TEST REPORT

EN 50549-1:2019

Requirements for generating plants to be connected in parallel with distribution networks - Part 1-1: Connection to a LV distribution network - Generating plants up to and including Type B

Report reference number .... :	**PV200511N080-7**
Date of issue .... :	2020-12-18
Total number of pages .... :	165
Testing laboratory name .... :	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
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Accrediation .... :	ilac-MRA; A2LA ACCREDITED Certificate # 2951.01
Applicant's name .... :	**Shenzhen SOFARSOLAR Co., Ltd.**
Address .... :	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China
Test specification	
Standard.. :	EN 50549-1:2019 with deviations according the national network and system protection for Poland, Netherlands, Turkey, Finland and Portugal.
Test Report Form No. .... :	EN 50549-1 VER.0
TRF Originator .... :	Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Master TRF .... :	Dated 2019-12-11
Test item description..................... :	**Solar Grid-tied Inverter**
Trademark....................................... :	SOFAR SOLAR
Model / Type .... :	SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3, SOFAR 22KTLX-G3, SOFAR 24KTLX-G3

Ratings .... :	**SOFAR 15KTLX-G3**	**SOFAR 17KTLX-G3**	**SOFAR 20KTLX-G3**	**SOFAR 22KTLX-G3**	**SOFAR 24KTLX-G3**
Input DC voltage [V]......................... :	Max. 1100Vd.c.				
MPP DC voltage range [V]............... :	140-1000Vd.c.				
Input DC current [A] .... :	26,0A / 26,0A				
Isc PV [A] .... :	36,0A / 36,0A				
Output AC voltage [V] .... :	380/400Va.c., 3W+N+PE; 50/60Hz				
Rated Output AC current [A]............ :	21,7	24,6	29,0	31,9	34,8
Max. Output AC current [A].............. :	23,9	27,1	31,9	35,1	38,3
Rated Output power [kW] .... :	15,0	17,0	20,0	22,0	24,0
Max Output power [kVA] .... :	16,5	18,7	22,0	24,2	26,4

Testing Location .... :	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address .... :	No. 96, Guantai Road (Houjie Section), Houjie Town, Dongguan City, Guangdong Province, 523942, People's Republic of China
Tested by (name and signature) .... :	Lukes Lin
Approved by (name and signature) .... :	James Huang
Manufacturer's name .... :	**Shenzhen SOFARSOLAR Co., Ltd.**
Manufacturer address .... :	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China
Factory's name .... :	**Dongguan SOFAR SOLAR Co.,Ltd.**
Factory address .... :	1F - 6F, Building E, No. 1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City

Document History			
Date	**Internal reference**	**Modification / Change / Status**	**Revision**
2020-12-18	Lukes Lin	Initial report was written	0
Supplementary information:			

Test items particulars

Equipment mobility ....:	Permanent connection
Operating condition ....:	Continuous
Class of equipment ....:	Class I
Protection against ingress of water ..:	IP65 according to EN 60529
Mass of equipment [kg] ....:	Approx. 20,0 kg for SOFAR 15KTLX-G3; Approx. 22,0 kg for SOFAR 17KTLX-G3, SOFAR 20KTLX-G3; Approx. 23,0 kg for SOFAR 22KTLX-G3, SOFAR 24KTLX-G3;

Test case verdicts

Test case does not apply to the test object ....:	N/A
Test item does meet the requirement ....:	P(ass)
Test item does not meet the requirement ....:	F(ail)

Testing

Date of receipt of test item ....:	2020-06-01
Date(s) of performance of test ....:	2020-06-01 to 2020-12-18

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 50549-1. 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.

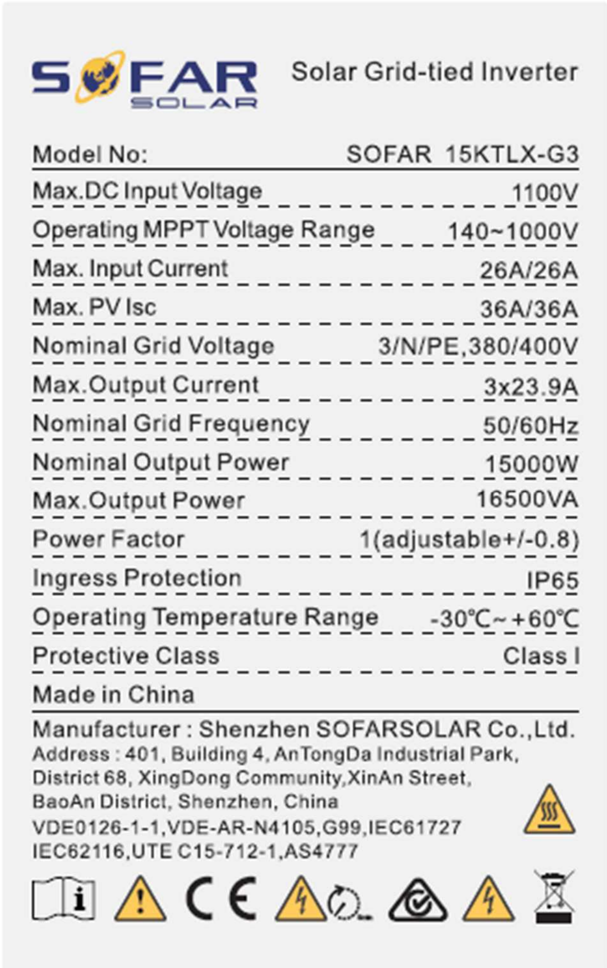
Throughout this report a comma is used as the decimal separator.

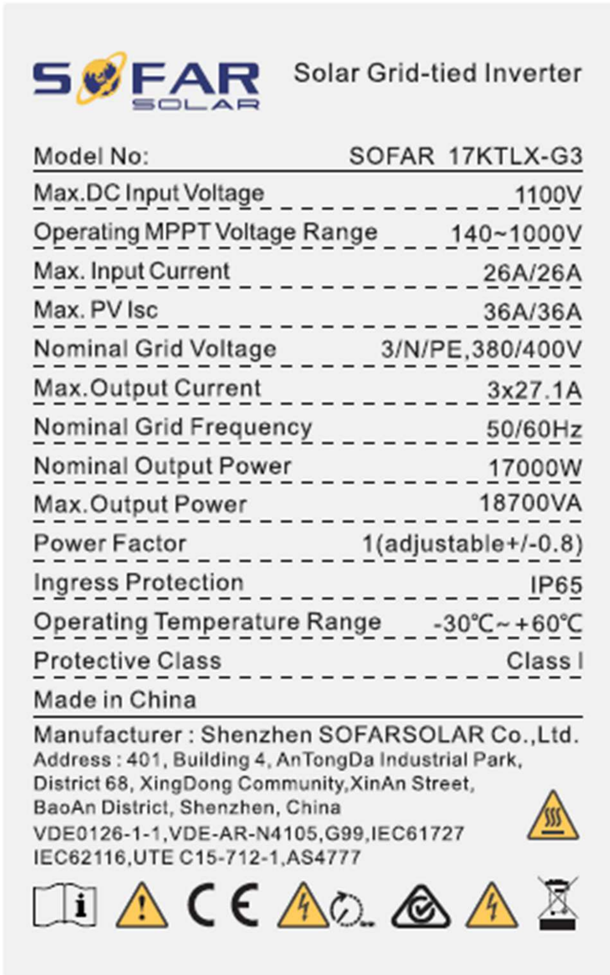
The tests were performed at 230Vac/50Hz condition.

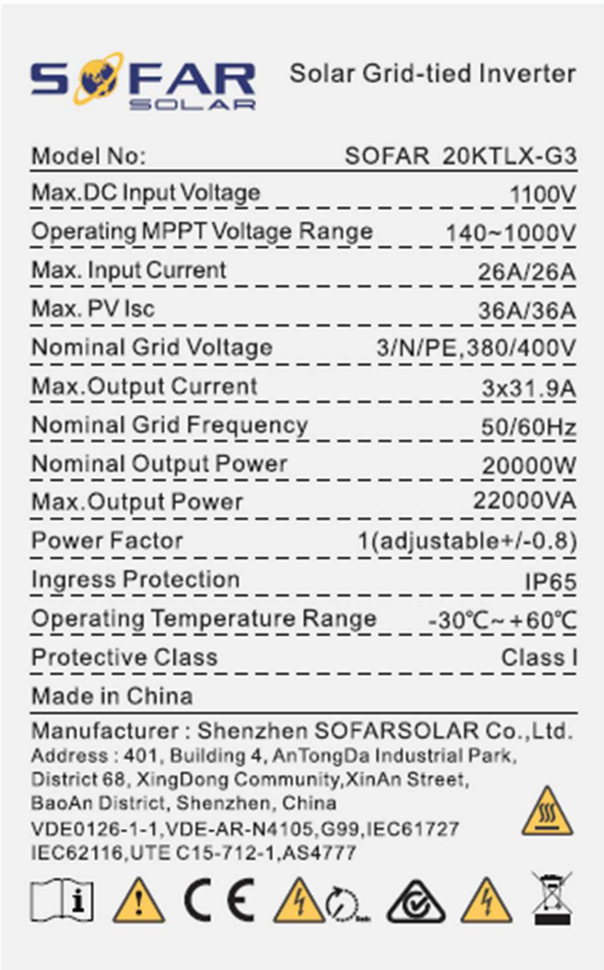
This Test Report consists of the following documents:

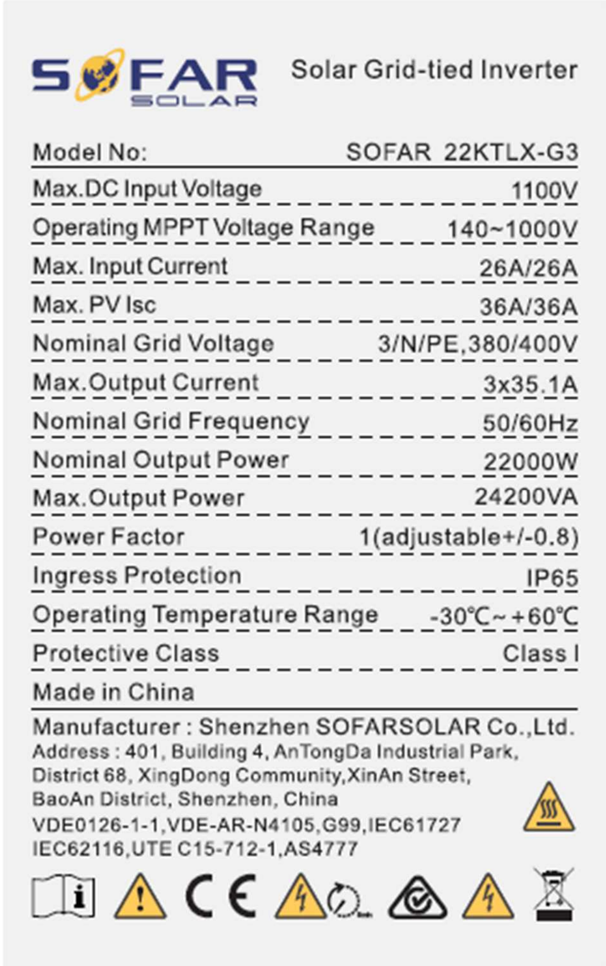
1. Test Report
   4.4 Normal operating range
   4.5 Immunity to disturbances
   4.6 Active response to frequency deviation
   4.7 Power response to voltage variations and voltage changes
   4.8 EMC and power quality
   4.9 Interface protection
   4.10 Connection and starting to generate electrical power
   4.11 Ceasing and reduction of active power on set point
   4.13 Requirements regarding single fault tolerance of interface protection system and interface switch
2. Annex No. 1 – Pictures of the unit
3. Annex No. 2 – Test equipment list

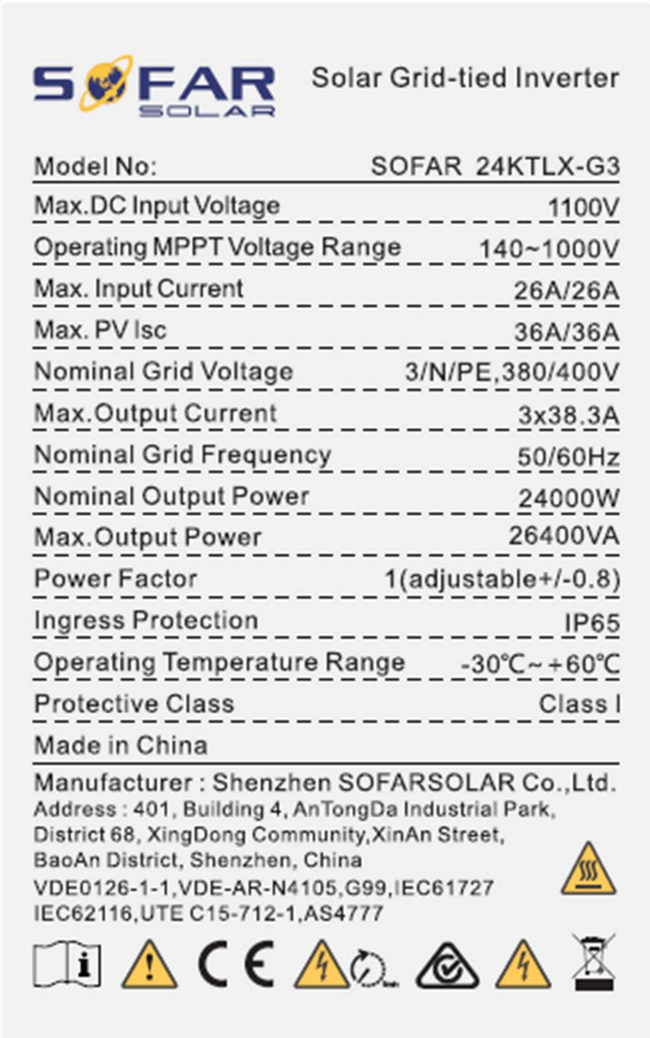
Copy of marking plate






SOFAR SOLAR
Solar Grid-tied Inverter
Model No: SOFAR 20KTLX-G3
Max.DC Input Voltage 1100V
Operating MPPT Voltage Range 140~1000V
Max. Input Current 26A/26A
Max. PV Isc 36A/36A
Nominal Grid Voltage 3/N/PE,380/400V
Max.Output Current 3x31.9A
Nominal Grid Frequency 50/60Hz
Nominal Output Power 20000W
Max.Output Power 22000VA
Power Factor 1(adjustable+/-0.8)
Ingress Protection IP65
Operating Temperature Range -30℃~+60℃
Protective Class Class I
Made in China
Manufacturer : Shenzhen SOFARSOLAR Co.,Ltd.
Address : 401, Building 4, AnTongDa Industrial Park,
District 68, XingDong Community,XinAn Street,
BaoAn District, Shenzhen, China
VDE0126-1-1,VDE-AR-N4105,G99,IEC61727
IEC62116,UTE C15-712-1,AS4777
CE


SOFAR SOLAR
Solar Grid-tied Inverter
Model No: SOFAR 22KTLX-G3
Max.DC Input Voltage 1100V
Operating MPPT Voltage Range 140~1000V
Max. Input Current 26A/26A
Max. PV Isc 36A/36A
Nominal Grid Voltage 3/N/PE,380/400V
Max.Output Current 3x35.1A
Nominal Grid Frequency 50/60Hz
Nominal Output Power 22000W
Max.Output Power 24200VA
Power Factor 1(adjustable+/-0.8)
Ingress Protection IP65
Operating Temperature Range -30℃~+60℃
Protective Class Class I
Made in China
Manufacturer : Shenzhen SOFARSOLAR Co.,Ltd.
Address : 401, Building 4, AnTongDa Industrial Park,
District 68, XingDong Community,XinAn Street,
BaoAn District, Shenzhen, China
VDE0126-1-1,VDE-AR-N4105,G99,IEC61727
IEC62116,UTE C15-712-1,AS4777
CE


SOFAR SOLAR
Solar Grid-tied Inverter
Model No: SOFAR 24KTLX-G3
Max.DC Input Voltage 1100V
Operating MPPT Voltage Range 140~1000V
Max. Input Current 26A/26A
Max. PV Isc 36A/36A
Nominal Grid Voltage 3/N/PE,380/400V
Max.Output Current 3x38.3A
Nominal Grid Frequency 50/60Hz
Nominal Output Power 24000W
Max.Output Power 26400VA
Power Factor 1(adjustable+/-0.8)
Ingress Protection IP65
Operating Temperature Range -30℃~+60℃
Protective Class Class I
Made in China
Manufacturer : Shenzhen SOFARSOLAR Co.,Ltd.
Address : 401, Building 4, AnTongDa Industrial Park,
District 68, XingDong Community,XinAn Street,
BaoAn District, Shenzhen, China
VDE0126-1-1,VDE-AR-N4105,G99,IEC61727
IEC62116,UTE C15-712-1,AS4777

General product information:

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

The DC input of Solar Grid-tied Inverter can be supplied from PV array.

The Solar Grid-tied Inverter is a three-phase type .

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

Description of the electrical circuit:

The internal control is redundant built. It consists of Main DSP (U30) and slave DSP(U23).

The Main DSP (U30) can control the relays, measures voltage, and frequency, AC current with injected DC, insulation resistance and residual current, In addition it tests the array insulation resistance and the RCMU circuit before each start up.

The slave DSP (U23) is using for detect residual current, also can open the relays independently and communicate with Main DSP (U30).

The unit provides two relays in series on Line and Neutral conductors. When single-fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the PV array and the mains. All the relays are tested before start up. Both controllers(Main DSP (U30), Slave DSP (U23) can open the relays.

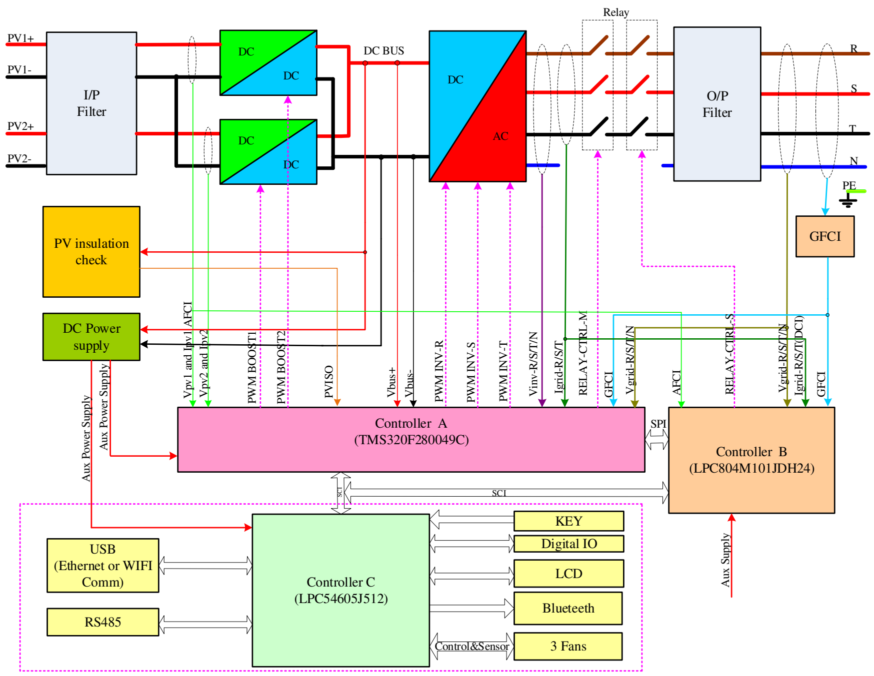


Figure 1 – Block diagram

The product was tested on:

Hardware version: V101

Software version: V010000

Model difference:

The models SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3, SOFAR 22KTLX-G3 and SOFAR 24KTLX-G3 are use the identical hardware platform, control unit, control system and software except the output power derated by software and in following table descripts for different.

	SOFAR 15KTLX-G3	SOFAR 17KTLX-G3	SOFAR 20KTLX-G3	SOFAR 22KTLX-G3	SOFAR 24KTLX-G3
Thin-film capacitor of BUS	4pcs (110uF, 550V)	6pcs (110uF, 550V)			
INV IGBT (Q60, Q67, Q71 Q72, Q75, Q76)	6pcs 40A, 1200V	6pcs 75A, 1200V			
External Fan	1		2		

General remarks:

The test results presented in this report relate only to the object(s) tested.
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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.

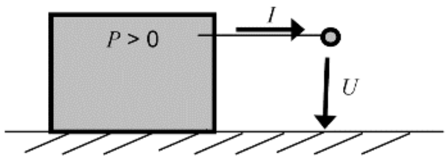
The following suffixes are used for variables in tables and figures:

- "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.

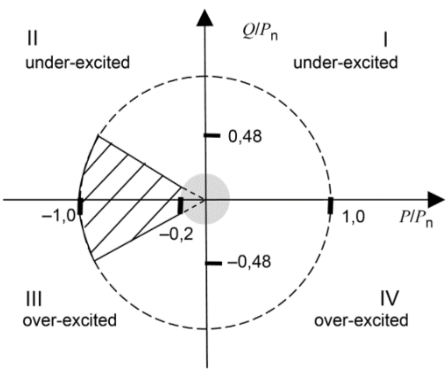


Figure 2

Default interface protection settings according EN 50549-1:2019:			
Parameter	**Max. disconnection time**	**Min. operate time**	**Trip value**
Over voltage – stage 1	61 s	0,1 s	230V +15% (264,5 V)
Over voltage – stage 2	0,2 s	0,1 s	230V +25% (287,5 V)
Under voltage – stage 1	5 s	0,1 s	230V -20% (184V)
Under voltage – stage 2	2 s	0,1 s	230V -50% (115V)
Over frequency – stage 1	0,5 s	0,3 s	51,5 Hz
Over frequency – stage 2	0,2 s	0,1 s	52 Hz
Under frequency– stage 1	0,5 s	0,3 s	47,5 Hz
Under frequency– stage 2	0,2 s	0,1 s	47 Hz
Reconnection settings for voltage		$0,85\ U_n \leq U \leq 1,10\ U_n$	
Connection settings for frequency (Normal operational start-up)		49,5 Hz ≤ f ≤ 50,1 Hz	
Reconnection settings for frequency (Automatic reconnection after tripping)		49,5 Hz ≤ f ≤ 50,2 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.			
Tolerances on trip values: - Voltage: ± 1% of U_n - Frequency: ± 0,05 Hz - Disconnection time : ± 10%			

The following deviations for Poland, have been applied according the EN 50438:2013:		
Parameter	**operate time**	**Trip value**
ROCOF (where used)	5 s	0,4 Hz/s
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.		

The following deviations for Netherland have been applied according NA/EEA-NE7-CH 2020:

Schutzfunktionen	Schutzrelais-Einstellwerte [a]			
	Direkte gekoppelte Synchron- und Asynchrongeneratoren mit P_n > 250 kW		Stromrichter	
Spannungssteigungsschutz *U*>>	1,20 U_n	≤ 100 ms	1,20 U_n	≤ 100 ms
Spannungssteigungsschutz *U*> *(gleitender 10min-Mittelwert)*	1,10 U_n [b), c)]	≤ 100 ms	1,10 U_n [b), c)]	≤ 100 ms
Spannungsrückgangsschutz *U*<	0,8 U_n	1,0 s [d)]	0,8 U_n	1,5 s
Spannungsrückgangsschutz *U*<<	0,45 U_n	300 ms [d)]	0,45 U_n	300 ms
Frequenzrückgangsschutz *f*<	47,5 Hz	≤ 100 ms	47,5 Hz	≤ 100ms
Frequenzsteigerungsschutz *f*>	51,5 Hz	≤ 100 ms	51,5 Hz	≤ 100ms

Tabelle 6: Einstellempfehlungen für den Entkupplungsschutz am (Haus-)Anschlusspunkt

a) Die zeitliche Vorgabe "≤ 100 ms" für den Schutzrelais-Einstellwert geht von einer maximalen Eigenzeit des NA-Schutzrelais inklusive Kuppelschalter von ebenfalls 100 ms aus. Damit ergeben sich maximal 200 ms Gesamtabschaltzeit.

b) Es ist sicherzustellen, dass am (Haus-)Anschlusspunkt die Spannung 1,10 U_n nicht überschritten wird. Wird diese Anforderung durch einen externen NA-Schutz sichergestellt, ist die Einstellung des Überspannungsschutzes U> an der dezentralen EEA resp. EEE auf bis zu 1,15 U_n zulässig. Der Anlagenschutz soll in diesem Fall mögliche Auswirkungen auf die Kundeninstallation berücksichtigen. Die Kombination von externem NA-Schutz (U>: 1,1 U_n) und integriertem NA-Schutz (U>: 1,1 U_n bis 1,15 U_n) ist dann zu empfehlen, wenn der Spannungsfall in der Hausinstallation nicht zu vernachlässigen ist. Dies ist typischerweise bei längeren Anschlussleitungen der Fall.

c) Wertet die U>-Funktion nicht den gleitenden 10-Minuten-Mittelwert aus, ist eine Einstellung von 1,10 U_n mit einer Verzögerung von 60 s empfohlen (ausserhalb des OVRT-Bereichs). Dabei sind die Rückfallverhältnisse (Hysterese) der Relais bzgl. Überfunktion/Wiederzuschaltung zu beachten.

d) Wird das der EEA vorgelagerte Mittelspannungsnetz des VNB mit einer AWE betrieben, so werden folgende Schutzeinstellungen an der EEA empfohlen: U<<-Funktion: 0,45 U_n, unverzögert

(d. h. kleinstmöglicher Zeitverzögerung) und U <-Funktion: 0,8 U_n, 300 ms. Die FRT-Anforderungen müssen in diesem Fall nicht eingehalten werden. Die Vorgaben für die Schutzeinstellungen trifft der VNB.

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

EN 50549:2019, clause 4: Tests		
Clause	**Test requirement (According to table C.1)**	**Result**
4.4	Normal operating range	**P**
4.5	Immunity to disturbances	**P**
4.6	Active response to frequency deviation	**P**
4.7	Power response to voltage variations and voltage changes	**P**
4.8	EMC and power quality	**P**
4.9	Interface protection	**P**
4.10	Connection and starting to generate electrical power	**P**
4.11	Ceasing and reduction of active power on set point	**P**
4.12	Remote information exchange	**N/A**
4.13	Requirements regarding single fault tolerance of interface protection system and interface switch	**P**

EN 50549-1:2019: Normal operating range			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.4.2	Power response to over-frequency	EN 50438, Annex D.3.1	**P**
4.4.3	Power response to under-frequency	G99/1-4, clause A.7.3.2	**P**
4.4.4	Continuous operating voltage range	EN 50438, Annex D.3.1	**P**

4.4.2 4.4.4	Operating frequency range Continuous operating voltage range		P
Setting values	Over-voltage [V]:	253	
	Under-voltage [V]:	195,5	
	Over-frequency [Hz]:	51,5	
	Under-frequency [Hz]:	47,5	

- Test 1: U = 195,5 V; f = 47,5 Hz; P = 1,00 S_n; cosφ = 1
- Test 2: U = 195,5 V; f = 48,5 Hz; P = 1,00 S_n; cosφ = 1
- Test 3: U = 253,0 V; f = 51,5 Hz; P = 1,00 S_n; cosφ = 1
- Test 4: U = 230,0 V; f = 50,0 Hz; Voltage Phase jumps Change +20 derees P = 1,00g S_n; cosφ = 1
- Test 5: U = 230,0 V; f = 50,0 to 50,5 Hz;RoCoF=1Hz/s； P = 1,00 S_n; cosφ = 1

Test result:

Test sequence	Voltage [V]	Frequency [Hz]	Output power [kW]	Cos φ
Test1	195,71	47,50	22,482	0,9999
Test2	195,74	48,50	22,551	0,9999
Test3	253,05	51,50	24,455	0,9999
Test4	231,61	50,00	24,444	0,9999
Test5	231,64	50,50	24,444	0,9999

Note:

Test method refer clause D.3.1 of EN 50438:2013.

During the tests the interface protection was disabled.

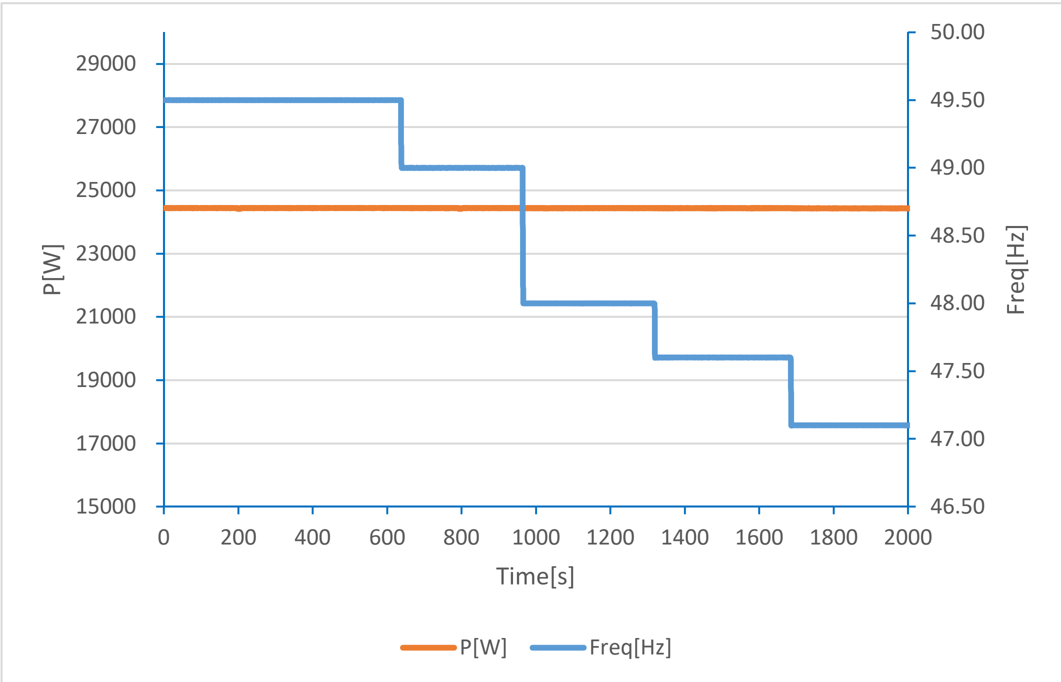
Operation at reduced power is allowed during test 1, equal to the maximum power that can be supplied on reaching the maximum output current limit (P ≥ 0,85 S_n).

During the sequence of test 3, automatic adjustment to reduce power in the case of over-frequency was disabled.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.4.3	Minimal requirement for active power delivery at under-frequency	P

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



Test result:

	Switch to:				
5-min mean value (each)	a) 49,50 Hz	b) 49,00 Hz	c) 48,00 Hz	d) 47,60 Hz	e) 47,10 Hz
Frequency [Hz]:	49,50	49,00	48,00	47,60	47,10
Active power [kW]:	24,442	24,441	24,439	24,438	24,436
$\Delta P/P_n$ [%] :	1,840	1,836	1,827	1,824	1,818

Assessment criterion:

Test method refer clause A.7.3.2 of G99/1-4

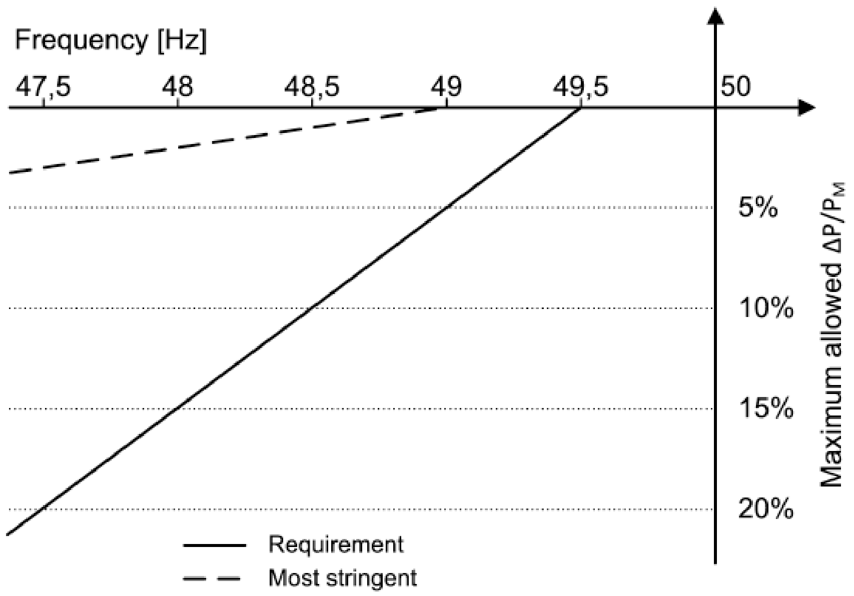
The frequency should then be set to 49,5 Hz for 5 minutes. The output should remain at 100% of registered Capacity.

The frequency should then be set to 49,0 Hz and once the output has stabilised, held at this frequency for 5 minutes. The Active Power output must not be below 99% of registered Capacity.

The frequency should then be set to 48,0 Hz and once the output has stabilised, held at this frequency for 5 minutes. The Active Power output must not be below 97% of registered Capacity.

The frequency should then be set to 47,6 Hz and once the output has stabilised, held at this frequency for 5 minutes. The Active Power output must not be below 96.2% of registered Capacity.

The frequency should then be set to 47,1 Hz and held at this frequency for 20s. The Active Power output must not be below 95,0% of registered Capacity and the Synchronous Power Generating Module must not trip in less than the 20s of the test.



Maximum allowable power reduction in case of under-frequency

Note:

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

EN 50549-1:2019: Immunity to disturbances			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.5.2	Rate of change of frequency (RoCoF) immunity	G99/1-4:2019, clause A.7.1.2.6	**P**
4.5.3	Low voltage ride through (LVRT)	VDE V 0124-100:2019-02 (Draft), clause 5.8.3.	**P**
4.5.4	High voltage ride through (HVRT)	VDE V 0124-100:2019-02 (Draft), clause 5.8.3.	**P**
4.7.4	Zero current mode for converter connected generating plants	VDE V 0124-100:2019-02 (Draft), clause 5.8.3.	**P**

4.5.2	Rate of change of frequency (ROCOF) immunity(default settings)			P
	Start Frequency	Change	End Frequency	Confirm no trip
Positive Frequency drift	49Hz	+2Hz/sec	51Hz	No trip
Negative Frequency drift	51Hz	-2Hz/sec	49Hz	No trip

Note:

Test method refer clause A.7.1.2.6 of G99/1-4:2019.

Hold for 10 s

Manufacturers considering new designs should allow for the RoCoF where stability is required to be increased to, up to 2Hz per second, as proposed in the new European network codes, which are expected to come into force over the period 2014/2015. Under these conditions RoCoF will cease to be an effective loss of mains protection and is unlikely to be permitted in future revisions of this document.

For the step change test the SSEG should be operated with a measureable output at the start frequency and then a vector shift should be applied by extending or reducing the time of a single cycle with subsequent cycles returning to the start frequency. The start frequency should then be maintained for a period of at least 10 seconds to complete the test. The SSEG should not trip during this test.

For frequency drift tests the SSEG should be operated with a measureable output at the start frequency and then the frequency changed in a ramp function at 0,95Hz per second to the end frequency. On reaching the end frequency it should be maintained for a period of at least10 seconds. The SSEG should not trip during this test.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.5.2	Rate of change of frequency (ROCOF) immunity (Poland settings)	P

	Start Frequency	Change	End Frequency	Confirm no trip
Positive Frequency drift	49Hz	+0,4Hz/sec	51Hz	No trip
Negative Frequency drift	51Hz	-0,4Hz/sec	49Hz	No trip

Note:

Test method refer clause A.7.1.2.6 of G99/1-4:2019.

Hold for 10 s

Manufacturers considering new designs should allow for the RoCoF where stability is required to be increased to, up to 0,4Hz per second, as proposed in the new European network codes, which are expected to come into force over the period 2014/2015. Under these conditions RoCoF will cease to be an effective loss of mains protection and is unlikely to be permitted in future revisions of this document.

For the step change test the SSEG should be operated with a measureable output at the start frequency and then a vector shift should be applied by extending or reducing the time of a single cycle with subsequent cycles returning to the start frequency. The start frequency should then be maintained for a period of at least 10 seconds to complete the test. The SSEG should not trip during this test.

For frequency drift tests the SSEG should be operated with a measureable output at the start frequency and then the frequency changed in a ramp function at 0,95Hz per second to the end frequency. On reaching the end frequency it should be maintained for a period of at least10 seconds. The SSEG should not trip during this test.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.5.3 **4.5.4** **4.7.4**	**Low voltage ride through (LVRT)** **High voltage ride through (HVRT)** **Zero current mode for converter connected generating plants**	**P**

General:

If the voltage on the generator terminals falls below <0.8 U_n and if the generator terminals exceed the voltage of> 1.15 U_n (start of fault), generator must pass through voltage dips without any current being drawn into the grid Network operator (limited dynamic network support).
This requirement is met if, for a voltage dip below 0.8 U_n or at a voltage increase above 1.15 U_n, the injected current of the generating unit (s) and / or the memory 60 ms after occurrence of this voltage dip in any outer conductor 20% of the rated current I_r and does not exceed> 10% I_r after 100 ms.

After the voltage returned to continuous operating voltage range of -15% U_n to +10% U_n, 90 % of pre fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 1 s unless the DSO and the responsible party requires another value.

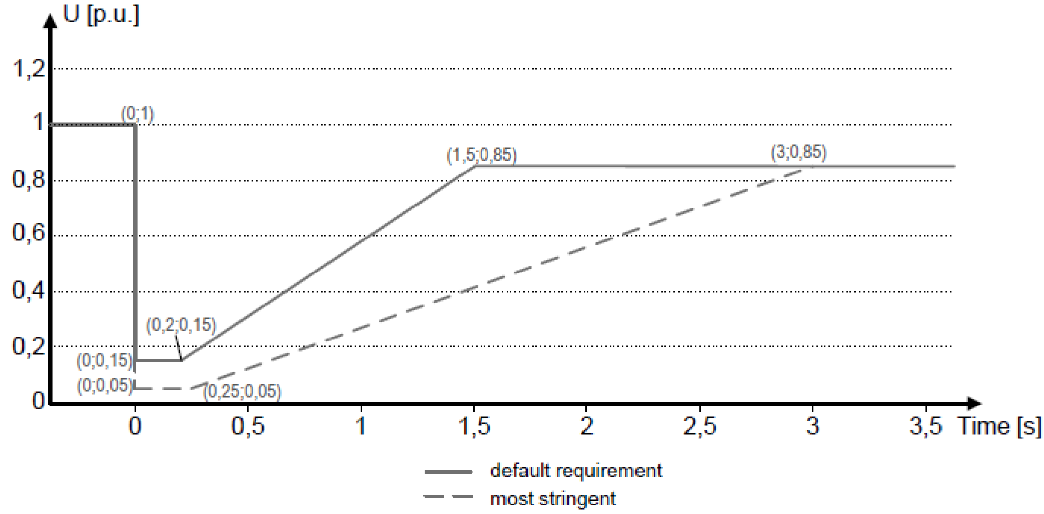


Figure 6 — Low voltage ride through capability for non-synchronous generating technology

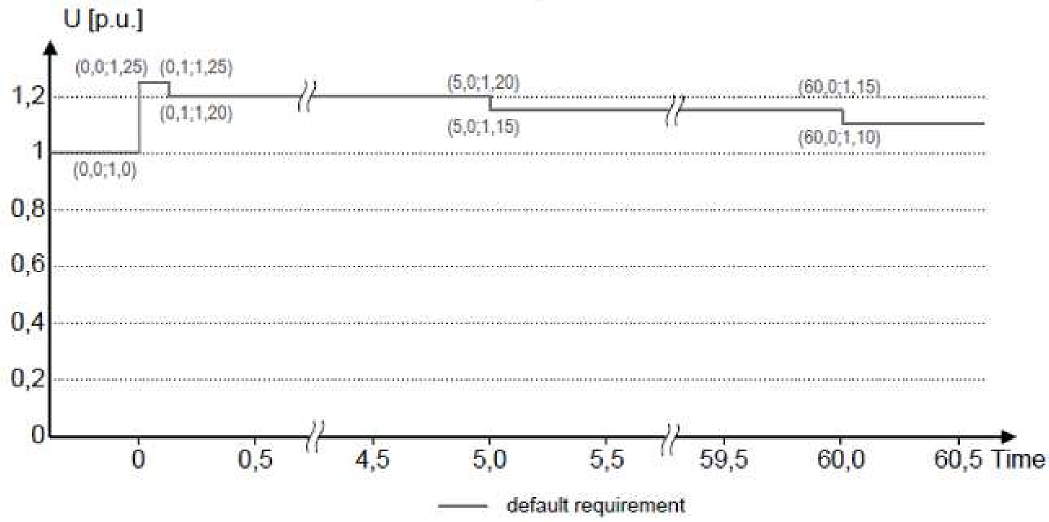


Figure 8 — Over-voltage ride through capability

Test	Drop depth requirement [p.u. U_n]	Symmetry	Fault duration [ms]	Output power level		k-factor	Test no.
				P set point (P_{rE} / p.u.)	Q set point (Q / p.u.)		
1.A.1	0,03	Symmetrical	250	1,0	0,00	0	1.A.1
1.A.2				0,2			1.A.2
1.D.1		Asymmetrical		1,0			1.D.1
1.D.2				0,2			1.D.2
1.B.1		Single phase*		1,0			1.B.1
1.B.2				0,2			1.B.2
2.A.1	0,31	Symmetrical	1300	1,0	0,00	0	2.A.1
2.A.2				0,2			2.A.2
2.D.1		Asymmetrical		1,0			2.D.1
2.D.2				0,2			2.D.2
2.B.1		Single phase*		1,0			2.B.1
2.B.2				0,2			2.B.2
3.A.1	0,82	Symmetrical	3000	1,0	0,00	0	3.A.1
3.A.2				0,2			3.A.2
3.D.1		Asymmetrical		1,0			3.D.1
3.D.2				0,2			3.D.2
3.B.1		Single phase*		1,0			3.B.1
3.B.2				0,2			3.B.2
OV1	1,25	Symmetrical	100	1,0	0,00	0	OV1
OV2	1,20		5000	1,0			OV2
OV3	1,15		60000	1,0			OV3

Note:

For every kind of voltage dip a test without load has to be performed in order to prove that the test condition was fulfilled. The voltage has to drop to AT LEAST the defined depth level. An exception can be considered in case no current is supplied during dips.

*** Single phase = “choose Typ 7 at BV-Lab Studio” ≙ LVRT Typ B**

Graph of FRT test one				
Test result:				
List of tests	**Residual amplitude of phase-to-phase voltage [p.u. U_n]**	**Duration limit [ms]**	**Duration [ms]**	**Result**
P_{Emax} in %	100% ±5%			
1.A.1- Symmetrical	0,03	250 ± 20	251	Pass
1.D.1- Asymmetrical	0,03	250 ± 20	251	Pass
1.B.1- Single phase	0,03	250 ± 20	252	Pass
2.A.1- Symmetrical	0,31	1300 ± 20	1301	Pass
2.D.1- Asymmetrical	0,31	1300 ± 20	1301	Pass
2.B.1- Single phase	0,31	1300 ± 20	1300	Pass
3.A.1- Symmetrical	0,82	3000 ± 20	3001	Pass
3.D.1- Asymmetrical	0,82	3000 ± 20	3001	Pass
3.B.1- Single phase	0,82	3000 ± 20	3001	Pass
P_{Emax} in %	20% ±5%			
1.A.2- Symmetrical	0,03	250 ± 20	250	Pass
1.D.2- Asymmetrical	0,03	250 ± 20	250	Pass
1.B.2- Single phase	0,03	250 ± 20	251	Pass
2.A.2- Symmetrical	0,31	1300 ± 20	1301	Pass
2.D.2- Asymmetrical	0,31	1300 ± 20	1300	Pass
2.B.2- Single phase	0,31	1300 ± 20	1301	Pass
3.A.2- Symmetrical	0,82	3000 ± 20	3002	Pass
3.D.2- Asymmetrical	0,82	3000 ± 20	3000	Pass
3.B.2- Single phase	0,82	3000 ± 20	3000	Pass
P_{Emax} in %	100% ±5%			
OV1- Symmetrical	1,25	100 ± 20	100	Pass
OV2- Symmetrical	1,20	5000 ± 20	5001	Pass
OV3- Symmetrical	1,15	60000 ± 20	60000	Pass

Test conditions:

Voltage simulator fall and rise time: < 20ms

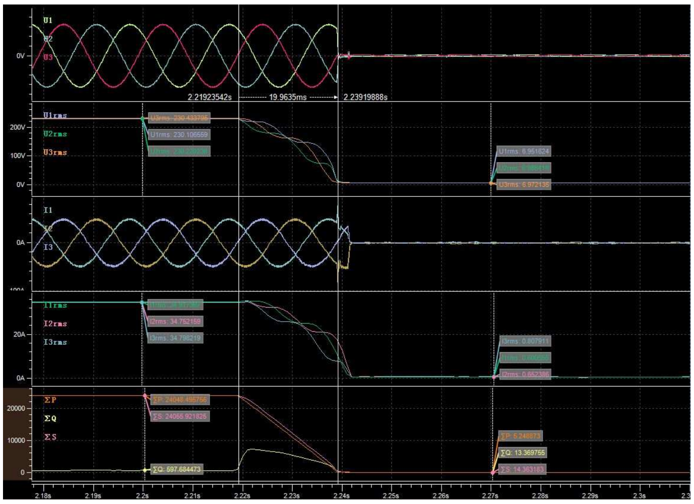
Used sample rate: 10 kHz

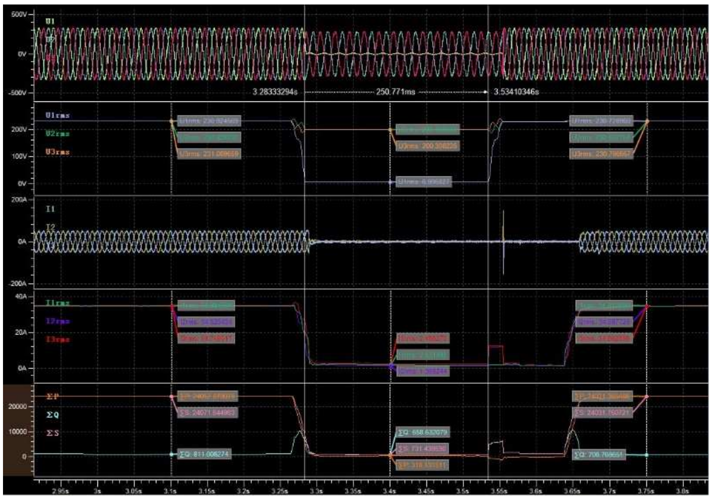
Note:

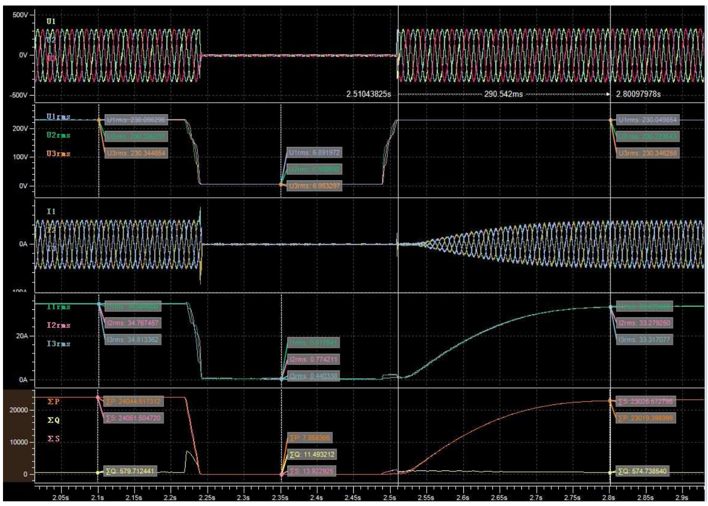
The test method refer to VDE V 0124-100:2019-02 (Draft), clause 5.8.3.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

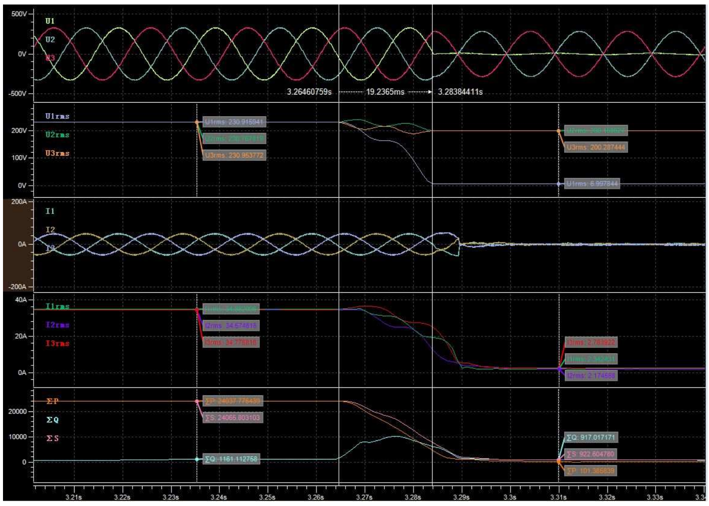
Test 1.A.1-Symmetrical fault (U/U_{nom} = 0,03); P = 100% ±5% P_n

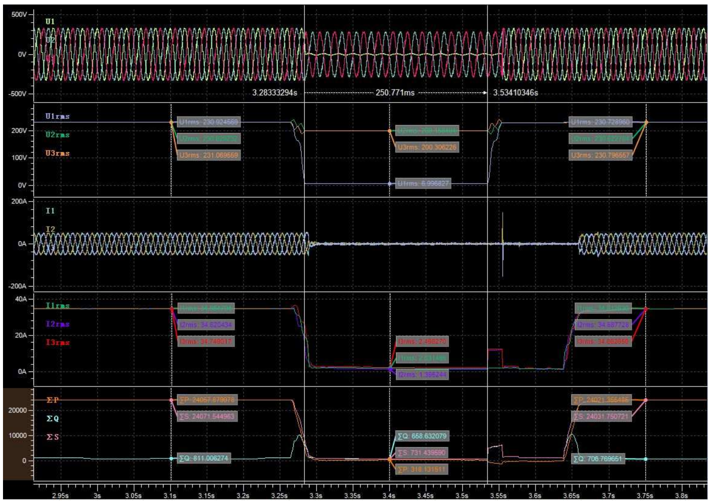


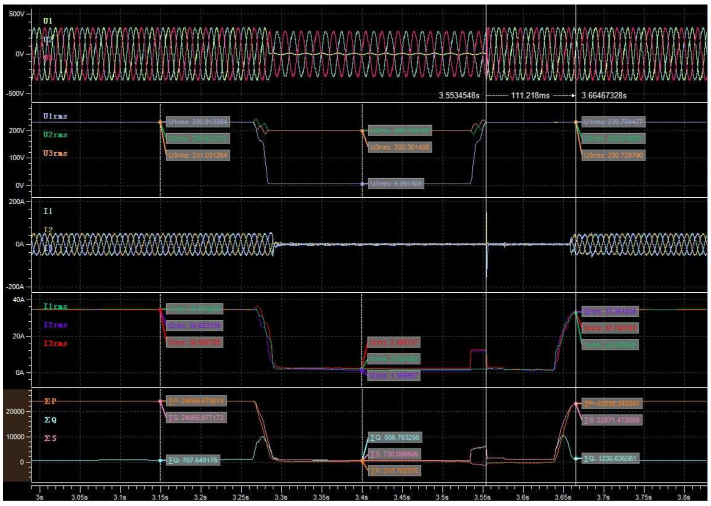




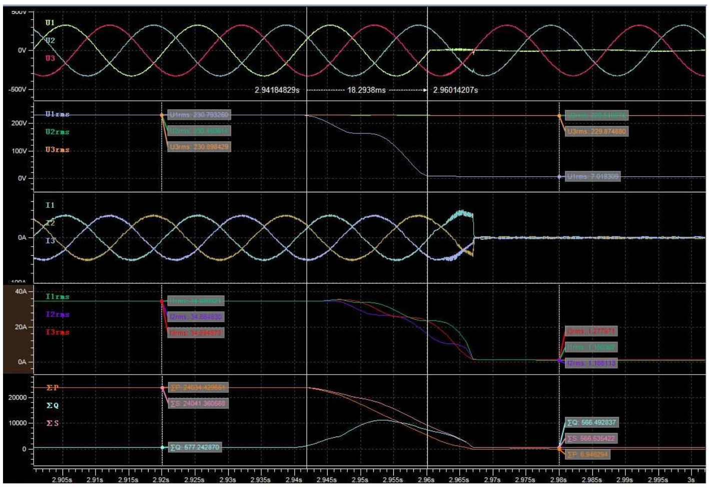
Test 1.D.1-Asymmetrical fault (U/U_{nom} = 0,03); P = 100% ±5% P_n

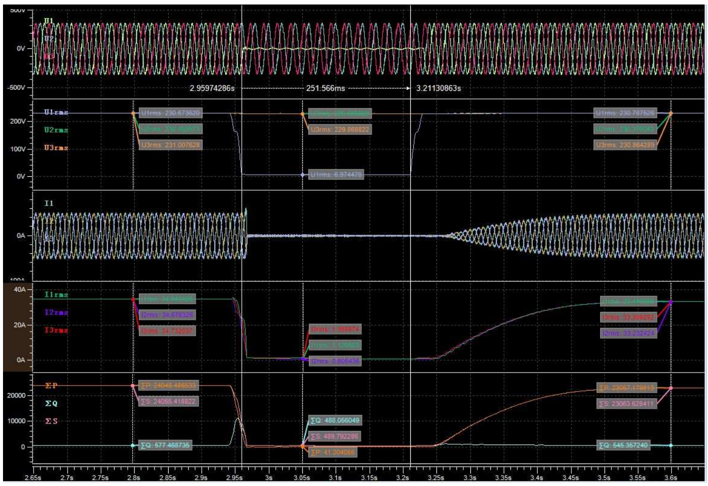


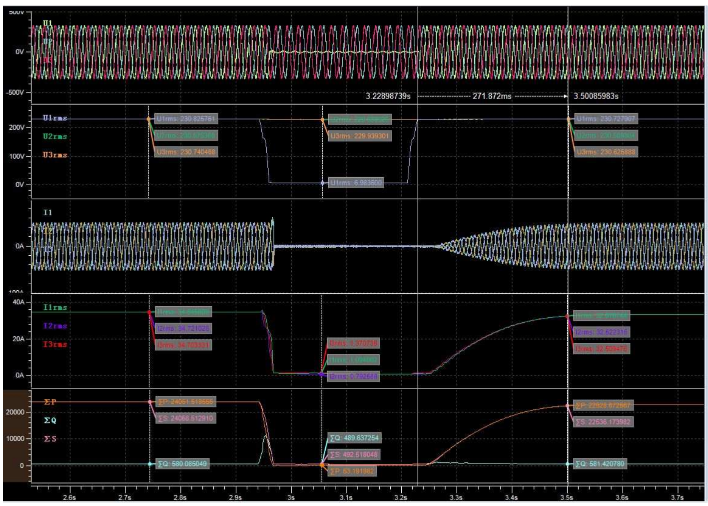




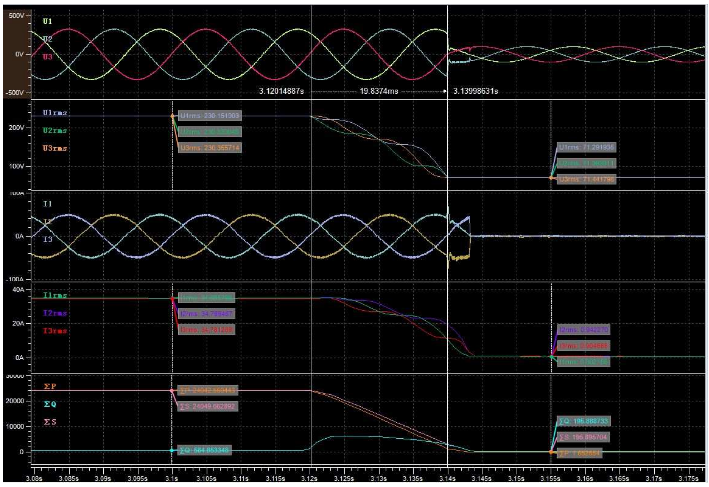
Test 1.B.1-Single phase fault (U/U_{nom} = 0,03); P = 100% ±5% P_n

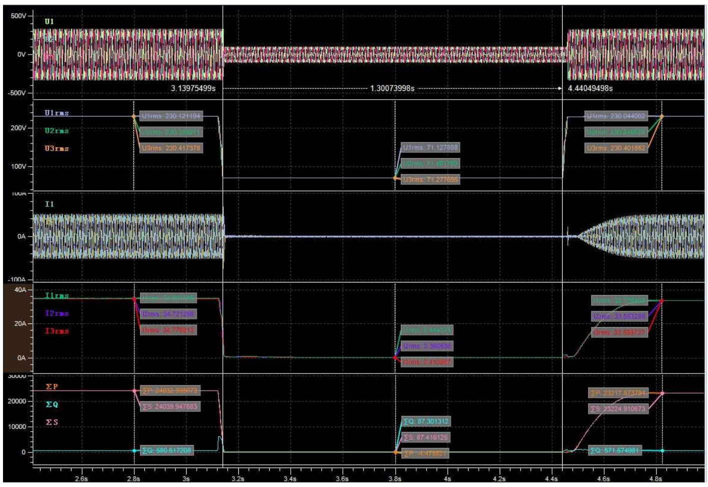


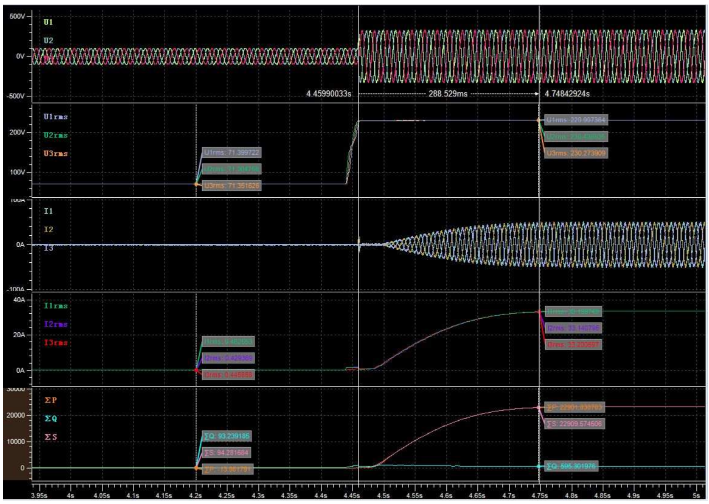


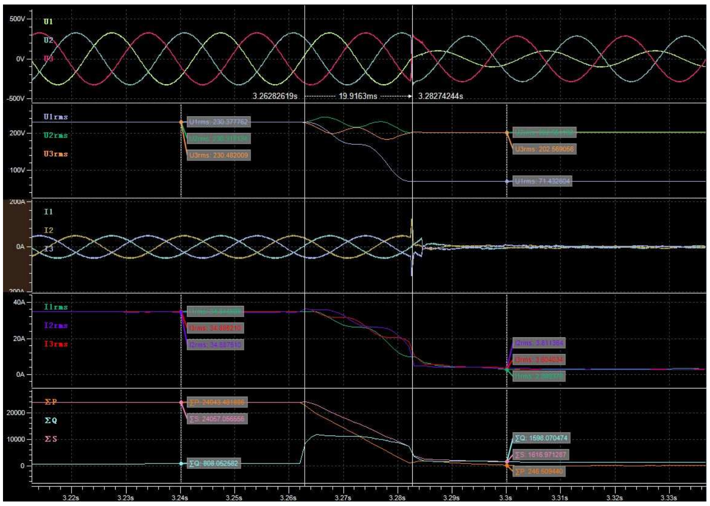
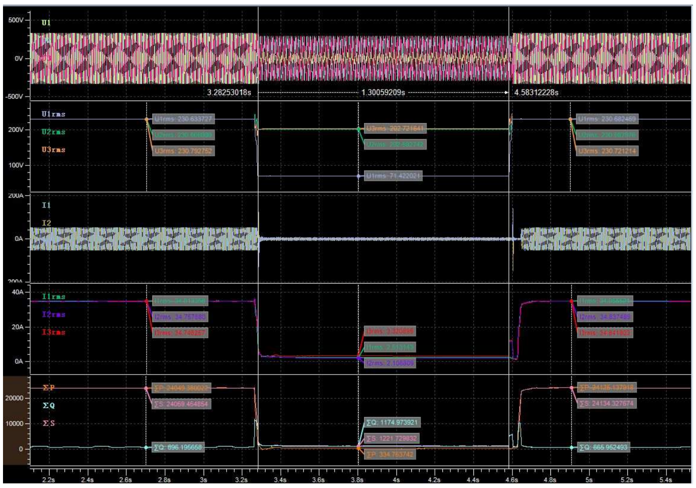
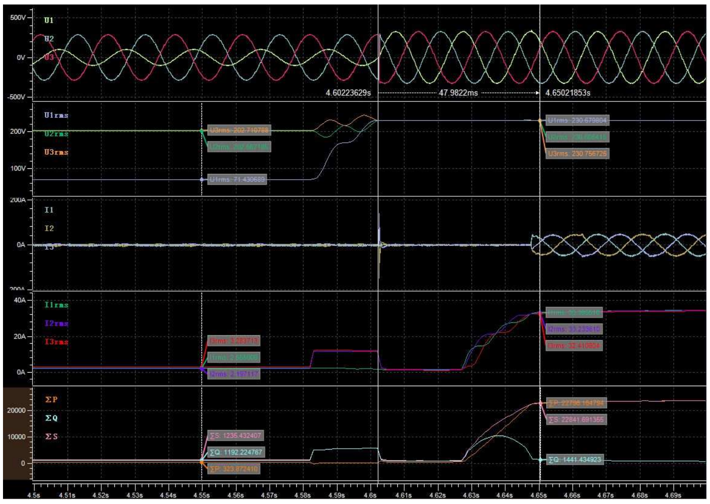


Test 2.A.1-Symmetrical fault (U/U_{nom} = 0,31); P = 100% ±5% P_n

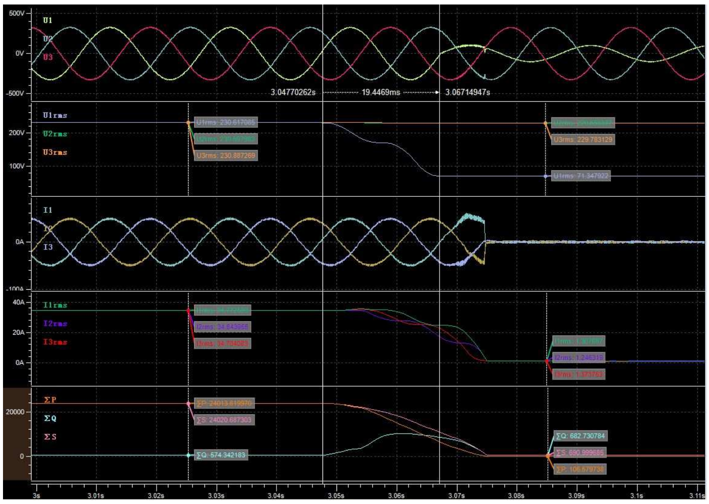


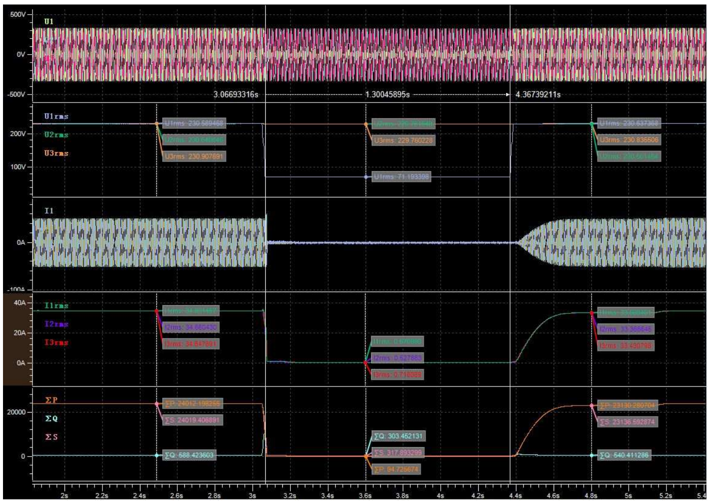


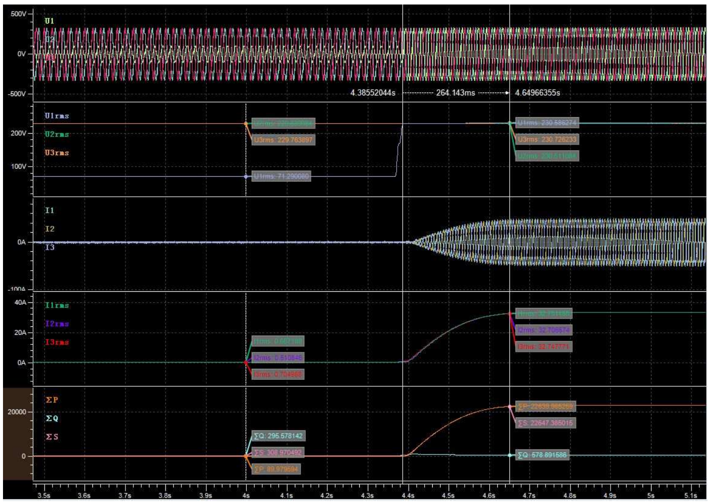


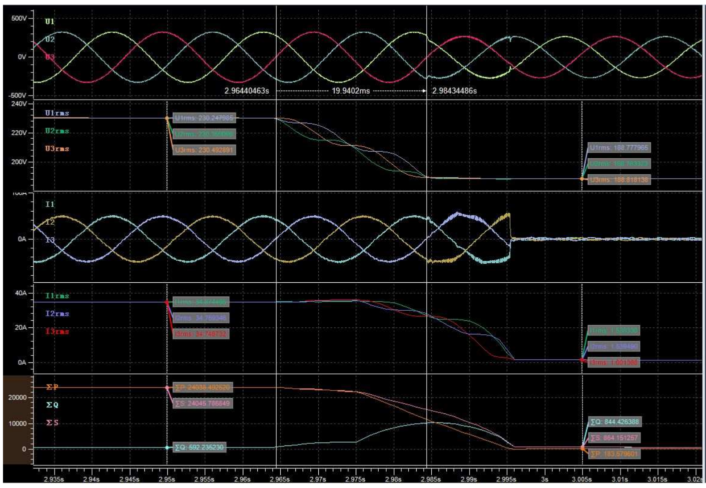
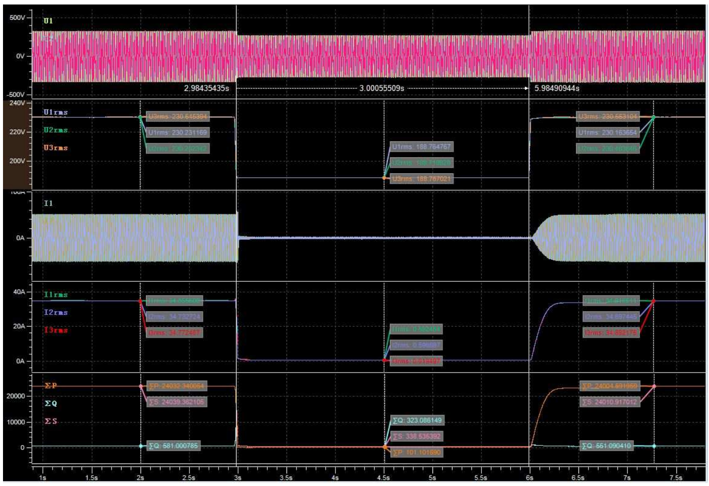
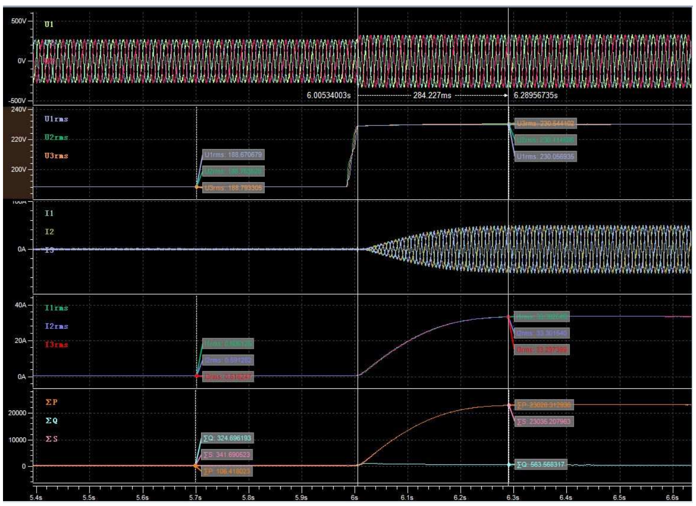
Test 2.D.1- Asymmetrical fault (U/U_{nom} = 0,31); P = 100% ±5% P_n
  

Test 2.B.1-Single phase fault (U/U_{nom} = 0,31); P = 100% ±5% P_n

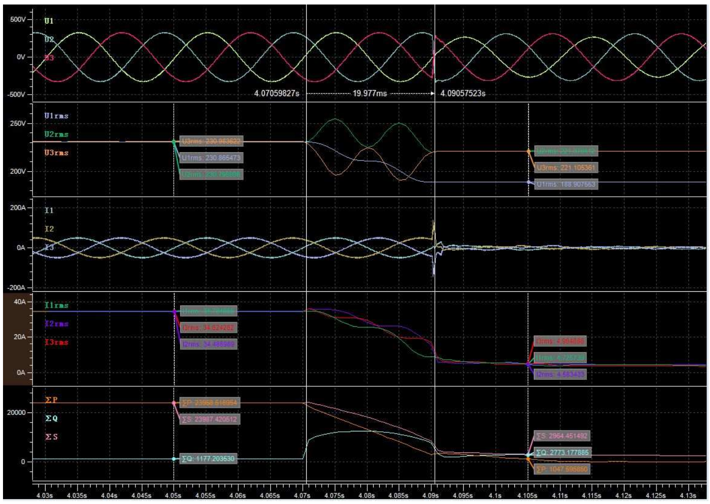


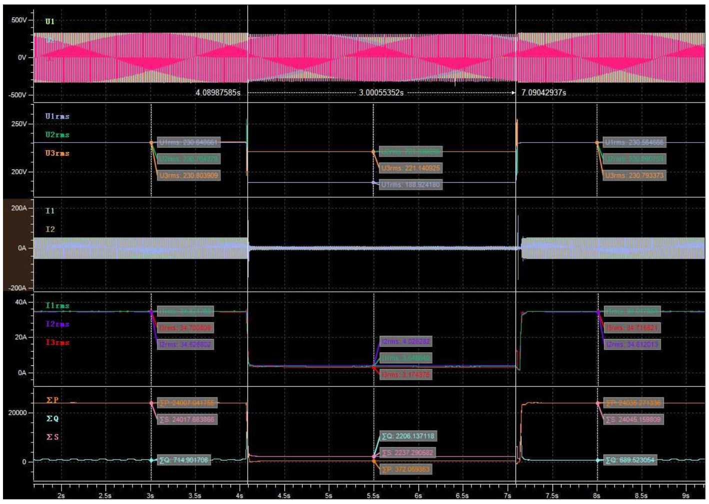


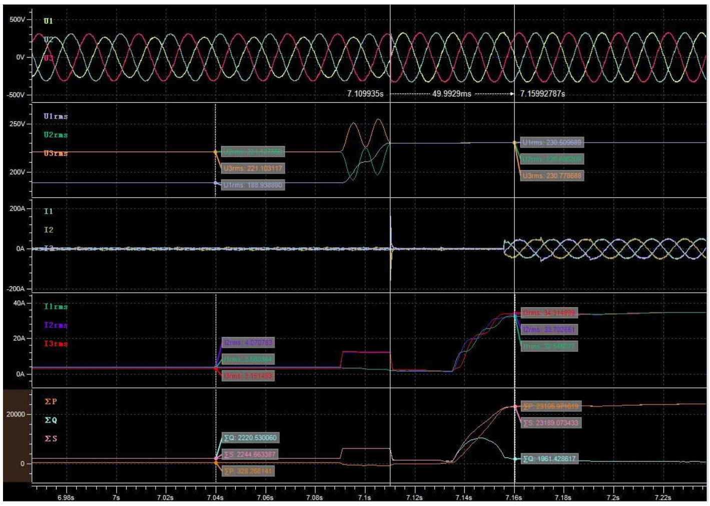


Test 3.A.1-Symmetrical fault (U/U_{nom} = 0,82); P = 100% ±5% P_n
  

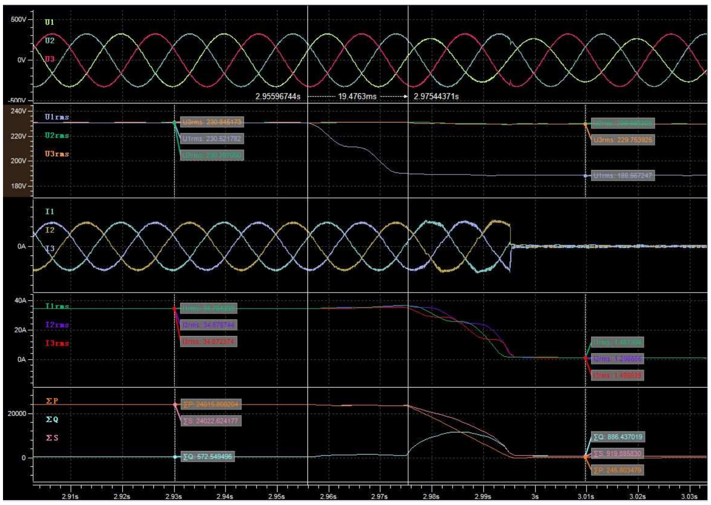
Test 3.D.1-Asymmetrical fault (U/U_{nom} = 0,82); P = 100% ±5% P_n

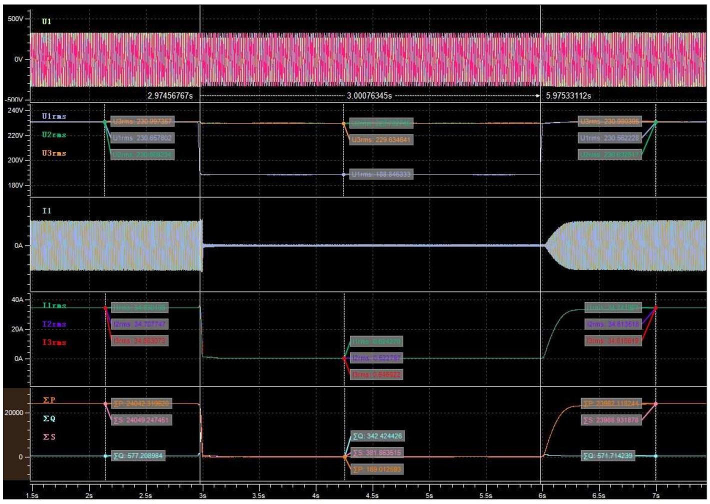


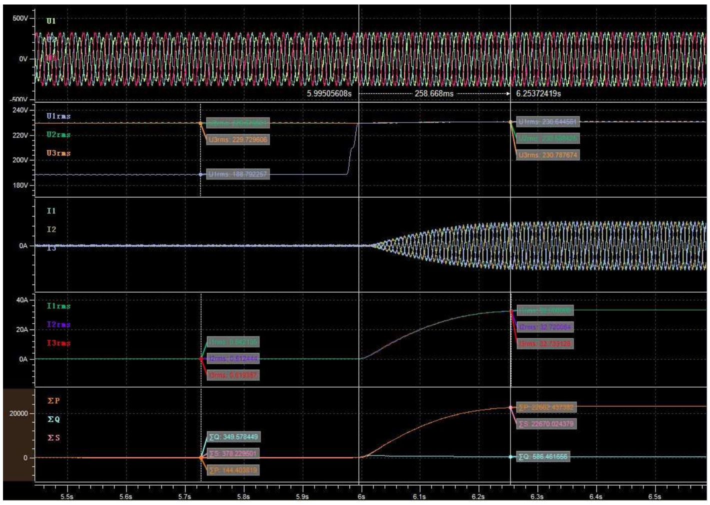




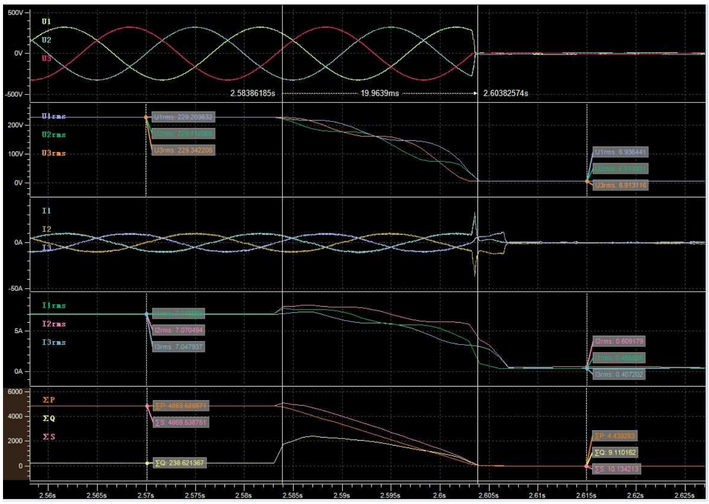
Test 3.B.1-Single phase fault (U/U_{nom} = 0,82); P = 100% ±5% P_n

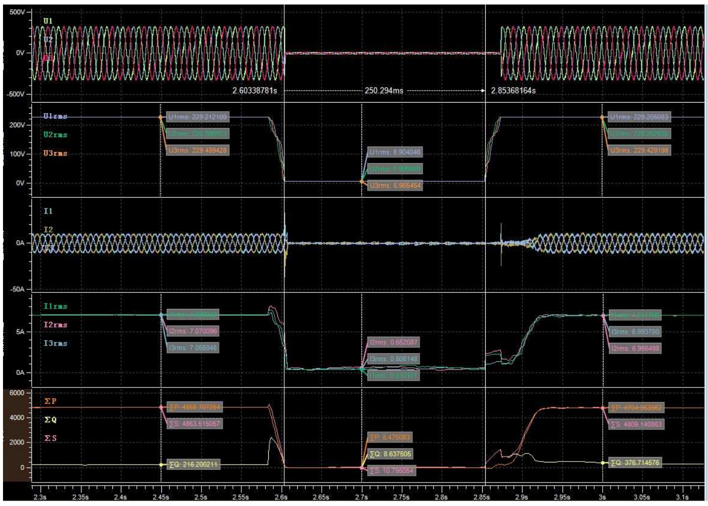


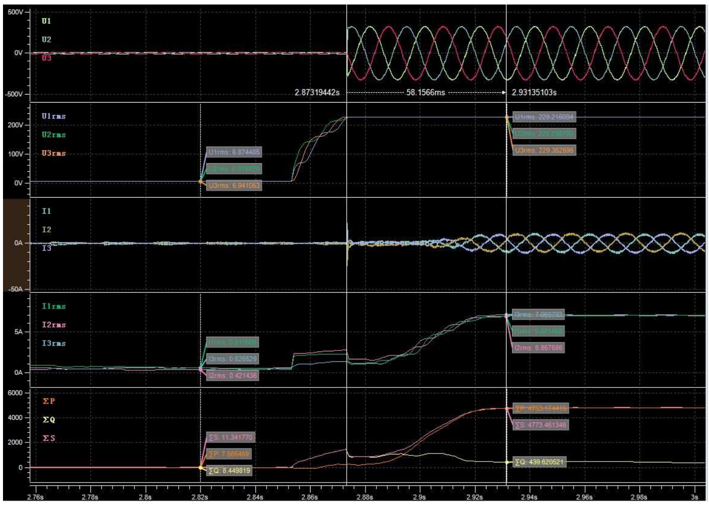


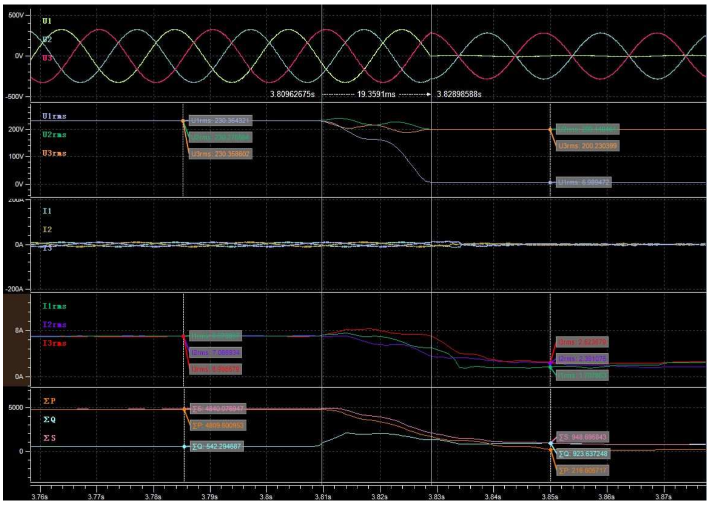
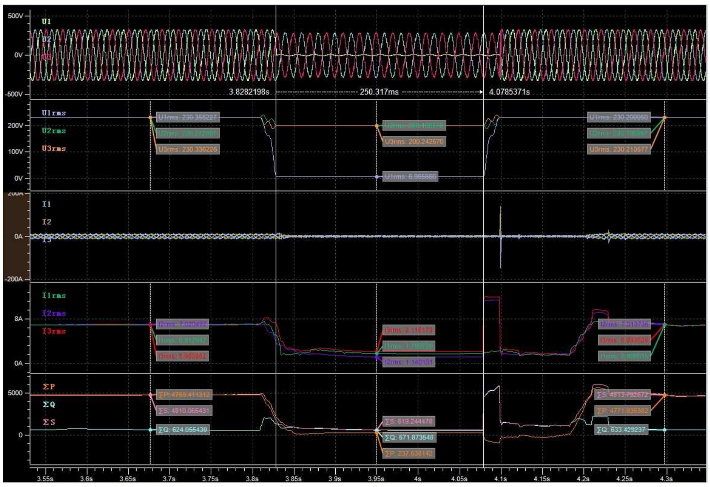
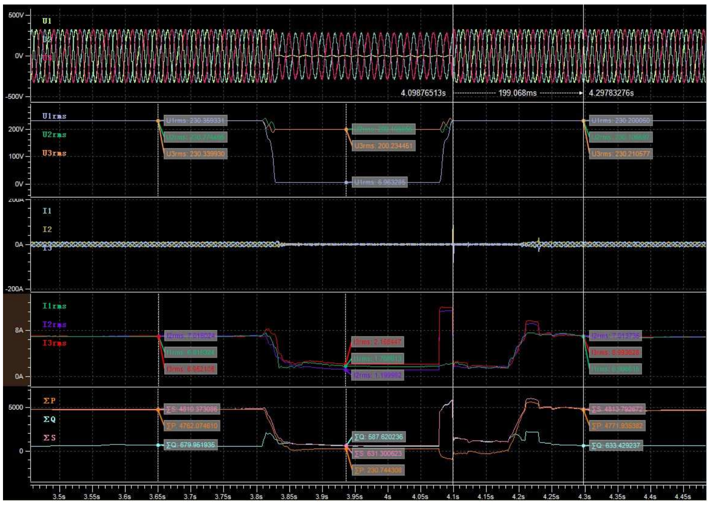


Test 1.A.2-Symmetrical fault (U/U_{nom} = 0,03); P = 20% ±5% P_n

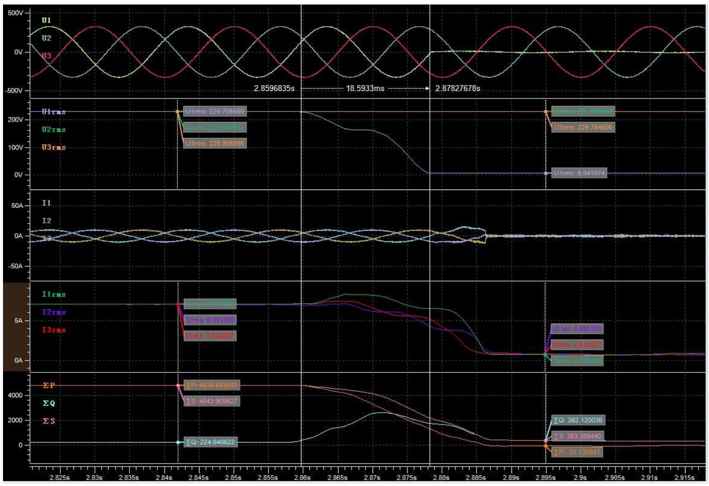


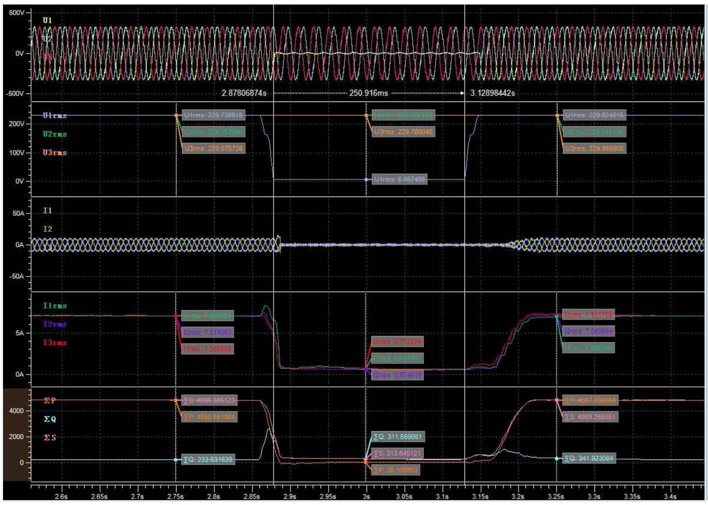


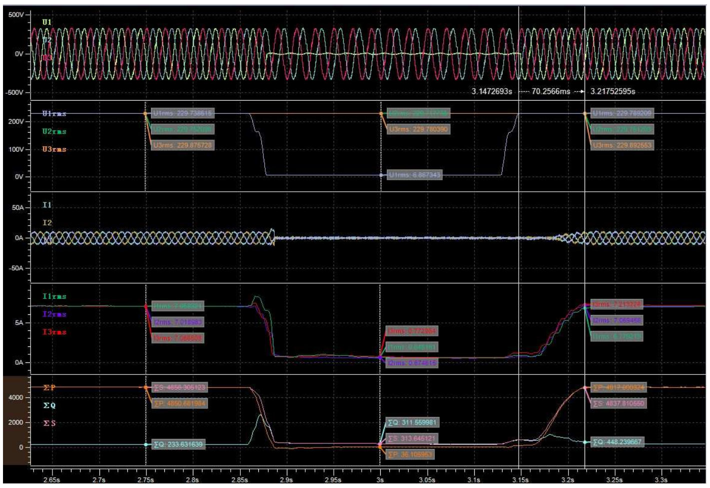


Test 1.D.2-Asymmetrical fault (U/U_{nom} = 0,03); P = 20% ±5% P_n
  

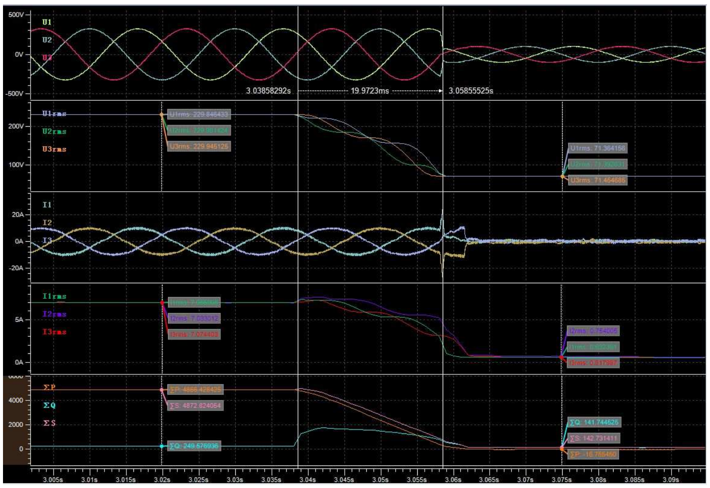
Test 1.B.2-Single phase fault (U/U_{nom} = 0,03); P = 20% ±5% P_n

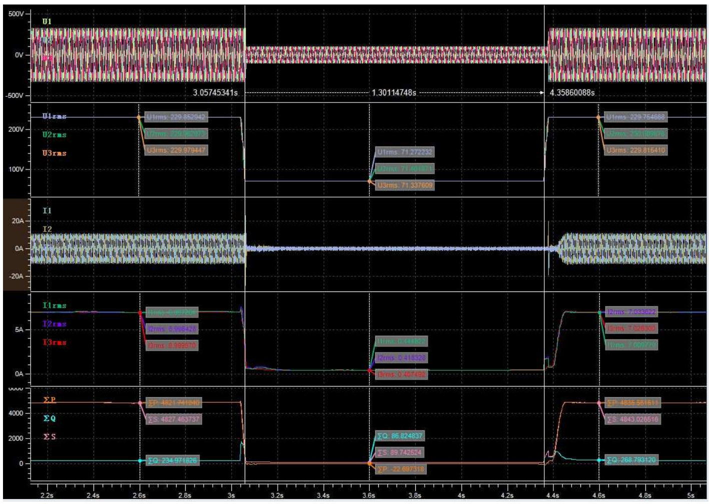


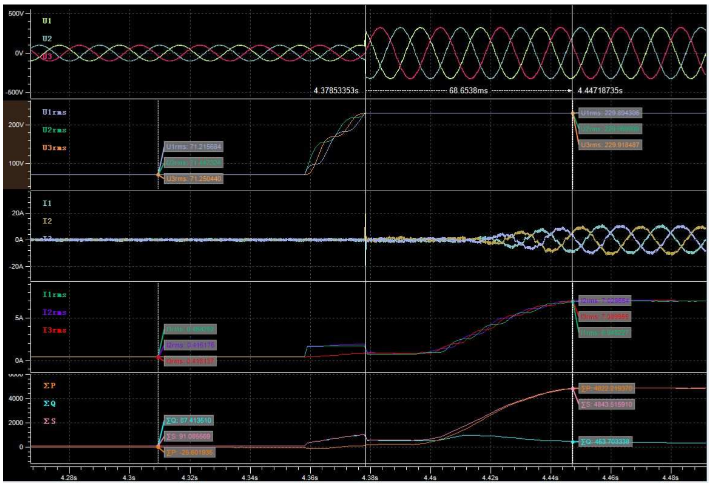




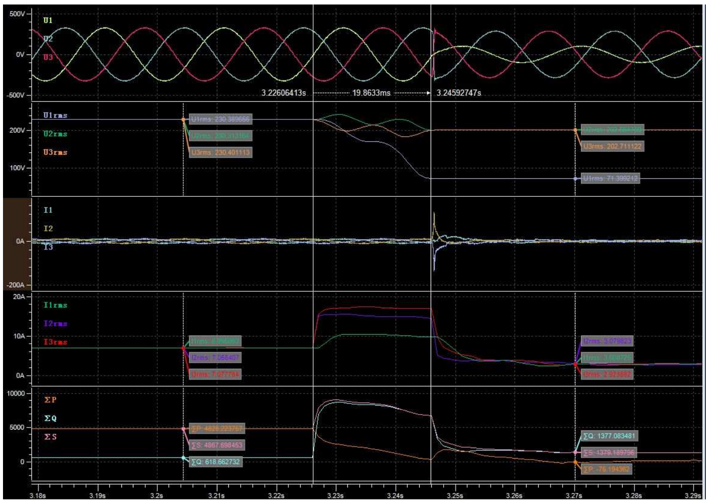
Test 2.A.2-Symmetrical fault (U/U_{nom} = 0,31); P = 20% ±5% P_n

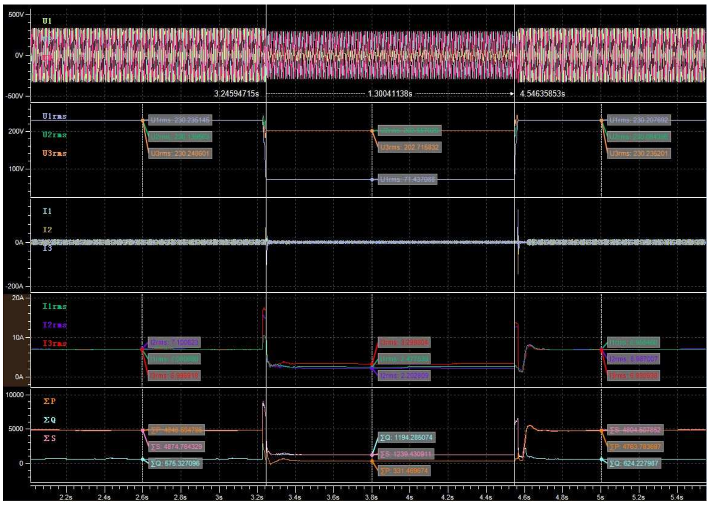


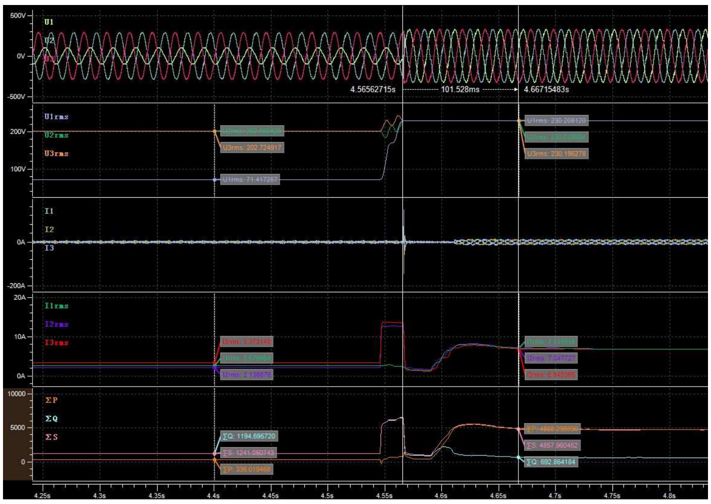




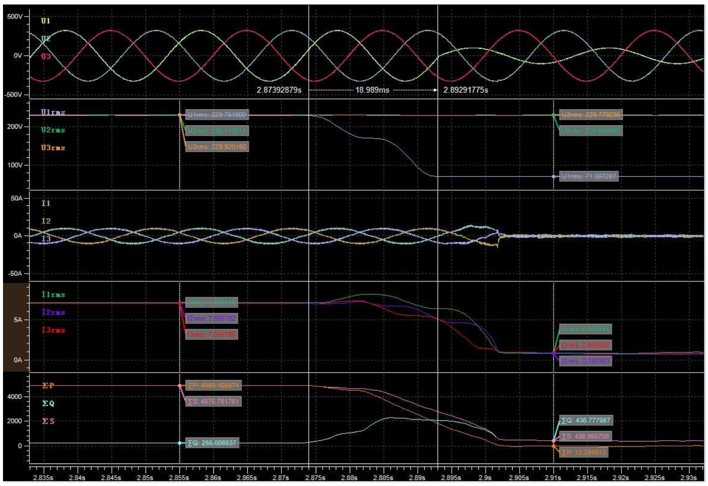
Test 2.D.2-Asymmetrical fault (U/U_{nom} = 0,31); P = 20% ±5% P_n

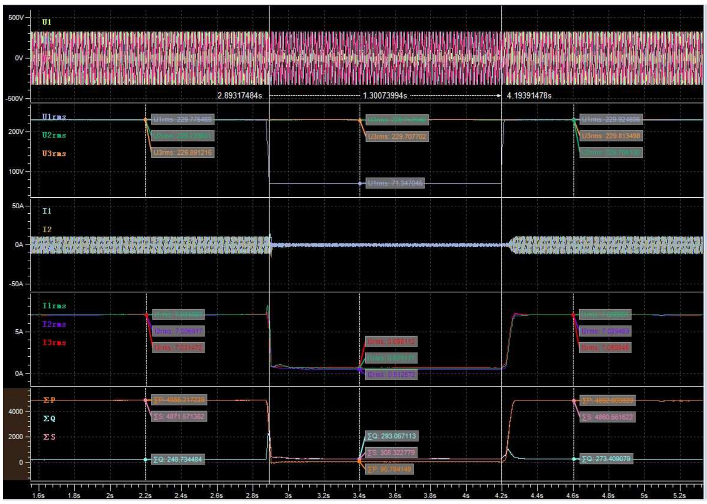


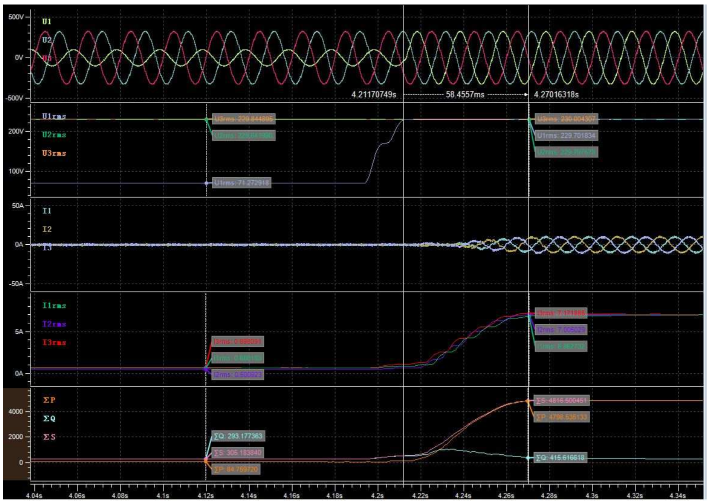


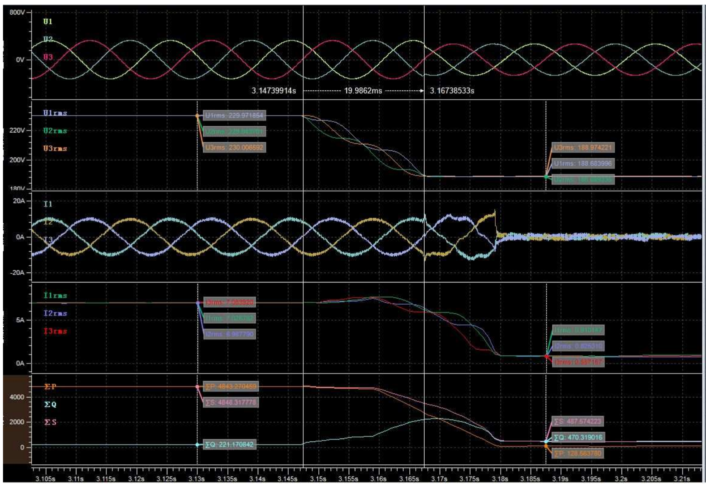
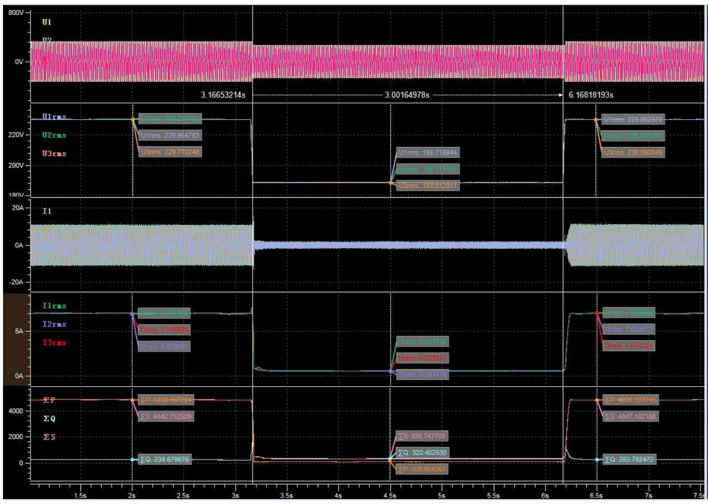
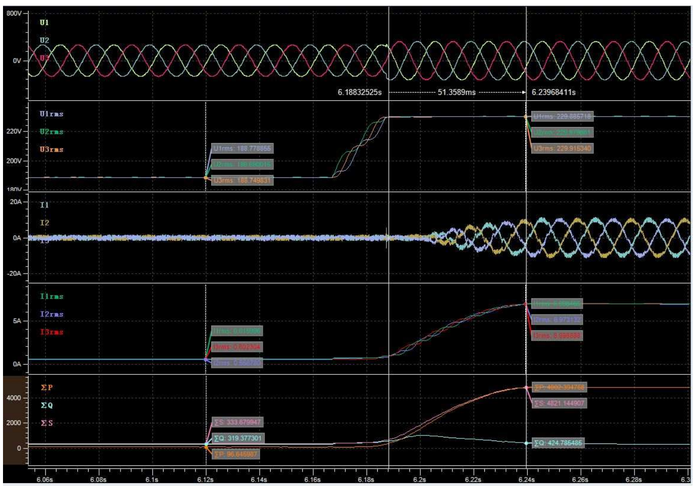


Test 2.B.2-Single phase fault (U/U_{nom} = 0,31); P = 20% ±5% P_n

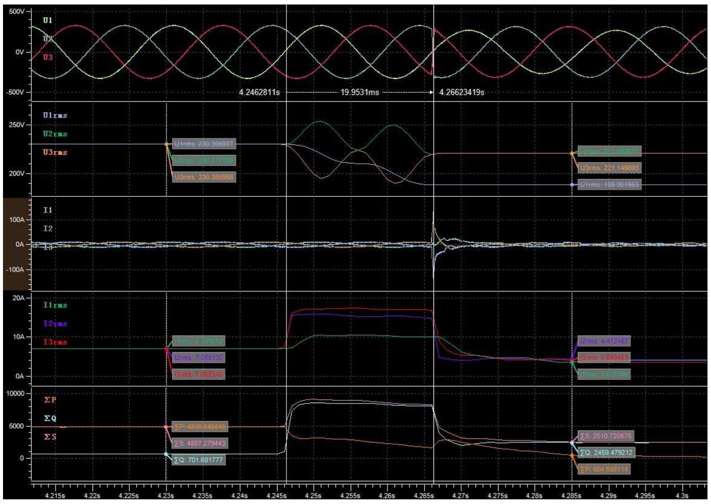


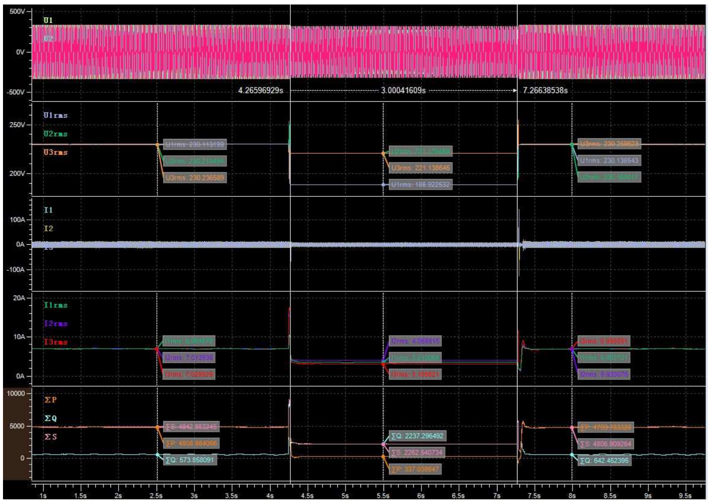


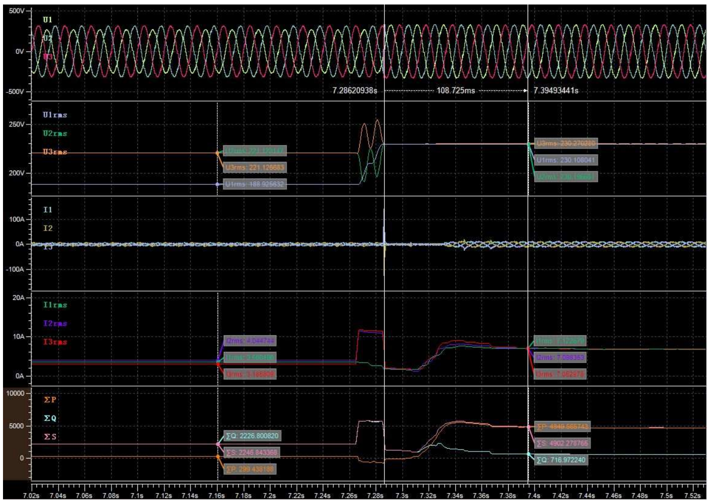


Test 3.A.2-Symmetrical fault (U/U_{nom} = 0,82); P = 20% ±5% P_n
  

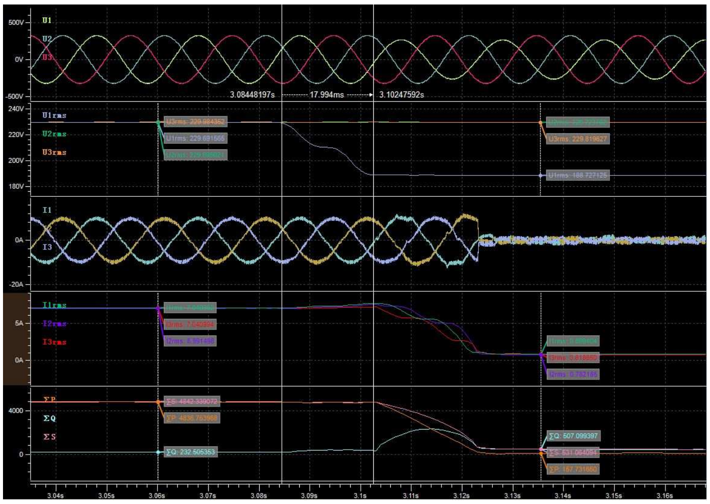
Test 3.D.2-Asymmetrical fault (U/U_{nom} = 0,82); P = 20% ±5% P_n

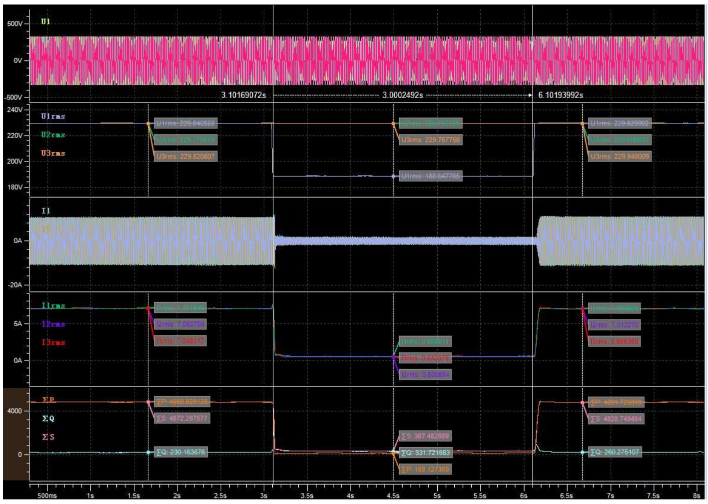


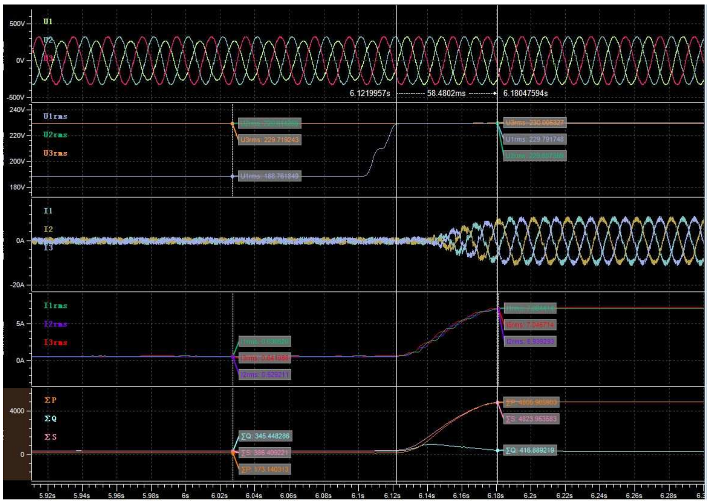




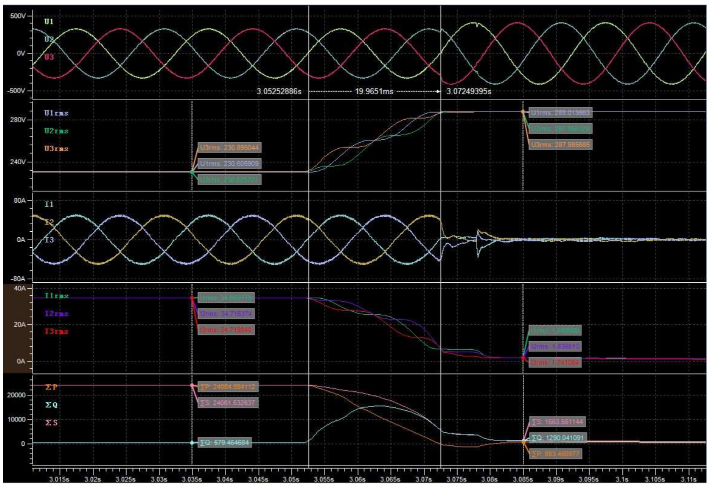
Test 3.B.2-Single phase fault (U/U_{nom} = 0,82); P = 20% ±5% P_n

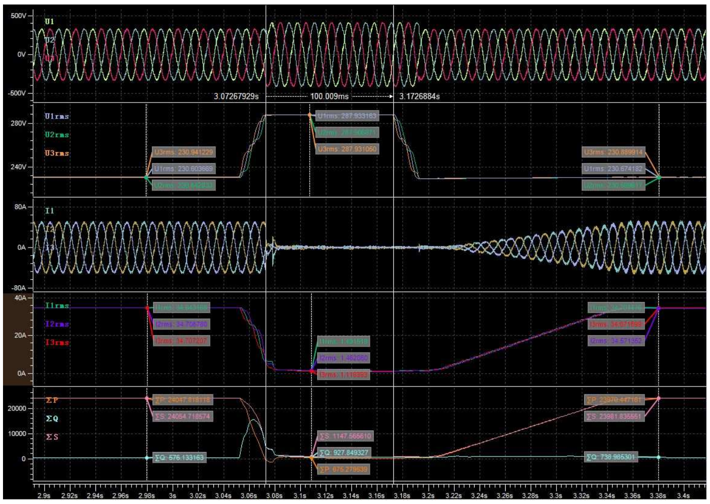


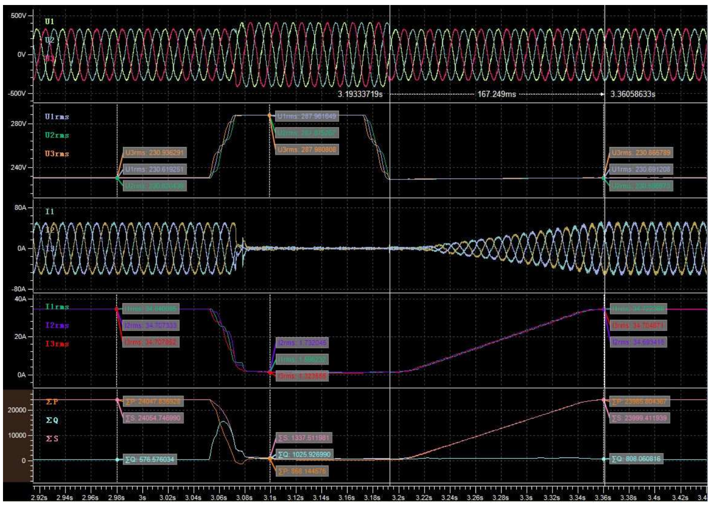




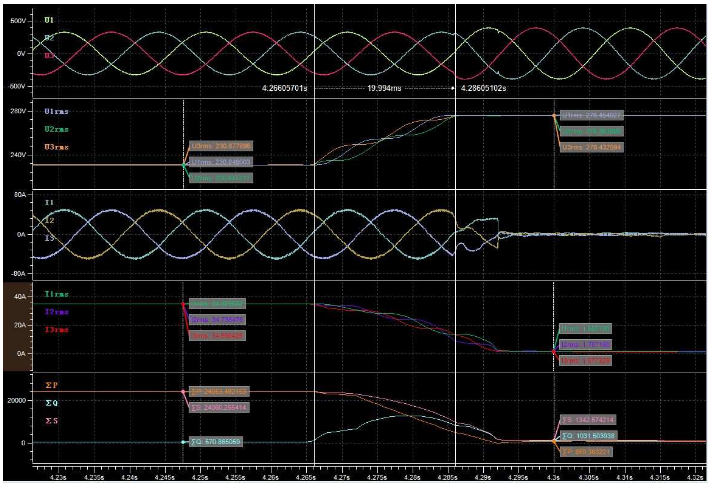
Test OV1-Symmetrical fault (U/U_{nom} = 1,25); P = 100% ±5% P_n

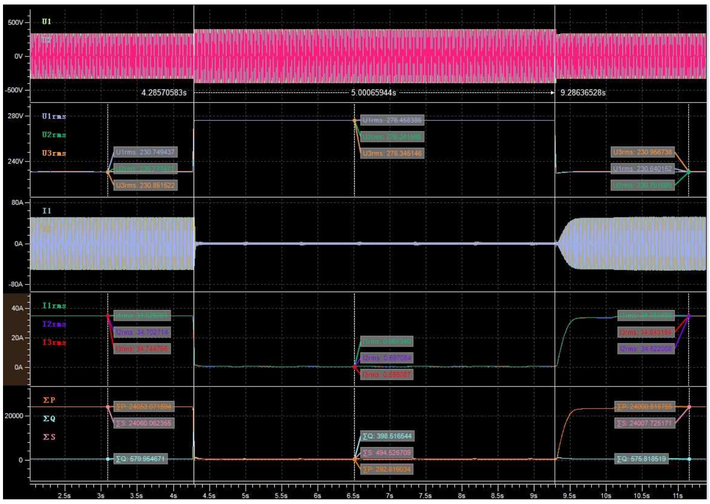


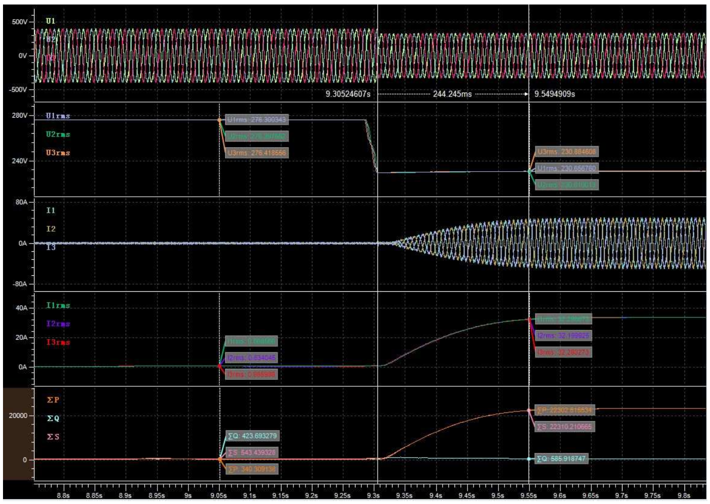


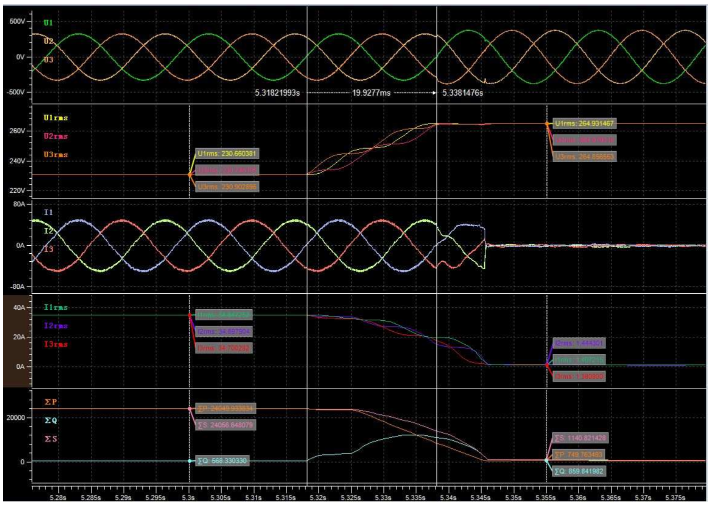
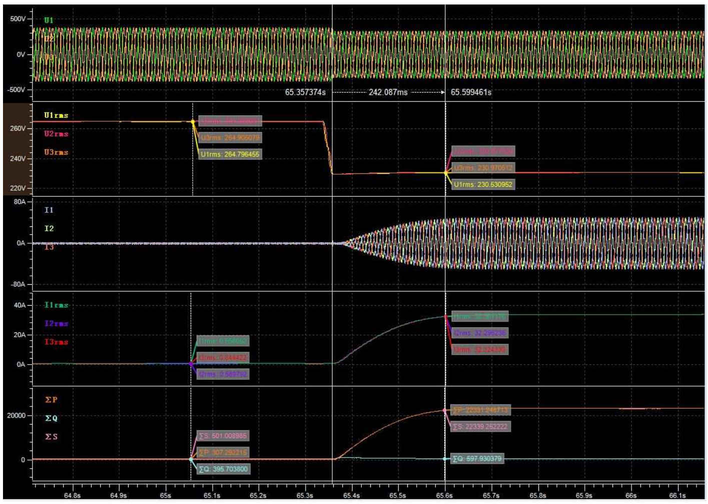


Test OV2-Symmetrical fault (U/U_{nom} = 1,20); P = 100% ±5% P_n



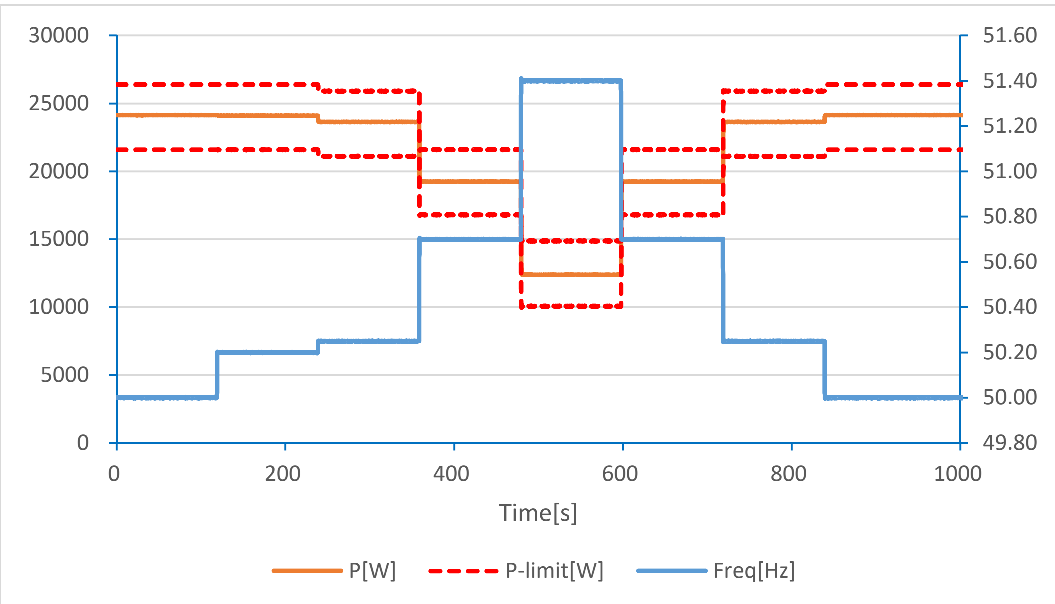




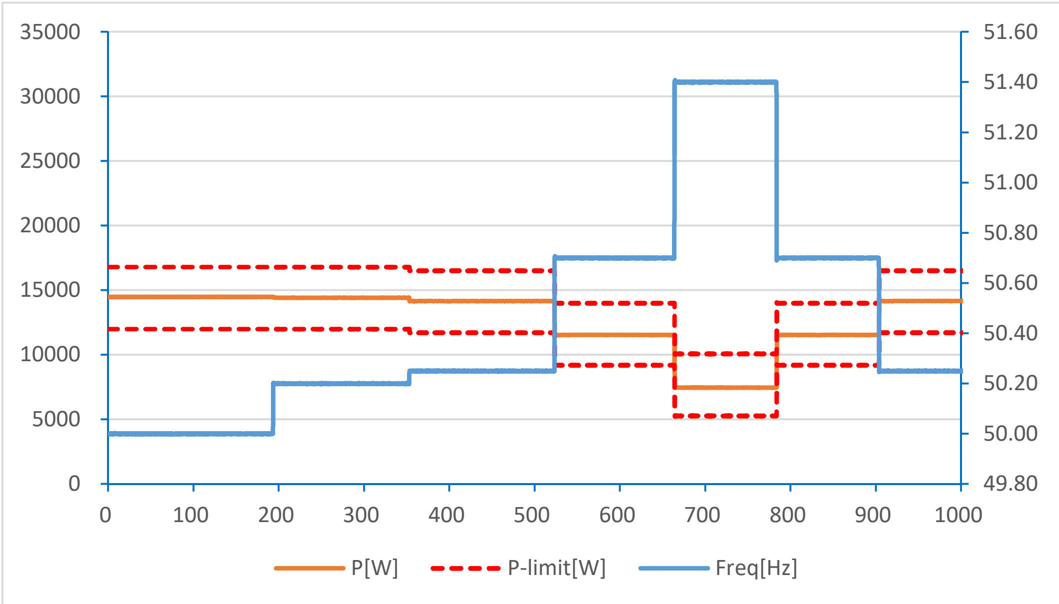
Test OV3-Symmetrical fault (U/U_{nom} = 1,15); P = 100% ±5% P_n
 

EN 50549-1:2019: Active response to frequency deviation			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.6.1	Power response to over-frequency	VDE V 0124-100:2019-02 (Draft), clause 5.4.4	**P**
4.6.2	Power response to under-frequency	VDE V 0124-100:2019-02 (Draft), clause 5.4.6	**P**

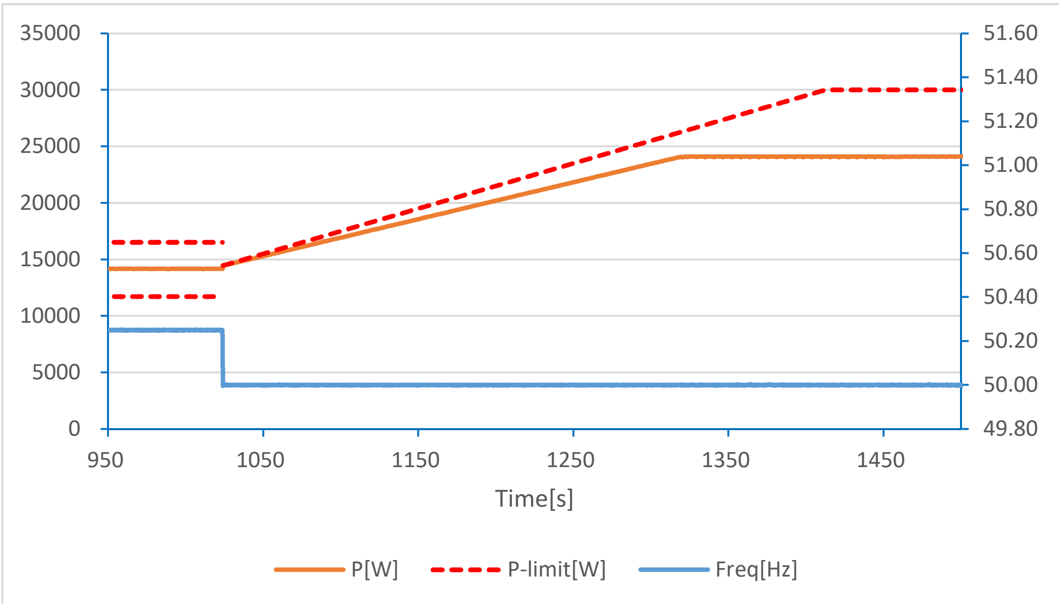
4.6.1	Power response to over-frequency						P
Test result:							
1-min mean value [Hz]:	a) 50,00	b) 50,25	c) 50,70	d) 51,40	e) 50,70	f) 50,25	g) 50,00
1. Measurement a) to g): Active power output =100% P_{Emax} s=5% (40% P_{ref} / Hz), threshold frequency for start/return: 50,2Hz							
Frequency [Hz]:	50,00	50,25	50,70	51,40	50,70	50,25	50,00
P_M [kW]:	N/A	23,521	19,202	12,482	19,202	23,522	N/A
P_{E60} [kW]:	24,138	23,637	19,237	12,378	19,236	23,636	24,145
$\Delta P_{E60}/P_M$ [%]:	N/A	0,483	0,145	-0,431	0,144	0,477	N/A
Test result:							
1-min mean value [Hz]:	a) 50,00	b) 50,25	c) 50,70	d) 51,40	e) 50,70	f) 50,25	g) 50,00
2. Measurement a) to g): Active power output 60% after freezing = 100% P_{Emax} s=5% (40% P_{ref} / Hz), threshold frequency for start/return: 50,2Hz							
Frequency [Hz]:	50,00	50,25	50,70	51,40	50,70	50,25	50,00
P_M [kW]:	N/A	14,113	11,521	7,489	11,521	14,113	N/A
P_{E60} [kW]:	14,477	14,157	11,536	7,468	11,534	14,160	24,088
$\Delta P_{E60}/P_M$ [%]:	N/A	-0,18	-0,06	0,09	-0,05	-0,20	N/A
Limit $\Delta P/P_{1min}$:	± 10 % of P_{Emax}						
Graph of Measurement 1.: Active power output > 80% P_{Emax}							



Graph of Measurement 2.:Active power output 40% and 60% after freezing > 80% P_{Emax}



Graph of power gradient:



Test:

The test is conducted for two powers. First, the test must start at a power =100% P_{Emax} ("Measurement 1"), and in a second test, for a power 60% P_{Emax} ("Measurement 2"). In the second test, after freezing of the P_M, the available active power output must be increased to a value =100% P_{Emax}, 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_{Emax} 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.

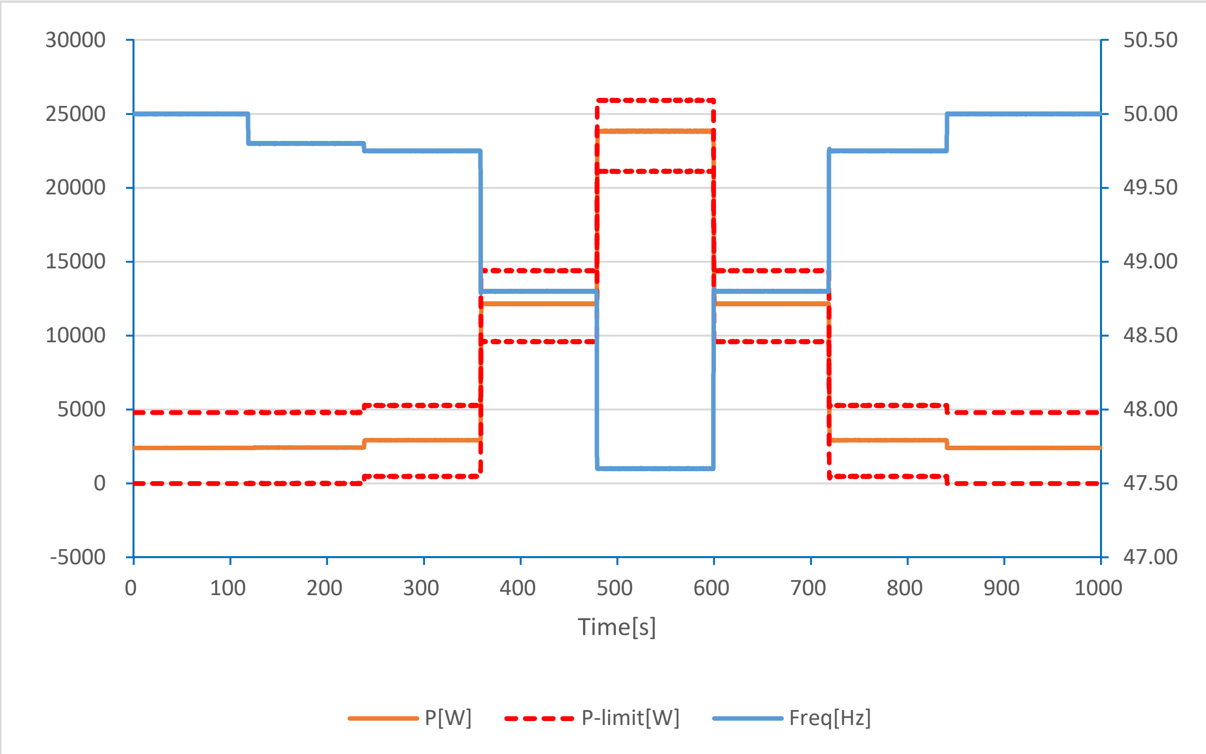
Note:

The test method refer to clause 5.4.4 of VDE V 0124-100:2019-02 (Draft).

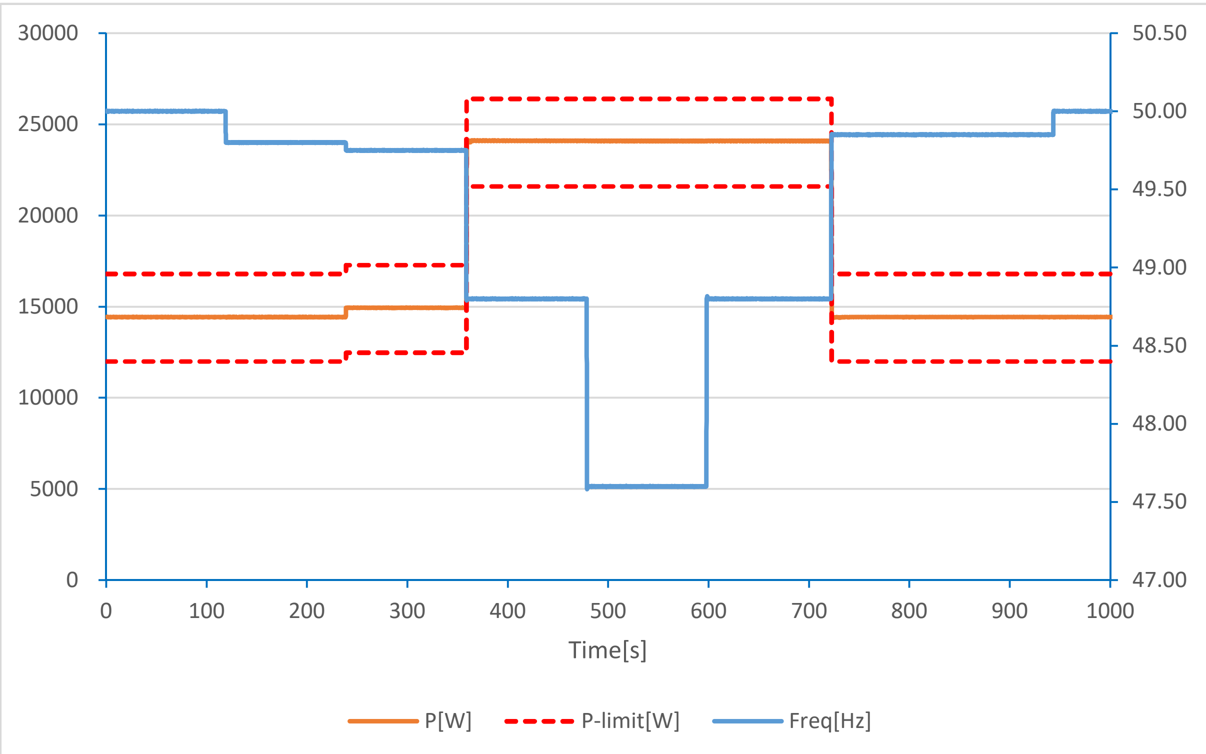
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.6.2	Power response to Under-frequency (For all other synchronous generating unit only if applicable)							P
Test result:								
1-min mean value [Hz]:	a) 50,00	b) 49,75	c) 48,80	d) 47,60	e) 48,80	f) 49,85	g) 50,00	
2. Measurement a) to g): Active power output = 10% P_{Emax} s=5% (40% P_{ref} / Hz), threshold frequency for start/return: 49,8Hz								
Frequency [Hz]:	50,00	49,80	49,75	48,80	47,60	48,80	49,75	50,00
P_M [kW]:	N/A	2,400	2,880	12,000	23,520	12,000	2,880	N/A
P_{E60} [kW]:	2,391	2,421	2,913	12,151	23,828	12,152	2,913	2,400
$\Delta P_{E60}/P_M$ [%]:	N/A	-0,089	-0,139	-0,628	-1,283	-0,633	-0,139	N/A
Test result:								
1-min mean value [Hz]:	a) 50,00	b) 49,75	c) 48,80	d) 47,60	e) 48,80	f) 49,85	g) 50,00	
3. Measurement a) to g): Active power output = 60% P_{Emax} s=5% (40% P_{ref} / Hz), threshold frequency for start/return: 49,8Hz								
Frequency [Hz]:	50,00	49,75	48,80	47,60	48,80	49,85	50,00	
P_M [kW]:	N/A	14,880	24,000	24,000	24,000	14,400	N/A	
P_{E60} [kW]:	14,432	14,938	24,096	24,086	24,085	14,423	14,431	
$\Delta P_{E60}/P_M$ [%]:	N/A	0,242	0,400	0,356	0,354	0,098	N/A	
Limit $\Delta P/P_{1min}$:	± 10 % of P_{Emax}							

Graph of Measurement 2.: Active power output 10% ±5% P_{Emax}



Graph of Measurement 3.: Active power output 60% ±5% P_{Emax}



Test: The test is conducted for two powers. First, the test must start at a power =10% P_{Emax} ("Measurement 2"), and in a second test, for a power 60% P_{Emax} ("Measurement 3"). In the second and third test, after freezing of the P_M, the available active power output must be increased to a value =100% P_{Emax}.
Assessment criterion: For f = 49,8 Hz, the value of the P_M active power currently being generated is "frozen". a) For adjustable micro-generators when: 1) the active power increase between measuring points b) and f) given above with the set gradient Pmax per Hz for a reduces frequency (or rises for a frequency again). 2) the reaction value of the setpoint determined by the gradient characteristic curve does not differ from P_{Emax} by more than ± 10%. 3) 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 47,5 Hz.
Note: The test method refer to clause 5.4.6 of VDE V 0124-100:2019-02 (Draft). The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

EN 50549-1:2019: Power response to voltage variations and voltage changes			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.7.2.2	Capabilities	--	**P**
4.7.2.3.2	Fix control modes (cos φ setpoint mode)	FGW TG3, Revision 25, clause 4.2.2	**P**
4.7.2.3.2	Fix control modes (Q setpoint mode, 48,43%)	EN 50438:2013, Annex D.3.4.2.1	**P**
4.7.2.2	Q Response time	CEI 0-21:2019-04, Annex B.1.2.4	**P**
4.7.2.3.3	Voltage related control modes (Q (U) controls)	VDE AR 4105:2018-05, clause 5.7.2.4.	**P**
4.7.2.3.4	Power related control modes (cos φ (P) curve)	VDE V 0124-100:2012, clause 5.3.6.4	**P**
4.7.3	Voltage related active power reduction (P(U) function)	CEI 0-21:2019-04, Annex B.1.3.1	**P**

4.7.2 4.7.2.2 4.7.2.3.2	Voltage support by reactive power Capabilities Fix control modes (cos φ setpoint mode)			P
Test result:				
PF = 0,9 / Inducitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
10%	2,391	-1,174	0,8977	230,10
20%	4,828	-2,270	0,9050	230,15
30%	7,247	-3,590	0,8960	230,27
40%	9,663	-4,770	0,8967	230,34
50%	12,067	-5,942	0,8971	230,46
60%	14,464	-7,117	0,8973	230,51
70%	16,860	-8,284	0,8975	230,61
80%	19,236	-9,436	0,8978	230,72
90%	21,600	-10,581	0,8980	230,81
100%	23,957	-11,665	0,8991	230,93
PF = 0,9 / Capacitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
10%	2,397	1,188	0,8959	230,18
20%	4,835	2,260	0,9059	230,27
30%	7,258	3,535	0,8991	230,35
40%	9,679	4,657	0,9011	230,44
50%	12,088	5,781	0,9021	230,54
60%	14,490	6,931	0,9021	230,65
70%	1,6880	8,073	0,9021	230,77
80%	19,263	9,213	0,9021	230,86
90%	21,635	10,346	0,9022	230,94
100%	23,993	11,468	0,9022	231,01

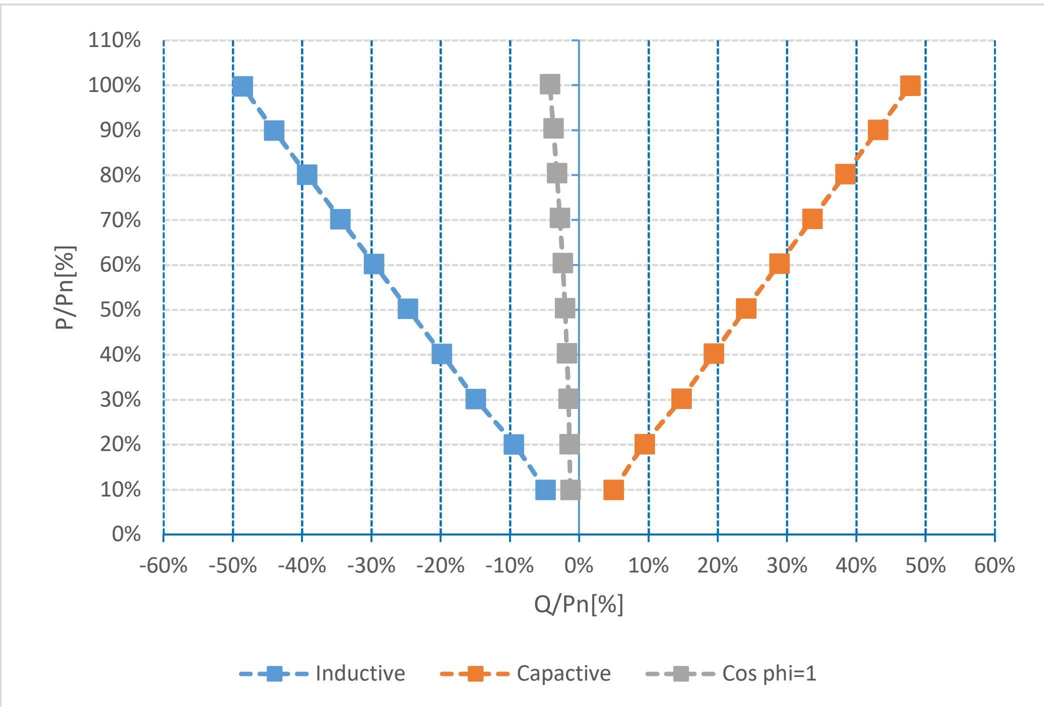
Cos phi=1 no reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
10%	2,394	-0,317	0,9999	230,10
20%	4,839	-0,342	0,9999	230,22
30%	7,268	-0,379	0,9999	230,31
40%	9,694	-0,432	0,9999	230,40
50%	12,111	-0,495	0,9999	230,51
60%	14,523	-0,576	0,9999	230,62
70%	16,928	-0,676	0,9999	230,73
80%	19,322	-0,782	0,9999	230,81
90%	21,707	-0,900	0,9999	230,92
100%	24,082	-1,024	0,9999	231,00

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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Diagram



4.7.2 4.7.2.2 4.7.2.3.2	Voltage support by reactive power Capabilities Fix control modes (Q setpoint mode, 48,43%)	P

Test result:

Inducitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
10%	2,364	-11,848	0,1957	230,01
20%	4,816	-11,903	0,3751	230,17
30%	7,237	-11,954	0,5179	230,29
40%	9,660	-12,025	0,6263	230,41
50%	12,080	-11,868	0,7133	230,48
60%	14,478	-11,932	0,7717	230,62
70%	16,875	-11,879	0,8177	230,69
80%	19,270	-11,947	0,8499	230,81
90%	21,648	-11,904	0,8763	230,91
100%	23,406	-11,874	0,8918	230,96
Capacitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
10%	2,383	11,886	0,1966	230,17
20%	4,841	11,819	0,3790	230,25
30%	7,260	11,731	0,5262	230,34
40%	9,692	11,767	0,6358	230,44
50%	12,108	11,817	0,7156	230,54
60%	14,516	11,873	0,7741	230,65
70%	16,919	11,817	0,8198	230,74
80%	19,281	11,877	0,8514	230,74
90%	21,674	11,817	0,8780	230,89
100%	23,235	11,924	0,8897	230,98
Cos phi=1 no reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
10%	2,394	-0,317	0,9999	230,10
20%	4,839	-0,342	0,9999	230,22
30%	7,268	-0,379	0,9999	230,31
40%	9,694	-0,432	0,9999	230,40
50%	12,111	-0,495	0,9999	230,51
60%	14,523	-0,576	0,9999	230,62
70%	16,928	-0,676	0,9999	230,73
80%	19,322	-0,782	0,9999	230,81
90%	21,707	-0,900	0,9999	230,92
100%	24,082	-1,024	0,9999	231,00

Assessment criterion:

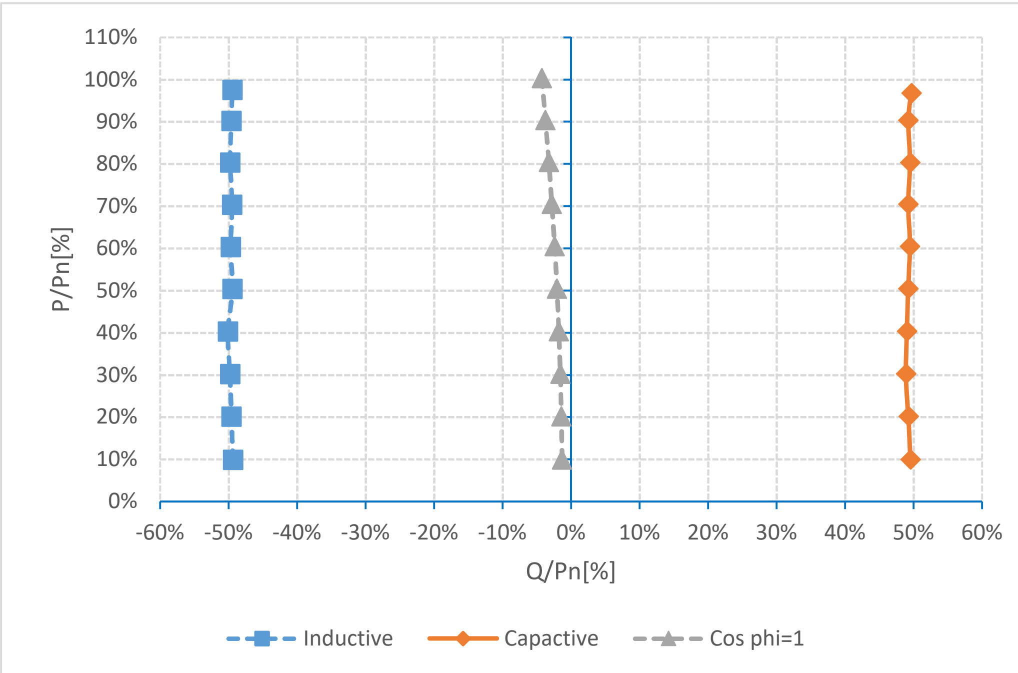
The power factor resulting in each of the measurement points between 20 % and 90 % of the nominal power is equal to or lower than 0,90 both in over excited and under excited operation,

The test method refer to clause CEI0-21 / EN 50438:2013, Annex D,3,4,2,1,

Generating plants must meet the reactive power requirement regardless of the number of feeding phases under normal steady-state operating conditions in the voltage tolerance band +10%U_n and -15%U_n.

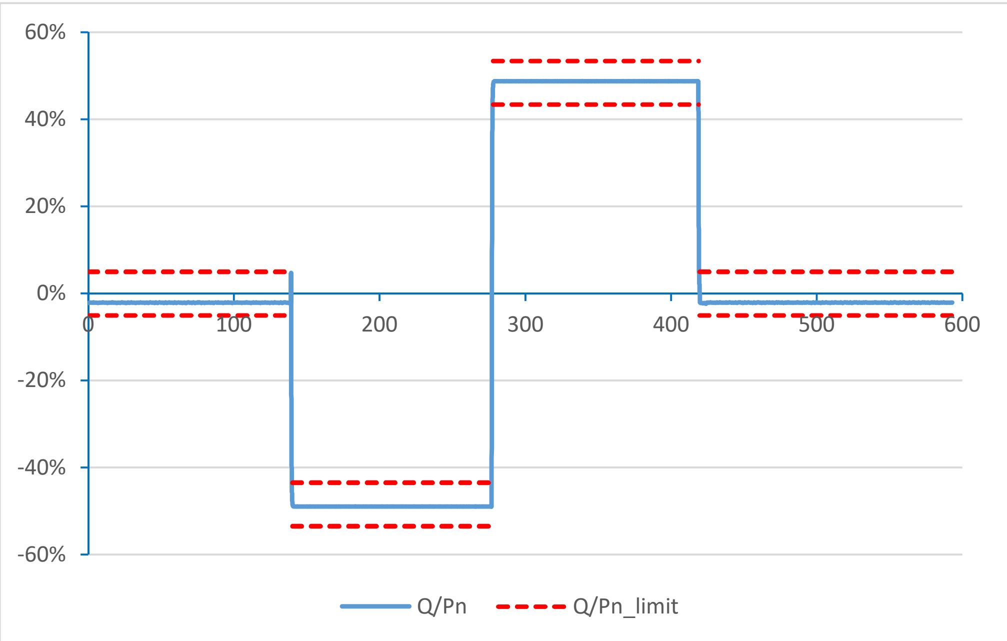
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Diagram

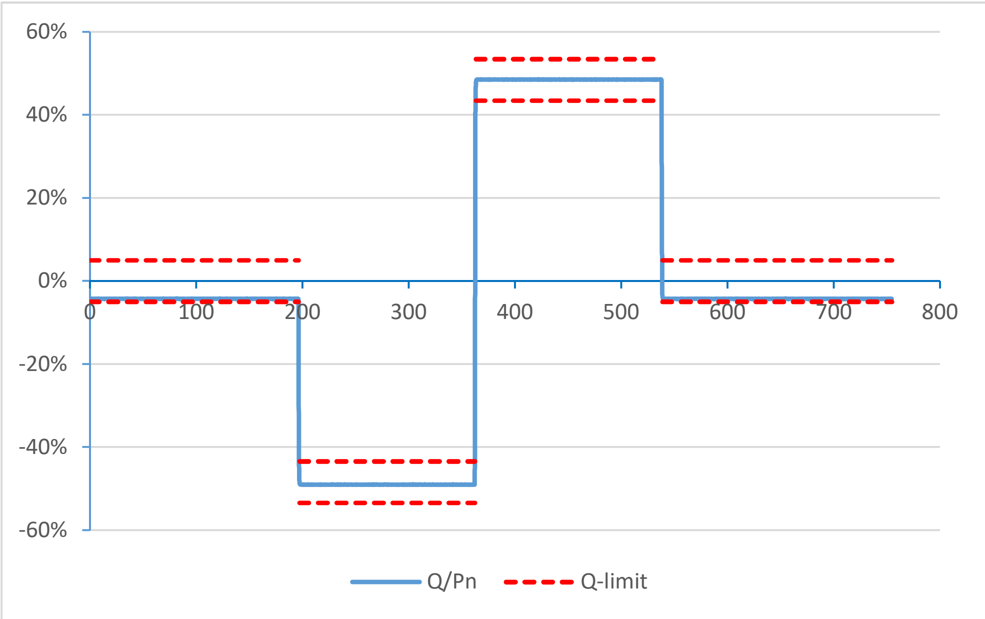


4.7.2.2	Capabilities Q Response time		P
Reaction time			
Test result:			
		Time	**Result**
1.	Reaction time Q=0 to Qmin (50% test)	0,6s	P
2.	Reaction time Qmin to Qmax (50% test)	1,2s	P
3.	Reaction time Qmax to Q=0 (50% test)	0,6s	P
4.	Reaction time Q=0 to Qmin (100% test)	0,6s	P
5.	Reaction time Qmin to Qmax (100% test)	1,2s	P
6.	Reaction time Qmax to Q=0 (100% test)	0,6s	P
Test result:			

Graph 50%Pn



Graph 100%Pn



Assessment criterion:

DC source should be set to 50%(test1) and 100%(test2) output power micro-generator.

Starting with Q=0 then Qmin≤ -0,4843 Pn to to Qmax≥ 0,4843 Pn, and then back to Q=0 in doing so each point must be kept for at least 2 minute.

The total tolerance is ΔQ ≤ ±5,0% of Pn or Δcosφ ≤ ±0,01

The maximum response time is 10s.

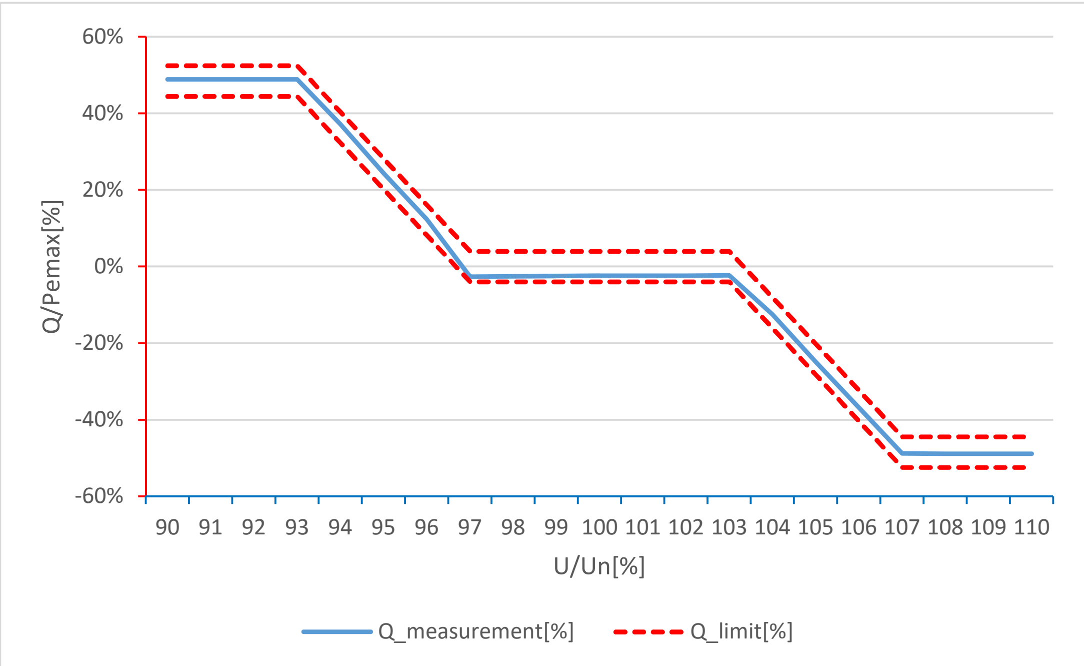
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.7.2.2 Capabilities 4.7.2.3.3 Voltage related control modes (Q (U) controls) The validation of the Q (U) regulation according to VDE-AR-N 4105: 2018-05, 5.7.2.4 is divided into two partial tests, so that on the one hand the accuracy and on the other hand the dynamics of the Q (U) control is checked. For all inverter-coupled systems, only the inverter must be tested.	P
Test result:	
Test of the reactive power-voltage characteristic Q (U)	P

Vac [% U_n] Set point	Vac [V] measured	P [kW] measured	Q [kVar] measured	Q [kVar] expected	ΔQ [% P_{Emax}]
100	230,21	24,039	-0,573	0	2,39
99	227,98	24,036	-0,582	0	2,43
98	225,69	24,029	-0,609	0	2,54
97	223,37	24,018	-0,648	0	2,70
96	220,82	24,003	2,976	2,906	-0,29
95	218,64	23,973	5,854	5,812	-0,18
94	216,33	23,277	8,749	8,717	-0,13
93	214,07	21,658	11,488	11,623	0,56
92	211,78	21,304	11,720	11,623	-0,40
91	209,48	21,073	11,722	11,623	-0,41
90	207,30	20,856	11,721	11,623	-0,41
91	209,46	21,073	11,719	11,623	-0,40
92	211,78	21,305	11,716	11,623	-0,39
93	214,08	21,536	11,715	11,623	-0,38
94	216,29	23,202	8,925	8,717	-0,87
95	218,73	23,959	5,851	5,812	-0,16
96	220,89	23,990	2,949	2,906	-0,18
97	223,37	24,011	-0,631	0	2,63
98	225,72	24,021	-0,605	0	2,52
99	228,03	24,027	-0,585	0	2,44
100	230,28	24,029	-0,578	0	2,41
101	232,61	24,031	-0,571	0	2,38
102	234,85	24,033	-0,567	0	2,36
103	237,18	24,035	-0,561	0	2,34
104	239,46	24,026	-3,006	-2,906	0,42
105	241,62	24,004	-5,964	-5,812	0,63
106	243,84	23,970	-8,829	-8,717	0,47

107	246,08	23,263	-11,716	-11,623	0,39
108	248,49	23,243	-11,735	-11,623	0,47
109	250,72	23,239	-11,735	-11,623	0,47
110	253,11	23,225	-11,736	-11,623	0,47
109	250,70	23,251	-11,716	-11,623	0,39
108	248,55	23,261	-11,715	-11,623	0,38
107	246,15	23,266	-11,715	-11,623	0,38
106	243,96	23,956	-8,957	-8,717	1,00
105	241,63	23,995	-5,969	-5,812	0,65
104	239,43	24,019	-2,993	-2,906	0,36
103	237,19	24,029	-0,566	0	2,36
102	234,89	24,027	-0,569	0	2,37
101	232,51	24,026	-0,574	0	2,39
100	230,31	24,024	-0,580	0	2,42
Limit ∆Q:	± 4% P_{Emax}				

Graph of characteristic Q (U):



Test:

The verification of the accuracy of the Q (U) control of the reactive power-voltage characteristic Un shown in VDE-AR-N 4105: 2018-11, 5.7.2.4, Figure 7 is effected by a slow variation of the line voltage U_n in the range 90% U_n to 110% U_n. Depending on the type of EZE (single- or three-phase), the voltage changes must be carried out simultaneously or symmetrically on all phases.

a) In order to check the stationary accuracy, the permissible voltage range shall be passed through within steps, with a step size of 1% U_n, but not greater than 2% U_n.

1. Pass the voltage range from 100% U_n down to the under voltage range to 90% U_n.
2. Pass the voltage range from 90% U_n up to the over voltage range to 110% U_n.
3. Pass the voltage range from 110% U_n down to the Nominal Voltage U_n.

The procedure is analogous to Figure 3 in Section 5.4.3.2.

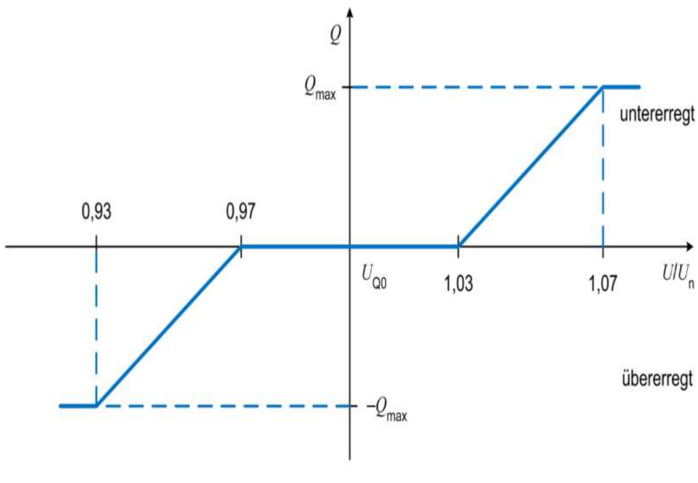


Bild 7 – Standard-$Q(U)$-Kennlinie

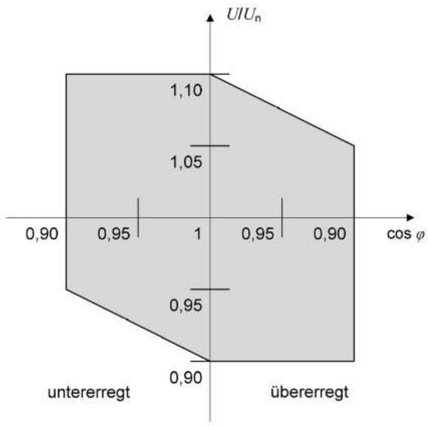


Bild 3 – Anforderungen an Erzeugungseinheiten bezüglich der Blindleistungsbereitstellung an den Generatorklemmen
($\sum S_{Emax} > 4{,}6$ kVA)

The voltages are to be set with a maximum deviation of 0.25% U_n.

Assessment criterion:

In order to pass the Q (U) accuracy test, the measured stationary value pairs U_{PGU} and Q_{PGU}, under taking account to the correct sign in the consumer metering system, must be within VDE-AR-N 4105: 2018-11, in 5.7.2.4, Figure 7 Q (U) shown characteristic. The stationary value pairs U_{PGU} and Q_{PGU} are determined by averaging over 30 seconds at the end of the respective measuring section analogously to Chapter 5.4.3.2. The permissible deviations are with the maximum measuring error of the voltage of 1% U_n stated in VDE-AR-N 4105: 2018-11 and a setting accuracy of 4% P_{EMax} at

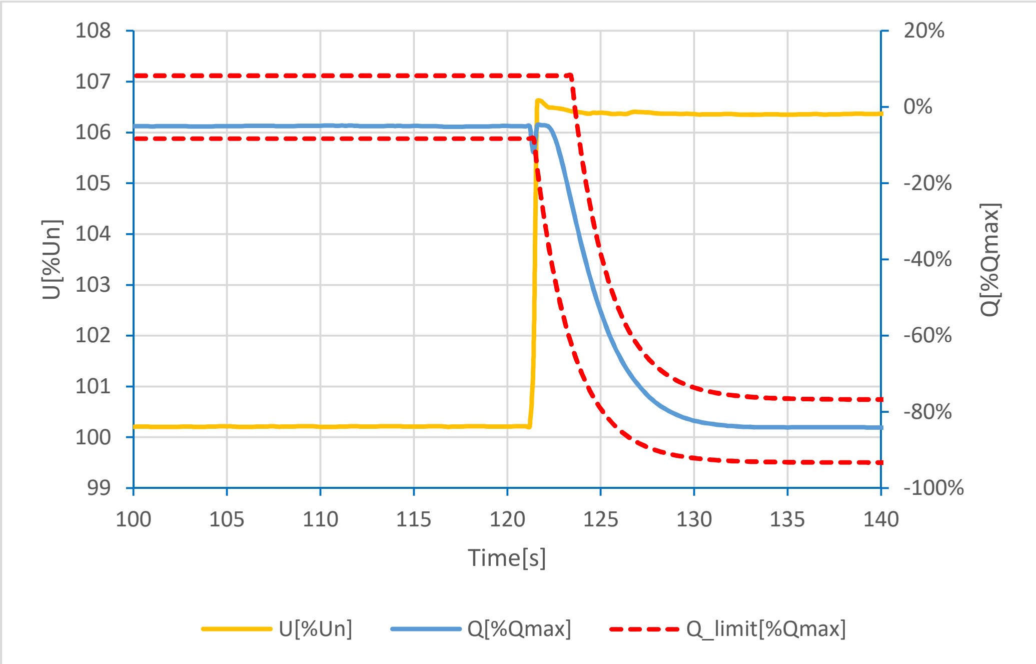
$$Q_{EZE,tol} = \pm(0.01 \cdot \mathrm{U_{N,Y}} \cdot \mathrm{k_{QU}} + 0.04 \cdot P_{EMax}) = \pm 0{,}25 \cdot P_{EMax} \cdot (\sin(\arccos(\varphi_{min})) + 0.16).$$

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

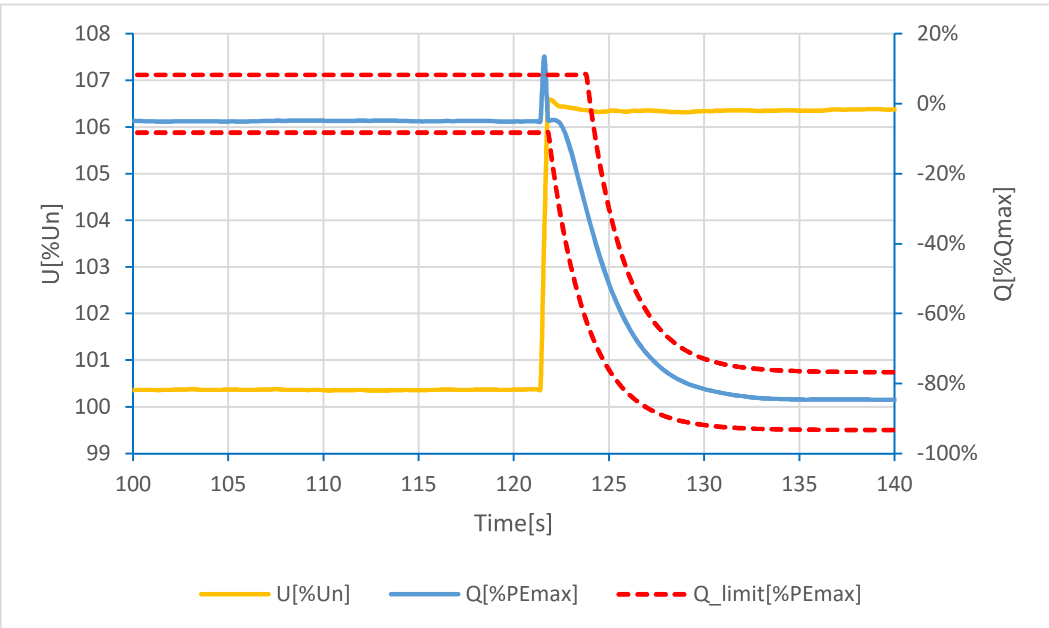
Test of the dynamics of the Q (U) regulation			P
Voltage jump Vac [% U_n]	Q [kVar] measured	Q [%Qmax] measured	T=3τmeasured
100 to 106,4	-9,993	-85,98	10,0 s
	-9,849	-84,74	11,0 s
	-9,928	-85,42	10,4 s
100 to 93,6	9,887	85,06	10,2 s
	9,871	84,92	11,2 s
	9,895	85,13	11,6 s

Note:
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

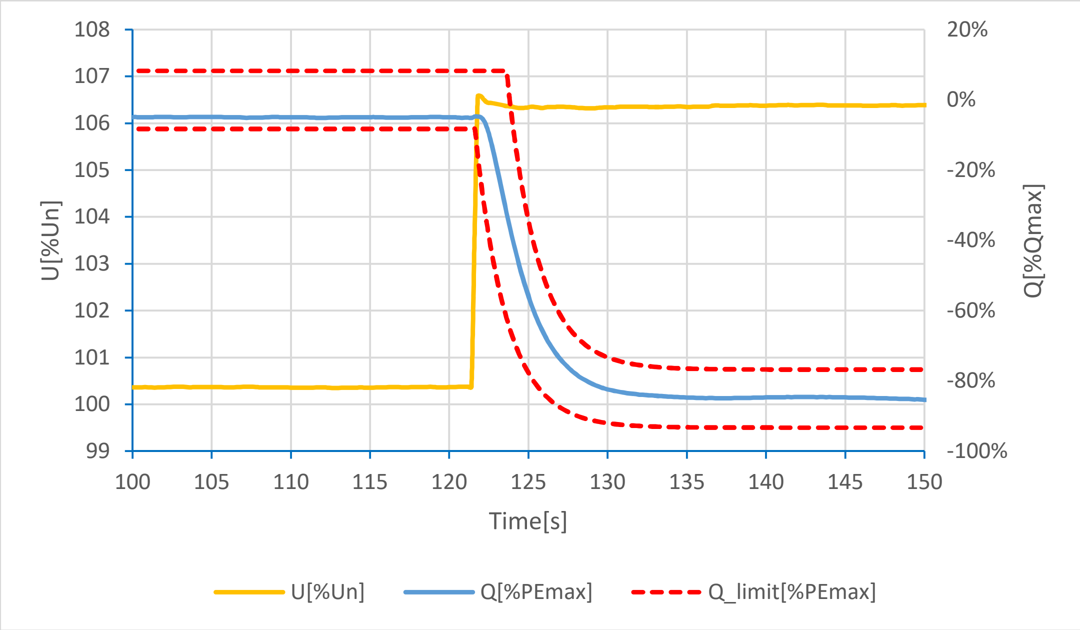
Graph of 100%U_n to 106,4% U_n: Test 1



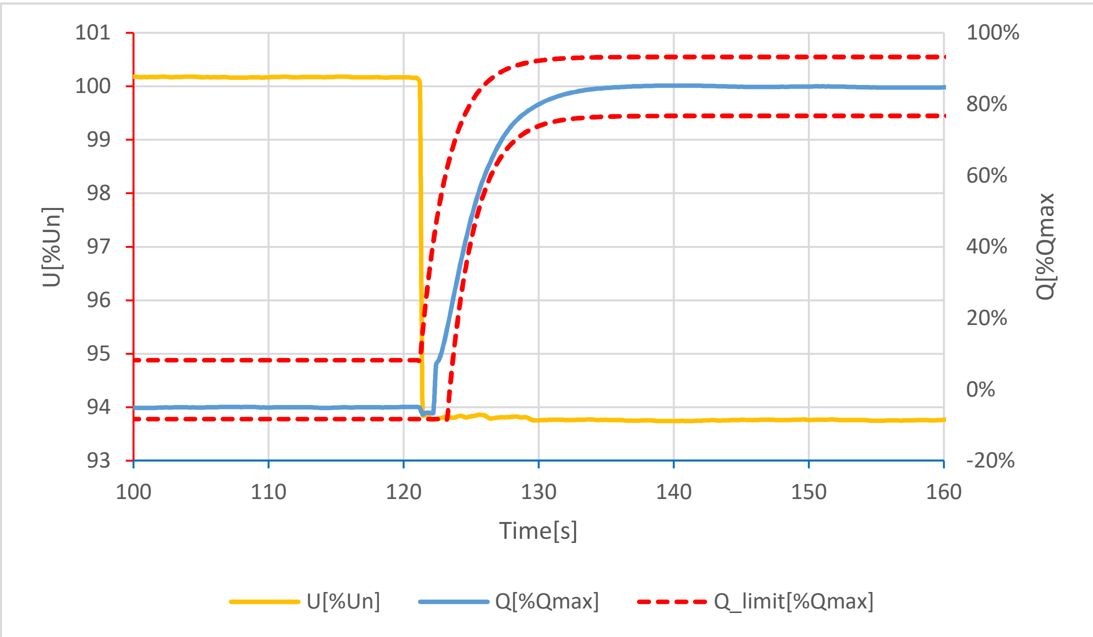
Graph of 100%U_n to 106,4% U_n: Test 2



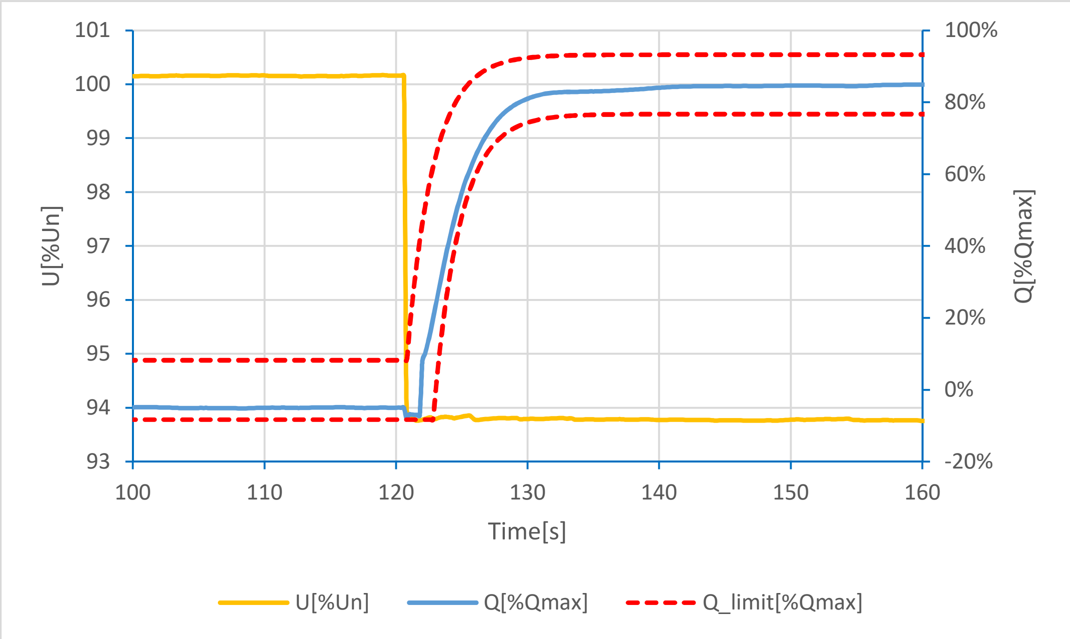
Graph of 100%U_n to 106,4% U_n: Test 3



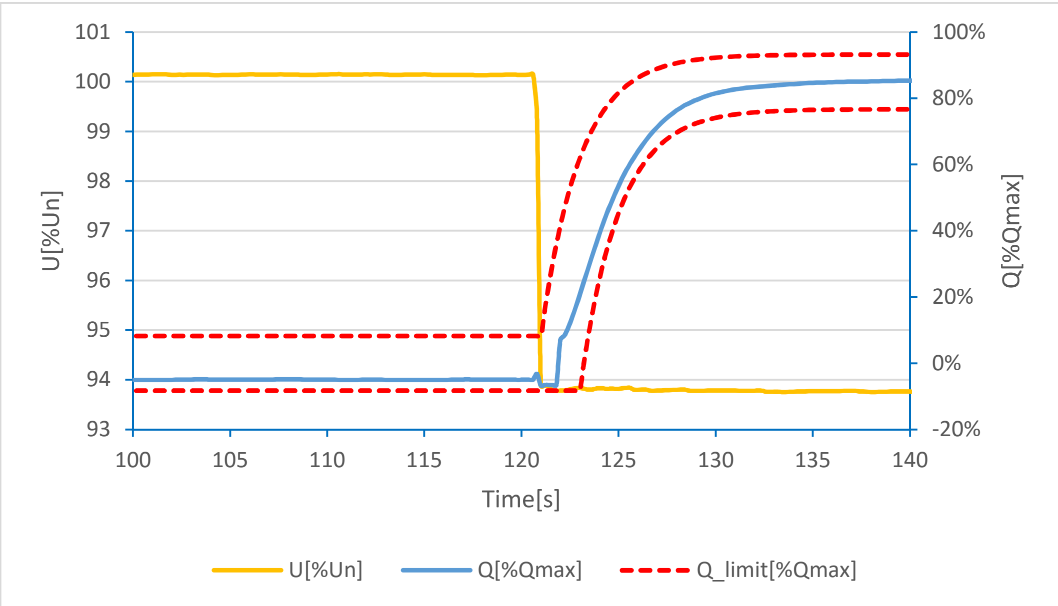
Graph of 100%U_n to 93,6% U_n: Test 1



Graph of 100%U_n to 93,6% U_n: Test 2



Graph of 100%U_n to 93,6% U_n: Test 3

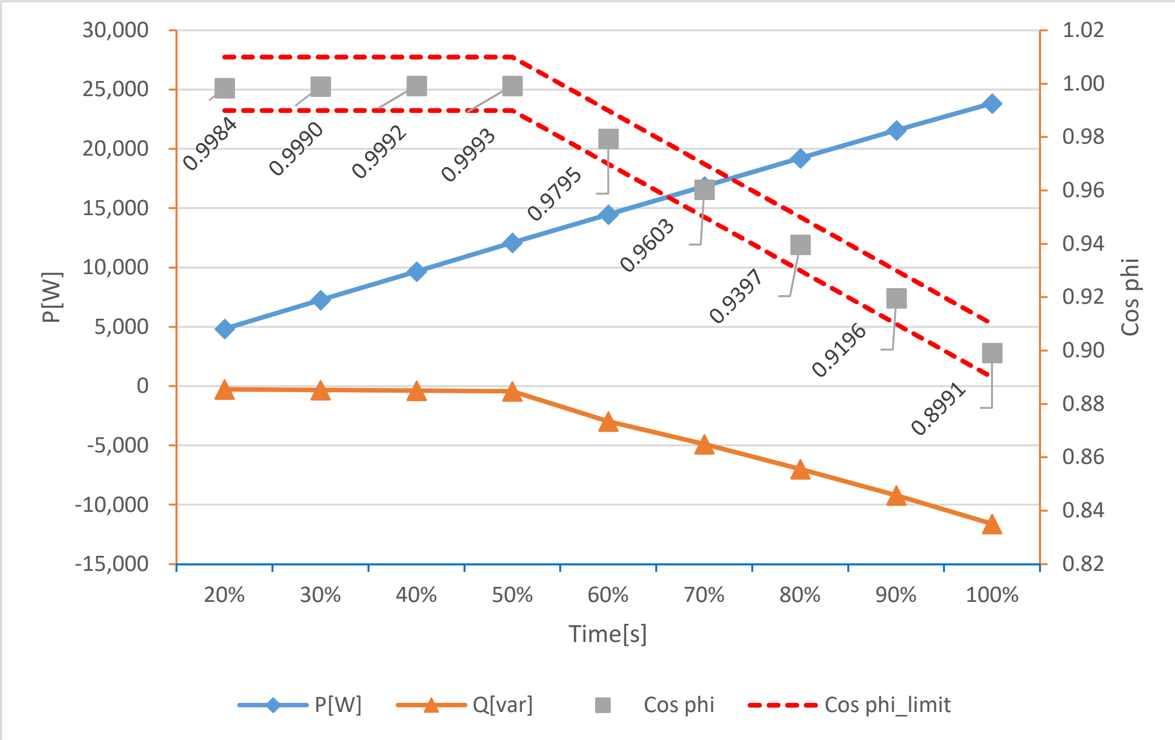


4.7.2.2 4.7.2.3.4	Capabilities Power related Control mode (cos φ (P) curve)									P
Test result:										
Test a):										
P_{Emax}/ P_n [%]	10	20	30	40	50	60	70	80	90	100
30 s mean value	20% to 100% P_{Emax}									
U [V]:	N/A	229,65	229,77	229,89	230,02	230,03	230,15	230,26	230,37	230,38
P_{E30} [kW]:	N/A	4,843	7,263	9,673	12,084	14,469	16,848	19,213	21,563	23,851
P_{E30} of P_n [%]:	N/A	20,18	30,26	40,30	50,35	60,29	70,20	80,06	89,84	99,38
Q_{E30} [kVAr]:	N/A	-0,267	-0,315	-0,371	-0,442	-2,976	-4,894	-6,989	-9,209	-11,611
cos $φ_{E30}$:	N/A	0,9984	0,9990	0,9992	0,9993	0,9795	0,9603	0,9397	0,9196	0,8991
cos $φ_{setpoint}$ of P_{E30}:	N/A	1,000	1,000	1,000	1,000	0,980	0,960	0,940	0,920	0,900
Limit cos φ $_{E30}$:	cos $φ_{setpoint}$ ± 0,01									

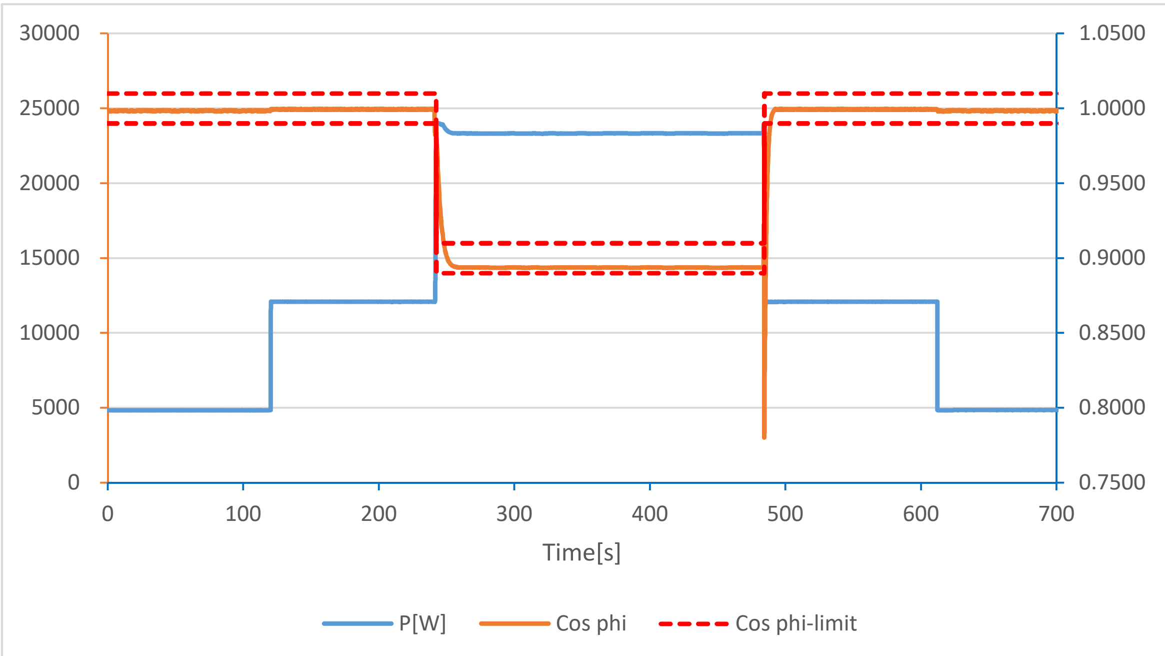
Test b):			
P_{Emax}/P_n [%]	20	50	100
30 s mean value	20% to 50% to 100% P_{Emax}		
U [V]:	230,34	230,64	231,08
P_{E30} [kW]:	4,838	12,084	23,319
P_{E30} of P_n [%]:	20,16	50,35	97,16
Q_{E30} [kVAr]:	-0,263	-0,433	-11,709
cos φ $_{E30}$:	0,9984	0,9993	0,8937
cos $φ_{setpoint}$ of P_{E30}:	1,0	1,0	0,90
T_0[s]:	0,6 s	6,6 s	
P_{Emax}/P_n [%]	100	50	20
30 s mean value	100% to 50% to 20% P_{Emax}		
U [V]:	231,08	230,34	230,03
P_{E30} [kW]:	23,319	12,084	4,848
P_{E30} of P_n [%]:	97,16	50,35	20,20
Q_{E30} [kVAr]:	-11,709	-0,446	-0,274
cos φ $_{E30}$:	0,8937	0,9993	0,9984
cos $φ_{setpoint}$ of P_{E30}:	0,90	1,0	1,0
T_0 [s]:	6,0 s	0,6 s	
Limit T_0 [s]:	10 s		
Limit cos φ $_{E30}$:	cos $φ_{setpoint}$ ± 0,02		

Test result:

Graph of cos φ(P): Test a)



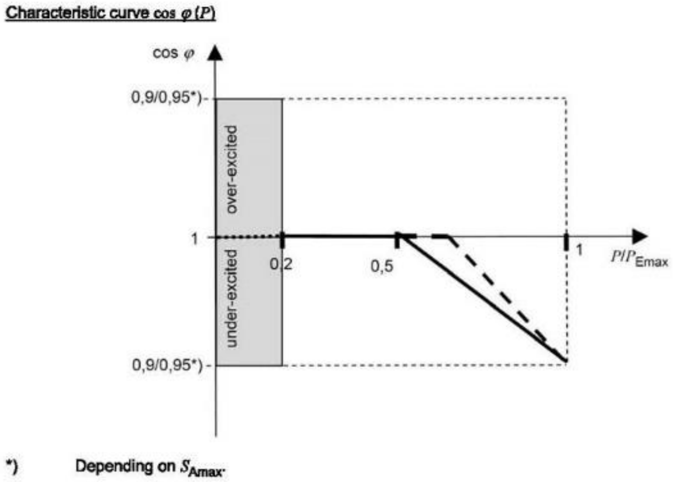
Graph of setting (T_0) time: Test b): 20% to 50% to 100% to 50% to 20%



Test:

Test 1: Using the standard characteristic curve increases the active power from 20% P_{Emax} in increments of 10% P_{Emax} to P_{Emax}, The test is carried out in reverse.

Test 2: Using the standard characteristic curve increases the active power from 20% P_{Emax} to 50% P_{Emax} and to P_{Emax}, The test is carried out in reverse, After the PGU has settled, the end value reached is determined as a 30 s mean value.



Assessment criterion:

Test 1: cos φ accuracy cos φ (±0,01)

Test 2: cos φ accuracy cos φ (±0,02)

For the test to be passed, the cos φ setpoint from the active power must be measured at the terminals of the PGU within a settling time of 10 s.

Note:

The test method refer to clause 5,3,6,4 of VDE V 0124-100:2012-07.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.7.3	**Voltage related active power reduction (P(U) function)**	**P**
Test result:		
Test:		
5-min mean value / P/ P_n [%]	100% to 20%	
Settling time [s]:	547 s	
P_{E60} [%]:	0,13%	
$\Delta P_{E60}/P_{Setpoint}$ [%]:	20 % or less of P_{Emax}	
Limit settling time:	600s	

Test:

a) Set the voltage to 2% Vn lower than the activation threshold stated by the manufacturer.

b) Set the voltage to 112%Vn, The inverter now has to reduce its output power to value lower than 20%Pn within 5min.

c) Set the voltage back to 2%Vn lower than the activation threshold, Check that the active power will return to the value consistent with the power available from the primary source or simulated.

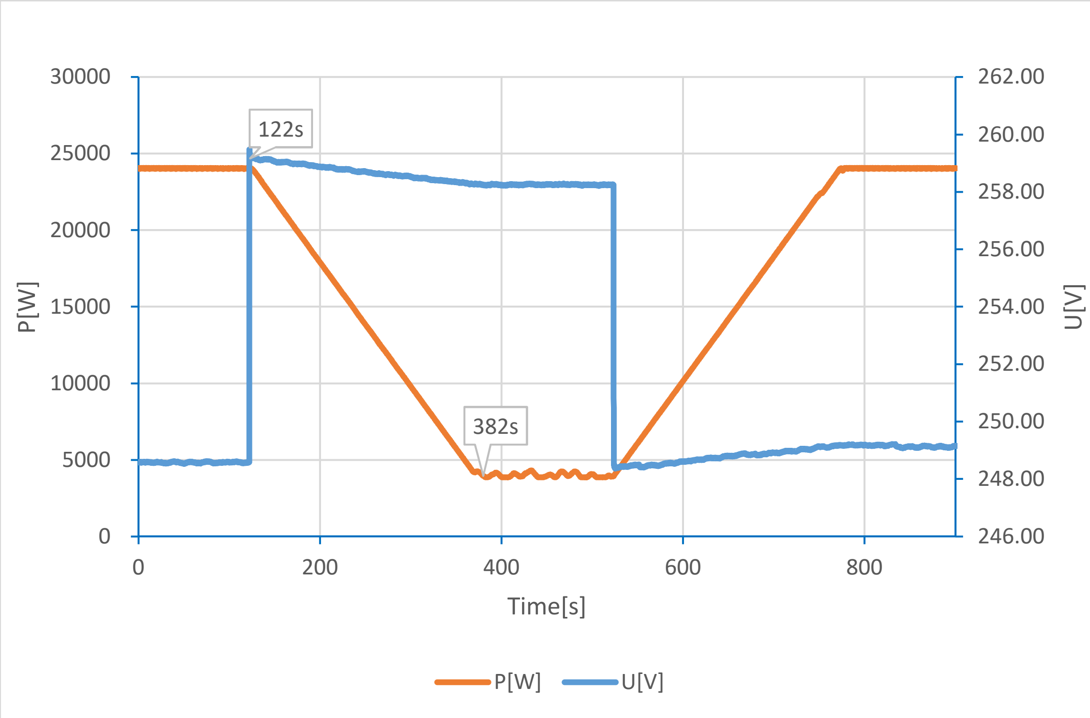
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Assessment criterion:

for adjustable PGUs:

- no network disconnection
- the active power value does not exceed the setpoint of 20% P_{Emax}
- the setting time determind is equal or less than 600s

Graph:


30000
25000
20000
15000
10000
5000
0
P[W]
262.00
260.00
258.00
256.00
254.00
252.00
250.00
248.00
246.00
U[V]
122s
382s
0
200
400
600
800
Time[s]
P[W]
U[V]

EN 50549-1:2019: Power quality			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.8	EMC and power quality	--	**P**
	Harmonic current emission	EN 61000-3-2, EN 61000-3-12	**P**
	Harmonic current emission	EN 61000-4-7	**P**
	Switching operations	IEC 61400-21	**P**
	Voltage fluctuation and flicker	EN 61000-3-3, EN 61000-3-11	**P**
	Flicker and voltage fluctuations	IEC 61400-21	**P**
	DC injection	EN 50438, Annex D,3,10	**P**
	Immunity to voltage dips and short interruptions	G59/3-4:2018-05, clause 13.8.4.5	**P**
	Unbalance	BDEW TG3, Revision 25, clause 4.3.5	**N/A**

4.8	EMC and power quality Harmonic current emission (EN 61000-3-12)	P

Test result: SOFAR 15KTLX-G3

Watts [KW]	4,981/5,145/4,889
Vrms [V]	230,80,230,74/230,76
Arms [A]	21,590/22,307/21,196
Frequency [Hz]	50,00
THD50* (100% output power)	1,957/1,896/1,851

Harmonic order n	Current Magnitude [A] at 100% rated output power			% of Fundamental			Phase	Harmonic Current Limits [%]
1st	21,580	22,297	21,186	-	-	-	Three Phase	--
2nd	0,006	0,004	0,005	0,029	0,018	0,023	Three Phase	8,000
3rd	0,080	0,014	0,079	0,370	0,061	0,371	Three Phase	21,600
4th	0,006	0,006	0,004	0,028	0,026	0,019	Three Phase	4,000
5th	0,296	0,293	0,264	1,372	1,315	1,247	Three Phase	10,700
6th	0,005	0,005	0,003	0,023	0,021	0,015	Three Phase	2,667
7th	0,172	0,173	0,165	0,797	0,775	0,781	Three Phase	7,200
8th	0,003	0,003	0,003	0,014	0,014	0,015	Three Phase	2,000
9th	0,009	0,007	0,019	0,044	0,030	0,087	Three Phase	3,800
10th	0,004	0,004	0,003	0,018	0,020	0,014	Three Phase	1,600
11th	0,099	0,101	0,071	0,460	0,455	0,335	Three Phase	3,100
12th	0,003	0,004	0,003	0,012	0,016	0,014	Three Phase	1,333
13th	0,044	0,047	0,038	0,204	0,210	0,181	Three Phase	2,000
14th	0,004	0,005	0,004	0,018	0,020	0,018	Three Phase	8,000
15th	0,009	0,005	0,006	0,041	0,024	0,029	Three Phase	N/A
16th	0,004	0,003	0,003	0,018	0,014	0,016	Three Phase	N/A
17th	0,076	0,092	0,081	0,351	0,412	0,380	Three Phase	N/A
18th	0,003	0,004	0,003	0,014	0,019	0,016	Three Phase	N/A
19th	0,123	0,134	0,126	0,568	0,599	0,597	Three Phase	N/A
20th	0,003	0,003	0,003	0,013	0,014	0,016	Three Phase	N/A
21th	0,005	0,009	0,009	0,025	0,042	0,044	Three Phase	N/A
22th	0,004	0,003	0,003	0,018	0,014	0,016	Three Phase	N/A
23th	0,028	0,021	0,025	0,130	0,093	0,116	Three Phase	N/A
24th	0,004	0,003	0,004	0,018	0,015	0,018	Three Phase	N/A
25th	0,089	0,095	0,089	0,410	0,427	0,420	Three Phase	N/A
26th	0,004	0,003	0,004	0,019	0,013	0,018	Three Phase	N/A
27th	0,006	0,010	0,008	0,028	0,045	0,040	Three Phase	N/A
28th	0,003	0,004	0,004	0,014	0,016	0,018	Three Phase	N/A
29th	0,047	0,047	0,045	0,219	0,211	0,215	Three Phase	N/A
30th	0,003	0,003	0,003	0,015	0,015	0,014	Three Phase	N/A
31th	0,071	0,079	0,073	0,329	0,353	0,345	Three Phase	N/A
32th	0,004	0,003	0,003	0,018	0,014	0,016	Three Phase	N/A
33th	0,006	0,007	0,006	0,027	0,032	0,029	Three Phase	N/A
34th	0,003	0,003	0,003	0,015	0,013	0,016	Three Phase	N/A
35th	0,054	0,053	0,048	0,250	0,239	0,227	Three Phase	N/A
36th	0,003	0,003	0,003	0,016	0,013	0,014	Three Phase	N/A
37th	0,030	0,032	0,031	0,141	0,144	0,148	Three Phase	N/A
38th	0,003	0,003	0,003	0,014	0,012	0,013	Three Phase	N/A
39th	0,006	0,006	0,005	0,026	0,027	0,026	Three Phase	N/A
40th	0,003	0,003	0,003	0,013	0,012	0,013	Three Phase	N/A
41th	0,032	0,031	0,028	0,150	0,138	0,132	Three Phase	N/A
42th	0,004	0,003	0,003	0,017	0,015	0,016	Three Phase	N/A
43th	0,008	0,009	0,010	0,037	0,041	0,045	Three Phase	N/A

44th	0,003	0,003	0,003	0,014	0,011	0,012	Three Phase	N/A
45th	0,006	0,005	0,004	0,026	0,022	0,021	Three Phase	N/A
46th	0,005	0,005	0,005	0,025	0,024	0,021	Three Phase	N/A
47th	0,022	0,020	0,019	0,101	0,091	0,092	Three Phase	N/A
48th	0,003	0,003	0,003	0,016	0,015	0,014	Three Phase	N/A
49th	0,008	0,009	0,010	0,039	0,041	0,046	Three Phase	N/A
50th	0,005	0,005	0,004	0,025	0,024	0,021	Three Phase	N/A

Test result: SOFAR 24KTLX-G3								
Watts [KW]				7,975/8,234/7,829				
Vrms [V]				230,79/230,80/230,82				
Arms [A]				34,569/35,691/33,931				
Frequency [Hz]				50,00				
THD50* (100% output power)				1,941/1,896/1,849				
Harmonic order n	**Current Magnitude [A] at 100% rated output power**			**% of Fundamental**			**Phase**	**Harmonic Current Limits [%]**
1st	34,553	35,675	33,915	-	-	-	Three Phase	--
2nd	0,009	0,006	0,007	0,026	0,017	0,020	Three Phase	8,000
3rd	0,120	0,022	0,125	0,348	0,061	0,368	Three Phase	21,600
4th	0,008	0,007	0,005	0,022	0,021	0,014	Three Phase	4,000
5th	0,470	0,468	0,422	1,362	1,310	1,246	Three Phase	10,700
6th	0,007	0,007	0,005	0,021	0,020	0,016	Three Phase	2,667
7th	0,276	0,281	0,264	0,798	0,788	0,777	Three Phase	7,200
8th	0,004	0,005	0,005	0,012	0,014	0,014	Three Phase	2,000
9th	0,012	0,012	0,027	0,034	0,033	0,081	Three Phase	3,800
10th	0,007	0,007	0,005	0,020	0,020	0,015	Three Phase	1,600
11th	0,156	0,161	0,116	0,450	0,451	0,343	Three Phase	3,100
12th	0,004	0,006	0,005	0,012	0,017	0,015	Three Phase	1,333
13th	0,069	0,075	0,061	0,198	0,211	0,180	Three Phase	2,000
14th	0,006	0,008	0,007	0,018	0,023	0,021	Three Phase	8,000
15th	0,014	0,008	0,009	0,040	0,024	0,026	Three Phase	N/A
16th	0,006	0,005	0,006	0,017	0,014	0,016	Three Phase	N/A
17th	0,125	0,149	0,128	0,362	0,418	0,377	Three Phase	N/A
18th	0,005	0,007	0,005	0,013	0,019	0,016	Three Phase	N/A
19th	0,196	0,214	0,205	0,567	0,600	0,603	Three Phase	N/A
20th	0,005	0,005	0,006	0,013	0,014	0,017	Three Phase	N/A
21th	0,009	0,014	0,015	0,026	0,040	0,044	Three Phase	N/A
22th	0,006	0,005	0,005	0,017	0,014	0,016	Three Phase	N/A
23th	0,044	0,029	0,040	0,127	0,082	0,117	Three Phase	N/A
24th	0,006	0,006	0,006	0,017	0,017	0,019	Three Phase	N/A
25th	0,140	0,151	0,142	0,406	0,423	0,420	Three Phase	N/A
26th	0,007	0,005	0,007	0,019	0,013	0,019	Three Phase	N/A
27th	0,010	0,015	0,014	0,029	0,043	0,040	Three Phase	N/A
28th	0,005	0,006	0,006	0,015	0,016	0,018	Three Phase	N/A
29th	0,074	0,074	0,073	0,215	0,207	0,215	Three Phase	N/A
30th	0,005	0,006	0,005	0,015	0,016	0,014	Three Phase	N/A
31th	0,113	0,125	0,117	0,327	0,350	0,344	Three Phase	N/A
32th	0,006	0,005	0,006	0,018	0,014	0,017	Three Phase	N/A
33th	0,010	0,012	0,010	0,029	0,034	0,031	Three Phase	N/A
34th	0,005	0,005	0,006	0,016	0,014	0,016	Three Phase	N/A
35th	0,085	0,084	0,075	0,245	0,235	0,222	Three Phase	N/A
36th	0,006	0,005	0,005	0,016	0,014	0,015	Three Phase	N/A
37th	0,049	0,051	0,049	0,141	0,144	0,145	Three Phase	N/A
38th	0,005	0,005	0,005	0,016	0,013	0,014	Three Phase	N/A
39th	0,010	0,011	0,010	0,028	0,031	0,029	Three Phase	N/A
40th	0,005	0,005	0,005	0,014	0,013	0,014	Three Phase	N/A
41th	0,051	0,048	0,044	0,147	0,135	0,129	Three Phase	N/A
42th	0,006	0,006	0,006	0,017	0,016	0,019	Three Phase	N/A
43th	0,013	0,014	0,015	0,039	0,040	0,043	Three Phase	N/A
44th	0,006	0,004	0,005	0,016	0,013	0,015	Three Phase	N/A
45th	0,010	0,008	0,008	0,030	0,024	0,024	Three Phase	N/A
46th	0,009	0,009	0,007	0,025	0,024	0,022	Three Phase	N/A

47th	0,034	0,032	0,030	0,098	0,090	0,088	Three Phase	N/A
48th	0,006	0,006	0,005	0,017	0,016	0,015	Three Phase	N/A
49th	0,013	0,015	0,016	0,038	0,042	0,047	Three Phase	N/A
50th	0,009	0,009	0,007	0,025	0,024	0,022	Three Phase	N/A

Note:

The tests should be based on the limits of the EN 61000-3-12 for more than 16A.

The tests had been performed on the SOFAR 24KTLX-G3 and SOFAR 15KTLX-G3 is valid for the SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.8	EMC and power quality Harmonic current emission (EN 61000-4-7)	P

The currents of the interharmonics to 2 kHz must be measured in accordance with DIN EN 61000-4-7 (VDE 0817-4-7), Annex A, The measurements of higher-frequency harmonic currents between 2 kHz and 9 kHz must be conducted in line with DIN EN 61000-4-7 (VDE 0847-4-7), Annex B.

Test result: SOFAR 24KTLX-G3

Harmonics

P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
1	3,053	10,156	20,303	30,420	40,511	50,567	60,570	70,532	80,410	90,303	100,148
2	0,046	0,059	0,060	0,058	0,065	0,066	0,071	0,072	0,083	0,093	0,098
3	0,181	0,193	0,199	0,209	0,218	0,227	0,248	0,290	0,325	0,361	0,402
4	0,048	0,046	0,041	0,041	0,040	0,039	0,043	0,042	0,042	0,044	0,046
5	0,457	0,378	0,372	0,346	0,338	0,335	0,340	0,433	0,591	0,820	1,075
6	0,027	0,023	0,020	0,023	0,025	0,027	0,025	0,025	0,027	0,030	0,032
7	0,248	0,224	0,233	0,243	0,250	0,253	0,276	0,380	0,531	0,692	0,856
8	0,027	0,021	0,018	0,021	0,024	0,023	0,023	0,025	0,028	0,031	0,033
9	0,058	0,058	0,062	0,063	0,068	0,073	0,075	0,076	0,077	0,071	0,065
10	0,024	0,018	0,017	0,018	0,022	0,021	0,021	0,024	0,031	0,036	0,037
11	0,161	0,110	0,099	0,114	0,136	0,152	0,174	0,199	0,200	0,247	0,330
12	0,025	0,016	0,017	0,017	0,020	0,022	0,020	0,024	0,029	0,031	0,032
13	0,132	0,053	0,064	0,075	0,087	0,098	0,106	0,119	0,086	0,092	0,164
14	0,027	0,018	0,017	0,019	0,022	0,020	0,020	0,023	0,029	0,032	0,033
15	0,032	0,029	0,030	0,028	0,034	0,033	0,038	0,044	0,059	0,067	0,088
16	0,031	0,020	0,016	0,017	0,020	0,020	0,022	0,030	0,023	0,024	0,026
17	0,152	0,100	0,078	0,088	0,084	0,084	0,102	0,114	0,167	0,232	0,294
18	0,026	0,016	0,015	0,015	0,020	0,019	0,020	0,019	0,024	0,029	0,030
19	0,127	0,068	0,047	0,064	0,049	0,044	0,041	0,097	0,187	0,290	0,384
20	0,031	0,023	0,015	0,017	0,020	0,022	0,018	0,021	0,024	0,025	0,028
21	0,020	0,021	0,023	0,027	0,032	0,029	0,032	0,022	0,037	0,053	0,066
22	0,030	0,020	0,019	0,021	0,017	0,018	0,017	0,019	0,020	0,021	0,026
23	0,127	0,066	0,091	0,085	0,089	0,071	0,044	0,051	0,067	0,092	0,132
24	0,026	0,018	0,015	0,016	0,020	0,021	0,020	0,023	0,027	0,032	0,035
25	0,128	0,038	0,055	0,040	0,039	0,042	0,058	0,102	0,143	0,198	0,260
26	0,029	0,015	0,014	0,015	0,019	0,019	0,019	0,022	0,025	0,030	0,030
27	0,018	0,021	0,021	0,021	0,023	0,026	0,029	0,028	0,040	0,055	0,068
28	0,030	0,019	0,011	0,012	0,015	0,017	0,018	0,020	0,023	0,027	0,033
29	0,139	0,055	0,064	0,050	0,070	0,071	0,068	0,112	0,162	0,182	0,210
30	0,023	0,014	0,011	0,013	0,015	0,019	0,017	0,020	0,025	0,032	0,035
31	0,092	0,057	0,088	0,057	0,050	0,050	0,083	0,136	0,196	0,238	0,283
32	0,027	0,016	0,012	0,013	0,017	0,017	0,020	0,020	0,028	0,029	0,033
33	0,024	0,015	0,015	0,016	0,017	0,019	0,020	0,021	0,030	0,045	0,052
34	0,025	0,020	0,010	0,011	0,014	0,017	0,017	0,019	0,021	0,023	0,029
35	0,045	0,077	0,038	0,046	0,030	0,059	0,076	0,092	0,132	0,171	0,228
36	0,021	0,013	0,010	0,011	0,015	0,018	0,015	0,017	0,019	0,023	0,026
37	0,074	0,051	0,080	0,068	0,078	0,066	0,081	0,100	0,115	0,142	0,171

38	0,024	0,014	0,014	0,013	0,016	0,014	0,030	0,019	0,020	0,023	0,028
39	0,029	0,023	0,017	0,021	0,028	0,027	0,020	0,025	0,027	0,033	0,041
40	0,024	0,020	0,011	0,013	0,016	0,021	0,019	0,020	0,020	0,023	0,027
41	0,050	0,072	0,042	0,025	0,026	0,041	0,068	0,095	0,118	0,141	0,171
42	0,019	0,011	0,010	0,011	0,016	0,018	0,022	0,017	0,017	0,021	0,025
43	0,065	0,031	0,086	0,081	0,083	0,072	0,069	0,063	0,056	0,079	0,109
44	0,025	0,012	0,009	0,011	0,014	0,016	0,013	0,021	0,018	0,018	0,040
45	0,028	0,027	0,024	0,024	0,020	0,021	0,019	0,021	0,022	0,030	0,031
46	0,017	0,013	0,011	0,030	0,015	0,020	0,016	0,014	0,015	0,017	0,021
47	0,072	0,058	0,093	0,058	0,034	0,038	0,060	0,086	0,113	0,140	0,167
48	0,017	0,022	0,009	0,010	0,016	0,019	0,040	0,016	0,017	0,019	0,022
49	0,036	0,043	0,075	0,078	0,068	0,061	0,049	0,054	0,035	0,057	0,084
50	0,029	0,014	0,009	0,011	0,014	0,016	0,014	0,013	0,016	0,019	0,019
Interharmonics											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
75	0,070	0,062	0,080	0,128	0,161	0,197	0,245	0,273	0,321	0,359	0,386
125	0,030	0,027	0,030	0,046	0,057	0,065	0,077	0,082	0,100	0,108	0,113
175	0,034	0,028	0,038	0,049	0,044	0,050	0,059	0,062	0,072	0,078	0,081
225	0,072	0,034	0,034	0,043	0,049	0,049	0,061	0,062	0,069	0,073	0,076
275	0,079	0,036	0,063	0,042	0,039	0,043	0,043	0,048	0,052	0,050	0,056
325	0,071	0,034	0,054	0,040	0,040	0,045	0,043	0,047	0,050	0,052	0,052
375	0,093	0,033	0,033	0,040	0,040	0,039	0,038	0,043	0,043	0,043	0,044
425	0,031	0,026	0,033	0,036	0,037	0,042	0,043	0,042	0,046	0,044	0,041
475	0,033	0,026	0,033	0,035	0,037	0,041	0,041	0,040	0,044	0,045	0,044
525	0,071	0,026	0,034	0,037	0,040	0,042	0,040	0,043	0,048	0,047	0,045
575	0,081	0,028	0,035	0,042	0,038	0,044	0,042	0,047	0,045	0,048	0,045
625	0,075	0,035	0,036	0,047	0,042	0,046	0,054	0,052	0,057	0,052	0,054
675	0,075	0,031	0,044	0,045	0,044	0,050	0,049	0,051	0,048	0,054	0,048
725	0,035	0,035	0,032	0,043	0,040	0,041	0,049	0,050	0,069	0,078	0,054
775	0,038	0,032	0,045	0,041	0,040	0,045	0,049	0,062	0,048	0,047	0,060
825	0,062	0,046	0,034	0,049	0,043	0,045	0,062	0,065	0,071	0,057	0,060
875	0,070	0,038	0,053	0,048	0,044	0,054	0,068	0,057	0,052	0,063	0,050
925	0,070	0,034	0,031	0,036	0,036	0,038	0,046	0,046	0,051	0,046	0,053
975	0,082	0,035	0,034	0,034	0,038	0,057	0,043	0,050	0,046	0,051	0,048
1025	0,029	0,038	0,027	0,028	0,046	0,032	0,033	0,039	0,041	0,039	0,044
1075	0,031	0,027	0,032	0,044	0,031	0,032	0,034	0,037	0,039	0,039	0,042
1125	0,043	0,029	0,034	0,028	0,033	0,034	0,036	0,044	0,046	0,042	0,048
1175	0,049	0,030	0,025	0,028	0,033	0,036	0,038	0,041	0,042	0,048	0,048
1225	0,055	0,028	0,025	0,029	0,031	0,035	0,039	0,045	0,045	0,044	0,049
1275	0,060	0,024	0,022	0,025	0,030	0,033	0,039	0,045	0,047	0,050	0,051
1325	0,024	0,021	0,021	0,024	0,028	0,030	0,034	0,043	0,050	0,055	0,053
1375	0,025	0,020	0,021	0,023	0,027	0,029	0,034	0,040	0,047	0,049	0,056
1425	0,031	0,024	0,021	0,023	0,028	0,031	0,035	0,043	0,048	0,050	0,062
1475	0,035	0,024	0,019	0,023	0,026	0,031	0,036	0,042	0,049	0,053	0,055
1525	0,041	0,025	0,020	0,023	0,026	0,029	0,035	0,040	0,046	0,051	0,059
1575	0,043	0,024	0,018	0,020	0,025	0,027	0,036	0,039	0,051	0,051	0,058
1625	0,019	0,019	0,017	0,019	0,023	0,025	0,037	0,040	0,045	0,046	0,060

1675	0,021	0,017	0,017	0,019	0,025	0,029	0,031	0,034	0,046	0,054	0,054
1725	0,023	0,020	0,017	0,019	0,022	0,030	0,031	0,034	0,043	0,047	0,061
1775	0,027	0,021	0,017	0,018	0,021	0,028	0,031	0,034	0,040	0,051	0,055
1825	0,030	0,020	0,017	0,019	0,023	0,024	0,030	0,033	0,040	0,052	0,053
1875	0,034	0,017	0,021	0,017	0,023	0,022	0,033	0,054	0,063	0,074	0,084
1925	0,017	0,014	0,024	0,037	0,020	0,026	0,026	0,029	0,034	0,049	0,048
1975	0,018	0,022	0,013	0,018	0,035	0,022	0,028	0,029	0,033	0,039	0,045
Higher Frequencies											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [kHz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2,1	0,097	0,088	0,099	0,091	0,097	0,099	0,114	0,130	0,142	0,177	0,221
2,3	0,088	0,075	0,105	0,081	0,081	0,082	0,091	0,102	0,135	0,164	0,190
2,5	0,064	0,064	0,084	0,085	0,081	0,077	0,080	0,098	0,106	0,123	0,137
2,7	0,087	0,096	0,109	0,106	0,074	0,071	0,081	0,106	0,123	0,141	0,162
2,9	0,085	0,063	0,053	0,085	0,089	0,104	0,143	0,178	0,201	0,222	0,248
3,1	0,052	0,083	0,095	0,098	0,089	0,063	0,072	0,090	0,111	0,118	0,116
3,3	0,050	0,079	0,061	0,067	0,079	0,085	0,091	0,102	0,117	0,132	0,131
3,5	0,044	0,048	0,034	0,046	0,050	0,058	0,069	0,080	0,105	0,121	0,114
3,7	0,039	0,047	0,035	0,037	0,048	0,060	0,074	0,082	0,081	0,081	0,100
3,9	0,045	0,038	0,033	0,040	0,046	0,060	0,071	0,081	0,109	0,136	0,144
4,1	0,033	0,031	0,027	0,029	0,036	0,038	0,038	0,044	0,066	0,099	0,138
4,3	0,033	0,029	0,032	0,036	0,042	0,049	0,057	0,063	0,074	0,087	0,101
4,5	0,050	0,047	0,046	0,052	0,056	0,061	0,067	0,072	0,083	0,100	0,132
4,7	0,053	0,050	0,044	0,050	0,057	0,059	0,056	0,055	0,058	0,066	0,083
4,9	0,050	0,049	0,049	0,047	0,054	0,053	0,055	0,059	0,062	0,071	0,091
5,1	0,037	0,038	0,040	0,041	0,041	0,048	0,050	0,053	0,057	0,065	0,078
5,3	0,032	0,029	0,028	0,035	0,035	0,036	0,038	0,042	0,046	0,051	0,057
5,5	0,026	0,030	0,029	0,025	0,031	0,036	0,038	0,038	0,037	0,035	0,041
5,7	0,035	0,035	0,033	0,033	0,038	0,041	0,044	0,047	0,049	0,050	0,052
5,9	0,034	0,029	0,023	0,025	0,028	0,048	0,058	0,064	0,073	0,080	0,084
6,1	0,019	0,025	0,029	0,037	0,041	0,027	0,030	0,031	0,037	0,042	0,045
6,3	0,020	0,020	0,018	0,019	0,021	0,023	0,027	0,032	0,036	0,042	0,048
6,5	0,018	0,018	0,019	0,020	0,022	0,023	0,023	0,022	0,025	0,026	0,030
6,7	0,020	0,020	0,021	0,023	0,023	0,025	0,027	0,030	0,032	0,037	0,043
6,9	0,024	0,024	0,025	0,024	0,026	0,026	0,027	0,029	0,029	0,032	0,035
7,1	0,025	0,025	0,025	0,026	0,027	0,027	0,029	0,030	0,031	0,032	0,032
7,3	0,016	0,016	0,017	0,017	0,017	0,017	0,018	0,019	0,019	0,021	0,023
7,5	0,019	0,020	0,020	0,020	0,020	0,021	0,022	0,022	0,023	0,024	0,024
7,7	0,014	0,015	0,015	0,015	0,015	0,016	0,016	0,017	0,018	0,019	0,019
7,9	0,013	0,013	0,013	0,014	0,014	0,014	0,014	0,015	0,016	0,016	0,016
8,1	0,012	0,012	0,012	0,012	0,012	0,013	0,014	0,015	0,016	0,016	0,017
8,3	0,011	0,012	0,012	0,012	0,013	0,013	0,013	0,013	0,014	0,015	0,017
8,5	0,012	0,011	0,011	0,012	0,012	0,013	0,013	0,013	0,014	0,014	0,014
8,7	0,011	0,012	0,012	0,012	0,013	0,013	0,013	0,013	0,013	0,014	0,015
8,9	0,011	0,010	0,010	0,011	0,012	0,012	0,012	0,013	0,013	0,014	0,015

Note:
The normalization current is 34,8 A.

The tests had been performed on the SOFAR 24KTLX-G3 and SOFAR 15KTLX-G3 are valid for the SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Test result: SOFAR 24KTLX-G3											
Harmonics											
P/Pn [%]	0	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
1	3,061	10,126	20,255	30,427	40,524	50,632	60,703	70,768	80,806	90,809	100,790
2	0,140	0,091	0,097	0,089	0,092	0,098	0,093	0,100	0,101	0,105	0,108
3	0,288	0,299	0,316	0,317	0,330	0,338	0,342	0,354	0,360	0,385	0,406
4	0,118	0,074	0,068	0,062	0,061	0,060	0,062	0,062	0,061	0,062	0,067
5	0,777	0,665	0,586	0,594	0,567	0,553	0,553	0,537	0,537	0,522	0,570
6	0,059	0,033	0,033	0,039	0,034	0,055	0,042	0,040	0,040	0,038	0,038
7	0,381	0,383	0,349	0,372	0,398	0,390	0,395	0,404	0,415	0,432	0,476
8	0,150	0,031	0,032	0,059	0,039	0,040	0,034	0,032	0,032	0,033	0,035
9	0,090	0,113	0,095	0,093	0,099	0,101	0,107	0,113	0,116	0,126	0,116
10	0,122	0,032	0,029	0,027	0,028	0,028	0,031	0,028	0,029	0,029	0,035
11	0,299	0,226	0,171	0,163	0,170	0,189	0,207	0,231	0,244	0,270	0,287
12	0,073	0,029	0,024	0,028	0,027	0,028	0,028	0,028	0,029	0,032	0,031
13	0,258	0,123	0,086	0,107	0,116	0,135	0,141	0,154	0,158	0,157	0,189
14	0,135	0,028	0,029	0,027	0,027	0,028	0,031	0,029	0,030	0,029	0,034
15	0,062	0,040	0,044	0,046	0,066	0,070	0,062	0,073	0,058	0,053	0,086
16	0,123	0,030	0,029	0,027	0,026	0,028	0,031	0,029	0,029	0,030	0,032
17	0,231	0,137	0,135	0,119	0,168	0,164	0,147	0,148	0,130	0,161	0,174
18	0,081	0,028	0,023	0,023	0,024	0,025	0,025	0,025	0,027	0,027	0,027
19	0,243	0,146	0,128	0,076	0,102	0,102	0,086	0,081	0,072	0,068	0,083
20	0,109	0,029	0,027	0,025	0,024	0,025	0,028	0,028	0,029	0,027	0,029
21	0,049	0,036	0,034	0,034	0,037	0,039	0,041	0,045	0,056	0,054	0,044
22	0,117	0,037	0,027	0,023	0,023	0,024	0,024	0,025	0,024	0,052	0,030
23	0,180	0,251	0,093	0,155	0,107	0,147	0,147	0,137	0,111	0,083	0,081
24	0,076	0,029	0,027	0,024	0,025	0,027	0,042	0,028	0,030	0,031	0,033
25	0,185	0,206	0,049	0,099	0,042	0,065	0,068	0,062	0,071	0,090	0,108
26	0,155	0,028	0,025	0,025	0,022	0,024	0,026	0,025	0,029	0,027	0,031
27	0,043	0,029	0,032	0,037	0,031	0,034	0,036	0,038	0,057	0,053	0,040
28	0,103	0,035	0,025	0,019	0,019	0,020	0,022	0,023	0,024	0,028	0,027
29	0,141	0,240	0,065	0,082	0,110	0,079	0,104	0,119	0,109	0,095	0,130
30	0,069	0,026	0,019	0,017	0,017	0,021	0,022	0,022	0,024	0,026	0,028
31	0,134	0,198	0,129	0,141	0,073	0,096	0,091	0,072	0,081	0,110	0,148
32	0,147	0,028	0,022	0,022	0,019	0,022	0,024	0,024	0,025	0,027	0,030
33	0,037	0,024	0,025	0,022	0,023	0,026	0,030	0,027	0,036	0,032	0,040
34	0,091	0,040	0,023	0,017	0,015	0,017	0,019	0,023	0,028	0,026	0,034
35	0,102	0,078	0,099	0,060	0,048	0,072	0,044	0,070	0,092	0,100	0,138
36	0,059	0,022	0,016	0,017	0,030	0,040	0,019	0,020	0,021	0,023	0,026
37	0,093	0,218	0,106	0,124	0,129	0,115	0,133	0,110	0,102	0,121	0,140
38	0,098	0,024	0,021	0,017	0,016	0,018	0,020	0,021	0,022	0,027	0,024
39	0,035	0,039	0,028	0,027	0,027	0,028	0,031	0,029	0,042	0,030	0,044
40	0,063	0,037	0,023	0,018	0,019	0,021	0,025	0,025	0,027	0,032	0,035
41	0,080	0,076	0,096	0,068	0,075	0,048	0,056	0,043	0,069	0,090	0,126
42	0,047	0,022	0,016	0,016	0,016	0,017	0,019	0,021	0,029	0,025	0,025
43	0,069	0,140	0,102	0,154	0,150	0,123	0,135	0,129	0,116	0,111	0,108

44	0,052	0,031	0,015	0,016	0,025	0,020	0,020	0,019	0,019	0,031	0,034
45	0,030	0,045	0,038	0,045	0,030	0,034	0,044	0,078	0,067	0,044	0,031
46	0,040	0,025	0,024	0,014	0,013	0,016	0,018	0,021	0,021	0,028	0,028
47	0,071	0,069	0,094	0,141	0,111	0,080	0,058	0,047	0,044	0,071	0,106
48	0,035	0,017	0,015	0,016	0,014	0,015	0,017	0,018	0,022	0,022	0,023
49	0,047	0,055	0,042	0,113	0,117	0,117	0,108	0,109	0,101	0,085	0,067
50	0,052	0,037	0,017	0,013	0,013	0,016	0,016	0,018	0,021	0,019	0,022
Interharmonics											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
75	0,119	0,097	0,098	0,120	0,174	0,207	0,244	0,290	0,330	0,353	0,400
125	0,051	0,044	0,041	0,045	0,066	0,073	0,081	0,101	0,112	0,110	0,123
175	0,058	0,045	0,044	0,046	0,061	0,062	0,066	0,077	0,095	0,091	0,096
225	0,135	0,076	0,047	0,049	0,076	0,065	0,078	0,091	0,084	0,089	0,105
275	0,148	0,081	0,051	0,057	0,053	0,065	0,058	0,060	0,080	0,068	0,071
325	0,121	0,066	0,058	0,054	0,085	0,059	0,070	0,070	0,067	0,076	0,072
375	0,137	0,062	0,060	0,089	0,093	0,065	0,061	0,062	0,075	0,070	0,061
425	0,068	0,057	0,122	0,065	0,054	0,055	0,057	0,057	0,062	0,061	0,080
475	0,073	0,046	0,062	0,055	0,059	0,056	0,056	0,055	0,062	0,078	0,066
525	0,141	0,068	0,049	0,056	0,060	0,060	0,062	0,060	0,064	0,070	0,074
575	0,156	0,071	0,051	0,056	0,058	0,062	0,064	0,062	0,070	0,072	0,080
625	0,136	0,066	0,055	0,074	0,078	0,072	0,063	0,076	0,078	0,134	0,094
675	0,151	0,082	0,079	0,078	0,057	0,075	0,095	0,072	0,110	0,064	0,086
725	0,073	0,050	0,054	0,074	0,077	0,066	0,059	0,073	0,075	0,135	0,096
775	0,077	0,072	0,078	0,079	0,051	0,066	0,089	0,063	0,105	0,057	0,075
825	0,111	0,074	0,063	0,089	0,092	0,077	0,067	0,085	0,088	0,182	0,119
875	0,132	0,101	0,100	0,095	0,052	0,077	0,115	0,075	0,137	0,057	0,077
925	0,114	0,073	0,049	0,059	0,063	0,056	0,057	0,064	0,066	0,106	0,080
975	0,133	0,083	0,066	0,064	0,048	0,059	0,075	0,061	0,089	0,056	0,062
1025	0,082	0,043	0,041	0,044	0,044	0,045	0,047	0,048	0,052	0,053	0,056
1075	0,059	0,063	0,040	0,043	0,042	0,044	0,046	0,048	0,054	0,066	0,098
1125	0,085	0,060	0,053	0,041	0,042	0,047	0,049	0,061	0,063	0,063	0,057
1175	0,090	0,063	0,062	0,041	0,042	0,045	0,067	0,064	0,070	0,059	0,063
1225	0,086	0,071	0,044	0,044	0,051	0,072	0,050	0,051	0,055	0,061	0,060
1275	0,105	0,064	0,037	0,061	0,041	0,041	0,045	0,049	0,056	0,057	0,060
1325	0,059	0,045	0,041	0,036	0,037	0,040	0,044	0,044	0,051	0,051	0,057
1375	0,047	0,037	0,033	0,034	0,034	0,037	0,040	0,042	0,048	0,054	0,059
1425	0,067	0,050	0,035	0,034	0,033	0,038	0,040	0,045	0,051	0,056	0,055
1475	0,067	0,053	0,032	0,032	0,031	0,035	0,039	0,044	0,051	0,055	0,059
1525	0,063	0,059	0,033	0,032	0,033	0,038	0,040	0,045	0,048	0,055	0,056
1575	0,077	0,052	0,030	0,030	0,029	0,034	0,037	0,040	0,046	0,049	0,056
1625	0,050	0,032	0,029	0,029	0,029	0,034	0,037	0,038	0,042	0,045	0,056
1675	0,041	0,030	0,027	0,028	0,026	0,030	0,034	0,036	0,041	0,046	0,062
1725	0,054	0,041	0,031	0,028	0,028	0,031	0,035	0,036	0,042	0,049	0,062
1775	0,048	0,040	0,030	0,047	0,047	0,031	0,032	0,037	0,042	0,047	0,053
1825	0,047	0,044	0,035	0,025	0,031	0,044	0,061	0,040	0,041	0,047	0,050
1875	0,052	0,040	0,045	0,023	0,025	0,027	0,031	0,068	0,080	0,043	0,048
1925	0,039	0,039	0,025	0,024	0,024	0,028	0,032	0,032	0,035	0,093	0,106

1975	0,048	0,026	0,022	0,024	0,022	0,025	0,041	0,045	0,052	0,039	0,045
Higher Frequencies											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [kHz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2,1	0,138	0,176	0,149	0,176	0,177	0,144	0,160	0,153	0,158	0,172	0,185
2,3	0,119	0,109	0,129	0,168	0,148	0,138	0,140	0,132	0,147	0,172	0,194
2,5	0,103	0,094	0,079	0,131	0,130	0,132	0,129	0,130	0,123	0,114	0,105
2,7	0,125	0,108	0,141	0,177	0,180	0,167	0,120	0,118	0,112	0,108	0,123
2,9	0,102	0,088	0,093	0,079	0,111	0,142	0,145	0,121	0,111	0,101	0,109
3,1	0,122	0,133	0,135	0,154	0,168	0,155	0,161	0,153	0,153	0,190	0,223
3,3	0,074	0,116	0,095	0,089	0,096	0,106	0,122	0,136	0,142	0,144	0,150
3,5	0,074	0,079	0,072	0,055	0,061	0,071	0,075	0,086	0,092	0,106	0,108
3,7	0,064	0,076	0,069	0,059	0,056	0,064	0,076	0,084	0,095	0,116	0,125
3,9	0,065	0,075	0,065	0,053	0,054	0,063	0,070	0,083	0,094	0,111	0,115
4,1	0,057	0,061	0,059	0,039	0,043	0,048	0,052	0,054	0,058	0,059	0,062
4,3	0,059	0,054	0,043	0,054	0,049	0,058	0,065	0,072	0,081	0,090	0,097
4,5	0,075	0,075	0,073	0,079	0,083	0,091	0,096	0,101	0,104	0,109	0,115
4,7	0,083	0,086	0,076	0,069	0,071	0,077	0,083	0,087	0,090	0,088	0,086
4,9	0,083	0,080	0,078	0,079	0,075	0,077	0,084	0,089	0,093	0,093	0,097
5,1	0,053	0,061	0,059	0,060	0,059	0,062	0,065	0,068	0,067	0,070	0,069
5,3	0,048	0,050	0,044	0,045	0,048	0,053	0,054	0,056	0,061	0,061	0,061
5,5	0,043	0,046	0,053	0,049	0,042	0,040	0,047	0,053	0,056	0,061	0,061
5,7	0,054	0,055	0,059	0,052	0,052	0,055	0,058	0,063	0,065	0,069	0,069
5,9	0,042	0,041	0,041	0,039	0,037	0,040	0,042	0,045	0,046	0,048	0,050
6,1	0,046	0,045	0,044	0,045	0,054	0,057	0,063	0,067	0,072	0,079	0,088
6,3	0,027	0,030	0,028	0,028	0,028	0,030	0,033	0,036	0,037	0,039	0,041
6,5	0,031	0,031	0,030	0,028	0,029	0,030	0,031	0,032	0,033	0,035	0,040
6,7	0,031	0,031	0,032	0,035	0,036	0,036	0,039	0,040	0,042	0,043	0,045
6,9	0,038	0,038	0,038	0,039	0,038	0,039	0,040	0,041	0,042	0,043	0,044
7,1	0,038	0,039	0,041	0,040	0,040	0,042	0,042	0,043	0,044	0,044	0,045
7,3	0,024	0,026	0,026	0,028	0,026	0,026	0,027	0,028	0,028	0,029	0,029
7,5	0,031	0,031	0,032	0,033	0,032	0,032	0,032	0,033	0,034	0,033	0,036
7,7	0,023	0,023	0,023	0,024	0,023	0,024	0,024	0,025	0,026	0,026	0,027
7,9	0,021	0,021	0,021	0,021	0,022	0,022	0,023	0,023	0,024	0,024	0,025
8,1	0,018	0,019	0,019	0,019	0,018	0,019	0,020	0,020	0,021	0,021	0,021
8,3	0,018	0,019	0,018	0,019	0,019	0,019	0,020	0,021	0,020	0,021	0,021
8,5	0,019	0,019	0,018	0,018	0,018	0,019	0,020	0,020	0,021	0,021	0,021
8,7	0,018	0,018	0,018	0,019	0,019	0,020	0,020	0,020	0,021	0,020	0,021
8,9	0,017	0,016	0,016	0,017	0,017	0,018	0,018	0,019	0,019	0,019	0,019

Note:
The normalization current is 21,7 A.
The tests had been performed on the SOFAR 24KTLX-G3 and SOFAR 15KTLX-G3 are valid for the SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.8	EMC and power quality Switching operation (Refer IEC 61400-21)				P
Test result:					
Max. number of switching operations, N_{10}	10				
Max. number of switching operations, N_{120}	120				
Case of switching operation	Cut-in at 9%P_{Emax}				
Grid impedance angle, ψ_k	30°	50°	70°	85°	
Flicker step factor, $k_f(\psi_k)$	0,06	0,09	0,12	0,14	
Voltage change factor, $k_u(\psi_k)$	0,37	0,31	0,21	0,19	
Maximum inrush current factor k_{imax}	0,06				
Case of switching operation	Cut-in at 100%P_{Emax}				
Grid impedance angle, ψ_k	30°	50°	70°	85°	
Flicker step factor, $k_f(\psi_k)$	0,53	0,87	1,25	1,43	
Voltage change factor, $k_u(\psi_k)$	2,98	2,87	2,47	1,98	
Maximum inrush current factor k_{imax}	0,06				
Case of switching operation	Service disconnection at rated power				
Grid impedance angle, ψ_k	30°	50°	70°	85°	
Flicker step factor, $k_f(\psi_k)$	1,11	0,89	0,57	0,31	
Voltage change factor, $k_u(\psi_k)$	2,78	2,16	1,31	0,60	
Maximum inrush current factor k_{imax}	0,02				
Worst case over all switching operations, k_{imax}	0,06				

Note:

$S_{k,fic}/S_n$ in the fictitious grid was set to:20.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.8	Voltage fluctuation and flicker					P
Test result:						
Test conditions:	Maximum permissible voltage fluctuation (expressed as a percentage of nominal voltage at 100 % power) and flicker as per EN 61000-3-3 and/or EN 61000-3-11.					
Test:						
Value	P_{st}	P_{lt} 2 hours	d(t) $_{500ms}$	d_c	d_{max}	
Limit	1,0	0,65	3,3%	3,3%	4%	
Test value	See below					
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	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.087	Pass	0.188	Pass	0.0	Pass	0.041	Pass		
2	0.085	Pass	0.159	Pass	0.0	Pass	0.039	Pass		
3	0.110	Pass	0.159	Pass	0.0	Pass	0.048	Pass		
4	0.113	Pass	0.161	Pass	0.0	Pass	0.054	Pass		
5	0.113	Pass	0.153	Pass	0.0	Pass	0.053	Pass		
6	0.115	Pass	0.136	Pass	0.0	Pass	0.058	Pass		
7	0.106	Pass	0.162	Pass	0.0	Pass	0.061	Pass		
8	0.103	Pass	0.137	Pass	0.0	Pass	0.057	Pass		
9	0.104	Pass	0.156	Pass	0.0	Pass	0.056	Pass		
10	0.097	Pass	0.134	Pass	0.0	Pass	0.054	Pass		
11	0.103	Pass	0.162	Pass	0.0	Pass	0.054	Pass		
12	0.099	Pass	0.154	Pass	0.0	Pass	0.057	Pass		
Result		Pass		Pass		Pass		Pass	0.053	Pass

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.004	Pass	0.111	Pass	0.0	Pass	0.142	Pass		
2	0.003	Pass	0.119	Pass	0.0	Pass	0.141	Pass		
3	0.011	Pass	0.101	Pass	0.0	Pass	0.140	Pass		
4	0.012	Pass	0.111	Pass	0.0	Pass	0.140	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.140	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.140	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.139	Pass		
8	0.018	Pass	0.158	Pass	0.0	Pass	0.140	Pass		
9	0.014	Pass	0.123	Pass	0.0	Pass	0.139	Pass		
10	0.009	Pass	0.107	Pass	0.0	Pass	0.140	Pass		
11	0.006	Pass	0.102	Pass	0.0	Pass	0.139	Pass		
12	0.009	Pass	0.117	Pass	0.0	Pass	0.140	Pass		
Result		Pass		Pass		Pass		Pass	0.140	Pass

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.000	Pass	0.000	Pass	0.0	Pass	0.053	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.051	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.049	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.050	Pass		
5	0.017	Pass	0.108	Pass	0.0	Pass	0.050	Pass		
6	0.020	Pass	0.106	Pass	0.0	Pass	0.049	Pass		
7	0.014	Pass	0.104	Pass	0.0	Pass	0.050	Pass		
8	0.057	Pass	0.109	Pass	0.0	Pass	0.050	Pass		
9	0.049	Pass	0.108	Pass	0.0	Pass	0.049	Pass		
10	0.002	Pass	0.106	Pass	0.0	Pass	0.048	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.049	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.049	Pass		
Result		Pass		Pass		Pass		Pass	0.050	Pass

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	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.114	Pass	0.159	Pass	0.0	Pass	0.044	Pass		
2	0.068	Pass	0.109	Pass	0.0	Pass	0.037	Pass		
3	0.092	Pass	0.132	Pass	0.0	Pass	0.027	Pass		
4	0.017	Pass	0.165	Pass	0.0	Pass	0.033	Pass		
5	0.098	Pass	0.213	Pass	0.0	Pass	0.025	Pass		
6	0.071	Pass	0.133	Pass	0.0	Pass	0.025	Pass		
7	0.078	Pass	0.171	Pass	0.0	Pass	0.026	Pass		
8	0.104	Pass	0.199	Pass	0.0	Pass	0.032	Pass		
9	0.036	Pass	0.151	Pass	0.0	Pass	0.027	Pass		
10	0.095	Pass	0.152	Pass	0.0	Pass	0.028	Pass		
11	0.081	Pass	0.146	Pass	0.0	Pass	0.030	Pass		
12	0.090	Pass	0.144	Pass	0.0	Pass	0.033	Pass		
Result		Pass		Pass		Pass		Pass	0.032	Pass

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.010	Pass	0.119	Pass	0.0	Pass	0.139	Pass		
2	0.007	Pass	0.111	Pass	0.0	Pass	0.138	Pass		
3	0.006	Pass	0.114	Pass	0.0	Pass	0.137	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.136	Pass		
5	0.007	Pass	0.104	Pass	0.0	Pass	0.136	Pass		
6	0.009	Pass	0.103	Pass	0.0	Pass	0.137	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.136	Pass		
8	0.006	Pass	0.105	Pass	0.0	Pass	0.137	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.137	Pass		
10	0.011	Pass	0.104	Pass	0.0	Pass	0.136	Pass		
11	0.010	Pass	0.119	Pass	0.0	Pass	0.137	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.137	Pass		
Result		Pass		Pass		Pass		Pass	0.137	Pass

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.000	Pass	0.000	Pass	0.0	Pass	0.048	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.047	Pass		
3	0.013	Pass	0.101	Pass	0.0	Pass	0.046	Pass		
4	0.009	Pass	0.101	Pass	0.0	Pass	0.045	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.046	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.046	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.046	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.046	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.046	Pass		
10	0.020	Pass	0.108	Pass	0.0	Pass	0.046	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.047	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.047	Pass		
Result		Pass		Pass		Pass		Pass	0.046	Pass

Note:

*The stationary deviance of dc% is more relevant than the dynamic deviance of dmax at starting and stopping, Mains Impedance according EN61000-3-11:

Rmax = 0,24Ω; jXmax= 0,15Ω @50Hz (|Zmax| = 0,283/0,4717Ω) for single phase inverter use also

R_n = 0,16Ω; jX_n= 0,1Ω.

Calculation of the maximum permissible grid impedance at the point of common coupling based on dc:

$Z_{max} = Z_{ref}$ * 3,3% / $d_c(P_n)$.

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

The test results refer to the original test report PV200511N080-2 issued by Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch, dated on 2020-10-21.

4.8	EMC and power quality Flicker and voltage fluctuations	P

Method: Measurement and evaluation was carried out according to the procedure in IEC 61400-21.

Test result:

Grid impedance angle, ψ_k	30°	50°	70°	85°
Operating point, P_a/P_{Emax} [%]	Flicker coefficient, $c(\psi_k)$			
2	3,01	1,96	1,60	1,51
10	3,01	1,96	1,60	1,51
20	2,95	1,92	1,57	1,48
30	2,90	1,90	1,55	1,46
40	2,86	1,87	1,52	1,44
50	2,97	1,94	1,58	1,49
60	2,95	1,92	1,57	1,48
70	2,93	1,91	1,56	1,47
80	3,03	1,98	1,61	1,52
90	3,33	2,17	1,77	1,67
100	3,26	2,13	1,74	1,64
Max. Flicker coefficient, c(ψk)	3,26	2,13	1,74	1,64
Max. Short-term flicker, Pst	0,163	0,107	0,087	0,082

Reactive power setpoint during testing [kVar]	0

P [%P_{Emax}]	2	10	20	30	40	50	60	70	80	90	100
Number of data sets	1	1	1	1	1	1	1	1	1	1	1

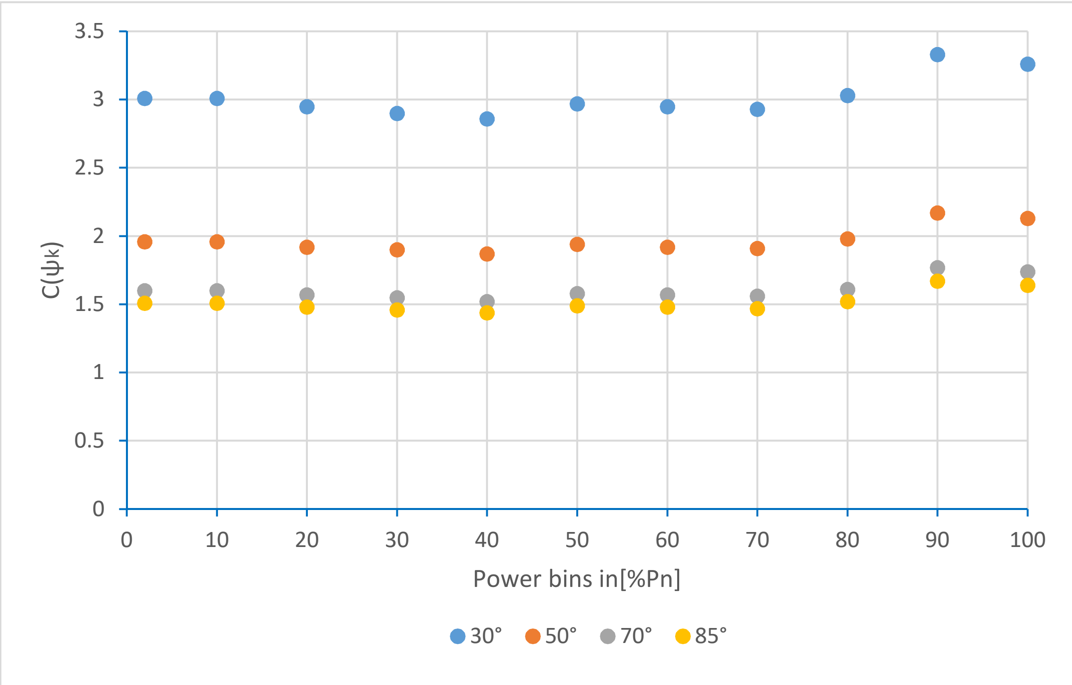
Note:

The table entries are worst case values.

$S_{k,fic}/S_n$ in the fictitious grid was set to:20.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Maximum Flicker coefficients $c(\psi_k)$ vs. power bins



4.8	EMC and power quality DC-Injection			P
Test result: SOFAR 15KTLX-G3				
Protection limit	**Tested at four power levels limit 0,5% of $I_{AC;nom}$ (43mA)**			
Output power	~20%	~50%	75%	~100%
Max. test value [mA]	31	56	56	55
Ave. test value [mA]	18	18	18	19
Test result: SOFAR 24KTLX-G3				
Protection limit	**Tested at four power levels limit 0,5% of $I_{AC;nom}$ (109mA)**			
Output power	~20%	~50%	75%	~100%
Max. test value [mA]	46	74	41	49
Ave. test value [mA]	17	19	19	21
Note: The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.				

Diagram of permanent dc-injection of SOFAR 15KTLX-G3

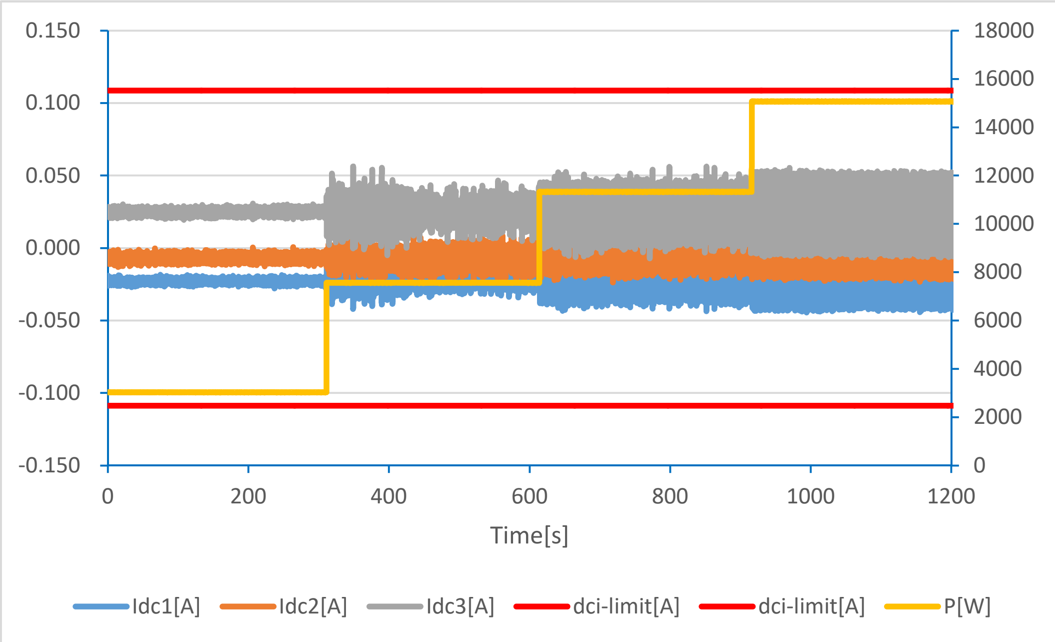
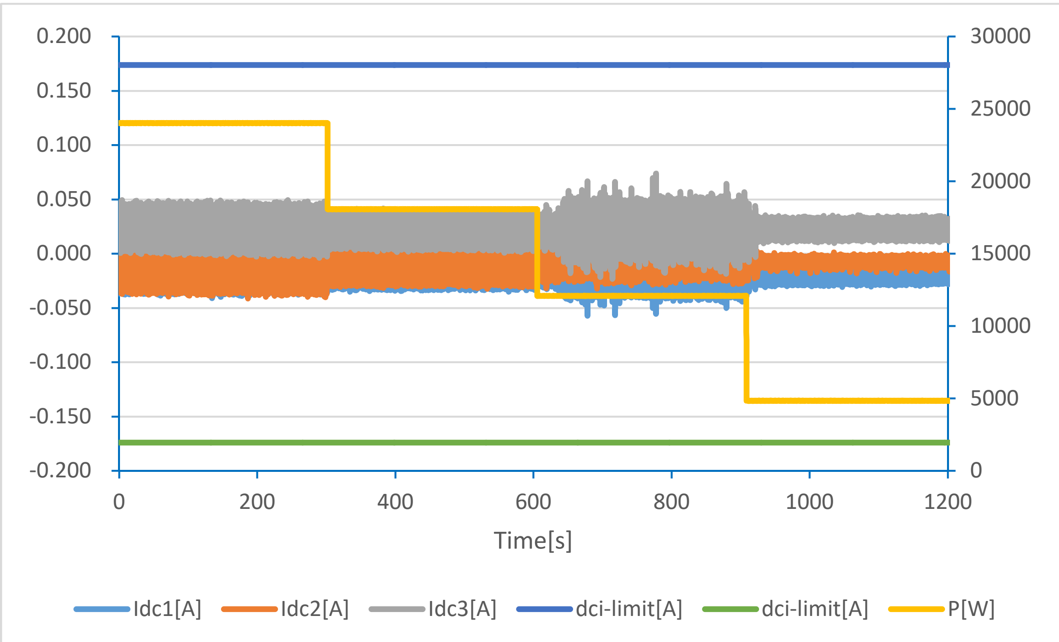
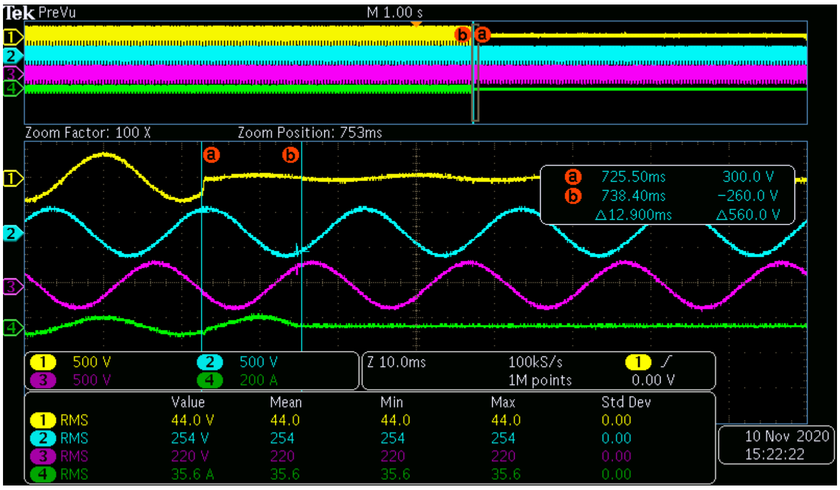


Diagram of permanent dc-injection of SOFAR 24KTLX-G3



4.8	Immunity to voltage dips and short interruptions				P
For a directly coupled SSEG			For a Inverter SSEG		
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	I_p	N/A	20ms	42,4	28,8
Initial Value of aperiodic current	A	N/A	100ms	37,1	13,7
Initial symmetrical short-circuit current*	I_k	N/A	250ms	N/A	N/A
Decaying (aperiodic) component of short circuit current*	i_{DC}	N/A	500ms	N/A	N/A
Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	12,9ms	In seconds

Diagram



Note:

For rotating machines and linear piston machines the test should produce a 0s – 2s plot of the short circuit current as seen at the Generating Unit terminals.

* Values for these parameters should be provided where the short circuit duration is sufficiently long to enable interpolation of the plot.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

EN 50549-1:2019: Interface protection			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.9.3	Requirements on voltage and frequency protection	CEI 0-21:2019-04, Annex A.3.1 to A.3.4	**P**
4.9.3.1	Undervoltage protection	EN 50438, Annex D.2.3	**P**
	Overvoltage protection	EN 50438, Annex D.2.3	**P**
	Overvoltage 10 min mean protection	EN 50160	**P**
	Underfrequency protection	EN 50438, Annex D.2.4	**P**
	Overfrequency protection	EN 50438, Annex D.2.4	**P**
4.9.4.2	Loss of Mains (LoM) detection	IEC 62116:2014	**P**

4.9.3	Requirements on voltage and frequency protection Checklist	P
Several points to check		
Clause 4.9.3.1 to 4.9.3.6	All thresholds must be adjustable	P

Voltage values

Threshold	Stage 1 [27 <]		Stage 2 [27 <<]	
	Operate voltage	Operate time	Operate voltage	Operate time
Range	0,2-1,0 U_n	0,1-100s	0,2-1,0 U_n	0,1-5s
Steps	0,01 U_n	0,1 s	0,01 U_n	0,05s

Threshold	Stage 1 [59 >]		Stage 2 [59 >>]		Overvoltage 10 min mean protection	
	Operate voltage	Operate time	Operate voltage	Operate time	Operate voltage	Operate time
Range	1,0-1,2 U_n	0,1-100s	1,0-1,3 U_n	0,1-5s	1,0-1,15 U_n	3s not adjustable
Steps	0,01 U_n	0,1s	0,01 U_n	0,05s	0,01 U_n	--

Frequency values

Threshold	Stage 1 [81 <]		Stage 2 [81 <<]	
	Operate frequency	Operate time	Operate frequency	Operate time
Range	47,0-50,0Hz	0,1-100s	47,0-50,0Hz	0,1-5s
Steps	0,1 Hz	0,1 s	0,1 Hz	0,05s
Threshold	Stage 1 [81 >]		Stage 2 [81 >>]	
	Operate frequency	Operate time	Operate frequency	Operate time
Range	50,0-52,0Hz	0,1-100s	50,0-52,0Hz	0,1-5s
Steps	0,1 Hz	0,1 s	0,1 Hz	0,05s

4.9.2.6	Insensitive against 40ms frequency transients, so that the unit will not trip	P

Note:

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

4.9.3 4.9.3.1	Requirements on voltage and frequency protection General (Interface protection: Over/under voltage) (Setting value refer EN 50438 for default settings)				P
Test conditions			Output power: 10,0kW Frequency: 50+/-0,2Hz		
Phase	**Limit [V]**	**Trip value [V]**	**Voltage step [V]**	**Disconnection time [s]**	**Limit [s]**
L1	Stage 1 115% of U_n = 264,5	266,0	230 to 269	60,4	≤61,0s
		266,0	230 to 269	60,3	
		266,0	230 to 269	60,2	
		266,0	230 to 269	60,3	
		266,0	230 to 269	60,4	
	Stage 2 125% of U_n = 287.5	287,8	230 to 292	0,124	0,1s ≤ t ≤ 0,2s
		287,8	230 to 292	0,127	
		287,6	230 to 292	0,135	
		287,8	230 to 292	0,129	
		287,8	230 to 292	0,136	
	Stage 80% of U_n = 184	184,0	230 to 189	4,04	2,0s ≤ t ≤ 5,0s
		184,0	230 to 189	4,02	
		184,0	230 to 189	4,06	
		184,1	230 to 189	4,02	
		184,1	230 to 189	4,04	
	Stage 2 50% of U_n = 115	114,8	230 to 120	1,82	0,1s ≤ t ≤ 2,0s
		114,9	230 to 120	1,83	
		114,9	230 to 120	1,84	
		114,9	230 to 120	1,82	
		114,8	230 to 120	1,83	
L2	Stage 1 115% of U_n = 264,5	264,7	230 to 269	60,3	≤61,0s
		264,5	230 to 269	60,2	
		264,6	230 to 269	60,1	
		264,9	230 to 269	60,1	
		264,9	230 to 269	60,1	
	Stage 2 125% of U_n = 287.5	287,9	230 to 292	0,138	0,1s ≤ t ≤ 0,2s
		287,7	230 to 292	0,130	
		287,7	230 to 292	0,135	
		287,3	230 to 292	0,140	
		287,3	230 to 292	0,137	
	Stage	184,1	230 to 189	4,06	2,0s ≤ t ≤ 5,0s
		183,9	230 to 189	4,04	

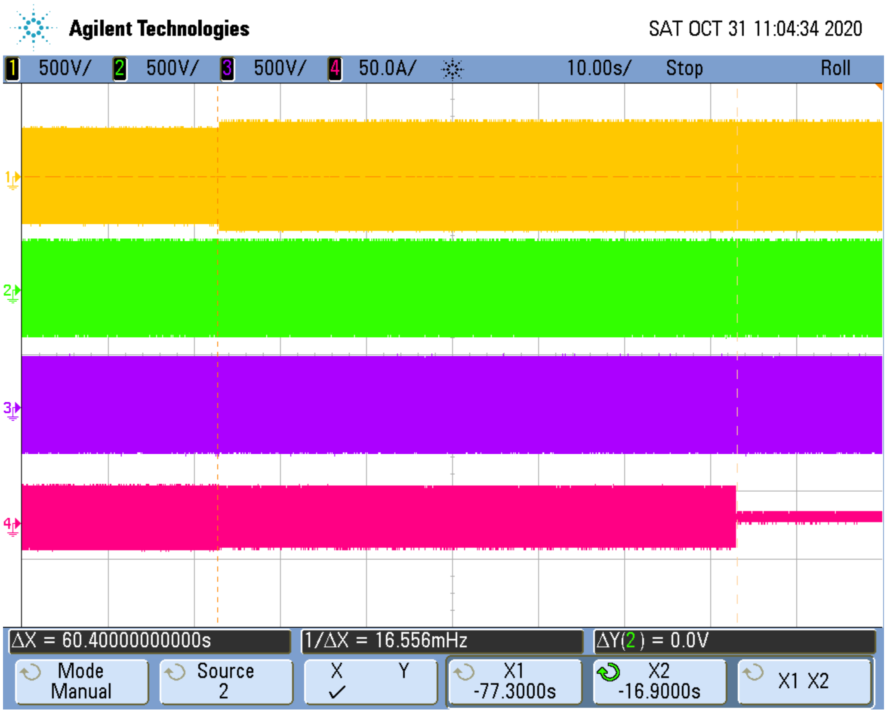
	80% of U_n = 184	184,0	230 to 189	4,08	
		184,1	230 to 189	4,02	
		184,0	230 to 189	4,04	
	Stage 2 50% of U_n = 115	114,7	230 to 120	1,83	0,1s ≤ t ≤ 2,0s
		114,7	230 to 120	1,84	
		114,8	230 to 120	1,82	
		114,8	230 to 120	1,83	
		114,8	230 to 120	1,81	
L3	Stage 1 115% of U_n = 264,5	265,9	230 to 269	60,2	≤61,0s
		265,9	230 to 269	60,1	
		265,8	230 to 269	60,1	
		265,9	230 to 269	60,2	
		265,8	230 to 269	60,1	
	Stage 2 125% of U_n = 287.5	288,1	230 to 292	0,120	0,1s ≤ t ≤ 0,2s
		287,8	230 to 292	0,123	
		287,4	230 to 292	0,130	
		287,9	230 to 292	0,125	
		287,9	230 to 292	0,132	
	Stage 80% of U_n = 184	185,0	230 to 189	4,04	2,0s ≤ t ≤ 5,0s
		184,0	230 to 189	4,06	
		184,0	230 to 189	4,08	
		185,0	230 to 189	4,04	
		184,1	230 to 189	4,04	
	Stage 2 50% of U_n = 115	114,8	230 to 120	1,82	0,1s ≤ t ≤ 2,0s
		114,9	230 to 120	1,82	
		114,9	230 to 120	1,85	
		115,0	230 to 120	1,85	
		115,0	230 to 120	1,84	

Note:

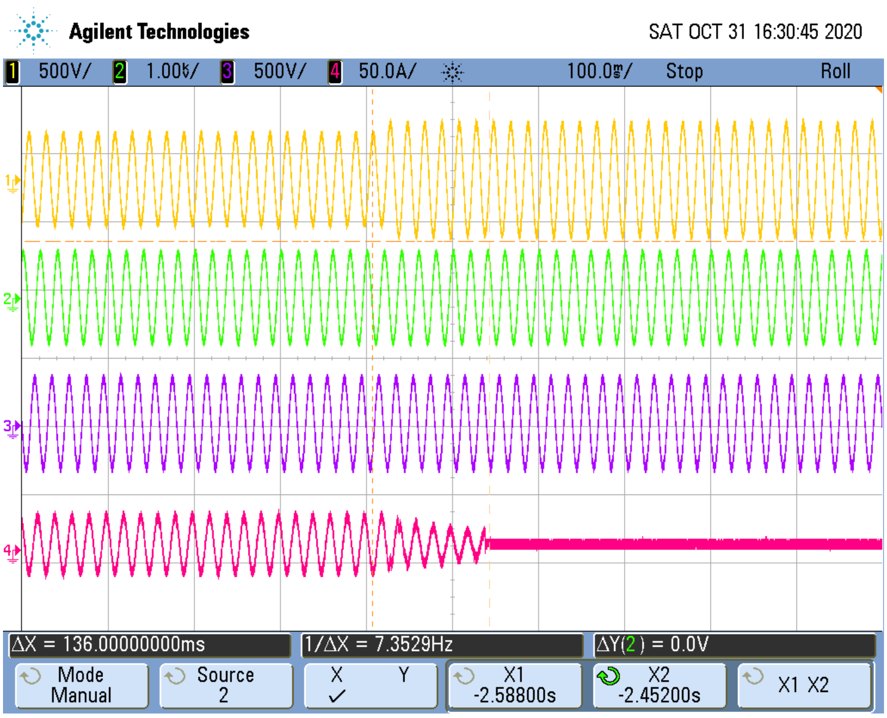
The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing, Lower and upper threshold voltage 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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

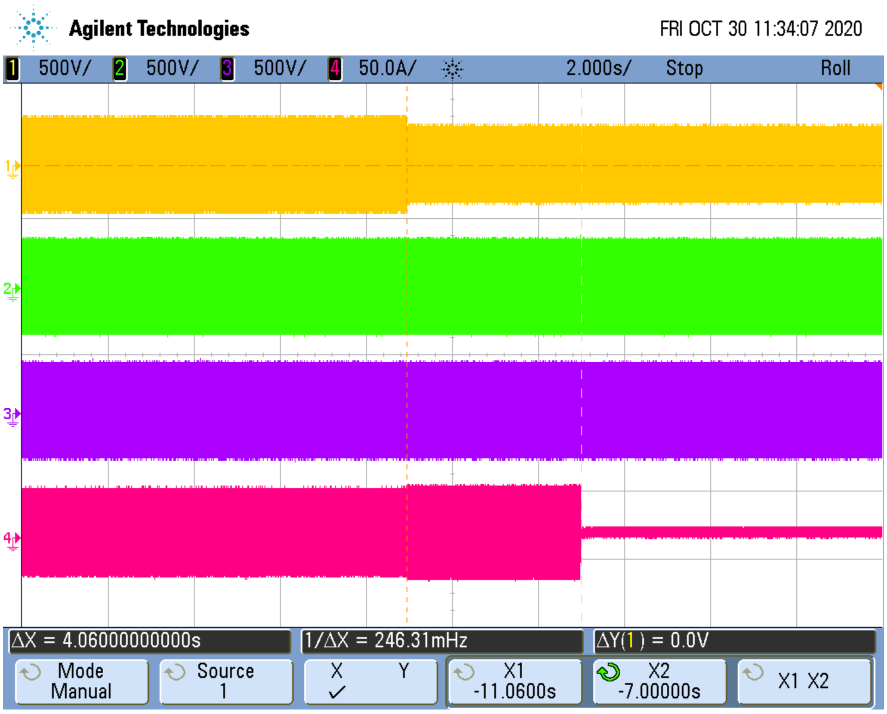
Scope pictures of the disconnection time
Over-voltage - Stage 1 (L1 phase)



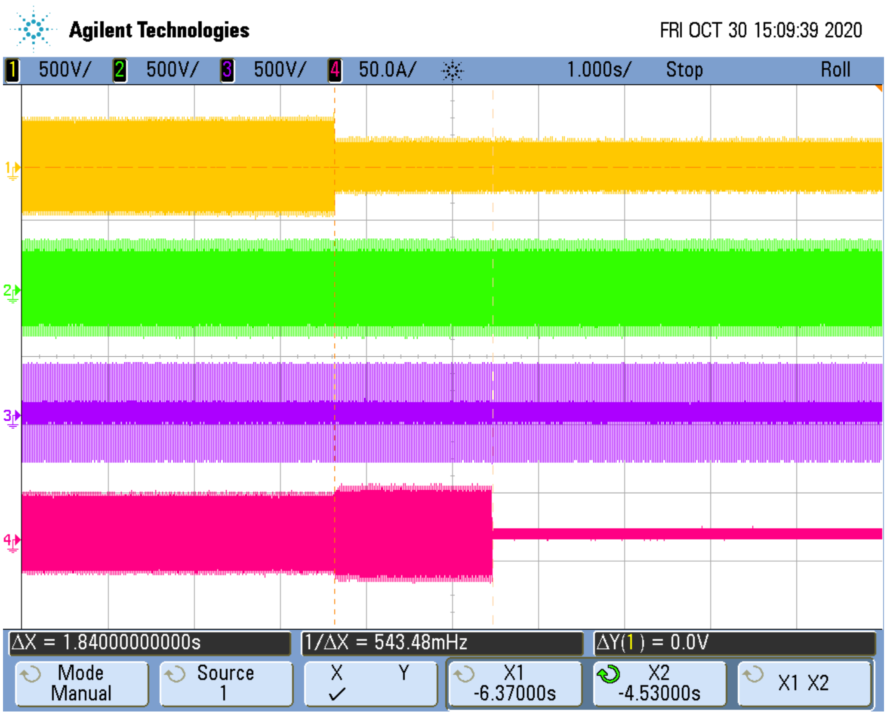
Over-voltage - Stage 2 (L1 phase)

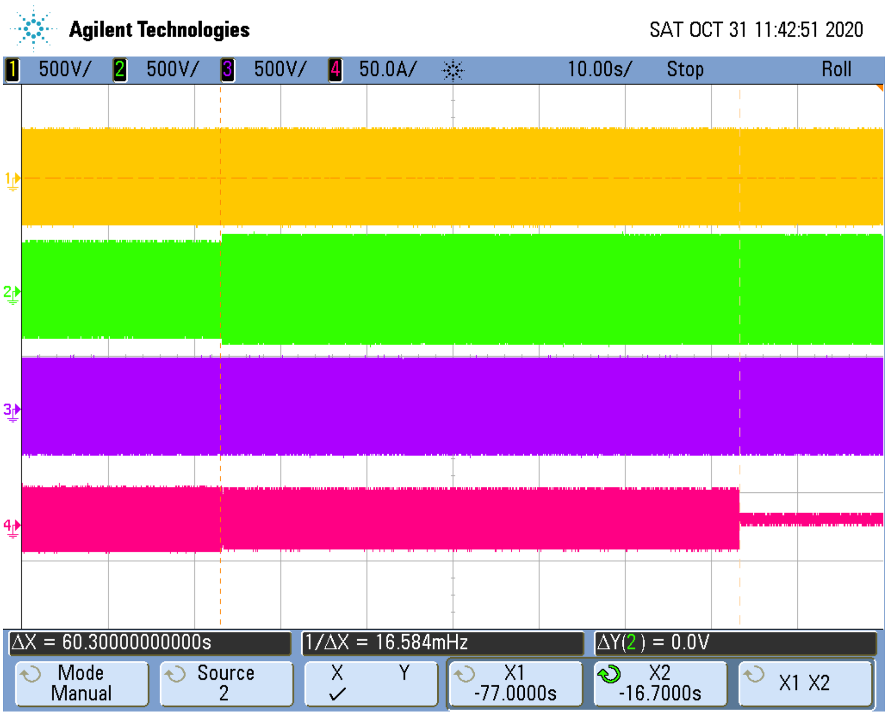
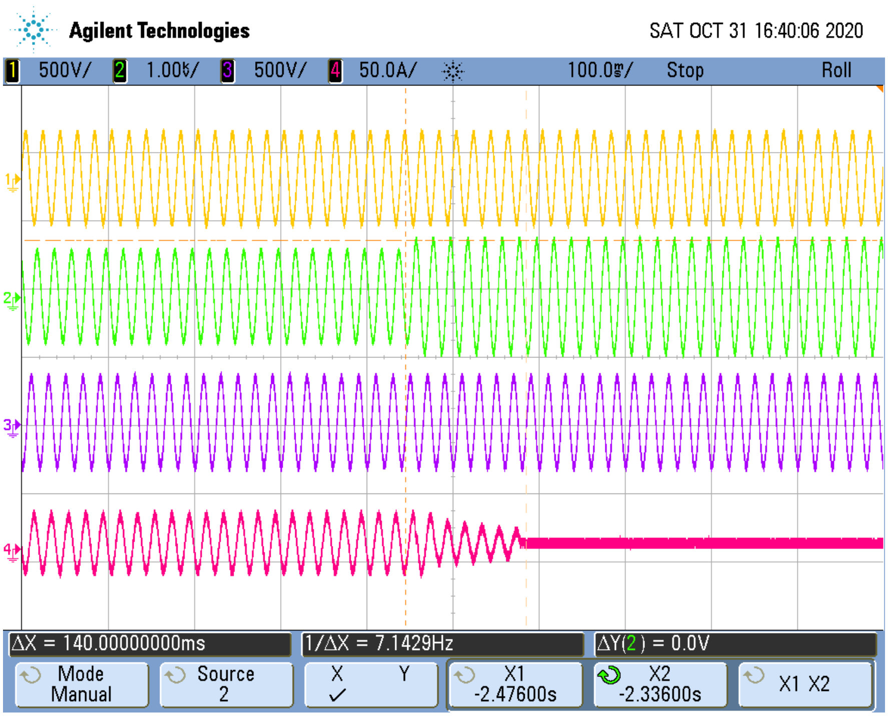


Under-voltage - Stage 1 (L1 phase)

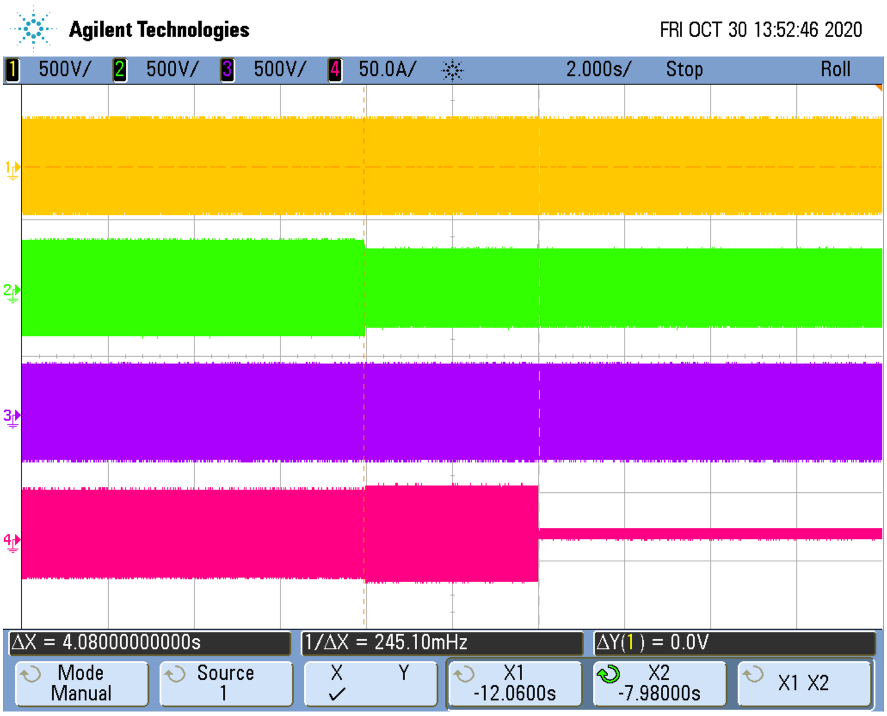


Under-voltage - Stage 2 (L1 phase)

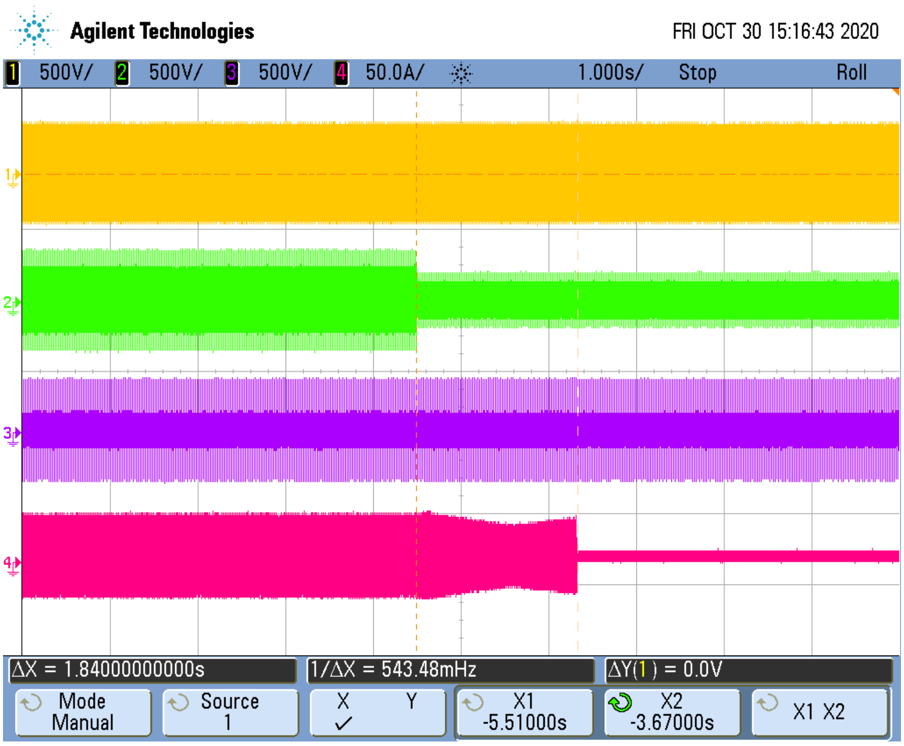


Over-voltage - Stage 1 (L2 phase)

Over-voltage - Stage 2 (L2 phase)


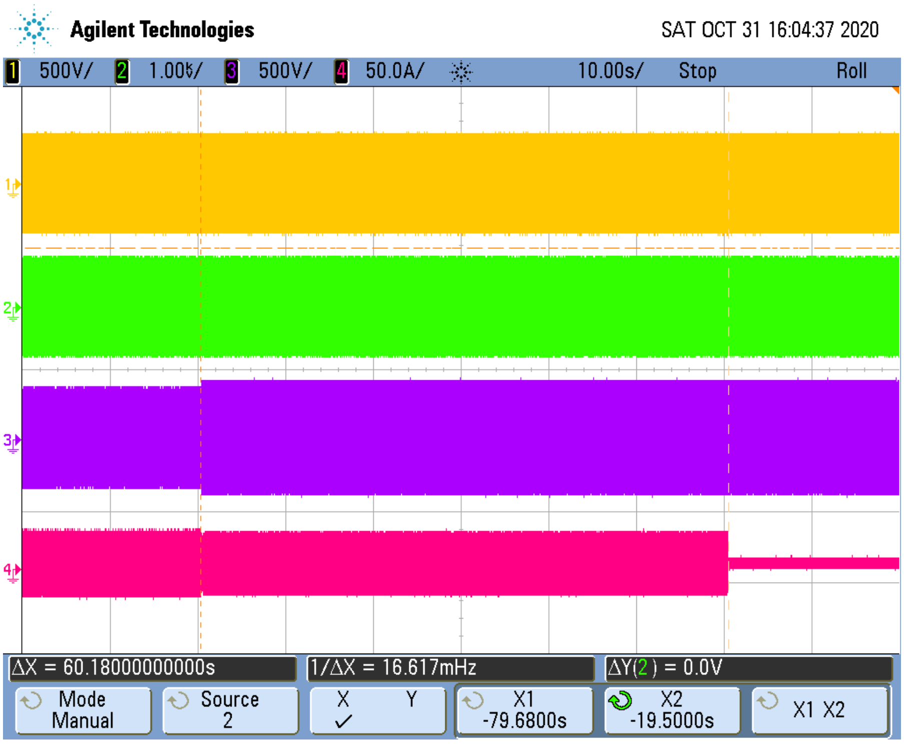
Under-voltage - Stage 1 (L2 phase)



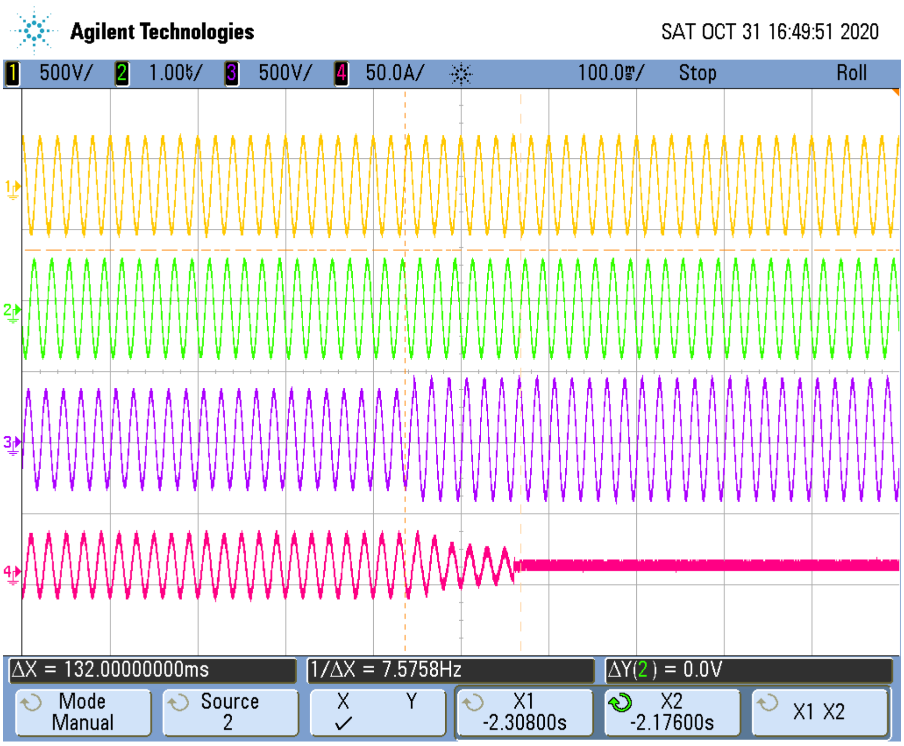
Under-voltage - Stage 2 (L2 phase)

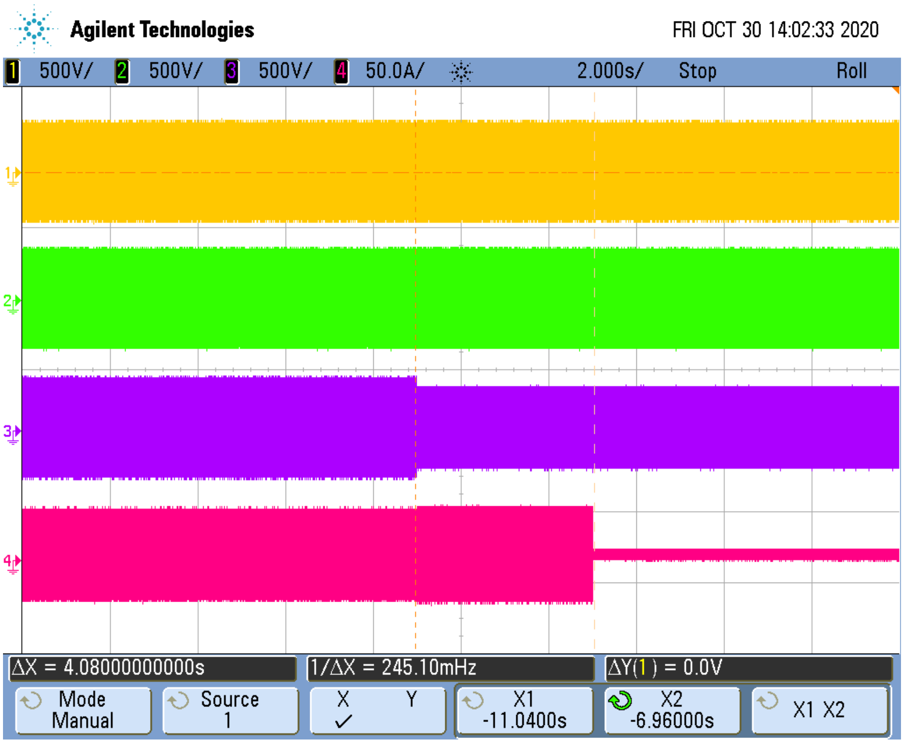


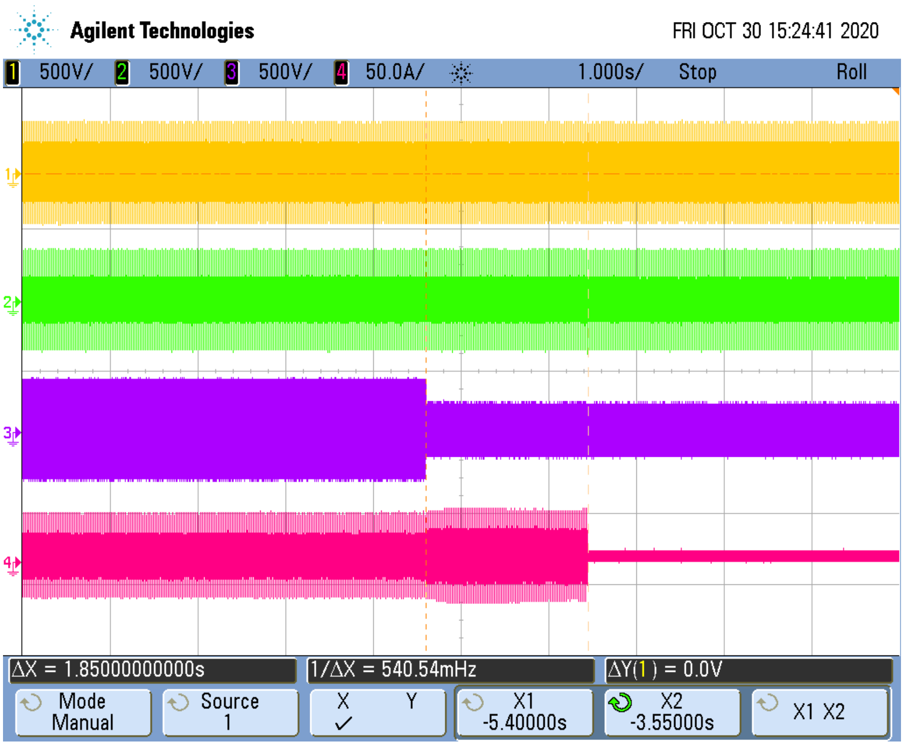
Over-voltage - Stage 1 (L3 phase)



Over-voltage - Stage 2 (L3 phase)



Under-voltage - Stage 1 (L3 phase)


Under-voltage - Stage 2 (L3 phase)


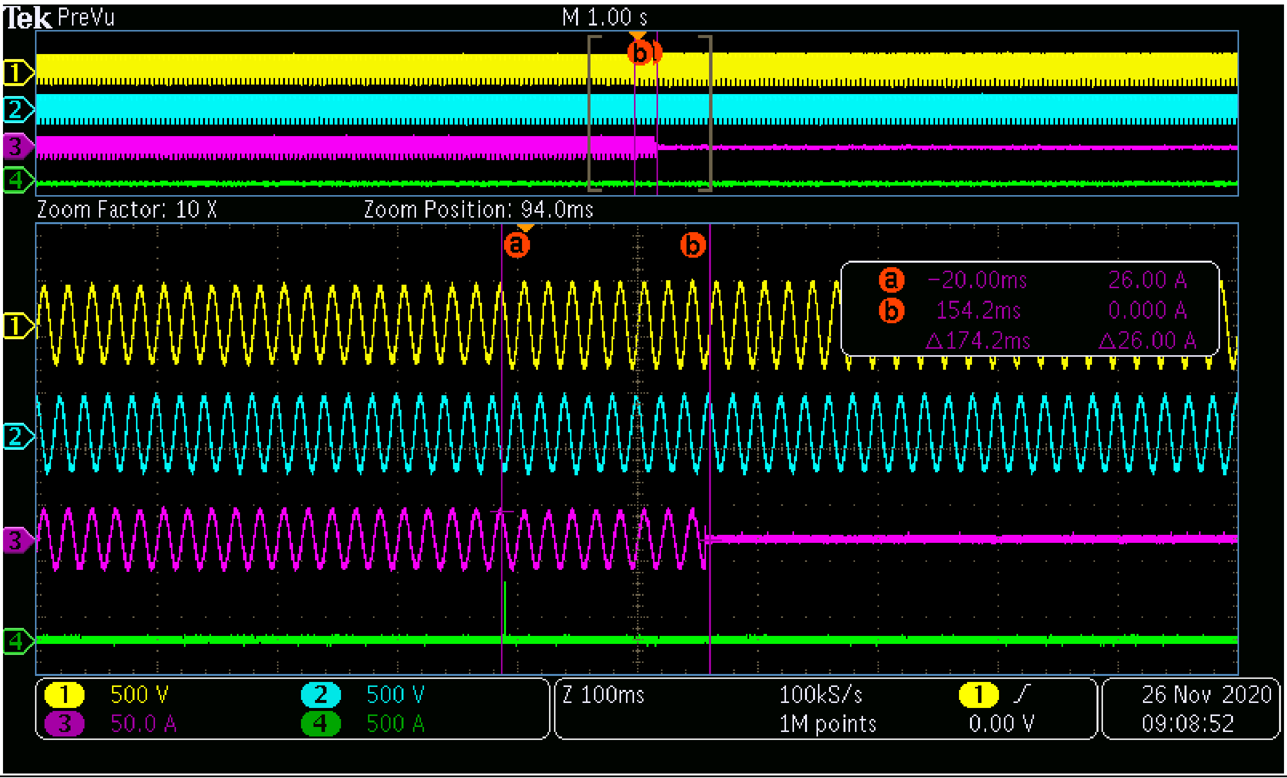
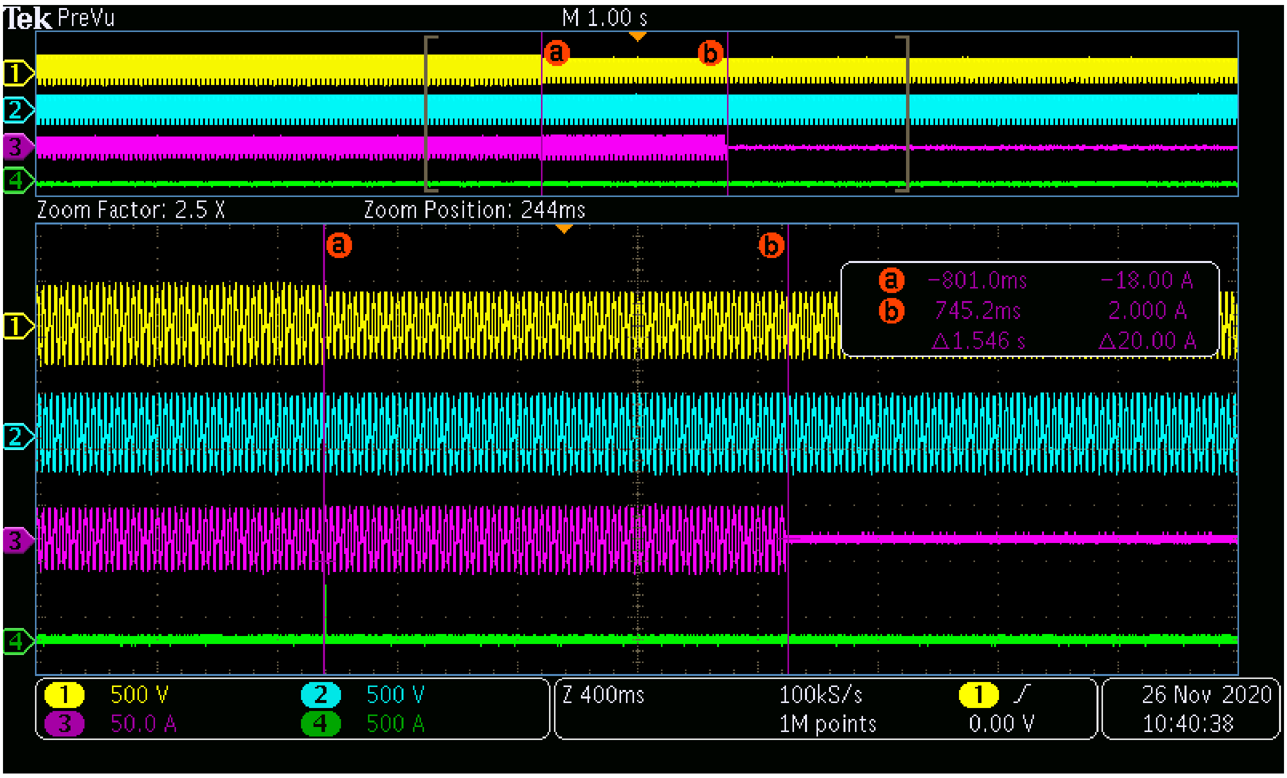
4.9.3 4.9.3.1	Requirements on voltage and frequency protection General (Interface protection: Over/under voltage) (Setting value refer NA/EEA-NE7-CH 2020 setting for Netherlands)				P
Test conditions			Output power: -kW Frequency: 50+/-0,2Hz		
Phase	**Limit [V]**	**Trip value [V]**	**Voltage step [V]**	**Disconnection time [s]**	**Limit [s]**
L1	110% of Un = 253,0 (stage 1)	254,64	230 to 258	0,167	0,1-0,2*
		254,74	230 to 258	0,168	
		254,72	230 to 258	0,170	
		254,73	230 to 258	0,174	
		254,72	230 to 258	0,163	
	120% of Un = 276,0 (stage 2)	277,21	230 to 280	0,166	0,1-0,2*
		277,20	230 to 280	0,171	
		277,20	230 to 280	0,176	
		277,20	230 to 280	0,157	
		277,20	230 to 280	0,167	
	80% of Un = 184,0 (stage 1)	184,28	230 to 180	1,534	1,5-1,6
		184,31	230 to 180	1,546	
		184,29	230 to 180	1,542	
		184,30	230 to 180	1,538	
		184,29	230 to 180	1,558	
	45% of Un = 103,5 (stage 2)	104,40	230 to 100	0,344	0,3-0,4
		104,85	230 to 100	0,350	
		104,88	230 to 100	0,338	
		104,38	230 to 100	0,346	
		103,89	230 to 100	0,348	
L2	110% of Un = 253,0 (stage 1)	254,74	230 to 258	0,173	0,1-0,2*
		254,72	230 to 258	0,171	
		254,81	230 to 258	0,185	
		254,80	230 to 258	0,175	
		254,78	230 to 258	0,182	
	120% of Un = 276,0 (stage 2)	277,22	230 to 280	0,177	0,1-0,2*
		277,25	230 to 280	0,175	
		277,22	230 to 280	0,168	
		277,23	230 to 280	0,162	
		277,23	230 to 280	0,169	
		184,38	230 to 180	1,554	1,5-1,6

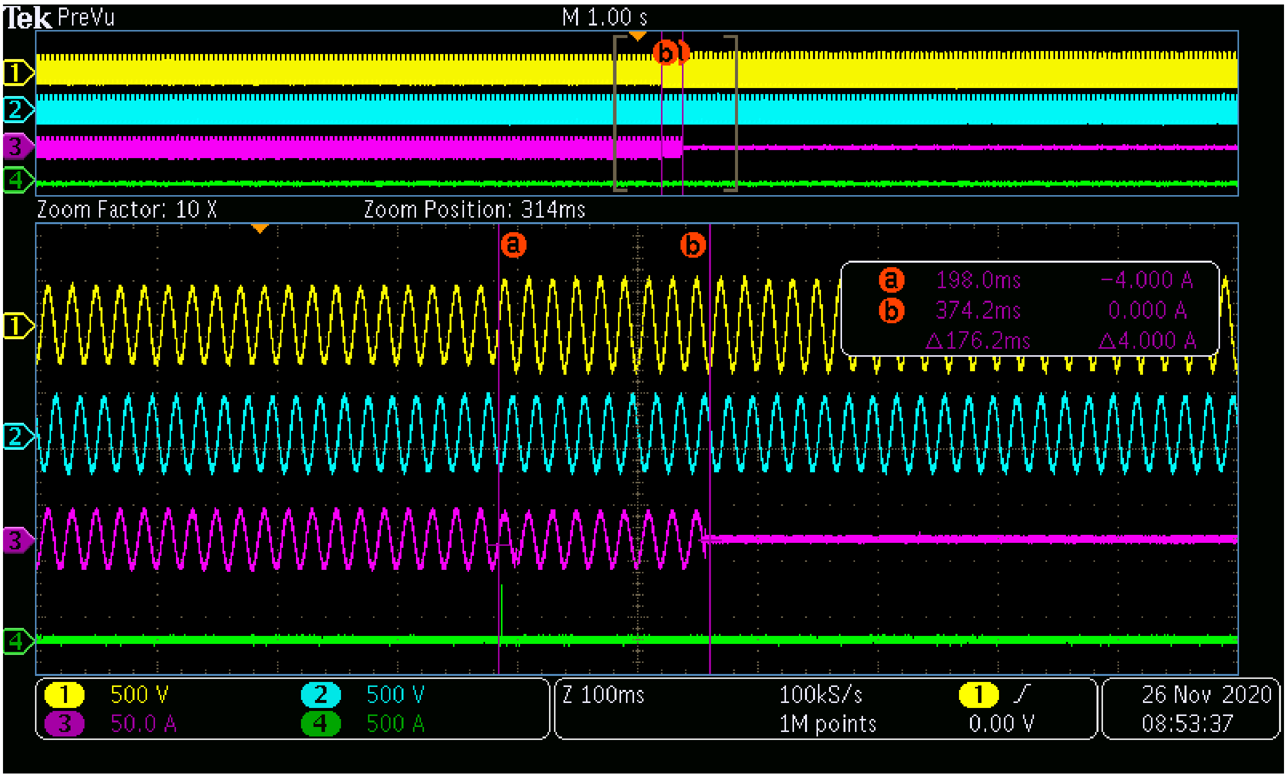
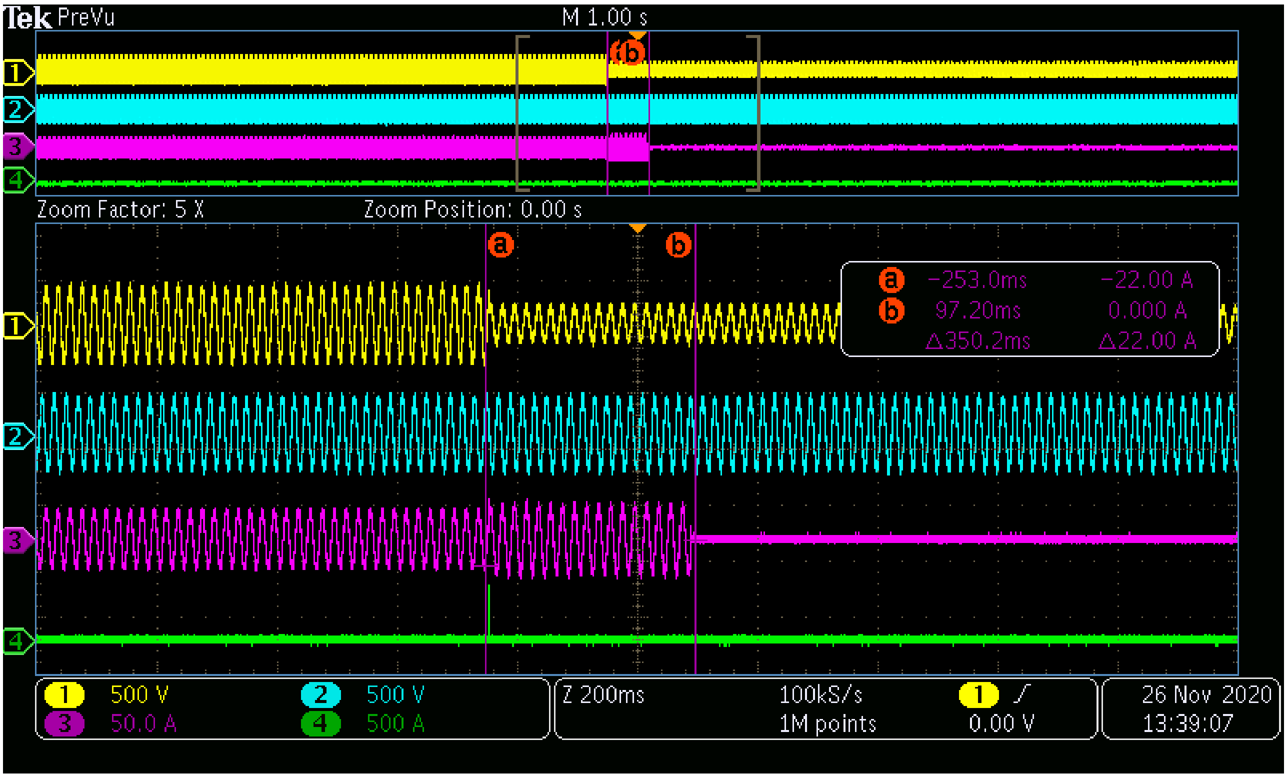
	80% of Un = 184,0 (stage 1)	184,36	230 to 180	1,550	
		184,37	230 to 180	1,546	
		184,36	230 to 180	1,558	
		184,36	230 to 180	1,538	
	45% of Un = 103,5 (stage 2)	104,45	230 to 100	0,328	0,3-0,4
		104,47	230 to 100	0,322	
		104,45	230 to 100	0,338	
		104,43	230 to 100	0,344	
		103,96	230 to 100	0,336	
L3	110% of Un = 253,0 (stage 1)	254,85	230 to 258	0,171	0,1-0,2*
		254,85	230 to 258	0,167	
		254,81	230 to 258	0,169	
		254,63	230 to 258	0,170	
		254,85	230 to 258	0,173	
	120% of Un = 276,0 (stage 2)	277,31	230 to 280	0,172	0,1-0,2*
		277,31	230 to 280	0,180	
		277,21	230 to 280	0,183	
		277,29	230 to 280	0,174	
		277,35	230 to 280	0,171	
	80% of Un = 184,0 (stage 1)	184,41	230 to 180	1,550	1,5-1,6
		184,89	230 to 180	1,546	
		184,39	230 to 180	1,554	
		184,40	230 to 180	1,556	
		184,43	230 to 180	1,560	
	45% of Un = 103,5 (stage 2)	103,98	230 to 100	0,334	0,3-0,4
		104,47	230 to 100	0,352	
		104,49	230 to 100	0,348	
		104,48	230 to 100	0,342	
		104,47	230 to 100	0,350	

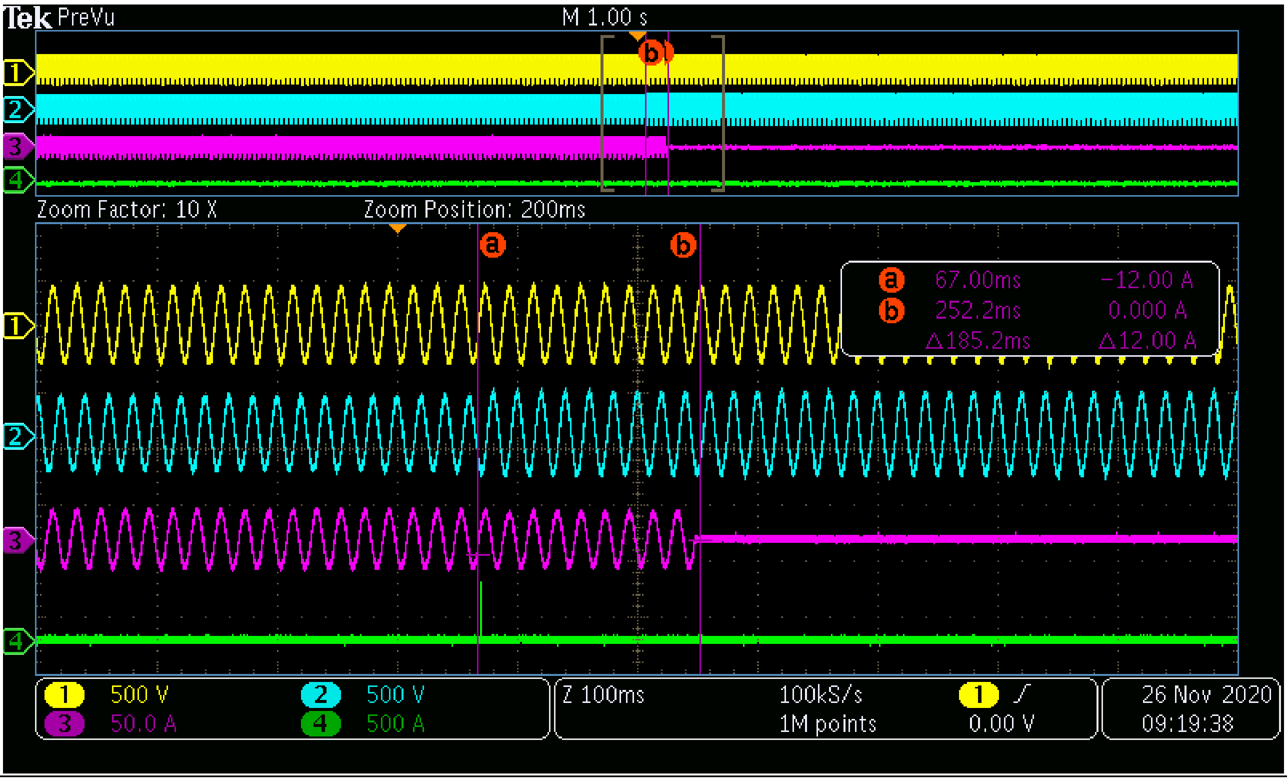
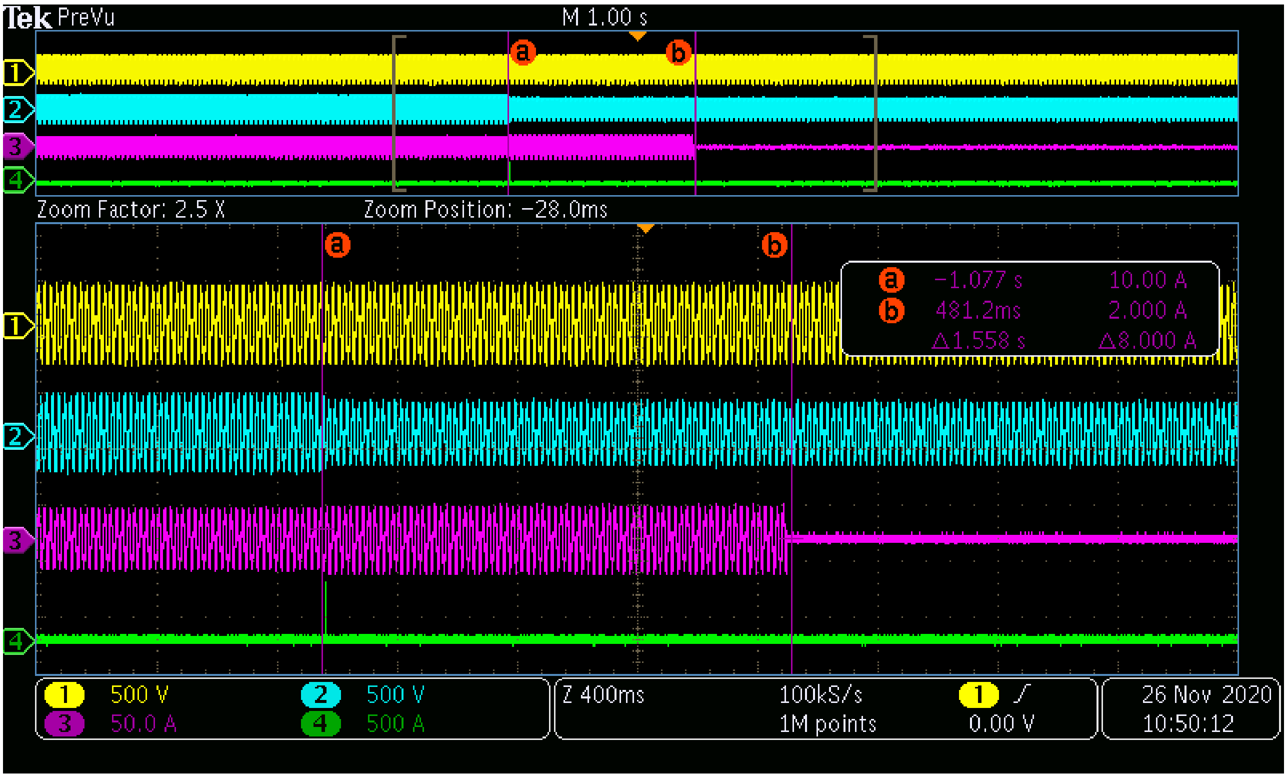
Note:

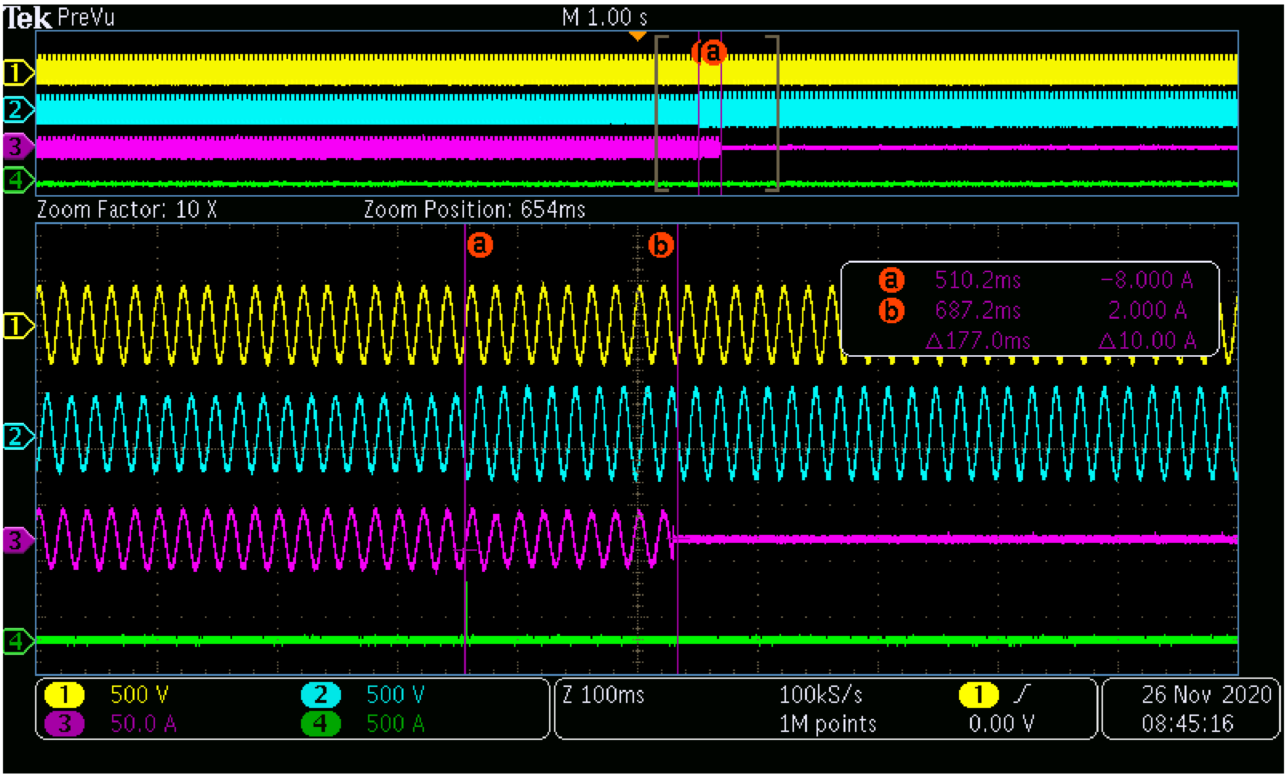
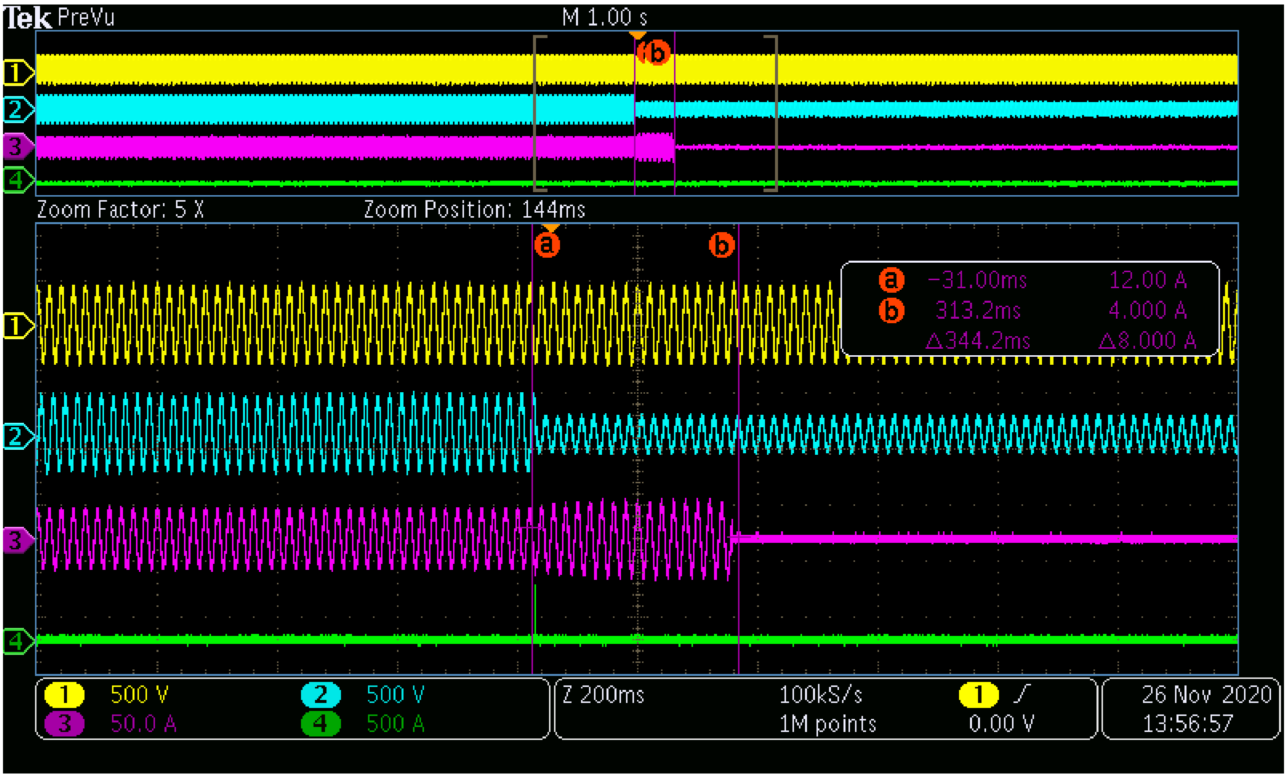
The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing, Lower and upper threshold voltage 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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

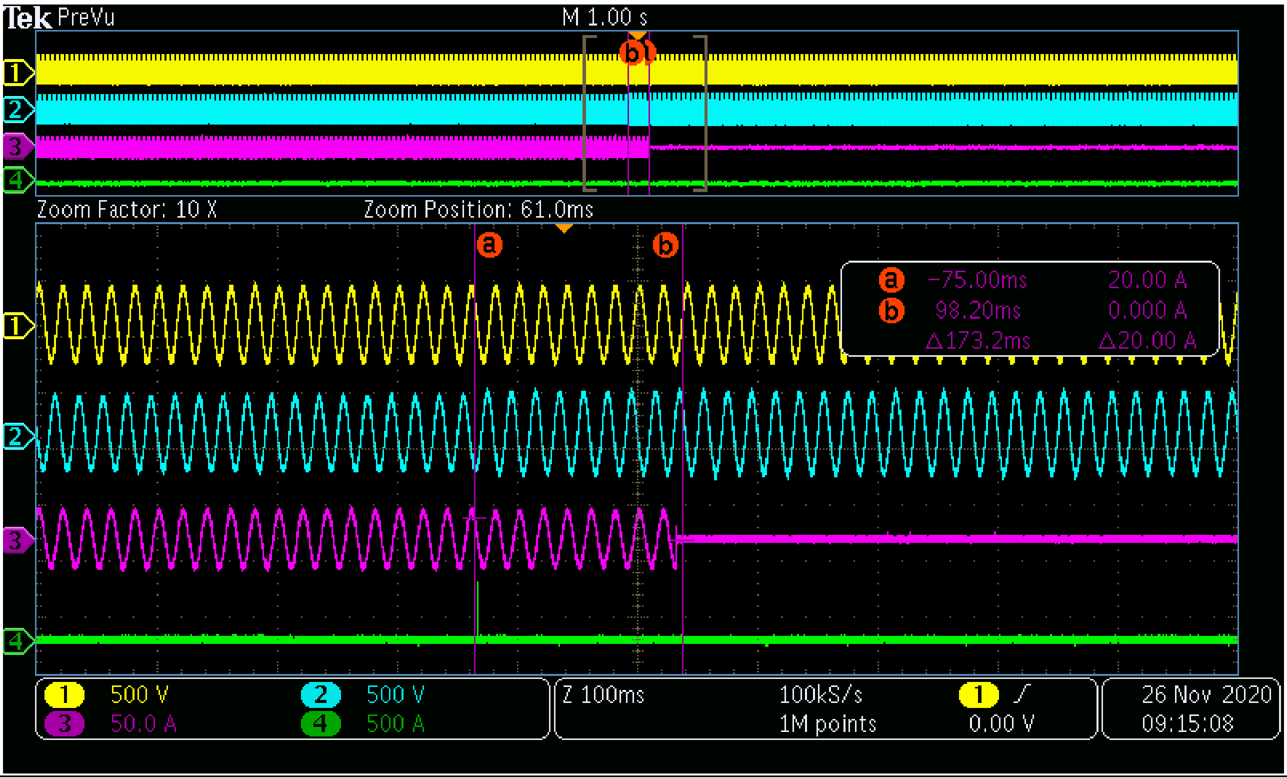
Scope pictures of the disconnection time
Over-voltage – Stage 1(L1 phase)

Under-voltage –Stage 1(L1 phase)


Over-voltage – Stage 2(L1 phase)

Under-voltage –Stage 2(L1 phase)


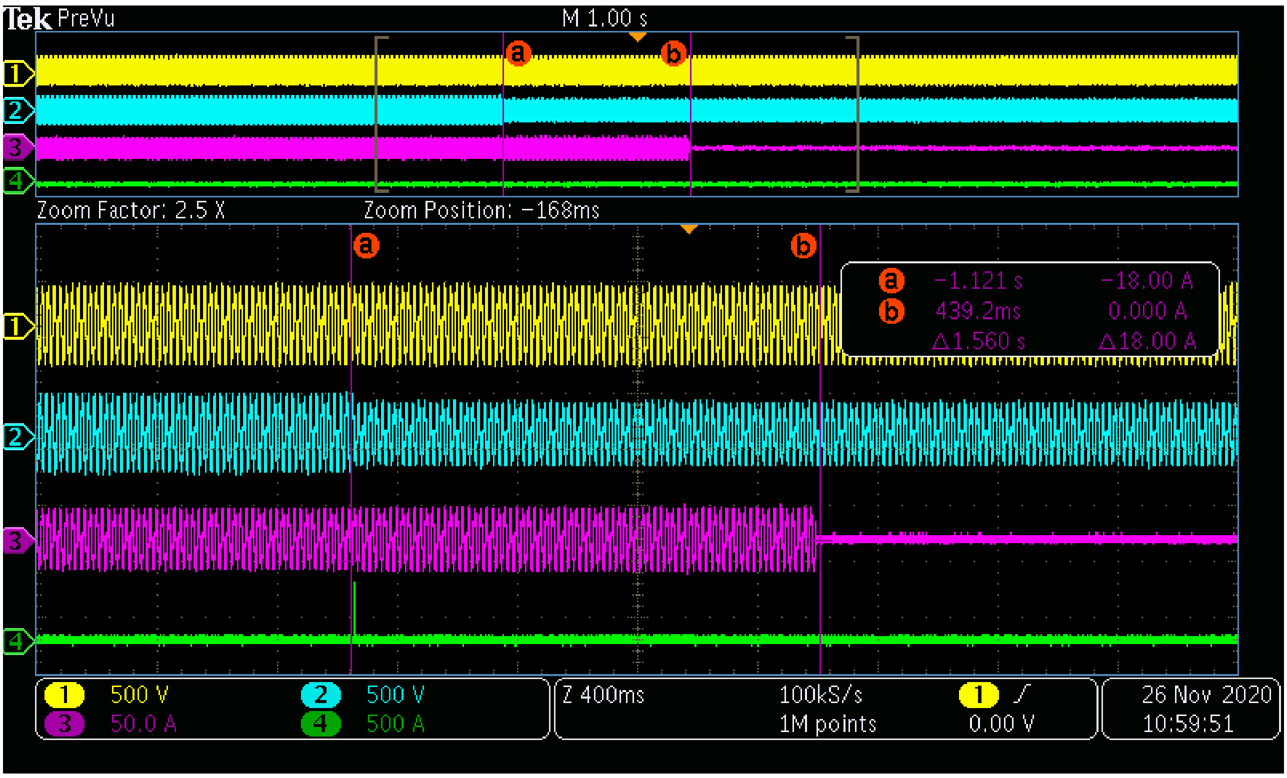
Over-voltage – Stage 1(L2 phase)

Under-voltage –Stage 2(L2 phase)


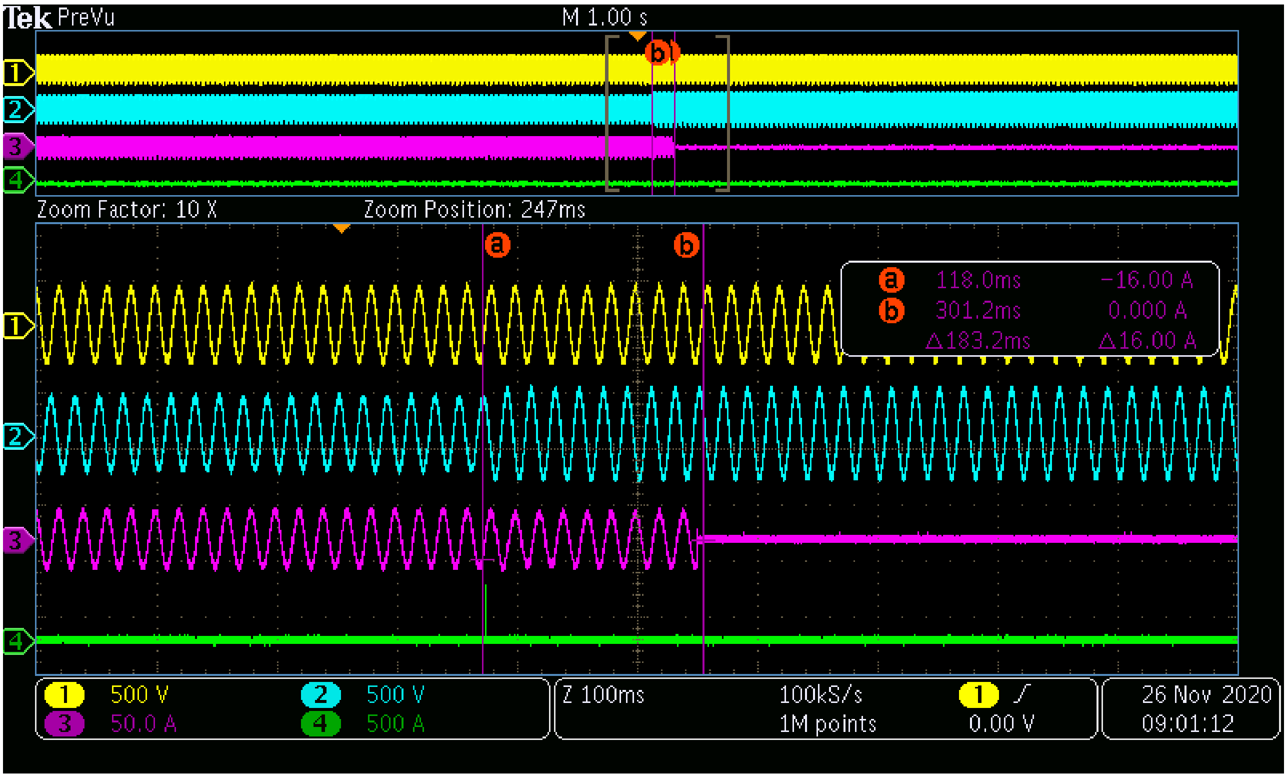
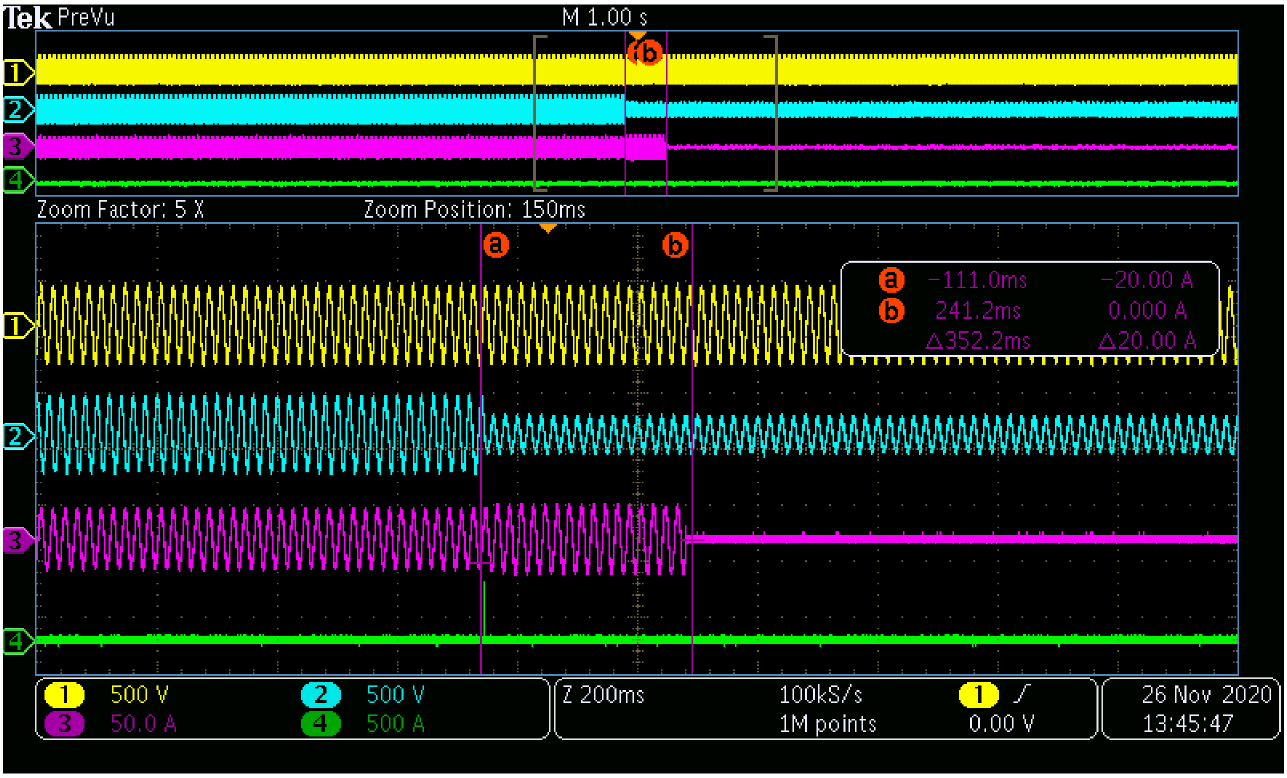
Over-voltage – Stage 2(L2 phase)

Under-voltage –Stage 2(L2 phase)


Over-voltage – Stage 1(L3 phase)



Under-voltage –Stage 1(L3 phase)



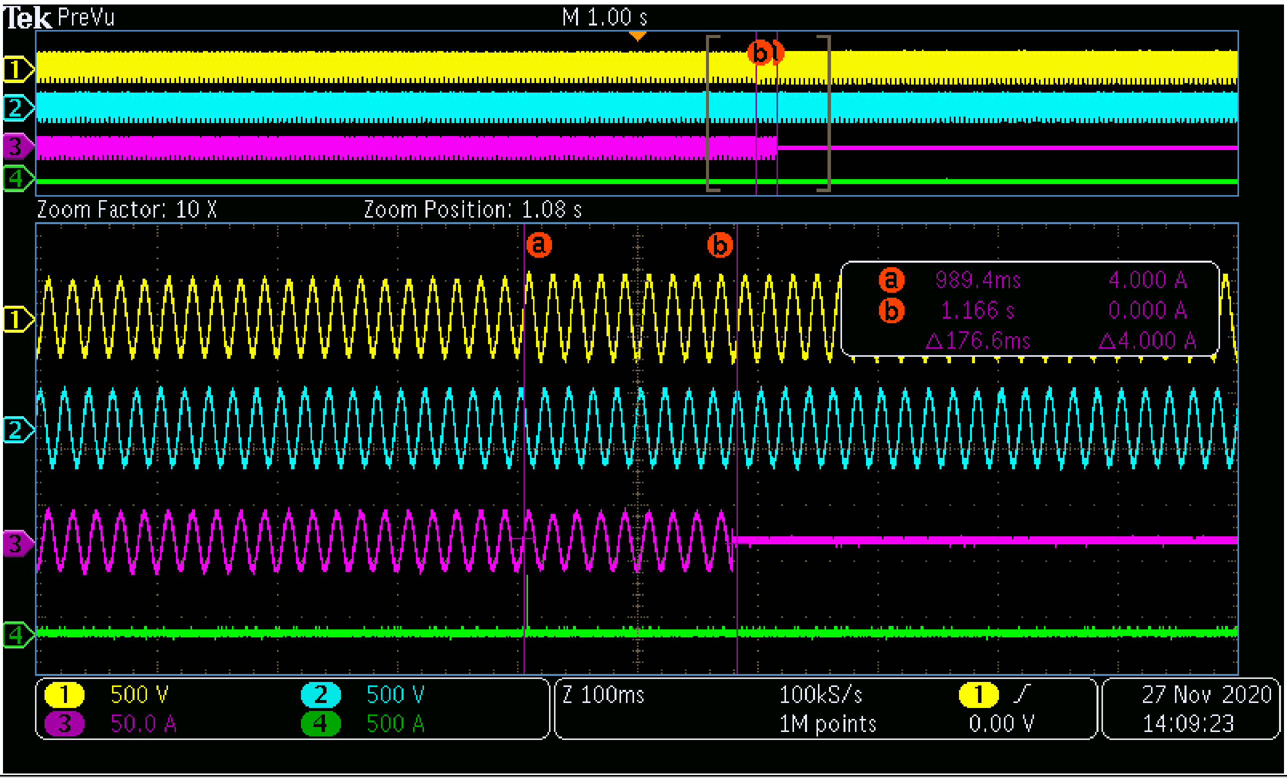
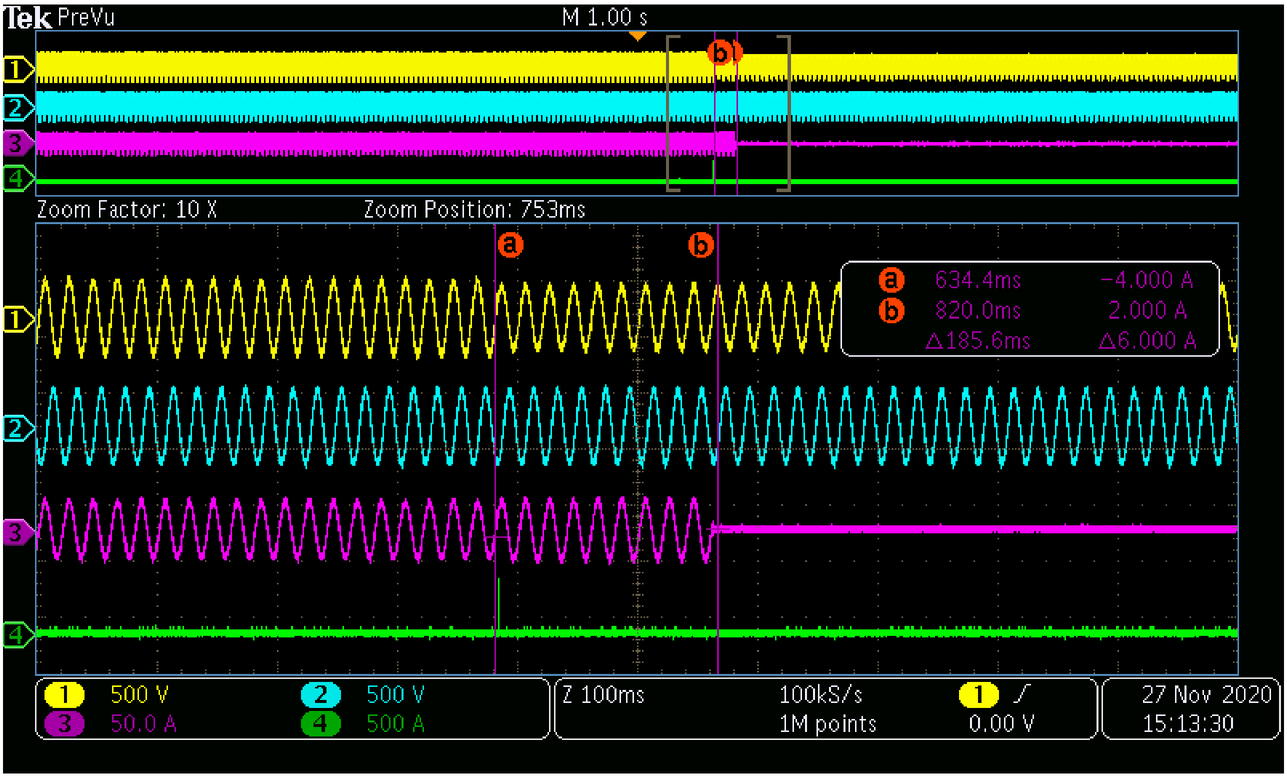
Over-voltage – Stage 2(L3 phase)

Under-voltage –Stage 2(L3 phase)


4.9.3 4.9.3.1	Requirements on voltage and frequency protection General (Interface protection: Over/under voltage) (Setting value refer EN50438 default setting for Finland)				P
Test conditions		Output power: -kW Frequency: 50+/-0,2Hz			
Phase	Limit [V]	Trip value [V]	Voltage step [V]	Disconnection time [s]	Limit [s]
L1	110% of Un = 253,0 (stage 1)	253,84	230 to 258	0,177	0,2
		253,91	230 to 258	0,174	
		253,89	230 to 258	0,164	
		253,91	230 to 258	0,166	
		253,94	230 to 258	0,173	
	85% of Un = 195,5 (stage 1)	196,22	230 to 190	0,172	0,2
		195,70	230 to 190	0,176	
		195,74	230 to 190	0,169	
		196,23	230 to 190	0,186	
		196,24	230 to 190	0,183	
L2	110% of Un = 253,0 (stage 1)	253,94	230 to 258	0,170	0,2
		253,94	230 to 258	0,186	
		253,99	230 to 258	0,168	
		253,94	230 to 258	0,176	
		253,94	230 to 258	0,182	
	85% of Un = 195,5 (stage 1)	196,31	230 to 190	0,163	0,2
		196,28	230 to 190	0,174	
		196,30	230 to 190	0,175	
		195,86	230 to 190	0,165	
		195,80	230 to 190	0,176	
L3	110% of Un = 253,0 (stage 1)	254,00	230 to 258	0,178	0,2
		254,00	230 to 258	0,180	
		253,90	230 to 258	0,167	
		254,06	230 to 258	0,161	
		254,02	230 to 258	0,163	
	85% of Un = 195,5 (stage 1)	195,81	230 to 190	0,173	0,2
		196,38	230 to 190	0,165	
		195,88	230 to 190	0,164	
		196,39	230 to 190	0,174	
		195,87	230 to 190	0,172	

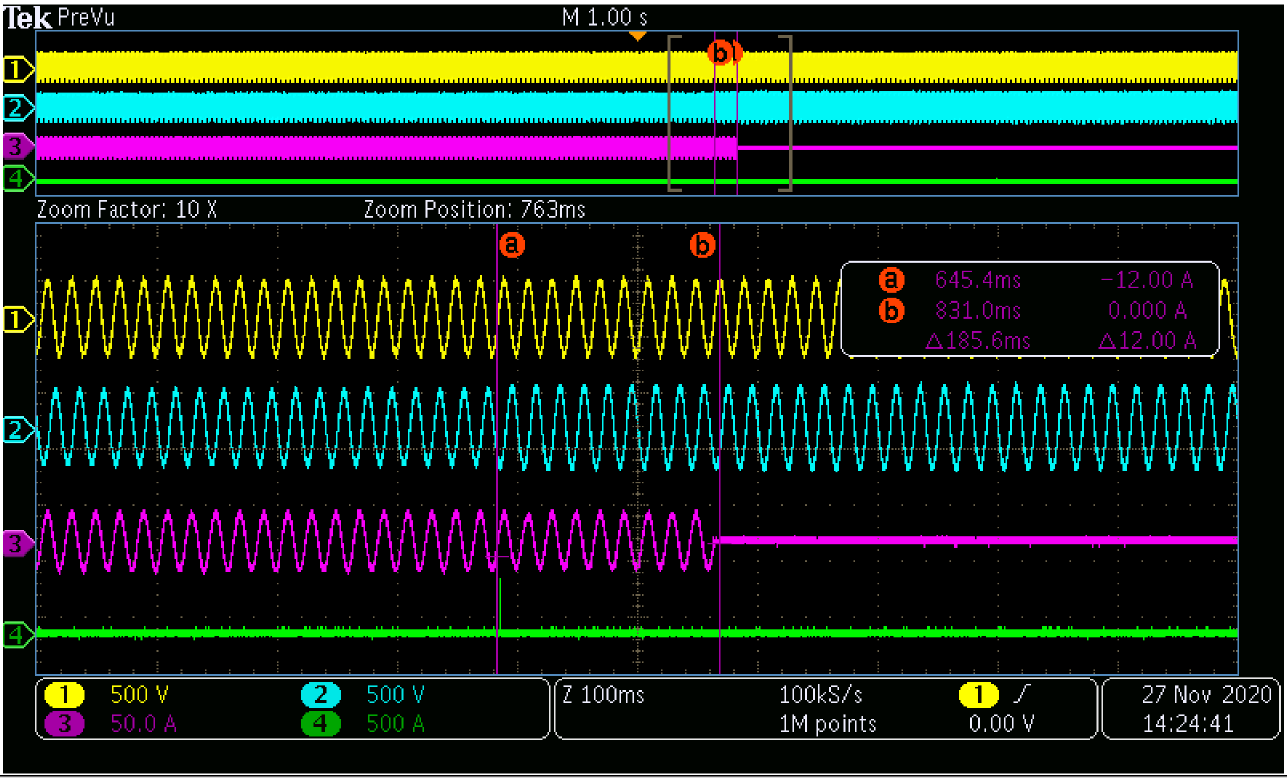
Note:

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.

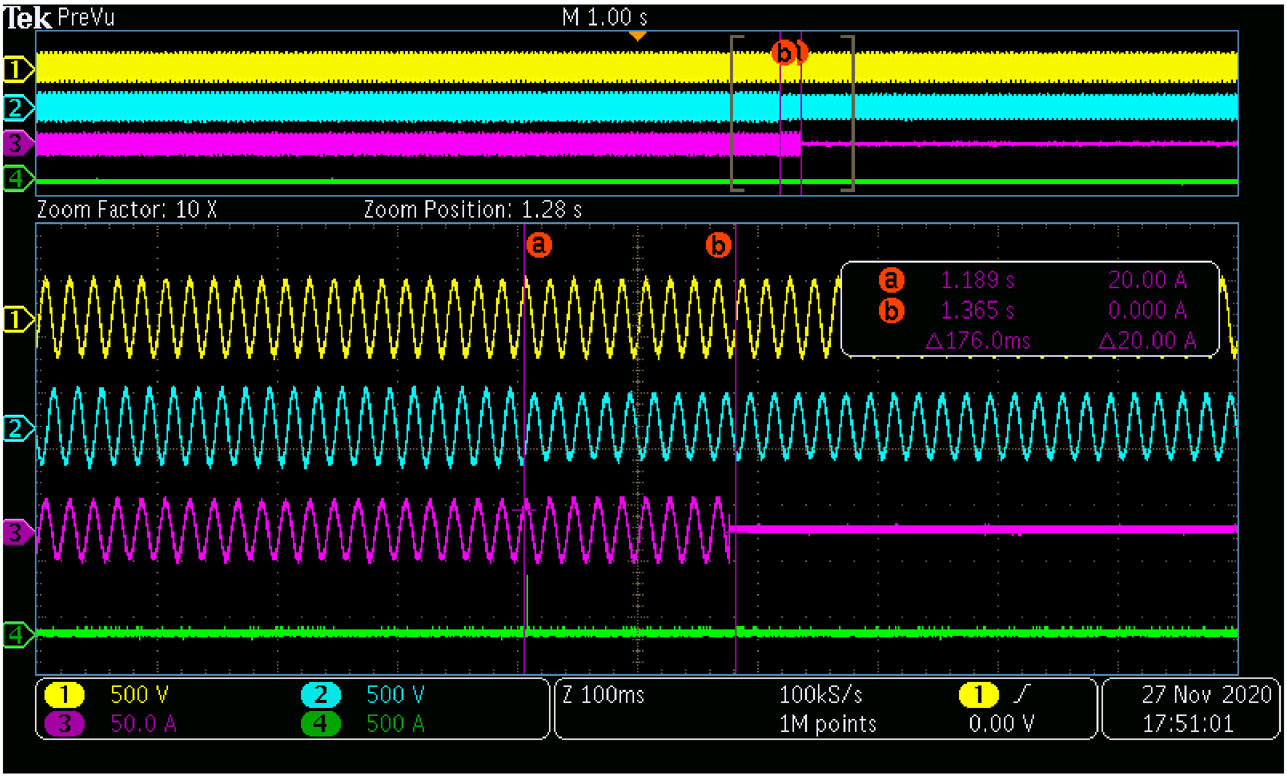
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

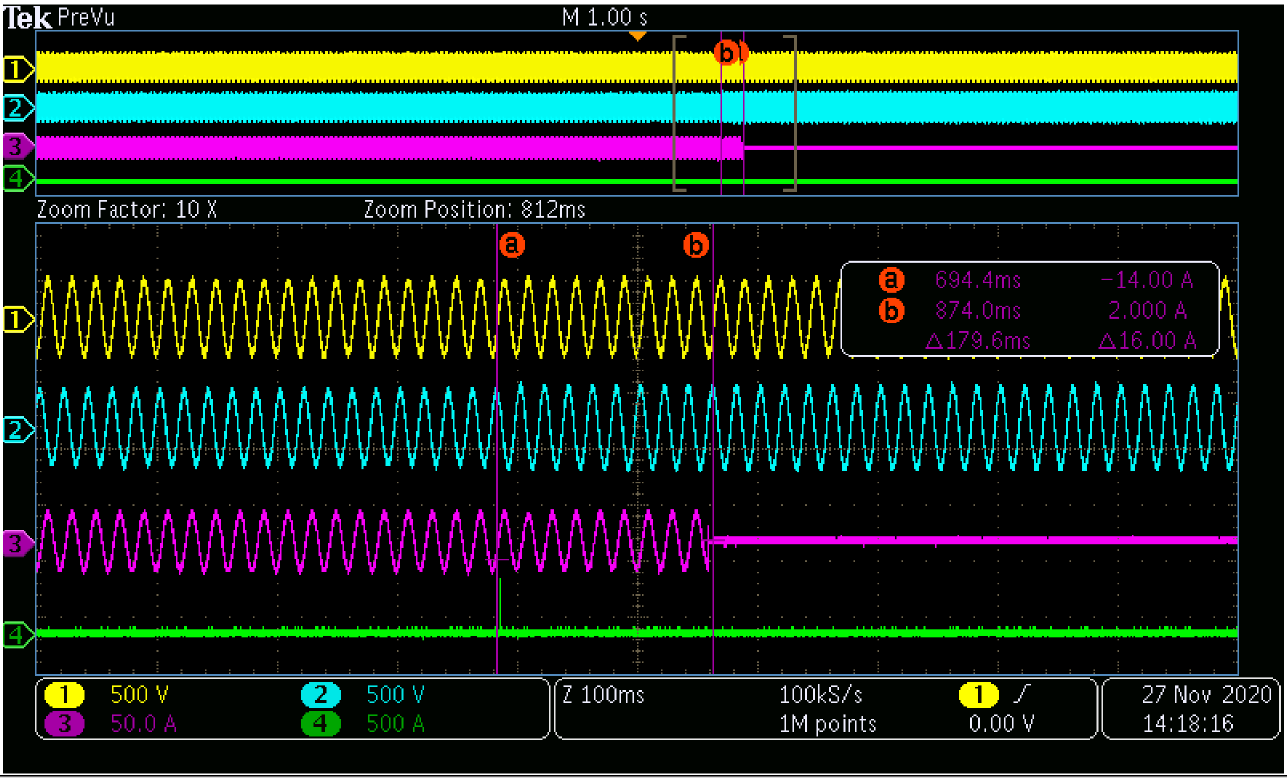
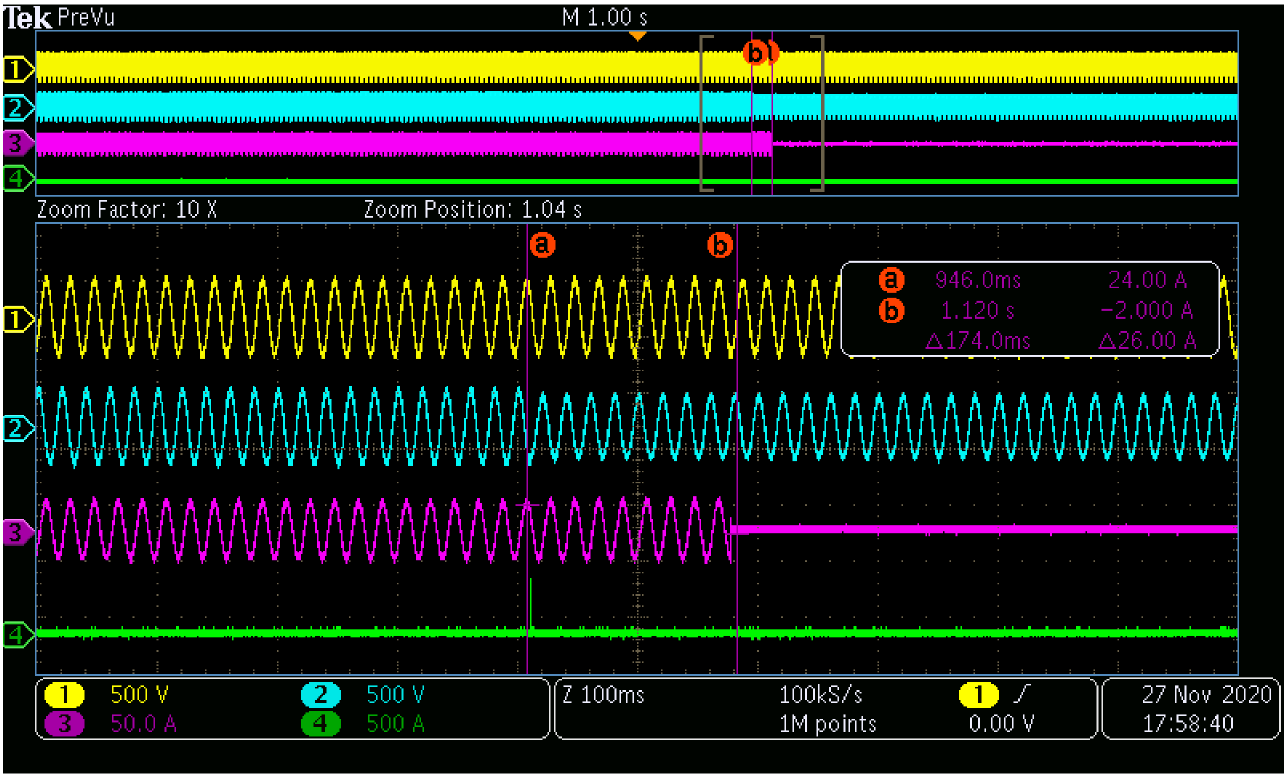
Scope pictures of the disconnection time
Over-voltage – Stage 1(L1 phase)

Under-voltage –Stage 1(L1 phase)


Over-voltage – Stage 1(L2 phase)



Under-voltage –Stage 1(L2 phase)



Over-voltage – Stage 1(L3 phase)

Under-voltage –Stage 1(L3 phase)


4.9.3 4.9.3.1	**Requirements on voltage and frequency protection** **General** **(Maximum voltage 10 min mean protection according to EN 50160)** **(Setting value refer EN 50438 for default settings)**		**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:	491 s	≤ 600 s
	Phase 2:	486 s	
	Phase 3:	486 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:	302 s	The disconnection time should be about 50 % of the value measured in a), *
	Phase 2:	294 s	
	Phase 3:	290 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.

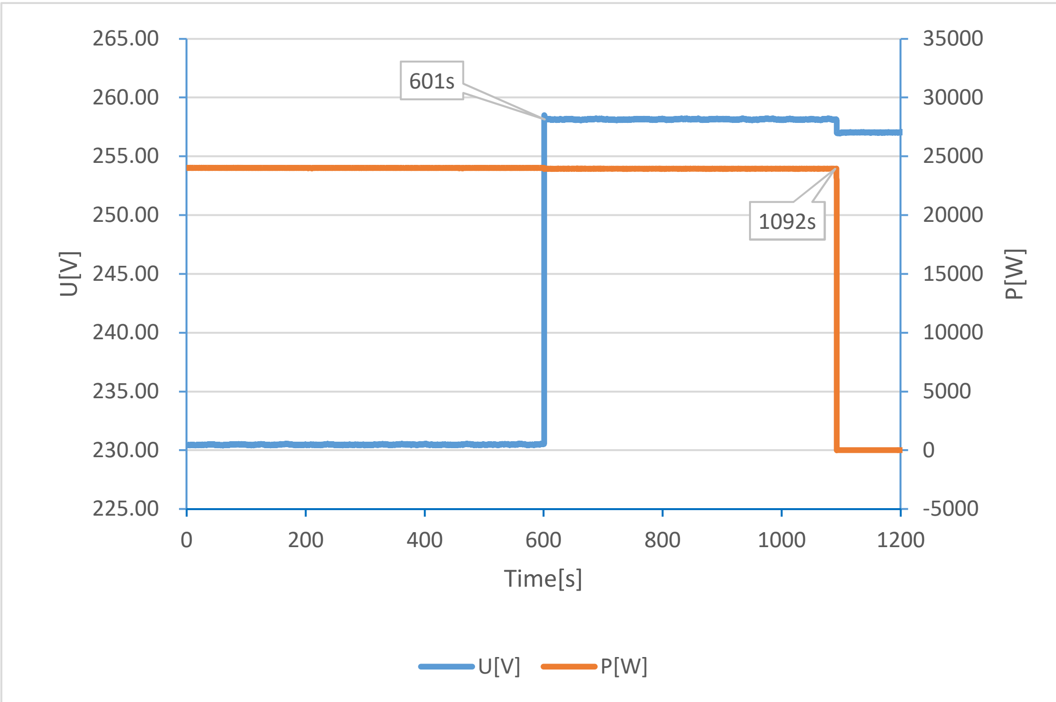
Assessment criterion:
The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1 % of U_N.

Limit values:
Rise-in voltage protection 1,1 U_N after a max. 600 s, the switch off after 200 ms.

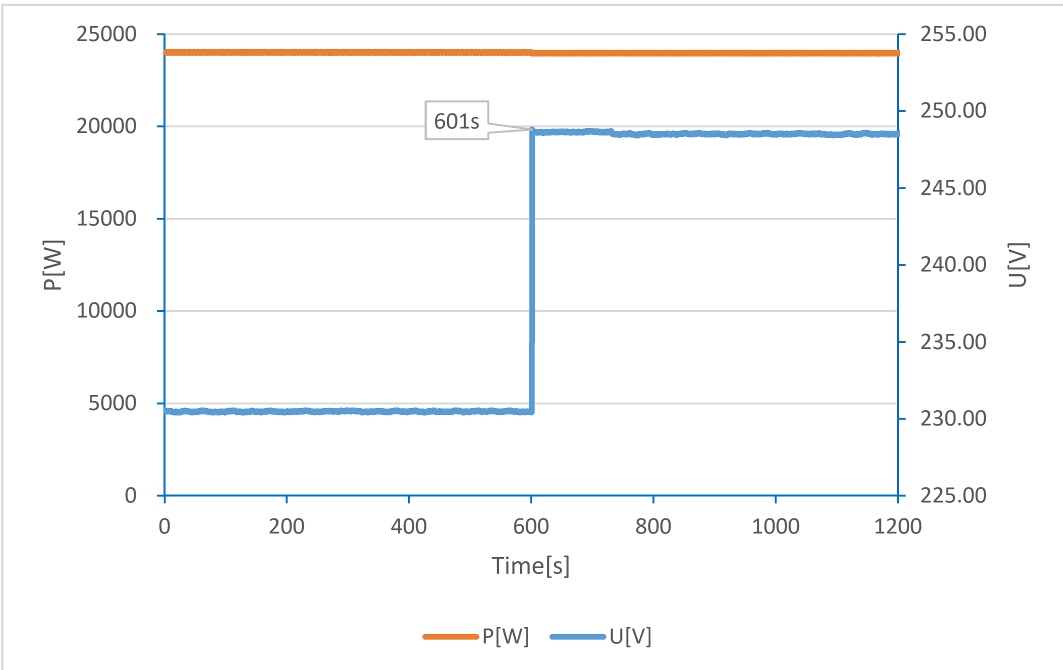
Note:
If only one integrated protection is used for the power generation systems, the value of the rise-in voltage protection of 1,1 U_N may not be changed.
*If the setting value is set to 600 s, then the disconnection time can be in the range between 225 s and 375 s.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

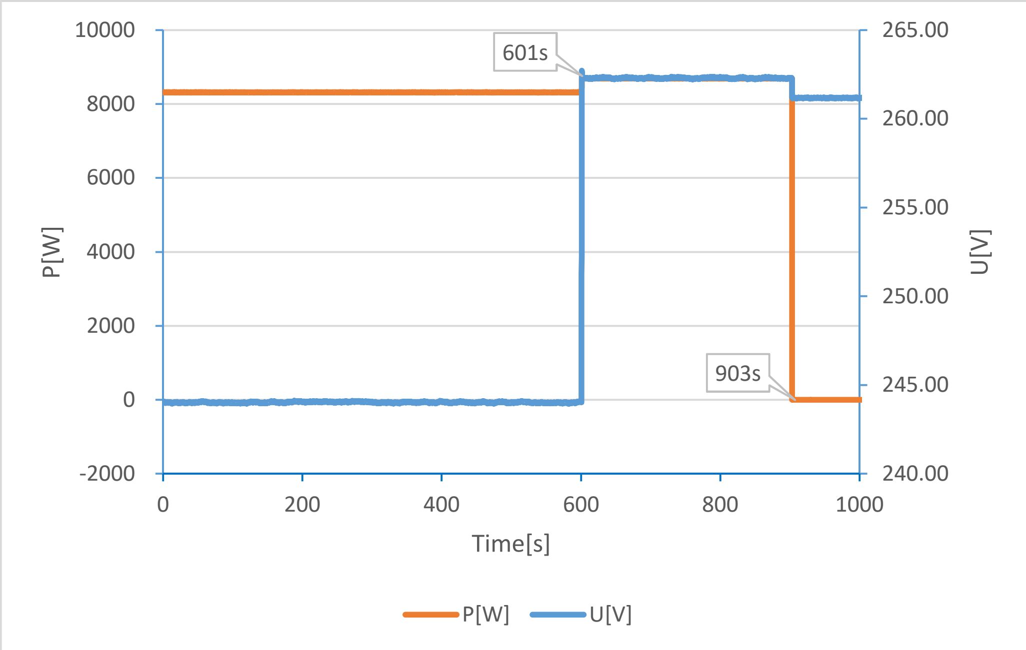
Graph of test a) Voltage set to 112 % U_n



Graph of test b) Voltage set to 108% U_n



Graph of test c) Voltage set to 106 % U_n, thereafter 114% U_n



4.9.3 4.9.3.1	Requirements on voltage and frequency protection General (Interface protection: Over/under frequency) (Setting value refer EN 50438 Default setting)			P
Test conditions	Output power: 5,0kW U_n = 230Vac			
	Under-frequency		**Over-frequency**	
Parameter	**Stage 1 Under-Frequency**	**Time**	**Stage 1 Over-Frequency**	**Time**
Limit	47,50 Hz	0,3 ≤ t ≤ 0,5 s	51,50 Hz	0,3 ≤ t ≤ 0,5 s
Trip value [Hz]	47,48		51,50	
	47,48		51,50	
	47,48		51,50	
	47,48		51,51	
	47,48		51,50	
Disconnection time [s]	50,00 Hz to 47,40 Hz	0,398	50,00 Hz to 51,60 Hz	0,396
		0,400		0,402
		0,402		0,392
		0,406		0,404
		0,405		0,400
Parameter	**Stage 2 Under-Frequency**	**Time**	**Stage 2 Over-Frequency**	**Time**
Limit	47,00 Hz	0,1 ≤ t ≤ 0,2 s	52,00 Hz	0,1 ≤ t ≤ 0,2 s
Trip value [Hz]	47,00		52,00	
	47,00		51,99	
	47,00		52,00	
	47,00		52,00	
	47,00		52,00	
Disconnection time [s]	50,00 Hz to 46,90 Hz	0,176	50,00 Hz to 52,10 Hz	0,173
		0,175		0,168
		0,170		0,176
		0,178		0,177
		0,182		0,170

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.

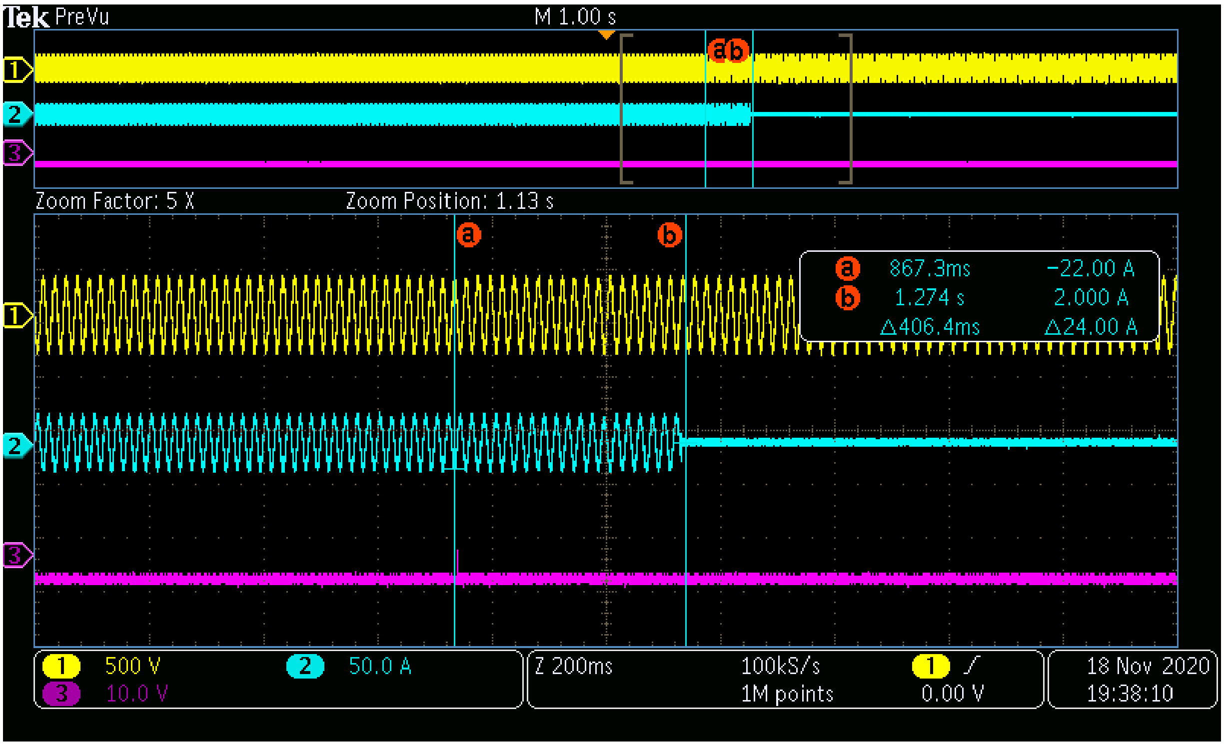
For over-frequency testing the applied frequency is varied from f_n up to $f_{th\text{-}high}$ + 0,1 Hz in steps of 0,025 Hz with a time duration per step exceeding the configured disconnection time, The operate value is the value of the applied frequency at which the protection function trips and shall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

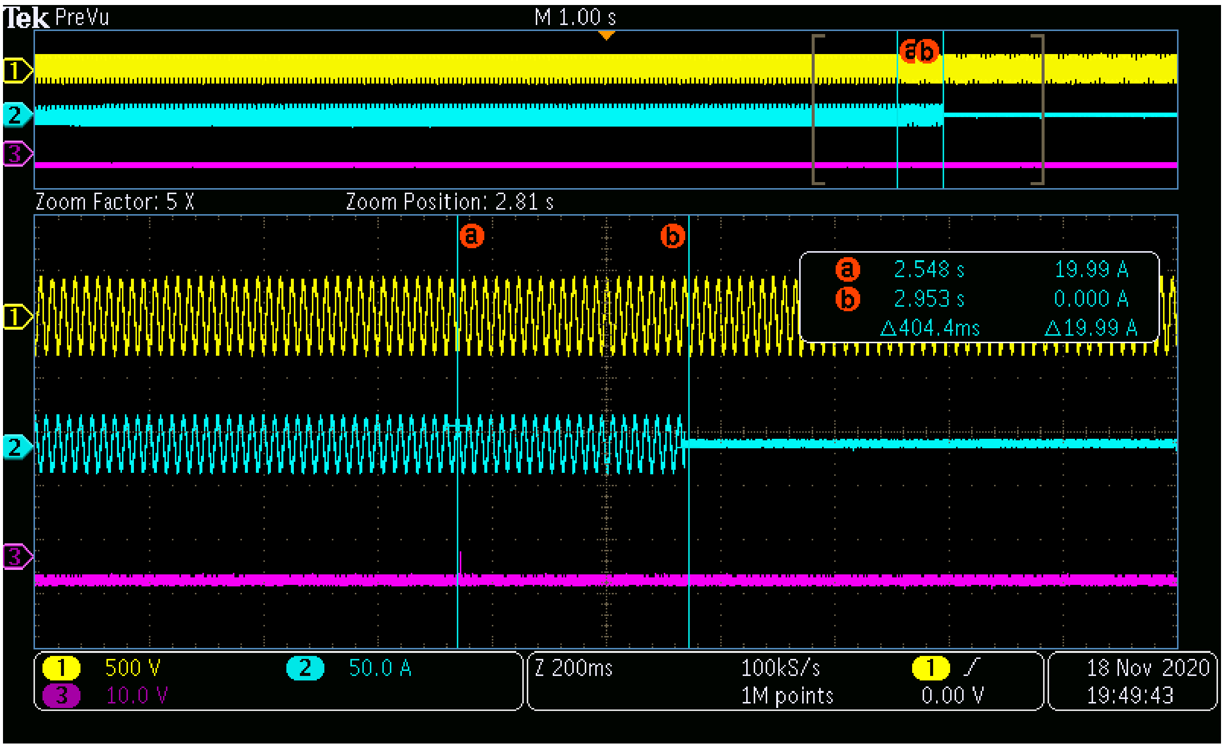
The oscilloscope pictures below show the measured worst case disconnection times.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

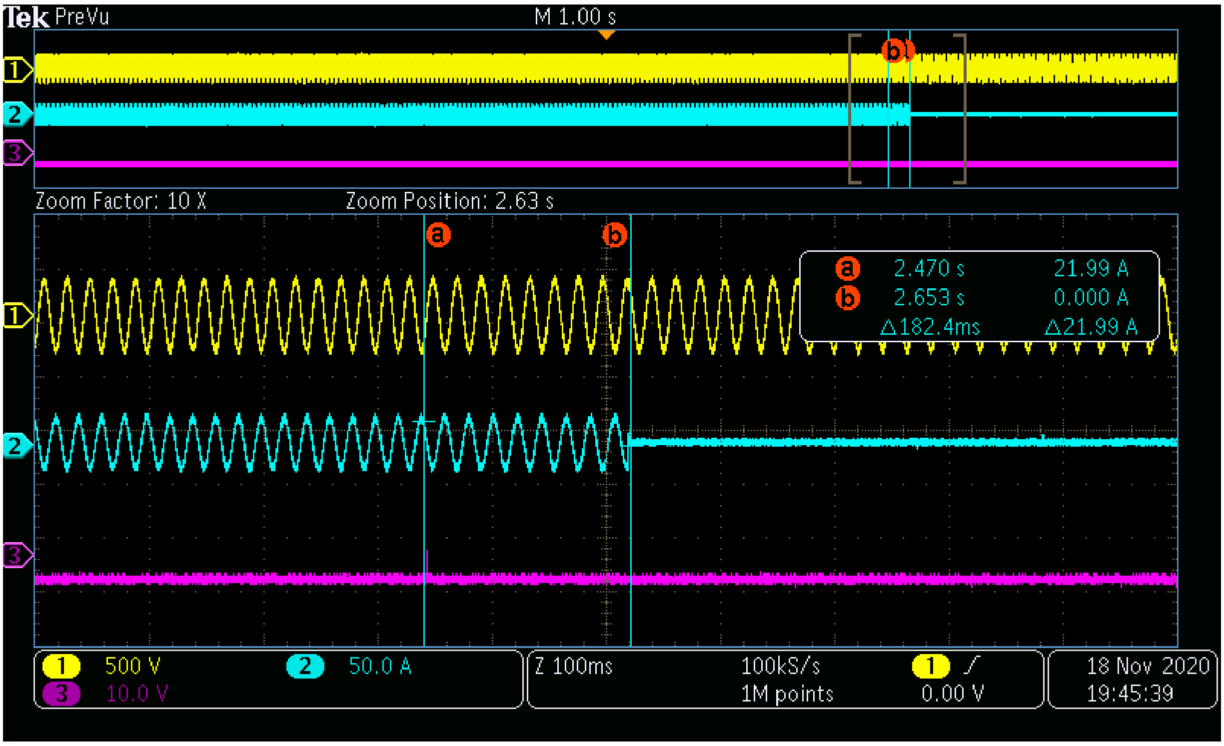
Scope pictures of the disconnection time
Under-frequency - Stage 1



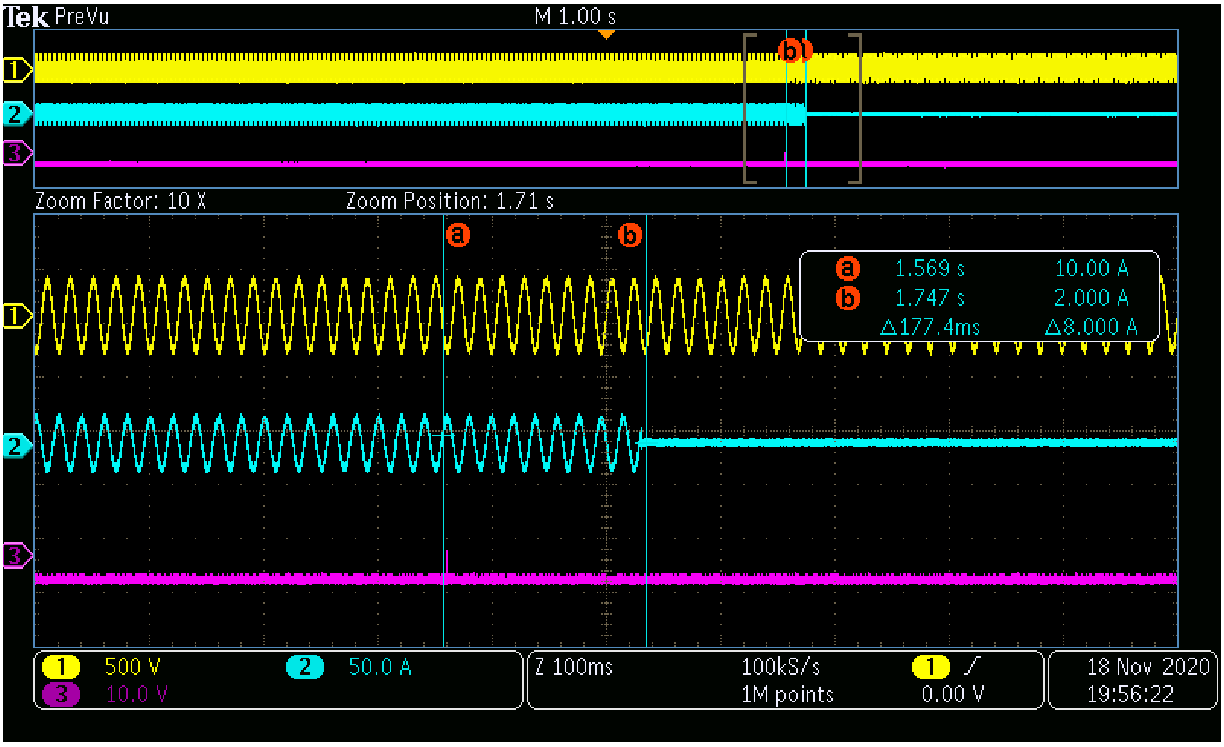
Over-frequency - Stage 1



Under-frequency - Stage 2



Over-frequency - Stage 2



4.9.3 4.9.3.1	Requirements on voltage and frequency protection General (Interface protection: Over/under frequency) (Setting value refer EN 50438 default setting for Netherlands)				P
Test conditions	Output power: 12,0kW U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	**Frequency**	**Time**	**Frequency**	**Time**	
Limit	47,50 Hz	200 ms	51,50 Hz	200 ms	
Trip value [Hz]	47,50		51,50		
	47,50		51,51		
	47,48		51,50		
	47,49		51,50		
	47,50		51,51		
Disconnection time [ms]	48,1 Hz to 47,9 Hz	160	50,9 Hz to 51,1 Hz	175	
		163		174	
		183		177	
		182		167	
		164		166	

Note:

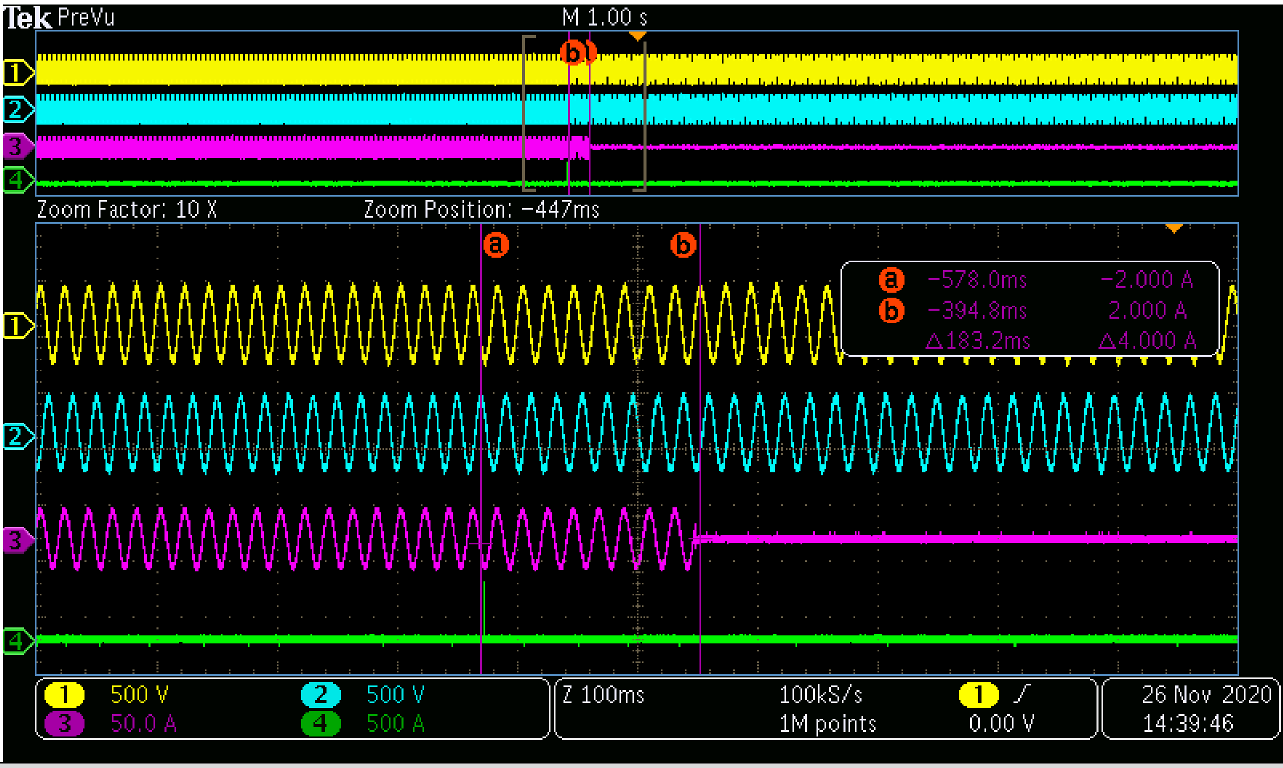
For under-frequency testing the applied frequency is varied from f_n down to $f_{th\text{-}low}$ -0,1 Hz in steps of 0,025 Hz with a time duration per step exceeding the configured disconnection time, The operate value is the value of the applied frequency at switch the protection function trips and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

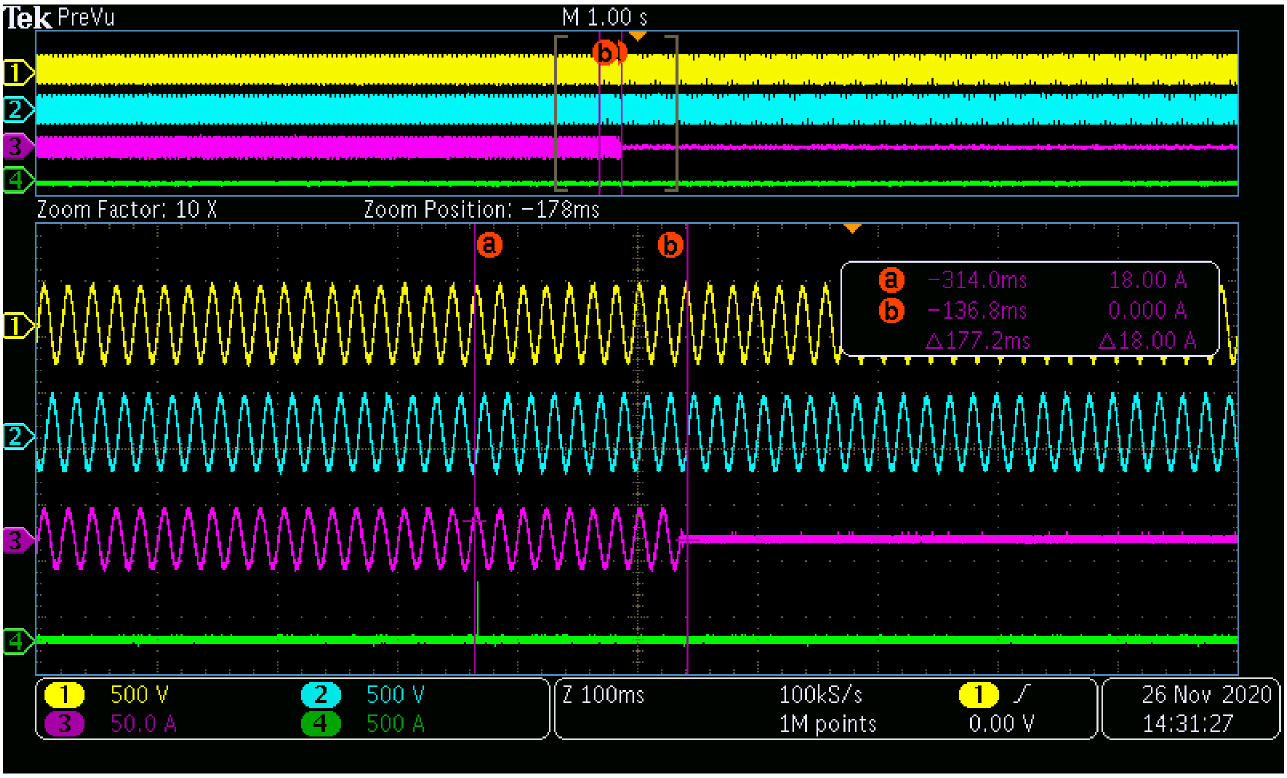
The oscilloscope pictures below show the measured worst case disconnection times.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Scope pictures of the disconnection time
Under-frequency



Over-frequency



4.9.3 4.9.3.1	**Requirements on voltage and frequency protection** **General (Interface protection: Over/under frequency)** **(Setting value refer EN 50438 default setting for Finland)**				**P**
Test conditions	Output power: 12,0kW U_n = 230Vac				
	Under-frequency		**Over-frequency**		
Parameter	**Frequency**	**Time**	**Frequency**	**Time**	
Limit	47,50 Hz	200 ms	51,50 Hz	200 ms	
Trip value [Hz]	47,50		51,50		
	47,50		51,51		
	47,50		51,50		
	47,50		51,50		
	47,50		51,50		
Disconnection time [ms]	50,0 Hz to 47,4 Hz	195	50,0 Hz to 51,6 Hz	177	
		185		187	
		197		157	
		174		183	
		182		172	

Note:

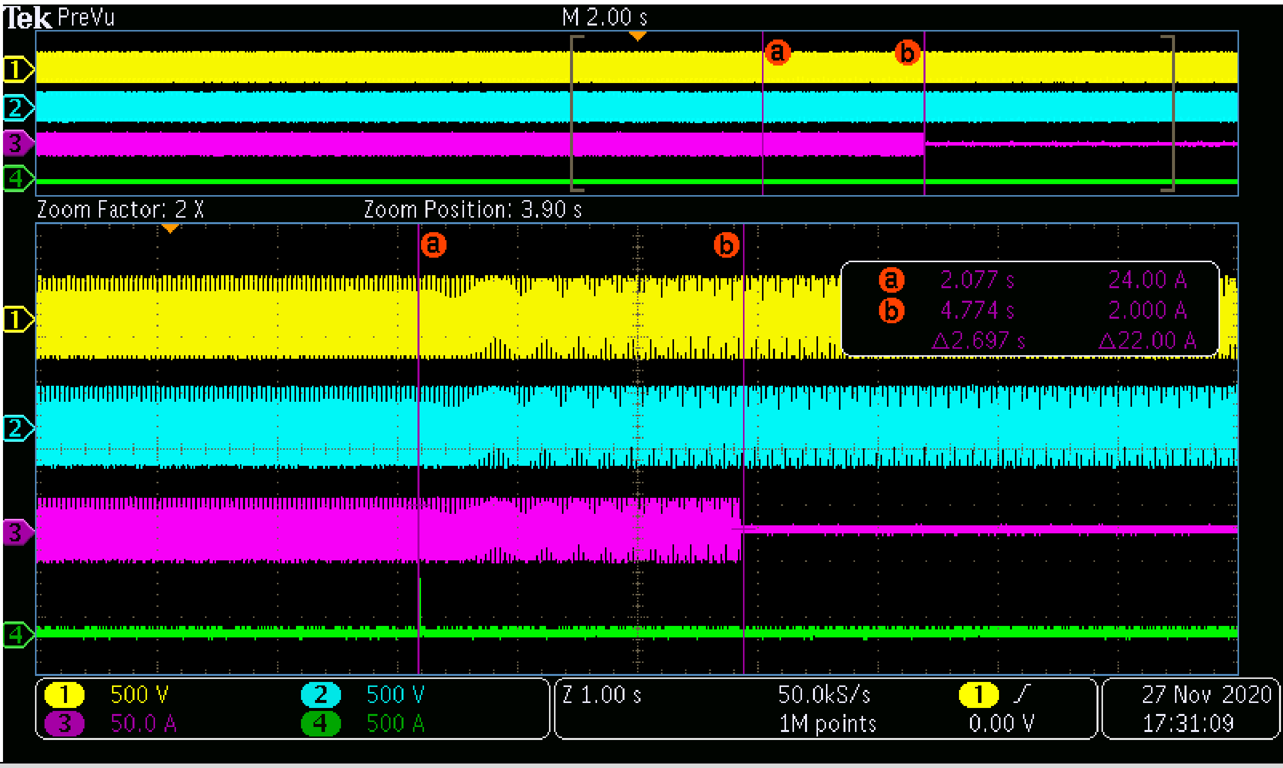
For under-frequency testing the applied frequency is varied from f_n down to f_{th-low} -0,1 Hz in steps of 0,025 Hz with a time duration per step exceeding the configured disconnection time, The operate value is the value of the applied frequency at switch the protection function trips and shall be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

For over-frequency testing the applied frequency is varied from f_n up to $f_{th-high}$ + 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 $f_{th-high}$ ± 0,05 Hz.

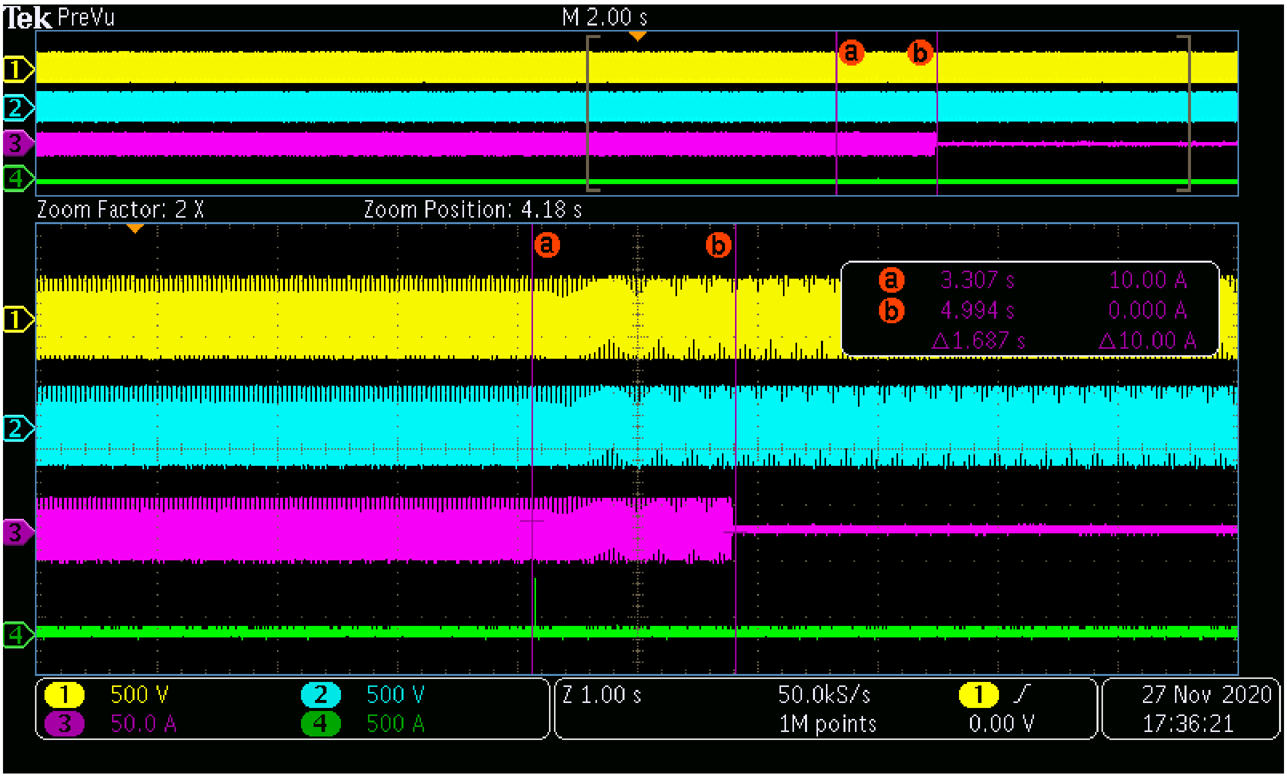
The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Scope pictures of the disconnection time

Under-frequency



Over-frequency



4.9.4.2 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

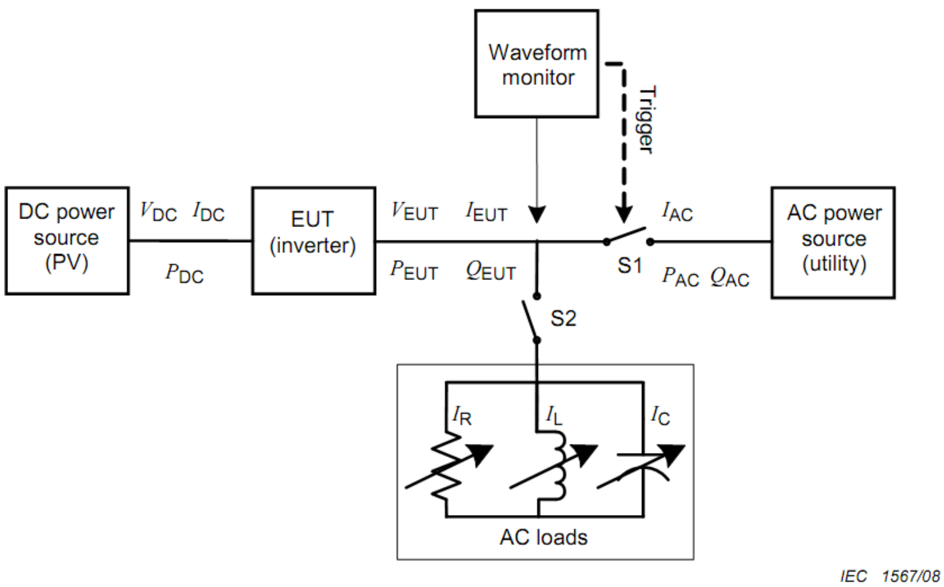


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

Load imbalance (real, reactive load) for test condition A (EUT output = 100%)										P
Test :										
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**	0,086	8000	695	1,002	501	**BL**
4	100	100	-5	-5	1,846	8000	695	1,028	449	IB
5	100	100	-5	0	1,891	8000	695	1,054	379	IB
6	100	100	-5	+5	1,844	8000	695	1,080	437	IB
7	100	100	0	-5	0,108	8000	695	0,976	438	IB
8	100	100	0	+5	0,107	8000	695	1,026	395	IB
9	100	100	+5	-5	1,802	8000	695	0,930	397	IB
10	100	100	+5	0	1,761	8000	695	0,954	469	IB
11	100	100	+5	+5	1,803	8000	695	0,978	416	IB
Parameter at 0% per phase			L= 21,01 mH			R= 6,61 Ω		C= 482,46 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:

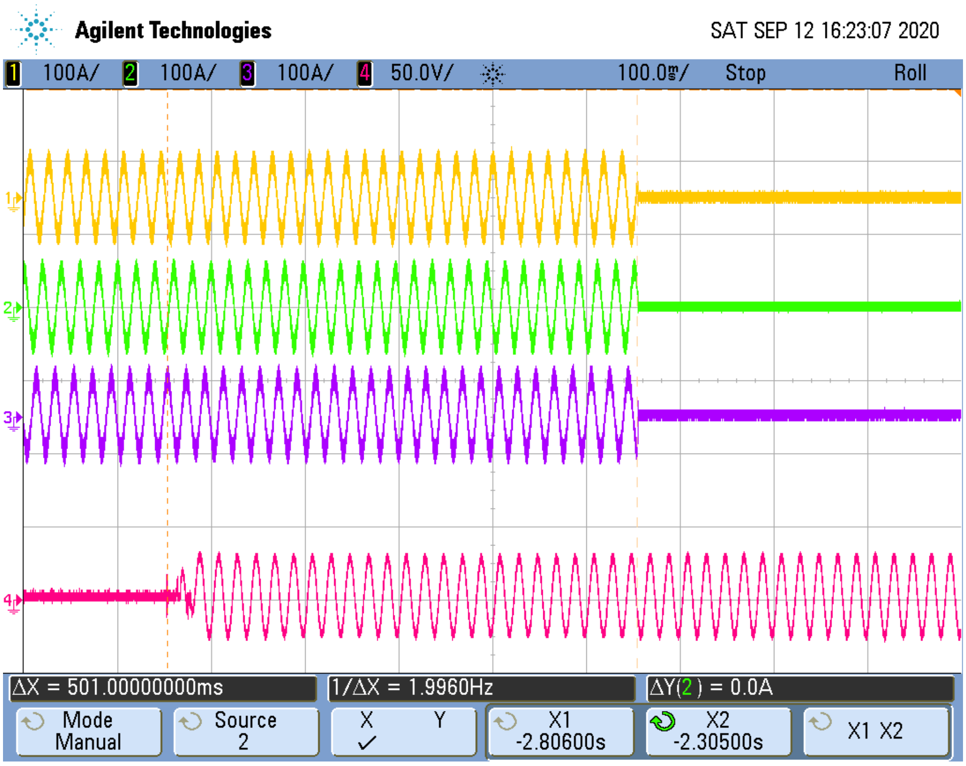
EUT output power P_{EUT} = Maximum 6)

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, 75 % 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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Scope pictures of the disconnection time
Disconnection at No. 1


Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %)										P
Test :										
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)
12	66	66	0	-5	0,218	5280	510	0,975	413	IB
13	66	66	0	-4	0,208	5280	510	0,980	481	IB
14	66	66	0	-3	0,200	5280	510	0,985	469	IB
15	66	66	0	-2	0,194	5280	510	0,990	463	IB
16	66	66	0	-1	0,190	5280	510	0,995	384	IB
2	**66**	**66**	**0**	**0**	0,089	5280	510	1,000	511	**BL**
17	66	66	0	1	0,190	5280	510	1,005	480	IB
18	66	66	0	2	0,193	5280	510	1,010	500	IB
19	66	66	0	3	0,199	5280	510	1,015	484	IB
20	66	66	0	4	0,207	5280	510	1,020	489	IB
21	66	66	0	5	0,217	5280	510	1,025	474	IB

Parameter at 0% per phase	L= 31,75 mH	R= 9,98 Ω	C= 319,21 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.

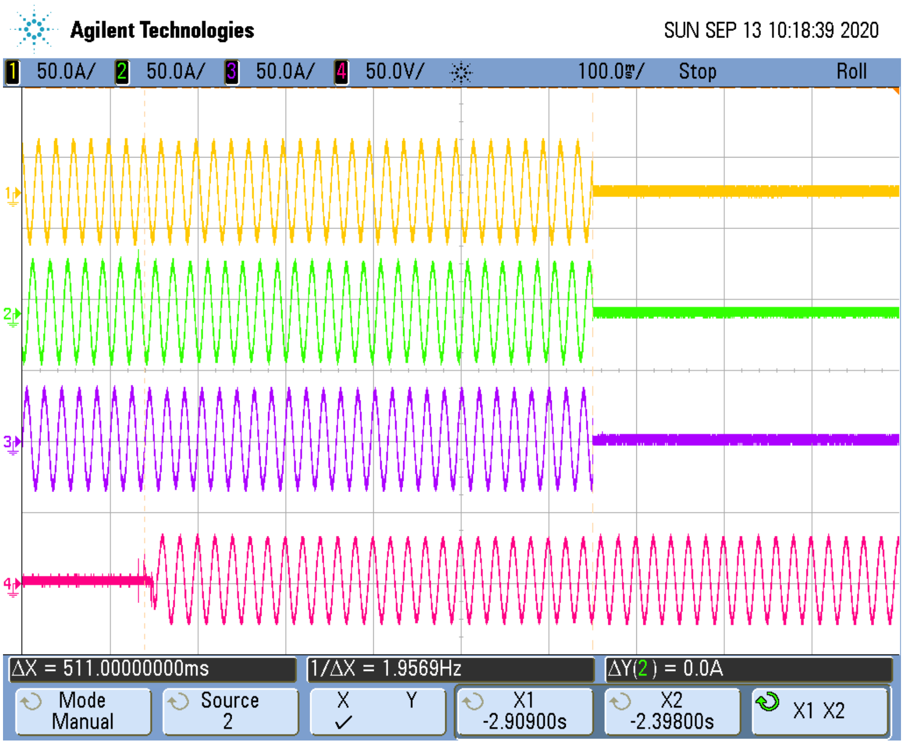
Condition B:

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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.The test results refer to the original test report PV191016N002-1 issued by Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch, dated on 2019-11-04.

Scope pictures of the disconnection time
Disconnection at No. 2


Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %)										P
Test :										
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)
22	33	33	0	-5	0,511	2640	288	0,974	411	IB
23	33	33	0	-4	0,506	2640	288	0,979	487	IB
24	33	33	0	-3	0,502	2640	288	0,984	368	IB
25	33	33	0	-2	0,499	2640	288	0,989	418	IB
26	33	33	0	-1	0,497	2640	288	0,994	410	IB
3	**33**	**33**	**0**	**0**	0,483	2640	288	0,999	497	**BL**
27	33	33	0	1	0,496	2640	288	1,004	372	IB
28	33	33	0	2	0,498	2640	288	1,009	439	IB
29	33	33	0	3	0,501	2640	288	1,014	348	IB
30	33	33	0	4	0,505	2640	288	1,019	445	IB
31	33	33	0	5	0,510	2640	288	1,024	414	IB
Parameter at 0% per phase			L= 63,71 mH			R= 20,02 Ω			C= 158,85 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:

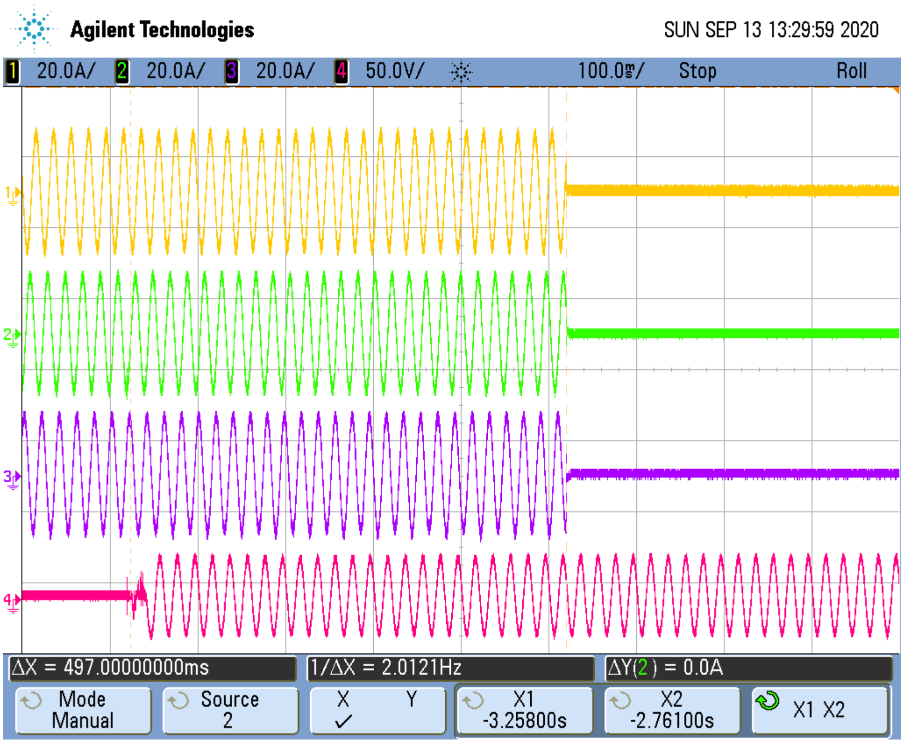
EUT output power P_{EUT} = 25 % – 33 % 6) of maximum

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, 20 % 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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Scope pictures of the disconnection time
Disconnection at No. 3


EN 50549-1:2019: Connection and starting to generate electrical power			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.10.2	Automatic reconnection after trippin	EN 50438, Annex D.3.6	**P**
4.10.3	Starting to generate electrical power	EN 50438, Annex D.3.6	**P**

4.10 4.10.2 4.10.3	**Connection and starting to generate electrical power** **Automatic reconnection after tripping** **Starting to generate electrical power**	**P**

Setting value	Min. voltage for connected to grid :	196
	Max. voltage for connected to grid :	253
	Min. frequency for connected to grid :	49,5
	Max. frequency for connected to grid (Normal operational start-up) :	50,1
	Max. frequency for connected to grid (Automatic reconnection after tripping) :	50,2
	Observation time (≥60s) :	60

Test:

	Voltage conditons	
a) Start up for voltage range	<85% Un for twice of observation time	>110% Un for twice of observation time
Connection:	No connection	No connection
Limit	No connection allowed	
b) In voltage range at start-up	≥85% Un within twice setting observation time	≤110% Un within twice setting observation time
Reconnection time [s]	68,0 s	68,0 s
Limit:	Connected after setting observation time (≥60s)	
Gradient:	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: disable, For recorded gradient see diagram below,	
c) In voltage range after voltage failture	≥85% Un for twice of setting observation time	≤110% Un for twice of setting observation time
Reconnection time [s]	76,0 s	76,0 s
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%P_{Emax}/min. 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. For recorded gradient see diagram below.	

	Frequency conditions	
d) Start up for frequency range	<49,50 Hz for twice of setting observation time	>50,10 Hz for twice of setting observation time
Connection:	No connection	No connection
Limit	No connection allowed	
e) In frequency range at start-up	≥49,50 Hz within twice of setting observation time	≤50,10 Hz within twice of setting observation time
Reconnection time [s]	69,0 s	68,0 s
Limit:	Connected after setting delay time(≥60s)	
Gradient:	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: disable. For recorded gradient see diagram below.	
f) In frequency range after frequency failture	≥49,50 Hz for twice of setting observation time	≤50,20 Hz for twice of setting observation time
Reconnection time [s]	75,0 s	68,0 s
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%P_{Emax}/min. 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. For recorded gradient see diagram below.	

Test:

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

Test condition e): frequency within the limits of 49,50Hz to 50,1Hz.

Test condition f): frequency within the limits of 49,50Hz to 50,2Hz.

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.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

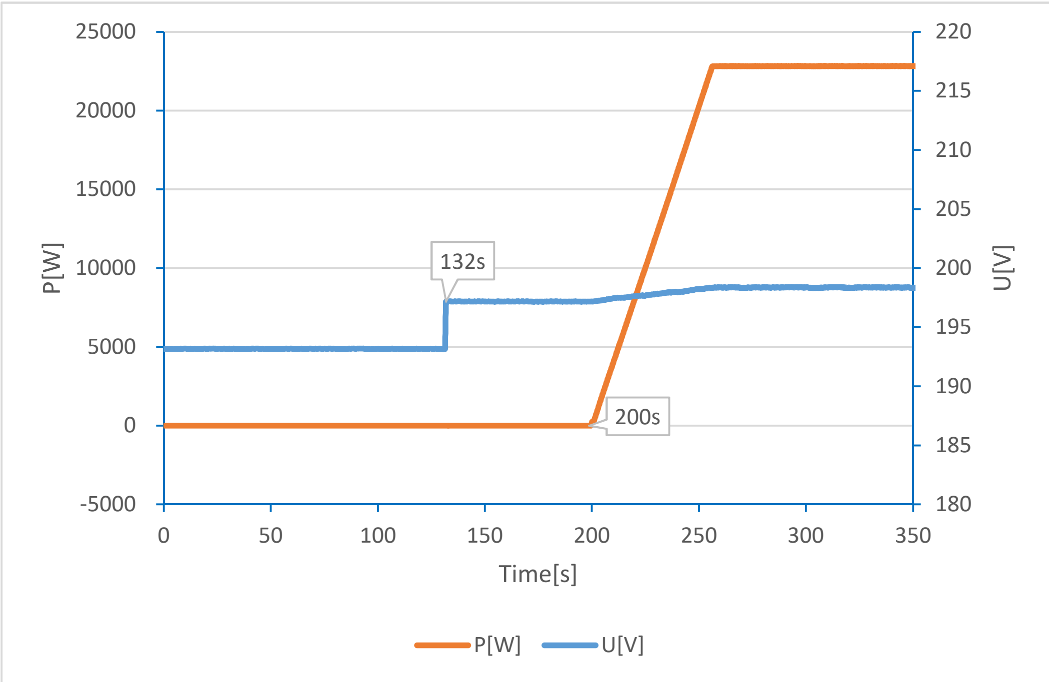
Assessment criterion:

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

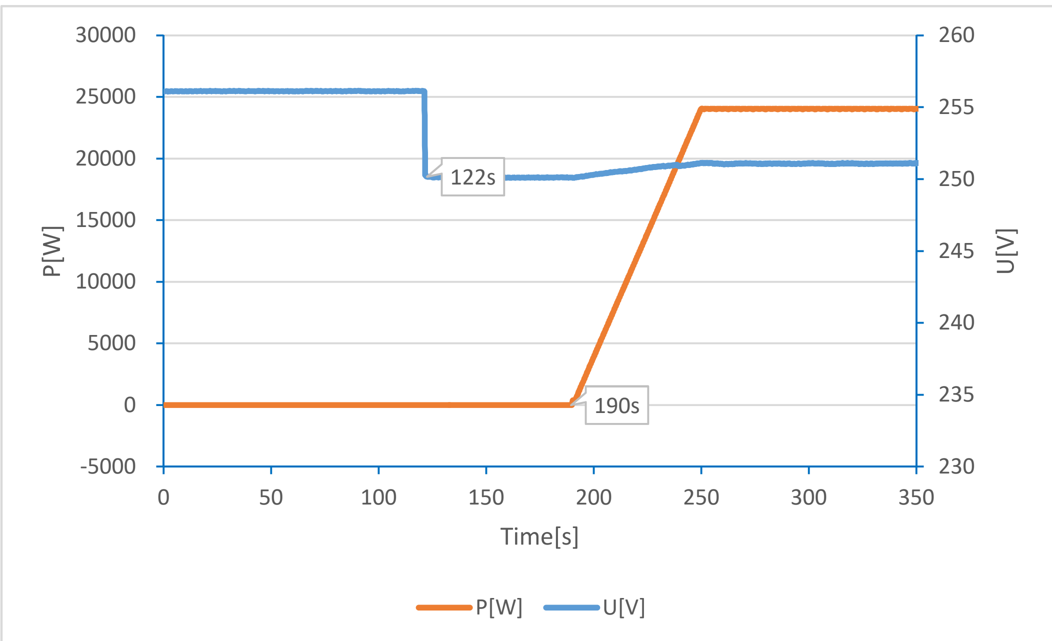
b) for adjustable micro generators the maximum occurring active power gradient after connection respectively start generating electrical power is less than the configured maximum active power per minute and

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.

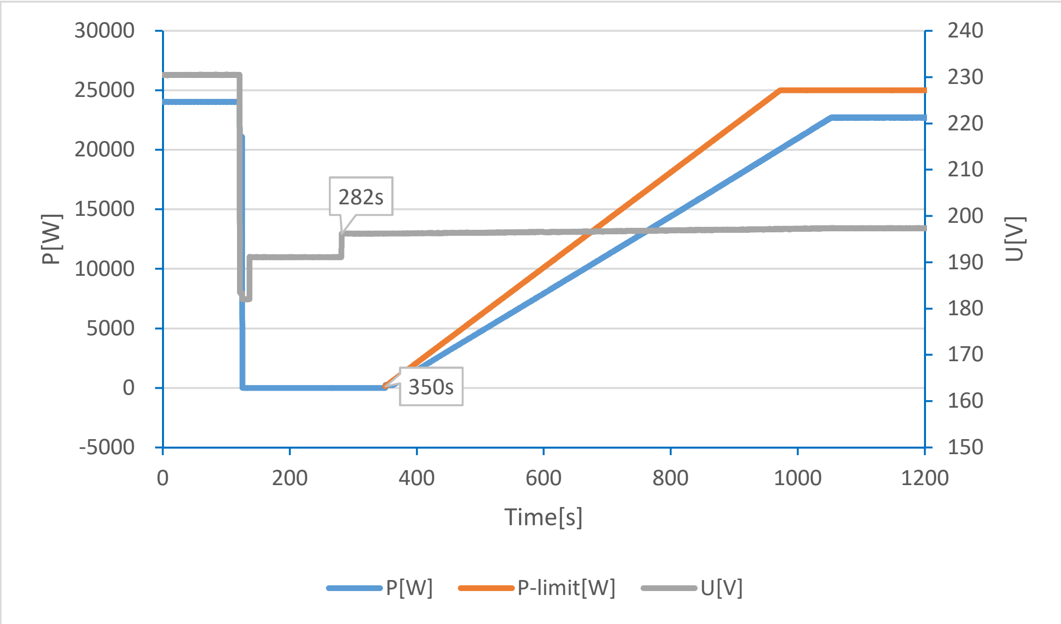
Graph of the gradual power supply : Test b) for ≥ 85% U_n



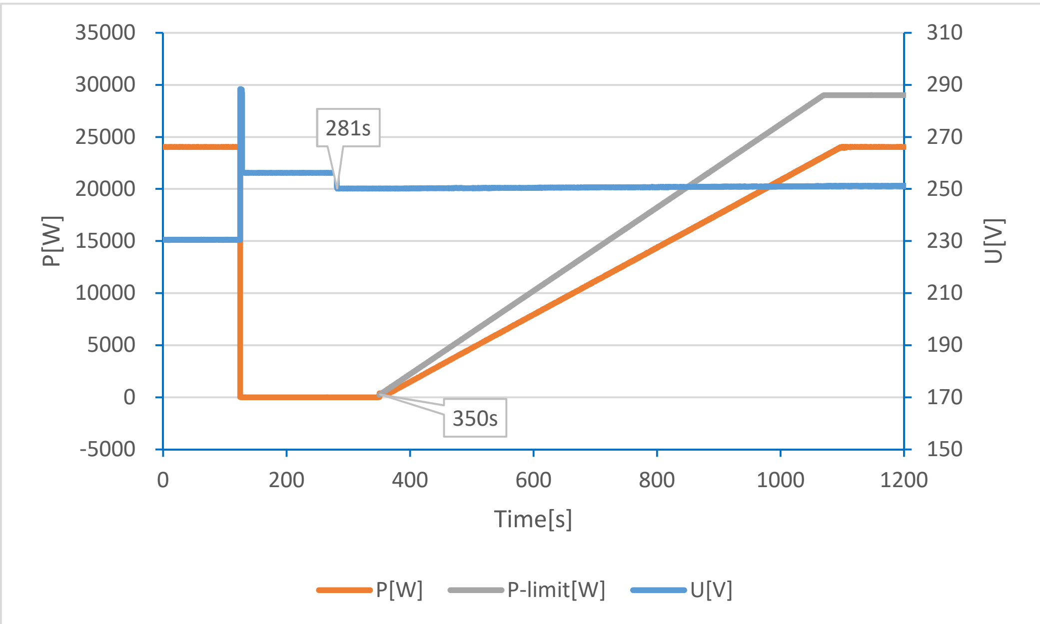
Graph of the gradual power supply : Test b) for ≤ 110% U_n



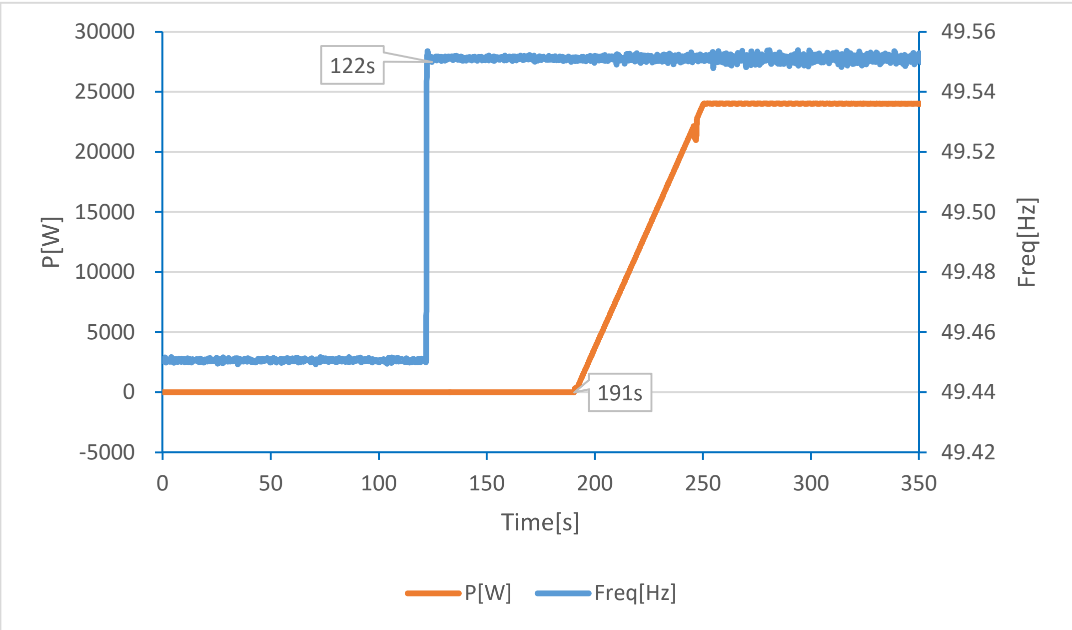
Graph of the gradual power supply : Test c) for ≥ 85% U_n



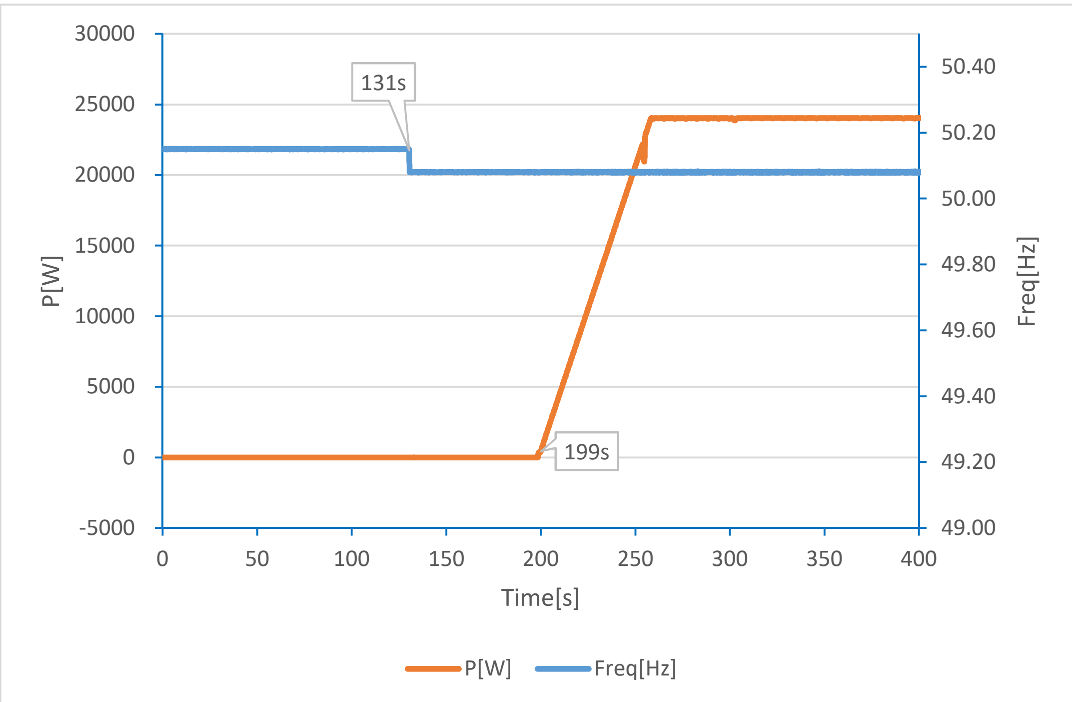
Graph of the gradual power supply : Test c) for ≤ 110% U_n



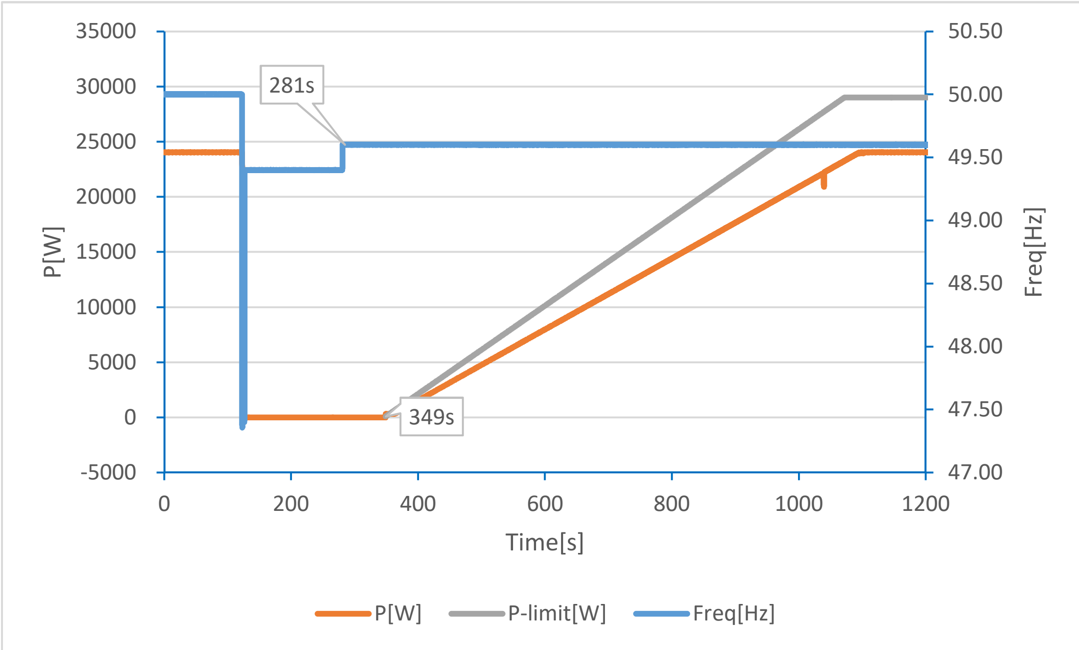
Graph of the gradual power supply : Test e) for ≥ 49,50Hz



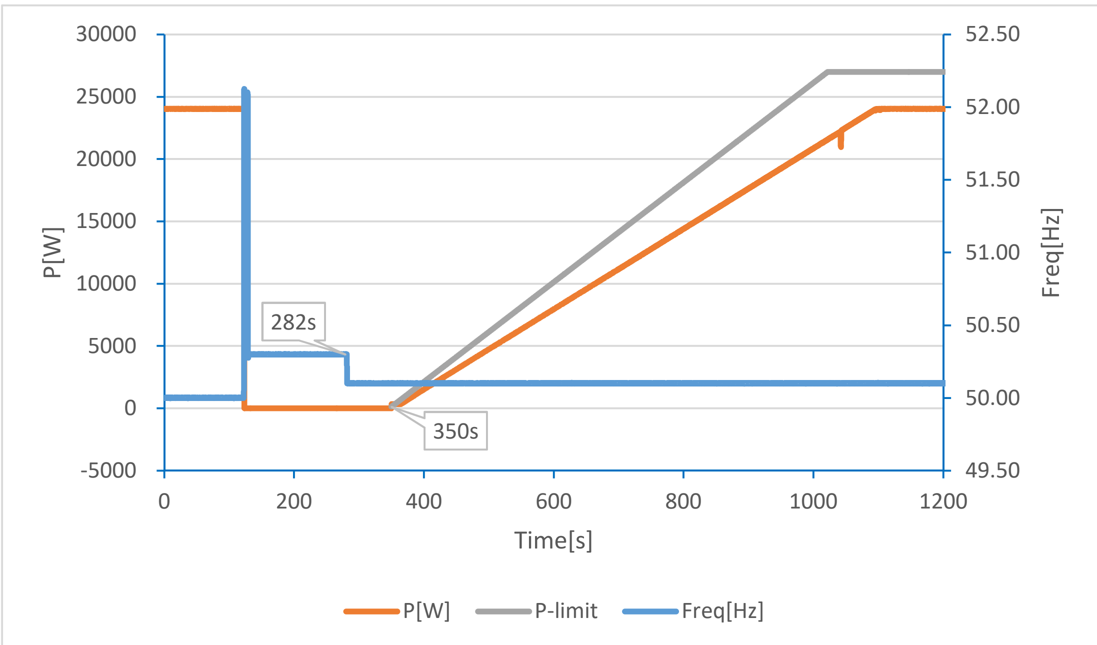
Graph of the gradual power supply : Test e) for ≤ 50,10Hz



Graph of the gradual power supply : Test f) for ≥ 49,50Hz



Graph of the gradual power supply : Test f) for ≤ 50,20Hz



EN 50549-1:2019: Ceasing and reduction of active power on set point			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.11.1	Ceasing active power	CEI 0-21:2019-04, Annex A.4.3.3.2	**P**
4.11.2	Reduction of active power on a set point	FGW TG3, Revision 25, clause 4.1.2	**P**

4.11.1	Ceasing active power	P

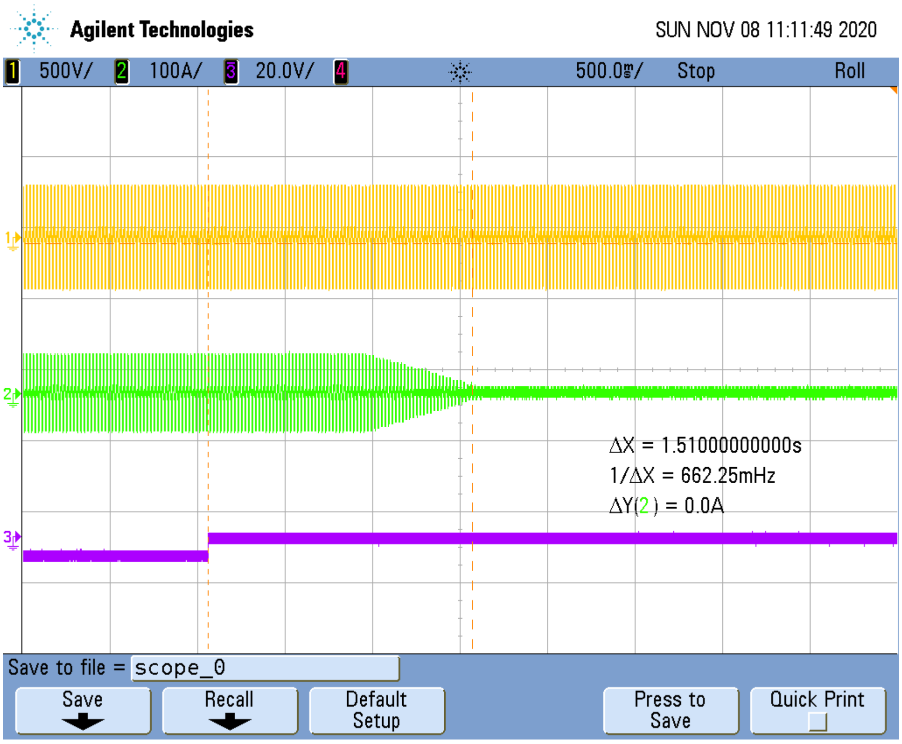
Operating time of the monitoring device	
Test:	Remote tripping signal for the external disconnection
Limit [s]:	5 s
Reaction time of the tripping value [s]:	1,51 s

Note:

The test method refer to Annex A,4,3,2 of CEI 0-21:2019-04.
Generating plants shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port, If required by the DSO, this includes remote operation.

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Graph of Remote trip signal :



4.11.2	Reduction of active power on set point			P
Test result:				
Setpoint power bin [%P_{Emax}]	P_{set} [kW]	P_{60} [kW]	Deviation [%P_{Emax}]	
100%	24,000	24,087	0,364	
90%	21,600	21,644	0,185	
80%	19,200	19,199	-0,003	
70%	16,800	16,747	-0,221	
60%	14,400	14,366	-0,140	
50%	12,000	12,084	0,351	
40%	9,600	9,648	0,201	
30%	7,200	7,214	0,059	
20%	4,800	4,773	-0,112	
10%	2,400	2,462	0,260	
3%	0,720	0,591	0,260	

	Setpoint power bin [%P_{Emax}]	Deviation [%P_{Emax}]
Max. deviation	100%	0,364
Limit $\Delta P_{E60}/P_{Setpoint}$:	+ 5 % of P_{Emax}	

Test:

The setpoint signal must be reduced from 100% to 0% P_{Emax}:

a) for adjustable PGUs in increments of 10% P_{Emax}, 1 minute must elapse after every change to the setpoint setting so that the PGU can settle at the new setpoint, Then the active power of the PGU must be measured as a 1-min mean value.

b) For all other PGUs, in line with their adjustable steps, 5 minutes must elapse after the setpoint setting is changed so that the PGU can settle at the new setpoint, Then the active power of the PGU must be measured as a 1-min mean value.

Assessment criterion:

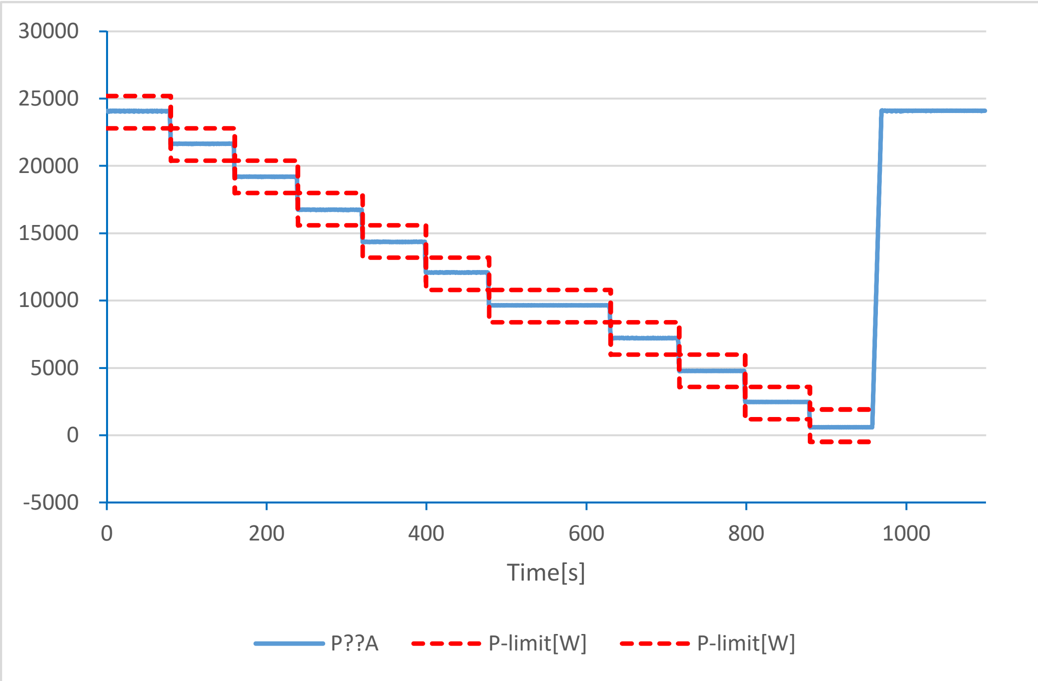
a) for adjustable PGUs:

- no network disconnection
- the active power value does not exceed the setpoint by more than 5% P_{Emax}
- the setting time determined this way is ≤ 1min

b) For all other PGUs:

- the active power value does not exceed the setpoint by more than 5% P_{Emax} or
- the setpoint is fallen below within 5 minutes or the PGU has switched off

Note: The setting time is ≤ 1min. See below “Graph of the setting accuracy”. The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.
Graph of active power on set point



EN 50549-1:2019			
Clause	**Test requirement**	**Test procedure according standard**	**Result**
4.13	Requirements regarding single fault tolerance of interface protection system and interface switch	VDE V 0124-100:2019-02 (Draft), clause 5.5.2	**P**

4.13	Requirements regarding single fault tolerance of interface protection system and interface switch	P

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
PV inverter current monitoring defect R3	Short	230V 35A	850V 29A	10min.	--	230V 0,1A	850V <1A	Inverter disconnected from grid immediately. Error message:" HwPVOCP". No damaged. No hazard.
PV current monitoring defect R852	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" HwPVOCP". No damaged.No hazard
PV inverter current monitoring defect U1 pin1-3	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" HwPVOCP". No damaged.No hazard.
Relay detect RL1	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter did not start-up. Error message:" RelayTestFail". No damage.No hazard.
Relay detect RL2	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter did not start-up. Error message:" RelayTestFail". No damage.No hazard.
Relay detect RL3	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter did not start-up. Error message:" RelayTestFail". No damage.No hazard.
Relay detect RL4	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter did not start-up. Error message:" RelayTestFail". No damage.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
Relay detect RL5	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter did not start-up. Error message:" RelayTestFail". No damage.No hazard.
Relay detect RL6	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter did not start-up. Error message:" RelayTestFail". No damage.No hazard.
AC Voltage monitoring defect R56	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
AC Voltage monitoring defect R58	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.
AC Voltage monitoring defect R95	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
AC Voltage monitoring defect R96	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
AC Voltage monitoring defect R97	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
AC Voltage monitoring defect R101	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
AC Voltage monitoring defect R102	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.
AC Voltage monitoring defect R103	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.
ISO detect R168	short before start-up	230V 0,1A	850V 0,1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R169	short before start-up	230V 0,1A	850V 0,1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R22	Open before start-up	230V 0,1A	850V 0,1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R23	short before start-up	230V 0,1A	850V 0,1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R186	Open before start-up	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R188	Short before start-up	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
ISO detect R193	Open before start-up	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R194	Short before start-up	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R174	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R175	Short before start-up	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R212	Open before start-up	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO detect R207	Short before start-up	230V 35A	850V 29A	10min.	--	230V 35A	850V 29A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
GFCI monitoring defect R421	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect R426	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
GFCI protect C275	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect C270	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect R413	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect U5-D pin12-14	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect U5-C pin10-8	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect C252	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
GFCI protect R411	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" AFCIFault". No damaged.No hazard.
PV voltage monitor defect R515	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvOVP" No damaged.No hazard.
PV voltage monitor defect R517	Open	230V 17A	850V 15A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvUVP" No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
PV voltage monitor defect R522	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvOVP" No damaged.No hazard.
PV voltage monitor defect R524	Open	230V 17A	850V 15A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvUVP" No damaged.No hazard.
PV voltage monitor defect R529	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvOVP" No damaged.No hazard.
PV voltage monitor defect R531	Open	230V 17A	850V 15A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvUVP" No damaged.No hazard.
PV voltage monitor defect R538	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvOVP" No damaged.No hazard.
PV voltage monitor defect R540	Open	230V 17A	850V 15A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" InvUVP" No damaged.No hazard.
Bus voltage detect R547	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Bus voltage detect R549	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Bus voltage detect R552	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
Bus voltage detect R554	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Bus voltage detect R557	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Bus voltage detect R559	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Bus voltage detect R562	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Bus voltage detect R564	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" VbusRmsUnbalance". No damaged.No hazard.
Grid voltage monitor defect R601	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
Grid voltage monitor defect R602	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.
Grid voltage monitor defect R589	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
Grid voltage monitor defect R590	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridUVP”. No damaged.No hazard.
Grid voltage monitor defect R597	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridOVP”. No damaged.No hazard.
Grid voltage monitor defect R596	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridUVP”. No damaged.No hazard.
Grid voltage monitor defect R569	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridOVP”. No damaged.No hazard.
Grid voltage monitor defect R836	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridUVP”. No damaged.No hazard.
Grid voltage monitor defect R574	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridOVP”. No damaged.No hazard.
Grid voltage monitor defect R839	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridUVP”. No damaged.No hazard.
Grid voltage monitor defect R578	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:” GridOVP”. No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
Grid voltage monitor defect R841	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
Grid voltage monitor defect R583	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridOVP". No damaged.No hazard.
Grid voltage monitor defect R587	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" GridUVP". No damaged.No hazard.
BUS voltage monitoring defect R613	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" BUS voltage is low". No damaged.No hazard.
BUS voltage monitoring defect R614	Short	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" Inverter bus hardware overvoltage". No damaged.No hazard.
ISO monitoring defect R189	Open before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO monitoring defect R510	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
ISO monitoring defect R799	Open before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.

Component No.	Fault	Test condition		Test time	Fuse No.	Fault condition		Result
		AC	DC			AC	DC	
ISO monitoring defect R801	Short before start-up	230V <1A	850V <1A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" IsoFault". No damaged.No hazard.
Communication defect U13 pin82	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" BluetoothFault". No damaged.No hazard.
Communication defect U13 pin95	Open	230V 35A	850V 29A	10min.	--	230V <1A	850V <1A	Inverter disconnected from grid immediately. Error message:" BluetoothFault". No damaged.No hazard.
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

Note:

The tests had been performed on the SOFAR 24KTLX-G3 is valid for the SOFAR 15KTLX-G3, SOFAR 17KTLX-G3, SOFAR 20KTLX-G3 and SOFAR 22KTLX-G3, since it is identical in hardware and software construction except output power derated by software.

Annex No. 1

Pictures of the unit

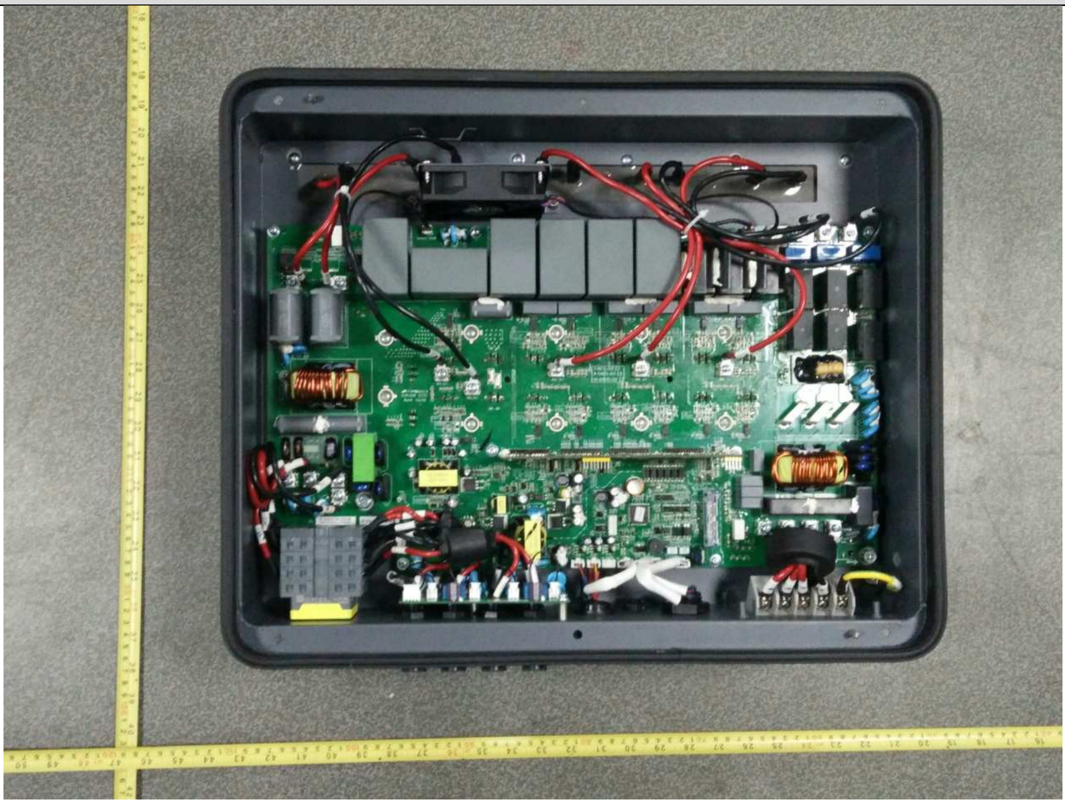
Enclosure front view

Enclosure side view

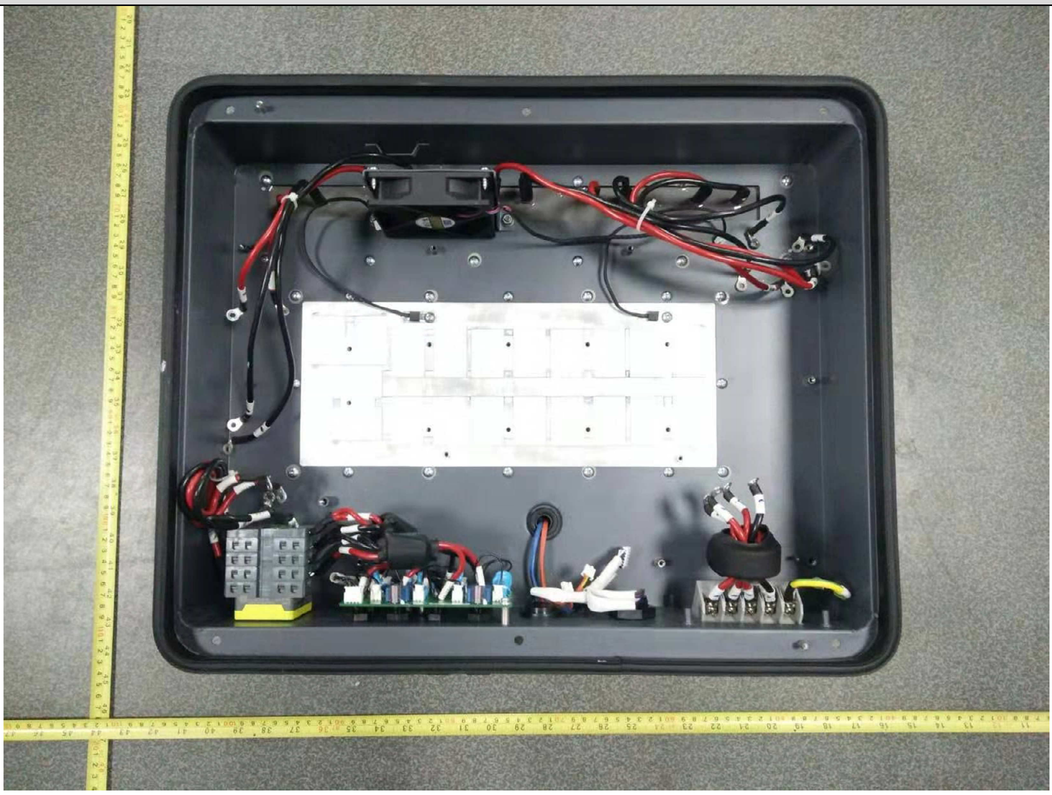
Enclosure bottom view SOFAR 15KTLX-G3, SOFAR 17KTLX-G3

Enclosure bottom view SOFAR 20KTLX-G3, SOFAR 22KTLX-G3, SOFAR 24KTLX-G3

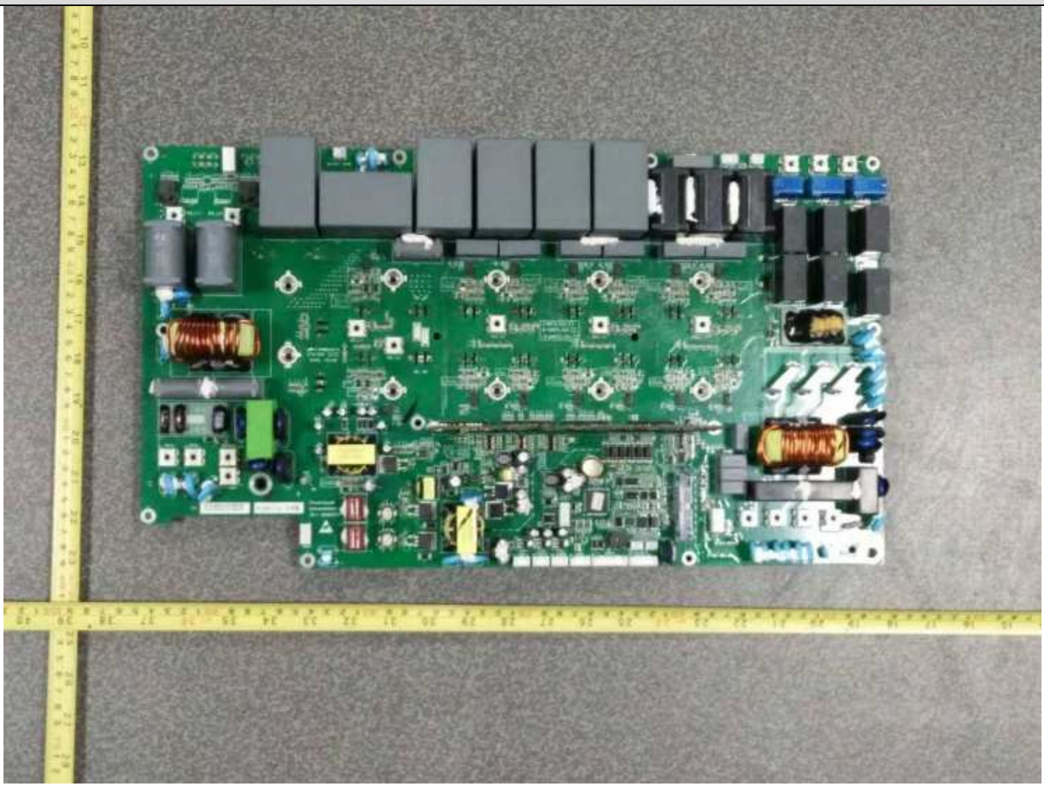

Enclosure rear view

Internal view


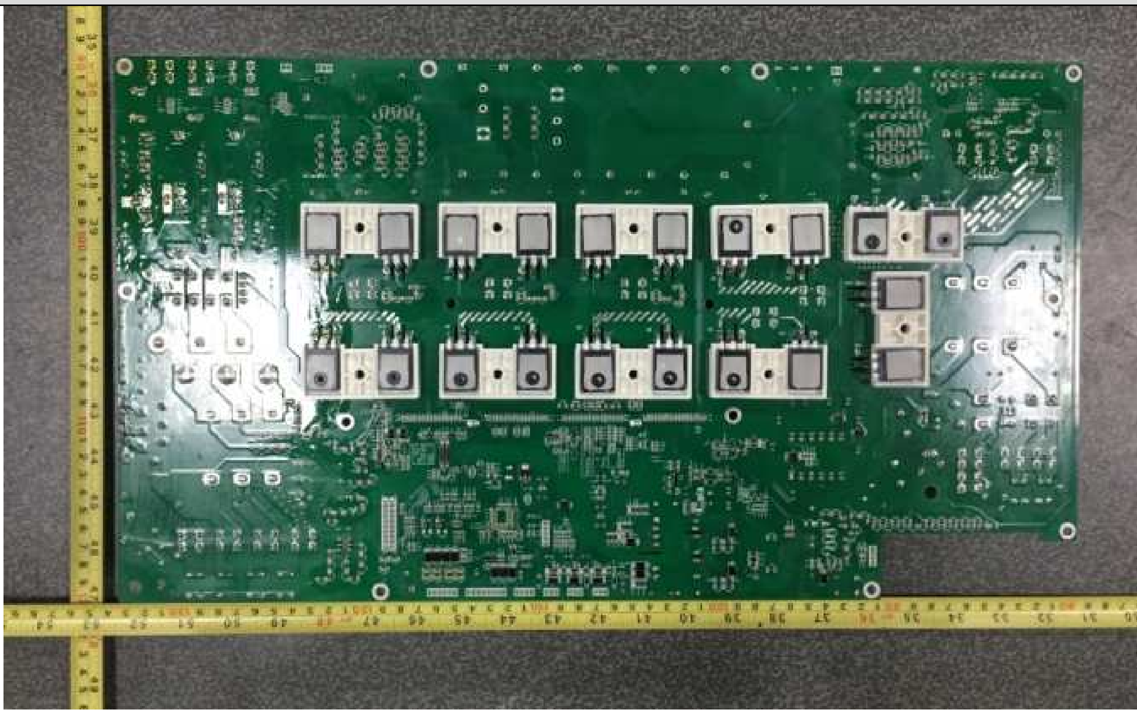
Internal view



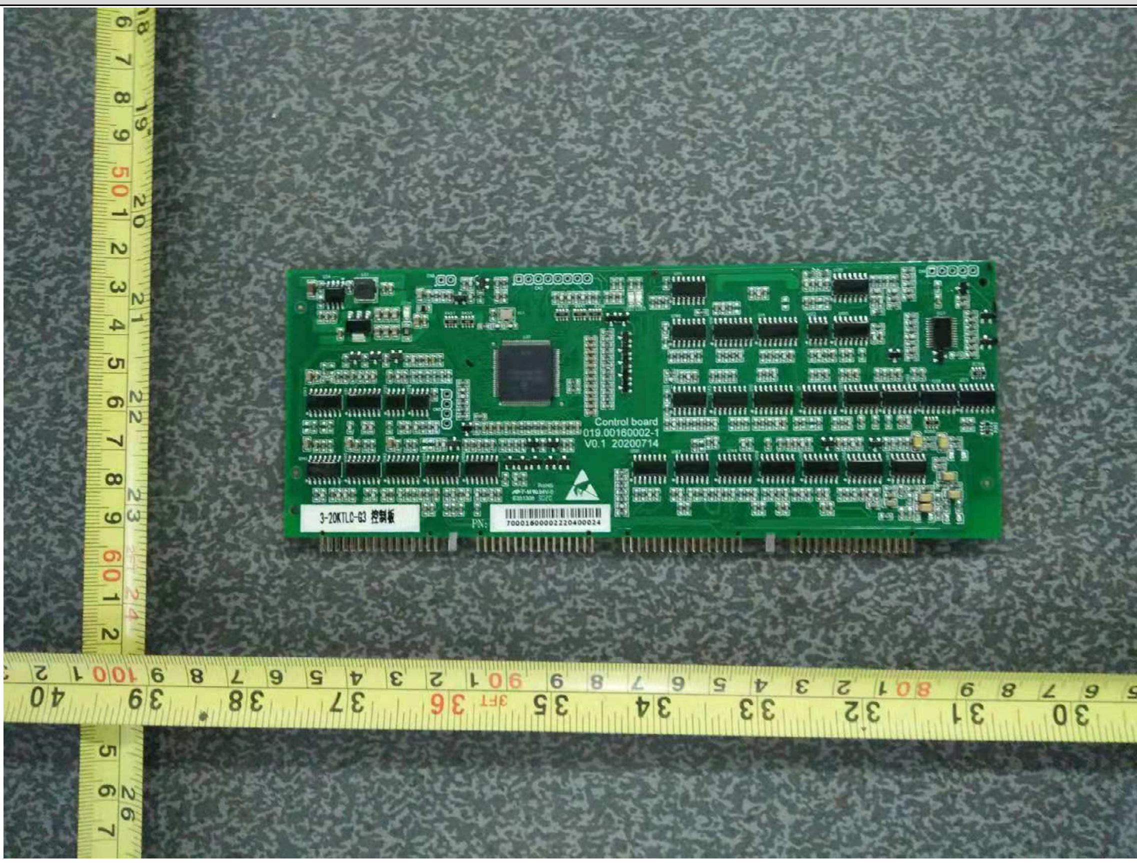
Power board component side view



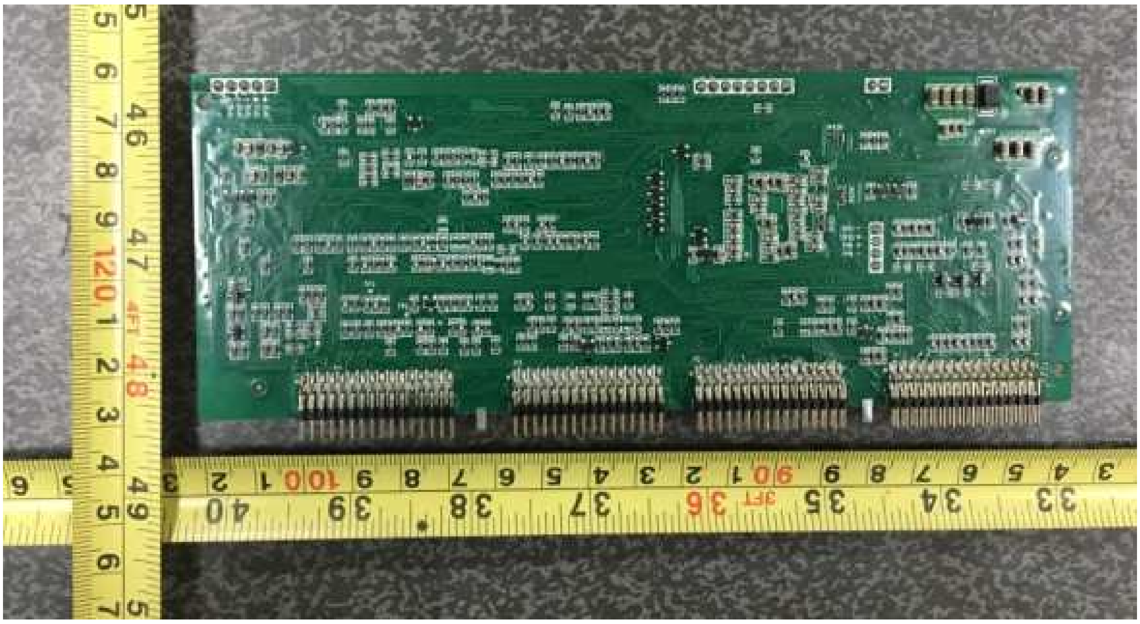
Power board solder side view



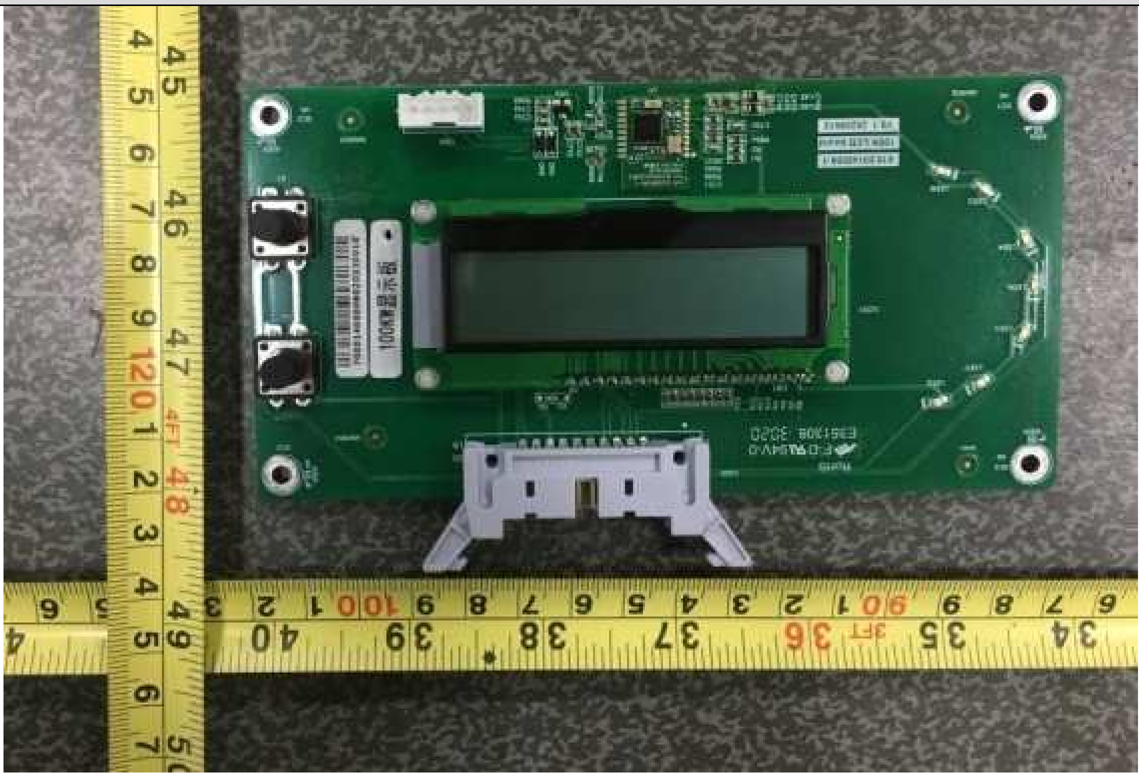
Control board component side view

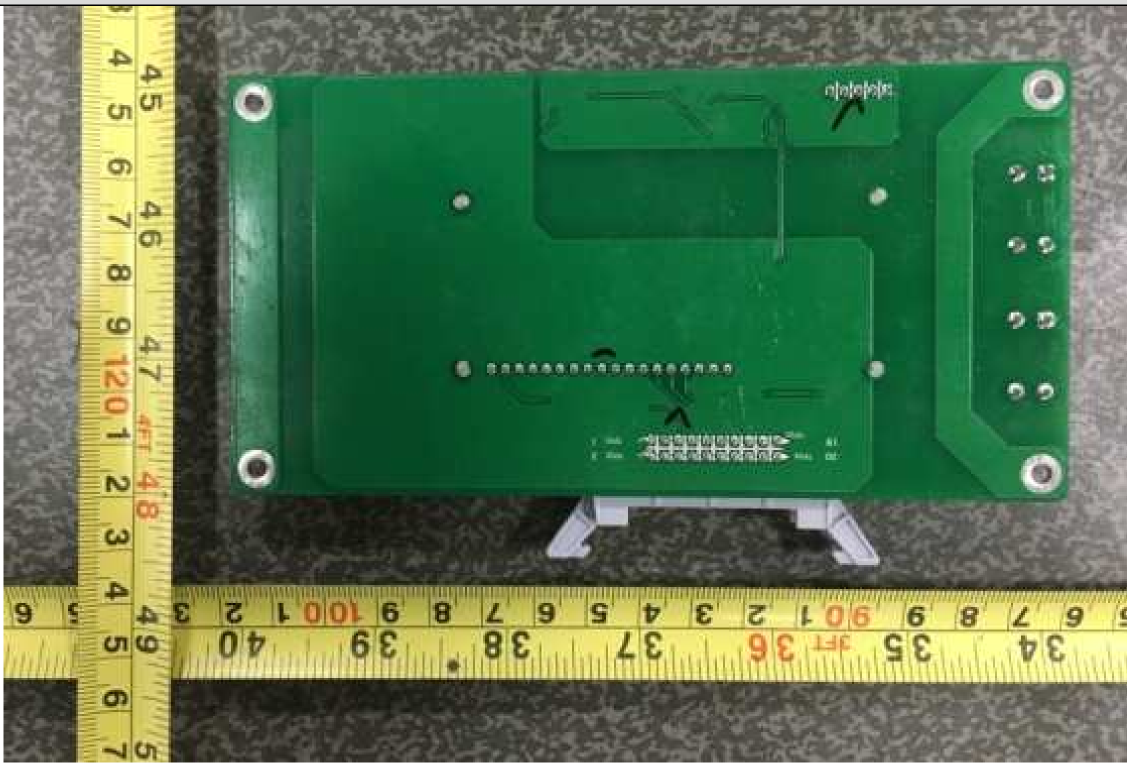


Control board solder side view



LCD board component side view



LCD board solder side view

General view of Grouding point


Annex No. 2

Test Equipment list

Dates of performance test: 2020-06-01 to 2020-12-18

Equipment	Internal No.	Manufacturer	Type	Serial No.	Next Calibration date
Power Analyser	A4080002DG	YOKOGAWA	WT3000	91M210852	Jun. 16, 2021
AC Source	A7040019DG	Chroma	61512	61512000439	Monitored by Power Analyser
	A7040020DG	Chroma	61512	61512000438	
DC Simulation Power Supply	A7040015DG	Chroma	62150H-1000S	62150EF00488	
	A7040016DG	Chroma	62150H-1000S	62150EF00490	
	A7040017DG	Chroma	620028	620028EF00120	
RLC Load	A7150027DG	Qunling	ACLT-3803H	93VOO2869	
Eight Channel Digital Phosphor Oscilloscope	A4089017DG	YOKOGAWA	DL850	91N726247	Sep. 24, 2020
Oscilloscope probe	A4089008DG	Tektronix	TPP1000	C008230	Aug. 10, 2021
	A4089010DG	Tektronix	TPP1000	C008228	Aug. 10, 2021
	A4089011DG	Tektronix	TPP1000	C008229	Aug. 10, 2021
Current transducer	A1060007DG	YOKOGAWA	CT200	1130700012	Sep. 02, 2021
	A1060008DG	YOKOGAWA	CT200	1130700017	Sep. 02, 2021
	A1060012DG	YOKOGAWA	CT200	1130700018	Sep. 02, 2021
Power Analyser	//	ZLG	PA5000H	C8202909082002110001	Mar. 02, 2021
Oscilloscope	//	Agilent	DS05014A	MY50070288	Jan. 13, 2021
Oscilloscope current probe	//	CYBERTEK	CP1000A	C181000922	Jan. 13, 2021
	//	CYBERTEK	CP1000A	C181000925	Jan. 13, 2021
	//	CYBERTEK	CP1000A	C181000929	Jan. 13, 2021
	//	CYBERTEK	CP1000A	C181000931	Jan. 13, 2021
Oscilloscope probe	//	SANHUA	SI-9110	152627	Jan. 13, 2021
	//	SIALENT	DS5034X	SDS5XEAC3R0011	Jan. 13, 2021
	//	AGILENT	N2863B	YF0139	Jan. 13, 2021