



HUAWEI SUN2000-330KTL-H1/-H2

Certification Report Fault Ride Through

Huawei Technologies Co., Ltd.

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Objective: Verification of the FRT-capability of the PV-Inverters HUAWEI SUN2000-330KTL-H1/-H2

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1 EXECUTIVE SUMMARY

The purpose of this certification report is to document the assessment of the low voltage ride-through (LVRT) as well as the high voltage ride-through (HVRT) capability of the inverters of the type HUAWEI SUN2000-330KTL-H1/-H2. In addition to LVRT and HVRT, this report also uses the general term fault ride-through (FRT).

Grid code requirements other than the FRT capability are not part of this report. The control behaviour and other grid code requirements are assessed within the scope of the certification report CR-GCC-TR8-09667-A067.

The documented results of the type tests and the corresponding manufacturer's documentation were assessed according to the assessment criteria of the guidelines in section 2. The result of the assessment is stated at the end of this certification report, which gives a recommendation as part of the final certification decision.

2 ASSESSMENT CRITERIA

- /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., vom November 2018
(VDE-AR-N 4110 Technical requirements for the connection and operation of customer installations to the medium voltage network (TCR medium voltage))
- /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., vom November 2018
(VDE-AR-N 4120 Technical requirements for the connection and operation of customer installations to the high voltage network (TCR high voltage))
- /C/ FGW TG3: 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)
- /D/ FGW TG8: 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)

3 SCOPE OF ASSESSMENT

3.1 General

The assessment of the fault ride-through capability of the inverter HUAWEI SUN2000-330KTL-H1/-H2 contains an assessment of the following:

- The completeness of documents and measurements
- The plausibility of the documents received
- The compliance of the test conditions of the documents with those listed in section 2
- Assessment of the measurement results against the requirements and guidelines listed in section 2

4 GENERAL INFORMATION

4.1 Schematic description of the generating unit

The Huawei solar inverter family SUN2000-330KTL-H1/H2, consisting of: SUN2000-330KTL-H1, SUN2000-330KTL-H2 convert electrical energy generated by photovoltaic modules (DC) to three-phase alternating current (AC).

The rated output voltage is 800 V. The inverter type SUN2000-330KTL-H1 was tested for the default rated active power of 300 kW, but the maximum active power limit can be increased up to the apparent power limit of 330 kVA when the ambient temperature is below 30 degrees Celsius.

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 HUAWEI SUN2000-330KTL-H1/-H2 is given below, as provided in the Manufacturer's Information /3/.

Table 4-1 General Specifications

Generating Unit	SUN2000-330KTL-H1	SUN2000-330KTL-H2
No. of phases	3	3
Max. apparent power	330 kVA	330 kVA
Rated active power	300 kW	275 kW
Rated AC-voltage (phase to phase)	800 V	800 V
Rated frequency	50 Hz	50 Hz
Rated current	216.6 A	198.5 A
Contribution to short circuit current	238.2 A	238.2 A

Table 4-2 DC Input

Generating Unit	SUN2000-330KTL-H1	SUN2000-330KTL-H2
Min. DC input voltage	500 Vdc	500 Vdc
Max. DC input voltage	1500 Vdc	1500 Vdc
Max. DC input current	65*6 A	65*6 A

Table 4-3 Inverter-Power section

Generating Unit	SUN2000-330KTL-H1	SUN2000-330KTL-H2
Manufacturer	HUAWEI	HUAWEI
Type name	SUN2000-330KTL-H1	SUN2000-330KTL-H2
Generic type	Transformerless	Transformerless
Pulse rate of inverter	14.1 kHz	14.1 kHz
Software Version	V500R023C00	V500R023C00

Table 4-4 Software version

Firmware version	V500R023
Software version	V500R023C00

Table 4-5 Disconnection device

Generating Unit	HUAWEI SUN2000-330KTL-H1/-H2
Manufacturer	HongFa
Type	HF192F12-H3F

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

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

All parameters are documented in the "Parameter list SUN2000-330KTL-H1/-H2"/4/.

4.3 Performed tests, test setup

The Fault Ride-Through (FRT) tests were performed on a HUAWEI SUN2000-330KTL-H1/-H2 inverter by DNV China Company Limited at the Huawei lab in Shanghai according to the requirements of the FGW TG3 /C/. The undervoltages and overvoltages were generated by a grid emulator (controlled voltage source) directly connected to the 800 V terminals of the inverter.

The 2-phase faults described in this report were realised on the LV side by the customer's grid emulator in such a way as if the fault had occurred on the MV side of a delta-star (Dy) transformer. A two-phase fault on the MV side (type C) therefore translates to a fault of type D on the LV side. (Refer to Figure D-3 out of the FGW TG3 /C/ given in the Figure 4-1).

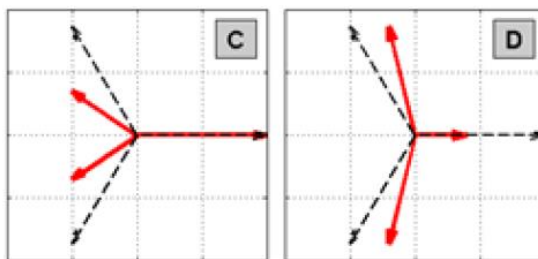


Figure 4-1: Transformation of a phase-to-phase fault clear of earth through a Dy transformer

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

5 ASSESSMENT ACCORDING TO FGW TG8, REV. 9 (A.1.2.7.3.1 AND A.2.2.7.3.1)

The following tables summarise the general assessment criteria and the results of the assessment. The tables were extracted from the FGW TG8 /D/. For this reason, the numbering given is not consecutive. The other tables on remaining on the grid, feed-in of fault current, limited dynamic grid support, multiple faults, and contribution to short-circuit current can be found in the corresponding chapters of this report.

For the following tables the assessments for each of VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/ have been combined, as they are basically identical.

Table 5-1 General criteria

No	Evaluation criteria	Acceptance criteria	Assessment result
1	Self-protection allows operation between the lower and upper FRT boundary curves.	The tests required by the VDE regulations /A/ and /B/ have been successfully completed	Compliant. See measurement report /2/.
2	FRT tests were successfully carried out with pre-fault reactive power inside the range of $\pm 10\%$ P_{FE} .	True	Compliant. See measurement report /2/.
3	An FRT test was successfully carried out with the maximum underexcited and one with the maximum overexcited reactive power according to the manufacturer's specification (or with $\cos \varphi \leq 0.95$ overexcited or underexcited, as long as the capacity of the PGU is higher).	True	Compliant. See measurement report /2/.
4	The behaviour of the PGU or the component in the event of abrupt voltage changes was verified by a voltage swell of at least 10% U_n to a value $> 110\%$ U_n for symmetrical voltage increases and to $\geq 110\%$ U_n as the greatest phase-to-phase voltage for asymmetrical voltage increases with a duration of ≥ 5 s.	Minimum duration ≥ 5 s	Compliant. See measurement report /2/. Please refer A) below for further explanations.
4.1	Starting from 2021-01-01, should the PGU be commissioned as part of a PGS, ride-through of a symmetrical voltage swell by at least 15% U_n to a value $> 115\%$ U_n for ≥ 5 s or $\geq 115\%$ U_n for ≥ 60 s has to be proved additionally in the form of a manufacturer's declaration.	True	Compliant.
4.2	It is shown under which assumptions a ride-through of a symmetrical voltage swell of at least 15% U_n up to a value $> 115\%$ U_n for ≥ 5 s or $\geq 115\%$ U_n for ≥ 60 s is possible or not possible.	True	No assumptions. Is always possible.
5	The correct behaviour in the transition from dynamic to quasi-stationary operation of the generating units must be demonstrated for a symmetrical voltage dip with a minimum duration of ≥ 60 s by reducing the grid voltage to a value between 85% and 90% U_n .	True	Compliant. See measurement report /2/.
6	The correct behaviour in the transition from dynamic to quasi-stationary operation of the generating units must be demonstrated for a symmetrical voltage swell by increasing the grid voltage to a value $\geq 110\%$ U_n for ≥ 60 s.	True	Compliant. See measurement report /2/.
7	During the fault, the PGU feeds a reactive current as required (see the following table for type 2).	True	Compliant.
8	The PGU can ride through multiple faults in accordance with the requirements.	True	Compliant. See measurement report /2/.

A) After an abrupt voltage change, the voltage reference value (1min average voltage), which is used for calculating the additional reactive current, is frozen for one second /5/. In the event of another abrupt voltage change (over 5%) within this 1 second, the reactive current feed-in takes place based on the frozen reference voltage value /5/.

Table 5-2: Additional Requirements for Type 2

No	Additional evidence	Acceptance criteria	Assessment result
A	The tests according to FGW TG3 /C/ were carried out without disconnecting the PGU from the grid. With that, the FRT capability of the auxiliary drives used in the measurement is proven.	True	All tests required according to FGW TG3 /C/ were performed without disconnection from the grid. See measurement report /2/ and.
B	A voltage-time characteristic (capacity of the PGU) is available. The manufacturer's specification should at least correspond to the required capacity defined in the VDE regulations /A/ and /B/.	Manufacturer's information available. (if necessary under conditions at PGS level)	Specification has been made and corresponds to the required capacity. See Figure 5-1 below as well as manufacturer's declaration /1/.

The voltage time characteristics for HVRT (OVRT) and LVRT (UVRT), given in the manufacturer's declaration /1/, is at the Figure 5-1.

Anhang 6 / Annex 6:

Fault Ride-Through (FRT) limit curve:

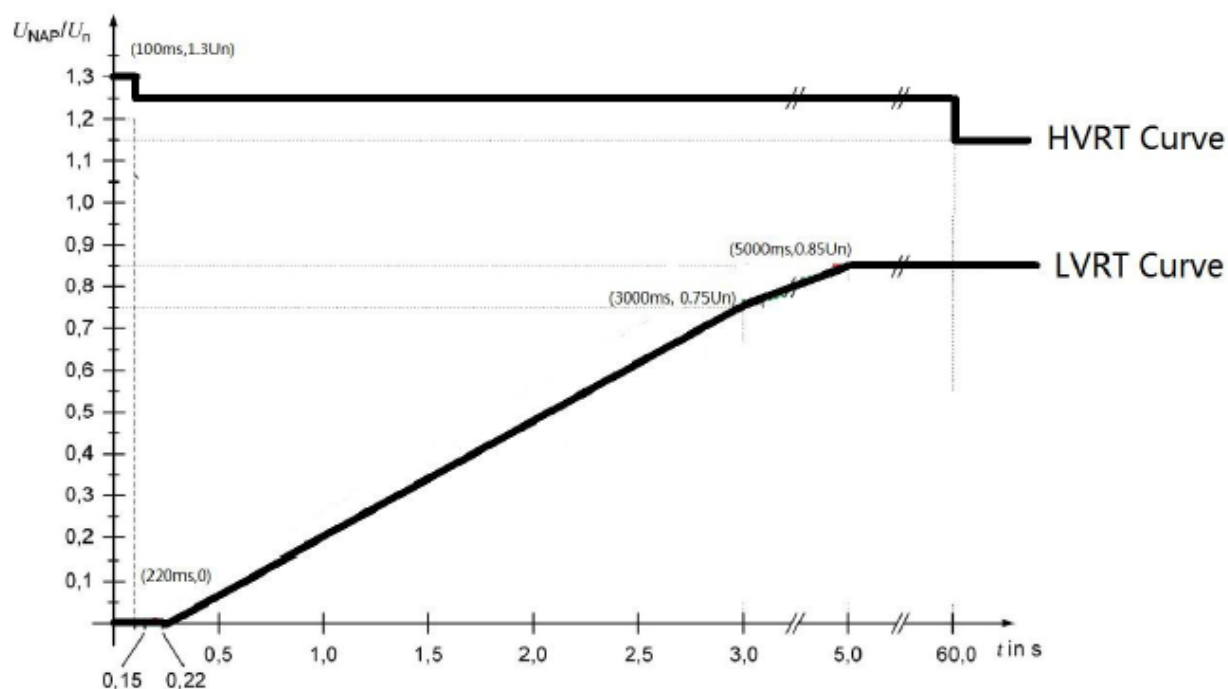


Figure 5-1: HVRT and LVRT voltage over time characteristics

5.1 Remaining on the grid

For type 2 PGUs the following applies:

Table 5-3: Remaining on the grid

No	Evaluation criteria	Acceptance criteria	Assessment result
Remaining on the grid			
1.1	The PGU does not become unstable and does not disconnect from the mains as long as all line-to-line voltages are within the limit curve required by the VDE regulations /A/ and /B/.	The tests required by the VDE regulation /A/ and /B/ have been successfully completed.	All required FRT tests were successfully completed. See measurement reports /2/.
1.2	All UVRT (LVRT) and OVRT (HVRT) tests have been fully completed.	True	All UVRT and OVRT tests were carried out completely. See measurement reports /2/. Please refer A) below for further explanations.
1.3	The PGU did not disconnect from the grid during all UVRT tests.	True	In all UVRT tests there was no disconnection from the grid. See measurement reports /2/.
1.4	The PGU did not disconnect from the grid during all OVRT tests.	True	In all OVRT tests there was no disconnection from the grid. See measurement reports /2/.

None of the documented FRT tests (two-phase or three-phase), including tests with a pre-fault reactive current, led to a shut-down of the inverter. All tests according to FGW TG3 /C/ were carried out twice. The inverter injected reactive current as required by VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/ as a result of a continuous voltage regulation (see section 5.2) and did not consume any more inductive reactive power than before the fault.

- A) The OVRT (HVRT) tests #115.1, #115.2, #110.1, #110.2 according from FGW TG3 /C/ are not listed in the measurement report /2/. However, those tests were performed by Huawei and the raw data was submitted to DNV. There is no disconnection from the grid and a corresponding reactive current injection is performed. Accordingly, all the under and over voltage ride through tests are completed.

5.2 Reactive current control

During two-phase and three-phase faults, the inverter injects reactive current in both the positive and negative sequence, in accordance with the characteristics given by VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/. The positive and negative sequence reactive current fed into the fault is proportional to the change in positive and negative sequence voltage, in both the overvoltage and undervoltage cases.

The proportionality constant (k-factor), which determines the magnitude of the injected reactive current, was set to 2 for most of the tests. The adjustability of the k-factor was verified, in accordance with FGW TG3 /C/, with further tests at partial power as well as with the k-factor set to 4. The k-factor applies to the reactive current control in both the positive and the negative sequence, but there are different k-factors for the LVRT and HVRT cases. The pre-fault reactive current was correctly taken into consideration for the calculation of the additional reactive current during the faults. Tests were also carried out with limited dynamic grid support activated.

For asymmetrical faults, the sum of the absolute values of reactive current in the positive and the negative sequence is limited to 1.0 p.u. in order to prevent any of the phase currents reaching values above 1 p.u. of the nominal current.

Faults are detected by using two voltage thresholds for detecting over voltage and under voltage, as well as a threshold for detecting abrupt voltage changes. In all cases, the phase voltages are assessed. The LVRT threshold is set to $0.9U_n$, while the HVRT threshold is set to $1.1U_n$. Noticed that there is a hysteresis implemented with a default threshold of $0.02U_n$. This threshold is adjustable in the range from $0.02U_n$ to $0.1U_n$ (U_n is the rated voltage of the inverter /4/) /3/. The abrupt voltage change threshold is set to 5%.

5.3 Feed-in of fault current

Table 5-4: Feed-in of fault current

No	Evaluation criteria	Acceptance criteria	Assessment result
Feed-in of fault current			
Note: It is also permissible to have continuous dynamic grid support in the sense of the following requirements, which is permanently active and active in parallel with steady-state voltage maintenance, independent of fulfilment of the criteria for the fault start and end.			
7.1	The rise time of max 30 ms of the additional reactive current in the positive and negative phase sequence system after the start of the fault is provided for each measurement in the measurement report according to TG3 and meets the requirements.	True *)	All rise times are ≤ 30 ms for the tests described in the measurement reports /2/. Please refer A) below for further explanations. (*)
7.2	The settling time of max 60 ms of the additional reactive current in the positive and negative phase sequence system after the start of the fault is provided for each measurement in the measurement report according to TG3 and meets the requirements.	True *)	All settling times are ≤ 60 ms for the tests described in the measurement reports /2/. Please refer A) below for further explanations. (*)
7.3	For all measurements according to TG3 where the required k-factor may not be possible to be reached due to a current limitation, a reactive current having the value of the rated current must be injected on each (affected) phase. (VDE 4110 /A/ section 10.2.3.3.2, 7th bullet point as well as VDE 4120 /B/ section 10.2.3.3, 7th bullet point)	True	Please refer A) below for further explanations.
7.4 (MV)	From section A.1.2.7.3.1 of TG8 /D/ (medium voltage): The additional positive and negative reactive current fed into the grid must comply with the limits specified in Annex C.1 of VDE 4110 /A/ (To be proven for voltage excursions with fault voltages $\geq 15\%$ Un bis 120% Un).	The limits according to Appendix C.1 of the VDE 4110 /A/ were observed for all measurements.	Tolerance bands are not exceeded in any of the tests. See measurement report /2/.
7.4 (HV)	From section A.2.2.7.3.1 of TG8 /D/ (high voltage): The rise time of a maximum of 30 ms of the additional positive and negative reactive current after onset of fault is to be reported according to TG3 /C/ for each test. (this criteria is identical to 7.1 above)	Rise times of sliding rms values shall be ≤ 50 ms for each test.	All rise times are ≤ 30 ms for the tests described in the measurement report /2/. Please refer A) below for further explanations. (*)
7.5	Not relevant for solar converters.	-	-
7.10			
7.11	The rise time of the active current after the end of the fault may be a maximum of 1 s. (VDE 4110 /A/ section 11.2.5.7 and VDE 4120 section 11.2.5.6)	True	The rise time of the active current after fault clearance is significantly less than 1 s for all tests. See measurement report /2/.
7.12	Continuous dynamic grid support is used.	Details provided below	Please refer B) below for further explanations.
(*)	according to VDE regulation /A/ voltage dips down to a remaining voltage of 0 % are not assessed for reactive current.		

- A) The injected reactive current of the inverter was assessed for two-phase and three-phase faults with a view to rise time and settling time according to FGW TG3 /C/ and FGW TG8 /D/. The voltage dips performed with a remaining voltage magnitude of less than 15 % were not considered for assessment of the reactive current injection. For all two-phase and three-phase faults, the determined rise times and settling times were below 50 ms (except the Case #72, which will be followingly explained) and 80 ms respectively. This assessment is based on the times stated in the measurement report /2/, which have been measured in the fundamental frequency positive sequence system which includes an additional 20 ms for calculation of the sliding RMS value. This means that the rise and settling times to be assessed are determined by subtracting 20 ms of the rise and settling times reported in the measurement report /2/. For the case #48, the settling time is also less than 60ms which shown in Figure 5-3, According to the VDE regulations /A/ and /B/ therefore, the required rise and settling times are therefore considered to have been met. At the test cases #1, #3, #72, #85, and #8, #10, #12, #14, the calculated k-factors were smaller than two due to the limit of reactive current injection which the algorithms of FRT control strategy is illustrated in Figure 5-2.

- B) The FRT control strategy implemented in the tested solar inverter is given in Figure 5-2 and is compliant to the VDE 4110 /A/ and VDE 4120 /B/.

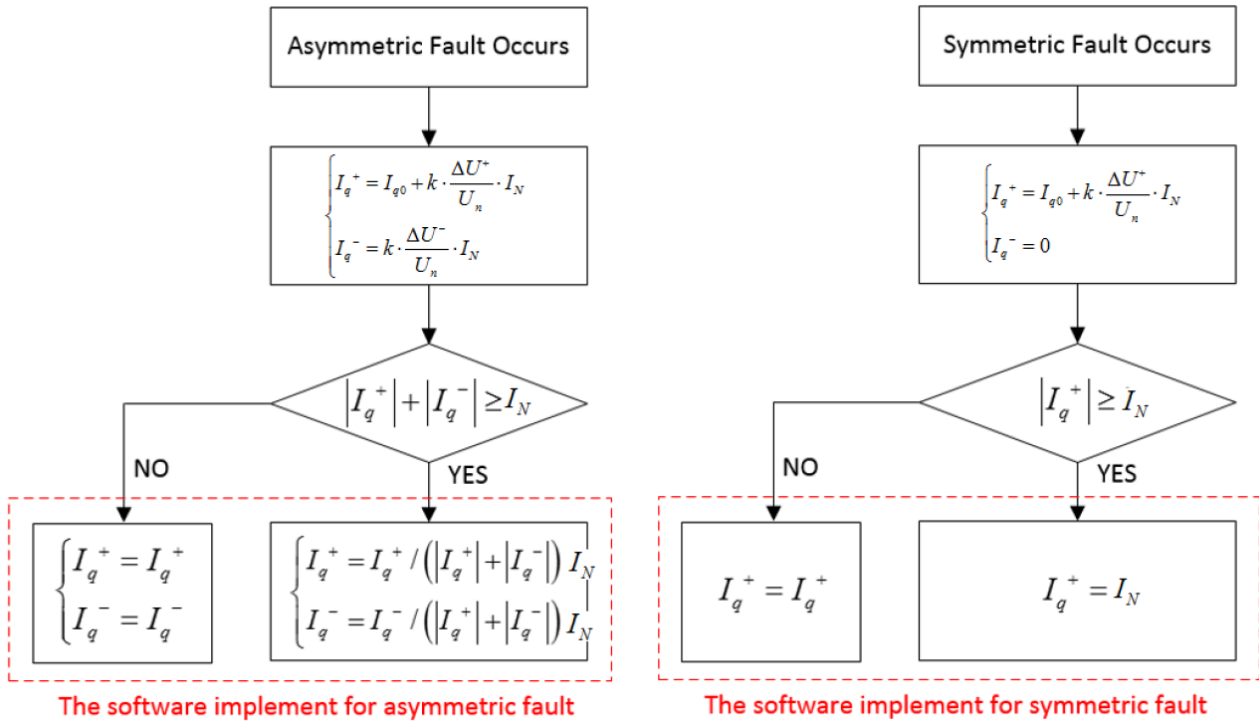


Figure 5-2: Control strategy for FRT /3/

In Figure 5-2, for asymmetric faults the positive reactive current I_{q+} and negative reactive current I_{q-} are limited to I_N separately in the first equation. The tests documented in the measurement report /2/ demonstrate that the control strategy depicted in the figure above was followed. In some asymmetrical cases, I_{q+} and I_{q-} does not decrease steadily (keep the same ratio) if one or both of the I_{q+} and I_{q-} components exceed the rated current I_N . This can be accepted as it is not a strict requirement, and the differences are not very significant.

The tests documented in the measurement report /2/ demonstrate that the control strategy depicted in the figure above was followed.

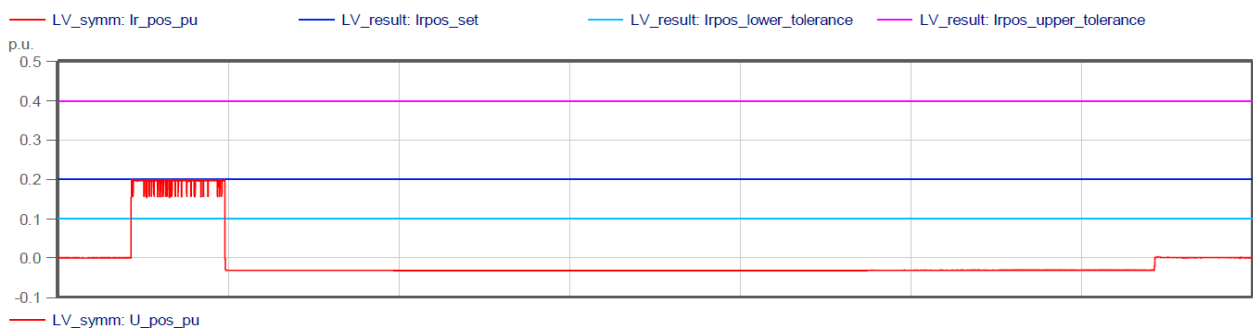


Figure 5-3: Positive sequence reactive current and voltage of case #48 /2/

Table 5-5: Additional Requirements about k-factor

No	Additional evidence	Acceptance criteria	Assessment result
C	The proportionality factor k is adjustable between 2 and 6 in steps of 0.5 or smaller.	True	The k-factor can be adjusted between 0 and 10 in steps of 0.1 for LVRT and between 0 and 6 for HVRT. In both cases the step size is 0.1. See parameter list /4/.
D	The adjustability of the k-factor must be proven through tests with different k-factors (k=2 and k=4). They have to be carried out in accordance with TG3.	(Manufacturer's declaration)	The adjustability has been proven by the corresponding tests. See measurement report /2/.

The proportionality factor, designated as k, which determines the level of the reactive current fed into the grid, was set to a value of $k = 2$ in the majority of the tests. The k factor can be set between 0 and 10. To prove the adjustability, the tests required according to FGW TG3 /C/ were carried out with test case number 75.5 (Case #36) and 75.8 (Case #42) and 110.4 (Case #87) and 115.1 (Case #76) with $k = 4$.

The pre-fault reactive current was correctly considered by the FRT controller for the calculation of the additional reactive current during FRT events. This has also been proven by the test case numbers 75.3 (Case #32) and 75.4 (Case #34) as required by the FGW TG3 /C/. The reactive power before the emulated fault was ± 0.67 p.u.. The active power output during these tests was 0.2 p.u. which corresponds to a power factor of approx. 0.29.

For three-phase voltage dips < 0.15 p.u., the reactive current is not assessed. In these cases, #1 and #3, an apparent current of approx. 1.0 p.u. was injected, approx. 0.95 p.u. of this being reactive current and approx. 0.3 p.u. being active current.

5.4 Limited dynamic grid support

Table 5-6:

No	Evaluation criteria	Acceptance criteria	Assessment result
Limited dynamic grid support			
4.1	All required UVRT (LVRT) tests according to FGW TG3 /C/ have been carried out completely regarding the limited dynamic grid support.	True	Compliant. See measurement report /2/ and explanation below.
4.2	The PGU type 2 can meet the requirements for limited dynamic grid support.	True	Compliant. See measurement report /2/ and explanation below.
4.3	The maximum apparent current of 10 % I_r is not exceeded after onset of the fault until the end of the fault (for a voltage dip down to between 45 % U_n and 60 % U_n).	True	Compliant. See measurement report /2/.
2.12	Full dynamic network support is fulfilled according to the requirements above 0.7 U_n .	True	Compliant.

The optional function of limited dynamic network support as required by the VDE-AR-N 4110 /A/ has been implemented.

The tests, below 0.7 U_n , were successfully proven by the test cases 50.5 (Case #25) and 50.6 (Case #83) stated in the test report /2/. The Case #83 is a replaced case, and it is showing that the maximum apparent current during the fault is not exceeded 10% I_r (this was also proven by the repeated tests #84). The case #83 was performed with a new setup of the grid simulator /5/. The test case #25 was performed with the old setup of the grid simulator and this case showing that apparent current is exceeding the limit of 10% I_r . Due to the fact that the grid simulator was the source of this incompliance this tests can be accepted.

5.5 Multiple faults

Table 5-7: Multiple faults

No	Evaluation criteria	Acceptance criteria	Assessment result
Multiple faults			
8.1	If the behaviour in case of multiple faults has not been mathematically proven by the manufacturer, the proof can alternatively be provided by measurement, i.e. by applying the test sequence for multiple faults in accordance with the requirements of Table 14 of the VDE regulation /A/ and Table 11 of the VDE regulation /B/ at $P \geq 75\%$ PrE without disconnection from the grid.	True	
8.2	Type 2 PGUs must be able to ride through any sequence of grid faults.	The PGU is able to dissipate $P_{E_{max}}$ for 2 s	Compliant. See test report /2/
8.3	On the basis of a manufacturer's declaration, it must be demonstrated in a comprehensible manner that the PGU is capable of running through another multiple fault after 30 minutes.	True	Compliant. See test report /2/

5.6 Contribution to short-circuit current (A.1.2.7.4.1 and A.2.2.7.4.1)

Assessment criteria according to FGW TG8 /D/ (A.1.2.7.4.1 and A.2.2.7.4.1):

For the following tables the assessments for each of VDE-AR-N 4110 /A/ and VDE-AR-N 4120 /B/ have been combined, as they are almost identical.

Table 5-8: Short-Circuit Current contribution – evaluation criteria

No	Evaluation criteria	Acceptance criteria	Assessment result
1	The short-circuit current after three-phase faults according to VDE 4110 section 11.2.9 /A/ and VDE 4120 section 11.2.9 /B/ is specified as follows:	True	See Table 5-11
1.1	At onset of fault: short-circuit current as highest instantaneous value i_p and as RMS value.	True	See Table 5-11
1.2	The short-circuit current (1-period RMS value) after three-phase faults was reported for the times shown in Table 16 of the VDE 4110 /A/ and in Table 13 of the VDE 4120 /B/. (i.e. 20, 100, 150, 300, 500 and 1000 ms)	True	See Table 5-11
1.3	The peak short-circuit current i_p was determined from the measured data according to DIN EN 60909-0 (VDE 0102).	True	See Table 5-11
1.4	The initial short-circuit alternating current I_k was determined and specified according to DIN EN 60909-0 (VDE 0102).	True	See Table 5-11
2	The necessary parameters for calculating the short-circuit alternating currents according to DIN EN 60909-0 (VDE 0102) are shown.	True	See Table 5-10

Table 5-9: Short-Circuit Current contribution – additional evidence

No	Additional evidence	Acceptance criteria	Assessment result
A	All time curves of the currents for three-pole faults are shown.	True	See Test Report /2/.
B	Manufacturer's specifications according to Table 15 of the VDE regulation /A/ and Table 12 of the VDE regulation /B/.	Specification is given.	See Table 5-10.

Table 5-10: Theoretical data on the short-circuit currents of the PGU based on the manufacturer's declaration /1/ according to DIN EN 60909-0

Description	Symbol	Value
RMS value of the source current for three-phase faults	I_{skPF}	238.2A
RMS value of the source current for two-phase faults	$I_{(1)sk2PF}$	238.2A
RMS value of the source current for single-phase faults	$I_{(1)sk1PF}$	238.2A
Negative-sequence short-circuit impedance (manufacturer's information) for integer k-factors only	$Z_{(2)PF}$	1/(k-factor)

The short-circuit currents measured and averaged according to FGW TG3 /C/ are given in the measurement report /2/. The Table 5-11 below summarises the measured short-circuit currents for the 3-phase FRT tests as required by FGW TG3 /C/. These include:

- Peak current i_p at the onset of the fault.
- The single-period RMS values of the short-circuit currents at the specified times (20 ms, 100 ms, 150 ms, 300 ms, 500 ms and 1000 ms after the onset of the fault depending on the duration of the fault).

The RMS and peak values stated below are the maximum values of all three phases, scaled to the rated current of 216.6 A (H1) 198.5 A (H2) (at 800 V), for the HUAWEI SUN2000-330KTL-H1/-H2 considering a rated power of 300 kW. The values were measured at the terminals of the inverter during two-phase and three-phase voltage dip tests as well as voltage swell tests. These tests were performed at partial and rated power with the k-factor set to $k=2$ and $k=4$.

Table 5-11: Maximum measured values of short-circuit currents during three-phase voltage dips and voltage swells

TG3 test case no.	Test conditions					I _p in p.u. (peak)	Time after onset of the fault in ms					
	U in % (no-load test)	P in p.u. (pre-fault)	Q in p.u. (pre-fault)	k	Duration of fault in ms		20	100	150	300	500	1000
							Contribution to short-circuit current in p.u. (RMS)					
0.1	3	1,00	-0,01	2	417	-1,46	1,04	1,01	1,01	1,01	n.a.	n.a.
0.2	3	0,20	0,00	2	417	-1,47	0,73	1,01	1,01	1,01	n.a	n.a.
25.1	30	1,00	-0,01	2	1170	-1,51	1,06	1,01	1,01	1,01	1,01	1,01
25.2	30	0,20	0,00	2	1170	-1,52	0,72	1,01	1,01	1,01	1,01	1,01
50.1	60	1,00	0,00	2	2483	1,54	1,04	1,02	1,01	1,01	1,01	1,02
50.2	60	0,20	0,00	2	2481	-1,01	0,37	0,84	0,84	0,84	0,86	0,86
50.5	60	1,00	0,00	2	2478	-1,50	0,74	0,15	0,15	0,10	0,04	0,03
75.1	80	1,00	0,00	2	3044	-1,54	1,04	1,03	1,03	1,03	1,03	1,04
75.2	80	0,20	0,00	2	3044	0,55	0,26	0,47	0,47	0,47	0,47	0,47
75.3	80	0,20	0,66	2	3044	-1,50	0,76	1,02	1,02	1,02	1,02	1,02
75.4	80	0,20	-0,67	2	3043	1,12	0,68	0,38	0,38	0,38	0,38	0,38
75.5	80	0,20	0,00	4	3042	-1,08	0,35	0,82	0,82	0,82	0,82	0,82
80.1	85	1,00	0,00	2	3041	1,56	1,03	1,03	1,03	1,03	1,03	1,03
85.1	90	0,22	0,00	2	60043	0,42	0,25	0,32	0,32	0,32	0,32	0,32
110.3	111	0,20	0,00	2	60033	0,45	0,18	0,29	0,29	0,29	0,29	0,30
115.1	115	0,20	0,00	4	5060	-0,83	0,27	0,61	0,61	0,61	0,61	0,62

6 CONDITIONS

- Any changes of the system design, software or the manufacturer's quality system are to be approved by DNV.

7 CONCLUSION

Different undervoltage and overvoltage tests (with different magnitudes of residual voltage, durations, k-factor settings, at different active and reactive power operating points) were performed at the inverter of the type HUAWEI SUN2000-330KTL-H1/-H2 Huawei Technologies Co., Ltd., according to the requirements of the FGW TG3 /C/. The measurement data received were assessed according to the criteria of section A.1.2.7.3.1 and A.2.2.7.3.1 of the FGW TG8 /D/.

Under consideration of the conditions given in section 6, the inverter HUAWEI SUN2000-330KTL-H1/-H2 from Huawei Technologies Co., Ltd. fulfil the requirements of 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-N4110:2018-11 / VDE-AR-N 4120:2018-11	21 pages	dated 2023-01-14
/2/	Fault ride-through tests on a PV inverter of the type HUAWEI SUN2000-330KTL-H1 according to FGW TG3 Rev. 25 Report No: 10332709-SHA-TR-08-C	263 pages	dated 2023-04-24
/3/	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, Revision V1.4	14 pages	dated 2023-07-26
/4/	Parameter list of SUN2000-330KTL-H1, SUN2000-330KTL-H2	7 pages	dated 2022-10-18
/5/	Verifying Comments Sheet (VCS) , revision 9, for Evaluation of Huawei SUN2000-330KTL-H1/H2,	15 pages	dated 2023-05-12
/6/	ISO 9001:2015 Certificate no. 17 100 1933213 issued to Huawei Technologies Co., Ltd. for the design, manufacture and service of inverters	15 pages	dated 2023-04-19

9 ANNEX

Table 9-1 Overview of annex

No.	Content	Filename	MD5-Checksum
1	Parameter list of SUN2000-330KTL-H1, SUN2000-330KTL-H2	F.2_Huawei_SUN2000-330KTL-H1、SUN2000-330KTL-H2 Series_Parameter list_V1.0	645145655201b6f535b9ce054b291fdc



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