LUNA2000-200KTL-H0

Certification Report: Control Behaviour and other Grid Code Requirements

Huawei Technologies Co., Ltd.

Report No.: CR-GCC-TR8-09385-A067-0
Date: 2022-12-22

Project name:	LUNA2000-200KTL-H0	DNV Energy Systems
Report title:	Certification Report:	Renewables Certification
	Control Behaviour and other Grid Code Requirements	Germanischer Lloyd Industrial
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Date of issue:	2022-12-22	
Project No.:	10309947	
Report No.:	CR-GCC-TR8-09385-A067-0	

Applicable contract(s) governing the provision of this Report: (L2C: 218394)

Objective: Verification of the electrical control behaviour and grid code requirements other than low voltage ride through-capability of the inverters LUNA2000-200KTL-H0

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Keywords:
GCC, VDE-AR-N 4110, VDE-AR-N 4120, FGW TR8, inverter

Rev. No.	Date	Reason for Issue	Prepared by	Verified and approved by
0	2022-12-22	First issue	Sofien Ben Saad	Hannes Pietsch

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1 EXECUTIVE SUMMARY

The purpose of this certification report is the documentation of the assessment of the control behaviour, including power quality, for the inverters LUNA2000-200KTL-H0. The Fault Ride Through (FRT) capability is not part of this report and is assessed within the scope of the certification report CR-GCC-TR8-09385-A066. The documented results of the type tests and the corresponding manufacturer documentation were assessed according to the assessment criteria of the mentioned guidelines in section 2. The final result of the assessment is stated in the end of this certification report, which gives a recommendation as part for the final certification decision.

2 ASSESSMENT CRITERIA

The assessment is based on the following, with the scope as specified in Section 3.

/A/ VDE-AR-N 4110, Technische Regeln für den Anschluss von Kundenanlagen an das Mittelspannungsnetz und deren Betrieb (TAR Mittelspannung), VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V.
(VDE-AR-N 4110 Technical requirements for the connection and operation of customer installations to the medium voltage network (TCR medium voltage), in the following: VDE-AR-N 4110)

/B/ VDE-AR-N 4120, Technische Regeln für den Anschluss von Kundenanlagen an das Hochspannungsnetz und deren Betrieb (TAR Hochspannung), VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V.
(VDE-AR-N 4120 Technical requirements for the connection and operation of customer installations to the high voltage network (TCR high voltage), in the following: VDE-AR-N 4120)

/C/ Technische Richtlinie für Erzeugungseinheiten und -anlagen, Teil 3: Bestimmung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Mittel-, Hoch- und Höchstspannungsnetz, Fördergesellschaft Windenergie und andere Dezentrale Energien (FGW), Revision 25, vom 01.09.2018
(FGW Technical Guidelines, Part 3: Determination of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as their Components in Medium, High and Extra-High Voltage Grids, in the following: FGW TG3)

/D/ Technische Richtlinie für Erzeugungseinheiten und -anlagen, Teil 8: Zertifizierung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Stromnetz, Fördergesellschaft Windenergie und andere Dezentrale Energien (FGW), Revision 9, vom 01.02.2019
(FGW Technical Guidelines, Part 8: Certification of the Electrical Characteristics of Power Generating Units and Systems, Storage Systems as well as their Components on the Grid, in the following: FGW TG8)

3 SCOPE OF ASSESSMENT

3.1 General

The assessment of the control behavior and other grid code requirements (this contains all grid code requirements, with the exception of the behavior of the generating unit during grid faults) of the generating unit contains the following:

- Completeness of documents and measurements.
- Plausibility of the documents received.
- Compliance of the test conditions of the documents listed in section 2.
- Assessment of the measurement results concerning the requirements of the documents listed in section 2.

4 GENERAL INFORMATION

4.1 Schematic description of the generating unit

The inverter HUAWEI LUNA2000-200KTL-H0 converts DC current to three-phase alternating current (AC).

The rated output voltage is 800 V. The inverter type LUNA2000-200KTL-H0 was tested for the default rated active power of 200 kW, but the maximum active power limit can also be increased up to the apparent power limit of 240 kVA, only for one minute.

The electrical data of the generating unit is summarized in the following section.

4.2 Technical data of main components

Technical data of the main components of the LUNA2000-200KTL-H0 is given below, as provided in the Manufacturer's Information /2/.

Table 4-1 General Specifications

Generating Unit	LUNA2000-200KTL-H0
No. of phases	3
Max apparent power	240 kVA (only for 1 minute)
Nominal apparent power	200 kVA
Nominal active power	200 kW
Rated AC-voltage (phase to phase)	800 Vac
Rated frequency	50 Hz
Rated current	144.3 A
Contribution to short circuit current	260 A

Table 4-2 DC Input

Generating Unit	LUNA2000-200KTL-H0
Min. DC input voltage	600 V
Max. DC input voltage	1500 V
Max. DC input current	207.6 A

Table 4-3 Inverter-Power section

Generating Unit	LUNA2000-200KTL-H0
Manufacturer	Huawei Technologies CO.,LTD
Type name	LUNA2000-200KTL-H0
Nominal apparent power	200 kVA
Generic type	Transformerless
Pulse rate of inverter	14.1 kHz
Generic type of power control	n. a.
Software Version	FusionSolar V800R021C10SPC030

Table 4-4 Software version

Generating Unit	LUNA2000-200KTL-H0
Firmware version	V800R021
Software version	FusionSolar V800R021C10SPC110

4.3 Unit Transformer

The transformer is not part of the generating unit and consequently has not been part of the assessment.

4.4 Grid protection

The grid protection is integrated into the control of the generating unit.

4.5 Disconnection device

Manufacturer	HongFa
Type name	HF192F12-H3F

4.6 Parameters of the generating unit

All parameters are documented in the “Huawei_LUNA2000-200KTL-H0_Parameter list_V1.0” dated 2020-06-09, V1.1 /6/.

4.7 Performed tests, test setup

The measurements of the control behaviour, including power quality, were performed on a LUNA2000-200KTL-H0 inverter by DNV Renewables Advisory at a test bench in Shanghai according to the requirements of the FGW TG3 /C/. The inverter was connected to a DC source, representing the PV modules, at the DC side and to a grid simulator (converter based controlled voltage source), representing the grid, at the AC side. The tests are documented in the measurement report /2/ and the corresponding extract from the measurement report /3/.

The tests were performed in accordance with the requirements of the FGW TG3 /C/. All tests required by FGW TG3 /C/ have been performed.

5 VERIFICATION OF CONTROL BEHAVIOUR AND OTHER GRID CODE REQUIREMENTS

5.1 Operating Range

5.1.1 Quasi-stationary operation

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1a	Quasi-steady-state operation in the frequency and voltage range according to Figure 4 of VDE-AR-N 4110 /A/ is possible.	True	Compliant, by manufacturer declaration /1/
1b	Quasi-steady-state operation in the frequency and voltage range according to Figure 4 of VDE-AR-N 4120 /B/ is possible.	True	Compliant, by manufacturer declaration /1/
1.1	Details of the capability of the PGU as a voltage-time characteristic curve.	Details provided	Compliant, see annex 6 in manufacturer declaration /1/ and manufacturer certificate /2/
1.2a	Verification of the manufacturer's information for quasi-steady-state voltage range based on example measurements completed in accordance with 11.2.4 in /A/	Details provided	Compliant, through manufacturer declaration. see section 4.2 in measurement report /2/
1.2b	Verification of the manufacturer's information for quasi-steady-state voltage range based on example measurements completed in accordance with 11.2.4 in /B/	Details provided	Compliant, through manufacturer declaration. Operating points at 0.85 U_n and 1.15 U_n not measured, see section 4.2.3 in measurement report /2/
1.3a	The requirement for operation ≥ 60 seconds between 85% U_n and 90% U_n as well as 110% U_n and 115% U_n) is met.	Measurement according to 11.2.5 carried out successfully	Compliant, please refer to FRT report CR-GCC-TR8-09385-A066
2a	The PGU is suitable for operation in the PGS in accordance with 10.2.1.2 in /A/	Details provided	Compliant, see manufacturer declaration /4/
2b	The PGU is suitable for operation in the PGS in accordance with 10.2.1.2 in /B/	Details provided	Compliant, see manufacturer declaration /4/

5.1.2 Grid oscillation

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Grid oscillation: Evidence of the capability of the PGU for dynamic grid support successfully provided.	True	Compliant, please refer to FRT report CR-GCC-TR8-09385-A066

5.1.3 Assessment

Huawei Technologies Co., Ltd. confirms that the LUNA2000-200KTL-H0 can operate within the requirements stated in figure 4 and Chapter 10.2.1.2 of VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/.

For the measurement validation of the maximum reactive power adjustment ranges as a function of active power and voltage values, only measurement data for the voltage range of 90 % U_n to 110% U_n was provided. Operating points at 0.85 U_n and 1.15 U_n were not measured, however compliance is had been proven through manufacturers declaration.

For the voltage ranges 110-115 % U_n and 85-90 % U_n this is also verified in testing as further assessed in the FRT report CR-GCC-TR8-09385-A066. Huawei Technologies Co., Ltd confirms that the genset can withstand the required voltage and frequency gradients (< 5 % U_n/min, and < 0.5 % f_n/min) while operation inside the quasi static window without interrupting any operational performance /4/.

5.2 System perturbations

5.2.1 Rapid voltage variations

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The voltage-effective switching factor dependent on the grid impedance phase angle $k_U(\psi)$ is identified.	No evaluation; data only shown	Compliant, see /2/ chapter 4.3.1
2	The flicker-effective switching factor dependent on the grid impedance phase angle $k_f(\psi)$ is identified.	No evaluation; data only shown	Compliant, see /2/ chapter 4.3.1
3	The frequency of the switching operations is shown.	True	Compliant, see /2/ chapter 4.3.1

5.2.2 Flicker

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The flicker coefficient depending on grid impedance phase angle c(ψ) identified.	No evaluation; data only shown	Compliant, see /2/ chapter 4.3.2, Table 4.3-12

5.2.3 Harmonics and interharmonics

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Details of harmonic currents provided.	No evaluation; data only shown	Compliant, see /2/ chapter 4.3.3.1
2	Details of interharmonic currents provided.	No evaluation; data only shown	Compliant, see /2/ chapter 4.3.3.2
3	Details of higher-frequency currents provided.	No evaluation; data only shown	Compliant, see /2/ chapter 4.3.3.3
A	Statement of levels as a function of active power starting from technical minimum power	True	Compliant, see /2/ chapter 4.3.3 Tables 4.3-15 to 4.3-18
B	Provided the alternative procedure under TG 3 is used, all variables determined are stated.	True	Not applicable, as alternative procedure was not used.

5.2.4 Asymmetries

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Positive and negative phase sequence system of the feed-in current must be provided as a function of the apparent power.	Details provided	Compliant, see /2/ chapter 4.3.4, Table 4.3-19
2a	Limit value is not exceeded according to /A/	Quotient of the currents from positive and negative phase sequence system ≤ 1.5%	Not compliant, $u_{i,max}$ = 1.78%
2b	Limit value is not exceeded according to /B/	Quotient of the currents from positive and negative phase sequence system ≤ 2.5%	Compliant, $u_{i,max}$ = 1.78%
Note: If the limit value is exceeded as part of the unit certification, the 1-minute mean has to be disclosed as a function of apparent power. It is then evaluated within the framework of system certification.			

For Type 2 PGUs the following applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Positive and negative phase sequence system of the feed-in current must be provided for each 10 % power bin (from 10 % to 100 % P_{rE}) as a function of the apparent power as 1-minute mean values.	Details provided	Compliant, see /2/ chapter 4.3.4 Table 4.3-19

5.2.5 Assessment

The measurement of power quality (flicker, switching operations and harmonics, current asymmetry) have been performed for the LUNA2000-200KTL-H0 according to FGW TG3 /B/ completely and are presented in the measurement report /2/. Some important results are presented below. An assessment of the results must be carried out within the scope of project certification at the grid connection point of the specific generating power plant.

For the voltage changes caused by switching operation, main results of the measurements are presented in Table 5-1. Flicker results are found in **Error! Reference source not found.**. The harmonic currents and voltages, including inter-harmonics and higher frequency current components, has been measured for different harmonics and power bins. The Quotient of the currents from positive and negative phase sequence system is shown in Table 5-3.

Table 5-1 Test results for switching operation at $P_{available} = P_n$ /2/

	Switch-in				Switch-off			
Grid impedance angle, ψ_k	**30°**	**50°**	**70°**	**85°**	**30°**	**50°**	**70°**	**85°**
Flicker form factor, $k_f(\psi_k)$	0.01	0.02	0.02	0.02	0.13	0.10	0.07	0.05
Voltage variation factor, $k_U(\psi_k)$	0.87	0.65	0.36	0.15	0.87	0.65	0.36	0.15

Table 5-2 Flicker coefficient per power bin (95th percentile) /2/

P_{bin} in %	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Grid impedance angle ψ_k in °						**Flicker coefficient c (ψ_k)**					
30	0.23	1.43	1.31	7.04	1.31	0.23	1.29	1.30	6.14	4.93	0.25
50	0.23	1.08	1.00	5.31	1.01	0.23	1.00	1.01	4.74	3.82	0.25
70	0.23	0.64	0.60	3.07	0.60	0.22	0.62	0.61	2.84	2.30	0.26
85	0.24	0.38	0.35	1.59	0.33	0.23	0.34	0.34	1.37	1.11	0.27

Table 5-3 Unbalances of the current vs. power bin, mean values /2/

Active power bin	**Average active power**	**Average voltage pos. comp.**	**Average voltage neg. comp.**	**Average current pos. comp.**	**Average current neg. comp**	**Asymmetry of current**	**Max. asymmetry of current for P ≥ 10 % of P_N**
% of P_N	**in kW**	**in V**	**in V**	**in A**	**in A**	**in %**	**in %**
0	1.85	461.99	0.22	1.34	0.12	9.17	
10	20.01	462.23	0.23	14.43	0.26	1.78	
20	40.12	462.36	0.27	28.93	0.38	1.30	
30	60.13	462.50	0.32	43.34	0.54	1.24	
40	80.36	462.62	0.38	57.91	0.61	1.04	
50	100.39	462.71	0.44	72.32	0.75	1.04	1.78
60	120.57	462.86	0.50	86.83	0.86	0.99	
70	140.61	463.01	0.57	101.23	0.97	0.95	
80	160.86	463.17	0.63	115.78	1.08	0.93	
90	180.92	463.31	0.70	130.17	1.21	0.93	
100	201.01	463.42	0.77	144.59	1.29	0.89	

The maximum unbalance of the current for P ≥ 10 % of P_N was measured to 1.78 %, which oversteps the limit of 1.5 % stipulated by VDE-AR-N 4110. Consequently, this will need to be assessed at project level, for which the 1-minute mean values stated in Table 5-3 can be used. The measurements were performed at Q=0, which means that the active power values stated are equal also to apparent power. The maximum unbalance of the current is well within the limits of 2.5 % as stipulated by VDE-AR-N 4120 /B/.

5.3 Reactive power

5.3.1 Reactive power provision

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Every setpoint value specified by the grid operator can be achieved within the required reactive power range (Figure 5). Note: In case the PGU does not meet the requirement, it has to be met at the level of the PGS at the latest.	≤ 4 min	Compliant, by manufacturer declaration /1/ and measurement report /2/
2	The types of setpoint value specifications and interfaces for control of the reactive power provision are documented.	Details provided	Compliant, following interfaces for control of the reactive power provision are provided on the PGU level: a) Connect a mobile phone that runs the SUN2000 app to the inverter using a Bluetooth module, a WLAN module, or a USB data cable. b) Connect the inverter to Smartlogger via MBUS or RS485. Control functions: - Power factor fix control - Reactive power fix control - Q-P characteristic curve - Q-U characteristic curve
3	Details of the Q-step response via a step response for the interface/setpoint value combinations.	Details provided	Compliant, by manufacturer declaration /1/
4	Representation of the reactive power capability as a function of the voltage and feed-in active power as an illustration and in a table. (Data for 0.85 U_n – 1.15 U_n provided in 5% steps)	True	Compliant, by manufacturer declaration /1/
5	PQ characteristic is verified for 'max underexcited', 'max overexcited' and 'Q=0'.	True	Compliant, see /2/ chapter 4.2.1 and 4.2.2
6a	Active power reduction may be parametrised to the benefit of reactive power feed-in.	Details provided	Compliant, by manufacturer declaration. Parametrizable through parameters P_{limit} and P_{max}. The reactive power is prioritized versus the active power /1/
7	Voltage-independence is verified for at least two conclusive operating points each for underexcited and overexcited operating ranges.	True	Compliant, see /5/

5.3.2 Procedure for reactive power feed-in

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The type of setpoint value specifications and interfaces for control of the reactive power provision is stated.	Details provided	Compliant, the following reactive power control functions are implemented on the PGU level /1/: a) Settable Q-parameter (range: +/- 100%Pmax) b) Settable cosφ-set-parameter (range: +/- 0.8) c) Configurable Q(U)-characteristic line (No. of supporting points: 10) (* d) Configurable Q(P)-characteristic line (No. of supporting points: 10)
2	In the event the communication with the PGS controller is disturbed, PGU can be operated with a predefined value or process.	Details provided	Compliant, the PGU will remain in operation with the predefined parameters

A selection of additional requirements from A.1.2.4.2.2 and A.2.2.4.2.2

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	A remote and/or manual switchover between the control processes is possible.	True	Process not available at unit level. Fulfil the requirement only in combination with plant controller
2	When switching over between control processes the new setpoint value should not be reached faster than the required PT1 behaviour and not more slowly than in 4 minutes.	$Q_{target} \geq t_{on}$ & $Q_{target} \leq 4$ min	Not relevant, no switching between different control Processes was tested. Needs to be fulfilled on the PGS controller level
3	Qualitatively, the control behaviour must take place according to PT1 behaviour. Each reactive power value resulting from the control behaviour specified by the grid operator must be possible to provide, adjusted between 6 s and 60 s (for Type 1 between 10 s and 60 s).	True	Compliant only for required time, but since the unit is sufficiently fast, the requirements of the PT1 behaviour could be achieved together with a plant controller at project level /2/
7a	Tolerance after settling of the reactive power value of ±2% P_{inst}; (or ±4% P_{inst} for systems with $S_{A,max}$ < 300 kVA) is complied with. If limits are exceeded due to dynamic voltage variations on the grid, these have to be assessed by the certification body.	True	Compliant, by measurement report /2/
7b	Tolerance after settling of the reactive power value of ±2% P_{inst}; (or ±4% P_{inst} for powers <10% $P_{AV,E}$) is complied with. If limits are exceeded due to dynamic voltage variations on the grid, these have to be assessed by the certification body.	True	Compliant, by measurement report /2/

A selection of additional requirements for the Q(U) control from A.1.2.4.2.2 and A.2.2.4.2.2

NOTE: The test for Q(U) control was carried correctly according to the TG3, but the characteristic curve does not match the requirements according to /A/ and /B/. Therefore, the following assessment is shown for informative purposes only, should the certificate be used for other international markets. The assessment results are not taken into consideration for the final compliance assessment according to the requirements of the VDE-AR-N-4110 /A/ and VDE-AR-N-4120 /B/.

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
8	Interface for the specified voltage U_{Q0}/U_C present. The specified voltage can be stipulated in steps of 0.5 U_C.	Details provided	Requirement not fulfilled, as no appropriate Interface is available. Fulfil the requirement only in combination with plant controller
9	Voltage dead band can be set in steps of maximum 0.5 % U_C.	±0% ... ±5% U_C	Requirement not fulfilled, as no dead band is implemented. Fulfil the requirement only in combination with plant controller
10	Q(U) characteristic / gradient m can be defined via value pair.	Details provided	compliant
11a	The gradient m can be set within the value range (according to VDE-AR N 4110 /A/)	5≤ m≤ 16.5	Compliant, by adjusting parameters 33-40
11b	The range of gradient m for Version 1 (Figure 5 of VDE-AR N 4120 /B/) can be adjusted.	7≤ m≤ 24	Compliant, by adjusting parameters 33-40
12a 13b	After adapting the specified voltage U_{Q0}/U_C the resulting setpoint value has to be approached within ≤ 4 min.	True	This test was not performed, but the unit is fast enough to meet these requirements.
12b	The range of gradient m for Version 2 and 3 (Figure 5 of VDE-AR N 4120 /B/) can be adjusted.	6≤ m≤ 20	Compliant, by adjusting parameters 33-40
14b	An actual value of 90% of the setpoint step must not be reached earlier than 0.8* $T_{an\ 90\%}$ (in case of a rise time of ≤ 2 s no earlier than 0.6 $T_{an\ 90\%}$).	True	This test was not performed, but the unit is fast enough to meet these requirements.
15b	For the settling time of a reactive power setpoint step the following applies.	$T_{ein\Delta Q}= T_{an90\ \%}$+3 s	This test was not performed, but the unit is fast enough to meet these requirements.
16b	For the permissible overshoot distance of a reactive power setpoint step the following applies.	ΔQ_{max} = (25% (2 s/ $T_{an90\%}$) + 5%)	Requirement cannot be evaluated as the corresponding test was not performed. Fulfil the requirement only in combination with plant controller

A selection of additional requirements for the Q(P) control from A.1.2.4.2.2

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
13a	Q(P) characteristic curve can be defined via at least 10 interpolation points / value pairs ($Q_{EA,target}/P_{b,inst}$).	True	Compliant, see manufacturer declaration and parameter list /6/.

A selection of additional requirements for reactive power with limitation function from A.1.2.4.2.2 and A.2.2.4.2.2

NOTE: The characteristic curve of the PV unit is not implemented according to the requirements of /A/ and /B/. The Interface for the specification of the reactive power value $Q_{ref}/P_{b\ inst}$ as well as a dedicated Q(U) with voltage limitation functionality is not available in the unit. Therefore, this functionality is not fulfilling the requirements of VDE-AR-N-4110 /A/ and VDE-AR-N-4120 /B/. As Information it shall be noted that a static reactive power with voltage limitation characteristic can be adjusted by using the Q(U) functionality described above.

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
14a 17b	Interface for the specification of the reactive power value $Q_{ref}/P_{b\ inst}$ is available	Details provided	Requirement cannot be evaluated as the corresponding test was not performed. Fulfil the requirement only in combination with plant controller
15a 18b	The reactive power value $Q_{ref}/P_{b\ inst}$ can be specified in steps of 1 % $Q/P_{b\ inst}$	Details provided	Requirement cannot be evaluated. Fulfil the requirement only in combination with plant controller
16a 19b	Procedure $Q_{U\ max}$ definable via value pairs	Details provided	Requirement cannot be evaluated. Fulfil the requirement only in combination with plant controller. Reactive power with voltage limiting function uses the Q(U) characteristic curve which is free programmable up to 10 supporting points
17a 20b	For stability reasons, gradients m greater than the limit value are not permitted (m ≥ 24)	True	Requirement cannot be evaluated. Fulfil the requirement only in combination with plant controller. Reactive power with voltage limiting function uses the Q(U) characteristic curve. The required gradient and setting time can be provided via suitable configuration of the Q(U) characteristic line
18a 21b	After adapting the reactive power value Q_{ref}/P_{binst} the resulting setpoint value has to be approached within ≤ 4 min	True	Requirement cannot be evaluated, but the unit is fast enough to meet the requirements. Fulfil the requirement only in combination with plant controller. Reactive power with voltage limiting function uses the Q(U) characteristic curve. The required setting time can be provided via suitable configuration of the time constant parameter
22b	The settling time must be a maximum of rise time plus 1 minute.	$T_{ein} \leq T_{an} + 1$ min	Requirement cannot be evaluated, but the unit is fast enough to meet the requirements. Fulfil the requirement only in combination with plant controller

5.3.3 Assessment

5.3.3.1 Reactive Power capability

The reactive power capability depends on the fixed rated apparent power, the rated active power and the voltage. For the LUNA2000-200KTL-H0 the reactive power capability has been measured for max. active power at charging and discharging mode.

The maximum reactive power (inductive and capacitive) for the full active power range was measured for the LUNA2000-200KTL-H0, changing active power from 0 % to 100 % P_n in steps of 10 %.

The inverter can provide up to 93.63 kVAr reactive power, capacitive or inductive (both in charging and discharging mode at 100 % P_N) up to 198.10 kW. Above 198 kW the inverter's reactive power capacity is reduced, which is due to the apparent power limitation. The results of the measurements, together with the manufacturer specification, is shown in Figure 5-1 and stated in Table 5-7. In general, the measurement results confirm the theoretical capability.

The power provision is limited by the maximum apparent current and maximum apparent power. The reactive power is prioritized versus the active power. A maximum reactive power provision of 100% S_{max} (using Q set-point) is possible.

At overvoltage the apparent / active power threshold limits the injected power. At undervoltage the apparent current limitation will also contribute. Continuous provision is possible within the voltage range 0.8 U_n - 1.2 U_n and the frequency range between 47.5 and 52 Hz /1/.

A permanent active power reduction can be applied by setting parameters P_{limilt} and P_{maxref} (the following applies: $P_{limilt} \leq P_{maxref} \leq P_{max}$. Default: $P_{limilt} = P_{maxref} = P_{max}$). Following interfaces for control of the active power provision are provided on the PGU level:

- Fixed active power derated
- Active power percentage derating

As required by the FGW TG8 /C/, the manufacturer Huawei Technologies Co., Ltd. also provided information on the reactive power capability in the 85 - 115% voltage range of the inverters /1/. This is shown in Figure 5-1 and Table 5-4.

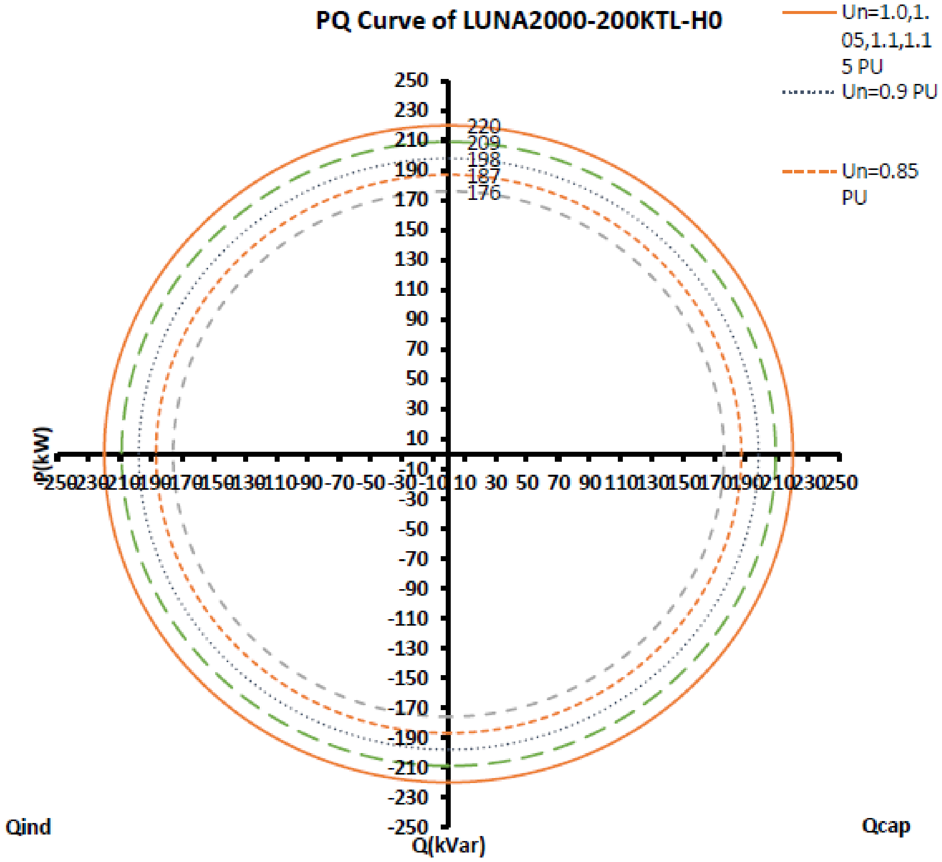

Figure 5-1 Reactive power capability of the Huawei LUNA2000-200KTL-H0 according to manufacturer declaration /1/

Table 5-4 Operating points in the voltage dependent PQ diagram according to manufacturer declaration /1/

Un = 1.00 / 1.05 / 1.10 / 1.15 p.u.			Un = 0.95 p.u.			Un = 0.90 p.u.		
P [kW]	Q_Cap [kvar]	Q_Ind [kvar]	P [kW]	Q_Cap [kvar]	Q_Ind [kvar]	P [kW]	Q_Cap [kvar]	Q_Ind [kvar]
±220	0.00	0.00	±209	0.00	0.00	-	-	-
±200	91.65	-91.65	±200	60.67	-60.67	±198	0.00	0.00
±180	126.49	-126.49	±180	106.21	-106.21	±180	82.49	-82.49
±160	151.00	-151.00	±160	134.47	-134.47	±160	116.64	-116.64
±140	169.71	-169.71	±140	155.18	-155.18	±140	140.01	-140.01
±120	184.39	-184.39	±120	171.12	-171.12	±120	157.49	-157.49
±100	195.96	-195.96	±100	183.52	-183.52	±100	170.89	-170.89
±80	204.94	-204.94	±80	193.08	-193.08	±80	181.12	-181.12
±60	211.66	-211.66	±60	200.20	-200.20	±60	188.69	-188.69
±40	216.33	-216.33	±40	205.14	-205.14	±40	193.92	-193.92
±20	219.09	-219.09	±20	208.04	-208.04	±20	196.99	-196.99
0	220.00	-220.00	0	209.00	-209.00	0	198.00	-198.00

Un = 0.85 p.u.		
P [kW]	Q_Cap [kvar]	Q_Ind [kvar]
±187	0.00	0.00
±180	50.69	-50.69
±160	96.79	-96.79
±140	123.97	-123.97
±120	143.42	-143.42
±100	158.02	-158.02
±80	169.02	-169.02
±60	177.11	-177.11
±40	182.67	-182.67
±20	185.93	-185.93
0	187.00	-187.00

The reactive power capability at nominal grid voltage conditions was also measured, for which the results are shown in Figure 5-2, Table 5-5 and Table 5-6.

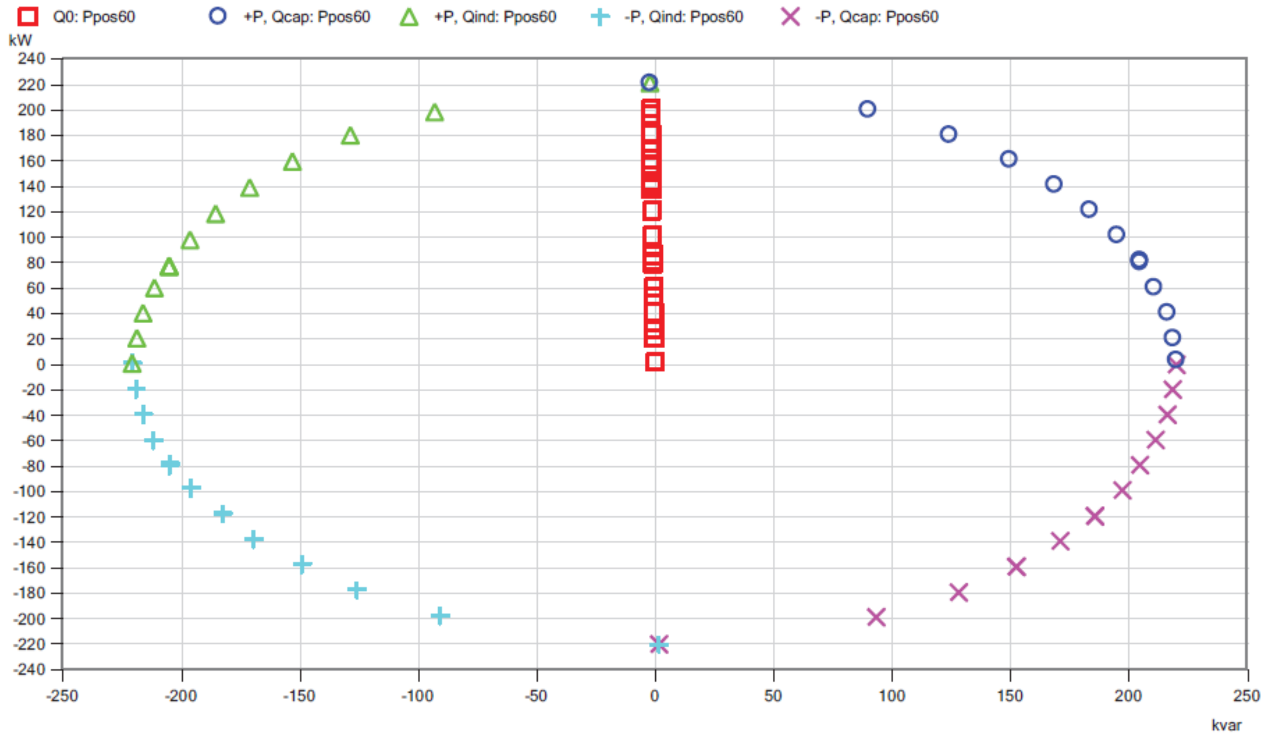

Figure 5-2 Reactive power capability of the Huawei SUN2000-60KTL-HV-D1-001 according to measurements /2/

Table 5-5 Reactive power capability in the voltage independent PQ diagram according to measurements results (charging mode) /2/.

P [%]	Q_{max} measurement [kvar]			Q_{min} measurement [kvar]		
	P [kW]	capacitive	Cos φ	P [kW]	inductive	Cos φ
0	2.87	220.39	0.013	0.11	- 220.69	0.000
10	20.19	218.92	0.091	20.01	- 218.83	0.091
20	40.18	216.52	0.182	39.91	- 216.11	0.181
30	60.05	211.02	0.273	59.82	- 211.29	0.272
40	80.73	204.89	0.366	76.79	- 205.14	0.350
50	101.02	195.41	0.459	97.36	- 196.34	0.444
60	121.02	183.76	0.550	118.04	- 185.51	0.536
70	140.79	168.78	0.640	138.74	- 171.11	0.629
80	160.52	149.86	0.731	159.11	- 152.96	0.720
90	180.19	124.49	0.822	179.65	- 128.60	0.813
100	199.82	90.12	0.911	198.22	- 92.95	0.905
110	-	-	-	-	-	-

Table 5-6 Reactive power capability in the voltage independent PQ diagram according to measurements results (discharging mode) /2/.

P [%]	Q_{max} measurement [kvar]			Q_{min} measurement [kvar]		
	P [kW]	capacitive	Cos φ	P [kW]	inductive	Cos φ
0	0.89	220.41	0.004	- 0.89	- 220.70	0.004
10	- 20.02	218.84	- 0.091	- 20.28	- 219.24	0.092
20	- 39.96	216.59	- 0.181	- 40.15	- 216.24	0.182
30	- 59.91	211.48	- 0.272	- 60.02	- 211.68	0.272
40	- 79.03	205.02	- 0.359	- 79.86	- 204.91	0.363
50	- 97.84	197.49	- 0.443	- 99.68	- 195.93	0.453
60	- 117.85	185.98	- 0.535	- 120.17	- 182.54	0.549
70	- 137.84	171.36	- 0.626	- 139.69	- 169.56	0.635
80	- 157.85	152.75	- 0.718	- 160.03	- 149.08	0.731
90	- 177.92	128.39	- 0.810	- 180.10	- 125.72	0.820
100	- 198.10	93.63	- 0.904	- 199.70	- 90.65	0.910
110	-	-	-	-	-	-

In the case of maximum inductive reactive power capability, only 3 1-min data sets were recorded for the 0% active power bin, although 7 are required by /C/. This is not seen as critical, due to the stable test conditions outlined in chapter 3 of the measurement report /2/.

Furthermore, the maximum inductive and capacitive reactive power was measured for different active power and voltage levels from for verification of the voltage dependent PQ diagram as follows:

a) Overexcited/variable voltage

b) Underexcited/variable voltage

c) Normal operation/variable voltage

The result of the measurements is shown in the following Table 5-7.

Table 5-7 Reactive power capability in the voltage dependent PQ diagram according to measurement results /2/.

Operating point	Active power in p.u.	Voltage in p.u.	Reactive power in p.u.	Displacement factor
Overexcited / Variable voltage	0.008	0.900	0.999	0.009
	0.995	0.900	- 0.009	1.000
	0.014	1.000	1.101	0.013
	0.014	1.100	1.100	0.013
	0.995	1.100	0.459	0.908
Underexcited / Variable voltage	0.008	0.900	-1.004	0.008
	1.000	0.900	0.009	1.000
	0.110	1.000	-1.103	0.000
	0.000	1.100	-1.101	0.000
	1.000	1.100	-0.457	0.909
Q = 0 mode / Variable voltage	0.009	1.000	0.000	0.999
	0.300	1.000	-0.003	0.999
	0.501	1.000	-0.005	0.999
	0.703	1.000	-0.006	1.000
	1.005	1.000	-0.009	1.000

In addition, a complete measurement was carried out for 0.9 U_N as shown in Figure 5-3 below.

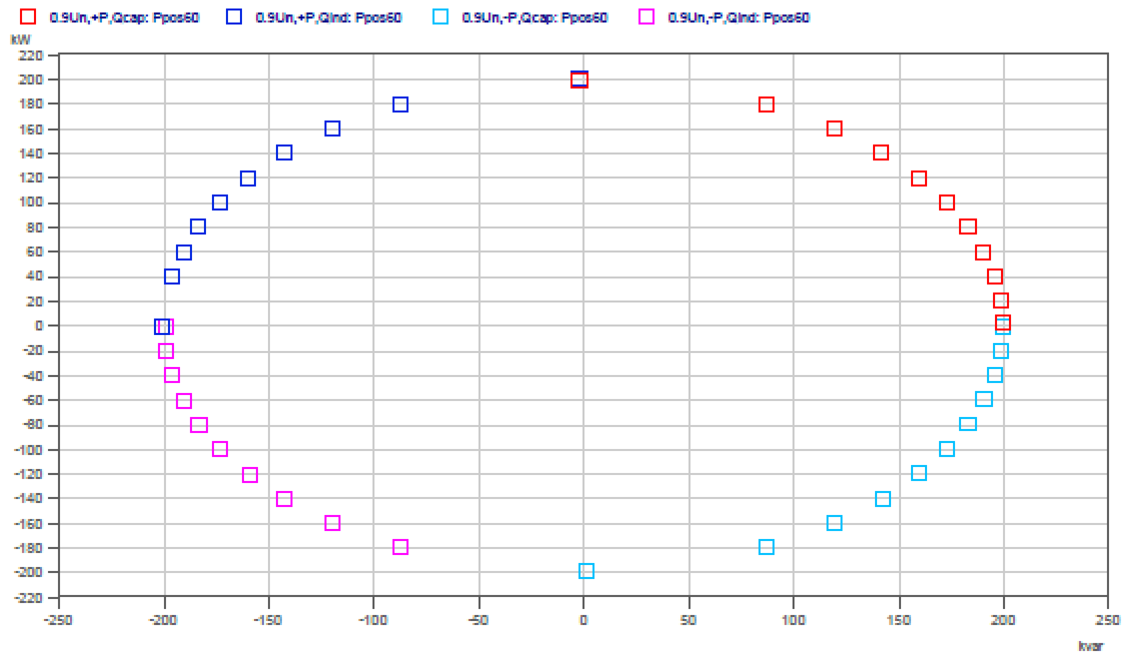

Figure 5-3 Reactive power capability over active power (P(Q) diagram), for 0.9 U_n /2/

5.3.3.2 Reactive power following set points

The results for the deviations between setpoint and actual values as well as the results for the settling times of two different parameter settings are shown in Table 5-8, Table 5-9 and Table 5-10.

Table 5-8 Setting accuracy for reactive power setpoint (Q-fixed reactive power value) /2/

Reactive power	Accuracy at 50 % P_N [% P_N]
Q_0	0,325
50% $Q_{max,cap}$	0.055
50% $Q_{max,ind}$	0.390

Table 5-9 Settling times for the reactive power setpoint when using fast settings (Q-fixed reactive power value) /2/

Reactive power Step	Set dynamic	Settling time in [s]
$Q = 0 \rightarrow Q_{max,overex.}$	1000% Q_{max}/s	0.50
$Q_{max,overex.} \rightarrow Q_{max,underex.}$		0.21
$Q_{max,underex.} \rightarrow Q = 0$		0.31
Longst measured settling time		0.50

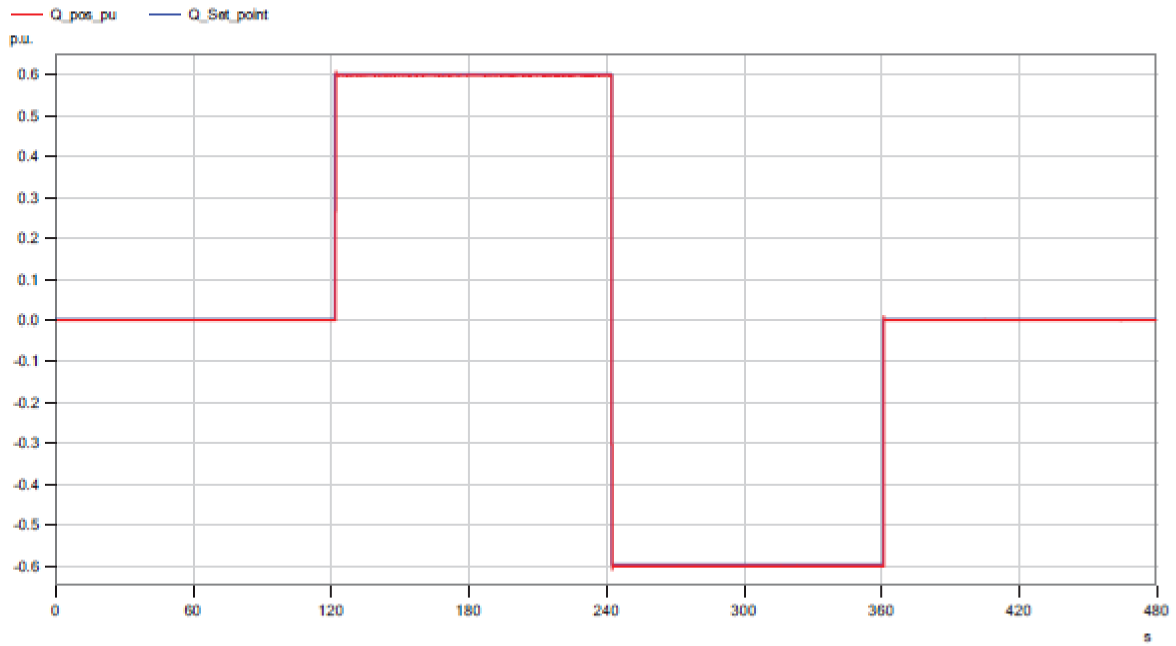

Figure 5-4 Transition function from max. capacitive to max. inductive reactive power taken from measurement report /2/ (Fastest settling time)

Table 5-10 Settling times for the reactive power setpoint using slow settings (Q-fixed reactive power value) /2/

Reactive power Steps	Set dynamic	Settling time in [s]
Q = 0 → Qmax,overex.	1.7% Q_{max}/s	58.45
Qmax,overex. → Qmax,underex.		119.92
Qmax,underex. → Q = 0		58.95
Longest measured settling time		119.92

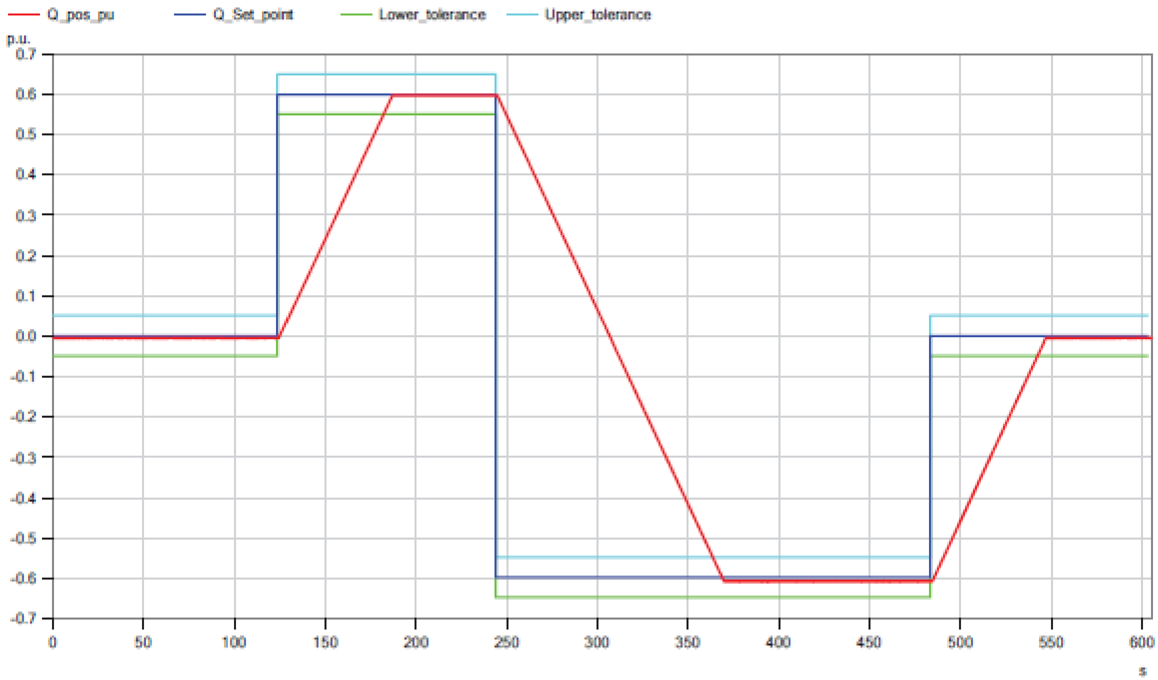

Figure 5-5 Transition function from max. capacitive to max. inductive reactive power taken from measurement report /2/ (slowest settling time)

Q(U) control

The test for Q(U) control was not carried out correctly, as the corresponding characteristic curve of the PV unit was not implemented according to the requirements of /A/ and /B/. Testing of the dead band and curve shift was not tested and is not implemented. The following results are shown for informative purposes only, in case the certificate is used for other international markets.

The operation mode of a Q(U) characteristic curve was measured with the fastest settling time at 60 % P_n. The results for the fastest settling times for the Q(U) characteristic are listed in Table 5-11.

Table 5-11 Settling time for the Q(U) characteristic curve based on the measurement results /2/

Step	Set dynamic	Settling time in [s]
1.00 U_N → 0.97 U_N	3 τ =1 s	0.17
0.97 U_N → 1.03 U_N		0.27
1.03 U_N → 1.00 U_N		0.19
Longest measured settling time		0.27

In addition, the operation mode of a Q(U) characteristic curve was measured with the slowest settling time 50 % P_n. The results for the fastest settling times for the Q(U) characteristic are listed in Table 5-12.

Table 5-12 Settling time for the Q(U) characteristic curve based on the measurement results /2/

Step	Set dynamic	Settling time in [s]
1.00 U_N → 0.97 U_N	3 τ =60 s	46.62
0.97 U_N → 1.03 U_N		54.21
1.03 U_N → 1.00 U_N		47.71
Longest measured settling time		54.21

Q(P) control

For this measurement the characteristic curve was taken from TR3 /C/ and the active power setpoint was set to 45 %, 55 %, 75 % and 95 % in successive steps. The output active power to follow accordingly as summarized in the table below. The results for the deviations between setpoint and actual values are shown in Table 5-13. The results for the settling times are shown in Table 5-14.

Table 5-13 Accuracy for the Q(P) characteristic curve based on the measurement results /2/

Setpoint in p.u.	Required Q in p.u.	Measured Q in p.u.	Q deviation in p.u.
0.45	0.000	-0.004	-0.004
0.55	-0.026	-0.030	-0.004
0.75	-0.190	-0.198	-0.008
0.95	-0.330	-0.34	-0.010

Table 5-14 Settling time for the Q(P) characteristic curve based on the measurement results /2/

Step change	45 % → 55 %	55 % → 75 %	75 % → 95 %
Settling time in s	0	0.19	0.15

Reactive power Q with voltage limitation

The test for Q with limiting function control was not carried out correctly, as the corresponding characteristic curve of the PV unit was not implemented according to the requirements of /A/ and /B/. The test was carried out by adjusting the supporting points of the Q(U) function curve. The following results are shown for informative purposes only, in case the certificate is used for other international markets.

The test was carried out for three different Q_{ref} settings: Q_{ref} = 0.0 p.u., Q_{ref} = 0.33 p.u. and Q_{ref} = -0.33 p.u.. The measured voltage, the corresponding calculated reactive power, the actual reactive power and its deviation for each applied step are shown in Table 5-15.

Table 5-15 Accuracy for the Q(U) characteristic curve based on the measurement results, Qref = 0.0 p.u. /2/

Measured voltage in p.u.	Q setpoint value in p.u.	Q actual value in p.u.	Deviation in p.u.
1.001	-0.005	-0.005	0.000
0.962	-0.005	-0.005	0.000
0.940	0.325	0.326	0.001
1.040	-0.005	-0.004	0.001
1.061	-0.335	-0.336	0.001
1.001	-0.005	-0.004	0.001

Table 5-16 Accuracy for the Q(U) characteristic curve based on the measurement results, Qref = 0.33 p.u. /2/

Measured voltage in p.u.	Q setpoint value in p.u.	Q actual value in p.u.	Deviation in p.u.
1.001	0.326	0.326	0.000
0.940	0.326	0.326	0.000
1.020	0.326	0.326	0.000
1.040	-0.005	-0.004	0.001
1.061	-0.334	-0.336	-0.002
1.001	0.336	0.356	0.000

Table 5-17 Accuracy for the Q(U) characteristic curve based on the measurement results, Qref = -0.33 p.u. /2/

Measured voltage in p.u.	Q setpoint value in p.u.	Q actual value in p.u.	Deviation in p.u.
1.001	-0.336	-0.336	0.000
0.981	-0.336	-0.336	0.000
0.961	-0.006	-0.005	0.001
0.940	0.324	0.326	0.002
1.061	-0.336	-0.336	0.000
1.001	-0.336	-0.336	0.000

Conclusions

The reactive power provision by fixed set-point control was performed for the LUNA2000-200KTL-H0 with the required accuracy. The tests were performed at an active power operating point of 50 % of rated active power (200 kW). The longest reactive power response time of the LUNA2000-200KTL-H0 was 0.50 s for the fastest time setting and 119.92 s for the slowest time setting (during a step from maximum inductive reactive power to maximum capacitive reactive power). The accuracy was only measured with the "standard" dynamic, which in the worst case is 0.39 % P_N.

The observed set point changes show a reactive power change without any overshoots and with faster settling time following the requested PT1 behavior. Since the shape of the different steps does not meet all the requirements of PT1 behavior at the unit level. But since the unit is sufficiently fast, the requirements of the PT1 behavior could be achieved together with a plant controller at project level. The reactive power provision by Q(P) control was performed for the LUNA2000-200KTL-H0. The tests were performed at an active power operating points of 45 %, 55 %, 75 % and 95 % of rated active power. The longest reactive power response time was 0.19 s (during a step from 55 % to 75 % of rated active power). The accuracy was measured, and the maximum deviation was determined to be 1 % P_N.

The reactive power provision by Q(U) control and Q with voltage limiting function were performed for the LUNA2000-200KTL-H0. Although the PV unit has these control options available, the test procedures in order to prove their functionalities according to the requirements of the VDE-AR-N-4110 /A/ and VDE-AR-N 4120 /B/ were not implemented correctly. As a result, the results obtained from these tests are not evaluated for the final assessment for this certification. Certification for these control functions must be proven on a plant controller at project level.

5.4 Active power

5.4.1 General information and grid safety management

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1a	Power gradient for increasing and reducing the active power.	0.33% P_{rE}/s ≤ gradient ≤ 0.66% P_{rE}/s (in case of setpoint values specified by third parties also more slowly, for power increase however not more slowly than 4% P_{rE}/min.)	Compliant, see 4.1.2.2 /2/ Can be adjusted by parameter no. 9 (active power change gradient)
2	Even progression of power increase/reduction	True	Compliant, see /2/ chapter 4.1.2.
3	Interfaces for specifying active power (grid operator, direct seller) implemented separately as well as the concept checked to make sure lowest active power value is accepted (even if specifications overlap in time).	True	Not compliant, only one interface for specifying active power implemented on the PGU. Separate specifying active power by grid operator and direct seller is not possible. For prioritization of different setpoints must be carried out on the plant level e.g. in the superimposed plant controller
4	Control deviation at PGU terminals identified.	True and deviation ≤ 5% P_{inst}	Compliant, max. deviation = 0,16%, see /2/ chapter 4.1.2.1 Table 4.1-4
5	The maximum active power output is identified as a mean value over 200 ms, 1 minute and 10 minutes.	True	Compliant, see /2/ chapter 4.1.1 Table 4.1-3
6	If active power output is dependent on environmental conditions (temperature, atmospheric pressure), these interrelationships were shown in the form of a manufacturer's declaration.	True	Compliant, see /1/ annex 5
7	If the power gradient is implemented at the PGS controller level, the settling time of the PGU due to an active power step from 90% to 10% P_{rE} and from 10% to 90% P_{rE} must be measured.	No evaluation– data only shown	Compliant, see /2/ chapter 4.1.2.2

5.4.2 Active power output as a function of grid frequency

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	PGU and controllable consumer units respond according to the requirement, if the grid frequency is outside of the tolerance band of ± 200 mHz.	True	Compliant, by measurement /2/, see chapter 4.1.3
1.1a	The frequency measurement meets the requirements with respect to accuracy and sampling /A/	$\lvert\Delta f\rvert \leq$ 10 mHz in the settled condition $\lvert\Delta f\rvert \leq$ 50 mHz for fast frequency changes $\Delta t_{Sampl} \leq$ 200 ms for fast frequency changes	Compliant, by manufacturer declaration /1/
1.1b	The frequency measurement meets the requirements with respect to accuracy and sampling /B/	$\lvert\Delta f\rvert \leq$ 50 mHz for fast frequency changes $\Delta t_{Sampl} \leq$ 200 ms for fast frequency changes	Compliant, by manufacturer declaration
1.2.1	The active power operating point can be increased in the range between $f_{Start<}$ to $f_{Stop<}$. The upper threshold can be adjusted between 49.5 Hz and 49.8 Hz. If available, standard values must be given.	P(f) increase is possible in the range 49.5 Hz $\leq f_{Start<} \leq$ 49.8 Hz to $f_{Stop<}$ = 47.5 Hz.	Compliant, adjustable in the range of 40 Hz to 60 Hz, for more details see parameter 22-24 /6/
1.2.2	The active power operating point can be reduced in the range between $f_{Start>}$ to $f_{Stop>}$. The lower threshold can be adjusted between 50.2 Hz and 50.5 Hz. If available, standard values must be given.	P(f) reduction is possible in the range 50.2 Hz $\leq f_{Start>} \leq$ 50.5 Hz to $f_{Stop>}$ = 51.5 Hz.	Compliant, adjustable in the range of 45 Hz to 55 Hz, for more details see parameter 16-18 /6/
1.2.3	The initial time delay T_V of the frequency- dependent active power variation is not more than 2 s, otherwise consultation with the grid operator is required.	$T_V \leq$ 2 s or justification to the grid operator.	Compliant, the initial time delay of the frequency-dependent active power variation is defined as 0 ms.
1.2.4	Conditions for T_V and $T_{an90\%}$ are met.	After T_V +0.1 ($T_{an90\%} - T_V$) at least 9% ΔP are produced; after $T_{an90\%}$ at least 90% ΔP are produced.	Compliant, through measurements /2/
1.3	The statics of the frequency-dependent active power variation is adjustable in the frequency ranges defined under 1b1 and 1b2 between 2% and 12%. Type testing takes place at a static value of 5%. Note: For Storage system a static value s of 2% applies	$2\% \leq S = \frac{\frac{\Delta f}{fn}}{\frac{\Delta P}{Pref}} \leq 12\%$ $S_{Standard}$ = 5 % (= 40 % P_{ref}/Hz)	Compliant, the required gradient (or droop) of the frequency dependent active power derating can be defined using the Parameters Trigger frequency of over frequency derating, Cuttoff frequency of over frequency derating and Cutoff power of over frequency derating /6/. The measurement is done with 2% droop.
1.4	In the frequency ranges between $f_{Start<}$ and $f_{Stop<}$ and/or $f_{Start>}$ and $f_{Stop>}$ (see 1b1 and 1b2) the PGU tracks up and down the characteristic curve with respect to power output.	True	Compliant, by measurement /2/ chapter 4.1.3.1 and 4.1.3.2
1.5	The active power reduction is possible down to the technical minimum power of the PGU.	True	Compliant, the min. active power in case of overfrequency derating can be limited using parameter Cutoff power of overfrequency deating. The PGU can be operated by an active power setpoint of 0. See manufacturer declaration /1/

1.6	Manufacturer's declaration documents: • The PGU can be operated another 5 s without active power increase above $f_{Stop>}$. • Separation from the grid only takes place for reasons of self-protection.	True	Compliant, the PGU can remain in operation in case that the grid frequency increases above f_{Stop}> but not triggered by the grid protection or self-protection, in this case the active power will be kept at the power level defined by parameter Cutoff power of overfrequency derating. See manufacturer declaration /1/
1.7	Transition from critical to normal grid conditions only takes place under the stipulated conditions.	Within 10 min after the frequency returns to the range of 50 Hz ± 0.2 Hz a reduction of active power to P_{mom} may take place with max. 10% $P_{b,Inst}$/min.	Compliant, see chapters 4.1.3.2 and 4.1.3.4 in measurement report
2	PGU transit through fast frequency changes (RoCoF) without disconnecting from the grid.	Manufacturer's declaration documents: ±2.00 Hz/s in rolling 0.5 s window; ±1.50 Hz/s in rolling 1.0 s window; ±1.25 Hz/s in rolling 2.0 s window can be transited without disconnection from the grid. Otherwise, the framework conditions for fulfilment of the requirement have to be shown in the certificate.	Compliant by manufacturer declaration /1/
2.1	Manufacturer's declaration documents: In the range between 50 Hz and the curve in Figure 17 of /A/ and Figure 14 of /B/, PGUs do not reduce their active power.	True	Compliant by manufacturer declaration /1/
3	Below 49.5 Hz gas or steam power plants as well as combustion engines do not reduce their maximum active power output by more than the specified value.	Max. permissible P- reduction $10\% \cdot P_{b,Inst} \cdot \frac{49{,}5\,Hz - f}{1\,Hz}$ for f < 49.5 Hz	Not relevant for PV inverter
4	Manufacturer's declaration documents: Combustion engines and gas turbines reduce their active power by a maximum of 3% P_{rE} until returning to above 49.5 Hz in the dynamic short- term range as presented in Figure 17.	True	Not relevant for PV inverter
5	Gas turbines or combustion engine PGUs vary their active power output with at least the specified gradient.	dP/dt ≥ 66 % P_n/min for P_n ≤ 2 MW; dP/dt ≥ 20 %P_n/min for Pn > 2 MW	Not relevant for PV inverter

Further evidence:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
A	Setting ranges for the active power reduction (f_{Start}>, f_{Stop}>, f_{Start}<, f_{Stop}<, static, "operating on the characteristic") are stated.	Shown in manufacturer's declaration.	Compliant, see parameters 16-18 and 22-24 in parameter list /6/
B.1 SP	On the characteristic curve according to Figure 26, the points 1., 2., 3., 4 and 5. In the overfrequency range were achieved in the indicated sequence.	True. The initial active power feed-in is at least 100% P_{rE}.	Compliant, see chapter 4.1.3.1 in measurement report, Table 4.1-12
B2	At each of the steps, a pause took place for at least the time required to demonstrate that no undamped power oscillations took place.	True, if decaying resonance behaviour evident.	Compliant, see chapter 4.1.3.1 in measurement report /2/
B3 SP	Rise and settling times have been determined for the steps from 2 to 3 and 3 to 4. They meet the specifications.	The rise and settling times determined meet the specifications.	Compliant, see chapter 4.1.3.1 in measurement report /2/
B4	The active power gradient has been determined for the step from 4 to 5. This meets the specifications.	The determined active power gradient meets the specifications.	Compliant, see measurement report Table 4.1-15 Gradient adjustable over parameter no. 20 (Power recovery gradient of overfrequency derating)
C1 SP	On the characteristic curve according to Figure 26, the points 1., 2., 3, 4., 5. and 6. in the underfrequency range were achieved in the indicated sequence.	True. The initial active power feed-in is a maximum of 100% P_{rE}.	Compliant, see chapter 4.1.3.2 in measurement report /2/
C2	At each of the steps, a pause took place for at least the time required to demonstrate that no undamped power oscillations took place.	True, if decaying resonance behaviour evident.	Compliant, see chapter 4.1.3.2 in measurement report
C3	Rise and settling times have been determined for the steps from 2 to 3 and 4 to 5. They meet the specifications.	The rise and settling times determined meet the specifications.	Compliant, see chapter 4.1.3.3 in measurement report
C4	The active power gradient has been determined for the step from 5. to 6. This meets the specifications.	The determined active power gradient meets the specifications.	Compliant, see measurement report Table 4.1-22 Gradient adjustable over parameter no. 26 (Power recovery gradient of underfrequency rise power)
D	An operating capability above 51.5 Hz has been shown, if present.	Shown in manufacturer's declaration.	Compliant, the PGU can remain in operation at the grid frequency above 51.5 Hz if not interfered by the grid protection setting range: OF: 60 Hz UF: 40 Hz

For Type 2 PGUs the following applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1.1.1a	PGU and controllable consumer units of Type 2 comply with the requirements for rise and settling times according to Table 9 of VDE-AR-N 4110 /A/ for the active power **increase** in the ranges 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz. (Limitations due to technical restrictions need to be observed)	$T_{an90\%} \leq 10$ s for $\Delta P \leq 50$ % $P_{b,Inst}$; $T_{ein} \leq 30$ s	Compliant /2/
1.1.1b	PGU and controllable consumer units of Type 2 comply with the requirements for rise and settling times according to Table 5 of VDE-AR-N 4120 /B/ for the active power **increase** in the ranges 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz. (Limitations due to technical restrictions need to be observed)	$T_{an90\%} \leq 10$ s for $\Delta P \leq 50$ % $P_{b,Inst}$; $T_{ein} \leq 30$ s	Compliant /2/
1.1.2a	PGU and controllable consumer units of Type 2 comply with the requirements for rise and settling times according to Table 9 of VDE-AR-N 4110 /A/ for the active power **reduction** in the ranges 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz. (Limitations due to technical restrictions need to be observed)	$T_{an90\%} \leq 2$ s for $\Delta P \leq 50$ % $P_{b,Inst}$; $T_{ein} \leq 20$ s	Compliant /2/
1.1.2b	PGU and controllable consumer units of Type 2 comply with the requirements for rise and settling times according to Table 5 of VDE-AR-N 4120 /B/ for the active power **reduction** in the ranges 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz. (Limitations due to technical restrictions need to be observed)	$T_{an90\%} \leq 2$ s for $\Delta P \leq 50$ % $P_{b,Inst}$; $T_{ein} \leq 20$ s	Compliant /2/
1.1.3	Storage systems of Type 2 comply with the requirements for rise and settling times according to Table 5 for the active power increase in the ranges 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz.	$T_{an90\%} \leq 1$ s for $\Delta P \leq 100$ % $P_{b,Inst}$ $Tein \leq 10$ s	Compliant, max T_{ein}= 1.28 s /2/
1.1.4	Storage systems of Type 2 comply with the requirements for rise and settling times according to Table 5 for the active power reduction in the ranges 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz.	$T_{an90\%} \leq 1$ s for $\Delta P \leq 100$ % $P_{b,Inst}$; $Tein \leq 10\ s$	Compliant, max T_{ein}= 1.28 s /2/
1.1.5	Wind turbines comply with the requirements for rise times for the active power increase in the range 49.8 Hz to 47.5 Hz as well as 51.5 Hz to 50.2 Hz. (Limitations due to technical restrictions need to be observed)	$T_{an90}\% \leq 5$ s for $\Delta P \leq 20$ % $P_{b,Inst}$ From P=50 % $P_{b,Inst}$	Not relevant for PV inverter
1.3	The standard value of the static behaviour is 2% for Type 2 storage systems.	$s_{Standard}$=2% (=100% P_{ref}/Hz)	Compliant /2/
6	Feed-in operation at 10% P_{rE} is possible.	True	Compliant, /2/
7	The specifications for frequency-dependent active power are met (Figure 17 in /A/ and Figure 15 in /B/).	True	Compliant, by manufacture-declaration /1/

5.4.3 Assessment

5.4.3.1 General information and grid safety management

Maximum active power output was measured, the ramp rate results and step point accuracy are found in measurement report /2/. The PGU stayed connected throughout all tests.

Table 5-18 presents the measurement results of maximum active power output, averaged over 200 ms, 1 minute and 10 minutes.

Table 5-18 Maximum values of active power /2/

	600-s-Average	60-s-Average	0.2-s-Average
Active power maxima [kW]	P_{600} = 201.04	P_{60} = 201.04	$P_{0.2}$ = 201.20
Relative active power maxima $p = P / P_N$ [p.u.]	P_{600} = 1.01	p_{60} = 1.01	$p_{0.2}$ = 1.01

The active power of the unit is limited by different reference quantities and values, which has inherent limitation at atmospheric pressure and temperatures. The active power will be de-rated if the temperature value(s) shown in /1/ Annex 5 are exceeded.

The accuracy of the set-point control, presented in /2/, was measured for 10 % steps from 100 % to the minimum capacity 0 % of rated power, using 1-minute average values, showing a maximum deviation of 0.16 % of rated power, which is well within the requirements of /A/ and /B/.

The maximum and minimum active power ramp rate of the PGU has been tested in accordance with FGW TG3 /C/, with the resulting gradients and settling times as presented in Table 5-19 which complies with the active power range requested by /A/ and /B/.

Table 5-19 Result for slow and fast ramp measurements /2/

Active power step	Gradient [%/s]	Rise and settling time [s]
Slow:		
P_0 = 70 % → P_{min} = 50 %	0.33	44.66
P_{min} = 50 % → P_0 = 70 %	0.33	44.54
Fast:		
P_0 = 90 % → P_{min} = 10 %	0.66	114.07
P_{min} = 10 % → P_0 = 90 %	0.66	113.34

5.4.3.2 Active power output as a function of grid frequency

As specified by the manufacturer /1/, the units RoCoF ride-though function complies with the requirements set out by /A/ and /B/. The LFSM-O tests were performed in steps as seen in Table 5-20. The mean active gradient was measured to 100 % P_{ref}/Hz for a gradient setting of 100 % P_{ref}/Hz, following the same gradient both for increase and decrease of frequency. The maximum and mean active power gradient when returning below 50.2 Hz was measured to 9.99 % P_{ref}/min, for a defined gradient of 10.0 % P_{ref}/min. The settling time is specified in Table 5-21, showing compliance with the requested active power gradient for PGU units of type 2 storage /A/ and /B/.

Table 5-20 LFSM- O tests. /2/

Step reference	Frequency [Hz]	Power set-point P_{set} [p.u.]	Power measured P_{set} [p.u.]	Power gradient [% P_M/Hz]
1	50.00	1.000	1.000	-
2	50.30	0.900	0.900	-
3	51.40	-0.200	-0.200	- 100.00
4	50.30	0.900	0.900	- 100.00
5	50.00	1.000	1.000	-

Table 5-21 Rise and settling times for LFSM-O tests /2/

Frequency step	Rise time [s]	Settling time [s]
2 → 3	1.28	1.28
3 → 4	1.28	1.28

The tests for LFSM-U was performed in a corresponding manner as the LFSM-O tests. The mean active gradient was measured to 100 % P_{ref}/Hz for a gradient setting of 100 % P_{ref}/Hz, following the same gradient both for increase and decrease of frequency. The maximum and mean active power gradient when returning below 49.8 Hz was measured to 9.99 % P_{ref}/min, for a defined gradient of 10.0 % P_{ref}/min. The settling time is specified in Table 5-23 and compliant with the requested active power gradient for PGU units of type 2 /A/ and /B/.

Table 5-22 LFSM- U tests /2/

Step reference	Frequency [Hz]	Power set-point P_{set} [p.u.]	Power measured P_{set} [p.u.]	Power gradient [% P_M/Hz]
1	50	- 1.000	0.099	-
2	49.70	- 0.900	0.103	-100.00
3	47.60	1.000	0.187	- 100.00
4	48.70	0.100	0.143	- 100.00
5	49.70	- 0.900	0.103	- 100.00
6	50.00	- 1.000	0.100	-

Table 5-23 Rise and settling times for LFSM-U tests /2/

Frequency step	Rise time [s]	Settling time [s]
2 → 3	0.93	0.93
4 → 5	1.16	1.16

As stated above all requirements in conjunction with “Active power output as a function of grid frequency” stated in the FGW TG8 /D/ and Chapter 11.2.8 of VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/ are fulfilled by the inverter. For this reason, this function can be considered as compliant. Should this functionality not be desired on project level, the operator also has the possibility to disable “Active power output as a function of grid frequency” altogether. In this case however, a plant controller is needed which takes over this functionality instead of the inverter.

5.5 Connection

5.5.1 Switching-in conditions

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1a	In the voltage-frequency range to be shown (47.5 Hz ± 0.1 Hz and at 50.2 Hz ± 0.1 Hz as well as at 90% U_n ± 2% Un and 110% ± 2% U_n) a connection of the PGU to the medium-voltage grid is technically possible /A/	True	Compliant, as by manufacturer declaration and measurement results chapter 4.5
1b	In the voltage-frequency range to be shown (47.5 Hz ± 0.1 Hz and at 50.2 Hz ± 0.1 Hz as well as at 90% U_n ± 2% Un and 110% ± 2% U_n) a connection of the PGU to the high-voltage grid is technically possible /B/	True	Compliant, connection settings adjustable in parameter no 72-81 in /6/
1.1.b	For evidence of cut-in above 50.2 Hz a manufacturer's declaration was submitted.	True	Compliant, by parameter no 76 "Grid reconnection frequency upper limit", adjustable between 50.0 Hz and 60.0 Hz
2	Automatic connection of the PGU after disconnection from the grid by triggering a grid protection device is only possible in given voltage and frequency ranges.	$U \geq 95\%\ U_n$ 49.9 Hz ≤ f ≤ 50.1 Hz	Compliant, as by measurement report chapter 4.5.2 Table 4.5-2
2.1.b	The concept for reconnection has to be shown	Details provided	Compliant, the reconnection can be switched between manual reconnection mode and automatic reconnection mode using the parameter *Auto start upon grid recovery*. Connection condition settings adjustable in parameters 72-81 in /6/
3	Automatic reconnection only takes place after grid stabilisation time which can be adjusted.	Stabilisation time can be adjusted from 0 to 30 min.	Compliant, time until reconnection adjustable in the range of 0 to 120 min, see parameter 28 in /6/
3.1	The evidence was provided based on a delay time of 5 min and the possible setting range was stated.	True	Compliant, by measurement report
4	The gradient of active power was shown. a) By means of manufacturer's declaration: Setpoint specifications (connection without protection being triggered previously) and b) By means of measurement: Reconnection after voltage loss (connection after grid protection was triggered)	True	Compliant a) Parametrizable through Soft start time, with a range of 1-1800 s (default value 600 s) /6/ b) See measurement report /2/, section 4.1.4
4.1	The gradients determined under 4 are always larger than 0.33% P_{rE}/s.	True	Compliant
4.2	The gradients determined under 4 are always smaller than 0.66% P_{rE}/s.	True	Compliant

Further evidence

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
A	The gradient was measured after a power outage of at least one minute up to an active power of at least 50% PrE.	True	Compliant, see measurement report /2/, section 4.1.4

For Type 2 PGU the following applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Asynchronous generators with drive unit are connected within the indicated speed range.	Connection within speed range 95% ns ≤ n ≤ 105% ns.	Not relevant for PV inverter

1.1	The connection of the asynchronous generators with drive unit takes place on a current-limited basis.	True. Information provided in the manufacturer declaration regarding the current-limiting measures.	Not relevant for PV inverter
2	Asynchronous generators which cannot be connected when de-energised (e.g. DFIG) comply with the general connection conditions.	True. Shown in manufacturer's declaration.	Not relevant for PV inverter

5.5.2 Assessment

The results of the verification of the reconnection condition, found in /2/ are showing that reconnection without previous protection triggering only takes place at voltages between 90 % and 110 % and at frequencies between 47.5 Hz and 50.2 Hz, as requested by the VDE-AR-N 4110 /A/. The same voltage range connection condition applies for the VDE-AR-N 4120 /B/ and can be adjusted if required.

After tripping by protection device, the integrated protection relay will keep monitoring the grid voltage and frequency. If the reconnection conditions are met, a timer (corresponding to the set reconnection delay) will start to count. Should a new grid fault be detected during this reconnection process, the timer will reset automatically. After the timer running out the integrated disconnection devices will reconnect the PGU to the grid and the active power will ramp up according to the defined gradient.

For connection after protection triggering, it has been demonstrated that reconnection is possible in for a voltage of at least 95 % and in the frequency range of 49.9 Hz to 50.1 Hz. Since the setting for the voltage and frequency range can be adjusted according to the parameter list /6/, the requirements are regarded as fulfilled, which would be easily achievable by changing the corresponding setting.

The limit values for voltage and frequency can be monitored continuously prior to reconnection, with a parametrizable time window of 0-120 minutes. This was verified during testing with a time delay of 5 minutes, as required by /A/ and /B/. No cut-in possible when external unblocking signal is inactive, this was tested and documented in the measurement report (applicable for /B/ only).

After reconnection, the active power will be resumed with a limited active power increase, as shown in corresponding tests presented in section 4.1.4 of /2/, which were done according the FGW TG3 Rev. 25 /C/. The average gradient was measured to be 9.90 $\%P_n$/min. However, the test procedure described in /C/ is not correct according to the requirements of /A/ and /B/. Upon reconnection after decoupling the PGU from the grid, the active power gradient shall be adjustable in the range $>0.33\%P_n/s$ and $<0.66\%P_n/s$. But since it was proven in chapter 5.4.1 that the unit can be within the mentioned gradient by adapting parameter 9 (active power change gradient) /6/, can this be considered as fulfilled.

5.6 Protection

5.6.1 Readability of the protection setting

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The protection devices on the power generating units have been designed in such a way that the settings can be easily read without additional equipment or if additional equipment is required, the authenticity and identification of the data read out is ensured.	True	Not compliant, the integrated grid monitoring/protection parameters can be checked per remote via WebUI or via SUN2000 app using a mobile phone

5.6.2 Test terminal

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Protection test is possible without disconnecting wires.	True	Not compliant, see below
1.1	The manufacturer's declaration includes a technical description of the test terminal demanded in requirement 1, as per Chapter 6.3.3.5 of the application rule.	True	Not compliant, the PGU does not provide test terminals for on-site testing. For necessary on-site testing, an external monitoring relay with corresponding test terminals must be installed and the PGU's monitoring parameters must be set accordingly

5.6.3 Operating range

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	A type test is available for the protection devices integrated in the PGU for the setting ranges required according to Table 11 or 13 according to FGW-TG3-Rev. 24 or later.	True	Compliant, see /2/ chapter 4.4.4 and 4.4.5
2	Additional protection devices which are present in the PGU are shown with their setting value range.	True	Self-protection: parameter 110 for overvoltage protection (1.3 Un for 150 ms) Undervoltage protection for self-protection has a default value of 80 V (L-L) for tU<<= 40ms. Huawei confirms that self-protection is disabled by software during an LVRT case. This prevents the self-protection from undercutting the required LVRT curve

5.6.4 Accuracy

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The required measurement accuracies for the protection devices of the PGU (voltage: ±1% U_n; frequency: ±0.1 Hz: see FNN-Recommendation Annex B) are met. Regarding the frequency support equipment, FGW TG3 is currently being revised. Until the next revision from a measurement perspective an accuracy of 0.1 Hz must be demonstrated.	True	Compliant, see /2/ chapter 4.4.4 and 4.4.5 Tables 4.4-2 to 4.4-8
2	The reset ratio of the voltage protection devices is complied with.	≥ 0.98 (overvoltage protection) ≤ 1.02 (undervoltage protection)	Compliant, see /2/ chapter 4.4.3

5.6.5 Independence of the protection functions

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The integrated protection in the PGU - if present - works independently of the control functions.	True	Compliant, the integrated protection functions are implemented independent from other parameters and control functions. See manufacturer declaration page 12
2	Function presentation to show that protection and control functions operate in different software blocks.	Details provided	Compliant, see /1/

5.6.6 Own and auxiliary power supply

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	Grid-independent auxiliary power supply is available and maintains protection functions for at least 5 s.	True	Compliant, the grid monitoring functions can be maintained for at least 5 s during grid voltage loss /1/
1.1	Functionality of the protection functions within the operating ranges shown in Figure 4 proven.	True	Compliant, see manufacturer declaration /1/
2	A failure of the auxiliary power supply of the protection devices leads to immediate switch-off of the PGU.	True	Compliant, see manufacturer declaration /1/
3	The protective functions are functional prior to the start of power input by the power generating unit.	True	Compliant, see manufacturer declaration /1/

Further evidence:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
A	A failure of the auxiliary power supply of the protection devices and/or system control leads to immediate triggering of the PGU's main switch.	True	Compliant, see manufacturer declaration /1/
Note: this evidence is optional			

5.6.7 Coupling switch

The following generally applies:

No.	Evaluation Criteria	Acceptance Criteria	Assessment result
1	The coupling switch ensures three-pole galvanic separation.	True	Compliant, see manufacturer declaration /1/ and measurement report chapters 4.4.4 and 4.4.5
2	The coupling switch is designed as specified by the manufacturer. The switching capacity of the coupling switch is stated.	True	Compliant, see manufacturer declaration /1/
3	The coupling switch is able to be triggered without delay taking into account the protection equipment required according to 10.3.	True	Compliant, see manufacturer declaration /1/
4	The sum of time elements of the protection and switching equipment does not exceed 100 ms.	True	Compliant, see manufacturer declaration /1/ and measurement report chapter 4.4.4 and 4.4.5

5.6.8 Assessment

Several tests were performed for the LUNA2000-200KTL-H0 for the verification of the disconnection of the generating unit from the grid during over-voltage and under-voltage, as well as during over-frequency and under-frequency events. In order to determine the release times of the protection system, the voltage and frequency was changed in steps, using a grid simulator. The tests were performed in accordance with FGW TG3 /C/ and comply with the requirements of FGW TR8 /D/. The minimum possible settable delay time for the protection was 50 ms and minimum value for undervoltage protection was 0.15 U_n.

The main-protection implemented in the software meets the requirements of the stated guidelines with regard to trigger accuracy, release ratio and triggering time.

The operation time of the circuit breaker was not tested separately for the LUNA2000-200KTL-H0, However, according to /2/, all over-/undervoltage and over-/underfrequency protection tests include the reaction time of the main breaker. Using these results, the operation time was presumed to be within 50 ms. Failure of auxiliary power supply was not tested separately, however the expected behaviour was confirmed by the manufacturer.

The under-voltage capability and over-voltage capability of the LUNA2000-200KTL-H0 is shown in Figure 5-6.

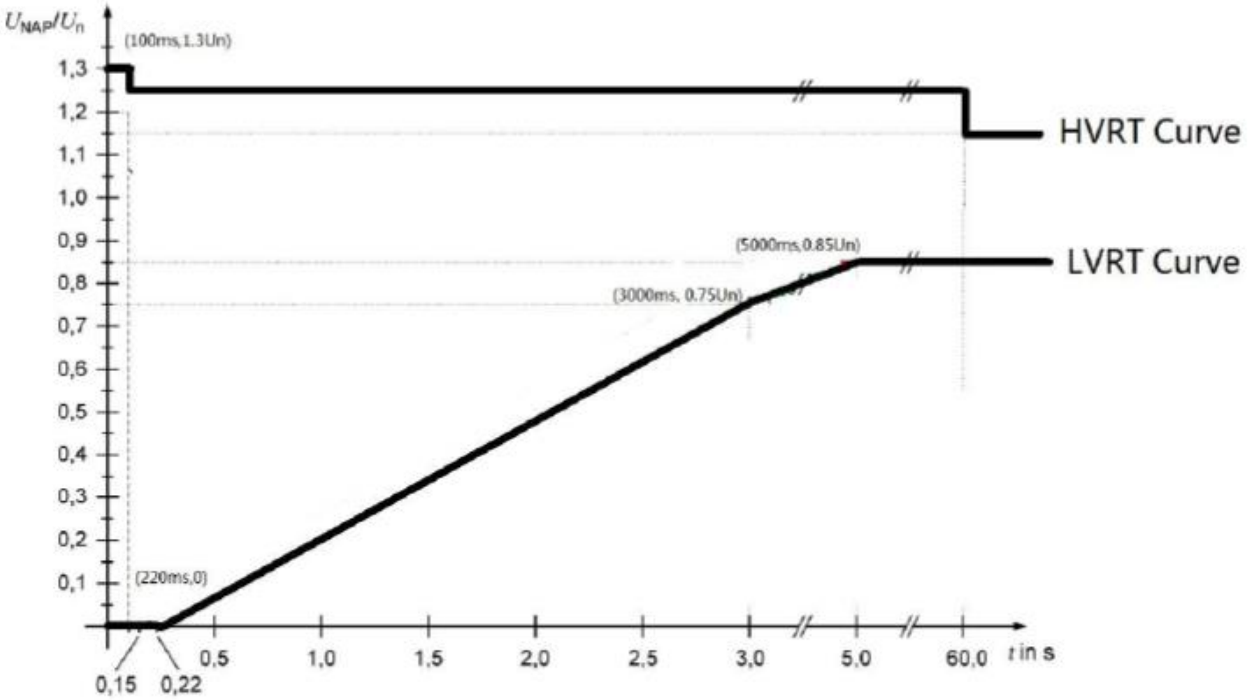

Figure 5-6 Under- and overvoltage capability of the LUNA2000-200KTL-H0 /1/.

The maximum and minimum operating range in terms of frequency is 50-60 Hz and 40-50 Hz respectively /6/.

Huawei Technologies Co., Ltd. provided corresponding manufacturer documentation /1/ regarding the requirements for the protection function of the medium- and high-voltage guidelines /A/ and /B/. The protective device operates independently of the inverter control (using a separate software module). It has a sufficient CPU resource and the auxiliary power supply can be maintained for at least 5 s. If the auxiliary power supply fails, the generating unit is immediately disconnected. Furthermore, a power-outage in the protection device will lead to an instantaneous tripping of the circuit breaker. Overall, the inverters fulfil the requirements with two exceptions: the inverters have no display to check the protection settings and the required test terminals are not available.

To check the protection settings, a corresponding Huawei application (app) for smartphones or tablets is available. Since the operator of the PV-plant is responsible to provide a proper method for assessing the correct settings, it might be necessary for them to either provide such a device (tablet or smartphone), with corresponding application, on demand or to keep such a device permanently on site, if requested by the grid operator.

Regarding the missing test terminals, the consequences need to be investigated on project level. Depending on the requirements of the corresponding grid operator, an additional “intermediate” protective disconnection device on the low-voltage side of the transformer might be necessary.

6 CONDITIONS

- The components listed in section 4.2 shall be used. Changes to the system design, software or the manufacturer's quality system are to be approved by DNV.
- In case PT1-behaviour for reactive power set point changes is requested on project level, this needs to be implemented by a plant controller providing the corresponding set-points to the generating unit.
- The PGU has one interface to handle active power set points. Consequently, prioritization of control input signals from different actors (such as grid operators and direct sellers) is not possible. To have this feature implemented a plant controller is needed in order to comply with A.1.2.5.1.1/A.2.2.5.1.1 No. 3 in FGW TG8 /D/ on project level.
- The display to check the protection settings is missing, as well as the test terminals used to enable protection tests without disconnecting any wires. This is not in agreement with the requirements of the VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/. Therefore, the following shall be taken into account:
  - With regard to the missing display, the operator of the PV-plant is responsible to provide a proper solution for checking the settings of the generating unit. If requested by the grid operator, it might therefore be necessary to provide such device (e.g. tablet or smartphone) with a corresponding application, which is either to be stored on site or need to be provided on demand.
  - With regard to the missing test terminals, the consequences need to be investigated on project level. Depending on the requirements of the corresponding grid operator, an additional "intermediate" protective disconnection device on the low-voltage side of the transformer might be necessary.
- The parameters of the generation unit are summarized in the parameter list provided by the manufacturer /6/. The specified "default values" do not automatically meet the requirements according to the guidelines mentioned in section 2. If necessary, the settings must be adjusted and checked on a project level.
- In general, it needs to be investigated on project level whether a permanent reduction of the rated active power is necessary to meet the reactive power requirement at the grid connection point.
- If a reactive power provision by the functionality "Q(U) control" or by "Q with voltage limiting function" is required on project level the use of a plant control having these functions implemented is mandatory.
- The maximum unbalance of the current for $P \geq 10$ % of P_N was measured to 1.78 %, which oversteps the limit of 1.5 % stipulated by VDE-AR-N 4110. Consequently, this will need to be assessed at project level.

7 CONCLUSION

The following tests and measurements were performed, according to the requirements of the FGW TG3 /C/:

- Active power peaks
- Active power control by means of set-point control
- Active power reduction at increased grid frequency (LFSM-O)
- Active power increase at reduced grid frequency (LFSM-U)
- Active power limitation during restart of the generating unit
- Voltage independent PQ diagram (Q capability)
- Separate operating points in the voltage dependent PQ diagram
- Reactive power control by means of fixed set-point control (Q setpoint)
- Q(P) control
- Power quality: flicker, measurement of harmonics and inter-harmonics of the currents, switching operations and current asymmetry
- Grid protection: over/under-voltage and over/under-frequency
- Reconnection conditions

The tests received were assessed according to the criteria given in the corresponding sections of the FGW TG8 /D/.

Under consideration of the conditions given in section 6, the inverter LUNA2000-200KTL-H0 of Huawei Technologies Co., Ltd. fulfil the requirements on the aforementioned criteria as given in the regulations cited in section 2.

8 REFERENCES

/1/	Manufacturer's declaration for compliance to technical requirements of the VDE-AR-N 4110:2018-11 and the VDE-AR-N 4120:2018, V1.0	21 pages	dated 2022-12-19
/2/	Measurement of power quality and power control characteristics of a PV inverter of the type HUAWEI LUNA2000-200KTL-H0 according to FGW TG3 Rev. 25, report no. 1033279-SHA-TR-02-B	111 pages	dated 2022-12-21
/3/	Extract of the measurement report "Measurement of power quality and power control characteristics of a PV inverter of the type LUNA2000-200KTL-H0", extract no. 10332709-SHA-TS-02-A	5 pages	dated 2022-12-21
/4/	Overview on the necessary documentation and data for the Prototype Confirmation of power generating units (PGU) in accordance to the VDE-AR-N-4110/4120 e Guideline, V1.3	13 pages	dated 2021-09-14
/5/	Email with the subject "答复: //答复: 【代邵武转发】LUNA2000-200KTL-H0 TR4 模型问题" with the topic "Self-protection will be disabled by software internally during LVRT", "rated apparent power" and "protection diagram"	-	dated 2022-12-21
/6/	Parameter list of LUNA2000-200KTL-H0, 03b0964bc462f12d41f3f3229abb3f91	12 pages	dated 2022-07-01
/7/	Description of the Function Blocks of the Voltage Protection, V1.0	5 pages	dated 2020-06-18
/8/	Email with the subject "答复: //答复: 【代邵武转发】LUNA2000-200KTL-H0 TR4 模型问题" with the topic "LFSM-O operation logic"	-	dated 2022-12-19
/9/	ISO 9001:2015 Certificate no. 17 100 1933213 issued to Huawei Technologies Co., Ltd. for the design, manufacture and service of inverters	11 pages	dated 2020-08-12

9 APPENDIXES

9.1 Overview of Documents

Table 9-1 Overview of Documents

No.	Content	Filename	MD5-Checksum
1	Parameter list_V1.0	Huawei_LUNA2000-200KTL-H0_Parameter list_V1.0.pdf	03b0964bc462f12d41f3f3229abb3f91

9.2 Extract from 10332709-SHA-TR-02-B

DNV

DNV

EXTRACT OF THE TEST REPORT "MEASUREMENT OF POWER QUALITY AND POWER CONTROL CHARACTERISTICS OF A PCS TYPE HUAWEI LUNA2000-200KTL-H0 ACCORDING TO FGW TG3 REV. 25"

„Technical Guideline Part 3", Revision 25, FGW

Extract No.
10332709-SHA-TS-02-A
Date of Issue
2022-12-21

Installation type	LUNA2000-200KTL-H0	Generic type of installation	PCS
Manufacturer	Huawei Technologies Co. Ltd.	Nominal power P_n in kW	200
Test report	10332709-SHA-TR-02-B	Period of measurement	2022-01-03 – 2022-12-19

Nominal Data

Nominal apparent power S_n in kVA	240	Nominal current I_n in A	144.34
Nominal frequency f_n in Hz	50	Nominal voltage U_n in V	800

Active power peaks

Active power P_x	$P_{0.2}$	P_{60}	P_{600}
Averaging time in s	0.2	60	600
Measured active power in kW	201.20	201.04	201.04
Normalized active power in p.u.	1.01	1.01	1.01

Switching operations – Cut-in at cut-in conditions

Max. number of switching operations N_{10}	20			
Max. number of switching operations N_{120}	240			
Grid impedance angle	**30°**	**50°**	**70°**	**85°**
Flicker step factor $k_f(\psi_k)$	0.02	0.03	0.03	0.04
Voltage change factor $k_u(\psi_k)$	0.09	0.07	0.05	0.05

Switching operations - Cut-in at full load conditions

Max. number of switching operations N_{10}	20			
Max. number of switching operations N_{120}	240			
Grid impedance angle	**30°**	**50°**	**70°**	**85°**
Flicker step factor $k_f(\psi_k)$	0.01	0.02	0.02	0.02
Voltage change factor $k_u(\psi_k)$	0.87	0.65	0.36	0.15

Switching operations – Cut-off at full load conditions

Max. number of switching operations N_{10}	1			
Max. number of switching operations N_{120}	12			
Grid impedance angle	**30°**	**50°**	**70°**	**85°**
Flicker step factor $k_f(\psi_k)$	0.13	0.10	0.07	0.05
Voltage change factor $k_u(\psi_k)$	0.87	0.65	0.36	0.15

Asymmetry

Power bin in % of P_n	u_i in %	Power bin in % of P_n	u_i in %
0	9.17	60	0.99
10	1.78	70	0.95
20	1.30	80	0.93
30	1.24	90	0.93
40	1.04	100	0.89
50	1.04	-	-
Max. current asymmetry $u_{i\,max}$ for P≥ 10 % P_n in %		1.78	

Flicker

ψ_k / P_{bin} in % of P_n	30°	50°	70°	85°
0	0.23	0.23	0.23	0.24
10	1.43	1.08	0.64	0.38
20	1.31	1.00	0.60	0.35
30	7.04	5.31	3.07	1.59
40	1.31	1.01	0.60	0.33
50	0.23	0.23	0.22	0.23
60	1.29	1.00	0.62	0.34
70	1.30	1.01	0.61	0.34
80	6.14	4.74	2.84	1.37
90	4.93	3.82	2.30	1.11
100	0.25	0.25	0.26	0.27

Harmonics

Power bin in % of P_n	0	10	20	30	40	50	60	70	80	90	100	max.
h						I_h/I_n in %						
2	0.21	0.07	0.07	0.08	0.08	0.09	0.08	0.07	0.08	0.09	0.09	0.21
3	0.09	0.08	0.13	0.11	0.11	0.10	0.08	0.08	0.06	0.10	0.09	0.13
4	0.14	0.11	0.03	0.03	0.04	0.05	0.05	0.06	0.08	0.08	0.09	0.14
5	0.74	0.27	0.24	0.18	0.20	0.31	0.38	0.43	0.48	0.52	0.57	0.74
6	0.15	0.10	0.04	0.03	0.03	0.03	0.02	0.03	0.04	0.05	0.06	0.15
7	0.39	0.57	0.27	0.23	0.30	0.38	0.48	0.57	0.65	0.73	0.77	0.77
8	0.06	0.03	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.06
9	0.10	0.09	0.16	0.08	0.15	0.15	0.16	0.16	0.15	0.17	0.19	0.19
10	0.07	0.07	0.04	0.04	0.03	0.04	0.05	0.05	0.04	0.04	0.04	0.07
11	0.44	0.15	0.25	0.21	0.14	0.14	0.10	0.06	0.14	0.16	0.21	0.44
12	0.04	0.05	0.03	0.02	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.05
13	0.27	0.10	0.26	0.35	0.28	0.24	0.17	0.17	0.28	0.31	0.37	0.37
14	0.08	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.08
15	0.05	0.11	0.08	0.16	0.18	0.12	0.09	0.09	0.10	0.11	0.14	0.18
16	0.09	0.06	0.05	0.04	0.03	0.06	0.05	0.05	0.05	0.06	0.05	0.09
17	0.35	0.28	0.06	0.13	0.24	0.16	0.12	0.06	0.12	0.13	0.20	0.35
18	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
19	0.16	0.19	0.17	0.09	0.24	0.26	0.23	0.21	0.22	0.19	0.25	0.26
20	0.05	0.04	0.05	0.05	0.03	0.03	0.04	0.05	0.06	0.05	0.05	0.06
21	0.06	0.06	0.12	0.08	0.10	0.13	0.08	0.11	0.10	0.08	0.08	0.13
22	0.08	0.04	0.05	0.04	0.03	0.04	0.03	0.04	0.04	0.05	0.06	0.08
23	0.22	0.09	0.13	0.07	0.06	0.08	0.08	0.11	0.14	0.13	0.11	0.22
24	0.05	0.04	0.03	0.03	0.04	0.03	0.05	0.06	0.06	0.05	0.06	0.06
25	0.16	0.27	0.14	0.23	0.16	0.17	0.23	0.25	0.22	0.21	0.24	0.27
26	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04	0.05
27	0.12	0.06	0.07	0.08	0.11	0.10	0.08	0.06	0.08	0.08	0.09	0.12
28	0.04	0.03	0.03	0.04	0.03	0.02	0.02	0.03	0.04	0.04	0.05	0.05
29	0.13	0.08	0.04	0.06	0.11	0.05	0.06	0.04	0.08	0.10	0.10	0.13
30	0.05	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.05
31	0.11	0.15	0.20	0.16	0.19	0.14	0.16	0.21	0.22	0.20	0.19	0.22
32	0.01	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
33	0.12	0.10	0.09	0.06	0.07	0.05	0.08	0.04	0.04	0.06	0.07	0.12
34	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.04	0.05	0.05	0.05
35	0.12	0.07	0.10	0.13	0.07	0.09	0.05	0.03	0.06	0.07	0.07	0.13
36	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.04	0.03	0.03	0.03	0.04
37	0.06	0.10	0.12	0.15	0.11	0.18	0.14	0.18	0.19	0.19	0.19	0.19
38	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03
39	0.10	0.07	0.04	0.08	0.07	0.04	0.07	0.07	0.05	0.07	0.07	0.10
40	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.05	0.05	0.05	0.05
41	0.09	0.13	0.11	0.13	0.13	0.12	0.09	0.07	0.09	0.09	0.10	0.13
42	0.03	0.03	0.04	0.04	0.02	0.02	0.03	0.04	0.03	0.02	0.02	0.04
43	0.04	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.17	0.16	0.17	0.17
44	0.03	0.04	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04
45	0.10	0.04	0.04	0.05	0.05	0.06	0.04	0.07	0.06	0.05	0.06	0.10
46	0.04	0.02	0.02	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05
47	0.07	0.17	0.15	0.14	0.15	0.15	0.10	0.10	0.10	0.09	0.10	0.17
48	0.03	0.03	0.04	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.04
49	0.06	0.10	0.12	0.12	0.14	0.09	0.14	0.12	0.15	0.15	0.14	0.15
50	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.03	0.03	0.03
THC (%)	**1.21**	**0.92**	**0.76**	**0.75**	**0.79**	**0.82**	**0.86**	**0.95**	**1.08**	**1.15**	**1.26**	

Interharmonics

Power bin in % of P_n	0	10	20	30	40	50	60	70	80	90	100	max.
f in Hz						I_f in % of I_n						
75	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
125	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.04	0.05	0.05
175	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.04	0.03	0.03	0.03	0.04
225	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.04	0.03	0.04	0.04
275	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.04	0.03	0.04	0.03	0.04
325	0.02	0.03	0.02	0.02	0.03	0.02	0.03	0.03	0.05	0.04	0.04	0.05
375	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.03	0.04
425	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.04	0.04
475	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
525	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
575	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
625	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
675	0.04	0.04	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.04	0.04	0.04
725	0.04	0.04	0.04	0.04	0.03	0.02	0.03	0.03	0.04	0.04	0.04	0.04
775	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
825	0.05	0.04	0.05	0.05	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05
875	0.05	0.04	0.05	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05
925	0.06	0.04	0.05	0.05	0.04	0.03	0.04	0.04	0.05	0.05	0.05	0.06
975	0.06	0.05	0.06	0.06	0.04	0.03	0.05	0.05	0.05	0.05	0.05	0.06
1025	0.05	0.06	0.06	0.07	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.07
1075	0.06	0.06	0.06	0.06	0.04	0.04	0.05	0.05	0.06	0.05	0.05	0.06
1125	0.05	0.06	0.06	0.06	0.04	0.04	0.05	0.05	0.06	0.05	0.06	0.06
1175	0.05	0.06	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06
1225	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05
1275	0.04	0.05	0.04	0.04	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05
1325	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.06
1375	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
1425	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
1475	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
1525	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
1575	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
1625	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
1675	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03
1725	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03
1775	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03
1825	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1875	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1925	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02
1975	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02

Higher frequencies components

Power bin in % of P_n	0	10	20	30	40	50	60	70	80	90	100	max.
f in kHz						I_f in % of I_n						
2.1	0.10	0.15	0.15	0.16	0.17	0.16	0.16	0.16	0.19	0.20	0.21	0.21
2.3	0.12	0.18	0.16	0.15	0.16	0.17	0.12	0.13	0.13	0.12	0.13	0.18
2.5	0.12	0.11	0.15	0.13	0.14	0.10	0.15	0.13	0.16	0.16	0.15	0.16
2.7	0.14	0.18	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.18
2.9	0.19	0.11	0.08	0.10	0.10	0.10	0.12	0.10	0.11	0.10	0.11	0.19
3.1	0.14	0.16	0.13	0.13	0.14	0.13	0.13	0.14	0.14	0.14	0.15	0.16
3.3	0.29	0.16	0.16	0.11	0.11	0.14	0.14	0.13	0.14	0.15	0.16	0.29
3.5	0.33	0.19	0.11	0.15	0.11	0.11	0.10	0.10	0.10	0.10	0.11	0.33
3.7	0.21	0.19	0.14	0.11	0.11	0.13	0.10	0.10	0.12	0.11	0.14	0.21
3.9	0.17	0.21	0.22	0.17	0.15	0.15	0.13	0.12	0.13	0.13	0.14	0.22
4.1	0.19	0.18	0.17	0.20	0.20	0.20	0.17	0.14	0.15	0.15	0.16	0.20
4.3	0.09	0.14	0.14	0.14	0.18	0.16	0.12	0.10	0.11	0.10	0.11	0.18
4.5	0.11	0.16	0.17	0.20	0.23	0.20	0.14	0.12	0.13	0.12	0.12	0.23
4.7	0.08	0.11	0.12	0.14	0.14	0.13	0.11	0.11	0.12	0.12	0.12	0.14
4.9	0.08	0.10	0.11	0.13	0.15	0.14	0.12	0.12	0.11	0.12	0.12	0.15
5.1	0.09	0.10	0.10	0.12	0.14	0.15	0.14	0.13	0.13	0.13	0.13	0.15
5.3	0.08	0.08	0.08	0.09	0.10	0.12	0.11	0.11	0.12	0.13	0.13	0.13
5.5	0.06	0.08	0.08	0.09	0.09	0.09	0.12	0.12	0.10	0.11	0.12	0.12
5.7	0.10	0.07	0.07	0.08	0.09	0.10	0.11	0.11	0.10	0.11	0.12	0.12
5.9	0.22	0.22	0.22	0.21	0.22	0.22	0.21	0.21	0.21	0.22	0.22	0.22
6.1	0.06	0.08	0.07	0.07	0.07	0.08	0.09	0.09	0.09	0.10	0.11	0.11
6.3	0.08	0.05	0.05	0.05	0.05	0.07	0.07	0.06	0.07	0.07	0.09	0.09
6.5	0.06	0.04	0.04	0.05	0.06	0.07	0.05	0.05	0.05	0.06	0.06	0.07
6.7	0.04	0.03	0.03	0.03	0.04	0.05	0.04	0.04	0.05	0.05	0.07	0.07
6.9	0.04	0.03	0.03	0.03	0.06	0.05	0.04	0.03	0.04	0.04	0.05	0.06
7.1	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.04
7.3	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.05
7.5	0.02	0.02	0.02	0.02	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04
7.7	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03
7.9	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03
8.1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
8.3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
8.5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8.7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8.9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

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About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.