TEST REPORT

EN 50438

Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks

Report reference number ..... :	**PV170207N030-1**
Date of issue ..... ……..:	2017-03-28
Total number of pages ..... ……..:	120
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 ..... :	**VOLTRONIC POWER TECHNOLOGY CORP.**
Address ..... :	5F, No. 151, Xinhu 1st Road, Neihu District, Taipei, Taiwan
Test specification	
Standard ..... :	EN 50438:2013
	with deviations according the national network and system protection for Czech Republic, Poland, Denmark, Finland, Ireland, Norway
Certificate ..... :	**Certificate of compliance**
Test report form number. ..... :	EN 50438:2013
Master TRF ..... :	Bureau Veritas Consumer Products Services Germany GmbH
Test item description ..... :	**Hybrid solar inverter**
Trademark ..... :	N/A
Model / Type ..... :	InfiniSolar 10kW
Ratings ..... :	See below
MPP DC voltage range [V] ..... :	400 - 800
Input DC voltage range [V] ..... :	300 - 900
Input DC current [A] ..... :	18,6 x 2 strings
Battery Input DC voltage range [V] .. [Discharge] ..... :	48Vdc
Battery Input AC current [A] ..... [Discharge] ..... :	275A
Output DC voltage range [V] ..... [Battery Charge] ..... :	48Vdc

Ratings ..... :	See below.
Output DC current [A] ..... [Battery Charge] ..... :	200A
Output AC voltage [V] ..... :	230/400, 3/N/PE
Output AC current [A]..... :	14,5
Output power [VA]..... :	10000

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)..... :	Kevin Liu	
Approved by (name and signature)..... :	James Huang	
Manufacturer's name..... :	**VOLTRONIC POWER TECHNOLOGY CORP.**	
Factory address ..... :	1-4F, Building 5, YuSheng Industrial Park, No. 467, Section Xixiang, National Highway 107, Xixiang, Bao An District, Shenzhen, China	

Document History			
Date	**Internal reference**	**Modification / Change / Status**	**Revision**
2017-03-28	Kevin Liu	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.. :	IP20 according to EN 60529
Mass of equipment [kg]..... :	45

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..... :	2016-02-01 2017-02-07
Date(s) of performance of test..... :	2016-02-01 to 2016-04-22 2017-02-07 to 2017-03-28

General remarks:

The test result presented in this report relate only to the object(s) tested. The report shall state compliance of the tested objects with the requirements of EN 50438. This report shall not be reproduced in part or in full without the written approval of the issuing testing laboratory.

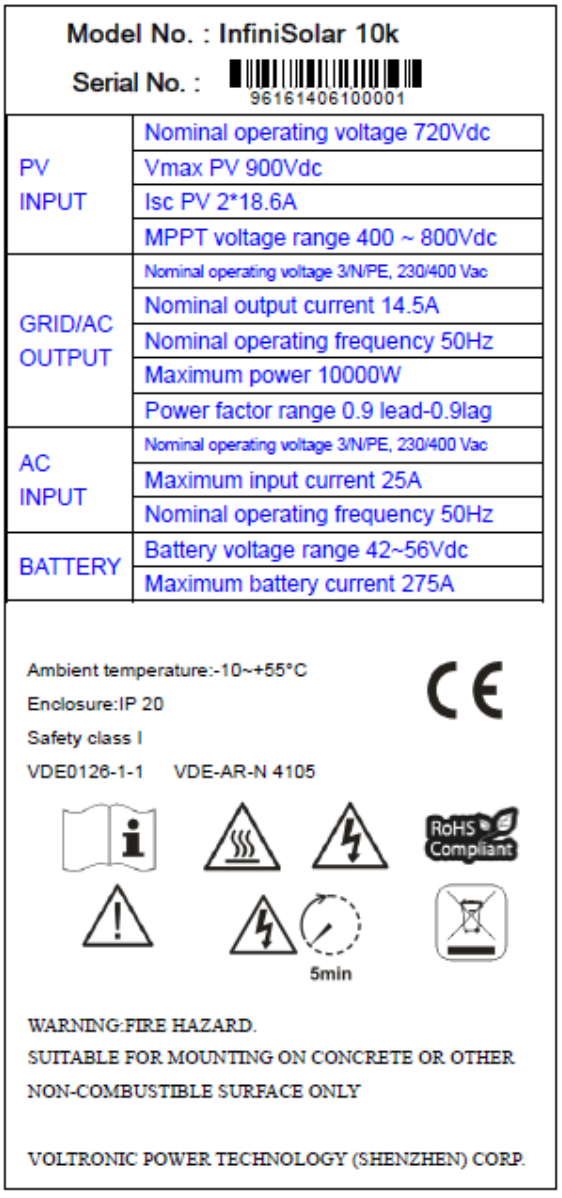
”(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

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

This Test Report consists of the following documents:

1. Test Report
   - 4.2. Normal operating range
   - 4.3 / 4.4. Reactive power capability and control modes
   - 4.5. Voltage control by active power
   - 4.6. Interface protection
   - 4.7. Connection and starting to generate electrical power
   - 4.8. Power quality
2. Pictures of the unit – Annex 1
3. Test equipment list – Annex 2

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 two relays. This assures that the opening of the output circuit will also operate in case of one error.

This unit is three phase inverter, that it is combine with UPS function and operation mode. The inverter is able to generate power from solar modules to feed the grid(utility) and charge extern battery, also feed in the power to grid from the extern batteries and PV array.

The Solar converter provides with PV array and external battery of input.

The input of Solar converter can be supplied from PV array and/or external battery only.

Rate of change of frequency (RoCoF) detection was used for LOM protection.

Description of the power circuit (Figure 1):

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

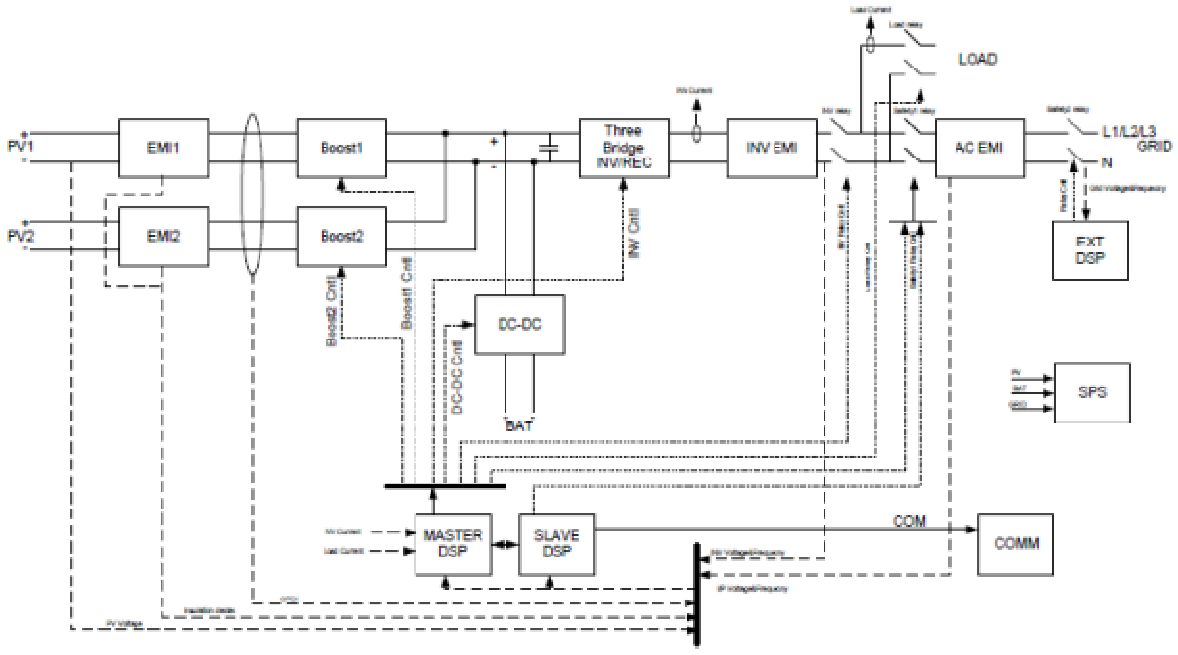


Figure 1 – Block diagram

The internal control is redundant built. It consists of Microcontroller Master DSP(U3) and Slave DSP(U4).

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

The Slave DSP is measures the grid voltage, AC current, grid frequency and residual current, also can switch off the relays independently, and communicate with Master DSP each other.

The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the Master DSP. The Master DSP 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. Both CPU can switch of the relays.

The product was tested on:
hardware version: 00G
software version: 00G

General remarks:

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"(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.

The following suffixes are used for variables in tables and figures:

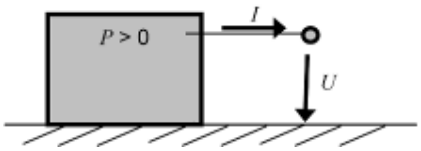
- "P_n" for the nominal active power:

  $P_n = U_n \times I_n \times \cos \varphi_n$ (single-Phase); $P_n = \sqrt{3}\ U_n \times I_n \times \cos \varphi_n$ (three-Phase)
- "P_M" for the momentary power
- "(c)" for over-excited
- "(i)" for under-excited

Active and reactive power:

The regarded system of the voltage and current vectors is the load view (Figure 2):

- If the inverter feeds to the grid the active power is measured with negative sign. For the sake of reading the document the measured active infeed power has a positive sign



- If the inverter consumes inductive reactive power the reactive power is marked "inductive" or has a positive sign.

- If the inverter consumes capacitive reactive power the reactive power is marked "capacitive" or has a negative sign.

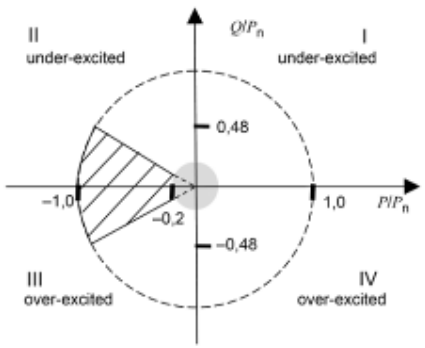


Figure 2

Default interface protection settings according EN 50438:2013:			
Parameter	**Max. disconnection time**	**Min. operate time**	**Trip value**
Over voltage – stage 1 [a]	3 s	-	230V +10% (253 V)
Over voltage – stage 2	0,2 s	0,1 s	230V +15% (264,5 V)
Under voltage	1,5 s	1,2 s	230V -15% (195,5V)
Over frequency	0,5 s	0,3 s	52 Hz
Under frequency	0,5 s	0,3 s	47,5 Hz
Reconnection settings for voltage		$0,85\ U_n \le U \le 1,10\ U_n$	
Reconnection settings for frequency		47,5 Hz ≤ f ≤ 50,05 Hz	
Reconnection time		≥ 60 s	
Active power gradient after reconnection		10 % P_n / min	
Permanent DC-injection		0,5% of rated inverter output current or 20mA	
Loss of mains according EN 62116		Inverter shall disconnect within 2 s.	

The stated currents and voltages are 'true r.m.s.'-values.

The voltages in this table are

- phase-to-neutral in 230 V single phase systems and 230/400 V systems,
- phase-to-phase in a multiphase 230 V system.

Poland with default settings, no deviations

[a] Over voltage – stage1: 10 min-mean-value corrsponding to EN 50160.

Tolerances on trip values:

- Voltage: ± 1% of U_n
- Frequency: ± 0,05 Hz
- Disconnection time : ± 10%

The following deviations for Czech Republic, have been applied according the EN 50438:2013:		
Parameter	**Max. clearance time**	**Trip setting**
Over voltage	0,2s	230V +15% (264,5V)
Under voltage	0,2s	230V -15% (195,5V)
Over frequency	0,5s	52Hz
Under frequency	0,5s	47,5Hz

In compliance with "Operational rules for distribution networks" of the Distribution System Operators.

Different settings as above shall be approved by DSO.

Document "Operational rules for distribution networks" is published by the DSO's of the Czech Republic – on their websites.

Settings for automatic reconnection shall be approved by DSO.

Prior to installation the DSO has to be requested for permission for the connection of the microgenerators.

The following deviations for Denmark, have been applied according the EN 50438:2013:			
Parameter	**Max. disconnection time**	**Min. relay operate time**	**Trip value[a]**
Over voltage (stage 2)[b]	0,2s	0,1s	230V +13% (259,9V)
Over voltage (stage 1)	40s	39s	230V +10% (253,0V)
Under voltage (stage 1)	10s	9s	230V -10% (207,0V)
Over frequency	0,2s	0,1s	52Hz
Under frequency	0,2s	0,1s	47,5Hz
ROCOF[c]	0,2s	0,1s	2,5 Hz/s

[a] All values are true 50 Hz RMS values. The micro-generator shall disconnect d if a parameter deviates more from its nominal value than the trip setting. A parameter shall not initiate a disconnection if it is between the nominal value and the trip setting.
Tolerances on trip values:
- voltage: ± 1 % of nominal voltage,
- frequency: ± 20 mHz,
- time: ± 10 %.

[b] A stage 2 protection is required if the micro-generator can generate voltages in excess of 230 V + 13 %.
[c] The use of phase shift relay as LoM detection is not allowed.
[d] Disconnection of the micro-generator in response to an interface protection operation shall be achieved by the separation of mechanical contacts providing at least the equivalent of basic insulation.

The following deviations for Finland, have been applied according the EN 50438:2013:		
Parameter	**Max. clearance time**	**Trip setting**
Over voltage	0,2s	230V +10% (253,0V)
Under voltage	0,2s	230V -15% (195,5V)
Over frequency	0,2s	51,5Hz
Under frequency	0,2s	47,5Hz
LOM[a]	Maximum clearance time: 5 s	

[a] LoM protection shall use recognised techniques suitable for the distribution network protection.
REMARK Isolation of the micro-generator shall be achieved by the separation of mechanical contacts.
This mechanical device shall be a lockable isolation switch.

The following deviations for Ireland, have been applied according the EN 50438:2013:		
Parameter	**Clearance time**	**Trip setting**
Over voltage	0,5s	230V +10% (253,0V)
Under voltage	0,5s	230V -10% (207,0V)
Over frequency	0,5s	50 Hz + 1% (50,5Hz)
Under frequency	0,5s	50 Hz – 4% (48,0Hz)
An explicit Loss of Mains functionality shall be included. Established methods such as, but not limited to, Rate of Change of Frequency, Vector Shift or Source Impedance Measurement may be used. Where Source Impedance is measured, this shall be achieved by purely passive means, Any implementation which involves the injection of pulses onto the distribution network, shall not be permitted.		
ROCOF (where used)	0,5s	0,4 Hz/s
Vector Shift (where used)	0,5s	6°

The following deviations for Norway, have been applied according the EN 50438:2013:
National requirements: In Norway, the Regulation REG. N° 301 of 11 March 1999: “Regulations governing metering, settlement and coordinated action in connection with electricity trading and invoicing of network services.” do not allow connection of a generator to the network without prior setting up of a new connection agreement with the DSO. The default setting of 4.6.2, Table 4 are applicable excepted as follows: – Footnote a for Norway: a Over-voltage – stage 1: 1 min mean value corresponding to Regulation 1557. (national deviation due to regulation Reg. N° 1557 of 30 November 2004: Regulations relating to the quality of supply in the Norwegian power system).

EN 50438:2013, clause 4: Tests			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.2	Normal operating range	D.3.1 / D.3.2 / D.3.3	**P**
4.3 / 4.4	Reactive power capability and control modes	D.3.4	**P**
4.5	Voltage control by active power	D.3.5 (under consideration)	**P**
4.6	Interface protection	Functional safety / D.2.3 / D. 2.4 / D.2.5 / D.3.7	**P**
4.7	Connection and starting to generate electric power	D.3.6	**P**
4.8	Power quality	D.3.8 / D.3.9 / D.3.10	**P**

EN 50438:2013: Interface protection			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.6	Interface protection	Functional safety / D.2.3 / D.2.4 / D.2.5	**P**

4.6.3 Single fault tolerance of the interface protection system			P
	Ambient temperature [°C] .....:	24°C	—
	Model/type of power supply .....:	DC: 62150H-1000S AC: AFC-33045T	—
	Manufacturer of power supply.....:	DC: Chroma AC: APC	—
	Rated markings of power supply.....:	DC: 0-1000V, 15A AC: 0-300V, 45KW	—

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-000293-00G Output current sensor defect CT3(Pin8)	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,05A	Error message:"05 ERROR" (Inverter current exceed the upper limit); Inverter was disconnect from grid immediately.
71-000293-00G Output current sensor defect CT2(Pin9)	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,05A	Error message:"05 ERROR" (Inverter current exceed the upper limit); Inverter was disconnect from grid immediately.
71-000293-00G Relay defect RY7(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY5(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY2(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY1(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY9(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY8(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY6(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.
71-000293-00G Relay defect RY4(Pin3&Pin4)	Short before start up	230V 0,01A	800V 0,02A	10min	--	230V 0,01A	800V 0,02A	Error message:"07 ERROR" (relay work abnormal)', Inverter does not start up.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-000293-00G Grid voltage monitoring R93	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R89	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R13	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R17	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R8	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R4	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R92	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R88	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R18	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R16	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000293-00G Grid voltage monitoring R7	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-000293-00G Grid voltage monitoring R3	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000297-00G Isolation monitoring defect R56	Open before start up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (insulation resistance); Inverter does not start up.
71-000297-00G Isolation monitoring R68	Open before start up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (insulation resistance); Inverter does not start up.
71-000297-00G Isolation monitoring defect R82	Open before start up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (insulation resistance); Inverter does not start up.
71-000297-00G Isolation monitoring defect R89	Open before start up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (insulation resistance); Inverter does not start up.
71-000297-00G Isolation monitoring defect R158	Open before start up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (insulation resistance); Inverter does not start up.
71-000368-00G Grid voltage monitoring defect R1	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R 5	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R9	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R13	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R17	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-000368-00G Grid voltage monitoring defect R21	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G RELAY Board R25	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R29	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R33	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R37	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R41	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R45	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R2	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R6	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R10	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R14	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-000368-00G Grid voltage monitoring defect R18	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R22	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R26	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R30	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R34	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R38	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R42	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G Grid voltage monitoring defect R46	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR" (Line voltage is different)'; PV inverter was disconnected from grid immediately.
71-000368-00G DSP lost of control C73	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Inverter was shut down immediately.
71-500375-00G DSP lost of control XL1	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Shutdown immediately, No breakdown
71-500375-00G DSP lost of control C12	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Shutdown immediately, No breakdown

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-500375-00G DSP lost of control C72	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Shutdown immediately, No breakdown
71-500375-00G DSP lost of control XL3	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Shutdown immediately, No breakdown
71-500375-00G DSPs communication defect R528	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: “17 ERROR” (Comminication loss between master CPU and slave CPU)’, PV inverter was disconnected from grid immediately.
71-500375-00G DSPs communication defect R527	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: “17 ERROR” (Comminication loss between master CPU and slave CPU)’, PV inverter was disconnected from grid immediately.
71-500375-00G Inverter voltage monitoring defect U10(Pin5&Pin6)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:”36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Inverter voltage monitoring defect R75	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:”36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Inverter voltage monitoring defect U10(Pin9&Pin10)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:”36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Inverter voltage monitoring defect R84	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:”36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Grid frequency monitoring defect R93	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: “04 warning” (Line frequency LOW)’, PV inverter was disconnected from grid immediately.
71-500375-00G Grid frequency monitoring defect U4(Pin8&Pin9)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: “04 warning” (Line frequency LOW)’, PV inverter was disconnected from grid immediately.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-500375-00G Grid voltage monitoring defect U11(Pin2&Pin3)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Grid voltage monitoring defect R101	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Grid voltage monitoring defect U11(Pin5&Pin6)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Grid voltage monitoring defect R106	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message:"36 ERROR(Line voltage is different), PV inverter was disconnected from grid immediately.
71-500375-00G Gird frequency monitoring defect U81(Pin5&Pin6)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: "04 warning" (Line frequency LOW)', PV inverter was disconnected from grid immediately.
71-500375-00G Gird frequency monitoring defect R119	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: "04 warning" (Line frequency LOW)', PV inverter was disconnected from grid immediately.
71-500375-00G Gird frequency monitoring defect U81(Pin2&Pin3)	Short	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: "04 warning" (Line frequency LOW)', PV inverter was disconnected from grid immediately.
71-500375-00G Gird frequency monitoring defect R126	Open	230V 14,3A	800V 2x6,25A	2min	--	230V 0,01A	800V 0,02A	Error message: "04 warning" (Line frequency LOW)', PV inverter was disconnected from grid immediately.
71-500375-00G Isolation detection defect U14(Pin9&Pin10)	Short before start-up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (Solar insulation resistance too low)', PV inverter was disconnected from grid immediately.
71-500375-00G Isolation detection defect R182	Open before start-up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (Solar insulation resistance too low)', PV inverter was disconnected from grid immediately.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
71-500375-00G Isolation detection defect U14(Pin12&Pin13)	Short before start-up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (Solar insulation resistance too low)', PV inverter was disconnected from grid immediately.
71-500375-00G Isolation detection defect R187	Open before start-up	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message:"13 ERROR" (Solar insulation resistance too low)', PV inverter was disconnected from grid immediately.
71-500375-00G Residual current monitoring defect R25	Open	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message: "16 ERROR" (GFCI Over), No hazard, PV inverter was disconnected from grid immediately.
71-500375-00G Residual current monitoring defect C52	Short	230V 0,01A	800V 0,02A	2min	--	230V 0,01A	800V 0,02A	Error message: "16 ERROR" (GFCI Over), No hazard, PV inverter was disconnected from grid immediately.
The errors in the control circuit simulate that the safety is even under one error ensured.								
Addendum – Shutdown device								
Each active phase can be switched. (L and N)								Yes
If no galvanic separation between AC and DC (PV): Two relays in series on each active phase are necessary to fulfil the basic insulation or simple separation based on the PV working voltage.								Two relays in series on each active phase

D.2.3 Interface protection: Over- /under-voltage (default settings) D.3.6.2 Connection after trip of interface protection	P

Test conditions			Output power: 6030W Frequency: 50+/-0,2Hz		
Phase	Limit [V]	Trip value [V]	Voltage step [V]	Disconnection time [s]	Limit [s]
L1	110% of Un = 253,0	252,0	230,0 to 258,0	0,066	t ≤ 3
		252,0	230,0 to 258,0	0,059	
		252,0	230,0 to 258,0	0,069	
		252,0	230,0 to 258,0	0,059	
		252,0	230,0 to 258,0	0,065	
	115% of Un = 264,5	264,8	230,0 to 268,0	0,170	0,1 ≤ t ≤ 0,2
		264,8	230,0 to 268,0	0,165	
		264,7	230,0 to 268,0	0,163	
		264,7	230,0 to 268,0	0,170	
		264,7	230,0 to 268,0	0,159	
	85% of Un = 195,5	195,0	230,0 to 192,0	1,373	1,2 ≤ t ≤ 1,5
		195,0	230,0 to 192,0	1,354	
		195,0	230,0 to 192,0	1,357	
		195,0	230,0 to 192,0	1,355	
		195,0	230,0 to 192,0	1,359	
L2	110% of Un = 253,0	252,0	230,0 to 258,0	0,073	t ≤ 3
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,072	
	115% of Un = 264,5	265,2	230,0 to 268,0	0,174	0,1 ≤ t ≤ 0,2
		265,2	230,0 to 268,0	0,175	
		265,2	230,0 to 268,0	0,176	
		265,2	230,0 to 268,0	0,179	
		265,2	230,0 to 268,0	0,173	
	85% of Un = 195,5	195,3	230,0 to 192,0	1,382	1,2 ≤ t ≤ 1,5
		195,3	230,0 to 192,0	1,370	
		195,3	230,0 to 192,0	1,386	
		195,3	230,0 to 192,0	1,369	
		195,3	230,0 to 192,0	1,362	
L3	110% of Un = 253,0	252,0	230,0 to 258,0	0,059	t ≤ 3
		252,0	230,0 to 258,0	0,069	
		252,0	230,0 to 258,0	0,076	
		252,0	230,0 to 258,0	0,063	
		252,0	230,0 to 258,0	0,063	
	115% of Un = 264,5	265,5	230,0 to 268,0	0,165	0,1 ≤ t ≤ 0,2
		265,5	230,0 to 268,0	0,162	
		265,5	230,0 to 268,0	0,166	
		265,5	230,0 to 268,0	0,175	
		265,5	230,0 to 268,0	0,157	
	85% of Un = 195,5	195,6	230,0 to 192,0	1,362	1,2 ≤ t ≤ 1,5
		195,6	230,0 to 192,0	1,377	
		195,6	230,0 to 192,0	1,370	
		195,6	230,0 to 192,0	1,376	
		195,6	230,0 to 192,0	1,293	

Note:

The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing. Lower and upper threshold voltage shall not fall or rise below or above 2,3V of the trip value itself. The disconnection time was measured by application of a negative voltage step from U_n to the operate value - 5% of U_n as well as positive voltage step from U_n to the operate value + 5% of U_n.

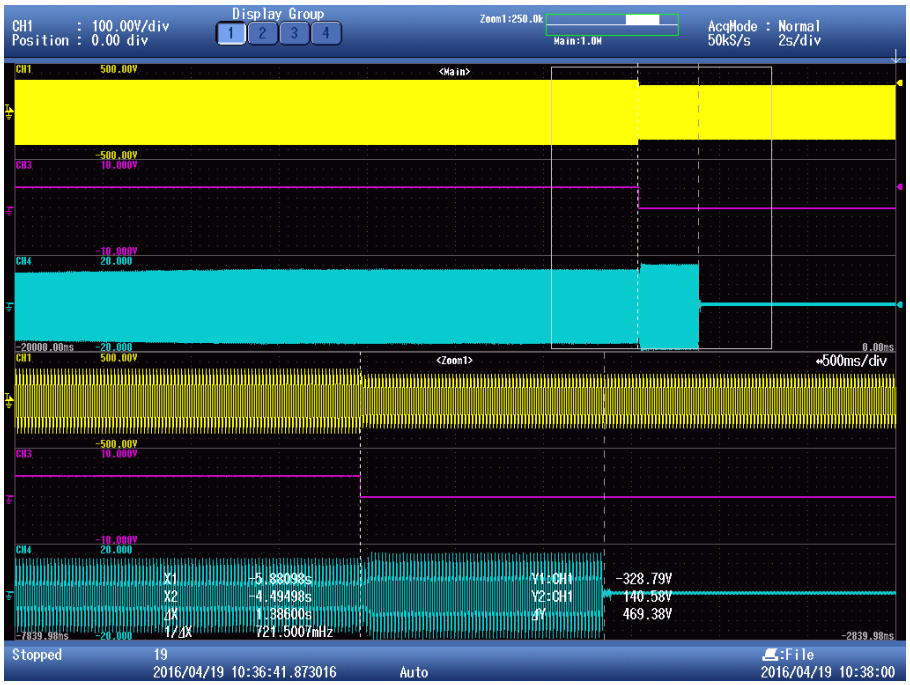
Scope pictures of the disconnection time_L1 Phase
Over-voltage – stage 1

Over-voltage – stage 2

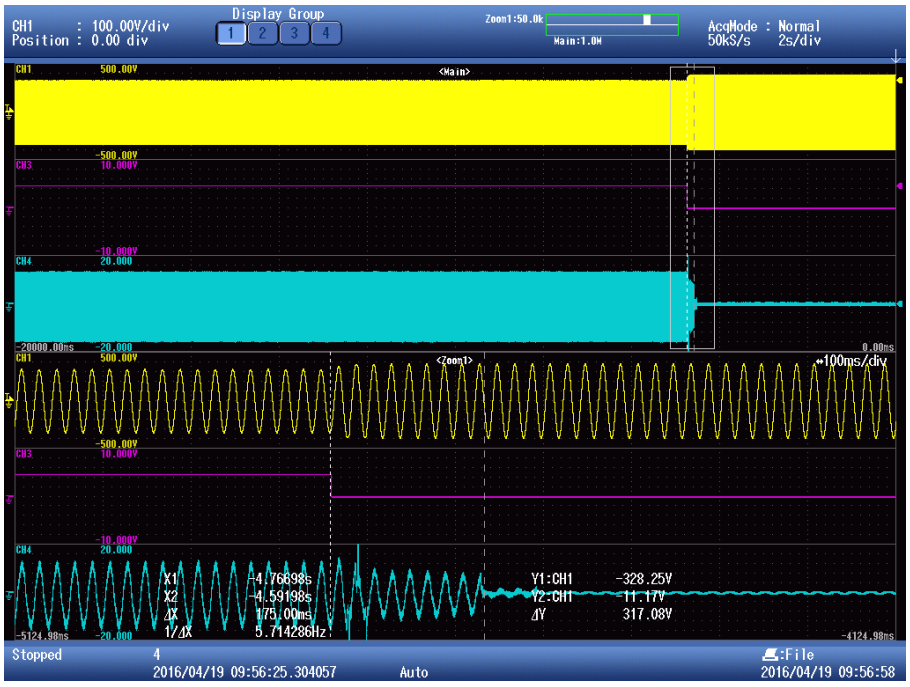
Under-voltage


Scope pictures of the disconnection time_L2 Phase
Over-voltage – stage 1

Over-voltage – stage 2


Under-voltage


Scope pictures of the disconnection time_L3 Phase
Over-voltage – stage 1

Over-voltage – stage 2


Under-voltage


D.2.3 Interface protection: Over- /under-voltage (Czech Republic settings) **D.3.6.2 Connection after trip of interface protection**	**P**

Test conditions			Output power: 6030W Frequency: 50+/-0,2Hz		
Phase	Limit [V]	Trip value [V]	Voltage step [V]	Disconnection time [s]	Limit [s]
L1	115% of Un = 264,5	264,5	230,0 to 268,0	0,072	t ≤ 0,2
		264,5	230,0 to 268,0	0,068	
		264,5	230,0 to 268,0	0,062	
		264,5	230,0 to 268,0	0,065	
		264,5	230,0 to 268,0	0,075	
	85% of Un = 195,5	196,0	230,0 to 192,0	0,070	t ≤ 0,2
		196,0	230,0 to 192,0	0,070	
		196,0	230,0 to 192,0	0,075	
		196,0	230,0 to 192,0	0,059	
		196,0	230,0 to 192,0	0,068	
L2	115% of Un = 264,5	264,5	230,0 to 268,0	0,068	t ≤ 0,2
		264,5	230,0 to 268,0	0,074	
		264,5	230,0 to 268,0	0,070	
		264,5	230,0 to 268,0	0,062	
		264,5	230,0 to 268,0	0,059	
	85% of Un = 195,5	195,5	230,0 to 192,0	0,073	t ≤ 0,2
		195,5	230,0 to 192,0	0,069	
		195,5	230,0 to 192,0	0,063	
		195,5	230,0 to 192,0	0,069	
		195,5	230,0 to 192,0	0,067	
L3	115% of Un = 264,5	266,3	230,0 to 268,0	0,065	t ≤ 0,2
		266,3	230,0 to 268,0	0,064	
		266,3	230,0 to 268,0	0,070	
		266,3	230,0 to 268,0	0,075	
		266,3	230,0 to 268,0	0,072	
	85% of Un = 195,5	197,6	230,0 to 192,0	0,067	t ≤ 0,2
		197,6	230,0 to 192,0	0,065	
		197,6	230,0 to 192,0	0,069	
		197,6	230,0 to 192,0	0,059	
		197,6	230,0 to 192,0	0,070	

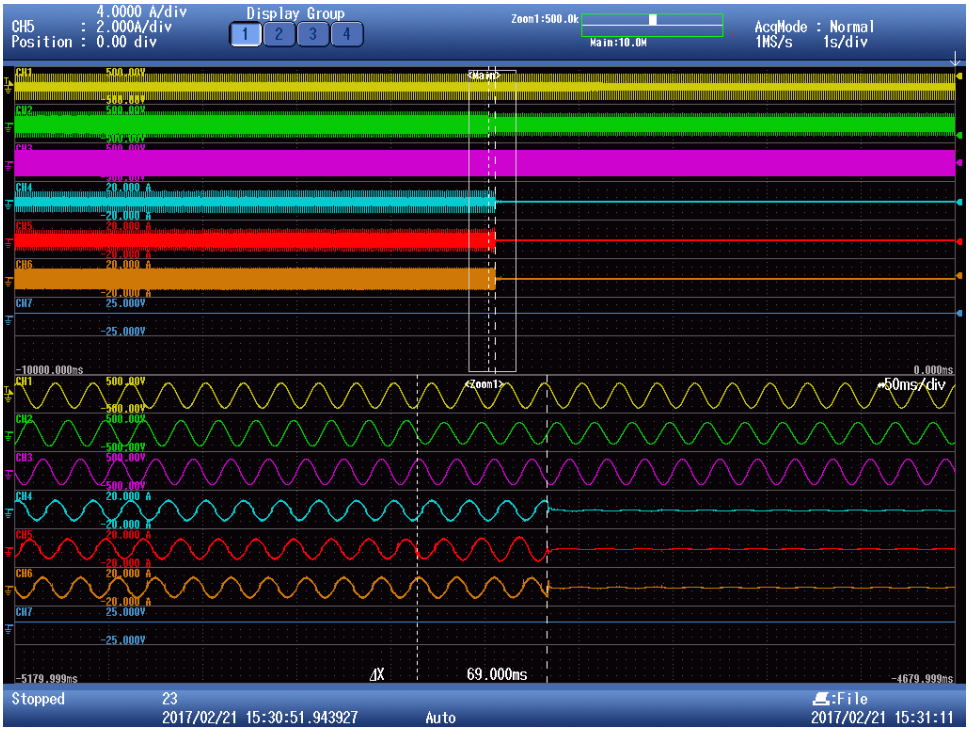
Note:

The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing. Lower and upper threshold voltage shall not fall or rise below or above 2,3V of the trip value itself. The disconnection time was measured by application of a negative voltage step from U_n to the operate value - 5% of U_n as well as positive voltage step from U_n to the operate value + 5% of U_n.

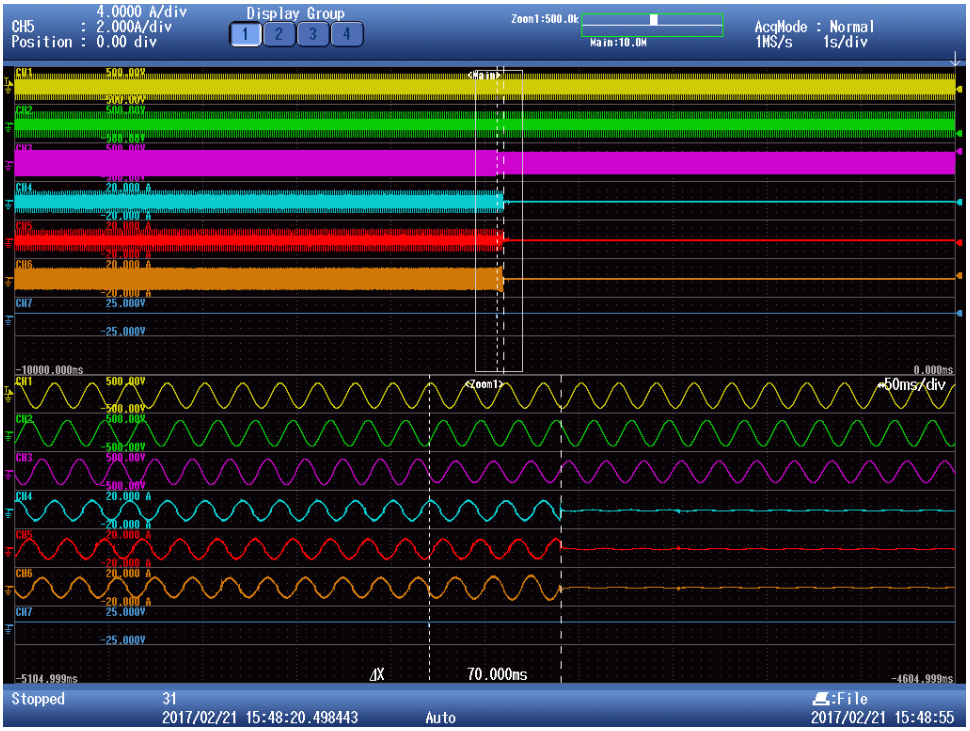
Scope pictures of the disconnection time_L1 Phase
Over-voltage

Under-voltage


Scope pictures of the disconnection time_L2 Phase
Over-voltage

Under-voltage


Scope pictures of the disconnection time_L3 Phase
Over-voltage

Under-voltage


D.2.3 Interface protection: Over- /under-voltage (Denmark settings) D.3.6.2 Connection after trip of interface protection	P

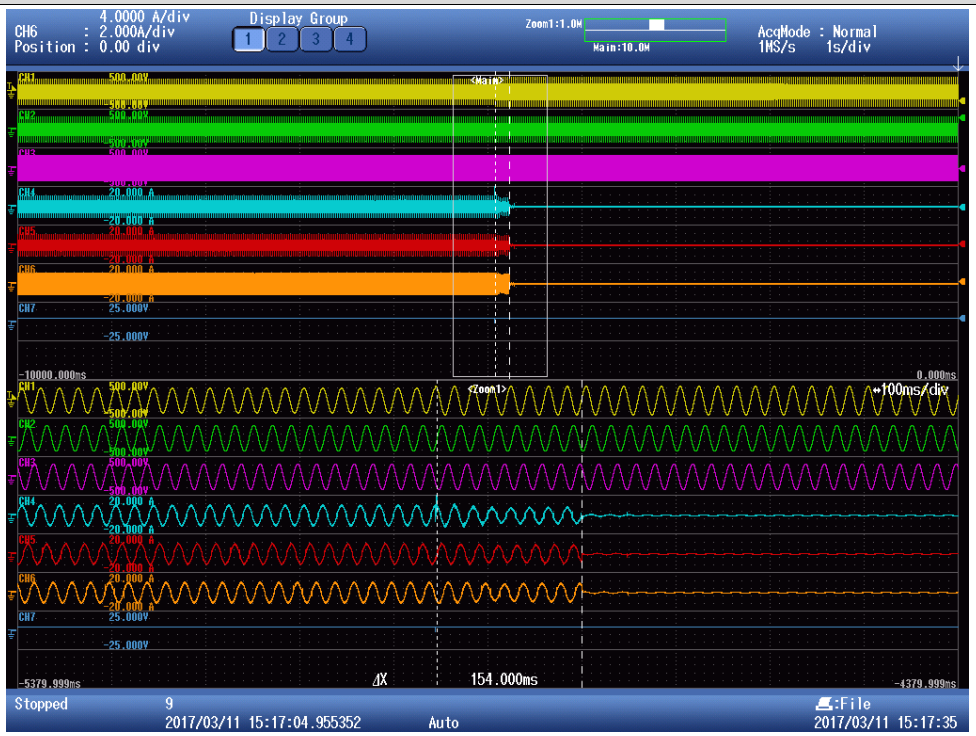
Test conditions			Output power: 6030W Frequency: 50+/-0,2Hz		
Phase	Limit [V]	Trip value [V]	Voltage step [V]	Disconnection time [s]	Limit [s]
L1	113% of Un = 259,9	260,0	230,0 to 265,0	0,145	0,1 ≤ t ≤ 0,2
		260,0	230,0 to 265,0	0,147	
		260,0	230,0 to 265,0	0,154	
		260,0	230,0 to 265,0	0,144	
		260,0	230,0 to 265,0	0,146	
	110% of Un = 253,0	253,0	230,0 to 258,0	39,5	39 ≤ t ≤ 40
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
	90% of Un = 207,0	207,0	230,0 to 212,0	9,5	9 ≤ t ≤ 10
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
L2	113% of Un = 259,9	260,0	230,0 to 265,0	0,150	0,1 ≤ t ≤ 0,2
		260,0	230,0 to 265,0	0,152	
		260,0	230,0 to 265,0	0,160	
		260,0	230,0 to 265,0	0,150	
		260,0	230,0 to 265,0	0,149	
	110% of Un = 253,0	253,0	230,0 to 258,0	39,5	39 ≤ t ≤ 40
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
	90% of Un = 207,0	207,0	230,0 to 212,0	9,5	9 ≤ t ≤ 10
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
L3	113% of Un = 259,9	260,0	230,0 to 265,0	0,155	0,1 ≤ t ≤ 0,2
		260,0	230,0 to 265,0	0,162	
		260,0	230,0 to 265,0	0,157	
		260,0	230,0 to 265,0	0,150	
		260,0	230,0 to 265,0	0,150	
	110% of Un = 253,0	253,0	230,0 to 258,0	39,5	39 ≤ t ≤ 40
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
		253,0	230,0 to 258,0	39,5	
	90% of Un = 207,0	207,0	230,0 to 212,0	9,5	9 ≤ t ≤ 10
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	
		207,0	230,0 to 212,0	9,5	

Note:

The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing. Lower and upper threshold voltage shall not fall or rise below or above 2,3V of the trip value itself. The disconnection time was measured by application of a negative voltage step from U_n to the operate value - 5% of U_n as well as positive voltage step from U_n to the operate value + 5% of U_n.

Scope pictures of the disconnection time_L1 Phase

Over-voltage (stage 2)



Over-voltage (stage 1)

Under-voltage

Scope pictures of the disconnection time_L2 Phase

Over-voltage (stage 2)

Over-voltage (stage 1)


Under-voltage


Scope pictures of the disconnection time_L3 Phase
Over-voltage (stage 2)

Over-voltage (stage 1)


Under-voltage


D.2.3 Interface protection: Over- /under-voltage (Finland settings) **D.3.6.2 Connection after trip of interface protection**	**P**

Test conditions			Output power: 6030W Frequency: 50+/-0,2Hz		
Phase	Limit [V]	Trip value [V]	Voltage step [V]	Disconnection time [s]	Limit [s]
L1	110% of Un = 253,0	252,0	230,0 to 258,0	0,066	t ≤ 0,2
		252,0	230,0 to 258,0	0,059	
		252,0	230,0 to 258,0	0,069	
		252,0	230,0 to 258,0	0,059	
		252,0	230,0 to 258,0	0,065	
	85% of Un = 195,5	196,0	230,0 to 192,0	0,070	t ≤ 0,2
		196,0	230,0 to 192,0	0,070	
		196,0	230,0 to 192,0	0,075	
		196,0	230,0 to 192,0	0,059	
		196,0	230,0 to 192,0	0,068	
L2	110% of Un = 253,0	252,0	230,0 to 258,0	0,073	t ≤ 0,2
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,072	
	85% of Un = 195,5	195,5	230,0 to 192,0	0,073	t ≤ 0,2
		195,5	230,0 to 192,0	0,069	
		195,5	230,0 to 192,0	0,063	
		195,5	230,0 to 192,0	0,069	
		195,5	230,0 to 192,0	0,067	
L3	110% of Un = 253,0	252,0	230,0 to 258,0	0,059	t ≤ 0,2
		252,0	230,0 to 258,0	0,069	
		252,0	230,0 to 258,0	0,076	
		252,0	230,0 to 258,0	0,063	
		252,0	230,0 to 258,0	0,063	
	85% of Un = 195,5	197,6	230,0 to 192,0	0,067	t ≤ 0,2
		197,6	230,0 to 192,0	0,065	
		197,6	230,0 to 192,0	0,069	
		197,6	230,0 to 192,0	0,059	
		197,6	230,0 to 192,0	0,070	

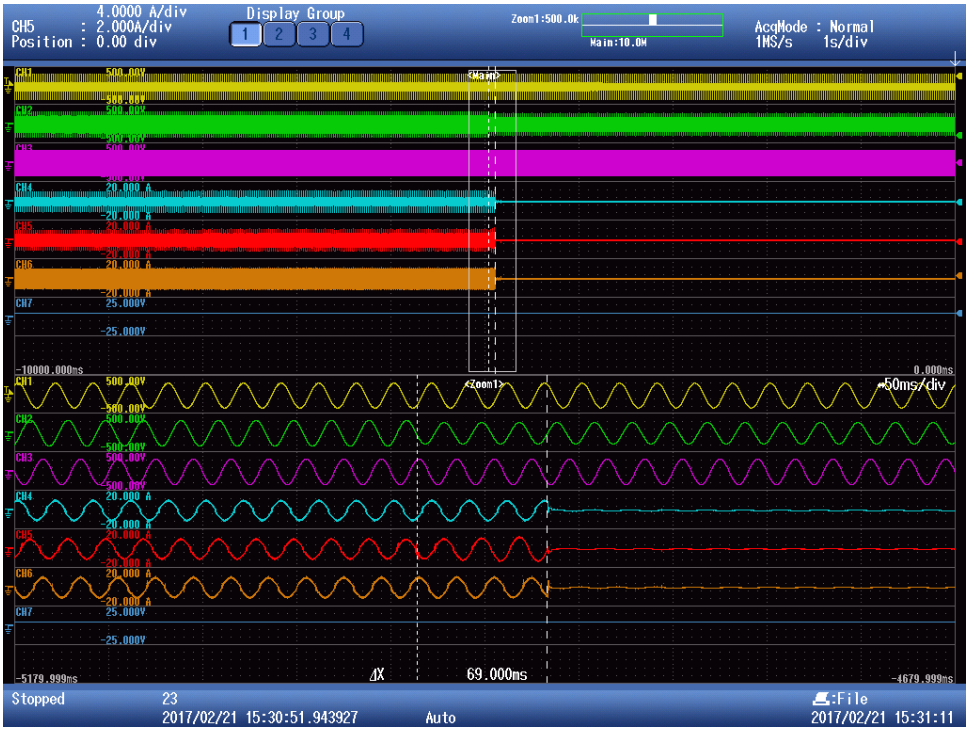
Note:

The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing. Lower and upper threshold voltage shall not fall or rise below or above 2,3V of the trip value itself. The disconnection time was measured by application of a negative voltage step from U_n to the operate value - 5% of U_n as well as positive voltage step from U_n to the operate value + 5% of U_n.

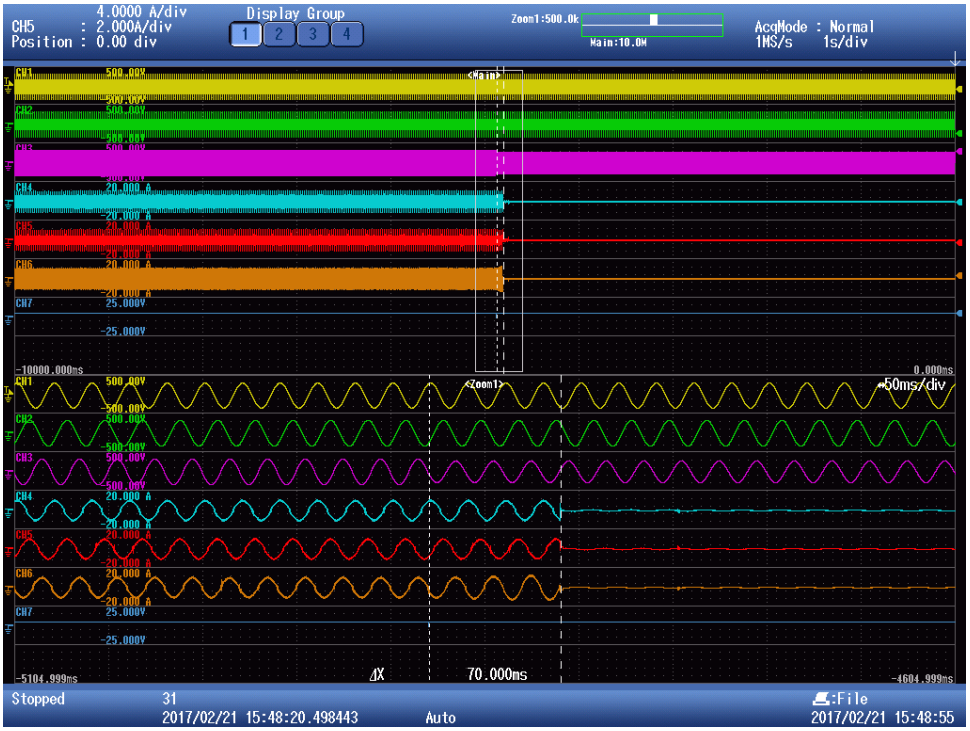
Scope pictures of the disconnection time_L1 Phase
Over-voltage

Under-voltage


Scope pictures of the disconnection time_L2 Phase
Over-voltage

Under-voltage


Scope pictures of the disconnection time_L3 Phase
Over-voltage

Under-voltage


D.2.3 Interface protection: Over- /under-voltage (Ireland settings) **D.3.6.2 Connection after trip of interface protection**	**P**

Test conditions			Output power: 6030W Frequency: 50+/-0,2Hz		
Phase	Limit [V]	Trip value [V]	Voltage step [V]	Disconnection time [s]	Limit [s]
L1	110% of Un = 253,0	252,0	230,0 to 258,0	0,066	t ≤ 0,5
		252,0	230,0 to 258,0	0,059	
		252,0	230,0 to 258,0	0,069	
		252,0	230,0 to 258,0	0,059	
		252,0	230,0 to 258,0	0,065	
	90% of Un = 207,0	207,0	230,0 to 203,0	0,061	t ≤ 0,5
		207,0	230,0 to 203,0	0,067	
		207,0	230,0 to 203,0	0,078	
		207,0	230,0 to 203,0	0,068	
		207,0	230,0 to 203,0	0,068	
L2	110% of Un = 253,0	252,0	230,0 to 258,0	0,073	t ≤ 0,5
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,065	
		252,0	230,0 to 258,0	0,072	
	90% of Un = 207,0	207,0	230,0 to 203,0	0,058	t ≤ 0,5
		207,0	230,0 to 203,0	0,064	
		207,0	230,0 to 203,0	0,063	
		207,0	230,0 to 203,0	0,068	
		207,0	230,0 to 203,0	0,075	
L3	110% of Un = 253,0	252,0	230,0 to 258,0	0,059	t ≤ 0,5
		252,0	230,0 to 258,0	0,069	
		252,0	230,0 to 258,0	0,076	
		252,0	230,0 to 258,0	0,063	
		252,0	230,0 to 258,0	0,063	
	90% of Un = 207,0	207,0	230,0 to 203,0	0,068	t ≤ 0,5
		207,0	230,0 to 203,0	0,067	
		207,0	230,0 to 203,0	0,076	
		207,0	230,0 to 203,0	0,059	
		207,0	230,0 to 203,0	0,070	

Note:

The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing. Lower and upper threshold voltage shall not fall or rise below or above 2,3V of the trip value itself. The disconnection time was measured by application of a negative voltage step from U_n to the operate value - 5% of U_n as well as positive voltage step from U_n to the operate value + 5% of U_n.

Scope pictures of the disconnection time_L1 Phase
Over-voltage

Under-voltage


Scope pictures of the disconnection time_L2 Phase
Over-voltage

Under-voltage


Scope pictures of the disconnection time_L3 Phase
Over-voltage

Under-voltage


4.2.2 Over-voltage-stage 1: 10-min-vale corresponding to EN 50160				P
Setting values of the protection:	Trip value Setting [V]	253		
	Setting $T_{disconnection\ trip\ value}$ [s]	600		
	Setting $T_{disconnection}$ [ms]	200		
Test:				
		Disconnection time [s]	Limit [s]	
a)	The voltage is set to 100% U_n and held for 600 s. Thereafter the voltage is set to 112% U_n. Disconnection must take place within 600 s.			
	Phase 1:	481 s	600 s	
	Phase 2:	495 s		
	Phase 3:	497 s		
b)	The voltage is set to U_n for 600 s and then to 108% U_n for 600 s. No disconnection should take place.			
	Phase 1:	No disconnection	Disconnection should not take place.	
	Phase 2:	No disconnection		
	Phase 3:	No disconnection		
c)	The voltage is set to 106 % U_n and held for 600 s. Thereafter the voltage is set to 114 % U_n. The disconnection should last for half the period as in Point a)*			
	Phase 1:	280 s	300 s	
	Phase 2:	280 s		
	Phase 3:	286 s		

Test:

a) This test serves as proof of the measurement accuracy and the maximum set time.

b) This test serves as proof of the measurement accuracy.

c) This test serves as proof of the correct formation of the 1 minute running mean value.

Assessment criterion:

The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1 % of U_N.

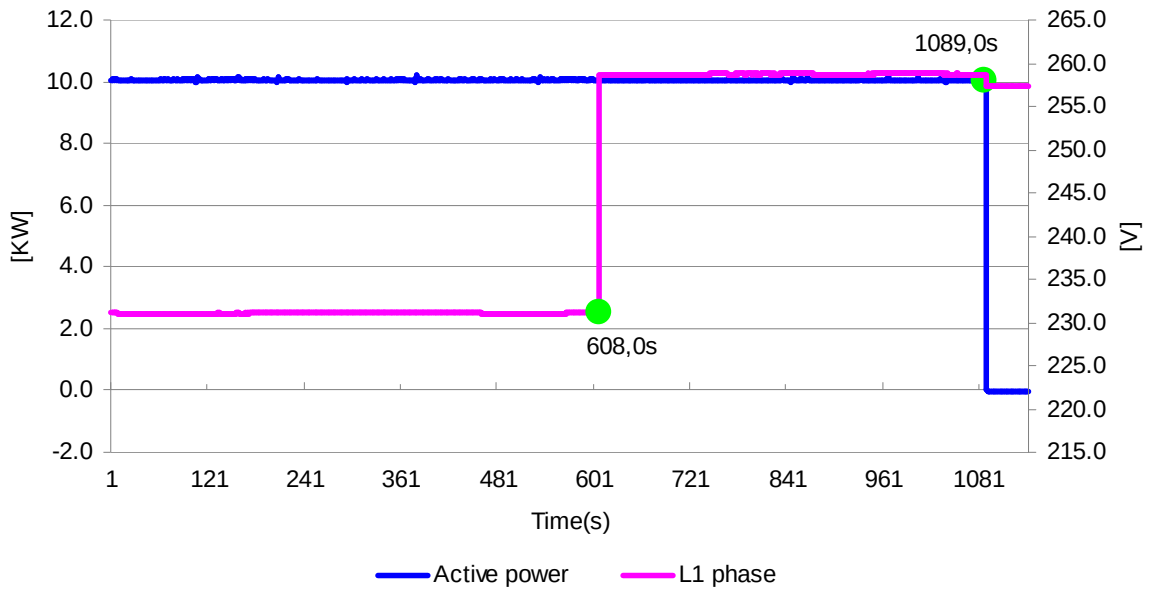
Limit values:

Rise-in voltage protection 1,1 U_N after a max. 60 s, the switch off after 200 ms.

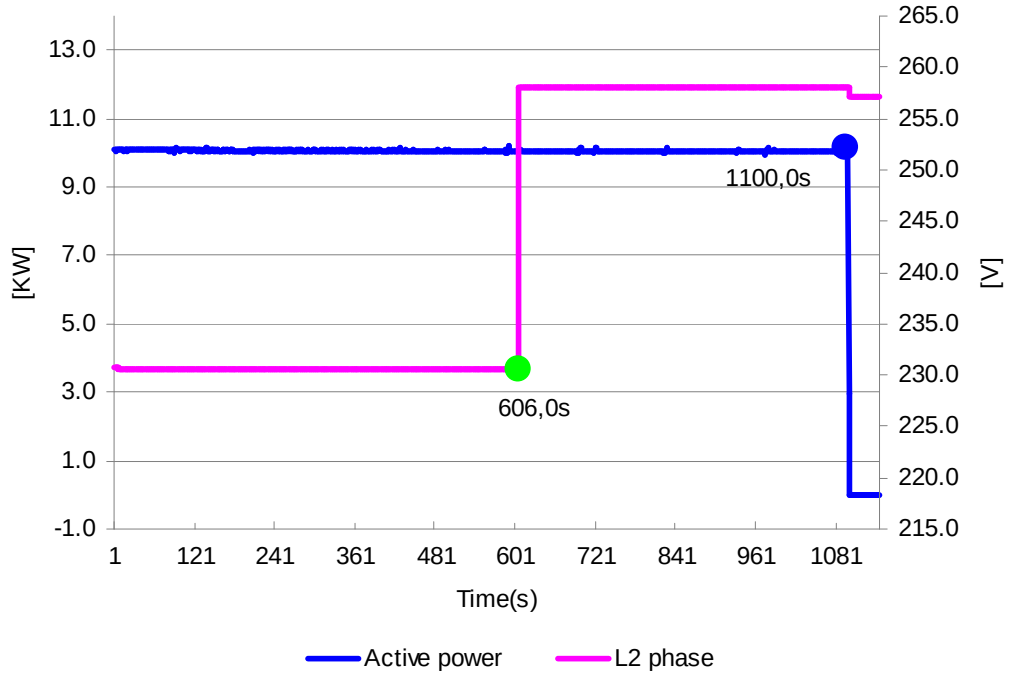
Note:

If only one integrated protection is used for the power generation systems, the value of the rise-in voltage protection of 1,1 U_N may not be changed.

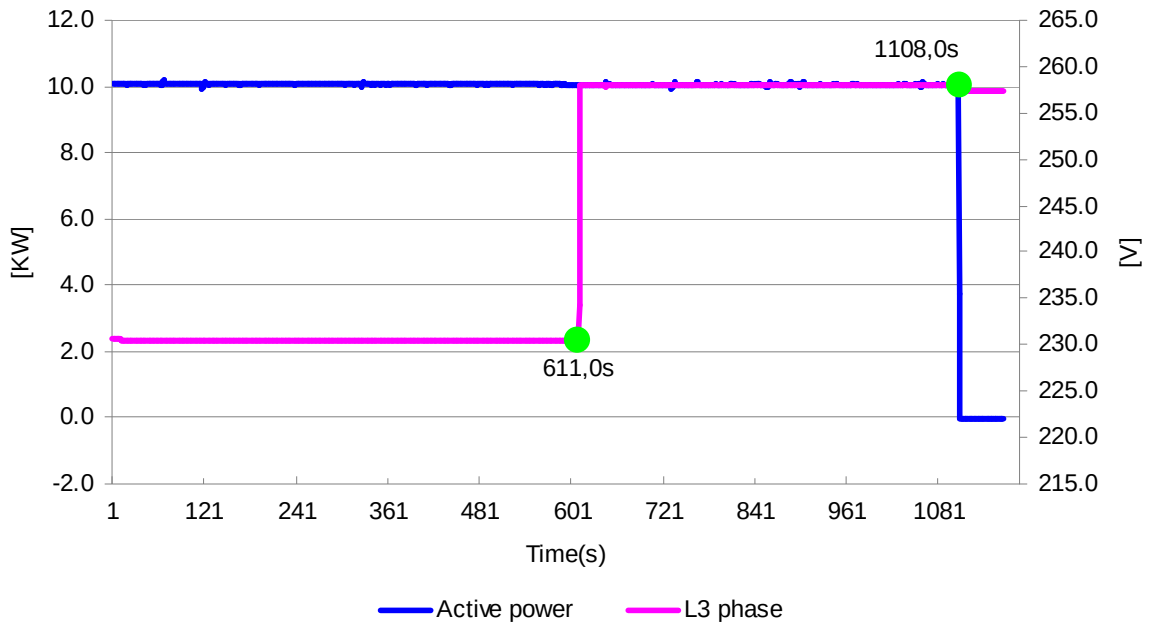
100% to 112% U_n : L1 Phase



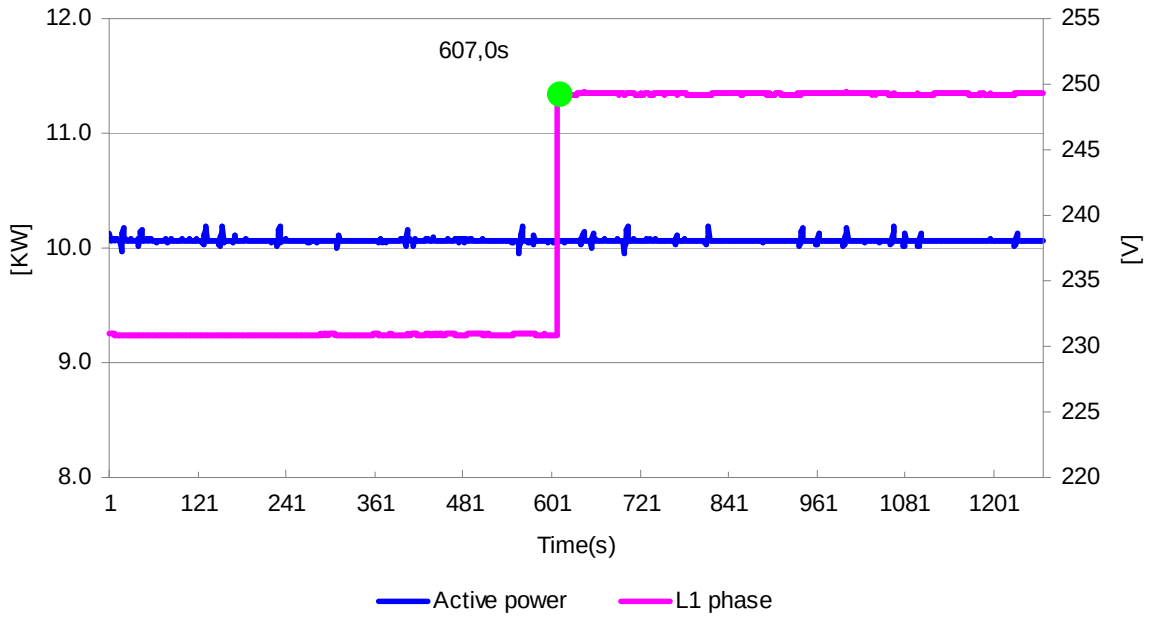
100% to 112% U_n : L2 Phase



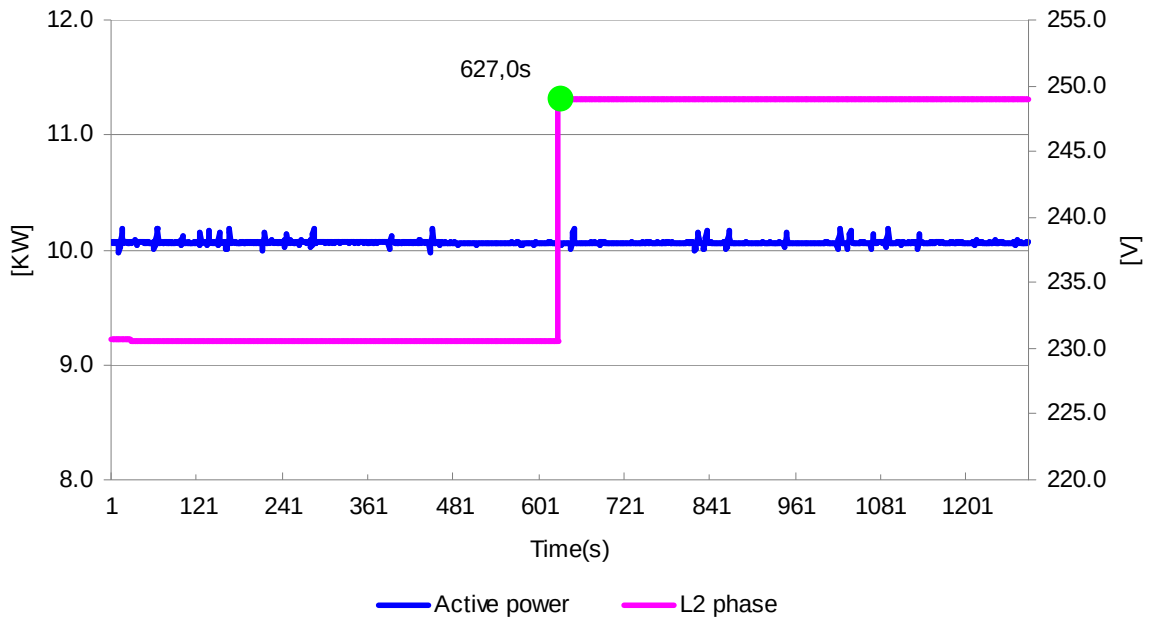
100% to 112% U_n : L3 Phase



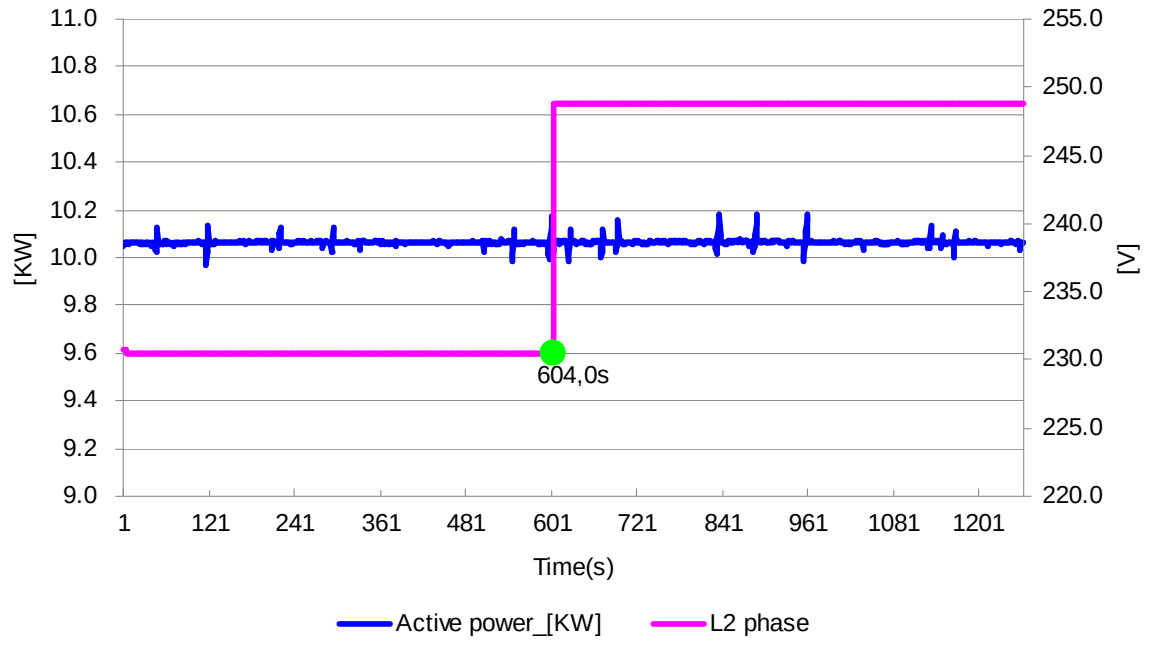
100% to 108% U_n : L1 Phase



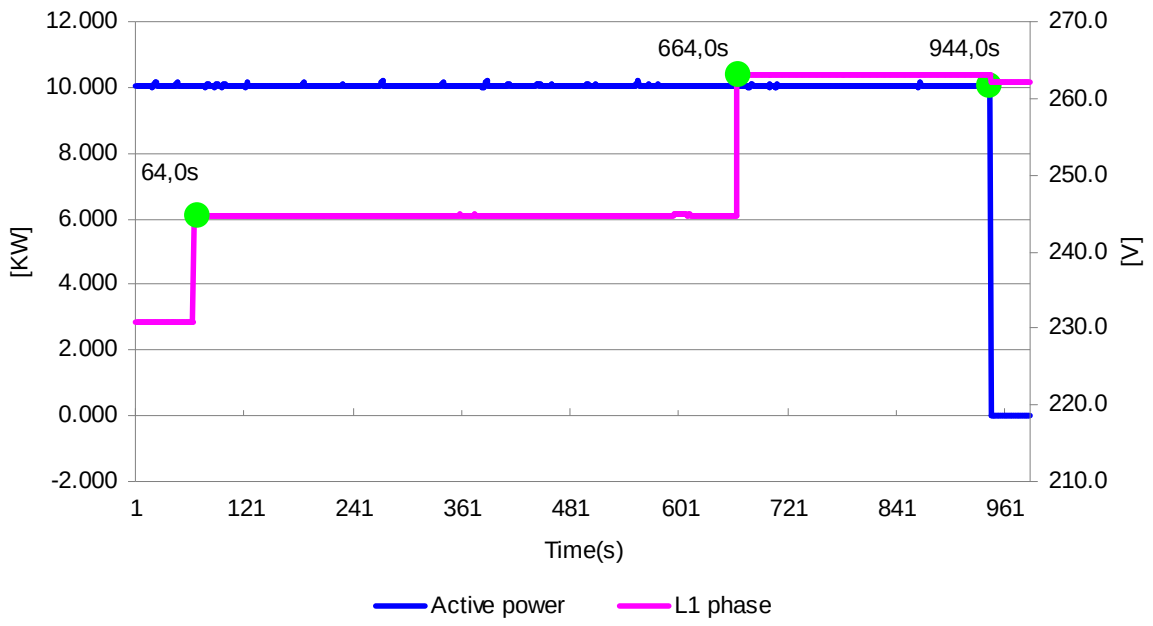
100% to 108% U_n : L2 Phase



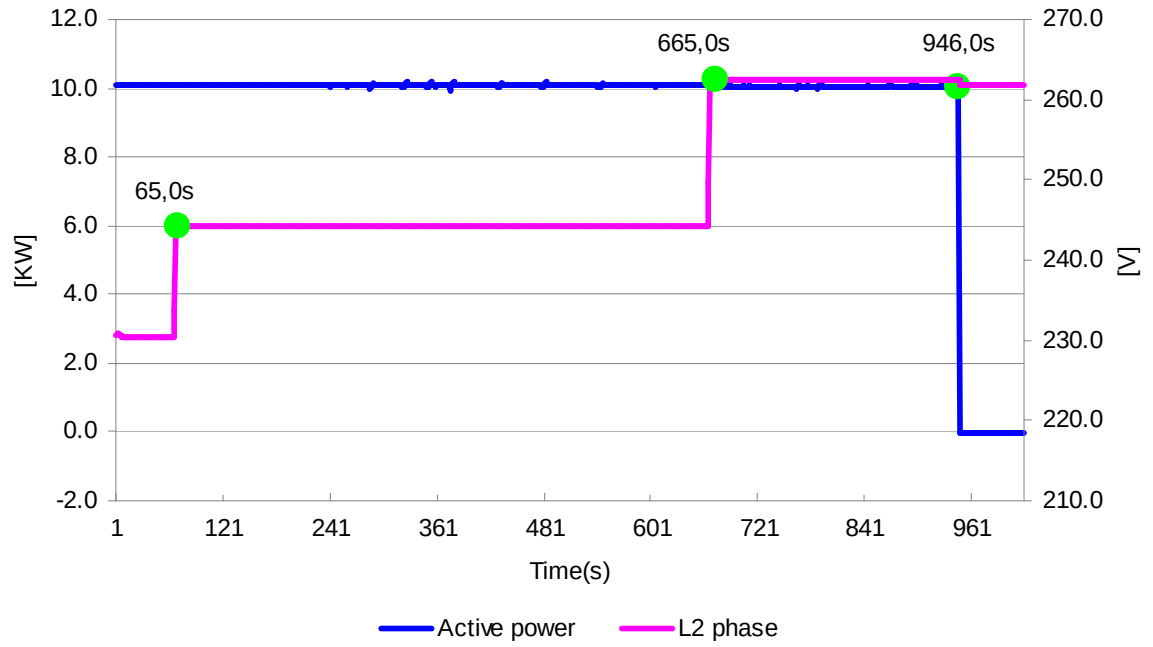
100% to 108% U_n : L3 Phase



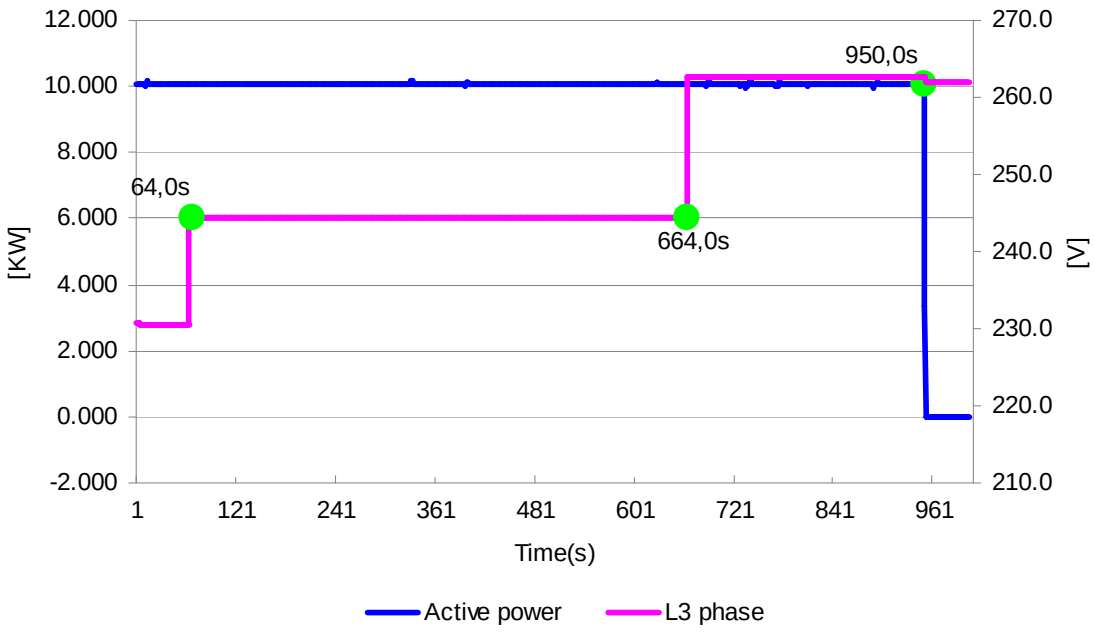
100% to 114% U_n : L1 Phase



100% to 114% U_n : L2 Phase



100% to 114% U_n : L3 Phase



4.2.2 Over-voltage-stage 1: 10-min-vale corresponding to EN 50160 (Norway setting)			**P**
Setting values of the protection:	Trip value Setting [V]	253	
	Setting $T_{disconnection\ trip\ value}$ [s]	60	
	Setting $T_{disconnection}$ [ms]	200	
Test:			
		Disconnection time [s]	Limit [s]
a)	The voltage is set to 100% U_n and held for 60 s. Thereafter the voltage is set to 112% U_n. Disconnection must take place within 60 s.		
	Phase 1:	54	60 s
	Phase 2:	52	
	Phase 3:	50	
b)	The voltage is set to U_n for 60 s and then to 108% U_n for 60 s. No disconnection should take place.		
	Phase 1:	No disconnection	Disconnection should not take place.
	Phase 2:	No disconnection	
	Phase 3:	No disconnection	
c)	The voltage is set to 106 % U_n and held for 60 s. Thereafter the voltage is set to 114 % U_n. The disconnection should last for half the period as in Point a)*		
	Phase 1:	34	30s
	Phase 2:	33	
	Phase 3:	30	

Test:

a) This test serves as proof of the measurement accuracy and the maximum set time.

b) This test serves as proof of the measurement accuracy.

c) This test serves as proof of the correct formation of the 1 minute running mean value.

Assessment criterion:

The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1 % of U_N.

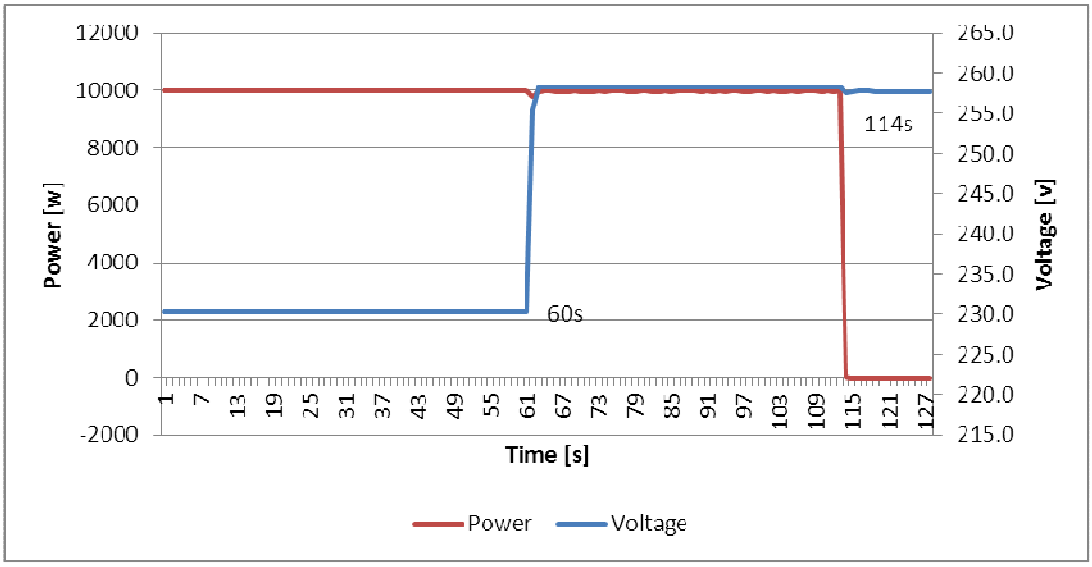
Limit values:

Rise-in voltage protection 1,1 U_N after a max. 60 s, the switch off after 200 ms.

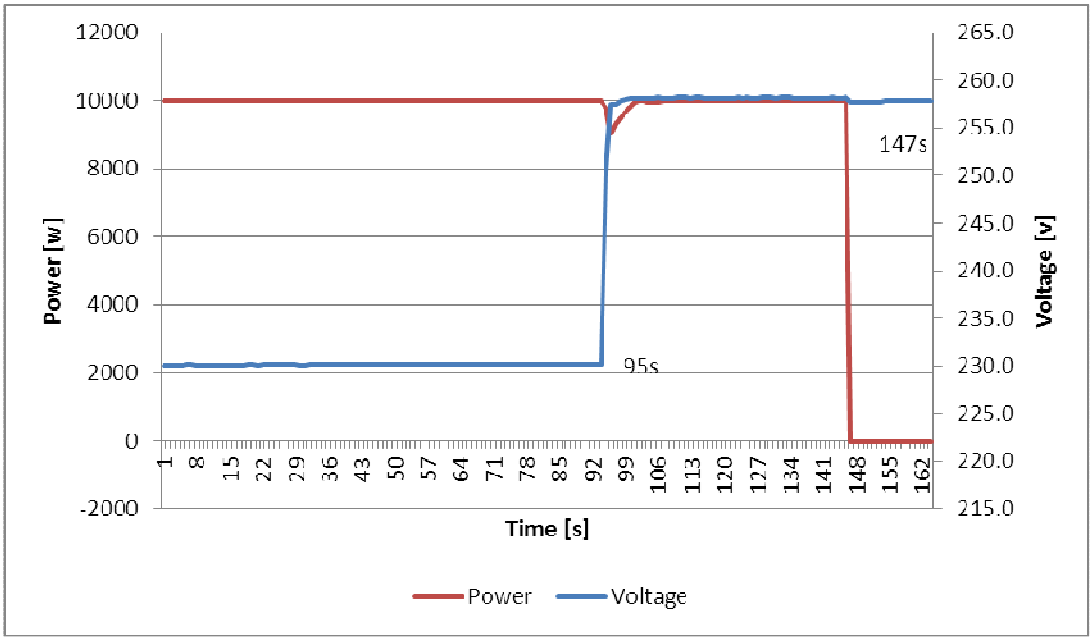
Note:

If only one integrated protection is used for the power generation systems, the value of the rise-in voltage protection of 1,1 U_N may not be changed.

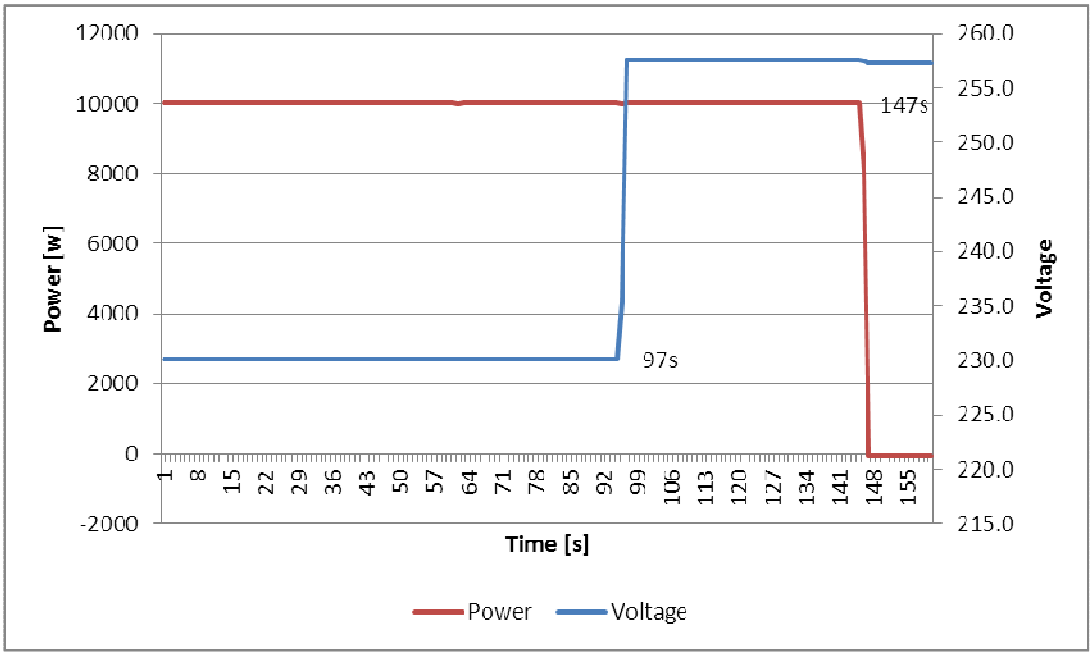
100% to 112% U_n : L1 Phase



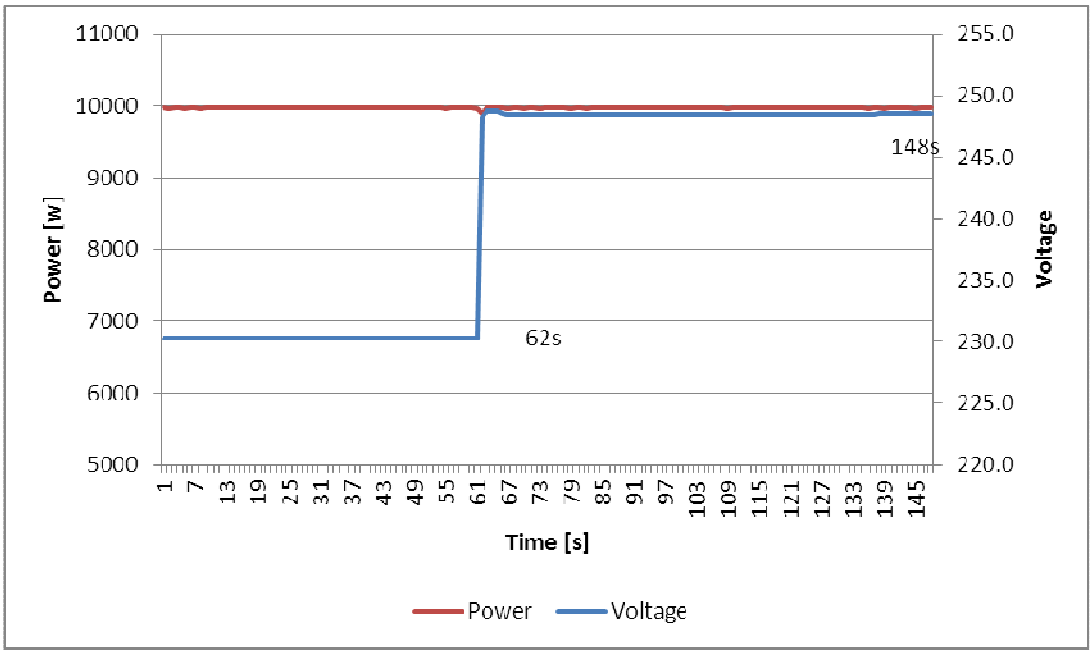
100% to 112% U_n : L2 Phase



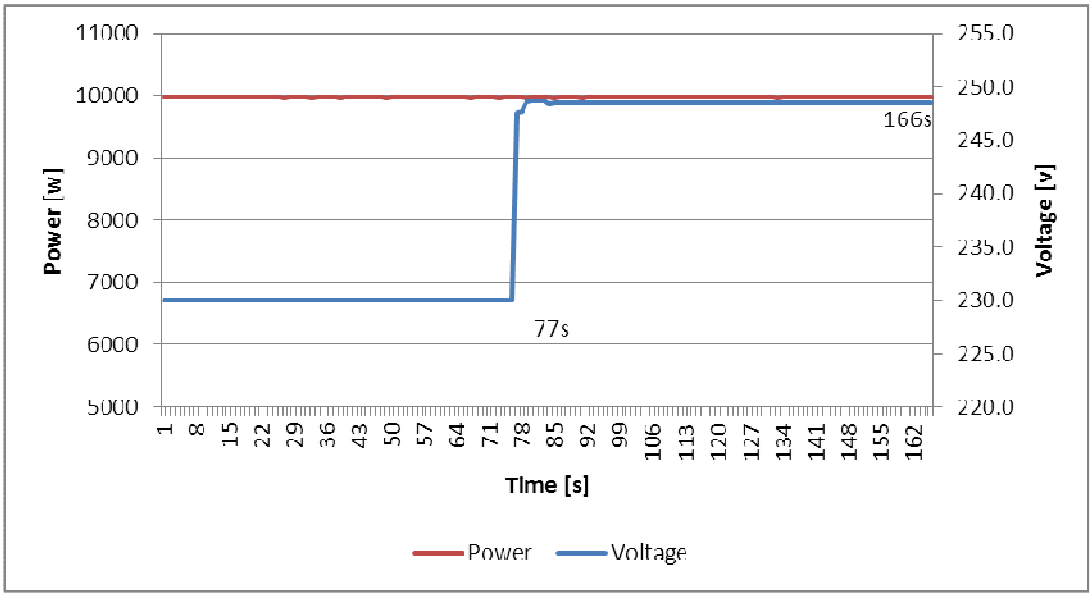
100% to 112% U_n : L3 Phase



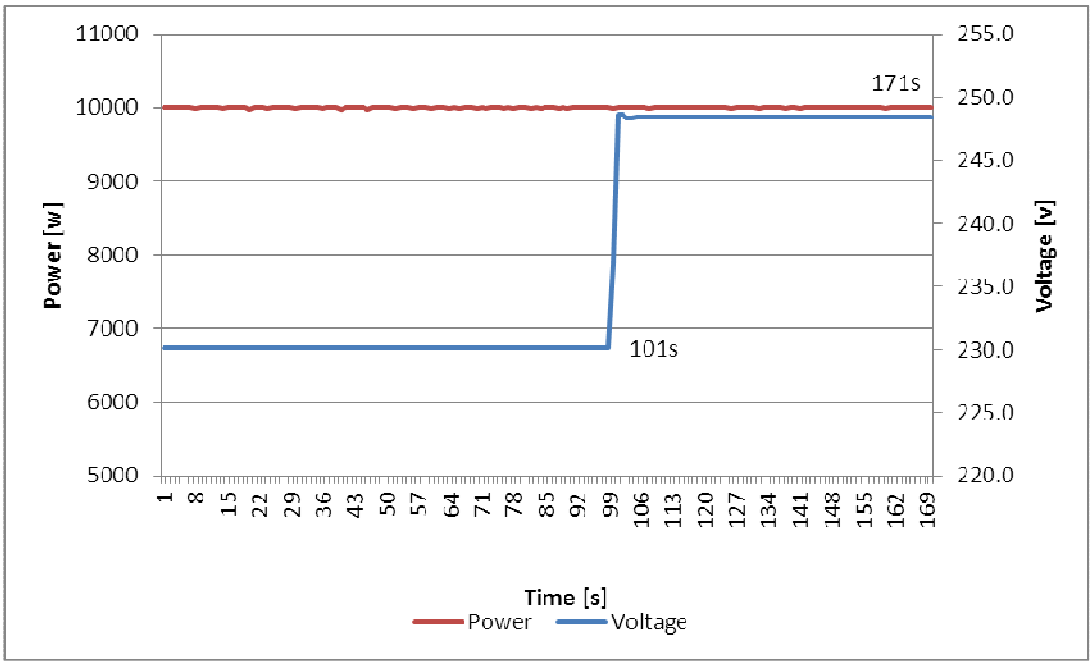
100% to 108% U_n : L1 Phase



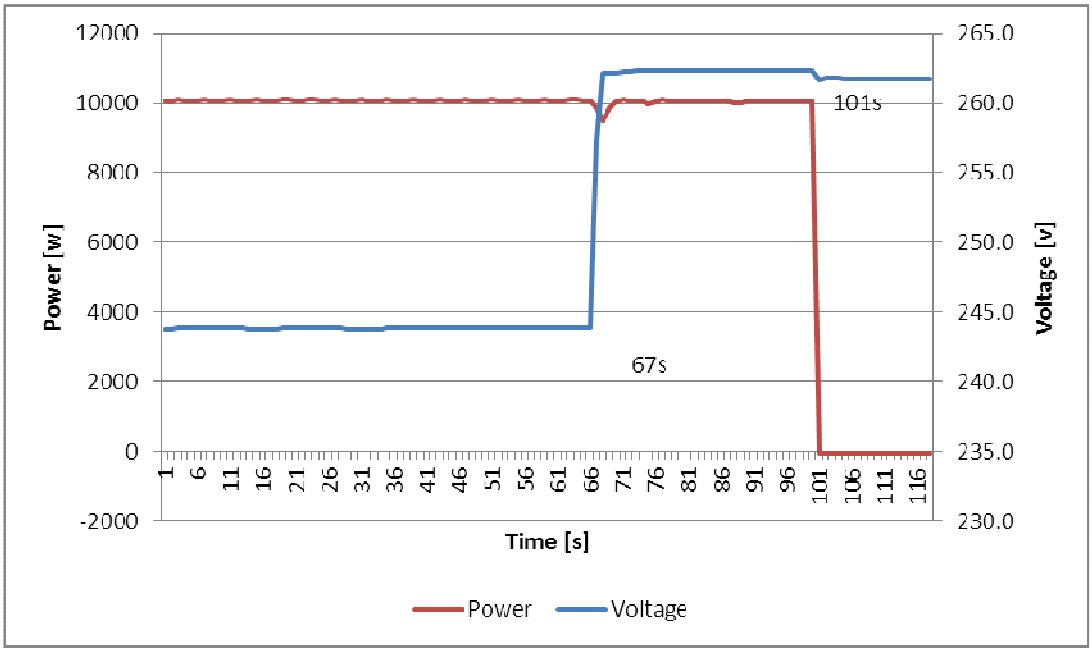
100% to 108% U_n : L2 Phase



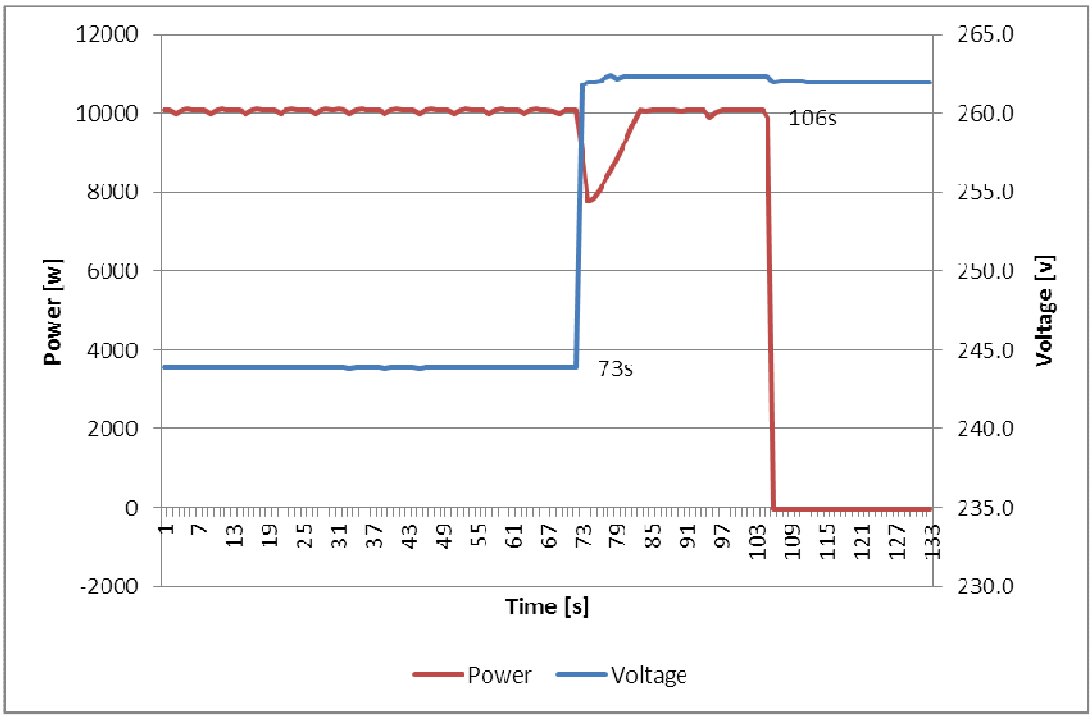
100% to 108% U_n : L3 Phase



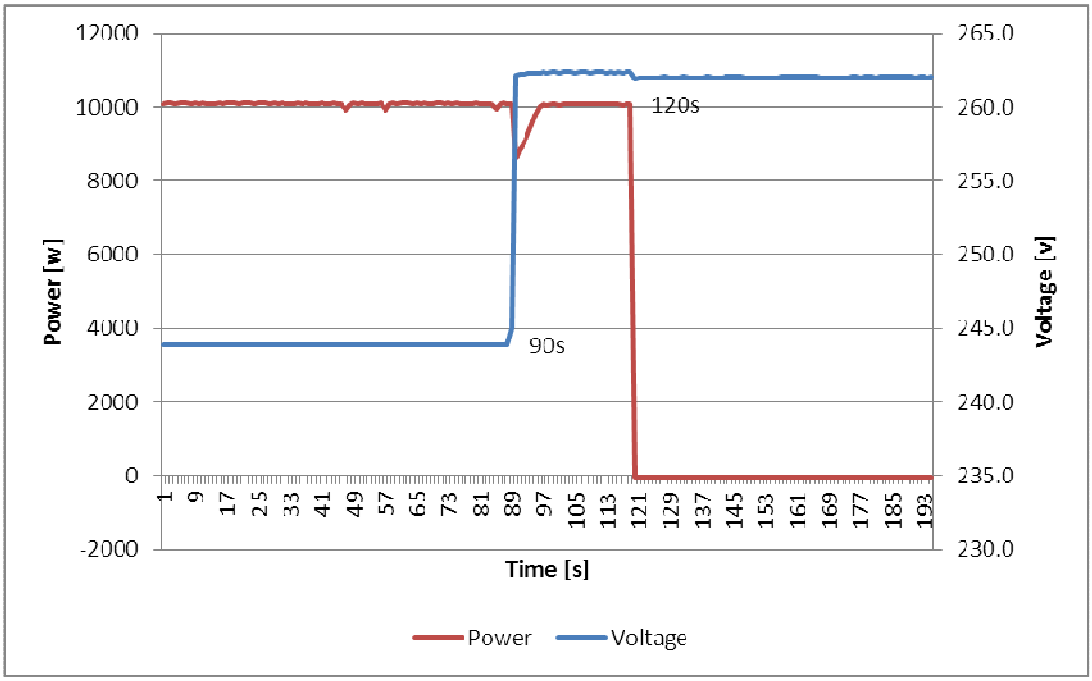
100% to 114% U_n : L1 Phase



100% to 114% U_n : L2 Phase



100% to 114% U_n : L3 Phase



D.2.4 Interface protection: Over- /under-frequency (default settings) **D.3.6.2 Connection after trip of interface protection**					**P**
Test conditions	Output power: 5100W U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	Frequency	Time	Frequency	Time	
Limit	47,50 Hz	0,3 ≤ t ≤ 0,5 s	52,00 Hz	0,3 ≤ t ≤ 0,5 s	
Trip value [Hz]	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
Disconnection time [s]	50,00 Hz to 47,40 Hz	0,115	50,00 Hz to 52,10 Hz	0,124	
		0,121		0,124	
		0,125		0,126	
		0,114		0,122	
		0,119		0,140	

Note:

For under-frequency testing the applied frequency is varied from f_n down to $f_{th\text{-}low}$ -0,1 Hz in steps of 0,025 Hz with a time duration per step exceeding the configured disconnection time. The operate value is the value of the applied frequency at switch the protection function trips and shall be within $f_{th\text{-}low}$ ± 0,05 Hz.

For over-frequency testing the applied frequency is varied from f_n up to $f_{th\text{-}high}$ + 0,1 Hz in steps of 0,025 Hz with a time duration per step exceeding the configured disconnection time. The operate value is the value of the applied frequency at which the protection function trips and shall be within $f_{th\text{-}high}$ ± 0,05 Hz.

The disconnection time was measured by applying a negative or positive frequency ramp from f_n to the operate value -0,1 Hz or +0,1 Hz, e.g. from 50 Hz to 47,4 Hz. The time elapsed between the application of the frequency ramp and the opening of the interface switch was calculated by the measured time minus the 2500 ms from 50,0 Hz to 47,5 Hz.

The oscilloscope pictures below show the measured worst case disconnection times.

Scope pictures of the disconnection time
Under-frequency

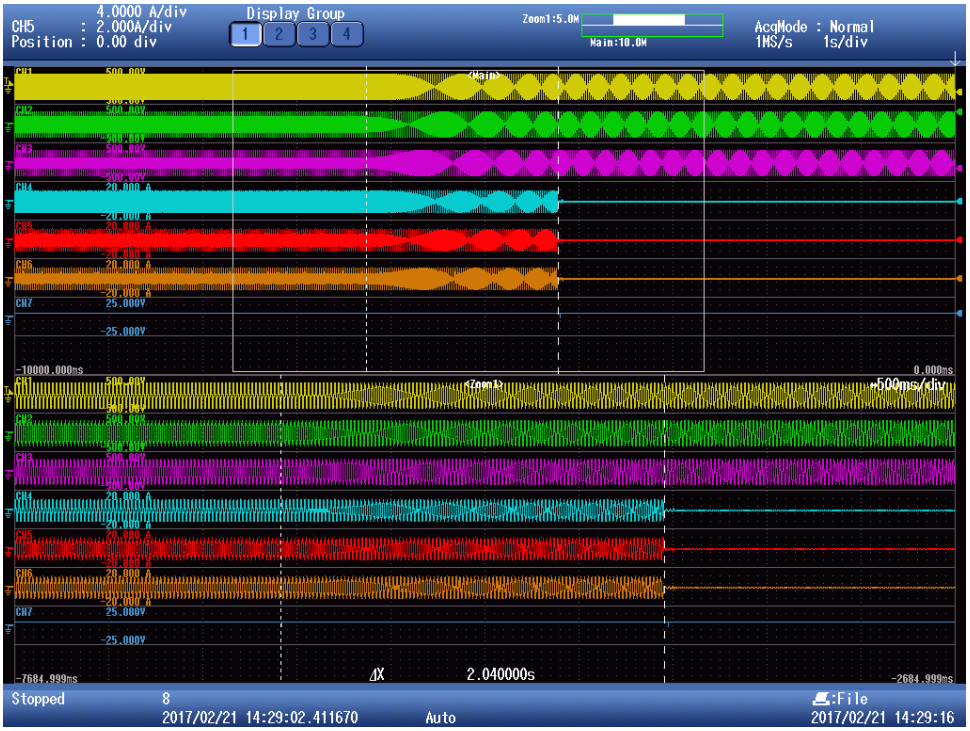
Over-frequency


D.2.4 Interface protection: Over- /under-frequency (Czech Republic settings) **D.3.6.2 Connection after trip of interface protection**					**P**
Test conditions	Output power: 5100W U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	Frequency	Time	Frequency	Time	
Limit	47,50 Hz	0,5 s	52,00 Hz	0,5 s	
Trip value [Hz]	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
Disconnection time [s]	50,00 Hz to 47,49 Hz	0,110	50,00 Hz to 52,01 Hz	0,030	
		0,110		0,030	
		0,120		0,040	
		0,125		0,030	
		0,130		0,030	

Note:

It was measured at a continuous change of frequency of 1Hz/s at lower, nominal and upper UN and arbitary output power. The trip value was determined manually by reducing the frequency in 10mHz steps. When the trip value is known (e.g. 47.5Hz), the ac-source is programmed to run from e.g. 50Hz to 47,49Hz with 1Hz/s. The disconnection time is calculated by the measured time minus the 2500ms from 50Hz to 47,50Hz.

Scope pictures of the disconnection time
Under-frequency

Disconnection time should minus 2500ms
Over-frequency

Disconnection time should minus 2000ms

D.2.4 Interface protection: Over- /under-frequency (Denmark settings) **D.3.6.2 Connection after trip of interface protection**					**P**
Test conditions	Output power: 5100W U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	Frequency	Time	Frequency	Time	
Limit	47,50 Hz	0,1 ≤ t ≤ 0,2	52,00 Hz	0,1 ≤ t ≤ 0,2	
Trip value [Hz]	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
	47,50		52,01		
Disconnection time [s]	50,00 Hz to 47,49 Hz	0,140	50,00 Hz to 52,01 Hz	0,124	
		0,140		0,124	
		0,140		0,126	
		0,130		0,122	
		0,150		0,140	

Note:

It was measured at a continuous change of frequency of 1Hz/s at lower, nominal and upper UN and arbitary output power. The trip value was determined manually by reducing the frequency in 10mHz steps. When the trip value is known (e.g. 47.5Hz), the ac-source is programmed to run from e.g. 50Hz to 47,49Hz with 1Hz/s. The disconnection time is calculated by the measured time minus the 2500ms from 50Hz to 47,50Hz.

Scope pictures of the disconnection time
Under-frequency

Disconnection time should minus 2500ms
Over-frequency

Disconnection time should minus 2000ms

D.2.4 Interface protection: Over- /under-frequency (Finland settings) **D.3.6.2 Connection after trip of interface protection**					**P**
Test conditions	Output power: 5100W U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	Frequency	Time	Frequency	Time	
Limit	47,50 Hz	0,2 s	51,50 Hz	0,2 s	
Trip value [Hz]	47,50		51,50		
	47,50		51,50		
	47,50		51,50		
	47,50		51,50		
	47,50		51,50		
Disconnection time [s]	50,00 Hz to 47,49 Hz	0,115	50,00 Hz to 51,51 Hz	0,040	
		0,121		0,035	
		0,125		0,035	
		0,114		0,045	
		0,119		0,040	

Note:

It was measured at a continuous change of frequency of 1Hz/s at lower, nominal and upper UN and arbitary output power. The trip value was determined manually by reducing the frequency in 10mHz steps. When the trip value is known (e.g. 47.5Hz), the ac-source is programmed to run from e.g. 50Hz to 47,49Hz with 1Hz/s. The disconnection time is calculated by the measured time minus the 2500ms from 50Hz to 47,50Hz.

Scope pictures of the disconnection time
Under-frequency

Disconnection time should minus 2500ms
Over-frequency

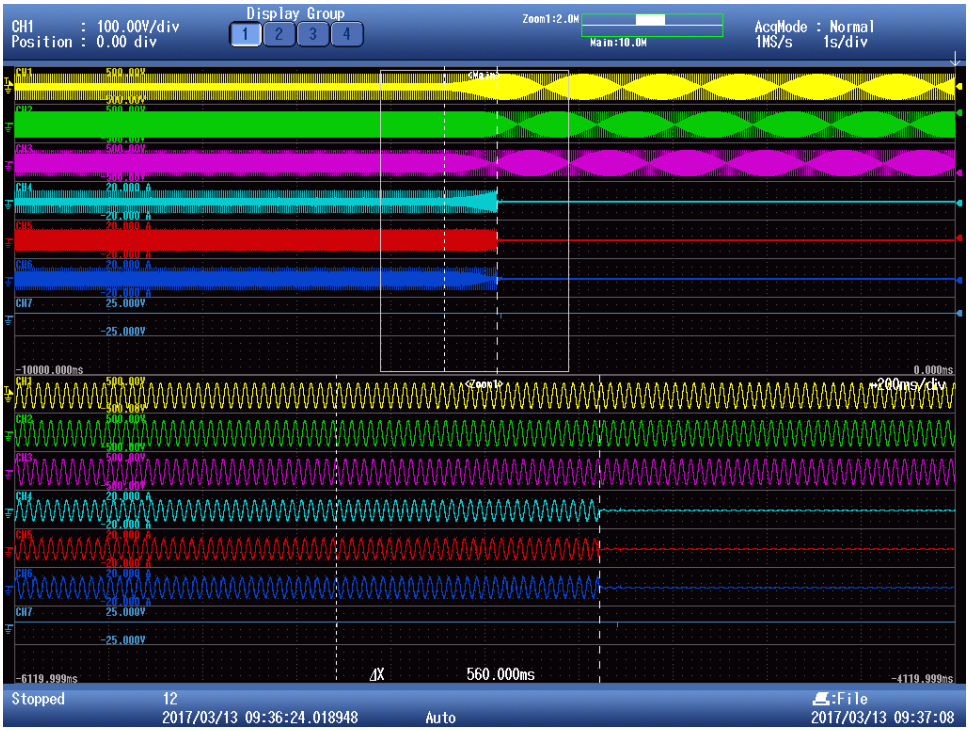
Disconnection time should minus 1500ms

D.2.4 Interface protection: Over- /under-frequency (Ireland settings) **D.3.6.2 Connection after trip of interface protection**					**P**
Test conditions	Output power: 5100W U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	Frequency	Time	Frequency	Time	
Limit	48,00 Hz	0,2 s	50,50 Hz	0,2 s	
Trip value [Hz]	48,00		50,50		
	48,00		50,50		
	48,00		50,50		
	48,00		50,50		
	48,00		50,50		
Disconnection time [s]	50,00 Hz to 47,99 Hz	0,107	50,00 Hz to 50,51 Hz	0,060	
		0,090		0,050	
		0,105		0,060	
		0,105		0,060	
		0,105		0,060	

Note:

It was measured at a continuous change of frequency of 1Hz/s at lower, nominal and upper UN and arbitary output power. The trip value was determined manually by reducing the frequency in 10mHz steps. When the trip value is known (e.g. 48.00Hz), the ac-source is programmed to run from e.g. 50Hz to 47,99Hz with 1Hz/s. The disconnection time is calculated by the measured time minus the 2000ms from 50Hz to 48,00Hz.

Scope pictures of the disconnection time
Under-frequency

Disconnection time should minus 2000ms
Over-frequency

Disconnection time should minus 500ms

D.2.5 Loss of Mains (LoM) detection

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 62116:2014

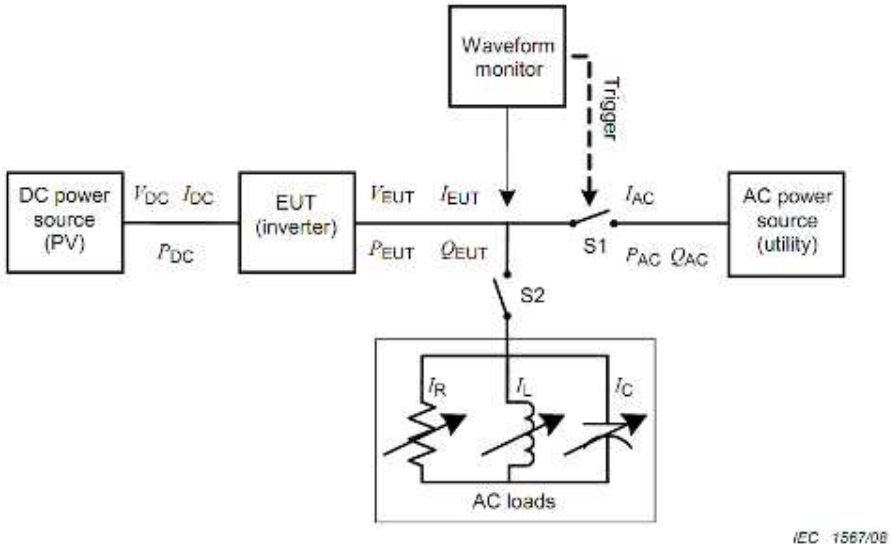


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

Load imbalance (real, reactive load) for test condition A (EUT ouput = 100%)										**P**
Test conditions			Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality = 1							
Disconnection limit			2s (IEC 62116)							
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]	I_{AC} [4] [A]	P_{EUT} [W per phase]	V_{DC} [V]	Q_f	Run on Time [ms]	Remarks [5]
1	100	100	0	0	0,014	3321	678	1,01	166	BL
8	100	100	-5	-5	0,014	3321	678	0,99	154	IB
9	100	100	-5	0	0,014	3321	678	0,96	111	IB
10	100	100	-5	+5	0,014	3321	678	0,94	109	IB
13	100	100	0	-5	0,014	3321	678	1,03	150	IB
14	100	100	0	+5	0,014	3321	678	0,98	121	IB
17	100	100	+5	-5	0,014	3321	678	1,09	138	IB
18	100	100	+5	0	0,014	3321	678	1,06	156	IB
19	100	100	+5	+5	0,014	3321	678	1,04	131	IB

Parameter at 0% per phase	L= 50,20 mH	R= 15,93 Ω	C= 201,83 µF

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] Fundamental of I_{AC} when RLC is adjusted

[5] BL: Balance condition, IB: Imbalance condition.

Condition A:

EUT output power P_{EUT} = Maximum [6]

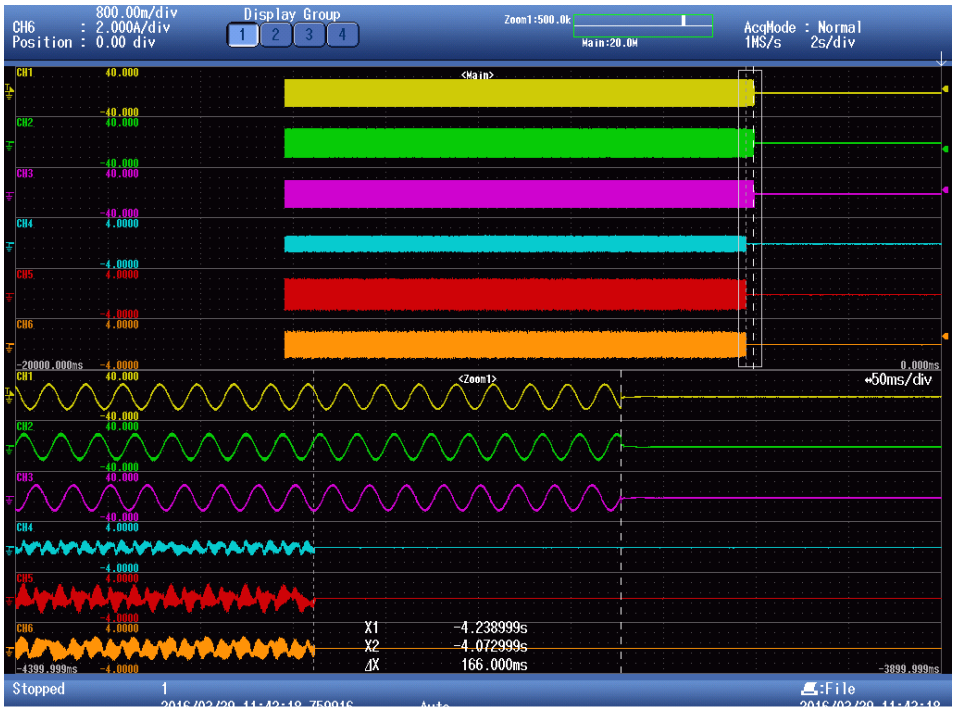
EUT input voltage [6] = >75% of rated input voltage range

[6] Maximum EUT output power condition should be achieved using the maximum allowable input power. Actual output power may exceed nominal rated output.

[7] Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 90 % of range =X + 0,75 × (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.

[a] Based on ROCOF (Rate Of Change Of Frequency), trip value currently 0,6 Hz/s, final to be announced.

Scope pictures of the disconnection time
Disconnection at No. 1



Fundamental of I_{AC} at balance condition = 14mA

Note:
CH1: EUT current phase 1
CH2: EUT current phase 2
CH3: EUT current phase 3
CH4: IAC current phase 1 into the grid
CH5: IAC current phase 1 into the grid
CH6: IAC current phase 1 into the grid

Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %)	**P**

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality = 1
Disconnection limit	2s (IEC 62116)

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]	I_{AC} [4)] [A]	P_{EUT} [W per phase]	V_{DC} [V]	Q_f [1]	Run on Time [ms]	Remarks [5)]
1	66	66	0	-5	0,053	1998	510	1,05	130	IB
2	66	66	0	-4	0,053	1998	510	1,04	134	IB
3	66	66	0	-3	0,053	1998	510	1,04	127	IB
4	66	66	0	-2	0,053	1998	510	1,03	142	IB
5	66	66	0	-1	0,053	1998	510	1,03	155	IB
6	66	66	0	0	0,053	1998	510	1,02	227	BL
7	66	66	0	+1	0,053	1998	510	1,01	120	IB
8	66	66	0	+2	0,053	1998	510	1,01	152	IB
9	66	66	0	+3	0,053	1998	510	1,00	129	IB
10	66	66	0	+4	0,053	1998	510	1,00	176	IB
11	66	66	0	+5	0,053	1998	510	0,99	125	IB

Parameter at 0% per phase	L= 82,62 mH	R= 26,48 Ω	C= 122,63 µF

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)] Fundamental of I_{AC} when RLC is adjusted

[5)] BL: Balance condition, IB: Imbalance condition.

Condition B:

EUT output power P_{EUT} = 50 % – 66 % of maximum

EUT input voltage [6)] = 50 % of rated input voltage range, ±10 %

[6)] 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.

[a] Based on ROCOF (Rate Of Change Of Frequency), trip value currently 0,6 Hz/s, final to be announced.

Scope pictures of the disconnection time
Disconnection at No. 6

Fundamental of I_{AC} at balance condition = 53mA

Note:

CH1: EUT current phase 1
CH2: EUT current phase 2
CH3: EUT current phase 3

CH4: IAC current phase 1 into the grid

CH5: IAC current phase 1 into the grid

CH6: IAC current phase 1 into the grid

Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %)	**P**

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality = 1
Disconnection limit	2s (IEC 62116)

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]	I_{AC} [4] [A]	P_{EUT} [W per phase]	V_{DC} [V]	Q_f	Run on Time [ms]	Remarks [5]
1	33	33	0	-5	0,033	996	342	1,06	144	IB
2	33	33	0	-4	0,033	996	342	1,05	185	IB
3	33	33	0	-3	0,033	996	342	1,05	152	IB
4	33	33	0	-2	0,033	996	342	1,04	150	IB
5	33	33	0	-1	0,033	996	342	1,04	216	IB
6	33	33	0	0	0,033	996	342	1,03	170	BL
7	33	33	0	1	0,033	996	342	1,02	135	IB
8	33	33	0	2	0,033	996	342	1,02	170	IB
9	33	33	0	3	0,033	996	342	1,01	116	IB
10	33	33	0	4	0,033	996	342	1,01	140	IB
11	33	33	0	5	0,033	996	342	1,00	135	IB

Parameter at 0% per phase	L= 164.14 mH	R= 53.11 Ω	C= 61.73 µF

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] Fundamental of I_{AC} when RLC is adjusted

[5] BL: Balance condition, IB: Imbalance condition.

Condition B:

EUT output power P_{EUT} = 25 % – 33 % [6] of maximum

EUT input voltage [7] = <20 % of rated input voltage range

[6] Or minimum allowable EUT output level if greater than 33 %.

[7] Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 10 % of range =X + 0,2 × (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.

[a] Based on ROCOF (Rate Of Change Of Frequency), trip value currently 0,6 Hz/s, final to be announced.

Scope pictures of the disconnection time
Disconnection at No.5
 Fundamental of I_{AC} at balance condition = 33mA
Note: CH1: EUT current phase 1 CH2: EUT current phase 2 CH3: EUT current phase 3 CH4: IAC current phase 1 into the grid CH5: IAC current phase 1 into the grid CH6: IAC current phase 1 into the grid

EN 50438:2013: Normal operating range			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.2	Normal operating range	D.3.1 / D.3.2 / D.3.3	**P**

D.3.1 Operating range			P
Setting values	Over-voltage [V]:	264,5	
	Under-voltage [V]:	195,5	
	Over-frequency [Hz]:	52,00	
	Under-frequency [Hz]:	47,50	

- Test 1: U = 195,5 V; f = 47,5 Hz; P = 1,00 Sn; cosφ = 1
- Test 2: U = 253,0 V; f = 51,5 Hz; P = 1,00 Sn; cosφ = 1

Test sequence	Voltage [V]	Frequency [Hz]	Output power [W]	Cos φ [1]
1	195,56	47,50	9683	0,9998
2	253,21	51,50	9769	0,9999

Note:

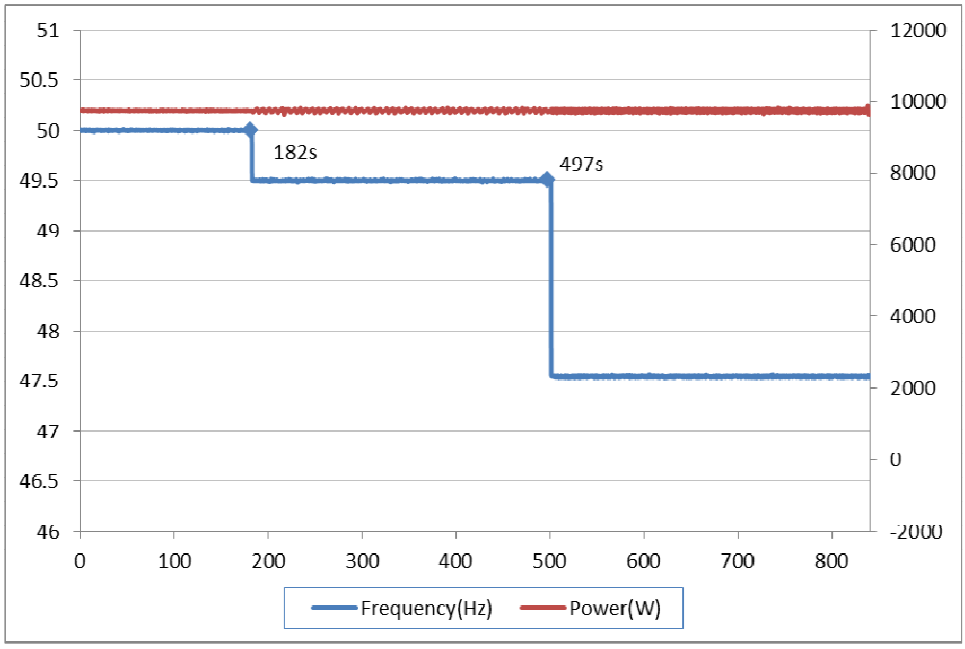
During the tests the interface protection was disabled.

Operation at reduced power is allowed during test 1, equal to the maximum power that can be supplied on reaching the maximum output current limit (P ≥ 0,85 Sn).

During the sequence of test 2, automatic adjustment to reduce power in the case of over-frequency was disabled.

D.3.2 Active power feed-in for under-frequency	P

Graph of frequency a) to b) to c):



Test:

	Switch to:		
5-min mean value (each)	a) 50 ± 0,01 [Hz]	b) - 0,4 to – 0,5 [Hz]	c) - 2,4 to - 2,5 [Hz]
Frequency [Hz]:	50,00	49,55	47,55
Active power [kW]:	9,754	9,754	9,755
$\Delta P/P_M$ [%] per 1 Hz:			0,012

Test:

Operating points b) and c) must be kept for at least 5 minutes.

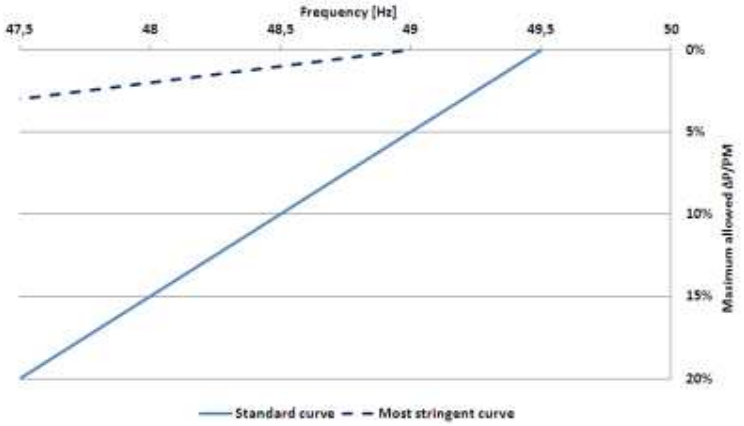
The test must be carried out at 100% P_n.

With a programmable AC source, the PGU is operated at 100% P_n and 50 ± 0,01 Hz, thereafter the frequency is reduced by 1 Hz/min. to - 0,4 to – 0,5 Hz and in addition to - 2,4 to - 2,5 Hz. A 5-min mean value is recorded both before and after the frequency change.

Assessment criterion:

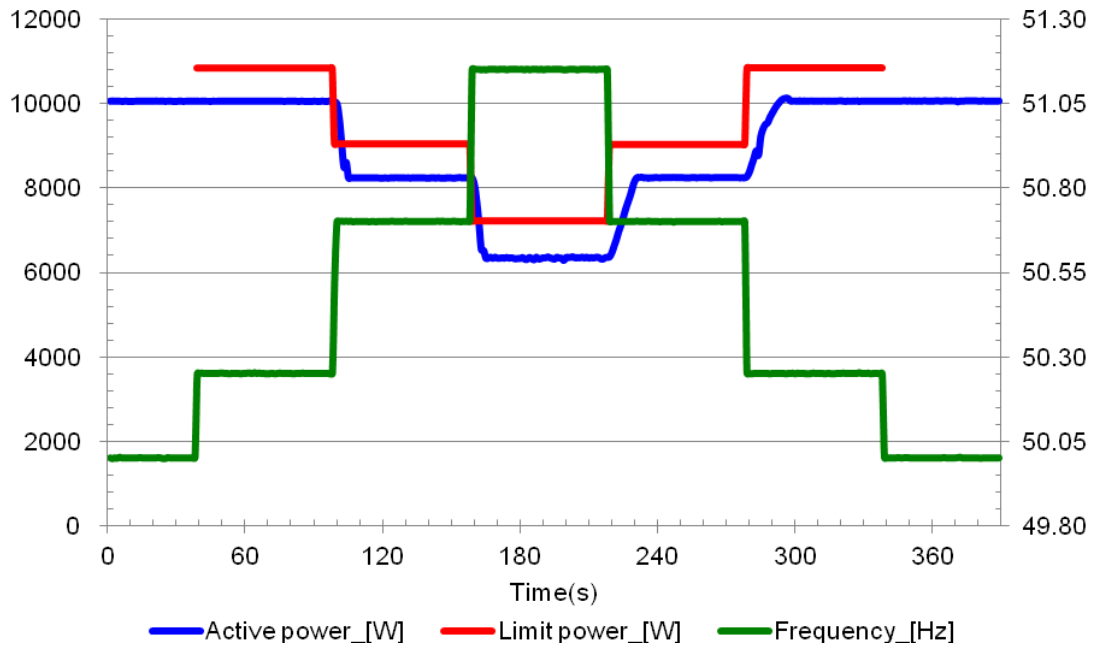
The test is passed when the micro-generator

- does not disconnect from the network on a network frequency change at the operating points a) to c),
- continues to feed in 100% P_n in b) and
- the power reduction in point c) is less or equal to the power reduction of 10 % P_M per 1 Hz drop.

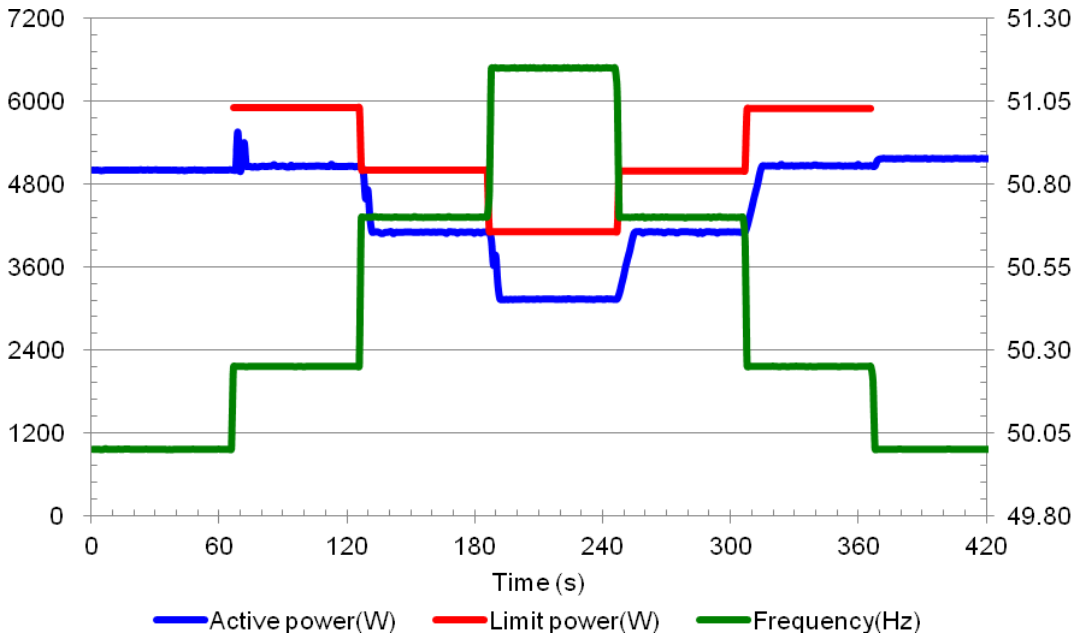


Maximum allowable power reduction in case of under-frequency

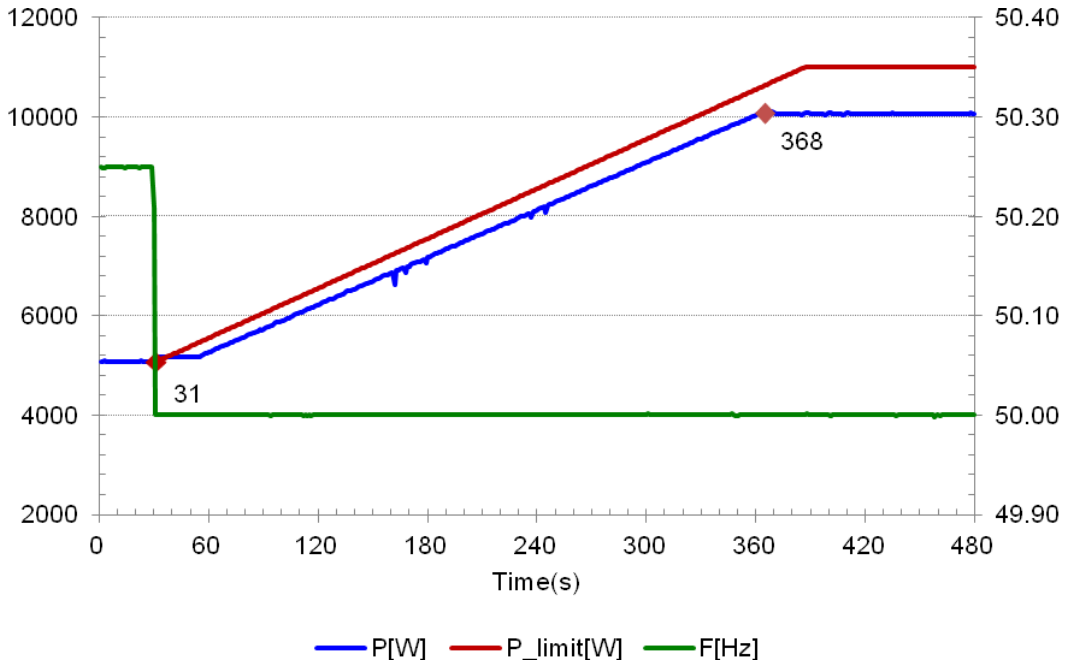
D.3.3 Power response to over-frequency							P
Test:							
1-min mean value [Hz]:	a) 50,00	b) 50,25	c) 50,70	d) 51,15	e) 50,70	f) 50,25	g) 50,00
1. Measurement a) to g): Active power output > 80% P_n							
Frequency [Hz]:	50,00	50,25	50,70	51,15	50,70	50,25	50,00
P_M [kW]:	N/A	9,855	8,056	6,235	8,045	9,856	N/A
P_{E60} [kW]:	10,056	10,056	8,352	6,456	8,051	9,857	10,060
$\Delta P_{E60}/P_M$ [%]:	N/A	2,01	2,96	2,21	0,06	0,01	N/A
2. Measurement a) to g): Active power output 40% and 60% after freezing > 80% P_n							
Frequency [Hz]:	50,00	50,25	50,70	51,15	50,70	50,25	50,00
P_M [kW]:	N/A	4,912	4,009	3,120	3,997	4,899	N/A
P_{E60} [kW]:	5,012	5,079	4,162	3,191	4,037	5,001	5,178
$\Delta P_{E60}/P_M$ [%]:	N/A	1,67	1,53	0,71	0,40	1,02	N/A
Limit $\Delta P/P_{1min}$:	+ 10 % of P_M						
Graph of Measurement 1.: Active power output > 80% P_n							



Graph of Measurement 2.:Active power output 40% and 60% after freezing > 80% P_n



Graph of power gradient:



Test:

The test is conducted for two powers. First, the test must start at a power > 80% P_n ("Measurement 1"), and in a second test, for a power between 40% to 60% P_n ("Measurement 2"). In the second test, after freezing of the P_M, the available active power output must be increased to a value > 80% P_n, and after the network frequency of 50,2 Hz is fallen below, the rise of the active power gradient must be recorded.

Point g) must be held until the micro-generator is again feeding in with the active power output available.

Assessment criterion:

For f = 50,2 Hz, the value of the P_M active power currently being generated is "frozen".

a) For adjustable micro-generators when:

1) the active power reduces between measuring points b) and f) given above with the set gradient P_M per Hz for a increasing frequency (or rises for a frequency decreasing again).

2) the maximum active power gradient occurring in point is less than the configured maximum active power per minute

3) the reaction value of the setpoint determined by the gradient characteristic curve does not differ from P_n by more than ± 10%.

4) the settling time is equal or below 2 s with an intentional delay set to zero

b) For partly adjustable micro-generators

1) when they behave as in a) within their adjustment range, and

2) when, outside the adjustable range, the power fed in on leaving the adjustment range remains constant until shutdown. Shutdown must be no later than at 51,5 Hz.

EN 50438:2013: Reactive power output capability			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.3 / 4.4	Reactive power capability and control modes	D.3.4	**P**

D.3.4.1 Test of no controllable reactive power			P
Test voltage / Output power	211,6 V	230 V	248,4 V
25% P_N	0,9999c	0,9999c	0,9999c
50% P_N	0,9999c	0,9999c	0,9999c
75% P_N	0,9999c	0,9999c	0,9999c
100% P_N	0,9999c	0,9999c	0,9999c
Limit:	>0,95	>0,95	>0,95

Note:

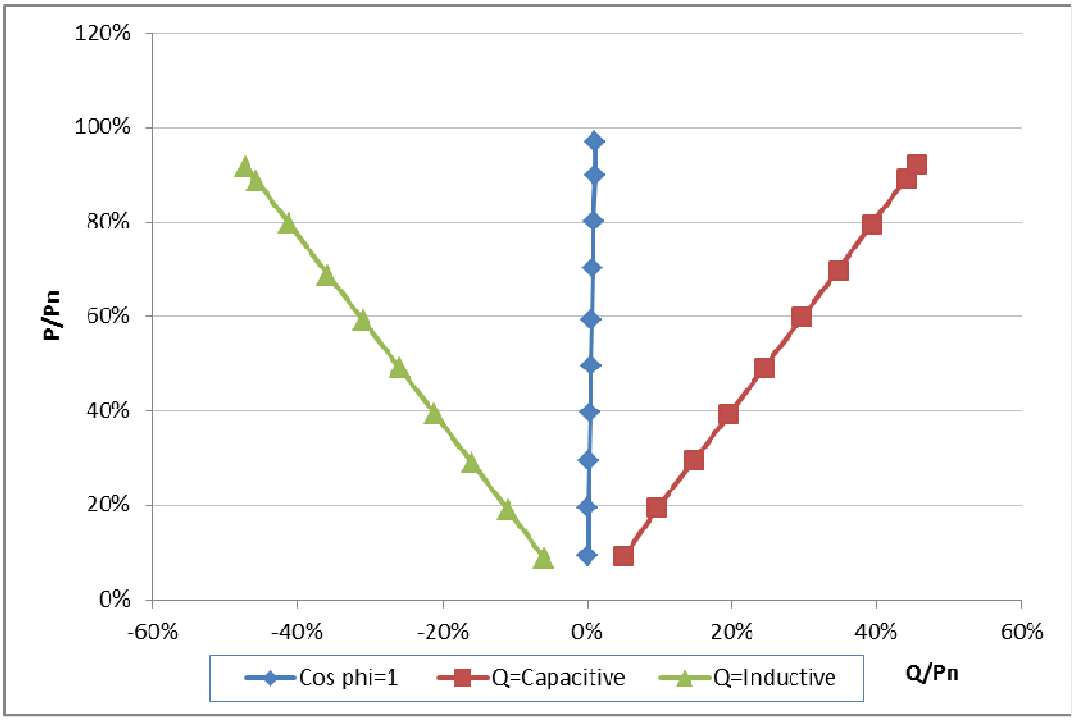
When operating at the 25%, 50%, 75% and 100% rated power the micro-generator operates at a power factor within the range 0.95 lagging to 0.95 leading relative to the voltage waveform.

D.3.4.2.1 Test of controllable reactive power				P
Inductive supply reactive power				
Rating power (%)	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0% -10%	895	-601	0,8302	230,32
10% -20%	1895	-1092	0,8678	230,22
20% -30%	2907	-1595	0,8773	230,08
30% -40%	3930	-2101	0,8811	229,93
40% -50%	4909	-2595	0,8840	229,77
50% -60%	5894	-3090	0,8858	229,64
60% -70%	6881	-3584	0,8869	229,53
70% -80%	7958	-4119	0,8882	229,49
80% -90%	8861	-4568	0,8887	229,48
90% -100%	9171	-4728	0,8890	229,55
Capacitive supply reactive power				
Rating power (%)	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0% -10%	934	506	0,8791	230,71
10% -20%	1943	958	0,8970	230,76
20% -30%	2943	1462	0,8956	230,77
30% -40%	3936	1955	0,8955	230,68
40% -50%	4921	2447	0,8954	230,48
50% -60%	6000	2973	0,8960	230,21
60% -70%	6976	3457	0,8960	229,99
70% -80%	7948	3924	0,8966	229,82
80% -90%	8915	4410	0,8963	229,71
90% -100%	9217	4551	0,8967	229,69
Cos phi=1 no reactive power supply				
Rating power (%)	Active power [W]	Reactive power [Var]	Power factor [cos φ]	Voltage [V]
0% -10%	927	7	1,0000	230,65
10% -20%	1948	6	1,0000	230,68
20% -30%	2957	25	1,0000	230,70
30% -40%	3957	37	1,0000	230,73
40% -50%	4949	51	0,9999	230,73
50% -60%	5937	59	1,0000	230,77
60% -70%	7023	76	0,9999	230,79
70% -80%	8005	87	0,9999	230,80
80% -90%	8987	107	0,9999	230,77
90% -100%	9708	112	0,9999	230,75

Assessment criterion:
The power factor resulting in each of the measurement points between 20 % and 90 % of the nominal power is equal to or lower than 0,90 both in over excited and under excited operation.

Note:
a) 1 min-average-values were calculated using measurements at the basic frequency in a period of 200 ms.
b) For each of the 10 active power levels, at least 3 under excited and 3 over excited reactive power levels were recorded.
c) 1 min-average-values were calculated using voltage measurements at the basic frequency in a period of 200 ms.

Diagram


120%
100%
80%
60%
40%
20%
0%
P/Pn
-60%
-40%
-20%
0%
20%
40%
60%
Q/Pn
Cos phi=1
Q=Capacitive
Q=Inductive

D.3.4.2.5 Procedures for performing tests and recording results (Q adjustment)	N/A

Test: 100%P_n

	Reactive power set point Q [Var]	Measured reactive power Q [Var]	Measured cos φ	Deviation compared to setpoint ΔQ / PN [%]
- Qmin	--	--	--	--
0	0	--	--	--
+ Qmax	--	--	--	--

Test: 50%P_n

	Reactive power set point Q [Var]	Measured reactive power Q [Var]	Measured cos φ	Deviation compared to setpoint ΔQ / PN [%]
- Qmin	--	--	--	--
0	0	--	--	--
+ Qmax	--	--	--	--

Assessment criterion:

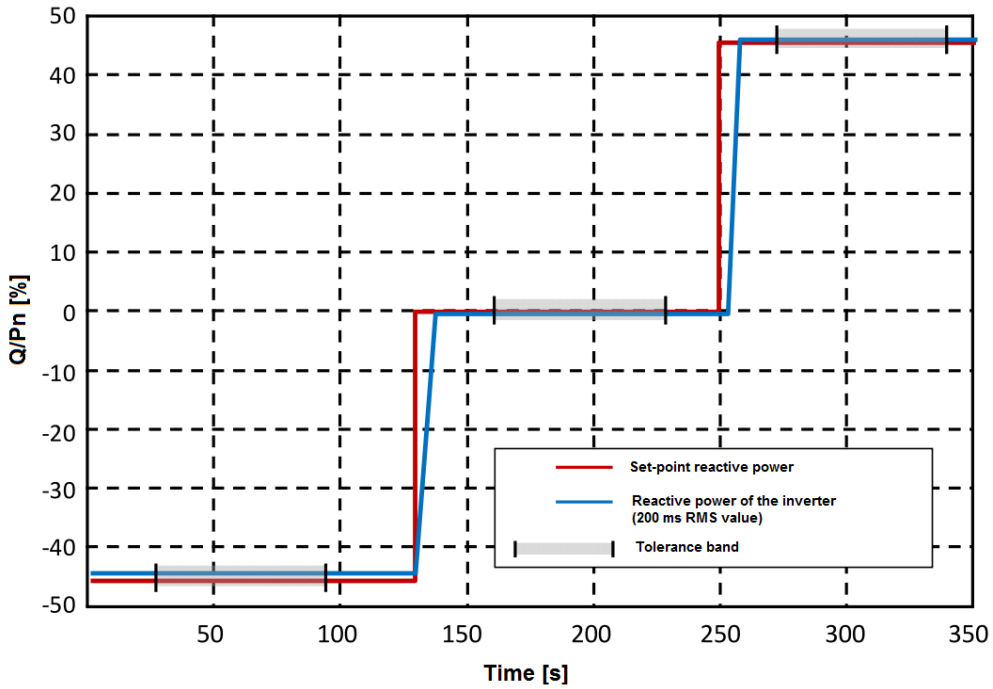
The 3 values measured for each set point to the set value is ΔQ ≤ ± 5 % of the nominal active power of the micro-generator.

Note:

a) 1 min-average-values were calculated using measurements at the basic frequency in a period of 200 ms.

b) For each of operation mode, at least 3 under excited and 3 over excited reactive power levels were recorded.

Diagram: 100%P_n



EN 50438:2013: Voltage control by active power			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.5	Voltage control by active power	D.3.5 (under consideration)	**N/A**

EN 50438:2013: Connection and starting to generate electric power			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.7	Connection and starting to generate electric power	D.3.6	**P**

D.3.6 Connection and starting to generate electrical power			P
Setting value	Min. voltage for connected to grid :	197,8	
	Max. voltage for connected to grid :	250,7	
	Min. Frequency for connected to grid :	47,55	
	Max. voltage for connected to grid :	50,05	
	Observation time (≥60s) :	60s	

Test:		
	Voltage conditons	
a) Start up for voltage range	<84% Un for twice of observation time	>111% Un for twice of observation time
Connection:	No connection	No connection
Limit	No connection allowed	
b) In voltage range at start-up	≥84% Un within twice setting observation time	≤111% Un within twice setting observation time
Reconnection time [s]	76	98
Limit:	Connected after setting observation time (≥60s)	
Gradient:	For adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: 10%Pn/min. For recorded gradient see diagram below.	
c) In voltage range after voltage failture	≥84% Un for twice of setting observation time	≤111% Un for twice of setting observation time
Reconnection time [s]	76	96
Limit:	Reconnection after setting observation time (≥60s)	
Gradient:	For adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: 10%Pn/min. For recorded gradient see diagram below.	

	Frequency conditions	
d) Start up for frequency range	<47,45 Hz for twice of setting observation time	>50,15 Hz for twice of setting observation time
Connection:	No connection	No connection
Limit	No connection allowed	
e) In frequency range at start-up	≥47,45 Hz within twice of setting observation time	≤51,15 Hz within twice of setting observation time
Reconnection time [s]	87	87
Limit:	Connected after setting delay time(≥60s)	
Gradient:	For adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: 10%Pn/min. For recorded gradient see diagram below.	
f) In frequency range after frequency failture	≥47,45 Hz for twice of setting observation time	≤51,10 Hz for twice of setting observation time
Reconnection time [s]	86	85
Limit:	Reconnection after setting observation time (≥60s)	
Gradient:	For adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute Max gradient: 10%Pn/min. For recorded gradient see diagram below.	

Test:

Test condition b) and c): voltage within the limits of 85% to 110%Vn.

Test condition e) and f): frequency within the limits of 47,50Hz to 51,10Hz.

In order to avoid continuous starting and disengaging operations of the interface protection relay, the disengaging value of frequency and voltage functions shall be above 2 % deviating from the operate value.

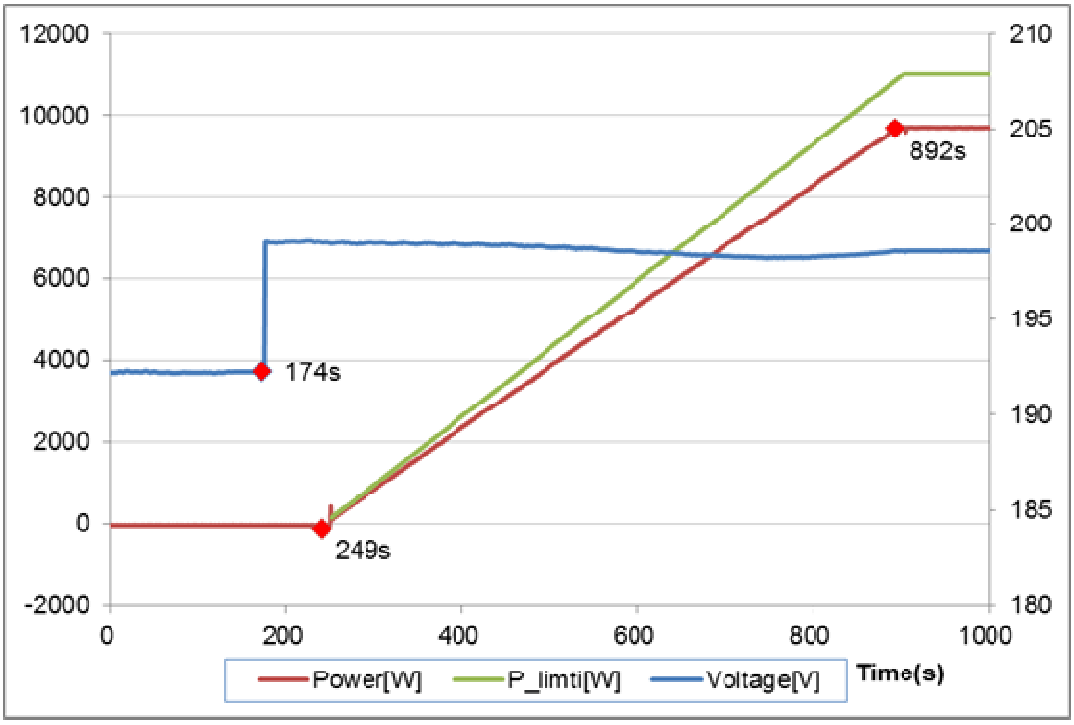
Assessment criterion:

a) the micro generator connects respectively starts generating electrical power only in the permitted range of voltage and frequency and

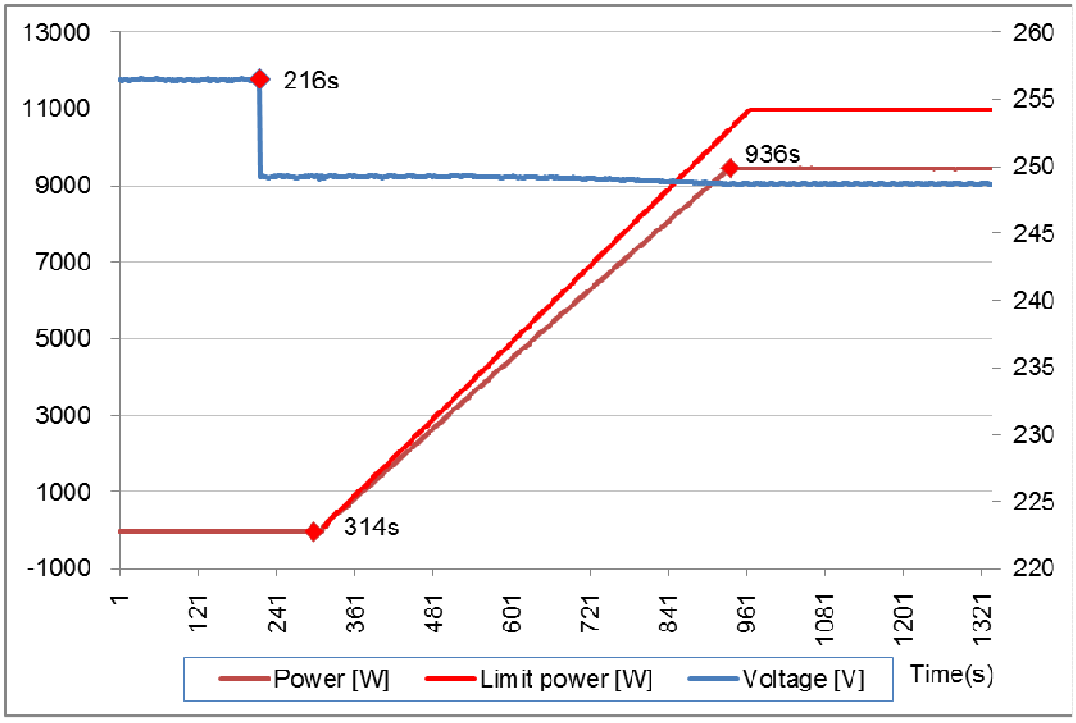
b) for adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute and

c) for non or partly adjustable generators the connection after trip of the interface protection is delayed by a randomised value between 1 min and 10 min.

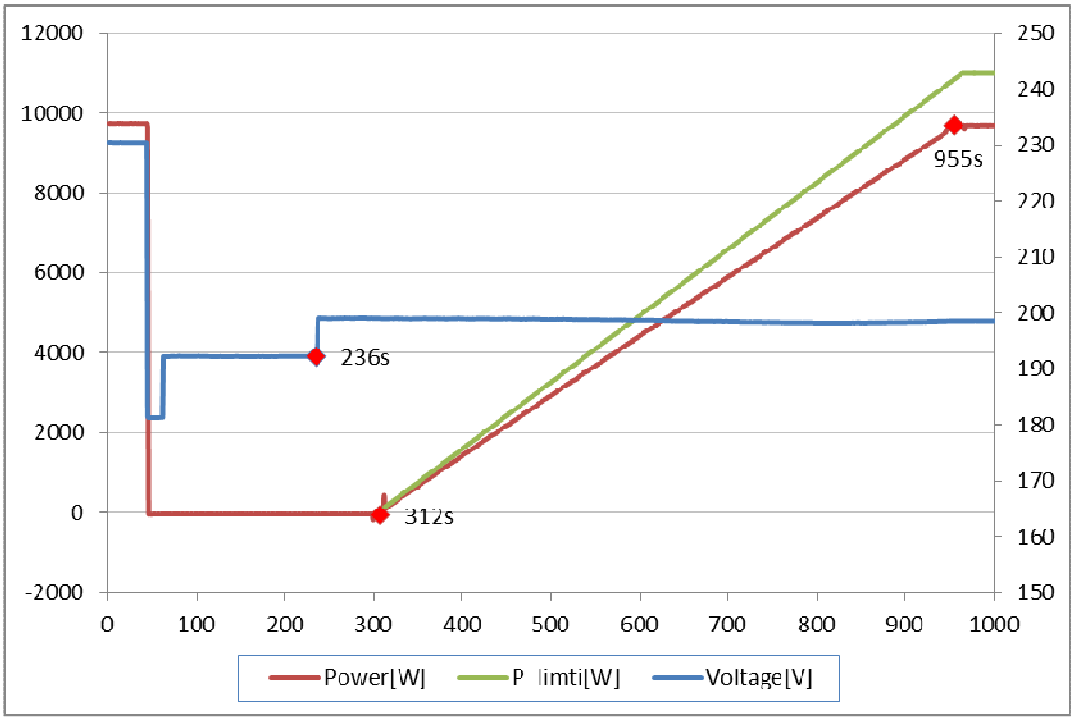
Graph of the gradual power supply: Test b) for ≥ 84% U_n



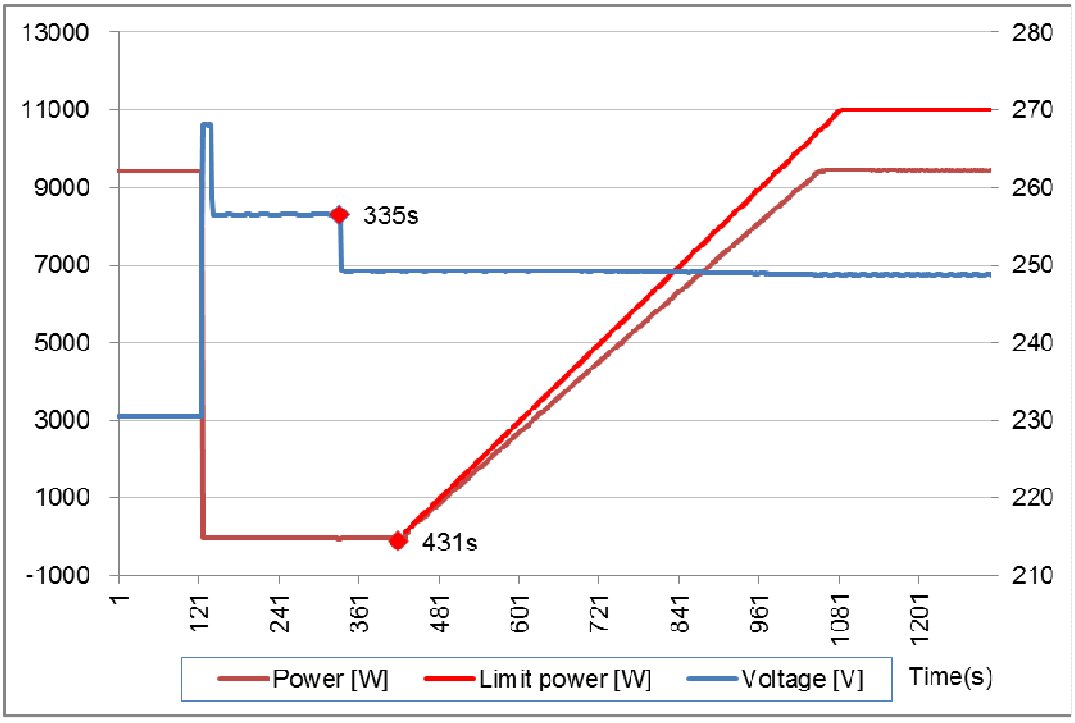
Graph of the gradual power supply: Test b) for ≤ 111% U_n



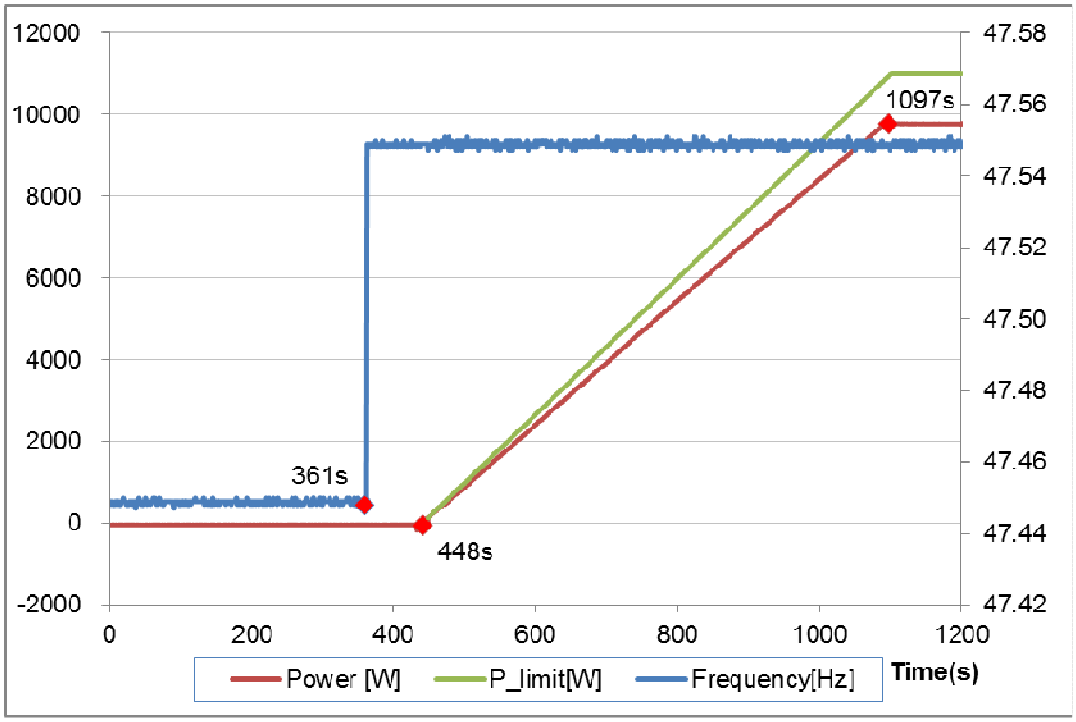
Graph of the gradual power supply: Test c) for ≥ 84% U_n



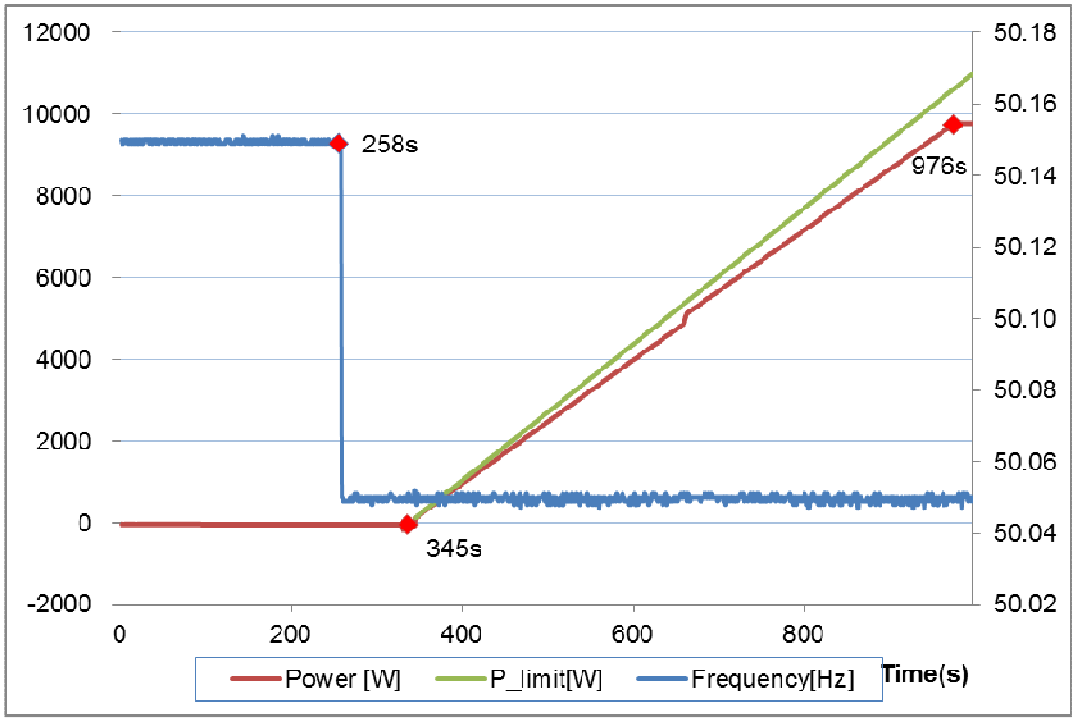
Graph of the gradual power supply: Test c) for ≤ 111% U_n



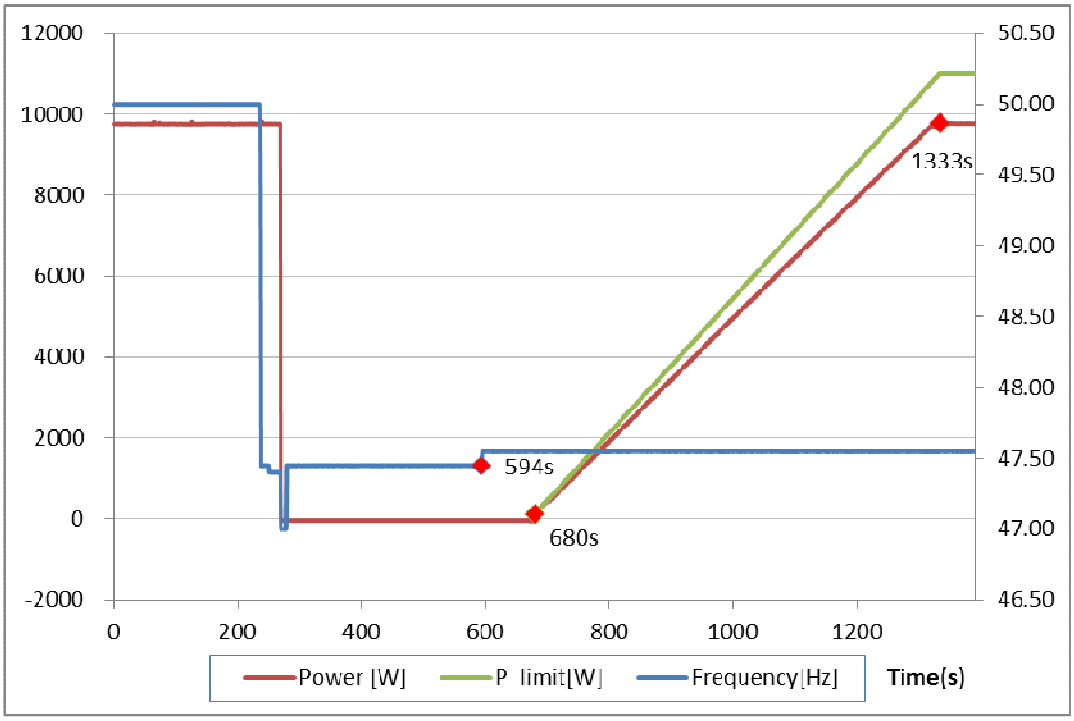
Graph of the gradual power supply: Test e) for ≥ 47,45Hz



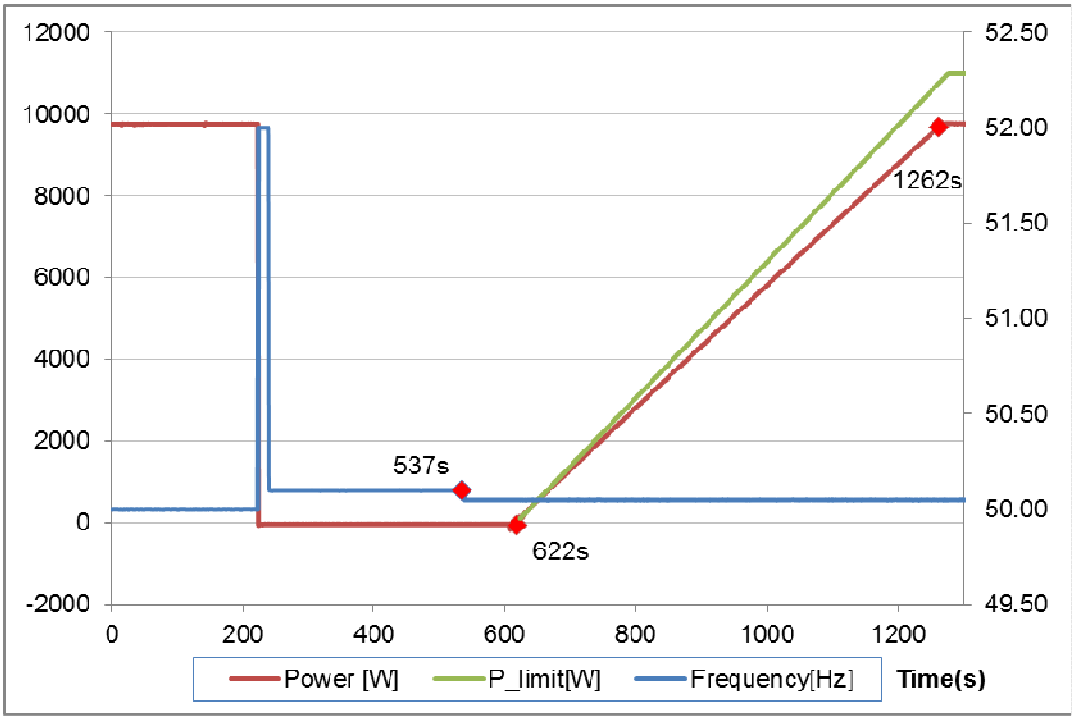
Graph of the gradual power supply: Test e) for ≤ 50,15Hz



Graph of the gradual power supply: Test f) for ≥ 47,45Hz



Graph of the gradual power supply: Test f) for ≤ 50,10Hz



EN 50438:2013: Short circuit current contribution			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.7	Short circuit current contribution	D.3.7	**P**

D.3.7 Short circuit Current Contribution					P
For a directly coupled generator			For an electronic inverter		
Parameter	Symbol	Value	Time after fault	Volts	Amps
L1 Phase					
Peak Short Circuit current	Ip	N/A	20ms	28,40V	2,578A
Initial Value of aperiodic current	A	N/A	100ms	N/A	N/A
Initial symmetrical short-circuit current*	Ik	N/A	250ms	N/A	N/A
Decaying (aperiodic) component of short circuit current*	iDC	N/A	500ms	N/A	N/A
Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	0,0057	In seconds
L2 Phase					
Peak Short Circuit current	Ip	N/A	20ms	47,66V	8,178A
Initial Value of aperiodic current	A	N/A	100ms	N/A	N/A
Initial symmetrical short-circuit current*	Ik	N/A	250ms	N/A	N/A
Decaying (aperiodic) component of short circuit current*	iDC	N/A	500ms	N/A	N/A
Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	0,0057	In seconds
L3 Phase					
Peak Short Circuit current	Ip	N/A	20ms	40,99V	6,062A
Initial Value of aperiodic current	A	N/A	100ms	N/A	N/A
Initial symmetrical short-circuit current*	Ik	N/A	250ms	N/A	N/A
Decaying (aperiodic) component of short circuit current*	iDC	N/A	500ms	N/A	N/A
Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	0,0057	In seconds

Diagram

Note:

The values of voltage and current should be recorded for a period of up to 1 second when the changeover switch should be returned to the normal position. The voltage and current at relevant times shall be recorded in the type test report (Appendix 4) including the time taken for the Inverter to trip.

EN 50438:2013: Power quality			
Clause	**Test requirement**	**Test procedure acc. to Annex D**	**Result**
4.8	Power quality	D.3.8 / D.3.9 / D.3.10	**P**

D.3.8 Harmonic current emission (EN 61000-3-2)	P

Watts [kW]	3,399/3,331/3,325
Vrms [V]	230,81/230,75/230,69
Arms [A]	14,726/14,438/14,412
Frequency [Hz]	50,00

Harmonic order n	Current Magnitude [A] at 100% rated output power			% of Fundamental			Phase	Harmonic current limit EN 61000-3-2, Class A [A]
	L1	L2	L3	L1	L2	L3		
1st	14,718	14,430	14,405	99,950	99,948	99,949	Three Phase	-
2nd	0,301	0,246	0,294	2,043	1,705	2,038	Three Phase	1,080
3rd	0,168	0,260	0,177	1,138	1,801	1,226	Three Phase	2,300
4th	0,064	0,062	0,064	0,431	0,432	0,447	Three Phase	0,430
5th	0,205	0,171	0,200	1,395	1,187	1,389	Three Phase	1,140
6th	0,033	0,031	0,035	0,227	0,213	0,240	Three Phase	0,300
7th	0,064	0,095	0,063	0,437	0,660	0,434	Three Phase	0,770
8th	0,022	0,021	0,023	0,151	0,144	0,158	Three Phase	0,230
9th	0,037	0,040	0,039	0,251	0,274	0,271	Three Phase	0,400
10th	0,019	0,018	0,020	0,131	0,125	0,137	Three Phase	0,184
11th	0,028	0,044	0,027	0,192	0,303	0,188	Three Phase	0,330
12th	0,021	0,020	0,023	0,145	0,140	0,162	Three Phase	0,153
13th	0,026	0,039	0,027	0,176	0,272	0,185	Three Phase	0,210
14th	0,022	0,022	0,023	0,147	0,149	0,161	Three Phase	0,131
15th	0,034	0,023	0,033	0,233	0,159	0,230	Three Phase	0,150
16th	0,024	0,020	0,023	0,160	0,136	0,157	Three Phase	0,115
17th	0,037	0,052	0,036	0,254	0,359	0,248	Three Phase	0,132
18th	0,028	0,023	0,029	0,192	0,157	0,203	Three Phase	0,102
19th	0,037	0,028	0,035	0,248	0,197	0,245	Three Phase	0,118
20th	0,031	0,029	0,032	0,208	0,202	0,225	Three Phase	0,092
21th	0,044	0,046	0,043	0,302	0,318	0,297	Three Phase	0,107
22th	0,033	0,029	0,031	0,225	0,200	0,218	Three Phase	0,084
23th	0,047	0,048	0,047	0,317	0,333	0,328	Three Phase	0,098
24th	0,040	0,031	0,040	0,270	0,217	0,278	Three Phase	0,077
25th	0,050	0,050	0,048	0,337	0,343	0,330	Three Phase	0,090
26th	0,040	0,039	0,045	0,268	0,267	0,309	Three Phase	0,071
27th	0,056	0,056	0,053	0,380	0,389	0,367	Three Phase	0,083
28th	0,043	0,038	0,041	0,293	0,266	0,284	Three Phase	0,066
29th	0,056	0,054	0,056	0,380	0,374	0,386	Three Phase	0,078
30th	0,043	0,030	0,041	0,295	0,210	0,283	Three Phase	0,061
31th	0,055	0,064	0,056	0,376	0,443	0,391	Three Phase	0,073
32th	0,041	0,038	0,041	0,280	0,262	0,287	Three Phase	0,058
33th	0,048	0,042	0,044	0,327	0,289	0,306	Three Phase	0,068
34th	0,036	0,031	0,036	0,247	0,212	0,248	Three Phase	0,054
35th	0,043	0,048	0,042	0,295	0,334	0,288	Three Phase	0,064
36th	0,030	0,026	0,030	0,204	0,178	0,211	Three Phase	0,051
37th	0,041	0,039	0,041	0,275	0,268	0,287	Three Phase	0,061
38th	0,029	0,024	0,029	0,197	0,168	0,198	Three Phase	0,048
39th	0,031	0,034	0,031	0,208	0,238	0,212	Three Phase	0,058
40th	0,025	0,021	0,025	0,171	0,143	0,176	Three Phase	0,046

D.3.9 Voltage fluctuation and flicker	P

	Maximum permissible voltage fluctuation (expressed as a percentage of nominal voltage at 100 % power) and flicker as per EN 61000-3-3				
Value	**Pst**	**Plt 2 hours**	**d(t) $_{500ms}$**	**dc**	**dmax**
Limit	1,0	0,65	3,3%	3,3%	4%
Test value:	See below				

L1 Phase:

No.	dc[%]	dmax[%]	d(t)[ms]	Pst
1	0.23	0.38	0.00	0.07
2	0.22	0.36	0.00	0.07
3	0.22	0.35	0.00	0.07
4	0.22	0.35	0.00	0.07
5	0.22	0.35	0.00	0.07
6	0.21	0.34	0.00	0.07
7	0.22	0.37	0.00	0.07
8	0.22	0.36	0.00	0.07
9	0.23	0.36	0.00	0.07
10	0.22	0.36	0.00	0.07
11	0.23	0.35	0.00	0.07
12	0.23	0.34	0.00	0.07

Plt
0.07

L2 Phase:

No.	dc[%]	dmax[%]	d(t)[ms]	Pst
1	0.00	0.00	0.00	0.07
2	0.00	0.00	0.00	0.07
3	0.00	0.00	0.00	0.07
4	0.00	0.00	0.00	0.07
5	0.00	0.00	0.00	0.07
6	0.00	0.00	0.00	0.07
7	0.00	0.00	0.00	0.07
8	0.00	0.00	0.00	0.07
9	0.00	0.00	0.00	0.07
10	0.00	0.00	0.00	0.07
11	0.00	0.00	0.00	0.07
12	0.00	0.00	0.00	0.07

Plt
0.07

L3 phase:

No.	dc[%]	dmax[%]	d(t)[ms]	Pst
1	0.24	0.26	0.00	0.07
2	0.01	0.25	0.00	0.07
3	0.00	0.00	0.00	0.07
4	0.01	0.27	0.00	0.07
5	0.00	0.28	0.00	0.07
6	0.01	0.26	0.00	0.07
7	0.00	0.00	0.00	0.07
8	0.00	0.00	0.00	0.07
9	0.00	0.00	0.00	0.07
10	0.00	0.00	0.00	0.07
11	0.00	0.00	0.00	0.07
12	0.00	0.00	0.00	0.07
				Plt
				0.07

Note:

* see Annex No. 1 – EMC Test report

Mains Impedance according EN61000-3-3: Rmax = 0,24 Ω; jXmax= 0,15 Ω @50Hz (|Zmax| = 0,472 Ω)

Calculation of the maximum permissible grid impedance at the point of common coupling based on dc:
Zmax = Zref * 3,3% / dc(Pn)

The tests should be based on the limits of the EN61000-3-3 for less than 16A.

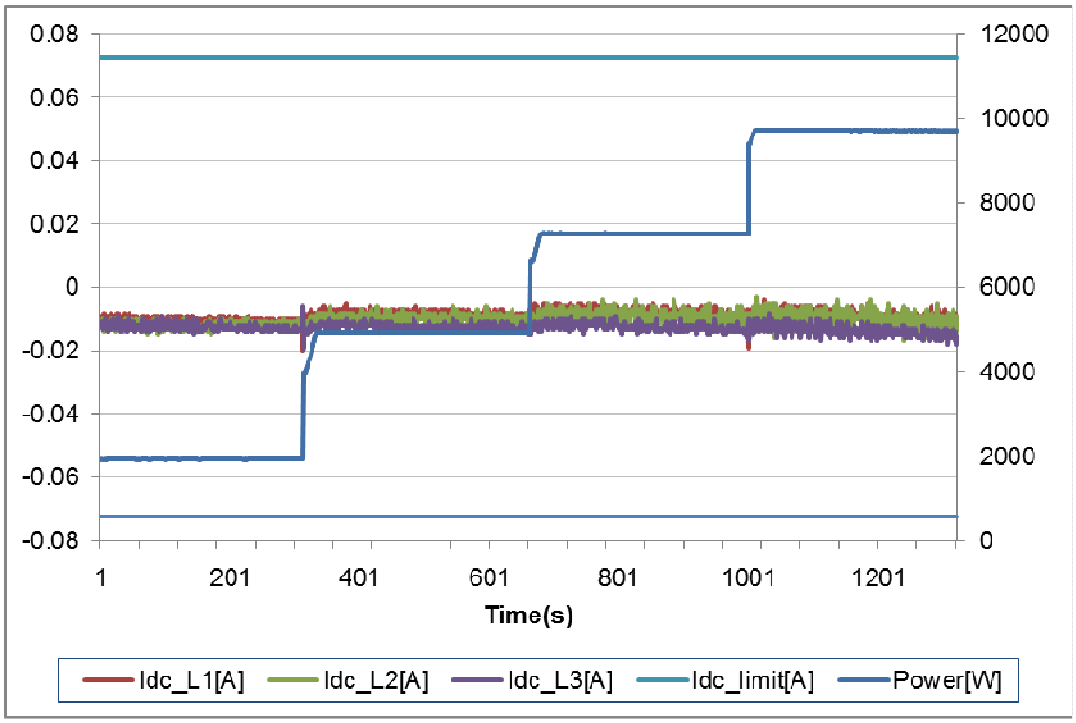
D.3.10 DC-Injection	P

Protection limit	Tested at four power levels limit 0,5% of $I_{AC;nom}$			
Output power	~20%	~50%	75%	~100%
Max. test value (phase L1) [mA]	-10	-8	-8	-9
Max. test value (phase L2) [mA]	-12	-10	-9	-10
Max. test value (phase L3) [mA]	-12	-12	-12	-14

Note:

Testing must be performed according to WI 10.4.-03.doc rev D. The internal temperature of the EUT must be stabilized. No temperature drift of more than 2K within 1 hour is allowed.

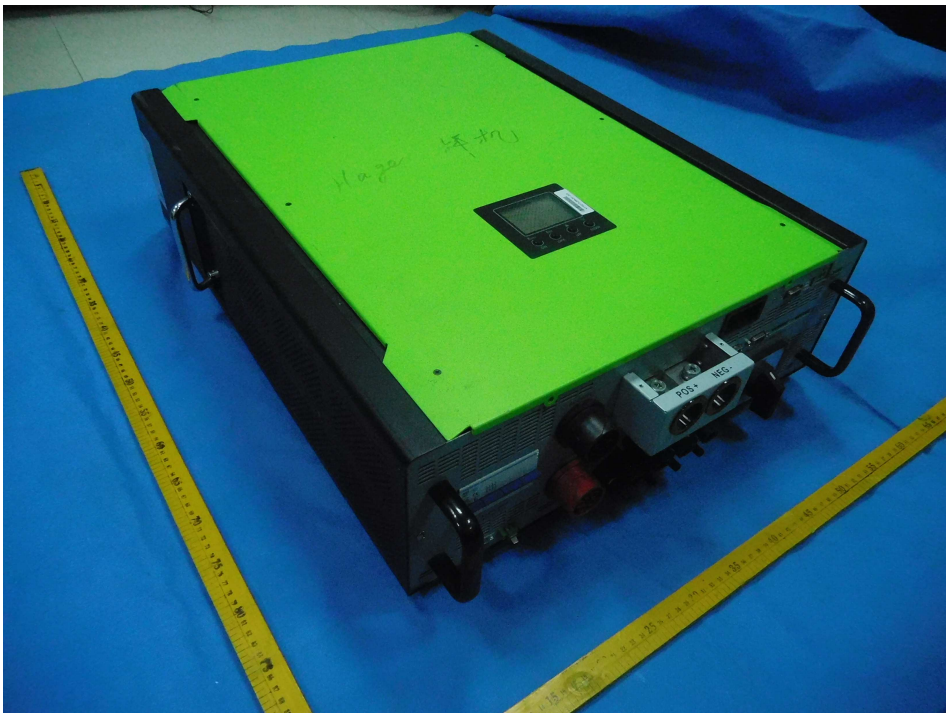
Diagram of permanent dc-injection (20% / 50% / 75% / 100%)



Annex 1

Pictures of the unit

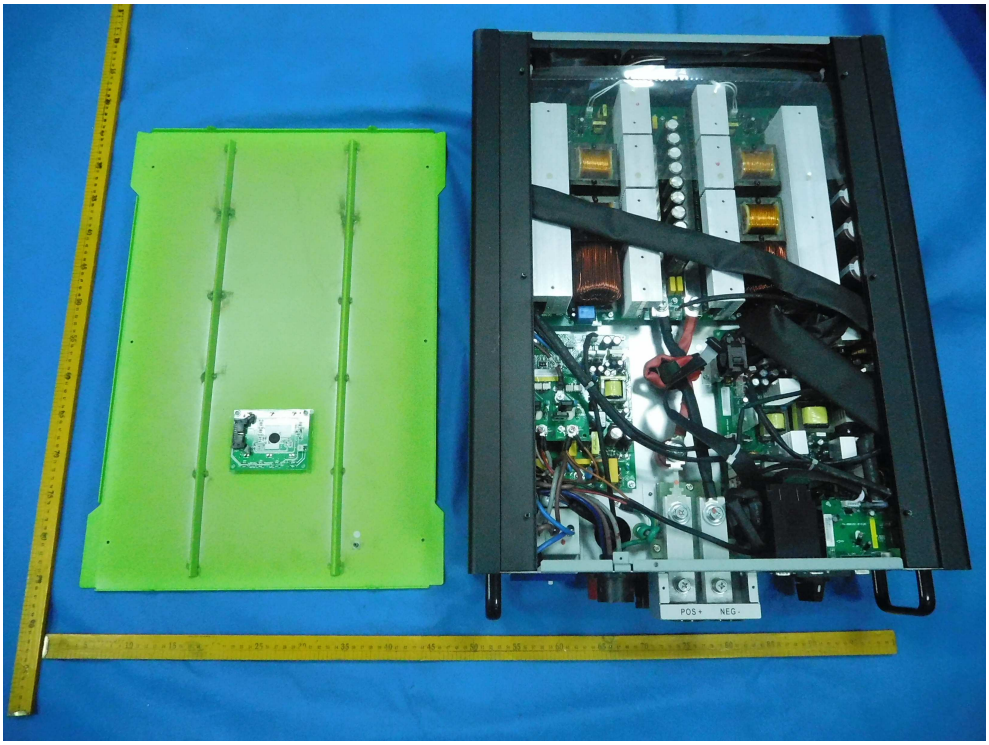
Enclosure front view:



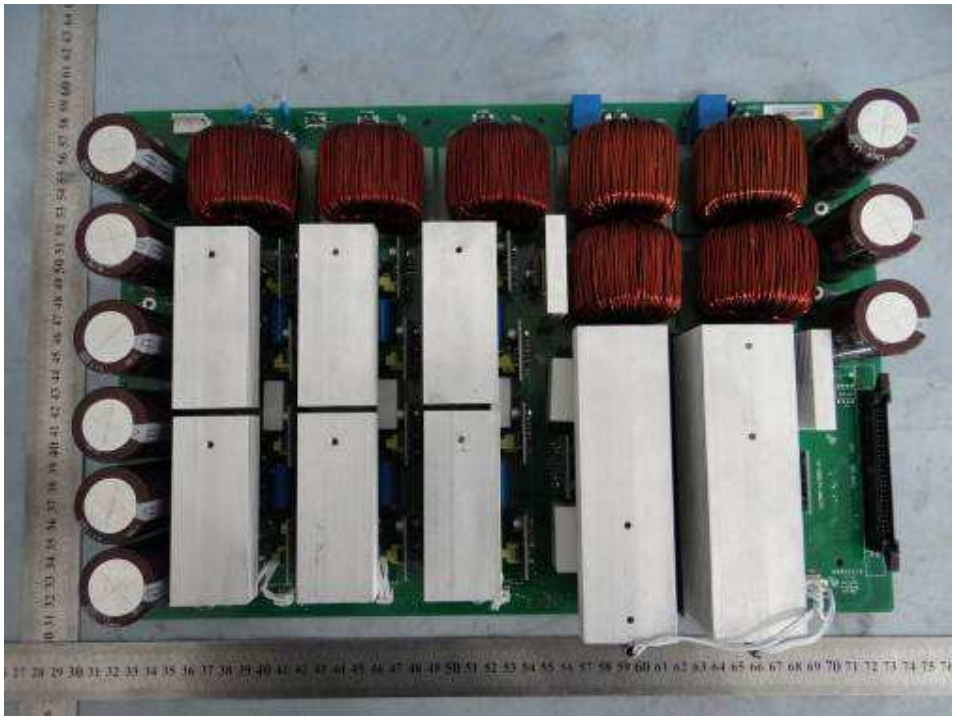
Enclosure rear view:

Enclosure bottom view:

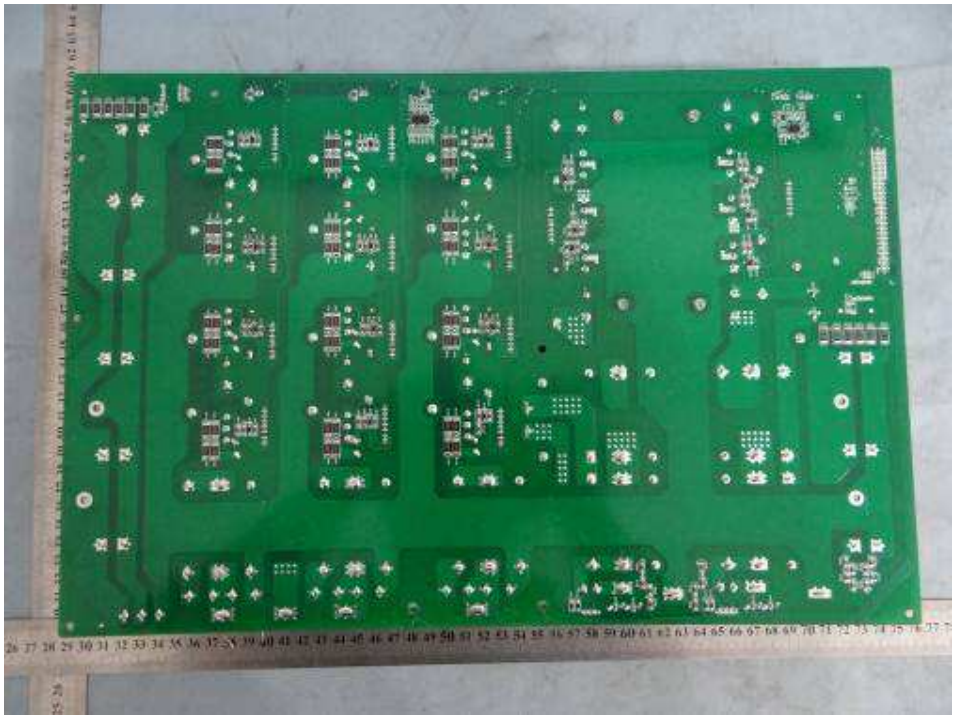
Internal view:



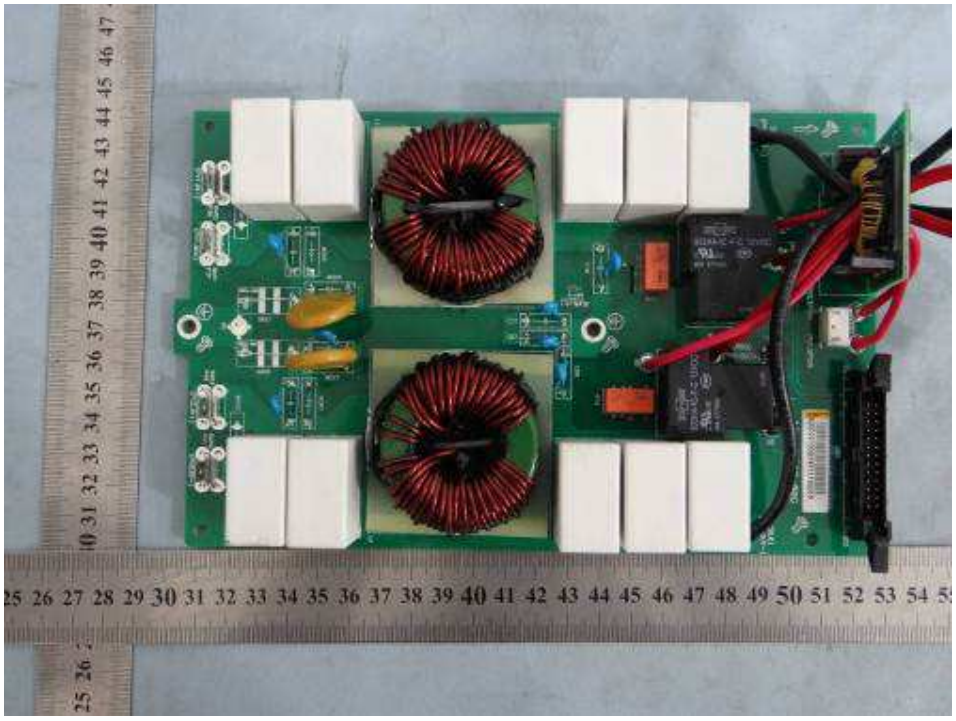
Inverter board - component side view:



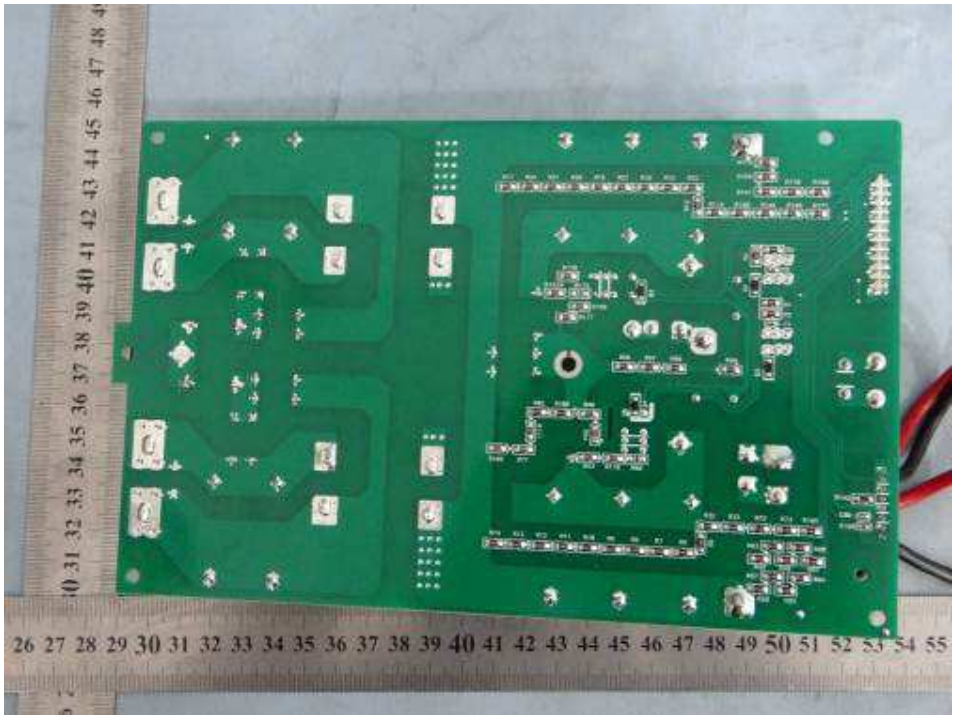
Inverter board - solder side view:



PV side EMI board - component side view:

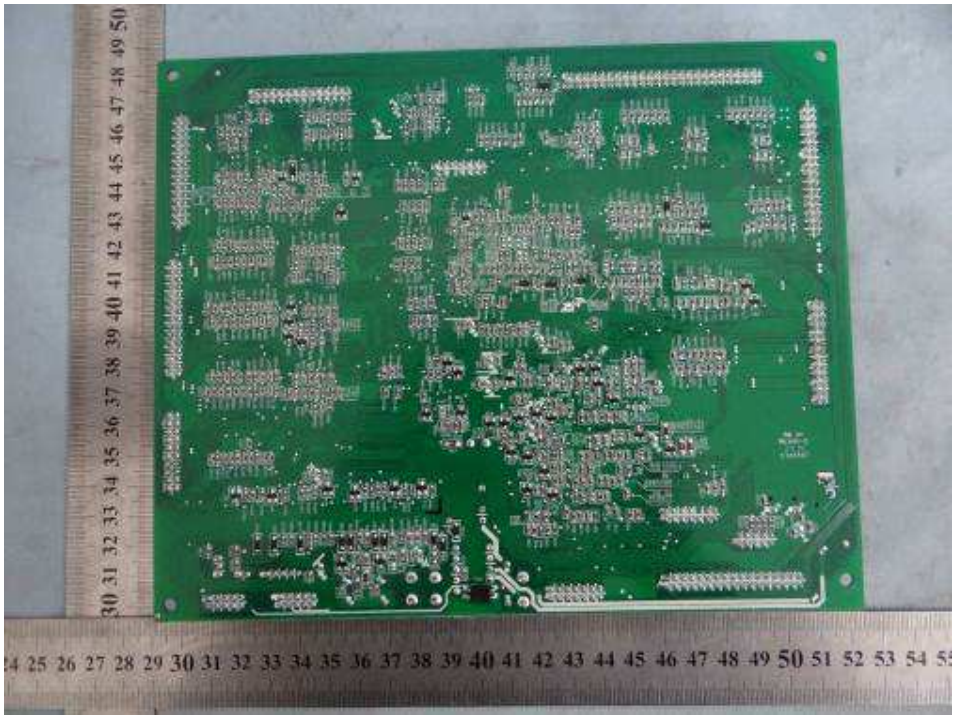


PV side EMI board - solder side view:

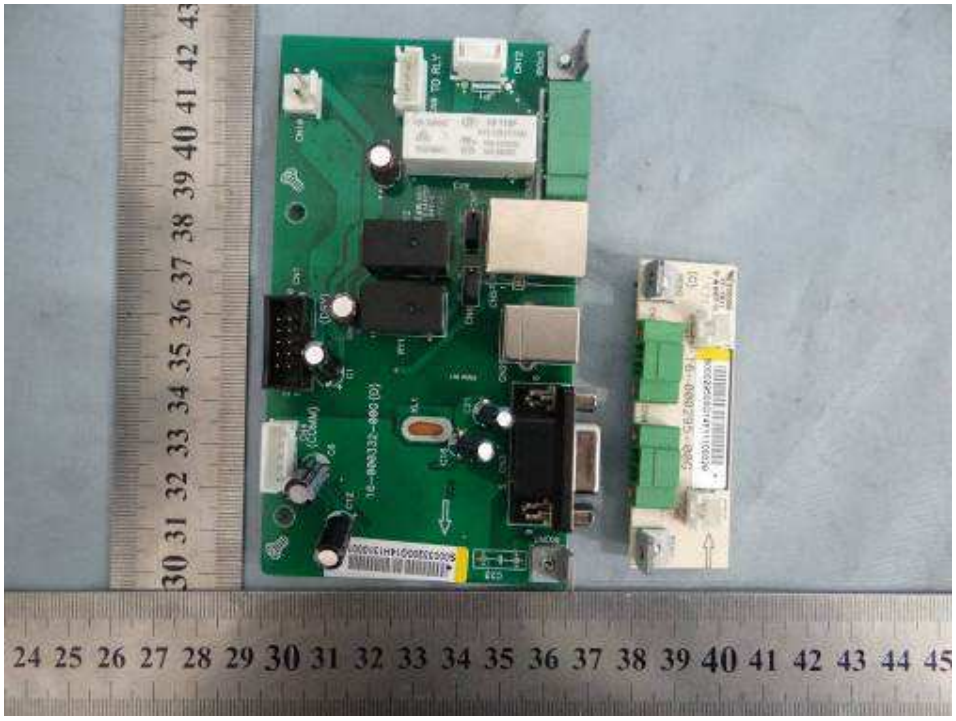


Control board - component side view:

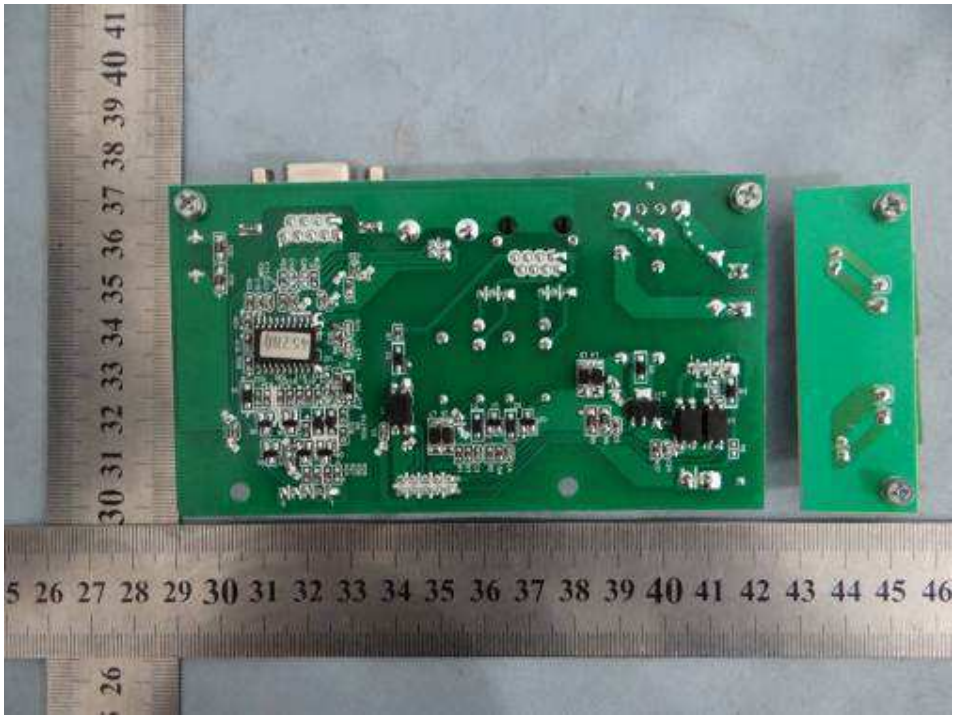
Control board - solder side view:



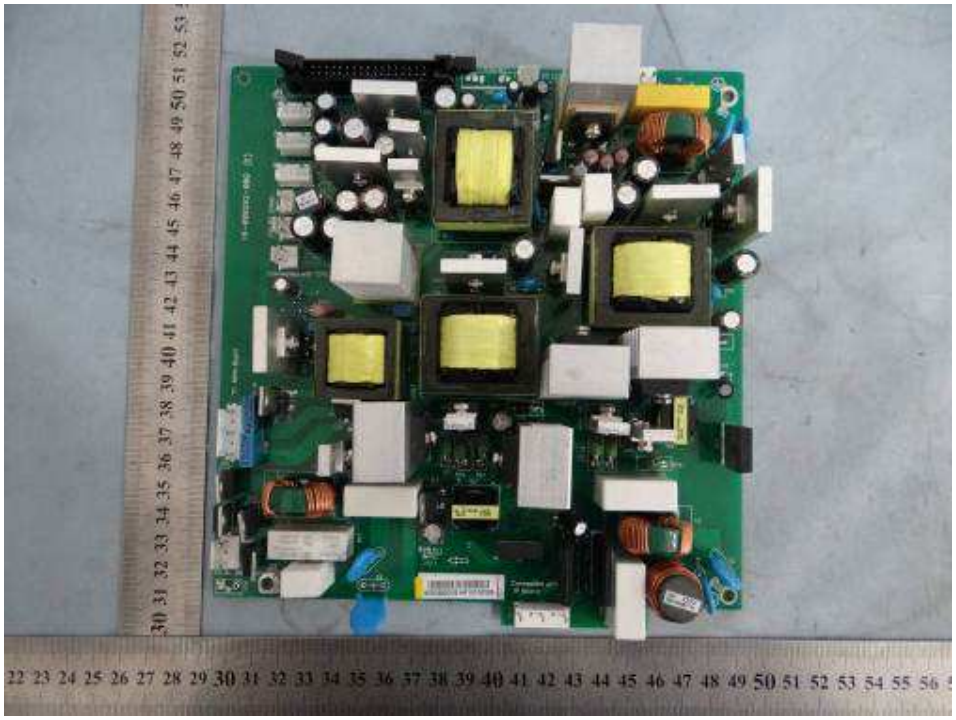
COM board - component side view:



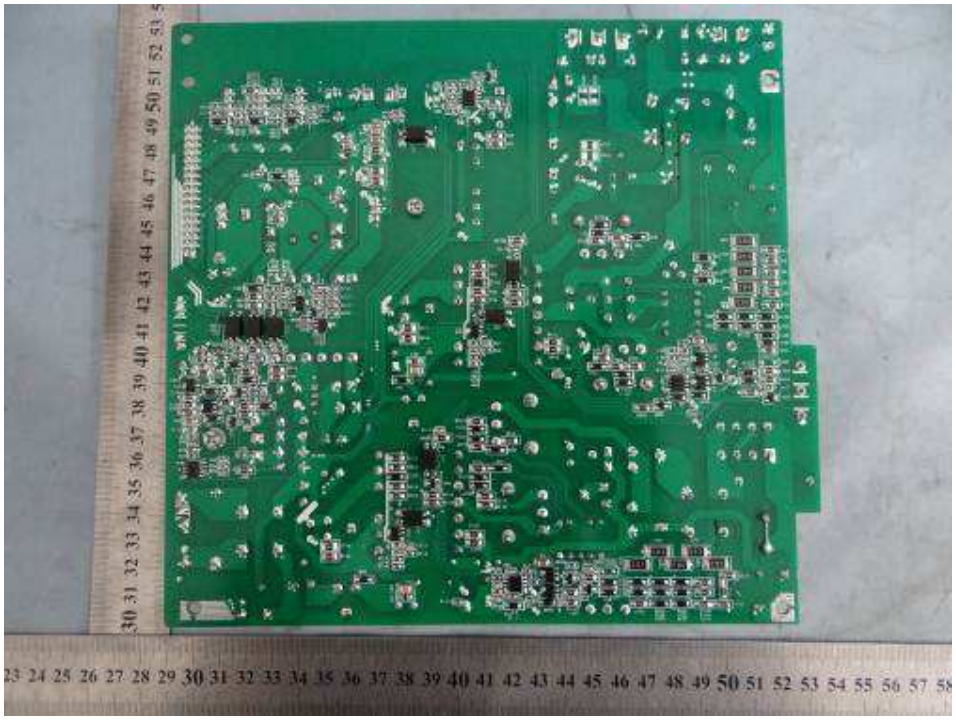
COM board - solder side view:



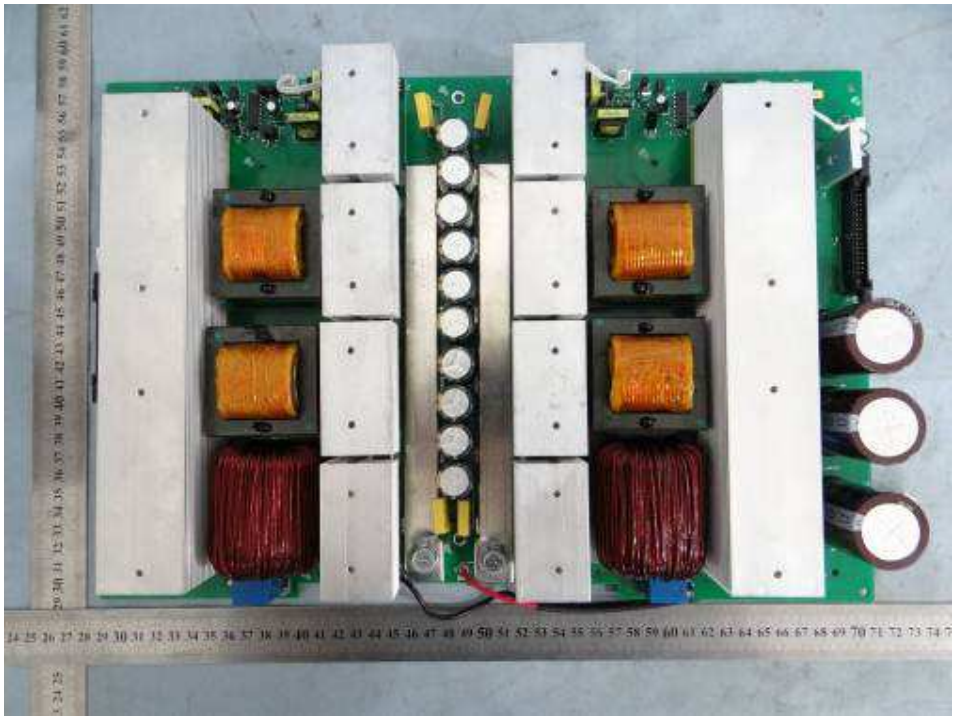
SPS board - component side view:



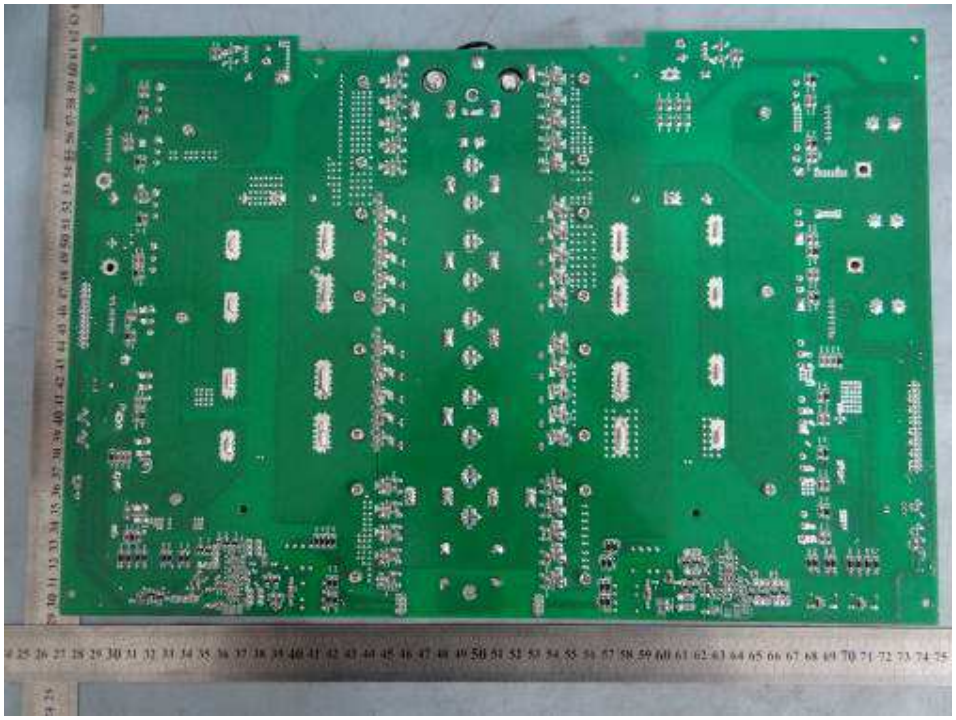
SPS board - solder side view:



DC-DC board - component side view:

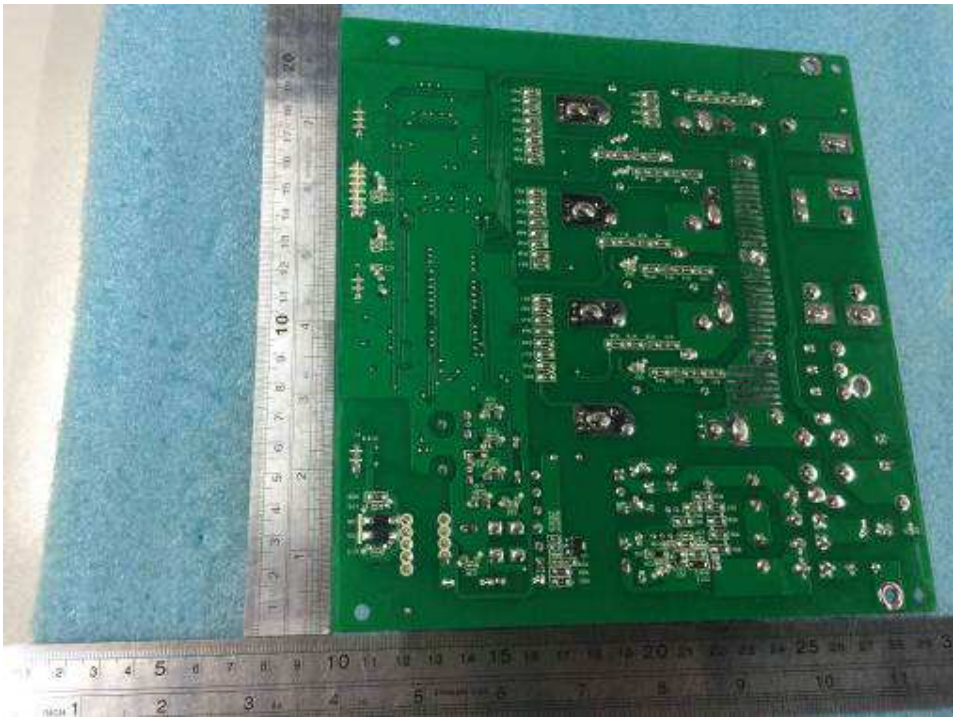


DC-DC board - solder side view:

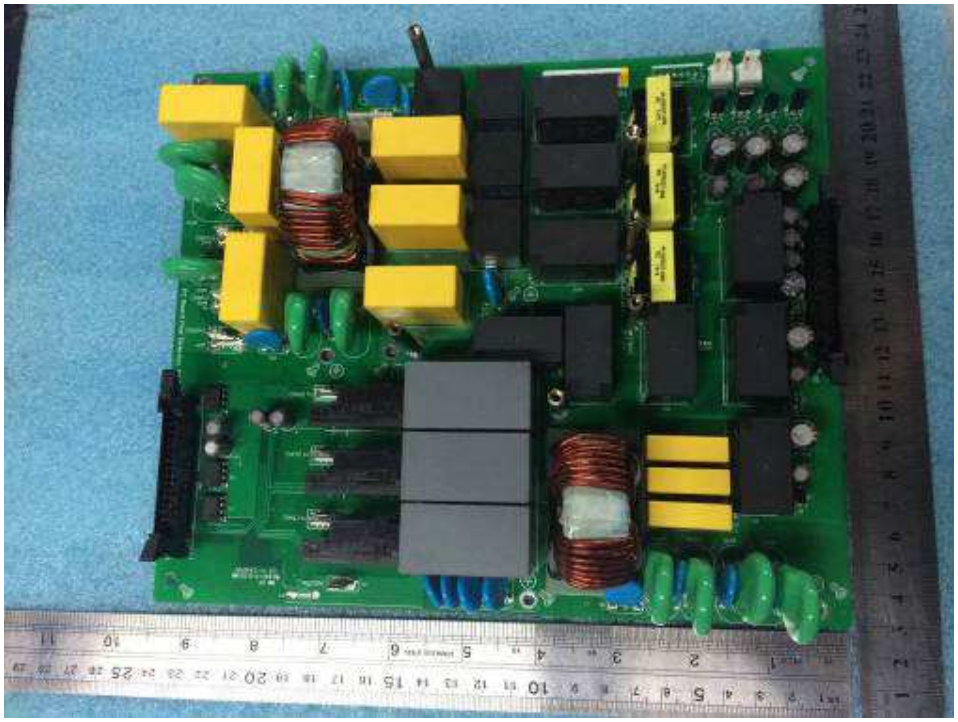


Relay board - component side view:

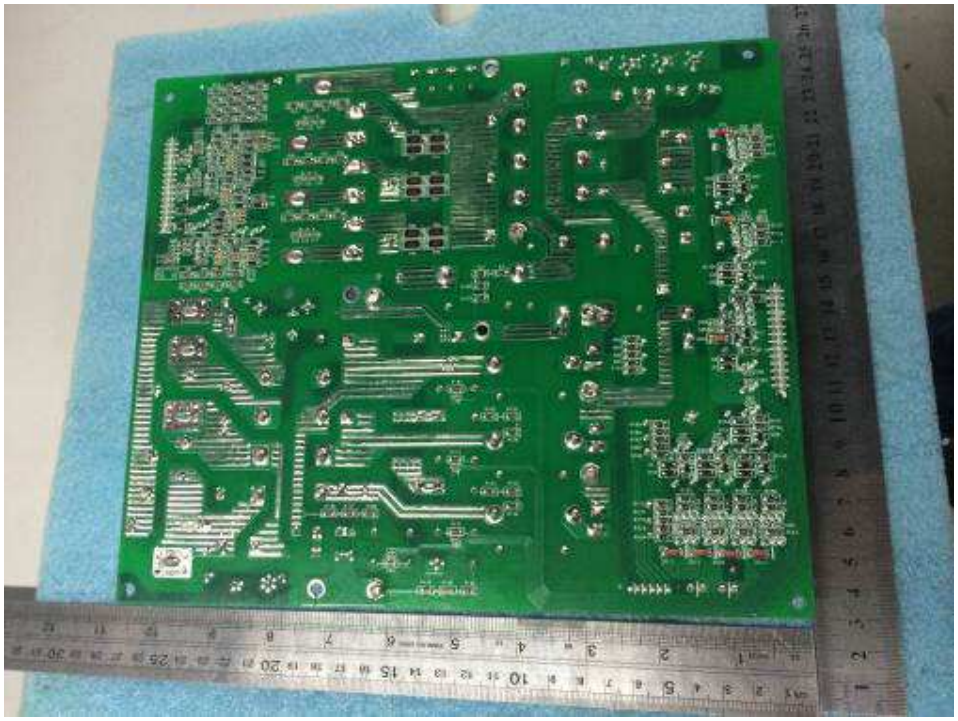
Relay board - solder side view:

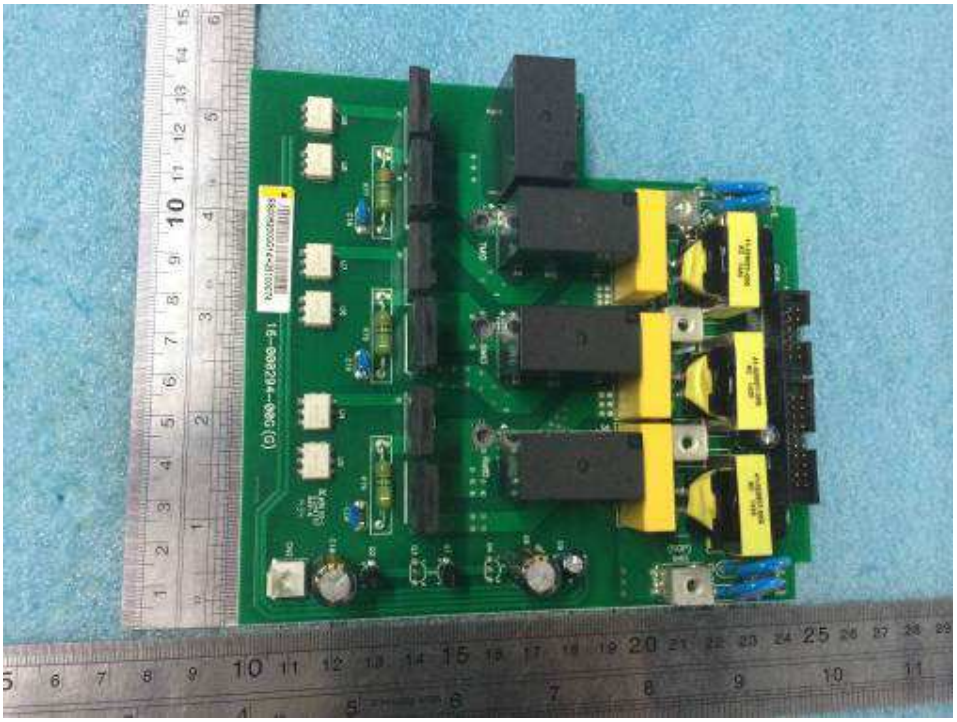
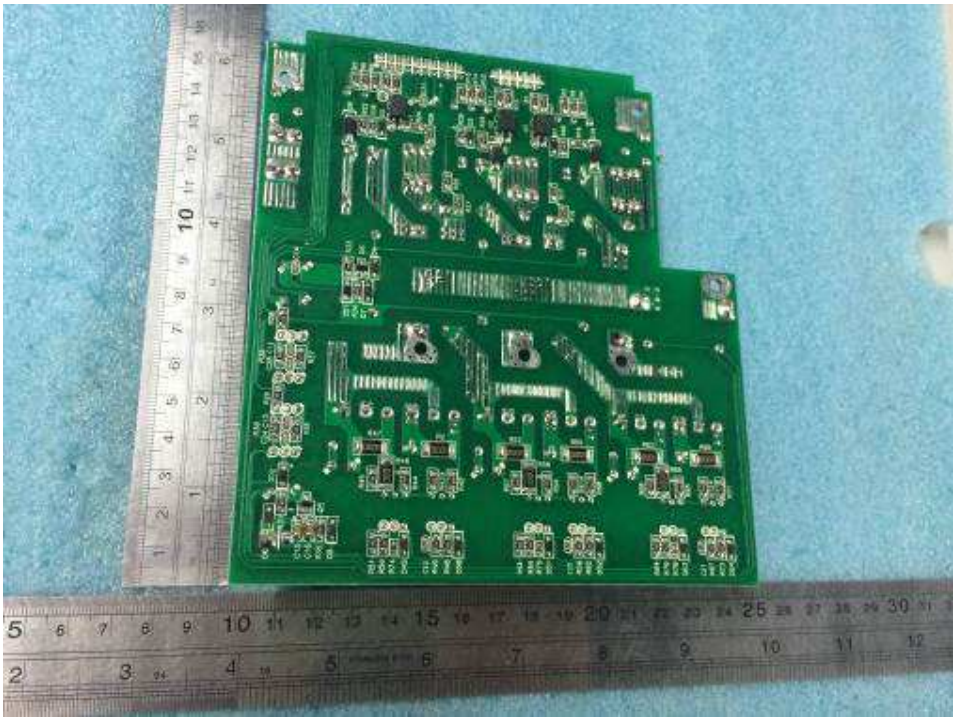


Grid board - component side view:

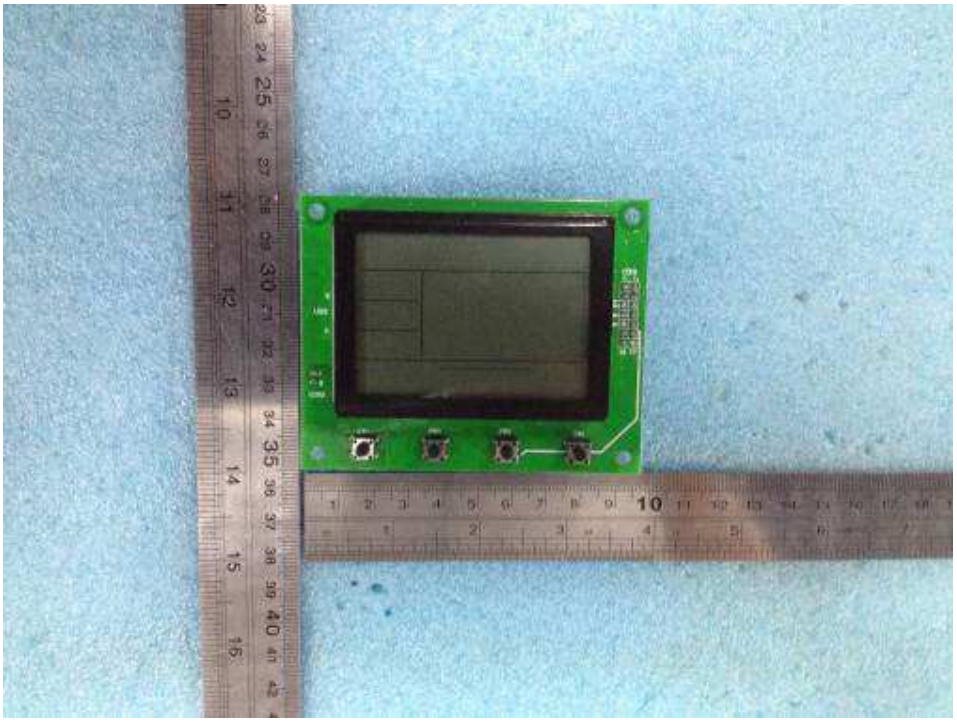


Grid board - solder side view:

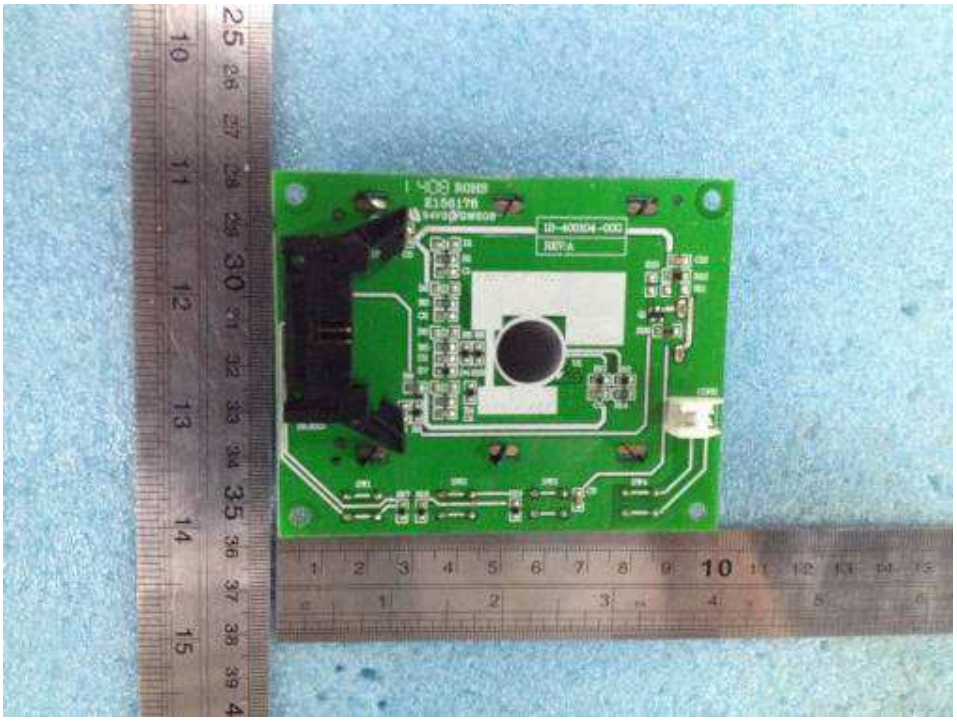


OP board - component side view:

OP board - solder side view:


LCD board - component side view:



LCD board - solder side view:



Anne 2

Test Equipment list

Test location: Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Date of performed test: 2016-02-01 to 2016-04-22

Equipment	Internal No.	Manufacturer	Type	Serial No.	Last Calibration
Power Analyzer	A4080002DG	YOKOGAWA	WT3000	91M210852	Mar. 07, 2016
AC Source	A7040019DG	Chroma	61512	61512000439	Monitored by Power Analyzer
AC Source	A7040020DG	Chroma	61512	61512000438	Monitored by Power Analyzer
DC Simulation Power Supply	A7040015DG	Chroma	62150H-1000S	62150EF00488	Monitored by Power Analyzer
DC Simulation Power Supply	A7040016DG	Chroma	62150H-1000S	62150EF00490	Monitored by Power Analyzer
RLC Load	A7150027DG	Qunling	ACLT-3803H	93VOO2869	Monitored by Power Analyzer
Four Channel Digital Phosphor Oscilloscope	A4089003DG	Tektronix	DPO4104B	C010624	Oct. 16, 2015
Current transducer	A1060007DG	YOKOGAWA	CT200	1130700012	Jan. 20, 2016
Oscilloscope probel	A4089010DG	Tektronix	TPP1000	C008228	Dec. 20, 2015
Oscilloscope probel	A4089011DG	Tektronix	TPP1000	C008229	Dec. 20, 2015
LCR Hitester	A1060006DG	HIOKI	3535	120112505	Mar. 06, 2016

Test location: Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Date of performed test: 2017-02-07 to 2017-02-21

Equipment	Internal No.	Manufacturer	Type	Serial No.	Last Calibration
Power Analyzer	A4080002DG	YOKOGAWA	WT3000	91M210852	Mar. 07, 2016
AC Source	A7040019DG	Chroma	61512	61512000439	Monitored by Power Analyzer
AC Source	A7040020DG	Chroma	61512	61512000438	Monitored by Power Analyzer
DC Simulation Power Supply	A7040015DG	Chroma	62150H-1000S	62150EF00488	Monitored by Power Analyzer
DC Simulation Power Supply	A7040016DG	Chroma	62150H-1000S	62150EF00490	Monitored by Power Analyzer
RLC Load	A7150027DG	Qunling	ACLT-3803H	93VOO2869	Monitored by Power Analyzer
Four Channel Digital Phosphor Oscilloscope	A4089003DG	Tektronix	DPO4104B	C010624	Oct. 11, 2016
Current transducer	A1060007DG	YOKOGAWA	CT200	1130700012	Nov. 29, 2016
Oscilloscope probel	A4089010DG	Tektronix	TPP1000	C008228	Dec. 15, 2016
Oscilloscope probel	A4089011DG	Tektronix	TPP1000	C008229	Dec. 15, 2016