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TEST REPORT

EN 50549-1:2019

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

Report Reference No......................:	211200318TPE-001
Date of issue....................................:	2022-01-13
Total number of pages......................	174 pages
Testing Laboratory ....:	Intertek Testing Services Taiwan Ltd.
Address ....:	5F, No. 423, Ruiguang Rd., Neihu District, Taipei 114, Taiwan
Tested by (name + signature) ....:	Ted Wu Project handler
Approved by (+ signature).................:	Hans Yang Reviewer
Applicant's name ....:	MASTER BATTERY, S.L.
Address ....:	Paseo de Extremadura, 39, 28935 Móstoles, Madrid, Spain
Test specification:	
Standard ....:	EN 50549-1:2019 with deviations according the national network and system protection for Czech Republic (PPDS:2020)
Test procedure ....:	Type approval for type B
Non-standard test method…………..:	N/A
Test Report Form No......................:	EN 50549-1a
Test Report Form(s) Originator ....:	Intertek Guangzhou
Master TRF.....................................:	Dated 2019-05

Test item description .... :	HYBRID MPPT SOLAR INVERTER			
Trade Mark ....:	None			
Manufacturer ....:	MASTER BATTERY, S.L. Paseo de Extremadura, 39, 28935 Móstoles, Madrid, Spain			
Model/Type reference.......................:	ALPHA WP 8KW, ALPHA WP 10KW, ALPHA WP 12KW, ALPHA WP 15KW			
Ratings ....:	ALPHA WP 8KW	ALPHA WP 10KW	ALPHA WP 12KW	ALPHA WP 15KW
Input DC voltage (V) ....:	320-1000Vdc			
MPP DC voltage range(V) ....:	350-950Vdc			
Input DC current (A) ....:	13A/13A	26A/13A	26A/26A	
Output AC voltage(V) ....:	3/N/PE, 230/400Vac			
Output AC current(A) ....:	3*11.6A	3*14.5A	3*17.4A	3*21.5A
Output power(W) ....:	8000W	10000W	12000W	15000W
Input AC voltage [V] ....:	3/N/PE, 230/400Vac			
Input AC current [A]..........................:	40A/40A/40A			
Battery voltage [V] ....:	40-62Vdc			
Maximum Battery current [A] ....:	200A	250A	300A	375A

Summary of testing:

Tests performed (name of test and test clause):

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
4.12	Remote information exchange
4.13	Requirements regarding single fault tolerance of interface protection system and interface switch

Testing location:

Intertek Testing Services Taiwan Ltd.

5F, No. 423, Ruiguang Rd., Neihu District, Taipei 114, Taiwan

Marking plate

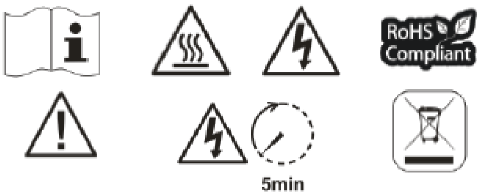
Model No. : INFINI WP 8KW

Serial No. : 96161406100001

PV INPUT	Nominal operating voltage 720Vdc	
	Vmax PV 1000Vdc	
	PV input voltage range 320-1000Vdc	
	Isc PV 2*13A	
	MPPT voltage range 350 ~ 950Vdc	
GRID/AC OUTPUT	Nominal operating voltage 3/N/PE, 230/400 Vac	
	Nominal output current 11.6A per phase	
	Nominal operating frequency 50Hz	
	Maximum power 8000W	
	Power factor range 0.9 lead-0.9lag	
AC INPUT	Nominal operating voltage 3/N/PE, 230/400 Vac	
	Maximum input current 40A per phase	
	Nominal operating frequency 50Hz	
BATTERY	Battery voltage range 40~62Vdc	
	Maximum battery current 200A	

Ambient temperature:-25~+60°C
Enclosure:IP 65
Safety class I
VDE0126-1-1 VDE-AR-N 4105

CE



WARNING:FIRE HAZARD.
SUITABLE FOR MOUNTING ON CONCRETE OR OTHER NON-COMBUSTIBLE SURFACE ONLY
CAUTION:THE DC AND AC BREAKER MUST HAVE BEEN TURNED OFF BEFORE SERVICING.
MADE IN CHINA
VOLTRONIC POWER TECHNOLOGY CORP.

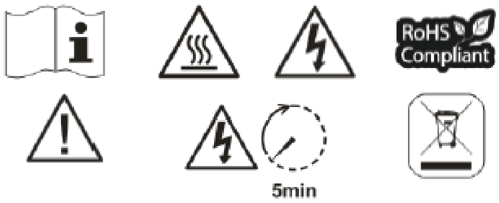
Model No. : INFINI WP 10KW

Serial No. : 96161406100001

PV INPUT	Nominal operating voltage 720Vdc	
	Vmax PV 1000Vdc	
	PV input voltage range 320-1000Vdc	
	Isc PV 26+13A	
	MPPT voltage range 350 ~ 950Vdc	
GRID/AC OUTPUT	Nominal operating voltage 3/N/PE, 230/400 Vac	
	Nominal output current 14.5A per phase	
	Nominal operating frequency 50Hz	
	Maximum power 10000W	
	Power factor range 0.9 lead-0.9lag	
AC INPUT	Nominal operating voltage 3/N/PE, 230/400 Vac	
	Maximum input current 40A per phase	
	Nominal operating frequency 50Hz	
BATTERY	Battery voltage range 40~62Vdc	
	Maximum battery current 250A	

Ambient temperature:-25~+60°C
Enclosure:IP 65
Safety class I
VDE0126-1-1 VDE-AR-N 4105

CE



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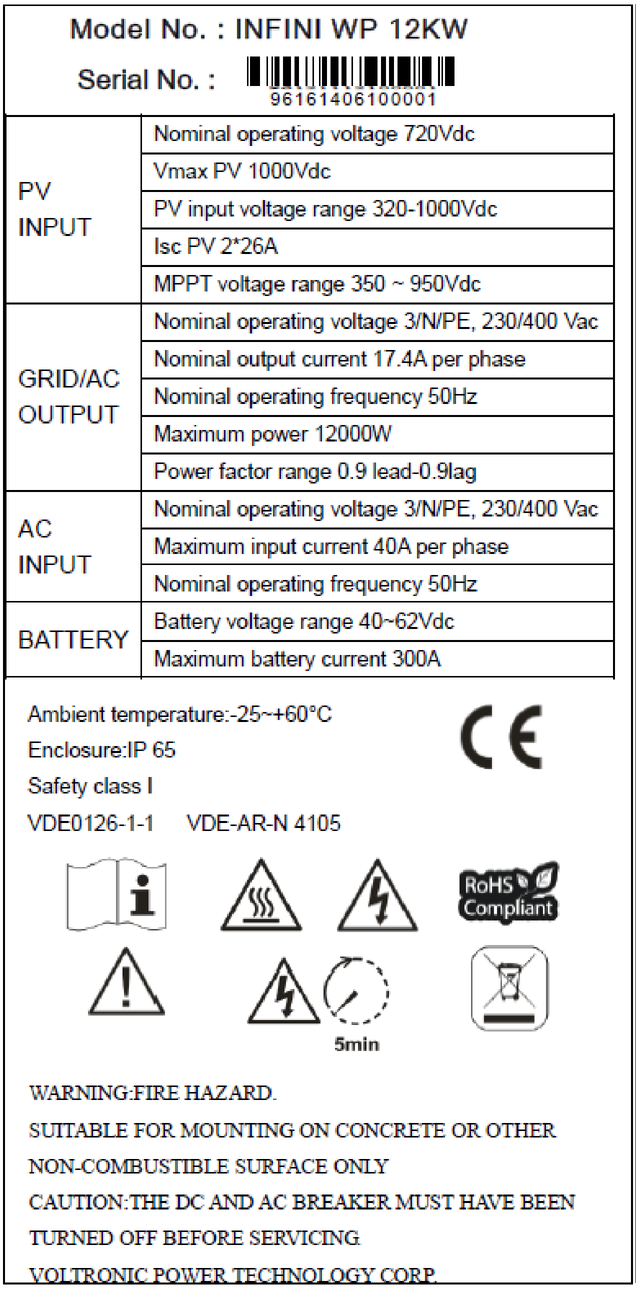


Model No. : INFINI WP 12KW

Serial No. : 96161406100001

PV INPUT	Nominal operating voltage 720Vdc
	Vmax PV 1000Vdc
	PV input voltage range 320-1000Vdc
	Isc PV 2*26A
	MPPT voltage range 350 ~ 950Vdc
GRID/AC OUTPUT	Nominal operating voltage 3/N/PE, 230/400 Vac
	Nominal output current 17.4A per phase
	Nominal operating frequency 50Hz
	Maximum power 12000W
	Power factor range 0.9 lead-0.9lag
AC INPUT	Nominal operating voltage 3/N/PE, 230/400 Vac
	Maximum input current 40A per phase
	Nominal operating frequency 50Hz
BATTERY	Battery voltage range 40~62Vdc
	Maximum battery current 300A

Ambient temperature:-25~+60°C

Enclosure:IP 65

Safety class I

VDE0126-1-1 VDE-AR-N 4105

RoHS Compliant

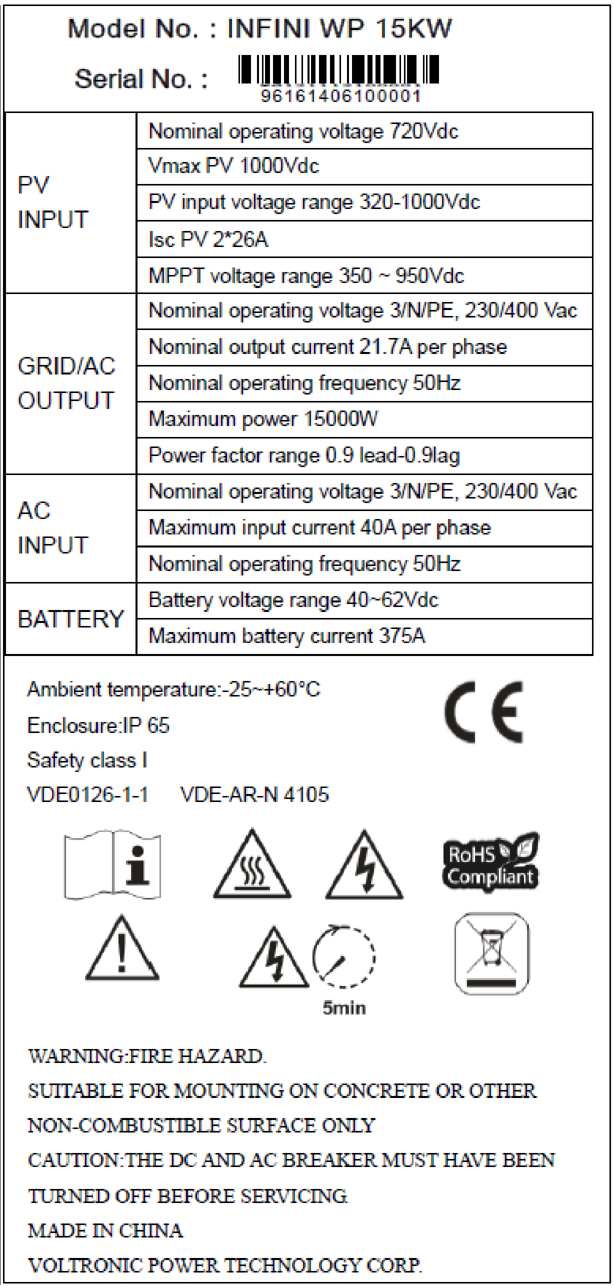
5min

WARNING:FIRE HAZARD.

SUITABLE FOR MOUNTING ON CONCRETE OR OTHER NON-COMBUSTIBLE SURFACE ONLY

CAUTION:THE DC AND AC BREAKER MUST HAVE BEEN TURNED OFF BEFORE SERVICING.

VOLTRONIC POWER TECHNOLOGY CORP.



Model No. : INFINI WP 15KW

Serial No. : 96161406100001

PV INPUT	Nominal operating voltage 720Vdc
	Vmax PV 1000Vdc
	PV input voltage range 320-1000Vdc
	Isc PV 2*26A
	MPPT voltage range 350 ~ 950Vdc
GRID/AC OUTPUT	Nominal operating voltage 3/N/PE, 230/400 Vac
	Nominal output current 21.7A per phase
	Nominal operating frequency 50Hz
	Maximum power 15000W
	Power factor range 0.9 lead-0.9lag
AC INPUT	Nominal operating voltage 3/N/PE, 230/400 Vac
	Maximum input current 40A per phase
	Nominal operating frequency 50Hz
BATTERY	Battery voltage range 40~62Vdc
	Maximum battery current 375A

Ambient temperature:-25~+60°C

Enclosure:IP 65

Safety class I

VDE0126-1-1 VDE-AR-N 4105

RoHS Compliant

5min

WARNING:FIRE HAZARD.

SUITABLE FOR MOUNTING ON CONCRETE OR OTHER NON-COMBUSTIBLE SURFACE ONLY

CAUTION:THE DC AND AC BREAKER MUST HAVE BEEN TURNED OFF BEFORE SERVICING.

MADE IN CHINA

VOLTRONIC POWER TECHNOLOGY CORP.

Note:

1. The above markings are the minimum requirements required by the safety standard. For the final production samples, the additional markings which do not give rise to misunderstanding may be added.
2. Label is attached on the side surface of enclosure and visible after installation.

Test item particulars...:	
Temperature range ....:	-25°C …60 °C
AC Overvoltage category...:	☐ OVC I ☐ OVC II ☒ OVC III ☐ OVC IV
DC Overvoltage category ....:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
IP protection class ....:	IP 65
Possible test case verdicts:	
- test case does not apply to the test object.................:	N/A (Not applicable)
- test object does meet the requirement ....:	P (Pass)
- test object does not meet the requirement ....:	F (Fail)
Testing..:	
Date of receipt of test item..:	2021-12-02
Date (s) of performance of tests..................................:	2021-12-02 to 2021-12-17

General remarks:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
"(see Enclosure #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

When determining for test conclusion, measurement uncertainty of tests has been considered.
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The test report only allows to be revised only within the report defined retention period unless standard or regulation was withdrawn or invalid.

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

General product information:

The inverter converts DC voltage, generated by batteries and PV array, into AC voltage. Battey can also be charged from the AC grid and PV array.

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

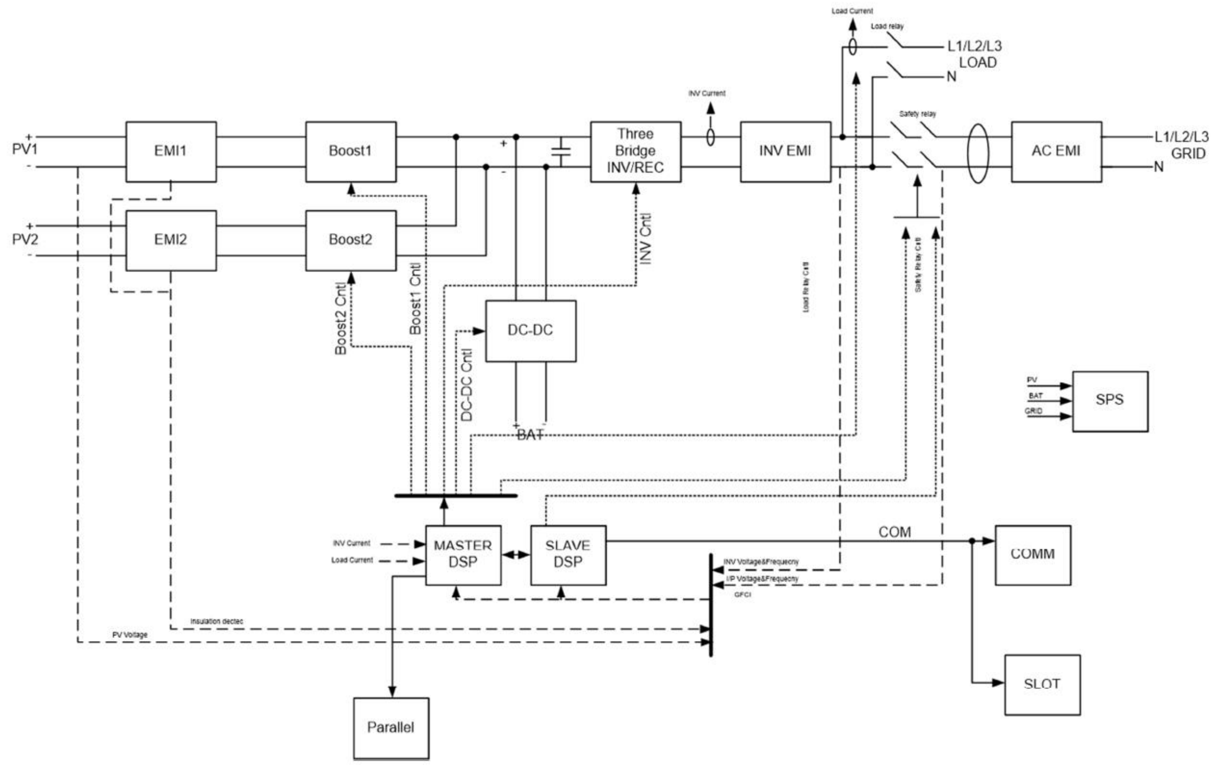
The internal control is redundant built. It consists of Microcontroller Main DSP (U3) and slave DSP (U6).

The Main DSP (U3) control the relays by switching signals; measures the battery voltage, battery current, Bus voltage, grid voltage, frequency, AC current with injected DC and the array insulation resistance to ground. In addition it tests the current sensors and the RCMU circuit before each start up.

The slave DSP (U3) is measures the grid voltage, grid frequency and residual current, also can switch off the relays independently, and communicate with Main DSP (U3) each other.

The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the Main DSP(U6). The Main DSP(U3) tests and calibrates before each start up all current sensors. The unit provides two relays in series in all output conductors. When single fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the battery and the mains. All the relays are tested before each start up.

The topology diagram as following:



Model differences:
The models ALPHA WP 8KW and ALPHA WP 10KW, ALPHA WP 12KW, ALPHA WP 15KW are completely identical except for the INV inductor, the output power derated by software.

The product was tested on:
Hardware version: V00
Software version: V00

The following deviations for Czech Republic according PPDS:2020		
Protections of plants with phase currents up to 16 A		
Parameter	**Max. clearance time**	**Trip value[a]**
Over voltage (Frist Level)	3 s [a]	230 V + 10% (253,0 V)
Over voltage (Second Level)	1 s	230 V + 15% (264,5 V)
Over voltage (Three Level)	0,1 s	230 V + 20% (276,0 V)
Under voltage	1,5 s	230 V - 15% (195,5 V)
Over frequency	0,5 s	51,5 Hz
Under frequency	0,5 s	47,5 Hz
[a] 10-minute values corresponding to ČSN EN 50160 shall be used for the 1st degree of overvoltage. The calculation of the 10-minute value must correspond to 10-minute aggregation according to ČSN EN 61000-4-30, class S. This function must be based on the average rms value 10 minutes. The deviation from ČSN EN 61000-4-30 consists in a sliding measuring window. To compare with the trip limit, a new 10-minute value calculation is sufficient at least every 3 s.		

The following deviations for Czech Republic according PPDS:2020		
Production site protection with modules (VM (A2), B1, B2, C)		
Parameter	**Recommended protection settings**	**Trip value**
Over voltage (Frist Level)	≤ 60 s [a]	230 V + 15% (264,5 V)
Over voltage (Second Level)	5 s	230 V + 20% (276,0 V)
Over voltage (Three Level)	0,1 s	230 V + 25% (287,5 V)
Under voltage (Frist Level)	0 ~ 2,7 s	230 V - 30% (161,0 V)
Under voltage (Second Level)	≥ 0,15 s	230 V - 65% (104,5 V)
Over frequency	≤ 0,1 s	51,5 Hz
Under frequency	≤ 0,1 s	47,5 Hz
[a] 10-minute values corresponding to ČSN EN 50160 shall be used for the 1st degree of overvoltage. The calculation of the 10-minute value must correspond to 10-minute aggregation according to ČSN EN 61000-4-30, class S. This function must be based on the average rms value 10 minutes. The deviation from ČSN EN 61000-4-30 consists in a sliding measuring window. To compare with the trip limit, a new 10-minute value calculation is sufficient at least every 3 s.		

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
4	**Requirements on generating plants**		P
4.1	**General**	This report is only evaluated and tested for generating unit; The generating plant incorporated with the generating unit shall further consider this clause and sub-clause.	N/A
4.2	**Connection scheme**	Shall consider in final PGS	N/A
4.3	**Choice of switchgear**		P
4.3.1	**General** Switches shall be chosen based on the characteristics of the power system in which they are intended to be installed. For this purpose, the short circuit current at the installation point shall be assessed, taking into account, *inter alia*, the short circuit current contribution of the generating plant.	The short circuit current at the installation point shall be considered in final PGS	P
4.3.2	**Interface switch** Switches shall be power relays, contactors or mechanical circuit breakers each having a breaking and making capacity corresponding to the rated current of the generating plant and corresponding to the short circuit contribution of the generating plant. The short-time withstand current of the switching devices shall be coordinated with rated short circuit power at the point of connection. In case of loss of auxiliary supply power to the switchgear, a secure disconnection of the switch is required immediately. Where means of isolation (according to HD 60364-5-551) is not required to be accessible to the DSO at all times, automatic disconnection with single fault tolerance according to 4.13 shall be provided. The function of the interface switch might be combined with either the main switch or the generating unit switch in a single switching device. In case of a combination, the single switching device shall be compliant to the requirements of both, the interface switch and the combined main switch or generating unit switch. As a consequence, at least two switches in series shall be present between any generating unit and the POC.	The interface switch is constructed of redundancy, made up of two series relays and power and control separately. The EUT is a PV inverter, further evaluation refers to EN 62109–1 and EN 62109–2 with respect to the interface switch.	P

4.4	**Normal operating range**		**P**
4.4.1	**General** Generating plants when generating power shall have the capability to operate in the operating ranges specified below regardless of the topology and the settings of the interface protection.		P
4.4.2	**Operating frequency range** The generating plant shall be capable of operating continuously when the frequency at the point of connection stays within the range of 49 Hz to 51 Hz. In the frequency range from 47 Hz to 52 Hz the generating plant should be capable of operating until the interface protection trips. Therefore, the generating plant shall at least be capable of operating in the frequency ranges, for the duration and for the minimum requirement as indicated in Table 1. Respecting the legal framework, it is possible that for some synchronous areas more stringent time periods and/or frequency ranges will be required by the DSO and the responsible party. Nevertheless, they are expected to be within the boundaries of the stringent requirement as indicated in Table 1 unless producer, DSO, TSO and responsible party agree on wider frequency ranges and longer durations.	(See appended table 4.4.2)	P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
4.4.3	**Minimal requirement for active power delivery at underfrequency** A generating plant shall be resilient to the reduction of frequency at the point of connection while reducing the maximum active power as little as possible. The admissible active power reduction due to underfrequency is limited by the full line in Figure 5 and is characterized by a maximum allowed reduction rate of 10 % of P_{max} per 1 Hz for frequencies below 49,5 Hz. It is possible that a more stringent power reduction characteristic is required by the responsible party. Nevertheless this requirement is expected to be limited to an admissible active power reduction represented by the dotted line in Figure 5 which is characterised by a reduction rate of 2 % of the maximum power P_{max} per 1 Hz for frequencies below 49 Hz. If any technologies intrinsic design or ambient conditions have influence on the power reduction behaviour of the system, the manufacturer shall specify at which ambient conditions the requirements can be fulfilled and eventual limitations. The information can be provided in the format of a graph showing the intrinsic behaviour of the generating unit for example at different ambient conditions. The power reduction and the ambient conditions shall comply with the specification given by the responsible party. If the generating unit does not meet the power reduction at the specified ambient conditions, the producer and the responsible party shall agree on acceptable ambient conditions.	(See appended table 4.4.3)	P
4.4.4	**Continuous operating voltage range** When generating power, the generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85 % U_n to 110 % U_n. Beyond these values the under and over voltage ride through immunity limits as specified in clause 4.5.3 and 4.5.4 shall apply. In case of voltages below U_n, it is allowed to reduce the apparent power to maintain the current limits of the generating plant. The reduction shall be as small as technically feasible. For this requirement all phase to phase voltages and in case a neutral is connected, additionally all phase to neutral voltages shall be evaluated.	(See appended table 4.4.4)	P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict

4.5	**Immunity to disturbances**		P
4.5.1	**General** In general, generating plants should contribute to overall power system stability by providing immunity towards dynamic voltage changes unless safety standards require a disconnection. The following clauses describe the required immunity for generating plants taking into account the connection technology of the generating modules. The following withstand capabilities shall be provided regardless of the settings of the interface protection.		P
4.5.2	**Rate of change of frequency (ROCOF) immunity** ROCOF immunity of a power generating plant means that the generating modules in this plant stay connected with the distribution network and are able to operate when the frequency on the distribution network changes with a specified ROCOF. The generating units and all elements in the generating plant that might cause their disconnection or impact their behaviour shall have this same level of immunity. The generating modules in a generating plant shall have ROCOF immunity for a ROCOF equal or exceeding the value specified by the responsible party. If no ROCOF immunity value is specified, the following ROCOF immunity shall apply, making distinction between generating technologies: • Non-synchronous generating technology: at least 2 Hz/s • Synchronous generating technology: at least 1 Hz/s The ROCOF immunity is defined with a sliding measurement window of 500 ms.	(See appended table 4.5.2) For 2Hz/s	P
4.5.3	**Under-voltage ride through (UVRT)**		P
4.5.3.1	**General** Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.5.3.2 and 4.5.3.3. Generating modules classified as type A and smaller according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of type A modules and smaller shall be specified in the connection agreement. The requirements apply to all kinds of faults (1ph, 2ph and 3ph).		P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
4.5.3.2	**Generating plant with non-synchronous generating technology** Generating modules shall be capable of remaining connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 6. The voltage is relative to U_n. The smallest phase to neutral voltage, or if no neutral is present, the smallest phase to phase voltage shall be evaluated. The responsible party may define a different UVRT characteristic. Nevertheless, this requirement is expected to be limited to the most stringent curve as indicated in Figure 6. This means that the whole generating module has to comply with the UVRT requirement. This includes all elements in a generating plant: the generating units and all elements that might cause their disconnection. For the generating unit, this requirement is considered to be fulfilled if it stays connected to the distribution grid as long as the voltage at its terminals remains above the defined voltage-time diagram. After the voltage returns to continuous operating voltage range, 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.	(See appended table 4.5.3)	P
4.5.3.3	**Generating plant with synchronous generating technology**		N/A
4.5.4	**Over-voltage ride through (OVRT)** Generating modules, except for micro-generating plants, shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains below the voltage-time curve of Figure 8. The highest phase to neutral voltage or if no neutral is present the highest phase to phase voltage shall be evaluated. This means that not only the generating units shall comply with this OVRT requirement but also all elements in a generating plant that might cause its disconnection..	(See appended table 4.5.4)	P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict

4.6	**Active response to frequency deviation**		P
4.6.1	**Power response to overfrequency** Generating plants shall be capable of activating active power response to overfrequency at a programmable frequency threshold f_1 at least between and including 50,2 Hz and 52 Hz with a programmable droop in a range of at least s=2 % to s=12 %. The droop reference is P_{ref}. Unless defined differently by the responsible party: • $P_{ref}=P_{max}$, in the case of synchronous generating technology and electrical energy storage systems. • $P_{ref}=P_M$, the actual AC output power at the instant when the frequency reaches the threshold f_1, in the case of all other non-synchronous generating technology The power value calculated according to the droop is a maximum power limit. If e.g. the available primary power decreases during a high frequency period below the power defined by the droop function, lower power values are permitted. The generating plant shall be capable of activating active power response to overfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s, unless another value is defined by the relevant party. An intentional delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.	(See appended table 4.6.1)	P
	After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power (see Figure 9). The resolution of the frequency measurement shall be ± 10 mHz or less. The accuracy is evaluated with a 1 min average value. At POC, loads if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.		P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
	Generating plants reaching their minimum regulating level shall, in the event of further frequency increase, maintain this power level constant unless the DSO and the responsible party requires to disconnect the complete plant or if the plant consists of multiple units by disconnecting individual units. The active power frequency response is only deactivated if the frequency falls below the frequency threshold f_1. If required by the DSO and the responsible party an additional deactivation threshold frequency f_{stop} shall be programmable in the range of at least 50 Hz to f_1. If f_{stop} is configured to a frequency below f_1 there shall be no response according to the droop in case of a frequency decrease (see Figure 10). The output power is kept constant until the frequency falls below f_{stop} for a configurable time t_{stop}.		P
	If at the time of deactivation of the active power frequency response the momentary active power PM is below the available active power PA, the active power increase of the generating plant shall not exceed the gradient defined in 4.10.2. Settings for the threshold frequency f_1, the droop and the intentional delay are provided by the DSO and the responsible party. If no settings are provided, the default settings in Table 2 should be applied.		P
	The enabling and disabling of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party.	The enabling and disabling can be access by communication interface	P
	Alternatively for the droop function described above, the following procedure is allowed for generating modules if permitted by the DSO and the responsible party: • the generating units shall disconnect at randomized frequencies, ideally uniformly distributed between the frequency threshold f_1 and 52 Hz; • in case the frequency decreases again, the generating unit shall start its reconnection procedure once the frequency falls below the specific frequency that initiated the disconnection; for this procedure, the connection conditions described in 4.10 do not apply; • the randomization shall either be at unit level by changing the threshold over time, or on plant level by choosing different values for each unit within a plant, or on distribution system level if the DSO specifies a specific threshold for each plant or unit connected to its distribution system.		P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
	EES units that are in charging mode at the time the frequency passes the threshold f_1 shall not reduce the charging power below P_M until frequency returns below f_1. Storage units should increase the charging power according to the configured droop. In case the maximum charging capacity is reached or to prevent any other risk of injury or damage of equipment, a reduction of charging power is permitted.		P
4.6.2	**Power response to underfrequency** EES units shall be capable of activating active power response to underfrequency. Other generating units/plants should be capable of activating active power response to underfrequency. If active power to underfrequency is provided by a generating plant/unit, the function shall comply with the requirements below. Active power response to underfrequency shall be provided when all of the following conditions are met: • when generating, the generating unit is operating at active power below its maximum active power P_{max}; • when generating, the generating unit is operating at active power below the available active power P_A; • the voltages at the point of connection of the generating plant are within the continuous operating voltage range; and • when generating, the generating unit is operating with currents lower than its current limit. In the case of EES units, active power frequency response to underfrequency shall be provided in charging and generating mode.	(See appended table 4.6.2)	P

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
	The active power response to underfrequency shall be delivered at a programmable frequency threshold f_1 at least between and including 49,8 Hz and 46,0 Hz with a programmable droop in a range of at least 2 % to 12 %. The droop reference P_{ref} is P_{max}. If the available primary power or a local set value increases during an underfrequency period above the power defined by the droop function, higher power values are permitted. The power value calculated according to the droop is therefore a minimum limit. The generating unit shall be capable of activating active power response to underfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s unless another value is defined by the relevant party. An intentional initial delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.		P
	After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power. The accuracy is evaluated with a 1 min average value. The resolution of the frequency measurement shall be ± 10 mHz or less. At POC loads, if present in the producer's network, might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.		P
	Generating modules reaching any of the conditions above during the provision of active power frequency response shall, in the event of further frequency decrease, maintain this power level constant. The active power frequency response is only deactivated if the frequency increases above the frequency threshold f_1.		P
	Settings for the threshold frequency f_1, the droop and the intentional delay are defined by the DSO and the responsible party, if no settings are provided, the function shall be disabled.		P
	The activation and deactivation of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party.		P

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Clause	Requirement - Test	Result - Remark	Verdict

4.7	**Power response to voltage changes**		P
4.7.1	**General** When the contribution to voltage support is required by the DSO and the responsible party, the generating plant shall be designed to have the capability of managing reactive and/or active power generation according to the requirements of this clause.		P
4.7.2	**Voltage support by reactive power**		P
4.7.2.1	**General** Generating plants shall not lead to voltage changes out of acceptable limits. These limits should be defined by national regulation. Generating units and plants shall be able to contribute to meet this requirement during normal network operation. Throughout the continuous operating frequency (see 4.4.2) and voltage (see 4.4.4) range, the generating plant shall be capable to deliver the requirements stipulated below. Outside these ranges, the generating plant shall follow the requirements as good as technically feasible although there is no specified accuracy required.		P
4.7.2.2	**Capabilities** Unless specified differently below, for specific generating technologies, generating plants shall be able to operate with active factors as defined by the DSO and the responsible party from active factor = $0{,}90_{underexcited}$ to active factor= $0{,}90_{overexcited}$ The reactive power capability shall be evaluated at the terminals of the/each generating unit	(See appended table 4.7.2.2)	P
	CHP generating units with a capacity ≤ 150 kVA shall be able to operate with active factors as defined by the DSO from $\cos \varphi = 0{,}95_{underexcited}$ to $\cos \varphi = 0{,}95_{overexcited}$ Generating units with an induction generator coupled directly to the grid and used in generating plants above micro generating level, shall be able to operate with active factors as defined by the DSO from $\cos \varphi = 0{,}95_{underexcited}$ to $\cos \varphi = 1$ at the terminals of the unit. Deviating from 4.7.2.3 only the cos φ set point mode is required. Deviating from the accuracy requirements below, the accuracy is only required at active power P_D.		N/A
	Generating units with an induction generator coupled directly to the grid and used in micro generating plants shall operate with an active factor above 0,95 at the terminals of the generating unit. A controlled voltage support by reactive power is not required from this technology.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	Generating units with linear generators, coupled directly and synchronously to the grid shall operate with an active factor above 0,95 at the terminals of the generating unit, and therefore a controlled voltage support by reactive power is not required from this technology.		N/A
	In case of different generating technologies with different requirements in one generating plant, each unit shall provide voltage support by reactive power as required for its specific technology. A compensation of one technology to reach the general plant requirement is not expected. The DSO and the responsible party may relax the above requirements. This relaxation might be general or specific for a certain generating plant or generating technology.		N/A
	All involved parties can expect to have access to information documenting the actual choices regarding active power capabilities relative to reactive power requirements and related to the power rating in the operating voltage range (see further in this clause). A P-Q Diagram shall be included in the product documentation of a generating unit. When operating above the apparent power threshold S_{min} equal to 10 % of the maximum apparent power S_{max} or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % S_{max}. Up to this apparent power threshold S_{min}, deviations above 2 % are permissible; nevertheless the accuracy shall always be as good as technically feasible and the exchange of uncontrolled reactive power in this low-power operation mode shall not exceed 10 % of the maximum apparent power S_{max}. At POC loads, if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant. For generating units with a reactive power capability according Figure 12 the reactive power capability at active power P_D shall be at least according Figure 13. For generating units with a reduced reactive power capability Figure 13 is only applicable up to the maximum reactive power capability.	(See appended table 4.7.2.2)	P
4.7.2.3	**Control modes**		P

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Clause	Requirement - Test	Result - Remark	Verdict
4.7.2.3.1	**General** Where required, the form of the contribution to voltage control shall be specified by the DSO. The control shall refer to the terminals of the generating units The generating plant/unit shall be capable of operating in the control modes specified below within the limits specified in 4.7.2.2. The control modes are exclusive; only one mode may be active at a time. • Q setpoint mode • Q (U) • Cos φ setpoint mode • Cos φ (P) For mass market products, it is recommended to implement all control modes. In case of site specific generating plant design, only the control modes required by the DSO need to be implemented. The configuration, activation and deactivation of the control modes shall be field adjustable. For field adjustable configurations and activation of the active control mode, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO. Which control modes are available in a product and how they are configured shall be stated in the product documentation.		P
4.7.2.3.2	**Setpoint control modes** Q setpoint mode and cos φ setpoint mode control the reactive power output and the cos φ of the output respectively, according to a set point set in the control of the generating plant/unit. In the case of change of the set point local or by remote control the settling time for the new set point shall be less than one minute.	(See appended table 4.7.2.2)	P
4.7.2.3.3	**Voltage related control mode** The voltage related control mode Q (U) controls the reactive power output as a function of the voltage. There is no preferred state of the art for evaluating the voltage. Therefore it is the responsibility of the generating plant designer to choose a method. One of the following methods should be used: • the positive sequence component of the fundamental; • the average of the voltages measured independently for each phase to neutral or phase to phase; • phase independently the voltage of every phase to determine the reactive power for every phase.	Method 2 used	P

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Clause	Requirement - Test	Result - Remark	Verdict
	For voltage related control modes, a characteristic with a minimum and maximum value and three connected lines according to Figure 16 shall be configurable. In addition to the characteristic, further parameters shall be configurable: • The dynamics of the control shall correspond with a first order filter having a time constant that is configurable in the range of 3 s to 60 s.	(See appended table 4.7.2.3.3)	P
	To limit the reactive power at low active power two methods shall be configurable: • a minimal cos φ shall be configurable in the range of 0-0,95; • two active power levels shall be configurable both at least in the range of 0 % to 100 % of P_D. The lock-in value turns the Q(U) mode on, the lock-out value turns Q(U) off. If lock-in is larger than lock-out a hysteresis is given. See also Figure 14. The static accuracy shall be in accordance with 4.7.2.2. The dynamic accuracy shall be in accordance with Figure 15 with a maximum tolerance of +/- 5% of P_D plus a time delay of up to 3 seconds deviating from an ideal first order filter response.		P
4.7.2.3.4	**Power related control mode** The power related control mode cos φ (P) controls the cos φ of the output as a function of the active power output. For power related control modes, a characteristic with a minimum and maximum value and three connected lines shall be configurable in accordance with Figure 16. Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached. The static accuracy of each cos φ set point shall be according to 4.7.2.2.	(See appended table 4.7.2.3.4)	P

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Clause	Requirement - Test	Result - Remark	Verdict
4.7.3	**Voltage related active power reduction** In order to avoid disconnection due to overvoltage protection (see 4.9.2.3 and 4.9.2.4), generating plants/units are allowed to reduce active power output as a function of this rising voltage. The final implemented logic can be chosen by the manufacturer. Nevertheless, this logic shall not cause steps or oscillations in the output power. The power reduction caused by such a function may not be faster than an equivalent of a time constant tau = 3 s (= 33%/s at a 100% change). The enabling and disabling of the function shall be field adjustable and means have to be provided to protect the setting from unpermitted interference (e.g. password or seal) if required by the DSO.	This function is chosen by manufacturer	P
4.7.4	**Short circuit current requirements on generating plants**		P
4.7.4.1	**General** The following clauses describe the required short circuit current contribution for generating plants taking into account the connection technology of the generating modules. Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.7.4.2 and 4.7.4.3. Generating modules classified as type A according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of type A modules shall be specified in the connection agreement.		P
4.7.4.2	**Generating plant with non-synchronous generating technology**		P
4.7.4.2.1	**Voltage support during faults and voltage steps** In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN 50549-2 applies.	Only EN 50549-1 applies, if required by the responsible party for additional reactive current, the EN 50549-2 shall be applied.	P

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Clause	Requirement - Test	Result - Remark	Verdict
4.7.4.2.2	**Zero current mode for converter connected generating technology** If UVRT capability (see 4.5.3) is provided additional to the requirements of 4.5, generating units connected to the grid by a converter shall have the capability to reduce their current as fast as technically feasible down to or below 10 % of the rated current when the voltage is outside of a static voltage range. Generating units based on a doubly fed induction machine can only reduce the positive sequence current below 10 % of the rated current. Negative sequence current shall be tolerated during unbalanced faults. In case this current reduction is not sufficient, the DSO should choose suitable interface protection settings. The static voltage range shall be adjustable from 20 % to 100 % of U_n for the undervoltage boundary and from 100 % to 130 % of U_n for the overvoltage boundary. The default setting shall be 50% of U_n for the undervoltage boundary and 120% of U_n for the overvoltage boundary. Each phase to neutral voltage or if no neutral is present each phase to phase voltage shall be evaluated. At voltage re-entry into the voltage range, 90% of pre-fault power or available power, whichever is the smallest, shall be resumed as fast as possible, but at the latest according to 4.5.3 and 4.5.4. All described settings are defined by the DSO and the responsible party. If no settings are provided, the function shall be disabled. The enabling and disabling and the settings shall be field adjustable and means have to be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO.	The test is performed together with the clause 4.5.3 and 4.5.4 Default setting for testing.	P
4.7.4.2.3	**Induction generator based units** In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
4.7.4.3	**Generating plant with synchronous generating technology - Synchronous generator based units** In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.		N/A
4.8	**EMC and power quality** Similar to any other apparatus or fixed installation, generating units shall comply with the requirements on electromagnetic compatibility established in Directive 2014/30/EU or 2014/53/EU, whichever applies. EMC limits and tests, described in EN 61000 series, have been traditionally developed for loads, without taking into account the particularities of generating units, such as their capability to create overvoltages or high frequency disturbances due to the presence of power converters, which were either impossible or less frequent in case of loads.	The units have declared to comply with Directive 2014/30/EU or 2014/53/EU	P
4.9	**Interface protection**		P
4.9.1	**General** According to HD 60364-5-551:2010, 551.7.4, means of automatic switching shall be provided to disconnect the generating plant from the distribution network in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values declared for normal supply. This automatic means of disconnection has following main objectives: • prevent the power production of the generating plant to cause an overvoltage situation in the distribution network it is connected to. Such overvoltages could result in damages to the equipment connected to the distribution network as well as the distribution network itself; • detect unintentional island situations and disconnect the generating plant in this case. This is contributing to prevent damage to other equipment, both in the producers’ installations and the distribution network due to out of phase re-closing and to allow for maintenance work after an intentional disconnection of a section of the distribution network; • assist in bringing the distribution network to a controlled state in case of voltage or frequency deviations beyond corresponding regulation values.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	• disconnect the generating plant from the distribution network in case of faults internal to the power generating plant. Protection against internal faults (short-circuits) shall be coordinated with network protection, according to DSO protection criteria. Protection against e.g. overload, electric shock and against fire hazards shall be implemented additionally according to HD 60364-1 and local requirements; • prevent damages to the generating unit due to incidents (e.g. short circuits) on the distribution network Interface protections may contribute to preventing damage to the generating units due to out-of-phase reclosing of automatic reclosing which may happen after some hundreds of ms. However, in some countries some technologies of generating units are explicitly required to have an appropriate immunity level against the consequences of out-of-phase reclosing. The type of protection and the sensitivity and operating times depend upon the protection and the characteristics of the distribution network. A wide variety of approaches to achieve the above mentioned objectives is used throughout Europe. Besides the passive observation of voltage and frequency other active and passive methods are available and used to detect island situations. The requirements given in this clause are intended to provide the necessary functions for all known approaches as well as to give guidance in their use. Which functions are available in a product shall be stated in the product documentation.		P
	The interface protection system shall comply with the requirements of this European Standard, the available functions and configured settings shall comply with the requirements of the DSO and the responsible party. In any case, the settings defined shall be understood as the values for the interface protection system, i.e. where there is a wider technical capability of the generation module, it shall not be withheld by the settings of the protections (other than the interface protection). For micro generating plants, the interface protection system and the point of measurement might be integrated into the generating units. For generating plants with nominal current above 16 A the DSO may define a threshold above which the interface protection system shall be realized as a dedicated device and not integrated into the generating units.	Integrated into the generating units If specified by country requirement, the interface protection shall not integrate	P

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Clause	Requirement - Test	Result - Remark	Verdict
	to place the protection system as close to the point of connection as possible, to avoid tripping due to overvoltages resulting from the voltage rise within the producer's network; • to allow for periodic field tests. In some countries periodic field tests are not required if the protection system meets the requirements of single fault safety. The interface protection relay acts on the interface switch. The DSO may require that the interface protection relay acts additionally on another switch with a proper delay in case the interface switch fails to operate. In case of failure of the power supply of the interface protection, the interface protection shall trigger the interface switch without delay. An uninterruptible power supply may be required by the DSO, for instance in case of UVRT capability, delay in protection etc. In case of field adjustable settings of threshold and operation time, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.9.2	**Void**		--
4.9.3	**Requirements on voltage and frequency protection**	(See appended table 4.9.3)	P
4.9.3.1	**General** Part or all of the following described functions may be required by the DSO and the responsible party. The protection functions shall evaluate at least all phases where generating units, covered by this protection system, are connected to. In case of three phase generating units/plants and in all cases when the protection system is implemented as an external protection system in a three phase power supply system, all phase to phase voltages and, if a neutral conductor is present, all phase to neutral voltages shall be evaluated. The frequency shall be evaluated on at least one of the voltages.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	If multiple signals (e.g. 3 phase to phase voltages) are to be evaluated by one protection function, this function shall evaluate all of the signals separately. The output of each evaluation shall be OR connected, so that if one signal passes the threshold of a function, the function shall trip the protection in the specified time. The minimum required accuracy for protection is: • for frequency measurement ± 0,05 Hz; • for voltage measurement ± 1 % of U_n. • The reset time shall be ≤50ms • The interface protection relay shall not conduct continuous starting and disengaging operations of the interface protection relay. Therefore a reasonable reset ratio shall be implemented which shall not be zero but be below 2% of nominal value for voltage and below 0,2Hz for frequency.		P
4.9.3.2	**Undervoltage protection [27]** The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed. Undervoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows. Undervoltage threshold stage 1 [27 <]: • Threshold (0,2 – 1) U_n adjustable by steps of 0,01 U_n • Operate time (0,1 – 100) s adjustable in steps of 0,1 s Undervoltage threshold stage 2 [27 < <]: • Threshold (0,2 – 1) U_n adjustable by steps of 0,01 U_n • Operate time (0,1 – 5) s adjustable in steps of 0,05 s The undervoltage threshold stage 2 is not applicable for micro-generating plants		P

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Clause	Requirement - Test	Result - Remark	Verdict
4.9.3.3	**Overvoltage protection [59]** The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed. Overvoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows. Overvoltage threshold stage 1 [59 >]: • Threshold (1,0 – 1,2) U_n adjustable by steps of 0,01 U_n • Operate time (0,1 – 100) s adjustable in steps of 0,1 s Overvoltage threshold stage 2 [59 > >]: • Threshold (1,0 – 1,30) U_n adjustable by steps of 0,01 U_n • Operate time (0,1 – 5) s adjustable in steps of 0,05 s		P
4.9.3.4	**Overvoltage 10 min mean protection** The calculation of the 10 min value shall comply with the 10 min aggregation of EN 61000-4-30 Class S, but deviating from EN 61000-4-30 as a moving window is used. Therefore the function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. The calculation of a new 10 min value at least every 3 s is sufficient, which is then to be compared with the threshold value. • Threshold (1,0 – 1,15) U_n adjustable by steps of 0,01 U_n • Start time ≤ 3s not adjustable • Time delay setting = 0 ms		P

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Clause	Requirement - Test	Result - Remark	Verdict
4.9.3.5	**Underfrequency protection [81 <]** Underfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows. Underfrequency threshold stage 1 [81 <]: • Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 – 100) s adjustable in steps of 0,1 s Underfrequency threshold stage 2 [81 < <]: • Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 – 5) s adjustable in steps of 0,05 s In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal. The frequency protection shall function correctly in the input voltage range between 20 % U_n and 120 % U_n and shall be inhibited for input voltages of less than 20 % U_n. Under 0,2 U_n the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.		P
4.9.3.6	**Overfrequency protection [81 >]** Overfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows. Overfrequency threshold stage 1 [81 >]: • Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 – 100) s adjustable in steps of 0,1 s Overfrequency threshold stage 2 [81 > >]: • Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz • Operate time (0,1 - 5) s adjustable in steps of 0,05 s In order to use narrow frequency thresholds for islanding detection (see4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal. The frequency protection shall function correctly in the input voltage range between 20 % U_n and 120 % U_n and shall be inhibited for input voltages of less than 20 % U_n.		P
4.9.4	**Means to detect island situation**		P

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Clause	Requirement - Test	Result - Remark	Verdict
4.9.4.1	**General** sides the passive observation of voltage and frequency further means to detect an island may be required by the DSO. Detecting islanding situations shall not be contradictory to the immunity requirements of 4.5. Commonly used functions include: • Active methods tested with a resonant circuit; • ROCOF tripping; • Switch to narrow frequency band; • Vector shift • Transfer trip. Only some of the methods above rely on standards. Namely for ROCOF tripping and for the detection of a vector shift, also called a vector jump, currently no European Standard is available.		P
4.9.4.2	**Active methods tested with a resonant circuit** These are methods which pass the resonant circuit test for PV inverters according to EN 62116.	(See appended table 4.9.4.2)	P
4.9.4.3	**Switch to narrow frequency band (see Annex E and Annex F)** In case of local phenomena (e.g. a fault or the opening of circuit breaker along the line) the DSO in coordination with the responsible party may require a switch to a narrow frequency band to increase the interface protection relay sensitivity. In the event of a local fault it is possible to enable activation of the restrictive frequency window (using the two underfrequency/overfrequency thresholds described in 4.9.2.5 and 4.9.2.6) correlating its activation with another additional protection function. If required by the DSO, a digital input according to 4.9.4 shall be available to allow the DSO the activation of a restrictive frequency window by communication.		P
4.9.5	**Digital input to the interface protection** If required by the DSO, the interface protection shall have at least two configurable digital inputs. These inputs can for example be used to allow transfer trip or the switching to the narrow frequency band.		P

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Clause	Requirement - Test	Result - Remark	Verdict

4.10	**Connection and starting to generate electrical power**		P
4.10.1	**General** Connection and starting to generate electrical power is only allowed after voltage and frequency are within the allowed voltage and frequency ranges for at least the specified observation time. It shall not be possible to overrule these conditions. Within these voltage and frequency ranges, the generating plant shall be capable of connecting and starting to generate electrical power. The setting of the conditions depends on whether the connection is due to a normal operational startup or an automatic reconnection after tripping of the interface protection. In case the settings for automatic reconnection after tripping and starting to generate power are not distinct in a generating plant, the tighter range and the start-up gradient shall be used. The frequency range, the voltage range, the observation time and the power gradient shall be field adjustable. For field adjustable settings, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.10.2	**Automatic reconnection after tripping** The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 3 column 2. If no settings are specified by the DSO and the responsible party, the default settings for the reconnection after tripping of the interface protection are according to Table 3 column 3. After reconnection, the active power generated by the generating plant shall not exceed a specified gradient expressed as a percentage of the active nominal power of the unit per minute. If no gradient is specified by the DSO and the responsible party, the default setting is 10 % P_n/min. Generating modules for which it is technically not feasible to increase the power respecting the specified gradient over the full power range may connect after 1 min to 10 min (randomized value, uniformly distributed) or later.	(See appended table 4.10.2)	P

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Clause	Requirement - Test	Result - Remark	Verdict
4.10.3	**Starting to generate electrical power** The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 4 column 2. If no settings are specified by the DSO and the responsible party, the default settings for connection or starting to generate electrical power due to normal operational startup or activity are according to Table 4 column 3. If applicable, the power gradient shall not exceed the maximum gradient specified by the DSO and the responsible party. Heat driven CHP generating units do not need to keep a maximum gradient, since the start up is randomized by the nature of the heat demand. For manual operations performed on site (e.g. for the purpose of initial start-up or maintenance) it is permitted to deviate from the observation time and ramp rate.	(See appended table 4.10.3) Default settings are applied	P
4.10.4	**Synchronization** Synchronizing a generating plant/unit with the distribution network shall be fully automatic i.e. it shall not be possible to manually close the switch between the two systems to carry out synchronization.		P
4.11	**Ceasing and reduction of active power on set point**		P
4.11.1	**Ceasing active power** Generating plants with a maximum capacity of 0,8 kW or more 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 and the responsible party, this includes remote operation.	(See appended table 4.11)	P
4.11.2	**Reduction of active power on set point** For generating modules of type B, a generating plant shall be capable of reducing its active power to a limit value provided remotely by the DSO. The limit value shall be adjustable in the complete operating range from the maximum active power to minimum regulating level. The adjustment of the limit value shall be possible with a maximum increment of 10% of nominal power. A generation unit/plant shall be capable of carrying out the power output reduction to the respective limit within an envelope of not faster than 0,66 % P_n/ s and not slower than 0,33 % P_n/ s with an accuracy of 5 % of nominal power. Generating plants are permitted to disconnect from the network at a limit value below it minimum regulating level. If required by the DSO, this includes remote operation.	(See appended table 4.11)	P

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Clause	Requirement - Test	Result - Remark	Verdict
4.12	**Remote information exchange** Generating plants whose power is above a threshold to be determined by the DSO and the responsible party shall have the capacity to be monitored by the DSO or TSO control centre or control centres as well as receive operation parameter settings for the functions specified in this European Standard from the DSO or TSO control centre or control centres. This information exchange is aimed at allowing the DSO and/or the TSO to improve, optimize and make safer the operation of their respective networks. The remote monitoring and operation parameter settings system that may be used by the DSO is not aimed at replacing the manual and automatic control means implemented by the generating plant operator to control the operation of the generating plant. It should not interact directly with the power generation equipment and the switching devices of the generating plant. It should interact with the operation and control system of the generating plant. In principle, standardized communication should be used. It is recommended that in case of using protocols for signal transmission used between the DSO or TSO control centre or control centres and the generating plant, relevant technical standards (e.g. EN 60870-5-101, EN 60870-5-104, EN 61850 and in particular EN 61850-7-4, EN 61850-7-420, IEC/TR 61850-90-7, as well as EN 61400-25 for wind turbines and relevant parts of IEC 62351 for relevant security measures) are recognized. Alternative protocols can be agreed between the DSO and the producer. These protocols include hardwired digital input/output and analogue input/output provided locally by DSO. The information needed for remote monitoring and the setting of configurable parameters are specific to each distribution network and to the way it is operated. Signal transmission times between the DSO and/or the TSO control centre and the generating plant will depend on the means of transmission used between the DSO and/or TSO control centre and the generating plant. Informative Annex B of EN50549-2 can be used as guidance regarding the monitoring information and the remote operation parameter setting.		N/A

EN 50549-1:2019			
Clause	Requirement - Test	Result - Remark	Verdict
4.13	**Requirements regarding single fault tolerance of interface protection system and interface switch** If required in 4.3.2, the interface protection system and the interface switch shall meet the requirements of single fault tolerance. A single fault shall not lead to a loss of the safety functions. Faults of common cause shall be taken into account if the probability for the occurrence of such a fault is significant. Whenever reasonably practical, the individual fault shall be displayed and lead to the disconnection of the power generating unit or system. Series-connected switches shall each have a independent breaking capacity corresponding to the rated current of the generating unit and corresponding to the short circuit contribution of the generating unit. The short-time withstand current of the switching devices shall be coordinated with maximum short circuit power at the connection point. At least one of the switches shall be a switch-disconnector suitable for overvoltage category 2. For single-phase generating units, the switch shall have one contact of this overvoltage category for both the neutral conductor and the line conductor. For poly-phase generating units, it is required to have one contact of this overvoltage category for all active conductors. The second switch may be formed of electronic switching components from an inverter bridge or another circuit provided that the electronic switching components can be switched off by control signals and that it is ensured that a failure is detected and leads to prevention of the operation at the latest at the next reconnection. For PV-inverters without simple separation between the network and the PV generating unit (e.g. PV Inverter without transformer) both switches mentioned in the paragraph above shall be switchdisconnectors with the requirements described therein, although one switching device is permitted to be located between PV array and PV inverter.	(See appended table 4.13)	P

Annex A	**Interconnection guidance**	Info
Annex B	**Void**	Info
Annex C	**Parameter Table**	Info
Annex D	**List of national requirements applicable for generating plants**	Info
Annex E	**Loss of Mains and overall power system security**	Info
Annex F	**Examples of protection strategies**	Info
Annex G	**Abbreviations**	Info
Annex H	**Relationship between this European standard and the COMMISSION REGULATION (EU) 2016/631**	Info

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 = 1,0 S_n; cosφ = 1, duration =20s.					
U_{P-P} [V]	U_{P-P} [p.u.]	f [Hz]	P [kW]	P [p.u.]	cosphi [-]
195,54	0,85	47,50	14,846	0,99	0,9997
Test 2: U = 195,5 V; f = 48,5 Hz; P = 1,0 S_n; cosφ = 1, duration >30min.					
U_{P-P} [V]	U_{P-P} [p.u.]	f [Hz]	P [kW]	P [p.u.]	cosphi [-]
195,49	0,85	48,50	14,881	0,99	0,9999
Test 3: U = 253,0 V; f = 51,5 Hz; P = 1,0 S_n; cosφ = 1, duration >30min.					
U_{P-P} [V]	U_{P-P} [p.u.]	f [Hz]	P [kW]	P [p.u.]	cosphi [-]
253,02	1,10	51,50	15,070	1,00	0,9999
Test 4: U = 230,0 V; f = 50,0 Hz; Voltage Phase jumps Change +20 degrees P = 1,0 S_n; cosφ = 1					
U_{P-P} [V]	U_{P-P} [p.u.]	f [Hz]	P [kW]	P [p.u.]	cosphi [-]
229,50	1,00	50,00	15,009	1,00	0,9999
Test 5: U = 230,0 V; f = 50,0 to 50,5 Hz;RoCoF=1Hz/s; P = 1,0 S_n; cosφ = 1					
U_{P-P} [V]	U_{P-P} [p.u.]	f [Hz]	P [kW]	P [p.u.]	cosphi [-]
229,08	1,00	50,50	15,031	1,00	0,9999

Note:

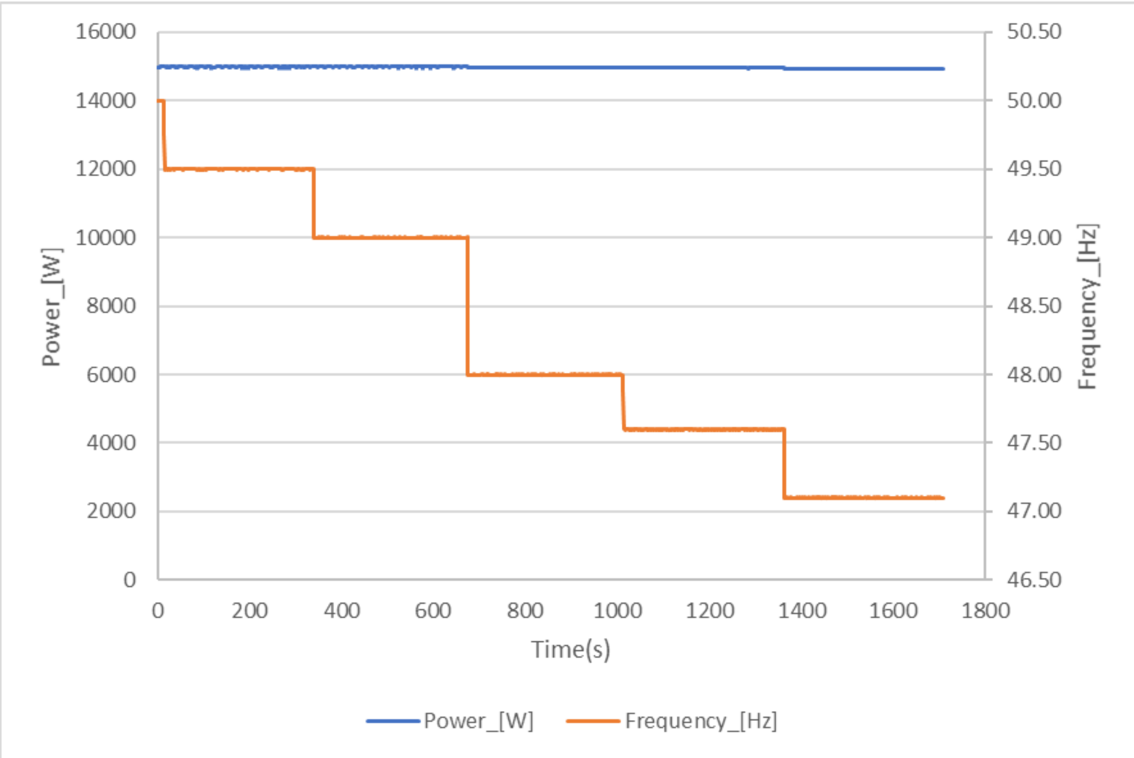
During the tests the interface protection was disabled.

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

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

The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.4.3	Minimal requirement for active power delivery at under-frequency				P
Test result：					
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]:	14,993	14,995	14,968	14,954	14,940
$\Delta P/P_n$ [%] :	0,048	0,035	0,212	0,307	0,401
Graph of frequency a) to b) to c) to d) to e):					



Assessment criterion:

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

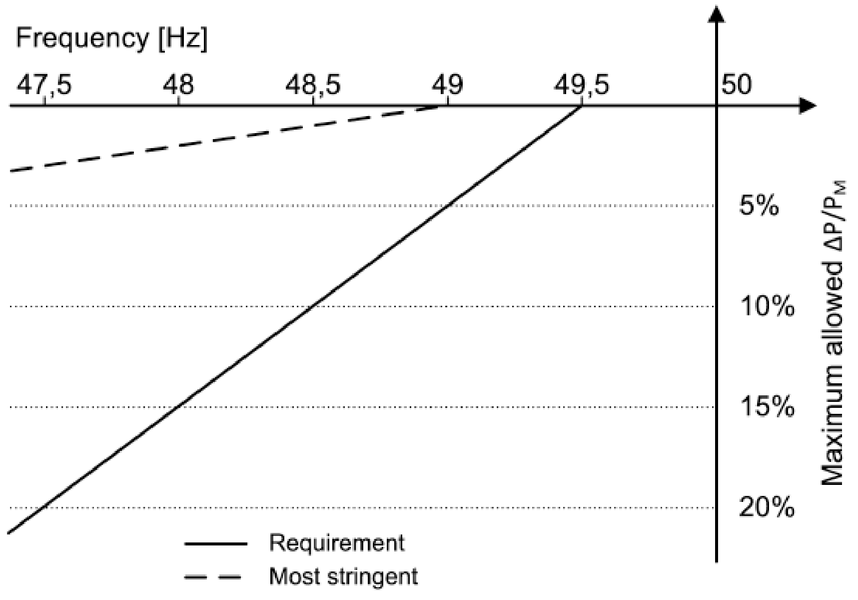
The frequency should then be set to 49,5 Hz for 5 minutes. The output should remain at 100% of registered Capacity.

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.



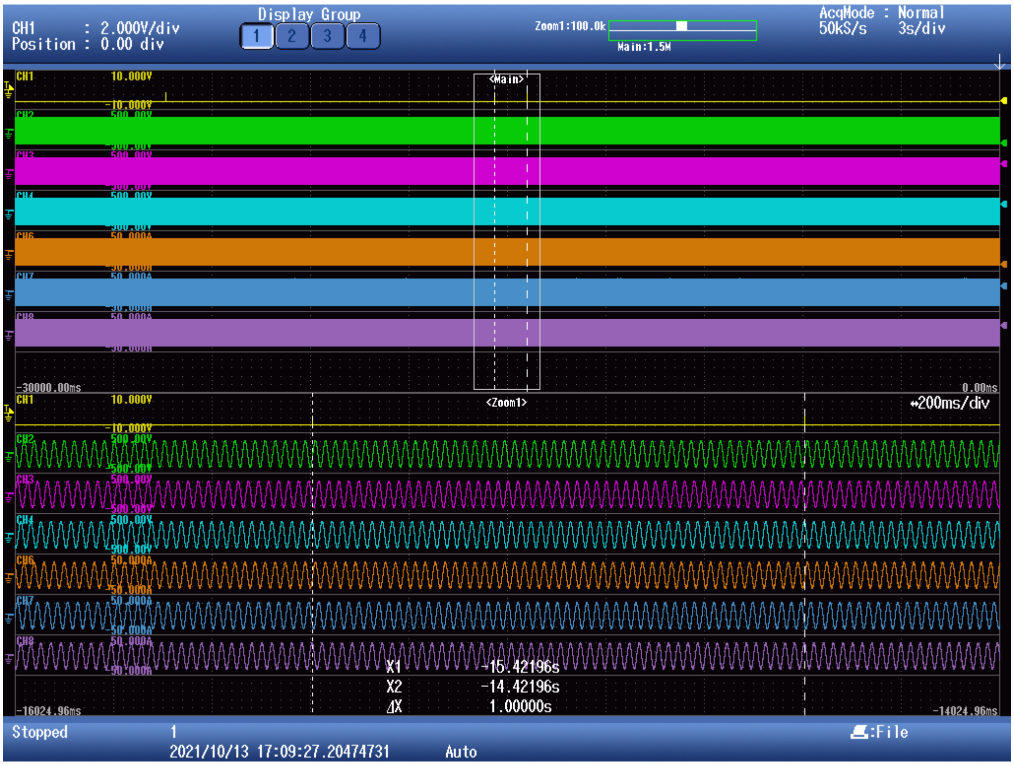
Note:
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

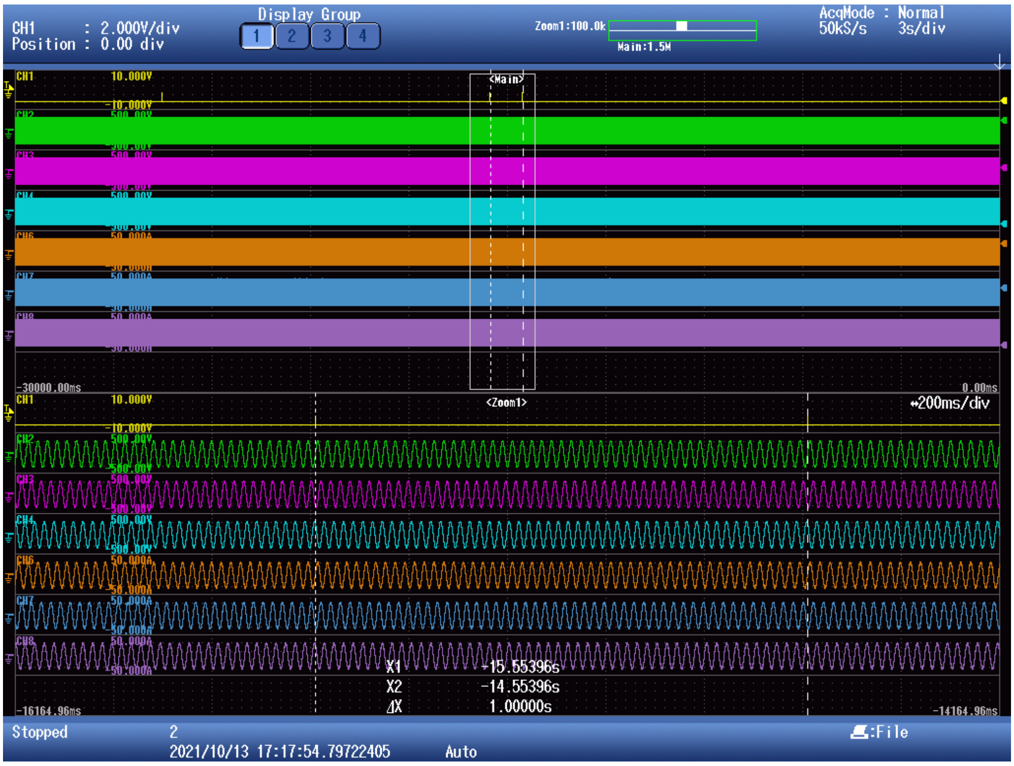
4.5.2	Rate of change of frequency (RoCoF) immunity	P

Test result：

	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

Graph of frequency 49Hz to 51Hz:



Graph of frequency 51Hz to 49Hz:

Assessment criterion: 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.
Note: The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.5.3 4.5.4 4.7.4	Operating frequency range Continuous operating voltage range 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.

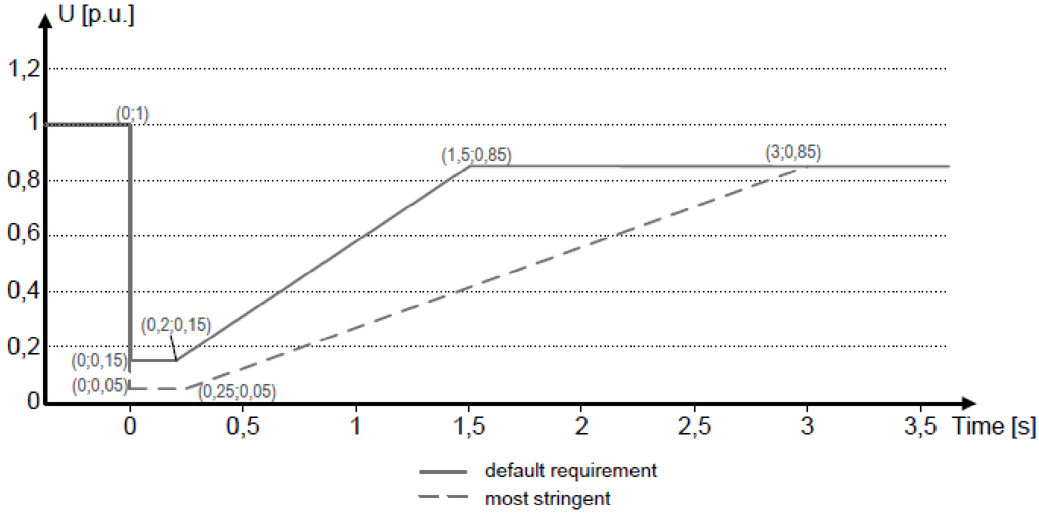


Figure 6 — Low voltage ride through capability for non-synchronous generating technology

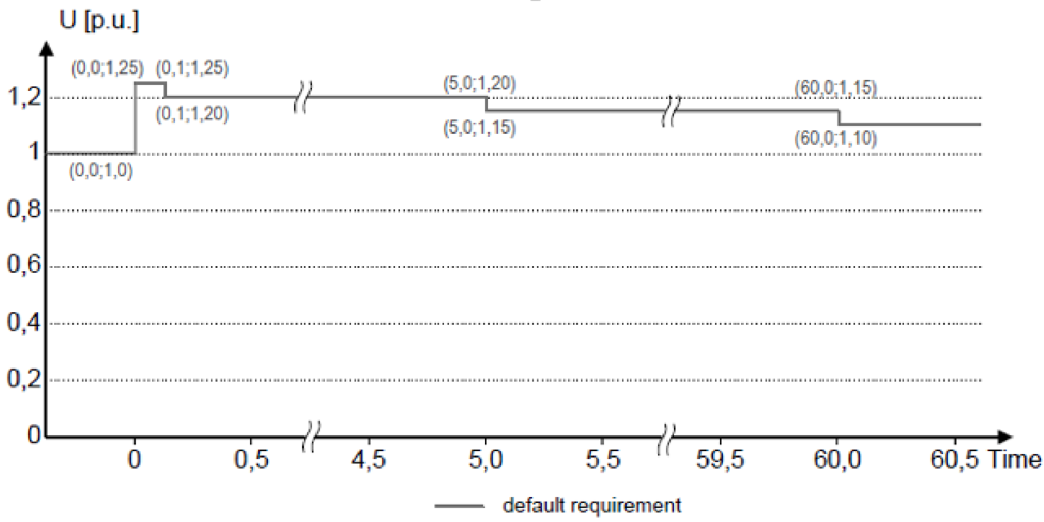


Figure 8 — Over-voltage ride through capability

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:

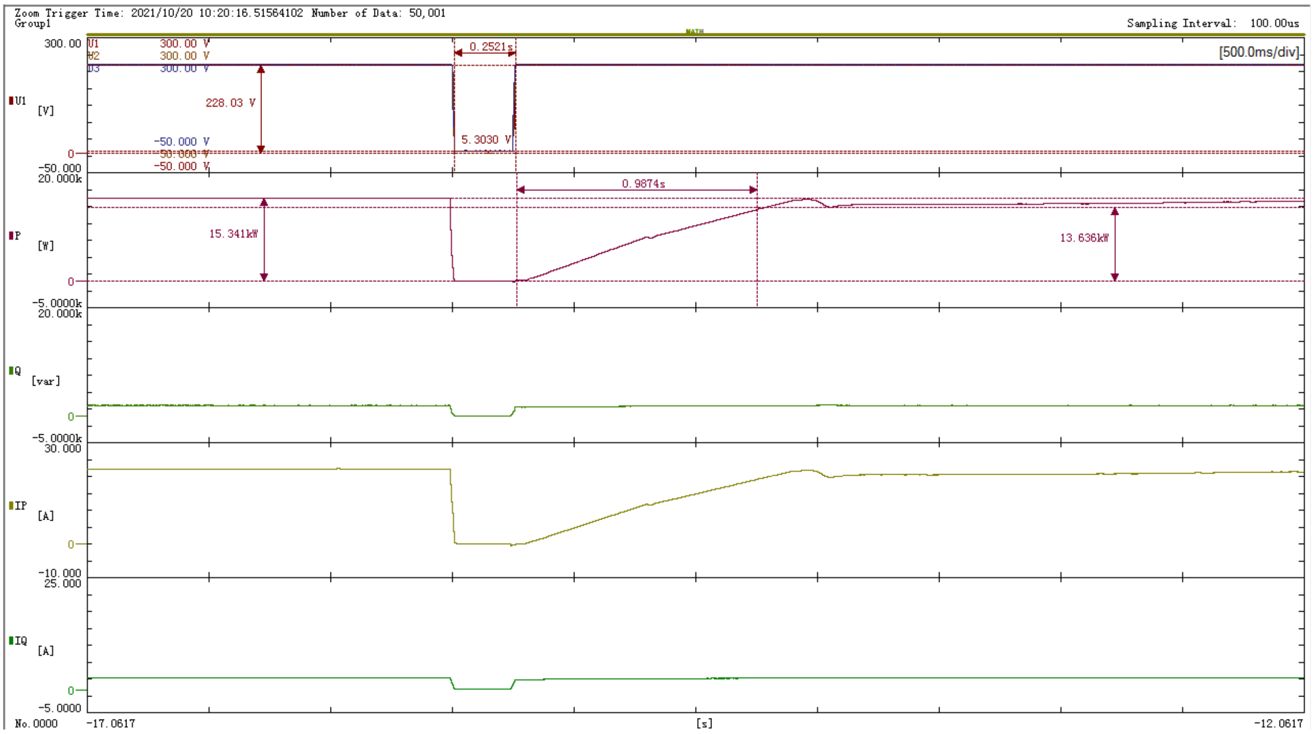
For every kind of voltage dip a test without load has to be performed in order to prove that the test condition was fulfilled. The voltage has to drop to AT LEAST the defined depth level. An exception can be considered in case no current is supplied during dips.

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

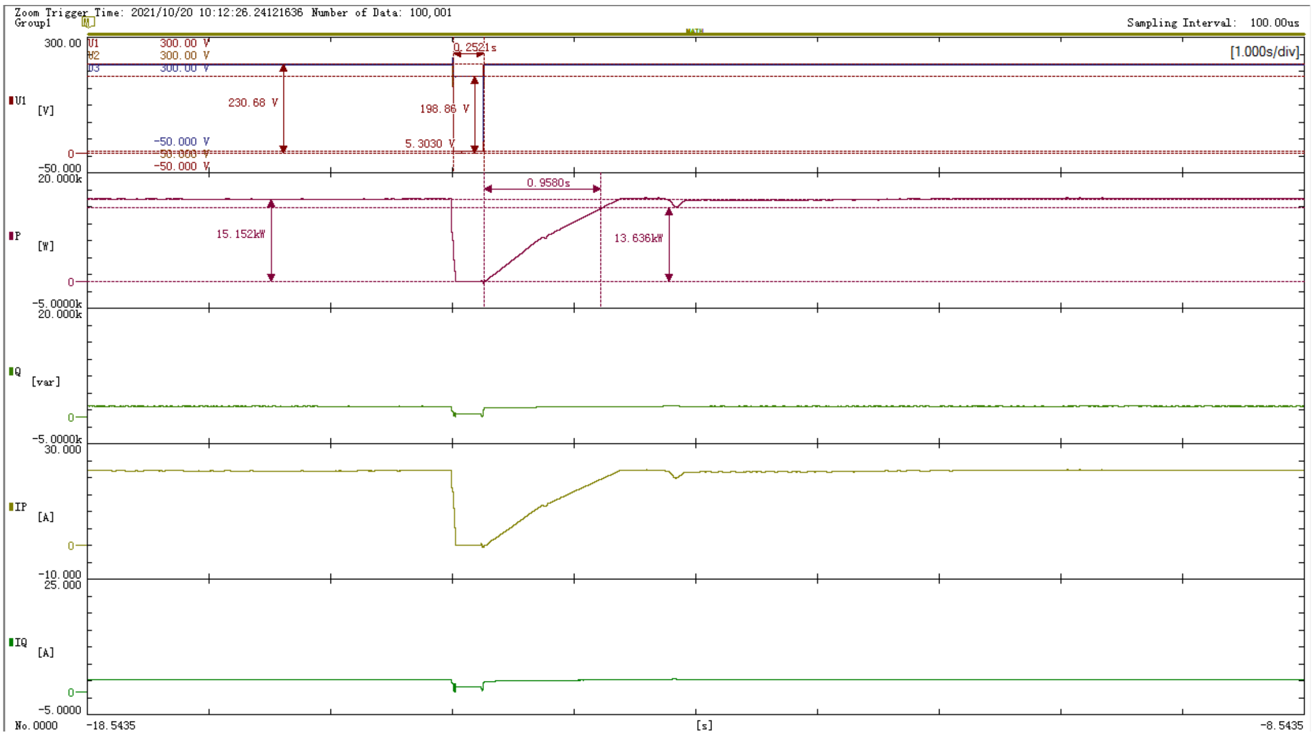
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

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	252	Pass
1.D.1- Asymmetrical	0,03	250 ± 20	252	Pass
1.B.1- Single phase	0,03	250 ± 20	252	Pass
2.A.1- Symmetrical	0,31	1300 ± 20	1303	Pass
2.D.1- Asymmetrical	0,31	1300 ± 20	1303	Pass
2.B.1- Single phase	0,31	1300 ± 20	1303	Pass
3.A.1- Symmetrical	0,82	3000 ± 20	3000	Pass
3.D.1- Asymmetrical	0,82	3000 ± 20	3000	Pass
3.B.1- Single phase	0,82	3000 ± 20	3000	Pass
P_{Emax} in %	20% ±5%			
1.A.2- Symmetrical	0,03	250 ± 20	252	Pass
1.D.2- Asymmetrical	0,03	250 ± 20	250	Pass
1.B.2- Single phase	0,03	250 ± 20	250	Pass
2.A.2- Symmetrical	0,31	1300 ± 20	1303	Pass
2.D.2- Asymmetrical	0,31	1300 ± 20	1303	Pass
2.B.2- Single phase	0,31	1300 ± 20	1303	Pass
3.A.2- Symmetrical	0,82	3000 ± 20	3000	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	101	Pass
OV2- Symmetrical	1,20	5000 ± 20	5002	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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.				

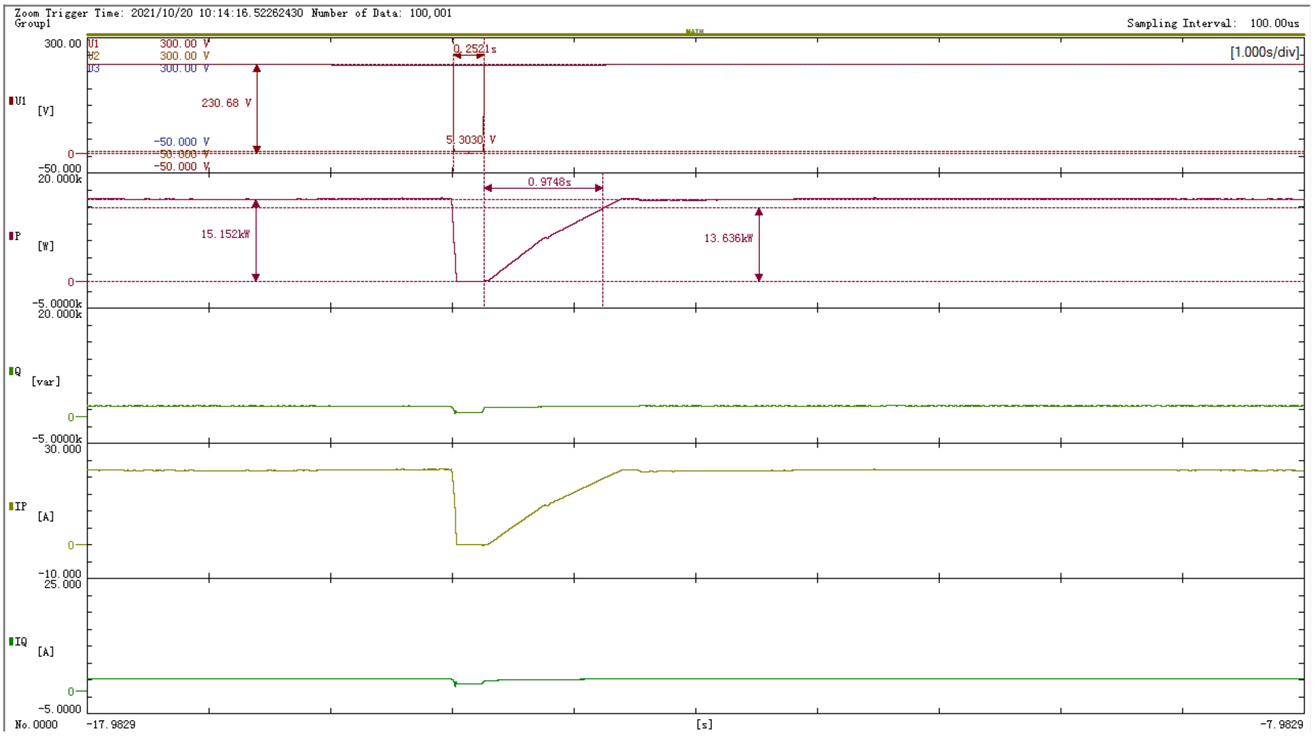
Test 1.A.1-Symmetrical fault (U/U_{nom} = 0,03); P = 100% ±5% P_n



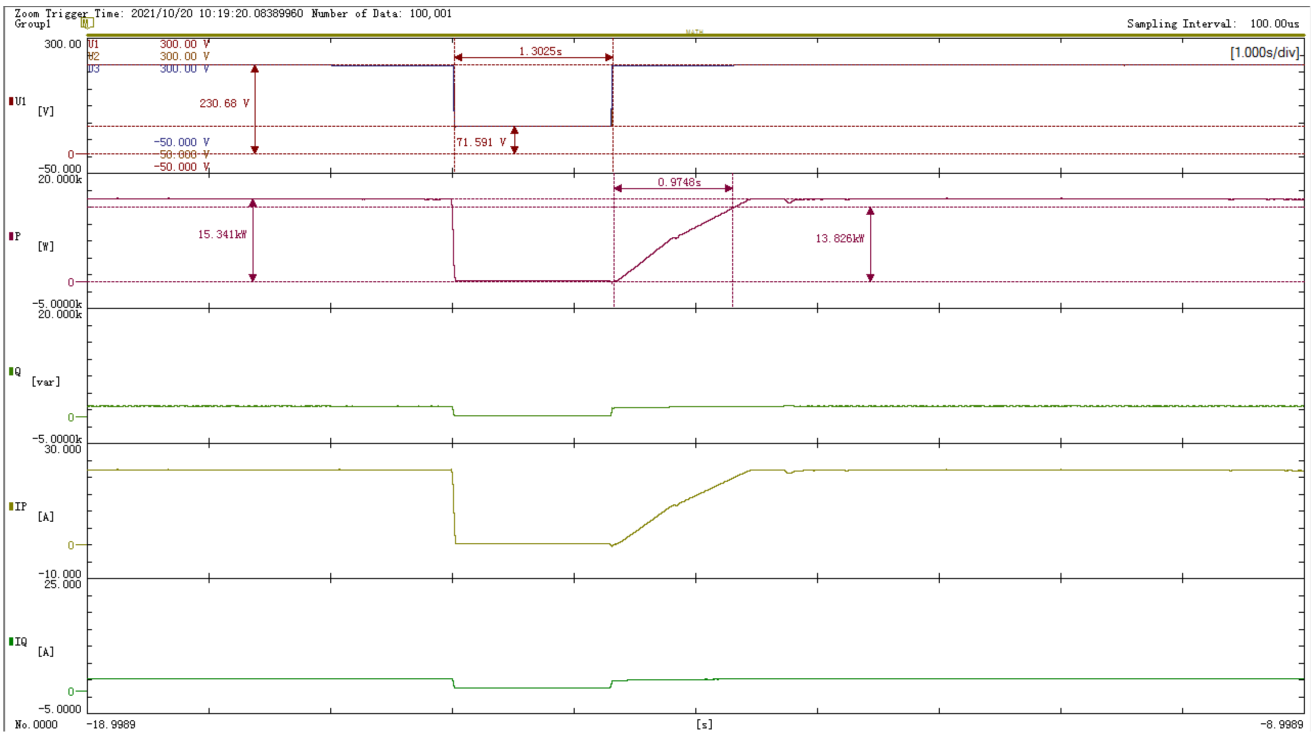
Test 1.D.1-Asymmetrical fault (U/U_{nom} = 0,03); P = 100% ±5% P_n



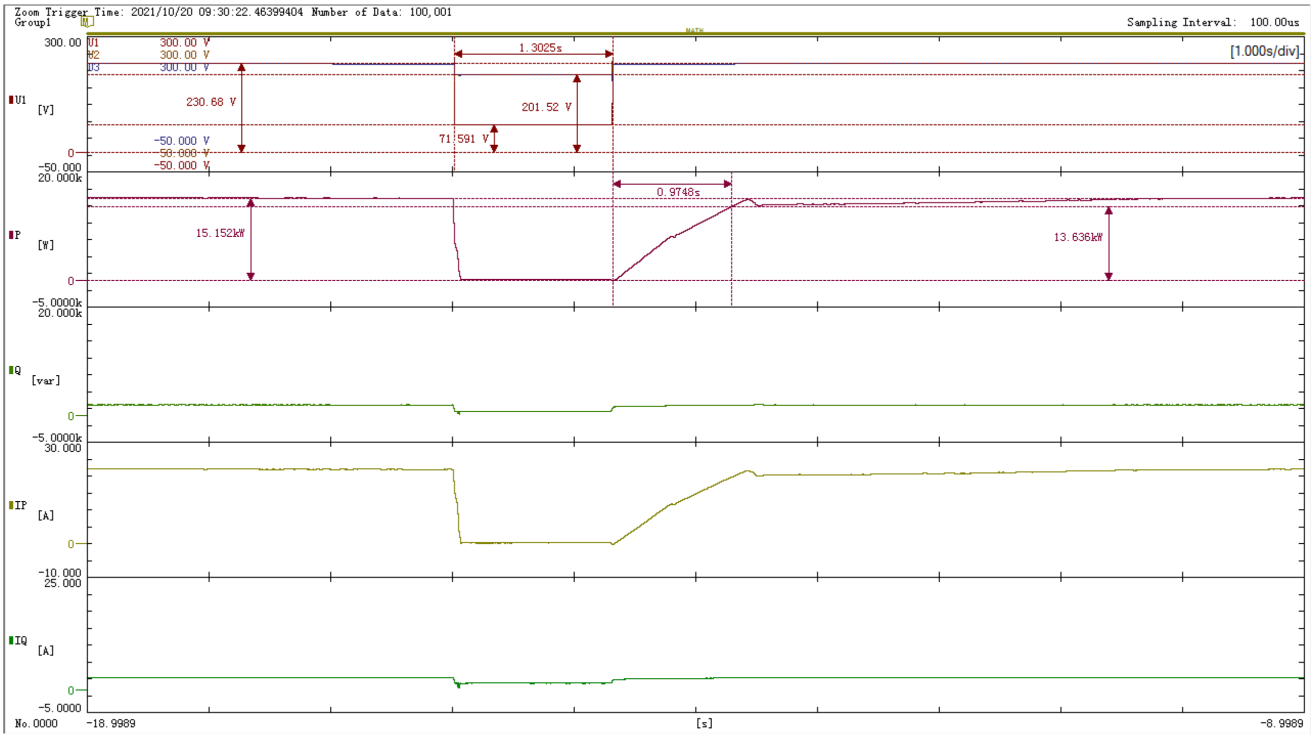
Test 1.B.1-Single phase fault (U/U_{nom} = 0,03); P = 100% ±5% P_n



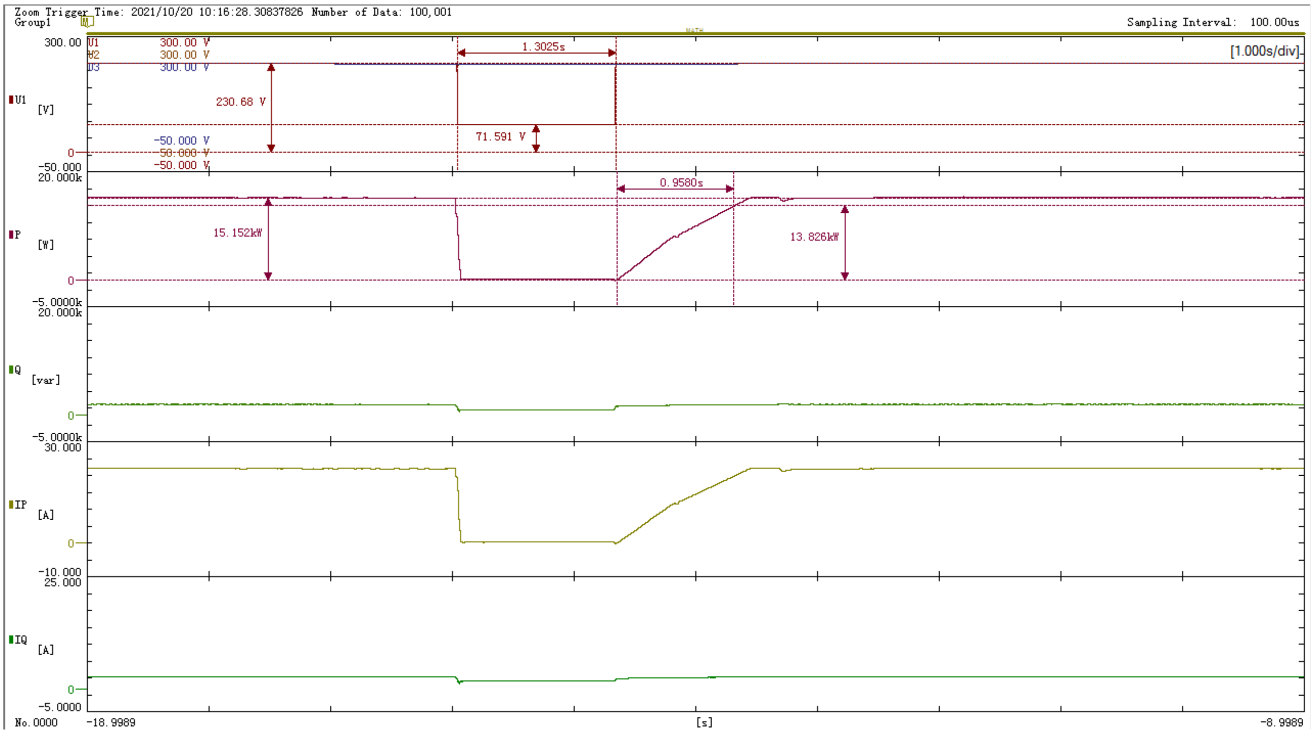
Test 2.A.1-Symmetrical fault (U/U_{nom} = 0,31); P = 100% ±5% P_n

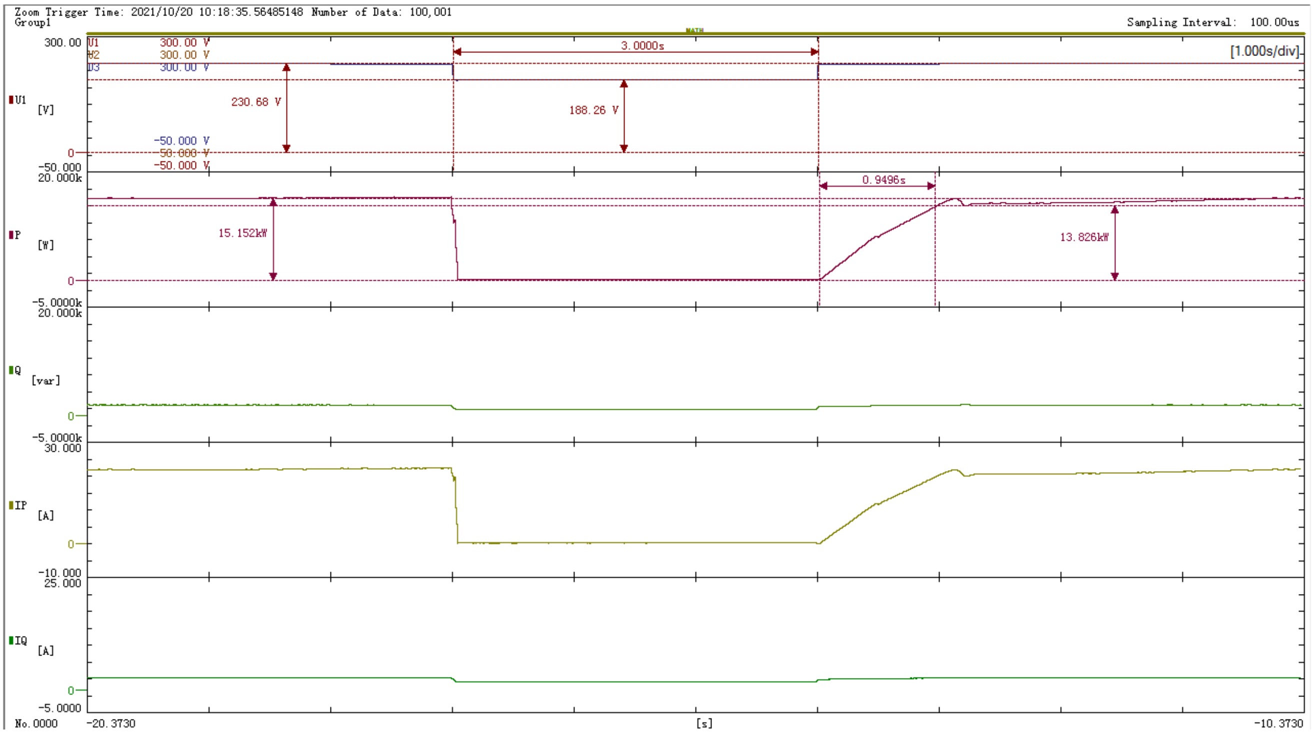
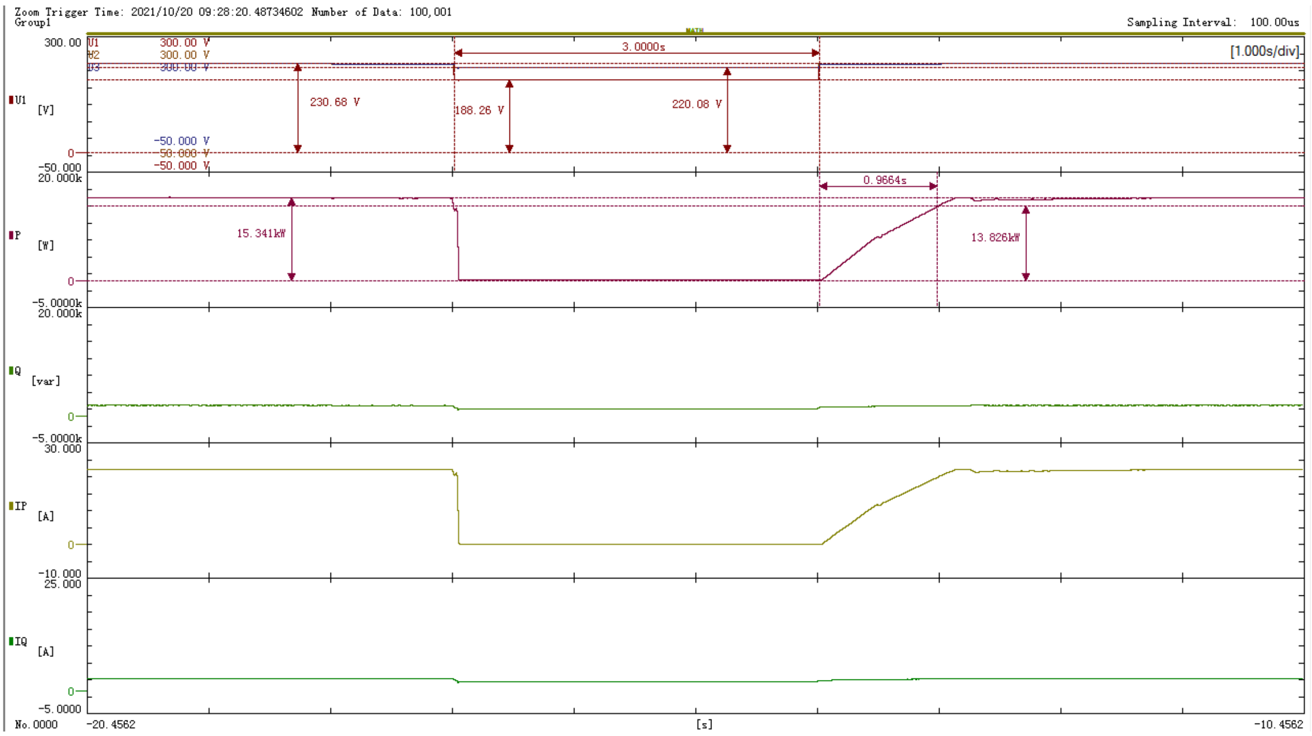


Test 2.D.1- Asymmetrical fault (U/U_{nom} = 0,31); P = 100% ±5% P_n

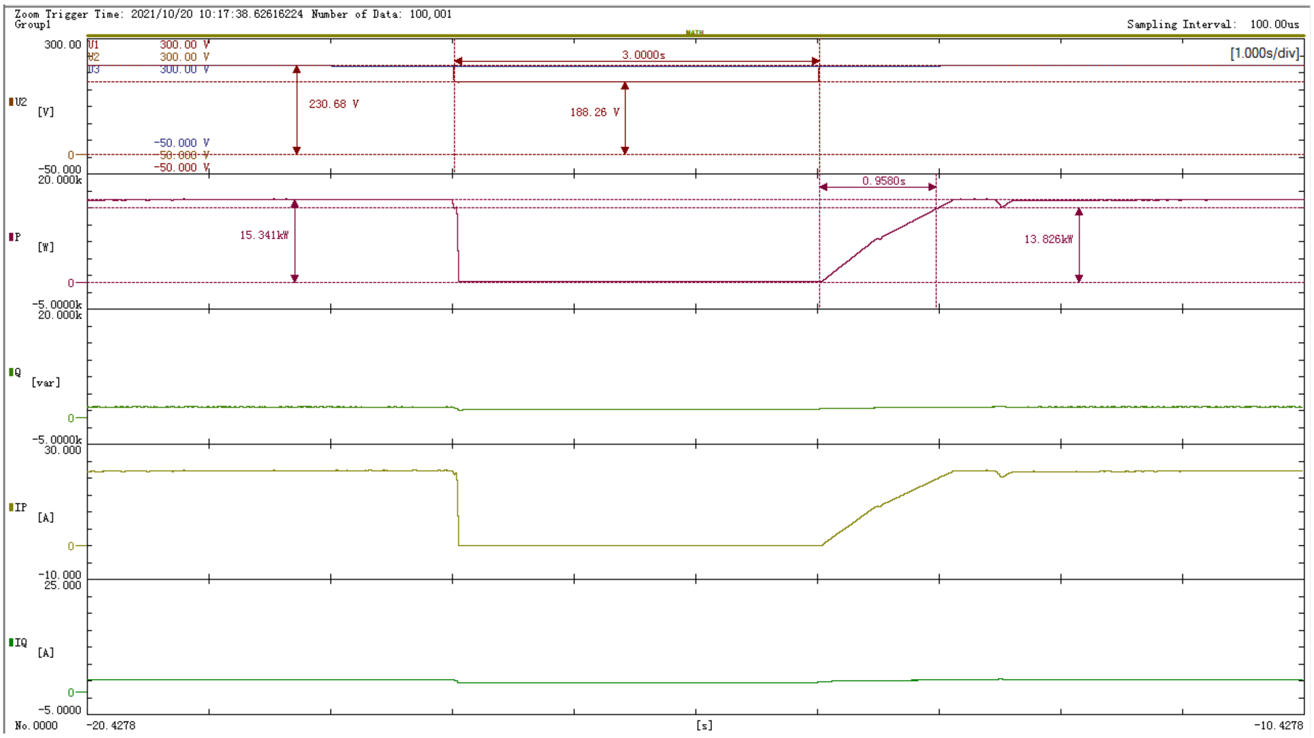


Test 2.B.1-Single phase fault (U/U_{nom} = 0,31); P = 100% ±5% P_n

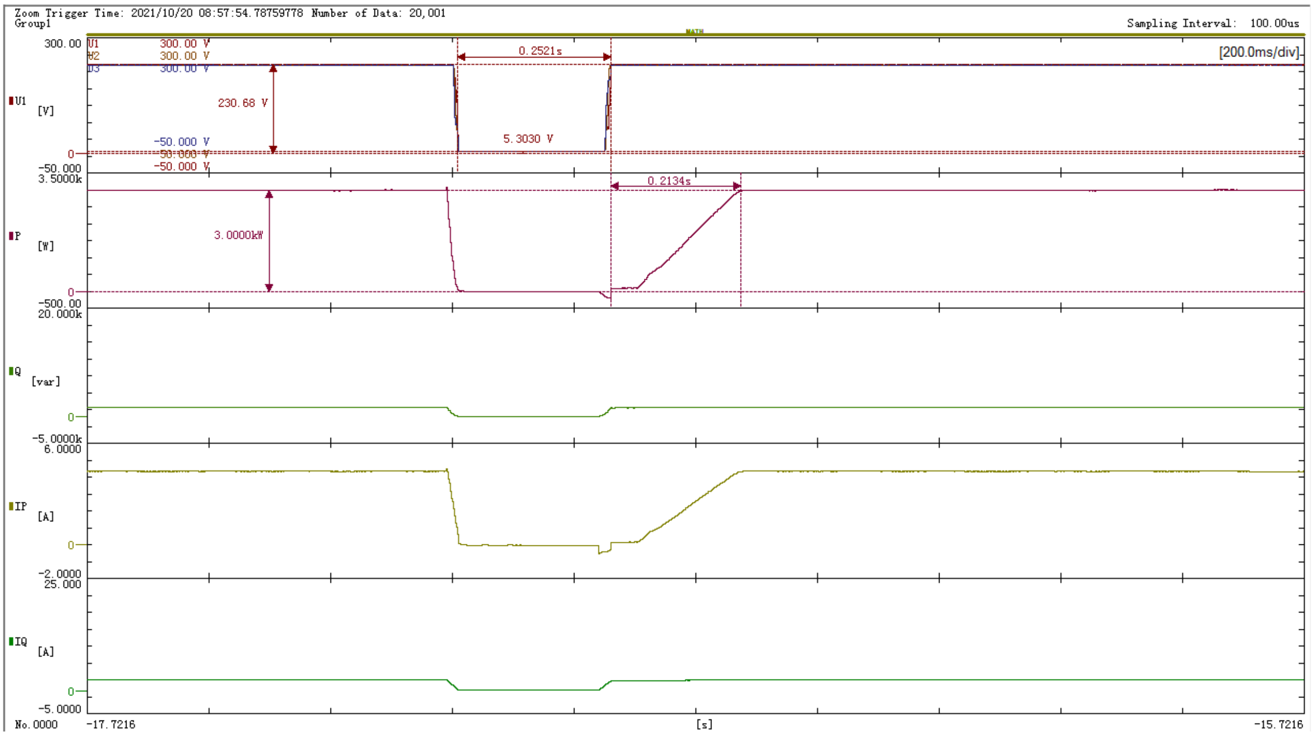


Test 3.A.1-Symmetrical fault (U/U_{nom} = 0,82); P = 100% ±5% P_n

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


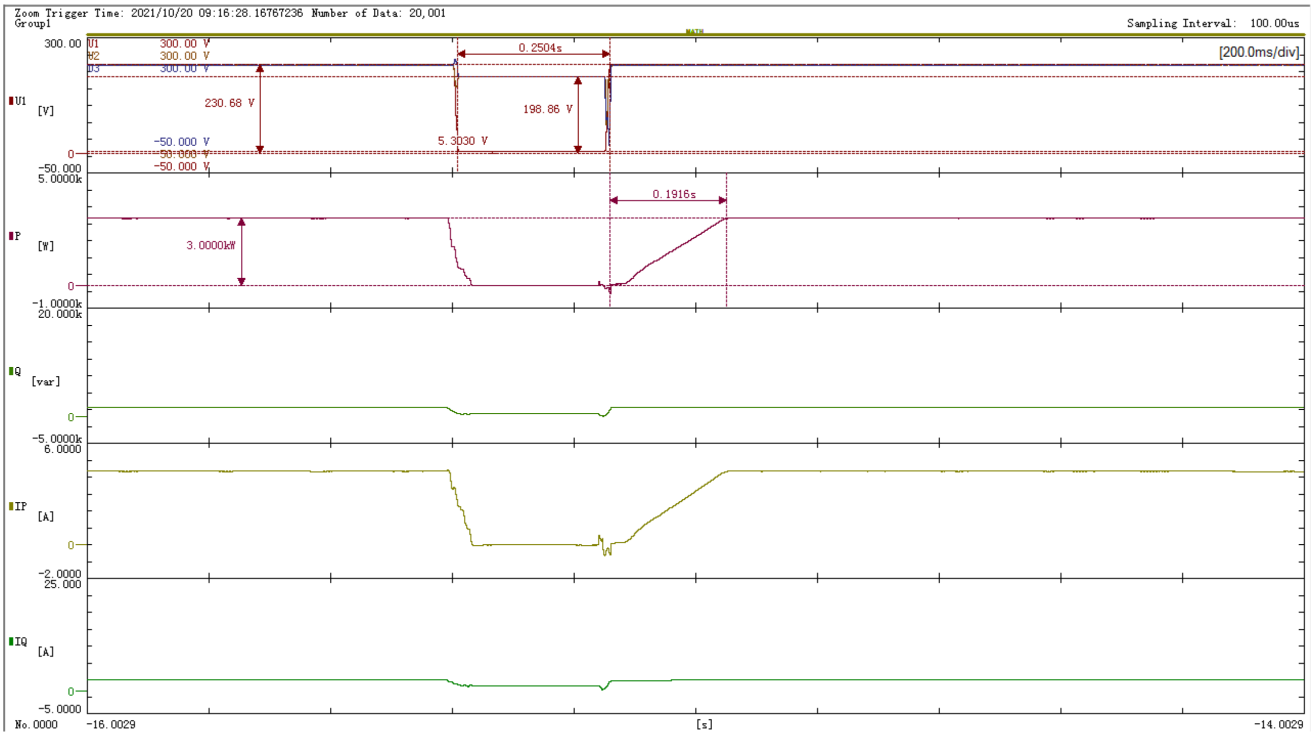
Test 3.B.1-Single phase fault (U/U_{nom} = 0,82); P = 100% ±5% P_n



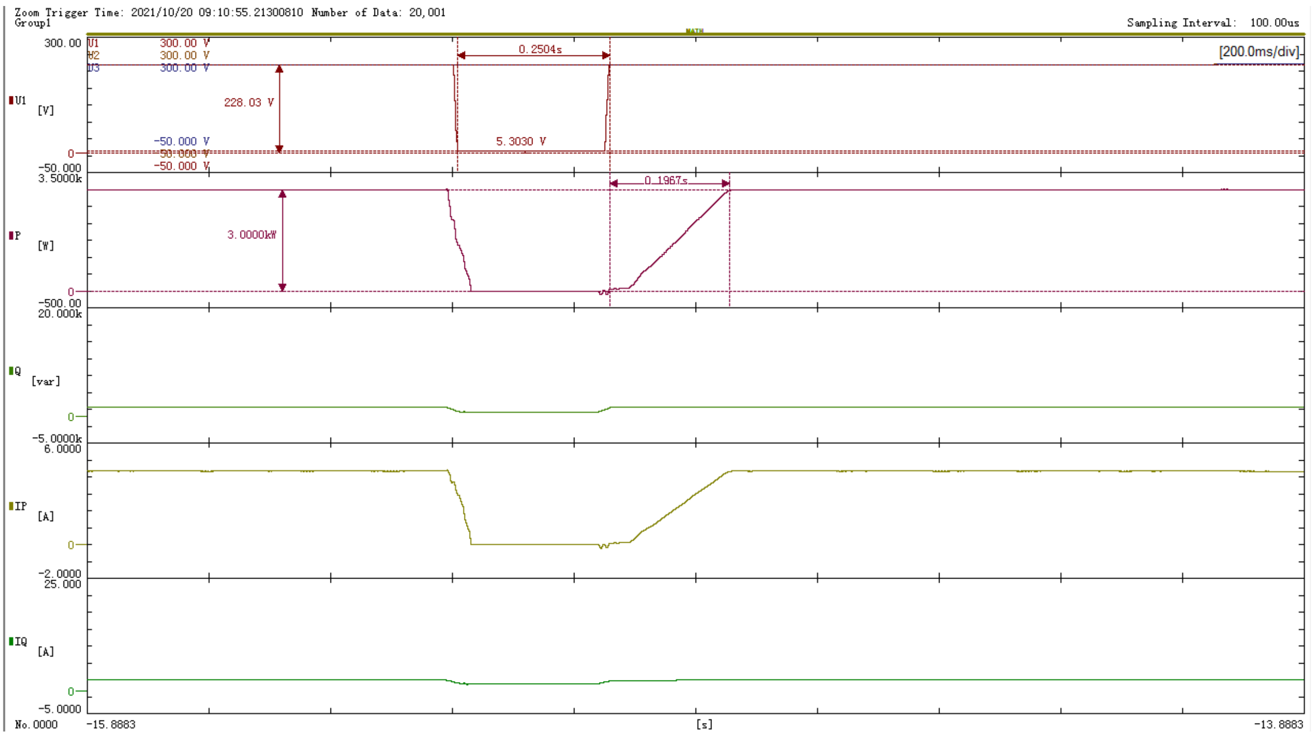
Test 1.A.2-Symmetrical fault (U/U_{nom} = 0,03); P = 20% ±5% P_n



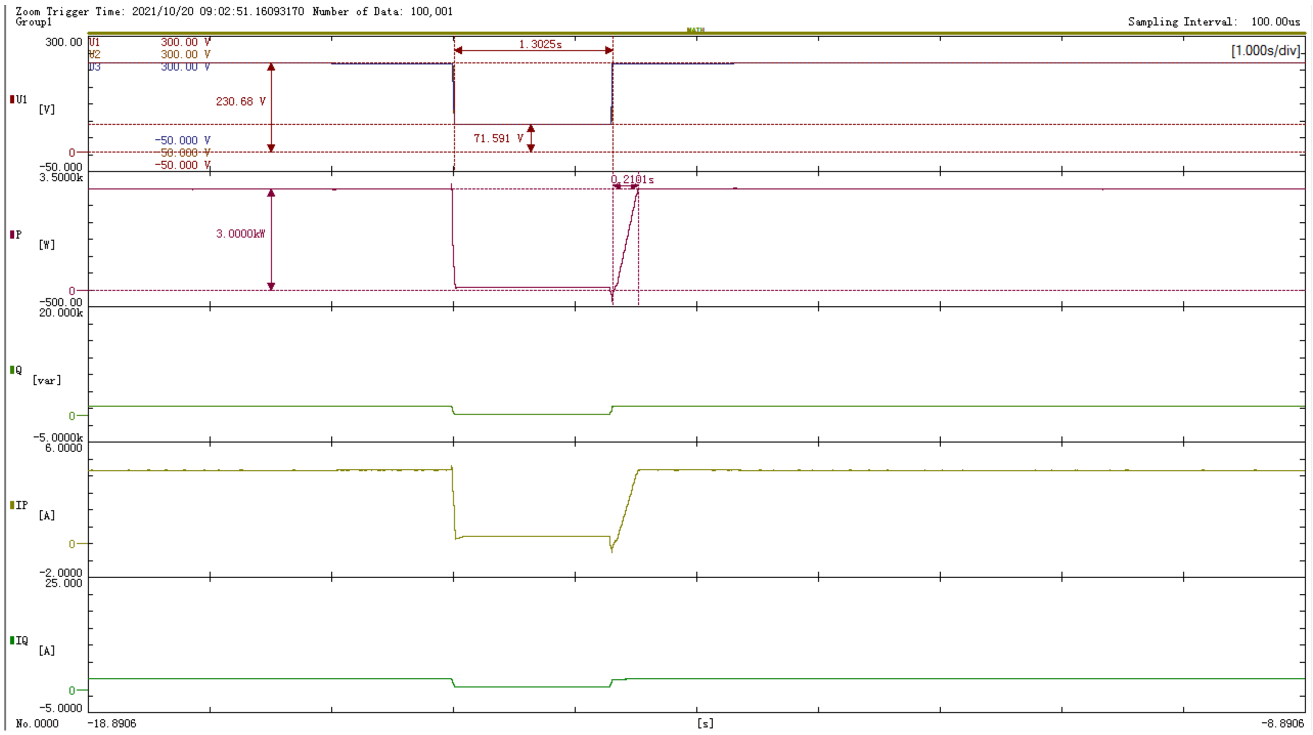
Test 1.D.2-Asymmetrical fault (U/U$_{nom}$ = 0,03); P = 20% ±5% P$_n$



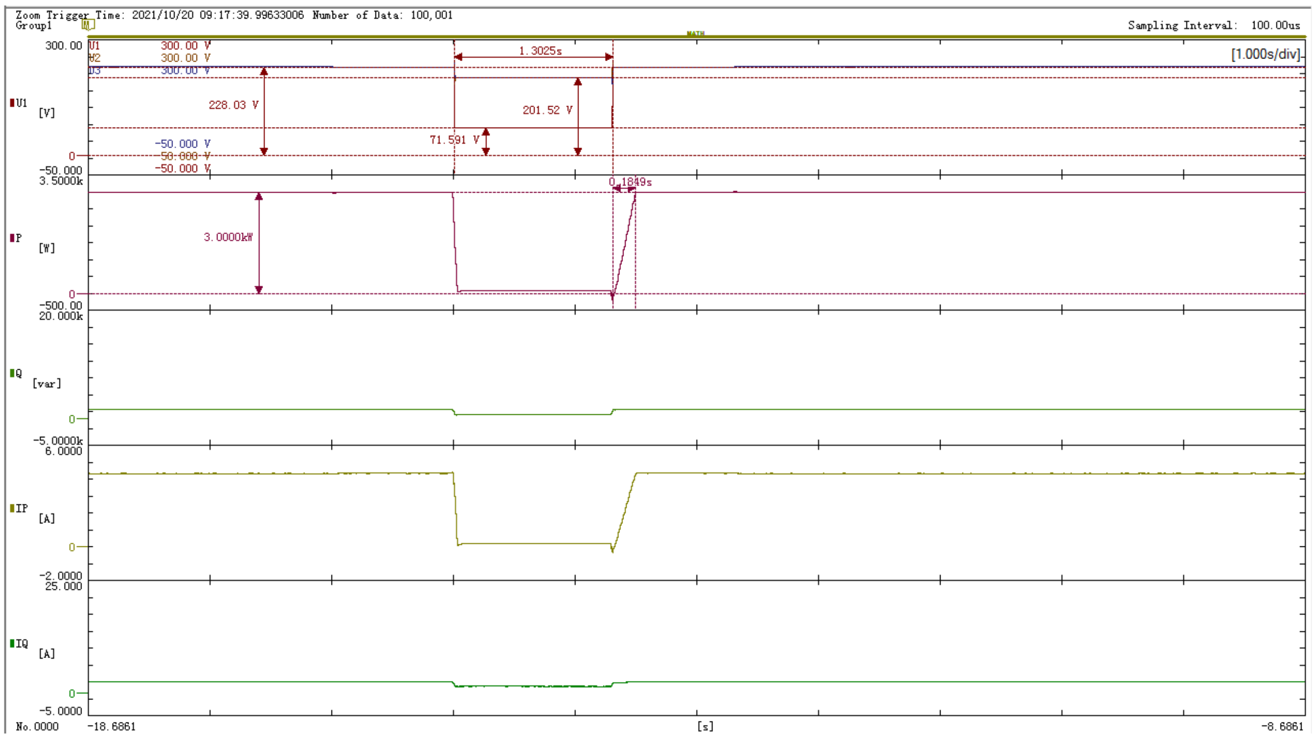
Test 1.B.2-Single phase fault (U/U$_{nom}$ = 0,03); P = 20% ±5% P$_n$



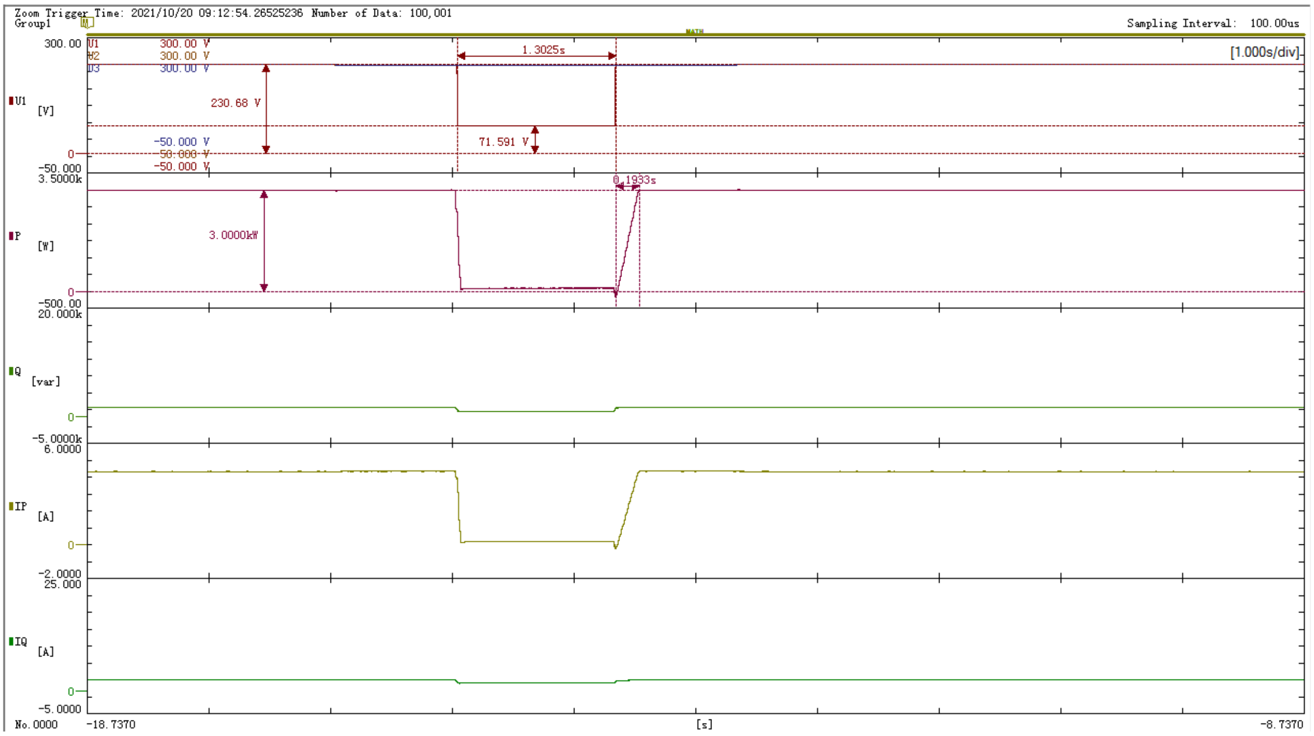
Test 2.A.2-Symmetrical fault (U/U_{nom} = 0,31); P = 20% ±5% P_n



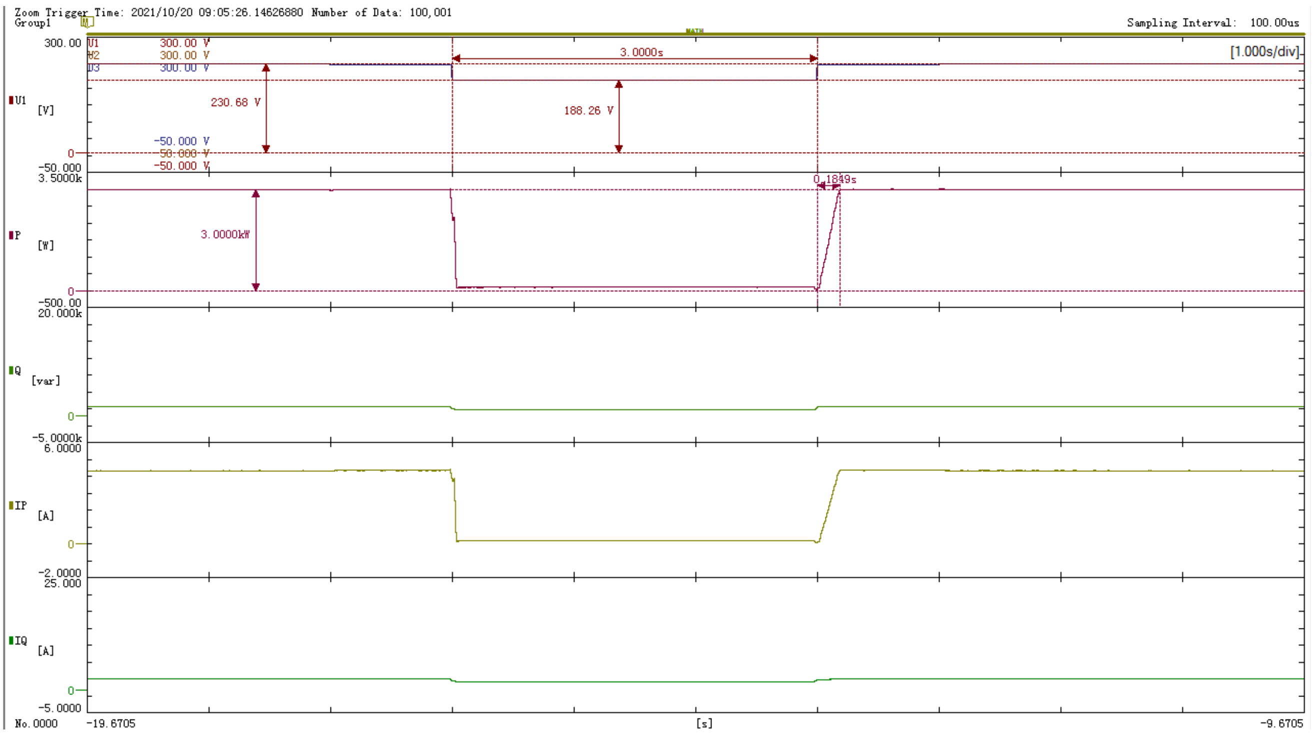
Test 2.D.2-Asymmetrical fault (U/U_{nom} = 0,31); P = 20% ±5% P_n



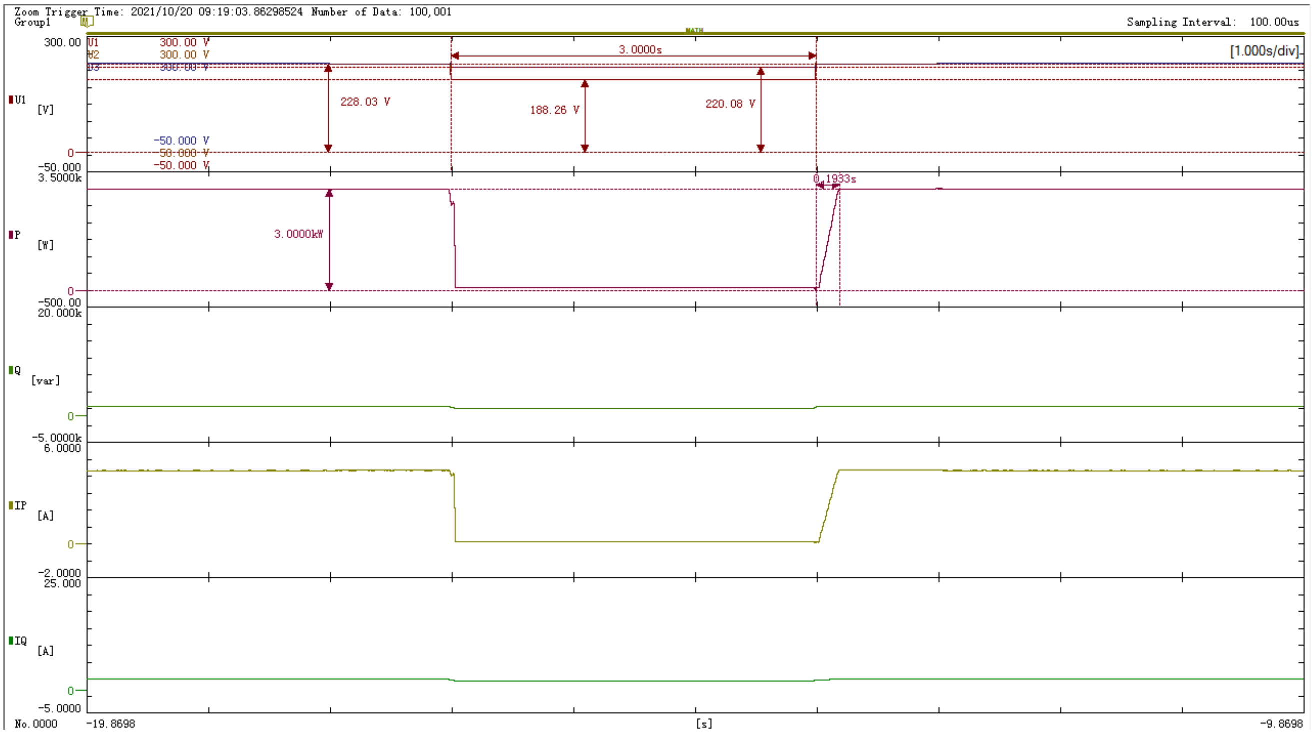
Test 2.B.2-Single phase fault (U/U_{nom} = 0,31); P = 20% ±5% P_n



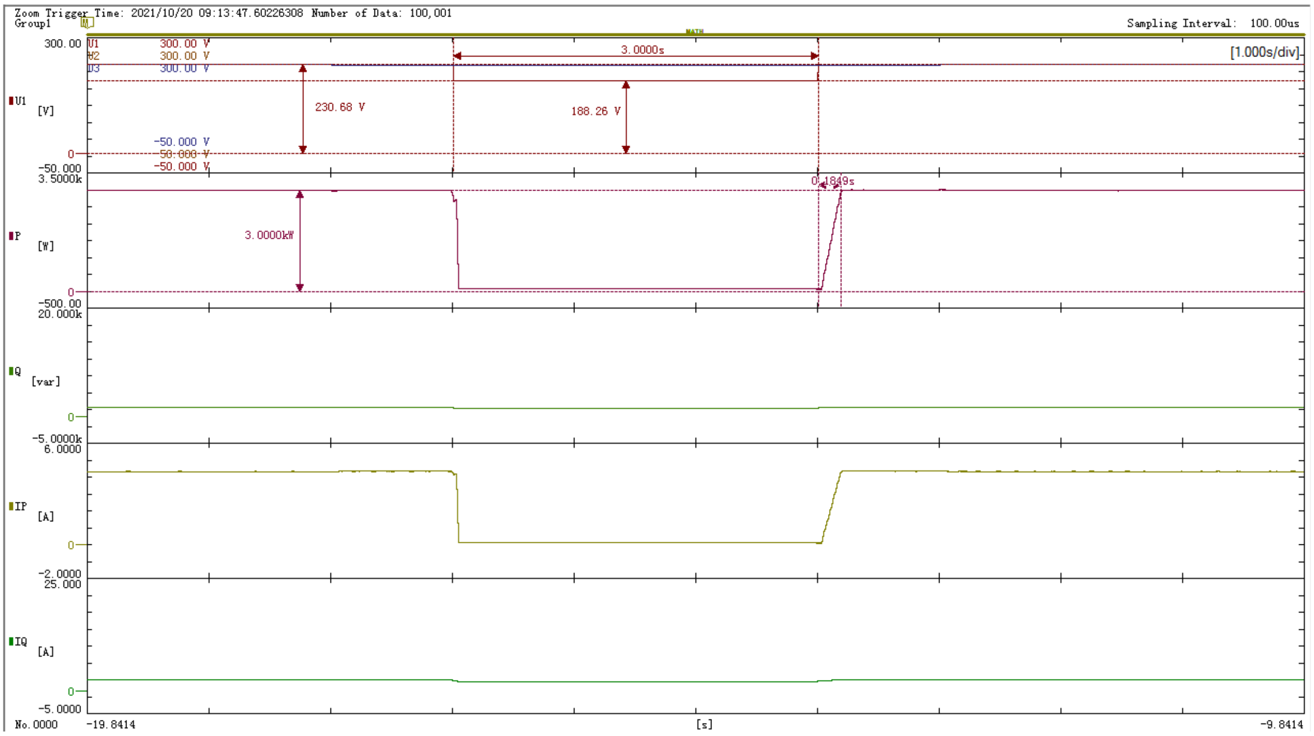
Test 3.A.2-Symmetrical fault (U/U_{nom} = 0,82); P = 20% ±5% P_n



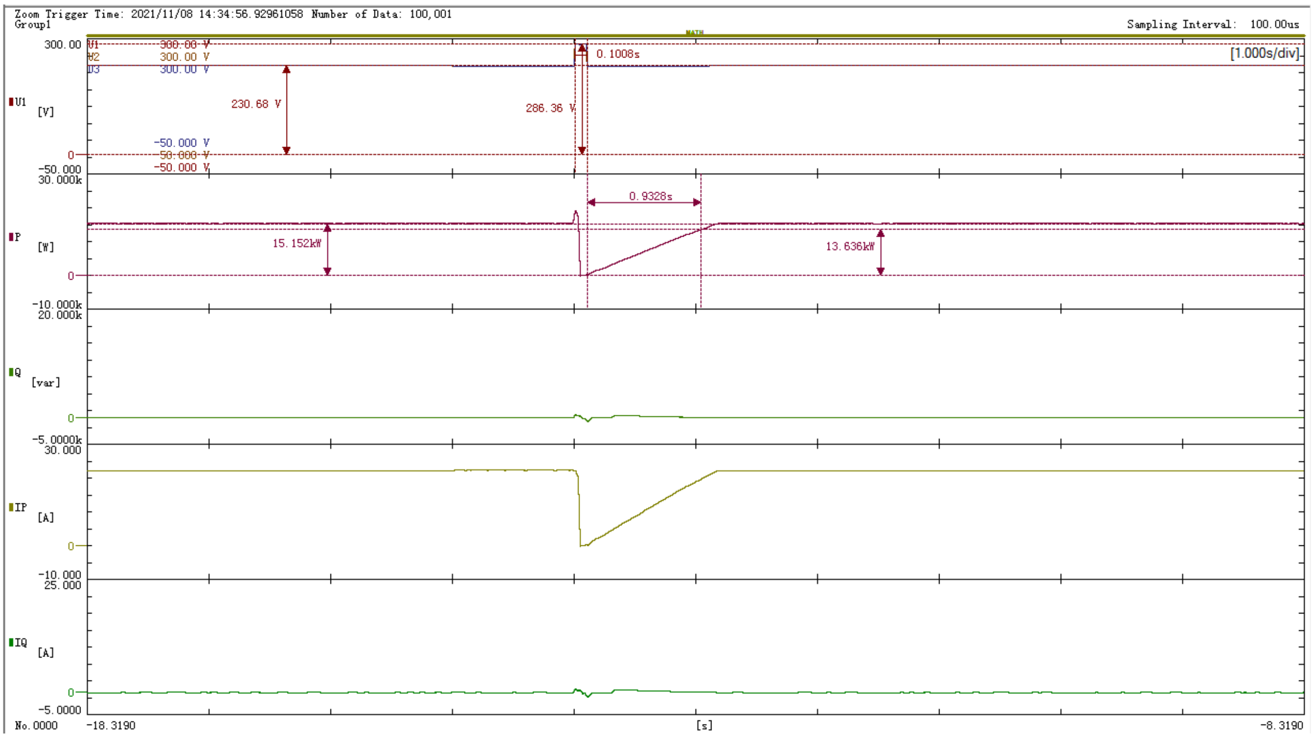
Test 3.D.2-Asymmetrical fault (U/U$_{nom}$ = 0,82); P = 20% ±5% P$_n$



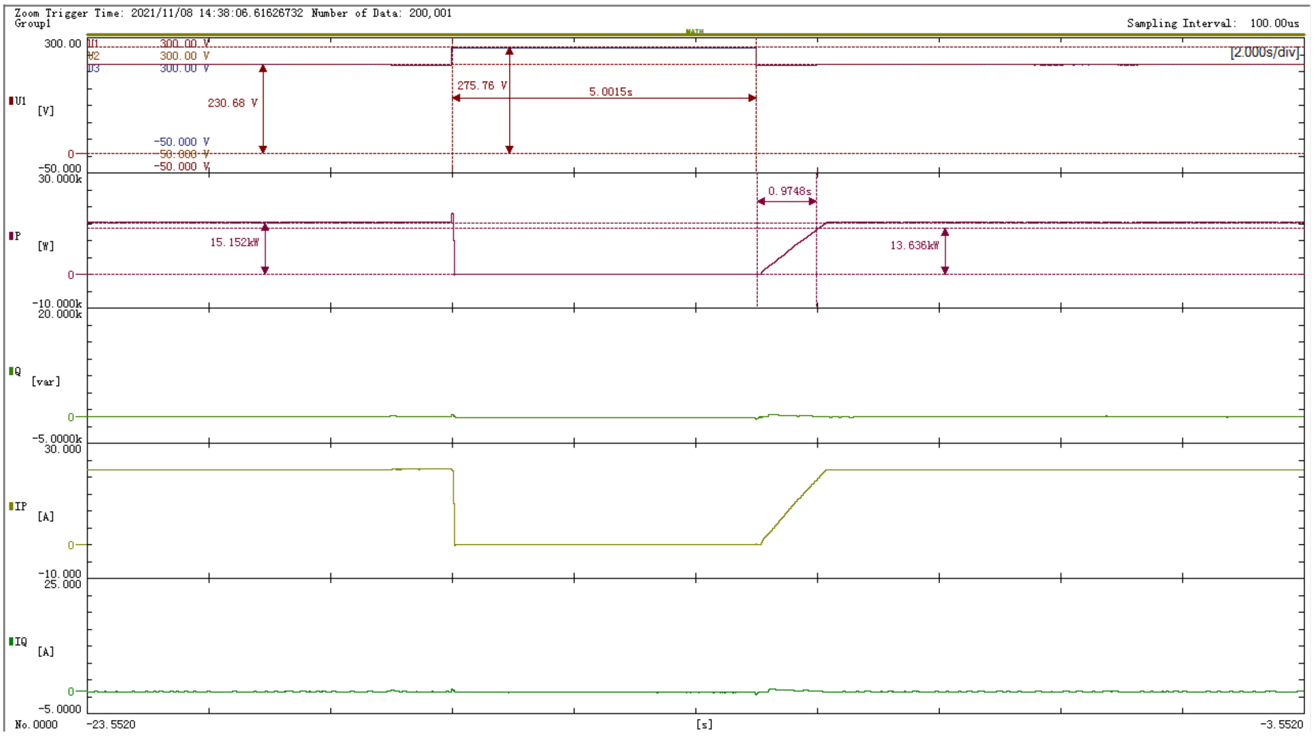
Test 3.B.2-Single phase fault (U/U$_{nom}$ = 0,82); P = 20% ±5% P$_n$



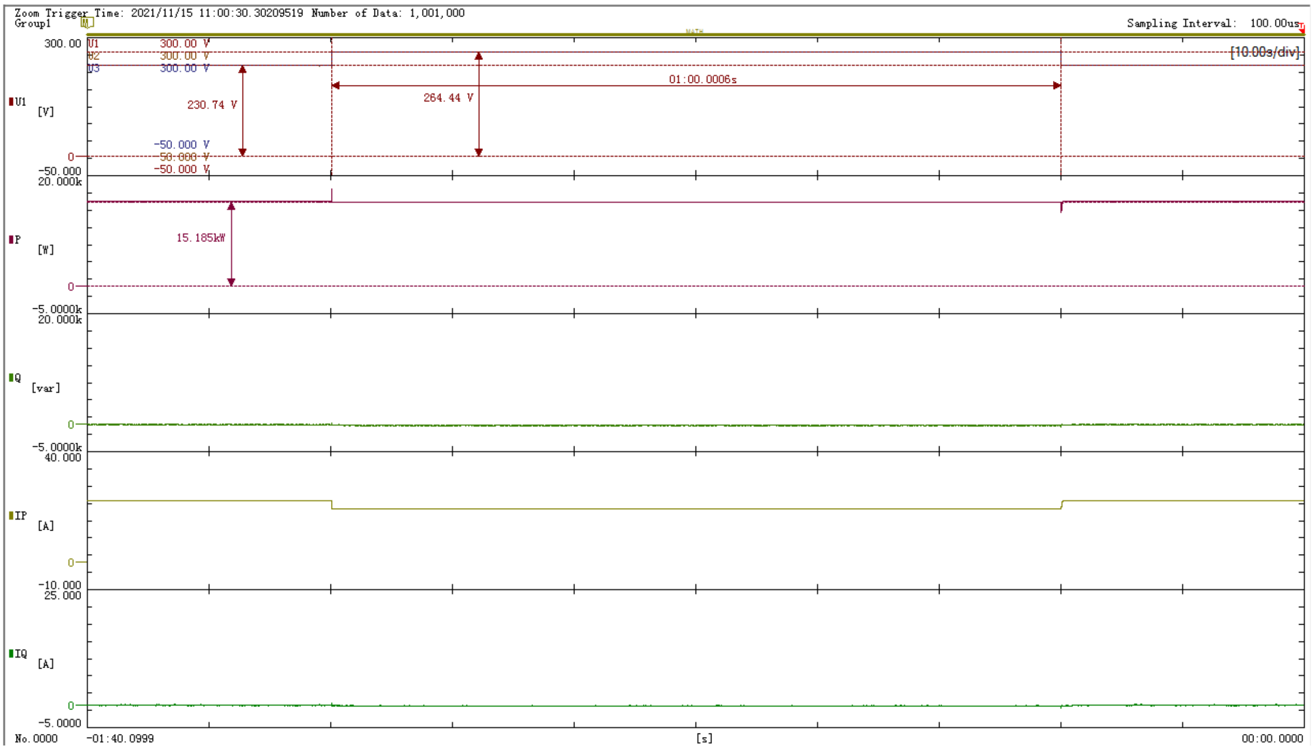
Test OV1-Symmetrical fault (U/U_{nom} = 1,25); P = 100% ±5% P_n



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

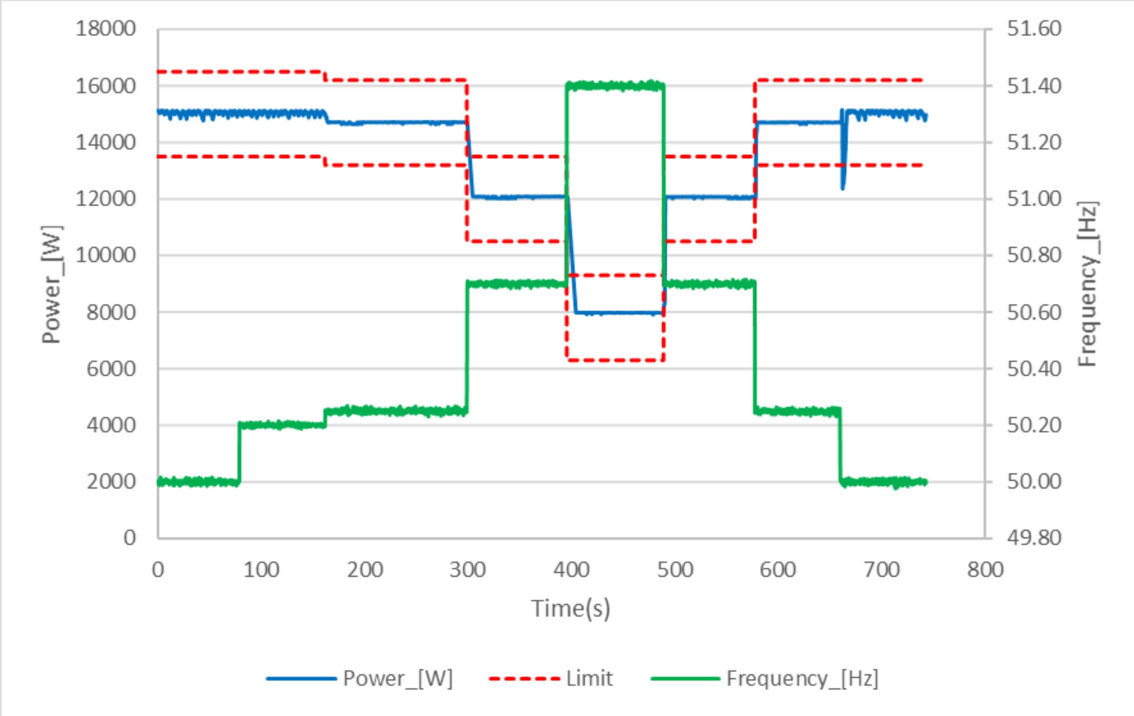


Test OV3-Symmetrical fault (U/U_{nom} = 1,15); P = 100% ±5% P_n

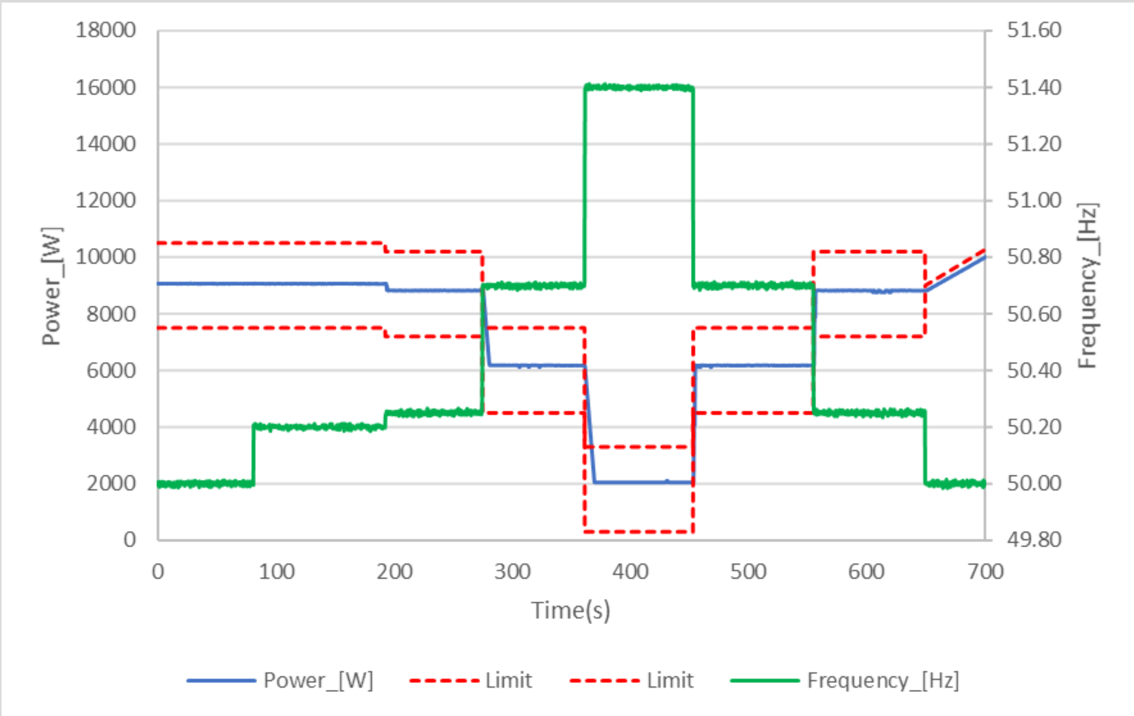


4.6.1	**Power response to over-frequency**						**P**
Test result：							
1-min mean value [Hz]:	a) 50,00	b) 50,25	c) 50,70	d) 51,40	e) 50,70	f) 50,25	g) 50,00
1**.** Measurement a) to g): Active power output =100% P_{Emax} s=5% (40% P_{ref} / Hz), threshold frequency for start/return: 50,2Hz							
Frequency [Hz]:	50,00	50,25	50,70	51,40	50,70	50,25	50,00
P_M [kW]:	15,000	14,700	12,000	7,800	12,000	14,700	15,000
P_{E60} [kW]:	15,049	14,703	12,083	7,975	12,056	14,703	15,035
$\Delta P_{E60}/P_M$ [%]:	0,32	0,02	0,55	1,17	0,37	0,02	0,23
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]:	9,000	8,700	6,000	1,800	6,000	8,700	15,000
P_{E60} [kW]:	9,066	8,824	6,176	2,048	6,177	8,810	15,052
$\Delta P_{E60}/P_M$ [%]:	0,44	0,82	1,18	1,65	1,18	0,73	0,35
Limit $\Delta P/P_{1min}$:	± 10 % of P_{Emax}						

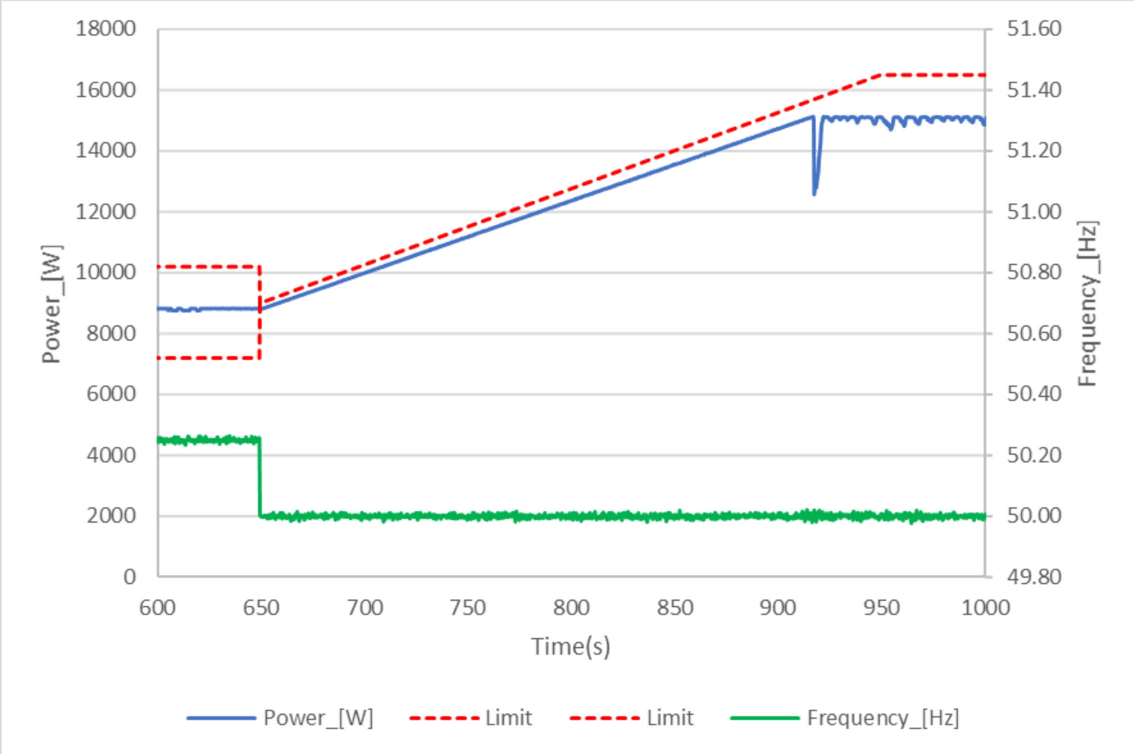
Graph of Measurement 1.: Active power output > 80% P_{Emax}



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



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.

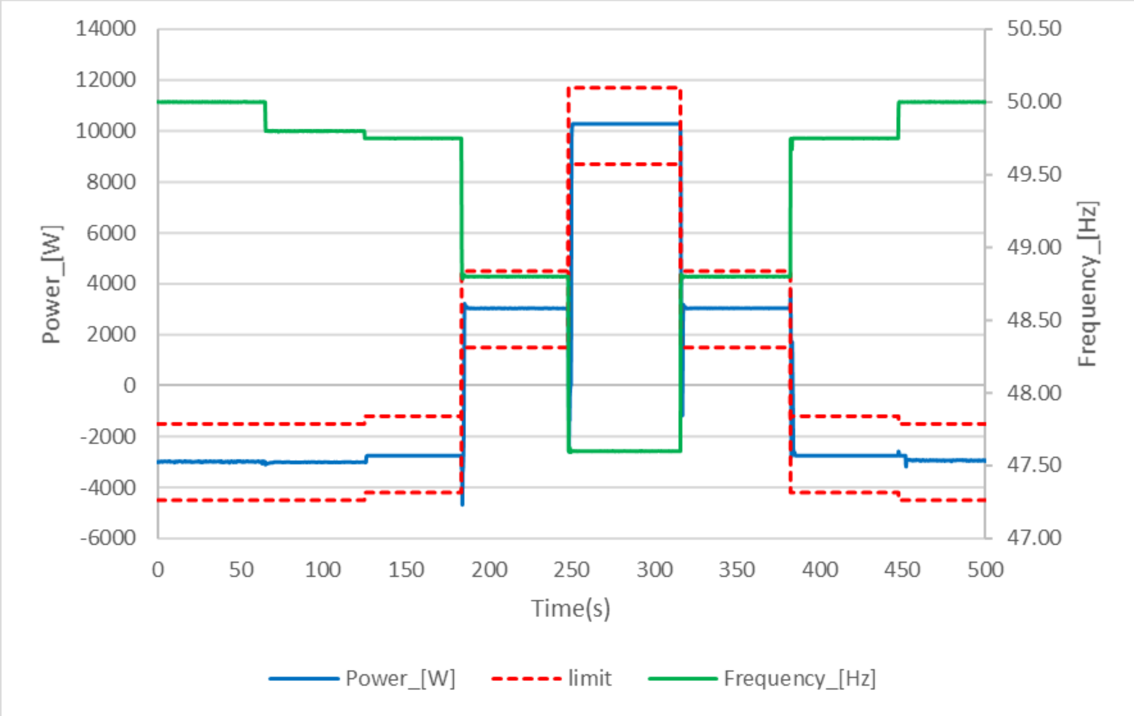
Note:

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

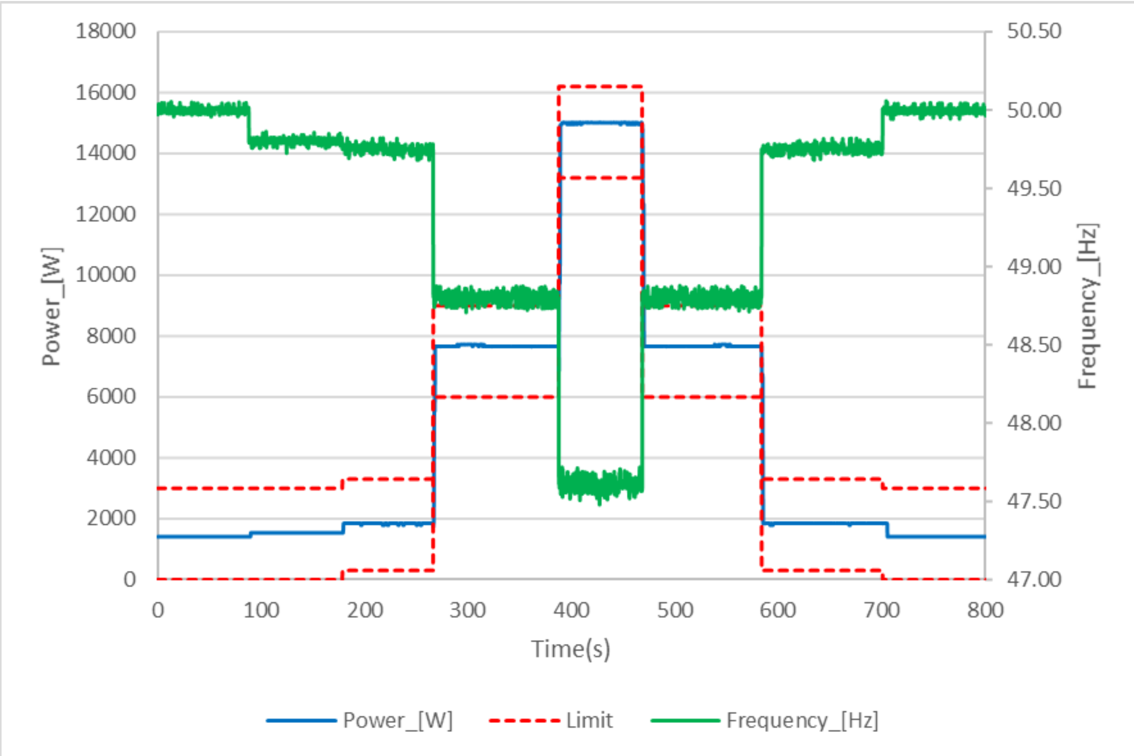
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.6.2	**Power response to under-frequency (For synchronous generating and Electrical Energy Storage System unit (EESS) only)**						**P**
Test result：							
1-min mean value [Hz]:	a) 50,00	b) 49,75	c) 48,80	d) 47,60	e) 48,80	f) 49,75	g) 50,00
1. Measurement a) to g): Active power output = -20% 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	49,75	50,00
P_M [kW]:	-3000	-2700	3000	10200	3000	-2700	-3000
P_{E60} [kW]:	-2984	-2748	3038	10285	3040	-2748	-2934
$\Delta P_{E60}/P_M$ [%]:	0,10	0,32	0,25	0,57	0,27	0,32	0,44
2. Measurement a) to g): Active power output 60% after freezing = 10% 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	49,75	50,00
P_M [kW]:	1500	1800	7500	14700	7500	1800	1500
P_{E60} [kW]:	1407	1840	7664	14999	7665	1848	1408
$\Delta P_{E60}/P_M$ [%]:	0,62	0,26	1,09	1,99	1,10	0,32	0,61
3. Measurement a) to g): Active power output 60% after freezing = 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]:	9000	9300	15000	15000	15000	9000	9000
P_{E60} [kW]:	9060	9538	15100	15096	15096	9062	9061
$\Delta P_{E60}/P_M$ [%]:	0,67	2,64	1,11	1,07	1,07	0,69	0,68
Limit $\Delta P/P_{1min}$:	± 10 % of P_{Emax}						

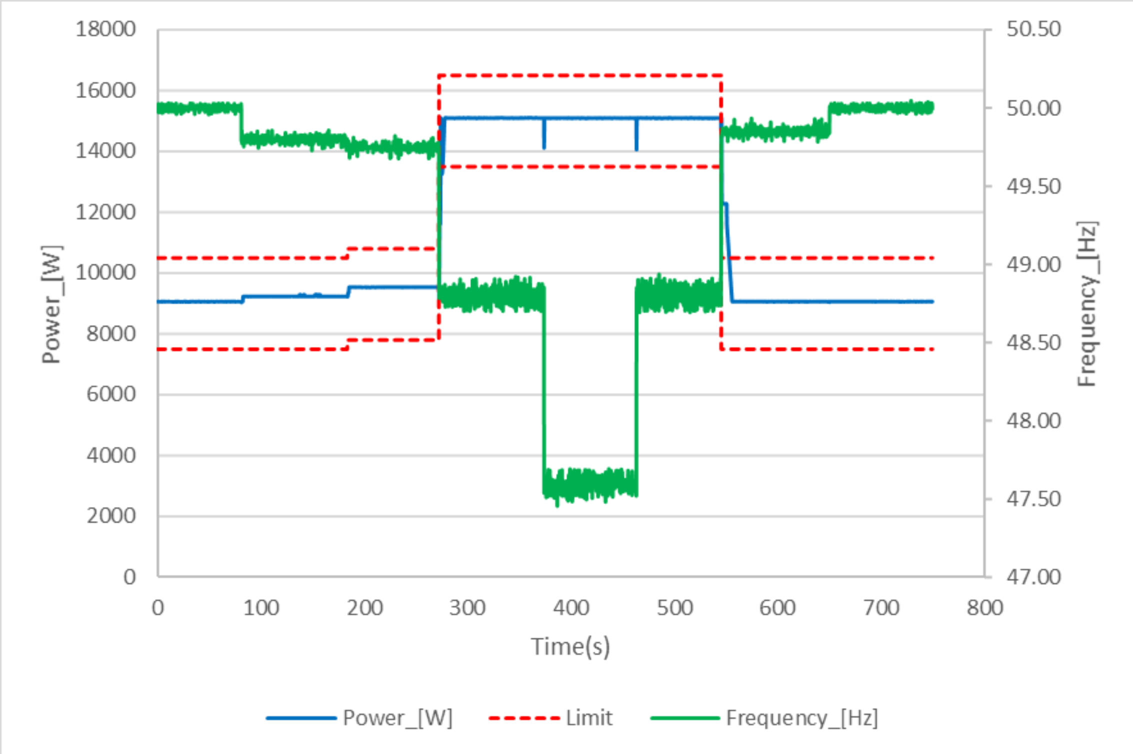
Graph of Measurement 1.: Active power output -20% P_{Emax}



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



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



Test:

The test method refer to clause 5.4.7 of VDE V 0124-100:2019-02 (Draft)
All generating units must increase the currently generated available active power PA with a gradient of 40%
P_{Emax} per Hertz (s = 5%) up to their technically possible maximum value at frequencies below 49,8 Hz. The
maximum value is determined by the current primary energy supply as well as the currently usable storage
capacity.
Power reductions, which serve to protect equipment, are also permitted at underfrequency.
While grid frequency is over frequency protection (Ex. f < 47,5 Hz), the generating units shall be disconnected
from the power supply when supplying energy.
It follows that generating units and memory also in the frequency range between 49,8 Hz and 47,5 Hz or 47,8
Hz with respect to their maximum possible active power feed permanently on the frequency characteristic up
and down move („driving on the curve")

Assessment criterion:

The generating plant shall be capable of activating active power response to under frequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s.
After settling time, the delivered active power should deviate from the nominal value by less than ± 10% PEmax.

Note:

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

The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

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：

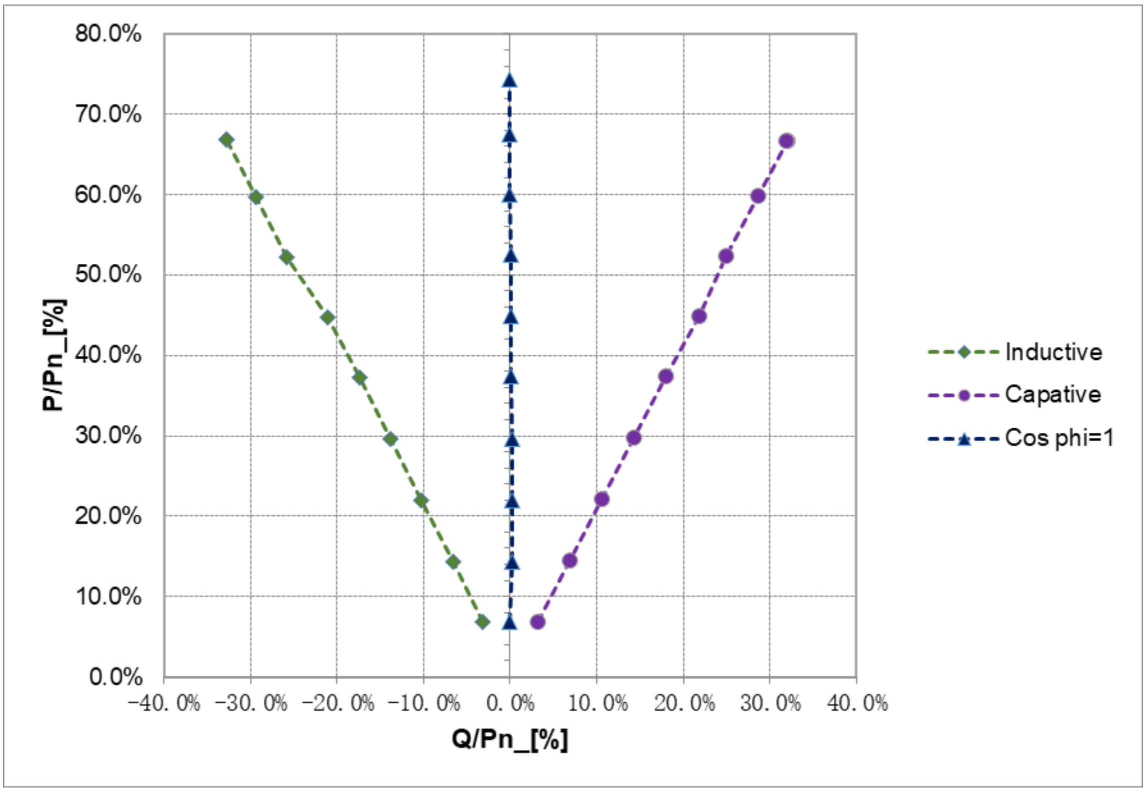
PF = 0,9 / Inducitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
0% -10%	1,355	-0,631	0,906	229,97
10% -20%	2,868	-1,325	0,908	230,05
20% -30%	4,394	-2,051	0,906	230,05
30% -40%	5,923	-2,764	0,906	230,08
40% -50%	7,439	-3,472	0,906	230,08
50% -60%	8,955	-4,201	0,905	229,99
60% -70%	10,434	-5,159	0,896	230,05
70% -80%	11,926	-5,869	0,897	230,02
80% -90%	13,359	-6,539	0,898	230,04
90% -100%	13,367	-6,544	0,898	230,04
PF = 0,9 / Capacitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
0% -10%	1,369	0,636	0,907	230,09
10% -20%	2,912	1,371	0,905	230,05
20% -30%	4,436	2,115	0,903	230,06
30% -40%	5,954	2,867	0,901	230,09
40% -50%	7,473	3,613	0,900	230,12
50% -60%	8,990	4,377	0,899	230,08
60% -70%	10,482	4,990	0,903	230,05
70% -80%	11,975	5,719	0,902	230,12
80% -90%	13,335	6,397	0,902	230,09
90% -100%	13,337	6,396	0,902	230,10

Cos phi=1 no reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
0% -10%	1,358	0,000	1,000	230,01
10% -20%	2,880	0,049	1,000	229,96
20% -30%	4,404	0,044	1,000	229,99
30% -40%	5,929	0,037	1,000	230,01
40% -50%	7,468	0,028	1,000	230,03
50% -60%	8,987	0,018	1,000	230,04
60% -70%	10,499	0,007	1,000	230,05
70% -80%	12,000	-0,003	1,000	230,07
80% -90%	13,499	-0,014	1,000	230,08
90% -100%	14,879	-0,024	1,000	230,06

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.

Diagram



Note:

The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

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：

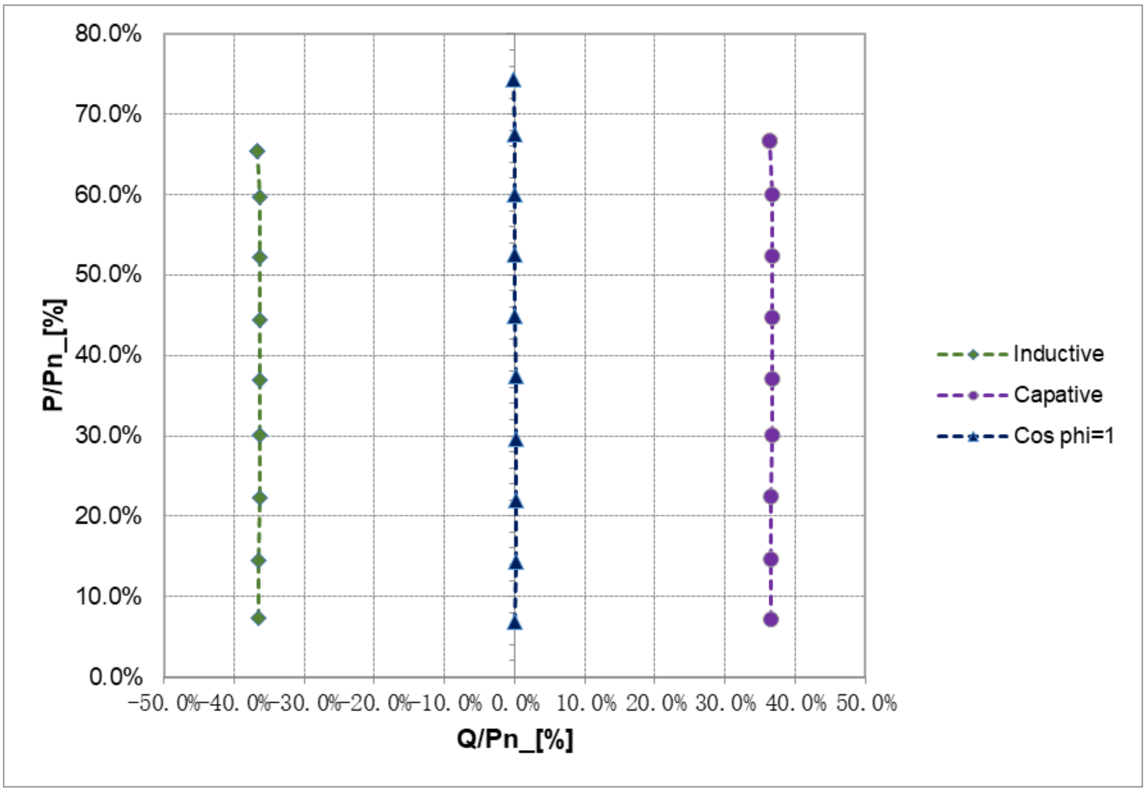
Inducitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
0% -10%	1,467	-7,297	0,197	229,98
10% -20%	2,900	-7,288	0,370	230,00
20% -30%	4,463	-7,280	0,522	230,00
30% -40%	6,011	-7,276	0,637	230,01
40% -50%	7,394	-7,275	0,713	229,96
50% -60%	8,897	-7,270	0,774	229,98
60% -70%	10,433	-7,270	0,820	230,01
70% -80%	11,954	-7,271	0,854	230,04
80% -90%	13,073	-7,340	0,872	230,05
90% -100%	13,077	-7,340	0,872	230,05
Capacitive reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
0% -10%	1,435	7,290	0,193	230,08
10% -20%	2,918	7,309	0,371	230,06
20% -30%	4,483	7,322	0,522	230,08
30% -40%	6,032	7,330	0,635	230,09
40% -50%	7,415	7,336	0,711	230,11
50% -60%	8,953	7,337	0,773	230,07
60% -70%	10,479	7,338	0,819	230,07
70% -80%	11,992	7,337	0,853	230,08
80% -90%	13,346	7,278	0,878	230,07
90% -100%	13,351	7,276	0,878	230,08

Cos phi=1 no reactive power supply				
Rating power [%]	Active power [kW]	Reactive power [kVar]	Power factor [cos φ]	Voltage [V]
0% -10%	1,358	0,000	1,000	230,01
10% -20%	2,880	0,049	1,000	229,96
20% -30%	4,404	0,044	1,000	229,99
30% -40%	5,929	0,037	1,000	230,01
40% -50%	7,468	0,028	1,000	230,03
50% -60%	8,987	0,018	1,000	230,04
60% -70%	10,499	0,007	1,000	230,05
70% -80%	12,000	-0,003	1,000	230,07
80% -90%	13,499	-0,014	1,000	230,08
90% -100%	14,879	-0,024	1,000	230,06

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.

Diagram



Note:

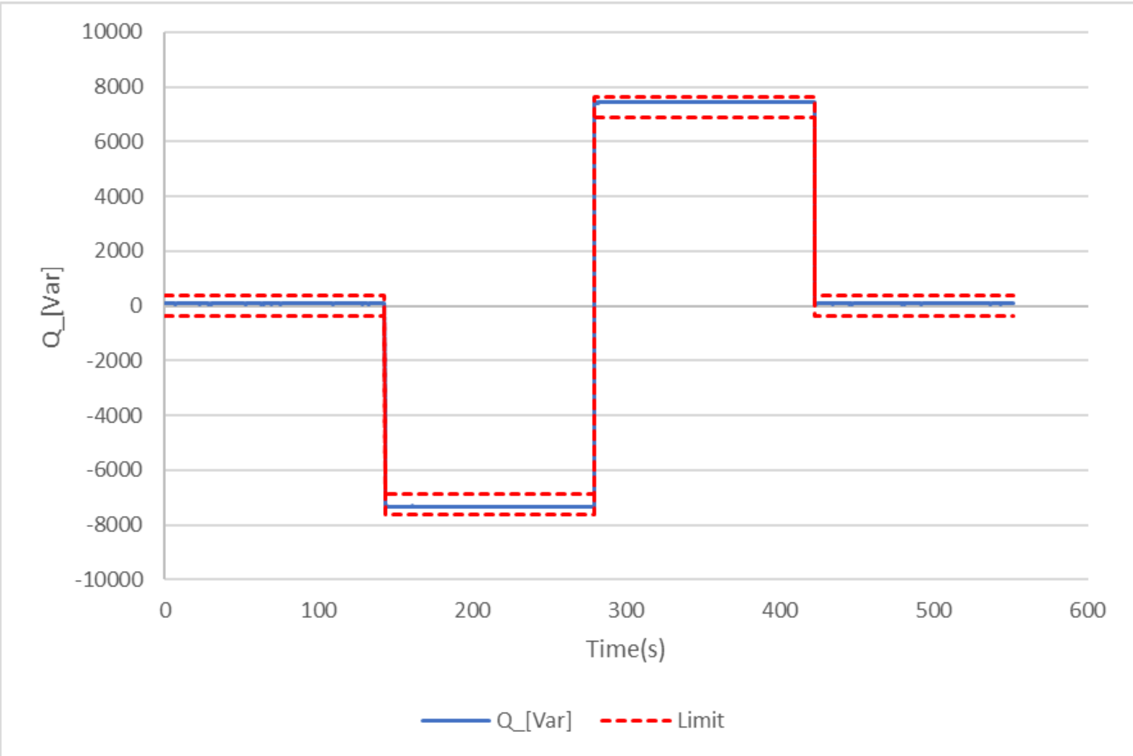
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.7.2 4.7.2.2	**Capabilities** **Q Response time**	**P**

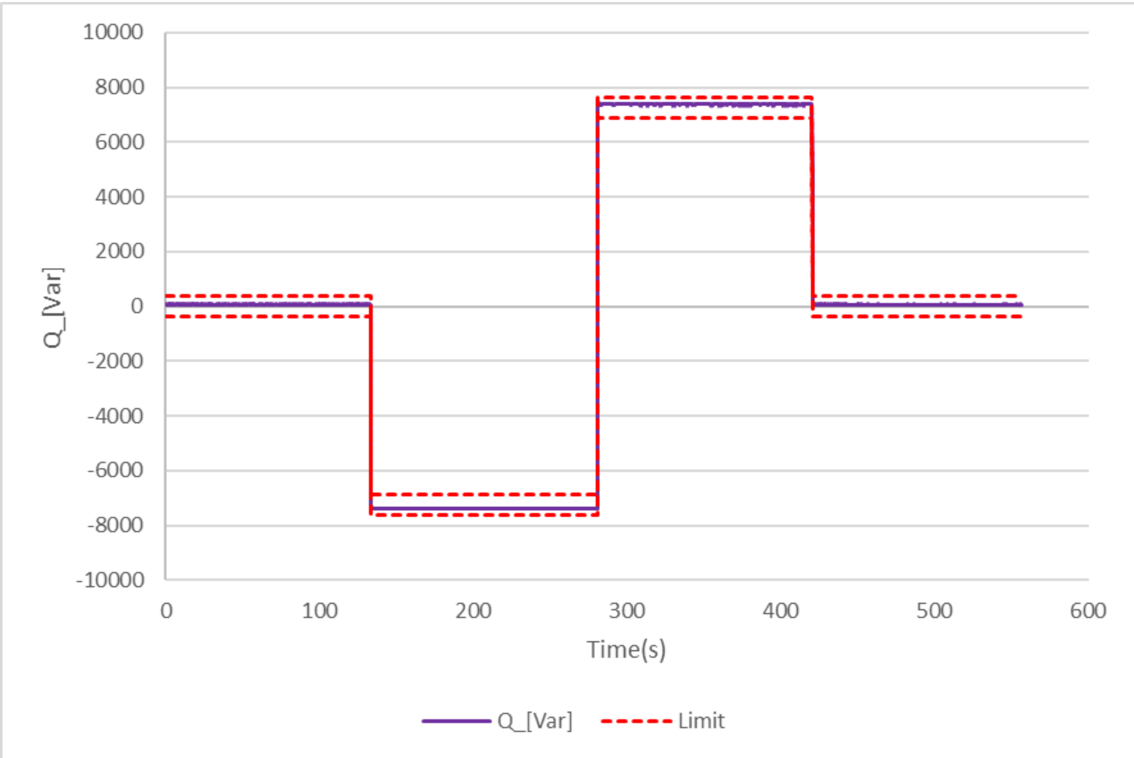
Test result：

		Active power [kW]	Reactive power [kVar]	Time [s]	Result
1	Reaction time Q=0 to Qmin (50% test)	7,508	0,084	0,4	P
2	Reaction time Qmin to Qmax (50% test)	7,382	-7,326	0,4	P
3	Reaction time Qmax to Q=0 (50% test)	7,438	7,438	0,4	P
4	Reaction time Q=0 to Qmin (100% test)	7,499	0,084	0,4	P
5	Reaction time Qmin to Qmax (100% test)	13,295	7,385	0,4	P
6	Reaction time Qmax to Q=0 (100% test)	15,029	0,060	0,4	P

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.

Note:

The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.7.2 4.7.2.3.3	**Capabilities** **Voltage related control modes (Q (U) controls)**	**P**

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.

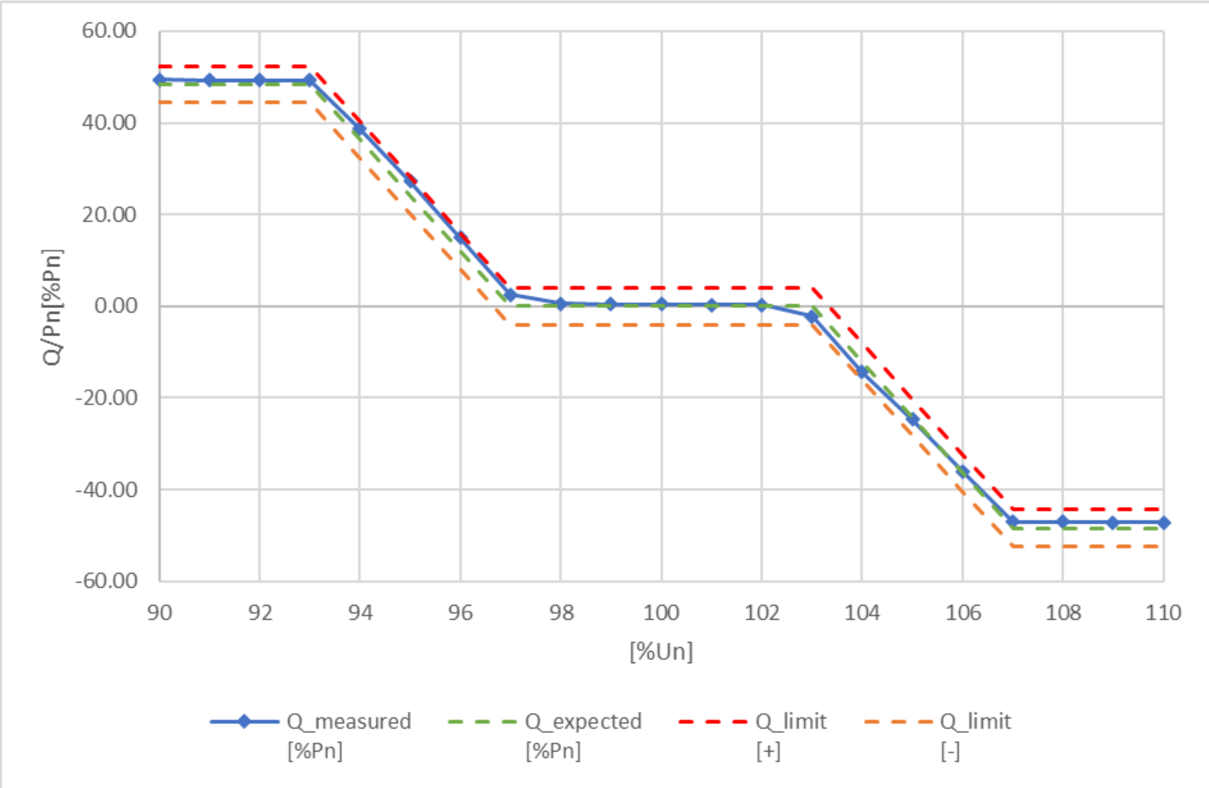
Test result

Test of the reactive power-voltage characteristic Q (U) **P**

Vac [% U_n] Set point	Vac_L1 [V] measured	Vac_L2 [V] measured	Vac_L3 [V] measured	P [kW] measured	Q [kVar] measured	Q [kVar] expected	ΔQ [% P_{Emax}]
100	230,11	230,11	230,13	14,992	0,066	0	0,40
99	227,70	227,69	227,68	14,982	0,074	0	0,45
98	225,43	225,35	225,37	14,975	0,086	0	0,52
97	223,16	223,10	223,06	14,970	0,551	0	3,34
96	220,88	220,78	220,77	14,959	2,286	1,816	2,85
95	218,66	218,58	218,58	14,683	4,032	3,632	2,42
94	216,35	216,29	216,32	14,058	5,778	5,448	2,00
93	213,99	214,03	214,11	13,214	7,389	7,265	0,75
92	211,87	211,74	211,74	13,216	7,397	7,265	0,80
91	209,38	209,43	209,48	13,202	7,405	7,265	0,85
90	207,12	207,15	207,14	13,172	7,416	7,265	0,92
91	209,46	209,44	209,45	13,172	7,404	7,265	0,84
92	211,74	211,73	211,70	13,230	7,399	7,265	0,81
93	214,07	213,98	214,04	13,224	7,389	7,265	0,76
94	216,28	216,27	216,25	14,051	5,806	5,448	2,17
95	218,49	218,50	218,47	14,669	4,094	3,632	2,80
96	220,72	220,77	220,77	14,959	2,238	1,816	2,55
97	223,29	223,10	223,17	14,965	0,376	0	2,28
98	225,30	225,38	225,40	14,976	0,080	0	0,49
99	227,77	227,69	227,72	14,982	0,074	0	0,45
100	230,08	230,00	230,00	14,990	0,064	0	0,38
101	232,32	232,29	232,26	14,998	0,052	0	0,32
102	234,61	234,59	234,57	15,002	0,045	0	0,27
103	236,90	236,86	236,84	15,012	-0,323	0	-1,96
104	239,25	239,21	239,19	15,005	-2,164	-1,816	-2,11
105	241,46	241,39	241,46	14,987	-3,711	-3,632	-0,47
106	243,85	243,58	243,60	14,508	-5,403	-5,448	0,28

107	246,15	245,99	246,07	13,816	-7,059	-7,265	1,25
108	248,41	248,36	248,36	13,832	-7,061	-7,265	1,23
109	250,67	250,65	250,68	13,812	-7,071	-7,265	1,17
110	253,03	252,96	252,95	13,812	-7,084	-7,265	1,09
109	250,68	250,67	250,67	13,820	-7,076	-7,265	1,15
108	248,38	248,35	248,40	13,822	-7,068	-7,265	1,19
107	246,10	246,05	245,89	13,832	-7,055	-7,265	1,27
106	243,85	243,67	243,59	14,493	-5,429	-5,448	0,12
105	241,45	241,48	241,49	14,969	-3,778	-3,632	-0,88
104	239,27	239,01	239,10	15,003	-2,091	-1,816	-1,66
103	236,97	236,91	236,90	15,009	-0,374	0	-2,27
102	234,55	234,63	234,58	15,004	0,041	0	0,25
101	232,31	232,27	232,27	14,995	0,056	0	0,34
100	230,06	229,95	229,95	14,990	0,063	0	0,38
Limit ΔQ:	± 4% P_{Emax}						

Graph


60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
Q/Pn[%Pn]
90
92
94
96
98
100
102
104
106
108
110
[%Un]
Q_measured [%Pn]
Q_expected [%Pn]
Q_limit [+]
Q_limit [-]

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.

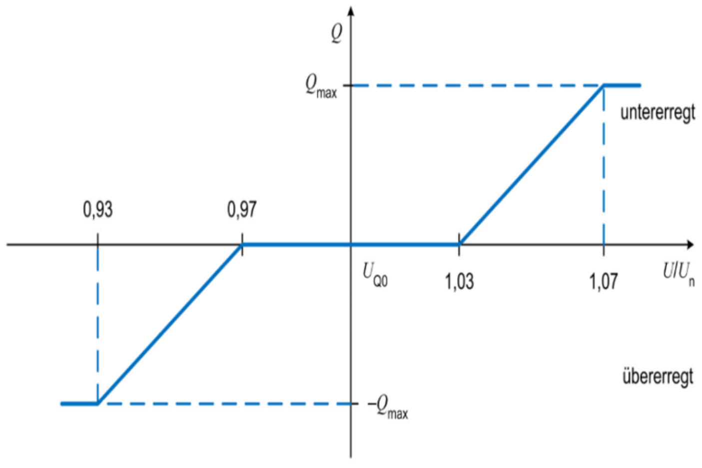


Bild 7 – Standard-Q(U)-Kennlinie

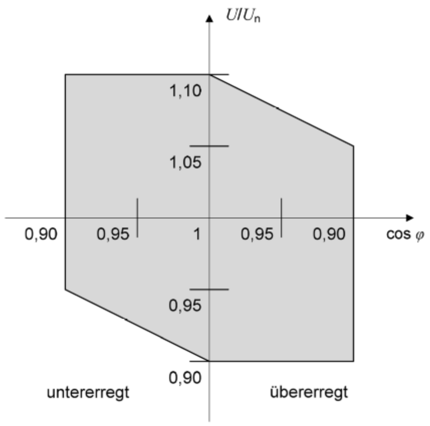


Bild 3 – Anforderungen an Erzeugungseinheiten bezüglich der Blindleistungsbereitstellung an den Generatorklemmen
$(\sum S_{Emax} > 4{,}6\,kVA)$

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

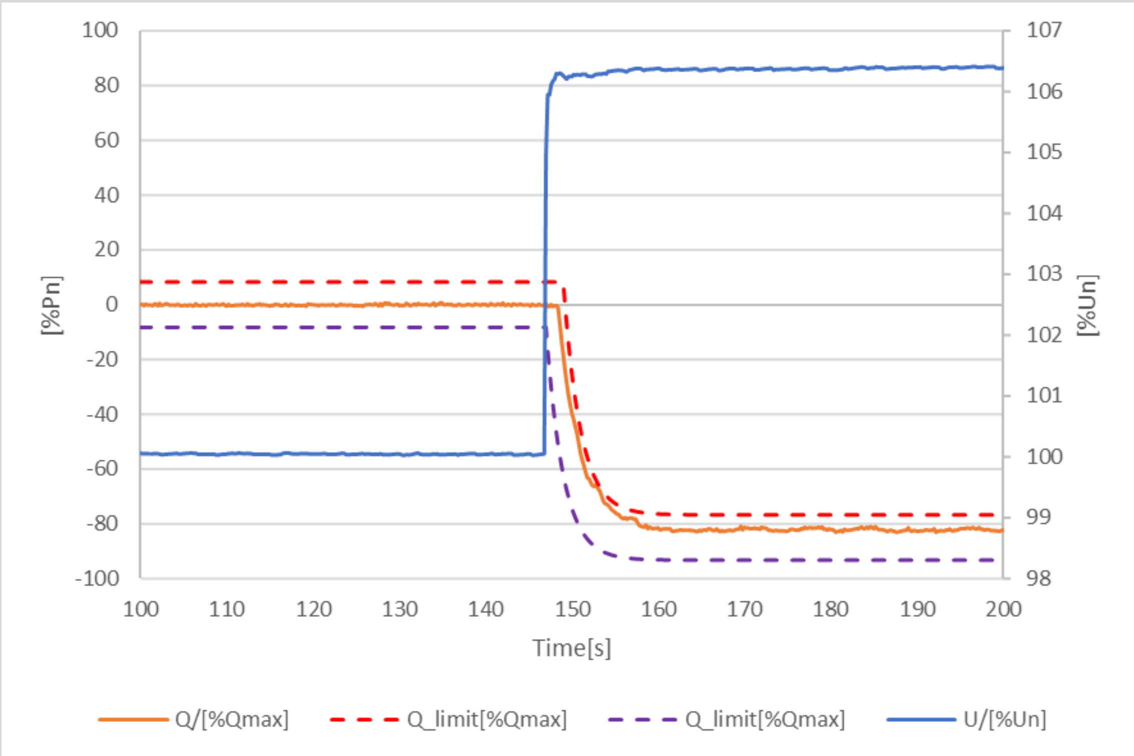
$$Q_{EZE,tol} = \pm(0.01 \cdot \mathrm{U_{N,Y}} \cdot \mathrm{k_{QU}} + 0.04 \cdot P_{EMax}) = \pm 0{,}25 \cdot P_{EMax} \cdot (\sin(\arccos(\varphi_{min})) + 0.16).$$

Note:

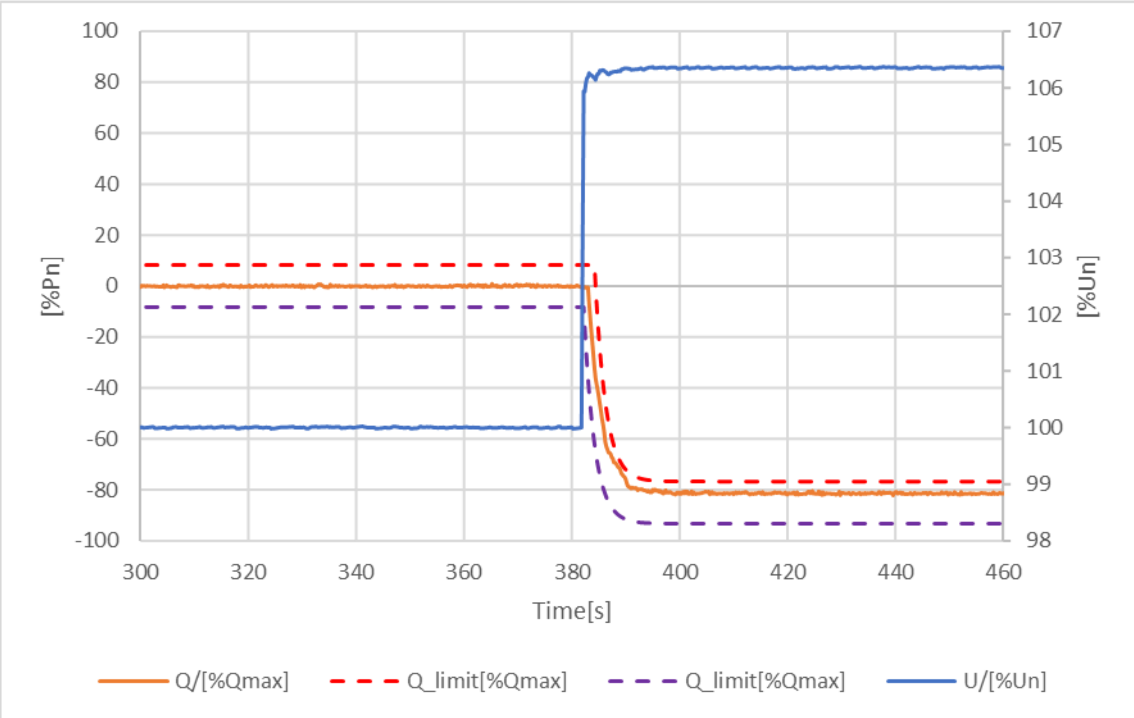
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

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	-5,973	-82,22	8,2s
	-5,917	-81,45	8,2s
	-5,931	-81,65	8,0s
100 to 93,6	6,415	88,31	6,2s
	6,433	88,56	6,0s
	6,426	88,45	7,2s

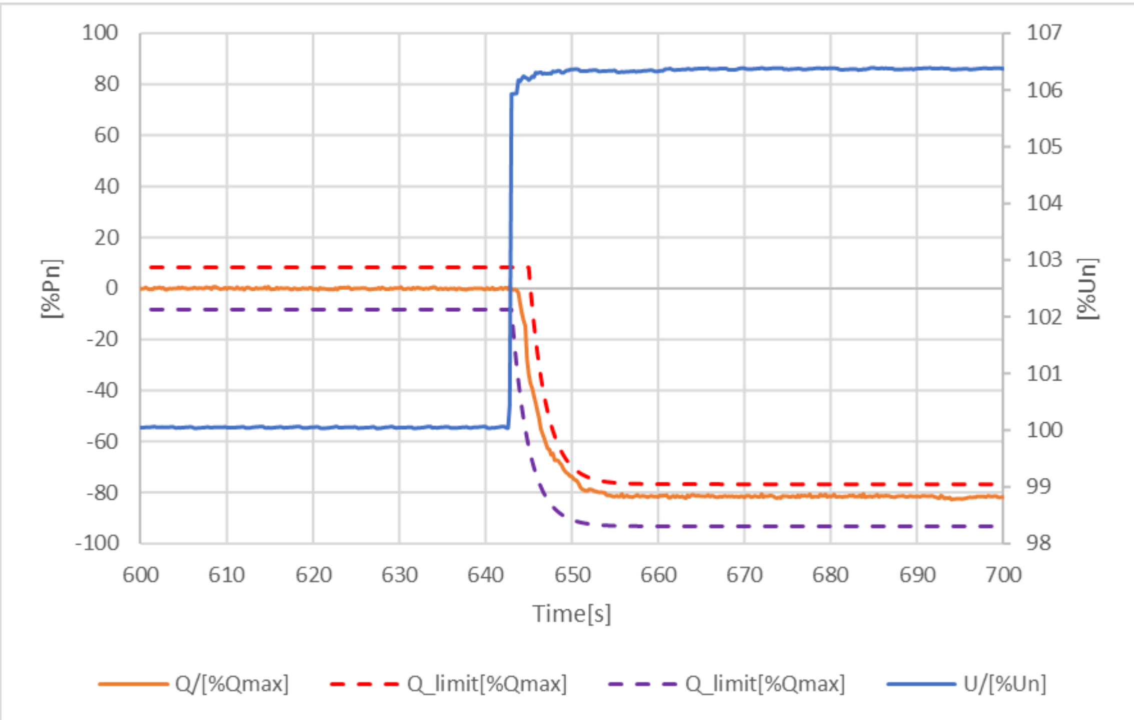
Graph of 100%U_n to 106,4% U_n: Test 1

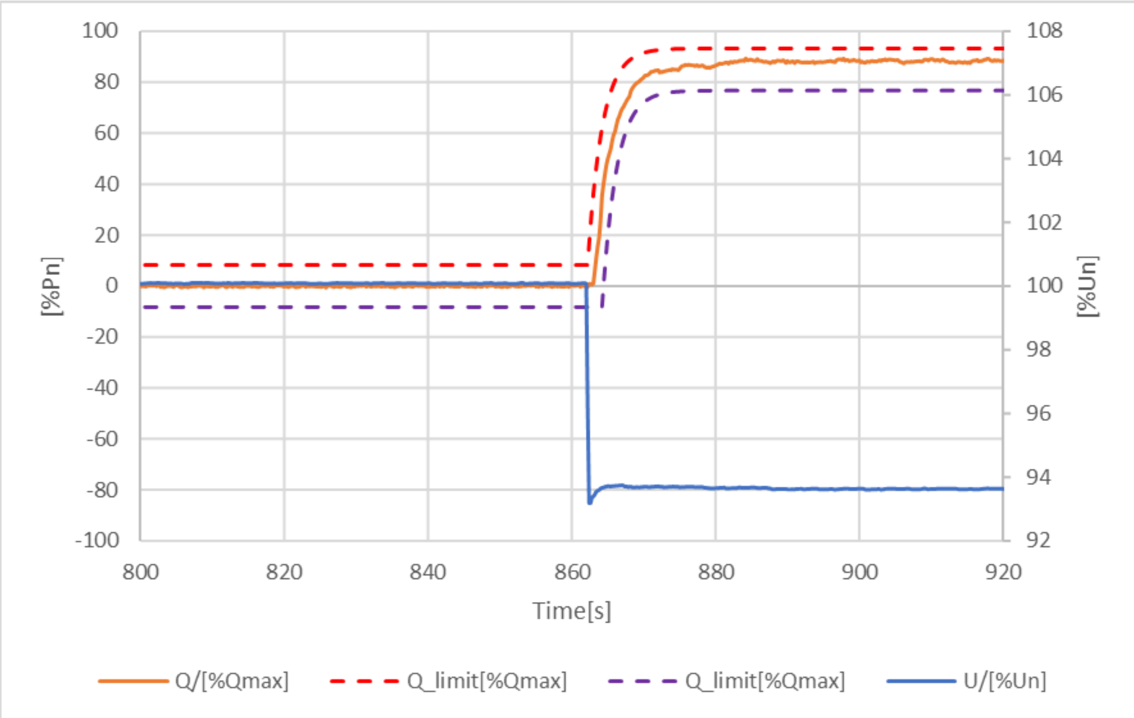
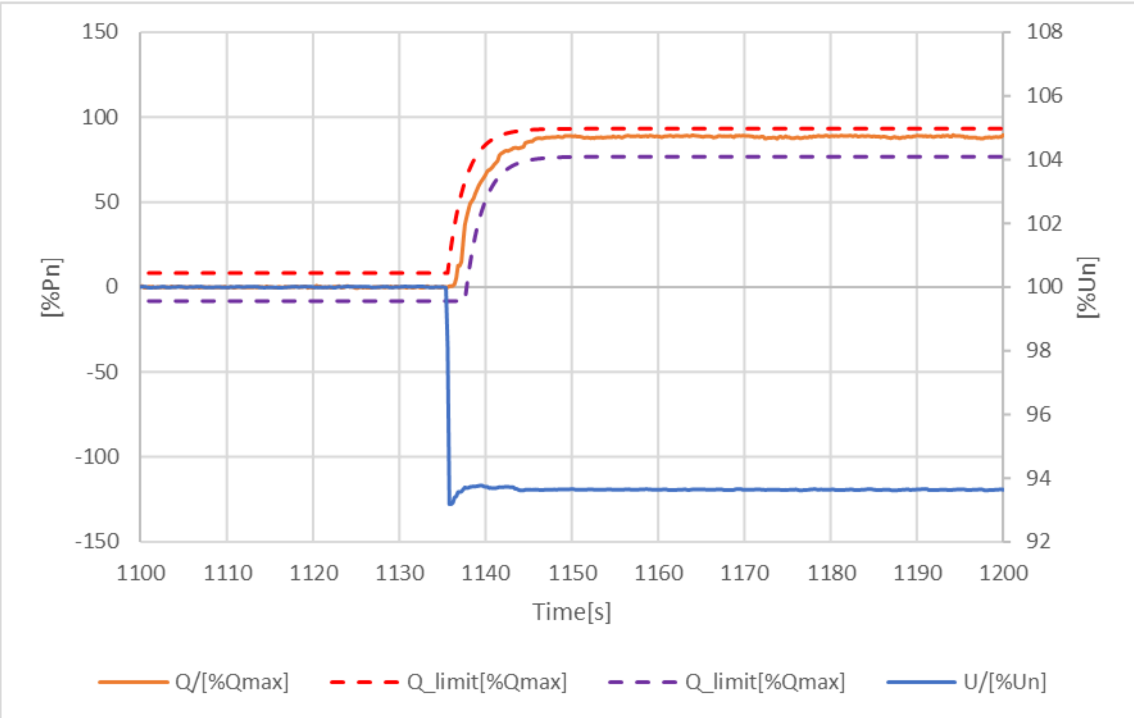


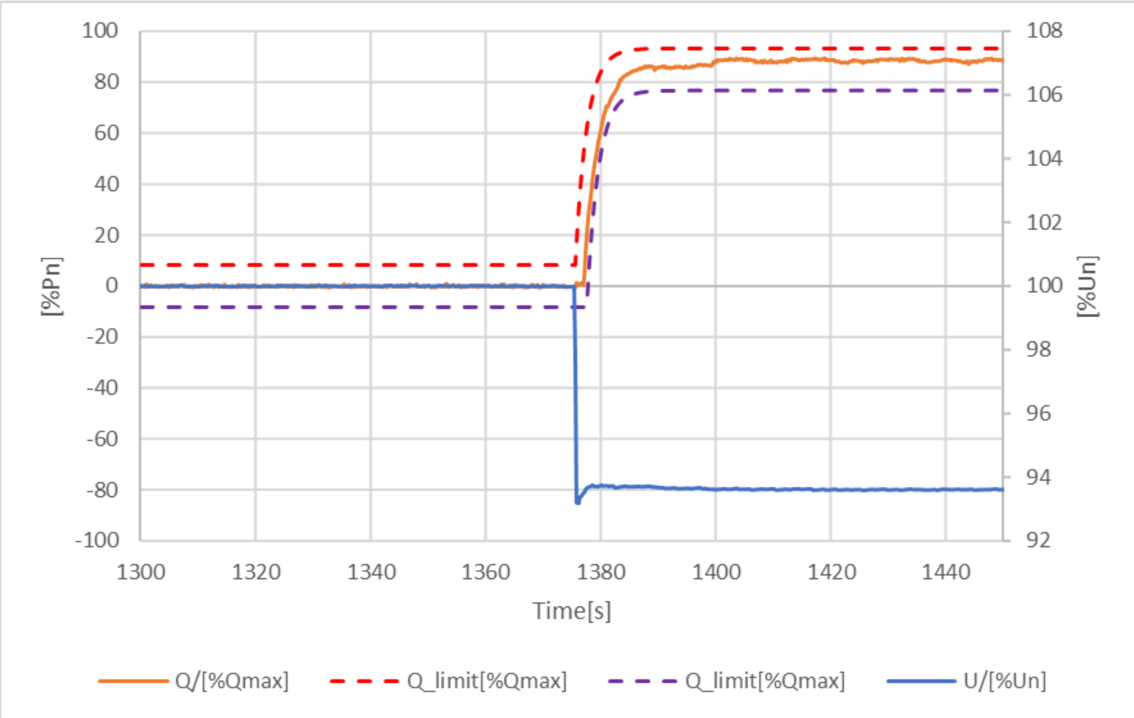
Graph of 100%U_n to 106,4% U_n: Test 2



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



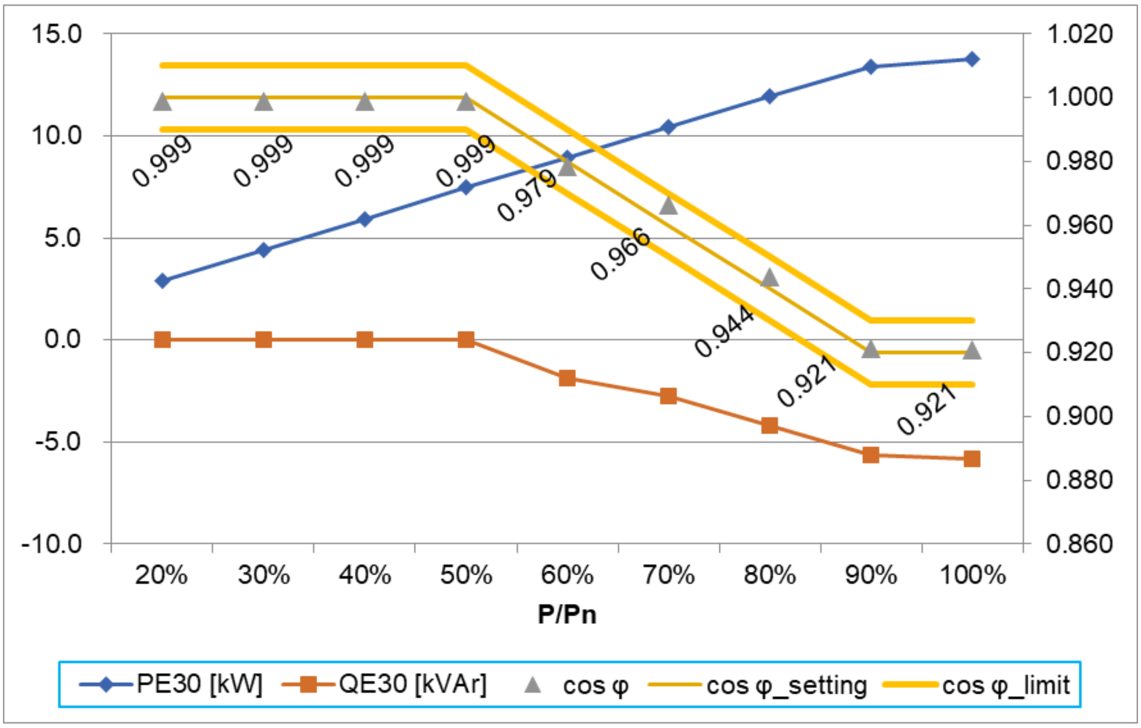
Graph of 100%U_n to 93,6% U_n: Test 1

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


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


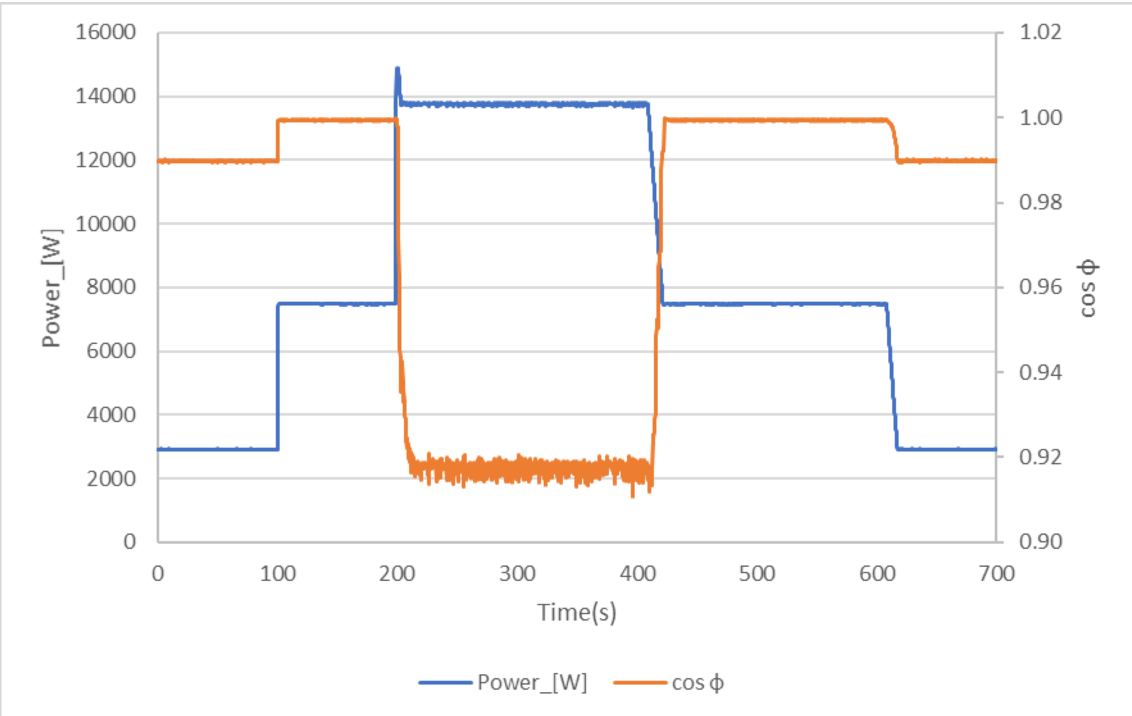
4.7.2 4.7.2.3.4	**Capabilities** **Power related Control mode (cos φ (P) curve)**									**P**
Test result：										
Test a):										
Pn/P [%]	10	20	30	40	50	60	70	80	90	100
30 s mean value	20% to 100% P_{Emax}									
U [V]:	--	230,05	230,08	230,12	230,14	229,97	229,96	229,96	229,99	229,97
P_{E30} [kW]:	--	2,909	4,422	5,942	7,456	8,943	10,441	11,924	13,406	13,782
P_{E30} of P_n [%]:	--	19,40	29,48	39,61	49,70	59,62	69,61	79,49	89,37	91,88
Q_{E30} [kVar]:	--	0,004	0,005	0,002	0,023	-1,880	-2,776	-4,175	-5,668	-5,830
cos φ_{E30}:	--	0,999	0,999	0,999	0,999	0,979	0,966	0,944	0,921	0,921
cos $\varphi_{setpoint}$ of P_{E30}:	--	1,00	1,00	1,00	1,00	0,98	0,96	0,94	0,92	0,92
Pn/P [%]	100	90	80	70	60	50	40	30	20	10
30 s mean value	100% to 20% P_{Emax}									
U [V]:	230,07	230,07	230,09	230,15	230,11	230,07	230,05	230,02	230,01	--
P_{E30} [kW]:	13,762	13,460	11,970	10,446	8,977	7,477	5,954	4,431	2,921	--
P_{E30} of P_n [%]:	91,74	89,74	79,80	69,64	59,84	49,84	39,69	29,54	19,48	--
Q_{E30} [kVar]:	-5,978	-5,861	-4,366	-3,025	-1,627	0,251	0,313	0,368	0,420	--
cos φ_{E30}:	0,917	0,917	0,939	0,961	0,984	0,999	0,999	0,997	0,990	--
cos $\varphi_{setpoint}$ of P_{E30}:	0,92	0,92	0,94	0,96	0,98	1,00	1,00	1,00	1,00	--
Limit cos φ_{E30}:	cos $\varphi_{setpoint}$ ± 0,01									

Test b):			
Pn/P [%]	20	50	100
30 s mean value	20% to 50% to 100% Pn		
U [V]:	230,00	230,04	230,02
P_{E30} [kW]:	2,922	7,477	13,758
P_{E30} of Pn [%]:	19,48	49,85	91,72
Q_{E30} [kVar]:	0,421	0,252	-5,958
cos φ $_{E30}$:	0,990	0,999	0,918
cos $φ_{setpoint}$ of P_{E30}:	1,00	1,00	0,92
T_0[s]:	1,0	8,2	
Pn/P [%]	100	50	20
30 s mean value	100% to 50% to 20% Pn		
U [V]:	230,02	230,11	230,08
P_{E30} [kW]:	13,758	7,477	2,921
P_{E30} of Pn [%]:	91,72	49,85	19,48
Q_{E30} [kVar]:	-5,958	0,250	0,419
cos φ $_{E30}$:	0,918	0,999	0,990
cos $φ_{setpoint}$ of P_{E30}:	0,92	1,00	1,00
T_0[s]:	9,0	1,0	
Limit T_0 [s]:	10 s		
Limit cos φ $_{E30}$:	cos $φ_{setpoint}$ ± 0,02		

Graph of cos φ(P): Test a)



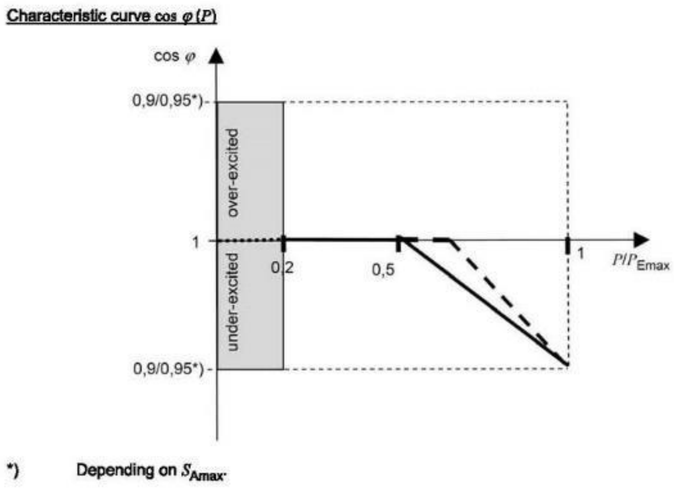
Graph of setting (T_0) time: Test b): 20% to 50% to 100% to 50% to 20%Pn



Test:

Test 1: Using the standard characteristic curve increases the active power from 20% Pn in increments of 10% Pn 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 had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.7.2	**Voltage related active power reduction (P(U) function)**	**P**

Test result：	
5-min mean value / P/ P_n [%]	100% to 20%
Response time [s]:	28,2
P_{E60} [%]:	3,24%
$\Delta P_{E60}/P_{Setpoint}$ [%]:	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.

Assessment criterion:

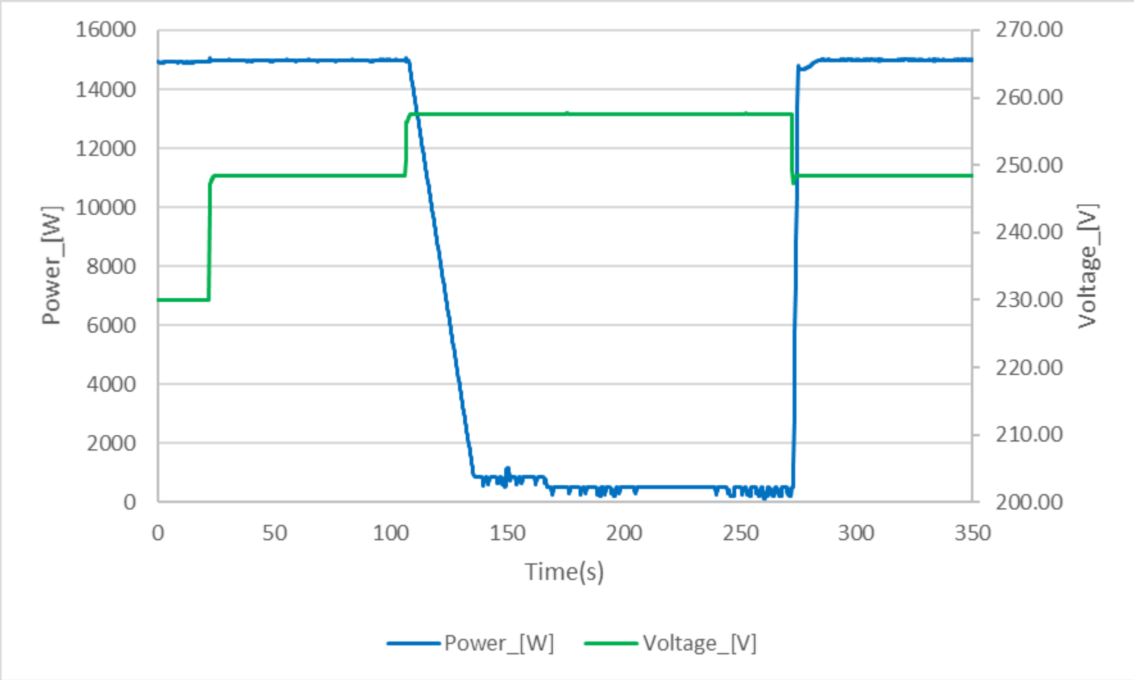
for adjustable PGUs:

- 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.

Note:

The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Graph:


16000
14000
12000
10000
8000
6000
4000
2000
0
Power_[W]
270.00
260.00
250.00
240.00
230.00
220.00
210.00
200.00
Voltage_[V]
0
50
100
150
200
250
300
350
Time(s)
Power_[W]
Voltage_[V]

4.8	**EMC and power quality** **Harmonic current emission (EN 61000-3-2)**	**P**

Test result：

Watts [KW]	2,658	2,630	2,676
Vrms [V]	230,2	230,1	230,5
Arms [A]	11,565	11,446	11,641
Frequency [Hz]	0,9987	0,9983	0,9974
THD40* (100% output power)	2,728	2,758	2,745

Harmonic order n	**Current Magnitude [A] at 100% rated output power**			**% of Fundamental**			**Phase**	**Harmonic Current Limits [A]**
1st	11,556	11,439	11,634	99,67	98,66	100,34	Three Phase	--
2nd	0,021	0,015	0,016	0,18	0,13	0,14	Three Phase	1,080
3rd	0,108	0,104	0,096	0,94	0,90	0,82	Three Phase	2,300
4th	0,008	0,005	0,007	0,07	0,05	0,06	Three Phase	0,430
5th	0,072	0,064	0,070	0,62	0,55	0,61	Three Phase	1,140
6th	0,003	0,005	0,006	0,03	0,04	0,05	Three Phase	0,300
7th	0,060	0,055	0,056	0,52	0,48	0,48	Three Phase	0,770
8th	0,006	0,005	0,006	0,05	0,04	0,05	Three Phase	0,230
9th	0,079	0,082	0,080	0,68	0,71	0,69	Three Phase	0,400
10th	0,010	0,007	0,009	0,09	0,06	0,08	Three Phase	0,184
11th	0,095	0,098	0,099	0,82	0,84	0,85	Three Phase	0,330
12th	0,016	0,013	0,014	0,14	0,11	0,12	Three Phase	0,153
13th	0,101	0,107	0,109	0,87	0,92	0,94	Three Phase	0,210
14th	0,020	0,019	0,018	0,17	0,17	0,16	Three Phase	0,131
15th	0,117	0,127	0,122	1,01	1,09	1,05	Three Phase	0,150
16th	0,023	0,022	0,024	0,20	0,19	0,21	Three Phase	0,115
17th	0,124	0,125	0,122	1,07	1,08	1,05	Three Phase	0,132
18th	0,024	0,016	0,024	0,21	0,14	0,20	Three Phase	0,102
19th	0,098	0,085	0,087	0,84	0,74	0,75	Three Phase	0,118
20th	0,015	0,012	0,013	0,13	0,11	0,11	Three Phase	0,092
21th	0,050	0,036	0,036	0,43	0,31	0,31	Three Phase	0,107
22th	0,010	0,009	0,009	0,09	0,08	0,08	Three Phase	0,084
23th	0,026	0,028	0,024	0,22	0,24	0,21	Three Phase	0,098
24th	0,008	0,005	0,007	0,07	0,05	0,06	Three Phase	0,077

25th	0,022	0,019	0,020	0,19	0,17	0,18	Three Phase	0,090
26th	0,007	0,007	0,007	0,06	0,06	0,06	Three Phase	0,071
27th	0,014	0,012	0,012	0,12	0,10	0,10	Three Phase	0,083
28th	0,004	0,005	0,006	0,04	0,04	0,05	Three Phase	0,066
29th	0,010	0,009	0,008	0,09	0,08	0,07	Three Phase	0,078
30th	0,004	0,005	0,004	0,04	0,04	0,03	Three Phase	0,061
31th	0,005	0,005	0,009	0,04	0,05	0,08	Three Phase	0,073
32th	0,004	0,005	0,004	0,04	0,04	0,03	Three Phase	0,058
33th	0,005	0,008	0,008	0,05	0,07	0,07	Three Phase	0,680
34th	0,006	0,006	0,003	0,05	0,05	0,03	Three Phase	0,054
35th	0,006	0,008	0,010	0,05	0,07	0,09	Three Phase	0,064
36th	0,007	0,004	0,004	0,06	0,03	0,04	Three Phase	0,051
37th	0,008	0,010	0,014	0,07	0,08	0,12	Three Phase	0,061
38th	0,007	0,004	0,006	0,06	0,03	0,05	Three Phase	0,048
39th	0,009	0,013	0,016	0,08	0,11	0,14	Three Phase	0,058
40th	0,007	0,006	0,006	0,06	0,06	0,05	Three Phase	0,046
41th	0,009	0,010	0,018	0,08	0,09	0,15	Three Phase	N/A
42th	0,007	0,004	0,007	0,06	0,03	0,06	Three Phase	N/A
43th	0,008	0,014	0,019	0,07	0,12	0,17	Three Phase	N/A
44th	0,007	0,003	0,007	0,06	0,03	0,06	Three Phase	N/A
45th	0,012	0,016	0,020	0,10	0,14	0,17	Three Phase	N/A
46th	0,004	0,003	0,006	0,04	0,02	0,05	Three Phase	N/A
47th	0,010	0,014	0,014	0,08	0,12	0,12	Three Phase	N/A
48th	0,004	0,003	0,005	0,03	0,03	0,04	Three Phase	N/A
49th	0,006	0,012	0,011	0,05	0,11	0,09	Three Phase	N/A
50th	0,004	0,004	0,005	0,04	0,04	0,05	Three Phase	N/A

Note:
The tests should be based on the limits of the EN 61000-3-2 for less than 16A.

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

Test result：

Watts [KW]	4,986	4,921	5,017
Vrms [V]	230,3	230,3	230,6
Arms [A]	21,662	21,386	21,782
Frequency [Hz]	0,9996	0,9993	0,9989
THD40* (100% output power)	1,245	1,163	1,153

Harmonic order n	**Current Magnitude [A] at 100% rated output power**			**% of Fundamental**			**Phase**	**Harmonic Current Limits [%]**
1st	21,658	21,383	21,778	99,63	98,36	100,18	Three Phase	--
2nd	0,143	0,124	0,128	0,66	0,57	0,59	Three Phase	1
3rd	0,111	0,112	0,103	0,51	0,51	0,47	Three Phase	4
4th	0,033	0,031	0,036	0,15	0,14	0,16	Three Phase	1
5th	0,063	0,054	0,061	0,29	0,25	0,28	Three Phase	4
6th	0,023	0,020	0,025	0,11	0,09	0,11	Three Phase	1
7th	0,061	0,054	0,051	0,28	0,25	0,24	Three Phase	4
8th	0,018	0,018	0,019	0,08	0,08	0,09	Three Phase	1
9th	0,050	0,045	0,042	0,23	0,21	0,19	Three Phase	4
10th	0,011	0,013	0,012	0,05	0,06	0,06	Three Phase	0,5
11th	0,045	0,041	0,042	0,21	0,19	0,19	Three Phase	2
12th	0,008	0,009	0,011	0,04	0,04	0,05	Three Phase	0,5
13th	0,050	0,049	0,049	0,23	0,22	0,23	Three Phase	2
14th	0,008	0,009	0,012	0,04	0,04	0,05	Three Phase	0,5
15th	0,059	0,059	0,058	0,27	0,27	0,27	Three Phase	2
16th	0,006	0,007	0,009	0,03	0,03	0,04	Three Phase	0,5
17th	0,060	0,058	0,057	0,27	0,27	0,26	Three Phase	1,5
18th	0,005	0,006	0,007	0,02	0,03	0,03	Three Phase	0,5
19th	0,048	0,043	0,043	0,22	0,20	0,20	Three Phase	1,5
20th	0,005	0,005	0,006	0,02	0,02	0,03	Three Phase	0,5
21th	0,037	0,031	0,029	0,17	0,14	0,13	Three Phase	1,5
22th	0,004	0,004	0,007	0,02	0,02	0,03	Three Phase	0,5
23th	0,030	0,026	0,024	0,14	0,12	0,11	Three Phase	0,6
24th	0,004	0,004	0,006	0,02	0,02	0,03	Three Phase	0,5
25th	0,030	0,026	0,024	0,14	0,12	0,11	Three Phase	0,6
26th	0,003	0,004	0,004	0,01	0,02	0,02	Three Phase	0,5

27th	0,029	0,025	0,024	0,13	0,11	0,11	Three Phase	0,6
28th	0,003	0,003	0,005	0,01	0,01	0,02	Three Phase	0,5
29th	0,028	0,023	0,022	0,13	0,11	0,10	Three Phase	0,6
30th	0,003	0,003	0,006	0,01	0,01	0,03	Three Phase	0,5
31th	0,026	0,021	0,019	0,12	0,10	0,09	Three Phase	0,6
32th	0,003	0,003	0,005	0,01	0,02	0,02	Three Phase	0,5
33th	0,027	0,019	0,022	0,12	0,09	0,10	Three Phase	0,6
34th	0,003	0,004	0,004	0,01	0,02	0,02	Three Phase	N/A
35th	0,025	0,017	0,021	0,12	0,08	0,09	Three Phase	N/A
36th	0,003	0,003	0,005	0,01	0,01	0,02	Three Phase	N/A
37th	0,022	0,013	0,017	0,10	0,06	0,08	Three Phase	N/A
38th	0,003	0,003	0,005	0,01	0,01	0,02	Three Phase	N/A
39th	0,022	0,014	0,016	0,10	0,07	0,07	Three Phase	N/A
40th	0,004	0,005	0,003	0,02	0,02	0,02	Three Phase	N/A
41th	0,019	0,010	0,014	0,09	0,04	0,07	Three Phase	N/A
42th	0,004	0,005	0,003	0,02	0,02	0,01	Three Phase	N/A
43th	0,017	0,010	0,012	0,08	0,05	0,06	Three Phase	N/A
44th	0,003	0,003	0,004	0,01	0,01	0,02	Three Phase	N/A
45th	0,018	0,010	0,009	0,08	0,05	0,04	Three Phase	N/A
46th	0,004	0,004	0,004	0,02	0,02	0,02	Three Phase	N/A
47th	0,008	0,011	0,011	0,04	0,05	0,05	Three Phase	N/A
48th	0,004	0,006	0,004	0,02	0,03	0,02	Three Phase	N/A
49th	0,006	0,011	0,010	0,03	0,05	0,05	Three Phase	N/A
50th	0,004	0,004	0,003	0,02	0,02	0,02	Three Phase	N/A

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

The test had been performed on the model ALPHA WP 8KW and ALPHA WP 15KW the test results are valid for the ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just 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：**(ALPHA WP 8KW)**

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	4,530	9,619	19,544	29,780	40,129	49,859	60,297	70,460	80,492	90,517	100,342
2	0,844	0,695	0,665	0,637	0,521	0,501	0,372	0,257	0,119	0,209	0,185
3	0,505	1,097	1,236	1,088	1,440	0,847	1,367	1,168	0,919	0,921	0,935
4	0,200	0,166	0,161	0,168	0,162	0,114	0,128	0,077	0,049	0,077	0,065
5	0,384	0,377	0,788	0,838	1,419	0,687	1,377	1,064	0,692	0,651	0,625
6	0,077	0,103	0,086	0,118	0,167	0,096	0,174	0,111	0,050	0,055	0,048
7	0,359	0,188	0,625	0,721	1,330	0,438	1,461	1,015	0,525	0,516	0,517
8	0,062	0,051	0,042	0,061	0,191	0,075	0,224	0,130	0,049	0,042	0,054
9	0,200	0,406	0,516	0,866	1,418	0,408	1,933	1,397	0,684	0,692	0,711
10	0,079	0,095	0,045	0,054	0,270	0,087	0,352	0,206	0,076	0,064	0,089
11	0,134	0,521	0,555	1,238	1,115	0,329	1,982	1,685	0,802	0,820	0,854
12	0,047	0,079	0,092	0,137	0,254	0,093	0,309	0,293	0,130	0,108	0,136
13	0,178	0,839	0,891	1,599	0,516	0,343	1,021	1,455	0,877	0,909	0,944
14	0,043	0,067	0,120	0,196	0,177	0,091	0,136	0,235	0,148	0,133	0,174
15	0,154	1,235	1,038	1,616	0,345	0,339	0,368	0,752	0,956	1,025	1,093
16	0,027	0,066	0,113	0,163	0,105	0,078	0,074	0,114	0,183	0,174	0,206
17	0,143	1,063	0,785	1,481	0,293	0,308	0,156	0,340	0,853	0,973	1,075
18	0,034	0,055	0,081	0,117	0,081	0,059	0,046	0,063	0,144	0,162	0,207
19	0,112	0,851	0,645	1,178	0,246	0,287	0,078	0,196	0,634	0,752	0,843
20	0,026	0,049	0,067	0,095	0,074	0,055	0,038	0,045	0,082	0,089	0,131
21	0,166	0,747	0,685	0,881	0,267	0,277	0,084	0,080	0,304	0,377	0,433
22	0,030	0,045	0,058	0,083	0,073	0,043	0,038	0,040	0,067	0,073	0,090
23	0,147	0,627	0,621	0,603	0,283	0,231	0,137	0,105	0,161	0,198	0,241
24	0,035	0,032	0,052	0,061	0,066	0,028	0,046	0,050	0,055	0,054	0,068
25	0,109	0,523	0,501	0,413	0,278	0,194	0,140	0,132	0,091	0,145	0,188
26	0,025	0,041	0,041	0,064	0,059	0,017	0,031	0,047	0,049	0,054	0,064
27	0,176	0,459	0,447	0,425	0,283	0,193	0,113	0,124	0,064	0,081	0,119
28	0,034	0,025	0,038	0,056	0,074	0,023	0,039	0,057	0,043	0,053	0,049
29	0,133	0,399	0,384	0,420	0,277	0,183	0,107	0,144	0,092	0,086	0,089
30	0,036	0,028	0,032	0,062	0,091	0,026	0,046	0,068	0,046	0,048	0,042

31	0,186	0,354	0,353	0,379	0,243	0,174	0,119	0,142	0,110	0,096	0,076
32	0,045	0,032	0,026	0,053	0,074	0,029	0,039	0,057	0,050	0,046	0,041
33	0,191	0,329	0,343	0,316	0,247	0,191	0,131	0,145	0,130	0,103	0,073
34	0,016	0,027	0,030	0,039	0,075	0,031	0,035	0,046	0,045	0,047	0,053
35	0,189	0,267	0,303	0,240	0,226	0,180	0,119	0,128	0,133	0,118	0,085
36	0,041	0,030	0,030	0,032	0,076	0,044	0,043	0,042	0,059	0,058	0,061
37	0,204	0,235	0,278	0,205	0,195	0,189	0,131	0,135	0,145	0,128	0,119
38	0,025	0,035	0,046	0,026	0,057	0,060	0,067	0,060	0,065	0,055	0,059
39	0,250	0,236	0,269	0,190	0,228	0,205	0,149	0,138	0,159	0,148	0,136
40	0,056	0,038	0,034	0,043	0,052	0,073	0,069	0,055	0,074	0,048	0,056
41	0,221	0,176	0,219	0,142	0,194	0,189	0,140	0,118	0,159	0,163	0,152
42	0,037	0,050	0,036	0,073	0,054	0,072	0,061	0,038	0,081	0,064	0,059
43	0,237	0,156	0,188	0,161	0,173	0,160	0,157	0,123	0,200	0,193	0,165
44	0,050	0,043	0,037	0,074	0,051	0,068	0,066	0,055	0,085	0,066	0,063
45	0,259	0,166	0,207	0,208	0,150	0,157	0,168	0,122	0,180	0,171	0,170
46	0,053	0,072	0,052	0,080	0,058	0,052	0,060	0,064	0,078	0,061	0,053
47	0,190	0,139	0,142	0,168	0,129	0,118	0,131	0,107	0,154	0,145	0,124
48	0,066	0,056	0,044	0,050	0,071	0,046	0,074	0,069	0,073	0,067	0,045
49	0,164	0,111	0,132	0,134	0,097	0,124	0,113	0,087	0,118	0,138	0,105
50	0,073	0,080	0,065	0,052	0,065	0,058	0,075	0,057	0,072	0,055	0,046
Interharmonics											
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 [%]
75	0,039	0,118	0,098	0,067	0,066	0,085	0,062	0,060	0,057	0,051	0,058
125	0,040	0,071	0,080	0,048	0,049	0,065	0,048	0,049	0,044	0,043	0,046
175	0,045	0,055	0,067	0,044	0,045	0,060	0,047	0,046	0,041	0,042	0,044
225	0,047	0,081	0,054	0,043	0,050	0,064	0,056	0,051	0,046	0,045	0,046
275	0,058	0,072	0,057	0,047	0,061	0,086	0,063	0,058	0,051	0,052	0,049
325	0,071	0,070	0,064	0,054	0,073	0,111	0,075	0,069	0,055	0,058	0,051
375	0,087	0,064	0,065	0,058	0,082	0,138	0,085	0,074	0,058	0,059	0,052
425	0,101	0,060	0,064	0,062	0,088	0,162	0,091	0,080	0,059	0,060	0,056
475	0,103	0,062	0,062	0,067	0,090	0,160	0,093	0,082	0,058	0,058	0,057
525	0,103	0,063	0,069	0,073	0,089	0,141	0,089	0,088	0,061	0,063	0,059
575	0,074	0,092	0,070	0,081	0,080	0,104	0,079	0,094	0,068	0,070	0,065
625	0,056	0,093	0,074	0,087	0,069	0,081	0,067	0,087	0,071	0,071	0,071
675	0,053	0,111	0,083	0,090	0,056	0,057	0,055	0,078	0,078	0,078	0,075
725	0,036	0,113	0,085	0,089	0,048	0,046	0,047	0,067	0,080	0,080	0,079
775	0,072	0,122	0,101	0,105	0,076	0,076	0,080	0,090	0,106	0,109	0,111
825	0,031	0,088	0,080	0,079	0,037	0,037	0,037	0,049	0,080	0,080	0,082

875	0,036	0,079	0,071	0,071	0,045	0,046	0,050	0,056	0,081	0,084	0,087
925	0,026	0,070	0,060	0,062	0,031	0,030	0,031	0,039	0,073	0,077	0,083
975	0,069	0,071	0,072	0,070	0,059	0,059	0,062	0,065	0,081	0,084	0,086
1025	0,026	0,053	0,051	0,050	0,029	0,029	0,028	0,034	0,064	0,069	0,077
1075	0,046	0,051	0,054	0,051	0,038	0,037	0,038	0,042	0,066	0,070	0,076
1125	0,024	0,038	0,044	0,039	0,027	0,025	0,025	0,030	0,056	0,061	0,067
1175	0,023	0,036	0,038	0,037	0,026	0,024	0,025	0,029	0,052	0,058	0,062
1225	0,022	0,034	0,037	0,035	0,026	0,025	0,024	0,028	0,049	0,054	0,059
1275	0,023	0,034	0,033	0,034	0,024	0,024	0,024	0,027	0,045	0,049	0,054
1325	0,035	0,037	0,036	0,038	0,031	0,031	0,033	0,033	0,044	0,047	0,052
1375	0,023	0,031	0,031	0,033	0,024	0,023	0,024	0,026	0,041	0,043	0,047
1425	0,034	0,038	0,038	0,039	0,032	0,032	0,033	0,035	0,046	0,047	0,050
1475	0,023	0,029	0,029	0,032	0,023	0,023	0,024	0,026	0,038	0,040	0,043
1525	0,022	0,031	0,030	0,032	0,023	0,023	0,024	0,027	0,038	0,040	0,043
1575	0,023	0,030	0,030	0,030	0,024	0,024	0,024	0,025	0,037	0,038	0,040
1625	0,024	0,030	0,030	0,031	0,023	0,023	0,025	0,027	0,037	0,038	0,040
1675	0,023	0,029	0,031	0,030	0,023	0,023	0,024	0,025	0,036	0,036	0,038
1725	0,023	0,030	0,031	0,030	0,024	0,025	0,027	0,025	0,036	0,036	0,038
1775	0,023	0,030	0,031	0,031	0,023	0,025	0,025	0,025	0,036	0,036	0,038
1825	0,024	0,030	0,032	0,031	0,025	0,025	0,026	0,026	0,036	0,036	0,038
1875	0,024	0,031	0,031	0,032	0,024	0,025	0,027	0,027	0,036	0,036	0,038
1925	0,025	0,031	0,033	0,033	0,027	0,025	0,029	0,027	0,037	0,037	0,038
1975	0,029	0,034	0,035	0,037	0,029	0,030	0,034	0,032	0,041	0,041	0,044
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	0,320	0,252	0,301	0,252	0,270	0,271	0,233	0,191	0,281	0,278	0,255
2,3	0,326	0,235	0,264	0,280	0,215	0,210	0,239	0,192	0,258	0,255	0,238
2,5	0,212	0,195	0,183	0,216	0,158	0,188	0,190	0,154	0,205	0,192	0,169
2,7	0,147	0,216	0,170	0,216	0,115	0,170	0,144	0,140	0,150	0,129	0,143
2,9	0,098	0,151	0,137	0,168	0,113	0,116	0,124	0,132	0,101	0,106	0,125
3,1	0,094	0,145	0,123	0,133	0,098	0,086	0,100	0,109	0,096	0,109	0,111
3,3	0,089	0,122	0,118	0,112	0,086	0,080	0,089	0,096	0,102	0,094	0,100
3,5	0,081	0,098	0,097	0,092	0,070	0,070	0,083	0,084	0,091	0,087	0,080
3,7	0,072	0,088	0,089	0,083	0,061	0,063	0,078	0,076	0,092	0,077	0,067
3,9	0,070	0,082	0,083	0,073	0,060	0,060	0,075	0,071	0,076	0,070	0,059
4,1	0,065	0,071	0,067	0,066	0,057	0,059	0,066	0,068	0,065	0,060	0,056
4,3	0,065	0,067	0,070	0,065	0,054	0,053	0,062	0,061	0,060	0,054	0,054
4,5	0,064	0,065	0,062	0,064	0,054	0,052	0,062	0,060	0,059	0,058	0,056

4,7	0,060	0,065	0,059	0,060	0,049	0,053	0,058	0,060	0,055	0,056	0,053
4,9	0,057	0,061	0,061	0,057	0,051	0,052	0,056	0,054	0,054	0,055	0,050
5,1	0,057	0,056	0,058	0,063	0,053	0,056	0,056	0,055	0,061	0,058	0,048
5,3	0,057	0,058	0,059	0,056	0,053	0,052	0,056	0,053	0,053	0,050	0,053
5,5	0,057	0,060	0,057	0,057	0,051	0,052	0,055	0,051	0,055	0,051	0,050
5,7	0,060	0,055	0,055	0,054	0,049	0,051	0,052	0,054	0,054	0,054	0,050
5,9	0,062	0,054	0,057	0,054	0,050	0,049	0,052	0,051	0,053	0,053	0,054
6,1	0,067	0,057	0,056	0,056	0,052	0,053	0,054	0,053	0,055	0,054	0,054
6,3	0,075	0,056	0,055	0,057	0,051	0,053	0,054	0,053	0,055	0,053	0,052
6,5	0,075	0,059	0,067	0,055	0,067	0,054	0,064	0,055	0,054	0,054	0,060
6,7	0,061	0,072	0,076	0,067	0,071	0,054	0,069	0,073	0,081	0,076	0,066
6,9	0,059	0,077	0,062	0,085	0,061	0,093	0,070	0,077	0,065	0,071	0,076
7,1	0,063	0,058	0,057	0,057	0,053	0,055	0,056	0,053	0,058	0,060	0,055
7,3	0,073	0,066	0,066	0,066	0,064	0,063	0,065	0,064	0,067	0,067	0,069
7,5	0,065	0,059	0,058	0,057	0,055	0,053	0,056	0,055	0,057	0,056	0,059
7,7	0,065	0,059	0,059	0,058	0,056	0,055	0,058	0,057	0,057	0,056	0,058
7,9	0,062	0,059	0,058	0,058	0,057	0,056	0,059	0,058	0,058	0,057	0,059
8,1	0,124	0,105	0,109	0,108	0,106	0,107	0,110	0,108	0,111	0,114	0,115
8,3	0,155	0,144	0,154	0,160	0,168	0,175	0,184	0,198	0,217	0,236	0,255
8,5	0,139	0,140	0,146	0,151	0,159	0,164	0,177	0,191	0,208	0,226	0,241
8,7	0,141	0,115	0,118	0,123	0,122	0,130	0,131	0,132	0,134	0,140	0,144
8,9	0,078	0,068	0,064	0,067	0,062	0,065	0,067	0,066	0,064	0,064	0,064

Note:
The normalization current is 11,6A.

Test result: **(ALPHA WP 10KW)**

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	3,660	9,715	19,640	30,003	40,238	50,276	60,275	70,448	80,708	90,686	100,627
2	0,651	0,440	0,427	0,362	0,241	0,143	0,095	0,240	0,372	0,481	0,579
3	0,407	0,796	0,806	0,728	0,671	0,632	0,620	0,606	0,609	0,623	0,658
4	0,153	0,099	0,108	0,088	0,056	0,033	0,052	0,081	0,110	0,139	0,159
5	0,302	0,286	0,549	0,570	0,541	0,505	0,464	0,424	0,388	0,362	0,343
6	0,060	0,061	0,062	0,072	0,058	0,046	0,038	0,059	0,066	0,083	0,100
7	0,290	0,144	0,334	0,343	0,328	0,330	0,325	0,318	0,311	0,312	0,315
8	0,046	0,036	0,040	0,052	0,046	0,038	0,038	0,042	0,055	0,066	0,074
9	0,159	0,120	0,239	0,304	0,315	0,338	0,357	0,356	0,356	0,349	0,336
10	0,061	0,048	0,041	0,048	0,056	0,049	0,043	0,043	0,046	0,052	0,057
11	0,102	0,155	0,213	0,285	0,263	0,309	0,335	0,335	0,323	0,321	0,312

12	0,035	0,056	0,045	0,051	0,061	0,057	0,050	0,044	0,044	0,051	0,057
13	0,142	0,152	0,192	0,328	0,262	0,229	0,266	0,286	0,286	0,299	0,323
14	0,034	0,041	0,034	0,048	0,062	0,055	0,044	0,040	0,041	0,044	0,047
15	0,121	0,231	0,215	0,284	0,272	0,203	0,225	0,256	0,291	0,320	0,346
16	0,022	0,026	0,024	0,035	0,052	0,050	0,041	0,034	0,031	0,033	0,035
17	0,115	0,235	0,225	0,225	0,254	0,181	0,177	0,224	0,257	0,277	0,295
18	0,026	0,022	0,027	0,021	0,042	0,041	0,032	0,027	0,026	0,024	0,026
19	0,088	0,136	0,147	0,173	0,216	0,172	0,130	0,159	0,181	0,198	0,230
20	0,021	0,023	0,031	0,023	0,038	0,038	0,029	0,025	0,023	0,025	0,028
21	0,133	0,127	0,087	0,173	0,212	0,199	0,125	0,092	0,120	0,147	0,182
22	0,024	0,017	0,021	0,022	0,032	0,041	0,035	0,027	0,023	0,018	0,021
23	0,117	0,154	0,150	0,187	0,201	0,207	0,140	0,086	0,105	0,130	0,153
24	0,028	0,027	0,032	0,021	0,018	0,032	0,032	0,026	0,019	0,016	0,025
25	0,087	0,146	0,194	0,178	0,159	0,181	0,133	0,083	0,084	0,096	0,114
26	0,020	0,017	0,031	0,025	0,021	0,034	0,029	0,027	0,024	0,024	0,034
27	0,143	0,153	0,178	0,162	0,151	0,180	0,147	0,103	0,060	0,068	0,092
28	0,027	0,030	0,035	0,022	0,014	0,023	0,037	0,038	0,031	0,024	0,030
29	0,106	0,136	0,157	0,136	0,149	0,169	0,170	0,123	0,066	0,058	0,078
30	0,029	0,022	0,027	0,030	0,021	0,034	0,045	0,037	0,031	0,026	0,036
31	0,150	0,146	0,158	0,138	0,161	0,166	0,164	0,122	0,079	0,052	0,056
32	0,036	0,026	0,025	0,035	0,018	0,019	0,024	0,029	0,033	0,032	0,038
33	0,153	0,196	0,175	0,158	0,160	0,162	0,185	0,151	0,100	0,065	0,047
34	0,012	0,018	0,018	0,047	0,022	0,022	0,021	0,033	0,038	0,038	0,036
35	0,152	0,169	0,164	0,166	0,154	0,140	0,168	0,149	0,122	0,072	0,055
36	0,033	0,021	0,029	0,038	0,016	0,028	0,026	0,035	0,038	0,036	0,036
37	0,163	0,167	0,159	0,183	0,142	0,126	0,167	0,170	0,145	0,088	0,071
38	0,020	0,016	0,026	0,036	0,038	0,032	0,024	0,028	0,037	0,044	0,035
39	0,201	0,209	0,208	0,220	0,167	0,139	0,175	0,175	0,153	0,102	0,065
40	0,043	0,039	0,039	0,039	0,039	0,048	0,044	0,036	0,039	0,043	0,029
41	0,177	0,193	0,208	0,168	0,130	0,114	0,148	0,170	0,148	0,098	0,056
42	0,030	0,029	0,031	0,036	0,066	0,047	0,051	0,035	0,041	0,040	0,029
43	0,189	0,192	0,206	0,171	0,110	0,106	0,134	0,157	0,145	0,119	0,063
44	0,039	0,037	0,032	0,048	0,049	0,041	0,054	0,032	0,027	0,038	0,038
45	0,207	0,225	0,196	0,117	0,083	0,100	0,145	0,145	0,125	0,124	0,049
46	0,042	0,035	0,045	0,047	0,060	0,056	0,053	0,043	0,024	0,034	0,039
47	0,152	0,179	0,161	0,113	0,087	0,086	0,103	0,116	0,106	0,118	0,077
48	0,053	0,045	0,042	0,053	0,054	0,064	0,056	0,052	0,025	0,034	0,037
49	0,130	0,153	0,135	0,094	0,071	0,078	0,098	0,081	0,105	0,116	0,101
50	0,062	0,047	0,071	0,058	0,041	0,066	0,051	0,035	0,026	0,026	0,035
Interharmonics											

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 [%]
75	0,029	0,080	0,062	0,051	0,048	0,048	0,051	0,053	0,046	0,057	0,064
125	0,030	0,056	0,045	0,041	0,048	0,058	0,061	0,056	0,043	0,044	0,049
175	0,033	0,069	0,053	0,041	0,044	0,044	0,045	0,043	0,049	0,051	0,051
225	0,038	0,068	0,056	0,051	0,056	0,060	0,061	0,059	0,054	0,061	0,063
275	0,044	0,079	0,074	0,067	0,068	0,068	0,070	0,071	0,072	0,076	0,079
325	0,056	0,092	0,087	0,086	0,093	0,090	0,090	0,084	0,080	0,088	0,092
375	0,069	0,102	0,108	0,105	0,113	0,107	0,106	0,103	0,100	0,104	0,107
425	0,079	0,121	0,120	0,124	0,131	0,135	0,127	0,124	0,121	0,123	0,126
475	0,082	0,111	0,116	0,118	0,130	0,140	0,131	0,129	0,127	0,124	0,128
525	0,081	0,125	0,115	0,105	0,110	0,120	0,124	0,125	0,124	0,122	0,126
575	0,059	0,077	0,072	0,075	0,085	0,095	0,104	0,110	0,114	0,114	0,119
625	0,043	0,080	0,057	0,054	0,061	0,068	0,079	0,087	0,100	0,107	0,112
675	0,042	0,054	0,041	0,042	0,045	0,049	0,057	0,067	0,082	0,092	0,102
725	0,029	0,057	0,034	0,034	0,037	0,039	0,043	0,049	0,062	0,075	0,087
775	0,057	0,064	0,060	0,059	0,060	0,062	0,065	0,068	0,075	0,084	0,094
825	0,024	0,045	0,031	0,026	0,029	0,031	0,032	0,034	0,042	0,050	0,059
875	0,028	0,041	0,038	0,037	0,037	0,039	0,040	0,043	0,047	0,052	0,059
925	0,021	0,036	0,026	0,023	0,024	0,025	0,026	0,028	0,032	0,037	0,043
975	0,055	0,050	0,049	0,048	0,048	0,049	0,050	0,050	0,051	0,055	0,061
1025	0,020	0,028	0,025	0,022	0,023	0,024	0,025	0,025	0,028	0,031	0,036
1075	0,037	0,032	0,031	0,029	0,030	0,031	0,032	0,031	0,032	0,035	0,040
1125	0,019	0,023	0,023	0,020	0,021	0,021	0,022	0,023	0,025	0,027	0,031
1175	0,018	0,022	0,021	0,019	0,019	0,020	0,022	0,021	0,022	0,025	0,028
1225	0,018	0,021	0,021	0,019	0,019	0,020	0,021	0,021	0,022	0,024	0,027
1275	0,018	0,023	0,021	0,019	0,019	0,019	0,020	0,020	0,021	0,023	0,025
1325	0,028	0,027	0,026	0,026	0,025	0,025	0,026	0,026	0,026	0,027	0,028
1375	0,018	0,023	0,021	0,019	0,019	0,018	0,019	0,019	0,020	0,022	0,023
1425	0,028	0,029	0,027	0,026	0,025	0,025	0,026	0,025	0,026	0,027	0,029
1475	0,019	0,024	0,020	0,019	0,018	0,018	0,019	0,019	0,019	0,020	0,024
1525	0,018	0,024	0,020	0,019	0,018	0,018	0,019	0,018	0,019	0,020	0,024
1575	0,019	0,023	0,019	0,019	0,018	0,019	0,019	0,019	0,019	0,020	0,023
1625	0,018	0,023	0,020	0,019	0,018	0,018	0,019	0,018	0,019	0,020	0,024
1675	0,018	0,022	0,020	0,019	0,018	0,019	0,019	0,018	0,019	0,020	0,024
1725	0,018	0,022	0,020	0,019	0,018	0,019	0,019	0,018	0,019	0,020	0,025
1775	0,018	0,022	0,019	0,019	0,019	0,020	0,019	0,019	0,019	0,020	0,025
1825	0,019	0,022	0,020	0,020	0,018	0,020	0,019	0,019	0,019	0,021	0,025
1875	0,019	0,022	0,019	0,019	0,020	0,021	0,020	0,020	0,020	0,020	0,024

1925	0,020	0,023	0,020	0,020	0,020	0,021	0,020	0,020	0,020	0,022	0,025
1975	0,023	0,026	0,024	0,024	0,024	0,025	0,024	0,025	0,026	0,026	0,029
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	0,256	0,270	0,286	0,249	0,194	0,173	0,211	0,240	0,214	0,171	0,109
2,3	0,261	0,288	0,256	0,181	0,145	0,162	0,199	0,203	0,173	0,185	0,108
2,5	0,169	0,219	0,195	0,132	0,107	0,144	0,151	0,132	0,154	0,152	0,142
2,7	0,121	0,148	0,108	0,094	0,107	0,125	0,111	0,111	0,154	0,103	0,121
2,9	0,080	0,088	0,081	0,076	0,102	0,088	0,084	0,094	0,102	0,094	0,082
3,1	0,076	0,078	0,082	0,073	0,083	0,073	0,066	0,071	0,077	0,092	0,080
3,3	0,071	0,076	0,071	0,075	0,074	0,070	0,067	0,063	0,071	0,067	0,075
3,5	0,065	0,073	0,064	0,063	0,060	0,057	0,058	0,057	0,056	0,055	0,051
3,7	0,058	0,067	0,063	0,060	0,056	0,056	0,057	0,050	0,048	0,050	0,047
3,9	0,056	0,068	0,062	0,061	0,054	0,052	0,048	0,046	0,044	0,049	0,055
4,1	0,053	0,062	0,055	0,054	0,052	0,046	0,045	0,044	0,042	0,046	0,056
4,3	0,052	0,057	0,052	0,050	0,049	0,049	0,045	0,045	0,043	0,042	0,047
4,5	0,050	0,053	0,049	0,050	0,048	0,044	0,041	0,039	0,039	0,038	0,039
4,7	0,048	0,055	0,051	0,049	0,047	0,044	0,039	0,040	0,039	0,038	0,038
4,9	0,046	0,048	0,045	0,048	0,049	0,042	0,041	0,038	0,037	0,038	0,038
5,1	0,045	0,050	0,048	0,045	0,045	0,046	0,040	0,037	0,038	0,038	0,038
5,3	0,046	0,048	0,046	0,046	0,046	0,041	0,043	0,040	0,037	0,038	0,038
5,5	0,046	0,045	0,045	0,047	0,044	0,041	0,040	0,041	0,039	0,039	0,039
5,7	0,048	0,048	0,046	0,044	0,042	0,042	0,039	0,040	0,041	0,040	0,041
5,9	0,051	0,047	0,045	0,044	0,042	0,040	0,041	0,038	0,041	0,040	0,039
6,1	0,052	0,047	0,046	0,045	0,043	0,041	0,041	0,040	0,041	0,044	0,042
6,3	0,057	0,047	0,045	0,044	0,043	0,041	0,040	0,040	0,040	0,040	0,040
6,5	0,062	0,048	0,048	0,046	0,042	0,047	0,042	0,051	0,043	0,042	0,044
6,7	0,049	0,048	0,045	0,046	0,059	0,068	0,071	0,061	0,050	0,067	0,055
6,9	0,047	0,048	0,047	0,063	0,061	0,044	0,045	0,045	0,051	0,053	0,051
7,1	0,050	0,049	0,061	0,061	0,044	0,043	0,042	0,043	0,060	0,046	0,056
7,3	0,059	0,069	0,070	0,052	0,051	0,051	0,052	0,051	0,051	0,050	0,051
7,5	0,049	0,065	0,049	0,045	0,044	0,044	0,043	0,045	0,044	0,044	0,044
7,7	0,054	0,049	0,047	0,047	0,045	0,044	0,043	0,043	0,046	0,045	0,047
7,9	0,051	0,050	0,048	0,049	0,045	0,045	0,045	0,047	0,044	0,044	0,044
8,1	0,098	0,085	0,086	0,084	0,085	0,088	0,089	0,090	0,091	0,095	0,101
8,3	0,125	0,114	0,123	0,132	0,141	0,156	0,168	0,189	0,210	0,235	0,264
8,5	0,111	0,109	0,113	0,121	0,134	0,144	0,161	0,177	0,197	0,224	0,248
8,7	0,113	0,091	0,092	0,102	0,101	0,102	0,105	0,108	0,117	0,121	0,131

8,9	0,061	0,053	0,063	0,055	0,051	0,050	0,050	0,051	0,051	0,052	0,054
Note: The normalization current is 14,5A											

Test result: **(ALPHA WP 12KW)**

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	3.142	9,837	20,035	29,942	40,349	50,531	60,520	70,634	80,509	90,589	100,452
2	0.619	0,291	0,267	0,203	0,085	0,099	0,242	0,379	0,477	0,536	0,593
3	1.101	0,679	0,645	0,577	0,535	0,514	0,503	0,510	0,531	0,566	0,595
4	0.206	0,068	0,066	0,051	0,024	0,052	0,079	0,113	0,137	0,153	0,164
5	0.204	0,302	0,479	0,459	0,424	0,383	0,341	0,307	0,282	0,273	0,277
6	0.101	0,042	0,052	0,051	0,041	0,035	0,051	0,064	0,081	0,097	0,106
7	0.794	0,129	0,289	0,263	0,260	0,253	0,247	0,245	0,250	0,272	0,297
8	0.101	0,029	0,031	0,039	0,030	0,029	0,038	0,052	0,060	0,071	0,083
9	0.849	0,083	0,252	0,253	0,262	0,280	0,277	0,281	0,282	0,276	0,281
10	0.084	0,033	0,035	0,046	0,038	0,033	0,035	0,039	0,045	0,049	0,056
11	0.451	0,125	0,235	0,227	0,239	0,275	0,279	0,278	0,281	0,263	0,246
12	0.031	0,039	0,036	0,046	0,048	0,043	0,039	0,043	0,045	0,049	0,061
13	0.342	0,160	0,226	0,247	0,188	0,223	0,243	0,255	0,264	0,266	0,275
14	0.032	0,031	0,034	0,044	0,044	0,037	0,037	0,040	0,047	0,052	0,059
15	0.126	0,102	0,189	0,259	0,174	0,181	0,216	0,248	0,269	0,291	0,320
16	0.030	0,023	0,021	0,035	0,037	0,030	0,028	0,030	0,033	0,038	0,042
17	0.261	0,168	0,179	0,242	0,169	0,139	0,183	0,219	0,243	0,264	0,291
18	0.026	0,018	0,017	0,022	0,026	0,024	0,023	0,020	0,023	0,026	0,032
19	0.194	0,177	0,170	0,184	0,149	0,114	0,149	0,170	0,184	0,203	0,223
20	0.026	0,020	0,016	0,024	0,030	0,020	0,016	0,016	0,021	0,027	0,032
21	0.157	0,129	0,150	0,164	0,150	0,085	0,095	0,115	0,134	0,153	0,178
22	0.017	0,016	0,019	0,016	0,027	0,024	0,020	0,020	0,027	0,027	0,027
23	0.174	0,116	0,128	0,145	0,175	0,118	0,065	0,078	0,107	0,136	0,156
24	0.012	0,013	0,023	0,016	0,033	0,027	0,016	0,016	0,017	0,018	0,019
25	0.150	0,110	0,104	0,139	0,170	0,121	0,067	0,074	0,099	0,117	0,135
26	0.011	0,015	0,028	0,012	0,018	0,022	0,020	0,016	0,016	0,020	0,021
27	0.147	0,120	0,116	0,128	0,142	0,114	0,066	0,060	0,087	0,107	0,128
28	0.017	0,016	0,029	0,022	0,030	0,028	0,022	0,018	0,025	0,022	0,028
29	0.144	0,140	0,144	0,114	0,131	0,138	0,099	0,048	0,061	0,087	0,122
30	0.017	0,017	0,027	0,019	0,024	0,030	0,030	0,032	0,030	0,021	0,024
31	0.150	0,143	0,155	0,136	0,135	0,147	0,114	0,061	0,046	0,079	0,113
32	0.014	0,013	0,031	0,020	0,019	0,033	0,031	0,022	0,021	0,019	0,022
33	0.142	0,149	0,172	0,148	0,134	0,155	0,121	0,062	0,043	0,078	0,113
34	0.029	0,015	0,024	0,023	0,014	0,017	0,017	0,025	0,025	0,024	0,030
35	0.133	0,143	0,150	0,138	0,125	0,144	0,121	0,076	0,029	0,059	0,098

36	0.027	0,016	0,026	0,028	0,023	0,019	0,021	0,030	0,029	0,027	0,034
37	0.133	0,156	0,133	0,116	0,104	0,143	0,127	0,094	0,053	0,043	0,086
38	0.036	0,019	0,020	0,025	0,021	0,022	0,036	0,033	0,029	0,027	0,027
39	0.144	0,185	0,156	0,128	0,124	0,169	0,147	0,114	0,067	0,038	0,089
40	0.031	0,021	0,025	0,040	0,034	0,032	0,032	0,034	0,034	0,028	0,032
41	0.115	0,150	0,148	0,141	0,095	0,128	0,129	0,111	0,069	0,048	0,073
42	0.057	0,036	0,033	0,036	0,030	0,046	0,026	0,028	0,035	0,034	0,033
43	0.113	0,147	0,140	0,133	0,106	0,126	0,132	0,123	0,092	0,055	0,061
44	0.049	0,040	0,039	0,030	0,037	0,044	0,032	0,034	0,034	0,032	0,030
45	0.097	0,154	0,170	0,133	0,077	0,107	0,131	0,113	0,086	0,045	0,063
46	0.050	0,043	0,044	0,027	0,027	0,048	0,034	0,041	0,038	0,036	0,035
47	0.117	0,126	0,144	0,112	0,078	0,086	0,125	0,112	0,102	0,064	0,038
48	0.059	0,044	0,037	0,025	0,034	0,055	0,050	0,046	0,038	0,037	0,036
49	0.066	0,091	0,122	0,085	0,051	0,060	0,092	0,103	0,099	0,055	0,040
50	0.077	0,058	0,033	0,030	0,058	0,054	0,055	0,036	0,036	0,044	0,035
Interharmonics											
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 [%]
75	0.024	0,071	0,039	0,041	0,038	0,042	0,043	0,041	0,046	0,045	0,073
125	0.026	0,049	0,033	0,033	0,031	0,035	0,035	0,035	0,040	0,041	0,053
175	0.028	0,050	0,036	0,035	0,034	0,037	0,036	0,053	0,055	0,043	0,064
225	0.031	0,060	0,059	0,043	0,045	0,055	0,062	0,044	0,046	0,049	0,053
275	0.036	0,058	0,056	0,058	0,058	0,052	0,052	0,056	0,062	0,061	0,072
325	0.045	0,074	0,070	0,078	0,076	0,066	0,065	0,065	0,066	0,072	0,088
375	0.049	0,090	0,094	0,097	0,095	0,089	0,090	0,080	0,078	0,085	0,091
425	0.050	0,102	0,099	0,108	0,112	0,099	0,096	0,098	0,092	0,098	0,118
475	0.041	0,091	0,094	0,104	0,114	0,108	0,109	0,103	0,100	0,105	0,115
525	0.033	0,098	0,087	0,098	0,103	0,109	0,111	0,105	0,101	0,108	0,129
575	0.027	0,059	0,061	0,070	0,081	0,093	0,102	0,105	0,105	0,108	0,117
625	0.023	0,059	0,045	0,050	0,058	0,074	0,087	0,096	0,099	0,111	0,134
675	0.032	0,040	0,035	0,037	0,041	0,052	0,066	0,082	0,092	0,106	0,111
725	0.019	0,043	0,029	0,030	0,033	0,040	0,051	0,064	0,076	0,097	0,119
775	0.046	0,055	0,051	0,051	0,053	0,056	0,062	0,071	0,082	0,101	0,112
825	0.017	0,032	0,024	0,023	0,025	0,027	0,032	0,040	0,051	0,068	0,089
875	0.022	0,034	0,030	0,031	0,033	0,035	0,037	0,042	0,049	0,061	0,075
925	0.016	0,025	0,022	0,019	0,021	0,022	0,025	0,028	0,035	0,048	0,062
975	0.046	0,043	0,040	0,040	0,042	0,042	0,043	0,045	0,048	0,055	0,061
1025	0.016	0,023	0,021	0,019	0,020	0,020	0,021	0,024	0,028	0,035	0,044
1075	0.030	0,026	0,028	0,025	0,025	0,026	0,026	0,028	0,031	0,035	0,043

1125	0.015	0,019	0,021	0,017	0,018	0,018	0,019	0,021	0,024	0,029	0,035
1175	0.014	0,017	0,020	0,016	0,017	0,018	0,018	0,019	0,022	0,026	0,032
1225	0.014	0,016	0,020	0,016	0,017	0,018	0,018	0,019	0,021	0,025	0,031
1275	0.014	0,017	0,020	0,016	0,016	0,017	0,016	0,018	0,020	0,023	0,028
1325	0.023	0,022	0,024	0,022	0,022	0,022	0,022	0,023	0,024	0,025	0,028
1375	0.014	0,017	0,020	0,018	0,016	0,017	0,016	0,017	0,019	0,021	0,026
1425	0.022	0,022	0,027	0,024	0,023	0,022	0,022	0,022	0,024	0,025	0,029
1475	0.016	0,017	0,022	0,019	0,016	0,016	0,016	0,016	0,018	0,020	0,024
1525	0.014	0,017	0,022	0,019	0,016	0,016	0,016	0,016	0,018	0,019	0,023
1575	0.014	0,017	0,022	0,018	0,016	0,016	0,015	0,016	0,017	0,019	0,023
1625	0.014	0,016	0,023	0,018	0,016	0,016	0,016	0,016	0,017	0,019	0,023
1675	0.014	0,017	0,024	0,019	0,016	0,017	0,016	0,016	0,017	0,019	0,023
1725	0.014	0,016	0,025	0,019	0,016	0,016	0,017	0,016	0,017	0,019	0,022
1775	0.015	0,016	0,026	0,020	0,016	0,016	0,016	0,016	0,017	0,019	0,021
1825	0.015	0,016	0,027	0,019	0,016	0,016	0,016	0,017	0,018	0,019	0,022
1875	0.015	0,016	0,029	0,021	0,016	0,016	0,016	0,016	0,017	0,019	0,022
1925	0.015	0,016	0,030	0,021	0,017	0,017	0,017	0,017	0,018	0,019	0,023
1975	0.019	0,019	0,033	0,024	0,020	0,020	0,021	0,021	0,022	0,024	0,028
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	0.181	0,219	0,220	0,203	0,155	0,194	0,191	0,176	0,128	0,095	0,113
2,3	0.173	0,203	0,219	0,177	0,122	0,154	0,192	0,173	0,143	0,093	0,093
2,5	0.137	0,136	0,178	0,130	0,112	0,118	0,151	0,143	0,127	0,089	0,077
2,7	0.094	0,096	0,134	0,097	0,082	0,092	0,117	0,103	0,085	0,095	0,075
2,9	0.072	0,070	0,107	0,077	0,074	0,075	0,094	0,089	0,070	0,064	0,059
3,1	0.064	0,057	0,089	0,064	0,073	0,069	0,076	0,081	0,065	0,058	0,056
3,3	0.065	0,056	0,082	0,065	0,067	0,064	0,059	0,069	0,059	0,051	0,052
3,5	0.052	0,049	0,079	0,061	0,057	0,054	0,049	0,063	0,060	0,049	0,047
3,7	0.051	0,048	0,076	0,057	0,048	0,049	0,043	0,054	0,057	0,049	0,045
3,9	0.048	0,047	0,081	0,058	0,047	0,045	0,042	0,045	0,049	0,045	0,043
4,1	0.042	0,043	0,076	0,058	0,043	0,042	0,043	0,038	0,045	0,044	0,043
4,3	0.041	0,043	0,065	0,053	0,047	0,042	0,040	0,036	0,041	0,042	0,042
4,5	0.040	0,045	0,060	0,047	0,044	0,039	0,040	0,036	0,037	0,040	0,041
4,7	0.040	0,042	0,060	0,048	0,042	0,040	0,037	0,037	0,036	0,040	0,041
4,9	0.039	0,037	0,055	0,043	0,037	0,035	0,033	0,038	0,039	0,040	0,040
5,1	0.037	0,038	0,055	0,044	0,038	0,037	0,036	0,036	0,034	0,036	0,038
5,3	0.039	0,037	0,053	0,044	0,039	0,041	0,041	0,036	0,034	0,036	0,038
5,5	0.038	0,036	0,052	0,043	0,041	0,038	0,035	0,034	0,034	0,034	0,037

5,7	0.037	0,037	0,053	0,045	0,039	0,037	0,036	0,033	0,033	0,033	0,035
5,9	0.038	0,036	0,053	0,042	0,036	0,036	0,035	0,033	0,033	0,033	0,035
6,1	0.049	0,036	0,054	0,041	0,037	0,035	0,035	0,034	0,035	0,035	0,035
6,3	0.049	0,037	0,052	0,042	0,036	0,034	0,034	0,035	0,035	0,034	0,034
6,5	0.042	0,039	0,049	0,040	0,038	0,036	0,036	0,035	0,036	0,037	0,038
6,7	0.040	0,038	0,051	0,042	0,039	0,038	0,037	0,037	0,038	0,037	0,036
6,9	0.041	0,038	0,049	0,040	0,038	0,038	0,037	0,036	0,035	0,037	0,037
7,1	0.041	0,037	0,048	0,040	0,037	0,037	0,036	0,036	0,035	0,035	0,036
7,3	0.051	0,044	0,054	0,047	0,044	0,043	0,043	0,043	0,043	0,043	0,044
7,5	0.042	0,037	0,049	0,041	0,039	0,038	0,037	0,038	0,037	0,037	0,041
7,7	0.040	0,069	0,049	0,041	0,039	0,038	0,037	0,038	0,039	0,044	0,060
7,9	0.042	0,038	0,052	0,042	0,039	0,038	0,038	0,059	0,065	0,064	0,049
8,1	0.084	0,072	0,072	0,070	0,071	0,072	0,073	0,077	0,081	0,085	0,090
8,3	0.099	0,098	0,103	0,110	0,121	0,136	0,155	0,180	0,206	0,234	0,261
8,5	0.091	0,094	0,098	0,103	0,115	0,130	0,149	0,169	0,192	0,218	0,243
8,7	0.091	0,078	0,077	0,081	0,084	0,087	0,091	0,097	0,104	0,112	0,122
8,9	0.052	0,041	0,051	0,044	0,045	0,045	0,045	0,044	0,045	0,047	0,052

Note:
The normalization current is 17,4A

Test result: **(ALPHA WP 15KW)**											
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	2.496	9,985	20,203	30,274	40,514	50,474	60,506	70,448	80,408	90,297	100,180
2	0.523	0,207	0,126	0,038	0,153	0,314	0,417	0,502	0,572	0,608	0,658
3	0.878	0,549	0,484	0,433	0,409	0,400	0,411	0,442	0,478	0,500	0,514
4	0.177	0,050	0,032	0,026	0,059	0,088	0,117	0,135	0,150	0,160	0,164
5	0.168	0,310	0,377	0,348	0,305	0,264	0,236	0,220	0,222	0,244	0,290
6	0.085	0,029	0,030	0,023	0,032	0,053	0,066	0,085	0,096	0,104	0,114
7	0.638	0,158	0,224	0,210	0,203	0,196	0,197	0,212	0,236	0,263	0,281
8	0.084	0,023	0,021	0,024	0,028	0,038	0,049	0,060	0,072	0,078	0,089
9	0.675	0,090	0,210	0,210	0,223	0,222	0,224	0,220	0,222	0,228	0,232
10	0.072	0,025	0,028	0,041	0,034	0,037	0,036	0,042	0,049	0,054	0,058
11	0.356	0,089	0,194	0,184	0,222	0,222	0,223	0,214	0,194	0,186	0,206
12	0.027	0,030	0,030	0,039	0,034	0,033	0,039	0,044	0,056	0,058	0,051
13	0.271	0,150	0,225	0,152	0,179	0,195	0,207	0,211	0,218	0,228	0,232
14	0.027	0,021	0,027	0,032	0,029	0,031	0,039	0,046	0,055	0,053	0,055
15	0.102	0,133	0,207	0,156	0,147	0,179	0,207	0,228	0,252	0,272	0,273

16	0.025	0,018	0,022	0,025	0,022	0,023	0,027	0,033	0,037	0,037	0,042
17	0.207	0,057	0,165	0,153	0,112	0,155	0,184	0,207	0,232	0,252	0,275
18	0.022	0,020	0,012	0,017	0,015	0,015	0,020	0,025	0,029	0,034	0,033
19	0.155	0,110	0,123	0,133	0,093	0,124	0,142	0,158	0,179	0,200	0,223
20	0.021	0,017	0,015	0,019	0,013	0,012	0,018	0,025	0,030	0,037	0,028
21	0.125	0,144	0,113	0,128	0,068	0,079	0,099	0,119	0,142	0,158	0,170
22	0.014	0,017	0,011	0,016	0,017	0,017	0,021	0,026	0,025	0,029	0,030
23	0.138	0,109	0,117	0,140	0,094	0,050	0,075	0,103	0,124	0,132	0,139
24	0.011	0,011	0,014	0,020	0,018	0,012	0,015	0,018	0,019	0,028	0,025
25	0.119	0,083	0,124	0,131	0,096	0,045	0,071	0,091	0,109	0,117	0,136
26	0.009	0,010	0,011	0,009	0,013	0,013	0,012	0,018	0,022	0,029	0,020
27	0.117	0,095	0,115	0,111	0,090	0,047	0,059	0,082	0,103	0,116	0,133
28	0.014	0,012	0,017	0,018	0,017	0,013	0,017	0,021	0,028	0,023	0,025
29	0.115	0,104	0,086	0,101	0,110	0,067	0,038	0,064	0,098	0,113	0,128
30	0.013	0,012	0,016	0,017	0,022	0,020	0,024	0,019	0,024	0,021	0,030
31	0.120	0,101	0,079	0,105	0,119	0,079	0,031	0,058	0,091	0,105	0,117
32	0.011	0,014	0,019	0,015	0,023	0,019	0,013	0,014	0,023	0,029	0,022
33	0.114	0,129	0,117	0,102	0,123	0,081	0,031	0,055	0,091	0,114	0,125
34	0.023	0,009	0,019	0,012	0,011	0,014	0,017	0,018	0,029	0,033	0,020
35	0.106	0,127	0,120	0,099	0,117	0,089	0,040	0,040	0,080	0,109	0,117
36	0.021	0,015	0,020	0,015	0,011	0,019	0,021	0,019	0,030	0,032	0,023
37	0.106	0,120	0,117	0,087	0,116	0,094	0,059	0,025	0,071	0,098	0,100
38	0.029	0,019	0,015	0,013	0,021	0,029	0,019	0,019	0,021	0,032	0,022
39	0.116	0,132	0,148	0,111	0,140	0,115	0,074	0,029	0,074	0,092	0,100
40	0.024	0,022	0,020	0,024	0,032	0,028	0,022	0,019	0,023	0,029	0,021
41	0.093	0,117	0,122	0,090	0,106	0,106	0,080	0,040	0,060	0,081	0,087
42	0.046	0,029	0,016	0,020	0,031	0,025	0,027	0,024	0,024	0,029	0,022
43	0.092	0,121	0,127	0,100	0,103	0,107	0,086	0,047	0,051	0,074	0,077
44	0.038	0,033	0,027	0,028	0,035	0,032	0,030	0,024	0,020	0,026	0,017
45	0.079	0,123	0,113	0,072	0,091	0,113	0,090	0,052	0,044	0,077	0,083
46	0.040	0,031	0,029	0,025	0,041	0,031	0,028	0,028	0,023	0,025	0,018
47	0.096	0,092	0,083	0,066	0,067	0,101	0,087	0,049	0,029	0,055	0,051
48	0.047	0,039	0,024	0,025	0,038	0,035	0,032	0,027	0,027	0,026	0,027
49	0.055	0,071	0,061	0,034	0,043	0,084	0,079	0,041	0,031	0,046	0,050
50	0.059	0,048	0,029	0,037	0,033	0,044	0,030	0,031	0,024	0,020	0,018
Interharmonics											
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 [%]
75	0.022	0,043	0,031	0,031	0,031	0,031	0,037	0,041	0,049	0,042	0,058

125	0.021	0,037	0,026	0,026	0,028	0,028	0,030	0,032	0,038	0,036	0,045
175	0.024	0,035	0,029	0,028	0,029	0,029	0,031	0,034	0,039	0,038	0,044
225	0.025	0,038	0,034	0,034	0,033	0,034	0,036	0,039	0,053	0,046	0,045
275	0.030	0,060	0,060	0,061	0,059	0,061	0,059	0,045	0,048	0,047	0,048
325	0.037	0,056	0,048	0,059	0,054	0,052	0,053	0,053	0,060	0,056	0,063
375	0.041	0,071	0,062	0,074	0,067	0,064	0,064	0,063	0,075	0,062	0,070
425	0.040	0,087	0,074	0,089	0,078	0,073	0,083	0,076	0,083	0,073	0,081
475	0.034	0,074	0,076	0,096	0,093	0,083	0,083	0,081	0,090	0,083	0,090
525	0.026	0,079	0,069	0,084	0,082	0,082	0,088	0,084	0,098	0,086	0,089
575	0.022	0,046	0,050	0,065	0,077	0,078	0,087	0,081	0,095	0,088	0,090
625	0.018	0,038	0,038	0,048	0,058	0,070	0,082	0,081	0,100	0,089	0,092
675	0.025	0,030	0,027	0,034	0,045	0,055	0,073	0,079	0,093	0,091	0,089
725	0.015	0,030	0,023	0,026	0,033	0,045	0,059	0,073	0,092	0,088	0,093
775	0.036	0,040	0,041	0,043	0,046	0,052	0,063	0,076	0,093	0,098	0,107
825	0.014	0,024	0,019	0,020	0,023	0,027	0,038	0,051	0,070	0,076	0,090
875	0.018	0,026	0,025	0,025	0,027	0,031	0,037	0,046	0,063	0,070	0,088
925	0.013	0,020	0,016	0,017	0,018	0,020	0,027	0,036	0,051	0,060	0,079
975	0.035	0,034	0,032	0,033	0,034	0,035	0,037	0,043	0,050	0,057	0,072
1025	0.013	0,017	0,016	0,015	0,017	0,018	0,021	0,027	0,037	0,045	0,063
1075	0.024	0,022	0,021	0,020	0,021	0,021	0,024	0,028	0,036	0,042	0,057
1125	0.012	0,015	0,014	0,014	0,015	0,016	0,018	0,022	0,029	0,035	0,049
1175	0.011	0,013	0,014	0,014	0,014	0,015	0,017	0,021	0,026	0,031	0,044
1225	0.011	0,014	0,015	0,013	0,014	0,015	0,016	0,020	0,024	0,029	0,039
1275	0.011	0,012	0,015	0,013	0,014	0,014	0,015	0,018	0,023	0,026	0,035
1325	0.017	0,017	0,017	0,017	0,018	0,017	0,018	0,020	0,023	0,025	0,033
1375	0.011	0,013	0,015	0,013	0,014	0,013	0,014	0,016	0,021	0,023	0,030
1425	0.018	0,017	0,020	0,019	0,018	0,018	0,019	0,020	0,024	0,026	0,030
1475	0.011	0,013	0,016	0,013	0,014	0,013	0,014	0,016	0,019	0,021	0,025
1525	0.013	0,012	0,017	0,014	0,014	0,013	0,014	0,016	0,019	0,021	0,025
1575	0.012	0,013	0,017	0,013	0,013	0,013	0,013	0,015	0,018	0,020	0,023
1625	0.011	0,013	0,017	0,013	0,013	0,013	0,014	0,015	0,018	0,020	0,022
1675	0.011	0,013	0,018	0,013	0,014	0,014	0,013	0,015	0,017	0,019	0,021
1725	0.011	0,012	0,018	0,013	0,014	0,014	0,013	0,015	0,017	0,020	0,021
1775	0.011	0,013	0,018	0,014	0,014	0,014	0,013	0,015	0,017	0,020	0,020
1825	0.012	0,013	0,019	0,014	0,014	0,014	0,014	0,015	0,018	0,020	0,020
1875	0.012	0,013	0,019	0,015	0,015	0,014	0,013	0,015	0,018	0,020	0,020
1925	0.012	0,014	0,021	0,015	0,015	0,014	0,014	0,015	0,019	0,021	0,021
1975	0.015	0,015	0,022	0,017	0,018	0,017	0,017	0,019	0,022	0,025	0,026
Higher Frequencies											

P/Pn [%]	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	0.146	0,172	0,179	0,142	0,156	0,160	0,129	0,078	0,091	0,123	0,124
2,3	0.141	0,155	0,148	0,106	0,123	0,161	0,133	0,083	0,068	0,103	0,100
2,5	0.111	0,104	0,111	0,076	0,086	0,125	0,108	0,079	0,062	0,084	0,088
2,7	0.075	0,075	0,080	0,069	0,079	0,084	0,077	0,076	0,058	0,056	0,077
2,9	0.057	0,057	0,072	0,060	0,062	0,066	0,069	0,059	0,051	0,053	0,060
3,1	0.053	0,049	0,067	0,067	0,055	0,055	0,058	0,052	0,046	0,043	0,047
3,3	0.049	0,045	0,072	0,058	0,049	0,049	0,054	0,046	0,044	0,039	0,044
3,5	0.041	0,038	0,067	0,045	0,044	0,042	0,046	0,042	0,041	0,043	0,040
3,7	0.040	0,037	0,058	0,040	0,041	0,036	0,042	0,038	0,038	0,041	0,038
3,9	0.038	0,036	0,049	0,041	0,037	0,033	0,036	0,036	0,036	0,037	0,039
4,1	0.035	0,035	0,048	0,036	0,033	0,033	0,034	0,032	0,032	0,033	0,035
4,3	0.032	0,034	0,043	0,035	0,033	0,034	0,032	0,033	0,031	0,032	0,034
4,5	0.031	0,033	0,042	0,034	0,031	0,031	0,028	0,030	0,030	0,032	0,034
4,7	0.033	0,032	0,041	0,033	0,030	0,029	0,028	0,028	0,030	0,032	0,032
4,9	0.032	0,029	0,037	0,035	0,029	0,028	0,027	0,027	0,028	0,029	0,030
5,1	0.030	0,030	0,038	0,031	0,031	0,027	0,026	0,026	0,028	0,029	0,031
5,3	0.030	0,030	0,038	0,032	0,028	0,028	0,026	0,026	0,029	0,030	0,031
5,5	0.030	0,028	0,038	0,032	0,030	0,029	0,029	0,029	0,028	0,029	0,031
5,7	0.029	0,030	0,038	0,029	0,028	0,028	0,027	0,027	0,027	0,027	0,029
5,9	0.033	0,029	0,036	0,029	0,028	0,027	0,027	0,026	0,027	0,027	0,029
6,1	0.037	0,029	0,035	0,030	0,028	0,028	0,027	0,028	0,028	0,028	0,030
6,3	0.036	0,029	0,035	0,030	0,028	0,028	0,027	0,028	0,027	0,028	0,028
6,5	0.033	0,032	0,037	0,030	0,030	0,030	0,027	0,027	0,027	0,029	0,029
6,7	0.035	0,032	0,050	0,032	0,033	0,048	0,034	0,030	0,031	0,029	0,030
6,9	0.032	0,039	0,036	0,051	0,034	0,030	0,047	0,036	0,030	0,030	0,030
7,1	0.035	0,035	0,035	0,031	0,042	0,028	0,029	0,046	0,045	0,031	0,030
7,3	0.041	0,035	0,041	0,036	0,035	0,034	0,034	0,034	0,042	0,047	0,037
7,5	0.033	0,030	0,037	0,032	0,031	0,030	0,031	0,030	0,030	0,041	0,043
7,7	0.032	0,030	0,038	0,033	0,031	0,031	0,030	0,030	0,030	0,030	0,043
7,9	0.034	0,031	0,039	0,032	0,031	0,032	0,031	0,031	0,030	0,030	0,033
8,1	0.067	0,058	0,055	0,056	0,059	0,059	0,062	0,067	0,074	0,081	0,085
8,3	0.078	0,081	0,088	0,095	0,110	0,131	0,153	0,181	0,211	0,235	0,250
8,5	0.073	0,077	0,080	0,092	0,105	0,122	0,146	0,170	0,196	0,220	0,232
8,7	0.072	0,064	0,063	0,067	0,071	0,073	0,080	0,090	0,101	0,107	0,116
8,9	0.041	0,034	0,039	0,035	0,034	0,035	0,035	0,036	0,038	0,047	0,043
Note: The normalization current is 21,7A											

4.8	**EMC and power quality** **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.					
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					

inverter <16A (ALPHA WP 8KW)

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
2	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
3	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
4	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
5	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
6	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
7	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
8	0.00 Pass	0.56 Pass	0 Pass	0.23 Pass	
9	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
10	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
11	0.00 Pass	0.56 Pass	0 Pass	0.24 Pass	
12	0.00 Pass	0.56 Pass	0 Pass	0.23 Pass	
Result	Pass	Pass	Pass	Pass	0.24 Pass

L1 phase

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
2	0.00 Pass	0.59 Pass	0 Pass	0.28 Pass	
3	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
4	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
5	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
6	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
7	0.00 Pass	0.59 Pass	0 Pass	0.28 Pass	
8	0.00 Pass	0.59 Pass	0 Pass	0.28 Pass	
9	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
10	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
11	0.00 Pass	0.59 Pass	0 Pass	0.28 Pass	
12	0.00 Pass	0.59 Pass	0 Pass	0.29 Pass	
Result	Pass	Pass	Pass	Pass	0.29 Pass

L2 phase

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
2	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
3	0.00 Pass	0.64 Pass	0 Pass	0.27 Pass	
4	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
5	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
6	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
7	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
8	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
9	0.00 Pass	0.64 Pass	0 Pass	0.28 Pass	
10	0.00 Pass	0.64 Pass	0 Pass	0.27 Pass	
11	0.00 Pass	0.64 Pass	0 Pass	0.27 Pass	
12	0.00 Pass	0.64 Pass	0 Pass	0.27 Pass	
Result	Pass	Pass	Pass	Pass	0.28 Pass

L3 phase

inverter >16A phase (ALPHA WP 15KW)

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.29 Pass	0.33 Pass	0 Pass	0.18 Pass	
2	0.27 Pass	0.33 Pass	0 Pass	0.18 Pass	
3	0.28 Pass	0.34 Pass	0 Pass	0.18 Pass	
4	0.30 Pass	0.34 Pass	0 Pass	0.19 Pass	
5	0.30 Pass	0.38 Pass	0 Pass	0.19 Pass	
6	0.27 Pass	0.33 Pass	0 Pass	0.19 Pass	
7	0.28 Pass	0.35 Pass	0 Pass	0.19 Pass	
8	0.29 Pass	0.33 Pass	0 Pass	0.19 Pass	
9	0.28 Pass	0.31 Pass	0 Pass	0.19 Pass	
10	0.28 Pass	0.33 Pass	0 Pass	0.19 Pass	
11	0.29 Pass	0.33 Pass	0 Pass	0.19 Pass	
12	0.27 Pass	0.38 Pass	0 Pass	0.19 Pass	
Result	Pass	Pass	Pass	Pass	0.19 Pass

L1 phase

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.31 Pass	0.36 Pass	0 Pass	0.14 Pass	
2	0.32 Pass	0.37 Pass	0 Pass	0.15 Pass	
3	0.30 Pass	0.37 Pass	0 Pass	0.15 Pass	
4	0.45 Pass	0.54 Pass	0 Pass	0.16 Pass	
5	0.35 Pass	0.46 Pass	0 Pass	0.17 Pass	
6	0.28 Pass	0.38 Pass	0 Pass	0.16 Pass	
7	0.26 Pass	0.38 Pass	0 Pass	0.16 Pass	
8	0.28 Pass	0.43 Pass	0 Pass	0.15 Pass	
9	0.30 Pass	0.34 Pass	0 Pass	0.15 Pass	
10	0.32 Pass	0.39 Pass	0 Pass	0.15 Pass	
11	0.28 Pass	0.34 Pass	0 Pass	0.15 Pass	
12	0.33 Pass	0.36 Pass	0 Pass	0.15 Pass	
Result	Pass	Pass	Pass	Pass	0.15 Pass

2 phase

	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.21 Pass	0.22 Pass	0 Pass	0.15 Pass	
2	0.19 Pass	0.23 Pass	0 Pass	0.15 Pass	
3	0.17 Pass	0.21 Pass	0 Pass	0.16 Pass	
4	0.20 Pass	0.24 Pass	0 Pass	0.16 Pass	
5	0.20 Pass	0.26 Pass	0 Pass	0.17 Pass	
6	0.22 Pass	0.25 Pass	0 Pass	0.17 Pass	
7	0.22 Pass	0.24 Pass	0 Pass	0.17 Pass	
8	0.25 Pass	0.28 Pass	0 Pass	0.16 Pass	
9	0.19 Pass	0.22 Pass	0 Pass	0.16 Pass	
10	0.18 Pass	0.21 Pass	0 Pass	0.16 Pass	
11	0.20 Pass	0.23 Pass	0 Pass	0.15 Pass	
12	0.18 Pass	0.22 Pass	0 Pass	0.15 Pass	
Result	Pass	Pass	Pass	Pass	0.16 Pass

L3 phase

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 had been performed on the model ALPHA WP 8KW and ALPHA WP 15KW the test results are valid for the ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

4.8	**EMC and power quality** **DC-Injection**	**P**

Test result：**ALPHA WP 8KW**				
Protection limit	**Tested at four power levels limit 0,5% of $I_{AC;nom}$ (58mA)**			
Output power	~20%	~50%	~75%	~100%
Abs. Max. Test Value: L1 [mA]	22	31	23	35
Abs. Ave. Test Value: L1 [mA]	9	14	8	13
Abs. Max. Test Value: L2 [mA]	24	22	33	35
Abs. Ave. Test Value: L2 [mA]	5	6	19	11
Abs. Max. Test Value: L3 [mA]	31	54	34	42
Abs. Ave. Test Value: L3 [mA]	15	38	31	16
Test result：**ALPHA WP 15KW**				
Protection limit	**Tested at four power levels limit 0,5% of $I_{AC;nom}$ (108mA)**			
Output power	~20%	~50%	~75%	~100%
Abs. Max. Test Value: L1 [mA]	22	34	42	76
Abs. Ave. Test Value: L1 [mA]	7	11	14	43
Abs. Max. Test Value: L2 [mA]	19	39	55	92
Abs. Ave. Test Value: L2 [mA]	5	14	21	46
Abs. Max. Test Value: L3 [mA]	54	41	61	81
Abs. Ave. Test Value: L3 [mA]	38	17	28	36

Note:

Test method and setting value refer Annex D.3.10 of EN 50438:2013.

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

The test had been performed on the model ALPHA WP 8KW and ALPHA WP 15KW the test results are valid for the ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Diagram of permanent dc-injection of ALPHA WP 8KW

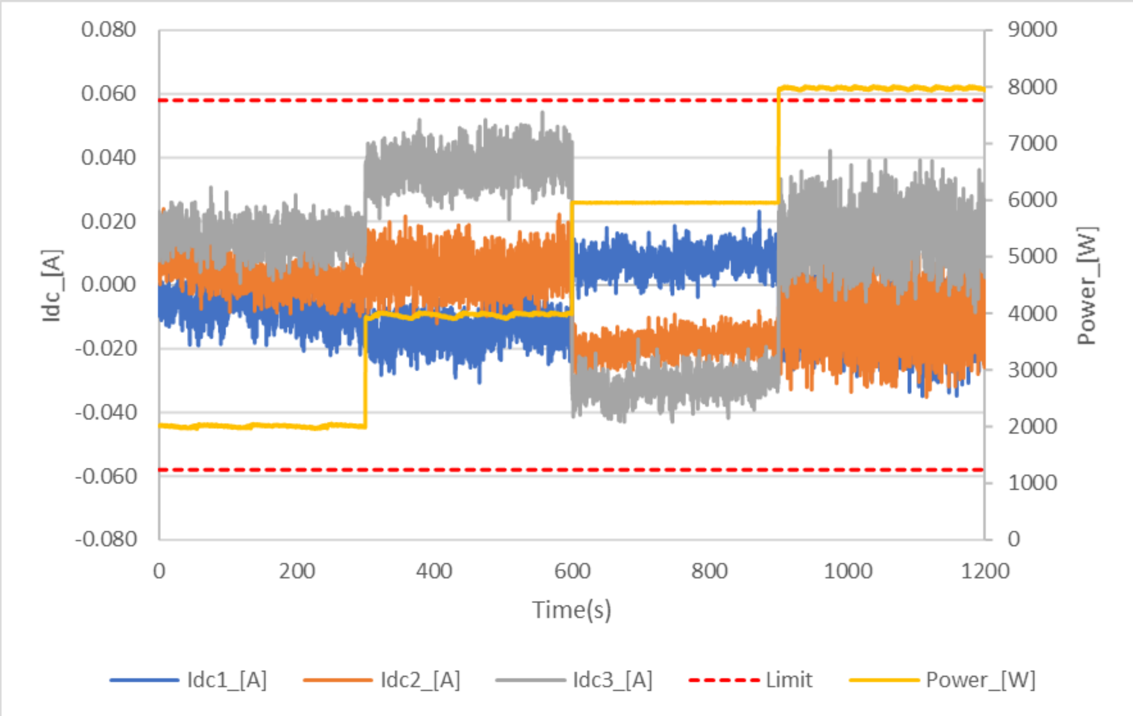
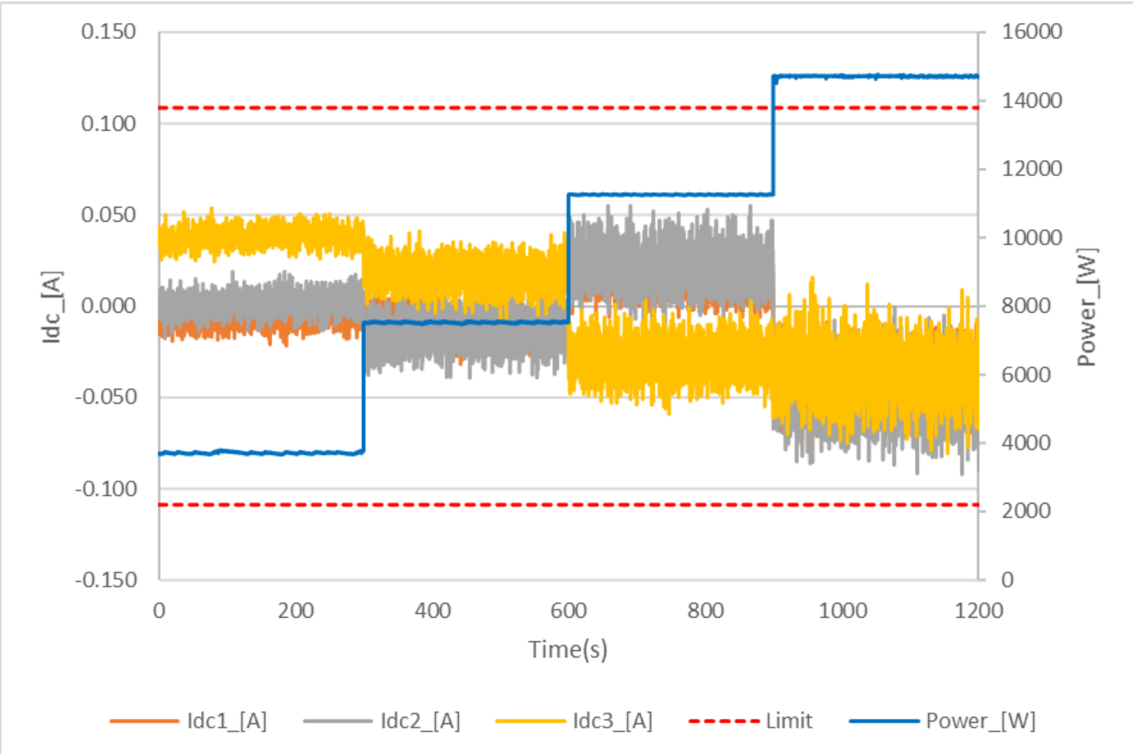


Diagram of permanent dc-injection of ALPHA WP 15KW



4.8	**EMC and power quality** **Immunity to voltage dips and short interruptions**	**P**

Test result：**ALPHA WP 15KW**					
For a directly coupled SSEG			For a Inverter SSEG		
Phase L1					
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	I_p	N/A	20ms	29,8 V	2,27 A
Initial Value of aperiodic current	A	N/A	100ms	29,9 V	1,17 A
Initial symmetrical short-circuit current*	I_k	N/A	250ms	29,9 V	0,92 A
Decaying (aperiodic) component of short circuit current*	i_{DC}	N/A	500ms	29,9 V	0,71 A
Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	0,875s	In seconds
Phase L2					
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	I_p	N/A	20ms	44,8	9,32
Initial Value of aperiodic current	A	N/A	100ms	29,9	2,05
Initial symmetrical short-circuit current*	I_k	N/A	250ms	29,9	1,35
Decaying (aperiodic) component of short circuit current*	i_{DC}	N/A	500ms	29,9	1,02
Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	0,930	In seconds
Phase L3					
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	I_p	N/A	20ms	37.5	6,01
Initial Value of aperiodic current	A	N/A	100ms	31,6	2,71
Initial symmetrical short-circuit current*	I_k	N/A	250ms	30,1	1,60
Decaying (aperiodic) component of short circuit current*	i_{DC}	N/A	500ms	30,0	1,17

Reactance/Resistance Ratio of source*	X/R	N/A	Time to trip	0,898	In seconds

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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Diagram

4.8	**EMC and power quality** **Unbalance**	**P**

Test result：**ALPHA WP 15KW**

P [%P_{max}]	P* [kW]	U_{1+}* [V]	U_{1-}* [V]	I_{1+}* [A]	I_{1-}* [A]	u_i* [% I_{1+}]	$u_{i\ abs}$* [% I_n]	Number of data sets
0 - 5	0,524	398,24	0,12	0,760	0,095	12,500	0,437	3
10	1,543	398,24	0,14	2,237	0,109	4,873	0,501	3
20	3,052	398,26	0,13	4,424	0,146	3,300	0,672	3
30	4,447	398,28	0,13	6,446	0,176	2,730	0,810	3
40	5,986	398,25	0,17	8,678	0,232	2,673	1,067	3
50	7,523	398,29	0,16	10,905	0,257	2,357	1,182	3
60	9,049	398,29	0,16	13,117	0,304	2,318	1,398	3
70	10,566	398,30	0,15	15,316	0,309	2,017	1,421	3
80	12,078	398,35	0,15	17,505	0,342	1,954	1,573	3
90	13,584	398,36	0,15	19,687	0,362	1,839	1,665	3
100	15,080	398,40	0,15	21,854	0,377	1,725	1,734	3
max	--	--	--	--	--	--	--	3

Maximum unsymmetry u_{imax} (≥10%Pn)	3,300

Note:

*1 min-average values of positive and negative sequence data.

The unsymmetry is calculated according to following equation:

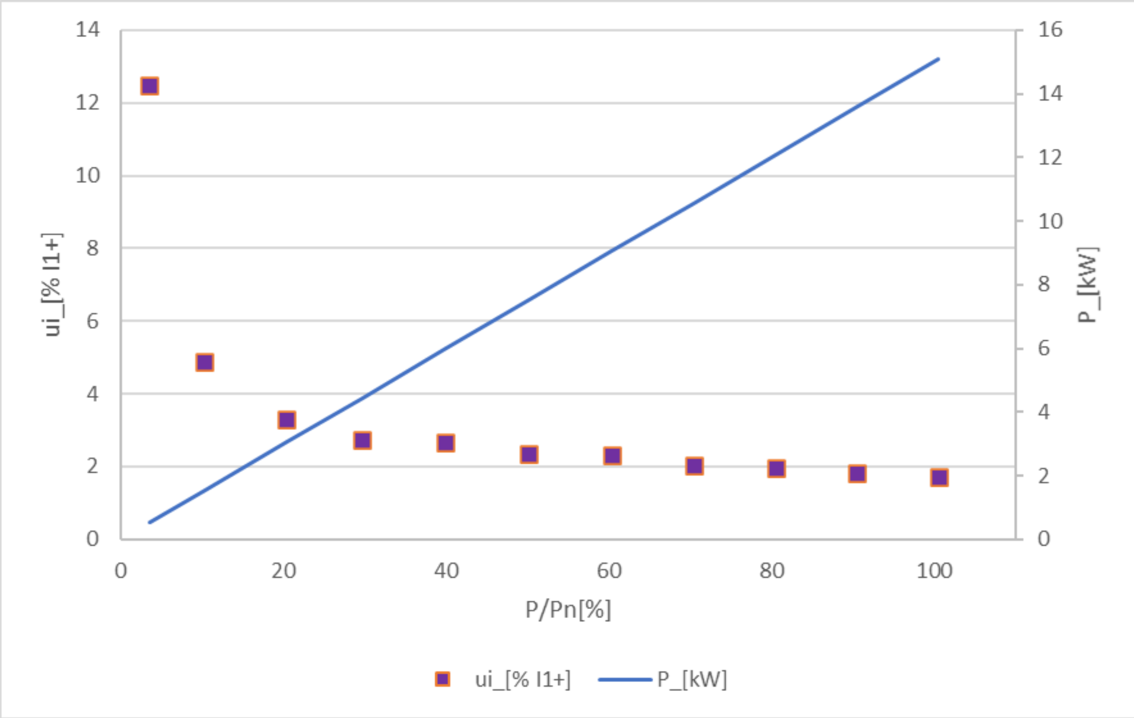
$$u_i = \frac{I_{1-}}{I_{1+}} \cdot 100\%$$

Additionally the unsymmetry is calculated relative to nominal current according to following equation:

$$u_{iabs} = \frac{I_{1-}}{I_n} \cdot 100\%$$

The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Diagram



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**

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: 12000W Frequency: 50Hz				
L1					
First Level					
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]	
194,8	230 to 193,2	< 195,5	1,310	1,2s ≤ t ≤ 1,5s	
194,7	230 to 193,2		1,315		
194,7	230 to 193,2		1,310		
194,7	230 to 193,2		1,315		
194,8	230 to 193,2		1,310		
253,8	230 to 255,3	> 253,0	0,148	≤3,0s	
253,8	230 to 255,3		0,139		
253,9	230 to 255,3		0,148		
253,8	230 to 255,3		0,139		
253,8	230 to 255,3		0,148		
Second Level					
263,9	230 to 266,8	> 264,5	0,138	0,1s ≤ t ≤ 0,2s	
264,4	230 to 266,8		0,137		
264,1	230 to 266,8		0,139		
264,1	230 to 266,8		0,146		
264,0	230 to 266,8		0,137		

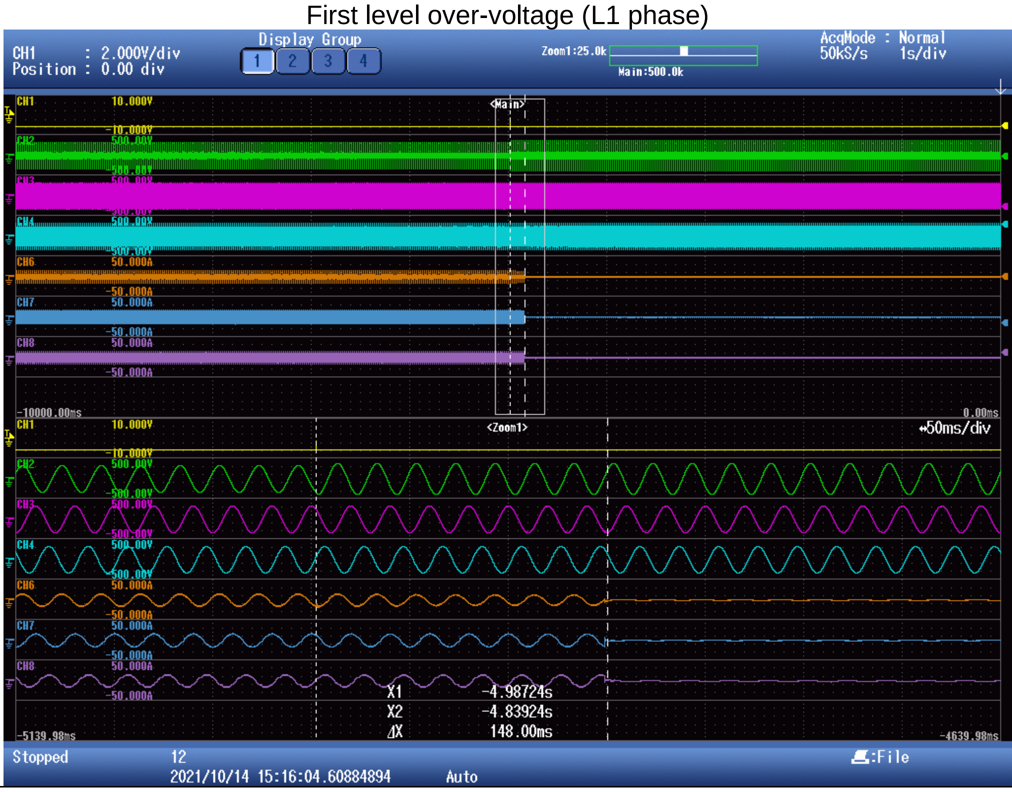
Note:

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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Scope pictures of the disconnection time
First level under-voltage (L1 phase)

First level over-voltage (L1 phase)

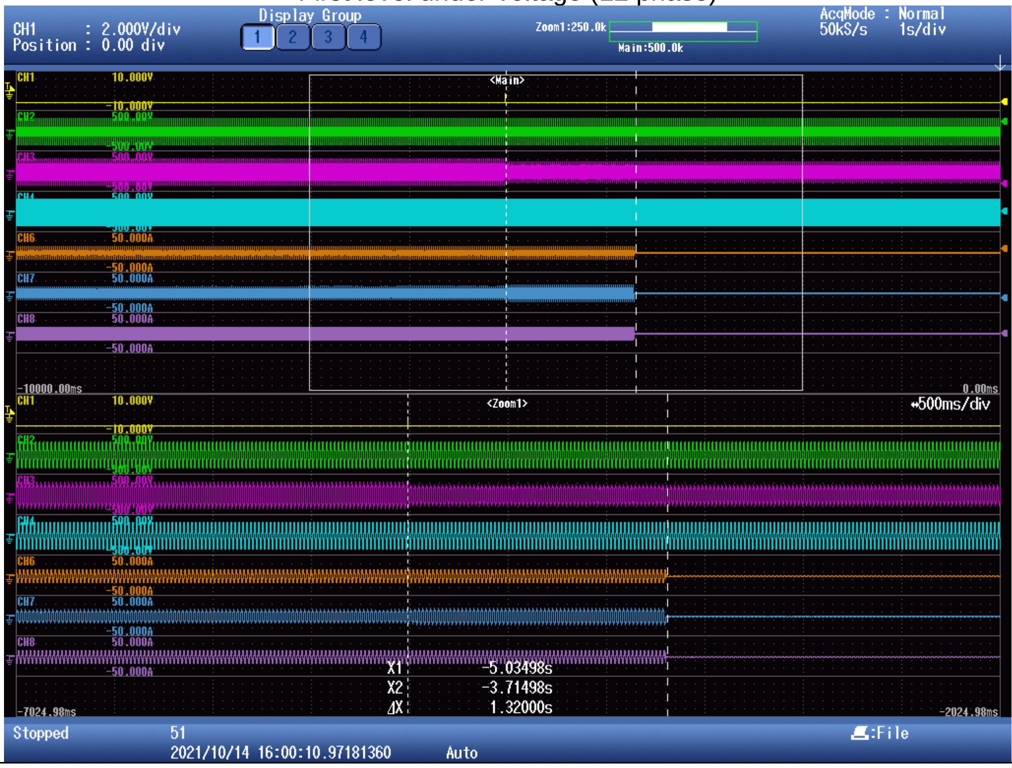


Second level over-voltage (L1 phase)

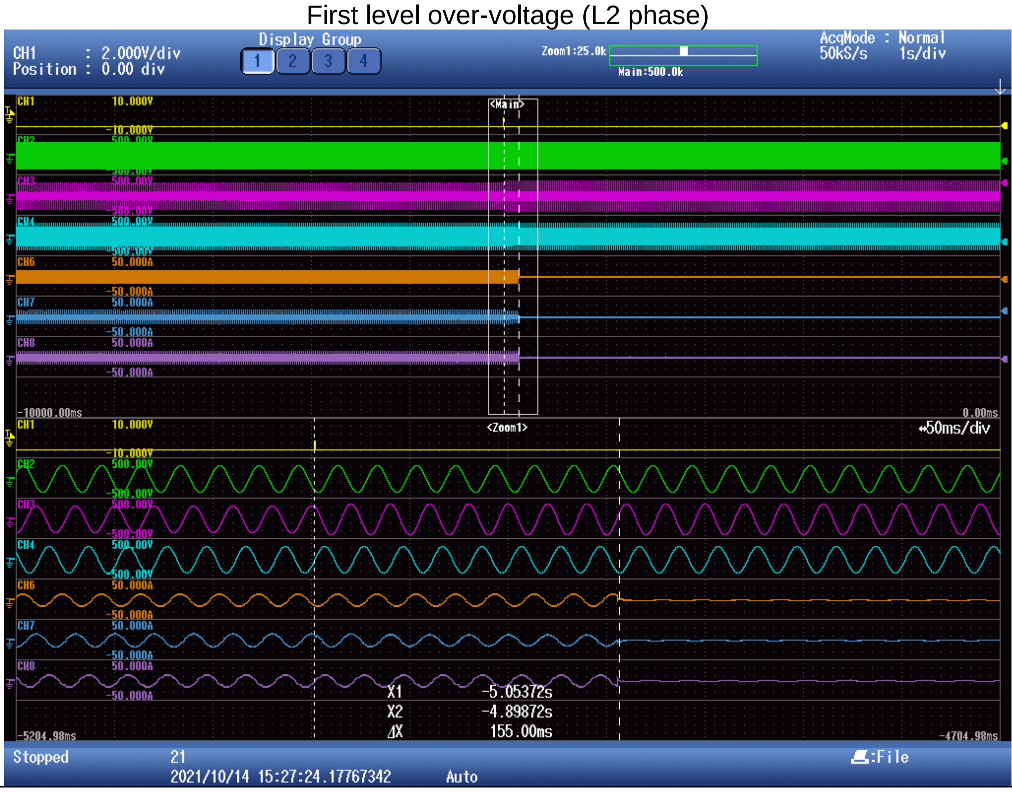
L2				
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
194,3	230 to 193,2	< 195,5	1,320	1,2s ≤ t ≤ 1,5s
194,2	230 to 193,2		1,310	
194,2	230 to 193,2		1,315	
194,3	230 to 193,		1,305	
194,3	230 to 193,2		1,320	
253,2	230 to 255,3	> 253,0	0,143	≤3,0s
253,2	230 to 255,3		0,138	
253,2	230 to 255,3		0,154	
253,3	230 to 255,3		0,145	
253,2	230 to 255,3		0,155	
Second Level				
263,8	230 to 266,8	> 264,5	0,153	0,1s ≤ t ≤ 0,2s
264,8	230 to 266,8		0,142	
264,8	230 to 266,8		0,151	
264,8	230 to 266,8		0,144	
264,9	230 to 266,8		0,143	

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

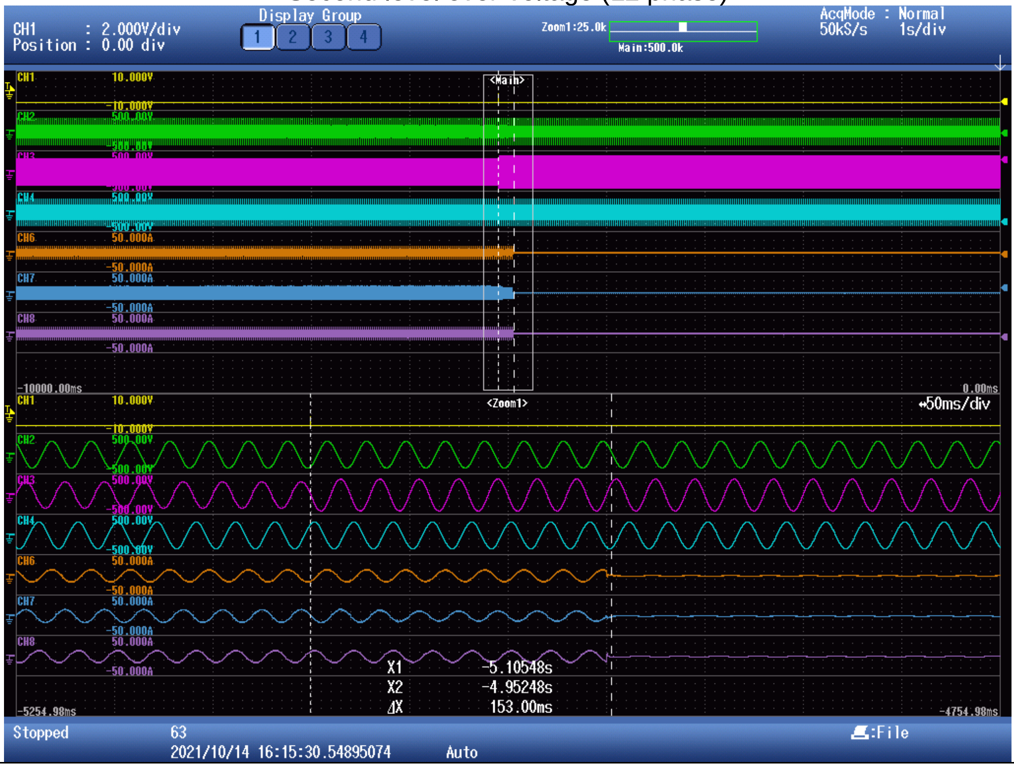
Scope pictures of the disconnection time
First level under-voltage (L2 phase)



First level over-voltage (L2 phase)

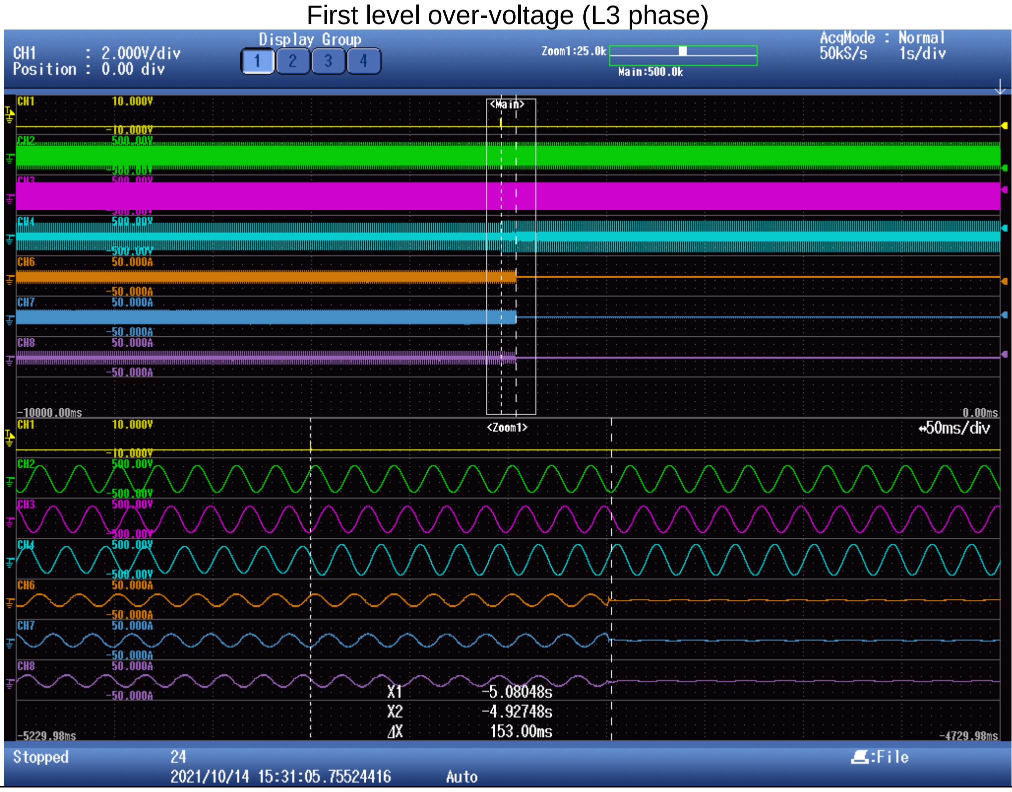


Second level over-voltage (L2 phase)



L3				
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
195,0	230 to 193,2	< 195,5	1,310	1,2s ≤ t ≤ 1,5s
194,9	230 to 193,2		1,315	
194,9	230 to 193,2		1,310	
195,0	230 to 193,2		1,315	
195,0	230 to 193,2		1,310	
254,3	230 to 255,3	> 253,0	0,140	≤3,0s
254,2	230 to 255,3		0,152	
254,3	230 to 255,3		0,153	
254,2	230 to 255,3		0,141	
254,3	230 to 255,3		0,138	
Second Level				
263,9	230 to 266,8	> 264,5	0,150	0,1s ≤ t ≤ 0,2s
264,4	230 to 266,8		0,139	
264,1	230 to 266,8		0,146	
264,1	230 to 266,8		0,138	
264,0	230 to 266,8		0,140	

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

Scope pictures of the disconnection time
First level under-voltage (L3 phase) 
First level over-voltage (L3 phase) 

Second level over-voltage (L3 phase)

4.9.3 4.9.3.1	**Requirements on voltage and frequency protection** **General (Interface protection: Over/under voltage)** **(Setting value refer Czech Republic (PPDS:2020) for default settings)** **Protections of plants with phase currents up to 16 A**	**P**
Test conditions:	Output power: 7,5kW Frequency: 50Hz	

Assessment criteria:

The following table applies to the protection of plants with phase currents up to 16 A (plants up to 800 W and plants with VM A1) operated in parallel with the LV distribution network to which it applies.

Parameter	Maximum switch-off time [s]	Off settings
Overvoltage (First level)	3	230V + 10%
Overvoltage (Second level)	1	230 + 15%
Overvoltage (Three level)	0,1	230V + 20%
undervoltage	1,5	230 - 15%
Over-frequency	0,5	52 Hz
underfrequency	0,5	47,5 Hz

Protections of plants with phase currents up to 16 A

L1

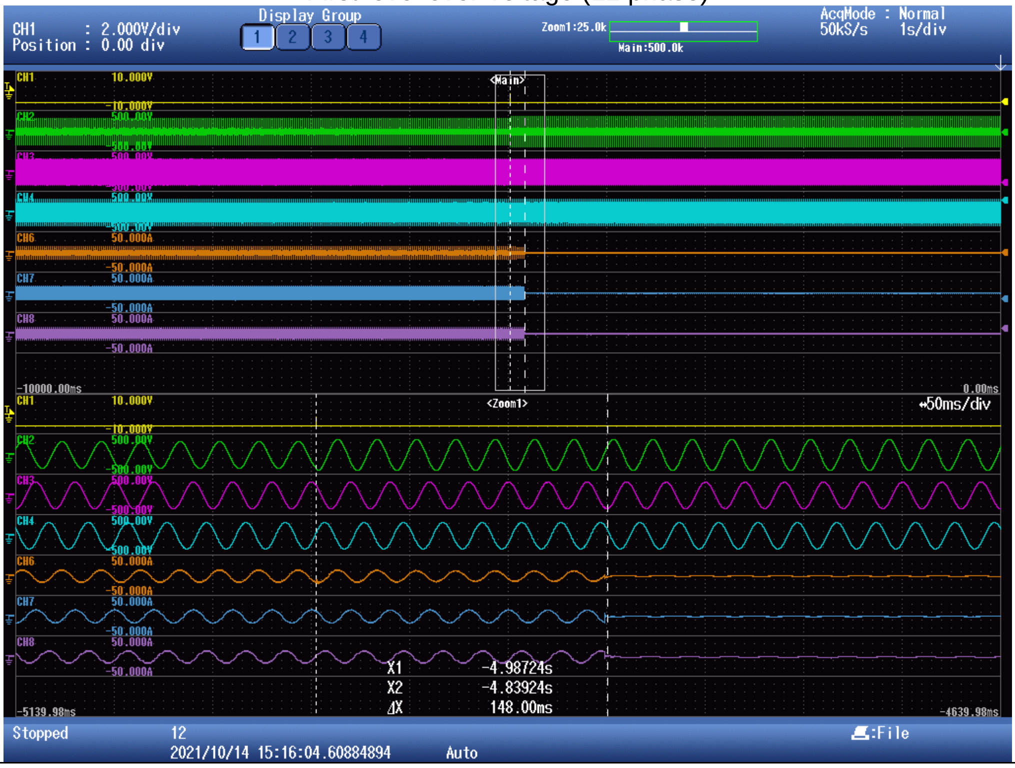
First Level

Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
194,8	230 to 193,2	< 195,5	1,310	≤ 1,5s
194,7	230 to 193,2		1,315	
194,7	230 to 193,2		1,310	
194,7	230 to 193,2		1,315	
194,8	230 to 193,2		1,310	
253,8	230 to 255,3	> 253,0	0,148	≤3,0s
253,8	230 to 255,3		0,139	
253,9	230 to 255,3		0,148	
253,8	230 to 255,3		0,139	
253,8	230 to 255,3		0,148	

Second Level				
263,9	230 to 266,8		0,138	
264,4	230 to 266,8		0,137	
264,1	230 to 266,8	> 264,5	0,139	≤ 1,0s
264,1	230 to 266,8		0,146	
264,0	230 to 266,8		0,137	
Three Level				
276,2	230 to 278		0,060	
276,2	230 to 278		0,069	
276,2	230 to 278	> 276,0	0,068	≤0,1s
276,2	230 to 278		0,067	
276,3	230 to 278		0,059	

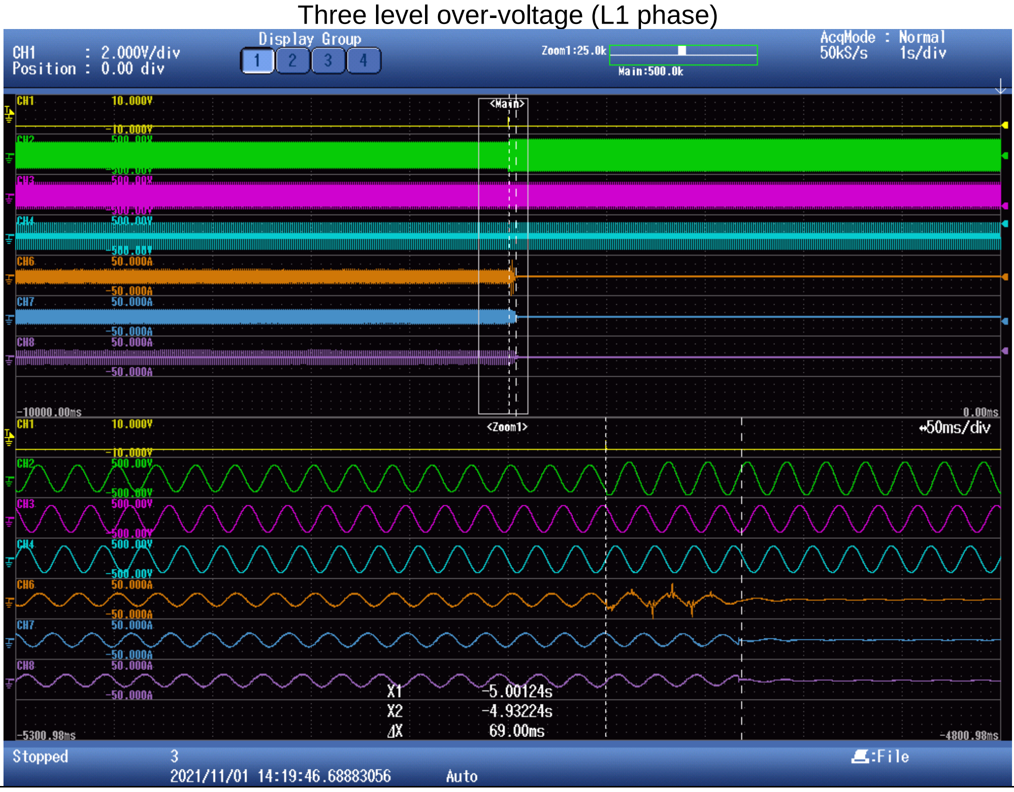
Note:
The trip values were evaluated by varying the applied voltage from U_n down to U_{th-low} - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th-high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing, Lower and upper threshold voltage shall not 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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Scope pictures of the disconnection time
First level under-voltage (L1 phase) 
First level over-voltage (L1 phase) 

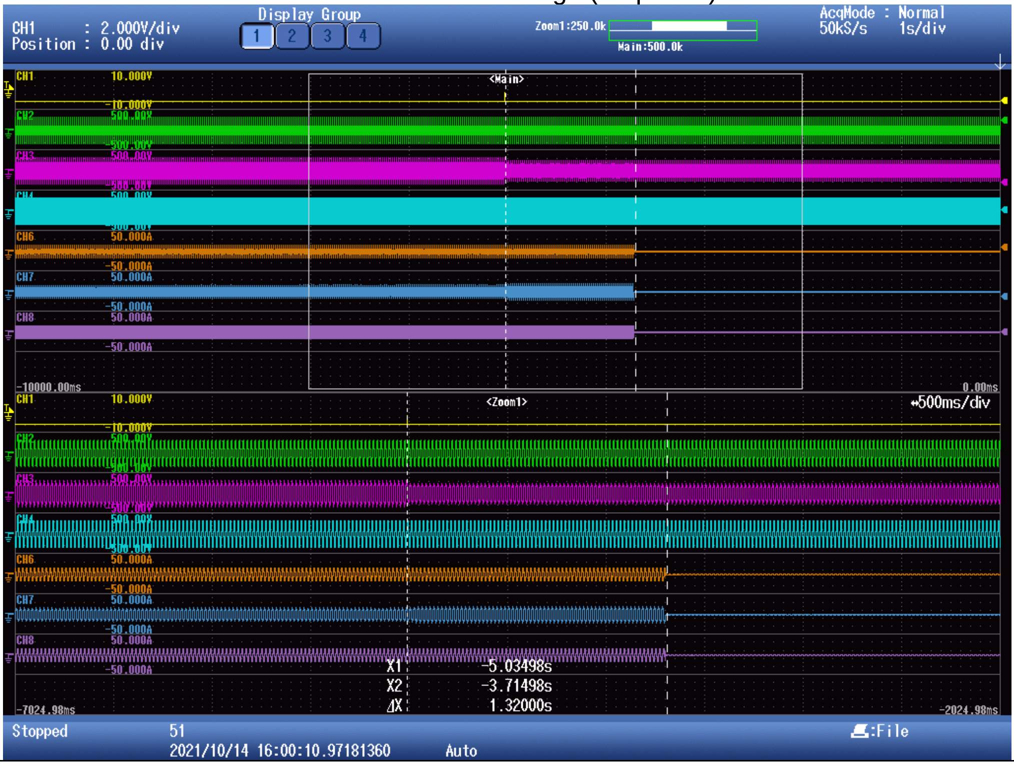
Second level over-voltage (L1 phase)

Three level over-voltage (L1 phase)

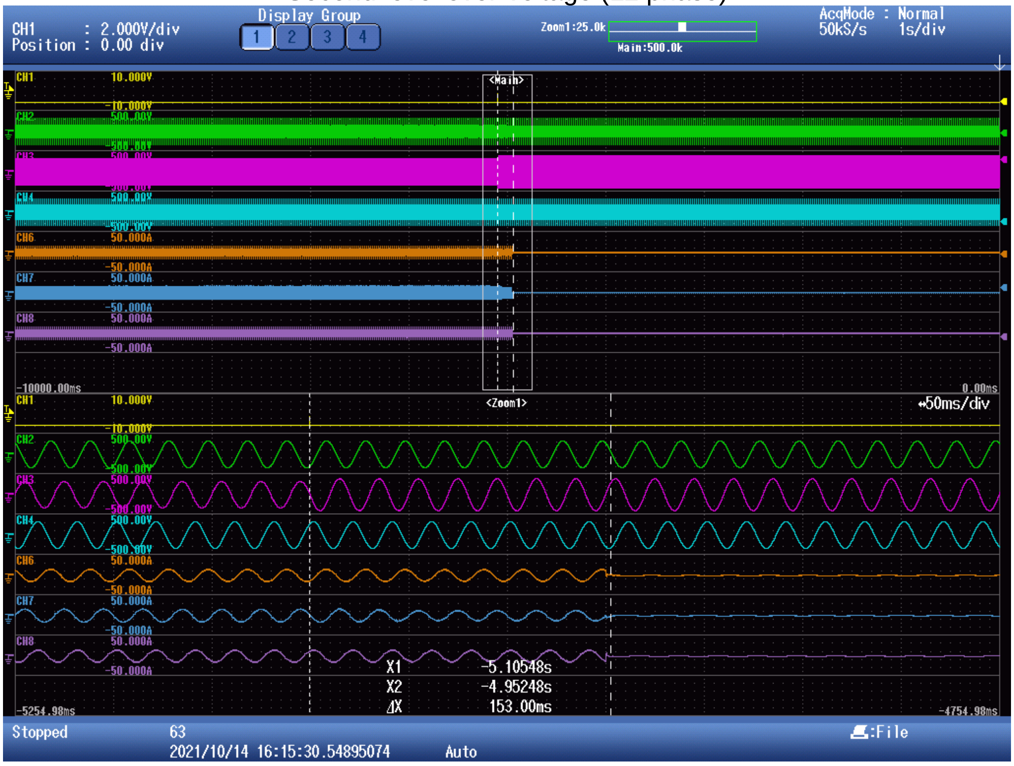


L2				
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
194,3	230 to 193,2	< 195,5	1,320	1,2s ≤ t ≤ 1,5s
194,2	230 to 193,2		1,310	
194,2	230 to 193,2		1,315	
194,3	230 to 193,		1,305	
194,3	230 to 193,2		1,320	
253,2	230 to 255,3	> 253,0	0,143	≤3,0s
253,2	230 to 255,3		0,138	
253,2	230 to 255,3		0,154	
253,3	230 to 255,3		0,145	
253,2	230 to 255,3		0,155	
Second Level				
263,8	230 to 266,8	> 264,5	0,153	0,1s ≤ t ≤ 0,2s
264,8	230 to 266,8		0,142	
264,8	230 to 266,8		0,151	
264,8	230 to 266,8		0,144	
264,9	230 to 266,8		0,143	
Three level				
276,1	230 to 278	> 276,0	0,064	≤0,1s
276,1	230 to 278		0,057	
276,1	230 to 278		0,066	
276,1	230 to 278		0,066	
276,1	230 to 278		0,065	

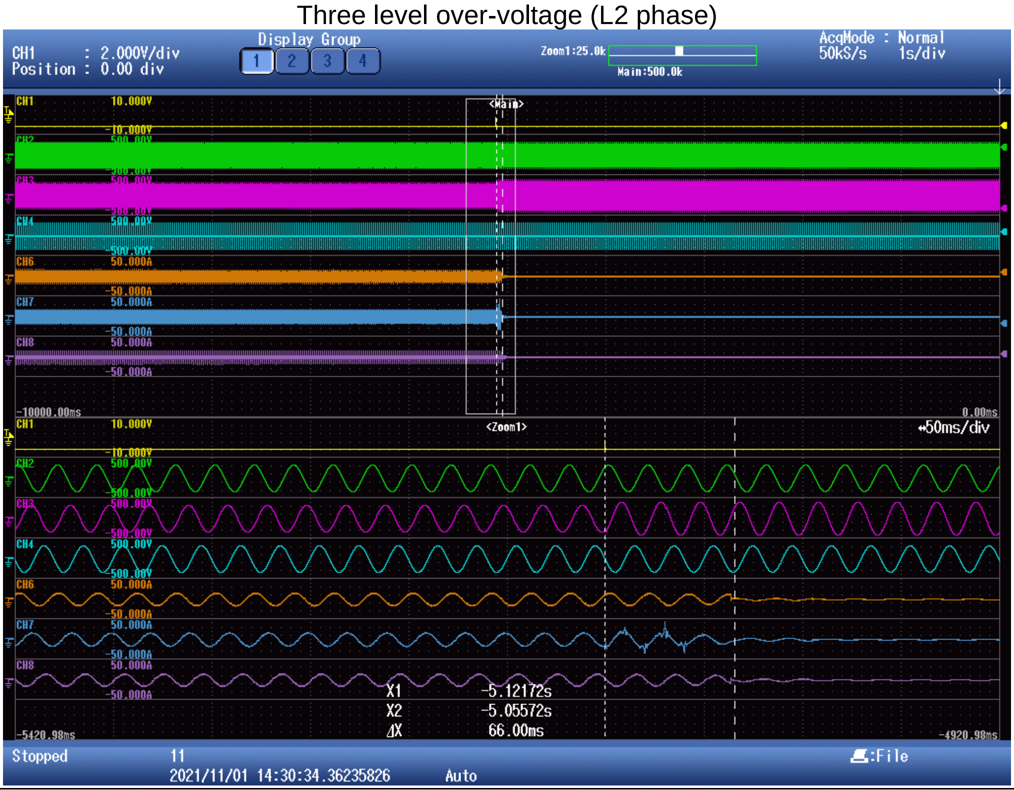
Note:
The trip values were evaluated by varying the applied voltage from U_n down to $U_{th\text{-}low}$ - 2% of U_n in steps of 0,5% of U_n for under-voltage testing as well as from U_n up to $U_{th\text{-}high}$ + 2% of U_n in steps of 0,5% of U_n for over-voltage testing, Lower and upper threshold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

Scope pictures of the disconnection time
First level under-voltage (L2 phase) 
First level over-voltage (L2 phase) 

Second level over-voltage (L2 phase)

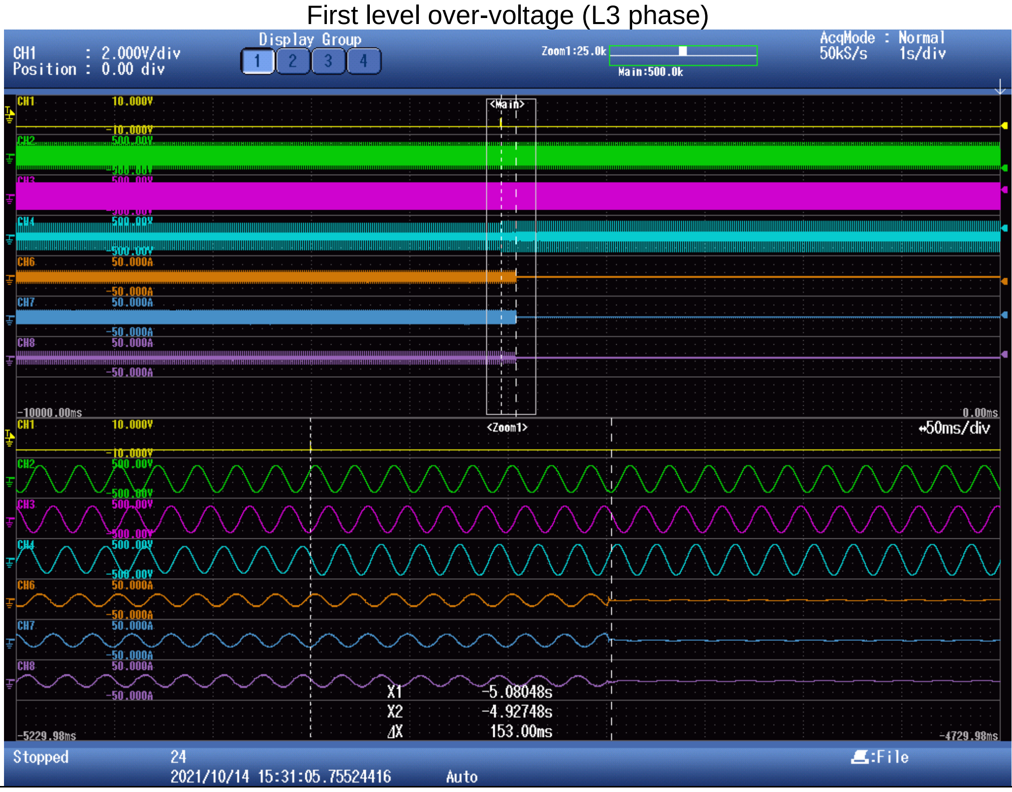


Three level over-voltage (L2 phase)



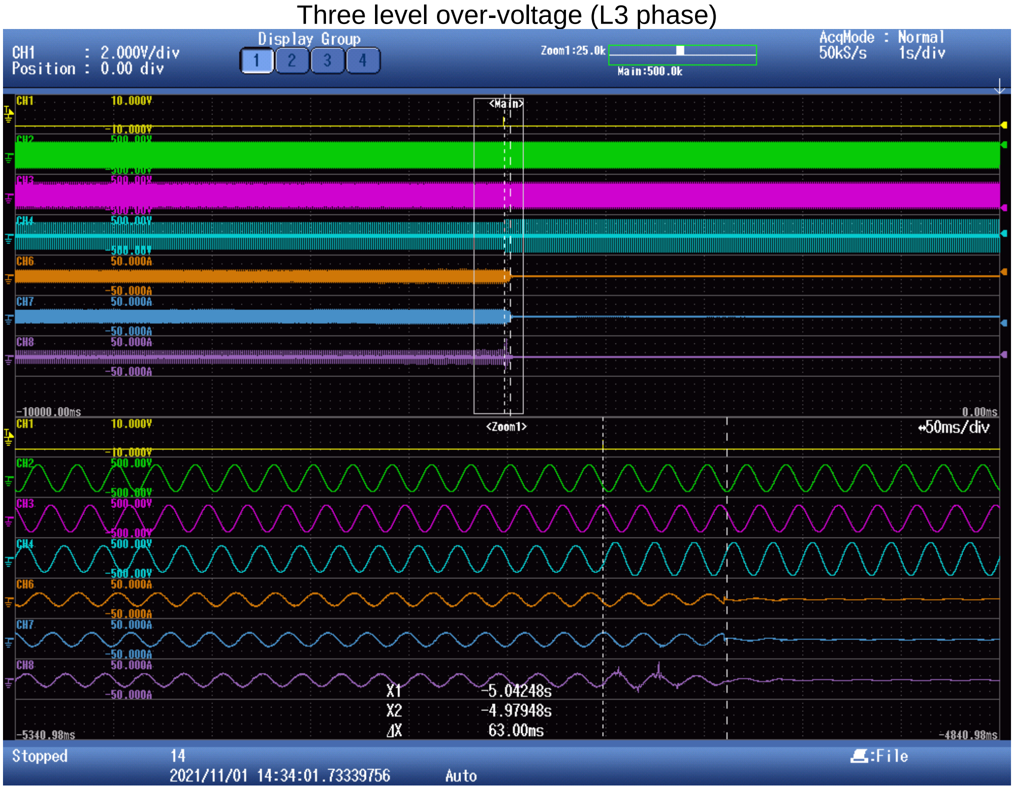
L3				
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
195,0	230 to 193,2	< 195,5	1,310	1,2s ≤ t ≤ 1,5s
194,9	230 to 193,2		1,315	
194,9	230 to 193,2		1,310	
195,0	230 to 193,2		1,315	
195,0	230 to 193,2		1,310	
254,3	230 to 255,3	> 253,0	0,140	≤3,0s
254,2	230 to 255,3		0,152	
254,3	230 to 255,3		0,153	
254,2	230 to 255,3		0,141	
254,3	230 to 255,3		0,138	
Second Level				
263,9	230 to 266,8	> 264,5	0,150	0,1s ≤ t ≤ 0,2s
264,4	230 to 266,8		0,139	
264,1	230 to 266,8		0,146	
264,1	230 to 266,8		0,138	
264,0	230 to 266,8		0,140	
Three Level				
276,2	230 to 278	> 276,0	0,062	≤0,1s
276,1	230 to 278		0,063	
276,2	230 to 278		0,053	
276,2	230 to 278		0,058	
276,2	230 to 278		0,054	

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

Scope pictures of the disconnection time
First level under-voltage (L3 phase) 
First level over-voltage (L3 phase) 

Second level over-voltage (L3 phase)

Three level over-voltage (L3 phase)



4.9.3 4.9.3.1	**Requirements on voltage and frequency protection** **General (Interface protection: Over/under voltage)** **(Setting value refer Czech Republic (PPDS:2020) for default settings)** **ELECTRICITY GENERATIONS WITH PHASE CURRENT OVER 16 A IN LV NETWORKS AND PRODUCTS CONNECTED TO MV NETWORKS AND 110 KV (VM A2, B1, B2, C, D)**	**P**

Test conditions:	Output power: 7,5kW Frequency: 50Hz			
		L1		
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
161,1	230 to 158,7	< 161,0	1,328	≤2,7s
161,2	230 to 158,7		1,325	
161,1	230 to 158,7		1,330	
161,2	230 to 158,7		1,335	
161,1	230 to 158,7		1,330	
265,1	230 to 266,8	> 264,5	0,138	≤60,0s
265,0	230 to 266,8		0,139	
265,0	230 to 266,8		0,137	
265,1	230 to 266,8		0,146	
265,1	230 to 266,8		0,137	
Second Level				
103,8	230 to 266,8	< 103,5	0,207	0,15s ≤ t
103,7	230 to 266,8		0,208	
103,9	230 to 266,8		0,217	
103,8	230 to 266,8		0,206	
103,8	230 to 266,8		0,205	
276,2	230 to 278	> 276,0	0,060	≤ 5,0s
276,2	230 to 278		0,069	
276,2	230 to 278		0,068	
276,2	230 to 278		0,067	
276,3	230 to 278		0,059	
Three Level				
287,5	230 to 289,7	> 287,5	0,058	≤0,1s
287,6	230 to 289,7		0,067	

287,5	230 to 289,7		0,057	
287,6	230 to 289,7		0,066	
287,5	230 to 289,7		0,065	

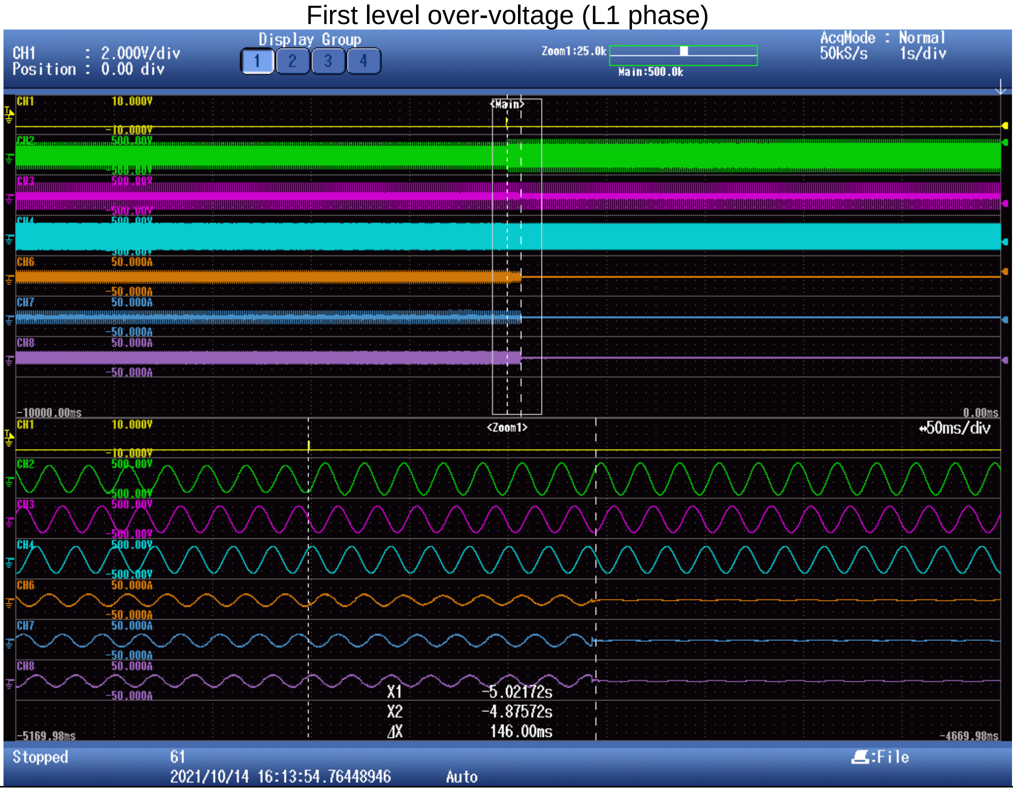
Note:

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

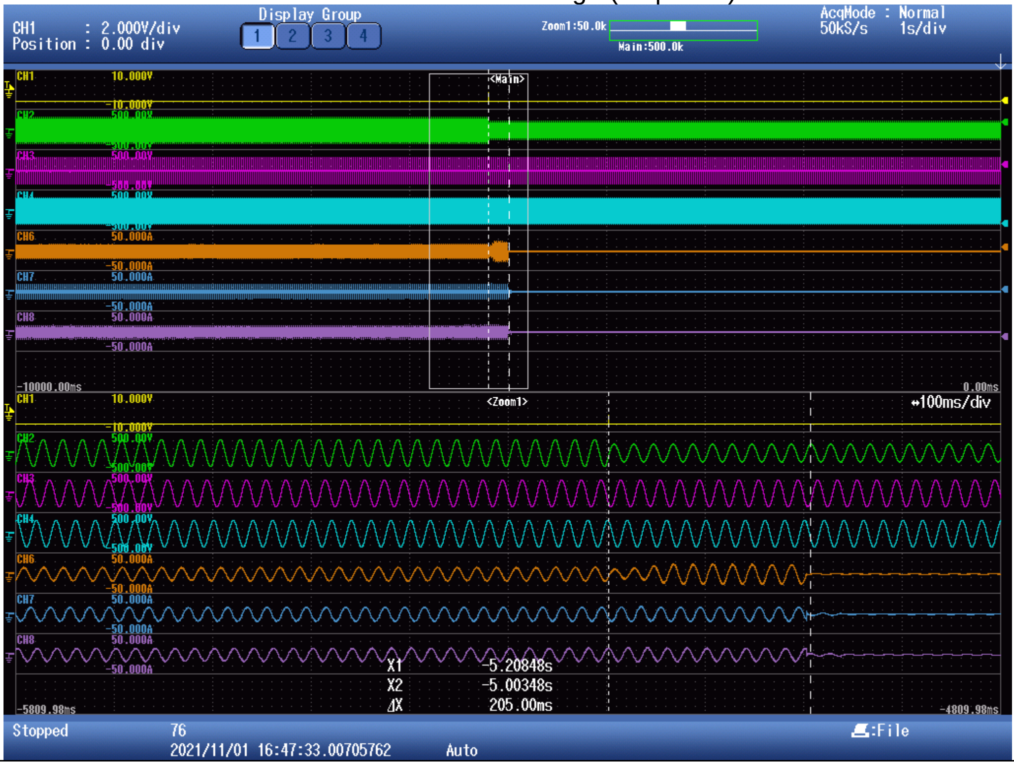
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Scope pictures of the disconnection time
First level under-voltage (L1 phase)

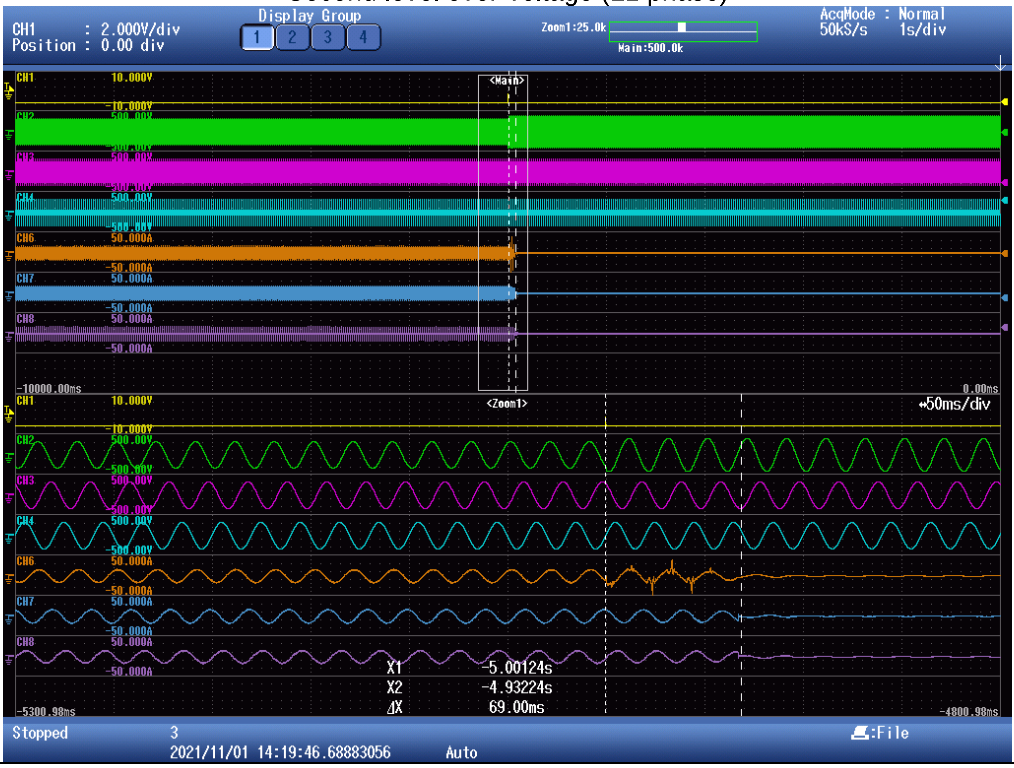
First level over-voltage (L1 phase)



Second level under-voltage (L1 phase)



Second level over-voltage (L1 phase)



Three level over-voltage (L1 phase)

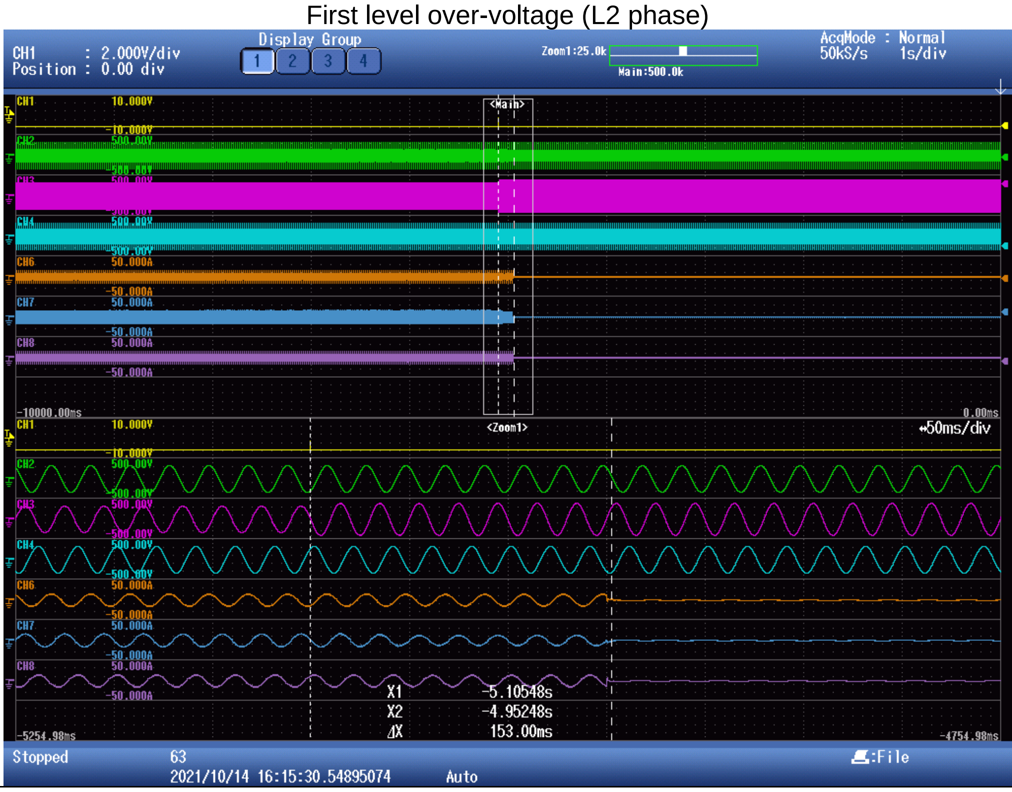
L2				
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
160,9	230 to 158,7	< 161,0	1,325	≤2,7s
161,0	230 to 158,7		1,330	
160,9	230 to 158,7		1,320	
160,9	230 to 158,7		1,325	
161,0	230 to 158,7		1,325	
264,8	230 to 266,8	> 264,5	0,153	≤60,0s
264,8	230 to 266,8		0,151	
264,8	230 to 266,8		0,142	
264,8	230 to 266,8		0,143	
264,9	230 to 266,8		0,144	
Second Level				
103,6	230 to 101,2	< 103,5	0,215	0,15s ≤ t
103,7	230 to 101,2		0,206	
103,6	230 to 101,2		0,200	
103,7	230 to 101,2		0,211	
103,6	230 to 101,2		0,203	
276,1	230 to 278	> 276,0	0,064	≤ 5,0s
276,1	230 to 278		0,057	
276,1	230 to 278		0,066	
276,1	230 to 278		0,066	
276,1	230 to 278		0,065	
Three Level				
287,5	230 to 289,7	> 287,5	0,064	≤0,1s
287,6	230 to 289,7		0,062	
287,5	230 to 289,7		0,062	
287,6	230 to 289,7		0,062	
287,5	230 to 289,7		0,053	

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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

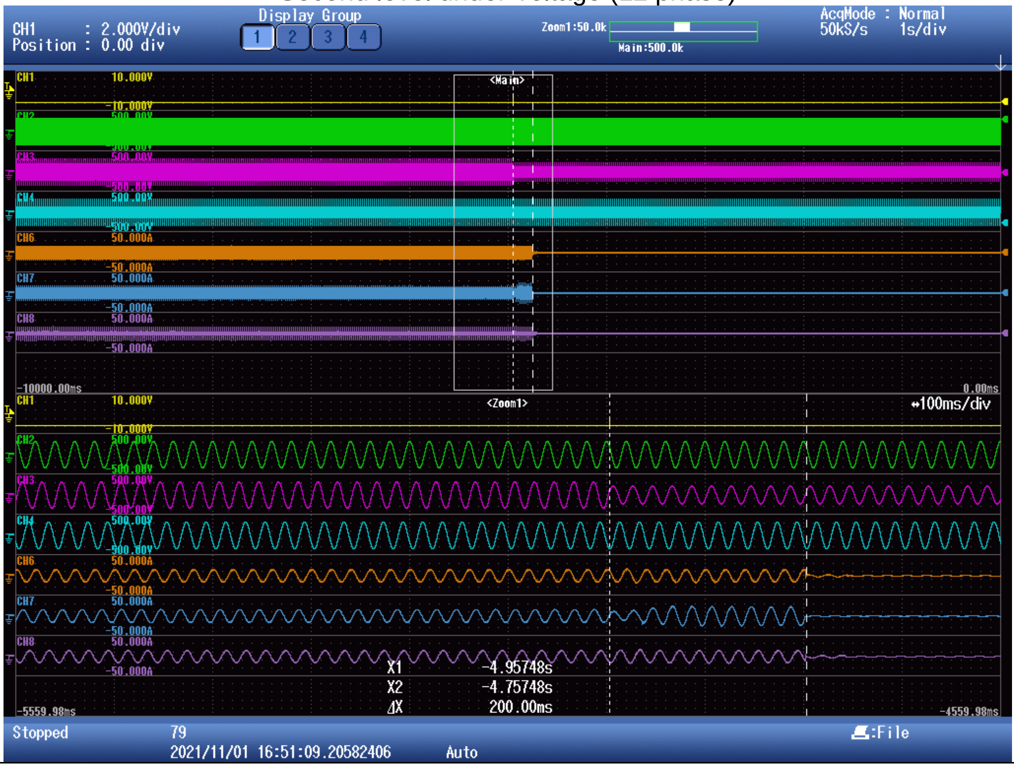
Scope pictures of the disconnection time

First level under-voltage (L2 phase)

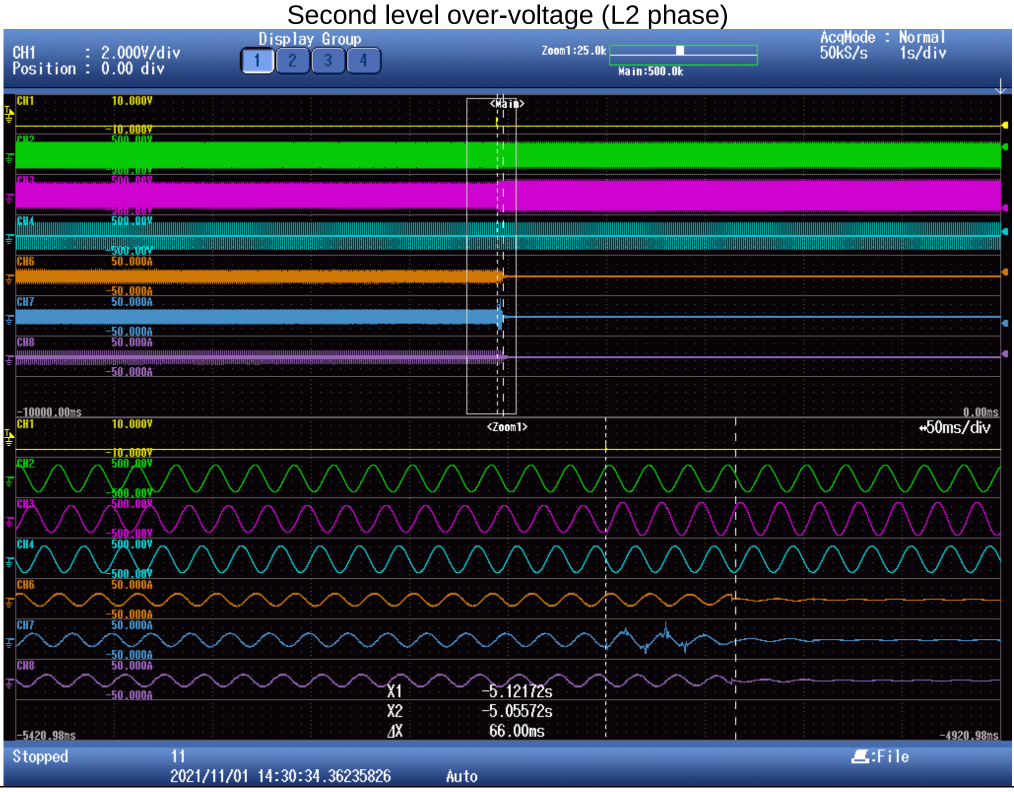
First level over-voltage (L2 phase)



Second level under-voltage (L2 phase)



Second level over-voltage (L2 phase)



Three level over-voltage (L2 phase)

L3				
First Level				
Trip value [V]	Voltage step [V]	Limit [V]	Disconnection time [s]	Limit [s]
161,1	230 to 158,7	< 161,0	1,330	≤2,7s
161,0	230 to 158,7		1,315	
161,1	230 to 158,7		1,330	
161,2	230 to 158,7		1,315	
161,1	230 to 158,7		1,325	
265,2	230 to 266,8	> 264,5	0,150	≤60,0s
265,1	230 to 266,8		0,139	
265,2	230 to 266,8		0,146	
265,2	230 to 266,8		0,138	
265,2	230 to 266,8		0,140	
Second Level				
104,1	230 to 101,2	< 103,5	0,213	0,15s ≤ t
104,1	230 to 101,2		0,212	
104,2	230 to 101,2		0,211	
104,2	230 to 101,2		0,209	
104,2	230 to 101,2		0,210	
276,2	230 to 278	> 276,0	0,062	≤ 5,0s
276,1	230 to 278		0,063	
276,2	230 to 278		0,053	
276,2	230 to 278		0,058	
276,2	230 to 278		0,054	
Three Level				
287,4	230 to 289,7	> 287,5	0,050	≤0,1s
287,4	230 to 289,7		0,060	
287,4	230 to 289,7		0,059	
287,5	230 to 289,7		0,058	
287,4	230 to 289,7		0,068	

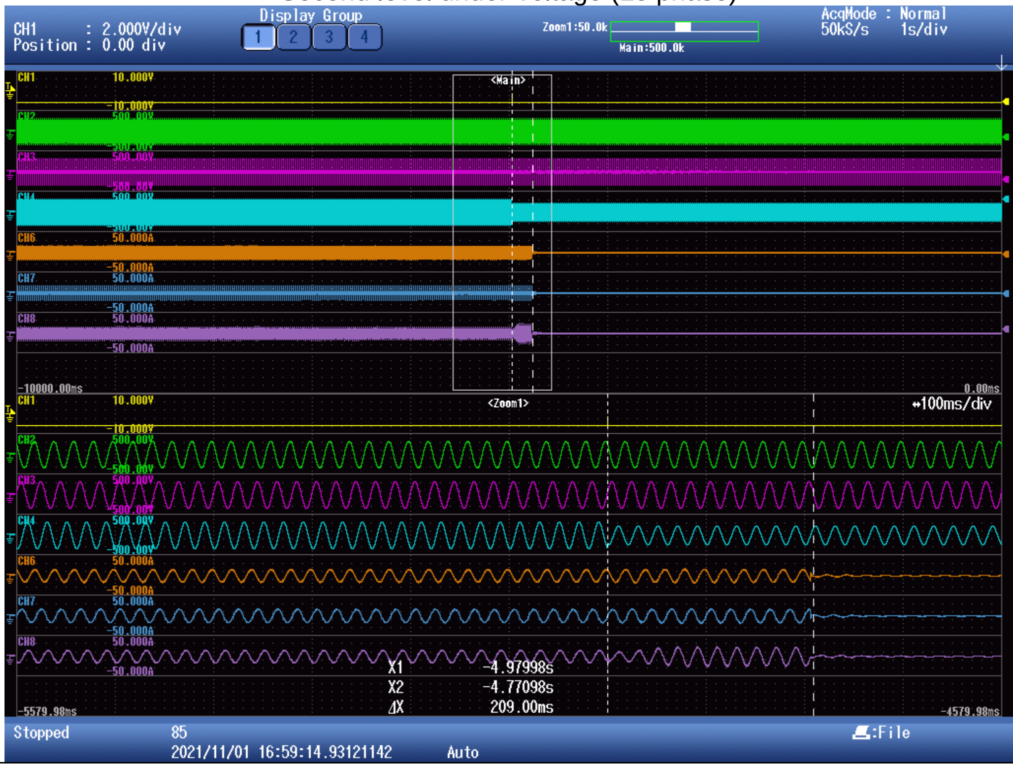
Note:

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

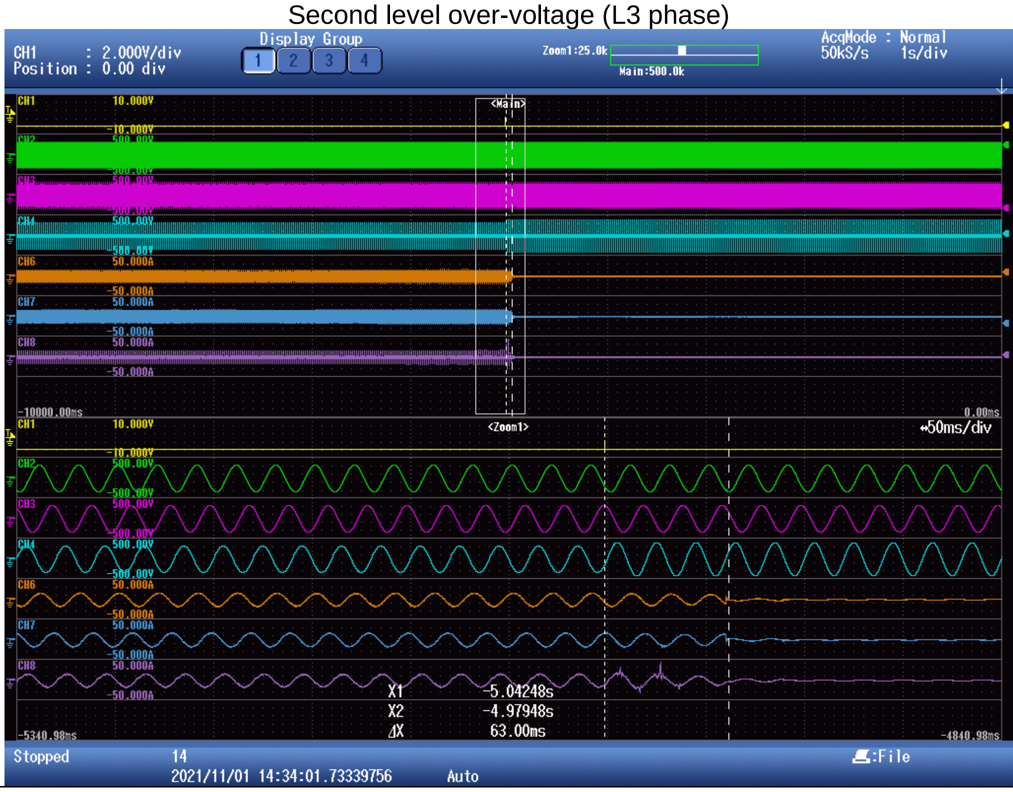
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Scope pictures of the disconnection time
First level under-voltage (L3 phase) 
First level over-voltage (L3 phase) 

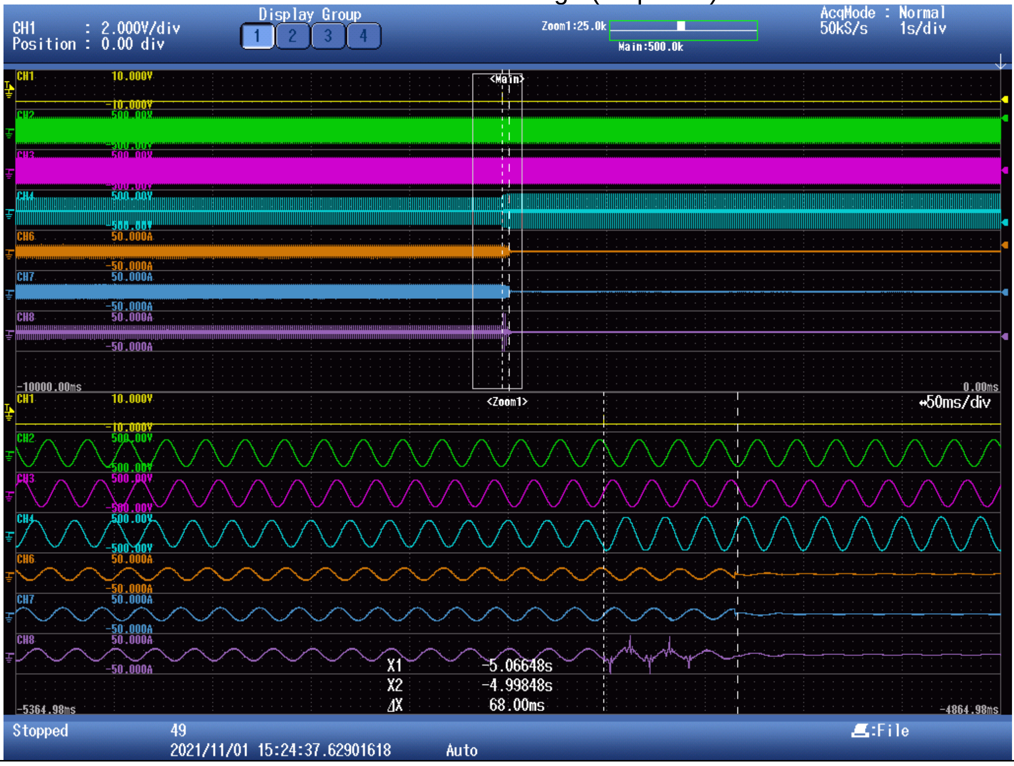
Second level under-voltage (L3 phase)



Second level over-voltage (L3 phase)



Three level over-voltage (L3 phase)



4.9.3 **4.9.3.1**	**Requirements on voltage and frequency protection** **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:	Limit:
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:	517	≤ 600 s
	Phase 2:	506	
	Phase 3:	523	
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:	321	The disconnection time should be about 50 % of the value measured in a). *
	Phase 2:	297	
	Phase 3:	334	

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:

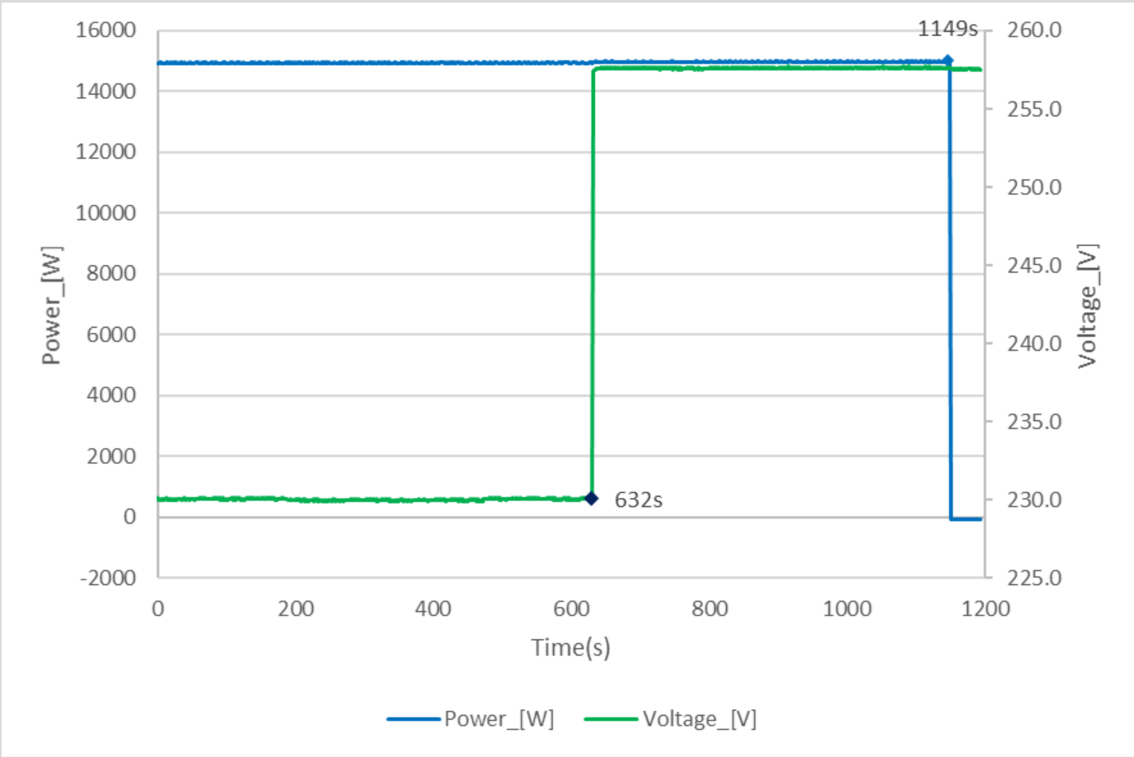
Rise-in voltage protection 1,1 U_N after a max. 600 s, the switch off after 200 ms.

Note:

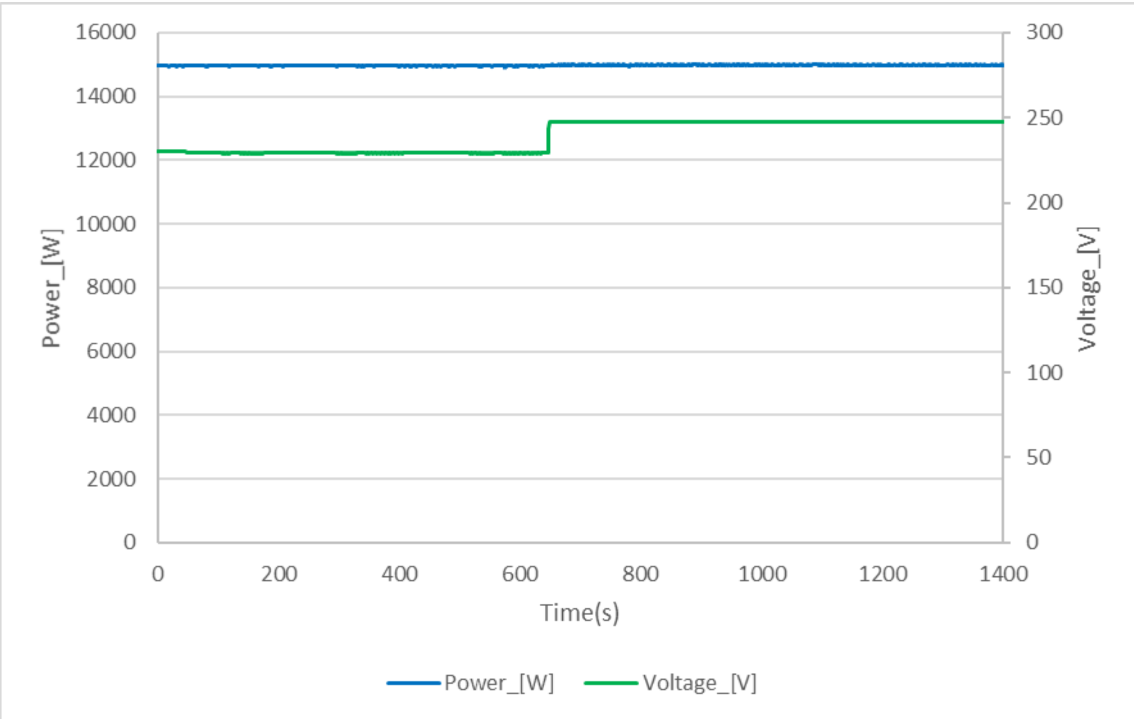
If only one integrated protection is used for the power generation systems, the value of the rise-in voltage protection of 1,1 U_N may not be changed.

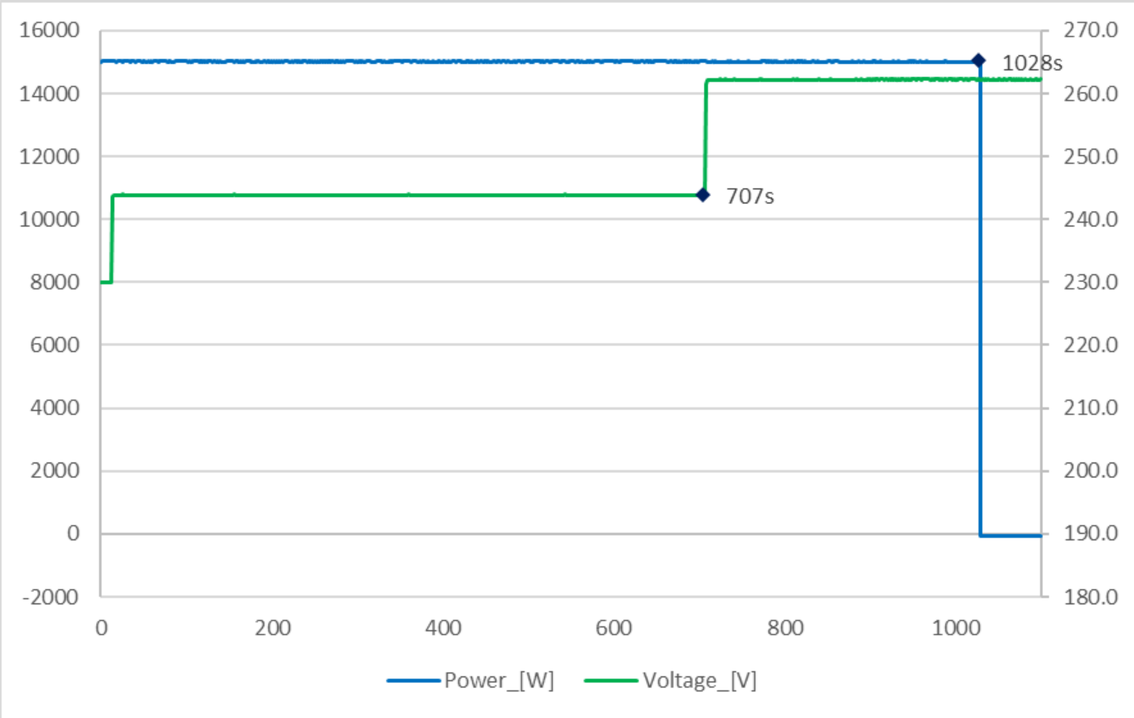
*If the setting value is set to 600 s, then the disconnection time can be in the range between 225 s and 375 s.

a) Voltage set to 112 % U_n:



b) Voltage set to 108% U_n:



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:	Any output power level U_n = 230Vac			
		Under frequency		
Trip value [Hz]	Frequency step [Hz]	Limit [Hz]	Disconnection time [ms]	Limit [ms]
47,48	50,00 to 47,40	47,50	424	0,3 ≤ t ≤ 0,5 s
47,48	50,00 to 47,40		425	
47,48	50,00 to 47,40		426	
47,48	50,00 to 47,40		428	
47,49	50,00 to 47,40		429	
		Over frequency		
Trip value [Hz]	Frequency step [Hz]	Limit [Hz]	Disconnection time [ms]	Limit [ms]
52,01	50,00 to 52,10	52,00	390	0,3 ≤ t ≤ 0,5 s
52,02	50,00 to 52,10		389	
52,01	50,00 to 52,10		388	
52,01	50,00 to 52,10		393	
52,02	50,00 to 52,10		392	

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.

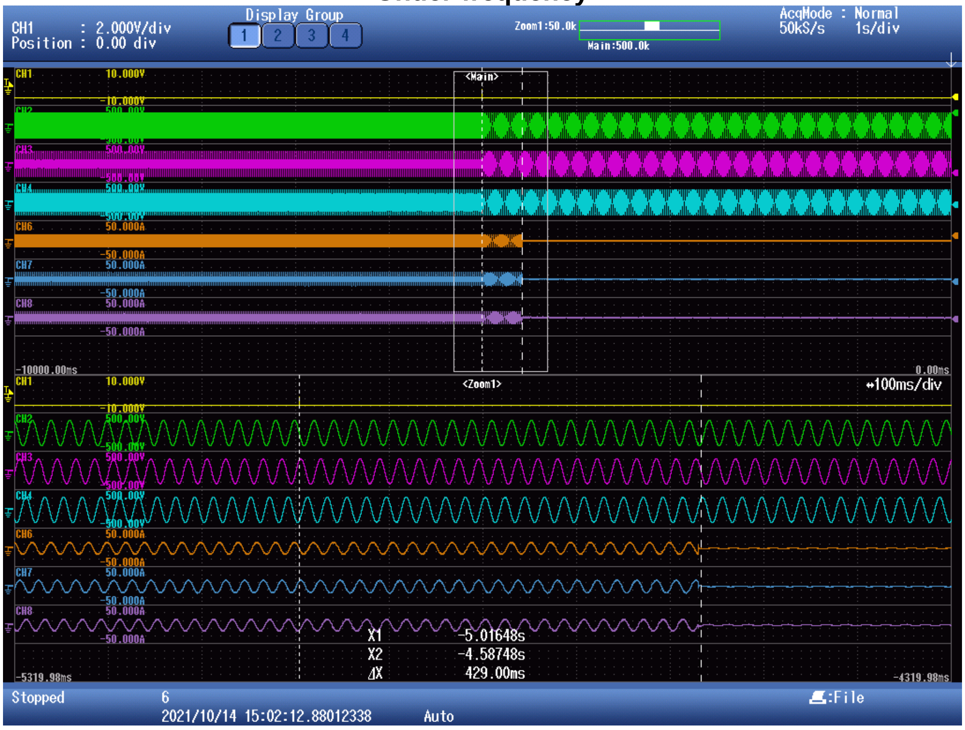
For over-frequency testing the applied frequency is varied from f_n up to $f_{th\text{-}high}$ + 0,1 Hz in steps of 0,025 Hz with a time duration per step exceeding the configured disconnection time, The operate value is the value of the applied frequency at which the protection function trips and shall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

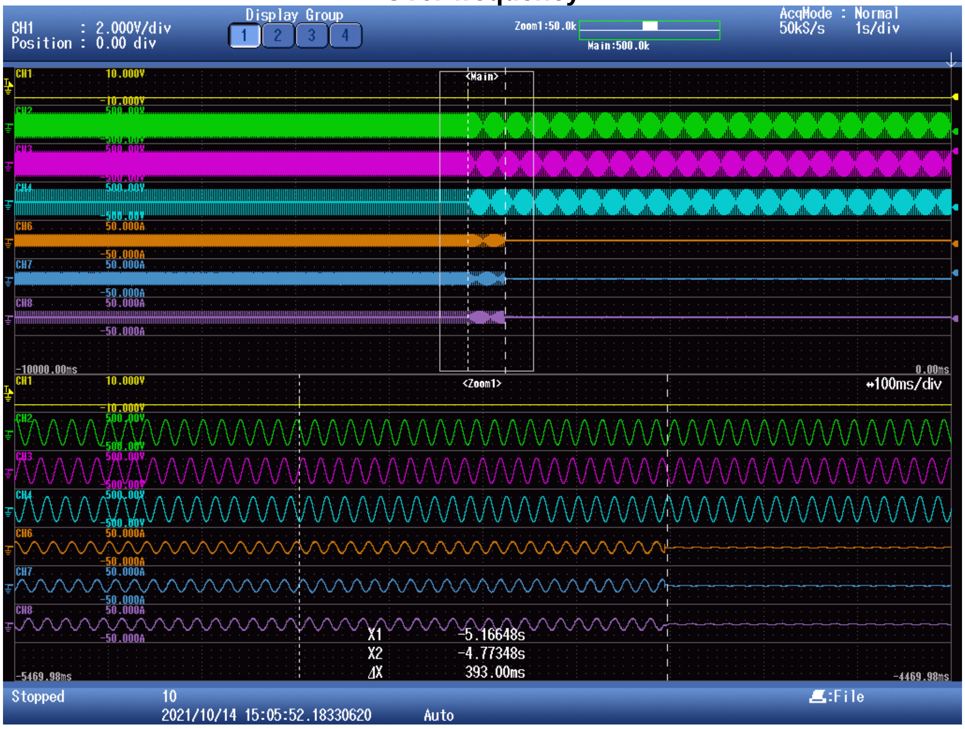
The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Scope pictures of the disconnection time

Under-frequency



Over-frequency



4.9.4.2	Loss of Mains (LoM) detection	P
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

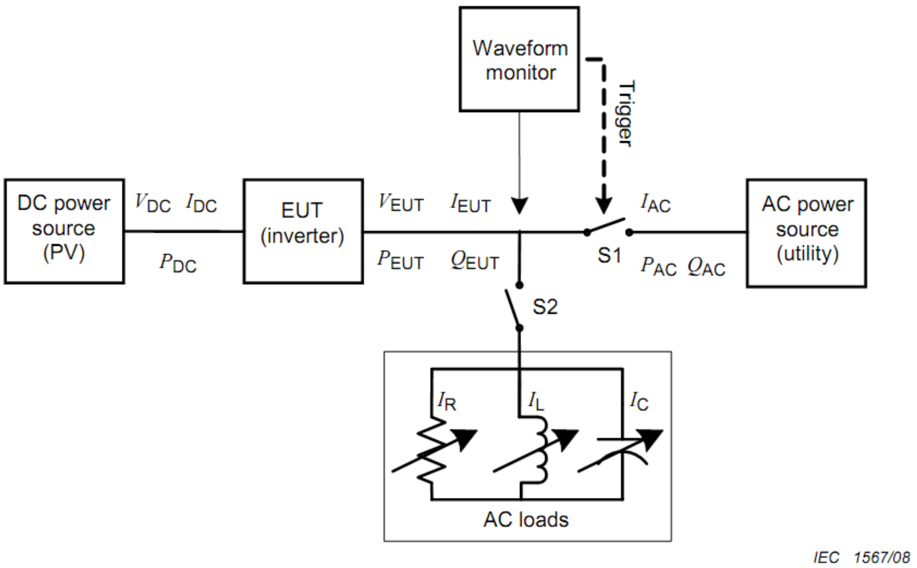


Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

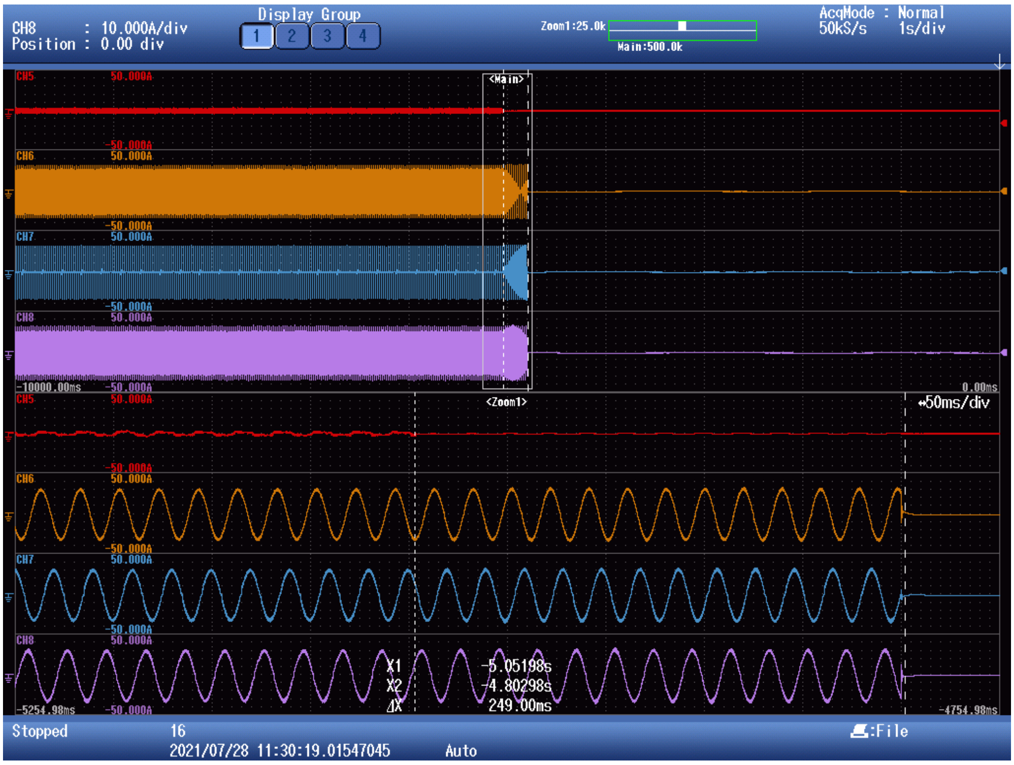
Load imbalance (real, reactive load) for test condition A (EUT output = 100%)									P
Test conditions		Frequency: 50+/-0,2Hz U_N=230+/-3Vac RLC consumes inverter real power within +/- 3% Distortion factor of chokes < 3% Quality =1							
Disconnection limit		2s							
No	P_{EUT} 1) (% of EUT rating)	Reactive load (% of Q_L in 6.1.d) 1)	P_{AC} 2) (% of nominal)	Q_{AC} 3) (% of nominal)	Run on Time (ms)	P_{EUT} (W per phase)	Actual Q_f	V_{DC}	Remarks4)
1	100	100	0	0	249	4950	1,003	680	Test A at BL
8	100	100	-5	-5	164	4950	1,029	680	Test A at IB
9	100	100	-5	0	160	4950	1,056	680	Test A at IB
10	100	100	-5	+5	80	4950	1,082	680	Test A at IB
13	100	100	0	-5	210	4950	0,978	680	Test A at IB
14	100	100	0	+5	212	4950	1,028	680	Test A at IB
17	100	100	+5	-5	163	4950	0,931	680	Test A at IB
18	100	100	+5	0	170	4950	0,955	680	Test A at IB
19	100	100	+5	+5	116	4950	0,979	680	Test A at IB

Parameter at 0% per phase	L= 33,48 mH	R= 10,64 Ω	C= 297,25 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) BL: Balance condition, IB: Imbalance condition.

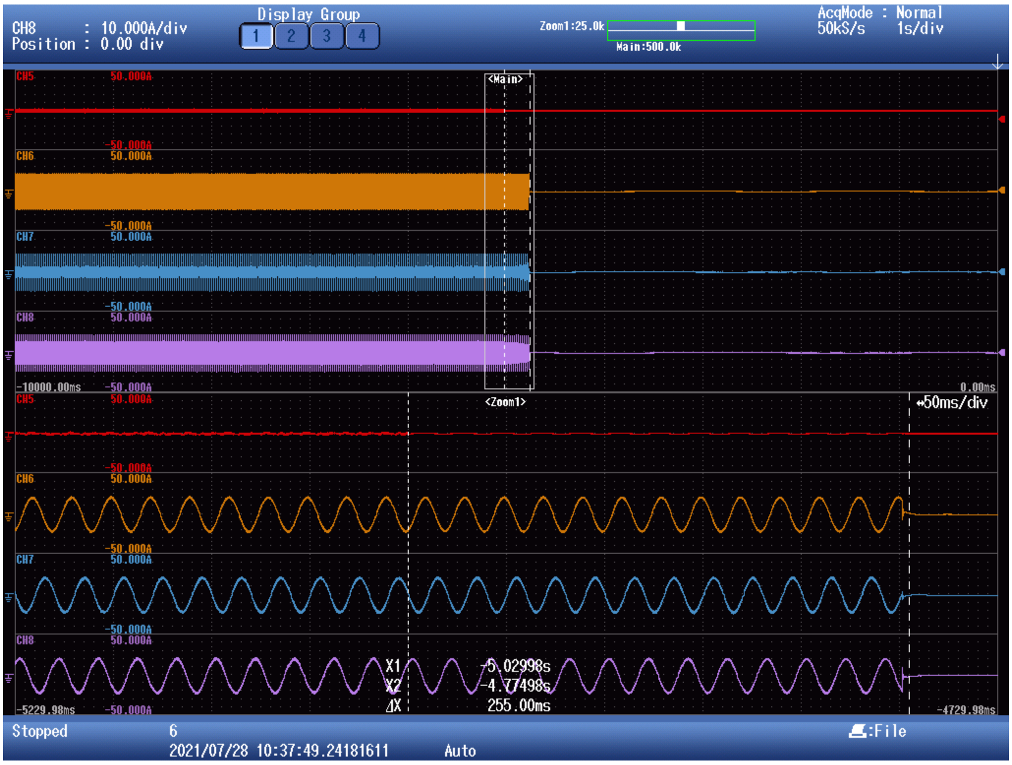
Condition A:
EUT output power PEUT = Maximum 5)
EUT input voltage 6) = >75% of rated input voltage range
5) Maximum EUT output power condition should be achieved using the maximum allowable input power. Actual output power may exceed nominal rated output.
6) Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 80 % of range =X + 0,8 × (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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Disconnection at Pac 0% and Qac 0% reactive load and 100% nominal power


Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %)									**P**
Test conditions	Frequency: 50+/-0,2Hz U_N=230+/-3Vac RLC consumes inverter real power within +/- 3% Distortion factor of chokes < 3% Quality =1								
Disconnection limit	2s								
No	P_{EUT} 1) (% of EUT rating)	Reactive load (% of Q_L in 6.1.d) 1)	P_{AC} 2) (% of nominal)	Q_{AC} 3) (% of nominal)	Run on Time (ms)	P_{EUT} (W per phase)	Actual Q_f	V_{DC}	Remarks4)
1	66	66	0	-5	111	3400	0,973	560	Test B at IB
2	66	66	0	-4	201	3400	0,978	560	Test B at IB
3	66	66	0	-3	145	3400	0,983	560	Test B at IB
4	66	66	0	-2	187	3400	0,988	560	Test B at IB
5	66	66	0	-1	255	3400	0,993	560	Test B at IB
6	66	66	0	0	152	3400	0,999	560	Test B at BL
7	66	66	0	1	140	3400	1,003	560	Test B at IB
8	66	66	0	2	162	3400	1,008	560	Test B at IB
9	66	66	0	3	150	3400	1,013	560	Test B at IB
10	66	66	0	4	144	3400	1,018	560	Test B at IB
11	66	66	0	5	91	3400	1,023	560	Test B at IB
Parameter at 0% per phase			L= 49,57 mH		R= 15,56 Ω		C= 204,38 µF		

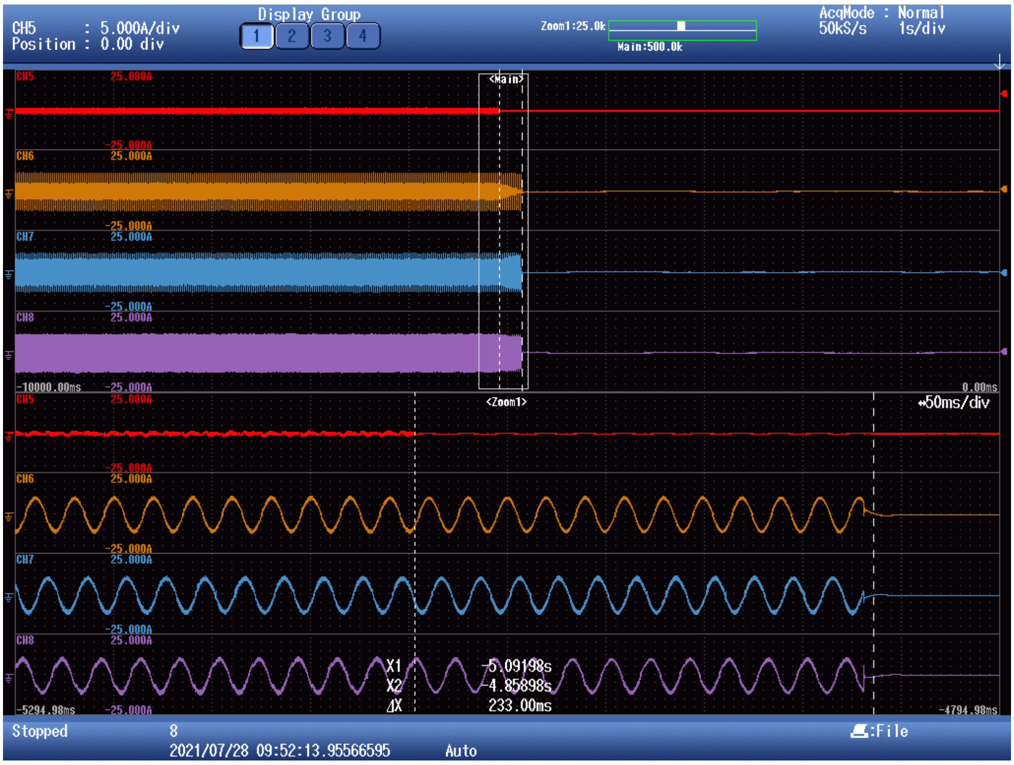
Note:
RLC is adjusted to min. +/-1% of the inverter rated output power
1) P_{EUT}: EUT output power
2) P_{AC}: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
3) Q_{AC}: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0 % test condition value.
4) BL: Balance condition, IB: Imbalance condition.
Condition B:
EUT output power PEUT = 50 % – 66 % of maximum
EUT input voltage 5) = 50 % of rated input voltage range, ±10 %
5) Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 50 % of range =X + 0,5 × (Y – X). Y shall not exceed 0,8 × EUT maximum system voltage (i.e., maximum allowable array open circuit voltage). In any case, the EUT should not be operated outside of its allowable input voltage range.

Disconnection at Pac 0% and Qac -1% reactive load and 66% nominal power


Load imbalance (reactive load) for test condition C (EUT output = 25 % – 33 %)									P
Test conditions	Frequency: 50+/-0,2Hz U_N=230+/-3Vac RLC consumes inverter real power within +/- 3% Distortion factor of chokes < 3% Quality =1								
Disconnection limit	2s								
No	P_{EUT} 1) (% of EUT rating)	Reactive load (% of Q_L in 6.1.d) 1)	P_{AC} 2) (% of nominal)	Q_{AC} 3) (% of nominal)	Run on Time (ms)	P_{EUT} (W per phase)	Actual Q_f	V_{DC}	Remarks4)
1	33	33	0	-5	125	1660	0,969	416	Test B at IB
2	33	33	0	-4	174	1660	0,974	416	Test B at IB
3	33	33	0	-3	233	1660	0,979	416	Test B at IB
4	33	33	0	-2	166	1660	0,984	416	Test B at IB
5	33	33	0	-1	207	1660	0,989	416	Test B at IB
6	33	33	0	0	172	1660	0,994	416	Test B at BL
7	33	33	0	1	154	1660	0,999	416	Test B at IB
8	33	33	0	2	161	1660	1,004	416	Test B at IB
9	33	33	0	3	127	1660	1,009	416	Test B at IB
10	33	33	0	4	117	1660	1,014	416	Test B at IB
11	33	33	0	5	113	1660	1,019	416	Test B at IB
Parameter at 0% per phase		L= 102,05 mH		R= 31,87 Ω			C= 99,29 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) BL: Balance condition, IB: Imbalance condition.

Condition C:
EUT output power PEUT = 25 % – 33 % 5) of maximum
EUT input voltage 6) = <20 % of rated input voltage range
5) Or minimum allowable EUT output level if greater than 33 %.
6) Based on EUT rated input operating range. For example, If range is between X volts and Y volts, 90 % of range =X + 0,2 × (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.

Disconnection at Pac 0% and Qac -3% reactive load and 33% nominal power


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:				
	f_{ist}	**Reset time:**	**Limit:**	
Connecting conditions for voltage:				
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]		62,5s	65,0s	
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]		66s	70,5s	
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.	
Connecting conditions for frequency:			
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]		65,0 s	65,2 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]		69,8 s	69,0 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.

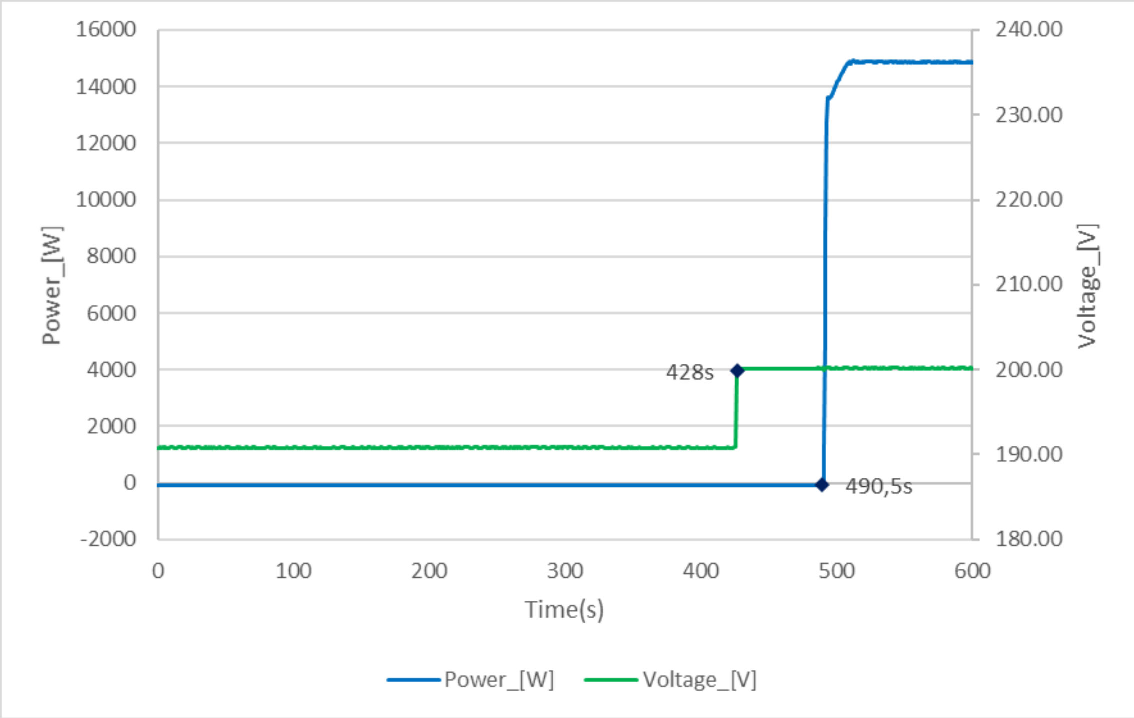
Test condition e): frequency within the limits of 49,50Hz to 50,1Hz.

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

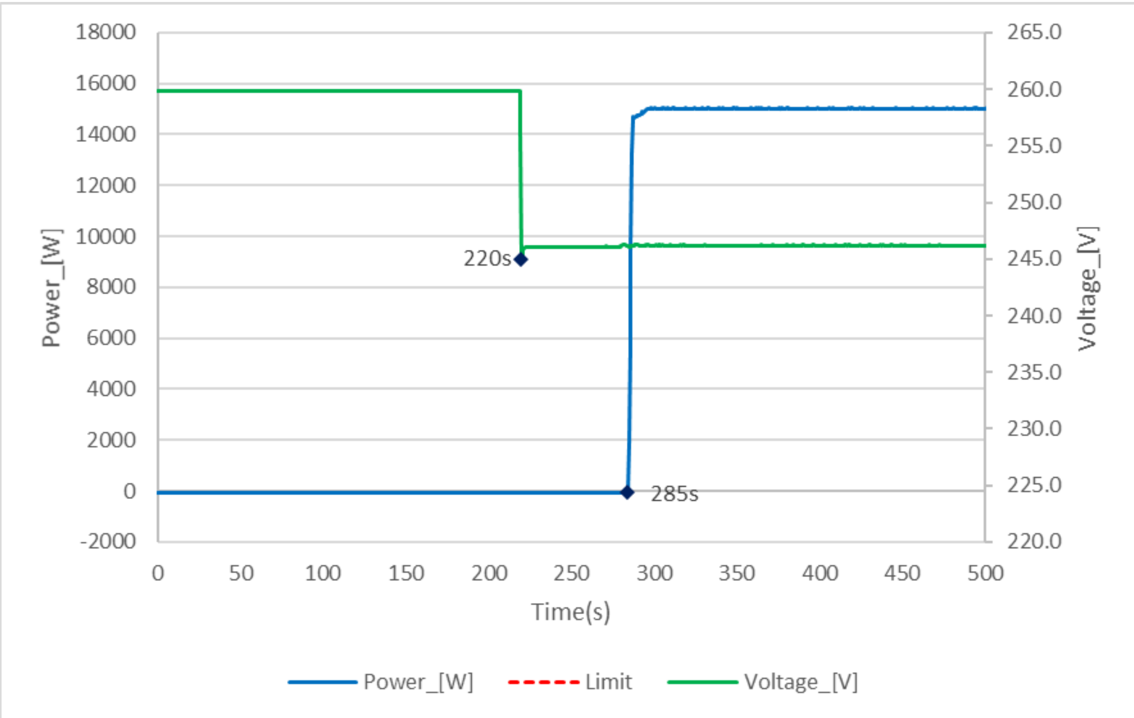
In order to avoid continuous starting and disengaging operations of the interface protection relay, the disengaging value of frequency and voltage functions shall be above 2 % deviating from the operate value.

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.
Note: The test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

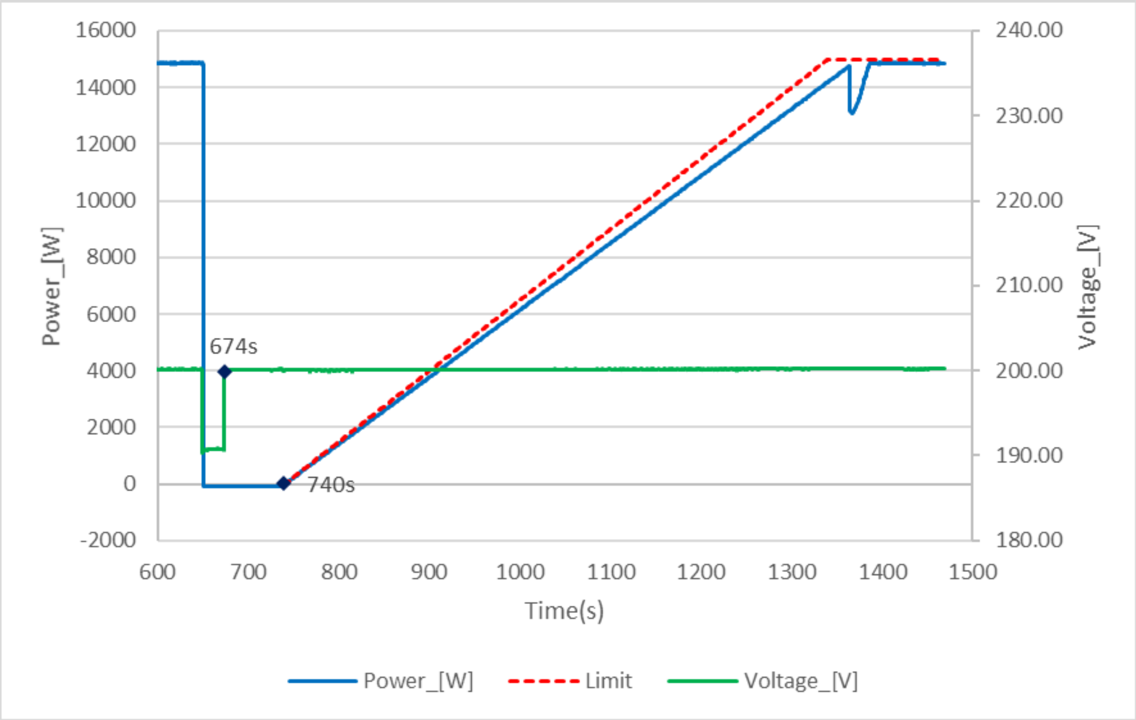
Graph of the gradual power supply: Test b) for ≥ 85% U_n



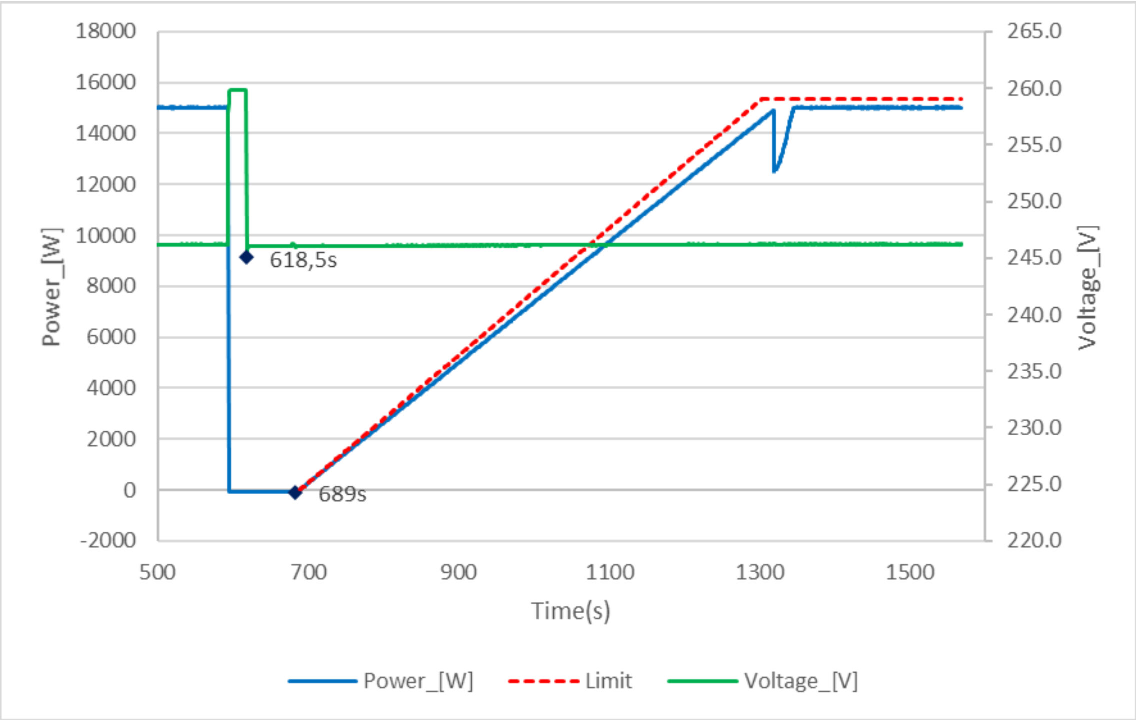
Graph of the gradual power supply: Test b) for ≤ 110% U_n



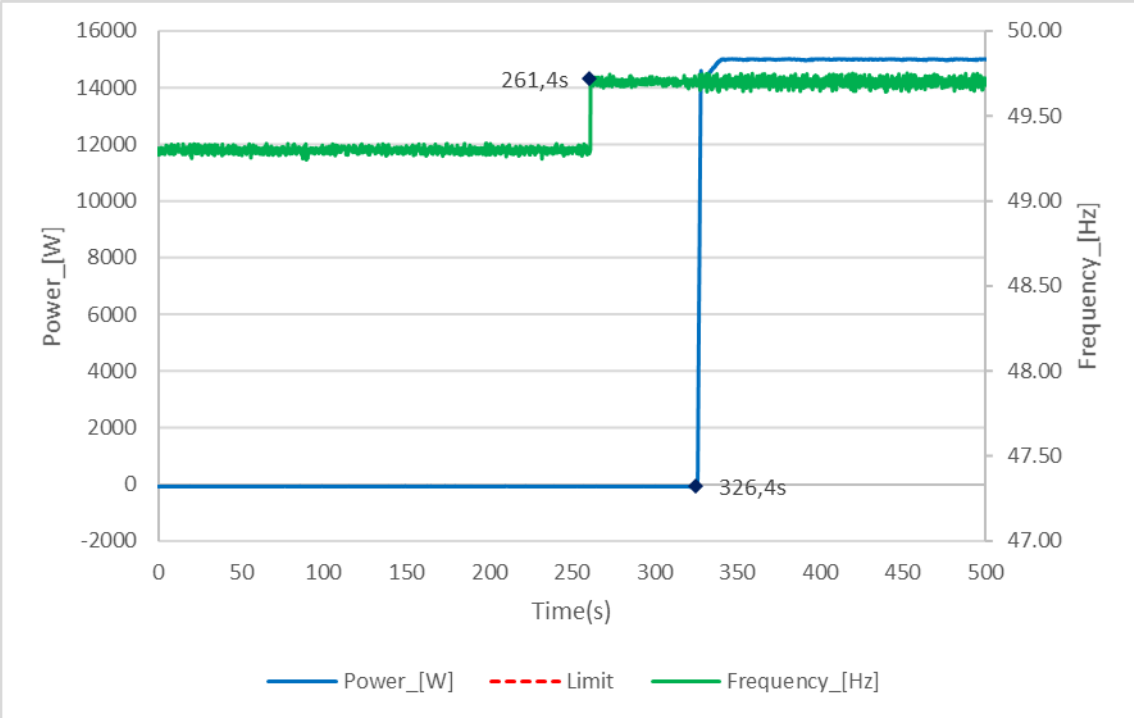
Graph of the gradual power supply: Test c) for ≥ 85% U_n



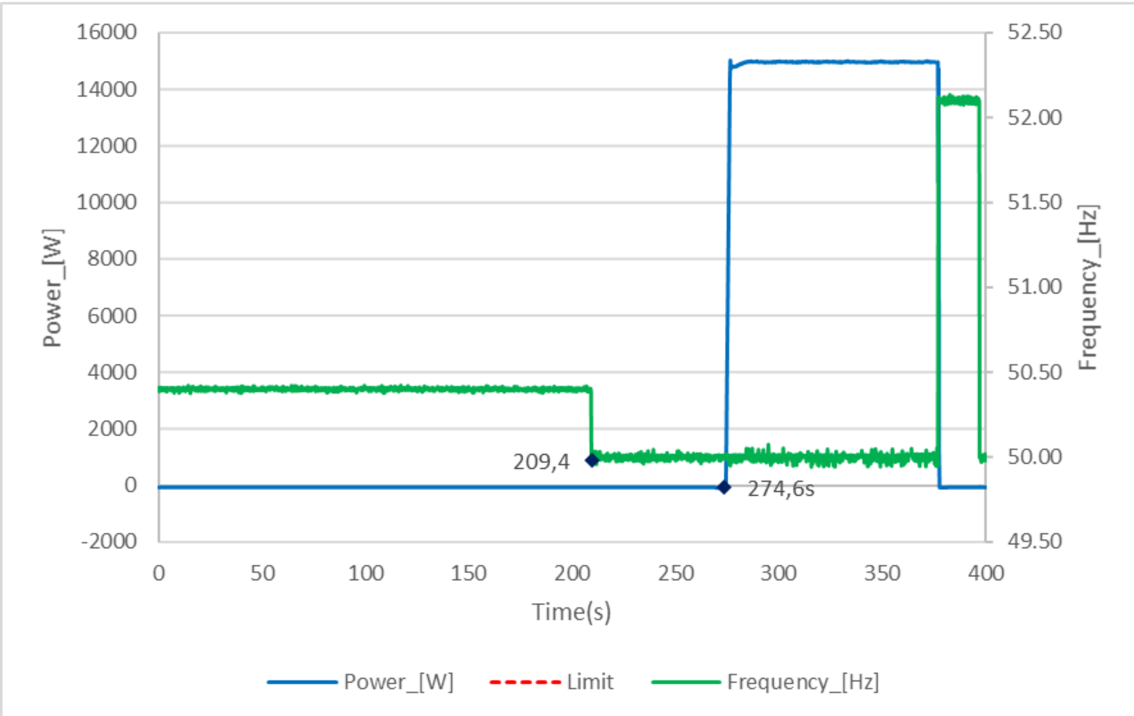
Graph of the gradual power supply: Test c) for ≤ 110% U_n



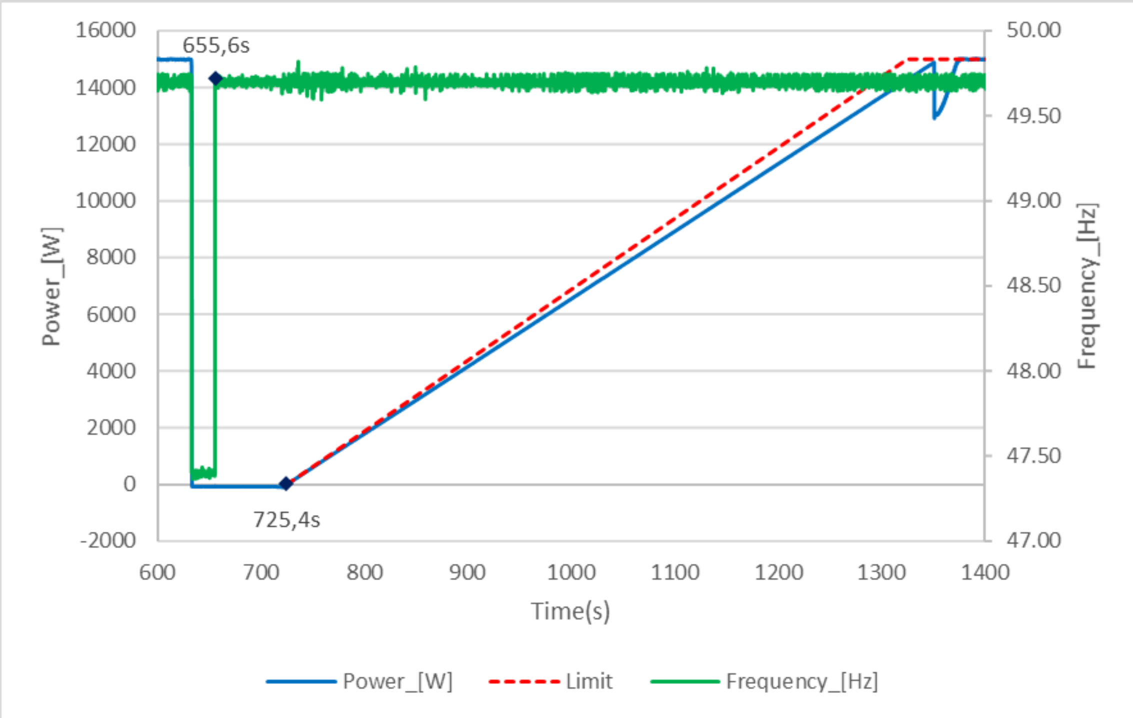
Graph of the gradual power supply: Test e) for ≥ 49,50Hz



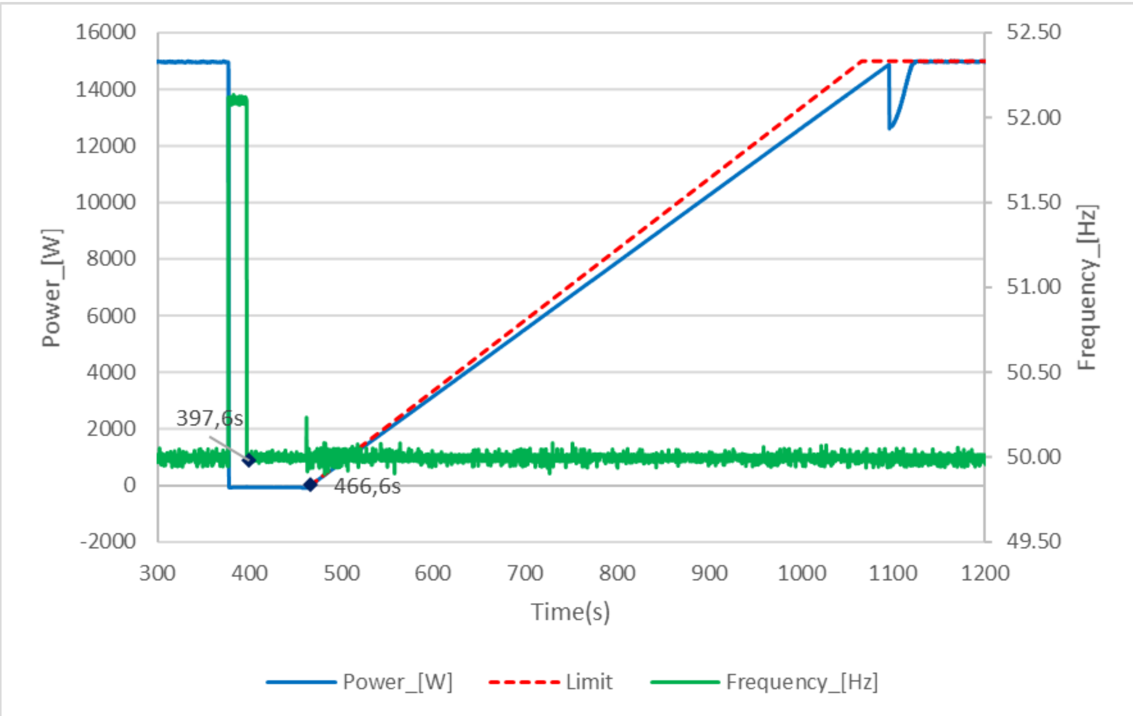
Graph of the gradual power supply: Test e) for ≤ 50,10Hz



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



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



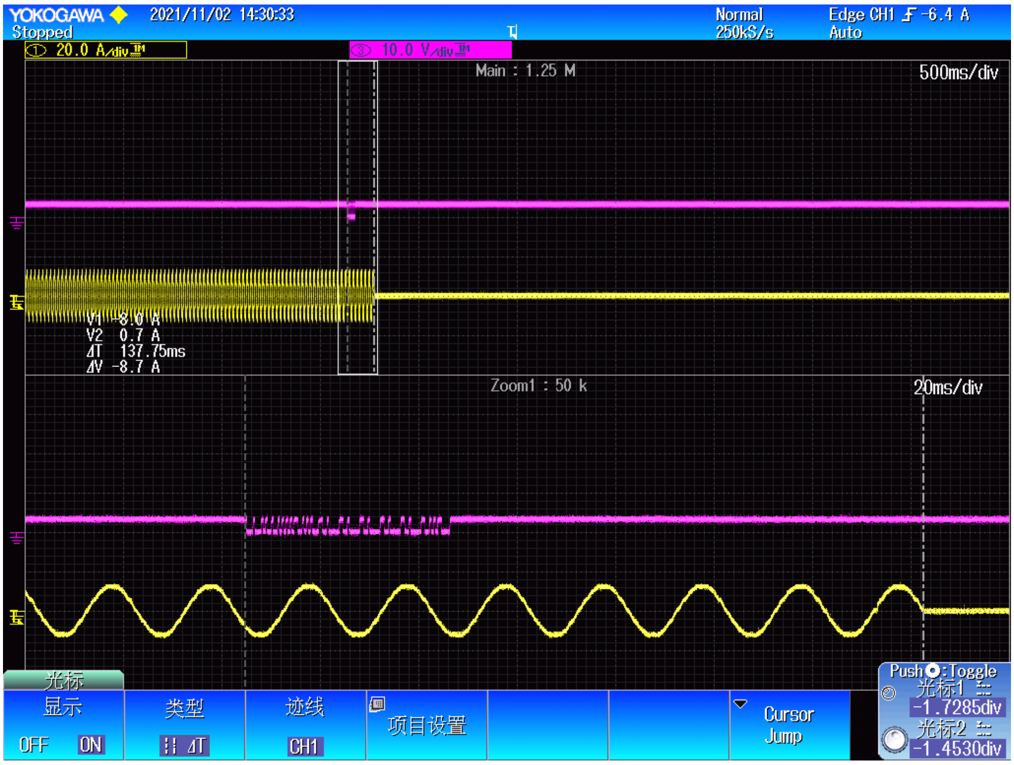
4.11.1	Ceasing active power	P
Operating time of the monitoring device		
Test:	Remote tripping signal for the external disconnection	
Limit [s]:	5 s	
Reaction time of the tripping value [s]:	0,137 s	

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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just 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 [%Pn]	P_{set} [kW]	P_{60} [kW]	Deviation [%Pn]
100%	15,000	14,667	2,218
90%	13,500	13,508	0,050
80%	12,000	12,010	0,064
70%	10,500	10,504	0,029
60%	9,000	8,992	0,055
50%	7,500	7,475	0,169
40%	6,000	5,946	0,360
30%	4,500	4,413	0,582
20%	3,000	2,901	0,661
10%	1,500	1,361	0,930
0%	0,000	0,509	3,393

	Setpoint power bin [%Pn]	Deviation [%Pn]	
Max. deviation	100%	97,8%	
Limit $\Delta P_{E60}/P_{Setpoint}$:	+ 5 % of P_{Emax}		

Test:

The setpoint signal must be reduced from 100% to 0% Pn:

a) for adjustable PGUs in increments of 10% Pn, 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

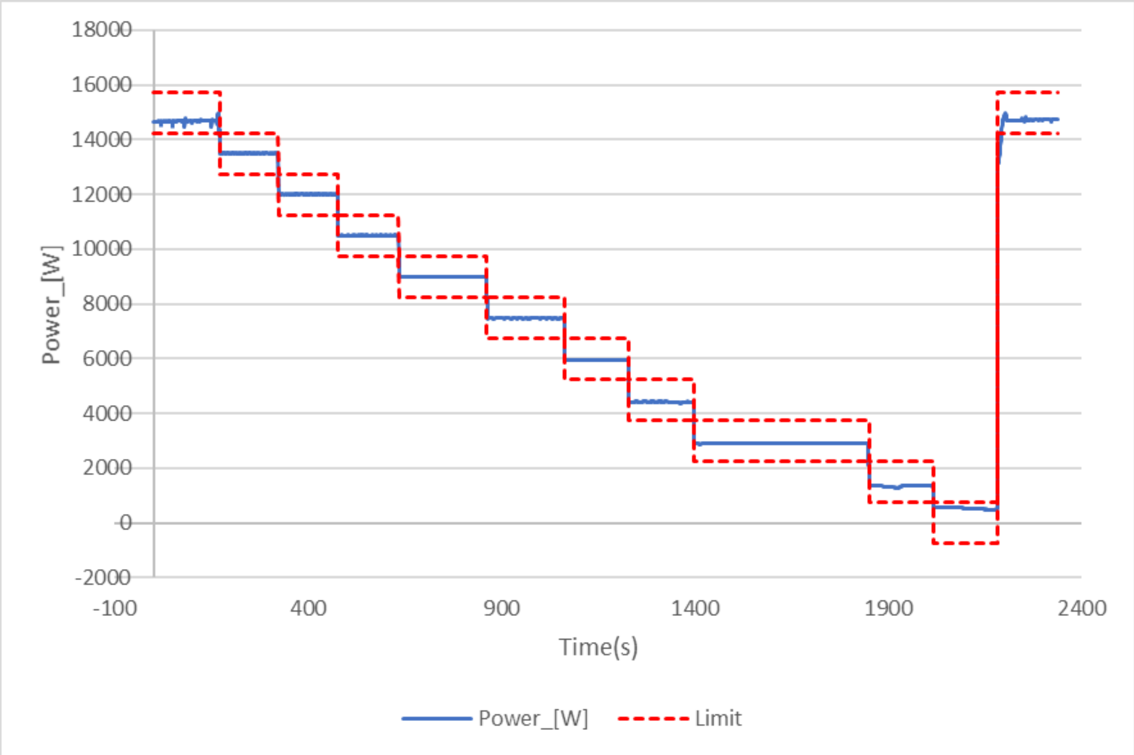
b) For all other PGUs:

- 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 test had been performed on the model ALPHA WP 15KW the test results are valid for the ALPHA WP 8KW, ALPHA WP 10KW and ALPHA WP 12KW since it is identical in hardware and just power derated by software.

Graph of active power on set point:



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

Test result:

Component No.	Fault	Test condition		Test time	Fuse No,	Fault condition		Result
		AC	DC			AC	DC	
Relay defect RY7 pin1-pin4	Short before start up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Relay defect RY9 pin1-pin4	Short before start up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Relay defect RY18 pin1-pin4	Short before start up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Relay defect RY22 pin1-pin4	Short before start up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Relay defect RY17 pin1-pin4	Short before start up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Relay defect RY21 pin1-pin4	Short before start up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R74	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID07” (RelayFail). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R76	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID01” (Line voltage high loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R84	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.

Grid voltage monitoring R91	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID01” (Line voltage high loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R97	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R101	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID01” (Line voltage high loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R94	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R79	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID01” (Line voltage high loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R88	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R102	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID01” (Line voltage high loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R 99	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Frequency measurement defect C133	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID04” (Line frequency low loss). Do not connect to AC mains. No damage,no hazards.

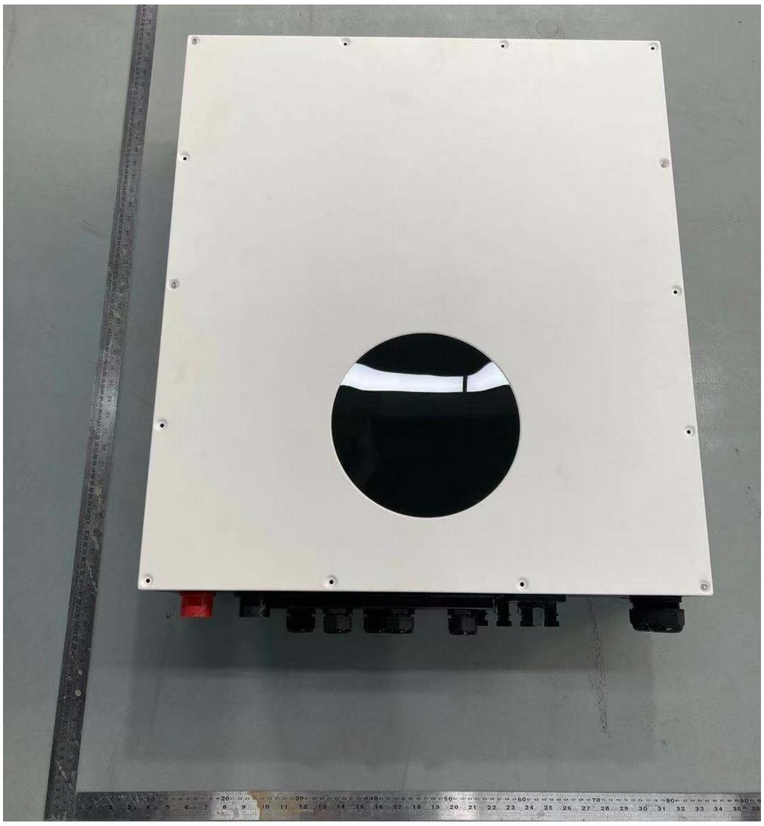
Frequency measurement defect C151	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID04” (Line frequency low loss). Do not connect to AC mains. No damage,no hazards.
Monitoring BUS voltage defect C178	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID02” (BUS voltage under). Do not connect to AC mains. No damage,no hazards.
Monitoring BUS voltage defect C182	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID02” (BUS voltage under). Do not connect to AC mains. No damage,no hazards.
Monitoring PV voltage defect R49	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate solar icon flashing (Solar low voltage). No damage,no hazards.
Monitoring PV voltage defect R48	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate solar icon flashing (Solar low voltage). No damage,no hazards.
PV Current measurement defect R29	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID01” (BUS voltage over). Do not connect to AC mains. No damage,no hazards.
PV Current measurement defect R28	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID01” (BUS voltage over). Do not connect to AC mains. No damage,no hazards.
GFCI detect defect C52	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID12” (GFCI fault). Do not connect to AC mains. No damage,no hazards.
GFCI detect defect R33	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID12” (GFCI fault). Do not connect to AC mains. No damage,no hazards.
GFCI detect defect R24	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID12” (GFCI fault). Do not connect to AC mains. No damage,no hazards.
GFCI detect defect R23	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID12” (GFCI fault). Do not connect to AC mains. No damage,no hazards.

Current sensor defect C70	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID14” (INV DC current over). Do not connect to AC mains. No damage,no hazards.
Current sensor defect C54	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID14” (INV DC current over). Do not connect to AC mains. No damage,no hazards.
Current sensor defect C52	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID14” (INV DC current over). Do not connect to AC mains. No damage,no hazards.
Current sensor defect R192	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID01” (BUS OVER VOLTAGE). Do not connect to AC mains. No damage,no hazards.
Current sensor defect R195	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID01” (BUS OVER VOLTAGE). Do not connect to AC mains. No damage,no hazards.
Current sensor defect R202	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID01” (BUS OVER VOLTAGE). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R94	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R104	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring R109	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.

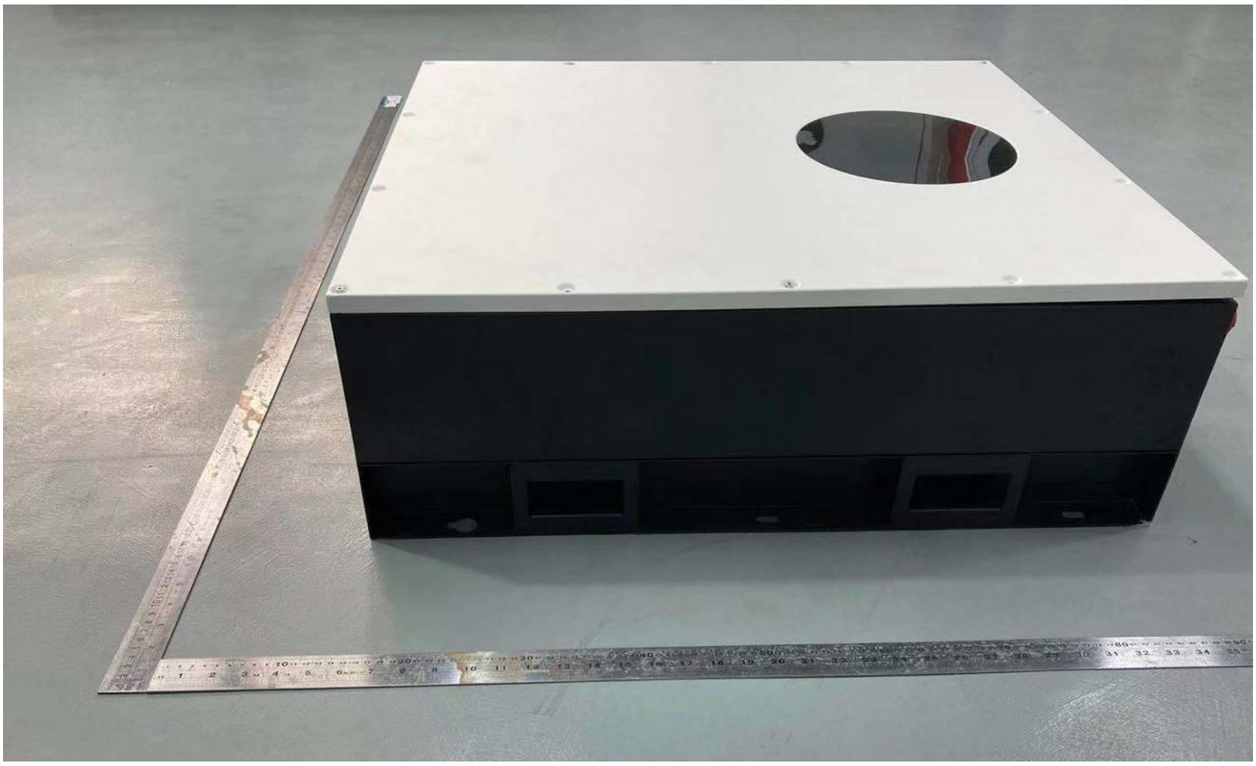
Grid voltage monitoring C126	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring C136	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Grid voltage monitoring C141	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
ISO detect defect R184	Short before start-up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID13” (PV ISO fault). Do not connect to AC mains. No damage,no hazards.
ISO detect defect C198	Short before start-up	230V 0,05A	720V 0,10A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID13” (PV ISO fault). Do not connect to AC mains. No damage,no hazards.
DSP communication defect R528	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID17” (M&S communication loss). Do not connect to AC mains. No damage,no hazards.
DSP communication defect R530	Open	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate error code “ID17” (M&S communication loss). Do not connect to AC mains. No damage,no hazards.
Loss of control C305	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
Loss of control C306	Short	230V 21,7A	720V 20,8A	10min.	--	230V 0,05A	720V 0,10A	Indicate warning code “ID02” (Line voltage low loss). Do not connect to AC mains. No damage,no hazards.
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:	

Appendix 1: Photos

Enclosure front view

Enclosure right side view


Enclosure left side view



Enclosure rear view

Enclosure bottom view

(End of Report)