TEST REPORT
VDE-AR-N 4105:2018-11
Generators connected to the low-voltage distribution network – Technical requirements for the connection to and parallel operation with low-voltage distribution networks

Report Reference No…… ...: 190325014GZU-001
Date of issue ……..: 20 Aug 2019
Total number of pages……..: 63 pages

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Testing location/ address	Same as above
Tested by (name + signature)……:	Jason Fu Technical Team Leader
Approved by (+ signature)	Tommy Zhong Technical Manager

Applicant's name	Shenzhen SOFAR SOLAR Co., Ltd.
Address.....	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China

Test specification:

Standard	VDE-AR-N 4105:2018-11
Test procedure.....	Type approval
Non-standard test method……..:	N/A

Test Report Form No.	VDE-AR-N 4105c
Test Report Form(s) Originator.....	Intertek Guangzhou
Master TRF.....	Dated 2019-03

Test item description	Solar Grid-tied Inverter
Trade Mark	SOFAR SOLAR
Manufacturer.....	Same as Applicant
Model/Type reference	SOFAR 1100TL, SOFAR 1600TL, SOFAR 2200TL, SOFAR 2700TL SOFAR 3000TL

Rating……:	Model	SOFAR 1100TL	SOFAR 1600TL	SOFAR 2200TL	SOFAR 2700TL	SOFAR 3000TL
	Input					
	Max. DC input Voltage:	450V		500V		
	Max. input current:	10A		13A		
	PV Isc	12A		15A		
	Output					
	Nominal AC output voltage:	230Vac				
	Nominal frequency:	50Hz				
	AC output power:	1000VA	1550VA	2100VA	2600VA	3000VA
	Max. AC output current:	4.5A	7.0A	9.5A	11.5A	13.0A
	Power factor:	0.8 Leading to 0.8 Lagging				
	Ingress protection:	IP65				
	Protection Class:	Class I				
	Operation Ambient Temp	-25℃ to +60℃				
	Software Version	V1.00				

Summary of testing:

Tests performed (name of test and test clause):

VDE4105	Test Description
5.5.2	PAV, E monitoring (feed-in limitation)
5.7	Behaviour of the power generation system at the network
5.7.2	Steady-state voltage stability/reactive power supply
5.7.4.2.2	Implementation of network security management
5.74.2.3	Active power adjustment at over-frequency and under-frequency
6.3	Integrated NS protection
6.4	Interface switch
6.5.2	Protective functions
6.5.3	Islanding detection
8.3	Connection conditions and synchronization
8.3.4	Connection of power generation units with inverters

Remark:

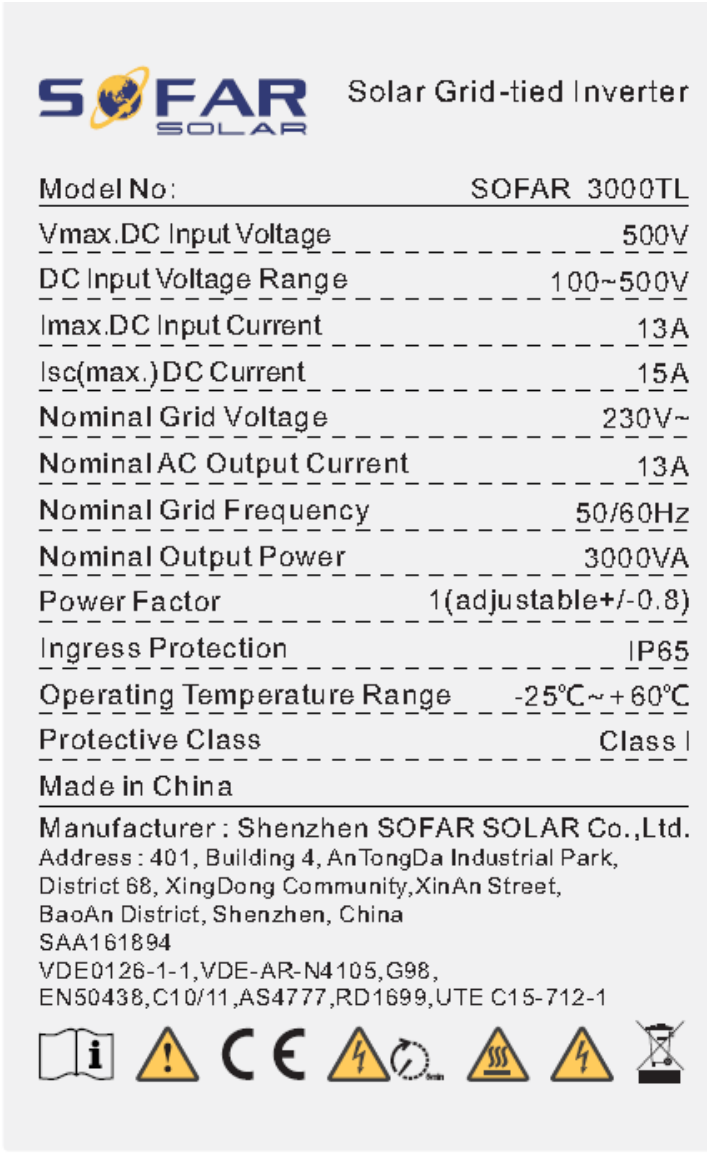
For all clauses, the model SOFAR 3000TL is type tested.

Testing location:

Intertek Testing Services Shenzhen Ltd. Guangzhou Branch

Block E, No.7-2 Guang Dong Software Science Park, Caipin Road, Guangzhou Science City, GETDD, Guangzhou, China

Copy of marking plate



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.
3. Other labels are identical to above, except the model name and ratings

Test item particulars.....:	
Temperature range .....:	-25℃ to +60℃
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 .....:	25 Mar 2019
Date (s) of performance of tests.....:	03 Jun 2019 – 12 Aug 2019

General remarks:

The test results presented in this report relate only to the object tested.
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"(see Enclosure #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

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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 point is used as the decimal separator.

General product information:

The unit is a single-phase hybrid inverter, it can convert the high PV and DC voltage to Grid voltage and feed into Grid network, also charging battery from Grid .

The input and output are protected by varistors to Earth. The unit is providing EMC filtering at the PV input and output toward mains. The unit does provide basic insulation from input to output . 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 master DSP and slave DSP
The master DSP control the relays by switching signals; measures the PV voltage, PV current, bus voltage, grid voltage and 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 other start up
The slave DSP is measured the grid voltage, AC current , frequency and residual current, also can switch off relays independently, and communicate with master DSP each other
The unit provides two relays in series in all output conductors. When single fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the PV array and the mains. All the relays are tested before each start up.

The topology diagram as following:

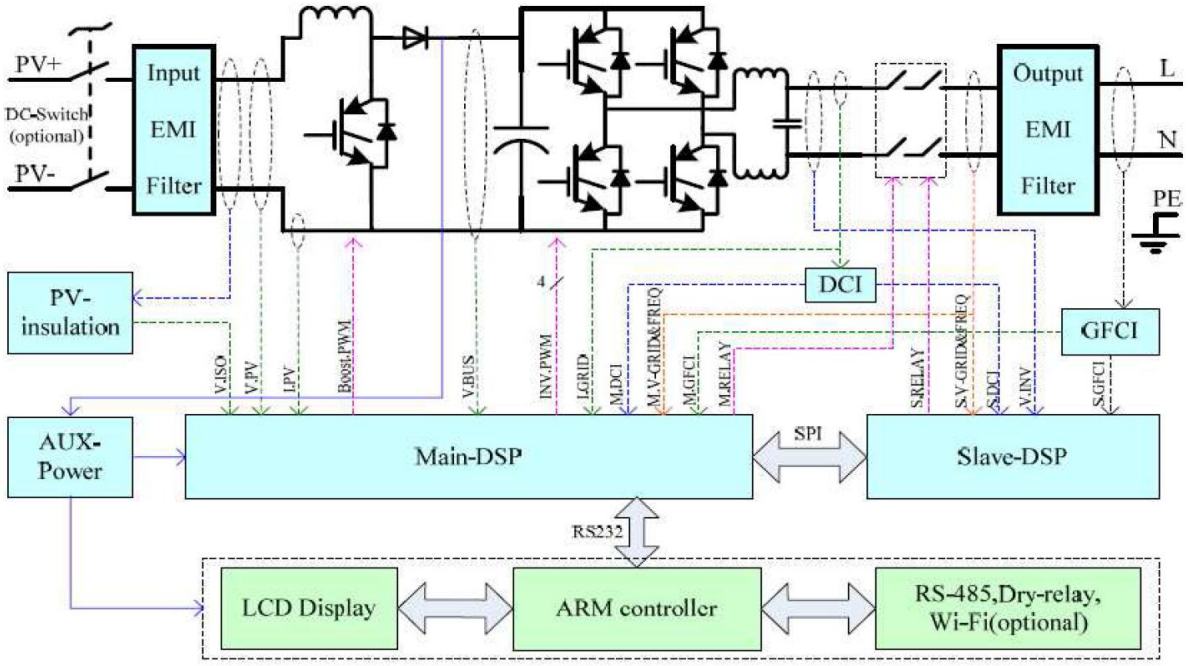

Figure 1 – Block diagram

Model differences:

The models SOFAR 1100TL, SOFAR 1600TL, SOFAR 2200TL, SOFAR 2700TL and SOFAR 3000TL are same as in hardware except the components are in the different table. Identical in software the output power just adjusted by software.

Difference table

	SOFAR 1100TL	SOFAR 1600TL	SOFAR 2500TL	SOFAR 2700TL	SOFAR 3000TL
Boost inductor	2,6mH	2,6mH	1,9mH	1,9mH	1,9mH
Resistor (RP105, RP108 /RP189,RP109)	220ohm / 10Kohm	220ohm / 10Kohm	200ohm / 7,5Kohm	200ohm / 7,5Kohm	200ohm / 7,5Kohm
BUS capacitor (ECP1, ECP2, ECP3, ECP4)	2 pcs	2 pcs	3 pcs	3 pcs	3 or 4 pcs
Inverter inductor	3,4mH	2,3mH	2,1mH	1,5mH	1,3mH
Resistor (RP118, RP119, RC18 /RP120, RP121,RC22)	499 Ω, 200 Ω, 200 Ω	1 KΩ, 200 Ω, 100 Ω	1 KΩ, 330 Ω, 330 Ω	2 KΩ, 100 Ω, 100 Ω	2 KΩ, 100 Ω, 100 Ω
DC switch and Wi-Fi module are optional.					

The product was tested on:

The Software version: V1.00

The Hardware version: V1.00

Factory information:

Dongguan SOFAR SOLAR Co., Ltd

1F-6F, Building E, No.1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict

4	**General framework conditions**		N/A
4.1	**Provisions and regulations**	This report is only evaluated and tested for PGU; The PGS incorporated with the PGU shall further consider this clause and sub-clause.	N/A
4.2	**Application procedure and relevant document for connection**	Shall consider in final PGS	N/A
4.3	**Commissioning of the power generation system and/or the storage unit**	Shall consider in final PGS	N/A

5	**Network connection**		**P**
5.1	**Principles for determination of the network connection point** Power generation systems and storage units shall be connected at a suitable point of the network, i. e. the network connection point. Based on the documents listed in 4.2, the network operator determines the suitable network connection point which will ensure safe network operation while also taking into account the power generation system and the storage unit and at which the requested power can be drawn and transmitted. The essential aspect for a network connection evaluation is always the behaviour of the power generation system and the storage unit at the network connection point or at the PCC. This is intended to ensure that the power generation system or storage unit is operated without adverse interactions and impairment of the supply of other customers. Annex D shows an example of the connection evaluation of power generation systems..	Shall consider in final PGS	N/A
5.2	**Rating of the network equipment** Due to their operating mode, power generation systems and storage units may cause higher loading of lines, transformers and other network equipment. Therefore, the network operator verifies the transmission capacity of the network equipment with regard to the connected power generation systems and storage units in accordance with the relevant rating regulations. For calculation purposes, the maximum apparent power of the sum of all power generation systems and storage units $\sum S_{Amax}$ and usually the load factor m = 1 shall be used. This does not apply to buried cables for the connection of photovoltaic systems where a load factor m = 0,7 shall be used.	Shall consider in final PGS	N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.3	Permissible voltage change For undisturbed operation of the network, the amount of the voltage change caused by all power generation systems with a network connection point in a low-voltage network shall at none of the PCCs in this network may a value of 3 % as compared with the voltage without power generation systems. Deviations from the value of $\Delta u_a \leq 3$ % are permissible as specified by the network operator (e. g. when using a controllable local network transformer). When calculating the voltage change, the displacement factor shall be taken into account which is provided by the network operator for the maximum apparent connection power of the power generation system S_{Amax}.	Shall consider in final PGS	N/A
5.4	**Network interactions** For power generation systems and storage units, the permissible limits for network interactions are also described in VDE-AR-N 4100, 5.4. For the connection evaluation of power generation systems and storage units, the connection owner provides the completed forms E.2 to E.5 to the network operator.		N/A
5.5	**Connection criteria**		P
5.5.1	**General** When connecting a power generation system or a storage unit, the technical connection conditions of the network operator shall be observed.	Shall be considered full feed-in or excess feed-in that in accordance with VDE-AR-N 4100 in the power system, where also considered whether valid of PAV, E monitoring	P

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Clause	Requirement - Test	Result - Remark	Verdict
5.5.2	**$P_{AV, E}$ monitoring (feed-in limitation)** $P_{AV, E}$ monitoring allows a connection power $P_{AV, E}$ deviating from the installed power to be agreed with the network operator and to be set. The feed-in limit described in this sub-clause shall be measured at the central meter panel in accordance with VDE-AR-N 4100, 7.2. $P_{AV, E}$ monitoring can be an independent equipment mounted at the central meter panel in accordance with VDE-AR-N 4100 or in a suitable circuit distributor or may also be part of a power generation unit or a storage unit or a charging unit for electric vehicles. When $P_{AV, E}$ is exceeded, the power of the power generation system and/or the storage unit causing the event shall be reduced. $P_{AV, E}$ monitoring is to be used for monitoring the agreed active connection power $P_{AV, E}$ of power generation systems and/or storage units if thefeed-in power at the network connection point $P_{AV, E}$ agreed with the network operator is smaller than the sum of the installed maximum active connection power of all power generation systems and/or storage units at that network connection point.	The function of PAV, E monitoring is verified with the active power limit curve (See appended table)	P
5.5.3	**Power generation systems ready for connection** In addition to the requirements specified in this VDE application guide, DIN VDE V 0100-551-1 (VDE V 0100-551-1) applies to power generation systems ready for connection. Provided a connection-ready power generation system is connected via an existing specific energy socket (e. g. complying with VDE V 0628-1 (VDE V 0628-1)) and a bidirectional meter is mounted at the central meter panel, the signature and the details of the system installer on the commissioning protocol E.8 may be omitted. A site map is not required in this case. This only applies up to a value $S_{Amax} \leq 600$ VA per network user installation..		N/A
5.6	**Three-phase inverter systems** For three-phase power generation systems feeding into the network via inverters, the power feed-in into the three line conductors shall be three-phase balanced. The inverter circuit shall preferably be set up as a three phase current unit. The positive sequence system of the terminal voltages, even if they are unbalanced, is to be used as the reference quantity for the currents.	Single-phase unit	N/A

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Clause	Requirement - Test	Result - Remark	Verdict
5.7	**Behaviour of the power generation system at the network**		P
5.7.1	**General** For frequencies between 47,5 Hz and 51,5 Hz, automatic disconnection from the network due to a frequency deviation is not permitted. The actual operating principle and the associated exceptions are detailed in 5.7.4.3. Frequency-dependent active power control is implemented in the open-loop control of the power generation units.. In the frequency range of 47,5 Hz to 51,5 Hz, power generation systems shall be capable of network parallel operation in compliance with the time-related minimum requirements given in Table 1. Power generation units shall be able to ride through rapid frequency changes without disconnection from the network. This requirement applies provided the following averaged rates of change of frequency (RoCoF) are not exceeded: – ± 2,0 Hz/s for a moving time slot of 0,5 s; or – ± 1,5 Hz/s for a moving time slot of 1 s; or – ± 1,25 Hz/s for a moving time slot of 2 s. In case of rapid frequency changes, frequency measurements shall not take more than 200 ms. The minimum accuracy of frequency measurements is ± 50 mHz.	(See appended table)	P
5.7.2	**Steady-state voltage stability/reactive power supply**		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.1	**General boundary conditions** Steady-state voltage stability means the reactive power supply provided by a power generation system and/or a storage unit when energy is supplied for the purpose of voltage stability in the distribution network. The steady-state voltage stability is intended to keep slow (steady-state) voltage changes in the distribution network within acceptable limits. In case of three-phase feed-in, the reactive power supply associated with all three methods described in 5.7.2.4 a) to c) refers to the positive sequence system components of the current and voltage fundamental component. In a passive sign convention system (see A.8), this means the operation of the power generation system in Quadrant II (under-excited) or Quadrant III (over-excited). If a storage unit consumes energy from the network, the reactive power exchange at the network connection point shall comply with the contractual agreements regarding the network connection for customer installations for consumption (see VDE-AR-N 4100). It shall be possible to approach each set-point resulting from the applied control method according to the required reactive power range given in 5.7.2.2 and to operate the power generation unit therein for any duration. Changes of the reactive power supply within the agreed reactive power range shall be possible at any time. Upon agreement with the network operator, the reactive power control range may be extended..		P
5.7.2.2	**Reactive power supply at $\sum S_{Emax}$**		P
5.7.2.2.1	**General** It is permissible in certain cases described in 5.7.2.2.2 and 5.7.3 to reduce the active power supply to the benefit of the reactive power supply. This is not considered a reduction of the active power supply in thecontext of network security management. Power generation systems shall comply with the reactive power supply irrespective of the number of feed-inphases under normal operating conditions in the voltage tolerance band $U_n \pm 10$ %.		P
5.7.2.2.2	**Type 2 systems – inverters only** At the generator terminals, each power generation unit to be connected shall meet the requirements according to Figure 2 and Figure 3.	The unit is <4.6KVA that according to figure 2	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.2.3	**Type 2 systems – Asynchronous generators (directly connected to the network and principally not able to control any reactive power)** For power generation units with generators that are directly connected to the network and principally not able to control any reactive power and therefore use constant capacities, a constant displacement factor cos ϕ = 0,95under-excited with an accuracy of ± 0,02 at nominal voltage and rated power shall be observed.	Inverter	N/A
5.7.2.2.4	**Type 1 systems and type 2 systems – stirling generators and fuel cells** For power generation systems with a rated apparent power of ∑SEmax ≤ 4,6 kVA , the network operator does not give any specifications. The value of cos ϕ lies within a range of cos ϕ = 0,95under-excited to 0,95over-excited. At its generator terminals, each power generation unit to be connected in systems ∑SEmax > 4,6 kVA shall meet the requirements according to Figure 4.		N/A
5.7.2.3	**Reactive power supply smaller than P_{EmaxP}** In addition to the requirements for reactive power supply at the operating point P_{Emax} of the power generation unit ($P_{mom} = P_{Emax}$), requirements also apply to operation with an instantaneous active power P_{mom} smaller than P_{Emax}. The minimum requirement for the reactive power supply in partial load operating mode at the generator terminals is indicated as a red triangle on the P/Q diagram. Within the ranges given in Figure 5 or Figure 6, the maximum residual deviation between the set-point and the actual value of the reactive power at the generator terminals shall not exceed ± 4,0 % in relation to P_{Emax}. Within the range of $0 \leq P_{mom}/P_{Emax} < 0,2$ (or 0,1, respectively), the power generation unit shall not exceed the reactive power value at the generator terminals of 10 % of the active power value P_{Emax} (reactive power supply and consumption respectively). Where a minimum technical power for a power generation unit has been agreed, the same conditions apply as for the range $0 \leq P_{mom}/P_{Emax} <$ 0,2 (or 0,1, respectively) between 0 and the minimum technical power.	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.4	**Methods for reactive power supply** The reactive power supply for steady-state voltage stability shall not impair the dynamic network stability. The reactive power to be provided by the power generation system is limited to the range given in Figure 5 or Figure 6, respectively. In the context of network connection planning, the network operator prescribes to the connection owner one of the following methods for reactive power supply at the generator terminals of the power generation unit: a) reactive power voltage characteristic curve $Q(U)$; or b) displacement factor/active power characteristic curve cos ϕ (P); or c) fixed displacement factor cos ϕ. The $Q(U)$ rule applies only to three-phase power generation units connected to the three-phase current system. Here, too, the reactive power requirements are implemented at the generator terminals of the power generation units.	Method b and c are used for reactive power supply PGU S_{Emax} ≦4.6 kVA characteristic curve provided by the network operator within cosφ= 0.95 under-excited to 0.95 over-excited.	P
	Re: a) reactive power voltage characteristic curve $Q(U)$ The objective of this method is the reactive power exchange between power generation unit and network depending on the actual voltage at the generator terminals of the power generation unit ($Q = f(U)$). The reference voltage U_{Q0} is 400 V / 3. The arithmetic mean of the r.m.s. values (optionally of the positive sequence system) of the three measured line-to-neutral voltages at the generator terminals of the power generation unit is the target value for the reactive power to be fed in on all line conductors. Voltage measurement shall not exceed a maximum measurement error of 1 % in relation to the nominal value.	PGU S_{Emax} ≦4.6 kVA	N/A
	Re: b) Displacement factor/active power characteristic curve cos ϕ (P) The objective of this method is the reactive power supply by the power generation unit depending on the actual active power output ($Q = f(P_{mom})$).	(See appended table)	P

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Clause	Requirement - Test	Result - Remark	Verdict
	Re: c) Displacement factor cos ϕ The objective of displacement factor control is the power feed-in by the power generation unit at a constant active power/apparent power ratio (cos ϕ = const). Thereby, the use of the reactive power control range given in Figure 5 and Figure 6 is restricted. For this purpose, the target value is defined with a minimum increment of Δ cos ϕ = 0,01. The maximum permissible error tolerance of the reactive power feed-in is calculated using the error tolerance given in 5.7.2.3 of ± 4 % in relation to P_{EMax}. The network operator predefines a displacement factor set-point.	(See appended table)	P
5.7.2.5	**Requirements for reactive power methods of type 2 systems (inverters only) and type 1 systems** In the delivery state, none of the three reactive power methods specified in 5.7.2.4 is set as default. During the commissioning of power generation units, the method specified by the network operator shall be set by the system installer. Without the setting of the method specified by the network operator, power generation units shall not feed in any power.		P
	The control behaviour of the reactive power (methods a), b) and c)) with respect to set-point offsets corresponds to the PT-1 behaviour shown in Figure 10. Method a) deals with a closed control circuit under consideration of the network impedance. Each reactive power value resulting from the control behavior predefined by the network operator shall be adjustable within a range of 6 s to 60 s (from 10 s to 60 s for type 1) when being provided by the power generation unit. The time specified by the network operator corresponds to 3 Tau of a PT-1 behaviour or to the time until reaching 95 % of the set-point. If no actual value is predefined by the network operator for this purpose, the applicable value is 10 s for 3 Tau or 95 % of the set-point, respectively. The envelop delay time includes the determination of the network voltage or the active and reactive powers.		P
5.7.2.6	**Special aspects regarding the extension of power generation systems** The requirements specified in 5.7.2.4 shall also be met by the newly added power generation units at their generator terminals. The reactive power supply by the added power generation units in accordance with 5.7.2.2 shall be determined based on the sum of the rated apparent powers of the existing power generation system and the newly added power generation units.		N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict

5.7.3	**Dynamic network stability**		N/A
5.7.3.1	**General**		N/A
5.7.3.2	**Dynamic network stability for type 1 units** **Transient stability – Reaction to network faults** Regarding the power generation unit remaining connected to the network, the following applies to type 1 units: Throughout the operating range of the power generation unit, voltage drops caused by single-phase, two phase or three-phase network faults and the subsequent voltage transient phenomena shall not cause the power generation unit to become unstable or to disconnect from the network if the voltage assumes values within the limit curves shown in Figure 11 (red for the under-voltage limit curve, blue for the over-voltage limit curve).		N/A
5.7.3.3	**Dynamic network stability for type 2 units and storage units** The following conditions apply to all type 2 power generation units and storage units: As long as the line-neutral-voltages at the generator terminals of the power generation unit or storage unit do not exceed the limit curves shown in Figure 12 (red for the under-voltage limit curve, blue for the over-voltage limit curve), both the power generation unit and the storage unit shall neither become unstable nor disconnect from the network throughout the operating range.		N/A
	For evaluating the curves, the smallest respective value of the line-neutral-voltages at the power generation unit or the storage unit shall be used in case of a voltage drop, and the highest respective value of the line-neutral- voltages at the power generation unit or the storage unit shall be used in case of a voltage rise. As far as the set values for the NS protection given in Table 2 (column “Inverter(s)”) anticipate the requirements given in Figure 12 in certain working points, merely the checking of the set values for NS protection is required for the verification procedure.		N/A
	If the voltage at the generator terminals falls below < 0,8 U_n or exceeds > 1,15 U_n (onset of fault), type 2 power generation units and storage units shall ride through voltage drops without feeding current into the network of the network operator (limited dynamic network stability).		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	This requirement is deemed to be met, if the current fed in by the power generation unit(s) and/or the storage unit in any line conductor does not exceed 20 % of the rated current I_r within 60 ms and 10 % of I_r within 100 ms upon a voltage drop below 0,8 U_n or a voltage rise above 1,15 U_n.		N/A
	Behaviour after the end of a fault If, after the end of a fault, the network voltage resumes a value within the voltage band from –15 % U_n to +10 % U_n and the active current of the power generation unit and/or the storage unit has been reduced during the network fault, it shall, immediately after the end of the fault, be increased to its pre-fault value as quickly as possible. The transient period shall not exceed a maximum of 1 s. The reactive power supply follows 5.7.2.5 in its time-related behaviour. In case of rotating machinery, the transient period shall not exceed a maximum of 6 s. At voltages of 1,15 U_n, the power generation units and storage units shall not disconnect from the network for a period of up to 60 s after the onset of the fault. If the tripping of the self-protection of the power generation units and/or the storage unit is imminent, these units can adjust their reactive power behaviour such as to prevent self-protection tripping.		N/A
5.7.4	**Active power output**		P
5.7.4.1	**General** In cases where set-points are specified by a third party (e. g. direct marketing) and of network security management in accordance with 5.7.4.2, the new set-point shall be approached with the customer installation's power gradients listed below in relation to the network connection point. Implementation of those power gradients directly at the power generation units or storage units is sufficient for meeting the requirement. The following power gradients shall be observed for increasing/reducing the active power output of power generation systems (minimum technical power or 5 % P_{Amax} ↔ 100 % P_{Amax}) as well as the energy supply and consumption by storage units (5 % P_{Amax} ↔ 100 % P_{Amax}): – at a maximum rate of 0,66 % P_{Amax} per s; – at a minimum rate of 0,33 % P_{Amax} per s. Power generation systems may react more slowly in case of set-points specified by third parties and of power increases. For this purpose, a minimum rate of 4 % P_{Amax} per minute should be observed.	The active power can be remote-controlled on the communication interface	P

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Clause	Requirement - Test	Result - Remark	Verdict
	Other technically induced power gradients (e. g. for hydro power generation systems with level control depending on network demands) are permissible upon approval by the network operator. The power increase or reduction of the customer installation shall be realised in a uniform process, i. e. with a behaviour as linear as possible. The specification of set-points by third parties shall be realised on the level of the individual customer installation or by the sum of all systems accessed by a third party (e. g. by uniform distribution of the active powers to be connected or disconnected over a total period of ≥ 2,5 min).		N/A
	The power generation system or storage unit shall be provided with a logical interface (inlet port) which, irrespective of the power gradients listed above, allows to terminate the active power output within 5 s upon reception of a corresponding signal from the network operator. Additionally, the interface may be used for network security management.		P
5.7.4.2	**Network security management**		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.4.2.1	**Types of power generation systems and storage units** If not specified otherwise by legislation, the requirements described below apply. **Photovoltaic systems** PV systems shall contribute to the avoidance of network overload. For this purpose, PV system power is divided into three power groups: – For PV systems up to and including 30 kWp, the system operator may chose between two options: a) by means of a corresponding inverter design or a certified technical control, the active power feed-in of the PV system shall be permanently limited to a maximum value of 70 % of the installed module power at the network connection point with the power gradients given in 5.7.4.1; or b) the PV system shall be provided with a technical means for remote-controlled reduction of the feedin power by the network operator. – PV systems > 30 kWp up to and including 100 kWp shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator. – PV systems > 100 kWp shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power. If the installed total power increases to > 100 kWp due to the installation of a further PV system on the same plot or building within a period of 12 months, legal provisions require implementation of the feed-in management for systems > 100 kWp while providing the actual feed-in power for the total power..	The active power can be remote-controlled on the communication interface	P
	Cogeneration of power and heat (CHP) systems, wind, biogas, hydroelectric power as well as landfill and sewage gas systems Those PV systems with P_{Amax} > 100 kW shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power.		N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Storage units buffering EEG or KWKG systems Those storage units with P_{Amax} > 100 kW shall be provided with a technical means enabling the remotecontrolled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power. These requirements do not apply if the feeding into the network of the network operator by a storage unit is prevented by technical control means. This shall be demonstrated by means of a manufacturer's declaration.		N/A
	Any EEG and KWKG systems with an intelligent measurement system If an intelligent measurement system is present, the network operator may demand the metering point operator to transmit network state data (i. e. also the actual feed-in power).		N/A
	Any power generation systems and storage units other than those indicated above All power generation systems and storage units shall be provided with technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power.		P
5.7.4.2.2	**Implementation of network security management** Power generation systems and storage units shall be able to reduce their active power to a power value predetermined by the network operator at the network connection point without disconnecting from the network. The following values have proved effective: 100 %/60 %/30 %/0 % in relation to the installed active feed-in power P_{Amax}. Instead of reducing the generated active power, the consumed power of the customer installation can be increased, too. The sum of the reduced generated active power and/or the increased consumed active power at the network connection point shall not deviate by more than ± 5 % from the setpoint of active power limitation. Power reduction shall be possible for any operating state and from any operating point. In case of a redispatch, the power generation systems shall be technically capable of increasing the power to a maximum of P_{Amax} upon the network operator's request.	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.4.2.3	**Active power adjustment at over-frequency and under-frequency** A network frequency outside the tolerance band of ± 200 mHz around the nominal network frequency of 50,0 Hz indicates the presence of a critical system state in the integrated network where any power generation units and storage units shall contribute to the network frequency support. The accuracy of the frequency measurement in the steady state shall be ≤ ± 10 mHz. The requirements given in 5.7.4.3 do not apply to storage units in standby mode. Additionally, DC coupled storage units shall behave as type 2 units. In case of **over-frequency**, an excess of generated power is opposed by a deficit of consumed power. Therefore, all power generation units and storage units shall be able to adjust the active power working point at an over-frequency up to a maximum of 51,5 Hz (see Figure 14 and Figure 15). Power generation units shall enable the frequency for starting this frequency-dependent active power feed-in to be set to a value between 50,2 Hz and 50,5 Hz. Unless specified otherwise by the network operator, this start frequency shall be set to 50,2 Hz. The static value of the frequency-dependent active power feed-in shall be adjustable within a range of 2 % to 12 %. This corresponds to a power gradient within a range of 16,67 % of P_{ref} per Hertz (s = 12 %) to 100 % of P_{ref} per Hertz (s = 2 %). Unless specified otherwise by the network operator, a gradient of 40 % of P_{ref} per Hertz (s = 5 %) shall be set (see Figure 14). For storage units, the generated active power with a gradient of 40 % of P_{Emax} per Hertz (s = 5 %) shall be reduced or increased (see Figure 15). Consequently, the power generation unit or the storage unit will constantly move up and down along the frequency characteristic within the frequency range of 50,2 Hz (unless specified otherwise for power generation units by the network operator) to 51,5 Hz with regard to its maximum possible active power feed-in (“operation along the characteristic”).	(See appended table) The starting frequency can be set from 50.2 to 50.5Hz, And, power gradient 2%-12% adjustable Default 50.2 and power gradient 5% setting.	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	At frequencies below 49,8 Hz, all power generation units shall increase the instantaneous generated active power P_{mom} with a gradient of 40 % P_{Emax} per Hertz (s = 5 %) to its technically possible maximum value. For storage units, a gradient of 100 % P_{Emax} per Hertz (s = 2 %) applies. The maximum value is determined by the actual primary energy supply as well as the actually usable storage power. Power reductions for the protection of operating equipment are permitted even at under-frequency. For CHP systems, power reductions resulting from a heat-lead operating mode or a power drop due to the rotational speed are also permitted. Storage units dedicated to other purposes (e. g. gas storage units in biogas systems, DC buffer storage elements for self-consumption etc.) should be activated for this purpose. System-integrated storage units with an energy level below $P_n \times 30$ s (e. g. smoothing chokes, indirect capacitors etc.) may be neglected for this application. Consequently, power generation units and storage units will constantly move up and down along the frequency characteristic also within the frequency range of 49,8 Hz to 47,5 Hz or 47,8 Hz with regard to their maximum possible active power feed-in ("operation along the characteristic"). At an under-frequency within the range of 49,8 Hz to 47,5 Hz, all storage units in charging mode shall reduce their instantaneous charging power according to the characteristic curve shown in Figure 15 to its technically possible minimum value ("operation along the characteristic"). In addition, storage units, as far as their charging state permits, shall change into the operating mode "energy supply" and increase their power according to the characteristic curve shown in Figure 15. In this case, system stability is of higher priority than a potential restraint for feeding storage energy into the network of the network operator based on technical/financial requirements. At network frequencies f < 47,5 Hz, power generation units and storage units shall disconnect from the network (see Figure 14 and Figure 15).	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Requirements for the control times for power generation units and storage units The initial time delay T_V of the frequency-dependent adjustment of the active power output at over-frequency and under-frequency is part of the transient period and shall preferably be ≤ 2 s. In case of a time delay > 2 s, the operator of the power generation system shall justify that delay by submitting technical proof to the transmission network operator. For type 2 power generation units and storage units, the necessary initial time delays T_V for reaching the required transient periods are significantly shorter than 2 s. For the time curve of the frequency-dependent active power adjustment, the following conditions regarding the initial time delay T_V and the transient period $T_{an\_90\ \%}$ shall be observed: – After $T_V + 0{,}1 \times (T_{an\_90\ \%} - T_V)$ has elapsed, a value of at least 9 % of the required power adjustment ΔP has been reached. – After the transient period $T_{an\_90\ \%}$ has elapsed, a value of 90 % of the power adjustment ΔP has been reached.		P
	During the control process (“operation along the characteristic”), the power generation unit and the storage unit shall respond as quickly as possible to sudden network frequency changes within a frequency range of 50,2 Hz to 51,5 Hz (subject to capability as declared by the manufacturer) with a transient period of 8 s for $\Delta P \leq 45\ \%$ of P_{Emax} and ΔP for power changes beyond that in case of type 1 units and type 2 units with rotating machinery and 2 s in case of all other type 2 power generation units and 1 s in case of storage units. The settling period shall not exceed 30 s for type 1 units and type 2 units with rotating machinery or 20 s for all other type 2 power generation units and for storage units. After settling, the supplied active power should deviate by ≤ ± 10 % P_{Emax} from the set-point. The same requirements shall be applied to the active power increase at an under-frequency between 49,8 Hz and 47,5 Hz.		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Conditional requirements based on technical restrictions As an alternative to active power reduction at over-frequency, non-controllable power generation units may disconnect from the network within the frequency range of 50,2 Hz to 51,5 Hz; in that case, uniform distribution of the disconnection frequency in maximum increments of 0,1 Hz shall be ensured for each system type by the manufacturer. Power generation units of limited variability, e. g. only within the range of 70 % to 100 % P_{Emax}, can be curtailed within that range in accordance with the characteristic curve. Outside the controllable range, disconnection is then carried out according to the uniformly distributed shut-down limit curve. For power generation units with combustion engines or gas turbines, active power reduction occurs with a power gradient of at least 66 % P_{Emax} per minute (equals 1,11 % P_{Emax} per second). Thus, the transient period of 8 s can be observed up to a power reduction of 8,88 % P_{Emax}. In case of a greater change of frequency, the transient period is accordingly higher. Linear generators, such as stirling machines up to a maximum apparent power of $S_{Amax} \leq 4{,}6$ kVA, are exempt from the active power feed-in at over/under-frequency. They may remain connected to the network within a frequency range between 50,2 Hz and their maximum upper frequency limit and may disconnect from the network if this value is exceeded or, at the latest, when a frequency of 51,5 Hz is reached or exceeded. At an under-frequency between 49,8 Hz and their maximum lower frequency limit, linear generators should remain connected to the network but shall disconnect from it at the latest when a frequency of 47,5 Hz is reached or exceeded.		N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	End of critical network state and return to normal operation Even if the network frequency has resumed a value within the tolerance band of 50,0 Hz ± 200 mHz after a frequency deviation, a critical network state has still to be assumed initially. The time for transition from the critical network state to normal operation is limited by a maximum change of the active power set-point based on P_{mom}. This change of the active power set-point (except for providing the operating reserve) shall be limited to a maximum gradient of 10 % of the active power P_{Emax} per minute (under consideration of 5.7.1). Only after the network frequency has been within the tolerance band of 50,0 Hz ± 200 mHz for 10 min continuously, the normal operation of the network is deemed to be restored whereupon this requirement does no longer apply.		P
5.7.4.4	**Voltage-dependent active power reduction** In order to avoid disconnection of the power generation system due to over-voltage protection $U>$, it is permissible to reduce the active power feed-in as a function of the voltage of (a) power generation unit(s). Implementation is then chosen by the system manufacturer. This is not considered an active power reduction in the context of feed-in management in compliance with EEG. Surges or oscillations of the active power feed-in are not permitted for that purpose.		N/A
5.7.5	**Short-circuit contribution** Due to the operation of a power generation system, the short-circuit current of the low-voltage network is increased by the short-circuit current of the power generation system. Therefore, the short-circuit current of the power generation system to be expected at the network connection point shall be indicated in accordance with 4.2. For the determination of the initial short-circuit AC current contribution I_{kA} of a power generation system, the following roughly estimated values can be assumed: – for synchronous generators: 8 times the rated current; – for asynchronous generators: 6 times the rated current; – for generators and storage units with inverters: the rated current. If the power generation system causes a short-circuit current increase in the network operator's network in excess of the rated value, then connection owner and network operator shall agree upon appropriate measures limiting the short-circuit current from the power generation system accordingly.		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6	**Construction of the power generation system/network and system protection (NS protection)**		P
6.1	**General requirements** The network and system protection (NS protection) is a type-tested protective device with a NS protection certificate (see Form E.6) wherein all protective functions specified in 6.5 are installed. The NS protection acts on the interface switch in accordance with 6.4. Depending on the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point $\sum S_{Amax}$, the following conditions apply to the NS protection:		P
6.2	**Central NS protection** The central NS protection shall be accommodated, installed and connected as an independent equipment at the central meter panel in a suitable circuit distributor in accordance with VDE-AR-N 4100, Clause 8, Paragraph 1, and not in the upper connection compartment according to VDE-AR-N 4100, 7.2, Paragraph 11. Examples of the arrangement of the central NS protection and hence the connection of power generation systems to meter panels are shown in Annex C. For central NS protection, it is additionally required to carry out a trigger test for checking the tripping circuit “NS protection – interface switch”. For this purpose, the central NS protection is provided with a means for tripping the interface switch (e. g. by means of a test button) for testing purposes. Activation shall be visualised at the interface switch.	Integrated NS protection	N/A
6.3	**Integrated NS protection** In the case of integrated NS protection, the NS protection can be integrated in the programmable system control of the power generation units (e. g. in the inverter control). In this case, the means for testing the tripping circuit “NS protection – interface switch” by the system installer is not required. The integrated NS protection acts on an integrated interface switch (see 6.4.3).		P
6.4	**Interface switch**	The PSU include integrated interface switch and is type tested in the report	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6.4.1	**General** For the connection of the power generation system to the network operator's low-voltage network or to the remaining customer installation, an interface switch shall be used. The interface switch is controlled by the NS protection and automatically triggers if at least one protective function responds. As interface switches, the switching devices of the individual power generation units (integrated interface switch) can be used. The integrated interface switches can also be used in combination with the central NS protection. In any case, central NS protection from $\sum S_{Amax}$>30 kVA (sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point; for exceptions, see 6.1) shall be directly connected to the central meter panel. Where a signal is routed to a spatially separate switching device, it shall be ensured that the required disconnection periods given in Table 2 are observed and lead to the disconnection of the power generation system. During commissioning of the power generation system, a tripping test of the interface switch shall be conducted. The interface switch shall be designed for the rated conditional short-circuit current and under consideration of the protective devices required according to 6.5 and it shall enable instantaneous tripping. The switching capacity of the interface switch shall be rated according to the rated current of the upstream fuse or the maximum initial short-circuit AC current contribution of the power generation system, whichever is the higher. The functional check of the interface switch shall be carried out according to a) or b) or c): a) by using an interface switch which, in its active state, requires a control voltage to be applied continuously and which disconnects automatically when this voltage is no longer applied. The operational connection and disconnection processes shall be monitored; b) by connection and disconnection of the interface switch via the NS protection and monitoring its proper functioning (e. g. break contact of a monitoring contact) at least once daily; c) by using the integrated interface switch and the integrated NS protection for PV and battery inverters in compliance with DIN EN 62109 (VDE 0126-14). When a defect of the interface switch is detected, the power generation system shall neither feed in nor reconnect.	Integrated interface switch has been type tested in compliance with DIN EN 62109	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6.4.2	**Central interface switch** The central interface switch shall be a galvanic break device (e. g. mechanical contactor, protective motor switch, mechanical circuit breaker). For a power generation system required to contribute to the dynamic network stability, an interface switch enabling compliance with the requirements specified in 5.7.3 (no malfunction at under-voltage in the context of the FRT requirements) shall be used. The interface switch shall be installed in the distribution field of or directly at the central meter panel in a circuit distributor. Examples of the arrangement of interface switches and hence the connection of power generation systems to meter panels are shown in Annex C.		N/A
6.4.3	**Integrated interface switch** For the construction of the interface switch, the requirements specified in 6.1 shall be considered. The interface switch (e. g. power relay, mechanical contactor, mechanical circuit-breaker, etc.) ensures galvanic breaking. For power generation systems with inverters, the interface switch shall be provided on the inverter's network side.	Both the relays have mechanical contacts rated 250V 16A, with the separation of the contacts of > 1.5 mm each. The switches are located both line and neutral poles. The rating of the interface switch as below 1, Hongfa HF161F-W 2, Panasonic,ALFG2P Interface switch's time delay is 10 ms max.	P
6.5	**Protective devices and protection settings**		P
6.5.1	**General** The purpose of NS protection is to disconnect the power generation system from the network in the event of inadmissible voltage and frequency values (also refer to DIN VDE 0100-551 (VDE 0100-551)). This is meant to prevent inadvertent feed-in from the power generation system into a partial network separated from the main distribution network.		P

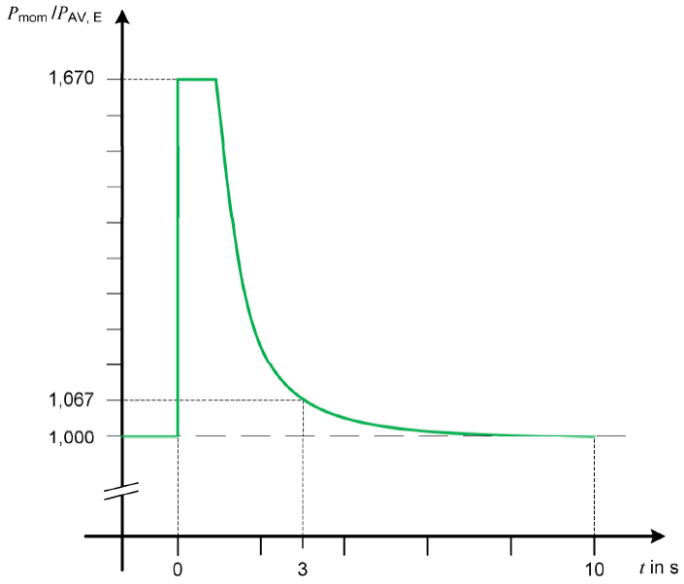
VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6.5.2	**Protective functions** The NS protection shall be provided with a means for preventing unauthorised access (z. B. sealable, password protection). The rise-in-voltage protection $U>$ shall be designed such as to be adjustable in the NS protection (see Table 2, Footnote b). Additionally, the time delay of the voltage drop protection $U<$ and $U<<$ for directly coupled synchronous and asynchronous generators with $P_n > 50$ kW shall also be designed such as to be adjustable in the NS protection (see Table 2, Footnote d). Any other protective functions listed in 6.5.1 are either to be installed permanently, i. e. not adjustable, in the NS protection or to be provided with an additional separate protection against unauthorised access (e. g. password protection) for preventing modifications.	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6.5.3	**Islanding detection**	(See appended table)	P
6.6	**Further requirements for power generation systems**	Shall be considered in PGS	N/A
7	**Metering for billing purposes**		N/A
8	**Operation of the system**		P
8.1	**General**		P
8.2	**Special aspects of the management of the network operator's network**		N/A
8.3	**Connection conditions and synchronisation**		P
8.3.1	**General** Power generation systems and storage units shall be connected to the network operator's network only if a suitable device determines that both the mains voltage and the mains frequency are within the tolerance range of 85 % U_n to 110 % U_n or 47,5 Hz to 50,1 Hz, respectively, for a period of at least 60 seconds. Additionally, the delay times for the reconnection of a generator and the staggered times applicable when connecting several generators shall be sufficient for safely finishing any control and adjustment processes within the power generation system and/or the storage unit caused by the connection. In case of power generation systems and storage units being reconnected to the network operator's network at the tripping of the NS protective device or the $P_{AV, E}$ monitoring, the active power of controllable power generation systems and storage units supplied to the network operator's network shall not exceed the gradient of 10 % of the active power P_{Amax} per minute. Non-controllable power generation systems and storage units can connect after 1 min to 10 min (random generator) or later.	(See appended table)	P
8.3.2	**Connection of synchronous generators**		N/A
8.3.3	**Connection of asynchronous generators**		N/A
8.3.4	**Connection of power generation units and storage units with inverters** Power generation units with inverters (such as photovoltaic systems) and storage units with inverters shall only be connected with $k_{imax} \leq 1,2$.	The k_{imax} is 0.06	P
8.4	**Special aspects regarding the planning, installation and operation of power generation systems and storage units each with PAmax ≥ 135 kW**		N/A
9	**Verification of electrical properties**		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Annex A: Explanations (informative)		
	Annex B: Connection examples and measurement strategies (informative)		
	Annex C: Examples of meter panel configurations (informative)		
	Annex D: Examples for the connection evaluation of power generation systems - Connection of a 20 kW PV system (informative)		
	Annex E: Forms (mandatory)		**P**
E.1	Application procedure		N/A
E.2	Data sheet for power generation systems		N/A
E.3	Data sheet for storage units		N/A
E.4	Unit certificate		P
E.5	Test report “Network interactions” for power generation units with an input current > 75 A		N/A
E.6	Certificate of the network and system protection		P
E.7	Requirements for the test report for the NS protection		P
E.8	Commissioning protocol for power generation systems and/or storage units		N/A
E.9	Type approval procedure		N/A

Appended Table - Testing Result

5.5.2	Table: $P_{AV, E}$ monitoring (feed-in limitation)	P



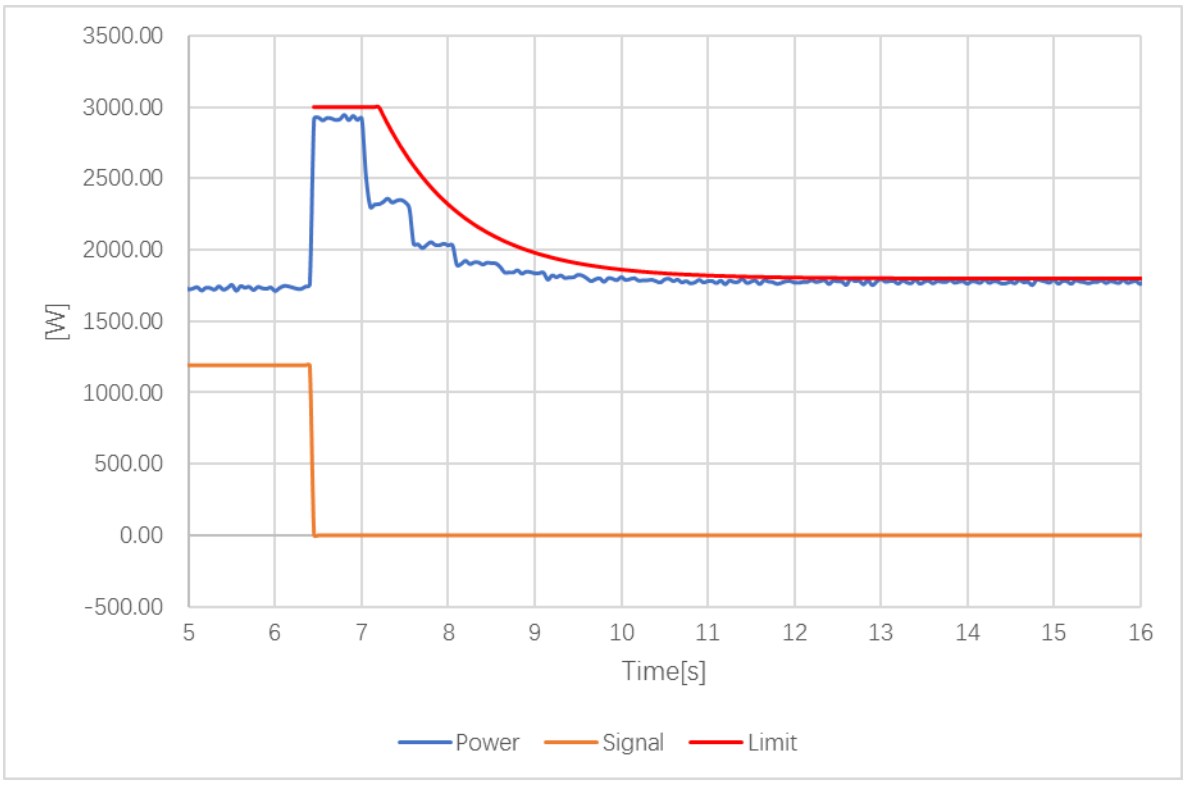
Before load drop			
Ouput power in the network connection		1766.27W	
After load drop			
Power in 3s	1787.78W	Power in 10 s	1780.11W
Time to exceed the ative power curve (ms)			173.2

Supplementary information:

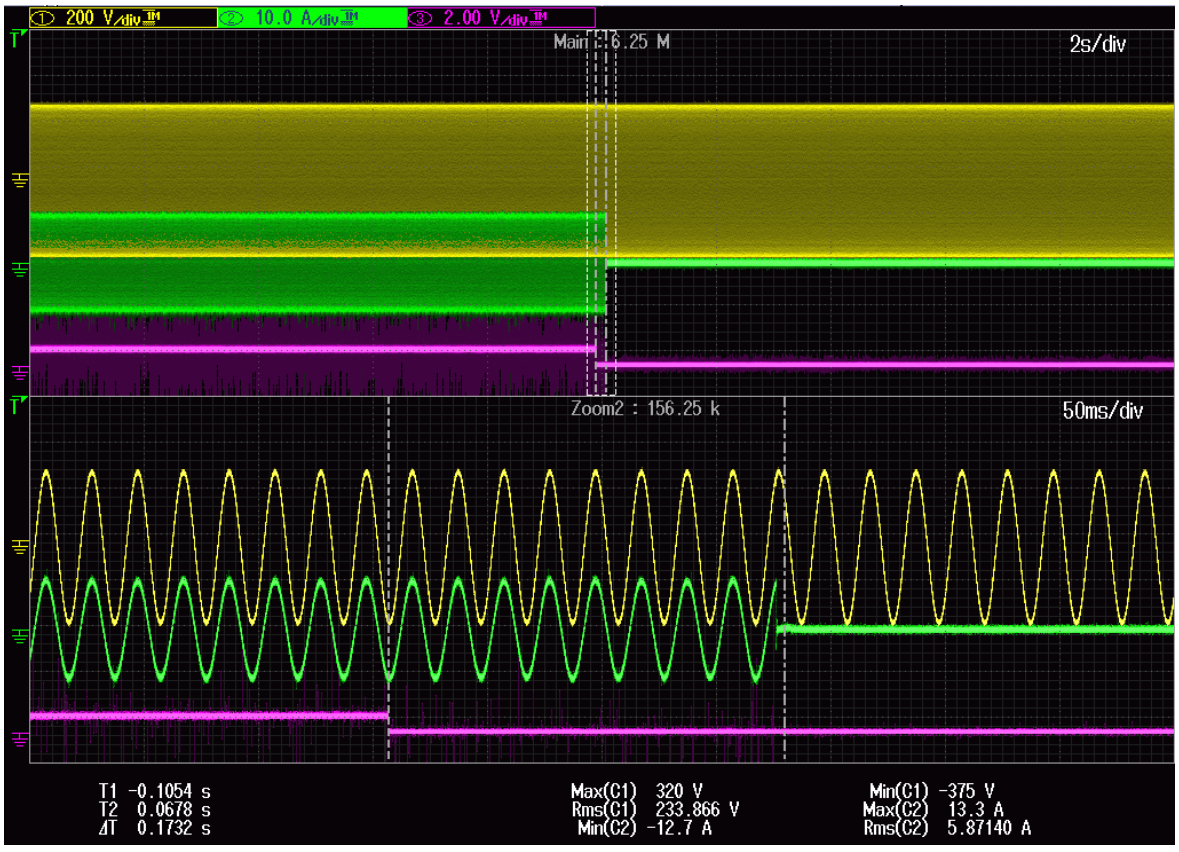
The CT is used for test together as following:

Manufacturer: BEIJING STM MEASUREMENT & CONTROL TECHNOLOGY CO., LTD

Type: HY33C1



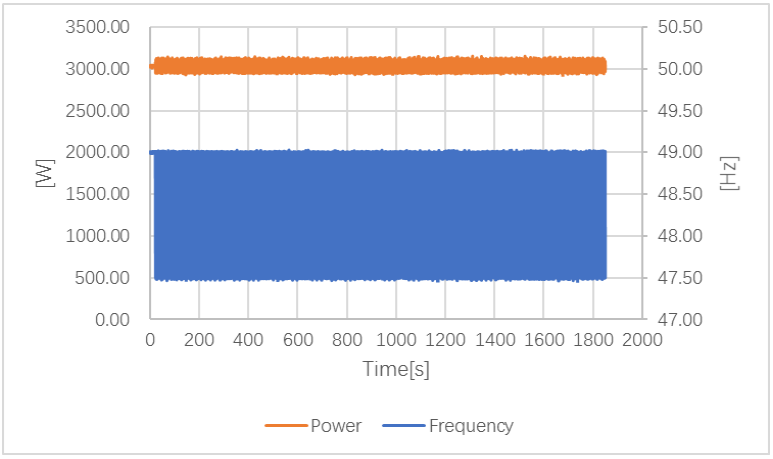
Disconnect time for exceeding

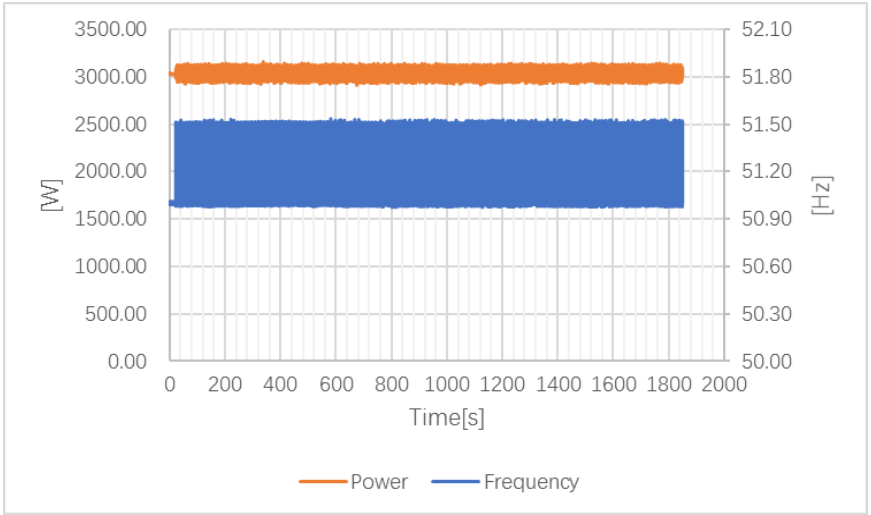


5.7	Table: Behaviour of the power generation system at the network	P

Frequency range	Operating period
47,5 Hz to 49,0 Hz	≥ 30 min
49,0 Hz to 51,0 Hz	unlimited
51,0 Hz to 51,5 Hz	≥ 30 min

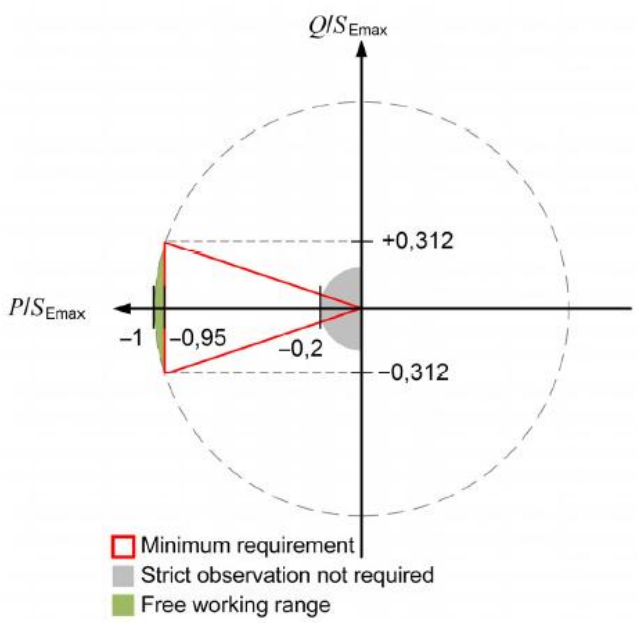
Power generation units shall be able to ride through rapid frequency changes without disconnection from the network. This requirement applies provided the following averaged rates of change of frequency (RoCoF) are
not exceeded:
– ± 2,0 Hz/s for a moving time slot of 0,5 s; or
– ± 1,5 Hz/s for a moving time slot of 1 s; or
– ± 1,25 Hz/s for a moving time slot of 2 s.
In case of rapid frequency changes, frequency measurements shall not take more than 200 ms. The minimum accuracy of frequency measurements is ± 50 mHz.

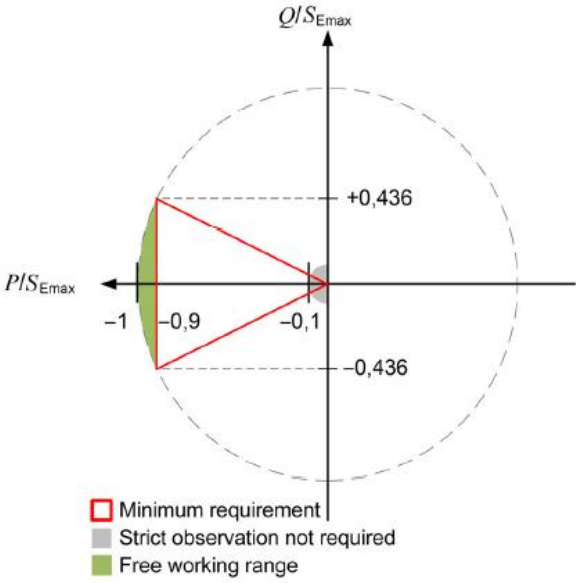




Supplementary information:

5.7.2.3	P/Q diagram	P

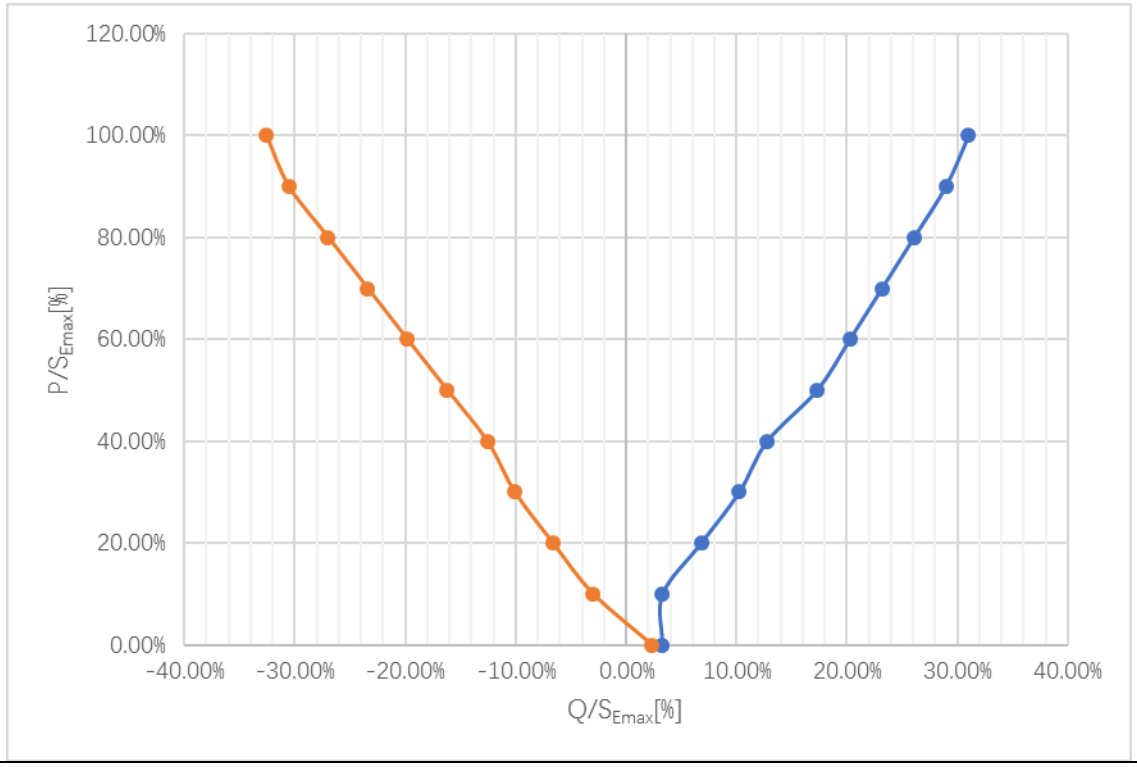




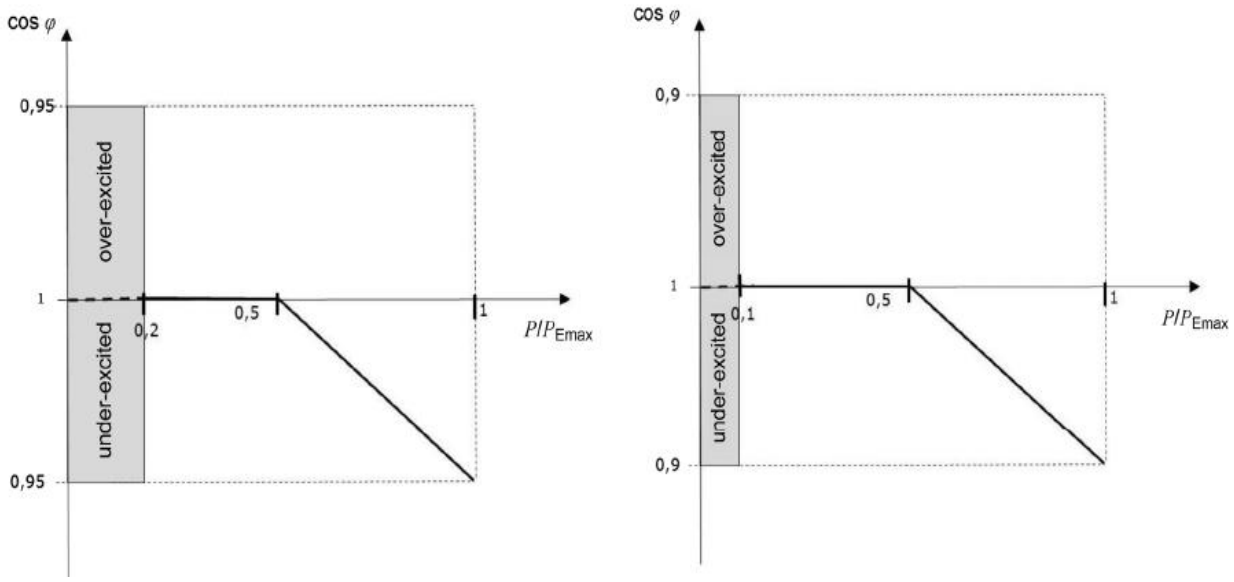
Model: SOFAR 3000TL

P/Pn[%] setpoint	P[W]	Q[Var]	Cosφ	Cosφ Set-point	Δcosφ	Q[Var] setpoint	$\Delta Q/P_{Emax}$ [%]	LIMITE ΔQ[%]
0	139.77	98.20	0.8168	--	--	--	3.2733	10%
10	294.81	98.94	0.9480	--	--	--	3.2980	10%
20	603.97	204.16	0.9471	0.95	-0.0029	197.21	0.2317	±4%
30	912.86	307.18	0.9478	0.95	-0.0022	295.82	0.3787	±4%
40	1220.76	382.98	0.9541	0.95	0.0041	394.42	-0.3813	±4%
50	1525.38	518.55	0.9468	0.95	-0.0032	493.03	0.8507	±4%
60	1830.73	607.71	0.9491	0.95	-0.0009	591.63	0.5360	±4%
70	2133.08	694.70	0.9508	0.95	0.0008	690.24	0.1487	±4%
80	2435.08	781.73	0.9521	0.95	0.0021	788.84	-0.2370	±4%
90	2735.41	868.24	0.9531	0.95	0.0031	887.45	-0.6403	±4%
100	2949.35	930.31	0.9537	0.95	0.0037	986.05	-1.8580	±4%

P/Pn[%] setpoint	P[W]	Q[Var]	Cosφ	Cosφ Set-point	Δcosφ	Q[Var] setpoint	$\Delta Q/P_{Emax}$ [%]	LIMITE ΔQ[%]
0	139.27	70.35	0.8925	--	--	--	2.3450	10%
10	293.54	-89.72	0.9563	--	--	--	-2.9907	10%
20	602.62	-199.22	0.9495	0.95	-0.0005	-197.21	-0.0670	±4%
30	910.84	-302.85	0.9505	0.95	0.0005	-295.82	-0.2343	±4%
40	1218.37	-377.72	0.9551	0.95	0.0051	-394.42	0.5567	±4%
50	1523.30	-486.04	0.9527	0.95	0.0027	-493.03	0.2330	±4%
60	1828.37	-594.72	0.9509	0.95	0.0009	-591.63	-0.1030	±4%
70	2131.13	-702.04	0.9498	0.95	-0.0002	-690.24	-0.3933	±4%
80	2432.57	-809.34	0.9489	0.95	-0.0011	-788.84	-0.6833	±4%
90	2732.84	-916.90	0.9481	0.95	-0.0019	-887.45	-0.9817	±4%
100	2900.99	-977.96	0.9476	0.95	-0.0024	-986.05	-0.0670	±4%

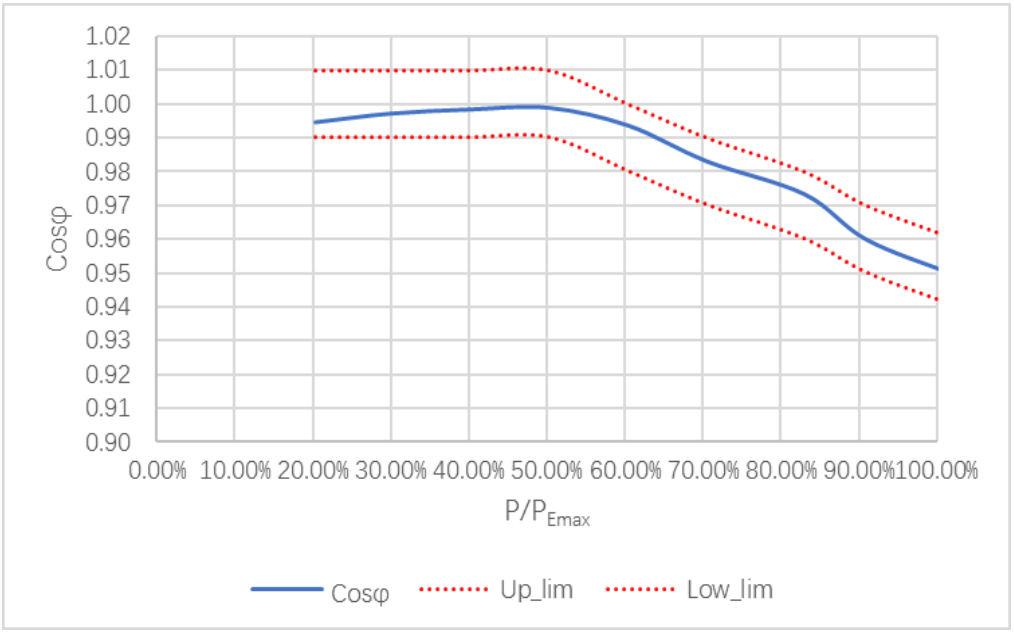


5.7.2.3	Table: Displacement factor/active power characteristic curve cos φ (P)	P

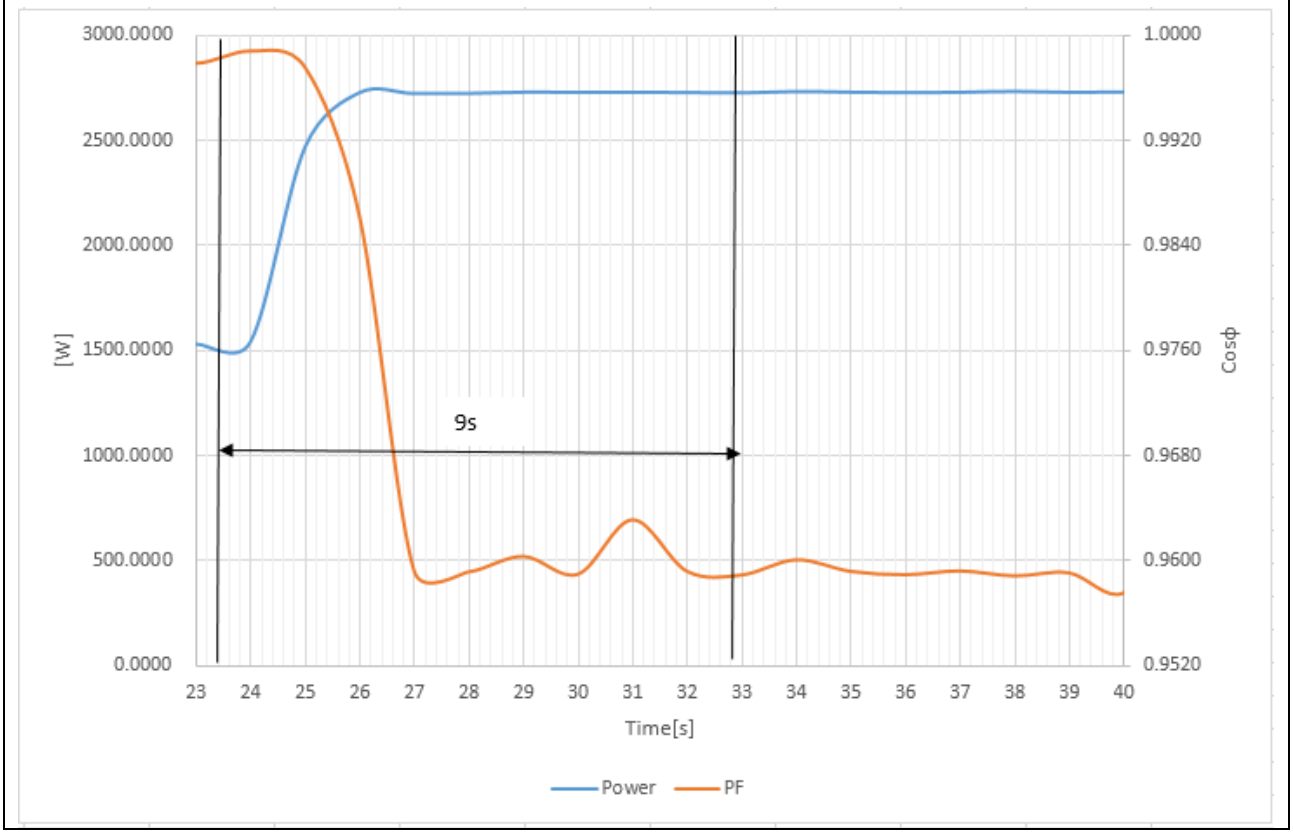


Model: SOFAR 3000TL

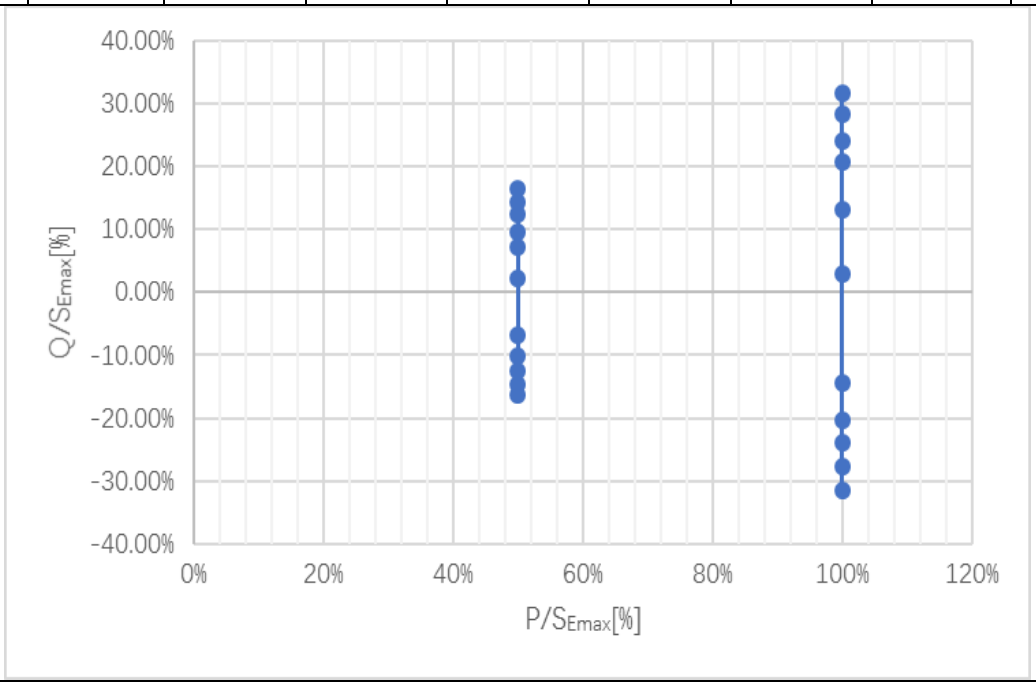
P/Pn[%] setpoint	P[W]	P/Pn [%]	Q[Var]	Cosφ	Cosφ Set-point	Δ Cosφ	LIMITE ΔCosφ
20	597.74	19.92	74.03	0.9924	1.00	-0.0076	±0.01
30	903.37	30.11	99.88	0.9939	1.00	-0.0061	±0.01
40	1208.30	40.28	104.57	0.9963	1.00	-0.0037	±0.01
50	1511.95	50.40	106.54	0.9975	1.00	-0.0025	±0.01
60	1813.78	60.46	-209.40	0.9932	0.99	0.0032	±0.01
70	2113.16	70.44	-392.25	0.9832	0.98	0.0032	±0.01
80	2410.98	80.37	-580.10	0.9723	0.97	0.0023	±0.01
90	2708.42	90.28	-780.64	0.9609	0.96	0.0009	±0.01
100	2920.76	97.36	-931.98	0.9527	0.95	0.0027	±0.01



Setting time:



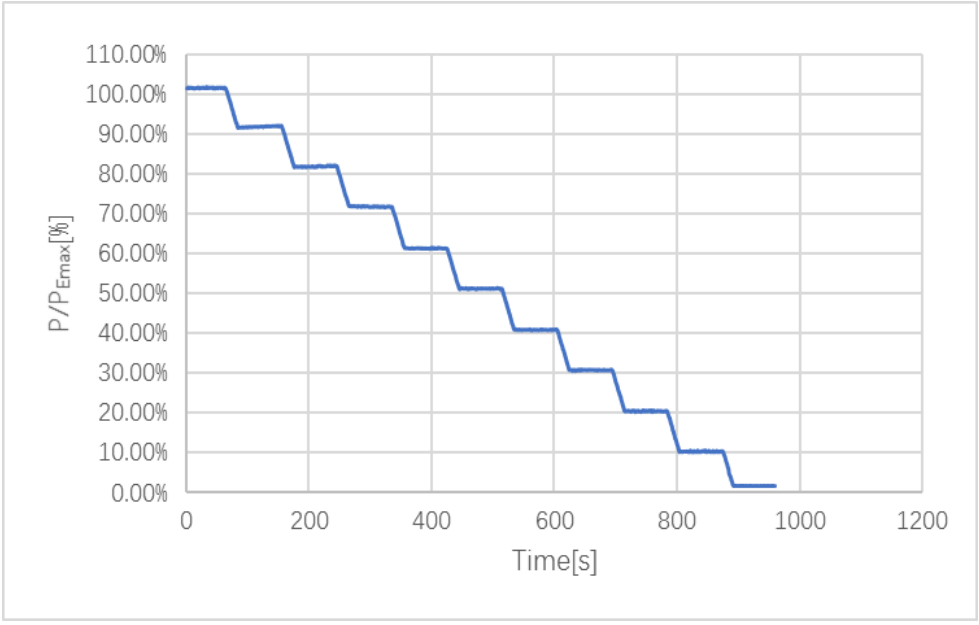
5.7.2.4	Table: Displacement factor cos ϕ							P
Model: SOFAR 3000TL								
P/Pn[%] setpoint	P[W]	Q[Var]	Cosφ	Cosφ Set-point	Δcosφ	Q[Var] setpoint	ΔQ/P_{Emax} [%]	LIMITE ΔQ[%]
50%	1521.45	518.24	0.9466	0.95	-0.0034	493.03	0.8403	±4%
50%	1521.90	457.06	0.9577	0.96	-0.0023	437.50	0.6520	±4%
50%	1522.23	386.26	0.9693	0.97	-0.0007	375.94	0.3440	±4%
50%	1522.47	296.50	0.9816	0.98	0.0016	304.59	-0.2697	±4%
50%	1522.67	107.24	0.9975	0.99	0.0075	213.74	-3.5500	±4%
50%	1526.78	104.79	0.9977	1.00	-0.0023	0.00	3.4930	±4%
50%	1525.56	-249.94	0.9868	0.99	-0.0032	-213.74	-1.2067	±4%
50%	1525.97	-250.99	0.9867	0.98	0.0067	-304.59	1.7867	±4%
50%	1525.38	-350.60	0.9744	0.97	0.0044	-375.94	0.8447	±4%
50%	1524.70	-435.77	0.9615	0.96	0.0015	-437.50	0.0577	±4%
50%	1524.28	-487.10	0.9525	0.95	0.0025	-493.03	0.1977	±4%
P/Pn[%] setpoint	P[W]	Q[Var]	Cosφ	Cosφ Set-point	Δcosφ	Q[Var] setpoint	ΔQ/PEmax [%]	LIMITE ΔQ[%]
100%	2912.32	1026.11	0.9431	0.95	-0.0069	936.75	2.9787	±4%
100%	2944.59	928.96	0.9537	0.96	-0.0063	840.00	2.9653	±4%
100%	2975.85	817.35	0.9643	0.97	-0.0057	729.31	2.9347	±4%
100%	3006.80	683.78	0.9751	0.98	-0.0049	596.99	2.8930	±4%
100%	3012.13	506.01	0.9862	0.99	-0.0038	423.20	2.7603	±4%
100%	3039.01	115.99	0.9993	1.00	-0.0007	0.00	3.8663	±4%
100%	2992.97	-363.21	0.9927	0.99	0.0027	-423.20	1.9997	±4%
100%	2991.55	-539.30	0.9841	0.98	0.0041	-596.99	1.9230	±4%
100%	2989.22	-679.46	0.9751	0.97	0.0051	-729.31	1.6617	±4%
100%	2960.23	-792.53	0.9660	0.96	0.0060	-840.00	1.5823	±4%
100%	2929.99	-890.63	0.9568	0.95	0.0068	-936.75	1.5373	±4%



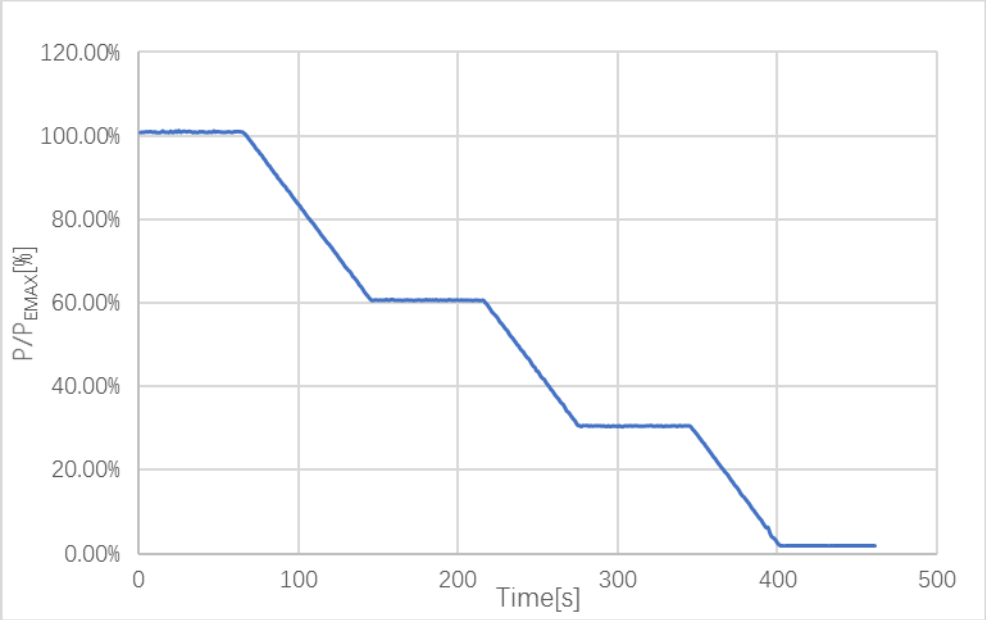
5.7.4	Table: Active power output					P
String	1	U_{DC} =	360 Vdc	Uac = Un	230Vac	P_{Emax} (KW)	3.0

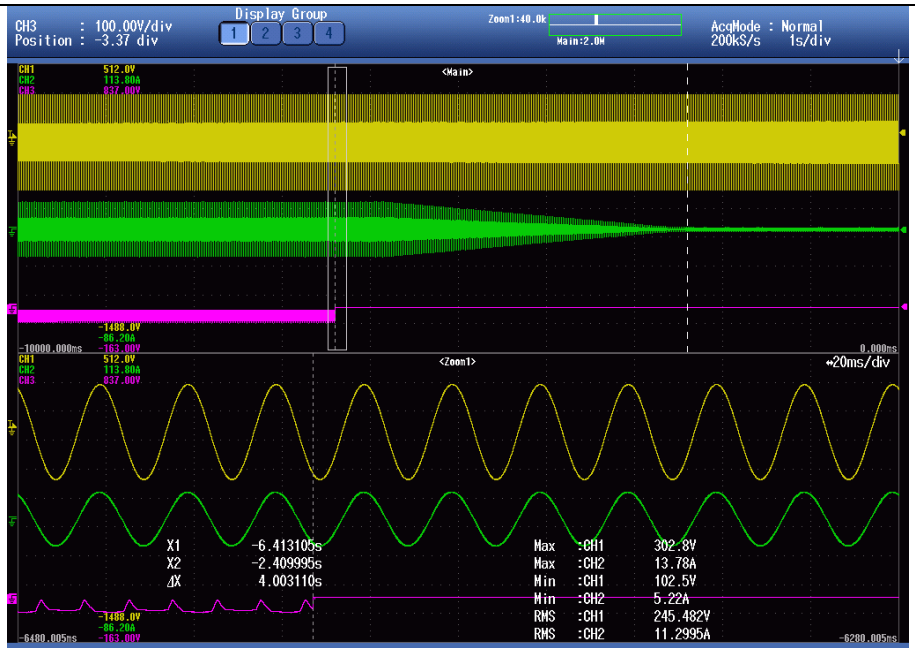
1 min mean value P/Pn Psetpoint (%)	Pmeasured (%)	ΔPmeasured (%)	Limit [%]
100%	101.43	1.43	±5%
90%	91.74	1.74	±5%
80%	81.78	1.78	±5%
70%	71.73	1.73	±5%
60%	61.29	1.29	±5%
50%	51.19	1.19	±5%
40%	40.85	0.85	±5%
30%	30.77	0.77	±5%
20%	20.49	0.49	±5%
10%	10.38	0.38	±5%
0%	1.75	1.75	±5%
The power gradient for increasing and reducing (P_{Emax}/s)			0.556%

Supplementary information:



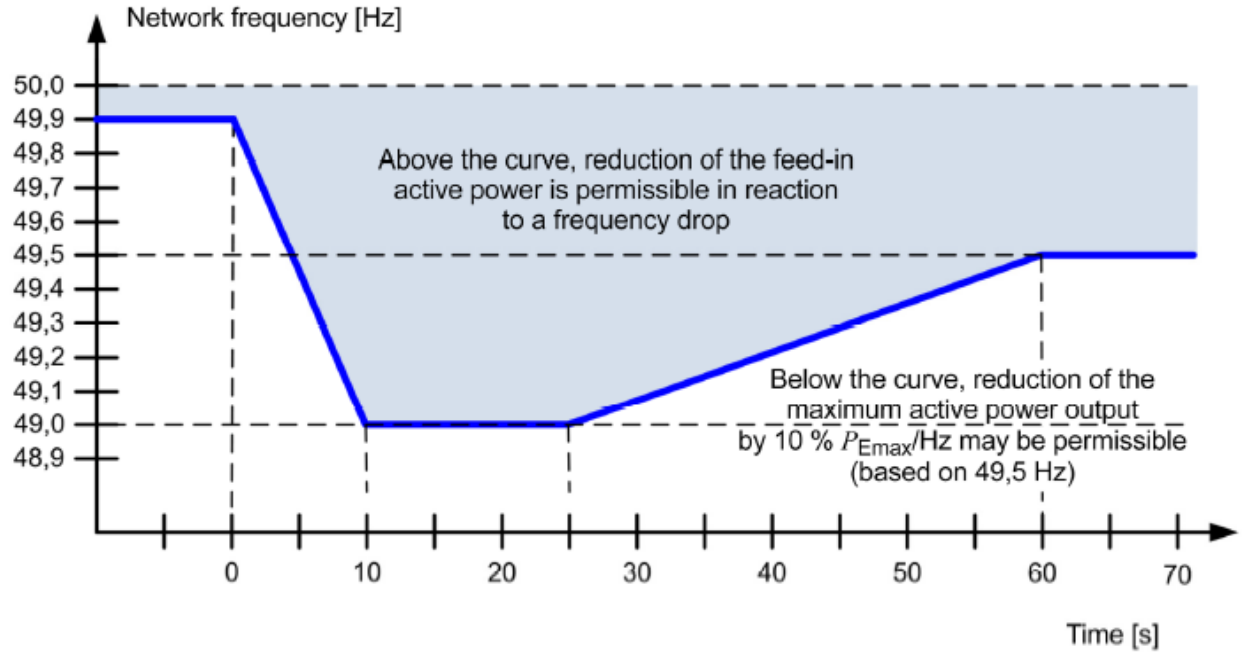
1 min mean value P/Pn	Pmeasured (%)	ΔPmeasured (%)	Limit [%]
100%	101.08	1.08	±5%
60%	60.71	0.71	±5%
30%	30.53	0.53	±5%
0%	1.76	1.76	±5%
The power gradient for increasing and reducing (P_{Emax}/s)			0.513%
Time for Logic interface (at input port) activated			4.0s





Noted: CH3 represents signal for activating logic interface, CH2: Current of EUT, CH1: Voltage of EUT
Logic interface will be specified in the manual

5.7.4.2.3	**Table: Requirement for the output power of the power generation units in the dynamic short-time range**	**P**

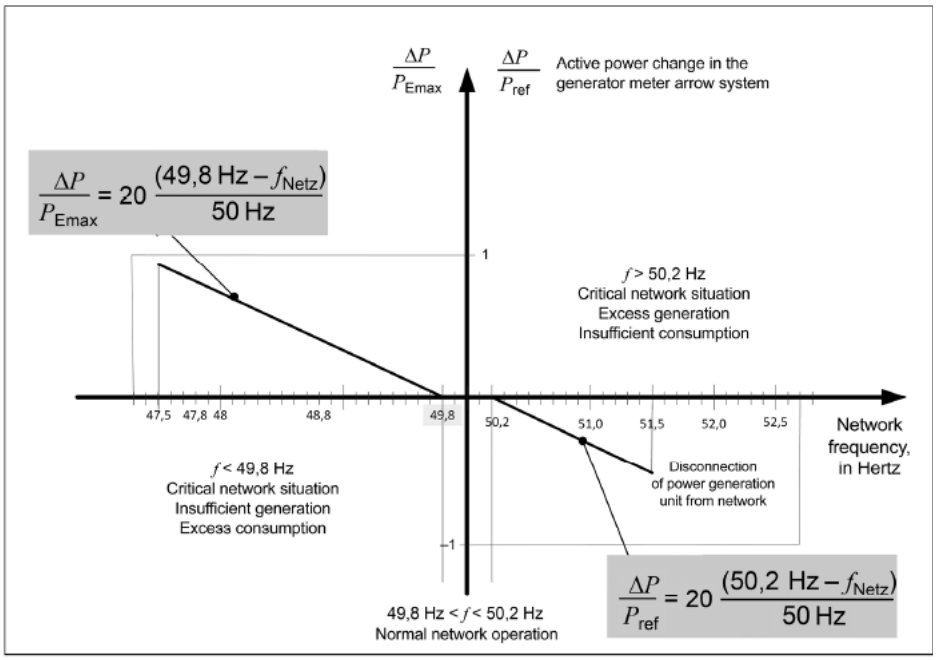


DC input:	AC output:	Rated Output Power
360Vdc	230Vac, 50Hz	3kW

Power Adjustable		
☒adjustable	☐conditionally adjustable PGU	☐linear generators with SEmax ≤ 30kVA

	f (Hz)	Power (W)
50.00 ± 0.01Hz	50.00	3037.16
47.50 ~ 47.60Hz	47.55	3035.26

5.7.4.2.3	Table: Active poewr output feed-in at overfrequency	P

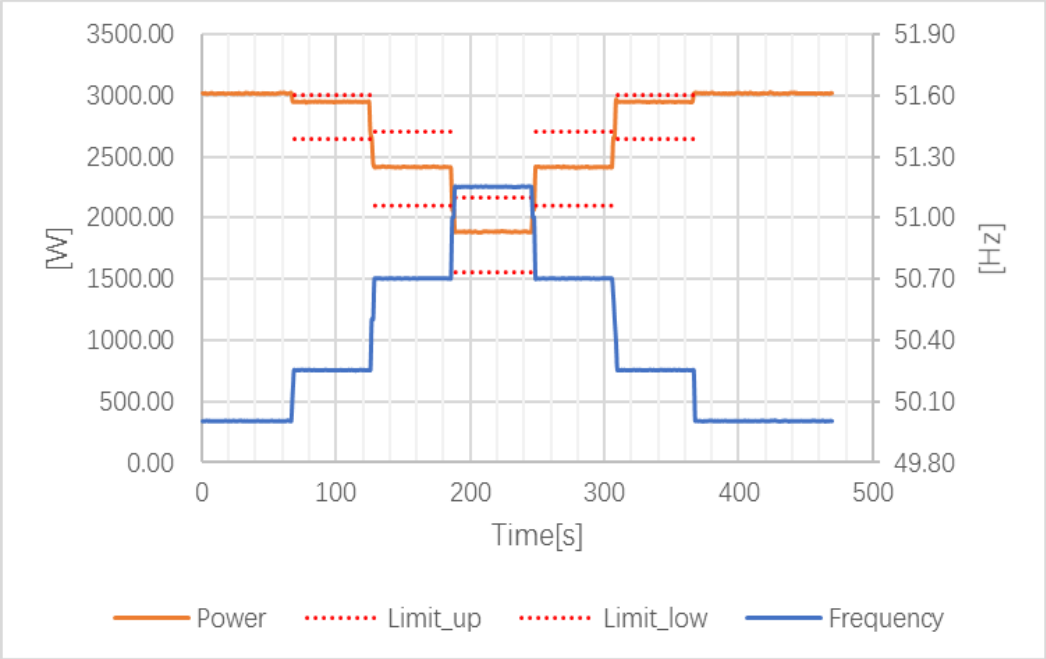


	> 80% P_{Emax}				
	40%P_{ref}(W)		1200	10%P_{Emax} (W)	300
	f (Hz)	Measured output Power (W)	Calculated from standard characteristic curve P (W)	Tolerance between measured P and calculated P (W)	Tolerance Limit (W)
50Hz ± 0.01Hz	50.00	3017.85	--	--	--
50.25Hz ± 0.01Hz	50.25	2945.42	2940	5.42	±300
50.70Hz ± 0.01Hz	50.70	2416.36	2400	16.36	±300
51.15Hz ± 0.01Hz	51.15	1886.02	1860	26.02	±300
50.70Hz ± 0.01Hz	50.70	2415.44	2400	15.44	±300
50.25Hz ± 0.01Hz	50.25	2950.85	2940	10.85	±300
50Hz ± 0.01Hz	50.00	3018.76	--	--	--
	40% ~ 60% of PEmax				
	40%P_{ref}(W)		600	10%P_{Emax} (W)	300
	f (Hz)	Measured output Power (W)	Calculated from standard characteristic curve P (W)	Tolerance between measured P and calculated P (W)	Tolerance Limit (W)
50Hz ± 0.01Hz	50.00	1506.14	--	--	--
50.25Hz ± 0.01Hz	50.25	1415.05	1470	-54.95	±300
50.70Hz ± 0.01Hz	50.70	1160.21	1200	-39.79	±300
51.15Hz ± 0.01Hz	51.15	905.72	930	-24.28	±300
50.70Hz ± 0.01Hz	50.70	1160.32	1200	-39.68	±300
50.25Hz ± 0.01Hz	50.25	1415.50	1470	-54.5	±300
50Hz ± 0.01Hz	50.00	3025.49	--	--	--

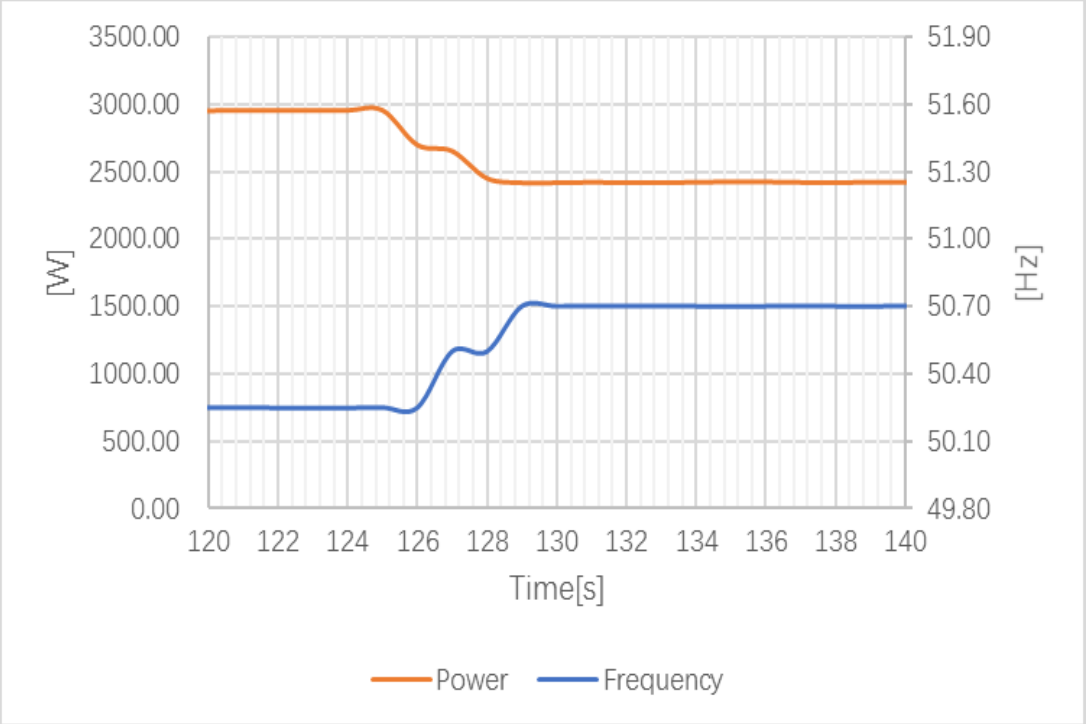
Supplementary information:

When the frequency is return to 50.0Hz, the waiting time in the status for more than 10 min

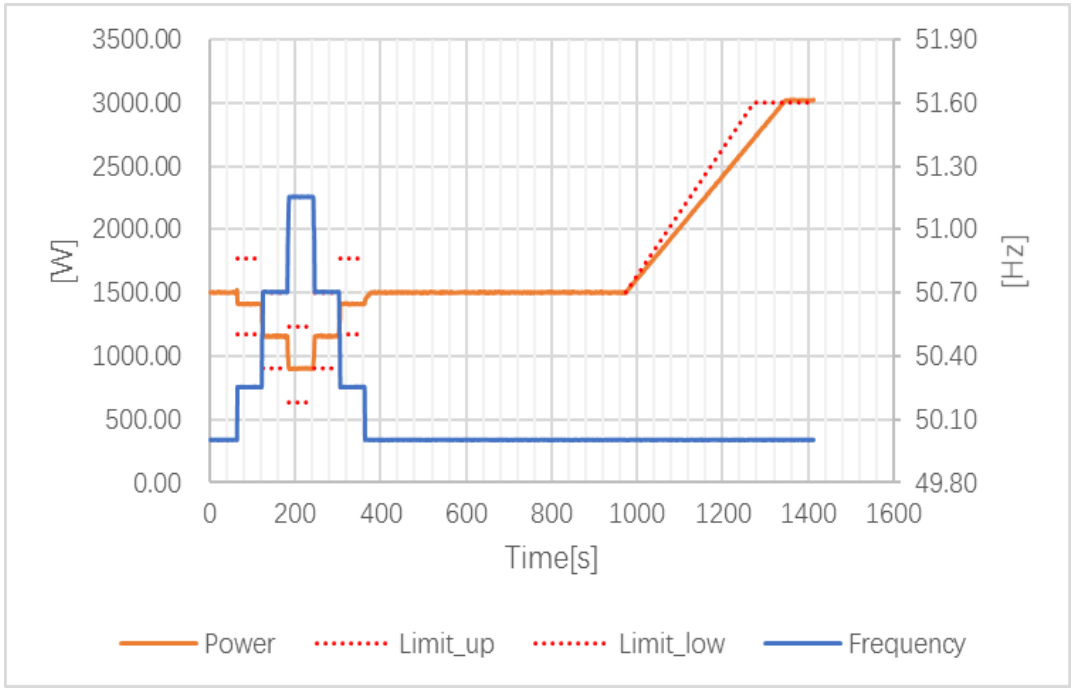
The power gradient is 8.11%P_{Emax}/min



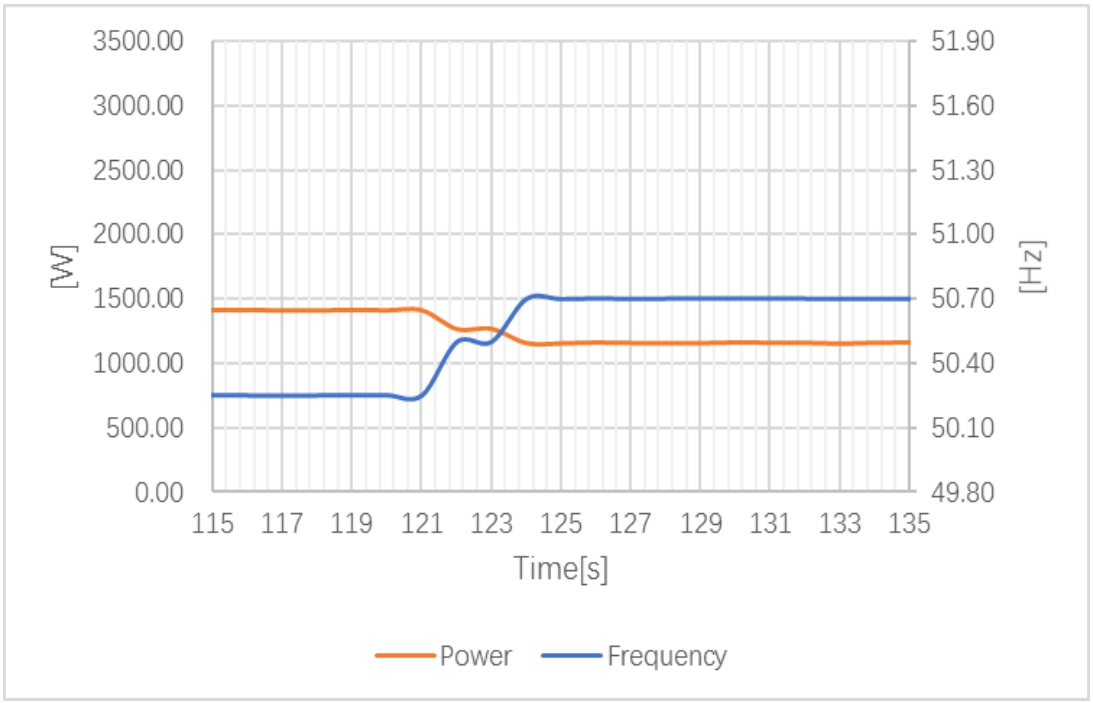
100%



The delay time and the settling time (0s)



50%



The delay time and the settling time (0s)

5.7.4.2.3	Table: Active poewr output feed-in at underfrequency	P

	50% P_{Emax}				
	40%P_{Emax}(W)	1200	10%P_{Emax}(W)	300	
	f (Hz)	Measured output Power (W)	Calculated from standard characteristic curve P (W)	Tolerance between measured P and calculated P (W)	Tolerance Limit (W)
50Hz ± 0.01Hz	50.0	1504.83	--	--	--
49.75Hz ± 0.01Hz	49.75	1542.22	1560	-17.78	±300
48.80Hz ± 0.01Hz	48.8	2667.93	2700	-32.07	±300
48.00Hz ± 0.01Hz	48.0	3013.38	2940	73.38	±300
47.80Hz ± 0.01Hz	47.8	3015.18	3000	15.18	±300
47.60Hz ± 0.01Hz	47.6	3015.56	3000	15.56	±300
47.80Hz ± 0.01Hz	47.8	3015.55	3000	15.55	±300
48.00Hz ± 0.01Hz	48.0	3014.39	2940	74.39	±300
48.80Hz ± 0.01Hz	48.8	2668.97	2700	-31.03	±300
49.75Hz ± 0.01Hz	49.8	1543.86	1560	-16.14	±300
50Hz ± 0.01Hz	50.0	3035.57	--	--	--

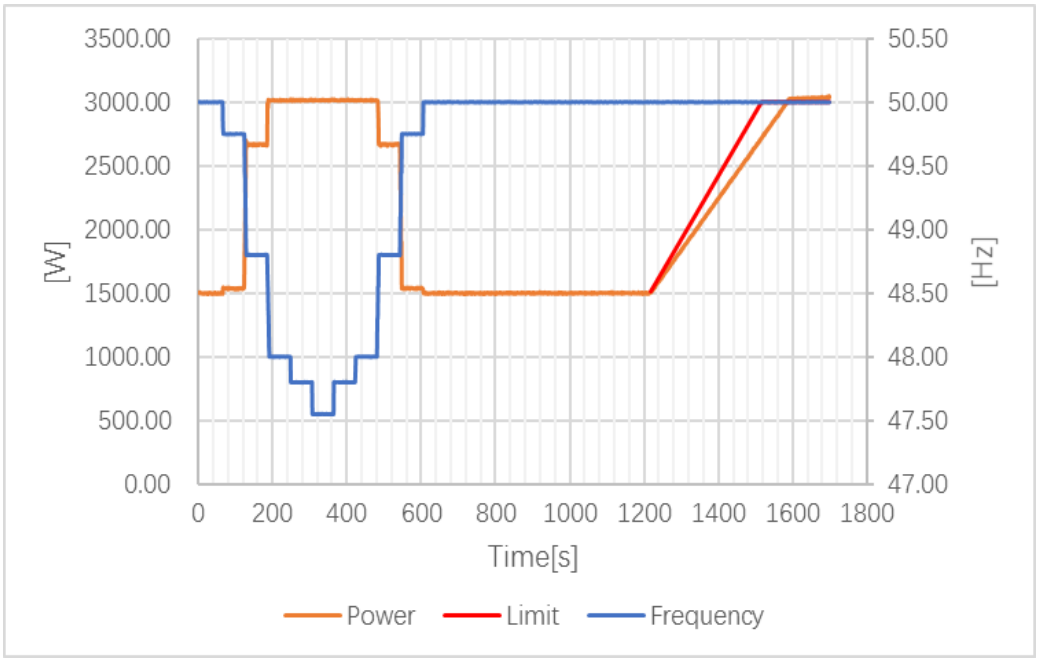
	0% of PEmax				
	40%P_{Emax}(W)	1200	10%P_{Emax}(W)	300	
	f (Hz)	Measured output Power (W)	Calculated from standard characteristic curve P (W)	Tolerance between measured P and calculated P (W)	Tolerance Limit (W)
50Hz ± 0.01Hz	50.0	46.34	--	--	--
49.75Hz ± 0.01Hz	49.75	56.95	60	-3.05	±300
48.80Hz ± 0.01Hz	48.8	1193.96	1200	-6.04	±300
48.00Hz ± 0.01Hz	48.0	2148.87	2160	-11.13	±300
47.80Hz ± 0.01Hz	47.8	2389.02	2400	-10.98	±300
47.60Hz ± 0.01Hz	47.6	2686.70	2640	46.70	±300
47.80Hz ± 0.01Hz	47.8	2388.41	2400	-11.59	±300
48.00Hz ± 0.01Hz	48.0	2150.10	2160	-9.90	±300
48.8Hz ± 0.01Hz	48.8	1191.52	1200	-8.48	±300
49.75Hz ± 0.01Hz	49.75	56.50	60	-3.50	±300
50Hz ± 0.01Hz	50.0	3034.98	--	--	--

Supplementary information:

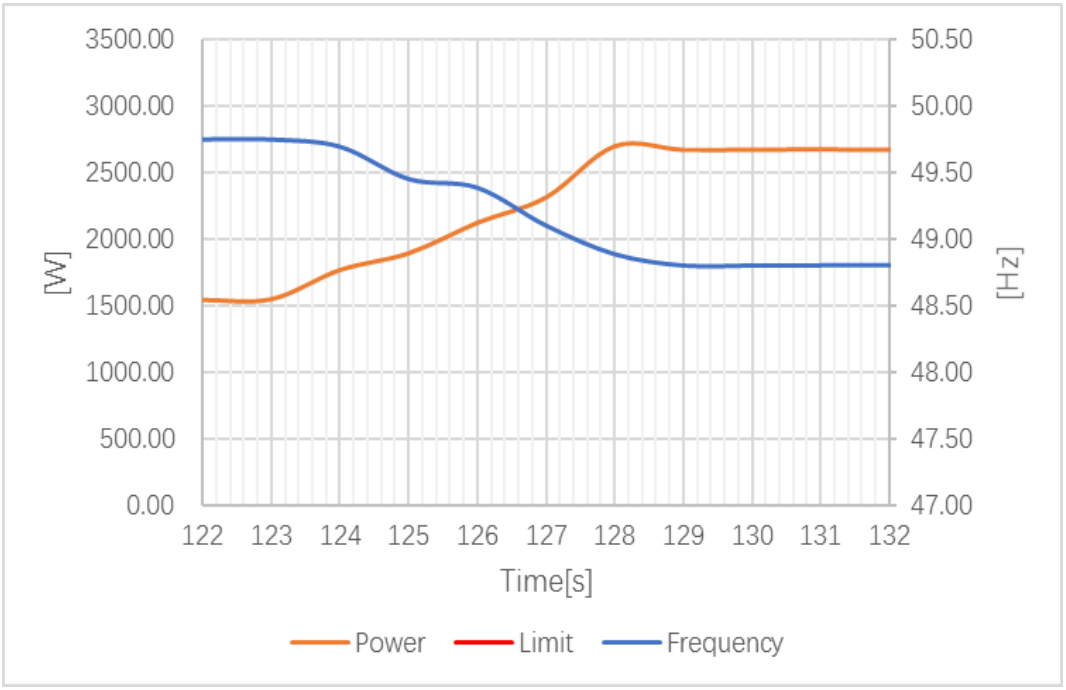
The delay time is less than 2s, the settling time is less than 20s

When the frequency is return to 50.0Hz, the waiting time in the status for more than 10 min

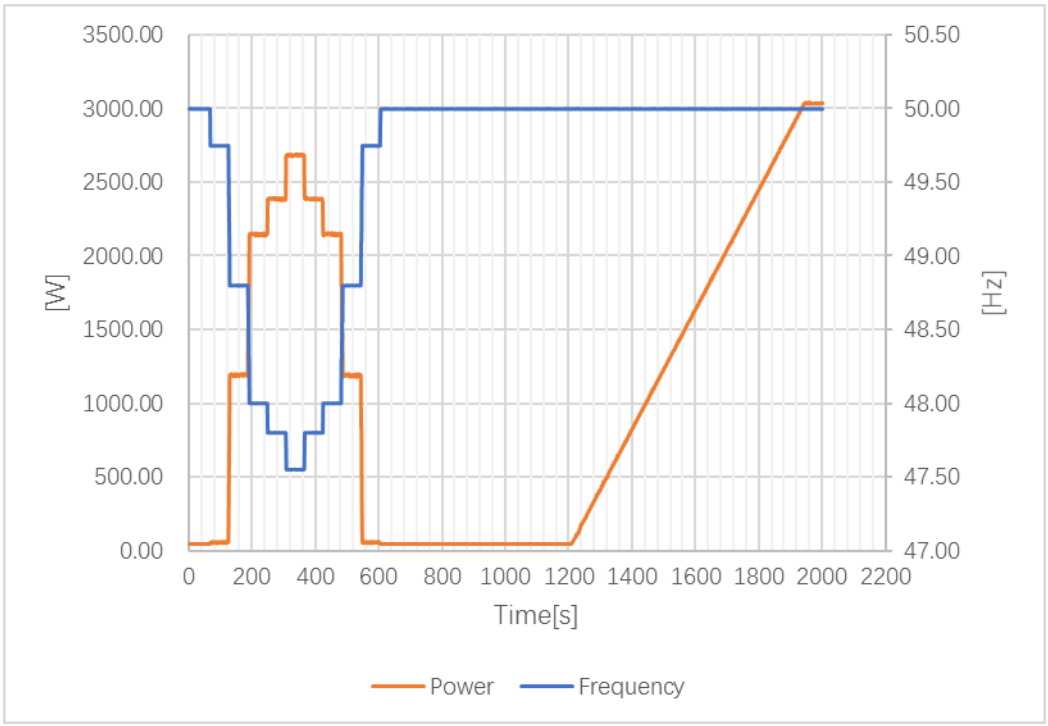
The power gradient is 8.11% P_{Emax}/min



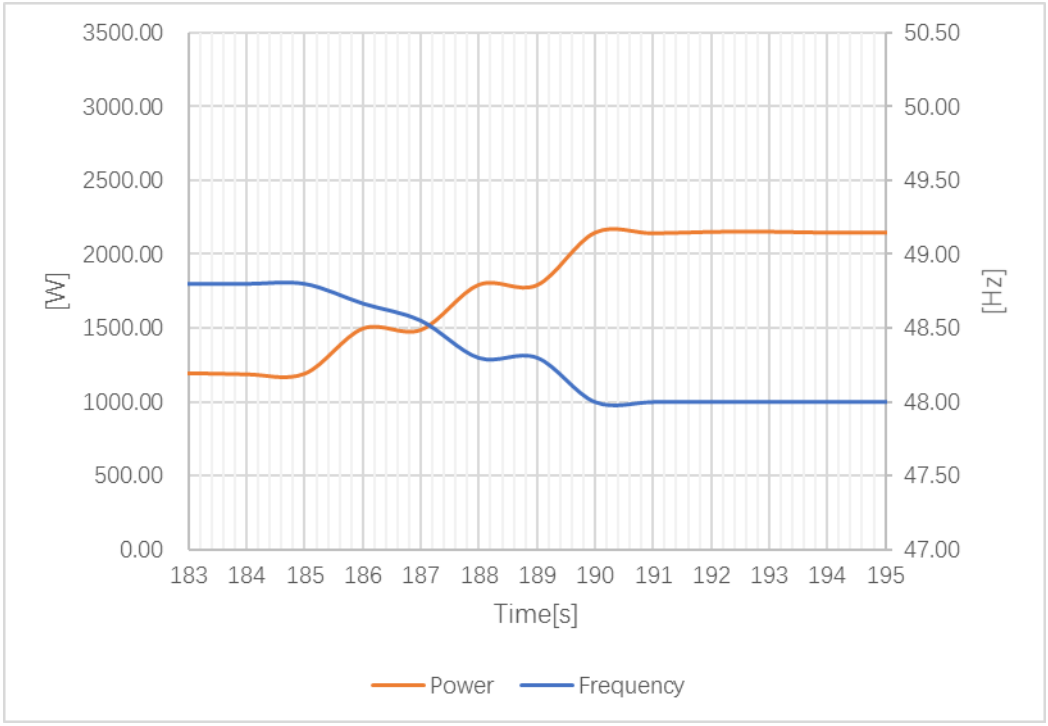
50%



The delay time and the settling time (0s)



0%



The delay time and the settling time (0s)

6.1	TABLE: General requirements	P

Design of functional safety:

The input and output are protected by varistors to Earth. The unit is providing EMC filtering at the PV input and output toward mains. The unit does provide basic insulation from input to output . 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 master DSP and slave DSP
The master DSP control the relays by switching signals; measures the PV voltage, PV current, bus voltage, grid voltage and 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 other start up
The slave DSP is measured the grid voltage, AC current , frequency and residual current, also can switch off relays independently, and communicate with master DSP each other
The unit provides two relays in series in all output conductors. When single fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the PV array and the mains. All the relays are tested before each start up.

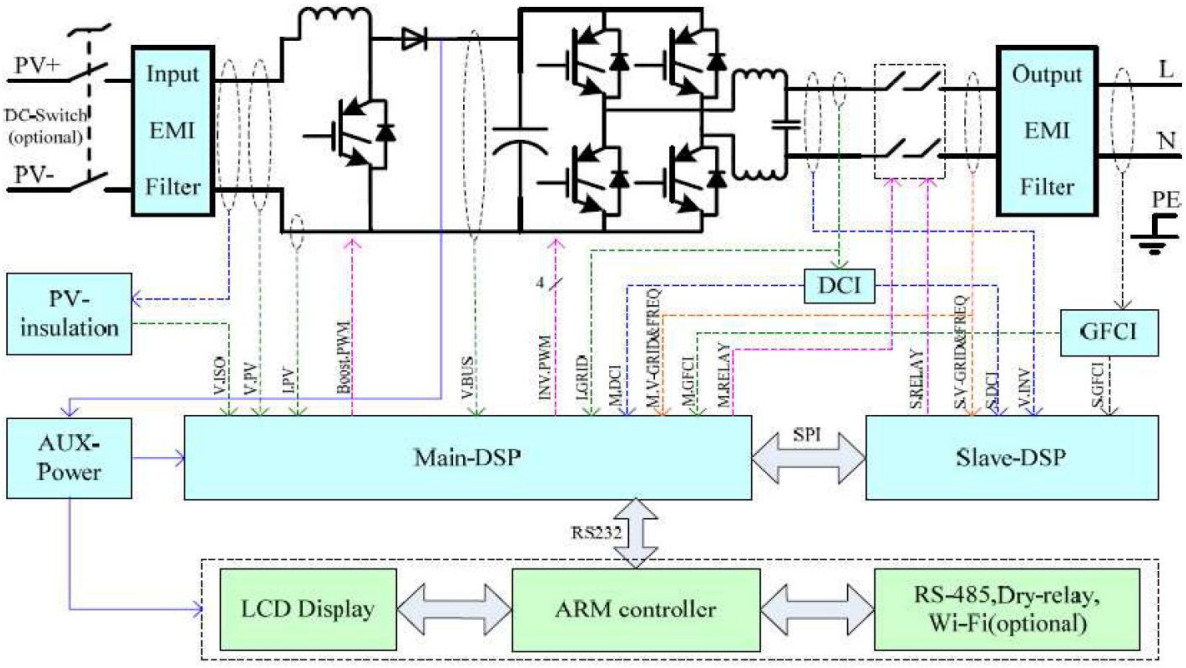


Figure 1 – Block diagram

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Supplementary information:

Two series relays would be automatically checked before the inverter starts operation

The functions are also verified in compliance with EN 62109-2

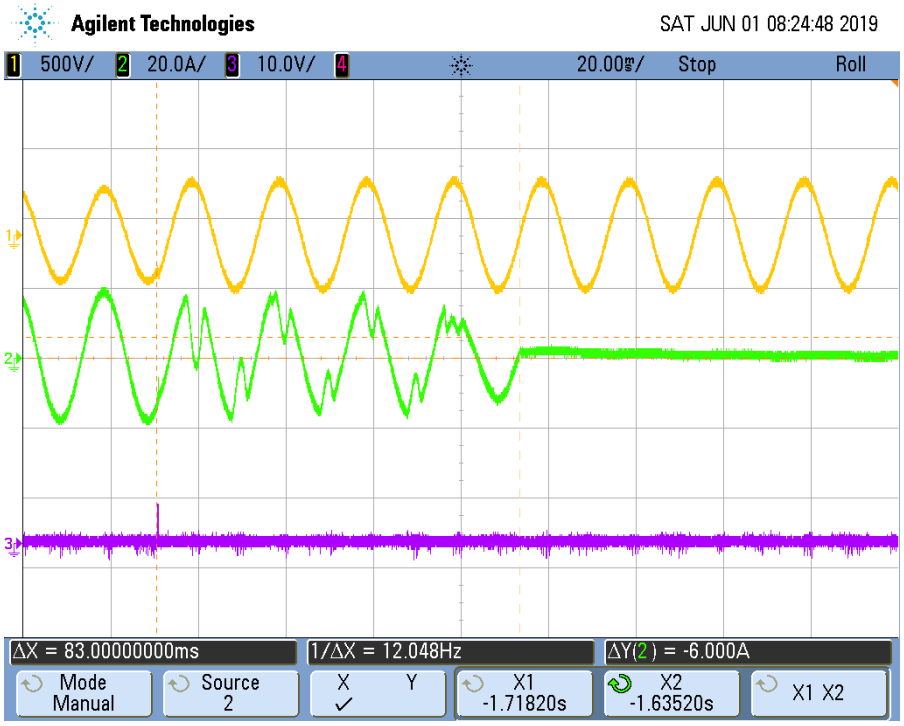
String	1	U_{DC} = Un	450Vdc	Uac = Un	230Vac	P = (W)	3.0K

Component No.	Fault	Observation
PV voltage detect UC1C Pin 9	Open	PV inverter disconnected from grid immediately, error message: ID09. (PV voltage over range)

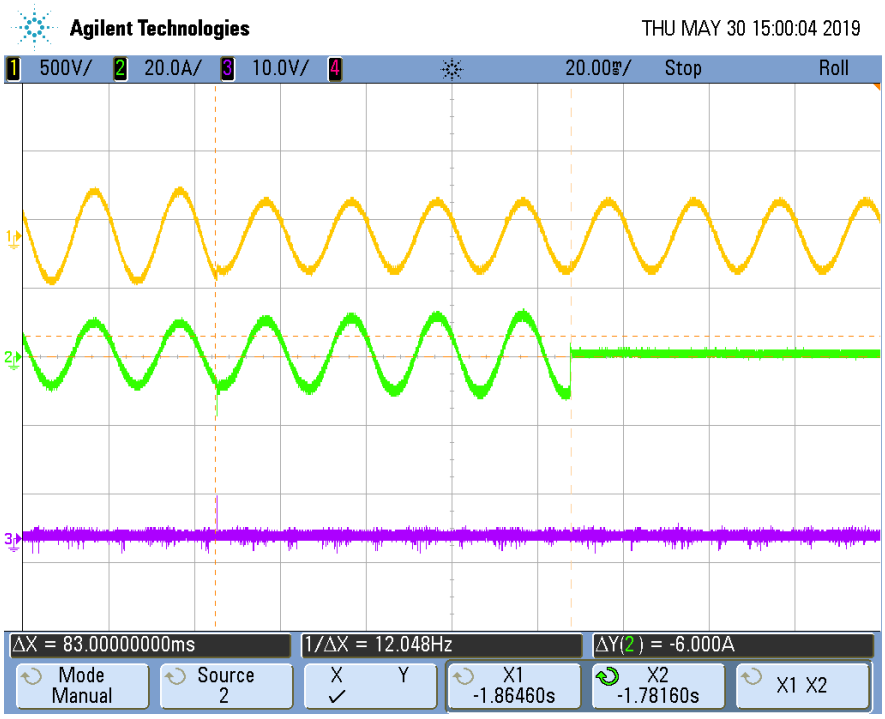
PV current detect UC1B Pin 5	Open	PV inverter disconnected from grid immediately, error message: ID14. (PV current over range)
GFCI detect UC2D Pin 12-13	Short	PV inverter disconnected from grid immediately, error message: ID12. (GFCI fault)
GFCI detect UC2C Pin 10	Short	PV inverter disconnected from grid immediately, error message:ID52. (GFCI fault)
Grid voltage detect UC2A Pin 3	Open	PV inverter disconnected from grid immediately, error message:ID15. (Grid current or voltage over range)
Grid voltage detect RC17	Open	PV inverter disconnected from grid immediately, error message: ID02, ID49, ID70. (Grid current or voltage under range)
Grid voltage detect RC25	Open	PV inverter disconnected from grid immediately, error message: ID55. (Relay fault)
DC current detect RC42	Open	PV inverter disconnected from grid immediately, error message: ID51. (DC current fault).
AC current detect RC61	Open	PV inverter disconnected from grid immediately, error message:ID15, ID65. (AC voltage or current over range).
AC current detect RC80	Open	PV inverter disconnected from grid immediately, error message:ID15, ID65. (AC voltage or current over range).
GFCI detect RP70	Open	PV inverter disconnected from grid immediately, error message:ID12. (GFCI fault).
GFCI detect RP80	Open	PV inverter disconnected from grid immediately, error message:ID12. (GFCI fault).
Relay detect RYP3 Pin3-4	Short before start	PV inverter can not start up, error message: ID55, ID77. (Relay fault).
Relay detect RYP4 Pin3-4	Short before start	PV inverter can not start up, error message: ID55, ID77. (Relay fault).
Relay detect RYP5 Pin3-4	Short before start	PV inverter can not start up, error message: ID55, ID77. (Relay fault).
Grid voltage detect RP150	Short before start	PV inverter can not start up, error message: ID55, ID77. (Relay fault).
Grid voltage detect RP150	Open	PV inverter disconnected from grid immediately, error message:ID02. (Grid voltage under range)
Grid voltage detect RP135	Short	PV inverter disconnected from grid immediately, error message:ID01. (Grid voltage over range)
Grid voltage detect RP135	Short	PV inverter disconnected from grid immediately, error message:ID01. (Grid voltage over range)

Loss of control CC100	Open	PV inverter disconnected from grid immediately, error message:ID02. (Grid voltage under range)
Loss of control XLC	Short	PV inverter disconnected from grid immediately, error message: DSP communicate fail
Communication microcontroller defect UC34 Pin 31	Open	PV inverter disconnected from grid immediately, error message:ID 53 (SPI Communication fault)
Communication microcontroller defect UC34 Pin 37	Open	PV inverter disconnected from grid immediately, error message:ID 53 (SPI Communication fault)
Communication microcontroller defect UC34 Pin 44	Open	PV inverter disconnected from grid immediately, error message:ID 53 (SPI Communication fault)
Communication microcontroller defect UC34 Pin 47	Open	PV inverter disconnected from grid immediately, error message:ID 53 (SPI Communication fault)
Supplementary information: SC: Short-circuited; OC: Open-circuited; O/L: Overloaded. During the test: Fire do not propagate beyond the EUT; Equipment do not emit molten metal; Enclosures do not deform to cause non-compliance with the standard.		

6.5	Protective functions (Results of Voltage monitoring)					
Rated Voltage (Un)	230V		Rated Frequency		50 Hz	
	1		2		3	
Phase	(V)	(ms)	(V)	(ms)	(V)	(ms)
118% Un	264.25	72.2	264.26	83.0	264.27	72.8
77% Un	183.52	75.5	183.54	82.8	183.48	83.0



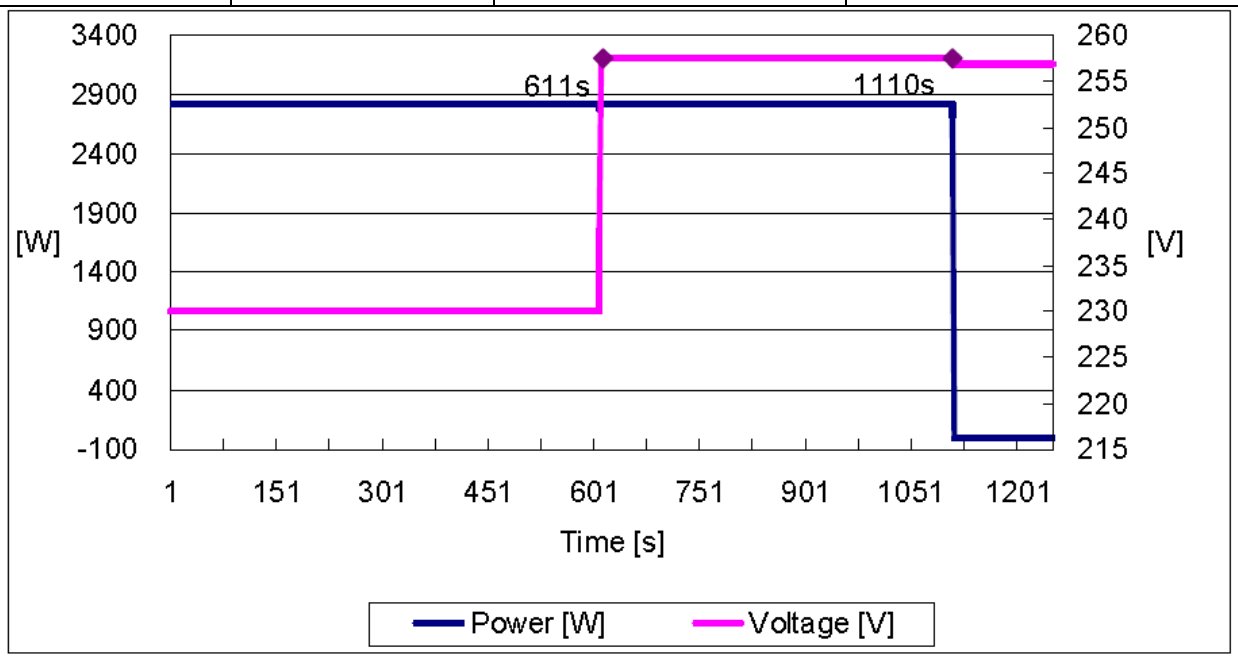
115% Un



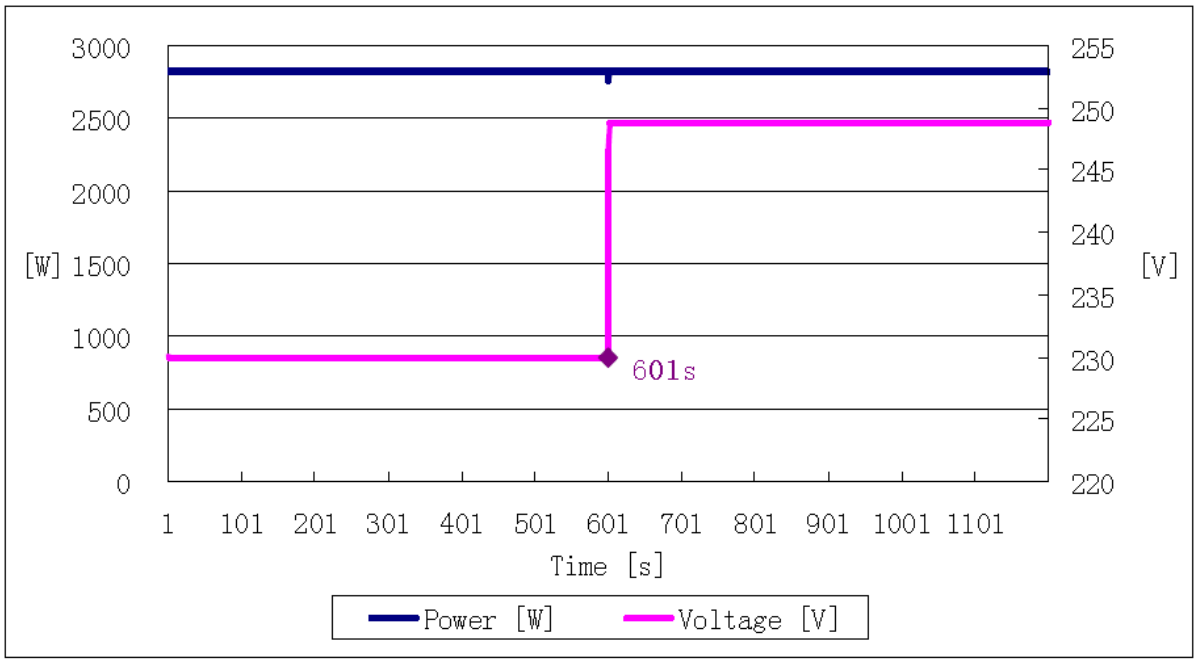
80% Un

CH1 denotes Voltage of output, CH2 denotes current of output, CH3 denotes trip signal.

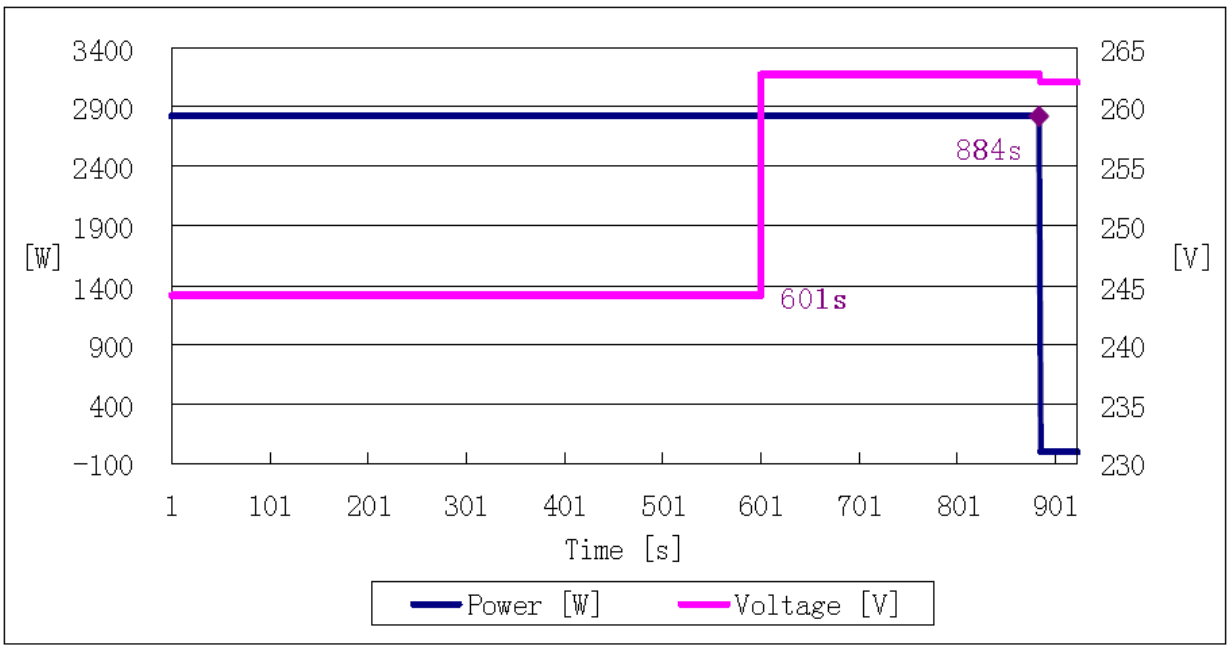
6.5	Protective functions (Results of the Protection of the Increase in Voltage as 10-min moving average)		
	Output Voltage (V)	Switch	
		On/Off state Finally	Time until Switch off (s)
100% Un	230.0	☒On ☐Off	Work normally
112% Un	257.6	☐On ☒Off	500
100% Un	230.0	☒On ☐Off	Work normally
108% Un	248.4	☒On ☐Off	Work normally
106% Un	243.8	☒On ☐Off	Work normally
114% Un	262.2	☐On ☒Off	282



Un to 1.12Un

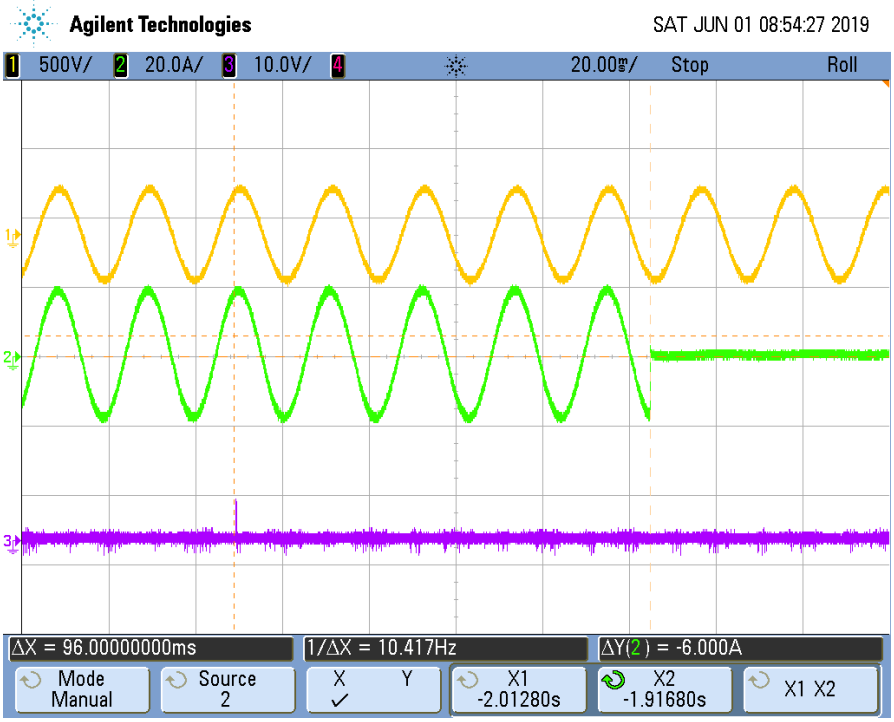


Un to 1.08Un

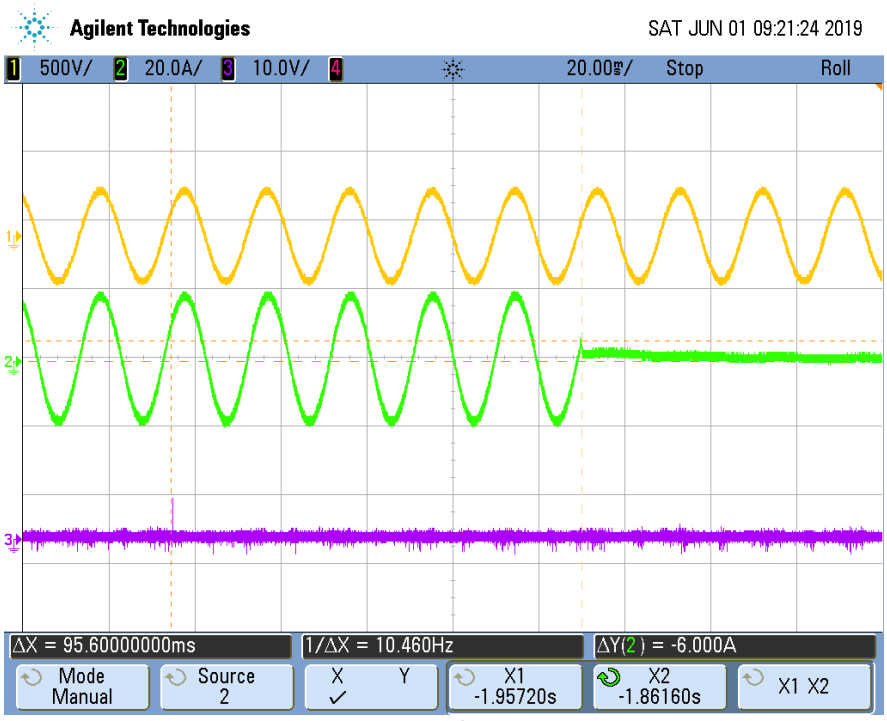


1.06 Un to 1.14Un

6.5.2	Protective functions (Results of Frequency)					
	1		2		3	
	f (Hz)	Trip time (ms)	f (Hz)	Trip time (ms)	f (Hz)	Trip time (ms)
Frequency decrease	47.50	78.2	47.50	91.2	47.50	96.0
Frequency increase	51.52	75.8	51.51	87.8	51.52	95.6



Frequency decrease



Frequency increase

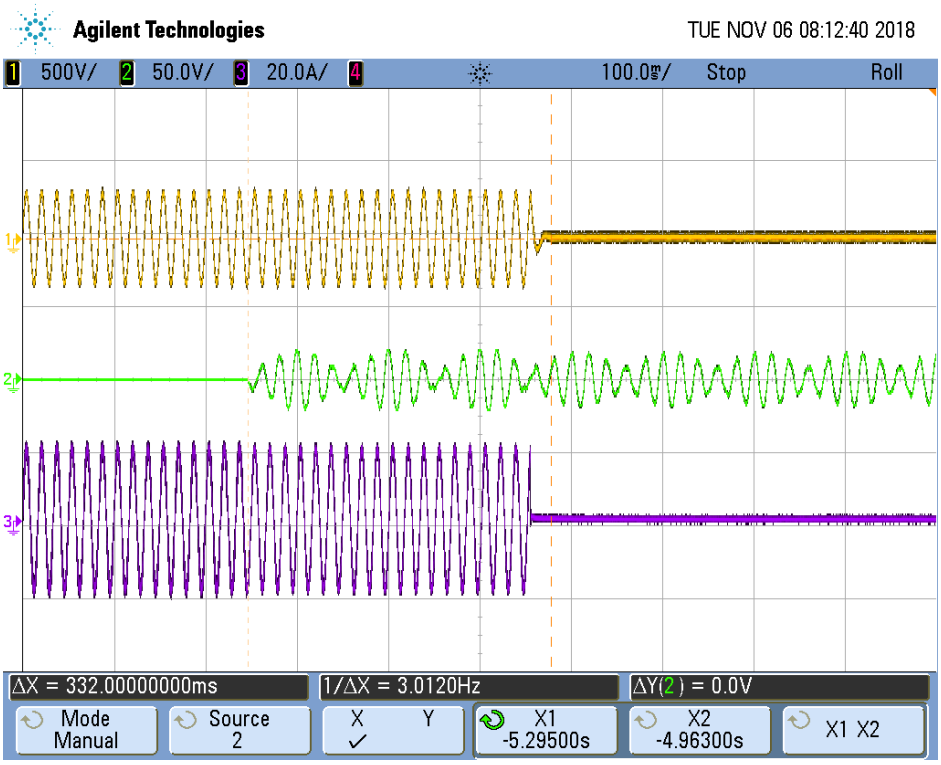
CH1 denotes Voltage of output, CH2 denotes current of output, CH3 denotes trip signal.

6.5.3 Islanding detection										P
No.	PEUT[1] (% of EUT rating)	Reactive load (% of QL in 6.1.d)1)	PAC[2] (% of nominal)	QAC[3] (% of nominal)	Run on time (ms)	PEUT (W)	Actual Qf	VDC	Remarks[4]	
1	100	100	0	0	332	3090	1.000	443	Test A at	BL
2	66	66	0	0	316	1960	1.001	295	Test B at	BL
3	33	33	0	0	290	955	1.000	147	Test C at	BL
4	100	100	-5	-5	248	3090	1.016	443	Test A at	IB
5	100	100	-5	0	220	3090	1.049	443	Test A at	IB
6	100	100	-5	5	305	3090	1.074	443	Test A at	IB
7	100	100	0	-5	245	3090	0.970	443	Test A at	IB
8	100	100	0	5	322	3090	1.020	443	Test A at	IB
9	100	100	5	-5	167	3090	0.920	443	Test A at	IB
10	100	100	5	0	202	3090	0.960	443	Test A at	IB
11	100	100	5	5	282	3090	0.972	443	Test A at	IB
12	66	66	0	-5	165	1960	1.022	295	Test B at	IB
13	66	66	0	-4	191	1960	1.020	295	Test B at	IB
14	66	66	0	-3	169	1960	1.012	295	Test B at	IB
15	66	66	0	-2	184	1960	1.014	295	Test B at	IB
16	66	66	0	-1	184	1960	1.007	295	Test B at	IB
17	66	66	0	1	220	1960	0.993	295	Test B at	IB
18	66	66	0	2	309	1960	0.998	295	Test B at	IB
19	66	66	0	3	171	1960	0.986	295	Test B at	IB
20	66	66	0	4	202	1960	0.982	295	Test B at	IB
21	66	66	0	5	177	1960	0.977	295	Test B at	IB
22	33	33	0	-5	214	955	1.022	147	Test C at	IB
23	33	33	0	-4	249	955	1.015	147	Test C at	IB
24	33	33	0	-3	169	955	1.011	147	Test C at	IB
25	33	33	0	-2	245	955	1.008	147	Test C at	IB
26	33	33	0	-1	209	955	1.004	147	Test C at	IB
27	33	33	0	1	228	955	0.997	147	Test C at	IB
28	33	33	0	2	286	955	0.995	147	Test C at	IB
29	33	33	0	3	281	955	0.993	147	Test C at	IB
30	33	33	0	4	237	955	0.984	147	Test C at	IB
31	33	33	0	5	212	955	0.978	147	Test C at	IB

Remark:

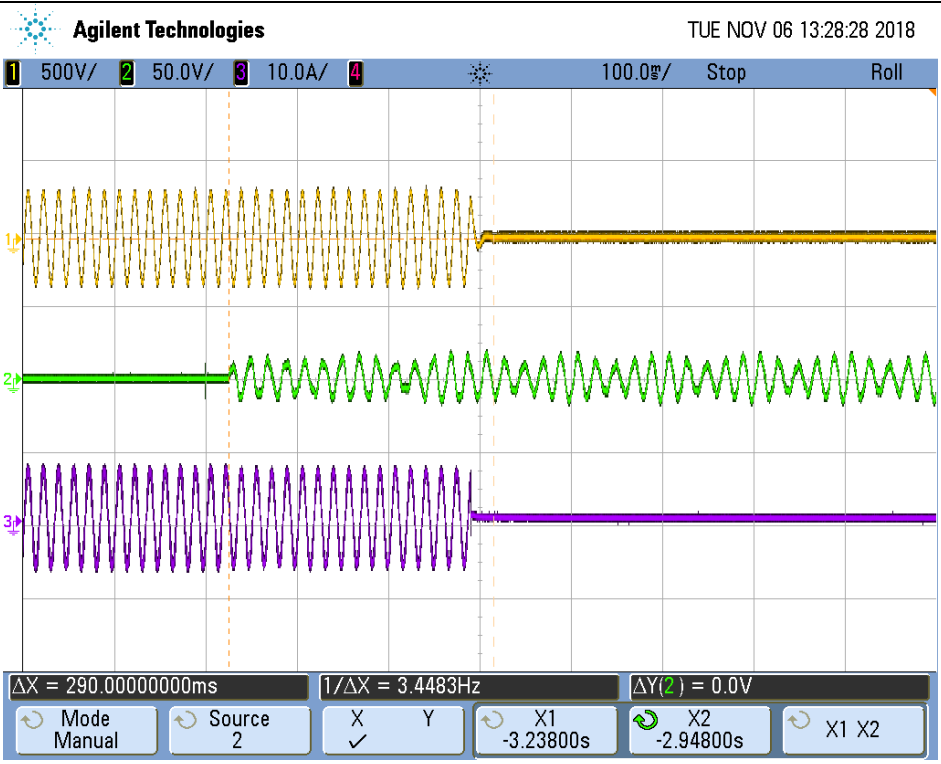
1) PEUT: EUT output power
2) PAC: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.
3) QAC: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.
4) BL: Balance condition, IB: Imbalance condition.
5) *Note: test condition A (100%): If any of the recorded run-on times are longer than the one recorded

for the rated balance condition, i.e. test procedure 6.1 f), then the non-shaded parameter combinations (no.32~47) also require testing.



P_{EUT} 100%, P_{AC} 0%, Q_{AC} 0%, = 332.0ms

P_{EUT} 66%, P_{AC} 0%, Q_{AC} 0%, = 316.0ms



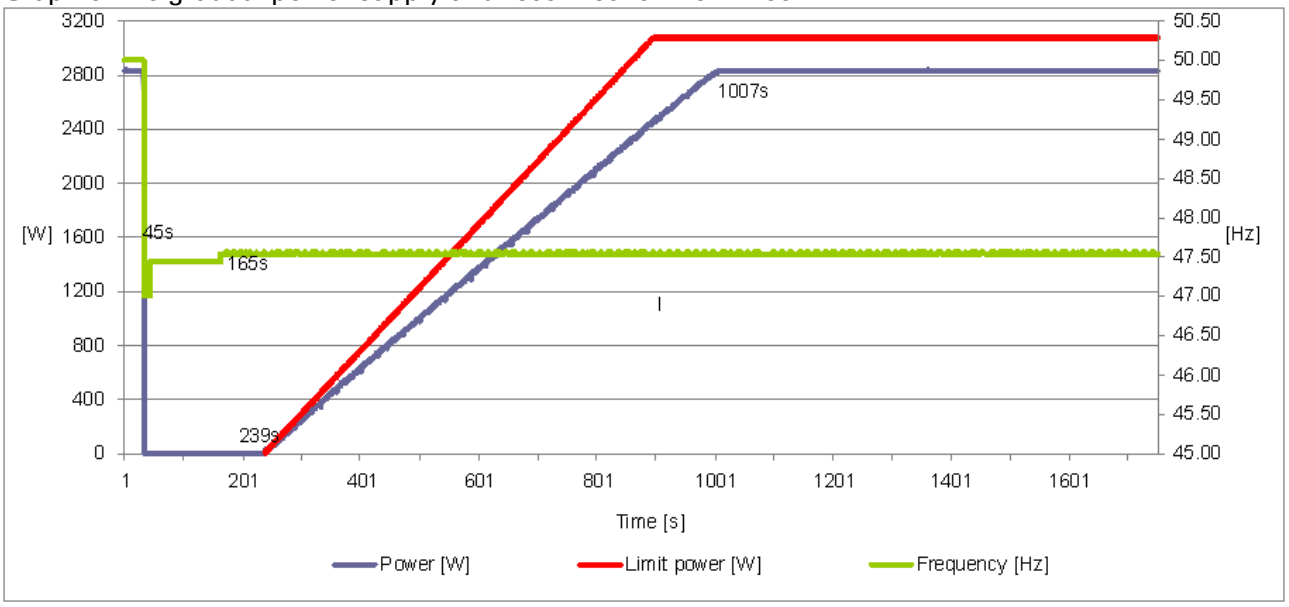
P_{EUT} 33%, P_{AC} 0%, Q_{AC} -0%, = 290.0ms

Note:
CH3: EUT output current
CH1: EUT output voltage
CH2: Voltage of trip signal

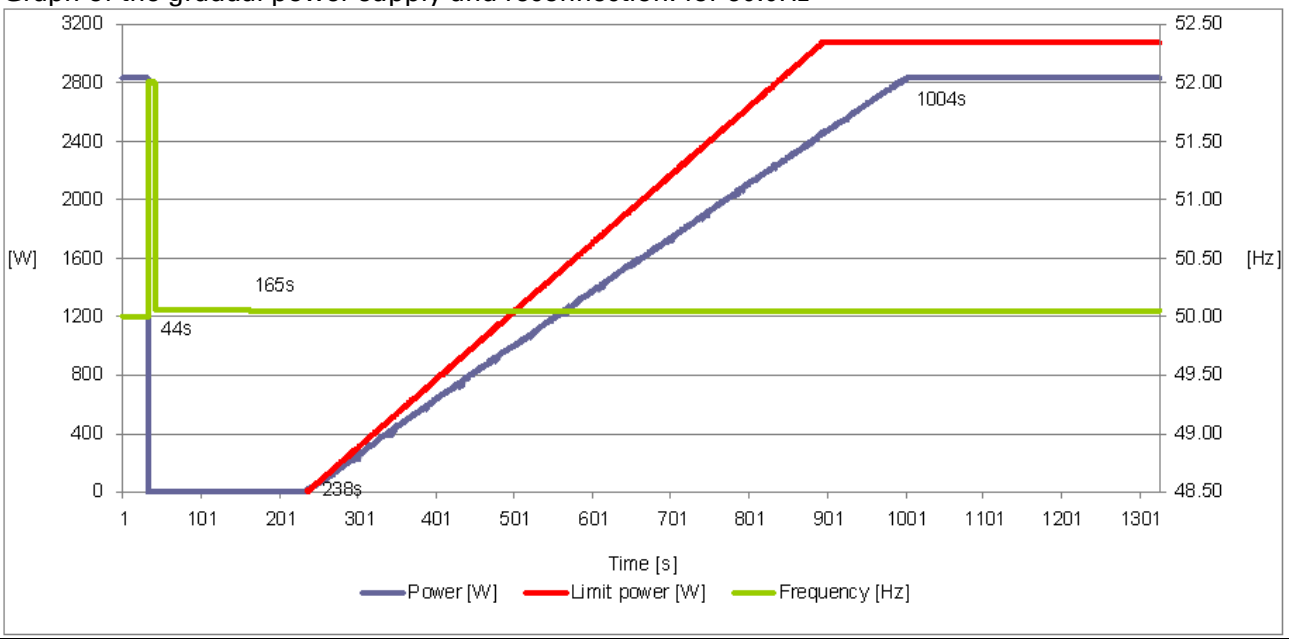
8.3.1	Connection conditions	
DC input:	AC output:	Rated Output Power
400Vdc	230Vac; 50Hz	3.0kVA

Measure Item	Reconnection?	Reconnection Time (>60s)
f_{ist} = 47,45Hz	☐ Yes ☒ No	Cannot reconnection
f_{ist} ≥ 47,55Hz	☒ Yes ☐ No	74.0s
f_{ist} = 50,1Hz	☐ Yes ☒ No	Cannot reconnection
f_{ist} ≤ 50,0Hz	☒ Yes ☐ No	73.0s
U_{ist} < 85% U_n	☐ Yes ☒ No	Cannot reconnection
U_{ist} ≥ 85% U_n	☒ Yes ☐ No	74.0s
U_{ist} > 110% U_n	☐ Yes ☒ No	Cannot reconnection
U_{ist} ≤ 110% U_n	☒ Yes ☐ No	74.0s

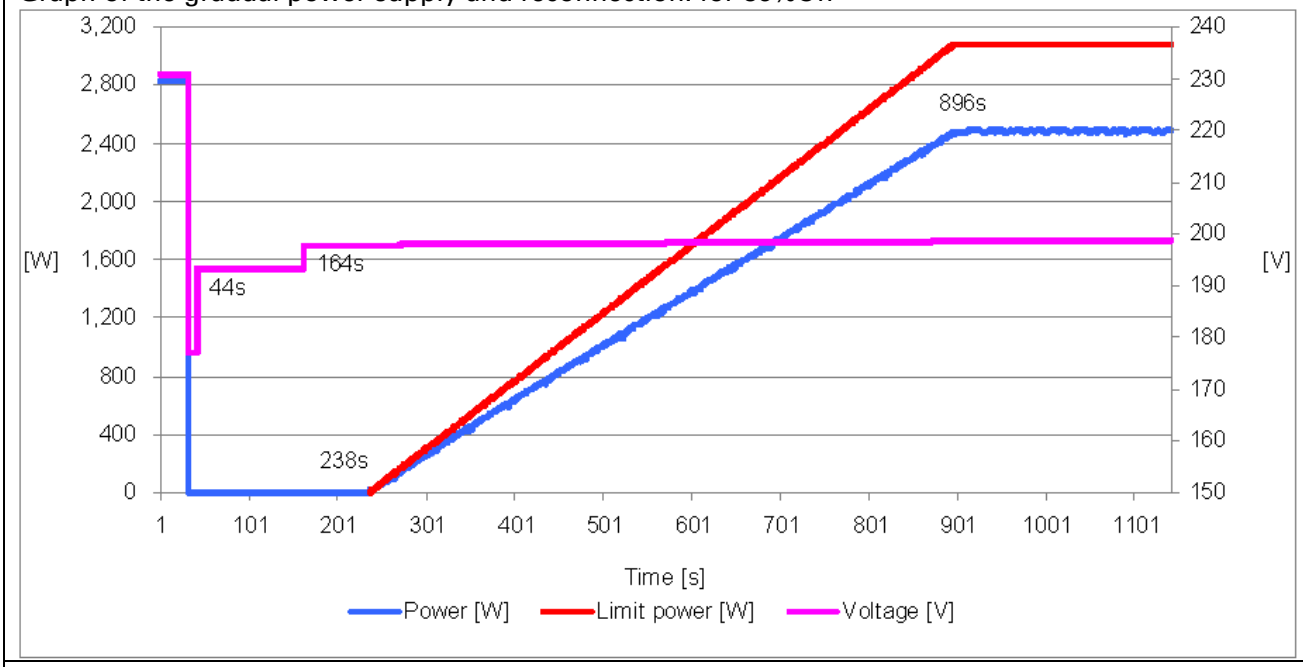
Graph of the gradual power supply and reconnection: for 47.55Hz



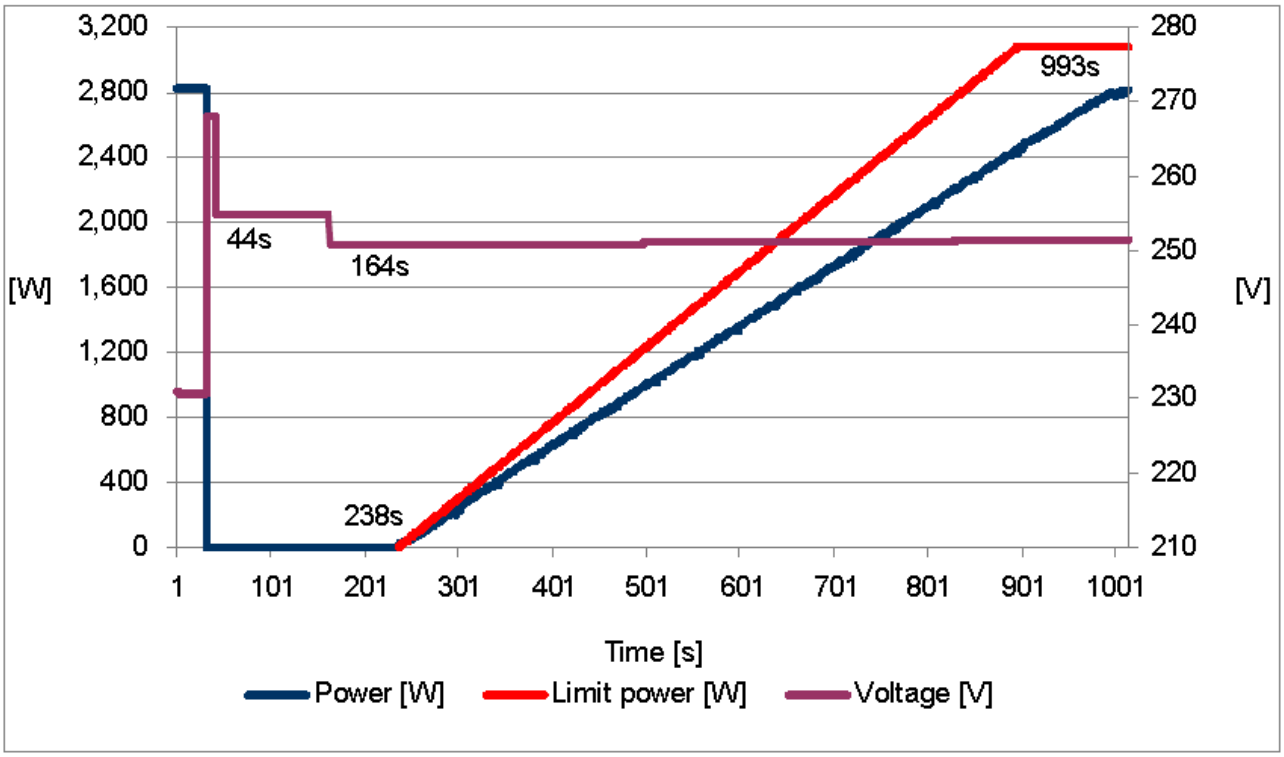
Graph of the gradual power supply and reconnection: for 50.0Hz



Graph of the gradual power supply and reconnection: for 85%Un

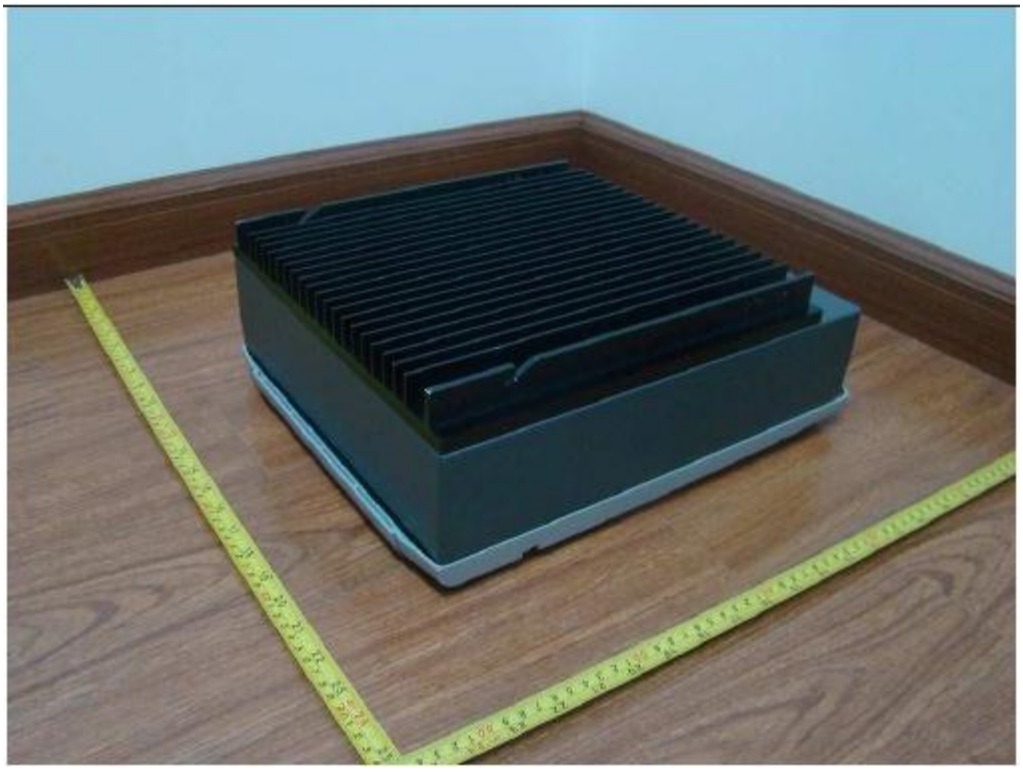


Graph of the gradual power supply and reconnection: for 110%Un



Appended photos

Front view of the unit



Bottom view of the unit

Connection interface of the unit

Internal view of the unit

Internal view of the unit

(End of Report)