,529	-0,705
90%	0,91Vn	52,359	200,47	13,942	14,529	-0,587
100%	0,91Vn	52,062	200,26	13,524	14,529	-1,005
100%	0,91Vn	45,078	198,81	29,185	29,058	0,127
100%-10%	0,90Vn	5,962	198,10	29,819	29,058	0,761
10%→ ≤5%	0,90Vn	2,803	197,92	0,001	≈0(<±2.5%Pn)	0,001

Note:
The lock-in value is adjustable between Vn and 1.1Vn and the lock-out value between Vn and 0.9Vn in 0,01V steps.

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%	60,000	59,454	
90%	54,000	54,030	1s
80%	48,000	48,469	1s
70%	42,000	42,454	1s
60%	36,000	36,424	1s
50%	30,000	30,390	1s
40%	24,000	24,343	1s
30%	18,000	18,281	1s
20%	12,000	12,207	1s
10%	6,000	6,101	1s
0%	3,000	2,935	1s

Graph of the setting accuracy



Note:

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

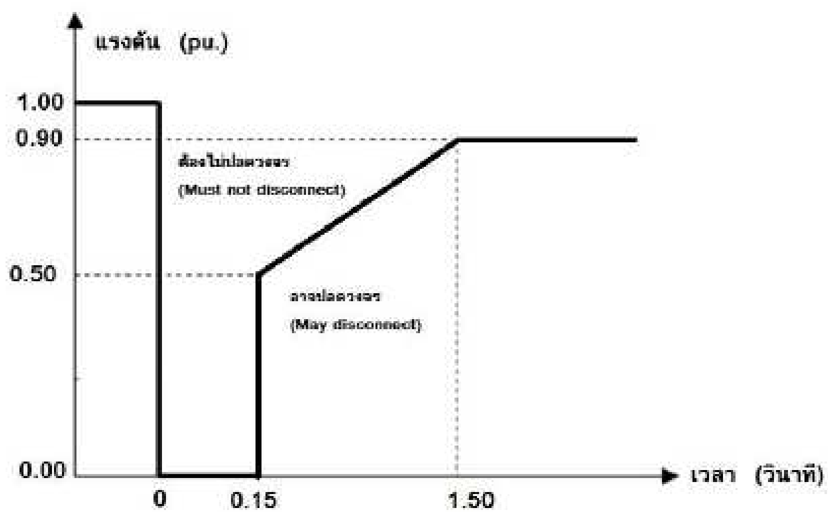
Test List	$V (V/V_n)$	Tested voltage (V/V_n)	Duration time (Sec)
Test $P>0,9P_n$*			
Three-phase faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,05V_n$	$0,049V_n$	0,160
Phase to phase faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,05V_n$	$0,049V_n$	0,160
Single phase to ground faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,05V_n$	$0,049V_n$	0,160
Test $P=0,3P_n$			
Three-phase faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,049V_n$	$0,049V_n$	0,160
Phase to phase faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,049V_n$	$0,049V_n$	0,160
Single phase to ground faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,049V_n$	$0,049V_n$	0,160
Test P=0,1 Pn			
Three-phase faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,049V_n$	$0,049V_n$	0,160
Phase to phase faults	$0,7\text{-}0,8V_n$	$0,75\ V_n$	1,011
	$0,3\text{-}0,5V_n$	$0,45\ V_n$	0,161
	$0\text{-}0,049V_n$	$0,049V_n$	0,160

Single phase to ground faults	0,7-0,8V_n	0,75 V_n	1,011
	0,3-0,5V_n	0,45 V_n	0,161
	0-0,049V_n	0,049V_n	0,160

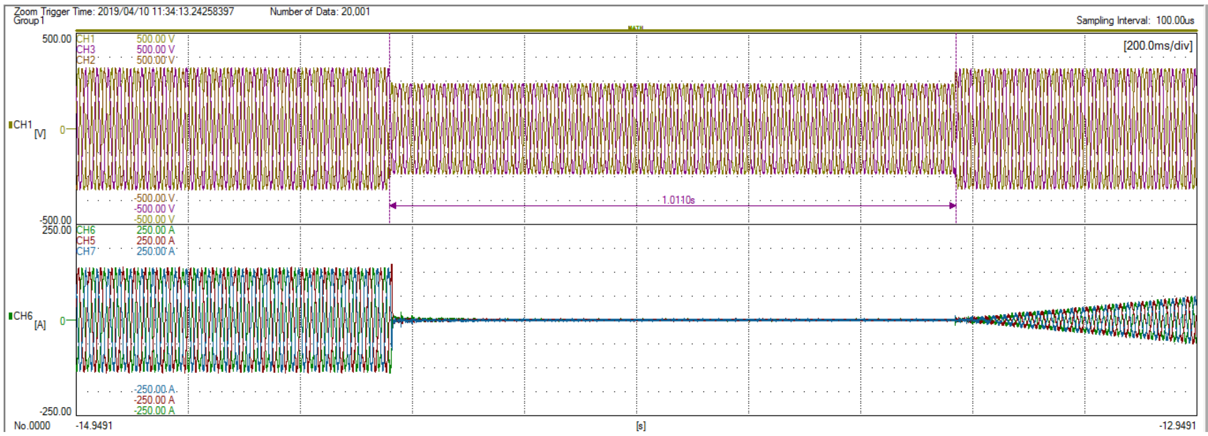
Note:

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

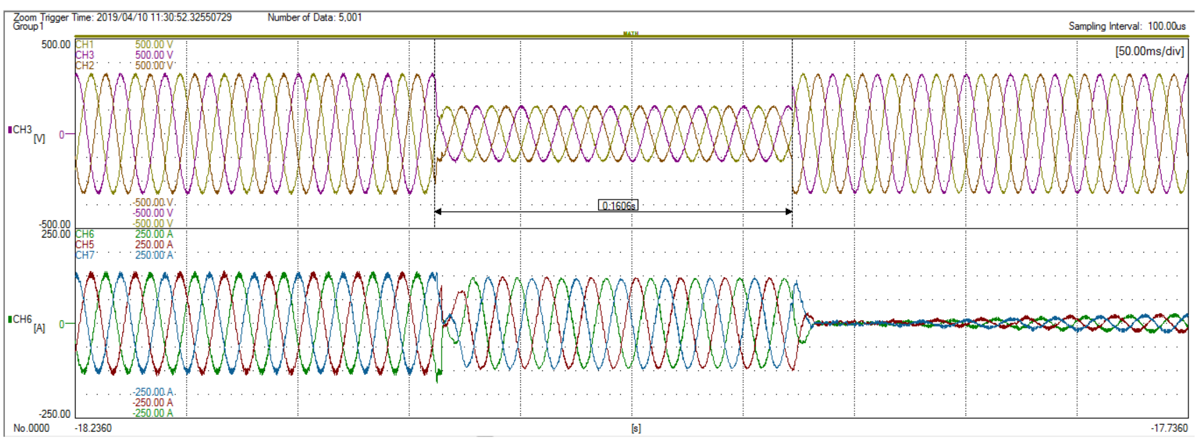
a) install and connect the PGS and recommendation of the technical requirements of the equipment manufacturer .
b) Check all parameters of power supply in normal conditions, the operation of power system equipment .
c) testing by simulation the voltage . (I try to short-circuit in the power network)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



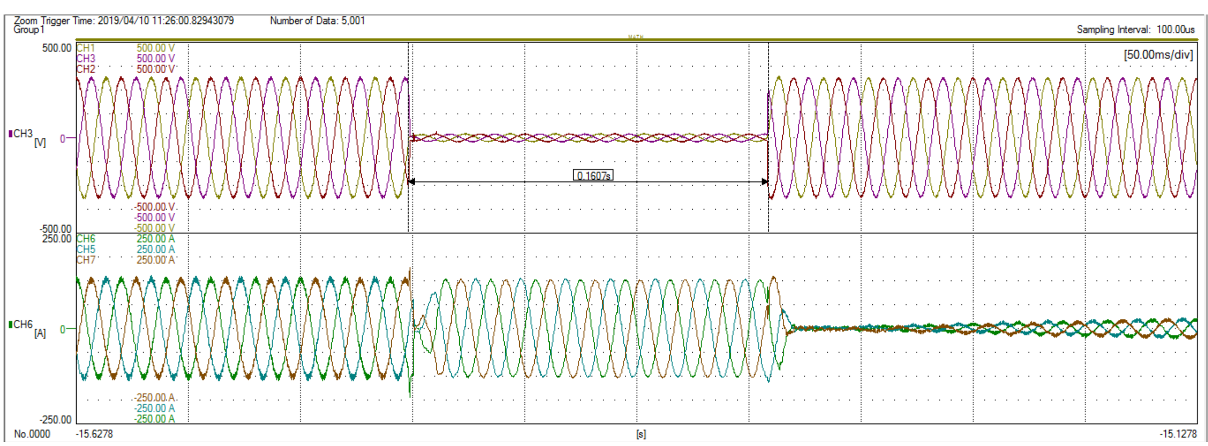
Three-phase faults graph at 100%P_n: 0,7-0,8U_n



Three-phase faults graph at 100%P_n: 0,3-0,5U_n

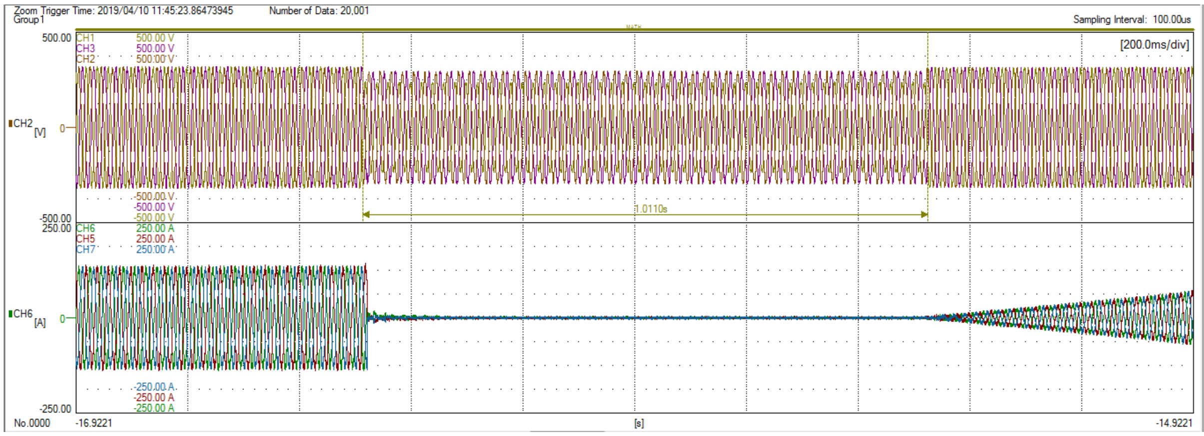


Three-phase faults graph at 100%P_n: 0,00Un-0,049U_n

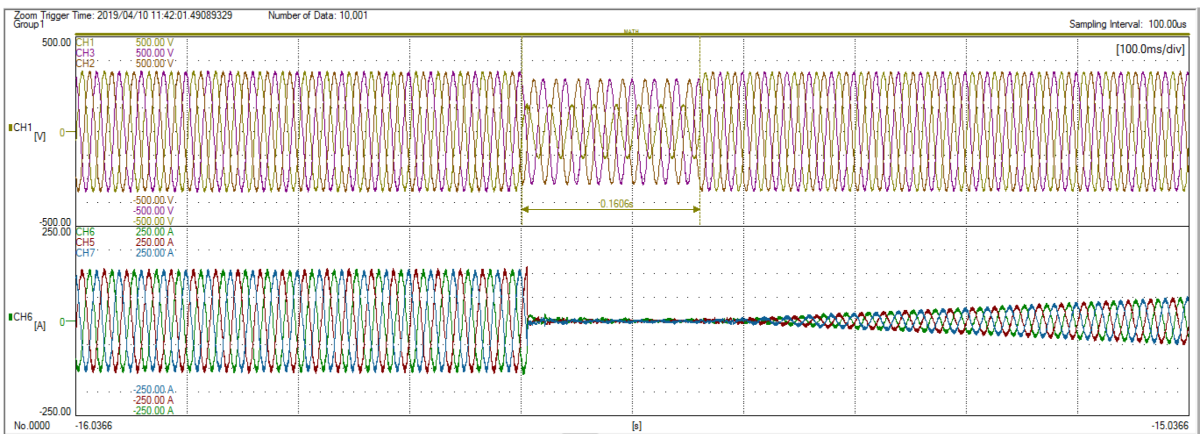


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

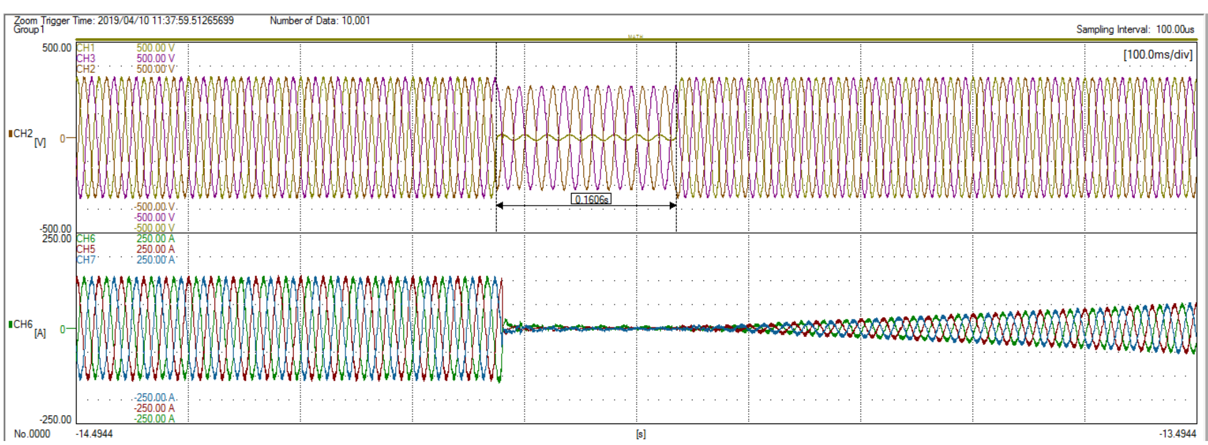
phase to phase faults 0,7-0,8Vn-Voltage graph at 100%P_n



phase to phase faults 0,3-0,5Vn -Voltage graph at 100%P_n

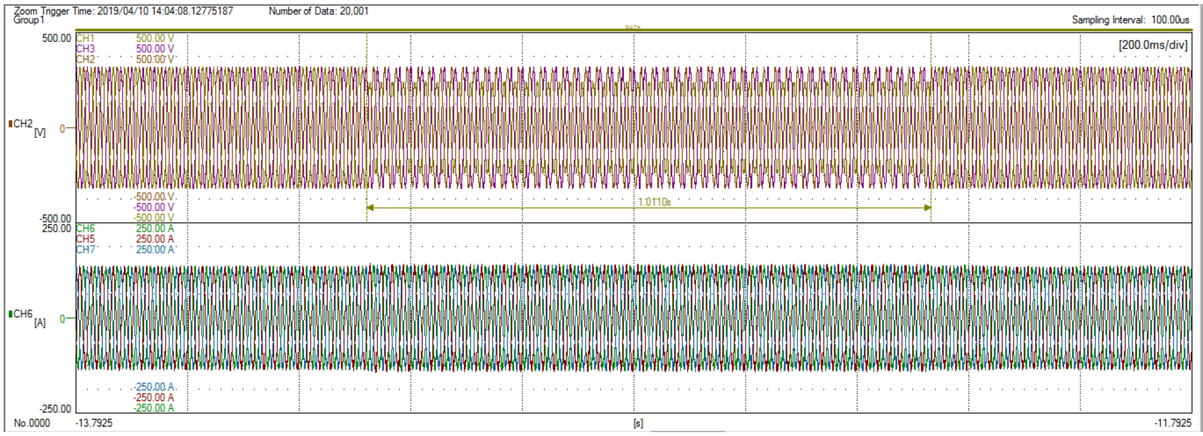


phase to phase faults 0-0,049Vn -Voltage graph at 100%P_n

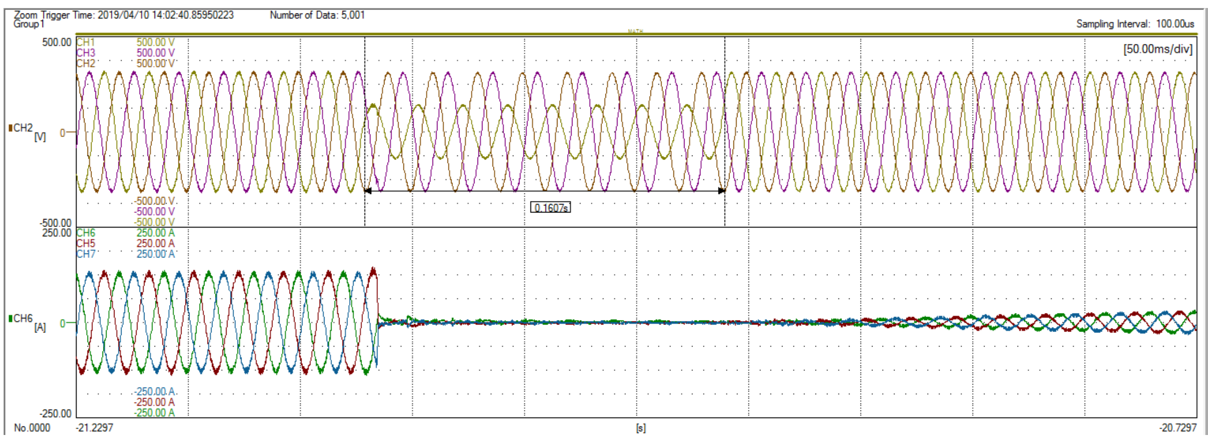


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

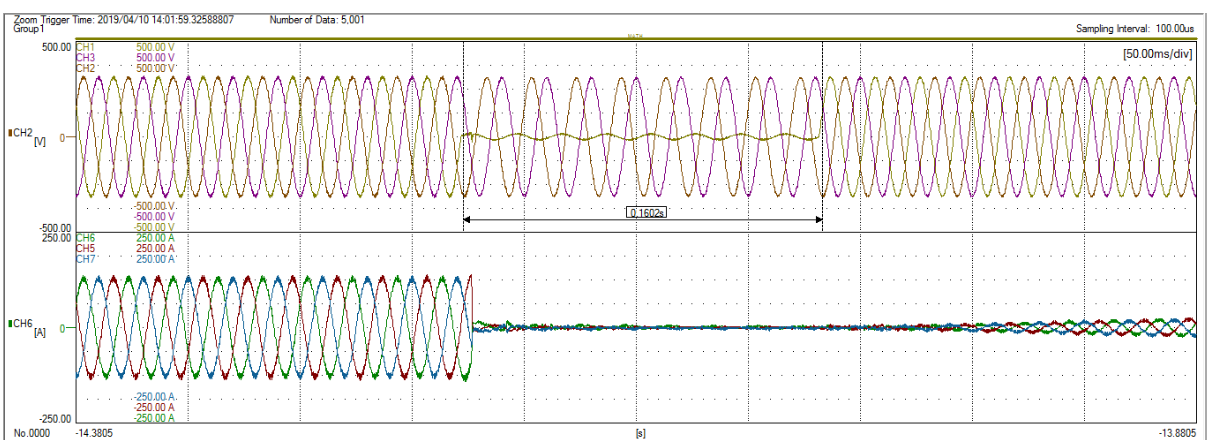
phase-ground faults 0,7-0,8Vn-Voltage graph at 100%P_n



phase-ground faults 0,3-0,5Vn-Voltage graph at 100%P_n

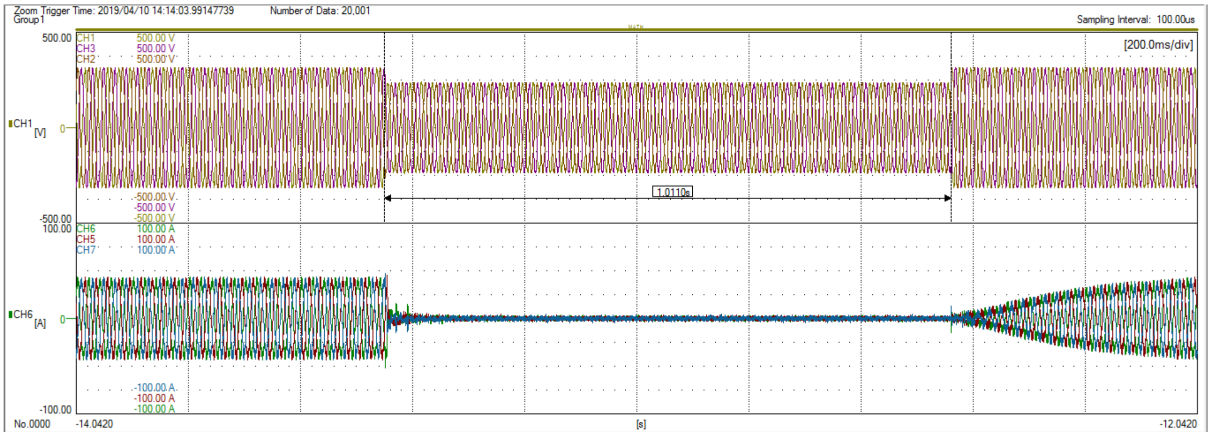


phase-ground faults 0-0,049Vn-Voltage graph at 100%P_n

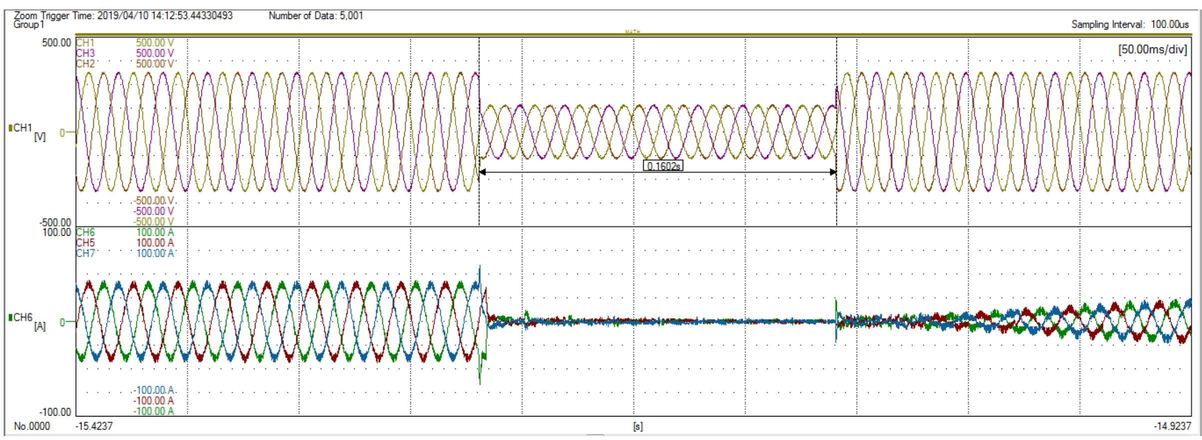


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

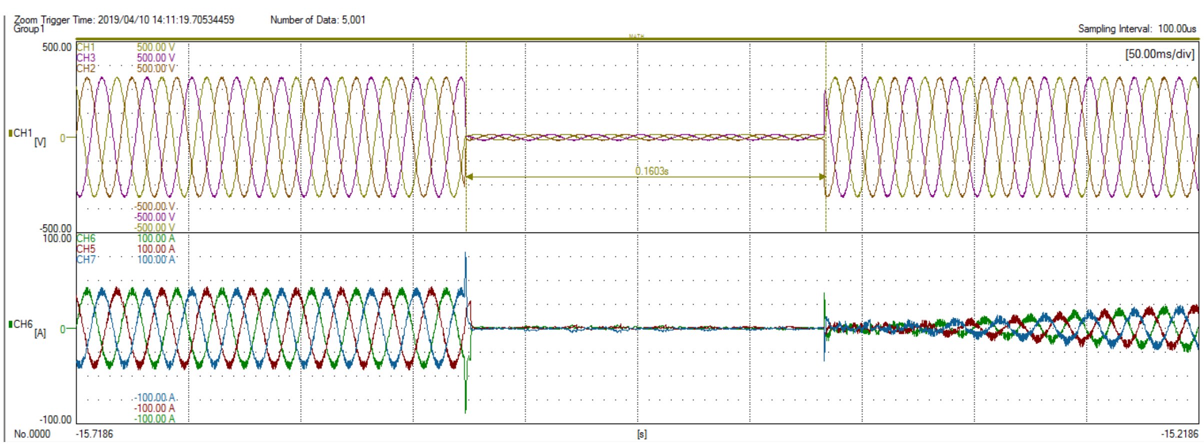
Three-phase faults graph at 30%P_n: 0,7-0,8U_n



Three-phase faults graph at 30%P_n: 0,3-0,5U_n

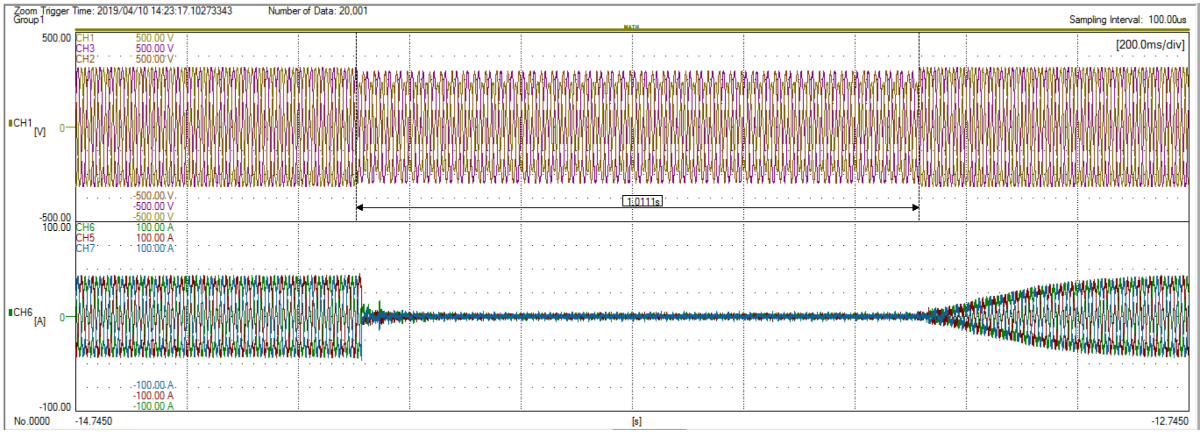


Three-phase faults graph at 30%P_n: 0,00Un-0,049U_n

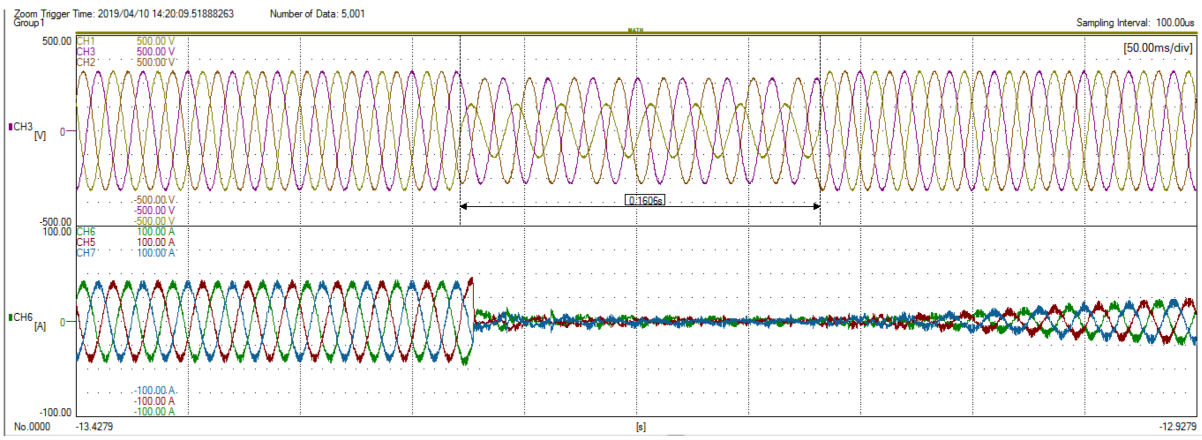


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

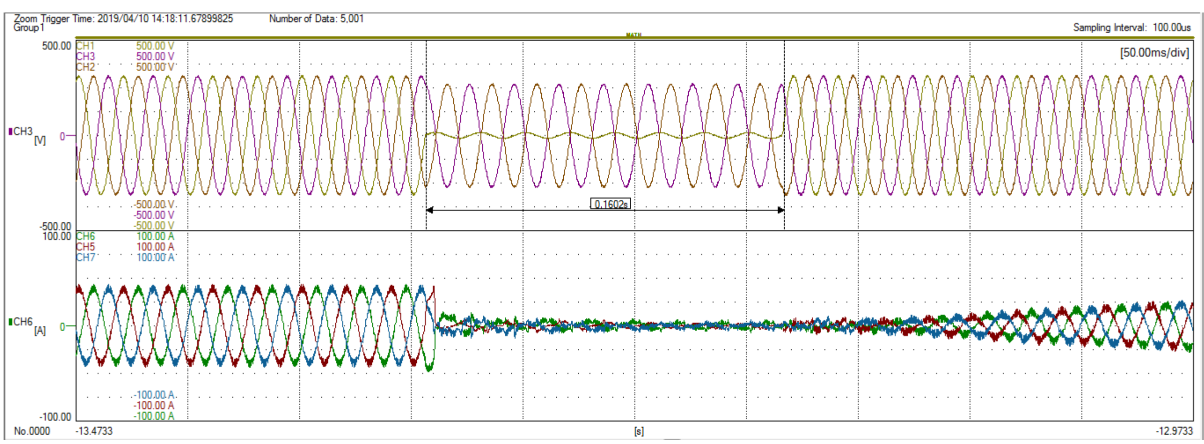
phase to phase faults 0,7-0,8Vn-Voltage graph at 30%P_n



phase to phase faults 0,3-0,5Vn -Voltage graph at 30%P_n

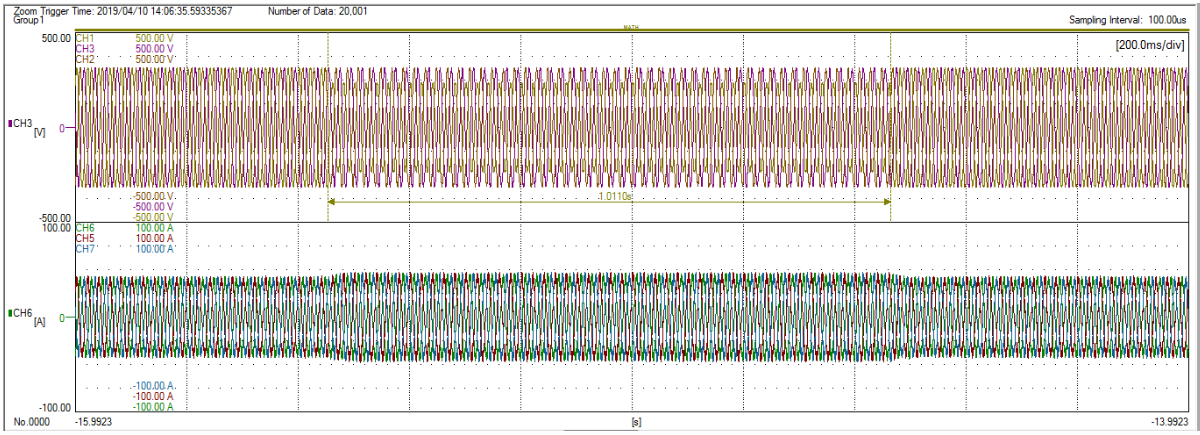


phase to phase faults 0-0,049Vn -Voltage graph at 30%P_n

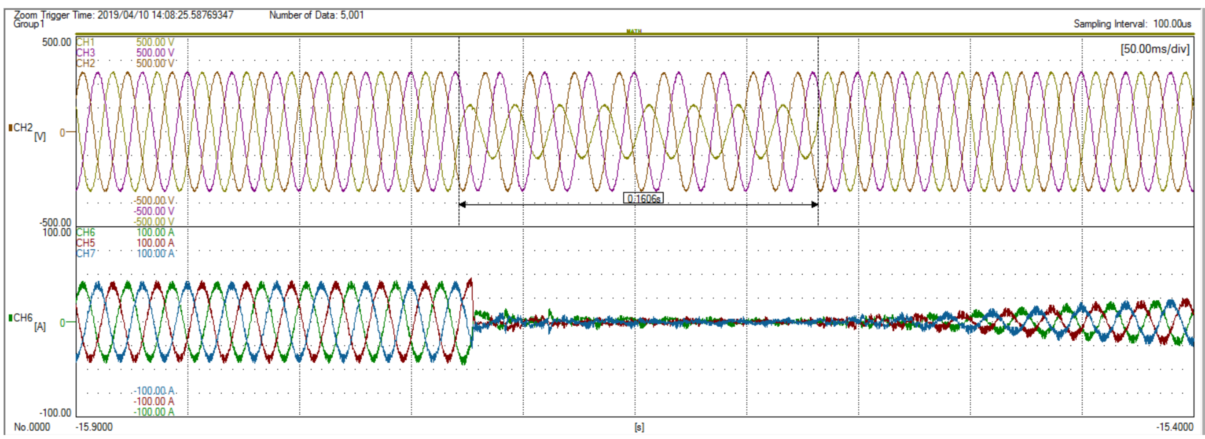


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

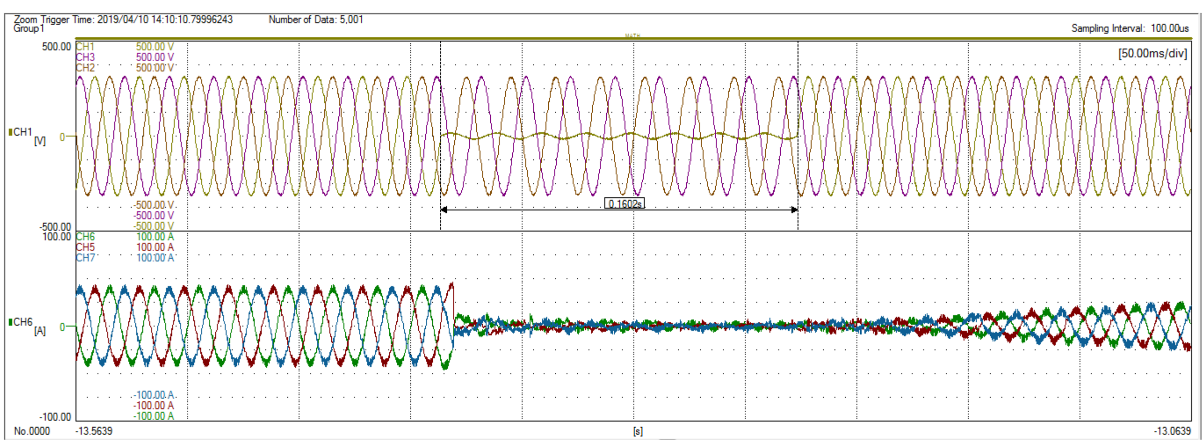
phase-ground faults 0,7-0,8Vn-Voltage graph at 30%P_n



phase-ground faults 0,3-0,5Vn-Voltage graph at 30%P_n

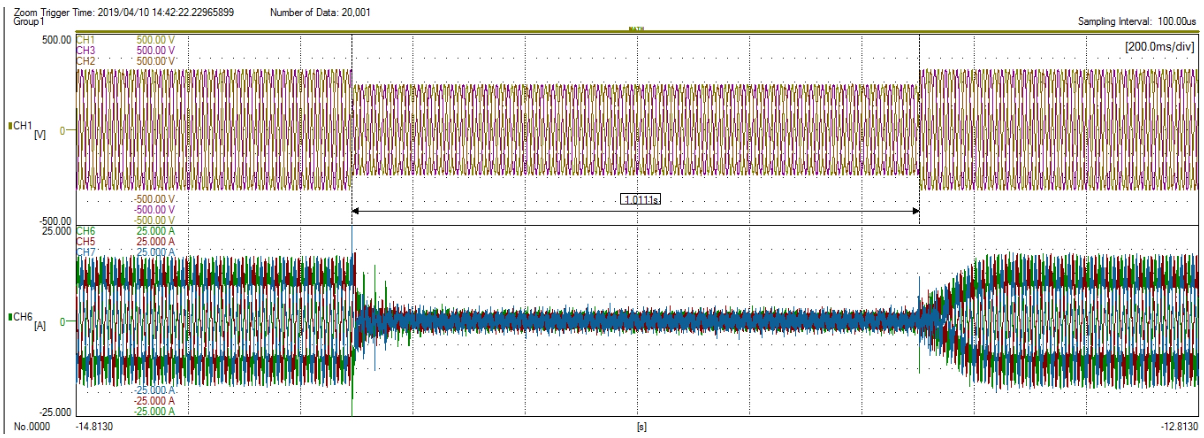


phase-ground faults 0-0,049Vn-Voltage graph at 30%P_n

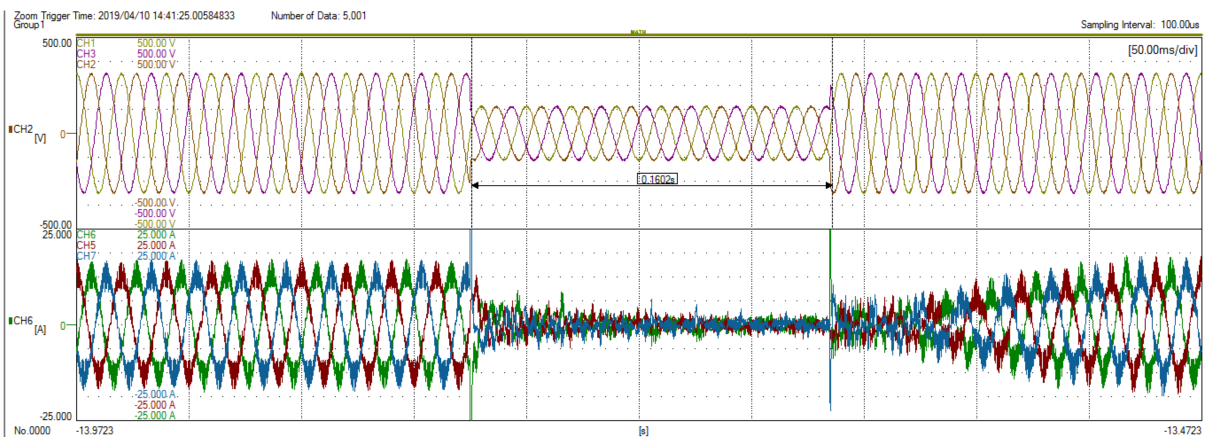


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

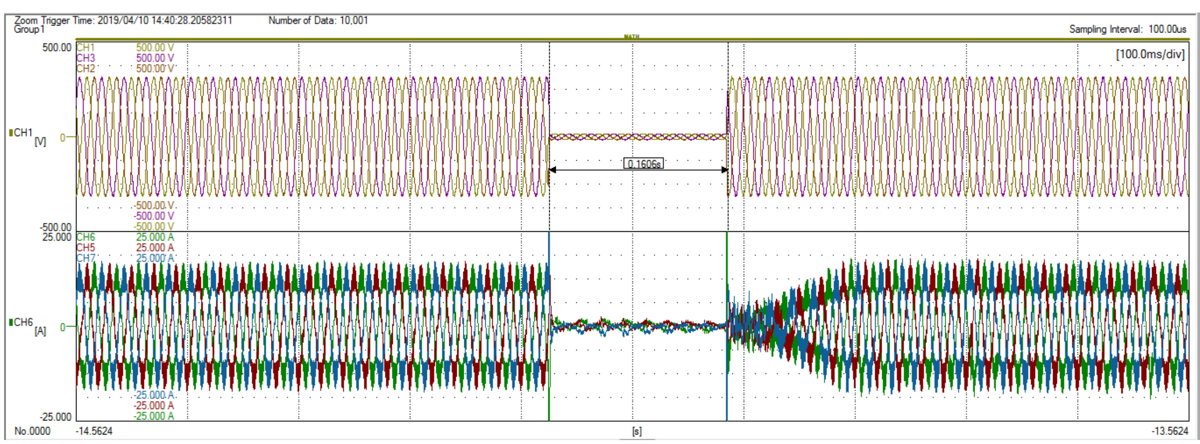
Three-phase faults graph at 10%P_n: 0,7-0,8U_n



Three-phase faults graph at 10%P_n: 0,3-0,5U_n

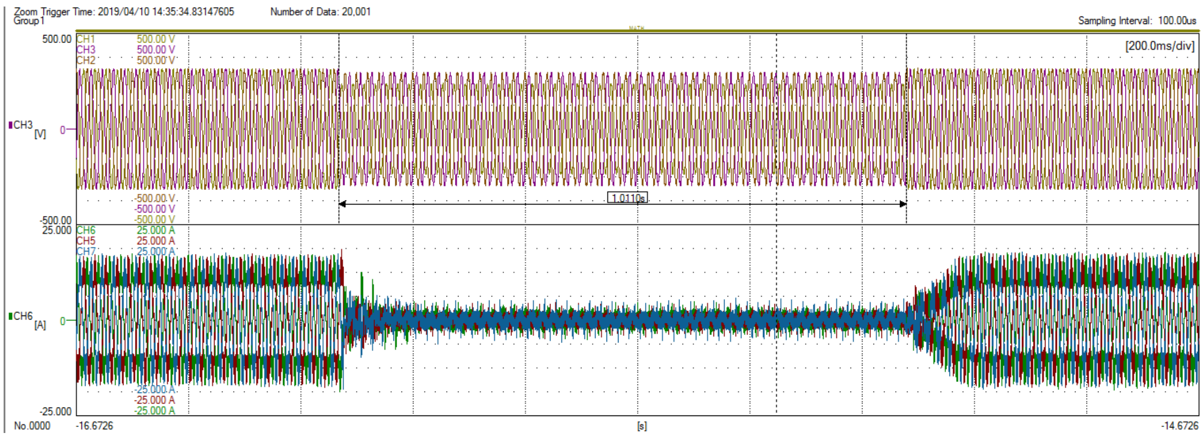


Three-phase faults graph at 10%P_n: 0,00Un-0,049U_n

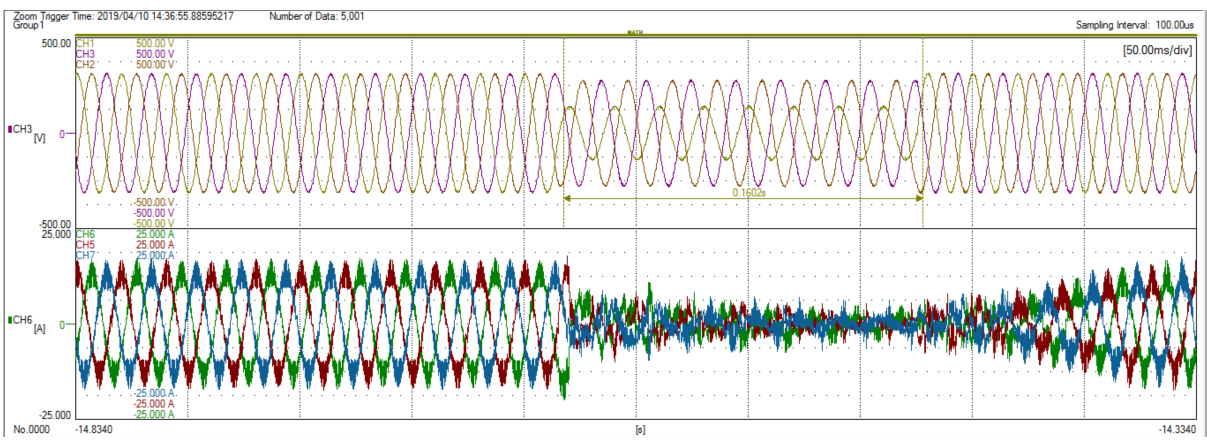


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

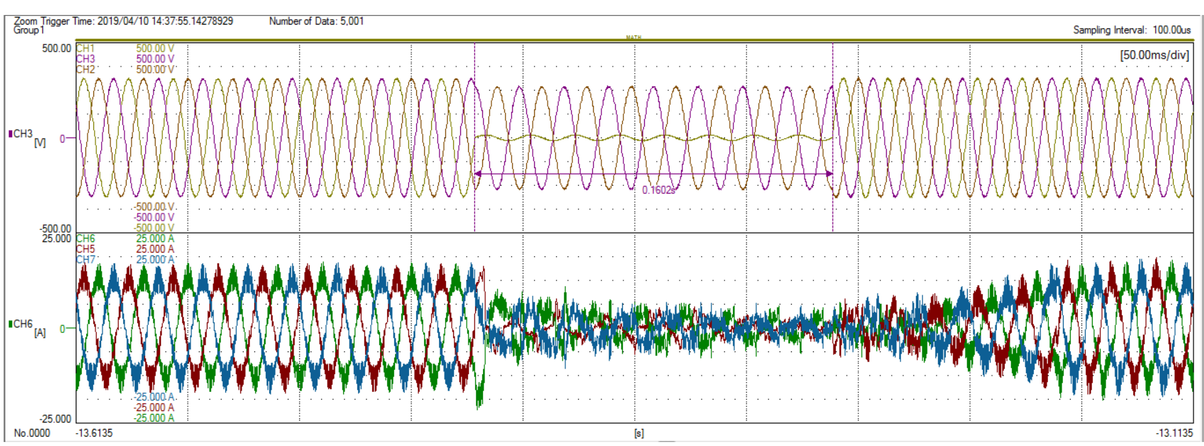
phase to phase faults 0,7-0,8Vn-Voltage graph at 10%P_n



phase to phase faults 0,3-0,5Vn -Voltage graph at 10%P_n

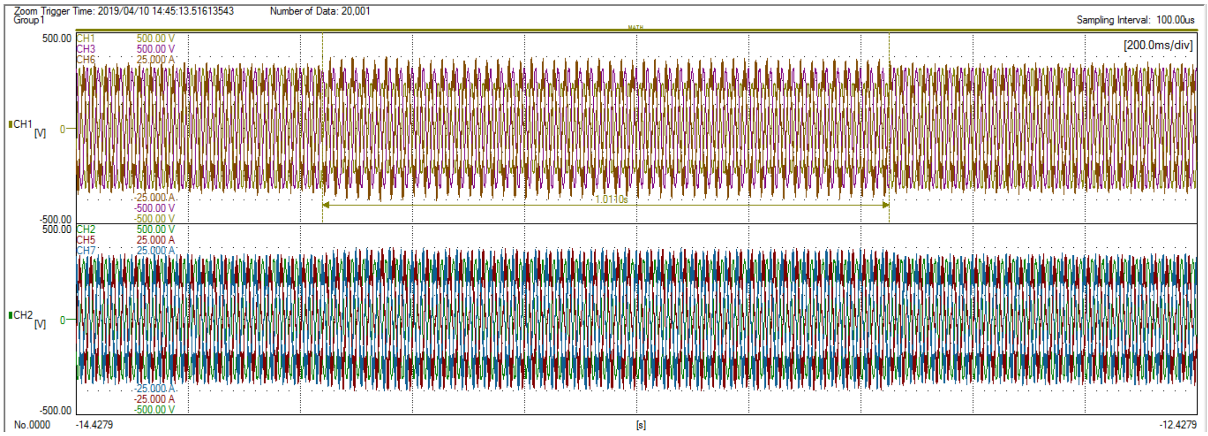


phase to phase faults 0-0,049Vn -Voltage graph at 10%P_n

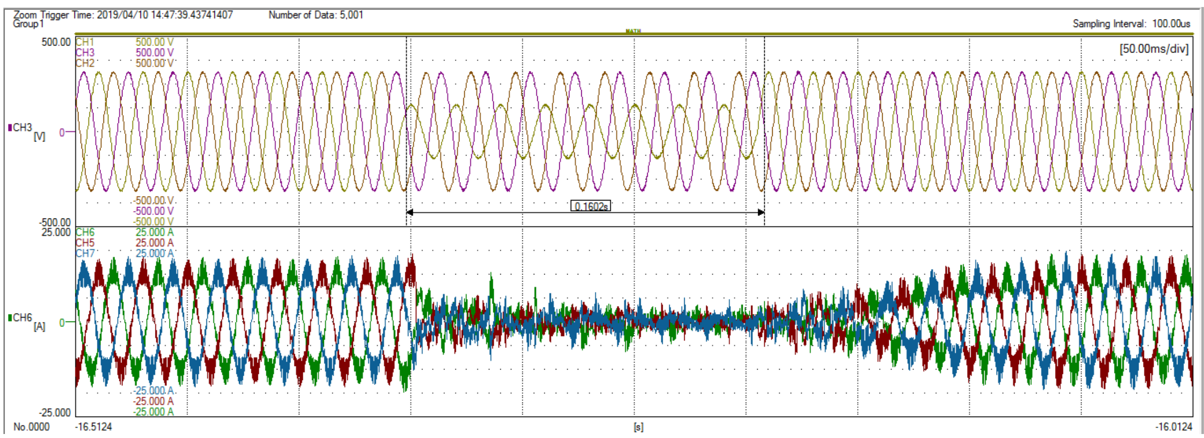


Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

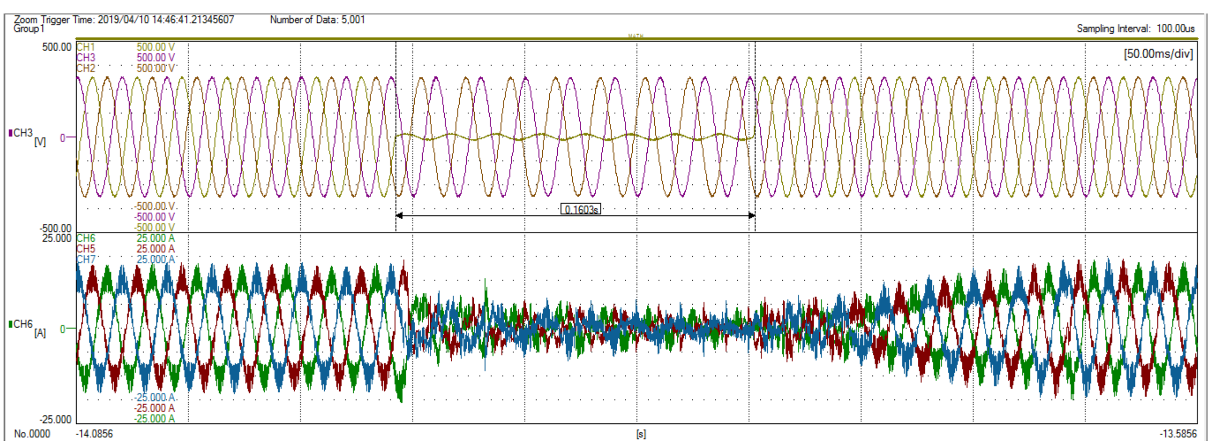
phase-ground faults 0,7-0,8Vn-Voltage graph at 10%P_n



phase-ground faults 0,3-0,5Vn-Voltage graph at 10%P_n



phase-ground faults 0-0,049Vn-Voltage graph at 10%P_n



Note: CH1, CH2, CH3: Phase voltage; CH5,CH6,CH7: Phase current

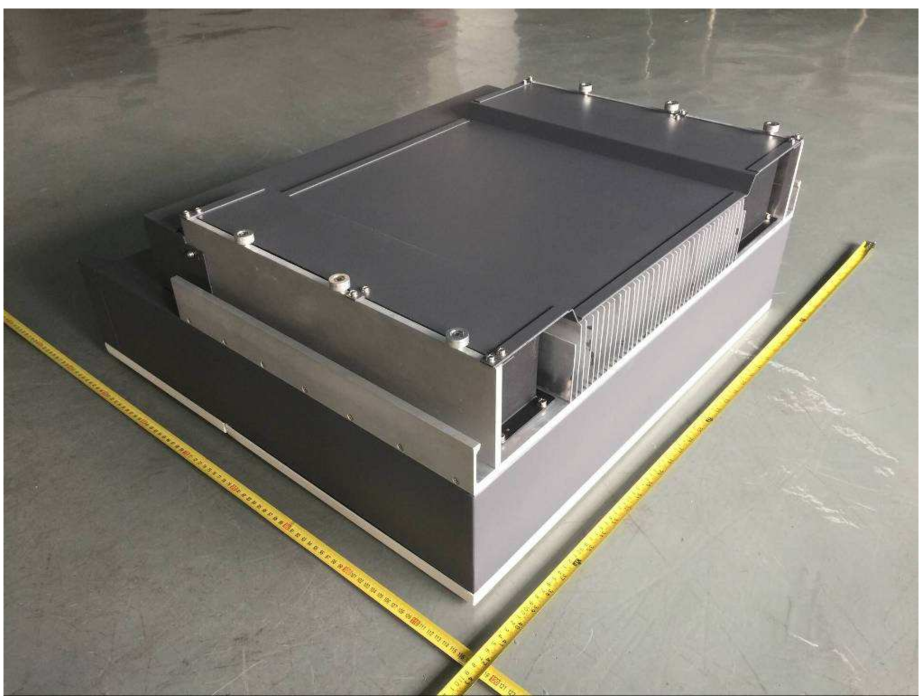
Annex 1

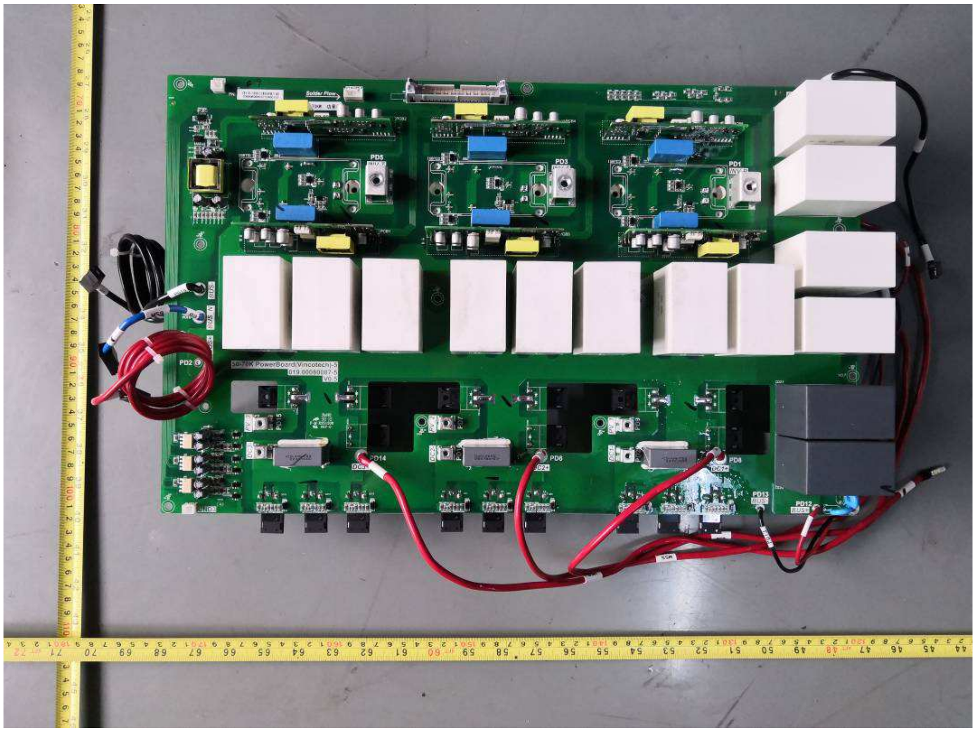
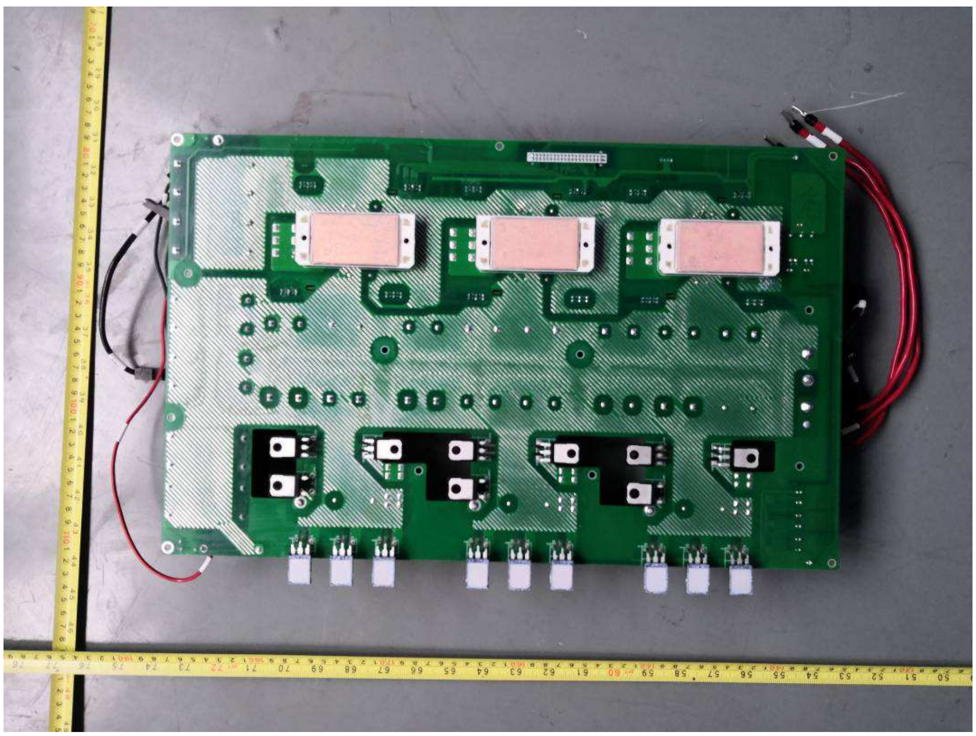
Test equipment list

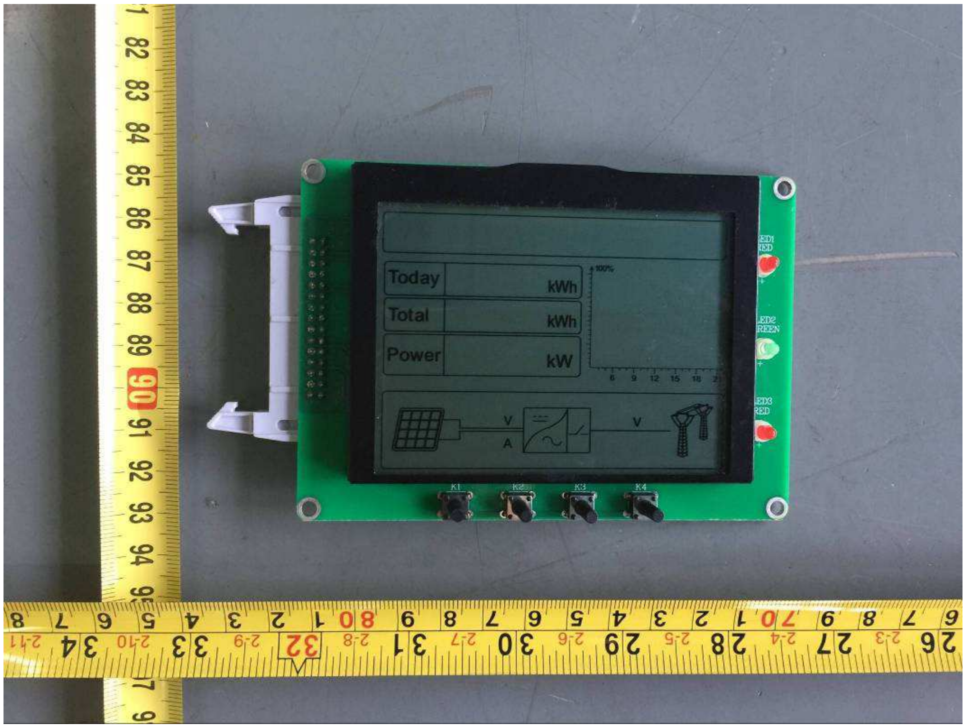
Equipment	Internal no.:	Manufacturer:	Type:	Serial no.:	Last calibration
Power Analyzer	A4080002DG	YOKOGAWA	WT3000	91M210852	Dec. 13, 2018
AC Source	A7040019DG	Chroma	61512	61512000439	Monitored by Power Analyzer
	A7040020DG	Chroma	61512	61512000438	
	SB14325	Chroma	61860	618603800236	
DC Simulation Power Supply	A7040015DG	Chroma	62150H-1000S	62150EF00488	
	A7040016DG	Chroma	62150H-1000S	62150EF00490	
	A7040017DG	Chroma	620028	620028EF00120	
	A7040021DG	Chroma	62150H-1000S	62150EF00609	
	A7040022DG	Chroma	62150H-1000S	62150EF00595	
	A7040023DG	Chroma	62150H-1000S	62150EF00601	
Load	A7150027DG	Qunling	ACLT-3803H	93VOO2869	
	A7150030DG	Shenzhen Weihuaer	//	//	
Eight Channel Digital Phosphor Oscilloscope	A4089017DG	YOKOGAWA	DL850	91N726247	Sep. 14, 2018
Four Channel Digital Phosphor Oscilloscope	A4089003DG	Tektronix	DPO4104B	C010624	Oct. 25, 2018
Oscilloscope probel	A1490008DG	YOKOGAWA	701901	//	Nov. 01, 2018
	A1490009DG	YOKOGAWA	701901	//	Nov. 01, 2018
	A1490010DG	YOKOGAWA	701901	//	Nov. 01, 2018
	A1490011DG	YOKOGAWA	701901	//	Nov. 01, 2018
Current transducer	A1060008DG	YOKOGAWA	CT200	1130700017	Nov. 17, 2018
	A1060009DG	YOKOGAWA	CT200	1130700019	Nov. 17, 2018
	A1060010DG	YOKOGAWA	CT200	1130700016	Dec. 11, 2018
	A1060011DG	YOKOGAWA	CT200	1130700011	Dec. 24, 2018

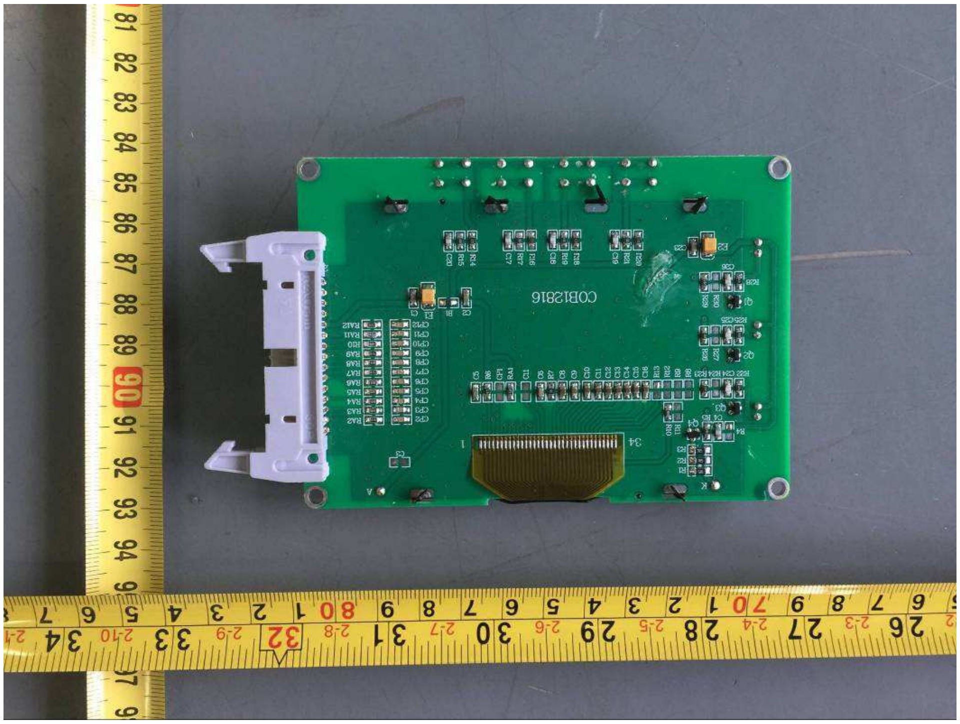
Pictures of the unit

Front view

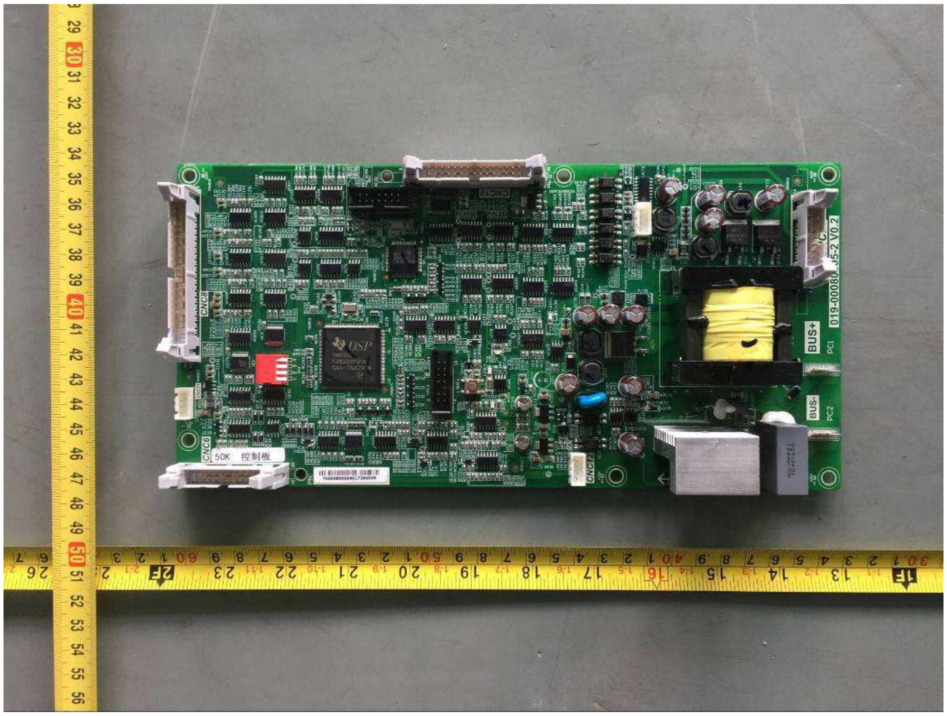
Rear view


Main power board component side view

Main power board solder side view


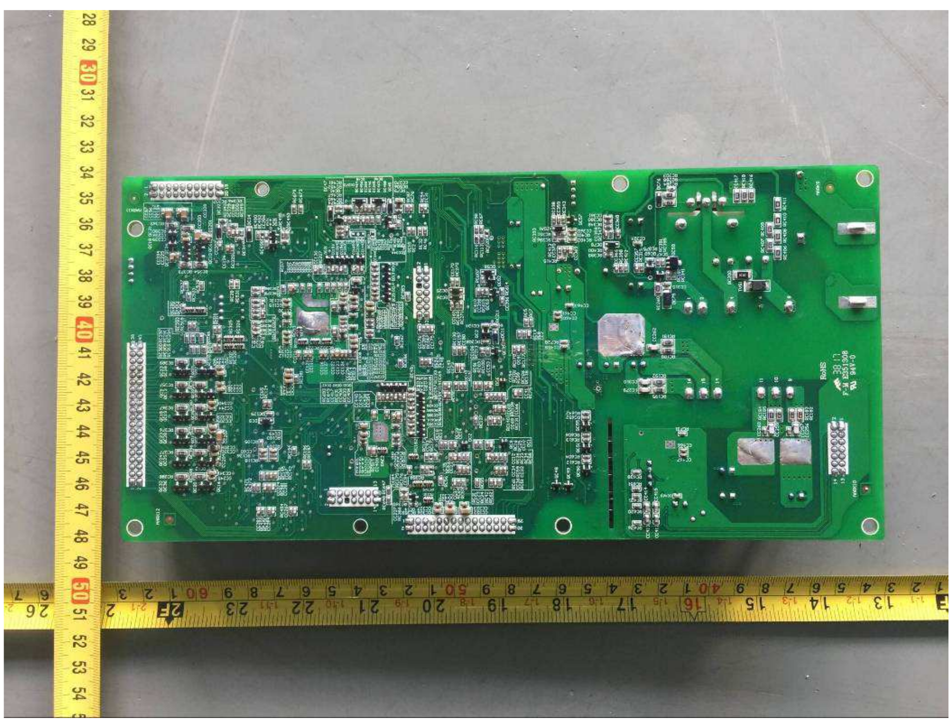
LCD board component side view


LCD board solder side view


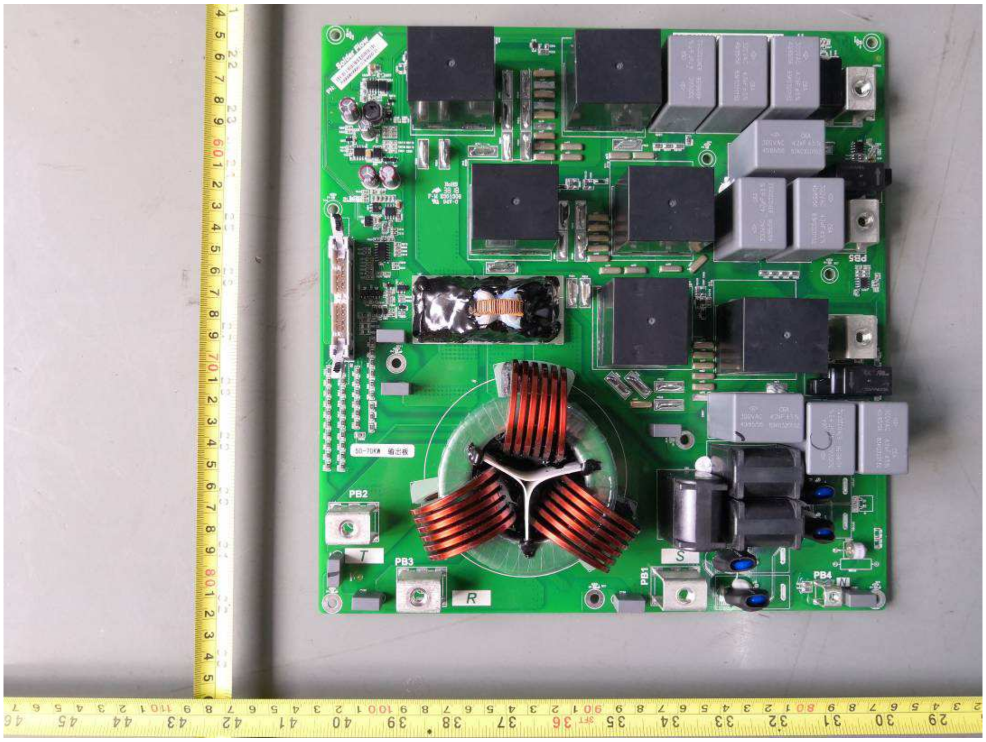
Control board component side view



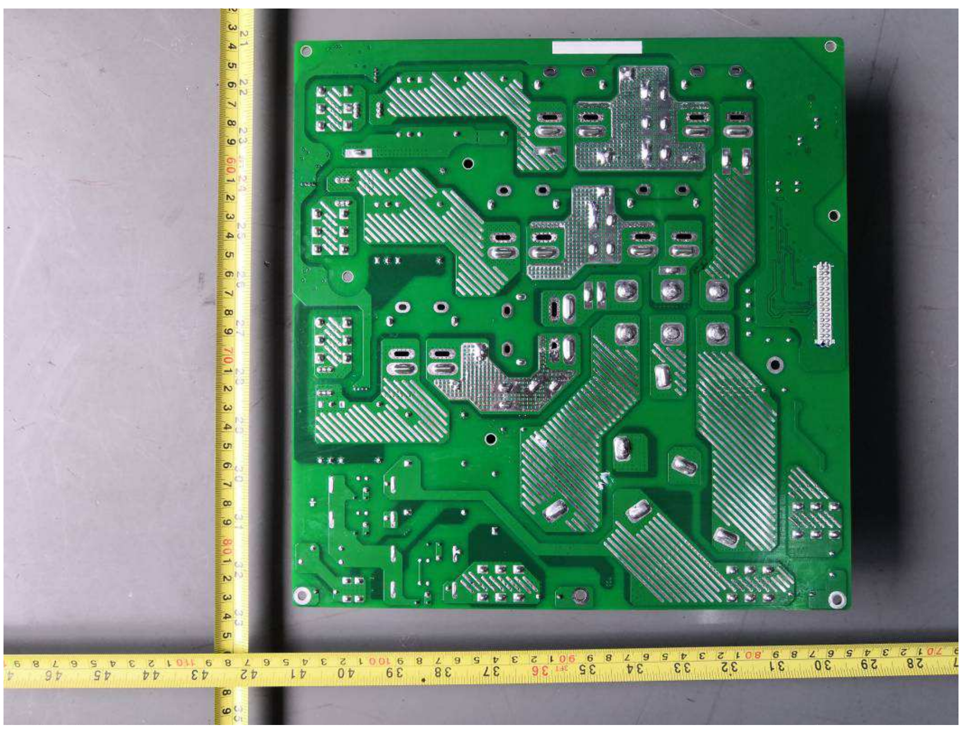
Control power board solder side view

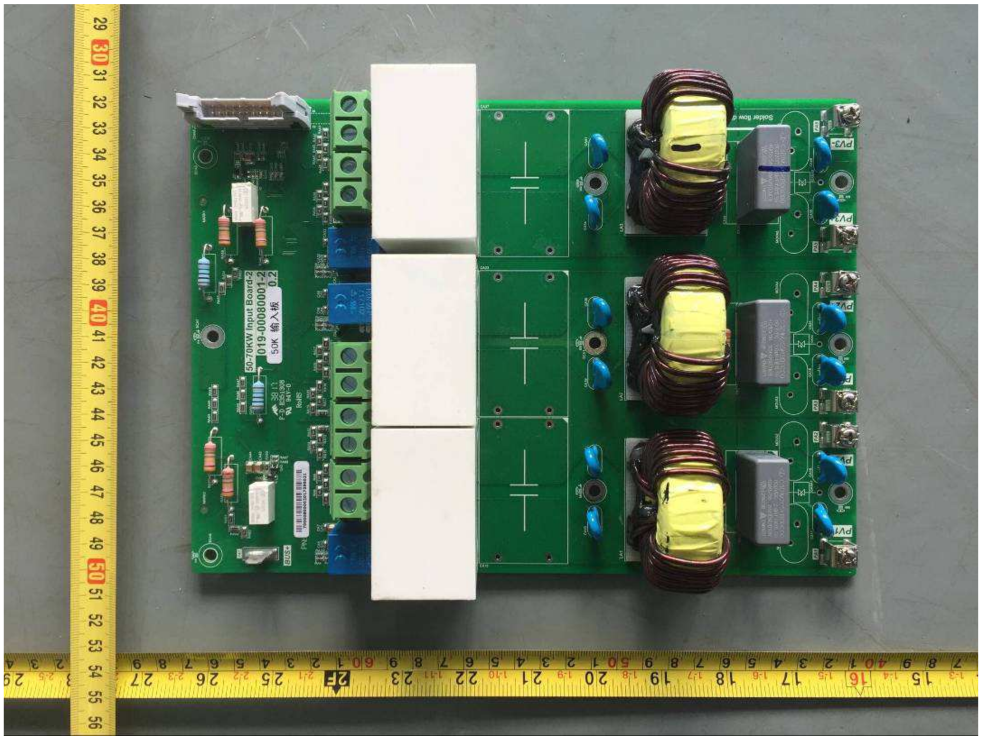
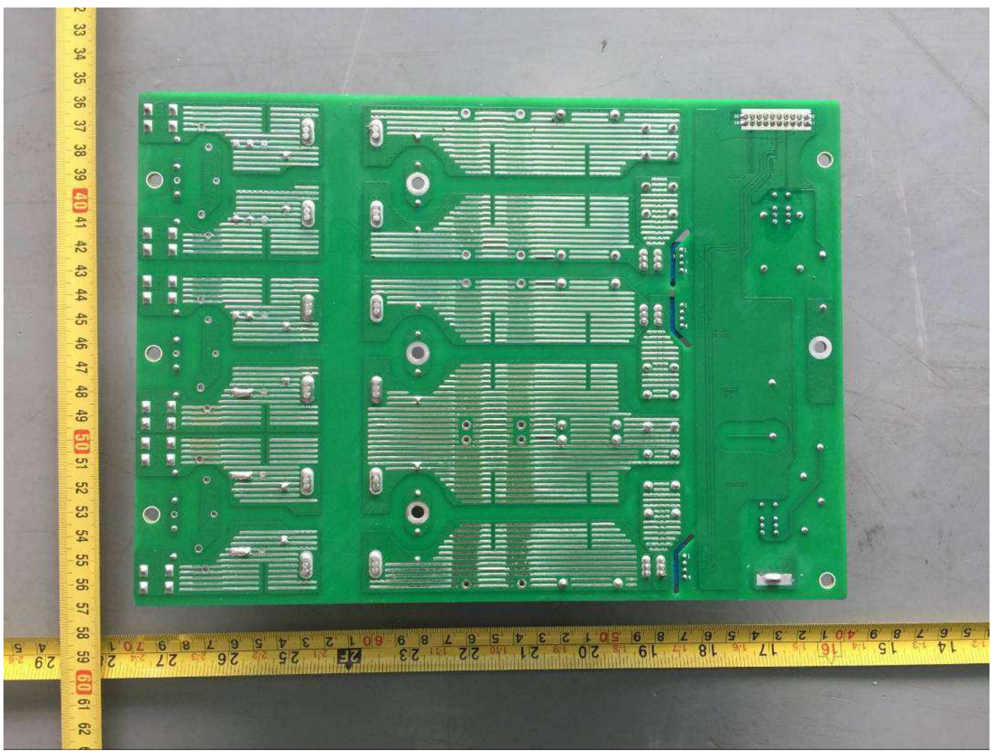


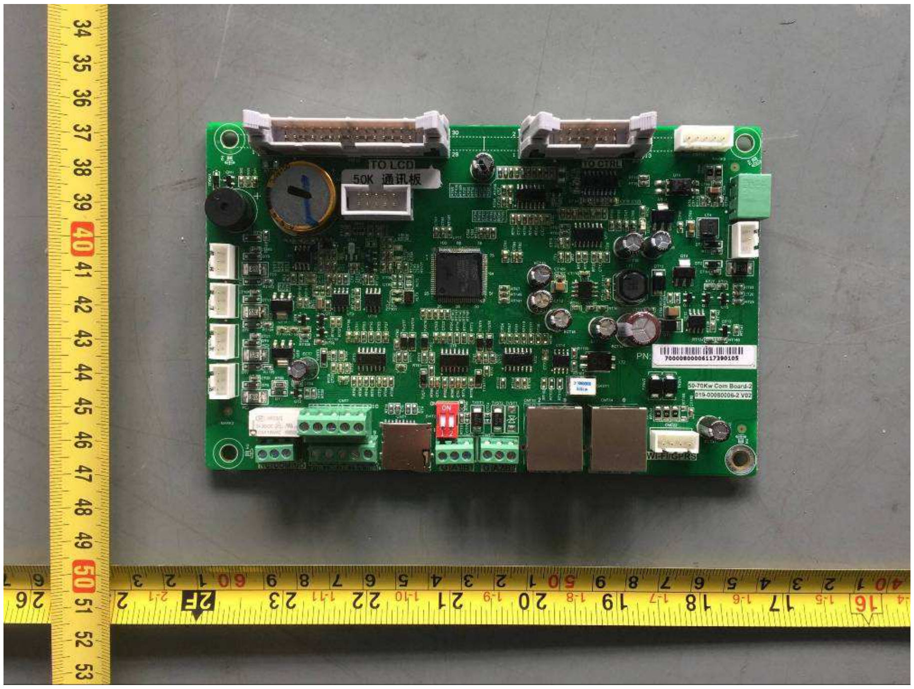
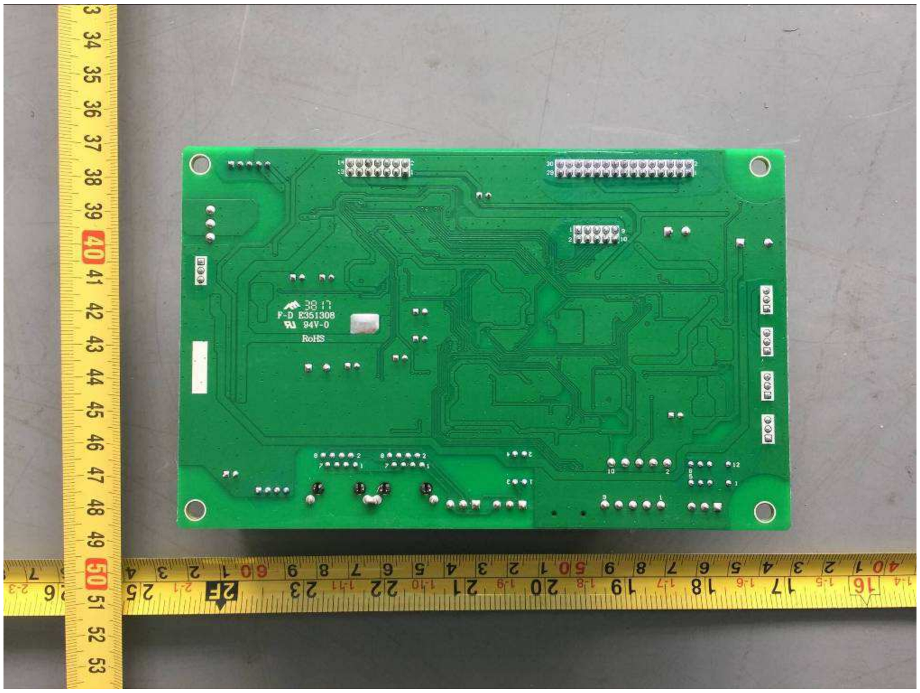
AC output board component side view

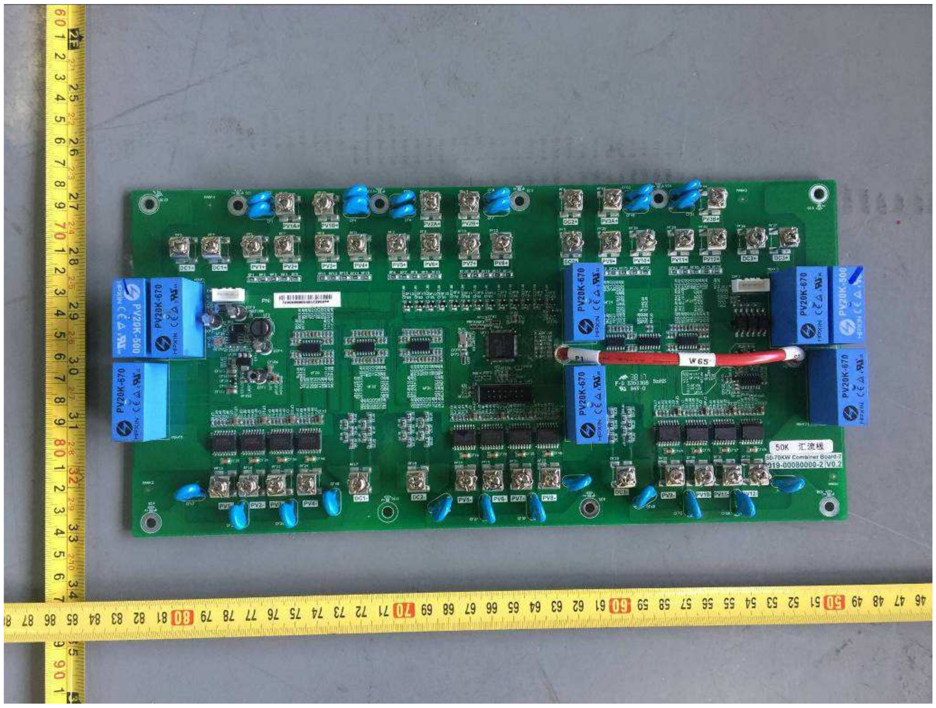
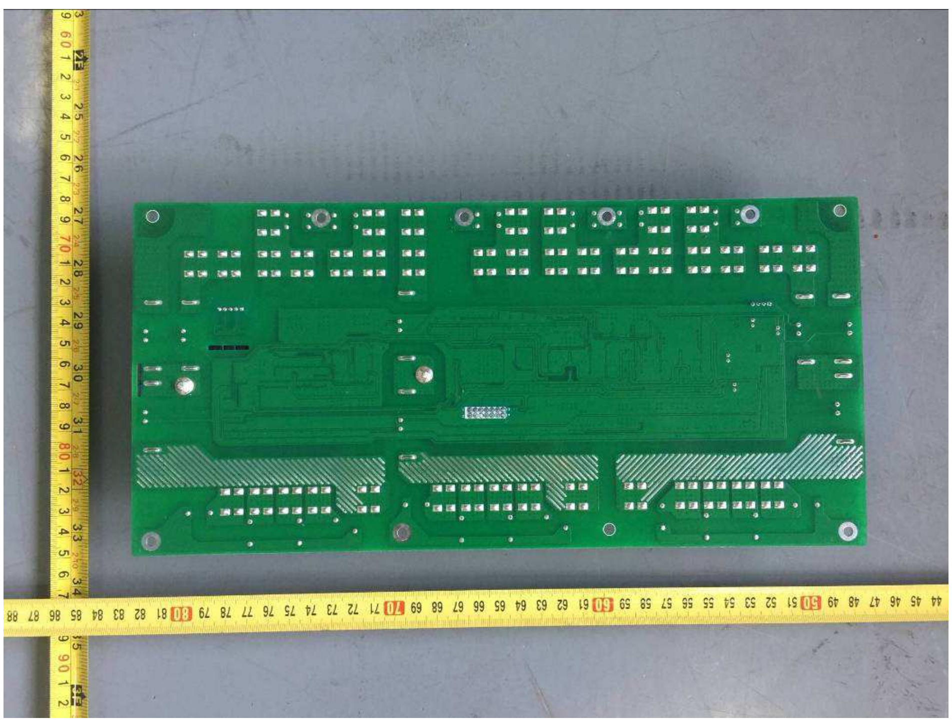


AC output board solder side view

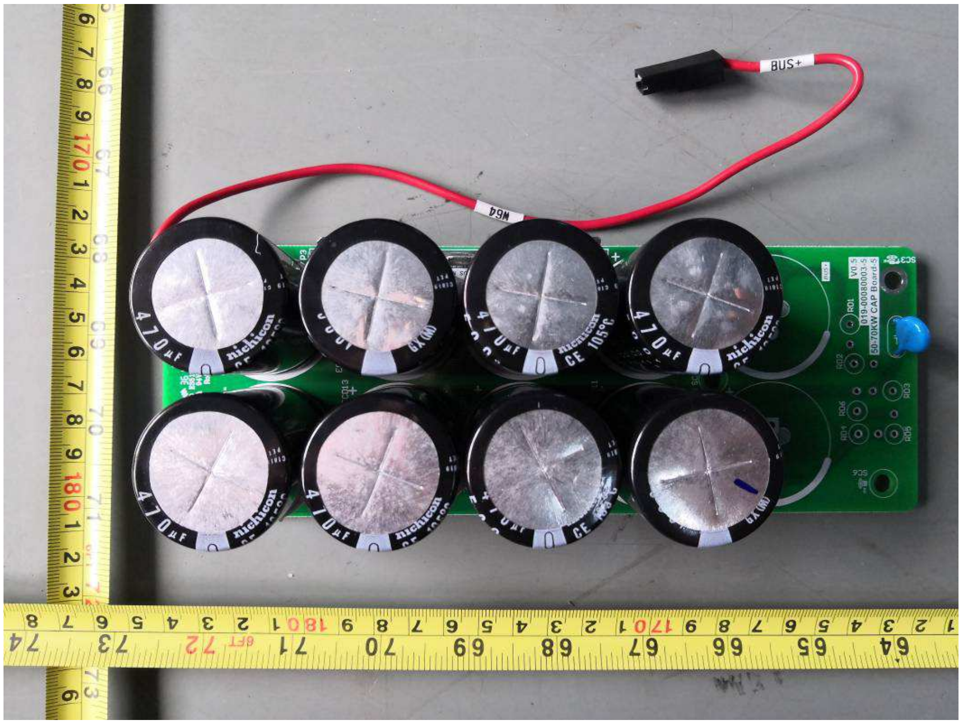


DC input board component side view

DC input board solder side view


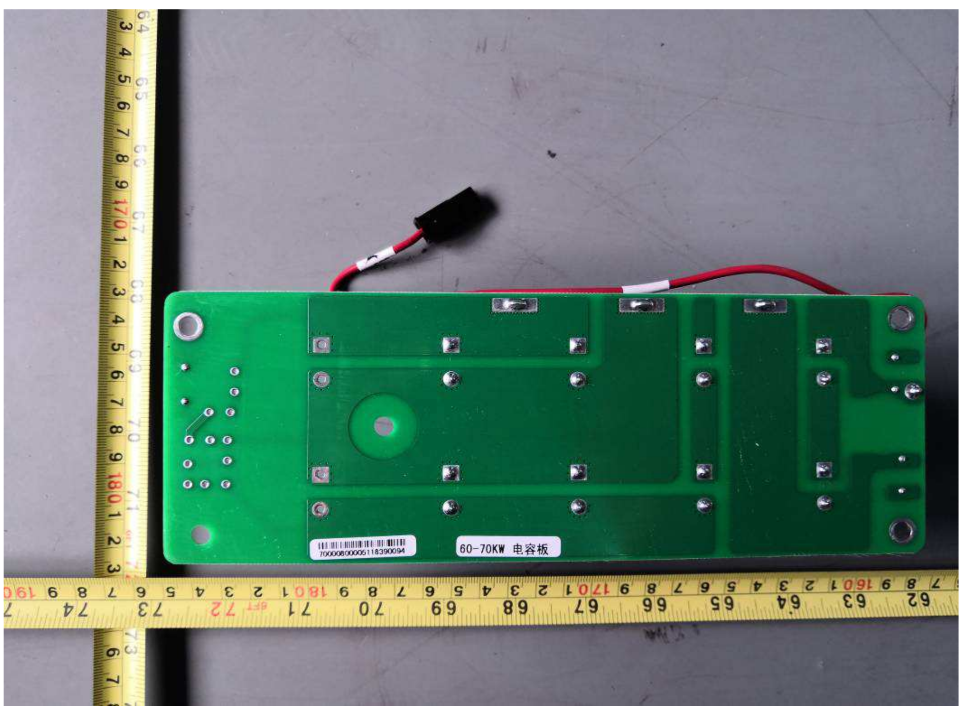
Communication board component side view

Communication board solder side view


Junction board component side view

Junction board solder side view


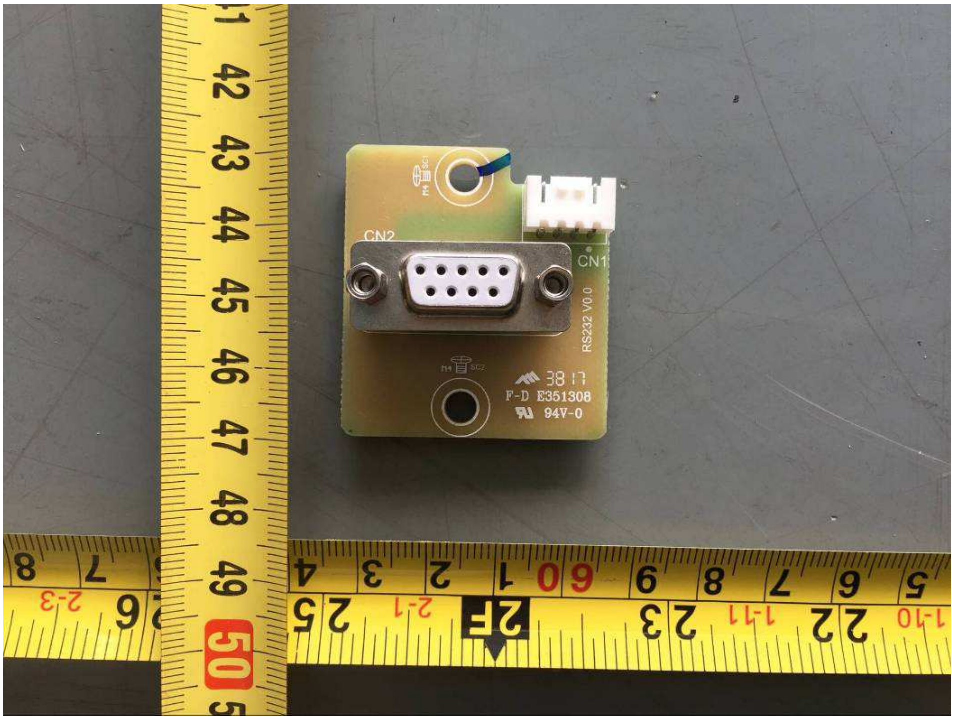
Capacitor board component side view



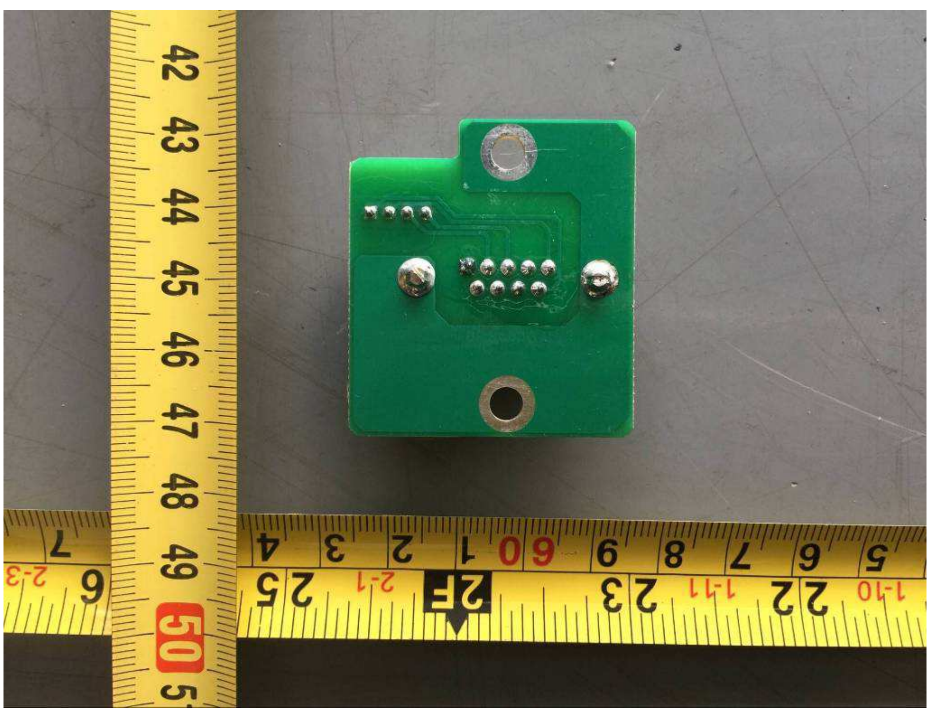
Capacitor board solder side view



RS232 board component side view



RS232 board solder side view



Internal view