TEST REPORT

VDE-AR-N 4105

Generators connected to the low-voltage distribution network – Technical requirements for the connection to and parallel operation with low-voltage distribution networks

Report reference number ..... :	**PVDE190905N026-R1**
Date of issue ..... ……..:	2019-12-06
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Applicant's name ..... :	**Huawei Technologies Co., Ltd.**
Address ..... :	Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, 518129, P.R.C
Test specification	
Standard ..... :	VDE-AR-N 4105:2018-11 (tested according to E DIN VDE V 0124-100:2019-09 draft)
Zertifikate ..... :	**Certificate of compliance**
Test report form number. ..... :	TEST REPORT VDE-AR-N 4105 VER.0
Master TRF ..... :	Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Test item description ..... :	**SOLAR INVERTER**
Trademark ..... :	HUAWEI
Model / Type ..... :	SUN2000-100KTL-M1

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Ratings ..... :	**SUN2000-100KTL-M1**
MPP DC voltage range [V] ..... :	200-1000
Input DC voltage range [V] ..... :	200-1100
Input DC current [A] ..... :	Max. 26A*10
Output AC voltage [V] ..... :	230/400 Vac, 3W+N+PE; 50Hz
Output AC current [A] ..... :	Max. 160,4 A
Nominal Output power [kW] ..... :	100
Maximum Output power [kVA] ..... :	110

Testing Location ..... :	**Huawei Technologies Co., Ltd.**
Address ..... :	Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, 518129, P.R.C
Tested by (name and signature) ..... :	Dora Zhang
Approved by (name and signature) ..... :	James Huang
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Factory's name 2 ..... :	**DongGuan Fuyi Precision Industry Co., Ltd.**
Factory address ..... :	Floor 1st-4th, Building 12, Weifeng Industrial City, No.6, Songshui Road, Songmu Village, Dalang Town, Dongguan, Guangdong 523770, China
Factory's name 3 ..... :	**Dongguan Yang Tian Electron Technology Co.,Ltd.**
Factory address ..... :	No. 152, LUYUAN RD. SCIENCE CITY, TANGXIA TOWN, DONGGUAN CITY, GUANGDONG PROVINCE,P.R.CHINA
Factory's name 4 ..... :	**Shenzhen Fugui Precision Industry Co., Ltd.**
Factory address ..... :	Building B4, Foxconn Science and Technology Industrial Park,East side of Min Qing Road Longhua District,Longhua Subdistrict Shenzhen

Document History

Date	Internal reference	Modification / Change / Status	Revision
2019-11-22	Dora Zhang	Initial report was written	0
2019-12-06	Dora Zhang	Update the test equipment list	R1

Supplementary information:

Test items particulars	
Equipment mobility..... :	Permanent connection
Operating condition..... :	Continuous
Class of equipment ..... :	Class I
Protection against ingress of water.. :	IP66 according to EN 60529
Mass of equipment [kg]..... :	Approximately 90kg

Test case verdicts

Test case does not apply to the test object..... :	N/A
Test item does meet the requirement..... :	P(ass)
Test item does not meet the requirement..... :	F(ail)

Testing

Date of receipt of test item ..... :	2019-09-05
Date(s) of performance of test ..... :	2019-09-05 to 2019-12-03

General remarks:

The test result presented in this report relate only to the object(s) tested. The report shall state compliance of the tested objects with the requirements of DIN VDE V 0124-100. This report shall not be reproduced, except in full, without the written approval of the applicant.

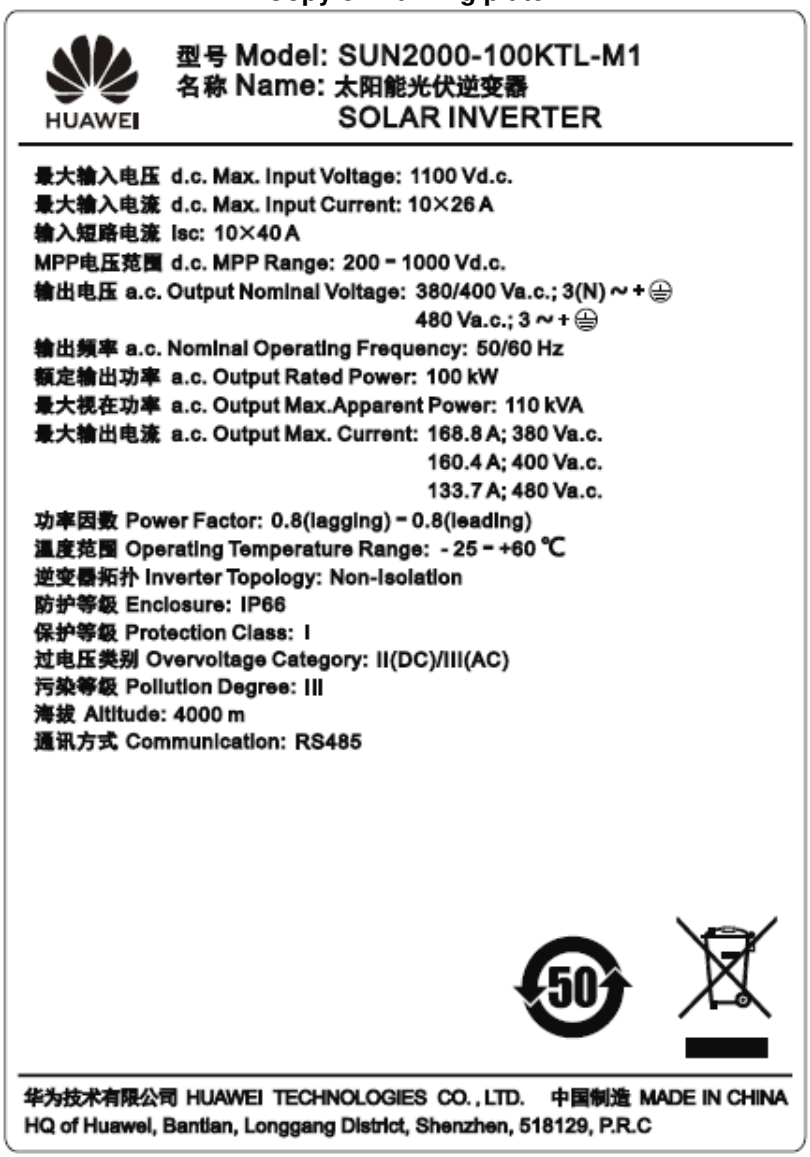
”(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

Throughout this report a comma is used as the decimal separator.
This report is to replace the earlier Test Report Ref. No. PVDE190905N026 issued by Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch, dated on Nov. 22, 2019.

This Test Report consists of the following documents:

1. Test Report
   5.2. Evidence of permissible network perturbations
   5.3. Evidence of symmetry behavior of inverters
   5.4. Evidence of the behavior of the generating unit on the network
   5.5. NS-protection
   5.6 Connecting conditions and synchronization
   5.7 Evidence of $P_{AV,E}$-Control (not implemented till yet in test plan)
   5.8 Evidence dynamic grid support
2. Pictures of the unit – Annex No. 1
3. Test equipment list – Annex No. 2

Copy of marking plate



General product information:

The Solar converter converts DC voltage into AC voltage.
The input and output are protected by Varistors to Earth. The unit is providing EMC filtering at the output toward mains. The unit does not provide galvanic separation from input to output (transformerless). The output is switched off redundant by the high power switching bridge and a two relays. This assures that the opening of the output circuit will also operate in case of one error.

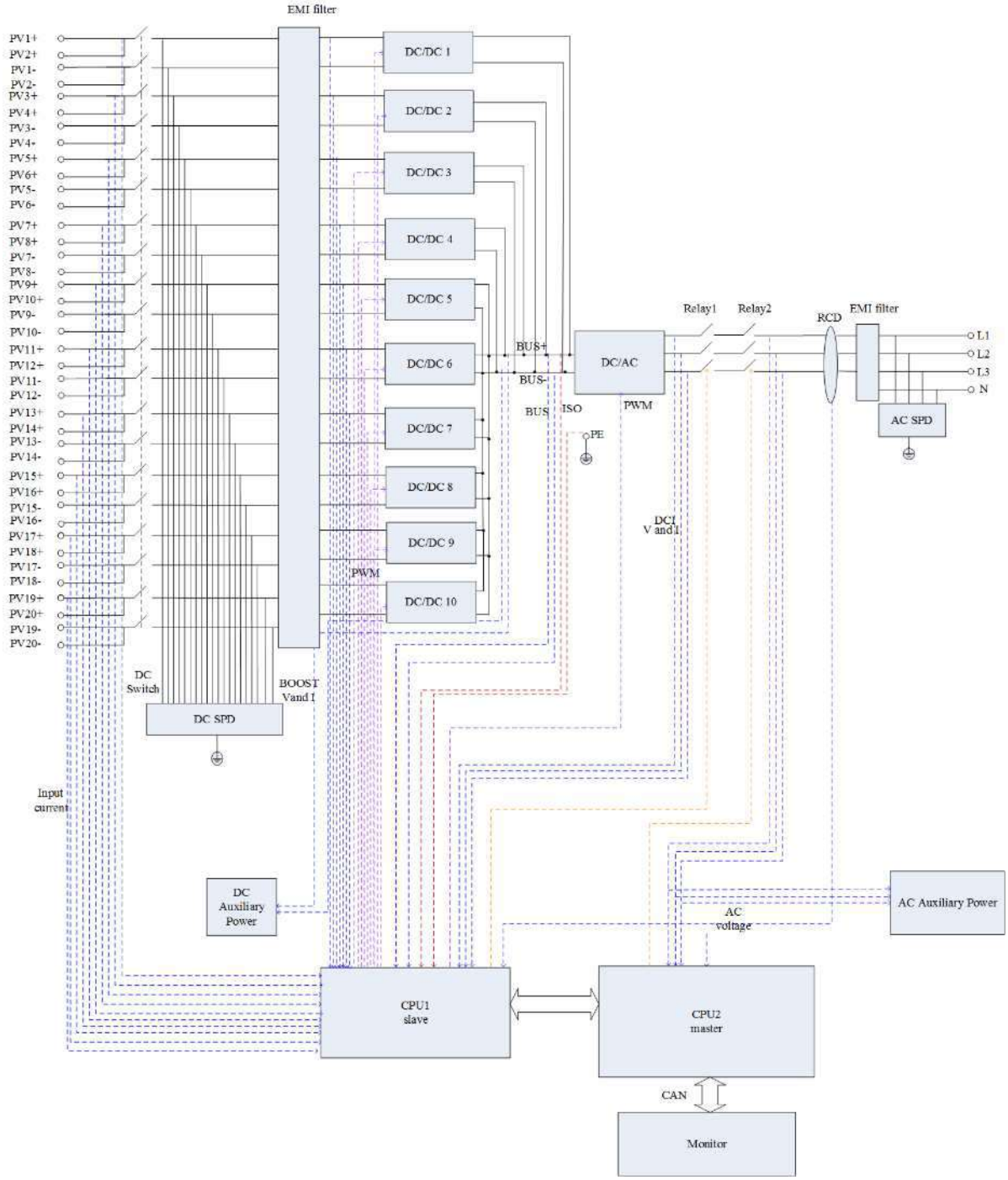


Figure 1 – Block diagram

Description of the electrical circuit: (Figure 1):

The internal control is redundant built. It consists of Microcontroller CPU2 (U101) and CPU1 (U100).

The CPU1 (U100) control the relays by switching signals; measures the PV voltage, PV current, Bus voltage, grid voltage, frequency, AC current with injected DC and the array insulation resistance to ground. In addition it tests the current sensors and the RCMU circuit before each start up.

The CPU2 (U101) is measures the grid voltage, grid frequency, DCI and residual current, also can switch off the relays independently, and communicate with the CPU1 (U100) each other.

The current is measured by a current sensor. The AC current signal and the injected DC current signal are sent to the CPU1 (U100). The CPU1 (U100) tests and calibrates before each start up all current sensors.

The unit provides two relays in series in all output conductors. When single fault applied to one relay, alarm an error code in display panel, another redundant relay provides basic insulation maintained between the PV array and the mains. All the relays are tested before each start up.

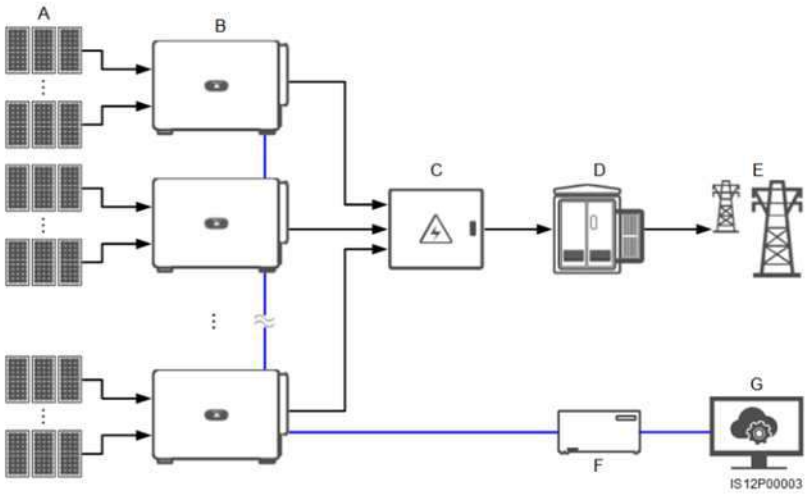
The product was tested on:

Hardware: V500R001
Software: V500R001

Description of the remote control in a typical installation:

Inverter support RS485 communication.

Figure 5-1 RS485 networking (SmartLogger)



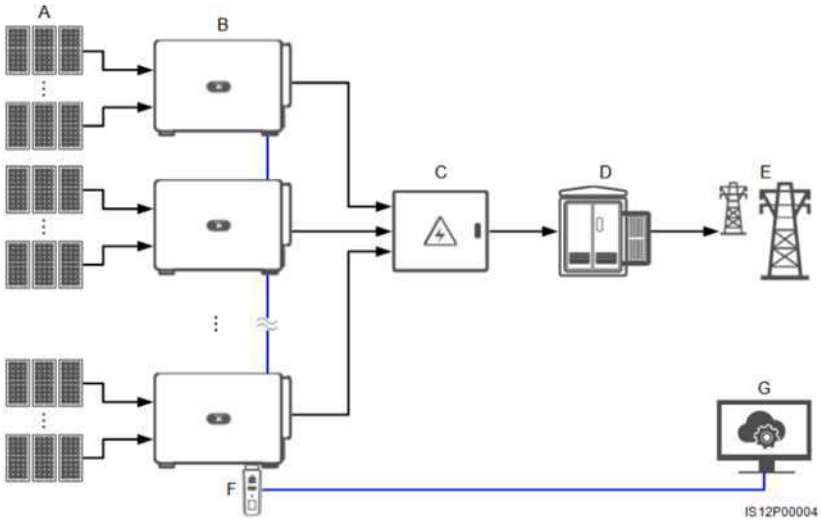
(A) PV string (B) SUN2000 (C) AC combiner box

(D) Transformer station (E) Power grid (F) SmartLogger

(G) Management system

Figure 2 – Scheme of RS485 netwaorking(SmartLogger)

Figure 5-2 RS485 networking (SDongle)



(A) PV string (B) SUN2000 (C) AC combiner box

(D) Transformer station (E) Power grid (F) SDongle

(G) Management system

Figure 3 – Scheme of RS485 netwaorking(SDongle)

Description of the connection to the ripple control receiver:

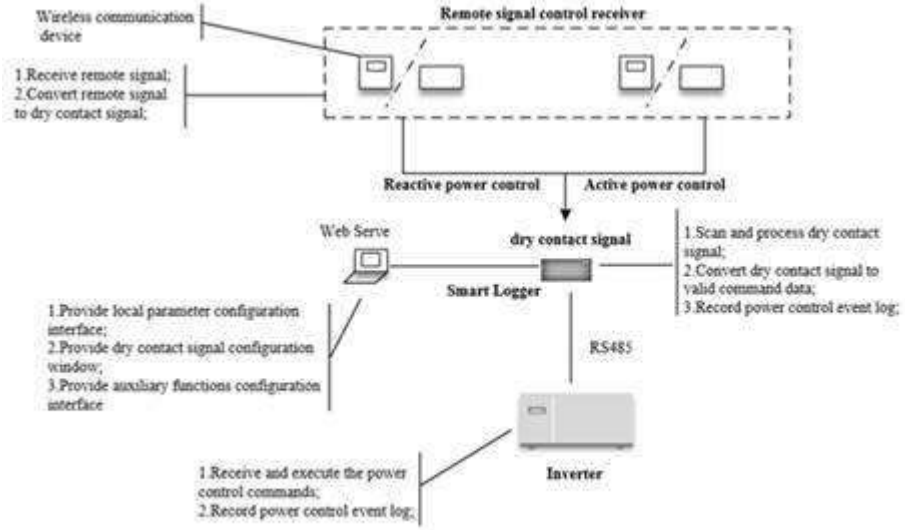


Figure 6 – Connection of the ripple control receiver in an installation

General remarks:

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

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

The following suffixes are used for variables in tables and figures:

- "P_N" for the nominal active power:
  $P_n = U_n \times I_n \times \cos \varphi_n$ (single-Phase); $P_n = \sqrt{3} U_n \times I_n \times \cos \varphi_n$ (three-Phase)
- "_E0,2" for gliding average values over 200 milliseconds
- "_E60" for gliding average values over 60 seconds.
- "_E600" for gliding average values over 10 minutes.
- "(c)" for over-excited
- "(i)" for under-excited

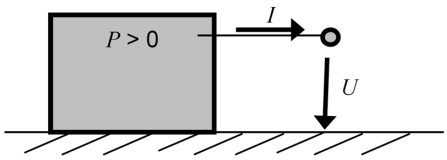
Acronyms:

PGU: power generating unit

PGS: power generating system

The regarded system of the voltage and current vectors is the load view (Figure 4):

- If the inverter feeds to the grid the active power is measured with negative sign. For the sake of reading the document the measured active infeed power has a positive sign



- If the inverter consumes inductive reactive power the reactive power is marked "inductive" or has a positive sign.
- If the inverter consumes capacitive reactive power the reactive power is marked "capacitive" or has a negative sign.

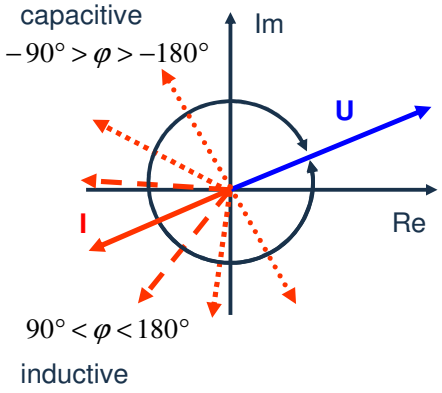


Figure 4

5 Prüfungen E DIN V 0124-100:(2019-09) draft		
Clause	**Test**	**Result**
5.2	Evidence of permissible network perturbations	**P**
5.3	Evidence of symmetry behavior of inverters	**P**
5.4	Evidence of the behavior of the generating unit on the network	**P**
5.5	NS-protection	**P**
5.6	Connecting conditions and synchronization	**P**
5.8	Evidence dynamic grid support	**P**
5.9	Test of Ancillary Unit (not implemented till yet in test plan)	**N/A**

5.2 Evidence of permissible network perturbations
E DIN V 0124-100:(2019-09) draft

Clause	Test	Result
5.2.1	General	**P**
5.2.2	Rapid voltage changes	**P**
5.2.3	Flicker	**P**
5.2.4	Harmonics and interharmonics	**P**
5.2.4.1	Test: 61000-3-3 / 61000-3-12	**P**
5.2.4.1	Test: 61000-4-7	**P**
5.2.5	Commutation “only for line-commutated inverter”	**N/A**
5.2.6	Feed in of DC current “only for inverter”	**P**

5.2.1 General These tests are designed to provide evidence that the requirements of VDE-AR-N 4105, 5.4 are met.	**P**

Network reactions in the sense of this document according to VDE-AR-N 4100: 2019-04, 5.4 are:

- fast voltage changes;
- flicker;
- Harmonics, interharmonics and super-harmonics (higher frequencies from 2 kHz to 9 kHz);
- Commutation “necessary only for mains-controlled inverter”
- Feed in of direct current “necessary only for inverter”

Note:

5.2.2 Rapid voltage changes These tests are designed to provide evidence that the requirements of VDE-AR-N 4100, 5.4.4.2 are met.	**P**

The purpose of the test is to determine ki and kimax.
The following cases must be tested to VDE-AR-N 4105, Annex E.5 (where applicable).

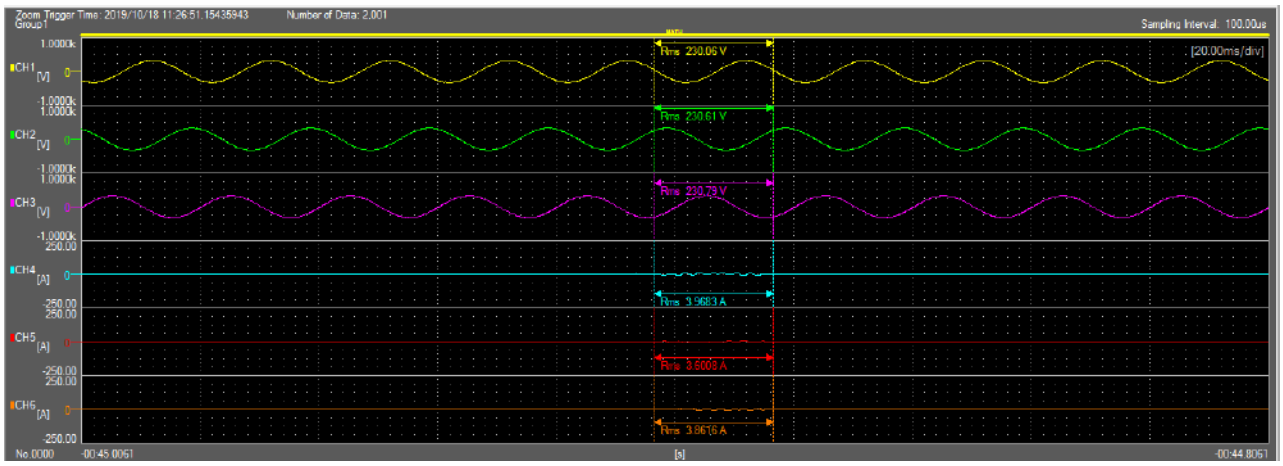
- Switch-on for any capacity
- Unfavorable case when switching the generator step (not for electrical inverter)
- Switch-on for nominal capacity
- Switch-off for nominal capacity (no emergency shutdown, but operational shutdown)

Test conditions:
Frequency: 50 Hz ± 0,5%
THD of the voltage supply: ≤ 3 %
Voltage rise of the PGU at 100 P_{Emax} %: ≤ 3 %

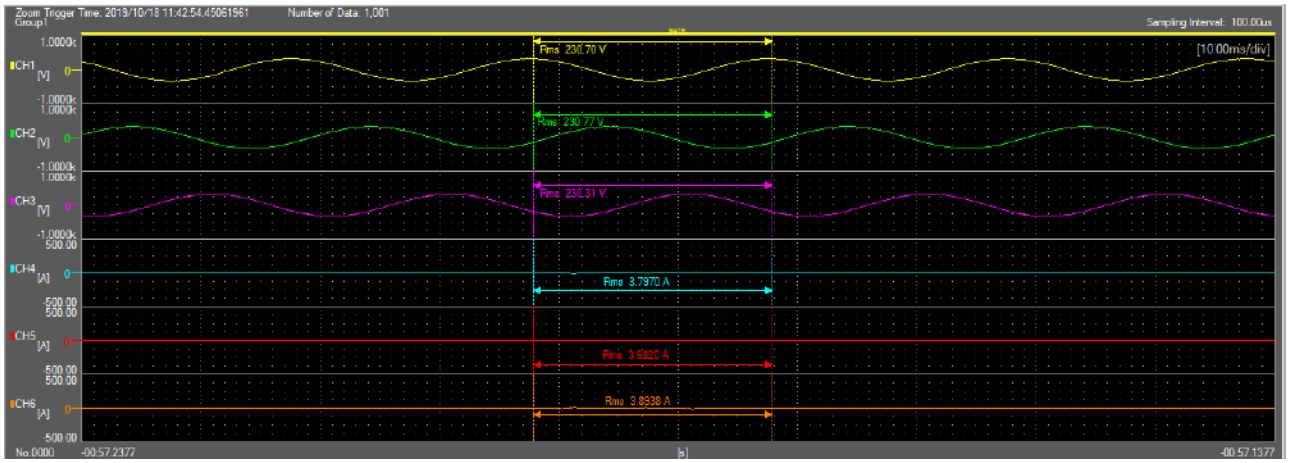
L1 Phase:			
Switch-on for any capacity (10% P_{Emax})			
Single period effective values of the current [A]	231,03	230,06	229,88
Single period effective values of the voltage [V]	3,487	3,968	3,604
k_i value	0,022	0,025	0,023
k_{imax} value	0,025		
Unfavourable case when switching the generator step			
Single period effective values of the current [A]	N/A	N/A	N/A
Single period effective values of the voltage [V]	N/A	N/A	N/A
k_i value	N/A	N/A	N/A
k_{imax} value	N/A		
Switch-on for nominal capacity			
Single period effective values of the current [A]	230,70	230,55	230,98
Single period effective values of the voltage [V]	3,797	3,517	3,355
k_i value	0,024	0,022	0,021
k_{imax} value	0,024		
L2 Phase:			
Switch-on for any capacity (10% P_{Emax})			
Single period effective values of the current [A]	230,80	230,60	230,47
Single period effective values of the voltage [V]	3,037	3,601	3,188
k_i value	0,019	0,023	0,020
k_{imax} value	0,023		
Unfavourable case when switching the generator step			

Single period effective values of the current [A]	N/A	N/A	N/A
Single period effective values of the voltage [V]	N/A	N/A	N/A
k_i value	N/A	N/A	N/A
k_{imax} value	N/A		
Switch-on for nominal capacity			
Single period effective values of the current [A]	230,77	230,66	230,18
Single period effective values of the voltage [V]	3,682	3,422	3,139
k_i value	0,023	0,022	0,020
k_{imax} value	0,023		
L3 Phase:			
Switch-on for any capacity (10% P_{Emax})			
Single period effective values of the current [A]	229,97	230,79	231,00
Single period effective values of the voltage [V]	3,233	3,862	3,226
k_i value	0,020	0,024	0,020
k_{imax} value	0,024		
Unfavourable case when switching the generator step			
Single period effective values of the current [A]	N/A	N/A	N/A
Single period effective values of the voltage [V]	N/A	N/A	N/A
k_i value	N/A	N/A	N/A
k_{imax} value	N/A		
Switch-on for nominal capacity			
Single period effective values of the current [A]	230,31	230,52	230,38
Single period effective values of the voltage [V]	3,894	3,609	3,564
k_i value	0,024	0,023	0,022
k_{imax} value	0,024		
Highest k_{imax} value for all switching operations			
0,025			
Note:			

Switch-on for any capacity (10% P_{Emax})



Switch-on for nominal capacity



5.2.3 Flicker

These tests are designed to provide evidence that the requirements of VDE-AR-N 4100:2109-04 are met.

Adherence to the thresholds for flicker must be verified as followed:

- For nominal currents ≤ 16 A per conductor to DIN EN 61000-3-3 (VDE 0838-3)
- For nominal currents > 16 A and ≤ 75 A per conductor to DIN EN 61000-3-11 (VDE 0838-11)
- For PGUs and PSUs intended for PGSs with nominal currents > 75 A, the measurements must be conducted as in 5.2.3.2.

Test conditions:
Voltage: 86% U_n to 109% U_n
Frequency: 50 Hz ± 0,5%
THD of the voltage supply: ≤ 3 %
Voltage rise of the PGU at 100 P_{Emax} %: ≤ 3 %

Flicker für Bemessungsströme >75A (bei SCR = 20)

Method: Measurement was carried out according to the procedure in IEC 61400-21.

Grid impedance angle, ψ_k	30°	50°	70°	85°
Flicker coefficient, $c(\psi_k)$	2,94	2,96	3,11	3,31
Short-term flicker, P_{st}	0,15	0,15	0,16	0,17

Note:
The table entries are worst case values.
$S_{k,fic}/S_n$ in the fictitious grid was set to: 20

5.2.4 Harmonics and interharmonics These tests are designed to provide evidence that the requirements of VDE-AR-N 4100:2109-04 are met.	**P**

Adherence to the thresholds for harmonic currents must be verified as followed:

- For nominal currents ≤ 16 A per conductor to DIN EN 61000-3-2 (VDE 0838-2)
- For nominal currents > 16 A and ≤ 75 A per conductor to DIN EN 61000-3-12 (VDE 0838-12)
- For PGUs and PSUs intended for PGSs with nominal currents > 75 A, the measurements must be conducted as in 5.2.4.2.

Test conditions:
Voltage: 86% U_n to 109% U_n
Frequency: 50 Hz ± 0,5%
THD of the voltage supply: ≤ 3 %
Voltage rise of the PGU at 100 P_{Emax} %: ≤ 3 %

5.1.4.1 Tests	P

The currents of the harmonics and interharmonics up to 2 kHz must be measured in accordance with DIN EN 61000-4-7 (VDE 0817-4-7), Annex A. The measurements of higher-frequency harmonic currents between 2 kHz and 9 kHz must be conducted in line with DIN EN 61000-4-7 (VDE 0847-4-7), Annex B.

Harmonics: SUN2000-100KTL-M1

P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
1	3,204	10,172	20,169	30,199	40,032	50,378	60,518	70,154	80,241	90,067	100,30
2	0,044	0,047	0,060	0,074	0,080	0,090	0,092	0,108	0,130	0,140	0,101
3	0,085	0,096	0,100	0,141	0,200	0,242	0,306	0,320	0,354	0,411	0,464
4	0,040	0,039	0,042	0,041	0,048	0,051	0,060	0,054	0,050	0,059	0,060
5	0,063	0,151	0,217	0,262	0,238	0,336	0,367	0,400	0,397	0,414	0,325
6	0,032	0,036	0,033	0,034	0,040	0,042	0,049	0,048	0,048	0,058	0,040
7	0,108	0,053	0,074	0,155	0,230	0,200	0,216	0,223	0,239	0,222	0,161
8	0,025	0,026	0,032	0,035	0,035	0,036	0,035	0,038	0,039	0,042	0,038
9	0,043	0,061	0,064	0,073	0,079	0,076	0,117	0,079	0,068	0,078	0,082
10	0,022	0,029	0,033	0,036	0,043	0,040	0,043	0,036	0,033	0,040	0,045
11	0,077	0,078	0,103	0,130	0,140	0,165	0,183	0,260	0,312	0,319	0,241
12	0,025	0,036	0,040	0,039	0,046	0,033	0,042	0,033	0,028	0,034	0,030
13	0,111	0,144	0,121	0,111	0,135	0,130	0,137	0,125	0,134	0,167	0,183
14	0,022	0,044	0,049	0,039	0,032	0,026	0,041	0,027	0,018	0,024	0,021
15	0,046	0,130	0,101	0,058	0,054	0,040	0,062	0,048	0,042	0,043	0,035
16	0,013	0,025	0,031	0,030	0,020	0,016	0,021	0,015	0,013	0,016	0,014
17	0,053	0,047	0,031	0,067	0,081	0,097	0,108	0,114	0,118	0,123	0,097
18	0,008	0,012	0,012	0,012	0,013	0,010	0,013	0,010	0,008	0,010	0,010
19	0,021	0,038	0,041	0,075	0,083	0,076	0,090	0,083	0,073	0,086	0,114
20	0,016	0,009	0,010	0,013	0,020	0,021	0,022	0,023	0,024	0,021	0,016
21	0,020	0,032	0,025	0,022	0,024	0,021	0,024	0,019	0,019	0,015	0,024
22	0,005	0,007	0,008	0,008	0,007	0,006	0,007	0,006	0,006	0,006	0,006
23	0,026	0,024	0,017	0,030	0,039	0,050	0,052	0,055	0,056	0,050	0,049
24	0,004	0,006	0,005	0,005	0,006	0,004	0,005	0,004	0,004	0,004	0,005
25	0,017	0,033	0,031	0,044	0,049	0,046	0,055	0,052	0,049	0,052	0,056
26	0,003	0,004	0,004	0,004	0,005	0,005	0,005	0,004	0,004	0,004	0,006
27	0,015	0,020	0,017	0,018	0,018	0,018	0,021	0,017	0,016	0,014	0,025
28	0,003	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,003	0,003	0,004
29	0,027	0,016	0,015	0,016	0,023	0,031	0,034	0,031	0,032	0,029	0,034
30	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,002	0,003	0,003
31	0,024	0,019	0,023	0,025	0,030	0,032	0,036	0,035	0,033	0,034	0,035
32	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
33	0,020	0,019	0,019	0,019	0,020	0,018	0,018	0,017	0,017	0,016	0,025
34	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,002	0,003	0,002
35	0,020	0,014	0,012	0,011	0,016	0,021	0,023	0,022	0,022	0,022	0,026
36	0,002	0,003	0,003	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,003
37	0,022	0,020	0,019	0,018	0,022	0,023	0,026	0,024	0,024	0,023	0,025
38	0,002	0,003	0,002	0,003	0,003	0,002	0,003	0,002	0,002	0,002	0,003

39	0,019	0,023	0,024	0,023	0,022	0,021	0,019	0,019	0,019	0,018	0,025
40	0,005	0,002	0,003	0,003	0,005	0,004	0,003	0,002	0,003	0,005	0,005
41	0,016	0,016	0,014	0,012	0,014	0,017	0,018	0,018	0,018	0,019	0,019
41	0,003	0,003	0,003	0,002	0,003	0,002	0,002	0,002	0,002	0,002	0,003
43	0,022	0,020	0,017	0,015	0,018	0,019	0,021	0,020	0,019	0,019	0,019
44	0,003	0,003	0,003	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,003
45	0,033	0,032	0,034	0,031	0,028	0,026	0,023	0,022	0,022	0,019	0,024
46	0,003	0,004	0,003	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,002
47	0,015	0,023	0,019	0,014	0,015	0,015	0,017	0,017	0,017	0,019	0,016
48	0,004	0,004	0,004	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,003
49	0,024	0,025	0,017	0,015	0,017	0,018	0,019	0,018	0,016	0,018	0,014
50	0,004	0,004	0,004	0,003	0,003	0,002	0,002	0,002	0,002	0,002	0,003

Interharmonics											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
75	0,044	0,052	0,048	0,054	0,071	0,073	0,081	0,074	0,063	0,066	0,056
125	0,029	0,037	0,042	0,046	0,053	0,052	0,058	0,052	0,049	0,058	0,038
175	0,042	0,032	0,034	0,045	0,061	0,047	0,070	0,056	0,060	0,066	0,054
225	0,036	0,046	0,051	0,058	0,080	0,095	0,108	0,091	0,085	0,100	0,036
275	0,033	0,035	0,038	0,044	0,056	0,057	0,057	0,055	0,055	0,055	0,030
325	0,037	0,046	0,049	0,052	0,074	0,082	0,097	0,085	0,081	0,093	0,033
375	0,036	0,041	0,043	0,050	0,060	0,058	0,058	0,058	0,061	0,053	0,042
425	0,028	0,039	0,041	0,045	0,049	0,063	0,054	0,052	0,052	0,058	0,044
475	0,028	0,042	0,042	0,045	0,049	0,058	0,060	0,045	0,045	0,056	0,042
525	0,028	0,039	0,041	0,042	0,056	0,061	0,064	0,056	0,052	0,067	0,040
575	0,038	0,043	0,044	0,047	0,061	0,061	0,061	0,057	0,059	0,084	0,038
625	0,030	0,037	0,034	0,032	0,046	0,039	0,046	0,043	0,040	0,048	0,030
675	0,039	0,053	0,042	0,044	0,049	0,042	0,048	0,047	0,049	0,065	0,025
725	0,018	0,033	0,031	0,026	0,023	0,021	0,023	0,021	0,021	0,024	0,015
775	0,013	0,031	0,026	0,022	0,019	0,017	0,019	0,016	0,017	0,018	0,012
825	0,020	0,018	0,019	0,019	0,021	0,029	0,027	0,028	0,026	0,028	0,020
875	0,011	0,015	0,014	0,014	0,015	0,014	0,014	0,013	0,013	0,016	0,009
925	0,009	0,011	0,011	0,011	0,012	0,011	0,012	0,011	0,010	0,011	0,008
975	0,009	0,011	0,010	0,010	0,011	0,010	0,011	0,010	0,010	0,011	0,007
1025	0,006	0,009	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,006
1075	0,006	0,008	0,007	0,007	0,008	0,007	0,007	0,007	0,007	0,007	0,006
1125	0,006	0,007	0,007	0,007	0,007	0,006	0,007	0,006	0,006	0,007	0,005
1175	0,009	0,006	0,006	0,007	0,011	0,011	0,010	0,010	0,009	0,009	0,009
1225	0,005	0,005	0,005	0,006	0,006	0,005	0,006	0,005	0,005	0,005	0,005
1275	0,005	0,006	0,005	0,005	0,006	0,005	0,005	0,005	0,005	0,005	0,004
1325	0,004	0,005	0,005	0,005	0,005	0,005	0,005	0,004	0,004	0,005	0,004
1375	0,004	0,004	0,004	0,004	0,005	0,005	0,005	0,005	0,005	0,005	0,005
1425	0,003	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004
1475	0,004	0,004	0,003	0,004	0,004	0,004	0,004	0,004	0,003	0,004	0,003
1525	0,003	0,004	0,003	0,004	0,004	0,004	0,004	0,004	0,003	0,003	0,003
1575	0,003	0,003	0,003	0,004	0,004	0,004	0,004	0,003	0,003	0,003	0,003
1625	0,003	0,003	0,003	0,003	0,004	0,004	0,004	0,004	0,004	0,004	0,004
1675	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
1725	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
1775	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
1825	0,004	0,003	0,003	0,003	0,005	0,004	0,004	0,004	0,004	0,004	0,004
1875	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
1925	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
1975	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003

Higher Frequencies											
P/Pn [%]	0	10	20	30	40	50	60	70	80	90	100
f [kHz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2,1	0,036	0,032	0,029	0,030	0,030	0,031	0,033	0,031	0,030	0,031	0,032
2,3	0,041	0,041	0,042	0,039	0,035	0,034	0,035	0,034	0,034	0,031	0,033
2,5	0,051	0,050	0,045	0,045	0,047	0,043	0,039	0,036	0,035	0,033	0,031
2,7	0,049	0,047	0,040	0,041	0,036	0,036	0,038	0,033	0,030	0,030	0,028
2,9	0,049	0,048	0,043	0,046	0,041	0,047	0,049	0,042	0,038	0,038	0,033
3,1	0,048	0,041	0,045	0,047	0,049	0,041	0,055	0,048	0,045	0,038	0,038
3,3	0,030	0,027	0,030	0,043	0,049	0,046	0,049	0,048	0,036	0,035	0,041
3,5	0,034	0,039	0,038	0,044	0,045	0,042	0,042	0,046	0,045	0,047	0,045
3,7	0,035	0,039	0,041	0,043	0,042	0,042	0,043	0,042	0,043	0,042	0,042
3,9	0,022	0,026	0,028	0,034	0,033	0,040	0,041	0,036	0,039	0,033	0,035
4,1	0,026	0,036	0,034	0,034	0,034	0,036	0,032	0,036	0,036	0,036	0,034
4,3	0,019	0,021	0,021	0,022	0,024	0,027	0,025	0,023	0,026	0,022	0,026
4,5	0,018	0,018	0,018	0,021	0,021	0,022	0,034	0,035	0,029	0,026	0,021
4,7	0,018	0,018	0,019	0,020	0,021	0,021	0,024	0,030	0,032	0,029	0,025
4,9	0,017	0,018	0,018	0,020	0,021	0,019	0,019	0,025	0,025	0,028	0,024
5,1	0,017	0,017	0,018	0,020	0,021	0,019	0,019	0,019	0,022	0,027	0,022
5,3	0,017	0,017	0,018	0,019	0,022	0,019	0,018	0,019	0,020	0,026	0,026
5,5	0,017	0,017	0,018	0,018	0,020	0,019	0,018	0,018	0,019	0,020	0,021
5,7	0,017	0,017	0,018	0,018	0,019	0,019	0,018	0,018	0,018	0,019	0,020
5,9	0,017	0,017	0,018	0,018	0,019	0,020	0,018	0,018	0,018	0,018	0,019
6,1	0,017	0,017	0,018	0,018	0,019	0,020	0,018	0,018	0,018	0,018	0,019
6,3	0,018	0,019	0,019	0,019	0,020	0,021	0,020	0,019	0,020	0,020	0,020
6,5	0,017	0,017	0,018	0,018	0,019	0,019	0,019	0,018	0,018	0,018	0,018
6,7	0,017	0,017	0,017	0,017	0,019	0,019	0,019	0,018	0,018	0,018	0,018
6,9	0,017	0,017	0,018	0,018	0,019	0,021	0,020	0,019	0,018	0,019	0,019
7,1	0,018	0,018	0,018	0,018	0,019	0,019	0,021	0,019	0,018	0,018	0,018
7,3	0,018	0,018	0,018	0,019	0,019	0,020	0,020	0,019	0,018	0,019	0,019
7,5	0,017	0,017	0,017	0,018	0,018	0,019	0,019	0,018	0,018	0,018	0,018
7,7	0,017	0,017	0,017	0,018	0,018	0,019	0,019	0,018	0,018	0,018	0,018
7,9	0,017	0,017	0,017	0,018	0,018	0,019	0,019	0,019	0,018	0,018	0,018
8,1	0,017	0,017	0,017	0,018	0,018	0,019	0,019	0,019	0,018	0,018	0,018
8,3	0,017	0,017	0,017	0,018	0,018	0,019	0,018	0,019	0,018	0,018	0,018
8,5	0,017	0,017	0,017	0,017	0,018	0,019	0,019	0,019	0,018	0,018	0,018
8,7	0,017	0,017	0,018	0,018	0,018	0,019	0,018	0,019	0,018	0,018	0,018
8,9	0,017	0,017	0,017	0,017	0,018	0,018	0,019	0,018	0,017	0,018	0,018

Note:

The normalization current is 144,93 A.

The stated harmonics are average values of all 3 phases.

5.2.6 Feed in of DC current	P

Test result:

Protection limit	Tested at four power levels limit 0,5% of $I_{AC;nom}$ (797mA)		
Output power	30% S_{Emax} to 40% S_{Emax}	60% S_{Emax} to 70% S_{Emax}	>95% S_{Emax}
L1 Max, test value [mA]	100	110	110
L1 Average, test value [mA]	3,3	0,2	5,3
L2 Max, test value [mA]	140	110	130
L2 Average, test value [mA]	18,8	15,8	12,0
L3 Max, test value [mA]	110	130	140
L3 Average, test value [mA]	6,9	12,0	10,8

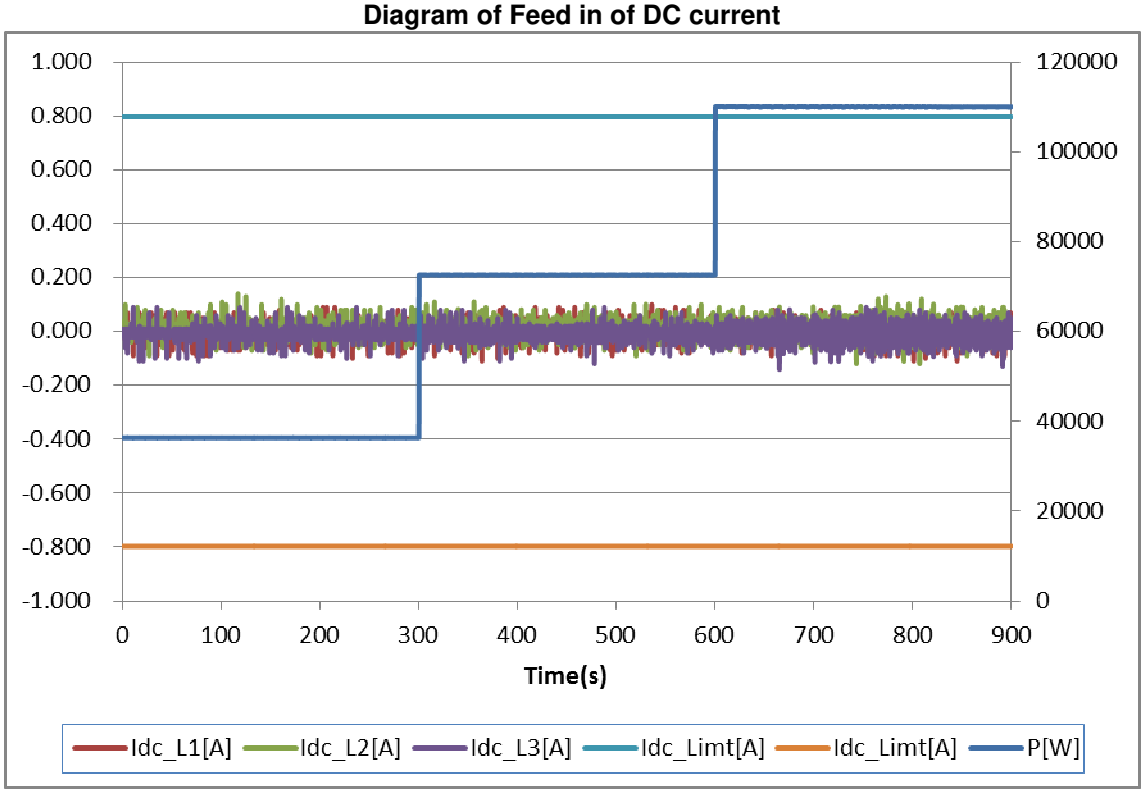
Test:

The inverter must be used in the adjustment range Test1, Test2 and Test 3. Each test point shall be held for min 5 minutes and I_{grid}, U_{grid}, I_{dc} of each phase has to be recorded. Measurement of I_{dc} must be done according to VDE AR-N 4100:2019-04 based on DIN EN 61000-4-7 (VDE-0847-4-7) over 10 fundamental periods.

Assessment criterion:

A inverter must not feed more than 0.5% of its rated current or a maximum of 20 mA (the higher value is to be selected) as direct current.

Diagram of Feed in of DC current



5.3 Evidence of symmetry behavior of inverters E DIN V 0124-100:(2019-09) draft		
Clause	**Test**	**Result**
5.3.1	General	**P**
5.3.2.1	Calculation of the asymmetry of three-phase inverters	**P**
5.3.2.2.1	Failure of single inverter modules	**N/A**
5.3.2.2.2	Power drop of single inverter modules	**N/A**
5.3.2.3.2	Symmetrical operation with a symmetry device	**N/A**

5.3.1 General These tests are designed to provide evidence that the requirements of VDE-AR-N 4105, 5.5 are met.	**P**
These tests serve to prove the requirements according to VDE-AR-N 4100: 2019-04, 5.5: These tests are not valid for direct connected rotating machines.	
Note:	

5.3.2 Test in the test laboratory		**P**
Test Condition:	The measurements were performed in the testing laboratory. at the grid-simulator: U_N = between 86 % Un and 109% Un until the test Frequency: 50 Hz +/- 0,5%	
Note: If an examination is required for any other requirements, these apply to this test.		

5.3.2.1 Calculation of the asymmetry of three-phase inverters						P
Setting values	cos φ = 1:	1,00				
	cos φ over-excited:	0,80				
	cos φ under-excited:	0,80				
Test:						
1-min mean value	L1	L2	L3	L1 – L2	L2 – L3	L3 – L1
a) cos φ = 1 at 100 % P_n ± 5 % P_{Emax}						
S_{E60} [kVA]:	36,775	36,658	36,654	0,117	0,005	0,122
	36,768	36,650	36,647	0,117	0,003	0,120
	36,765	36,653	36,637	0,112	0,016	0,128
	36,765	36,652	36,632	0,113	0,020	0,133
	36,764	36,649	36,631	0,115	0,018	0,132
cos φ_{E60}:	0,999					
max. asymmetry [kVA]:	0,133					
b) maximum under-excited (i) at 100 % P_n ± 5 % P_{Emax}						
S_{E60} [kVA]:	36,963	36,800	36,834	0,163	0,034	0,129
	36,937	36,799	36,815	0,138	0,015	0,122
	36,935	36,799	36,816	0,136	0,018	0,118
	36,939	36,799	36,820	0,140	0,021	0,120
	36,942	36,800	36,828	0,142	0,028	0,114
cos φ_{E60}:	0,799					
max. asymmetry [kVA]:	0,163					
c) maximum over-excited (c) at 100 % P_n ± 5 % P_{Emax}						
S_{E60} [kVA]:	36,861	36,800	36,800	0,061	0,000	0,061
	36,874	36,800	36,800	0,074	0,000	0,074
	36,877	36,802	36,796	0,075	0,006	0,081
	36,881	36,816	36,783	0,066	0,033	0,099
	36,885	36,823	36,782	0,062	0,041	0,104
cos φ_{E60}:	0,802					
max. asymmetry [kVA]:	0,104					
d) cos φ = 1 at 50 % P_n ± 5 % P_{Emax}						
S_{E60} [kVA]:	18,400	18,302	18,300	0,098	0,002	0,100
	18,400	18,302	18,300	0,098	0,002	0,100
	18,400	18,301	18,301	0,099	0,000	0,099
	18,400	18,302	18,300	0,098	0,001	0,100
	18,400	18,302	18,300	0,098	0,001	0,100
cos φ_{E60}:	0,999					

max. asymmetry [kVA]:	0,100

e) maximum under-excited (i) at 50 % P_n ± 5 % P_{Emax}						
S_{E60} [kVA]:	23,001	22,908	22,904	0,092	0,005	0,097
	23,001	22,912	22,905	0,090	0,007	0,096
	23,001	22,913	22,904	0,088	0,009	0,097
	23,001	22,916	22,904	0,085	0,012	0,097
	23,001	22,909	22,902	0,092	0,008	0,100
cos φ_{E60}:	0,800					
max. asymmetry [kVA]:	0,100					
f) maximum over-excited (c) at 50 % P_n ± 5 % P_{Emax}						
S_{E60} [kVA]:	22,955	22,899	22,875	0,056	0,024	0,080
	22,957	22,899	22,879	0,059	0,019	0,078
	22,948	22,899	22,878	0,049	0,021	0,070
	22,959	22,899	22,877	0,060	0,022	0,083
	22,958	22,898	22,877	0,060	0,021	0,081
cos φ_{E60}:	0,802					
max. asymmetry [kVA]:	0,083					
Limit [kVA]:	≤ 5 % S_{Emax} and 4,6 kVA					

Test:
The maximum absolute difference between the apparent powers of the three phases is determined for each of the five measurements (1-min means) in the respective operating point. The maximum of these five values is again determined.

Example:

Messung Nr.	**1**	**2**	**3**	**4**	**5**
L1	8	7	9	10	9
L2	9	10	10	10	10
L3	10	10	11	8	8
Rechnung					
|L1 - L2|	1	3	1	0	1
|L2 - L3|	1	0	1	2	2
|L3 – L1|	2	3	2	2	1
Unsymmetrie	2	3	2	2	2
max. Unsymmetrie	**3**				

Assessment criterion:
The test is passed if the maximum value from the above measurements does not exceed 5 % S_{Emax} and 4,6 kVA.

Note:
The maximum inductive and capacitive values are specified by the manufacturer.

5.4 Evidence of the characteristics of the power generation unit on the network E DIN V 0124-100:(2019-09) draft		
Clause	**Test**	**Result**
5.4.1	General	**P**
5.4.2	Measurement of the active power and reactive power range	**P**
5.4.3.2	Measurement of setting accuracy	**P**
5.4.3.3	Measurement of the power gradient	**P**
5.4.3.4	Measurement Priority Interfaces / Energy Management	**P**
5.4.4	Active power feed-in for PGUs at overfrequency	**P**
5.4.5	Active power feed-in of Storage systems for overfrequency	**P**
5.4.6	Active power feed-in for PGUs at Underfrequency	**P**
5.4.7	Active power feed-in for storage systems at Underfrequency	**P**
5.4.8.1	Tests of the Reactive power / cos φ setting accuracy	**P**
5.4.8.2	Test of the displacement factor/active power characteristic curve cos φ (P)	**P**
5.4.8.3.1	Test of the accuracy of the Q (U) regulation	**P**
5.4.8.3.2	Test of the dynamics of the Q (U) regulation	**P**

5.4.1 General (these tests are designed to provide evidence that the requirements of VDE-AR-N 4105:2018-11, 5.7.2.2 are met and to determine the values for SEmax and PEmax)	**P**
Test Condition:	The measurements were performed in the testing laboratory. at the grid-simulator: U_N = between 86 % Un and 109% Un until the test Frequency: 50 Hz +/- 0,5%
Designation for under-excited and over-excited: - “(c)” stands for over-excited. - “(i)” stands for under-excited.	
Note: If an examination is required for any other requirements, these apply to this test. The RoCoF requirements of the VDE-AR-N 4105:2018-11, 5.7.1 are not part of the Unit certification.	

5.4.2 Measurement of the active power and reactive power range (these tests are designed to provide evidence that the requirements of VDE-AR-N 4105, 5.7.5 are met)					**P**
Setting values	cos φ = 1:	1,00			
	cos φ max. over-excited:	0,80			
	cos φ max. under-excited:	0,80			
Test:					
600 s mean value	0,90 ± 0,2 U_n	0,95 ± 0,2 U_n	1,0 ± 0,2 U_n	1,05 ± 0,2 U_n	1,09 ± 0,2 U_n
a) cos φ 1 at 100% P_{Emax}					
U [V]:	207,31	218,61	230,77	241,79	250,77
$P_{Emax600\ a)}$ [kW]	100,018	106,000	110,005	110,000	110,000
$S_{Emax600\ a)}$ [kVa]	100,685	106,000	110,125	110,000	110,000
cos $\varphi_{Emax600}$	0,999	0,999	0,999	0,999	0,999
b) maximum under-excited (i) at 100% P_{Emax}					
U [V]:	207,05	218,53	230,55	241,80	250,81
$P_{Emax600\ b)}$ [kW]	80,206	84,606	88,278	88,309	88,342
$S_{Emax600\ b)}$ [kVa]	100,000	106,000	110,112	110,987	111,000
cos $\varphi_{Emax600\text{-}under\text{-}excited}$	0,800	0,800	0,799	0,799	0,799
c) maximum over-excited (c) at 100% P_{Emax}					
U [V]:	207,11	218,57	230,60	241,60	250,98
$P_{Emax600\ c)}$ [kW]	80,209	84,706	88,800	88,501	88,602
$S_{Emax600\ c)}$ [kVa]	100,000	106,000	111,000	110,000	110,217
cos $\varphi_{Emax600\text{-}over\text{-}excited}$	0,801	0,801	0,802	0,802	0,802
d) cos φ 1 at 50% P_{Emax}					
U [V]:	207,20	218,66	230,50	241,75	250,86
$P_{Emax600\ a)}$ [kW]	55,060	55,100	55,106	55,183	55,175
$S_{Emax600\ a)}$ [kVa]	55,068	55,100	55,112	55,183	55,175
cos $\varphi_{Emax600}$	0,999	0,999	0,999	0,999	0,999
e) maximum under-excited (i) at 50% P_{Emax}					
U [V]:	207,20	218,60	230,46	241,68	250,72
$P_{Emax60\ d)}$ [kW]	55,100	55,066	55,183	55,183	55,177
$S_{Emax60\ d)}$ [kVa]	68,931	68,830	68,985	68,975	68,975
cos $\varphi_{Emax60\text{-}over\text{-}excited}$	0,800	0,800	0,800	0,800	0,800
f) maximum over-excited (c) at 50% P_{Emax}					
U [V]:	208,10	218,78	230,21	241,80	250,91
$P_{Emax60\ e)}$[kW]	55,112	55,100	55,108	55,084	55,191
$S_{Emax60\ e)}$ [kVa]	68,788	68,759	68,739	68,698	68,793
cos $\varphi_{Emax60\text{-}over\text{-}excited}$	0,802	0,802	0,802	0,802	0,802
$S_{Emax600}$ and $P_{Emax\ 600}$					

$S_{Emax600}$= max($S_{Emax600\ a)}$, $S_{Emax600\ b)}$, $S_{Emax600\ c)}$)	110,987
$P_{Emax\ 600}$= max($P_{Emax600\ a)}$, $P_{Emax600\ b)}$, $P_{Emax600\ c)}$)	110,005

Test:

The PGU is operated in all of the following, possible operating points. Every operating point must be retained for at least 600s after the transient effect has faded. During the measurements, there may be no power limitation by the primary energy source.

a) For cos φ = 1, the maximum active power possible in this range is set.

b) For maximum under-excited operation, the maximum active power possible in this operating point is set.

c) For maximum over-excited operation, the maximum active power possible in this operating point is set.

Assessment criterion:

$S_{Emax600}$ and $P_{Emax\ 600}$ are determined by the highest value measured.

$S_{Emax600}$ = max($S_{Emax600a)}$, $S_{Emax600b)}$, $S_{Emax600c)}$)

$P_{Emax600}$ = max($P_{Emax600a)}$, $P_{Emax600b)}$, $P_{Emax600c)}$)

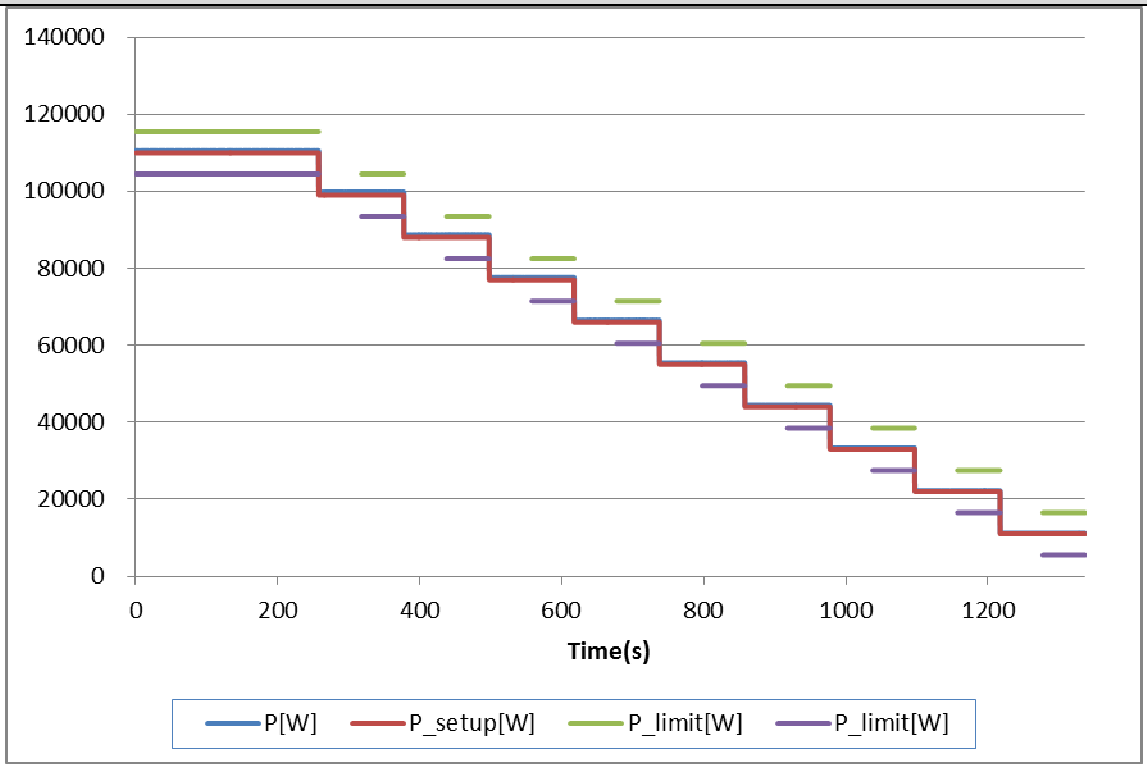
Note:

φ 0,95 (i) and (c): PGU ≤ 4,6 kVA

φ 0,90 (i) and (c): PGU > 4,6 kVA

5.4.3.2 Measurement of setting accuracy	P

Graph of the setting accuracy:



Test:

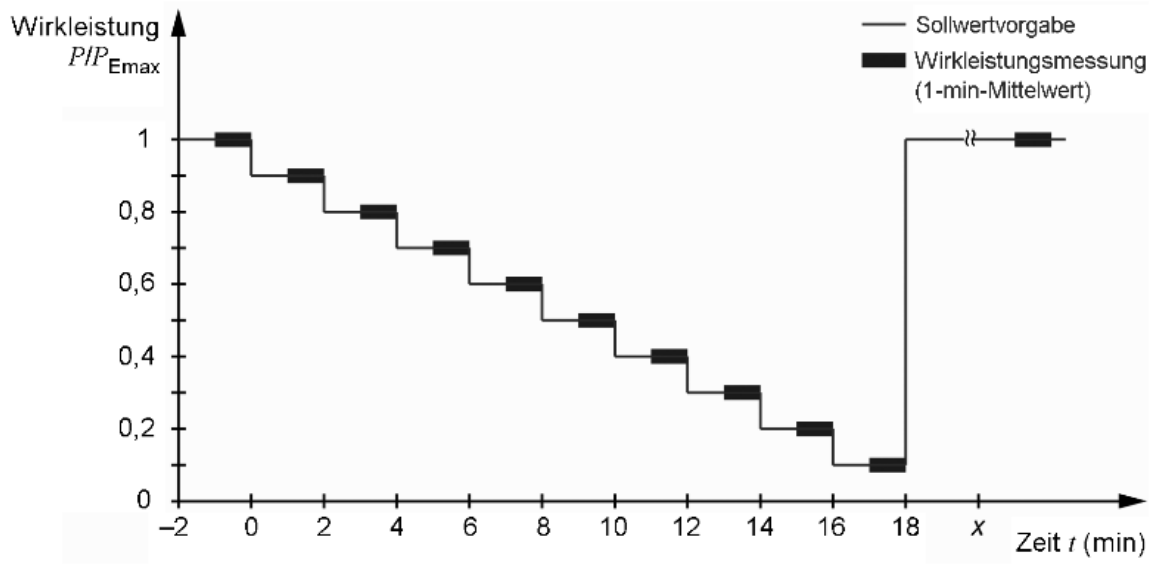
1-min mean value / P_n/P [%]	100	90	80	70	60	50	40	30	20	10
$P_{Setpoint}$[kW]:	110,000	99,000	88,000	77,000	66,000	55,000	44,000	33,000	22,000	11,000
P_{E60} [kW]:	110,539	99,832	88,741	77,595	66,535	55,468	44,435	33,258	22,246	11,157
$\Delta P_{E60}/P_{Setpoint}$ [%]:	0,490	0,756	0,673	0,541	0,486	0,425	0,395	0,234	0,223	0,143
Limit $\Delta P_{E60}/P_{Setpoint}$:	+ 5 % of P_{Emax}									

Test:

The setpoint signal must be reduced from 100% to 10% P_{Emax}:

a) for adjustable PGUs in increments of 10% P_{Emax}. 1 minute must elapse after every change to the setpoint setting so that the PGU can settle at the new setpoint. Then the active power of the PGU must be measured as a 1-min mean value.

b) For all other PGUs, in line with their adjustable steps. 1 minutes must elapse after the setpoint setting is changed so that the PGU can settle at the new setpoint. Then the active power of the PGU must be measured as a 1-min mean value.



Assessment criterion:

a) for adjustable PGUs:

- no network disconnection
- the active power value does not exceed the setpoint by more than 5% PEmax
- the power gradient determined according 5.4.3.3 not be less than 0.33% PrE/s and not more than 0.66% PrE/s.

Note:

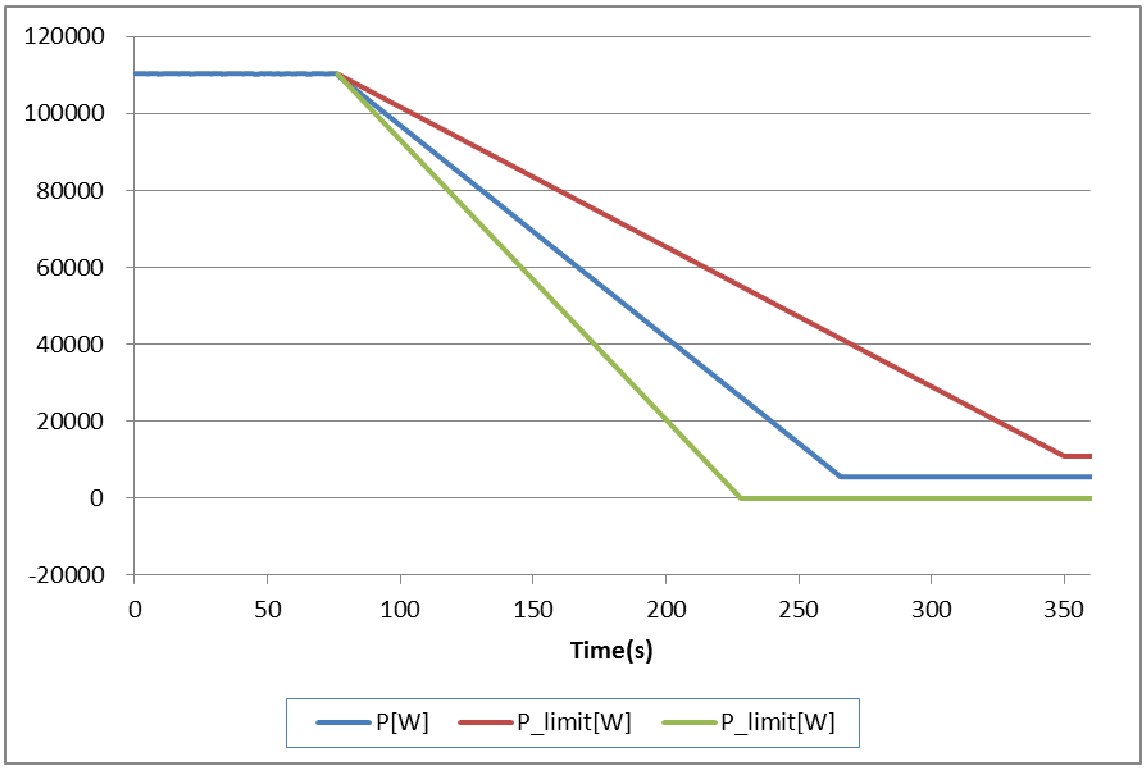
5.4.3.3 Measurement of the power gradient					P
Test:					
$P_{Setpoint}$	100% to 5% P_{Emax}		5% to 100% P_{Emax}		
$P_{Setpoint}$[kW]:	110,000	5,500	5,500	110,000	
P_{E60} [kW]:	110,317	5,594	5,593	110,582	
$\Delta P_{E60}/P_{Setpoint}$ [%]:	0,288	0,085	0,085	0,529	
Limit $\Delta P_{E60}/P_{Setpoint}$:	+ 5 % of PEmax				
Gradient[P_{rE}/s.]:	0,501		0,500		
Limit Gradient [P_{rE}/s.]:	0,33 to 0,66				

Test:
The measurement of the power gradient takes place :
- Via a setpoint change from 100% to 5% of the rated effective power PrE at time t0. If the technical performance is> 5%, this should be specified.
- Via a setpoint change from 5% to 100% of the rated effective power PrE at time t0. Is the technical Performance> 5%, this should be specified

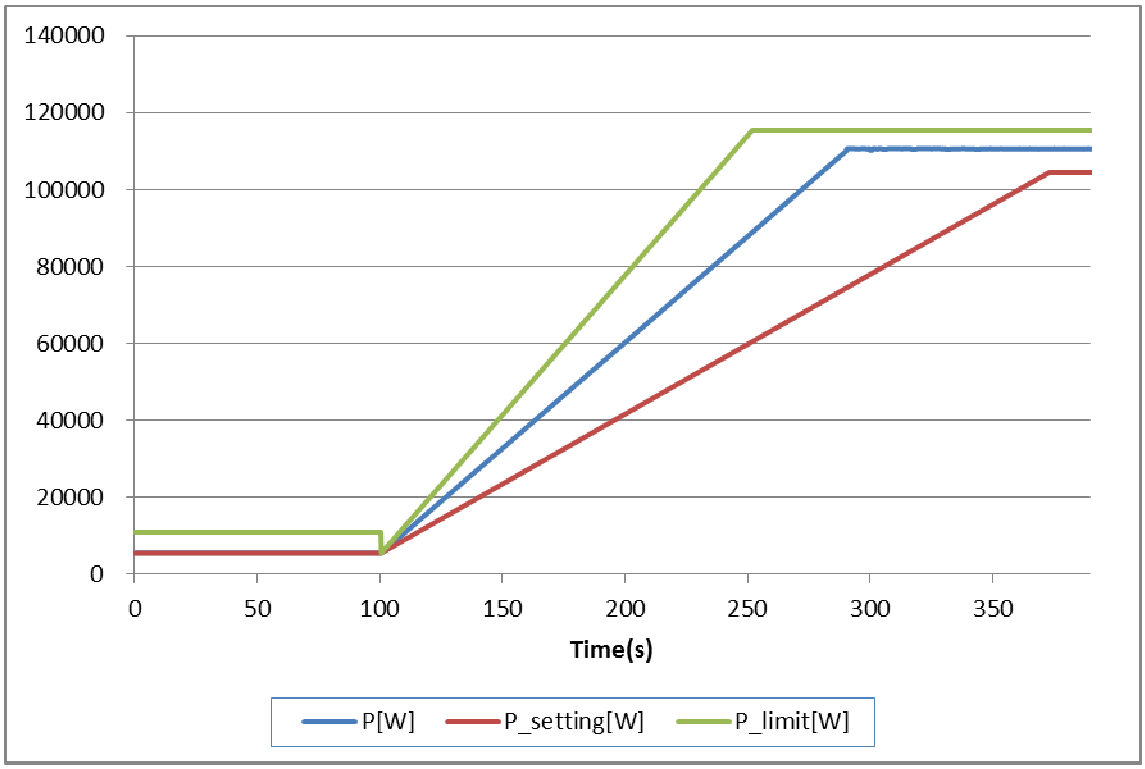
Assessment criterion:
a) for adjustable PGUs:
- no network disconnection
- the active power value does not exceed the setpoint by more than 5% PEmax
- the power gradient determined according 5.4.3.3 not be less than 0.33% PrE/s and not more than 0.66% PrE/s.

Note:

Graph of power gradient: 100% to 5% P_{Emax}



Graph of power gradient: 5% to 100% P_{Emax}



5.4.4 Active power feed-in for overfrequency
(these tests are designed to provide evidence that the requirements of VDE-AR-N 4105, 5.7.3.3 are met)

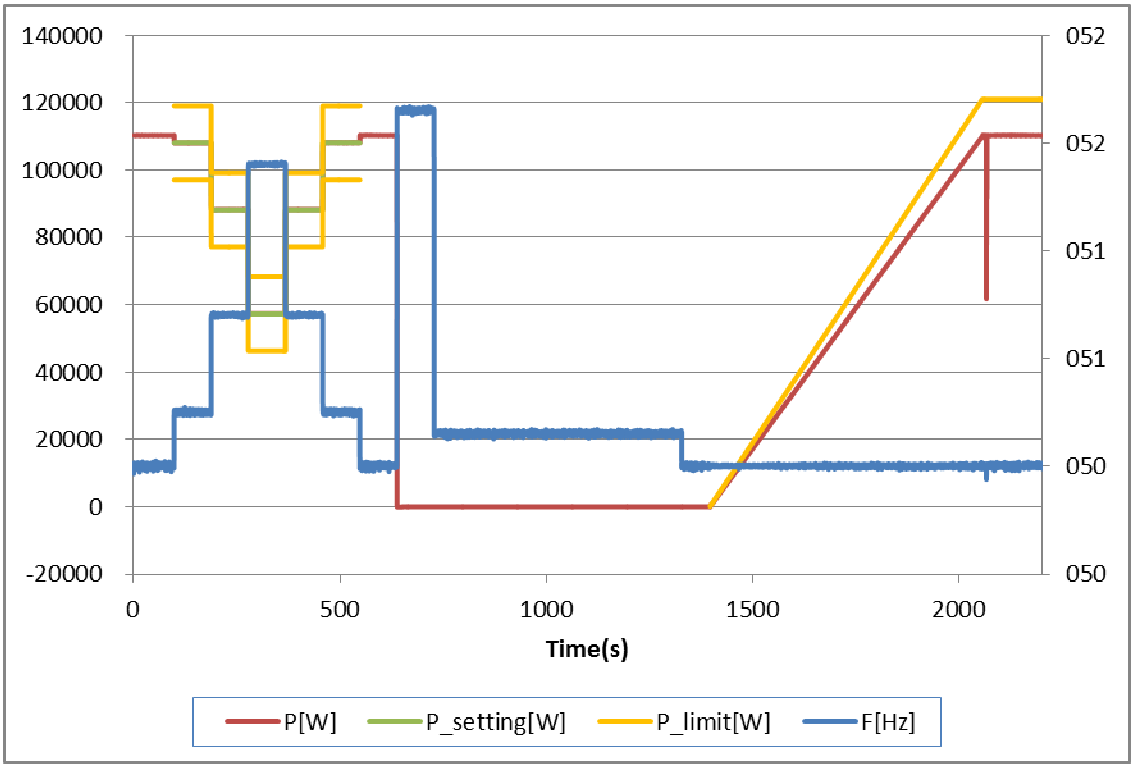
5.3.4.1.1 Test cycle for adjustable/conditionally adjustable PGUs — **P**

Test:

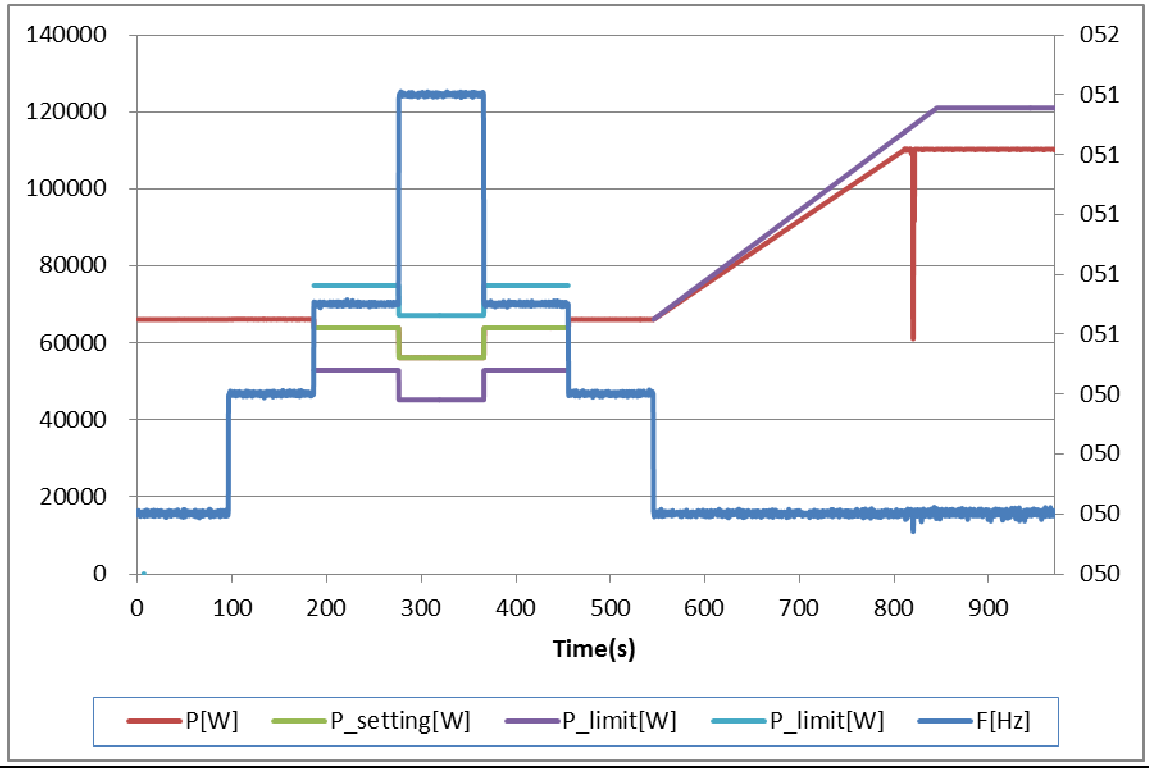
f [Hz]	a) 50,00	b) 50,25	c) 50,70	d) 51,40	e) 50,70	f) 50,25	g) 50,00	h) 51,65	i) 50,15	j) 50,00
Test 1:										
Frequency [Hz]:	50,00	50,25	50,70	51,40	50,70	50,25	50,00	51,65	50,15	50,00
$P_{setpoint}$ [% P_{Emax}]:	100,00	98,21	80,13	52,06	80,13	98,22	100,00	0,00	0,00	100,00
P_{E60} [% P_{Emax}]:	100,25	98,20	80,16	52,08	80,19	98,21	100,25	-0,01	-0,01	99,32
$\Delta P_{E60}/P_{Setpoint}$ [% P_{Emax}]:	0,25	-0,01	0,04	0,02	0,06	0,00	0,25	-0,01	-0,01	-0,68

Test 2:							
f [Hz]	a) 50,00	b) 50,40	c) 50,70	d) 51,40	e) 50,70	f) 50,40	g) 50,00
Frequency [Hz]:	50,00	50,40	50,70	51,40	50,70	50,40	50,00
$P_{setpoint}$ [% P_{Emax}]:	60,00	60,00	58,09	51,08	58,08	60,00	100,00
P_{E60} [% P_{Emax}]:	60,10	60,11	58,09	51,08	58,09	60,10	100,26
$\Delta P_{E60}/P_{Setpoint}$ [% P_{Emax}]:	0,10	0,11	0,01	0,01	0,01	0,10	0,26
Limit $\Delta P_{E60}/P_{Setpoint}$:	+ 10 % of P_{Emax}						

Graph of Test 1:



Graph of Test 2:



Tests:

The test is conducted for two powers.

Test1:

First, the test must start at a power > 100% PEmax ("Measurement 1") Start of the Power reduction at 50,20Hz s =5% (40% Pref/Hz), the rise of the active power gradient must be recorded.

Test2:

In a second test, for a power 60% PEmax ("Measurement 2"). Start of the Power reduction at 50,50Hz s =12% (16,67% Pref/Hz). After freezing of the PM, the available active power output must be increased to a value 100% PEmax, and after the network frequency of 50,2 Hz is raised above, the rise of the active power gradient must be recorded.

Assessment criterion:

The test is regarded as passed:

a) for controllable PGU if:

- The active power reduces between measuring points 5.4.4.1 a) to g) and j), the expected active power output, after settling, adjusts with a deviation ≤ ± 10% PEmax.
  In the measurement points h) and i) shall no active power be given.
- The initial time delay TV of the frequency-dependent adaptation of the active power output ≤ 2 s.
- The response time of the adaptation of the active power output is a maximum of 8 s (type 1 units and type 2 units with rotating machines) or 2 s (all other type 2 units)
- the settling time of the adaptation of the active power output is a maximum time of 30 s (for type 1 units and for type 2 units with rotating machines) or respectively a maximum time of 20 s (for all other generation units type 2) and
- The connection time at point j) is at least 60 s and the power is then increased with a gradient of ≤ 10% PEmax / min.
- In the case of generating units with combustion engines or gas turbines, if the criteria for response time and settling time are not met, the test shall be passed, even if the adaptation of active power output occurs with a power gradient of at least 66% PEmax per min (corresponding to 1.11% PEmax per s).

b) for conditionally adjustable PGU, if:

- they behave as described in a) inside their control range and
- outside the control range, the power supplied when leaving the control range remains constant until it is switched off
- the connection time in j) and where appropriate in g) corresponds to the manufacturer's information on the random number generator;

NOTE: The Uniform distribution of the disconnection frequency in maximum increments of 0.1 Hz between the end of the control range (at least 50.2 Hz) and 51.5 Hz shall be proofed by a manufacturer's declaration.

c) for non-adjustable EZE, if

- a disconnection takes place between 50.2 Hz and 51.5 Hz;
- the connection time in j) and where appropriate in g) corresponds to the manufacturer's information on the random number generator;

NOTE The Uniform distribution of the disconnection frequency in maximum increments of 0.1 Hz between 50.2 Hz and 51.5 Hz shall be proofen by a manufacturer's declaration.

d) for linear generators with SEmax ≤ 4.6 kVA,

- if they disconnect from the mains at a frequency ≥ 50.2 Hz and their maximum upper frequency limit (as specified by the manufacturer), but at the latest when they exceed 51.5 Hz.
- the connection time in j) and where appropriate in g) corresponds to the manufacturer's information on the random number generator;

Subsequently no more resynchronisation/active power feed-in is permitted, also while the frequency 5.4.4.1 i) is maintained (i.e no running on the characteristic curve as previously tested in a) at g).

Note:

5.4.6 Active power feed-in for PGUs at Underfrequency (these tests are designed to provide evidence that the requirements of VDE-AR-N 4105:2018-11 5.7.4.3. and VDE-AR-N 4105:2018-11 8.3.1. are met) (not for DC-coupled Storage systems)	**P**

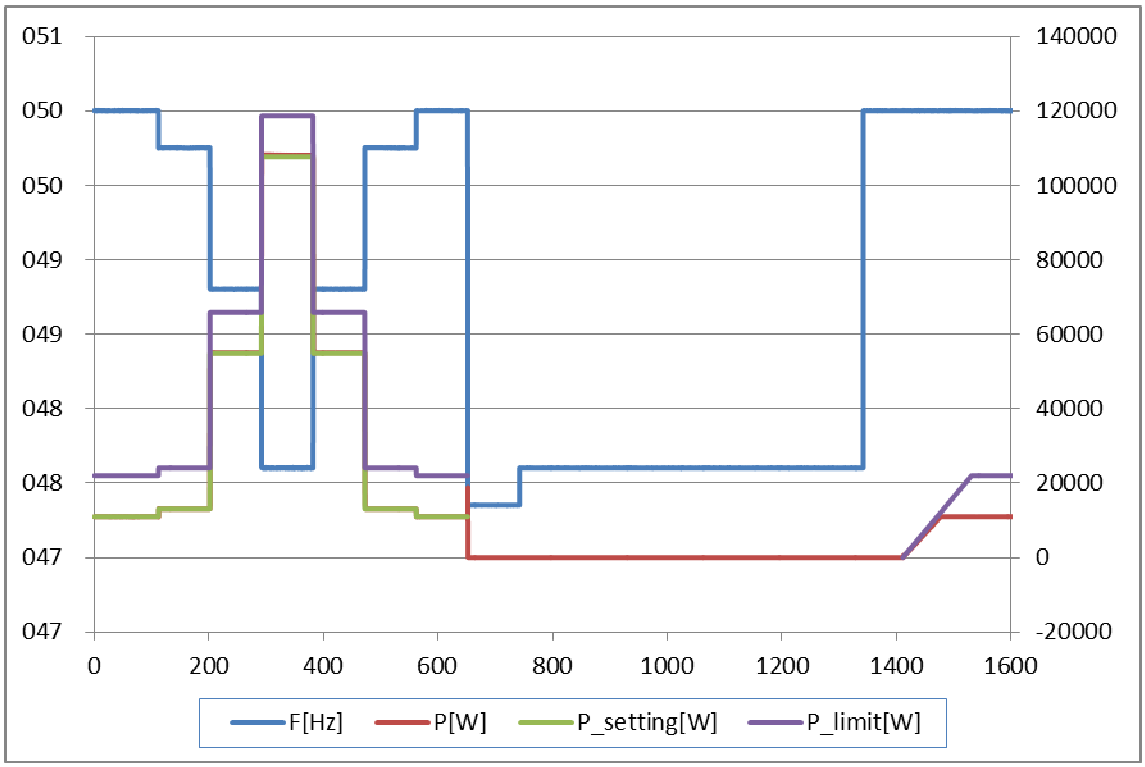
Test:

f [Hz]	a) 50,00	b) 49,75	c) 48,80	d) 47,60	e) 48,80	f) 49,75	g) 50,00	h) 47,35	i) 47,60	j) 50,00
Test 1:										
Frequency [Hz]:	50,00	49,75	48,80	47,60	48,80	49,75	50,00	47,35	47,60	50,00
$P_{setpoint}$ [% P_{Emax}]:	10,00	11,85	49,86	97,87	49,86	11,88	10,00	0,00	0,00	10,00
P_{E60} [% P_{Emax}]:	9,96	11,90	50,05	98,31	50,02	11,90	9,96	-0,01	-0,01	9,98
$\Delta P_{E60}/P_{Setpoint}$ [% P_{Emax}]:	-0,04	0,05	0,19	0,45	0,16	0,02	-0,04	-0,01	-0,01	-0,02

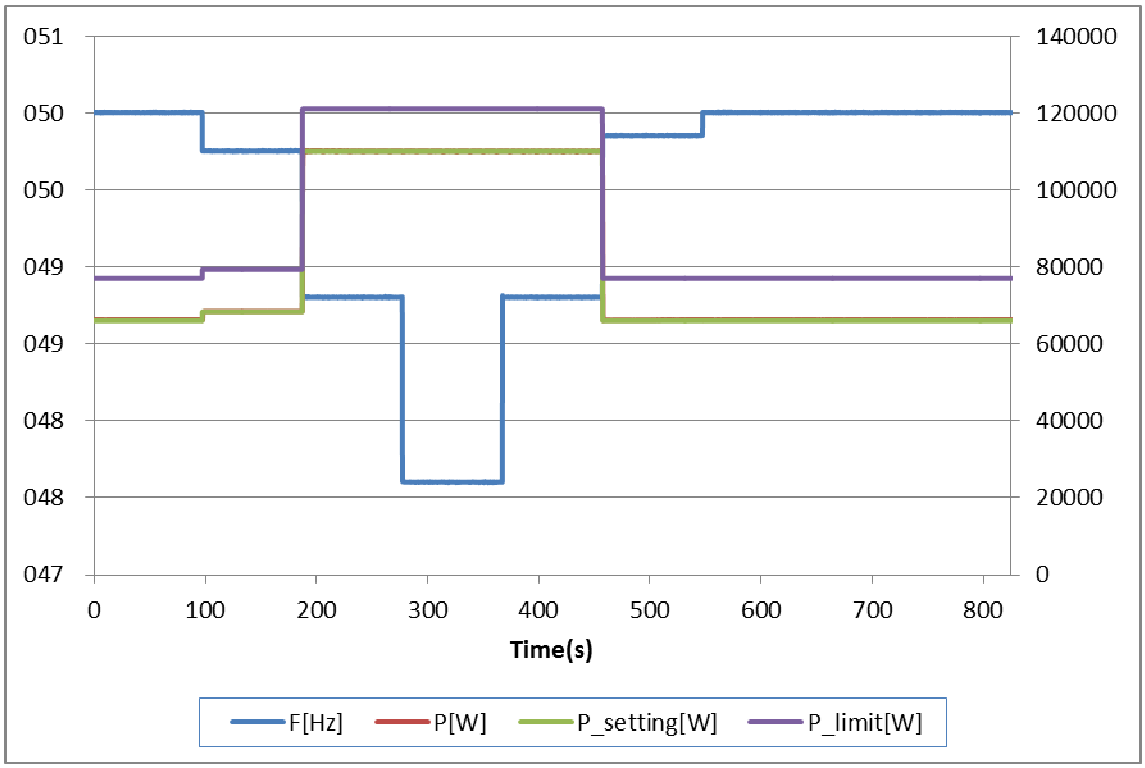
Test 2:

f [Hz]	a) 50,00	b) 49,75	c) 48,80	d) 47,60	e) 48,80	f) 49,85	g) 50,00
Frequency [Hz]:	50,00	50,40	50,70	51,40	50,70	50,40	50,00
$P_{setpoint}$ [% P_{Emax}]:	60,00	62,11	100,00	100,00	100,00	60,00	60,00
P_{E60} [% P_{Emax}]:	60,20	62,17	100,07	100,02	100,00	60,14	60,21
$\Delta P_{E60}/P_{Setpoint}$ [% P_{Emax}]:	0,20	0,07	0,07	0,02	0,00	0,14	0,21
Limit $\Delta P_{E60}/P_{Setpoint}$:	+ 10 % of P_{Emax}						

Graph of Test 1:



Graph of Test 2:



Tests:
The test is conducted for two powers.
In both tests, the following measuring points a) to j) must be approached with an accuracy of ± 10 mHz. The measuring points a) to h) and j) are to be approached for at least 60 s or until the maximum power is reached after a shutdown. The measuring point i) must be started for at least 10 min. The specified initial active power must be maintained with a tolerance of ± 5% PEmax. The deviation must be taken into account during the evaluation.
Start of the increase of active power at 49,8Hz s =5% (40% Pref/Hz), the rise of the active power gradient must be recorded.
Test1:
First, the test must start at a power > 10% PEmax ("Measurement 1")
Note: Testing is only valid for adjustable PGUs
Test2:
First, the test must start at a power > 60% PEmax ("Measurement 2")
Note: If the technical minimum line is above 60% PEmax, this must be taken into account accordingly. In the case of non-controllable EZE, this test is omitted.

Assessment criterion:
The test is regarded as passed:
a) for controllable PGU if:
- The active power reduces between measuring points 5.4.4.1 a) to g) and j), the expected active power output, after settling, adjusts with a deviation ≤ ± 10% P_{Emax}. Deviations according to VDE-AR-N 4105: 2018-11, 5.7.4.3, Figure 13 and due to the technical restrictions described are permissible. In the measuring points h) and i) no active power may be delivered,
- The initial time delay T_V of the frequency-dependent adaptation of the active power output ≤ 2 s.
- The response time of the adaptation of the active power output is a maximum of 8 s (type 1 units and type 2 units with rotating machines) or 2 s (all other type 2 units)
- the settling time of the adaptation of the active power output is a maximum time of 30 s (for type 1 units and for type 2 units with rotating machines) or respectively a maximum time of 20 s (for all other generation units type 2) and
- The connection time at point j) is at least 60 s and the power is then increased with a gradient of ≤ 10% P_{Emax} / min.
- In the case of generating units with combustion engines or gas turbines, if the criteria for response time and settling time are not met, the test shall be passed, even if the adaptation of active power output occurs with a power gradient of at least 66% P_{Emax} per min (corresponding to 1.11% P_{Emax} per s).

b) for conditionally adjustable PGU, if:
- they behave as descripted in a) inside their control range and
- no disconnection takes place between 49,8 Hz and 47,5 Hz;
- the connection time in j) corresponds to the manufacturer's information on the random number generator;

NOTE: The Uniform distribution of the disconnection frequency in maximum increments of 0.1 Hz between the end of the control range (at least 50.2 Hz) and 51.5 Hz shall be proofed by a manufacturer's declaration.

c) for non-adjustable EZE, if
- no disconnection takes place between 49,8 Hz and 47,5 Hz;
- the connection time in j) corresponds to the manufacturer's information on the random number generator;

NOTE The Uniform distribution of the disconnection frequency in maximum increments of 0.1 Hz between 50.2 Hz and 51.5 Hz shall be proofen by a manufacturer's declaration.

d) for linear generators with S_{Emax} ≤ 4.6 kVA,
- if they disconnect from the mains at a frequency ≤ 49,8 Hz and their maximum upper frequency limit (as specified by the manufacturer), but at the latest when they exceed 47.5 Hz.
the connection time in j) corresponds to the manufacturer's information on the random number generator;

Subsequently no more resynchronisation/active power feed-in is permitted, also while the frequency 5.4.4.1 i) is maintained (i.e no running on the characteristic curve as previously tested in a) at g).

Note:

5.4.8 Static voltage stability / reactive power supply

The test serves as verification of the reactive power mode according to VD-AR-N 4105: 2018-11, 5.7.2 of the EZE in normal operation.

The PGU has:
applies for PGUs Type 2 - only inverter $\Sigma S_{Emax} \geq 4.6$ kVA

5.4.8.1 Tests of the Reactive power / cos φ setting accuracy — P

Setting values	cos φ over-excited:	0,80
	cos φ under-excited:	0,80

Test:

30 s mean value	0,90U_n		U_n		1,1 U_n	
	S_{Emax}	40 – 60 %P_{Emax}	S_{Emax}	40 – 60 %P_{Emax}	S_{Emax}	40 – 60 %P_{Emax}
cos φ (1)						
U [V]:	207,17	207,20	230,67	230,47	253,09	253,12
P_{E30} [kW]:	99,770	55,131	110,324	55,121	110,000	55,100
Q_{E30} [kVAr]:	-0,302	-0,201	-0,367	-0,215	-0,006	0,059
S_{E30} [kVA].	99,771	55,131	110,324	55,121	110,000	55,100
cos $\varphi_{E30\text{-over-excited}}$:	0,999	0,999	0,999	0,999	0,999	0,999
$Q_{setpoint}$ [kVAr]:	0	0	0	0	0	0
$\Delta Q/P_{Emax}$[%]	-0,274	-0,183	-0,334	-0,196	-0,005	0,053
cos φ (i)						
U [V]:	207,05	207,20	230,55	230,46	253,12	253,07
P_{E30} [kW]:	80,206	55,100	88,265	55,183	88,177	55,100
Q_{E30} [kVAr]:	-60,132	-41,386	-66,415	-41,402	-66,063	-41,227
S_{E30} [kVA].	100,000	68,931	110,461	68,985	110,000	68,838
cos $\varphi_{E30\text{-over-excited}}$:	0,800	0,800	0,799	0,800	0,800	0,801
$Q_{setpoint}$ [kVAr]:	60,000	41,359	66,277	41,391	66	41,303
$\Delta Q/P_{Emax}$[%]	-0,120	-0,025	-0,125	-0,010	-0,057	0,069
cos φ (c)						
U [V]:	207,11	208,10	230,60	230,21	253,11	253,18
P_{E30} [kW]:	80,209	55,112	88,800	55,108	88,199	55,200
Q_{E30} [kVAr]:	60,055	41,129	66,129	41,047	65,956	41,289
S_{E30} [kVA].	100,000	68,788	111,000	68,739	110,000	68,915
cos $\varphi_{E30\text{-over-excited}}$:	0,801	0,802	0,802	0,802	0,801	0,801
$Q_{setpoint}$ [kVAr]:	60,000	41,273	66,600	41,243	66	41,3488
$\Delta Q/P_{Emax}$[%]	0,050	-0,131	-0,428	-0,179	-0,040	-0,055
Limit ΔQ:	± 4% P_{Emax}					

Test:

applies for PGUs Type 2 - only inverter $\Sigma S_{Emax} \leq 4.6$ kVA

a)and b) For cos φ 0,95 over-excited and φ 0,95 under-excited, the active power will be measured at value between 40% P_{Emax} and 60% and S_{Emax} and a second time,
for cos φ 0,975 over-excited and φ 0,975 under-excited, the active power will be measured at a value between 40% P_{Emax} and 60% and S_{Emax}

applies for PGUs Type 2 - only inverter $\Sigma S_{Emax} \geq 4.6$ kVA

c) and d) For cos φ 0,90 over-excited and φ 0,90 under-excited, the active power will be measured at value between 40% P_{Emax} and 60% and S_{Emax} and a second time,
for cos φ 0,95 over-excited and φ 0,95 under-excited, the active power will be measured at a value between 40% P_{Emax} and 60% and S_{Emax}

applies PGUs Type 1 as well as for type 2 plants with Stirling generators and fuel cells $\Sigma S_{Emax} \leq 4.6$ kVA

e) without specification of the cos φ the active power will be measured at value between 40% P_{Emax} and 60% and S_{Emax}.

applies for PGUs Type 1 as well as for type 2 plants with Stirling generators and fuel cells $\Sigma S_{Emax} \geq 4.6$ kVA

f) and g) For cos φ 0,95 over-excited and cos φ 0,95 under-excited, the active power will be measured at value between 40% P_{Emax} and 60% and S_{Emax} and a second time,
for cos φ 0,975 over-excited and φ 0,975 under-excited, the active power will be measured at a value between 40% P_{Emax} and 60% and S_{Emax}

applies for PGUs Type 2 Asynchronous generators:

h) without specification of the cos φ the active power will be measured at value between 40% P_{Emax} and 60% and S_{Emax}

Assessment criterion:

applies for PGUs Type 2 - only inverter $\Sigma SEmax \leq 4.6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.95 and one time at 0,975 and the measured apparent power of the fundamental. The test is passed if all the Q 60 s mean values of the fundamental component for a) are in the range of Q set point ± 4% P_{Emax} overexcited and for b) in the range of Q set point ± 4% P_{Emax} under-excited. In addition, a setting of the cos φ must be possible within a step size of at least 0.01.

applies for PGUs Type 2 - only inverter $\Sigma SEmax \geq 4.6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.90 and one time at 0,95 and the measured apparent power of the fundamental. The test is passed if all the Q 60 s mean values of the fundamental component for a) are in the range of Q set point ± 4% P_{Emax} overexcited and for c) in the range of Q set point ± 4% P_{Emax} under-excited. In addition, a setting of the cos φ must be possible within a step size of at least 0.01.

applies for PGUs Type 1 as well as for type 2 plants with Stirling generators and fuel cells $\Sigma SEmax \leq 4.6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.95 and one time at 0,975 and the measured apparent power of the fundamental. The test is passed if all the Q 60 s mean values of the fundamental from e) are in the range Q maximal overexcited till Q minimal under-excited.

applies for PGUs Type 1 as well as for type 2 plants with Stirling generators and fuel cells $\Sigma SEmax \geq 4.6$ kVA

The Q setpoint is calculated by using the required cos φ setpoint one time at 0.95 and one time at 0,975 and the measured apparent power of the fundamental. The test is passed if all the Q 60 s mean values of the fundamental component for a) are in the range of Q set point ± 4% P_{Emax} overexcited and for f) in the range of Q set point ± 4% P_{Emax} under-excited. In addition, a setting of the cos φ must be possible within a step size of at least 0.01.

applies for PGUs Type 1 Asynchronous generators:

The test is passed if the cos φ Q 60 s mean values of h) is in the range cos φ = 0,95 underexcited ±0,02.

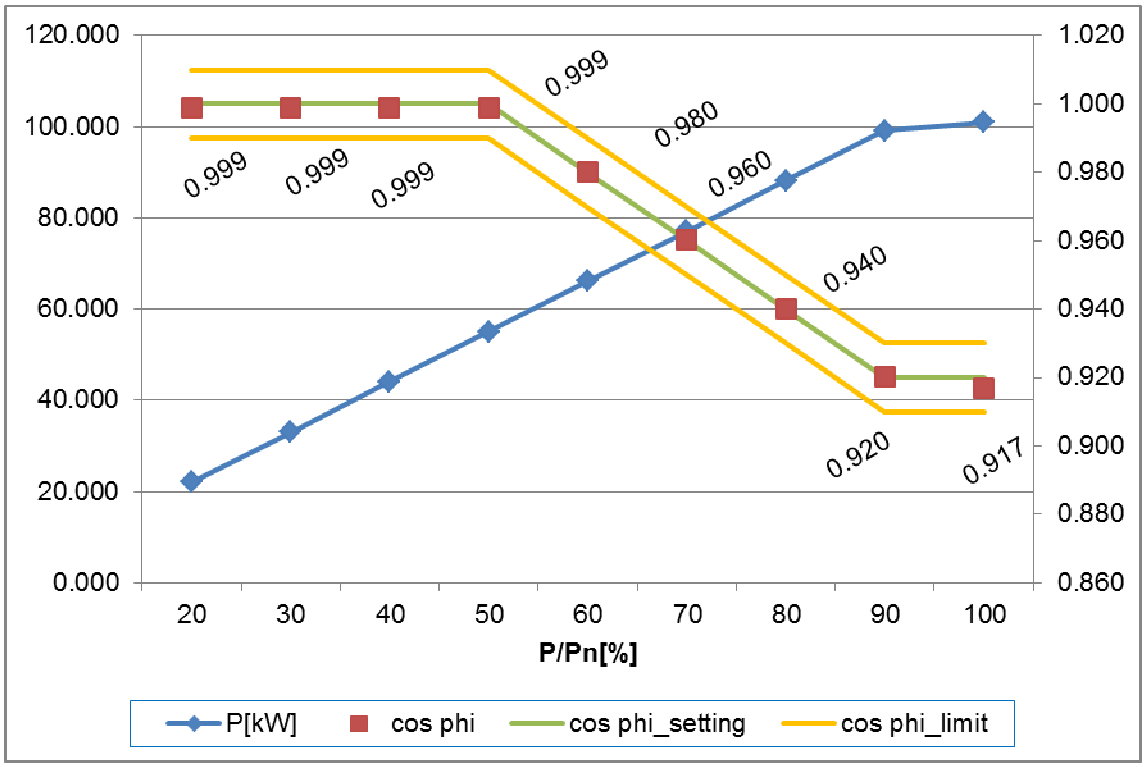
Note:

5.4.8.2 Test of the displacement factor/active power characteristic curve cos φ (P) The test serves as verification of the standard cos φ (P) curve according to VDE-AR-N 4105:2018-11, 5.7.2.4.	**P**

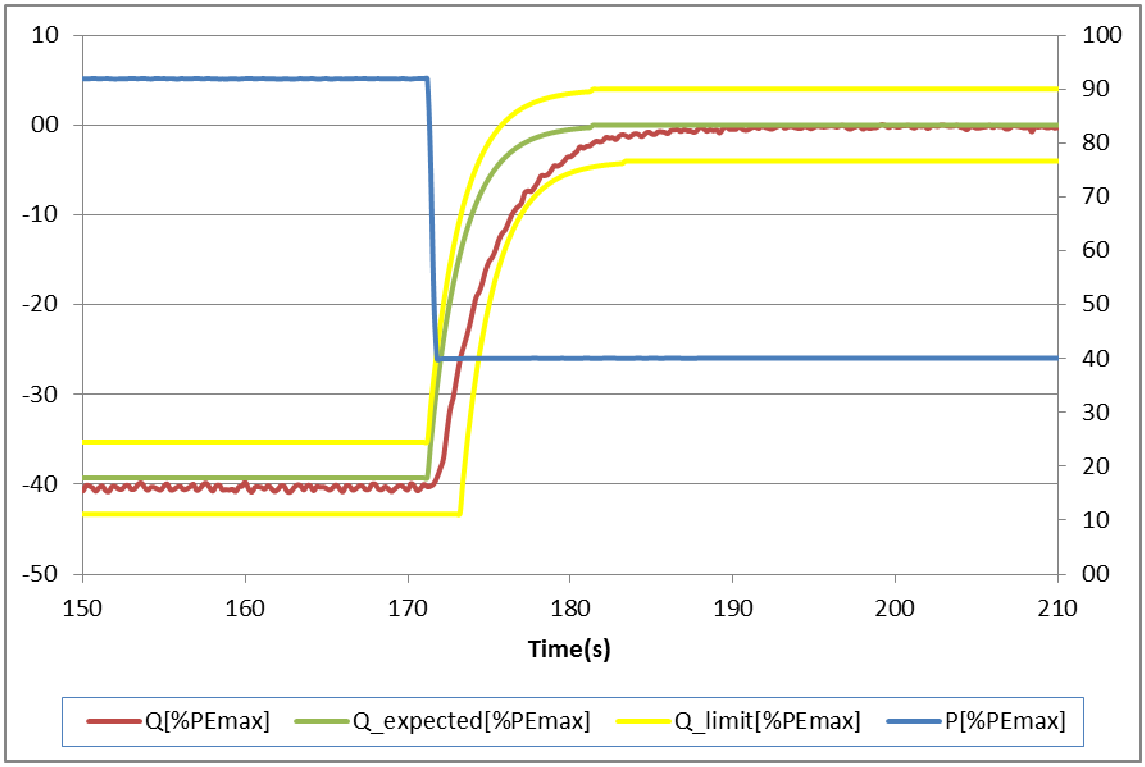
Test c): supply-dependent PGUs - Accuracy (characteristic curve)										
P_{Emax}/P [%]	10	20	30	40	50	60	70	80	90	100
30 s mean value	20% to 100% P_{Emax}									
U [V]:	--	230,25	230,30	230,32	230,35	230,36	230,38	230,40	230,42	230,43
P_{E30} [kW]:	--	22,015	33,077	44,068	55,096	66,087	77,122	88,181	99,146	100,953
P_{E30} of P_{Emax} [%]:	--	20,01	30,07	40,06	50,09	60,08	70,11	80,16	90,13	91,78
Q_{E30} [kVAr]:	--	0,096	0,079	0,070	-0,064	-13,347	-22,423	-31,940	-42,178	-43,957
S_{E30} [kVA].	--	22,016	33,077	44,068	55,096	67,421	80,316	93,787	107,744	110,108
cos φ_{E30}:	--	0,999	0,999	0,999	0,999	0,980	0,960	0,940	0,920	0,917
cos $\varphi_{setpoint}$ of P_{E30}:	--	1,00	1,00	1,00	1,00	0,98	0,96	0,94	0,92	0,92
$Q_{setpoint}$ [kVAr]:	--	0	0	0	0	-13,417	-22,488	-31,998	-42,227	-43,153
$\Delta Q/P_{Emax}$[%]	--	0,087	0,071	0,064	-0,058	0,063	0,059	0,052	0,044	-0,731
Limit ΔQ:	± 4% P_{Emax}									
P_{Emax}/P [%]	100	90	80	70	60	50	40	30	20	10
30 s mean value	100% to 20% P_{Emax}									
U [V]:	230,43	230,44	230,43	230,41	230,39	230,37	230,34	230,30	230,27	--
P_{E30} [kW]:	100,942	99,118	88,135	77,110	66,078	55,096	44,072	33,076	22,076	--
P_{E30} of P_{Emax} [%]:	91,77	90,11	80,12	70,10	60,07	50,09	40,07	30,07	20,07	--
Q_{E30} [kVAr]:	-43,960	-42,167	-31,946	-22,425	-13,367	-0,057	0,059	0,074	0,080	--
S_{E30} [kVA].	110,100	107,715	93,746	80,305	67,417	55,096	44,072	33,076	22,076	--
cos φ_{E30}:	0,917	0,920	0,940	0,960	0,980	0,999	0,999	0,999	0,999	--
cos $\varphi_{setpoint}$ of P_{E30}:	0,92	0,92	0,94	0,96	0,98	1,00	1,00	1,00	1,00	--
$Q_{setpoint}$ [kVAr]:	-43,150	-42,215	-31,984	-22,485	-13,416	0	0	0	0	--
$\Delta Q/P_{Emax}$[%]	-0,736	0,044	0,034	0,055	0,044	-0,052	0,054	0,067	0,073	--
Limit ΔQ:	± 4% P_{Emax}									

Test d): supply-dependent PGUs - Dynamic				
P_{Emax}/P_n [%]	100	40	100	75
30 s mean value	100% to 40% to 100% to 75% P_{Emax}			
U [V]:	230,60	230,46	230,61	230,56
P_{E30} [kW]:	101,127	44,116	101,135	82,785
P_{E30} of P_{Emax} [%]:	91,93	40,11	91,94	75,26
Q_{E30} [kVAr]:	-44,455	-0,227	-44,452	-27,573
S_{E30} [kVA].	110,467	44,117	110,473	87,257
cos φ_{E30}:	0,915	0,999	0,915	0,949
cos $\varphi_{setpoint}$ of P_{E30}:	0,92	1,00	0,92	0,95
$Q_{setpoint}$ [kVAr]:	-43,294	0	-43,297	-27,246
$\Delta Q/P_{Emax}$[%]	-1,055	-0,206	-1,050	-0,298
Limit ΔQ:	± 4% P_{Emax}			

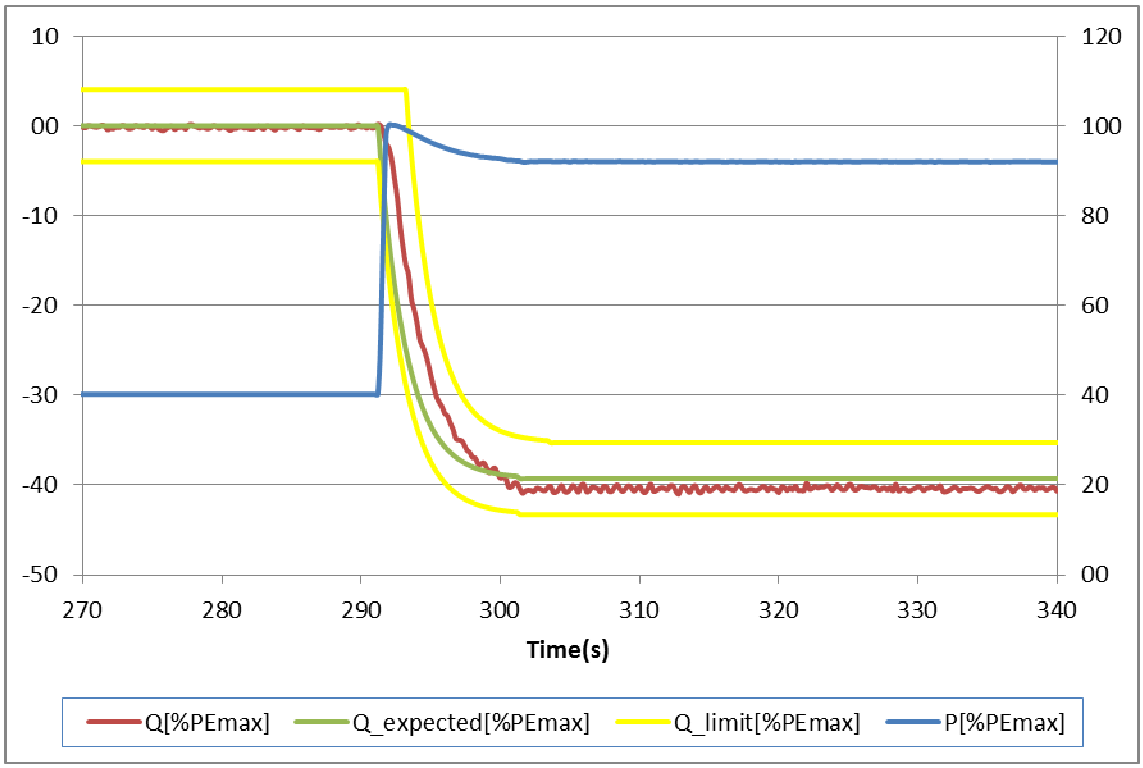
Graph of cos φ(P): Test c)



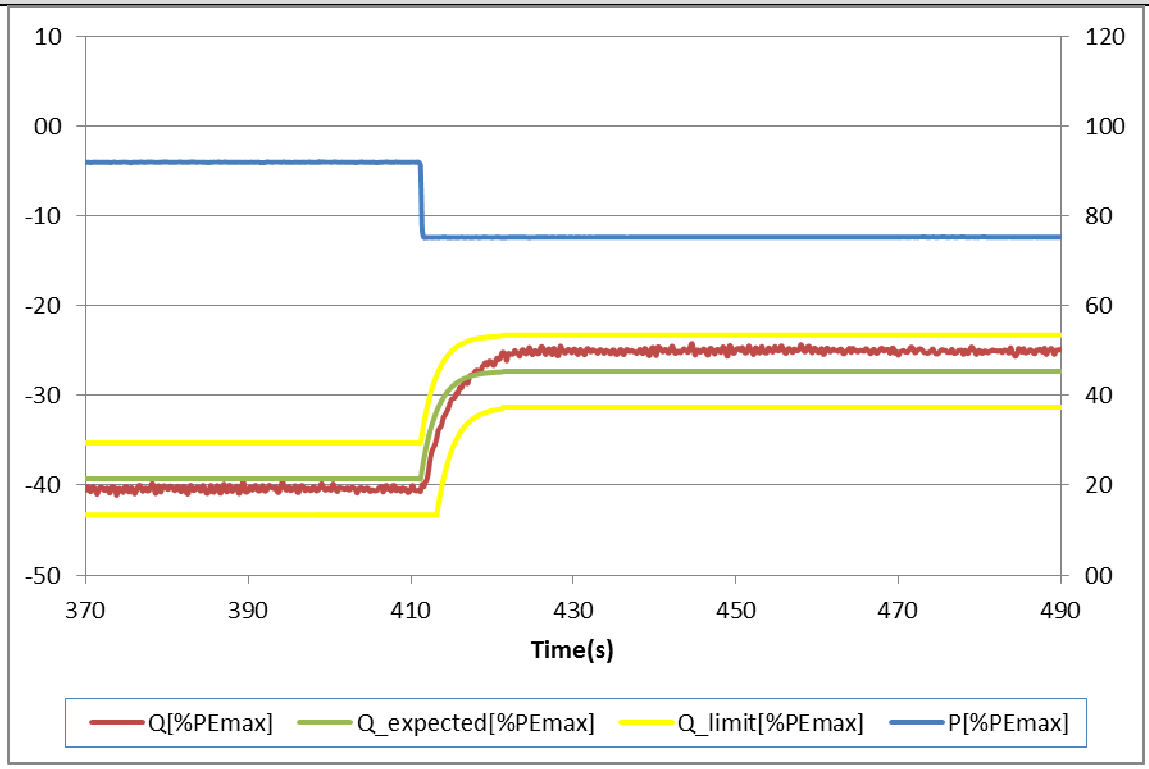
Graph of Test d): 100% to 40% P_{Emax}



Graph of Test d): 40% to 100% P_{Emax}



Graph of Test d): 100% to 75% P_{Emax}



Assessment criterion:

Test 5.4.8.2 a) and c) are passed if the maximum deviation between the reactive power setpoint (calculated from the characteristic) and the reactive power actual value at the generator terminals for all calculated reactive power values is a maximum of ± 4.0% relative to P_{Emax}.

Test 5.4.8.2 (b) is regarded as passed if the PGU demonstrably complies with the performance gradient requirements of VDE-AR-N 4105: 2018-11 in Section 5.7.4.2.

Test 5.4.8.2 d) is passed if the step response of the reactive power in the test steps c) and e) exhibits the PT1 behavior according to VDE-AR-N 4105: 2018-11 Section 5.7.2.5 and for test step d) the power gradient between the Limits of VDE-AR-N 4105: 2018-11 Section 5.7.4.2.

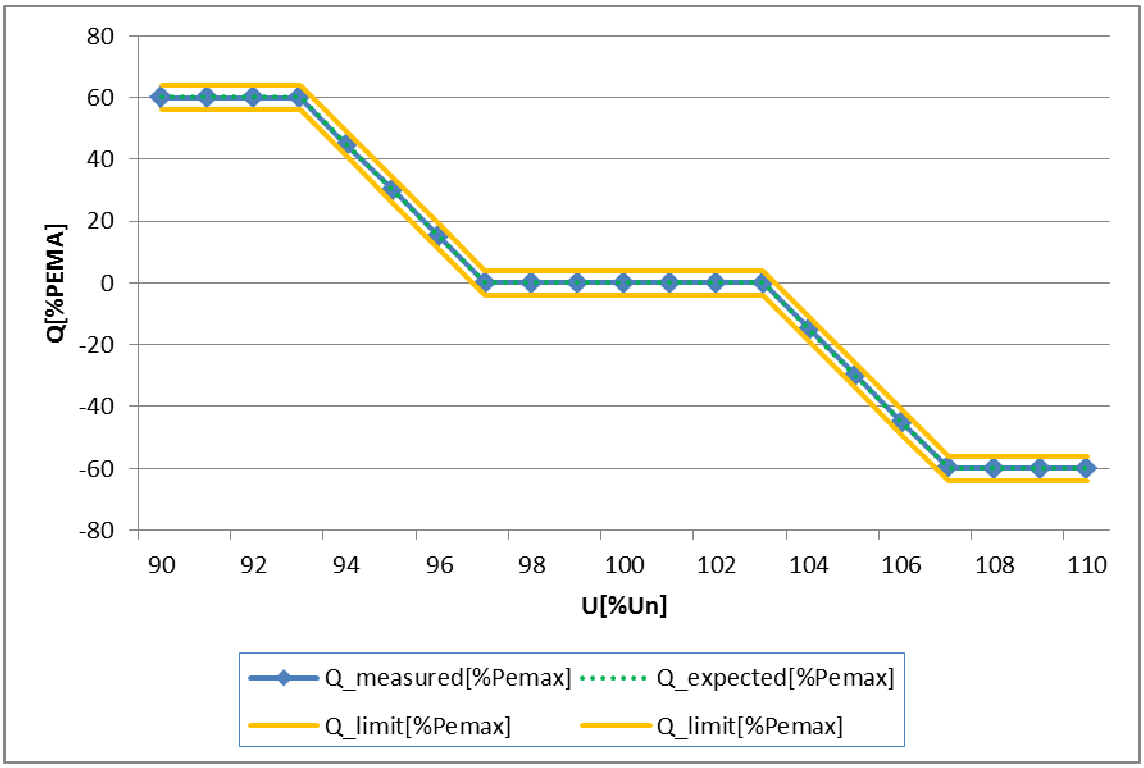
Note:

5.4.8.3 Test the reactive power-voltage characteristic Q (U) The validation of the Q (U) regulation according to VDE-AR-N 4105: 2018-05, 5.7.2.4 is divided into two partial tests, so that on the one hand the accuracy and on the other hand the dynamics of the Q (U) control is checked. For all inverter-coupled systems, only the inverter must be tested.	**P**

5.4.8.3.1	**Test of the reactive power-voltage characteristic Q (U)**						**P**
Vac [% U_n] Set point	Vac_L1 [V] measured	Vac_L2 [V] measured	Vac_L3 [V] measured	P [kW] measured	Q [kVar] measured	Q [kVar] expected	ΔQ [% P_{Emax}]
100	229,98	230,03	229,95	110,328	0,030	0,000	0,028
99	227,69	227,75	227,68	109,552	0,028	0,000	0,026
98	225,41	225,47	225,40	108,505	0,014	0,000	0,013
97	223,13	223,17	223,11	107,530	-0,003	0,000	-0,002
96	220,76	220,81	220,75	105,193	16,584	16,500	0,076
95	218,48	218,53	218,48	100,103	33,227	33,000	0,206
94	216,18	216,23	216,19	92,150	49,041	49,500	-0,417
93	213,86	213,92	213,88	79,538	65,871	66,000	-0,117
92	211,57	211,62	211,58	78,107	65,871	66,000	-0,117
91	209,26	209,32	209,28	76,606	65,872	66,000	-0,117
90	206,96	207,02	206,98	75,202	65,879	66,000	-0,110
91	209,26	209,32	209,28	76,607	65,878	66,000	-0,111
92	211,57	211,62	211,58	78,108	65,867	66,000	-0,121
93	213,87	213,92	213,88	79,540	65,859	66,000	-0,128
94	216,18	216,23	216,19	92,148	49,042	49,500	-0,417
95	218,48	218,53	218,48	100,104	33,195	33,000	0,177
96	220,76	220,81	220,75	105,188	16,575	16,500	0,068
97	223,13	223,18	223,12	107,768	-0,008	0,000	-0,007
98	225,42	225,47	225,40	108,441	0,008	0,000	0,007
99	227,70	227,75	227,68	109,565	0,016	0,000	0,014
100	229,98	230,04	229,96	110,271	0,026	0,000	0,024
101	232,42	232,48	232,41	110,247	-0,025	0,000	-0,023
102	234,63	234,68	234,61	110,280	-0,025	0,000	-0,022
103	236,94	237,00	236,93	110,298	-0,033	0,000	-0,030
104	239,23	239,28	239,21	108,899	-16,338	-16,500	0,147
105	241,50	241,55	241,48	105,154	-32,672	-33,000	0,298
106	243,85	243,90	243,83	98,269	-49,605	-49,500	-0,096
107	246,16	246,21	246,14	88,737	-65,769	-66,000	-0,210
108	248,49	248,54	248,47	88,059	-66,031	-66,000	-0,028

109	250,69	250,73	250,67	88,053	-66,031	-66,000	-0,028
110	253,09	253,13	253,08	88,057	-66,030	-66,000	-0,027
109	250,69	250,73	250,68	88,051	-66,027	-66,000	-0,025
108	248,49	248,53	248,47	88,052	-66,019	-66,000	-0,017
107	246,18	246,22	246,16	88,740	-65,772	-66,000	0,207
106	243,85	243,90	243,83	98,258	-49,636	-49,500	-0,124
105	241,51	241,56	241,49	105,152	-32,691	-33,000	0,280
104	239,24	239,29	239,22	108,899	-16,360	-16,500	0,128
103	236,94	236,99	236,92	110,308	-0,032	0,000	-0,029
102	234,63	234,68	234,62	110,271	-0,029	0,000	-0,026
101	232,35	232,41	232,34	110,216	-0,043	0,000	-0,039
100	230,05	230,11	230,04	110,191	-0,035	0,000	-0,032
Limit ΔQ:	± 4% P_{Emax}						

Graph of characteristic Q (U):



Test:

The verification of the accuracy of the Q (U) control of the reactive power-voltage characteristic Un shown in VDE-AR-N 4105: 2018-11, 5.7.2.4, Figure 7 is effected by a slow variation of the line voltage U_n in the range 90% U_n to 110% U_n. Depending on the type of EZE (single- or three-phase), the voltage changes must be carried out simultaneously or symmetrically on all phases.

a) In order to check the stationary accuracy, the permissible voltage range shall be passed through within steps, with a step size of 1% U_n, but not greater than 2% U_n.

1. Pass the voltage range from 100% U_n down to the under voltage range to 90% U_n.
2. Pass the voltage range from 90% U_n up to the over voltage range to 110% U_n.
3. Pass the voltage range from 110% U_n down to the Nominal Voltage U_n.

The procedure is analogous to Figure 3 in Section 5.4.3.2.

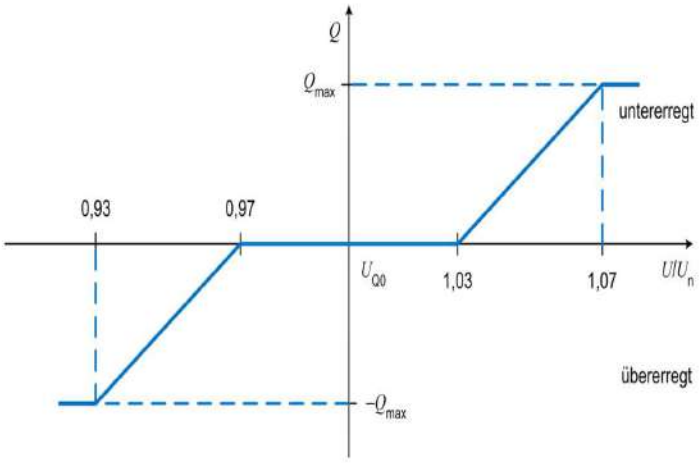


Bild 7 – Standard-$Q(U)$-Kennlinie

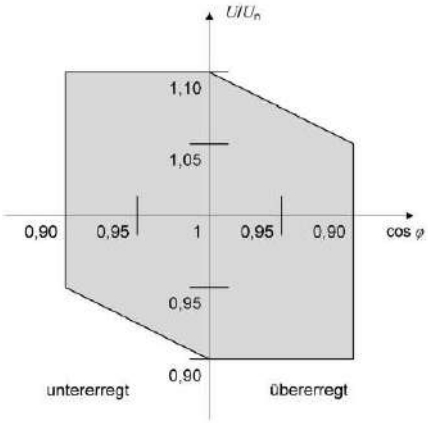


Bild 3 – Anforderungen an Erzeugungseinheiten bezüglich der Blindleistungsbereitstellung an den Generatorklemmen ($\sum S_{Emax} > 4{,}6$ kVA)

The voltages are to be set with a maximum deviation of 0.25% U_n.

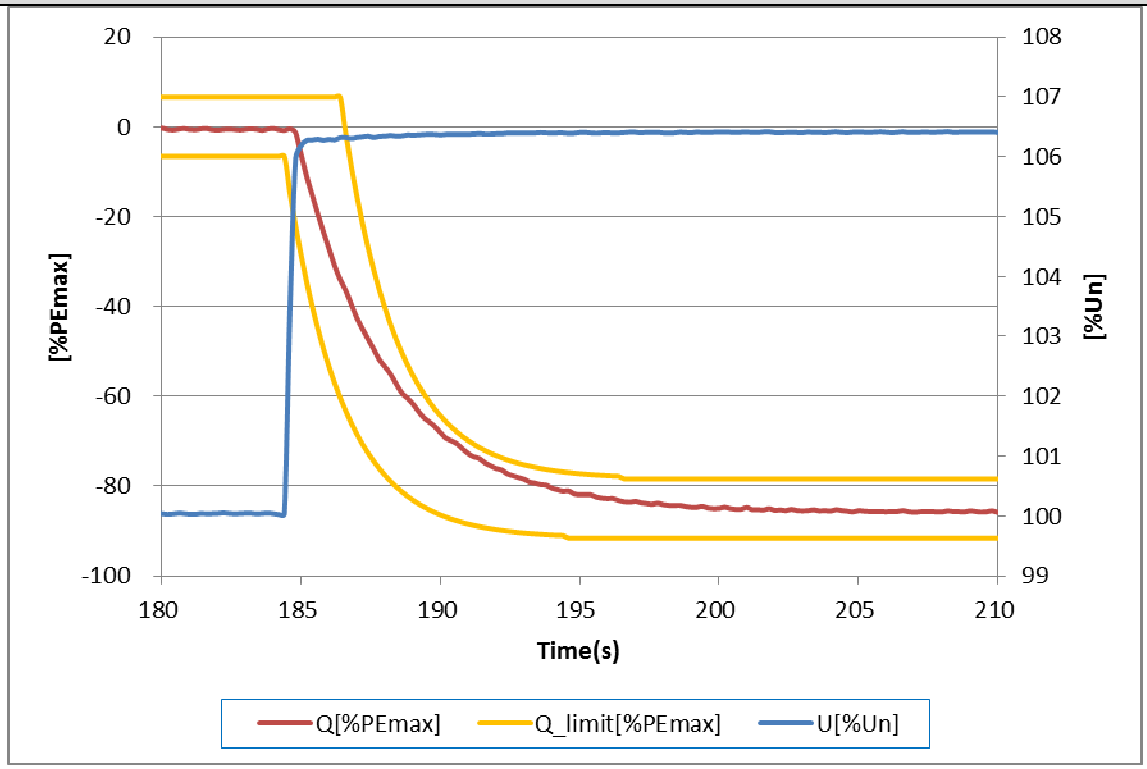
Assessment criterion:

In order to pass the Q (U) accuracy test, the measured stationary value pairs U_{PGU} and Q_{PGU}, under taking account to the correct sign in the consumer metering system, must be within VDE-AR-N 4105: 2018-11, in 5.7.2.4, Figure 7 Q (U) shown characteristic. The stationary value pairs U_{PGU} and Q_{PGU} are determined by averaging over 30 seconds at the end of the respective measuring section analogously to Chapter 5.4.3.2. The permissible deviations are with the maximum measuring error of the voltage of 1% U_n stated in VDE-AR-N 4105: 2018-11 and a setting accuracy of 4% P_{EMax} at

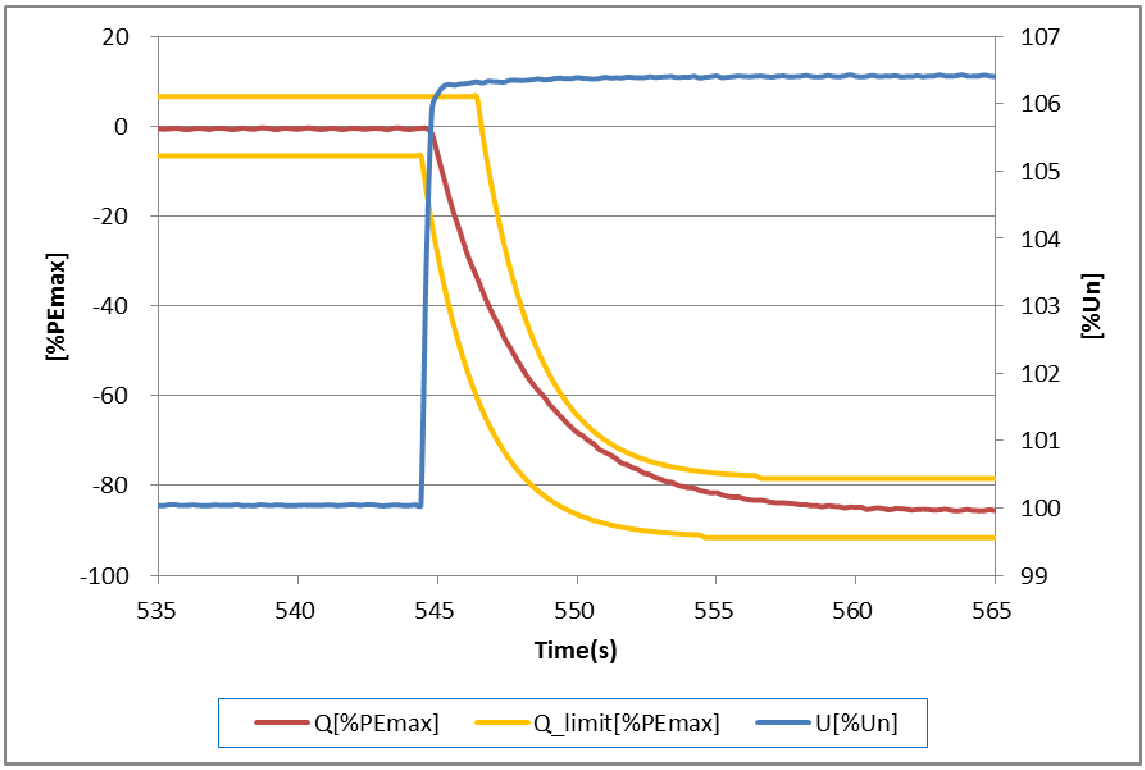
$$Q_{EZE,tol} = \pm(0.01 \cdot U_{N,Y} \cdot k_{QU} + 0.04 \cdot P_{EMax}) = \pm 0{,}25 \cdot P_{EMax} \cdot (\sin(\arccos(\varphi_{min})) + 0.16).$$

5.4.8.3.2 Test of the dynamics of the Q (U) regulation			P
Voltage jump Vac [% U_n]	Q [kVar] measured	Q [%Qmax] measured	T=3τmeasured
100 to 106,4	-56,612	-85,78	9,6 s
	-56,596	-85,75	9,4 s
	-56,616	-85,78	9,4 s
100 to 93,6	55,914	84,72	10,2 s
	55,923	84,73	10,2 s
	55,916	84,72	10,2s
Note			

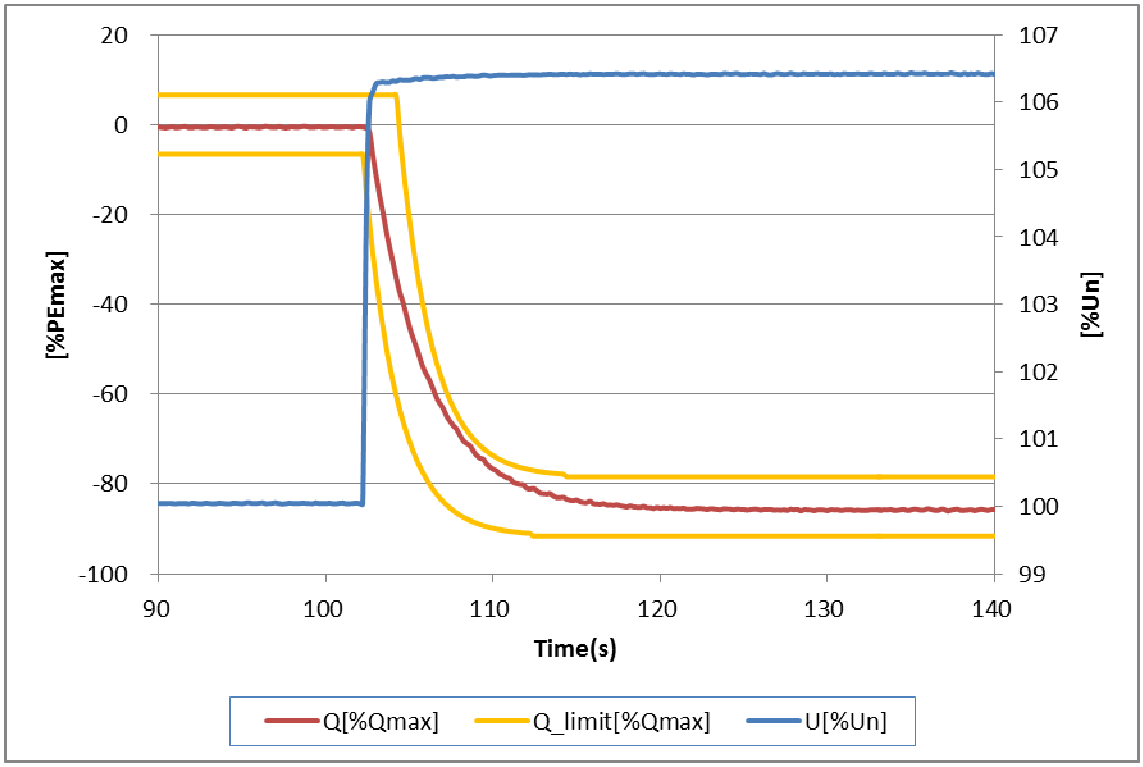
Graph of 100% U_n to 106,4% U_n: Test 1



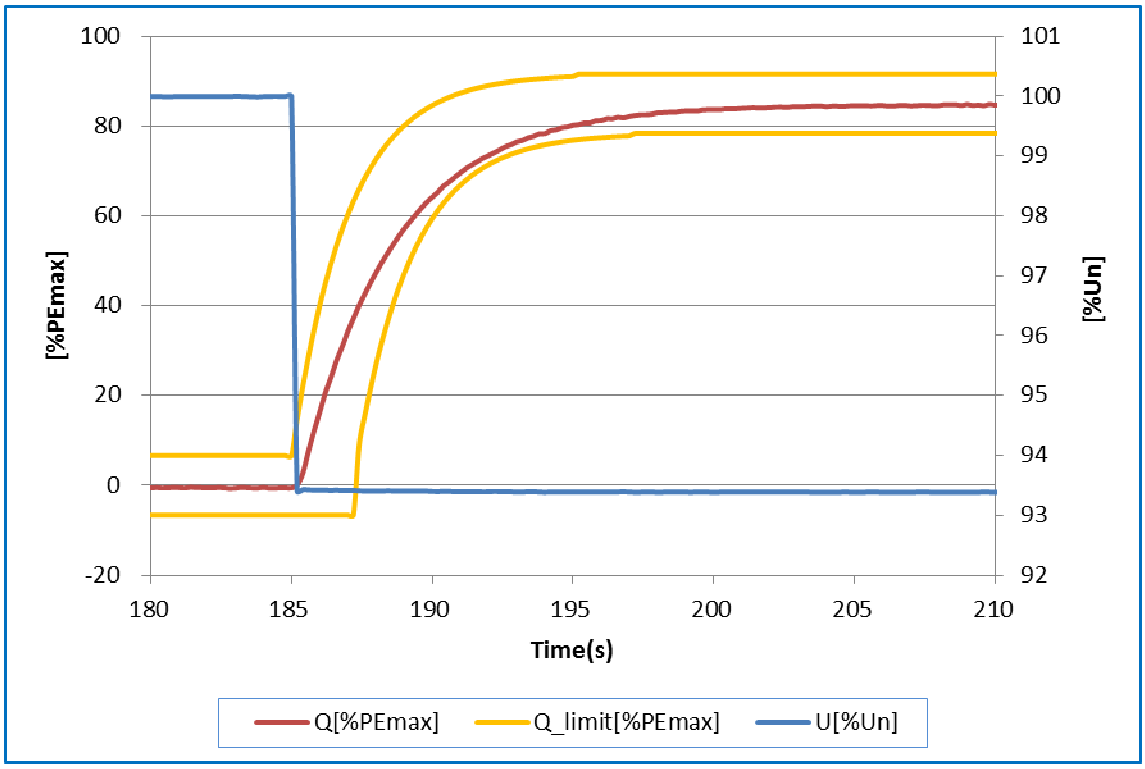
Graph of 100% U_n to 106,4% U_n: Test 2



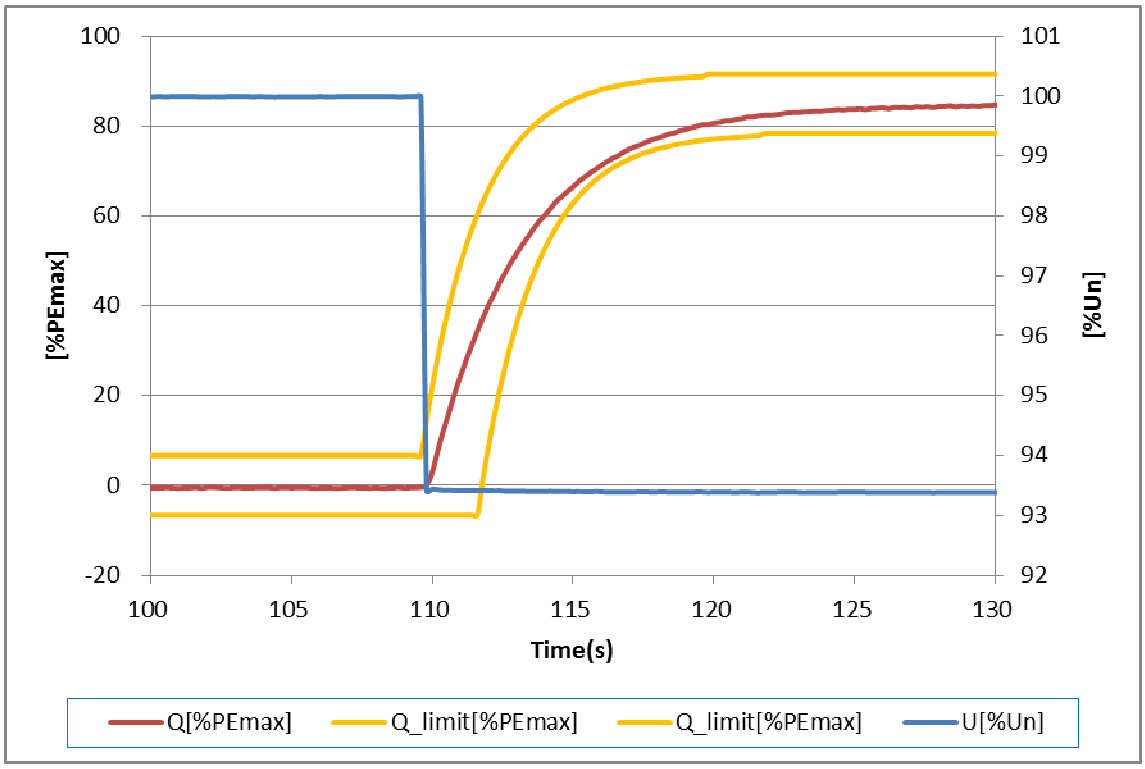
Graph of 100% U_n to 106,4% U_n: Test 3



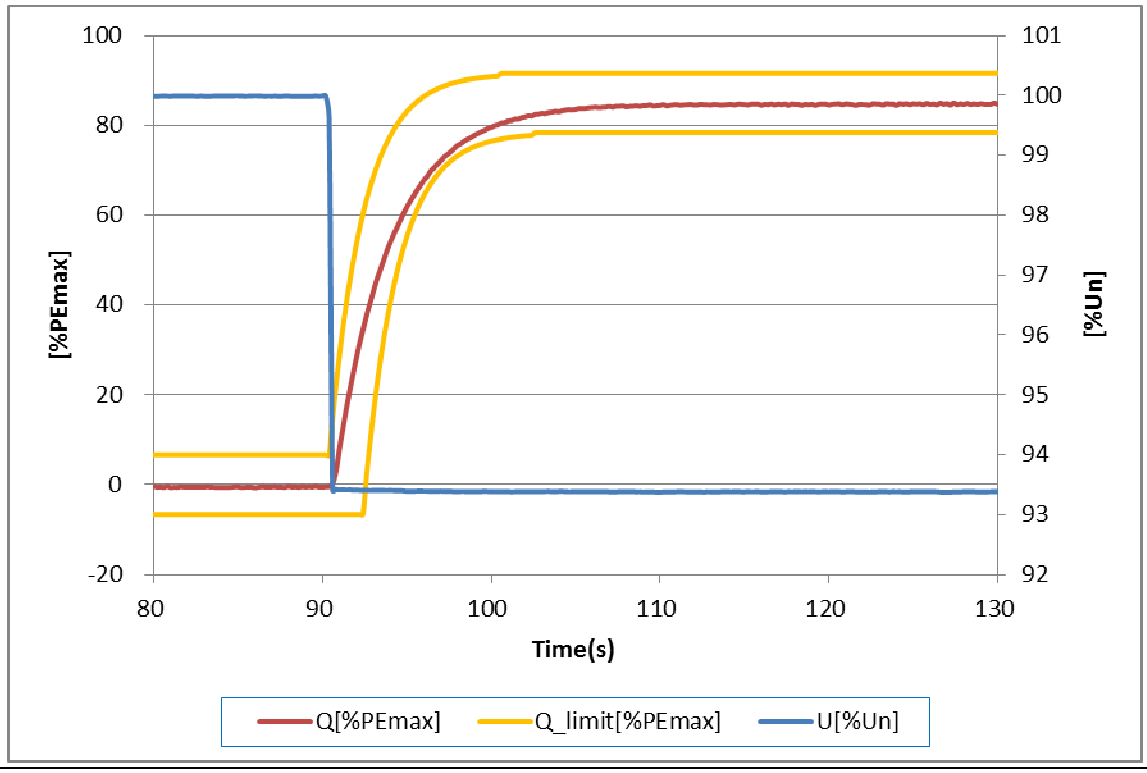
Graph of 100% U_n to 93,6% U_n: Test 1



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



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



5.5 Testing of NS protection E DIN V 0124-100:(2019-09) draft		
Clause	**Test**	**Result**
5.5.1	General	**P**
5.5.2.1	Functional safety	**P**
5.5.4	Integrated NS-protection	**P**
5.5.6	Section switch	**P**
5.5.6.2	Central section switch	**N/A**
5.5.6.3	Integrated section switch	**P**
5.5.7.2	Voltage control Single Phase	**N/A**
5.5.7.2	Voltage control Multi Phase (Phase to N)	**P**
5.5.7.2	Voltage control Multi Phase (Phase to Phase)	**P**
5.5.7.2.1.3	Measuring the rise-in voltage protection as a running 10-minute mean value	**P**
5.5.7.2.1.9	Frequency measurement	**P**
5.5.8	Reporting of NS protection	**P**
5.5.9	Constructional characteristics of NS protection	**P**
5.5.10.2	Passive Islanding Protection	**P**
5.5.10.3	Islanding protection according table 6 – Load imbalance (real, reactive load) for test condition A (EUT ouput = 100%)	**P**
5.5.10.3	Islanding protection according table 6 – Load imbalance (real, reactive load) for test condition A (EUT ouput = 66%)	**P**
5.5.10.3	Islanding protection according table 6 – Load imbalance (real, reactive load) for test condition A (EUT ouput = 33%)	**P**

5.5.2.1 Functional safety			P
	Ambient temperature [°C] :	24°C	—
	Model/type of power supply :	DC: N8957APV AC: RS180-3PI / RS90-3PI	—
	Manufacturer of power supply :	DC: Keysight AC: Ametek	—
	Rated markings of power supply :	DC: 0-1500V, 15KW AC: 0-650V, 270KW	—

Component No,	Fault	Test condition		Test time	Fuse No,	Fault condition		Result
		AC	DC			AC	DC	
Relay defect K5 Pin 1-pin 2	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
Relay defect K8 Pin 1-pin 2	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
Relay defect C956	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
Relay defect R144	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
Relay defect Q5	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
Relay defect Q14	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.

Component No,	Fault	Test condition		Test time	Fuse No,	Fault condition		Result
		AC	DC			AC	DC	
Relay defect R104	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
Relay defect C28	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: alarm grid relay abnormal No hazard, no damage, no reconnection.
PV insulation measurement defect Q7	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	EUT can't start up. Error message: Unit can't power on, alarm, ISO fault. No hazard, no damage, no reconnection.
PV insulation measurement defect D98	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: Unit can't power on, alarm, ISO fault. No hazard, no damage, no reconnection.
PV insulation measurement defect R1058	Short before start-up	230V <0,1A	600V <0,1A	10min	--	230V <0,1A	600V <0,1A	PCE can't start up. Error message: Unit can't power on, alarm, ISO fault. No hazard, no damage, no reconnection.
RCMU measurement defect Q14	s-c	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PCE shutdown immediately. Error message: alarm boost input over current No hazard, no damage, no reconnection.
RCMU measurement defect C747 +5V	s-c	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PCE shutdown immediately. Error message: alarm boost input over current No hazard, no damage, no reconnection.
RCMU measurement defect R126	o-c	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PCE shutdown immediately. Error message: alarm boost input over current No hazard, no damage, no reconnection.

Component No,	Fault	Test condition		Test time	Fuse No,	Fault condition		Result
		AC	DC			AC	DC	
RCMU measurement defect R461	o-c	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PCE shutdown immediately. Error message: alarm boost input over current No hazard, no damage, no reconnection.
RCMU measurement defect U34 pin1 to pin4	s-c	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PCE shutdown immediately. Error message: alarm boost input over current No hazard, no damage, no reconnection.
PV voltage detect D1502 PIN2-PIN3	short	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “High String Input Voltage”. No components damage, no hazard.
PV voltage detect D1502 PIN1-PIN3	short	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “High String Input Voltage”. No components damage, no hazard.
PV current detect C3201 SMP_BOOST _A_CUR_DC-3V3	open	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
PV current detect C3201 SMP_BOOST _A_CUR_DC-AGND	open	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
PV current detect D1501 PIN2-PIN3	short	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
PV current detect D1501 PIN1-PIN3	short	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
Grid voltage L2L3 line monitoring U59,PIN8-+5V	short	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Grid Overvoltage”. No components damage, no hazard.

Component No,	Fault	Test condition		Test time	Fuse No,	Fault condition		Result
		AC	DC			AC	DC	
Grid voltage L2L3 line monitoring U59,PIN8-AGND	short	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Grid Overvoltage”. No components damage, no hazard.
Grid voltage L3 phase monitoring U59,PIN8-+5V	short	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “alarm grid relay abnormal”. No components damage, no hazard.
Grid voltage L3 phase monitoring U59,PIN8-AGND	short	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “alarm grid relay abnormal”. No components damage, no hazard.
Grid frequency monitoring U50 PIN2-PIN3	short	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Grid Under frequency”. No components damage, no hazard.
Grid frequency monitoring U50 PIN2-PIN12	open	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Grid Under frequency”. No components damage, no hazard.
Main ARM pin 139 R1767	open	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
Main ARM pin 140 R1766	open	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
Slave ARM pin 139 R1733	open	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.
Slave ARM pin 140 R1732	open	230V 144,9A	600V 166,7A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. Error message “Device Fault”. No components damage, no hazard.

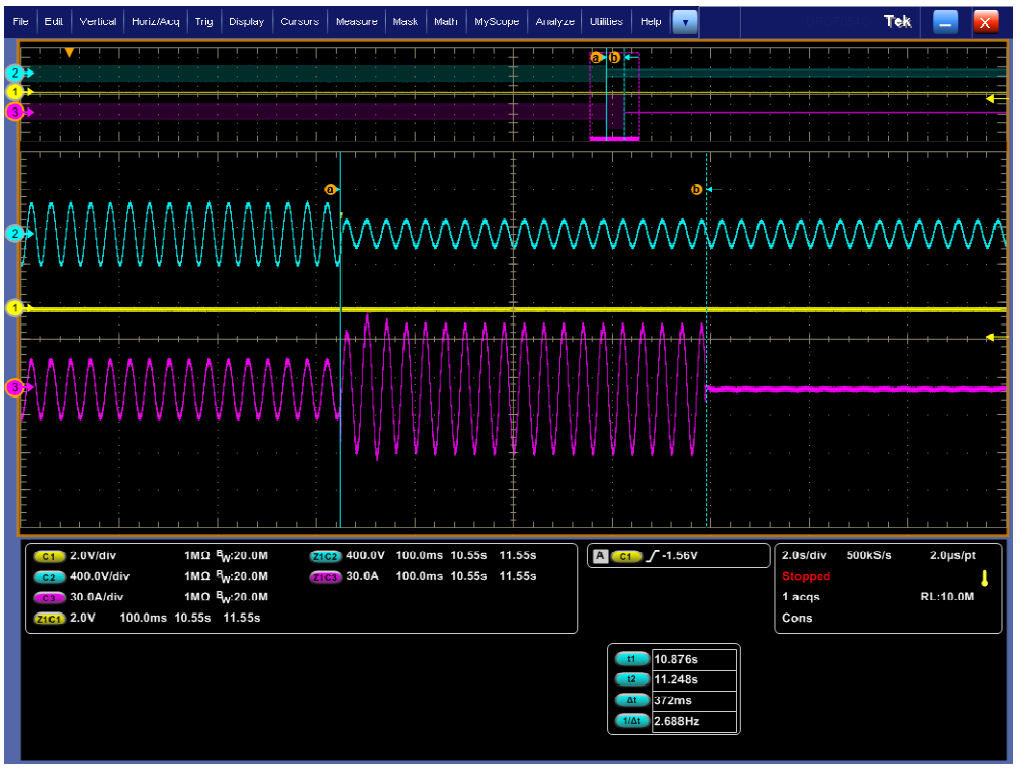
Component No,	Fault	Test condition		Test time	Fuse No,	Fault condition		Result
		AC	DC			AC	DC	
Loss of control DSP failure CPU, C104	+3,3V power short	230V 144,9A	600V 166,7 A	10min	--	230V <0,1A	600V <0,1A	PV inverter shut down. No components damage, no hazard. Inverter can be restarted and operated normally when the fault was removed, no alarm.
The errors in the control circuit simulate that the safety is even under one error ensured,								
Addendum – Shutdown device								
Each active phase can be switched, (L and N)								Yes
If no galvanic separation between AC and DC (PV): Two relays in series on each active phase are necessary to fulfil the basic insulation or simple separation based on the PV working voltage,								Two relays in series on each active phase
Note: s-c: short circuit; o-c: open circuit before start-up The errors in the control circuit simulate that the safety is even ensured during a single fault,								

5.5.7.2 Voltage control							**P**
Integrated NS protection multi phase ≤30kVA (phase to neutral)							
Setting values of the NS protection:	Setting U< [V]:		184				
	Setting U>>[V]:		287,5				
	Setting $T_{disconnection}$ [ms]		/				
Operating time of the monitoring device:							
L1 to N:							
	Under voltage 1:			**Over voltage 1:**			
Step [V to V]:	230,0 V to 177,1 V			230,0 V to 294,5 V			
Limit [V]:	184,0 V			287,5 V			
Measurement [V:]	183,7	183,7	183,7	287,1	287,2	287,2	
Limit [ms]:	≤ 3100 ms			≤ 200 ms			
Disconnection time [ms]:	3080	3076	3085	179	177	178	
	Under voltage 2:						
Step [V to V]:	230,0 V to 96,6 V						
Limit [V]:	103,5 V						
Measurement [V:]	103,7	103,8	103,8				
Limit [ms]:	≤ 400 ms						
Disconnection time [ms]:	371	372	371				
L2 to N:							
	Under voltage 1:			**Over voltage 1:**			
Step [V to V]:	230,0 V to 177,1 V			230,0 V to 294,5 V			
Limit [V]:	184,0 V			287,5 V			
Measurement [V:]	183,2	183,2	183,2	287,4	287,4	287,4	
Limit [ms]:	≤ 3100 ms			≤ 200 ms			
Disconnection time [ms]:	3080	3080	3080	168	168	169	
	Under voltage 2:						
Step [V to V]:	230,0 V to 96,6 V						
Limit [V]:	103,5 V						
Measurement [V:]	104,1	104,0	104,0				
Limit [ms]:	≤ 400 ms						
Disconnection time [ms]:	382	384	382				

L3 to N:						
	Under voltage 1:			**Over voltage 1:**		
Step [V to V]:	230,0 V to 177,1 V			230,0 V to 294,5 V		
Limit [V]:	184,0 V			287,5 V		
Measurement [V:]	184,2	184,3	184,3	287,0	287,3	287,3
Limit [ms]:	≤ 3100 ms			≤ 200 ms		
Disconnection time [ms]:	3080	3080	3080	168	168	169
	Under voltage 2:					
Step [V to V]:	230,0 V to 96,6 V					
Limit [V]:	103,5 V					
Measurement [V:]	102,7	102,8	102,8			
Limit [ms]:	≤ 400 ms					
Disconnection time [ms]:	388	387	387			

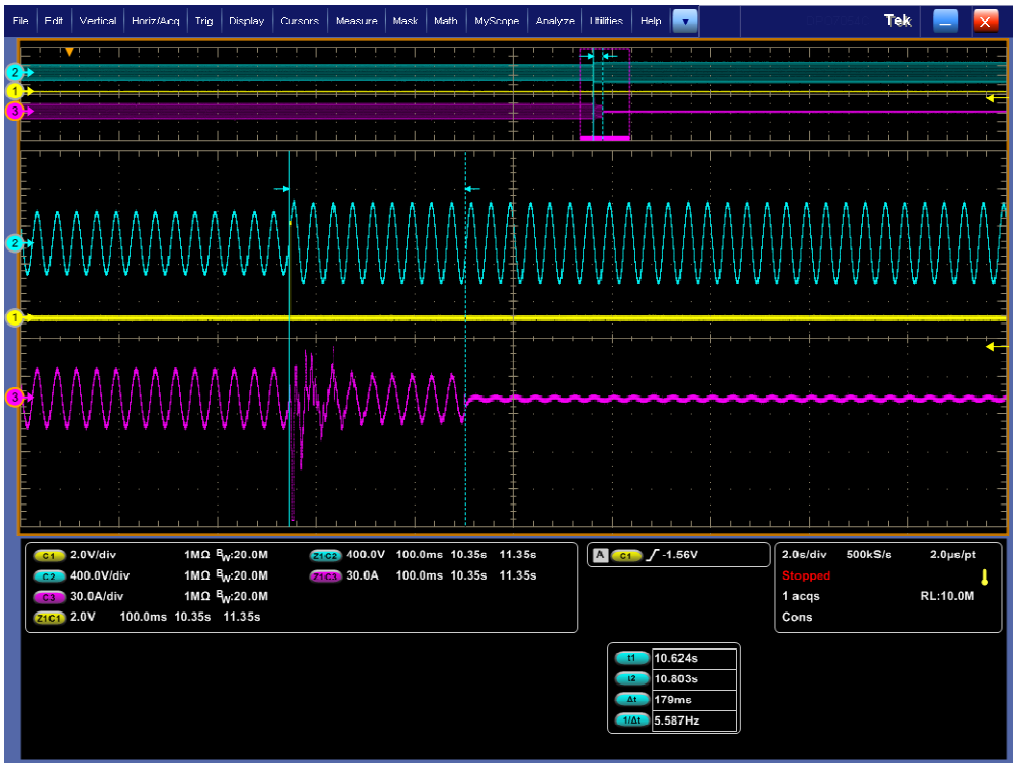
Note:
The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1% of U_n.
The disconnection time includes disconnect time + operate time of the integrated relay. Therefore limit is give with +100ms according to Table 2 set values of the NS-protection according to VDE AR-N 4105:2018.

Under voltage 2 L1 to N:

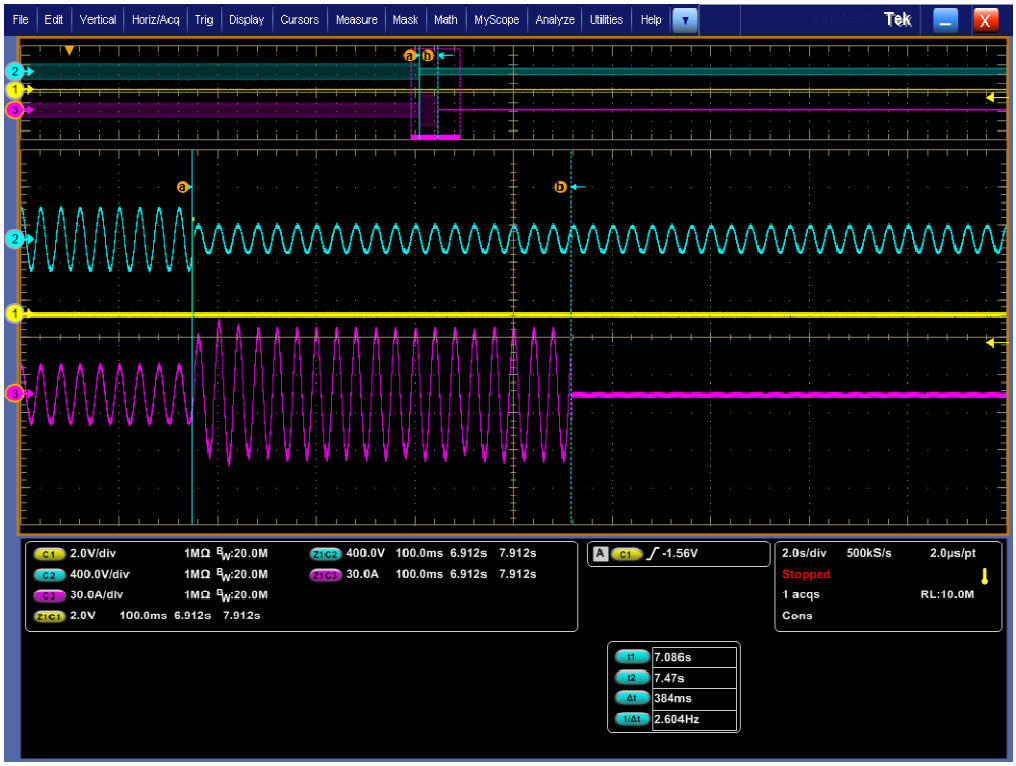


Under voltage 1 L1 to N:

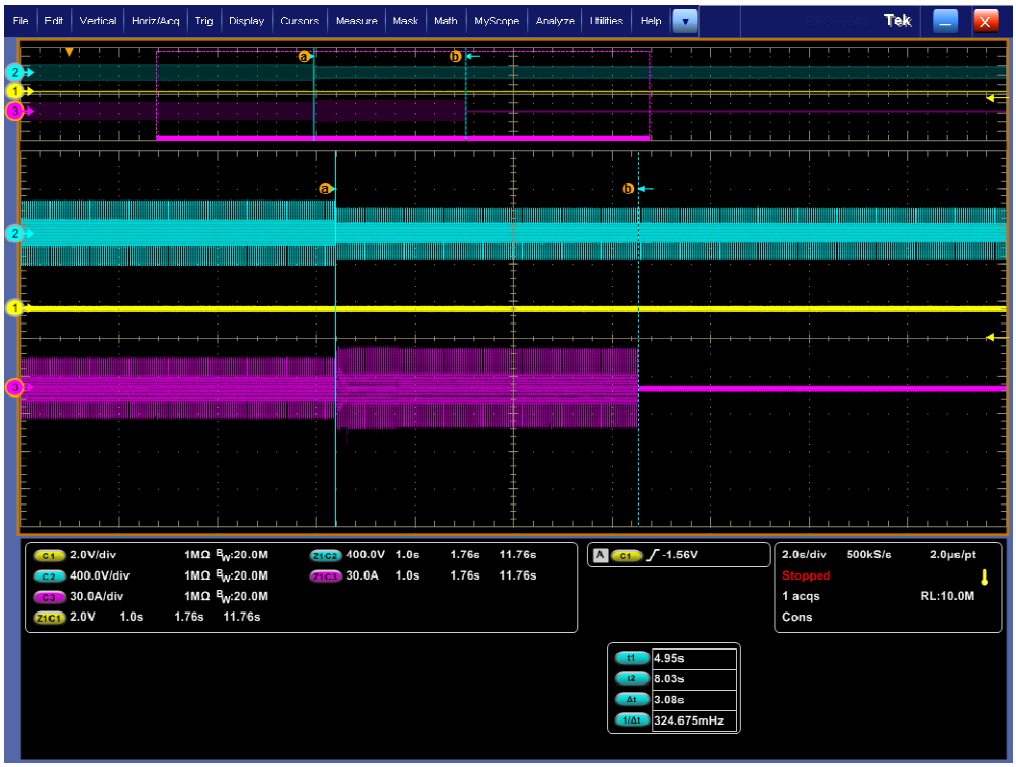
Over voltage L1 to N:



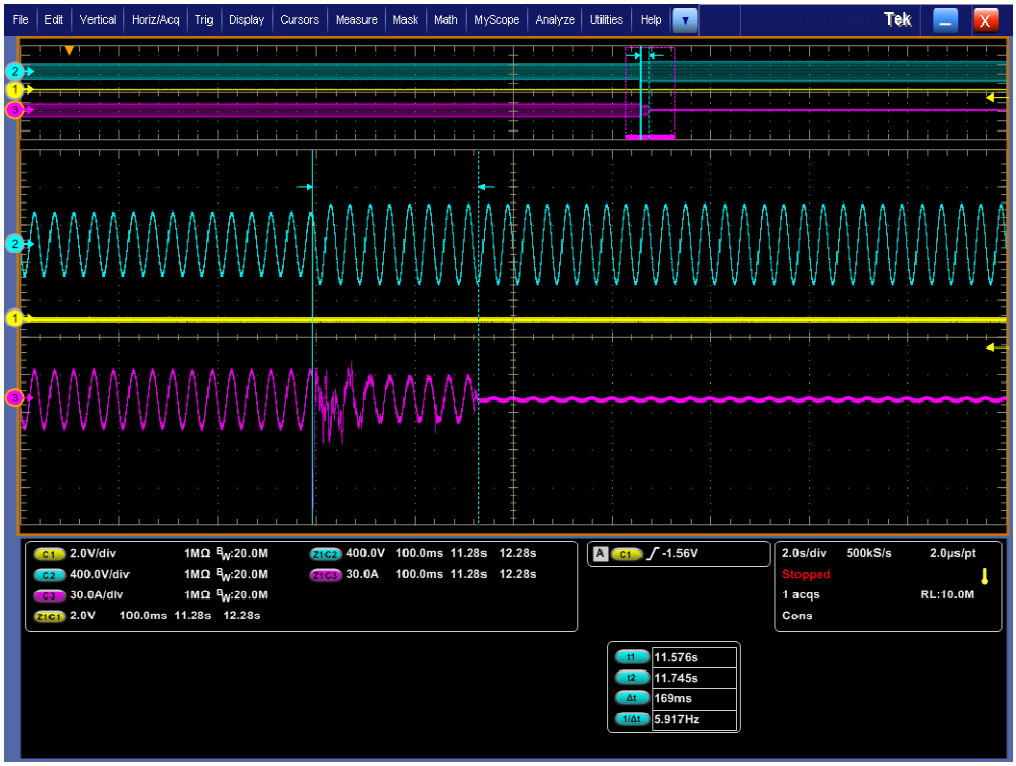
Under voltage 2 L2 to N



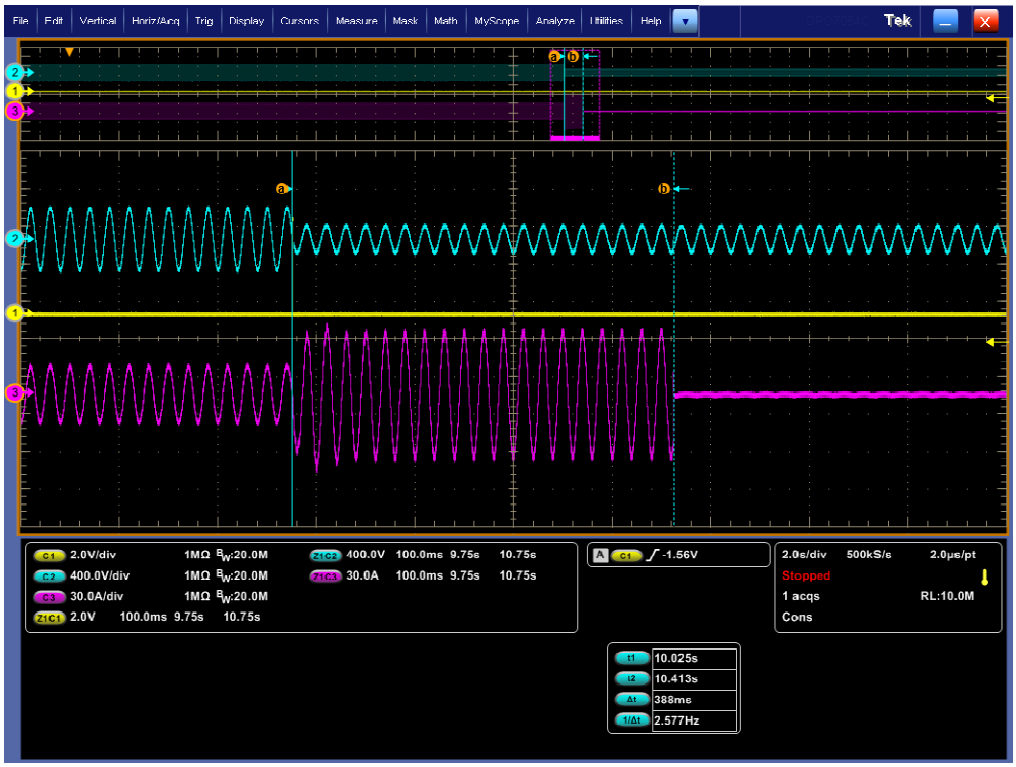
Under voltage 1 L2 to N



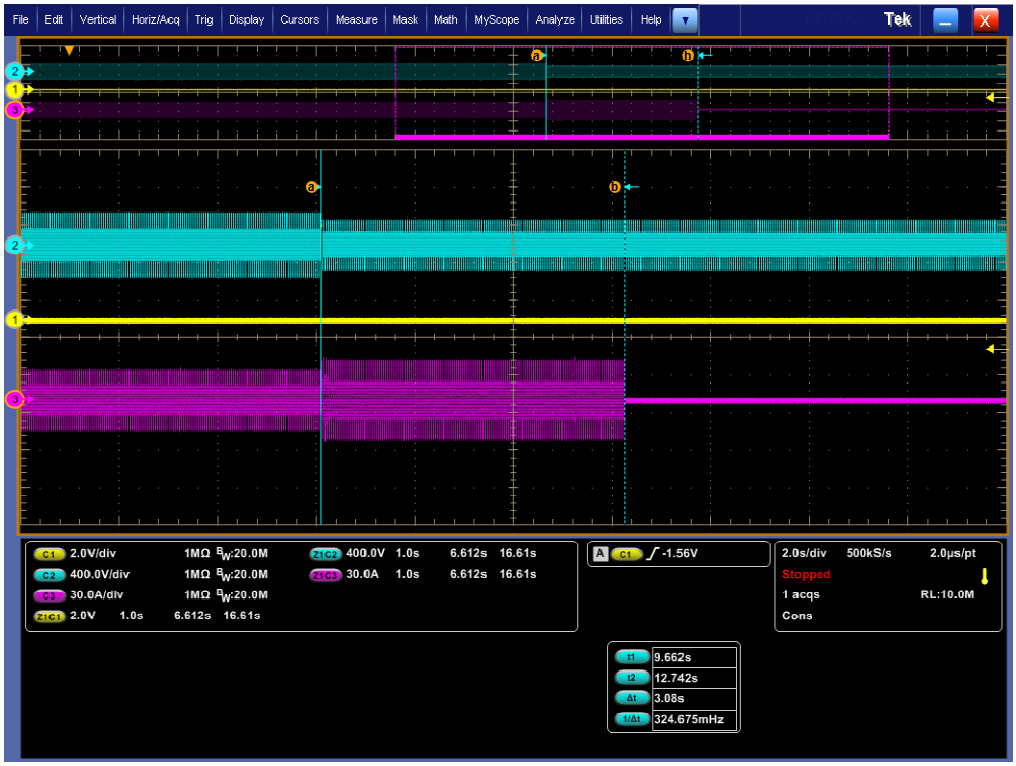
Over voltage L2 to N:



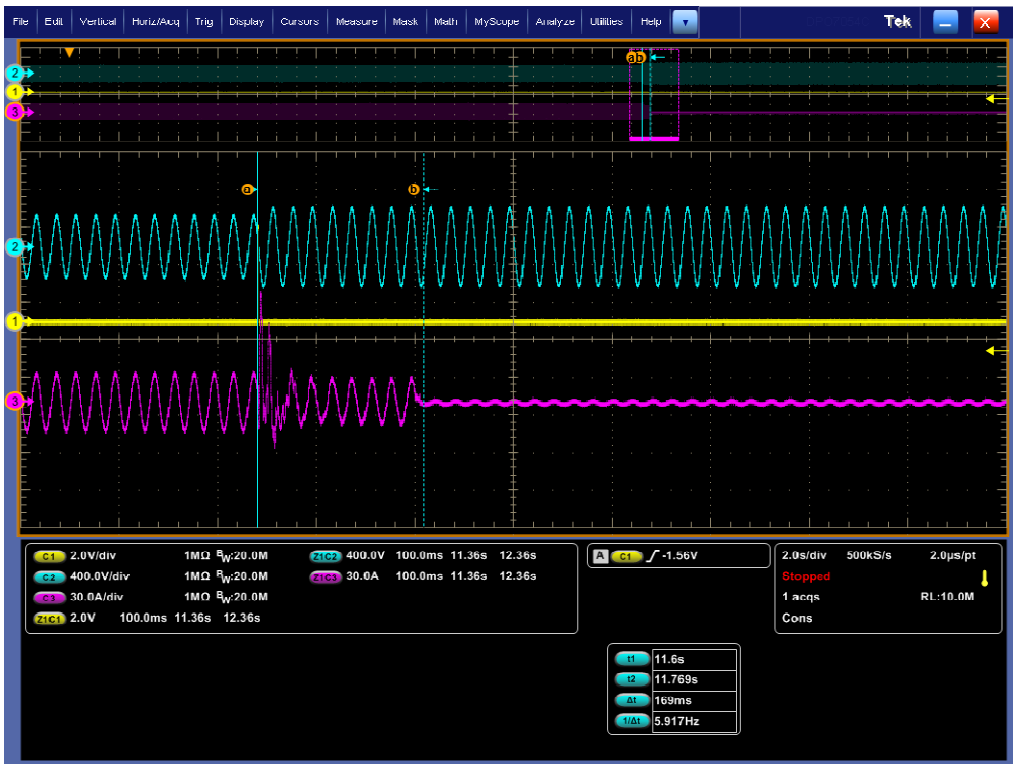
Under voltage 2 L3 to N:



Under voltage 1 L3 to N:



Over voltage L3 to N:

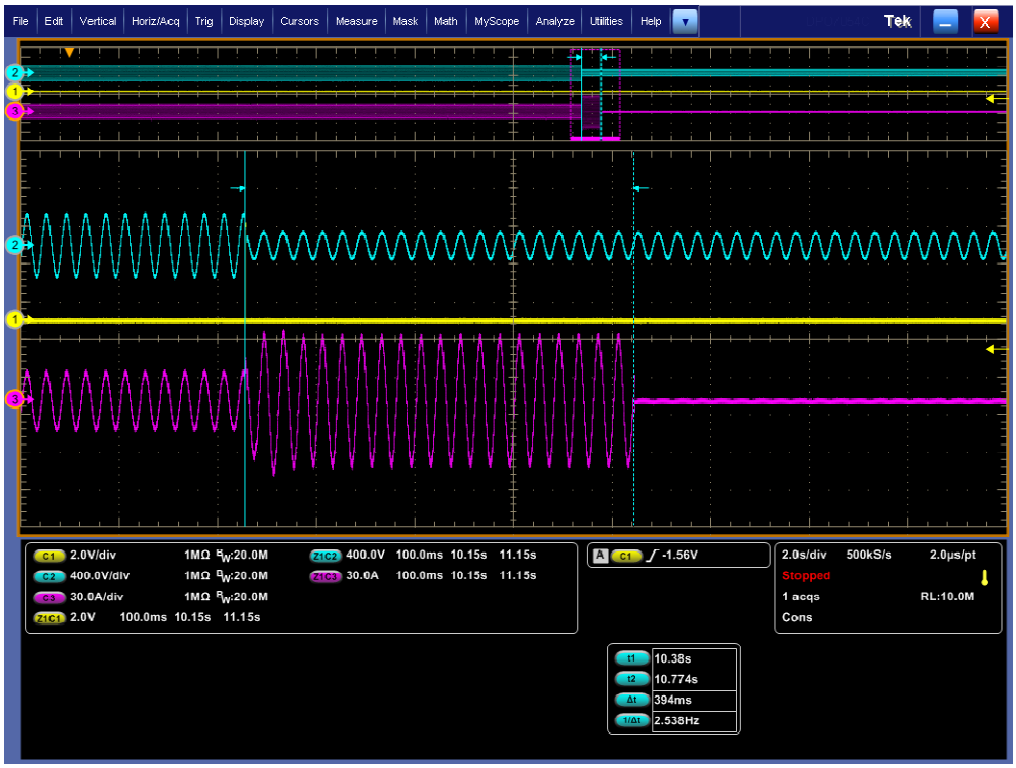


5.5.7.2 Voltage control							**P**
Integrated NS protection multi phase ≥30kVA (phase to phase)							
Setting values of the NS protection:	Setting U< [V]:		318,7				
	Setting U>>[V]:		498,0				
	Setting $T_{disconnection}$ [ms]		/				
Operating time of the monitoring device:							
L1 to L2:							
	Under voltage 1:			**Over voltage 1:**			
Step [V to V]:	400,0 V to 306,7 V			400,0 V to 510,1 V			
Limit [V]:	318,7 V			498,0 V			
Measurement [V:]	319,8	319,8	319,8	500,8	500,5	500,6	
Limit [ms]:	≤ 3100 ms			≤ 200 ms			
Disconnection time [ms]:	3070	3070	3070	161	162	163	
	Under voltage 2:						
Step [V to V]:	400,0 V to 167,3 V						
Limit [V]:	179,3 V						
Measurement [V:]	180,0	180,0	180,0				
Limit [ms]:	≤ 400 ms						
Disconnection time [ms]:	392	393	394				
L2 to L3:							
	Under voltage 1:			**Over voltage 1:**			
Step [V to V]:	400,0 V to 306,7 V			400,0 V to 510,1 V			
Limit [V]:	318,7 V			498,0 V			
Measurement [V:]	320,5	320,5	320,5	500,8	500,7	500,7	
Limit [ms]:	≤ 3100 ms			≤ 200 ms			
Disconnection time [ms]:	3070	3070	3070	177	176	177	
	Under voltage 2:						
Step [V to V]:	400,0 V to 167,3 V						
Limit [V]:	179,3 V						
Measurement [V:]	180,5	180,5	180,5				
Limit [ms]:	≤ 400 ms						
Disconnection time [ms]:	387	388	389				

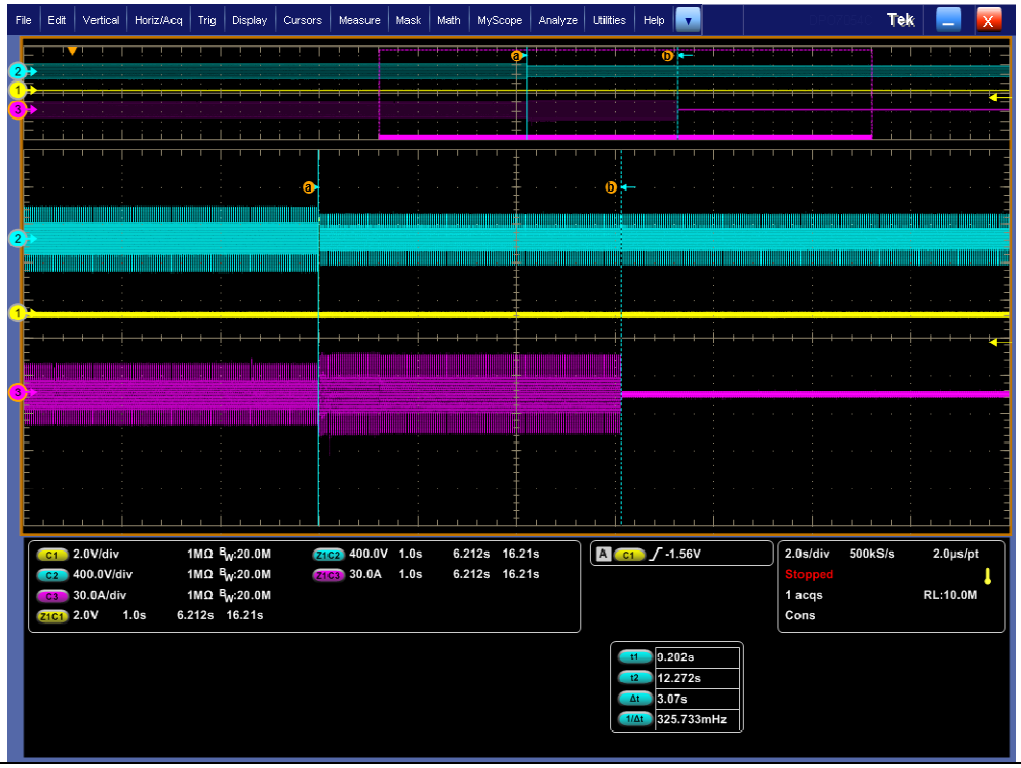
L3 to L1:						
	Under voltage 1:			**Over voltage 1:**		
Step [V to V]:	400,0 V to 306,7 V			400,0 V to 510,1 V		
Limit [V]:	318,7 V			498,0 V		
Measurement [V:]	320,1	320,1	320,1	500,3	500,2	500,2
Limit [ms]:	≤ 3100 ms			≤ 200 ms		
Disconnection time [ms]:	3080	3078	3088	163	166	164
	Under voltage 2:					
Step [V to V]:	400,0 V to 167,3 V					
Limit [V]:	179,3 V					
Measurement [V:]	179,7	179,7	179,7			
Limit [ms]:	≤ 400 ms					
Disconnection time [ms]:	390	389	390			

Note:
The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1% of U_n.
The disconnection time includes disconnect time + operate time of the integrated relay. Therefore limit is give with +100ms according to Table 2 set values of the NS-protection according to VDE AR-N 4105:2018.

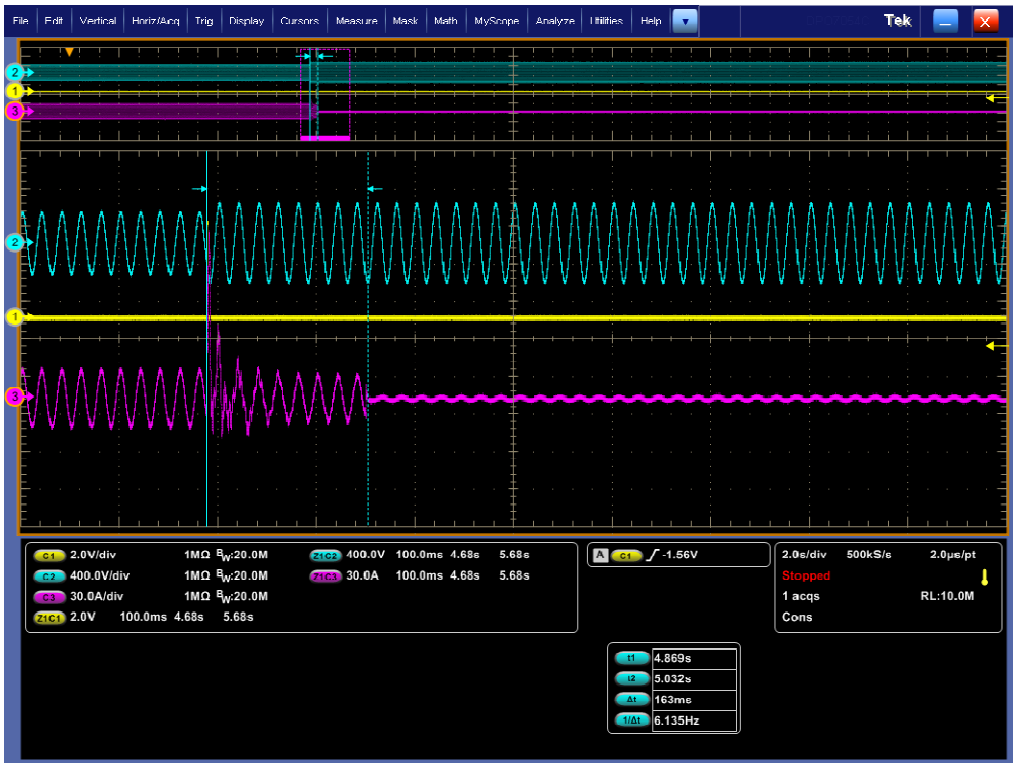
Under voltage 2 L1 to L2:



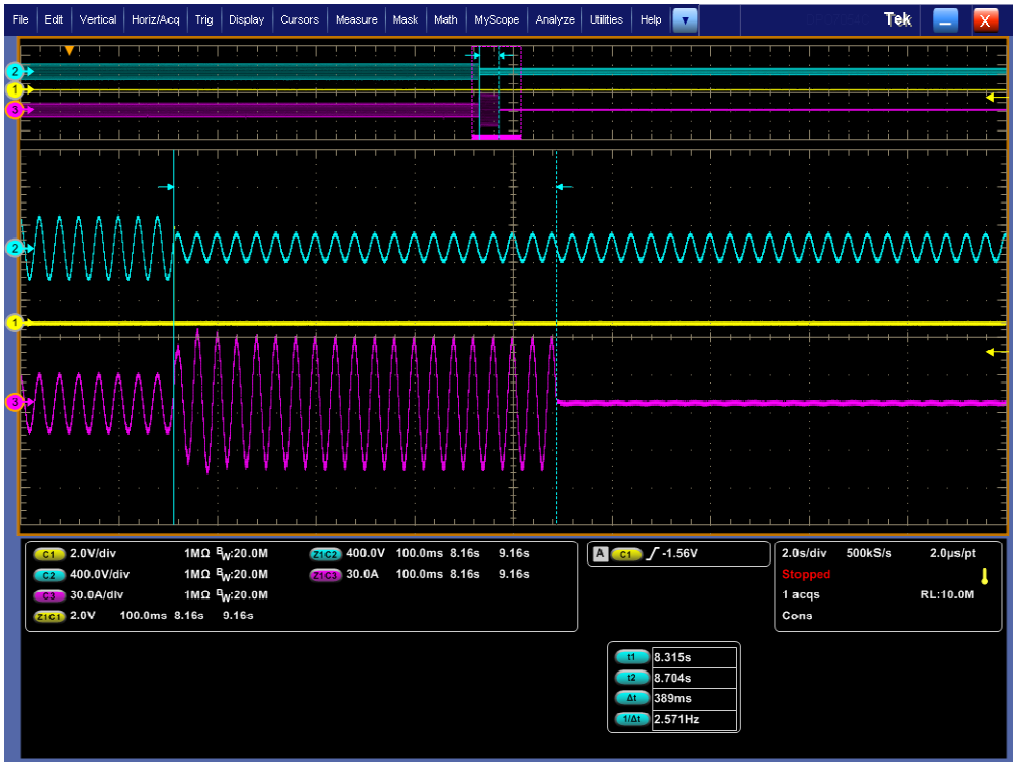
Under voltage 1 L1 to L2:



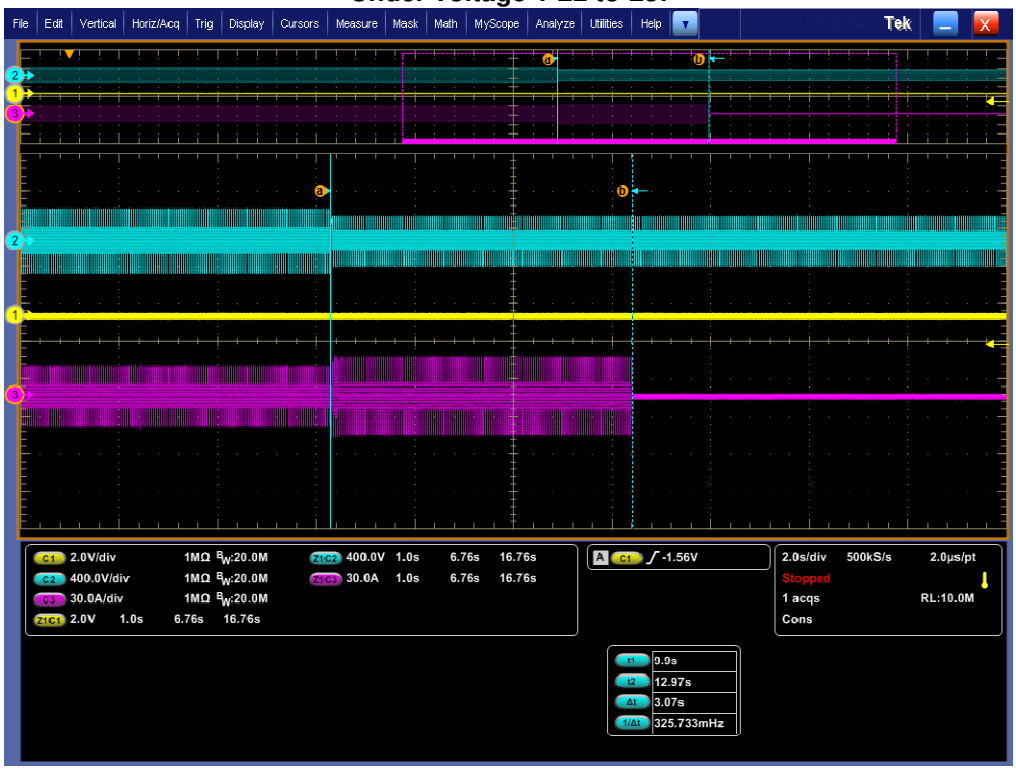
Over voltage L1 to L2:



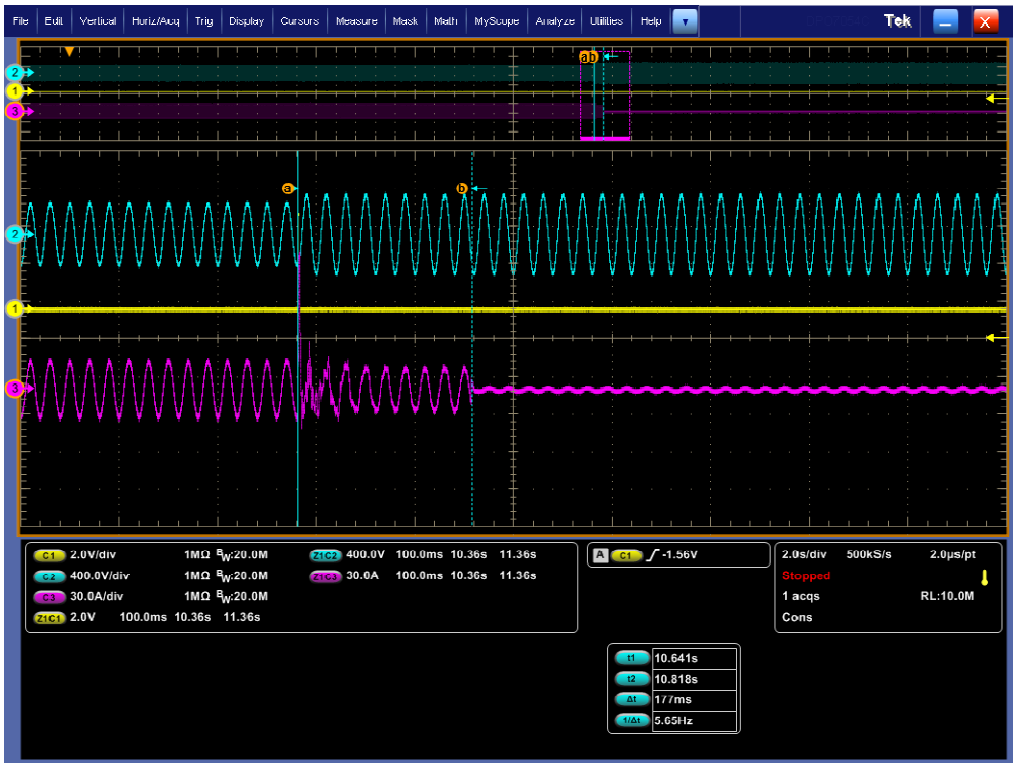
Under voltage 2 L2 to L3:



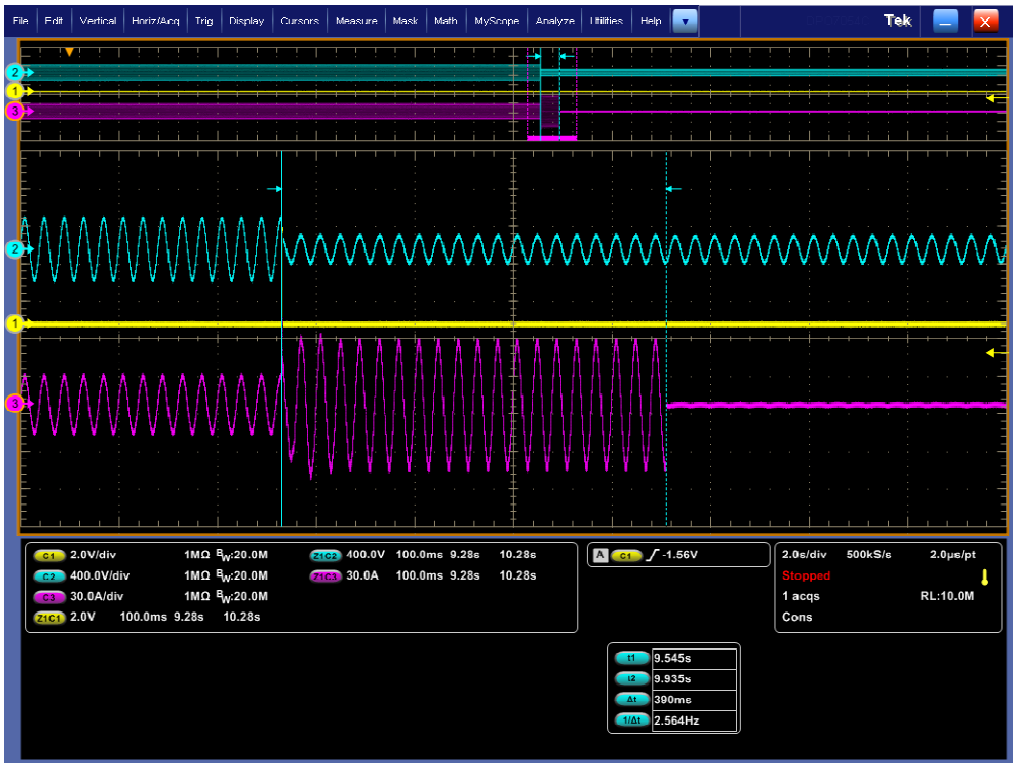
Under voltage 1 L2 to L3:



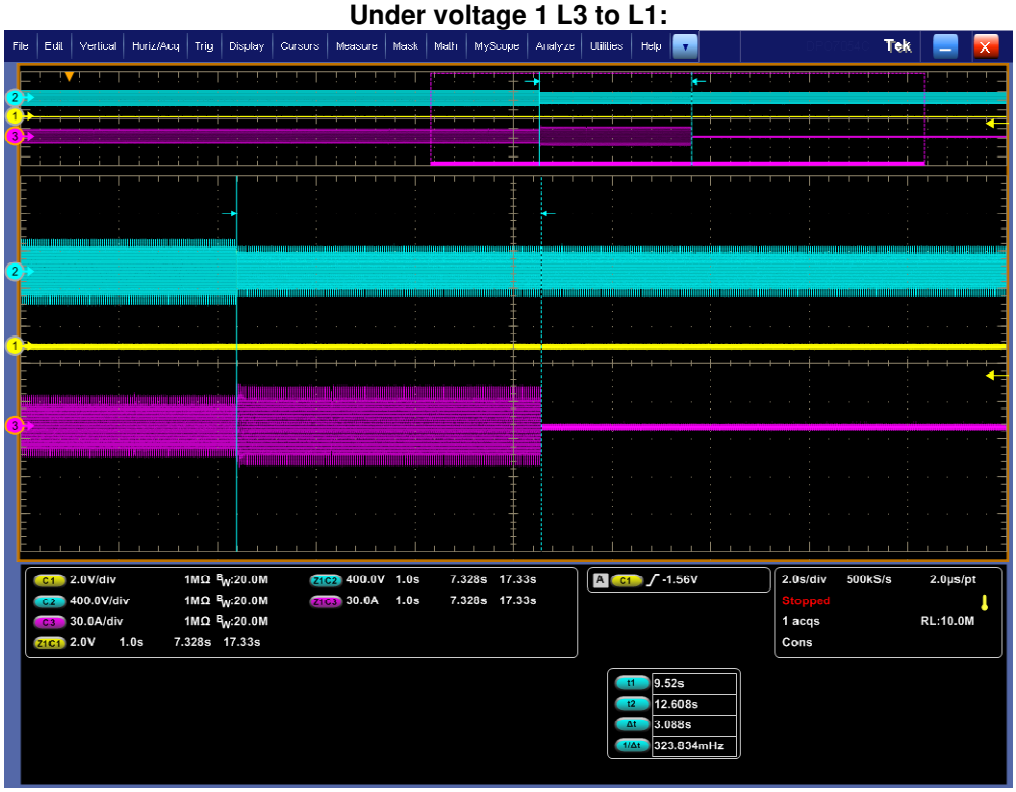
Over voltage L2 to L3:



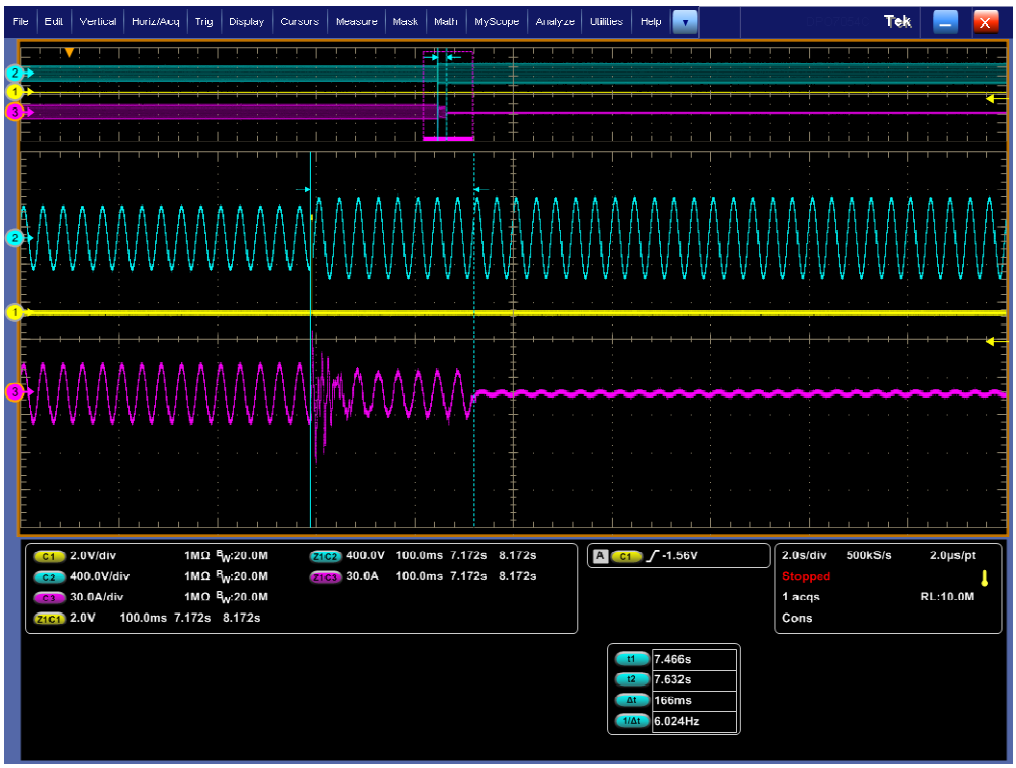
Under voltage 2 L3 to L1:



Under voltage 1 L3 to L1:

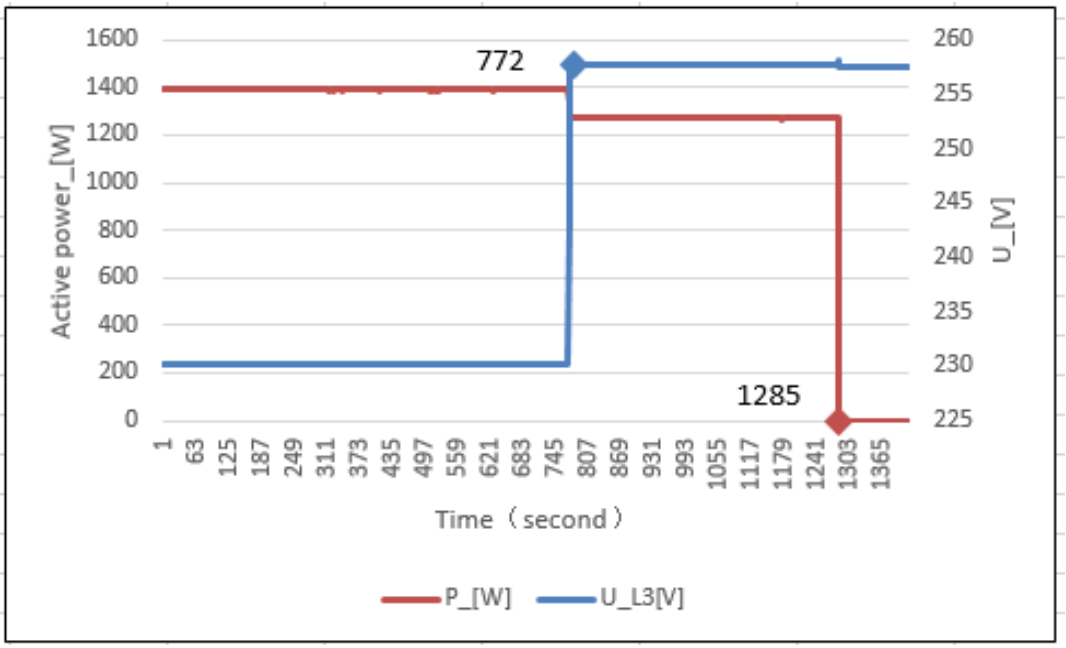


Over voltage L3 to L1:

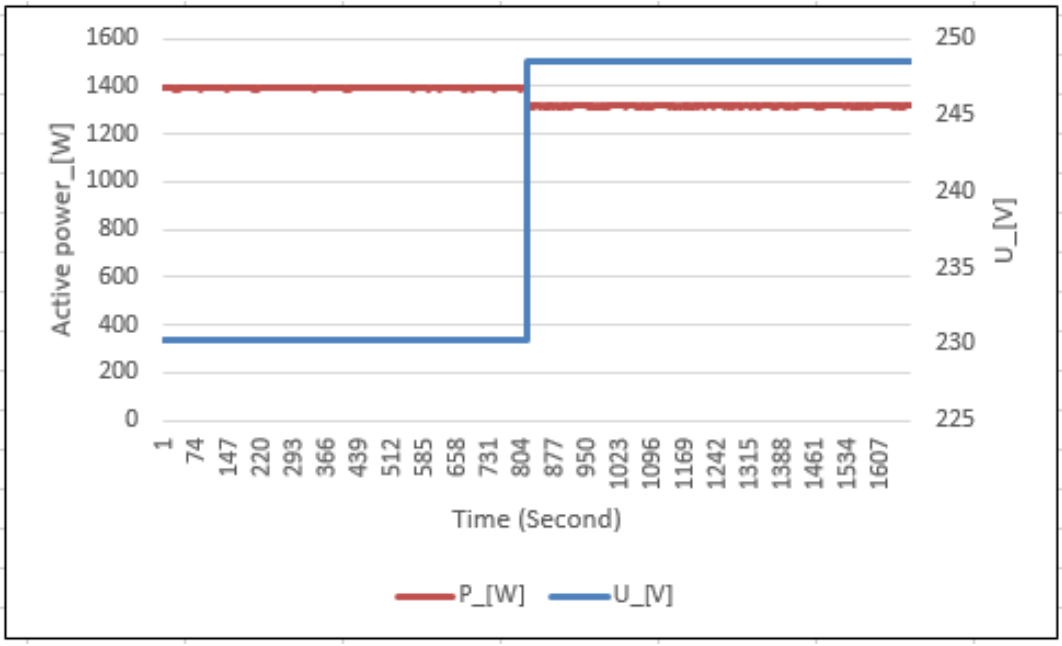


5.5.7.2.1.3 Measuring the rise-in voltage protection as a running 10-minute mean value			**P**
Setting values of the NS protection:	Setting U> [V]	253	
	Setting $T_{disconnection\ U>}$ [s]	600	
	Setting $T_{disconnection}$ [ms]	100	
Test:			
		Disconnection time:	Limit:
a)	The voltage is set to 100% U_n and held for 600 s. Thereafter the voltage is set to 112% U_n. Disconnection must take place within 600 s.		
	Phase 1	501s	≤ 600 s
	Phase 2	502s	
	Phase 3	513s	
b)	The voltage is set to U_n for 600 s and then to 108% U_n for 600 s. No disconnection should take place.		
	Phase 1	No Disconnection	Disconnection should not take place.
	Phase 2	No Disconnection	
	Phase 3	No Disconnection	
c)	The voltage is set to 106 % U_n and held for 600 s. Thereafter the voltage is set to 114 % U_n. Disconnection must take place within 300 s or about 50 % of the disconnection time measured in point a).*		
	Phase 1	299s	The disconnection time should be about 50 % of the value measured in a). *
	Phase 2	294s	
	Phase 3	295s	
Note: *If the setting value is set to 600 s, then the disconnection time can be in the range between 225 s and 375 s.			

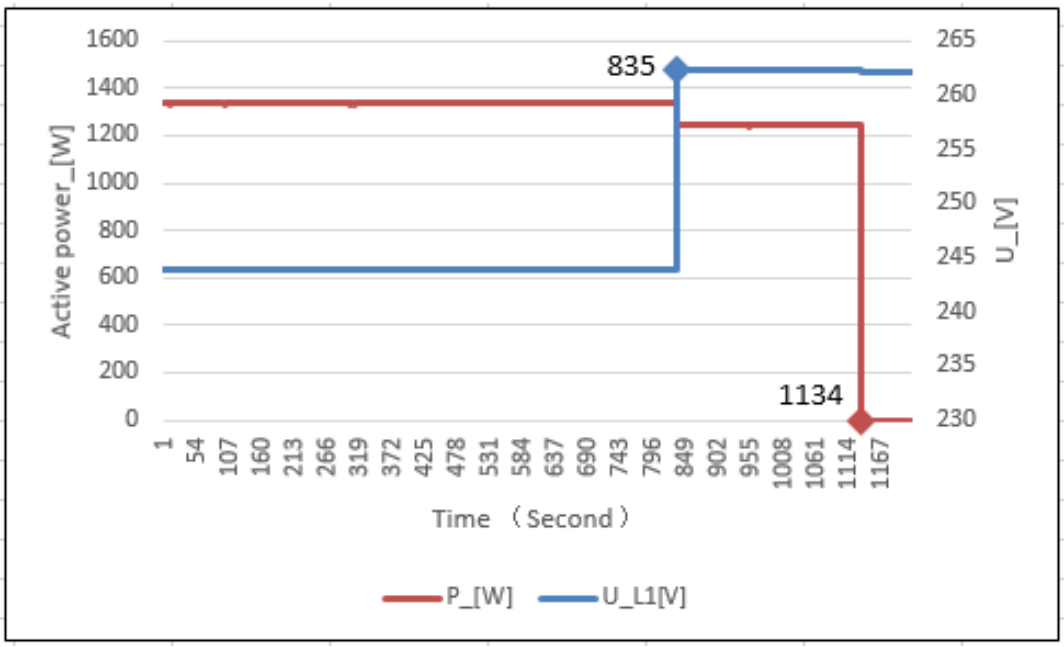
a) Voltage set to 112 % U_n:



b) Voltage set to 108% U_n:



c) Voltage set to 106 % U_n, thereafter 114% U_n:



5.5.7.2.1.9 Frequency measurement							P
Setting values of the NS protection:	Setting f< [Hz]:	47,50					
	Setting f>[Hz]:	51,50					
	Setting $T_{disconnection}$ [ms]	/					
Operating time of the monitoring device							
	Under frequency:				**Over frequency:**		
Jump [Hz to Hz]:	47,70 Hz -> 47,30 Hz				51,30 Hz -> 51,70 Hz		
Limit [Hz]:	47,50 Hz				51,50 Hz		
Measurement [Hz]:	47,51	47,50	47,50		51,59	51,50	51,49
Limit [ms]:	≤ 200 ms				≤ 200 ms		
Disconnection time [ms]:	180	179	178		179	177	179

Test:
Testing of the frequency over protection f> and of the under frequency protection f <.

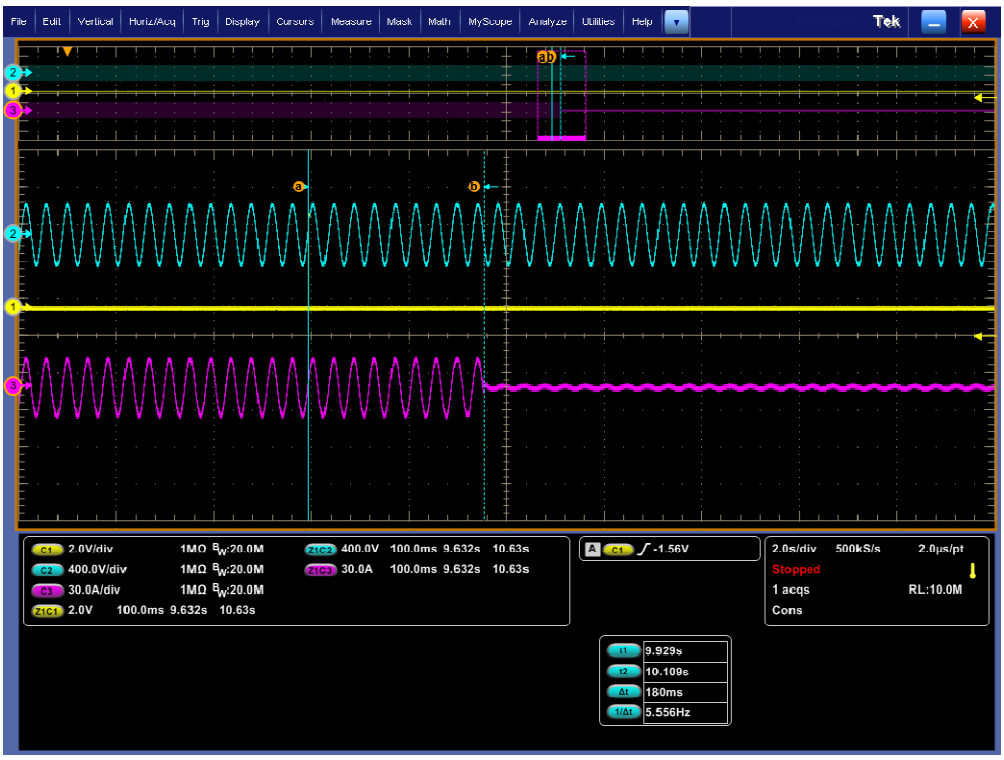
a) The frequency must be set to f_n 50.0 Hz and kept. A jump to 51.3 Hz must be performed and held for 60 sec. Afterwards, a jump to 51.7 Hz must be performed and held.
b) The frequency must be set to f_n 50.0 Hz and kept. A jump to 47,7 Hz must be performed and held for 60 sec. Afterwards, a jump to 47,3 Hz must be performed and held.

Assessment criteria:
The Test is passed if

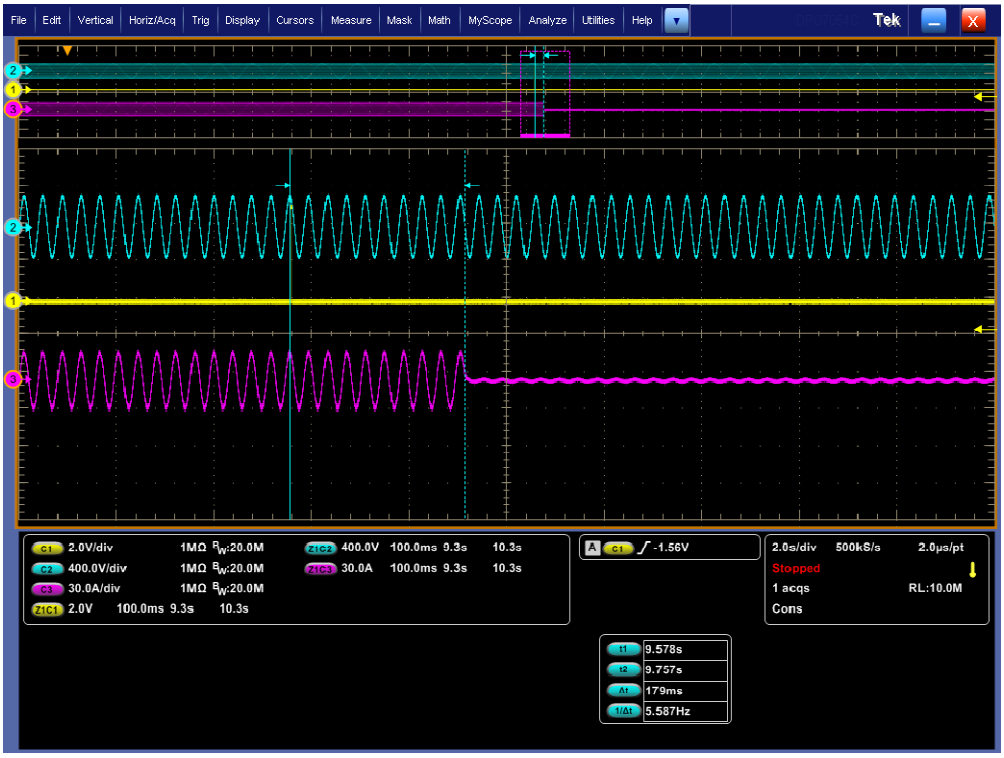
a) after the jump to 51.3 Hz no shutdown has taken place and after the jump to 51.7 Hz, a shutdown within 200ms is done.
b) after the jump to 47,7 Hz no shutdown has taken place and after the jump to 47,3 Hz, a shutdown within 200ms is done

Note:
The setting value and the trip value of the frequency may not vary by more than ±0.1 % f_n.

Under frequency:



Over frequency:



5.5.8 Reporting NS protection	P
The last 5 dated failure reports on the NS protection can be read. An interruption in the supply voltage of ≤ 3s does not result in any loss of failure reports. Central NS protection: It is possible to read the setting values and the failure reports of the NS protection independently of the operational state and without any additional aids. Integrated NS protection: It is possible to read out the values of the NS protection via the data interface, if the values are not directly readable.	
Note:	

5.5.10 Islanding detection (these tests are designed to provide evidence that the requirements of VDE-AR-N 4105, 6.5.3 are met)
For power generation systems, islanding detection must be carried out using one of the following processes: a) active method, e.g. by means of frequency – shift process (oscillating circuit) b) passive method with the help of the three-phase voltage control (only possible for power generation systems without converters or for single-phase generation units with converters). (see 5.4.5.3 3-phase voltage control) With the passive process, it is important to provide evidence that the power generation unit can be set not equal to 120°.

5.5.10.3 Islanding protection according table 6 - Load imbalance (real, reactive load) for test condition A (EUT ouput = 100%)	**P**

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality = 1
Disconnection limit	2s (IEC 62116)

No	P_{EUT} 1) [% of EUT rating]	Reactive load [% of Q_L in 6,1,d) 1)	P_{AC} 2) [% of nominal]	Q_{AC} 3) [% of nominal]	I_{AC} 4) [A]	P_{EUT} [kW per phase]	V_{DC} [V]	Q_f	Run on Time [ms]	Remarks5)
1	100	100	0	0	0,340	33,333	650	1,001	**752,4**	BL
2	100	100	-10	-10	14,051	33,333	650	1,055	390,0	IB
3	100	100	-10	-5	14,643	33,333	650	1,084	429,4	IB
4	100	100	-10	0	14,832	33,333	650	1,113	422,8	IB
5	100	100	-10	+5	14,618	33,333	650	1,140	341,0	IB
6	100	100	-10	+10	14,002	33,333	650	1,167	407,2	IB
7	100	100	-5	-10	6,845	33,333	650	1,000	462,0	IB
8	100	100	-5	-5	7,406	33,333	650	1,027	426,4	IB
9	100	100	-5	0	7,586	33,333	650	1,054	397,6	IB
10	100	100	-5	+5	7,383	33,333	650	1,080	392,4	IB
11	100	100	-5	+10	6,800	33,333	650	1,105	370,6	IB
12	100	100	0	-10	1,044	33,333	650	0,950	401,2	IB
13	100	100	0	-5	0,511	33,333	650	0,976	544,0	IB
14	100	100	0	+5	0,533	33,333	650	1,026	575,0	IB
15	100	100	0	+10	1,088	33,333	650	1,050	533,6	IB
16	100	100	+5	-10	8,257	33,333	650	0,905	467,0	IB
17	100	100	+5	-5	7,749	33,333	650	0,929	400,0	IB
18	100	100	+5	0	7,586	33,333	650	0,954	678,8	IB
19	100	100	+5	+5	7,770	33,333	650	0,977	406,6	IB
20	100	100	+5	+10	8,298	33,333	650	1,000	477,2	IB
21	100	100	+10	-10	15,473	33,333	650	0,864	327,0	IB
22	100	100	+10	-5	14,988	33,333	650	0,887	322,8	IB
23	100	100	+10	0	14,833	33,333	650	0,910	405,8	IB
24	100	100	+10	+5	15,008	33,333	650	0,933	351,6	IB

25	100	100	+10	+10	15,513	33,333	650	0,955	460,6	IB
Parameter at 0% per phase			L= 5,05 mH			R= 1,59 Ω			C= 2009,74 µF	

Note:

RLC is adjusted to min, +/-1% of the inverter rated output power

[1] P_{EUT}: EUT output power

[2] P_{AC}: Real power flow at S1 in Figure 1, Positive means power from EUT to utility, Nominal is the 0 % test condition value,

[3] Q_{AC}: Reactive power flow at S1 in Figure 1, Positive means power from EUT to utility, Nominal is the 0 % test condition value,

[4] Fundamental of I_{AC} when RLC is adjusted

[5] BL: Balance condition, IB: Imbalance condition,

Condition A:

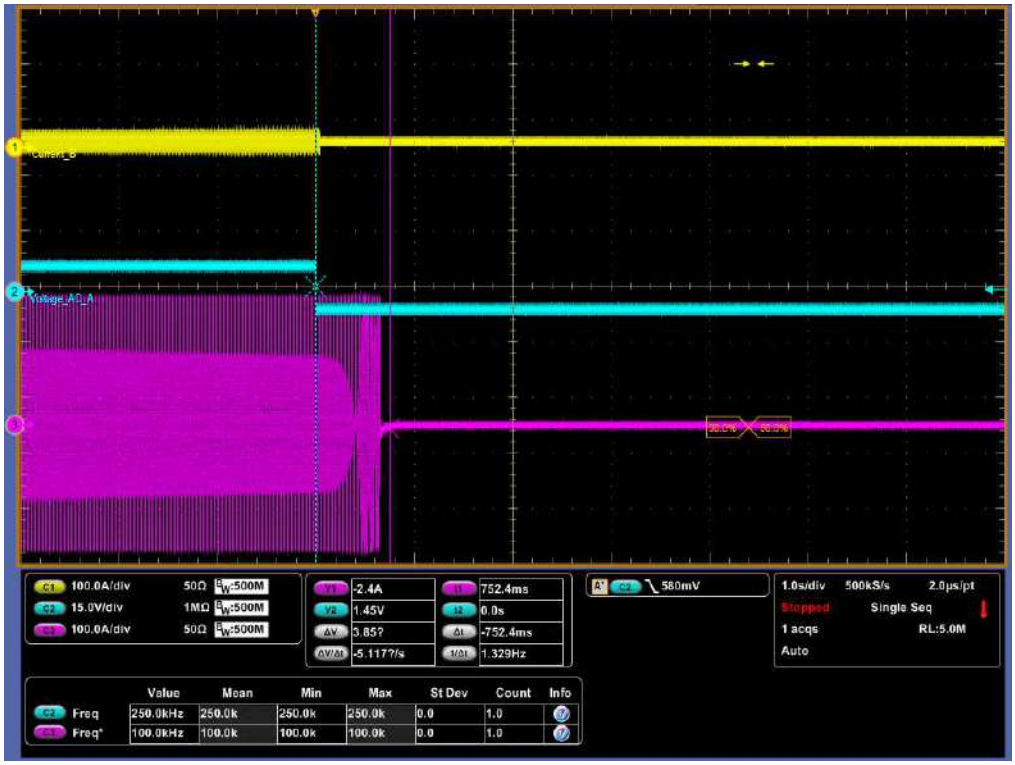
EUT output power P_{EUT} = Maximum [6]

EUT input voltage [6] = >75% of rated input voltage range

[6] Maximum EUT output power condition should be achieved using the maximum allowable input power, Actual output power may exceed nominal rated output,

[7] Based on EUT rated input operating range, For example, If range is between X volts and Y volts, 75 % of range =X + 0,75 × (Y – X), Y shall not exceed 0,8 × EUT maximum system voltage (i,e,, maximum allowable array open circuit voltage), In any case, the EUT should not be operated outside of its allowable input voltage range,

Scope pictures of the disconnection time
Disconnection at No, 1



5.5.10.3 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (EUT output = 50 % – 66 %)	**P**

Test :

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	2s (IEC 62116)

No	P_{EUT} 1) [% of EUT rating]	Reactive load [% of Q_L in 6,1,d) 1)	P_{AC} 2) [% of nominal]	Q_{AC} 3) [% of nominal]	I_{AC} 4) [A]	P_{EUT} [kW per phase]	V_{DC} [V]	Q_f	Run on Time [ms]	Remarks5)
1	66	66	0	-5	0,453	22,000	500	0,976	368,2	IB
2	66	66	0	-4	0,407	22,000	500	0,981	369,6	IB
3	66	66	0	-3	0,372	22,000	500	0,986	417,2	IB
4	66	66	0	-2	0,346	22,000	500	0,991	434,0	IB
5	66	66	0	-1	0,329	22,000	500	0,996	536,0	IB
6	66	66	0	0	0,322	22,000	500	1,001	**590,0**	BL
7	66	66	0	+1	0,325	22,000	500	1,006	544,6	IB
8	66	66	0	+2	0,337	22,000	500	1,011	480,0	IB
9	66	66	0	+3	0,359	22,000	500	1,016	426,6	IB
10	66	66	0	+4	0,390	22,000	500	1,021	426,0	IB
11	66	66	0	+5	0,431	22,000	500	1,026	402,4	IB

Parameter at 0% per phase	L= 7,64 mH	R= 2,40 Ω	C= 1323,78 µF

Note:

RLC is adjusted to min, +/-1% of the inverter rated output power

1) P_{EUT}: EUT output power

2) P_{AC}: Real power flow at S1 in Figure 1, Positive means power from EUT to utility, Nominal is the 0 % test condition value,

3) Q_{AC}: Reactive power flow at S1 in Figure 1, Positive means power from EUT to utility, Nominal is the 0 % test condition value,

4) Fundamental of I_{AC} when RLC is adjusted

5) BL: Balance condition, IB: Imbalance condition,

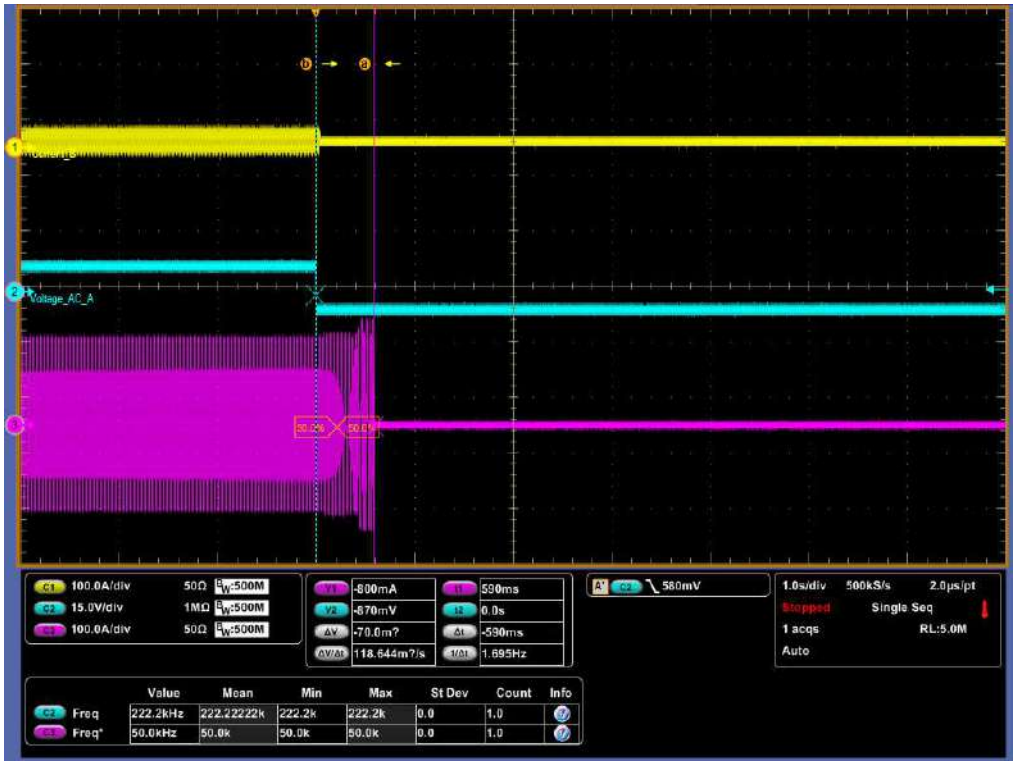
Condition B:

EUT output power P_{EUT} = 50 % – 66 % of maximum

EUT input voltage 6) = 50 % of rated input voltage range, ±10 %

6) Based on EUT rated input operating range, For example, If range is between X volts and Y volts, 50 % of range =X + 0,5 × (Y – X), Y shall not exceed 0,8 × EUT maximum system voltage (i,e,, maximum allowable array open circuit voltage), In any case, the EUT should not be operated outside of its allowable input voltage range,

Scope pictures of the disconnection time
Disconnection at No, 6



5.5.10.3 Islanding protection according Table 7 – Load imbalance (reactive load) for test condition B (EUT output = 25 % – 33 %)	**P**

Test conditions	Frequency: 50+/-0,1Hz U_N=230+/-3Vac Distortion factor of chokes < 2% Quality =1
Disconnection limit	2s (IEC 62116)

No	P_{EUT} 1) [% of EUT rating]	Reactive load [% of Q_L in 6,1,d) 1)	P_{AC} 2) [% of nominal]	Q_{AC} 3) [% of nominal]	I_{AC} 4) [A]	P_{EUT} [W per phase]	V_{DC} [V]	Q_f	Run on Time [ms]	Remarks5)
1	33	33	0	-5	0,293	11,000	320	0,975	305,0	IB
2	33	33	0	-4	0,271	11,000	320	0,980	354,0	IB
3	33	33	0	-3	0,255	11,000	320	0,985	356,2	IB
4	33	33	0	-2	0,243	11,000	320	0,990	382,4	IB
5	33	33	0	-1	0,235	11,000	320	0,995	424,0	IB
6	33	33	0	0	0,233	11,000	320	1,000	**478,8**	BL
7	33	33	0	+1	0,235	11,000	320	1,005	420,0	IB
8	33	33	0	+2	0,243	11,000	320	1,010	405,0	IB
9	33	33	0	+3	0,255	11,000	320	1,015	356,6	IB
10	33	33	0	+4	0,271	11,000	320	1,020	345,4	IB
11	33	33	0	+5	0,293	11,000	320	1,025	329,4	IB

Parameter at 0% per phase	L= 15,31 mH	R= 4,81 Ω	C= 661,89 µF

Note:

RLC is adjusted to min, +/-1% of the inverter rated output power

1) P_{EUT}: EUT output power

2) P_{AC}: Real power flow at S1 in Figure 1, Positive means power from EUT to utility, Nominal is the 0 % test condition value,

3) Q_{AC}: Reactive power flow at S1 in Figure 1, Positive means power from EUT to utility, Nominal is the 0 % test condition value,

4) Fundamental of I_{AC} when RLC is adjusted

5) BL: Balance condition, IB: Imbalance condition,

Condition B:

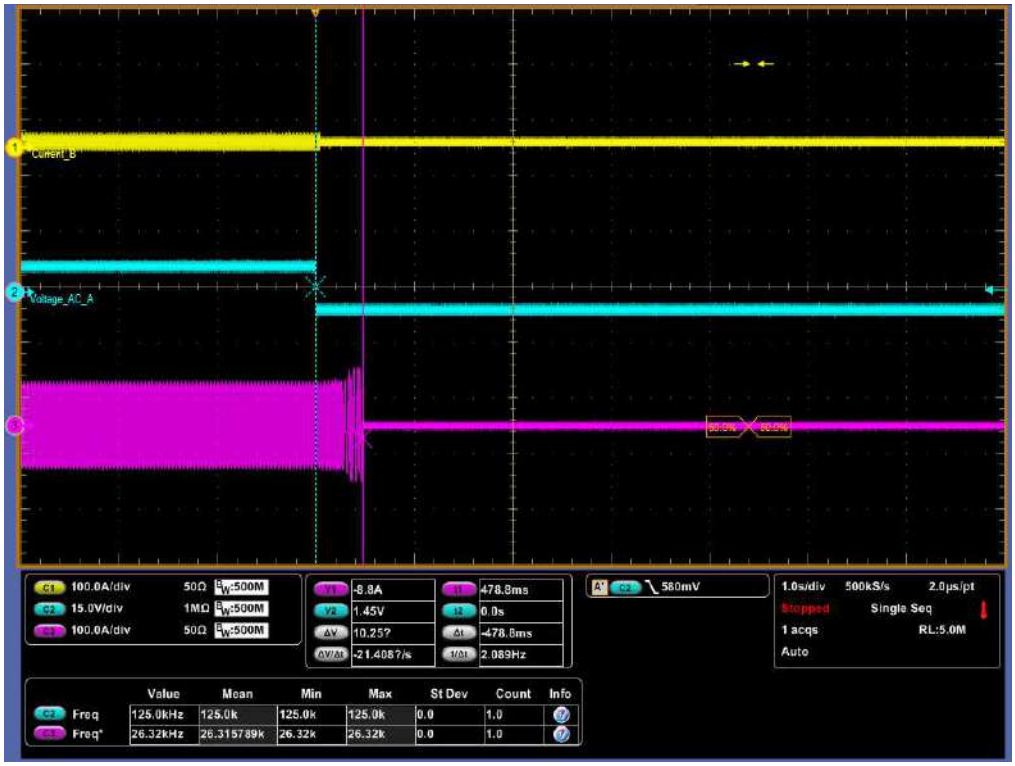
EUT output power P_{EUT} = 25 % – 33 % 6) of maximum

EUT input voltage 7) = <20 % of rated input voltage range

6) Or minimum allowable EUT output level if greater than 33 %,

7) Based on EUT rated input operating range, For example, If range is between X volts and Y volts, 20 % of range =X + 0,2 × (Y – X), Y shall not exceed 0,8 × EUT maximum system voltage (i,e,, maximum allowable array open circuit voltage), In any case, the EUT should not be operated outside of its allowable input voltage range.

Scope pictures of the disconnection time
Disconnection at No, 6



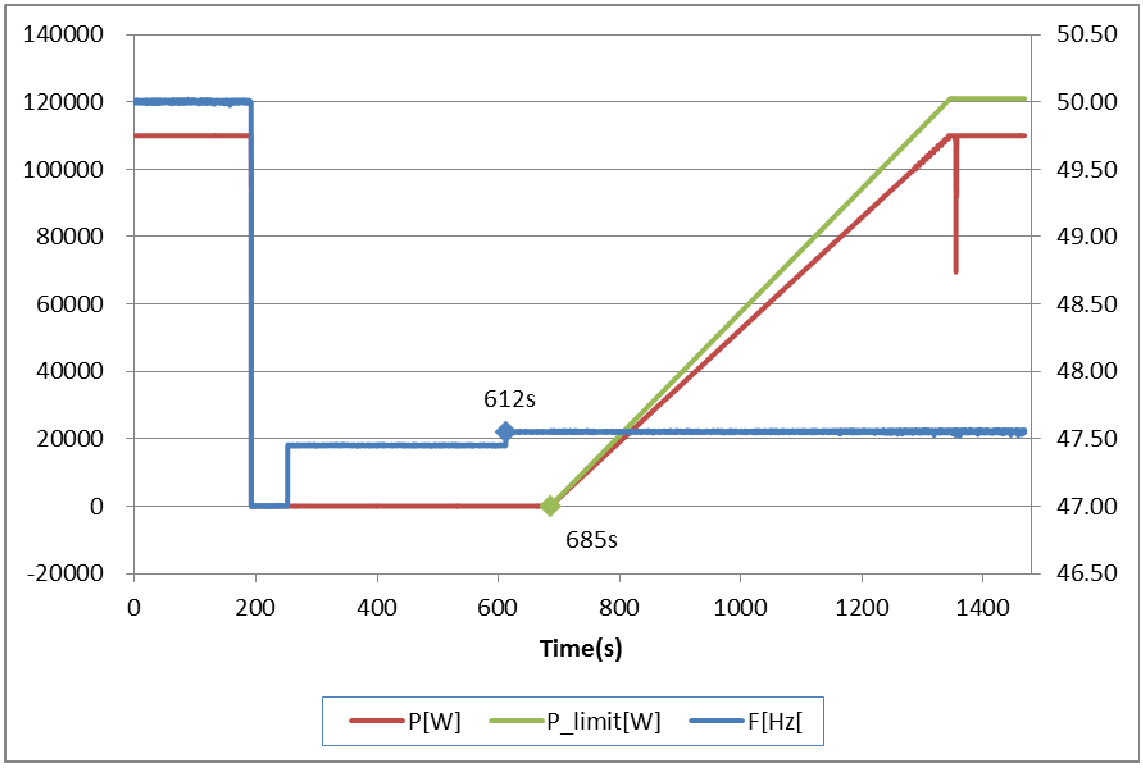
5.6 Connecting conditions and synchronization
E DIN V 0124-100:(2019-09) draft

Clause	Test	Result
5.6.1	General	**P**
5.6.2	Test	**P**

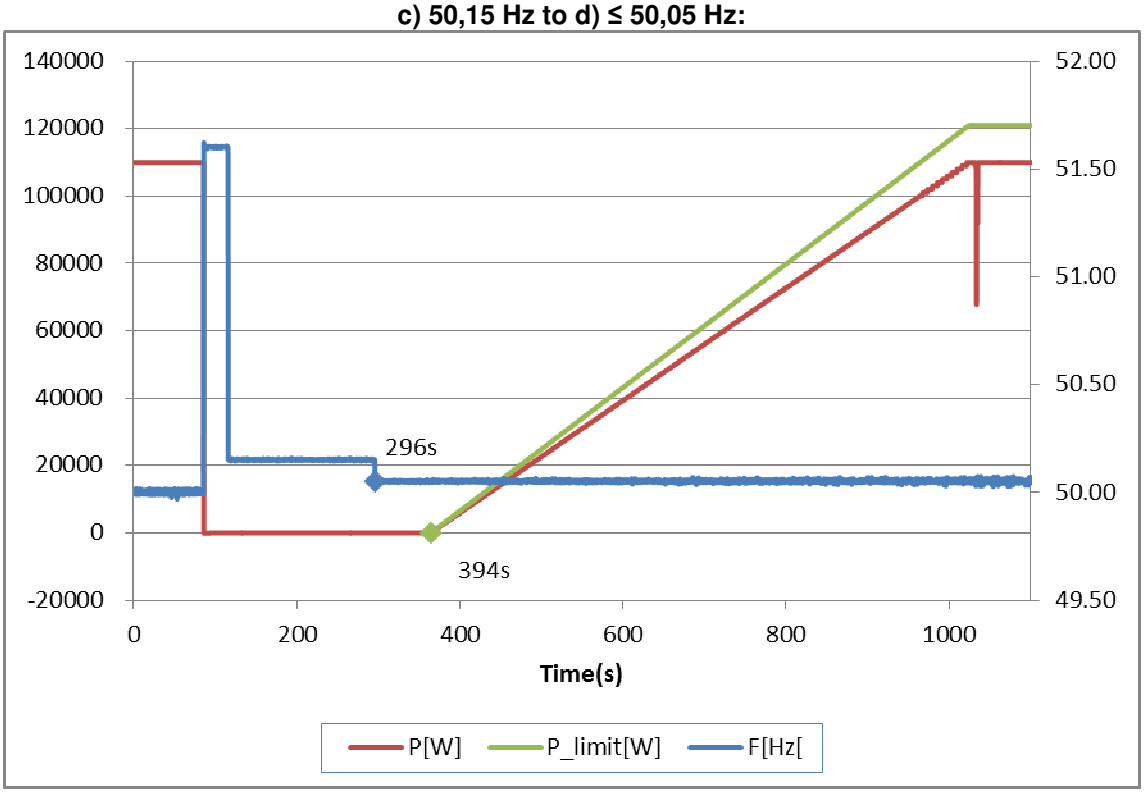
5.6 Connecting conditions and synchronisation			P
Setting values of the NS protection:	Setting $T_{reconnection\ 60s}$ [s]:	60	
	Setting f< [Hz]:	47,5	
	Setting f> [Hz]:	50,1	
	Setting V< [V]:	195,5	
	Setting V>> [V]:	253,0	

Test:			
	f_{ist}	**Reset time:**	**Limit:**
Connecting conditions for frequencies:			
a)	47,45 Hz	No reconnected.	No resetting allowed
	Switch to:		
b)	≥ 47,55 Hz	73 s	≥ 60 s
c)	> 50,15 Hz	No reconnected.	No resetting allowed
	Switch to:		
d)	≤ 50,05 Hz	98 s	≥ 60 s
Connecting conditions for voltages: L1 phase			
e)	84%	No reconnected.	No resetting allowed
	Switch to:		
f)	≥ 86%	68 s	≥ 60 s
g)	111 %	No reconnected.	No resetting allowed
	Switch to:		
h)	≤ 109%	68 s	≥ 60 s
Connecting conditions for voltages: L2 phase			
e)	84%	No reconnected.	No resetting allowed
	Switch to:		
f)	≥ 86%	68 s	≥ 60 s
g)	111 %	No reconnected.	No resetting allowed
	Switch to:		
h)	≤ 109%	68 s	≥ 60 s
Connecting conditions for voltages: L3 phase			
e)	84%	No reconnected.	No resetting allowed
	Switch to:		
f)	≥ 86%	68 s	≥ 60 s
g)	111 %	No reconnected.	No resetting allowed
	Switch to:		
h)	≤ 109%	68 s	≥ 60 s

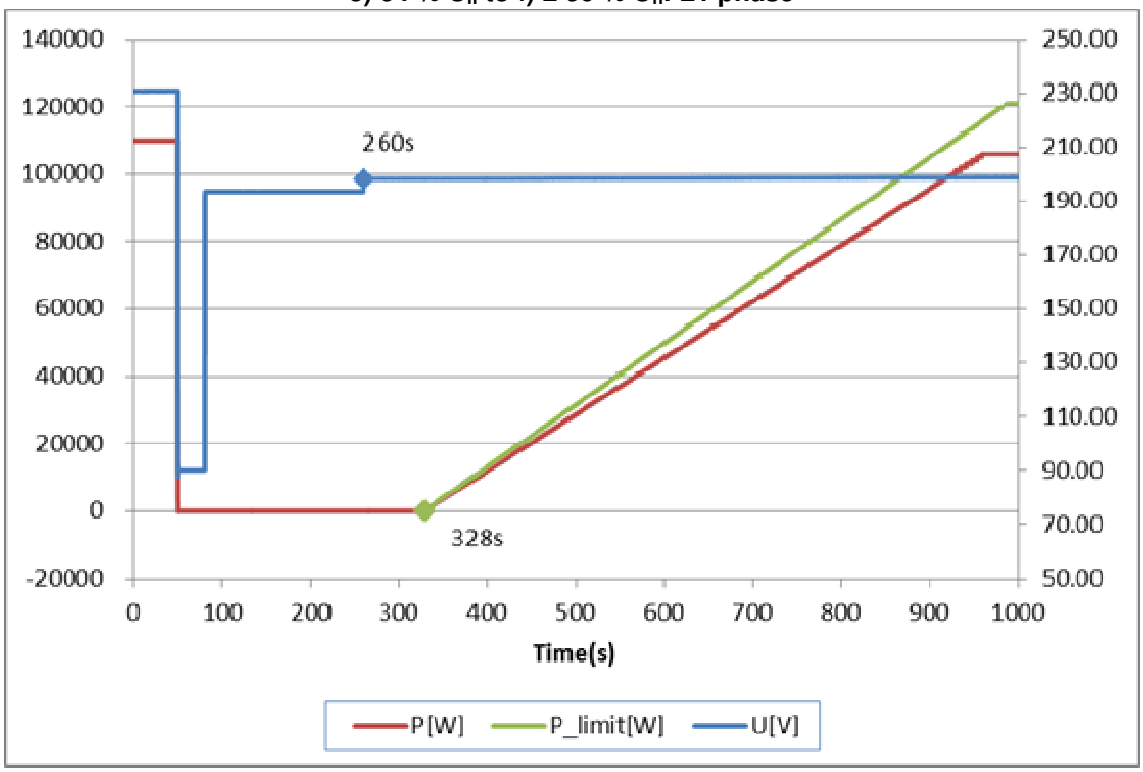
a) 47,50 Hz to b) ≥ 47,55 Hz:



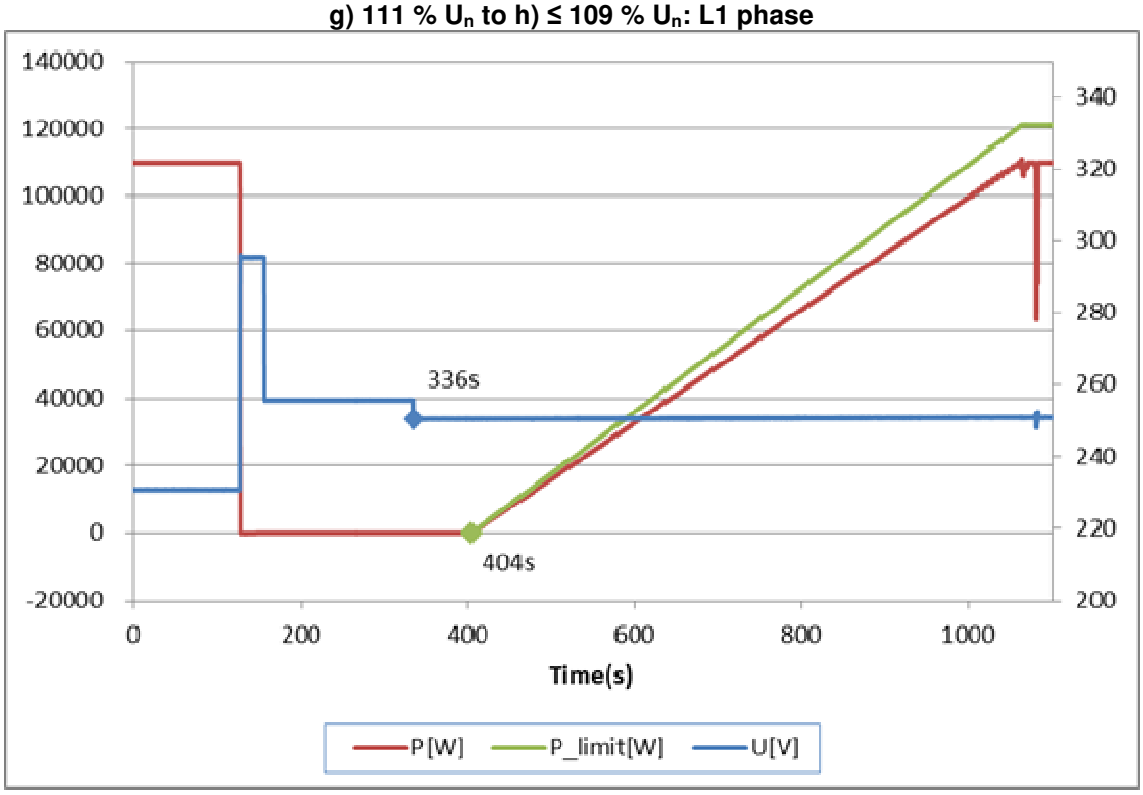
c) 50,15 Hz to d) ≤ 50,05 Hz:



e) 84 % U_n to f) ≥ 86 % U_n: L1 phase



g) 111 % U_n to h) ≤ 109 % U_n: L1 phase



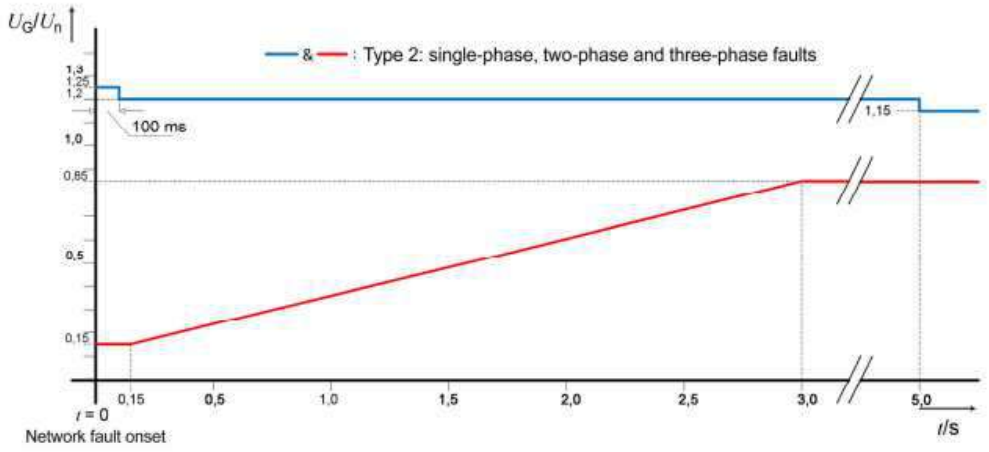
5.8 Evidence dynamic grid support
E DIN V 0124-100:(2019-09) draft

Clause	Test	Result
5.8.1	General	**P**
5.8.3	Testing of the dynamic grid support PGU Type 1	**N/A**
5.8.3	Testing of the dynamic grid support PGU Type 2	**P**

5.8.3 Testing of the dynamic grid support	P

For PGUs Type 2 and storage systems

General:



Key

& 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

Test	Voltage dip to (U_n / p.u.)	Dip type	duration (ms) [2]*	P set point (P_{rE} / p.u.)	Q set point (Q / p.u.)	Comment	Test ref. No.	Result
1	0,15 to 0,25	A	for 0,15 ≥ 150 / for 0,25 ≥ 250	1	0 to ± 0,1	Symetric	1.1	P
				0,2 to 0,6			1.2	P
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	1.5	P
				0,2 to 0,6			1.6	P
2	0,50 to 0,60	A	for 0,50 ≥ 1500 / for 0,60 ≥ 1500	1	Max. over exceeded	Symetric	2.1	P
				0,2 to 0,6			2.2	P
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	2.5	P
				0,2 to 0,6			2.6	P
3	0,50 to 0,60	A	for 0,50 ≥ 1500 / for 0,60 ≥ 1500	1	Max. under exceeded	Symetric	3.1	P
				0,2 to 0,6			3.2	P
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	3.5	P
				0,2 to 0,6			3.6	P
4	0,85 to 0,90	A	≥ 60000	1	0 to ± 0,1	Symetric	4.1	P
				0,2 to 0,6			4.2	P
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	4.5	P
				0,2 to 0,6			4.6	P
5	1,20 to 1,25	A	≥ 100	1	0 to ± 0,1	Symetric	5.1	P
				0,2 to 0,6			5.2	P
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	5.5	P
				0,2 to 0,6			5.6	P

6	1,15 to 1,20	A	≥ 5000	1	0 to ± 0,1	Symetric	6.1	☐
				0,2 to 0,6			6.2	☐
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	6.5	☐
				0,2 to 0,6			6.6	☐
7	1,10 to 1,15	A	≥ 60000	1	0 to ± 0,1	Symetric	7.1	☐
				0,2 to 0,6			7.2	☐
		D		1		Asymetric (ph-2-ph + Dy5-Trafo)	7.5	☐
				0,2 to 0,6			7.6	☐

Graph of FRT test one				
Test result:				
List of tests	**Residual amplitude of phase-to-phase voltage [p.u. U_n]**	**Duration limit [ms]**	**Duration [ms]**	**Result**
P_{Emax} in %	20% ±5%			
1.A.1- Symmetrical	0,15	160 ± 20	161	Pass
1.D.1- Asymmetrical	0,15	160 ± 20	160	Pass
2.A.1- Symmetrical	0,50	1500 ± 20	1511	Pass
2.D.1- Asymmetrical	0,50	1500 ± 20	1511	Pass
3.A.1- Symmetrical	0,50	1500 ± 20	1496	Pass
3.D.1- Asymmetrical	0,50	1500 ± 20	1511	Pass
4.A.1- Symmetrical	0,85	60000 ± 20	60000	Pass
4.D.1- Asymmetrical	0,85	60000 ± 20	60001	Pass
5.A.1- Symmetrical	1,25	100 ± 20	110	Pass
5.D.1- Asymmetrical	1,25	100 ± 20	107	Pass
6.A.1- Symmetrical	1,20	5000 ± 20	5007	Pass
6.D.1- Asymmetrical	1,20	5000 ± 20	5007	Pass
7.A.1- Symmetrical	1,15	60000 ± 20	60001	Pass
7.D.1- Asymmetrical	1,15	60000 ± 20	60000	Pass
P_{Emax} in %	100% ±5%			
1.A.1- Symmetrical	0,15	160 ± 20	160	Pass
1.D.1- Asymmetrical	0,15	160 ± 20	161	Pass
2.A.1- Symmetrical	0,50	1500 ± 20	1504	Pass
2.D.1- Asymmetrical	0,50	1500 ± 20	1511	Pass
3.A.1- Symmetrical	0,50	1500 ± 20	1511	Pass
3.D.1- Asymmetrical	0,50	1500 ± 20	1511	Pass
4.A.1- Symmetrical	0,85	60000 ± 20	60001	Pass
4.D.1- Asymmetrical	0,85	60000 ± 20	60000	Pass
5.A.1- Symmetrical	1,25	100 ± 20	109	Pass
5.D.1- Asymmetrical	1,25	100 ± 20	109	Pass
6.A.1- Symmetrical	1,20	5000 ± 20	5002	Pass
6.D.1- Asymmetrical	1,20	5000 ± 20	5002	Pass
7.A.1- Symmetrical	1,15	60000 ± 20	60001	Pass
7.D.1- Asymmetrical	1,15	60000 ± 20	60000	Pass

Test conditions:

Voltage simulator fall and rise time: < 20ms

Used sample rate: 10 kHz

Note:

At lease The recording must begin at least 10 s before the error occurs. After a faulty declaration (Voltage in the range 0,85 $U_n \leq U \leq 1,1\ U_n$), the recording must continue for at least another 60 s.

Behavior during the network error:
No disconnection of the PGU during the voltage drops the grid. If the PGU disconnects from the grid, the time of disconnection must be documented.

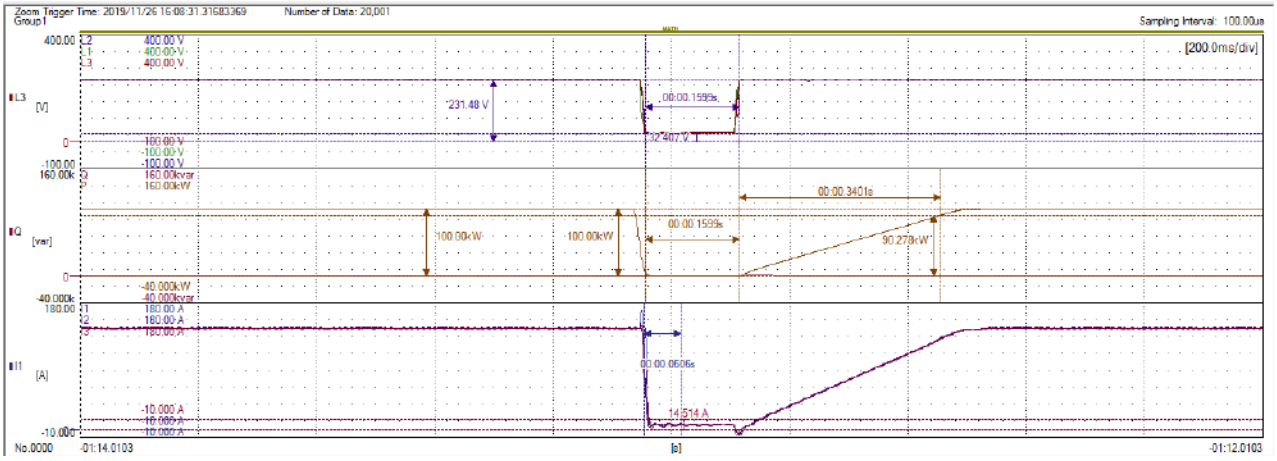
- Type 1 units have to support the line voltage during a line fault principle by supplying a suitable active and reactive current. It is not permitted that the increase in the voltage due to the reactive current supply cause the overvoltage limit curve (cf. VDE-AR-N 4105:2018-11) to be exceeded during a network fault and / or after a network fault.
- Asynchronous generators must remain connected to the grid during the tests shown and principle, may supply an active and reactive current.
- Type 2 units and storage systems are not allowed to inject neither active or reactive current during a line voltage at the PGUs terminals below 0.8 Un and above 1.15 Un. This requirement is met if, in the event of a under-/ under voltage dip, the injected current of the generating unit and / or the storage systems does not exceed 20% of the rated current Ir and no more than 10% Ir after 60 ms after the occurrence of this under-/ under voltage dip in any phase.

Behavior after the end of the error:

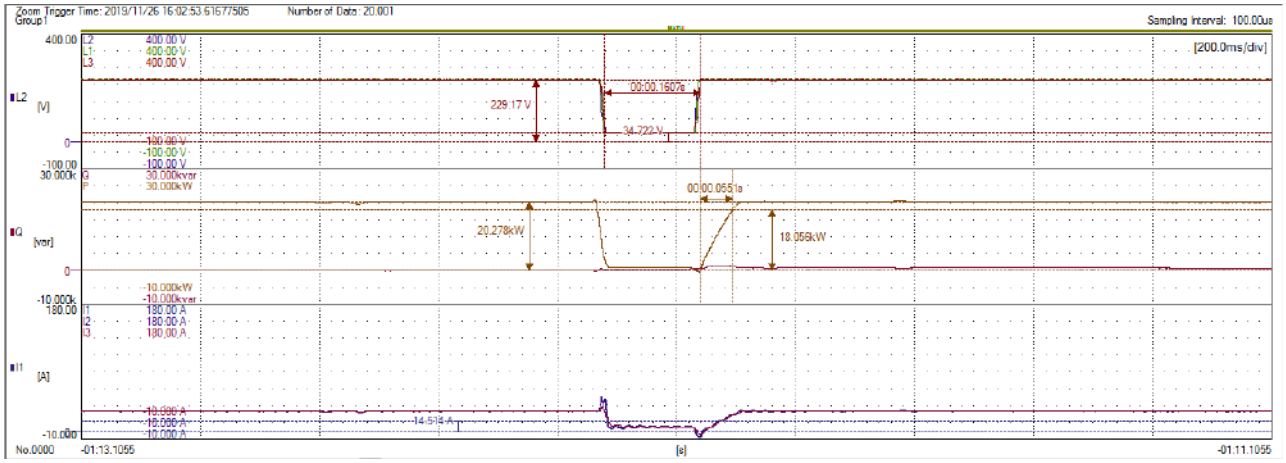
- Not disconnection of the PGU within 60 s after the end of the fault.
- Type 1 units and asynchronous machines: Reaction time of active power maximum 6 s, Reaction time of reactive power as fast as possible.

Type 2 units and storage systems: Reaction time of active power up to 1 s, Reaction time of reactive power according to PT1 behavior with 3 tau = 10 s in accordance with VDE-AR-N 4105: 2018-11, 5.7.2.5

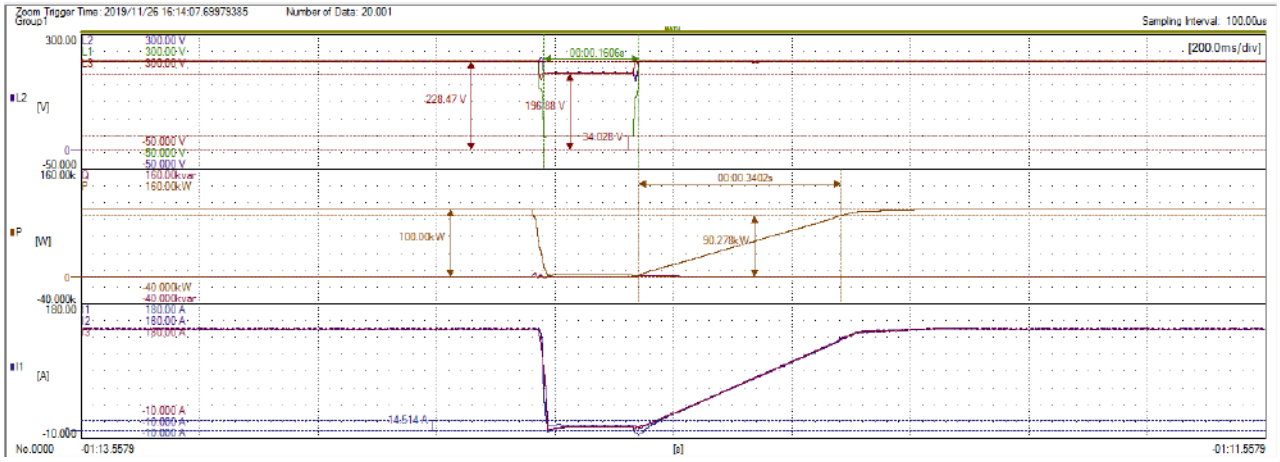
Test 1.A.1-Symmetrical fault (U/U_{nom} =0,15); P = 100% P_n



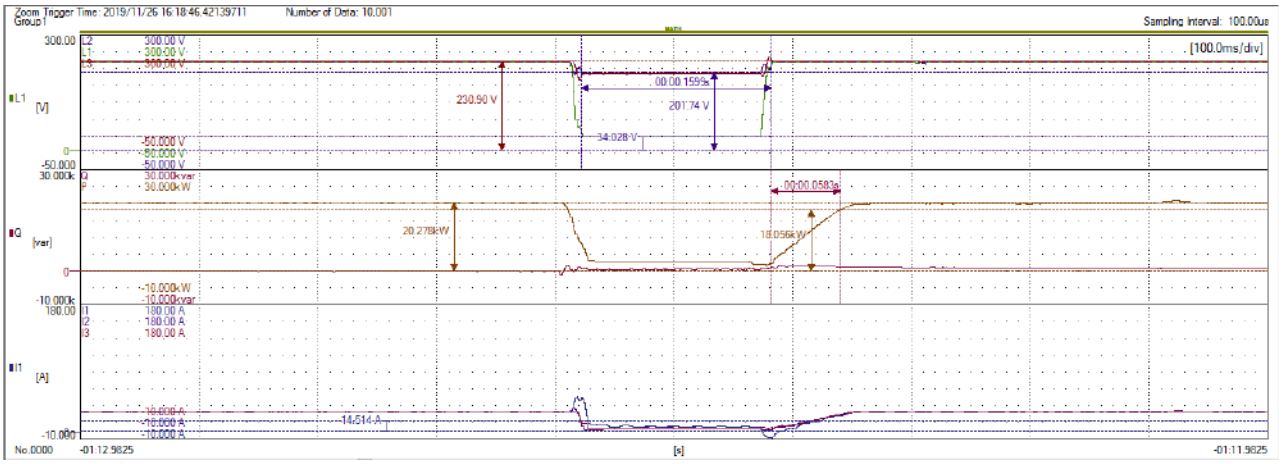
Test 1.A.2-Symmetrical fault (U/U_{nom} =0,15); P = 20%P_n



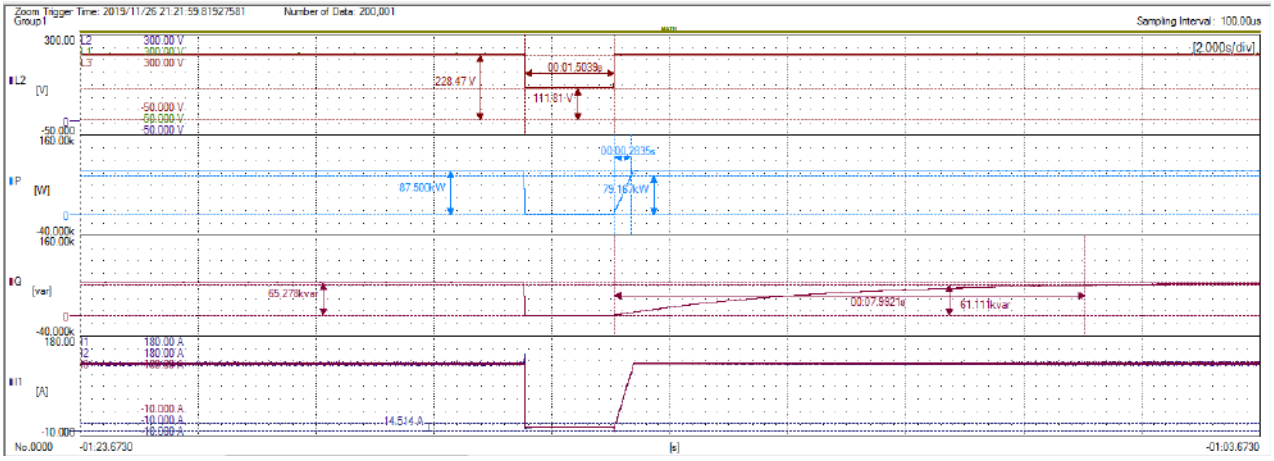
Test 1.D.1-Asymmetrical fault (U/U_{nom} =0,15); P = 100% P_n



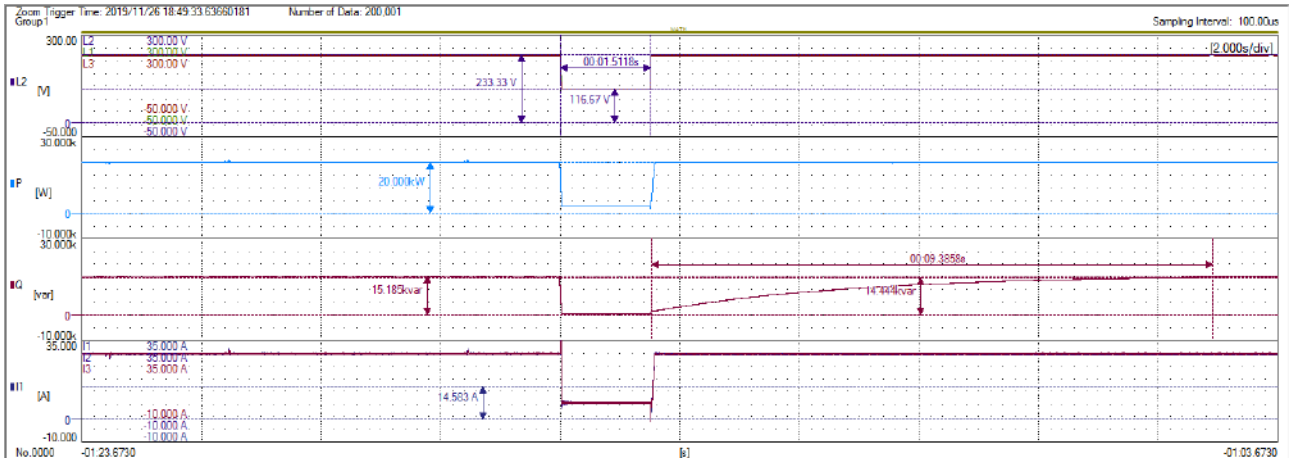
Test 1.D.2-Asymmetrical fault (U/U_{nom} =0,15); P = 20%P_n



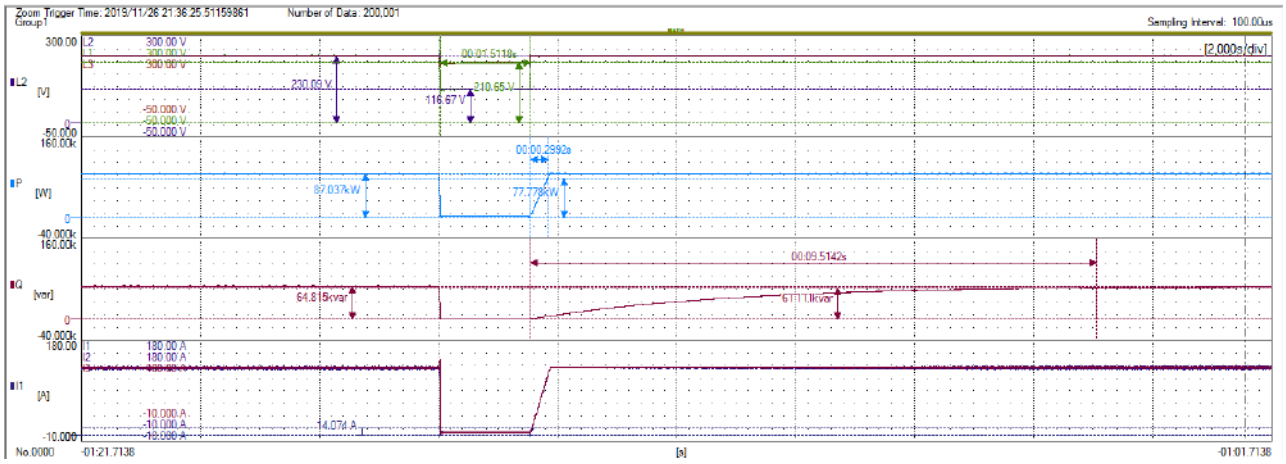
Test 2.A.1-Symmetrical fault (U/U_{nom} =0,50); P =100% P_n



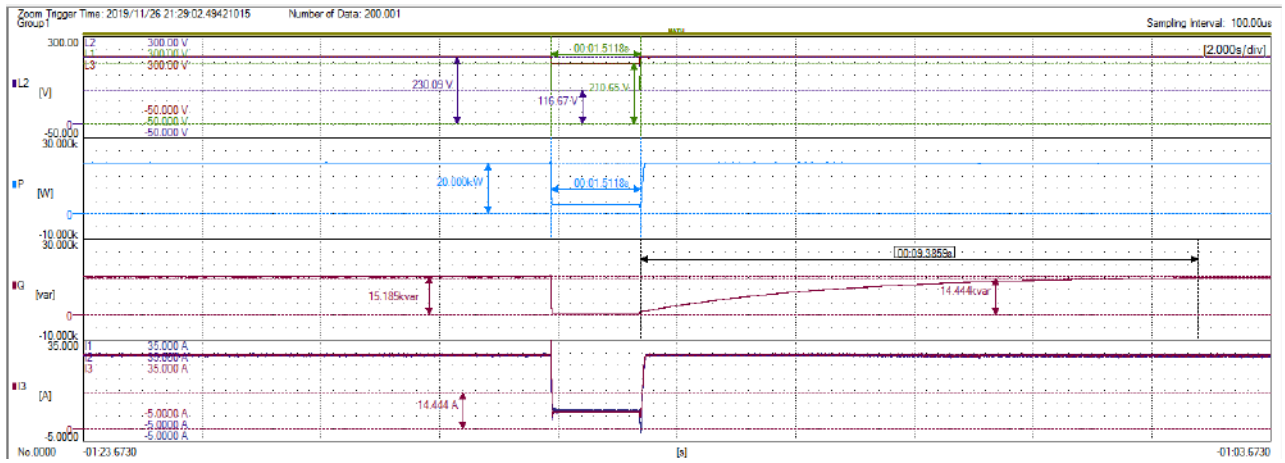
Test 2. A.2-Symmetrical fault (U/U_{nom} =0,50); P = 20% P_n



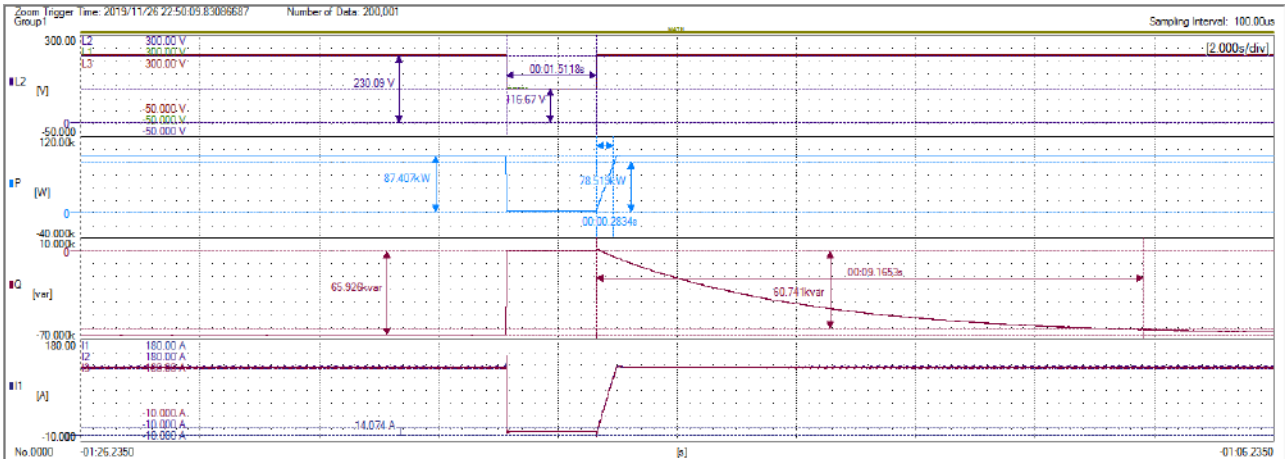
Test 2.D.1-Asymmetrical fault (U/U_{nom} =0,15); P = 100% P_n



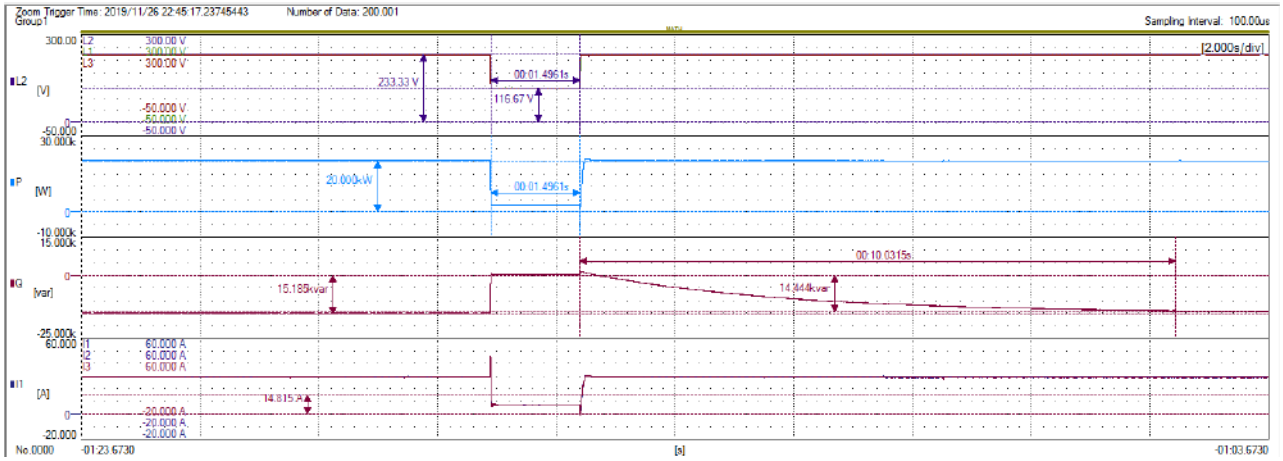
Test 2.D.2-Asymmetrical fault (U/U_{nom} =0,15); P = 20% P_n



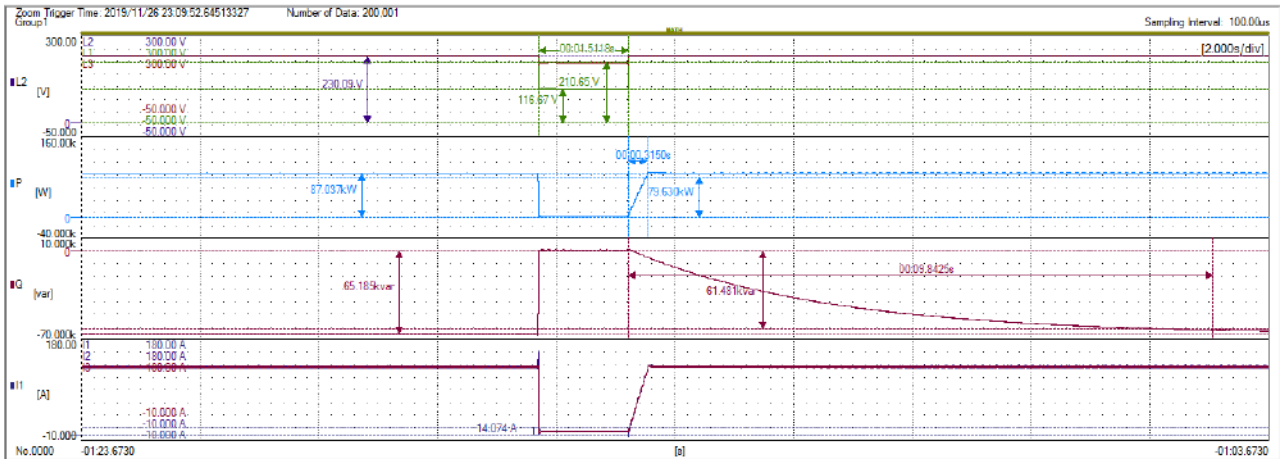
Test 3.A.1-Symmetrical fault (U/U_{nom} =0,50); P =100% P_n



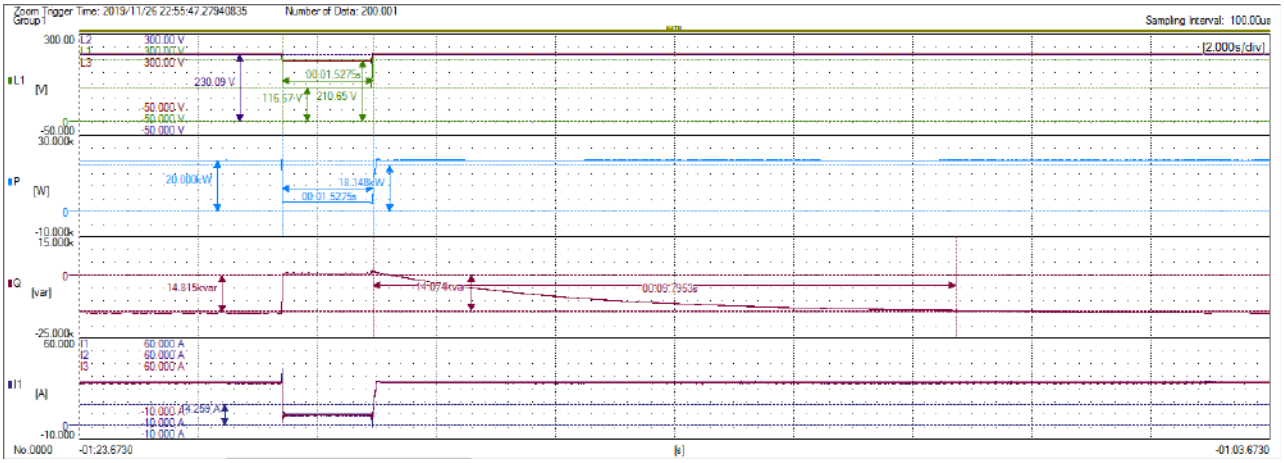
Test 3. A.2-Symmetrical fault (U/U_{nom} =0,50); P = 20% P_n



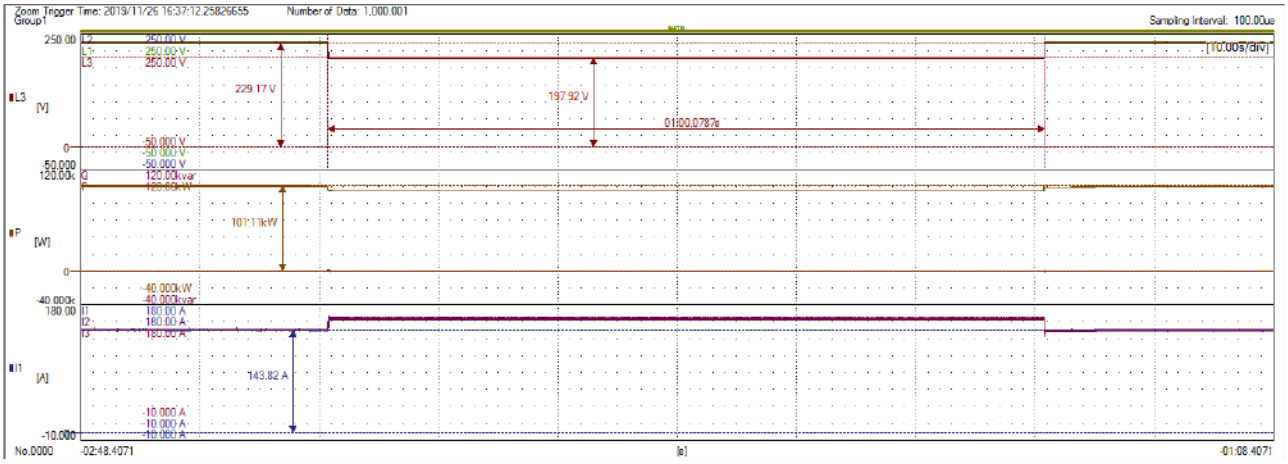
Test 3.D.1-Asymmetrical fault (U/U_{nom} =0,15); P = 100% P_n



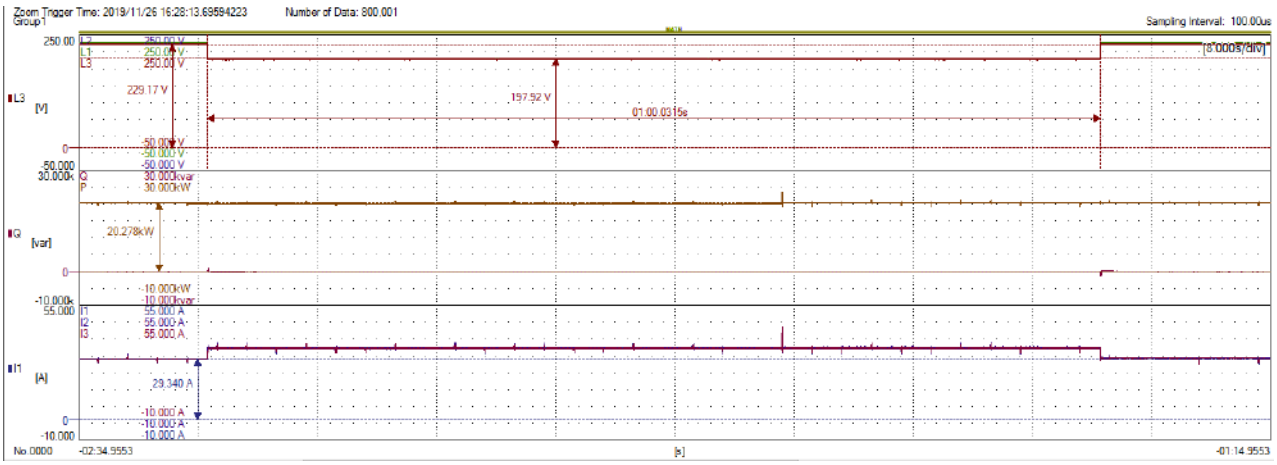
Test 3.D.2-Asymmetrical fault (U/U_{nom} =0,15); P = 20% P_n



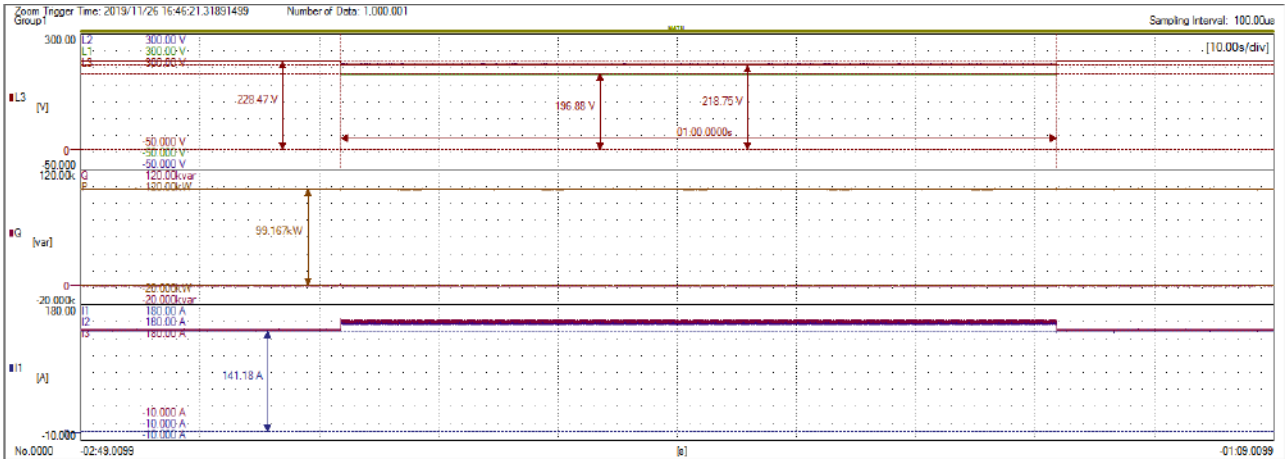
Test 4.A.1-Symmetrical fault (U/U_{nom} =0,85); P =100% P_n



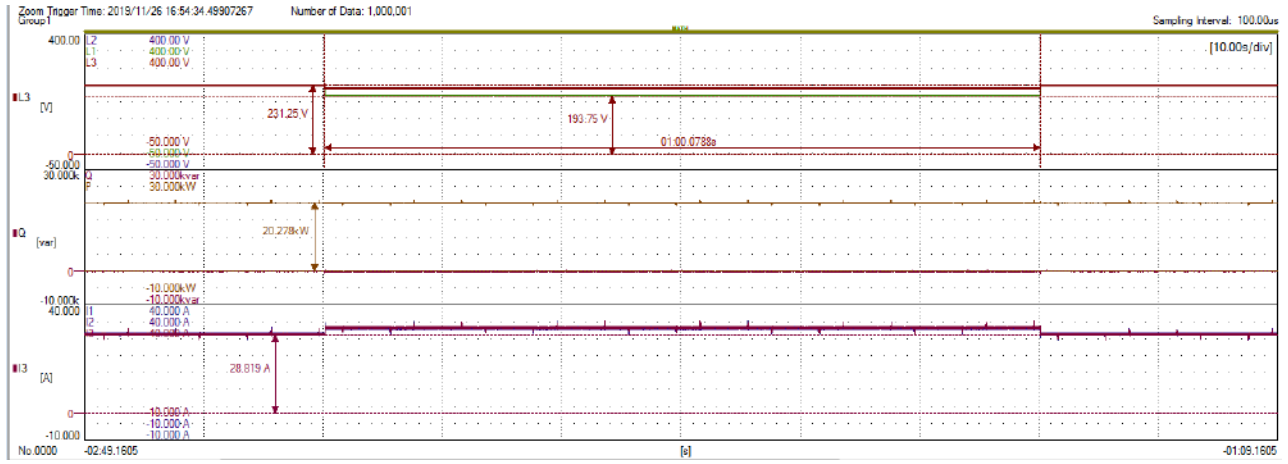
Test 4. A.2-Symmetrical fault (U/U_{nom} =0,85); P = 20% P_n



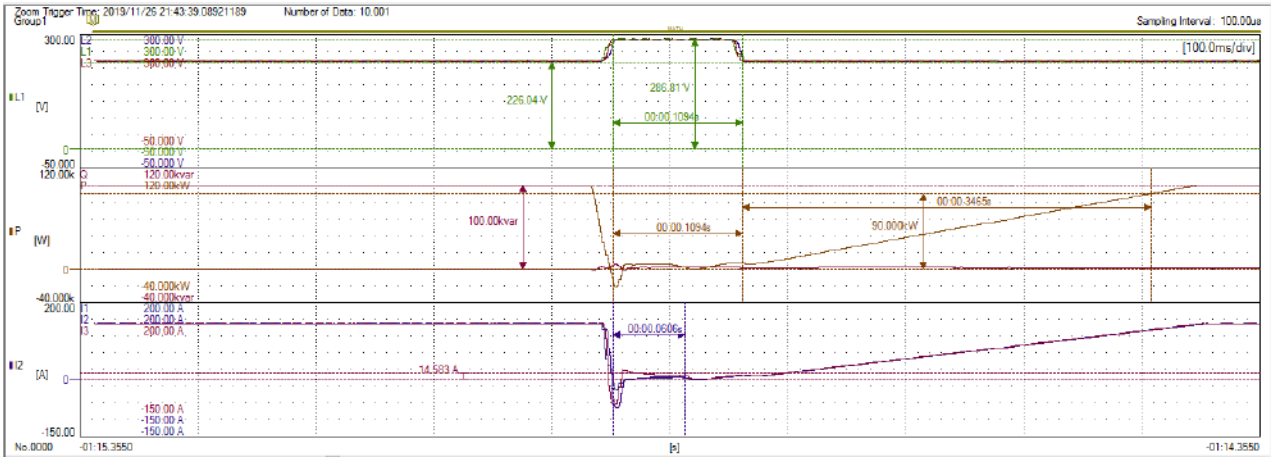
Test 4.D.1-Asymmetrical fault (U/U_{nom} =0,85); P = 100% P_n



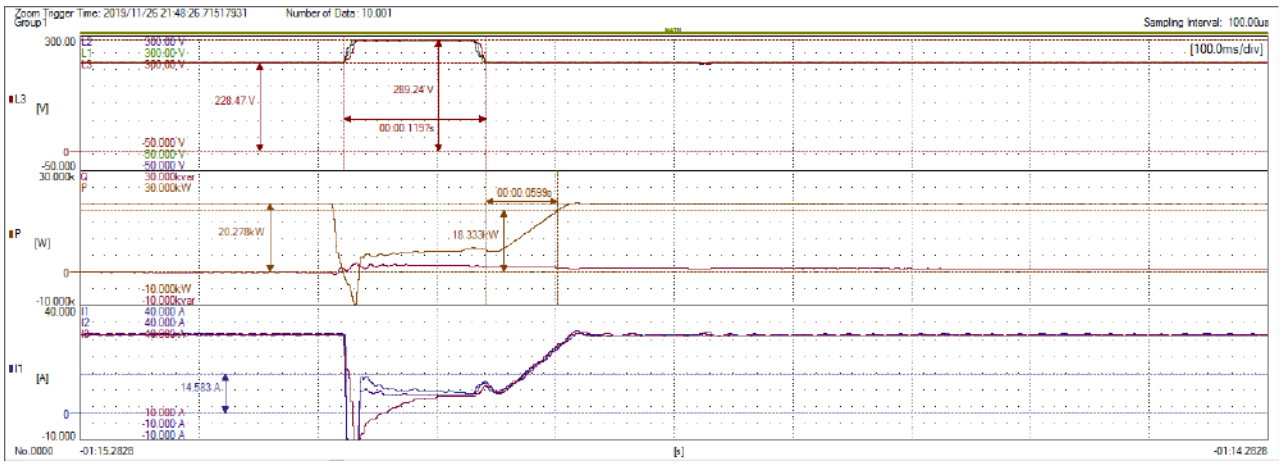
Test 4.D.2-Asymmetrical fault (U/U_{nom} =0,85); P = 20% P_n



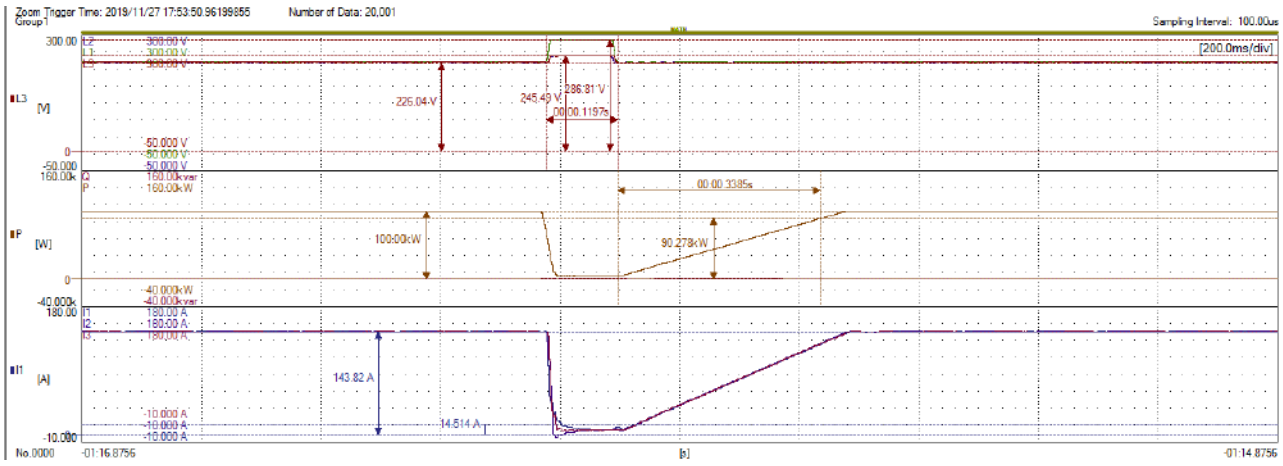
Test 5.A.1-Symmetrical fault (U/U_{nom} =1,25); P =100% P_n



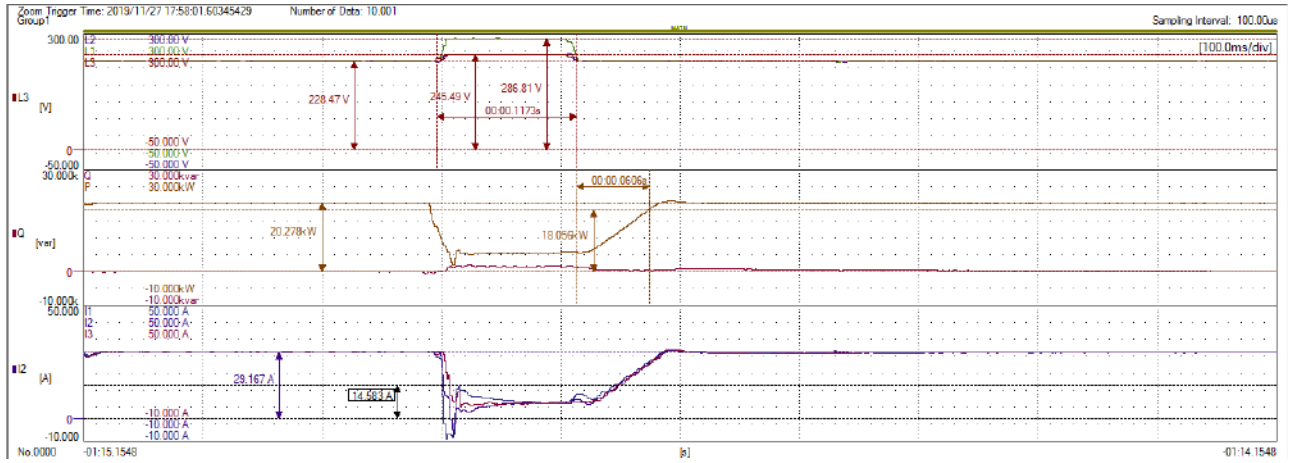
Test 5. A.2-Symmetrical fault (U/U_{nom} =1,25); P = 20% P_n



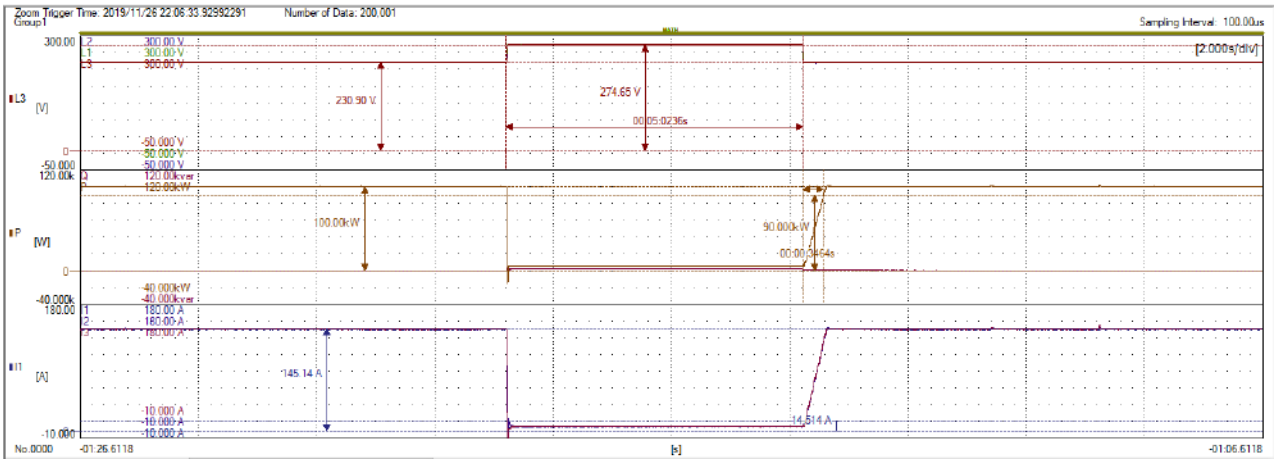
Test 5.D.1-Asymmetrical fault (U/U_{nom} =1,25); P = 100% P_n



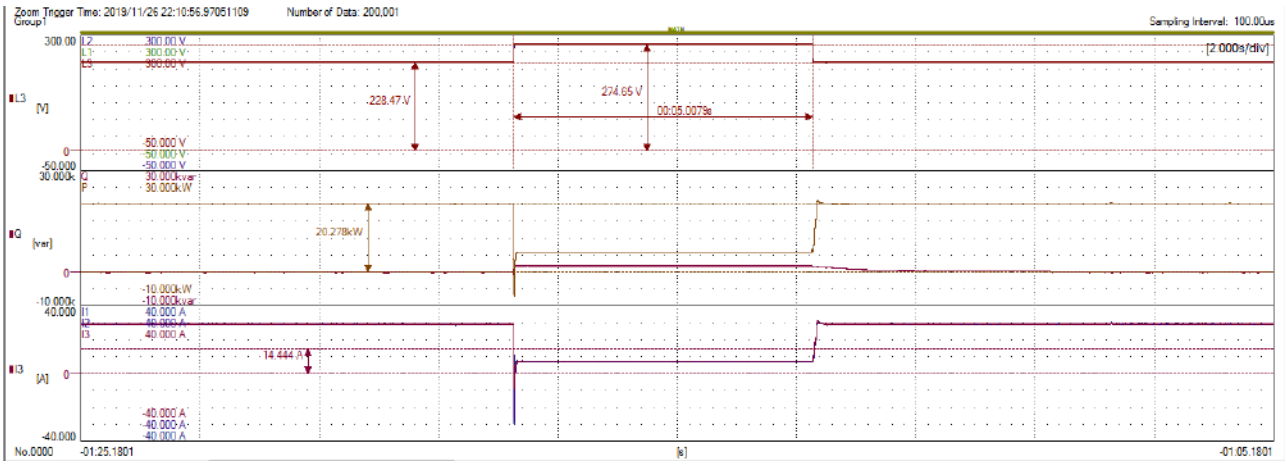
Test 5.D.2-Asymmetrical fault (U/U_{nom} =1,25); P = 20% P_n



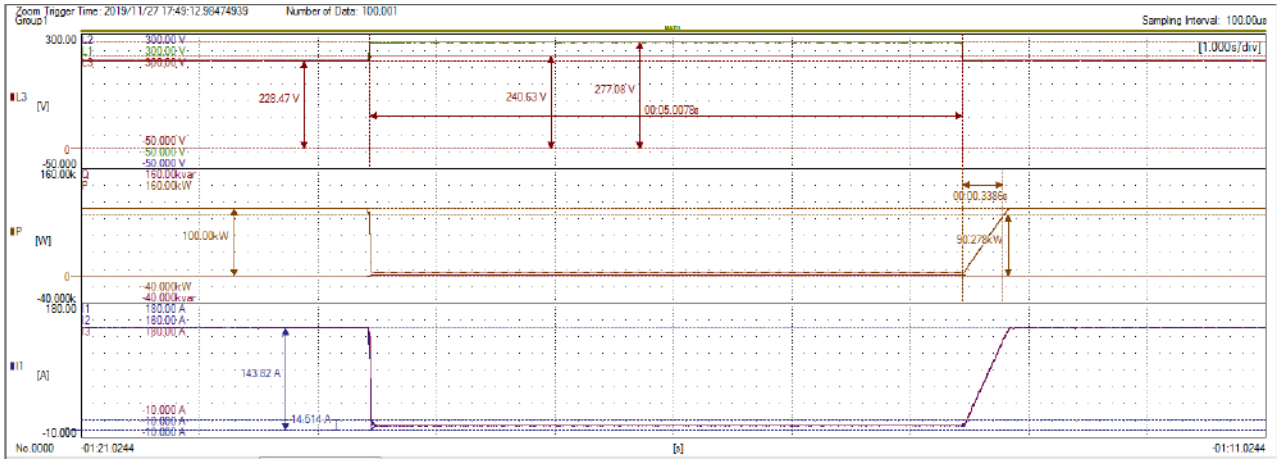
Test 6.A.1-Symmetrical fault (U/U_{nom} =1,20); P =100% P_n



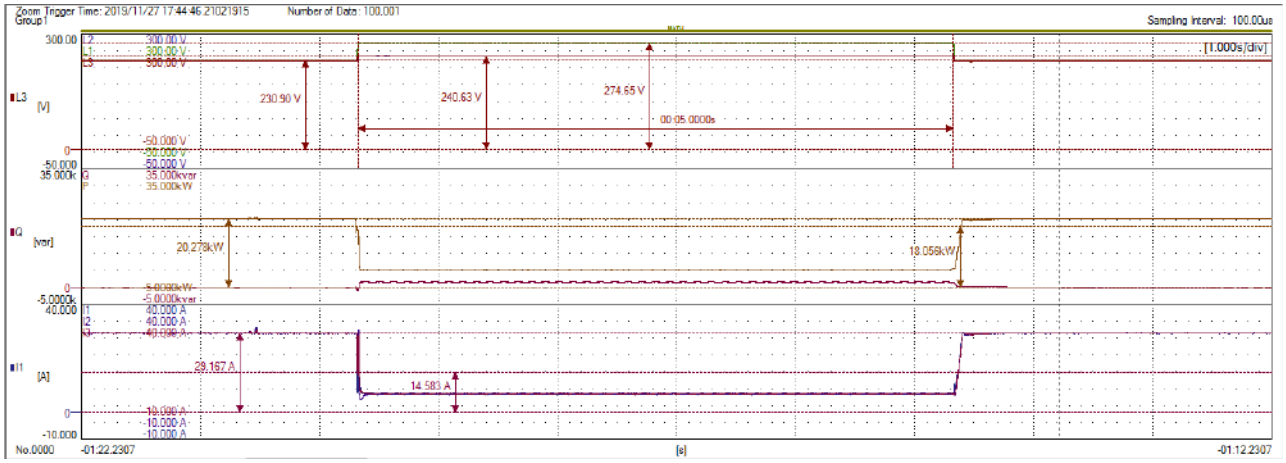
Test 6. A.2-Symmetrical fault (U/U_{nom} =1,20); P = 20% P_n



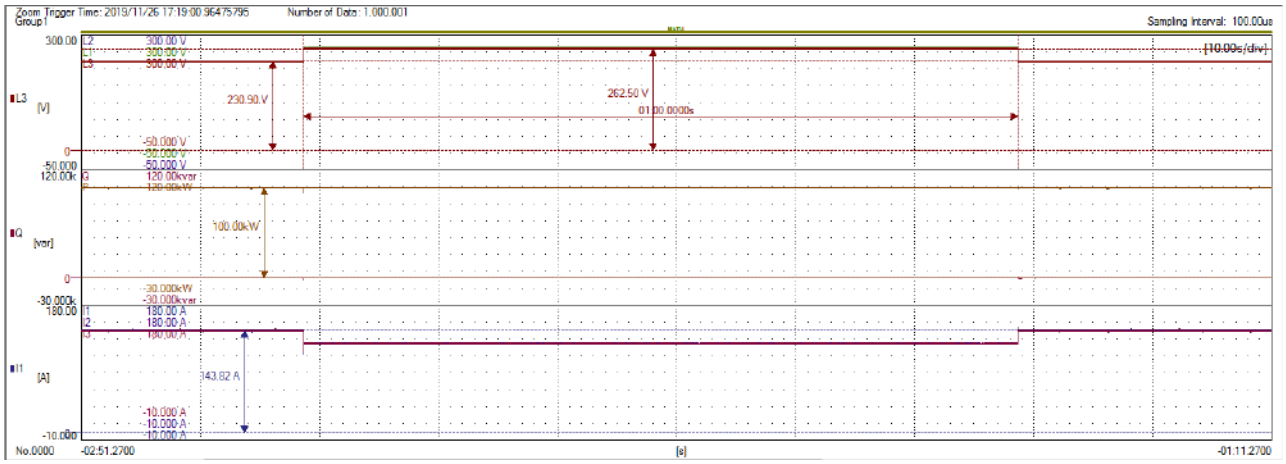
Test 6.D.1-Asymmetrical fault (U/U_{nom} =1,20); P = 100% P_n



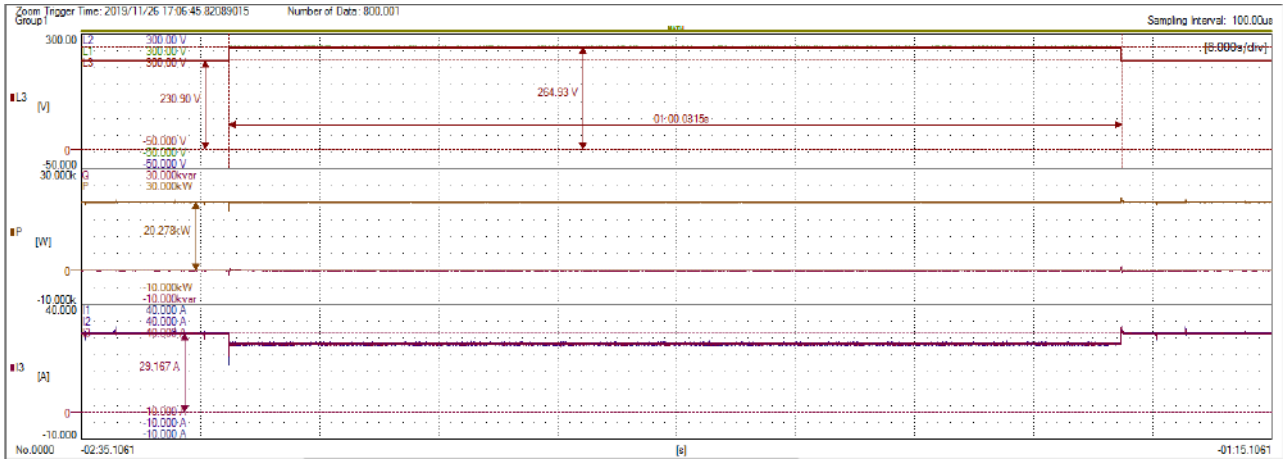
Test 6.D.2-Asymmetrical fault (U/U_{nom} =1,20); P = 20% P_n



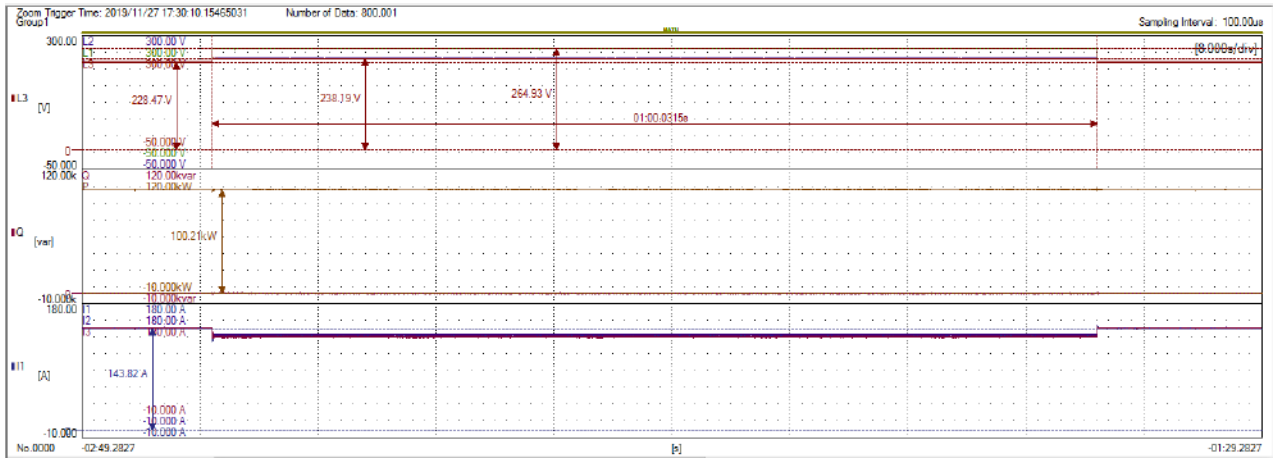
Test 7.A.1-Symmetrical fault (U/U_{nom} =1,15); P =100% P_n



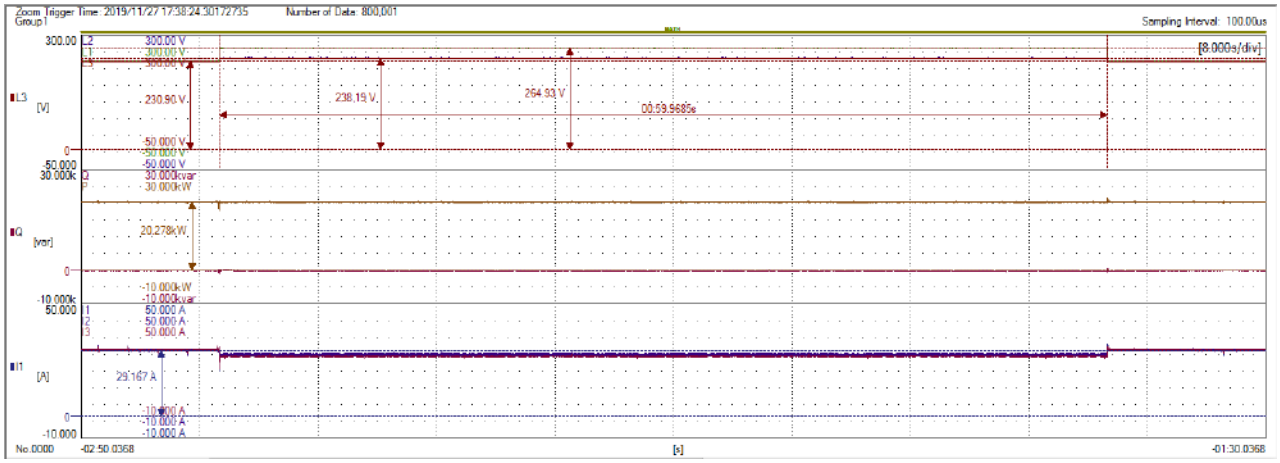
Test 7. A.2-Symmetrical fault (U/U_{nom} =1,15); P = 20% P_n



Test 7.D.1-Asymmetrical fault (U/U_{nom} =1,15); P = 100% P_n



Test 7.D.2-Asymmetrical fault (U/U_{nom} =1,15); P = 20% P_n



Annex No, 1

Pictures of the unit
The full pictures refer to PHOTO DOCUMENT
Project No.: 190905N026
Date: 20190918

Enclosure front view

Enclosure top view

Enclosure side view

Enclosure bottom view

Annex No. 2

Test Equipment list

Date(s) of performance test: 2019-09-05 to 2019-12-03

Equipment	Internal No,	Manufacturer	Type	Serial No,	Calibration is valid to
DC power supply	A170511605	Keysight	N8957APV	DE17072174	2020-03-17
	A170511606	Keysight	N8957APV	DE17082201	2020-03-17
	A170511607	Keysight	N8957APV	DE17082185	2020-03-18
	A170511608	Keysight	N8957APV	DE17082199	2020-03-19
	A170511609	Keysight	N8957APV	DE17082189	2020-03-19
	A170511610	Keysight	N8957APV	DE17082187	2020-03-19
	A170511611	Keysight	N8957APV	DE17082179	2020-03-17
	A170511612	Keysight	N8957APV	DE17082186	2020-03-17
	A170511613	Keysight	N8957APV	DE17082181	2020-03-17
	A170511614	Keysight	N8957APV	DE17082191	2020-03-19
	A170511615	Keysight	N8957APV	DE17082200	2020-03-19
	A170511616	Keysight	N8957APV	DE17102217	2020-03-19
	A170513133	Keysight	N8957APV	DE17122257	2020-03-18
	A170513134	Keysight	N8957APV	DE17122258	2020-03-18
AC Simulator	A171247305	Ametek	RS180-3PI	1751A02055	2020-05-23
	A161218075	Ametek	RS90-3PI	1623A00088	2019-12-19
Power analyzer	A170410202	HIOKI	PW6001	170200696	2020-02-20
Oscilloscope	A160514132	Tektronix	DP07054C	C200858	2020-04-29
	A180213713	YOKOGAWA	DL850E	91U116322	2020-08-14
Current sensor	A140413550	HIOKI	CT6863	140201351	2020-02-23
	A140413552	HIOKI	CT6863	140201344	2020-02-23
	A140413555	HIOKI	CT6863	140201347	2020-02-23