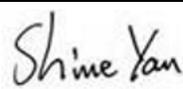
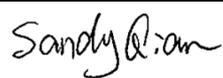


<p><b>TEST REPORT</b>  <b>VDE-AR-N 4105</b>  <b>Generators connected to the low-voltage distribution network –</b>  <b>Technical requirements for the connection to and parallel operation</b>  <b>with low-voltage distribution networks</b>  <b>DIN VDE V 0124-100</b>  <b>Grid integration of generator plants – Low-voltage – Test requirements</b>  <b>for generator units to be connected to and operated in parallel with</b>  <b>low-voltage distribution networks</b></p>	
Report Number.....	6209661.50
Date of issue.....	2025-01-17
Total number of pages.....	255 pages
Testing Laboratory .....	DEKRA Testing and Certification (Suzhou) Co., Ltd.
Address .....	No.99, Hongye Road, Suzhou Industrial Park, Suzhou, Jiangsu, P.R. China
Applicant's name .....	Solenso electronic materials Co., LTD.
Address.....	4F., No. 56, Zili 5th St., Zhongli Dist., Taoyuan City 320, Taiwan
Test specification:	
Standard .....	VDE-AR-N 4105:2018-11 DIN VDE V 0124-100:2020-06
Test procedure.....	Type test
Non-standard test method.....	N/A
Test Report Form No.....	VDE-AR-N 4105_V2.0
Test Report Form(s) Originator .....	DEKRA Testing and Certification (Suzhou) Co.,Ltd.
Master TRF.....	Dated 2020-10
Test item description .....	PV Microinverter
Trade Mark .....	
Manufacturer.....	Same as the applicant
Model/Type reference.....	SG1600, SG2000

Ratings.....:	Operating temperature range: - 40°C to + 65°C Protective class: IP67 Power factor range (adjustable): -0.8(lagging)~0.8(leading)  SG1600: DC: Max input voltage:65Vdc, MPPT voltage range: 25-55 V, Max input current: 4*14A AC: Max. Output Power: 1.6 kVA, rated voltage: 230 Vac, Max. current: 6.96A, 50Hz, LN-PE  SG2000: DC: Max input voltage:65Vdc, MPPT voltage range: 25-55 V, Max input current: 4*16A AC: Max. Output Power: 2.0 kVA, rated voltage: 230 Vac, Max. current: 8.7A, 50Hz, LN-PE
---------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):		
<input checked="" type="checkbox"/>	Testing Laboratory:	DEKRA Testing and Certification (Suzhou) Co., Ltd.
Testing location/ address:		No.99, Hongye Road, Suzhou Industrial Park, Suzhou, Jiangsu, P.R. China
Tested by (name, function, signature):		Shine Yan (ENG) 
Approved by (name, function, signature):		Sandy Qian (REW) 
<hr/>		
<input type="checkbox"/>	Testing procedure: CTF Stage 1:	
Testing location/ address.....:		
Tested by (name, function, signature).....:		
Approved by (name, function, signature).....:		
<hr/>		
<input type="checkbox"/>	Testing procedure: CTF Stage 2:	
Testing location/ address.....:		
Tested by (name + signature).....:		
Witnessed by (name, function, signature).....:		
Approved by (name, function, signature).....:		
<hr/>		
<input type="checkbox"/>	Testing procedure: CTF Stage 3:	
<input type="checkbox"/>	Testing procedure: CTF Stage 4:	
Testing location/ address.....:		
Tested by (name, function, signature).....:		
Witnessed by (name, function, signature).....:		
Approved by (name, function, signature).....:		
Supervised by (name, function, signature).....:		
<hr/>		

<b>List of Attachments (including a total number of pages in each attachment):</b>	
<ul style="list-style-type: none"> <li>- Annex 1: Datasheet of the relay (8 pages)</li> <li>- Annex 3: Forms (8 pages)</li> <li>- Annex 2: Pictures of the product (3 pages)</li> </ul>	
<b>Summary of testing:</b>	
<b>Tests performed (name of test and test clause):</b>	<b>Testing location:</b>
<p><b>Original report 6196343.50:</b></p> <p>All applicable tests were performed.</p> <p><b>Amendment 1 Report 6209661.50:</b></p> <p>No testing.</p>	<p>DEKRA Testing and Certification (Suzhou) Co., Ltd. No.99, Hongye Road, Suzhou Industrial Park, Suzhou, Jiangsu, P.R. China</p>

## Copy of marking plate:

## Rating label

**Solense** PV Microinverter  
Model: SG1600

Max.Input Voltage	65V d.c.	Nominal Output Frequency	50Hz
Max. Continuous Input Current	14A*4 d.c.	Over Voltage Category	PV:II ,Mains:III
Range of MPPT Voltage	25-55(V)d.c.	MPPT Efficiency	99.9%
Min./Max. Start Voltage	22-60(V)d.c.	Peak Conversion Efficiency	96.5%
Max.Short-circuit Current	25A*4 d.c.	Protective Rating(IP)	IP67
Max. Continuous Output Power	1600VA	Protective Class	I
Max. Continuous Output Current	6.96A a.c	Pollution Degree	PD3
Output Power Factor	>0.99(Default)	Operating Ambient Temp	-40°C~+65°C
Nominal Output Voltage	230V a.c.		



 Solenso electronic materials  
Co., Ltd

**Solense** PV Microinverter  
Model: SG2000

Max.Input Voltage	65V d.c.	Nominal Output Frequency	50Hz
Max. Continuous Input Current	16A*4 d.c.	Over Voltage Category	PV:II ,Mains:III
Range of MPPT Voltage	25-55(V)d.c.	MPPT Efficiency	99.9%
Min./Max. Start Voltage	22-60(V)d.c.	Peak Conversion Efficiency	96.5%
Max.Short-circuit Current	25A*4 d.c.	Protective Rating(IP)	IP67
Max. Continuous Output Power	2000VA	Protective Class	I
Max. Continuous Output Current	8.7A a.c	Pollution Degree	PD3
Output Power Factor	>0.99(Default)	Operating Ambient Temp	-40°C~+65°C
Nominal Output Voltage	230V a.c.		



 Solenso electronic materials  
Co., Ltd

## Remark:

According to customer's requirement and Germany low-voltage distribution networks code, these models were only evaluated under the grid frequency of 50 Hz.

Test item particulars.....	: PV microinverter
Class of equipment .....	: Class I
Connection to the mains .....	: Permanent connection
IP protection class .....	: IP67
Possible test case verdicts:	
- test case does not apply to the test object.....	: N/A
- test object does meet the requirement .....	: P (Pass)
- test object does not meet the requirement .....	: F (Fail)
- this clause is information reference for installation...	: Info.
Testing.....	
Date of receipt of test item(s) .....	: 2024-12-01 (samples provided by applicant)
Dates tests performed.....	: 2024-12-01 to 2024-12-06
<b>General remarks:</b>	
<p>The test results presented in this report relate only to the object tested.  This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.  The measurement result is considered in conformance with the requirement if it is within the prescribed limit, It is not necessary to account the uncertainty associated with the measurement result.  This report is only for reference and is not used for legal proof function in China market.  The information provided by the customer in this report may affect the validity of the results, the test lab is not responsible for it.</p> <p>"(See Enclosure #)" refers to additional information appended to the report.  "(See appended table)" refers to a table appended to the report. The table clause no. including two standard VDE-AR-N 4105:2018-11 and DIN VDE V 0124-100.  In case of doubt the German version standard will be valid.  Throughout this report a <input type="checkbox"/>comma / <input checked="" type="checkbox"/>point is used as the decimal separator.  The following suffixes are used for variables in tables and figures:</p> <ul style="list-style-type: none"> <li>• “P<sub>N</sub>” for the nominal active power.  <math>P_n = U_n \times I_n \times \cos \varphi_n</math> (single-Phase); <math>P_n = \sqrt{3} U_n \times I_n \times \cos \varphi_n</math> (three-Phase).</li> <li>• “_E0,2” for gliding average values over 200 milliseconds.</li> <li>• “_E60” for gliding average values over 60 seconds.</li> <li>• “_E600” for gliding average values over 10 minutes.</li> <li>• “(c)” for over-excited.</li> <li>• “(i)” for under-excited.</li> <li>• If the inverter consumes inductive reactive power the reactive power is marked “inductive” or has a positive sign.</li> <li>• If the inverter consumes capacitive reactive power the reactive power is marked “capacitive” or has a negative sign.</li> </ul> <p>Acronyms:  PGUs: power generating units.  PGSs: power generating systems.</p>	
<b>Name and address of factory (ies) .....</b>	: Zhejiang Wellsun Intelligent Technology Co.,Ltd No.109 Yongchang Road, Shifeng Street, Tiantai County, Taizhou City, Zhejiang Province, China

**General product information:**

General product information:

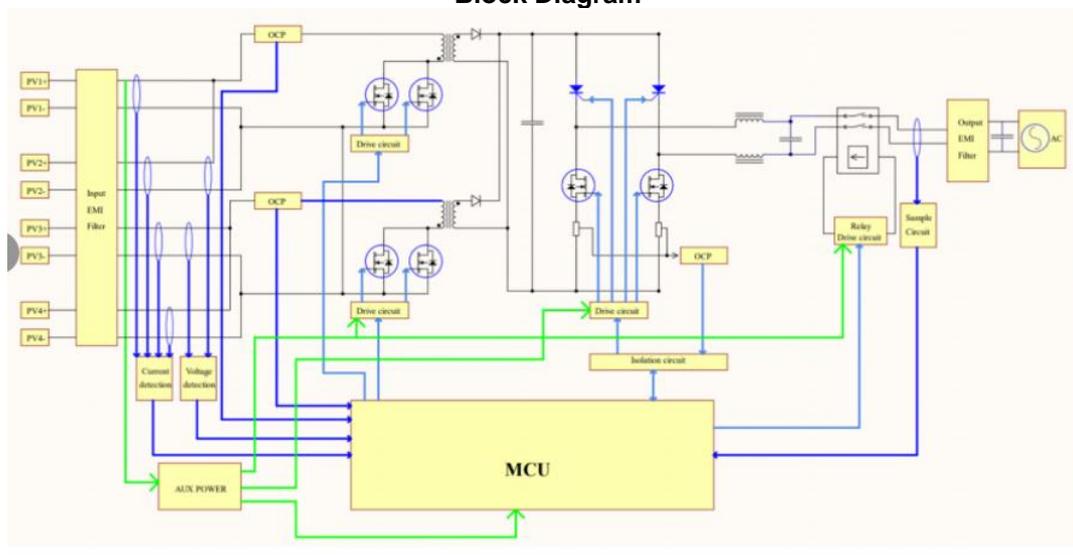
This product is a Single-phase grid-connected photovoltaic inverter, which converts the DC voltage of solar panels into single -phase AC voltage and connects to the 220V/230V/240V grid to achieve power generation function.

There is an auxiliary power supply inside the product. The AC side has a dedicate relay, which is to ensure the safety and reliability of the system. The product can generate full power up to ambient temperature 45°C. When the temperature exceeds 45°C, the output power derates linearly until maximum ambient temperature 65°C.

Description of the power circuit:

The internal control of the circuit adopts redundant structure, the booster part and the inverter part are controlled by the controller U25. U25 detects DC voltage and current, DC side insulation impedance, AC voltage, current, frequency, leakage current, etc., for boost circuit control and solar power tracking;

Model difference:

**Block Diagram****Model difference:**

Models JPM-800, SG2000, SG1600 are identical except for different rated output power

**Hardware version:** WS0512Nx A1.V03.

**Software version:** V2.10-2024.06.15

**Amendment 1:**

The report 6209661.50 was based on the report 6196343.50 issued by DEKRA Testing and Certification (Suzhou) Co., Ltd., issued on 2024-11-11, and COC No.: 6209661.01, COC No.: 6209661.02 issued by DEKRA Testing and Certification (Shanghai) Ltd., issued on 2024-11-11. It was issued due to below modifications:

---Update the the applicant, trade mark, model names and the marking plate.

After technical review, tests were not considered necessary.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
<b>5</b>	<b>NETWORK CONNECTION</b>		<b>P</b>
<b>5.1</b>	<b>Principles for determination of the network connection point</b>		Info.
	<p>Power generation systems and storage systems must be connected to a suitable point in the network, the network connection point. Based on the documents listed in 4.2, the network operator determines the suitable network connection point, which also ensures secure network operation taking into account the power generation system and the storage system and at which the requested service can be received and transmitted.</p> <p>Decisive for a network connection assessment is always the performance of the power generation system and the storage system at the network connection point and/or at the point of common coupling. This is to ensure that the power generation system and/or the storage system are operated without disturbing interactions and that the supply of other customers is not impaired. An example of the connection assessment of power generation systems is given in Appendix D.</p>		Info.
	As a rule, power generation systems and storage units are connected to the supply point of the extraction or within the consumption system.		Info.
	<p>Multiple connections within one building are permissible only if the connection and operation of the power generation system or storage unit cannot be ensured by means of a network connection. Deviations from this principle shall be agreed with the network operator. It shall be ensured that the power generation system or storage unit is clearly separated electrically from any other power consuming equipment of the customer. Each of the two supply points shall be labelled with an indication of the location of the other supply point. Each separate supply point for the power generation system or of a storage unit shall be permanently labelled with "Sectioning point: power generation system - supply network" or "Sectioning point: storage unit - supply network" by the connection owner.</p>		Info.
	<p>Power generation systems and storage systems installed on different sites, each with its own network connection, must not be combined at a network connection point to the network of the network operator. The same applies to power generation systems and storage systems that are installed on different buildings, each with its own network connection. PV systems that are installed on a building with continuous roofing (e.g. block of flats or terraced houses) with several network connections may be combined at a network connection point and connected to the network of the network operator (identification of the supply point as described above).</p>		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For the purpose of evaluating the connectivity with regard to the network interactions, the impedance of the network at the PCC (network short-circuit power, resonances), the maximum apparent connection power as well as the type and operating mode of the power generation system or the storage unit are considered. The evaluation is made assuming the normal switching state and undisturbed operation of the network. If more than one power generation system or storage unit is connected within the same low-voltage network, their total effect shall be considered. For circuit modifications due to maintenance or forced outage reasons, the determined network connection point may require temporary reduction of the output power of the power generation system or the storage unit or the system's/unit's disconnection from the network. For connection examples, see Annex B (Figure B.1 to Figure B.10).		Info.
	For type 1 systems, a specific minimum short-circuit power at the network connection point $S_{kV}$ is required for the purpose of system stability and compliance with the requirements for dynamic network stability and steady-state voltage stability. This minimum short-circuit power shall be verified by the network operator during the connection evaluation of type 1 systems using the following simplified procedure:	The PGS is type 2	N/A
	– the network short-circuit power at the low-voltage busbar of the supplying local network transformer $S_{k_{NS-SS}}$ shall be equal to at least 10 times the total apparent power of all type 1 systems connected to this low-voltage network ( $S_{k_{NS-SS}} \geq 10 \cdot \Sigma S_{Amax}$ ) (type 1 systems throughout the NS network of the local network transformer); and		N/A
	– at the network connection point, the network short-circuit power $S_{kV}$ shall be at least equal to 10 times the total apparent power of all type 1 systems to be connected to this network connection point. For this purpose, it shall be noted that the apparent power values of all type 1 systems at this network connection point itself and at the downstream low-voltage network to the standard sectioning point or the line end have to be added.		N/A
	In case of non-compliance with the limit values, the power generation system shall not be connected.		Info.
<b>5.2</b>	<b>Rating of the network equipment</b>		P
	Due to their operating mode, power generation systems and storage units may cause higher loading of lines, transformers and other network equipment. Therefore, the network operator verifies the transmission capacity of the network equipment with regard to the connected power generation systems and storage units in accordance with the relevant rating regulations.		P

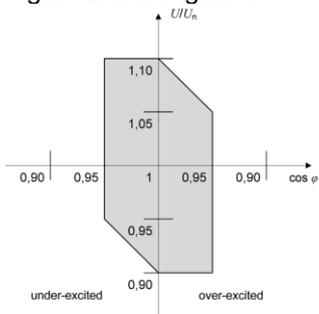
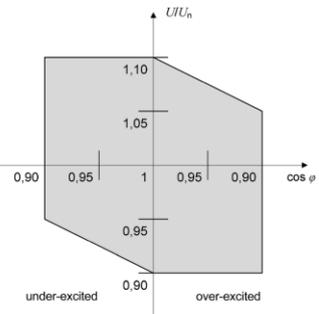
VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For calculation purposes, the maximum apparent power of the sum of all power generation systems and storage units $\Sigma S_{Amax}$ and usually the load factor $m = 1$ shall be used. This does not apply to buried cables for the connection of photovoltaic systems where a load factor $m = 0.7$ shall be used.		P
<b>5.3</b>	<b>Permissible voltage change</b>		P
	For the undisturbed operation of the network, the level of slow voltage change caused by all power generation systems and storage units with a network connection point in a low-voltage network shall at none of the PCCs in this network exceed a value of 3 % as compared with the voltage without power generation systems and storage units: $\Delta u_a \leq 3 \%$ Deviations from the value of $\Delta u_a \leq 3 \%$ are permissible as specified by the network operator (e. g. when using a controllable local network transformer).	(See appended table)	P
	When calculating the voltage change, the displacement factor shall be taken into account which is provided by the network operator for the maximum apparent connection power of the power generation system $S_{Amax}$ .		P
<b>5.4</b>	<b>Network interactions</b>		P
	For power generation systems and storage units, the permissible limits for network interactions are also described in VDE-AR-N 4100, 5.4. For the connection evaluation of power generation systems and storage units, the connection owner provides the completed forms E.2 to E.5 to the network operator.	(See appended table)	P
<b>5.5</b>	<b>Connection criteria</b>		P
5.5.1	General		Info.
	When connecting a power generation system or a storage unit, the technical connection conditions of the network operator shall be observed.		Info.
	Full feed-in		Info.
	In case of a full feed-in into the network of the network operator, the connection line of the power generation system shall be permanently connected to the meter panel; the meter panel shall be designed in accordance with VDE-AR-N 4100 and the TAB of the network operator. For this purpose, supply to the meter panel is always carried out via the connection compartment on the system side.		Info.
	Excess feed-in		Info.
	In case of self-supply with excess feed-in (e. g. according to EEG [2] or KWKG [3]), the connection line of the power generation system can be connected centrally at the meter panel or decentralised in a sub-distribution. The meter panels for generation meters (see Clause 7 and connection examples in Annex B) shall then be designed as follows:		Info.
	a) for a central position, in accordance with VDE-AR-N 4100;		Info.

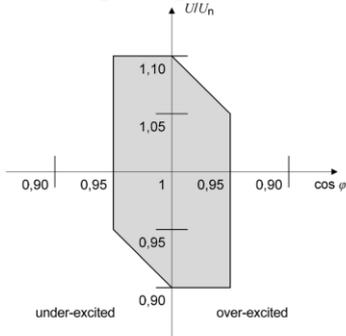
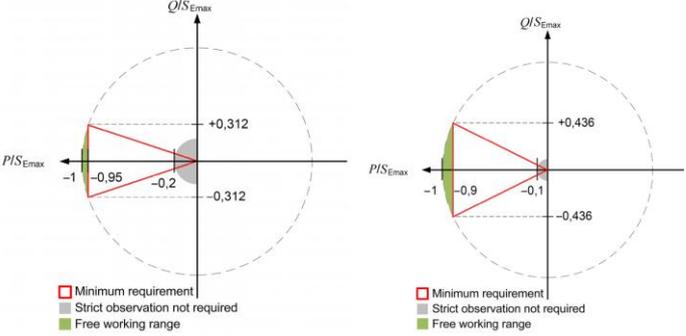
VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	b) for a decentralised position beside the power generation system, in accordance with VDE-AR-N 4100 or– in case of KWKG systems – in the small distributor in accordance with DIN EN 60670-24 (VDE 0606-24), also with a top hat rail meter meeting the requirements of § 29 MsbG for a modern measurement device or an intelligent measuring system;		Info.
	c) in case of KWKG systems and when being in a decentralised position in the power generation unit under consideration of the specifications of the chosen meter construction and the product standard of the power generation unit.		Info.
	The operation of the net current meter listed under c) may also be realised by a third-party operator of a metering point.		Info.
	Examples of meter panel configurations are shown in Annex C (see Figure C.1 to Figure C.5).		Info.
5.5.2	$P_{AV, E}$ monitoring (feed-in limitation)		P
	$P_{AV, E}$ monitoring allows a connection power $P_{AV, E}$ deviating from the installed power to be agreed with the network operator and to be set.		P
	The feed-in limit described in this sub-clause shall be measured at the central meter panel in accordance with VDE-AR-N 4100, 7.2.		P
	$P_{AV, E}$ monitoring can be an independent equipment mounted at the central meter panel in accordance with VDE-AR-N 4100 or in a suitable circuit distributor or may also be part of a power generation unit or a storage unit or a charging unit for electric vehicles. When $P_{AV, E}$ is exceeded, the power of the power generation system and/or the storage unit causing the event shall be reduced. $P_{AV, E}$ monitoring is to be used for monitoring the agreed active connection power $P_{AV, E}$ of power generation systems and/or storage units if the feed-in power at the network connection point $P_{AV, E}$ agreed with the network operator is smaller than the sum of the installed maximum active connection power of all power generation systems and/or storage units at that network connection point.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	<p><math>P_{AV, E}</math> monitoring shall cover all line conductors. The active power fed into the low-voltage network and measured at the central meter panel represents the reference value for the active connection power <math>P_{AV, E}</math> agreed with the network operator. If the r.m.s. value of the active power measured at the central meter panel exceeds the active power <math>P_{AV, E}</math>, the active power fed in by the power generation system and/or storage unit shall be reduced. Power generation systems shall not exceed the active power limit curve shown in Figure 1.</p> <p style="text-align: center;">Figure 1 – Active power limit curve for power generation systems</p>		P
	<p>NOTE 1 In its exponential course, the active power limit curve follows the function below:  <math>P_{AV, E}(t) = 0.67 \times e^{-1,05 \times (t - 0,8)} + 1</math>.</p>		P
	<p>Here, the active connection power <math>P_{AV, E}</math>, as agreed with the network operator, shall be at least 60 % of the installed active power <math>P_{inst}</math> of all power generation systems operated within the customer installation and all storage units feeding simultaneously into the network of the network operator. Therefore  <math>P_{AV, E} \geq 0.6 P_{inst}</math></p>		P
	<p>Load drop or cloud drift can cause a short-term feed-in of the entire installed active power at the network connection point into the network of the network operator. The surplus power, i. e. the difference between <math>P_{inst}</math> and <math>P_{AV, E}</math>, shall be reduced to merely 10 % of the initial value within 3 s according to Figure 1. After a maximum of 10 s, the agreed active connection power <math>P_{AV, E}</math> shall be fully resumed.</p>		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Usually, power generation units with a relatively low power gradient such as BHKW, are not able to adjust the exceeding of power limit values according to Figure 1, as may occur during the disconnection of high loads, within the permissible times according to Figure 1. Nevertheless, installation of and operation with a connection power $P_{AV, E}$ deviating from the installed power is possible. For this purpose, the power generation system(s) and the storage units feeding into the network, adjusted to the consumption load profile of the customer installation, shall be dimensioned and operated such as to prevent power limit values from being exceeded even at the disconnection at high loads.		P
	When the active power limit curve is exceeded, the power generation systems and/or storage units operated in the customer installation shall be disconnected automatically within 200 ms. Automatic reconnection complies with the connection conditions in accordance with 8.3.		P
	For the determination of the maximum connection power, storage units exclusively feeding into the customer installation need not to be taken into account. The functions for the feed-in limitation of $P_{AV, E}$ monitoring can be taken on by the energy flow direction sensor (see VDE-AR-N 4100), provided it has the technical properties of the $P_{AV, E}$ monitoring.		P
5.5.3	Power generation systems ready for connection		Info.
	In addition to the requirements specified in this VDE application guide, DIN VDE V 0100-551-1 (VDE V 0100-551-1) applies to power generation systems ready for connection.		Info.
	Provided a connection-ready power generation system is connected via an existing specific energy socket (e. g. complying with VDE V 0628-1 (VDE V 0628-1)) and a bidirectional meter is mounted at the central meter panel, the signature and the details of the system installer on the commissioning protocol E.8 may be omitted. A site map is not required in this case. This only applies up to a value $S_{Amax} \leq 600$ VA per network user installation.		Info.
<b>5.6</b>	<b>Three-phase inverter systems</b>		N/A
	For three-phase power generation systems feeding into the network via inverters, the power feed-in into the three line conductors shall be three-phase balanced. The inverter circuit shall preferably be set up as a three-phase current unit. The positive sequence system of the terminal voltages, even if they are unbalanced, is to be used as the reference quantity for the currents.	Not three phase systems	N/A
	Descriptions of the three-phase current and three-phase voltage systems are given in Section A.4.		N/A
<b>5.7</b>	<b>Behaviour of the power generation system at the network</b>		P
5.7.1	General		P

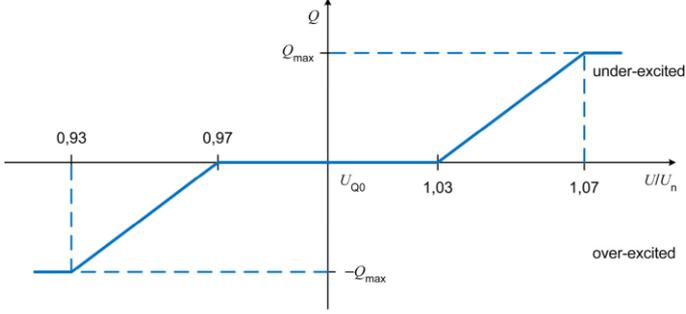
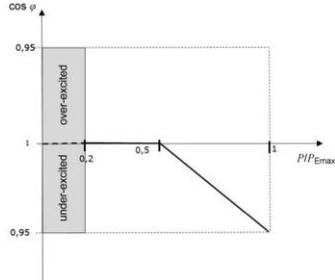
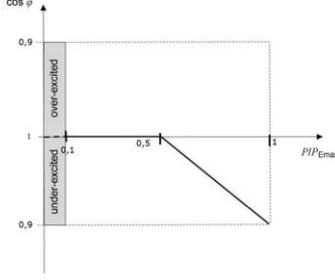
VDE-AR-N 4105											
Clause	Requirement - Test	Result - Remark	Verdict								
	For frequencies between 47.5 Hz and 51.5 Hz, automatic disconnection from the network due to a frequency deviation is not permitted. The actual operating principle and the associated exceptions are detailed in 5.7.4.3. Frequency-dependent active power control is implemented in the open-loop control of the power generation units.		P								
	In the frequency range of 47.5 Hz to 51.5 Hz, power generation systems shall be capable of network parallel operation in compliance with the time-related minimum requirements given in Table 1. <b>Table 1 – Frequency/time ranges for the proper operation of power generation systems</b> <table border="1"> <thead> <tr> <th>Frequency range</th> <th>Operating period</th> </tr> </thead> <tbody> <tr> <td>47,5 Hz to 49,0 Hz</td> <td>≥ 30 min</td> </tr> <tr> <td>49,0 Hz to 51,0 Hz</td> <td>unlimited</td> </tr> <tr> <td>51,0 Hz to 51,5 Hz</td> <td>≥ 30 min</td> </tr> </tbody> </table>	Frequency range	Operating period	47,5 Hz to 49,0 Hz	≥ 30 min	49,0 Hz to 51,0 Hz	unlimited	51,0 Hz to 51,5 Hz	≥ 30 min		P
Frequency range	Operating period										
47,5 Hz to 49,0 Hz	≥ 30 min										
49,0 Hz to 51,0 Hz	unlimited										
51,0 Hz to 51,5 Hz	≥ 30 min										
	Power generation units shall be able to ride through rapid frequency changes without disconnection from the network. This requirement applies provided the following averaged rates of change of frequency (RoCoF) are not exceeded: – ± 2.0 Hz/s for a moving time slot of 0.5 s; or – ± 1.5 Hz/s for a moving time slot of 1 s; or – ± 1.25 Hz/s for a moving time slot of 2 s. In case of rapid frequency changes, frequency measurements shall not take more than 200 ms. The minimum accuracy of frequency measurements is ± 50 mHz.		P								
5.7.2	Steady-state voltage stability / reactive power supply		P								
5.7.2.1	General boundary conditions		P								
	Steady-state voltage stability means the reactive power supply provided by a power generation system and/or a storage unit when energy is supplied for the purpose of voltage stability in the distribution network. The steady-state voltage stability is intended to keep slow (steady-state) voltage changes in the distribution network within acceptable limits.		P								
	In case of three-phase feed-in, the reactive power supply associated with all three methods described in 5.7.2.4 a) to c) refers to the positive sequence system components of the current and voltage fundamental component. In a passive sign convention system (see A.8), this means the operation of the power generation system in Quadrant II (under-excited) or Quadrant III (over-excited).	(See appended table)	P								
	If a storage unit consumes energy from the network, the reactive power exchange at the network connection point shall comply with the contractual agreements regarding the network connection for customer installations for consumption (see VDE-AR-N 4100).		P								

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Clause	Requirement - Test	Result - Remark	Verdict
	It shall be possible to approach each set-point resulting from the applied control method according to the required reactive power range given in 5.7.2.2 and to operate the power generation unit therein for any duration. Changes of the reactive power supply within the agreed reactive power range shall be possible at any time.		P
	Upon agreement with the network operator, the reactive power control range may be extended.		P
	When switching compensation systems that are part of a power generation system, a maximum voltage increment of 0.5 % $U_n$ shall not be exceeded.		P
	In addition, the minimum requirements specified in the clauses below shall apply to the power generation system.		P
5.7.2.2	Reactive power supply at $\Sigma S_{E_{max}}$		P
5.7.2.2.1	General		P
	It is permissible in certain cases described in 5.7.2.2.2 and 5.7.3 to reduce the active power supply to the benefit of the reactive power supply. This is not considered a reduction of the active power supply in the context of network security management.		P
	Power generation systems shall comply with the reactive power supply irrespective of the number of feed-in phases under normal operating conditions in the voltage tolerance band $U_n \pm 10\%$ .		P
5.7.2.2.2	Type 2 systems - inverters only		P
	At the generator terminals, each power generation unit to be connected shall meet the requirements according to Figure 2 and Figure 3.   <p>Figure 2 – Requirements for power generation units regarding the reactive power supply at the generator terminals (<math>\Sigma S_{E_{max}} \leq 4,6 \text{ kVA}</math>)</p> <p>Figure 3 – Requirements for power generation units regarding the reactive power supply at the generator terminals (<math>\Sigma S_{E_{max}} &gt; 4,6 \text{ kVA}</math>)</p>		P
5.7.2.2.3	Type 2 systems – Asynchronous generators (directly connected to the network and principally not able to control any reactive power)	The PGU is storage units.	N/A
	For power generation units with generators that are directly connected to the network and principally not able to control any reactive power and therefore use constant capacities, a constant displacement factor $\cos \varphi = 0.95_{\text{under-excited}}$ with an accuracy of $\pm 0.02$ at nominal voltage and rated power shall be observed.		N/A
5.7.2.2.4	Type 1 systems and Type 2 systems - Stirling generators and fuel cells	The PGU is storage units.	N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For power generation systems with a rated apparent power of $\sum S_{E_{max}} \leq 4.6 \text{ kVA}$ , the network operator does not give any specifications. The value of $\cos \varphi$ lies within a range of $\cos \varphi = 0.95_{\text{under-excited}}$ to $0.95_{\text{over-excited}}$ .		N/A
	At its generator terminals, each power generation unit to be connected in systems $\sum S_{E_{max}} > 4.6 \text{ kVA}$ shall meet the requirements according to Figure 4.  <p>Figure 4 – Reactive power supply at power generation units of types 1 and 2, stirling generators, fuel cells with <math>\sum S_{E_{max}} &gt; 4,6 \text{ kVA}</math></p>		N/A
5.7.2.3	Reactive power supply smaller than $P_{E_{max}}$		P
	In addition to the requirements for reactive power supply at the operating point $P_{E_{max}}$ of the power generation unit ( $P_{\text{mom}} = P_{E_{max}}$ ), requirements also apply to operation with an instantaneous active power $P_{\text{mom}}$ smaller than $P_{E_{max}}$ .		P
	The minimum requirement for the reactive power supply in partial load operating mode at the generator terminals is indicated as a red triangle on the P/Q diagram.	(See appended table)	P
	On the P/Q diagram, the ordinate indicates the reactive power $Q_{vb}$ to be provided in relation to the apparent power $S_{E_{max}}$ . The abscissa indicates the instantaneous active power $P_{\text{mom}}$ (negative value in a passive sign convention system) in relation to the apparent power $S_{E_{max}}$ .		P
	Within the ranges given in Figure 5 or Figure 6, the maximum residual deviation between the set-point and the actual value of the reactive power at the generator terminals shall not exceed $\pm 4.0 \%$ in relation to $P_{E_{max}}$ .  <p>Figure 5 – P/Q diagram for type 2 <math>\sum S_{E_{max}} \leq 4,6 \text{ kVA}</math> and type 1, stirling generator, fuel cell <math>\sum S_{E_{max}} &gt; 4,6 \text{ kVA}</math> at the generator terminals in the passive sign convention system</p> <p>Figure 6 – P/Q diagram for type 2 (inverters only) <math>\sum S_{E_{max}} &gt; 4,6 \text{ kVA}</math> at the generator terminals in the passive sign convention system</p>		P

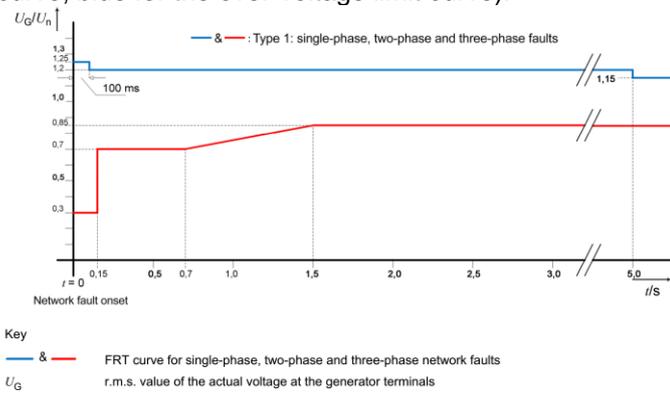
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Clause	Requirement - Test	Result - Remark	Verdict
	Within the range of $0 \leq P_{\text{mom}}/P_{\text{Emax}} < 0.2$ (or 0.1, respectively), the power generation unit shall not exceed the reactive power value at the generator terminals of 10 % of the active power value $P_{\text{Emax}}$ (reactive power supply and consumption respectively). Where a minimum technical power for a power generation unit has been agreed, the same conditions apply as for the range $0 \leq P_{\text{mom}}/P_{\text{Emax}} < 0.2$ (or 0.1, respectively) between 0 and the minimum technical power.		P
	For type 2 systems with generators directly connected to the network (asynchronous generators) that are principally not able to control any reactive power, the conditions given in 5.7.2.2 result in a combination of a generator and associated compensation devices. This combination shall not be changed for power values $< S_{\text{Emax}}$ . When disconnecting the asynchronous generator, the associated compensation device shall also be disconnected from the network.	Not asynchronous generators.	N/A
5.7.2.4	Methods for reactive power supply		P
	In the context of network connection planning, the network operator prescribes to the connection owner one of the following methods for reactive power supply at the generator terminals of the power generation unit:		P
	a) reactive power voltage characteristic curve $Q(U)$ ; or	The PGU is single phase unit.	N/A
	b) displacement factor/active power characteristic curve $\cos \varphi (P)$ ; or		P
	c) fixed displacement factor $\cos \varphi$ .		P
	The $Q(U)$ rule applies only to three-phase power generation units connected to the three-phase current system. Here, too, the reactive power requirements are implemented at the generator terminals of the power generation units.	The PGU is single phase unit.	N/A
	<ul style="list-style-type: none"> <li>– three-phase power generation units and storage units connected to the three-phase current system should be operated with a reactive power voltage characteristic curve <math>Q(U)</math>;</li> <li>– any other power generation units should be operated with a permanent <math>\cos \varphi = 1</math>.</li> </ul>	The PGU is single phase unit.	N/A
	<b>Re: a) Reactive power voltage characteristic curve <math>Q(U)</math></b>		N/A
	The objective of this method is the reactive power exchange between power generation unit and network depending on the actual voltage at the generator terminals of the power generation unit ( $Q = f(U)$ ).	The PGU is single phase unit.	N/A
	The reference voltage $U_{Q0}$ is $400 \text{ V} / \sqrt{3}$ .		N/A
	The arithmetic mean of the r.m.s. values (optionally of the positive sequence system) of the three measured line-to-neutral voltages at the generator terminals of the power generation unit is the target value for the reactive power to be fed in on all line conductors. Voltage measurement shall not exceed a maximum measurement error of 1 % in relation to the nominal value.		N/A

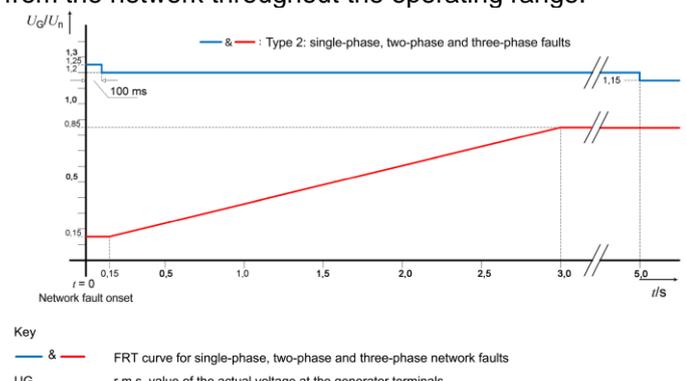
VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
	 <p>Figure 7 – Standard <math>Q(U)</math> characteristic curve</p>		N/A
	<p><b>Re: b) Displacement factor/active power characteristic curve <math>\cos \varphi</math> (P)</b></p>		P
	<p>The objective of this method is the reactive power supply by the power generation unit depending on the actual active power output (<math>Q = f(P_{\text{mom}})</math>).</p> <div style="display: flex; justify-content: space-around;"> <div>  <p>Figure 8 – Characteristic curve for type 2 generator, fuel cell <math>\sum S_{E\text{max}} &gt; 4,6 \text{ kVA}</math></p> </div> <div>  <p>Figure 9 – Standard characteristic curve for type 2 (inverters only) <math>\sum S_{E\text{max}} &gt; 4,6 \text{ kVA}</math></p> </div> </div>	(See appended table)	P
	<p><b>Re: c) Displacement factor <math>\cos \varphi</math></b></p>		P
	<p>The objective of displacement factor control is the power feed-in by the power generation unit at a constant active power/apparent power ratio (<math>\cos \varphi = \text{const}</math>). Thereby, the use of the reactive power control range given in Figure 5 and Figure 6 is restricted.</p>	(See appended table)	P
	<p>For this purpose, the target value is defined with a minimum increment of <math>\Delta \cos \varphi = 0,01</math>. The maximum permissible error tolerance of the reactive power feed-in is calculated using the error tolerance given in 5.7.2.3 of <math>\pm 4 \%</math> in relation to <math>P_{E\text{max}}</math>.</p>		P
	<p>The network operator predefines a displacement factor set-point.</p>		P
<p>5.7.2.5</p>	<p>Requirements for reactive power methods of type 2 systems (inverters only) and type 1 systems</p>		P
	<p>In the delivery state, none of the three reactive power methods specified in 5.7.2.4 is set as default. During the commissioning of power generation units, the method specified by the network operator shall be set by the system installer. Without the setting of the method specified by the network operator, power generation units shall not feed in any power.</p>		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For type 2 systems with a rated apparent power of $S_{Amax} \leq 4.6$ kVA, the network operator predefines either <ul style="list-style-type: none"> <li>– a reactive current feed-in with the characteristic curve <math>\cos \varphi (P)</math> as shown in Figure 8; or</li> <li>– a fixed <math>\cos \varphi</math> between <math>\cos \varphi = 0.95_{\text{under-excited}}</math> and <math>\cos \varphi = 0.95_{\text{over-excited}}</math>.</li> </ul>		P
	For type 1 systems with a rated apparent power of $S_{Amax} \leq 4.6$ kVA, the network operator does not predefine a value for the reactive power behaviour. Such type 1 systems may also feed in power without setting the method specified by the network operator.	Not type 1 systems.	N/A
	For type 2 systems with a rated apparent power of $S_{Amax} > 4.6$ kVA, the network operator predefines either <ul style="list-style-type: none"> <li>– a reactive current feed-in with the characteristic curve <math>Q(U)</math> as shown in Figure 7 with a control range between <math>\cos \varphi = 0.90_{\text{under-excited}}</math> and <math>\cos \varphi = 0.90_{\text{over-excited}}</math>; or</li> <li>– a reactive current feed-in with the characteristic curve <math>\cos \varphi (P)</math> as shown in Figure 8; or</li> <li>– a fixed <math>\cos \varphi</math> between <math>\cos \varphi = 0.90_{\text{under-excited}}</math> and <math>\cos \varphi = 0.90_{\text{over-excited}}</math>.</li> </ul>		N/A
	For type 2 systems with a rated apparent power of $S_{Amax} > 4.6$ kVA, the network operator predefines either <ul style="list-style-type: none"> <li>– a reactive current feed-in with the characteristic curve <math>Q(U)</math> as shown in Figure 7 with a control range between <math>\cos \varphi = 0.95_{\text{under-excited}}</math> and <math>\cos \varphi = 0.95_{\text{over-excited}}</math>; or</li> <li>– a reactive current feed-in with the characteristic curve <math>\cos \varphi (P)</math> as shown in Figure 9; or</li> <li>– a fixed <math>\cos \varphi</math> between <math>\cos \varphi = 0.95_{\text{under-excited}}</math> and <math>\cos \varphi = 0.95_{\text{over-excited}}</math>.</li> </ul>		N/A
	When storing with a rated apparent power of $S_{Amax} \leq 4.6$ kVA, the network operator predefines a fixed value for $\cos \varphi$ between $\cos \varphi = 0.95_{\text{under-excited}}$ and $\cos \varphi = 0.95_{\text{over-excited}}$ .		P
	When storing with a rated apparent power of $S_{Amax} > 4.6$ kVA, the network operator predefines either <ul style="list-style-type: none"> <li>– a reactive current feed-in with the characteristic curve <math>Q(U)</math> as shown in Figure 7 with a control range between <math>\cos \varphi = 0.90_{\text{under-excited}}</math> and <math>\cos \varphi = 0.90_{\text{over-excited}}</math>; or</li> <li>– a fixed <math>\cos \varphi</math> between <math>\cos \varphi = 0.90_{\text{under-excited}}</math> and <math>\cos \varphi = 0.90_{\text{over-excited}}</math>.</li> </ul> All storage units shall be delivered with a fixed $\cos \varphi = 1$ .		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	<p>The control behaviour of the reactive power (methods a), b) and c)) with respect to set-point offsets corresponds to the PT-1 behaviour shown in Figure 10. Method a) deals with a closed control circuit under consideration of the network impedance. Each reactive power value resulting from the control behaviour predefined by the network operator shall be adjustable within a range of 6 s to 60 s (from 10 s to 60 s for type 1) when being provided by the power generation unit. The time specified by the network operator corresponds to 3 Tau of a PT-1 behaviour or to the time until reaching 95 % of the set-point. If no actual value is predefined by the network operator for this purpose, the applicable value is 10 s for 3 Tau or 95 % of the set-point, respectively. The envelop delay time includes the determination of the network voltage or the active and reactive powers.</p> <p style="text-align: center;"><b>Step response with analysis-relevant tolerances</b></p> <p style="text-align: center;">Figure 10 – Illustration of 3 Tau = 10 s</p>		P
5.7.2.6	Special aspects regarding the extension of power generation systems		P
	The requirements specified in 5.7.2.4 shall also be met by the newly added power generation units at their generator terminals.		P
	The reactive power supply by the added power generation units in accordance with 5.7.2.2 shall be determined based on the sum of the rated apparent powers of the existing power generation system and the newly added power generation units.		P
5.7.3	Dynamic network support		P
5.7.3.1	General		P
	The objective of dynamic network stability is to prevent any unintentional disconnection of the generation power in case of short-term voltage drops/rises thereby avoiding to jeopardise the network stability.		P
	A network fault is present if the voltage at the generator terminals of the power generation unit is below 0.85 Un or exceeds 1.15 Un.		P
	<p>The criterion for the end of a fault is defined as the earlier of the following two events:</p> <ul style="list-style-type: none"> <li>– the line-neutral-voltage at the power generation unit and/or the storage unit resumes a value within the range of –15 % Un to +10 % Un;</li> <li>– 5 s after the onset of the fault.</li> </ul>		P

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Clause	Requirement - Test	Result - Remark	Verdict
5.7.3.2	Dynamic network support for Type 1 units(Transient stability - performance in case of network faults)	The PGU is Type 2 unit.	N/A
	Regarding the power generation unit remaining connected to the network, the following applies to type 1 units:		N/A
	Throughout the operating range of the power generation unit, voltage drops caused by single-phase, two-phase or three-phase network faults and the subsequent voltage transient phenomena shall not cause the power generation unit to become unstable or to disconnect from the network if the voltage assumes values within the limit curves shown in Figure 11 (red for the under-voltage limit curve, blue for the over-voltage limit curve).		N/A
	 <p>Figure 11 – Fault Ride-Through (FRT) limit curve for the voltage curve at the generator terminals for a type 1 power generation unit</p>		N/A
	Voltage controllers are recommended which take into account all applied line-neutral voltages.		N/A
	The voltage controller may change the exciting current during a network fault (additional exciting current) in order to reduce the synchronous generated angle and thereby improve the stability of the power generation unit. During and after a network fault, the voltage rise due to the reactive power feed-in shall not lead to a violation of the over-voltage limit curve.		N/A
	Behaviour after the end of a fault		N/A
	If, after the end of a fault, the network voltage resumes a value within the voltage band from –15 % $U_n$ to +10 % $U_n$ and the active power of the power generation unit has been reduced during the network fault, it shall be increased to its pre-fault value immediately after the end of the fault. The transient period shall not exceed a maximum of 6 s. The reactive power supply succeeds the active power supply as soon as possible.		N/A
	At voltages of 1,15 $U_n$ , the power generation unit shall not disconnect from the network for a period of up to 60 s after the onset of the fault. If the tripping of the power generation unit's self-protection is imminent, the unit can adjust its reactive power behaviour such as to prevent the self-protection tripping.		N/A
5.7.3.3	Dynamic network stability for type 2 units and storage units		P
	The following conditions apply to all type 2 power generation units and storage units:		P

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Clause	Requirement - Test	Result - Remark	Verdict
	<p>As long as the line-neutral-voltages at the generator terminals of the power generation unit or storage unit do not exceed the limit curves shown in Figure 12 (red for the under-voltage limit curve, blue for the over-voltage limit curve), both the power generation unit and the storage unit shall neither become unstable nor disconnect from the network throughout the operating range.</p>  <p>Key  — &amp; — : Type 2: single-phase, two-phase and three-phase faults  — &amp; — FRT curve for single-phase, two-phase and three-phase network faults  UG r.m.s. value of the actual voltage at the generator terminals</p> <p>Figure 12 – Fault Ride-Through (FRT) limit curve for the voltage curve at the generator terminals for a type 2 power generation unit and for storage units</p>	(See appended table)	P
	<p>For evaluating the curves, the smallest respective value of the line-neutral-voltages at the power generation unit or the storage unit shall be used in case of a voltage drop, and the highest respective value of the line-neutral-voltages at the power generation unit or the storage unit shall be used in case of a voltage rise.</p>		P
	<p>As far as the set values for the NS protection given in Table 2 (column “Inverter(s)”) anticipate the requirements given in Figure 12 in certain working points, merely the checking of the set values for NS protection is required for the verification procedure.</p>		P
	<p>If the voltage at the generator terminals falls below <math>&lt; 0.8 U_n</math> or exceeds <math>&gt; 1.15 U_n</math> (onset of fault), type 2 power generation units and storage units shall ride through voltage drops without feeding current into the network of the network operator (limited dynamic network stability).</p>	(See appended table)	P
	<p>This requirement is deemed to be met, if the current fed in by the power generation unit(s) and/or the storage unit in any line conductor does not exceed 20 % of the rated current <math>I_r</math> within 60 ms and 10 % of <math>I_r</math> within 100 ms upon a voltage drop below <math>0.8 U_n</math> or a voltage rise above <math>1.15 U_n</math>.</p>	(See appended table)	P
	Behaviour after the end of a fault		P
	<p>If, after the end of a fault, the network voltage resumes a value within the voltage band from <math>-15 \% U_n</math> to <math>+10 \% U_n</math> and the active current of the power generation unit and/or the storage unit has been reduced during the network fault, it shall, immediately after the end of the fault, be increased to its pre-fault value as quickly as possible. The transient period shall not exceed a maximum of 1 s. The reactive power supply follows 5.7.2.5 in its time-related behaviour. In case of rotating machinery, the transient period shall not exceed a maximum of 6 s.</p>	(See appended table)	P

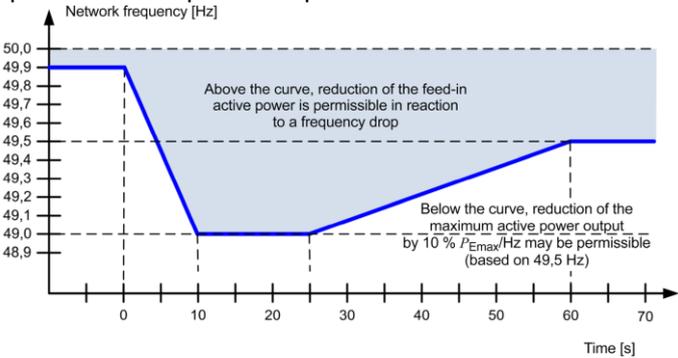
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Clause	Requirement - Test	Result - Remark	Verdict
	At voltages of $1.15 U_n$ , the power generation units and storage units shall not disconnect from the network for a period of up to 60 s after the onset of the fault. If the tripping of the self-protection of the power generation units and/or the storage unit is imminent, these units can adjust their reactive power behaviour such as to prevent self-protection tripping.		P
5.7.4	Active power output		P
5.7.4.1	General		P
	In cases where set-points are specified by a third party (e. g. direct marketing) and of network security management in accordance with 5.7.4.2, the new set-point shall be approached with the customer installation's power gradients listed below in relation to the network connection point. Implementation of those power gradients directly at the power generation units or storage units is sufficient for meeting the requirement.		P
	The following power gradients shall be observed for increasing/reducing the active power output of power generation systems (minimum technical power or $5\% P_{Amax} \leftrightarrow 100\% P_{Amax}$ ) as well as the energy supply and consumption by storage units ( $5\% P_{Amax} \leftrightarrow 100\% P_{Amax}$ ):		P
	<ul style="list-style-type: none"> <li>– at a maximum rate of <math>0.66\% P_{Amax}</math> per s;</li> <li>– at a minimum rate of <math>0.33\% P_{Amax}</math> per s. Power generation systems may react more slowly in case of set-points specified by third parties and of power increases. For this purpose, a minimum rate of <math>4\% P_{Amax}</math> per minute should be observed.</li> </ul>		P
	Other technically induced power gradients (e. g. for hydro power generation systems with level control depending on network demands) are permissible upon approval by the network operator.		N/A
	The power increase or reduction of the customer installation shall be realised in a uniform process, i. e. with a behaviour as linear as possible. The specification of set-points by third parties shall be realised on the level of the individual customer installation or by the sum of all systems accessed by a third party (e. g. by uniform distribution of the active powers to be connected or disconnected over a total period of $\geq 2.5$ min).		Info.
	The specifications are based on the active power. For this purpose, the reactive power shall comply with the specifications in 5.7.2 of this VDE application guide.		Info.
	For power generation systems with combustion engines, the maximum permissible operating durations of the combustion engine shall be taken into account when reducing the active power output at set-points below the engine's technical minimum continuous power. If the power value is below the combustion engine's minimum technical power output and the permissible operating duration is exceeded, the combustion engine may disconnect from the network.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	The power generation system or storage unit shall be provided with a logical interface (inlet port) which, irrespective of the power gradients listed above, allows to terminate the active power output within 5 s upon reception of a corresponding signal from the network operator. Additionally, the interface may be used for network security management.		P
	According to EnWG [4], the network operator is entitled to request and apply a temporary limitation of the active power output or a system shut-down at any time.		P
5.7.4.2	Network security management		P
5.7.4.2.1	Types of power generation systems and storage units		P
	If not specified otherwise by legislation, the requirements described below apply.		P
	Photovoltaic systems	Not PV systems	N/A
	PV systems shall contribute to the avoidance of network overload. For this purpose, PV system power is divided into three power groups:		N/A
	<ul style="list-style-type: none"> <li>– For PV systems up to and including 30 kWp, the system operator may chose between two options: <ul style="list-style-type: none"> <li>a) by means of a corresponding inverter design or a certified technical control, the active power feed-in of the PV system shall be permanently limited to a maximum value of 70 % of the installed module power at the network connection point with the power gradients given in 5.7.4.1; or</li> <li>b) the PV system shall be provided with a technical means for remote-controlled reduction of the feed-in power by the network operator.</li> </ul> </li> </ul>		N/A
	<ul style="list-style-type: none"> <li>– PV systems &gt; 30 kWp up to and including 100 kWp shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator.</li> </ul>		N/A
	<ul style="list-style-type: none"> <li>– PV systems &gt; 100 kWp shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power.</li> </ul>		N/A
	If the installed total power increases to > 100 kWp due to the installation of a further PV system on the same plot or building within a period of 12 months, legal provisions require implementation of the feed-in management for systems > 100 kWp while providing the actual feed-in power for the total power.		N/A
5.7.4.2.2	Implementation of network security management		P

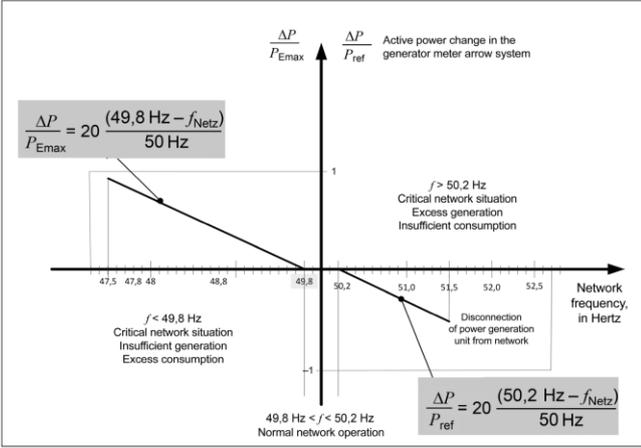
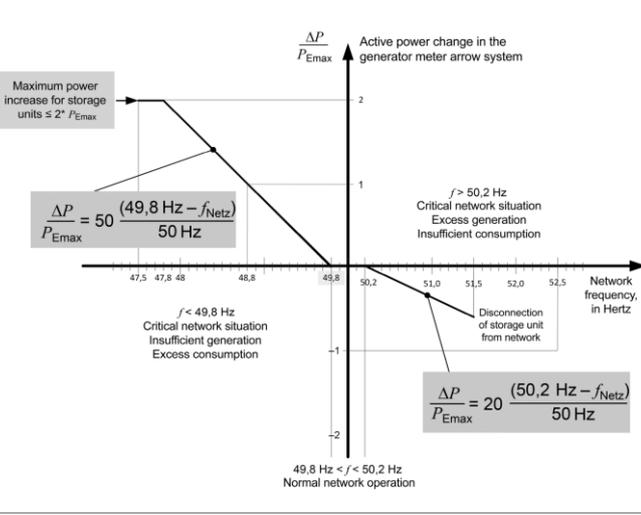
VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Power generation systems and storage units shall be able to reduce their active power to a power value predetermined by the network operator at the network connection point without disconnecting from the network. The following values have proved effective: 100 %/60 %/30 %/0 % in relation to the installed active feed-in power $P_{Amax}$ . Instead of reducing the generated active power, the consumed power of the customer installation can be increased, too. The sum of the reduced generated active power and/or the increased consumed active power at the network connection point shall not deviate by more than $\pm 5\%$ from the setpoint of active power limitation. Power reduction shall be possible for any operating state and from any operating point. In case of a redispatch, the power generation systems shall be technically capable of increasing the power to a maximum of $P_{Amax}$ upon the network operator's request.		P
	It shall be noted for combined systems that the total effect at the network connection point is resulting from the power of the power generation system and the power of the consumption system. The power reduction requirement relates to the installed active feed-in power $P_{Amax}$ irrespective of the actual power flow or its direction at the network connection point. Power reduction implemented directly at the power generation units and/or by connection of electric equipment in combined systems is sufficient for meeting the requirement. Self-consumption strategies involving storage units shall not be in conflict with these requirements. Each network operator's reduction request shall be justifiable based on the metering strategy or a remote controlled connection for the network operator.		P
	The power generation system may be disconnected from the network below the minimum technical power (also refer to the exceptions for combustion engines given in 5.7.4.1). In case of a predefined power value of 0 % $P_{Amax}$ , disconnection from the network is not strictly necessary.		P
	The active power value is specified separately for each primary energy carrier (where multiple primary energy carriers are connected to the customer installation).		P
	Requirements of the network security management invariably take precedence over market-relevant requirements.		P
5.7.4.3	Active power adjustment at over-frequency and under-frequency		P
	A network frequency outside the tolerance band of $\pm 200$ mHz around the nominal network frequency of 50.0 Hz indicates the presence of a critical system state in the integrated network where any power generation units and storage units shall contribute to the network frequency support.		P
	The accuracy of the frequency measurement in the steady state shall be $\leq \pm 10$ mHz.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Storage systems in standby mode are exempted from the requirements of 5.7.4.3. In addition, DC-coupled storage systems shall perform as Type 2 units.		Info.
	In case of over-frequency, an excess of generated power is opposed by a deficit of consumed power.		P
	Therefore, all power generation units and storage units shall be able to adjust the active power working point at an over-frequency up to a maximum of 51.5 Hz (see Figure 14 and Figure 15).		P
	Power generation units shall enable the frequency for starting this frequency-dependent active power feed-in to be set to a value between 50.2 Hz and 50.5 Hz. Unless specified otherwise by the network operator, this start frequency shall be set to 50.2 Hz. The static value of the frequency-dependent active power feed-in $s = \frac{\Delta f}{f_n} / \frac{\Delta P}{P_{ref}}$ shall be adjustable within a range of 2 % to 12 %. This corresponds to a power gradient within a range of 16.67 % of $P_{ref}$ per Hertz ( $s = 12 \%$ ) to 100 % of $P_{ref}$ per Hertz ( $s = 2 \%$ ). Unless specified otherwise by the network operator, a gradient of 40 % of $P_{ref}$ per Hertz ( $s = 5 \%$ ) shall be set (see Figure 14).	(See appended table)	P
	For storage units, the generated active power with a gradient of 40 % of $P_{E_{max}}$ per Hertz ( $s = 5 \%$ ) shall be reduced or increased (see Figure 15).		P
	Consequently, the power generation unit or the storage unit will constantly move up and down along the frequency characteristic within the frequency range of 50.2 Hz (unless specified otherwise for power generation units by the network operator) to 51.5 Hz with regard to its maximum possible active power feed-in ("operation along the characteristic").		P
	At network frequencies $f > 51.5$ Hz, power generation units and storage units shall disconnect from the network if energy is supplied (see Figure 14 and Figure 15).		P
	Reduction of the active power output shall be continued at least until the minimum technical power is reached. Further reduction below the minimum technical power is permitted. During this, stable operation of the power generation unit shall be ensured.		P
	If the value of 50.2 Hz has been exceeded, controllable storage units in charging mode shall not reduce their charging power until the frequency has dropped below 50.2 Hz with a gradient of 10 % $P_{ref}$ per minute. During the over-frequency, storage units in charging mode should adjust their charging power according to Figure 15 (i. e. an increase of the charging power according to the characteristic curve is explicitly desired). This does not apply to the reduction of the charging power in order to prevent overcharge or harm to persons or damages to property.		P
	In case of under-frequency, a deficit of generated power is opposed by an excess of consumed power.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	<p>Figure 13 shows the requirement for the output power of the power generation units in the dynamic short-time range. At frequency curves between 50 Hz and the blue curve, the power generation unit shall not reduce its specified active power output.</p>  <p>Figure 13 – Requirement for the output power of the power generation units in the dynamic short-time range</p>		P
	<p>At frequencies below 49.8 Hz, all power generation units shall increase the instantaneous generated active power <math>P_{mom}</math> with a gradient of 40 % <math>P_{E_{max}}</math> per Hertz (<math>s = 5\%</math>) to its technically possible maximum value. For storage units, a gradient of 100 % <math>P_{E_{max}}</math> per Hertz (<math>s = 2\%</math>) applies. The maximum value is determined by the actual primary energy supply as well as the actually usable storage power. Power reductions for the protection of operating equipment are permitted even at under-frequency. For CHP systems, power reductions resulting from a heat-lead operating mode or a power drop due to the rotational speed are also permitted.</p>		P
	<p>Consequently, power generation units and storage units will constantly move up and down along the frequency characteristic also within the frequency range of 49.8 Hz to 47.5 Hz or 47.8 Hz with regard to their maximum possible active power feed-in (“operation along the characteristic”).</p>		P
	<p>At an under-frequency within the range of 49.8 Hz to 47.5 Hz, all storage units in charging mode shall reduce their instantaneous charging power according to the characteristic curve shown in Figure 15 to its technically possible minimum value (“operation along the characteristic”). In addition, storage units, as far as their charging state permits, shall change into the operating mode “energy supply” and increase their power according to the characteristic curve shown in Figure 15. In this case, system stability is of higher priority than a potential restraint for feeding storage energy into the network of the network operator based on technical/financial requirements.</p>		P
	<p>At network frequencies <math>f &lt; 47.5</math> Hz, power generation units and storage units shall disconnect from the network (see Figure 14 and Figure 15).</p>	Comply with Figure 14.	P

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Clause	Requirement - Test	Result - Remark	Verdict
	 <p>Key</p> <p><math>P_{E_{max}}</math> highest active power of a power generation unit (10 min mean value)</p> <p><math>P_{ref}</math> equals <math>P_{E_{max}}</math> for type 1 power generation units or <math>P_{nom}</math> for type 2 power generation units at the moment when 50,2 Hz is exceeded.</p> <p><math>\Delta P</math> power change</p> <p><math>f</math> network frequency</p> <p><b>Figure 14 – Active power adjustment for type 1 and type 2 power generation units at over-frequency and under-frequency with a static value of 5 % and frequency limit values of 49,8 Hz and 50,2 Hz for starting the adjustment</b></p>		N/A
	 <p>Key</p> <p><math>P_{E_{max}}</math> highest active power of a power generation unit (10 min mean value)</p> <p><math>\Delta P</math> power change</p> <p><math>f</math> network frequency</p> <p><b>Figure 15 – Active power adjustment for storage units at an over-frequency with a static value of 5 % and an under-frequency with a static value of 2 % and frequency limit values of 49,8 Hz and 50,2 Hz for starting the adjustment</b></p>		P
	Requirements for the control times for power generation units and storage units		P
	The initial time delay $T_V$ of the frequency-dependent adjustment of the active power output at over-frequency and under-frequency is part of the transient period and shall preferably be $\leq 2$ s. In case of a time delay $> 2$ s, the operator of the power generation system shall justify that delay by submitting technical proof to the transmission network operator. For type 2 power generation units and storage units, the necessary initial time delays $T_V$ for reaching the required transient periods are significantly shorter than 2 s.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	For the time curve of the frequency-dependent active power adjustment, the following conditions regarding the initial time delay $T_V$ and the transient period $T_{an\_90\%}$ shall be observed: – After the expiration of $T_V + 0.1 \times (T_{an\_90\%} - T_V)$ at least 9% of the required power adjustment $\Delta P$ is achieved. – After the transient period $T_{an\_90\%}$ has elapsed, a value of 90 % of the power adjustment $\Delta P$ has been reached.		P
	During the control process (“operation along the characteristic”), the power generation unit and the storage unit shall respond as quickly as possible to sudden network frequency changes within a frequency range of 50.2 Hz to 51.5 Hz (subject to capability as declared by the manufacturer) with a transient period of 8 s for $\Delta P \leq 45\%$ of $P_{E_{max}}$ and $\Delta P$ for power changes beyond that in case of type 1 units and type 2 units with rotating machinery and 2 s in case of all other type 2 power generation units and 1 s in case of storage units.		P
	The settling period shall not exceed 30 s for type 1 units and type 2 units with rotating machinery or 20 s for all other type 2 power generation units and for storage units.		P
	After settling, the supplied active power should deviate by $\leq \pm 10\%$ $P_{E_{max}}$ from the set-point.		P
	The same requirements shall be applied to the active power increase at an under-frequency between 49.8 Hz and 47.5 Hz.		P
	Conditional requirements based on technical restrictions		P
	As an alternative to active power reduction at over-frequency, non-controllable power generation units may disconnect from the network within the frequency range of 50.2 Hz to 51.5 Hz; in that case, uniform distribution of the disconnection frequency in maximum increments of 0.1 Hz shall be ensured for each system type by the manufacturer.		P
	Power generation units of limited variability, e. g. only within the range of 70 % to 100 % $P_{E_{max}}$ , can be curtailed within that range in accordance with the characteristic curve. Outside the controllable range, disconnection is then carried out according to the uniformly distributed shut-down limit curve.		P
	For power generation units with combustion engines or gas turbines, active power reduction occurs with a power gradient of at least 66 % $P_{E_{max}}$ per minute (equals 1.11 % $P_{E_{max}}$ per second). Thus, the transient period of 8 s can be observed up to a power reduction of 8.88 % $P_{E_{max}}$ . In case of a greater change of frequency, the transient period is accordingly higher.	The power generation units not with combustion engines or gas turbines.	N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	Linear generators, such as Stirling machines up to a maximum apparent power of $S_{Amax} \leq 4.6$ kVA, are exempt from the active power feed-in at over/under-frequency. They may remain connected to the network within a frequency range between 50.2 Hz and their maximum upper frequency limit and may disconnect from the network if this value is exceeded or, at the latest, when a frequency of 51.5 Hz is reached or exceeded. At an under-frequency between 49.8 Hz and their maximum lower frequency limit, linear generators should remain connected to the network but shall disconnect from it at the latest when a frequency of 47.5 Hz is reached or exceeded.	Not linear generators.	N/A
	End of critical network status and return to normal operation		P
	Even if the network frequency has resumed a value within the tolerance band of 50.0 Hz $\pm$ 200 mHz after a frequency deviation, a critical network state has still to be assumed initially.		P
	The time for transition from the critical network state to normal operation is limited by a maximum change of the active power set-point based on $P_{nom}$ .		P
	This change of the active power set-point (except for providing the operating reserve) shall be limited to a maximum gradient of 10 % of the active power $P_{Emax}$ per minute (under consideration of 5.7.1). Only after the network frequency has been within the tolerance band of 50.0 Hz $\pm$ 200 mHz for 10 min continuously, the normal operation of the network is deemed to be restored whereupon this requirement does no longer apply.		P
5.7.4.4	Voltage-dependent active power reduction		P
	In order to avoid disconnection of the power generation system due to over-voltage protection $U >$ , it is permissible to reduce the active power feed-in as a function of the voltage of (a) power generation unit(s). Implementation is then chosen by the system manufacturer. This is not considered an active power reduction in the context of feed-in management in compliance with EEG.		P
	Surges or oscillations of the active power feed-in are not permitted for that purpose.		P
5.7.5	Short-circuit current contribution		P
	Due to the operation of a power generation system, the short-circuit current of the low-voltage network is increased by the short-circuit current of the power generation system. Therefore, the short-circuit current of the power generation system to be expected at the network connection point shall be indicated in accordance with 4.2. For the determination of the initial short-circuit AC current contribution $I''_{kA}$ of a power generation system, the following roughly estimated values can be assumed: <ul style="list-style-type: none"> <li>– for synchronous generators: 8 times the rated current;</li> <li>– for asynchronous generators: 6 times the rated current;</li> <li>– for generators and storage units with inverters: the rated current.</li> </ul>		P

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Clause	Requirement - Test	Result - Remark	Verdict
<b>6</b>	<b>CONSTRUCTION OF THE POWER GENERATION SYSTEM/NETWORK AND SYSTEM PROTECTION (NS PROTECTION)</b>		P
<b>6.1</b>	<b>General requirements</b>		P
	The network and system protection (NS protection) is a type-tested protective device with certificate for the NS protection (see form E.6), in which all protection functions according to 6.5 are implemented. NS protection acts on the interface switch according to 6.4.		P
	Depending on the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point $\Sigma S_{Amax}$ , the following conditions apply to the NS protection: <ul style="list-style-type: none"> <li>- <math>\Sigma S_{Amax} &gt; 30 \text{ kVA}</math>: <ul style="list-style-type: none"> <li>• Central NS protection at the central meter panel.</li> </ul> <p>Exception 1: In the case of combined heat and power units, integrated NS protection is also permitted for power generation systems of <math>&gt; 30 \text{ kVA}</math>, if, at the network connection point, a disconnection device is provided that is accessible for the network operator's staff at all times.</p> <p>Exception 2: For storage units not feeding into the low-voltage network of the network operator, integrated NS protection is also permitted at <math>&gt; 30 \text{ kVA}</math>.</p> </li> <li>- <math>\Sigma S_{Amax} \leq 30 \text{ kVA}</math>: <ul style="list-style-type: none"> <li>• Central NS protection at the central meter panel or decentralised in a sub-distribution; or</li> <li>• integrated NS protection.</li> </ul> </li> </ul>	$\Sigma S_{Amax} \leq 30 \text{ kVA}$ , integrated NS protection used.	P
	When determining the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point $\Sigma S_{Amax}$ , it is necessary to consider both any existing as well as any new systems. Storage units not feeding into the low-voltage network of the network operator at this network connection point and combined heat and power units connected via a disconnection device that is accessible at all times shall not be taken into account when determining $\Sigma S_{Amax}$ .		Info.
	Where the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point whereat they feed into the low-voltage network of the network operator is a value $\Sigma S_{Amax} > 30 \text{ kVA}$ , a central NS protection shall be installed or, if applicable, retrofitted. This also applies if the limit value of 30 kVA is exceeded due to later measures. This includes e. g.: <ul style="list-style-type: none"> <li>- addition of new power generation units;</li> <li>- the operating mode of the storage unit(s) is modified such that it/they feed(s) into the low-voltage network of the network operator;</li> <li>- combined heat and power units no longer connected and operated via a disconnection device that is accessible at all times.</li> </ul>		Info.
	The loss of the auxiliary voltage of the central NS protection or the control of the integrated NS protection shall lead to an instantaneous tripping of the interface switch. Protective tripping of the integrated protection shall not be inadmissibly delayed by other control functions in order to observe the required disconnection periods. The protective functions shall be maintained even in the event of a malfunction in the system control.		Info.
	The central NS protection, the integrated NS protection, the central and the integrated interface switch as well as the associated tripping circuits shall meet the following requirements:		Info.

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Clause	Requirement - Test	Result - Remark	Verdict
	<ul style="list-style-type: none"> <li>- such equipment shall be designed, constructed, chosen, assembled and combined at least such as to be able to withstand the operating conditions (e. g. reliability with regard to their breaking capacity and switching frequency) and external influences (e. g. mechanical vibration, external fields, interruptions or disturbances of the energy supply) to be expected.</li> <li>- A single fault shall not lead to a loss of the protective function of the NS protection. Faults of common cause shall be taken into account if the probability of their occurrence is of any significance. Each single fault should be indicated and lead to shut-down of the respective power generation unit or system.</li> </ul>		Info.
<b>6.2</b>	<b>Central NS protection</b>		N/A
	The central NS protection shall be accommodated, installed and connected as an independent equipment at the central meter panel in a suitable circuit distributor in accordance with VDE-AR-N 4100, Clause 8, Paragraph 1, and not in the upper connection compartment according to VDE-AR-N 4100, 7.2, Paragraph 11. Examples of the arrangement of the central NS protection and hence the connection of power generation systems to meter panels are shown in Annex C.		N/A
	For central NS protection, it is additionally required to carry out a trigger test for checking the tripping circuit "NS protection – interface switch". For this purpose, the central NS protection is provided with a means for tripping the interface switch (e. g. by means of a test button) for testing purposes. Activation shall be visualised at the interface switch.		N/A
<b>6.3</b>	<b>Integrated NS protection</b>		P
	In the case of integrated NS protection, the NS protection can be integrated in the programmable system control of the power generation units (e. g. in the inverter control). In this case, the means for testing the tripping circuit "NS protection – interface switch" by the system installer is not required.		P
	The integrated NS protection acts on an integrated interface switch (see 6.4.3).		P
<b>6.4</b>	<b>Interface switch</b>		P
6.4.1	General		P
	For the connection of the power generation system to the network operator's low-voltage network or to the remaining customer installation, an interface switch shall be used. The interface switch is controlled by the NS protection and automatically triggers if at least one protective function responds		P
	As interface switches, the switching devices of the individual power generation units (integrated interface switch) can be used.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The integrated interface switches can also be used in combination with the central NS protection. In any case, central NS protection from $\Sigma S_{Amax} > 30$ kVA (sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point; for exceptions, see 6.1) shall be directly connected to the central meter panel. Where a signal is routed to a spatially separate switching device, it shall be ensured that the required disconnection periods given in Table 2 are observed and lead to the disconnection of the power generation system. During commissioning of the power generation system, a tripping test of the interface switch shall be conducted.		P
	The interface switch shall be designed for the rated conditional short-circuit current and under consideration of the protective devices required according to 6.5 and it shall enable instantaneous tripping. The switching capacity of the interface switch shall be rated according to the rated current of the upstream fuse or the maximum initial short-circuit AC current contribution of the power generation system, whichever is the higher. The functional check of the interface switch shall be carried out according to a) or b) or c): a) The use of an interface switch, where a control voltage must always be present when the unit is switched on, and which switches off automatically if this voltage is not present. The operational switch-on or switch-off procedures must be monitored. b) At least once daily switching on or off of the interface switch by the NS protection and monitoring of the proper function of the interface switch (e.g. normally closed contact of a feedback contact). c) Use of the integrated interface switch and the integrated NS protection for PV and battery inverters according to DIN EN 62109 (VDE 0126-14).		P
	When a defect of the interface switch is detected, the power generation system shall neither feed in nor reconnect.		P
6.4.2	Central interface switch		N/A
	The central interface switch shall be a galvanic break device (e. g. mechanical contactor, protective motor switch, mechanical circuit breaker). For a power generation system required to contribute to the dynamic network stability, an interface switch enabling compliance with the requirements specified in 5.7.3 (no malfunction at under-voltage in the context of the FRT requirements) shall be used.		N/A
	The interface switch shall be installed in the distribution field of or directly at the central meter panel in a circuit distributor. Examples of the arrangement of interface switches and hence the connection of power generation systems to meter panels are shown in Annex C.		N/A
6.4.3	Integrated interface switch		P
	For the construction of the interface switch, the requirements specified in 6.1 shall be considered		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The interface switch (e.g. power relay, contactor, mechanical circuit breaker, etc.) ensures galvanic shutdown.		P
	For power generation systems with inverters, the interface switch must be provided on the network side of the inverter.		P
<b>6.5</b>	<b>Protective devices and protection settings</b>		P
6.5.1	General		P
	The purpose of NS protection is to disconnect the power generation system from the network in the event of inadmissible voltage and frequency values (also refer to DIN VDE 0100-551 (VDE 0100-551)). This is meant to prevent inadvertent feed-in from the power generation system into a partial network separated from the main distribution network.		P
	The specifications given in 6.5.2 do not refer to the protective functions of short-circuit protection, overload protection, protection against electric shock and all-phase separator of the circuit to the power generation system (e. g. by means of line circuit breakers, residual current operated circuit-breakers (RCD)) which shall be carried out in accordance with the applicable VDE regulations and for which the connection owners are themselves responsible (to ensure self-protection). In this respect, the protection function described in this VDE application guide may have to be extended accordingly by the connection owner of the power generation system. However, the self-protection shall not undermine the requirements described in this VDE application guide.		P
	System operators shall themselves take precautions to prevent damages to their systems and installations due to switching actions, voltage fluctuations and automatic reclosings in the upstream network or other processes in the network of the network operator. The following functions of the NS protection shall be implemented: – rise-in-voltage protection $U >>$ ; – rise-in-voltage protection $U >$ ; – voltage drop protection $U <$ ; – voltage drop protection $U <<$ ; – frequency decrease protection $f <$ ; – frequency increase protection $f >$ ; – islanding detection.		P
	Voltage protection devices should evaluate the r.m.s. value. Evaluation of the 50 Hz fundamental component is sufficient.		P
	Rise-in-voltage protection $U >$ must be designed as a sliding 10-minute mean value protection which prevents the upper voltage limit according to DIN EN 50160 from being exceeded (monitoring of the voltage quality). It is sufficient if a new 10-minute mean value is formed every 3 s at the latest, which must be compared with the setting value for $U >$ from Table 2.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Voltage protection devices must be designed in such a way that they monitor the feeding external conductors. With power generation systems $\leq 30$ kVA, the voltage(s) (per individual line to which power is fed) between the individual lines and the neutral conductor must be measured		P
	For power generation systems $> 30$ kVA, the voltage protection devices must be three-phase. For this purpose, the three voltages between the individual lines and the neutral conductor must be measured; the three interlinked individual line voltages must either be calculated from the three line-to-neutral voltages or measured separately. This means that 2 x 3 voltages are to be recorded here.	Power generation systems $\leq 30$ kVA.	N/A
	The voltages are to be logically OR linked. Logic OR linking here means: <ul style="list-style-type: none"> <li>– For rise-in-voltage protection relays, exceeding the threshold value leads to an excitation for at least one measuring voltage;</li> <li>– For voltage-drop protection relays, a drop below the threshold value leads to an excitation for at least one measuring voltage.</li> </ul>		P
	Frequency protection devices can be single-phase equipment		P
	The setting values of the protective functions and the last five dated error messages (relative time stamp is sufficient, i.e. no real-time clock required) must be readable on the NS protection. Supply interruptions $\leq 3$ s must not lead to any loss of the error messages. At central NS protection, readout must be possible independently of the operating status of the power generation system and without additional aids (e.g. on a display). With the integrated NS protection, the readout can be affected via a data interface.		P
	Where systems are provided with functions such as unbalance protection (see VDE-AR-N 4100, 5.5.3) or $P_{AV, E}$ monitoring (see 5.5.2), those functions may be implemented within a device in combination with the NS protection.	This inverter has $P_{AV, E}$ monitoring function.	P
6.5.2	Protective functions		P
	The NS protection shall be provided with a means for preventing unauthorised access (z. B. sealable, password protection). The rise-in-voltage protection $U >$ shall be designed such as to be adjustable in the NS protection (see Table 2, Footnote b). Additionally, the time delay of the voltage drop protection $U <$ and $U \ll$ for directly coupled synchronous and asynchronous generators with $P_n > 50$ kW shall also be designed such as to be adjustable in the NS protection (see Table 2, Footnote d). Any other protective functions listed in 6.5.1 are either to be installed permanently, i. e. not adjustable, in the NS protection or to be provided with an additional separate protection against unauthorised access (e. g. password protection) for preventing modifications.		P
	The setting values for protection purposes are considered to be functionally dependent on the technical capabilities of the power generation units.		P

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Clause	Requirement - Test	Result - Remark	Verdict																																																														
	<p>The protection functions according to Table 2 must be set in NS protection. The protection relay settings, which can be changed by the network operator or the system operator according to specifications, are listed below Table 2.</p> <p style="text-align: center;"><b>Table 2 – Setting values for NS protection</b></p> <table border="1"> <thead> <tr> <th rowspan="2">Protective function</th> <th colspan="6">Setting values for protection relays<sup>a</sup></th> </tr> <tr> <th colspan="2">Stirling generators, fuel cells</th> <th colspan="2">Directly coupled synchronous and asynchronous generators with <math>P_n &gt; 50</math> kW</th> <th colspan="2">Inverter(s)</th> </tr> <tr> <td></td> <td colspan="2">Synchronous and asynchronous generators with <math>P_n \leq 50</math> kW coupled directly or via inverters</td> <td colspan="2"></td> <td colspan="2"></td> </tr> </thead> <tbody> <tr> <td>Rise-in-voltage protection <math>U &gt;&gt;</math></td> <td><math>1,15 U_n</math></td> <td><math>\leq 100</math> ms</td> <td><math>1,25 U_n</math></td> <td><math>\leq 100</math> ms</td> <td><math>1,25 U_n</math></td> <td><math>\leq 100</math> ms</td> </tr> <tr> <td>Rise-in-voltage protection <math>U &gt;</math></td> <td><math>1,10 U_n^b</math></td> <td><math>\leq 100</math> ms</td> <td><math>1,10 U_n^b</math></td> <td><math>\leq 100</math> ms</td> <td><math>1,10 U_n^b</math></td> <td><math>\leq 100</math> ms</td> </tr> <tr> <td>Voltage drop protection <math>U &lt;</math></td> <td><math>0,8 U_n^c</math></td> <td><math>\leq 100</math> ms</td> <td><math>0,8 U_n</math></td> <td><math>1,0</math> s<sup>d</sup></td> <td><math>0,8 U_n</math></td> <td><math>3,0</math> s</td> </tr> <tr> <td>Voltage drop protection <math>U &lt;</math></td> <td colspan="2">Not applicable</td> <td><math>0,45 U_n</math></td> <td><math>300</math> ms<sup>d</sup></td> <td><math>0,45 U_n</math></td> <td><math>300</math> ms</td> </tr> <tr> <td>Frequency decrease protection <math>f &lt;</math></td> <td><math>47,5</math> Hz</td> <td><math>\leq 100</math> ms</td> <td><math>47,5</math> Hz</td> <td><math>\leq 100</math> ms</td> <td><math>47,5</math> Hz</td> <td><math>\leq 100</math> ms</td> </tr> <tr> <td>Frequency increase protection <math>f &gt;</math></td> <td><math>51,5</math> Hz</td> <td><math>\leq 100</math> ms</td> <td><math>51,5</math> Hz</td> <td><math>\leq 100</math> ms</td> <td><math>51,5</math> Hz</td> <td><math>\leq 100</math> ms</td> </tr> </tbody> </table> <p><sup>a</sup> The duration set-point "<math>&lt; 100</math> ms" for the protection relay setting value is based on the assumption that the maximum response time for NS protection + interface switch is also 100 ms. This results in a maximum "total disconnection time" of 200 ms. If the response time of the components is <math>&lt; 100</math> ms (e. g. 50 ms), then this allows for a longer period during which to perform the measurements and the evaluation of the protective function (e. g. up to 150 ms). This would then result in a protection relay setting value higher than "<math>&lt; 100</math> ms", i. e. "<math>&lt; 150</math> ms". However, in that case, only the 100 ms shall be visualised as the setting value at the NS protection. Nevertheless, the disconnection time of 200 ms shall in no case be exceeded.</p> <p><sup>b</sup> It shall be ensured, that the voltage <math>1,10 U_n</math> is not exceeded at the network connection point. If compliance with this requirement is ensured by a central NS protection, then it is permissible to set the rise-in-voltage protection at the decentralised power generation unit/system to a value of up to <math>1,15 U_n</math>, in that case, the system installer should consider any potential effects on the customer installation. Combination of central NS protection (<math>U &gt;: 1,1 U_n</math>) and integrated NS protection (<math>U &gt;: 1,1 U_n</math> to <math>1,15 U_n</math>) is recommended, if the voltage drop in the house installation cannot be neglected. This is typically the case with longer connection lines.</p> <p><sup>c</sup> For the protection of the power generation unit, disconnection may also be realised by means of an additional self-protection setting value (e. g. <math>0,83 U_n</math>) before the setting value of <math>0,8 U_n</math> is reached.</p> <p><sup>d</sup> Where the medium-voltage network of the network operator upstream of the power generation system is operated with automatic reclosing (AWE, de: automatische Wiedereinschaltung), the following protective settings are recommended: <math>U &lt;&lt;</math>-Relay: <math>0,45 U_{NS}</math>, undelayed (i. e. shortest possible time delay) and <math>U &lt;</math>-Relay: <math>0,8 U_{NS}</math>, 300 ms. The requirement is specified by the network operator.</p>	Protective function	Setting values for protection relays <sup>a</sup>						Stirling generators, fuel cells		Directly coupled synchronous and asynchronous generators with $P_n > 50$ kW		Inverter(s)			Synchronous and asynchronous generators with $P_n \leq 50$ kW coupled directly or via inverters						Rise-in-voltage protection $U >>$	$1,15 U_n$	$\leq 100$ ms	$1,25 U_n$	$\leq 100$ ms	$1,25 U_n$	$\leq 100$ ms	Rise-in-voltage protection $U >$	$1,10 U_n^b$	$\leq 100$ ms	$1,10 U_n^b$	$\leq 100$ ms	$1,10 U_n^b$	$\leq 100$ ms	Voltage drop protection $U <$	$0,8 U_n^c$	$\leq 100$ ms	$0,8 U_n$	$1,0$ s <sup>d</sup>	$0,8 U_n$	$3,0$ s	Voltage drop protection $U <$	Not applicable		$0,45 U_n$	$300$ ms <sup>d</sup>	$0,45 U_n$	$300$ ms	Frequency decrease protection $f <$	$47,5$ Hz	$\leq 100$ ms	$47,5$ Hz	$\leq 100$ ms	$47,5$ Hz	$\leq 100$ ms	Frequency increase protection $f >$	$51,5$ Hz	$\leq 100$ ms	$51,5$ Hz	$\leq 100$ ms	$51,5$ Hz	$\leq 100$ ms		P
Protective function	Setting values for protection relays <sup>a</sup>																																																																
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Frequency increase protection $f >$	$51,5$ Hz	$\leq 100$ ms	$51,5$ Hz	$\leq 100$ ms	$51,5$ Hz	$\leq 100$ ms																																																											
	If only integrated NS protection is used for power generation systems $\leq 30$ kVA, the value of the rise-in-voltage protection $U >$ of $1.1 U_n$ must not be changed.		P																																																														
	The permissible tolerance between setting value and trigger value is for the voltage maximum $\pm 1\% U_n$ and for the frequency maximum $\pm 0.1\% f_n$ .		P																																																														
	The conditions for connection/re-connection of the power generation system are described in 8.3.		P																																																														
6.5.3	Islanding detection		P																																																														

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	<p>For power generation systems, islanding detection shall be carried out using one of the following methods:</p> <p>a) Active method, e.g. by means of a frequency shift method (generally for PV systems); or a combination of active and passive methods, whereby for instance the RoCoF method can be used as the passive method; NOTE 1 For the RoCoF method, a setting value of 2 Hz/s with a minimum measurement period of 0.5 s is recommended in order to avoid jeopardising the system stability.</p> <p>b) Passive method by means of the three-phase voltage monitoring (possible only for power generation units without inverters or for single-phase power generation units with inverters). NOTE 2 Three-phase voltage monitoring is also permissible for structural integration of several single-phase power generation units feeding into different line conductors provided the currents of those power generation units are regulated independently of each other such as to allow the development of arbitrary phase relationships.</p>		P
	Method a) shall be verified by means of a resonant circuit test in accordance with DIN EN 62116 (VDE 0126-2), whereas method b) is already implemented by means of the rise-in-voltage protection and the voltage drop protection of the NS protection.	(See appended table)	P
	The islanding detection is implemented in either the central or the integrated NS protection of the power generation unit. If an islanding detection system acting on the integrated interface switch is integrated in all power generation units of a power generation system, then the islanding detection in the central NS protection may be omitted irrespective of the system power.		P
	Detection of an island network and disconnection of the power generation system by means of the interface switch shall be completed within 2 s. Since the execution of dynamic network stability and the subsequent increase of the active power feed-in has a higher priority than the islanding detection, the latter may be deactivated for the duration of dynamic network stability. If the islanding detection remains active, it shall not undermine the dynamic network stability and the subsequent increase of the active power feed-in.		P
	Islanding detection and the resulting disconnection of the power generation system shall be completed within 9 s.		P
<b>6.6</b>	<b>Further requirements for generation systems</b>		Info.
6.6.1	Ability to provide primary control power		Info.
	Power generation systems connected to low-voltage networks are not subject to any requirements regarding the provision of primary control power. Where it is intended that power generation systems connected to low voltage networks contribute to the primary control, they shall meet the requirements specified in VDE-AR-N 4120, 10.5.3.		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
6.6.2	Ability to provide the secondary control power and tertiary control		Info.
	The power generation systems connected to low-voltage networks are not required to provide secondary control power and minute reserve. If power generation systems with connection to low-voltage networks wish to participate in the secondary control power and/or the minute reserve, they must meet the requirements of VDE-AR-N 4120, 10.5.4.		Info.
<b>7</b>	<b>METERING FOR BILLING PURPOSES</b>		N/A
	Installation and operation of the measuring device required in business transactions with an energy supplier or the network operator for the billing of purchased or generated energy is affected in accordance with MsbG, VDE-AR-N 4400, VDE-AR-N 4100 and the technical connection conditions of the network operator.	It's depended on energy supplier or the network operator and the tested units not with this function.	N/A
	The meter section shall be marked permanently and legibly with the label "power generation system".		N/A
<b>8</b>	<b>OPERATION OF THE SYSTEM</b>		P
<b>8.1</b>	<b>General</b>		P
	The systems and settings for the protection of a customer installation against internal electrical faults (self-protection), network protection, as well as regulations for system operation are to be designed in such way that the ability of the system to meet the requirements described in this application guide is not conceptually restricted.		P
	During operation of the customer installation, network situations may occur in which the requirements of this application guide cannot be fulfilled simultaneously without contradiction. In these situations, the following prioritisation applies to the tasks and modes of operation of self-protection, network protection and operational control functions (in descending order): 1) avoidance or limitation of any damage to systems and equipment, in particular, at overload and short-circuit protection; 2) compliance with the requirements for dynamic network stability according to 5.7.3; 3) specifications by the network security management of the network operator according to 5.7.4.2; 4) compliance with the requirements for $P_{AV,E}$ monitoring according to 5.5.2; 5) compliance with the requirements for the reaction to over-frequency and under-frequency according to 5.7.4.3; 6) compliance with the requirements for the reactive power operating mode for steady-state voltage stability according to 5.7.2.2; 7) frequency control (control power) according to 6.6.1 and 6.6.2.		P
	The prioritisation does not restrict the requirements for the design of the system and its protective devices.		P
	The requirements of lower priority are to be implemented unless in conflict with the requirements of higher priority.		P
	The requirements by the network security management of the distribution network operator in accordance with 5.7.4.2 take precedence over the requirements for power increase in the event of under-frequency in accordance with 5.7.4.3. The distribution network operators shall comply with the following conditions: – The network bottlenecks must be monitored promptly by the distribution network operator and must not have been forecast based on projections – the precedence shall apply to the bottleneck area only.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The operation of electrical installations shall include all technical and organisational activities necessary to ensure that installations are functional and safe. The activities include all operating actions as well as electro-technical and non-electrical work as described in the relevant regulations and rules. Special reference is made to DIN VDE 0105-100 (VDE 105-100).		Info.
	The system operator is responsible for the operation of the power generation system and/or storage system. If required by the network operator, the system operator will name an electrician for the network operator who may carry out the necessary work on the electrical system of the system operator.		Info.
	For the connection of the power generation system as well as the storage system the conditions according to 8.3 have to be observed. During operation, the conditions according to Section 5, on which the decisions regarding the connection of the power generation system and/or the storage system are based, may only be changed with the consent of the network operator.		P
	The result shall be recorded in a test protocol which shall be provided on request to the network operator		P
	When using certified NS protective devices, regular maintenance testing of the NS protection, the interface switch and the functional chain "NS protection – interface switch" is not required.		Info.
	In justified cases, the network operator may demand a test of the NS protection and the interface switch to prove their functionality.		Info.
	<b>Power reduction or disconnection required due to network conditions</b>		Info.
	Upon request of the network operator, the system operator is obliged to switch off the power generation system and/or the storage unit and to disconnect it from the network if required for conducting works in the network operator's network that are necessary for operational purposes. Scheduled disconnections shall be announced to the system operator in a timely and suitable manner.		Info.
	In case of danger, breakdown or imminent loss of network security, the network operator is entitled to immediately disconnect the power generation system and/or the storage unit from the network or to reduce its active power output, respectively.		Info.
	If the agreed maximum connection power is exceeded, the network operator is entitled to disconnect the power generation system and/or the storage system from the network. For this purpose, the network operator may require the system operator to install appropriate technical equipment that disconnects the power generation system and/or the storage system from the network operator's network if certain limit values (e.g. maximum apparent connection power) are exceeded (see 5.5.2).		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	If the network operator detects serious defects in the power generation system or the storage system with regard to personal and system safety, he is entitled to disconnect these system components from the network or to demand disconnection from the network by the system operator until the defects have been rectified.		Info.
	<b>Access</b>		Info.
	Upon co-ordination with the system operator, the network operator shall be granted access to all components of the power generation system and/or storage system (meter panel, central NS protection (if available), interface switch, facilities of the power generation/network security management (if available), and the power generation units).		Info.
	<b>Exchange of information</b>		Info.
	The network operator will inform the system operator about substantial modifications in his network which will have an impact on the current parallel operation. The system operator shall, in due time, co-ordinate with the network operator any scheduled modifications to his power generation system as well to his storage system which will have an impact on the parallel operation or the decoupling protection or NS protection, such as increase or decrease of the system power, replacement of protective devices or modifications to the compensation equipment.		Info.
	<b>Coupling of network connection points</b>		Info.
	Different network connection points on the network of the network operator(s) shall not be operated by systems of one or more system operator(s).		Info.
	<b>Reaction to disturbances</b>		Info.
	The reconnection conditions given in 8.3 shall be satisfied.		Info.
	The system operator shall immediately inform the network operator about any incidents detected as far as they are of importance to the network operator.		Info.
	Due to the possibility of voltage recovery at any time after an interruption of supply, the network connection point is to be considered to be constantly energised. Reconnection is usually carried out by the network operator without prior consultation with the system operator.		Info.
	Fault clearance may require unscheduled investigations and measurements which the network operator and the system operator shall carry out on their respective operating equipment. For fault clearance and remedy, the network operator and the system operator shall provide mutual support. All information required for fault clearance shall be exchanged between them.		Info.
<b>8.2</b>	<b>Special aspects of the management of the network operator's network</b>		Info.
	<b>Earthing and short-circuiting for works on the network</b>		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	After isolation, a prerequisite for the safety of works on the network is to prevent any voltage sources and - as working methods in accordance with DIN VDE 0105-100 (VDE 0105-100) - from reconnecting unintentionally. Earthing and short-circuiting are required upstream as well as downstream of the point where the work is done. For this, sufficiently dimensioned house connection boxes should also be used.		Info.
	This means that network operators are required to consistently apply all five of the safety rules when works are carried out on the low-voltage network (with the exception of live working). It is therefore required also to provide earthing and short-circuiting downstream of a disconnected line in the network operator's low-voltage network (when viewed from the local network transformer, i.e. on the customer side of the sectioning point). If earthing and short-circuiting are not provided on the customer side of the sectioning point, then third-party feed-in (e.g. via an emergency power generator as used in farming) shall be prevented by other means.		Info.
	It should also be noted that an NA protective device integrated in the power generation unit or in a storage system can obtain its supply voltage from the network. Connection to the network is also required for voltage and frequency measurement. Furthermore, passive elements (e.g. EMC filters) can be mounted unconnected on the network side of the interface switch. When determining zero potential within the scope of the five safety regulations (according to DIN VDE 0105-100 (VDE 0105-100)), it must be noted that in systems with capacitors, the discharge must be waited for before determining the zero potential. For stationary capacitors, the discharge times can be taken from the relevant standards (10 min to < 75 V residual voltage or separate labelling of the discharge time on the system).		Info.
	<b>Operation of network stand-by systems</b>		Info.
	For certain works on the network (e.g. replacement of a local network transformer), the network operator has to disconnect sub-networks from the remaining network. In order to ensure continuous supply to the customers during this time, the network operator may use network stand-by systems. Normally, the network operator will not inform the customers concerned about the use and operation of network stand-by systems		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	<p>However, if the feed-in power of the power generation systems and storage systems exceeds the load extraction in this separated sub-network, it is possible for the network stand-by system to be disconnected by the protection system. Stable operation of the network stand-by system would then no longer be possible. In order to prevent this from happening, care shall be taken that the power generation systems and storage systems (regardless of extraction or feed-in) are and remain disconnected in the event of such an operating state or that in case of an emergency power operation of the customer installation it is disconnected from the public network at the network connection point. To this end, the network stand-by system is connected and started in parallel to the low-voltage network. Afterwards, the local network transformer is switched off and the network stand-by system takes over the supply of the "network island". The network stand-by system shall be set to 51.7 Hz to 52.0 Hz, so that all power generation systems and storage systems can safely disconnect from the network. Given that operating mode, all power generation systems and storage systems will remain separated from the network operator's network (prior to this VDE application guide VDE-AR-N 4105:2011-08 between 50.05 Hz and 51.5 Hz, starting with the application of this VDE application guide VDE-AR-N 4105:2011-08 between 50.05 Hz and 50.1 Hz/60 s; see 8.3).</p>		Info.
	<p>In order to enable uninterrupted resynchronisation of the sub-network with the rest of the network, the frequency is realigned to the current mains frequency once operation of the network stand-by system is ended and the local network transformer is returned to service. In order to prevent the power generation systems and storage systems from immediately switching on again as soon as the frequency returns to within the tolerance range specified by the connection and reconnection conditions given in 8.3, which would, at that time, put the stability of the network operation at risk, it is required to ensure a waiting period of at least 60 seconds after a shutdown time of the power generation systems and storage systems of more than 3 s.</p>		Info.
	<p>For uninterrupted supply of the network – in particular, when the network stand-by system connects at a moment of a power surplus in the low-voltage network – it is recommended to use network stand-by systems that are able to reverse power on a short-term basis.</p>		Info.
<b>8.3</b>	<b>Connection conditions and synchronisation</b>		P
8.3.1	General		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Power generation systems and storage systems may only be connected to the network of the network operator if a suitable device determines that both the network voltage is within the tolerance range of 85% $U_n$ to 110% $U_n$ and the mains frequency is within the tolerance range of 47.5 Hz to 50.1 Hz for a duration of at least 60 s. In addition, the delay times when a generator is switched on again and the staggered times when several generators are switched on must be long enough to ensure that all control and compensation processes within the power generation system and/or the storage systems are safely completed due to the switch-on.		P
	In case of reconnection of power generation systems and storage systems to the network of the network operator when the NA protective device or the $P_{AV,E}$ monitoring is triggered, the active power of controllable power generation systems and storage systems delivered to the network of the network operator must not exceed the gradient of 10% of the active power $P_{Amax}$ per minute. Non-controllable power generation systems and storage systems can be switched on after 1 min to 10 min (random generator) or later. Therefore, after 10 min the power can be fed in with $P_{Amax}$ . In the case of manual operation on site (e.g. for reasons of commissioning or maintenance), the reconnection conditions described in this paragraph may be deviated from.		P
	In the event of manual disconnection of the power generation system and/or storage system by the network operator, the system operator shall coordinate the reconnection with the network operator's unit responsible for network operation.		P
8.3.2	Connection of synchronous generators		N/A
	At an adequate point, a synchronisation device shall be provided for synchronous generators coupled directly to the network. While the synchronisation equipment for power generation systems that are not capable of island operation is expediently assigned to the generator switch, power generation systems capable of island operation should additionally be provided with synchronisation equipment at the interface switch. An automatic parallel connection device shall be provided. The setting values shall be coordinated with the network operator.	Not synchronous generators.	N/A
	The following common maximum values can be assumed: - $\Delta\varphi = \pm 10^\circ$ ; - $\Delta f = \pm 500$ mHz; - $\Delta U = \pm 10\%$ $U_n$ .		N/A
	Depending on the ratio of network short-circuit power to generator power it may be necessary to establish narrower limits to avoid inadmissible system reactions at the moment of connection.		N/A
8.3.3	Connection of asynchronous generators		N/A
	For asynchronous generators started by a prime mover and connected at a rotational speed between 95% and 105% of the synchronous rotational speed, $k_{imax}$ is expected to be = 4.	Not asynchronous generators.	N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For asynchronous generators, which are not connected dead, the connection conditions specified for synchronous generators shall be satisfied		N/A
8.3.4	Connection of power generation units with inverters		P
	Power generation units with inverters (e.g. photovoltaic systems) shall only be connected with $k_{i\max} \leq 1.2$ .		P
<b>8.4</b>	<b>Special features in the planning, installation and operation of power generation systems and storages systems with <math>P_{A\max} \geq 135</math> kW each</b>		N/A
	For power generation systems and storage units with an active power each of $P_{A\max} \geq 135$ kW, compliance with the requirements of VDE-AR-N 4110 shall be demonstrated. For the planning, installation and operation of such power generation systems and storage units certified in accordance with VDE-AR-N 4110 and connected to a low-voltage network of the network operator, the following requirements shall be met:		N/A
	– Network interactions: The test report for the unit certificate according to VDE-AR-N 4110 shows the network interactions with their measured values. These must be evaluated by the network operator according to VDE-AR-N 4100, 5.4.		N/A
	– Protection settings: The central NS protection must be parameterised according to the specifications in Table 2 in 6.5.2 of this VDE application guide. If integrated NS protection is still present in the power generation units, it must not compromise the requirements regarding static voltage stability and dynamic network support from this application guide. A setting of the rise-in-voltage protection $U >$ to values $> 1.10 U_n$ is only permissible to the extent that it corresponds to the capability of the power generation system and/or storage system. The exceptions according to 6.1 remain valid.		N/A
	– Steady-state voltage stability: <ul style="list-style-type: none"> <li>• When selecting the operating mode “reactive power characteristic curve <math>Q(U)</math>”, it shall be parametrised as specified in Figure 7 in 5.7.2.4 of this VDE application guide (e. g. by applying the method “reactive power with voltage limiting function” according to VDE-AR-N 4110). For this purpose, <math>Q_{\max} = P_{E\max} \times 0,33</math> (equal to <math>\cos \varphi = 0,95</math>) shall be set.</li> <li>• When selecting the operating mode “displacement factor/active power characteristic curve <math>\cos \varphi (P)</math>” according to this application guide, the method “reactive power/active power characteristic curve <math>Q(P)</math>” according to VDE-AR-N 4110 shall be selected. For this purpose, the following support points shall be parametrised in accordance with VDE-AR-N 4110, Figure 9: P1 (0,0/0,0), P2 (– 0,5/0,0), P3 (– 1,0/0,33).</li> </ul> <p>NOTE 1 The first value within the brackets represents the ratio <math>P/P_{E\max}</math>, the second represents the ratio <math>Q/P_{E\max}</math>.</p>		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	<ul style="list-style-type: none"> <li>– For the dynamic network stability, type 2 power generation systems shall be set to the operating mode “limited dynamic network stability” in accordance with VDE-AR-N 4110, 10.2.3.3.2.</li> </ul> <p>NOTE 2 From 01/01/2021 onwards at the latest, type 2 power generation units in the operating mode “limited dynamic network stability” will also conduct full dynamic network stability at voltages higher than 0,7 Un.</p>		N/A
	<ul style="list-style-type: none"> <li>– Connection condition: The connection of a power generation system or storage unit in accordance with VDE-AR-N 4110 is conducted at an operating voltage between 90 % Un and 110 % Un at the generator terminals of the power generation unit with the permissible power gradients as specified in VDE-AR-N 4110.</li> </ul>		N/A
<b>9</b>	<b>VERIFICATION OF THE ELECTRICAL PROPERTIES</b>		<b>P</b>
	This VDE application guide does not itself require certificates and/or proofs of conformity, but only provides the proofs required in NC RfG and NELEV [8] (see Preface, Section 4).		Info.
	<p>Together with the registration for the network connection, the connection owner hands over the cover pages of the following certificates to the network operator:</p> <ul style="list-style-type: none"> <li>– Certificate for each planned type of power generation unit and storage system (unit certificate(s), see form E.4);</li> <li>– Certificate for network and system protection (integrated or central) (certificate for NS protection, see form E.6);</li> <li>– If required in the respective connection case: Certificate for power flow monitoring at the network connection point (<math>P_{AV,E}</math> monitoring, 70% limitation according to 5.7.4.2, symmetry device according to VDE-AR-N 4100, 5.5).</li> </ul>		P
	In the test reports for the certificates, the electrical properties of the power generation unit, the storage system and/or the NS protection are shown. In an excerpt from the test reports (according to E.5 and E.7) the data relevant for the connection evaluation by the network operator shall be summarized.		P
	The certificates themselves prove that the planned power generation unit, storage system and/or NS protection meets all the requirements of this VDE application guide.		P
	The basis for the preparation of a unit certificate is the measurement by a test laboratory accredited according to DIN EN ISO/IEC 17025 for this area of application.		P
	The certification of power generation units, storage systems and NS protection must be carried out by a certification body accredited according to DIN EN ISO/IEC 17065 for this area of application.		P
	Details regarding the design of the metrological verification and the documentation of the measurement results are described in DIN VDE-V 0124-100 (VDE V 0124-100). The requirements of this VDE application guide must neither be compromised nor toughened.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
<b>ANNEX A</b>	<b>EXPLANATIONS (INFORMATIVE)</b>		Info.
A.1	“Power generation system” (3.1.8) and “power generation unit” (3.1.9)		Info.
A.2	Permissible voltage change (5.3)		Info.
A.3	Implementation of the power generation system/network and system protection (NS protection) (6.1)		Info.
A.4	Three-phase current and three-phase voltage system (5.6)		Info.
A.5	Static voltage stability/binary power supply (5.7.2)		Info.
A.6	Interface switch (6.4)		Info.
A.7	Basic controller performance		Info.
A.8	Direction definition of P and Q		Info.
<b>ANNEX B</b>	<b>CONNECTION EXAMPLES AND MEASUREMENT STRATEGIES (INFORMATIVE)</b>		Info.
B.1	Maximum apparent connection power $S_{Amax} \leq 4.6$ kVA		Info.
B.2	Maximum apparent connection power $S_{Amax} \leq 13.8$ kVA		Info.
B.3	Power generation system with symmetry device of single-phase inverter and integrated NS protection		Info.
B.4	Apparent connection power $S_{Amax} > 30$ kVA		Info.
B.5	Apparent connection power $S_{Amax} > 30$ kVA with $P_{AV,E}$ - monitoring		Info.
B.6	New power generation unit in parallel to an existing system $S_{Amax} > 30$ kVA		Info.
B.7	Connection for excess feed-in (EEG and CHP-G)		Info.
B.8	Apparent connection power $S_{Amax} > 30$ kVA with full feed-in		Info.
B.9	PV system $S_{Amax} = 6$ kVA with storage system $P_{Emax} = 3$ kW and symmetry device		Info.
B.10	Connection with meter port column		Info.
B.11	Example circuit diagram PV system with storage system in consumer load path		Info.
<b>ANNEX C</b>	<b>EXAMPLES OF METER PANEL CONFIGURATIONS (INFORMATIVE)</b>		Info.
C.1	Meter panel for the connection of a power generation system with a maximum apparent connection power of $S_{Amax} \leq 30$ kVA		Info.
C.2	Meter panel for connecting a power generation system with an apparent connection power $S_{Amax} > 30$ kVA and central NS protection		Info.
C.3	Meter panel for connecting a power generation system with transformer measurement		Info.
C.4	Meter panel (can also be configured decentrally) for the connection of a power generation system in self-consumption and/or excess feed-in according to EEG and CHP-G $\leq 30$ kVA		Info.
C.5	Generation meters in the power generation system		Info.
<b>ANNEX D</b>	<b>EXAMPLE CONNECTION EVALUATION OF POWER GENERATION SYSTEMS – CONNECTION OF A 20 KW PV SYSTEM (INFORMATIVE)</b>		Info.
<b>ANNEX E</b>	<b>FORMS (NORMATIVE)</b>		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
E.1	Application procedure		Info.
E.2	Data sheet for power generation systems		Info.
E.3	Data sheet for storage units		Info.
E.4	Unit certificate		P
E.5	Test report "Network interactions" for power generation units with an input current > 75 A		P
E.6	Certificate of the network and system protection		P
E.7	Requirements for the test report for the NS protection		P
E.8	Commissioning protocol for power generation systems and/or storage units		Info.
E.9	Type approval procedure		Info.

DIN VDE V 0124-100															
Clause	Requirement - Test	Result - Remark	Verdict												
<b>4</b>	<b>REQUIREMENTS FOR MEASURING INSTRUMENTS AND TEST BENCHES</b>		P												
<b>4.1</b>	<b>General</b>		P												
	This section specifies general requirements for measurements and measuring devices. Different test specific requirements can be found in the individual sections of the respective tests.		P												
<b>4.2</b>	<b>Measurement</b>		P												
	At least the line currents (L1 and, if present, L2 and L3) and all phase-to-neutral voltages and, if available, phase-to-phase voltages are to be regarded as measurement.		P												
<b>4.3</b>	<b>Measuring devices used</b>		P												
	The metrological traceability of the measuring devices used must be ensured in accordance with the specifications in DIN EN ISO/IEC 17025.		P												
	The following requirements in Table 1 apply to the sampling rates of measurements. Table 1 - Requirements applicable to the sampling rates of measurements		P												
	<table border="1"> <thead> <tr> <th>Measurement</th> <th>Sampling rate current/voltage</th> <th>Sampling rate additional signals</th> </tr> </thead> <tbody> <tr> <td>Behaviour in the event of grid faults</td> <td>≥10 kHz</td> <td>≥1 Hz</td> </tr> <tr> <td>Harmonics</td> <td>≥20 kHz</td> <td>≥1 Hz</td> </tr> <tr> <td>Other measurements</td> <td>≥3 kHz</td> <td>≥1 Hz</td> </tr> </tbody> </table>	Measurement	Sampling rate current/voltage	Sampling rate additional signals	Behaviour in the event of grid faults	≥10 kHz	≥1 Hz	Harmonics	≥20 kHz	≥1 Hz	Other measurements	≥3 kHz	≥1 Hz		
Measurement	Sampling rate current/voltage	Sampling rate additional signals													
Behaviour in the event of grid faults	≥10 kHz	≥1 Hz													
Harmonics	≥20 kHz	≥1 Hz													
Other measurements	≥3 kHz	≥1 Hz													
<b>4.4</b>	<b>Measurement conditions</b>		P												
	In order to ensure comparable measurement results, on the one hand, and to prevent unfavourable conditions of the surrounding electrical grid from falsifying the results of the device under test (DUT), on the other hand, the following conditions must be checked and observed during the measurement:		P												
	– A specification of $\cos \varphi = 1 (\pm 0.05)$ must be set for all measurements in which no explicit reactive power value is required.		P												
	– The limits of the IEC 61000-4-30 procedure must be adhered to in laboratory measurements provided VDE-AR-N 4105:2018-11 does not impose any different requirements.		P												
	– The field measurements must be based on the limits of the IEC 61000-4-30 procedure. Any deviations must be documented and evaluated in terms of their influence on the measurement results.		P												
<b>5</b>	<b>TESTS</b>		P												
<b>5.1</b>	<b>General</b>		P												
	With full power converter based PGU and a sufficiently realistic simulation of the electrical energy source or storage system, measurements may only be carried out for the converter and the relevant components.		P												
<b>5.2</b>	<b>Demonstration of permissible system perturbations</b>		P												
	This section serves to demonstrate the requirements in VDE-AR-N 4105:2018-11, 5.4. It refers to VDE-AR-N 4100:2019-04, 5.4 with regard to system perturbations.		P												
<b>5.2.1</b>	<b>General</b>		P												
	For the purpose of this document according to VDE-AR-N 4100:2019-04, 5.4, system perturbations are as follows:		P												

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	– Rapid voltage changes;		P
	– Flicker;		P
	– Harmonics, interharmonics and high-harmonics(higher frequencies from 2 kHz to 9 kHz);		P
	– Commutation notches;		N/A
	– Infeed of direct currents.		P
5.2.2	Rapid voltage changes		P
	These tests serve to comply with the requirements of VDE-AR-N 4100:2019-04, 5.4.		P
5.2.2.1	Tests		P
	a) Power generation units and storage systems (individual devices) with rated current $\leq 75$ A: According to VDE-AR-N 4100:2019-04, 5.4.2.1, the following standards must be used for verification: – DIN EN 61000-3-3 (VDE 0838-3) for devices with a rated current $\leq 16$ A – DIN EN 61000-3-11(VDE 0838-11) for devices with a rated current $>16$ A and $\leq 75$ A		P
	b) Power generation units and storage systems (individual devices) with rated current $>75$ A: The following measurements must be carried out according to VDE-AR-N 4100:2019-04, 5.4.4.2: – Measurements of the time profiles for currents and phase-to-neutral voltages; – Determination of the one-period r.m.s. values for current and voltage. The aim of the tests is to determine $k_i$ and $k_{imax}$ .		P
	The four following cases (if applicable) according to VDE-AR-N 4105:2018-11, E.5 must be checked three times each: – Switching on at any power (without specification for the primary energy source); – Most unfavourable case when switching the generator stages; – Switching on at nominal power; – Switching off at rated power (no emergency shutdown, but operational shutdown). NOTE: In PV systems, the inverter is considered a generator.		P
	If the manufacturer is aware of deviating critical cases (e.g. deviating $\cos(\varphi)$ ~ specifications), these must also be checked and identified.		P
5.2.2.2	Evaluation criteria		P
	The evaluation procedures, success criteria and permissible limits for power generation systems and storage systems are specified in VDE-AR-N 4100:2019-04, 5.4.		P
5.2.2.3	Test documentation	(see appended table)	P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	a) Power generation units and storage systems (individual devices) with rated current $\leq 75$ A: Test results must be documented in accordance with the requirements of DIN EN 61000-3-3 (VDE 0838-3):2014-03 or DIN EN 61000-3-11 (VDE 0838-11):2001-04.		P
	b) Power generation units and storage systems (individual devices) with rated current $> 75$ A: At least the following should be documented: 1) Measuring devices used; 2) Mains frequency; 3) One-period r.m.s. values for current and voltage; 4) All $k_i$ values; 5) $k_{i\max}$ value		P
5.2.3	Flicker		P
	These tests serve to comply with the requirements of VDE-AR-N 4100:2019-04.		P
5.2.3.1	Tests		P
	a) Power generation units and storage systems (individual devices) with rated current $\leq 75$ A: According to VDE-AR-N 4100:2019-04, 5.4.2.1, the following standards must be used for verification: – DIN EN 61000-3-3 (VDE 0838-3) for devices with a rated current $\leq 16$ A – DIN EN 61000-3-11(VDE 0838-11) for devices with a rated current $> 16$ A and $\leq 75$ A		P
	b) Power generation units and storage systems (individual devices) with rated current $> 75$ A: The aim of the test is to determine the system flicker coefficient at the grid impedance angles $30^\circ$ , $50^\circ$ , $70^\circ$ and $85^\circ$ . The system flicker coefficient $c_{\text{flk}}$ is determined for failure-free continuous operation. It must be standardized to the rated apparent power. For three-phase DUTs, short-circuit apparent power $S_k$ must be related to a symmetrical short-circuit of the test source; in the case of single-phase DUTs, it must be related to the single-phase short-circuit power. For adjustable PGUs with rated currents $> 75$ A, at least 12 measurements of 10 min each must be carried out. One measurement must be carried out for each of the 10% active power bins from 0% $P_{rE}$ to 90% $P_{rE}$ and three measurements for the 10% active power bin of 100% $P_{rE}$ . A measurement consists of determining the short-term flicker strength $P_{st}$ as a 3-phase (phase L1, L2 and L3). A 3-phase must be determined for the adjustable operating points and $P_{E\max}$ for non-adjustable and conditionally adjustable PGUs. The maximum over all $P_{st}$ must be selected as the value for the long-term flicker strength $P_{lt}$ .		P
5.2.3.3	Test Documentation	(see appended table)	P
	The following should be documented:		P

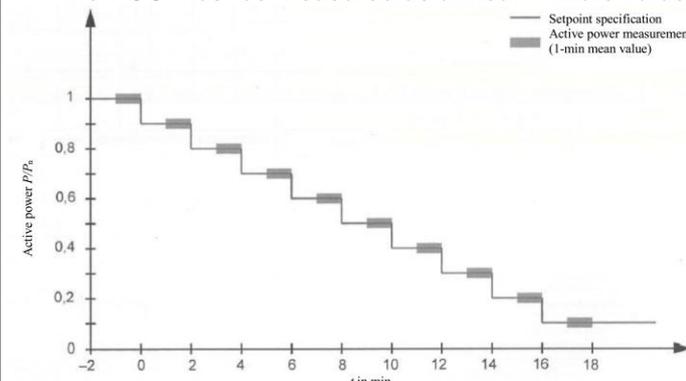
DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	1) Measuring devices used; 2) Output voltage of the line impedance stabilization grid; 3) Reference impedance/test impedance; 4) The largest $C_{\psi k}$ value determined; 5) $P_{st}$ , $P_{It}$ .		P
5.2.4	Harmonics and inter-harmonics		P
	These tests serve to comply with the requirements of VDE-AR-N 4100:2019-04, 5.4.		P
	The aim of the test is to determine the harmonic, inter-harmonic and high frequency harmonic currents (between 2 kHz and 9 kHz).		P
5.2.4.1	Tests		P
	Compliance with the limits for harmonic currents must be demonstrated as follows:		P
	a) Power generation units and storage systems (individual devices) with rated current $\leq 75$ A: For individual devices with rated current $\leq 16$ A per phase, according to DIN EN 61000-3-2 (VDE 0838-2):2019-12; For individual devices with rated current $> 16$ A and $\leq 75$ A per phase, according to DIN EN 61000-3-12 (VDE 0838-12):2012-06.	(see appended table)	P
	b) Power generation units and storage systems (individual devices) with rated current $> 75$ A: Power generation units and storage systems (individual devices) with rated current $\leq 75$ A must be evaluated according to VDE AR-N 4100:2019-04, 5.4.2.2.2, Table 1. Harmonic currents must be measured according to DIN EN 61000-4-7 (VDE 0847-4-7):2009-12. Inter-harmonic currents up to 2 kHz must be measured according to DIN EN 61000-4-7 (VDE 0847-4-7):2009-12, Appendix A. High frequency between 2 kHz and 9 kHz must be measured according to DIN EN 61000-4-7 (VDE 0847-4-7):2009-12, Appendix B. Optionally, the tests can be carried out in the open field according to DIN EN 61400-21-1 (VDE 0127-21-1) if tests in the test laboratory are not possible or feasible. Harmonic, inter-harmonics and high frequency currents are determined for each 10% active power bin. This means that the centres of the bins are close to 0% $P_{rE}$ , 10% $P_{rE}$ , 20% $P_{rE}$ to 100% $P_{rE}$ of the PGU.	(see appended table)	P
5.2.4.2	Evaluation criteria		P
	The evaluation procedures, success criteria and permissible limits for power generation systems and storage systems are specified in VDE-AR-N 4100:2019-04, 5.4.		P
5.2.4.3	Test documentation	(see appended table)	P
	At least the following should be documented:		P
	1) Measuring devices used;		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	2) Additionally: <ul style="list-style-type: none"> <li>– Reference or grid impedance;</li> <li>– For each active power bin: the values of the individual current components in tables according to VDE-AR-N 4105:2018-11, E.5 as percentages of <math>I_r</math>;</li> <li>– For each active power bin: the values of the individual current components for each phase of the harmonic subgroup according to DIN EN 61000-4-7 (VDE 0847-4-7):2009-12, 5.6, the interharmonic group according to DIN EN 61000-4-7 (VDE 0847-4-7):2009-12, Appendix A, the frequency bands in the range above the 40th harmonic up to 9 kHz according to DIN EN 61000-4-7 (VDE 0847-4-7):2009-12, Appendix B.</li> </ul>		P
5.2.5	Commutation notches		N/A
	This test serves to determine the commutation currents required for the project-specific determination and evaluation of the commutation notches according to VDE-AR-N 4100:2019-04, 5.4.4.5, taking into account the short-circuit power at the connection point. This test is only required for line-commutated inverters.		N/A
5.2.5.1	Tests		N/A
	The PGU is operated at all of the following operating points, whereby three oscillograms of the grid currents are recorded for each operating point after the settling process has subsided. The resolution of the oscillograms must be at least 10 kHz, the record length per oscillogram must be at least 100 ms. Operating points: I) between 25% $P_{E_{max}}$ and 35% $P_{E_{max}}$ II) between 65% $P_{E_{max}}$ and 75% $P_{E_{max}}$ III) > 90% $P_{E_{max}}$		N/A
5.2.5.2	Evaluation criteria		N/A
	The evaluation procedures, success criteria and permissible limits for power generation systems and storage systems are specified in VDE-AR-N 4100:2019-04, 5.4.		N/A
5.2.5.3	Test documentation		N/A
	The maximum commutation current is determined for each operating point from the oscillograms. The maximum commutation current is specified.		N/A
5.2.6	Infeed of direct currents		P
	These tests serve to comply with the requirements of VDE-AR-N 4100:2019-04, 5.4.4.9.		P
	The aim of the test is to prove that no impermissible direct current components are fed into the low-voltage grid.		P
	This test is only required for inverters.		P
5.2.6.1	Tests		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	The converter is operated within the control range of the PGU at the following operating points, with the direct current components of the grid currents being recorded in all individual lines for each operating point after reaching a stable operating temperature for at least 5 minutes. According to VDE-AR-N 4100:2019-04, direct currents are measured on the basis of DIN EN 61000-4-7 (VDE 0847-4-7):2009-12 over 10 fundamental oscillation periods. Operating points: I) between 30% $S_{E_{max}}$ and 40% $S_{E_{max}}$ II) between 60% $S_{E_{max}}$ and 70% $S_{E_{max}}$ III) > 95% $S_{E_{max}}$	(see appended table)	P
	The low-voltage grid or network simulator on which these tests are carried out must meet the following conditions: I) Mains voltage: Nominal value $\pm 5\%$ II) Mains frequency: 50 Hz $\pm 0.2$ Hz III) THD of the mains voltage: < 2.5% IV) When using power simulators: DC component of voltage < 0.1%		P
	In addition, during these tests it is important to ensure that the current sensors used are suitable for detecting direct currents. The fault limit of these current sensors must meet the requirements of 4.2.		P
5.2.6.2	Evaluation criteria		P
	The evaluation procedures, success criteria and permissible limits for generation plants and storage are described in VDE-AR-N 4100: 2019-04, 5.4.		P
5.2.6.3	Documentation of Tests		P
	At least the following should be documented: 1) Measuring devices used; 2) Statement that the limits specified in 5.2.6.1 regarding the voltage quality of the test grid were observed during the test; 3) Additionally for each operating point according to 5.2.6.1 – The mean r.m.s. value of the grid currents and grid voltages for each phase during the measurement period; – The average values of the individual DC components for each phase as percentages of $I_r$ .		P
<b>5.3</b>	<b>Demonstration of the symmetry behaviour of converters</b>		N/A
5.3.1	General		N/A
	These tests serve to comply with the requirements of VDE-AR-N 4100:2019-04, 5.5.		N/A
5.3.2	Testing three-phase converters	The PGU is single phase unit	N/A
	The test should be carried out under voltage conditions that are as symmetrical as possible and with symmetrical grid impedance.		N/A
	At least 5 measurements at nominal active power and 5 measurements at 50% of the nominal active power must be carried out over a period of 1 min each.		N/A

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	<p>These measurements must each be carried out with the following reactive power setting:</p> <ul style="list-style-type: none"> <li>– <math>\cos \varphi = 1</math>,</li> <li>– maximum under-excited,</li> <li>– maximum over-excited.</li> </ul> <p>The maximally overexcited or under excited <math>\cos \varphi</math> values result from the information provided by the manufacturer.</p>		N/A
5.3.2.1	Calculating the asymmetry of three-phase converters		N/A
	<p>The asymmetry is measured in the form of the unbalanced load and must be calculated for an operating point characterised by power and <math>\cos \varphi</math>. The maximum difference between the apparent powers of the three phases is determined for each of the 5 measurements (mean minute values) at the respective operating point. The maximum value is again determined from these 5 values. This maximum value must be given for the following operating points:</p>		N/A
	<ul style="list-style-type: none"> <li>a) 100% nominal power <math>\pm 5\% P_{E_{max}}</math>, <math>\cos \varphi = 1</math>;</li> <li>b) 100% nominal power + 5% <math>P_{E_{max}}</math>, <math>\cos \varphi =</math> maximally under-excited;</li> <li>c) 100% nominal power + 5% <math>P_{E_{max}}</math>, <math>\cos \varphi =</math> maximally overexcited;</li> <li>d) 50% nominal power <math>\pm 5\% P_{E_{max}}</math>, <math>\cos \varphi = 1</math>;</li> <li>e) 50% nominal power + 5% <math>P_{E_{max}}</math>, <math>\cos \varphi =</math> maximally under-excited;</li> <li>f) 50% nominal power <math>\pm 5\% P_{E_{max}}</math>, <math>\cos \varphi =</math> maximally overexcited.</li> </ul>		N/A
	<p>The test is considered to have been passed if the maximum value of the asymmetry from the above measurements a) to f) does not exceed 5% <math>S_{E_{max}}</math>.</p>		N/A
5.3.3	Symmetrical operation with a symmetry device		N/A
<b>5.4</b>	<b>Demonstration of behaviour of the power generation unit in the grid</b>		<b>P</b>
5.4.1	General		P
	<p>The tests in the following subsections are carried out in order to demonstrate the compliance with the requirements of VDE-AR-N 4105:2018-11 with regard to the active and reactive power range, active power reduction through setpoint specifications, frequency-dependent active power control as well as the reactive power provision for static voltage stability.</p>		P
	<p>Compliance with the RoCoF requirements from VDE-AR-N 4105:2018-11, 5.7.1, must be demonstrated on the basis of a manufacturer's declaration.</p>		P
5.4.2	Measuring active and reactive power range		P
5.4.2.1	General		P
	<p>These tests serve to meet the requirements for the adjustable reactive power range according to VDE-AR-N 4105:2018-11, 5.7.2.2, as well as to check the manufacturer's specifications for <math>S_{E_{max}}</math> and <math>P_{E_{max}}</math>.</p>		P
5.4.2.2	Tests		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	All tests must be carried out at the specified voltages. If test bench measurements are not possible, a technically based explanation must be provided.		P
	The PGU is operated at all of the following operating points, whereby each operating point must be held for at least 10 minutes after the settling process has subsided. During the partial measurements a) to c) below, the primary energy source must not limit the power. The voltage must be set with a tolerance of $\pm 2\%$ $U_n$ .		P
	<p>a) For <math>0.9 U_n</math>, <math>U_n</math>, and <math>1.09 U_n</math>, the highest possible active power must be set under the specification of <math>\cos(\varphi) = 1</math>.</p> <p>b) For <math>0.95 U_n</math>, <math>U_n</math>, and <math>1.09 U_n</math>, the highest possible active power must be set with max under excited operation.</p> <p>c) For <math>0.9 U_n</math>, <math>U_n</math>, and <math>1.05 U_n</math>, the highest possible active power must be set with max overexcited operation.</p> <p><math>S_{E_{max}}</math> and <math>P_{E_{max}}</math> are determined by the highest measured value:  <math>S_{E_{max}} = \max(S_{E_{max} a}), S_{E_{max} b}), S_{E_{max} c})</math>  <math>P_{E_{max}} = \max(P_{E_{max} a}), P_{E_{max} b}), P_{E_{max} c})</math></p> <p>Adjustment range limitations of reactive power provision according to VDE-AR-N 4105:2018-11, Table A.2, must be taken into account.</p>		P
5.4.2.3	Evaluation criteria		P
	<p>The test is considered to have been passed if:</p> <ul style="list-style-type: none"> <li>– depending on the PGU type, the determined <math>\cos(\varphi)</math> values at least cover the range required according to VDE-AR-N 4105:2018-11, up to 5.7.2.2.4</li> <li>– the measured values for <math>S_{E_{max}}</math> and <math>P_{E_{max}}</math> do not exceed the manufacturer's specifications by more than 2%.</li> </ul>		P
5.4.2.4	Test documentation		P
	At least the following should be recorded as 10-minute mean values:		P
	– $U$ , $\cos(\varphi)$ , $P$ and $S$ from a) to c);		P
	– $S_{E_{max}}$ and $P_{E_{max}}$ .		P
5.4.3	Active power reduction through setpoint specification		P
5.4.3.1	General		P
	The following tests apply to PGUs that must be involved in the feed-in management/grid safety management according to VDE-AR-N 4105:2018-11, 5.7.4.2.1, and PGUs that can be involved in the feed-in management/grid safety management according to the manufacturer's specifications.		P
	Where technically possible, measurements must be carried out with a displacement factor of 1.		P
	Functionality can also be checked for a combination of PGU and higher-level control.		P
5.4.3.2	Tests		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	<p>Testing of the active power setpoint control must be carried out using the following procedure:</p> <ul style="list-style-type: none"> <li>a) The test must be carried out as part of a time-related test procedure;</li> <li>b) The available active power output must be at least 90% <math>P_{rE}</math> throughout the test;</li> <li>c) The active power must be measured at the PGU generator terminals;</li> <li>d) If the PGU has several different interfaces for specifying the setpoint, the interface that delivers the most unfavourable results must be tested;</li> <li>e) If there are several interfaces or if the adjustment takes place via an energy management system, different and inconsistent targets must be specified. It must be demonstrated that the setpoint specified for the GSM is never exceeded. Further details about this test can be found in 5.4.3.5.</li> </ul>		P
5.4.3.3	Measuring setting accuracy	(see appended table)	P
	<p>For this test, the setpoint signal is reduced from 100% <math>P_{rE}</math> to 10% <math>P_{rE}</math> as follows:</p> <ul style="list-style-type: none"> <li>a) for adjustable PGUs in 10% <math>P_{rE}</math> steps according to fig. 4. Each time you change the setpoint specification, wait 1 minute so that the PGU can adjust to the new setpoint. Then the active power of the PGU must be measured as a mean minute value;</li> <li>b) for all other PGUs according to their adjustable levels. Each time you change the setpoint specification, wait 1 minute so that the PGU can adjust to the new setpoint. Then the active power of the PGU must be measured as a mean minute value.</li> </ul>  <p><b>Legend</b>  X time <math>t</math> in min  Y active power <math>P/P_n</math></p> <p>Fig. 4 - Measuring setting accuracy for adjustable PGU</p>		P
5.4.3.4	Measuring power gradients	(see appended table)	P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	The power gradient is measured by: <ul style="list-style-type: none"> <li>– changing the setpoint from 100% to 5% of the nominal active power <math>P_{rE}</math> at time <math>t_0</math>. If the minimum technical power is &gt;5%, it must be specified;</li> <li>– changing the setpoint from 5% to 100% of the nominal active power <math>P_{rE}</math> at time <math>t_0</math>. If the minimum technical power is &gt;5%, it must be used as a starting value.</li> </ul>		P
	The power gradient of the PGU ( $dP/dt$ ) is continuously determined during this test. To determine the power gradient, a sliding 10-second mean value of the active power is calculated, whereby the 10-second mean value must be recalculated from the previous data at least every second. The active power gradient is calculated from the 10-second mean values from the difference of the 10-second mean value at time $t_1$ and at time $t_1 + 10$ s as follows: $(\Delta P/10 \text{ s}) = (P_{t=t_1+10\text{s}} - P_{t=t_1}) / 10 \text{ s}$		P
5.4.3.5	Measuring priority interfaces/energy management system		P
	If an active power reduction can be requested via more than one interface, different and random values must be specified as multiples of 10% $P_{rE}$ for all existing interfaces.		P
	All specified values must be within the possible and permissible working range for the tested PGU, i.e. they must be reachable.		P
	The specified values must be documented in a table, and the operating point reached by the PGU (and thus the effective setpoint specification) must be clearly identified.		P
5.4.3.6	Evaluation criteria		P
	The tests referred to in 5.4.3.2 to 5.4.3.5 are considered to have been passed if		P
	– there is no grid disconnection and		P
	– the active power value does not deviate from the setpoint by more than +5% $P_{rE}$ and		P
	– the power gradients determined according to 5.4.3.4 do not fall below 0.33% $P_{rE}/s$ and do not exceed 0.66% $P_{rE}/s$ . The first gradient must be formed 30 seconds after the setpoint step has been set. The formation of gradients is terminated 30 seconds before the stationary end value is reached.		P
	– during measurement 5.4.3.5 either a) the lowest setpoint always has priority or b) the setpoint at the interface programmed for the GSM is never exceeded,		P
	– during testing of the logical interface (input port), the active power feed-in of the PGU is completely terminated within a maximum of 5 seconds after the change of state of the logical signal.		P
5.4.3.7	Test documentation		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The setpoint values and the calculated gradients must be documented. Test results must be documented in tabular form as mean minute values for each setpoint specification.		P
	When testing the logical interface (input port), it must be documented whether the active power feed-in is completely terminated within a maximum of 5 seconds after the change of state of the logical signal. The manufacturer's specifications according to 5.3.3.4, (a) to (g) must be included in the test report.		P
	If a higher-level control is used, the device combination involved in the test must be fully documented.		P
5.4.4	Active power feed-in of PGUs at overfrequency	The PGU is not storage unit.	P
5.4.4.1	General		P
	The test serves to meet the requirement for the active power reduction of the PGU at overfrequency according to VDE-AR-N 4105:2018-11, 5.7.4.3, as well as to demonstrate the active power gradient after reconnection according to VDE-AR-N 4105:2018-11, 8.3.1. If adjustable, the test must be carried out with a $\cos(\varphi)$ specification of 1 for the sake of comparability.		P
	Tests that serve to demonstrate compliance with the requirements for the frequency-dependent active power feed-in of the PGU must be carried out using a grid simulator.		P
	NOTE: DC-coupled storage systems are classified as Type 2 units according to VDE-AR-N 4105. Therefore, these are also tested according to this section.		P
5.4.4.2	Tests		P
	The test is carried out in two test runs, with the specified PGU setting parameters: In both test runs, the following measuring points a) to j) must be reached with an accuracy of $\pm 10$ mHz. Measuring points a) to h) and j) must be reached for at least 60 seconds or until the highest power is reached after shutdown. Measuring point i) must be reached for at least 10 minutes. The specified initial active power must be observed with a tolerance of $\pm 5\%$ $P_{E_{max}}$ . The deviation must be taken into account during the evaluation. If no internal NS protection is implemented in the PGU, the NS protection triggering must be simulated and the PGU must be disconnected from the grid in measuring point h).		P

## DIN VDE V 0124-100

Clause	Requirement - Test	Result - Remark	Verdict																																																																	
	<p><b>Table 15- Test run for testing active power feed-in of PGUs at overfrequency (Test 1)</b></p> <table border="1"> <thead> <tr> <th>Test 1</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{Emax}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>100</td></tr> <tr><td>b)</td><td>50.25</td><td>98</td></tr> <tr><td>c)</td><td>50.70</td><td>80</td></tr> <tr><td>d)</td><td>51.40</td><td>52</td></tr> <tr><td>e)</td><td>50.70</td><td>80</td></tr> <tr><td>f)</td><td>50.25</td><td>98</td></tr> <tr><td>g)</td><td>50.00</td><td>100</td></tr> <tr><td>h)</td><td>51.65</td><td>0</td></tr> <tr><td>i)</td><td>50.15</td><td>0</td></tr> <tr><td>j)</td><td>50.00</td><td>100</td></tr> </tbody> </table> <p>Setting parameter of the PGU: <math>P = 100\% P_{Emax}</math>  Start of power reduction at 50.2 Hz.  <math>s = 5\%</math> (40% <math>P_{ref}</math> / Hz)</p> <p><b>Table 16- Test run for testing active power feed-in of PGUs at overfrequency (Test 2)</b></p> <table border="1"> <thead> <tr> <th>Test 2</th> <th>Frequency Hz</th> <th>Expected active power output (for Type 1 PGU) % <math>P_{Emax}</math></th> <th>Expected active power output (for Type 2 PGU) % <math>P_{Emax}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>60</td><td>60</td></tr> <tr><td>b)</td><td>50.40</td><td>60</td><td>60</td></tr> <tr><td>c)</td><td>50.70</td><td>57</td><td>58</td></tr> <tr><td>d)</td><td>51.40</td><td>45</td><td>51</td></tr> <tr><td>e)</td><td>50.70</td><td>57</td><td>58</td></tr> <tr><td>f)</td><td>50.40</td><td>60 to 100</td><td>60 to 100</td></tr> <tr><td>g)</td><td>50.00</td><td>100</td><td>100</td></tr> </tbody> </table> <p>Setting parameter of the PGU: <math>P = 60\% P_{Emax}</math> (The reduction of the primary energy supply to limit the active power output, and the limiting setting of the active power output must be cancelled from measuring point c)).  If the minimum technical power is above 60% <math>P_{Emax}</math>, this must be taken into account accordingly. The test is not carried out for non-adjustable PGUs.  Start of power reduction at 50.5 Hz.  <math>s = 12\%</math> (16.67% <math>P_{ref}</math> / Hz)</p>	Test 1	Frequency Hz	Expected active power output % $P_{Emax}$	a)	50.00	100	b)	50.25	98	c)	50.70	80	d)	51.40	52	e)	50.70	80	f)	50.25	98	g)	50.00	100	h)	51.65	0	i)	50.15	0	j)	50.00	100	Test 2	Frequency Hz	Expected active power output (for Type 1 PGU) % $P_{Emax}$	Expected active power output (for Type 2 PGU) % $P_{Emax}$	a)	50.00	60	60	b)	50.40	60	60	c)	50.70	57	58	d)	51.40	45	51	e)	50.70	57	58	f)	50.40	60 to 100	60 to 100	g)	50.00	100	100	(see appended table)	P
Test 1	Frequency Hz	Expected active power output % $P_{Emax}$																																																																		
a)	50.00	100																																																																		
b)	50.25	98																																																																		
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h)	51.65	0																																																																		
i)	50.15	0																																																																		
j)	50.00	100																																																																		
Test 2	Frequency Hz	Expected active power output (for Type 1 PGU) % $P_{Emax}$	Expected active power output (for Type 2 PGU) % $P_{Emax}$																																																																	
a)	50.00	60	60																																																																	
b)	50.40	60	60																																																																	
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g)	50.00	100	100																																																																	
	During the tests, the frequency applied or simulated for the PGU and the active power must be recorded as 200 ms sliding average values. The active power output available during the test must be demonstrated.		P																																																																	
	The power gradient (dP/dt) of the PGU must be continuously determined for measuring point j). To determine the power gradient, a sliding mean minute value of the active power is calculated, whereby the mean minute value must be recalculated from the previous data at least every second. The active power gradient is calculated from the mean minute values from the difference of the mean minute value at time $t_1$ and at time $t_1 + 1$ min as follows: $(\Delta P / 1 \text{ min}) = (P_{t = t_1 + 1 \text{ min}} - P_{t = t_1}) / 1 \text{ min}$		P																																																																	
	Here $t_1$ is the time from the start of active power feed-in of the PGU after reconnection until the end of power limitation. The averaging starts at $t_1 - 1$ min.		P																																																																	
5.4.4.3	Evaluation criteria		P																																																																	
	The test is considered to have been passed		P																																																																	

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Clause	Requirement - Test	Result - Remark	Verdict
	<p>a) for adjustable PGUs if:</p> <ul style="list-style-type: none"> <li>– the expected active power output after settling in the above mentioned measuring points 5.4.4.1 a) to g) and j) is established with a deviation of less than or equal to + 10% <math>P_{E_{max}}</math>;</li> <li>– no active power output is permissible in measuring points h) and i);</li> <li>– the initial time delay <math>T_V</math> of the frequency-dependent adjustment of the active power output is <math>\leq 2</math> s;</li> <li>– the response time for the adjustment of the active power output does not exceed 8 seconds (for Type 1 units and Type 2 units with rotating machines) or 2 seconds (for all other Type 2 units) and</li> <li>– the settling time for the adjustment of the active power output does not exceed 30 seconds (for Type 1 units and Type 2 units with rotating machines) or 20 seconds (for all other Type 2 power generation units) and</li> <li>– the connection time in j) is at least 60 seconds and the power is eventually increased with a gradient of <math>\leq 10\%</math> <math>P_{E_{max}}/\text{min}</math>;</li> <li>– the active power in Test 2, measuring point f) is eventually increased with a gradient of <math>\leq 10\%</math> <math>P_{E_{max}}/\text{min}</math>;</li> </ul>		P
	<p>b) for conditionally adjustable PGUs if</p> <ul style="list-style-type: none"> <li>– if their behaviour is within their control range as referred to in a) and</li> <li>– the power fed in when exiting the control range remains constant outside the adjustable range until it is switched off;</li> <li>– the connection time in j) and, if applicable, in g) corresponds to the manufacturer's specifications for the random generator;</li> </ul> <p>The uniform distribution of the cut-off frequency in max. increments of 0.1 Hz between the end of the adjustable range (at least 50.2 Hz) and 51.5 Hz must be demonstrated by the manufacturer's declaration.</p>	Not conditionally adjustable PGUs.	P
	<p>c) for non-adjustable PGUs if</p> <ul style="list-style-type: none"> <li>– shutdown takes place between 50.2 Hz and 51.5 Hz;</li> <li>– the connection time in j) and, if applicable, in g) corresponds to the manufacturer's specifications for the random generator;</li> </ul> <p>The uniform distribution of the cut-off frequency in max. increments of 0.1 Hz between 50.2 Hz and 51.5 Hz must be demonstrated by the manufacturer's declaration.</p>	Not non-adjustable PGUs.	P

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Clause	Requirement - Test	Result - Remark	Verdict
	d) for linear generators with $S_{E_{max}} \leq 4.6$ kVA if <ul style="list-style-type: none"> <li>– they disconnect from the grid at a frequency of <math>\geq 50.2</math> Hz and their maximum upper frequency limit (according to the manufacturer's specification), but at the latest when exceeding 51.5 Hz;</li> <li>– the connection time in j) and, if applicable, in g) corresponds to the manufacturer's specifications for the random generator.</li> </ul>	Not linear generators.	P
5.4.4.4	Test documentation		P
	At least the following must be documented:		P
	a) variation of the grid frequency over time; b) measured active power over time; c) available active power output (depending on the primary energy supply or the limiting setting).		P
5.4.5	Active power feed-in of storage systems at overfrequency		N/A
5.4.5.1	General		N/A
	The test serves to meet the requirement for the active power reduction of the storage system at overfrequency according to VDE-AR-N 4105:2018-11, 5.7.4.3, as well as to demonstrate the active power gradient after reconnection according to VDE-AR-N 4105:2018-11, 8.3.1. If adjustable, the test must be carried out with a $\cos(\varphi)$ specification of 1 for the sake of comparability.		N/A
	Tests that serve to demonstrate compliance with the requirements for the frequency-dependent active power feed-in of the storage system must be carried out using a grid simulator.		N/A
	NOTED: DC-coupled storage systems are classified as Type 2 units according to VDE-AR-N 4105. For this reason, the test regulations according to 5.4.4 Active power feed-in for PGUs at overfrequency must be applied.		N/A
5.4.5.2	Tests		N/A
	The test is carried out in two test runs, with the specified active power output (before the frequency change) and the specified start of the storage system power control. In both test runs, the following measuring points a) to j) must be reached with an accuracy of $\pm 10$ mHz. Measuring points a) to h) and j) must be reached for at least 60 seconds or until the highest power is reached after shutdown. Measuring point i) must be reached for at least 10 minutes. The specified initial active power must be observed with a tolerance of $+ 5\% P_{E_{max}}$ . The deviation must be taken into account during the evaluation. The charge level of the storage system must not limit the active power output of the PGU. If no internal NS protection is implemented in the PGU, the NS protection triggering must be simulated and the PGU must be disconnected from the grid in measuring point h).		N/A

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Clause	Requirement - Test	Result - Remark	Verdict																																																									
	<p><b>Table 18- Test run for testing active power feed-in of storage systems at overfrequency (Test 1)</b></p> <table border="1"> <thead> <tr> <th>Test 1</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{E_{max}}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>100</td></tr> <tr><td>b)</td><td>50.25</td><td>98</td></tr> <tr><td>c)</td><td>50.70</td><td>80</td></tr> <tr><td>d)</td><td>51.40</td><td>52</td></tr> <tr><td>e)</td><td>50.70</td><td>80</td></tr> <tr><td>f)</td><td>50.25</td><td>98</td></tr> <tr><td>g)</td><td>50.00</td><td>100</td></tr> <tr><td>h)</td><td>51.65</td><td>0</td></tr> <tr><td>i)</td><td>50.15</td><td>0</td></tr> <tr><td>j)</td><td>50.00</td><td>100</td></tr> </tbody> </table> <p>Setting parameters of the storage system: <math>P = 100\% P_{E_{max}}</math> Start of power reduction at 50.2 Hz.</p> <p><b>Table 19- Test run for testing active power feed-in of storage systems at overfrequency (Test 2)</b></p> <table border="1"> <thead> <tr> <th>Test 2</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{E_{max}}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>60</td></tr> <tr><td>b)</td><td>50.40</td><td>60</td></tr> <tr><td>c)</td><td>50.70</td><td>52</td></tr> <tr><td>d)</td><td>51.40</td><td>24</td></tr> <tr><td>e)</td><td>50.70</td><td>52</td></tr> <tr><td>f)</td><td>50.10</td><td>60-100</td></tr> <tr><td>g)</td><td>50.00</td><td>100</td></tr> </tbody> </table> <p>Setting parameters of the storage system: <math>P = 60\% P_{E_{max}}</math> (the limiting setting of the active power output must be cancelled from measuring point c)) Start of power reduction at 50.5 Hz.</p>	Test 1	Frequency Hz	Expected active power output % $P_{E_{max}}$	a)	50.00	100	b)	50.25	98	c)	50.70	80	d)	51.40	52	e)	50.70	80	f)	50.25	98	g)	50.00	100	h)	51.65	0	i)	50.15	0	j)	50.00	100	Test 2	Frequency Hz	Expected active power output % $P_{E_{max}}$	a)	50.00	60	b)	50.40	60	c)	50.70	52	d)	51.40	24	e)	50.70	52	f)	50.10	60-100	g)	50.00	100		N/A
Test 1	Frequency Hz	Expected active power output % $P_{E_{max}}$																																																										
a)	50.00	100																																																										
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Test 2	Frequency Hz	Expected active power output % $P_{E_{max}}$																																																										
a)	50.00	60																																																										
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e)	50.70	52																																																										
f)	50.10	60-100																																																										
g)	50.00	100																																																										
	During the tests, the frequency applied or simulated for the PGU and the active power must be recorded as 200 ms sliding average values. The active power output available during the test must be demonstrated.		N/A																																																									
	<p>The power gradient (dP/dt) of the PGU must be continuously determined for measuring point j). To determine the power gradient, a sliding mean minute value of the active power is calculated, whereby the mean minute value must be recalculated from the previous data at least every second. The active power gradient is calculated from the mean minute values from the difference of the mean minute value at time <math>t_1</math> and at time <math>t_1 + 1</math> min as follows:</p> $(\Delta P/1 \text{ min}) = (P_{t=t_1+1 \text{ min}} - P_{t=t_1}) / 1 \text{ min}$ <p>Here <math>t_1</math> is the time from the start of active power feed-in of the PGU after reconnection until the end of power limitation. The averaging starts at <math>t_1 - 1</math> min.</p>		N/A																																																									
5.4.5.3	Evaluation criteria		N/A																																																									
	<p>The test is considered to have been passed if:</p> <ul style="list-style-type: none"> <li>– the expected active power output after settling in the above mentioned measuring points 5.4.7.1 a) to g) and j) is established with a deviation of less than or equal to <math>\leq 10\% P_{E_{max}}</math>. Deviations resulting from the maximum charging or discharge power being less than <math>P_{E_{max}}</math> are permissible. No active power output is permissible in measuring points h) and i);</li> <li>– the initial time delay <math>T_v</math> of the frequency-dependent adjustment of the active power output is <math>\leq 2</math> s;</li> <li>– the response time for the adjustment of the active power output / consumption does not exceed 1 second and</li> <li>– the settling time for the adjustment of the active power output / consumption does not exceed 20 second;</li> <li>– the connection time in j) is at least 60 seconds and the power is eventually increased with a gradient of <math>\leq 10\% P_{E_{max}}/\text{min}</math>.</li> </ul>		N/A																																																									

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
5.4.5.4	Test documentation		N/A
	At least the following must be documented:		N/A
	<ul style="list-style-type: none"> <li>– variation of the grid frequency over time;</li> <li>– measured active power over time;</li> <li>– available active power output / consumption (depending on the charge level).</li> </ul>		N/A
5.4.6	Active power feed-in for PGUs at under frequency		P
5.4.6.1	General		P
	The test serves to meet the requirement for the active power increase of the PGU at under frequency according to VDE-AR-N 4105:2018-11, 5.7.4.3, as well as to demonstrate the active power gradient after reconnection according to VDE-AR-N 4105:2018-11, 8.3.1. If adjustable, the test must be carried out with a $\cos(\varphi)$ specification of 1 for the sake of comparability.		P
	Tests that serve to demonstrate compliance with the requirements for the frequency-dependent active power feed-in of the PGU must be carried out using a grid simulator.		P
	DC-coupled storage systems are classified as Type 2 units according to VDE-AR-N 4105. For this reason, the test regulations in this section must apply to these units.		P
5.4.6.2	Tests		P
	The test is carried out in two test runs, with the specified active power output (before the frequency change) of the PGU. NOTE: The start of the active power increase is specified at 49.8 Hz and the statics at $s = 5\%$ ( $40\% P_{E_{max}}/Hz$ ).		P
	In both test runs, the following measuring points a) to j) must be reached with an accuracy of $\pm 10$ mHz. Measuring points a) to h) and j) must be reached for at least 60 seconds or until the highest power is reached after shutdown. Measuring point i) must be reached for at least 10 minutes. The specified initial active power must be observed with a tolerance of $\pm 5\% P_{E_{max}}$ . The deviation must be taken into account during the evaluation.		P
	If no internal NS protection is implemented in the PGU, the NS protection triggering must be simulated and the PGU must be disconnected from the grid in measuring point h).		P

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Clause	Requirement - Test	Result - Remark	Verdict																																																									
	<p><b>Table 21- Test run for testing active power feed-in of PGUs at under frequency (Test 1)</b></p> <table border="1"> <thead> <tr> <th>Test 1</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{E_{max}}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>10</td></tr> <tr><td>b)</td><td>49.75</td><td>12</td></tr> <tr><td>c)</td><td>48.80</td><td>50</td></tr> <tr><td>d)</td><td>47.60</td><td>98</td></tr> <tr><td>e)</td><td>48.80</td><td>50</td></tr> <tr><td>f)</td><td>49.75</td><td>12</td></tr> <tr><td>g)</td><td>50.00</td><td>10</td></tr> <tr><td>h)</td><td>47.35</td><td>0</td></tr> <tr><td>i)</td><td>47.60</td><td>0</td></tr> <tr><td>j)</td><td>50.00</td><td>10</td></tr> </tbody> </table> <p>Setting parameter of the PGU: <math>P = 10\% P_{E_{max}}</math> The test only applies to adjustable PGU.</p> <p><b>Table 22- Test run for testing active power feed-in of PGUs at under frequency (Test 2)</b></p> <table border="1"> <thead> <tr> <th>Test 2</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{E_{max}}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>60</td></tr> <tr><td>b)</td><td>49.75</td><td>62</td></tr> <tr><td>c)</td><td>49.20</td><td>84</td></tr> <tr><td>d)</td><td>48.80</td><td>100</td></tr> <tr><td>e)</td><td>49.20</td><td>84</td></tr> <tr><td>f)</td><td>49.85</td><td>60</td></tr> <tr><td>g)</td><td>50.00</td><td>60</td></tr> </tbody> </table> <p>Setting parameter of the PGU: <math>P = 60\% P_{E_{max}}</math> If the minimum technical power is above <math>60\% P_{E_{max}}</math>, this must be taken into account accordingly. The test is not carried out for non-adjustable PGUs.</p>	Test 1	Frequency Hz	Expected active power output % $P_{E_{max}}$	a)	50.00	10	b)	49.75	12	c)	48.80	50	d)	47.60	98	e)	48.80	50	f)	49.75	12	g)	50.00	10	h)	47.35	0	i)	47.60	0	j)	50.00	10	Test 2	Frequency Hz	Expected active power output % $P_{E_{max}}$	a)	50.00	60	b)	49.75	62	c)	49.20	84	d)	48.80	100	e)	49.20	84	f)	49.85	60	g)	50.00	60		P
Test 1	Frequency Hz	Expected active power output % $P_{E_{max}}$																																																										
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e)	49.20	84																																																										
f)	49.85	60																																																										
g)	50.00	60																																																										
	The same frequency deviations must result from the application of the alternative test procedure by adjusting the limits.		P																																																									
	During the tests, the frequency applied or simulated for the PGU and the active power must be recorded as 200 ms sliding average values. The active power output available during the test must be demonstrated.		P																																																									
	The power gradient (dP/dt) of the PGU must be continuously determined for measuring point j). To determine the power gradient, a sliding mean minute value of the active power is calculated, whereby the mean minute value must be recalculated from the previous data at least every second.		P																																																									
	The active power gradient is calculated from the mean minute values from the difference of the mean minute value at time $t_1$ and at time $t_1 + 1$ min as follows: $(\Delta P/1 \text{ min}) = (P_{t=t_1+1 \text{ min}} - P_{t=t_1})/1 \text{ min}$		P																																																									
	Here $t_1$ is the time from the start of active power feed-in of the PGU after reconnection until the end of power limitation. The averaging starts at $t_1 - 1$ min.		P																																																									
5.4.6.3	Evaluation criteria		P																																																									

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Clause	Requirement - Test	Result - Remark	Verdict
	<p>The test is considered to have been passed</p> <p>a) for adjustable PGUs if</p> <ul style="list-style-type: none"> <li>– the expected active power after settling in the above mentioned measuring points 5.4.6.1 a) to g) and j) is established with a deviation of less than or equal to + 10% <math>P_{E_{max}}</math>. Deviations according to VDE-AR-N 4105:2018-11, 5.7.4.3, fig. 13, as well as due to the technical restrictions described are permissible. No active power output is permissible in measuring points h) and i);</li> <li>– the initial time delay <math>T_V</math> of the frequency-dependent adjustment of the active power output is <math>\leq 2</math> s;</li> <li>– the response time for the adjustment of the active power output does not exceed 8 seconds (for Type 1 units and Type 2 units with rotating machines) or 2 seconds (for all other Type 2 units) and</li> <li>– the settling time for the adjustment of the active power output does not exceed 30 seconds (for Type 1 units and Type 2 units with rotating machines) or 20 seconds (for all other Type 2 power generation units);</li> <li>– the connection time in j) is at least 60 seconds and the power is eventually increased with a gradient of <math>\leq 10\%</math> <math>P_{E_{max}}/\text{min}</math>.</li> </ul>		P
	<p>b) for conditionally adjustable PGUs if</p> <ul style="list-style-type: none"> <li>– if their behaviour is within their control range as referred to in a) and</li> <li>– no shutdown takes place between 49.8 Hz and 47.5 Hz;</li> <li>– the connection time in j) corresponds to the manufacturer's specifications for the random generator;</li> </ul>	Not conditionally adjustable PGUs.	P
	<p>c) for non-adjustable PGUs if</p> <ul style="list-style-type: none"> <li>– no shutdown takes place between 49.8 Hz and 47.5 Hz;</li> <li>– the connection time in j) corresponds to the manufacturer's specifications for the random generator;</li> </ul>	Not non-adjustable PGUs.	P
	<p>d) for linear generators with <math>S_{E_{max}} \leq 4.6</math> kVA if</p> <ul style="list-style-type: none"> <li>– they disconnect from the grid at a frequency of <math>\leq 49.8</math> Hz and their maximum upper frequency limit (according to the manufacturer's specification), but at the latest when falling below 47.5 Hz;</li> <li>– the connection time in j) corresponds to the manufacturer's specifications for the random generator.</li> </ul>	Not linear generators.	P
5.4.6.4	Test documentation		P

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Clause	Requirement - Test	Result - Remark	Verdict
	At least the following must be documented: <ul style="list-style-type: none"> <li>- variation of the grid frequency over time;</li> <li>- measured active power over time;</li> <li>- available active power output (depending on the primary energy supply or the limiting setting).</li> </ul>		P
5.4.7	Active power feed-in of storage systems at under frequency		N/A
5.4.7.1	General		N/A
	The test serves to meet the requirement for the active power increase of the storage system at under frequency according to VDE-AR-N 4105:2018-11, 5.7.4.3, as well as to demonstrate the active power gradient after reconnection according to VDE-AR-N 4105:2018-11, 8.3.1. If adjustable, the test must be carried out with a $\cos(\varphi)$ specification of 1 for the sake of comparability.		N/A
	The tests must be carried out using an interface for active power reduction, which has a lower priority than the active power feed-in at under frequency (details are given in VDE-AR-N 4105:2018-11, 8.1). If such an interface is not available, this must be documented and the test is not required.		N/A
	Tests that serve to demonstrate compliance with the requirements for the frequency-dependent active power feed-in of the storage system must be carried out using a grid simulator.		N/A
	DC-coupled storage systems are classified as Type 2 units according to VDE-AR-N 4105. For this reason, the test regulations according to 5.4.6 Active power feed-in for PGUs at under frequency must be applied.		N/A
5.4.7.2	Tests		N/A
	The test is carried out in two test runs, with the specified active power output / consumption (before the frequency change) of the storage system.		N/A
	In both test runs, the following measuring points a) to j) must be reached with an accuracy of $\pm 10$ mHz. Measuring points a) to h) and j) must be reached for at least 60 seconds or until the highest power is reached after shutdown. Measuring point i) must be reached for at least 10 minutes. The specified initial active power must be observed with a tolerance of $\pm 5\%$ $P_{E_{max}}$ . The deviation must be taken into account during the evaluation. The charge level of the storage system must not limit the active power output of the PGU.		N/A
	If no internal NS protection is implemented in the PGU, the NS protection triggering must be simulated and the PGU must be disconnected from the grid in measuring point h).		N/A

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Clause	Requirement - Test	Result - Remark	Verdict																																	
	<p><b>Table 24- Test run for testing active power feed-in of storage systems at under frequency (Test 1)</b></p> <table border="1"> <thead> <tr> <th>Test 1</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{E_{max}}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>-100</td></tr> <tr><td>b)</td><td>49.75</td><td>-95</td></tr> <tr><td>c)</td><td>48.80</td><td>0</td></tr> <tr><td>d)</td><td>47.60</td><td>100</td></tr> <tr><td>e)</td><td>48.80</td><td>0</td></tr> <tr><td>f)</td><td>49.85</td><td>-100</td></tr> <tr><td>g)</td><td>50.00</td><td>-100</td></tr> <tr><td>h)</td><td>47.35</td><td>0</td></tr> <tr><td>i)</td><td>47.60</td><td>0</td></tr> <tr><td>j)</td><td>50.00</td><td>-100</td></tr> </tbody> </table> <p>Setting parameters of the storage system: <math>P = -100\% P_{E_{max}}</math>, <math>s = 2\%</math> (100% <math>P_{E_{max}}/Hz</math>)</p>	Test 1	Frequency Hz	Expected active power output % $P_{E_{max}}$	a)	50.00	-100	b)	49.75	-95	c)	48.80	0	d)	47.60	100	e)	48.80	0	f)	49.85	-100	g)	50.00	-100	h)	47.35	0	i)	47.60	0	j)	50.00	-100		N/A
Test 1	Frequency Hz	Expected active power output % $P_{E_{max}}$																																		
a)	50.00	-100																																		
b)	49.75	-95																																		
c)	48.80	0																																		
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f)	49.85	-100																																		
g)	50.00	-100																																		
h)	47.35	0																																		
i)	47.60	0																																		
j)	50.00	-100																																		
	<p><b>Table 25- Test run for testing active power feed-in of storage systems at under frequency (Test 2)</b></p> <table border="1"> <thead> <tr> <th>Test 2</th> <th>Frequency Hz</th> <th>Expected active power output % <math>P_{E_{max}}</math></th> </tr> </thead> <tbody> <tr><td>a)</td><td>50.00</td><td>10</td></tr> <tr><td>b)</td><td>49.75</td><td>15</td></tr> <tr><td>c)</td><td>48.80</td><td>100</td></tr> <tr><td>d)</td><td>47.60</td><td>100</td></tr> <tr><td>e)</td><td>48.80</td><td>100</td></tr> <tr><td>f)</td><td>49.85</td><td>10</td></tr> <tr><td>g)</td><td>50.00</td><td>10</td></tr> </tbody> </table> <p>Setting parameters of the storage system: <math>P = 10\% P_{E_{max}}</math>, <math>s = 2\%</math> (100% <math>P_{E_{max}}/Hz</math>)</p>	Test 2	Frequency Hz	Expected active power output % $P_{E_{max}}$	a)	50.00	10	b)	49.75	15	c)	48.80	100	d)	47.60	100	e)	48.80	100	f)	49.85	10	g)	50.00	10		N/A									
Test 2	Frequency Hz	Expected active power output % $P_{E_{max}}$																																		
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	During the tests, the frequency applied or simulated for the PGU and the active power must be recorded as 200 ms sliding average values. The active power output available during the test must be demonstrated.		N/A																																	
	<p>The power gradient (dP/dt) of the PGU must be continuously determined for measuring point j). To determine the power gradient, a sliding mean minute value of the active power is calculated, whereby the mean minute value must be recalculated from the previous data at least every second. The active power gradient is calculated from the mean minute values from the difference of the mean minute value at time <math>t_1</math> and at time <math>t_1 + 1</math> min as follows:</p> $(\Delta P/1 \text{ min}) = (P_{t = t_1 + 1 \text{ min}} - P_{t = t_1})/1 \text{ min}$		N/A																																	
	Here $t_1$ is the time from the start of active power feed-in of the PGU after reconnection until the end of power limitation. The averaging starts at $t_1 - 1$ min.		N/A																																	
5.4.7.3	Evaluation criteria		N/A																																	
	<p>The test is considered to have been passed if:</p> <ul style="list-style-type: none"> <li>- the expected active power output after settling in the above mentioned measuring points 5.4.7.1 a) to g) and j) is established with a deviation of less than or equal to <math>\leq 10\% P_{E_{max}}</math>. Deviations resulting from the maximum charging or discharge power being less than <math>P_{E_{max}}</math> are permissible. No active power output is permissible in measuring points h) and i);</li> <li>- the initial time delay <math>T_V</math> of the frequency-dependent adjustment of the active power output is <math>\leq 2</math> s;</li> <li>- the response time for the adjustment of the active power output / consumption does not exceed 1 second;</li> <li>- the settling time for the adjustment of the active power output / consumption does not exceed 20 second;</li> <li>- the connection time in j) is at least 60 seconds and the power is eventually increased with a gradient of <math>\leq 10\% P_{E_{max}}/\text{min}</math>.</li> </ul>		N/A																																	

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Clause	Requirement - Test	Result - Remark	Verdict
5.4.7.4	Test documentation		N/A
	At least the following must be documented: – variation of the grid frequency over time; – measured active power over time; – available active power output / consumption (depending on the charge level).		N/A
5.4.8	Static voltage stability/reactive power provision		P
5.4.8.1	General		P
	The tests serve to meet the requirements for the reactive power mode of the PGU in normal operation according to VDE-AR-N 4105:2018-11, 5.7.2.		P
	All tests must be carried out at the specified voltages. If test bench measurements are not possible, a technically based declaration from the manufacturer must be provided. For systems that are connected to the grid via inverters, only the inverter may be tested.		P
	For tests, a distinction is made between guided PGUs and supply-dependent PGUs. – A guided PGU receives control commands for active power e.g. from a higher-level control. According to this test instruction, guided PGUs do not depend on fluctuating primary energy supply. – A supply-dependent PGU feeds in active power depending on the available primary energy supply.		P
5.4.8.2	Testing reactive power/displacement factor setting accuracy		P
	The PGU is operated at all of the following operating points, whereby a data set with a 60-second averaging must be recorded for each operating point after the transient response of the active power has subsided. During the partial measurements a) to h) below, the primary energy source must not limit the power. Measurements must be carried out at $0.9 U_n$ , $U_n$ and $1.1 U_n$ with a tolerance of $\pm 2\% U_n$ .		P
	The restrictions of the voltage-dependent reactive power control ranges according to VDE-AR-N 4105:2018-11, Figure 2 to Figure 4, must be taken into account.		P
	For each of the measurements at different voltages, a different value between 40% and 60% $P_{E_{max}}$ must be reached.		P
	The following applies for Type 2 PGUs - only converter $\sum S_{E_{max}} \leq 4.6 \text{ kVA}$ : a) For $\cos \varphi = 0.95$ overexcited and a second time for $\cos \varphi = 0.98$ overexcited, the active power will be measured at value between 40% $P_{E_{max}}$ and 60% $P_{E_{max}}$ as well as at $S_{E_{max}}$ . b) For $\cos \varphi = 0.95$ under excited and a second time for $\cos \varphi = 0.98$ under excited, the active power will be measured at value between 40% $P_{E_{max}}$ and 60% $P_{E_{max}}$ as well as at $S_{E_{max}}$ .	(see appended table)	P

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Clause	Requirement - Test			Result - Remark	Verdict																																									
	<p>The following applies for Type 2 PGUs - only converter <math>\sum S_{E_{max}} &gt; 4.6</math> kVA:</p> <p>c) For <math>\cos \varphi = 0.90</math> overexcited and a second time for <math>\cos \varphi = 0.95</math> overexcited, the active power will be measured at value between 40% <math>P_{E_{max}}</math> and 60% <math>P_{E_{max}}</math> as well as at <math>S_{E_{max}}</math>.</p> <p>d) For <math>\cos \varphi = 0.90</math> under excited and a second time for <math>\cos \varphi = 0.95</math> under excited, the active power will be measured at value between 40% <math>P_{E_{max}}</math> and 60% <math>P_{E_{max}}</math> as well as at <math>S_{E_{max}}</math>.</p>				N/A																																									
	<p>The following applies for Type 1 PGUs as well as for Type 2 systems with Stirling generators and fuel cells at <math>\sum S_{E_{max}} \leq 4.6</math> kVA:</p> <p>e) Without specification of the <math>\cos \varphi</math>, the active power will be measured at value between 40% <math>P_{E_{max}}</math> and 60% <math>P_{E_{max}}</math> as well as at <math>S_{E_{max}}</math>.</p>				N/A																																									
	<p>The following applies for Type 1 PGUs as well as for Type 2 systems with Stirling generators and fuel cells at <math>\sum S_{E_{max}} &gt; 4.6</math> kVA:</p> <p>f) For <math>\cos \varphi = 0.95</math> overexcited and a second time for <math>\cos \varphi = 0.98</math> overexcited, the active power will be measured at value between 40% <math>P_{E_{max}}</math> and 60% <math>P_{E_{max}}</math> as well as at <math>S_{E_{max}}</math>.</p> <p>g) For <math>\cos \varphi = 0.95</math> under excited and a second time for <math>\cos \varphi = 0.98</math> under excited, the active power will be measured at value between 40% <math>P_{E_{max}}</math> and 60% <math>P_{E_{max}}</math> as well as at <math>S_{E_{max}}</math>.</p>				N/A																																									
	<p>The following applies for Type 2 PGUs with asynchronous generators:</p> <p>h) Without specification of the <math>\cos \varphi</math>, measurement will be carried out at <math>S_{E_{max}}</math>. This test must only be carried out at <math>U_n</math>.</p>				N/A																																									
	<p>Test requirements are given in Table 27 for clarity. If the aforementioned active power values cannot be achieved due to the design, the possible active power values must be achieved and measured.</p> <p style="text-align: center;">Table 27- Overview of requirements from 5.4.8.2</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2">Equation symbols</th> <th colspan="2">Type 2 - only converter</th> <th>Type 2 - asynchronous generators</th> <th colspan="2">Type 1 and Type 2 - synchronous generators, fuel cells and Stirling generators</th> </tr> <tr> <th><math>\leq 4.6</math> kVA</th> <th><math>&gt; 4.6</math> kVA</th> <th>All</th> <th><math>&lt; 4.6</math> kVA</th> <th><math>&gt; 4.6</math> kVA</th> </tr> </thead> <tbody> <tr> <td><math>\sum S_{E_{max}}</math></td> <td><math>\leq 4.6</math> kVA</td> <td><math>&gt; 4.6</math> kVA</td> <td>All</td> <td><math>&lt; 4.6</math> kVA</td> <td><math>&gt; 4.6</math> kVA</td> </tr> <tr> <td><math>P</math> [kW]</td> <td>40% to 60% <math>P_{E_{max}}</math> and <math>S_{E_{max}}</math></td> <td>40% to 60% <math>P_{E_{max}}</math> and <math>S_{E_{max}}</math></td> <td><math>S_{E_{max}}</math></td> <td>40% to 60% <math>P_{E_{max}}</math> and <math>S_{E_{max}}</math></td> <td>40% to 60% <math>P_{E_{max}}</math> and <math>S_{E_{max}}</math></td> </tr> <tr> <td><math>\cos \varphi</math></td> <td><math>\cos \varphi = 0.95</math> overexcited and under excited <math>\cos \varphi = 0.98</math> overexcited and under excited</td> <td><math>\cos \varphi = 0.90</math> overexcited and under excited <math>\cos \varphi = 0.95</math> overexcited and under excited</td> <td><math>\cos \varphi = 0.95</math> under excited</td> <td>between <math>\cos \varphi = 0.95</math> overexcited and <math>\cos \varphi = 0.95</math> under excited</td> <td><math>\cos \varphi = 0.95</math> overexcited and under excited <math>\cos \varphi = 0.98</math> overexcited and under excited</td> </tr> <tr> <td>Tolerance <math>\cos \varphi</math></td> <td colspan="2">-</td> <td><math>\pm 0.02</math></td> <td>-</td> <td>-</td> </tr> <tr> <td>Tolerance <math>Q</math> [kVAR]</td> <td colspan="2"><math>\pm 4\% P_{E_{max}}</math></td> <td>-</td> <td colspan="2"><math>\pm 4\% P_{E_{max}}</math></td> </tr> </tbody> </table>			Equation symbols	Type 2 - only converter		Type 2 - asynchronous generators	Type 1 and Type 2 - synchronous generators, fuel cells and Stirling generators		$\leq 4.6$ kVA	$> 4.6$ kVA	All	$< 4.6$ kVA	$> 4.6$ kVA	$\sum S_{E_{max}}$	$\leq 4.6$ kVA	$> 4.6$ kVA	All	$< 4.6$ kVA	$> 4.6$ kVA	$P$ [kW]	40% to 60% $P_{E_{max}}$ and $S_{E_{max}}$	40% to 60% $P_{E_{max}}$ and $S_{E_{max}}$	$S_{E_{max}}$	40% to 60% $P_{E_{max}}$ and $S_{E_{max}}$	40% to 60% $P_{E_{max}}$ and $S_{E_{max}}$	$\cos \varphi$	$\cos \varphi = 0.95$ overexcited and under excited $\cos \varphi = 0.98$ overexcited and under excited	$\cos \varphi = 0.90$ overexcited and under excited $\cos \varphi = 0.95$ overexcited and under excited	$\cos \varphi = 0.95$ under excited	between $\cos \varphi = 0.95$ overexcited and $\cos \varphi = 0.95$ under excited	$\cos \varphi = 0.95$ overexcited and under excited $\cos \varphi = 0.98$ overexcited and under excited	Tolerance $\cos \varphi$	-		$\pm 0.02$	-	-	Tolerance $Q$ [kVAR]	$\pm 4\% P_{E_{max}}$		-	$\pm 4\% P_{E_{max}}$			P
Equation symbols	Type 2 - only converter		Type 2 - asynchronous generators		Type 1 and Type 2 - synchronous generators, fuel cells and Stirling generators																																									
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DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	The following applies for Type 2 PGUs - only converter $\sum S_{E_{max}} \leq 4.6$ kVA: The Q setpoint is calculated by using the required $\cos \varphi$ setpoint one time at $\cos \varphi = 0.95$ and another time at $\cos \varphi = 0.98$ and the measured apparent power of the fundamental oscillation. The test is considered to have been passed if all the Q 60-second mean values of the fundamental oscillation for a) are in the range of the Q setpoint $\pm 4\% P_{E_{max}}$ overexcited and for b) in the range of the Q setpoint $\pm 4\% P_{E_{max}}$ under excited. In addition, a setting of the $\cos \varphi$ must be possible within a step size of at least 0.01.		P
	The following applies for Type 2 PGUs - only converter $\sum S_{E_{max}} > 4.6$ kVA: The Q setpoint is calculated by using the required $\cos \varphi$ setpoint one time at $\cos \varphi = 0.90$ and another time at $\cos \varphi = 0.95$ and the measured apparent power of the fundamental oscillation. The test is considered to have been passed if all the Q 60-second mean values of the fundamental oscillation for c) are in the range of the Q setpoint $\pm 4\% P_{E_{max}}$ overexcited and for d) in the range of the Q setpoint $\pm 4\% P_{E_{max}}$ under excited. In addition, a setting of the $\cos \varphi$ must be possible within a step size of at least 0.01.		N/A
5.4.8.2.2	Test documentation		P
	At least the following should be documented:		P
	– tabular representation of all measuring points from a) to h) for $P$ , $Q$ , $S$ , $U$ , $\cos \varphi$ values as a 60-second mean value;		P
	– graphical representation of all measuring points from a) to h) for $P$ and $Q$ as a 60-second mean value;		P
	– “Pass”/“Fail” for the adjustable $\cos \varphi$ range and, if applicable, restrictions for use of PGUs > 4.6 kVA.		N/A
	– The minimum possible $\cos \varphi$ setting step size, if available.		P
5.4.8.3	Testing displacement factor/active power characteristic curve $\cos \varphi (P)$		P
	This section serves to verify the standard characteristic curve for $\cos \varphi (P)$ shown in VDE-AR-N 4105: 2018-11, 5.7.2.4 b). The reactive power control for this characteristic curve method must be evaluated with regard to stationary accuracy and dynamics.		P
	1) Test steps for conducted PGU – accuracy (characteristic curve):	(see appended table)	P
	a) Operating point $P \leq 20\% P_{TE}$ or minimum technical performance with activated $\cos \varphi (P)$ – adjust regulation.		P
	b) Start measurement.		P
	c) Set the active power setpoint to $100\% P_{TE}$ , wait until the stationary end values for $P$ and $Q$ are set.		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	d) Set active power setpoint to $P \leq 20\% P_{TE}$ or technical minimum power, wait until the stationary end values for $P$ and $Q$ are set.		P
	e) Stop measurement.		P
	NOTE 1 Due to the prescribed power gradients for PGU, the test steps lead to a very slow, double traversing of the entire characteristic curve within about 2.5 min to 5 min in each case. Since the required PT1 behaviour for reactive power provides settling times in the range of seconds for the very small differential changes in reactive power which thus occur, the test sequence allows an evaluation of whether the characteristic curve is maintained with sufficient accuracy.		P
	NOTE 2 All operating points, in particular point d), must be selected in such a way that switching off the PGU is avoided.		P
	2) Test steps for conducted PGU – dynamics	(see appended table)	P
	A test of the PT1 behaviour specified in VDE-AR-N 4105:2018-11 on the transition dynamics is not necessary due to the required limitations of the effective power gradient.		P
	3) Test steps for supply-dependent PGU – accuracy (characteristic curve):		P
	<p>a) Operating point <math>S \geq 99\% S_{E_{max}}</math> with activated <math>\cos \varphi (P)</math> – adjust regulation. Start measurement.</p> <p>b) Reduce DC power or primary energy ramped with <math>\leq 30\% P_{TE}/\text{min}</math> from <math>\geq 99\% P_{TE}</math> to <math>\leq 20\% P_{TE}</math>, wait until the stationary end values for <math>P</math> and <math>Q</math> are set.</p> <p>c) Increase DC power or primary energy ramped with <math>\leq 30\% P_{TE}/\text{min}</math> from <math>\leq 20\% P_{TE}</math> to <math>\geq 99\% P_{TE}</math>, wait until the stationary end values for <math>P</math> and <math>Q</math> are set.</p> <p>d) Stop measurement.</p> <p>NOTE For test steps b) and c), the DC power or primary energy may alternatively be varied in steps <math>\leq 10\% P_{TE}</math>. Before setting a new step value, it must be ensured that <math>P</math> and <math>Q</math> have engaged.</p>		P
	4) Test steps for supply-dependent PGU – dynamics:		P
	<p>a) Operating point <math>S \geq 99\% S_{E_{max}}</math> with activated <math>\cos \varphi (P)</math> – adjust regulation.</p> <p>b) Start measurement.</p> <p>c) After 60 s DC power or primary energy, decrease abrupt from <math>\geq 99\% P_{TE}</math> to <math>\leq 50\% P_{TE}</math>, wait until the stationary end values for <math>P</math> and <math>Q</math> are set.</p> <p>d) After 60 s DC power or primary energy, increase abrupt from <math>\leq 50\% P_{TE}</math> to <math>\geq 99\% P_{TE}</math>, wait until the stationary end values for <math>P</math> and <math>Q</math> are set.</p> <p>e) After 60 s DC power or primary energy, decrease abrupt from <math>\geq 99\% P_{TE}</math> to <math>75 + 5\% P_{TE}</math>, wait until the stationary end values for <math>P</math> and <math>Q</math> are set.</p> <p>f) Stop measurement after 60 s.</p> <p>NOTE Abrupt change means: “with a response time <math>&lt; 1</math> s and a settling time <math>&lt; 3</math> s”.</p>		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
5.4.8.3.1	Evaluation criteria		P
	Tests (1) and (3) in 5.4.8.3 are considered to be passed if for all calculated reactive power values the maximum deviation between reactive power setpoint (calculated from the characteristic curve to be verified) and actual reactive power at the generator terminals is at most $\pm 4.0\%$ , based on $P_{Emax}$ .		P
	Test (2) in 5.4.8.3 is considered to have been passed if the PGU demonstrably meets the requirements for the power gradient in accordance with VDE-AR-N 4105:2018-11, 5.7.4.2.		P
	Test (4) in 5.4.8.3 is considered to have been passed if the step response of the reactive power in test steps c) and e) PT1 behaviour is in accordance with VDE-AR-N 4105:2018-11, 5.7.2.5 and for test step d) optionally the power gradient lies between the limits defined in VDE-AR-N 4105:2018-11, 5.7.4.1 or the step response of the reactive power also shows PT1 behaviour according to VDE-AR-N 4105:2018-11, 5.7.2.5.		P
5.4.8.3.2	Documentation		P
	For the tests 5.4.8.3 (1), (3) and (4), an x-t diagram shall be presented:		P
	<ul style="list-style-type: none"> <li>– Time response of active and reactive power including calculated setpoint and tolerance according to 5.4.8.3.1;</li> <li>– Time response <math>\cos \varphi</math>;</li> <li>– Time response <math>P_{\text{setpoint}}</math> (only guided PGU);</li> <li>– Time response <math>P_{\text{DC}}</math> (inverter systems and PV);</li> <li>– Time response <math>P_{\text{prim}}</math> (only presentation-dependent PGU without measurement of the accessible DC link).</li> </ul>		P
	For the tests 5.4.8.3 (2) it shall be documented whether the requirements for the power gradient have been fulfilled.		P
5.4.8.4	Test of the reactive power voltage characteristic curve $Q(U)$	Only for three phase unit.	N/A
	The inspection of the $Q(U)$ regulation according to VDE-AR-N 4105:2018-05, 5.7.2.4, is divided into two partial tests, so that on the one hand the accuracy and on the other hand the dynamics of the $Q(U)$ regulation is tested.		N/A
5.4.8.4.1	Accuracy test of the $Q(U)$ regulation		N/A
	Testing of the accuracy of the $Q(U)$ regulation on the basis of the values specified in VDE-AR-N 4105:2018-11, 5.7.2.4, Figure 7 is achieved by a slow variation of the reactive power grid voltage characteristic curve in the range $90\% U_n$ to $110\% U_n$ . The voltage changes must be carried out symmetrically on all phases.		N/A

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	a) The permissible voltage range must be passed through in steps. Each voltage must be applied to PGU for at least 1 minute. The test should be performed with a step size of 1% $U_n$ , but not greater than 2% $U_n$ . First of all, the voltage range starting from 100% of the nominal voltage $U_n$ must be run through to the under voltage range up to 90% $U_n$ . Then the voltage range starting from 90% $U_n$ to 110% $U_n$ must be passed through into the overvoltage. Finally, the voltage of 110% $U_n$ is brought back to 100% of the nominal voltage. The procedure is analogous to Figure 3 in 5.4.3.2.		N/A
	b) The voltage applied to the PGU $U_{PGU}$ and the reactive power provided by it in the positive sequence $Q_{PGU}$ are recorded in the form of floating 200 ms averages with correct algebraic signs. The voltages shall be set with a maximum deviation of $\pm 0.25\% U_n$ . As an alternative to using an adjustable voltage source, the variation of the voltage can also be specified by a differential manipulation of the measured voltage on the controller side. For this purpose, the boundary conditions in 5.4.8.4.2 b) must be observed.		N/A
5.4.8.4.2	Dynamics test of the $Q(U)$ regulation	Only for three phase unit	N/A
	In order to check the dynamic behaviour required in VDE-AR-N 4105:2018-11, 5.7.2.5, the closed control loop of PGU including the feedback over the grid impedance must be considered. This is required because the feedback can lead to a change in the dynamic behaviour and thus to a deviation from the required behaviour of a PT1 filter. It is therefore not sufficient to consider the open loop.		N/A
	Decisive for a safe and stable behaviour on the grid is the total gain of the control loop, consisting of the $Q(U)$ characteristic curve and the strength of the feedback in the form of the grid backup reactance $X_{grid}$ . It is assumed that the $Q(U)$ standard characteristic curve from VDE-AR-N 4105:2018-11, 5.7.2.4, Figure 7 is used. In order to maintain constant test conditions for all PGU, the grid backup reactance $X_{grid}$ should be selected as a function of the apparent power of the PGU to be tested using the following formula: $X_{grid} = \frac{0,0218 \cdot 3 \cdot U_n \cdot Y^2}{0,85 \cdot  Q_{max} }$ corresponds to the short-circuit power $S_K = \frac{0,85 \cdot  Q_{max} }{0,0218}$		N/A
	The parameters described take into account both the stability of the individual PGU and that of a compound operation in the form of an PGS. The active power feed required to reach the reactive power setpoint according to the associated PQ diagram from VDE-AR-N 4105:2018-11, 5.7.2.3 must be ensured.		N/A

DIN VDE V 0124-100																																													
Clause	Requirement - Test	Result - Remark	Verdict																																										
	<p><b>Initial state:</b> The <math>Q(U)</math> regulation of the PGU must be parameterized with the smallest possible response time according to VDE-AR-N 4105:2018-11, 5.7.2.5. The voltage source must be set so that the positive sequence corresponds to the voltage applied to the PGU 100% <math>U_n</math>. If no adjustable voltage source can be used, the voltage at point 1 must be symmetrical during the entire measurement (tolerance of unbalance: 0.5%) and constant (tolerance <math>\pm 1\% U_n</math> more than 1 min before the respective measurement) and the voltage at the PGU (point 2) is within the <math>Q(U)</math> dead band from 97% to 103% <math>U_{n,y}</math>. The voltage applied to the PGU is designated <math>U_{PGU}</math>.</p>		N/A																																										
	<p>To prove the required dynamics (PT1 behaviour), a reactive power setpoint of 85% <math>Q_{max}</math> under excited (inductive) or 85% <math>Q_{max}</math> overexcited (capacitive) must be set by means of a step-shaped voltage excitation. The following two options a) and b) are permissible, which are carried out three times per algebraic sign direction starting from the initial state defined above. The measuring duration is 1 min from the voltage excitation. The measurement shall be started at least 10 s before the voltage excitation. Table 30 outlines the examination procedure.</p> <p><b>Table 30- Individual steps for testing the dynamics of the <math>Q(U)</math> regulation</b></p> <table border="1"> <thead> <tr> <th>Test</th> <th>Expected PGU behaviour</th> <th>Change of voltage (Measuring duration: at least 10 s advance before excitation, at least 1 min after excitation)</th> </tr> </thead> <tbody> <tr> <td colspan="3">Starting up the initial state, <math>Q_{PGU} = 0</math></td> </tr> <tr> <td>1a</td> <td>Inductive <math>\Delta Q</math></td> <td>Voltage increase by <math>\Delta U_{ind,y}</math></td> </tr> <tr> <td>1b</td> <td>Capacitive <math>\Delta Q</math></td> <td>Reversing the voltage increase <math>\Delta U_{ind,y}</math></td> </tr> <tr> <td>2a</td> <td>Inductive <math>\Delta Q</math></td> <td>Voltage increase by <math>\Delta U_{ind,y}</math></td> </tr> <tr> <td>2b</td> <td>Capacitive <math>\Delta Q</math></td> <td>Reversing the voltage increase <math>\Delta U_{ind,y}</math></td> </tr> <tr> <td>3a</td> <td>inductive <math>\Delta Q</math></td> <td>Voltage increase by <math>\Delta U_{ind,y}</math></td> </tr> <tr> <td>3b</td> <td>Capacitive <math>\Delta Q</math></td> <td>Reversing the voltage increase <math>\Delta U_{ind,y}</math></td> </tr> <tr> <td>4a</td> <td>Capacitive <math>\Delta Q</math></td> <td>Voltage decrease by <math>\Delta U_{kap,y}</math></td> </tr> <tr> <td>4b</td> <td>inductive <math>\Delta Q</math></td> <td>Reversing the voltage decrease <math>\Delta U_{kap,y}</math></td> </tr> <tr> <td>5a</td> <td>Capacitive <math>\Delta Q</math></td> <td>Voltage decrease by <math>\Delta U_{kap,y}</math></td> </tr> <tr> <td>5b</td> <td>inductive <math>\Delta Q</math></td> <td>Reversing the voltage decrease <math>\Delta U_{kap,y}</math></td> </tr> <tr> <td>6a</td> <td>Capacitive <math>\Delta Q</math></td> <td>Voltage decrease by <math>\Delta U_{kap,y}</math></td> </tr> <tr> <td>6b</td> <td>inductive <math>\Delta Q</math></td> <td>Reversing the voltage decrease <math>\Delta U_{kap,y}</math></td> </tr> </tbody> </table>	Test	Expected PGU behaviour	Change of voltage (Measuring duration: at least 10 s advance before excitation, at least 1 min after excitation)	Starting up the initial state, $Q_{PGU} = 0$			1a	Inductive $\Delta Q$	Voltage increase by $\Delta U_{ind,y}$	1b	Capacitive $\Delta Q$	Reversing the voltage increase $\Delta U_{ind,y}$	2a	Inductive $\Delta Q$	Voltage increase by $\Delta U_{ind,y}$	2b	Capacitive $\Delta Q$	Reversing the voltage increase $\Delta U_{ind,y}$	3a	inductive $\Delta Q$	Voltage increase by $\Delta U_{ind,y}$	3b	Capacitive $\Delta Q$	Reversing the voltage increase $\Delta U_{ind,y}$	4a	Capacitive $\Delta Q$	Voltage decrease by $\Delta U_{kap,y}$	4b	inductive $\Delta Q$	Reversing the voltage decrease $\Delta U_{kap,y}$	5a	Capacitive $\Delta Q$	Voltage decrease by $\Delta U_{kap,y}$	5b	inductive $\Delta Q$	Reversing the voltage decrease $\Delta U_{kap,y}$	6a	Capacitive $\Delta Q$	Voltage decrease by $\Delta U_{kap,y}$	6b	inductive $\Delta Q$	Reversing the voltage decrease $\Delta U_{kap,y}$	(see appended table)	N/A
Test	Expected PGU behaviour	Change of voltage (Measuring duration: at least 10 s advance before excitation, at least 1 min after excitation)																																											
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	<p>The voltage applied to the PGU <math>U_{PGU}</math> and the reactive power provided by it in the positive sequence <math>Q_{PGU}</math> are recorded in the form of sliding 200 ms averages with correct algebraic signs. The voltages shall be set with a maximum deviation of <math>\pm 0.25\% U_n</math>.</p>		N/A																																										
5.4.8.4.3	Evaluation criteria for the accuracy of the $Q(U)$ regulation		N/A																																										
	<p>To pass the test for the accuracy of the <math>Q(U)</math> regulation, the measured stationary value pairs <math>U_{PGU}</math> and <math>Q_{PGU}</math> must lie on the <math>Q(U)</math> characteristic curve shown in VDE-AR-N 4105:2018-11, 5.7.2.4, Figure 7, while observing the correct counting arrow system. The stationary value pairs <math>U_{PGU}</math> and <math>Q_{PGU}</math> are determined by 30-second moving averaging at the end of the respective measuring section analogous to 5.4.3.2. The permissible deviations are with the maximum measuring error of the voltage of 1% <math>U_n</math> and a setting accuracy of 4% <math>P_{E_{max}}</math> as specified in VDE-AR-N 4105:2018-11</p>		N/A																																										
5.4.8.4.4	Dynamics evaluation criteria of the $Q(U)$ regulation		N/A																																										

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Clause	Requirement - Test	Result - Remark	Verdict
	In order to pass the dynamics test of the $Q(U)$ regulation, the measured reactive power curves over time in the positive sequence $Q_{PGU}$ must be within the tolerances similar to PT1 according to the formulae in Table 31 during the entire measurement period. In addition to compliance with the tolerances, for each of the tests 1b, 2b, 3b, 4b, 5b and 6b the final stationary reactive power value $Q_{setpoint}$ within the tolerance of $\pm 4\%$ $P_{E_{max}}$ around the start value $Q_{start}$ of the initial state.		N/A
5.4.8.4.5	Documentation		N/A
	For each voltage change in test 5.4.8.4.1 shall be specified in tabular form: <ul style="list-style-type: none"> <li>– Start value and stationary end value of the reactive power in the positive sequence of the PGU;</li> <li>– Start value and stationary end value of the voltage at the PGU.</li> </ul>		N/A
	All measuring points are to be visualized with the characteristic curve set in the inverter in a voltage reactive power diagram.		N/A
	The grid backup reactance $X_{grid}$ used and the recalculation factor shall be documented. For each step response measurement from test 5.4.8.4.2 a) or b), a table shall be recorded: <ul style="list-style-type: none"> <li>– the start value <math>Q_{start}</math> and the stationary end value of the reactive power <math>Q_{setpoint}</math> in the positive sequence;</li> <li>– the parameterized response time <math>T</math>;</li> <li>– the measured and converted response time <math>T_{mess}</math>,</li> <li>– the assessment of compliance with the tolerance band.</li> </ul> In addition, a step response with expected inductive $\Delta Q$ and expected capacitive $\Delta Q$ is shown in a diagram in comparison to VDE-AR-N 4105:2018-11, 5.7.2.5, Figure 10, including the tolerance bands.		N/A
<b>5.5</b>	<b>Proof of NS protection</b>		P
5.5.1	General		P
	The sections from X to Y represent the test requirements for issuing the certificate (according to E.6) of NS protection for VDE-AR-N 4105:2018:11,6.1.		P
5.5.2	NS protection		P
	Testing for fault detection with subsequent shutdown is carried out by fault simulation, if necessary with additional fault tests (see VDE-AR-N 4105:2018-11, 6.1).		P
5.5.2.1	Tests		P
	It must be checked that a single fault does not lead to the loss of the safety function.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	<p>Typical faults are to be checked, if applicable:</p> <ul style="list-style-type: none"> <li>a) Fault of an AD converter or measuring card for voltage measurement;</li> <li>b) Malfunction or freezing of a microprocessor or PLC;</li> <li>c) Fusing or jamming of the contacts of the switching output;</li> <li>d) Overvoltage of the supply voltage;</li> <li>e) Line break in connecting lines between measuring input and control output to the interface switch;</li> <li>f) Failure of the supply voltage (auxiliary voltage).</li> </ul>		P
5.5.2.2	Evaluation criteria		P
	<p>The NS protection must send a shutdown command to the interface switch.</p> <p>If the faults a) to e) are detected, the system is switched off within 10 s after fault detection.</p> <p>In case of failure of the auxiliary voltage at the central NS protection or in case of failure of the controls at the integral NS protection, the tripping command must be instantaneous.</p>		P
5.5.3	Central NS protection	Integrated NS protection.	N/A
5.5.3.1	Tests		N/A
	<p>The following tests shall be carried out in sequence:</p> <ul style="list-style-type: none"> <li>– The auxiliary voltage of the NS protection is switched off.</li> <li>– The test device on the NS protection is actuated.</li> </ul>		N/A
5.5.3.2	Evaluation criteria		N/A
	The test is considered to have been passed if a signal for instantaneous shutdown is generated.		N/A
5.5.4	Integrated NS protection	(see appended table)	P
	The test of the integrated NS protection is carried out in 5.5.7 and in connection with the test of the overall effect chain NS protection – interface switch.		P
5.5.5	Documentation		P
	At least the following should be documented:		P
	<ul style="list-style-type: none"> <li>– the fault simulation and/or fault tests carried out and the result;</li> <li>– the type of NS protection (central or integrated);</li> <li>– whether the signal for instantaneous tripping has been generated;</li> <li>– The manufacturer's documentation of the interface of the PGU or interface switch must be checked.</li> </ul>		P
5.5.6	Interface switch		P
5.5.6.1	General		P
	These tests serve to meet the requirements of VDE-AR-N 4100:2019-04, 6.4.		P
5.5.6.2	Documentation for designing the central interface switch		P
5.5.6.2.1	Tests		P

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Clause	Requirement - Test	Result - Remark	Verdict
	For the design of a central interface switch some information of the central NS protection and the PGU are necessary. The manufacturer's documentation must therefore contain the following information: <ul style="list-style-type: none"> <li>– the maximum proper time of the central interface switch (manufacturer NS protection);</li> <li>– the proper time of the protection device (manufacturer NS protection);</li> <li>– the maximum initial short-circuits AC current (manufacturer PGU);</li> <li>– the maximum back-up fuse (manufacturer PGU).</li> </ul> The circuit diagram/terminal diagram (NS protection, interface switch) contains the required control and feedback signals (manufacturer NS protection).		P
5.5.6.2.2	Evaluation criteria		P
	The test is passed if the manufacturer's documentation contains the information required in 5.5.6.2.1.		P
5.5.6.2.3	Documentation		P
	The review of the manufacturer's documentation shall be documented.		P
5.5.6.3	Integrated interface switch		P
	When combining an integrated interface switch and integrated NS protection, the entire chain of action must be checked. The PGU must be connected to the grid.		P
5.5.6.3.1	Tests		P
	A visual inspection must be carried out to check whether a galvanic switching device is present.		P
	The manufacturer's documentation must be checked for information on the proper time of the integrated interface switch.		P
5.5.6.3.2	Evaluation Criteria		P
	The galvanic switching device is available.		P
	The breaking capacity of the interface switch must be sufficient for the PGU.		P
5.5.6.4	Documentation		P
	The result shall be recorded in tabular form or with reference to DIN EN 62109-1 (VDE 0126-14-1).		P
	At least the following should be documented: <ul style="list-style-type: none"> <li>– the simulated faults and their effects;</li> <li>– the breaking capacity of the interface switch;</li> <li>– the proper time of the interface switch;</li> <li>– the shutdown time of the overall effect chain;</li> <li>– the maximum initial short-circuiting AC current of the generating unit.</li> </ul>		P
5.5.7	Protective devices and protection settings		P
5.5.7.1	General		P
	These tests serve to meet the requirements of VDE-AR-N 4100:2019-04, 6.5.1 and 6.5.2.		P

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Clause	Requirement - Test	Result - Remark	Verdict																																																																																																																																																																																																							
	The voltage and frequency generators used and the measuring chain for voltage and frequency measurement shall be such that the accuracy required by the assessment criteria can be demonstrated beyond doubt within the specified tolerances.		P																																																																																																																																																																																																							
	The measurement of an integrated NS protection is performed on a grid simulator. The measurement of a central NS protection or an internal NS protection with test terminal strip is carried out with a relay test device or on a grid simulator. For single-phase PGU, single-phase measurements are permitted.		P																																																																																																																																																																																																							
5.5.7.2	Adjustment of the setting values		P																																																																																																																																																																																																							
5.5.7.2.1	Tests		P																																																																																																																																																																																																							
	In the case of central NS protection, it must also be checked whether the other data records from Table 36 can be set in setting value and delay time.		P																																																																																																																																																																																																							
	<p><b>Table 36- Setting values for testing voltage monitoring and frequency monitoring</b></p> <table border="1"> <thead> <tr> <th>PGU type</th> <th>Description</th> <th>Parameter name</th> <th>Setting value in pu</th> <th>Setting value L-N</th> <th>Setting value L-L *b</th> </tr> </thead> <tbody> <tr> <td rowspan="14">Stirling generators, fuel cells, synchronous and asynchronous generators coupled directly or via converters with <math>P_{N} \leq 50</math> kW</td> <td>Nominal voltage</td> <td><math>U_n</math></td> <td>1</td> <td>230 V</td> <td>400 V</td> </tr> <tr> <td>Nominal frequency</td> <td><math>F_n</math></td> <td>1</td> <td>50 Hz</td> <td>50 Hz</td> </tr> <tr> <td>Excitation threshold <math>U_{&gt;&gt;}</math></td> <td><math>AU_{&gt;&gt;}</math></td> <td>1.15</td> <td>264,5 V</td> <td>460 V</td> </tr> <tr> <td>Delay time <math>U_{&gt;&gt;}</math></td> <td><math>IU_{&gt;&gt;}</math></td> <td>-</td> <td>100 ms</td> <td>100 ms</td> </tr> <tr> <td>Excitation threshold 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pu	Setting value L-N	Setting value L-L *b	Stirling generators, fuel cells, synchronous and asynchronous generators coupled directly or via converters with $P_{N} \leq 50$ kW	Nominal voltage	$U_n$	1	230 V	400 V	Nominal frequency	$F_n$	1	50 Hz	50 Hz	Excitation threshold $U_{>>}$	$AU_{>>}$	1.15	264,5 V	460 V	Delay time $U_{>>}$	$IU_{>>}$	-	100 ms	100 ms	Excitation threshold $U_{>}$	$AU_{>}$	1.10	253 V	440 V	Delay time $U_{>}$ <sup>a</sup>	$IU_{>}$	-	100 ms *	100 ms *	Excitation threshold $U_{<}$	$AU_{<}$	0.8	184,0 V	320 V	Delay time $U_{<}$	$IU_{<}$	-	100 ms	100 ms	Excitation threshold $U_{<<}$	$AU_{<<}$	deactivated	-	-	Delay time $U_{<<}$	$IU_{<<}$	deactivated	-	-	Excitation threshold $f_{>}$	$Af_{>}$	1.03	51.5 Hz	51.5 Hz	Delay time $f_{>}$	$Tf_{>}$	-	100 ms	100 ms	Excitation threshold $f_{>}$	$Af_{<}$	0.95	47.5 Hz	47.5 Hz	Delay time $f_{>}$	$Tf_{<}$	-	100 ms	100 ms	Directly coupled synchronous and asynchronous generators with $P_{N} > 50$ kW	Excitation threshold $U_{>>}$	$AU_{>>}$	1.25	287,5 V	500 V	Delay time $U_{>>}$	$IU_{>>}$	-	100 ms	100 ms	Excitation threshold $U_{>}$	$AU_{>}$	1.10	253 V	440 V	Delay time $U_{>}$ <sup>a</sup>	$IU_{>}$	-	100 ms *	100 ms *	Excitation threshold $U_{<<}$	$AU_{<<}$	0.8	184 V	320 V	Delay time $U_{<<}$	$IU_{<<}$	-	1 s	1 s	Excitation threshold $U_{<<}$	$AU_{<<}$	0.45	103,5 V	180 V	Delay time $U_{<<}$	$IU_{<<}$	-	300 ms	300 ms	Excitation threshold $f_{>}$	$Af_{>}$	1.03	51.5 Hz	51.5 Hz	Delay time $f_{>}$	$Tf_{>}$	-	100 ms	100 ms	Excitation threshold $f_{<}$	$Af_{<}$	0.95	47.5 Hz	47.5 Hz	Delay time $f_{<}$	$Tf_{<}$	-	100 ms	100 ms	Inverters	Excitation threshold $U_{>>}$	$AU_{>>}$	1.25	287,5 V	500 V	Delay time $U_{>>}$	$IU_{>>}$	-	100 ms	100 ms	Excitation threshold $U_{>}$	$AU_{>}$	1.10	253 V	440 V	Delay time $U_{>}$ <sup>a</sup>	$IU_{>}$	-	100 ms *	100 ms *	Excitation threshold $U_{<}$	$AU_{<}$	0.8	184 V	320 V	Delay time $U_{<}$	$IU_{<}$	-	3s	3s	Excitation threshold $U_{<<}$	$AU_{<<}$	0.45	103,5 V	180 V	Delay time $U_{<<}$	$IU_{<<}$	-	300 ms	300 ms	Excitation threshold $f_{>}$	$Af_{>}$	1.03	51.5 Hz	51.5 Hz	Delay time $f_{>}$	$Tf_{>}$	-	100 ms	100 ms	Excitation threshold $f_{<}$	$Af_{<}$	0.95	47.5 Hz	47.5 Hz	Delay time $f_{<}$	$Tf_{<}$	-	100 ms	100 ms	(see appended table)	P
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		If the test object is a central NS protection, the reading must be taken without auxiliary means on the device.		N/A																																																																																																																																																																																																						
		If the test object is an integrated NS protection, either the device display or a data interface must be used to read the setting values. If software is required for this purpose, the manufacturer must make it available for the purpose of testing.		P																																																																																																																																																																																																						

DIN VDE V 0124-100															
Clause	Requirement - Test	Result - Remark	Verdict												
	Furthermore, it must be checked whether the limit value for $U>$ can be set between 110% and 115% and whether it is adjustable for directly coupled synchronous and asynchronous generators with $P_{TE} > 50$ kW whether the time delays for $U<$ and $U\ll$ are adjustable. All other limit values must be protected against unauthorized access.		P												
5.5.7.2.2	Evaluation criteria		P												
	<ul style="list-style-type: none"> <li>– The factory settings correspond to:               <ul style="list-style-type: none"> <li>a) with integrated NS protection of VDE-AR-N 4105:2018-11, 6.5.2 Table 2 (see also Table 36).</li> <li>b) with central NS protection either the factory settings according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2 (see also Table 36) or these values can be set.</li> </ul> </li> <li>– In the case of operator input, the test object does not go into operation until settings have been selected.</li> <li>– The setting values which can be changed in accordance with VDE-AR-N 4105:2018-11, 6.5.1 and 6.5.2 can be set within the specified limits and are protected against unauthorised access.</li> <li>– The setting values which cannot be changed according to VDE-AR-N 4105:2018-11, 6.5.1 and 6.5.2 are either not changeable or are protected against unauthorized access by an additional separate protection.</li> </ul>		P												
5.5.7.2.3	Documentation		P												
	It must be documented which values are set in the test object. If a predefined parameter set is selected, the name of the parameter set must also be documented.		P												
	Due to the technical implementation in the test object, there may be deviations between the setting values of the test object to be documented and the actually effective values according to Table 36 (example: Device does not allow separate setting of the phase-to-phase voltages; it only accepts referred values)		P												
	The method of protection of the adjustable settings shall be described. The type of protection of the non-adjustable settings shall be described.		P												
5.5.7.3	Wiring test		P												
5.5.7.3.1	Tests		P												
	<p>The wiring of the test object must be checked by applying the test voltages according to Table 37. For single-phase PGU, the wiring test is adapted, only the feed phase is to be evaluated.</p> <p style="text-align: center;"><b>Table 37 - Wiring test voltage monitoring and frequency monitoring</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td style="text-align: center;">U L1-E</td> <td style="text-align: center;">219.4 V</td> <td style="text-align: center;">0°</td> <td style="text-align: center;">50 Hz</td> </tr> <tr> <td style="text-align: center;">U L2-E</td> <td style="text-align: center;">230.9 V</td> <td style="text-align: center;">-120°</td> <td style="text-align: center;">50 Hz</td> </tr> <tr> <td style="text-align: center;">U L3-E</td> <td style="text-align: center;">242.5 V</td> <td style="text-align: center;">120°</td> <td style="text-align: center;">50 Hz</td> </tr> </tbody> </table>	U L1-E	219.4 V	0°	50 Hz	U L2-E	230.9 V	-120°	50 Hz	U L3-E	242.5 V	120°	50 Hz		P
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	<p>Subsequently, it must be checked by applying the test voltages according to Table 38 that the test object correctly evaluates phase-to-phase voltages and phase-to-neutral voltages. This test step is not applicable to single-phase PGU.</p> <p><b>Table 38- Check voltage reference Voltage monitoring and frequency monitoring</b></p> <table border="1"> <tr> <td>U L1-E</td> <td>0.0 V</td> <td>0.00°</td> <td>50 Hz</td> </tr> <tr> <td>U L2-E</td> <td>230.9 V</td> <td>150.00°</td> <td>50 Hz</td> </tr> <tr> <td>U L3-E</td> <td>230.9 V</td> <td>-150.00°</td> <td>50 Hz</td> </tr> </table>	U L1-E	0.0 V	0.00°	50 Hz	U L2-E	230.9 V	150.00°	50 Hz	U L3-E	230.9 V	-150.00°	50 Hz		P																																				
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5.5.7.3.2	Evaluation criteria		P																																																
	This test will not be evaluated. If a phase rotation is detected, it shall be corrected and the test repeated.		P																																																
5.5.7.3.3	Documentation		P																																																
	The set voltage and the voltage read on the NS protection must be documented.		P																																																
5.5.7.4	Voltage monitoring and frequency monitoring NS protection		P																																																
5.5.7.4.1	Tests		P																																																
	For a single-phase PGU only the feed-in phase needs to be tested. For stirling generators, fuel cells and synchronous or asynchronous generators ≤ 50 kW the test steps for $U_{<<}$ do not have to be carried out.		P																																																
	Before each test step, the PGU must be operated symmetrically with nominal voltage and nominal frequency in feed mode for at least 10 s. With external NS protection, the nominal voltage and nominal frequency must be applied symmetrically for at least 10 s. For the test steps for $U_{>}$ , the NS protection must be operated with the starting voltage for at least 600 s before each test step, see Figure 10.		P																																																
	With PGU, the test $f_{>}$ and $f_{<}$ may be affected by the $P(f)$ function. This is especially the case with the random over-frequency shutdown of non-adjustable PGU. In these cases the $P(f)$ function must be deactivated.		P																																																
	<p>The following tests must be carried out in each case:</p> <p><b>Table 39- Checking the voltage monitoring and frequency monitoring (1 of 3)</b></p> <table border="1"> <thead> <tr> <th>Test step</th> <th>Size</th> <th>Ramp, Jump</th> <th>Apply to</th> <th>Start</th> <th>End</th> <th>Jump height <math>\Delta U, \Delta f</math></th> <th>Step length <math>\Delta t</math></th> </tr> </thead> <tbody> <tr> <td>1.1</td> <td><math>U_{&gt;&gt;}</math></td> <td>Ramp</td> <td><math>U_{L1-N^c} U_{L2-N^c} U_{L3-N^c}</math></td> <td>&lt;282.9 V &lt;259.9 V</td> <td>&gt;292.1 V &gt;269.1 V</td> <td>&lt; 1.15 V</td> <td>&gt; 400 ms</td> </tr> <tr> <td>1.2<sup>a</sup></td> <td><math>U_{&gt;&gt;}</math></td> <td>Ramp</td> <td><math>U_{L1-N^c}</math></td> <td>&lt;282.9 V &lt;259.9 V</td> <td>&gt;292.1 V &gt;269.1 V</td> <td>&lt; 1.15 V</td> <td>&gt; 400 ms</td> </tr> <tr> <td>1.3<sup>a</sup></td> <td><math>U_{&gt;&gt;}</math></td> <td>Ramp</td> <td><math>U_{L2-N^c}</math></td> <td>&lt;282.9 V &lt; 259.9 V</td> <td>&gt;292.1 V &gt;269.1 V</td> <td>&lt; 1.15 V</td> <td>&gt; 400 ms</td> </tr> <tr> <td>1.4<sup>a</sup></td> <td><math>U_{&gt;&gt;}</math></td> <td>Ramp</td> <td><math>U_{L3-N^c}</math></td> <td>&lt;282.9 V &lt;259.9 V</td> <td>&gt;292.1 V &gt;269.1 V</td> <td>&lt; 1.15 V</td> <td>&gt; 400 ms</td> </tr> <tr> <td>1.5<sup>b</sup></td> <td><math>U_{&gt;&gt;}</math></td> <td>Ramp</td> <td><math>U_{L1+L2^c}</math></td> <td>&lt;492.0 V &lt;452.0 V</td> <td>&gt;508.0 V &gt;468.0 V</td> <td>&lt; 2.0 V</td> <td>&gt; 400 ms</td> </tr> </tbody> </table>	Test step	Size	Ramp, Jump	Apply to	Start	End	Jump height $\Delta U, \Delta f$	Step length $\Delta t$	1.1	$U_{>>}$	Ramp	$U_{L1-N^c} U_{L2-N^c} U_{L3-N^c}$	<282.9 V <259.9 V	>292.1 V >269.1 V	< 1.15 V	> 400 ms	1.2 <sup>a</sup>	$U_{>>}$	Ramp	$U_{L1-N^c}$	<282.9 V <259.9 V	>292.1 V >269.1 V	< 1.15 V	> 400 ms	1.3 <sup>a</sup>	$U_{>>}$	Ramp	$U_{L2-N^c}$	<282.9 V < 259.9 V	>292.1 V >269.1 V	< 1.15 V	> 400 ms	1.4 <sup>a</sup>	$U_{>>}$	Ramp	$U_{L3-N^c}$	<282.9 V <259.9 V	>292.1 V >269.1 V	< 1.15 V	> 400 ms	1.5 <sup>b</sup>	$U_{>>}$	Ramp	$U_{L1+L2^c}$	<492.0 V <452.0 V	>508.0 V >468.0 V	< 2.0 V	> 400 ms	(see appended table)	P
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Clause	Requirement - Test	Result - Remark	Verdict																																																																																																																																																																																																																																																
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It must be ensured that no voltage other than the voltage to be tested exceeds one of the set and active limit values. For these test steps, a zero-system free voltage system according to FRT fault type D as shown in Figure A.1 may be used.</p> <p>b. These test steps are only to be carried out for PGU &gt; 30 kVA and for central NA protective devices. If the outer conductor voltages are monitored at an PGU &lt; 30 kVA, these test steps must also be applied. It must be ensured that no voltage other than the voltage to be tested exceeds one of the set and active limit values. For these test steps, a zero-system free voltage system according to FRT-fault type C as shown in Figure A.1 may be used.</p> <p>c. For Stirling generators, fuel cells and synchronous or asynchronous generators ≤ 50 kW the lower voltages apply.</p>	Test step	Size	Ramp, jump	Apply to	Start	End	Jump height $\Delta U, \Delta f$	Step length $\Delta t$	6.4 <sup>a</sup>	U<<	Ramp	$U_{L3-N}$	> 108.1 V	< 98.9 V	< 1.15 V	> 500 ms	6.5 <sup>b</sup>	U<<	Ramp	$U_{L1-L2}$	> 188.0 V	< 172.0 V	< 1.15 V	> 500 ms	6.6 <sup>b</sup>	U<<	Ramp	$U_{L2-L3}$	> 188.0 V	< 172.0 V	< 1.15 V	> 500 ms	6.7 <sup>b</sup>	U<<	Ramp	$U_{L3-L1}$	> 188.0 V	< 172.0 V	< 1.15 V	> 500 ms	7.1	U<<	Jump	$U_{L1-N}U_{L2-N}U_{L3-N}$	> 108.1 V	<98.9 V	> 9.2 V	> 500 ms	7.2 <sup>a</sup>	U<<	Jump	$U_{L1-N}$	> 108.1 V	< 98.9 V	>9.2 V	> 500 ms	7.3 <sup>a</sup>	U<<	Jump	$U_{L2-N}$	> 108.1 V	<98.9 V	> 9.2 V	> 500 ms	7.4 <sup>a</sup>	U<<	Jump	$U_{L3-N}$	> 108.1 V	<98.9 V	> 9.2 V	> 500 ms	7.5 <sup>b</sup>	U<<	Jump	$U_{L1-L2}$	> 188.0 V	< 172.0 V	> 16.0 V	> 500 ms	7.6 <sup>b</sup>	U<<	Jump	$U_{L2-L3}$	> 188.0 V	< 172.0 V	> 16.0 V	> 500 ms	7.7 <sup>b</sup>	U<<	Jump	$U_{L3-L1}$	> 188.0 V	< 172.0 V	> 16.0 V	> 500 ms	8.1	f>	Ramp	$f_{grid}$	<51.4 Hz	>51.6 Hz	< 25 mHz	> 400 ms	9.1	f>	Jump	$f_{grid}$	<51.4 Hz	>51.6 Hz	> 0.2 Hz	> 400 ms	10.1	f<	Ramp	$f_{grid}$	>47.6	< 47.4 Hz	< 25 mHz	> 400 ms	11.1	f<	Jump	$f_{grid}$	>47.6	< 47.4 Hz	> 0.2 Hz	> 400 ms		P																																																																																																																
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5.5.7.4.2	Evaluation criteria		P																																																																																																																																																																																																																																																
	The test is passed if points a) to h) are fulfilled:		P																																																																																																																																																																																																																																																
	a) Test steps 1.1 to 1.7, 4.1 to 4.7, 6.1 to 6.7, 8.1 and 10.1. These tests have been passed if the permissible tolerances between the setting value according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2 and the trigger value are max ± 1% $U_n$ for the voltage and max ± 1% $f_n$ for the frequency. For synchronous and asynchronous generators coupled directly or via converters with $P_{rE} \leq 50$ kW as well as for Stirling generators and fuel cells, shutdown at $U >$ already at 0.85% $U_n$ is permissible.		P																																																																																																																																																																																																																																																

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	b) Test steps 2.1 to 2.7, 5.1 to 5.7, 9.1 and 11.1. These tests are passed if the tripping time after application of the jump is within the specifications according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2.		P
	c) For criteria (a) and (b) it is ensured that no voltage other than the voltage under test exceeds any of the set and active limits.		P
	d) Test step 3.1: The test is passed if the shutdown occurs between 450 s and 550 s after the jump, see Figure 11.		P
	e) Test step 3.2: The test is passed if no shutdown has occurred after 600 s, see Figure 11.		P
	f) Test step 3.3: The test is passed if the shutdown occurs between 225 s and 375 s after the jump, see Figure 11.		P
	g) Test steps 5.1 to 5.7: The test has been passed for Stirling generators, fuel cells and synchronous or asynchronous generators $\leq 50$ kW, if the shutdown is performed within 200 ms after the jump has been applied. For directly coupled synchronous or asynchronous generators $> 50$ kW, the test is passed if the shutdown occurred within a range between 1.0 s and 1.1 s. For converters, the test is passed if the shutdown occurred within a range between 3.0 s and 3.1 s.		P
	h) Test steps 7.1 to 7.7: The test has been passed if the shutdown occurs within between 300 ms and 400 ms after the jump is applied.		P
5.5.7.4.3	Documentation		P
	The following values shall be given for each test step:		P
	Target value, actual value, permissible tolerances, the difference between actual value and target value and an assessment of whether the test was passed, failed or not evaluated.		P
	It must also be specified whether the triggering signal of the interface switch or the opening of the interface switch has been evaluated for time determination.		P
	If the triggering signal of the interface switch has been evaluated, the maximum time remaining available for the interface switch's proper time must be specified. In the case of internal NS protection, the actual proper time of the interface switch used must also be indicated.		P
5.5.7.5	Reading the fault messages		P
5.5.7.5.1	Tests		P
	At least the last 5 fault messages must be read out at the PGU or the external NS protection. Then the supply voltage must be interrupted for 3 s. Then the fault messages must be read out again.		P
5.5.7.5.2	Evaluation criteria		P
	The test is passed if at least the last 5 fault messages can be read out and the chronological sequence can be traced by a time stamp. The fault messages must not be lost after the voltage interruption.		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
5.5.7.5.3	Documentation		P
	At least the last 5 fault messages including time stamps recorded before the voltage interruption and at least 5 fault messages including time stamps recorded after the power interruption shall be documented.		P
5.5.9	Structural features of NS protection		P
5.5.9.1	General		P
	These tests serve to meet the requirements of VDE-AR-N 4100:2019-04, 6.5.2.		P
5.5.9.2	Test		P
	It should be checked whether the NS protection is provided with protection against unauthorised access, e.g.:		P
	<ul style="list-style-type: none"> <li>– NS protection, sealable: by visual inspection, or</li> <li>– NS protection, password-protected: testing, on the basis of the manufacturer's specifications, or</li> <li>– other appropriate measures.</li> </ul>		P
	<p>The adjustability of the protection functions must also be checked. The following test must be carried out for the integrated NS protection:</p> <ul style="list-style-type: none"> <li>– It must be checked whether <math>U&gt;</math>, or, in the case of directly coupled synchronous and asynchronous machines with <math>P_n &gt; 50</math> kW, the time delay for <math>U &lt;</math> and <math>U \ll</math> can also be set.</li> <li>– It must be checked whether all other protective functions described in VDE-AR-N 4105:2018-11, 6.5, are either fixed or protected by an additional, separate protection against unauthorized access.</li> </ul>		P
	<p>For the central NS protection, the following test must be carried out:</p> <ul style="list-style-type: none"> <li>– It must be checked whether <math>U &gt;</math> and the time delay for <math>U &lt;</math> and <math>U \ll</math> can be set.</li> <li>– It must be checked whether all other protective functions described in VDE-AR-N 4105:2018-11, 6.5, are either fixed or protected by an additional, separate protection against unauthorized access.</li> </ul> <p>NOTE Since it is not clear which PGU is protected by an external NS protection when testing it, it must be possible to adjust the setting of <math>U &gt;</math> and the time delay for <math>U &lt;</math> and <math>U \ll</math>.</p>		N/A
5.5.9.3	Documentation		P
	<p>At least the following should be documented:</p> <ul style="list-style-type: none"> <li>– the type and form of protection (central/integrated);</li> <li>– Adjustability <math>U &gt;</math> and the time delays for <math>U &lt;</math> and <math>U \ll</math>;</li> <li>– whether all other protection functions are either fixed or protected by an additional, separate protection against unauthorized access.</li> </ul>		P
5.5.10	Islanding detection		P
5.5.10.1	Active procedure		P
	These tests serve to meet the requirements of VDE-AR-N 4100:2019-04, 6.5.3.	see appended table)	P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	The maximum shutdown time is 9 s.		P
5.5.10.2	Passive procedure		P
	The passive procedure is realized by the voltage increase and voltage decrease protection of the NS protection.		P
5.5.10.3	Active procedure		P
5.5.10.4	Tests		P
	The test circuit switches $S_1$ and $S_2$ refer to the test setup in DIN EN 62116 (VDE 0126-2). The active procedure for island grid detection is tested according to DIN EN 62116 (VDE 0126-2).		P
	According to DIN EN 62116 (VDE 0126-2) the averaging times depend on the island detection algorithm used.		Info.
5.5.10.5	Documentation		P
	At least the following should be documented: – the island grid detection procedure; – when using a procedure according to DIN EN 62116 (VDE 0126-2), the test report according to DIN EN 62116 (VDE 0126-2) must be submitted.		P
<b>5.6</b>	<b>Connection conditions and synchronisation</b>		P
	These tests serve to meet the requirements of VDE-AR-N 4100:2019-04, 8.3.		P
5.6.1	General		P
	Connection and synchronization are carried out or monitored by at least one suitable device. This device can be implemented in the control unit of the PGU, in the integrated NS protection or in the central NS protection and must be set according to VDE-AR-N 4105:2018-11, 8.3 and tested as follows:		P
	a) The manufacturer shall provide the testing laboratory with documentation showing which functions are implemented in which component.		P
	b) When PGU is not switched on, the test is carried out by changing the set nominal frequency and nominal voltage in the control unit.		P
	Alternatively, other methods such as grid simulator or a test bench test may be used for verification.	This test was used grid simulator for verification.	P
	After tripping the NS protection, it must be checked that the system can only be switched on within the tolerance bands ( $85\% U_n < U \leq 110\% U_n$ and $47,5 \text{ Hz} \leq f_{is} \leq 50,1 \text{ Hz}$ ) and after voltage and frequency remain within the tolerance bands, after 60 s at the earliest.		P
5.6.2	Tests and evaluation criteria		P
	a) $f_{is} < 47.45 \text{ Hz}$ : no reconnection allowed; b) Change to $f_{is} \geq 47.55 \text{ Hz}$ : Reconnection possible; c) $f_{is} > 50.15 \text{ Hz}$ : no reconnection allowed; d) Change to $f_{is} \leq 50.05 \text{ Hz}$ : Reconnection possible; e) $U_{is} < 84\% U_n$ : no reconnection allowed; f) $U_{is} \geq 86\% U_n$ : Reconnection possible; g) $U_{is} > 111\% U_n$ : no reconnection allowed; h) $U_{is} \leq 109\% U_n$ : Reconnection possible.	(see appended table)	P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	The reconnection time shall be specified by the manufacturer.		P
5.6.3	Test documentation		P
	The set frequencies and voltages and the test result shall be documented.		P
<b>5.7</b>	<b>Proof of <math>P_{AV,E}</math> monitoring</b>		P
5.7.1	General		P
	The test serves to verify that the requirements of VDE-AR-N 4105:2018-11, 5.5.2 are met. The $P_{AV,E}$ monitoring may, but does not have to be integrated in the PGU. If $P_{AV,E}$ monitoring is not built as a unit, but is distributed to several devices, the entire chain of effects must be tested in the same way as the testing of the NS protection, including the communicative coupling.		P
5.7.2	Tests		P
	The test must be carried out at nominal frequency and nominal voltage. If $P_{AV,E}$ monitoring is tested with a real PGU, the primary energy supply must be sufficient for operation at rated power.		P
5.7.2.1	Testing the control dynamics		P
	This test shall be applied if, according to the manufacturer, the feed-in limitation is implemented by a regulation of the PGU.		P
	The PGU with any necessary additional components is installed according to the manufacturer's specifications and parameterised so that the feed-in limitation $P_{AV,E}$ is activated at $\geq 60\% P_{FE}$ . The power jump must be simulated by the omission of a load and, in the case of supply-dependent PGU, additionally by a jump in the primary energy supply.		P
	a) Elimination of the load: The PGU is operated at nominal power. Via a load, which is to be connected symmetrically to all feeding phases parallel to PGU, the power at the grid connection point is set to $P_{AV,E}$ with a tolerance of -2%. At point in time $t_0$ the load is switched off. The loss of load may also be simulated by an appropriate offset on the power measurement signal. The closed control loop must not be opened.		P
	b) Jump in primary energy supply: The primary energy supply is adjusted so that the PGU feeds in the power $P_{AV,E} = 60\% P_{FE}$ with a tolerance of -2%. At point in time $t_0$ the primary energy supply must be increased abruptly so that the PGU can produce the rated output.		P
	The sum of the effective active power values of all 3 phases at the grid connection point must be recorded for at least 15 s from the power jump.		P
5.7.2.2	Testing the shutdown function		N/A

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Clause	Requirement - Test	Result - Remark	Verdict															
	This test shall be applied if, according to the manufacturer, $P_{AV,E}$ monitoring is implemented in the form of a shutdown. The test shall be performed as a primary test. To check the shutdown function, any existing control of the PGU must be deactivated. If, according to the manufacturer's specifications, the feed-in limitation is implemented by a regulation of the PGU, a test according to this section is not necessary.		N/A															
	The following operating points and the trigger signal of $P_{AV,E}$ monitoring must be recorded for at least 15 s each.		N/A															
	The active power must be made available to $P_{AV,E}$ monitoring in a suitable symmetrical form. After each tripping event, the $P_{AV,E}$ monitoring unit must be reset to its initial state. The reconnection time of $P_{AV,E}$ monitoring must be documented.		N/A															
	<p style="text-align: center;"><b>Table 42- Operating point of <math>P_{AV,E}</math> monitoring</b></p> <table border="1"> <thead> <tr> <th>Case</th> <th>Active power at meter location <math>P</math></th> </tr> </thead> <tbody> <tr> <td>a)</td> <td><math>0,98 P_{AV,E}</math></td> </tr> <tr> <td>b)</td> <td><math>1,02 P_{AV,E} - 1,067 P_{AV,E}</math></td> </tr> <tr> <td>c)</td> <td><math>1,067 P_{AV,E} - 1,670 P_{AV,E}</math></td> </tr> <tr> <td>d)</td> <td><math>1,690 P_{AV,E}</math></td> </tr> </tbody> </table>	Case	Active power at meter location $P$	a)	$0,98 P_{AV,E}$	b)	$1,02 P_{AV,E} - 1,067 P_{AV,E}$	c)	$1,067 P_{AV,E} - 1,670 P_{AV,E}$	d)	$1,690 P_{AV,E}$		N/A					
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d)	$1,690 P_{AV,E}$																	
	The measuring tolerance must not exceed 2% of the smallest possible effective power of the area of application. The area of application is defined by the manufacturer. If transducers are used for measurement, they shall have an accuracy of Class 1 or better.		N/A															
	The 200 ms shutdown time already includes the proper time of the PGU switch.		N/A															
	If a separate signal input is used to switch off the PGU by $P_{AV,E}$ monitoring, the shutdown function must be checked separately. The gradient of the active power when the PGU is switched on again must be checked according to the switching conditions in 5.6.		N/A															
5.7.3	Evaluation criteria		N/A															
	The test according to 5.7.2.1 shall be deemed to have been passed if the active power measured at the mains connection point does not exceed the limit curve in VDE-AR-N 4105: 2018-11, 5.5.2, Figure 1.		N/A															
	The test in accordance with 5.7.2.2 is considered to have been passed if in case a) no shutdown has occurred and in cases b), c) and a shutdown after the time $t$ defined in Table 43 has occurred and the reconnection is made in accordance with 5.6.		N/A															
	<p style="text-align: center;"><b>Table 43- Shutdown times for evaluating the measurement results of <math>P_{AV,E}</math> monitoring</b></p> <table border="1"> <thead> <tr> <th>Case</th> <th>Active power <math>P</math></th> <th>Shutdown time <math>t</math></th> </tr> </thead> <tbody> <tr> <td>a)</td> <td><math>0,98 P_{AV,E}</math></td> <td>No shutdown</td> </tr> <tr> <td>b)</td> <td><math>1,02 P_{AV,E} - 1,067 P_{AV,E}</math></td> <td><math>t &lt; 10 \text{ s} + 200 \text{ ms}</math></td> </tr> <tr> <td>c)</td> <td><math>1,067 P_{AV,E} - 1,670 P_{AV,E}</math></td> <td><math>t &lt; 3 \text{ s} + 200 \text{ ms}</math></td> </tr> <tr> <td>d)</td> <td><math>1,690 P_{AV,E}</math></td> <td><math>t &lt; 200 \text{ ms}</math></td> </tr> </tbody> </table>	Case	Active power $P$	Shutdown time $t$	a)	$0,98 P_{AV,E}$	No shutdown	b)	$1,02 P_{AV,E} - 1,067 P_{AV,E}$	$t < 10 \text{ s} + 200 \text{ ms}$	c)	$1,067 P_{AV,E} - 1,670 P_{AV,E}$	$t < 3 \text{ s} + 200 \text{ ms}$	d)	$1,690 P_{AV,E}$	$t < 200 \text{ ms}$		N/A
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d)	$1,690 P_{AV,E}$	$t < 200 \text{ ms}$																
5.7.4	Test documentation		N/A															
	At least the following should be documented: <ul style="list-style-type: none"> <li>– Test procedure;</li> <li>– Offset on the measured power value, if the loss of load was simulated;</li> <li>– tested active power at the meter location;</li> <li>– Recording of the total of the active powers of the phases for tests according to 5.7.2.1;</li> <li>– Shutdown time for tests according to 5.7.2.2;</li> <li>– Reconnection time in case of shutdown.</li> </ul>		N/A															

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Clause	Requirement - Test	Result - Remark	Verdict
<b>5.8</b>	<b>Verification of the dynamic grid support</b>		P
5.8.1	General		P
	These tests serve to meet the requirements of VDE-AR-N 4100:2019-04, 5.7.3.		P
	The aim of these tests is to determine whether the DUT is capable of passing through voltage dips and voltage surges without damage and whether it behaves in accordance with VDE-AR-N 4105:2018-11, 5.7.3. The DUT may be a generating unit (PGU) or a storage system.		P
	The DUT includes:		P
	– the control system and the auxiliary power units including the self-supply installed in the PGU;		P
	– the generator (type 1 or asynchronous generator) or the inverter (type 2 or storage).		P
	The following PGU are excluded from the test:		N/A
	– Stirling generators and fuel cells, which cannot provide dynamic network support due to their principle;		N/A
	– Synchronous and asynchronous generators coupled directly or via converters, with $P_{FE} < = 50$ kW.		N/A
	The passing through of several successive grid faults is not subject of the test. However, the tests listed below can be repeated for any sequence of grid faults with fixed or variable pause time to check the passage of multiple grid faults.		P
5.8.2	Procedure		P
	The DUT is connected to a grid with downstream test equipment (or a grid simulator with downstream grid simulation). This test equipment shall be capable of simulating the corresponding voltage dip(s) on the DUT side as described in the following procedure. Unless stated otherwise, all voltages specified in 5.8 including subsections refer to the conductor-neutral voltages at the PGU terminals. All requirements for the test facilities are listed in Annex A.		P
	The correct parameterisation of the test equipment in order to obtain the respective voltage dips/surges according to Table 17 and Table 18 shall be checked for each test by an open-circuit test (separately symmetrical, asymmetrical). For voltage dips, the value to be set in each case is the respective resulting smallest conductor-neutral conductor voltage related to the nominal value. For voltage surges, the value to be set is the respective resulting maximum conductor-neutral conductor voltage related to the nominal value. The tests shall be started at a voltage in the range of $U_n \pm 5\% U_n$ .		P
	The reference point for the dynamic grid support of the PGU or the storage system are the grid-side connection terminals of the DUT.		P

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Clause	Requirement - Test	Result - Remark	Verdict																																																																																																
	It shall be tested at full load ( $P_{rE} \pm 2\% P_{rE}$ ) as well as in the partial load range from $0.2 P_{rE}$ to $0.6 P_{rE}$ . The reference value is the measured active power as a 10 s average value immediately before the voltage dip/surge.		P																																																																																																
	The FRT tests are carried out with normal pin assignment according to Table 44. In addition, for the unbalanced tests, the lowest voltage drops and the highest voltage surges at full load must be tested again with cyclically exchanged pin assignment according to Table 45.		P																																																																																																
	Single-phase PGU are connected to terminals W and N for fault pattern D1. For fault pattern D2, the connection is made to terminals V and N.  Table 44- Normal pin assignment (fault type D1) for testing dynamic grid support <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>Test facility</th> <th>Test object</th> </tr> </thead> <tbody> <tr> <td>U</td> <td>L1</td> </tr> <tr> <td>V</td> <td>L2</td> </tr> <tr> <td>W</td> <td>L3</td> </tr> </tbody> </table> Table 45- Cyclically exchanged pin assignment (fault type D2) for testing dynamic grid support <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>Test facility</th> <th>Test object</th> </tr> </thead> <tbody> <tr> <td>U</td> <td>L3</td> </tr> <tr> <td>V</td> <td>L1</td> </tr> <tr> <td>W</td> <td>L2</td> </tr> </tbody> </table>	Test facility	Test object	U	L1	V	L2	W	L3	Test facility	Test object	U	L3	V	L1	W	L2		P																																																																																
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	Recording must start at least 10 s before the fault occurs. After fault clearance (voltage in the range of $0.85 U_n < U < 1.1 U_n$ ) the recording must continue to run for at least another 60 s.		P																																																																																																
	With two successive test runs per test, the grid fault must be completely run through for the test to be passed.		P																																																																																																
	A direct temporal connection between the test and the repeat test is not required by the standard if the accredited testing laboratory ensures and confirms that the PGU has not been changed in hardware or software between the test and the repeat test.		P																																																																																																
5.8.3	Tests		P																																																																																																
	For PGU type 1 (directly coupled synchronous generator) and asynchronous generators the following tests (Table 47) shall be performed:  Table 47- Tests of dynamic grid support for type 1 PGU and asynchronous motors <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>Test</th> <th>Residual voltage in pu (dip or voltage surge, conductor-neutral conductor at PGU)</th> <th>Fault type</th> <th>Fault duration in ms</th> <th>Load</th> <th>Reactive power before test in <math>Q/P_{rE}</math></th> <th>Test number</th> </tr> </thead> <tbody> <tr> <td rowspan="6">1</td> <td rowspan="6">0.30 to 0.40</td> <td rowspan="2">A</td> <td rowspan="6"><math>\geq 150</math></td> <td>Full load</td> <td rowspan="6">0 to <math>\pm 10\%</math></td> <td>1.1</td> </tr> <tr> <td>Partial load</td> <td>1.2</td> </tr> <tr> <td rowspan="2">D1</td> <td>Full load</td> <td>1.3</td> </tr> <tr> <td>Partial load</td> <td>1.4</td> </tr> <tr> <td rowspan="2">D2</td> <td>Full load</td> <td>1.5</td> </tr> <tr> <td>Full load</td> <td>2.1</td> </tr> <tr> <td rowspan="6">2</td> <td rowspan="6">0.70 to 0.85</td> <td rowspan="2">A</td> <td rowspan="6">at <math>U = 0.7 \geq 700</math> at <math>U = 0.85 \geq 1\ 500</math></td> <td>Full load</td> <td rowspan="6">0 to <math>\pm 10\%</math></td> <td>2.2</td> </tr> <tr> <td>Partial load</td> <td>2.3</td> </tr> <tr> <td rowspan="2">D1</td> <td>Full load</td> <td>2.4</td> </tr> <tr> <td>Partial load</td> <td>3.1</td> </tr> <tr> <td rowspan="4">3</td> <td rowspan="4">0.85 to 0.90</td> <td rowspan="2">A</td> <td rowspan="4"><math>\geq 60\ 000</math></td> <td>Full load</td> <td rowspan="4">0 to <math>\pm 10\%</math></td> <td>3.2</td> </tr> <tr> <td>Partial load</td> <td>3.3</td> </tr> <tr> <td rowspan="2">D1</td> <td>Full load</td> <td>3.4</td> </tr> <tr> <td>Partial load</td> <td>4.1</td> </tr> <tr> <td rowspan="6">4</td> <td rowspan="6">1.20 to 1.25</td> <td rowspan="2">A</td> <td rowspan="6"><math>\geq 100</math></td> <td>Full load</td> <td rowspan="6">0 to <math>\pm 10\%</math></td> <td>4.2</td> </tr> <tr> <td>Partial load</td> <td>4.3</td> </tr> <tr> <td rowspan="2">D1</td> <td>Full load</td> <td>4.4</td> </tr> <tr> <td>Partial load</td> <td>4.5</td> </tr> <tr> <td rowspan="2">D2</td> <td>Full load</td> <td>5.1</td> </tr> <tr> <td>Full load</td> <td>5.2</td> </tr> <tr> <td rowspan="6">5</td> <td rowspan="6">1.15 to 1.20</td> <td rowspan="2">A</td> <td rowspan="6"><math>\geq 5\ 000</math></td> <td>Full load</td> <td rowspan="6">0 to <math>\pm 10\%</math></td> <td>5.3</td> </tr> <tr> <td>Partial load</td> <td>5.4</td> </tr> <tr> <td rowspan="2">D1</td> <td>Full load</td> <td>6.1</td> </tr> <tr> <td>Partial load</td> <td>6.2</td> </tr> <tr> <td rowspan="2">6</td> <td rowspan="2">1.10 to 1.15</td> <td rowspan="2">A</td> <td rowspan="2"><math>\geq 60\ 000</math></td> <td>Full load</td> <td rowspan="2">0 to <math>\pm 10\%</math></td> <td>6.3</td> </tr> <tr> <td>Partial load</td> <td>6.4</td> </tr> </tbody> </table>	Test	Residual voltage in pu (dip or voltage surge, conductor-neutral conductor at PGU)	Fault type	Fault duration in ms	Load	Reactive power before test in $Q/P_{rE}$	Test number	1	0.30 to 0.40	A	$\geq 150$	Full load	0 to $\pm 10\%$	1.1	Partial load	1.2	D1	Full load	1.3	Partial load	1.4	D2	Full load	1.5	Full load	2.1	2	0.70 to 0.85	A	at $U = 0.7 \geq 700$ at $U = 0.85 \geq 1\ 500$	Full load	0 to $\pm 10\%$	2.2	Partial load	2.3	D1	Full load	2.4	Partial load	3.1	3	0.85 to 0.90	A	$\geq 60\ 000$	Full load	0 to $\pm 10\%$	3.2	Partial load	3.3	D1	Full load	3.4	Partial load	4.1	4	1.20 to 1.25	A	$\geq 100$	Full load	0 to $\pm 10\%$	4.2	Partial load	4.3	D1	Full load	4.4	Partial load	4.5	D2	Full load	5.1	Full load	5.2	5	1.15 to 1.20	A	$\geq 5\ 000$	Full load	0 to $\pm 10\%$	5.3	Partial load	5.4	D1	Full load	6.1	Partial load	6.2	6	1.10 to 1.15	A	$\geq 60\ 000$	Full load	0 to $\pm 10\%$	6.3	Partial load	6.4		N/A
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## DIN VDE V 0124-100

Clause	Requirement - Test	Result - Remark	Verdict																																																																																																															
	<p>The following tests (Table 48) must be carried out for PGU type 2 and storage units:</p> <p>Table 48- Dynamic grid support tests for type 2 PGU and Storage Unit</p> <table border="1"> <thead> <tr> <th>Test</th> <th>Residual voltage in pu (dip or voltage surge, conductor-neutral conductor at PGU)</th> <th>Fault type</th> <th>Fault duration in ms</th> <th>Load</th> <th>Reactive power before test in <math>Q/P_{FE}</math></th> <th>Test number</th> </tr> </thead> <tbody> <tr> <td rowspan="4">1</td> <td rowspan="4">0.15 to 0.25</td> <td>A</td> <td rowspan="4">At 0.15 pu <math>\geq</math> 150 At 0.25 pu <math>\geq</math> 500</td> <td>Full load</td> <td rowspan="4">0 to <math>\pm</math>10%</td> <td>1.1</td> </tr> <tr> <td>Partial load</td> <td>1.2</td> </tr> <tr> <td>Full load</td> <td>1.3</td> </tr> <tr> <td>Partial load</td> <td>1.4</td> </tr> <tr> <td rowspan="4">2</td> <td rowspan="4">0.50 to 0.60</td> <td>A</td> <td rowspan="4">At 0.5 pu <math>\geq</math> 1 500 At 0.6 pu <math>\geq</math> 2 000</td> <td>Full load</td> <td rowspan="4">maximum overexcited</td> <td>2.1</td> </tr> <tr> <td>Partial load</td> <td>2.2</td> </tr> <tr> <td>Full load</td> <td>2.3</td> </tr> <tr> <td>Partial load</td> <td>2.4</td> </tr> <tr> <td rowspan="4">3</td> <td rowspan="4">0.50 to 0.60</td> <td>A</td> <td rowspan="4">At 0.5 pu <math>\geq</math> 1 500 At 0.6 pu <math>\geq</math> 2 000</td> <td>Full load</td> <td rowspan="4">maximum under excited</td> <td>3.1</td> </tr> <tr> <td>Partial load</td> <td>3.2</td> </tr> <tr> <td>Full load</td> <td>3.3</td> </tr> <tr> <td>Partial load</td> <td>3.4</td> </tr> <tr> <td rowspan="4">4</td> <td rowspan="4">0.85 to 0.90</td> <td>A</td> <td rowspan="4"><math>\geq</math> 60 000</td> <td>Full load</td> <td rowspan="4">0 to <math>\pm</math>10%</td> <td>4.1</td> </tr> <tr> <td>Partial load</td> <td>4.2</td> </tr> <tr> <td>Full load</td> <td>4.3</td> </tr> <tr> <td>Partial load</td> <td>4.4</td> </tr> <tr> <td rowspan="4">5</td> <td rowspan="4">1.20 to 1.25</td> <td>A</td> <td rowspan="4"><math>\geq</math>100</td> <td>Full load</td> <td rowspan="4">0 to <math>\pm</math>10%</td> <td>5.1</td> </tr> <tr> <td>Partial load</td> <td>5.2</td> </tr> <tr> <td>Full load</td> <td>5.3</td> </tr> <tr> <td>Partial load</td> <td>5.4</td> </tr> <tr> <td rowspan="4">6</td> <td rowspan="4">1.15 to 1.20</td> <td>A</td> <td rowspan="4"><math>\geq</math>5 000</td> <td>Full load</td> <td rowspan="4">0 to <math>\pm</math>10%</td> <td>5.5</td> </tr> <tr> <td>Partial load</td> <td>6.1</td> </tr> <tr> <td>Full load</td> <td>6.2</td> </tr> <tr> <td>Partial load</td> <td>6.3</td> </tr> <tr> <td rowspan="4">7</td> <td rowspan="4">1.10 to 1.15</td> <td>A</td> <td rowspan="4"><math>\geq</math> 60 000</td> <td>Full load</td> <td rowspan="4">0 to <math>\pm</math>10%</td> <td>6.4</td> </tr> <tr> <td>Partial load</td> <td>7.1</td> </tr> <tr> <td>Full load</td> <td>7.2</td> </tr> <tr> <td>Partial load</td> <td>7.3</td> </tr> <tr> <td rowspan="4"></td> <td rowspan="4"></td> <td rowspan="4">D1</td> <td rowspan="4"></td> <td>Full load</td> <td rowspan="4"></td> <td>7.4</td> </tr> <tr> <td>Partial load</td> <td></td> </tr> <tr> <td>Full load</td> <td></td> </tr> <tr> <td>Partial load</td> <td></td> </tr> </tbody> </table>	Test	Residual voltage in pu (dip or voltage surge, conductor-neutral conductor at PGU)	Fault type	Fault duration in ms	Load	Reactive power before test in $Q/P_{FE}$	Test number	1	0.15 to 0.25	A	At 0.15 pu $\geq$ 150 At 0.25 pu $\geq$ 500	Full load	0 to $\pm$ 10%	1.1	Partial load	1.2	Full load	1.3	Partial load	1.4	2	0.50 to 0.60	A	At 0.5 pu $\geq$ 1 500 At 0.6 pu $\geq$ 2 000	Full load	maximum overexcited	2.1	Partial load	2.2	Full load	2.3	Partial load	2.4	3	0.50 to 0.60	A	At 0.5 pu $\geq$ 1 500 At 0.6 pu $\geq$ 2 000	Full load	maximum under excited	3.1	Partial load	3.2	Full load	3.3	Partial load	3.4	4	0.85 to 0.90	A	$\geq$ 60 000	Full load	0 to $\pm$ 10%	4.1	Partial load	4.2	Full load	4.3	Partial load	4.4	5	1.20 to 1.25	A	$\geq$ 100	Full load	0 to $\pm$ 10%	5.1	Partial load	5.2	Full load	5.3	Partial load	5.4	6	1.15 to 1.20	A	$\geq$ 5 000	Full load	0 to $\pm$ 10%	5.5	Partial load	6.1	Full load	6.2	Partial load	6.3	7	1.10 to 1.15	A	$\geq$ 60 000	Full load	0 to $\pm$ 10%	6.4	Partial load	7.1	Full load	7.2	Partial load	7.3			D1		Full load		7.4	Partial load		Full load		Partial load			P
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5.8.4	Evaluation criteria		P																																																																																																															
	For each test, the following criteria must be evaluated and indicated:		P																																																																																																															
5.8.4.1	Behaviour during a power failure		P																																																																																																															
	<ul style="list-style-type: none"> <li>No disconnection of the PGU from the grid during the dip. If the PGU disconnects from the grid, the time of disconnection must be documented.</li> </ul>		P																																																																																																															
	<ul style="list-style-type: none"> <li>Type 1 units support the grid voltage during a grid fault by feeding in a suitable active and reactive current. During a grid fault and after a grid fault, the voltage surge caused by the reactive current supply must not cause the overvoltage limit curve (see VDE-AR-N 4105:2018-11) to be violated.</li> </ul>		N/A																																																																																																															
	<ul style="list-style-type: none"> <li>Asynchronous generators must remain connected to the grid within the tests shown and may, depending on their principle, supply active and reactive current.</li> </ul>		N/A																																																																																																															
	<ul style="list-style-type: none"> <li>Type 2 units and storage units must not supply either an active or a reactive current during a grid fault and a voltage at the terminals of the PGU below <math>0.8 U_n</math> and above <math>1.15 U_n</math>. This requirement is met if, in the event of a voltage dip or voltage surge, the current fed into the generating unit and/or the storage unit does not exceed 20% of the rated current <math>I_r</math> in any phase conductor 60 ms after the occurrence of this voltage dip/surge and 10% <math>I_r</math> in any phase conductor after 100 ms.</li> </ul>		P																																																																																																															
5.8.4.2	Performance after the end of the fault		P																																																																																																															
	<ul style="list-style-type: none"> <li>No separation of the PGU within 60 s after end of fault.</li> </ul>		P																																																																																																															

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Clause	Requirement - Test	Result - Remark	Verdict
	<ul style="list-style-type: none"> <li>Type 1 units and asynchronous machines: Settling time of active power max. 6 s, settling time of reactive power as fast as possible.</li> </ul>		N/A
	<ul style="list-style-type: none"> <li>Type 2 units and storage unit: Settling time of active power max 1 s, settling time of reactive power according to PT1 behaviour with <math>3 \tau = 10</math> s according to VDE-AR-N4105:2018-11, 5.7.2.5.</li> </ul>		P
5.8.5	Documentation		P
	Necessary information:		P
	<ul style="list-style-type: none"> <li>Calculation method for the effective values, power and offset factor;</li> <li>Description of the measurement technology, test equipment and DUT used. The description of the test facility must define the complete operating principle, in particular with regard to the correct consideration of the interactions on the grid side;</li> <li>Voltage level at which the grid fault is generated;</li> <li>Short-circuit power of the test equipment at the generator terminals;</li> <li>if modifications have been made to the DUT to ensure its function during the test, these must be clearly specified;</li> </ul>		P
	<ul style="list-style-type: none"> <li>Measuring point of the recorded currents and voltages;</li> <li>Settings NS protection;</li> <li>relevant FRT parameters of the PGU or the memory (for type 1 e.g. setting AVR).</li> </ul>		P
	Diagrams:		P
	For each of the tests, the following diagrams shall be presented as time curves from $t_1 - 1$ s (one second before fault occurrence) to $t_2 + 6$ s (six seconds after fault clearance), zoomed if necessary.		P
	<u>No load tests:</u> <ul style="list-style-type: none"> <li>Line-to-line voltages and line-to-neutral voltages (signal curves);</li> <li>Full-period effective values of the line-neutral voltages with a recalculation rate of at least 1/ms.</li> </ul>		P
	<u>Test with DUT:</u> <ul style="list-style-type: none"> <li>Line-to-line voltages and line-to-neutral voltages (signal curves);</li> <li>Phase currents (signal curves);</li> <li>Full-period effective values of the line-to-neutral voltages with a recalculation rate of at least 1/ms;</li> <li>Full-period effective values of the Full-period effective values of the phase currents with a recalculation rate of at least 1/ms (if necessary, additionally divided into active and reactive components),</li> <li>Active power and reactive power in the positive sequence with a recalculation rate of at least 1/ms.</li> <li>Voltage and current in the positive sequence with a recalculation rate of at least 1/ms.</li> </ul>		P
	For each of the tests the data according to Table 49 shall be reported:		P

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Clause	Requirement - Test	Result - Remark	Verdict																																																																																																																																																																										
	<p style="text-align: center;"><b>Table 49- Tabular documentation of the dynamic grid support test</b></p> <table border="1"> <thead> <tr> <th>No.</th> <th>Parameter</th> <th>Phase reference</th> <th>Reference time</th> <th>Value [Unit]</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>Test number</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <td>1</td> <td>Date</td> <td>-</td> <td>-</td> <td>[dd.mm.yyyy]</td> </tr> <tr> <td>2</td> <td>Time (start of the test)</td> <td>-</td> <td>-</td> <td>[hh:mm:ss.s.f]</td> </tr> <tr> <td>3</td> <td>Type of fault (affected phases)</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <td>4</td> <td>Setpoint dip depth</td> <td>Phase conductor</td> <td>-</td> <td>[pu]</td> </tr> <tr> <td>5</td> <td>Setpoint dip time</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <td>6</td> <td>Time of occurrence of fault (<math>t_f</math>)</td> <td>Total</td> <td>-</td> <td>[ms]</td> </tr> <tr> <td>7</td> <td>Time of fault clearance (<math>t_2</math>)</td> <td>Total</td> <td>-</td> <td>[ms]</td> </tr> <tr> <td>8</td> <td>Fault duration determined from zero test</td> <td>Total</td> <td>-</td> <td>[ms]</td> </tr> <tr> <td>9</td> <td rowspan="2">Voltage dip depth or Voltage surge determined from zero test</td> <td>Total</td> <td><math>t_1+100</math> ms to <math>t_2</math> and <math>t_1-10</math> s to <math>t_1</math>.</td> <td>[pu]</td> </tr> <tr> <td>10</td> <td>Positive sequence</td> <td></td> <td></td> </tr> <tr> <td>11</td> <td>Voltage</td> <td>Conductor-neutral conductor voltage</td> <td><math>t_1-10</math> s to <math>t_1</math></td> <td>[pu]</td> </tr> <tr> <td>12</td> <td>Current</td> <td>Positive sequence</td> <td><math>t_1-500</math> ms to <math>t_1-100</math> ms</td> <td>[pu]</td> </tr> <tr> <td>13</td> <td rowspan="2">Active power</td> <td>Total</td> <td><math>t_1-10</math> s to <math>t_1</math></td> <td>[pu]</td> </tr> <tr> <td>14</td> <td>Positive sequence</td> <td><math>t_1-10</math> s to <math>t_1</math></td> <td>[pu]</td> </tr> <tr> <td>15</td> <td rowspan="2">Reactive power</td> <td>Positive sequence</td> <td><math>t_1-10</math> s to <math>t_1</math></td> <td>[pu]</td> </tr> <tr> <td>16</td> <td>Total</td> <td><math>t_1-10</math> s to <math>t_1</math></td> <td>[pu]</td> </tr> <tr> <td>17</td> <td><math>\cos \varphi</math></td> <td>-</td> <td><math>t_1-10</math> s to <math>t_1</math></td> <td>[pu]</td> </tr> <tr> <td>18</td> <td>Voltage</td> <td>Conductor-neutral conductor voltage</td> <td><math>t_1+100</math> ms to <math>t_2-20</math> ms</td> <td>[pu]</td> </tr> <tr> <td>19</td> <td rowspan="3">Line conductor current</td> <td>Phase 1</td> <td><math>t_1+60</math> ms</td> <td>[pu]</td> </tr> <tr> <td>20</td> <td>Phase 2</td> <td><math>t_1+60</math> ms</td> <td>[pu]</td> </tr> <tr> <td>21</td> <td>Phase 3</td> <td><math>t_1+60</math> ms</td> <td>[pu]</td> </tr> <tr> <td>22</td> <td rowspan="3">Line conductor current</td> <td>Phase 1</td> <td><math>t_1+100</math> ms</td> <td>[pu]</td> </tr> <tr> <td>23</td> <td>Phase 2</td> <td><math>t_1+100</math> ms</td> <td>[pu]</td> </tr> <tr> <td>24</td> <td>Phase 3</td> <td><math>t_1+100</math> ms</td> <td>[pu]</td> </tr> <tr> <td>25</td> <td rowspan="2">Active power</td> <td>Total</td> <td><math>t_1+100</math> ms to <math>t_2-20</math> ms</td> <td>[pu]</td> </tr> <tr> <td>26</td> <td>Positive sequence</td> <td><math>t_1+100</math> ms to <math>t_2-20</math> ms</td> <td>[pu]</td> </tr> <tr> <td>27</td> <td>Voltage</td> <td>Conductor-neutral conductor voltage</td> <td><math>t_2+3</math> s to <math>t_2+10</math> s</td> <td>[pu]</td> </tr> <tr> <td>28</td> <td rowspan="2">Active power</td> <td>Positive sequence</td> <td><math>t_2+3</math> s to <math>t_2+10</math> s</td> <td>[pu]</td> </tr> <tr> <td>29</td> <td>Total</td> <td><math>t_2+3</math> s to <math>t_2+10</math> s</td> <td>[pu]</td> </tr> <tr> <td>30</td> <td>Response time Active power</td> <td>Positive sequence</td> <td>-</td> <td>[s]</td> </tr> <tr> <td>31</td> <td rowspan="2">Reactive power</td> <td>Positive sequence</td> <td><math>t_2+3</math> s to <math>t_2+10</math> s</td> <td>[pu]</td> </tr> <tr> <td>32</td> <td>Total</td> <td><math>t_2+3</math> s to <math>t_2+10</math> s</td> <td>[pu]</td> </tr> <tr> <td>33</td> <td>Response time Reactive power</td> <td>Positive sequence</td> <td>-</td> <td>[s]</td> </tr> <tr> <td>34</td> <td>PGU has not disconnected from the grid within 60 s after end of fault yes/no</td> <td>-</td> <td><math>t_2</math> to <math>t_2+60</math>s</td> <td>-</td> </tr> </tbody> </table>	No.	Parameter	Phase reference	Reference time	Value [Unit]	0	Test number	-	-	-	1	Date	-	-	[dd.mm.yyyy]	2	Time (start of the test)	-	-	[hh:mm:ss.s.f]	3	Type of fault (affected phases)	-	-	-	4	Setpoint dip depth	Phase conductor	-	[pu]	5	Setpoint dip time	-	-	-	6	Time of occurrence of fault ( $t_f$ )	Total	-	[ms]	7	Time of fault clearance ( $t_2$ )	Total	-	[ms]	8	Fault duration determined from zero test	Total	-	[ms]	9	Voltage dip depth or Voltage surge determined from zero test	Total	$t_1+100$ ms to $t_2$ and $t_1-10$ s to $t_1$ .	[pu]	10	Positive sequence			11	Voltage	Conductor-neutral conductor voltage	$t_1-10$ s to $t_1$	[pu]	12	Current	Positive sequence	$t_1-500$ ms to $t_1-100$ ms	[pu]	13	Active power	Total	$t_1-10$ s to $t_1$	[pu]	14	Positive sequence	$t_1-10$ s to $t_1$	[pu]	15	Reactive power	Positive sequence	$t_1-10$ s to $t_1$	[pu]	16	Total	$t_1-10$ s to $t_1$	[pu]	17	$\cos \varphi$	-	$t_1-10$ s to $t_1$	[pu]	18	Voltage	Conductor-neutral conductor voltage	$t_1+100$ ms to $t_2-20$ ms	[pu]	19	Line conductor current	Phase 1	$t_1+60$ ms	[pu]	20	Phase 2	$t_1+60$ ms	[pu]	21	Phase 3	$t_1+60$ ms	[pu]	22	Line conductor current	Phase 1	$t_1+100$ ms	[pu]	23	Phase 2	$t_1+100$ ms	[pu]	24	Phase 3	$t_1+100$ ms	[pu]	25	Active power	Total	$t_1+100$ ms to $t_2-20$ ms	[pu]	26	Positive sequence	$t_1+100$ ms to $t_2-20$ ms	[pu]	27	Voltage	Conductor-neutral conductor voltage	$t_2+3$ s to $t_2+10$ s	[pu]	28	Active power	Positive sequence	$t_2+3$ s to $t_2+10$ s	[pu]	29	Total	$t_2+3$ s to $t_2+10$ s	[pu]	30	Response time Active power	Positive sequence	-	[s]	31	Reactive power	Positive sequence	$t_2+3$ s to $t_2+10$ s	[pu]	32	Total	$t_2+3$ s to $t_2+10$ s	[pu]	33	Response time Reactive power	Positive sequence	-	[s]	34	PGU has not disconnected from the grid within 60 s after end of fault yes/no	-	$t_2$ to $t_2+60$ s	-		P
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12	Current	Positive sequence	$t_1-500$ ms to $t_1-100$ ms	[pu]																																																																																																																																																																									
13	Active power	Total	$t_1-10$ s to $t_1$	[pu]																																																																																																																																																																									
14		Positive sequence	$t_1-10$ s to $t_1$	[pu]																																																																																																																																																																									
15	Reactive power	Positive sequence	$t_1-10$ s to $t_1$	[pu]																																																																																																																																																																									
16		Total	$t_1-10$ s to $t_1$	[pu]																																																																																																																																																																									
17	$\cos \varphi$	-	$t_1-10$ s to $t_1$	[pu]																																																																																																																																																																									
18	Voltage	Conductor-neutral conductor voltage	$t_1+100$ ms to $t_2-20$ ms	[pu]																																																																																																																																																																									
19	Line conductor current	Phase 1	$t_1+60$ ms	[pu]																																																																																																																																																																									
20		Phase 2	$t_1+60$ ms	[pu]																																																																																																																																																																									
21		Phase 3	$t_1+60$ ms	[pu]																																																																																																																																																																									
22	Line conductor current	Phase 1	$t_1+100$ ms	[pu]																																																																																																																																																																									
23		Phase 2	$t_1+100$ ms	[pu]																																																																																																																																																																									
24		Phase 3	$t_1+100$ ms	[pu]																																																																																																																																																																									
25	Active power	Total	$t_1+100$ ms to $t_2-20$ ms	[pu]																																																																																																																																																																									
26		Positive sequence	$t_1+100$ ms to $t_2-20$ ms	[pu]																																																																																																																																																																									
27	Voltage	Conductor-neutral conductor voltage	$t_2+3$ s to $t_2+10$ s	[pu]																																																																																																																																																																									
28	Active power	Positive sequence	$t_2+3$ s to $t_2+10$ s	[pu]																																																																																																																																																																									
29		Total	$t_2+3$ s to $t_2+10$ s	[pu]																																																																																																																																																																									
30	Response time Active power	Positive sequence	-	[s]																																																																																																																																																																									
31	Reactive power	Positive sequence	$t_2+3$ s to $t_2+10$ s	[pu]																																																																																																																																																																									
32		Total	$t_2+3$ s to $t_2+10$ s	[pu]																																																																																																																																																																									
33	Response time Reactive power	Positive sequence	-	[s]																																																																																																																																																																									
34	PGU has not disconnected from the grid within 60 s after end of fault yes/no	-	$t_2$ to $t_2+60$ s	-																																																																																																																																																																									
<b>5.9</b>	<b>Testing of auxiliary power units</b>		N/A																																																																																																																																																																										
5.9.1	General		N/A																																																																																																																																																																										
	Auxiliaries that have not been included in the FRT tests according to 5.8 may be checked according to the procedure described here.		N/A																																																																																																																																																																										
5.9.2	Tests		N/A																																																																																																																																																																										
	the generating unit is operated at rated power during the test. To test the auxiliaries, the supply voltage to the auxiliaries to be tested and their control shall be interrupted for a minimum period of 1 500 ms.		N/A																																																																																																																																																																										
	If a permit from the responsible grid operator is required for this, this must be obtained. The test may be carried out at the manufacturer's premises.		N/A																																																																																																																																																																										
	For the entire duration of the tests, the currents and voltages at the PGU terminals and the voltages at the auxiliary units must be recorded. Recording starts 10 s before voltage drop and ends 10 min after voltage recovery.		N/A																																																																																																																																																																										

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	Alternatively, an auxiliary unit can be tested independently of an PGU. For this purpose, the auxiliary power unit shall be operated at full load according to its specifications or under those operating conditions which correspond to full load operation in the associated PGU. The operating conditions used shall be documented in the test report. Instead of the currents and voltages at the PGU terminals, suitable signals must be recorded, by which the successful continued operation of the auxiliary unit can be verified.		N/A
	If communication with the PGU control system is provided (e.g. status monitoring), it must be ensured, if necessary by recording appropriate signals, that the auxiliary unit does not generate any fault states within the measuring period which could lead to the PGU being switched off.		N/A
5.9.3	Evaluation criteria		N/A
	It applies: The drop in the supply voltage of the auxiliary units and their control must not cause disconnection of the generating unit from the grid. Proof has been provided if no disconnection of the generating unit from the grid has occurred up to 10 minutes after voltage recovery.		N/A
5.9.4	Test documentation		N/A
	For the entire duration of the test up to 10 min after voltage recovery, the voltage, active and reactive power of the PGU in the positive sequence sizes and the voltages at the auxiliary units shall be shown as diagrams.		N/A
<b>6</b>	<b>NOTES ON THE CERTIFICATION PROCEDURE</b>		P
<b>6.1</b>	<b>General</b>		P
	The generally accepted form of verification is the presentation of certificates to the grid operator in accordance with VDE-AR-N 4105:2018-11, Section 9. The evaluation of the measurement results is carried out according to the evaluation criteria in this document.		P
<b>6.2</b>	<b>Transferability of measurements</b>		P
	Measurement results can be transferred between generating units/components if it can be ensured that the software used to control/regulate the generating unit/component is identical or equivalent and the hardware is technically equivalent. This must be checked on the basis of the documents to be submitted. The manufacturer must also provide an estimate of possible differences.		P
	If results of the measurement of a generating unit (reference PGU) of type 1 are to be transferred in total or in part to other generating units, this must be done in accordance with the rules in VDE-AR-N 4110:2018-11, section 11 and the generally accepted rules of technology.		N/A
	The results of the measurement of a type 2 generating unit may, in total or in part, be transferred to other generating units if		P

DIN VDE V 0124-100			
Clause	Requirement - Test	Result - Remark	Verdict
	<ol style="list-style-type: none"> <li>1) the design and the control technology, including the software used in these generating units, which is decisive for the electrical properties are technically equivalent, and</li> <li>2) the results are available for the smallest and largest power variant or alternatively the rated apparent power of the generating unit to be certified is between <math>\frac{1}{\sqrt{10}}</math> times and 2 times of the rated apparent power of the measured generating unit.</li> <li>3) For the verification of steady state operation and static voltage range, the limits mentioned under 2) can be extended for the validation of the manufacturer's data, if the concept of the generating unit and the components used are technically equivalent.</li> </ol>		P
<b>6.3</b>	<b>Alternative form of FRT verification</b>		N/A
	By default, the proof must be provided by measurements. An alternative form of verification is not provided for by the TAR and is not necessary as the services in question can always be tested directly. If this is nevertheless not possible in justified cases, the FRT verification for type 1 PGU can alternatively be carried out by means of computational simulation with a synchronous machine model. This is done by referring directly to the specifications in VDE-AR-N 4110 and requires at least the following steps:		N/A
	<ol style="list-style-type: none"> <li>1) Preparation of a plant certificate "C" according to FGW TR8: 2019-02 including a preliminary simulation model according to FGW TR 4: 2019-02.</li> <li>2) Commissioning and surveying according to PUS according to FGW TR 3: 2018-09.</li> <li>3) Creation of an extended declaration of conformity including optimization of the created simulation model according to FGW TR 4: 2019-02.</li> <li>4) Preliminary operation of the EZA under monitoring with fault recorders. Notification and correction of network events (at least 5 years of supervision by the certification body).</li> </ol>		N/A
	The auxiliary equipment of the PGU must be tested separately for under- and overvoltage. The testing of the auxiliary equipment shall be carried out according to 5.9.		N/A

<b>ANNEX A</b>	<b>FRT TEST (NORMATIVE)</b>		P
<b>A.1</b>	<b>Requirements for test benches</b>		P
	The generated voltage drops and voltage increases should meet the following requirements:		P

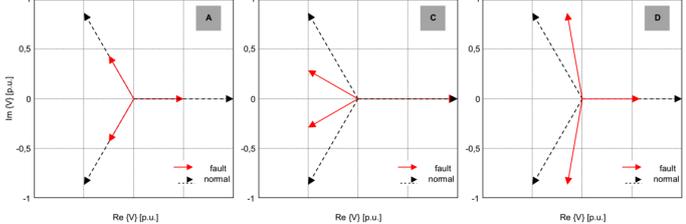
DIN VDE V 0124-100

Clause	Requirement - Test	Result - Remark	Verdict
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	<p>The effective network impedance from an PGU point of view (in the case of voltage divider principle: with connected mains impedance) must meet the following criteria:</p> <ul style="list-style-type: none"> <li>– Short-circuit power at the PGU before and after the fault must be between <math>10 \times S_n</math> and <math>30 \times S_n</math></li> <li>– R/X 0.3-3 (for the impedances used in the test facility)</li> </ul>		P
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	<p>The test equipment and, if necessary, the grid simulator must be capable of carrying the maximum current of the DUT in both the generator and motor areas. The energy consumption must be designed for the occurring surge short-circuit current <math>i_p</math> (according to DIN EN 60909-0 (VDE 0102)). <math>i_p</math> of the DUT types is different. Guide values are:</p> <ul style="list-style-type: none"> <li>– for inverter-coupled systems approx. <math>2.2 I_r</math>,</li> <li>– for direct-coupled asynchronous or synchronous machines approx. <math>7 I_r</math>.</li> </ul>		P
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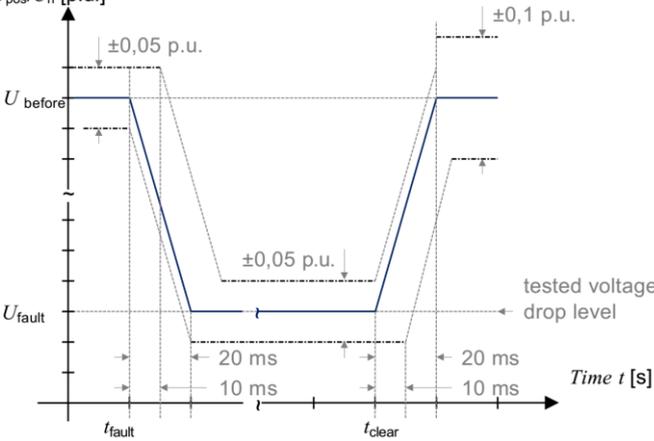
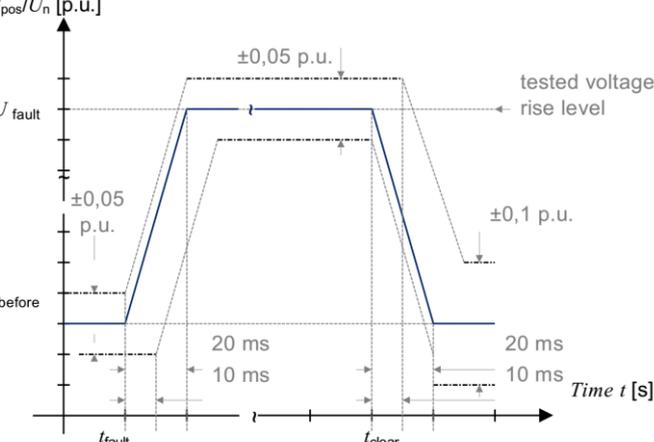
	<p>In the case of symmetrical and asymmetrical voltage dips and voltage increases, taking into account the switching group effect, the fault forms A and D according to Figure A.1 with the phase angles of the voltages according to Table A.1 must be observed. The representations show phase-neutral voltages.</p> <p style="text-align: center; font-size: small;">Table A.1- Fault types for FRT tests on Type 2 PGU and Storage Unit when performed on electronic grid simulators</p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <thead> <tr> <th>Test number</th> <th>L1</th> <th>L2</th> <th>L3</th> <th>Type</th> <th>Remark</th> </tr> </thead> <tbody> <tr> <td>-</td> <td>1.00 &gt;-150.0°</td> <td>1.00 &gt;90.0°</td> <td>1.00 &gt;-30.0°</td> <td>A</td> <td>Initial state</td> </tr> <tr> <td>1.3, 1.4</td> <td>0.62 &gt;-173.3°</td> <td>0.15 &gt;90.0°</td> <td>0.62 &gt;-6.9°</td> <td>D 1</td> <td rowspan="2">UVRT</td> </tr> <tr> <td>2.3, 2.4, 3.3, 3.4</td> <td>0.76 &gt;-161.1°</td> <td>0.50 &gt;90.0°</td> <td>0.76 &gt;-19.1°</td> <td>D 1</td> </tr> <tr> <td>4.3, 4.4</td> <td>0.93 &gt;-152.8°</td> <td>0.85 &gt;89.9°</td> <td>0.93 &gt;-27.4°</td> <td>D 1</td> <td rowspan="4">OVRT</td> </tr> <tr> <td>5.3, 5.4</td> <td>1.08 &gt;-144.5°</td> <td>1.25 &gt;89.1°</td> <td>1.06 &gt;-36.3°</td> <td>D 1</td> </tr> <tr> <td>6.3, 6.4</td> <td>1.06 &gt;-145.5°</td> <td>1.20 &gt;89.3°</td> <td>1.05 &gt;-35.1°</td> <td>D 1</td> </tr> <tr> <td>7.3, 7.4</td> <td>1.04 &gt;-146.6°</td> <td>1.15 &gt;89.4°</td> <td>1.04 &gt;-33.9°</td> <td>D 1</td> </tr> </tbody> </table>	Test number	L1	L2	L3	Type	Remark	-	1.00 >-150.0°	1.00 >90.0°	1.00 >-30.0°	A	Initial state	1.3, 1.4	0.62 >-173.3°	0.15 >90.0°	0.62 >-6.9°	D 1	UVRT	2.3, 2.4, 3.3, 3.4	0.76 >-161.1°	0.50 >90.0°	0.76 >-19.1°	D 1	4.3, 4.4	0.93 >-152.8°	0.85 >89.9°	0.93 >-27.4°	D 1	OVRT	5.3, 5.4	1.08 >-144.5°	1.25 >89.1°	1.06 >-36.3°	D 1	6.3, 6.4	1.06 >-145.5°	1.20 >89.3°	1.05 >-35.1°	D 1	7.3, 7.4	1.04 >-146.6°	1.15 >89.4°	1.04 >-33.9°	D 1		P
Test number	L1	L2	L3	Type	Remark																																										
-	1.00 >-150.0°	1.00 >90.0°	1.00 >-30.0°	A	Initial state																																										
1.3, 1.4	0.62 >-173.3°	0.15 >90.0°	0.62 >-6.9°	D 1	UVRT																																										
2.3, 2.4, 3.3, 3.4	0.76 >-161.1°	0.50 >90.0°	0.76 >-19.1°	D 1																																											
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7.3, 7.4	1.04 >-146.6°	1.15 >89.4°	1.04 >-33.9°	D 1																																											

	<p>The diagrams show phase-neutral voltages:</p>  <p style="text-align: center;"><b>Figure A.1- Fault types “A”, “C” and “D” according to [M. H. J. Bollen “Understanding Power Quality Problems”]</b></p>		P
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	<p>In the case of a medium-voltage, two-phase fault without ground contact (phase-to-phase voltages: fault type D) in front of a Dy transformer results in fault type D (phase-to-phase voltages) on the low voltage side of the transformer when looking at the phase-to-neutral voltages: fault type C).</p>		P
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	<ul style="list-style-type: none"> <li>• The slope of the voltage must correspond to that of a circuit breaker in the event of a fault and in the event of a fault clearing.</li> </ul> <p>A change of the instantaneous voltage from 90% to 10% of the pre-fault voltage occurs at UVRT within a period of max. 4 ms.</p>		P
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Clause	Requirement - Test	Result - Remark	Verdict
	The requirements for the waveform of the test voltage must be verified in no load tests. The test voltage must be within the tolerances shown in Figure A.2 for voltage dip tests and Figure A.3 for overvoltage tests.		P
	The requirements for the waveform of the test voltage must be verified in no load tests. The test voltage must be within the tolerances shown in Figure A.2 for voltage dip tests and Figure A.3 for overvoltage tests.		P
	<p>System voltage <math>U_{pos}/U_n</math> [p.u.]</p>  <p><b>Figure A.2 - Tolerances for voltage dips (positive sequence voltage calculation according to DIN EN 61400-21-1 (VDE 0127-21-1))</b></p>		P
	<p>System voltage <math>U_{pos}/U_n</math> [p.u.]</p>  <p><b>Figure A.3 - Tolerances for voltage increases (positive sequence voltage calculation according to DIN EN 61400-21-1 (VDE 0127-21-1))</b></p>		P
<b>A.2</b>	<b>Examples of possible test bench for UVRT (informative)</b>		Info.
A.2.1	Grid simulator		Info.
A.2.2	Short-circuit simulator		Info.
<b>A.3</b>	<b>Examples of possible test bench for OVRT (informative)</b>		Info.
A.3.1	List of test facilities:		Info.
	<ul style="list-style-type: none"> <li>• Grid simulator (converter system);</li> </ul>		Info.

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Clause	Requirement - Test	Result - Remark	Verdict
	<ul style="list-style-type: none"><li>transformer-based test equipment (auto or bypass transformer system);</li></ul>		Info.
	<ul style="list-style-type: none"><li>capacitor-based test equipment.</li></ul>		Info.
A.3.2	Transformer-based test equipment		Info.
A.3.3	Capacitor-based test equipment		Info.

DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
Clause	Test		Verdict (P/F/N/A)
<b>5.2 (5.4)</b>	<b>Demonstration of permissible system perturbations</b>		
5.2.2 (E.5)	Rapid voltage changes		P
5.2.3 (E.5)	Flicker		P
5.2.4 (E.5)	Harmonics and Interharmonics		P
5.2.5	Commutation notches		N/A
5.2.6	DC current feed-into network		P
<b>5.3</b>	<b>Demonstration of the symmetry behaviour of inverters</b>		
5.3.2.1	Calculating the asymmetry of three-phase inverter		N/A
5.3.3	Symmetrical operation with a symmetry device		N/A
<b>5.4</b>	<b>Evidence of the behavior of the power generation unit on the network</b>		
5.4.2 (5.7.2.2)	Measurement of the active power and reactive power range		P
5.4.3 (5.7.4.2.1)	Active power reduction by setpoint specification		P
5.4.3.3 (5.7.4.2.1)	Measurement of setting accuracy		P
5.4.3.4 (5.7.4.2.1)	Measurement of the power gradient		P
5.4.3.5 (5.7.4.2.1)	Measurement Priority Interfaces / Energy Management System		P
5.4.4 (5.7.4.3 & 8.3.1)	Active power feed-in of PGUs at over-frequency		P
5.4.5 (5.7.4.3 & 8.3.1)	Active power feed-in of storage systems at over-frequency		N/A
5.4.6 (5.7.4.3 & 8.3.1)	Active power feed-in of PGUs at under-frequency		P
5.4.7 (5.7.4.3 & 8.3.1)	Active power feed-in of storage systems at under-frequency		N/A
5.4.8 (5.7.2)	Static voltage stability / reactive power supply		P
5.4.8.2 (5.7.2.4c)	Test of reactive power / $\cos \varphi$ setting accuracy		P
5.4.8.3 (5.7.2.4b)	Test for a displacement factor / active power characteristic curve $\cos \varphi$ (P)		P
5.4.8.4.1 & 5.4.8.4.3 (5.7.2.4a & 5.7.2.5)	Testing the accuracy of the Q(U) control		N/A
5.4.8.4.2 & 5.4.8.4.4 (5.7.2.4a & 5.7.2.5)	Testing the dynamics of the Q(U) control		N/A
<b>5.5</b>	<b>Testing of NS protection</b>		
5.5.2 to 5.5.6 (6.2 to 6.4)	NS protection		P
5.5.7.4 (6.5.1 & 6.5.2)	Test for overvoltage protection $U_{>>}$		P
5.5.7.4 (6.5.1 & 6.5.2)	Test for overvoltage protection $U_{>}$		P
5.5.7.4 (6.5.1 & 6.5.2)	Test for undervoltage protection $U_{<}$		P
5.5.7.4 (6.5.1 & 6.5.2)	Test for undervoltage protection $U_{<<}$		P
5.5.7.4 (6.5.1 & 6.5.2)	Test for frequency protection $f_{>}$ and $f_{<}$		P
5.5.9 (6.5.2)	Structural features of NS protection		P
5.5.10 (6.5.3)	Islanding detection		P
<b>5.6 (8.3)</b>	<b>Connection conditions and synchronization</b>		P

DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
Clause	Test	Verdict (P/F/N/A)	
<b>5.7 (5.5.2)</b>	<b>Evidence of P<sub>AV,E</sub> monitoring (feed-in limitation)</b>		
5.7.2.1	Testing of the dynamics control (P <sub>AV,E</sub> -Monitoring)		P
5.7.2.2	Testing of disconnection function		N/A
<b>5.8 (5.7.3)</b>	<b>Testing of the dynamic grid support</b>		P
<b>5.9</b>	<b>Testing of auxiliary power units</b>		N/A
Remark: The clause number including two standards DIN VDE V 0124-100:2020-06 and VDE-AR-N 4105: 2018-11. The clause before parenthesis is representing for DIN VDE V 0124-100:2020-06 and clause in the parenthesis is representing for VDE-AR-N 4105: 2018-11.			

DIN VDE V 0124-100, VDE-AR-N 4105						
Clause	Requirement - Test			Result - Remark		Verdict
<b>5.2.2 (5.3)</b>	<b>TABLE: Rapid voltage changes</b>					<b>P</b>
Model	SG2000					
Test cases:	Switching on without specification (10% rated output power)			Most unfavourable case when switching the generator (10% → 100% rated output power)		
Cos $\varphi$ setting	Cos $\varphi=1.00$	Cos $\varphi=\text{max.}$ over-excited	Cos $\varphi=\text{max.}$ under- excited	Cos $\varphi=1.00$	Cos $\varphi=\text{max.}$ over- excited	Cos $\varphi=\text{max.}$ under- excited
Single period effective values of the voltage [V]	230.00	229.99	229.99	231.55	229.99	229.99
Single period effective values of the current [A]	0.346	0.418	0.419	3.243	3.005	3.247
$k_i$	0.039	0.048	0.048	0.373	0.345	0.373
Test cases:	Switching on at rated power			Switch off at rated power		
Cos $\varphi$ setting	Cos $\varphi=1.00$	Cos $\varphi=\text{max.}$ over-excited	Cos $\varphi=\text{max.}$ under- excited	Cos $\varphi=1.00$	Cos $\varphi=\text{max.}$ over- excited	Cos $\varphi=\text{max.}$ under- excited
Single period effective values of the voltage [V]	229.99	229.99	229.99	229.99	229.99	229.99
Single period effective values of the current [A]	3.134	2.931	2.627	8.920	8.908	9.203
$k_i$	0.360	0.337	0.302	1.026	1.025	1.059
$k_{i\text{max}}$	1.059					
Test conditions: Frequency: 50 Hz $\pm$ 0.5% THD of the voltage supply: $\leq$ 3% Voltage rise of the PGU at 100% $P_{E\text{max}}$ : $\leq$ 3%						
Note: $k_{i\text{max}}$ : ratio of the highest current occurring during a switching operation (e. g. starting or connecting current or the highest breaking current under normal operating conditions) to the normal generator current $I_E$ . For this purpose, the current is to be considered as an r.m.s. value over a period.  Power generation units with inverters (such as photovoltaic systems) and storage units with inverters shall only be connected with $k_{i\text{max}} \leq 1.2$ .  The tests were performed on model SG2000 also applicable for all other models stated in this report.						

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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5.2.4.1 (E.5)	TABLE: Harmonics and Interharmonics a) Generation units and storage (single devices) with a rated current $\leq 75$ A							P
Maximum permissible harmonic current as per EN 61000-3-2 Class A								
Model	SG2000							
Harmonics	2 <sup>nd</sup>	3 <sup>rd</sup>	5 <sup>th</sup>	7 <sup>th</sup>	9 <sup>th</sup>	11 <sup>th</sup>	13 <sup>th</sup>	15 <sup>th</sup> $\leq$ n $\leq$ 39 <sup>th</sup>
Limit [A]	1.08	2.30	1.14	0.77	0.4	0.33	0.21	0.15 * (15/n)
Test value [A]	0.009	0.103	0.034	0.034	0.033	0.036	0.036	0.035
Note: The tests should be based on the limits of the EN61000-3-2 for less than 16 A.								

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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<b>5.2.4.1 (E.5)</b>	<b>TABLE: Harmonics and Interharmonics b) Generation units and storage (single devices) with a rated current &gt;75 A</b>	<b>P</b>
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Model	SG1600
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Harmonics										
P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
Order	I [%]									
1	10.232	20.589	31.452	41.213	51.954	61.123	71.789	79.624	91.753	99.254
2	0.023	0.023	0.046	0.023	0.023	0.023	0.023	0.023	0.023	0.046
3	0.853	3.157	3.157	3.364	2.880	3.341	3.364	3.134	3.295	3.802
4	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
5	0.668	0.922	0.829	1.359	0.991	1.313	1.336	1.106	0.922	0.714
6	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
7	0.945	0.184	0.115	1.014	0.507	0.392	0.461	0.714	0.783	0.530
8	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
9	0.922	0.323	0.369	1.014	0.945	0.899	0.991	1.313	1.498	1.705
10	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
11	0.783	0.461	0.553	0.829	0.991	1.060	1.175	1.382	1.544	1.659
12	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
13	0.438	0.392	0.691	0.760	0.968	1.198	1.244	1.313	1.359	1.475
14	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
15	0.276	0.346	0.438	0.599	0.806	1.198	1.290	1.152	1.083	1.359
16	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
17	0.253	0.069	0.438	0.507	0.645	1.060	1.244	1.083	0.968	0.806
18	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
19	0.415	0.392	0.576	0.415	0.484	0.806	1.014	0.922	0.829	0.876
20	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
21	0.714	0.622	0.438	0.369	0.438	0.599	0.691	0.714	0.760	0.530
22	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
23	0.329	0.360	0.346	0.461	0.461	0.392	0.369	0.461	0.499	0.499
24	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
25	0.468	0.483	0.230	0.484	0.484	0.230	0.207	0.207	0.438	0.461
26	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
27	0.484	0.576	0.323	0.415	0.461	0.207	0.230	0.023	0.230	0.369
28	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
29	0.438	0.323	0.276	0.207	0.415	0.323	0.276	0.115	0.046	0.323
30	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
31	0.369	0.161	0.161	0.115	0.323	0.369	0.276	0.184	0.115	0.138
32	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
33	0.276	0.115	0.207	0.115	0.253	0.323	0.276	0.207	0.230	0.115
34	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
35	0.161	0.161	0.276	0.046	0.207	0.207	0.300	0.184	0.253	0.161
36	0.023	0.023	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.023
37	0.230	0.230	0.276	0.207	0.115	0.069	0.253	0.161	0.253	0.276
38	0.023	0.023	0.069	0.000	0.000	0.000	0.000	0.023	0.000	0.023
39	0.246	0.253	0.115	0.192	0.138	0.115	0.161	0.161	0.184	0.146
40	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.023	0.000	0.023

Note:

The nominal current is 8.69 A.

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict							
<b>5.2.4.1 (E.5)</b>	<b>TABLE: Harmonics and Interharmonics b) Generation units and storage (single devices) with a rated current &gt;75 A</b>									
Model	SG2000									
<b>Harmonics</b>										
P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
1	10.899	20.622	31.498	41.106	51.590	61.797	71.797	79.539	91.037	98.512
2	0.023	0.023	0.046	0.023	0.023	0.023	0.023	0.023	0.023	0.046
3	0.853	3.157	3.157	3.364	2.880	3.341	3.364	3.134	3.295	3.802
4	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
5	0.668	0.922	0.829	1.359	0.991	1.313	1.336	1.106	0.922	0.714
6	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
7	0.945	0.184	0.115	1.014	0.507	0.392	0.461	0.714	0.783	0.530
8	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
9	0.922	0.323	0.369	1.014	0.945	0.899	0.991	1.313	1.498	1.705
10	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
11	0.783	0.461	0.553	0.829	0.991	1.060	1.175	1.382	1.544	1.659
12	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
13	0.438	0.392	0.691	0.760	0.968	1.198	1.244	1.313	1.359	1.475
14	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
15	0.276	0.346	0.438	0.599	0.806	1.198	1.290	1.152	1.083	1.359
16	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
17	0.253	0.069	0.438	0.507	0.645	1.060	1.244	1.083	0.968	0.806
18	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
19	0.415	0.392	0.576	0.415	0.484	0.806	1.014	0.922	0.829	0.876
20	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
21	0.714	0.622	0.438	0.369	0.438	0.599	0.691	0.714	0.760	0.530
22	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
23	0.329	0.360	0.346	0.461	0.461	0.392	0.369	0.461	0.499	0.499
24	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
25	0.468	0.483	0.230	0.484	0.484	0.230	0.207	0.207	0.438	0.461
26	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
27	0.484	0.576	0.323	0.415	0.461	0.207	0.230	0.023	0.230	0.369
28	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
29	0.438	0.323	0.276	0.207	0.415	0.323	0.276	0.115	0.046	0.323
30	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
31	0.369	0.161	0.161	0.115	0.323	0.369	0.276	0.184	0.115	0.138
32	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
33	0.276	0.115	0.207	0.115	0.253	0.323	0.276	0.207	0.230	0.115
34	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
35	0.161	0.161	0.276	0.046	0.207	0.207	0.300	0.184	0.253	0.161
36	0.023	0.023	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.023
37	0.230	0.230	0.276	0.207	0.115	0.069	0.253	0.161	0.253	0.276
38	0.023	0.023	0.069	0.000	0.000	0.000	0.000	0.023	0.000	0.023
39	0.246	0.253	0.115	0.192	0.138	0.115	0.161	0.161	0.184	0.146
40	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.023	0.000	0.023
Note: The nominal current is 8.69 A.										

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test										Result - Remark	Verdict
<b>Interharmonics</b>												
P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100		
f [Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	
75	0.092	0.069	0.069	0.046	0.046	0.046	0.046	0.046	0.069	0.084		
125	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.046	0.038		
175	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.046	0.045		
225	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.046	0.042		
275	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022		
325	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022		
375	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022		
425	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022		
475	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022		
525	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
575	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
625	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
675	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
725	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
775	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022		
825	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
875	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
925	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
975	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1025	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1075	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1125	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1175	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1225	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1275	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1325	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1375	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1425	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1475	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1525	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1575	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1625	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1675	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023		
1725	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.023	0.023	0.023		
1775	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.023	0.023	0.023		
1825	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023		
1875	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023		
1925	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023		
1975	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023		
2025	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023		
Note: The nominal current is 8.69 A.												

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Higher Frequencies**

P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
f [kHz]	I [%]									
2.1	0.007	0.004	0.006	0.005	0.007	0.003	0.002	0.002	0.002	0.006
2.3	0.006	0.002	0.007	0.002	0.010	0.005	0.004	0.002	0.002	0.005
2.5	0.004	0.003	0.003	0.002	0.003	0.008	0.002	0.003	0.003	0.004
2.7	0.002	0.004	0.001	0.002	0.003	0.004	0.003	0.003	0.002	0.004
2.9	0.002	0.002	0.001	0.001	0.002	0.003	0.003	0.001	0.002	0.004
3.1	0.002	0.003	0.002	0.003	0.002	0.005	0.002	0.001	0.003	0.003
3.3	0.002	0.003	0.004	0.003	0.001	0.002	0.005	0.001	0.001	0.003
3.5	0.001	0.004	0.003	0.002	0.002	0.002	0.005	0.003	0.003	0.004
3.7	0.002	0.003	0.002	0.006	0.002	0.001	0.002	0.005	0.004	0.004
3.9	0.002	0.001	0.002	0.005	0.001	0.001	0.001	0.004	0.004	0.004
4.1	0.001	0.002	0.001	0.005	0.001	0.001	0.002	0.002	0.002	0.002
4.3	0.001	0.001	0.001	0.003	0.001	0.001	0.002	0.001	0.002	0.002
4.5	0.003	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.003	0.003
4.7	0.003	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.004
4.9	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.002	0.003
5.1	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.002	0.001
5.3	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.003
5.5	0.002	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002	0.002
5.7	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
5.9	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.002
6.1	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.002	0.003	0.002
6.3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
6.5	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.002
6.7	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.001
6.9	0.001	0.002	0.001	0.001	0.001	0.000	0.002	0.001	0.001	0.002
7.1	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.002	0.002	0.002
7.3	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.002	0.003	0.002
7.5	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002
7.7	0.001	0.001	0.001	0.003	0.001	0.001	0.000	0.001	0.001	0.001
7.9	0.001	0.001	0.001	0.003	0.001	0.001	0.000	0.002	0.001	0.001
8.1	0.001	0.002	0.002	0.002	0.001	0.002	0.001	0.002	0.002	0.002
8.3	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.002	0.003
8.5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
8.7	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8.9	0.001	0.002	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.001

Note:

The nominal current is 8.69 A.

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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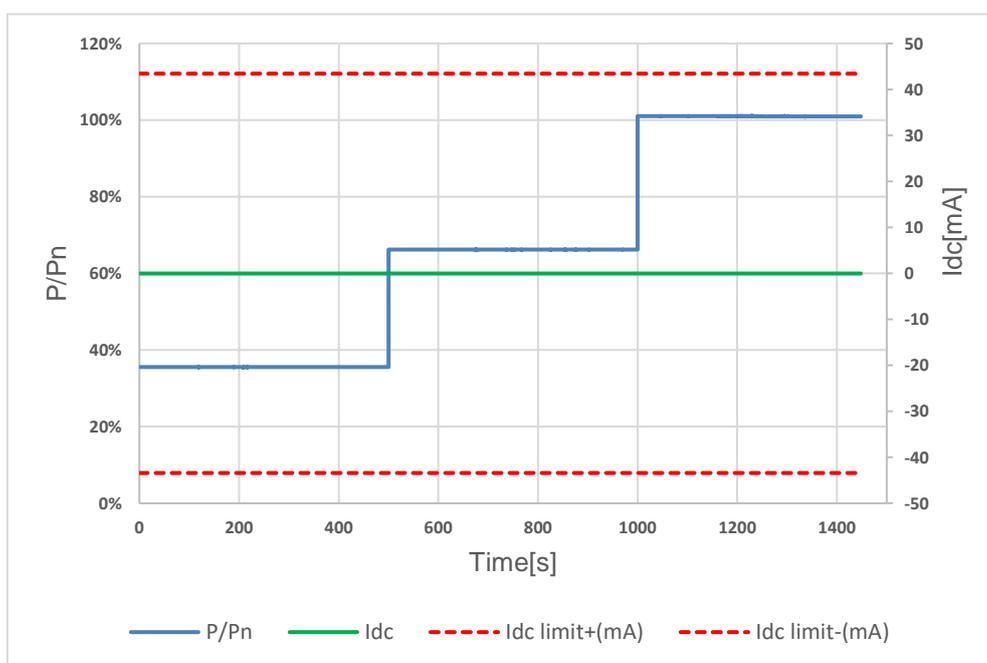
<b>5.2.6</b>	<b>TABLE: Infeed of direct currents</b>		<b>P</b>
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Model	SG2000
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## Energy supply

Test conditions	Power[W]	DC current [mA]			Limited
		L1	L2	L3	
Between 30 % $S_{E_{max}}$ and 40 % $S_{E_{max}}$	2019.78	0.001	-	-	0.5% (43.4mA)
Between 60 % $S_{E_{max}}$ and 70 % $S_{E_{max}}$	1324.48	0.001	-	-	0.5% (43.4mA)
> 95 % $S_{E_{max}}$	711.78	0.001	-	-	0.5% (43.4mA)

## Diagram

**Note:**

The tests are carried out according to DIN VDE V 0124-100:2020-06 clause 5.2.6.

The inverter is operated within the control range of the EZE in the following operating points, whereby for each operating point after reaching a stable operating temperature for at least 5 min the direct current portions of the mains currents are recorded in all external conductors to become. According to VDE-AR-N 4100: 2019-04, the measurement of currents based on DIN EN 61000-4-7 (VDE-0847-4-7) is carried out over 10 basic vibration periods.

**Operating points:**

- I) between 30%  $S_{E_{max}}$  and 40%  $S_{E_{max}}$
- II) between 60%  $S_{E_{max}}$  and 70%  $S_{E_{max}}$
- III) > 95%  $S_{E_{max}}$

The low-voltage grid or network simulator on which these tests are carried out must meet the following conditions:

- I) Mains voltage: nominal value  $\pm 5\%$
- II) Mains frequency: 50 Hz  $\pm 0.2$  Hz

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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III) THD of the mains voltage: &lt; 2.5%

IV) When using power simulators: DC component of voltage &lt; 0.1%

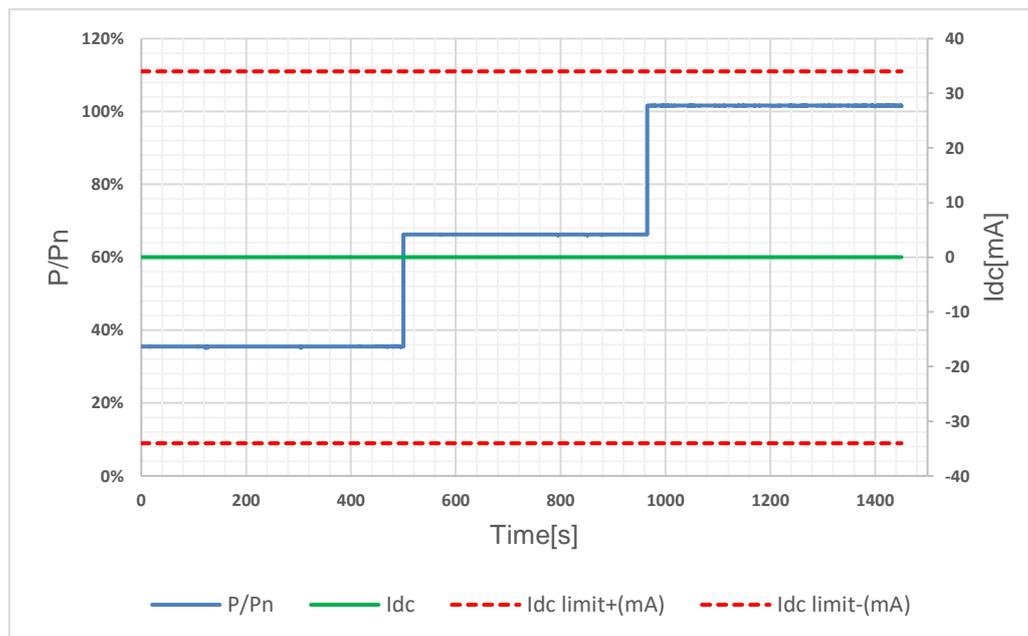
5.2.6	TABLE: Infeed of direct currents	P
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Model	SG1600
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## Energy supply

Test conditions	Power [W]	DC current [mA]			Limited
		L1	L2	L3	
Between 30 % $S_{E_{max}}$ and 40 % $S_{E_{max}}$	568.35	0.001	-	-	0.5% (34 mA)
Between 60 % $S_{E_{max}}$ and 70 % $S_{E_{max}}$	1059.97	0.001	-	-	0.5% (34 mA)
> 95 % $S_{E_{max}}$	1625.58	0.001	-	-	0.5% (34 mA)

## Diagram

**Note:**

The tests are carried out according to DIN VDE V 0124-100:2020-06 clause 5.2.6.

The inverter is operated within the control range of the EZE in the following operating points, whereby for each operating point after reaching a stable operating temperature for at least 5 min the direct current portions of the mains currents are recorded in all external conductors to become. According to VDE-AR-N 4100: 2019-04, the measurement of currents based on DIN EN 61000-4-7 (VDE-0847-4-7) is carried out over 10 basic vibration periods.

**Operating points:**I) between 30%  $S_{E_{max}}$  and 40%  $S_{E_{max}}$ II) between 60%  $S_{E_{max}}$  and 70%  $S_{E_{max}}$

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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III) > 95%  $S_{E_{max}}$

The low-voltage grid or network simulator on which these tests are carried out must meet the following conditions:

I) Mains voltage: nominal value  $\pm 5\%$

II) Mains frequency: 50 Hz  $\pm 0.2$  Hz

III) THD of the mains voltage: < 2.5%

IV) When using power simulators: DC component of voltage < 0.1%

DIN VDE V 0124-100, VDE-AR-N 4105

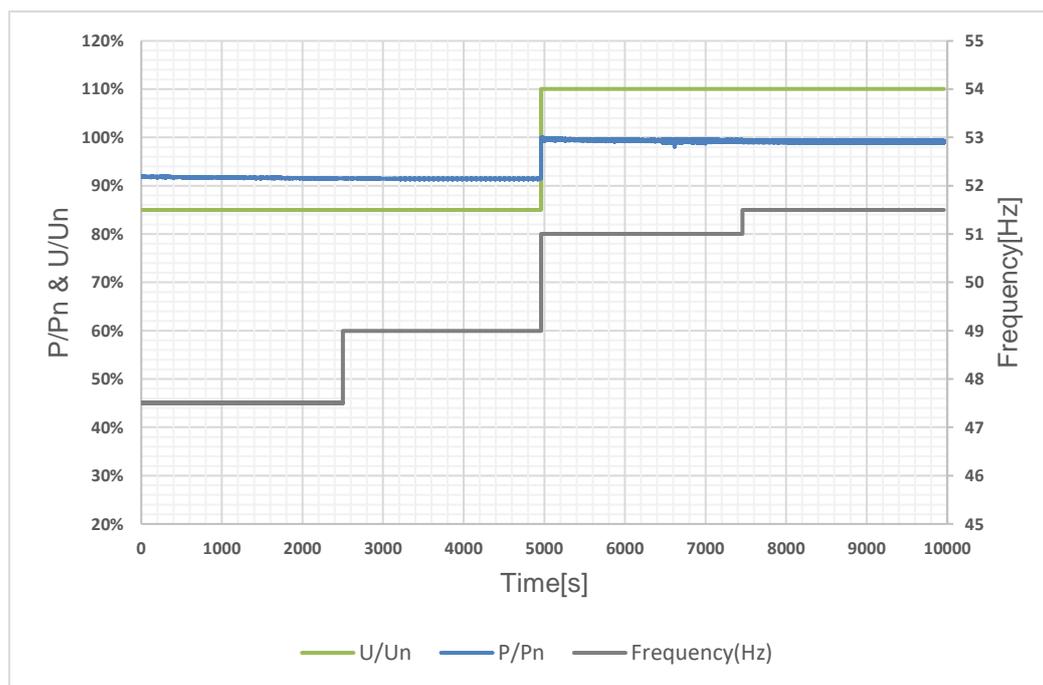
Clause	Requirement - Test	Result - Remark	Verdict
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<b>5.7.1</b>	<b>TABLE: Operating frequency and voltage range</b>							<b>P</b>
<b>Model</b>	SG2000							
Test sequence	Test condition		Measurement					Limits
	U/U <sub>n</sub>	f (Hz)	U/U <sub>n</sub>	f (Hz)	P/P <sub>n</sub>	Cosφ	Duration T (s)	Cont. T
1	85%	47.5	84.99%	47.49	91.68%	0.999	2450	≥ 1800s
2	85%	49.0	84.99%	48.99	91.46%	0.999	2458	Not required
3	110%	51.0	109.99%	51.00	99.15%	0.999	2450	Not required
4	110%	51.5	109.99%	51.49	99.41%	0.999	2450	≥ 1800s

Note:

Respecting the legal framework, it is possible that longer time periods are required by the responsible party in some synchronous areas.

Diagram



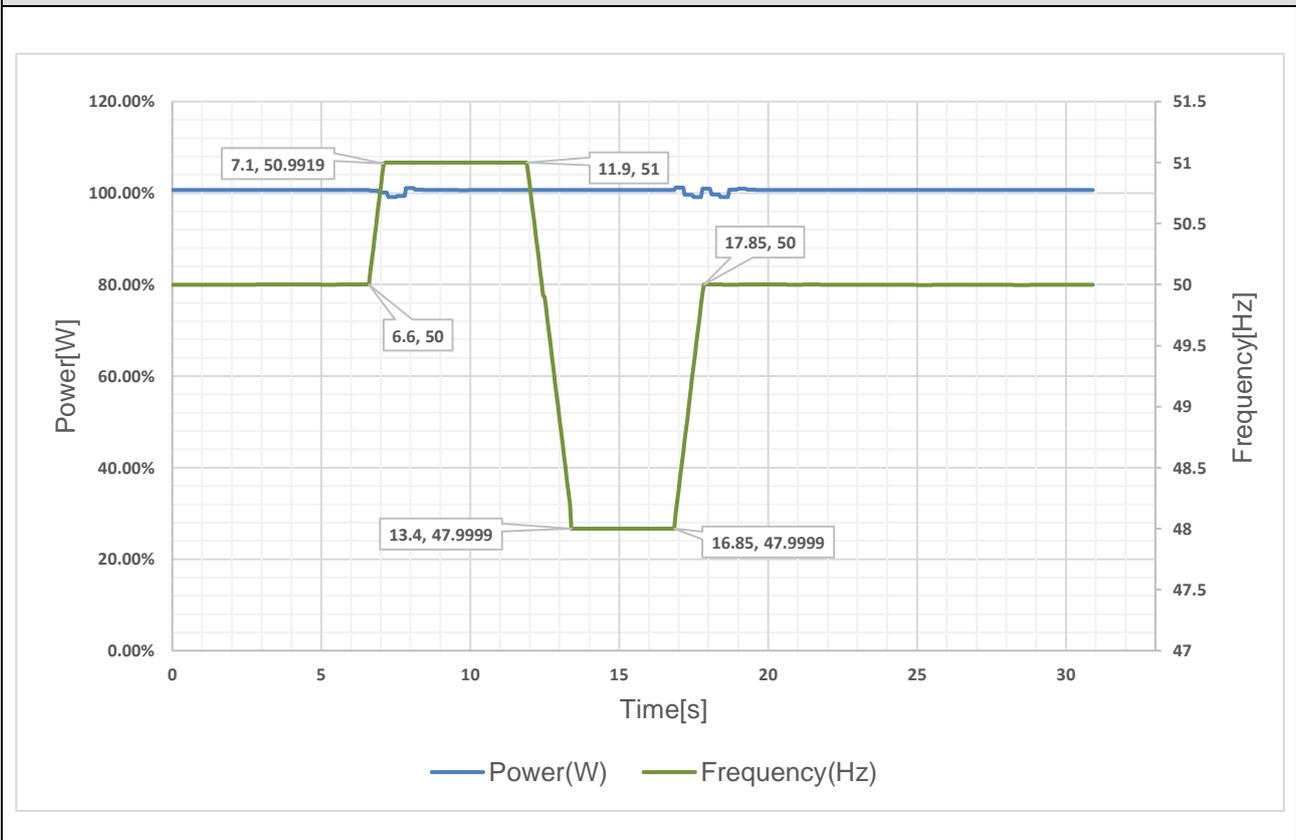
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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5.7.1	TABLE: Rate of change of frequency (ROCOF) immunity					P
Model	SG2000					
Test step	Ramp	From (Hz)	To (Hz)	Time (s)	Power (W)	Limit
1	dwll	50.0	50.0	5.0	2023.1	No disconnection
2	+1.5 Hz/s	50.0	51.5	1.0	2003.1	
3	dwll	51.5	51.5	5.0	2013.6	
4	-2 Hz/s	51.5	50.5	0.5	2016.4	
5	-1.25 Hz/s	50.5	48.0	2	2023.2	
6	dwll	48.0	48.0	5.0	2020.3	
7	-1.25 Hz/s	48.0	50.5	2	2012.2	
8	+2 Hz/s	50.5	51.5	0.5	2012.4	
9	dwll	51.5	51.5	5.0	2020.2	
10	-1.5 Hz/s	51.5	50.0	1.0	2016.0	
11	dwll	50.0	50.0	5.0	2022.5	

Note: For rapid frequency changes, the frequency measurement must not exceed 200 ms.

Graph of Test



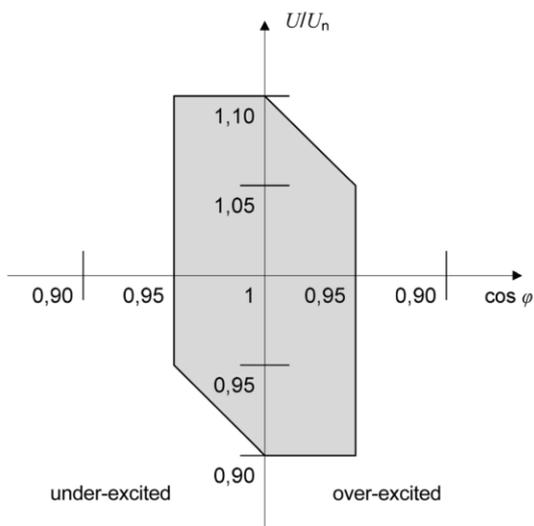
DIN VDE V 0124-100, VDE-AR-N 4105					
Clause	Requirement - Test	Result - Remark			Verdict
<b>5.4.2 (5.7.2.2)</b>	<b>TABLE: Measurement of the active power and reactive power range</b>				<b>P</b>
Model	SG2000				
Setting values	cos $\varphi = 1$ :	1			
	cos $\varphi$ max over-excited:	+0.95			
	cos $\varphi$ max under-excited:	-0.95			
<b>Test:</b>					
600 s mean value	0.9U <sub>n</sub>	0.95U <sub>n</sub>	U <sub>n</sub>	1.05 U <sub>n</sub>	1.09U <sub>n</sub>
a) cos $\varphi = 1$ at 100% P <sub>E<sub>max</sub></sub>					
U [V]:	206.9	N/A	229.9	N/A	250.6
P <sub>E<sub>max</sub>600 a)</sub> [W]	1971.4	N/A	2011.1	N/A	2027.1
S <sub>E<sub>max</sub>600 a)</sub> [VA]	1972.2	N/A	2012.0	N/A	2028.1
COS $\varphi_{E_{max}600}$	0.999	N/A	0.999	N/A	0.999
b) maximum under-excited (i) at 100% P <sub>E<sub>max</sub></sub>					
U [V]:	N/A	218.4	229.9	N/A	250.6
P <sub>E<sub>max</sub>600 b)</sub> [W]	N/A	1928.8	1918.75	N/A	1921.8
S <sub>E<sub>max</sub>600 b)</sub> [VA]	N/A	2035.3	2031.6	N/A	2036.5
COS $\varphi_{E_{max}600}$ -under-excited	N/A	0.947	0.945	N/A	0.945
c) maximum over-excited (c) at 100% P <sub>E<sub>max</sub></sub>					
U [V]:	206.9	N/A	229.9	241.4	N/A
P <sub>E<sub>max</sub>600 c)</sub> [W]	1912.7	N/A	1906.2	1923.1	N/A
S <sub>E<sub>max</sub>600 c)</sub> [VA]	2026.5	N/A	2015.9	2037.6	N/A
COS $\varphi_{E_{max}600}$ -over-excited	-0.945	N/A	-0.945	-0.944	N/A
P <sub>E<sub>max</sub> 600</sub> and S <sub>E<sub>max</sub>600</sub>					
P <sub>E<sub>max</sub> 600</sub> = max(P <sub>E<sub>max</sub>600 a)</sub> , P <sub>E<sub>max</sub>600 b)</sub> , P <sub>E<sub>max</sub>600 c)</sub> ) [W]				2027.1	
S <sub>E<sub>max</sub>600</sub> = max(S <sub>E<sub>max</sub>600 a)</sub> , S <sub>E<sub>max</sub>600 b)</sub> , S <sub>E<sub>max</sub>600 c)</sub> ) [VA]				2037.6	
Note:					
At least 10-minute averages value must be recorded:					
– U, cos( $\varphi$ ), P and S from a) to c)					
– S <sub>E<sub>max</sub></sub> and P <sub>E<sub>max</sub></sub>					
These tests serve to prove the adjustable reactive power range according to the requirements of VDE-AR-N 4105: 2018-11 (chapter 5.7.2.2), as well as to determine the values for S <sub>E<sub>max</sub></sub> and P <sub>E<sub>max</sub></sub> .					
These tests are carried out according to DIN VDE V 0124-100 Clause 5.4.2.1.					

DIN VDE V 0124-100, VDE-AR-N 4105

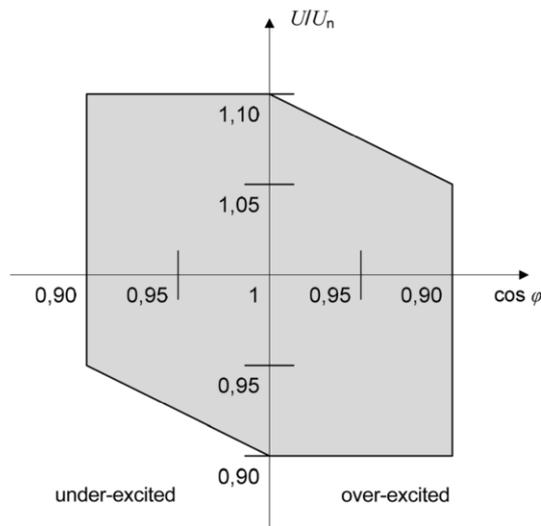
Clause	Requirement - Test	Result - Remark	Verdict
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**5.7.2.2.2 Type 2 systems – inverters only**

At the generator terminals, each power generation unit to be connected shall meet the requirements according to Figure 2 and Figure 3.



**Figure 2 – Requirements for power generation units regarding the reactive power supply at the generator terminals**  
 ( $\sum S_{E_{max}} \leq 4,6 \text{ kVA}$ )



**Figure 3 – Requirements for power generation units regarding the reactive power supply at the generator terminals**  
 ( $\sum S_{E_{max}} > 4,6 \text{ kVA}$ )

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**5.4.3.3 (5.7.4.2.1) TABLE: Active power reduction by set-point** **P**

Model SG2000

**5.4.3.3 Measurement of adjustment accuracy (according to VDE V 0124 clause)**

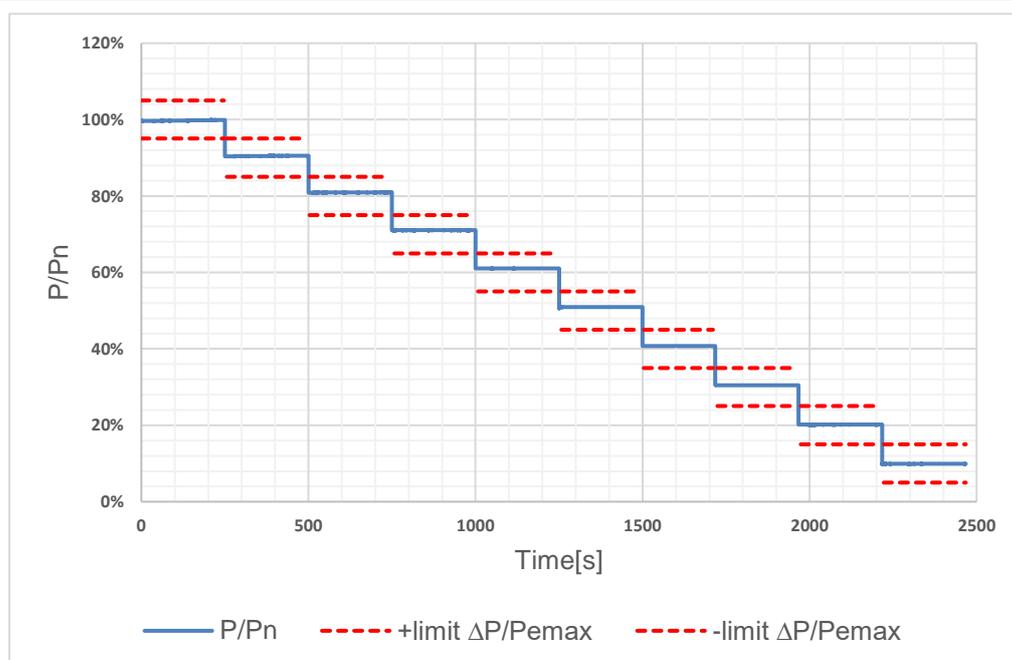
1-min mean value, $P/P_n$ [%]	100	90	80	70	60	50	40	30	20	10
$P_{\text{Setpoint}}$ [W]:	2000	1800	1600	1400	1200	1000	800	600	400	200
$P_{E60}$ [W]:	1994.8	1809.3	1618.2	1420.9	1220.5	1018.5	814.3	609.9	403.7	197.6
$\Delta P_{E60}/P_{E\text{max}}$ [%]:	-0.26	0.46	0.91	1.04	1.02	0.92	0.71	0.49	0.18	-0.12
Limit of $\Delta P_{E60}/P_{E\text{max}}$ [%]:	+5% $P_{E\text{max}}$									

Assessment criterion:

-no network disconnection

-the active power value does not exceed the setpoint value for more than 5%  $P_{E\text{max}}$

**Curve for adjustment accuracy**

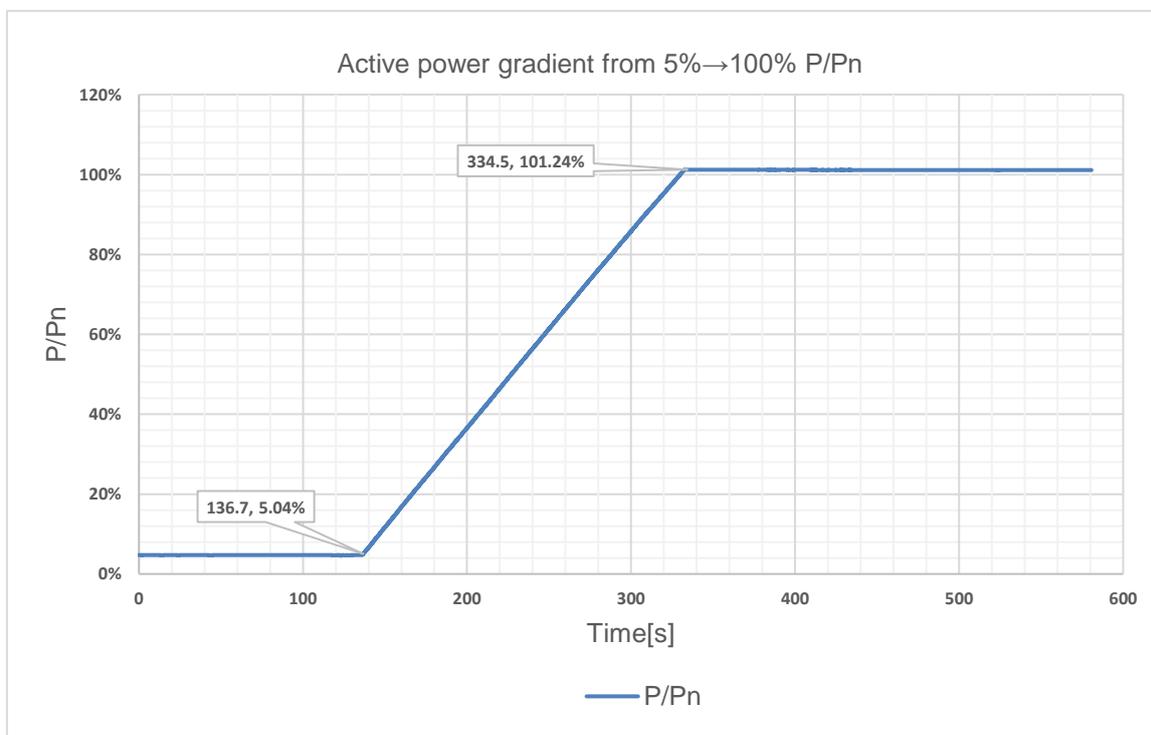
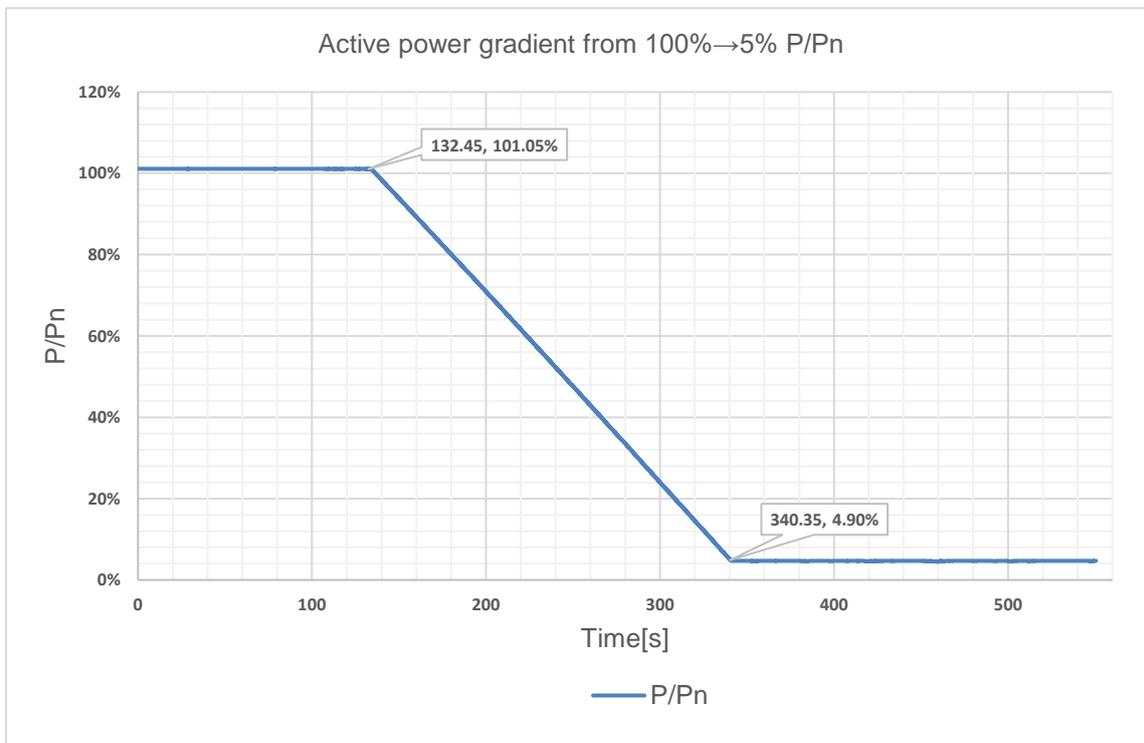


DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
<b>5.4.3.4 (5.7.4.2.1)</b>	<b>TABLE: Measurement of the power gradient</b>		<b>P</b>
Model:	SG2000		
Test sequence	Max. Power gradient as calculated from the difference of the 10 s mean value at time t1 and at time t1 + 10 s [%Pn/s]	Limit of power gradient [%Pn/s]	
100%P <sub>n</sub> to 5% P <sub>n</sub>	0.462	≥ 0.33 and ≤ 0.66	
5%P <sub>n</sub> to 100% P <sub>n</sub>	0.486	≥ 0.33 and ≤ 0.66	
<p>Note:</p> <p>In this test, the power gradient of the PGU (dP/dt) is determined continuously. To determine the power gradient, a 10-second moving average of the active power is calculated, and the 10-second average must be recalculated at least every second from the previous data. From the 10 s mean values, the active power gradient is calculated from the difference of the 10 s mean value at time t<sub>1</sub> and at time t<sub>1</sub> + 10 s as follows:</p> $(\Delta P / 10 s) = (P_{t = t_1 + 10s} - P_{t = t_1}) / 10 s$			

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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Diagram



## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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<b>5.4.3.5</b>	<b>TABLE: Measurement Priority Interfaces / Energy Management System</b>	<b>P</b>	
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Model	SG2000		
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Interface No.	1	2	Measured Active power P/P <sub>n</sub>	Gradient(% P <sub>n</sub> /s)
Test 1: P <sub>setpoint</sub> in pu	1,0	0,7	71.3%	0.47%
Test 2: P <sub>setpoint</sub> in pu	0,7	0,6	61.1%	0.49%
Test 3: P <sub>setpoint</sub> in pu	0,6	0,5	50.9%	0.46%

**Note:**

If a power reduction can be requested via more than one interface, different random values as multiples of 10% PrE must be specified at all available interfaces.

measurement 5.4.3.4 either

a) always receives the lowest set-point priority, or

b) the set-point on the interface programmed for the NSM is never overstated.

**5.4.3.6 Evaluation criteria**

Tests 5.4.3.2 to 5.4.3.5 are passed if:

- there is no mains disconnection and

- the active power value does not deviate by more than +5% PrE from the set-point and

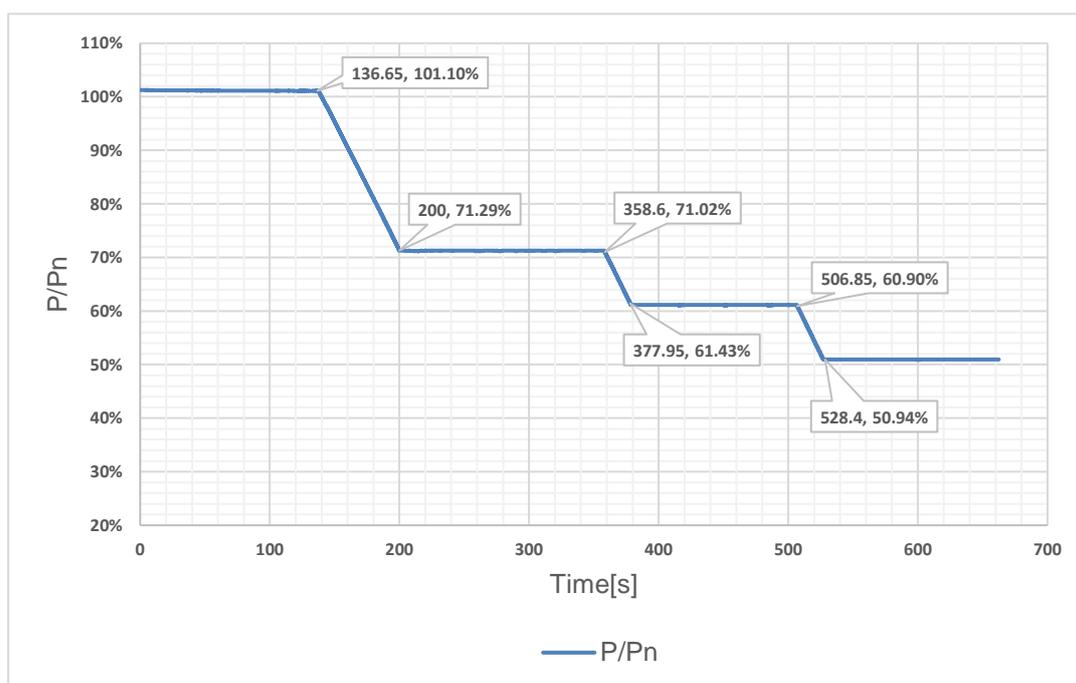
- the performance gradients determined according to 5.4.3.3 do not fall below 0.33% PrE/s and do not exceed 0.66% PrE/s.

- measurement 5.4.3.4 either

a) always receives the lowest set-point priority, or

b) the set-point on the interface programmed for the NSM is never overstated.

during testing of the logical interface (input port), the active power feed-in of the PGU is completely terminated within a maximum of 5 seconds after the change of state of the logical signal.

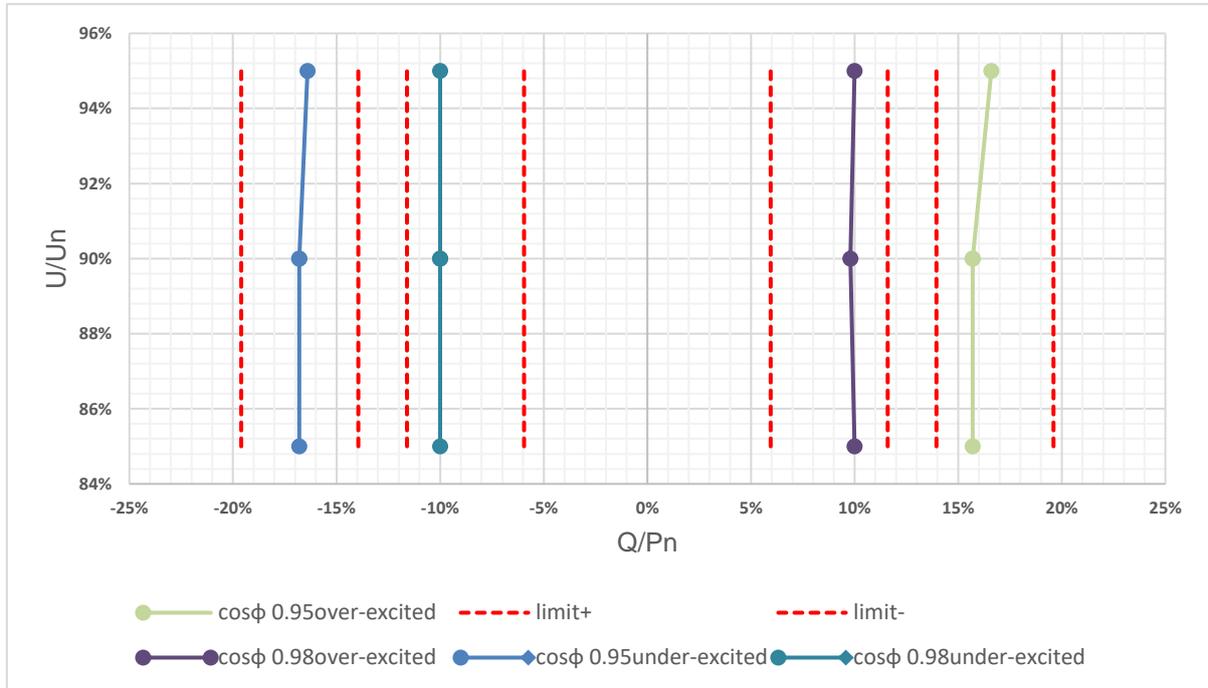
**Diagram**

DIN VDE V 0124-100, VDE-AR-N 4105											
Clause	Requirement - Test						Result - Remark			Verdict	
<b>5.4.8.2 (5.7.2.4c)</b>	<b>TABLE: Test of reactive power / cos <math>\varphi</math> setting accuracy</b>									<b>P</b>	
Model	SG2000										
<b>For Type 2 PGUs-only inverters, <math>\Sigma S_{E_{max}} \leq 4.6</math> kVA:</b>											
<b>Test 1:</b>											
Test condition				Measurement						Limit	
P/P <sub>n</sub>	U/n	Target cos $\varphi$	Target Q/P <sub>n</sub>	U <sub>E60</sub> /U <sub>n</sub>	P <sub>E60</sub> /P <sub>n</sub>	S <sub>E60</sub> /P <sub>n</sub>	Q <sub>E60</sub> /P <sub>n</sub>	$\Delta Q$ /P <sub>n</sub>	cos $\varphi_{E60}$	$\Delta Q$ /P <sub>n</sub>	$\Delta$ cos $\varphi$
40%-60%	90%	0.95 <sup>over-excited</sup>	15.6%	89.9%	50.5%	52.9%	15.7%	0.10%	0.954	±4%	±0.01
	100%			99.9%	50.7%	53.1%	15.7%	0.10%	0.955		
	110%			109.9%	50.7%	53.4%	16.6%	1.00%	0.950		
	90%	0.98 <sup>over-excited</sup>	9.95%	89.9%	50.8%	51.8%	10.0%	0.05%	0.980		
	100%			99.9%	50.9%	51.8%	9.8%	-0.15%	0.981		
	110%			109.9%	51.0%	51.9%	10.0%	0.05%	0.981		
	90%	0.95 <sup>under-excited</sup>	-15.6%	89.9%	50.6%	53.4%	-16.8%	-1.20%	0.949		
	100%			99.9%	50.8%	53.5%	-16.8%	-1.20%	0.949		
	110%			109.9%	50.2%	52.8%	-16.4%	-0.80%	0.938		
	90%	0.98 <sup>under-excited</sup>	-9.95%	89.9%	50.7%	51.7%	-10.0%	-0.05%	0.981		
	100%			99.9%	50.8%	51.8%	-10.0%	-0.05%	0.980		
	110%			109.9%	50.9%	51.9%	-10.0%	-0.05%	0.981		
<b>Test 2:</b>											
100%	90%	0.95 <sup>over-excited</sup>	31.2%	89.9%	95.4%	100.4%	31.3%	0.10%	0.950	±4%	±0.01
	100%			99.9%	96.2%	101.4%	31.8%	0.60%	0.949		
	110%			109.9%	96.7%	101.9%	31.9%	0.70%	0.949		
	90%	0.98 <sup>over-excited</sup>	19.9%	89.9%	97.8%	99.7%	19.7%	-0.20%	0.980		
	100%			99.9%	99.0%	100.9%	19.4%	-0.50%	0.981		
	110%			109.9%	99.6%	101.6%	20.0%	0.10%	0.980		
	90%	0.95 <sup>under-excited</sup>	-31.2%	89.9%	95.0%	99.9%	-31.1%	0.10%	0.950		
	100%			99.9%	95.7%	100.8%	-31.5%	-0.30%	0.949		
	110%			109.9%	96.3%	101.4%	-31.7%	-0.50%	0.949		
	90%	0.98 <sup>under-excited</sup>	-19.9%	89.9%	97.5%	99.4%	-19.6%	0.30%	0.980		
	100%			99.9%	98.6%	100.6%	-19.8%	0.10%	0.980		
	110%			109.9%	99.2%	101.2%	-19.9%	0.00%	0.980		
Note(s): The test was conducted at 50% P <sub>n</sub> (Test 1) and 100% P <sub>n</sub> (Test 2) of output power.											

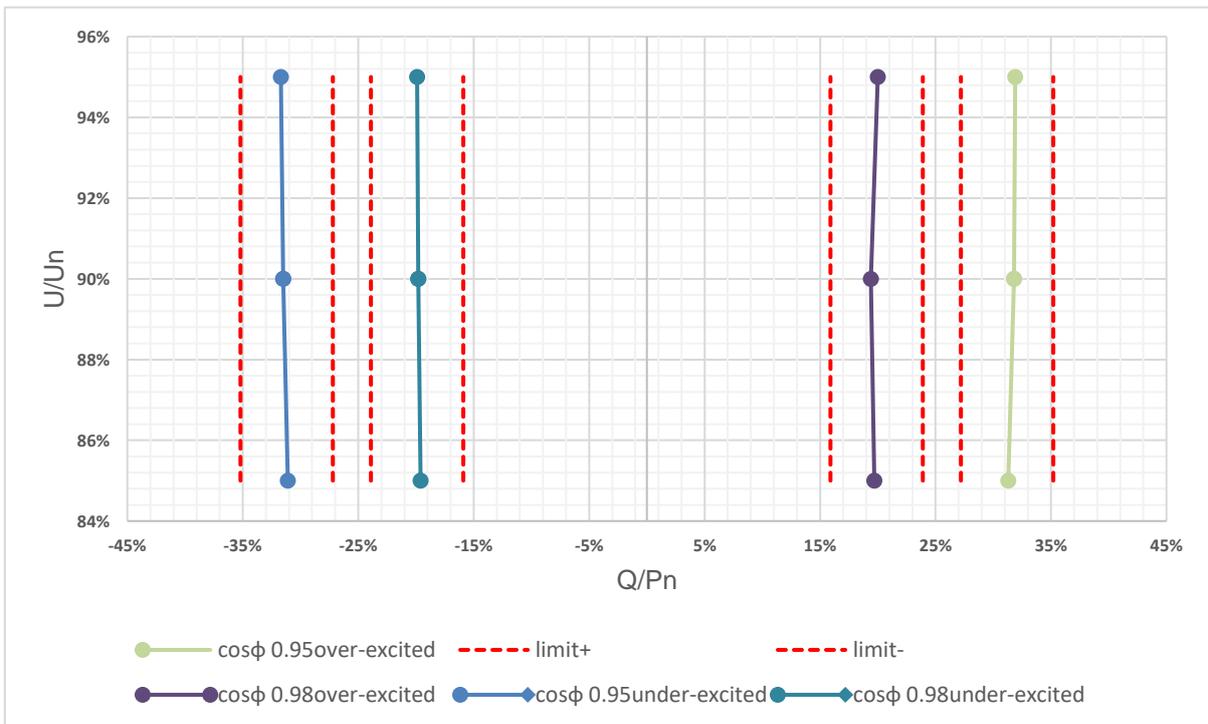
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Graph of cos φ setting accuracy at 50% P<sub>n</sub> (Test 1)**



**Graph of cos φ setting accuracy at 100% P<sub>n</sub> (Test 2)**



DIN VDE V 0124-100, VDE-AR-N 4105										
Clause	Requirement - Test						Result - Remark		Verdict	
<b>5.4.8.3 (5.7.2.4b)</b>	<b>TABLE: Test for a displacement factor / active power characteristic curve <math>\cos \varphi</math> (P)</b>								<b>P</b>	
Model	SG2000									
<b>Test a): Static test for accuracy</b>										
Test Conditions	Measurements					Target value		Limits		
P/Sn	$U_{E60}/U_n$	$P_{E60}/Sn$	$Q_{E60}/Sn$	$\cos \varphi_{E60}$	$\Delta Q/Sn$	Q/Sn	$\cos \varphi$	$\Delta Q/Sn$		
95%	99.9%	96.5%	31.3%	0.950	0.1%	+31.2%	0.95*	$\leq \pm 4\%$		
90%	99.9%	90.1%	26.1%	0.960	-0.2%	26.3%	0.96			
80%	99.9%	80.4%	21.3%	0.966	1.3%	20.0%	0.97			
70%	99.9%	70.6%	13.5%	0.982	-0.7%	14.2%	0.98			
60%	99.9%	60.7%	8.2%	0.990	-0.3%	8.5%	0.99			
50%	99.9%	50.6%	1.5%	0.999	1.5%	0.0%	1.00			
40%	99.9%	40.5%	1.4%	0.999	1.4%	0.0%	1.00			
30%	99.9%	30.4%	1.2%	0.999	1.2%	0.0%	1.00			
20%	99.9%	20.1%	1.2%	0.997	1.2%	0.0%	1.00			
10%	99.9%	9.8%	1.4%	0.999	1.4%	0.0%	1.00			
<b>Test a): Static test for accuracy</b>										
10%	99.9%	9.8%	1.4%	0.989	1.4%	0.0%	1	$\leq \pm 4\%$		
20%	99.9%	20.2%	1.2%	0.998	1.2%	0.0%	1			
30%	99.9%	30.5%	1.2%	0.999	1.2%	0.0%	1			
40%	99.9%	40.7%	1.4%	0.999	1.4%	0.0%	1			
50%	99.9%	50.9%	1.6%	0.999	1.6%	0.0%	1			
60%	99.9%	61.1%	8.4%	0.990	-0.1%	8.5%	0.99			
70%	99.9%	71.1%	13.8%	0.981	-0.4%	14.2%	0.98			
80%	99.9%	81.1%	20.0%	0.970	0.0%	20.0%	0.97			
90%	99.9%	90.9%	26.5%	0.959	0.2%	26.3%	0.96			
95%	99.9%	96.9%	31.5%	0.951	0.3%	31.2%	0.95*			
<b>Test b): Dynamic test</b>										
Test Conditions	Measurements						Target value		Limits	
P/Sn	$U_{E60}/U_n$	$P_{E60}/Sn$	$Q_{E60}/Sn$	$\cos \varphi_{E60}$	$\Delta Q/Sn$	$T_{sr\_95\%}$	Q/Sn	$\cos \varphi$	$\Delta Q/Sn$	$T_{sr\_95\%}$
a) $\geq 99\%$	99.9%	99.0%	32.0%	0.951	0.8%	-	31.2%	0.950*	$\leq \pm 4\%$	$\leq 10s$
b) $\leq 50\%$	99.9%	45.7%	1.5%	0.999	1.5%	12.8	0	1		
c) $\geq 99\%$	99.9%	96.3%	31.3%	0.950	0.1%	11.9	31.2%	0.950*		
d) $75\% \pm 5\%$	99.9%	76.6%	17.5%	0.974	0.4%	11.2	17.1%	0.975		

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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Note(s):

\* Actual active power (P) output de-rating while rated Pn equal to Sn.

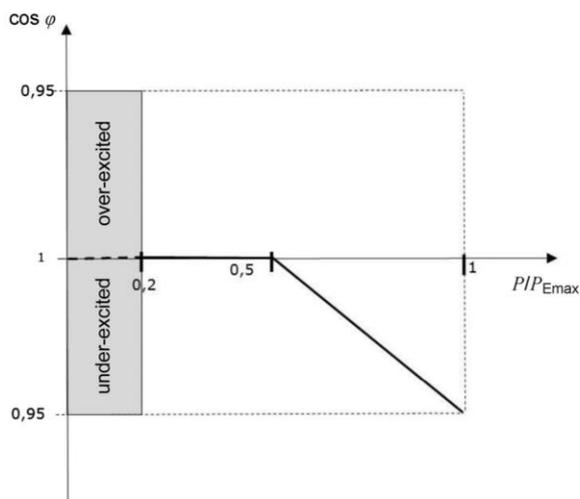
the maximum deviation between reactive power setpoint (calculated from the characteristic to be demonstrated) and reactive power actual value at the generator terminals is a maximum of  $\pm 4.0\%$  based on P<sub>E</sub>max.

For the test steps c) and d) the DC power or primary energy may be varied in steps  $\leq 10\%$  PrE step by step. Before setting a new level value, make sure that P and Q have swung in.

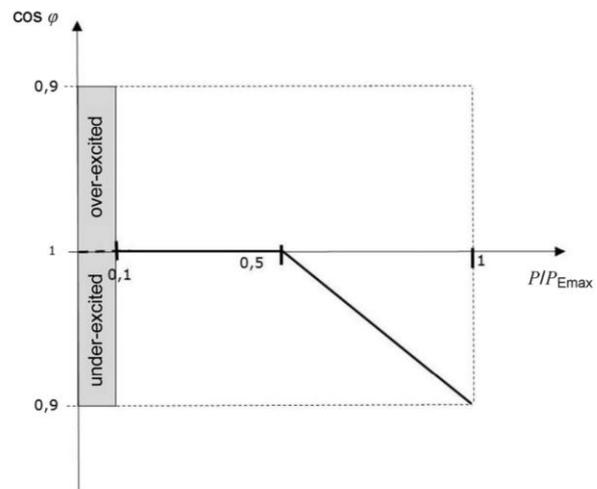
Jumping change means: "with a settling time of 1 s and a settling time"

**Re: b) Displacement factor/active power characteristic curve  $\cos \varphi (P)$**

The objective of this method is the reactive power supply by the power generation unit depending on the actual active power output ( $Q = f(P_{mom})$ ).



**Figure 8 – Characteristic curve for type 2**  
 $\sum S_{E_{max}} \leq 4,6 \text{ kVA}$  and type 1, stirling  
 generator, fuel cell  $\sum S_{E_{max}} > 4,6 \text{ kVA}$

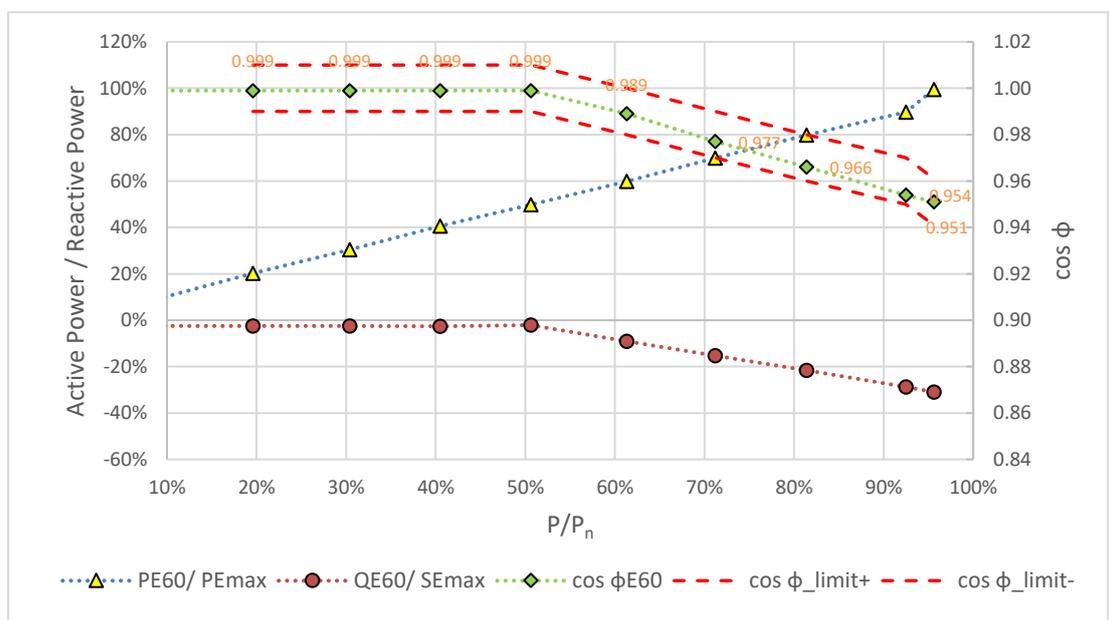


**Figure 9 – Standard characteristic curve**  
 for type 2 (inverters only)  
 $\sum S_{E_{max}} > 4,6 \text{ kVA}$

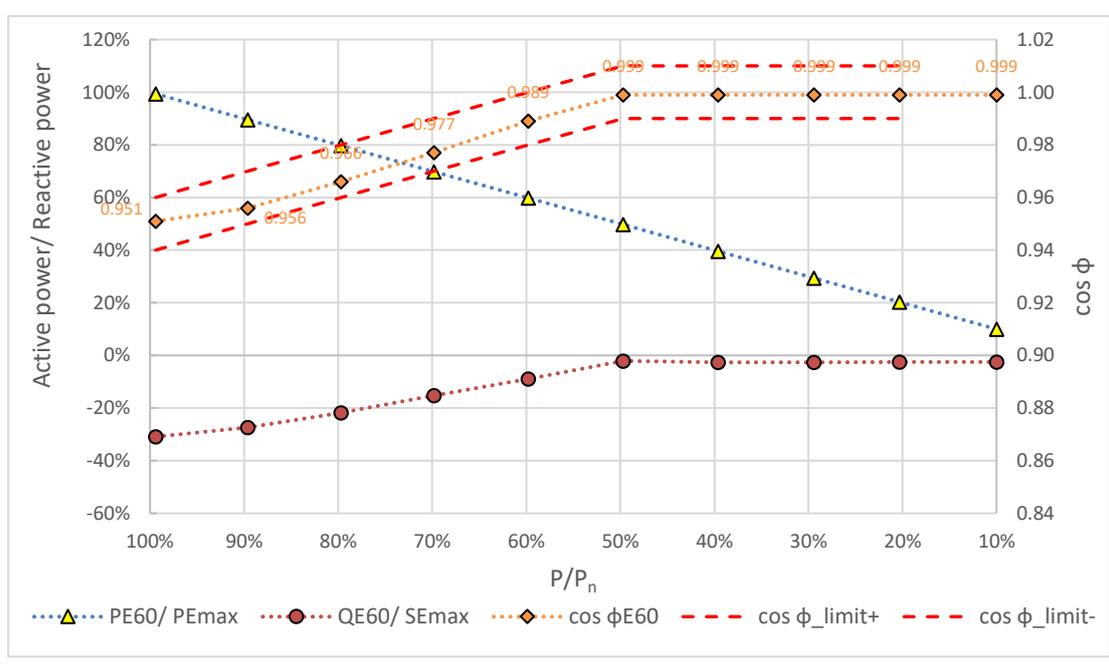
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Diagram of Static test for accuracy from 100% to 10%  $P_{E_{max}}$**



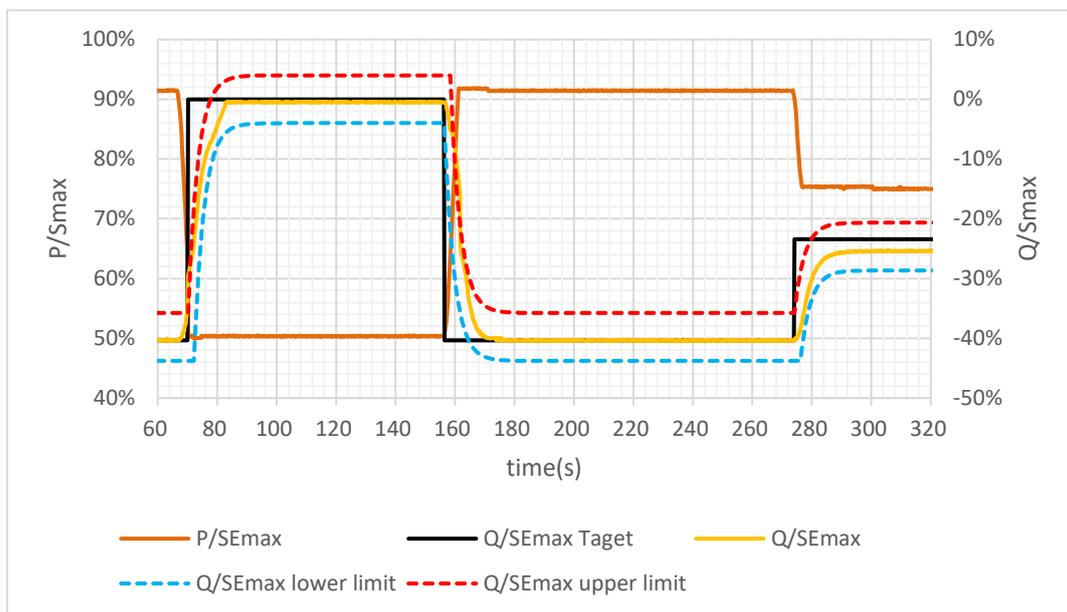
**Diagram of Static test for accuracy from 10% to 100%  $P_{E_{max}}$**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Diagram of Dynamic test from 100% → 50% → 100% → 75% P<sub>E</sub>max**



DIN VDE V 0124-100, VDE-AR-N 4105						
Clause	Requirement - Test				Result - Remark	Verdict
<b>5.5.2 to 5.5.6 (6.2 to 6.4)</b>	<b>TABLE: Proof of GS protection</b>					P
Ambient temperature (°C) .....					24	
Model	SG2000					
Component No.	Fault	Supply voltage (V)	Test time	Fuse #	Fuse current (A)	Observation
AC relay K1; PIN3-4; PIN5-6	Short circuit before start up	PV 65V, AC 230V	10min	-	-	Unit can't start up, error message"Relay FAULT". No damage, no hazards, no fire.
Relay R63, C130	Short circuit before start up		10min	-	-	Unit can't start up, error message"Relay FAULT". No damage, no hazards, no fire.
Relay Q17 E-C	Short circuit before start up		10min	-	-	Unit can't start up, error message"Relay FAULT". No damage, no hazards, no fire.
<b>Check that the relays fulfil the basic insulation or simple separation based on the PV circuit working voltage.</b>						<b>P</b>
<b>Each active phase can be switched. (L and N)</b>						<b>P</b>
<b>Supplementary information:</b>						

DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict

**Note:**

The functional check of the interface switch shall be carried out according to a) or b) or c):

- a) by using an interface switch which, in its active state, requires a control voltage to be applied continuously and which disconnects automatically when this voltage is no longer applied. The operational connection and disconnection processes shall be monitored;
- b) by connection and disconnection of the interface switch via the NS protection and monitoring its proper functioning (e. g. break contact of a monitoring contact) at least once daily;
- c) by using the integrated interface switch and the integrated NS protection for PV and battery inverters in compliance with DIN EN 62109 (VDE 0126-14).

A single fault shall not lead to a loss of the protective function of the NS protection. Faults of common cause shall be taken into account if the probability of their occurrence is of any significance. Each single fault should be indicated and lead to shut-down of the respective power generation unit or system.

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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5.5.7.4 (6.5.1 & 6.5.2)	<b>TABLE: Voltage monitoring and frequency monitoring NS protection Test of voltage rise protection U&gt;&gt;</b>		<b>P</b>
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Model	SG2000
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1. Ramp test for determining U>> trip value:

Test step	Test phase	Start voltage	End voltage	Setting trip value	Measured trip value	Trip value tolerance	Jump height $\Delta U$	Step length $\Delta t$
1.1	U <sub>L-N</sub>	<282.9 V	>292.1 V	287.5 V	287.76 V	$\pm 1\% U_n$	< 1.15 V	> 400 ms

2. Jump test for determining U>> trip time:

Test step	Test phase	Start voltage	End voltage	Setting trip time	Measured trip time	Disconnect time limit	Jump height $\Delta U$	Step length $\Delta t$
2.1	U <sub>L-N</sub>	<282.9 V	>292.1 V	100 ms	116 ms	$\leq 200$ ms	>9.2 V	>400 ms

## Jump test for determining U&gt;&gt; trip time

**Note:****Evaluation criteria:**

- Test steps 1.1 to 1.7, 4.1 to 4.7, 6.1 to 6.7, 8.1 and 10.1: These tests have been passed if the permissible tolerances between the setting value according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2 and the trip value are max  $\pm 1\% U_n$  for the voltage and max  $\pm 0.1\% f_n$  for the frequency. For synchronous and asynchronous generators coupled directly or via converters with  $P_{re} \leq 50$  kW as well as for Stirling generators and fuel cells, shutdown at  $U >$  already at  $0.85\% U_n$  is permissible.
- Test steps 2.1 to 2.7, 5.1 to 5.7, 9.1 and 11.1: These tests are passed if the tripping time after application of the jump is within the specifications according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2.

For criteria a) and b) it is ensured that no voltage other than the voltage under test exceeds any of the set and active limits.

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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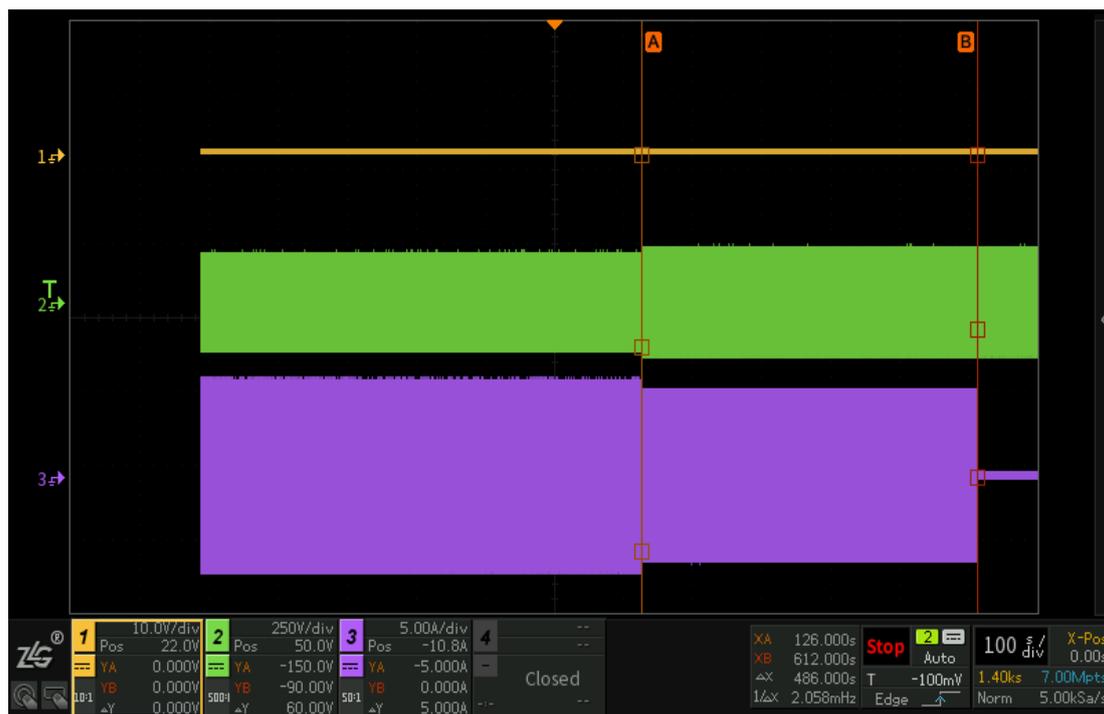
<b>5.5.7.4 (6.5.1 &amp; 6.5.2)</b>	<b>TABLE: Voltage monitoring and frequency monitoring NS protection Test for overvoltage protection U&gt;</b>		<b>P</b>
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Model	SG2000
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3. Test of voltage rise protection U>

Test step	Test phase	Measured disconnection time	Disconnection time limit
3.1	The voltage is set to 100% U <sub>n</sub> and held for >600.2 s. Thereafter the voltage is set to 112% U <sub>n</sub> (257.6 V). Disconnection must take place between 450 s and 550 s.		
	U <sub>L-N</sub>	486.0 s	450 to 550
3.2	The voltage is set to U <sub>n</sub> for >600.2 s and then to 108% U <sub>n</sub> (248.4 V) for >600.2 s. No disconnection should take place.		
	U <sub>L-N</sub>	No disconnection	Disconnection should not take place.
3.3	The voltage is set to 106% U <sub>n</sub> (243.8 V) and held for >600.2 s. Thereafter the voltage is set to 114% U <sub>n</sub> (262.2 V). Disconnection must take place between 225 s and 375 s.		
	U <sub>L-N</sub>	272.2 s	225 s to 375 s

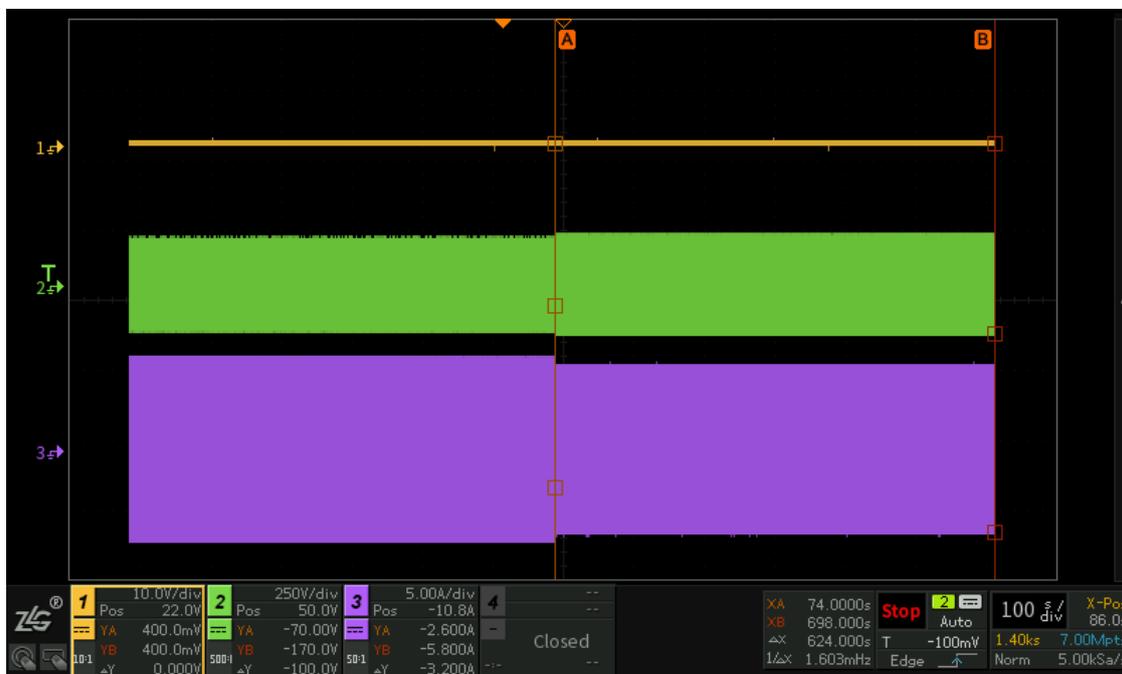
**3.1 Voltage set to 112 % Un:**



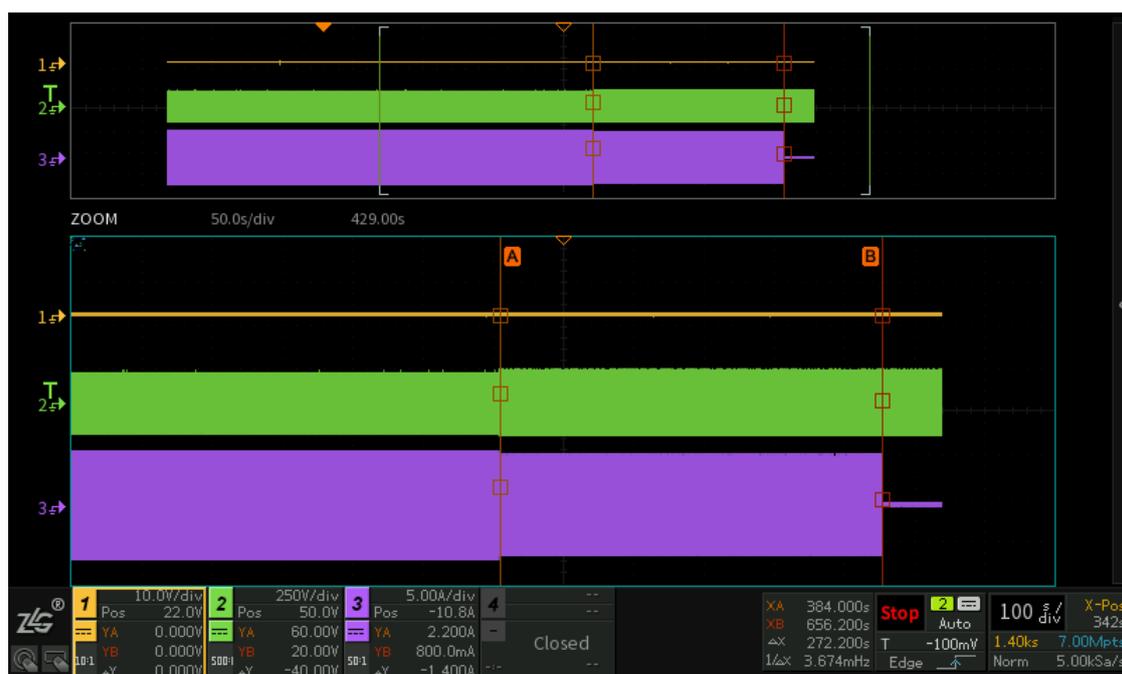
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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3.2 Voltage set to 108 % Un:



3.2 Voltage set to 114 % Un:

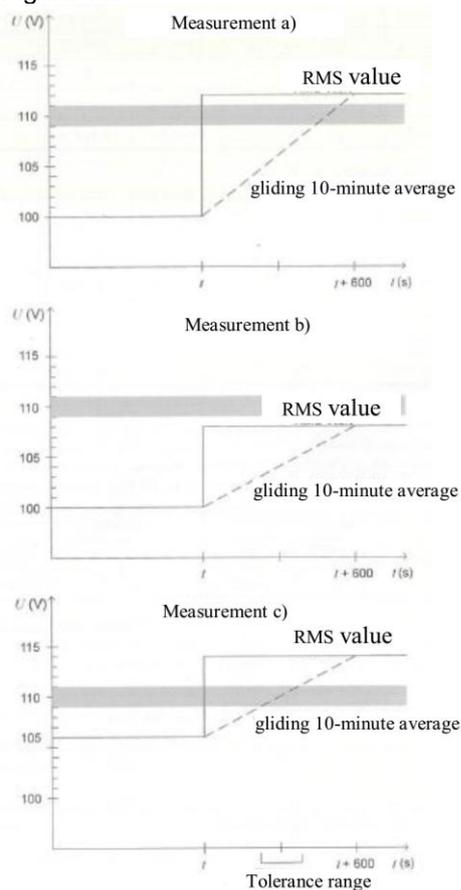


## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Evaluation criteria:**

- c) Test step 3.1: The test is passed if the shutdown occurs between 450 s and 550 s after the jump, see Figure 11.
- d) Test step 3.2: The test is passed if no shutdown has occurred after 600 s, see Figure 11.
- e) Test step 3.3: The test is passed if the shutdown occurs between 225 s and 375 s after the jump, see Figure 11.



**Figure 11 - Testing of the voltage increase protection as a 10-minute moving average – Measurements a), b), c)**

DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict

5.5.7.4 (6.5.1 & 6.5.2)	<b>TABLE: Voltage monitoring and frequency monitoring NS protection Test for undervoltage protection U&lt;</b>		<b>P</b>
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Model	SG2000
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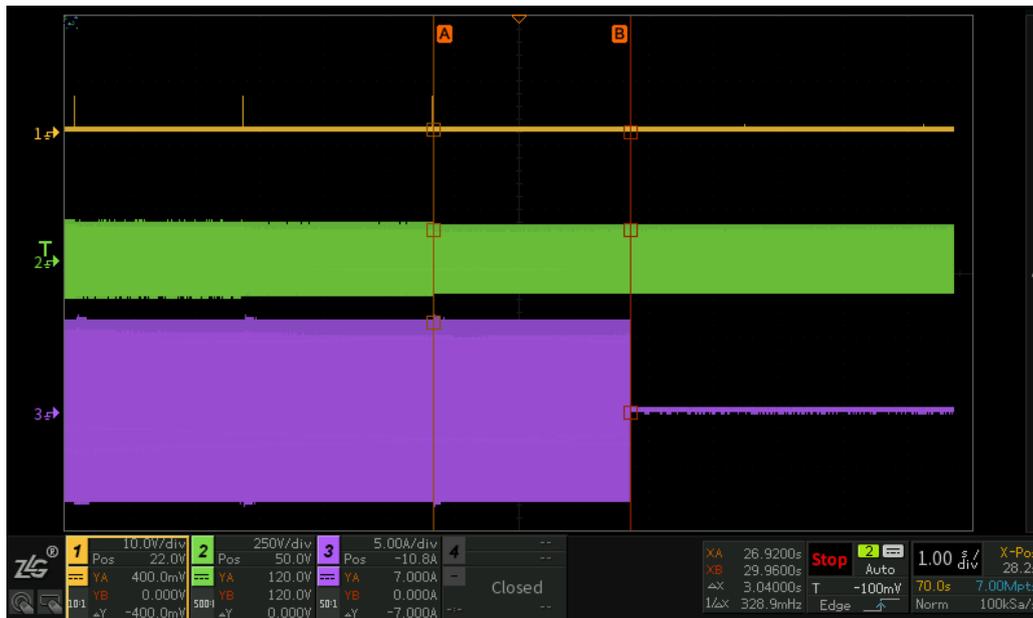
4. Ramp test for determining U< trip value:

Test step	Test phase	Start voltage	End voltage	Setting trip value	Measured trip value	Trip value tolerance	Jump height $\Delta U$	Step length $\Delta t$
4.1	U <sub>L-N</sub>	>188.6 V	<179.4 V	184.0 V	182.7 V	$\pm 1\% U_n$	< 1.15 V	>3200 ms

5. Jump test for determining U< trip time:

Test step	Test phase	Start voltage	End voltage	Setting trip time	Measured trip time	Disconnect time limit	Jump height $\Delta U$	Step length $\Delta t$
5.1	U <sub>L-N</sub>	> 200.1 V	< 179.4 V	3000	3040.0 ms	3.0 - 3.1 s	> 9.2 V	>3200 ms

**Jump test for determining U< trip time**



**Note:**

**Evaluation criteria:**

- Test steps 1.1 to 1.7, 4.1 to 4.7, 6.1 to 6.7, 8.1 and 10.1: These tests have been passed if the permissible tolerances between the setting value according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2 and the trip value are max  $\pm 1\% U_n$  for the voltage and max  $\pm 0.1\% f_n$  for the frequency. For synchronous and asynchronous generators coupled directly or via converters with  $P_{re} \leq 50$  kW as well as for Stirling generators and fuel cells, shutdown at  $U >$  already at  $0.85\% U_n$  is permissible.
- Test steps 2.1 to 2.7, 5.1 to 5.7, 9.1 and 11.1: These tests are passed if the tripping time after application of the jump is within the specifications according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2.
- For criteria a) and b) it is ensured that no voltage other than the voltage under test exceeds any of the set and active limits.
- Test steps 5.1 to 5.7: The test has been passed for Stirling generators, fuel cells and synchronous or asynchronous generators  $\leq 50$  kW, if the shutdown is performed within 200 ms after the jump has been applied. For directly coupled synchronous or asynchronous generators  $> 50$  kW, the test is passed if the shutdown occurred within a range between 1.0 s and 1.1 s. For converters, the test is passed if the shutdown occurred within a range between 3.0 s and 3.1 s.

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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<b>5.5.7.4 (6.5.1 &amp; 6.5.2)</b>	<b>TABLE: Voltage monitoring and frequency monitoring NS protection Test for undervoltage protection U&lt;&lt;</b>		<b>P</b>
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Model	SG2000
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## 6. Ramp test for determining U&lt;&lt; trip value:

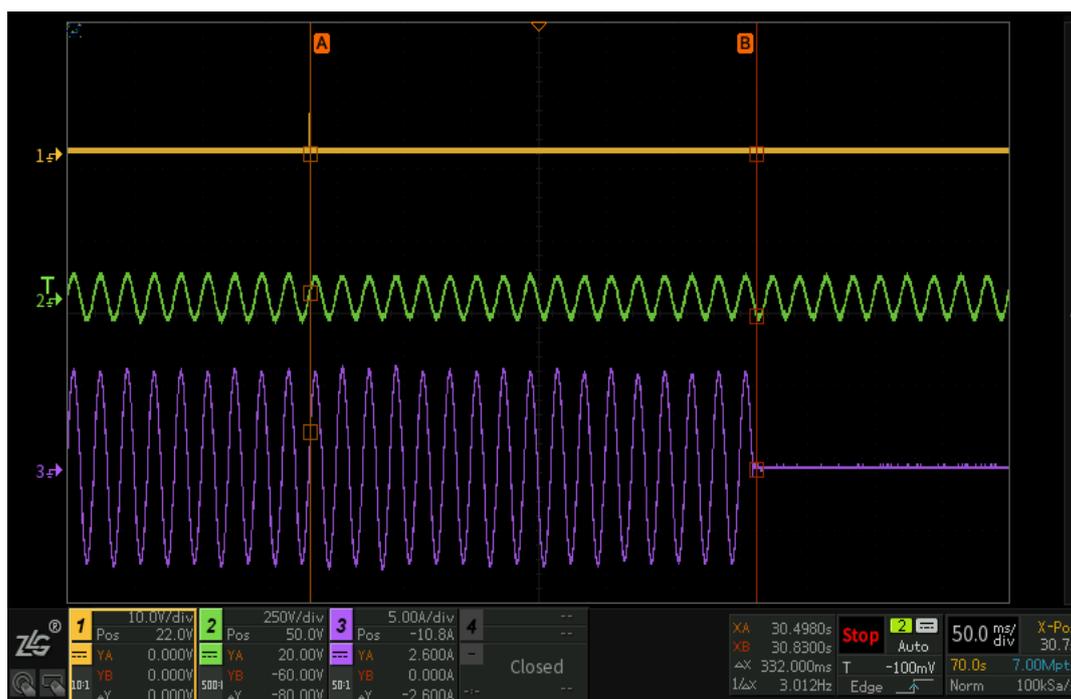
Test step	Test phase	Start voltage	End voltage	Setting trip value	Measured trip value	Trip value tolerance	Jump height $\Delta U$	Step length $\Delta t$
6.1	U <sub>L-N</sub>	>108.1 V	<98.9 V	103.5 V	102.2 V	$\pm 1\% U_n$	< 1.15 V	>500 ms

## 7. Jump test for determining U&lt;&lt; trip time:

Test step	Test phase	Start voltage	End voltage	Setting trip time	Measured trip time	Disconnection time limit	Jump height $\Delta U$	Step length $\Delta t$
7.1	U <sub>L-N</sub>	>108.1 V	<98.9 V	300	332.0 ms	300-400 ms	>9.2 V	>500 ms

**Note:****Evaluation criteria:**

- Test steps 1.1 to 1.7, 4.1 to 4.7, 6.1 to 6.7, 8.1 and 10.1: These tests have been passed if the permissible tolerances between the setting value according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2 and the trip value are  $\max \pm 1\% U_n$  for the voltage and  $\max \pm 0.1\% f_n$  for the frequency. For synchronous and asynchronous generators coupled directly or via converters with  $P_{RE} \leq 50$  kW as well as for Stirling generators and fuel cells, shutdown at  $U >$  already at 0.85%  $U_n$  is permissible.
- Test steps 2.1 to 2.7, 5.1 to 5.7, 9.1 and 11.1: These tests are passed if the tripping time after application of the jump is within the specifications according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2.
- For criteria a) and b) it is ensured that no voltage other than the voltage under test exceeds any of the set and active limits.
- Test steps 7.1 to 7.7: The test has been passed if the shutdown occurs within between 300 ms and 400 ms after the jump is applied.

**Jump test for determining U<< trip time**

DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict

<b>5.5.7.4 (6.5.1 &amp; 6.5.2)</b>	<b>TABLE: Voltage monitoring and frequency monitoring NS protection Test for frequency protection f&gt; and f&lt;</b>	<b>P</b>
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Model	SG2000
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8. Ramp test for determining f> trip value:

Test step	Apply to	Start frequency	End frequency	Setting trip value	Measured trip value	Trip value tolerance	Jump height Δf	Step length Δt
8.1	f <sub>grid</sub>	<51.4 Hz	>51.6 Hz	51.5 Hz	51.48 Hz	± 0.1% f <sub>n</sub>	< 25 mHz	>400 ms

9. Jump test for determining f> trip time:

Test step	Apply to	Start frequency	End frequency	Setting trip time	Measured trip time	Disconnect time limit	Jump height Δf	Step length Δt
9.1	f <sub>grid</sub>	<51.4 Hz	>51.6 Hz	100 ms	152.0 ms	< 200	>0.2 Hz	>400 ms

10. Ramp test for determining f< trip value:

Test step	Apply to	Start frequency	End frequency	Setting trip value	Measured trip value	Trip value tolerance	Jump height Δf	Step length Δt
10.1	f <sub>grid</sub>	<47.6 Hz	>47.4 Hz	47.5 Hz	47.48 Hz	± 0.1% f <sub>n</sub>	< 25 mHz	>400 ms

11. Jump test for determining f< trip time:

Test step	Apply to	Start frequency	End frequency	Setting trip time	Measured trip time	Disconnect time limit	Jump height Δf	Step length Δt
11.1	f <sub>grid</sub>	<47.6 Hz	>47.4 Hz	100 ms	184.0 ms	< 200	>0.2 Hz	>400 ms

**Jump test for determining f> trip time**



## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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Jump test for determining  $f < \text{trip time}$ **Evaluation criteria:**

- Test steps 1.1 to 1.7, 4.1 to 4.7, 6.1 to 6.7, 8.1 and 10.1: These tests have been passed if the permissible tolerances between the setting value according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2 and the trip value are  $\max \pm 1\% U_n$  for the voltage and  $\max \pm 0.1\% f_n$  for the frequency. For synchronous and asynchronous generators coupled directly or via converters with  $P_{RE} \leq 50 \text{ kW}$  as well as for Stirling generators and fuel cells, shutdown at  $U >$  already at  $0.85\% U_n$  is permissible.
- Test steps 2.1 to 2.7, 5.1 to 5.7, 9.1 and 11.1: These tests are passed if the tripping time after application of the jump is within the specifications according to VDE-AR-N 4105:2018-11, 6.5.2, Table 2.
- For criteria a) and b) it is ensured that no voltage other than the voltage under test exceeds any of the set and active limits.

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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<b>5.5.7.5 (6.5.1)</b>	<b>TABLE: Reading the fault messages</b>		<b>P</b>
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At least the last 5 fault messages must be read out at the EZE or the external GS protection. Then the supply voltage must be interrupted for 3 s. Then the fault messages must be read out again.

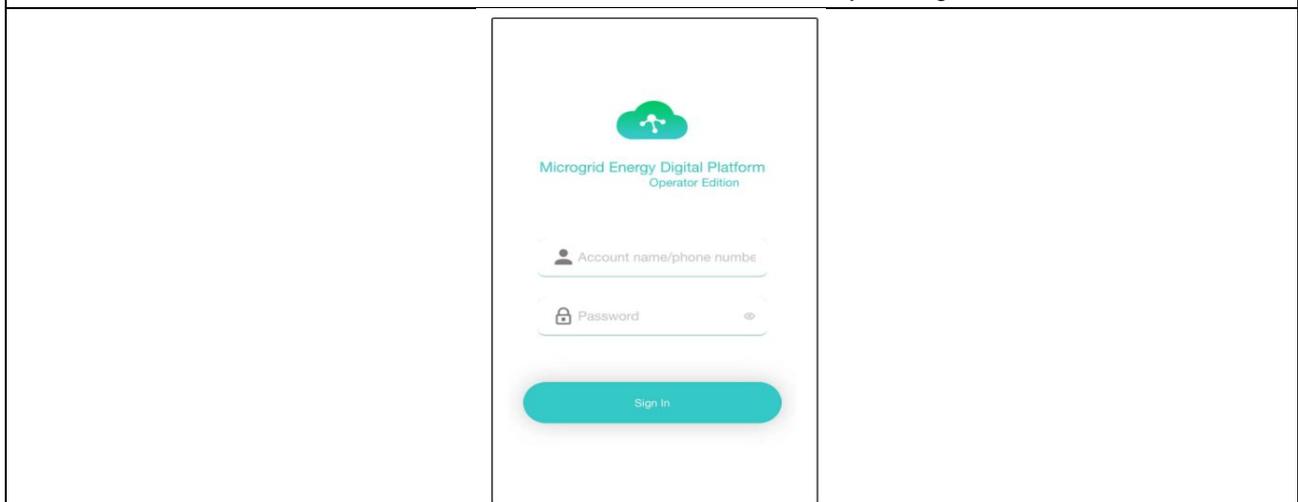
Integrated NS protection:  
It is possible to read out the values of the GS protection via the data interface, unless values can be read directly.

Note:

<b>5.5.9 (6.5.2)</b>	<b>TABLE: Structural features of NS protection</b>		<b>P</b>
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Type and form of protection against unauthorized access	<input type="checkbox"/> NS protection sealable	<input checked="" type="checkbox"/> NS protection password protected	<input type="checkbox"/> other appropriate measure
If NS protection password protected	Testing based on the manufacturer's instructions		<input checked="" type="checkbox"/> Pass <input type="checkbox"/> Fail
NS protection functions setting value	Trip value		Trip time
Rise-in-voltage protection $U >>$	<input type="checkbox"/> fixed in software	<input checked="" type="checkbox"/> adjustable and protected	<input type="checkbox"/> fixed in software <input checked="" type="checkbox"/> adjustable and protected
Rise-in-voltage protection $U >>$	<input type="checkbox"/> fixed in software	<input checked="" type="checkbox"/> adjustable and protected	<input type="checkbox"/> fixed in software <input checked="" type="checkbox"/> adjustable and protected
Voltage drop protection $U <$	<input type="checkbox"/> fixed in software	<input checked="" type="checkbox"/> adjustable and protected	<input type="checkbox"/> fixed in software <input checked="" type="checkbox"/> adjustable and protected
Voltage drop protection $U <<$	<input type="checkbox"/> fixed in software	<input checked="" type="checkbox"/> adjustable and protected	<input type="checkbox"/> fixed in software <input checked="" type="checkbox"/> adjustable and protected
Frequency decrease protection $f <$	<input type="checkbox"/> fixed in software	<input checked="" type="checkbox"/> adjustable and protected	<input type="checkbox"/> fixed in software <input checked="" type="checkbox"/> adjustable and protected
Frequency increase protection $f >$	<input type="checkbox"/> fixed in software	<input checked="" type="checkbox"/> adjustable and protected	<input type="checkbox"/> fixed in software <input checked="" type="checkbox"/> adjustable and protected

Password used for Parameters and Country settings



Note:  
The selection of Germany parameters and country setting can only be completed in the factory or authorised person by password, the user cannot change the country setting.

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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5.5.10 (6.5.3)		TABLE: Active methods tested with a resonant circuit (Active method according to EN 62116)							P		
Model		SG2000									
No.	P <sub>EUT</sub> (% of EUT rating)	Reactive load (% of normal)	P <sub>AC</sub>	Q <sub>AC</sub>	Run-on time (ms)	P <sub>EUT</sub> (W)	Actual Q <sub>f</sub>	V <sub>DC</sub>	Remark		
Disconnection limited			9 s								
Test condition A											
1	100	100	0	0	406	2000	1.000	48	Test A at BL		
2	100	100	-5	-5	352	2000	0.98	48	Test A at IB		
3	100	100	-5	0	344	2000	1.05	48	Test A at IB		
4	100	100	-5	+5	480	2000	1.02	48	Test A at IB		
5	100	100	0	-5	396	2000	1.01	48	Test A at IB		
6	100	100	0	+5	333	2000	0.97	48	Test A at IB		
7	100	100	+5	-5	451	2000	0.92	48	Test A at IB		
8	100	100	+5	0	431	2000	1.05	48	Test A at IB		
9	100	100	+5	+5	348	2000	1.08	48	Test A at IB		
10	100	100	-10	+10	346	2000	1.02	48	Test A at IB		
11	100	100	-5	+10	326	2000	1.06	48	Test A at IB		
12	100	100	0	+10	332	2000	1.10	48	Test A at IB		
13	100	100	+5	+10	338	2000	1.09	48	Test A at IB		
14	100	100	+10	+10	359	2000	1.06	48	Test A at IB		
15	100	100	+10	+5	408	2000	1.02	48	Test A at IB		
16	100	100	+10	0	354	2000	1.12	48	Test A at IB		
17	100	100	+10	-5	323	2000	1.10	48	Test A at IB		
18	100	100	+10	-10	326	2000	1.06	48	Test A at IB		
19	100	100	+5	-10	309	2000	1.00	48	Test A at IB		
20	100	100	0	-10	328	2000	0.95	48	Test A at IB		
21	100	100	-5	-10	306	2000	0.90	48	Test A at IB		
22	100	100	-10	-10	348	2000	0.94	48	Test A at IB		

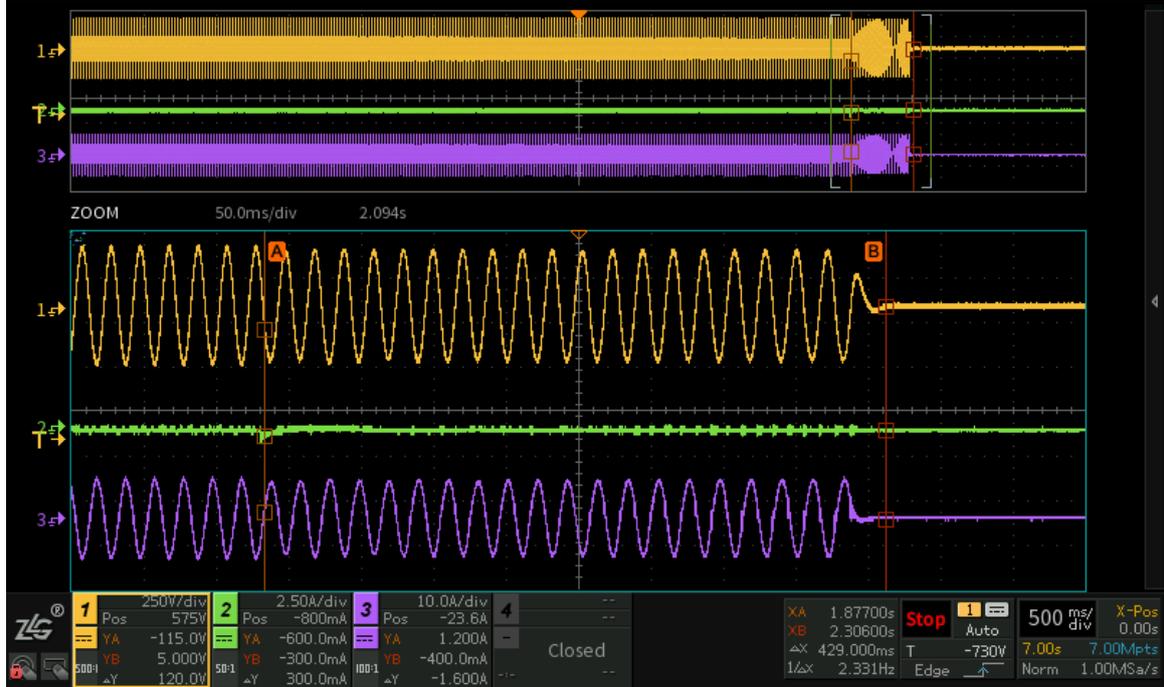
DIN VDE V 0124-100, VDE-AR-N 4105									
Clause	Requirement - Test					Result - Remark			Verdict
23	100	100	-10	-5	382	2000	0.96	48	Test A at IB
24	100	100	-10	0	357	2000	1.02	48	Test A at IB
25	100	100	-10	+5	342	2000	1.08	48	Test A at IB
Test condition B									
1	66	66	0	-5	343	1320	0.99	48	Test B at IB
2	66	66	0	-4	347	1320	0.99	48	Test B at IB
3	66	66	0	-3	351	1320	1.00	48	Test B at IB
4	66	66	0	-2	362	1320	1.01	48	Test B at IB
5	66	66	0	-1	385	1320	0.99	48	Test B at IB
6	66	66	0	0	429	1320	1.03	48	Test B at BL
7	66	66	0	1	349	1320	1.04	48	Test B at IB
8	66	66	0	2	342	1320	1.02	48	Test B at IB
9	66	66	0	3	321	1320	1.01	48	Test B at IB
10	66	66	0	4	315	1320	1.00	48	Test B at IB
11	66	66	0	5	269	1320	0.99	48	Test B at IB
Test condition C									
1	33	33	0	-5	36	660	1.10	48	Test C at IB
2	33	33	0	-4	43	660	1.08	48	Test C at IB
3	33	33	0	-3	46	660	1.07	48	Test C at IB
4	33	33	0	-2	204	660	1.05	48	Test C at IB
5	33	33	0	-1	243	660	1.03	48	Test C at IB
6	33	33	0	0	264	660	1.07	48	Test C at BL
7	33	33	0	1	38.4	660	1.04	48	Test C at IB
8	33	33	0	2	37.8	660	1.06	48	Test C at IB
9	33	33	0	3	35.2	660	1.07	48	Test C at IB
10	33	33	0	4	35	660	1.05	48	Test C at IB
11	33	33	0	5	29.8	660	1.04	48	Test C at IB



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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Graph of disconnection at P<sub>AC</sub> 0% and Q<sub>AC</sub> 0% reactive load and 66% nominal power



Graph of disconnection at P<sub>AC</sub> 0% and Q<sub>AC</sub> 0% reactive load and 33% nominal power

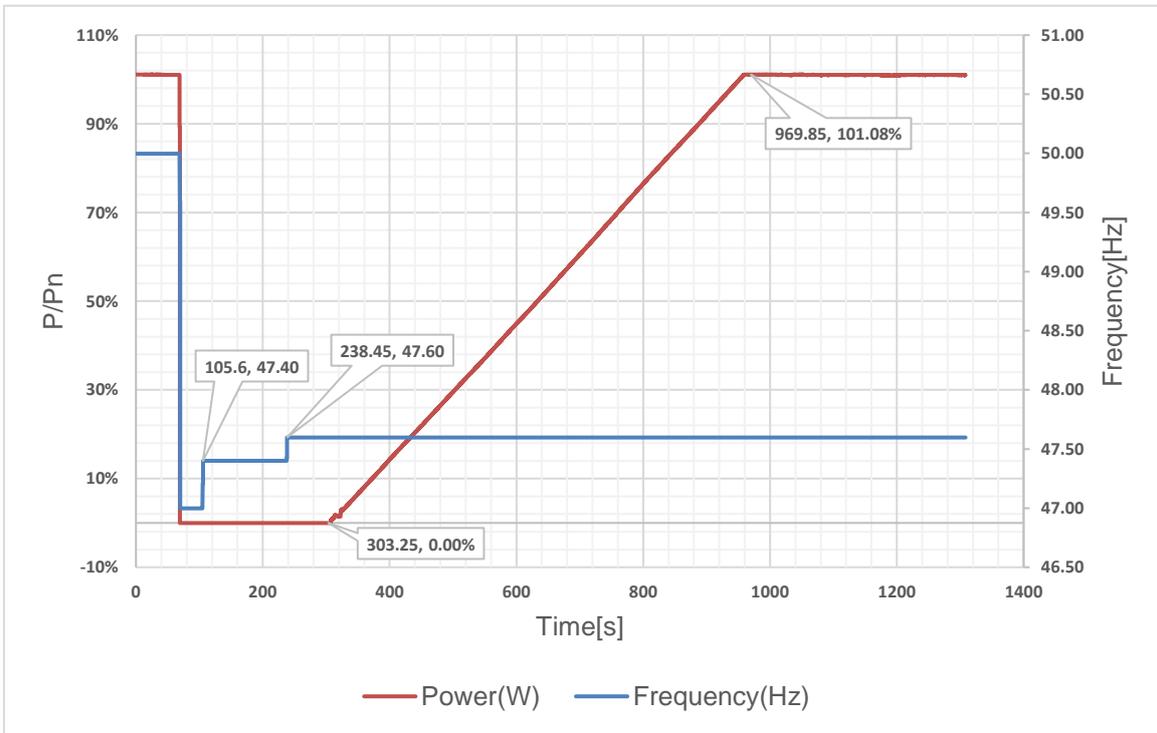


DIN VDE V 0124-100, VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
<b>5.6 (8.3)</b>	<b>TABLE: Connecting conditions and synchronisation</b>		<b>P</b>
Model	SG2000		
Setting values:	Setting $T_{\text{reconnection}}$ [s]:	60	
	Setting $f_{<}$ [Hz]:	47.5	
	Setting $f_{>}$ [Hz]:	50.1	
	Setting $U_{<}$ [V]:	195.5	
	Setting $U_{>>}$ [V]:	253	
Test:			
	Test condition	Reconnection time [s]:	Limit [s]:
Connecting conditions for frequencies:			
a)	< 47.45 Hz	No reconnection	No resetting allowed
	Switch to:		
b)	≥ 47.55 Hz	64.8 s	≥ 60 s
c)	> 50.15 Hz	No reconnection	No resetting allowed
	Switch to:		
d)	≤ 50.05 Hz	65.9 s	≥ 60 s
Connecting conditions for voltages:			
e)	< 84% $U_n$	No reconnection	No resetting allowed
	Switch to:		
f)	≥ 86% $U_n$	65.3 s	≥ 60 s
g)	> 111% $U_n$	No reconnection	No resetting allowed
	Switch to:		
h)	≤ 109% $U_n$	65.4 s	≥ 60 s
Note:			
The conditions and testing is performed according to VDE V 0124-100, clause 5.5.1.			
The tests were performed on model SG2000 also applicable for all other models stated in this report.			

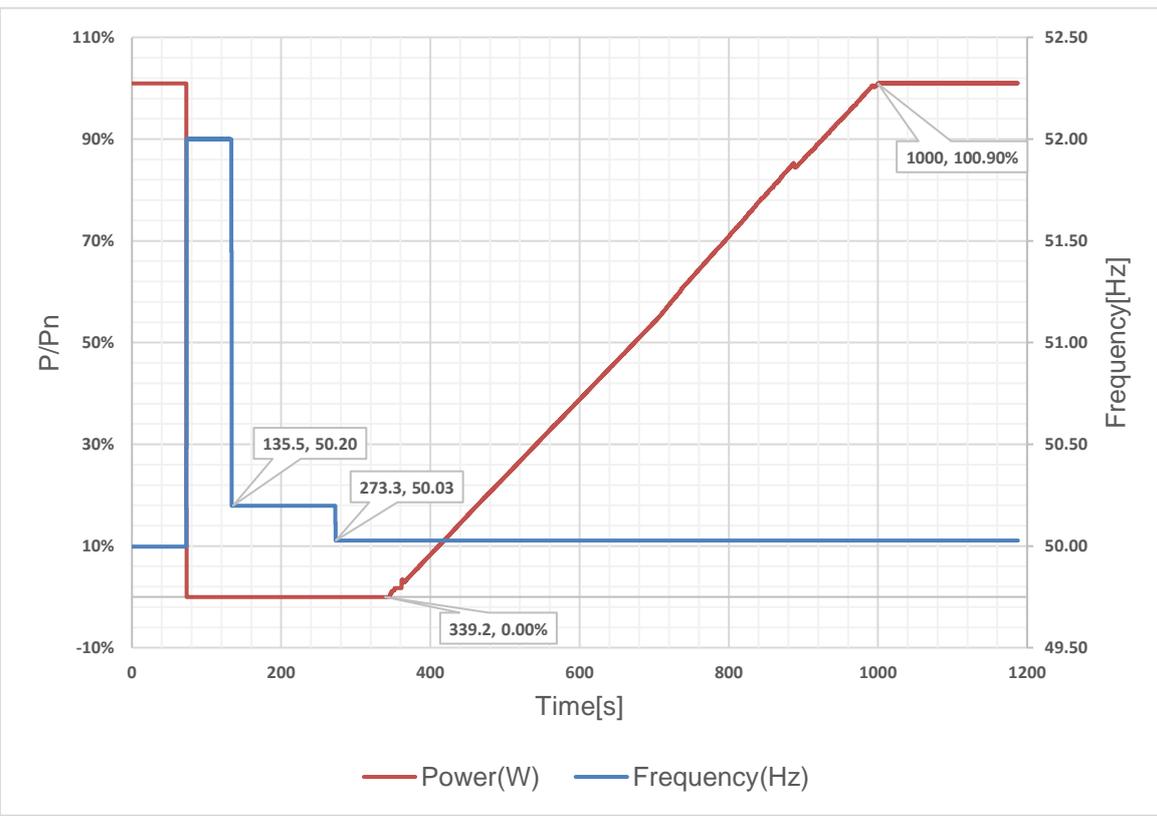
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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Connecting conditions for  $f <$



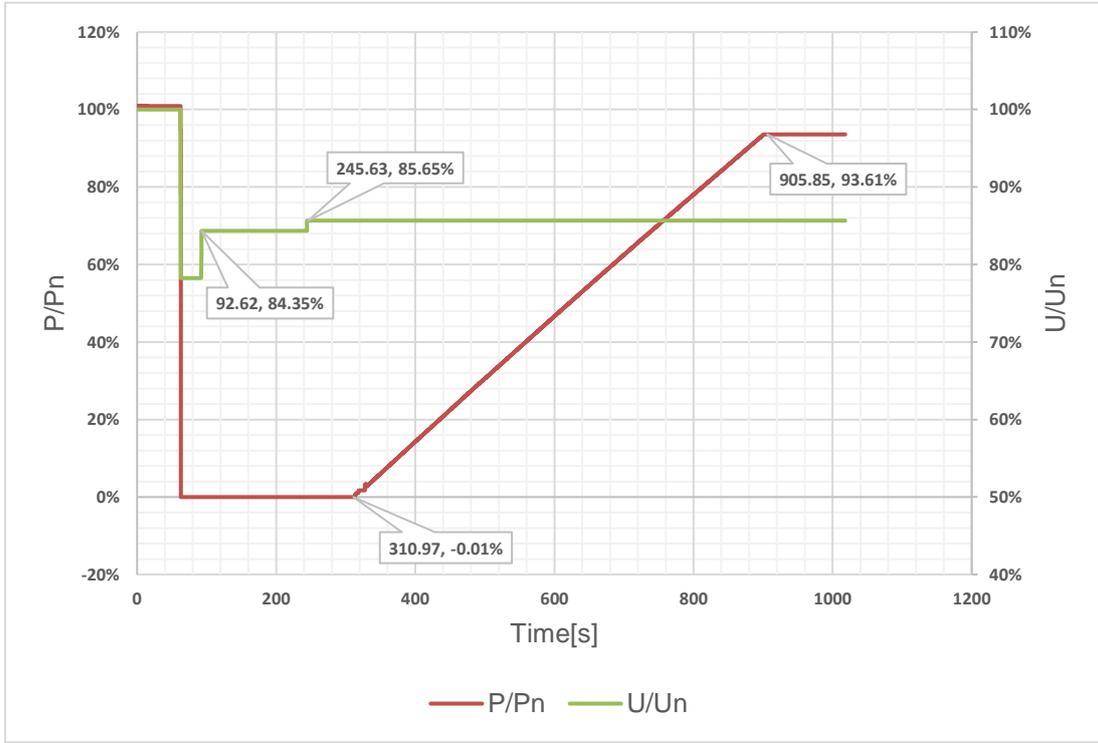
Connecting conditions for  $f >$



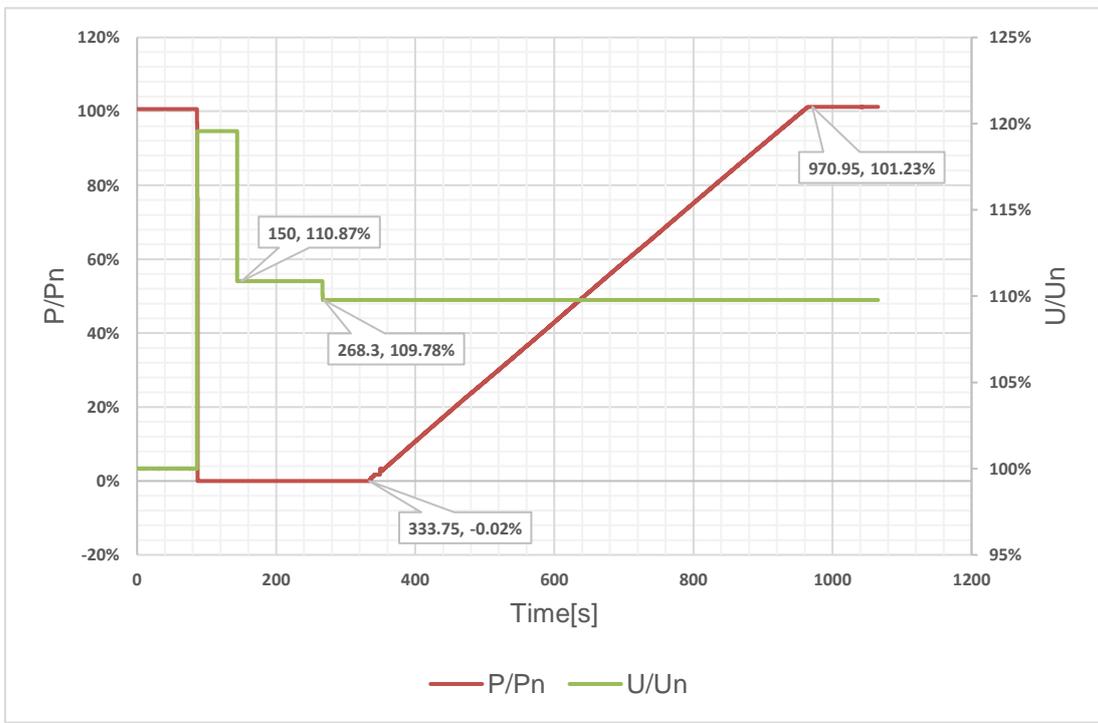
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Connecting conditions for U<**



**Connecting conditions for U>**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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<b>5.7.2.1</b>	<b>TABLE: Testing of the dynamics control (<math>P_{AV,E}</math>-Monitoring)</b>	<b>P</b>
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Model:	SG2000
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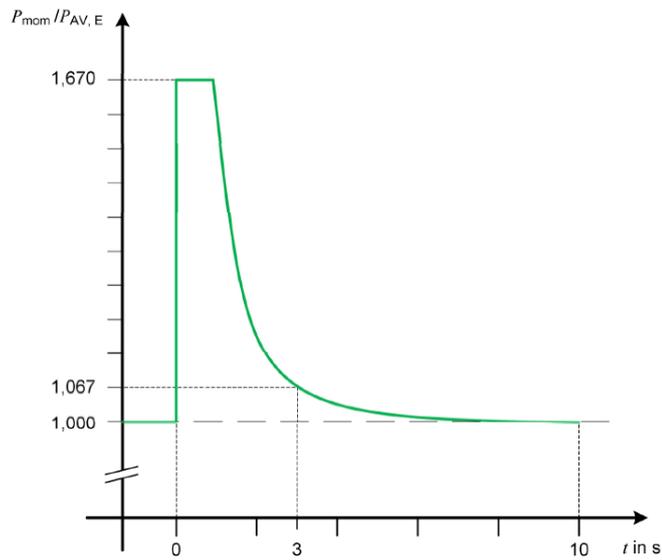
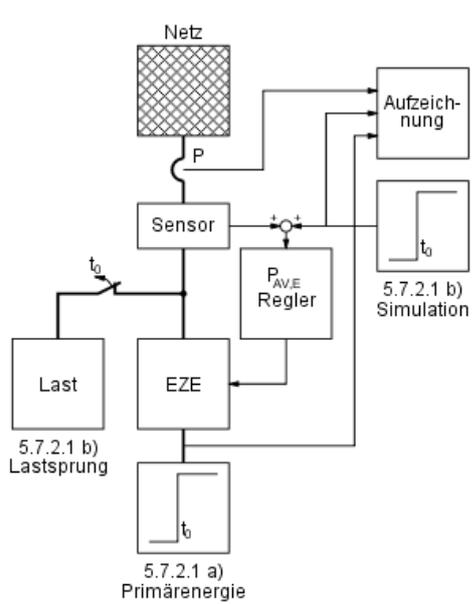


Figure 1 – Active power limit curve for power generation systems

Aufzeichnung: recording; Last: load;  
 Regler: regulator; Lastsprung: load jump;  
 Primärenergie: Primary energy

Figure 8 – Sketch of the test setup for test the dynamic control

**Procedure of the test:**

Adjust DC source to inverter 100% $P_n$  output  
 Adjust load in order to keep active power at connection point to  $P_{AV,E}$  with a tolerance of -2%.  
 At the time  $t_0$ , disconnect the local load, meanwhile, offset the power measurement of recorder  
 Recording the active power at meter counter continuously for at least 15s after  $t_0$ .

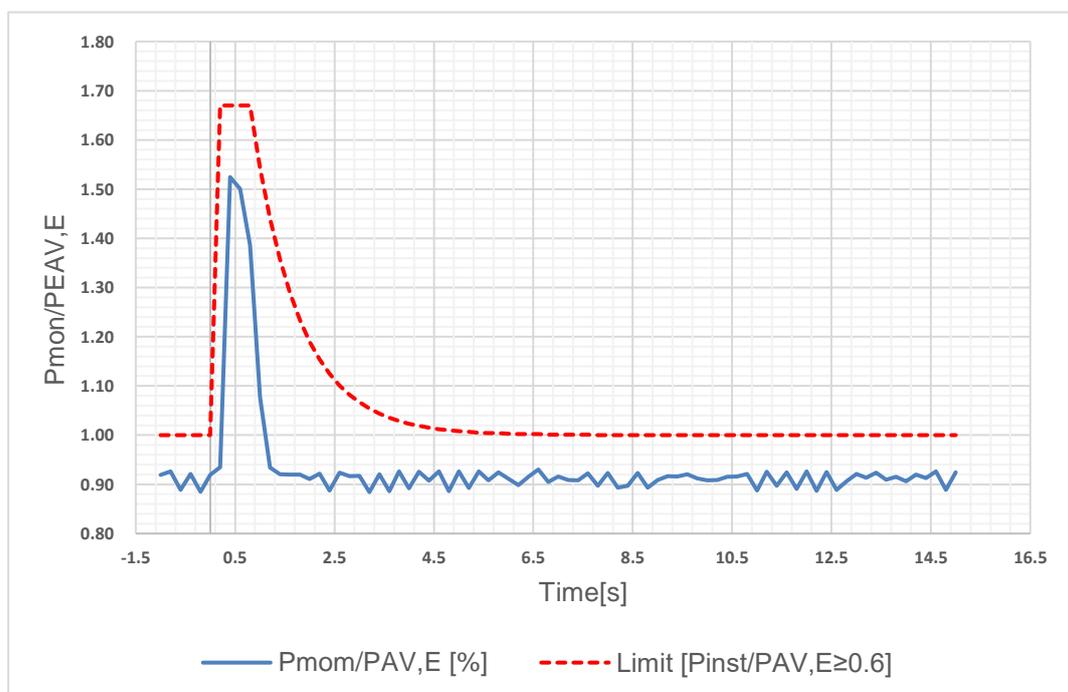
Time (s)	$P_{mom}$ [kW]	$P_{mom}/P_{AV,E}$ [%]	Limit [ $P_{inst}/P_{AV,E} \geq 0.6$ ]
-1	1103.2	0.92	1.000
-0.8	1111.7	0.93	1.000
-0.6	1066.4	0.89	1.000
-0.4	1105.7	0.92	1.000
-0.2	1061.5	0.88	1.000
0	1102.7	0.92	1.000
0.2	1122	0.94	1.670
0.4	1829.3	1.52	1.670
0.6	1800.6	1.50	1.670
0.8	1663.1	1.39	1.670
1	1292.3	1.08	1.543
1.2	1121	0.93	1.440
1.4	1104.5	0.92	1.357
1.6	1103.7	0.92	1.289
1.8	1103.7	0.92	1.234
2	1093	0.91	1.190

DIN VDE V 0124-100, VDE-AR-N 4105				
Clause	Requirement - Test		Result - Remark	Verdict
2.2	1105.8	0.92	1.154	
2.4	1064.6	0.89	1.125	
2.6	1108.5	0.92	1.101	
2.8	1099.9	0.92	1.082	
3	1101	0.92	1.067	
3.2	1061	0.88	1.054	
3.4	1104.2	0.92	1.044	
3.6	1063	0.89	1.035	
3.8	1111.9	0.93	1.029	
4	1070.4	0.89	1.023	
4.2	1110.5	0.93	1.019	
4.4	1088.6	0.91	1.015	
4.6	1111.6	0.93	1.012	
4.8	1063.6	0.89	1.010	
5	1111.9	0.93	1.008	
5.2	1071.1	0.89	1.007	
5.4	1111.7	0.93	1.005	
5.6	1089.7	0.91	1.004	
5.8	1109.3	0.92	1.004	
6	1093.3	0.91	1.003	
6.2	1077.8	0.90	1.002	
6.4	1098	0.92	1.002	
6.6	1116.2	0.93	1.002	
6.8	1085.9	0.90	1.001	
7	1099	0.92	1.001	
7.2	1090.5	0.91	1.001	
7.4	1089.6	0.91	1.001	
7.6	1107.1	0.92	1.001	
7.8	1076.8	0.90	1.000	
8	1107.7	0.92	1.000	
8.2	1071.7	0.89	1.000	
8.4	1076.8	0.90	1.000	
8.6	1107.7	0.92	1.000	
8.8	1071.7	0.89	1.000	
9	1090.6	0.91	1.000	
9.2	1099.9	0.92	1.000	
9.4	1099.4	0.92	1.000	
9.6	1104.9	0.92	1.000	
9.8	1094.8	0.91	1.000	
10	1089.6	0.91	1.000	
10.2	1090.2	0.91	1.000	
10.4	1098.1	0.92	1.000	
10.6	1098.8	0.92	1.000	
10.8	1105.4	0.92	1.000	

## DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
11	1064.6	0.89	1.000
11.2	1110.8	0.93	1.000
11.4	1076.7	0.90	1.000
11.6	1109.5	0.92	1.000
11.8	1068.6	0.89	1.000
12	1111.8	0.93	1.000
12.2	1063.9	0.89	1.000
12.4	1109.8	0.92	1.000
12.6	1066.6	0.89	1.000
12.8	1087.8	0.91	1.000
13	1105.5	0.92	1.000
13.2	1096	0.91	1.000
13.4	1108.1	0.92	1.000
13.6	1091	0.91	1.000
13.8	1098	0.92	1.000
14	1087.4	0.91	1.000
14.2	1103.8	0.92	1.000
14.4	1095.1	0.91	1.000
14.6	1111.2	0.93	1.000
14.8	1066.5	0.89	1.000
15	1109.2	0.92	1.000

## Diagram



DIN VDE V 0124-100, VDE-AR-N 4105						
Clause	Requirement - Test	Result - Remark			Verdict	
<b>5.8 (5.7.3.3)</b>	<b>TABLE: Verification of the dynamic grid support</b>				<b>P</b>	
Model	SG2000					
Single Phase						
Test	Voltage Depth [p.u.]	Fault type	Fault duration [ms]	P set point [P <sub>rE</sub> ]	Q set point [Q/P <sub>rE</sub> ]	Test number
1	0.15	A	≥150	100%	0~10%	1.1
				20-60%		1.2
		D1	≥150	100%		1.3
				20-60%		1.4
				D2		≥150
2	0.5	A	≥1500	100%	max overexcited	2.1
				20-60%		2.2
		D1	≥1500	100%		2.3
				20-60%		2.4
3	0.5	A	≥1500	100%	max underexcited	3.1
				20-60%		3.2
		D1	≥1500	100%		3.3
				20-60%		3.4
4	0.85	A	≥60000	100%	0~10%	4.1
				20-60%		4.2
		D1	≥60000	100%		4.3
				20-60%		4.4
5	1.25	A	≥100	100%	0~10%	5.1
				20-60%		5.2
		D1	≥100	100%		5.3
				20-60%		5.4
		D2	≥100	100%	0~10%	5.5
6	1.20	A	≥5000	100%	0~10%	6.1
				20-60%		6.2
		D1	≥5000	100%		6.3
				20-60%		6.4
7	1.15	A	≥60000	100%	0~10%	7.1
				20-60%		7.2
		D1	≥60000	100%		7.3
				20-60%		7.4

## DIN VDE V 0124-100, VDE-AR-N 4105

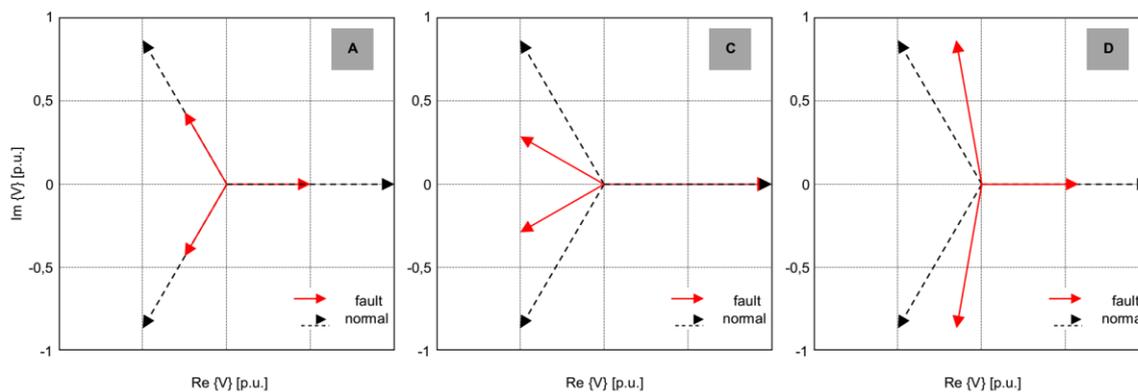
Clause	Requirement - Test	Result - Remark	Verdict
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**Setting:**

Test number	Voltage Depth [p.u.]	$U_1/U_{1nom}$	$U_2/U_{2nom}$	$U_3/U_{3nom}$	$\varphi_1$	$\varphi_2$	$\varphi_3$
1.1; 1.2	0.15	0.15	0.15	0.15	-150.0°	90°	-30.0°
1.3; 1.4		0.62	0.15	0.62	-173.3°	90°	-6.9°
2.1; 2.2	0.50	0.50	0.50	0.50	-150.0°	90°	-30.0°
2.3; 2.4		0.76	0.50	0.76	-161.1°	90°	-19.1°
3.1; 3.2	0.50	0.50	0.50	0.50	-150.0°	90°	-30.0°
3.3; 3.4		0.76	0.50	0.76	-161.1°	90°	-19.1°
4.1; 4.2	0.85	0.85	0.85	0.85	-150.0°	90°	-30.0°
4.3; 4.4		0.93	0.85	0.93	-152.8°	89.9°	-27.4°
5.1; 5.2	1.25	1.25	1.25	1.25	-150.0°	90°	-30.0°
5.3; 5.4		1.08	1.25	1.06	-144.5°	89.1°	-36.3°
6.1; 6.2	1.20	1.20	1.20	1.20	-150.0°	90°	-30.0°
6.3; 6.4		1.06	1.20	1.05	-145.5°	89.3°	-35.1°
7.1; 7.2	1.15	1.15	1.15	1.15	-150.0°	90°	-30.0°
7.3; 7.4		1.04	1.15	1.04	-146.6°	89.4°	-33.9°

**Note:**

Single-phase PGU are connected to terminals W(L3) and N for fault pattern D1. For fault pattern D2, the connection is made to terminals V(L1) and N.



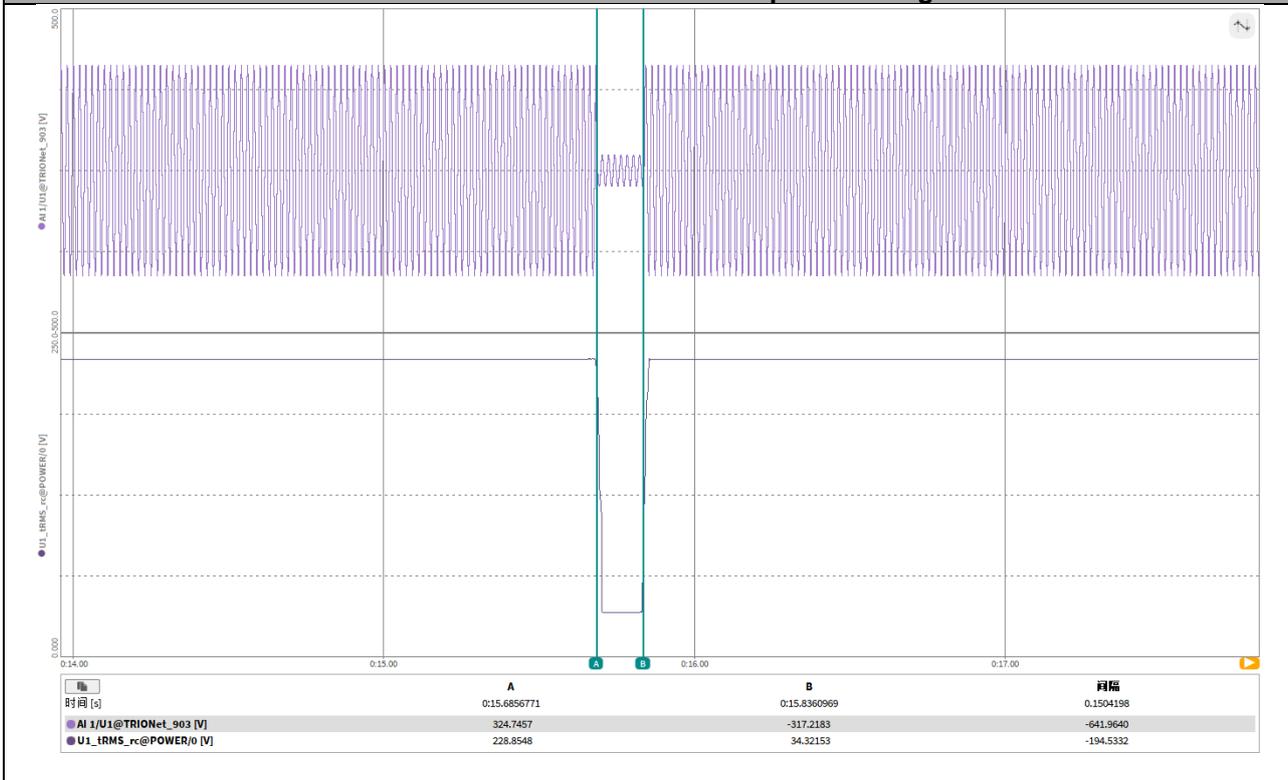
**Figure A.1- Fault types "A", "C" and "D" according to [M. H. J. Bollen "Understanding Power Quality Problems"]**

DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test			Result - Remark		Verdict		
Condition						Measured value		
Item	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	1.1	1.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:34	13:32	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.15	0.15
	5	Setting dip duration		--	--	--	150	150
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	15686	15686
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	15836	15836
	8	Fault duration in empty load test	Total	--	--	ms	150	150
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.15	0.15	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	0.99	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.09	0.05	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	1.00	0.996		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.15	0.15	
	19	Line current	Phase 1	t1+60ms	p.u.	0.01	0.01	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.01	0.01	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00	0.00	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.99	0.51	
	29		Pos.			N/A	N/A	
	30	Response time active power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.09	0.05	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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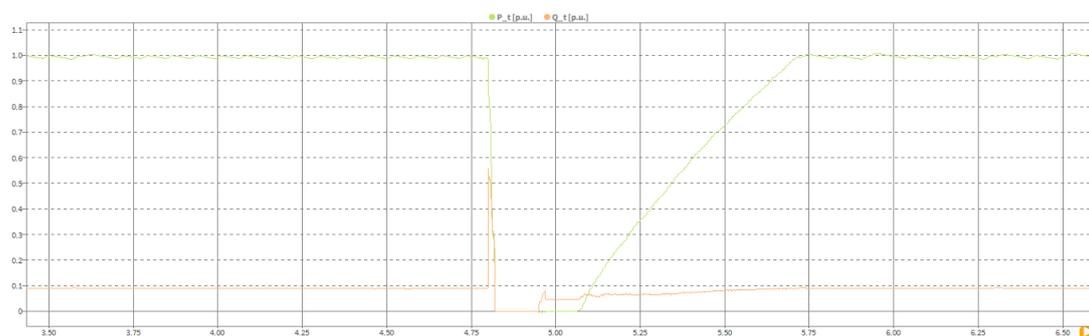
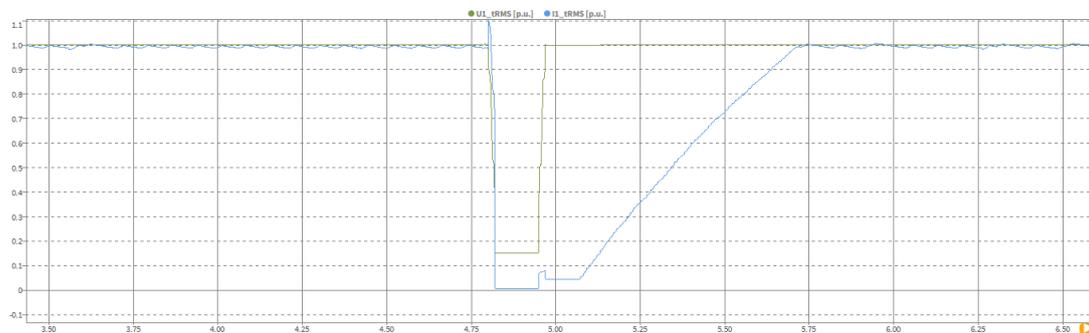
**Test 1.0 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



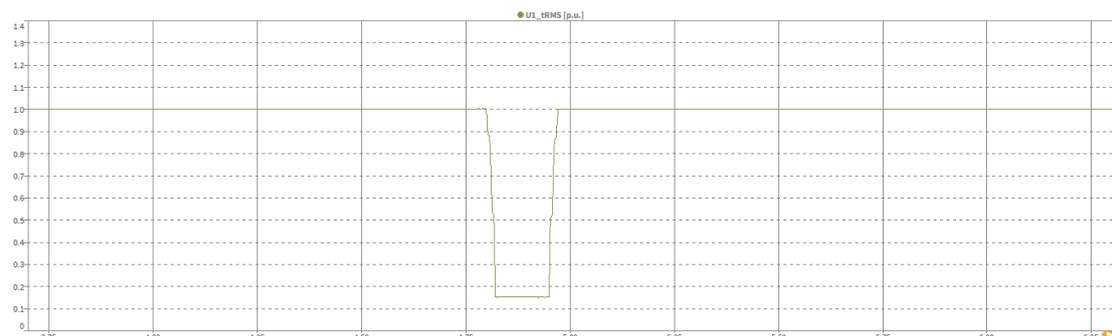
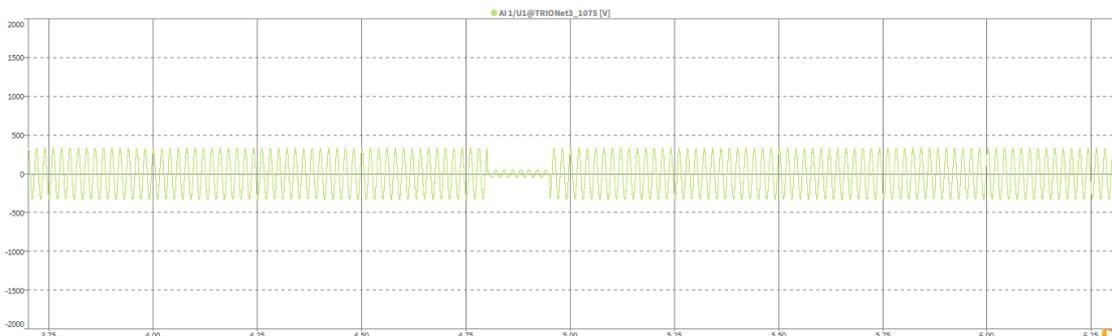
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.1 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 100% load**  
**Test overview (voltage, current, active and reactive power)**



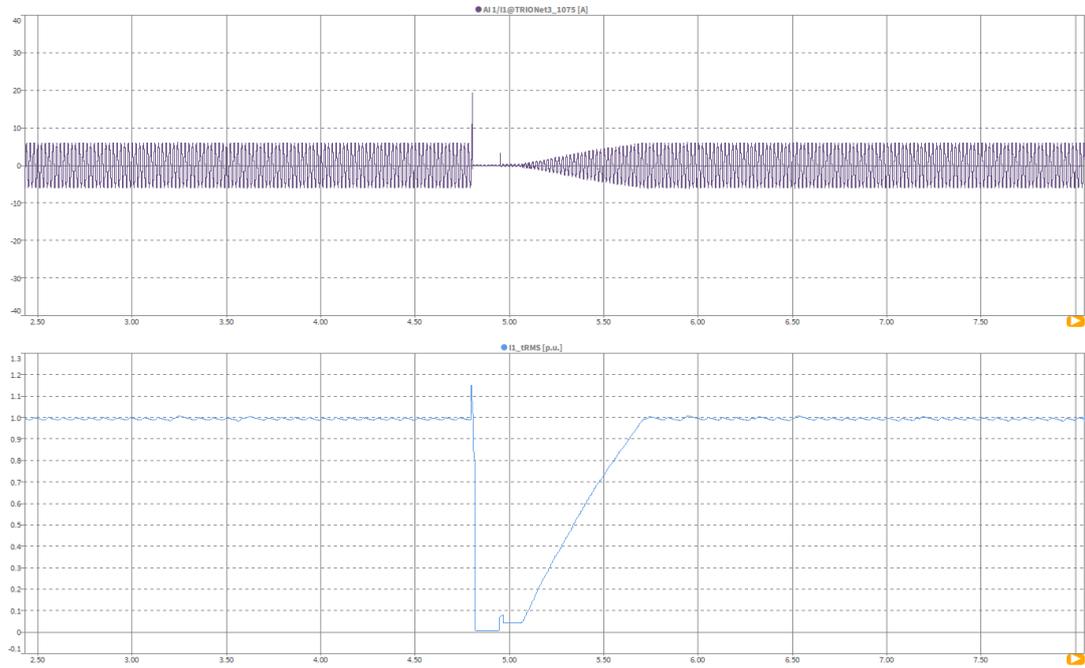
**Test 1.1 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



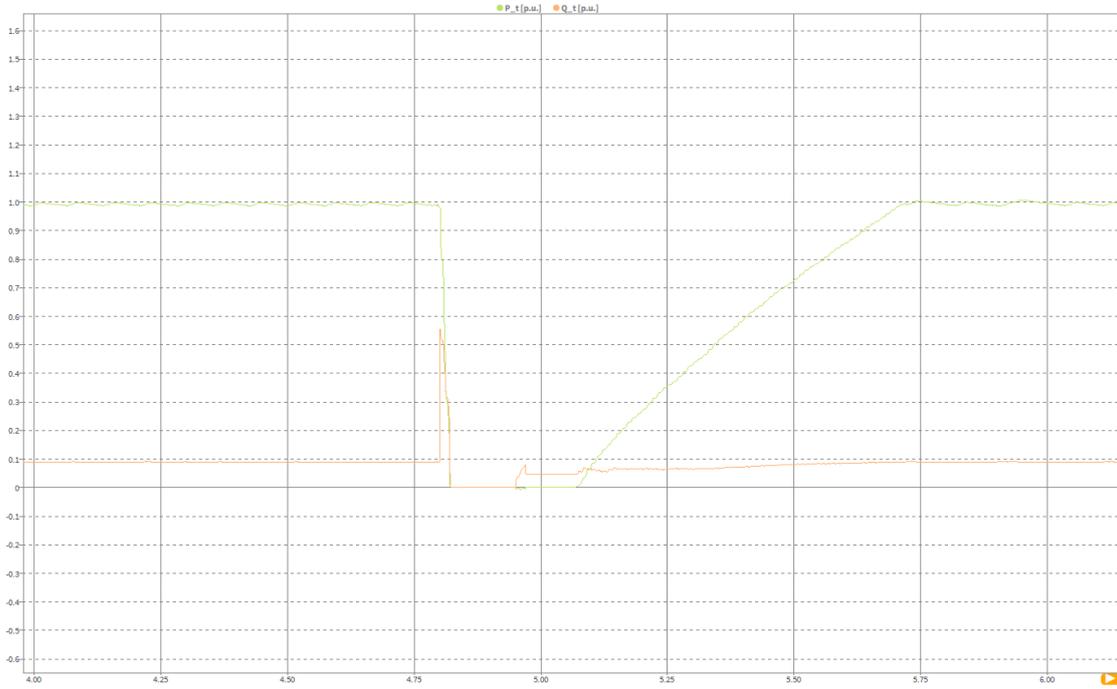
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.1 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve and RMS values of phase currents**



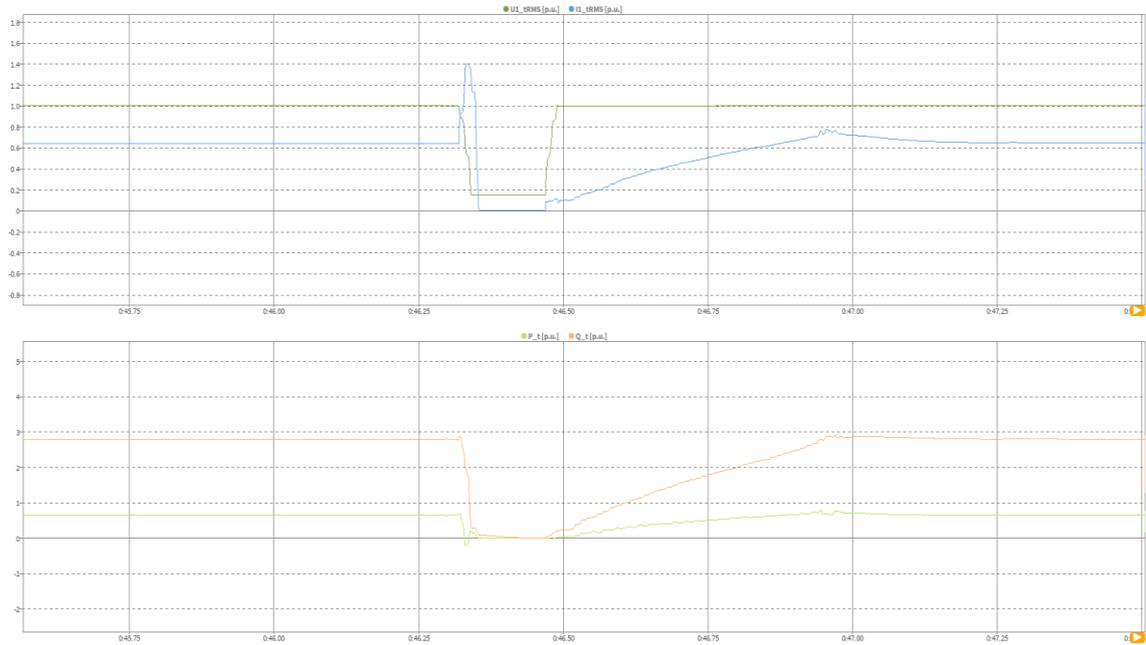
**Test 1.1 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 100% load  
Total values of active and reactive power**



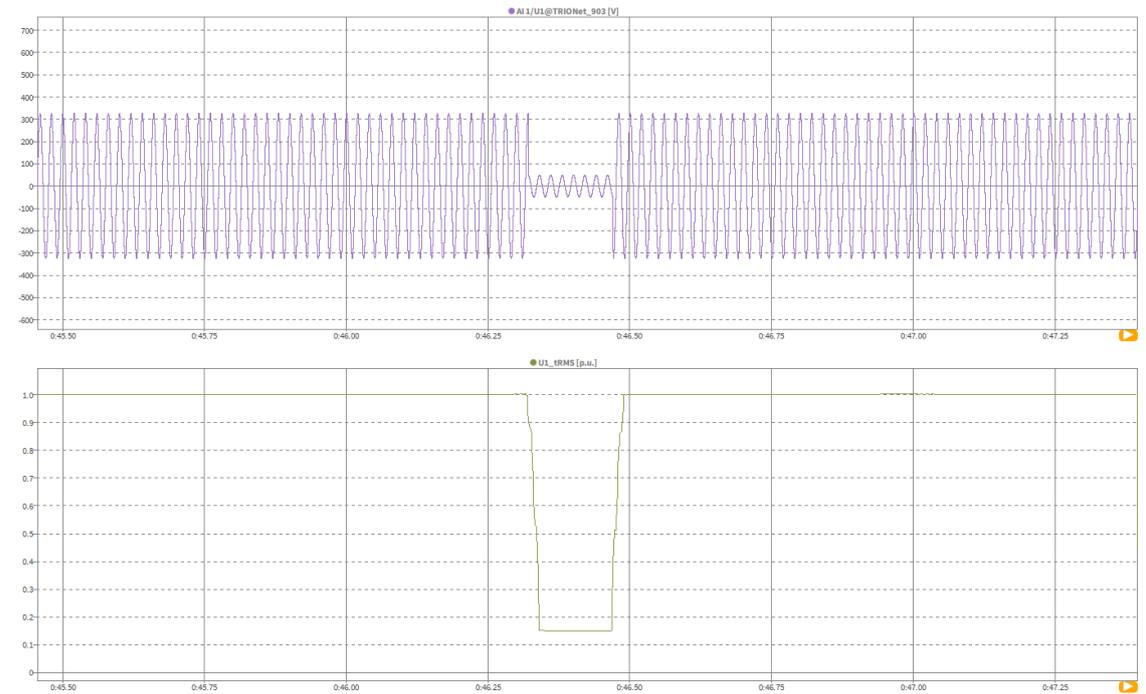
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.2 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 25% load  
Test overview (voltage, current, active and reactive power)**



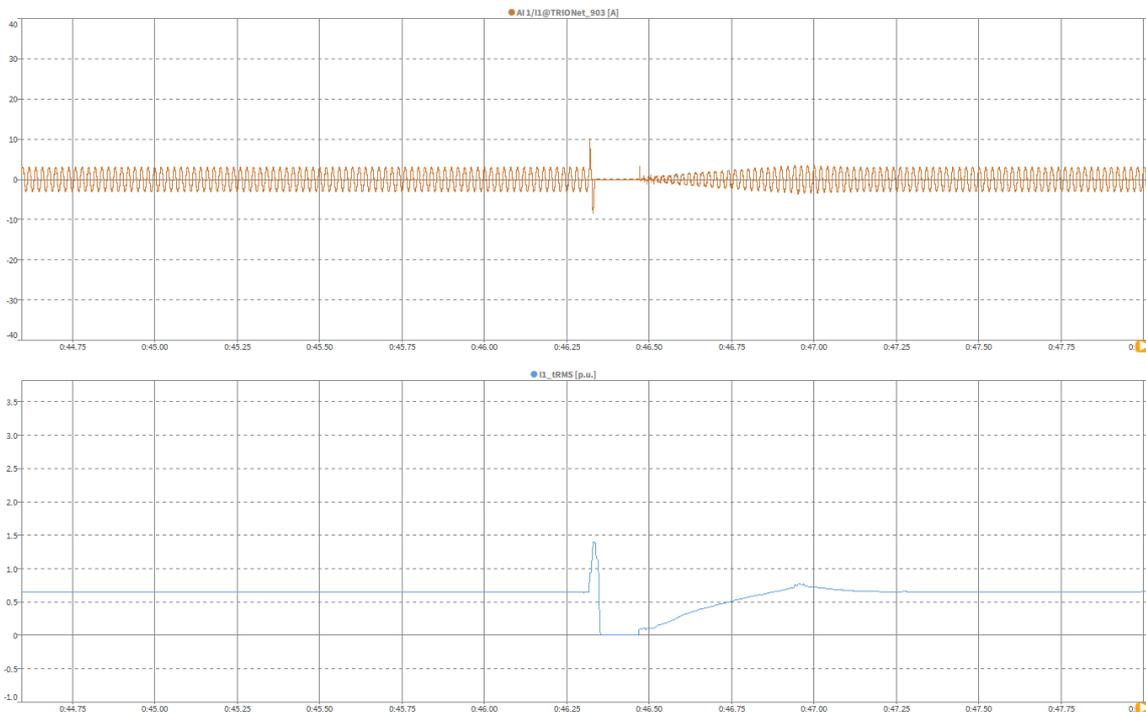
**Test 1.2 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 25% load  
Instantaneous curve curve and RMS values of phase to natural voltages**



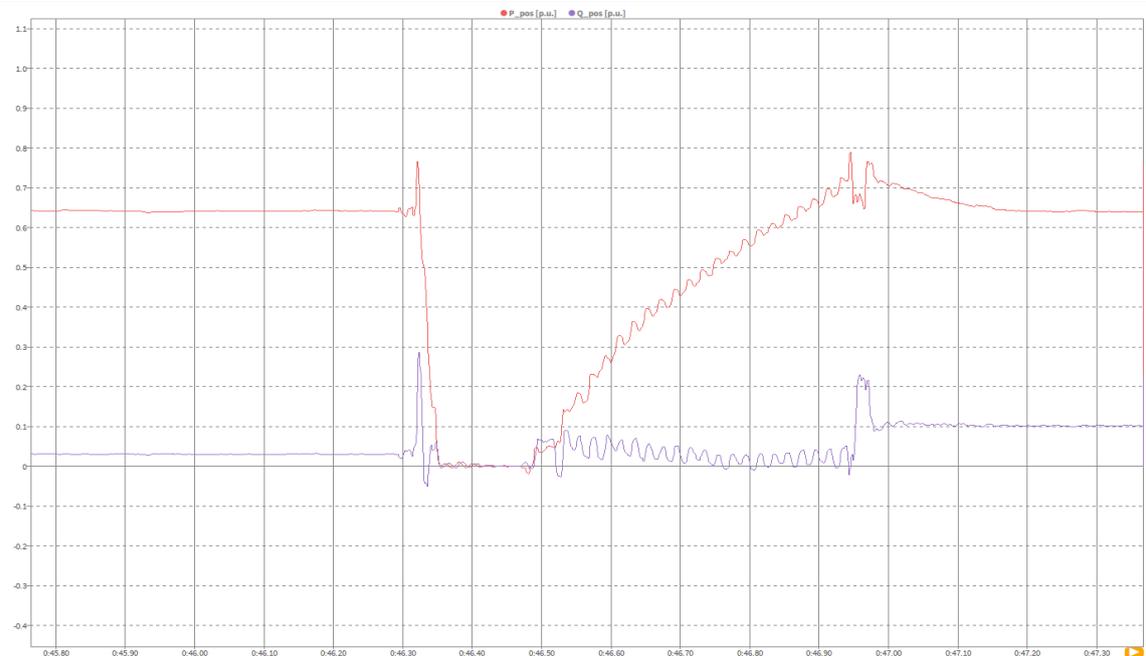
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.2 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 1.2 Depth of fault phase: 0.15 p.u.(U-N), balanced fault (type A), 25% load  
Total values of active and reactive power**

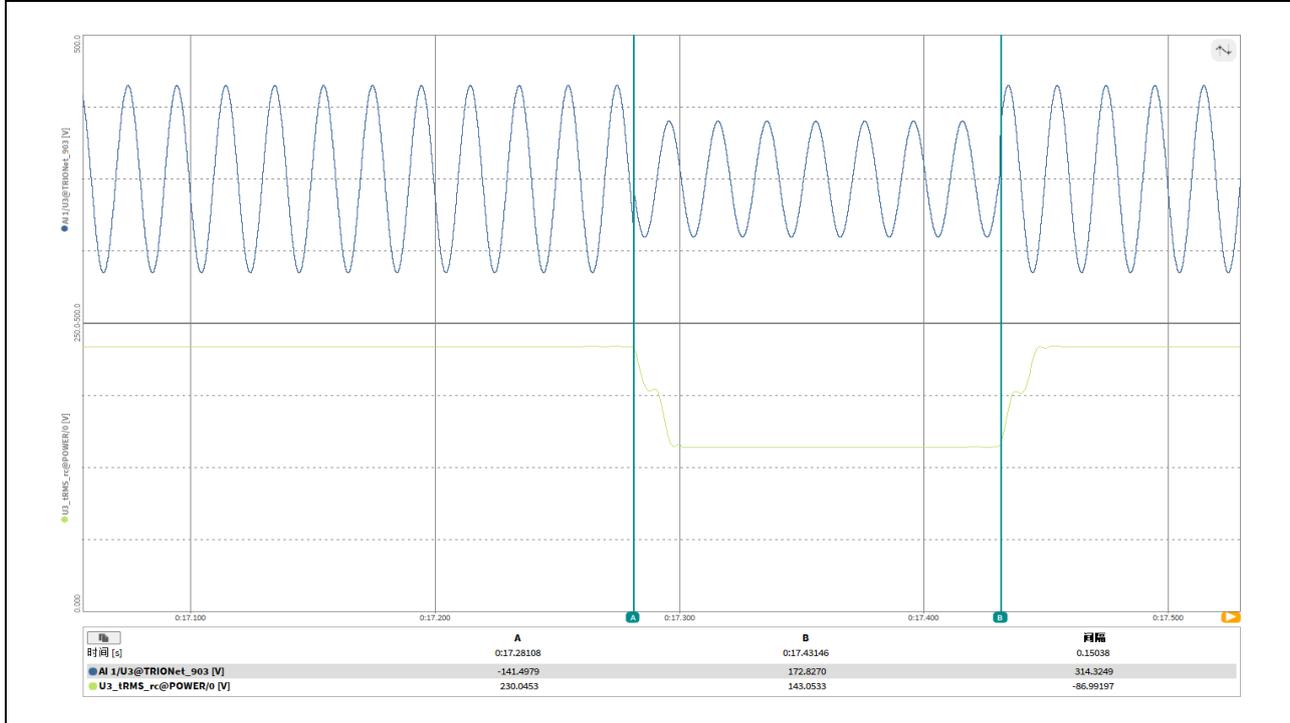


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	1.3	1.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	20:58	20:53	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.62	0.62
	5	Setting dip duration	--	--	--	--	150	150
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	17281	17281
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	17431	17431
	8	Fault duration in empty load test	Total	--	--	ms	150	150
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.62	0.62	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	0.98	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.07	0.05	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.998	0.995		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.62	0.62	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	N/A	
	21		Phase 3			0.10	0.08	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	N/A	
	24		Phase 3			0.04	0.04	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00	0.00	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.85	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.07	0.05	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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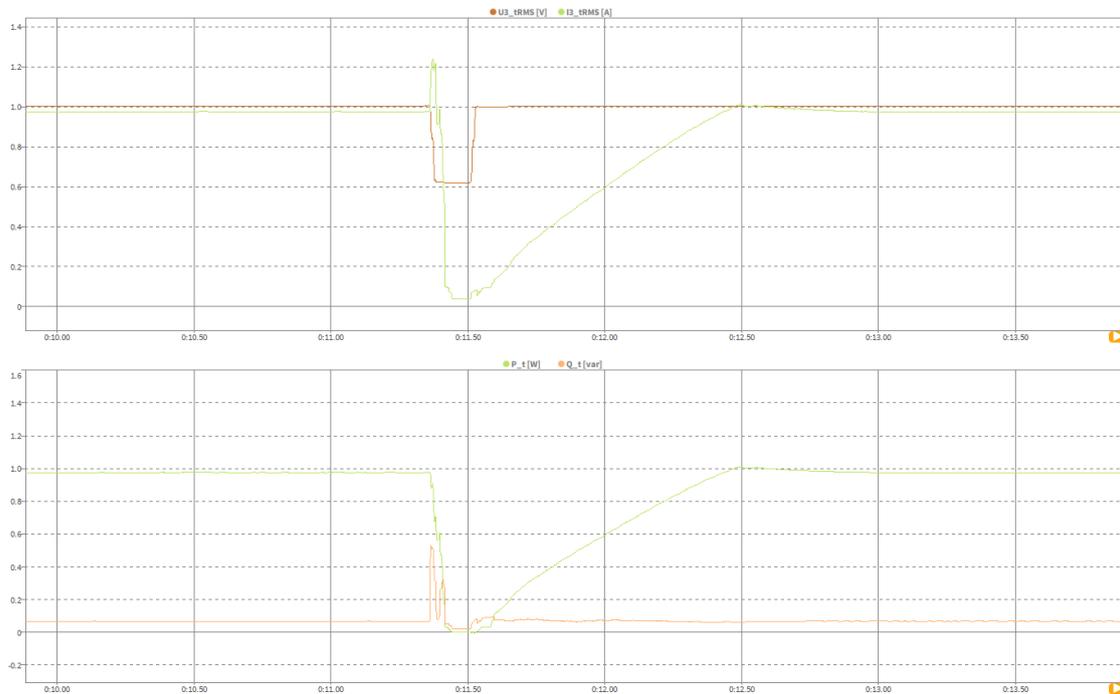
**Test 1.0.2 Voltage Depth: 0.62 p.u. (W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



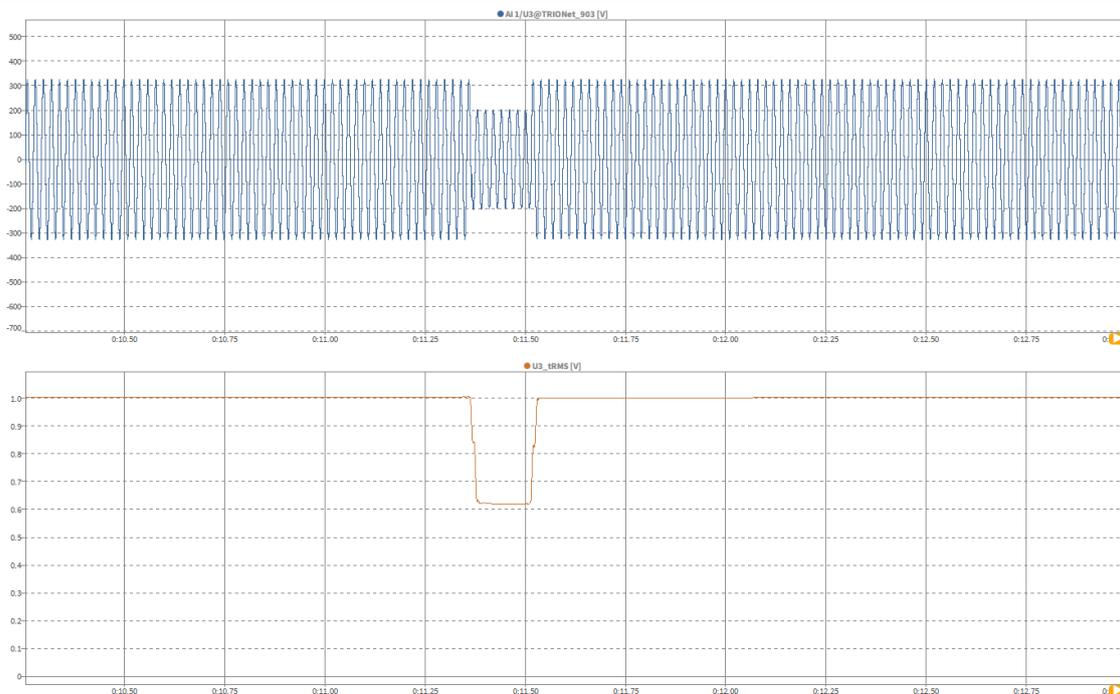
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.3 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Test overview (voltage, current, active and reactive power)**



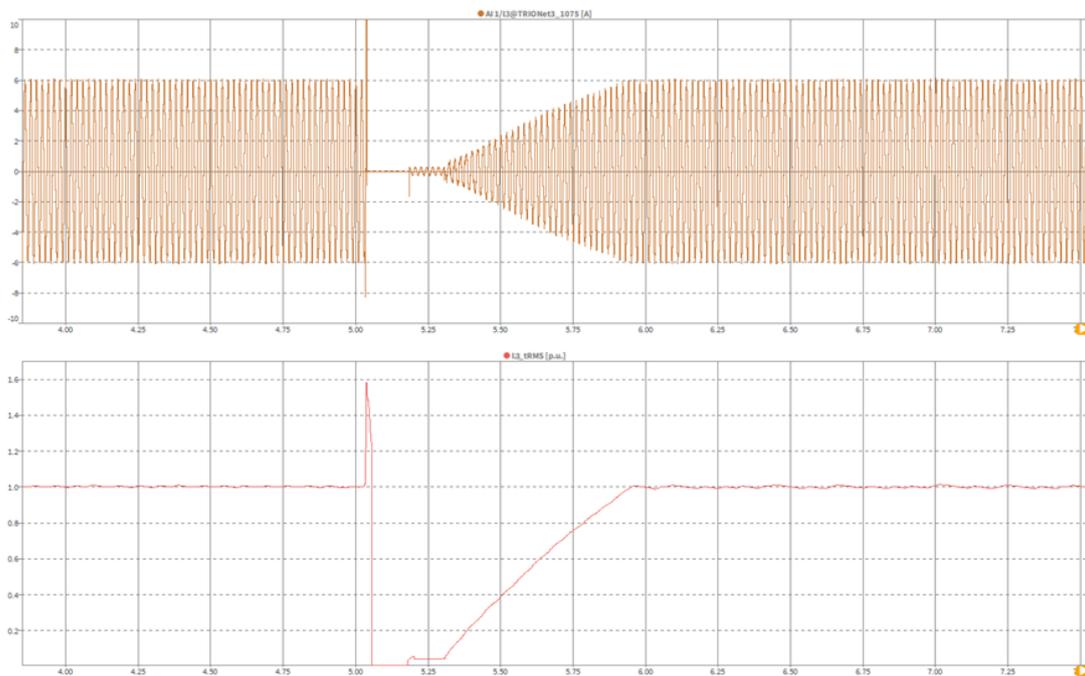
**Test 1.3 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve curve and RMS values of phase to natural voltages**



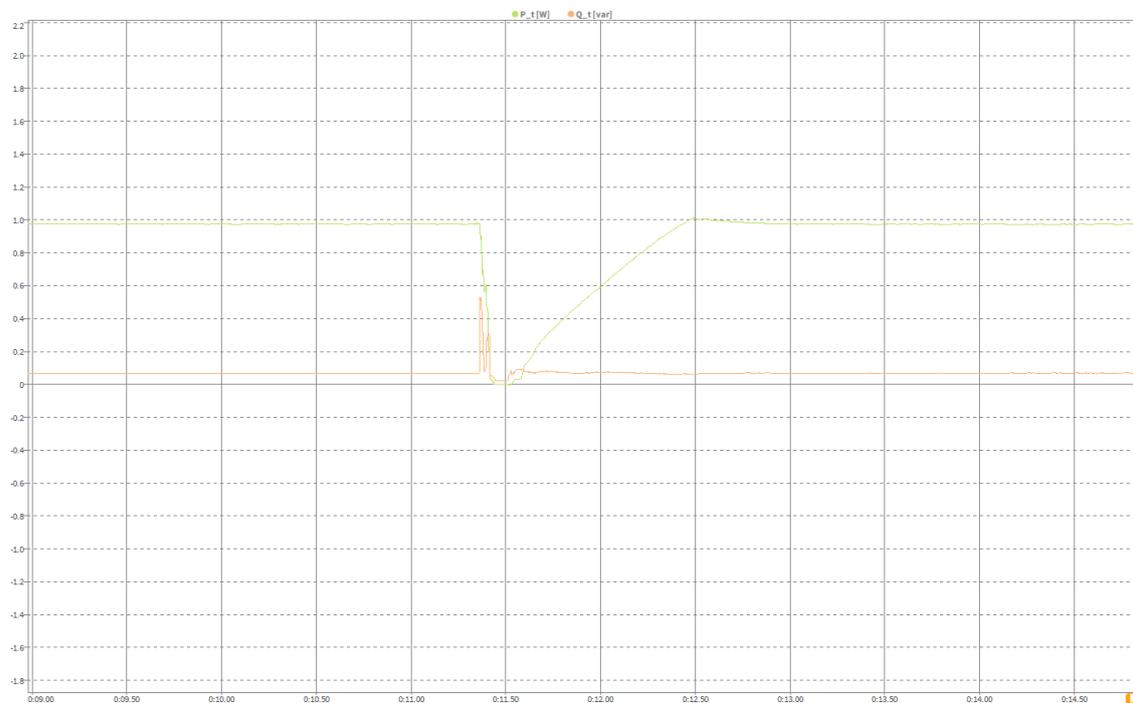
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.3 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve and RMS values of phase currents**



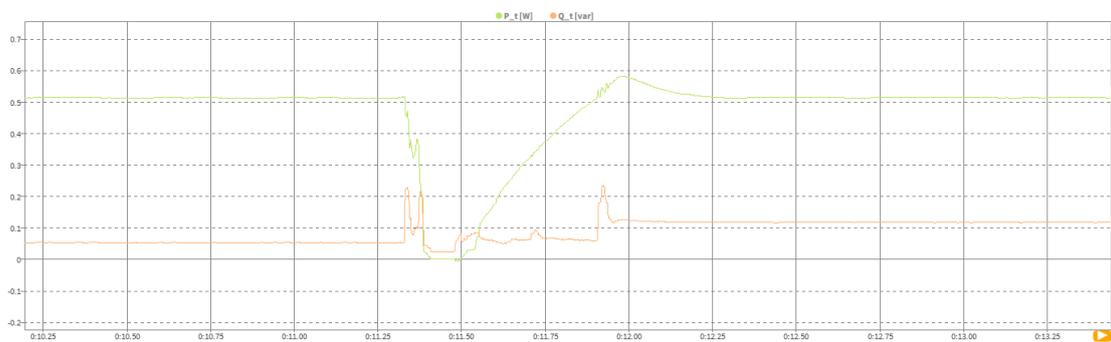
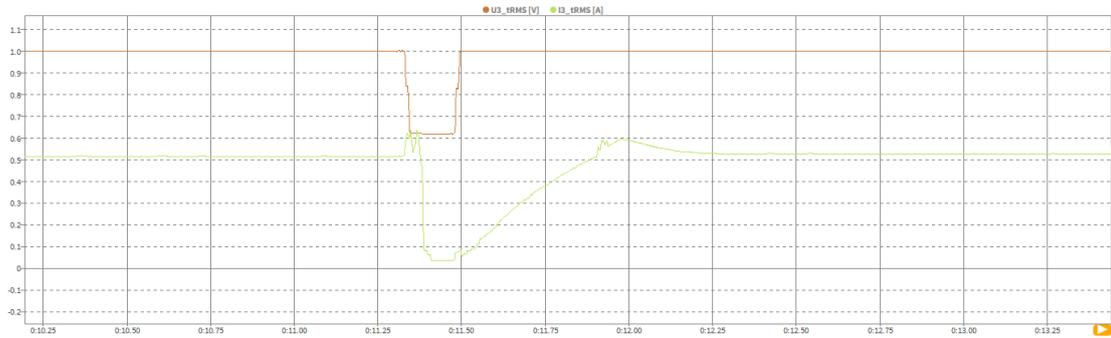
**Test 1.3 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Total values of active and reactive power**



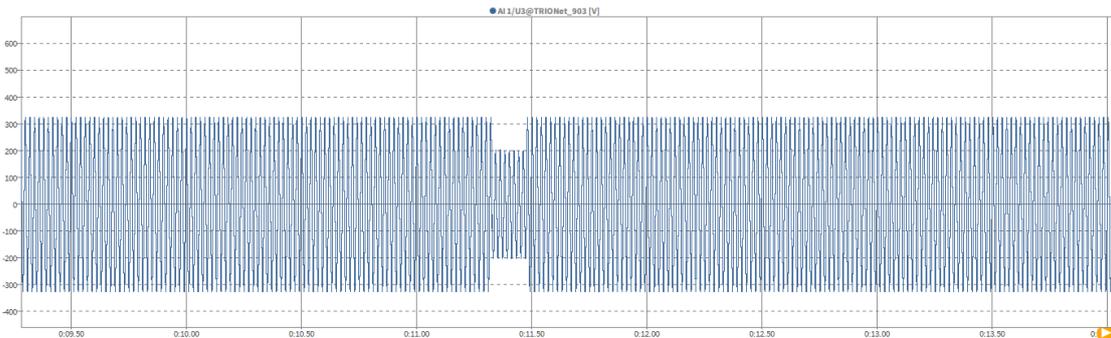
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.4 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Test overview (voltage, current, active and reactive power)**



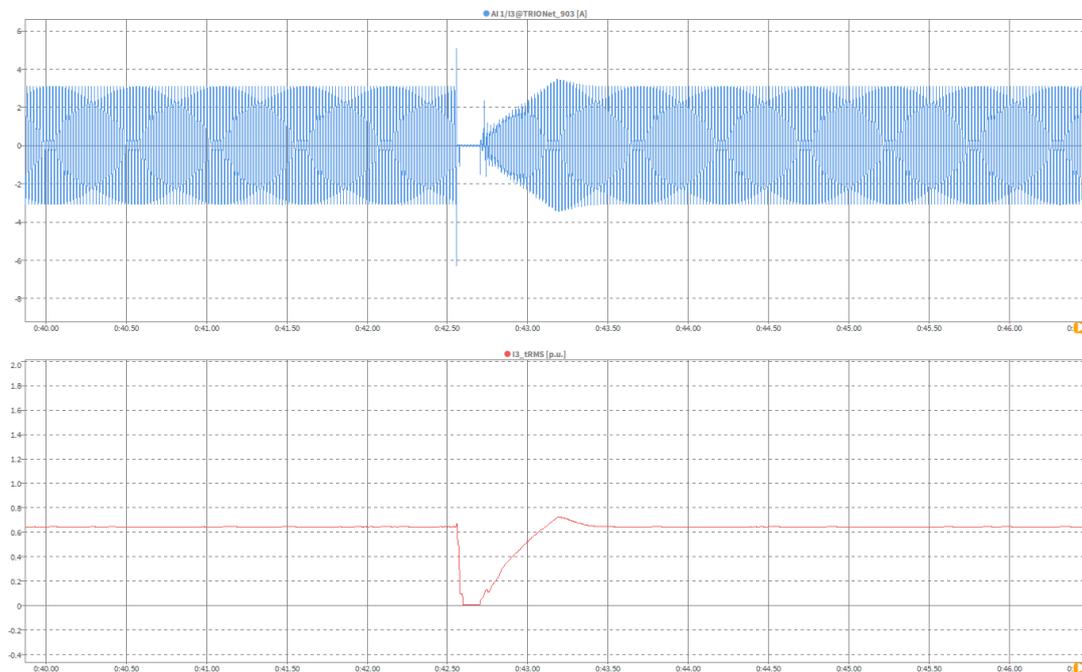
**Test 1.4 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



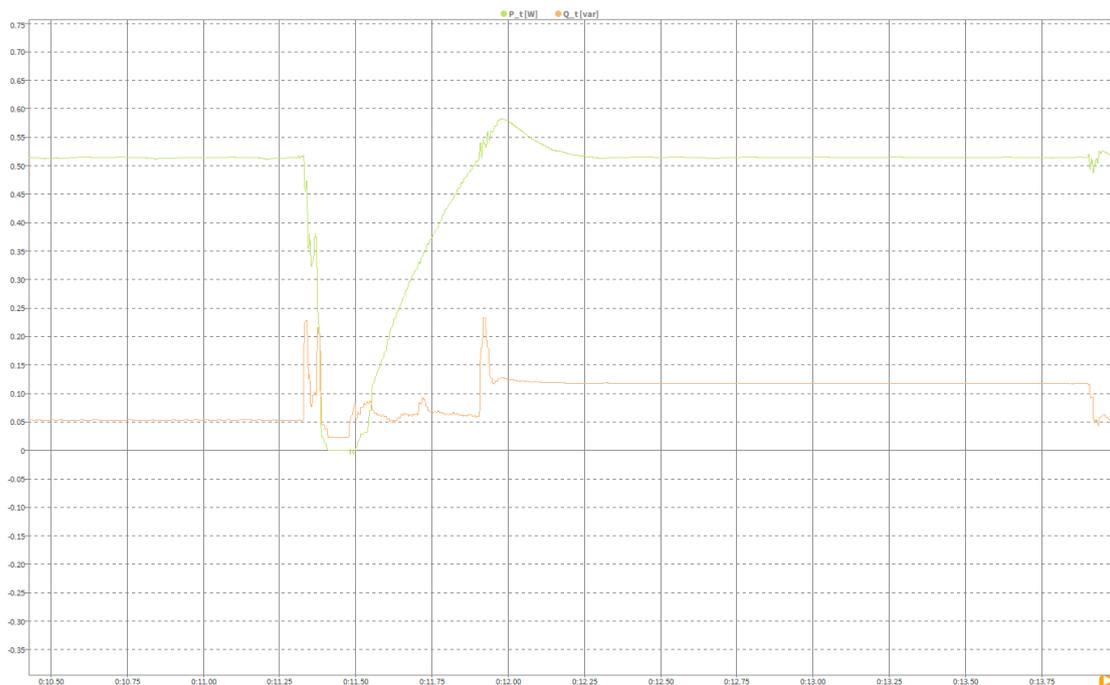
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.4 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 1.4 Depth of fault phase: 0.62 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Total values of active and reactive power**

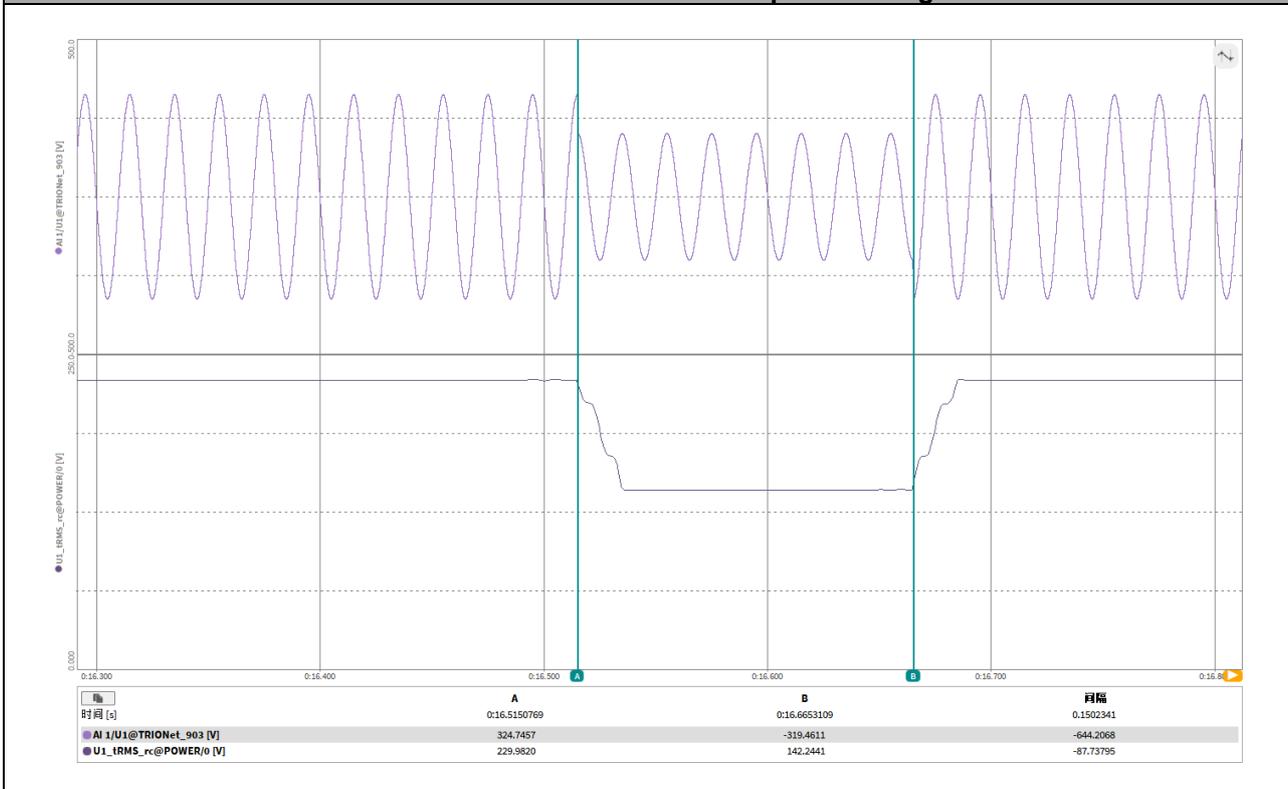


DIN VDE V 0124-100, VDE-AR-N 4105						
Clause	Requirement - Test				Result - Remark	Verdict
Item	Condition					Measured value
	No.	Parameter	Phase ref.	Time ref.	unit	
General Info.	0	Test number	--	--	--	1.5
	1	Date	--	--	yyyy.mm.dd	2025.01.01
	2	Time (start of test)	--	--	hh:mm:ss.f	14:32
	3	Fault type (phase)	--	--	--	D2
	4	Setting voltage depth	Phase conductor	--	p.u.	0.62
	5	Setting dip duration		--	--	150
	6	Point of fault entry( $t_1$ )	Total	--	ms	16515
	7	Point of fault clearance( $t_2$ )	Total	--	ms	16665
	8	Fault duration in empty load test	Total	--	ms	150
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.62
10	Pos.		N/A			
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A
	13	Active power	Total	t1-10s to t1	p.u.	0.00
	14		Pos.			N/A
	15	Reactive power	Total	t1-10s to t1	p.u.	0.00
	16		Pos.			N/A
17	Cosφ	--	t1-10s to t1	--	-0.002	
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.62
	19	Line current	Phase 1	t1+60ms	p.u.	0.11
	20		Phase 2			N/A
	21		Phase 3			N/A
	22	Line current	Phase 1	t1+100ms	p.u.	0.01
	23		Phase 2			N/A
	24		Phase 3			N/A
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00
26	Pos.		N/A			
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.00
	29		Pos.			N/A
	30	Response time reactive power	Pos.	--	s	N/A
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.00
	32		Pos.			N/A
	33	Reactive power rising time	Pos.	--	s	N/A
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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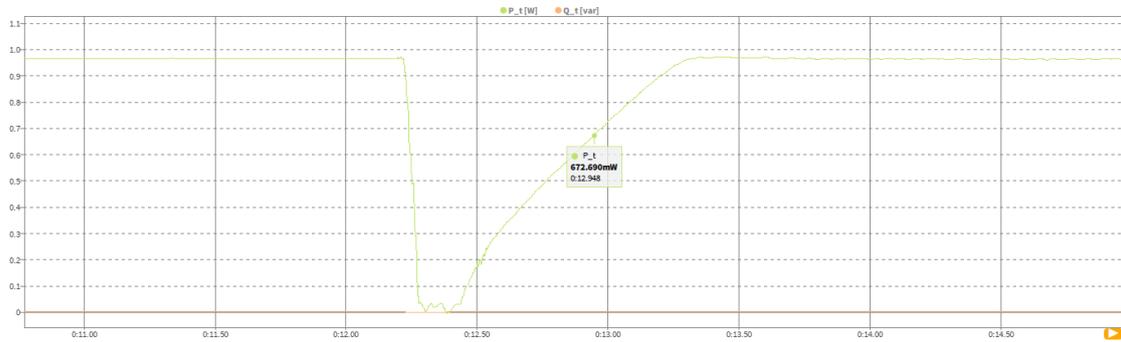
**Test 1.0.3 Depth of fault phase: 0.62 p.u.(V-N), Unbalanced fault (type D2), No load, Instantaneous and RMS values of phase voltages**



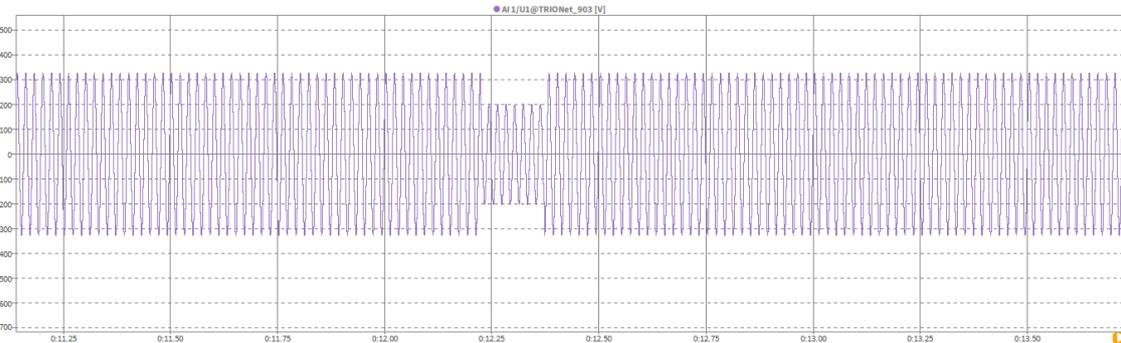
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.5 Depth of fault phase: 0.62 p.u.(U-N), Unbalanced fault (type D2), 100% load**  
**Test overview (voltage, current, active and reactive power)**



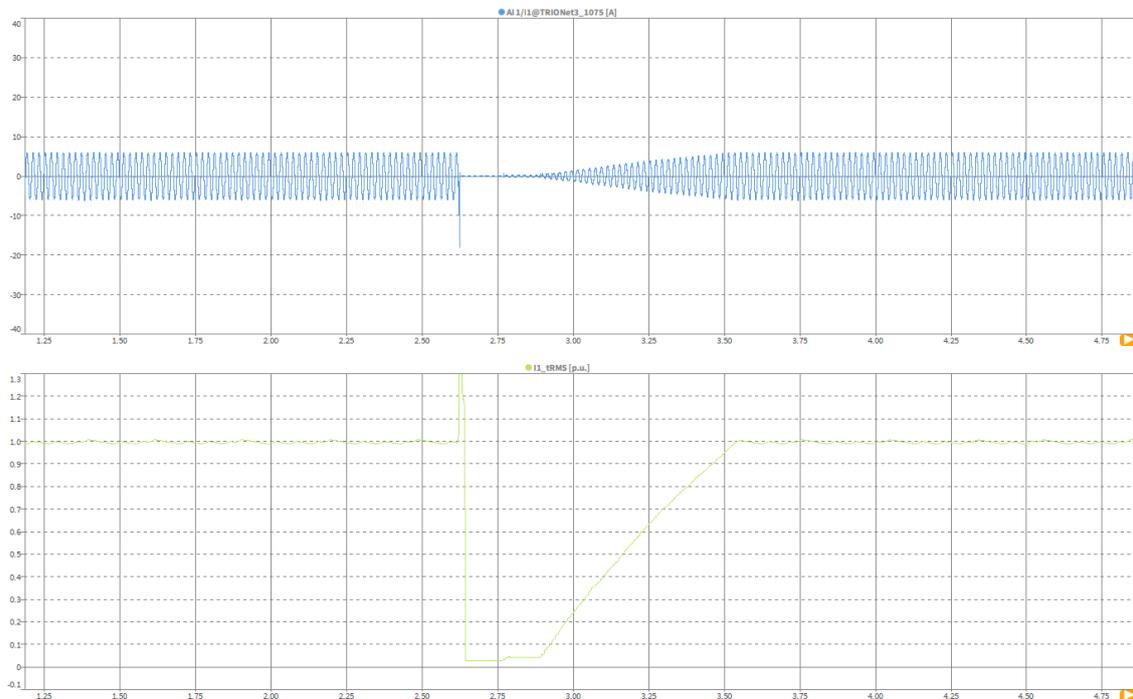
**Test 1.5 Depth of fault phase: 0.62 p.u.(U-N), Unbalanced fault (type D2), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



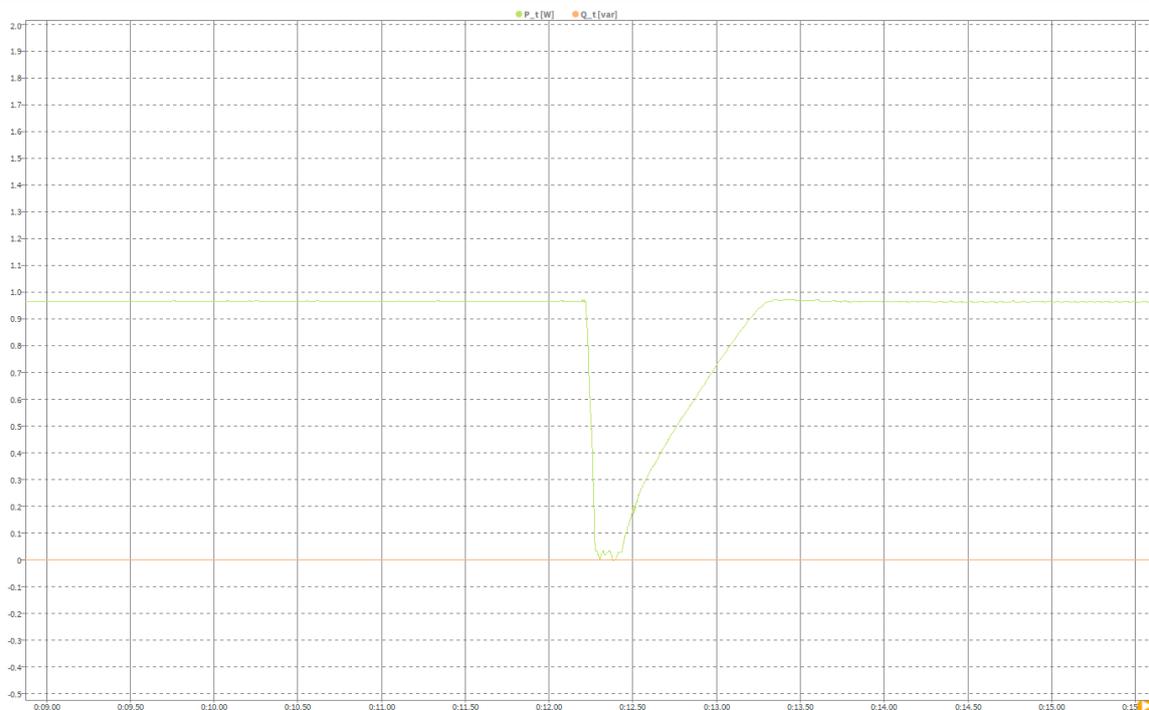
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 1.5 Depth of fault phase: 0.62 p.u.(U-N), Unbalanced fault (type D2), 100% load  
Instantaneous curve and RMS values of phase currents**



**Test 1.5 Depth of fault phase: 0.62 p.u.(U-N), Unbalanced fault (type D2), 100% load  
Total values of active and reactive power**

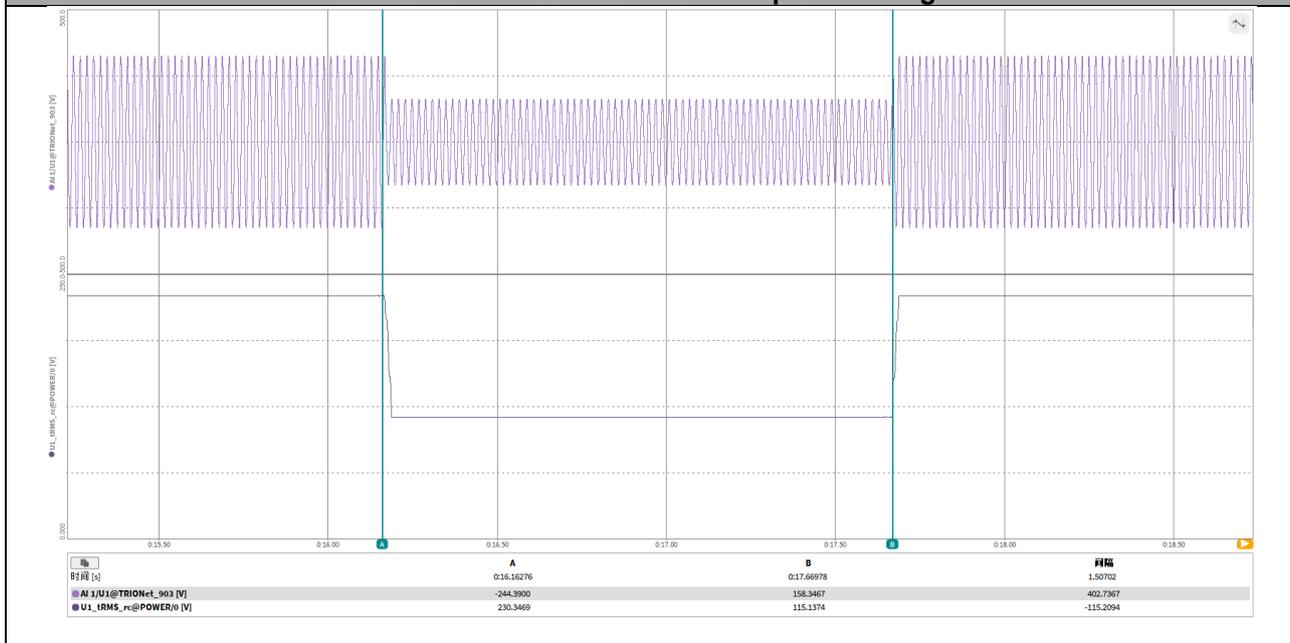


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	2.1	2.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:34	13:36	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.5	0.5
	5	Setting dip duration		--	--	--	1500	1500
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16162	16162
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	17669	17669
	8	Fault duration in empty load test	Total	--	--	ms	15070	15070
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.50	0.50	
10	Pos.				N/A	N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	0.99	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.47	0.25	
	16		Pos.			N/A	N/A	
	17	Cosφ	--	t1-10s to t1	--	0.905	0.896	
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.50	0.50	
	19	Line current	Phase 1	t1+60ms	p.u.	0.10	0.09	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.02	0.02	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00	0.00	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.37	0.21	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	11.56	10.12	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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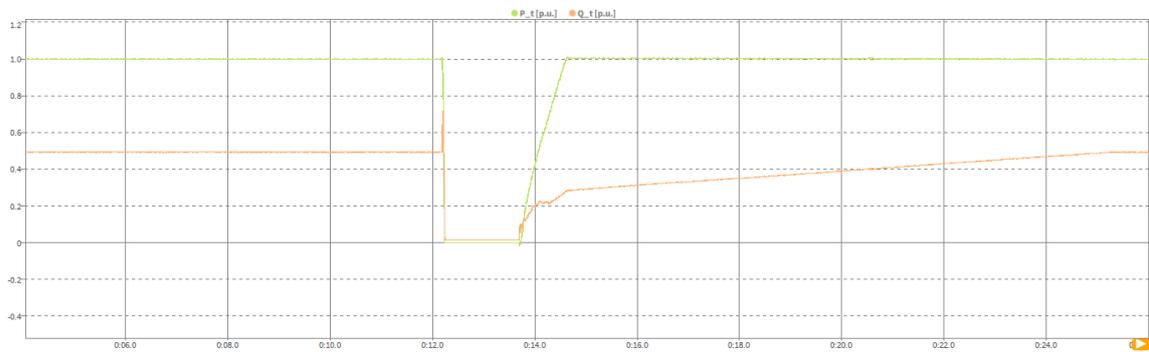
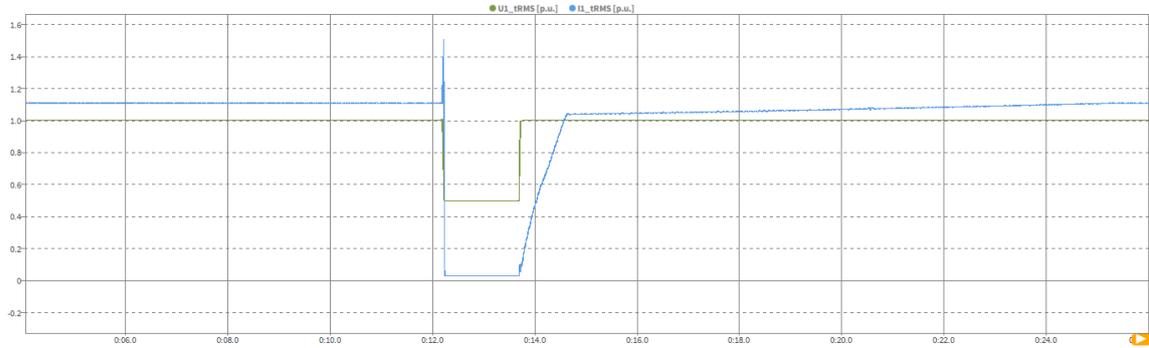
**Test 2.0.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



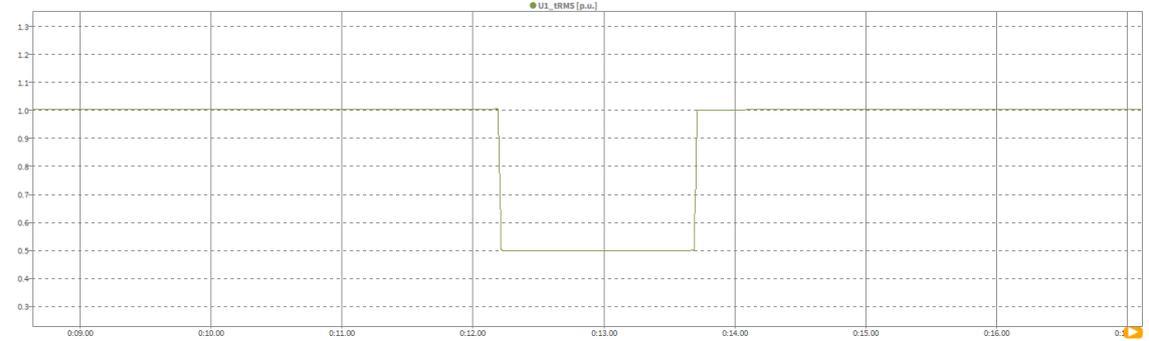
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, -Qmax  
Test overview (voltage, current, active and reactive power)**



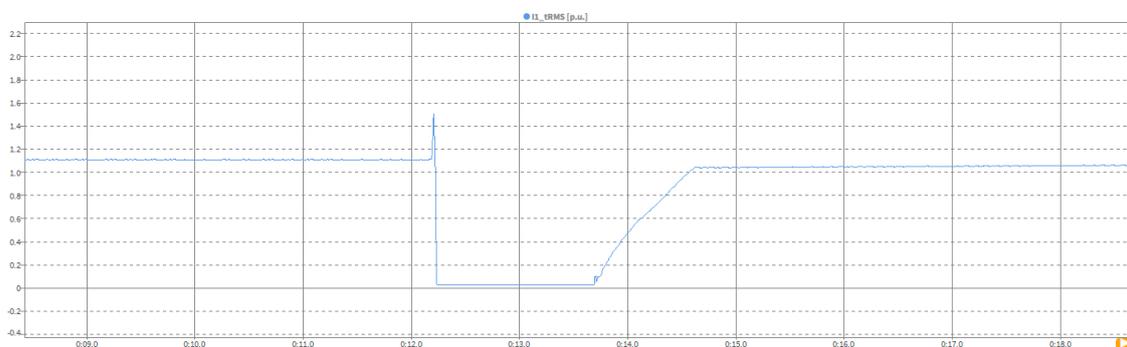
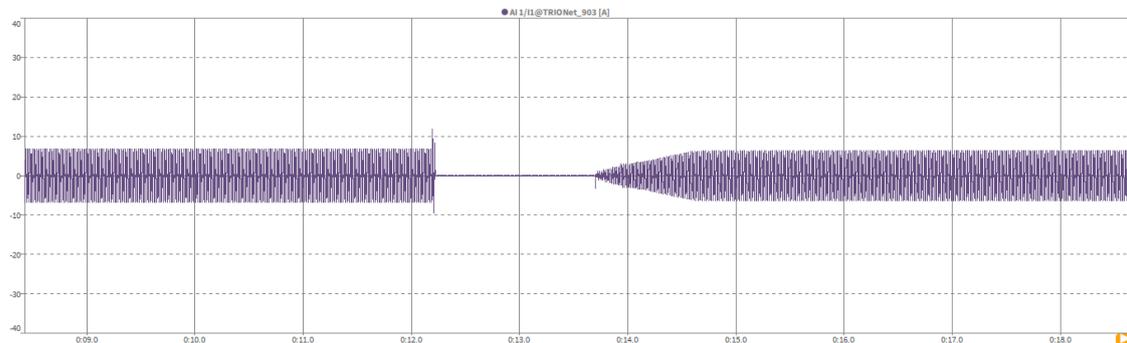
**Test 2.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, -Qmax  
Instantaneous curve curve and RMS values of phase to natural voltages**



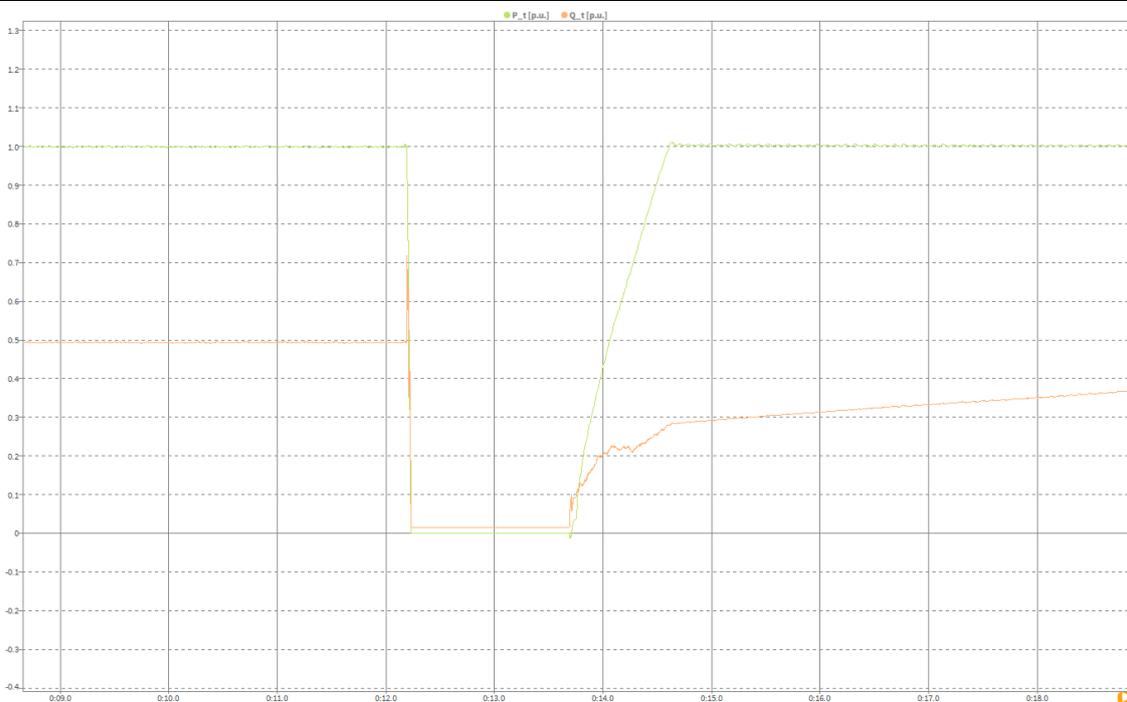
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, -Qmax  
Instantaneous curve and RMS values of phase currents**



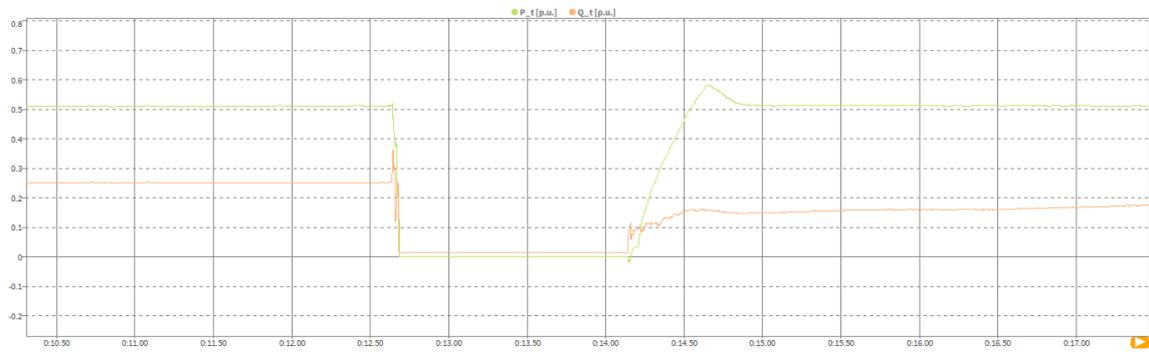
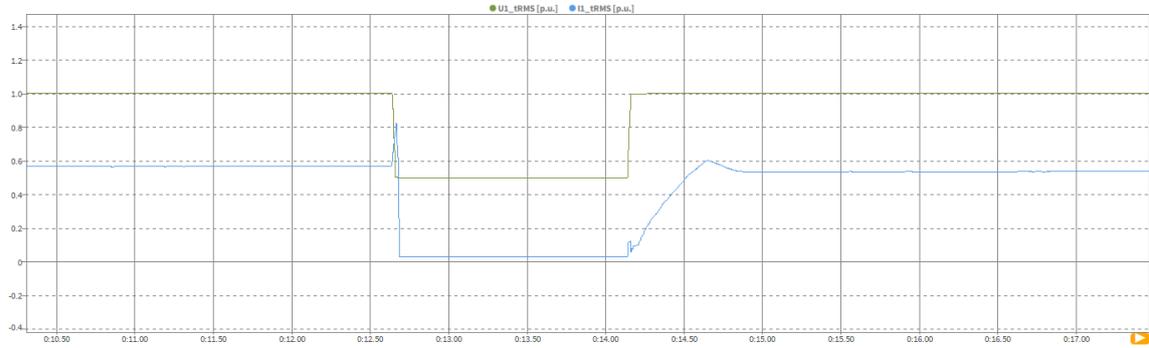
**Test 2.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, -Qmax  
Total values of active and reactive power**



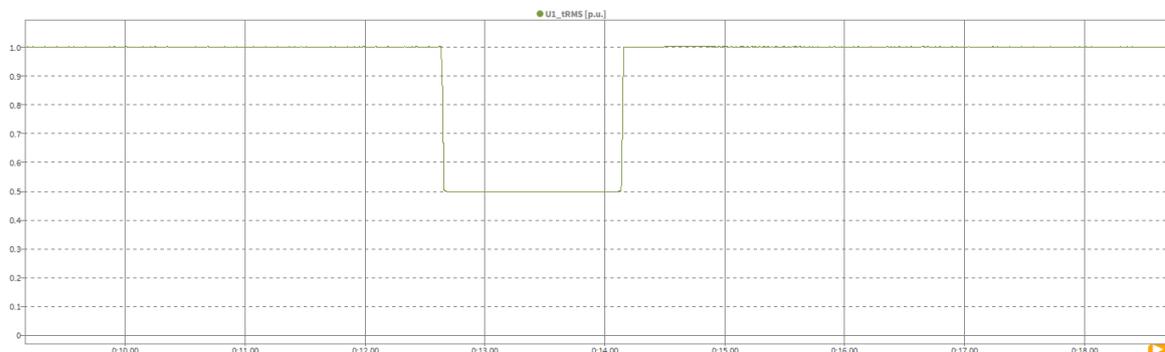
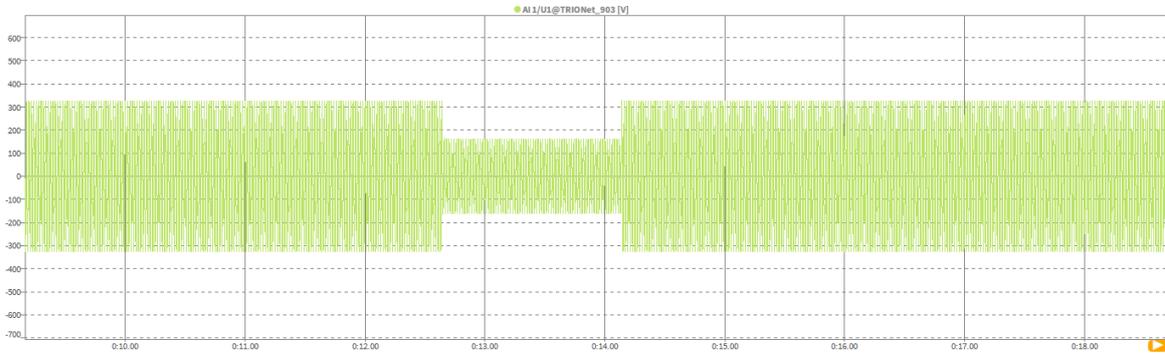
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, -Qmax**  
**Test overview (voltage, current, active and reactive power)**



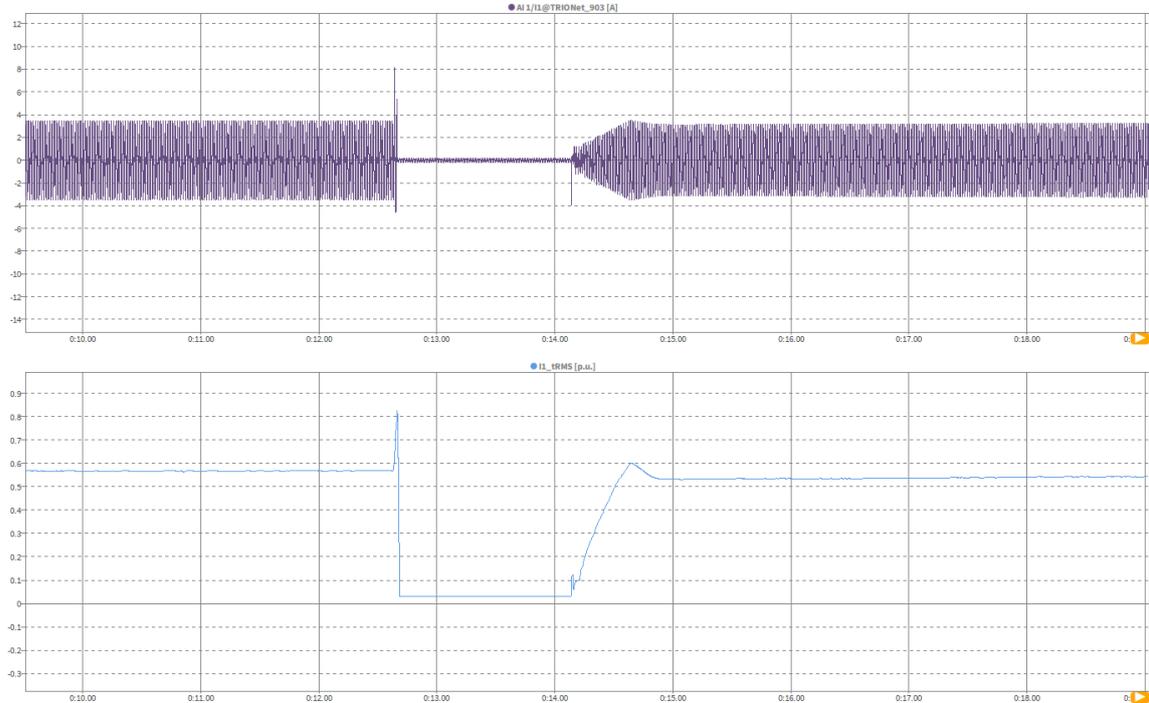
**Test 2.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, -Qmax**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



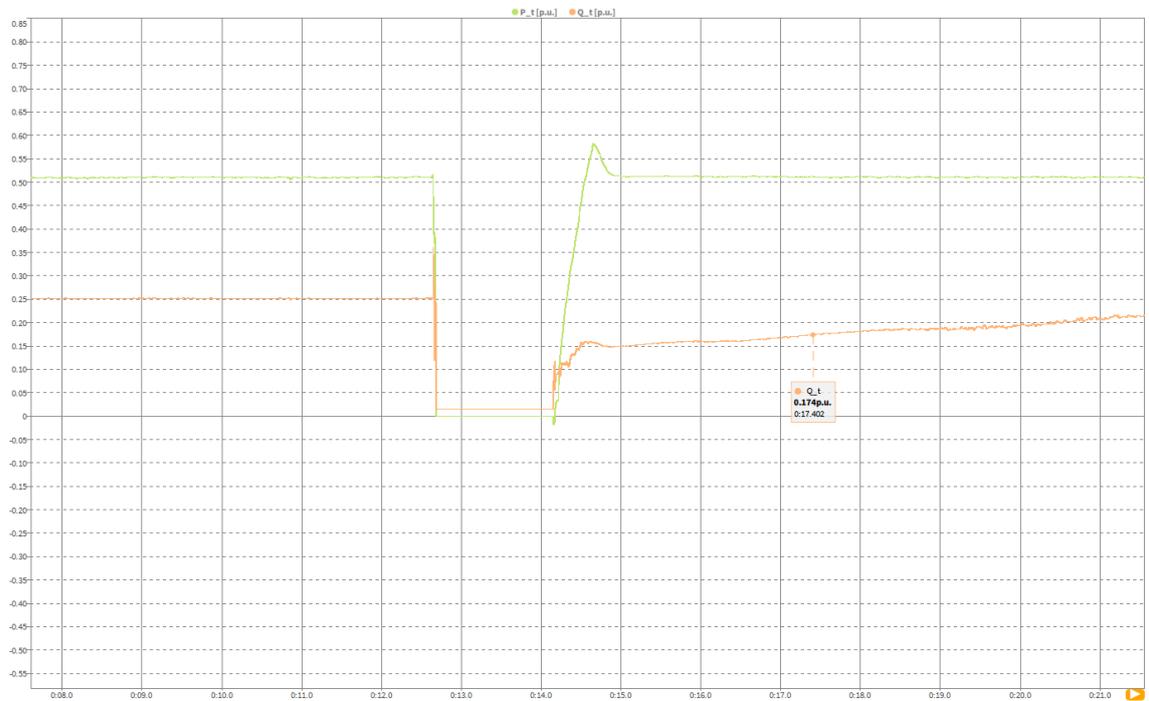
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, -Qmax  
Instantaneous curve and RMS values of phase currents**



**Test 2.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load  
Total values of active and reactive power**

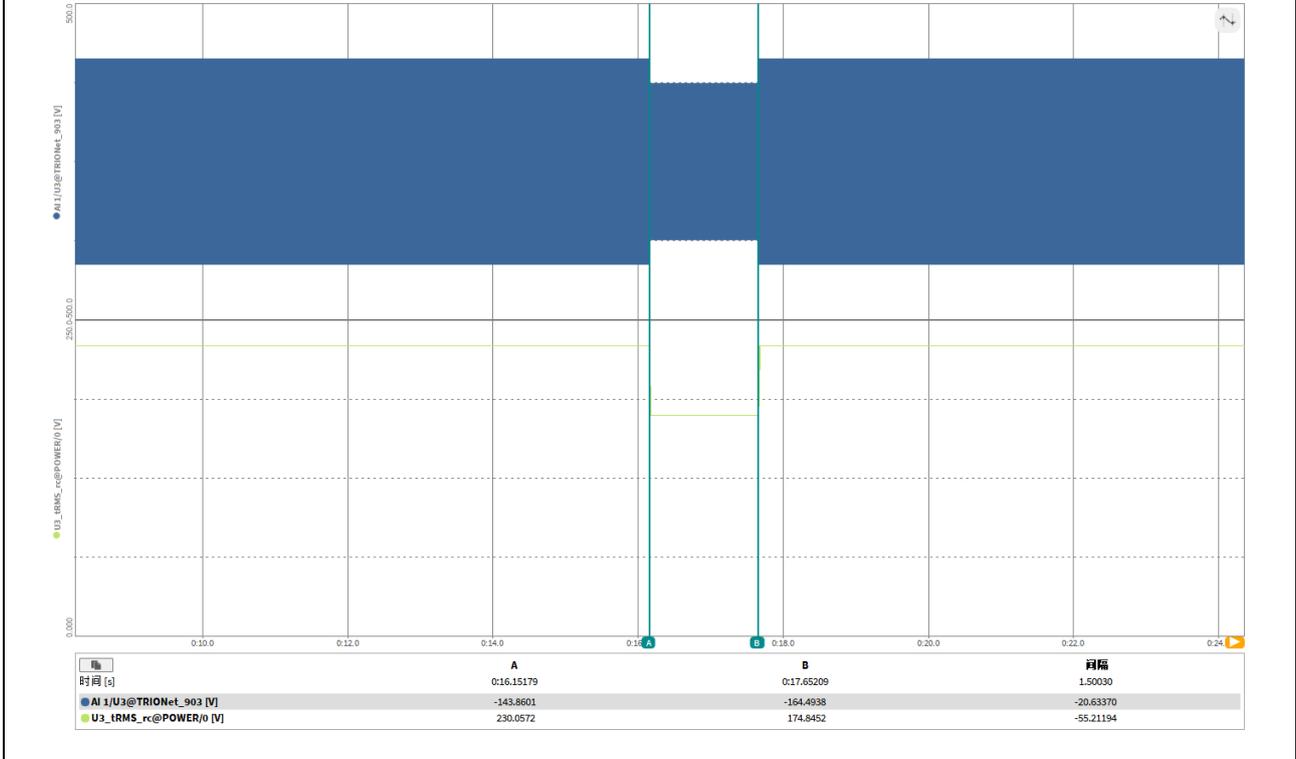


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	2.3	2.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	14:08	14:10	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.76	0.76
	5	Setting dip duration		--	--	--	1500	1500
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16151	16151
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	17652	17652
	8	Fault duration in empty load test	Total	--	--	ms	1500	1500
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.76	0.76	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.48	0.26	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.901	0.892		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.76	0.76	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	N/A	
	21		Phase 3			0.05	0.05	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	N/A	
	24		Phase 3			0.05	0.05	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00	0.00	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.41	0.21	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	10.09	11.2	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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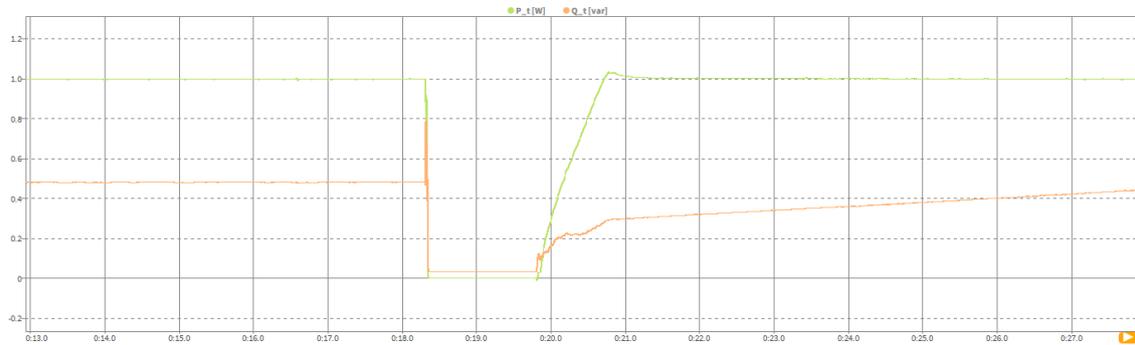
**Test 2.0.2 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



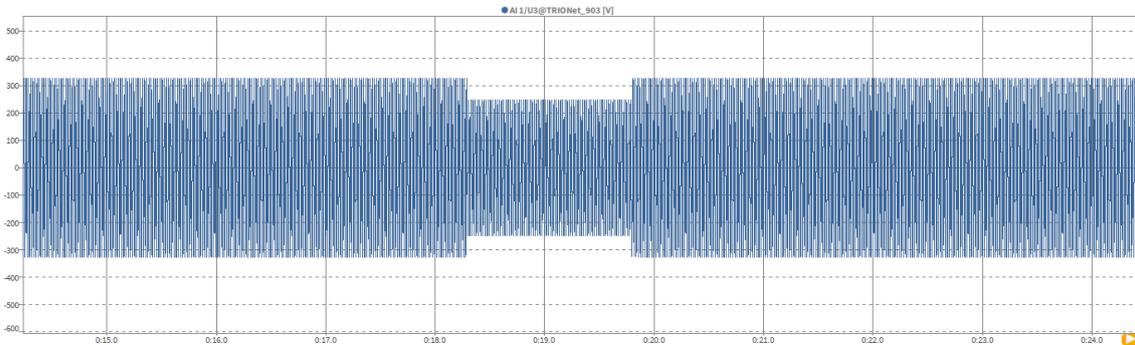
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, -Qmax  
Test overview (voltage, current, active and reactive power)**



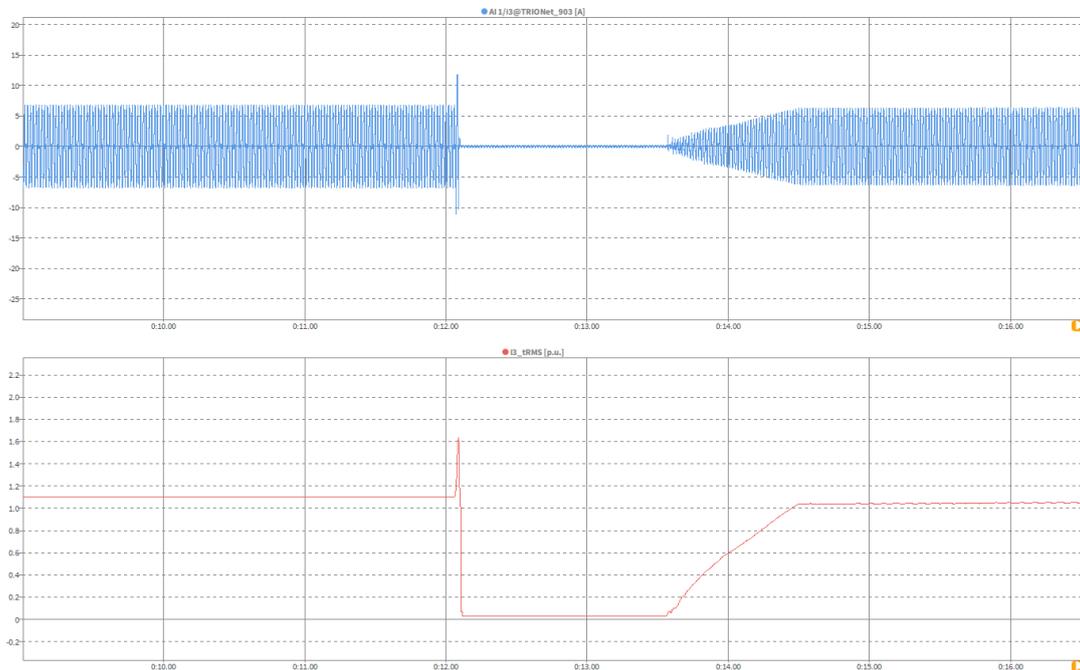
**Test 2.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, -Qmax  
Instantaneous curve curve and RMS values of phase to natural voltages**



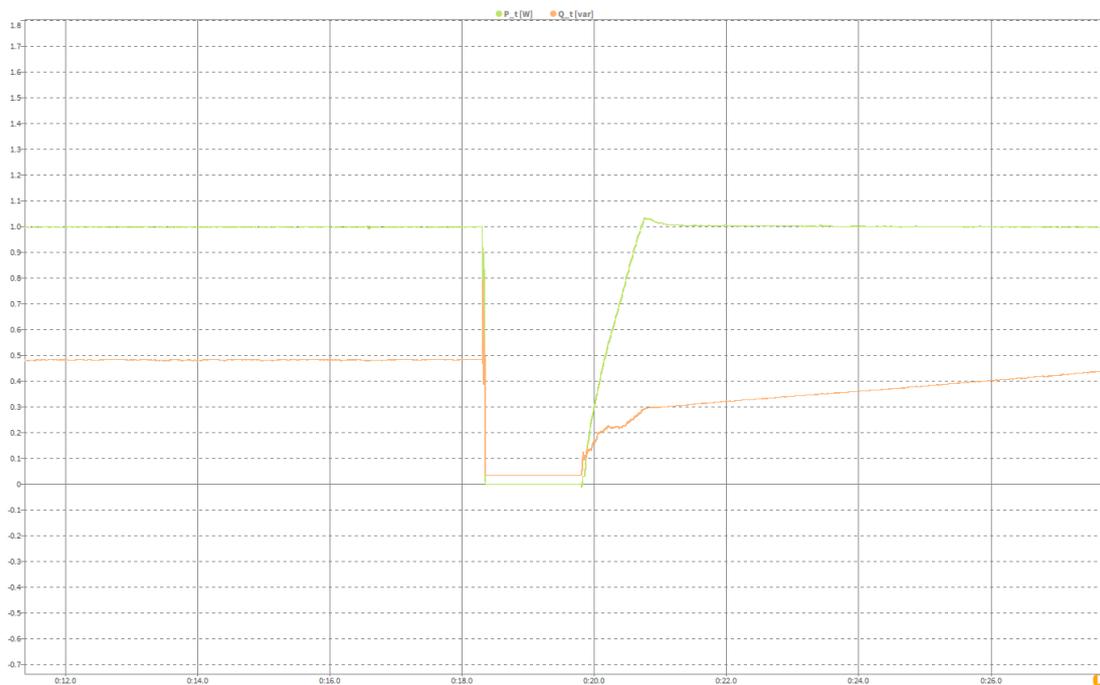
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, -Qmax  
Instantaneous curve and RMS values of phase currents**



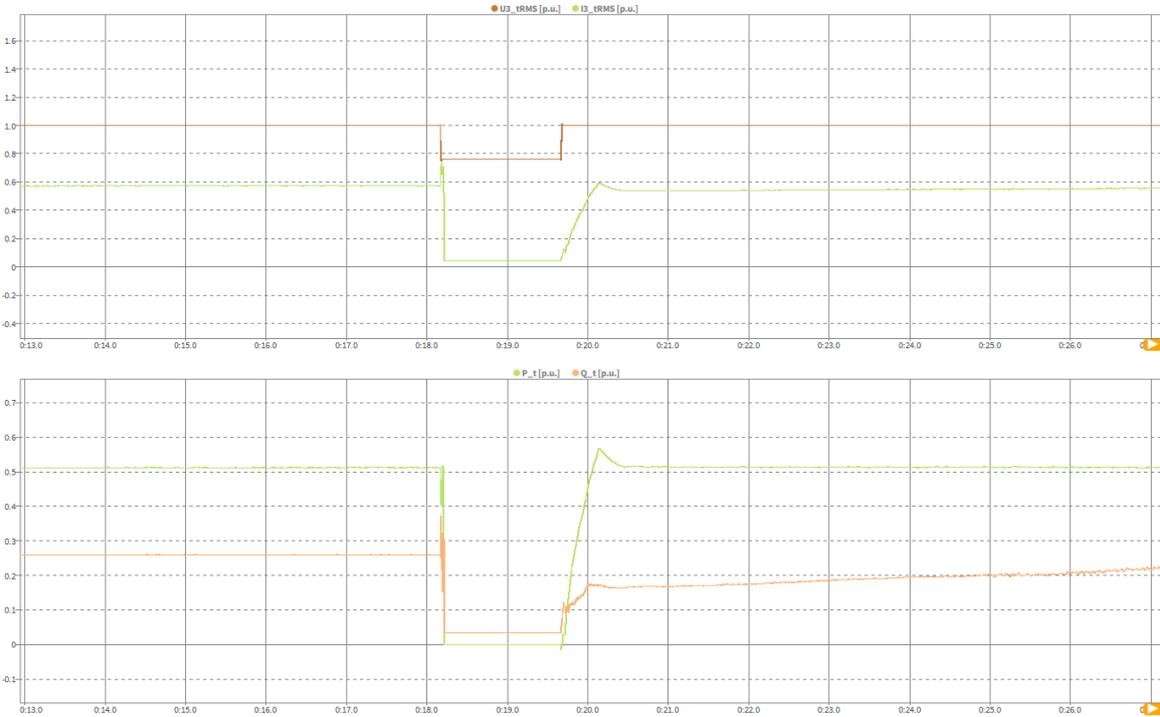
**Test 2.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, -Qmax  
Total values of active and reactive power**



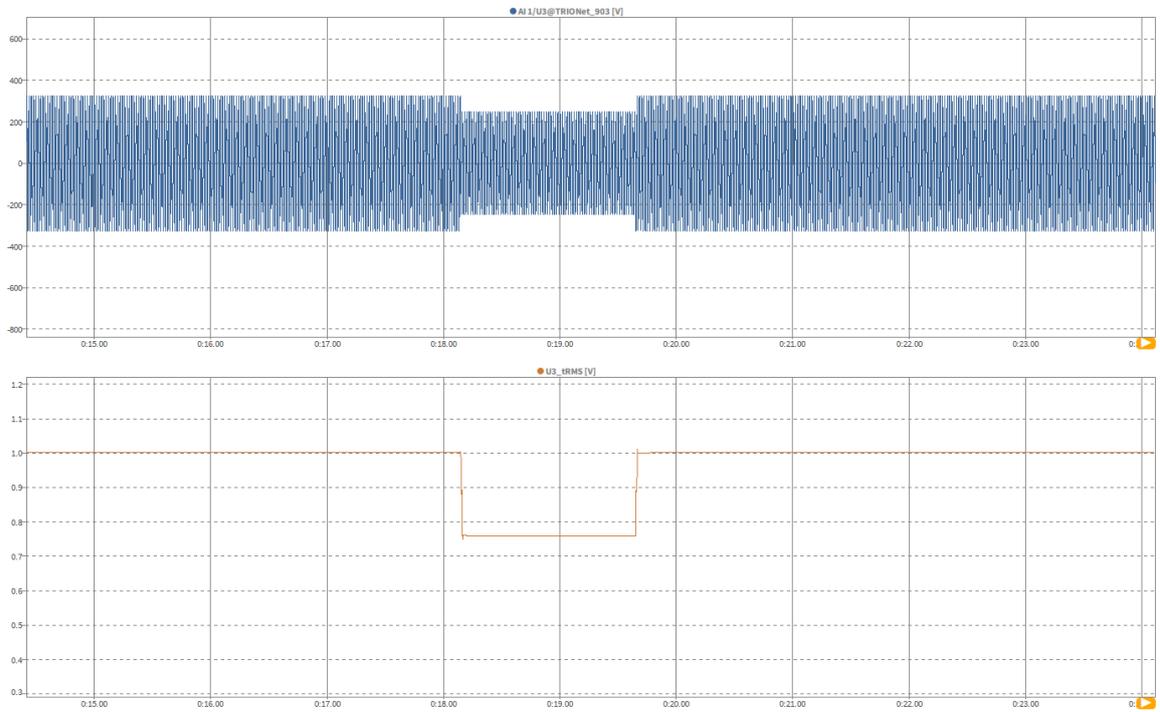
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, -Qmax  
Test overview (voltage, current, active and reactive power)**



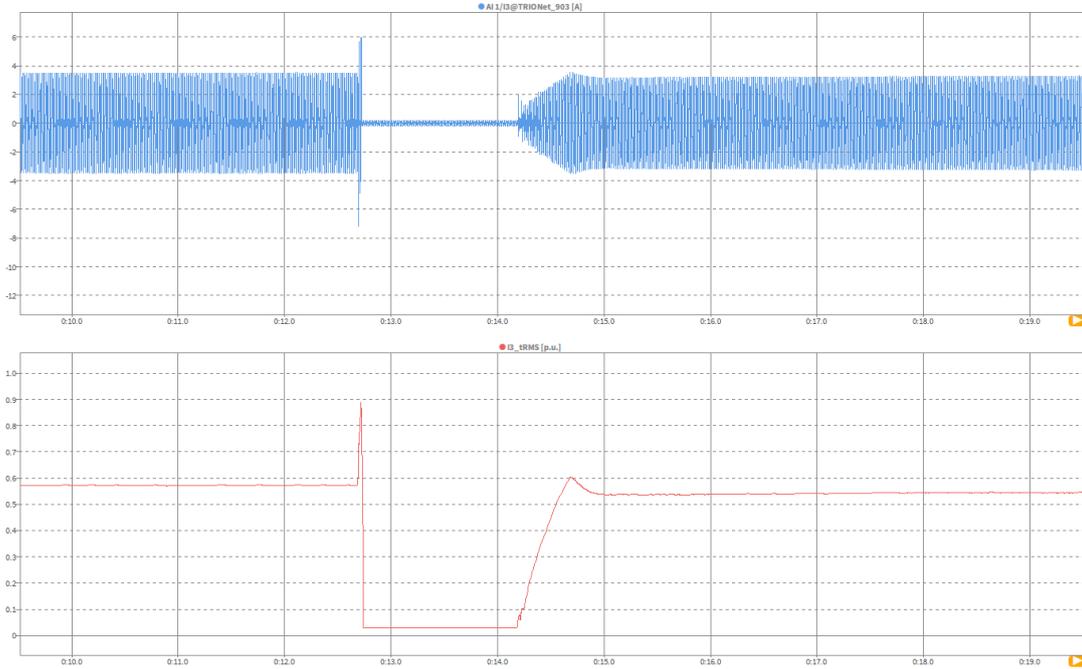
**Test 2.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, -Qmax  
Instantaneous curve curve and RMS values of phase to natural voltages**



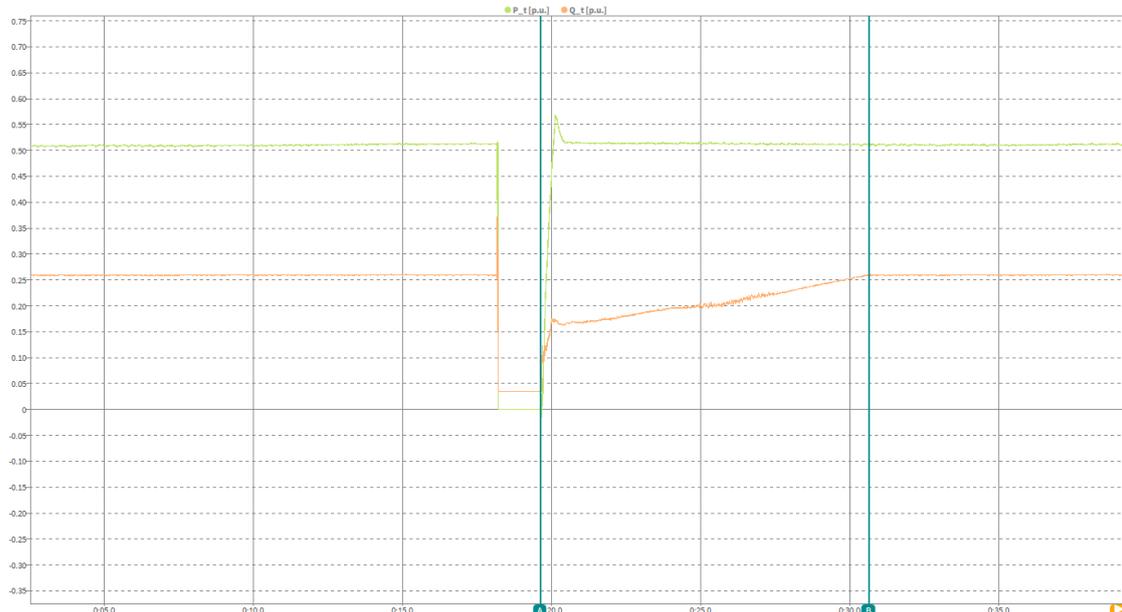
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 2.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, -Qmax Instantaneous curve and RMS values of phase currents**



**Test 2.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, -Qmax Total values of active and reactive power**



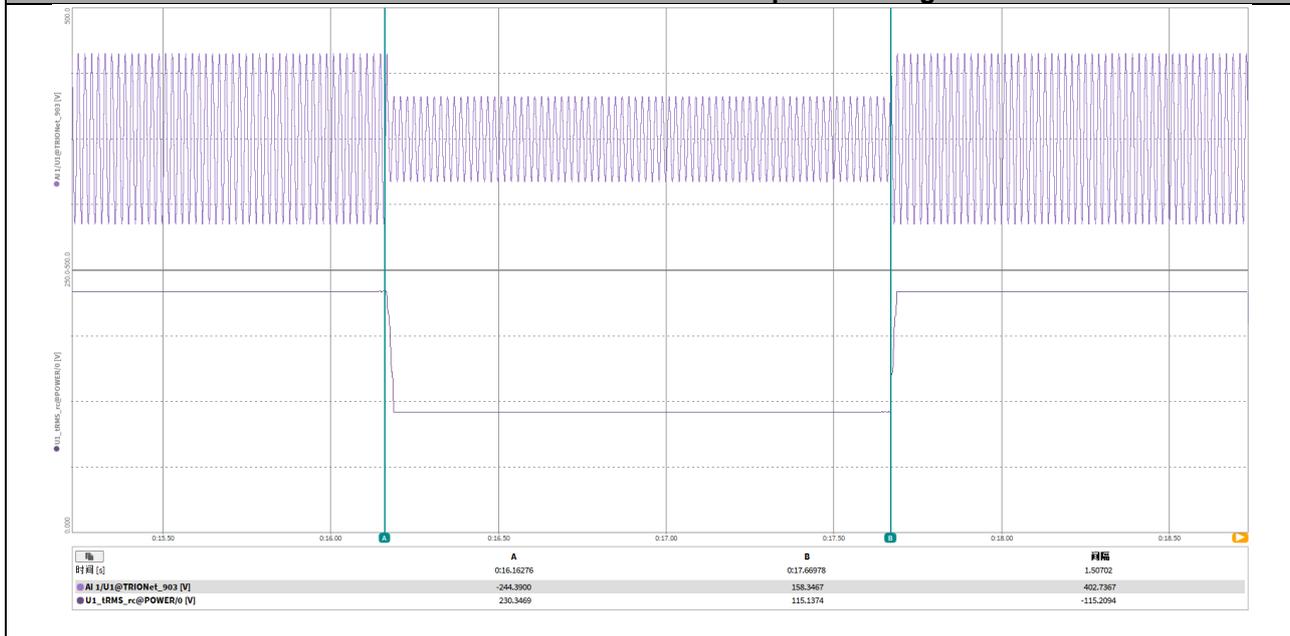
时间 (s)	A	B	时间
0.19.62656	0.30.63630	0.11.00974	
P_t [p.u.]	-8.266e-5	0.512179	0.512242
Q_t [p.u.]	0.034708	0.259447	0.224739

DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	3.1	3.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:38	13:40	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.5	0.5
	5	Setting dip duration		--	--	--	1500	1500
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16162	16162
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	17669	17669
	8	Fault duration in empty load test	Total	--	--	ms	1507	1507
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.50	0.50	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	0.97	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	-0.32	-0.14	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.901	0.901		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.50	0.50	
	19	Line current	Phase 1	t1+60ms	p.u.	0.11	0.08	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.02	0.02	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00	0.00	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.99	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	-0.26	-0.12	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	10.77	10.23	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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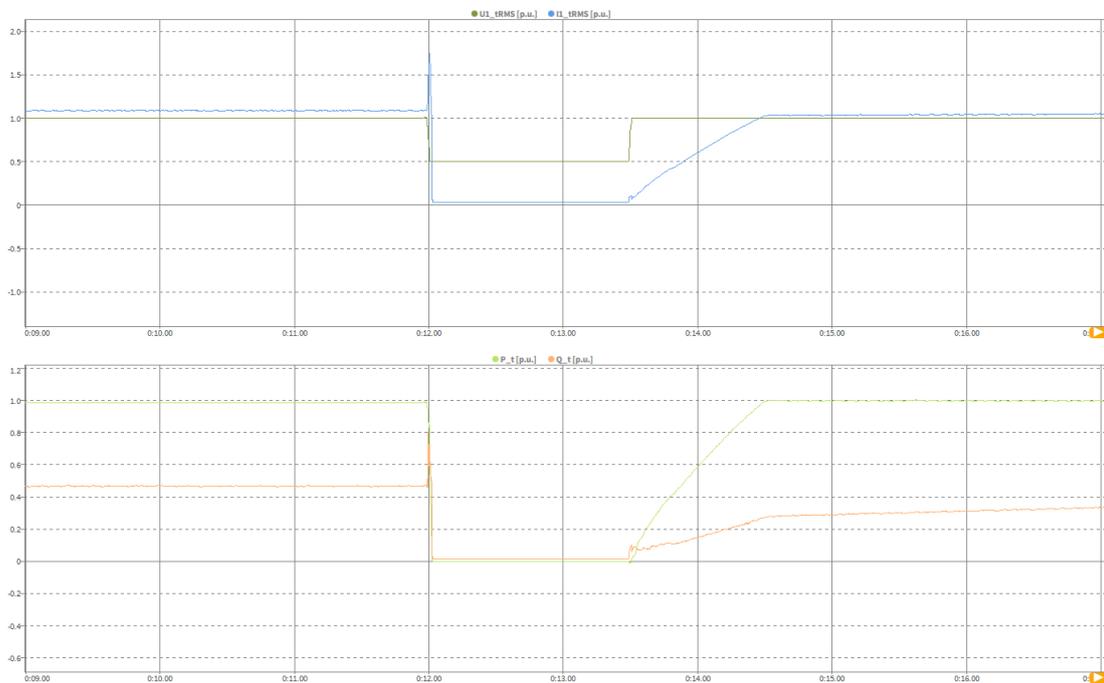
**Test 3.0.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



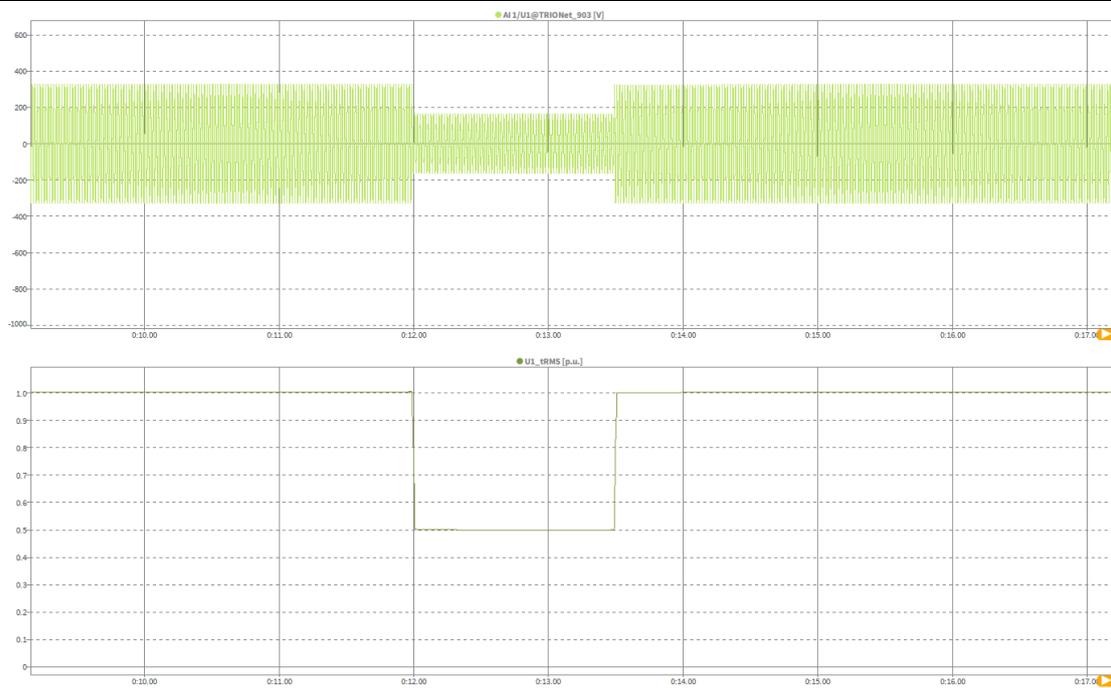
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, Qmax  
Test overview (voltage, current, active and reactive power)**



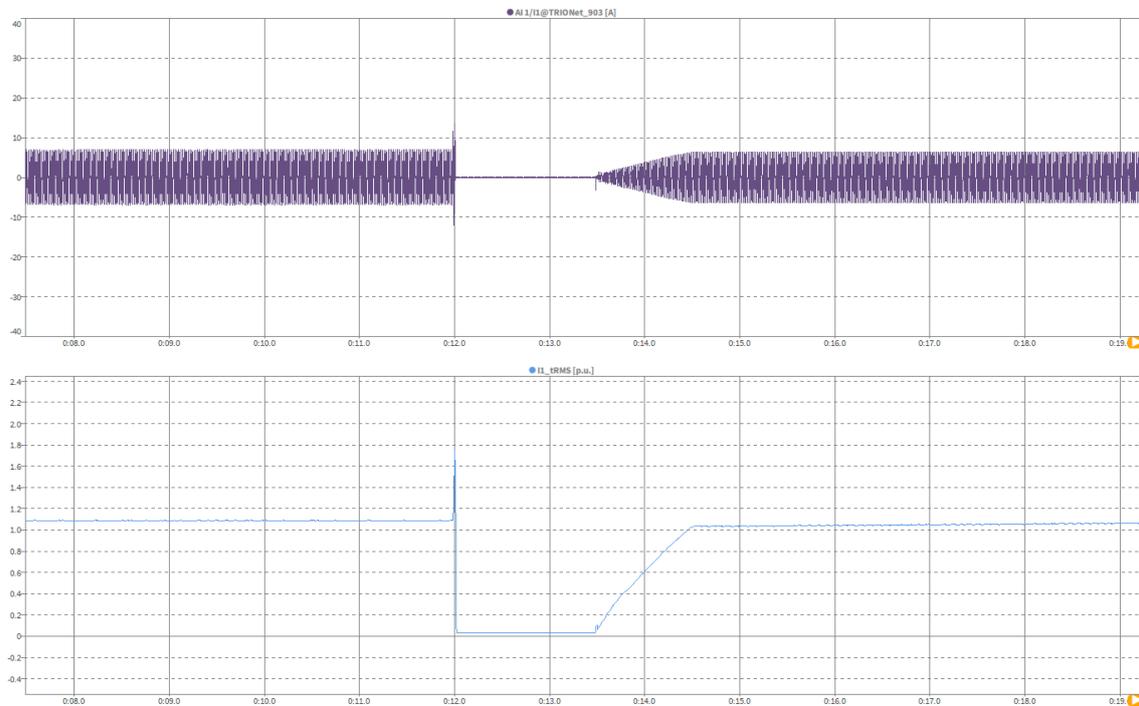
**Test 3.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, Qmax  
Instantaneous curve curve and RMS values of phase to natural voltages**



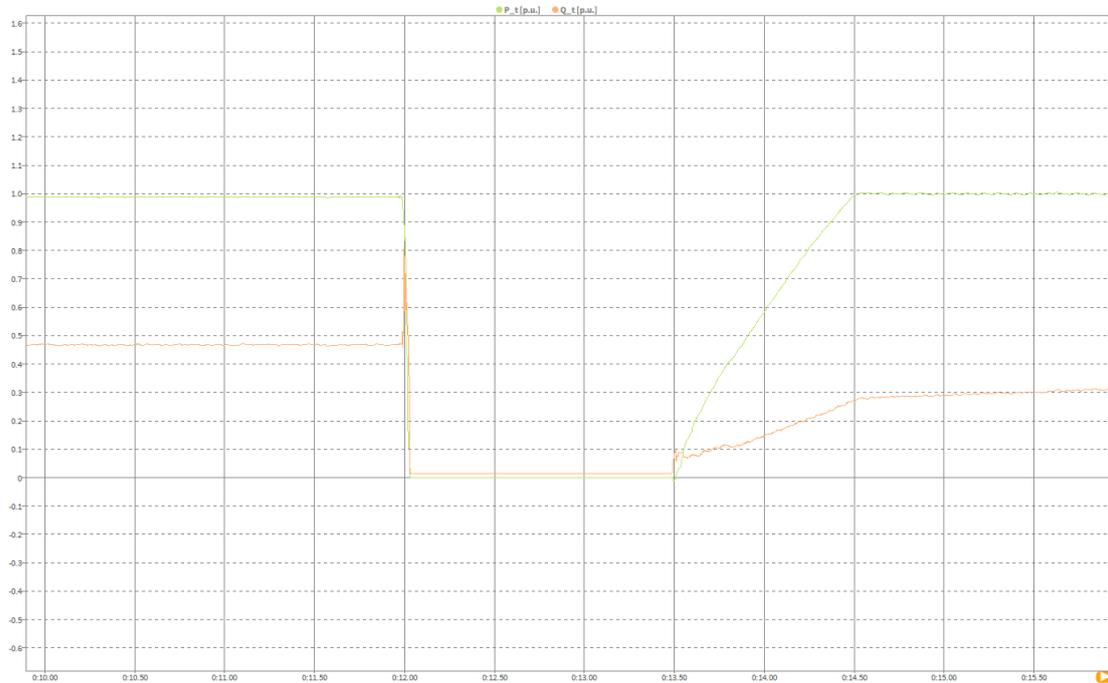
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, Qmax  
Instantaneous curve and RMS values of phase currents**



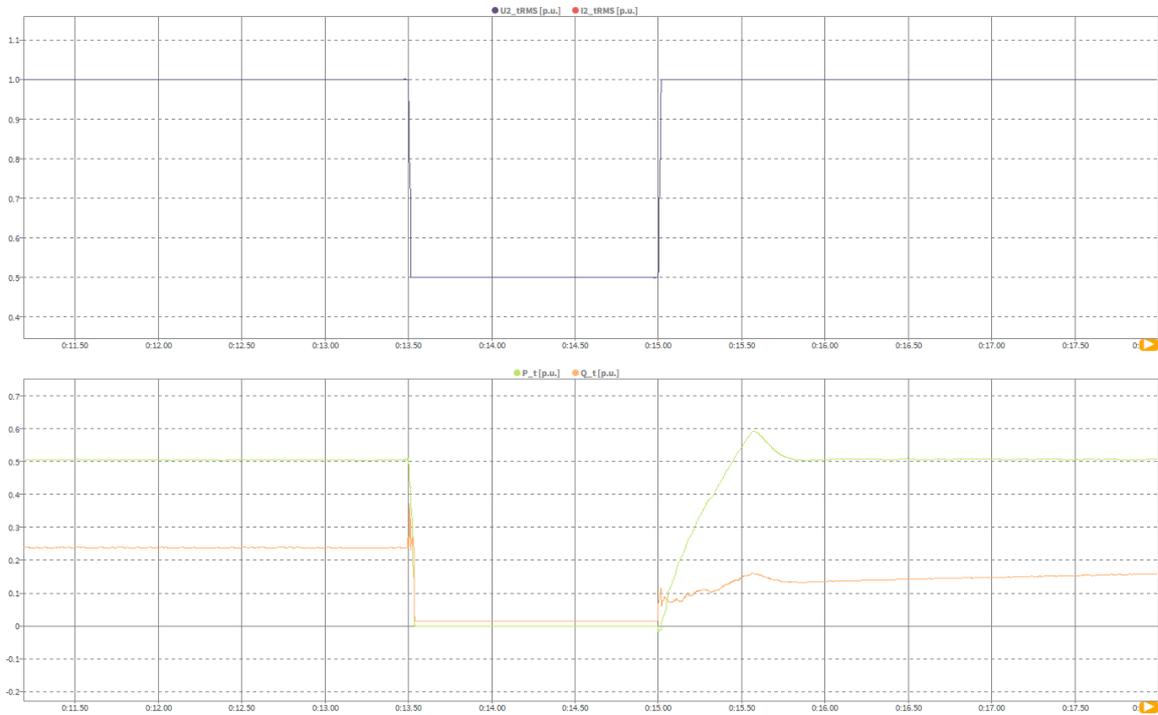
**Test 3.1 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 100% load, Qmax  
Total values of active and reactive power**



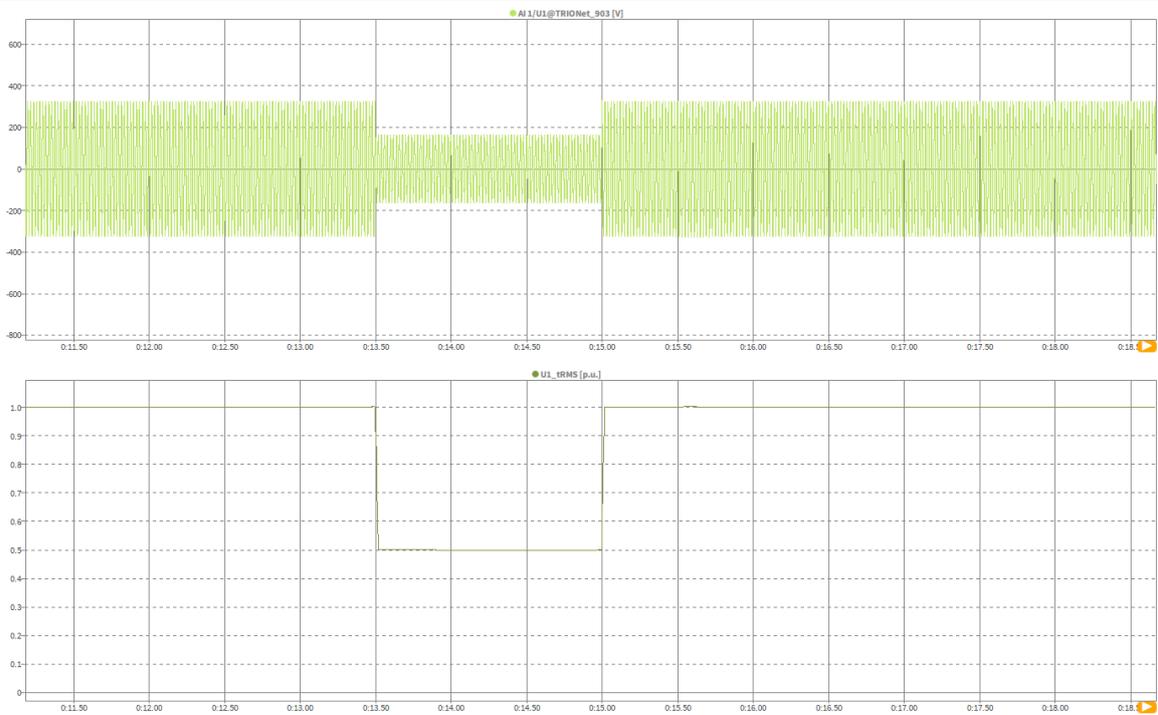
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, Qmax**  
**Test overview (voltage, current, active and reactive power)**



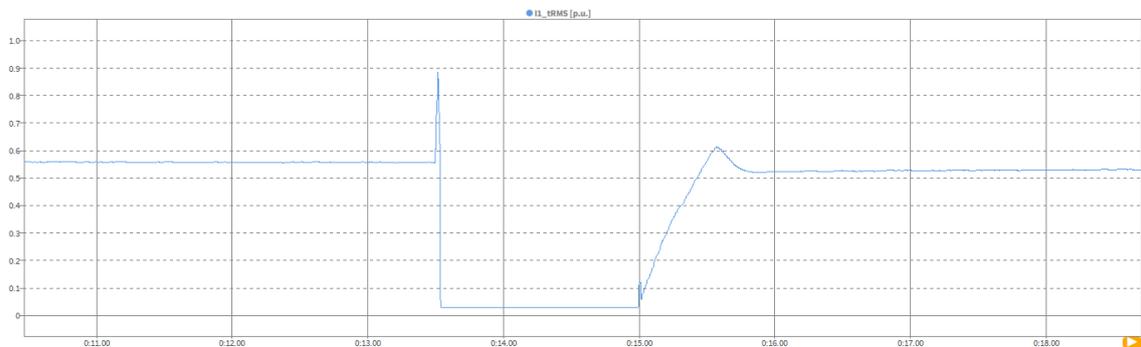
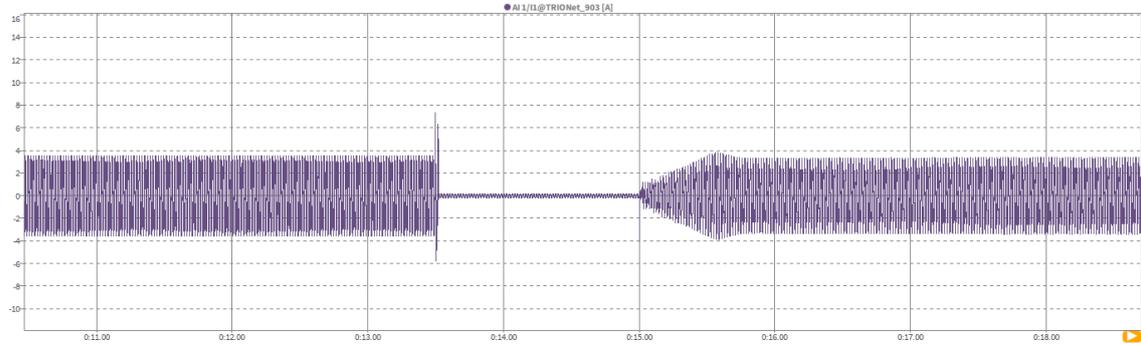
**Test 3.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, Qmax**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



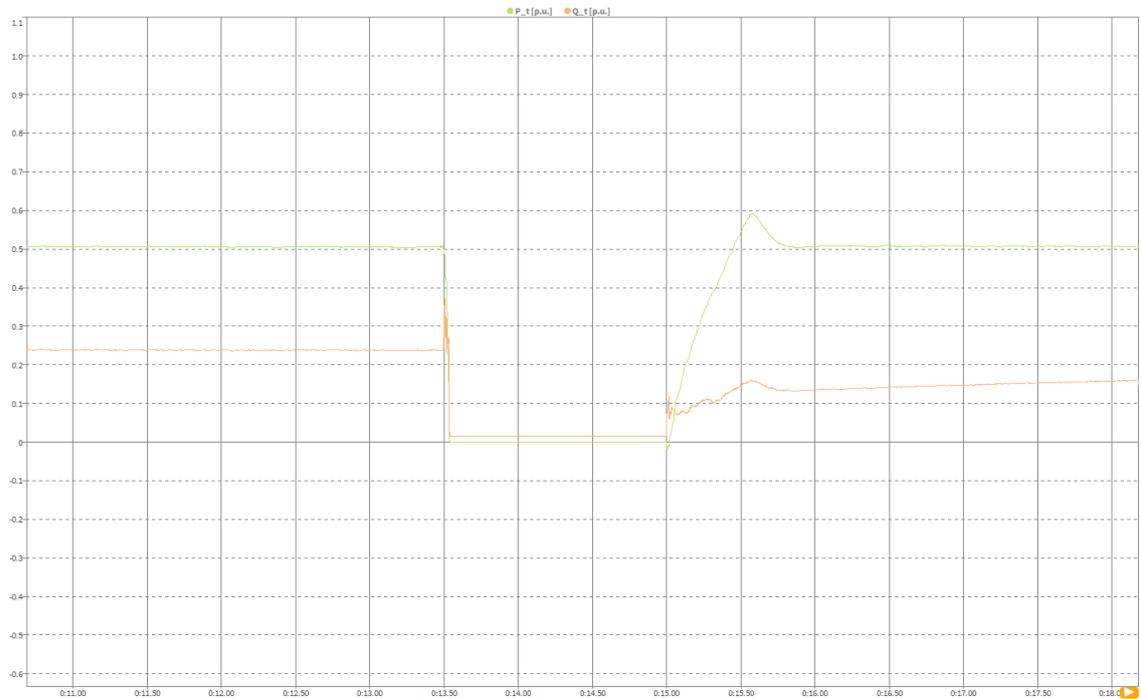
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test3.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, Qmax  
Instantaneous curve and RMS values of phase currents**



**Test 3.2 Depth of fault phase: 0.5 p.u.(U-N), balanced fault (type A), 25% load, Qmax  
Total values of active and reactive power**

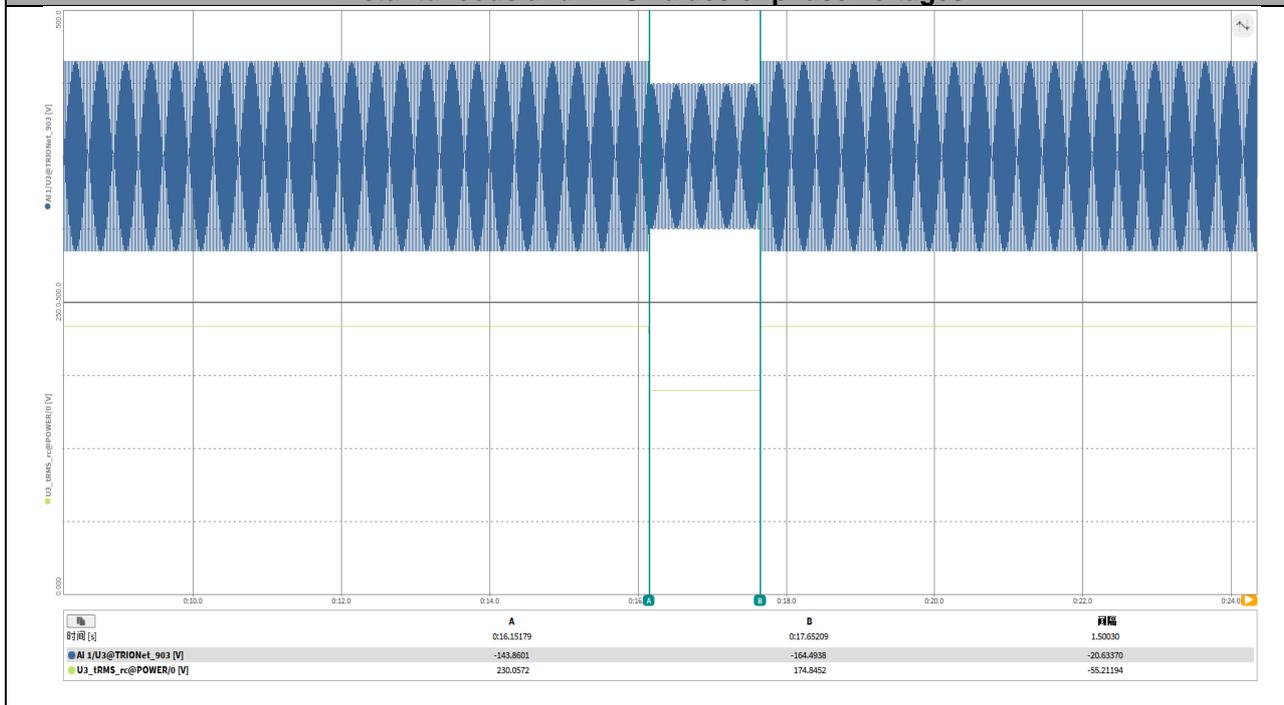


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	3.3	3.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	14:12	14:15	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.76	0.76
	5	Setting dip duration		--	--	--	1500	1500
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16151	16151
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	17652	17652
	8	Fault duration in empty load test	Total	--	--	ms	1501	1501
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.76	0.76	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	0.99	0.50	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.48	0.24	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.899	0.904		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.76	0.76	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	N/A	
	21		Phase 3			0.05	0.05	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	N/A	
	24		Phase 3			0.05	0.05	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.00	0.00	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.99	0.50	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.40	0.15	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	9.63	10.09	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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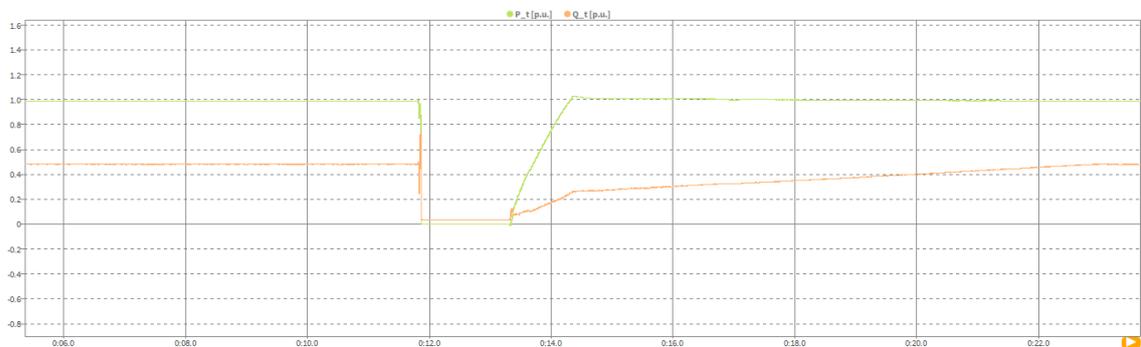
**Test 3.0.2 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



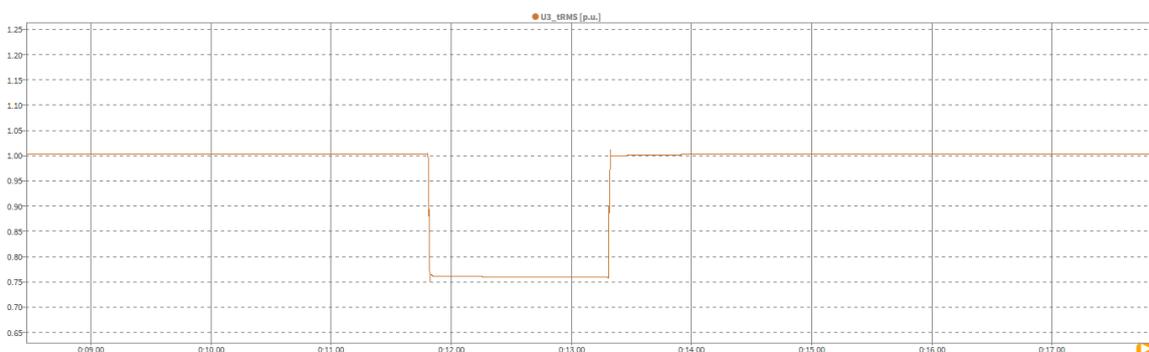
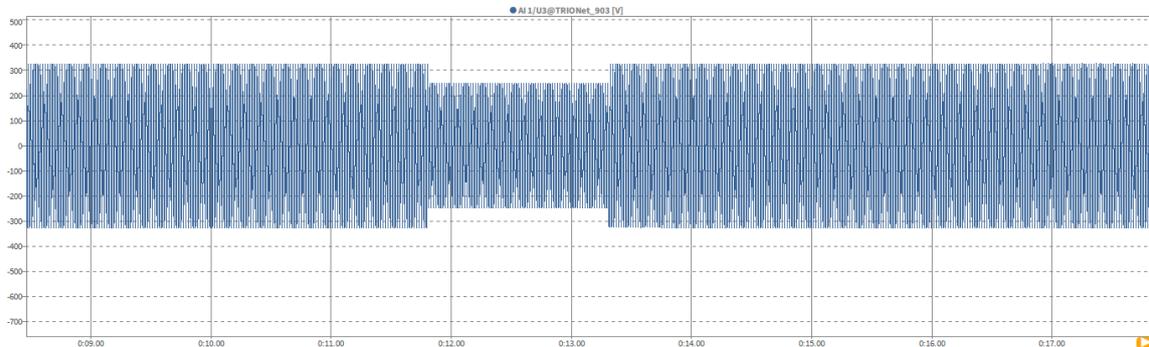
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, Qmax  
Test overview (voltage, current, active and reactive power)**



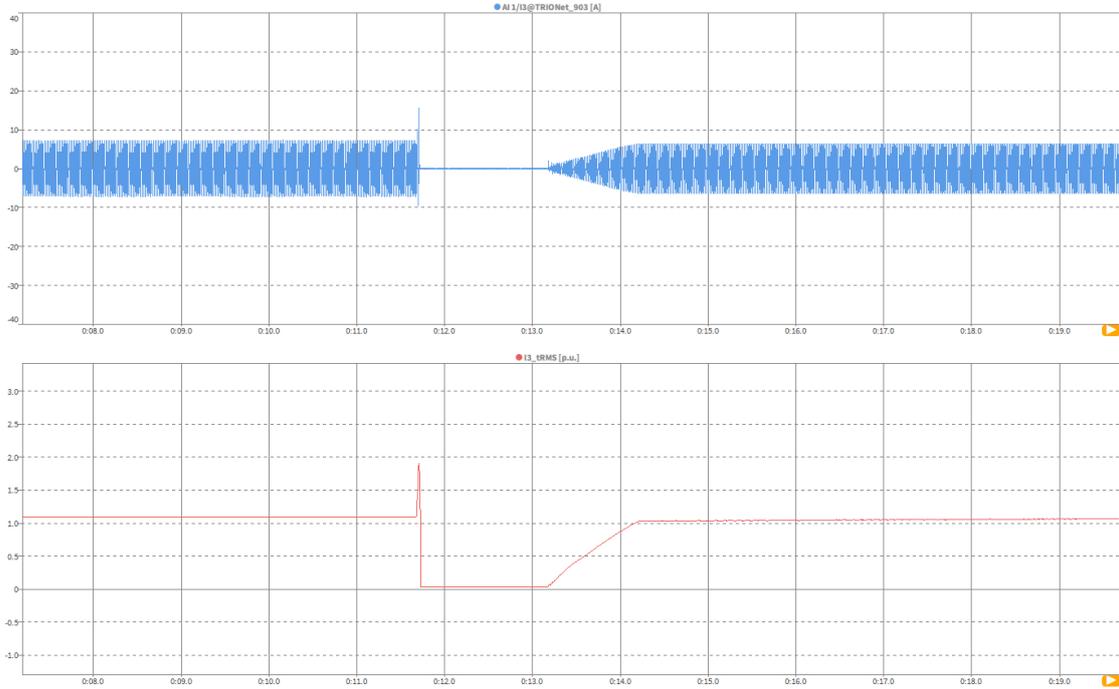
**Test 3.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, Qmax  
Instantaneous curve curve and RMS values of phase to natural voltages**



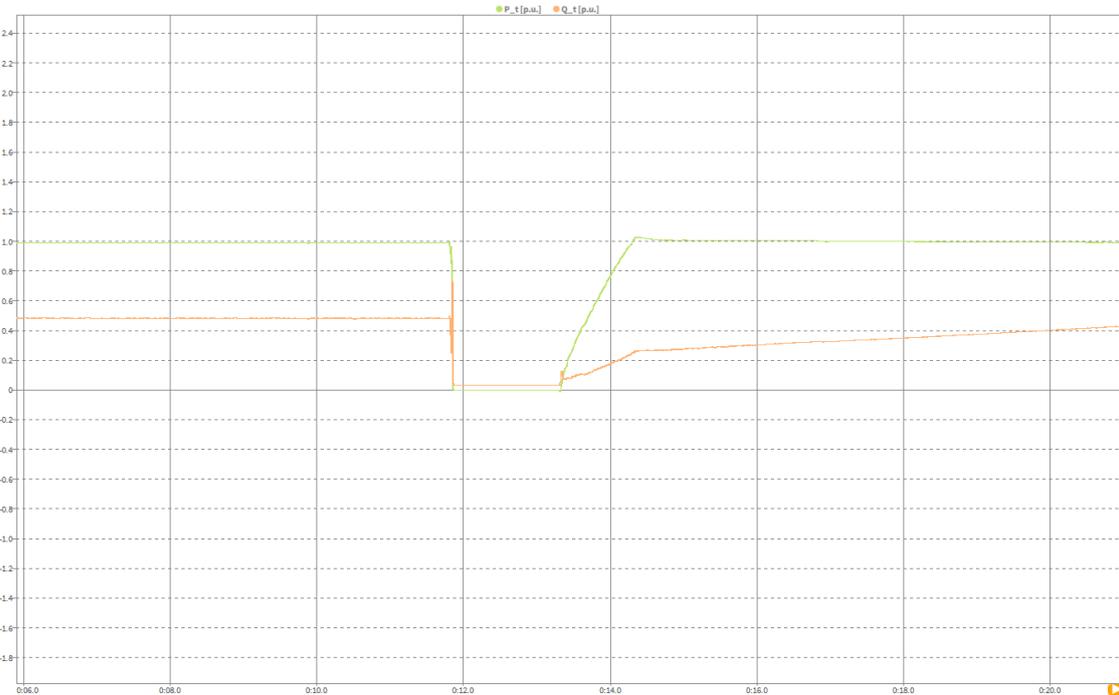
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, Qmax  
Instantaneous curve and RMS values of phase currents**



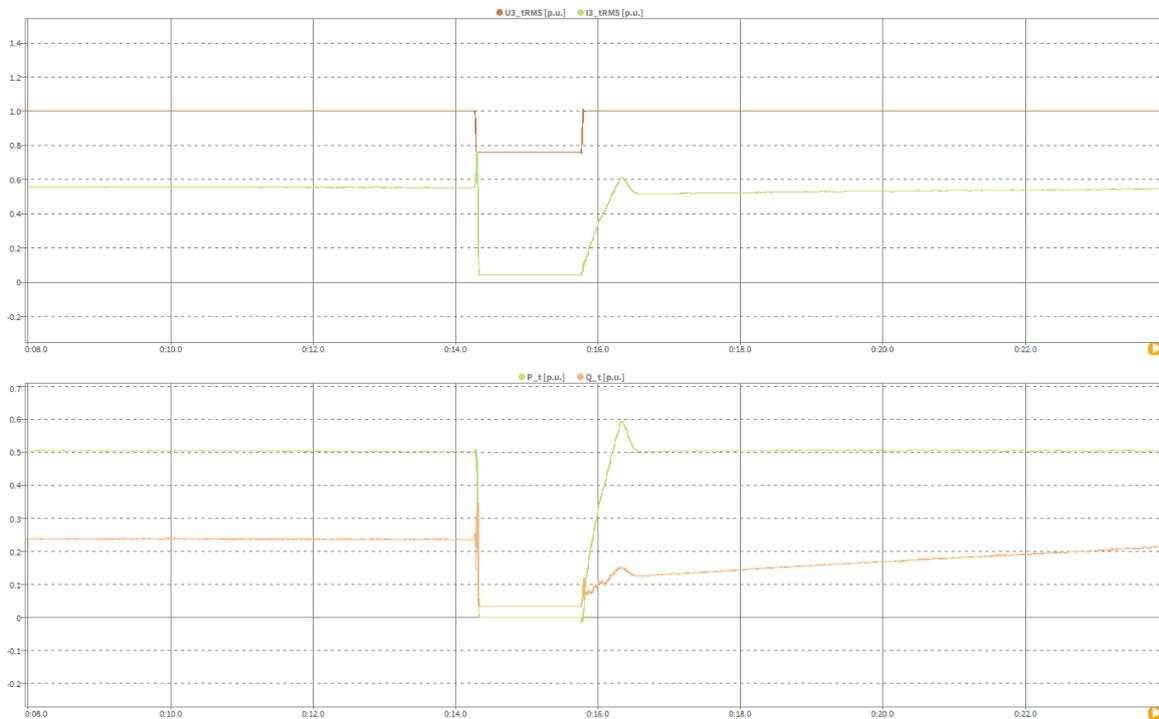
**Test 3.3 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 100% load, Qmax  
Total values of active and reactive power**



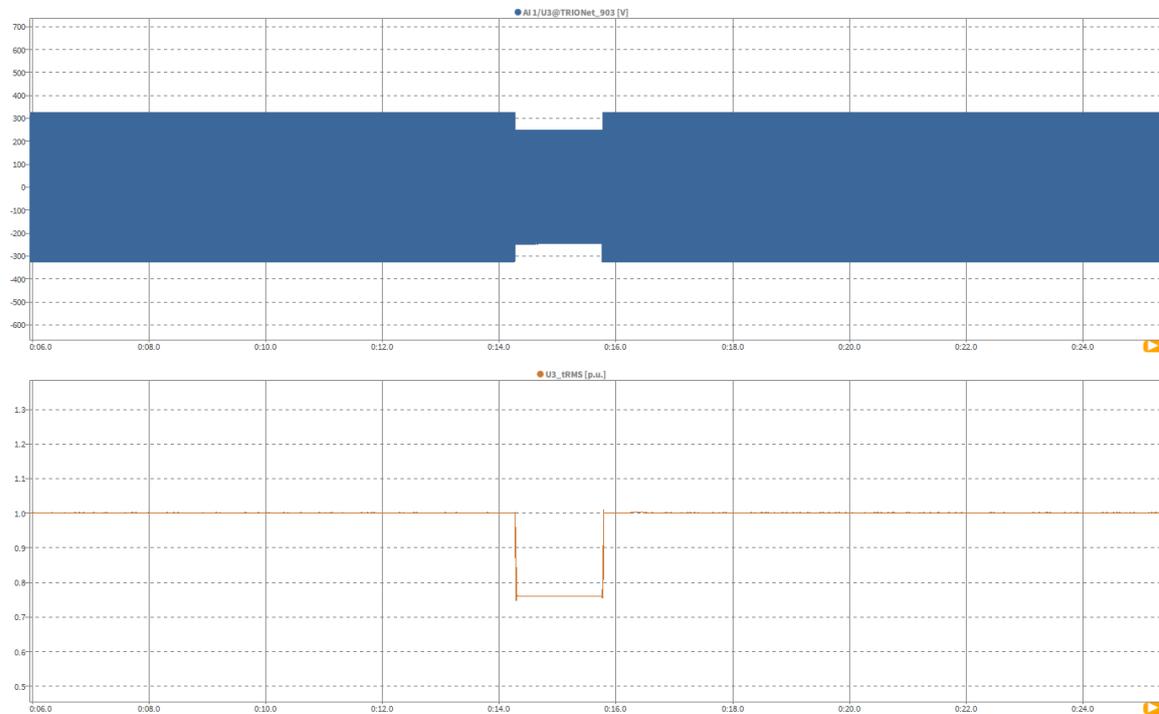
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, Qmax  
Test overview (voltage, current, active and reactive power)**



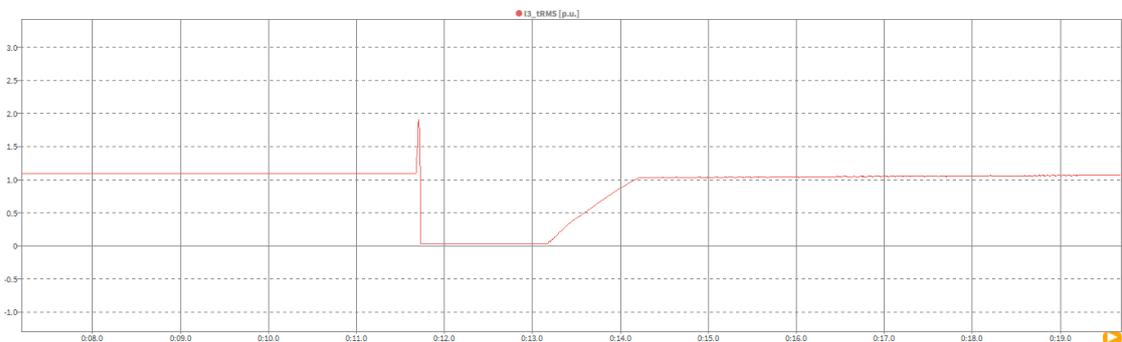
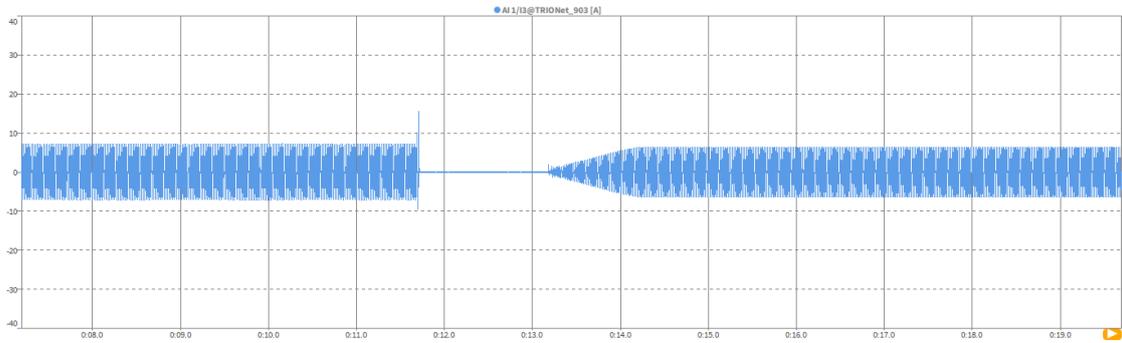
**Test 3.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, Qmax  
Instantaneous curve curve and RMS values of phase to natural voltages**



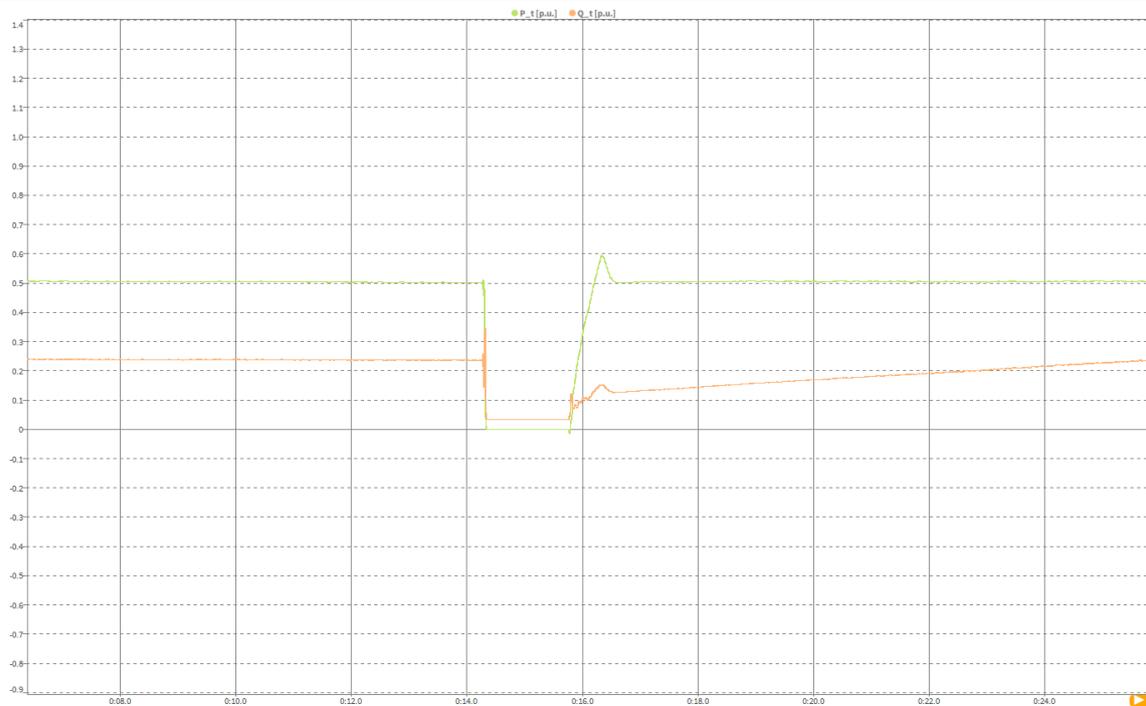
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 3.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, Qmax Instantaneous curve and RMS values of phase currents**



**Test 3.4 Depth of fault phase: 0.76 p.u.(W-N), Unbalanced fault (type D1), 25% load, Qmax Total values of active and reactive power**

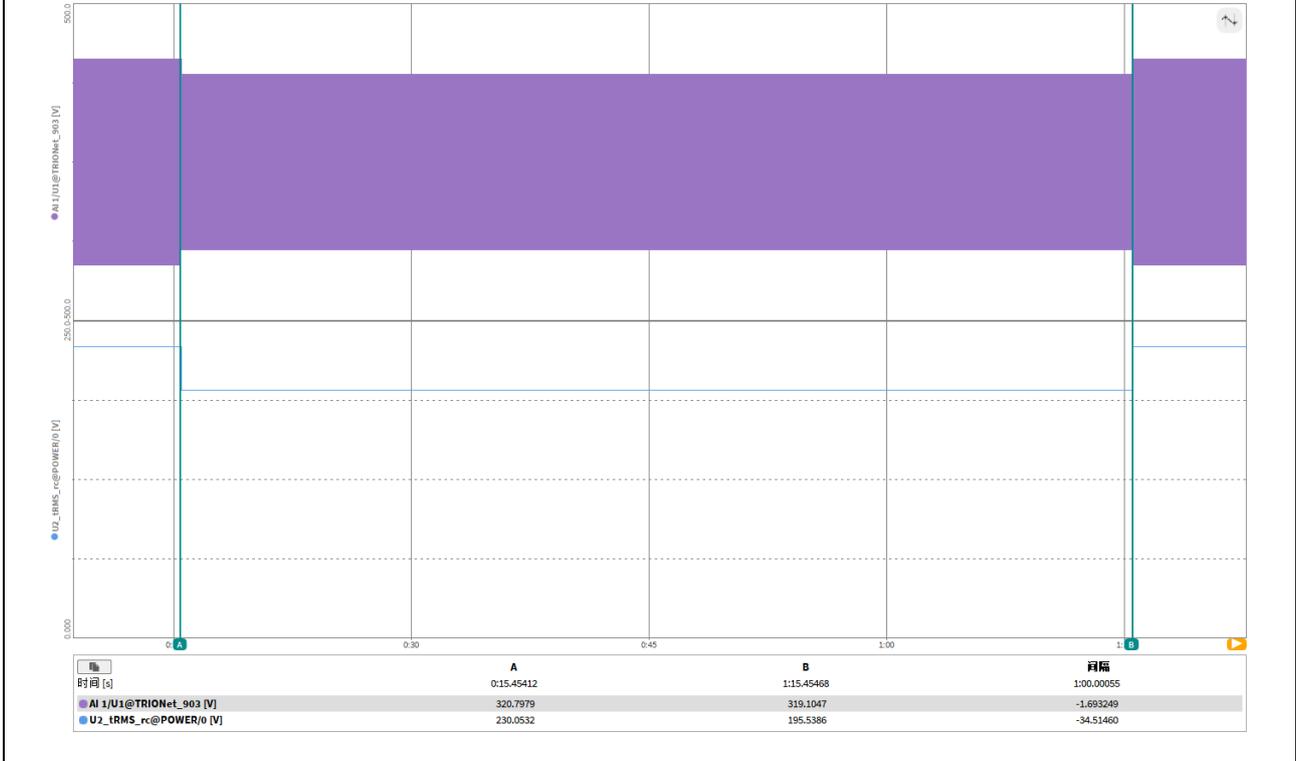


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	4.1	4.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:40	13:42	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.85	0.85
	5	Setting dip duration		--	--	--	60000	60000
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	15454	15454
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	75454	75454
	8	Fault duration in empty load test	Total	--	--	ms	60000	60000
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.85	0.85	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.52	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.09	0.07	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.996	0.991		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.85	0.85	
	19	Line current	Phase 1	t1+60ms	p.u.	1.15	0.61	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	1.16	0.60	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.97	0.50	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.99	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.09	0.07	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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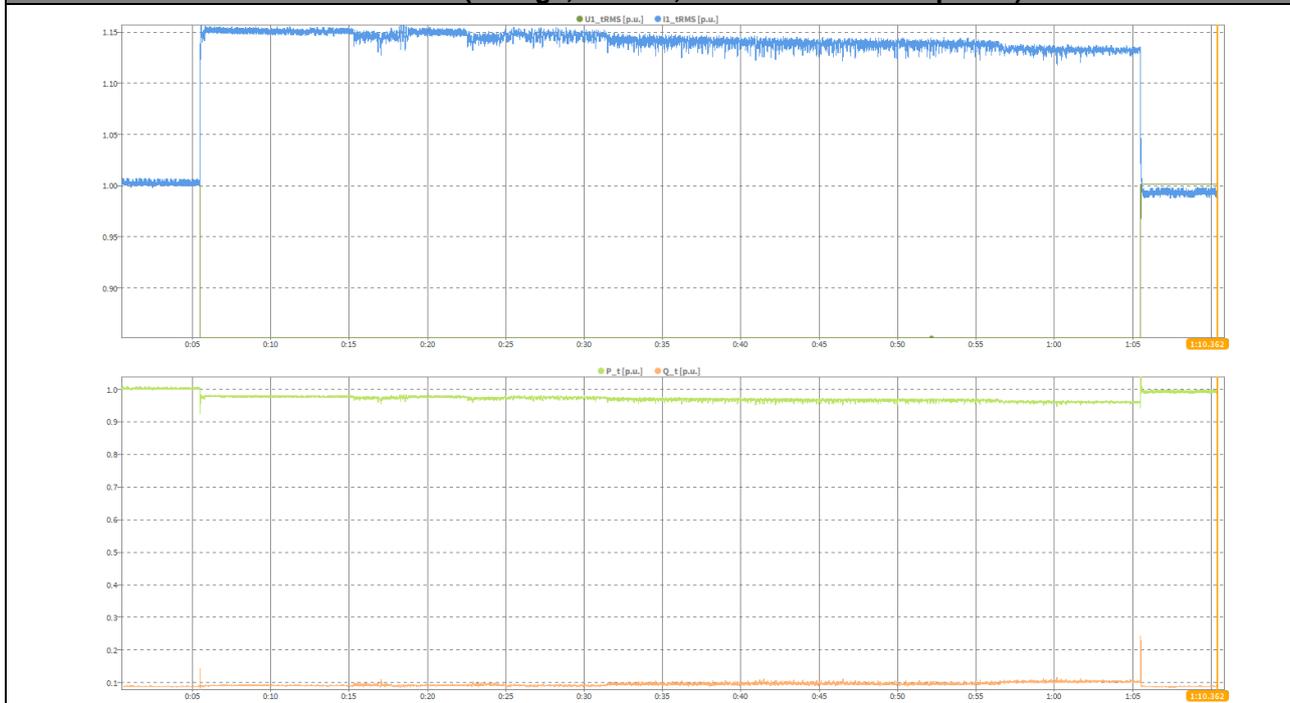
**Test 4.0.1 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



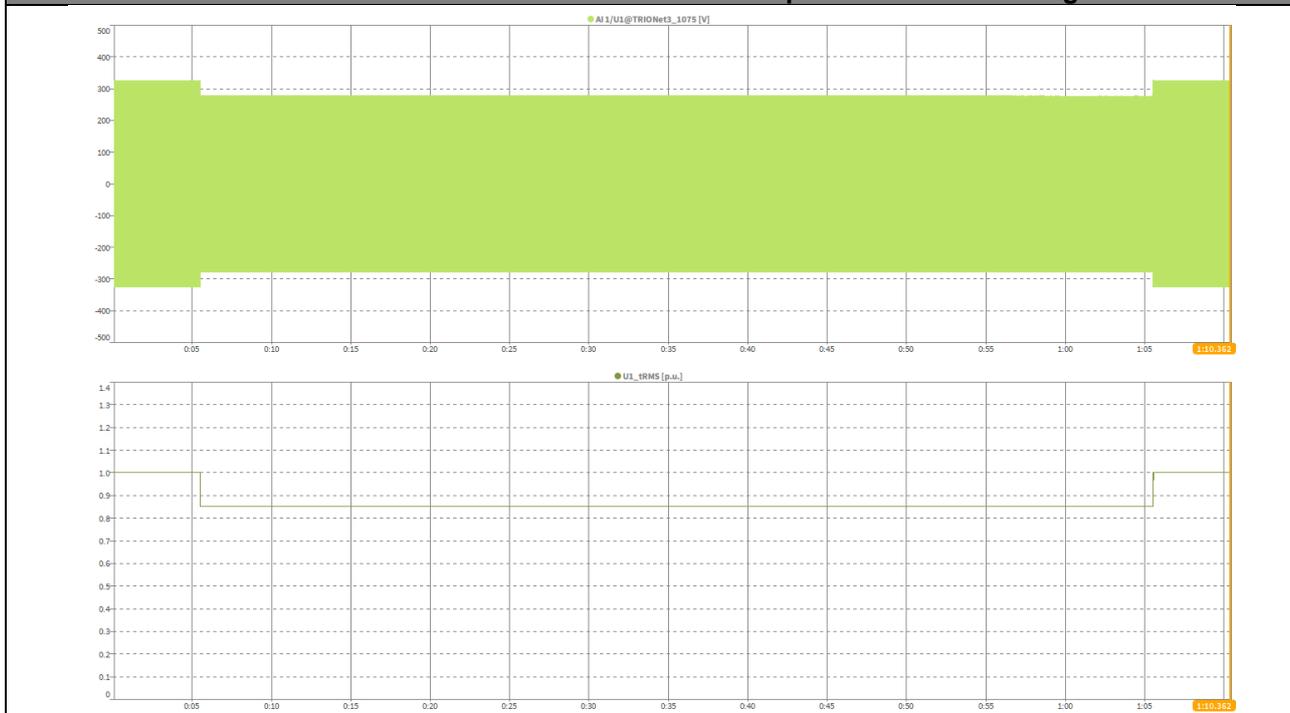
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.1 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 100% load**  
**Test overview (voltage, current, active and reactive power)**



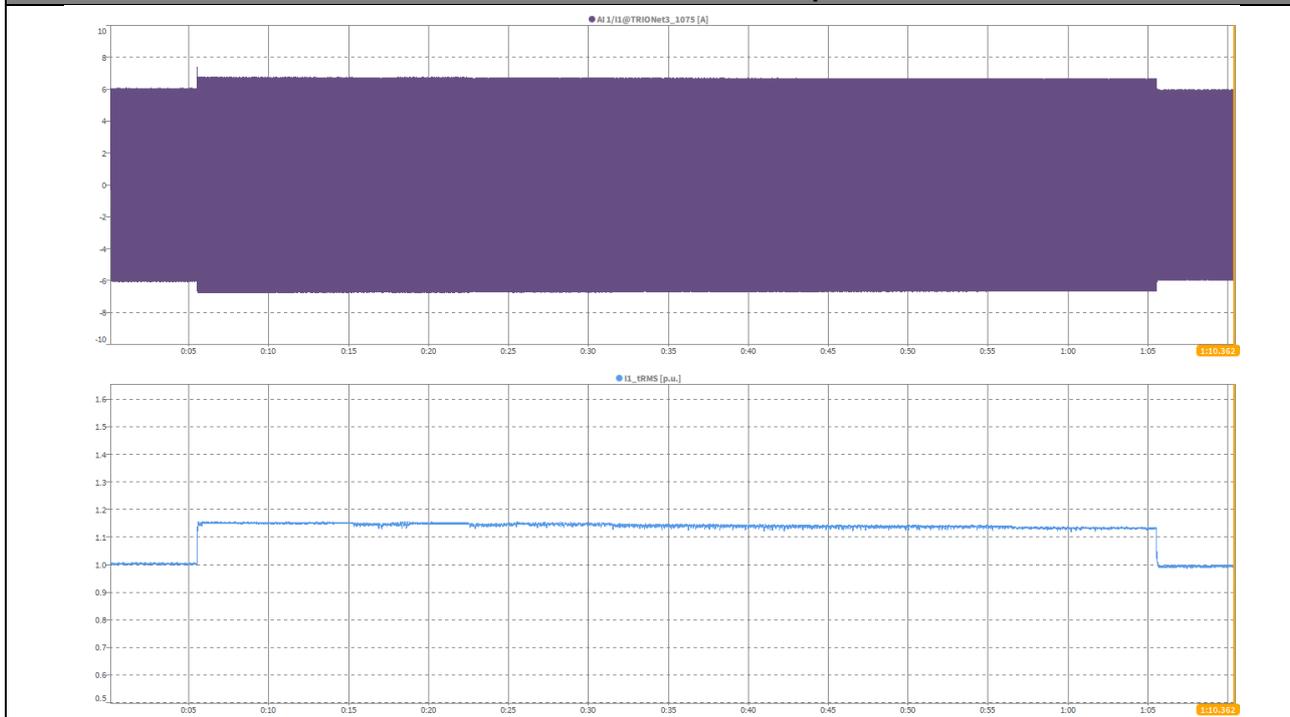
**Test 4.1 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



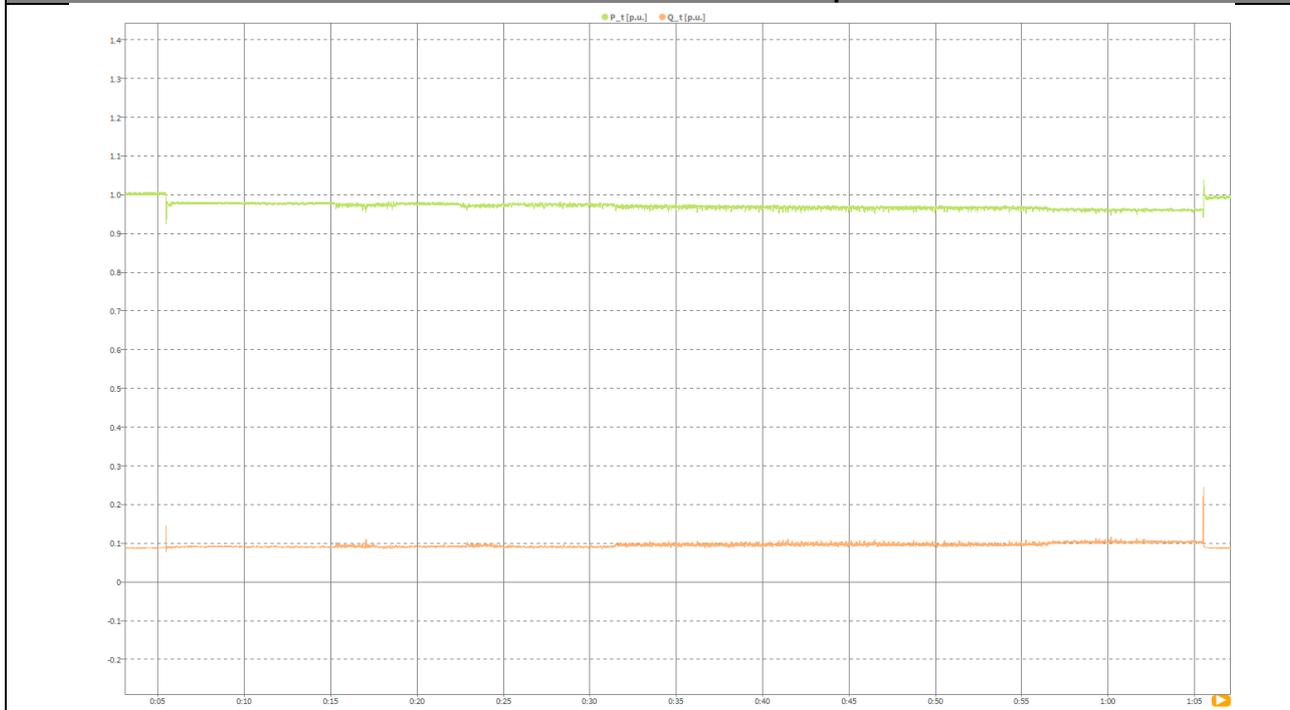
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.1 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve and RMS values of phase currents**



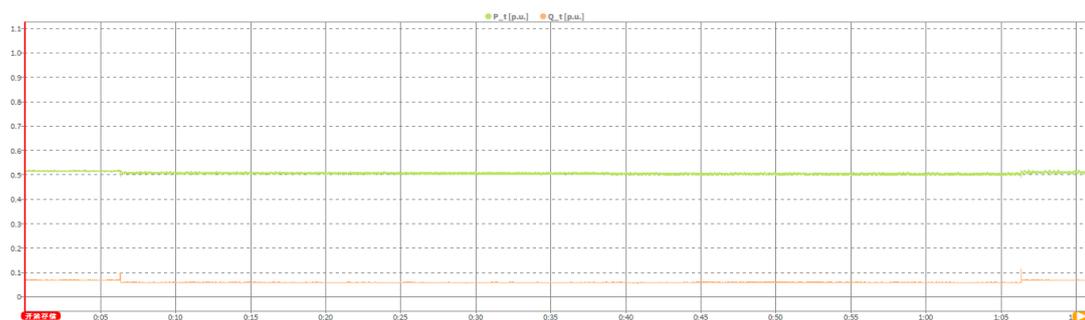
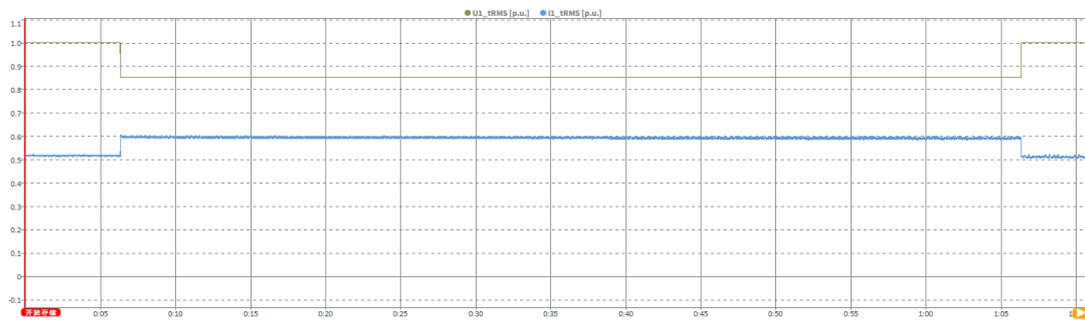
**Test 4.1 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 100% load  
Total values of active and reactive power**



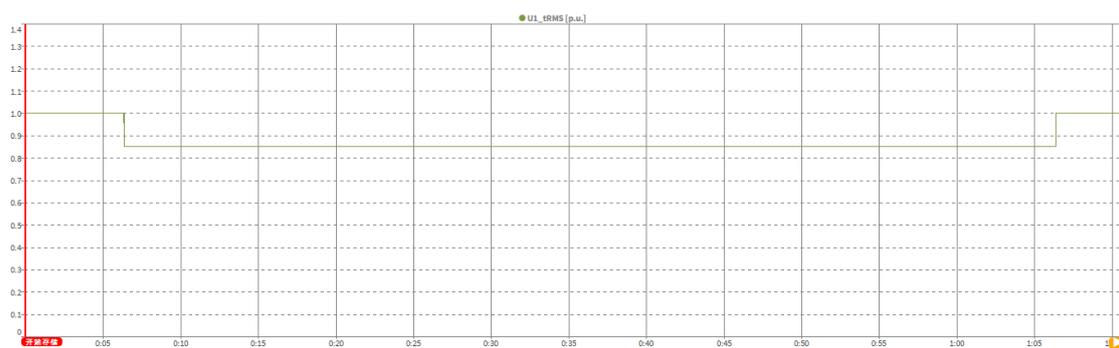
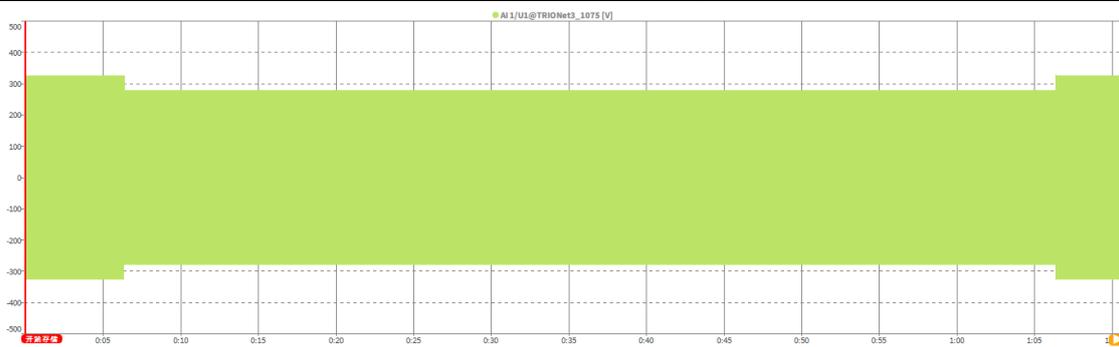
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.2 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 25% load**  
**Test overview (voltage, current, active and reactive power)**



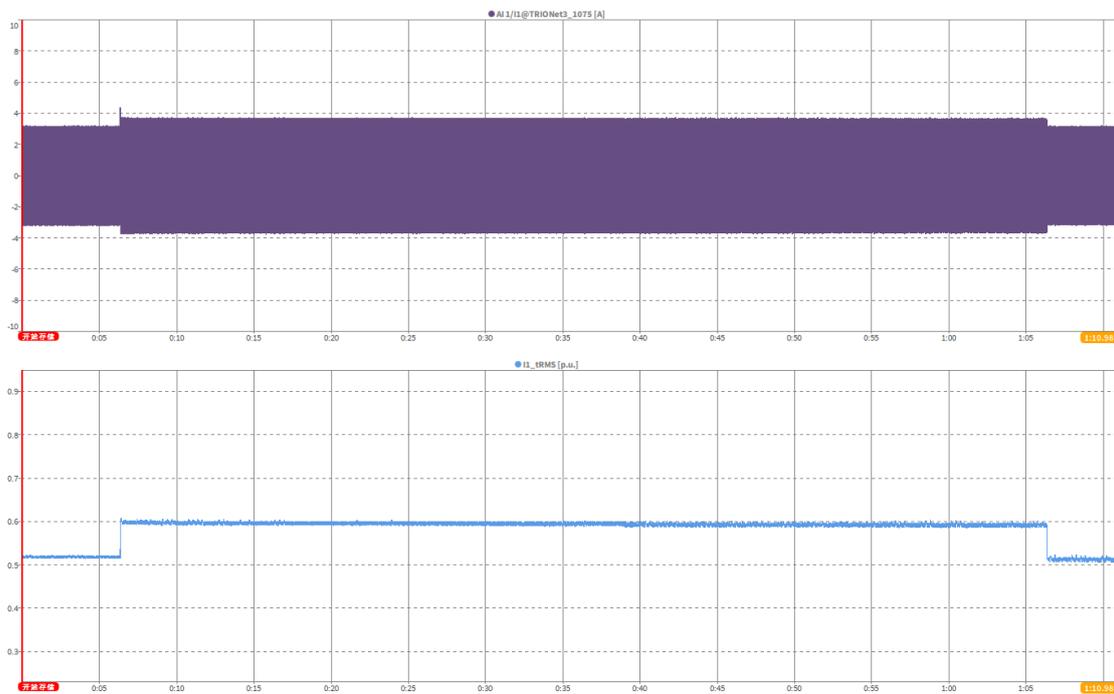
**Test 4.2 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



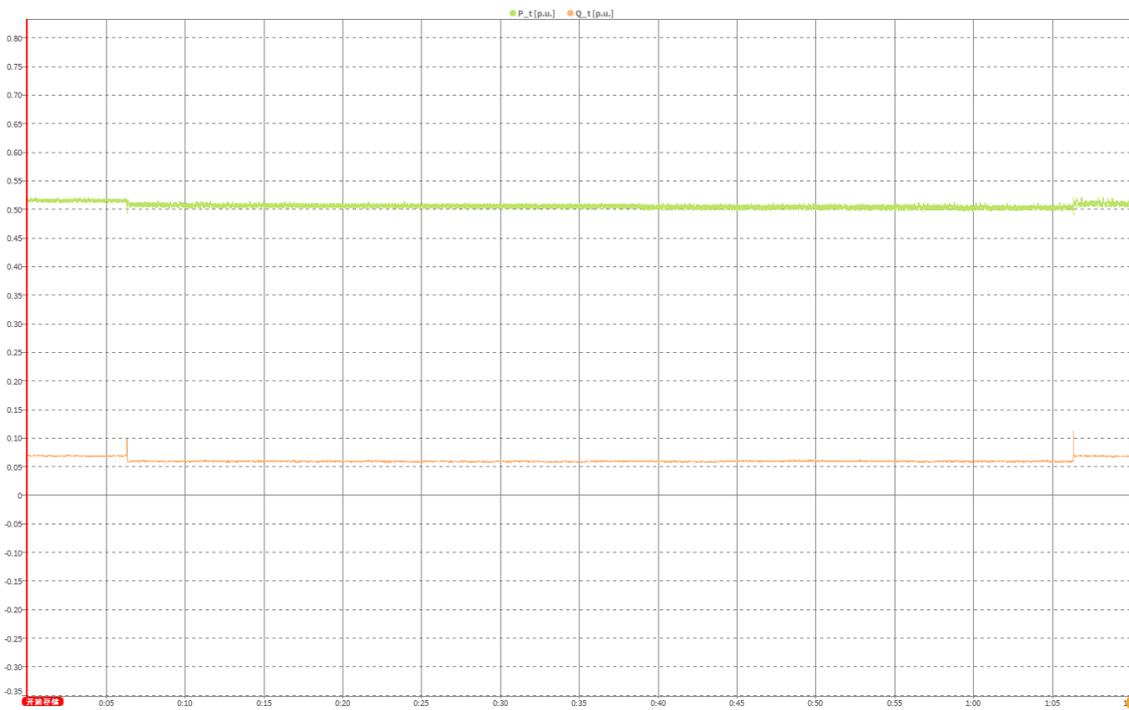
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.2 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 25% load**  
**Instantaneous curve and RMS values of phase currents**



**Test 4.2 Depth of fault phase: 0.85 p.u.(U-N), balanced fault (type A), 25% load**  
**Total values of active and reactive power**

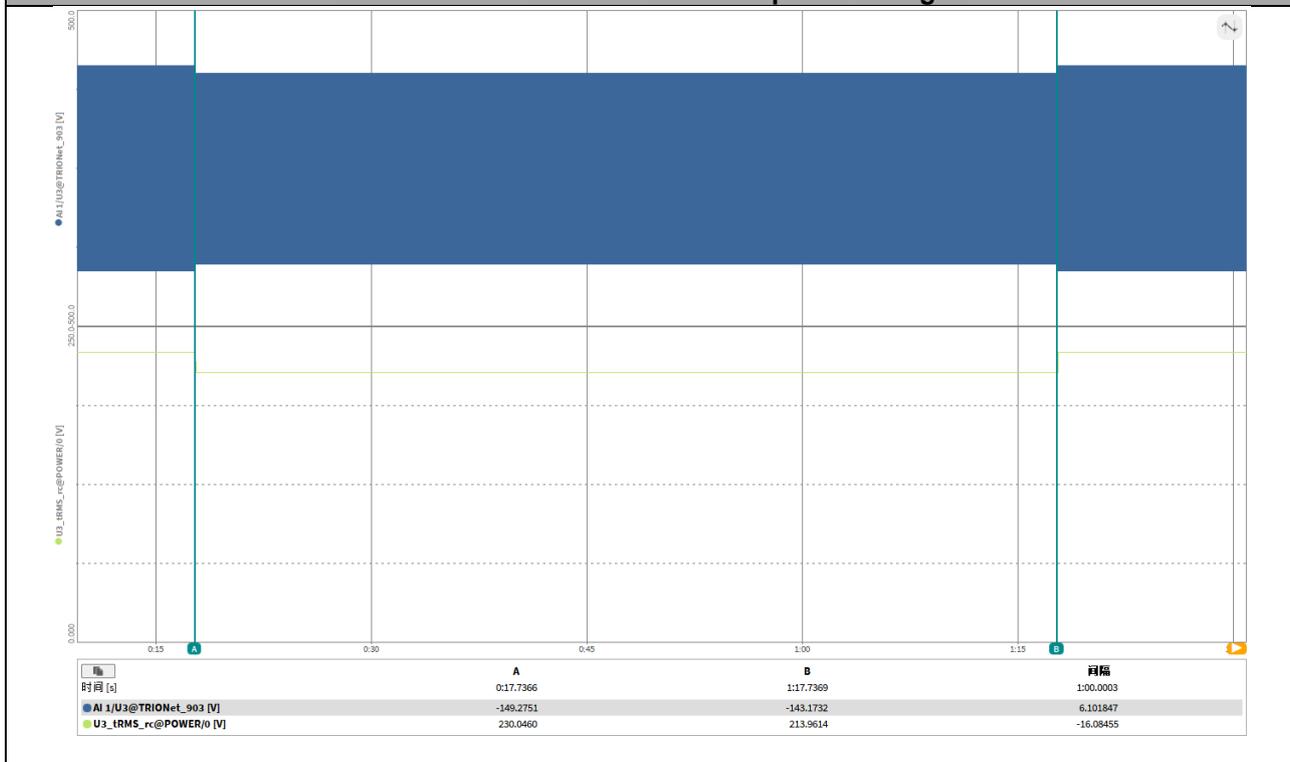


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	4.3	4.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	21:16	21:09	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	0.93	0.93
	5	Setting dip duration		--	--	--	60000	60000
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	17736	17736
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	67736	67736
	8	Fault duration in empty load test	Total	--	--	ms	60000	60000
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.93	0.93	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.06	0.05	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.998	0.995		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.93	0.93	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	N/A	
	21		Phase 3			1.09	0.56	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	N/A	
	24		Phase 3			1.08	0.56	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	1.00	0.51	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.06	0.05	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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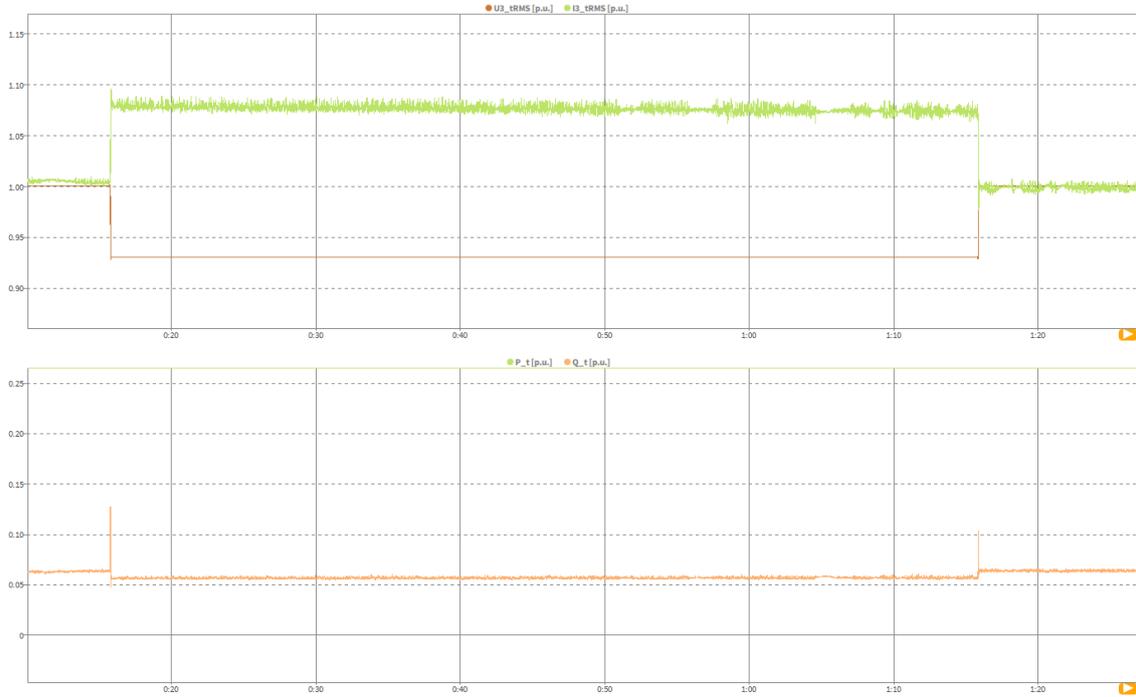
**Test 4.0.2 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



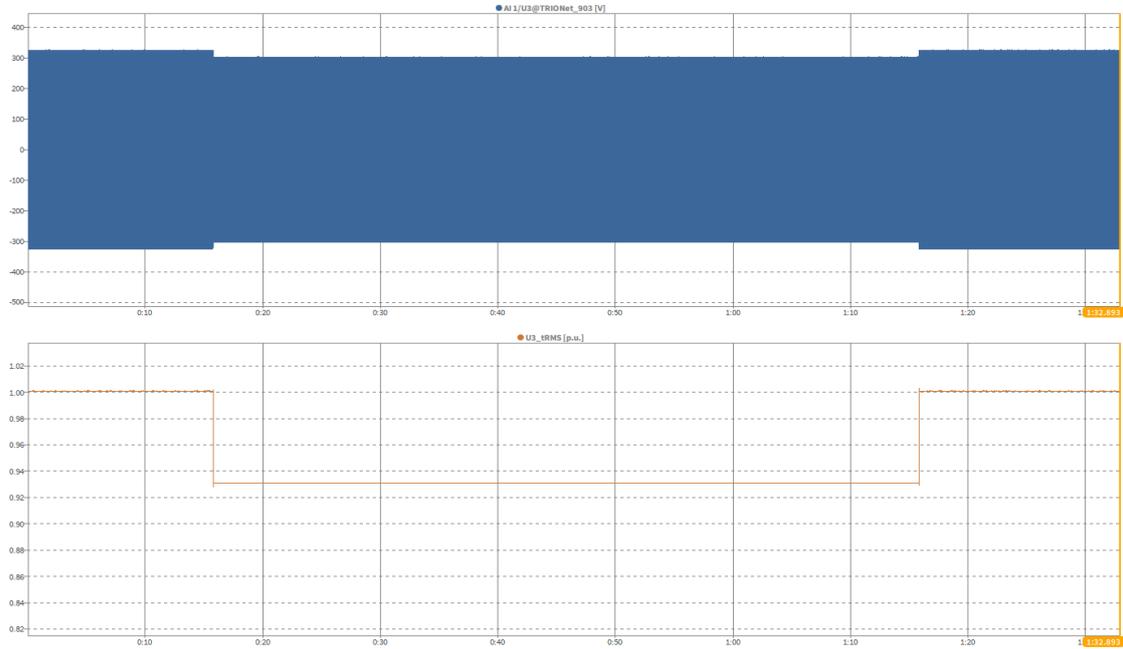
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.3 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 100% load**  
**Test overview (voltage, current, active and reactive power)**



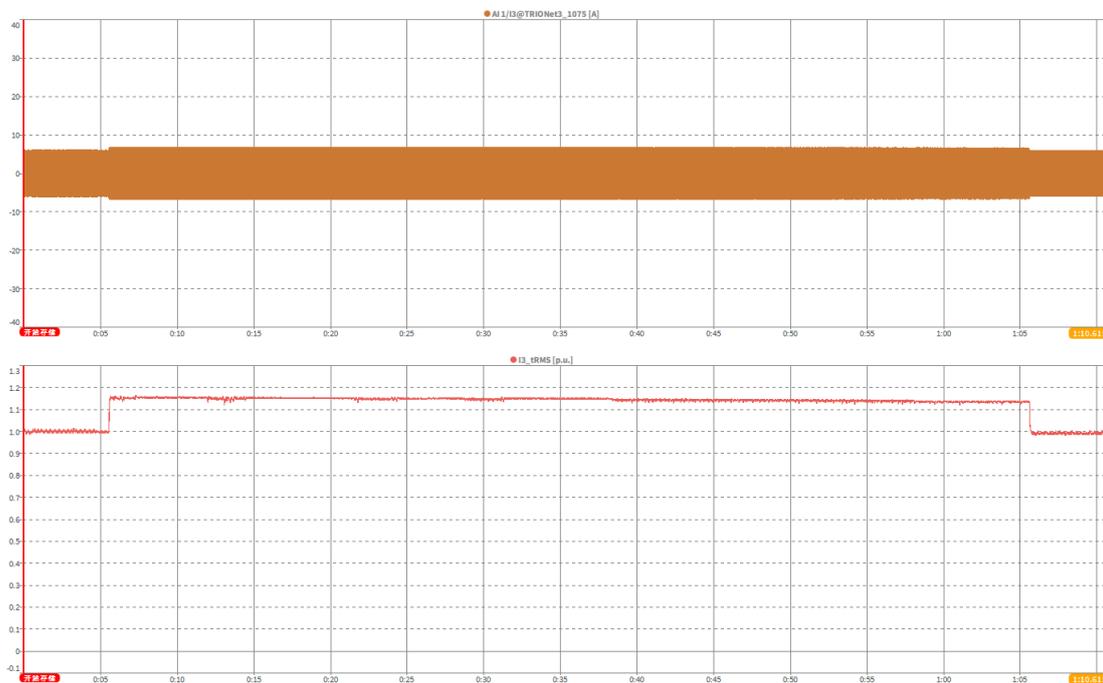
**Test 4.3 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



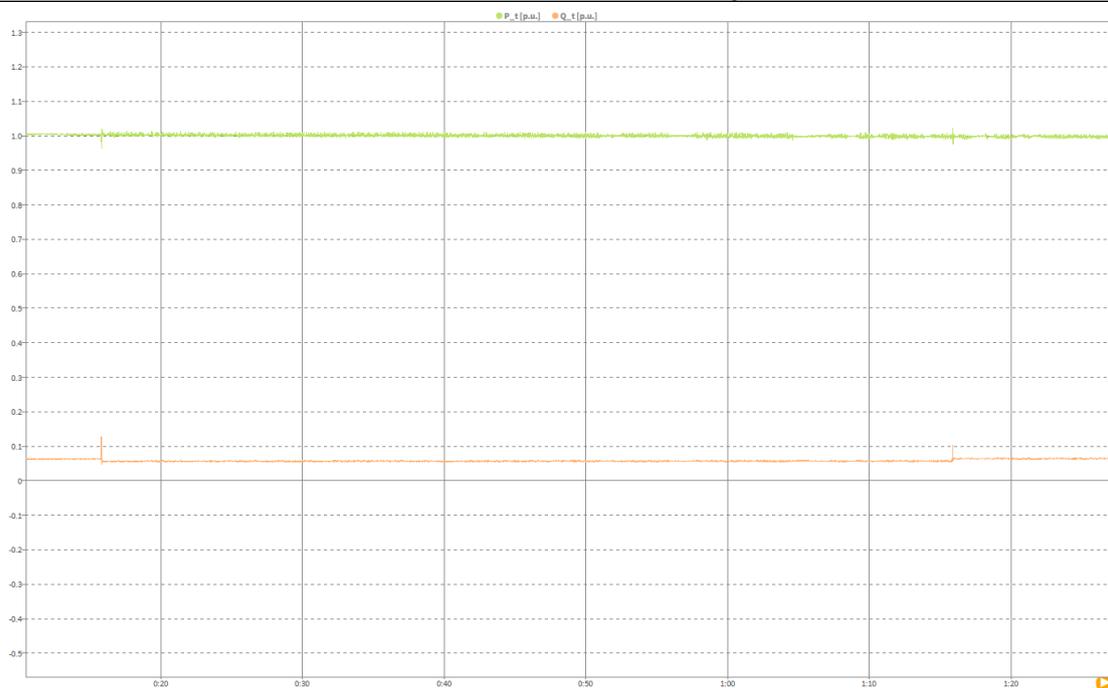
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.3 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve and RMS values of phase currents**



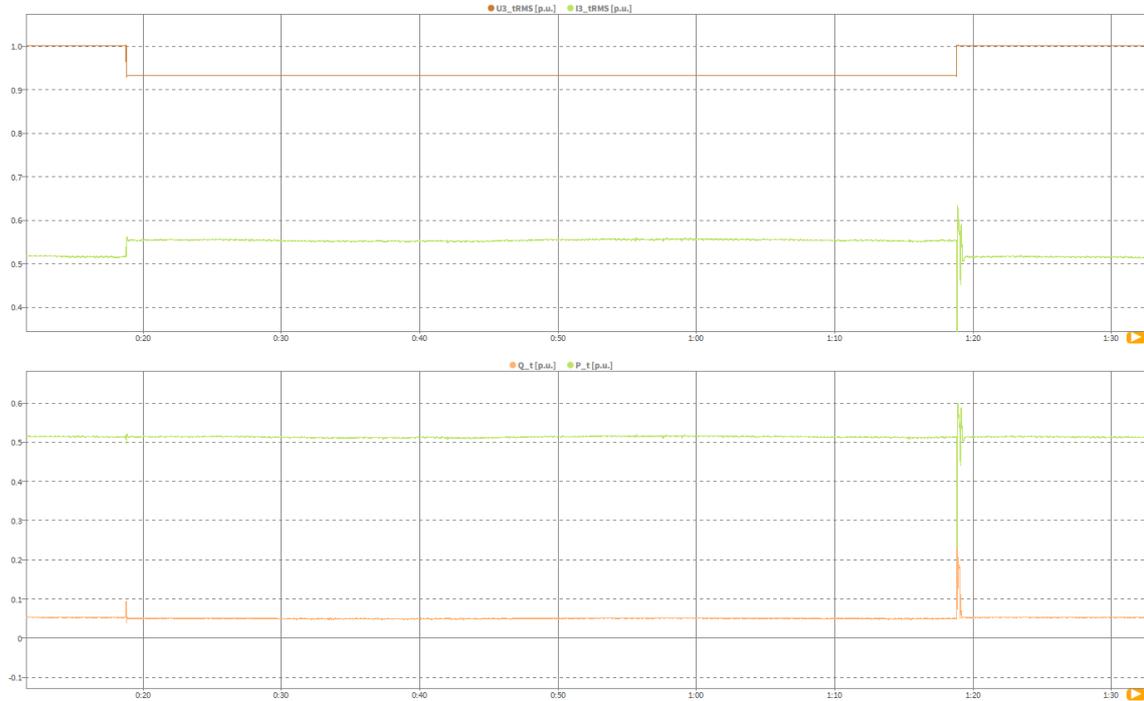
**Test 4.3 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Total values of active and reactive power**



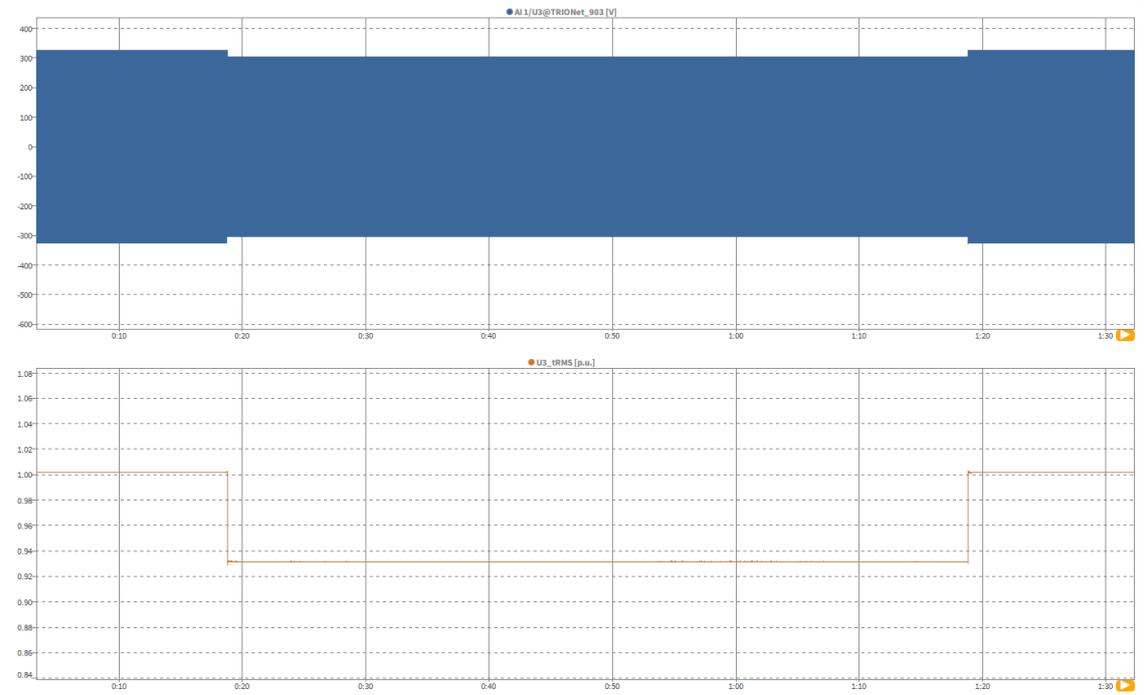
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.4 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Test overview (voltage, current, active and reactive power)**



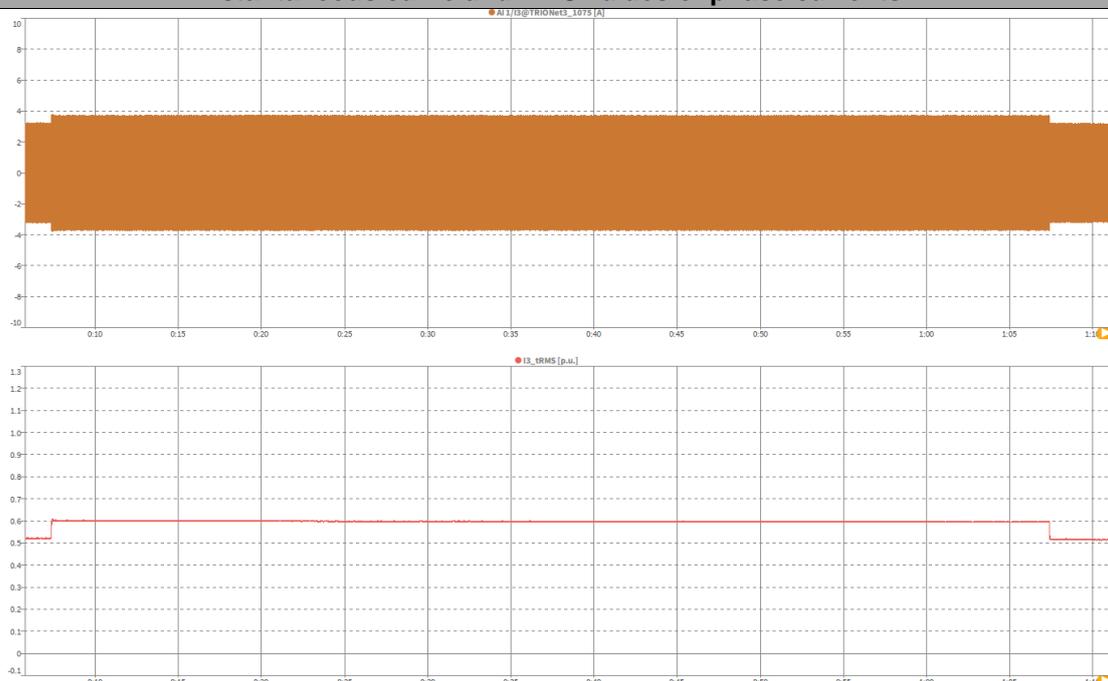
**Test 4.4 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



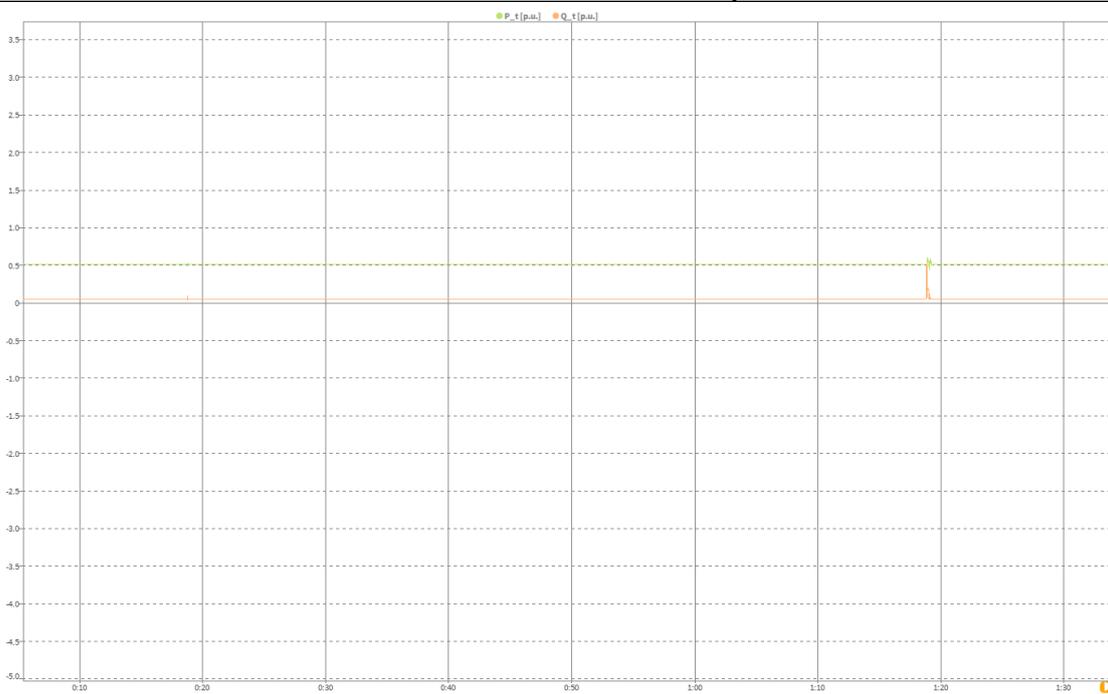
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 4.4 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 4.4 Depth of fault phase: 0.93 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Total values of active and reactive power**

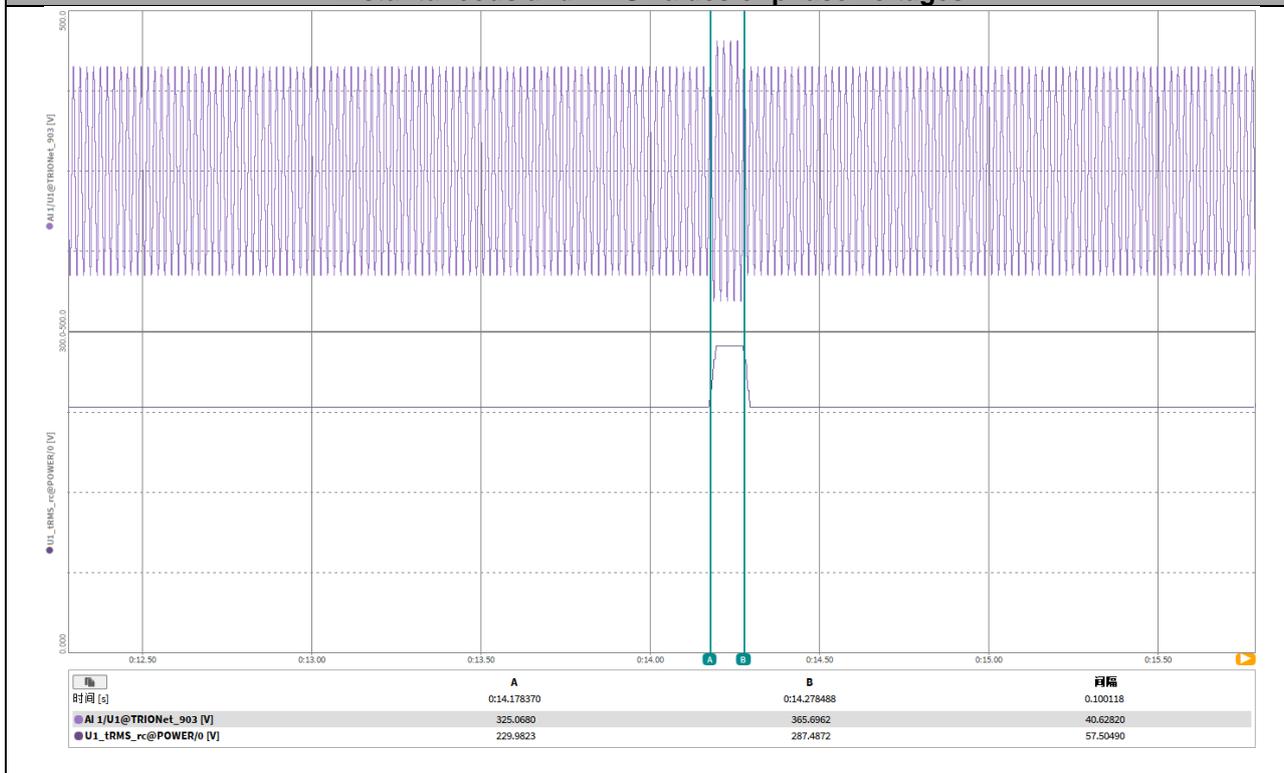


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	5.1	5.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:26	13:48	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.25	1.25
	5	Setting dip duration		--	--	--	100	100
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	14178	14178
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	14278	14278
	8	Fault duration in empty load test	Total	--	--	ms	100	100
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.25	1.25	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.09	0.07	
	16		Pos.			N/A	N/A	
17	Cosp	--	t1-10s to t1	--	0.996	0.991		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.25	1.25	
	19	Line current	Phase 1	t1+60ms	p.u.	0.07	0.07	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.07	0.07	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.01	0.01	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.94	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.08	0.07	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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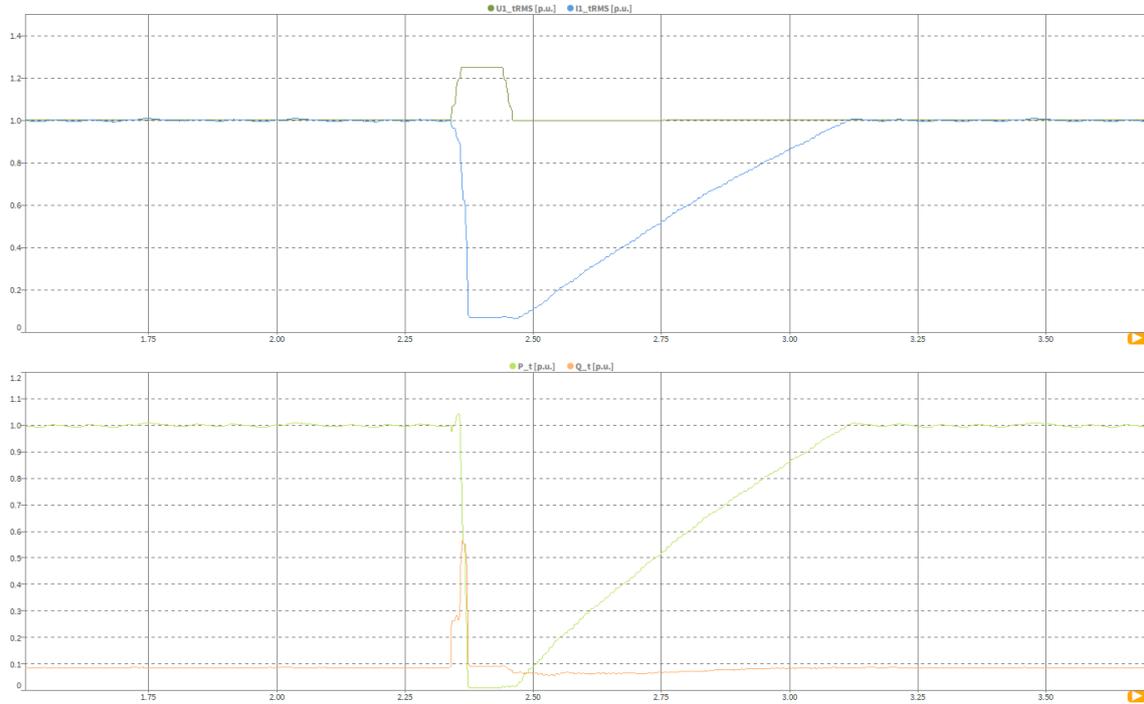
**Test 5.0.1 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



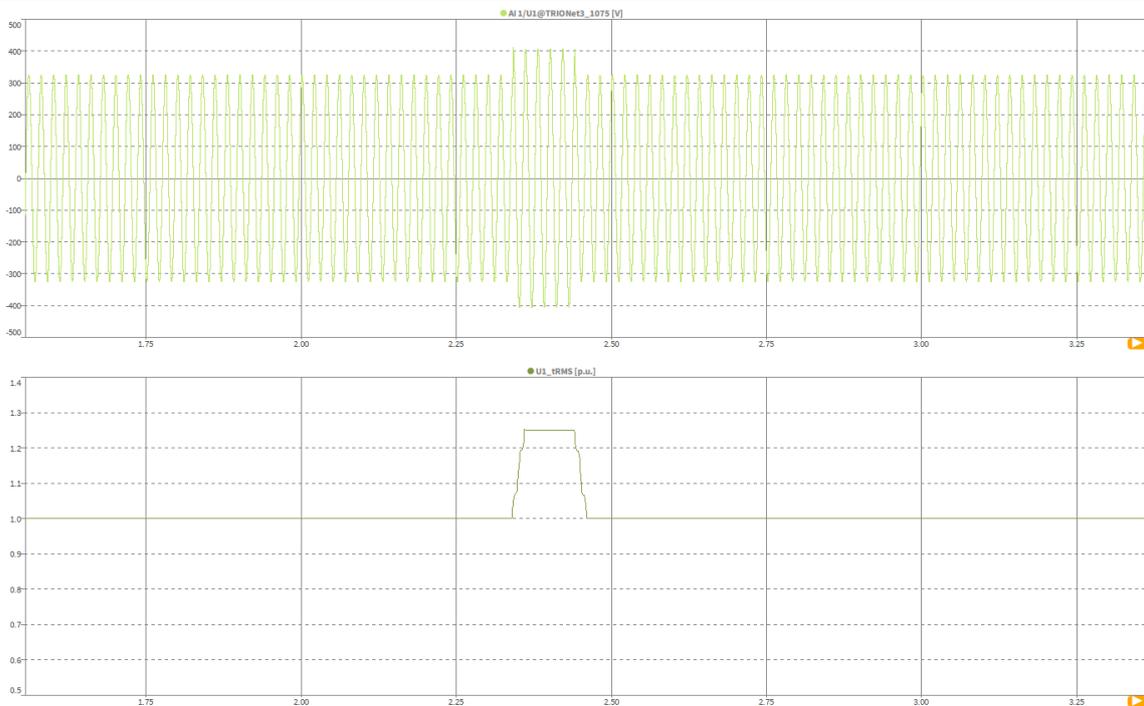
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.1 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 100% load  
Test overview (voltage, current, active and reactive power)**



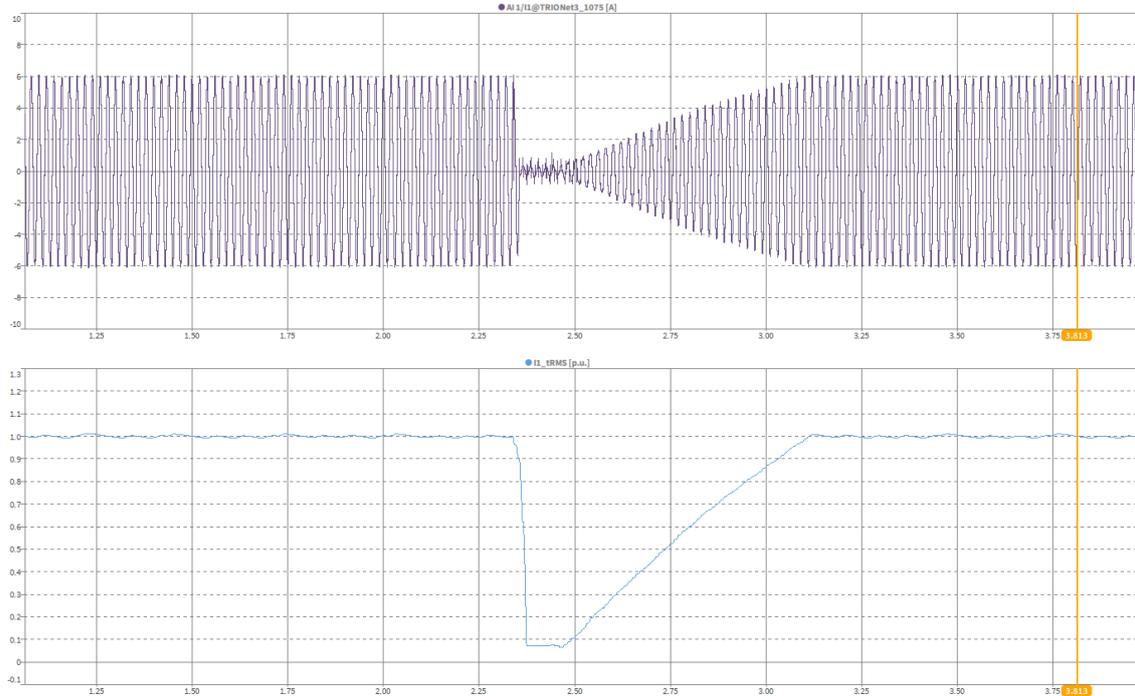
**Test 5.1 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve curve and RMS values of phase to natural voltages**



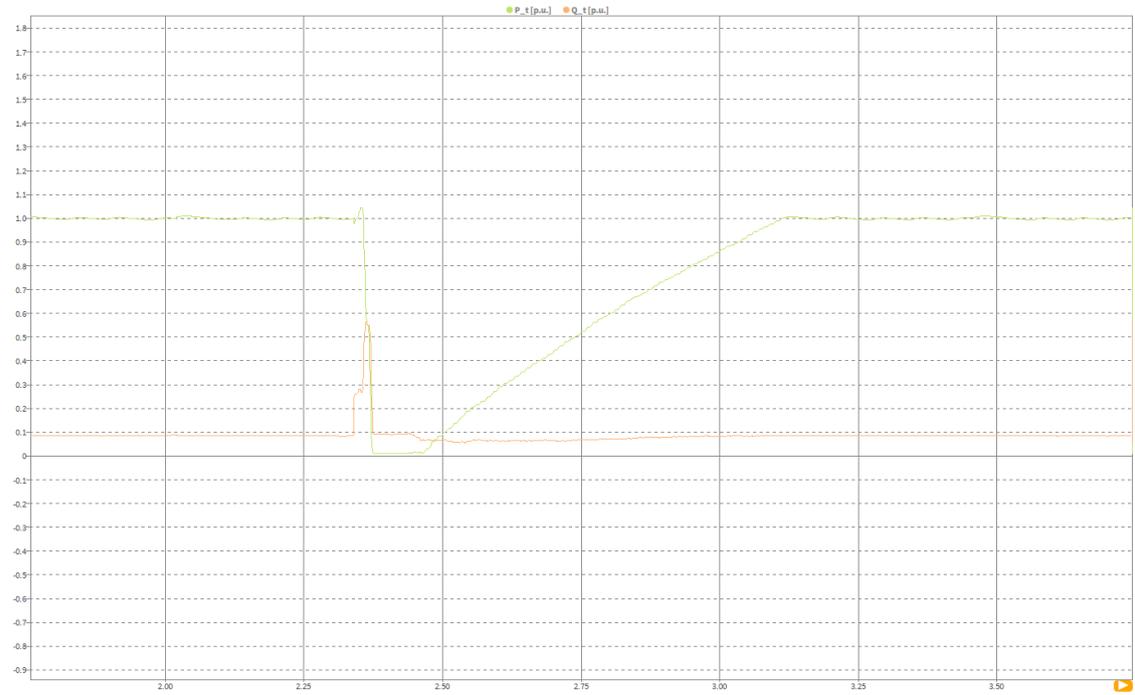
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.1 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve and RMS values of phase currents**



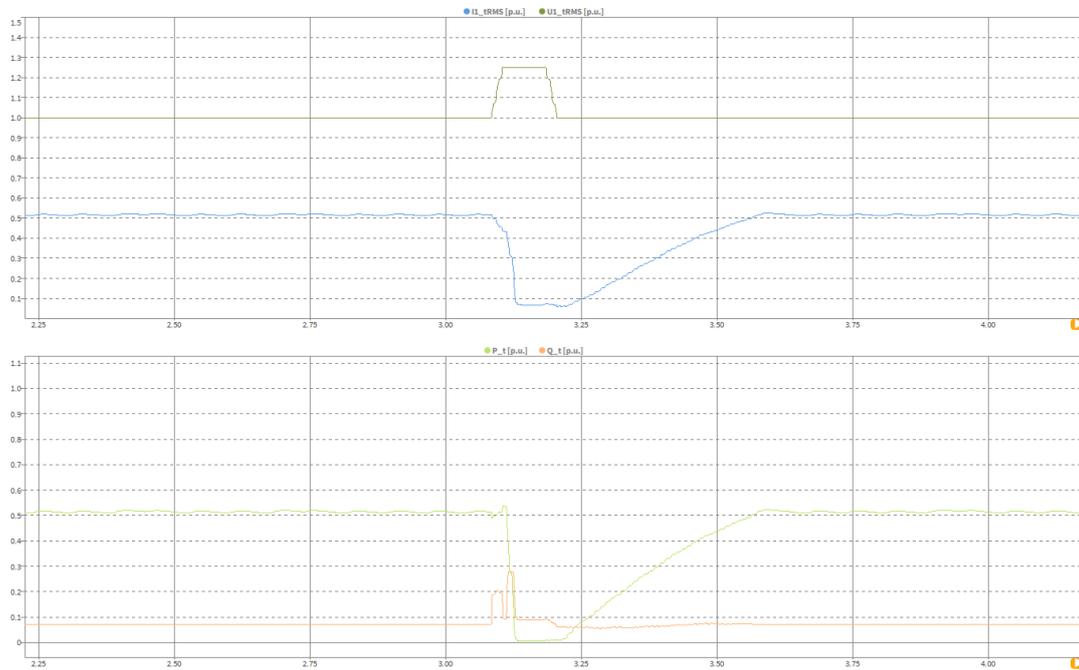
**Test 5.1 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 100% load  
Total values of active and reactive power**



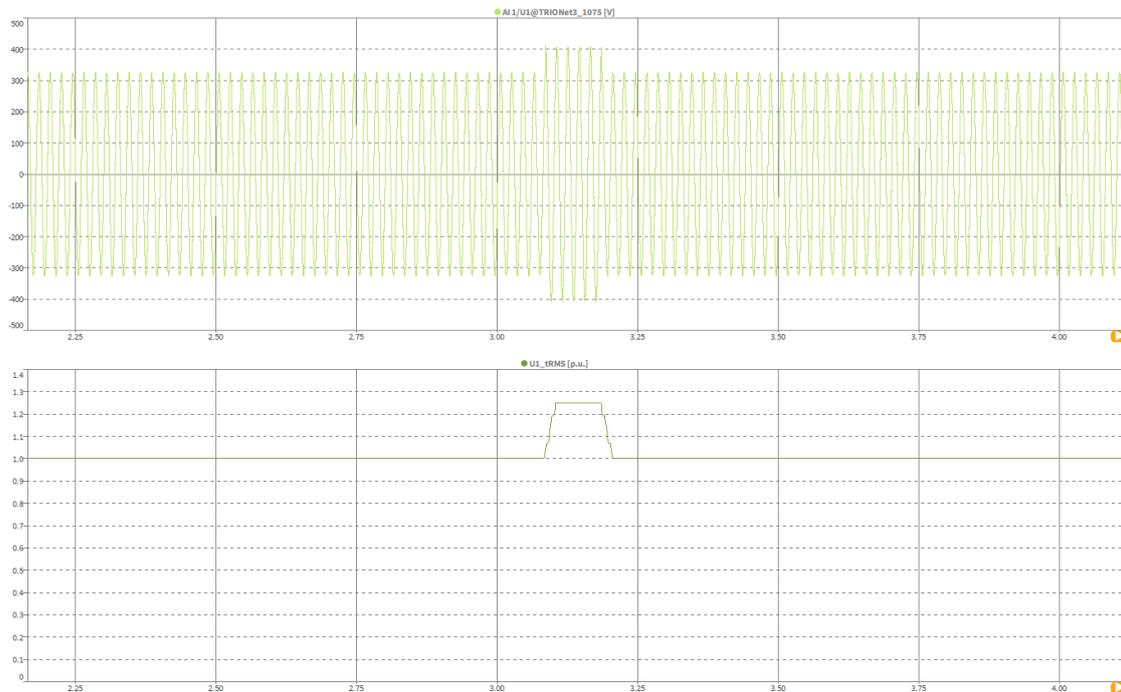
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.2 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 25% load  
Test overview (voltage, current, active and reactive power)**



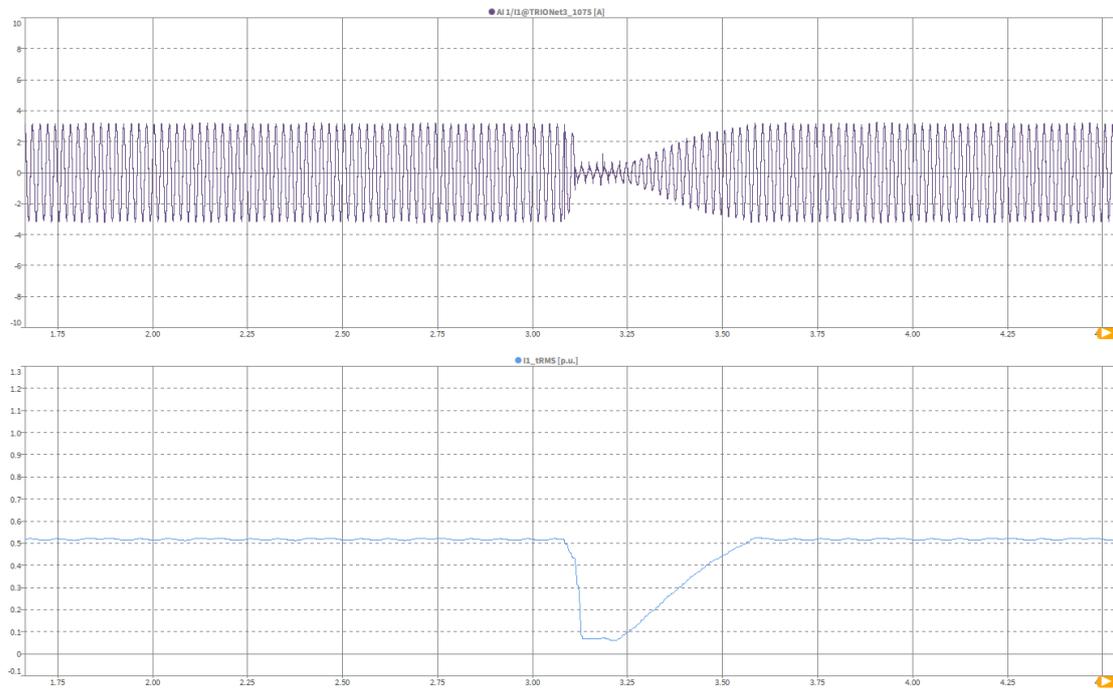
**Test 5.2 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 25% load  
Instantaneous curve curve and RMS values of phase to natural voltages**



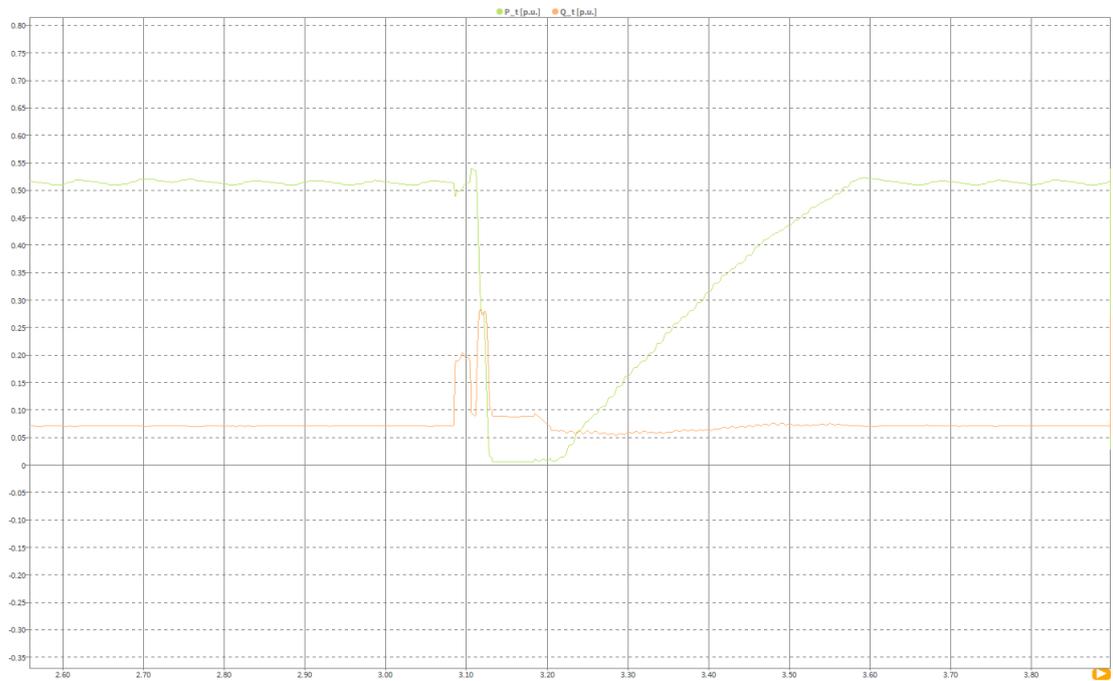
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.2 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 5.2 Depth of fault phase: 1.25 p.u.(U-N), balanced fault (type A), 25% load  
Total values of active and reactive power**

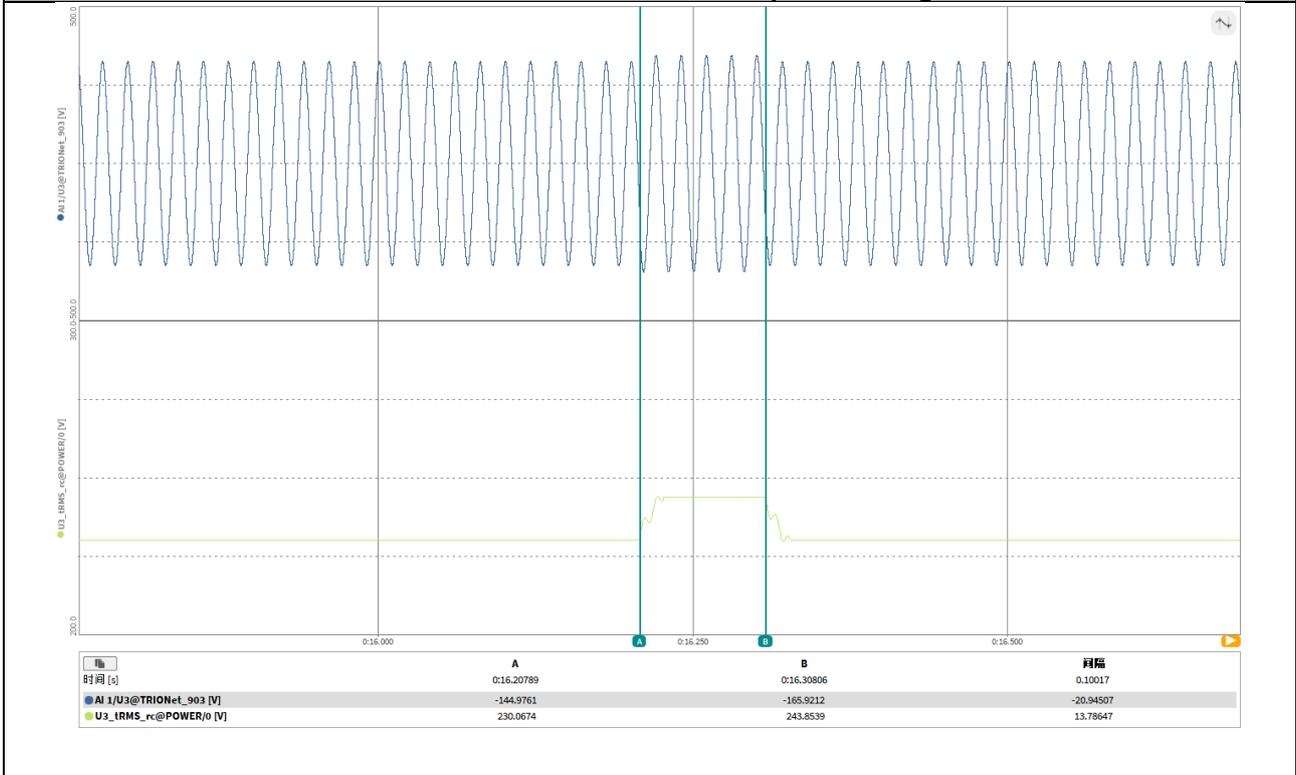


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	5.3	5.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	14:20	14:22	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.06	1.06
	5	Setting dip duration		--	--	--	100	100
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16208	16208
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	16308	16308
	8	Fault duration in empty load test	Total	--	--	ms	100	100
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.06	1.06	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.52	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.06	0.06	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.998	0.994		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.06	1.06	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	N/A	
	21		Phase 3			0.94	0.48	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	N/A	
	24		Phase 3			0.95	0.49	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	1.00	0.52	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.52	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.06	0.05	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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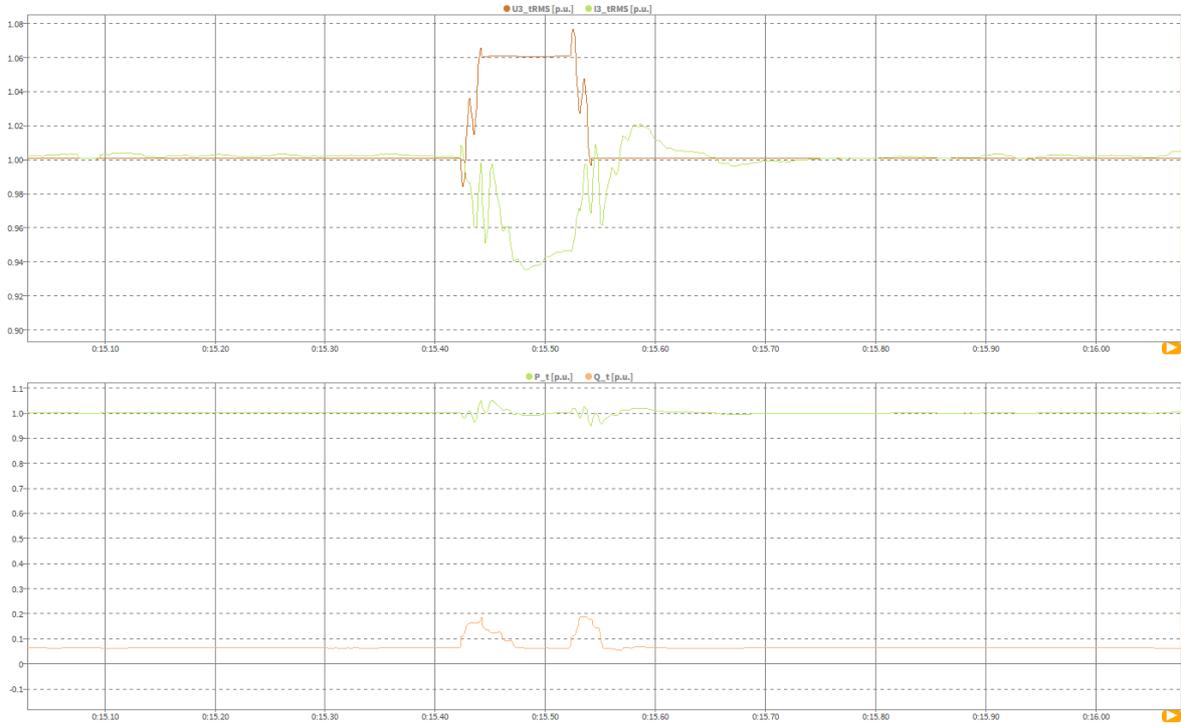
**Test 5.0.2 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



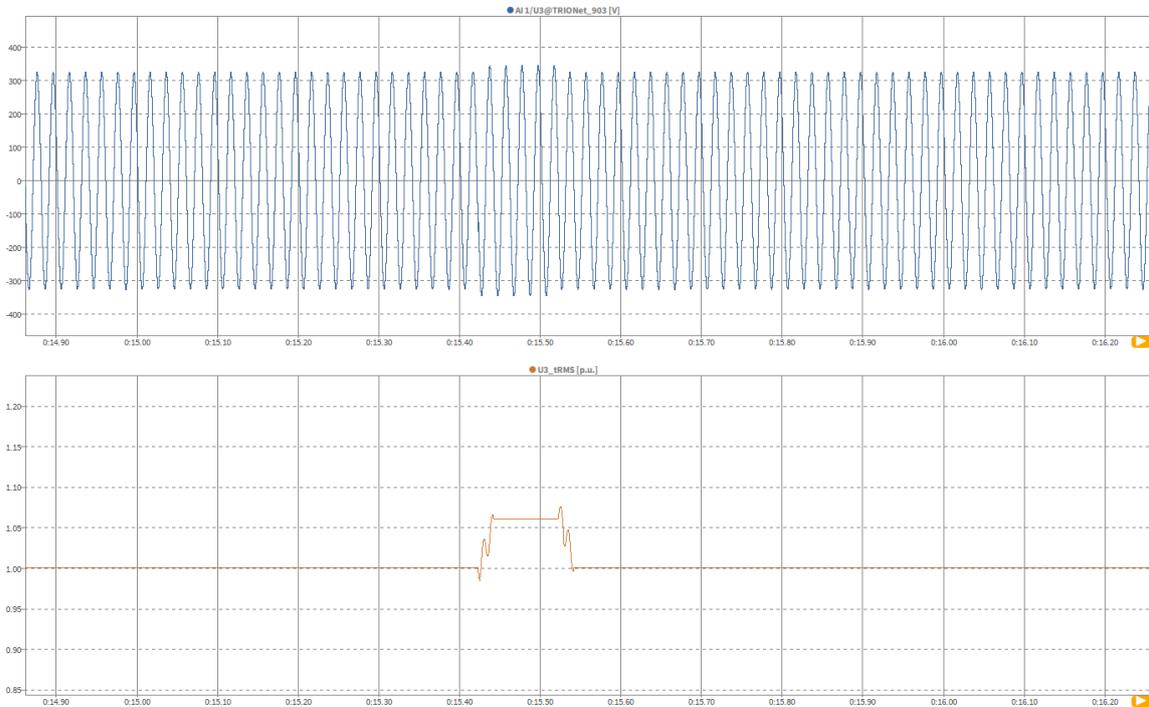
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.3 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 100% load**  
**Test overview (voltage, current, active and reactive power)**



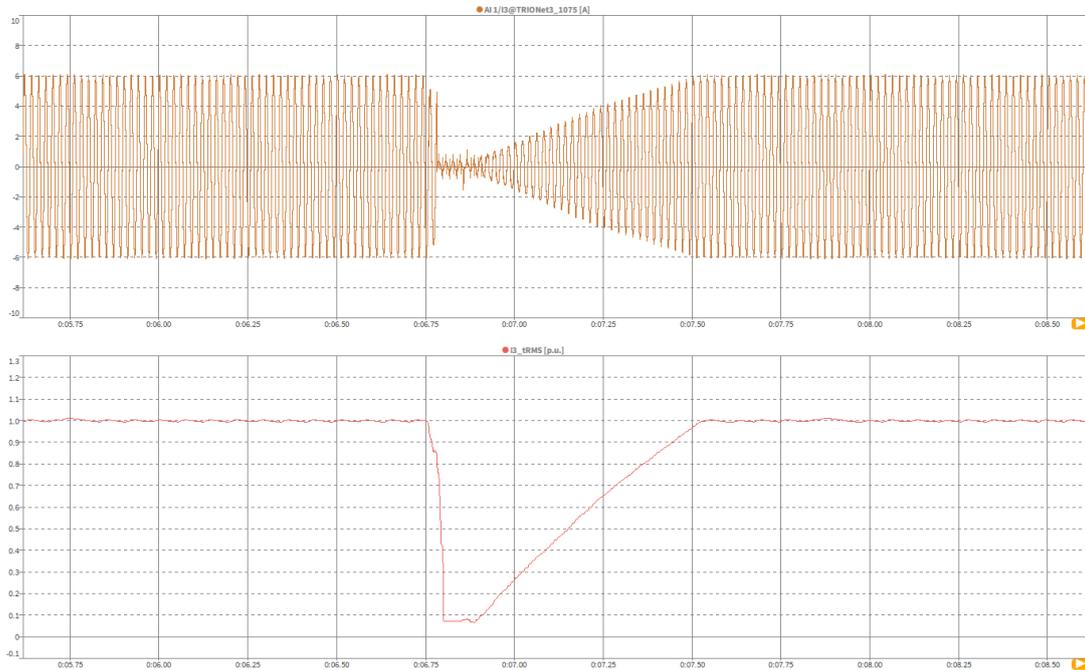
**Test 5.3 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



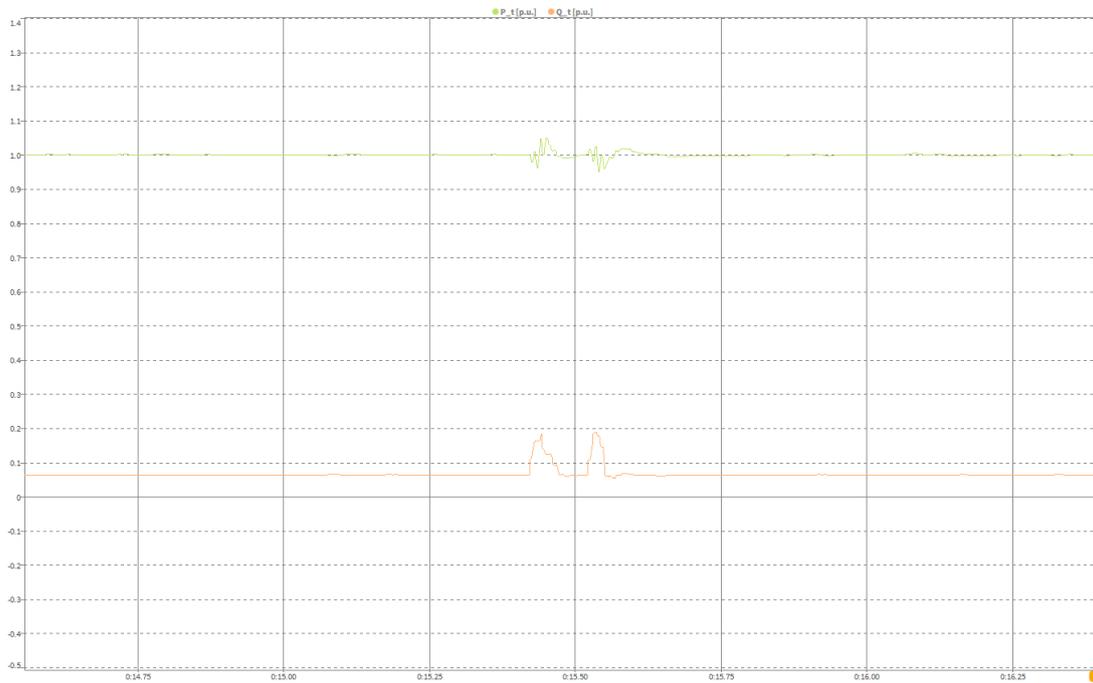
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.3 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve and RMS values of phase currents**



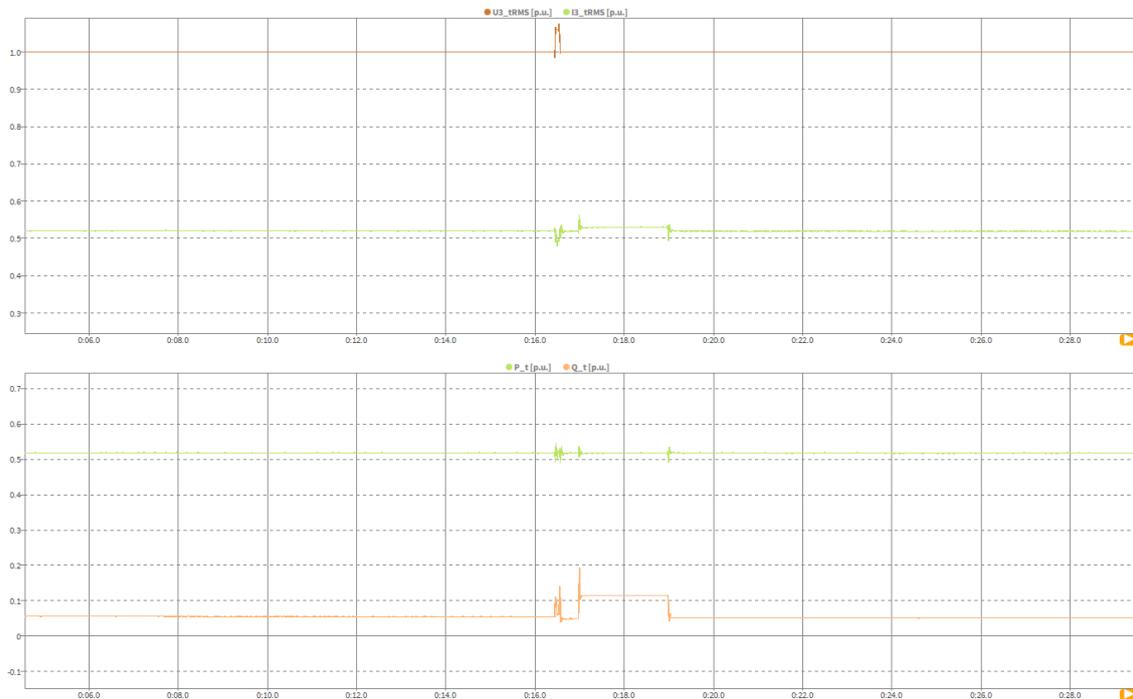
**Test 5.3 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Total values of active and reactive power**



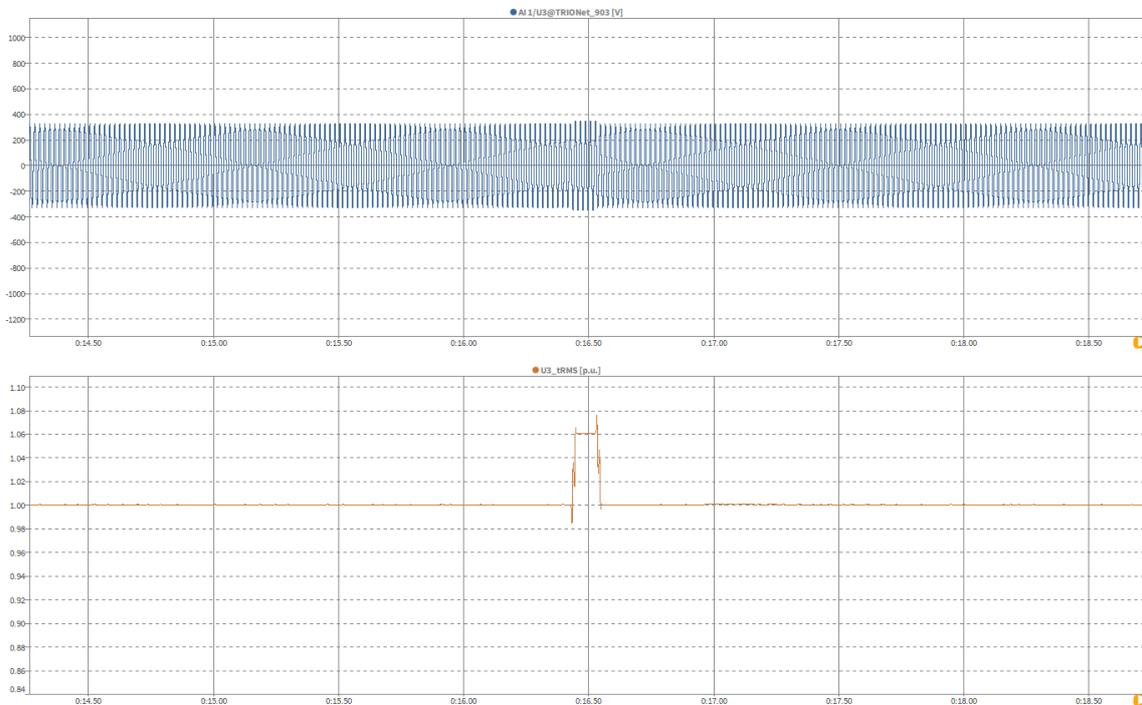
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.4 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Test overview (voltage, current, active and reactive power)**



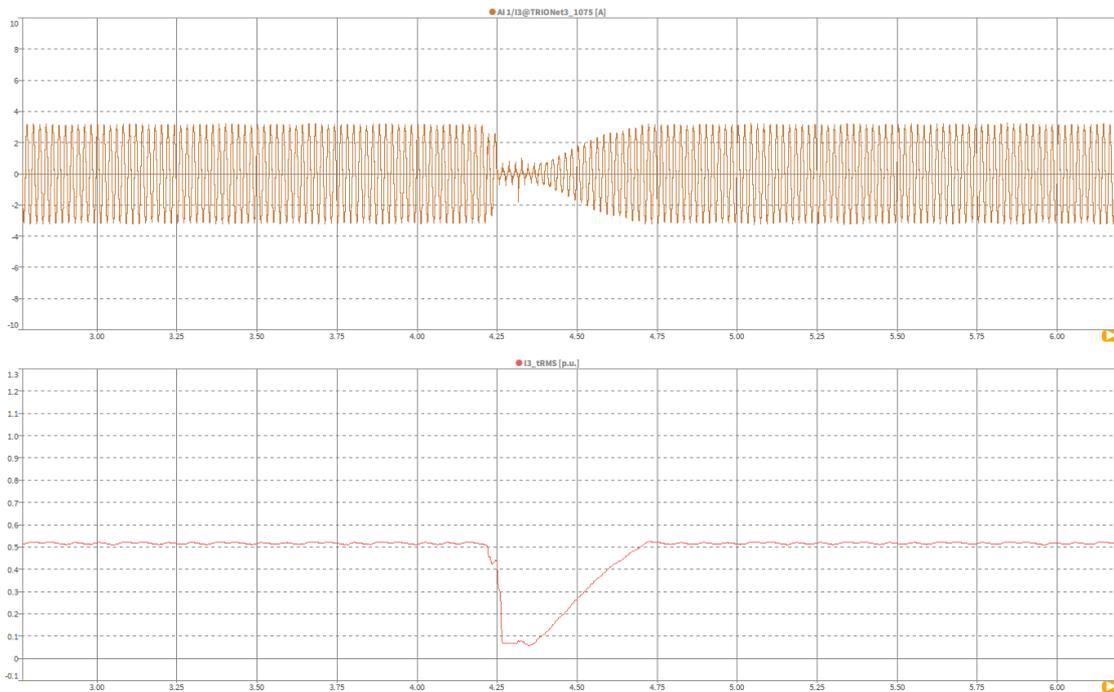
**Test 5.4 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



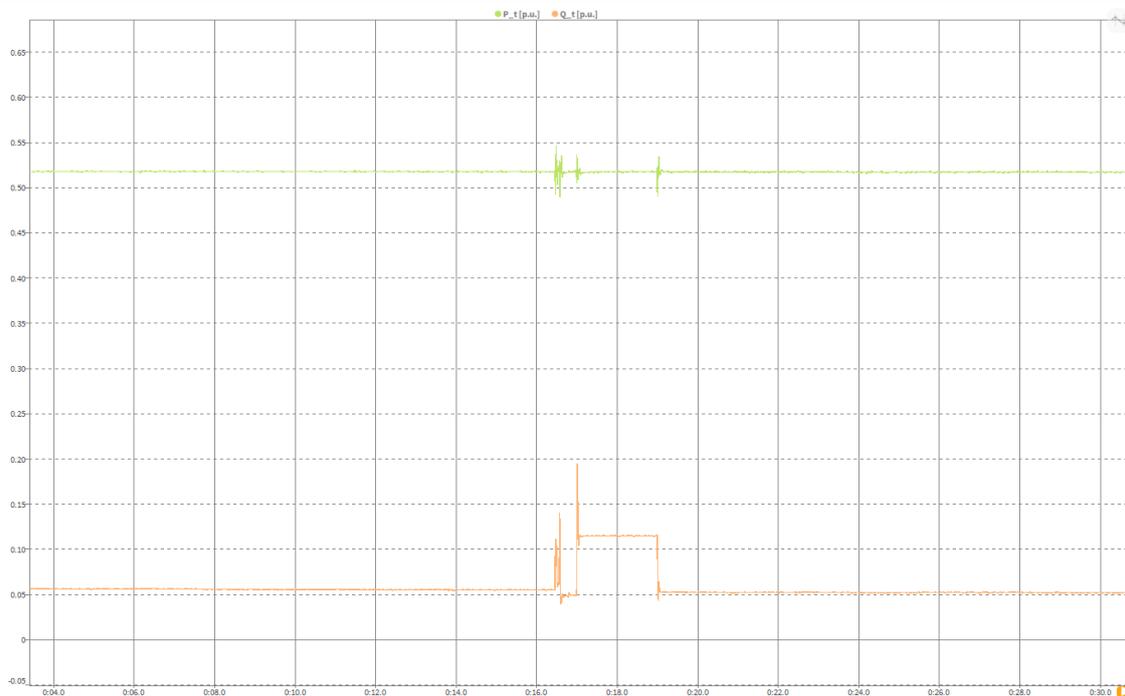
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.4 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 5.4 Depth of fault phase: 1.06 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Total values of active and reactive power**

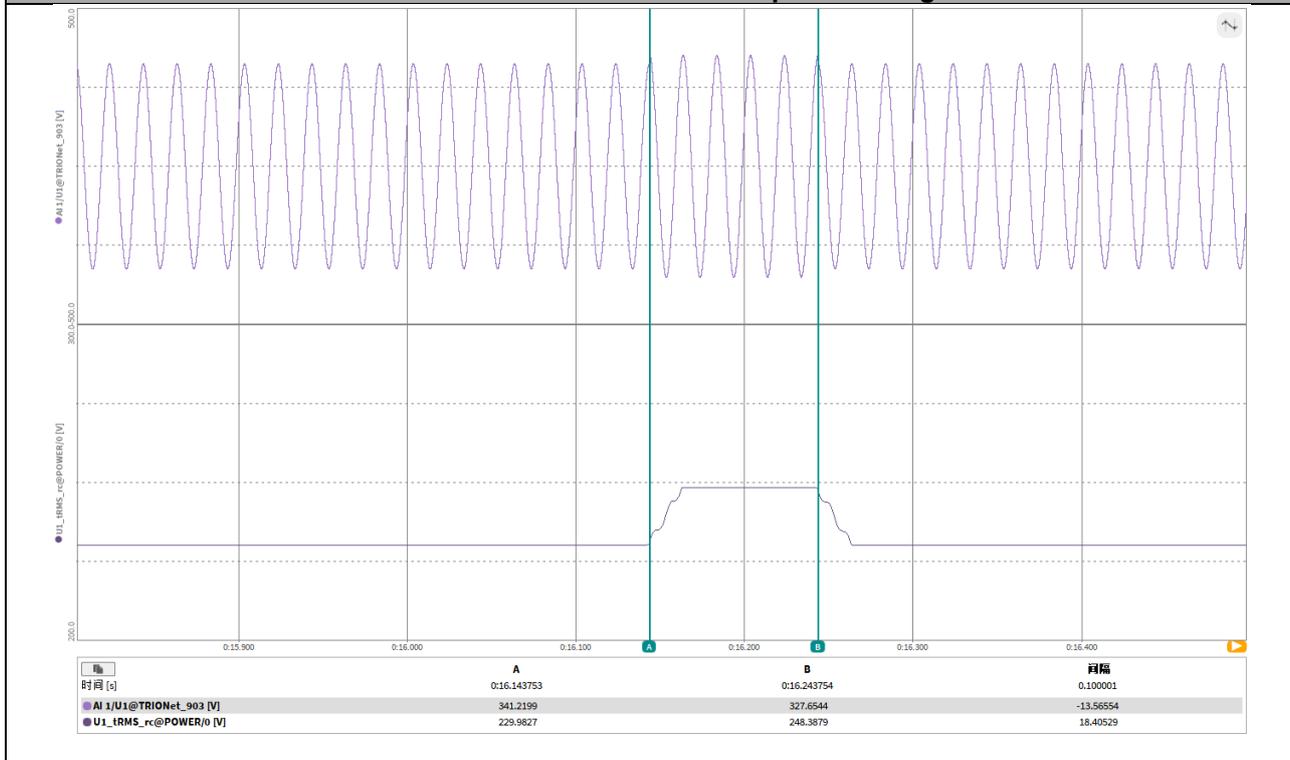


DIN VDE V 0124-100, VDE-AR-N 4105							
Clause	Requirement - Test				Result - Remark	Verdict	
Item	Condition					Measured value	
	No.	Parameter	Phase ref.	Time ref.	unit		
General Info.	0	Test number	--	--	--	5.5	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	14:40	
	3	Fault type (phase)	--	--	--	D2	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.08
	5	Setting dip duration		--	--	--	100
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16143
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	16243
	8	Fault duration in empty load test	Total	--	--	ms	100
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.08	
10	Pos.		N/A				
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	
	14		Pos.			N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.06	
	16		Pos.			N/A	
17	Cosφ	--	t1-10s to t1	--	0.998		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.08	
	19	Line current	Phase 1	t1+60ms	p.u.	0.91	
	20		Phase 2			N/A	
	21		Phase 3			N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.93	
	23		Phase 2			N/A	
	24		Phase 3			N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.99	
26	Pos.		N/A				
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.99	
	29		Pos.			N/A	
	30	Response time reactive power	Pos.	--	s	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.06	
	32		Pos.			N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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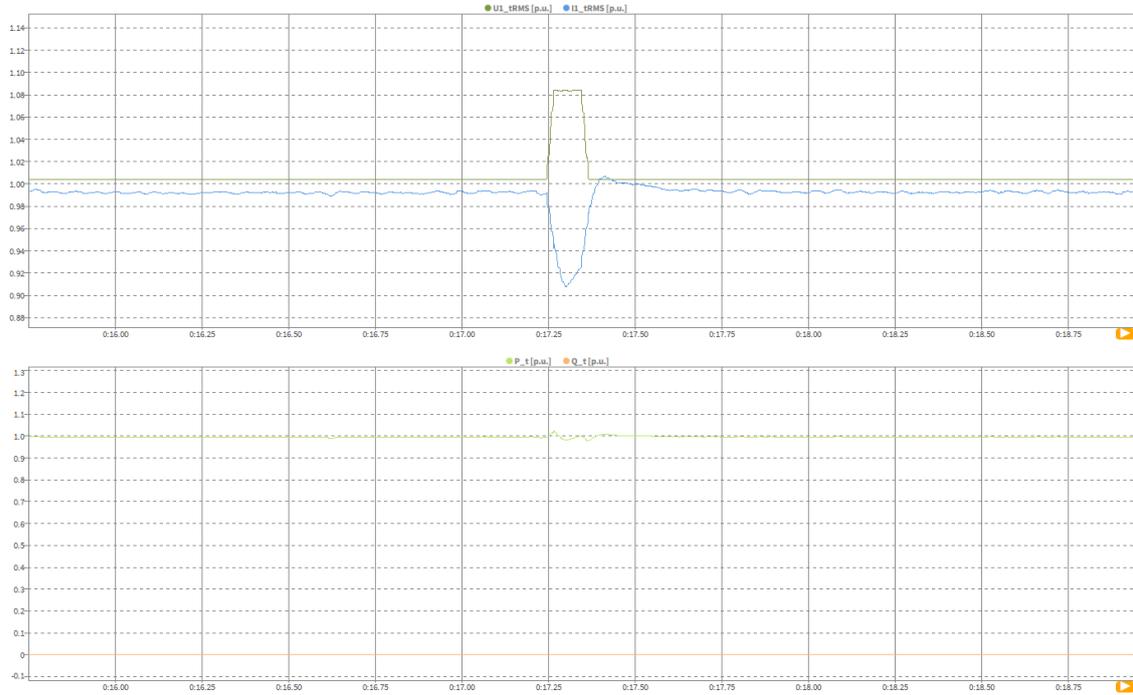
**Test 5.0.3 Depth of fault phase: 1.08 p.u.(U-N), Unbalanced fault (type D2), No load, Instantaneous and RMS values of phase voltages**



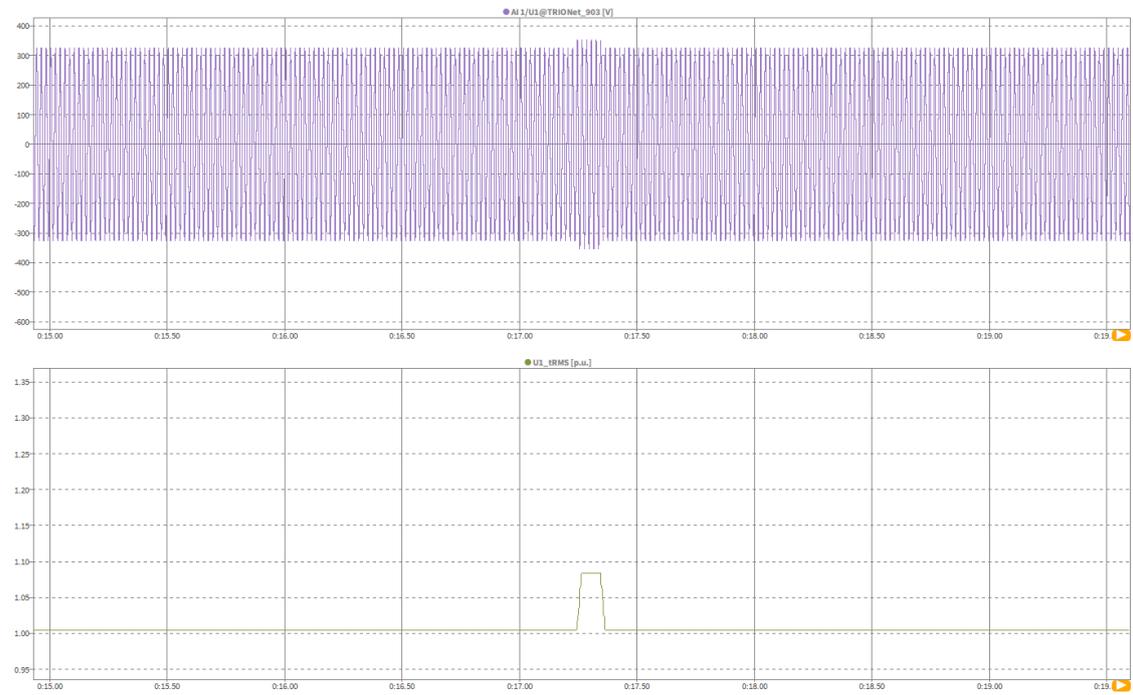
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.5 Depth of fault phase: 1.08 p.u.(U-N), Unbalanced fault (type D2), 100% load**  
**Test overview (voltage, current, active and reactive power)**



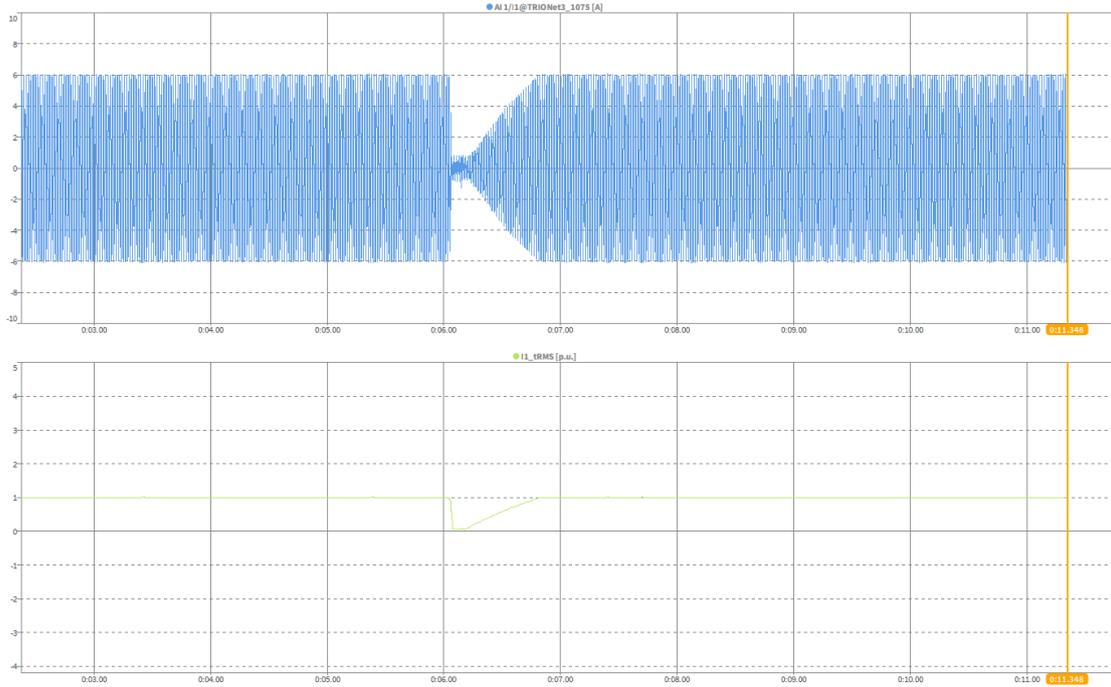
**Test 5.5 Depth of fault phase: 1.08 p.u.(U-N), Unbalanced fault (type D2), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 5.5 Depth of fault phase: 1.08 p.u.(U-N), Unbalanced fault (type D2), 100% load  
Instantaneous curve and RMS values of phase currents**



**Test 5.5 Depth of fault phase: 1.08 p.u.(U-N), Unbalanced fault (type D2), 100% load  
Total values of active and reactive power**

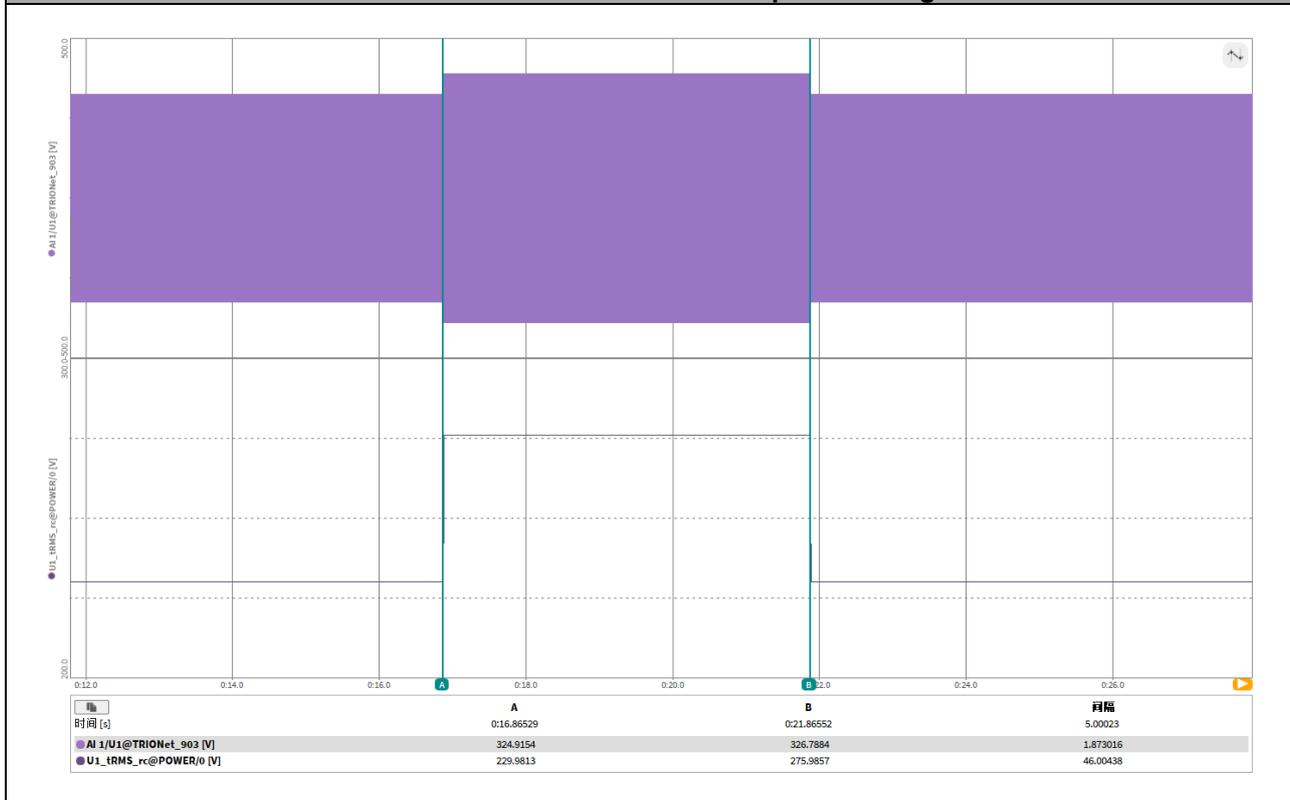


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	6.1	6.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:50	13:52	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.2	1.2
	5	Setting dip duration		--	--	--	5000	5000
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	16865	16865
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	21865	21865
	8	Fault duration in empty load test	Total	--	--	ms	5000	5000
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.20	1.20	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.52	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.09	0.07	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.996	0.990		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.20	1.20	
	19	Line current	Phase 1	t1+60ms	p.u.	0.07	0.07	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.07	0.07	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.01	0.01	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	0.98	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.09	0.10	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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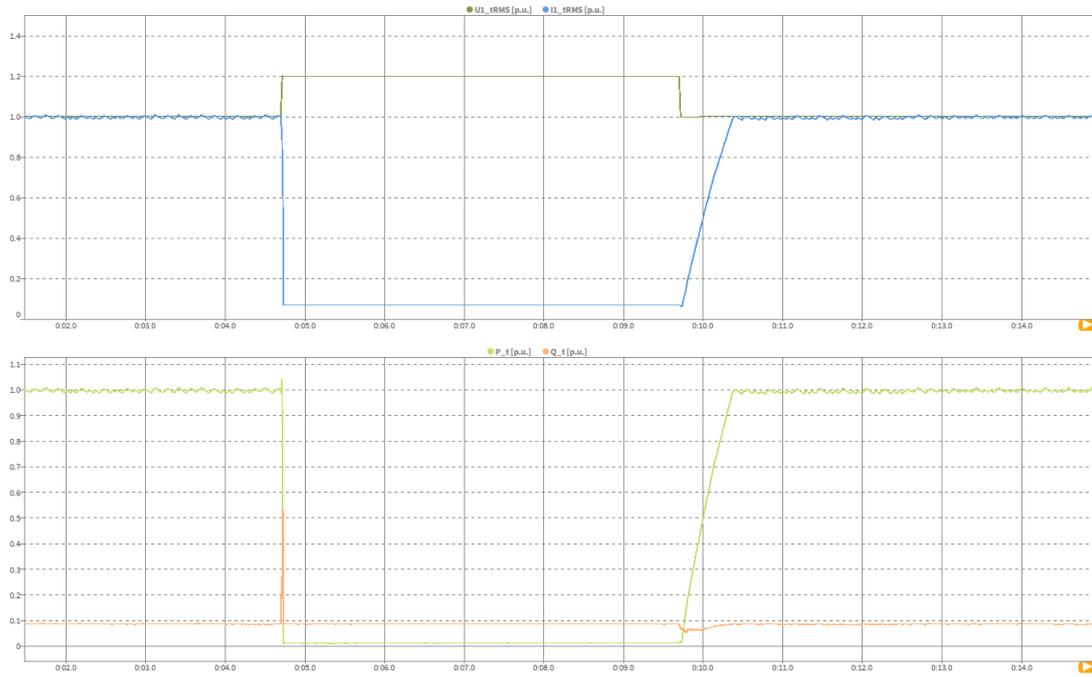
**Test 6.0.1 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



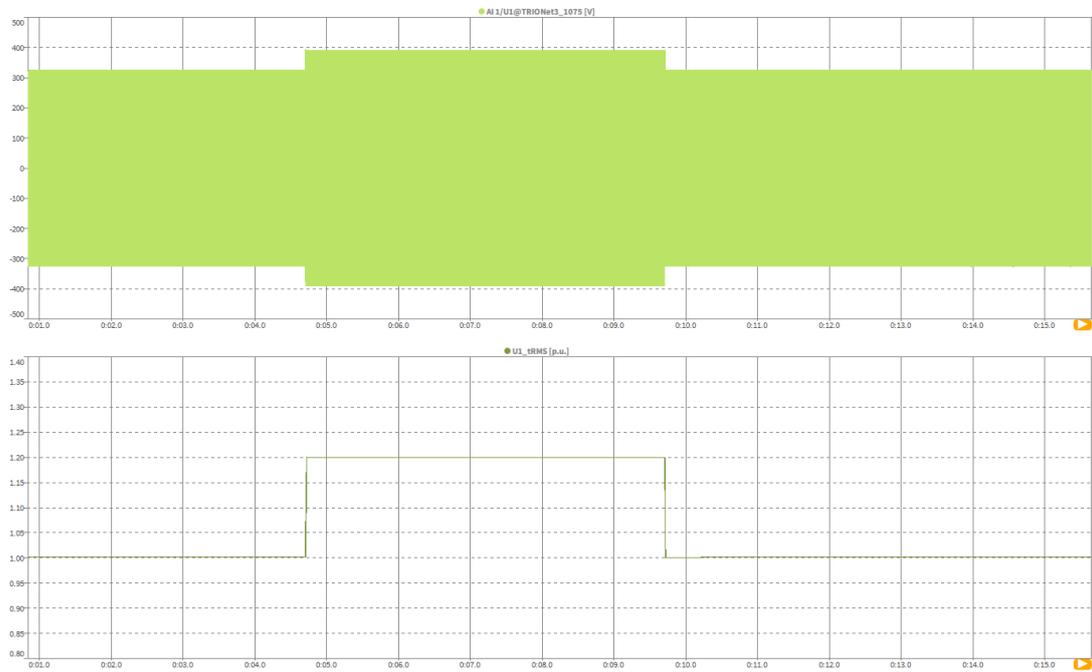
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.1 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 100% load**  
**Test overview (voltage, current, active and reactive power)**



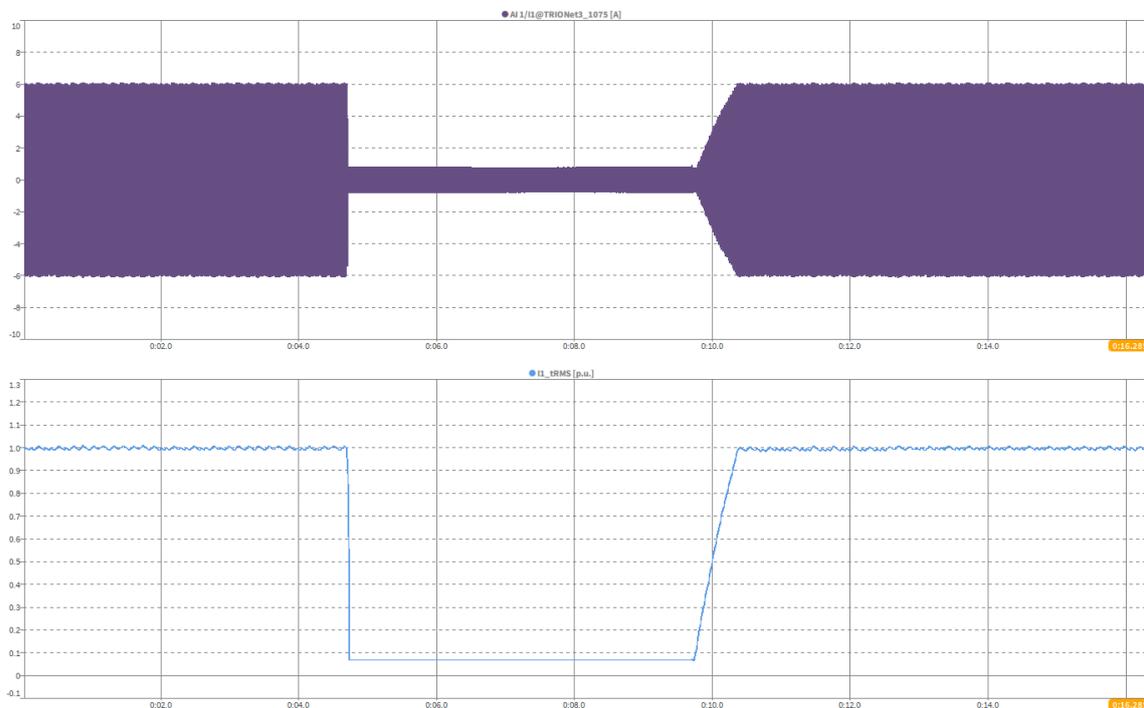
**Test 6.1 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



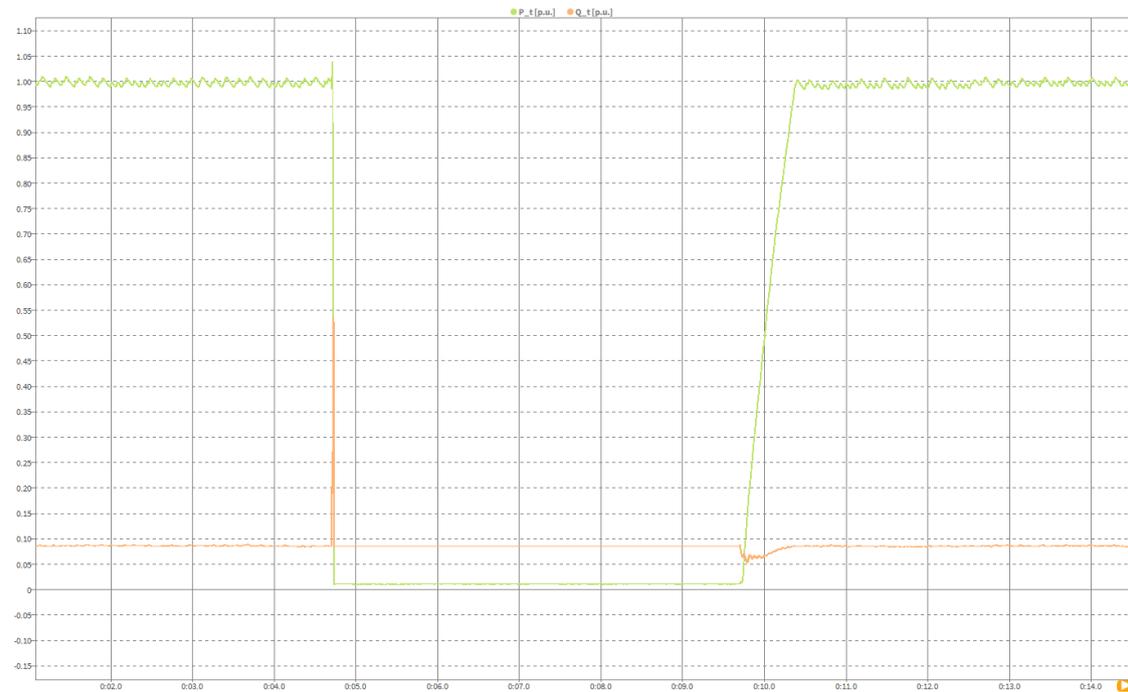
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.1 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve and RMS values of phase currents**



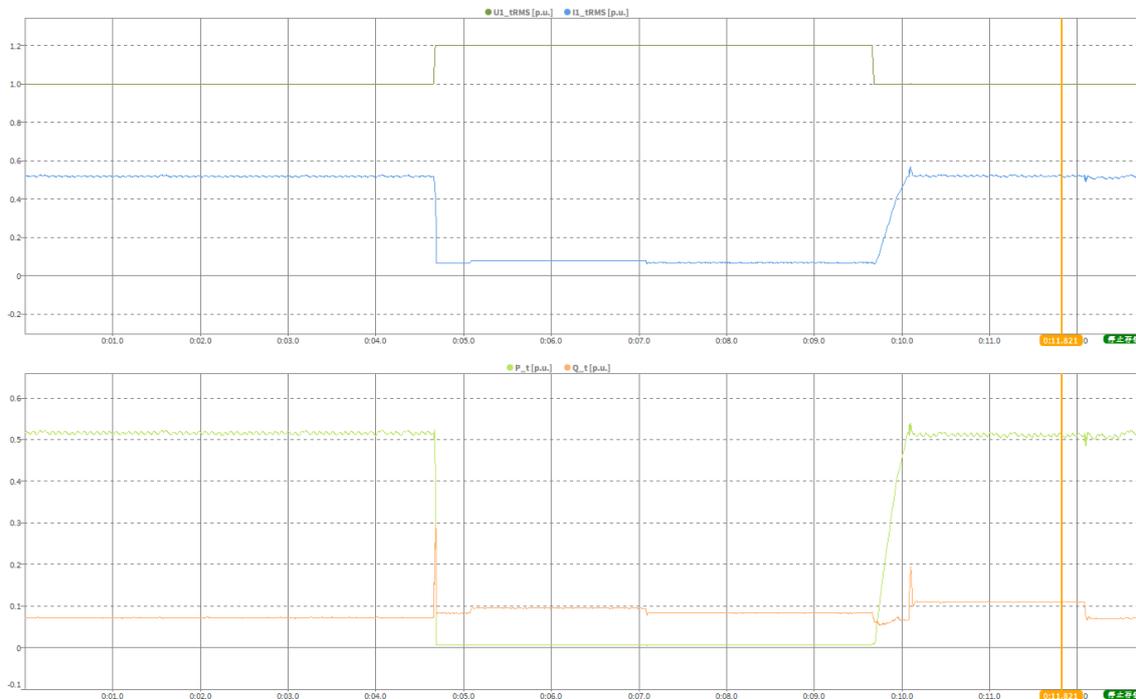
**Test 6.1 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 100% load  
Total values of active and reactive power**



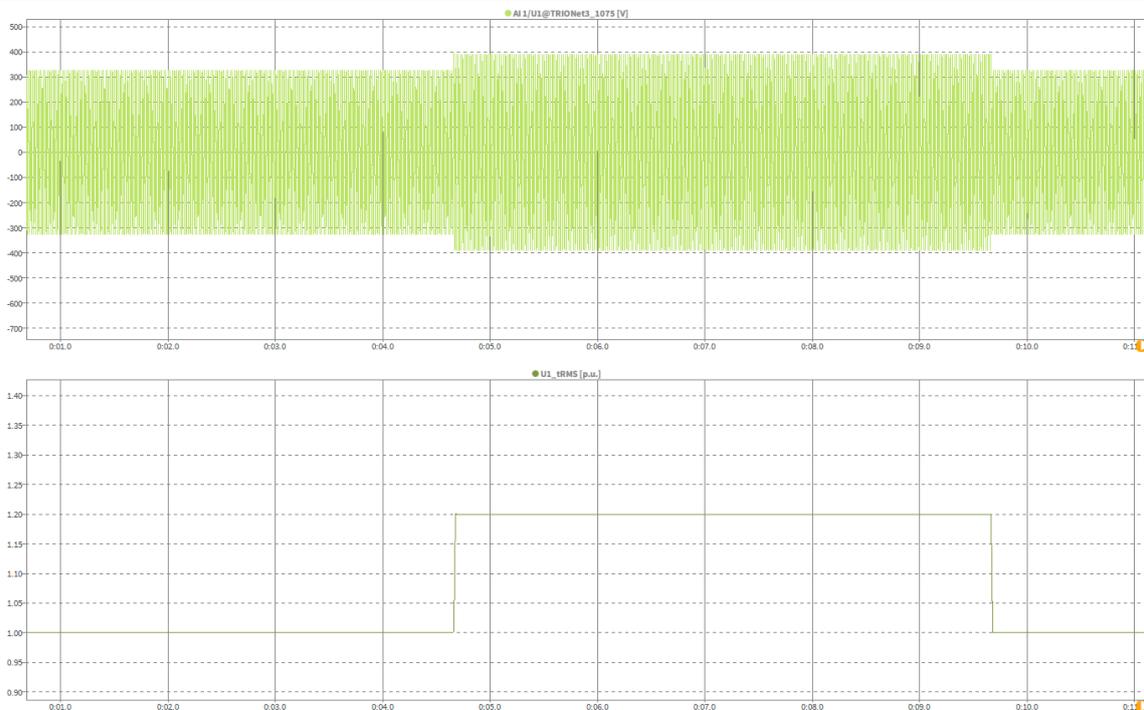
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.2 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 25% load**  
**Test overview (voltage, current, active and reactive power)**



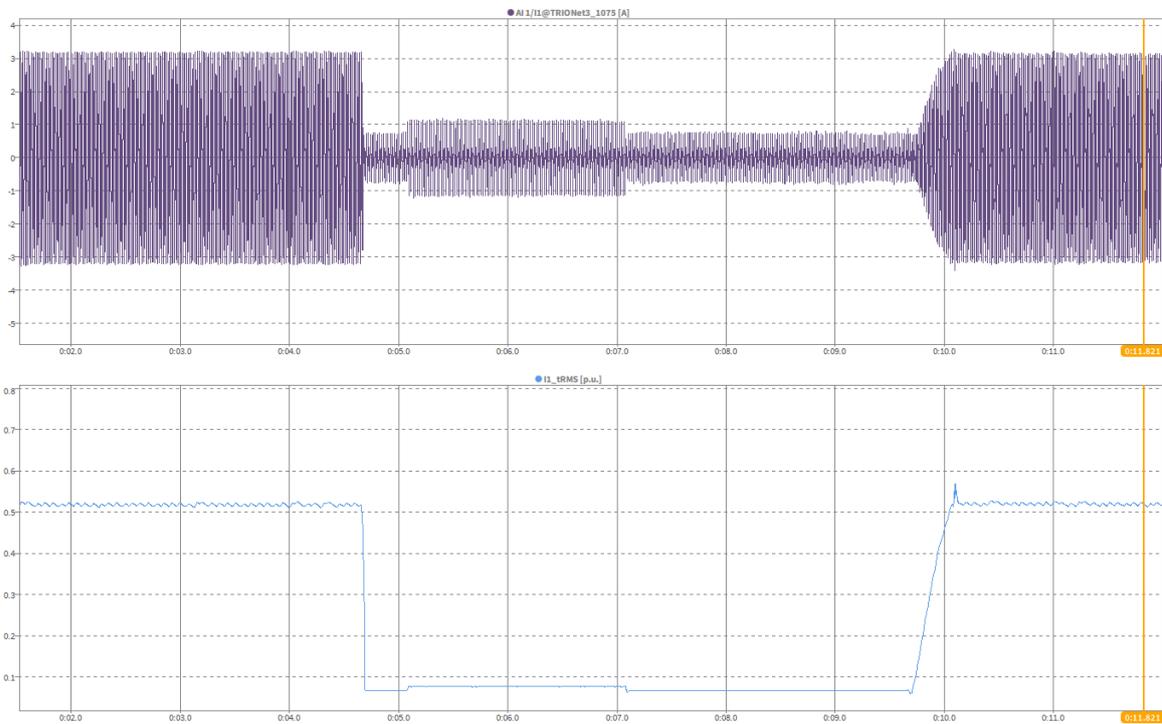
**Test 6.2 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



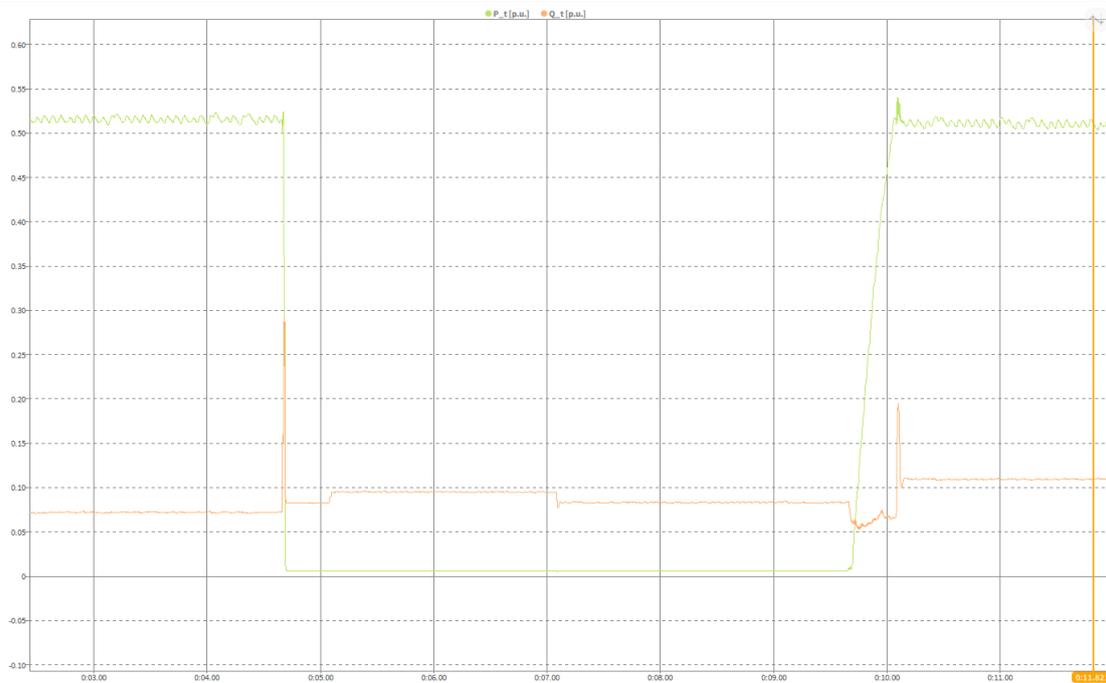
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.2 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 6.2 Depth of fault phase: 1.2 p.u.(U-N), balanced fault (type A), 25% load  
Total values of active and reactive power**

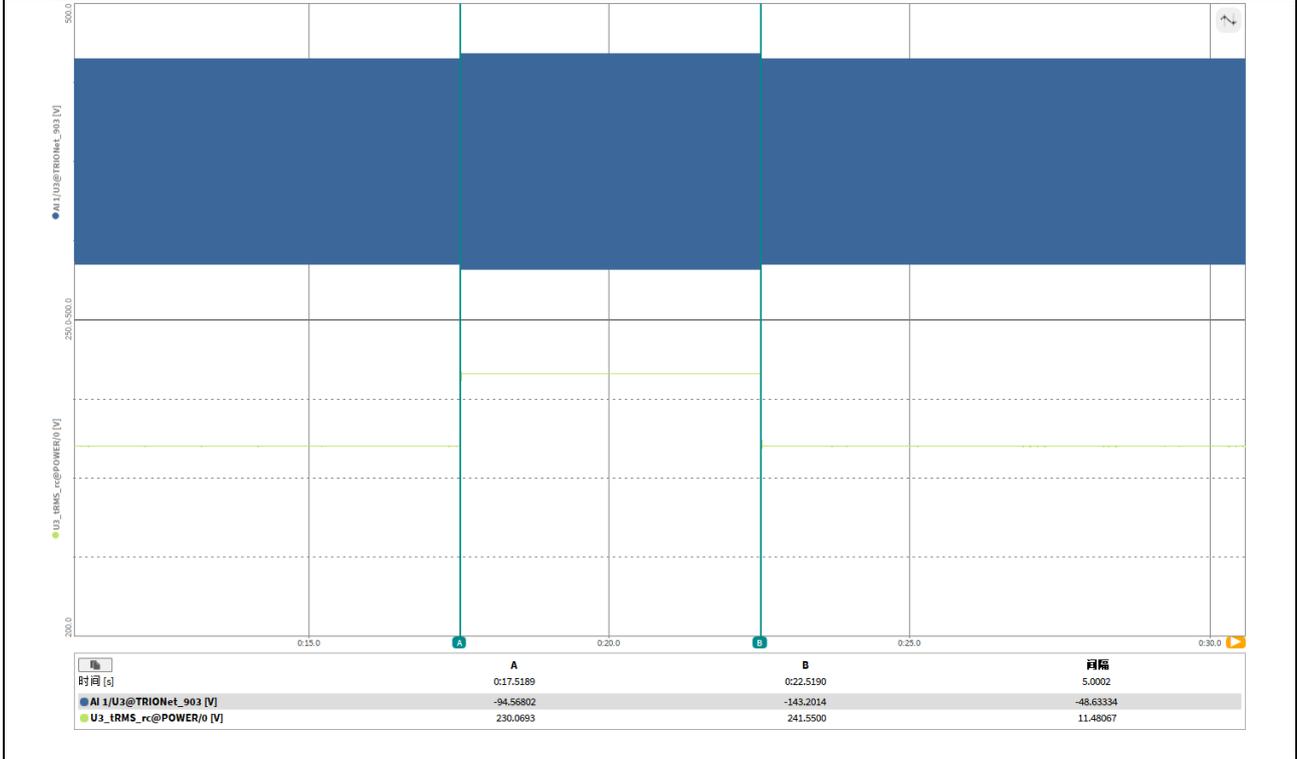


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	6.3	6.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	14:20	14:20	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.05	1.05
	5	Setting dip duration		--	--	--	5000	5000
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	17519	17519
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	22519	22519
	8	Fault duration in empty load test	Total	--	--	ms	5000	5000
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.05	1.05	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.52	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.06	0.05	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.998	0.995		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.05	1.05	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	N/A	
	21		Phase 3			0.96	0.49	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	N/A	
	24		Phase 3			0.97	0.50	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	1.01	0.52	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.52	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.06	0.05	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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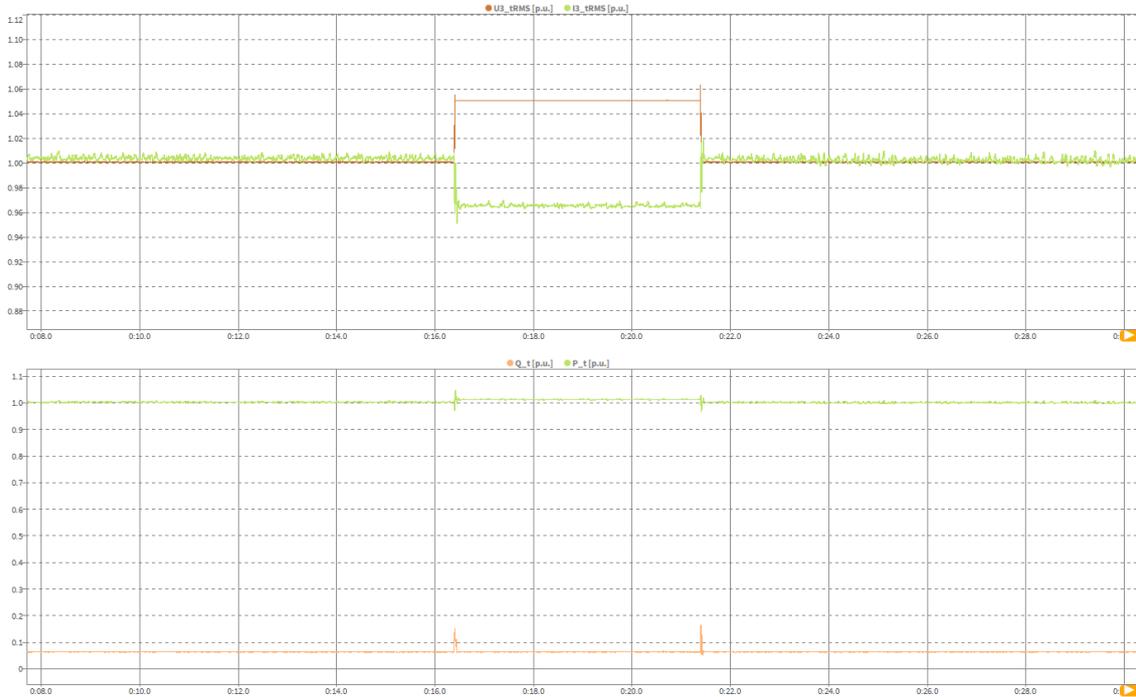
**Test 6.0.2 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



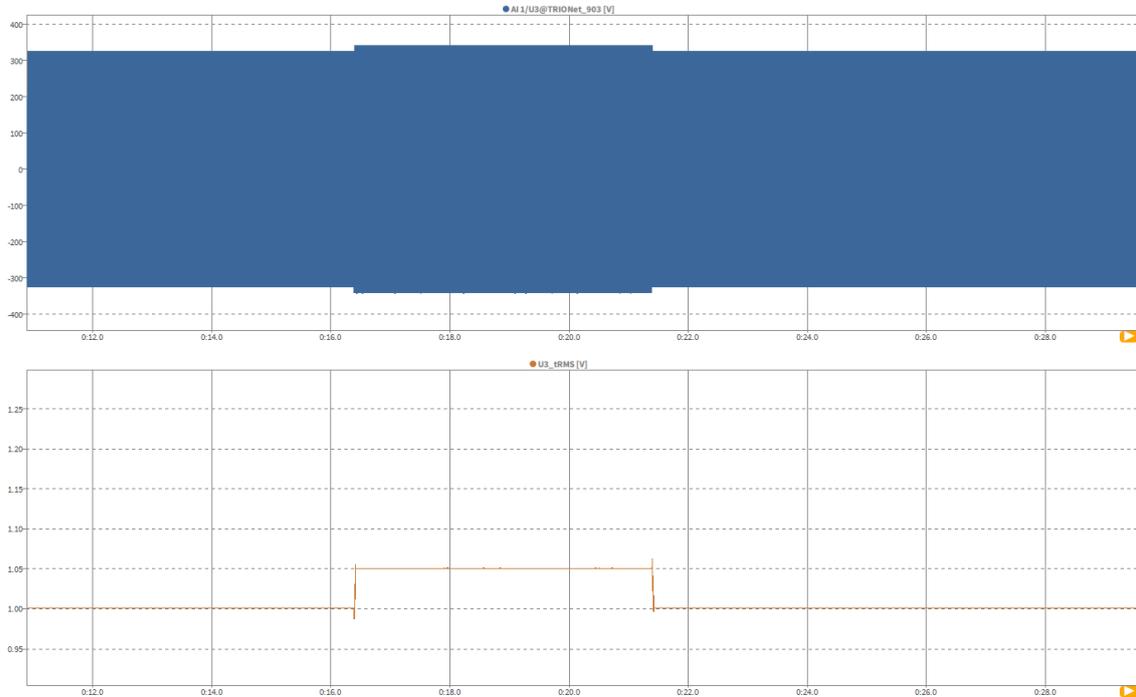
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.3 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 100% load**  
**Test overview (voltage, current, active and reactive power)**



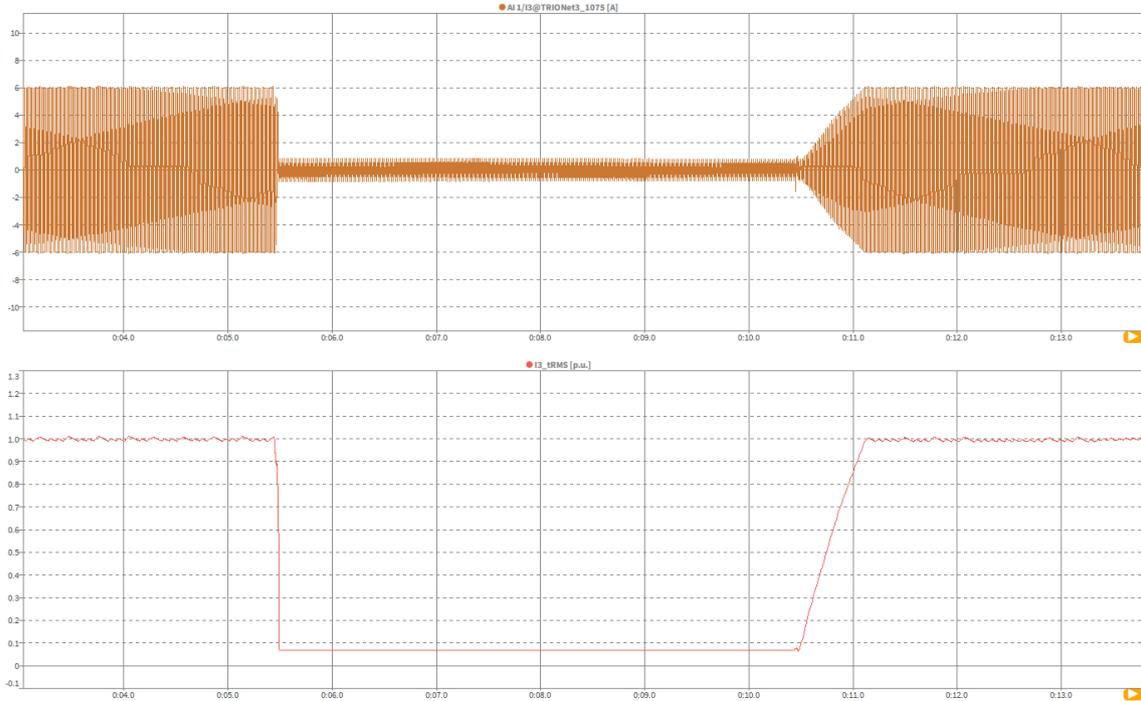
**Test 6.3 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 100% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.3 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve and RMS values of phase currents**



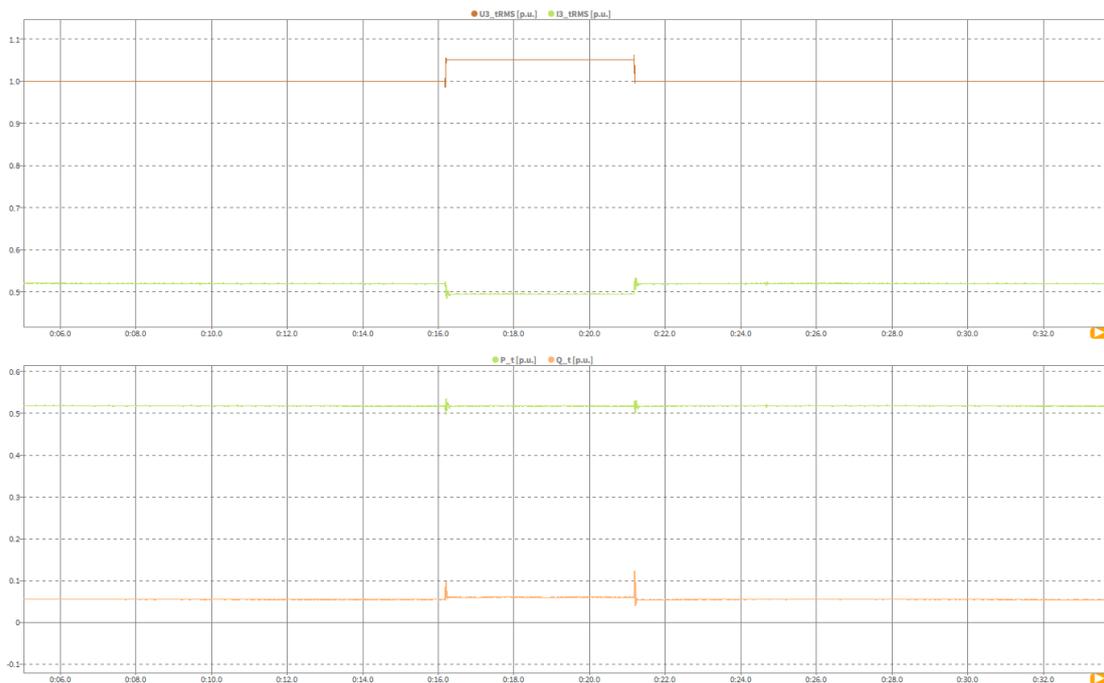
**Test 6.3 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Total values of active and reactive power**



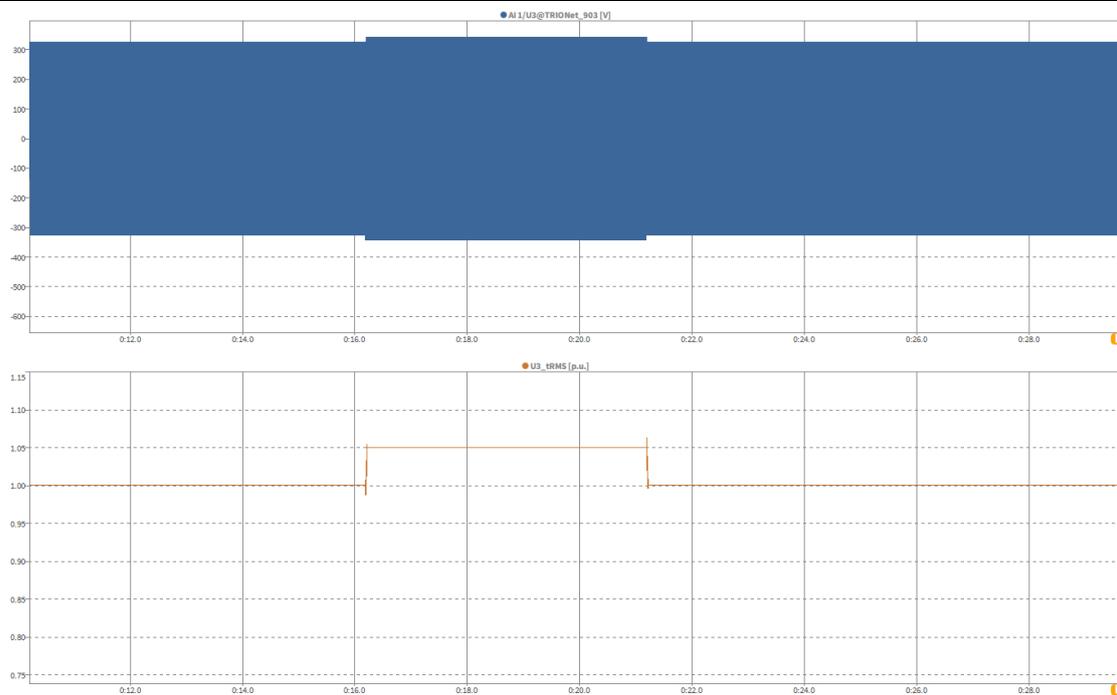
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.4 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Test overview (voltage, current, active and reactive power)**



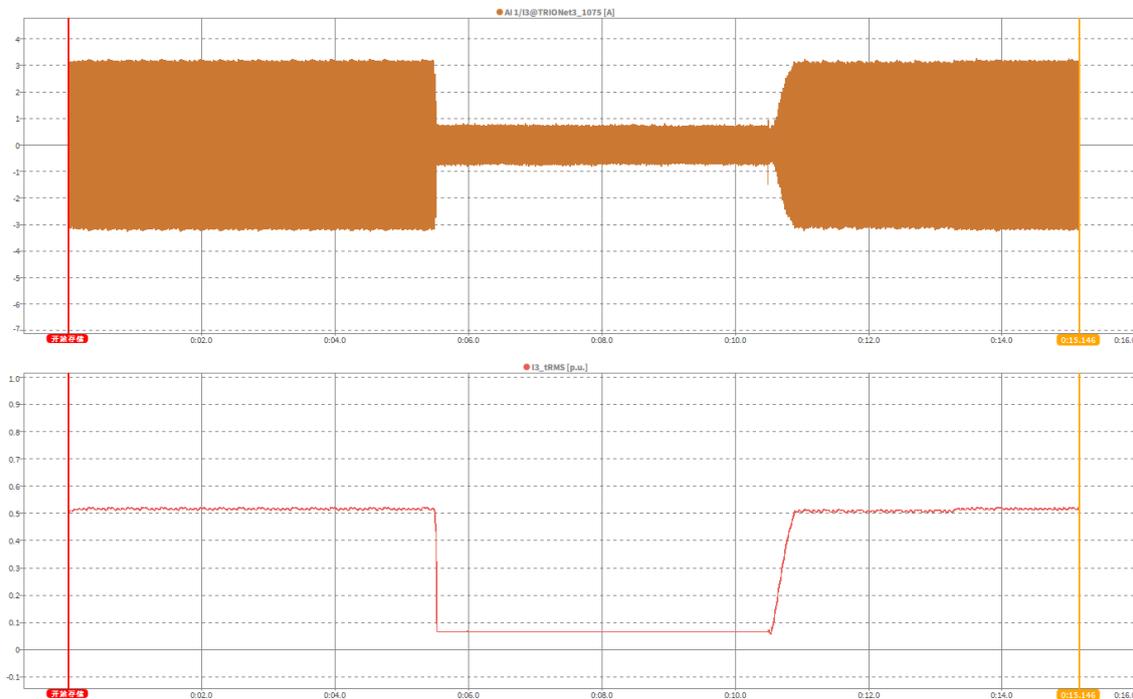
**Test 6.4 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



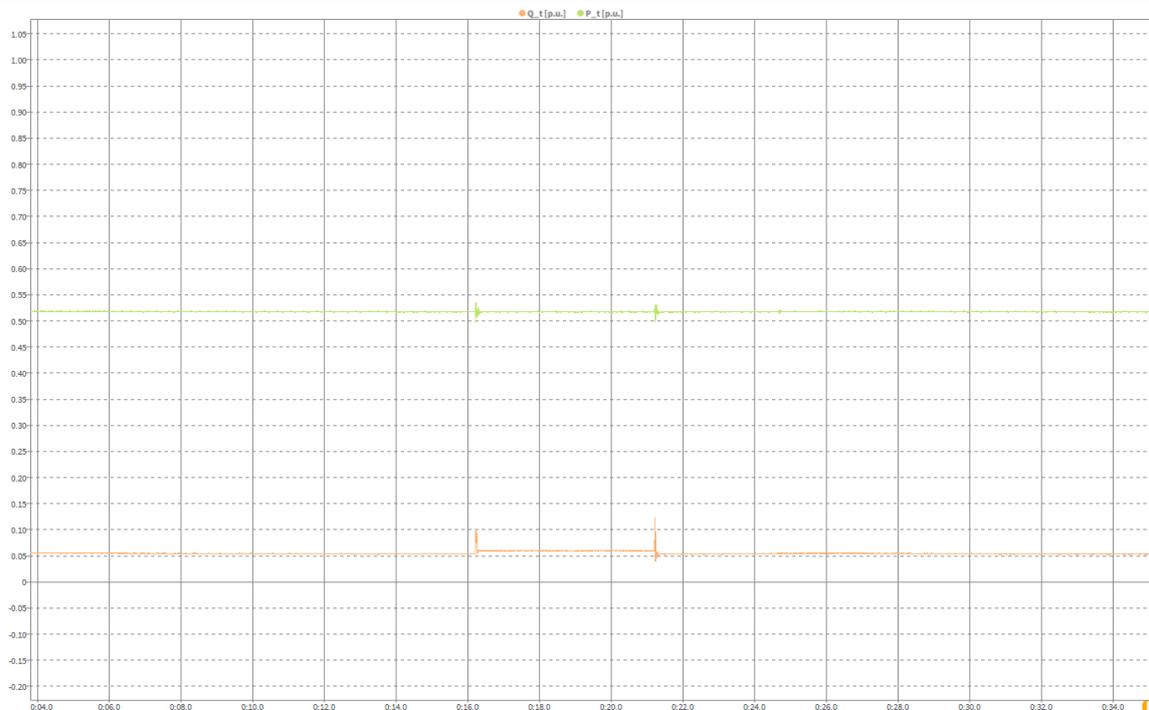
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 6.4 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 6.4 Depth of fault phase: 1.05 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Total values of active and reactive power**

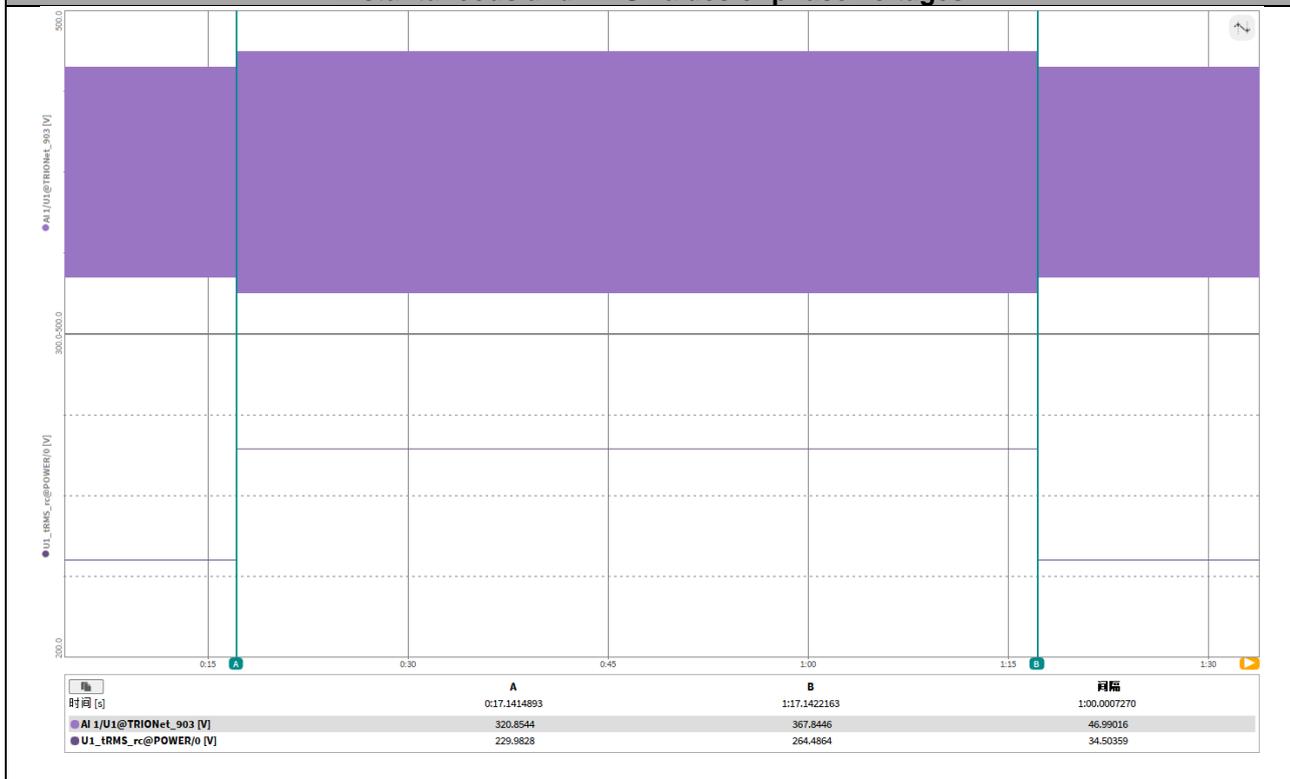


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	7.1	7.2	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	13:54	13:56	
	3	Fault type (phase)	--	--	--	A	A	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.15	1.15
	5	Setting dip duration		--	--	--	60000	60000
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	17142	17142
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	77142	77142
	8	Fault duration in empty load test	Total	--	--	ms	60000	60000
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.15	1.15	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.51	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.09	0.07	
	16		Pos.			N/A	N/A	
17	Cosp	--	t1-10s to t1	--	0.996	0.991		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.15	1.15	
	19	Line current	Phase 1	t1+60ms	p.u.	0.41	0.32	
	20		Phase 2			N/A	N/A	
	21		Phase 3			N/A	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	0.07	0.07	
	23		Phase 2			N/A	N/A	
	24		Phase 3			N/A	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.01	0.01	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.09	0.07	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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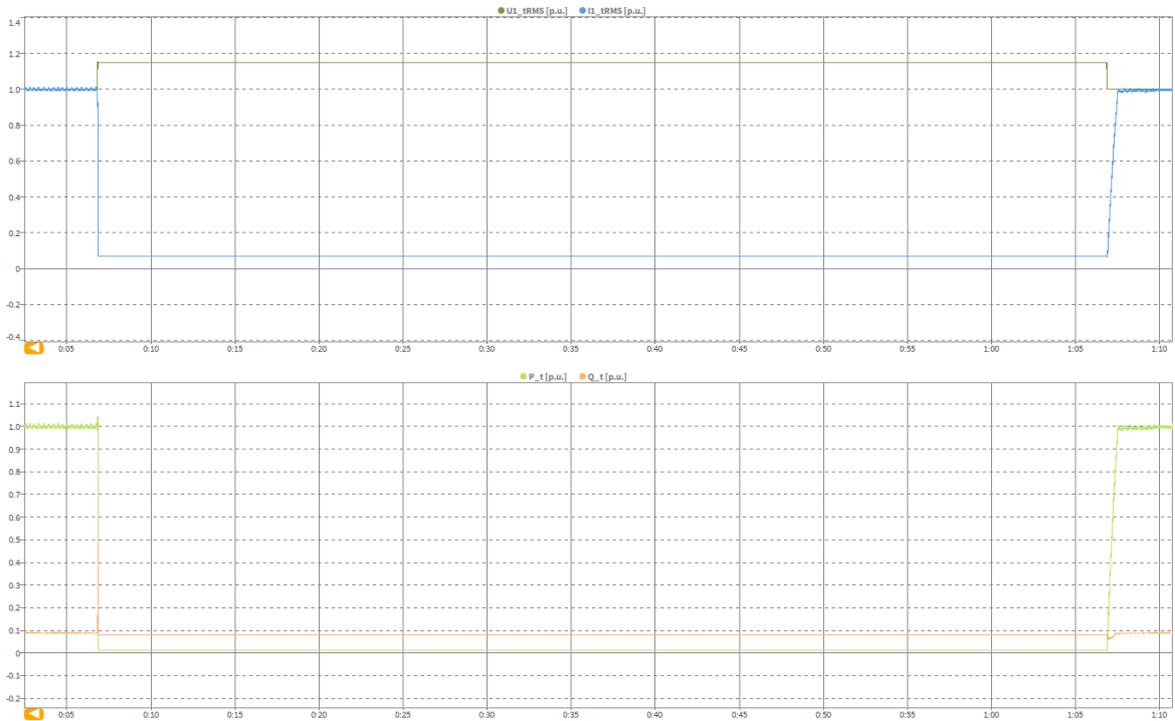
**Test 7.0.1 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), No load, Instantaneous and RMS values of phase voltages**



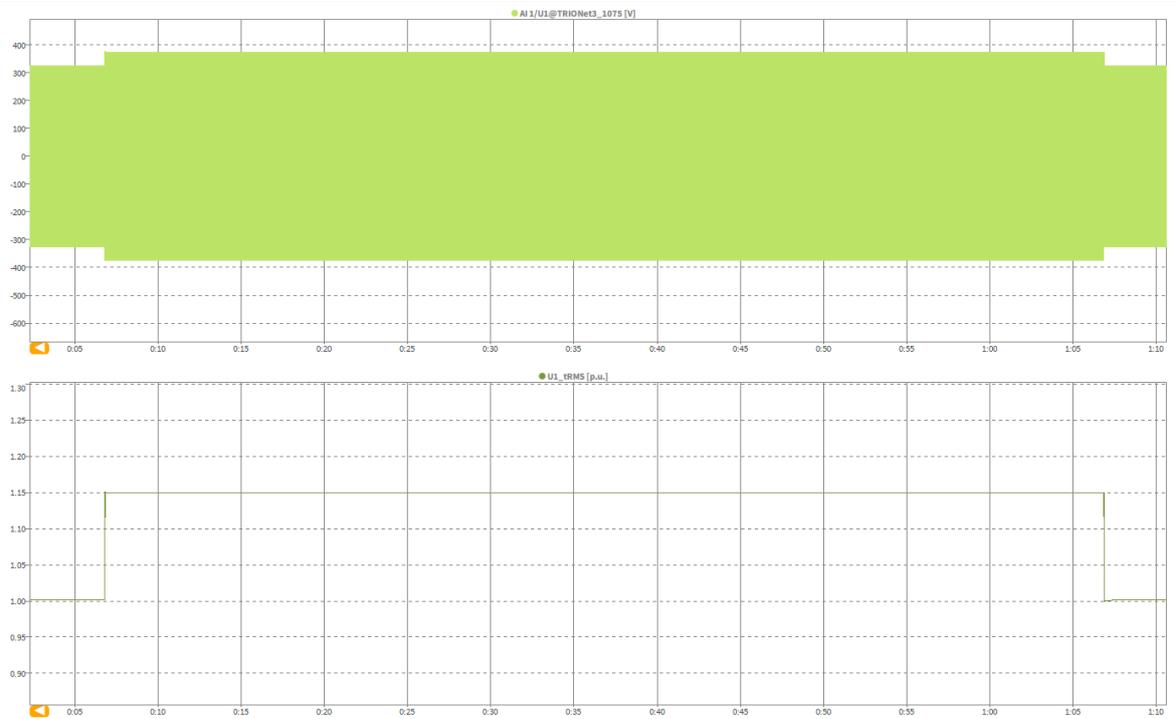
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.1 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 100% load  
Test overview (voltage, current, active and reactive power)**



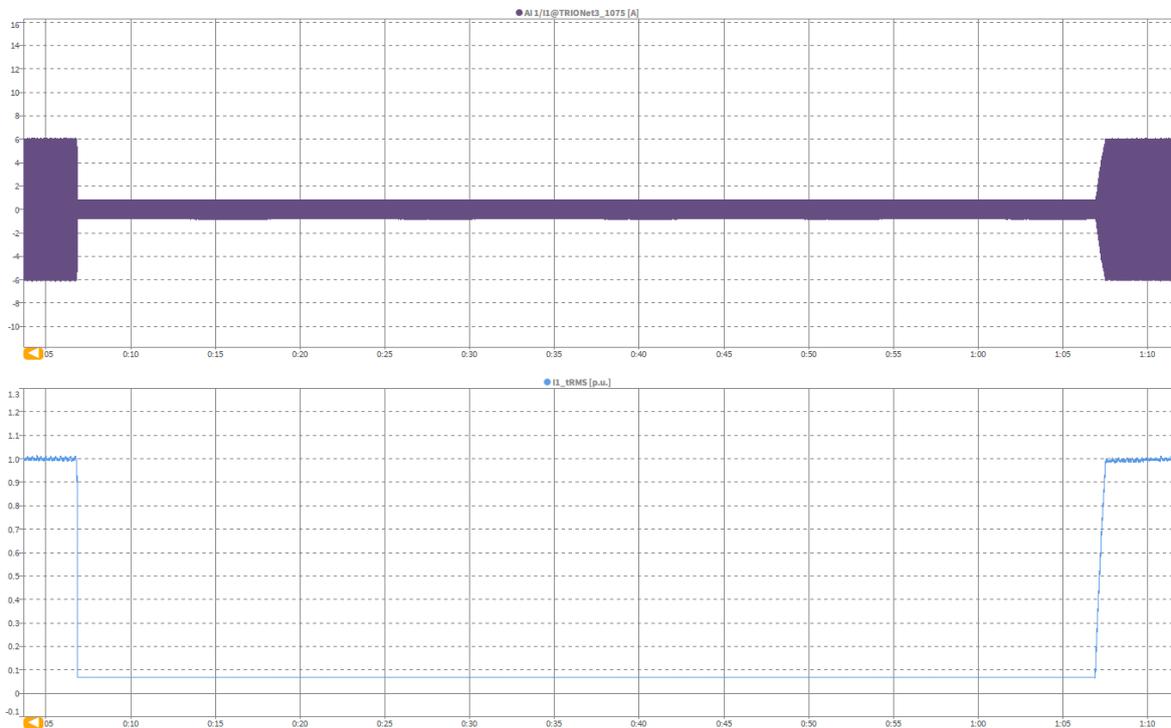
**Test 7.1 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve curve and RMS values of phase to natural voltages**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.1 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 100% load  
Instantaneous curve and RMS values of phase currents**



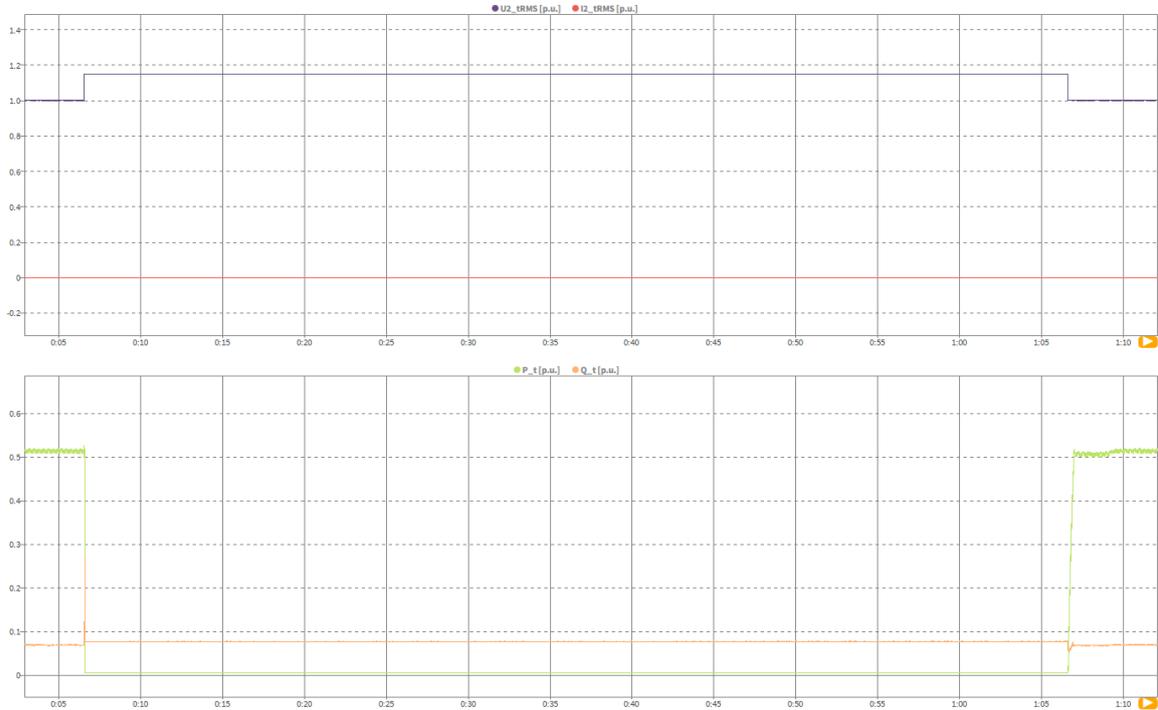
**Test 7.1 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 100% load  
Total values of active and reactive power**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.2 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 25% load**  
**Test overview (voltage, current, active and reactive power)**



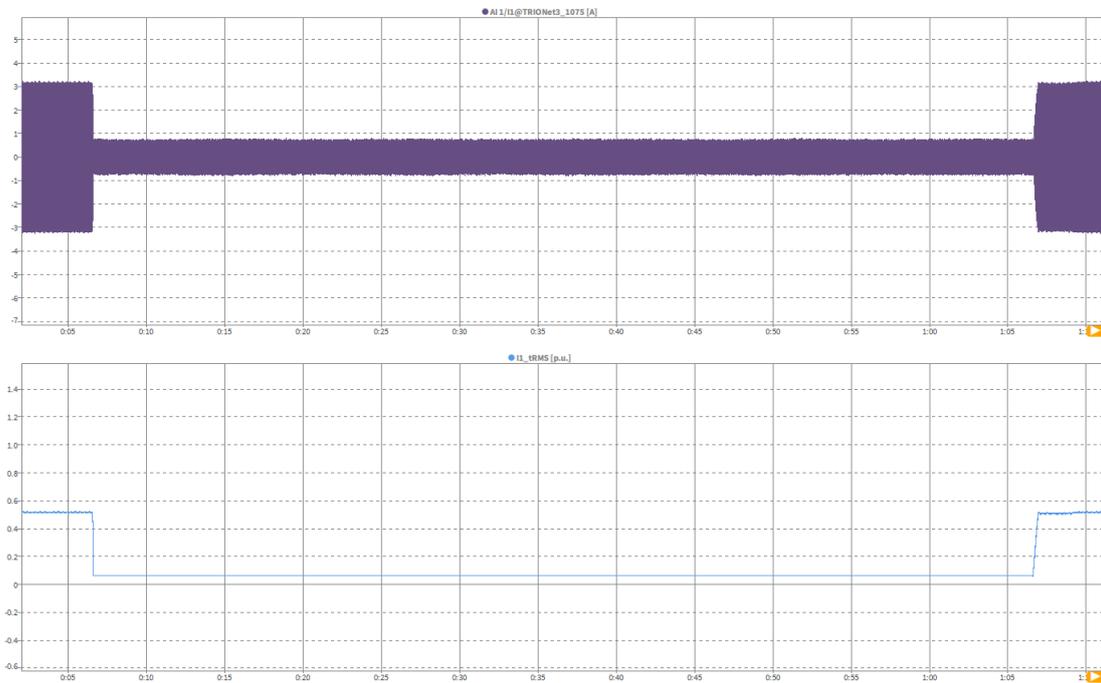
**Test 7.2 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.2 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 7.2 Depth of fault phase: 1.15 p.u.(U-N), balanced fault (type A), 25% load  
Total values of active and reactive power**

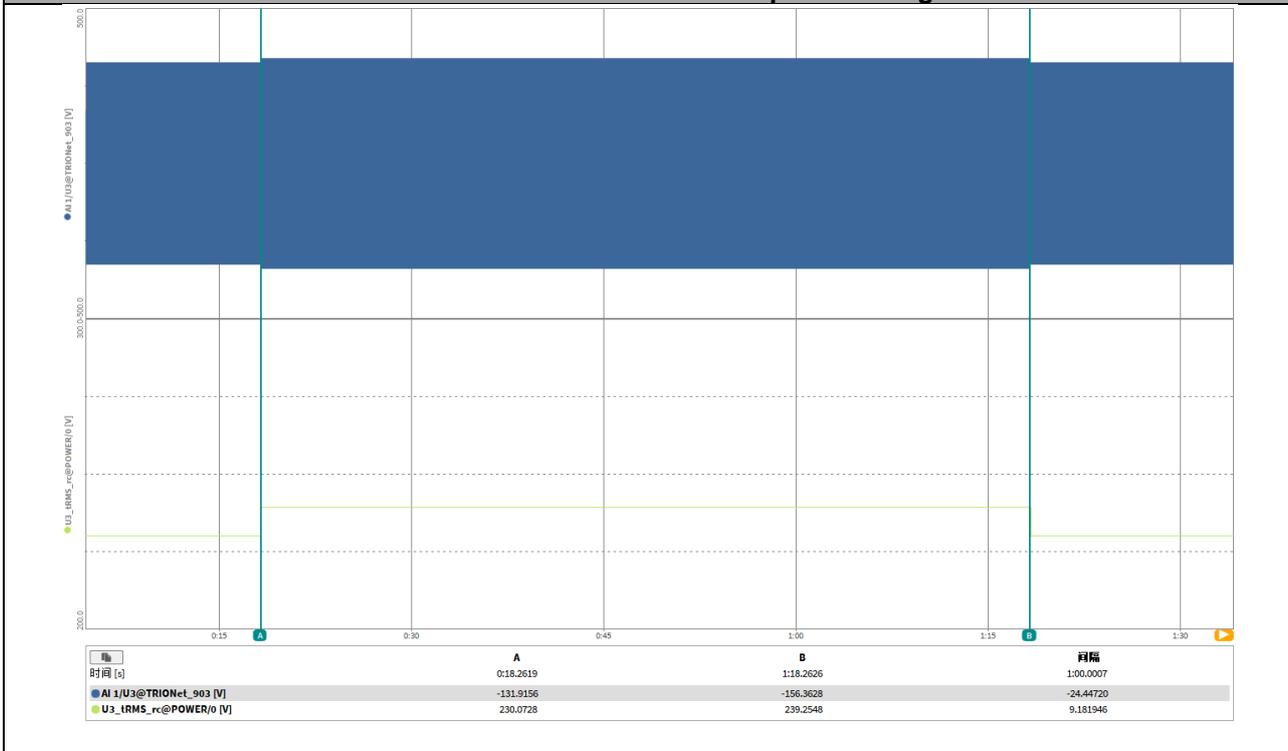


DIN VDE V 0124-100, VDE-AR-N 4105								
Clause	Requirement - Test				Result - Remark		Verdict	
Item	Condition					Measured value		
	No.	Parameter	Phase ref.	Time ref.	unit			
General Info.	0	Test number	--	--	--	7.3	7.4	
	1	Date	--	--	yyyy.mm.dd	2025.01.01	2025.01.01	
	2	Time (start of test)	--	--	hh:mm:ss.f	14:30	14:33	
	3	Fault type (phase)	--	--	--	D1	D1	
	4	Setting voltage depth	Phase conductor	--	--	p.u.	1.04	1.04
	5	Setting dip duration		--	--	--	60000	60000
	6	Point of fault entry( $t_1$ )	Total	--	--	ms	18262	18262
	7	Point of fault clearance( $t_2$ )	Total	--	--	ms	78262	78262
	8	Fault duration in empty load test	Total	--	--	ms	60000	60000
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.04	1.15	
10	Pos.		N/A			N/A		
Before dip <t1	11	Voltage	Line to neutral	t1-100s to t1	p.u.	1.00	1.00	
	12	Current	Pos.	t1-500ms to t1-100ms	p.u.	N/A	N/A	
	13	Active power	Total	t1-10s to t1	p.u.	1.00	0.52	
	14		Pos.			N/A	N/A	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.07	0.07	
	16		Pos.			N/A	N/A	
17	Cosφ	--	t1-10s to t1	--	0.998	0.990		
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.04	1.15	
	19	Line current	Phase 1	t1+60ms	p.u.	N/A	N/A	
	20		Phase 2			N/A	0.07	
	21		Phase 3			0.96	N/A	
	22	Line current	Phase 1	t1+100ms	p.u.	N/A	N/A	
	23		Phase 2			N/A	0.07	
	24		Phase 3			0.96	N/A	
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	1.01	0.01	
26	Pos.		N/A			N/A		
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	
	28	Active power	Total	t2+3s to t2+10s	p.u.	1.00	0.51	
	29		Pos.			N/A	N/A	
	30	Response time reactive power	Pos.	--	s	N/A	N/A	
	31	Reactive power	Total	t2+3s to t2+10s	p.u.	0.07	0.07	
	32		Pos.			N/A	N/A	
	33	Reactive power rising time	Pos.	--	s	N/A	N/A	
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	YES	YES	

DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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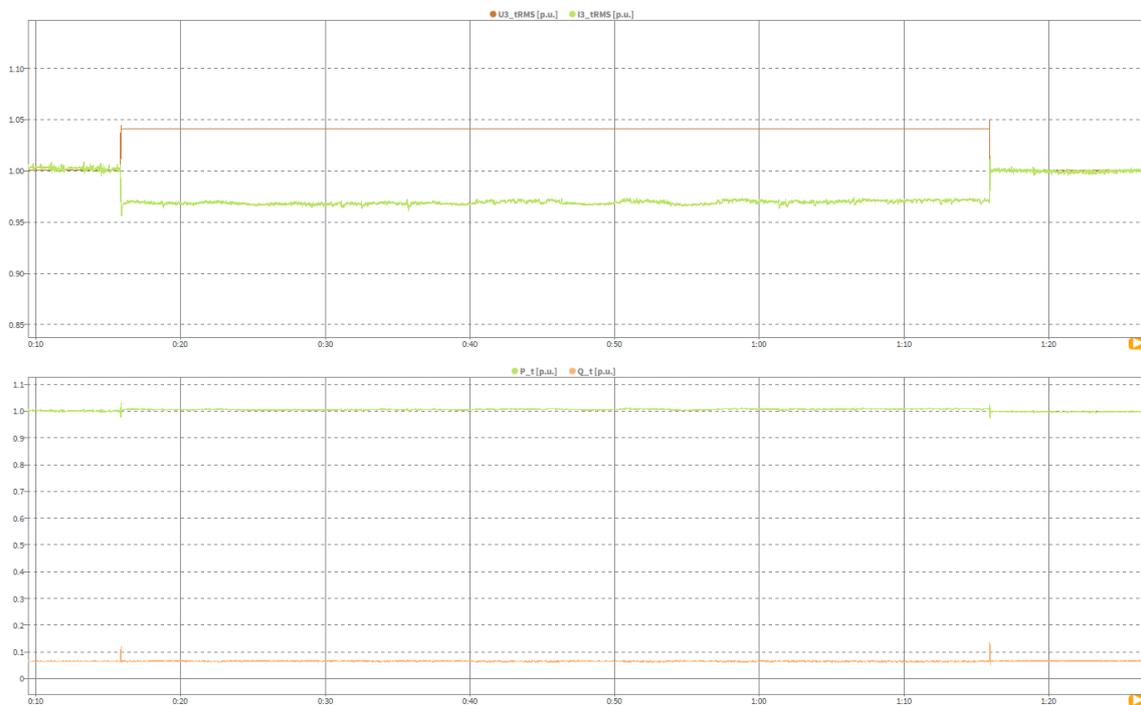
**Test 7.0.2 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), No load, Instantaneous and RMS values of phase voltages**



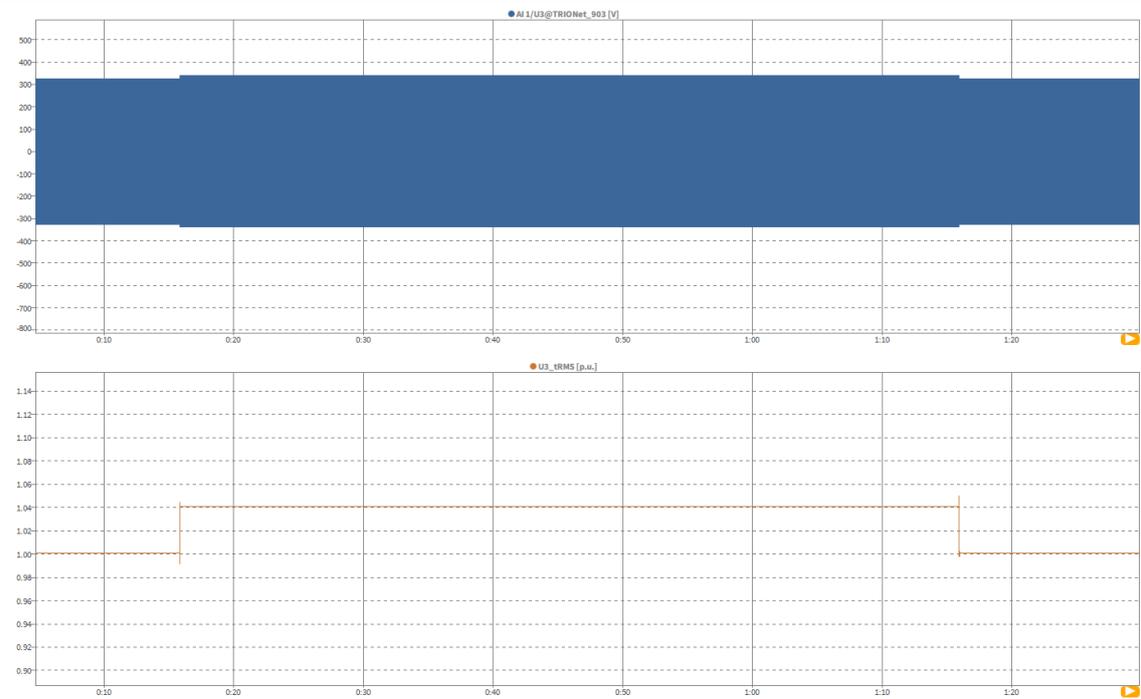
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.3 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Test overview (voltage, current, active and reactive power)**



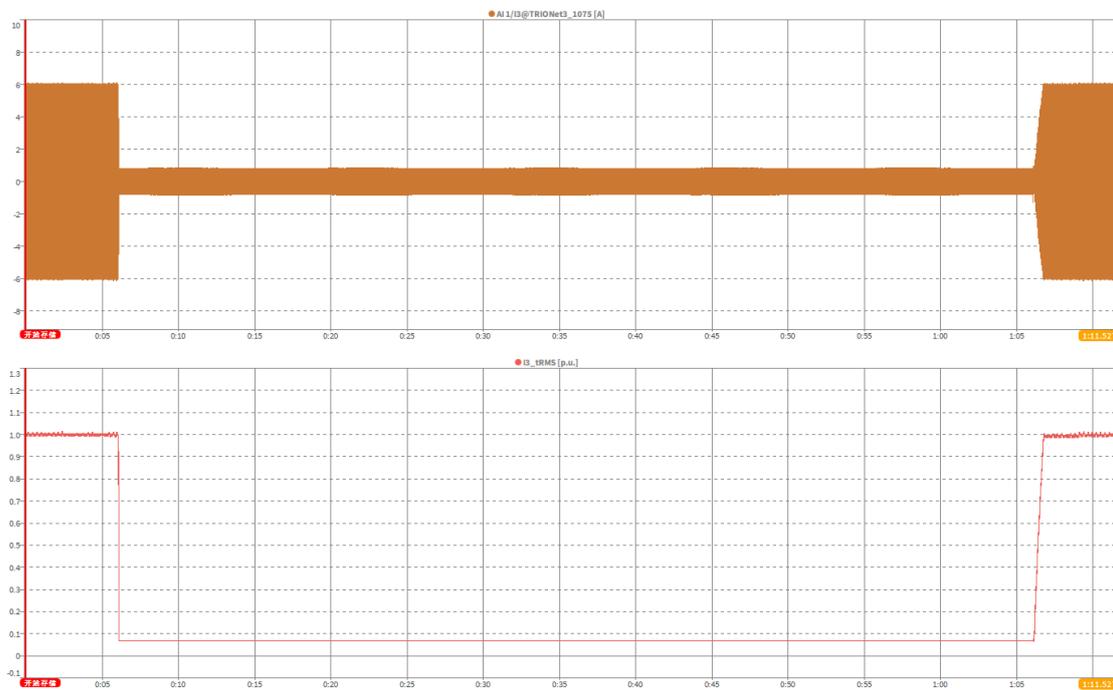
**Test 7.3 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve curve and RMS values of phase to natural voltages**



DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.3 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Instantaneous curve and RMS values of phase currents**



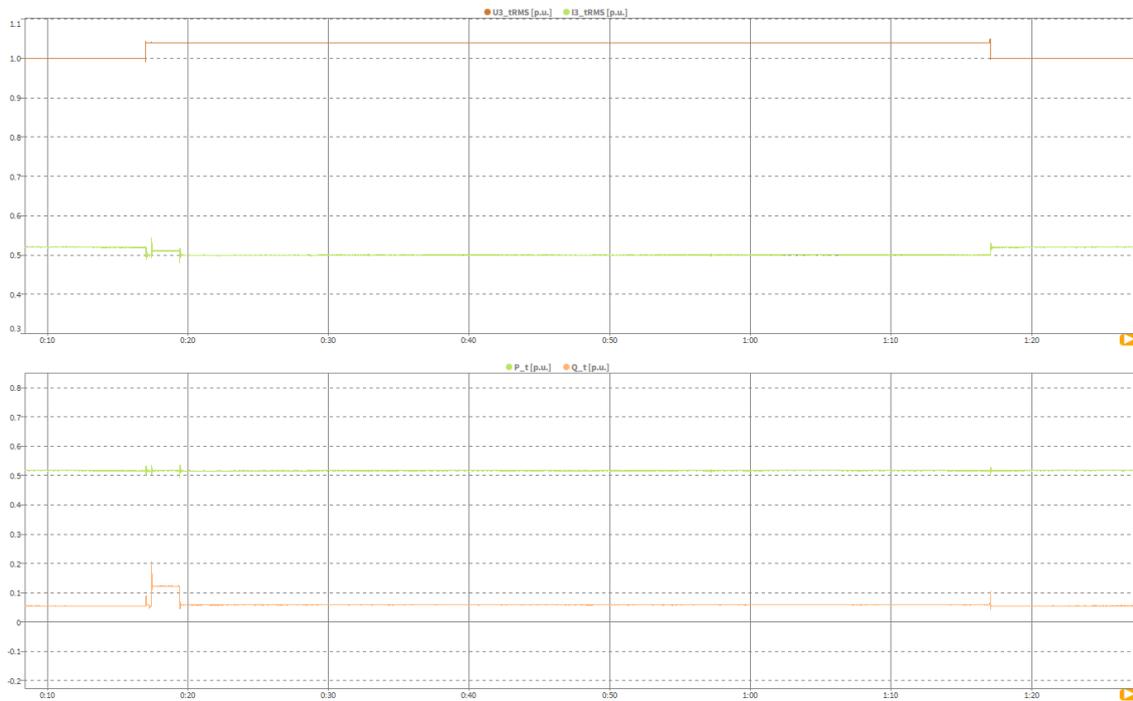
**Test 7.3 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 100% load  
Total values of active and reactive power**



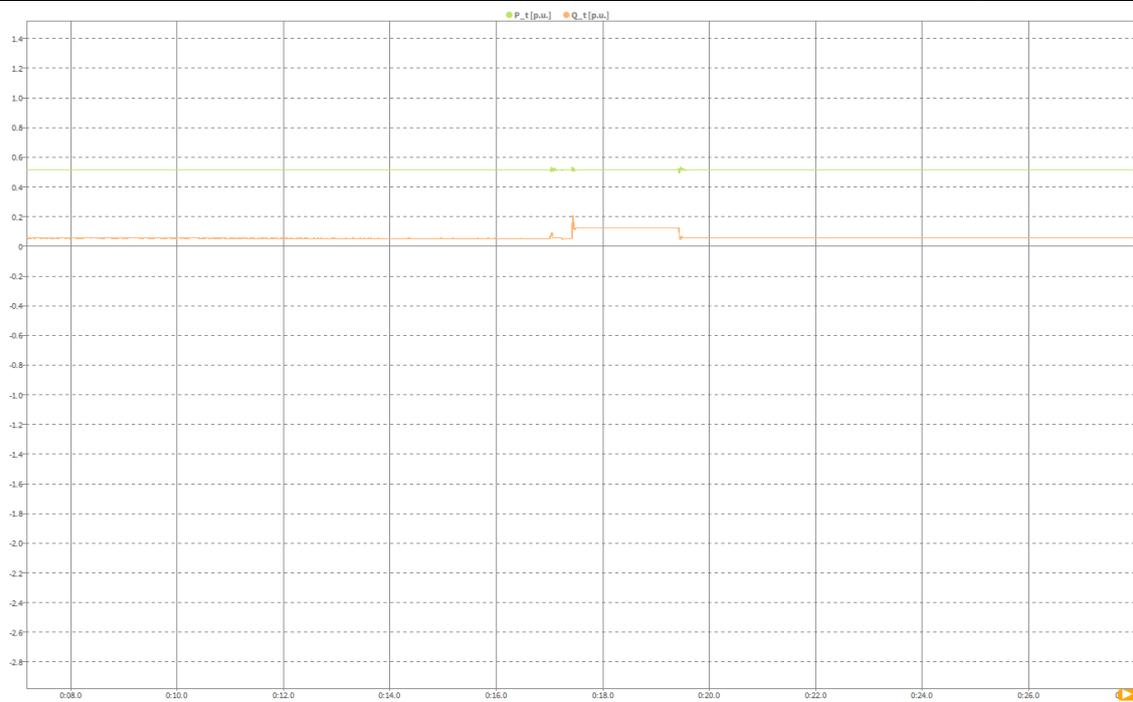
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.4 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Test overview (voltage, current, active and reactive power)**



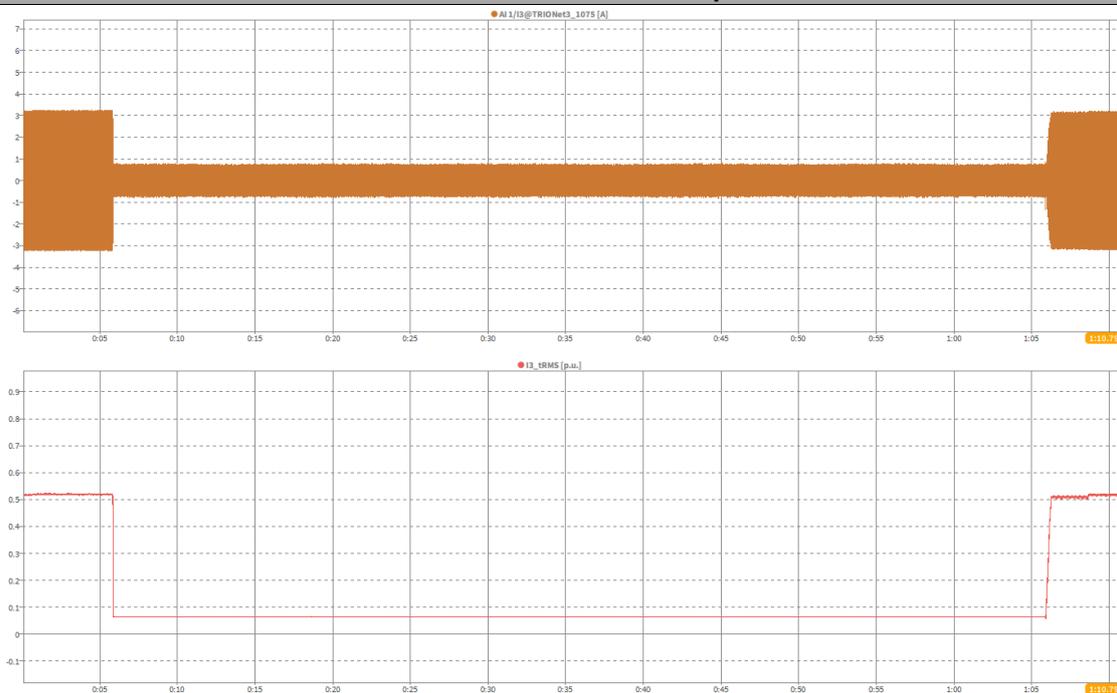
**Test 7.4 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 25% load**  
**Instantaneous curve curve and RMS values of phase to natural voltages**



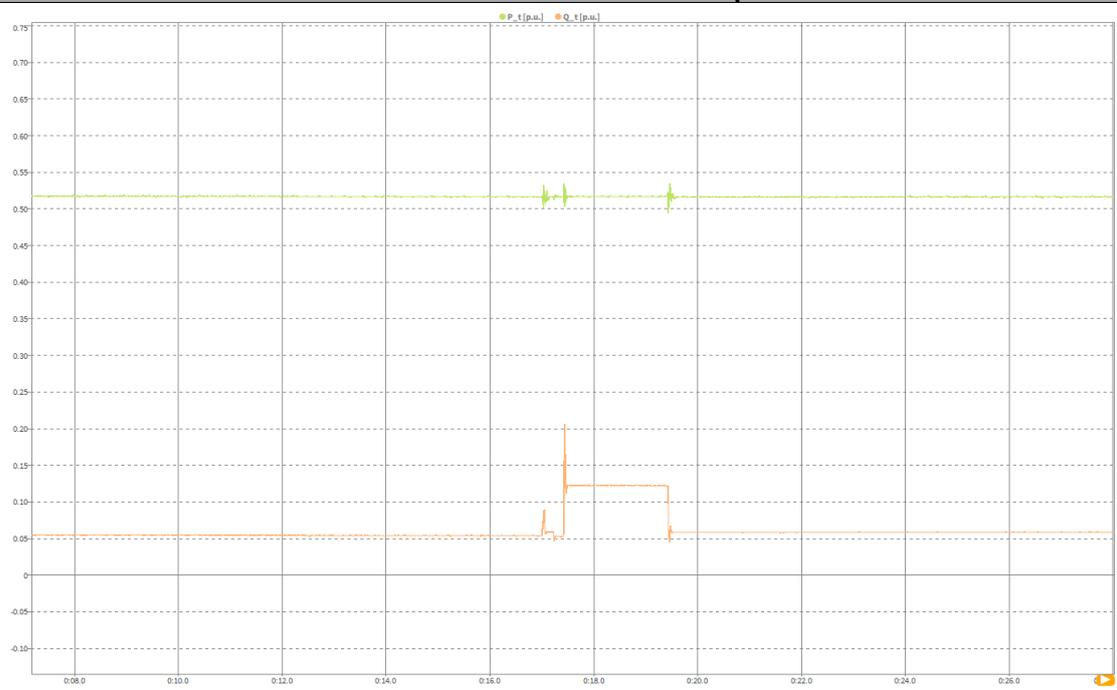
DIN VDE V 0124-100, VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
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**Test 7.4 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Instantaneous curve and RMS values of phase currents**



**Test 7.4 Depth of fault phase: 1.04 p.u.(W-N), Unbalanced fault (type D1), 25% load  
Total values of active and reactive power**



**Annex 1: Datasheet of the relay**顾客 Customer: 浙江万胜智能科技股份有限公司**1 品种 Type Model**1.1 种类 Type: 电磁继电器 Electromagnetic Relay1.2 型号 Part NO.: HF115F/012-2HS41.3 外形尺寸 Outline dimensions: 29mm×12.7mm×15.7mm1.4 触点形式 Contact Form: 2组常开 2 Form A1.5 触点材料 Contact Material: AgSnO<sub>2</sub>**2 安全认证 Safety Approvals**

认证机构 Certification Agency	认证号 File No.
UL/CUL	E134517
VDE	116934
CQC	CQC17002168381

上述认证号代表该产品取得相关认证,但具体认证内容请以我公司提交的认证证书为准。The above certificate No. is just a license No. Please refer to the certificates we supplied for detail information.

**3 线圈额定参数 Coil Rating**

at 23 °C

额定电压 Rated Voltage Vd. c.	动作电压 (1) Operate Voltage Vd. c.	释放电压 (1) Release Voltage Vd. c.	允许最大线圈电压 (2) Max Allowable Coil Voltage Vd. c.	线圈电阻 Coil Resistance  Ω	线圈功耗 Coil Power 大约 Approx. W
12	≤8.4	≥1.2	18	360×(1±10%)	0.4

备注: (1) 上述值为初始值。

(2) 允许最大线圈电压是指继电器线圈在短时间内能够承受的最大电压值。

Note: (1) The data shown above are initial values

(2) Maximum allowable coil voltage refers to the maximum voltage which relay coil could endure in a short period of time.

**4 触点参数 Contact Parameters**4.1 触点额定负载 Contact Rating: 8 A 250 Va. c.4.2 最大切换电流 Max Switching Current: 8 A4.3 最大切换电压 Max Switching Voltage: 250 Va. c.4.4 最小适用负载 Min Applicable Load: 6 V, 1 A**5 性能 Performance**

**5.1 接触电阻 Contact Resistance:** 100 mΩ max (at 6 Vd.c. 1A)。(四端法 Four Probe Method)

**5.2 动作时间 Operate Time:** ≤ 15 ms。

**5.3 释放时间 Release Time:** ≤ 8 ms。

**5.4 耐久性 Endurance**

**5.4.1 电耐久性 Electrical Endurance**

结构型式 Version	触点材料 Contact Material	触点负载 Contact Rating	环境温度 Ambient Temperature	通断比 ON: OFF	电耐久性 Electrical Endurance
4 型 type 4	AgSnO <sub>2</sub>	阻性负载 Resistive Load 8 A 250 Va.c.	常温 Room Temperature	1 s: 9 s	NO 端: 5×10 <sup>6</sup> 次 (ops)

注: 塑封型规格在电耐久性测试时需要打开外壳透气孔/For plastic sealed type, the venting-hole should be excised.

**5.4.2 机械耐久性 Mechanical Endurance**

结构型式 Version	触点负载 Contact Rating	环境温度 Ambient Temperature	通断比 ON: OFF	机械耐久性 Mechanical Endurance
4 型 type 4	无负载 No load	常温 Room Temperature	0.1s: 0.1s	1×10 <sup>7</sup> 次 (ops)

**5.5 介质耐电压 Dielectric Strength (漏电流 Leakage Current: 1 mA)**

**5.5.1 断开触点电路的各引出端之间** Between terminals of each opened contact circuit: 1000 Va.c. (50/60 Hz 1 min)。

**5.5.2 所有线圈引出端与所有触点电路引出端之间** Between all coil terminals and all contact circuit terminals: 5000 Va.c. (50/60 Hz 1 min)。

**5.5.3 各独立的触点电路的引出端之间** Between terminals of separate contact circuits: 2500 Va.c. (50/60 Hz 1 min)。

**5.6 绝缘电阻 Insulation Resistance**

**5.6.1 断开触点电路的各引出端之间** Between terminals of each opened contact circuit: 1000 MΩ (500 Vd.c.)。

**5.6.2 所有线圈引出端与所有触点电路引出端之间** Between all coil terminals and all contact circuit terminals: 1000 MΩ (500 Vd.c.)。

**5.6.3 各独立的触点电路的引出端之间** Between terminals of separate contact circuits: 1000 MΩ (500 Vd.c.)。

**5.7 线圈温升 Coil Temperature Rise:** 55 K max.

以 110% 额定电压激励, 触点负载 8 A. 环境温度: 85 ℃。

Coil voltage: 110% of the rated coil voltage, Contact load: 8 A. Environmental temperature is 85 ℃.

**5.8 振动 Vibration**

非励磁状态: 继电器长度垂直于振动方向, 频率 10 Hz~150 Hz 加速度 49 m/s<sup>2</sup>;

继电器长度平行于振动方向, 频率 10 Hz~150 Hz 加速度 14.7 m/s<sup>2</sup>。

No energized: Vibration direction vertical to the relay length, frequency 10 Hz~150 Hz acceleration 49 m/s<sup>2</sup>;

Vibration direction parallel to the relay length, frequency 10 Hz~150 Hz acceleration 14.7 m/s<sup>2</sup>.

励磁状态: 频率 10 Hz~150 Hz 加速度 98 m/s<sup>2</sup>。

Energized: Frequency 10 Hz~150 Hz acceleration 98 m/s<sup>2</sup>.

继电器外观、结构和性能不应有异常。It shall be no abnormalities in appearance, construction and performance.

**5.9 冲击 Shock**

稳定性: 98 m/s<sup>2</sup> (脉冲持续时间 11 ms), 6 次(三个相互垂直轴线的每一个方向 6 次, 总共 36 次), 闭合回路的断开或开路回路的闭合时间应不超过 100 μs。

Functional: 98m/s<sup>2</sup>(Duration 11ms), 6 shocks (six ops in both directions of each of the three mutually perpendicular axes, totally 36 ops), No opening or closing of any closed or opened contact circuit respectively shall exceed 100 μs.

强度: 980 m/s<sup>2</sup> (脉冲持续时间 6 ms), 6 次(三个相互垂直轴线的每一个方向 6 次, 总共 36 次) 继电器外观、结构和性能不应有异常。

Destructive: 980 m/s<sup>2</sup>(Duration 6 ms), 6 shocks (six ops in both directions of each of the three mutually perpendicular axes, totally 36 ops) There should be no abnormalities in appearance, construction and performance.

**5.10 引出脚强度 Terminal Strength**

PCB 引出脚: 在 PCB 引出脚轴线方向上施加 5 N 拉力或压力, 持续时间 6 s, 继电器应无异常。

PCB Terminals: No damage on the relay when applying 5 N tension or pressure for 6 s on the axis direction of terminals.

**5.11 耐焊接热 Soldering Heat Resistance**

**5.11.1 焊接温度 Soldering Temperature: (260±5) °C**

**5.11.2 焊接时间 Soldering Time: (3~5) s**

**5.12 焊接性能 Solderability**

继电器引出端在焊锡温度 (250±3) °C 下, 浸锡时间 (3±0.3) s 之后, 被浸锡部分应有 90% 以上连续覆盖一层锡层

Terminals dipped into the soldering bath should be 90% tin plated at (250±3) °C for (3±0.3) s.

**5.13 耐温性 Temperature Resistance**

**5.13.1 耐热 Heat Resistance**

(85±2) °C 温度中放置 16 h, 恢复常温 2 h 后, 继电器的结构及性能应无异常。

At (85±2) °C for 16h storage follow by 2 hours at room temperature, no damage on internal structure, all parameters conform.

#### 5.13.2 耐寒 Cold Resistance

(-40±2) °C 温度中放置 16 h, 恢复常温 2 h 后, 继电器的结构及性能应无异常。

At (-40±2) °C for 16h storage follow by 2 hours at room temperature, no damage on internal structure, all parameters conform.

#### 5.14 耐湿性 Moisture Resistance

在温度 (40±2) °C 湿度 90%~95% RH 中放置 16 h, 恢复常温 2 h 后, 继电器的结构及性能应无异常。且绝缘电阻应不小于 10 MΩ (500 Vd.c.)。

The humidity was 90%~95% RH at (40±2) °C for 16h storage follow by 2 hours at room temperature, no damage on internal structure, all parameters conform. Insulation resistance should be not less than 10 MΩ (500 Vd.c.).

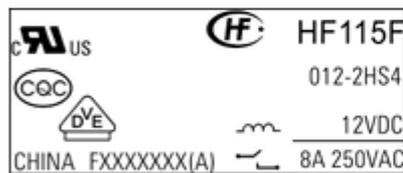
### 6 产品标识 Marking

6.1 外壳颜色 Case Color: 黑色 Black

6.2 印字位置 Marking Position: 顶面 Top Face

6.3 印字颜色 Ink Color: 激光 Laser

6.4 印字图



### 7 标准测试条件 Standard Test Conditions

7.1 温度 Temperature: 23°C ± 5°C

7.2 湿度 Humidity: 25%~75% RH

7.3 方向 Direction of Measurement: 任意 Free

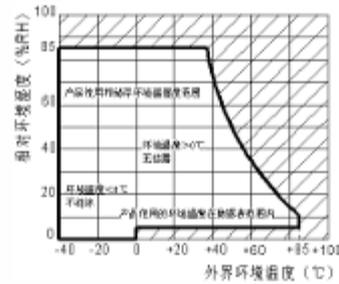
### 8 使用环境条件 Operate Ambient Conditions

8.1 环境温度 Ambient Temperature: -40 °C ~ 85 °C

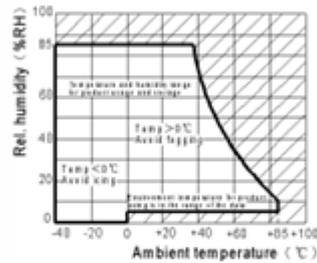
8.2 环境湿度 Ambient Humidity: 5%~85% RH

8.3 安装方向 Mounting Direction: 任意 Free

注: 使用环境条件不能导致继电器内部产生结露、结冰, 否则会导致继电器失效。另外, 湿度范围会随温度而有所不同, 因此请控制在下图所示的范围。



Note: The ambient environment of application shall not cause any dewing or icing inside the relay. Otherwise, the relay may not work properly. The humidity range varies with the temperature. Use within the range indicated in the graph below.



## 9 贮存条件 Storage Conditions

9.1 温度 Temperature: 0 °C ~ 40 °C

9.2 湿度 Humidity: 20%~80% RH

9.3 环境 Environment

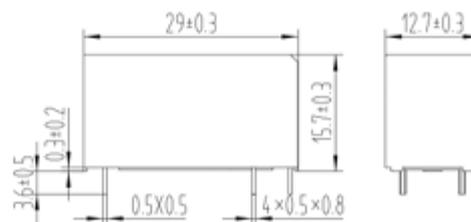
9.3.1 产品贮存场地不能有腐蚀性气体 Store in locations where the product is not exposed to corrosive gas.

9.3.2 贮存中应避免阳光直照产品 Avoid sunshine during storage.

9.3.3 堆码高度 Stacking Height: ≤ 7层 layers

## 10 产品结构 Configuration

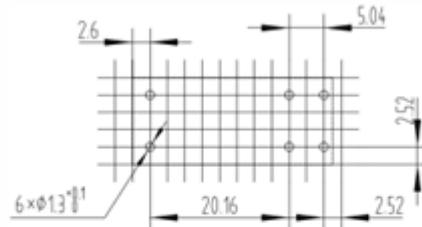
### 10.1 外形图 Outline Dimensions



### 10.2 接线图 (底视图) Wiring Diagram (Bottom View)



### 10.3 安装孔尺寸图 (底视图) PCB Layout (Bottom View)



注：产品外形尺寸未注尺寸公差及 PCB 板未注尺寸公差按下表执行。

Note: All unspecified tolerance (including outline dimensions and PC board dimensions) please refer to the following table.

产品外形尺寸未注尺寸公差 Outline dimensions with no tolerance specified mm		PCB 板未注尺寸公差 PC board dimensions with no tolerance specified mm
外形尺寸 Outline Dimensions	公差 Tolerance	±0.1
≤1	±0.2	
>1~5	±0.3	
>5	±0.4	

### 11 订货标记 Ordering Information

HF115F / 012 - 2H S 4

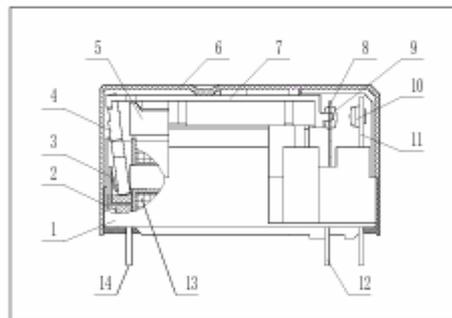
① ② ③ ④ ⑤

① 产品型号 Product part NO.	HF115F
② 线圈电压 Coil voltage	012:12 Vd.c.
③ 触点形式 Contact form	2H: 两组常开 (2 Form A)
④ 封装形式 Construction	S: 塑封型 (Plastic sealed)
⑤ 结构形式 Version	4: 5.0mm 两组 8A (5.0mm 2 pole 8A)

### 12 主要零部件 Important Parts And Components

序号 Serial No.	零部件名称 Parts And Components Name	材料名称 Material Name	备注 Remark
1	底座 Base	工程塑料 plastic	
2	线圈架 Bobbin	工程塑料 plastic	
3	压簧片 Hing spring	铜合金 Copper alloy	
4	衔铁 Armature	纯铁 Fe	
5	轭铁 Yoke	纯铁 Fe	
6	外壳 Cover	工程塑料 plastic	
7	推动块 Card	工程塑料 plastic	
8	动簧片 Mov. spring	铜合金 Copper alloy	
9	动触点 Mov. contact	银氧化锡 AgSnO <sub>2</sub>	
10	静触点 Stat. contact	银氧化锡 AgSnO <sub>2</sub>	
11	静簧片 Stat. spring	纯铜 Copper	
12	焊片 Terminal	纯铜 Copper	
13	漆包线 Coil wire	纯铜 Copper	
14	线圈引出脚 Coil Terminal	铜合金 Copper alloy	

结构图 Construction Schematic



### 13 其他说明 Others

**13.1** 对于塑封型产品,在焊接完成后,如果要进行清洗,请与宏发技术中心联系。Regarding the plastic sealed relay, if cleaning is necessary after soldering, please contact Hongfa R&D center.

**13.2** 避免在强磁场条件下使用继电器,外界强磁场会造成继电器动作和释放等参数发生变化。Avoid using relays in strong magnetic field because it will change the parameters of relay such as operate and release voltage.

**13.3** 对宏发而言,不可能评定继电器在每个应用领域、应用环境的所有性能参数要求,因而,客户应根据具体的使用条件选择与之相匹配的产品,若有疑问,请与宏发联系获得更多的技术支持。但产品的选型责任仅由客户负责。We could not evaluate all the performance and all the parameters for every possible application field and environment. Thus

the user should be in a right position to choose the suitable produce for their own application. If there is any query, please contact Hongfa for the technical service. However, it is the use' s responsibility to determine which product should be used only.

**13.4** 本产品规格书中标称的使用环境温度范围指的是产品在特定负载条件下的最大耐受温度范围。对于防爆规格产品的使用环境温度按相应防爆认证证书的规定。Operating temperature range in this specification refers to the maximum tolerable temperature range under specific load conditions. To explosion-proof product, the ambient temperature should conform to regulations in related explosion-proof certification.

**13.5** 继电器的电耐久性次数可能会因使用环境条件的不同而有差异。对于部分产品, 为获得更好的电耐久性性能, 需打开外壳的透气孔。产品的电耐久性性能详细情况见认证证书。本产品规格书中电耐久性所列的试验条件、触点负载可能未包含在认证证书中, 当使用环境条件与认证条件不同时, 电耐久性性能需要由具体试验确认。Differences in relay electrical endurance cycles would exist due to difference in operating ambient conditions. To some products, in order to better perform in electrical endurance, vent hole is required to be opened. The electrical endurance of the products detailed in the safety certificates. The test condition and contact rating for electrical endurance in this specification may not be included in the safety certificates, in case that the condition in real applications is different from safety certificates, the electrical endurance of the relay must be confirmed by tests.

**13.6** 本产品规格书供客户使用时参考, 其中, 未明确规定的要求条件, 参考“继电器术语解释及使用指南”(见 <https://source.cn.hongfa.com/pdf/web/viewer.html?file=\Uploads\Down\PDF\GR1001.pdf>)。The specification is for reference only. See to “Terminology and Guidelines”(see <https://source.cn.hongfa.com/pdf/web/viewer.html?file=\Uploads\Down\PDF\GR1005.pdf>) for more information.

**13.7** 为了保持继电器的性能, 请注意不要使继电器掉落或受到强冲击。掉落后的继电器建议不再使用。To maintain the performances of relays, please do not make the relay drop or be shocked strongly. Suggest that the relays dropped not be used.

**13.8** 规格书内的各项性能参数是基于标准测试条件下测得的初始值。All the performance data listed in the datasheet are the initial values tested under standard testing condition.

**13.9** 请避免让继电器在含有机硅的环境下使用，否则有机硅进入继电器内部后，有可能会导致继电器触点加速失效。使用环境气体中，如果含有水汽及 H<sub>2</sub>S、SO<sub>2</sub>、NO<sub>2</sub>、Cl、P、粉尘等以及目前未知的有害物质、元素，可能会导致继电器使用过程中，触点发生电阻变大、接触不良等。以上情况下，请对产生有害物质、元素的物料进行管控或使用塑封继电器规格，并进行相关试验验证，确认是满足使用要求。Please avoid using the relay in an environment containing organic silicon, otherwise the entry of organic silicon into the relay may acceleration contact failure. If there are harmful substances and elements such as water vapor, H<sub>2</sub>S, SO<sub>2</sub>, NO<sub>2</sub>, Cl, P, dust, etc. , as well as unknown harmful substances and elements, In the use of environmental gases, it may lead to increased contact resistance and poor contact during the use of relays. In the above situations, please control the materials that produce harmful substances and elements or use plastic sealed type, and arrange relevant tests to confirm that it meet the requirements for actual use.

**13.10** 环保措施 Environmental Protection

宏发产品均符合 RoHS 要求。Hongfa products are all RoHS compliant.

**13.11** 宏发保留对产品更改的权利，客户在首次下单之前应确认此规格书内容，必要时可要求我司提供新的规格书。Hongfa reserves the right to make changes. Customers should reconfirm the contents of the specification before first orders and ask for us to supply a new specification if necessary.

**13.12** 事前协议事项 Priority Consultation

无

## Annex 2: Form

<b>E.4 Unit certificate (VDE-AR-N 4105:2018-11)</b> <i>E.4 Einheitenzertifikat</i>		
<b>Manufacturer / Address:</b> <i>Hersteller / Adresse:</i>	Solenso electronic materials Co., LTD. 4F., No. 56, Zili 5th St., Zhongli Dist., Taoyuan City 320, Taiwan	
<b>Type of power generation unit:</b> <i>Typ Erzeugungseinheit:</i>	SG1600, SG2000	
<input checked="" type="checkbox"/> Inverter <i>umrichter</i>	<input type="checkbox"/> Asynchronous generator <i>Asynchrongenerator</i>	<input type="checkbox"/> Synchronos generator <i>Synchrongenerator</i>
<input type="checkbox"/> Stirling generator <i>Stirlinggenerator</i>	<input type="checkbox"/> Fuel cell <i>Brennstoffzelle</i>	<input type="checkbox"/> Others <i>andere</i>
<b>Rated values</b> <i>Bemessungswerte</i>	SG1600	SG2000
<b>Max. active power <math>P_{E_{max}}</math></b> <i>Max. Wirkleistung <math>P_{E_{max}}</math></i>	1600 (W)	2000 (W)
<b>Max. apparent power <math>S_{E_{max}}</math></b> <i>Max. Scheinleistung <math>S_{E_{max}}</math></i>	1600 (VA)	2000 (VA)
<b>Rated voltage:</b> <i>Bemessungsspannung:</i>	230, L/N/PE	
<b>Rated current:</b> <i>Bemessungsstrom:</i>	7.82 (A)	8.69 (A)
<b>Network connection rule:</b> <i>Netzanschlussregel</i>	<b>VDE-AR-N 4105 „Erzeugungsanlagen am Niederspannungsnetz“</b> <i>Technische Mindestanforderungen für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Niederspannungsnetz</i>	
<b>Test requirement:</b> <i>Prüfanforderung</i>	<b>DIN VDE V 0124-100 (VDE V 0124-100) „Netzintegration von Erzeugungsanlagen – Niederspannung“</b> <i>Prüfanforderungen an Erzeugungseinheiten vorgesehen zum Anschluss und Parallelbetrieb am Niederspannungsnetz</i>	
<b>The power generation unit described above meets the requirements of VDE-AR-N 4105.</b> <i>Die oben bezeichnete Erzeugungseinheit erfüllt die Anforderungen der VDE-AR-N 4105.</i>		

<b>E.5 Test report "Utility interactive" for power generation units with an input current &gt; 75A (VDE-AR-N 4105:2018-11)</b> <i>E.5 Prüfbericht „Netzurückwirkungen“ für Erzeugungseinheiten mit einem Eingangsstrom &gt; 75 A</i>					
<b>Manufacturer:</b> <i>Anlagenhersteller</i>		Solenso electronic materials Co., LTD.			
<b>Manufacturer specifications:</b> <i>Herstellerangaben</i>		<b>Type (Hybrid-inverter):</b> <i>Anlagenart (PV-WR):</i>		PV Microinverter	
		<b>maximum active power</b> $P_{E_{max}}$ : <i>maximale Wirkleistung</i> $P_{E_{max}}$ :		SG1600	SG2000
				1600 (W)	2000 (W)
		<b>Rated voltage:</b> <i>Bemessungsspannung:</i>		230, L/N/PE	
<b>Measuring period:</b> <i>Messzeitraum:</i>		<b>From 2025-01-01 to 2025-01-07</b> <i>Vom 2025-01-01 bis 2025-01-07</i>			
<b>Rapid voltage changes</b> <i>Schnelle Spannungsänderungen</i>					
<b>Model / Modell:</b> SG2000					
<b>Switching on without specification</b> <i>Einschalten ohne Vorgabe (zum Primärenergieträger)</i>			$k_i$ :	0.089	
<b>Most unfavorable case when switching the generator</b> <i>Ungünstigster Fall beim Umschalten der Generatorstufen</i>			$k_i$ :	0.698	
<b>Switching on at rated power</b> <i>Einschalten bei Nennbedingungen (des Primärenergieträgers)</i>			$k_i$ :	0.662	
<b>Switch off at rated power</b> <i>Ausschalten bei Bemessungsleistung</i>			$k_i$ :	1.049	
<b>Worst-case value of all switching operations</b> <i>Schlechtester Wert aller Schaltvorgänge</i>			$k_{imax}$ :	1.049	
<i>Flicker</i>	Angle of network impedance $\psi_k$ : <i>Netzimpedanzwinkel <math>\psi_k</math></i>	32°	50°	70°	85°
	Coefficient of system flicker $c_\psi$ : <i>Anlagenflickerbeiwert <math>c_\psi</math></i>	180.241	--	--	--

Test report "Utility interactive" for power generation units with an input current > 75A (VDE-AR-N 4105:2018-11) Prüfbericht „Netzurückwirkungen“ für Erzeugungseinheiten mit einem Eingangsstrom > 75 A										
Extract from test report for unit certificate "Determination of electrical properties" Auszug aus dem Prüfbericht für Gerätezertifikat "Bestimmung elektrischer Eigenschaften"						Report No.: 6209661.50 Bericht Nr.: 6209661.50				
Harmonics / Oberschwingungen: Model / Modell: SG1600 Tested according to DIN VDE V 0124-100 clause 5.2.4 / geprüft nach DIN VDE V 0124-100 Punkt 5.2.4										
Active power Wirkleistung P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
Harmonic order Ordnungszahl	I [%]	I [%]	I [%]	I [%]	I [%]					
2	0.023	0.023	0.046	0.023	0.023	0.023	0.023	0.023	0.023	0.046
3	0.853	3.157	3.157	3.364	2.880	3.341	3.364	3.134	3.295	3.802
4	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
5	0.668	0.922	0.829	1.359	0.991	1.313	1.336	1.106	0.922	0.714
6	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
7	0.945	0.184	0.115	1.014	0.507	0.392	0.461	0.714	0.783	0.530
8	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
9	0.922	0.323	0.369	1.014	0.945	0.899	0.991	1.313	1.498	1.705
10	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
11	0.783	0.461	0.553	0.829	0.991	1.060	1.175	1.382	1.544	1.659
12	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
13	0.438	0.392	0.691	0.760	0.968	1.198	1.244	1.313	1.359	1.475
14	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
15	0.276	0.346	0.438	0.599	0.806	1.198	1.290	1.152	1.083	1.359
16	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
17	0.253	0.069	0.438	0.507	0.645	1.060	1.244	1.083	0.968	0.806
18	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
19	0.415	0.392	0.576	0.415	0.484	0.806	1.014	0.922	0.829	0.876
20	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
21	0.714	0.622	0.438	0.369	0.438	0.599	0.691	0.714	0.760	0.530
22	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
23	0.329	0.360	0.346	0.461	0.461	0.392	0.369	0.461	0.499	0.499
24	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
25	0.468	0.483	0.230	0.484	0.484	0.230	0.207	0.207	0.438	0.461
26	0.023	0.023	0.069	0.023	0.000	0.000	0.000	0.000	0.000	0.023
27	0.484	0.576	0.323	0.415	0.461	0.207	0.230	0.023	0.230	0.369
28	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
29	0.438	0.323	0.276	0.207	0.415	0.323	0.276	0.115	0.046	0.323
30	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
31	0.369	0.161	0.161	0.115	0.323	0.369	0.276	0.184	0.115	0.138
32	0.023	0.023	0.023	0.023	0.000	0.000	0.000	0.000	0.000	0.023
33	0.276	0.115	0.207	0.115	0.253	0.323	0.276	0.207	0.230	0.115
34	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.000	0.000	0.023
35	0.161	0.161	0.276	0.046	0.207	0.207	0.300	0.184	0.253	0.161
36	0.023	0.023	0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.023
37	0.230	0.230	0.276	0.207	0.115	0.069	0.253	0.161	0.253	0.276
38	0.023	0.023	0.069	0.000	0.000	0.000	0.000	0.023	0.000	0.023
39	0.246	0.253	0.115	0.192	0.138	0.115	0.161	0.161	0.184	0.146
40	0.023	0.023	0.046	0.023	0.000	0.000	0.000	0.023	0.000	0.023

## Test report "Utility interactive" for power generation units with an input current > 75A (VDE-AR-N 4105:2018-11)

### Prüfbericht „Netzurückwirkungen“ für Erzeugungseinheiten mit einem Eingangsstrom > 75 A

Extract from test report for unit certificate  
**"Determination of electrical properties"**  
*Auszug aus dem Prüfbericht für Gerätezertifikat*  
*"Bestimmung elektrischer Eigenschaften"*

Report No.: 6209661.50  
 Bericht Nr.: 6209661.50

Interharmonics / Zwischenharmonische:  
 Model / Modell: SG2000

Tested according to DIN VDE V 0124-100 clause 5.2.4 / geprüft nach DIN VDE V 0124-100 Punkt 5.2.4

Active power Wirkleistung P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
Frequency Frequenz [Hz]	I [%]									
75	0.092	0.069	0.069	0.046	0.046	0.046	0.046	0.046	0.069	0.084
125	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.046	0.038
175	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.046	0.045
225	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.046	0.042
275	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022
325	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022
375	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022
425	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022
475	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022
525	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
575	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
625	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
675	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
725	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
775	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.022
825	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
875	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
925	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
975	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1025	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1075	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1125	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1175	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1225	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1275	0.069	0.069	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1325	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1375	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1425	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1475	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1525	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1575	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1625	0.069	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1675	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.023	0.023
1725	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.023	0.023	0.023
1775	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.023	0.023	0.023
1825	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023
1875	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023
1925	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023
1975	0.026	0.026	0.026	0.026	0.023	0.023	0.023	0.026	0.023	0.023

## Test report "Utility interactive" for power generation units with an input current > 75A (VDE-AR-N 4105:2018-11)

### Prüfbericht „Netzurückwirkungen“ für Erzeugungseinheiten mit einem Eingangsstrom > 75 A

Extract from test report for unit certificate  
**"Determination of electrical properties"**  
*Auszug aus dem Prüfbericht für Gerätezertifikat*  
*"Bestimmung elektrischer Eigenschaften"*

Report No.: 6209661.50  
 Bericht Nr.: 6209661.50

Higher Frequencies / *Höhere Frequenzen:*

Model / *Modell:* SG1600

Tested according to DIN VDE V 0124-100 clause 5.2.4 / *geprüft nach DIN VDE V 0124-100 Punkt 5.2.4*

Active power <i>Wirkleistung</i> P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
Frequency <i>Frequenz</i> [kHz]	I [%]									
2.1	0.007	0.004	0.006	0.005	0.007	0.003	0.002	0.002	0.002	0.006
2.3	0.006	0.002	0.007	0.002	0.010	0.005	0.004	0.002	0.002	0.005
2.5	0.004	0.003	0.003	0.002	0.003	0.008	0.002	0.003	0.003	0.004
2.7	0.002	0.004	0.001	0.002	0.003	0.004	0.003	0.003	0.002	0.004
2.9	0.002	0.002	0.001	0.001	0.002	0.003	0.003	0.001	0.002	0.004
3.1	0.002	0.003	0.002	0.003	0.002	0.005	0.002	0.001	0.003	0.003
3.3	0.002	0.003	0.004	0.003	0.001	0.002	0.005	0.001	0.001	0.003
3.5	0.001	0.004	0.003	0.002	0.002	0.002	0.005	0.003	0.003	0.004
3.7	0.002	0.003	0.002	0.006	0.002	0.001	0.002	0.005	0.004	0.004
3.9	0.002	0.001	0.002	0.005	0.001	0.001	0.001	0.004	0.004	0.004
4.1	0.001	0.002	0.001	0.005	0.001	0.001	0.002	0.002	0.002	0.002
4.3	0.001	0.001	0.001	0.003	0.001	0.001	0.002	0.001	0.002	0.002
4.5	0.003	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.003	0.003
4.7	0.003	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.004
4.9	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.002	0.003
5.1	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.002	0.001
5.3	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.002	0.003
5.5	0.002	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002	0.002
5.7	0.002	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
5.9	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.002	0.002
6.1	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.002	0.003	0.002
6.3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
6.5	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.002
6.7	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.001
6.9	0.001	0.002	0.001	0.001	0.001	0.000	0.002	0.001	0.001	0.002
7.1	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.002	0.002	0.002
7.3	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.002	0.003	0.002
7.5	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002
7.7	0.001	0.001	0.001	0.003	0.001	0.001	0.000	0.001	0.001	0.001
7.9	0.001	0.001	0.001	0.003	0.001	0.001	0.000	0.002	0.001	0.001
8.1	0.001	0.002	0.002	0.002	0.001	0.002	0.001	0.002	0.002	0.002
8.3	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.002	0.003
8.5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
8.7	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8.9	0.001	0.002	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.001

### Test report "Utility interactive" for power generation units with an input current > 75A (VDE-AR-N 4105:2018-11)

#### Prüfbericht „Netzurückwirkungen“ für Erzeugungseinheiten mit einem Eingangsstrom > 75 A

Extract from test report for unit certificate  
**"Determination of electrical properties"**  
*Auszug aus dem Prüfbericht für Gerätezertifikat*  
*"Bestimmung elektrischer Eigenschaften"*

Report No.: 6209661.50  
 Bericht Nr.: 6209661.50

Higher Frequencies / Höhere Frequenzen:

Model / Modell: SG2000

Tested according to DIN VDE V 0124-100 clause 5.2.4 / geprüft nach DIN VDE V 0124-100 Punkt 5.2.4

Active power Wirkleistung P/P <sub>n</sub> [%]	10	20	30	40	50	60	70	80	90	100
Frequency Frequenz [kHz]	I [%]									
2.1	0.008	0.005	0.007	0.006	0.008	0.004	0.003	0.003	0.003	0.007
2.3	0.007	0.003	0.008	0.003	0.011	0.006	0.005	0.003	0.003	0.006
2.5	0.005	0.004	0.004	0.003	0.004	0.009	0.003	0.004	0.004	0.005
2.7	0.003	0.005	0.002	0.003	0.004	0.005	0.004	0.004	0.003	0.005
2.9	0.003	0.003	0.002	0.002	0.003	0.004	0.004	0.002	0.003	0.005
3.1	0.003	0.004	0.003	0.004	0.003	0.006	0.003	0.002	0.004	0.004
3.3	0.003	0.004	0.005	0.004	0.002	0.003	0.006	0.002	0.002	0.004
3.5	0.002	0.005	0.004	0.003	0.003	0.003	0.006	0.004	0.004	0.005
3.7	0.003	0.004	0.003	0.007	0.003	0.002	0.003	0.006	0.005	0.005
3.9	0.003	0.002	0.003	0.006	0.002	0.002	0.002	0.005	0.005	0.005
4.1	0.002	0.003	0.002	0.006	0.002	0.002	0.003	0.003	0.003	0.003
4.3	0.002	0.002	0.002	0.004	0.002	0.002	0.003	0.002	0.003	0.003
4.5	0.004	0.002	0.003	0.002	0.003	0.002	0.002	0.002	0.004	0.004
4.7	0.004	0.003	0.002	0.003	0.003	0.002	0.003	0.003	0.003	0.005
4.9	0.002	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.003	0.004
5.1	0.002	0.002	0.002	0.002	0.002	0.004	0.002	0.003	0.003	0.002
5.3	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.003	0.004
5.5	0.003	0.002	0.002	0.003	0.002	0.003	0.002	0.002	0.003	0.003
5.7	0.003	0.002	0.003	0.002	0.002	0.003	0.002	0.002	0.002	0.002
5.9	0.002	0.002	0.003	0.002	0.002	0.003	0.002	0.002	0.003	0.003
6.1	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.003	0.004	0.003
6.3	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003
6.5	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.003
6.7	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.001	0.002
6.9	0.002	0.003	0.002	0.002	0.002	0.001	0.003	0.002	0.002	0.003
7.1	0.002	0.002	0.002	0.002	0.002	0.001	0.003	0.003	0.003	0.003
7.3	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.003	0.004	0.003
7.5	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.003	0.003
7.7	0.002	0.002	0.002	0.004	0.002	0.002	0.001	0.002	0.002	0.002
7.9	0.002	0.002	0.002	0.004	0.002	0.002	0.001	0.003	0.002	0.002
8.1	0.002	0.003	0.003	0.003	0.002	0.003	0.002	0.003	0.003	0.003
8.3	0.002	0.002	0.002	0.003	0.002	0.002	0.001	0.002	0.003	0.004
8.5	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003
8.7	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
8.9	0.002	0.003	0.002	0.003	0.002	0.002	0.001	0.002	0.002	0.002

<b>E.7 Requirement for the NS protection test report (VDE-AR-N 4105:2018-11)</b>			
<b>E.7 Anforderungen an den Prüfbericht zum NA-Schutz</b>			
<b>Test report NS protection</b> <i>Prüfbericht NA-Schutz</i>			
<b>Type of NS protection:</b> <i>Typ NA-Schutz:</i>	<b>Integrated NS protection</b> <i>Integrierter NA-Schutz</i>		
<b>Software version:</b> <i>Software version:</i>	V1.03		
<b>Manufacturer:</b> <i>Hersteller:</i>	Solenso electronic materials Co., LTD.		
<b>Measuring period:</b> <i>Messzeitraum:</i>	<b>From 2023-10-28 to 2024-04-11</b> <i>Vom 2023-10-28 to 2024-04-11</i>		
	<b>Inverter</b> <i>Umrichter</i>		
<b>Protection function</b> <i>Schutzfunktion</i>	<b>Setting tripping value</b> <i>Einstellwert</i>	<b>Measured tripping value</b> <i>Auslösewert</i>	<b>Measured tripping time</b> <i>Auslösezeit</i> <i>NA-Schutz</i>
<b>Rise-in-voltage protection <math>U &gt;&gt;</math></b> <i>Spannungssteigerungsschutz <math>U &gt;&gt;</math></i>	$1.25 * U_n$	288.9 V	148.4 ms
<b>Rise-in-voltage protection <math>U &gt;</math></b> <i>Spannungssteigerungsschutz <math>U &gt;</math></i>	$1.1 * U_n$	--	$\leq 100 \text{ ms} *$
<b>Voltage drop protection <math>U &lt;</math></b> <i>Spannungsrückgangsschutz <math>U &lt;</math></i>	$0.8 * U_n$	183.9 V	3225.0ms
<b>Voltage drop protection <math>U &lt;&lt;</math></b> <i>Spannungsrückgangsschutz <math>U &lt;&lt;</math></i>	$0.45 * U_n$	104.9 V	352.0 ms
<b>Frequency decrease protection <math>f &lt;</math></b> <i>Frequenzrückgangsschutz <math>f &lt;</math></i>	47.5 Hz	47.52 Hz	110.0 ms
<b>Frequency decrease protection <math>f &gt;</math></b> <i>Frequenzsteigerungsschutz <math>f &gt;</math></i>	51.5 Hz	51.48 Hz	112.0 ms
* The rise-in voltage protection as a running 10-minute mean value, Max. disconnecting time is 509.0 s. * Der anstiege Spannungsschutz als laufender 10-Minuten-Mittelwert, Max. Trennzeit beträgt 509.0 s.			
<b>The tripping time covers the period from the limit value violation <math>U/f</math> to the tripping signal to the interface switch.</b> <i>Die Auslösezeit umfasst den Zeitraum von der Grenzwertverletzung <math>U/f</math> bis zum Auslösesignal an den Kuppelschalter.</i>			
<b>When planning the power generation system, the inherent time of the interface switch must be added to the highest time value determined above.</b> <i>Bei der Planung der Erzeugungsanlage ist die Eigenzeit des Kuppelschalters zum höchsten oben ermittelten Zeitwert zu addieren.</i>			
<b>The switch-off time (total of the tripping time NS protection plus the inherent time of the interface switch) must not exceed 200 ms.</b> <i>Die Abschaltzeit (Summe der Auslösezeit NA-Schutz zzgl. Eigenzeit des Kuppelschalters) darf 200 ms nicht überschreiten.</i>			
<input checked="" type="checkbox"/> <b>By integrated NS Protection</b> <i>Bei integriertem NA-Schutz</i>			
<b>Assigned to PGU type:</b> <i>Typ Erzeugungseinheit:</i>	SG1600, SG2000		
<b>Integrated interface switch type:</b> <i>Typ integrierter Kuppelschalter</i>	Xiamen Hongfa Electroacoustic Co.,Ltd. Relay: HF115F/012-2HS4		
<b>Interface switch own time with integrated NS protection</b> <i>Eigenzeit des Kuppelschalters bei integriertem NA-Schutz</i>	Operation time: max 15 ms; Release time: max 8 ms		
<b>The verification of the full function chain "NS protection- Interface switch" has yield to intended disconnection.</b> <i>Die Überprüfung der Gesamtwirkungskette „integrierter NA-Schutz – Kuppelschalter“ führte zu einer erfolgreichen Abschaltung.</i>			

**Annex 3: Pictures of the product**

**Enclosure – Front View**



**Enclosure – Rear View**



**Enclosure – Left side view**



**Enclosure – Right side view**



**Enclosure – Top View**



**Internal view**



--- End of test report---

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